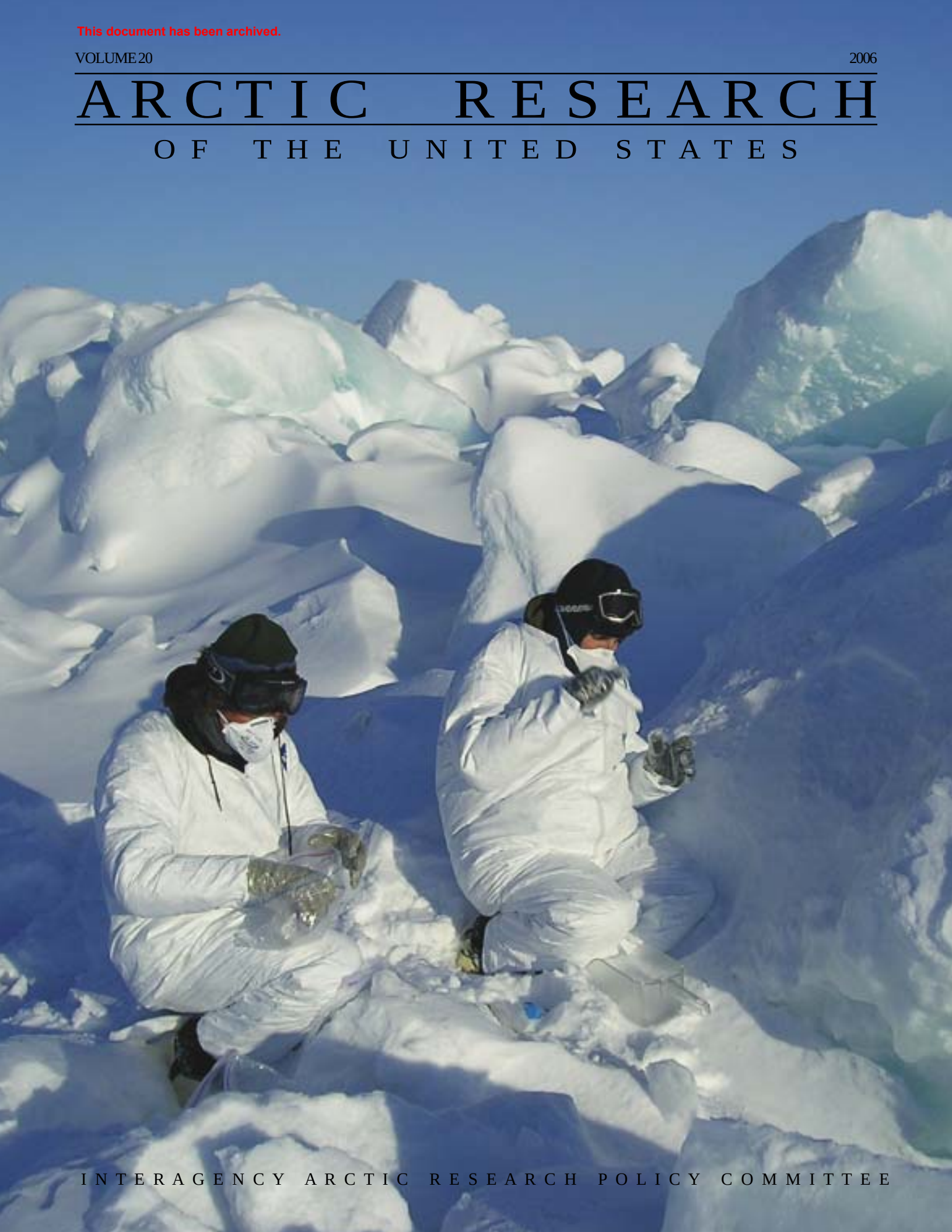
VOLUME 20 2006

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 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 Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230.

Cover

Tom Douglas (left) and William Simpson (right) sampling snow at a pressure ridge on the sea ice near Point Barrow, Alaska. The samples are analyzed for mercury, ions, and halogens. The work is part of a project funded by the National Science Foundation's Office of Polar Programs on the Arctic coastal environment. Mercury is mainly deposited in the winter into the snowpack through complex chemical reactions that require halogens, light, water vapor, and sea ice leads. (Photo by Matthew Sturm.)

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Report from Federal Agencies for 2004–2005

This is a special double issue of *Arctic Research of the United States*. It presents highlights and results of major fiscal year 2004 and 2005 Arctic research programs and selected projects of the Federal agencies. For more information, you may contact the agency staff representatives listed on page 163.

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 areas: 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.

The following sections present highlights of several major programs and selected projects. A complete listing of NSF-funded Arctic projects can be obtained from the Office of Polar Programs, National Science Foundation, Arlington, VA 22230.

	Funding (thousands)	
	FY 04	FY 05
Arctic Res. and Policy Support	90	94
Arctic Res. Supp. and Logistics	36,565	35,047
Arctic Res. and Education	250	320
Arctic System Science Program	20,250	20,250
Arctic Social Sciences	2,455	2,415
Cyberinfrastructure and Sensors	1,240	924
Information and Advisory Serv.	90	90
Arctic Natural Sciences	12,258	12,900
Arctic Research Commission	1,556	1,190
Funds Reprog. to Coast Guard	0	2,400
OPP Total	74,753	75,630
Non-OPP	26,000*	26,000*
Grand Total	100,753	101,630

* Estimated

Arctic System Science

The Arctic System and the ARCSS Program

The Arctic is a complex system consisting of physical, biological, and social components that interact across a wide range of temporal and spatial scales. Sea ice, ice sheets, and permafrost are key features that distinguish the Arctic from lower latitude systems. The Arctic system behaves in ways that are not fully understood, and it has demonstrated the capacity for rapid, amplified, and unpredictable change with global implications. Because of the Arctic's pivotal role in the earth's climate, it is critical—perhaps even urgent—that we understand this system in light of abundant evidence that a set of linked and pervasive changes are underway. What do these changes mean for the future of both the Arctic and the earth? To address this question, ARCSS research focuses on understanding the fundamental characteristics, dynamics, and controlling principles of the Arctic system through integration and synthesis of knowledge from past and ongoing studies.

In 1989 the NSF established the Arctic System Science (ARCSS) program, an interdisciplinary program that strives 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. ARCSS works towards advancing the scientific understanding needed to predict environmental change on a decade-to-centuries time scale and to inform policymakers on 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, especially with NASA and NOAA on projects dealing with Arctic climate and ocean processes and modeling research. ARCSS research continues to contribute to the U.S. Global Change Research Program.

The ARCSS program adapts its structure and goals to the progress of its research. This adaptation is achieved through various mechanisms, including a scientific committee erected by the research community, that provides a community perspective on the overall coordination and integration of ARCSS. To ensure community participa-

tion, ARCSS has used various methods to develop new ideas and set priorities, including workshops and open meetings. Recently the program has sought to improve its facilitation of dialogue in the research community and improve the exchange of ideas between the program and its constituents. As outlined below, ARCSS is exploring new modes of pursuing its science and of interacting with the broader scientific community with the intent of engaging as many people as possible in a responsive planning process.

The guiding question for ARCSS at present is: What do changes in the Arctic system imply for the future?

Planning is focused on three science questions:

- How do the interconnected social, physical, chemical, and biological systems of the Arctic operate and interact to define and drive the Arctic system (broadly defined)?
- How does the Arctic system interact with the larger earth system?
- What is the trajectory of the Arctic system and the implications of that trajectory in the years and decades to come?

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.

To address these questions ARCSS must:

- Advance from a component understanding to a system understanding of the Arctic;
- Understand the behavior of the Arctic system, past, present, and future;
- Understand the role of the Arctic as a component of the global system; and
- Include society as an integral part of the Arctic system.

In recent years ARCSS focused on several disciplinary components: Ocean/Atmosphere/Ice Interactions; Land/Atmosphere/Ice Interactions; Human Dimensions of the Arctic System, and Paleoenvironmental Arctic Sciences (PARCS), under which research activities were developed. (PARCS proposals were considered within the Earth System History competition at NSF.) This disciplinary focus was necessary to build communities and knowledge bases for these disciplines. However, once that was achieved, the structure of the program began to evolve to one more amenable to its goal of understanding the Arctic as a system. Thus, most of these components have now been replaced by a more proactive ARCSS committee that guides the system-level thinking of the program, strives to develop more extensive connections to a broader array of disciplines for new ideas, and devotes considerable attention to fostering ARCSS research efforts during their full life cycle from inception of ideas through archival of data, synthesis of results, and communication of scientific knowledge to the research community and the public.

Shelf–Basin Interactions

A current example of a process-oriented ARCSS research activity is the Shelf–Basin Interactions (SBI) project, established to improve understanding of the role of the large continental shelf seas off Alaska in marine 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:

- 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.

The SBI project has finished most of its field activities and is now analyzing the results of its work and producing scientific summary documents. It is anticipated that it would eventually participate in a final phase in which SBI results are incorporated with other similar results and related to the functioning of the Arctic system.

Researchers retrieving a CTD (conductivity, temperature, depth profiler) rosette on the USCGC Healy *during the Shelf–Basin Interaction (SBI) study of the northern Bering Sea in 2005.*

Freshwater Cycle Integration Study

The first exercise in a new mode of ARCSS research, the Freshwater Cycle Integration Study, was developed as a thematic interdisciplinary approach that addressed a major part of the Arctic system. This research addresses the physical, chemical, and biogeochemical character of the Arctic freshwater system and its interactions with the polar ocean and subpolar seas. The 22 projects constituting the effort are not only engaged in field research on Arctic freshwater systems, but they have also begun formulating a series of united research perspectives and project outputs. The strategy has been to foster mechanisms to achieve a project synthesis by uniting available water system data streams, process studies, and modeling. The goals are to reveal processes, linkages, and causes of variability in the Arctic terrestrial, atmosphere, and upper-ocean hydrologic cycle through an integrated set of research activities focused on three science questions: Is the Arctic freshwater cycle intensifying; if so, why; and what are the implications? These questions span traditional land–ocean–atmosphere communities and have brought diverse communities into active cross-disciplinary dialogue.

Two avenues of investigation have been pursued. One aims to synthesize existing quantitative information to construct a comprehensive freshwater budget linking fluxes and stocks through all major domains of the pan-Arctic system: atmosphere, land, ocean, and sea ice. The articulation of such a budget has highlighted several chal-

Scientist taking an ocean temperature and salinity profile at the side of a lead during field work.

lenges in establishing the "fundamentals" of the Arctic water system and has identified critical existing unknowns in data coverage, spatial and temporal harmony, and consistency across measurement campaigns. It has also shown the need for coherent strategies to address the subtleties associated with the inherent variability of the Arctic hydrological system. A second direction is the attempt to establish the consistency of changes across observational studies of paleo, historic, and contemporary water systems with simulated behaviors generated by Arctic and earth system models. This will allow us to assess our system understanding of observed changes and search for the attribution of such changes. To make these efforts relevant to the policy community, a new emphasis is on the implications and impacts of Arctic system change, specifically on ecosystems, on climate, and on humans living both in and outside of the Arctic.

Scientists on the Lena River in Siberia. After sampling the river at approximately 71°N, they disembarked at the village of Kyusyur to meet with the local hydrologist responsible for making Lena River discharge measurements. The Lena River, roughly equal in discharge to the Mississippi, has been monitored daily since 1936. Its discharge has increased substantially over the past several decades, likely in response to global warming.

Study of the Northern Alaskan Coastal System

Lying at the intersection of the land, ocean, and atmosphere, and the locus of much human activity, the coast is a critical interface in the Arctic system and was considered to be an ideal test bed for tackling the kinds of complex scientific issues required to develop a true systems approach to Arctic research. In early 2004, NSF released an announcement of opportunity for a Study of the Northern Alaska Coastal System, a second effort towards system-wide research, this time with a regional approach. The announcement defined the coastal system very broadly, as the region extending from the Brooks Range in Alaska to the ice edge at sea, and was open to all disciplines. Six projects were supported on subjects including bowhead whales and the marine ecosystem, carbon interconnections, organic carbon and eroding coastlines, halomethane gas exchange, synthesis and scaling, and the deposition and fate of mercury. Although it was not through any active steering or design, most of these projects focused their field activities in Barrow, Alaska, and this circumstance provided excellent opportunities for close collaboration with one another and with scientists from other agencies, as well as for outreach to the community. Although widely divergent in discipline and approach, these projects are working closely together and finding unexpected synergies in their research.

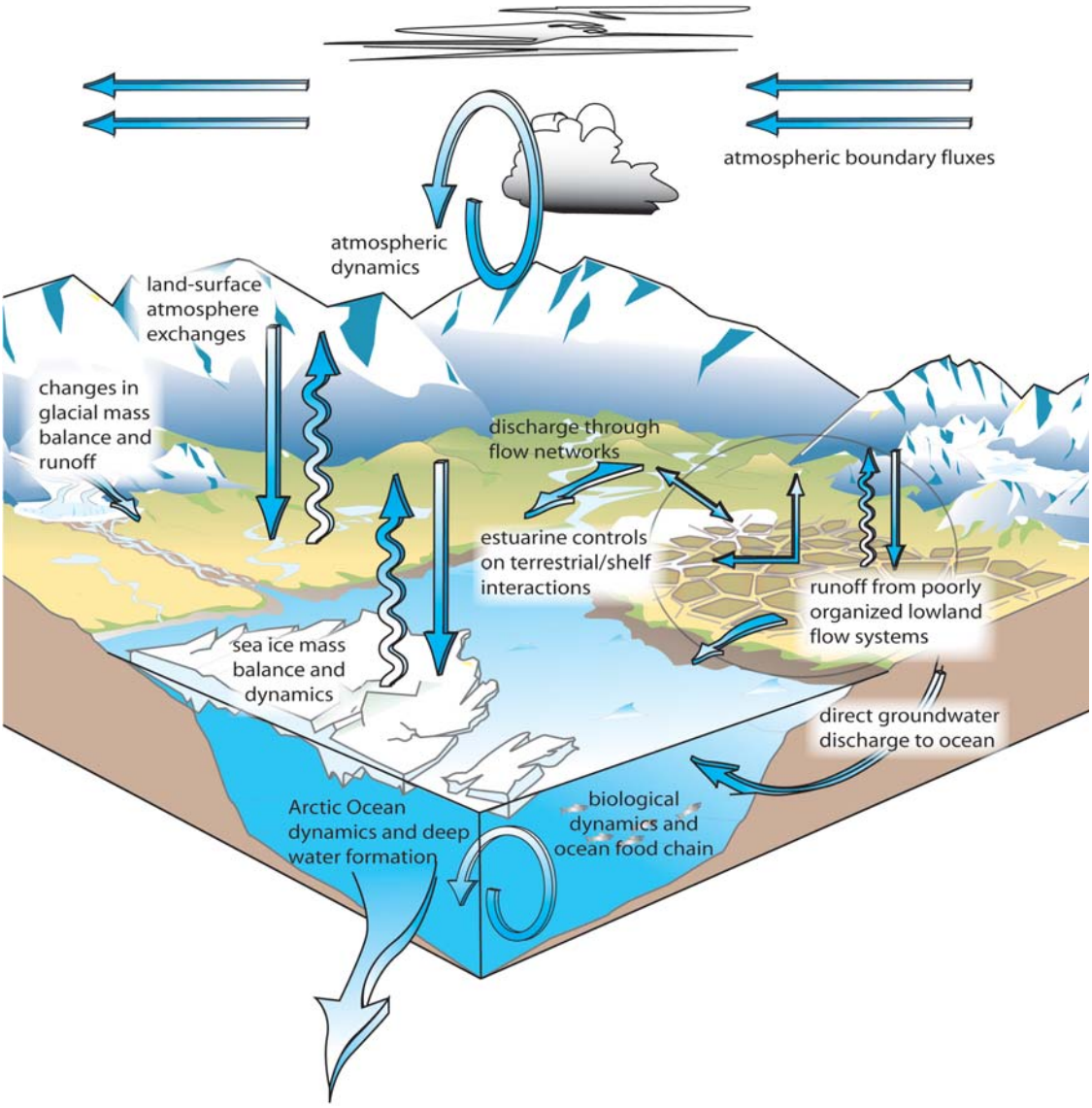
Human Dimensions of the Arctic System

Human Dimensions of the Arctic System (HARC) has been a collaborative effort with the Arctic Social Sciences Program to integrate natural and social sciences research that demonstrates 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. 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 and social sciences will increase policymakers' understanding of regional natural and social systems and build linkages among 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. This effort is still being fostered actively in ARCSS; the goal is not to establish a social science sub-program, but rather to make social science a part of the fabric of all ARCSS research. ARCSS has supported the HARC effort by funding several large collaborative projects. An example can be found in a large project funded in 2004 called The Intersection Between Climate Change, Water Resources and Humans in the Arctic. In this project, researchers in natural science, engineering, and social science are linking hydrological, cultural, and engineering studies in the Seward Peninsula of Alaska with the goal of understanding the vital role that fresh water plays in the lives of humans in the Arctic.

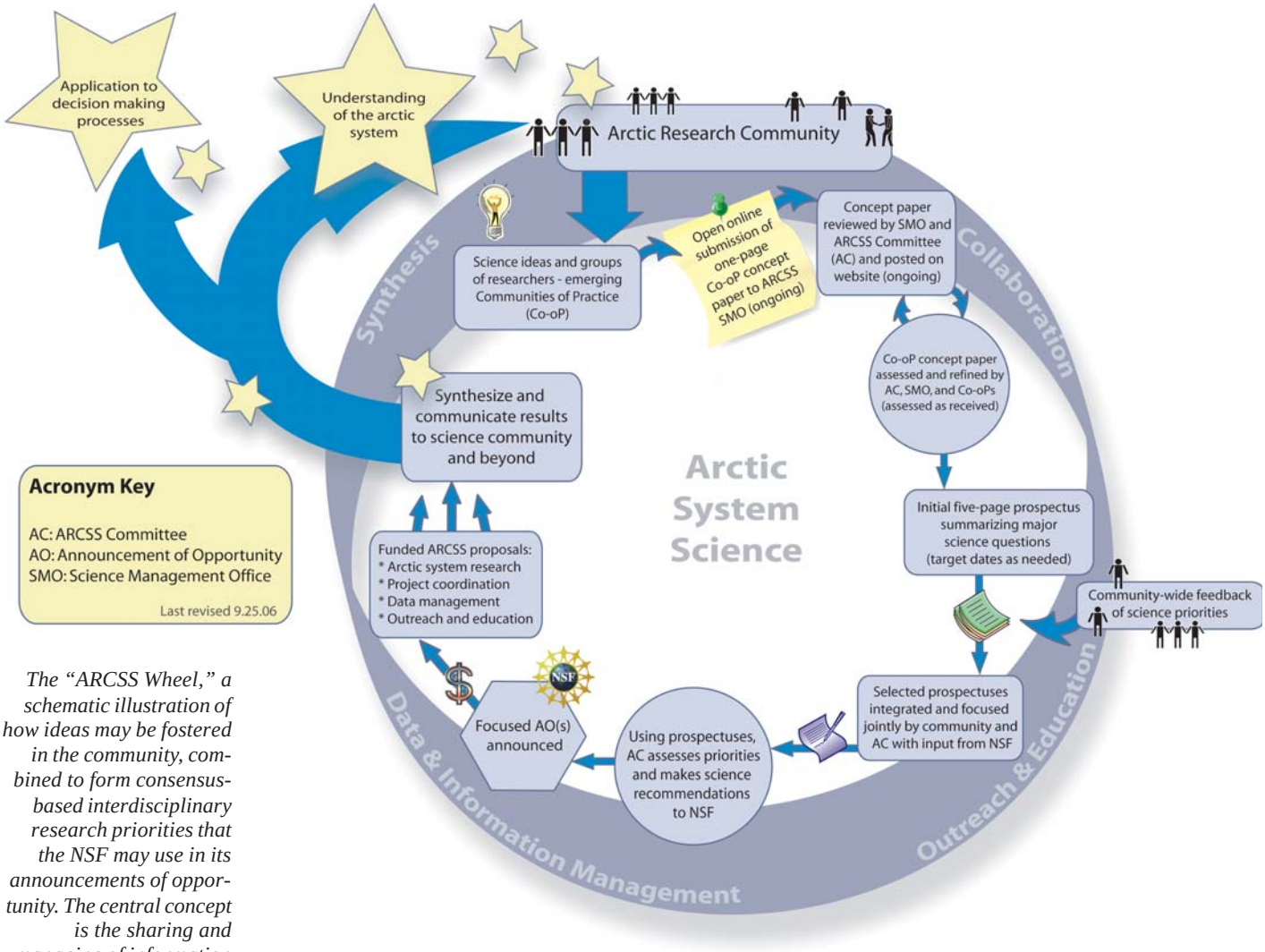
Synthesis in ARCSS

ARCSS has long supported the idea of integrating research results across components through a Synthesis, Integration and Modeling Studies (SIMS) effort. This activity is now achieving renewed prominence in the program. As ARCSS ventures into its first program-wide synthesis, the program is expanding on the existing data-oriented SIMS effort to synthesize knowledge of how the Arctic system works, with a major emphasis on understanding the linkages between parts of the system and better articulation of the implications for the future. "Synthesis," as ARCSS has employed it, is essentially the juxtaposition of disparate ideas, facts, or data to gain unexpected insight. In essence it is the pursuit of surprise by design.

Although it was not widely called synthesis then, the process of synthesizing the community's collective knowledge of the Arctic system really began at an ARCSS All-Hands Workshop, with more than 300 ARCSS researchers participating. It continued formally with the Big Sky Synthesis Retreat (Big Sky, Montana) of a few dozen scientists in August 2003. The retreat's goals were to analyze and then synthesize available knowledge into a system perspective of the Arctic. Scientists from a variety of disciplines investigating many components of the Arctic system attended, and most called it a tremendous learning experience in the form of an opportunity to discuss commonalities and linkages among researchers who rarely cross paths. Discussions centered on the interwoven complexity of recent Arctic change, how this



Schematic of the Arctic system, showing the areas of current ARCSS synthesis activity.



The "ARCSS Wheel," a schematic illustration of how ideas may be fostered in the community, combined to form consensus-based interdisciplinary research priorities that the NSF may use in its announcements of opportunity. The central concept is the sharing and managing of information throughout the cycle of inquiry, from conception of idea to publication and interpretation of research results, informing the public and policy makers, as well as feeding further idea development.

fabric of change is tied to the larger global system, how it will unfold in coming years, and what the implications for humans may be. This assembly of expertise led to the realization that Arctic change is pervasive, widespread, and dramatic, and hence to the "Big Sky Question," "Is the Arctic system moving to a new state outside the envelope of the natural glacial–interglacial cycle?" Throughout the week, the participants worked together, offering their own expertise and perspectives, to give their best determination of whether the Arctic is moving toward a new state. By the end of the week, participants reached near-unanimous agreement that the Arctic is likely moving outside the envelope of past experience, and possibly toward a new state, and that we do not yet understand the implications for the Arctic, the global climate system, or human society. Participants also agreed that a state change could include major surprises and non-linear responses of Arctic components and that the implications could be wide-ranging and substantial for humans.

An important product from the retreat was a paper (*EOS*, Vol. 86, No. 34, 23 August 2005, p. 309–316) describing the motivation for the synthesis approach, as well as new insights from discussions at the Big Sky gathering. Numerous other questions were raised at the retreat too; some were pursued in a second retreat a year later, and a group funded to synthesize the results of the paleoenvironmental efforts in ARCSS is examining others.

To engage the larger community in this effort, ARCSS held a special competition called Synthesis of Arctic System Science (SASS) in 2005, soliciting proposals to consider the Arctic as a system. There were nine successful projects supporting 44 investigators to explore various aspects of the system. A supplemental activity will engage these various projects in seeking synergies among their

efforts and identifying how well their collective results describe the system.

ARCSS will likely continue to support efforts that synthesize knowledge of how the Arctic system works (including a focus on the linkages between parts of the system) and better articulation of the implications for the future. In general the program is trying to concentrate on understanding the relations among the components of the system and leaving the detailed studies at the subcomponent level to other, more disciplinary programs. ARCSS will also continue to conduct field research to address key questions but will use its ongoing synthesis to help identify the problems of highest priority to be pursued in the field.

Engaging the Community

ARCSS is both a program that funds research projects and a process to plan for future directions of its science. In the latter mode, it has moved deliberately away from a hierarchical array of committees that developed disciplinary projects, to experimenting with new ways of bringing ideas into the program. Most recently the program has engaged the community directly using electronic discussion groups. Thus, immediately after the most recent competition results were released, an open meeting was held with the community (an "e-town meeting") in which over 60 people discussed the results and considered directions of ARCSS synthesis. Other mechanisms will include sponsored Communities of Practice that will develop new ideas. The intent is that these communities will generate science ideas, and as they mature and are combined with other ideas, they will progress through a series of steps to feed into mature interdisciplinary research priorities that NSF may draw upon to develop new announcements of opportunity. This approach is very much in keeping with NSF's goal of listening to the community in order to respond quickly in developing research priorities, but it also allows these ideas to be focused to meet ARCSS goals. ARCSS will continue to explore new ways of engaging as many people as possible in its research agenda.

Arctic Natural Sciences

Arctic Natural Sciences (ANS) provides core support for disciplinary research addressing Arctic processes in the areas of cryospheric sciences, atmospheric sciences, ocean sciences, earth sciences, and biological sciences.

Cryospheric Sciences

Research in the cryospheric sciences focuses on the history and dynamics of all naturally occurring forms of snow and ice, including seasonal snow, glaciers, sea ice, permafrost, and the Greenland ice sheet. The program also supports studies of glacial geology.

A significant focus of glacial field research continues to be the collection of observations sufficient to develop theory and predictive models of glacial dynamics and mass balance, as well as the subsequent validation of those models. Observations of Helheim Glacier, in East Greenland, indicate rapid retreat associated with thinning of the glacier and acceleration of its seaward velocity. Lagged acceleration of tributary glaciers is also occurring. Comparison of these data with theory suggests that the acceleration and thinning are, predominantly, responses to the calving and retreat of the glacier front, rather than to thermal melting during summer. The potential for enhanced calving and retreat associated with a thinner glacier suggests that an important positive feedback mechanism is at work. In related studies of Bench Glacier, in the Chugach Mountains of Alaska, associations between the horizontal motion of the glacier and excess pressure at the base of the glacier suggest that increased subglacial connectivity of the water flow may result initially in increased velocity, but that rapid drainage then leads to increased friction and slower velocity for the glacier. Observations of Breiðamerkurjökull, Iceland, following liquid precipitation events support these suggestions. Two neighboring sections of the glacier sat on rough bedrock and smoother till, respectively. Excess pressure at the bed diminished following the precipitation and initial drainage events, allowing the ice over rough bedrock to settle back onto the bottom features, the water connectivity to diminish, and the ice velocity to decrease. Over the smoother till, connectivity was maintained, even after the initial drainage event, and high ice velocities persisted. The fact that high velocity leads to further bed erosion again suggests significant potential feedback mechanisms on the glacier's dynamics.

Atmospheric Sciences

Research in the atmospheric sciences focuses on stratospheric and tropospheric processes, climate, and meteorology. Upper atmosphere and space physics concerns include auroral studies, atmospheric dynamics and chemistry, and magnetosphere–ionosphere coupling. These efforts

are often supported jointly by the Division of Atmospheric Sciences and the Antarctic Aeronomy and Astrophysics Program. The difficulties associated with obtaining the direct observations necessary for structuring model development and then for model–data comparison continue to argue for significant resources being devoted to observational programs in these latter disciplines.

A large international collaboration recently has completed a comprehensive campaign that directly measured the size and composition of particles forming polar stratospheric clouds. These data clearly define the importance of nitric acid trihydrate in such clouds.

Observations continue to indicate initial cooling of the Arctic mesopause approximately two days prior to a stratospheric warming event, thus offering the possibility of early warning of such an event. This seems to be associated with intense planetary wave oscillations of the mesopause–lower thermosphere region at least four weeks earlier. The observations suggest that the planetary waves alter the structure of the atmosphere, lowering the regions where upward-propagating gravity waves break and causing the associated warming to occur in the stratosphere rather than in the mesopause.

Numerous ground-based observation systems observe the dynamics and consequences of space weather. Recent observations suggest that substorm initiation does not require plasma sheet changes as intense as previously thought. They also suggest that a majority of substorms with well-defined onsets are associated with a reduction of large-scale convection.

Space weather studies have been hampered by the inconsistent definition of the polar cap index, a proxy for various measures of the coupling between the solar wind and the magnetosphere, in the northern and southern hemispheres. Ongoing development of a more accurate and objective technique for deriving these indices is anticipated to facilitate the use of extensive data sets being collected in both polar regions.

Ocean Sciences

Research in the ocean sciences is focused on understanding and predicting the structure and dynamics 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. This last topic involves close linkages with the cryospheric sciences.

An important aspect of the Arctic Ocean transport system is an anticlockwise boundary current, which carries Atlantic (warm, salty) waters and Pacific (fresher, nutrient-rich) waters along the continental slopes and major trans-Arctic ridges. This current system is undersampled in both time and space. Detailed numerical modeling is being applied to study three regions of the system where the topography is believed to be particularly important: St. Anna Trough, where the two inflowing branches of Atlantic Water, each having been modified by atmospheric cooling and/or ice melt, converge and interact to produce a single current; Lomonosov Ridge, where the current system bifurcates, with part flowing north along the ridge and the rest continuing into the Canadian Basin; and the Mendeleyev Ridge/Chukchi Borderland, where the remainder of the current system that passed the Lomonosov Ridge encounters particularly tortuous topography. As an extension of these studies, rotating stratified hydraulic theory has been applied to the deepest pass through the Lomonosov Ridge. The resultant flow rates have been used to estimate the age of the deep water in the Canadian Basin. The theory suggests water ages roughly 150 years older than in the Eurasian Basin, in good agreement with the 200-year age difference previously estimated from carbon-14 dating.

Processes within this boundary current system have been implicated in the transport of shelf water into the subsurface interior of the Arctic Ocean (ventilation). Arctic Ocean 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 result in thinning of the sea ice. Furthermore, the course and final depth of the nutrient-rich Pacific waters entering the Canadian Basin from the Chukchi Sea affect the local biological productivity, with implications up the food chain. These ventilation processes are also being modeled numerically in an effort to understand controls on the exchange processes. Initial results from a stratified model of Chukchi Sea dynamics confirm the main flow features anticipated from sparse observations and earlier non-stratified modeling results. They also suggest a significant role for local atmospheric forcing within the Chukchi Sea in controlling the water mass characteristics of those waters ultimately advected into the Canadian Basin.

An intriguing situation arises when one performs a model–data comparison of flow within the Atlantic Water layer of the Arctic Ocean. The Arctic Ocean Model Intercomparison Project

(AOMIP), an international consortium that compares Arctic Ocean models by driving them with identical forcing fields, finds that its model results can be separated into two groups with almost exactly opposite patterns; among 11 model results posted in their web site, 6 are counterclockwise and 5 are clockwise, while observations suggest a counterclockwise circulation. Theoretical studies of the circulation of the Arctic Ocean suggest that modeled circulation fields are sensitive to the circulation structure (potential vorticity) at the inflow through Fram Strait, requiring great care in accurate depiction of this condition in realistic models.

Earth Sciences

Research in the earth sciences includes all subdisciplines of terrestrial and marine geology and geophysics. Of particular interest are studies leading to an improved understanding of Arctic geological processes that enhance our ability to interpret the geologic record of environmental change in the polar regions and to reconstruct the plate tectonic history of the Arctic Ocean.

Warming of the northern latitudes during the Middle Miocene is particularly clear in the north Pacific region. Recent collections of bivalves and gastropods have been used to document, contrast, and compare this climate change and its impact in Alaska and Kamchatka, Russia. The principal samples were derived from Kodiak Island and regions near the Bay of Korf. At the beginning of the Middle Miocene Climatic Optimum (14.5–17 Ma BP), these regions suffered a molluscan community shift from cool- and cold-water mollusks to warm-water species. Analyses of $\delta^{18}O$ within the mollusk shells indicate seasonal temperature ranges of 8–22°C in the Bay of Korf samples and 14.7–28.7°C in the Kodiak Island samples, similar to present-day ranges from much lower latitudes. In contrast, samples from the Sea of Okhotsk, at the same latitude as the Bay of Korf, suggest temperature ranges of 0.5–5.9°C, similar to the range that exists today. Both the faunal and the isotopic data further suggest that the climatic changes in the region occurred as a series of events that perturbed a cooler water background, potentially because of warm water advection into the region, in contrast to the situation at lower latitudes, where the Middle Miocene Climatic Optimum is seen as a single event.

Existing theories of the timing and extent of the Eurasian/Fennoscandian ice sheet over the Barents Sea are conflicting. The lack of glacial geomorphic depositional features exacerbates the situation. Recent ^{26}Al and ^{10}Be ages of common glacially eroded bedrock quartz veins and granitic glacial erratics are beginning to shed light on the history of the region. The observed $^{26}Al/^{10}Be$ ratios suggest long prior burial (greater than 200,000 years) and minimal erosion (less than half a meter) during the last glacial maximum. Related work over the East Greenland shelf recently has used seismic and core data to document the retreat of the Greenland ice sheet from the shelf break in the Denmark Strait to the present coast during the period from 17 to 11.5 ka BP. In related studies, a major meltwater pulse from the Greenland ice sheet has been documented to have begun during the Allerod chron and intensified at the onset of the Younger Dryas period. The relationship of this meltwater pulse to the timing of the Younger Dryas remains to be clarified, but theoretical work has suggested that freshwater pulses that alter the thermohaline circulation of the North Atlantic Ocean presage the onset of cold climatic periods. Other work has long suggested a relationship between the commencement of the Younger Dryas and the draining of Lake Agassiz. Recent theoretical and modeling work, though, notes that freshwater pulses from Lake Agassiz would be confined to the shelf/slope regions at least as far south as the Tail of the Grand Banks. This is consistent with the lowered $\delta^{18}O$ in shelf cores and the lack of such a signal in the Nordic Seas. These findings raise questions concerning the role of Lake Agassiz disharge in modifying deep convection in the Nordic Seas and, consequently, driving the Younger Dryas cold period.

Biological Sciences

Research in the biological science emphasizes understanding ecosystem processes and the adaptation of organisms to Arctic conditions.

A study of muco-polysaccharide produced and excreted (exopolymeric substances, EPSs) by microorganims living in Arctic sea ice concluded that EPSs protect microbial communities from encroaching ice crystals through alteration of their microhabitat. The research has yielded a number of interesting results that are of relevance well beyond the original aims of the study. Apart from finding EPS throughout the ice cover in copious amounts, more was learned about its little-known contribution to organic carbon cycling in sea ice. Furthermore, the polysaccharide slime matrix appears to be important in allowing diatoms and other microorganisms to survive and remain viable

at temperatures below –10°C. The study was able to show that a large fraction of the algal population in Arctic sea ice is enveloped in a slimy matrix of EPS, which creates a transparent and flexible physical barrier between the organism and its environment. Since EPS modifies the shape and connectivity of pore space in the ice as fluid inclusions containing microalgae shrink with dropping temperatures, work has begun to investigate other impacts of EPS on the physical properties of ice, leading to interesting insights concerning potential industrial applications of EPS and related classes of polymer compounds that modulate the physical properties of ice. In related studies of bacteria in sea ice, extracellular enzyme activity was clearly recorded at –12°C and indications of activity were recorded at –18°C, a record low temperature for natural samples, while viral activity was recorded as low as –12°C, another record low temperature observation.

Another adaptation to cold environments is the production of anti-freeze proteins (AFPs). A comparative study of beetle larvae in Alaska and Indiana provided insights into polar adaptations. While larvae from both produce similar levels of AFP, the Alaskan larvae develop extreme dehydration during the winter, enhancing the concentration of AFP during winter. This allows their observed mean supercooling point to be as low as –42°C in January 2003, with some individuals having supercooling points as low as –50°C. In the laboratory, some individuals did not freeze at temperatures of –130°C, well below anything that would be observed in the natural environment! Larvae supercooled to below –98°C are vitrified (glassy). Associated studies suggest AFP production, not previously observed, in 19 species of insect and 3 species of spider.

Recent studies have shown that lichens available to caribou and reindeer in Alaska are low in the nitrogen (N) and sulfur (S) required for maintenance and production of lean body tissues. The preferred lichens in the diet of these animals are below the dietary requirement of the animals, although less preferred lichens exceed the requirement. Reindeer and caribou fed low-N diets, similar to lichen and winter forages, do not gain N in late winter, even though lean mass is gained on diets high in N and energy. Lean mass is lost over winter in reindeer and maintained in caribou. Studies of ^{15}N indicate that reindeer and caribou deposit a store of N in autumn and early winter, which is extensively recycled through late winter and spring. Tolerance of low-N diets is therefore due to the mobilization of body protein stores in late winter and spring, especially when calves are born before the resumption of plant growth.

Arctic Social Sciences

The Arctic Social Sciences Program was established at NSF in 1990 and is in the middle of its second decade providing support for social science research across the Arctic. The program is unique at NSF in its support for a diverse portfolio of research projects from many social science disciplines, including anthropology, sociology, economics, political science, geography, 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. Other ways in which the program has increased Arctic social science research is by collaborating with other NSF directorates and other science funding agencies. Currently the program is collaborating with the NSF Directorate for Social, Behavioral, and Economic Sciences on a joint NSF/NEH program called Documenting Endangered Languages. FY 2005 is the first year that Arctic-relevant social science full research projects have been funded through the Biocomplexity in the Environment: Coupled Natural and Human Systems competition. Two projects represented a total of $3.9 million to northern social science research. In addition, the Arctic Social Sciences Program is the first NSF program to cooperate with the EUROCORES initiative at the European Science Foundation to fund Arctic social science research through the Programme BOREAS: Histories from the North—Environments, Movements, Narratives.

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

Pedagogical Grammar of Gwich'in

This research project was funded collaboratively by the Linguistics Program in the SBE Directorate and the Arctic Social Sciences Program through the Documenting Endangered Languages Program

of the NSF and National Endowment for the Humanities. This award funds a Gwich'in scholar who is creating a pedagogical grammar text for use in teaching Gwich'in to students and community members. The Gwich'in language is one of the largest and most unusual of the Northern Athabascan language family. Although the language is severely endangered, there is enormous interest in language revitalization within the Gwich'in community. However, in spite of a rich history of linguistic documentation of Gwich'in, it has no accessible reference or pedagogical grammar. The grammar created by this project will serve as a key component of the developing Gwich'in language curriculum at the Alaska Native Language Center. In addition, it will provide a primary scholarly resource documenting the structure of a typologically unusual language. The grammar will be accompanied by a curriculum guide to aid in the teaching of Gwich'in. This guide may serve as a model that may be adapted for other languages. In addition, interested K–12 language teachers and language learners may find the model beneficial for their own use.

Yatsushiro Research Materials Repatriation

This award provided the resources for the preservation and repatriation of research materials collected by Dr. Toshio Yatsushiro in his 1959–1960 field season in the Arctic indigenous communities in the Nunavut Territory, Canada. Dr. Yatsushiro, now 87 years old, agreed to have the materials preserved and repatriated, including his field notes, household surveys, more than 80 ft of analog tapes of interviews and origin stories, genealogies, maps, over 500 black and white photographs, and more than 600 ft of 16 mm black and white film. Included in the project are contemporary interviews with Yatsushiro about the collection and his field work in Nunavut. The materials will be repatrated to the archives in Iqaluit, the capitol of Nunavut, and copies will be distributed to other interested organizations, such as schools, museums, and colleges. This is an unprecedented act by a social scientist and will not only comply with the communities' wishes for the return of the materials but will also include research among the current residents on the context of memory and history among Arctic indigenous peoples.

Indigenous Knowledge about Arctic Climate Change

This award to the Tapestry Institute, an American Indian institute, is to make indigenous knowledge about Arctic climate change widely available for research and education. The project is to develop a Digital Library of Indigenous Science using materials collected by Snowchange, a non-profit organization located in Finland, working with Arctic indigenous communities in Russia. The Snowchange data consist of audio, video, photographs, indigenous artwork, diary text, and research notes, all on climate change observations from Arctic communities. This project will develop a database in a standardized format, utilizing best practices, to digitize the primary data, produce the metadata that can be utilized by researchers, and develop a format that will be accessible to indigenous, academic, and education communities. In addition, the project is in close cooperation with local indigenous organizations and includes widening the participation of indigenous people in the digital science library effort, as well as disseminating materials to indigenous communities and schools.

Historical Ethnography of Tuberculosis Among Yup'ik Peoples of Southwestern Alaska

This award funds an integrated, medical anthropological research project, drawing on ethnographic, oral history, and archival research methods to examine the complex relationship between Alaska Native culture and contemporary western medicine. Based on the specific case of tuberculosis among the Yup'ik of southwest Alaska, this project will provide insights on how the structures of power and historical processes interacted with Alaska Native experiences. The focus on the Yup'ik experience of the 1930s to the 1990s through the lens of tuberculosis will help shed light on the complexities of radical social and cultural change. There will be extensive local participation, both as researchers and as formal advisors to the project.

Northern Science Education Program

The Northern Science Education Program is the continuation of a Research Experience for Undergraduates grant that provides a unique science education for urban undergraduate minority and non-minority students in Iceland by working on an early human settlement and historical landscape project. Based on the curriculum of interdisciplinary science (such as 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.

Biocomplexity of Sanak Island

The Office of Polar Programs has participated in the Biocomplexity in the Environment priority area since its conception. The Sanak Island project was one of two Arctic-relevant social science research projects funded this year through this program, the other studying the paleobiogeography of Kuril Island. The Sanak Island project will investigate the complex interactions among natural and human systems on and around Sanak Island in the Aleutian chain of Alaska. An interdisciplinary research team will study humans as part of the northern ecosystem. The investigators will examine interrelationships among the modern and prehistoric, terrestrial and marine, and local and regional systems, including both empirical and theoretical explorations. The project will incorporate indigenous knowledge, local history, and direct community participation in data collection, and it will give residents a voice in the scientific process through both collaboration and the analysis of marine policy that directly affects their daily lives.

Arctic Research and Education

Involving students and the broader public in Arctic research is an important goal of the Arctic Sciences Section. The Arctic is a naturally intriguing region, and NSF projects in the Arctic provide a natural hook for science, technology, engineering, and mathematics education. It is also important to provide opportunities for people who live in the Arctic to be involved in the science that NSF supports there. The fund for Arctic Research and Education accomplishes these goals by supporting researchers and educators who integrate research with education through effective and imaginative means.

Arctic Research and Education supports Teachers and Researchers Exploring and Collaborating (TREC), an effort that sends teachers to the Arctic to work with research teams. The TREC program provides hands-on research and professional development experiences for teachers, who then engage their students and colleagues in experience-based learning in the sciences. In two years, over 15 teachers representing over 10 states have been involved in Arctic research. These teachers continue to work together and with other teachers as a learning community of experts who mentor their students and peers in current polar research.

Researchers have also found ways that residents of the Arctic can be integral contributors to their research projects. Arctic residents can enrich projects by sharing traditional ecological knowledge and improving data quality by virtue of being located near field sites year-round. Two funded research projects are benefiting by involving communities and schools in the Arctic. Teachers who are trained by the researchers on data collection protocols lead their students in field data collection of lake snow and ice or river water sampling for large scientific research projects. The teachers receive mentorship from the researchers, the students gain hands-on research experience, and the researchers gain access to time series data with a spatial coverage that they would not be able to obtain without the participation of Arctic communities. The collaboration has other rewards as well, through the cultural exchange taking place among the participants.

Many of the projects supported by Arctic Research and Education are co-funded with other parts of NSF, including programs in the Education and Human Resources (EHR) Directorate, the Geosciences Education program and the Environmental Research and Education program. Other examples of innovative projects sponsored by Arctic Research and Education are:

- Science journalists working on Arctic field research projects to gain a better understanding of the process of science;
- Education and outreach conducted during a dogsled expedition in the Arctic to collect natural and social science data on Arctic environmental change;
- Development of an undergraduate research and education program for interdisciplinary studies of the sustainability and resilience of Arctic communities;
- Graduate student support as part of a Graduate Fellowship in K–12 Education project through EHR;
- Planning workshops for polar science education and outreach; and
- Graduate student travel to scientific workshops and conferences.

These projects and others supported by Arctic Research and Education are part of the effort to ensure the broader impacts of NSF research, to increase diversity in the sciences, and to develop the next generation of scientists and engineers.

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 Congress in 2005. This revision to the U.S. Arctic Research Plan included two major sections. The first of these presented the Special Focus Interagency Research Programs:

- The International Polar Year;
- Arctic Environmental Change;
- Bering Sea Research;
- Arctic Health Research;
- Resource Evaluation; and
- Civil Infrastructure.

The second major section was Agency Programs, which represents the objectives of Federal agencies, focusing on the period covered by this revision (2006–2010). 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
- Education, Training, and Outreach.

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;
- Development of technology and instruments;
- 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 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 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.

The North Slope Science Initiative

Alaska's North Slope encompasses 233,500 square kilometers of diverse and unique ecosystems rich in natural resources. The North Slope Science Initiative (NSSI) is intended to enhance the quality and quantity of the scientific information available for aquatic, terrestrial, and marine environments on the North Slope and make this information available to decision-makers, governmental agencies, industry, and the public.

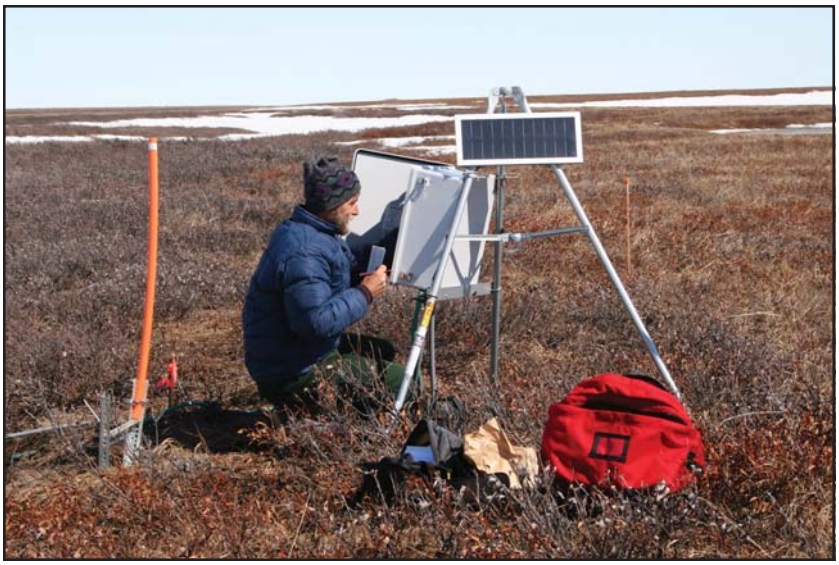
Established by Congress in the Energy Policy Act of 2005, the NSSI will focus on prioritization of pressing natural resource management and ecosystem information needs, coordination and cooperation among agencies and organizations, competitive selection of approved projects, enhanced information availability, and public involvement.

The Alaska leadership of ten local, state, and Federal land and resource agencies, including the Arctic Slope Regional Corporation as the largest private landowner on the North Slope, signed a charter establishing the Oversight Group for the NSSI, consisting of the following:

- The Mayor of the North Slope Borough;
- The President of the Arctic Slope Regional Corporation;
- The Commissioner of the Alaska Department of Fish and Game;
- The Commissioner of the Alaska Department of Natural Resources;
- The Regional Director of the U.S. Geological Survey;
- The Regional Director of the U.S. Fish and Wildlife Service;
- The Regional Director of the Minerals Management Service;
- The Regional Director of the National Marine Fisheries Service;
- The Regional Director of the National Park Service; and
- The State Director of the Bureau of Land Management.

The U.S. Arctic Research Commission and the Department of Energy serve as advisors to the Oversight Group.

Resource management agencies administering the resources of the North Slope of Alaska, include those at the local, state, and Federal level.



Hydrology study. BLM and USGS are cooperating to establish additional hydrologic gauging stations on the North Slope.

Objectives incorporated in the NSSI charter include to:

- Identify and prioritize information needs for inventory, monitoring, and research activities to address the individual and cumulative effects of past, ongoing, and anticipated development activities and environmental change on the North Slope;
- Develop an understanding of information needs for regulatory and land management agencies, local governments, and the public;
- Focus on prioritization of pressing natural resource management and ecosystem information needs, coordination, and cooperation among agencies and organizations;
- Coordinate ongoing and future inventory, monitoring, and research activities to minimize duplication of effort, share financial resources and expertise, and assure the collection of quality information;
- Identify priority needs not addressed by agency science programs currently in effect and develop a funding strategy to meet those needs;
- Provide a consistent approach to high-caliber science, including inventory, monitoring, and research;
- Maintain and improve public and agency access to accumulated and ongoing research and contemporary and traditional local knowledge; and
- Ensure through appropriate peer review that the science conducted by participating agencies and organizations is of the highest technical quality.

Budget

While the Energy Policy Act authorized to be appropriated such sums as are necessary to carry out this initiative, no appropriations have yet passed Congress. Contributions from the member agencies have been pooled to fund the position of Executive Director and some high-priority field studies. A dedicated long-term funding source that meets the objectives of the NSSI is currently being pursued.

2005 Activities

The Oversight Group met several times in 2005 to receive briefings on current North Slope inventory, monitoring, and research activities being conducted by each member agency, as well as the oil and gas industry, related organizations, and the various institutes within the University of Alaska. A database of all activities, now being compiled, will provide access for all project leaders to determine potential opportunities for collaboration and increased communication.

The charter for the Science Technical Group (STG) was drafted by the Oversight Group and approved by the Secretary of the Interior. As required by the Energy Policy Act, the STG will consist of a representative group of not more than 15 scientists and technical experts from diverse professions and interests, including the oil and gas industry, subsistence users, Native Alaskan entities, conservation organizations, wildlife management organizations, and academia. Members of the STG will provide advice on proposed inventory, monitoring, and research functions. The Secretary of the Interior appointed the STG members in January 2006.

Nesting goose on the North Slope. Researching the potential disturbance effects from aircraft, vehicles, pedestrians, and facility noise on populations of molting geese is critical prior to development in areas of high-density waterfowl populations.

Young caribou. Determining the effects of North Slope development on caribou populations and harvests is a priority for NSSI.

Priorities for the Future

The NSSI has developed an understanding of the scientific information needed by researchers and land managers. A 2004 assessment identified a need to develop infrastructure and communication pathways to support the continued exchange of information relevant to the North Slope. These include identifying and incorporating major endeavors, such as National Science Foundation programs for global climate monitoring and research and interfacing with initiatives such as North Pacific Research Board. The 2004 assessment also identified several areas where improvement is needed to afford a more complete understanding and analysis of Arctic environments. The assessment indicated incomplete baseline data for the North Slope at both spatial and temporal scales, insufficiently organized data management, and a lack of coordination to maximize and leverage data use. The NSSI Science Strategy, developed in concert with member agencies, provides a broad strategy for identifying priorities and addressing development issues. An Implementation Plan will be developed this year that incorporates a monitoring plan to more efficiently assess the impacts of oil and gas exploration and development on various surface resources of the National Petroleum Reserve–Alaska (NPRA) and to determine the effectiveness of current mitigation measures and management policies. The following areas within the biological, physical, and social systems sensitive to development on the North Slope have been identified as priorities for the NSSI:

- Regional long-term hydrologic gauging stations in areas of potential development;
- Caribou populations and harvest (the effects of ice roads and facilities on habitat use and migration; disturbance effects from vehicle and aircraft traffic, seismic exploration, and drilling activities; and potential displacement from areas of high forage quality, possibly affecting rates of reproduction and survival);
- Molting geese (the disturbance effects of aircraft, vehicles, pedestrians, and facility noise, potentially affecting survival);
- Potential impacts to fish caused by changes in hydrology from infrastructure and roadways (including ice roads), and changes in water quality caused by water withdrawals or sedimentation and scouring during spring floods;
- Change in access to subsistence resources (altered distribution or abundance of subsistence resources and physical or perceptual barriers to subsistence users);
- Alteration of predator/prey relationships (increased predator populations resulting from human developments and activities, and any resulting adverse impacts on prey species);
- Impacts to local cultural systems (any changes to the sharing network that may result from altered subsistence activities);

Seal hunters. Access to subsistence resources, including altered distribution or abundance of wildlife and physical or perpetual barriers to subsistence users, must be addressed as development expands into new areas of the North Slope.

- Populations of cliff-nesting raptor species (effects of disturbance and habitat loss);
- Effects on migrating bowhead whales in autumn (deflection of migrations from noise associated with barging, seismic exploration, and drilling in marine waters);
- Populations of threatened eider species (effects of collision and oil spill related mortality, increased predator density, habitat loss, and disturbance); and
- Environmental contaminants (oil or hazardous chemical spills, water effluent, and air emissions, resulting in contaminants in water, sediments, invertebrates, plants, fish, birds, and mammals).

The oil and gas industry has also recognized a need for continued technological improvements. To protect the integrity of the unique environment on the North Slope, oil and gas development in this area is subject to the most stringent laws and regulations in the U.S. The industry has conducted inventory, monitoring, and research to understand the effects of oil and gas exploration, development, and production while continuously developing technology that reduces the development footprint. The NSSI will help to integrate and coordinate an approach to making science-based resource decisions that consider the findings of agencies, researchers, and industry. Further development of the NSSI depends on continued support and interest from the U.S. Federal government and relies on participation from Federal, state, and local stakeholders, research institutes, and the oil and gas industry.

While the NSSI has already begun to address some of the priorities listed above, such as dedicating additional funding to establish four long-term hydrologic gauging stations in the NPRA and appropriating additional funding to ongoing research of the Central Arctic caribou herd, a constant funding source is needed to address priority information needs not met by current inventory, monitoring, or research efforts. Once a constant funding source is obtained, the STG will address additional priorities, review proposals to address those priorities, and provide recommendations to the Oversight Group for approval and implementation.

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 addition, MMS is the lead agency for Federal offshore renewable energy and alternate use of America's offshore public 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 (ESP), focuses on issues related to assessing and predicting potential environment and socioeconomic impacts. MMS utilizes the capabilities of universities, private firms, and state and Federal government laboratories to carry out most of its research.

Technology Assessment and Research Program

The MMS supports an active research program to understand the engineering constraints for offshore operations, especially as they relate to the structural integrity of structures 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 has two functional research activities: Operational Safety and Engineering Research (OSER) and Oil Spill Research (OSR).

	Funding (thousands)	
	FY 04	FY 05
Technology Assessment & Research	434	689
Environmental Studies Program*	5,915	5,054
Total	6,349	5,743

*Includes research conducted in Cook Inlet, Alaska

The MMS 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 clean-up of oil spills. Ohmsett is the only facility in North America where full-scale response equipment and techniques (such as containment booms, skimmers, chemical dispersants, and remote sensing equipment) can be tested in a controlled environment using real oil.

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 has provided new goals and directions for offshore oil and gas research initiatives.

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 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 organization factors and how they can be addressed to mitigate accidents;
- The aging offshore infrastructure, including platforms and pipelines;
- The impacts of hurricanes Ivan, Rita, and Katrina; and
- Oil spill mitigation measures, should a spill occur (including remote sensing and surveillance, containment and cleanup technologies, chemical treating agents and dispersants, in situ burning, and sorbents).

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 increased interest by the oil and gas industry in Arctic offshore resources.

Sea ice is still the most severe environmental hazard to future offshore development in the Arctic. Such hazards include forces that moving sea ice may exert against offshore structures, icing of structures resulting from freezing spray, gouging of the sea floor 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.

Phase I of a study of interstitially insulated pipe found that the use of a low-thermal-conductivity, high-strength wire screen mesh between a pipe and its interior liner creates superior passive thermal insulation for cold-water (i.e. Arctic and deep water) flow lines and risers. The screen mesh creates an "air gap" or thermal resistance between the pipe and liner, thus reducing heat transfer. Further reductions were gained by adding a layer of Mylar film. Experiments with coupons of pipe/mesh/liner materials found that the thermal conductivity was reduced by up to 50 times over pipe material alone. Now under Phase II, laboratory experiments on a small-scale prototype are being conducted to validate the concept with regard to a pipe's geometry and to demonstrate its performance under steady and transient flow conditions. A model to estimate the thermal performance of the system under realistic conditions will be developed and calibrated with experimental data. The interstitially insulated pipe's insulation system is expected to be comparable with other insulation systems presently used for subsea applications, and it could prove to be less expensive, easier to install, and more robust than present insulation technologies.

Another project is identifying and assessing the current state of the practice for the construction and maintenance of ice islands. It will evaluate ice island technology to identify areas where further research and development would decrease the effort required to construct and maintain ice islands.

To better understand the challenges, impacts, and possible solutions that the oil and gas industry faces in the Arctic, MMS contracted with Det Norske Veritas to conduct a two-day workshop in May 2004 on the fundamentals, technical issues, and remediation of vortex-induced vibration of free-spanning pipelines in Cook Inlet, strudel scour in the Beaufort Sea, and wind-induced vibrations for elevated pipelines on the North Slope.

Oil Spill Response Research

The MMS is the principal U.S. government agency funding offshore oil spill response research. Through funding provided by MMS, scientists and engineers from the public and private sectors worldwide are working to address outstanding gaps in information and technology concerning the cleanup of oil spills. Credible scientific research and technological innovation 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. Information derived from the Oil Spill Response Research 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. The OSRR program has funded a variety of projects to develop and improve Arctic oil spill response. MMS research currently underway focuses on four types of response technologies: remote sensing and surveillance, mechanical response, chemical treating agents including dispersants, and in situ burning.

Chemical Treating Agents and Dispersants. 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 they are seldom used. Analyses of tradeoffs between dispersant use and conventional mechanical recovery demonstrate 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. The 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 meso-scale 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 Subarctic environments. The results of this research will facilitate the acceptance and use of dispersants throughout the U.S and North America.

An international joint research project gathering data to support decision makers in the process of determining whether dispersants should be

Radar team from Boise State University towing one of the two radar systems used at the U.S. Army Cold Regions Research and Engineering Laboratory to map oil under the ice in 2004.

used in low-energy environments. This information will be useful for dispersant decision making in ice cover (an ice field reduces wave motion) or other calm conditions. Questions to be addressed are:

- Will the dispersant stay with the oil until there is enough energy to disperse the slick?
- How much energy is needed to disperse the slick after dispersants are applied?
- If energy is provided to facilitate dispersion, will the droplets stay in the water column after mixing or will they resurface?

The researchers are working on laboratory-scale dispersant effectiveness tests in which four commercial dispersants have been applied to four oils (a naphthenic oil, an asphaltenic oil, waxy oil, and a paraffinic oil). Additional tasks for this project include developing a numerical model to predict the energy needed to shear dispersed oil droplets from a slick and energy needed to keep a dispersed oil droplet in the water column and validating the numerical model using test tanks. This project currently has nine partners representing the oil industry and agencies from Texas and Canada.

Remote Sensing and Surveillance. The present inability to reliably detect and map oil trapped in, under, on, or among ice is a critical deficiency, affecting all aspects of response to oil spills in ice. Although there is still no practical operational system to remotely detect or map oil in ice, there are several technology areas where further research into ground-based remote sensing could yield major benefits. Examples include ground-penetrating radar, optical beams for river spills, and vapor detection (for example, gas-sniffer systems) for oil trapped in and under ice.

A project that is developing new and innovative equipment and technologies for the remote sensing and surveillance of oil in and under ice is now in Phase 2. This project represents follow-on work to develop technologies to detect oil located in or under ice. In one task, detailed chemical analyses were completed to complement and further interpret results obtained from ethane flux measurements. Additionally, analyses were completed to enable efficient acquisition of data in the form necessary to properly measure and account for sea ice anisotropy and signal depolarization. In another task, field testing of several radar systems and antenna configurations over a variety of sea ice conditions was completed at Prudhoe Bay in 2005. A three-person team documented the ability of the systems to reliably measure sea ice up to 2 m thick and explored the potential to operate in rough ice areas commonly encountered as part of the land-fast ice. The Prudhoe Bay trials also provided an opportunity to further monitor the performance of the electronics at low temperatures.

Radar team at Prudhoe Bay in April 2005 during cold weather reliability trials and thick ice (up to 6.5 feet) profiling without oil.

In still another task, software is being developed and tested to provide for near-real-time data analysis, to determine and account for sea ice anisotropy and signal depolarization caused by surface irregularity, and to develop and test combined GPR attributes to minimize the potential for false positives. All analysis software was tested both with the data previously acquired in the test

basin at the U.S. Army Cold Regions Research and Engineering Laboratory and with new data collected on natural sea ice during April 2005 field tests. These data were used as input into a suite of model predictions showing the expected radar performance in a variety of oil-in-ice scenarios (varying thickness, oil pool depth, etc.).

The ultimate goal is to test a developed radar system incorporating improvements described above with crude oil spilled under actual sea ice over a large enough area to allow airborne measurements. Given the constraints on permitting such work in North America, the only realistic location for such work is Svalbard, Norway. Planning has been completed for a full-scale field experiment to evaluate the ability of ground penetrating radar to locate and map crude oil in and under sea ice in April 2006.

Ohmsett–The National Oil Spill Response Test Facility. Ohmsett 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 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, U.S. Navy, National Oceanic and Atmospheric Administration, and Environmental Protection Agency.

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 enable the Ohmsett facility to remain open year-round, offering cold water testing and training during the winter months. Recent testing activities include evaluation 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. Additional information describing Ohmsett is available online at www.ohmsett.com.

Environmental Studies Program

Environmental studies have been conducted in Alaska under the auspices of the Department of the Interior's Outer Continental Shelf offshore oil and gas leasing program since 1974 to obtain information needed to make sound leasing decisions and to monitor the human, marine, and coastal environments. More than $285 million has been spent on studies in 15 OCS planning areas in the Arctic, Bering Sea, and Gulf of Alaska subregions. 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, local and traditional knowledge sources, research contractors, scientists, and government personnel from Federal, state, and local agencies help the MMS 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.

Coastal Marine Institutes (CMI) were initiated by MMS to take advantage of highly qualified scientific expertise at local levels and to achieve cooperative research goals in key OCS regions. In 2005, the MMS renewed funding of the CMI at the University of Alaska Fairbanks (UAF) to benefit from its scope and depth of scientific expertise. This cooperative agreement commits up to $1 million per year for research if matching state or other non-Federal funds are available. The CMI 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 CMI, managed by the internationally renowned UAF School of Fisheries and Ocean Science, creates an opportunity for the MMS and the state to jointly accomplish research that could not otherwise be carried out. In addi-

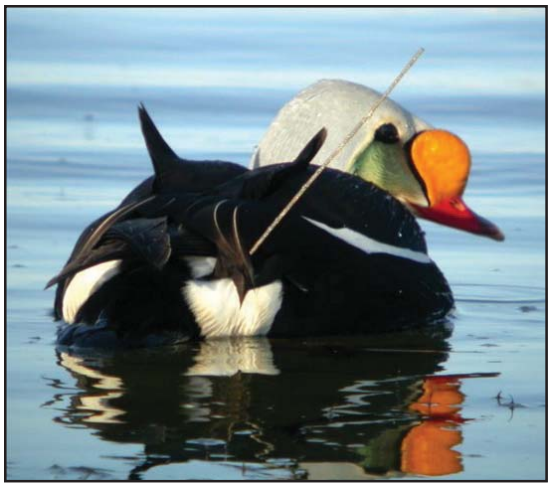
tion to 28 ongoing studies, several new studies are being evaluated for funding through the CMI in 2006.

Endangered and Protected Species

Marine mammals. The bowhead whale, an endangered species of high importance to Native cultures in the Arctic, migrates through areas of oil and gas exploration and development, including near the Northstar offshore production site. Efforts to monitor the fall migration of bowhead whales and related environmental factors continued through 2005 as the MMS conducted its Bowhead Whale Aerial Survey Project (BWASP). BWASP results indicate that fall bowhead whale sightings tend to be farther offshore in heavy ice years across the central Alaskan Beaufort Sea. 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.

A recently initiated effort to document the movements and migratory behavior of bowhead whales using satellite tagging began in 2004 as an MMS/UAF CMI project designed to study the feasibility of direct involvement of Native hunters in the deployment of the tags. In 2005, MMS funded the Alaska Department of Fish and Game to coordinate a five-year effort to tag bowheads, with extensive involvement of whale hunters from villages along the migratory route of the bowhead whale from Kaktovik to Savoonga, Alaska.

Ringed seals are the primary prey of polar bears and also a significant source of food for Natives living in the Arctic. A recently completed MMS/UAF CMI project focused on the timing and reinterpretation of ringed seal surveys as a follow-on to a previous study that developed correction factors for ringed seal surveys in northern Alaska. Sixty ringed seals had been monitored with radio-transmitters. The proportion of seals visible during aerial surveys was found to vary as a function of snow conditions on the surface of shorefast ice. A correction factor has been developed, and density estimates derived from previous surveys are now being reanalyzed.



Male king eider with an internal satellite transmitter.

Harbor seals are another important subsistence species that is abundant in the Gulf of Alaska region, including Cook Inlet. In 2003, the MMS funded two new studies of harbor seals conducted by the National Marine Fisheries Service, National Marine Mammal Laboratory. The first of these supported repeated, seasonal aircraft surveys of seals at haulouts to characterize the distribution and abundance of harbor seals in Cook Inlet, with an emphasis on the seasonal variability in relation to key life history events. The second study uses remote cameras to observe variations in haulout patterns at selected haulouts. This study will provide insight into sources of variation in observations by the aircraft surveys. In 2004, the MMS funded a related study, Movements and Habitat Use of Harbor Seals in Cook Inlet, that employs satellite tags to study individual harbor seals. This suite of studies is expected to provide comprehensive information for evaluating the potential effects of oil and gas development on the Cook Inlet population.

Another marine mammal study was funded by the MMS through an Interagency Agreement with the U.S. Fish and Wildlife Service. The study, 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 whale hunters near the village of Kaktovik (in the Arctic National Wildlife Refuge) and near a traditional subsistence whale hunting camp on Cross Island (near Prudhoe Bay). Increasing numbers of bears have aggregated and fed on whale remains at these locations. This study is yielding important new data on the patterns of use of these sites by individual bears and on other bear behaviors and will be useful for providing better estimates of bear mortality.

Seabirds. Eiders (a group of sea ducks) are harvested for subsistence by Alaska Natives, who have expressed concerns that the abundance of four species living in the Alaskan Arctic may be declining. From 2001 to 2003, the MMS funded

five research projects through the MMS/UAF CMI that study the population biology of eiders and the potential risk of effects from offshore oil and gas development. A new study of king eiders discovered that king eiders staged (the duration varied by sex) in the Beaufort Sea before migrating south-southwest to molt along the Chukotka and Kamchatka Peninsulas and Mechimegan, Karagin, and Anadyr Bays in Russia and in U.S. waters off St. Lawrence Island and the Alaska Peninsula. Marked king eiders with functioning transmitters

Scientist placing a temperature datalogger in a king eider nest at the Kuparuk oilfield.

wintered along the Chukotka and Kamchatka Peninsulas in Russia and in Kvichak and Togiak Bays and along the Alaska Peninsula in U.S. waters.

A multiyear study of the breeding biology and habitat use of king and common eiders on the coastal plain of northern Alaska examined and compared timing of nesting, 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 oilfield (2002–2004). The number of monitored nests varied by year and area, with 37–44 and 31–42 nests monitored each year at Teshekpuk and Kuparuk, respectively. Apparent nest success each year ranged from about 18–33% and 26–43% at Teshekpuk and Kuparuk, respectively. Incubation constancy was high (95–98%) for female king eiders at both sites, though incubation behavior appeared to differ. Nest site selection apparently differed for females nesting at the two study sites.

Another study, King and Common Eider Migrations Past Point Barrow, repeated migration counts of king and common eiders during the spring and fall (2002 and 2003), similar to surveys conducted periodically for several decades. The 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 indicate differential peaks in migration chronology for king and common eiders, at least in the fall. In addition, there appeared to be variation in the timing of fall migration relative to sex and age for a given species. Estimates of passage for king eiders suggest that this population may no longer be declining and may have actually increased since 1996. In related research, stable isotopes were used to analyze marine versus freshwater "signatures" from feathers collected from eiders (largely from subsistence hunters at Barrow) during 2003 and 2004. During wing molt, there appeared to be sex-specific differences, with female diets coming from both marine and freshwater habitats, while male diets were largely derived from marine habitats. The third study, Population Structure of Common Eiders Nesting on Coastal Barrier Islands Adjacent to Oil Facilities in the Beaufort Sea, was 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. The results of this study indicate that common eiders breeding on the North Slope of Alaska are genetically distinct from other eider breeding groups. It appears that common eiders were historically subdivided into two refugia during the last Pleistocene glaciation and that North Slope common eiders may have been colonized from a different refugium than eiders elsewhere in North America and Scandinavia. In addition, because of the high fidelity of females and young to nesting areas, gene flow appears to be largely mediated by males.

A study of the foraging ecology of common ravens 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 industrial areas of Arctic Alaska. Among the questions this study is addressing is whether industrial infrastructure is advantageous to ravens and the extent to which proximity to such infrastructure

Common raven nest at the Kuparuk oilfield.

increases raven depredation of eider nests and ducklings. During the spring and summer of 2004, 10 adult breeding ravens were captured and fitted with transmitters to document their home range size and movements in and around Kuparuk and Prudhoe Bay. In addition, 17 nests (7 at Kuparuk, 10 at Prudhoe Bay) were monitored to determine nest site selection, nest success, and number of young fledged; some fledglings were color-marked to document dispersal, movements, and fidelity. Pellets were collected in the vicinity of nest sites to determine diet. Additional data were also collected during the spring and summer of 2005, and these data are being analyzed.

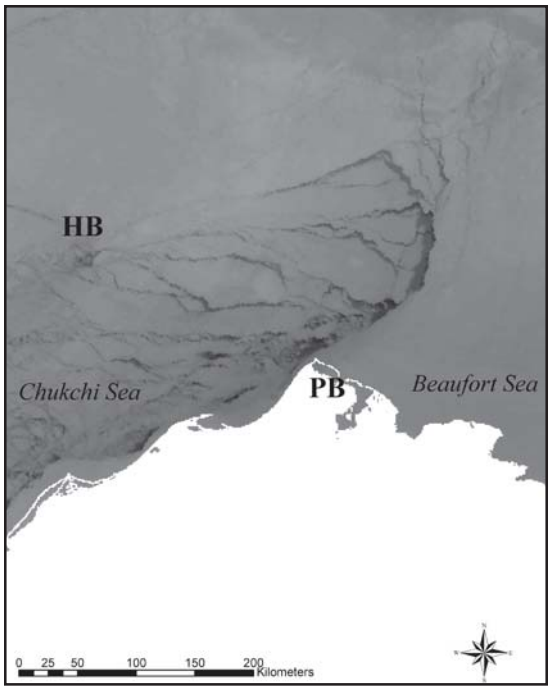
Physical Oceanography

The study entitled Synthesis and Collection of Meteorological Data in the Nearshore Beaufort Sea has collected over four and half years of meteorological data from five stations along the central Beaufort Sea coast. A project web site (www.resdat.com/mms) provides up-to-date project information, station locations, pictures, data downloads, and quarterly graphical data results. When completed, this study will provide a time series of wind data from January 2001 through September 2006. The wind data have been used to compare coastal and offshore winds along the central Beaufort Sea coast to surface current data collected from high-frequency Doppler radar and sub-surface current information collected with acoustic Doppler current profiler meters. MMS will continue to collect data from these stations through September 30, 2006.

During the summer of 2005, researchers from the Geophysical Institute at the University of Alaska Fairbanks stationed two high-frequency Doppler radars (CODAR) at BP Exploration, Alaska oil fields at Endicott and West Dock located along the Beaufort Sea coast for radar mapping of the surface circulation in Alaska coastal waters. Surface current measurements were transmitted in near real time to a central web site at the University of Alaska Fairbanks http://www.ims.uaf.edu/salmon/CIBS-MAP/index.htm. From June through the middle of October, two CODAR systems collected surface current speed and direction measurements over approximately 5000 square kilometers. The 12- and 25-MHz CODAR systems collected surface current data in open water and mixed ice conditions in front of the remnant landfast ice (June and July), in mixed ice conditions during breakup of the inner shelf ice (July and August), and out to 80 km during open water conditions (September and early October). Preliminary results indicate that the surface current measurements correlated well with wind measurements collected from the local MMS meteorological stations, although local changes in bathymetry and other variables may have also played a role in steering the surface currents offshore. These data are being analyzed. A second season along the Beaufort Sea coast is planned for the summer and fall of 2006. This project was undertaken as a collaborative effort with NOAA through the National Oceanographic Partnership Program.

Researchers from the Geophysical Institute at the University of Alaska Fairbanks processed and interpreted over 10 years of Radarsat synthetic aperture radar (SAR) and advanced very high resolution radiometer (AVHRR) data to map and document changes in the spatial and temporal distribution of recurring lead systems and landfast ice off the coast of northern Alaska in the Chukchi Sea between Wainwright and Barrow and the Beaufort Sea between Barrow and the Mackenzie River Delta. One conclusion was that major lead patterns and landfast ice extents were found to recur from year to year. These patterns are controlled to a large extent by a combination of topo-

MMS Cottle Island Meteorological Station, summer 2002.



Leads converging to grounded ice on Hanna Bank (HB) in the Chukchi Sea, Alaska, April 8, 1994. PB is Point Barrow, Alaska. The dark spot at Hanna Bank is open water or thin ice on the "downstream" side of the grounded ice.

graphic (bathymetric) constraints, atmospheric forcing, and large-scale ice dynamics.

Three MMS/UAF CMI oceanographic studies completed four of six years of planned effort, including the first successful winter-long measurements of currents directly under the ice at three locations from Camden Bay to Smith Bay in the nearshore Beaufort Sea. Three upward-looking acoustic Doppler current profilers were moored on the sea bottom to profile the entire water column. They have collected data on water and ice velocity, temperature, salinity, and water clarity (transmissivity) from August 1999 to August 2002 and from August 2004 to August 2005. Once landfast ice formed and blocked the wind, current speeds dropped drastically, with less than 1% of current speeds exceeding 20 cm/s. The most recent study, Beaufort Sea Nearshore Currents, will continue to deploy three similar moorings for two additional years.

A MMS/UAF CMI study entitled Sea-Ice-Ocean-Oil Spill Modeling System (SIOMS) for the Nearshore Beaufort and Chukchi Seas: Improvement and Parameterization continues the development of a new 3-D coupled ice-ocean model with links to a regional mesoscale atmospheric model. The resolution of the model is 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.

Two other modeling efforts are proceeding in parallel to help advance the state of the art in ice modeling. The MMS/CRREL Simulation of Landfast Sea Ice along the Alaska Coast study focuses on seasonal development of the extensive landfast ice zone along the Beaufort Sea coast, including breakout events. A new study, Basin Scale Model of Sea Ice Dynamics, is developing a state-of-the-art ice model that will include deformation on discontinuities and anisotropic failure to better describe the behavior of pack ice. This is a collaborative project with NASA on oriented fracture patterns and frazil/pancake ice formation.

Another MMS/CMI effort to collect monthly in situ measurements of boundary conditions in lower Cook Inlet is ongoing. The results of this study, along with recently concluded in situ measurements to characterize hydrographic effects on salinity and temperatures and the effects of diurnal and semidiurnal tidal cycles, will improve the results of oceanographic modeling for Cook Inlet.

Fate and Effects

The MMS study Empirical Weathering Properties of Oil in Snow and Ice is examining the behavior in snow and ice of a range of Arctic Alaska crudes in small-scale and OHMSETT-scale experiments. Included are spreading over and under ice and snow, spreading through broken ice, migration through brine channels, and evaporation at very low temperatures, all for low- and high-pour-point crudes. The primary purposes are to improve our understanding of how specific crude properties affect oil behavior and weathering in Arctic conditions and to develop better Arctic algorithms for oil weathering models. The MMS is investigating oil spill occurrence estimators for Arctic conditions through a study called Alternative Oil Spill Occurrence Estimators for the Beaufort and Chukchi OCS, Statistical Approach and a parallel series of fault-tree studies, most recently Alternative Oil Spill Estimators for the Beaufort and Chukchi Sea, and Updates to Fault Tree Approach to Oil Spill Occurrence Estimators for the Chukchi and Beaufort Sea Planning Areas. These studies address differences in potential spill causes in these Arctic areas compared to elsewhere in the U.S. OCS, primarily the Gulf of Mexico.

Marine Fish

Arctic cisco, a whitefish especially important for subsistence by Nuiqsut residents, are shared with other villages throughout the region. Recent low subsistence catches have raised concern about the possible causes of the variable catches. An ongoing study, begun after a 2003 workshop

of scientists and local elders, is collating and evaluating existing fisheries oceanography information to answer many of the questions raised and to suggest the most important information to collect in the future. The current study also emphasizes methods to integrate information through the joint efforts of local experts and scientists. This information will have increasing importance as oil and gas resources are developed in the Beaufort Sea.

Arctic cisco caught in a subsistence net that had been set under the ice in the Colville River, Alaska.

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 as a means to locate and evaluate overwintering habitats. An effort to quantify inter-annual variation in winter abundances and to estimate which environmental factors contribute to observed variation will help minimize or avoid potential effects of offshore development on anadromous species.

Drift gillnetter in Cook Inlet, Alaska.

Socioeconomics

MMS environmental research in Alaska has included social and economic studies relating to the potential effects of offshore oil and gas development since the program's inception. Because of the distinctive nature of subsistence activities and socio-cultural attributes throughout rural villages and coastal communities in Alaska, MMS social research goes well beyond conventional economic considerations.

MMS initiated a study in 2001 to describe the potential impacts of OCS activities on bowhead whale hunting and subsistence activities in the Beaufort Sea. The study, to be completed in 2006, focuses on Native perceptions of the acute and cumulative effects of oil industry operations on bowhead whale hunting. The study has collected information from residents of Nuiqsut, Kaktovik, Barrow, and Savoonga through survey instruments and considers both beneficial and detrimental potential effects.

Another socioeconomic project has developed and will implement a GIS mapping system to describe subsistence hunting and fishing activities for Nuiqsut, Kaktovik, and Barrow for bowhead whales, ringed seals, caribou, Arctic cisco, broad whitefish, Arctic char, and various waterfowl. The project focuses on describing contemporary subsistence patterns while accommodating the addition of past and future harvest data to enable the analysis of pattern changes over time. A sample of hunters in each community has been selected using systematic social networking methods. In addition, the project is documenting the location of harvest campsites and travel routes.

In Cook Inlet, the prospect of OCS oil and gas development has the 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 completed in 2004 determined that:

- Navigational challenges and spatial conflicts may be avoided through strategic planning on the part of the oil and gas industry and its regulators.
- Many problems for the drift gillnet fleet potentially associated with prospective drilling on the OCS can be mitigated.

Stern section of the Selendang Ayu, *December 2005.*

- The salience of the issue of interaction between the fishery and the oil and gas industry is in reality overshadowed by a host of economic and social challenges confronting the drift fleet.

On Kodiak Island, a study began in 2003 to collect and analyze data on the socio-economic 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 followed 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. The study was modified in 2005 to include a longitudinal analysis of the accidental grounding, spill, and potential litigation of the M/V *Selendang Ayu* along the Bering Sea coastline of Unalaska Island.

A study entitled "North Slope Economy, 1965 to 2005" is analyzing local government revenues and expenditures, including capital projects of coastal communities (both prior to and after the formation of the North Slope Borough), as well as property tax and other fiscal categories that merit analysis. The study:

- Classifies local government services by departments and other major categories;
- Describes how the revenues and expenditures have been a component and shaping force of the local economy;
- Describes the structure of the economy, including employment, income, and their fluctuations;
- Describes how quantifiable, non-cash economic factors for households have changed from 1965 to 2005 in relation to the greater availability of salaried jobs;
- Describes the role of the Arctic Slope Regional Corporation, the Ukpeagvik Inupiat Corporation, and other village for-profit corporations in the economy; and
- Describes how individual and household economies have responded to changes in the regional economy.

Some of the empirical measures include income and changes in quality of life such as housing and sewer and water facilities. The final report was published in April 2006.

In 2005, MMS began the process of working cooperatively through the Cooperative Ecosystem Studies Units (CESU) Network to initiate a new social research study to provide an empirical basis from which to quantify food sharing behaviors and to assess the plausibility of hypothetical associations between regional oil development

activities and changes in distribution or consumption of subsistence resources over time and geographic space. This is necessary because existing subsistence harvest data may be insufficient to assess the impact of potential disruptions.

Based on the extensive social research in Alaska and the substantial information accumulated over 30 years, MMS will soon publish a book that will enhance the accessibility of research products and summary findings for all interested parties. Currently under review for publication, the peer-reviewed book explains and synthesizes the results of more than 200 MMS-funded studies.

Environmental Research Monitoring

The Alaska OCS Region has collected baseline monitoring data in the vicinity of the Liberty Prospect and Northstar since 1999, as part of the ANIMIDA (Arctic Nearshore Impact Monitoring in the Development Area) study and its continuation, cANIMIDA. Designed to provide long-term continuity beyond what could be expected through industry-sponsored studies alone, ANIMIDA and cANIMIDA study:

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

BPXA put its plan for developing the Liberty Prospect on hold in January 2002; as of January 2006, it is pursuing options for development and production through directional drilling from onshore. Offshore development is still possible at this site or others in the central Beaufort Sea. Thus, the summer of 2007 will be the last field season for cANIMIDA until further developments occur.

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, 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 near-shore Beaufort Sea has remained relatively clean as far as trace metals and hydrocarbons are concerned, despite the adjacent petroleum-related industrial activities over the past 30 years. A follow-up CMI study documents trace metals and hydrocarbons in sediments across the Beaufort Sea from Elson Lagoon near Barrow, to Prudhoe Bay, to Beaufort Lagoon in the eastern Alaska.

More information about the MMS Alaska OCS Region's ongoing environmental research monitoring projects can be obtained at http://www.mms.gov/envmonitoring/ResearchMonitoring.htm.

Information Management and Transfer

Studies within the Alaska program generally result in data and scientific peer-reviewed products derived from the analysis or summarization of data and expressed in reports published on paper or as electronic media. Most Environmental Studies Program (ESP) information is acquired by MMS through contracts, or other agreements, that support scientifically qualified entities to acquire, analyze, report, and archive relevant data. Organizations conducting oceanographic studies for MMS generally archive data at the National Oceanographic Data Center (NODC), in addition to any in-house systems they may have developed. MMS direct archival of some ESP-generated data is also accomplished within the MMS's centralized corporate database.

Reports and analyses resulting from studies supported by MMS are readily available from two sources. Copies of all MMS final reports by investigators are available at the Alaska Resources Library and Information Services (ARLIS). Another convenient source for hundreds of MMS final reports is the Environmental Studies Program Information System (ESPIS), which is easily accessed by the public through the ESP web site (http://www.gomr.mms.gov/homepg/espis/espisfront.asp). Additional information describing environmental studies in Alaska can be found at the MMS web site (http://www.mms.gov/alaska/ess/index.htm).

MMS Alaska OCS Region held its Tenth Information Transfer Meeting in Anchorage in March 2005. Principal investigators presented information on 43 ongoing studies in the Beaufort Sea, Chukchi 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. Also, an Information

Update Meeting was convened by the MMS Alaska OCS Region in Barrow in March 2005. The MMS and officials of the North Slope Borough scheduled this meeting in Barrow 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.

In 2004, the MMS Alaska OCS Region also sponsored an international workshop designed to produce recommendations regarding future Arctic Alaska hydrological modeling research needs. The MMS/UAF CMI workshop brought together international hydrological modelers and researchers to develop strategies to advance the state of the art in hydrological modeling.

Coordination and Cooperation

The Environmental Studies Program in Alaska carries out extensive coordination in the planning of research and conduct of ongoing studies. A major portion of the ESP in Alaska is conducted on a cooperative basis with the University of Alaska Fairbanks (UAF). In addition to funding CMI scientific research, a substantial portion of the MMS contribution supports education in Alaska by funding tuition and travel for UAF graduate-student research related to CMI projects.

The ESP in Alaska also coordinates with other U.S. and local research entities and has developed additional international linkages with other Arctic nations' research and regulatory entities. The U.S. and seven other Arctic nations voluntarily agreed to cooperate on an Arctic Environmental Protection Strategy (AEPS), which evolved into the formation of the Arctic Council in 1996. The ESP in Alaska maintains contacts and coordination with Arctic Council activities, such as the Arctic Monitoring and Assessment Program (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Arctic Climate Impact Assessment (ACIA), and others. The ESP provides information to these working groups through review of reports and plans, and it helps to inform participants of available information sponsored by MMS. Further, specific studies that can coordinate and integrate with working group activities are identified and beneficial linkages facilitated.

The polar regions play a key role in our global environment. Many important broad and interlinked research challenges involving polar regions exist today. At its most fundamental level, the International Polar Year (IPY) 2007–2008 is a coordinated campaign of polar observations, research, and analysis that will be multi-disciplinary in scope and international in involvement. The IPY will use today's research tools to better understand the key roles of the polar regions in global processes. MMS has several proposed studies that are expected to dovetail with the IPY activities.

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 04	FY 05
Migratory Birds	3,550	3,490
Fisheries and Ecological Services	3,875	3,552
Marine Mammals	2,822	2,759
Refuges	8,761	8,494
Conserv. of Arctic Flora and Fauna	190	190
Total	19,198	18,485

Fisheries and Ecological Services

Fishery research in the Arctic by the FWS continues to focus on Yukon River salmon shared by the U.S. and Canada in support of the U.S.–Canada Yukon River Salmon Agreement. The FWS continues to implement enumeration techniques for Yukon River salmon to quantify abundance and to apply genetic stock identification techniques to assess genetic diversity and estimate the run timing of salmon stocks. These studies also generate data needed for in-season management of Yukon River salmon, including distinguishing those that are of Canadian origin. Research includes a mark–recapture study of fall chum salmon at Rapids/Rampart that uses video technology to determine the marked-to-unmarked ratio of these fish as well

as the catch-per-unit-effort for Chinook and fall chum salmon. To manage U.S. stocks of salmon, the FWS also 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. FWS also shares responsibility with an Alaskan Native nonprofit organization to operate a weir on Henshaw Creek to enumerate summer chum and Chinook salmon. Split-beam sonar is used to count fall chum salmon on the Chandalar River, and new imaging sonar is being tested to count Chinook in the same stream. 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 also becoming recognized.

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. In conjunction with physical movement studies, genetic work is being conducted to define the population structure of Alaskan whitefish, which will help to determine the geographical scale at which these species should be monitored and managed.

Fish stocks of Alaska's North Slope in the Arctic National Wildlife Refuge have also received 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-per-unit-effort, length frequencies, and length–weight relationships will be compared to baseline data collected on these species between 1988 and 1991. A second study is testing imaging sonar as a method for estimating the number of Dolly Varden that return to spawn in the Hulahula River. A third study is also testing the imaging sonar as a method for identifying unique habitats within the nearshore Beaufort Sea. These studies will provide valuable information to use for conserving these populations should the area be made available for oil and gas development.

Similar to whitefish, Dolly Varden is an important component of sport and subsistence fisheries and shows complex movement patterns between spawning and overwintering areas in fresh water and feeding areas in marine waters. Genetic data are being used to estimate the extent of reproductive isolation among Dolly Varden populations and to estimate the origin of Dolly Varden in overwintering areas. The data indicate that Dolly Varden return to natal streams to spawn; Dolly Varden overwintering in the Wulik River in Northwestern Alaska are a mixture of Dolly Varden originating from streams in Norton and Kotzebue sounds, but Dolly Varden overwintering in the Ivishak River, a tributary to the Sagavanirktok River on the North Slope, originate mainly from the Sagavanirktok River. These results show how Dolly Varden movement patterns vary across Arctic Alaska.

Environmental Contaminants

The FWS and its partners have actively pursued scientific studies and management solutions related to contaminants exposure in the Arctic for several decades. International research efforts such as the Arctic Monitoring and Assessment Program (AMAP) have shown that pollutants are both a circumpolar issue and a global issue. Highlights from FWS contaminants studies that were conducted or published during 2004–2005 are summarized below.

The Alaska breeding population of red-throated loons declined 53% from 1977 to 1993 and has since remained at a low level. Environmental contaminants specialists with the FWS served as co-investigators with the U.S. Geological Survey's Biological Resources Division (USGS-BRD) on an investigation to determine factors contributing to these declines in various parts of Alaska. Contaminant samples were obtained from eggs and whole blood from four Alaskan study areas: the Colville Delta on the North Slope; Cape Espenberg on the northern Seward Peninsula; the Yukon–Kuskokwim Delta; and the Copper River Delta. The study found that red-throated loons that nest in northern Alaska and winter in Asia have a different suite of contaminants, and greater body burdens, compared to other Alaska-nesting loons that winter along the Pacific coast of North America.

Although the direct toxic effects of large oil spills on sea ducks are relatively well understood,

the risk from low-level chronic oiling has received less attention. FWS biologists in the Environmental Contaminants Program served as co-investigators with the USGS-BRD on the effects of chronic oiling on sea ducks at Sand Point and Dutch Harbor, Alaska. Both Steller's eiders and harlequin ducks from industrialized areas such as Dutch Harbor show increased blood biomarker responses (indicating contaminant exposure) compared to other areas. Mussels and sediments from Dutch Harbor also exhibit greater contaminant concentrations than in other areas sampled. This project included collaboration with the FWS's Endangered Species program and the Alaska SeaLife Center (ASLC). Technical reports on the sea duck and red-throated loon studies will be completed in 2006.

Lead exposure from spent shot was identified as the primary contaminant concern for threatened eiders and other declining waterfowl species in Alaska by investigations completed by the FWS in 2004. In 2005, management actions to address this problem included a renewed focus on reducing lead shot input into Alaska's environment, primarily through outreach activities such as community and school presentations, partnerships with communities to develop their own lead shot outreach programs, incorporation of lead shot messages into other regional outreach products (including subsistence hunting regulations), and steel shot clinics and law enforcement activities. Because the use of lead shot to hunt waterfowl and other food items has the potential to result in unhealthy exposure to lead, particularly in children, the FWS has worked with human health professionals to explore links between human health, bird health, and lead shot. The FWS's partners in this effort include the USGS's Alaska Science Center, the ASLC, the Alaska Native Tribal Health Consortium, and the Centers for Disease Control.

Environmental contaminants specialists with the FWS are investigating the presence of mercury in northern pike, a locally important subsistence food item. Northern pike from Alaska contain mercury concentrations that often exceed the Environmental Protection Agency's critical value for human consumption and the Food and Drug Administration's action level for human consumption of fish tissue. For example, in 1987, eight of nine northern pike from Nowitna National Wildlife Refuge (NWR) and six of nine in 1991 had mercury concentrations in tissues exceeding the EPA critical value. More recently, eight of nine northern pike examined from the Andreafsky River, a tributary on the lower Yukon River, had mercury concentrations in muscle that exceeded the higher FDA action level. Overall, mean mercury concentrations in northern pike from Alaska and Arctic Canada equal or exceed those from the lower 48 U.S. states. Existing information on mercury con-

Pacific walruses.

Netting for live capture of sea otters.

centrations in northern pike from Alaska is numerically and spatially depauperate. To address this lack of data, which FWS managers need when making subsistence management decisions, FWS biologists are conducting a multi-year, systematic sampling for mercury and methyl-mercury in northern pike on several National Wildlife Refuges in western and interior Alaska: Yukon Delta, Selawik, Koyukuk, Nowitna, Yukon Flats, and the Northern Unit of Innoko. This study was initiated in FY 2005 and will be completed in FY 2008.

Marine Mammals

Pacific Walruses. Research on Pacific walruses continues to focus on developing and implementing a range-wide population survey for this subspecies, monitoring haulouts in Bristol Bay, and monitoring the spring Alaska Native subsistence harvest to collect information on the size and demographics of the harvest. In 2003, based on results from preliminary studies conducted in 2002, the FWS initiated a study of the application of airborne thermal scanner techniques to determine Pacific walrus population estimates. A survey was conducted in the area north and south of Saint Lawrence Island, encompassing a traditional walrus wintering, breeding, and calving area. Favorable results from this survey as well as discussions with Russian colleagues at the Polar Research Institute of Marine Fisheries and Oceanography, where similar research on ice seals is being conducted, resulted in the FWS and USGS efforts to mount a range-wide population survey of Pacific walruses scheduled for spring 2006. The survey will provide the FWS with information on the current population of Pacific walruses.

The FWS, with the Alaska Department of Fish and Game, also began an analysis of the age structure and productivity of Pacific walruses harvested in the Bering Strait region from 1952 through 2002. This study, utilizing biological samples collected from Alaska Native subsistence harvests, examines whether the age structure and productivity of harvested animals has changed over time. The analysis should be completed in 2006.

Northern Sea Otters. The FWS continued survey efforts for northern sea otters in southwest Alaska, including the Near and Fox Island groups in the Aleutian chain, several islands along the Alaska Peninsula, and the Kodiak archipelago. These surveys have documented continued sea otter declines in the eastern Aleutians (48%), on Pavlof and Shumagin Islands (33%), and along Sutwick Island (68%) since 2001. In the Kodiak

archipelago, population estimates declined significantly between 1989 and 2001. In 2004, the FWS estimated the population along the Kodiak archipelago to be 6,284 sea otters, a result that was slightly, but not significantly, higher than the previous survey in 2001. The reasons for differences in population trend in the southwest Alaska area remain unclear, and further investigation is warranted. The FWS also collaborated with USGS on capture studies to monitor the health and condition of sea otter stocks. Analyses on health and condition are still pending.

Mortality studies, initiated in the winter of 2002 by the FWS in collaboration with the USGS, the ASLC, and Alaska Veterinary Pathology Services, are providing a baseline of, as well as an opportunity for, biomedical studies to establish the causes of mortality (other than hunting) for northern sea otters throughout Alaska. Prior to this effort there was little information available on mortality trends for northern sea otters. Since 2002 almost 100 otters have been studied by the program, most being prime-age adult males from the south-central population stock. Comprehensive necropsies, including histopathology and screening for protozoal, viral, and bacterial pathogens, provide information that can be compared to work being conducted in California with southern sea otters. Comparison of the cause of mortality in the northern and southern populations will allow sea otter researchers to better monitor patterns and changes in disease risks affecting these populations. The leading causes of death for Alaska sea otters are trauma and cardiac disease. The primary source of carcasses has been local volunteers who were trained by the FWS, NOAA Fisheries, and the ASLC to participate in a marine mammal stranding network in Alaska. The first training was held in Homer, Alaska, in 2004, and another is planned for Kodiak, Alaska, in 2005. Additional funding for this project came from the Oiled Wildlife Care Network and the Minnesota Zoo.

On February 11, 2004, the FWS proposed listing the southwest Alaska Distinct Population Segment (DPS) of the northern sea otter as threatened under the Endangered Species Act. This determination was based on range-wide population surveys that indicated dramatic declines throughout much of the population stock. A 120-day public comment period ended on June 10, 2004. The FWS reviewed the comments received, as well as other available information, and on August 9, 2005, made a decision to list this DPS of the northern sea otter as threatened pursuant to section 4 of the Endangered Species Act. The listing took effect on September 8, 2005, and the FWS is currently preparing a recovery outline.

Polar Bears. In 2000–2005, the FWS conducted weekly aerial surveys for polar bears along the coastline and barrier islands of the Beaufort Sea during the open water period (September and October). An increasing number of polar bears have been observed during the fall months along the Beaufort Sea coast of Alaska in recent years, particularly around human settlements. The purpose of the surveys is to monitor the distribution and abundance of polar bears along the coast to better understand the importance of coastal habitat to polar bears, as well as to assess the potential impacts of climate change and offshore oil exploration, development, and production activities on polar bears.

The number of observations varied considerably among years, with the greatest number of observations in the fall of 2004 (five surveys, 405 observations). Regression analysis of bear sightings indicates that there is a significant relationship between the number of bears on shore and the distance to pack ice. As the distance to the ice increased, the number of bears near the shore increased; conversely, as ice advanced near shore, the numbers of bears decreased. In other words, more bears used coastal habitat during years when the pack ice remained farther offshore for extended periods of time. Adult females with dependent young comprised the majority (49%) of bears observed in all years. The survey results for 2000–2005 also indicate that 71% (1,100 of 1,547) of all bears observed were within 30 km of the Native village of Kaktovik, on Barter Island.

In 2002–2004, the FWS, with support from the Minerals Management Service, the Alaska Nanuuq Commission, the North Slope Borough, and the villages of Kaktovik and Nuiqsut, conducted a ground-based study on polar bears at Barter and Cross Islands during the fall, open water period. These areas were selected because of the annual presence of hunter-harvested bowhead whale carcasses, which apparently attract relatively large numbers of bears. The objectives of the study were to determine the number, sex, age, and activity patterns of polar bears using Barter and Cross Islands during the fall, open water period.

A total of 1,230 hours of observations were conducted in 2002–2004. A range of 0–65 polar bears were observed each year at Barter Island, with a three-year mean of 33.1 bears. At Cross Island, a range of 0–13 bears were observed, with

a three-year mean of 6.1 bears. At the bowhead whale carcass feeding sites at Barter and Cross Islands, the three-year mean was 4.9 and 2.8, respectively. All age/sex classes used the feeding sites at both islands. The majority of bear use at Barter Island was by bears in family groups (47%); at Cross Island, it was by single adult bears (66%).

Polar bear.

Overall, polar bears were primarily inactive during day, with activity levels (particularly feeding) increasing with the onset of darkness. Frequently, all age/sex classes of polar bears were observed feeding simultaneously in close proximity to each other, with relatively little time spent in aggressive interactions. When aggressive interactions did occur, they tended to be initiated by mothers accompanied by dependent cubs. Interestingly, 8–12 brown bears also used the Barter Island carcass feeding site, often displacing polar bears that were already feeding there. The study was continued at Barter Island in 2005, with an added component of documenting bear–bear and bear–human interactions.

A study on the use of trained dogs to verify polar bear den occupancy was conducted in 2002. The purpose of the "dog verification study" was to determine whether trained, air-scenting dogs could verify the locations of known or suspected polar bear dens. Preliminary results from 2002 indicate that the use of dogs, particularly in combination with forward-looking infrared technology (FLIR), can be considered a viable technique to help minimize the impacts from oil and gas industry activities on denning polar bears. Since then, the FWS, in cooperation with Alaska Department of Fish and Game brown bear biologists, has continued to use trained dogs opportunistically to locate and verify dens in areas where oil and gas activities occur.

Threatened and Endangered Species

Spectacled and Steller's Eiders. Virtually the entire Pacific population of Steller's eider (both Russia-breeding population and the threatened Alaska-breeding population) molts and winters in the nearshore waters of southwestern Alaska. This population is estimated at roughly 100,000 individuals and, based on annual aerial surveys, appears to have been declining at 3.8% annually over the last 13 years. The Alaska-breeding population includes, at most, 2,500 individuals. In 2004 and 2005, the FWS continued to participate with the North Slope Borough in a long-term study of Steller's eiders nesting near Barrow. The study documents their abundance and distribution and the primary influences on their survival and reproduction. Nesting effort and success of Steller's eiders vary tremendously from year to year; 2005 was the first year since 2000 in which nesting was observed. Predation is considered to be the main cause of Steller's eider nest failure near Barrow. In 2005, this study included foot and aerial surveys, video monitoring of nests to identify avian predators responsible for egg loss, removal of arctic foxes from the study area, marking of females at hatch with VHS transmitters to measure brood success, and collaborative efforts with the ASLC to develop artificial incubation techniques. In preparation for potential re-introduction efforts, FWS and ASLC salvaged eggs to begin a captive flock of birds with a known geographic origin.

Spectacled eider populations on the Yukon Delta National Wildlife Refuge (YDNWR) declined more than 90% from the 1970s until they were listed as threatened in 1993. Probable reasons for the decline include subsistence harvest and lead poisoning due to the ingestion of spent lead shot. Education efforts on these issues have been intense over the past decade. An annual nest plot survey on YDNWR indicated that the nest population in 2005 was the highest in 17 years. A long-term study on productivity and annual survival continued on Kigigak Island, YDNWR; ongoing analyses will provide information on current sources of mortality.

Satellite telemetry has confirmed 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. In 2004 and 2005, the FWS continued to support a nesting biology and survival study of spectacled eiders in the Chaun River Delta, Chukotka, initiated in 2003. The goal of this project, in concert with the study on YDNWR described above, is to compare the productivity and survival of spectacled eiders in Russia and Alaska. The FWS also continued to sponsor subsistence harvest surveys in villages in the Yakutia and Chukotka regions in 2004 and 2005. Results indicate that hunting pressure on eiders is variable among villages, but high in some areas, and that local knowledge of waterfowl conservation issues, such as the effects of lead shot, is very low.

In 2004 and 2005, the FWS continued to support eider research at the ASLC, including reproductive studies; nutrition, physiology and biomarker development studies; immunology and disease ecology studies; and contaminant, endocrine, and immune studies. FWS also supported a Steller's eider banding project to estimate annual survival, a project to monitor blood lead levels in both species, and satellite telemetry studies of Steller's eiders and glaucous gulls (potential predators of Steller's eider nests) to determine annual movement patterns.

Short-tailed albatrosses. Once numbering in the millions, the short-tailed albatross was driven to the brink of extinction by feather hunters. Today, about 2,000 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. Japanese attempts to establish an additional albatross colony at a safer location on Torishima appear to be achieving success, after more than 10 years. In December 2005, there were 15 nests, each with an egg, at this artificial colony site.

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.

The draft short-tailed albatross recovery plan was recently released, and a final plan should be available in 2006. One of the primary criteria for recovery of the short-tailed albatross is the establishment of an additional breeding colony or colonies on "safe" (non-volcanic) island locations. Joint Japan–U.S. plans are underway to initiate a new breeding colony, through both passive attraction of breeding birds and active translocation of older chicks, at a location in the Bonin Islands, some 300 miles south of Torishima.

National Wildlife Refuges

The National Wildlife Refuge system in Alaska encompasses 16 refuges and approximately 77 million acres. The staff of each refuge conducts 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 Arctic Alaska.

Arctic National Wildlife Refuge

Muskoxen were extirpated from Alaska in the late 1800s. The species was re-introduced to its former range within the Arctic National Wildlife Refuge in 1969–1970. In April 2005, about 350 muskoxen were estimated to be present in the total population, with approximately 50 in the refuge; this is down from nearly 370 in 1986. Low calf

Bull muskox on the coastal plain of the Arctic National Wildlife Refuge.

recruitment, increased adult mortalities, and shifts in distribution have caused a decline of muskoxen in the refuge. Calf production and adult survival were likely affected by severe winter weather conditions that reduced the availability of winter forage and increased energetic costs. Predation may have also played a role. Since 1998, several incidents of grizzly bear predation have been documented. Predation events may cause abandonment of calves, fracturing of groups, and shifts in distribution. The NWS is currently monitoring radiocollared muskoxen. In addition, they are cooperating with the Alaska Department of Fish and Game to study predator–prey relationships. Researchers are using stable isotope analysis of hair and serum samples collected from grizzly bears over the last 30 years to examine whether bear diets have shifted. Four grizzly bears will be outfitted with satellite collars in late winter 2006. Their daily movements will be tracked to document predation events and other resource use.

Seismic exploration was conducted on the coastal plain of the Arctic National Wildlife Refuge during the winters of 1984 and 1985. The coastal plain has rolling to level topography, with tundra plant communities underlain by continuous permafrost. Exploration occurred along 2000 km of seismic line traversed by tracked vehicles with low ground pressure. At least 2000 km of additional trails were created adjacent to the seismic lines by D-7 Caterpillar tractors pulling ski-mounted trailers between camps. In the summer of 1984, the FWS initiated a long-term monitoring program to document the initial vegetation and soil disturbance and to track natural recovery. There was significant recovery over an 18-year period for deciduous shrubs, forbs, and lichens but not for mosses. The response to disturbance was more complex for evergreen shrubs, which recovered well in some vegetation types but not in others, and for graminoids, for which the response depended on the severity of the initial disturbance. The greatest disturbance persisted where vehicle traffic had broken the insulating vegetative mat, allowing warming of the soil. This caused the subsurface ice to melt and the trail to subside into a trough. At these sites the vegetation in the trough had more sedges and fewer shrubs than the surrounding tundra.

Selawik National Wildlife Refuge

The terrestrial and wetland ecosystems of Selawik NWR form a significant and diverse landscape where the boreal forest of interior Alaska meets the Arctic tundra. Vegetation ecologists from the FWS and the University of California at Davis carried out an ecosystem field survey of the refuge to establish a hierarchical classification of plant communities and gather location-specific baseline data for representative sites that are important correlates of biological productivity. This is the first quantitative vegetation study of the refuge that includes vascular plants as well as lichens and mosses. The specific objectives of this study are to:

- Record the floristic composition and structure of plant communities present in the variety of

Repeat photographs of a study plot on a winter seismic exploration trail on the coastal plain of the Arctic National Wildlife Refuge. Scuffing and crushing of vegetation and compression of soil were evident in 1984, the summer following disturbance (top). By 2002, a network of sedge-filled troughs had developed where melting ice wedges caused ground subsidence (bottom).

Hockley Hills, Selawik National Wildlife Refuge. The foreground shows an alpine tundra fellfield on a rounded mountain summit. White spruce woodlands occur on lower and middle mountain slopes; these grade into alder shrublands on upper slopes.

major vegetation types spanning elevational gradients from lowlands to alpine;

- Classify the plant communities into community types on an ecosystem basis;
- Record bryophyte, lichen, and vascular plant diversity within individual plant communities; and
- Document plant species distribution and correlate this with gradients in the environment, including landform, substrate type, elevation, soil chemistry, and permafrost depth.

One hundred fifty nine plots, of which 30% are permanent, were used to document the major vegetation types of the refuge. These types included alpine tundra, low-elevation tundra, upland forests and woodlands, lowland forests and woodlands, riparian forests and shrublands, and aquatic and semi-aquatic vegetation. Should the biota change through climatic modification or other circumstances, comparisons can be made through time to show the explicit biological consequences of this change.

The Selawik NWR and the Fairbanks Fish and Wildlife Field Office collaborated to identify seasonal migrations and important habitats of humpback and broad whitefish using radio-tagged fish in the Selawik River drainage. Whitefish are a key subsistence resource in the Kotzebue Sound region. Preliminary data from radio-tagged fish suggest that broad whitefish found in the Selawik River delta come from Kobuk River spawning stocks, and humpback whitefish appear to spawn in several locations within the Selawik River drainage. As in 2004, no radio-tagged fish were reported captured by Selawik or other Kotzebue region village residents in 2005. Since many people are fishing and thousands of fish are captured each season, these data suggest that there is an abundance of fish in the system. Refuge and fisheries office staff will continue to monitor the 2005 transmitters for two to three years, allowing an assessment of spawning frequency and long-term habitat fidelity.

Another study is establishing an abundance estimate of spawning inconnu (sheefish) in the Selawik River approximately 10 years after a similar study was conducted on the same population. A fall and winter mixed-stock fishery in Hotham Inlet and Selawik Lake impacts Kobuk and Selawik River inconnu. The fall and winter harvests totaling 20,000 inconnu from the Kotzebue area are substantial compared to annual spawning aggregates that were found in the Kobuk River (30,000 fish) and the Selawik River (less than 6,000 fish) in the mid-1990s. From early July through mid-August 2005, fishery biologists captured 627 inconnu and marked them with Floy anchor tags. During the subsequent recapture event, they captured 1,243 inconnu, including 16 tagged fish. The preliminary estimate of spawning inconnu in the Selawik River is 46,472 fish. This estimate is substantially higher than the previous estimates generated from similar mark–recapture statistical methods (5,190 fish in 1995, 5,157 fish in 1996, and a preliminary estimate of 23,480 fish in 2004). In a concurrent study, 31 radio transmitters were implanted in pre-spawning inconnu. These transmitters were intended to confirm spawning area locations and measure inconnu spawning periodicity. Also, a major proportion of the radio-marked inconnu migrated from the marking event area to the spawning area and provided preliminary validation that inconnu marked with Floy tags were meeting the conditions of the mark–recapture assumptions.

Biologist implanting sheefish with a radio transmitter.

Flagged bar-tailed godwit banded on Yukon Delta National Wildlife Refuge.

Yukon Delta National Wildlife Refuge

Each fall, tens of thousands of bar-tailed 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 biologists have studied flocks of godwits staging along the coast of the Yukon–Kuskokwim Delta. The proportion of juveniles in the fall staging flocks has been consistently low, exceeding 3% only once in six years. A population model recently developed in collaboration with the USGS to assess the impact of chronically low productivity indicated a population declining at 9% per year. A joint FWS–USGS survey of the staging grounds in fall 2005 corroborated the model results. Only about 42,000 godwits were counted, down from 94,000 in 1997. In 2004, the refuge initiated a study of the godwit's breeding ecology to elucidate potential causes of the low productivity. Among 27 nests located in the main study area in 2004 and 2005, no eggs hatched. Future field work aims to determine if poor nesting success is a local or regional phenomenon.

The Kwethluk River was selected as one of the "observatory rivers" in a suite of many that circle the Pacific Rim as part of a ten-year project called the Salmon Rivers Observatory Network (SaRON). The Kwethluk annually averages returns of over 100,000 salmon. Food web dynamics are being evaluated in the context of this source of marine-derived carbon, nitrogen, and phosphorus subsidies to the various habitats that characterize these alluvial river systems. Data on hydrological, physical, and other biotic factors are also being collected in a temporally and spatially explicit way to evaluate their effects on salmon productivity and diversity. Innovative remote sensing techniques such as GPS-fitted acoustic doppler current meters used to interpolate high-resolution satellite imagery allow for detailed mapping of stream depth, veloc-

Complexity of habitats on the Kwethluk River, Yukon Delta National Wildlife Refuge.

ity, and temperature over large areas and at different stage heights. This allows researchers to model nutrient flux, thermal regimes, stream velocities, groundwater flow, and availability of habitats in three dimensions and through time in this complex ecosystem. Preliminary results indicate that springbrooks (isolated relic side channels) show the highest productivity and diversity for all salmon species studied. Springbrooks are recharged by groundwater, resulting in a more stable thermal regime, staying cooler in the summer and warmer in the winter. Turbidity is also significantly less and the percentage of canopy closure greater than in the main stem and side channels. Springbrooks also represent transitional zones between the aquatic and terrestrial ecosystems, sharing food web elements from both.

Although there is plentiful moose habitat in the lower Kuskowim River drainage, moose have been struggling to colonize this region for years, and population numbers remain low. The Lower Kuskokwim River Moose Project is designed to investigate how patterns of landscape factors and variables hinder or foster movement, habitat use, and colonization patterns. In April 2005, 25 moose were fitted with VHF and GPS transmitters. Resource selection models based on landcover maps and other datasets are being developed to help understand habitat use and movements. Population dynamics are being investigated by monitoring the reproduction and survival of collared moose, as well as by using standardized censuses. In 2006 the FWS will fit an additional 20–30 moose with radiotelemetry collars.

Moose captured at Yukon Delta National Wildlife Refuge in 2005.

Alaska Maritime National Wildlife Refuge

One of the establishing purposes of the Alaska Maritime NWR is to conserve marine bird populations, which requires the ability to detect large changes in abundance. Monitoring populations of auklets and other crevice-nesting seabirds has proven problematic, even though numerous methods have been attempted since the mid 1960s. Quantifying changes in the geographical size of auklet colonies may be useful as an alternative to attempts to directly measure population size. Anecdotal evidence suggests that several large colonies have decreased recently in both extent and abundance, simultaneously with vegetation encroachment and succession. The FWS recently developed a new standardized method for mapping colonies using a randomized systematic grid survey, which they employed in July 2005 on Hall and St. Matthew Islands in the Bering Sea. The survey had two components: a simple presence/absence survey and an auklet sign density survey. Quantitatively mapping all large auklet colonies using this method could provide an important, and logistically feasible, baseline for monitoring the status of auklet colonies through time.

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 shorebirds, sea ducks, and other waterfowl that inhabit areas undergoing exploration and development by the oil and gas industry.

Waterfowl Population Surveys, Banding, and Research on the North Slope of Alaska

Since 1986 the FWS has conducted systematic aerial waterbird breeding pair surveys on the North Slope of Alaska. Together these surveys have shown that the breeding populations of most species are stable, although declines in long-tailed ducks and increases in Arctic terns, king eiders, red-breasted mergansers, tundra swans, and sandhill cranes have been detected. The FWS has also conducted annual surveys of molting geese in the Teshekpuk Lake Special Area (TLSA) since 1982. This survey brought important recognition of the TLSA, which attracts up to 30% of all black brant and growing numbers of mid-continent greater white-fronted geese during the July molting period. In addition to trend and abundance surveys, the

FWS renewed annual goose-banding efforts on the North Slope, which provide data necessary to calculate annual survival and harvest distribution throughout Alaska, the Central and Mississippi Flyways, and Mexico. Finally, increased interest in the status of yellow-billed loons led to collaborative efforts between the FWS and USGS to develop a habitat selection model, currently on schedule to be completed in 2006.

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 estimates of abundance;
- 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 the actual population size and thus of the change in size since the last major survey. During the past eight years, 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. Such surveys have been conducted across most of the Arctic Slope of Alaska, providing the first detailed information on shorebird species distribution. Full implementation of the program awaits additional funding.

Beginning in 2003, the breeding biology of shorebirds has been studied at Barrow, Alaska, with the goal of accomplishing the second component, that is, annual surveys at non-random, permanent shorebird sites. Data collected include site and mate fidelity, adult survival, natal philopatry, and hatching success of a variety of upland and wetland species. In addition, information on lemming abundance, climate, and predator numbers is being collected to relate to the breeding parameters. Recently, researchers have begun to investigate the effects of a new landfill and climate change on shorebirds.

In addition to the breeding biology studies, an extensive study on post-breeding shorebirds was begun in 2004. Starting in Barrow, this study expanded to Peard Bay, the Colville River Delta, the Sagavanirktok River Delta, and the Okpilak River Delta in 2005. The principal goals of this study are to:

- Document shorebird diversity, abundance, and tenure times at each coastal staging area;
- Document movements between breeding and post-breeding areas and among post-breeding areas; and
- Determine how physiological measurements (fat metabolism and stress) from captured birds can be used to predict site quality.

International Activities

Arctic Monitoring and Assessment Program

Polar bears are a primary indicator species within the Arctic Council's Arctic Monitoring and Assessment Program (AMAP) because of their position at the top of the Arctic foodweb. Two technical reports summarizing the concentrations of trace elements and organochlorine compounds (OCs) in adult male polar bears from Alaska were completed by the FWS in 2004. Mercury, cadmium, and selenium were significantly higher in liver and kidney tissues from bears harvested in the southern Beaufort Sea compared to polar bears from the Chukchi and Bering Seas. Mercury concentrations were about half those found in polar bears in the western Canadian Arctic and are similar to values reported for Svalbard, Norway. Concentrations of polychlorinated biphenyls (PCBs) and chlordanes were significantly higher in adipose tissue in polar bears in the southern Beaufort Sea than in polar bears from the Chukchi and Bering Seas. Except for hexachlorocyclohexane isomers (HCHs), OCs including the sum of the major PCB congeners, chlordane-related compounds, and DDT-related compounds were relatively low in polar bears from Alaska compared to other Arctic populations.

The FWS also collaborated with scientists from Canada, Norway, Greenland, Denmark, and academic institutions in the U.S. in publishing several papers over the past two years. These papers primarily examined OCs, perfluorinated compounds such as perfluorooctane sulfonate (PFOS), and polybrominated diphenyl ethers (PBDEs). The latter two classes of compounds have received less study than the OC compounds until recently. Concentrations of PFOS were greater than other organic compounds in polar bears from the Chukchi Sea region, including chlordanes, PCBs, HCHs, and DDTs. In contrast, concentrations of chlordanes and PCBs were greater or equal to PFOS levels in polar bears from the Beaufort Sea region. Compared to polar bears from other Arctic regions, polar bears from Alaska were characterized by higher proportions of relatively volatile compounds such as HCHs, pentachlorobenzenes, and less-chlorinated PCBs. Concentrations of PBDEs (sum of all congeners) were lower in polar bears from Alaska and Canada than from East Greenland and Svalbard. Concentrations of PFOS in South Hudson Bay, East Greenland, and Svalbard were significantly higher than in western locations such as the Chukchi Sea.

The FWS also contributed polar bear tissue samples to the Alaska Marine Mammal Tissue Archival Project (AMMTAP). These samples have been archived so they can be analyzed in the future for environmental contaminants. Such retrospective studies are important when emerging issues arise.

Conservation of Arctic Flora and Fauna

The FWS is the designated Federal agency for participation in the Arctic Council's Conservation of Arctic Flora and Fauna (CAFF) program. Between 2002 and 2004, FWS employees chaired CAFF as well as its Flora Group and the Circumpolar Seabird Working Group. Shorebird biologists within the circumpolar Arctic recently formed the Committee for Holarctic Shorebird Monitoring (CHASM), an organization formed as the essential first step for guiding the implementation of an effective circumpolar program for monitoring Arctic-nesting shorebirds. CHASM is a "project" within the International Wader Study Group and is one of seven networks within the Circumpolar Flora and Fauna's Circumpolar Biodiversity Monitoring Program.

National Park Service

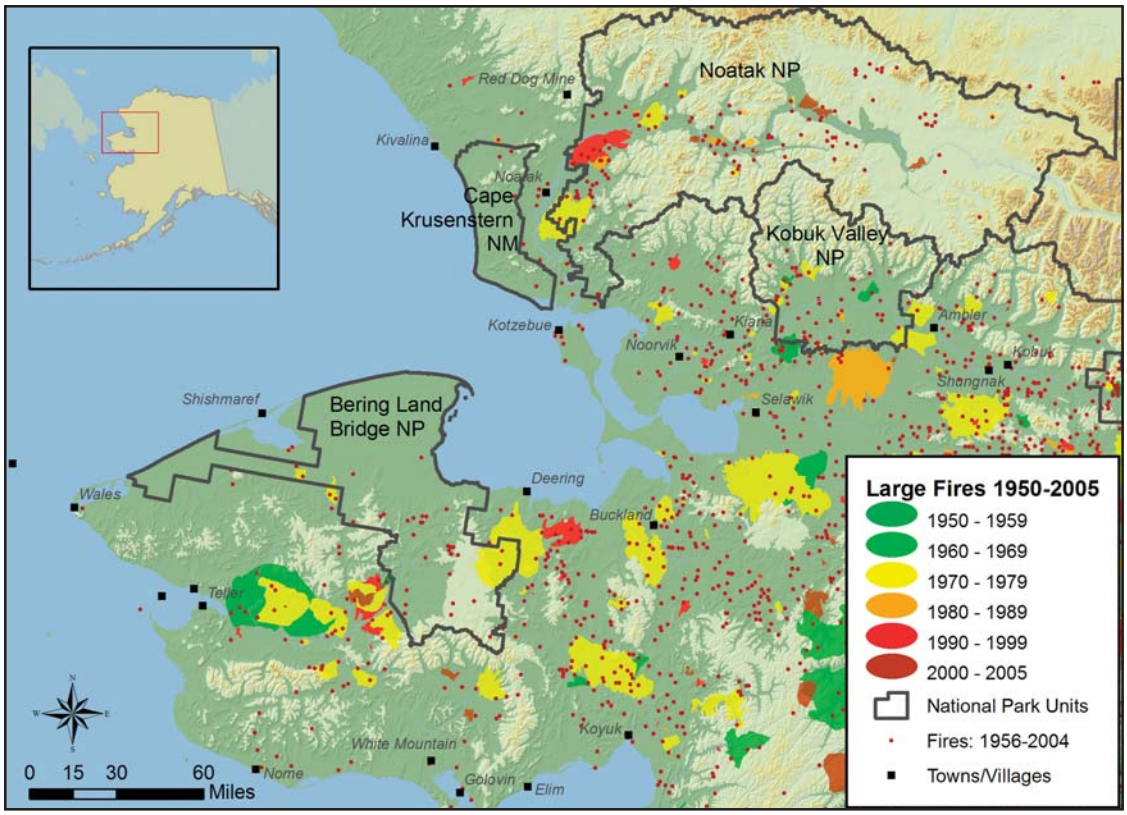
	Funding (thousands)	
	FY 04	FY 05
Cultural Resources	552	579
Natural Ecology	697	694
Inventory & Monitoring	263	1,392
Total	1,512	2,666

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.

Specific objectives for NPS research in the Arctic are generated within each of the Arctic park units' enabling legislation, which includes the directives to maintain the environmental integrity of the natural features, to protect and interpret cultural resources, and to protect habitat for, and populations of, wildlife. Established in 1980, the Arctic park units include Bering Land Bridge National Preserve, Cape Krusenstern National Monument, Gates of the Arctic National Park and Preserve, Kobuk Valley National Park, and Noatak National Preserve. Cultural and natural resource research provides necessary data and information to managers, while it also benefits the public. Work is accomplished through partnerships with educational institutions and intergovernmental organizations at all levels. In addition, the National Park Service is increasingly enlisting the skills and talents of research partners to develop the scientific information needed to make effective management decisions.

Fire in the Western Arctic Parklands

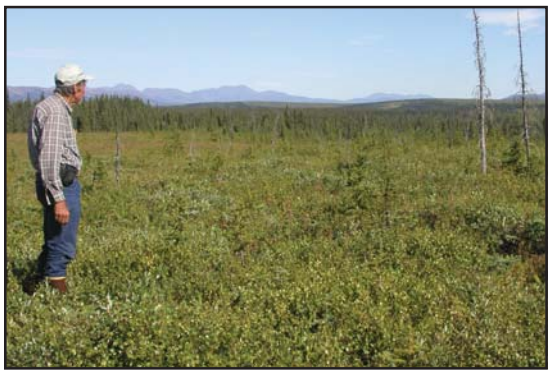
Climate, terrain, and vegetation strongly influence the occurrence and extent of fires within the western Arctic parklands: Noatak National Preserve, Bering Land Bridge National Preserve,



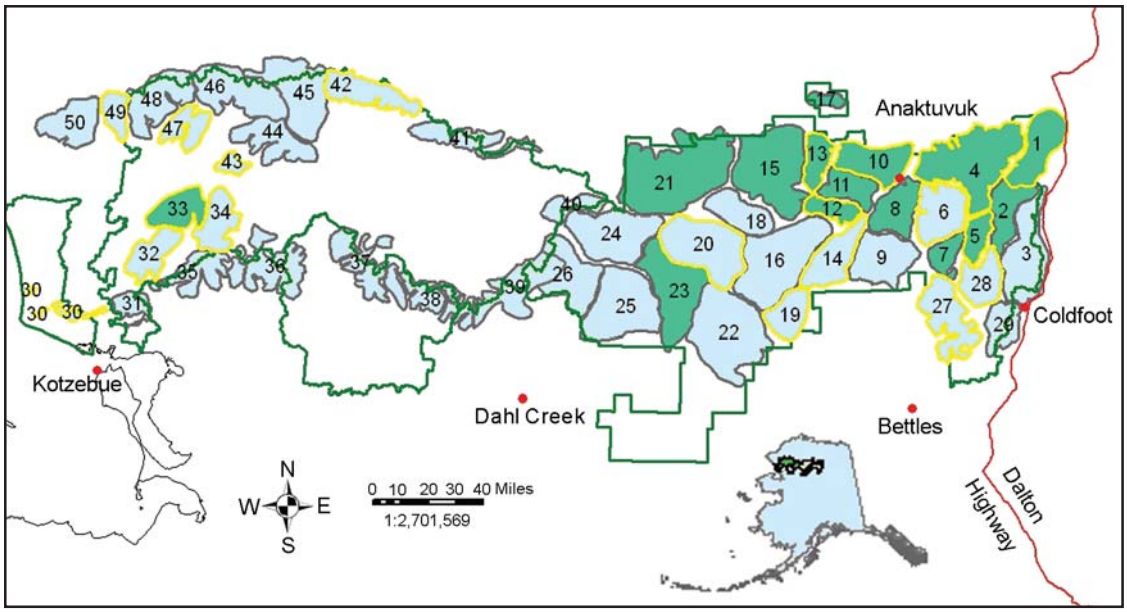
Fire history of northwest Alaska. The points show fire starts from 1956 to 2004. Historical wildland fire perimeters are shown for fires generally larger than 1000 acres prior to 1988 and larger than 100 acres after 1988.

Kobuk Valley National Park, and Cape Krusenstern National Monument. The subarctic boreal forests and low Arctic tundra biomes are subject to periodic, sometimes large fires. Over the last 50 years, more than 280,000 hectares have burned within the western Arctic park units; 96% of the fires are caused by lightening. The frequency and extent of the fires are variable within the park units, governed by vegetative, geographic, and climatic factors. During 2005, 16 fires occurred in Noatak NP, with a total of 7,300 hectares burned, and 2 fires were detected in Bering Land Bridge NP. Fires can exert landscape-scale controls on vegetation structure and composition, permafrost dynamics, nutrient cycling, carbon loss and gain, primary productivity for herbivores, and biodiversity.

The natural fire regime (fire frequency, extent, and severity) and resulting fire effects are likely to respond to local and global climate changes. Very few studies have looked at the effects of fire in tundra ecosystems. During 1981 and 1982, eight tundra fire plot sites were established in Noatak National Preserve in burned areas of varying ages (1972, 1977, and 1982 fires). None of these plots had been re-measured since their initial establishment. As part of the Arctic Network Inventory and Monitoring Program, a Cooperative Agreement was established with the original investigator to re-locate, re-measure, analyze, and report on these



Fire effects plots in the Noatak National Preserve. The left picture shows the plots in 1982, 10 years after the fire. The right picture shows the same site in 2005, 33 years after the fire. There was an increase in dwarf birch and a decrease in grasses and willow.



Sheep survey units in the Arctic Network. The survey units are based on Singer's work from 1983 and 1984 and were classified as high-density sheep areas (more than 1.3 sheep per square mile; dark green) or low-density sheep areas (less than 1.3 sheep per square mile; light green) based on Singer's original data. Units surveyed during June and July 2005 are outlined in yellow.

fire effects plots. During 2005, the researchers relocated and re-measured eight fire plot transects. The objectives of the project are to assess the changes in vascular and non-vascular plant composition and structure, depth of active layer, and thermokarst development, and to initially assess the potential of shrub and tree-line expansion in relation to fire and climate. Preliminary results indicate an increase in shrub cover and a decrease in graminoids and forbs. In addition, six fire effects plots were established immediately after the 2004 Uvgoon Creek fire in Noatak NP by NPS personnel. During 2005, these plots were re-measured by NPS fire staff. The objectives of these plots are to understand plant succession under varying burn severities.

Western Brooks Range Dall's Sheep Survey

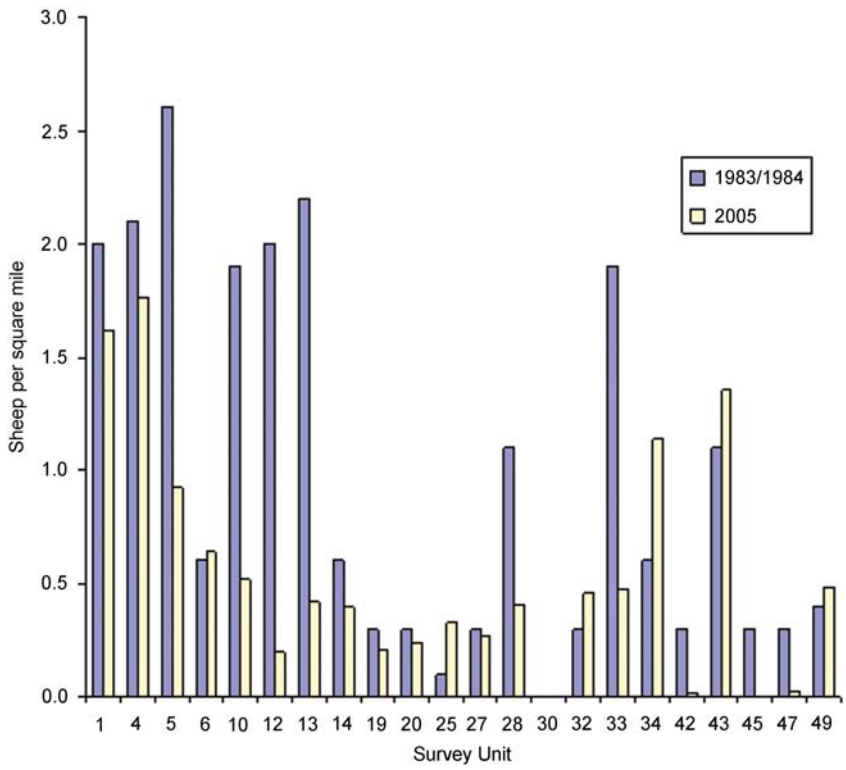
The Brooks Range is the northernmost limit of Dall's sheep range, and little is known regarding their population health and distribution. For the majority of the western Brooks Range, the last comprehensive survey was in the early 1980s. Dall's sheep are of interest because they are a resident alpine and Arctic species that is sensitive to environmental variation. In addition, a widespread decline in Dall's sheep occurred throughout the Brooks Range in late 1980s and early 1990s, but the extent of the decline and the degree of recovery since the decline are unknown.

During the early 1980s, Frank Singer, a biologist with the National Park Service (NPS), inventoried suitable Dall's sheep habitat within what is now the Arctic network of parks. Since that time, surveys have been performed consistently in only a few areas of the Arctic network; for the majority of the Arctic network the last survey conducted was Singer's. In June 2005, the first year of a two-year project was initiated to examine population levels and Dall's sheep distribution in the western Brooks Range.

Singer's original survey units were mapped using a GIS. Units were then randomly chosen for surveying. Units were surveyed using small, fixed-wing aircraft to arrive at a minimum sheep count. Sheep were classified as lambs, rams (legal and sublegal), ewe-like, and unclassified.

In the summer of 2005, surveys in 18 units (out of a targeted 25 units) were completed, and two more were mostly completed. The total number of units in the survey area is 50. Sheep densities were historically higher in the northeastern portion of the survey area than in the southern and western portions of the survey area, and this pattern was evident in 2005. In 13 out of 20 survey

Dall's sheep grazing.



Dall's sheep densities observed in survey units in the western Brooks Range during the summers of 1983–1984 and 2005.

units, the density of sheep observed in 2005 was lower than in 1983 and 1984, and these survey units were in the eastern portion of the survey area. Units in the western portion showed an increase in sheep density from the early 1980s to 2005. In units that were surveyed in their entirety, there were 33% fewer sheep observed in 2005 than in 1983 and 1984.

In the summer of 2006, surveys are planned for all units not surveyed in 2005. The final report from this project will evaluate changes in sheep densities in the entire survey area between 1983–1984 and 2005–2006 and will provide a population estimate of Dall's sheep in the western Brooks Range. Sex and age composition data from this survey will provide additional detail regarding changes in sheep density.

This information will be of great use to the NPS and other natural resource agencies as a baseline data set. It will also be of use for park managers evaluating the condition of the Dall's sheep population in the western Brooks Range and will help guide the management of this unique alpine and Arctic species.

Genetic Variation of Moose

An ongoing study assesses the baseline levels of genetic variation and connectivity among the moose populations of the Selawik, Noatak, and Gates of the Arctic regions of Alaska. In an interagency collaboration between NPS and the USGS Alaska Science Center's Molecular Ecology Laboratory, molecular genetics are used to analyze over 200 unique blood and tissue samples collected from moose in these areas. Nuclear-DNA microsatellite genotyping, the polymerase chain reaction, and mitochondrial-DNA sequencing are used to determine population levels of heterozygosity, allelic composition, inbreeding, and connectivity (gene flow) among these moose populations. Genetic characterization of these moose, together with radiotelemetry (demographics), will provide better information to monitor the "natural and healthy" status of these populations as mandated by the Alaska National Interest Lands Conservation Act (ANILCA) of 1980. Determination of a genetic baseline for these moose populations will both enable the detection of population change and assist in the development of long-term management plans to ensure population persistence. The results from this study will be summarized in an internal NPS report and submitted to a scientific journal for publication. The data will also contribute to the effort of USGS to assess genetic variation in moose populations statewide.

Nuclear and MtDNA analyses being used to reveal relationships among populations of wild moose in Arctic Alaska.

Inventory and Monitoring Program, Arctic Network

Fresh Waters in Gates of the Arctic National Park and Preserve

The Noatak River and its surrounding watershed is an internationally recognized UNESCO Biosphere Reserve, established for its unique contribution to the conservation of biological diversity and biological resources. The first step in conserving biological diversity is to conduct baseline surveys using an "ecosystem approach" to better understand the species present, the community composition, the species of concern, and the ecosystems that sustain them.

Understanding and forecasting the impacts of current and future change on biodiversity and ecosystem function in the Noatak Basin will depend on understanding the ecosystems of this unique and relatively undisturbed area. Except for a few isolated studies, little is known about the current geographic ranges of most aquatic species in the Arctic National Parklands. This includes freshwater and riparian vertebrates, nonvascular and vascular plants, invertebrates, and a multitude of microorganisms. Even less information is known about the ecosystems that sustain these organisms and how they are changing. For example, little is known about the effects of global climate change, Arctic haze, and airborne pollutants on species and ecosystems in the parks.

The primary purpose of this project was to extend the limited base of data and knowledge about freshwater resources of Gates of the Arctic. This initiative is part of NPS's Inventory and Monitoring program. The 2005 field initiative included landscape and freshwater ecosystem experts from the University of Vermont, University of Alaska Fairbanks, University of Alabama, Utah State University, Marine Biological Laboratory, and NPS. The study area for the 2005 effort focused on a portion of the Noatak River from 12-Mile Creek to Lake Matcharak in the western region of Gates of the Arctic. During the two-week field period, 20 stream tributaries and 12 lakes were assessed. All stream and lake sites were documented with digital photography and GPS.

The stream assessments included measurements of the physical characteristics of the streams (such as width, depth, substrate type and size, stability, and riparian cover). Dissolved oxygen, pH, temperature, conductivity, nitrates, total nitrogen, total phosphorus, base cations, and metals were measured. Benthic algal biomass was assessed in the field as extractable chlorophyll a and samples of benthic algae were identified. Representative specimens of key macroinvertebrates, riparian vegetation, and fish were collected and identified.

The lake assessments included detailed bathymetric surveys by GPS-linked sonar depth sounding. Light, temperature, and dissolved oxygen were measured in selected vertical profiles of each lake using an automated sonde. Zooplankton were collected by timed tows with a mesh net. Fish were collected by gill netting and by angling.

In general, the streams in this region were found to be naturally unproductive (oligotrophic), although the specific conductance (electrical conductivity) of the water was relatively high in all but one stream. The higher values are much higher than normally seen in Arctic tundra streams on the North Slope. High conductivity values are likely due to base cations dissolved from the carbonate geology that is prevalent in this area of the Noatak watershed. Algal and macroinvertebrate biomass was low and consistent with expectations for oligotrophic rivers. Tributary streams appeared to have few fish. Sculpin were found in several streams, with young-of-the-year salmonids (char or grayling) in some streams. The most productive and diverse stream site was at Kugrak Spring; juvenile char were observed at this site.

Lakes were more diverse than the streams. Lake types included glacial-kettle, oxbow, and thaw ponds, with maximum depths up to 35 m. Most of the surveyed lakes lacked stream inflows, and preliminary observations suggest that many of these lakes are primarily fed by groundwater inflows. Depth-specific conductivity gradients observed in some lakes suggest that the epilimnion and hypolimnion have different inflow sources. Also, chlorophyll concentrations were up to 14 times higher below the thermocline than in the epilimnion. Seven of the lakes contained fish, including populations of Arctic grayling, lake trout, northern pike, round whitefish, and nine-spine stickleback. The highest catch rates for young-of-year Arctic grayling occurred in a small pond with a maximum depth of 1 m that was dominated by bacterial mats. The highest diversity and catch rates for adult fish occurred in a spring-fed, high-mountain lake with relatively low conductivity. Northern pike were found in large thaw ponds and, when present, no other fish were observed.

Comparisons between lakes sampled in 1973 and 2005 indicate that the water clarity was 2.6 times higher during the 2005 survey. In 2005, fish

were caught in two lakes where fish were not observed during the 1974 survey (Lake Matcharak and Lake Omelaktivik). During the 1973 survey, Lake Matcharak also lacked a clearly defined outflow to the Noatak River; however, in 2005, there was a well-defined connection to the Noatak, and water clarity in the lake was six times higher than in 1973.

In general, the streams and lakes in this area of the Noatak River are oligotrophic and in good health. Spring streams, seepage lakes, and oxbow sloughs have higher productivity and diversity and should be considered areas of special ecological importance.

Arctic Network Coastal Erosion Study

In 2005, the Arctic Network initiated a study on coastal erosion in Cape Krusenstern National Monument and Bering Land Bridge National Preserve. Shoreline erosion is one of the most rapid and observable changes in Arctic environments. Protected by sea ice for much of the year, coastal ecosystems are sensitive to climate change and environmental stressors such as permafrost melting, sea-level rise, the frequency and intensity of storms, and the length of the summer ice-free season. With losses on the order of about 1–10 m/year (3–30 ft/year), coastal erosion threatens archeological sites and a variety of nearshore marine, terrestrial, and freshwater habitats.

Coastal ecosystems of Bering Land Bridge National Park, as viewed through the perspective, fly-through environment of www.EarthSLOT.org. The false-color Landsat satellite imagery shows the diversity of coastal landform types, including lagoons, spits, barrier islands, and low tundra bluffs.

In collaboration with researchers from the University of Colorado, this study will take advantage of GIS and high-resolution imagery. Orthophoto mosaics will be assembled with resolution as good as 0.5 m (1.6 ft) for the coastal environments of Bering Land Bridge National Preserve and Cape Krusenstern National Monument. Across this broad area, shorelines will be analyzed with "time slices" from approximately 1950, 1980, 1997, 2003, and possibly 2006. The aerial photography and satellite imagery will provide the basis to collect baseline data, determine long-term trends, and understand how landscape components interact and change over time. For more information, see http://www1.nature.nps.gov/im/units/arcn/index.cfm or http://instaar.colorado.edu/QGISL/ARCN.

Arctic Archeology

Archaeological Mentorship Program

The summer of 2005 was the second of three summer seasons for the Archeological Mentorship Program. Funded by an NPS Shared Beringian Heritage grant, the program provides training and archeological fieldwork opportunities for young people from villages in northwest Alaska. The program was envisioned as a way to bridge the gap between professional archeologists and young people in NPS-affiliated villages.

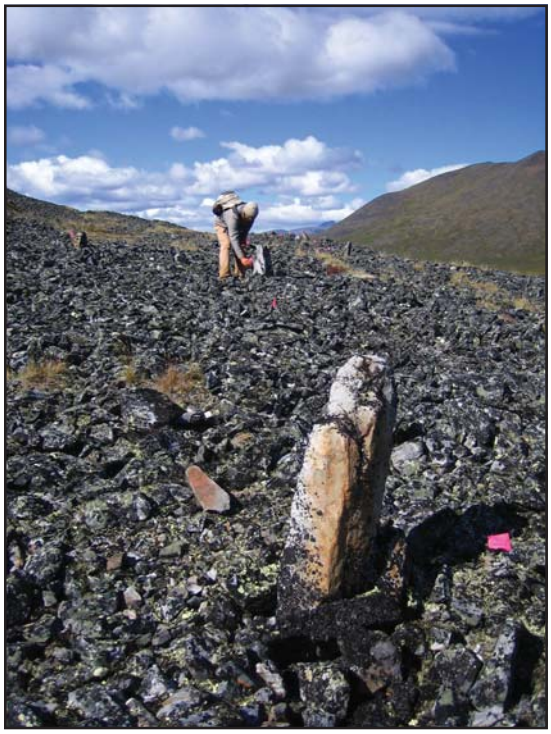
Archeologists from the Alaska Regional Office (ARO), Western Arctic National Parklands (WEAR), and Gates of the Arctic National Park and Preserve collaborated to provide training for five young people, aged 17–22, from the villages of Point Hope and Kiana in 2005. The mentorship lasted five weeks, from early July to mid-August. The five students, along with a community coordinator from Point Hope and one from Kiana, were all employed for the duration by the NPS as temporary summer hires. During the first week, they traveled to Kotzebue for training, delivered by ARO and WEAR archeologists and staff. The second week was spent back in their home villages working on specific projects they designed for their own communities. In Kiana, they mapped the old village site, now in ruins; in Point Hope, they planned and began construction of a traditional sod house. The final component of the mentorship was fieldwork. Two of the students traveled to Anchorage, and then to the Knik, to participate in an ongoing historic archeological project at the old townsite of Knik, while two students traveled to Bettles, and on to Agiak Lake in Gates of the Arctic National Park and Preserve to join an archeological crew mapping and testing an extensive landscape of ancient caribou-hunting sites.

Tent Ring Project

During the archaeological surveys in Gates of the Arctic in 2005, an undergraduate student in anthropology at the University of Alaska Fairbanks undertook a study of tent rings as part of an honors thesis project. These stone circles, once used to anchor skin tents, are a common but poorly understood part of the archaeological

Archaeologist recording a historic tent ring at the Iniqagliq site, which translates roughly to "they always camped here." The camp was last occupied by the Killikmiut band of Nunamiut in the 1930s and 1940s.

record in northern Alaska. The study sought to explore the age, function, design, and distribution of tent rings through an examination of newly discovered sites in combination with literature research. Preliminary results have been interesting and suggest that tent rings are much older than had been previously thought. Furthermore, distinct variation in the size and shape of tent rings suggest that methods of tent ring construction have changed over time and appear to differ from region to region, perhaps a reflection of cultural or linguistic boundaries. So far the work has documented more than 300 tent rings within and adjacent to the park and resulted in the discovery of 52 tent rings during 2005 field surveys.



Mapping a series of rock cairns that make up a caribou drive line at Agiak Lake. Several extensive drive lines were found at Agiak Lake and are composed of hundreds of such cairns. Caribou were likely steered into the lake, where they were speared by hunters from kayaks.

Agiak Lake Archaeological Survey and Mapping

In the summer of 2005, a Gates of the Arctic National Park and Preserve field crew documented archaeological features in the vicinity of Agiak Lake, about 30 miles west of the village of Anaktuvuk Pass. Agiak Lake was used in the past as a trap for migrating caribou, and it contains a dense and amazingly well preserved complex of hunting features, such as drift fences, blinds, storage pits, and camp locations. Archaeologists mapped more than 800 such features and produced a detailed map of the valley. One interesting site contained 41 tent rings—the largest single known concentration of prehistoric house remains in northern interior Alaska. Small-scale excavations at this site indicate that the tent remains are much older than previously thought, possibly as much as several thousand years old.

Killik–Nigu–Noatak Archaeological Inventory

Archaeologists conducted the first season of a three-year reconnaissance inventory of cultural resource sites in the Killik, Nigu, and Noatak River basins in Gates of the Arctic National Park and Preserve. This year crews focused on the Killik River. The work was undertaken by Gates of the Arctic park staff in cooperation with the University of Alaska Museum and involved graduate and undergraduate students from the University of Alaska Anchorage and University of Alaska Fairbanks.

Initial findings and achievements include:

- The discovery of 181 new sites, which brings the total number of known sites in the park to over 1200;
- Visits to 100 previously recorded sites to update location and condition information;
- The collection of radiocarbon samples from 20 sites, which will increase by 50% the total number of dated sites in the park;
- The discovery of rare preserved wood artifacts, including bow and arrow fragments, at two sites; and
- The discovery of unique high-altitude sites that consist of single historic- or prehistoric-age rock cairns perched on high mountain peaks; the function of these structures is unknown.

Killik River Nunamiut Ethnohistory and Archaeology

A component of the Killik–Nigu–Noatak River cultural resource inventory project was a series of site visits to historic Nunamiut camps on the Killik River with the participation of elders from Anaktuvuk Pass, who last occupied the sites in the 1940s. These camps are some of the most significant sites in the park. They figure prominently in Nunamiut cultural history as one of the areas where the Nunamiut first returned to an inland lifestyle after a time spent living on the Arctic coast, and they also document one of the last examples of a mobile hunting, fishing, and gathering lifestyle in North America. The work consisted of site visits, interviews, and archival research and was a cooperative effort between Gates of the Arctic and the North Slope Borough/Simon Paneak Museum. The elders were Justus and Ethel Mekiana, Rhoda Aghook, and Mollie Aghook. James and Anna Nageak translated between Inupiaq and English. Grant Spearman, the director of the Simon Paneak Museum, was instrumental in organizing the project, which built on decades of his careful research.

The highlights of the project include:

- Sharing by the elders of more than 20 hours of stories and knowledge that were captured with video and audio recordings;
- Documenting 50 place names and associated oral history and stories from the Killik and Nigu Rivers; and
- Relocating and recording detailed oral history and archaeological information from seven historic camp sites.

Elders examining an old wash bin at the Sulupaat camp on the Killik River. Sulupaat was the last Nunamiut camp on the Killik and was abandoned in 1949 when the Killik band walked to Anaktuvuk Pass.

Riparian Area Bird Inventory

Many migratory species face widespread alteration or loss of habitats at important sites along their migration routes. The impacts of habitat loss may be first detected through changes in the patterns of bird abundance and distribution on the breeding grounds. The riparian bird inventory was designed to document bird species distribution, diversity, density, and habitat within the major riparian corridors of Gates of the Arctic National Park and Preserve.

Bonapart's gull chicks on Kutuk Lake adjacent to the Alatna River. About 60 bird species were detected along the Alatna River in June 2005.

In 2005, the third year of this project, more than 150 points were sampled for landbirds along the Alatna and Itkillik Rivers, bringing the total number of survey points conducted in 2003–2005 to more than 800. The 2005 work completed surveys along all the major rivers in Gates of the Arctic, which also include the Noatak, North Fork of the Koyukuk, John, Kobuk, and Killik.

Before the riparian bird inventory and 2003's shorebird inventory, Gates of the Arctic was largely unsurveyed, leaving a gap in knowledge of the breeding distribution and habitat requirements of many migrant and resident bird species. Future field work will include the use of sound equipment to record songs and calls for 10-minute intervals throughout the day during the breeding season. The information will assist in determining daily and monthly timing of future monitoring efforts.

This bird inventory project was established through the Park Flight Program, which is a partnership between the NPS, National Park Foundation, National Fish and Wildlife Foundation/USAID, American Airlines, and the University of Arizona.

Bureau of Land Management

Mineral Assessments

In 2005, BLM's Branch of Solid Minerals initiated a mineral assessment of the southern portion of the National Petroleum Reserve–Alaska (NPRA). The 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. BLM work includes locating, sampling, mapping, and evaluating historic mines, prospects, and occurrences and investigating newly discovered mineralization. This assessment is part of BLM's mineral assessment program, authorized under the Alaska National Interest Lands Conservation Act (ANILCA), which has been ongoing since the early 1980s.

The NPRA contains many documented mineral occurrences, including deposits of lead, zinc, silver, barite, and phosphate. In addition, the reserve contains extensive resources of coal, sand, and gravel. The metallic minerals are concentrated in the southern portion of the reserve, while the coal is concentrated in the central and northern portions. An airborne geophysical survey was conducted over the southern portion to better map geologic formations and delineate anomalous mineral occurrences. Over ten thousand line-kilometers were flown, sampling magnetic field strength and electromagnetic conductivity at multiple frequencies. This work was accomplished through a cooperative agreement with the Alaska Division of Geological and Geophysical Surveys. Also, an interagency agreement was established with the U.S. Geological Survey to conduct detailed site investigations to gain a better understanding of the bedded barite deposits and the correlation between trace elements and silver-lead-zinc occurrences.

Airborne geophysical survey getting underway at the Ivotuk field camp in the southern National Petroleum Reserve–Alaska.

	Funding (thousands)	
	FY 04	FY 05
Natural Ecology	1,172	1,288
Minerals Research (Non-O&G)	2,030	3,868
Minerals Research (O&G, NPRA)	2,767	2,534
Cultural Resources	260	200
Pipeline Monitoring	0	0
Fire Control	339	317
Total	5,610	5,320

Other mineral assessment accomplishments include the following:

- In 2004, the final field season for the Delta River Mining District Study was completed. BLM collected and analyzed 446 rock chip, placer, pan concentrate, and stream sediment samples. A geologist from the Environmental Careers Organization served a summer field internship.
- The Aniak Mining District Study completed fieldwork in 2004 and 2005, collecting 932 rock chip, placer, pan concentrate, and stream sediment samples. Through a cooperative agreement with the Geologic Society of America, a student was able to spend the summer as an intern under the GeoCorps program.
- In 2005, two additional mining district studies were initiated in the Bristol Bay Mining District and the Admiralty Mining District.

Juneau–John Rishel Mineral Information Center

The Juneau–John Rishel Mineral Information Center (JRMIC) is home to a library with a collection of over 20,000 geologic and minerals publications focused on Alaska and available nowhere else in southeast Alaska. The Center's resources provide invaluable support to the mineral assessment program, and it is home to one of the mineral assessment teams. The JRMIC also maintains the Minerals Availability System files. These are the accumulations of Alaska-specific minerals data that, in many cases, can be found nowhere else in the world. In addition, JRMIC serves as a neutral intermediary for making private minerals industry data public. The JRMIC holds and disseminates many Alaska-specific mineral data sets. All current and past technical reports are available at the JRMIC website (http://www.blm.gov/ak/jrmic/).

GeoCorps intern measuring the strike and dip of exposed bedrock at Canyon Creek.

Through the JRMIC, the BLM provides public outreach and minerals education to the communities of southeast Alaska. In addition to responding to many request for presentations at area schools, the JRMIC staff also supports numerous annual events and programs, including Sea Week, evening classes, and Gold Rush Days.

Sea Week is an outdoor program held in April for fourth graders of the Juneau school district. Each year, a member of the JRMIC staff mans the geology/soils/glaciers station for part of the week. Over 400 students are served by this program, which focuses on Alaskan marine and coastal ecology.

Each year during fall and spring, JRMIC offers evening classes for adults and children. The classes focus on mineral uses, history, and field identification, with an emphasis on the physical properties of minerals and the mineral resources of Alaska.

At one of the many exhibition booths at Gold Rush Days, an annual Juneau event, JRMIC presents visitors with information about services and educational opportunities available at its BLM office in Juneau, as well as other resources managed by BLM throughout Alaska.

Weed Management in Alaska

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 2004 and 2005, through a National Fish and Wildlife Foundation matching grant awarded to the Fairbanks District Office, BLM worked with grant partners to successfully develop and provide workshops for developing cooperative weed management areas and conducted additional inventory on public and private lands. Through the project, BLM also continued to build on the education awareness campaign begun through the previous grant and contributed to the building of an invasive species ranking system. A research needs assessment authored by University of Alaska and BLM scientists was published in the journal *Agroborealis*.

BLM continued to conduct invasive plant inventories on BLM-managed lands in 2004 and 2005, primarily within the Dalton Management Area (Fairbanks District Office) and Glennallen Field Office area. During 2005, BLM concentrated its inventory and control efforts within and adjacent to ten 2004 fires. Inventory data will be used to prioritize future control efforts in and around these burns. BLM began assessing weed inventory, control, and monitoring needs in and adjacent to the 2005 fires. The fire seasons of 2004 and 2005 resulted in the highest and third highest number of acres burned in Alaska, respectively, since records have been kept.

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

BLM technician conducting surveys of invasive, non-native plants in the Dalton Management Area.

Neotropical Migratory Bird Surveys

The BLM Alaska wildlife biologists continued to participate in the Neotropical Migratory Bird (NTMB) conservation program during FY 2004 and 2005. The program is better known as Partners In Flight.

In an effort to monitor trends in North American bird populations, 11 breeding bird surveys (BBS) and 7 off-road breeding birds surveys (ORBBS) 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.

BBS routes were also conducted along the Unalakleet and Anvik Rivers in western Alaska, adapting standard protocols to a river setting, rather than a roadside. Sixty-seven species have been recorded on the Unalakleet route, and 66 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 BBS 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 were continued to be run in FY 2004 and 2005. 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 ORBBS established in 1998 on Old Woman Mountain provides information 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.

A fall-migration bird banding station was established at the BLM's Campbell Tract in Anchorage in 1997 and continued to be run through FY 2004 and 2005. Migrant birds were captured with mist nets and banded and released annually from mid-August through September. In past years, 413 individuals were banded in 1997, 961 in 1998, 1010 in 1999, 1254 in 2000, 1343 in 2001, 924 in 2002, 1167 in 2003, 1228 in 2004, and 841 in 2005. The slate-colored junco was the primary species captured, followed by Wilson's warbler, orange-crowned warbler, and ruby-crowned kinglet. Band recoveries include yellow warbler, slate-colored junco, hermit thrush, fox sparrow, and black-capped chickadee banded since 1997.

BLM is working with USGS-BRD to determine the cause of a large number of black-capped chickadees found with deformed bills in south-central Alaska. Black-capped chickadees banded by BLM biologists in fall migration since 1997 with normal bills are being recaptured by USGS-BRD biologists, but with deformed, elongated bills. The banding data on these birds will give clues on the cause and age of onset of bill deformation in this species.

BLM partnered with state agencies and other organizations in 2004 to support a three-year research project on the Arctic warbler. The Alaska Bird Observatory (ABO) is conducting the study on BLM-managed and adjacent lands between the Tangle Lakes and Maclaren Summit. The study addresses the breeding ecology and habitat requirements of Arctic warblers. Little is known about this long-distance migratory bird, which is currently listed by the U.S. Fish and Wildlife Service as a Species of High Conservation Concern.

Arctic warbler just before being released.

After the second field season, ABO has assembled the largest database on Arctic warbler breeding ecology and habitat needs in North America. The results from the study will provide guidance to BLM and other agencies for future management plans and land use actions.

BLM biologists also participated in environmental outreach, presenting programs to students and the public on bird identification, biology, and conservation.

Mapping Arctic warbler breeding territories.

Fortymile Caribou Herd Monitoring

BLM and the Alaska Department of Fish and Game continue to cooperate in the monitoring and management of the Fortymile Caribou Herd (FCH), which ranges through the eastern interior of Alaska. Through this cooperative project, population and composition trends have been studied.

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, numbered about 568,000. As the FCH has recovered from 22,104 in 1994 to approximately 40,000 in 2005, the herd has begun to occupy more of the original range, including the highlands of the Steese National Conservation Area and east into former ranges in Yukon.

BLM joined state and Federal agencies, Yukon First Nations, Yukon and Canadian agencies, and concerned citizens in Alaska and Canada to plan for the recovery of the FCH, completing the FCH Management Plan in 1995. BLM and the Alaska Department of Fish and Game began implementing the plan in 1996 through 2001. BLM continues to monitor the FCH, managing for continued growth and expansion into former range.

A coalition of Alaska Fish and Game Advisory Committees and the local Subsistence Resource Advisory Council, in consultation with BLM, other Federal agencies, and partner agencies in Yukon and Canada and First Nations, began writing a harvest management plan in 2005. The plan will guide harvest for continued growth from 2006 to 2012. Data collected through cooperative projects contributed to the successful implementation of the 2001–2006 harvest plan and the development of the new plan.

Fire Ecology and Management Studies in Interior Alaska

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. In 2004, the BLM Alaska Fire Service and Tanana Chiefs Conference, Inc. completed a four-year Fuels Treatment Demonstration project, 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 forests, with the concomitant risk reduction, visual impact, environmental effects, and cost–benefit ratio.

The BLM Fairbanks District Office and Alaska Fire Service collaborated with the Army's Cold Regions Research and Engineering Laboratory to revisit tundra fire effects transects established 25 years ago. Permanent transects to monitor fire recovery on a tundra fire were established after severe fires in 1977 at Imuruk Basin, which is now within the Bering Land Bridge National Park. With assistance from the National Park Service,

BLM botanist conducting a tundra fire recovery study in a 25-year-old tundra burn scar on the Seward Peninsula. Note the abundant willow shrub.

Large mud flow into a stream channel caused by permafrost melting during the Hodzana River fire of 2004.

transects were re-located and re-sampled under the guidance of the original investigator. Vegetation and permafrost depths were compared to previous results from earlier stages of recovery, and the results were recently published. Notable findings included the slow recovery of lichens important for caribou forage and the new establishment of willow shrubs dating from the fire occurrence.

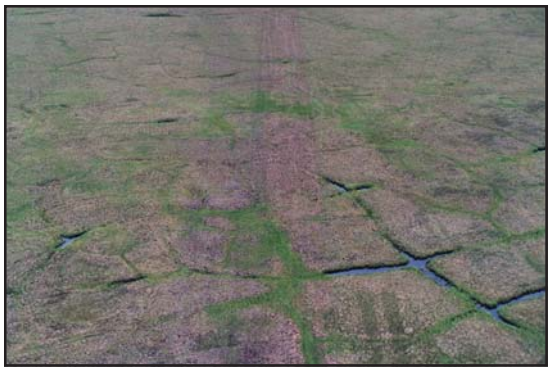
The 2004 and 2005 fire seasons in Alaska together burned over 11 million acres of boreal forest and tundra. These two years represent the largest and third largest annual areas burned, respectively, since record keeping began in 1950. Climate is changing rapidly in the Arctic, and fire seasons like 2004 and 2005 may become more common. Burn severity was uncharacteristically high, particularly in the central and upper Yukon regions, because of historic drought conditions. Erosion and permafrost degradation were striking in some burned areas.

Burn severity evaluation team on a large mud flow clogging a stream.

BLM and other Federal agencies mounted an extensive interagency effort to map burn severity over some of the large fire complexes using Burned Area Reflectance Changes (BARC) on pre- and post-burn satellite images. Field visits and aerial reconnaissance were used to tune the maps to reflect burn severity level on the ground surface. Federal land managers in Alaska feel that the rendering of BARC maps to preliminary burn severity maps will be a valuable legacy after the 2004 fires. Quantifying adverse or positive effects from the burns on managed resources such as wildlife habitat and subsistence users requires a landscape perspective and generally several years of data to determine ultimate effects. The burn severity maps covering entire fire complexes will be key data for determining effects as recovery proceeds and will yield important feedback to managers who need to revise and tune fire management plans to protect key resources.

NPRA Ice Roads

A study by the BLM of the effects on tundra vegetation of overlapping, multi-winter ice roads was begun in 2002 and continued until 2005. This study was intended as a pilot study, and the sample size (five) was limited by the availability of overlapping ice road paths in suitable vegetation cover types. The resulting power of the statistical tests was low. The four treatments in the study were a control, ice road paths from 2001 only, ice road paths from 2002 only, and overlapping ice road paths from both winters. The characteristics measured were the depth of thaw (the 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. The third and final year of data collection on the ice road study occurred in 2004. Specialists returned in 2005 to take additional photos. As in previous years, there were no statistically significant differences in thaw depth among the treatments, but the trend toward greater thaw depths over time among all the treatments continued. Likewise, there were no differences in tussock damage among the three manipulated treatments, but evidence of recovery continued. Measurements of vegetation cover showed a significantly greater effect in the overlap treatment in only one of the three years when the data were analyzed separately by year, but this effect did not appear in an analysis of the data for



Ice road study site in 2002.

Ice road study site in 2005.

all three years combined. Thus, there is no evidence of additive impacts from building ice roads over the same path in two subsequent years. Given the fairly rapid recovery of the tundra, it is doubtful that any significant environmental benefit would be gained by requiring that all ice roads be completely offset from previous years' paths.

Human Impacts on Winter Movements of Wolves

The ecological effects of snowmobile activity on wildlife are increasingly a concern for resource managers and planners, yet little is understood about the implications for predators, particularly wolves, and the dynamic role that OSV (over-snow vehicle) trails can have on predator–prey interactions. As of 2003, there were more than 2.4 million snowmobiles registered in North America, 34,000 of which were in Alaska. The production of light-weight, fuel-efficient snowmobiles in the mid-1990s has expanded snowmobile activity into areas where little or no activity previously existed. OSVs and the alterations made to the landscape from their activity can have profound impacts on wolf–prey dynamics. The presence and noise from OSVs could displace and disrupt animal activity and movement patterns, while the creation of trails could allow energy-efficient travel for wolves (and increasing likelihood of encountering and successfully capturing prey). High hunting and trapping pressure could exacerbate these effects, particularly during critical periods such as late winter, when animals are most stressed and when anthropogenic activity is greatest.

Beginning in October 2004, the Alaska Department of Fish and Game and the University of Northern British Columbia, in cooperation with BLM, began addressing the ecological implications of OSV activity on predator–prey interactions in the Nelchina Basin (Game Management Unit 13) of south-central Alaska. With its dense network of trails and the increasing predator management program, the Basin presents a unique opportunity to quantitatively assess the spatial and temporal relationships of wolves, human activity, prey resources, and snow characteristics.

It is anticipated that this two-year research project will also begin to provide an essential component in unraveling the complexity of factors that affect ungulate survival, as well as providing a baseline for future investigations into the energetic implications associated with anthropogenic activity.

ADFG research biologist fitting a satellite collar on gray wolf. Transmitters on wolf collars report the animal's location at 15-minute intervals.

Shorebirds Staging on Alaska's North Slope

In 2005, the Arctic Field Office of BLM Alaska joined with many other agencies and private companies [University of Alaska's Coastal Marine Institute, Minerals Management Service, Barrow Arctic Science Consortium, North Slope Borough Department of Wildlife Management, U.S. Fish and Wildlife Service, Conoco Phillips Inc., BP Alaska (Exploration) Inc.] to participate in an effort to gain a better understanding of the abundance, distribution, phenology, movements, and physiology of post-breeding shorebirds during the staging period and to aid in assessing how future industrial and human activity across the North Slope may affect shorebird populations. A two-level approach was used, consisting of site-specific and broad-scale components:

- A site-specific, in-depth analysis of staging phenology, behavior, and physiology at five locations across the North Slope; and
- A broad-scale aerial survey and telemetry effort to investigate pre-migratory shorebird abundance, distribution, and movement patterns across the entire North Slope coastline.

BLM provided funding to conduct the first aerial survey specifically designed to count staging shorebirds along the entire North Slope coastline. The survey extended from the southern end of Kasegaluk Lagoon to the eastern border of the Arctic National Wildlife Refuge (2,468 km) and was conducted in August 2005. Approximately 16,850 individual shorebirds were counted during the survey; the majority of these were small calidrid sandpipers and phalaropes.

Radiotelemetry techniques being used to relocate radio-tagged shorebirds at Peard Bay, Alaska.

Red phalarope at Peard Bay, Alaska.

BLM also provided funding and staff for a field camp at Peard Bay. Personnel at each of the five field camps conducted regular surveys to examine shorebird abundance, distribution, species composition, and habitat use from late July to late August. Field camp crews also captured birds to collect blood samples for physiological analysis and to band or radio-equip individuals to determine tenure time at that site. Each camp maintained an automated telemetry station and conducted manual telemetry on a regular basis to examine the probability of birds dispersing between and among breeding and staging areas.

Cliffs along the Colville River, Alaska.

Raptor Surveys along the Colville River

Surveys for peregrine falcons were first conducted along the Colville River in 1952. Following that, 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

Attaching a satellite transmitter to a raven along the Colville River to gather distribution and productivity information.

detected in 1973 and a high of 62 pairs in 1998. Since 1981, the U.S. Fish and Wildlife Service and the BLM have been collaborating to provide funding and personnel to conduct surveys of the Colville River to document the occupancy and productivity of cliff-nesting raptors. Extensive data have been collected on gyrfalcons and rough-legged hawks in addition to peregrine falcons, and for many years an active banding program was conducted for peregrine falcons. Surveys were conducted in 2005 and are scheduled to be conducted every three years to maintain this long-term data set.

NPRA: Colville River Common Raven Project

In 2005 the Arctic Field Office of BLM Alaska funded a portion of a research project in collaboration with the University of Alaska Fairbanks and other government agencies and organizations [U.S. Fish and Wildlife Service, North Slope Borough Department of Wildlife, Phillips Alaska, Inc., BP Exploration (Alaska), Inc.] to collect data on foraging ecology and basic life history questions for common ravens in the NPRA. Funding from BLM paid for satellite transmitters and ARGOS satellite time for six transmitters to be deployed on ravens along the upper Colville River. The data from these transmitters will be combined with information that this study is collecting using ten other satellite transmitters in developed and undeveloped areas of the North Slope. This broader study will collect information on:

- The distribution of ravens on the North Slope prior to oil development in comparison to the current distribution;
- Foraging patterns and diet in developed areas (oil facilities and villages) in comparison to less developed areas (Long Range Radar Sites and undeveloped sites); and
- Nesting productivity of ravens in developed and undeveloped areas.

This study allows for data collection in undeveloped areas of NPRA and will allow informed management decisions regarding the effects of ravens as predators on nesting birds if and when industrial development moves into these areas.

Spectacled and Steller's Eider Surveys on the North Slope

In 2004 and 2005, the Arctic Field Office of BLM Alaska provided funding for two projects to conduct aerial surveys of the federally listed threatened spectacled and Steller's eiders on the North Slope of Alaska. The first survey was conducted along the entire North Slope and surveys for both Steller's and spectacled eiders. The Teshekpuk Lake region in the northeast area of the NPRA was surveyed at double the intensity of the remaining survey area in order to increase the precision of the estimates and the resolution of the distributional data in this area, which has high potential for oil and gas leasing and development as well as very high wildlife resource values. This survey had three main objectives:

- Determine the population trend for spectacled eiders in light of recovery and reclassification criteria, including power analysis;
- Estimate the abundance of spectacled eiders observable from the air; and
- Develop and implement a detectability study to correct for birds present but not detected in the sample area by observers.

In 1997, the Alaska breeding population of the Steller's eider was listed as threatened. Historical data suggest that Steller's eiders formerly nested widely across much of northern Alaska. Recent records suggest that the species' current range in northern Alaska has been greatly reduced, mostly to the vicinity of Barrow. Barrow is the only area in Alaska known to be used regularly by nesting Steller's eiders, with a few dozen pairs in most years. The spatial extent and the population size of the Barrow "cluster" is not known, because ground access is limited in this area. Thus, the second survey was designed to survey for Steller's eiders in the Barrow region. Aerial surveys

conducted annually are useful for describing the general distribution and relative abundance of Steller's eiders in the Barrow area and will be valuable for monitoring their population over time as required by the Steller's eider recovery plan.

Monitoring the Teshekpuk Caribou Herd in NPRA

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. The project team continued to collect data in 2004 and 2005, and they now have a general picture of broad-scale annual movements and range use. There remains a need to collect detailed information to assess the impacts of specific developments within that range.

Critical Habitat for Subsistence Fish Species in NPRA

During 2004 and 2005, BLM became part of a cooperative effort to identify critical habitat for subsistence fish species utilized by villages within NPRA. The groups collaborating on this project include the North Slope Borough, Alaska Department of Natural Resources, MJM Research, and ABR, Inc. Much of the subsistence fish harvest for Barrow occurs in the complex network of interconnected streams and lakes that drain into Admiralty Bay and Smith Bay, including Teshekpuk Lake, the third largest lake in Alaska, and five major river systems, the Ikpikpuk/Chipp, Alaktak, Topagoruk, Meade, and Inaru. Broad whitefish and Arctic grayling are the most abundant subsistence fish species. High-value oil and gas interests in this area substantiate the need to identify high-use habitats for these species and examine stock structure; knowledge that is fairly limited at this time.

Fyke net sampling in targeted areas within the region of interest helped to identify some high-use summer habitat for broad whitefish and Arctic grayling. Stock structure was characterized in terms of fish length, age, and sex. Catch records and measurements were also maintained for other species, including least cisco, Bering cisco, humpback whitefish, burbot, northern pike, Arctic char, and lake trout. These species are utilized in the subsistence harvest as well, although to a much lesser extent. Broad whitefish and Arctic grayling over 300 mm were tagged with numbered Floy tags to document movements upon recapture. Over sixty radio transmitters were surgically implanted into broad whitefish, and these were tracked intermittently throughout the year in an attempt to identify migration patterns and summer feeding, fall spawning, and overwintering habitat. The developing data set from tracking efforts is beginning to fulfill project objectives. The project is scheduled to continue in 2006 and beyond.

Winter Water Withdrawals from Lakes in NPRA

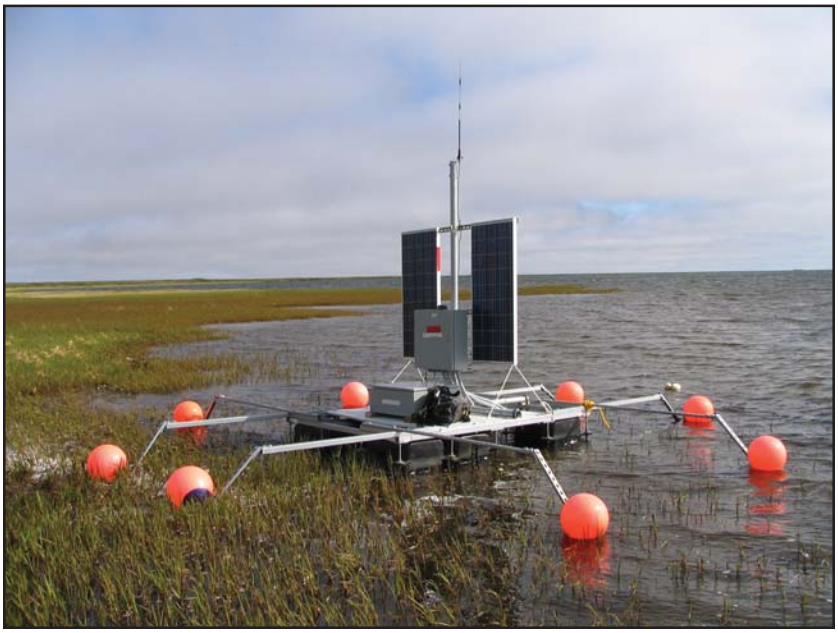
In the winter of 2004-2005, BLM began cooperating with the Water and Environmental Research Center at the University of Alaska Fairbanks and GW Scientific to assist in a study of the potential impacts from winter water withdrawals from lakes for the purpose of oil exploration. Water is removed from lakes in winter for building ice roads and drilling pads, and the amount of water permitted for removal is based on conservative guidelines designed to protect fish. The objectives of this project include examining lake recharge and chemistry parameters in pumped lakes to determine what impacts, if any, are occurring and whether or not different levels of water removal may be detrimental to fish. This project, largely supported by the Department of Energy and the oil industry, is scheduled for funding through 2008.

Flow Monitoring of NPRA Rivers

In 2005, BLM operated two gaging stations and provided funding to the USGS to operate four gaging stations in NPRA. They are distributed from the coastal plain to the Brooks Range foothills to enhance regional flood frequency equations with site-specific peak flow data.

Most rivers are affected by ice jamming, with snow and/or ice present on the bottom of the river during the peak flow. These effects raise the water surface elevations and can produce flooding at relatively low discharges. It is important that the range of these effects are known before planning

Transporting and setting up an instrumented raft for monitoring levels and chemistry of Arctic lakes.



Instrumented raft in summer, moved by the wind to the edge of the lake.

the construction of structures across rivers or the siting of facilities adjacent to rivers. Additional peak flow data will increase the design accuracy and safety for future stream crossing structures and will provide baseline streamflow data collection for researchers. Flows at all gaging sites begin during snowmelt in late May to early June and cease in November in most years. The Arctic coastal plain sites reach maximum flows during breakup, while the Brooks Range maximum flows occur primarily after intense summer rainfall events.

Winter ice roads for oil exploration may extend 80 miles and cross numerous rivers from their starting points. Ice bridges are constructed at stream crossings with enough strength to handle drilling rigs moving over them. These bridges must be mechanically removed before breakup to prevent water from being impounded and to allow upstream movement of fish. Scour and deposition of bottom sediments at these crossings can result from improperly breached ice bridges. The Ublutuoch River gaging station is near an annual ice bridge on this stream, and the real-time data transmissions from this site allow optimum timing of field visits to make discharge and velocity measurements in the vicinity of the ice bridge.

BLM assists the USGS in the operation of a gaging station on the Colville River at Umiat. This gage provides advance warning of peak flows for numerous data collection activities occurring downstream and within the Colville River delta. Many years of peak stage records have been collected in the Colville River delta and discharges estimated from them. Substantial errors in discharge estimates can occur when downstream ice jams and bottom ice affect stage values. The use of an ice-free upstream gage at Umiat is critical to evaluating discharge estimates made within the delta.

The Colville River ceases flow in February, allowing a saltwater wedge of water to move upstream from the ocean past Nuiqsut and as far as Ocean Point. The movement of this salt water upstream can affect the distribution of fish within the lower Colville River system and can halt water withdrawals from the Colville River for ice bridge construction. Flows measured at Umiat provide a reference from which to compare to downstream sites that are hampered by physical conditions preventing direct measurments of flow.

A long-term climate monitoring station was re-established at Umiat by BLM in 2004 after being discontinued in April 2001. This site has weather records extending back to 1949, with a total of 29 years of observations. Current climate records are available at http://www.colville-watershed.org/.

The BLM helped initiate a data collection network in NPRA in 2005, integrating scientific data collection objectives with agency resource management needs. This collaborative data network will provide weather, climate, and hydrology information. Management applications of the data

Rivers involved in BLM/USGS flow studies to increase the design accuracy and safety of stream crossing structures used in ice road construction.

include tundra travel and water use logistics. Scientific applications include climate change, Arctic hydrology, and active layer processes. The major partners in the collaborative network include USGS, University of Alaska Fairbanks (Water and Environmental Research Center), Department of Energy (Arctic Energy Office), and industry partners.

BLM–USGS Bering Glacier System Program

The BLM and the 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 with Federal, state, local, academic, and nongovernmental 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 the 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, 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. NTM contributions are coordinated through the Civil Applications Committee. 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 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.

U.S. Geological Survey

The U.S. Geological Survey (USGS) has conducted research in the Arctic since the late 1800s. Today the USGS addresses a complex array of earth science issues through its water science studies, specialized mapping and land cover efforts, geological programs, and expansive biological studies on DOI lands and of trust species. Most Arctic research is conducted from the Alaska Science Center (ASC) in Anchorage and the Cooperative Fish and Wildlife Research Unit at the University of Alaska Fairbanks. Additional specialists from USGS facilities across the U.S. provide unique research and technical expertise required to address the complex issues of Arctic lands and resources, particularly for energy and mineral assessments.

	Funding (thousands)	
	FY 04	FY 05
Water Resources	2,568	2,400
Geography Program	1,837	1,708
Minerals Program	3,543	2,915
Biological Sciences	7,115	6,938
Energy Resources	3,000	3,000
Hazards Program	1,558	1,107
Total	19,621	18,068

USGS streamgaging station surrounded by the annual overbank flooding during the spring breakup along the Kuparuk River.

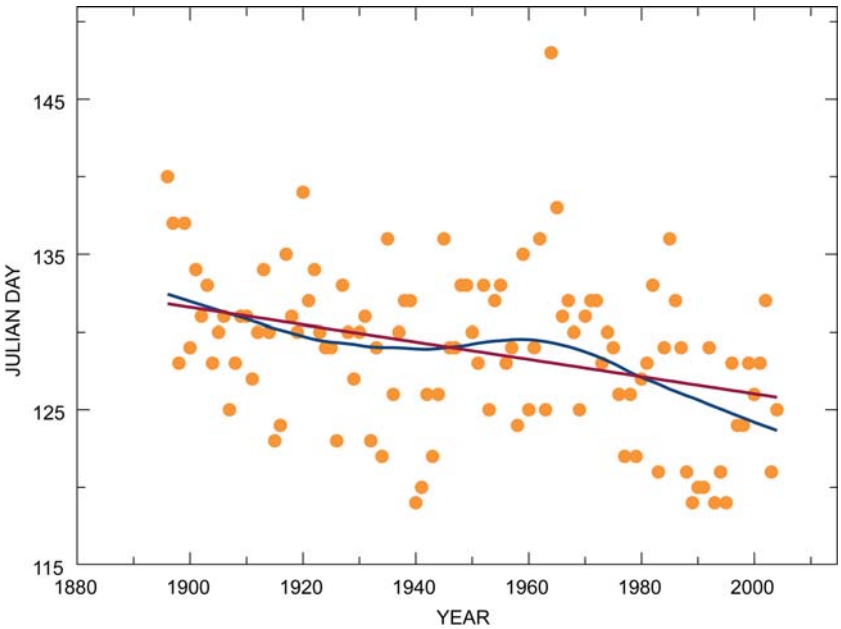
Water Research and Assessments

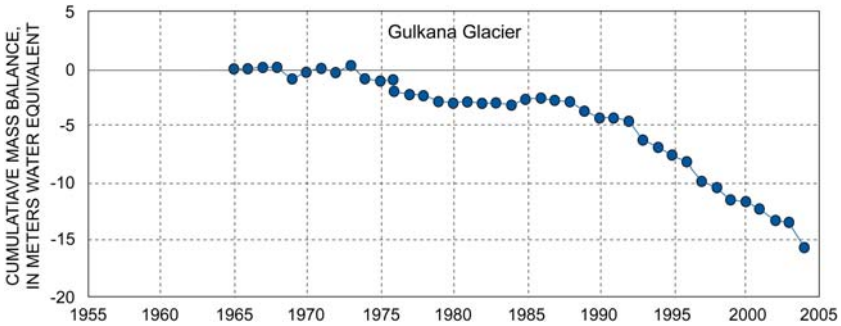
The USGS continued to conduct streamgaging, water quality, and glacier mass balance studies during FY 2004 and 2005. Some 120 stream gages were operated in Alaska, with approximately 90 providing real-time streamflow information; only a few of these were within Arctic Alaska, where the extreme Arctic climate and intense flow patterns after ice breakup and snowmelt make retention of gaging equipment difficult. However, the few streamgages operational in the Arctic, near the Trans Alaska Pipeline, provide valuable insight into patterns of streamflow that influence the stability of the infrastructure and rural community safety. For example, a trend toward earlier breakup is seen at stations with long periods of record, such as gage on the Yukon River near Dawson, Yukon Territory, Canada. Four new stream gages were added in the Northern Petroleum Reserve-Alaska (NPR-A) in FY 2005 in partnership with the Bureau of Land Management, which will add valuable insight into water flow timing and intensity.

The USGS completed data collection activities for a focused Yukon River Basin water quality study in FY 2005. The Yukon River is the fifth largest contributor of fresh water to the Arctic and is a basin dominated by permafrost and glacial inputs. As such, studies of water resources in this basin contribution to understanding climate change in the Arctic. Over the last five years, five fixed sites—the Yukon River at Eagle, near Stevens Village, at Pilot Station, the Porcupine River near Fort Yukon, and the Tanana River at Nenana—were sampled seven times per year. In addition, six synoptic sampling trips were made down the Yukon, sampling other tributaries that flow into the Yukon as well as the main stem of the Yukon.

The USGS monitored the mass balance at two glaciers in Alaska, providing long-term insight into modern patterns of glacier growth or retreat. For example, Gulkana Glacier in south-central Alaska now has a continuous record of mass balance of 40 years, one of the longest records worldwide.

Date of spring breakup on Yukon River at Dawson, Yukon Territories. Spring breakup on the Yukon River has come earlier in the year since records have been collected beginning around 1900. The straight line represents the best linear fit of the data over the entire period of record. The curved line uses a smoothing function to give more weighting to nearby (in time) points, showing the possible influence of shifts in decadal or longer climate patterns.





Annual mass balance records for the Gulkana Glacier in south-central Alaska. (See http://ak.water.usgs.gov/glaciology.)

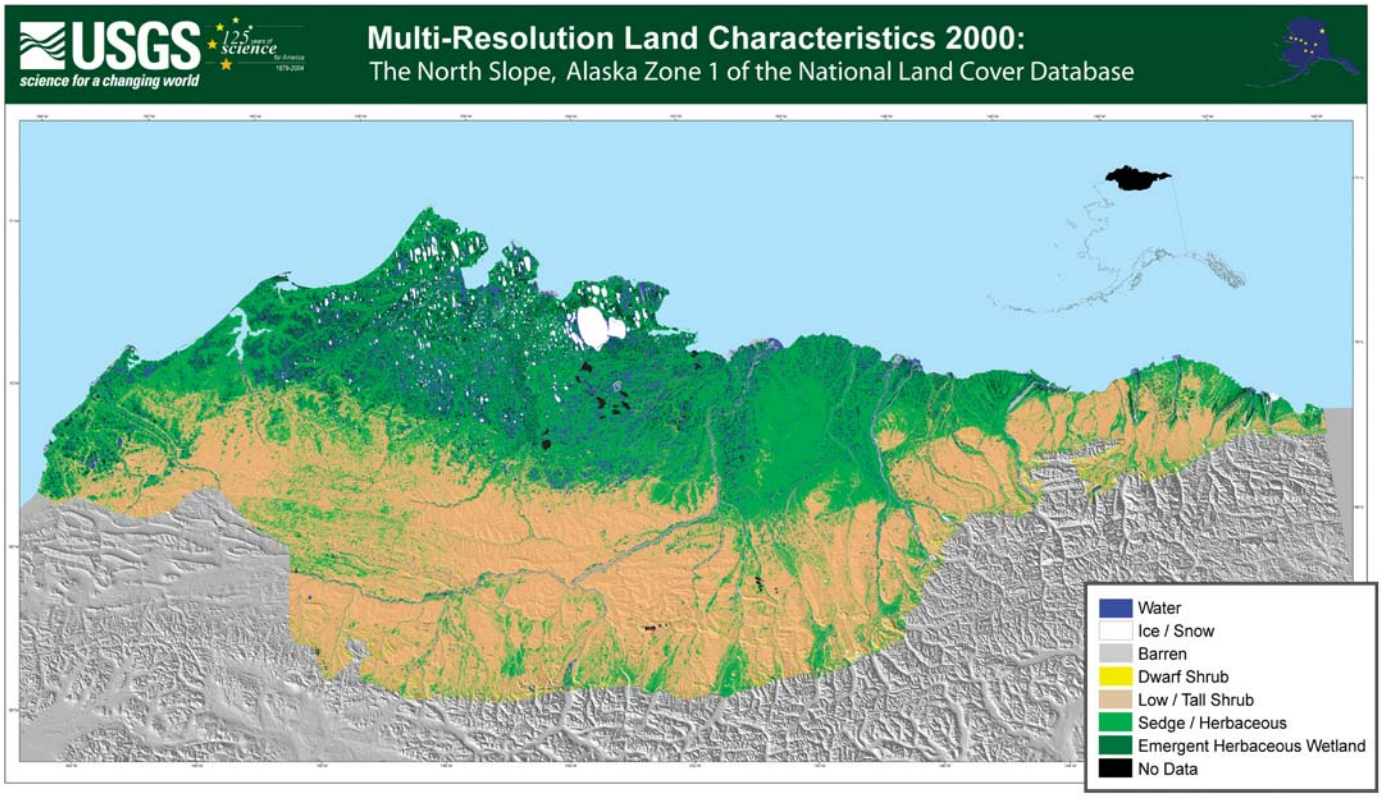
Gulkana Glacier shows a pattern of loss of mass balance over the past 20 years of nearly 15 meters of water equivalent.

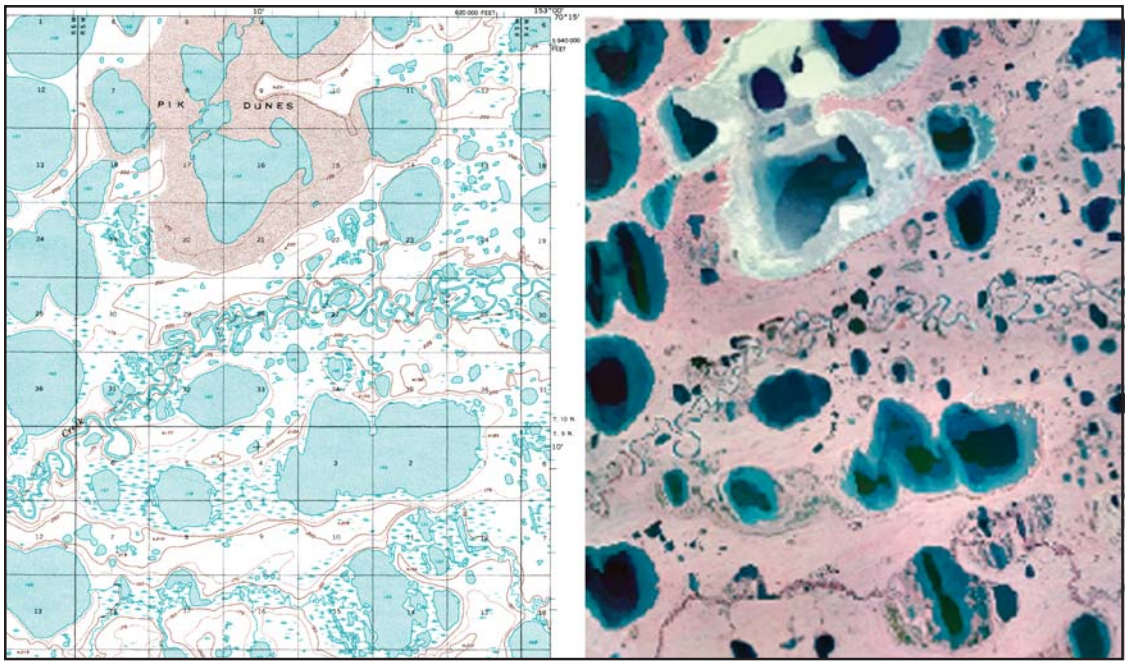
USGS Land Cover and Mapping Efforts

Land cover information is one of the highest-priority information layers requested by land management agencies, but there is little to no consistent medium-scale land cover information for Alaska. The 2001 National Land Cover Database project, established through the Multi-Resolution Land Characteristics consortium, is a national effort to provide such data. The state is divided into 11 mapping zones, and the database for Alaska Mapping Zone 1, covering the North Slope region, has been completed. This zone was a priority because of the need for sound environmental data for resource management and for assessing climate change in the Arctic. Database development involved acquiring existing field data from multiple Federal agencies and University of Alaska researchers and interpreting 1999 Landsat ETM+ satellite imagery. A decision-tree-based land cover classification was produced using the field data and ancillary raster data layers composed of Tasseled cap and reflectance imagery derived from Landsat imagery and elevation, aspect, slope, position index raster data sets. The land cover classification, ancillary data layers, and metadata are included within the final database along with the classification rules to allow modification of the decision tree by users seeking to derive land cover products specific to their local applications.

An assessment of a new approach to facilitate detailed land cover database for Alaska was completed. The objective of this project was to evaluate the use of fused, airborne, high-resolution Inter-Ferometric Synthetic Aperture Radar (IFSAR) with Landsat ETM+ data against digital ortho-photo quads (DOQQs) for generating land cover maps using digital image processing tech-

Land cover classification of the Alaskan North Slope based on the multi-resolution land characteristics mapping protocols.





Comparison of a 1955-based USGS topographic map and a 2002-based DOQQ.

niques. The study area covers the majority of the Harrison Bay quadrangle in the National Petroleum Reserve–Alaska and consists of a 2.5-m IFSAR/Landsat fusion product, DOQQs produced using aerial photography, and IFSAR-derived digital terrain models (DTMs) and digital surface models (DSMs). An existing Ducks Unlimited land cover classification and associated field data were used to label unsupervised classifications of the IFSAR/Landsat fusion product and DOQQ products and to assess vegetation heights using the difference between the DTM and DSM data. The Ducks Unlimited data also provided a consistent accuracy assessment of each classification. The evaluation of the various classifications indicated that the DOQQ and fusion product are not recommended for digital image processing to generate land cover classifications of any sizeable area. The variation introduced by the aircraft flight lines and the aerial photo mosaic process resulted in significant error being introduced into the classification. Although the fusion product increases the resolution of the spectral information in the Landsat data from 30 to 2.5 m, it decreases the information content and thus is useful only for photo interpretation.

The USGS, in partnership with the Bureau of Land Management, continued its efforts to replace severely outdated (circa 1950s) USGS topographic maps with new DOQQs and DEMs for Alaska in 2004 and 2005 with the acquisition of new imagery over the NPRA. Using color infrared aerial photography and airborne Inter-Ferometric Synthetic Aperture Radar (IFSAR) data, new DOQQs and DEMs were produced for the north and central portions of the NRPA.

Mineral Resource Assessments

The goal of USGS mineral research in the Arctic is to provide current and impartial information on the occurrence, quality, quantity, and availability of such resources. This goal is met through a variety of research projects on the origin, resources, and environmental behavior of mineral deposits in the Arctic. During FY 2004-2005, several projects addressed this goal as well as helping to address the 2003 U.S. Arctic Research Commission recommendation “that the Department of the Interior resume its resource evaluation activities and cooperate with the other Federal agencies, the State of Alaska, and institutional partners to provide widely available and comprehensive coverage of all Federal lands in Alaska.”

In the southern NPRA, the USGS began various mineral resource assessments in support of and in cooperation with the Bureau of Land Management. The USGS conducted geologic mapping, stream sediment sampling, and ground geophysical studies to better characterize known lead-zinc mineralization through geochemical analysis of rocks and stream sediments; to define the size and extent of barite mineralization through gravity measurements; and to assess occurrences of bar-

ite, phosphate, and metalliferous oil shales in the area. Data analysis is underway.

The USGS, in cooperation with the Alaska Division of Geological and Geophysical Surveys, began a study of the base metal resources of the Seward Peninsula, Alaska. A major goal of this investigation is to evaluate whether the numerous stratiform lead-zinc (silver) occurrences represent a group of unrelated, small occurrences with limited resource potential or a large, regional mineralizing system that could produce a significant base metal resource such as at Red Dog in northwest Alaska or the Selwyn Basin in Canada. Preliminary analyses suggest that, indeed, the Seward Peninsula occurrences share mineralogical and host rock similarities with like deposits in the Selwyn Basin.

The Arctic Foothills of the Brooks Range contain an enormous accumulation of zinc (e.g., Red Dog deposit) and barite in Carboniferous sedimentary rocks. The resources surpass most deposits worldwide in terms of size and grade. Furthermore, prolific hydrocarbon source rocks generated considerable amounts of petroleum that contributed to the world-class petroleum resources of the North Slope. The USGS undertook a project that was aimed at understanding the petroleum maturation and mineralization history of parts of the Brooks Range that were previously poorly characterized and understood. The project was in collaboration with industry, academia, and other government agencies.

Arctic Foothills region, showing the typical topography of low rolling hills and broad valleys. This view is looking south in the north-central Brooks Range.

Significant findings to date include:

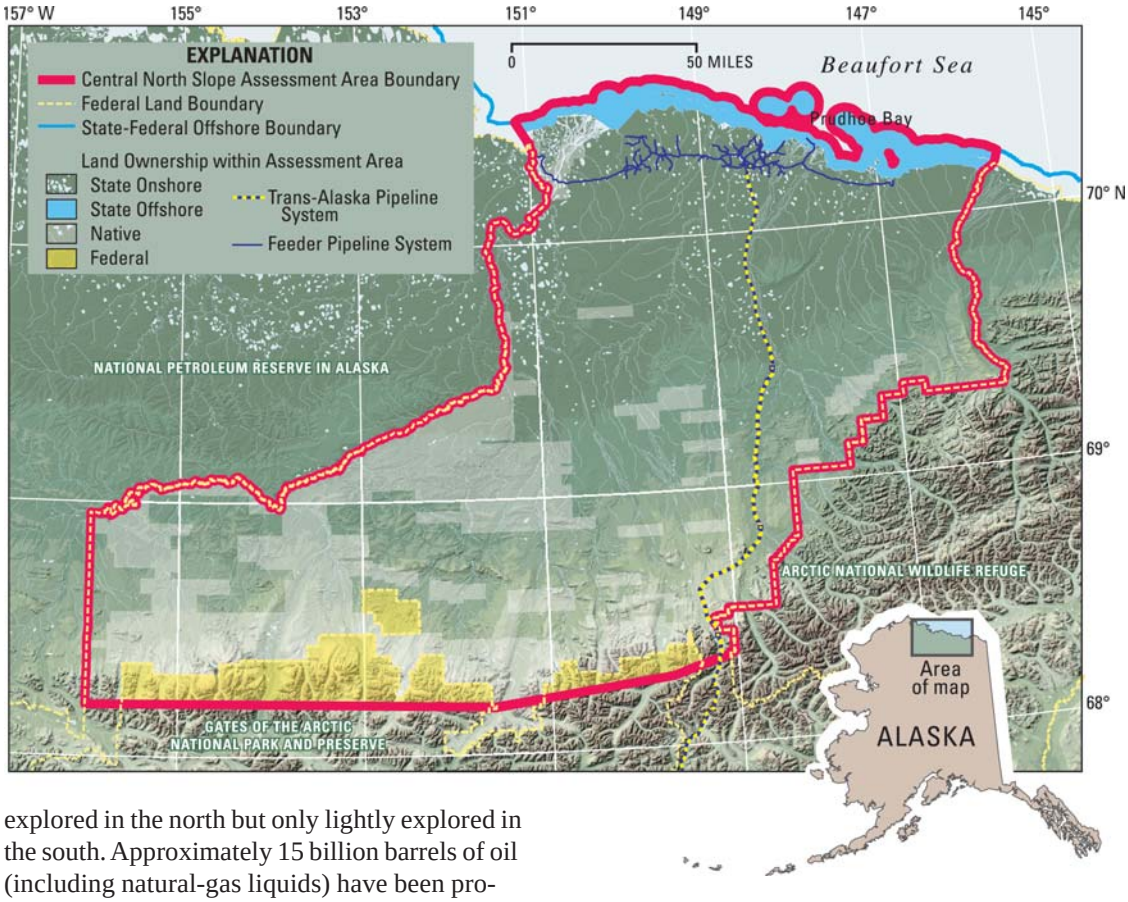
- Deep-water strata of the Kuna Formation (host to the massive sulfide zinc-lead-silver deposits) accumulated in a basin partly rimmed by carbonate platforms that preserved organic carbon.
- The local presence of red beds and/or supratidal dolostones suggest that the climate became increasingly arid during Late Mississippian time.
- Brines produced in shallow settings were a probable source of the ore-forming fluids.
- High hydrogen sulfide (H_2S) production rates may have led to the efficient precipitation of sulfide minerals and, thus, may explain the high grades of the zinc deposits
- Thallium is an especially valuable trace element in distinguishing areas of the Kuna Formation with potential for economic shale-hosted massive sulfide deposits.
- Rocks that were important for zinc mineralization (e.g., the Kuna Formation of the Lisburne Group) are also potential source rocks for sulfide-rich oils found in some wells on the North Slope.

Petroleum Resource Potential of Northern Alaska and the Circum-Arctic Region

Alaska is rich in biologic and mineral resources and has more Federal land and more potential undiscovered energy resources than anywhere else in the U.S. Energy resource considerations play an important part in Alaskan land management decisions and in energy policy development. The USGS Energy Resources Program research activities in Alaska, through collaboration with Federal and state agencies and Native corporations, are focused toward the understanding, geologic evaluation, and resource assessment of energy resources throughout Alaska.

Undiscovered Oil and Gas Resources in the Central North Slope of Alaska

In 2005 the USGS completed an assessment of undiscovered oil and gas resources of the central portion of the Alaska North Slope and the adjacent state offshore area, and they found that a significant amount of oil and a large amount of gas remains to be discovered. The central North Slope area of Alaska lies between the National Petroleum Reserve–Alaska (NPRA) and the Arctic National Wildlife Refuge (ANWR) and extends from the Brooks Range northward to the state–Federal offshore boundary. Most commercial oilfields and virtually all petroleum-producing infrastructure in northern Alaska, including the Trans-Alaska Pipeline System, are located within the assessment area. This area, which consists mostly of state and Native lands covering about 23,000 square miles (about half the size of New York state), is maturely



Boundary of, and land ownership within, the central North Slope petroleum resource assessment area.

explored in the north but only lightly explored in the south. Approximately 15 billion barrels of oil (including natural-gas liquids) have been produced from the assessment area (most from the giant Prudhoe Bay field), and remaining (discovered) reserves include about 7 billion barrels of oil and about 35 trillion cubic feet of natural gas.

This assessment used the same geology-based methodology as in the recent USGS assessments of NPRA and the ANWR 1002 area. The assessment was based on a comprehensive review of all available geological, geophysical, and geochemical evidence, including hydrocarbon source rocks, reservoir rocks, and traps. The minimum accumulation sizes considered in the assessment were 5 million barrels of technically recoverable oil and 100 billion cubic feet of technically recoverable gas. These minimum accumulation sizes are smaller than those used in USGS assessments of NPRA and the ANWR 1002 area in recognition of the extensive infrastructure and recent development of relatively small oil accumulations in the central North Slope assessment area. Resources assessed include technically recoverable conventional oil, natural gas, and natural-gas liquids. Although six petroleum systems were defined, geologic evidence suggests significant mixing of hydrocarbons among those systems. Therefore, the assessment was conducted under the assumption of a single, composite total petroleum system. Twenty-four plays (assessment units) were defined and assessed.

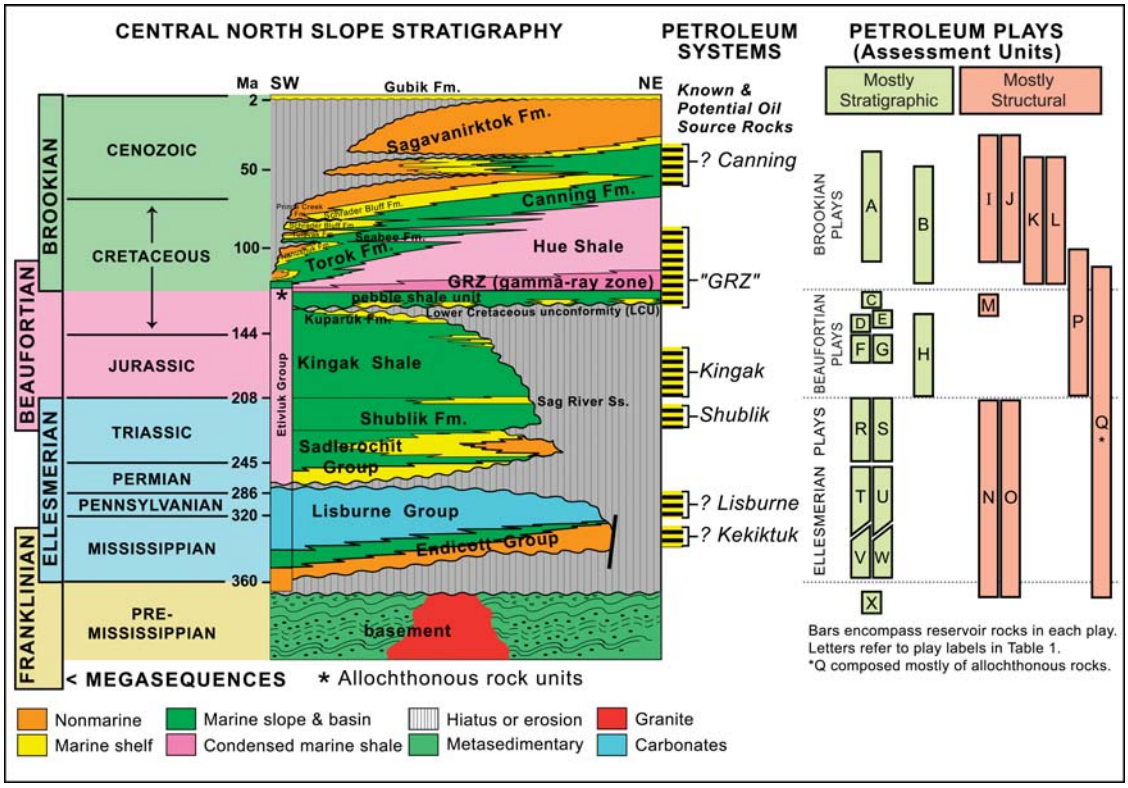
The USGS estimated technically recoverable, undiscovered resources of oil, natural gas (nonassociated and associated), and natural-gas liquids (from nonassociated and associated gas) in the central North Slope assessment area. Technically recoverable resources are the amount of petroleum that may be recovered using current technology. Oil resources are estimated to range between 2.6 and 5.9 billion barrels of oil (BBO) (95% and 5% probabilities, respectively), with a mean of 4.0 BBO. For comparison, recent USGS estimates of mean undiscovered oil in adjacent areas include 10.6 BBO in the entire NPRA and 10.4 BBO in the entire ANWR 1002 assessment areas. In the central North Slope, nonassociated gas resources range between 23.9 and 44.9 trillion cubic feet (TCF) (95% and 5% probabilities, respectively), with a mean of 33.3 TCF. In addition, means of 4.2 TCF of associated gas, 387 million barrels of natural-gas liquids (MMBNGL) from nonassociated gas, and 91 MMBNGL from associated gas are estimated to occur.

Most undiscovered oil and gas accumulations in the central North Slope assessment area are

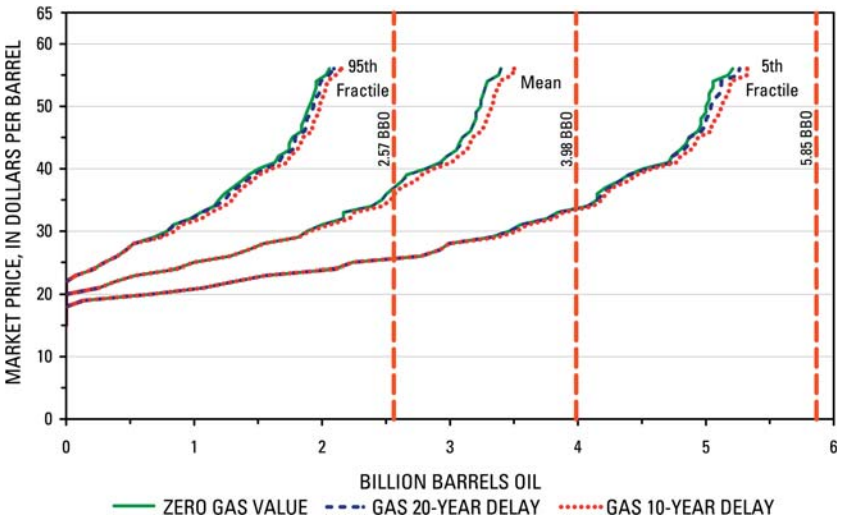
estimated to be relatively small compared to those already discovered: 91% of undiscovered oil resources are estimated to occur in accumulations of less than 250 million barrels of oil (MMBO) recoverable, and 96% of undiscovered nonassociated gas resources occurs in accumulations smaller than 3.0 TCF recoverable. The occurrence of larger oil and gas accumulations is unlikely. In total, there is estimated to be approximately 37 TCF of undiscovered natural gas in the central North Slope, with the majority located in the southern half of the assessment area in the foothills of the Brooks Range. This total is about half of what has been estimated to occur in NPRA (73 TCF of natural gas) and significantly more than has been estimated to occur in the ANWR 1002 area (9 TCF of natural gas). The natural gas resources in the central North Slope are accessible to existing infrastructure and to the route of the proposed gas pipeline.

In a report published in 2005, the costs and product prices required to transform these undiscovered, technically recoverable resources into producible reserves were evaluated. This economic component of the central North Slope assessment is intended to place the geologic resource analysis into an economic context that is informative and easily understood by policy makers and decision makers. This analysis estimates the part of the assessed distribution of undiscovered accumulations that can be commercially developed at particular market prices based on the incremental costs of finding, developing, producing, and transporting the oil and gas. The economic analysis is limited to the evaluation of general finding costs, development costs (including the costs of primary recovery and some aspects of secondary recovery), and the costs of transporting the product to market. Undiscovered technically recoverable conventional oil and gas resources are resources that are estimated to exist in undiscovered accumulations outside of known fields. Economically recoverable resources are the portion of the assessed technically recoverable resource for which the costs of finding, developing, and producing them, including an after-tax 12% rate of return on capital, can be recovered by production revenues at a particular price.

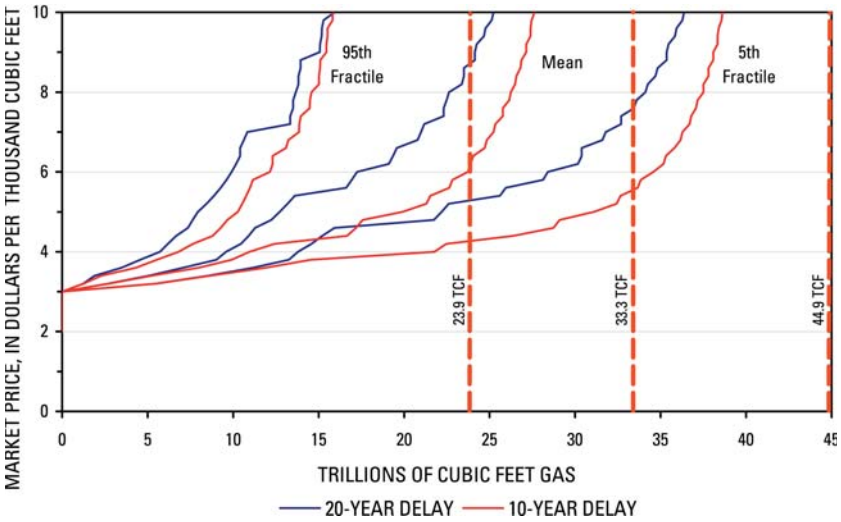
Recent economic analyses of undiscovered hydrocarbon resources of the North Slope have not considered natural gas because there is currently no infrastructure for transporting gas to markets located outside the North Slope. There is also a large inventory—in excess of 25 TCF—of very low cost stranded gas in rapidly depleting oilfields that may have priority access to a gas product pipeline when it is built. This study attempts to gauge, by a scenario analysis, the



Summary of ages, names, and rock types present in the central North Slope petroleum resource assessment area. The colored bars at the right show the stratigraphic position of the 24 petroleum plays evaluated in the 2005 assessment. The letters on the colored bars refer to play labels assigned in the assessment report.



Incremental costs, in 2003 dollars per barrel, of finding, developing, producing, and transporting crude oil from undiscovered oil accumulations in the central North Slope study area, where computations were prepared assuming that gas is valued at two-thirds the value of oil and that the present value of gas accumulations are 1) valued at zero (Scenario 1), 2) discounted for a 10-year delay (Scenario 2), and 3) discounted for a 20-year delay (Scenario 3). The 95th, mean, and 5th fractile estimates refer to the oil estimates with the concomitant gas assessed in gas accumulations. The vertical lines represent the technically recoverable oil at the 95th fractile, the mean, and the 5th fractile estimates of the geologic assessment as reported in U.S. Geological Survey Fact Sheet 2005–3034.



Incremental costs, in 2003 dollars per thousand cubic feet, of finding, developing, producing, and transporting nonassociated gas from undiscovered gas accumulations in the central North Slope study area, where computations were prepared assuming that gas is valued at two-thirds that of oil at the market and that the present values of commercial gas accumulations are discounted for a 10-year delay (Scenario 2) and a 20-year delay (Scenario 3). The 95th, mean, and 5th fractile estimates refer to gas estimates. The dashed vertical lines represent the technically recoverable nonassociated gas at the 95th fractile, the mean, and the 5th fractile estimates of the geologic assessment as reported in U.S. Geological Survey Fact Sheet 2005–3034.

economic influence that potentially commercial but currently undiscovered non-associated gas resources could have on exploration decisions. Past exploration in the study area has resulted in discoveries of more than 17 BBO and more than 35 TCF gas. Of the crude oil discovered, about 12.4 BBO has already been produced. At the mean estimates, the assessed undiscovered oil is 3.98 BBO and 37.52 TCF gas (4.20 TCF associated gas and 33.32 TCF non-associated gas). Almost 90% of the assessed undiscovered oil is assigned to plays that have already had discoveries. In contrast, less than half of the undiscovered gas in gas accumulations was assigned to plays with discoveries.

The USGS economic analysis shows that an increase in the commercial value of natural gas has a small but positive effect on the volume of economically recoverable oil. If gas is assigned no commercial value, above a market price of $40 per barrel for oil, the volume of economically recoverable oil is reduced by about 2–4%. (All calculations and costs were in constant 2003 U.S. dollars.) This analysis assumes sharing of processing facilities with adjacent oil fields, thus permitting development of smaller oil accumulations. At a market price of $55 per barrel, economic oil represents 79–88% of the assessed technically recoverable oil.

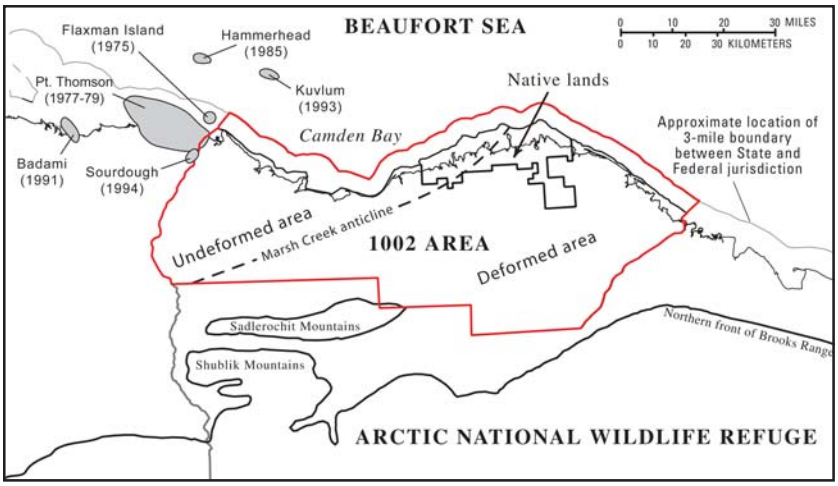
Available information on Arctic gas field development and operational costs are limited because there is no gas market transport system. It is estimated that it would take about 10 years from the decision to construct a gas pipeline to the lower 48 states until the pipeline was complete. Recent estimates of Alaska natural gas export pipeline tariffs of just under $3.00 per thousand cubic feet (mcf) limit the effects that gas commercialization have on oil development when the after-tax net present values are discounted for 10- and 20-year delays in development. The plot for economically recoverable gas reflects the results of analyzing the two scenarios of pipeline access and discounting to net present value. Even though the proportion of economically to technically recoverable gas is low, significant amounts of economically recoverable gas would still be present. However, more than 25 TCF of stranded gas is currently ready to market from existing oilfields on the North Slope at much lower cost than what it would take to discover and develop new gas accumulations. Assuming an Alaskan natural gas export pipeline tariff under $3.00 per mcf and a ready but delayed market, given the primitive gas field development

cost data used in this study, the volumes of undiscovered gas that could be identified and produced at $5 per mcf range from 7.9 to 22.1 TCF.

An Economic Update of the 1998 USGS Assessment of the ANWR 1002 Area

The Alaska National Interest Lands Conservation Act (1980) established the 19-million-acre Arctic National Wildlife Refuge (ANWR). In section 1002 of that Act, Congress deferred a decision on the permanent status of the 1.5-million-acre Federal part of coastal plain ("1002 Area") in recognition of its potential oil and gas resources and its importance as a wildlife habitat. The USGS released in 2005 two reports updating the economic analysis of their 1998 petroleum assessment of the combined lands consisting of the Federal 1002 Area of ANWR, Native Lands inside the boundary of the 1002 Area, and the lands underlying the adjacent Alaska State waters. The updates include newer field development practices based on horizontal development wells and satellite/cluster field development, as well as an update of the 1996 base costs to a new base year of 2003. The 1998 USGS assessment of undiscovered oil resources (in-place and technically recoverable) was retained as the geologic basis for the economic analysis. The mean technically recoverable undiscovered oil for the entire study area (Federal 1002 Area, Native Lands, and lands under adjacent State waters) is 10.36 BBO, while the 95th fractile estimate is 5.72 BBO and the 5th fractile estimate is 15.96 BBO. The Federal 1002 Area averaged about 74% of the assessed resources of the entire study area. The minimum accumulation size considered in the assessment was 50 million barrels of oil in place. Although the 95th and 5th fractile estimates show a wide range in total volumes, for each estimate a substantial fraction of the assessed oil was assigned to large accumulations (500 million barrels or greater), which are of economic interest even though they are located far from infrastructure.

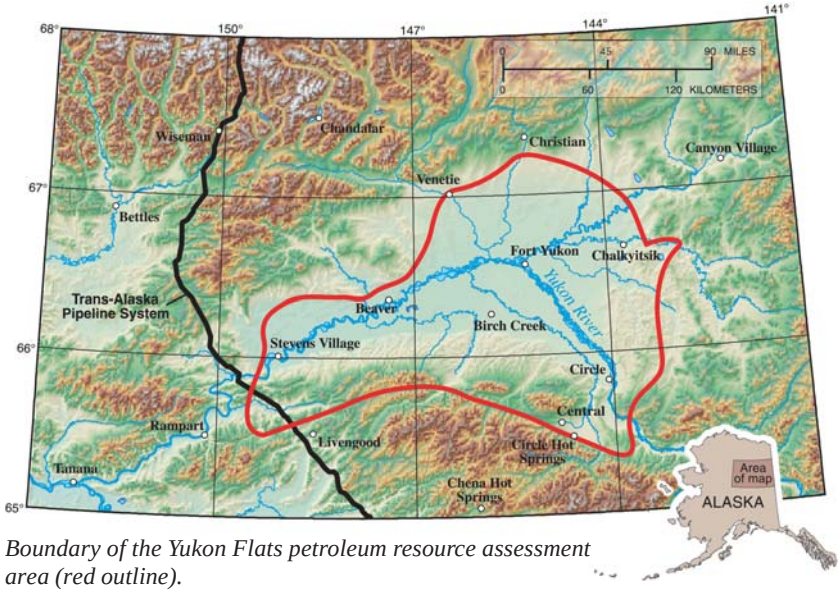
The results of the economic analysis are summarized as incremental cost functions that included the full costs (including a return to capital) of finding, developing, producing, and transporting the oil. The functions show that at $30 per barrel (2003 dollars), between 73 and 82% of the assessed technically recoverable resources are economic. At $55 per barrel, the economic resources represent more than 90% of the assessed technically recoverable resource estimate, that is, between 5.37 and 14.65 BBO. These estimates are generally within 10% of the estimates of the economically recoverable resources published earlier for the entire study area, when those estimates were adjusted to 2003 dollars. This finding suggests that improvements in productivity have to a large extent offset increased costs that occurred between the 1996 and 2003 base years.



The study area (red outline) of the USGS economic update for undiscovered oil in the ANWR 1002 Area. The study area included the Federal part of the 1002 Area, Native lands within the 1002 Area, and lands underlying adjacent Alaska state waters. The black, dashed line labeled "Marsh Creek anticline" marks the approximate boundary between the undeformed area (where rocks are generally horizontal) and the deformed area (where rocks are folded and faulted). Also shown are oil accumulations discovered near the entire Study Area during the past three decades.

Petroleum Resource Assessment of the Yukon Flats Area

Yukon Flats is a region of low, forested hills and flatlands with numerous streams and lakes, situated generally to the east of the TAPS in east-central Alaska. The USGS recently completed its first detailed assessment of the undiscovered oil and gas potential of the Yukon Flats region. At present, there is no commercial petroleum production in the Yukon Flats region, but the new USGS assessment indicates the probable existence of technically recoverable oil and gas resources—in other words, those resources that can be discovered, developed, and produced by using current technology—in rocks of Tertiary age (about 1.8 to 65 million years old). The assessment was based on the general geologic elements used to define a Total Petroleum System (TPS), which include hydrocarbon source rocks (source-rock maturation, hydrocarbon generation, and hydrocarbon migration), reservoir rocks (sequence stratigraphy and petrophysical properties), and hydrocarbon traps (trap formation and timing). The Yukon Flats TPS is a "composite" petroleum system because



Boundary of the Yukon Flats petroleum resource assessment area (red outline).

available geologic evidence suggests that it contains multiple horizons of petroleum source rocks—including shale, mudstone, and coal of Tertiary and Mesozoic age—rather than a single horizon of source rock, as in some other petroleum systems of the world. Using this geologic framework, the USGS quantitatively assessed undiscovered, conventional oil and gas resources in four assessment units within the Yukon Flats Tertiary Composite TPS. The Coalbed Gas Assessment Unit, which may contain continuous (unconventional) gas resources, was not quantitatively assessed for this study and will be considered at a future date, along with other potential coalbed gas units in Alaska.

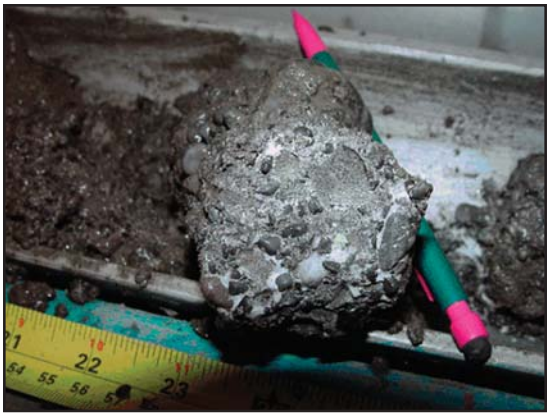
For the Yukon Flats Tertiary Composite Total Petroleum System, the USGS estimates a mean of 5.46 trillion cubic feet of gas (TCFG), a mean of 172.66 million barrels of oil (MMBO), and a mean of 126.67 million barrels of natural-gas liquids (MMBNGL). Nearly all of these undiscovered resources are estimated to be within the Tertiary Sandstone Assessment Unit.

Gas Hydrates

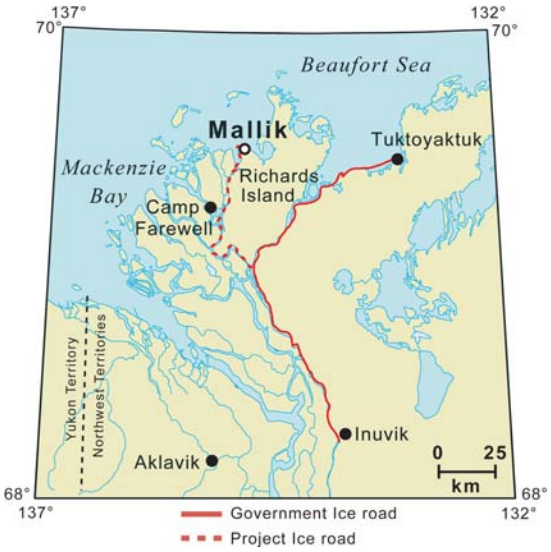
Gas hydrates, which are unconventional accumulations of natural gas (methane) trapped in ice-like structures with water, represent an immense energy resource underlying large portions of the world's Arctic continental areas and marine continental shelves. While these accumulations ultimately may yield important sources of energy for the world, additional scientific and engineering research needs to be undertaken to render feasible gas production from these accumulations. The potential future contribution of gas hydrate to the world energy mix depends on the availability, producibility, and cost of extracting methane from the hydrate phase. The immense potential of this resource has garnered significant national and international attention, and the USGS is involved in several partnerships with Federal and international agencies to collectively leverage resources and improve the understanding of this unconventional energy resource.

One of these partnerships, known as the Mallik International Research Consortium, is a cooperative research project with numerous research partners, including the USGS, the Geological Survey of Canada, the Japan National Oil Corporation, the Japan Petroleum Exploration Company, the GeoForschungsZentrum Potsdam, the DOE, and the India Ministry of Petroleum and Natural Gas. USGS scientists have provided scientific leadership, including one of two project co-leaders, management of all production modeling and testing efforts, management of all downhole logging efforts, scientific leadership of the gas geochemistry program, and scientific leadership of the gas hydrate core analysis efforts.

In 2002 the Research Consortium drilled three dedicated gas hydrate research wells at the Mallik site in the Mackenzie Delta, Canada. The goal was to establish a benchmark contribution by producing hydrates using various production methods, characterizing the engineering properties of gas-hydrate-bearing sediments, determining the geophysical properties of gas hydrates as they apply to surface prospecting techniques, and continuing research to improve drilling, coring, and well completion methods. The Mallik International Research Consortium, for the first time, proved that it was



Sample of core material, recovered from the Mallik Research Consortium drilling effort, showing the presence of gas hydrate (white).

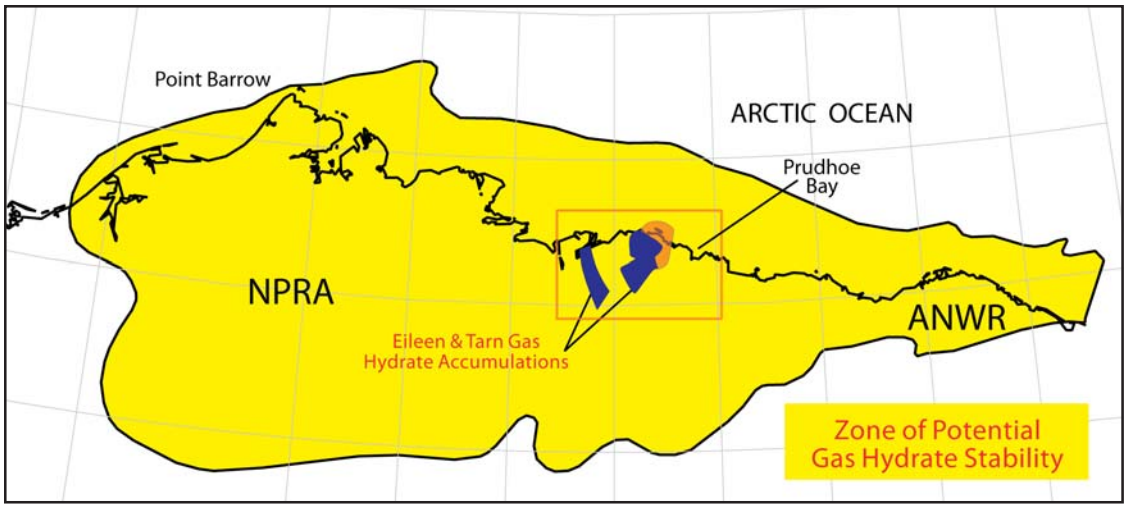


Location of the Mallik Research Consortium drilling site on the Mackenzie Delta of northern Canada.

technically feasible to produce gas from gas hydrates. Depressurization and thermal heating experiments, with real-time formation monitoring, were successful at the Mallik site. One test demonstrated that gas could be produced from gas hydrates with different concentrations and characteristics, exclusively through pressure stimulation, which will have implications for the economic viability of hydrate production. The resulting data support the interpretation that the gas-hydrate-bearing sediments are much more permeable and conducive to flow from pressure stximulation than previously thought. In another test, the gas production rates were substantially enhanced by artificially fracturing the reservoir. This work demonstrated that gas hydrates are a producible energy source, but much research remains to be done to translate these results into technically recoverable resource assessments for gas hydrates.

Results of these efforts were released at a meeting in Chiba, Japan, in December 2003 (abstracts can be found at http://www.mh21japan.gr.jp/english/index.html). Some of the findings from this work were also highlighted in a 2004 Hedberg Research Conference entitled "Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards," which the USGS helped to organize and co-hosted. This conference brought together scientists from around the world representing government agencies, academia, and industry to critically examine and discuss gas hydrate research efforts. The Geological Survey of Canada and the USGS co-edited a special volume, *Scientific Results from the Mallik 2002 Gas Hydrate Production Research Well Program, Mackenzie Delta, Northwest Territories, Canada,*

The Mallik drilling site.



Zone of potential gas hydrate stability in permafrost and shallow continental shelves along the Alaska North Slope. Note the locations of the Eileen and Tarn accumulations.

which was published in 2005 as Geological Survey of Canada Bulletin 585.

In addition to the Mallik Consortium, the USGS has ongoing efforts to assess the recoverability and production characteristics of permafrost-associated natural gas hydrates and associated free-gas accumulations in the Prudhoe Bay–Kuparuk River area on the North Slope of Alaska. The objective is to examine the resource potential of two known gas hydrate/free-gas accumulations (Eileen and Tarn) and possibly to drill and test a viable gas-hydrate/free-gas prospect. Technical support and data access are being supplied by industry and academic cooperators on the North Slope. In addition, the USGS is assessing the recoverability, resource potential, environmental effects, and production characteristics of Alaskan permafrost-associated natural gas hydrates in cooperation with the BLM and the State of Alaska Department of Natural Resources (DNR) through the Division of Geological and Geophysical Surveys. The primary goal of the research effort is to lay the groundwork for assessing the recoverability and potential production characteristics of the onshore natural gas hydrates and associated free-gas accumulations on the North Slope. Work will include identifying and mapping gas-hydrate/free-gas accumulations, as well as evaluating well log and seismic studies of existing North Slope developments. The primary goal of this cooperative effort is to assess the resource potential of known and undiscovered gas hydrate and associated conventional gas accumulations on both Federal and state lands in northern Alaska. This work builds on the efforts described above that focus on the known gas hydrate accumulations overlying the Prudhoe Bay and Kuparuk River oilfields and will develop a framework from which to assess the occurrence of gas hydrate accumulations on unexplored state and Federal lands. USGS's cooperators (BLM and Alaska DNR) are responsible for oil and gas development on Alaskan public lands, as well as for most pipeline rights of way. With the basic and applied research in support of this study provided by the USGS, the BLM, and the Alaska DNR will have the knowledge of where potential gas hydrate development will take place.

Geology and Energy Resource Potential of the Circum-Arctic

The Circum-Arctic is an area of high energy resource potential, low data density, sensitive environmental conditions, and great geologic uncertainty. A large portion of the remaining global endowment of oil and gas resources is known to exist in the high northern latitudes of Russia, Norway, Greenland, the U.S., and Canada. Although a few Arctic basins are known to be world-class petroleum provinces, including the West Siberian Basin, the Arctic has not been extensively explored. The quantity, distribution, and quality of resources in this region are poorly understood.

As part of its ongoing mission to provide up-to-date, objective assessments of oil and gas resources of the world, the USGS is conducting a resource assessment of the Circum-Arctic region as part of its World Energy Assessment project. The USGS World Petroleum Assessment (WPA) 2000 indicated that a significant portion of the world's undiscovered technically recoverable petroleum resources may reside within this region. A relatively small portion of the Arctic region was evaluated in the WPA 2000; the remaining areas

with high resource potential are currently being investigated. The Arctic Petroleum Assessment will utilize a methodology similar to that used in the WPA 2000 but with modifications to accommodate the unique circumstances surrounding this area, such as disparate data density, environmental quality concerns, high development costs, and technological requirements. The development of a modified methodology is the focus of an international collaborative effort to delineate the geologic framework and assess the resource potential of this province. The USGS, together with the Geological Survey of Denmark and Greenland, convened an international workshop devoted to exploring and discussing the issues surrounding the assessment of petroleum resource potential of the Circum-Arctic. Participants in the workshop included geoscientists from the U.S., Canada, France, Greenland, Denmark, Norway, and the United Kingdom, including assessment methodologists from various government agencies, industry, and academia. As part of the framework-building process, the USGS published in 2003 a digital geologic map of the Circum-Arctic region, representing a synthesis of data from multiple sources, including the *Circumpolar Geological Map of the Arctic* (published by the Geological Survey of Canada in 1989), bathymetric data, and oil and gas field centerpoints. Map units were kept as close as possible to the original map (more than 100 unique values).

Biological Studies

The USGS conducts research in the Arctic to generate information that will help DOI agencies and other partners in Alaska meet their resource management responsibilities. These responsibilities include the conservation of migratory birds, certain marine mammals, endangered species, anadromous fishes, and all biota inhabiting National Wildlife Refuges and National Parks and Preserves. In addition, 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.

The USGS continued to serve as the Federal representative to the Scientific and Technical Committee of the Arctic–Yukon–Kuskokwim Sustainable Salmon Initiative, overseeing the internal and external review of proposals and developing a research and restoration plan for salmon in western Alaska. A draft of this plan was developed in July 2005 and was reviewed by the National Research Council, other Federal agencies, and the public. Completed in June 2006, the plan will direct research conducted by Federal and state agencies, non-governmental organizations, and others.

A multi-year study of spectacled eiders provided the first assessment of characteristics of Bering Sea wintering habitats and evaluated these characteristics in relation to long-term trends. Extreme sea ice in winter, extreme winds, and winds in spring explained the greatest variability in annual indices of eiders. Further, 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. These findings are of importance to the Spectacled Eider Recovery Team in understanding factors limiting the recovery of nesting birds, especially on the Yukon–Kuskokwim Delta, Alaska, where the breeding population has been reduced by 96%.

USGS scientists and multi-disciplinary cooperators are assessing how recent and ongoing ecological change affects the distribution and abundance of important bird populations on the North Slope of Alaska. The primary goal is to understand how physical variability in the environment manifests biological change. The resulting models will allow better prediction of species responses to various future habitat conditions and inform long-range planning for resource development. Preliminary analyses (2004-2005) of the long-term distribution of four species of geese molting on lakes near Teshekpuk Lake within NPRA reveal that their distribution has shifted from 20 years ago. One hypothesis for these distributional changes is that habitats have changed. USGS's analyses of a time series of aerial photographs show that lakes used by molting geese have increased in size by 3–36% between 1979 and 2002. There is evidence that much of this lake change is caused by shoreline erosion driven by wind, waves, and ice gouging. Photo interpretation of habitats favored by foraging geese at one study lake reveals that flooded tundra has decreased by 81%, whereas the proportions of moist tundra, wet tundra, and shoreline moss have all increased. These results are consistent with higher evaporative water loss caused by elevated temperatures in recent decades. Further analyses of this time series of photos document substantial amounts of Beaufort Sea coastal erosion. In some areas, hundred of

meters of shoreline were lost between 1979 and 2002. Coastal erosion has led to saltwater intrusion into freshwater habitats, particularly in the northeastern NPRA. Such saltwater intrusion is expected to quickly alter foraging habitats for geese.

Satellite telemetry has been used to document the migration of yellow-billed and red-throated loons from breeding areas in Alaska to their wintering areas. Of the 24 red-throated loons captured at various breeding areas in Alaska, all 19 loons marked at breeding areas south of the Brooks Range wintered within North America. The five marked loons that bred on Alaska's North Slope migrated along the east Asian coastline, completed their annual molt along the northern shores of Hokkaido Island, Japan, and the southeastern shore of Sakhalin Island, Russia, and wintered in the coastal waters of South Korea. The eleven breeding yellow-billed loons initially marked on Alaska's North Slope migrated along the east Asian coastline, where six wintered along the coast of Hokkaido Island. USGS researchers measured organic and inorganic contaminant levels in eggs, including specific types of PCBs. These analyses documented 35 different PCB congeners in eggs from loons breeding in northern Alaska and wintering in east Asia that were not present in any eggs from loons from the other areas. They also documented greater occurrences of dieldrin, DDT, and HCB in the eggs of loons from the North Slope. These results are significant in understanding factors that may be limiting populations of yellow-billed loons, which were recently petitioned for listing under authority of the Endangered Species Act

A multi-year study described the importance of key habitats used by four nesting populations of nearctic brant and the relationship between changes in these habitats and population dynamics of brant. Nearctic brant rely on marine habitats and native intertidal plants during the non-breeding season, particularly the seagrass *Zostera* and the macroalgae *Ulva*. Atlantic and eastern high Arctic brant have experienced the greatest degradation of their winter habitats and have also shown the most plasticity in feeding behavior. Black and western high Arctic brant of the Pacific Flyway are the most dependent on *Zostera* and are undergoing a shift in winter distribution that is likely related to climate change and its associated effects on *Zostera* dynamics. Variation in the breeding propensity of the black brant associated with winter location and climate strongly suggests that food abundance on the wintering grounds directly affects reproductive performance in these geese. In summer, salt marshes, especially those containing *Carex* and *Puccinellia*, are key habitats for raising young, while lake shorelines with fine freshwater grasses and sedges are important for molting birds. The availability and abundance of salt marshes has a direct effect on the growth and recruitment of goslings and ultimately plays an important role in regulating the size of local brant populations.

The USGS completed a significant effort to monitor long-term trends of passerines and other landbirds breeding in remote areas of Alaska, including lands under management by Federal and state agencies, using survey protocols and a stratified random sampling design developed by the USGS. This program, the Alaska Landbird Monitoring Survey (ALMS), has been adopted by Boreal Partners in Flight as a state-wide monitoring program for Alaska. A Memorandum of Understanding supporting ALMS was approved by the leaders of nine agencies and organizations in Alaska, including the U.S. Fish and Wildlife Service, National Park Service, Bureau of Land Management, USDA Forest Service, Alaska Department of Fish and Game, National Audubon Society, Alaska Natural Heritage Program, Alaska Bird Observatory, and USGS.

Research on demographic parameters such as survival and dispersal and gene flow is ongoing to better understand the population biology of a group of sea ducks, which are in decline across North America. Three important contributions in this area were made during FY 2005. Population genetic assessments of king eiders and the threatened Steller's eider were completed, and a demographic analysis of band-recovery data was completed for common mergansers across much of North America. These contributions highlight the need for multiple marker assessments of migratory waterfowl, such as jointly examining data from both genetic and demographic markers.

Breeding and molting locations and migration patterns of the Atlantic population of Steller's eiders were studied applying satellite telemetry techniques. This study, concluded in 2005, provides the first information on the staging distribution, migration routes, and timing of migration of the Atlantic population of Steller's eiders. The wintering population in northern Norway was linked to staging and breeding areas from the Kola Peninsula to the eastern Taymyr Peninsula, which confirmed and expanded information on the breed-

ing distribution of this little-known population. The previously unknown molting region for the majority of the Atlantic population was also located in remote Russia. The findings of this study will be used in Norwegian and Russian recovery and management plans and for updating the EU Action Plan for Steller's eiders.

The USGS concluded an inventory of montane-nesting birds in the Arctic Network of National Parks in 2005, providing the first comprehensive assessment of breeding range and habitat associations for the majority of avian species across the vast National Parks of northwestern Alaska. The data from this inventory provide a framework upon which to design future monitoring programs.

Between late July and mid-October 2005, the USGS, in conjunction with the Yukon Delta NWR, Lund University in Sweden, Groningen University in The Netherlands, and the University of Otago in New Zealand, participated in a multi-faceted research program on long-distance migration of shorebirds. This research is part of the Swedish Polar Research Secretariat's Beringia 2005 Expedition to the Bering and Chukchi Seas.

The Department of the Interior has trust responsibility for managing two marine mammal species in Arctic waters: polar bears and Pacific walruses. Research continues on developing and implementing an effective survey method for estimating the Pacific walrus population size. The results include:

- An analysis of pilot study data that established the potential for integrating scanner technology with digital photography in a two-stage aerial survey of walruses on sea ice;
- The development of a population size estimator for the new survey methodology with an explicit variance estimator; and
- An extension of the simulation method developed to incorporate new data and refine estimates of sample size requirements.

This work will ultimately provide managers with a reliable estimate of the Pacific walrus population size and a technique for continued monitoring of its status and trends. Also, a remotely deployed satellite radio transmitter for walruses has been developed that is attached with a crossbow, the first such deployments on a pinniped. This system enabled the collection of unique haul-out behavior data from female walruses in ice habitats in 2004 and 2005. In addition, USGS has summarized data from walrus radio-tagging efforts in Bristol Bay over a 15-year period. The data were used to estimate haul-out fidelity, broadly describe seasonal foraging distributions, and determine the approximate timing of autumn migration from Bristol Bay. This study documented the use of terrestrial haul-outs and at-sea foraging areas and demonstrated year-round residence in the bay by some animals. It provided baseline information on changes in the distribution of walruses in the bay, which is of interest to both Federal and state resource managers.

USGS polar bear studies have focused for nearly two decades on providing research results that help management agencies in decisions concerning the possible impacts of human activity on polar bear populations and habitats. In FY 2004, the USGS completed forward-looking infrared (FLIR) viewing research, which has provided another tool to mitigate the impacts of human activities on denning polar bears. Polar bears give birth in snow dens in mid-winter and remain in the dens until early spring. The survival and development of neonates depends on the stable environment within the maternal den. Development activities are a potential threat to polar bears, especially as they might disturb denning females. USGS scientists described tests to determine whether FLIR could be effective at detecting heat rising through the roofs of polar bear dens and thus be a potential monitoring tool. Biologists surveyed 23 dens on 67 occasions, with 9 dens always detected, 10 dens visited more than once detected on some flights and not on others, and 4 dens visited under marginal conditions never detected. Models of how detection probability varied with environmental conditions revealed that the odds of detecting a den increased three times for every one degree centigrade increase in the temperature–dewpoint spread. The odds of detection also were 4.8 times higher when airborne moisture (snow, blowing snow, fog etc.) was absent than when it was present. While the data suggested that some dens never will be detectable with FLIR, surveys conducted during conditions that maximize odds of detection will locate most dens most of the time and can be an important management tool.

Also in FY 2004, the USGS completed a new method of analyzing radiotelemetry data that greatly expands the utility of telemetry data to delineate and manage wildlife populations. Radiotelemetry has provided previously unavailable insights into the movements and activities of many wild animal species. Unfortunately, the inability to estimate the error in animals' utilization distributions (UDs) has prevented probabilistic linkage of radiotelemetry data, which are always retrospective, with future management actions. In 2004, the

USGS used the example of the harvested population of polar bears in the southern Beaufort Sea to illustrate a method that provides that linkage. With this method, wildlife biologists can derive previously unavailable information from radiotelemetry data and apply it across a broad spectrum of management and research topics.

Since 1990, the USGS Alaska Science Center has collaborated with the Russia Academy of Sciences in Moscow on studies of Arctic sea ice as it pertains to habitat for shared marine mammal populations. During FY 2004, two papers were published about the summer melt season over Arctic sea ice that show that the summer sea-ice melt season was positively correlated with strength of the previous winter's Arctic Oscillation (AO) index, based on analyses of passive microwave satellite data from 1979 to 2001. Following high-index AO winters, spring melt tended to be earlier and autumn freeze later, leading to longer melt seasons. The largest increases in melt duration were in the eastern Siberian Arctic, coincident with cyclonic atmospheric circulation and ice motion anomalies associated with high-index AO phases. These results contribute to a growing body of literature about Arctic Ocean processes. During FY 2005, and through collaborations with the Russia Academy of Sciences and the Cooperative Institute for Research in Environmental Sciences, several papers were published about the diminishing extent of perennial sea ice, the decreasing age of the ice, and the role of atmospheric circulation patterns in determining the timing of spring snow melt in the western Arctic. Globally, the products of these collaborations are contributing to a growing understanding of the integrated ocean–ice–atmosphere system. Locally, the products are providing knowledge about how climate variability is affecting the habitats of Arctic wildlife populations (see http://alaska.usgs.gov/announcements/sea_ice.html).

Gray wolves are viewed as obligate predators of ungulates, with other prey contributing little nutritional benefit. In northwestern North America, Pacific salmon have largely been ignored as a potential food source for inland wolves. However, salmon are seasonally abundant during summer–fall spawning and are widely distributed at great distances from the coast. The USGS tested the hypothesis that salmon could contribute substantially to wolf diets in non-coastal areas (i.e., Denali National Park). Using $^{15}N/^{14}N$ ratios, USGS researchers estimated the proportion of wolf's diets that were composed of salmon. Overall, salmon averaged 7% of the diets of the 46 wolves sampled. Ninety percent of the wolves with home ranges encompassing salmon spawning areas consumed salmon, and their diets averaged 11% salmon. These findings indicate that Pacific salmon can be important prey for wolves where spawning salmon occur and may represent a substantial marine influence on terrestrial wolf/prey systems, even at great distances inland.

The USGS analyzed aerial methods for surveying Dall's sheep in Alaska to provide insights to wildlife managers on the quality of survey data currently being collected. The sightability of sheep was generally high and related to group size. Sightability did not differ between helicopters and fixed-wing aircraft, as commonly believed. Double-count methods were difficult to apply to sheep because groups tended to change in size between successive observations by two aircraft. The development and use of sightability models based on group size would improve the accuracy of sheep surveys and provide a measure of precision.

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.

Army

U.S. Army Research Institute of Environmental Medicine

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 the 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. 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 that predict 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 non-intrusive, ambulatory, real-time monitoring of warfighter physiological status during military operations in cold conditions.

USARIEM maintains a very active research program in the area of human physiological responses to cold. A current emphasis concerns establishing guidance for soldiers in order to prevent cold injury and maintain physical and cognitive performance. A series of studies have demonstrated that dehydration does not adversely impact thermoregulation, cardiovascular strain, and physical performance during exercise in the cold. Studies were also conducted to examine the effect of exercise intensity, water depth, and water temperature on the risk of hypothermia. The studies demonstrated that a slight increase in exercise intensity significantly reduces the risk of hypothermia. Those studies also determined that a USARIEM biophysical model better predicted the core temperature response during light exercise than currently used thermoregulatory models. Studies have also determined that the nutritional supplement tyrosine can ameliorate the decline in cognitive performance that occurs when humans are hypothermic. Furthermore, tyrosine supplementation attenuated the decline in marksmanship performance in hypothermic humans. USARIEM also recently updated TB MED 508 – Prevention and Management of Cold Weather Injuries. This document is the Army's medical doctrine for cold weather operations.

	Funding (thousands)	
	FY 04	FY 05
Arctic Engineering	1,150	1,138
Permafrost/Frozen Ground	400	327
Snow and Ice Hydrology	1,900	1,187
High Latitudes Program	2,959	0
Lower Atmosphere	100	0
High-Freq Active Auroral Prog	5,000	5,500
Medical and Human Engineering	700	512
Total	12,209	8,664

Cold Regions Research and Engineering Laboratory

The U. S. Army Cold Regions Research and Engineering Laboratory (CRREL) of the Corps of Engineers, Engineer Research and Development Center (ERDC), is recognized as a primary Federal

Winter field test of Stryker vehicle mobility impacts at Donnelly Training Area, Alaska.

source for Arctic and Subarctic expertise. It is an internationally recognized center of excellence in polar science and applied cold regions engineering research with a host of unique research laboratory facilities in Hanover, New Hampshire, and offices in Fairbanks and Anchorage, Alaska. CRREL advances and applies cold regions science and engineering technologies and leverages this knowledge to provide all-season solutions to a wide range of environmentally driven problems. The CRREL research program responds to the needs of Army, the Corps of Engineers, and the Department of Defense, but much of the research it performs also benefits the Nation and the private sector. In recent years, CRREL has placed greater emphasis on environmental physics, with a goal of understanding the dynamic processes that govern the character and appearance of the natural and man-made environments and their impacts on military activities. This transition contributes to high-priority defense needs while exploiting the physics-based talents that cold regions process research require. CRREL has sustained and extended its Arctic and cold regions research efforts and capabilities through reimbursable and collaborative work with other cold-focused DOD users, NASA, NSF, and academia. CRREL also continues to maintain the world's foremost library of cold regions scientific and technical literature. Highlights of some of the recent research follow.

Arctic Engineering

Arctic engineering has an emphasis on operating in harsh conditions with little infrastructure. Understanding how to modify traditional equipment and procedures to enhance their suitability for use in extreme environments has strong relevance for today's expeditionary military. CRREL has a long history of performing such research on the design and construction of Arctic infrastructure and facilities and supporting military and logistics operations in the polar regions.

The training lands utilized by U.S. Army Alaska (USARAK) include more than 1.6 million acres of widely varied terrain, including areas of continuous and discontinuous permafrost subject to climate and weather extremes. These training lands are primarily used by light tracked vehicles associated with light infantry units. Military vehicle operations on these training lands during spring thaw can cause significant disturbance to soil and vegetation. The military training lands in Alaska have experienced thermokarst erosion caused by the loss of insulating vegetation in permafrost zones. The need to maximize training capacity is important for the Army, but environment disturbance must be kept to a minimum to reduce environmental consequences and terrain reclamation or restoration needs.

The transformation of the 172nd Brigade to a Stryker Brigade Combat Team required re-equipping the unit with the 20-ton Stryker wheeled vehicle. To gain a better understanding of the terrain disturbance generated by Stryker vehicles on training lands, USARAK and CRREL, in cooperation with the Army's Cold Regions Test Center, conducted Stryker impact tests at Alaska's Donnelly Training Area in late winter and spring. The winter test was conducted when the ground was frozen and coverd by approximately six inches of snow. Follow-on Stryker impact tests were performed on various terrains during spring breakup.

The sites of the winter and spring tests were revisited later in the summer to evaluate the soil and vegetation recovery. Because the ground was frozen, the winter maneuvers caused no rutting; the impact to vegetation was minimal, and all roots were intact. Rutting that occurred during the spring test was closely related to thaw depth, which ranged from 0 to 15 inches in that location. Terrain disturbance varied from minimal (tire imprint with vegetation still intact) to severe (deep ruts, piles, and clumps of dirt on the side of the ruts). A follow-up site visit was conducted after one year to survey and quantify the recovery from the terrain disturbances. This research supported an environmental assessment of impacts of proposed range expansion projects and helped quantify the disturbance that the Stryker vehicle will be generating on the terrain for planning and sustainable land management.

The Alaskan Arctic has several coastal communities that are being threatened by shoreline erosion. Mitigation options are being studied for cities and villages such as Barrow, Kivalina, and Shishmaref. Virtually all northern Alaska construction sites are remote, and the season for completing work is short, resulting in high construction costs and logistical challenges. The permafrost regime at these coastal sites adds to the problems faced by engineers and designers. Ways to improve the durability and long-term performance of these erosion control structures are important to the impacted communities and supporting agencies.

The Corps of Engineers Alaska District recently completed the construction of 230 feet of shore protection at Shishmaref, a Native Alaskan community on Sarichef Island. Sarichef is one of a chain of barrier islands in the Chukchi Sea located on the north coast of the Seward Peninsula, about 100 miles southwest of Kotzebue. The soils of Sarichef Island are primarily fine-grained sand permafrost that is highly erodible when thawed. The most common mechanism by which shoreline banks fail is when permafrost thaws and is washed away at the water line. This results in an undercut bank with large blocks of permafrost soil breaking off and falling onto the beach. This behavior is accelerated by storm erosion events.

Intense fall storms prior to the establishment of shore ice have become more frequent, resulting in severe erosion and adverse impacts on the integrity of the Shishmaref School, teacher's quarters, and commercial and private buildings in the community. The recently completed Corp of Engineers shore protection project tied together a prior shore protection project constructed by the Natural Resources Conservation Service (NRCS) and another project currently under construction by the city of Shishmaref funded by the Alaska Department of Commerce, Community, and Economic Development.

Installation of a thermistor during the Shishmaref shoreline protection project.

The design of the Corps of Engineers shore protection project included several layers of varying rock size over a filter fabric to prevent the fine sand from washing away. As part of the project, CRREL designed and installed thermistor instrumentation beneath the filter fabric to provide information on changes in the permafrost temperature during fall storm events and the thickness of the active layer of soil freezing and thawing over the course of a year. CRREL is also investigating whether using a layer of 3- to 5-inch coarse rock can set up a thermal convection cell in the rock layer to increase the extent or thickness of the permafrost layer, making it more resistant to thawing and thus providing additional protection. A convection cell layer will be designed into future shore protection projects planned for Barrow, Alaska. If successful, this increase in the permafrost's resistance to thaw will improve the performance of the shoreline erosion control structures for these and other communities and result in significant long-term construction and maintenance savings.

Extreme conditions and problems in the Arctic require an increased understanding of fundamental soil phenomena such as freeze-thaw cycles, phase changes, and biological adaptations that vary with season. These conditions make the already complicated problem of environmental remediation even more difficult. CRREL 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 plant roots and indigenous microbial communities, known as the rhizosphere effect. Exudates from the plant's root system stimulate microorganisms to more rapidly and completely 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. In a series of replicated Alaskan field studies at Barrow, Galena, Fairbanks, and Annette Island reported in 2004, CRREL has shown statistically significant enhancement effects as a result of

Fescue and ryegrass growing on petroleum-contaminated soil in test plots near the Naval Arctic Research Laboratory site at Barrow, Alaska.

incorporating rhizosphere phenomena into treatment strategies.

Robots have the potential to play increasingly important roles in support of polar science and operations. Mobile robots could significantly expand the scientific utilization of Antarctica and Greenland summit regions by creating networks of instruments that can be tailored to specific experiment plans. Potential missions include snow characterization and biological sampling along transects and upper atmosphere or magnetosphere observations using broadly spaced instrument arrays. Understanding the design and performance of polar robots for scientific use also has relevance to Army-funded research on the performance of robots in harsh environments.

Polar regions pose numerous challenges for mobile robots, including extremely low temperatures, blowing snow, and mobility over vast distances. Nevertheless, it is possible to capitalize on conditions unique to polar snowfields to design a simple robot capable of long-distance autonomous travel. During polar summers, the sun is above the horizon all day and the skies are frequently clear, making solar power an attractive power source. Firm snow permits the use of low-pressure wheels, which are preferred over tracks for simplicity and mechanical efficiency. Four-wheel drive provides good mobility and is consistent with high reliability and low cost. Vast areas of the Antarctic and Greenland plateaus are obstacle-free provided the vehicle can negotiate wind-sculpted sastrugi.

In collaboration with an NSF-funded effort at Dartmouth College's Thayer School of Engineering, CRREL supported the development and testing of a solar-powered rover, Cool Robot, designed to deploy instrument networks in polar regions. The Cool Robot performed well during mobility and cross-country traverse tests conducted this summer at Summit Camp, Greenland, verifying the key features of the design, including an ability to tow significant science payloads and the tools to optimize it for specific missions.

Permafrost and Frozen Ground

The challenging conditions in the Arctic offer exceptional opportunities to increase our understanding of the fundamental nature of soil phenomena such as freeze-thaw cycles, phase changes, and biological adaptations. Understanding these topics is critical not only for addressing cold regions problems, but also to provide insights valuable for understanding similar processes in less extreme conditions. Permafrost underlies 20% of the world's land and 85% of Alaska. In permafrost regions, remote geotechnical, geophysical, and environmental site assessments often need to be made before large oil, gas, and mining business infrastructure development can occur.

Global air temperatures have increased since the 1800s. Increases in the Arctic are significantly greater than those in the lower latitudes. For example, the 2002 *United States Climate Action Report* indicates that Alaska has experienced the greatest warming of any state, with a 3°C increase in aver-

Cool Robot climbing a 0.3-m-high, steep-faced snow berm at Summit Camp, Greenland.

age temperature since the 1960s. This has been accompanied by melting permafrost and related geotechnical problems. Consequently, permafrost engineering techniques must be adapted to account for such increases in temperature.

The CRREL Farmers Loop Road test site, near Fairbanks, Alaska, has been used for geotechnical research since the mid-1940s. Recently, the Farmers Loop Road permafrost site was established as a component of the National Geotechnical Experimentation Site (NGES) program. As a permafrost site, with its unique technical challenges, it adds geotechnical diversity to the NGES program. Data and results from studies performed at the site will become available to practitioners and engineering students nationally and internationally through the NGES public database. A preliminary version of an NGES bibliography covering previous and ongoing work conducted at the site is now available.

Farmers Loop Road is experiencing increased permafrost temperatures and permafrost melting. It has been proposed that the site be added to the CALM (Circumpolar Active Layer Monitoring) network by instituting a grid in a relatively undisturbed location where annual measurements can be made to determine the extent of the active layer. Data collection protocols and equipment are being established to provide the specific meteorological information required for a CALM site. The data collected will be uploaded to a database that currently contains more than 125 other locations around the circumpolar north. This will assist by giving a first indication of warming soils, which can lead to thawing of permafrost.

A collateral benefit of using the Farmers Loop Road site is that several older reports contain temperature data that provide a historical record for comparison to current conditions. Thus, Farmers Loop Road can be used to monitor temperatures as well as the performance of experimental geotechnical structures constructed on warming permafrost.

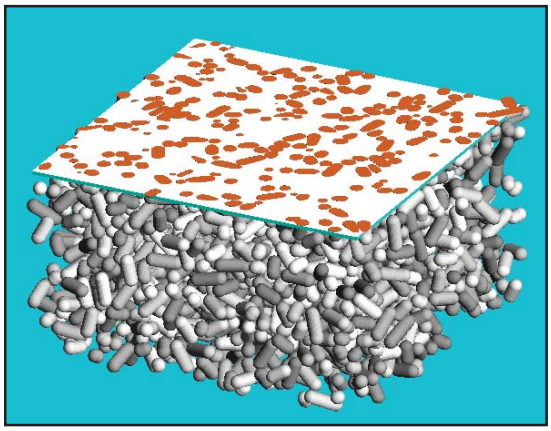
A July 2005 study to determine the suitability of the soils at the Alaska National Guard's Stewart River Training Area near Nome, Alaska, to allow a trail relocation was initiated to evaluate various geophysical tools. The area contains classic Arctic cryogenic features, including thermokarst ponds, ice wedge polygons, sorted circles, cobble pavement, and solifluction lobes. The soils range from silty gravel to clayey silt, typical of a glacial depositional environment. Discontinuous permafrost is present in the region.

Data were collected using 2D resistivity electrical imaging surveys and EM31 electromagnetic ground conductivity techniques on a study grid 525 m long by 300 m wide that was bisected north to south by a stream valley. Soil pits were excavated to determine the depth to the top of permafrost, measure soil horizontal thicknesses, and collect soil samples for water content measurements. Frost probes were also used to determine permafrost depth. Soil moisture content ranged from 47% by weight in frozen silt to 11% in thawed, poorly sorted silty gravel. The depth to permafrost ranged from 15 to 120 cm below the surface. Soil type appeared to be the dominant control on the presence of permafrost in the study area, with all permafrost found in silt and no permafrost found in gravels. The presence of willow thickets corresponded with thawed areas. Willows were absent in areas containing massive permafrost but were present in low numbers where permafrost was degrading. High resistivity anomalies correlated with frozen soil on the east side of the stream. On the west side of the stream, high resistivity associated with a cobble pavement and large gravel clasts had similar resistivity values as permafrost.

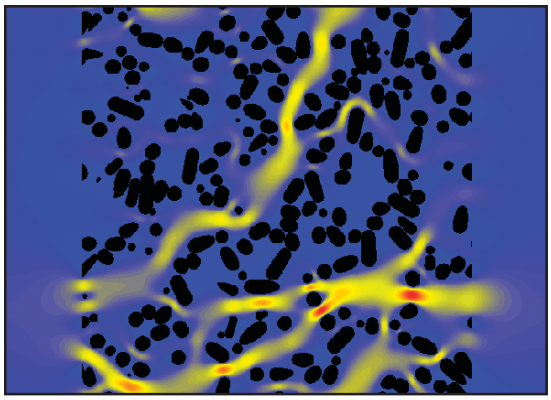
The EM31 data correlated well with permafrost and determined the location of a highly conductive area in the schistose bedrock. The results of this study suggest that a combination of geophysical tools and shallow ground truth explorations using probes and shovels can provide an accurate delineation of horizontal and vertical permafrost extent.

Snow and Ice Hydrology

CRREL has developed a virtual snow model laboratory. The snow model is based on a discrete element approach. The model snow has an explicit geometry composed of discrete particles or grains that are frozen together. The project has four main focus areas: snow dynamics, permeability, thermal conductivity, and electromagnetic interaction. The dynamics of model snow samples undergoing deformation are studied using the discrete element approach. Constitutive models have been developed to simulate freezing, creep and fracture between ice grains that allow simulation of shear, biaxial deformation, and settlement. Thermal conductivity is modeled using a coupled finite difference solver. Air flow through the complex pore space is modeled using a coupled lattice Boltzmann code. Albedo, transmissivity, and absorption of the model snow are modeled using a Monte-Carlo approach in which photons illumi-



Cross section through a model snow sample.



Two-dimensional lattice Boltzmann flow through the same cross section.

nate the snow sample. Morphological approaches are also being developed to characterize samples of real snow and incorporate them into the virtual snow framework. The goal is to be able to test samples of real snow in a virtual snow laboratory.

Understanding the dispersion, persistence, fate, and environmental impact of airborne pollutants in Arctic conditions is increasingly important. CRREL 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 dispersion and deposition of petroleum-aerosol-based fogs used for military training. Such aerial plumes behave differently in winter and summer. Predicting their deposition area and monitoring the process will enhance environmental monitoring and permitting of military training activities in sub-Arctic areas in Alaska.

Air Force

The Air Force conducts research in upper atmosphere and ionosphere 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 research goal is understanding the basic physical and chemical processes and dynamics of the polar ionosphere in order to identify, predict, and mitigate disruptions to DOD communications, navigation, and surveillance systems. The research program includes experimental measurements to determine specific physical processes augmented by first-principles numerical modeling efforts to correlate with ongoing theoretical research.

High-Latitude Ionosphere Studies

Recent efforts in polar ionosphere research have focused on additional capabilities made possible by new, more sensitive detectors, such as CCD (charged-couple device) cameras and the combined operation of instruments as networks rather than individual measurement tools. Experiments to test a specific theoretical mechanism for creation of polar cap patches were conducted at sites in Svalbard, Norway, and Greenland. This work demonstrated how reconnection of magnetic lines of force at the boundary between Earth's magnetosphere and the solar wind can result in the capture of higher-density ionosphere plasma from sunlit latitudes and transport it across the polar cap. The resulting kilometer-sized irregularities formed within these high-density patches can produce severe scintillation on trans-ionosphere radio wave signals. Another study comparing radar data with high-resolution optical images illustrated how this process can operate in two horizontal dimensions.

The enhanced understanding obtained by observing ionosphere processes over larger areas and multiple sites motivated efforts to better coordinate observations and fill coverage gaps between stations. To achieve this, DOD recently concluded an international agreement with the Home Rule Government of Greenland, the Denmark Ministry of Defence, and the Denmark Ministry of Transport and Energy to establish an ionosphere research site at Station Nord in northeast Greenland. The measurements from Nord will overlap with measurements from Svalbard to the east and the Thule area to the west, allowing the development, transport, and evolution of ionospheric structures to be observed continuously as the plasma travels from the auroral zone over the magnetic pole. The extremely high geographic latitudes of stations in the chain, all north of 77° latitude, will allow low-light optical observations to be made even at noon in the winter. This is cru-

cial to determine processes operating in the cusp region of the auroral oval in the noon sector.

High-Frequency Active Auroral Research Program

A major facility for conducting ionosphere and radio science experimental research is being developed in Gakona, Alaska, under the High-Frequency Active Auroral Research Program (HAARP). The facility is jointly managed by the Air Force Research Laboratory and the Office of Naval Research. The facility includes a high-power, high-frequency (HF) transmitting system and a suite of radio and optical diagnostic instruments. Research has been conducted at the facility since 1999 using an HF phased-array antenna system 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 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 40-acre antenna array and 15-MW power plant to achieve this capability were completed in 2004-2005, and installation of additional HF transmitters to drive the antenna array was initiated. The facility is scheduled for completion in 2006.

Significant additions to the facility's suite of radio and optical diagnostic instruments were also implemented over the past two years. New radio frequency diagnostic instruments include a 37-MHz imaging riometer to observe changes in the background galactic noise, and a phased-array UHF (446-MHz) diagnostic radar to study physical processes produced in the ionosphere by the facility's high-power HF transmissions. The UHF diagnostic radar, acquired in conjunction with the University of Alaska Fairbanks, comprises a small portion (8 panels, 256 antenna elements) of an innovative Advanced Modular Incoherent Scatter Radar (AMISR) (180 panels, 5760 elements) developed by the National Science Foundation with the Stanford Research Institute. State-of-the-art optical instruments employed at the facility include imagers, multi-channel photometers, telescopes, and sensitive webcams. These instruments are used to study artificial airglow produced by HF radio wave interactions in the ionosphere.

The suite of radio and optical diagnostic instruments provide important data to characterize the physical processes in the ionosphere produced during operation of the facility's high-power HF transmitter. When the HF transmitter is not in operation, they provide real-time data on geophysical parameters that characterize the state of the ionosphere and magnetosphere under both normal and disturbed (solar-related) conditions. As such, the instruments constitute a ground-based space weather station. The data are available on the internet at www.haarp.alaska.edu.

Recent optical research results include the creation of artificial spots in the natural aurora bright enough to be seen with the naked eye, a result that cannot be explained by existing ionosphere/radio theory. Other new results have been obtained by operating the facility's HF transmitter at the second harmonic of the local electron gyrofrequency (approximately 2.8 MHz), including the production of strong optical emissions and electron acceleration, even at very low transmitter powers.

A variety of experiments have been conducted in conjunction with space platforms, including the CLUSTER, IMAGE, WIND, and DEMETER 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 research includes techniques to increase the efficiency of ELF/VLF wave generation in the ionosphere, and the observation of ELF/VLF waves in space at the conjugate point of the HAARP facility off the coast of New Zealand. These techniques are used to study the interactions of ELF/VLF radio waves with charged particle populations in Earth's radiation belts and their subsequent effects, including guided (ducted) propagation and wave amplification in the magnetosphere.

National Aeronautics and Space Administration

NASA's Science Mission Directorate 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.

A glacier feeding the floating ice tongue of the Petermann Glacier in northwestern Greenland, in an image taken from a twin-otter aircraft during a joint NASA/NSF field campaign.

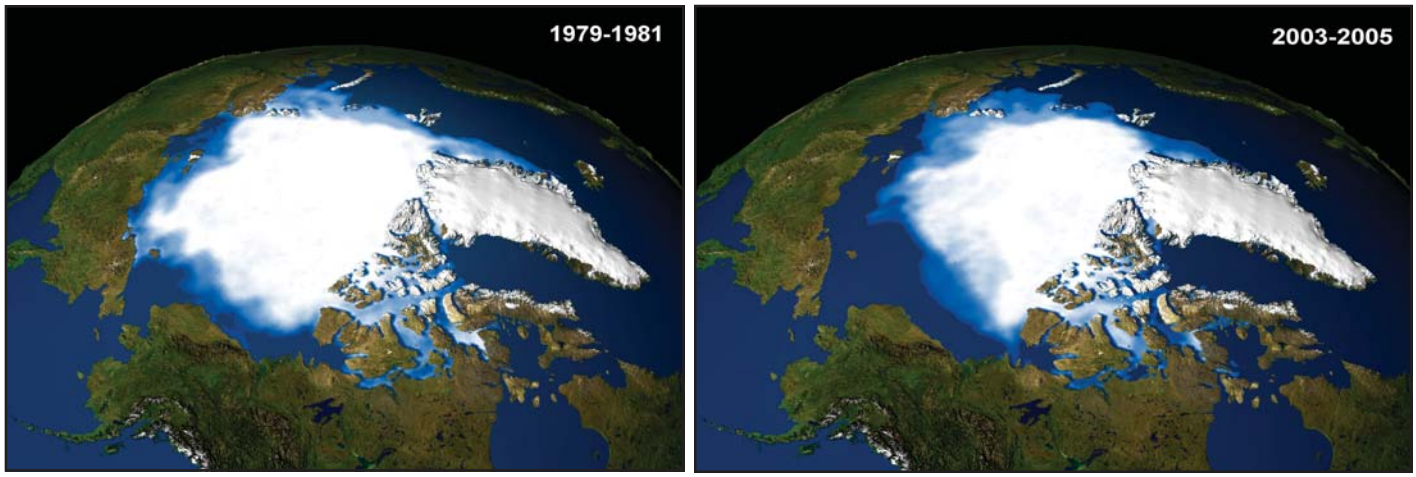
By taking advantage of the unique vantage from space, NASA achieves the perspective, sampling, and context needed to study the Arctic as an entire region. Combining these observations with modeling efforts and measurements on the ground and from the air enables NASA to continue to support advances in understanding the Arctic system. These efforts complement those of its interagency partners, such as NSF and NOAA, to provide an integrated understanding of the Arctic as a whole.

Cryospheric Science Research

NASA's investments in cryospheric science research have led to significant advances in our understanding of the Arctic ice, as satellite data have revealed remarkable behavior of the Greenland ice sheet and Arctic sea ice. In Greenland, passive microwave satellite data have shown that the melt on the ice sheet has increased by about 30% since 1979, contributing to the thinning of the margins of the ice sheet. At the same time, satellite radar altimetry data are showing that the ice sheet is growing at its higher and colder interior, presumably as a result of increased snow accumulation. These findings are consistent with predictions for both increased snowfall and increased melt in a warming climate. What is especially significant about Greenland, however, is that many of its outlet glaciers that drain the ice from the ice sheet and dump it into the ocean in the form of calving icebergs have accelerated in speed. In some cases, the speed has doubled, hastening the loss of Greenland's ice to the sea. This acceleration is largely a result of the melting and break-up of floating ice "tongues" at the front of these glaciers, which have historically been buttressing the ice and slowing its discharge.

There has been a wide range of estimates for the current rate of loss of Greenland ice that have been derived from the Gravity Recovery and Cli-

	Funding (thousands)	
	FY 04	FY 05
Polar Ice Interactions	4,000	4,700
Terrestrial Ecology	1,400	1,000
Solid Earth Sciences	4,200	4,200
Hydrological Science	700	700
Modeling	500	500
Atmospheric Chemistry	300	3,400
Clouds and Radiation	500	600
Suborbital Sciences	2,500	2,500
Physical Oceanography	400	400
Biological Oceanography	100	100
Satellite Algorithms/Data Analysis	6,000	6,000
Data Systems	13,200	12,500
Exploration Habitat	400	400
Total	34,200	37,000



Three-year average extent of the perennial Arctic ice cover for the start of the passive microwave satellite record, 1979–1981, and for the most recent period, 2003–2005.

mate Experiment (GRACE), radar altimetry, aircraft laser altimetry, and interferometric synthetic aperture radar, and while they vary considerably in magnitude, they all tell a consistent story of an ice sheet that is losing mass much more rapidly in the last few years than in the past.

In addition to ice sheet research, NASA continues to invest in research in understanding changes in glaciers and ice caps to assess their mass balance characteristics, including support of airborne surveys of elevation changes of the Canadian ice caps and interpretation of observed changes in Alaskan glaciers. Most recently, results from the GRACE mission have provided estimates of the seasonal and interannual mass loss from Alaskan glaciers and the glacier systems of northwest Canada by monitoring changes in the gravitational signal. This new approach is the first direct measurement of ice mass change over these smaller glacier systems.

Passive microwave observations of perennial sea ice in the Arctic reveal that its extent has continued to decline at a rate of about 10% per decade, while the total ice cover has diminished by about 3% per decade. This significantly higher percentage for the perennial ice cover is especially important because this is the ice that survives the summer melt season. It is generally thicker than the seasonal ice cover, so even if it grows back, it will take multiple years of sustained growth before new ice can develop to a similar thickness. The implications for the energy exchanges between the ocean and atmosphere are significant. In addition, the melting of perennial sea ice results in a significant input of relatively fresh water to the Arctic Ocean, which has uncertain implications for ocean circulation.

As a result, there is a very strong interest in measuring thickness changes on large scales, as can potentially be done from space. NASA's Ice Cloud and Land Elevation Satellite (ICESat) mission has demonstrated a new capability to estimate sea ice thickness from measured freeboard height (the portion of the floating ice cover that extends above water). A challenge remains in identifying the thickness of snow that might be on the sea ice, but efforts continue in improving the microwave-derived snow depth on sea ice in the Arctic. These thickness measurements, which have been a major goal since the first satellite observations of sea ice, will provide essential information for understanding the interactions between the ice, ocean, and atmosphere and for predicting the rate and consequences of sea ice decay.

Arctic Hydrologic Change

NASA is making investments in improving our understanding of variability and change in the Arctic hydrologic system. A key tool in support of this effort is the Arctic Rapid Integrating Monitoring System (Arctic-RIMS), which synthesizes station precipitation, river discharge, and information from NASA satellite platforms, along with output from hydrologic, thermal, and numerical weather prediction models. The Arctic-RIMS web site (rims.unh.edu/) contains background material, a tutorial for site navigation, and visualization and analysis tools. Current research foci include understanding recent increases in river discharge to the Arctic Ocean, variability in the freeze–thaw state of the Arctic surface, changes in active-layer depth in permafrost regions, and changes in lake levels and glacier mass balance. A major study, to appear in a forthcoming issue of the *Journal of Geophysical Research*, has synthesized available information to quantify the large-scale freshwater

cycle of the Arctic, "following the water" through the atmospheric, terrestrial, and oceanic branches of the hydrologic system.

Arctic Climate Modeling

NASA makes significant investments in improving the representation of the Arctic in climate models and understanding its interactions with the rest of the Earth System through the inclusion of satellite data for assimilation, initialization, and validation. One focus of these efforts has been examining the Goddard Institute for Space Studies (GISS) coupled atmosphere–ocean models for Arctic sea ice from the runs performed for the Intergovernmental Panel on Climate Change. Two ocean models are being run with GISS Model E: the Russell et al. model and the HYCOM model. In the control run simulations, the sea ice distribution is generally realistic in both models. The primary discrepancies are that sea ice concentrations tend to be too large in the northeast North Atlantic, and polar sea ice is too thick (especially in the Russell et al. model). Model simulations for the past few decades have been compared with observations. Both models underestimate the reduction in northern hemisphere sea ice. Sea ice changes are also small in simulations of the future climate. Warming at high northern latitudes is also underestimated, perhaps in conjunction with the lack of sea ice response. Part of the problem may be associated with a weaker change in high-latitude atmospheric circulation. Current efforts are focusing on whether finer-resolution models produce a more realistic atmospheric response. Efforts continue toward improving model physics as a result of what is learned through these studies.

Atmospheric Chemistry

NASA continues its support of high-quality, long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed research stations under the international Network for the Detection of Stratospheric Change (NDSC), recently changed to the Network for the Detection of Atmospheric Composition Change (NDACC). In the Arctic, NASA supports the operation of a high-resolution, FTIR (Fourier-transform infrared) spectrometer operated at Thule, Greenland, by investigators from the National Center for Atmospheric Research.

The Polar Aura Validation Experiment (PAVE) was conducted by NASA in January 2005 as an international science mission to acquire critical, high-quality measurements of the polar region in support of the Aura satellite. PAVE was the third of a series of Aura validation missions designed to provide correlative measurements to help understand the transport of gases and aerosols in the troposphere and their exchange with the lower stratosphere. The measurements from the Aura satellite are helping to improve modeling of global-scale air quality and climate change predictions.

Utilizing the NASA DC-8 and high-altitude balloons, PAVE aimed to collect valuable science data from a suite of atmospheric remote sensing and in situ instruments. Based at the Pease Tradeport in New Hampshire and the ESRANGE balloon facility in Sweden, approximately 80 scientists, managers, and support personnel were deployed to perform the science flights in the Arctic. The DC-8 component of PAVE was very successful in fulfilling the mission objectives of:

- Obtaining high-quality in situ and remote sensing measurements of the polar region for validation of Aura satellite measurements;
- Making observations of the influx of material from the troposphere into the stratosphere;
- Characterizing the high gradients of stratospheric trace gases both in and outside the polar vortex; and
- Measuring outflow from the North American continent.

The balloon component suffered a launch failure of the large remote sensing instrument package, and instrument damage prevented another launch attempt. The balloon measurements (with a larger suite of instruments) are rescheduled for January 2007.

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

In the fall of 2005, NOAA's Arctic Research Office moved into NOAA's Climate Program Office and was renamed the Arctic Research Program. At this transition the program's goals were redefined to the following:

- To build and maintain a suite of Arctic climate observing networks (ocean, sea ice, atmosphere) in association with international partners;
- To support continuing analysis of Arctic climate data from program and other sources;
- To provide data and analyses to operational centers, climate assessment activities, and the research community; and
- To participate in public education and outreach.

	Funding (thousands)	
	FY 04	FY 05
Cloud Radiation	10	10
Atmos. Trace Constituents	400	425
Fisheries Assess./Manage.	17,000	17,500
Marine Mammal Assessment	6,675	7,325
Ocean Assessment	10	50
Stratospheric Ozone	250	250
Data Management	331	340
Remote Sensing	345	435
Aircraft/Vessels	950	1,100
Weather Research	25	50
Western Arctic/Bering Sea Ecosys.	2,100	2,100
Barrow Observatory	600	600
Ocean Exploration	355	2,300
Tsunami Warning/Env. Obs.	250	250
Arctic Research Initiative	1,650	1,060
Ocean Observations/Arctic Fluxes	360	360
Arctic Climate Research (SEARCH)	2,000	1,960
Undersea Research	2,530	0
Total	35,841	36,115

Observing Systems

The developing Arctic Observing networks include the development of atmospheric, ocean and ice systems.

The Arctic Climate Atmospheric Observatory Network is planned to consist of three to five observatories around the rim of the Arctic Ocean. The initial observatory is the NOAA Global Monitoring Division Barrow Observatory and the Department of Energy's Atmospheric Radiation Measuring Program Observatory. These co-located facilities have been in operation for 33 and 10 years, respectively, and together they provide the model for observatories planned for other portions of the Arctic. The second observatory in the network is distributed between Alert and Eureka, Canada, on Ellesmere Island. NOAA and Canadian partners have deployed instruments to the observatory with the goal of having the full observatory operational by the end of 2008. The third link in the planned network will be located at Tiksi in Siberian Russia. NOAA and NSF will be U.S. co-sponsors of this observatory. An implementation plan for the Tiksi observatory is under development, and initial measurements should start in the fall of 2006. NOAA will coordinate with an already established atmospheric observation program in Ny Ålesund, Norway, and the Greenland Summit Station to complete the circumpolar network. The goal of the observatory network is to provide long time-series data on clouds and cloud properties, aerosols, radiation, and trace gases. The data will support research on atmospheric climate processes, provide calibration and validation data for current and planned satellite sensors, and provide data to develop and test global and regional climate models with a goal of answering questions of attribution. The observatories will be sites at which shorter-term research projects can be conducted by scientists from the broad community.

NOAA has developed plans to support long-

term ocean and sea ice observations in the Arctic as a subcomponent of the NOAA Integrated Ocean Observing System. There are three elements to the Arctic component: ice-tethered buoys in the perennial Arctic sea ice, oceanographic moorings along the shelf and slope and in the deep basins, and ship-based observations.

A small network of autonomous ice mass-balance buoys (IMBs) has been continually deployed since late summer 2003. These buoys are unique in their ability to determine whether changes in the thickness of the ice cover occur at the top or bottom of the ice cover and hence provide insight on the driving forces behind the change. They can be used in validating and calibrating other ice-based and remote ice thickness measurement systems and numerical forecast models of the ice cover. The network of IMBs has been augmented by the establishment of a moored, ice-profiling sonar on the Chukchi Plateau in the summer of 2003. This region of the Arctic Ocean has experienced record extremes in ice retreat over the past few summers. Data from this mooring, designed to monitor ice thickness, have been successfully recovered in 2004 and 2005, and the analysis of the 2004 data will be available in 2006.

The International Arctic Buoy Program (IABP) provides a denser network of simpler buoys that measure only surface air temperature and pressure and location. All of these buoys are coupled to the Global Telecommunication System and support operational weather forecasting, ice trajectory and forecasting, and the creation of climate data sets from throughout the Arctic Ocean perennial ice zone.

A mooring deployed in the western Bering Strait in the summer of 2004 has been successfully recovered, and three new more-capable moorings were deployed for recovery in the summer of 2006. The data from the recovered mooring are the first obtained in this Russian area since the early 1990s. It is essential for blending with data from the U.S. side for computing net flow through the Bering Strait, which should be a critical indicator of global ocean circulation. Flow through the strait also is a determining factor in controlling ecosystem function in the Chukchi Sea.

The summer of 2005 marked the inauguration of a new NOAA-sponsored mooring program being conducted by the International Arctic Research Center (IARC) at the University of Alaska Fairbanks. This program, the Nansen–Amundsen Basin Observing System (NABOS), has deployed moorings along the shelf edge of the Russian Federation and will provide new data on internal Arctic Ocean circulation.

NOAA conducted its first Arctic Ocean research cruise with the Russian Academy of Sciences in the summer of 2004 through what has become known as the Russian–American Long-term Census of the Arctic (RUSALCA) project. One objective of RUSALCA is to document the changes in the physical state of the northern Bering and Chukchi Seas, regions that have experienced significant change over the past few decades and that models predict will experience even greater change in the decades ahead. General ocean and atmospheric warming and loss of sea ice should be accompanied by changes in water column structure and possible changes in circulation and flux through the Bering Strait, which may have implications for the entire Arctic Ocean. A second objective of RUSALCA is to observe changes in ecosystem structure and productivity that result from the physical changes and to identify a set of ecosystem indicators that might be applied throughout the Arctic marine region. Marine ecosystem alterations will affect Native subsistence harvests and possibly commercial fisheries and protected mammals and birds. RUSALCA was co-funded by NOAA's Office of Ocean Exploration. Planning is underway for a major international research expedition during the International Polar Year. The current strategy is to conduct a multidisciplinary cruise every four years, with mooring and physical oceanographic-based expeditions conducted annually.

Data Analysis

During 2004 and 2005, work continued to define an Arctic Climate Change Detection Protocol and to gather and analyze historical and current data from diverse sources to evaluate variability and change in the Arctic climate. One approach has been to gather different types of data from throughout the Arctic region and analyze spatial and temporal relationships. This effort has identified that widespread ocean, ice, and terrestrial changes are continuing their multi-decade trend even while the presumed driver, atmospheric circulation, is experiencing significant changes in trend. This work has been presented through a website (www.arctic.noaa.gov/detect) and through scientific publications. Another approach has been to gather historical data not yet in the digital archives to provide added context for more recent observations. During 2005, a project was initiated to "rescue" early 20th century radiosonde data from the

Russian Arctic. These data will be very useful in helping to quantify the period of Arctic warming in the early 20th century and will allow better comparison of it to the current warming period. The data rescue project should be completed in 2006.

The Arctic Climate Change Detection project will focus more explicitly on the northern Bering and Chukchi Seas during FY 2006. It will obtain all of the data collected by the program in this region since 2003 and as much relevant external data as possible. The data will be assembled in a form suitable for use in a GIS framework.

In 2005 the Arctic Research Office (now Program) contributed to the funding of a State of the Arctic (SOA) Report. Experts from several countries are preparing a report summarizing the current physical state of the Arctic that will be submitted for peer-reviewed publication during 2006. This will be an update to the Arctic Climate Impact Assessment. If well received, the SOA report may be produced every two to three years and may grow to include biological and other aspects of the Arctic environment. A workshop will be held during 2006 to explore the state of the Arctic carbon cycle and discuss how it might be expected to change under a global warming scenario. Results of the workshop will guide future program activities related to carbon in the Arctic.

Outreach

NOAA's Arctic Theme Page (www.arctic.noaa.gov) is a mechanism for describing NOAA's Arctic programs and for providing a scientific resource to the public.

In 2003–2005, NOAA's Arctic Research Office contributed funding to the Smithsonian's National Museum of Natural History to create a special exhibit called *Arctic: A Friend Acting Strangely*. This exhibit has been developed in collaboration with scientists at NASA, NSF, and the Department of Energy. The exhibition is an outreach contribution to the Study of Environmental Arctic Change (SEARCH) interdisciplinary research program being conducted by eight Federal agencies.

Office of Ocean Exploration

In 2005 the Office of Ocean Exploration sponsored the Hidden Ocean 2005 Expedition. The expedition focused on assessing the diversity of life and the environment in all three major realms of the Arctic—the sea ice, the water column, and the seafloor. For one month the U.S. Coast Guard Cutter *Healy* conducted round-the-clock science operations. The team visited 14 stations covering poorly known areas of the southwestern Canada Basin, Northwind Ridge, Northwest Abyssal Plain, and Chukchi Plateau. Core science operations included measuring sea ice properties, primary productivity, and pelagic (water column) and benthic (seafloor) community composition.

The sea ice team conducted research on and underneath the ice. Ice corers were used to collect samples of ice that are being analyzed to estimate the diversity and quantity of sea ice algae and fauna to search for rare and unidentified microscopic creatures living in the ice. The understanding of the sea ice realm was enhanced through the collection of temperature, salinity, fluorescence, and light profiles under the ice from all 14 stations. These measurements help to define the growing conditions for tiny, single-celled plants known as phytoplankton, which provide food for other microscopic animals. The growth rates of sea ice algae and phytoplankton were studied using primary production measurements conducted in the water column under the ice. Phytoplankton form the base of the Arctic marine food web, so understanding its growth is important to understanding the amount of food available to creatures living at different depths under the ice.

Ice divers collected video and still images of amphipods (small creatures living on the underside of the sea ice) and Arctic cod under the drifting pack ice. Two of the amphipod species studied were previously unknown to inhabit the region; one was known only as a pelagic species, and the other had been known only in association with coastal waters.

Built by Deep Sea Systems, Inc., the *Global Explorer* remotely operated vehicle (ROV), equipped with three standard cameras and one high-definition camera, provided scientists with an eye into the sea. During the expedition, the ROV descended as deep as 2,900 m, collecting samples of creatures in the water column and on the seafloor.

The pelagic team focused on identifying unknown or poorly known gelatinous zooplankton and the organisms they feed on in the Canada Basin. Tools including live nets, a multi-net, and the *Global Explorer* captured live specimens of zooplankton living from the surface to 2,900 m. Numerous first records of many of these species in the Amerasian Arctic were recorded, 6–10 of which represent undescribed "new" species.

The benthic team utilized a variety of tools to view and sample the seafloor. The ROV performed

eight benthic dives ranging from 880 to 2250 m deep, collecting high-definition video footage and samples of flora and fauna living on the seafloor. A photo platform was constructed and used for the expedition to conduct quantitative image sampling of the seafloor, and box cores were deployed to collect cookie-cutter-like samples of the sea bottom and the creatures living within it. Among the species viewed and collected were at least seven polychaete (marine bristle worm) species marking significant range extensions in geographical area and/or depth, at least three suspected new species of polychaetes, and many more samples and species in need of further analysis before conclusions can be made.

The creatures living in the water were not the only subjects studied; a science team on board focused on characterizing the environments in which the creatures live through instrument deployments as well as in situ experiments. In addition to a winch-operated CTD (conductivity, temperature, and depth sensor), one CTD was attached to the ROV and collected water mass characteristics to provide an oceanographic context for each sampling site; this information can be used to find where the water at each site originated and help explain the observed species composition and nutrient regime in the Canada Basin. Deep CTD water samples were also collected and analyzed for nutrients and plant pigments to assess the environment and food available for animals living in the deep sea.

This expedition represents the first comprehensive, multidisciplinary effort towards understanding and characterizing the diversity of life in all realms of the ice-covered Arctic Ocean.

Earth System Research Laboratory

Global Monitoring Division

In October 2005 the former Climate Monitoring and Diagnostics Laboratory (CMDL) of NOAA was reorganized into the Global Monitoring Division (GMD) of the newly created Earth System Research Laboratory (ESRL) of NOAA/. Included in the new GMD division is the former Surface Radiation Research Branch (SRRB) of the NOAA Air Resources Laboratory. The total staff in GMD numbers 106, inclusive of Federal, joint institute, and contract employees. The GMD conducts sustained observations and research related to source and sink strengths, trends, and global distributions of atmospheric constituents that are capable of forcing change in the climate of earth by modifying the atmospheric radiative environment, those constituents that may cause depletion of the global ozone layer, and those that affect baseline air quality. GMD accomplishes this mission primarily through long-term measurements of key atmospheric species at 105 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, Antarctica. A sixth station, at Summit, Greenland, is being developed and has been manned by GMD staff six months per year for the past two years. Depending upon FY 2007 funding, the station may be manned year-round by a GMD staff member from 2007 onward.

In the Arctic, GMD 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 GMD 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.

Arctic Baseline Atmospheric Observatory Operations. GMD has operated the Atmospheric Baseline Observatory at Barrow, Alaska (BRW), manned by a staff of two, for 32 years. In addition to 28 core atmospheric baseline measurement projects, BRW supports 20 cooperative research projects, with a majority coming from universities or agencies in Alaska. As part of the Barrow Arctic Science Consortium (BASC) facilities upgrade, GMD is in the design phase of a new observatory building at the present BRW site. This would triple the size of the 800-square-foot facility, which has reached operational capacity. This expansion of the NOAA BRW facility has not yet been funded. New housing for the Barrow staff is on the drawing board, and construction may begin in 2008. Initial funds for the housing construction are in hand.

At Summit, Greenland, an NSF-supported research facility, GMD initiated year-round carbon cycle air flask sampling and in situ surface ozone and black carbon measurements in the spring of 2003, conducted firn air measurements in June

2004 and June 2005 and surface ozone measurements from June 2000 to July 2003, and undertook continuous surface ozone measurements from August 2004 onward. Weekly balloon-borne ozonesondes were added in November 2004, and stratospheric water vapor sondes began operation in November 2005. A complete, high-quality surface meteorology system was added at Summit by GMD in August 2005. In addition to manning the facility with NOAA staff year-round, plans include adding a suite of instrumentation to measure a wide range of aerosol parameters, a solar radiation Baseline Surface Radiation Network program, and continuous trace gas measurements (up to 15 species).

GMD collects weekly pairs of discrete air samples from a 65-site global carbon cycle glass flask sampling network that includes Arctic or near-Arctic sites at Barrow, Cold Bay, and Shemya, Alaska; Ocean Station "M" in the Norwegian Sea; 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 (including halocarbon species) are obtained over Poker Flats, Alaska, on a biweekly basis with an aircraft flying profiles to 8,000 m above sea level. Gases are also collected in high-pressure metal flasks at a much smaller number of sites for measurement of chlorofluorocarbon gases.

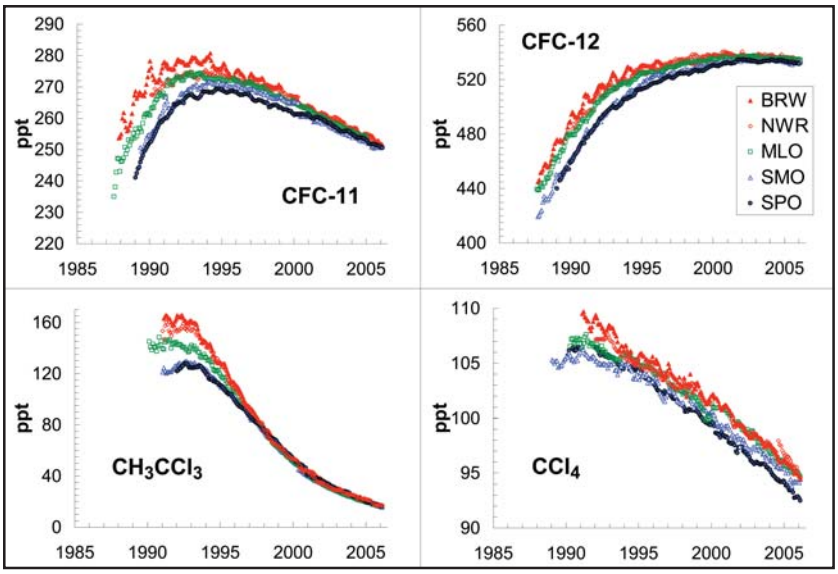
Surface Ozone Observations in the Arctic. Sites operated by GMD make surface ozone observations in three distinct regimes within the Arctic. Barrow represents an Arctic Ocean environment with seasonal ice cover. Summit, Greenland, is a high-altitude site on the permanent ice cap, while Westman Islands, 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 ingredients 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. At Summit, long-range transport of forest fire smoke from Alaska and Russia is regularly measured, and occasionally large-scale air pollution from Europe is observed at Westman Islands and Summit. These transport events bring elevated ozone levels to the Arctic.

Springtime Incursions and Impacts of Asian Dust and Air Pollution in the Arctic. During the spring of each year, frontal systems in Asia generate dust storms that push dust and air pollution eastward across the Pacific, and some of that dust reaches the Alaskan Arctic. GMD measurements show that when Asian dust is present in the Arctic atmosphere over the BRW observatory, 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 Arctic due to greenhouse gases could be episodically negated because of this dust-aerosol-induced negative feedback. On the other hand, should the dust contain high concentrations of carbonaceous particles that directly absorb sunlight, additional atmospheric heating could occur.

In the past, the focus of aerosol research at Barrow 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, as 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.

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. 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.

Russia ended the production of chlorofluorocarbons (CFCs, used as refrigerants), chlorinated



Concentrations of chlorofluorocarbons controlled by the Montreal Protocol measured by NOAA/GMD at Barrow, Alaska (BRW); Niwot Ridge, Colorado (NWR); Mauna Loa, Hawaii (MLO); American Samoa (SMO); and South Pole, Antarctica (SPO). Clearly evident are the north-to-south gradient with Alaska having the highest gas concentrations and the effects of the controls on the production of the gases.

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.). Measurements onboard the carriage include oxides of nitrogen (NO_x), ozone, aerosols, radon-222, CO, CH_4, CO_2, and meteorological parameters including vertical temperature profiles. In addition, continuous measurements are conducted on nitrous oxide (N_2O), sulfur hexafluoride (SF_6), CFC-12 (CCl_2F_2), halon-1211 ($CBrClF_2$), CFC-11 (CCl_3F), CFC-113 ($CClF_2$-CCl_2F), chloroform ($CHCl_3$), CH_3CCl_3, CCl_4, hydrogen (H_2), methane (CH_4), and CO. One goal of this program is to measure the expected reduction of the ozone-depleting substances between 2001 and 2004 and in 2007 when the next TROICA mission will occur.

Arctic Water Vapor Measurements, 2004–2005. Water vapor observations at Sodankylä, Finland, and Ny Ålesund, Spitzbergen, were continued in cooperation with the Finnish Meteorological Institute (FMI) and the Alfred Wegener Institut, with support from the European LAPBIAT and SCOUT projects. At Sodankylä these measurements continue the stratospheric water vapor data set, which was started in 1996. In January and February 2004, the intensive campaign LAUTLOS-WAVAP (Lapbiat Upper Troposphere, Lower Stratosphere Water Vapor Project) took place at Sodankylä, which compared a number of in situ and remote sensing instruments capable of measuring tropospheric and stratospheric water vapor. A total of 33 payloads were launched during this project, with 14 carrying instruments capable of measuring stratospheric water vapor, namely the fluorescent Lyman Alpha stratospheric hygrometer of the Central Aerological Observatory, Moscow, the NOAA/GMD frost-point hygrometer, and the University of Colorado cryogenic frost-point hygrometer. In addition, these payloads carried ozone sondes.

The comparison of these instruments showed excellent agreement in the stratosphere and upper troposphere and described and quantified several instrumental artifacts that had not been identified previously. This high density of water vapor and ozone observations during February 2004 allowed a detailed study of the composition of the lowermost Arctic stratosphere and its relation to cut-off lows, which are a regular feature over the northern Atlantic Ocean. This data set also allowed a detailed investigation of transport processes across the polar vortex edge. The winter 2004–2005 measurements collected data on a rare Arctic dehydration event first observed in 1996. Water vapor observations at Sodankylä and Ny Ålesund will continue, depending on available funds.

Physical Science Division

In October 2005, the former Environmental Technology Laboratory (ETL) of NOAA was reorganized into the Physical Science Division. One of the new groups in the division is the Polar Region Processes Group. The primary activity of this group is the NOAA Atmospheric Observatory Program.

The NOAA Atmospheric Observatory Program is establishing sites for long-term, intensive measurements of clouds, radiation, aerosols, surface energy fluxes, and chemistry in Eureka/Alert, Canada, and Tiksi, Russia. These measurements will allow comparison with similar observatory measurements in Barrow, Alaska. The three sites in combination encompass three major Arctic climate regimes. The locations and measurement suite have been carefully designed so that the collected data can be used to determine the mechanisms that drive climate change through a combination of process studies, satellite validation, and modeling work. It is anticipated that the Atmospheric Observatory sites will also be the focus of a number of interdisciplinary measurements of regional hydrology, permafrost, ecosystems, and the cryosphere that will link the atmospheric measurements into the broader Arctic system. The program is heavily leveraged against Canadian and Russian programs and has a vigorous interagency cooperation with NSF and DOE.

Originally, the principal hypothesis of the SEARCH program was that Arctic climate change is related to the Arctic Oscillation (AO). There appeared to have been large-scale spatial co-variability between a number of climatic variables and the primary modes of the AO. However, the most recent research indicates that during 2000–2005, new climate patterns have evolved, and there now appears to be less of a correlation between the AO and other physical parameters of the Arctic system. This may be the first sign of new climate regimes that have resulted from recent feedbacks such as evolving albedo, cloud properties, and reduction of sea ice. Investigating and monitoring these climate shifts in detail may well require the detailed measurements proposed by the NOAA Atmospheric Observatory Program.

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 observatory (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 later in central Siberia.

The NOAA Atmospheric Baseline Observatory at Barrow, Alaska (Longitude: 71.3°N; Latitude: 156.61°W).

The full complement of proposed instruments is designed to acquire long-term records of cloud properties, aerosol properties, radiative fluxes, and surface energy exchanges. It is expected that these data sets will provide information necessary for understanding the processes that determine the regional climate, with a focus on how clouds and aerosols affect the balance between the surface and the atmosphere. These data sets will also allow statistical validation of satellite retrievals in the Arctic.

A microwave radiometer was installed in Eureka in July 2006. In collaboration with the NSF, it is expected that infrastructure improvements and first gas and aerosol measurements will begin in Tiksi, Russia, in the spring of 2007, followed by cloud and radiation measurements in the fall of 2007.

As part of the NOAA SEARCH program, the observatory was deployed to improve atmospheric and sea ice observations. These observations will be combined with historical data to better understand Arctic change.

This installation represents almost a decade of technological development, resulting in research-grade instruments adapted for long-term studies in remote regions. The data collected by these instruments will be critical for untangling natural and anthropogenic influences on cloud properties that may be a key factor in changing atmospheric radiation budgets in the Arctic.

Many indicators suggest that the impacts of climate change will be observed most rapidly in the Arctic. This is a critical region of the global atmospheric and ocean system where changes in deep ocean circulations, the distribution and thickness of Arctic Ocean ice, the extent of the Greenland ice, and terrestrial carbon dioxide storage could have far-reaching impacts for our environment.

While there is a history of basic measurements in the Arctic that are measuring *how* the Arctic climate may be changing, there are almost no monitoring programs that provide information to determine *why* the Arctic climate is changing. Consequently, NOAA has teamed with Canadian and U.S. university researchers to deploy a comprehensive suite of atmospheric sensors in Eureka, Canada, at 80°N/ 86°W. This site will collect detailed measurements of clouds radiation, aerosols, surface fluxes, and chemistry in the lower atmosphere, as well as key measurements in the middle and upper atmosphere, that will be sufficient to determine the processes driving climate change.

The International Polar Year committee has received over 1000 expressions of intent (EoI) in 2005 from researchers from around the world regarding activities that could contribute to the International Polar Year. The IPY committee organized these into a number of clusters along disciplinary lines. The International Arctic Systems for Observing the Atmosphere EoI that originated in NOAA was chosen to lead a cluster of about 20 separate EoIs from 10 countries. The main mission of the IASOA is to coordinate efforts to collect atmospheric data at existing and newly established intensive Atmospheric Observatories, distributed networks, and field campaigns during the IPY. A second mission of the IASAO is coordinate Arctic atmospheric measurements with those of other IPY activities that are coordinating hydrology, permafrost, terrestrial, cryospheric, and oceanographic measurements. The primary IASAO mechanism will be to establish a Program Coordination office that will facilitate planning meetings as well as maintain a dynamic website that can be used as a coordination tool internationally for Arctic atmospheric research (http://www.ipy.org/development/eoi/proposal-details.php?id=196).

Chemical Science Division

In the fall of 2005, the former Aeronomy Laboratory of NOAA was reorganized into the Chemical Science Division.

In 2004, NOAA scientists participated in the DOE-sponsored Atmospheric Radiation Measurement (ARM) program, a multi-laboratory, interagency program that is a key contributor to national and international research efforts related to global climate change. A primary objective of the program was to improve scientific understanding of the fundamental physics related to interactions between clouds and radiative feedback processes in the atmosphere, with the ultimate aim of promoting the advancement of climate models. Aeronomy Laboratory scientists were at the North Slope of Alaska ARM site, which is centered at Barrow, throughout much of September and October 2004 to take part in an Intensive Operational Period project known as the Spectral Water Phase. The site is the highest latitude site in the U.S., and the measurements made there have provided data about cloud and radiative processes at high latitudes. The Aeronomy Lab made measurements with a near-infrared spectrometer. The instrument analyzes the sunlight that is scattered by clouds and distinguishes between absorption by the vapor, liquid, and ice phases of water.

Pacific Marine Environmental Laboratory

NOAA's Pacific Marine Environmental Laboratory (PMEL) conducts ecosystem-based fisheries oceanography (Eco-FOCI) studies in the Bering Sea and the western Gulf of Alaska, principally through two programs, North Pacific Climate Regimes and Ecosystem Productivity (NPCREP) and Fisheries–Oceanography Coordinated Investigations (FOCI). These are cooperative programs among PMEL, NMFS's Alaska Fisheries Science Center, and other academic and government partners. Eco-FOCI's goals are to increase understanding of the Alaskan marine ecosystem, to document the roles of commercially valuable and endangered species in the ecosystem, to determine factors that affect their survival, and to develop and test annual indices and models that predict ecosystem and commercial fish stock status for guidance to marine resource managers.

Eco-FOCI scientists conduct research on the character and dynamics of the biophysical environment through field and laboratory experiments, computer simulations, and conceptual models. Eco-FOCI investigates decadal climate variability and its effects on North Pacific and western Arctic ecosystems, particularly in light of the development of an ecosystem-based approach to fisheries management.

In the Gulf of Alaska, FOCI since 1992 has predicted annual walleye pollock recruitment from relationships of fish survival to baroclinicity, transport, wind mixing, and climate forcing. Recent investigations have disclosed the importance of near-coastal eddies to the transport of nutrients and other water properties across the continental shelf between nearshore areas and the basin. Such processes may explain, in part, why the Gulf of Alaska is so productive.

In the Bering Sea, Eco-FOCI, principally through NPCREP, has extended monitoring of the eastern shelf environment northward toward St. Lawrence Island. Seasonal Bering Sea ice has diminished significantly in extent, duration, and thickness in the past decade. This has caused a gradual warming of the southeastern shelf waters to the degree that the regional composition and distribution of species is changing.

PMEL also participates in the Study of Environmental Arctic Change (SEARCH). PMEL, with support from NSF, maintains a weather station at the North Pole and is currently developing protocols for monitoring and detecting Arctic change.

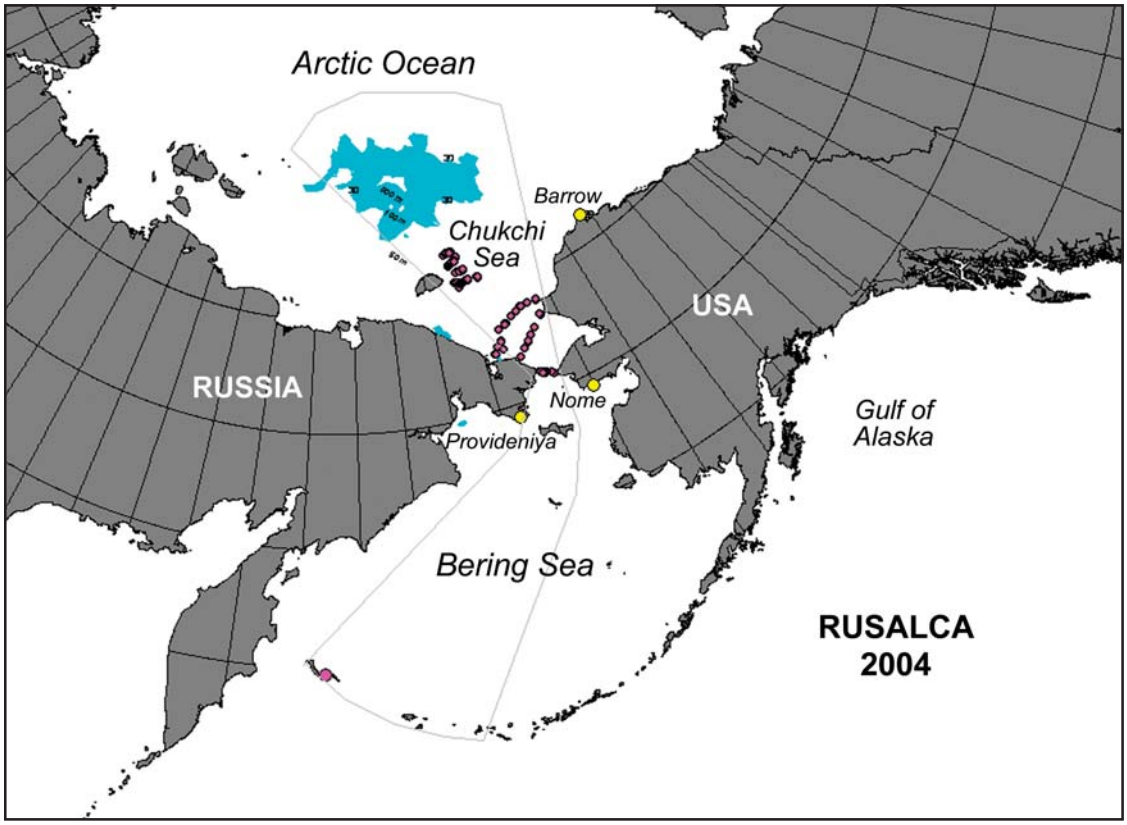
Cooperative Institute for Arctic Research

Arctic Climate Impact Assessment

The Arctic Climate Impact Assessment, an activity of the Arctic Council to assess the impacts of climate and UV radiation changes in the Arctic, was completed in 2005. An ACIA Secretariat, supported by the U.S. through NSF and NOAA, was located in the Cooperative Institute for Arctic Research (CIFAR) at the University of Alaska Fairbanks and was responsible for the conduct of the assessment, including support of the ACIA Executive Committee and coordination of the technical editors, production manager, and lead authors. During 2003–2005, the 200 international authors of the assessment participated in various meetings and forums to prepare the assessment. After an internal review, an extensive external review of the assessment by about 190 international experts took place. Responses to thousands of specific reviewer comments were documented and incorporated into the final text. The final report, which is 1046 printed pages, deals with impacts of climate and ultraviolet radiation on the environment, on economic sectors, and on peoples' lives. A 140-page overview report entitled *Impacts of a Warming Arctic* and an 18-page highlights document were also produced for a more general readership. The overview report and the highlights document were released at a final ACIA scientific conference in Reykjavik, Iceland, on 9–12 November 2004. The complete report was published by Cambridge University Press and released in November 2005. The ACIA report received an honorable mention for the ASLI (Atmospheric Sciences Librarians International) Choice Award in 2005. Post-ACIA activity at CIFAR has included responses to many inquiries from the media, science communities, nongovernmental and other organizations, and the general public, in addition to distributing the ACIA documents.

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. The first of the joint projects mentioned in the memorandum is a collaborative U.S.–Russian Federation oceanographic expedition to the Arctic seas regions shared by both countries: the Bering and Chukchi Seas. 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



Stations sampled during the voyage of the Professor Khromov, *a Russian research vessel engaged in the 2004 RUSALCA cruise. The colored area in the Arctic Ocean indicates a region of enhanced ice melting between 1970 and 2001.*

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 pieces of information needed prior to the emplacement of a climate monitoring network in this region.

Sorting samples during the 2004 RUSALCA cruise.

The Russian–American Long Term Census of the Arctic (RUSALCA) objectives include support the U.S. interagency Study of Environmental Arctic Change (SEARCH) program (psc.apl. washington. edu/search/) and the NOAA Ocean Exploration Program (www.oceanexplorer.noaa. gov). Because of the trend in reduction of the ice cover in the Arctic and the possibility of permanent loss of seasonal ice cover in the study region as shown by climate models, it is thought that this area might be subject to significant ecosystem change. RUSALCA is intended to help provide a foundation for detecting future ecosystem change and to provide the potential for discovery of new marine resources.

In November 2003, a workshop on the RUSALCA expedition mission was held in Moscow, Russia, to define the main research topics and geographical scope. Calls for Letters of Interest were released by CIFAR for response by scientists from the U.S. and by the Russian Academy of Sciences for response by scientists from Russia. In February 2004, after panelists met in Russia and the U.S., fourteen programs were funded for a joint U.S.–Russian cruise in the summer of 2004.

The primary study area for the first RUSALCA cruise was the northern Bering Sea (north of 60°N) and the Chukchi Sea to the extent that ice conditions permitted. The cruise took place 23 July–24 August 2004 on the R/V *Khromov*, a Russian ice-strengthened research ship. Hydrographic, biochemical, and productivity data were collected from the northern Bering and Chukchi Seas and are being combined with other data from RUSALCA investigators (both in the U.S. and Russia) to assess nutrient and productivity processes.

Participants included individuals from the following organizations through funding provided by NOAA and the Russian Academy of Sciences:

- University of Alaska Fairbanks
- Smithsonian Institution
- University of Tennessee
- University of Texas
- University of Washington
- Woods Hole Oceanographic Institution
- NOAA Fisheries
- NOAA's Arctic Research Office
- NOAA's Ocean Exploration Office
- Fish and Wildlife Service
- U.S. Army Cold Regions Research and Engineering Laboratory
- Shirshov Institution of Oceanology, Moscow
- VNIIOkeangeologia, St. Petersburg
- Zoological Institute, St. Petersburg
- Institute of Microbiology, Moscow
- Arctic and Antarctic Research Institute, St. Petersburg
- Pacific Oceanographical Institute, Vladivostok
- Roshydromet, Vladivostok
- Russian Federation Navy
- ECOSEA, Group Alliance.

Benthic macrofaunal biomass was found to be very high in the southern Chukchi Sea in a known region of high water column production. Several specimens of northern Pacific crab were collected in the southeastern Chukchi Sea, which is the third northernmost documentation of this species in the Chukchi Sea. In addition, the Pacific crab *Oregonia gracilis* and the bivalve *Pododesmus macrochisma* were also found, which appears to be the first time in the Chukchi Sea. These findings of Pacific taxa in Arctic waters are indications of an ecologically significant warming trend.

Clear and persistent patterns in species composition of the copepod *Pseudocalanus* exist in the study area tied to the different water masses, but

there was no obvious pattern in weight-specific egg production despite strong chlorophyll gradients associated with these water masses.

In the Chukchi Sea, benthic communities varied along an east–west gradient, with the same species feeding on higher trophic levels in the east compared to the west, suggesting a stronger pelagic link in the food web in eastern areas, where pelagic primary production is limited. In western areas, the higher primary production results in a significant amount of fresh phytodetritus reaching the seafloor and feeding benthic communities directly.

A second RUSALCA cruise is planned for the summer of 2007. An announcement of opportunity, issued through CIFAR in February 2006, has led to the submission of approximately 20 proposals now under review.

Workshop on NOAA Arctic Priorities

A Workshop on Arctic Priorities, convened by NOAA on 2–3 February 2005, was coordinated by CIFAR. The workshop served to focus input to NOAA's planning process for 2008–2012, particularly for the International Polar Year and SEARCH. Additional objectives were to identify priorities for NOAA's response to the Arctic Climate Impact Assessment. Approximately 30 scientists, primarily from NOAA and the Cooperative Institutes, participated in the workshop. The workshop report was provided to NOAA in March.

The workshop's recommendations were intended to foster the environmental and economic missions of NOAA's Office of Oceanic and Atmospheric Research by identifying priorities for Arctic research, product development, and the provision of scientific understanding and leadership in the Arctic. Among the recommendations were the establishment of several intensive atmospheric observatories around the periphery of the Arctic; the development of a network of ice-based and moored observing sites to monitor and permit attribution of changes in the Arctic Ocean and its ice cover; the extension of operational and retrospective analyses of snow cover to include Alaska and the Arctic; an Arctic system reanalysis in coordination with the next global reanalysis; the development of regional decision support for Alaska; and an assessment of the state of the Arctic on a regular basis. An additional priority—measurements of Arctic aerosols and their roles in cloud and radiative processes—emerged from a presentation of the workshop report to the NOAA Climate Working Group in March 2005.

Copies of the workshop report can be obtained from CIFAR or from the NOAA Climate Program.

Office of Marine and Aviation Operations

Eco-FOCI had extensive field seasons in 2004 and 2005, and the *Miller Freeman* was the primary platform for the deployment and recovery of the program's biophysical moorings in the Gulf of Alaska and Bering Sea. In 2004 approximately 34 sea days over three cruises were dedicated to mooring work and hydrography.

In 2005 the *Miller Freeman* continued to be the primary platform for the deployment and recovery of the program's biophysical moorings, ecosystem observations, and process studies on recruitment of larval fish. Mooring deployment and recovery cruises on the *Miller Freeman* were lasted 42 days. Ecosystem observations and recruitment process studies were also conducted in the early spring in the Bering Sea (12 days). A humpback whale survey was also conducted in the summer by the *Oscar Dyson* (20 days) in and around the Aleutian Islands and Bering Sea.

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, soon to become STAR, the Center for Satellite Applications and Research) is the NESDIS research organization that, among other things, supports research activities at NIC. Real-time global, regional, and tactical-scale ice guidance products are generated by NIC in support of mission planning, navigation safety, 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 a variety of formats including geographic information system (GIS)-compatible files via the NIC web page (www.natice.noaa.gov). Metadata that detail the data sources integrated into routine ice analysis products are also available on the NIC web

page. As of 2006, the NIC has added a daily marginal ice zone (MIZ) product to augment the enhanced daily ice edge product already provided for the Alaska and Great Lakes region to the National Weather Service. These products are being used to enhance the forecast within the Advanced Weather Interactive Processing System (AWIPS). Through a collaborative project with the National Snow and Ice Data Center and the NIC, extension of the High-Resolution Arctic Sea Ice Climatology to encompass historical data from 1972 to 2004 is near completion. This product is scheduled to be publicly released by the end of 2006. The NIC has also begun work on a 1972–2004 sea ice climatology project for the Antarctic region.

During 2004–2005, the NIC Science and Applied Technology Department reorganized and increased interaction with outside research and operational groups in government and academia, both nationally and internationally. These relationships are being leveraged to support the main goals of the department, which include the following:

- Evaluate new developments in remote sensing, digital image processing, automated sea ice analysis, and forecasting methods and determine potential applications for NIC operations:
  - Automate the analysis and classification of data;
  - Improve operational ice forecasting models;
  - Optimize active and passive microwave algorithms for operational sea ice analysis;
- Develop and execute plans and programs, both evolutionary and revolutionary, which enhance the quality and efficiency of ice analysis and forecasting processes to fulfill current and emerging operational requirements;
- Select and transition mature scientific research to operations, maintain oversight of the distribution of research and development resources dedicated to the NIC program from supporting agencies, and recommend appropriate courses of action based on these investments;
- Improve efficiency of data processing and analysis through the development of automated data fusion techniques; and
- Develop new ice products by applying new techniques and by incorporating data from new sensors.

The NIC science team transitioned a wide number of data and products from models, satellites, and in situ sensors to operations. In particular, ENVISAT Advanced Synthetic Aperture Radar (ASAR) Global Monitoring Mode (GMM), Advanced Microwave Scanning Radiometer - EOS (AMSR-E), Moderate Resolution Imaging Spectroradiometer (MODIS), and WindSat data and products were evaluated for operational ice analysis. Daily remote sensing and ice model products are available in near-real time on the improved NIC experimental products web page (science.natice.noaa.gov). The cross-validation and use of submarine ice draft data, shipboard observations, thickness estimates from ice age and buoy tracking, shipboard observations, ice mass balance buoy data, and NIC chart ice thickness proxy estimates are now under study. ORA has also continued to explore the application of airborne and satellite altimetry data for estimating sea ice thickness, notwithstanding the failed launch of CryoSat, through the support of NASA P3 altimetry campaigns for the validation of IceSat freeboard measurements.

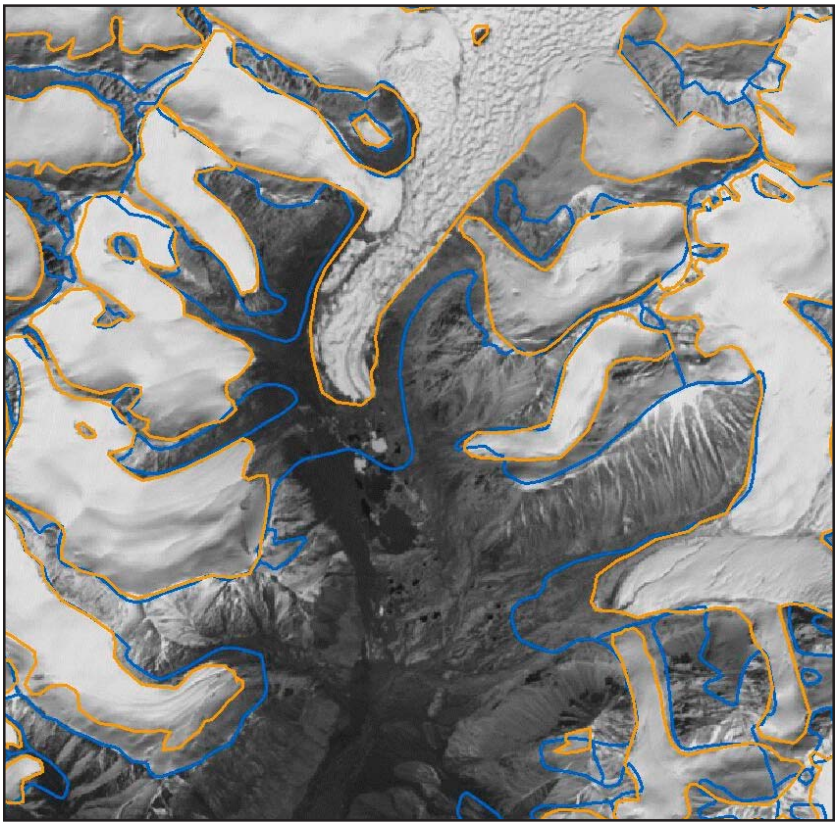
ORA implemented a new capability to track winds in the polar regions using observations from the MODIS sensor aboard the polar-orbiting satellites Terra and Aqua. The winds are derived by tracking water vapor structures in successive MODIS swaths. This new product provides unprecedented coverage of the polar wind field and has shown a positive impact on medium-range global weather forecasts. The MODIS winds are now assimilated operationally at the National Centers for Environmental Prediction (NCEP) and the European Centre for Medium Range Weather Forecasts (ECMWF). Access to MODIS polar winds is available through the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin-Madison web page (stratus.ssec.wisc.edu/projects/polarwinds).

ORA has continued to maintain and develop 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 (www.orbit.nesdis.noaa.gov/sod/mecb/sar). 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 safety of coastal transportation. SAR wind products are being evaluated as a tool for the site selection and placement of offshore and coastal wind farms. AKDEMO SAR imagery, along with vessel positions, has been used in Alaska to improve guidance to fishing

vessels operating near the ice edge. SAR imagery is also used for monitoring river ice breakup in the larger Alaskan rivers, such as the Yukon and Kuskokwim, and the Yellowstone River in Montana.

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 the coordination of deployments and the cooperation of USIABP participants in the International Arctic Buoy Program (IABP). Areas of cooperation include the development of new buoy technologies, the acquisition of replacement buoys, the monitoring of sea ice buoy network, and the exploitation of the buoy network observations. During 2004–2005, 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. In 2005, NIC joined the Steering Committee of the International Programme for Antarctic Buoys (IPAB) as it seeks to participate in expanding the in situ sea ice observational network globally.

ASTER image showing part of the glacier system of the Akshiyrak Range, Tien Shan Mountains, central Asia, with glacier outlines from a 1943 map in blue and from the 2001 ASTER image in orange. The image and outlines are from the GLIMS Viewer.

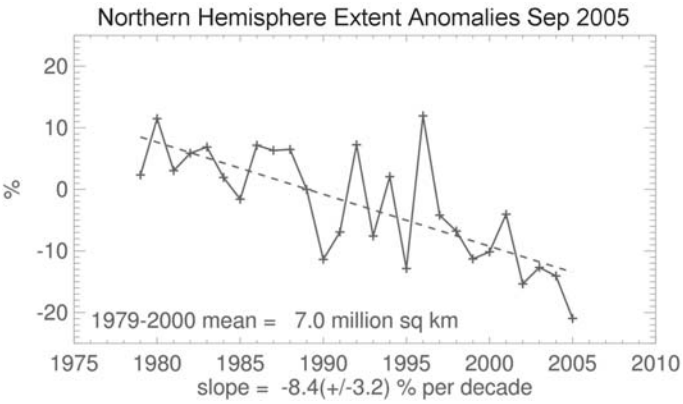


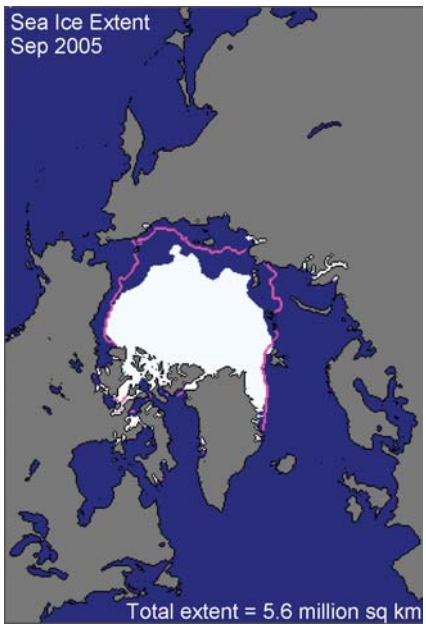
National Snow and Ice Data Center/ World Data Center for Glaciology

The National Snow and Ice Data Center (NSIDC) 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 (1976– present). NSIDC is co-located with the World Data Center for Glaciology, Boulder, as well as several agency-funded data management activities. These include the NSF-funded Arctic System Sciences Data Center, U.S. Antarctic Data Coordination Center, and Antarctic Glaciological Data Center; the Frozen Ground Data Center, supported by the International Arctic Research Center, University of Alaska Fairbanks; the NOAA@NSIDC program; and the NASA Distributed Active Archive Center (DAAC) for Snow and Ice. The latter program provides more than 80% of NSIDC's annual budget and supports Earth System Enterprise data sets such as AMSR-E and MODIS products, as well as "heritage" data sets such as the nearly 30-year record of sea ice concentration from satellite passive microwave data and numerous in situ records of snow, ice, and frozen ground.

The number of data management centers at NSIDC implies a compartmentalization that in fact is largely absent. All programs share the expertise of each, and NSIDC's scientists, through their interactions with data management staff, help keep data management efforts focused on science support. In 2004 and 2005, 106 data sets were added to the catalog. The online interface provides access to 562 data sets. These data sets exemplify the spirit of cooperation that the cryospheric research community shares, as it would not be possible to make them available without support from several agencies and many individual investigators.

NSIDC is exploring new methods of data management and data access. The Global Land Ice Measurements from Space (GLIMS) project, for example, uses map server technology with an Open Geospatial Consortium-compliant interface. This collaborative effort between NASA, the U.S. Geological Survey (USGS), and more than sixty institutions worldwide is creating a glacier inventory containing information about the current extent and rates of all the world's glacial resources derived from satellite imagery (largely Advanced Spaceborne Thermal Emission and Reflection Radiometer, or ASTER, and Landsat).





Graphics from the Sea Ice Index site, updated monthly, showing Arctic ice in retreat. The magenta line on the right image is the median September ice extent for 1979–2000.

One of the top science stories in 2005 was the marked decline of the Arctic sea ice cover. In a March press release, NSIDC scientists noted that while summertime ice extent had been trending downward for some time, the sea ice tended to recover its full extent in the Arctic winter. That has changed: ice reached new record lows in December, January, and February 2005. The trend in winter ice extent is now about –3% per decade. The downward trend in summertime extent is steeper (–8% per decade). The September minimum marked the fourth consecutive year of exceptionally low Arctic ice extent. In a joint press release with colleagues at the NASA Goddard Space Flight Center and the University of Washington, NSIDC scientists argued that beyond the continuing influence of higher temperatures on the ice pack, we may be seeing the beginning of an acceleration as feedbacks in the climate system take hold. NSIDC's Mark Serreze called 2005 the year that "puts an exclamation point on the pattern of Arctic warming we've seen in recent years."

The Sea Ice Index interactive web site allows scientists and the public to track ongoing changes in ice extent. The site received almost 40,000 visits in September 2005, as ice reached a new record low extent.

On an international level, activity in 2004 and 2005 built toward NSIDC's planned role in the International Polar Year (IPY), which begins in 2007. NSIDC leads or is involved in about 10% of the over-200 IPY lead projects. NSIDC has a proposed leading international coordination role for IPY data management, with an IPY Data and Information Management Service Expression of Intent. NSIDC scientists are also involved in the Fourth Assessment Report for the IPCC for The Cryosphere (Working Group 1) and Polar Regions (Working Group 2).

NSIDC is the repository for data from the USIABP. All buoy data are quality controlled within six months of receipt and then assembled into a historical (1979–2004) database that is analyzed by the Polar Science Center of the University of Washington (iabp.apl.washington. edu) and archived at NSIDC. These data have been useful in validating global climate 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 Oceanographic Data Center

NODC and the co-located World Data Center for Oceanography (WDC Oceanography) in Silver Spring, Maryland, continue to have an active data exchange program and engage in collaborative joint projects with many Arctic countries, academic institutions, other Federal agencies, and international organizations. In June 2006, NODC/Ocean Climate Laboratory (OCL) will release the World Ocean Database 2005 (WOD05), which will contain oceanographic physical, chemical, and biological data dating back to 1827. These profiles reflect data obtained from bottles, conductivity–temperature–depth instruments and plankton measurements, mechanical bathythermographs, expendable bathythermographs, surface-only instruments (bucket, thermosalinograph), subsurface drifting floats, and surface drifting buoys with thermistor

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 point of contact is Igor Smolyar, U.S. Department of Commerce, NOAA/OCL, 1315 East-West Highway (E/OC5), Silver Spring, MD 20910; 301-713-3295, ext. 206.

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.

The point of contact on access to the on-line publications listed in the International Polar Year 2007–2008: Resources on Polar Research in the NOAA Central Library Network: A Selected Bibliography *is Anna Fiolek, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, NOAA Central Library, 1315 East-West Highway (E/OC4), 2nd Floor, Silver Spring, MD 20910; 301-713-2607, ext. 147.*

chains. Approximately 20% of these data were added since the 2002 publication of World Ocean Database 2001. 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. Another product has been published, *Climatic Atlas of the Arctic Seas 2003: Part 1, Database of the Barents, Kara, Laptev, and White Seas*. It was prepared jointly with the Murmansk Marine Biological Institute (MMBI), Russian Academy of Sciences. This atlas contains data from about 400,000 oceanographic stations from 1810 to 2002. There are 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 also includes about 100 benthos samples collected along the Kola Meridian in 1921–1922 and 1977. All of these data are incorporated into the World Ocean Database and made available online.

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 www.nodc.noaa.gov/OC5/indprod.html.

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 online catalog has over 1,800 entries related to Arctic activities and another 1,000 entries related to oceanography and fisheries of the Arctic marginal seas. The library's on-site collection is supplemented by an additional 1,200 historical documents that can be found through the library's traditional card catalog. Access can be gained to the full range of publications that are dedicated specifically to Arctic science and issues. Pages of climate data from the polar areas of Alaska, Norway, and Russia beginning from 1824 are also available online, funded by the NOAA Climate Data Modernization program.

As an adjunct to textual material, the Central Library also manages the NOAA Photo Library Collection. There is an archive of over 1,000 black and white Arctic photographs and negatives and an online collection of over 600 public domain images related to Arctic themes.

In support of the International Polar Year 2007–2008, the Central Library has created a comprehensive bibliography entitled *International Polar Year 2007–2008: Resources on Polar Research in the NOAA Central Library Network: A Selected Bibliography*. The bibliography is formatted by title from entries in the library's online catalog and from the library's historical collections. The data and listings are comprehensive from the 18th century to the present. This resource contains many formats, including print, CD-ROM, online full-text documents, digital videos, digital images, online cruise data, and web resources. This document provides full-text links, copyright permitting, to significant polar documents in the NOAA library collections. Over 150 of the publications were scanned as full text, and there are also links to scientific data sets available from the National Oceanographic Data Center (NODC) Ocean Archive System. This bibliography is also an Internet locator for printed and online resources in polar research.

The bibliography is available online for downloading in Microsoft Word and in PDF formats at docs.lib.noaa.gov/rescue/Bibliographies/IPY2007.doc and docs.lib.noaa.gov/rescue/Bibliographies/IPY2007.pdf. Publications listed in the bibliography may also be requested through interlibrary loan.

National Climatic Data Center

NCDC was actively engaged in the Arctic Climate Impact Assessment, which was published in 2005. Specifically, two NCDC researchers were contributing authors to Chapter 2 ("Arctic Climate: Past and Present"). NCDC contributions focused on changes in land-surface air temperature and precipitation in the Arctic during the 20th century.

National Marine Fisheries Service–Alaska Fisheries Science Center

Resource Assessment and Conservation Engineering Division

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 2004 and 2005. 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 2004 and 2005, 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 and a combination of hydroacoustics and trawls (both midwater and bottom gear) for semipelagic fish. 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. Besides providing a time series, annual assessment surveys provide opportunities and platforms for intra- and interagency programs for collecting physical and biological data for understanding ecological processes in the Arctic region over a range of spatial and temporal scales. Universities and other outside organizations also participate in and benefit from collaborative research done during assessment surveys.

In addition, researchers launched a new NOAA program—Climate Regimes and Ecosystem Productivity (NPCREP) —whose focus is to monitor and understand climate-induced change in marine ecosystems and apply this knowledge to NOAA's ecosystem approach to management. The program is a partnership between the AFSC and NOAA's Pacific Marine Environmental Laboratory (PMEL). The program's major efforts are in the eastern Bering Sea, where researchers maintain a network of biophysical buoys and conduct monitoring and process cruises to examine how variations in atmosphere–ice–ocean coupling modulates the production at lower trophic levels and the abundance, distribution, and transport of larval fishes. Sea time included three cruises on NOAA vessels, one on a UNOLS vessel, and one on a foreign research vessel. Field operations included mooring deployments and recovery, deployment of satellite-tracked drifters, measurements of water column properties (heat, salt, nutrients, chlorophyll), and net tows for zooplankton and larval and juvenile fishes. Studies to understand the linkages to higher trophic levels will begin in FY 2006.

To manage the Arctic ecosystem, we need to accurately assess species diversity and composition. To greatly improve the identification of known species, the Groundfish Assessment Program's Systematics Laboratory publishes field guides and scientific papers on taxonomic revisions. One of the publications involved collaboration with the Recruitment Processes Program to describe the complete developmental series (larval to adult fish) of one family of fishes. The Systematics Laboratory instituted a vouchering system for documenting occurrences of unusual species and depositing specimens in university and museum collections. In 2004 –2005, the Systematics Laboratory described nine new species from three families of fishes in the Arctic. Fish specimens potentially representing at least 12 more new species have been collected and still need to be described. New invertebrate species from the Arctic also continue to be collected, and the staff is collaborating with experts from universities and other institutions to have them cataloged and described. Accurate identification and enumeration of every marine species in the Arctic is essential if we expect to understand the dynamics of the Arctic ecosystem.

Indices of ecosystem status and recruitment success are continually being developed, refined, and evaluated by the Ecosystem and Fisheries Oceanography Coordinated Investigations (Eco-FOCI), a collaborative program between the AFSC and PMEL. The indices generated by the FOCI and NPCREP programs are included in the "Ecosystems Considerations" chapter of the council's Stock Assessment and Fishery Evaluation (SAFE) reports and the PICES North Pacific Ecosystem Status Report. They are also available on NOAA's Bering Climate web page (www.beringclimate.noaa.gov). They are one source of information available for an ecosystem approach to management. In addition, the program is actively working on models that couple physics and lower trophic levels to fishes. One goal of such models is to generate predictions on the future recruitment success of fish populations with enough lead time to be of use to resource managers.

Resource Ecology and Fisheries Management Division

The REFM Division conducts research to assess the abundance, dynamics, and ecosystem interactions of crab and groundfish stocks off Alaska in support of their optimal utilization and management. It also conducts socioeconomic

studies to assist NMFS in meeting its stewardship responsibilities. Research is focused towards providing fishery, socioeconomic, and ecosystem assessment advice to decision makers to advance an ecosystem approach to management of Alaska's living marine resources. The REFM Division provides scientific support to U.S. delegations to international commissions and bilateral fisheries agreements, as well as central coordination of the AFSC's responsibilities involving the National Environmental Policy Act (NEPA) and the Freedom of Information Act (FOIA). The following is a brief summary of key research activities and accomplishments during FY 2004–2005 by the REFM Division's four main research programs: Status of Stocks and Multispecies Assessments, Resource Ecology and Ecosystems Modeling, Economic and Social Sciences Research, and Age and Growth Studies.

Status of Stocks and Multispecies Assessments. The Stock Assessment and Multispecies Assessments (SSMA) program is responsible for determining the condition of fisheries resources in the U.S. Exclusive Economic Zone off Alaska using data collected by AFSC scientists and others and for developing strategies for managing those resources. Research in FY 2004–2005 focused on updating information on population trends, estimating acceptable biological catch and overfishing levels, and developing management strategies as presented in annual stock assessments. Research conducted by the SSMA program staff has included retrospective studies of processes underlying shifts in production, distribution, or abundance of groundfish in the Bering Sea, Aleutian Islands, and Gulf of Alaska regions. The SSMA program has focused on developing next-generation analytical methods for evaluating stock condition, including new methods for improving the accuracy and predictability of stock status and trends and developing improved modeling techniques. Scientists within the group conducted numerous studies to assess key vital rates, including growth, mortality, and maturity schedules. SSMA staff also designed and implemented field studies to improve data collection on ships of opportunity. Finally, forecast models were developed by SSMA staff to assist in the analysis of environmental impacts of fishing.

The Fishery Interaction Team (FIT), a component of the SSMA program, investigates the effects of commercial fishing on top trophic level consumers. During FY 2004–2005, members of the team conducted studies to determine whether commercial fishing operations are capable of impacting the foraging success of sea lions, either through disturbance of prey schools or through direct competition for a common prey. Research focused on the three major groundfish prey of sea lions: walleye pollock, Pacific cod, and Atka mackerel. FIT investigated the potential effects of commercial fishing on sea lion prey fields in two ways: by conducting field studies to directly examine the impact of fishing on sea lion prey fields and to evaluate the efficacy of trawl exclusion zones; and by studying fish distribution, behavior, and life history at spatial scales relevant to sea lion foraging (tens of nautical miles).

Resource Ecology and Ecosystems Modeling. The Resource Ecology and Ecosystem Modeling program focuses on the collection and analysis of data relating to trophic interactions in the North Pacific and Bering Sea regions. During FY 2004–2005, these data were incorporated into environmental assessments and single-species, multispecies, and ecosystem models. Groundfish food habits data were systematically collected and analyzed, and groundfish feeding ecology was studied. Research on quantifying seabird–fishery interactions was conducted, along with efforts to work with industry in reducing these interactions. Ecosystem indicators have also been developed and incorporated into ecosystem-level assessments of the effects of climate and fishing on ecosystems. A variety of predator–prey models are being developed to forecast the effects of fishing and climate on marine ecosystem production and food web structure.

Economic and Social Sciences Research. The primary mission of the Economic and Social Sciences Research program is to provide economic and sociocultural information that will assist NMFS in meeting its stewardship responsibilities. Research activities in FY 2004–2005 in support of this mission have included collecting economic and sociocultural data relevant for the conservation and management of living marine resources; developing models to monitor changes in economic and sociocultural indicators and to estimate the economic and sociocultural impacts of alternative management measures; providing baseline sociocultural information and analyses of fishing communities of the North Pacific and Bering Sea regions; and improving the economic analysis of bycatch regulations in Alaskan fisheries.

Age and Growth Studies. The Age and Growth Studies program provides age data that contributes to the basic understanding of a species,

whether it is in the context of sustainable fisheries, species conservation, or species ecology. During FY 2004–2005, the program focused primarily on the production of age data for age-structured modeling of exploited fish populations, such as yellowfin sole, walleye pollock, Pacific cod, Atka mackerel, northern rockfish, and Pacific ocean perch populations in the Bering Sea and Aleutian Islands regions. In FY 2005 alone, the program aged over 33,000 individual groundfish specimens from Alaska waters. The program also conducts research in age validation to assess the accuracy of the aging methods that are being applied. Also being studied is the aging of new species, such as Greenland turbot and shortraker rockfish, which may require new aging methodologies.

National Marine Mammal Laboratory

The National Marine Mammal Laboratory (Alaska Fisheries Science Center) and the Protected Resources Management Division (Alaska Regional Office) are responsible for research on and management of 22 species of marine mammals that commonly occur in Alaska. These marine mammals include five endangered cetacean species (bowhead, fin, humpback, North Pacific right, and sperm whales), one pinniped species (Steller sea lion) that is threatened in one portion and endangered in another portion of its range, and three depleted stocks (Cook Inlet beluga whale, northern fur seal, and AT1 killer whales). Field research by NMML staff on marine mammals off central and northern Alaska focused on seven pinniped and two cetacean species during 2004 and 2005: Steller sea lions, harbor seals, northern fur seals, bearded seals, ribbon seals, ringed seals, spotted seals, Cook Inlet beluga whales, and bowhead whales in the Bering Sea. In addition, passive acoustic technology has recently been used to provide new information on the seasonal distribution of large whales.

Northern Fur Seals. Population assessment studies during the 2004 and 2005 breeding seasons established that the Pribilof Island population declined at 6% per year since 1998, while the Bogoslof Island (nearer the Aleutian Island chain) population increased at 12% per year since 1997. Long-term declines of the Pribilof Island population, which account for about 56% of the global fur seal population, had previously stabilized since 1983 and 1988 at Saint Paul and Saint George Islands, respectively. A suite of studies were continued or initiated investigating multiple hypotheses that may account for these trends, including studies of diet habits, foraging and migratory behavior, and causes of pup mortality. An at-sea tracking study in 2004 examined foraging site fidelity of lactating fur seals in the Bering Sea and will compare results with similar studies conducted in the previous decade. In collaboration with researchers from the University of Alaska Fairbanks and Dalhousie University in Nova Scotia, Canada, with funding from NOAA and the North Pacific Research Board, studies were conducted during 2004–2005 investigating the consequences of adult female foraging strategies during summer (in the Bering Sea) and winter (in the North Pacific Ocean) on condition, pup production, and growth. NMML's telemetry data on fur seal foraging and migration behavior are also combined with satellite-derived oceanographic data to investigate the importance of oceanographic features. In the fall of 2005, a total of 99 weaned pups at the Pribilof and Bogoslof Islands were instrumented with satellite telemeters to investigate post-weaning dispersal from rookeries.

Steller Sea Lions. NMML continued to monitor sea lion population status, foraging behavior, and health and condition to test hypotheses about the decline or lack of recovery of endangered Steller sea lions in the Bering Sea and Aleutian Islands. This research was composed of a suite of studies including aerial and ship-based surveys of abundance, survival and vital rate estimation, genetic stock differentiation, satellite tracking of dive behavior and movements and relationships with oceanographic features, and dietary habits. Although there were small increases in pup numbers at trend rookeries in the Kenai–Kiska area (4%) and in the western stock overall (3%) during 2001–2005, there were strong regional differences in the recent trends, suggesting that the magnitude or number of factors affecting the western stock of Steller sea lions also varied regionally. The largest decline in pup counts (–30%) occurred in the western Aleutian Islands, while smaller declines were observed in the central Gulf of Alaska (–4%) and central Aleutian Islands (–2%). In the Bering Sea, counts of Steller sea lion pups on Walrus Island (near St. Paul Island in the Pribilof Islands) in 2005 were the smallest on record.

Ice-Associated Seals. The four species of ice-associated seals (bearded, spotted, ribbon, and ringed seals), collectively known as "ice seals," are important resources for northern coastal Alaska Native communities and are likely to be key ecological components of Arctic marine ecosystems. Yet, despite mandates by the Marine Mammal Pro-

tection Act to assess the status of these species, relatively little is known of their abundance, population trends, seasonal distributions, stocks, and food habits. The distributions and densities of ice-dwelling seals are highly sensitive to suitable sea ice conditions, and as such, these seals may be particularly vulnerable to climate change. Changes in sea ice extent have been non-uniform; therefore, the effects on seals are likely to occur on regional scales, emphasizing the need for quality data throughout their range. NMML researchers have recently initiated projects to address these issues by supporting the genetic analyses of tissues collected during field research projects and by instrumenting these species with satellite-linked data recorders (SDRs). The SDRs, which fall off when the seals molt in the spring, provide data on a seal's location and the timing and depths of its dives. The data, received through the Argos system, can be analyzed to provide correction factors for seals missed (not hauled out) during sightings surveys, information on habitat selection (foraging and haul-out locations) and seasonal movements (post-molt migration routes), and information on foraging behavior.

In October 2004, in cooperation with the Kotzebue Native village and researchers from the University of Alaska Fairbanks and the Alaska Department of Fish and Game, two female young-of the-year bearded seals were captured in set nets in Kotzebue Sound and instrumented with SDRs. An additional seven female and eight male young-of-the-year bearded seals and two adult male and three female young-of-the-year spotted seals were captured and instrumented in October 2005. The 17 bearded seals were the first to be instrumented with SDRs in Alaska. Data from instrumented individuals are being collected on a continuing basis. Further analyses of these data will include investigations of the potential effects of bathymetry, ice concentration, and ice extent on their movements and diving behavior.

In June 2005, NMML researchers successfully live-captured ten ribbon seals off the coast of eastern Kamchatka, Russia. The seals were captured in hoop nets on the ice floes where they were resting, and they were physically restrained and instrumented. The two adult males, three adult females, and five pups were outfitted with SDRs, representing the first instance of live-capture and instrumentation of ribbon seals. Unlike ringed seals, which follow the ice edge north as it melts, some researchers have speculated that most ribbon seals remain in the Bering Sea and become pelagic during the summer. If true, the impact that ribbon seals may have on the Bering Sea's invertebrate and fish stocks could be significant. Preliminary results indicate that these pagophilic seals may, after the molt, remain primarily in the ice-free areas south of the Bering Strait. Most of the seals dispersed southeast into ice-free areas soon after they were tagged, with some adults traveling into the North Pacific, foraging south of the central Aleutian Islands. Data from instrumented individuals are still being collected, and a cruise to capture and instrument additional ribbon seals at the southern ice edge of the eastern Bering Sea was completed in the spring of 2006.

Accurate population estimates will be of little value without proper identification of stock structure, and while collecting tissue samples for genetic analysis from the subsistence harvest is useful, the harvest rarely takes place during the breeding season, so it is not possible to relate those samples to stock structure. In June 2005, researchers from NMML, University of Alaska Southeast, and the North Slope Borough conducted a pilot study at Peard Bay, Alaska, which utilized small, location-only SDRs, mounted on flipper tags, to determine whether ringed seals returned to the same breeding locations in successive breeding seasons. Such a result would indicate that dispersal rates are low and that populations are therefore more susceptible to depletion or extinction. The genetic diversity within a breeding location could also provide strong evidence for or against philopatry, so researchers collected genetic samples from captured ringed seals and from molted skin found on the ice around seals' breathing holes that will be analyzed for indications of site fidelity and stock structure. This work was continued and expanded in the summer of 2006.

The best way to conserve and provide stewardship of marine mammal populations that are critical to the subsistence of Alaska Natives is through a partnership between NOAA Fisheries—the Federal agency with management authority—and the Alaska Native resource users. Such a partnership should provide for the full and equal participation by Alaska Native tribes in decisions affecting the subsistence management of marine mammals. Recent workshops have resulted in the creation of an ice seal co-management committee consisting solely of representatives of Alaska Native tribes. The AFSC has the responsibility for scientific research and stock assessments of ice seals in Alaska and therefore has expertise and data relevant to many issues of concern of the potential ice

seal co-management partners. The AFSC is an active participant in their meetings and has taken a lead role in developing the Alaska ice seal statewide research plan.

In 1999 the first phase of a multi-year program to advance the use of passive acoustics for detection and assessment of large whales in offshore Alaskan waters was initiated at NOAA's National Marine Mammal Laboratory and Pacific Marine Environmental Laboratory (PMEL). To date, autonomous recorders have been successfully deployed in the Gulf of Alaska (1999–2001), the southeastern Bering Sea (2000–present), and the western Beaufort Sea (003–2004). Seasonal occurrences of six endangered species (blue, fin, humpback, North Pacific right, bowhead, and sperm whales) have been documented based on call receptions in these remote ocean regions (www.magazine.noaa.gov/). Detection of North Pacific right whale calls was given highest priority in the southeastern Bering Sea because of the whale's critically endangered status. Analyses to date show that right whales occur there from May through November, with the greatest number of calls recorded in September and October. In addition, calls from fin and humpback whales were ubiquitous on recorders deployed in the Bering Sea. Three recorders deployed in the Beaufort Sea were placed near an oceanographic mooring line in collaboration with the Western Arctic Shelf–Basin Interaction (SBI) project (sbi.utk.edu). Although the target species in this case was the bowhead whale, data analyses revealed calls of North Pacific gray whales each month from October 2003 through May 2004. The discovery of these calls through the Arctic winter was truly a surprise and may indicate a shift in range and behavior for this species.

Cook Inlet Beluga Whales. Systematic aerial surveys have been conducted in Cook Inlet to document beluga distribution and abundance each June or July since 1993. During this period, the distribution has shrunk to only the northern portions of the inlet. Abundance declined until 1998, when unregulated hunting was stopped, but since then the abundance—approximately 340 whales—has not changed appreciably. This stock was designated as depleted under the Marine Mammal Protection Act in 2000, and a status review is underway to determine whether this stock should be listed as threatened or endangered. In addition to the aerial surveys, the research program includes tagging effort to determine location, dive timing, and movements of belugas; aerial photography to discriminate color phases of whales (belugas become whiter as they age); fatty acid analysis to record beluga diet; genetic analysis to document how distinct belugas of Cook Inlet are from other stocks; and habitat modeling. Scientists from NMML work 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.

Bowhead Whale Stock Structure. Concerns were expressed at the 2004 Scientific Committee meeting of the International Whaling Commission that there might be more than one stock of bowhead whales in the seas around Alaska. These discussions initiated a research program that led to a range of proposed studies, including analysis of aerial photographs of bowheads (comparing images provides ratios of re-identifications of individual whales between years and sample areas); genetic analysis for stock discreteness; satellite tagging to track individual whales through their migrations; moored recorders to provide acoustic monitors of whales in the sample area year-round; interviews to collect traditional knowledge from whaling villages; reviews of historical whaling records to better determine the distribution of bowheads during the time of commercial whaling; and modeling exercises to provide a probability analysis of various hypothetical scenarios. These studies were underway in 2005 and 2006 in preparation for a critical review of bowhead information at the 2007 IWC meeting.

Auke Bay Laboratory

Nearshore Fish Assemblages near Barrow, Alaska. In 2004 and 2005 the Auke Bay Laboratory assisted the U.S. Army Corps of Engineers in a Coastal Storm Damage Reduction Study near Barrow, Alaska. The objective of the study was to evaluate the potential effects of beach erosion and replenishment on nearshore fishery resources. Fish assemblages were sampled with a beach seine at 26 sites. The beach adjacent to Barrow is eroding at a rapid rate, and Cooper Island, Point Barrow, and Skull Cliff have been proposed as possible sources of replacement sediment or rock. The total catch at all sites was over 3,000 fish in 2004 and 718 fish in 2005. The mean catch per seine haul was greatest for sites near Barrow and least at Cooper Island. At Cooper Island, the mean catch per seine haul was greater on the Beaufort Sea side of the island than in Elson Lagoon. The most abundant fish captured on the seaward side

of Cooper Island were juvenile cottids, whereas the most abundant species captured in Elson Lagoon was least cisco. The most abundant fish near Barrow and Skull Cliff were juvenile poachers, juvenile gadids, and capelin. Overall, the most abundant fish captured were juvenile gadids, comprising 51% of the total catch in 2005. A third year of the study will be completed in 2006 to provide a better understanding of the inter-annual variability in species composition and fish abundance.

Contaminant Research in the Bering Sea and Gulf of Alaska. Auke Bay Laboratory collected forage fish species from the Bering Sea and eastern Gulf of Alaska and examined them for organochlorines between 2001 and 2003. They have since reported on a comparison of walleye pollock from the perimeter of the Bering basin and southeastern Alaska, which indicated that the highest levels of polychlorinated biphenyls (PCBs) and DDTs were found among southeastern Alaska fish. In addition, data describing organochlorines in demersal species (Pacific cod, arrowtooth flounder, and Atka mackerel) collected from the Aleutian Islands suggest that Adak Island is a significant point source of contamination.

Yukon River Radio Telemetry Program. The Yukon River chinook salmon radio telemetry program, a cooperative study between the Alaska Department of Fish and Game and the National Marine Fisheries Service, conducted a full-scale, basin-wide tagging and monitoring program in 2004. A total of 995 fish were radio-tagged during the study and monitored during up-river migration by 39 remote tracking stations and aerial tracking surveys. Movement rates averaged 55 km/day for fish returning to the upper Yukon River, whereas fish returning to the lower basin traveled substantially slower (34–38 km/day). A total of 320 fish that moved up-river were harvested in fisheries, including 276 fish in the U.S. and 44 fish in Canada. A total of 719 fish were tracked to specific reaches within the basin: 283 fish to the Alaska portion of the Yukon River; 8 fish to the Porcupine River; 195 fish to the Canadian portion of the Yukon River main stem; and 58 fish to Canadian reaches of the Yukon River main stem or to associated tributaries not monitored by tracking stations or surveyed by aircraft.

Pacific Salmon: Bering Sea and Western Alaska Salmonid Populations. To provide critical information on the marine ecology of Pacific salmon and other important commercial fish species, scientists from the Alaska Fisheries Science Center's Ocean Carrying Capacity (OCC) program conducted fall surveys in 2004 and 2005 on nekton along the eastern Bering Sea shelf. The surveys were extensive, covering eastern Bering Sea shelf waters from the Alaska Peninsula to Kotzebue Sound. The research is part of a larger Bering Sea salmon ecology study conducted by the North Pacific Anadromous Fish Commission, the Bering–Aleutian Salmon International Survey (BASIS) program. The goal of the OCC/BASIS salmon research is to understand the mechanisms underlying the effects of the environment on the distribution, migration, and growth of juvenile salmon on the eastern Bering Sea shelf. The primary objectives of the survey are to determine the extent of offshore migrations of juvenile salmon from rivers draining into the eastern Bering Sea, to describe the physical environment of the epipelagic waters along the eastern and northeastern Bering Sea shelf occupied by juvenile salmon, and to collect biological information of other ecologically important species.

Results indicate that juvenile salmon are widely distributed across the eastern Bering Sea shelf; species-specific distributional patterns of juvenile salmon can exist; distributional patterns are likely related to principal prey sources (for example, age-0 pollock for juvenile sockeye and chum salmon, larval and juvenile sand lance for juvenile chinook); size and relative abundance of juvenile sockeye salmon, chum salmon, and age-0 walleye pollock were greatest during 2002 through 2004 compared to 2000 and 2001; size of juvenile salmon is related to marine survival (for example, larger fish have higher marine survival); sea surface temperatures have warmed considerably during 2002–2005 compared to 2000 and 2001; and oceanographic characteristics can influence distribution, migration pathways, and early marine growth (for example, warm sea surface temperatures are associated with offshore distribution and increased early marine growth for juvenile sockeye salmon).

Sablefish Longline Survey, 2004–2005. The AFSC has conducted an annual longline survey of sablefish and other groundfish in Alaska since 1987, a continuation of Japan–U.S. cooperative longline surveys conducted from 1978 to 1994. The survey is a joint effort involving two AFSC research divisions: the Auke Bay Laboratory and the Resource Assessment and Conservation Engineering Division. The continental slope of Bering Sea and Aleutian Islands are sampled on alternate years at depths between 200 and 1000 m. In 2005, 20 Bering Sea stations were sampled between 59 and 53°N latitude, while in 2004, 21 stations were

sampled in the Aleutians from 179 to 165°W longitude. Sablefish is the most frequently caught species, followed by giant grenadier, shortspine thornyhead, and Pacific cod.

Deep-Sea Coral Distribution and Habitat in the Aleutian Islands 2004. Two studies were completed in the Aleutian Islands in the summer of 2004 on the distribution and habitat of deep sea corals and the associated biological communities. The first study used the piloted submersible *Delta* in June and July to complete the second and final phase of a project to assess Aleutian Islands coral habitat in waters less than 365 m deep (the maximum depth at which the submersible can operate). Scientists visited 10 sites and collected video of the seafloor on 23 strip transects. Previously undocumented beds of sponges, predominantly demosponges, were documented on an additional six dives. More than 150 coral specimens were collected for molecular and morphological taxonomic identification and for studies on reproduction. More than 100 sponge specimens were also collected, and 5 of the first 10 specimens analyzed microscopically were confirmed as species new to science.

The second study in late July used the RV *Roger Revelle* as a support vessel for the remotely operated vehicle (ROV) *Jason II*, attended by a team of biologists, fisheries scientists, and geologists to study deep sea coral habitat at depths ranging from 131 to 2,948 m in the central Aleutian Islands. Coral and sponge habitat was documented and a number of deep-water specimens—many new to science—were collected for ecological and taxonomic studies. This cruise was the final component of a comprehensive study initiated in 2003 and funded by NOAA Fisheries, NOAA's Undersea Research Program, and the North Pacific Research Board. The team hopes to use their findings to construct a model to predict where coral habitat is located throughout the Aleutian Islands region. The model will provide fisheries managers with a powerful tool to conserve the region's coral habitat.

Survey Strategies for Assessment of Bering Sea Forage Species, 2005. In June 2005, two research cruises were conducted in the southeastern Bering Sea, with one group of scientists onboard the F/V *Great Pacific* targeting offshore waters of the continental slope and continental shelf and a second group of scientists onboard the F/V *Kema Sue* targeting nearshore waters. A third group of scientists employed lidar and visual surveys from a chartered airplane. The primary objective of this study was to test a suite of methods for estimating forage species abundance in the Bering Sea. Aerial surveys covered 23,125 km; acoustic surveys covered 540 km; 24 stations were completed by the offshore vessel and included 22 MultiNet (multi-opening zooplankton net) deployments, 18 CTD casts, 2 ZOOVIS-SC (zooplankton camera) deployments, and 21 midwater trawl deployments; and 18 stations were completed by the nearshore vessel, which included 70 beach seine deployments and 11 jigging locations.

The dominant forage species catch in the midwater trawl was northern smoothtongue. Common forage species were the myctophids, northern lampfish and California headlight fish, squid, and Pacific herring. Shallow nearshore stations were dominated by walleye pollock and Pacific herring.

The dominant forage species in nearshore surveys was Pacific sand lance; approximately 35,000 were captured, and they occurred in 60% of the seine hauls. Other commonly captured forage fish species were Pacific sandfish and young-of-the-year gadids. Aerial surveys offshore found a surface layer from 2 to 5 m deep and varying in thickness; net sampling showed that it consisted mainly of large copepods. Patchy, larger targets lay from 8 to 30 m deep and probably extended below attenuation range (30 m). Aerial surveys also located "hot spots" mainly along the continental shelf break. The hot spots consisted of 3–40 humpback, fin, and sei whales, thousands of seabirds (mostly shearwaters), concentrated patchy targets characteristic of fish schools, and obvious foraging activity (for example, bubble feeding by humpback whales and regurgitated euphausiids from shearwaters). These hot spots were observed on multiple days and appeared to move northeast along the shelf break at about 20 km per day. Fewer signal targets, seabirds, and marine mammals were located nearshore; however, a few fish schools were visible and may have been sand lance and herring.

Habitat and Ecological Processes Research Program. The AFSC initiated the Habitat and Ecological Processes Research (HEPR) program in February 2005 to develop scientific research that supports implementation of an ecosystem approach to fishery management. The HEPR program focuses on integrated research studies involving habitat and ecological processes.

An identified research area for the HEPR program is the Loss of Sea Ice (LOSI) study. Specific research questions are: How can AFSC scientists improve their understanding of the natural and

anthropogenic processes in the Bering Sea that influence sea ice thickness, timing, and seasonal extent, and how do changes in sea ice properties influence living marine resources? How can this information enable more accurate forecasts of future ecosystem status and trends? How can this information be incorporated into management advice and thresholds for regulatory actions? Three LOSI research areas are planned: expand existing surveys to cover apparent northern migration of species; create new surveys of ice-dependent species not presently assessed; and acquire the understanding to create spatially explicit models to predict the effects of loss of sea ice on fish and marine mammal abundance trends. LOSI funding is scheduled to begin in FY 2008.

National Weather Service

NOAA's National Weather Service focuses mostly on operations and spends the bulk of its associated research time collaborating with others in NOAA and academia. The NWS's most significant efforts have involved sponsoring and collaborating on research associated with coastal erosion and climate change.

The NWS has also collaborated with the Cooperative Institute for Arctic Research on the development of the Alaska Regional Integrated Sciences and Assessments Program, tsunami operations and research (the Tsunami Warning and Environmental Observatory at the University of Alaska Fairbanks), and climate change (including participation in the ACIA report development). They are active participants in the Alaska Ocean Observing System (AOOS) and have sponsored and/or collaborated in numerous research and operational endeavors with other AOOS participants. The NWS worked with the National Academy of Science on the requirements and needs associated with establishing the Arctic Observing Network and with International Polar Year (IPY) collaborators on potential IPY research activities.

In 2005 the NWS sponsored a workshop in collaboration with the International Arctic Research Center, Fairbanks, Alaska entitled "Toward an Alaskan Wind/Wave Climatology." This workshop was organized as part of an Alaskan sector contribution to the NOAA Pacific Regional Integrated Data Enterprise (PRIDE) initiative call for proposals that took place in FY 2005. The objective of this proposal was to initiate work leading to an improved operational capacity for predicting coastal erosion and flooding with a demonstration project in place by IPY (FY 2007–2008). The project's specific FY 2005 objective was to initiate work in support of this objective using directed research activity and a workshop. Another important objective at this stage was to map out linkages with corresponding needs and activities in Hawaii and the U.S. Pacific regions.

The specific goals for the workshop were to identify capacity and needs for wave modeling in the Alaska region, stakeholder requirements, data availability, and aspects of the terrestrial zone. Given that relevant experience in many of these areas is available in various agencies, a wide range of participation was solicited from a variety of Federal, state, academic, and other research groups.

Solid links between Alaska, Hawaii, and the broader Pacific region were identified. These included:

- Aspects of a conceptual coastal dynamics model framework that can be imported and exported to various regions to build complete models at all locations;
- Partnerships with the existing Hawaii PRIDE data teams;
- Guidance from an established template outlined by the NOAA Pacific Risk Management 'Ohana (PRiMO) project (www.csc.noaa.gov/psc/FHMPPI/);
- Inclusion in the Integrated Ocean Observing System initiative;
- Identification of a denser ocean observing network in the Pacific that would greatly enhance the ability of the Global Forecast System to predict the heavy storms that start life as Pacific typhoons and then curve back to the northeast and can hit Alaska.

This material was summarized at the 2nd PRIDE workshop in Honolulu, which was held the following week. At that time, meetings were held with Hawaii representatives, and as a result of those, to further the integration of Alaska into the NOAA Pacific sphere, arrangements are being made with NOAA Hawaii to have the talks, participant lists, and other information related to the Anchorage workshop placed on a web site hosted in Hawaii.

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.

	Funding (thousands)	
	FY 04	FY 05
Agricultural Research Service	2,000	2,000
Coop. State Res., Ed. and Ext. Serv.	1,389	1,389
Forest Service	653	653
Natural Res. Cons. Service	260	260
Total	4,302	4,302

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. Currently the mission of the unit is:

- To improve the understanding and control of invasive plant pests, plant pathogens, weeds of agricultural importance in Subarctic cropping, and Alaskan natural systems;
- To collect and preserve important Arctic plant germplasm resources;
- To develop virus-free potato germplasm; and
- To develop effective and economical utilization of fish processing byproducts.

Since it establishment in Alaska, USDA-ARS has released more than 40 cultivars of potatoes, barley, raspberry, and grasses. The research of USDA-ARS has enhanced the productivity, profitability, and environmental quality of Alaska's farming and fishing industries and natural resource areas by reducing threats posed by wind and water erosion, invasive insect pests, weeds, and pathogens through research and technology transfer resulting in the introduction of new and innovative IPM (integrated pest management) strategies suitable to northern latitudes; an increased utilization of seafood byproducts; and the collection, conservation, and characterization of germplasm adapted to Arctic and Subarctic environments.

Arctic, Subarctic, and Alpine Plant Genetic Resources Conservation, Research, and Information Management

Agricultural development in Arctic, Subarctic, and alpine regions depends on the availability of improved plant cultivars adapted to the limiting growing conditions. However, the biological properties of high-latitude species and crops are not known or are poorly documented. Adequate characterizations of germplasm and subsequent documentation in appropriate databases are critical for germplasm management, utilization, and the development of new crops at northern latitudes and high altitudes. The Subarctic Agricultural Research Unit is the only unit of the Agricultural Research Service's National Plant Germplasm System (NPGS) that addresses Arctic, Subarctic, and alpine germplasm research.

The goals of this project are to conserve, evaluate, and distribute a broad spectrum of genetic resources of plants adapted to short, cool seasons and long photoperiods; to generate and manage associated information; and to provide a scientific base for its use in research and crop improvement. Its objectives are:

- To conserve, evaluate, characterize, and distribute Arctic, Subarctic, and alpine-adapted plant germplasm and associated information to scientists worldwide;
- To characterize diseases and their etiological agents on selected crop and native plant

species from Arctic, Subarctic, and alpine ecosystems; and
- To identify key insect pests on selected crop and native plant species from Arctic, Subarctic, and alpine ecosystems.

The project supports the NPGS in the regeneration of accessions of seed and clonal germplasm not adapted to other NPGS locations.

Collection, Evaluation, and Maintenance of Arctic Plant Germplasm

The objectives of this project are to maintain and improve a plant germplasm repository specifically targeted for the acquisition, evaluation, maintenance, and regeneration of Arctic species or crop species adapted to Arctic conditions, and to conduct a research program to improve methods for disease-free propagation and conservation of Arctic germplasm.

Germplasm increase and conservation priorities will be conducted in consultation with National Crop Germplasm Committees, the NPGS, and ARS's Plant Exchange Office in Beltsville, Maryland, and in collaboration with Alaska Department of Natural Resources' Division of Agriculture. Germplasm received at Palmer will be logged in to the Germplasm Resources Information Network (GRIN) so that passport and other data are available to the user community. The seeds will be stored in refrigerated, dry conditions to delay loss of viability. Evaluation data will be collected from scientists at Palmer and other cooperators. Research will focus on factors influencing seed and/or propagule quality, both from the genetic and viability/longevity standpoints.

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. A study of diseased twisted-stalk in Denali State Park and near Skwentna revealed two 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 unexpectedly high number of infected plants in two isolated natural habitats.

Integrated Pest Management for Alaska Agriculture

The objectives of this project are to enhance the productivity, profitability, and environmental quality of Alaska's farming industry and natural resource areas by reducing threats posed by invasive insect pests, weeds, and pathogens through research and technology transfer resulting in the introduction of new and innovative IPM strategies, and to develop IPM applications suitable to northern latitudes that support viable crop and nursery production systems and the sustainability of natural resource areas. This project will develop IPM systems incorporating biologically based control, host resistance, cultural control, resistance management, and application technology for the control and suppression of major insect, pathogen, and noxious weed pests affecting field, vegetable, and horticultural crops, as well as rangeland ecosystems in the Delta Junction region and other areas of Alaska.

Cooperative State Research, Education and Extension Service

CSREES's unique mission is to advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs in the Land-Grant University System and other partner organizations. CSREES doesn't perform actual research, education, and extension but rather helps fund it at the state and local level and provides program leadership in these areas. CSREES collaborates or has working partnerships with many institutions and individuals. The key partners are the institutions of higher learning making up the Land-Grant University System. However, CSREES also partners with other Federal agencies, within and beyond USDA; non-profit associations; professional societies; commodity groups and grower associations; multistate research committees; private industry; citizen groups; foundations; regional centers; the military; task forces; and other groups. CSREES and its partners focus on critical issues affecting people's daily lives and the nation's future. The advanced research and educational technologies empower people and communities to solve problems and improve their lives on the local level.

The Alaska Native-Serving and Native Hawaiian-Serving Institutions Education Grants Program promotes and strengthens the ability of Alaska Native-serving and Native Hawaiian-serving (ANNH) institutions to carry out education, applied research, and related community development programs within a broadly defined arena of food and agricultural sciences. The ANNH program aims to attract, retain, and graduate outstanding students capable of enhancing the

nation's food and agricultural scientific and professional workforce. Projects may involve individual institutions, consortia, or cooperative initiatives between two or more ANNH institutions or with other colleges and universities, units of government, or the private sector. In 2004 and 2005, the following Alaska institutions received grants.

Ilisagvik College

Ilisagvik College successfully developed and implemented a USDA-funded project titled "Arctic Subsistence Education and Experience: Joining Traditional Knowledge and Modern Education." The project introduced students to the scientific and traditional Inupiat methods and ways of observing and learning about the environment. Students attended experiential training in traditional hunting, fishing, and gathering and bridged that knowledge with Western scientific methods of observing and learning about the environment. Initial instruction was delivered in a classroom setting at the campus in Barrow. Students were taken for field experience to a remote location in the Arctic tundra, where they learned the local geography and traditional knowledge of traveling in the ocean and up rivers, weather attributes, and the nature and use of local land and sea animals and birds. Twenty-five students benefited from the courses; all were encouraged to pursue future training and employment in wildlife, land management, and other related fields. All students gave presentations on their experiences in this program and shared with other students their perspectives on the similarities and differences between Western science and traditional knowledge and how both can be used to build life skills. The Inupiaq Land Use Values and Resources course was so successful that the North Slope Borough School District has requested a special offering for teacher development.

Prince William Sound Community College

"Welcome to Alaska's Copper River Valley!" That's the headline of a newly published map for visitors to rural Alaska. The informative, colorful map is among the products of regional economic development efforts that began with "Development of Local Tourism" workshops sponsored by Prince William Sound Community College. The series of ecotourism workshops involved seven Native villages and six communities. Several classes were offered in hospitality services including safe food handling, culinary arts, developing small businesses, marketing and web design. A publication, "Tourism in Rural Alaska: A Community Education Curriculum, 2nd Edition," was completely revised, expanded, and reprinted for use throughout Alaska in regions where people are interested in starting or expanding tourism-based programs. This publication has gained wide recognition and was presented at an international hospitality and tourism conference in 2003 in Costa Rica. The curriculum is used by universities, businesses, and agencies around the world.

Sheldon Jackson College

Sheldon Jackson College used CSREES grants to advance its environmental sciences and fisheries programs in several areas. Water supply to the college hatchery has been improved. Incubators, net pens, and other supportive materials, including safety, electronic, and science field education resources, have been obtained, and the infrastructure has been upgraded. Well-qualified hatchery staff have been employed. Student hands-on learning and fieldwork research have been enhanced by obtaining boats and charters. Appropriate professional development for science faculty and hatchery personnel has increased, and computer equipment has been made available to faculty for teaching, research, and communication purposes. Recruitment of students has been improved through print and electronic media and financial assistance.

University of Alaska Fairbanks: College of Rural Alaska

At the University of Alaska Fairbanks (UAF): College of Rural Alaska, CSREES funded improvements in student and community education; the goal is for students to apply their education to improve their communities and quality of life. The continuing impact of the project is manifest in:

- The increased numbers of community leaders and stakeholder groups that are becoming involved in the collaborative efforts of their respective regional consortium/alliance in identifying and resolving critical issues (such as education and economic development) that are affecting the quality of life of the people in their region;
- The increased number of educators in rural secondary schools who are developing and implementing creative projects (mini-grants) designed to facilitate secondary education students' mastery of mathematics and science concepts through the use of natural resources education (subsistence agriculture);

- The development and validation of eight curriculum units that integrate mathematics and science concepts through natural resources education and are adapted to regional and cultural usage; and
- The establishment and active functionality of a UAF clearinghouse dedicated to promoting mathematics, science, and natural resources education at the middle and secondary school levels.

University of Alaska Southeast Sitka

The University of Alaska Southeast Sitka Campus has used CSREES funding to expand an existing 12-credit Community Wellness Advocate (CWA) program. Offered in partnership with the Southeast Alaska Regional Health Consortium (SEARHC) and targeted at rural Alaska Natives in underserved areas, the program has added training that is heavily focused on nutrition and healthy lifestyle choices as the basis for health promotion and disease prevention for women, infants, and children as well as other rural community residents. The program is distance-delivered throughout the state. Specific goals met include:

- Creating a 30-credit CWA certificate program that increases educational opportunities and provides career advancement for practicing CWAs;
- Expanding the program statewide to increase the number of professionals trained to serve in rural, underserved areas of Alaska;
- Involving other Native health corporations; and
- Helping them to better serve needs of people living in their regions of the state.

Efforts are underway to institutionalize the program throughout the University of Alaska system.

Forest Service

The Pacific Northwest (PNW) Research Station is part of the Research Branch of the Department of Agriculture's Forest Service and comprises ten research laboratories in Oregon, Washington, and Alaska, as well as the headquarters office in Portland, Oregon. The PNW Research Station is one of eight Forest Service research facilities throughout the United States. Forest Service Research develops and provides scientific and technical knowledge for all 1.6 billion acres of forests and rangelands in the United States, including, but not limited to, the National Forests. The Forest Service has the most extensive and productive program of integrated forestry research in the world. The PNW Research Station is a group of about 522 scientists, professionals, technicians, administrative staff employees, and research managers. Station expertise is in biological, physical, and social sciences. Their mission is to generate and communicate scientific knowledge that helps people understand and make informed choices about people, natural resources, and the environment.

The USDA Forest Service's 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; 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.

The BECRU is located within the Ecosystem Processes Program Core. Areas of study include:

- Understanding interactions between climate, disturbance, and ecosystems in central and northern Alaska;
- Developing conceptual and real models of multiple spatial and temporal scales of patterns in Alaska vegetation; and
- Leading cooperative research at the Bonanza Creek Long-Term Ecological Research site.

Invasive Species and Floodplain Wildlife Habitat

Alaska's glacial rivers are dynamic, with frequent changes in water level and river course. Floodplains are constantly in flux, and recently deposited surfaces have been found to be susceptible to invasion by certain exotic plant species. These sites are often highly productive with lush plant growth, which makes them prime habitat for moose, an ecologically and economically important species in the state. Such floodplain surfaces are often dominated by willows, an important

browse species for moose. In interior Alaska, for example, the Tanana Flats supports more than 15,000 animals, or more than three moose per square mile. The willow stands along the Tanana River provide critical winter forage for this population. However, in a survey of floodplain plant species composition, scientists found sweet clover, an invasive flowering plant belonging to the pea family, invading the floodplains of three Alaskan rivers, moving from south to north. Sweet clover has come to dominate the lower reaches of the Stikine River in southeast Alaska, is a major component of portions of the Matanuska River floodplain in south-central Alaska, and has been detected in small amounts on the floodplain of the Nenana River in interior Alaska. Although sweet clover has not yet been found on the floodplains of the Tanana or Yukon Rivers, it is common along roadsides that cross or are adjacent to t hose habitats. As sweet clover invades and establishes itself on the floodplains of Alaska's major river systems, significant changes in critical moose habitat may occur. Because of concerns that sweet clover may replace native floodplain species, research has begun to examine competitive interactions between sweet clover and willows to better understand potential effects on native plants, wildlife forage, and habitat quality.

Bonanza Creek Experimental Forest

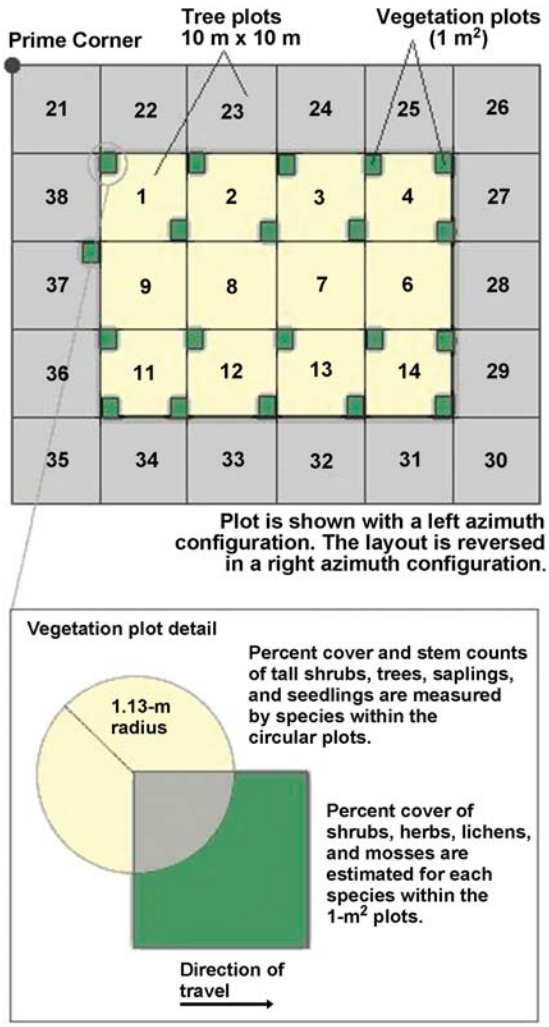
The Bonanza Creek Experimental Forest is an ecological research forest in interior Alaska. The BCEF and the Caribou-Poker Creeks Research Watershed are the only two boreal forest research facilities in the boreal forest, or taiga, zone of Alaska. The forest provides a place to conduct ecological and forestry research, unencumbered by other management objectives. BCEF is leased to the PNW Research Station by the State of Alaska. University research activities are coordinated through the Boreal Ecology Cooperative Research Unit (BECRU) formed through a cooperative agreement between the University of Alaska and the USDA Forest Service.

Location of the Bonanza Creek Experimental Forest, site of the Bonanza Creek Long-Term Ecological Research project.

The majority of the research being conducted at BCEF is organized under the Bonanza Creek Long-Term Ecological Research (LTER) program. The LTER research program at BCEF is designed to study ecosystem structure and function by examining controls over successional processes in taiga forests of interior Alaska. This study tests hypotheses in two successional sequences; three replicates each of six successional stages of primary succession on the floodplain of the Tanana River and three stages of succession following wildfire on south-facing slopes in the uplands. The Bonanza Creek LTER program focuses on improving our understanding of the long-term consequences of changing climate and disturbance regimes in the Alaskan boreal forest. Its overall objective is to document the major controls over forest dynamics, biogeochemistry, and disturbance and their interactions in the face of a changing climate.

The forest dynamics theme addresses successional changes in population and community processes following disturbance, emphasizing the relative importance of historical legacies, stochastic processes, and species effects in determining successional trajectories and the sensitivity of these trajectories to climate. Changes in the carbon cycle during succession hinge on changes in forest dynamics and other element cycles, but they also influence nutrient availability and microenvironment and therefore successional changes in forest dynamics. Regional and landscape control over disturbance regimes focuses on regional and landscape processes that are responsible for the timing, extent, and severity of disturbance.

The research design uses experiments and observations in intensive sites in three successional sequences (floodplains, south-aspect uplands, north-aspect uplands) to document the processes that drive successional change. The regional context for these intensive studies is established by analysis of ecosystem processes in two large regions, one in a relatively uniform region in interior Alaska and a second along a climate gradient from the warmest to the coldest areas in Alaska. Species effects on ecosystem and landscape processes explores how species characteristics and



Bonanza Creek Long-Term Ecological Research plot layout.

diversity influence biogeochemistry and disturbance regime. Spatio-temporal scaling provides the conceptual basis for linking process and pattern. Ecosystem sustainability explores how the positive and negative feedbacks that operate within ecosystems influence the sensitivity of ecosystems to perturbations such as changes in climate and disturbance regime.

Research at this LTER site has contributed substantively to understanding the relationship between "independent" state factors and internal ecosystem dynamics in causing successional change in the boreal forest of Alaska. Major findings of the program include the following:

- Species effects are strong in the boreal forest.
- Successional changes in species composition are not a simple consequence of changes in competitive balance but involve species-driven changes in biogeochemistry and the physical environment.
- Vertebrate herbivores are a powerful force driving successional change through their effects on plant competitive interactions and biogeochemistry.
- Succession influences exchanges of CH_4, CO_2, water, and energy in ways that could feed back to climate.

This research on succession raises important questions about the broader regional context in which succession occurs. The current phase of LTER addresses the question: How do changes in climate and disturbance regime alter the functioning of the Alaskan boreal forest?

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 Research Station with research on permafrost soils and wetland soils.

The research activities of the NRCS are done in cooperation with several universities. 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.

Alaska NRCS Snow Programs

The NRCS Alaska Snow, Water and Climate Services is a highly collaborative network providing monthly, daily, and hourly information. The monthly information is available in published Basin Outlook Reports, where more than 200 snow courses and precipitation gauges are measured across Alaska. Historical snow course data are available from active and discontinued snow course sites in Alaska and the Yukon Territories. Various analyses are available in the form of snowpack maps, reports, and precipitation reports. Raw daily and hourly information may be obtained from 31 SNOTEL (SNOw TELemetry) sites. The information from these sites varies. The site sensors may have temperature (current, maximum, minimum, and average), precipitation, snow water equivalent, snow depth, wind speed and direction, relative humidity, solar radiation, and soil temperature/moisture.

NRCS information helps landowners and communities select the best sites for homes, schools, airfields, roads, landfills, and agriculture. Soil surveys provide a scientific inventory of soil resources for making maps and identifying physical and chemical properties of soils, as well as supplying current information on potential uses and limitations of each soil.

Alaska Major Land Resource Area Soil Survey

The Alaska MLRA Soil Survey Office coordinates the collection of soils and related natural resource data for Alaska. This office is one of 17 offices nationwide coordinating soil survey data. All work is done in partnership with other Federal, state, and local agencies, as well as private landowners and community groups. This partnership comprises the National Cooperative Soil Survey (NCSS). The data and associated information assistance are provided to the public to aid in wise land use management and planning. The Alaska MLRA Soil Survey Office also coordinates the Alaska portion of the National Resource Inventory (NRI). This inventory is an on-going effort to monitor the changes and trends in natural resource use and condition over time.

The new Web Soil Survey site provides public access to the national soils information system. This web site allows online viewing of soil survey maps and reports. This new application greatly enhances access to information on soils. The site operates similarly to Internet sites that provide locator and directional information.

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 Subarctic activities support the DOE mission through studies of energy production, relevant atmospheric/environmental measurements, and modeling.

The Arctic and Subarctic activities of the Department of Energy (DOE) include support for projects in three general areas:

- Energy production and power generation;
- Atmospheric/environmental measurements; and
- Modeling related to climate change and other DOE missions.

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, which is now part of the ARM Climate Research Facility, a national user facility. The data are used to refine atmospheric models critical for understanding potential climate change.

The following is a list of DOE projects and programs that are wholly or partly focused on the Arctic.

	Funding (thousands)	
	FY 04	FY 05
Amchitka Island Project	1,533	520
Arctic Energy Office	5,500	7,000
Arctic Methane Hydrates	1,160	4,900
Atmos Radiation Meas Prog	3,200	3,200
Geothermal Activities in Alaska	233	414
Nat Institute for Global Env Change	225	113
Neighborhood Environmental Watch	40	25
Wind Activities in the Arctic	0	1,500
Total	11,891	17,677

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 2004 the Alaska Department of Environmental Conservation approved DOE's National Nuclear Security Administration's Nevada Site Office (NNSA/NSO) closure report for the surface remediation work completed in 2001. The report included a risk assessment for material existing on the surface from past spills. In addition, the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) completed field work as part of an independent assessment to determine if radionuclides from DOE's underground nuclear testing on Amchitka have contaminated the surrounding marine environment. In addition, the study collected geophysical data that will be used to reduce uncertainty in the groundwater modeling completed previously by NNSA/NSO.

In 2005 the CRESP issued the *Amchitka Independent Science Assessment* report, which provided results of the field work carried out in 2004. Researchers sampled biota from seabirds, marine algae, invertebrates, and fish throughout the island. The results showed that radionuclide levels were within the range of biota found in other marine environments in the Northern Hemisphere. In fact, all levels of radionuclides measured "far below" any human health food safety standard.

The point of contact for the Amchitka Island, Alaska, Project is Peter Sanders, U.S. Department of Energy, Environmental Restoration Division, Nevada Operations Office, Las Vegas, NV; 702-295-103; sanders@nv.doe.gov.

Arctic Energy Office

With extreme climatic conditions, varying terrain, and areas that are both large and sparsely populated, Alaska provides an opportunity to explore the limits of new energy technologies.

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 Edith Allison, Exploration Program Manager, Department of Energy Office of Natural Gas and Petroleum Technology, 202-586-1023, Fax: 202-586-6221; edith.allison@hq.doe.gov

DOE's Arctic Energy Office is part of DOE's National Energy Technology Laboratory (NETL). It facilitates research related to fossil energy resources (oil, natural gas, and coal) and remote electrical power generation to address Alaska's unique energy needs.

DOE's Arctic Energy Office, located at the University of Alaska Fairbanks, was first advanced and funded by the Alaska Congressional delegation in FY 2001. A five-year cooperative agreement was signed between the Department of Energy and the University of Alaska Fairbanks to conduct Arctic-related research in two key areas: fossil energy and remote electrical power generation. In addition to coordinating activities with the University, the Arctic Energy Office collaborates with the energy industry and state agencies. The funding profile increased from $1 million in FY 2001 to $7.0 million in FY 2005

Alaska produces nearly 20% of the Nation's oil, has roughly half of the Nation's remaining oil reserves, and contains over half the Nation's coal. Still, there are many technological and economic challenges associated with the discovery and development of these resources because of the geographic, climatic, environmental, and cultural heritages unique to Alaska's Arctic regions. To address the challenges associated with the development of these energy resources, Congress requested that the Secretary of Energy establish an Arctic Energy Office.

Projects completed or underway during FY 2004–2005 include the following.

Tundra Travel Model for the North Slope of Alaska

The results of DOE-sponsored studies are enabling regulators and producers on Alaska's North Slope to determine when oil and gas equipment can be moved overland without risking damage to the tundra. On December 10, 2004, the Alaska Department of Natural Resources opened the east coastal area of the North Slope. This was the earliest opening since 1995 and was two weeks earlier than the previous year. The DOE project investigated 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.

Ice road. Travel across the open tundra with heavy equipment for oil exploration is restricted to winter, when seasonal ice roads can be created.

Water spray truck drawing water from a local North Slope lake. Trucks like this are used to create the ice roads.

Tundra Lakes Water Withdrawals

This project assesses the environmental impacts of pumping more than 15% of the free water from these lakes in order to support time-dependent construction of ice roads in the relatively brief exploration season on the North Slope. Outcomes to date include the following:

- It was found that past withdrawal rates have not resulted in measurable adverse impacts for the Kuparuk area.
- Data collected have enabled the development of lake recharge models to estimate the maximum quantity of water that might be available without adverse environmental impact.
- The Alaska Department of Fish and Game permitted Lake 9817, in the National Petroleum Reserve–Alaska (NPRA), for 30% withdrawal because of their interest/participation in this study (previously 15% withdrawal was the rule).
- The State of Alaska and the Bureau of Land Management are now considering the use of watershed and recharge estimates when issuing water withdrawal permits.

South Central Alaska Natural Gas Supply Study

This study on the future supply of Cook Inlet natural gas, released in 2004, identified key shortages for the local population in natural gas beginning in 2009 unless further exploration and development is conducted. This study was coordinated

with Enstar Natural Gas, Municipal Light and Power, Chugach Electric, the Alaska Gas Pipeline Authority, the Alaska Department of Natural Resources, and the U.S. Department of the Interior. The study played a key role in a recent workshop by the Federal Energy Regulatory Commission on permitting of the Alaska Natural Gas Pipeline project.

South Central/Cook Inlet Gas Spur Pipeline Analysis

The objective of this project, which began in FY 2005, is to compare routes for the installation of a natural gas pipeline between interior Alaska and south-central Alaska. The intent of the study is threefold:

- To identify all possible uses of gas, both traditional and non-traditional, to assist in the sizing of the line;
- To optimize the line routing by understanding permitting, right-of-way, and community and commercial uses; and
- To develop a study of the social impact on the affected communities, both positive and negative.

Injection of Carbon Dioxide for Recovery of Methane from Gas Hydrates

This project investigates the possible use of CO_2 to displace methane in hydrate structures. The process, if successful, will allow for the production of methane from hydrates while stabilizing the hydrate structure. In addition to producing methane from hydrates, it may prove to be a method for sequestering carbon.

Source Rock Potential, Fossil Fuel Resources, and Basin Analyses, Bristol Bay Basin

The current state of geological knowledge of Bristol Bay is insufficient to attract private exploration investment or to allow assessment of potential hydrocarbon resources. Lacking coherent basin analyses integration, the Bristol Bay basin remains enigmatic as a hydrocarbon basin. The first phase of investigating the geological resources of Bristol Bay was completed in the summer of 2004 and has led to renewed interest in oil and gas exploration in this region. The second phase will continue throughout 2005.

Novel Chemically Bonded Phosphate Ceramic Borehole Sealants for Arctic Environments

One of the basic material requirements in exploration and completions operations in permafrost regions is a suitable insulating cement that will keep the permafrost frozen and undisturbed during the production and transport of oil and gas. A novel ceramic borehole cement developed at Argonne National Lab (ANL) may fulfill this need. ANL, in partnership with the University of Alaska, will tailor this cement for permafrost regions and demonstrate its applications in Alaska.

Low Rank Coal Grinding and Boiler Performance

Low rank coal from the Usibelli Mine in Healy, Alaska, is pulverized and used to generate electrical power in Alaska and Asia. Preliminary results support the theory that the coal does not have to be ground as finely as is currently the case, thus lowering operating and maintenance costs.

Beluga Coal Power Study

This study is being developed to look at possible uses of Beluga Field coal, including gasification, power generation, and drying, to take advantage of the coal's location relative to export facilities and to the natural gas infrastructure of south-central Alaska. This project is currently in the scoping stage. It is anticipated that the report will be used by the State of Alaska as part of statewide energy planning.

Rural Alaska Coalbed Methane Local Energy Supply in Rural Alaska

The first phase of this project—the successful completion of a slimhole well—was completed in the fall of 2004 at Fort Yukon. This is the first time that a light-weight drill rig was used to drill through the coals, gravels, and permafrost necessary to produce natural gas from coalbed seams in a remote area. This information will be used to develop an economic model to establish if coalbed methane can replace diesel fuel for generating electricity, thus lowering the production costs and securing a local source of power for remote Alaskan villages. A key component of this study will be to understand the uses of the water that is produced; this source of power may be a source of water to the villages.

Alaska Coalbed Methane Water Disposal Methods: A Review of Available Coalbed Methane Information and Disposal and Treatment Options for Alaska

An important issue to resolve for coalbed methane production is water disposal or treatment methods. This project will collect and analyze

known information about coalbed methane formations, available water-quality data, community systems that could be used for water treatment systems and other water use, and general information for each community needed for evaluating coalbed methane water management issues.

Galena Electric Power: A Situational Analysis

The purpose of the study was to evaluate electrical costs and possible options for electric power for Galena. Options included enhancement of the current diesel generation system, opening a small nearby coal seam and installing a coal-fired power plant, and installing a modular small-scale nuclear reactor (a 10-MW model made by Toshiba). Of these three options, the installation of the nuclear reactor was the most economical. While the study was done with Galena as the basis, the results of the study can be applied at other rural locations with similar conclusions.

Diesel-fueled Solid Oxide Fuel Cell System for Remote Power Generation

Solid oxide fuel cells have been demonstrated to generate electrical power at high efficiency at the 5-kW range when operated on natural gas. However, natural gas is not readily available in remote locations where the value of electrical power is very high, so operating these fuel cells on liquid fuels, preferably diesel fuel, is critical to the use of fuel cells in remote locations. This program is designed to test a solid oxide fuel cell operated using hydrogen from reformed diesel.

Future DOE–University Collaborative Research

The Alaska North Slope contains over 20 billion barrels of heavy/viscous oil, the largest unexploited heavy oil resource in the United States. Industry has just begun to use new advanced technologies to tap a portion of this relatively shallow oil resource in the Schrader Bluff and West Sak formations on the North Slope. The potential production rates may approach 150,000 barrels per day by 2010. Conventional heavy oil recovery techniques are not practical because of the proximity of this shallow oil to the permafrost layer. To fully exploit the extra heavy oil resource, significant new advances in production technology are needed. Shallow gas resources are plentiful in Alaska and include coal bed natural gas in rural Alaska and methane hydrates on the North Slope. The methane hydrate resource on the North Slope is in close proximity to the heavy/viscous oil resources and can potentially be used to enhance the recovery of the heavy oil resources. With support from NETL's Arctic Energy Office, the University of Alaska Fairbanks is making these areas a major research focus and is working with industry to develop and test the essential technology.

Basin-Oriented Carbon Dioxide-EOR Assessment

In 2004, the DOE Office of Fossil Energy initiated a series of basin-oriented CO_2-Enhanced Oil Recovery (EOR) studies to examine the potential for economically recovering the oil remaining in mature fields in the U.S. using CO_2-EOR technologies. An initial scoping effort identified 490 reservoirs, with 113 billion barrels of "stranded" oil in place, that screen favorably for CO_2-EOR based on economics, technological issues, and the feasibility for benefit from CO_2 injection. Given these initial findings, detailed basin-oriented assessments were undertaken in six states or regions. Although the final reports have not yet been released, draft reports have been circulated in Alaska as part of the peer review process. Preliminary results show the North Slope and Cook Inlet regions of Alaska hold 45 billion barrels of stranded oil, of which an additional 12 billion could be recoverable using CO_2-EOR technology.

Oxygen Transport Ceramic Membrane–University of Alaska Fairbanks

The purpose of this project is to develop an innovative "electro-ceramic membrane" that separates oxygen from the air and uses it to convert natural gas to chemical "building blocks" that can be used to synthesize clean liquid fuels. Successful development of this membrane technology could lead to ways for converting remote natural gas reserves on the North Slope into clean-burning motor fuels. In turn, gas-to-liquid (GTL) processes could extend the lifetime of the Trans Alaska Pipeline System (TAPS). Preliminary analyses suggest that a 30–50% cost savings in the production of synthesis gas can be achieved.

Operational Challenges in Gas-to-Liquid Transportation–University of Alaska Fairbanks

This three-year comprehensive research program has examined the operational challenges of transporting GTL products through the existing TAPS. This study effort was designed to augment a project titled "Study of Transportation of GTL Products from Alaskan North Slope (ANS) to Market" and provide practical insights on the successful future commercialization of GTL technology in Alaska, including the feasibility of moving GTL

products through the TAPS and the impact of GTL movement on TAPS operation.

Arctic Methane Hydrates

The DOE Office of Oil and Natural Gas supports research and policy options to ensure clean, reliable, and affordable supplies of oil and natural gas for American consumers. The Alaska North Slope contains huge gas hydrate deposits, which have the potential to provide the U.S. with needed supplies of clean-burning natural gas starting in 2015. The U.S. Geological Survey estimates that roughly 45 Tcf (trillion cubic feet) of methane is stored in the form of hydrate beneath the North Slope permafrost. DOE is involved in projects aimed at evaluating the methane hydrate resource and potential production technologies on the North Slope of Alaska.

The Hot Ice well was drilled during the 2002–2003 and 2003–2004 winter drilling seasons, at a location approximately 40 miles southwest of Prudhoe Bay, Alaska. The well was drilled as part of a two-year, cost-shared partnership between DOE, Anadarko Petroleum Corp., Maurer Technology Inc., and Noble Engineering and Development. It was drilled to test an Upper West Sak potential hydrate accumulation, based on updip hydrate shows in nearby Cirque and Tarn wells. The Hot Ice well was drilled to a depth of 2300 feet. Although the Upper West Sak sands lie within the theoretical Hydrate Stability Zone, and they have very good reservoir quality, they did not contain any hydrate. Instead of hydrate, the project team encountered free gas and water in the target interval. The project successfully developed and demonstrated for the first time a number of innovative technologies, including Anadarko's Arctic Drilling Platform, a mobile hydrate core analysis laboratory, and a new application of a continuous coring rig. A 3D vertical seismic profile at the well indicated possible hydrate deposits updip and east of the well site. Analyses of the core, log, and seismic data from the well indicate that the hydrate in this region occurs in patchy deposits and may require a high methane flux from the subsurface in order to form more continuous drilling prospects.

In 2000, BP Exploration Alaska, Inc. proposed to provide a state-of-the-art 3-D seismic survey over its Milne Point production unit to provide a starting point for a full evaluation of the feasibility of commercial production from Arctic hydrates. Phase 1 resulted in the delineation and characterization of more than a dozen discrete gas hydrate accumulations within the Milne Point Area. Phase 2 provided detailed analyses and evaluation of the prospects identified in Phase 1 in order to develop a detailed and specific plan for potential Phase 3 field operations. Highlights of this work include:

- Geophysical modeling that has enabled the correlation of seismic attributes with critical hydrate reservoir parameters such as zone thickness and hydrate saturation; and
- Confirmation of up to 33 Tcf of resource in place in the Eileen trend, with up to 12 Tcf technically recoverable.

Phase 3, which began October 1, 2005, will include the drilling of one or more wells through the hydrate stability zone, with comprehensive petrophysical analyses of targeted zones. This drilling will test the geophysical prospecting technologies and enable the selection of target zones and field parameters for potential Phase 4 production testing.

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.

A small fraction of the instrumentation at the Atqasuk, North Slope of Alaska ARM Climate Research Facility.

The point of contact for the ARM program is Dr. Wanda R. Ferrell, Atmospheric Radiation Measurement Program Manager, Climate Change Research Division, SC-23.3, U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC 20585; 301-903-004; wanda.ferrell@science.doe.gov; see www.arm.gov.

ARM created a number of long-term, highly instrumented climate research sites in carefully selected locations around the world. The site locations were selected to provide laboratories in different climate regimes for studying clouds and radiation with the intent of improving the models. Three Cloud and Radiation Testbed (CART) sites were developed, each with facilities at more than one location. The first site, in the U.S. Southern Great Plains in Oklahoma, began operations during 1992. The Tropical Western Pacific (TWP) site began phased operations in 1996 and has facilities in Manus, Nauru, and Darwin. The third site, the North Slope of Alaska and Adjacent Arctic Ocean (NSA/AAO) at Barrow, was dedicated in July 1997 and ramped up operations over the following year. Subsequently an outlying facility was established at Atqasuk, 100 km inland from Barrow.

In FY 2004, the fixed CART sites, together with the ARM Mobile Facility, were declared by DOE to be a National User Facility: the ARM Climate Research Facility (ACRF). With that declaration, the ACRF became available, through a proposal process, to researchers from around the world.

During this reporting period, several field experiments took place at the NSA/ACRF site. Here, we focus on the two most significant: the Mixed-Phase Arctic Cloud Experiment (M-PACE), and the Boundary Layer Cloud Experiment (BLCE).

Support crew for the University of North Dakota Citation research aircraft used in the Mixed-Phase Arctic Cloud Experiment.

Mixed-Phase Arctic Cloud Experiment

M-PACE took place during September and October 2004. As the name implies, it studied clouds that consisted of a mix of water droplets and ice crystals—the most difficult type of cloud to model and also a type of cloud capable of producing icing conditions dangerous to aircraft.

M-PACE was the largest field experiment conducted at the NSA/ACRF to date. It involved operations at six locations, two manned and one unmanned research aircraft, routine weather balloon launches at four locations, the installation and operation of a transportable ARM facility at Oliktok Point near Prudhoe Bay, and the operation of several "visitor" instruments that were deployed specifically for M-PACE. These various capabilities were tended by approximately 50 researchers from a dozen institutions.

Although the data sets acquired during M-PACE will be studied for years, certain results have already been noted:

- All sampled clouds contained liquid water (the lowest temperature sampled was –30°C). This finding may potentially be explained by the very low numbers of ice nuclei observed during the experiment. Indications are that models are highly sensitive to ice nuclei concentrations and nucleation mode. Models typically cannot maintain liquid without low ice nuclei amounts.
- Initial indications are that models perform reasonably well within the Arctic region, but far from perfectly. For instance, the European Center for Medium Range Weather Forecasting Cloud Model simulations include cloud amounts that tend to be too small, with too little liquid. However, the model simulation does capture the main features of Arctic cloud evolution.
- A large number of aircraft-measured vertical profiles taken over surface remote sensing sites documented mixed-phase cloud profiles, providing detailed microphysical characteristics, including liquid/ice fractions throughout the atmosphere. These measurements, coupled with the ground-based measurements, provide a high-quality data set. This data set will be valuable for studying the detailed processes determining the microphysical characteristics of mixed-phase clouds, for investigating parameterization of these characteristics, and for testing remote sensing algorithms.

Boundary Layer Cloud Experiment

BLCE, which took place during July and August 2005, focused on low-level liquid water clouds. The objective was to understand the coupling between the underlying surface and the properties of the low-lying clouds. BLCE was a smaller experiment than M-PACE, but was still quite intense. Weather balloons were launched from both Barrow and Atqasuk six times a day for four weeks running, and various additions to the standard NSA/ACRF instrument suite were deployed in support of BLCE. The latter included sensible

Additional instrument shelters and topside deck for "visiting" upward-looking instrumentation installed at the Barrow, North Slope of Alaska ARM Climate Research Facility during FY 2005.

and latent heat flux measuring instrumentation deployed not only at the ACRF locations at Barrow and Atqasuk, but also at Pt. Barrow, a few meters from the shore, as well. The Pt. Barrow instrumentation characterized the air mass advecting over the land from the ocean environment.

A secondary goal of the field experiment was to acquire extensive radiosonde (weather balloon) data sets for all times of day to drive radiative transfer simulation codes for comparison with observed radiative fluxes measured at the ground.

Besides field experiments, this reporting period was notable for significant additions and improvements to the NSA/ACRF facilities. Instrument shelter space was approximately doubled at Barrow, while high deck space for deploying upward-looking instrumentation was increased by about 50%. The additional space is welcome, as the NSA/ACRF had become increasingly space-limited. More users means more demands on space.

The point of contact for the Geothermal Program is Ray Fortuna, Office of Energy Efficiency and Renewable Energy (EE-2C), U.S. Department of Energy, Washington, DC 20585; 202-586-1711; Raymond.Fortuna@hq.doe.gov.

Geothermal Energy Activities in Alaska

In FY 2004, GeoPowering the West (DOE's geothermal outreach program) and the State of Alaska hosted a two-day meeting at Chena Hot Springs near Fairbanks. This meeting galvanized the Alaska GPW Working Group and focused state attention on Chena.

Also in FY 2004, DOE initiated a cost-shared geothermal resource exploration with the Chena Hot Springs Resort. The exploration consisted of performing geophysical surveys, creating geologic and surface temperature maps, drilling shallow temperature gradient holes, and conducting geochemical analyses of thermal water. After the analysis of field data is completed, a conceptual geological model of the Chena Hot Springs system will be created and a drill site will be selected.

In FY 2005, DOE initiated a cost-shared initial phase of field verification of a low-temperature energy conversion system with the Chena Hot Springs Resort. This consisted of securing the financing, permits, documentation, etc. necessary for the project to proceed into actual design and construction of the power plant in the second phase.

The point of contact for the NIGEC program is Dr. Jeff Amthor, NIGEC Program Manager, Climate Change Research Division, SC-23.3, U.S. Department of Energy, 1000 Independence Ave., SW, Washington, DC, 20585; 301-903-2507; jeff.amthor@science.doe.gov.

National Institute for Global Environmental Change

Through NIGEC, university scientists can apply for DOE research support to study the ecological effects of climatic change in Alaska (and all other states). In FY 2004, two projects were funded in Alaska. One study is examining the effects of climate on plant pests (pathogens and insect feeders). The results so far indicate that a warmer summer would reduce pathogen damage on alder trees but that warming would increase damage from insects. Changes in plant pests caused by any climatic changes such as warming have important implications for the production of ecosystem goods and services in Alaska. The study is continuing in FY 2005. The second study was completed in FY 2004. The results indicated that warming in the Arctic near the elevational treeline (the maximum elevation at which trees grow) has the potential to reduce tree growth near the treeline. An implication is that high-elevation forest health in Alaska could be diminished by further warming in the Arctic.

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

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; mcnaught@lanl.gov.

The point of contact for the Department of Energy Wind Activities in Alaska is 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; Dennis.Lin@ee.doe.gov

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 the measurements.

Stations 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 and the University of Alaska Fairbanks. More information on NEWNET, including readings from NEWNET stations, can be found on the web at http://newnet.lanl.gov/.

Wind Activities in the Arctic

A project initiated by the Alaska Wind Energy Authority was begun in FY 2005. The project will support the design and construction of wind energy power plants that demonstrate the feasibility and methods necessary for widespread adoption of wind energy systems in rural Alaska. The project objectives include:

- Lowering and/or stabilizing the cost of power generation in rural Alaska;
- Increasing the knowledge base of wind resource data and wind energy systems for Alaska;
- Producing a summary document for wind turbine foundation design in permafrost and situations without large equipment;
- Improving the understanding of wind-diesel integration issues related to available control system packages;
- Starting the NEPA Process for at least two probable wind sites (Dillingham, Naknek); and
- Supporting the construction of a viable wind project in rural Alaska.

Two of the more than a dozen wind turbines forming the wind farm at Kotzebue, Alaska.

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 (NIH) is an agency of the Department of Health and Human Services. NIH is headquartered at Bethesda, Maryland, and is composed of 27 institutes and centers. 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.

NIH works with colleagues around the world to achieve its mission. In the area of Arctic research, NIH has fostered international research collaborations and agreements with a range of counterparts abroad. For example, NIH and its Canadian counterpart, the Canadian Institutes of Health Research (CIHR), signed a Letter of Intent on September 20, 2004, directed at strengthening research cooperation between the U.S. and Canada on the issues related to indigenous peoples. This agreement serves as a cornerstone for future bilateral health-related activities in the circumpolar region.

In May 2005, NIH hosted a delegation from CIHR, with representation from the Institute of Neurosciences, Mental Health and Addiction (INMHA), Institute of Genetics, and Institute of Aboriginal Peoples' Health Research (IAPHR). The primary purpose of this visit was to discuss the opportunities for moving forward on the 2004 NIH–CIHR Letter of Intent on collaboration in indigenous peoples' health research. A presentation was made on IAPHR activities and priorities as a platform for collaboration with NIH. In addition, the Fogarty International Center (FIC) hosted a roundtable discussion on the Regenerative Medicine and Nanomedicine initiative with the National Institute of Neurological Disorders and Stroke (NINDS), the National Institute of Mental Health (NIMH), and the National Institute on Drug Abuse (NIDA) at NIH and the Institute of Genetics of the CIHR. This initiative is a partnership involving CIHR and a number of other leading Canadian organizations, and the discussion focused on updating NIH on its current status, receiving feedback, and exploring future collaboration.

	Funding (thousands)	
	FY 04	FY 05
National Institutes of Health	25,000	22,000
Centers for Dis. Control/Prevent.	3,400	3,700
Subst. Ab. & Men. Health Serv. Ad.	25,900	21,200
Total	54,300	46,900

Fogarty International Center

The FIC's mission is to address global health challenges through innovative and collaborative research and training programs and to advance the NIH mission through international partnerships. As the designated focal point for Arctic issues at the NIH, FIC plays a key role in advancing bilateral and multilateral ties between and among governments, institutions, and scientists working on circumpolar issues. In 2004 and 2005, FIC led the development and conduct of two international scientific conferences on inhalant abuse and suicide, two critical Arctic health needs areas. FIC worked closely with all relevant NIH partners in developing and conducting these conferences, each of which provided insights to researchers and policymakers on gap areas and areas of potential collaboration. In addition, FIC, working across NIH and with CDC, has been a key partner in preparing for the International Polar Year (IPY) to take place in 2007–2008. FIC provided leadership and input to a range of groups working to prepare for IPY, including the Polar Research Board of the National Academies of Science, the Department of State, and the CDC.

National Institute on Aging

The National Institute on Aging (NIA) is continuing to fund the Age, Gene/Environment Sus-

ceptibility (AGES) Study: The Reykjavik Healthy Aging Study for the New Millennium introduced in 2001. This initiative was launched under the U.S. Arctic Research Plan and is part on the ongoing collaboration between NIA and the Icelandic Heart Association. The first round of data collection was completed in February 2006, with approximately 5,800 individuals examined on four physical and neuropsychological domains, including neurocognitive, cardiovascular, musculoskeletal, body composition, and metabolic functioning. A major aspect of the study is a cross-sectional examination of phenotypes to be used for candidate gene studies and to allow for a better understanding of factors contributing to disease in old age, apart from genetic factors. These phenotypes will also be examined in relation to specific mortality outcomes such as coronary heart disease, fractures, and cancers that are ascertained in Iceland. In addition, a large specimen bank and repository is being established as part of this study, and collaborations with interested investigators outside of the study are actively sought. A follow-up measure is planned for 2007–2011.

The NIA also continues to fund the Native Elder Research Center, located within the Division of American Indian and Alaska Native Programs of the Department of Psychiatry, School of Medicine, at the University of Colorado Health Sciences Center in Denver. The center coordinates a culturally relevant, scientifically meritorious research career development program targeted at American Indian (AI) and Alaska Native (AN) investigators, focusing on aging, health, and culture. The center augments ongoing partnerships with AI/AN communities to ensure access to and involvement of elders, their families, and local systems of care in aging.

National Institute on Alcohol Abuse and Alcoholism

Alcoholism continues to be one of the most important public health problems among Alaska Natives in the Arctic region. Alaska's alcohol consumption rate is among the highest in the nation. Alaska Natives have unusually high rates of drinking and associated health problems, including fetal alcohol syndrome. Furthermore, alcohol is substantially involved in accidents and injuries among both Alaska Natives and Alaska whites. A review of medical records indicated that alcohol was noted on the record of 37.5% of injuries to Alaska Natives and 15.5% of injuries to Alaskan Caucasians. Alcohol use has also been linked to child abuse, accidental death, assaults, rapes, and suicides in Alaska. 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 three projects in the Arctic region in FY 2003–2005. One project examined the economic and public health impact of raising alcoholic beverage taxes in Alaska. A second project examined the efficacy of a pharmacological treatment on relapse rates among alcohol-dependent Native Alaskans in treatment. The third project supports the development of a culturally specific alcohol abuse prevention intervention for Yupik Eskimo children.

National Institute on Drug Abuse

Since 1994 the National Institute on Drug Abuse (NIDA) has been funding basic and applied research on drug abuse in the Alaskan Native population. Several of these NIDA-funded research projects have published data on sexually transmitted disease in Alaskan Native drug users and have also focused on unemployment, HIV risk, and alcohol use. NIDA's current portfolio of Alaska-Native-relevant research focuses on the prevention of inhalant abuse; chronic stress and substance use; co-occurrence of substance use, depression, and risk of HIV/AIDS; and tobacco cessation programs for youth. During 2005, NIDA sponsored two scientific meetings that included research presentations addressing issues of Alaska Natives and aboriginal people in Canada. The first conference was entitled "Bridging Science and Culture to Improve Drug Abuse Research in Minority Communities" and the second meeting was entitled "Inhalant Abuse among Children and Adolescents: Consultation on Building an International Research Agenda." The latter conference included a description of a new research project on the implementation of inhalant abuse prevention programs in four relatively small communities in Alaska. In the first year the project mobilized the interest of communities to ensure their buy-in and the cultural appropriateness of the programs. The next steps included setting up retailer, family, and school environmental strategies and testing a prevention curriculum for fifth-graders based on life-skills training for Native Americans. Subsequent efforts will involve testing the school-based curriculum in 16 other Alaskan communities. A

complete description is available at international.drugabuse.gov/downloads/Inhalant_Summary.pdf.

National Institute of Allergy and Infectious Disease

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 the use of a conjugate vaccine developed with support from NIAID, Hib bacterial infection has been reduced by 99% in the U.S. Interestingly there is evidence that the Hib vaccine decreases the rate of Hib carriage among vaccinated children, decreasing the chance that unvaccinated children will be exposed.

NIAID provided support for a three-year pilot intervention trial that was initiated in FY 2002 in three Alaska Native villages known to have high numbers of asymptomatic carriers of Hib. The goal was to determine if Hib conjugate vaccine could be given to persons of all ages to eliminate or reduce Hib colonization. The researchers hoped to determine what treatment most effectively eliminated the Hib reservoir from a village. Several treatment regimes were compared, including a comparison of treatment with the Hib conjugate vaccine, with and without the antibiotic rifampin, to that of treatment with rifampin alone (the standard treatment).

Various immunologic parameters were measured before and after Hib vaccination. Prior to vaccination, Hib carriers had a higher IgG antibody level than controls, as well as higher serum bactericidal activity (SBA). Both groups responded to vaccination with increased IgG and SBA levels. These results suggest that Hib colonization can induce an immune response, so Hib carriage in these communities is likely due to multiple factors rather than an overall lack of immune response.

Hepatitis C

Hepatitis C virus (HCV) is a blood-borne agent that usually causes chronic infection of the liver, leading to severe progressive liver diseases such as cirrhosis and primary liver cancer and resulting in an estimated 12,000 deaths per year in the U.S.

There is poor understanding at present of the mechanisms of virus-induced immune failure and pathogenesis. Studies suggest that dynamic interactions between HCV and the infected host—such as the genetic evolution of HCV in response to host neutralizing antibodies and CD4 and CD8 T cell activity against virus proteins—are linked to the persistence of infection and progression of chronic liver disease.

NIAID has long supported a large study of the relationship between HCV replication, evolution, and disease progression in Alaska Natives and American Indian populations. In studies published in April 2006 in *Clinical Infectious Diseases*, it was shown that, at least in Alaska Natives, sporadic episodes of viral control in patients with chronic HCV infection are more common than had been appreciated. This clinically surprising, and potentially very important, observation, if independently confirmed, could open new avenues for the development of future therapies.

In ongoing studies, serum samples, stored in a serum bank dating back over 30 years and representing approximately 1,000 subjects, in conjunction with a large clinical and virology database, are being studied for HCV genetic evolution in the context of host immune responses in different clinical settings. Results from these studies, in the well-defined Alaska Native populations, will provide additional important insights regarding the natural history of hepatitis C, HCV persistence, and liver disease progression.

Histocompatibility and Immune Recognition

In FY 2004 and 2005, 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 (IHWG) through a resource-related research project cooperative agreement at the Fred Hutchinson Cancer Research Center in Seattle, Washington. The IHWG is 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.

The Alaskan Yupik project was an integral part of one of the seven projects conducted by the Fred Hutchinson Cancer Research Center. Researchers analyzed HLA genes in the Yupik cohort to determine the different types of histocompatibility genes and their frequency in that population. Data from the Yupik population were placed with data from thousands of other individuals to catalog and enable discoveries about human diversity in the HLA region of the genome. The project ended officially in June 2005 but was extended through June 2006 without funding.

National Cancer Institute

Division of Cancer Control and Population Sciences

Alaska Native Tumor Registry. The Alaska Native Tumor Registry was initiated in 1974 as a collaboration between the National Cancer Institute, the NIH, and the CDC using procedures developed by the National Cancer Institute's Surveillance, Epidemiology and End Results Program. In 1989 the National Cancer Institute entered into an interagency agreement with the Alaska Native Medical Center through the Indian Health Service, with technical assistance provided by the University of New Mexico. In 1999 the Alaska Native Tumor Registry became an official part of the Surveillance, Epidemiology and End Results (SEER) program. Accurate information on the unique cancer patterns occurring in this population is useful for provider education and training, program planning, studies of cancer etiology, evaluation of screening programs, and the development of interventions to improve patient care and programs for cancer prevention and risk reduction. The Alaska Native Tumor Registry is participating in several research projects, including a study of breast cancer and exposure to environmental organochlorines among Alaska Native women and the Nicotine Research and Tobacco Control Program. The registry will play an important role in the collaborative project between the U.S. and Canada described below.

Cancer Burden in Native Populations in the U.S. and Canada. With a difference of 6.4 years in life expectancy compared to the general population, the First Nations and Inuit populations of Canada experience similar health disparities as American Indian and Alaska Natives in the U.S., who experience life expectancies 4.7 years less than the general U.S. population. In Canada, cancer is the third leading cause of death, following injuries/poisonings and cardiovascular disease. In the U.S., cancer is the second leading cause of death for American Indians and the leading cause of death for Alaska Natives. In addition, five-year survival of American Indians and Alaska Natives is poorer than the general population. A better understanding of the cancer burden in these culturally and genetically related populations exposed to differing health care and social environments could lead to improved understanding of risk factors for cancer and effective preventive interventions.

In September 2004, Canadian Institutes of Health Research (CIHR) President Dr. Alan Bernstein and NIH Director Dr. Elias Zerhouni signed an agreement intended to strengthen research cooperation on health issues of priority to American Indian, Alaska Native, Canadian First Nations, Métis, and Inuit populations of the U.S. and Canada. This represents important institutional support for a collaborative project under development through the CDC, the National Cancer Institute, the Indian Health Service, and several health organizations in Canada. The purpose of the project is to assemble existing cancer surveillance data on American Indian/Alaska Native populations in the U.S. and First Nations and Inuit populations of Canada into a North American cancer surveillance and cancer burden profile that will be useful for better identifying cancer risk factors and high risk groups, learning more about and improving our ability to generate accurate data, and promoting collaboration between the U.S. and Canada. Several challenges face the collaborating partners, including the fact that the health agencies in the U.S. and Canada operate independently with distinct systems of health care and health data collection. The complexity and political sensitivity of indigenous health issues and autonomous tribal governments, U.S. health information privacy laws and their Canadian equivalents, tribal distrust of research and government, and tribal taboos related to cancer pose additional challenges for this project. This project will address the need to improve cancer surveillance for Native peoples in North America by assembling existing data for a North American cancer profile and promoting cross-border collaborative research addressing data gaps.

Network for Cancer Control Research among American Indian and Alaska Native Populations. The National Cancer Institute, through its Surveillance Research Program, Division of Cancer Control and Population Sciences, supports the Network for Cancer Control Research between American Indian and Alaska Native Populations. Established in 1990, this network of researchers working among American Indians and Alaska Natives developed a National Strategic Plan for Cancer Prevention and Control Research in 1992. The National Cancer Institute shares support for network meetings with the Mayo Comprehensive Cancer Center.

Northwest Portland Tribal Registry Project. Over the last two decades, health care delivery for Northwest American Indians and Alaska Natives 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, a tribally operated program located at the Northwest Portland Area Indian Health Board (NPAIHB) in Portland, Oregon. Through a contract with the National Cancer Institute, the existing disease registry has completed record linkage studies with state vital statistics data. The goal is to ascertain the incidence and prevalence of diseases such as cancer among Northwest American Indians and Alaska Natives with an accuracy not previously possible. A critical difference between the Northwest Tribal Registry Project and previous linkage studies is the longitudinal focus on building trend data.

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 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.

Native Cancer Information Resource Center and Learning Exchange. Native 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.

In 2005 the National Cancer Institute assisted the Native C.I.R.C.L.E. in funding the semi-annual meetings of the Network for Cancer Control Research among American Indian and Alaska Native Populations, in Rochester, Minnesota, and Rockville, Maryland.

Division of Cancer Biology

EBV Expression in Nasopharyngeal Carcinoma. The University of North Carolina–Chapel Hill is conducting research to determine 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. To investigate the high incidence in specific populations and to explore a possible genetic contribution to NPC, additional NPC samples will be obtained from Chinese, Caucasian, Black, and possibly Inuit Americans.

National Heart, Lung, and Blood Institute

NHLBI has supported the Genetics of Coronary Artery Disease in Alaska Natives (GOCADAN), which is a working partnership between the Native-owned corporation that manages the health care of the Alaska Natives of Norton Sound and investigators from the Strong Heart Study. The Strong Heart Study is an 18-year study of cardiovascular disease (CVD) in American Indians. GOCADAN presents an important opportunity to examine the marked increase in the prevalence of atherosclerosis and coronary artery disease among the indigenous peoples of American Indian and Alaskan descent. Furthermore, this is the first project to identify and map genes that contribute to the risk of CVD in this unique and understudied population. The Eskimo villages that are participating in GOCADAN are located in remote areas around the Norton Sound region of Alaska, where the traditional Eskimo lifestyle is slowly being eroded by mechanization and a westernized diet and where there has been relatively little outside genetic influence. The initial five-year (FY 2000–2004), $7.8 million study documented CVD and related risk factors among 1,214 Alaska Natives who are members of approximately 40 families. During 2005 the initial GOCADAN study was extended to continue through 2010. This will enable a thorough reexamination of the family cohort. Early findings indicate high levels of smoking consumption, low but rising levels of diabetes, and blood pressures and cholesterol levels that are similar to the general U.S. population.

NHLBI and the Canadian Institutes of Health Research (CIHR) cosponsored a Working Group meeting in July 2004 titled “Research with Arctic

Peoples: Unique Research Opportunities in Heart, Lung, Blood and Sleep Disorders" to address three objectives related to research with Arctic peoples. The meeting included investigators from Greenland, Iceland, and Russia, as well as Canada and the U.S. The meeting concluded with a list of recommendations for future research priorities, barriers, and solutions to Arctic research (available at www.nhlbi.nih.gov/meetings/workshops/arcticpeoples.htm). A summary of the working group recommendations was published in the February 2006 issue of the *International Journal of Circumpolar Health*.

National Institute on Mental Health

NIMH, in partnership with other agencies, has held two major conferences to introduce the importance of suicide prevention in indigenous youth in the Americas for the International Polar Year in 2007. In September 2005, NIMH and the Fogarty International Center sponsored a half-day symposium on international suicide prevention research at the XXII World Congress of the International Association of Suicide Prevention (IASP) in Durban, South Africa. The presentations featured findings from evidenced-based interventions and current information on the prevalence, risk factors, and prevention strategies in circumpolar countries.

In February 2006, NIMH held a second conference in conjunction with the IHS, the Canadian Institutes of Health Research, Health Canada, and the Assembly of First Nations and Inuit Tapiriit Kanatomi. The goals of this meeting were to foster knowledge exchange on suicide prevention strategies, increase the number of indigenous researchers, and promote collaborative projects. Recommendations that arose from the conference focused on increasing the dialogue between communities and researchers in order to capture traditional cultural knowledge and practices and to refocus treatment on life-affirming messages rather than on suicide and death.

National Institute of Environmental Health Sciences

NIEHS has been at the forefront of working toward addressing dietary questions raised by Native people living in villages throughout Alaska. Issues include the risks associated with environmental contaminants bioaccumulating in traditional foods and how they compare with the health, social, economic, and cultural consequences that could result from a shift to alternative, market-based diets.

Many Alaska Natives obtain the majority of their diet through the harvest of wild foods, foods that are collected from the land and sea near their villages. Often the local economy is similarly driven. Such is the case with the villages of Atka and St. Paul, Aleut villages dependent on traditional foods collected from the Bering Sea. NIEHS funded a four-year project, focused on establishing a model for addressing traditional food concerns and designed to demonstrate methods for increasing village-based leadership and cooperation among communities, researchers, and government agencies. Over the next four years the project will develop a curriculum about dietary risks and benefits in rural Alaska and disseminate it throughout the state. If successful, these efforts will provide the capacity to address widespread popular concerns about the contamination of the Alaskan traditional food supply and a methodology for villages to examine other food types that may be widely consumed and potentially suffer from contamination because of environmental releases.

Another NIEHS-funded project, Alaska Community Action on Toxics, works in partnership with fifteen communities in the Norton Sound region of Alaska to find effective means to limit the release of contaminants in the natural environment and to mitigate the human health effects. The majority of the residents of these villages are Inupiat and Yupik, indigenous people who depend on the harvest of wild foods to sustain them and their ways of life. Collaborative work will include constructing a database of information regarding formerly used defense sites (FUDS) in the region and the contaminants found at these sites. Building on successful work at St. Lawrence Island, Alaska, investigators will develop a model for exchanging information among the communities about those strategies that proved effective with the government agencies responsible cleaning up FUDS in the region. They will work with village leaders to provide training to oversee FUDS clean-up work, establish independent monitoring programs for contaminants, and develop an environmental health care curriculum for the diagnosis and treatment of human health problems associated with environmental contaminants.

The investigators will work with regional health care providers to develop an information exchange for health care professionals in the Norton Sound region to discuss the diagnosis and effective

treatment of human health effects of environmental contaminants. They will analyze historical data from the Alaska Birth Defects Registry and work with regional health care providers to collect data on the frequency of birth defects among children in the region.

Another goal of the project is to build the research capacity in the affected communities. A pilot study will analyze breast milk samples for the presence of contaminants. This study will help residents design a methodology for conducting research on contaminants that may be important factors affecting the health of their communities so that they can be fully engaged in future human health and contaminants studies planned for the region. This methodology will include protocols for environmental sampling near FUDS in the region, examining body burdens of contaminants in residents, and documenting incidences of environmental diseases.

National Center on Minority Health and Health Disparities

NCMHD was charged by Congress to lead the Federal effort in health disparities research, research capacity-building, and outreach. The NCMHD has fostered many initiatives to address health disparities through collaborations across the DHHS) and through implementing and nurturing its congressionally mandated programs. Below is an overview of NCMHD programs that have supported research in the Arctic region, in countries such as Finland, Sweden, Canada, Russia, and Norway.

The NCMHD administers two loan repayment programs that support its mission to attract health professionals to careers in clinical and health disparities research. The programs—Health Disparities Research (HDR-LRP) and Loan Repayments for Clinical Researchers from Disadvantaged Backgrounds (ECR-LRP)—provide loan repayment of up to $35,000 per year to qualified doctoral degree professionals in exchange for two years of service in health disparities research or clinical research. These programs promote a diverse and strong scientific work force of individuals from health disparity, medically underserved, and disadvantaged communities. In FY 2005 these programs supported 12 researchers specifically targeting their research studies towards the Alaska Native and/or Native American communities. Examples of HDR-LRP awardees' research projects at the University of Alaska Fairbanks include Ethnographic Research of Cultural–Behavioral Influences on Health among Alaska Natives, and Trauma and Treatment Paths for Alaska Native Children, Families, and Communities.

The NCMHD Community-Based Participatory Research Program (CBPR) aims to develop effective community-based participatory research programs, which will accelerate both the translation of research advances to health disparity communities and the elimination of health disparities.

The University of Alaska Fairbanks' Center for Alaska Native Health Research and the Yukon Kuskokwim Health Corporation are collaborating to design, plan, and implement a CBPR project called Ellangneq (Awareness), which has the following aims:

- To determine the highest-priority behavioral health need in a preventative intervention in the largest Alaska Native cultural group, the Yupik of southwestern Alaska, through a CBPR process led by a group of Yupik leaders who will constitute the Yupik Research Coordinating Council (YRCC);
- To develop a manual of interventions appropriate to a multilevel and multifactorial culturally based intervention procedure at the community, family, and individual levels;
- To pilot test a universal, selective, or combined preventative intervention model for the behavioral health need identified; and
- To design a five-year project for a randomized, community-based prevention trial to compete for the next round of funding.

The process involves a partnership led by a Yupik Research Coordinating Council in which university researchers and community partners become co-researchers. The knowledge acquired from this research project can contribute to the design of prevention projects for small, remote, rural contexts and small neighborhoods in the U.S., as well as internationally within the developing world and circumpolar north.

The Minority Health and Health Disparities International Research Training (MHIRT) program enables U.S. institutions to tailor short-term basic science, biomedical, and behavioral mentored student international research training opportunities to address global issues related to eliminating health disparities. Students participating in the MHIRT program address cultural, linguistic, and ethical issues associated with biomedical, clinical, or behavioral health research. The program has exposed students to research training opportunities in Sweden, Russia, and Finland. While in these countries, the students have the opportunity

to conduct health disparities research in areas such as cell biology, molecular biology, toxicology, endocrinology, genetics, and pharmacology.

A Florida International University (FIU) MHIRT program focuses on providing international research training opportunities to U.S. students. FIU's nursing faculty will partner with foreign nursing faculty at the University of Tampere, Finland, and other institutions in Europe to provide minority undergraduate and graduate nursing students with international research training focused on clinical research about disparities in the care of chronically ill patients and their families. Students become part of a faculty research team, choose a topic of interest within the area of health disparity in chronic illness care, and continue their study in a European country with an international mentor. Students will take additional courses focused on research conduct, culture and health, skill development, attitudes, team roles, and the rationale underlying the research. They will also learn about the other country, its culture, and the health needs of ill patients and families. They will be mentored in research throughout their current educational program and will participate actively in the research team and contribute to disseminating the collaborative research through publications and presentations toward promotion of a research career. Over the four years of the FIU MHIRT grant, it plans to recruit and mentor 19 undergraduate students and 6 graduate students.

The Project EXPORT Centers of Excellence Program promotes minority health and/or health disparities research; encourages the participation of members of health disparity populations in biomedical and behavioral research, prevention, and intervention activities through education and training; and builds research capacity in minority-serving institutions.

The University of Alaska Anchorage's three-year Project EXPORT grant established a Center for Minority Health Research, for and with Alaska Natives. The program, through the Alaska Native Science Research Partnerships for Health (ANSRPH), had three aims. Alaska Natives were mentored and trained to initiate and conduct health science research with disparate minority populations in Alaska. Non-Native researchers were mentored and trained to work within cross-cultural settings. Health science research partnerships (with the Alaska Native Health Board, for example) were fostered for the development of new investigations and for building on historic or current endeavors.

National Institute of Neurological Disorders and Stroke

Alaska Native Stroke Registry. The Alaska Native Medical Center maintains several Alaska Native disease registries, including ones for cancer and diabetes. These registries have existed for several decades and have provided valuable data for epidemiological studies of disease trends and for clinical studies of heath care management and treatment intervention outcomes in the Alaska Native population.

This hospital-based stroke registry started in the fall of 2005 at the Alaska Native Medical Center in Anchorage. Its purpose is to study the unique determinants of stroke in Native Americans/Alaska Natives, a population with an increasing incidence of stroke. A pilot stroke registry, targeting Yupik Eskimos living in the Yukon–Kuskokwim Delta and Bristol Bay regions, will establish registry infrastructure and data gathering methods. The registry will then expand statewide and will include all Alaska Native subgroups. Ultimately this information will be used to construct uniquely tailored prevention and intervention programs that are pertinent to Alaska residents, as well as people from other regions of the U.S.

National Library of Medicine

NLM has served as the primary repository of electronic resources on Arctic health-related issues, through the development of a web site: arctichealth.org. In 2001 the Arctic Health web site was moved to the University of Alaska, where it has been supported with $65,000 annually. NML continues to contribute with recent updates focused on the International Polar Year.

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. For the period 2004–2005, programs were conducted by the National Center for Infectious Disease (NCID), the National Center for Environmental Health (NCEH), and the National Institute for Occupational Safety and Health (NIOSH). These programs represent an excellent example of interagency cooperation and collaboration with the

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.

The CDC's goals include:

- Healthy People in Every Stage of Life: All people, and especially those at greater risk of health disparities, will achieve their optimal lifespan with the best possible quality of health in every stage of life.
- Healthy People in Places: The places where people live, work, learn, and play will protect and promote their health and safety, especially those at great risk of health disparities.
- People Prepared for Emerging Health Threats: People in all communities will be protected from infectious, occupational, environmental, and terrorist threats.
- Healthy People in a Healthy World: Peoples around the world will live safer, healthier, and longer lives through health promotion, protection, and health diplomacy.

National Center for 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.

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. The mission of AIP is prevention of infectious diseases among residents of all ages who live in the Arctic and Subarctic regions, and in particular the elimination of health disparities that exist among the indigenous populations of these regions. Research on the prevention and control of infectious diseases in these remote and widely scattered populations with limited resources is accomplished through the development of partnerships with communities; local, regional, and Native health organizations; universities; other divisions, programs and centers within CDC; the National Institutes of Health; the Indian Health Service; and the State of Alaska.

Streptococcus pneumoniae

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 non-Natives living in Alaska. This disease is most common in the very young and the elderly. The case fatality from pneumococcal infection is highest in the elderly. Once fully susceptible to antibiotics, *Streptococcus pneumoniae* has acquired resistance to commonly used antibiotics, which has complicated therapy. 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 above 65 years of age is 75%; however, efficacy may decrease with increasing age.

A new 7-valent pneumococcal conjugate vaccine (PCV7) was licensed in 2000 for the prevention of pneumococcal disease in infants and young children. Since then, routine use of PCV7 has resulted in a 90% decrease in invasive disease in children less than two years old. This decline was seen among both Alaska Native and non-Native children. This has eliminated the long-standing health disparity suffered by Alaska Native children for vaccine-type disease. Because the vaccine protects against the acquisition of new colonizing vaccine-type pneumococcus, vaccination has had the indirect effect of reducing transmission from vaccinated children to older children and adults. As a result, disease rates in adults declined by 60% for vaccine serotypes. In addition, because vaccine-type pneumococci tend to be more often drug-resistant, the percentage of invasive pneumococci nonsusceptible to penicillin fell from 24% in 2000 to 15% in 2005.

AIP's efforts to prevent pneumococcal disease include ongoing pneumococcal disease surveillance, case investigation, and efforts to evaluate the best ways to promote and use pneumococcal vaccines in the U.S. Arctic. This includes statewide laboratory surveillance, including confirmation, serotyping, antimicrobial susceptibility testing, and molecular methods of diagnosis and characterization through the use of polymerase chain reaction and pulsed-field gel electrophoresis. AIP also collaborates on pneumococcal disease prevention through the International Circum-

polar Surveillance, with all participating countries involved in surveillance and standardization of laboratory methods.

Haemophilus influenzae

Haemophilus influenzae type b (Hib) was the most common cause of bacterial meningitis in preschool-aged children prior to the development and widespread use of protein conjugate vaccines. Routine immunization of all Alaska Native infants with an Hib conjugate vaccine began in 1991, reducing the incidence of invasive Hib infection more than ten-fold by 1993. The effectiveness of these vaccines is largely due to the induction of circulating antibodies and the interruption of oropharyngeal carriage, leading to protection of susceptible children through herd immunity. Despite high vaccination rates and the success of Hib conjugate vaccines in preventing disease, cases continue to occur among fully and partially vaccinated Alaska Native children at rates higher than for children in the general U.S. population. Investigations into causes for the persistent cases included a community-wide colonization survey in rural Alaska communities that revealed a continued reservoir of Hib colonization among school-aged children and adults, indicating ongoing transmission. A case-controlled study of Hib-colonized persons who revealed no immunologic deficiencies at the time of colonization showed that the response to the vaccine was robust among children and adults. Future studies into factors related to transmission and virulence factors among disease-causing organisms (such as excess capsule production) are planned.

A recent outbreak of *Haemophilus influenzae* serotype A (Hia) disease among Alaska Native children raised concerns about the emergence of a new pathogenic type. Data from the International Circumpolar Surveillance revealed that an elevated rate of Hia was also present in Inuit children of northern Canada. In response, in 2004 AIP developed a rapid response plan to investigate each case of invasive *H. influenzae* disease in children less than 10 years old in Alaska to determine risk factors for disease acquisition, prevalence of colonization of the causal agent among close contacts and the general community, immunologic response to infection, and effectiveness of chemoprophylaxis used to treat persons colonized with non-b serotypes. This effort is expected to provide some of the data necessary for developing a prevention strategy in case non-b-type *Haemophilus* should increase as a public health threat.

Methicillin-Resistant Staphylococcus aureus

In the past ten years, community-acquired MRSA soft tissue infections have become a problem among certain populations. In Alaska, outbreaks of furuncles (boils) associated with *S. aureus* have long been a problem, especially in rural villages, although reports suggest that episodic clusters also occur in urban areas. Past investigations by AIP have revealed that MRSA has become the predominant *S. aureus* type (more than 85% of isolates) in large parts of rural Alaska and has increased in urban Alaska, too. Risk factors for acquisition of MRSA infections in rural villages include prior increased use of antimicrobials, household members with boils, use of crowded saunas, and use of a sauna with evidence of MRSA surface contamination. The public health response to this outbreak has included a revision of treatment guidelines emphasizing more careful use of antibiotics and recommendations for community education regarding judicious use of antibiotics and the proper cleaning of home saunas. In addition, in 2005 the AIP established surveillance for MRSA infections in an urban location and a rural location to better understand the epidemiology of the disease and to characterize the circulating types by their Staphylococcal chromosomal cassette carrying the mec A gene, the presence of virulence factors, and antimicrobial resistance elements.

Helicobacter pylori

High rates of *Helicobacter pylori* infection have been documented in Alaska Natives. In general, *Helicobacter pylori* causes stomach ulcers, and gastritis in about 10% of persons infected has been associated with iron deficiency anemia and the development of gastric cancer. Past research has established that Alaska Natives have high rates of *H. pylori* infection that is acquired early in childhood and that these infections are associated with high rates of antimicrobial resistance, frequent treatment failures, and a high rate of recurrence. In addition, gastric cancer rates among Alaska Natives are three times higher than the general U.S. population. Ongoing studies on *Helicobacter pylori* infection in three groups—urban Alaska Natives, rural Alaska Natives, and urban non-Natives following successful treatment of infection—are now being completed. These studies indicate that reinfection rates are much higher in urban than non-urban residents; risk factors for reinfection are being evaluated. Also, to promote diagnosis of antimicrobial resistance among clini-

cal *H. pylori* infections, AIP has evaluated a rapid fluorometric technique for determining Clarithromycin resistance, a key antimicrobial in *H. pylori* treatment. AIP also supported a recently completed study of *H. pylori* treatment among children with iron deficiency anemia that shows anemia to be refractory to eradication of *H. pylori* infection.

Respiratory Syncytial Virus and Respiratory Disease

The highest published RSV hospitalization rate was reported in Native infants from Alaska's Yukon–Kuskokwim (YK) Delta. These illnesses have been implicated in a cycle of repeated lung infections requiring hospitalizations leading to severe lung damage and bronchiectasis in some children. Ongoing disease surveillance, which has been conducted in this region since 1993, has shown a remarkably high RSV hospitalization rate of 156 per 1,000 infants per year. During this period, lower respiratory tract infections (LRTIs) accounted for 67% of all infant hospitalizations, and 32% of the hospitalizations were associated with RSV infection. Introduction of a monoclonal antibody treatment (palivizumab) has prevented illness among the highest-risk infants, but a prevention strategy for other children is lacking. Additionally, although the rate of RSV hospitalization in YK Delta children decreased from 178 per 1,000 infants per year (1994–1997) to 104 per 1,000 infants per year (2001–2004), the rate of non-RSV LRTI hospitalizations increased, and the overall LRTI hospitalization rate remained stable at 284 per 1,000 infants per year.

Recent efforts have been to enhance utilization of palivizumab in rural Alaska and to use surveillance data to determine what months of the year it needs to be administered to high-risk children. Also, a recent study to evaluate the non-RSV burden of respiratory hospitalizations among Alaska Native children was begun in 2005 using polymerase chain reaction diagnostics to detect infection of nine viral pathogens. This is intended to provide an understanding of what pathogens have increased to replace the declining burden of disease due to RSV.

National Center for Environmental Health

CDC's National Center for Environmental Health (NCEH) strives to promote health and quality of life by preventing or controlling diseases or deaths that result from interactions between people and their environment. NCEH conducts research in the laboratory and in the field to investigate the effects of the environment on health. They track and evaluate environment-related health problems through surveillance systems, and they also help domestic and international agencies and organizations prepare for and respond to natural, technologic, humanitarian, and terrorism-related environmental emergencies.

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. The Maternal Organics Monitoring Study (MOMS) collects serum and urine samples from mothers during one pre-natal visit and umbilical cord blood samples at delivery from Alaska Natives. These samples are analyzed for persistent organic pollutants, non-persistent pesticides, and trace metals, as well as for various nutritional markers. Pregnant women are enrolled at the Yukon–Kuskokwim Delta Regional Hospital in Bethel in collaboration with the Yukon–Kuskokwim Health Corporation Delta and in communities in the Aleutian and Pribilof Islands in collaboration with the Aleutian–Pribilof Island Association. Additional sites may be added as the study progresses.

Preliminary results from MOMS suggest that lead concentrations in Bethel are two times higher than in northern Alaska, where steel shot is the predominant form of ammunition used for hunting animals, waterfowl in particular, which make up part of the Native subsistence diet. A study was conducted to identify whether lead shot used for hunting is a source of lead exposure in Alaska Natives. A cross-sectional exposure assessment study utilized isotope ratio (IR) methodology to compare the isotopic profiles of blood lead in Alaska Native women of Bethel and Barrow, lead shot samples from Bethel and Barrow, and lead mineral and ore from a large smelter in Torreon, Mexico, implicated as the source of the lead in the shot. The lead IRs from Torreon were significantly different from the blood samples of residents in Bethel and Barrow, implying a different source of lead exposure.

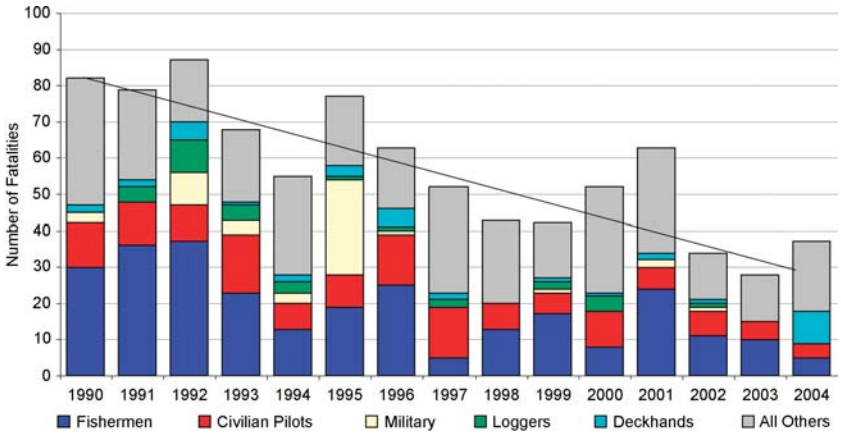
A study of environmental contaminants as cofactors in breast cancer in Alaska Natives is nearing completion. Two hundred study subjects were enrolled, and analysis of their serum is complete. A unique aspect of this study is the inclusion of serum collected from the women over time and stored in the Alaska Area Specimen Bank. By analyzing stored serum and serum collected for

this study, researchers will be able to model exposure to organochlorines over time. Preliminary results indicate a decline in levels of PCBs as well as DDT and its metabolites. No relationship was found between breast cancer and PCBs or DDT. Analysis of adipose tissue collected during breast biopsy will be completed this summer.

National Institute for Occupational Safety and Health

Occupational Injury Prevention

The National Institute for Occupational Safety and Health (NIOSH) is the Federal agency responsible for conducting research and making recommendations for preventing work-related injury and illness. NIOSH has made a concerted effort to decrease the number and rate of work-related injuries in the U.S. Arctic through its establishment of the Alaska Field Station (AFS). During 1990–2004, the number of occupational fatalities in Alaska decreased by 60%, an average decrease of almost four deaths per year. AFS was established to specifically target industries that face extreme hazards due to the Arctic environment. This report contains information on recent progress in preventing work-related injuries in the air transportation industry, the commercial fishing industry, and during subsistence activities, as well as summarizing NIOSH's international work. NIOSH continues its commitment to preventing work-related injuries in the Arctic through research, outreach with industry and community partners, and active prevention activities.



Occupational fatalities in Alaska by occupation, 1990–2004. The total was 862.

Air Transportation

Air transportation is the main method for transporting goods and people between rural Arctic villages and larger Alaskan cities. This dependence on aviation, in conjunction with long distances, rapidly changing weather, and often poor local airport infrastructure, presents numerous challenges to commercial pilots. Between 1990 and 2002, aviation crashes in Alaska caused 130 occupational pilot deaths. As part of the Alaska Interagency Aviation Safety Initiative, NIOSH conducted a survey of air taxi and commuter operators and pilots across the state between August 2001 and January 2002. In 2004 and 2005 the final results of these surveys were published in two articles appearing in *Aviation, Space and Environmental Medicine*. When NIOSH compared companies with high fatal accident rates to other companies, it found that pilots who worked for companies with high fatal accident rates:

- Were three times more likely than pilots who worked for other companies to fly daily into unknown weather conditions;
- Had less career flight experience than their counterparts who worked for companies without high fatal accident rates; and
- Worked an average of ten more hours per week than their counterparts who worked for companies without high fatal accident rates.

These results have been used by the nonprofit Medallion Foundation and local Federal offices to target their prevention activities. During the 10-year period of 1990–1999, there was an average of 11 fatal occupational aviation accidents per year; however, since the start of the initiative (2000–2004), that number had been reduced to an average of seven fatal occupational aviation accidents per year. NIOSH will continue to work with other Federal agencies, industry, and local safety organizations to improve aviation safety in the Arctic.

Commercial Fishing

The commercial fishing industry is a vital component of Alaska's economy. The crab fishing vessels operating in the Bering Sea have historically had the highest work-related fatality rate of all fishing operations in Alaska. NIOSH has worked with the U.S. Coast Guard, industry, and safety organizations to develop practical injury prevention solutions, evaluate these interventions, and organize scientific conferences to discuss findings. From 1990 through 2004, deaths in commercial fishing in Alaska declined by 77%, due to stronger safety policies under the Commercial Fishing Industry Vessel Safety Act and partnerships between CDC/NIOSH, the U.S. Coast Guard, and other programs and agencies

In addition to collecting information on fatal work-related events, NIOSH also conducts sur-

veillance for non-fatal injuries occurring to Alaskan workers. NIOSH found that severe injuries in the commercial fishing industry most commonly were caused by deck machinery and fishing gear. In November 2004 the NIOSH Alaska Field Station partnered with the NIOSH Spokane Research Laboratory to develop engineering solutions for hazards posed by fishing machinery and gear. An emergency-stop system for use on capstan-style deck winches, typically found on purse seine fishing vessels, has been developed and tested at sea. These winches have a long history of causing severe or fatal injuries to fishermen, who can become entangled in the capstan as the purse line is being retrieved. The "e-Stop" system adds a switch that can immediately shut off hydraulic power at the winch in the event someone becomes entangled, thus stopping it in time to prevent a serious injury or fatality. This technology is the latest effort in ongoing injury prevention partnerships between CDC/NIOSH, other government agencies, NGOs, industry, and workers.

Additionally, in 2005 NIOSH evaluated the Commercial Fishing Industry Vessel Safety Act requirements. When NIOSH compared victims from fishing vessel sinkings to survivors, it found that victims were 7 times more likely not to have worn an immersion suit and 15 times more likely not to have used a life raft. This study shows that immersion suits and life rafts save lives and that training in the use of equipment and the enforcement of current regulations is needed.

Subsistence Injuries

NIOSH has also started to characterize the injuries that occur during subsistence activities to formulate recommendations for injury prevention. Subsistence hunting, fishing, and gathering are common ways to supplement food supplies for people living in rural Alaska. It is also an important part of the Alaska Native lifestyle and tradition. However, the nature of these activities and the harsh Alaskan environment may introduce multiple hazards that could cause serious injury.

Injury events were identified using the Alaska Trauma Registry (ATR), a population-based surveillance system that compiles comprehensive information on all injuries requiring hospitalization in Alaska. Cutting instruments, firearms, and falls were the three most common causes of injury. Efforts are being made to prevent these injuries, including firearm safety programs and local training in the safe use of knives and other cutting instruments. Cleats or spike boot covers are also being made available in these communities to help decrease falls on ice and snow.

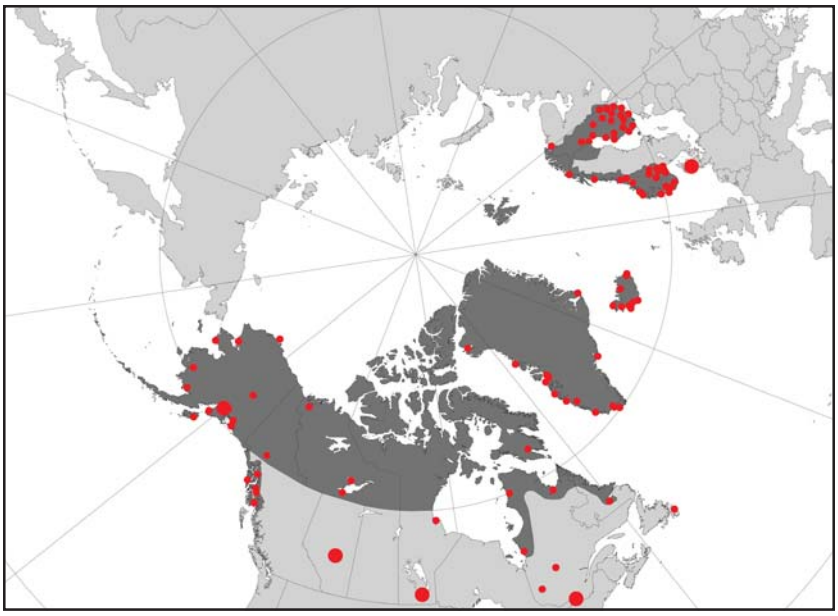
International and Circumpolar Collaboration, Conferences, and Workshops

The NIOSH Alaska Field Station 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.

A representative from the NIOSH Alaska Field Station co-chairs the International Union for Circumpolar Health's Injury and Occupational Safety and Health Working Groups. In addition, the AFS staff continues to work on hypothermia and cold-water drowning, on the prevention of worker deaths in Alaska, and on deaths of scientific field workers in Alaska. In addition, AFS staff have continued to provide technical assistance to colleagues at Karolinska Institute, Stockholm, Sweden; Linkopping University, Sweden; The Alberta Injury Prevention Center, Alberta, Canada; and Harstad Safe Communities, Harstad, Norway. They also assisted in planning and vetting Occupational Safety and Health submissions for the 13th International Congress on Circumpolar Health held in Novosibirsk, Siberia, Russia, in June 2006.

International Circumpolar Surveillance Initiative

The ICS network was established in 1999 by the CDC's Arctic Investigations Program, first linking clinical and public health laboratories in Alaska and northern Canada for the surveillance of invasive diseases caused by *Streptococcus pneumoniae*. Greenland joined the pneumococcal surveillance network in 2000, followed by Iceland, Norway, and Finland in 2001. In 2000 an expand surveillance of other invasive bacterial diseases caused by *Haemophilus influenzae*, *Neisseria meningitidis*, and groups A and B streptococcus was implemented in the U.S. Arctic and northern Canada. A northern region of Sweden joined ICS in 2003. Surveillance of invasive disease caused by these bacteria was chosen because rates of these diseases are elevated in indigenous northern peoples, strains of these bacteria may acquire antibiotic resistance, these bacteria are routinely cultured in the clinical laboratory, and diseases caused by clinically important serotypes of *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Neisseria meningitidis* are preventable by vaccine.



Locations of clinical and hospital laboratories (small red dots), reference laboratories (large red dots), and countries (shaded) participating in the International Circumpolar Surveillance of infectious diseases during 2004–2005.

Rates of invasive pneumococcal disease (commonly pneumonia and bacteremia) for the period 1999–2005 were higher in Alaska Native and northern Canadian aboriginal populations than in non-Native and non-aboriginal populations. The highest rates occur in Native and aboriginal children under the age of two years. Analysis of pneumococcal serotypes causing disease in Arctic northern American populations indicates that 78–84% of invasive pneumococcal disease could potentially be prevented. In Alaska, statewide use of the infant 7-valent conjugate vaccine began in 2001. Immunization programs using both the 23-valent adult vaccine and the 7-valent conjugate vaccine were begun in two northern Canadian regions in 2002. Continued surveillance of invasive pneumococcal disease in these regions will monitor the impact and effectiveness of these vaccine programs.

Prior to 1991, rates of invasive *Haemophilus influenzae* type b (Hib) disease in the U.S. Arctic were among the highest in the world. However, since the introduction of conjugate vaccine programs in 1991, the rates of invasive Hib disease have declined by 92%. Universal vaccine programs for invasive Hib disease began in Canada in 1992, and there have been similar reductions in rates of the disease there. Surveillance in 2000–2005 show that overall rates of Hib remain elevated in the U.S. Arctic compared to the general U.S. population. The most common serotype in northern Canada was serotype a.

Continued surveillance for invasive diseases caused by all serotypes of *Haemophilus influenzae* in Arctic countries is important to be able to monitor the impact of conjugate vaccine programs and the potential emergence of other serotypes that may replace Hib as a major cause of severe diseases in Arctic populations.

Similarly, surveillance of diseases caused by *Neisseria meningitidis* showed that in the U.S. Arctic, the highest rates of disease occurred in Alaska Native children less than two years old (19.5 per 100,000). As in the case of *Streptococcus pneumoniae* and *Haemophilus influenzae*, continued surveillance of invasive diseases caused by *Neisseria meningitidis* allows for the monitoring of disease trends in populations and the detection of clusters of disease, and it provides serogroup information critical for vaccine recommendations.

The transfer of the Arctic Council chair to the Russian Federation for 2005–2006 presents a unique opportunity to explore the possibility of expanded ICS activities to include the northern regions of the Russian Federation. Other plans for ICS include the continued surveillance of invasive diseases caused by *Streptococcus pneumoniae*, *Haemophilus influenza*, *Neisseria meningitidis*, and groups A and B streptococcus in the U.S. Arctic, northern Canada, Greenland, and one region of northern Sweden and expansion in 2006 of the surveillance of diseases caused by *Haemophilus influenza*, *Neisseria meningitidis*, and groups A and B streptococcus to include Iceland and Norway. The surveillance of other diseases, such as tuberculosis, HIV/AIDS, and hepatitis, as well as those infectious diseases that may emerge as a consequence of climate change, can be added to ICS as the need and support arise.

International Polar Year: Arctic Human Health Initiative

The Arctic Human Health Initiative (AHHI) is a U.S.-led IPY (2007–2008) Arctic Council (AC) project that aims to increase the visibility and awareness of health concerns of Arctic peoples, foster human health research, and promote health protection strategies that will improve the health and well-being of all Arctic residents. The AHHI is co-coordinated by the Department of State, the U.S. Centers for Disease Control and Prevention's Arctic Investigations Program, the National Institutes for Health's Fogarty International Center, and the International Union for Circumpolar Health.

The AHHI core project will seek to advance the joint circumpolar human health research agendas

of the Arctic Council (www.arcticcouncil.org), an eight-nation intergovernmental forum for sustainable development and environmental protection, and the working groups of the International Union for Circumpolar Health (IUCH). Current AC human health activities include monitoring the human health impact of anthropogenic pollutants, climate variability, and infectious diseases and expanding and assessing tele-health innovations in Arctic regions. The IUCH (www.iuch.org) promotes international cooperation, research, scientific information exchange, and education in the areas of Arctic health policy, birth defects and genetics, cancer, diet and heart, environmental health and subsistence food security, family health, fetal alcohol syndrome, health surveys, HIV/AIDS, STDs, indigenous peoples' health, infectious diseases, injury prevention, occupational safety and health, population-based planning, tobacco and health, and women's health. An anticipated outcome of the AHHI will be the development of an organizational infrastructure for coordinating human health research activities in Arctic regions.

A key element of the AHHI will be developing new, and expanding existing, human health surveillance, monitoring, and research networks. These circumpolar networks will allow the monitoring of diseases of concern in Arctic communities through the development of standardized study protocols, data collection, laboratory methods, and data analysis. Once established, these networks will allow monitoring of disease prevalence over time, determination of risk factors for disease, and evaluation and implementation of disease prevention and control strategies. Networks also provide opportunities for the development of sustainable partnerships between communities and researchers through community-based monitoring activities.

A focus of the AHHI is the establishment of research activities related to human health issues of concern to Arctic residents. Priority areas include the human health impact of:

- Regional and intercontinentally transported anthropogenic pollution in Arctic regions;
- Oil, gas, and other sustainable development activities;
- Contaminants and zoonotic infectious diseases, particularly as they relate to the traditional food supply;
- Climate variability, also as it relates to the traditional food supply;
- Infectious diseases, including tuberculosis, HIV/AIDS, hepatitis, vaccine-preventable diseases, and emerging infectious diseases such as SARS;
- The changing Arctic environment, as it affects the evolution, ecology, and emergence of zoonotic disease, particularly avian influenza;
- Chronic diseases such as cancer, cardiovascular diseases, obesity, and diabetes; and
- Behavioral issues, such as suicide, interpersonal violence, and substance abuse, and unintentional injuries.

Research activities will include the use of culturally sensitive health interview surveys, which are a useful tool for characterizing health and risky behaviors, the health status of populations, and the development of culturally appropriate interventions.

In the area of health communication, several symposia and topic-specific workshops are planned before, during, and following IPY, which will allow the development of new collaborations, evaluations of advances made in the health of Arctic peoples, assessments of the health disparities that remain, and examinination of future risks to the health and well-being of all Arctic residents. Details regarding AHHI specific projects, plans, and progress can be found at www.arctichealth.org.

Substance Abuse and Mental Health Services Administration

Cooperative Agreements for the Comprehensive Community Mental Health Services for Children and Their Families Program

Under this program the Center for Mental Health Services (CMHS) provides grants and cooperative agreements for states and tribal governments to develop systems of care for children with severe emotional disturbance, along with their families. Grantees include the Yukon Kuskokwim Health Corporation's People Working Together Project in Bethel, which completed the six years of funding at the end of September 2005. Key program elements of their system of care initiative were sustained by the corporation and program partners and were expected to continue to function successfully and serve children and families in the remote villages of southeast Alaska in the post-Federal funding phase. The Fairbanks Native Association's Ch'eghutsen' Project completed their third of six years of funding under a coopera-

tive agreement at the end of September 2005 and were developing their system for providing comprehensive services to Alaska Natives in Fairbanks and the surrounding remote villages.

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 services system models for American Indian and Alaska Native children and their families. There were no grants awarded this year for a new cohort of Circles of Care. However, bidders meetings were held by contractors, and several Alaska Native corporations submitted proposals for the next cohort of Circles of Care grants announced in October 2005.

Alaska Fetal Alcohol Syndrome/ Alcohol-Related Birth Defects Program

Alaska has had a relatively high incidence of fetal alcohol syndrome/alcohol-related birth defects (FAS/ARBD) births. The overall goal of this program was to improve the practice of identifying, preventing, and treating FAS/ARBD. The project was a comprehensive, integrated approach to FAS, involving prevention, intervention, and service delivery in Alaska. It was a $5.8-million Congressionally earmarked project that was jointly funded by the Center for Substance Abuse Prevention and the Center for Substance Abuse Treatment. The project provided prevention activities, including education and training of service providers, public school students and their families, and the general public. Interventions included family planning, alcohol treatment, and other services for women of childbearing age at high risk for having a child with FAS/ARBD. The project ended in September 2005.

Fetal Alcohol Spectrum Disorders Center for Excellence

Supported by the Center for Substance Abuse Prevention and funded for approximately $38 million for five years (through FY 2006), the Fetal Alcohol Spectrum Disorders 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 these 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 these individuals and their families;
- Developing innovative techniques for preventing alcohol use by women in childbearing years; and
- Supporting 35 subcontractors to integrate evidence-based practices to eliminate alcohol consumption by pregnant women or improve functioning and quality of life of those with a fetal alcohol spectrum disorder. Subcontracts were awarded in FY 2005 to initiate the planning year. The Bristol Bay Area Health Corporation, located in southwest Alaska, was one of the 35 subcontractors funded to serve rural communities. Bristol Bay developed a plan in FY 2005 to implement both FASD prevention and treatment services in FY 2006.

State Targeted Capacity Expansion Screening, Brief Intervention, Referral and Treatment Program

Through a grant with the Cook Inlet Tribal Council, the Screening, Brief Intervention, Referral and Treatment program enhances screening, referral, brief intervention, and treatment services for adults and establishes those services for adolescents. Its overarching goal is to reduce substance use by participating patients.

Targeted Capacity Expansion— American Indians/Native Alaskans Program

The project will expand service to provide residential substance abuse treatment to 32 Alaska Native Elders annually. The project is through the Cook Inlet Tribal Council, and clients are drawn from throughout the state. The grantee uses a therapeutic community treatment model, modified for Alaska Native culture and conceptualized as a "Therapeutic Village of Care."

Enhanced New Life Project

The Enhanced New Life Project expands a comprehensive continuum of care for 12 additional adolescents living in interior and northern Alaska. Services are provided through the Fairbanks Native Association and range from residential co-occurring disorders treatment to outpatient chemical dependence treatment. The continuum of care embraces an evidence-based treatment model integrating

conventional western treatment and traditional Athabascan healing techniques, practices, and principles.

Pregnant/Post-Partum Women Program

This program expands the availability of comprehensive, high-quality residential substance abuse treatment coupled with primary health, mental health, and social services to women and their children. The grant funds the Fairbanks Native Associations' Women and Children's Center for Inner Healing to expand its services through the Healthy Women–Healthy Children Project. It provides critical medical and substance abuse treatment services, including residential services, particularly to Alaska Native women in isolated rural areas with limited health care available.

Treatment of Persons with Co-Occurring Substance Related and Mental Disorders

This grant to the State of Alaska is designed to improve the identification and treatment of individuals with co-occurring disorders throughout a diverse delivery system. Alaska has committed to addressing SAMHSA goals of improved screening, assessment, treatment, and training, which is accomplished by developing infrastructure and focusing on staffing competency, credentialing and licensure, financial planning and reimbursement, and information sharing and data collection.

Treatment for Homelessness Grants

The goal of the Treatment for Homelessness Grants is to reduce substance abuse among Anchorage's population of homeless individuals with substance abuse disorders by expanding and strengthening services. Wraparound and case management services are provided to move homeless people who chronically abuse substances toward self-sufficiency in health and basic needs, including housing.

Through the Homeless Addictions Treatment Program in Anchorage, the Rural Alaska Community Action Program provides services for homeless, late-stage chronic alcoholics by using engagement, detoxification, case management, and life skills training.

The Cook Inlet Tribal Council operates the Transitions Program in the Recovery Services Division. The Transitions Program is a one-stop access point for health care, mental health care, self-sufficiency services, social supports, housing and substance abuse treatment, and follow-up services for persons with chronic alcoholism.

Smithsonian Institution

Of all governmental agencies, the Smithsonian has the longest record of involvement in Arctic research, which started in the 1850s. Today, most of the Smithsonian Arctic activities are focused on studies of northern cultural heritage and environments and on the use of the institution's unique national collections for research, public outreach, and educational programs.

Since the mid-1800s, Smithsonian scientists have produced an outstanding array of research in all regions of the Arctic. They also amassed unique national collections of northern natural and cultural specimens. Today, Smithsonian scientists maintain their strong interest in many fields of northern research, including botany, zoology, marine ecosystem, and socio-cultural studies.

The institution's current research activities are being carried primarily via the Arctic Studies Center (ASC) of the Smithsonian National Museum of Natural History (NMNH). Established in 1988, the ASC is the only active long-term Federal program that has a special mission in Arctic cultural research, education, and outreach, with programs developed in partnership with other Federal agencies (such as NOAA, NSF, DOI, and others), as well as with universities, museums, and local indigenous communities across the Arctic. ASC scientists, fellows, and associates have conducted studies throughout the entire circumpolar zone, including Alaska, Canada, Greenland, Scandinavia, and northern Russia. The ASC publishes an annual *Arctic Studies Center Newsletter* (with a current print run of about 2,000 copies) and maintains a web site at www.mnh.si.edu/arctic. The ASC also supports its own publication series, *Contributions to Circumpolar Anthropology*; six volumes and four off-series collections have been produced in 2001–2005.

In fulfilling the institution's stated mission in "the increase and dissemination of knowledge," the Smithsonian and the Arctic Studies Center promote research, collections development, and public programs that are driven by the growing public interest in the Arctic environment, history, cultures, and heritage of northern people. Interdisciplinary scholarship, heritage documentation, museum and educational training programs for northern residents, traveling exhibits reaching out to the most distant northern communities, and cooperative 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), advancing Smithsonian research and its strong public focus to local scholars, residents of Anchorage, and rural Alaskan communities.

	Funding (thousands)	
	FY 04	FY 05
Anthropology	450	500
Arctic Biology	50	50
Public Programs	0	50
Total	500	600

The Smithsonian internal funding for its Arctic-focused research has remained fairly steady over the last several years, at an annual level of $0.5–0.6 million. Substantial additional funds are generated each year through outside grants and interagency partnerships. In recent years the total amount of Smithsonian Arctic funding has significantly increased, thanks to many successful ventures, primarily in publications, exhibits, and public programs.

Research and Public Outreach Initiatives

Smithsonian scholars are engaged in several research, collection, and outreach projects across the Arctic region. The efforts described below illustrate the Smithsonian research approach and its strong focus on collaboration with other agencies and northern communities.

International Polar Year, 2007–2008

Smithsonian has a long record of association with IPY activities because of its role in the first U.S. IPY field expeditions of 1881–1884. The Smithsonian houses voluminous natural history, ethnological, and archival collections returned by the U.S. teams from the first IPY missions to Alaska

and Canada. Thanks to the preparation for the IPY 2007–2008, those collections have been recently inventoried and brought to public attention for the first time since the 1880s.

Over the last three years, Smithsonian scientists have been instrumental in promoting IPY 2007–2008 at numerous meetings, interagency sessions, and workshops and via its newsletter and web site. The Smithsonian has emerged as one of the critical hubs for the prospective IPY sociocultural studies and public outreach activities. Smithsonian scholars are also active in other fields of Arctic and Antarctic research, particularly in biology, paleontology, ocean, astrophysics, and the history of polar science, that will be included in the Smithsonian IPY program.

The Smithsonian offers its Arctic and Antarctic collections—ethnological, botanical, zoological, mineral, films and archival materials, etc.—to scholars for all types of IPY research. Of particular value are the early ethnological and biological collections from Barrow, Alaska (1881–1883), and Ellesmere Island (1881–1884), from the first IPY era, as well as the scientific instrument collections and records of the early IPY stations. The Smithsonian thus aims at becoming a key IPY interagency hub for education, outreach, and public programs during 2007–2009 through its museum, outreach, and exhibit ventures.

Early camera (around 1880) that used glass plate negatives. All photographs from the First International Polar Year, 1881–1883, were taken by such equipment.

The first Smithsonian contribution to the forthcoming IPY is a new exhibit, *Arctic: A Friend Acting Strangely*, which opened in April 2006. Under development since 2003, the 1800-square-foot exhibit is the first and so far the only governmental outreach and educational venture that brings the issues of Arctic climate change and environmental research to the general public. It has been developed jointly by the ASC and the NMNH Office of Exhibits in collaboration with NOAA, NASA, and NSF, as the main Smithsonian contribution to the Study of Environmental Arctic

Opening section of the new Smithsonian exhibit, Arctic: A Friend Acting Strangely *(April 2006).*

Iñupiaq bowl from Wales, Alaska.

Change (SEARCH) interagency program and to the forthcoming IPY 2007–2008 outreach activities. This exhibit will be open for nine months, until November 2006.

Alaska Collections Project

The 30,000 Alaskan ethnological objects in the collections of the Smithsonian National Museum of Natural History and National Museum of the American Indian represent all of the Native Alaskan cultures and span 150 years. The collections are a national treasure and an unparalleled resource of cultural heritage of more than 100,000 Alaska Natives. The Smithsonian care for these collections entails responsibilities for public dissemination, scholarly study, and engagement with Alaskan communities in training, exhibits, and education. These priorities are reflected in the Alaska Collections Project (ACP), which over the past five years (since 2000) has engaged several museum curators and over 50 Alaska cultural experts (Native Elders, community leaders, artists, and educators) in the cultural and linguistic documentation of many hundreds of objects. The initial results of this project may be viewed at arctic.si.edu.

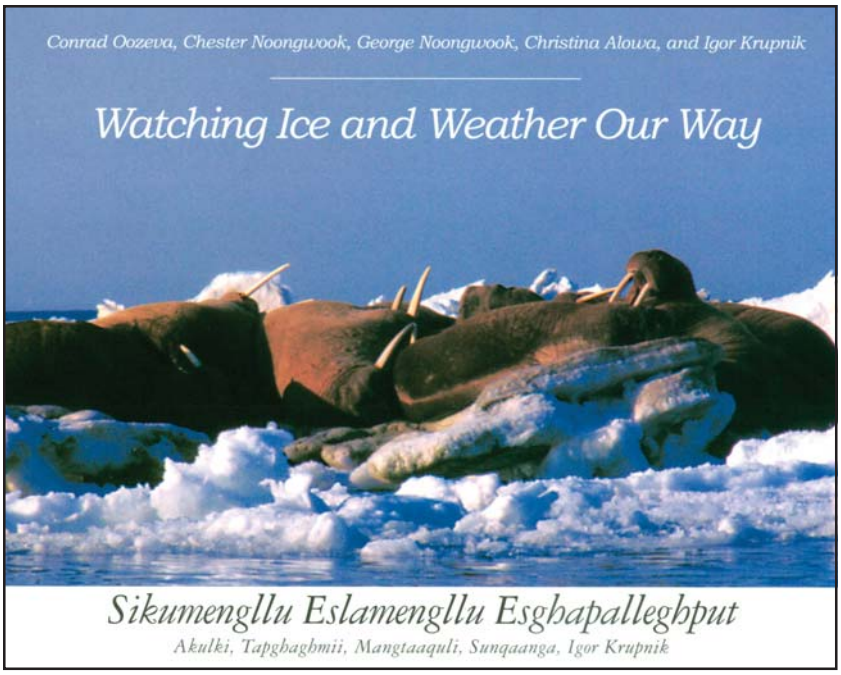
Through an ASC partnership with the Anchorage Museum of History and Art in Anchorage that began in 1994, the project will also lead to a permanent presence for the Smithsonian Alaska collections in Alaska. A new 10,000-square-foot exhibition gallery and cultural resource center will be a prominent attraction of the museum's new wing, scheduled to open in 2010. The new facility will display a collection of some 600–700 Smithsonian objects to be brought north on a rotating loan program. Sponsorship for the Alaska Collections Project has been provided by the Rasmuson Foundation, Smithsonian Institution, National Park Service, Anchorage Museum Foundation, Museum Loan Network, and Alaska Humanities Forum.

Athabascan Elders (left to right) Phillip Arrow, Trimble Gilbert, Eliza Jones, and Judy Woods examining the Smithsonian's Alaska collections at the National Museum of Natural History.

Prospective view of the new gallery at the Anchorage Museum of History and Art, which will feature Smithsonian Alaska collections.

Preservation of Indigenous Knowledge and Languages

The Smithsonian is playing an active role in many interagency and international programs in support of endangered northern languages and in the documentation of indigenous environmental and cultural heritage knowledge. Recently, Smithsonian scientists made several critical contributions to this field, such as *Watching Ice and Weather Our Way* (2004, joint publication with the Marine Mammal Commission and the Savoonga Whaling Captains Association) and *Northern Ethnographic Landscapes: Perspectives from*



Cover page of the bilingual volume on indigenous knowledge of sea ice and weather (2004), produced jointly by the ASC, the Marine Mammal Commission, and the Savoonga Whaling Captains Association.

Circumpolar Nations (2004, joint publication with the Alaska Office of National Park Service). ASC scientists have been active in the production of the ACIA report *Impacts of a Warming Arctic* (2004) and in its subsequent dissemination through public hearings, lectures, and other outreach events, including a special panel on the impacts of Arctic climate change on Alaska native communities held at the NMNH in November 2005.

In 2004 the ASC collaborated with Université Laval in Québec, Canada, in co-organizing an international symposium titled *Reversing Language and Knowledge Shift in the North*, which brought together northern specialists in indigenous languages, traditional knowledge systems, and educational practices. Speakers included academic researchers, linguists, and anthropologists, but also many aboriginal and non-aboriginal specialists in Native languages and education from Alaska, Nunavut, Greenland, and Russia. The funding for the symposium was granted by the NSF Office of Polar Programs, the Social Sciences and Humanities Research Council of Canada, Centre Interuniversitaire d'Études et de Recherches Autochtones, the Government of Nunavut, the Greenland Home Rule Government, and other agencies. The proceedings of the symposium were published in 2005 as a special issue of the journal *Etudes/Inuit/Studies* titled *Preserving Language and Knowledge of the North*.

Saami sacrificial structure on the island of Stora Fjäderägg in northern Sweden.

Saami Heritage in Northern Scandinavia

The Search for a Past; The Indigenous Saami of Northern Coastal Sweden is a three-year (2004–2007) interdisciplinary project in research and documentation of the Saami prehistory in northern Sweden. The project has documented archaeological sites in three counties (Norrbotten, Västerbotten and Hälsingland), together forming a north–south transect of almost 700 kilometers. Dozens of huts have been mapped and sampled along this coast, resulting in over 40 radiocarbon dates, finds of animal bone, and evidence of animal husbandry and iron working. Saami ritual sites, including a bear grave and circular sacrificial sites, have helped establish the identity of these sites as truly Saami in origin. These results are combined with the oral history and place-name studies.

The project has made special efforts at public outreach and education. Information is disseminated online at www.mnh.si.edu/arctic/features/saami/intro.html, which is accessible through the main ASC web site at www.mnh.si.edu/arctic. An archaeology field school was carried out in the summer of 2005, with students from Harvard University, the University of Western Michigan, George Washington University, and the University of Minnesota.

Through the ASC partnership with the Smithsonian Associates and the Royal Norwegian Embassy, a Saami lecture series, several cultural programs, and a photo exhibit have been facilitated at the Smithsonian. From October 2005 until June 2006, the exhibit *Frost: Life and Culture of the Saami Reindeer People of Norway* was on display at the NMNH. This exhibit of over 50 black and white and color images by Norwegian Saami photographer Fred Ivar Utsi Klemetsen illustrates the meeting of old and new traditions in the Saami culture of today.

Community Archaeology in Labrador

The ASC has a long-established network of partnerships with various indigenous communities across the Arctic, particularly in Alaska and Canada.

Indicative of this long-term commitment are a pair of ongoing community research initiatives in Labrador that involve ASC scholars, Innu and Inuit community leaders, educators, and elders in developing local archaeological research and educational programs. The Central Coast of Labrador Community Archaeology Program, now in its seventh year, is undertaken jointly by the ASC, the Canadian Labrador Inuit communities of Makkovik and Hopedale (including schools, local historical societies, and community museums), the Robert S. Peabody Museum of Archaeology in Andover, MA, and Brown University. The project integrates methods of archaeological research, high school curriculum development, and local heritage training in site preservation, archaeological fieldwork, and museum development. This research has culminated with the publication of *Anguti's Amulet/ Angutiup ânguanga* (2005: Eastern Woodlands Publishing, Truro, N.S.), a bilingual introduction to archaeology for grade 8 students. Prepared for and distributed to all the Inuit schools in Labrador, the booklet is the first curriculum publication in the Labrador Inuktitut dialect.

A second Labrador initiative has the ASC working cooperatively with the Tshikapisk Foundation, an Innu experiential education program based in the Innu communities of Sheshatshit and Natuashish. Tshikapisk is committed to reconnecting Innu families with the land through a variety of country-based programs that seek to enhance Innu awareness of, and pride in, Innu identity, language, and culture.

Cultural Festivals: Greenland and Alaska

In 2005 the Smithsonian hosted two northern cultural festivals at the National Museum of Natural History. Festival of Greenland: Kalallit Nunaat was held over a weekend in late May and brought nearly fifty Greenlanders, led by Henriette Rasmussen, Greenland's Home Rule Minister of Culture, Education, and the Church, to share their history and culture with scholars and museum visitors. The programs, organized jointly by the Smithsonian, the Greenland Home Rule Government, and the Danish Royal Embassy, included exhibitions of Greenlandic traditional ethnography, art, and history; lectures and seminars; performances by dancers, musicians, and storytellers; a photo exhibit; and a Greenland film festival. The Arctic Studies Center presented exhibits of 19th century Greenland ethnography and William Bradford photography from his Greenland art expedition of 1869, as well as a display titled *Across Arctic North America*, presenting Knut Rasmussen's epic anthropological expedition from Greenland to Alaska in 1921–1924. Lectures included talks on cultural history, geology and natural history, and history and contemporary society in Greenland.

A similar event, Festival of Alaska Native Arts and Culture, took place at the NMNH in November 2005. It was organized jointly by the ASC and the Alaska Native Arts Foundation and included lectures, seminars, displays by modern Alaska Native artists; photography from early explorers and naturalists; films; and music. The festival acquainted museum-goers with Alaska Native arts and crafts and educated the public about Alaska Natives' close and continuing relationships with animals and the land that sustain their cultural values and beliefs.

Knut Rasmussen, a Danish–Inuit anthropologist and polar explorer, at Starvation Cove, the resting place of some members of the Franklin expedition, 1923.

Interagency Collaboration

The Smithsonian has long-established partnerships with many Federal agencies, such as NASA, NOAA, NSF, DOI (National Park Service), DOA, and others. For many decades, interagency partnership was pivotal in expanding resources and logistical support to Smithsonian scientists working in the polar regions. It also allowed the Smithsonian to advance high-quality research, public and educational programs, and management of the national collections. Recently these ties have been strengthened through several new cooperative research and public initiatives.

The Smithsonian is a member of the Interagency Arctic Research Policy Committee (IARPC) and other bodies that promote interagency collaboration. ASC members and associates represent the Smithsonian and Arctic social sciences at the Polar Research Board of the National Academies and other science policy groups.

Environmental Protection Agency

The U.S. Environmental Protection Agency's Arctic-related work is designed to protect the health of Arctic residents and safeguard the Arctic environment.

The U.S. Environmental Protection Agency's (EPA's) research in the Arctic is focused on the source, transport, fate, and effects of contaminants in the environment; the 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:

- Improving basic knowledge about Arctic stressors and effects;
- Understanding and reducing risk to Arctic residents and the Arctic environment; and
- Implementing innovative technologies to solve environmental problems.

These primary objectives are being addressed through a variety of research and project implementation efforts. The following discussion provides a brief summary of EPA-sponsored research and demonstration projects, each highlighted under a particular objective, although individual projects may address more than one objective.

Arctic Stressors and Effects

The 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 status and trends in the Arctic, investigating mercury deposition, and studying airborne contaminants.

Recent warming of the Arctic, thawing permafrost, increased infestations to vegetation, changes in migration patterns, increased fire activity, loss of sea ice, and increased coastal erosion are all signs of a changing climate that significantly affect Alaskans. Also of grave concern are the potential impacts from persistent and bioaccumulative toxic substances that are beginning to appear in the environment and some subsistence foods. Threats to subsistence species pose serious threats to traditional lifestyles in which subsistence foods provide not only nutrition but also form a solid foundation for the culture and social life that date back for generations.

	Funding (thousands)	
	FY 04	FY 05
Research and Development (including grants)	500	500
Regional Activities	100	100
International Activities	150	250
Total	750	850

The fact that the majority of sources are non-domestic has proven a challenge in determining the most appropriate and effective role for the EPA Region 10. The Alaska Office of the EPA works directly with tribes and other partners such as the Alaska Conservation Foundation and the Yukon River Intertribal Watershed Council to assist in collaborative efforts between tribes, the EPA, states, scientists, academia, and NGOs, as well as to facilitate the exchange of information. The Alaska Forum on the Environment (AFE) is an annual venue for the dissemination of research results, among other things. It has also provided an opportunity for ongoing dialogue to better understand priorities and firsthand observations from those living in the extreme Arctic conditions. The Alaska Office organized a contaminant track during both AFE '04 and '05 (44 presentations in 11sessions). The office has also promoted guidelines for scientists to follow when working with communities; this information was gleaned from NSF, ANSC, and the Northern Contaminant Program (NCP).

Environmental Monitoring and Assessment Program

The Environmental Monitoring and Assessment Program (EMAP) is a national research pro-

gram to develop the tools necessary to monitor and assess the status and trends of ecological resources. EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of current ecological condition and forecasts of future risks to our natural resources. EMAP aims to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate multi-agency monitoring through large regional projects. EMAP develops indicators to monitor the condition of ecological resources. EMAP also investigates designs that address the acquisition, aggregation, and analysis of multi-scale and multi-tier data.

Alaska REMAP

The Alaska Department of Environmental Conservation's (DEC) Environmental Monitoring and Assessment Program is using the national EMAP approach at the regional and local scales (REMAP) to provide a practical, cost-effective method to characterize Alaska's coastal and surface waters. The EPA has been the funding source for EMAP, but partnerships are necessary to carry out the projects. The Alaska EMAP program has sampled both coastal and fresh waters since 2002. Coastal sampling projects have been completed in south-central Alaska (2002) and in southeast Alaska (2004) and will soon be completed in the Aleutian Islands (2006). A freshwater sampling project was completed in the Tanana River basin in 2004.

Southeast Alaska was studied by EMAP protocols in 2004 as the second of the five Alaska regions. The region was selected as the second-most accessible region given DEC's resources. The sampling was done in July and August 2004 aboard a chartered vessel, the *Ocean Cape*, from Bering Sea Eccotech. The vessel mobilized and demobilized for the cruise in Sitka. Fifty-one sites were sampled, 11 of which were sampled for bacteria only, for the DEC Cruise Ships Program. Forty sites were sampled according to EMAP protocol and for many parameters. The final report for southeast Alaska is expected to be released in early 2007.

The Tanana River watershed, located in interior Alaska, was selected for the location of the EMAP wadeable streams demonstration project. This region was chosen because of the wide variety of land uses occurring within the watershed, including forestry, agriculture, mining, recreation, subsistence, national defense, and communities with suburban, urban, and village characteristics. The sampling took place in the summers of 2004 and 2005. The final report for this project is scheduled to be completed in the fall of 2006.

Western Airborne Contaminants Assessment Project

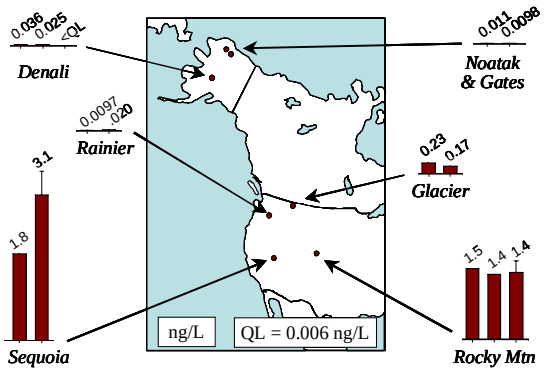
The Western Airborne Contaminants Assessment Project (WACAP) has been initiated to determine the risk to ecosystems and food webs in western national parks from the transport of airborne contaminants. WACAP was designed and implemented by the Environmental Protection Agency and the National Park Service's Air Resources Division in cooperation with many western National Parks, the U.S. Geological Survey, USDA Forest Service, and several universities. There are two parks, Gates of the Arctic and Noatak (one site each), located above the Arctic Circle and two sites in Denali National Park among the eight primary National Parks involved in WACAP. At each of the eight park units, two relatively high elevation, small lake catchments have been selected. Samples are collected at these sites to reveal where and to what extent airborne contaminants have been deposited on these landscapes and how these contaminants may be distributed within food webs.

Airborne contaminants can pose serious health threats to wildlife and humans. Some toxic compounds tend to "biomagnify," meaning that small concentrations in air, water, snow, and plants can result in large concentrations at higher levels of the food chain, such as fish and mammals. The biological effects of airborne contaminants include impacts on reproductive success, growth, behavior, disease, and survival. Subsistence hunters and gatherers in Alaska depend on wild food sources that may be affected by airborne contaminants.

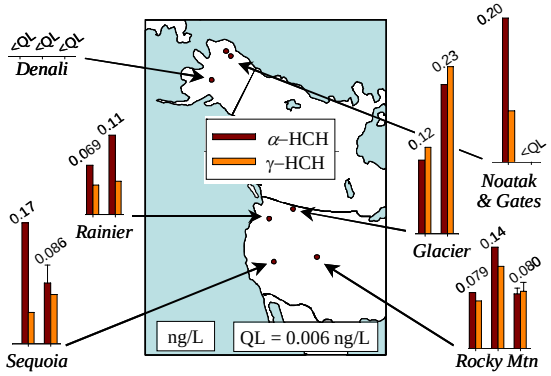
The contaminants of concern are compounds that are sometimes called semi-volatile organic compounds, or SOCs. This group contains a variety of persistent organic pollutants (POPs) such as PCBs and DDT. The element mercury (Hg) behaves similarly to SOCs and is also being investigated by WACAP. These materials are direct or indirect products of human industrial activity and can be transported thousands of miles in the atmosphere. In some cases, they can be deposited to aquatic or terrestrial ecosystems and then be re-emitted back into the atmosphere. Some of these materials have physical properties that permit them to accumulate preferentially in

Concentrations of dacthal, a currently used pesticide that has much higher concentrations in snow near agricultural regions (Sequoia and Rocky Mountain sites) than in remote sites in Alaska. The hexachlorocyclohexanes are banned (a-HCH) or are being phased out (g-HCH, also known as lindane) in North America. The HCH concentrations in snow are more uniform throughout the WACAP sites and have lower concentrations in snow than dacthal. (QL is the detection limit.)

DACTHAL *(current-use pesticide)*



Hexachlorocyclohexanes *(α is banned pesticide)*



colder areas of the global environment. This phenomenon has been termed "cold fraction" and has been observed for some types of PCBs, hexachlorocyclohexane (HCH), and even mercury. Therefore, high-elevation and high-latitude ecosystems may be at greater risk because of the accumulation of these toxic compounds, simply because they are colder than other locations.

WACAP completed all field work in September 2005. Now that samples are in hand and analytical methods have been tested and confirmed adequate, samples are being analyzed for organic and inorganic contaminants at a rapid pace.

Snowfall provides 50–90% of the annual precipitation in high-altitude and high-latitude areas of the western United States, and seasonal snowpacks that accumulate during the fall, winter, and spring contain a record of chemicals deposited during the snow-covered season. By collecting a full-depth column of the snowpack near the time of maximum snow accumulation, the EPA can cost-effectively determine seasonal atmospheric deposition inputs to these types of ecosystems. Twenty-three samples from eight parks were sampled for organic and inorganic contaminants in FY 2004. Processes controlling mercury deposition in the snowpack have been investigated as part of WACAP, including the relation between mercury concentration and particulate concentration, canopy cover, and snow-water equivalent. These findings are important to the scientific community and to resource managers, because they will improve estimates of total mercury deposition based on other measurement techniques.

Two years of mercury concentration data for snowpack samples are now available, and they reveal spatial patterns in mercury deposition. Mercury concentrations in samples from the Alaska parks tend to be quite variable. This is likely related to the shallow depth of snowpacks at low-elevation inland sites in Alaska and the relatively large amounts of windblown "crustal" material in the snowpack. Even when concentrations were moderately high in Alaska snow, the total atmospheric loading of mercury via snow was not great because the volume of snow deposited in the Alaska sites is quite low in comparison to sites in the lower 48 states. Along the west coast of the lower 48 states, most of the parks had fairly low concentrations of mercury, while inland sites at Glacier and Rocky Mountain National Parks had somewhat higher concentrations of mercury, which, again, were related to higher concentrations of particulates.

Airborne contaminants have been detected in alpine aquatic ecosytems and fish in Canada and Europe. However, little information exists about similar occurrences in the U.S., despite the preferential deposition of some contaminants in high-elevation and polar ecosystems. The fish component of WACAP focuses on determining the impacts and appropriate indicators of contaminant exposure in fish. In the summer of 2003, salmonid fishes from five lakes in Sequoia, Rocky Mountain, and Olympic National Parks were captured and assessed for endocrine disruption, physiological impairment, and, in some lakes, contaminant loads. General health, histopathology, age, and sex steroids were also determined. In the summer of 2004, fish were collected from four sites in Alaska.

One of the WACAP objectives is to determine the sources for contaminants measured at the National Park sites. Because of the strong westerly flow in the middle latitudes, it is anticipated that long-range transport from distant sources in Asia will be important in explaining some of the WACAP results, but contributions from other sources will not be overlooked. In particular, transport from major agriculture regions in California, Mexico, and Canada appear to be important in explaining the concentrations of pesticides in

some of the WACAP parks. The primary goal of the atmospheric component of WACAP is to help elucidate the time-varying transport of air masses from all major source regions that may be affecting western National Parks.

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 the 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 the 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.

Understanding and Reducing Risk

EPA and others have broadened the risk assessment approach to effectively bring together scientific research and management strategies for reducing risks. In the Arctic this specifically targets reducing risk to humans potentially exposed to contaminants in traditional foods, as well as 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.

Monitoring of Umbilical Cord and Maternal Blood

Alaska Native populations became concerned in the early 1990s with the accumulation of organic and heavy metal pollutants, which were accumulating in subsistence foods. Accordingly, and in response to Alaska Area Native Health Service (AANHS) concerns with Arctic contamination, the EPA, along with the National Center for Environmental Health (NCEH) of the Centers for Disease Control (CDC), proposed a project, supporting AMAP, to monitor selected heavy metals and persistent organic pollutants (including PCB congeners) in umbilical cord blood and maternal blood of indigenous groups of the Arctic, with a focus on Alaska Native populations.

The program was a collaborative project involving the AANHS, the Alaska Native Regional Health Corporations, the CDC Arctic Investigations Program (AIP), the CDC National Center for Environmental Health (NCEH), and the Alaska Native Tribal Health Consortium (ANTHC). Funding support came from the EPA Office of International Affairs. The responsible Federal agency was the Indian Health Service (IHS), which was represented by the AANHS and acted through the ANTHC. The ANTHC was responsible for managing all aspects of an interagency agreement, in collaboration with CDC.

Analysis of the initial 200 women in the program has generally found levels of persistent organic pollutants (POPs) similar to those found in western Arctic Canadian Inuits but lower than values from Greenland Inuits. Toxaphene, perfluorooctanyl sulfonate (PFOS), and brominated flame retardants (BFR) were higher than in other regions. PCB levels are much higher for Aleut women living in the Commander Islands, with a congener pattern similar to women on the Bering

Sea coast, suggesting a common, transboundary source.

The program will continue to monitor Yupik and Aleut Alaska Natives residing along the Bering Sea Coast, the rivers that drain into it, and the Aleutian Islands. Analyses will include blood levels of POPs, PCBs (including congener analysis required to help track sources), BFRs, toxaphene, and PFOS. An additional 200 pregnant women were recruited between March 2005 and January 2006. The EPA will also open discussions with the health corporations in the monitored regions to initiate POP measurements in relevant subsistence species important in these regions.

Indian 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 Indian General Assistance Program (IGAP) 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 IGAP funds has resulted in research to develop sustainable technologies amenable to remote areas of the Arctic that assist in achieving local environmental goals. Funding has enabled the pursuit of low-tech alternatives for pollution prevention, specifically in the area 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. The EPA is continuing to support emerging management strategies and technologies to reduce local environmental pollution and improve quality of life.

ACAP Community-Based Projects with Indigenous Peoples

New projects initiated in 2005 by the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP) include:

- A community-based model for PCB mitigation in the Arctic, by the Gwich'in Council International (GCI). On-site inspection for obsolete electrical equipment has been completed in four Alaskan villages. Six obsolete electrical transformers have been identified. The next step is to sample the transformer liquids and package the transformers for shipment to safe storage and disposal. An additional village has recently notified GCI that they have 15 improperly discarded obsolete transformers.
- A dioxin/furan project, also by the GCI. The focus is on community training awareness programs to reduce dioxin/furan emissions from open burning (barrel burning).
- A community-based model for identifying sources of PCBs and obsolete pesticides in the Russian North, by the Russian Association of Indigenous People of the North (RAIPON). Activities started in three indigenous villages in the Nenets Autonomous Region, including training the local population to identify sources of PCBs, collecting samples from the local landfills to test for PCBs and pesticides, and providing new food storage containers to local communities to replace POPs-contaminated containers used in the households.

Collaborating with the AIA (Aleut International Association) and the Northwest Public Health Research Center in St. Petersburg, Russia, the human assessment of POPs exposure in the Russian Commander Islands (CI) will include the non-Aleut women and the adult household members of highly exposed individuals. The relevant subsistence species for the CI will also be sampled and tested for POPs, in cooperation with the U.S. Fish and Wildlife Service and Russian authorities. Further analysis of the existing data from both the CI and the Alaska Native Monitoring Program will continue looking for health effects from the POPs and heavy metals in the data collected thus far.

Additional analysis of congener patterns of PCBs will be sought to identify patterns indicative of particular sources of PCBs, both in human and in wildlife tissues, from existing data. At present, preliminary analysis points to a PCB source in the western North Pacific circulation that results in particular congener ratios in the residents on both sides of the Bering Sea, but this needs further work. It is proposed to continue to fund the Aleut International Association for epidemiologic and laboratory analysis by the Northwest Institute for Public Health Research, in St. Petersburg, Russia.

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. Since 2003, the EPA Office of International Affairs has chaired ACAP. Under the U.S. chairmanship, ACAP has broadened its sphere of activities to include emerging chemical contaminants such as brominated flame retardants and has extended its cooperative initiatives to include formal projects with the indigenous peoples and the Barents Euro-Arctic Council's Working Group on Environment.

Reducing Atmospheric Mercury Releases from Arctic States

The Arctic Council agreed to act to reduce exposures to a number of priority pollutants, such as mercury, in the Arctic region. To accomplish this, the ACAP Mercury Project was initiated in 2002. The project is being led by the Danish 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 release should serve as a demonstration of existing possibilities, giving inspiration to other measures in the region."

In 2005, two ACAP mercury reports were issued. The first, *Arctic Mercury Releases Inventory*, summarizes and discusses current releases, usage, and disposal of mercury within all eight Arctic countries. The second, *Assessment of Mercury Releases from the Russian Federation*, represents the first comprehensive assessment of mercury releases at the national level by that country. Sectors include coal combustion, non-ferrous metallurgy, chlor-alkali production, gold mining, and management of mercury-containing products. All of these materials have been shared with the UNEP Global Mercury Program and other international fora, including regional bodies such as the Barents Euro-Arctic Council. Two additional reports are in the final stages of preparation: *Russia Mercury Action Plan to Reduce Major Mercury Release Sources* and *Assessment of Mercury Reduction Measures in Existing Binding and Non-Binding International Instruments*.

With the cooperation of the Russian authorities, a limited number of point sources in the Russian Federation are being evaluated in terms of their potential as sites for demonstration projects on mercury reduction measures. Potential projects that have been identified for further evaluation by the Mercury Project Steering Group include:

- Mercury-specific air pollution controls on a coal-fired facility;
- Technical upgrades and improved air pollution controls on a mercury-recycling plant; and
- Collection and preliminary treatment of mercury waste in an existing recycling facility in northwest Russia.

An additional ACAP mercury project was endorsed by the Mercury Project Steering Group in September 2005 that directly responds to the UNEP Governing Council (GC23) Partnership initiative to reduce sources of mercury in the environment. This project, jointly funded by Canada and the U.S., will assist Russian chlorine production facilities to reduce mercury consumption and release when using mercury cell technology.

Reducing PCBs in Russia

The Russian Federation no longer produces, but still uses, 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. However, Russia has signed the Stockholm Convention on Elimination of Persistent Organic Pollutants, which includes PCBs and obsolete and prohibited pesticides. To assist Russia in phasing out PCB use, EPA has proposed a multilateral technology transfer and demonstration project under the auspices of 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 of PCB sources in the Russian Federation;
- Ceasing the use of PCBs; and
- Providing safe disposal and destruction of PCBs and PCB-contaminated equipment and material.

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 began in mid-2002. The project for destroying PCBs in active use in Russia is underway.

Environmentally Safe Management of Obsolete and Prohibited Pesticides

To protect northern villages, including those of indigenous peoples, from the Soviet legacy of stockpiled and unused pesticides that have been released into their environment, ACAP began a program to address this problem. Over 854 tons of obsolete pesticides have been inventoried, repackaged, and placed into safe storage in six Russian regions impacting the Arctic. Over 216 additional tons of obsolete and prohibited pesticides were discovered during the inventory development. Eighty-eight tons of unidentified pesticides have been analyzed in the six regions. Work is underway in an additional five regions impacting the Arctic.

Science To Achieve Results Program

The EPA supports high-quality research by the nation's leading scientists and engineers to strengthen the basis for decisions about local and national environmental issues. Through its Science to Achieve Results (STAR) grants and fellowship programs, EPA works with academia, state and local agencies, other Federal agencies, and scientists in EPA to increase our knowledge of how to protect our health and natural resources in Alaska and the rest of the U.S.

Two hallmarks of the STAR program are competition and high-quality science. STAR counts four Nobel Prize winners among its grant recipients. In addition, all awards are made using competitive requests for applications and peer-review panels that are outside the EPA to ensure no conflict of interest. Each year, EPA uses about 1,000 outside scientific experts to peer-review its grant and fellowship submissions.

Research on Subsistence Lifestyles

The STAR-funded Alaska Community Action on Toxics program is working with the Siberian Yupik people of St. Lawrence Island, Alaska, who have relatively high levels of PCBs and pesticides in their blood. This research is examining the traditional foods of the Yupik people, including seal, whale, walrus, fish, seal oil, greens, sea bird eggs, and berries, to determine which foods could cause them to be exposed to significant levels of PCBs, three pesticides, and several metals. They are also investigating how the foods are prepared to see if preparation influences the levels of these contaminants in the foods.

Mote Marine Laboratory scientists have focused on the potential effects of petroleum hydrocarbons on the Inupiat people who have subsistence lifestyles. Oil and gas production in the Arctic occurs at a high level and may increase. Humans can be exposed to petroleum hydrocarbons by consuming species that form a major part of the Inupiat diet in northern Alaska. In Barrow, 75% of households consume bowhead whale, and nearly 50% consume bearded seals. Marine mammals are exposed to petroleum directly or through their diet and may metabolically transform petroleum-related compounds. Preliminary results show that there are no detectable levels of hydrocarbons in the tissues of these two marine mammals. In fact, the whales harvested in Barrow in the fall of 2004 traveled through waters where oil and gas development occur, but they did not have any detectable levels of hydrocarbon contamination in the portions of the animal typically consumed. The researchers are recording traditional knowledge on the quality of meat and other tissues obtained from subsistence hunting. Preliminary results suggest that hunters and consumers are sensitized to inedible seal and whale meat and that they are vigilant in their monitoring of animals' conditions.

Mercury Research

Mercury, a silvery metal that is very poisonous, can have adverse health effects on mammals, fish, and birds. Understanding why and how atmospheric mercury becomes part of the food chain is also important for mercury control. STAR researchers at the University of Connecticut are analyzing the mercury in sediment cores collected from the Tongass National Forest of southeastern Alaska in the spring of 2004. These scientists are attempting to determine whether the mercury is produced by natural or manmade sources, the mechanisms by which mercury is removed from the atmosphere, and the bioaccumulation of mercury in sensitive aquatic ecosystems. The results of this research should have major implications since atmospheric mercury deposition in southeastern Alaska can be viewed as an integrated sample of global mercury pollution in the northern hemisphere.

Understanding the chemical reactivity, atmospheric concentrations, and rates of emission and deposition of mercury are important in understand-

ing its atmospheric transformation. Researchers at the University of Miami are developing measurements and techniques to better define these criteria by studying the depletion of elemental mercury that occurs in the Arctic every spring. By monitoring the role of the various halogen species in the depletion of mercury, they hope to determine the rate of chemical conversion of elemental mercury to less-toxic, chemically bound mercury in beach areas.

POP Goes the Pollutant

The Arctic is considered one of the most pristine and remote environments on Earth. However, increasing evidence is showing that long-range atmospheric migration is bringing persistent organic pollutants, or POPs, to the region. POPs are toxic chemicals that adversely affect human health and the environment around the world. Because they can be transported by wind and water, most POPs generated in one country can affect people and wildlife far from where they are used and released. At the University of Alaska, a STAR fellow is using new tools to measure the levels and determine the types of POPs at five locations in Alaska. This research will provide baseline concentrations for many POPs that can be used in future work in Alaska.

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 and the Federal Highway Administration.

Federal Aviation Administration

The FAA is the principal sponsor of the Capstone project, which links multiple programs and initiatives under a common umbrella for planning, coordination, focus, and direction. It enables aircraft traffic control and enhances safe air operations in the remote regions of Arctic Alaska.

Federal Highway Administration

No resources are devoted specifically to Arctic concerns under the FHWA Road Weather Management program; however, the mandate is to address all aspects of weather as it affects highway operations (e.g., mobility and safety). Consequently, research is conducted on road weather information systems and decision support systems that enable transportation users and operators to make more informed decisions regarding highway use and management under all weather conditions. This includes everything from buckling of pavements because of heat to snow and ice on pavements. Much of FHWA's work is on high-resolution observing and forecasting systems, since there is great variation in road weather conditions at small scales (for example, a bridge deck can freeze but the road on either side of it may be ice free).

	Funding (thousands)	
	FY 04	FY 05
FAA Capstone Project	21	28
Total	21	28

One activity in this regard is the Clarus initiative (www.clarusinitiative.org). Under this initiative, FHWA will design, develop, and demonstrate a system that will assimilate, quality-check, and disseminate the Nation's road weather observations. Such a system will enable public and private sector weather providers to develop tailored road weather information products for the host of road users and operators. These observations include more than 2,300 fixed sensors deployed by state transportation departments across the country, as well as the emerging capability to gather observations from mobile sensors (for example, cars and trucks). FHWA is working with the Alaska Department of Transportation and Public Facilities as part of a proof-of-concept test of the Clarus system.

In 2005, a Memorandum of Understanding was signed between FHWA and NOAA to support surface transportation weather challenges and to work together to address this challenge.

Department of Homeland Security

U.S. Coast Guard

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.

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.

	Funding (thousands)	
	FY 04	FY 05
Arctic Science/Logistics Support	21,691	16,800
Extramural Science Support	30	38
Total	21,721	16,838

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 accommo-

date 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

USCGC Healy *enters the ice for the first time, April 2000.*

profiling system, a Seabeam bottom mapping sonar system, a data acquisition unit, and an acoustic Doppler current profiler. Lab spaces are equipped with 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 Summer (AWS) Cruises aboard *Healy* in 2004 and the Arctic West and East Summer (AWES) Cruises aboard *Healy* in 2005.

USCGC Healy *2004*

On 27 April *Healy* sailed for the six-month AWS 2004 mission to support three multidisciplinary projects: the National Tsunami Hazard Mitigation Program, the Western Arctic Shelf Basin Interactions (SBI) project, and the NOAA Ocean Floor Mapping project.

National Tsunami Hazard Mitigation Program. As part of the U.S. National Tsunami Hazard Mitigation Program, the Deep Ocean Assessment and Reporting of Tsunamis (DART) Project is an ongoing effort to maintain and improve the capability for the early detection and real-time reporting of tsunamis in the open ocean. A DART station consists of an anchored seafloor-bottom pressure recorder and a companion moored surface buoy for real-time communications. An acoustic link transmits from the bottom pressure recorder on the seafloor to the surface buoy. The data are then relayed via a satellite link to ground stations, which demodulate the signals for immediate dissemination to several sites, including NOAA's Tsunami Warning Centers. More information is available at the NOAA tsunami website (www.tsunami.noaa.gov).

During this mission (27 June–4 July), led by Shannon McArthur of NOAA, three DART stations off the coast of Alaska were serviced. Institutions participating included the NOAA National Data Buoy Center, the Lamont–Doherty Earth Observatory, and Science Applications International Corporation.

SBI 2004 Processing Cruises. The SBI project is a multi-year, 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 (sbi.utk.edu).

There were two SBI processing cruises on *Healy* in 2004: the SBI 2004 May/June Processing Cruise (15 May–23 June), led by Jackie Grebmeier of the University of Tennessee Knoxville, and the SBI 2004 July/August Processing Cruise (18 July–26 August), led by Lee Cooper of the University of Tennessee Knoxville. During these cruises a wide variety of interdisciplinary research projects participated, ranging from hydrographic measurements to biological studies of various trophic levels.

Physical, biogeochemical, and biological measurements were made in the Bering Strait and over the shelf, slope, and basin of the Chukchi and Beaufort Seas using a variety of sampling devices. Subsamples from four CTD (conductivity, temperature, depth)/rosette casts were used for measuring 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. Acoustic Doppler current profiler data were obtained with both a 75-kHz phased-array system and a 153-kHz discrete-array system. Scientists were lowered to the ice to collect ice cores and make in situ measurements of the ice. Marine mammal surveys were conducted from the bridge. Helicopters were used for sampling of the Colville River Delta, small boat operations in support of experimental floating sediment trap deployments, ice reconnaissance, and observing and photographing marine mammals.

The institutions participating included the University of Tennessee Knoxville, the University of Alaska Fairbanks, the Woods Hole Oceanographic Institution, the University of Washington, the Scripps Institution of Oceanography, the University of Maryland, the University of Delaware, the Lamont–Doherty Earth Observatory, the University of Rhode Island, the Canadian Department of Fisheries and Oceans, the University of South Carolina, Old Dominion University, the University of Texas, Hokkaido University, the University of Miami, the Bermuda Biological Station for Research, the University Corporation for Atmospheric Research, Oregon State University, the Alaska Eskimo Whaling Commission, Bigelow Laboratory for Ocean Science, Tenino High School (Tenino, Washington), and Newman High School (Wausau, Wisconsin).

SBI 2004 Mooring Cruise. From 2 September to 1 October, Robert Pickett of the Woods Hole Oceanographic Institution led a cruise in support of the SBI project. During the main effort, 12 moorings deployed by *Healy* in 2003 (to measure temperature, conductivity, and currents) were recovered. Two acoustical recording platforms were also recovered. The cruise collected other data, including 157 CTD stations and water sampling at 117 of these stations. A study of the boundary current running on the slope to the north was conducted using XBTs (expandable bathythermographs) to define the current, plus CDTs, VPRs (video plankton recorders), and net tows for further analysis.

Institutions participating included the University of Alaska Fairbanks, the Woods Hole Oceanographic Institute, the University of Washington, the Scripps Institution of Oceanography, the University of Delaware, the Lamont–Doherty Earth Observatory, the University of Miami, the University of Rhode Island, and the University of Cadiz.

NOAA Ocean Floor Mapping. The primary purpose of this leg was to continue mapping the seafloor north of Alaska for use in future Exclusive Economic Zone (EEZ) claims, an effort that NOAA began on a *Healy* cruise in September 2003. 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. One of the key pieces of evidence to support a claim is the location 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 only our second Law of the Sea bottom mapping survey for the Arctic Ocean.

During the 20-day cruise (6–26 October) led by Chief Scientist Larry Mayer of the University of New Hampshire, *Healy* ran 6,700 km of tracklines and completed most of the mapping of the 2,500-m isobath begun on *Healy* in 2003, as well as a survey of the "foot of the slope" over a segment of the continental margin east of Barrow, Alaska. The survey also revealed a complex margin with drift deposits, suggesting contour currents that are cut by numerous canyons.

Institutions included the University of New Hampshire, the Lamont–Doherty Earth Observatory, NOAA, and the Danish Hydrographic Agency.

USCGC Healy, *2005*

From 1 June to 28 November 2005, *Healy* completed three missions in support of Arctic research. The first and third missions of AWES-05 were NSF funded and focused on coring and col-

lecting geophysical transect data with a towed seismic source and receiving streamer. The second cruise, funded by NOAA Ocean Exploration, focused on cataloging the biomass of Arctic marine species.

Canada Basin Coring. The purpose of this two-week mission (13–26 June), led by Chief Scientist Dennis Darby of Old Dominion University, was to obtain expanded sections of Holocene and older sediment from the North American continental slope between Barrow and the Northwind Ridge. Multibeam sonar and 3.5-kHz seismic profiles were used to locate cores in areas of high sediment accumulation. *Healy* completed eight successful jumbo piston cores (JPCs), six multicores, six vertical plankton tows, and two CTD casts. The JPC deployments produced over 100 meters of sediment samples. Helicopters conducted seven ice reconnaissance sorties in search of "dirty ice," ice infused with sediment. During four flights, the helicopters landed so that the scientific party member could collect samples. Seven dirty ice samples were collected

Scientists were from Old Dominion University, the University of New Hampshire, Ohio State University, the University of Hawaii, the Desert Research Institute, Kent State University, Université de Quebec, Oregon State University, Kings Fork High School (Suffolk, Virginia), Science Applications Research International Incorporated, Johns Hopkins University, the Lamont–Doherty Earth Observatory, and the University Corporation for Atmospheric Research. This project was funded by the National Science Foundation

NOAA Ocean Exploration. During the 30-day (27 June–26 July) NOAA Ocean Exploration cruise, Rolf Gradinger of the University of Alaska Fairbanks led an international team of scientists from the U.S., Canada, China, and Russia in exploration of the Canada Basin. The major objective was to improve the inventory of life in the Canada Basin as part of the worldwide Census of Marine Life study. Sample stations were designated along the slope and within the deep basin and included studies of biota in the sea ice, water column, and seafloor. Each of the 14 stations was projected to last 24 hours and would encompass CTD casts, plankton net tows, ice team deployments, divers, pelagic and benthic ROV (remotely operated vehicle) deployments, box cores, and a towed camera platform. At each station, divers collected ctenopheres, amphipods, and Arctic cod and took video images of the under-ice surface. Near the end of the mission, several media personnel came onboard to document the discoveries and daily operations. Scientists discovered new species of pelagic and benthic organisms and determined range extensions for some known species.

Institutions involved in this effort included the University of Alaska Fairbanks, the Polar Research Institute of China, Texas A & M University, the Zoological Institute of St. Petersburg, the Harbor Branch Oceanographic Institution, California State University at Monterey Bay, Western Washington University, the P.P. Shirshov Institute, Barrow High School (Barrow, Alaska), NOAA, Deep Sea Systems, the National Ice Center, the Lamont–Doherty Earth Observatory, the University of Hawaii, Census of Marine Life, Blue Land Media, National Public Radio, ABC News, and *The New York Times*.

Healy–Oden Trans-Arctic Expedition. The Healy–Oden Trans-Arctic Expedition 2005 involved the joint crossing of the central Arctic Ocean by *Healy* and the Swedish icebreaker *Oden*. Anders Karqvist of the Swedish Polar Research Secretariat and James Swift of the Scripps Institution of Oceanography led the planning for the physical oceanographic projects, and Dennis Darby and Bernard Coakley, co-Chief Scientists for *Healy*, led the planning for the coring and geophysics projects.

Scientists were from Old Dominion University, the University of Alaska Fairbanks, Ohio State University, the University of Bergen, Stockholm University, the Desert Research Institute, Texas A & M University, the Scripps Institution of Oceanography, the U.S. Army Cold Regions Research and Engineering Laboratory, the University of Washington, Thor Heyerdahl High School (Larvik, Norway), the U.S. Arctic Research Commission, Alta High School (Alta, Norway), Uppsala University, Universite de Quebec, the Bergen School of Engineering, the Japan Agency for Marine–Earth Science and Technology, the Canadian Coast Guard, the University of Oslo, LGL Ltd, the Barrow Arctic Science Consortium, the Lamont–Doherty Earth Observatory, the Swedish Polar Research Secretariat, Vibackeskolan (Sundsvall, Sweden), Homer Hanna High School (Brownsville, Texas), Oregon State University, the Hawaii Mapping Research Group, and the University of New Hampshire. U.S. researchers were supported by the National Science Foundation.

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 research is part of Polar View, a satellite remote-sensing program that is supported by the European Space Agency (ESA) and the European Commission, with participation by the Canadian Space Agency. C-CORE, a global research and development corporation located in St. John's, Newfoundland, is the prime contractor of the Polar View team. IIP is participating as an end user. C-CORE provides IIP the locations of icebergs and ships obtained from the analysis of images by the synthetic aperture radar on two satellites, Canada's RADARSAT-1 and the European Space Agency's ENVISAT. During 2004 and 2005, IIP compared the satellite observations with observations from other sources, including IIP's aerial reconnaissance.

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. As part of this research, IIP plans to deploy ice beacons by aircraft onto icebergs. The observed iceberg 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.

The Department of State leads the development of U.S. Arctic policy, a key component of U.S. foreign policy. 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, agreed on the Arctic Environmental Protection Strategy (AEPS), designed to identify priorities for regional cooperation with regard to environmental protection in the Arctic.

In 1996 the eight Arctic countries signed a declaration establishing the Arctic Council. The Council took over the work of the AEPS and added issues related to 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 State Department appoints the Senior Arctic Official, who represents the U.S. government at Council meetings. 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. The U.S. chaired CAFF from 2002 to 2004 and in 2003 assumed the chair of the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP). The U.S. became chair of AMAP in 2004. Finland chaired the Council in 2000–2002 , and Iceland assumed the chair for 2002–2004. Russia chairs the Council for 2004–2006. Norway will chair the Council for 2006–2008.

	Funding (thousands)	
	FY 04	FY 05
Department of State	175	173

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 2002 Johannesburg 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, evaluates and synthesizes knowledge on climate change, climate variability, and increased ultraviolet radiation and their consequences on the Arctic environment. The final report was approved in November 2004. The ACAP steering committee delivered a 120-page summary of the results to the ministerial meeting in Reykjavik in November 2004, and the ministers approved a policy statement based on the report at their meeting. The final 1,000-page report was published in 2005 and is available from Cambridge University Press (www.cambridge.org).

The U.S. is taking the lead on other circumpolar efforts of the Arctic Council. Under the PAME banner, the U.S., along with Canada and Finland, is launching an assessment of the current state of Arctic marine shipping and the potential of shipping in a warming Arctic, scheduled to be delivered in 2008.

In the area of sustainable development, the U.S. focuses on human health in the Arctic. The State Department took the lead in developing and proposing a large-scale human health project for the Arctic Council for the International Polar Year. The Arctic Human Health Initiative includes existing projects and encourages the development of additional projects to assess and improve the health of Arctic residents. 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 disease in the Arctic.

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 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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