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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 semi-annually (spring and fall) by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee and the Arctic Research Commission. Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act 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 ARC and IARPC meetings;
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector and other nations; and
- A calendar of forthcoming local, national and international meetings.

Arctic Research is aimed at national and international audiences of government officials, scientists, engineers, educators, private and public groups, and residents of the Arctic. The emphasis is on summary and survey articles covering U.S. Government-sponsored or -funded research rather than on technical reports, and the articles are intended to be comprehensible to a nontechnical

audience. Although the articles go through the normal editorial process, manuscripts are not refereed for scientific content or merit since the journal is not intended as a means of reporting scientific research. Articles are generally invited and are reviewed by agency staffs and others as appropriate.

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

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

Address correspondence to Editor, *Arctic Research*, Arctic Research and Policy Staff, Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington VA 22203.

Cover *In the Arctic, where roads and surface transportation are few or nonexistent, rivers provide a means for investigators to travel and conduct surveys and studies. Here, a wildlife biologist, conducting a study of birds, floats a Yukon River tributary in interior Alaska.*

ARCTIC RESEARCH

OF THE UNITED STATES

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This issue of *Arctic Research of the United States* presents highlights and results of major fiscal year 1994 and 1995 Arctic research programs and selected projects of the Federal agencies. For more information, you may contact the agency staff representatives listed on page 123.

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National Science Foundation

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

A complete list of NSF Arctic funded projects may be found in the publication Arctic Science, Engineering and Education Awards FY 1995, available from the Office of Polar Programs, National Science Foundation, Arlington, VA 22204.

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 Arctic research as part of their overall funding. Research grants are provided on the basis of unsolicited proposals that are peer reviewed.

In FY 94, NSF provided funds for 355 awards at 132 institutions in 38 states. In FY 95, NSF provided funds for Arctic research to 138 institutions in 40 states and the District of Columbia, representing 352 projects.

Arctic System Science

The National Science Foundation established the Arctic System Science (ARCSS) program in 1989. ARCSS is structured to be a regional component within the U.S. Global Change Research Program. Administration of the program utilizes review expertise and financial support from the Office of Polar Programs, Divisions of the Geosciences Directorate, and other components of NSF as appropriate. ARCSS is coordinated and managed by the Office of Polar Programs. Through a series of workshops and interactions with a broad scientific community, ARCSS has developed goals and priorities aimed at understanding the role of the Arctic in global change and how the Arctic will respond to global change. ARCSS is an interdisciplinary program that examines the interactions within and between the climatic, geologic, biologic and socioeconomic subsystems of the Arctic. ARCSS is predicated on the knowledge that the Arctic system is sensitive to and important in global change. The ARCSS program and related logistics support awards included 112 projects totaling \$16.0 million in FY 95.

ARCSS has six linked components. The original ARCSS program included the Greenland Ice Sheet Project (GISP2), Paleoclimates from Lakes and Estuaries (PALE), Ocean/Atmosphere/Ice Interac-

	Funding (thousands)	
	FY 94	FY 95
Atmospheric sciences	9,130	8,781
Ocean sciences/ship support	2,738	834
Biological sciences	4,274	4,252
Glaciology	4,101	2,515
Earth sciences	3,440	2,957
Arctic System Science	13,326	16,037
Engineering	62	372
Social science/education	2,018	7,982
Coordination	835	895
Arctic Research Commission	560	570
Total	40,484	45,195

tions (OAIT) and Land/Atmosphere/Ice Interactions (LAI). Two new programs, Synthesis, Integration and Modeling Studies (SIMS) and Human Dimensions of the Arctic System (HARC), were established in 1994 and 1995, respectively.

Science Steering Committees (SSCs) for each component facilitate and enhance the ARCSS program and provide a focal point for communication with the scientific community. Overall coordination and integration of the ARCSS components and individual projects are accomplished by the ARCSS Advisory Committee. The Committee includes representatives from each SSC, as well as an investigator not supported by ARCSS with disciplinary interest in that component of ARCSS to enhance the scientific breadth and experience of the group.

NSF/ARCSS has been particularly successful at establishing partnerships with other Federal agencies. In 1994 and 1995 significant cost-sharing on Arctic ocean science for ARCSS projects came from the Office of Naval Research (ONR). ARCSS anticipates considerable cost-sharing with NASA, DOE, ONR and NOAA in the future on aspects of common concern, such as Arctic climate and ocean process and modeling research.

Paleoenvironmental Studies

GISP2 and PALE both contribute to understanding the past climate, atmosphere and ecology of the Arctic. This historical information gives valuable insight into understanding system interactions.

Current information on scientific contributions from GISP2 may be found on the home page <http://arcoss.umd.edu/projects/gisp.html>

The overall goal of GISP2 was to obtain a 200,000-year history of global climate and atmospheric chemistry from the Greenland Ice Cap. This very successful program began in FY 86, completed its field phase in FY 93 and will complete the laboratory analysis of the ice core in FY 96.

The overall goal of PALE is to construct paleoclimatic history from the sediments of Arctic and sub-Arctic bogs, lakes and seas. A variety of proxy indicators (such as pollen, diatoms, sediment chemistry and grain size) in the sediments yields vital information on the responses of terrestrial and marine ecosystems to climate and land-use change. PALE is complementary to GISP2 and provides information on local, regional and global changes. An Arctic circumpolar network of sampled sites has been established to describe the regional variation of climate over the past 18,000 years. PALE has been accepted by PAGES (PAst Global changes) of the International Geological Biological Project (IGBP) as a core project.

Contemporary and Process Studies

OAI and LAI are process oriented and rely more on experiment and less on description than GISP2 and PALE. An important goal of OAI is to investigate the effects of energy exchange on the water-column structure of the Arctic Ocean and the interactions within the overlying atmosphere. Carbon sequestration, ecosystem dynamics, sedimentation and carbon deposition in the Arctic Ocean, and its interactions with the surrounding land and river systems are also important topics of investigation.

An objective of the major LAI study, called LAI-Flux, is to investigate feedback processes within the Arctic terrestrial system that modify global climate change, climate variability and fluxes of ice, fresh water, water-borne materials and greenhouse gases. LAI will also assess the effect of changing temperature and snow regimes on critical terrestrial organisms and their communities. LAI-Flux has discovered that the Alaskan tundra has shifted in the last 20 years from being a net sink of carbon dioxide to being a net source. The Arctic had been a net sink for millennia. If this change is long-term, it could lead to major positive reinforcement of global warming via the greenhouse effect. LAI-Flux has been accepted as a core project of the IGBP. LAI has joined ITEX (International Tundra Experiment of UNESCO/Man and the Biosphere), which is a study of the effects of climate warming on circumpolar plant species and community dynamics.

LAI-Flux is testing, among other things, the following three hypotheses:

- Whether greenhouse-gas-induced changes in

temperature and moisture are large enough to trigger changes in trace gas fluxes from Arctic land areas;

- Whether climate change and the related oxidation of soil organic matter will increase the nutrient flux to streams, lakes and the Arctic Ocean; and
- Whether Arctic trace gas feedbacks will be sufficient to impact climate beyond the Arctic.

Synthesis, Integration and Modeling Studies

SIMS is an integrative program that links all of the ARCSS components to provide a suite of model simulations for understanding the behavior, feedbacks, dynamics and function of the interactive Arctic system. Models will be at all scales appropriate to building connections between LAI, OAI, PALE, GISP2 and HARC research, but those that provide a regional synthesis will be emphasized. These models are essential to the ARCSS goal of developing a model that will predict the natural responses to global changes that affect the human condition.

The initial SIMS activity is TAWS (The Arctic Watershed System). TAWS takes a system perspective to the study of the hydrology and biogeochemistry of the Arctic drainage basin and therefore integrates the goals of LAI and OAI with direct implications for HARC. Research related to water quality, bioaccumulation, sediment and dissolved material pathways, flux rates and ocean circulation are emphasized. Linkages will be determined between climate variables and the land and ocean components of the whole Arctic system. A baseline of the contemporary water budgets and annual variations will be determined for the pan-Arctic. TAWS will provide a framework for assessing the societal impacts of climatically induced changes in freshwater runoff to the Arctic Ocean.

Human Dimensions of the Arctic System

HARC, the ARCSS component of the NSF Human Dimensions of Global Change program, is a collaborative effort with the Arctic Social Sciences Program. Its goal is to integrate natural and social sciences research that will demonstrate the interactions of climate and human development on the use of natural resources. Arctic Native peoples have sustained themselves through hunting, fishing, whaling and wage employment derived from petroleum revenues. The continued sustainability of that culture and regional development could be affected by global environmental changes that may affect vegetation and marine productivity, year-round sea ice maintenance, and construction and land use practices. In the next five years, interdisciplinary groups will focus on developing models

Current information on OAI research may be found on the home page <http://arcoss-oon.apf.washington.edu/8086/arcoss-oon.html>

that predict natural responses to global changes. Research at the interface of the natural sciences and the human dimension will increase policymakers' understanding of regional natural and social systems and will build linkages between scientific communities in the Arctic. Those linkages will enhance the knowledge base necessary for examining policy choices and risk assessment within the context of global and regional climate change.

Arctic Natural Sciences

The National Science Foundation established Arctic Natural Sciences (ANS) in 1995. ANS supports research in space sciences, atmospheric sciences, geology, biology, glaciology and oceanography in the Arctic. Arctic Natural Sciences uses expertise from the Office of Polar Programs, Divisions of the Geosciences Directorate and other components of NSF as appropriate. ANS is coordinated by the Office of Polar Programs. Across NSF there were 175 projects totaling \$19.34 million in FY 95.

Glaciology

The Glaciology component supported 32 projects totaling \$2.51 million in FY 95. The research includes the study of all forms of naturally occurring ice and its history. Some examples are studies of past climates and atmospheric paleochemistry from ice cores, ice stream and valley glacier dynamics, glacial geology, glacial hydrology and the mass balance of mountain glaciers and ice sheets. The research takes place primarily in Alaska, Greenland, Arctic Canada, Svalbard, Arctic Russia and Sweden. In addition, some limited funding goes to support research in high-altitude, mid- and low-latitude regions of the Northern Hemisphere.

The program also supports research on new methods of studying glaciers and ice sheets, including the development of improved remote sensing capabilities, drilling methods and methods for analyzing ice cores. In addition a variety of theoretical, laboratory and data analysis projects are funded. These include studies of water in frozen porous media, a study of the motion of particles in melting snow, and analyses and syntheses of glaciological data from Greenland and Alaska.

A new facility, the U.S. National Ice Core Laboratory (NICL), is now operational. The NICL is located on the grounds of the Denver Federal Center in the same building as the U.S. Geological Survey's Core Research Center. The NICL is operated jointly by the University of Colorado, Boulder, and the U.S. Geological Survey in Denver. The NSF funding for partial construction, operation and

maintenance of this facility was provided partially by the Arctic Glaciology program.

Arctic Glacier Studies. The purpose of these projects was to increase understanding of the mechanisms responsible for the surge behavior of glaciers and the seasonal fluctuations of glacier flow. Work has focused on the role of subglacial water and basal water pressure, ice temperature, internal deformation, electrical conductivity and turbidity of meltwater. These parameters can be measured in boreholes in the ice at various places on the glacier. A multi-year study of the Greenland ice cover has shown that the surface of melted ice around the Greenland periphery has substantially increased over the past decade.

Glacial Geological Studies. One of the largest uncertainties in ice volume changes during the late Quaternary are the areal and vertical extent of ice sheets over Franz Josef Land, Novaya Zemlya and the adjacent Barents and Kara Seas. Deglaciation of Franz Josef Land and the northern Barents Sea occurred surprisingly early, according to glacial geologists funded by the Arctic Glaciology program. Deglaciation of the Barents and Kara Sea ice sheet may have been initiated by rapid global sea-level rise 13,000 years ago. Sea-level rise would have destabilized this marine-based ice sheet, particularly in the deep troughs bordering the Russian Arctic seas.

Greenland Ice Sheet Project Two. In 1993, after five years of drilling, the GISP2 program reached bedrock at a depth of 3053 m, immediately below several meters of silty ice; the bedrock was penetrated to a depth of 1.55 m. Several important scientific observations have already been reported, both in the scientific literature and in the popular press. The interpretation of the paleoclimate record from the GISP2 ice core will be further enhanced by ice dynamics analysis and associated geophysical data and computer modeling. A major retrospective review of GISP2 appeared in the Fall/Winter 1995 issue of this publication.

Atmospheric Sciences

NSF Atmospheric Sciences programs supported 55 projects totaling \$8.78 million in FY 95.

Arctic Aeronomy and Astrophysics provides approximately \$1 million per year to support research on Arctic stratospheric ozone and to support upper-atmospheric studies as well as space physics. Experimental data taken from Greenland and Canada have helped elucidate the mechanism that triggers substorms. Substorms, not unlike the atmospheric storms we are familiar with, are an explosive release of energy that occurs in outer space. Energetic particles are released and come crashing towards the Earth, and large electric fields

and currents flow in the upper atmosphere. Researchers have been able to pinpoint what change in the solar wind is responsible for the complex set of events that leads to this explosive release of energy.

Stratospheric constituents were measured from an infrared emission spectrometer at Eureka, NWT, Canada, and a solar absorption spectrometer at Fairbanks, Alaska. These data are used for understanding both the short- and long-term variations in stratospheric composition, as well as for radiation balance studies.

The winter polar vortex was more stable than usual in 1995, providing extensive regions of very low temperatures. The balloon flights showed the existence of dense, persistent polar stratospheric clouds (PSCs) over almost all of the Arctic sites. As the season continued, it became increasingly clear that noticeable ozone depletion was occurring at the same altitude that the PSCs were observed. The measurements made promised to be the most definitive so far in demonstrating Arctic ozone depletion. Furthermore, the results from stratospheric observations documented the penetration and decay of the Pinatubo aerosol in the north polar vortex; they identified the role of volcanic aerosols in PSC formation and ozone depletion.

Researchers have now installed imaging riometers (relative ionospheric opacity meters) called IRISes at both Kangerlussuaq, Greenland, and Iqaluit, NWT, Canada, as well as the original IRIS at South Pole, Antarctica. This array permits the study of auroral morphology in both hemispheres at any time of year or in any weather. ANS continues to support magnetometers at several sites and to provide funds for data analysis to several groups.

Ocean Sciences

The Ocean Sciences component supported 12 projects totaling \$0.83 million in FY 95. Much of the funding for Arctic research was for ship support of the R/V *Alpha Helix* and through cosponsorship of several ARCSS projects. The ARCSS research primarily involved work in the western Arctic and the Northeast Water Polynya (NEWP) project.

The R/V *Alpha Helix*, operated by the University of Alaska, is the primary research platform for Arctic research off Alaska and the Bering Sea. This logistic support included onboard technical support services and ship-based equipment acquisitions.

During April and May 1995 a U.S. Navy submarine, the USS *Cavalla*, deployed to the Arctic Ocean for an unprecedented mission to support unclassified oceanographic research conducted by

and for researchers from academic institutions in the U.S. and Canada. The *Cavalla's* deployment was the first of five annual Submarine Arctic Science Cruise (SCICEX) missions dedicated to providing a detailed view of the Arctic Ocean and the nature of its seasonal variations.

SCICEX-95 took place during the annual period of maximum Arctic ice cover (March–May). The cruise covered 10,800 nautical miles within the Arctic Ocean basin over the course of 44 days in April and May 1995. Four civilian scientists, assisted by three from the Navy's Arctic Submarine Laboratory in San Diego, California, collected data for 26 investigations from 12 institutions.

SCICEX-95 collected 4725 water samples as well as continuous data on ice draft, bathymetry, gravity and sea-water conductivity and temperature. Primary projects included:

- A geophysical survey of the Chukchi Borderland and a very detailed shallow near-shelf survey for biological and chemical information, including water sampling while underway and from three stations on the surface of the ice;
- A cross-basin transect from Pt. Barrow, Alaska, to north of Franz Josef Land, where researchers mapped physical oceanographic features, sub-ice topography and bathymetry in support of Arctic acoustic thermometry experiments; and
- A survey of the Lomonosov Ridge, where researchers evaluated the positions of physical ocean fronts and gathered additional geophysical information.

In 1994, under the auspices of the Gore–Chernomyrdin Commission, the U.S. and Russia agreed to collaborate on acoustic thermometry in the world's oceans. A new activity called Arctic Climate Observations using Underwater Sound (ACOUS) is being planned and will be one of the first joint activities to be carried out under this agreement. The April 1994 Transarctic Acoustic Propagation (TAP) experiment was the first joint exercise. The TAP experiment propagated acoustic transmission at 19.6 Hz over 2600 km from a Russian–U.S. ice camp north of Spitsbergen to a U.S. ice camp in the Beaufort Sea and 900 km to a U.S.–Canadian ice camp in the Lincoln Sea. The acoustic data interpretation was corroborated with the SCICEX-95 observations that provided physical oceanography measurements along the propagation track. To validate the interpretation of the acoustic data, sound speed profiles along a trans-Arctic track nearly coincident with the TAP acoustic track were obtained. Analysis of this joint data set supports the hypothesized physical oceanography model that the Atlantic intermediate water in the Arctic has warmed since the 1970s.

Biological Sciences

NSF Biological Sciences programs supported 26 projects totaling \$4.25 million in FY 95. Research topics spanned a broad range of biological disciplines, with several projects multidisciplinary and interdisciplinary in design. The Biological Sciences component of the Arctic Natural Sciences supports research in all aspects of Arctic biology, including topics in biological oceanography and marine ecology, terrestrial and freshwater ecology, and solar irradiance monitoring (UV-B) at Point Barrow, Alaska.

The two largest projects supported by the Biological Sciences programs were the ongoing Long-Term Ecological Research (LTER) projects on tundra, freshwater and taiga ecosystems in Alaska. The Arctic (Toolik Lake) and Bonanza Creek LTER projects continue the successful pursuit of their individual project objectives and their participation in the national network of LTER sites. The LTER network and individual LTER projects are actively developing research collaborations with scientists supported by other agencies and scientists in other countries who share research interests.

The Arctic LTER is a major interdisciplinary project continuing in the foothills on the North Slope of Alaska. Funding has supported a large group of biologists, ecologists, limnologists and hydrologists from major universities and research centers in the U.S. to study terrestrial and freshwater ecosystems. In conjunction with the LTER program, this project has developed a multidisciplinary team approach to ecosystem studies. The specific goals of this site are to better understand land–water interactions, long-term change in ecosystems and control of ecosystem dynamics by resources (bottom up) and by predation (top down) at terrestrial, stream and lake sites. Toolik Lake scientists have produced a large database on the physical, chemical and biological cycles in the streams, rivers and lakes, which has allowed long-term changes to be identified in the region. Many of these changes involve biologic and chemical processes, such as photosynthesis, predation and nutrient cycling in the soil. These processes occur in all ecosystems across a continuum of environmental conditions. By studying them in the Arctic, which lies at one end of the continuum, a great deal of information about how these processes respond to change can be transferred to the understanding of other ecosystems. Overall, the Toolik Lake project has been successful in separating biotic and abiotic factors that control the structure and function of aquatic ecosystems and in examining how Arctic freshwater ecosystems are regulated relative to known temperate freshwater ecosystems.

The principal focus of the Bonanza Creek LTER program is the study of taiga ecosystem structure

and function, emphasizing the pattern and rate of successional change as well as the controls over these processes. A secondary and developing focus concerns aquatic–terrestrial interactions, including watershed biogeochemistry and linkages between terrestrial and running water ecosystems. To document the changing nature of ecosystems, a series of long-term experiments were initiated to examine:

- Vegetation change and demographic controls over successional processes;
- Vegetation-induced modifications in resources (light, moisture, nutrients, etc.) and compartment sizes of biomass and nutrients;
- Controls over nutrient supply; and
- The influence of herbivores on ecosystem structure and function.

Three other ecosystem projects were supported during FY 94 and FY 95. One project examined carbon–nutrient interactions in vegetation at the whole ecosystem level in three contrasting tundras in northern Alaska. This research was conceived in a global warming context that predicts that a global temperature increase would affect carbon–nutrient interactions at the ecosystem level. The central idea is that primary production in Arctic ecosystems is strongly nutrient-limited, and thus its ability to respond to higher temperatures is constrained by the nutrient supply.

A second project evaluated the dynamics of biologically available carbon and nitrogen across the tundra landscape. The work was designed to elucidate how much carbon and nitrogen is biologically available, what controls availability and how it will change with climate warming.

A third project was designed to test the importance of geomorphology in determining food web (trophic) structure. This research, termed the geomorphic–trophic hypothesis, postulates that landscape characteristics, including lake outflow gradient, lake depth and lake area, determine the distribution of fish species, which in turn controls benthic and pelagic trophic structure. The scope of this proposed work has four major components:

- Assembling and interpreting a geographic information system database of lake area, lake depth and outflow gradient for lakes in the vicinity of the Toolik Lake LTER site;
- Sampling a subset of these lakes in an experiment designed to evaluate landscape control of fish distributions and their impact on benthic and planktonic food webs;
- Sampling a group of experimental lakes, also in the context of the geomorphic–trophic hypothesis; and
- Constructing food web models to test whether the geomorphic–trophic hypothesis governs food web characteristics.

One of the central themes of ecological research in recent decades has been the relative importance of abiotic (physical and chemical) versus biotic (competition and predation) environmental factors in regulating natural populations and community structure. With evidence that important abiotic factors such as climate and UV-B radiation are changing, there is a crucial need to better understand the interactions between abiotic and biotic variables in natural communities. One project is investigating the role of damaging solar radiation on zooplankton communities and more specifically on the ecological interactions between this abiotic factor and predation, an important biotic factor.

In Arctic marine systems, scientists continue to study the ecology and adaptation of marine organisms exposed to short light periods, ice-covered seas and low seawater temperatures. Related oceanographic studies are also focusing on the influence of hydrographic features in the Bering Sea that influence benthic communities at the St. Lawrence Island polynya. Results have shown that the productivity of benthic communities is most directly affected by polynya dynamics compared to communities in other offshore regions.

Earth Sciences

The Earth Sciences component supported 50 projects totaling \$2.96 million in FY 95. The Earth Sciences program supports research in a wide diversity of fields of geology, including paleoclimatology, glaciomarine sedimentology, surficial processes, paleontology, petrology, tectonics and solid earth geophysics. However, the majority of support has gone toward research in paleoclimatology, glaciomarine sedimentology and investigations of surficial processes in the Arctic. The field programs for this research take place in Arctic Canada, Arctic Alaska, Arctic Russia, Greenland and Svalbard.

Geologic Record of Glacial and Periglacial Environments. These projects focus on unraveling the history of Arctic glaciation and understanding the past Arctic environments by examining the sedimentary and paleontological record of terrestrial coastal plain, continental shelf and deep marine sediments. Although the program supports many diverse projects in this general field, four major geographical areas are the focus of particular interest at present. These are western Alaska and eastern Siberia, the eastern continental shelf of Greenland, the Hudson Strait and the Kara and Barents Seas.

Bilateral field work and laboratory analyses of fossil materials collected on the Chukotka Peninsula over the last several years indicates that the late Cenozoic stratigraphic framework for north-

east Russia is in need of significant revision. Work funded by NSF now casts doubt on the number of glacial events recorded in the coastal stratigraphy and undermines the correlation of disjunct interglacial marine sequences based on studies done by Russian workers on biostratigraphy and elevation above sea level. Knowledge of glacial ice extent in the Russian Arctic is important for establishing accurate boundary conditions for paleoclimatic modeling. The paleoclimatic history is the backdrop against which all past migration, dispersal and land use took place. Based upon field work on the outer coast of Chukotka and a complete inventory of moraines and other glaciogenic deposits using European Space Agency synthetic-aperture radar images across northeast Russia, the late Cenozoic stratigraphy of the region is being revised via a joint study of crucial stratigraphic sections and moraine sequences on both sides of the Bering Strait.

Geology and Geophysics. Several projects focus on understanding the tectonic and petrogenetic evolution of the continents and ocean basins of the Arctic. Geophysical projects have focused on the continental margins of Alaska and northeastern Siberia, and the Arctic Ocean, whereas tectonic and petrogenetic studies of the geologic record have focused on Greenland and Svalbard.

Engineering and Technology

NSF Engineering supported three projects totaling \$372,000 in FY 95. Support in engineering, material sciences and permafrost is provided by the Engineering, Geosciences, and Mathematical and Physical Sciences Directorates. Research includes studies of the mechanical properties of ice, the hydraulic conductivity of frozen soils, metamorphism of dry snowpacks, permafrost and three-dimensional analyses of ice.

NSF also sponsors a program for science-based and high-technology small business firms, the Small Business Innovative Research (SBIR) program in the Engineering Directorate. SBIR is interested in research on advanced concepts in scientific or engineering areas, particularly where the research may serve as a base for technological innovations. In FY 95 the SBIR program funded a project evaluating the microstructural processes affecting saline ice properties. The objective of this research is to gain an understanding of why sea ice is a much more compliant material than nonsaline ice.

Social Science

In FY 95 the Arctic Social Sciences Program supported 33 projects totaling \$2.41 million. The research projects were in archaeology, anthropology,

physical anthropology, sociology, linguistics, the human dimensions of global change and other fields. Field work was conducted in Alaska, Siberia, Canada, Iceland and Greenland. Research on the Y-chromosome in Siberian Natives demonstrated links between the new and old worlds and the tracing of human origins to an ancestral "Adam" in Africa. Archaeologists recovered the well-preserved body of a prehistoric child in Barrow, Alaska, adding to our knowledge of ancient health and genetic diseases among Native Alaskans. Of special significance is that new and productive research collaboration between scientists and Native peoples has been forged. Grants were awarded to Native organizations, including the Alaska Native Whaling Commission, the Alaska Federation of Natives and the Association of Village Council Presidents. Support was also provided for the start-up of the Alaska Native Science Commission, a new body committed to Native involvement in research.

Education

NSF funded 14 Education projects in Alaska and the Arctic in FY 95. Among these was an award to the Alaska Native/Rural Education Consortium (ANREC) for a project on systemic integration of indigenous and western scientific knowledge. The Alaska Federation of Natives and the University of Alaska Fairbanks established ANREC to implement recommendations that focused on instruction to Alaskan Native students. Working through institutions of higher education, the Alaska Department of Education and tribal councils, the consortium is undertaking a five-year initiative to:

- Systemically document the indigenous knowledge systems of Alaskan Native people;
- Develop pedagogical practices that will integrate indigenous knowledge into the curriculum;
- Restructure instructional practices to capitalize on Native learning styles; and
- Improve the science and mathematics achievement of students in Alaskan Native village schools.

The focus of the initiative is on providing an opportunity for the Native people of Alaska to formulate a renewed educational agenda regarding the structure, content and processes that are needed to increase the application of Native and non-

Native science, mathematics, engineering and technology knowledge to the solution of educational problems.

Arctic Research Coordination

NSF Arctic coordination and information programs supported 15 projects totaling \$1.47 million in FY 95. 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 Arctic Research Plan was prepared by the Interagency Arctic Research Policy Committee and submitted to the President, who transmitted it to Congress in July 1995. The fourth revision to the U.S. Arctic Research Plan included two major sections. The first of these presented the Integrated Interagency Research Plans:

- Arctic Contamination Research and Assessment;
- Surface Heat Budget of the Arctic Ocean;
- Beringian Systems Program; and
- Arctic Data and Information.

The second major section was Agency Programs, which represents the objectives of Federal agencies, focusing on the period covered by this revision (1996–2000). They were presented in six major categories:

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

The Interagency Committee also addressed issues related to logistics support 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.

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

Department of the Interior

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

Minerals Management Service

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

In support of these responsibilities the MMS conducts two major programs of research that are relevant to activities in the Arctic. One focuses on engineering technology issues. The other focuses on issues related to assessing and predicting potential environmental and socioeconomic impacts.

Technology Assessment and Research Program

The MMS supports an active research program to understand the engineering constraints for offshore operations, especially as related 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 Technology Assessment and Research (TA&R) Program was established in 1975 and has become an integral part of MMS's mission. It was initiated in the spirit and letter of the Outer Continental Shelf Lands Act, which specifies "The Secretary (of the Interior) ...shall require, on all new drilling and production operations, and wherever practicable, on existing operations, the use of the best available and safest technologies which the Secretary determines to be economically feasible

	Funding (thousands)	
	FY 94	FY 95
Technology Assessment and Research	2,322	1,792
Environmental Studies	1,936	1,740
Total	4,258	3,532

wherever failure of equipment would have a significant effect on safety, health, or the environment...." Information derived from the research is integrated into offshore operations and is used in making regulatory decisions pertaining to issuing permits and reviewing applications.

The TA&R Program is a contract research program; that is, the research is not performed within the agency but is conducted by academic institutions, private industry and government laboratories. Studies are performed in cooperation with the offshore industry or with other agencies or governments. This aspect of the program provides an important multiplier of funding support, but probably of equal importance is the discourse it provides with the industry. The ability to work together to assess a particular technology or the rationale for future technical developments helps both industry and government. Such cooperation and dialogue allow us to understand each other's needs and eliminate possible conflicts or misunderstandings concerning the engineering feasibility of an operational decision. As a result of this dialogue, a valuable exchange of information is provided between MMS and the industry.

Exploration activities in the Arctic offshore have been hampered more by the lack of commercially economic discoveries than by technology. Sea ice in its various forms is the most severe environment in the Arctic, creating potential hazards greater than those for open-ocean operations. Such hazards range from the forces that moving sea ice may exert against offshore structures and the icing of structures resulting from freezing spray, to the gouging of the sea floor by sea ice (which could interfere with buried pipelines) to interference with locating or cleaning up a potential oil spill. Engineering data for these hazards will become increasingly more 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.

Safety and Pollution Prevention Research

The TA&R Program has funded a variety of projects and major international workshops to develop a better understanding of the engineering constraints for operating in the ice-infested Arctic:

- International Workshop on Sea Ice Mechanics and Arctic Modeling;
- Pressure Ridge Ice Scour Experiment;
- Management of Human Error in Operations of Offshore Facilities;
- Methodology for Risk-Based Optimization of Pipeline Integrity Maintenance Activities;
- Sea Ice Mechanics; and
- Offshore Earthquake Monitoring and Analysis.

The International Workshop on Sea Ice Mechanics and Arctic Modeling was held in Anchorage, Alaska, on April 25–28, 1995, and focused on the current state of practice and future research needs relative to Arctic offshore oil and gas operations and the results of the U.S. Navy's Office of Naval Research Sea Ice Mechanics Initiative (SIMI) Program. The workshop provided information on the measurement of sea-ice stress, ice motion, ice-thickness distribution, keel depths, ice and keel strength, ice-friction coefficients and fracture properties, meteorological parameters and ocean currents. The modeling results included data on scales ranging from ice crystals to the whole Arctic Ocean. Volume 1 of the proceedings, distributed before the workshop, contains the preliminary work completed by the SIMI researchers. Volume 2 contains the papers presented at the workshop, including a summary of the workgroup presentations.

The Pressure Ridge Ice Scour Experiment addresses the most likely transportation mode for commercial development of oil and gas prospects in the Arctic and sub-Arctic offshore regions—a product pipeline laid on or under the seabed. Marine pipelines in areas frequented by ice will be threatened by grounded or scouring ice masses, which occur periodically throughout the ice season. Pipelines must therefore be protected by trenching or burial to a safe, yet manageable and economical depth below the seabed. The major question facing industry planners, regulators and design engineers concerns the depth of burial required or trenching and trench backfill requirements. This question arises due to an incomplete understanding of the ice below the incision scour depth. The Pressure Ridge Ice Scour Experiment is designed to increase knowledge of the scouring process and specifically of subscour deformation

processes. This integrated, multidisciplinary approach progresses from the selection and development of theoretical and numerical models to corroboration of these models with results of small-scale, high-gravity centrifuge modeling and validation of model results with full-scale observations. The result of the program will be an industry-accepted design tool (a field-verified finite-element model) complete with a set of specific design guidelines.

A study on the management of human error in operations of offshore facilities seeks to develop and verify engineering reliability analysis procedures to allow quantitative evaluation of the alternatives from management of human and organizational errors in the operation of offshore facilities. Human error accounts for 60–80% of the failures of marine systems. Recent examples include the *Piper Alpha* platform explosion in the North Sea and the *Exxon Valdez* tanker grounding in Prince William Sound, Alaska. Traditional engineering approaches used in the design, construction and operation of marine systems have largely ignored this aspect. If the marine safety record is to be improved, then this aspect must be addressed by engineers. This is particularly true of existing marine systems, where there have been dramatically increased pressures for environmentally safe and economically sound operations. It is also very important in the development of new innovative marine systems (such as very deep-water platforms, pipelines and floating structures), where experience does not exist to ensure proper management of potential human errors. This study will offer information on how to control the human error sources.

The MMS is part of a joint industry program (JIP) through the Center for Engineering Research in Canada directed at optimizing pipeline integrity maintenance activities using a risk-based approach. The goal of the JIP is to develop models and software tools for estimating the risk levels associated with individual pipelines or individual segments within a pipeline system. The models and tools developed will allow risk reductions associated with various inspection and maintenance activities to be quantified, providing a basis for comparing alternatives. The overall framework will include an approach to evaluate potential risk-reduction benefits against the associated costs, thus allowing optimal decisions to be made regarding the choice of an integrity maintenance strategy.

Integrity maintenance decisions have traditionally been based on subjective assessments of pipeline inspection data. More recently, engineering analysis of the data has provided a more rational basis for technical decisions. Risk analysis can

transform inspection data into information that is directly related to the operator's objective, namely to reduce the probability of failure of individual segments within a pipeline system in a balanced manner that acknowledges the potential differences in the consequences of failure associated with different line segments.

The potential economic benefits to pipeline operators of using a risk-based approach are significant. On one hand, any small reduction in failure rates resulting from better maintenance planning would reduce the potentially high cost of failure. On the other hand, if excessive conservatism in repair strategies can be identified and eliminated, costly premature maintenance activities may be avoided.

In another research area, a joint university-industry-government consortium was formed to conduct studies to elucidate the structure-property relationships that govern the mechanical properties of saline ice. A prime consideration is to establish physically based constituting causes. Major areas of consideration will be the effects of interrupted loading on the compressive strength of saline ice and the effects of grain size, brine volume, crack orientation and temperature on the fracture toughness of saline ice.

Data on the response of seafloor sediments to earthquake-induced motions have been scarce, thus introducing significant uncertainty into the seismic hazards of offshore structural design. This is especially true in Arctic areas. To reduce this uncertainty, MMS, in cooperation with the industry, is supporting a program to develop and install seafloor instrumentation to measure seismic motions. Data collected will be used to verify or, if necessary, modify existing codes and standards. The methods developed will be used in the future to gather information on earthquake response motions in Arctic areas.

Composite materials are increasingly considered for use in offshore petroleum production engineering operations. This is particularly true for deep-water offshore platform and drilling technologies, with many applications to Arctic facilities as well. Composite materials offer substantial weight reduction, superior fatigue and corrosion resistance, outstanding vibration damping and acoustic and energy absorption, and unlimited potential for innovative material and structural tailoring to desired stiffnesses and strengths. Combined with low maintenance and total life-cycle costs and ease of fabrication and construction, composite materials are an enabling technology ideally suited for both immediate and future Arctic challenges and may offer the biggest payoff potential in offshore operations.

Oil Spill Response Research

The MMS is the principal U.S. government agency sponsoring offshore oil-spill response research. For the past 12 years, MMS has maintained a comprehensive internationally applied research program to improve oil-spill response technologies and procedures and thus enhance capabilities to respond to an open-ocean oil spill.

These efforts focused on improving capabilities to burn oil in situ, modeling the dispersion pattern of smoke emissions from in-situ burns, updating the performance database for new and improved booms and skimmers by reopening Ohmsett (the National Oil Spill Research Test Facility), remote sensing and measuring of spilled oil, studying oil-spill chemical treating agents (including dispersants), understanding the properties and behavior of spilled oil in the marine environment, and developing shoreline cleanup strategies.

The TA&R program provides funds for the operation and maintenance of the Ohmsett facility, which is located in Leonardo, New Jersey. It is the only facility in the world where clients can conduct full-scale oil-spill-response equipment tests with a variety of crude oils and refined petroleum products. The tests are under controlled, reproducible conditions and include the capability for variable, artificial wavemaking. Ohmsett provides a unique facility to conduct tests and develop new devices and techniques that detect, map, contain and clean up oil spills.

The MMS, with financial support from the U.S. Coast Guard (USCG) and Environment Canada, sponsored and directed a \$1.5 million refurbishment of the facility, which has extended the life of Ohmsett an estimated 15–20 years. Testing resumed in 1992, and seventeen tests have been conducted to date.

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. Promising results have been obtained in many technology areas, such as the burning of spilled oil, mechanical containment/cleanup devices and techniques, behavior of spilled oil, airborne and satellite remote sensing, and oil-spill chemical treating agents such as dispersants.

One significant technological improvement is the use of in-situ burning of spilled oil. This was an experimental concept at the time of the *Exxon Valdez* oil spill in Prince William Sound, Alaska. It is now an established oil-spill response technique used throughout the United States and has the potential to remove up to 98% of the spilled oil from the water's surface. This new response tech-

nique may have substantially reduced the impact and damage caused by the *Exxon Valdez* spill.

The TA&R Program is funding several projects to develop a greater understanding of the technologies required to contain and cleanup oil spills.

One project will:

- Conduct laboratory and mesoscale experiments on the burning of weathered and emulsified oils, with emphasis on the quantities and behavior of airborne and waterborne pollutants;
- Improve the Large Eddy Simulation (LES) smoke plume dispersion model through enhanced visualization and the addition of capabilities to model terrain effects, which are features of great interest to response organizations and regulatory agencies to address health and safety issues;
- Provide field verification of the LES smoke plume model; and
- Investigate and improve efficiencies of burning water-in-oil emulsions in realistic wave conditions, including the effects of slick weathering on ignitability, burn rate and oil removal efficiency.

On August 12, 1993, the Newfoundland Off-shore Burn Experiment was conducted 15 miles east of St. John's, Newfoundland. Two full-scale crude oil burns (12,760 and 7,635 gallons) were successfully conducted. Results continue to indicate that burning is a rapid, effective and environmentally safe means for removing large quantities of oil from the surface of the water.

On September 12–17, 1994, Alaska Clean Seas conducted the North Slope Emulsion Burns at ARCO's Fire Training Grounds, located within the Prudhoe Bay unit, Eastern Operating Area, Alaska. This was a series of three inland in-situ burn experiments in a water-filled, lined burn pit. Researchers evaluated different types of ignition sources on oil with varying degrees of water content (oil/water emulsions). Scientist used hand-held ignitors and a helitorch to ignite and burn the emulsions. Researchers also monitored the air emissions to test these against the recently enhanced LES smoke plume model.

All three burns were successful. The oil removal rate was at least 95% for all burns. The results indicate that the LES model accurately predicted the downwind deposition of soot particles. Very little oil was detected beyond 1000 m from the fires. The "break and burn" technology for the burning of emulsions is very promising and expands our "window of opportunity" for initiating and carrying out in-situ burn operations. The results of these experiments are particularly significant to the State of Alaska, as the Alaska Regional

Response Team has recently issued preauthorization and burn guidelines for conducting in-situ burns of spilled oil.

On October 17–19, 1994, three mesoscale burns were conducted at the USCG Fire and Safety Test Detachment in Mobile, Alabama. The purpose was to evaluate the burning rates, smoke emissions and downwind transport of chemical compounds resulting from the burns. Diesel fuel was used in place of crude oil. Researchers also monitored the air emissions to evaluate these against the recently upgraded LES model.

The FY 95 research project answered important questions on the factors contributing to the loss of oil under a boom in waves and current. Another major project, funded by five agencies, evaluated a multiple boom-skimming system designed by an Alaskan fisherman. Unlike most skimmers, this novel system performs very well in waves and currents and may be a breakthrough in mechanical cleanup technology. The multiple boom system would never have been tested if it were not for the availability of the tank and MMS funding.

New types of research were conducted in FY 95 and more are planned for FY 96. A remote-sensing system capable of detecting oil-slick thickness was tested last October. In August 1995 the U.S. Army Corps of Engineers evaluated 14 passive optical, thermal and ultraviolet remote-sensing instruments and cameras that were developed for detecting and measuring oil slicks. Environment Canada evaluated the water jet barrier, a prototype containment boom that uses high-pressure fans of water to hold back spilled oil. In October 1995 a sorbent manufacturer evaluated and demonstrated a new sorbent material and delivery system, and in December 1995 the Canadian Coast Guard used Ohmsett to verify satisfactory performance of a recently purchased remote-sensing package.

The TA&R program is developing a scanning laser environmental airborne fluorosensor (SLEAF), which is a remote airborne surveillance system that can detect oil contamination on shorelines, land, snow, ice and the marine environment. It will have an adjustable scanning capability that will allow for selection of the optimum swath to respond to various spill scenarios. This capability will maximize coverage on shorelines, ice-infested waters and other complicated surfaces. The SLEAF has been designed from the outset to provide a real-time annotated map. This georeferenced map, which can be faxed or downlinked, will provide oil-spill response personnel with accurate oil contamination location information. The timely information provided by the SLEAF sensor will help mitigate the harmful effects of spilled oil by ensuring fast and effective response. The SLEAF will be

capable of detecting and classifying oil in real time. Georeferenced oil contamination locations will be easily visible on the hard-copy map output.

One of the major problems associated with oil spills on the ocean is determining the thick oil regions so that appropriate countermeasures can be applied to those areas. Although oil slicks can cover very large areas, more than 80% of the slick is contained in less than 20% of the slick area. Therefore, it is crucial that an accurate spatial-oil-thickness map be constructed so that spill countermeasures can be efficiently employed. The TA&R Program is developing an all-weather, airborne remote-sensing instrument capable of measuring and mapping oil thickness over an oil slick in real time and transmitting images to the response vessels. This year's work will involve constructing a prototype unit and field testing it at Ohmsett.

To develop an accurate understanding of the behavior and fate of spilled oil in the marine environment, the TA&R program continues to fund studies of spilled oil to acquire understanding of the long-term behavior and to develop models to predict this behavior. Elements to be addressed include oil weathering, evaporation, water-in-oil emulsification, dispersion, dissolution and photo-oxidation. The physical and chemical properties of oils will be measured and included in a database.

The TA&R program continues to study oil-spill chemical treating agents. The objectives of these studies are to develop repeatable tests for oil spill treating agents, test commercial products, understand dispersant action mechanisms and test new product ideas. Work will continue on developing standard test protocols for evaluating the performance for ten categories of oil-spill chemical treating agents. Work will also continue on evaluating existing agents, including dispersants for

efficacy and toxicity, and applying lessons learned to develop new oil spill chemical treating agents.

The TA&R Program continues to test and evaluate oil spill sorbents, determine the biological effects on intertidal biota associated with hydraulic cleaning operations, and examine the effects of oil viscosity on skimmers and pumps.

Alaska Environmental Studies Program

As the managing agency for the OCS leasing program in Alaska, the MMS has conducted environmental, social and economic studies to obtain information needed to make sound leasing decisions, as well as to monitor human, marine and coastal environments. In anticipation of shifts in information needs, the MMS Environmental Studies Program has refocused studies to meet postlease and monitoring information requirements.

In 1993 the MMS established a Coastal Marine Institute (CMI) through a five-year cooperative agreement with the University of Alaska Fairbanks and the State of Alaska. Research conducted through the CMI focuses on environmental and socioeconomic studies that are relevant to both Federal and State offshore oil and gas and mineral resource management issues. With the provision to match funds for relevant research, the CMI creates the opportunity for the MMS and the State to accomplish research programs that could not otherwise be carried out.

Endangered Species

The bowhead whale, an endangered marine mammal of high importance to Native cultures in the Arctic, migrates through areas in which oil and gas have been discovered. Efforts to define the migration corridors of bowhead whales and their responses to offshore operations continued through 1995 under the MMS Bowhead Whale Aerial Survey Project. Annual reports of the fall migration of bowheads are available through the fall of 1994.

A final report on the effects of production noise on bowhead whales also was completed. This study was conducted in ice leads during the spring of 1992 and 1995, and the responses of whales to drilling and icebreaking noises were measured. The report was reviewed by a Scientific Review Board that included representatives from the National Marine Fisheries Service, the North Slope Borough and the Alaska Eskimo Whaling Commission.

The MMS has long sponsored the development and field testing of satellite tags on whales. A final report on satellite tracking of bowhead whales in the Beaufort Sea was recently received by MMS.

University of Alaska researchers and students collecting Ponar grab samples during a Coastal Marine Institute project studying recruitment of juvenile flatfish near Kodiak, Alaska.



Living Resources

The MMS studies focus on species that are most vulnerable during further exploration for and possible development of OCS oil and gas resources in the Arctic. There have been recent studies on walrus, sea otters and eiders.

A study of the responses of satellite-tagged walrus to helicopter overflights, as well as the distribution of walrus and eiders in the Chukchi Sea, is being conducted under a memorandum of understanding (MOU) between MMS and the National Biological Service (NBS).

A study of the relative abundance and nearshore distribution of sea otters along the Gulf of Alaska near Yakutat Bay was conducted in 1995 under an interagency agreement between MMS and the Fish and Wildlife Service.

Environmental Monitoring

In 1995 a report was received from the Environmental and Natural Resources Institute at the University of Alaska Anchorage that detailed the results of water and sediment quality sampling in Cook Inlet in 1993. The study found no evidence of significant contamination of Cook Inlet, despite its 32-year history of oil development. The results of this survey are consistent with three reports issued by the Cook Inlet Regional Citizens Advisory Council in 1995, which describe the results of similar but less comprehensive samplings for 1993–1995.

Seabird colonies continue to be monitored in the Chukchi Sea and Cook Inlet through the MOU with NBS. These studies use standardized protocols to monitor numbers of birds on pre-established plots, reproductive success and feeding habits. Complementary studies by NBS personnel examined relationships between densities of foraging seabirds, reproductive success, oceanographic conditions and availability of prey species in the lower Cook Inlet region. Also, satellite telemetry was used to determine summer foraging and seasonal dispersal patterns of murres from Chukchi Sea and Barren Islands colonies.

A multiyear study, conducted by the National Institute of Standards and Technology and now funded through the MOU with NBS, continues to acquire, curate and analyze marine mammal tissues. This study archives tissues cryogenically for future analyses and samples baseline levels of chemical contaminants in tissues to monitor any increases that might be associated with oil and gas drilling and production. Called the Alaska Marine Mammal Tissue Archival Project, this project has been ongoing since 1987 and has served as a model for other similar programs. The project works closely with subsistence hunters to obtain needed tissues.

Social and Economic Studies

The MMS released an OCS study report entitled "Social Indicators Study of Alaskan Coastal Villages, Volume VI, Analysis of the *Exxon Valdez* Spill Area, 1988–1992." The original social indicators study was conducted with the Subsistence Division of the Alaska Department of Fish and Game (ADF&G) over four years among 31 villages in coastal Alaska. The project developed two valid social indicator systems sensitive to internal and external socioeconomic factors. The social indicators study was then enlarged to encompass several villages that were directly affected by the *Exxon Valdez* oil spill of March 24, 1989. This volume incorporates the results of interviews conducted in 10 villages in the oiled area and two villages outside the oiled area.

The MMS released an OCS Study Report entitled "An Investigation of the Sociocultural Consequences of Outer Continental Shelf Development in Alaska." The report provides selected findings from a three-year study; the findings are primarily organized by study community. The project was conducted by the ADF&G, under a cooperative agreement with MMS. The primary purpose of the research was to investigate the long-term social and cultural consequences of development of the resources of Alaska's OCS, especially as these affect subsistence uses of fish and wildlife. Investigation of the consequences of the *Exxon Valdez* oil spill was a major focus of the research.

A report on commercial fisheries in the Gulf of Alaska includes historical data and a forecast model. A study on migration and oil industry employment of Natives from the North Slope of Alaska is based on 52 interviews. The Rural Alaska Model, a predictive demographic model for several coastal Alaska communities, has been updated with 1990 census data and other post-1990 data.

The Alaska OCS Region has convened a number of large public meetings to summarize its research and communicate the results to the public. These information transfer meetings have been convened about every other year for the past two decades. In October 1995 an Arctic Synthesis Meeting focused on environmental information for the region around four Beaufort Sea development prospects. The technical sessions of the meeting were chaired by scientists from the University of Alaska, Fish and Wildlife Service and National Biological Service; additional presentations were given by Native whalers and scientists from the Environmental Protection Agency, the U.S. Navy and Canadian organizations. Copies of reports or plans are available from the Alaska OCS Region.

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The MMS Alaska OCS Region Environmental Studies Program released its "Alaska Environmental Studies Strategic Plan for FY 1996-97" in May 1995. The plan reflects priority information needs to support the MMS Alaska mission for those years.

Input from more than 150 sources was sought, including State and Federal agencies, environmental groups, industry, village councils and tribes, local governments, the MMS Scientific Committee, international contacts and other stakeholders.

National Biological Service

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

Most Arctic research of the Fish and Wildlife Service (FWS), the Minerals Management Service (MMS) and the National Park Service (NPS) is conducted from the Alaska Science Center, Anchorage, and the Cooperative Fishery and Wildlife Research Units at the University of Alaska Fairbanks. Some additional research is performed by others of the 15 national research centers or the more than 50 cooperative research units, each of which has special capabilities that may be applicable to problems in Arctic research.

In early 1993 FWS and NPS research programs were proposed for transfer to the NBS, a new bureau constituted by combining the biological research functions of a number of DOI bureaus. This transfer became effective with passage of the FY 94 Appropriations Act in November 1993. All FWS and NPS research activities reported in previous reports were transferred to the NBS, together with a few research-related activities formerly performed by operational units of the FWS.

Ecological research in Arctic ecosystems is difficult, given the harsh conditions, frequently inac-

cessible habitats and often wide-ranging movements of Arctic biota. It is also very costly. Since it has often been necessary to develop new methods of obtaining information, some of the most advance technologies have been developed for, or first applied to, research in the Arctic. Satellite-linked biotelemetry and molecular genetics are but two of many new techniques that have first been successfully applied to the problems of fish and wildlife conservation in the Arctic.

Wildlife Ecology

Since 1987, NBS scientists have conducted research on large predator-prey relationships in Denali National Park and Preserve. The studies are designed to determine the population dynamics of wolves and their major prey species and to investigate the effects of weather and differential landscape use on predator-prey relationships. To date, the studies have focused on wolves and caribou and have provided new information on the dynamics, social structure and genetic relationships of the wolf population; calf production, calf survival and adult survival patterns of the caribou herd; and the effects of winter snowfall relationships. At the beginning of the study, wolves occurred at a density of nearly 4/1000 km², and the Denali Caribou Herd numbered 2600 and was increasing at about 10% per year. With the onset of severe winters in 1988 and 1989 and the resulting increased vulnerability of prey, the wolf population increased by almost 60% in one year and ultimately doubled by the spring of 1990. Growth of the caribou herd stopped by the fall of 1990 at about 3500. By the fall of 1993 the herd had declined to 1700 after five severe winters in a row. The wolf population leveled off at about 7/1000 km² and then began to decline. The spring 1993 estimate was 6.2 /1000 km², or 17% less than the peak numbers. During

	Funding (thousands)	
	FY 94	FY 95
Marine mammals	1,600	1,342
Migratory birds	2,500	3,111
Fisheries research	360	898
Wildlife ecology	2,600	1,782
Total	7,060	7,133



Grizzly bear at Denali National Park and Preserve. Forty bears in the park have radio collars, allowing NBS to study reproduction and survival.

1993, survival of adult caribou cows was poor (80% compared to 96% in low-snowfall years) and of 40 calves born to radio-collared cows, only 2 survived to the fall of 1993. Wolf density continued to decline in the study population as the caribou population declined, reaching 5.8 /1000 km² during the spring of 1994. Winter 1993-94 was mild compared to the previous five winters, and overwinter survival of caribou improved. Calf production in 1994 was the highest during the study, with a 95% natality rate for 397 cows observed in mid-May. Radio-collared cows also experienced high productivity overall, primarily because of increased production by 2- to 4-year-old cohorts. Of 70 calves produced by radio-collared cows, 44 died by June 1994, and the herd had 38 calves: 100 cows, the highest since 1989. The fall 1994 herd size was estimated at 2100 caribou, indicating that the decline during 1991-1993 had ended.

Another study related to predator-prey relationships was initiated in Wrangell-St. Elias National Park and Preserve in 1993. This study is monitoring the annual demographics of the Mentasta Caribou Herd and determining factors influencing the neonatal survival of caribou calves. The herd had declined from approximately 3200 caribou in the late 1980s to less than 900 in 1995, leading to controversial closures of state and Federal hunting seasons in the early 1990s. From 1993 to 1995, pregnancy rates of cows greater than one year old ranged from 65 to 92%, but mortality rates of calves ranged from 76 to 97% each year. Of 112 dead calves examined over three years, 96 died from predation (86%), including from wolves (54%), bears (35%), wolverines (2%), coyotes (1%), eagles (2%) and unknown predators (6%). Through future analyses NBS hopes to improve understanding of population limitation of caribou

at low densities by examining relationships among population density, calving distribution and cause-specific mortality rates of caribou calves in the absence of intensive management of predators.

A naturally regulated grizzly bear population is under investigation in Denali National Park and Preserve. The primary objectives of grizzly bear research are to determine factors that drive bear population dynamics and to develop cost-effective, long-term monitoring techniques for bears. Radio transmitters on 40 bears allow close monitoring of the reproductive performance and survival of individual bears and a measure of visibility bias during aerial surveys. The female age distribution was bimodal, with 11 bears 16-26 years of age and 10 independent bears 3-9 years. The average litter size was 2.2 cubs at the time of den emergence. The annual mortality averaged 0.61 for cubs-of-the-year and 0.47 for yearlings. Such high mortality of dependent bears may be the cause for the lack of young adult females in the population. Grizzly bear density was 27.3 independent bears/1000 km², fairly high for an interior Alaska grizzly population. Published densities for hunted bear populations east of Denali varied from 6.7 to 19.1 bears/1000 km². Fall density estimates provided higher sightability and lower visibility bias than spring bear surveys. Ninety-five percent confidence intervals were within 10% of the mean after only three repetitions during September, compared to spring densities from nearby populations with confidence intervals in excess of 20% of the mean after seven repetitions.

A coastal brown bear study in Katmai National Park and Preserve was recently completed after seven years of intensive field work. The project was a cooperative effort of the Alaska Department of Fish and Game, the NPS and the NBS. Research objectives included an estimation of the bears' reproductive histories and population dynamics, their movements and distributions, and habitat relationships. Radio transmitters were placed on 122 bears between 1989 and 1993, with an average of 35 transmitting at any point in time. Preliminary data analyses indicate that the population structure and dynamics of the unhunted Katmai bears differ significantly from those of a hunted population at nearby Black Lake: Katmai has a higher ratio of adult males to females, adults with a higher mean age, a lower survival rate for cubs, and lower productivity (litter size) than Black Lake bears. These observations support the primary research hypothesis that selective removal of male adults from the Black Lake population will result in predictable changes in overall population dynamics. Habitat relationships, movements and home ranges are being analyzed. Additional work in Katmai has

focused on brown bear and human interactions at various backcountry locations. The work sought to quantify these interactions and provide management instruction for park staff. In conjunction with the coastal brown bear study, an effort was made to generate a land-cover classification for plant communities within Katmai National Park and Preserve. Field work provided raw data, which, when used with Landsat imagery, will be used to map plant communities in the park. This land-cover map will provide an integral baseline for future research as well as interpretation of brown bear habitat relationships for the studied coastal brown bear population.

Research on the coastal plain of the Arctic National Wildlife Refuge (ANWR) seeks basic information on the ecology of species of management concern to the FWS and specific information on the effects of development in order to understand and predict the effects of potential petroleum exploration and development. The species of greatest concern are polar bears, certain populations of Arctic-nesting geese and populations of large herbivores, including caribou and muskoxen. A focal point for investigations is the "1002 Area," a portion of the refuge potentially available for petroleum development. Related studies focus on areas outside the refuge where petroleum has been under production for more than a decade.

Caribou occupying areas now in petroleum production belong to the Central Arctic Herd (CAH), while those that occupy the 1002 Area are from the Porcupine Caribou Herd (PCH). Caribou undertake annual migrations, driven by the need to find suitable wintering grounds, favorable areas for calving and relief from harassment by biting insects. The PCH winters in Canada and migrates northward and westward toward the coast of the

Beaufort Sea at calving time. The exact location of calving varies, depending on snow cover, but calving grounds consistently occur on the Arctic coastal plain. Calving caribou are thought to be safer there, because the open topography permits the caribou to sight any predators at relatively great distances. Forage species are generally abundant, but their availability depends on the timing of annual weather events. The concentrated calving appears to be correlated with the zone of peak plant biomass production. In 1995, 92% of the calving occurred within the 1002 Area. Research on breeding success indicates that reproduction is much more likely to be successful if calving takes place on the coastal plain; losses of calves from various causes are greater when calving occurs closer to the foothills. After calving, caribou move toward the coast or mountains to seek relief from insects, which reach greater abundance in the short summer. The use of specific habitats by the PCH has been documented, with the intent of evaluating their availability within the 1002 Area and adjacent areas and their importance to caribou. Parallel studies of the CAH have sought to understand their relationship to the disturbance caused by oil production activities and the possible effects of developments in disrupting normal migration routes. Reproductive success in the portion of the CAH studies is lower than in the PCH, but the reason for this is still unknown. Also, the CAH has shown an initial period of growth despite apparently poorer reproduction; the population appears to be declining from a high of 21,000 in 1994.

Research on muskoxen examines the ecology of a small reintroduced population. Muskoxen are year-round inhabitants of the Arctic coastal plain and could conceivably be affected by oil-drilling activities in winter. The population has grown to about 750 animals but seems to have stabilized at 300–400 adults on the refuge. Continuing research focuses on dispersal patterns, habitat utilization and status of the population.

Between 1987 and 1995 the NBS measured nesting territory occupancy and reproduction of golden eagles in Denali National Park, Alaska. Data on occupancy and three reproductive variables (pairs nesting, pairs producing fledglings and fledgling production) were collected at 66–111 nesting territories each year using two aerial surveys. From 1987 to 1995 the total number of fledglings produced annually averaged 44.8, ranging from 9 fledglings in 1994 to 83 fledglings in 1989. Overall nesting territory occupancy averaged 66.33% and did not vary significantly among years. The proportion of pairs nesting averaged 65% and varied significantly among years. The proportion of pairs producing fledglings averaged

*Caribou in the 1002 Area
of the Arctic National
Wildlife Refuge.*



48% and differed significantly among years. Decreases in pairs nesting were correlated with decreases in average daily numbers of snowshoe hare and willow ptarmigan observed in the study area.

Placer mining for gold has severely disturbed many riparian ecosystems in northern regions. A long-term, multidisciplinary study was initiated in 1988 to test methods to promote the restoration of a placer-mined watershed in Denali National Park and Preserve. Research components of the project include:

- Hydrologically restoring the unstable and excessively confined stream with heavy equipment;
- Developing and testing bioengineering techniques to stabilize the floodplain until natural revegetation occurred, including alder and willow brush bars anchored laterally to the channel, willow cuttings along the channel, and buried alder and willow brush projecting from the bank;
- Monitoring aquatic invertebrates and water chemistry;
- Measuring natural succession on regraded spoil with differing moisture and nutrient conditions; and
- Testing revegetation techniques for dry, low-nutrient spoil above the active floodplain, including planting alder, willow, white spruce and soapberry.

A moderate flood near the end of the construction phase of the hydrological restoration showed that the brush bars provided substantial protection, but some bank erosion, slope changes and sinuosity increase occurred in several stream reaches. An analysis of the effects led to further experiments with increased channel depth and sinuosity, pool/riffle construction and bank protection. The reconstructed stream and floodplain have remained stable for three years but have not been retested by another large flood. Natural revegetation to the typical willow/alder riparian plant community has occurred on the new floodplains, but the plants are still small after four years, and the vigorous willows that sprouted from branches in brush bars and planted cuttings still provide the erosion protection. Processed spoil above the floodplain has not naturally revegetated after seven years, but the planted alders have grown well on these harsh sites and have promoted vigorous willow growth.

An integrated watershed approach to ecological monitoring has been under development at Denali National Park and Preserve since 1992. The research is part of the National Inventory and Monitoring Program of the National Park Service. The multidisciplinary research has concentrated on

protocol development and testing in four habitats characteristic of Rock Creek watershed, a head-water stream in the northeastern section of the park. Core measurement programs address air, land and water components of the ecosystem, as well as connecting physical, chemical and biological interactions. A major research endpoint will be the description of a sustainable, long-term monitoring program. At present, much, but not all, of the research is confined to the 825-ha watershed.

Fifteen monitoring protocols are being developed. A significant new research direction emphasizes terrestrial and aquatic systems interactions. The objective of this research is to describe chemical changes in soil water as it migrates downslope and into the mountain stream. In-situ experiments are being conducted in Rock Creek to examine nutrient effects on primary and secondary productivity. Investigators hypothesize that the relationships between soil water, stream nutrient status, algal response and invertebrate community structure will result in an aquatic monitoring program that provides early signals of change occurring in the terrestrial environment.

Fisheries Research

NBS fishery research in Alaska continued to focus on Yukon River salmon, an anadromous resource shared by the U.S. and Canada. Allocation of the salmon harvest continues to be an international issue. The objective of the research has been to determine what portion of harvested populations are of U.S. and Canadian origin, as a basis for allocating the harvest. U.S. harvest limits must ensure an adequate escapement of migrating fish to Canadian portions of the river system. There is an extended period of migration, with different peaks for chinook and chum salmon and for fish populations spawning in different part of the river system. At any given time the salmon runs at a particular point will be composed of different proportions of different stocks. Using innovative molecular DNA techniques, scientists have been able to more accurately distinguish stocks. Further molecular DNA studies are underway to refine estimates of the percentage of chum salmon stocks that originate from U.S. and Canadian waters. The information produced in these studies has been an important component of international treaty negotiations and was presented as a report for the U.S./Canada Joint Technical Meeting in March and November 1995. Preliminary work on determining limits to the freshwater production of fall chum salmon and on the distribution of spawners, run timing and run composition through radiotelemetry was also begun in 1995.

Migratory Birds

The buff-breasted sandpiper is a medium-sized shorebird that breeds sporadically along Arctic coasts from central Alaska to Devon Island, Canada. It winters in South America on the pampas of Argentina, Uruguay and Paraguay. The species is unique among North American shorebirds in having a lek mating system. Males defend relatively small territories that provide no resources for females and are simply display sites to which females can be attracted. Females select a mate and then leave to nest and raise their chicks elsewhere.

An intensive behavioral ecology study of this species, involving the marking of a large number of individuals and genetic paternity assessment, produced some surprising findings. Behaviorally buff-breasted sandpipers were found to be unlike most other lek-breeding birds. Within- and among-year surveys indicated that buff-breasted sandpiper leks were seldom traditional among years, that most leks lasted for only a few days within a year, and that males regularly displayed on solitary sites, as well as leks, throughout the breeding season. Some males also displayed near nests, apparently in an attempt to copulate with egg-laying females. This variable male mating behavior appears to be tied to the species' ability to move easily over a large area and hence take advantage of unpredictable breeding conditions in the high Arctic.

Paternity analyses of some 47 broods over a two-year period also yielded unpredictable results. Behavioral observations of females copulating with males on leks indicated that a small percentage of males acquired most of the copulations (similar skews in male mating success are seen in most lemming species). However, paternity analysis using DNA fingerprinting indicated that few males copulated with more than one female. This discrepancy appears to result from males using alternative reproductive tactics (for example, stealing copulations from other males on leks), females mating with solitary males off leks, and multiple mating by females. Indeed, multiple-paternity was documented in 19 of 47 broods. This low variance in male mating success also helps explain the variable mating behavior of males.

One of the last mysteries in North American waterfowl biology was the location of the wintering area of the spectacled eider. No one had ever found the hundreds of thousands of birds that disappeared from the breeding grounds at the end of the nesting season and appeared again the next spring. As the nesting population on the Yukon-Kuskokwim Delta declined dramatically from the 1970s to the 1990s, it became increasingly important to locate previously unknown molting, staging

and wintering areas. Was the decline a result of something happening to the birds while they were at sea?

Miniaturization of satellite transmitters had developed by 1993 to the point that they were small enough for an eider. In addition the techniques for implanting transmitters with an external transmitter were perfected. Satellite tracking of adult males and females from the breeding grounds resulted in locating concentrations of molting males and females at sea, following their general migration routes from the molting areas to the fall staging area, and a possible location for the previously undescribed wintering area. Subsequent aerial surveys of those areas verified that thousands to tens of thousands of birds were in these locations. One area, eastern Norton Sound, Alaska, was the only area used by females from the Yukon-Kuskokwim Delta. An area close to the eastern Chukotsk Peninsula, Russia, was used by males from the Yukon-Kuskokwim Delta and the Indigirka River Delta, Russia, and an area off the coast of Alaska in the Chukchi Sea was used by females from the North Slope of Alaska. It is also probable that most males that breed in Russia molt off the coast in the Russian Arctic Ocean. Birds move many miles offshore parallel to the coast or across the Bering Sea until they reach an area south of St. Lawrence Island, Alaska, in the fall. Contrary to what had been hypothesized in the literature, spectacled eiders winter in dense flocks in holes in the pack ice in the northeastern Bering Sea.

Although the mystery of where this colorful bird molts and winters has been solved, the questions remain as to the cause of the decline of nesting birds on the Yukon-Kuskokwim Delta. Related research by biologists from the Alaska Science Center, the U.S. Fish and Wildlife Service, the North Slope Borough and several private consulting firms is being conducted in a coordinated attempt to determine the cause(s) for the decline and the status of the populations remaining in eastern Arctic Russia, the North Slope of Alaska and the Yukon-Kuskokwim Delta.

Prior to autumn migration, up to 400,000 lesser snow geese from the western Canadian Arctic population use the coastal plain of the Beaufort Sea as a staging area. The staging area includes part of the ANWR in Alaska. Snow geese arrive on the staging area in late August and remain until winter storms in September cause them to migrate. They feed intensively and accumulate body fat that is used as a source of energy during migration.

During staging on the ANWR, snow geese primarily consume two items: the underground stem-base of tall cottongrass and the aerial shoots of

northern scouring rush. Cottongrass stembases are highly digestible, and on a daily basis a snow goose consumes the equivalent of about 30% of its body mass in cottongrass. Because they consume large volumes of a highly digestible forage, adult snow geese on the ANWR have one the highest daily rates of fat accumulation (22 g/day) reported for an Arctic goose.

Snow geese are highly selective in their choice of feeding habitats. They use riparian terraces when feeding on northern scouring rush. They exploit small patches of cottongrass in flooded areas of thermokarst pits, water tracks and troughs. Because forage patches are small, subdominant geese are displaced to poor-quality habitats, where their rates of nutrient intake are reduced. Cottongrass forage patches are widely distributed but comprise less than 3% of the ANWR coastal plain east of the Hulahula River. Snow geese use a very large staging area because they consume large volumes of forage in feeding habitats that are small and patchily distributed and comprise a small percentage of the landscape. Temporal and spatial distribution of snow geese is likely influenced by forage availability.

Marine Mammals

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

Studies of polar bear movement patterns have been ongoing for a number of years using satellite telemetry technology. Movements of bears marked in the Chukchi population are the most extensive recorded for polar bears, where annual ranges may exceed 400,000 km². Over 95% of all detected denning occurs in Russian territory, with the majority occurring on Wrangel and Herald Islands. Survey methodologies for aerial censuses of polar bears in

western Alaska were tested in northern Alaska, and a final survey protocol is being developed for a range-wide census of the Chukchi Sea population during minimum ice cover in late summer. Movement data from satellite instrumented females indicate that the population is concentrated along the ice edge at this time, and the minimum areal extent of the population occurs during this period. Movement and DNA data indicate that the Beaufort and Chukchi Sea populations are somewhat segregated, with an undefined degree of interchange occurring during the winter. Further genetic research and detailed analyses of all available movement data will be used to define the degree of interchange between the two populations.

Research using satellite radiotelemetry has revealed previously unknown features of polar bear ecology and population dynamics. Most polar bears maintain large but relatively discrete activity areas. Multi-year activity areas averaged 160,000 km², and some exceeded 500,000 km². Some animals seasonally moved east into Canada and west into Russia, but most showed summertime fidelity to the central Beaufort Sea north of Alaska. Rare individuals, however, migrated across the remotest portions of the polar basin, suggesting that genetic mixing among polar bears is global. Polar bears give birth in dens of ice and snow that females construct in autumn. In the Beaufort Sea region, over half of the dens observed in the last 12 years were on the drifting pack ice remote from the coast. The proportion of dens on land, however, appears to be increasing. The total hunting take in Alaska declined after the early 1970s, and takes of bears in denning areas by local Native people have declined since the 1920s and 1930s. Accordingly the population has grown, and land denning areas apparently are being re-established. Hunting, even though it is now limited to local resident Native people, remains the single most significant cause of death among adult polar bears. It appears that polar bears are relatively resilient to human perturbations other than shooting. The size of the Beaufort Sea population apparently has grown steadily since the discovery of oil in northern Alaska and Canada, despite the attendant increases in human presence. Evidence suggests that the Beaufort Sea population may now be at or near the carrying capacity of the environment. Radio-collared adult polar bears had very high annual survival rates, actually approaching 1.0, but recruitment of new animals into the population appeared to be low and was inversely related to population size. Young animals apparently are having a difficult time surviving in the crowded and competitive environment. Added studies of ecological interactions among polar bears, seals and other compo-



Collecting data on polar bears on Wrangel Island, Russia.

nents of the ecosystem are necessary to verify this hypothesis and to identify limiting factors.

Past research on Pacific walrus was primarily concerned with refining current census methodologies to account for those portions of the herd that may periodically be unavailable for sighting during aerial surveys. Because of the logistical considerations of surveying such a vast area, the technical difficulties of operating in Russian territory and the increasing costs of surveys, the NBS research program on Pacific walrus has been refocused on the trophic ecology of Pacific walrus in Bristol Bay. Initial efforts include the development of an international Pacific walrus database, which will include data from Russian and American scientists concerning census, harvest and habitats. Research is also underway to develop more effective drugging protocols for tagging walrus, with special emphasis on safely extending the anesthetization and marking period by using isoflurane gas. In conjunction with the immobilization work, studies of improved satellite tags have been implemented at summer haulouts in western Alaska to better define offshore feeding areas and haulout patterns. These data will be used to develop a research program that investigates the interrelationships between walrus and their prey in western Alaska and the Chukchi Sea.

Division of Cooperative Research

The NBS is involved in a national program of cooperative fish and wildlife research in partnership with state fish and wildlife agencies, land grant universities and, in some instances, the Wildlife Management Institute. The cooperative units were organized within the FWS but were transferred to

the NBS in 1994. The Cooperative Fish and Wildlife Research Unit Program has university-based units in 38 states and is nationally administered from a headquarters office in Washington, D.C. Cooperative Fish and Wildlife Research Units have traditionally had a great deal of latitude to respond to local issues and needs in choosing research projects. The major goals of the cooperative research program are to provide specialized graduate-level training for fish and wildlife biologists, to conduct related research and to provide technical assistance to cooperating national resource agencies. The training is usually provided by joint participation in research projects by faculty and students. The NBS funds salaries and some administrative costs, but funding for research projects is usually obtained elsewhere on a project-by-project basis. Research funding for the Alaska Unit, for example, comes from the Alaska Department of Fish and Game, other bureaus of the Department of the Interior (including the Fish and Wildlife Service, the Geological Survey, the National Park Service and the Bureau of Land Management) and other Federal agencies (including the National Science Foundation, the U.S. Forest Service and the Environmental Protection Agency).

The Alaska Cooperative Fish and Wildlife Research Unit continued studies of water quality in Arctic wetlands and continued a variety of fishery investigations, emphasizing rainbow and steelhead trout, Dolly Varden and northern pike. Studies of Arctic grayling examined the feasibility of culturing yearling fish in net pens. Studies of threatened, endangered and candidate species included investigations of the effects of low-level aircraft disturbance and of survival rates of peregrine falcons in Alaska and of the status and ecology of island subspecies of wolves and voles proposed for listing. Waterfowl investigations included studies of brant, lesser snow geese and pintails, conducted in cooperation with related studies at the NBS Alaska Science Center. Research on mammals also included work related to Alaska Science Center studies of muskoxen, caribou and walrus, as well as unrelated studies of black bears in interior Alaska, reindeer in the Beringian Heritage International Park and Sitka black-tailed deer on Kodiak National Wildlife Refuge. Research on nongame mammals included the development of a small-mammal monitoring program at Denali National Park, and mink and marten habitat and distribution studies. The expertise of Cooperative Fish and Wildlife Research Units located in other states is also applied to Arctic research issues. For example, the Ohio Cooperative Fish and Wildlife Research Unit is conducting research on breeding birds in Alaska.

Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) conducts research, including inventories and monitoring, in the Arctic to generate information that will help meet its resource management responsibilities. These responsibilities include conservation of migratory birds, certain marine mammals, endangered species, anadromous fishes and all biota inhabiting National Wildlife Refuges and other FWS lands. Most Arctic research of the FWS is conducted from the Alaska Fish and Wildlife Research Center, Anchorage, and the Cooperative Fishery and Wildlife Research Units at the University of Alaska Fairbanks. Some additional Arctic research is performed by others of the 13 national research centers or the more than 30 cooperative research units, each of which has special capabilities that may be applicable to problems in Arctic research.

In November 1993, FWS research programs were transferred to the National Biological Survey (NBS), a new bureau that was formed by combining the biological research functions of a number of Department of Interior bureaus. The FWS continues to conduct inventory and monitoring programs of biota in the Arctic at both the national and international levels.

Migratory Birds

Migratory birds of the Arctic regions of Alaska include substantial populations of Arctic nesting geese, swans, ducks, shorebirds and seabirds. A few populations of migratory birds have declined to levels that cause concern. Factors affecting population status include harvest, predation, impact of human activities and habitat disturbance. Inventory and monitoring efforts continue on Pacific black brant, white-fronted geese, lesser snow geese, northern pintails and bristle-thighed curlews. Substantial monitoring programs also coexist for several species of seabirds, raptors and shorebirds, such as black-legged kittiwakes, pigeon guillemots, bald eagles, marbled murrelets and murres.

Marine Mammals

The FWS in Alaska is responsible for managing three species of marine mammals: the polar bear, the Pacific walrus and the northern sea otter. Of these three species, the polar bear and walrus are characteristic of Arctic regions. Populations of both species are shared with Russia, and polar bear populations are also shared with Canada. A major focus of research on these populations relates to international actions that will be neces-

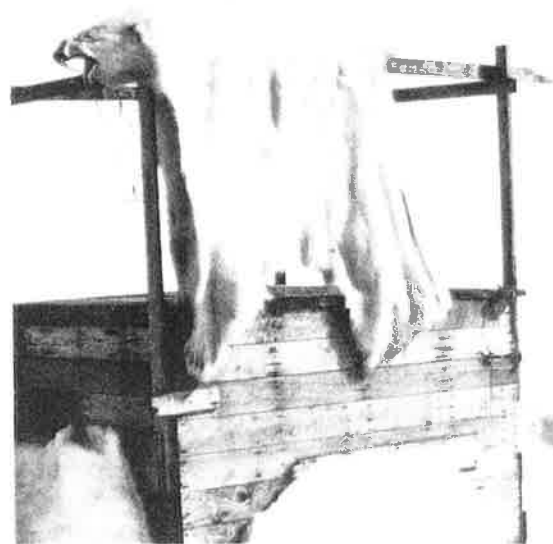
	Funding (thousands)	
	FY 94	FY 95
Migratory birds	2,817	2,718
Fisheries	3,103	2,739
Marine mammals	1,593	1,572
Total	7,513	7,029

sary to conserve populations. The issue of harvest is important, because both species have been subject to legal or subsistence harvest or both, and research seeks to develop methods of defining and monitoring populations so that local or region-wide populations do not become depleted by excess harvest. Another issue addressed by research is the potential impact of human activities on areas that may be essential for the stability of populations.

The FWS Marine Mammals Management Office continued to collect information from polar bears taken by Native hunters in coastal villages for subsistence purposes. The majority of polar bears are killed during the winter, when advancing pack ice brings bears into contact with coastal Alaska Natives. Harvest numbers are therefore reported on a "harvest year" basis, which runs from July 1 through June 30. The Alaska kill during the 1993-94 and 1994-95 harvest years totaled 123 and 80 bears, respectively. The recent harvest trend continues to be approximately 33% below the long-term average. The sex ratio of known-sex polar bears in 1993-94 was 58% male:42% female; in 1993-94 it was 66% male:34% female. Sex was unrecorded for less than 10% of the harvest.

Specimens to evaluate genetic proof of sex and contaminants continue to be collected as part of the harvest monitoring program. To verify the sex of

For more information about
migratory birds, please
contact Robert Leedy at
(907) 786-3446.



One of the subsistence-harvested polar bears that provide samples for a variety of research projects.

harvested bears, 177 muscle and tissue samples—40 (28.8%) from the southern Beaufort Sea stock and 99 (71.2%) from the Chukchi Sea stock—were analyzed using genetic techniques. Sex could not be determined for 30 samples due to tissue degradation and subsequent desiccation, which prevented DNA amplification. The sex was correctly identified for 86% of the harvest. Many of the misidentifications occurred when multiple bears were harvested and the sex associated with a hide or skull was not properly remembered or reported. In other cases, morphological characteristics on the hides were incorrectly identified. Thirteen of the 19 bears that were incorrectly sexed were subadults or cubs. The findings of this study reveal a need for improvement in reporting the sex of harvested animals. Modification of the harvest data collection procedures is warranted and may include the continued genetics verification of sex of all harvested animals or the development of a requirement that a baculum accompany all harvested males.

Elevated heavy metal and organochlorine concentrations have been documented in Canadian polar bear populations. Heavy metal concentrations had been documented in polar bears in the 1970s, prior to oil and gas development on the North Slope. However, recent information on heavy metal contamination of polar bears in Alaska is scarce. The preliminary results of a recent circumpolar study on organochlorine concentrations in Alaska reveal some of the lowest levels present in Alaska bears. Polar bears are ideally suited for monitoring the level and distribution of heavy metal and organochlorine levels in the Arctic ecosystem because of their position at the top of the Arctic marine food chain and their wide distribution. To date, tissue samples from six bears have been collected and submitted for organochlorine and heavy metal analysis, with results pending.

In August 1995 the FWS completed the Polar Bear Habitat Conservation Strategy (HCS). One of the goals of the HCS was to develop and implement measures to protect polar bear feeding habitat. Marine mammal carcasses represent tons of potential food for polar bears and may be particularly important for the survival of females with cubs and younger bears during the fall. To document the abundance and distribution of marine mammal carcasses, primarily Pacific walruses, bearded and ringed seals, and beluga, bowhead and gray whales, aerial surveys were conducted in 1995 along the Alaska coast from Nome to the Canadian border. In July 1995, 168 carcasses (83 walruses, 79 seals and 6 whales) were recorded along the coastline of the Bering, Chukchi and

Beaufort Seas. In September 1995, 94 carcasses were recorded (68 walruses, 20 seals and 6 whales) along the coastline from Nome to Barrow. Future research objectives are to determine the gross caloric value of carcasses and their utilization by polar bears.

The Pacific walrus is also subject to subsistence harvest by Alaska Natives. The estimated state-wide harvest of walruses in 1994 and 1995 from Marking, Tagging and Reporting Program (MTRP) data collected by village taggers was 1305 and 973, respectively. In addition to the MTRP, the FWS conducts the Walrus Harvest Monitoring Project (WHMP) to monitor the spring walrus harvest in the villages of Gambell, Savoonga, Diomede and Wales, Alaska. The spring harvest estimates from these selected villages were 984 and 1205 in 1994 and 1995, respectively. Analysis of the data from both the MTRP and the WHMP indicates that compliance with the MTRP ranged from a low of 41% in Savoonga in 1994 to a high of 99% in Diomede in 1995.

The FWS continues several studies assessing walrus health. In cooperation with the Armed Forces Institute of Pathology, a study was initiated to examine the relationship between concentrations of heavy metals in liver and kidney tissues and organ function. In 1995, biological samples were collected from walruses harvested by Native hunters near Gambell, St. Lawrence Island, during hunts observed by a biologist from FWS. Tissue samples from 12 animals were collected for the Alaska Marine Mammals Tissue Archival Project, an interagency project dedicated to the collection and long-term storage of marine mammal tissues suitable for determining levels of organic and inorganic toxic substances. Blood samples from 20 walruses collected during the hunts were analyzed for infectious disease serology and toxicology. The toxicology results will be compared with similar tests on liver and kidney tissues.

The FWS continued to monitor the number of walruses at selected sites in Bristol Bay. In addition, a study to monitor the impact of human activities on walruses at two major terrestrial haulouts was conducted in 1994 and 1995. At Round Island, Walrus Islands State Game Sanctuary, FWS and Alaska Department of Fish and Game biologists performed daily counts of the number of walruses using terrestrial haulouts and collected hundreds of hours of behavioral observations. At Cape Pierce, Togiak National Wildlife Refuge staff performed daily counts of walruses and collected behavioral observations on an opportunistic basis. This information will be used to assess the impact of tourism, aircraft and Native hunting activities on the use of the island as a walrus haulout.

Fisheries

FWS fishery research in Alaska focused on Yukon River salmon, an anadromous resource shared by the U.S. and Canada. Allocation of the harvest has been an international issue. The objective of the research has been to determine what portion of harvested populations are of U.S. and Canadian origin, as a basis for allocating the harvest.

The Alaska Region of the FWS has participated in U.S.–Canada Yukon River treaty negotiations under the Pacific Salmon Treaty and has been instrumental in providing technical guidance in support of the international negotiations. As part of the effort, the FWS Fish Genetics Laboratory has tested the feasibility of using genetic stock identification (GSI) methods to determine what portions of the chum and chinook salmon harvests are of U.S. and Canadian origins. GSI methods are also used to assess run timing, bank orientation and stock composition in mixed-stock fisheries. The goal of this research is to maximize harvests while ensuring that individual stocks achieve spawning escapement objectives.

Most of the GSI work has used protein electrophoresis as the primary source of genetic information. Recent advances in genetics technology now allow biologists to easily access new sources of genetic information in the DNA molecules. In a continuing effort to improve the utility of the GSI methods for stock discrimination, the Fish Genetics Laboratory has collaborated with NBS and the Alaska Department of Fish and Game (ADF&G) to determine the suitability of applying new molecular genetics methods to better discriminate between Canada and U.S. fall-run chum salmon stocks. These methods have been applied in other systems to describe patterns of genetic substructuring, with better resolution than could be obtained from protein-based methods. The results will conclusively determine the suitability of specific genetic markers for resolving stocks of Yukon River fall-run chum salmon.

To maintain biodiversity and resource health, an adequate number of salmon in any particular stock must be permitted to return to their home stream of origin. The number that returns to spawn is called escapement. Escapement information is used to schedule fishery openings and to ensure stock conservation, so it is crucial that fisheries managers have accurate and timely information. The FWS has operated floating resistance board weirs and split-beam sonar to ensure adequate escapement of National Wildlife Refuge salmon stocks. Floating weirs spanning 100 m have been used to count over 500,000 salmon in Yukon River tributaries. The FWS has also pioneered the devel-

opment of split-beam sonar technology to count riverine populations of adult salmon.

On the Selawik National Wildlife Refuge and Kobuk Valley National Park, sheefish support substantial subsistence fisheries that are of great practical and cultural importance to the residents of the region. In cooperation with the ADF&G, the FWS initiated a study in 1994 to quantify distribution, abundance, genetics and life history characteristics of Selawik and Kobuk River sheefish populations. Distribution and abundance were assessed with mark–recapture techniques. To locate spawning grounds, adult sheefish were surgically implanted with radio transmitters to permit biologists to track their movements from airplanes and boats. The Fish Genetics Laboratory characterized the genetic substructuring of the population using nonlethal tissue sampling and new molecular genetics methods. The information derived from the study will permit managers to maintain healthy, naturally reproducing stocks of sheefish.

Kuiyah Flats on the Koyukuk River supports Alaska's most northern population of trophy northern pike. The FWS implanted radio transmitters in adult northern pike and monitored their movements for 18 months to determine their range and identify overwintering areas. A large population of northern pike spent the winter concentrated in small areas, indicating that wintering habitat was an important density-dependent factor influencing population dynamics.

International Circumpolar Activities

Area V

Since 1972 the U.S. and Russia have been involved in international negotiations regarding the protection of nature and the organization of reserves. In 1994 the U.S.–Russia Environmental Agreement was signed (renegotiated from the 1972 U.S.–U.S.S.R. Environmental Agreement). Under this agreement, conservation agencies and other organizations in both countries actively sponsor exchanges of American and Russian specialists in rare and endangered fauna and flora, refuges and reserves, migratory birds, marine mammals, fish husbandry and terrestrial/marine ecosystem biodiversity. Joint projects have made significant contributions to the protection and management of shared species.

The FWS is involved in a number of Area V initiatives. The Conservation of Wild Species of Fauna and Flora and the Protection of Natural Areas project's primary goal is to promote conservation of individual species or groups of species

(especially migratory) and their habitats. Biologists from both countries continually exchange expertise and collaborate in field studies to contribute to scientific knowledge and foster a more effective management approach. Six activities comprise the work of this project:

- Implementation of the 1976 U.S.–Russia Convention Concerning the Conservation of Migratory Birds and their Environment, which monitors and promotes the study and protection of more than 200 bird species;
- Study and conservation of cranes, raptors and other rare birds, including the establishment and maintenance of stable, reproducing populations of rare and endangered species of birds, both in the wild and in captivity;
- Study and conservation of rare and endangered mammals, including the development of specific measures for their protection and management, such as the development of a Bilateral Polar Bear Management Agreement, joint polar bear denning surveys and the study of radionuclide accumulation in polar bears;
- Study and conservation of protected natural areas, including military–civilian cooperation in land management and a small grants program where the U.S. awards small grants for technical assistance to nature reserves, parks and other protected areas of Russia;
- Cooperation among zoos in captive breeding of rare and endangered animals; and
- Conservation and management of marine birds, including coordination of joint seabird studies and exchanges of data through annual meetings.

Plans for 1996 include preparation of a status assessment of marine birds breeding in the Beringia region; hosting a Russian Far East Seabird Symposium; completion of a Beringian Seabird Colony Catalog and bibliographic database, and a Beringian Seabird Bulletin; and completion of a bibliography of the literature of north Pacific shorebirds.

Another Area V initiative that FWS leads is the Aleutian Chain Biodiversity Project, which focuses on joint studies of the species occurring in National Wildlife Refuges of southeastern Alaska, the Alaska Peninsula and the Aleutian Islands, and the nature reserves of northeastern Russia, the Kamchatka Peninsula and the Commander Islands of Russia. In a Sister Refuge program, proposed for establishment in 1996, scientists and information will be exchanged regarding inventory and monitoring of brown bears, migrating raptors and coastal plant communities.

Cooperative studies of the biology, ecology and population dynamics of marine mammals species

are also underway. FWS species studied under the Area V initiatives include sea otters and walrus.

The Animal and Plant Ecology Project focuses on cooperative research into the ecology of single species and communities of fauna and flora in the U.S. and Russia. Activities include studies of:

- Rare and endangered species of plants and the introduction of exotic species in both countries;
- Northern migratory waterfowl, specifically snow geese, Aleutian Canada geese and spectacled and Steller's eiders;
- Holarctic mammals;
- Chemical senses and communication in animals;
- Application of contemporary technology, such as sea ice mapping distribution, in studies of large mammals such as polar bears; and
- Wildlife health and disease, such as the effects of lead poisoning in waterfowl.

The Area V Ichthyology and Aquaculture Project seeks to improve fisheries management, increase productivity through intensive fish culture, restore fishery resources and exchange information on the physiology, nutrition, diseases genetics and reproductive biotechnology of mutual fish species.

The FWS also leads the effort to facilitate cooperation in wildlife trade and law enforcement activities to provide technical assistance and training for the conservation of endangered species in the Russian Far East. In addition, conservation education efforts are underway to enhance public awareness of and commitment to the need to conserve wild species of flora and fauna, as well as their habitats.

Conservation of Arctic Flora and Fauna

The FWS participates in a separate international initiative that falls under the umbrella of the Arctic Environmental Protection Strategy (AEPS) and is known as the Conservation of Arctic Flora and Fauna (CAFF). CAFF is one of four programs under AEPS, which was adopted by Canada, Denmark/Greenland, Finland, Iceland, Norway, Russia, Sweden and the U.S. in 1991. The FWS participates on the CAFF International Working Group, which was established in 1992 and consists of scientists, conservation managers and groups, and indigenous peoples of the north. CAFF provides a circumpolar forum in which a wide range of Arctic conservation issues can be discussed. CAFF's focus is habitat conservation, species conservation within an ecosystem approach, biodiversity and the integration of indigenous peoples and their knowledge into the work of CAFF. Some

CAFF projects are:

- Inventory and monitoring of rare, vulnerable and endangered plants and animals of the Arctic;
- Development of circumpolar conservation strategies for certain species;
- Inventory and mapping of Arctic vegetation;
- Analysis and recommendations on threats to Arctic species and habitat;
- An indigenous peoples mapping project; and
- Development of a strategy for the Convention on Biological Diversity in the Circumpolar Arctic.

In 1995 CAFF also developed a strategy and action plan for the Circumpolar Protected Areas Network (CPAN). This plan provides a complete directory of protected areas in the Arctic, describes strategies for assuring the continued viability of Arctic ecosystems and provides a common frame-

work for use by the Arctic countries to ensure a necessary level of habitat protection. Other mapping efforts underway include ice-edge ecosystem mapping, wildlife habitat mapping and circumpolar Arctic vegetation mapping. The FWS is also involved in CAFF's efforts to list and map rare endemic vascular plants and other taxa with restricted ranges.

In 1994 the Circumpolar Seabird Working Group was formed to promote, facilitate and coordinate seabird conservation, management and research activities among circumpolar countries and to improve communication between scientists and managers concerned with seabirds of the Arctic. The FWS participated in murre monitoring and banding projects, development of the International Murre Conservation Strategy and Action Plan, and development of an eider management strategy.

National Park Service

It is the central mission of the National Park Service (NPS) in Alaska, as elsewhere in the United States, to preserve unimpaired the natural and cultural resources under its stewardship so that these resources may continue to be enjoyed by both present and future generations. However, the NPS charge in Alaska is different in that the Alaska National Interest Lands Conservation Act (ANILCA) specifically assures the continuation of traditional subsistence pursuits in most of the park areas and allows sport hunting in the national preserves. Despite the relatively vast size of the Alaska park areas (two-thirds of the total NPS lands), these units still fail to protect complete ecosystems and they remain vulnerable to outside influences such as air pollution, oil pollution, mining, commercial fishing, air and boat traffic, poaching and archeological looting. The resource management challenges are many, and knowledge and information obtained through research and monitoring are essential for the continuation of effective programs of protection, preservation and public interpretation.

The way in which the NPS carries out research in Alaska has been affected by the recent restructuring of the agency as well as the establishment of the National Biological Service (NBS). Now, many of the NPS's larger and more complex biological studies are performed by the NBS. Also, in the new, more decentralized NPS, park staffs have assumed greater responsibilities for research activities that once were the exclusive prerogative of central offices. Further, in step with the intent of the Arctic Research and Policy Act, the NPS

	Funding (thousands)	
	FY 94	FY 95
Cultural resources	850	790
Natural ecology	1,400	1,650
Total	2,250	2,440

has made a major effort to enlist and involve other Federal agencies, the State of Alaska, adjacent northern nations, Native groups, educational institutions and other potential partners in cooperative research ventures whenever possible and appropriate. Another general trend, exemplified in the NPS's Shared Beringian Heritage Program, is increased cooperation between natural and social scientists—an interaction that has proved extremely productive in generating answers as well as new questions in common areas of interest.

The goals of NPS research in Alaska are driven by the Service's central mission; basically, to conserve and interpret the resources within their charge. The natural resource goals are to:

- Identify and quantify natural resources at risk;
- Examine and understand basic ecological processes and interactions;
- Determine and evaluate influences from human activities; and
- Detect and measure the results of natural and anthropogenic causes of change.

The cultural resource goals are to:

- Acquire and maintain accurate and usable park information bases on cultural resources;
- Identify and evaluate the full range of cultural resources contained in the parks;
- Develop effective strategies for treating, protecting and interpreting cultural resources;
- Develop ethnographically sensitive approaches to cultural and natural resource management; and

- Effectively employ social science as a basis for informed human-use resource management decisions.

Joint Cultural and Natural Resource Research

To provide an information background for planning the proposed Beringian Heritage International Park, a flagship research program called the Shared Beringian Heritage Program (SBHP) was established in 1991. This program was designed to unite Russian and American scientists, land managers and Native people in a long-term multidisciplinary research effort focused on the study of traditional lifeways, biogeography, paleoenvironment and landscape history on the Seward and Chukotka Peninsulas. The program, in its fifth and final year, has resulted in the completion of one Ph.D., two Ph.D.'s to be completed in FY 96 and three completed Master's theses. Two additional Master's theses are underway.

The program produced 37 published professional papers (with an additional 13 currently in press), over 45 papers presented at scientific meetings, and one broadcast-quality videotape, "Siu-lipta Paitaat: Our Ancestors' Heritage." In FY 95 the SBHP initiated work on a second videotape, focused on the landscape history of the Bering Land Bridge National Preserve (BELA) and on the history of David Hopkins' ground-breaking geomorphological research on the Seward Peninsula.

David M. Hopkins excavates a 17,500-year-old buried surface in Bering Land Bridge National Preserve.



It also contributed funding to the Arctic Studies Center, National Museum of Natural History, Smithsonian Institution, for the completion of a traveling museum exhibit, "Crossroads Alaska: Native Cultures of Alaska and Siberia." Many participant researchers presented papers at the American Association for the Advancement of Science international conference, "Bridges of Science Between North America and the Russian Far East," held in Anchorage and in Vladivostok in 1994.

The SBHP also provided support for the completion of "The Inupiaq Nations of Northwest Alaska," by Ernest Burch. This largely ethnohistorical document is Volume 5 of a series on the cultural and natural heritage of northwest Alaska. The Northwest Alaska Native Association (NANA) Museum of the Arctic had also supported and initiated this proposed ten-part series. A revised version of Volume 5 has been accepted for publication by the University of Alaska Fairbanks Press.

The SBHP also funded the Bering Straits Heritage Foundation to conduct a traditional-use study for Serpentine Hot Springs in BELA. It is hoped that this study will culminate in a traditional cultural property nomination giving the site National Register of Historic Places recognition as a traditional cultural property.

Additionally the NPS supported the completion of a study of Inupiaq societies in the northern Seward Peninsula, Alaska, between A.D. 1500 and 1800. In this study, survey data are presented from an archeological inventory of the 2.7-million-acre BELA, and information gathered from two decades of NPS-sponsored research are synthesized. The study presents overviews of archeological, oral historical and ethnographic data and research histories for the Seward Peninsula and Bering Strait areas, emphasizing unpublished original data from various personal sources, archives and agency literature. These data, which include nearly 500 mapped houses, are examined from a landscape perspective in a pattern-recognition study of late-prehistoric settlement systems, from A.D. 1500 to 1800. The study demonstrates that surface-survey data can be used to address questions concerning prehistoric lifeways and cultural processes, beyond standard inventory and descriptive documentation. It also shows that survey data, closely scrutinized, can be effectively used to study sites in nondestructive ways and to better focus limited archeological research dollars to address key research and resource management problems.

A three-year program, jointly funded by the National Science Foundation, the SBHP, the University of Massachusetts and the University of Alaska Fairbanks (UAF), concluded that the late-

Cenozoic stratigraphic framework for northeast Russia is in need of significant revision. The development of a unified stratigraphic scheme for those parts of Beringia on both sides of the Bering Strait requires new work on the Pleistocene stratigraphy of northeast Russia. A new bilateral study has been initiated (1995) to revise the late-Cenozoic stratigraphy of the region. Knowledge of the glacial ice extent in the Russian Arctic is important for establishing accurate boundary conditions for paleoclimatic modeling. Likewise, knowledge of interglacial marine conditions in the region is important for understanding changes in the distribution of water masses and heat transport, as well as understanding the role of the Bering Strait in global ocean circulation models.

The International Panarctic Biota project on the Seward Peninsula, partially funded by the SBHP, is nearing completion, with publication of results expected during the summer of 1996. More than 300 endemic vascular plant taxa have been identified, for which distribution, habitat, bedrock and soil preferences, chromosome number(s) and taxonomy will be compiled in both electronic and hard-copy forms. From the 450 species of lichens identified for the Seward Peninsula, about 100 species are new to the Peninsula, about 25 are new for Alaska, 18 are new for North America and about 200 are noteworthy because of distribution or taxonomy. The results for mosses are similar to those reported for lichens. A number of liverwort taxa new to Alaska and/or rare and unknown in North America, and one species new to science, were found.

A number of agencies, foundations and universities joined the SBHP in support of an inventory of mushrooms and other fungi in BELA; near Magadan, Russia; in Denali National Park and Preserve; on St. Paul–Pribilof Island; and on the Macquarie Islands (sub-Antarctica).

Finally, an SBHP-sponsored bilateral study of vertebrates of central Beringia is nearing completion. The study will include scientific, English, Russian, Siberian Yupik and Inupiaq names for each species.

Natural Resources

In FY 94 most NPS biological research scientists, their program funds, research projects and support staff were transferred to the newly formed National Biological Survey (NBS, now the National Biological Service). However, many biological and physical science research, inventory and monitoring programs remained with the NPS, including cooperative research programs with state agencies, the University of Alaska, the

U.S. Fish and Wildlife Service (FWS), the U.S. Forest Service (USFS) and other entities.

Denali National Park and Preserve

The NPS conducts and supports a substantial interdisciplinary natural resource inventory, monitoring and research program at Denali National Park and Preserve (DENA). This program is aimed at developing a better understanding of the resources at DENA, documenting their condition over time, providing information useful in making management decisions, and resolving threats to or restoring natural conditions. The program is implemented through efforts by park scientific staff, cooperating state and Federal agencies and various academic institutions. During any given year, there are nearly 100 individual studies or projects underway.

DENA is a vast wilderness over 6 million acres in size. Documentation of the presence and condition of resources is a massive task that has gone on for many years and will continue for years to come. In recent years, studies such as inventories of fungi (UAF), macroinvertebrates (University of Alaska Anchorage [UAA]), plant distribution (park staff), geologic mapping (park staff and U.S. Geological Survey [USGS]) and water resources conditions (Water Resources Division, NPS) are contributing to a fundamental understanding of park resources. During 1995 a geographic information system, employing Arcinfo and Arcview software and Sun hardware, became fully operational at the park. Park staff have continued to develop traditional information (specimens, maps, written records) as well as automation of that information.

Since the 1930s DENA park staff have been engaged in natural resource monitoring efforts, with emphasis on Dall sheep, moose, caribou, raptors, air quality, water chemistry, glaciers, wildfire occurrence, rare plants and climatic information. Early studies focused on large mammals and climatic conditions, while more-recent investigations have been broadened to include more emphasis on abiotic resources. Significant amounts of data have been collected for many resources, but close examination of these data reveals that much of it is limited in geographic scope. Just within the past three years, studies have been expanded to include park and preserve additions that were made in 1980. These monitoring projects represent a major augmentation to the Long-Term Ecological Monitoring Program, which is being developed jointly by park staff and NBS personnel.

The NPS has also encouraged research aimed at understanding ecological processes and factors

of influence in DENA. Most of this research is conducted by staff from cooperating agencies and academic institutions. Examples of 1995 projects include the ecology of moose in DENA (USFS), volcanism along the Denali Fault and Cantwell Formation (Allegheny College), forest insect outbreaks (USFS), a peak wind gust survey (Mount Washington Observatory) and documentation of the freeze/thaw transition on a regional scale in boreal forests using satellite data (NASA).

Finally the NPS and cooperating agency personnel engaged in numerous research and monitoring activities in DENA directed at resolving specific resource issues during 1995. Particular emphasis was placed on documenting impacts from vehicular use and associated visitor use on the park road. Studies dealing with wildlife behavioral response and visibility, visitor use patterns, roadside impacts (trail development) and road dust were all initiated. Closely related studies on the environmental fate and impact of dust palliatives were also started. The Alaska Department of Fish and Game (ADF&G) also launched a pilot study to help determine the economic value of wildlife viewing. Information to deal with wolf management, one of the most controversial resource issues at DENA, was developed through an extensive monitoring program using radio telemetry. Investigations related to other issues and threats included such things as monitoring exotic plant populations, assessing the macroinvertebrate response to stream reclamation and monitoring gravel extraction from the Toklat River.

Aniakchak National Monument

DENA may be Alaska's most accessible and visited park, but the NPS also supports biological and physical science research in its more remote park areas. Vascular and nonvascular vegetation was sampled in Aniakchak Caldera, Aniakchak National Monument, in the summer of 1993. The results were analyzed and published as a Master's thesis in FY 94 and FY 95. Data were analyzed to determine vegetation patterns as they related to environmental gradients. The proximity to water, presence of rock and steepness of slope were determined to be the most important environmental factors controlling vegetation groups. The study provided the first nonvascular inventory of the caldera and added many species to the previous vascular list. Successional processes controlling revegetation following the 1931 eruption were also discussed, with the observation that an abundance of nitrogen-fixing lichen exist in the caldera. Additional field sampling occurred outside the caldera in FY 95.

Katmai National Park and Preserve

In 1993 and 1994, a sockeye salmon smolt outmigration project occurred cooperatively with the ADF&G on the Naknek River adjacent to Katmai National Park and Preserve (KATM). In 1991, due to a commercial fisher strike, approximately 3.6 million sockeye salmon escaped the fishery and entered the drainage to spawn. This extraordinary event was the largest escapement on record and was 40% greater than the previous high of 2.6 million fish. Project costs were shared between agencies with the intent of determining the growth and survival of outmigrating smolts for two successive years. Generated data, including the number, age and size composition of outmigrating smolt, will prove to be very important in assessing carrying capacities and production curves to determine optimum adult escapements that meet both the goals of the park and ADF&G.

Kenai Fjords National Park

Beginning in 1992 the colonization and community development mechanisms of aquatic macroinvertebrates and salmonids were studied in several streams draining into McCarty Fjord. Each drainage has a known chronological history of glacial retreat, facilitating ecological comparisons of streams with progressive dates of origin. Macroinvertebrate densities and taxa were determined between years and between streams, as well as salmonid distribution and abundance. Lake primary productivity was estimated, and leaf retention and algae experiments conducted. Several progress reports have been completed, with the final report anticipated in 1996.

Resource managers at Kenai Fjords National Park (KEFJ) have been monitoring the coastal bald eagle population since 1986. Special funding was received in 1995 to conduct aerial nest occupancy and productivity surveys. Nesting success and the number of young per occupied nest were extremely low in 1995, at 33% and 42%, respectively. Initial analysis indicates that heavy rains in April and May may have been a significant factor contributing to this low level of productivity. In addition, the results of concurrent aerial and ground surveys from 1992 and 1995 are being compared to evaluate the effectiveness of the two survey techniques.

Another species of concern at KEFJ is the harbor seal. Surveys were conducted in Aialik Bay during pupping and molting in 1994 and 1995. Maximum daily counts have decreased alarmingly from over 1600 individuals in 1980 to 208 in 1994 and 226 in 1995. Other researchers from the State of Alaska and National Marine

Fisheries Service are investigating the cause of this regional decline.

The movements of Exit Glacier are also being closely monitored in KEFJ. Detailed measurements of changes in the terminus position of the glacier have been recorded since 1988. In 1995 a radio transmitter was lowered into a crevasse in the upper reaches of the glacier in an effort to determine flow rates of the ice over several years and also to compare at-depth ice movement with surface flow rates.

Northwest Areas

As part of the Partners in Flight/Aves de las Americas program, the Northwest Areas (NWAK) (Noatak National Preserve, Kobuk Valley National Park and Cape Krusenstern National Monument), in cooperation with the FWS and local landowners, conducted breeding bird surveys and banded songbird species under the MAPS (Monitoring Avian Productivity and Survivorship) program protocol established by the Institute for Bird Populations at Point Reyes, California. During 1994 and 1995 the NPS operated bird-banding stations at the Kelly River and the lower Kobuk River from June through August. In addition, a banding station was operated cooperatively during 1995 by the staff of NWAK and Selawik National Wildlife Refuge on Native corporation land near Kotzebue to allow for public participation in banding and educational outreach. During 1994 and 1995, 1105 birds were captured, representing 29 species. Seven species banded were neotropical migrants that winter primarily south of the Mexican border. Banding stations will remain active for at least five years.

Since 1992 the ADF&G and NWAK staff have cooperatively conducted a moose research project within the Noatak River drainage. The project objectives are to document the movements and seasonal distribution of moose and to determine the mortality rate of large bull moose in the most heavily hunted portion of Unit 23. In the first year of the study (1992) 25 bulls and 25 cows were radiocollared. An additional 33 bulls were ear-tagged in drainages receiving high harvest. This provided a double sample, which was used to assess harvest bias for radiocollared bulls. During 1993 and 1994 additional moose were radiocollared to increase the sample size to over 100 individuals. Using movement data, a 2200-km² survey area was established and censused during 1993. During 1994 and 1995 the western half of the survey area was censused. Survey data indicate that the middle Noatak moose population is declining. The mortality of collared moose ranged from 10 to 25% annually. Fall bull:cow ratios in

the Noatak survey area averaged 40:100, compared to 75:100 for the unhunted Salmon River area within Kobuk Valley National Park. Fall calf:cow ratios ranged from 16 to 25 calves:100 cows for 1993–1995.

Gates of the Arctic National Park and Preserve

Park staff worked cooperatively with the ADF&G, Sport Fish Division, to design and conduct a three-year sheefish population census in the upper Kobuk River. The first-year (1994) sampling efforts met with minimal success because of a 100-year flood in the region, making it difficult to locate spawners and resulting in insufficient data to determine the size of this alternate-year spawning population. However, the effort was still worthwhile because of the support and information gained by working with Inupiat villages in the area. The estimated abundance of spawning sheefish in 1995 was 32,273. A total of 2,266 fish were captured and examined during two capture events. Numbered Floy tags marked 910 fish as part of mark-recapture efforts. Sheefish examined ranged from age 9 to 23. The largest proportion of spawning female sheefish was age 14 and for males, age 12. The sex composition of sheefish examined was 54% males and 46% females.

A second year of neotropical bird information was collected through three point-count censuses. Three habitat types are being monitored: Arctic tundra, sub-Arctic riparian and boreal riverine. The monitoring program is part of the international efforts of Partners in Flight/Aves de las Americas program. Censuses will continue for an indefinite time.

The final year of field research on small-mammal distribution in the Kobuk Preserve Unit was conducted in 1994. The objectives were to determine small-mammal species diversity and abundance in different-aged seral stands in the area and to examine population dynamics for small-mammal species through age, sex, weight and reproductive information. A variety of species (shrews, voles and lemmings) were captured during the study. Species diversity and abundance were greatest on a 15-year-old burn and lowest on an unburned alluvial stream terrace. The final report will be published in 1996.

Major efforts of park staff in 1994–1995 were aimed at designing and initiating an inventory and monitoring program for soils and vegetation impacts from all-terrain vehicle use in the Anaktuvuk Pass area. A legislative proposal to deauthorize designated wilderness and increase dispersed use of ATVs in the area was submitted to Congress in 1994. To address protection of nat-

ural resources, park staff agreed to work with surrounding land owners to implement a monitoring program to determine the extent of related impacts and propose mitigation measures. The monitoring program includes aerial photography of trail formation, interpretation of vegetation classes from photos and on-the-ground vegetation plots, and soils classification. Monitoring is being conducted on both presently disturbed and undisturbed areas and in areas that will be opened to dispersed ATV use in the future.

A Landscape Ecosystem Mapping project report was completed in 1995 and published in the NPS Regional Technical Report Series. Data gathered for this project will assist park management in determining preferred future road routes through the preserve to the Ambler Mining District. Vegetation and soils data from this study will also be used for future wetland inventory mapping efforts. Another study published through the NPS Regional Technical Report Series details the results from a long-term monitoring effort on furbearer harvest in the park/preserve.

Yukon-Charley Rivers National Preserve

In 1993 the NPS began a two-year study to evaluate the role of beaver in the natural recovery of placer-mined areas. The study included analyses of pond features, beaver demography and vegetation characteristics in an abandoned mine drainage. Beaver selected trees for harvest that were 4.5–4.8 cm. in diameter, 17–24 years in age and available within 30 m of water. Data also indicated preferred forage species as well as minimum pond dimensions to support healthy populations. Management implications include the development of low-cost methods to reclaim mine tailings through manipulation of habitat to accelerate beaver colonization.

A neotropical migrant passerine monitoring program was begun in 1994 to determine fluctuations in the American peregrine falcon prey base. The preserve established two monitoring stations to mist-net passerines using MAPS protocols. Thirty-three species of birds were identified, and 147 passerines representing 18 species were banded. Seven species were identified to be of special concern for Alaska. Peregrine falcons are known to prey on 78% of the species detected. Although five years of data collection were planned, monitoring efforts were discontinued in 1995 due to lack of funds.

Since 1993 the preserve has studied potential sources of toxicity in surface waters at an abandoned placer mine site on Coal Creek. Increased mortality of ceriodaphnia, isopods and fathead

minnows exposed to waters throughout the drainage pinpointed suspected mercury, heavy metal and/or petroleum contamination at Beaton Pup Creek. Toxicity tests in 1995 focused on selected reaches of Beaton Pup Creek, as well as an upstream Coal Creek tributary that exhibited unusual water chemistry. The species composition of macroinvertebrates from both sites is being analyzed.

In 1995 UAF botanists and preserve staff began a survey of four rare plant taxa currently listed as a candidate species under the Endangered Species Act. All are associated with relict Arctic steppe communities distributed along the Yukon River. The objectives were to determine plant phenologies, population demographics, recruitment, habitat parameters, distribution and potential threats. Healthy and widespread populations of *Draba murrayi* led to the recommendation that it be dropped from candidate status. As a result of this survey the preserve and FWS are pursuing a conservation agreement to monitor and protect a suite of rare plant species at Kathul Mountain, where three candidate taxa are found. A few sites known to harbor populations of *Eriogonum flavum* var. *aquilinum* remain to be visited in 1996.

Preserve Dall sheep exhibit unusual behavior by traveling from tundra habitat through forested areas to utilize open steep south-facing bluffs along the Charley River. Rare plant taxa in similar habitats along the Yukon are absent from bluffs along the Charley, possibly because of fire or sheep herbivory. In 1994 the NPS installed three sheep exclosures in Arctic steppe habitat and one exclosure on tundra. A second tundra exclosure was installed in 1995. Vegetation in two steppe exclosures had burned during 1991. Plant cover, both inside and outside of the exclosures, was measured in 1994 and 1995. Monitoring is planned for at least five years to detect species composition changes. This information, coupled with a planned demographic sheep study, will help determine the significance of habitat and patterns of Dall sheep use along the Charley River.

Annual aerial surveys of Dall sheep are used to monitor a harvested population of approximately 250 sheep in two trend areas in the preserve. An estimated 25,000 low-level military jet overflights (expected to double over the next few years) over critical lambing habitat requires long-term evaluation of Dall sheep demographics. Large fluctuations in survey data from 1987, 1990, 1993, 1994 and 1995 emphasize the need to develop new strategies to monitor Dall sheep populations in partially forested habitat.

Wrangell-St. Elias National Park and Preserve

The USGS and park staff initiated a hydrologic hazards investigation within the Kennicott Basin in 1994. A stream gage was installed on the Kennicott River, stream channel cross sections were surveyed, and six glacier-dammed outburst lakes were monitored. Hidden Creek Lake, the largest outburst lake, released in late July, causing a large flood in the outwash regions downstream of the Kennicott Glacier. In 1995 the stream gage on the Kennicott River was maintained, flood discharges were calculated, and glacier-dammed outburst lakes were monitored. Historical records enabled researchers to reconstruct the 1900s geomorphic evolution within the outwash proximal to the glacier. Cross sections and pre-1995 water levels were surveyed, and a hypsometric curve was generated for Hidden Creek Lake.

In 1994 the NPS initiated a study of ATV impacts and their mitigation in the sub-Arctic "discontinuous-permafrost zone within Wrangell-St. Elias National Park and Preserve (WRST). Color infrared aerial photography of the trails was obtained, and park staff field-tested impact assessment and trail-use monitoring techniques. During 1995, researchers measured the amount and types of ATV use on trails and trail segments, used photointerpretation to classify vegetation types and delineate the predominate vegetation types along the trails, and sampled ATV impacts. The sampling method was a stratified randomized-block design, with samples distributed over the range of trail use, vegetation types and impacts experienced in the study area. During 1996 the park will test several trail-hardening techniques and compare their efficacy, cost effectiveness, durability and ease of installation in a back-country situation. Treatments will be replicated over four trail segments in a split-plot design, with four materials plus a control being installed in both high- and low-impact areas.

A vascular floristic inventory of 13.2 million acres in WRST was conducted during the 1994 and 1995 field seasons. Site selections emphasized areas with unique lithology and geomorphology, areas with no previous botanical collections, and communities known to have sensitive and endemic taxa. Preliminary results include four taxa new to Alaska, a previously undescribed species, 140 populations of 23 taxa that the Alaska Natural Heritage Program are tracking and consider rare either in Alaska or globally, eight populations of a FWS Category 2 taxon, 459 significant range extensions (represented by 208 taxa that are greater than 200 km from previously known collections) and 106 taxa new to the park herbarium.

In 1995 the NPS and the Geophysical Institute at UAF submitted a proposal to measure ice velocities using synthetic-aperture radar imagery on the Malaspina Glacier and determine the origin of the glacier's medial moraines. The proposal was funded, and a cooperative agreement was developed between WRST and the Institute.

The primary goal of Dall sheep research in WRST in 1995 was to continue studies to determine the minimum sampling intensity needed to reliably estimate sex and age ratios of Dall sheep for specific management areas within the park and preserve. A secondary objective was to compare sightability biases of Dall sheep surveys as computed from logistic modeling and ratio-estimation procedures. The logistic modeling method, developed by WEST, Inc., computes visibility biases by comparing individual groups of sheep seen by observers in fixed-wing aircraft and helicopters, and determining the probability that groups of different size are seen by observers in the airplane. The ratio-estimation procedure computes visibility biases by comparing the total number of sheep seen in a sample of survey areas flown at two survey intensities: a relatively low-intensity survey from an airplane and a high-intensity survey from a helicopter. The comparison was of interest because the ADF&G has recently favored using the ratio-estimation procedure over the logistic modeling method previously used in the park and preserve.

Cultural Resources

There is a curious and significant irony in the history of human settlement in the Arctic; in the Old World this cold, challenging geographical zone was the last to be occupied by humans, but in the New World it is the first environment migrating peoples encountered and made their home. In this sense, all Native American cultures can be said to share common cultural "ancestry" in Arctic adaptations, a fact that may have profound theoretical implications for understanding the directions and trajectories taken by New World cultures as they evolved and diversified from their basal origins in an ancient Arctic homeland. This is but one more reason why the study of the human story in the Arctic, both past and present, merits serious scientific attention. Alaska, because it once formed what was the eastern flank of the Beringian core region, in all probability represents the area of longest continuous human occupation in the New World. Despite Alaska's popular image as a recently transformed pristine wilderness, it is here that humans and the

natural environment have had the longest association of anywhere in the New World, and the record of this lengthy interaction will no doubt reveal many unexpected linkages and feedback loops between the human and natural components of Alaskan ecosystems. The identification and study of such linkages could have important practical implications for future resource management in the Arctic. It is in recognition of the potential value inherent in these and other related research themes, plus the fact that human uses and influences remain significant components in the park management equation, that the NPS continues to promote a strong program of cultural and social science studies in Alaska.

Gulf of Alaska Coastal Survey

The Gulf of Alaska Coastal Archeological Survey project, funded by the Systemwide Archeological Inventory Program (SAIP), in its third and fourth years completed surveys of coastal areas within Katmai National Park and Preserve (KATM) and Glacier Bay National Park and Preserve (GLBA). This project continues to



High-elevation prehistoric "stone nests" or cairns in Glacier Bay National Park and Preserve.

be interdisciplinary, placing emphasis on the construction of a regional model of prehistoric settlement patterns in relation to Holocene sea-level changes, glacial action and the distribution of subsistence resources along the coast. The research is led by investigators from the Arctic Studies Center, National Museum of Natural History, Smithsonian Institution and UAF through the National Biological Service Cooperative Research Unit. The FY 94 investigations along the KATM coast showed that heavy Pleistocene glaciation, combined with an early withdrawal of the ice, caused an isostatic rebound effect that caused the coast to rise faster than the sea level. The result is that early sites dating to at

least 7000 years ago are preserved at elevations of 4–10 m above the present sea level. The FY 95 investigations along the GLBA coast revealed that coastal glaciers increased dramatically in size during the Little Ice Age, ca. A.D. 1200–1900. The coast sank 5–7 m in response to the burden of ice. Few shoreline settlement sites predating the Little Ice Age maximum of 250 years ago are preserved, as most were flooded and washed away or were destroyed by repeated glacial advances. However, there is potential for sites dating to the early Holocene in areas that remained above the marine transgressions.

Cultural Resources Mining Inventory and Monitoring Program

The Cultural Resources Mining Inventory and Monitoring (CRMIM) Program has the responsibility of ensuring that all mining-related activities within Alaska's National Parks are in full compliance with Federal historic and cultural resource preservation laws, policies and regulations. These responsibilities, carried out by archeologists and historians at the Alaska Systems Support Office, as well as cultural resources personnel assigned to various park units, involve surveys of valid and abandoned mining claims and inventories of all sites identified.

In 1994 and 1995 field crews conducted mining-related surveys and site documentation in five NPS units: Wrangell–St. Elias National Park and Preserve (WRST), Yukon–Charley Rivers National Preserve (YUCH), Gates of the Arctic National Park and Preserve (GAAR), Denali National Park and Preserve (DENA) and Lake Clark National Park and Preserve (LACL). Surveys, totaling 440 acres of coverage, were completed in areas with active mining claims and on abandoned mining lands. As a result of these surveys, 15 new sites were recorded, and the documentation for seven previously recorded sites and two isolates was updated. The focus of activity in WRST was the Gold Hill–Chisana Historic Mining District, where a team of archeologists, historians and architects continued work on a cultural landscape inventory for the district. Research also continued on a National Register of Historic Places nomination for the Stampede mine, the state's premiere historic antimony mine, in DENA.

Work also continued in 1994–1995 on the overview report for the CRMIM program. This report documents 344 archeological sites inventoried during 10 years of field work in nine of the NPS units in Alaska. The goal of this research is to identify patterns associated with specific mining districts and to depict the character or unique qualities of each district.

Archeological Overviews and Assessments

The text of an archeological overview and assessment was completed for WRST, and two others were initiated, one for LACL and the other for Aniakchak National Monument and Preserve. The WRST overview and assessment will be published soon and will be available from the Alaska Systems Support Office. The outcome of these projects is the publication of synthesis documents that compile, review and evaluate all existing archeological data for a park and its immediate vicinity. The results include an up-to-date park resource information base, recommendations and directions for future research and management of the resources.

During 1995 a reconnaissance survey, focused on areas that are projected to receive heavy impact from ATV use, was undertaken in GAAR. These areas included a 5.6-km stretch of the Anaktuvuk River about 21 km east of Anaktuvuk Pass and a short stretch of Ekokpuk Creek. The project also included a survey of the perimeter of Loon Lake, including an 80-acre parcel recently acquired by NPS. During the course of the survey, three sites were recorded: a historic Nunamiut cairn site on the Anaktuvuk River and two prehistoric lithic scatters of unknown date at Loon Lake. The purpose of the ongoing research is to assess the impacts of ATV use on cultural resources.

Archeological Research in Northwest Areas

A multi-year reconnaissance-level survey, under the direction of NWAK archeologists, continued in Noatak National Preserve during 1994–1995. Survey efforts focused on the upper Noatak River from Sapun Creek to Cutler River and on the upper Anisak River drainage. One hundred ninety-five new archeological sites, representing the last 12,000 years of human occupation of the area, were identified and documented in 1994. Several projects related to the reconnaissance study were funded in whole or in part under the auspices of the reconnaissance survey, including:

- Test excavations at the Irwin Sluiceway site, a possibly very ancient site with technological similarities to the Mesa site, and testing and mapping of other early site candidates in the area, one of which confirmed a new cultural assemblage for the Noatak drainage and has been radiocarbon dated to 9,800 years ago (corrected);
- Reconnaissance of surficial geology and archeology of Nimiuktuk River, which determined that the Nimiuktuk was unglaciated in the late Pleistocene and tentatively is identified as a refugium with high potential for Early Man research;

- A survey of chert sources (used for stone tool manufacture) in the Brooks Range of Noatak National Preserve;
- Paleoenvironmental studies of the upper Noatak, where the team identified the Old Crow tephra in the Noatak basin, which will provide a critical horizon marker for the Pleistocene history of the landscape;
- An investigation of late-prehistoric villages, including documentation of karigis (community houses) lined with petroglyph-marked boulders and the production of topographic and feature maps of three major villages;
- The excavation of a prehistoric (ca. A.D. 1400–1550) house near the confluence of Sapun Creek with Noatak River, focusing on the recovery and disposition of faunal elements; and
- Tree-ring analysis in the Kobuk Valley National Park in 1994 to provide comparative data with 1993 work from the Noatak basin.

In 1994 a long-term project for systematically confirming the location and assessing and photographing the condition of sites that comprise the core of the Cape Krusenstern National Monument was initiated. Work focused on Beachridge 35 (Ipiutak) and 26 settlements/features were documented.

The summer of 1995 saw the beginning of a multi-year project to assess and mitigate the destruction by erosion of significant archeological sites within the Cape Krusenstern National Monument. An NPS crew revisited a number of sites on the park coast previously identified as under threat of erosion. The sites were mapped, and test excavations were conducted to evaluate the sites and develop a plan for mitigation.

The NPS-NWAK, at the request of the affiliated Alaska Native organizations, conducted an excavation of two burials found on private land within Kotzebue. Both individuals were accompanied by numerous artifacts, including several gender-specific tool kit bundles. Preliminary analysis indicates the burials probably date from the late prehistoric, Kotzebue Period (ca. A.D. 1400–1550).

Cultural Anthropology Research

In an ethnographic overview and assessment at Gates of the Arctic, the NPS developed a research design and contracted with the North Slope Borough to provide a summary of knowledge about Nunamiut culture and history, especially Nunamiut culture in the Anaktuvuk Pass area. The overview will critically review past scholarship, identify gaps in the cultural anthropological literature, and provide a summary

narrative aimed at educating NPS managers about the Nunamiut culture and relationship to Anaktuvuk Pass lands and resources and inform a Nunamiut audience about various "studies" about themselves.

A Wrangell-St. Elias ethnographic overview and assessment will provide a broad synthesis of Ahtna cultural history, traditional territory, contemporary socio-political organization and cultural change, and persistence in the last 100 years. Other components will discuss the government-to-government relationship between the NPS and Federally recognized Ahtna village councils and community histories of seven Ahtna-dominated villages.

A Glacier Bay National Park ethnographic overview and assessment, conducted by the University of Washington Cooperative Parks Study Unit, seeks to document the nature and depth of the Hoonah Tlingit relationship with Glacier Bay terrestrial resources. As a secondary purpose the study will provide an overview of Tlingit social organization and traditional behaviors, and religious ritual and belief.

A cooperative effort with the State of Alaska, Southeast Subsistence Division, and the Hoonah Indian Association will produce a Tlingit place-name map of Glacier Bay to be made available to park visitors. The purpose of the map is to acknowledge and document Tlingit geographic ties to the park.

At Kenai Fjords National Park a documentary study, recently completed by Impact Assessment, collected ethnographic recordings and photographic images of historic Alaska Native use of the outer Kenai coast, an area for which extremely little prior information existed. The study provides a documentary baseline to be drawn upon for an additional ethnographic work. Building on the recording project, efforts have begun to complete an ethnographic overview and assessment of Kenai Fjords National Park, which is directed at historic use and presence on the coast by Alutiiq peoples. The study seeks to characterize the degree of resource use as well as demographics and historic social structure.

Subsistence Research

A recent Alaska Supreme Court decision contradicted existing Federal regulations with respect to subsistence activities on Federal lands. This conflict has led to a resumption of Federal management responsibilities for wildlife resources on lands administered by the Bureau of Land Management, the U.S. Fish and Wildlife Service and the NPS. Realizing that informed management decisions require reliable and valid data, the NPS

initiated (actually revived) a subsistence research program. For FY 94 and FY 95, data collection and the production of draft final reports were accomplished for the following ongoing projects.

A draft final report on the Wiseman area of Alaska was completed in 1993. The report contains a description of contemporary and historical patterns of subsistence use and an analysis of community and agency management concerns regarding the use of renewable resources.

A draft final report on subsistence uses of forest resources at Lake Clark National Park and Preserve was submitted. The report describes the "traditional and customary" subsistence uses of timber and plant material in five communities (Port Alsworth, Iliamna, Nondalton, Newhalen, Lime Village). The intent of the report is to help guide the NPS staff in their responsibility for managing the resource base and legally mandated subsistence activities in the park and preserve.

The Katmai Research Project is a comprehensive baseline analysis for the communities of Levelock, Igiugig, Kokhanok and South Naknek and contains survey research on subsistence harvests through a cooperative agreement with Alaska Department of Fish and Game (ADF&G), Subsistence Division, and additional survey research investigating such topics as how subsistence skills are taught (socialization), sharing of wildlife harvests (reciprocity/redistribution), regulatory impact on harvest activities, and long-term personal and family use of wildlife resources. Other products include GIS community maps of wildlife harvest and use areas, ethnohistorical and ethnographic analyses, and oral history collections and biographies.

The Northwest Arctic Cooperative Management Research Project combined a literature review and a key informant interview project to investigate cooperative management regimes in northwest Alaska and Canada. This research will seek to identify legal, political, socioeconomic, cultural, geographical and ecological factors important to the success or failure of cooperative management regimes, as they relate to the NPS mandate in Alaska. A two-hundred page annotated bibliography on cooperative management and traditional ecological knowledge has been submitted and distributed in FY 95.

The management plan for Denali National Park states that the park will maintain an ongoing inventory of the location and description of all cabins and temporary facilities in the park and preserve. The park currently has several requests for reconstruction of subsistence trapping cabins. Knowledge of customs and traditions regarding cabin use and construction is needed to formulate

an effective and consistent cabin management policy that conforms with legal guidelines established by ANILCA. A project is underway to document the traditional use of cabins and other shelters associated with subsistence uses (especially trapping) in selected areas of the North Addition to the park. The study uses quantitative survey techniques, ethnographic approaches, a literature review and historical analysis, and participant observation. The fieldwork for this research was completed in FY 94, and a draft ethnohistory for the region has been submitted.

In the Wrangell-St. Elias area, detailed GIS coverage of traditional subsistence use areas has been delivered to the NPS/BLM under an agreement with the Copper River Native Association. The principal intent of this project was to gather and analyze data on customary and traditional uses of wildlife harvests in the Copper River area. The project included graphic documentation of the historic use of subsistence resources (particularly moose and caribou) in terms of spatial use patterns and harvest levels (GIS database) and graphic documentation of the relationship between current hunting regulations and both traditional hunting patterns and subsistence needs.

A comprehensive baseline harvest assessment (including factors of distribution and reciprocity)

has been completed for the communities of Wales, Deering and Noatak as part of the Bering Land Bridge Research Project. FY 96 will see the completion of this research for the community of Shishmaref.

Field work and some draft documentation have been completed on the contemporary and historic subsistence use patterns at Yukon-Charley Rivers National Preserve. The intent of this research has been to complete a literature review, field data collection and analysis to describe the contemporary and historic subsistence use patterns for Eagle, Eagle Village, Central and Circle; a comprehensive list of natural resources used by residents of these villages, including harvest levels of subsistence resources; and an examination of the economic and social role of natural resource utilization within local communities.

Efforts began in FY 95 on a two-phased study on human use and behavior of commercial fishers in Glacier Bay. The study will obtain and analyze quantitative socioeconomic data on commercial fishing for major fishery types, describe the cultural and historical practices and significance of fishing, and describe the qualitative nature of the fishers' relationship to Glacier Bay marine resources.

Bureau of Land Management

The Federal Land Policy and Management Act of 1976 gives the Bureau of Land Management (BLM) responsibility for managing the land and resources of the public lands of the United States, including those in Arctic Alaska. Management is based on the principles of multiple use and sustained yield, a combination of uses that takes into account the long-term needs of future generations for renewable and nonrenewable resources. These resources include soils, recreation, range, timber, minerals, watersheds, fish and wildlife, wilderness, and natural, scientific and cultural values. The research work is typically site specific for identified problems, as opposed to research for the sake of expanding knowledge.

The BLM's focus has been shifting from commodity development through stages of multiple-use management and resource conservation to ecosystems management. In 1993 the Department of the Interior established the National Biological Service, which is responsible for most of the Department's biological research (including BLM's).

	Funding (thousands)	
	FY 94	FY 95
Minerals (Ahtah)	10	10
Natural ecology	1,175	1,175
Cultural resources	168	150
Fishing resources	600	50
Fire control	330	30
Range administration	250	20
Total	2,633	2,315

Arctic Minerals Assessment and Evaluation

North Slope exploration is expanding to the Chukchi Sea. Thus far, five wells have been drilled in this vast province. This drilling has yielded non-commercial discoveries of gas or oil in four wells, which were drilled on the prospects initially perceived as most promising. With some modification the major stratigraphic depositional systems of the North Slope persist offshore. However, indigenous and primary reservoir properties are limited to the Neocomian Breakup Sequence sandstones, rather than the Ellesmerian reservoirs of the Prudhoe Bay area, found downsection.

Of the known North Slope oil-source rocks, geochemistry shows that the predominantly carbonate Shublik Formation is the richest source rock of the Chukchi. However, the Chukchi oil does not correlate well with the Prudhoe oil suite, which is also derived from the Shublik. Instead the chemistry of the Chukchi oil indicates that it is derived from marine clastic rocks. Drilling in the Chukchi shows that none of the potential marine clastic rocks have sufficient richness or kerogens to generate oil.

The geology found in the coastal plain of the Arctic National Wildlife Refuge in northeastern-most Alaska indicates that the area has high potential for the accumulation of oil and gas. Discoveries peripheral to the area, and oil seeps and stains within the area, suggest that there are at least two petroleum systems in operation.

Oil, condensate and gas are present in the lower Paleozoic basement, lower Cretaceous sandstones, and upper Cretaceous to Tertiary turbidite sandstones at the Point Thomson Unit immediately west of the Refuge. Available analyses indicate that the oil in the Cretaceous sandstones correlates to the oil from the Prudhoe Bay field and peripheral fields. Two distinctly different oils are found at seeps and stained sandstones on the coastal plain. Upper Cretaceous- to Tertiary-age turbidites, Miocene-age siltstones and a currently active oil seep contain a marine, clastic-derived oil. This is the JKM (Jago, Katakturuk, Manning) oil type, derived from upper Cretaceous highly bentonitic shales. Heavily weathered bitumen at the Angun Point seep has characteristics similar to marine, Tertiary-age oils.

Kinetic modeling of the large seismically mapped structures beneath the coastal plain suggest that either the Prudhoe oil or JKM oil could successfully charge potential reservoirs.

National Petroleum Reserve in Alaska Land Cover

The National Petroleum Reserve in Alaska (NPRA) includes over 9.4 million hectares and is located on the North Slope of Alaska, much of which falls within the Arctic Coastal Plain physiographic province. The Arctic Coastal Plain contains one of the largest and most stable collections of wetlands in North America. Lake and emergent marsh coverage has been estimated at 50% of the total area. These wetlands support large numbers of breeding and postbreeding waterfowl, loons, terns, gulls and shorebirds, including the spectacled eider, which is a Federally listed endangered species, and the Stellar's eider, which is proposed for list-

ing. The king eider migration alone has been estimated at one million birds passing Point Barrow. The interspersed tundra habitats are used by caribou, brown bears, polar bears, foxes, lemmings, ptarmigan, passerines and raptors. There are millions of thermokarst pits among the shallow soils overlying continuous permafrost. The region has little or no relief and mimics hot desert precipitation levels, with less than 10.9 cm in the average year. The cool summer growing season is approximately 6 weeks long, with 24-hour daylight.

The objective of this project is to create an updated and detailed land cover inventory in computer database format for the entire NPRA. In addition, information collected by the U.S. Fish and Wildlife Service (FWS) on observed spectacled eider locations will be related to the land cover types. The NPRA project has been divided into three phases because of the immense size of the project area, limited field access time due to the unpredictable weather, and difficulty in coordinating field logistical support because of the lack of transportation infrastructure. The three phases are planned to be completed in 1995, 1996 and 1997, respectively.

Seven near-date Landsat thematic mapper (TM) satellite scenes and two Systeme Pour l'Observation de la Terre (SPOT) satellite scenes will be used to classify the project area into land cover categories. An unsupervised clustering, or seeding, technique is used to determine the location of field verification sites. A custom field data collection card is used to record field information. Helicopters are used to gain access to the field sites throughout the project area. Global positioning system (GPS) technology is used both to navigate to preselected sites and to record locations of new sites selected in the field. When Phase III is complete in 1997, approximately 1800 field sites will have been recorded, and a final mosaic of the entire NPRA will be complete.

The results for Phase I indicate that the dominant land cover is 39% moist tundra, 21% open water, 15% flooded tundra, 11% shrub, 8% wet tundra, 4% aquatic and 2% barren ground. The overall accuracy of the major land cover categories, in Phase I, is 91%. The land mix related to spectacled eider locations is 74% water, 12% *Carex aquatilis*, 5% *Arctophylla fulva*, 3% wet tundra, 2% low-centered polygons, 2% non-pattern and 2% other.

Carter Spit Wildlife Survey

A complex of spits and tidal mud flats in the Carter Spit area of western Alaska (59°15'N, 162°00'W) were surveyed for migrating and stag-

samples from beluga whale carcasses were collected for genetic analysis by the Alaska Department of Fish and Game (ADF&G).

Watersheds and Fish Habitat

The Bureau of Land Management (BLM) is emphasizing collaborative work on Arctic ecosystems and watersheds. BLM is currently an active partner with state and Federal agencies and industry in efforts to design a statewide approach to watersheds, to develop and establish methods, standards and criteria for aquatic resource restoration and mitigation of deteriorating impacts, and to develop and integrate information management standards and data sharing capabilities across the area.

The Nome Creek project in the upper Beaver Creek watershed will restore approximately four miles of placer-mined stream channel. The project is a cooperative effort between the BLM, the ADF&G and the Department of Transportation. Several stream channels in the Hogatza and Beaver Creek drainages are being surveyed to design and implement mitigation of placer mining impacts and design restoration of impacted channels.

The BLM, the ADF&G and the Bering Sea Fisherman's Association are conducting stock restoration activities stemming from over-harvest in western Alaska. This cooperative project is aimed at restoring sockeye salmon to historic levels in Salmon and Glacial Lakes.

Cultural Resources

Studies at the Mesa site continue at a similar rate as in past field seasons. Interim results support earlier reports. This work receives much favorable exposure at the local, national and international levels. It is of major significance in helping to better understand how and when humans migrated to America and the relationship of early cultural groups in Alaska to those in the smaller states. The Mesa site and related studies also provide important new paleoclimatic information for northern Alaska, including insights relevant to issues of global warming and climate change. Numerous visitors have toured the Mesa field site. Reports have been made at Anaktuvuk Pass, many elementary and secondary schools in Alaska, the Alaska Public Lands Information Center, the University of Wisconsin, and in magazines and newspapers, as well as in a series of showings on the Learning Channel's "Ice-Age Crossings" program. A professional article was published in *Arctic Anthropology*.



Conducting ground migration surveys along Carter Spit.

ing shorebirds and waterfowl in July and August of 1994 and 1995. Surveys of upland tundra, alpine areas and stream drainages for songbirds, as well as waterfowl brood surveys on inland tundra ponds, were also conducted. The project objectives were to determine the importance of the area to migrating shorebirds and waterfowl during the fall migration and to determine if the area qualifies for inclusion into the Western Hemisphere Shorebird Reserve Network. The work was completed through a cooperative agreement with the Alaska Bird Observatory in Fairbanks and the help of the FWS, Yukon Delta National Wildlife Refuge.

A total of 127 species of birds were recorded, including 31 species of shorebirds and 20 species of ducks. More than 50,000 western sandpipers and 7,000 dunlins were seen each season, and in August 10,000 northern pintails and green-winged teal staged in Carter Bay each year. Groups of Stellar's eiders, a proposed endangered species, regularly used the site. Six species of duck were found breeding during aerial waterfowl brood surveys. Significant numbers of Hudsonian godwits were also found staging on inland ponds and tidal flats.

During monitoring of bird migrations, occurrences of marine mammals, fish and land mammals were also recorded. Many more dead sea mammals, particularly walrus and seals, were found along the spits and bays relative to other coastal areas. Tissue

The BLM is continuing work on the Obsidian Hydration study, the only approved research project for the agency in Alaska. Preliminary findings, presented at various professional meetings, have shown the complexities of developing obsidian hydration dating for the Arctic. Soil temperatures may vary within a single site, leading to differences in hydration rates because of the location of the obsidian and the length of time it was within the site. The results have also included the loca-

tion of several new obsidian sources important for better understanding trade and contact patterns among prehistoric peoples in Alaska.

The BLM, in cooperation with University of Alaska Fairbanks, is involved in excavations at the historic mining community of Coldfoot. Work is providing new insights into how Gold Rush inhabitants of the area adapted to this region, which represents the northernmost extension of the mining frontier of a century ago.

U.S. Geological Survey

Workshop on Dumped Nuclear Waste

On January 12 and 13, 1995, the U.S. Geological Survey (USGS), in cooperation with the Center for International Security and Strategic Studies at Mississippi State University and with Vanderbilt University, held a workshop entitled, "The Japan-Russia-United States Study Group on Dumped Nuclear Waste in the Sea of Japan, Sea of Okhotsk and the North Pacific Ocean" in Biloxi, Mississippi. This groundbreaking meeting created a highly productive Japan-Russia-United States dialogue, which in turn established a basis for further cooperation among nations in Asia and the Pacific Rim in order to develop a satisfactory program for dealing with nuclear waste disposal problems. The interaction of the workshop participants was vital in providing a firm grasp of empirical reality and served as a necessary confidence-building step on the road to more concrete cooperation.

The Biloxi workshop produced 20 scientific papers, as well as a number of scientifically based presentations and panel discussions. New material presented added to the existing knowledge base being used for comprehensive evaluation of the physical environments of all three dump areas.

Russian scientists and representatives of the Russian Navy offered comprehensive and detailed pictures of the past activities of Soviet naval dumping of nuclear wastes and described the Russian Navy's practices of nuclear waste disposal. Not surprisingly, this presentation was disturbing, considering the unsophisticated methods of disposal used by the Soviets for the last 20 years. During the workshop, Russian participants were quite forthcoming about the amount and character of radioactive waste disposed of in the Sea of Japan and went beyond the well-known Yablokov Commission report by disclosing at least one

	Funding (thousands)	
	FY 94	FY 95
Energy and minerals	6,500	4,500
Natural hazards	3,500	3,500
Global change	2,000	1,500
Marine and coastal geology	1,000	1,000
Geomorphology	250	250
Ice and climate	400	400
Hydrology	100	100
Mapping	1,000	1,070
Total	14,860	12,430

additional dumping—the 1993 disposal of 0.38 curies of low-level liquid waste.

Presentations made by the Russian Navy indicated that the amount of dumped liquid and solid low-level waste in the Sea of Japan is not significantly greater than the approximately 250,000 curies described by the Yablokov Commission report. However, extensive details concerning the disposal of low-level waste in the Sea of Japan were presented by chemical experts of the Russian Navy. Contamination created by an accidental release of ^{137}Co in 1985 has been monitored to provide data concerning the transport of radionuclides in the Sea of Japan. Some indication of the magnitude of radioactive waste disposal problems confronting the Russians was presented candidly at the conference. Not only did the Russian attendees identify the history of radioactive waste disposal activities carried out by the Navy of the Former Soviet Union (FSU), but from several sources there was a reasonably consistent identification of the storage and disposal requirements that result from the normal operation and decommissioning of nuclear submarines and surface ships. Annually, 20,000 m³ of liquid radioactive waste and 6,000 tons of solid radioactive waste are generated from naval operations. While the actual volume produced depends upon the treatment technology used, it is obvious that considerable quantities of waste, liquid and solid, must be handled.

However, the data presented at the Biloxi

workshop indicate that transportation pathways for materials released at dump sites are still unknown. Preliminary results suggest that the Sea of Japan upper-level water mass circulation would probably transport suspended or dissolved materials in a south to southeasterly direction toward the northern Japanese islands.

The Biloxi workshop provided a forum for identifying and describing Russian Navy nuclear waste disposal at sea since the beginning of the use of nuclear propulsion in the FSU. The Russian attendees provided a complete record of disposal at sea. Their information was verified, as measurements and analyses presented at the workshop by American and Korean scientists were generally consistent with Russian reports of dumping. Problems, such as the hazards and potential risks caused by stored radionuclides, were identified. Scientists, private sector participants, and representatives of nongovernment or-

Crevasse and fracture patterns that formed on the surface of the Bering Glacier in response to complex stresses acting on and in the glacier (May 1994). The individual prisms of ice are about 25 m square.



ganizations worked together to suggest solutions to the radioactive waste disposal and storage crisis in Russia.

However, this workshop also established that more scientific work is needed, including more accurate identification of marine dumping sites. A clearer picture needs to be formed as to how spent liquid and solid nuclear waste will be disposed of in the future. It is not known how close the sampling locations were to the dumping sites. No remote operational vehicle studies or photographic examinations were conducted of the disposal sites. To supplement existing data, these studies are desirable. In addition, environmental risk assessments would be appropriate to determine the extent of the threat regarding the Sea of Japan, the Sea of Okhotsk and the North Pacific Ocean. Also, research about sublethal effects of radiation upon simpler life forms in the ocean could be a subject of investigation. Finally, the workshop results indicate that more information gathering on the land-based waste situation is warranted.

The proceedings of this workshop were published in the Fall/Winter 1995 issue of *Arctic Research of the United States*.

Bering Glacier Surge

In April 1995, following a seven-month period characterized by minor terminus retreat and near-stagnation, Bering Glacier started to surge again, with part of the terminus advancing about 750 m in the 13-day period between May 19 and June 1. Bering, the largest surging glacier on Earth, had experienced a major, 17-month-long surge, ending in September 1994. That 1993-94 surge, which was closely monitored by the USGS, resulted in a maximum of about 9 km of terminus displacement; a substantial increase in iceberg production; significant changes in the size, bathymetry, hydrology and water chemistry of ice-marginal Vitus Lake; and the complete or partial covering by advancing ice of all of the islands within Vitus Lake. These islands were the locations of rookeries of many species of waterfowl, including the threatened dusky Canada goose. The new surge overrode two of the islands at the peak of the nesting season.

On April 14, 1995, the first observations that a new surge was underway were made when USGS volunteers noted that a section of the ice cover of Vitus Lake was being compressed, resulting in a series of accordion-like folds. They also observed numerous deep, fresh cracks and rifts, as well as a number of blue-water lakes

forming on the glacier's surface. The lakes, fractures and rifts were characteristic features of the 1993-94 surge. Weekly observations of the terminus made prior to their April 14th observations, as well as oblique aerial photographs of the Bering's terminus region and piedmont lobe from late November 1994 and late January 1995, showed no evidence of surge activity.

As no observations of the upper piedmont lobe or valley glacier tributaries had been made since the fall of 1994, the timing of the surge's onset and the extent of renewed surge activity in the upper regions of the glacier were not known.

Vertical aerial photography of the eastern piedmont lobe, the terminus and Vitus Lake, made by the USGS on May 1, 1995, confirmed the new fracturing and rifting, as well as the numerous lakes. When compared to November 1994 USGS vertical photography, the May 1995 photographs also showed that the terminus was advancing over the north end of Beringia Noyava, the largest island in Vitus Lake and over the north-central part of Pointed Island. The margin showed a significant amount of iceberg production, including several bergs that were more than 0.5 km long.

May 19, 1995, oblique aerial photography confirmed that the terminus was continuing to advance. On the southeast shoreline of the lake, the advancing ice margin was forcing the entire drainage from the eastern part of the glacier to flow in a narrow channel, resulting in several hundred meters of shoreline retreat and the development of a high bluff.

A two-day visit to the glacier by project chief Bruce Molnia on June 1 and 2, 1995, confirmed that the surge was not only affecting the eastern terminus region but that it was also affecting the northern piedmont lobe as much as 30 km north of the terminus. There, the winter 1994-95 snow surface was complexly fractured and rifted, with

the reappearance of several large ice-surface lakes in the same location where lakes had existed during the January to July 1994 period. Whiteout conditions prevented determining whether the surge was active farther up-glacier. The terminus was continuing to advance over the north end of Beringia Noyava. On June 1, only the southernmost 50 m of Pointed Island remained exposed, with about 750 m of the island covered since May 19.

Another interesting facet of the renewed surge activity was the turbidity of Vitus Lake. During the summer of 1994, Vitus Lake and its primary distributary, Seal River, had large suspended sediment loads, generally more than 2 gm/L. This load decreased to near zero during the winter of 1994-95 and remained at this low level through the last week of May 1995. On about May 27, 1995, a large quantity of suspended sediment began to discharge through the Seal River into the Pacific Ocean, resulting in a large offshore suspended sediment plume. On June 2, this plume was more than 5 km wide and extended more than 35 km to the west of Seal River. When observed in October 1995, the plume was about 100 km long. Some of the sediment was probably the result of shoreline erosion on the southeast side of Vitus Lake.

By October 1995, all visible surge activity had ceased. Bering Glacier's terminus was stable, and there was a significant increase in iceberg production from the terminus.

The USGS is continuing to monitor the Bering Glacier with both aerial and field observations. An area of major concern is the potential for an increase in the number and size of icebergs that will enter the Pacific Ocean through the Seal River, the primary outlet of Vitus Lake. Seal River is located only about 100 km from the Pacific Ocean tanker lanes that exit and enter Prince William Sound.

Bureau of Mines

Since 1911, one year after its creation, the U.S. Bureau of Mines (USBM) has maintained research and field offices in Alaska. Its first functions in the Territory of Alaska included developing and leasing coal resources, improving coal mine health and safety, establishing the National Petroleum Reserve and organizing the territory's Alaska Division of Mines. Wartime functions in the 1940s and 1950s included investigating strategic and critical mineral deposits throughout Alaska, establishing a mining experi-



ment station in Juneau, doing cold-weather mining research and implementing the Defense Minerals Administration Program. Since the late 1950s the USBM's minerals investigations in Alaska have largely responded to the Alaska Statehood Act, the Wilderness Act of 1964 and the Alaska National Interest Lands Conservation



USBM Alaska Field Operations Center assessment team examining a gold trend near Hyder, Alaska.

Act, as well as other major public lands and environmental legislation. Numerous mineral economic investigations and mining-related research into environmental remediation and impact mitigation technologies specific to Alaskan mineral deposits and Arctic conditions have been conducted by the USBM.

In deliberations over the Department of the Interior's FY 96 Appropriations Bill, the Administration and the Congress decided to close the USBM. However, the USBM mineral land assessment function in Alaska was retained and transferred to the Bureau of Land Management, Alaska State Director, by Secretarial Order.

Mineral Land Assessments

The USBM mineral land assessments in Alaska support Department of the Interior responsibilities to foster Federal policies that ensure the

sound use of natural resources and that preserve and protect environmental and cultural values, and are done in partnership with other Federal, State and nongovernmental organizations. Typically the role of the USBM mineral land assessments is, through field geologic investigations and technical and economic feasibility evaluations, to identify those Federal mineral resources that might be mined in the future. Hence, the mineral assessments address specific data and analysis requirements of the National Environmental Policy Act, the Federal Land Policy and Management Act and the National Forest Management Act, as well as other statutes.

Under the terms of Memoranda of Understanding among them, the USBM, U.S. Geological Survey (USGS), Bureau of Land Management (BLM) and U.S. Forest Service (USFS) have conducted a long-term, coordinated program in Alaska to develop geoscience, mining engineering and mineral economic information for land-use planning. This mineral assessment program meets requirements of the Federal Land Policy and Management Act and the National Forest Management Act to maintain a comprehensive inventory of resources on Federal lands and to ensure the integrated consideration of physical, biological and economic sciences in Federal land planning and decision making. Under this interagency assessment program, USBM has investigated several national forests and BLM resource management area planning units each year.

In 1993 the BLM requested that the USBM conduct a mineral-resource inventory of the Fortymile River and Black River planning units to be used in completing the resource management plan for the areas. During 1994 the field efforts concentrated on refining areal geology, delineating mineral resources, and examining and characterizing most of the known Inactive and Abandoned Mine Land (IAML) sites in the Fortymile River planning unit. The results of the three-year mineral resource study, and a summary of the Fortymile River IAML hazards survey were published in 1995.

Also in 1993 the USFS requested that the USBM perform a mineral-resource assessment of the Sitka and Hoonah ranger districts, on Chichagoff Island, in the Tongass National Forest in southeast Alaska. The study area covers 10,436 km², of which the USFS manages 87% and the State, 9%; the remainder consists of Native and local community lands. Mineralization was identified at 211 sites, and the areal geology is favorable for a variety of mineral deposit types, including copper-zinc-silver massive sul-

fide, vein gold, copper–molybdenum porphyry, and nickel–copper–cobalt–PGM magmatic segregation. A field reconnaissance of the area was made in August 1994, with more field work in 1995. USBM geologists investigated over 50 mines, prospects and occurrences, mapped over a kilometer of mine workings, and took nearly 400 rock, placer and sediment samples.

In a related Tongass National Forest mineral study, the USBM used digital environmental data from the USFS and impact analysis scenarios from other agencies to create a geographic information system (GIS) model of an ecosystem encompassing the Greens Creek Mine on Admiralty Island near Juneau; this model was used to evaluate the impacts of mine development on wildlife habitat, both with and without the mitigation required by the USFS. The final report was published in 1995.

In 1995 the USBM also evaluated abandoned mine sites in the northern Tongass National Forest for the USFS. Potential hazards identified at IAML sites included unstable explosives, dangerous underground workings, collapsed surface structures and abandoned process chemicals. Physical and environmental hazards at 50 IAML sites in the northern Tongass were assessed, mapped and/or sampled. More than 100 water samples were collected and analyzed.

To further USFS planning, the USBM identified and digitized, in 1995, all active mining claims in the Chugach National Forest. A total of 830 active claims in the forest, or within 5 km of the boundary, were analyzed in a GIS format. The project identified considerable overlap of mining claims within the forest, and this has already been used by the USFS in their planning.

Under section 1010 of the Alaska National Interest Lands Conservation Act, which requires the Secretary of the Interior to assess the “mineral potential on all public lands in the State of Alaska in order to expand the data base with respect to the mineral potential of such lands,” the USBM has conducted comprehensive geologic, mining and economic assessments of mining districts in Alaska. These mining district studies develop understanding of the mineral development potential of each district by inventorying mineral resources and reserves, evaluating the probability that more resources exist, and estimating the technical and economic feasibility of mining certain mineral deposits.

The USBM published its final report on the results of the five-year Colville Mining District assessment in 1995. The Colville Mining District is in northern Alaska and includes the southern part of the National Petroleum Reserve, Alaska (NPR). The USBM identified 48 mineral depos-

its and occurrences, 27 of which were new discoveries. Lead–zinc–silver mineralization occurs primarily in massive stratiform deposits, vein breccias and sandstone-hosted disseminated deposits in the southwestern third of the district. Mining feasibility studies were conducted for known lead–zinc–silver, barite and coal resources. Areas in the central and eastern parts of the district have the highest potential for future mineral discoveries. The USGS, BLM, the Alaska State Division of Geological and Geophysical Surveys and several other government and non-government organizations participated in the assessment.

The USBM’s five-year study of the Ketchikan Mining District (KMD) provided mineral data that the USFS used to revise the Tongass National Forest land management plan. Work was performed on 446 mines, prospects and mineral occurrences within the 28,288-km² district. Over 4,800 mineral samples were collected, and several kilometers of underground and surface workings were mapped. A variety of mineral deposits were examined in detail, including metallic resources of copper, silver, gold, uranium, lead, zinc, tungsten, molybdenum, chromite, iron, platinum-group metals (PGM) and rare earth elements. Limestone deposits (an industrial mineral) were also investigated. The final reports for the KMD study cover resource descriptions and evaluations, beneficiation techniques, economic feasibility studies and a discussion of ecosystem issues relevant to mineral development activities.

Other published, multivolume reports of mining district studies are available for the Juneau and Valdez Creek districts.

Mining Technology Research

Much of the USBM’s mining technology research is high risk, intended to develop major technological improvements or solutions over the long term, and aimed at maximizing mineral recoveries while minimizing the environmental impacts of mining. Research in Alaska also considers the state’s distinctive climate and geologic conditions. The USBM research is conducted by research staff previously located at any of nine USBM research centers in the lower 48 states. USBM research objectives have also been addressed by university-based, and partially USBM-funded, Mineral Institutes. Researchers from the Mineral Industry Research Laboratory of the University of Alaska, the Fairbanks Mineral Institute, were active in 1994 and 1995.

In 1994 the USBM conducted research at the

Arctic Slope Regional Corporation's Aluaq/Kuchiak Research Mine in northwestern Alaska. Research focused on blasting methods, temperature profile modeling, water quality and restoration techniques. In 1995 no field research was done beyond project consultation and monitoring.

At the USBM Spokane Research Center, laboratory simulations of the subaqueous disposal of mining wastes have shown no long-term release of toxic metals from depyritized tailings in an oxidizing environment. Because the tailings are benign, permits were granted for a site demonstration in Auke Bay, southeast Alaska. Approximately 1.4 metric tons of inert tailings have been placed in several containers on the bottom of Auke Bay; these will be retrieved individually over a two-year period. The primary purpose of the demonstration is to determine the benthic organism recolonization characteristics of the tailings and correlate these characteristics with pore water chemistry. Personnel from the University of

Alaska Southeast at Juneau will conduct the recolonization characterization, and USBM personnel in Spokane will characterize the pore water chemistry.

An experimental ground-penetrating radar, developed at the USBM Pittsburgh Research Center, is being used to identify ancient Inupiat fishing village sites near Point Franklin in northwest Alaska. The radar uses electromagnetic measurements to distinguish between materials such as bone, wood, coal and rock, and three-dimensional images of the sites can be configured. Archaeological investigations can be directed to identified sites, avoiding costly excavation efforts at inappropriate locations. Begun in 1994 the project is funded by the National Science Foundation's Office of Polar Programs and is a partnership of universities; private business; the North Slope Borough Commission on History, Language and Culture; and Department of the Interior agencies, including the USBM, the BLM, the National Park Service and the Fish and Wildlife Service.

Department of Defense

The Department of Defense continues to operate and maintain facilities in the Arctic. To support these operations, the DOD conducts a broad-based Arctic research program. This Arctic program is conducted by all three services and extends from the ocean floor to the magnetosphere.

The DOD conducts research in response to the specific requirements of the operating forces. These requirements range from understanding the unique needs of building and maintaining facilities in the Arctic, to understanding the interactions of the ionosphere and electromagnetic propagation, to evaluating the trafficability of frozen soils, to understanding the human response to working and living in the Arctic, to predicting Arctic weather. The Army concentrates on terrain, frozen soils and engineering problems. The Navy's efforts focus primarily on oceanography and meteorology. Arctic ionospheric phenomena and their effects on navigation and communications are the primary interests of the Air Force.

A variety of DOD facilities are involved in Arctic research. The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), with offices in Hanover, New Hampshire, and Fairbanks, Alaska, is the center of engineering expertise for cold regions and winter conditions for the Corps of Engineers, the Army and DOD. It is the only Federal laboratory that focuses solely on Arctic and cold regions problems; CRREL is internationally recognized as a center of excellence in Arctic research.

The U.S. Army Research Office (ARO), located in Research Triangle Park, North Carolina, has a mission to support basic research that increases fundamental knowledge that may have a short- or long-range impact on Army capabilities. ARO is involved in Arctic research and development largely through the sponsorship of extramural basic research directed toward the studies of snow, ice and frozen ground, environmental quality and the propagation and backscatter of near-millimeter waves. The ARO program is executed largely through grants to the university research community and contracts to private industry. This ARO extramural research program provides support to CRREL and other Army research and development activities.

The United States Army Research Institute of Environmental Medicine (USARIEM) conducts research to sustain and enhance health and performance of military personnel in cold environments, including Arctic areas, through basic and

	Funding (thousands)	
	FY 94	FY 95
Arctic engineering	2,475	2,324
Permafrost/frozen ground	1,243	901
Snow and ice hydrology	7,131	3,290
Oceanography	0,663	6,435
Lower atmosphere	397	147
Upper atmosphere	2,349	2,254
Medical and human engineering	2,262	940
Arctic contamination studies	10,000	14,500
Total	35,520	29,011

applied biological and biophysical research. Researchers employ human, animal, tissue, cellular and mathematical models using multidisciplinary team approaches. A principal research goal is to elucidate complex interactions of climatic stress (heat, cold, altitude) and the body's physiologic defense mechanisms. From this information USARIEM develops biomedical strategies, provides input for the development of training/ doctrine and materiel that enhance warfighters' operational effectiveness. Strategies developed from USARIEM research include acclimation and physical fitness programs, nutritional recommendations, pharmacological interventions, ergogenic aids and other novel approaches. Also, USARIEM collaborates with the Soldier Systems Command to develop clothing, protective equipment and rations.

The Office of Naval Research in Arlington, Virginia, supports the Navy's Arctic basic and applied research, which is conducted primarily by the Naval Research Laboratory, which has facilities both in Washington, D.C., and at the Stennis Space Center, Mississippi. Applied research and development is performed through the Navy's warfare centers: the Naval Undersea Warfare Center in New London, Connecticut; the Naval Command, Control and Ocean Surveillance Center in San Diego, California; the Naval Surface Warfare Center in Silver Spring, Maryland; and the Naval Facilities Engineering Service Center in Port Hueneme, California. In addition, specific applications research is supported by the Chief of Naval Operations through the Space and Naval Warfare Command.

The Air Force is the lead service for research

in space environments, devoting its effort to understanding and predicting the polar ionosphere, magnetosphere and thermosphere and their interactions. Of particular interest is the effects of these interactions on communications and navigation. These efforts are centered at the Geophysics Directorate of the Phillips Laboratory at Hanscom Air Force Base, Massachusetts.

Arctic Engineering

CRREL is the only laboratory within DOD whose primary mission is to address engineering concerns unique to the world's cold regions and winter environments. The current CRREL program reflects recent world events and the resulting changing national policy. The engineering emphasis has shifted to technologies needed to:

- Rehabilitate and more efficiently operate an aging military infrastructure that must support forces returning from foreign posts;
- Assess and clean up contamination from past activities; and
- Extend the capability of existing equipment to function more effectively in a broader range of operating conditions.

These objectives are especially important for the DOD efforts to meet the goals of the national security strategy and represent opportunities for developing dual-use technologies that have direct application to cold-related issues of concern to civilian agencies and the public. A primary goal is to advance knowledge of the cold regions, including the Arctic, through scientific and engineering research and to put that knowledge to work for the Army, the Department of Defense and the Nation.

Several recent research studies have focused on building technology. As a result of CRREL research the American Society for Testing and Materials adopted a standard test method for determining air exchange in a single zone by means of a tracer gas dilution. This technique allows building inspectors to check for adequate ventilation rates when the mechanical ventilating system is operating and for air infiltration when the ventilating system is off. CRREL developed a series of guidelines for the proper design of standing-seam metal roofs in areas of snow and ice. These guidelines address such issues as proper under-the-roof ventilation, control of condensation, handling of sliding snow hazards, and the use of electric heater cables to cope with roof ice dam problems. Because metal roofs are often used on military installations, these guidelines will be particularly helpful. The guidelines

include the recommendation that under-roof ventilation systems be sized to maintain an attic temperature that would prevent severe icing from developing under designated outside winter air temperatures.

Developing criteria for the design, construction and maintenance of pavements in cold regions is a major program for Army facilities research. An advanced design code was completed for improving the maintenance-free life of pavement systems in cold regions by 50%. The code is being validated through a partnership with the Federal Highways Administration and the Minnesota Department of Transportation. In cooperation with the town of Richmond, Maine, the Department of Civil Engineering at the University of Maine and CRREL, a new application has been developed that uses chips of recycled tires in gravel-surfaced roadways to minimize frost damage. The 2- to 3-inch chips act as an insulating layer to mitigate the effects of frost heave and thaw weakening. In addition to their insulating benefit, the tire chips also drain well. This concept has the potential for cost-effectively improving the trafficability of gravel-surfaced roads in cold climates during spring thaw, as well as productively using some of the two billion waste tires piled up in the U.S.

The Construction Productivity Advancement Research program continues to be an excellent vehicle for cooperating with industry on research that is important to both the private sector and the Army. In a study with two commercial partners, Master Builders and W.R. Grace, CRREL has been working to develop a practical and effective antifreeze admixture to allow the placement of concrete at below-freezing temperatures. These studies have resulted in successful tests down to -5°C using chemicals already approved by the industry for use in concrete; this should greatly facilitate the acceptance of these products for general use. By having a different successful admixture for each private-sector partner, two competitive products will be introduced into the marketplace, thus avoiding reliance on a single source. These admixtures were field tested during the winter of 1994. Additional research with antifreeze admixtures has found one that may be effective down to -15°C ; a patent is pending for this product. The U.S. spends more than \$800 million annually to provide thermal protection for winter placement of concrete. As a potentially economical approach to winter concreting, antifreeze admixtures appear to provide excellent strength development at low temperatures, no apparent corrosion and higher ultimate strength than conventional concrete at low temperatures.

A model to predict ice accumulation for freezing rain events has been developed at CRREL. The precipitation rate, temperature and wind speed are used by the model to calculate accumulation amounts and loads resulting from given icing events. The model can be applied to a variety of structures and material types.

Low temperatures and the special geological conditions of cold regions present unique challenges for cleaning up contaminants. Many sites are remote or inaccessible to conventional equipment, species diversity is low, low temperatures affect the availability of contaminants and chemical reaction rates, and the extremely short summers limit the technologies that can be applied. All of these effects dramatically influence cost. CRREL is developing the knowledge base and techniques that enhance the DOD's abilities to detect, characterize and clean up contaminants on military installations. This program is a cooperative effort with the Army, the Air Force, the Environmental Protection Agency, the Department of Energy and the Federal Aviation Administration in Alaska, along with the State of Alaska and academia.

Bioremediation techniques using both landfarming and subsurface aeration via infiltration galleries were demonstrated, and a variety of innovative detection methods were explored, ranging from ground-penetrating radar studies to trace chemical "sniffing" methods. Enhanced landfarming was demonstrated at several sites, including the Fairbanks International Airport in Alaska. Degradation rates within the landfarm have varied by sevenfold and have been associated with nutrient additions and soil moisture potential. The results suggest that treatment in one season is feasible. The cost for this technology has been \$20–40 per cubic yard.

CRREL investigated the effectiveness of ex-situ bioventing for the remediation of petroleum products in a sub-Arctic climate at a demonstration site in Alaska. The technique, which combined biodegradation and vapor extraction, consisted of aeration and moisture replacement in two treatment biopits. Inorganic macronutrients were added to enhance microbial remediation in one of the biopits. The biopits permitted a modified year-round operation and could be reused. The nutrient-amended biopit had more rapid remediation and consistently higher soil temperatures than the control pile, suggesting greater production of microbial heat in the amended soil-pile system.

Rhizosphere-enhanced natural bioremediation may provide a tenfold cost savings over conventional remediation techniques for contaminated

soils in remote sites. The rhizosphere is the zone of soil adjacent to plant roots; the exudation and sloughing-off of carbon compounds from root surfaces into the rhizosphere stimulates microbial activity that can enhance degradation of hazardous compounds in the soil. CRREL researchers, working with other laboratories and universities, have focused on characterizing rhizosphere systems and reducing limitations on favorable microbial and enzyme activity in the rhizosphere zone. They have successfully enhanced rhizosphere treatment for heavy petroleum compounds in the laboratory and in the field.

Permafrost and Frozen Ground

Army research on permafrost and frozen ground is performed by CRREL and ARO. Research on permafrost and frozen ground provides design data and criteria for constructing and operating facilities in cold regions. Other efforts include studies of toxic and hazardous waste movement and control in frozen soils. In continuing studies at CRREL addressing cost-effective means for delineating subsurface contamination and transport, extensive use has been made of improved techniques for utilizing ground-penetrating radar. This radar has been used to map the total thickness of permafrost, with confirmation from the extensive drilling necessary to map the subsurface extents of contamination. Additionally, the radar is being used to detect buried metallic objects such as containers of toxic waste and ordnance.

In the terrestrial sciences, ARO interest stems from the impact that the environment has on important aspects of Army activities, such as reconnaissance, vehicle mobility, survival and environmental quality. Despite continuing efforts to develop an all-weather/all-terrain capability, land-surface conditions still constrain Army operations in cold climates. Snow, ice and frozen ground may be present, either seasonally or continuously, from the midlatitudes poleward. Depending on particular conditions and equipment availability, Army mobility and operability in cold regions can be either hindered or enhanced. Particular research undertaken in this area includes studies related to:

- The physical behavior and chemical properties of snow, ice and frozen ground;
- Frozen ground processes; and
- Constitutive models of material behavior as a function of crystal structure, temperature, loading rates and time.

CRREL is developing techniques and analytical methods for determining concentrations of con-

taminants in soil/water/snow environments useful for both assessing and monitoring sites with contamination. CRREL is working with the Army, the Air Force and the Federal Aviation Administration in Alaska, along with other national laboratories, to develop these monitoring capabilities. CRREL is also addressing conservation issues for DOD lands in cold environments. New initiatives include geographic information system and image processing techniques for delineating Arctic wetlands on military lands, floristic inventory methods for cold regions, and methods to prevent erosion of training lands from military traffic. Work is currently being done with the Department of Agriculture, The Nature Conservancy, the National Biological Service, the Fish and Wildlife Service, various universities and other Army laboratories.

The use of microwell technology was shown to be a cost-effective alternative to conventional well-drilling methods for mapping the extent of groundwater contaminant plumes. Microwells are small-diameter steel wells that are vibrated into unconsolidated formations. They may be used for site investigation or remediation. During the summer of 1994, CRREL and cooperating investigators conducted successful demonstrations of microwells for rapidly delineating and quantifying volatile organic contaminants in groundwater at Fort Wainwright, Alaska, and Eielson Air Force Base, Alaska. Vertical profiling of contaminants was accomplished by driving a well to successively deeper intervals, developing and sampling the well at each interval. Field application of a laboratory-grade gas chromatography for rapid analysis was also demonstrated. Both projects were conducted to fill data gaps in support of Defense Environmental Restoration Account remedial actions.

ARO has sponsored research at Purdue University to apply statistical mechanics and high-performance computing to model the properties of vicinal water, a superthin film of water present on the surface of soil particles, in the context of a study of frost heaving. Special attention is being given to the influence of mineral surface molecular structure and electrical charge. The goals of the study are to determine the dynamic mechanism of freezing and thawing of vicinal solutions under equilibrium and nonequilibrium conditions and to better understand the transport of chemical constituents by vicinal solutions. A complete thermodynamic characterization of the vicinal phase in the interfacial region between an ice lens and host soil grains, a new statistical-based computational approach to the calculation of the chemical potential of components in a vicinal system, and

refinement of the "Stockmeyer Fluid" as a model for vicinal water are among the recent accomplishments.

Snow and Ice Hydrology

DOD research in snow and ice is primarily carried out by CRREL and ARO. Mapping snow extent is one of the critical uses of remote sensing for hydrologic and climatic studies in both temperate and Arctic regions. The sensor platforms commonly used for these purposes depend on the scale of the information needed. CRREL has developed an automated snow mapper for use with Landsat thematic mapper (TM) imagery that has been extensively tested over the mountainous regions of the western U.S. This algorithm rapidly finds the fraction of snow, or materials with snow-like spectra in the TM bands, in each pixel, based on an idealized spectral mixture model.

ARO is sponsoring an experimental study of ice deformation at Dartmouth College. In-situ synchrotron x-ray topographic techniques are being used to observe interactions between grain boundaries and dislocations in polycrystalline ice samples during deformation.

At the University of Washington, theoretical studies and field-based experiments are focusing on the deformation of low-density snow. Six tasks will be accomplished during the study:

- The existing continuum mechanics theories for snow, and the range of parameters, if any, that would describe the observed patterns of snow deformation on slopes, will be reviewed.
- Alternative processes, such as metamorphism, that might contribute to the behavior of snow during deformation will be examined.
- A series of in-situ creep experiments will be conducted over a wide range of natural conditions, with the results interpreted in the context of evolving stress, snow texture and experimental conditions.
- A suite of confined and unconfined axial compression tests using different snow types will be completed in order to identify the Poisson's behavior of snow.
- Low-density snow will be artificially warmed and liquid water will be introduced into the snow to examine how metamorphic changes influence patterns of deformation.
- A numerical model will be developed that relates continuum mechanics concepts to microstructural processes and that describes the general rheological behavior of snow in terms of easily measured bulk properties and conditions.

Fundamental knowledge about the process of ice adhesion, particularly the molecular bonding between ice and solids as well as the microstructure and physical properties of the thin ice layer next to the interfaces, is being developed at Dartmouth College using conducting scanning force microscopy and electromagnetic spectroscopy studies. The research is addressing three questions that are critical to the ice adhesion problem:

- What is the nature and strength of molecular bonding between ice and various solids?
- What are the molecular structures and physical properties of the thin surface layer of ice next to the ice-coating interface?
- What changes occur over time in the bonding and structure of the ice-solid interface?

Surface force microscopy and electromagnetic spectroscopy are used to study ice adhesion in the temperature range of -80°C to 0°C , under conditions of well-controlled temperature and humidity, in a special cold chamber within the Dartmouth Ice Research Laboratory. Specific measurements and calculations to be made include:

- Determination of surface electrical charge density, surface charge thickness and the degree of polarization of water molecules on the ice surface;
- Theoretical calculations of the electrostatic contribution to ice adhesion strength from the microscopic and macroscopic experiments to determine the parameters of ice surface charge; and
- Measurements of the effect of an extreme applied electrical bias on ice-solid adhesion.

ARO periodically sponsors workshops, the results from which are incorporated into the planning process for the Terrestrial Sciences Program. A workshop on "Future Directions in Snow and Ice Research" was held in Gallatin, MT, in October 1995. Scientists from North America, Europe and Japan representing the scientific disciplines of physics/geophysics, civil and mechanical engineering, hydrology, geology/geography and atmospheric sciences participated in the workshop, which reviewed the current state of research in the two subject areas and recommended the most promising directions for future research. Other topics presently being considered for potential workshops are "The Computational Chemistry of Freezing Soils" and "Strength-Deformation Properties of Frozen Soils."

Medical and Human Engineering

The Army Natick Research Development and Engineering Center (NRDEC) awarded a contract

to develop heated handwear that would provide auxiliary heat to the hand while allowing maximum dexterity and facility. Most of the testing was favorable; however, during testing the major shortcoming identified was hot spots in the glove. To eliminate these hot spots the spinning (blending) of the wire used in the heating element of the glove and the lead wire used to bring power to the heated areas was improved.

USARIEM published a study of military cold-weather operations designed to document the magnitude of dehydration via total body water measurements and identify simple clinical predictors (urine specific gravity, hematocrit etc.) of dehydration. Marines were studied in the field during eight days of intense training in moderately cold weather. Dehydration was expected because of cold exposure, high activity levels and dependence on melted snow as the major source of water. Simple clinical measurements did not accurately predict levels of dehydration. The study also demonstrated that during cold-weather military operations, body fluid balance can be maintained when emphasis is placed on rehydration.

USARIEM published a study that examined the effects of cold on skeletal muscle metabolic adaptations produced by physical training. Soldiers performed daily physical training for eight weeks in either cold water (which prevented muscle temperatures from increasing) or hot water (which accentuated muscle temperature increases). Metabolic adaptations were the same from physical training, regardless of the thermal condition. Therefore, physical training in cold weather will not modify skeletal muscle's metabolic adaptations.

A continuing study at USARIEM examines the effects of dehydration on whole-body heat balance and extremity vascular responses during cold exposure. Cold can elicit two types of dehydration and both are being studied: hyperosmotic-hypovolemic dehydration (as elicited by underdrinking and sweating in clothing) and isosmotic-hypovolemic dehydration (as elicited by cold diuresis). Dehydration has been suggested to contribute to cold injury susceptibility; however, data supporting that belief are tenuous.

USARIEM previously demonstrated that humans can acclimatize to cold. Cold acclimatization requires several weeks of repeated exposure and has several distinct physiologic components, including metabolic and insulative adaptations. USARIEM has an ongoing study to extend previous research. The purpose of this study is to determine how different patterns of cold exposure alter human cold acclimatization. Specifically, the relative importance of lowering core temperature



Volunteer immersed in cold water during the USARIEM cold acclimatization study.

versus lowering peripheral tissue temperatures is being determined. The results will provide important insight into the development of specific cold acclimatization programs for soldiers. The influence of whole-body thermal status (mean body temperature and heat content) on human cold-induced vasodilation (CIVD) responses are under investigation at USARIEM. The CIVD response provides periodic restoration of blood flow to cold-exposed, vasoconstricted fingers and is thought to decrease susceptibility to cold injury. This ongoing study is examining how central temperature affects the onset and pattern of CIVD. This information will be used to refine USARIEM's extremity cold injury prediction models.

A lumped parameter model of a fingertip (the anatomical site with most susceptibility to cold injury) is now available, and it predicts digit heat exchange fairly accurately. A successful analyti-

cal solution of the effects of CIVD is a key feature to the model's structure. The critical phenomenon of CIVD (but not its mechanism) is simulated by depicting the behavior of finger skin blood flow upon exposure to cold. The model's algorithm features will be used to run a sensitivity analysis on CIVD responses observed in female subjects under a current Defense Women's Health Research program.

USARIEM has initiated a study to determine the effects of severe fatigue, sleep deprivation and chronic caloric deficit on thermoregulatory responses to cold exposure. U.S. Army Ranger student volunteers complete cold exposure tests immediately, 2 days and 16 weeks after completing the Ranger training course. These data will be used to modify USARIEM cold-tolerance prediction models and provide guidance to the Ranger cold injury prevention program.

USARIEM has an ongoing study of the thermoregulatory responses of women to cold transients in support of the Defense Women's Health Research program. Military women are exposed to a cold ramp test (dropping from 20°C to -5°C at a rate of 0.35°C/min) when in the follicular phase and luteal phase of their menstrual cycle. When data collection is completed, a thermoregulatory model will be developed that predicts women's physiologic responses to cold stress during military operations.

USARIEM sponsored an Institute of Medicine, National Academy of Sciences workshop on the nutritional requirements of military personnel in cold and high-altitude environments. The results of this workshop will be published in a book this year.

USARIEM conducted an epidemiological study on a battalion of Marines undergoing intense cold-weather training at the Marine Corps Mountain Warfare Training Center, Bridgeport, CA. Data are being analyzed to determine injury and illness incidence and to identify modifiable risk factors for injury. This may provide the nucleus for future prevention programs to reduce injuries associated with cold weather training operations.

USARIEM conducted biophysical studies in which four Extended Cold Weather Clothing System (ECWCS) outer shells were evaluated using a copper mannequin to determine if differences in thermal properties of the standard ECWCS are created by substituting outer shells. Thermal copper mannequin evaluations were conducted in a chamber with a temperature of 50°F, a relative humidity of 50% and wind velocities of 0.9, 2.5 and 5.0 mph.

USARIEM conducted biophysical studies to evaluate new materials intended to improve the

insulative protection of the U.S. Air Force S-1034 PPA flight suit. This suit is worn during U2 high-altitude reconnaissance flights, which expose pilots to extreme cold, leading to whole-body cooling and subsequent decrements in performance. Nineteen prototype configurations representing the layers of a flight suit were analyzed on a physical model of the human skin, which measured thermal resistance. The control consisted of a Nomex shell, an inflated garment and cotton underwear. The results indicate a probable improvement in the thermal comfort of the current flight suit system by using recently developed materials.

USARIEM evaluated the biophysical thermal transfer characteristics of boots worn by military pilots as well as other commercially available flight boots using high-technology protective materials. These footwear were assessed for thermal insulative values with an automated regionally heated copper foot model that tests dry insulation over 29 sites, including the toes (generally the most susceptible to non-freezing cold injury). All footwear were tested in the dry condition and after 18 hours of an upright placement in 7 cm of water. USARIEM recommended that modern footwear systems incorporate state-of-the-art insulative and moisture protective materials for high-cold-stress zones. Potential reductions in the incidence of non-freezing cold injury among air-crew personnel would be possible in such cold areas, particularly during emergency operations in cold and wet environments.

Efforts have been directed to implement the USARIEM Heat Strain Model into a comprehensive tactical weather information system applicable to cold-stress regions. Work is in progress to integrate a Canadian Cold Survival Time prediction algorithm (developed by the Canadian Defence and Civil Institute of Environmental Medicine) with real-time analysis and forecast weather data from various Army resources. This prototype system should allow uncomplicated merging of archived weather data and soldier system-oriented Intelligence Preparation of the Battlefield (IPB) products useful for predicting both cold and heat injury risk, drinking water needs, maximum safe work time and optimal work-rest cycle limits over a corps- or brigade-sized region.

USARIEM recently developed and characterized a large animal model (miniswine) of human whole-body hypothermia. In addition to quantifying the effects of whole-body hypothermia on clinical chemistry and endogenous endotoxin, they assessed the central arterial hemodynamic changes occurring during cooling, hypothermia

and rewarming in splenectomized and unsplenectomized male Yucatan miniature swine. They concluded from these studies that hypothermia causes significant hemoconcentration and that splenic contraction is the major cause of this hemoconcentration during hypothermia and initial rewarming in miniature swine. A splenectomized design should be considered for swine studies that purport to pattern human pathophysiology, especially for modeling hypothermia and rewarming pathophysiology.

USARIEM has performed lipopolysaccharide (LPS) analyses on blood samples taken from patients rendered hypothermic to core temperatures as low as 28°C for specialized surgery at Stanford, CA, Medical Center. A rise in plasma LPS (endotoxin) concentration upon rewarming has been seen in some of those patients. This research should clarify the role of endotoxin in deep-body hypothermia and rewarming injury or shock.

Air-Ice-Ocean Interaction

A singular feature of the Arctic Ocean is a permanent, dynamic ice cover. This ice cover significantly impacts the environment on all scales from climatic to molecular. Critical processes governing this impact occur in the atmospheric and oceanic boundary layers above and below the ice. Turbulent boundary layer processes regulate the evolution of larger-scale features within the atmosphere and ocean through dissipation downscale and/or feedback upscale. Understanding the dynamics controlling the vertical fluxes of mass, momentum and energy within the coupled air-ice-ocean system is critical to prediction on all scales.

Air-ice-ocean mechanics involves the coupling of two fluids by a solid plate that can sustain and redistribute stress. Due to the nature of fracture and failure within the plate and the effects of boundaries, the stress-strain relationship within the system is highly scale dependent (both space and time). Over the characteristic scales of atmospheric and oceanic stress fields, ice material properties and surface morphology are inhomogeneous, including the extreme cases of discontinuity (leads) and multiple-connectivity (rafts and ridges). The response of the ice plate to variable stress fields is typically transient and nonlinear. It remains a major challenge to properly integrate ice-floe-scale (1 km) response to synoptic-scale (10 km, ocean; 100 km, atmosphere) forcing to accurately predict regional-scale (50 km) effects.

Current ONR efforts in air-ice-ocean interac-

tion focus on ice fracture mechanics through the Sea Ice Mechanics Initiative. However, the Surface Heat Budget of the Arctic (SHEBA) program is currently under development by the U.S. science community. In partnership with the National Science Foundation, ONR plans to support SHEBA as its continuing contribution to air-ice-ocean research.

Shelf-Basin Interactions

The three principal components of Arctic Ocean upper-water mass structure are a cold, low-salinity mixed layer from the surface to 50 m, cold halocline water between 50 and 200 m, and a layer of warm Atlantic water with a core between 300 and 500 m. Because of the strong dependence of density on salinity at low temperatures, the halocline is also a well-defined pycnocline. The pycnocline effectively decouples the warm Atlantic water from mechanical mixing with the surface layer, thus insulating the surface ice cover from a large subsurface heat source. In a steady state the advection of heat by Atlantic water is balanced by vertical diffusion into the pycnocline layer, rather than into the overlying ice. The persistence and extent of the Arctic ice pack depends critically on the nature of this balance. The effectiveness of this decoupling and insulation is directly related to the thickness of the pycnocline layer. The observed thickness of this layer is much larger and the temperature much lower than can be explained using only river discharge and ice melt as sources. A current hypothesis is that the cold upper halocline of the Arctic Ocean is maintained by lateral advection and mixing from the broad continental shelves bordering the polar basin.

About one third of the Arctic Ocean surface lies above the continental shelf. Based on analysis of water properties, including nutrients, the area from Spitzbergen to Severnaya Zemlya appears to supply the upper halocline water to the Eurasian Basin, while the Chukchi and northern Bering Seas, possibly supplemented by the region north of the Canadian Archipelago, feeds the Canadian Basin. Cold, saline water in these areas is produced during fall and winter freezing, with the production greatest in zones of persistent wind-driven ice divergence. The annual rate of shelf water supply to the polar basin has been estimated at about $2.5 \times 10^6 \text{ m}^3/\text{s}$. In contrast, the total freshwater supply to the low-salinity surface layer from runoff and the Bering Strait inflow is about $0.15 \times 10^6 \text{ m}^3/\text{s}$, with an equivalent volume provided by ice melt during the summer. Refining

these estimates and understanding the nature of annual and interannual variability remain active areas of research.

The dynamics governing the production of dense shelf water are related to the thermodynamics of ice formation, and the process of tenuous freezing provides cold, dense water through brine rejection. Ice divergence is driven by shear in mesoscale wind and ocean current fields. Coastlines and shelfbreaks play significant roles in creating this divergence and providing a shallow-water mixing environment, as evidenced by recurrent polynyas in some regions. The extent and persistence of fall-winter ice divergence in locations conducive to cross-shelf transport remain to be investigated.

Once formed inshore, relatively dense water driven by gravity tends to flow across the Arctic shelves toward deeper water of similar density. Flow on this scale is influenced by the Earth's rotation: a water column stretched vertically tends northward to conserve angular momentum. In most oceans this tendency impedes cross-shelf (increasing-depth) transport, as interior flows align with isobaths. Arctic basin geometry is such that cross-shelf flow is predominantly northward, minimizing the rotational effects on cross-shelf transport. Such transport may also be concentrated in relatively narrow troughs driven by ageostrophic pressure gradients or may be more widely distributed in a bottom Ekman boundary layer. The magnitude and relative importance of the different cross-shelf transports (barotropic, channeled, boundary layer) under different forcing conditions is unknown and remains an active area of ONR-sponsored research.

Once over the shelfbreak, cold, saline water mixes and sinks to an equilibrium density level and spreads laterally into the interior along isopycnal surfaces. An unknown proportion of this water sinks to abyssal depths, filling the basins with bottom water masses. In the Eurasian Basin, tracer data indicate the main shelf source to be Atlantic water cooled in the Barents Sea. Eurasian Basin bottom water has a ventilation age of about 200 years. There is some evidence that this water mass circulates cyclonically as a boundary current in the Nansen Basin, upwelling and mixing in the interior to form Eurasian Basin deep water above 2600 m. This water mass, with a residence time of about 60 years, is above the Fram Strait sill depth, enabling exchange with the Greenland Sea. Circulation pathways at all depths in the Fram Strait region are critical to net transport between ocean basins and are poorly understood. The bottom water mass in the Canadian Basin, although apparently of similar origin to that in the Eurasian

Basin (Atlantic water, not riverine), is several times older, about 700 years. Differences are related to processes of formation and renewal, which have not been directly observed nor dynamically modeled. Basin-wide budgets, emerging from recent studies using tracer data and mass balance models, will soon be available to provide integral constraints on needed process models.

Critical to the continuing success of this program has been data collected through the auspices of the U.S. Navy, which is sponsoring Arctic Ocean research cruises aboard nuclear attack submarines. Called SCICEX, this program has sponsored two cruises to the Arctic and is anticipated to continue through the end of the decade. This program has provided researchers with unprecedented access to the winter Arctic Ocean. Science sponsorship for this program has been provided by ONR, the National Science Foundation, the National Oceanic and Atmospheric Administration and the U.S. Geological Survey.

High-Latitude Marginal Seas

This topic area focuses on the dynamics of high-latitude semi-enclosed seas. The Arctic has a large number of marginal seas (Greenland, Iceland, Norwegian, Barents, Kara, Laptec, Bering and Okhotsk), whose effects extend far beyond their boundaries. Accurate projections of regional and global environmental change depend on understanding the governing processes within marginal seas and the extent to which such seas exchange with the open ocean. Major issues include the relative roles of buoyancy and local wind forcing, including the development of deep convective overturning and dynamics and transport through wide straits; water type/mass generation mechanisms; trapped long-wave motions including tides; and enhanced biological productivity and atmospheric fluxes. The Deep Convective Overturning Accelerated Research Initiative will address the scales of overturning events that will lead to proper modeling parameterizations for this process.

In high-latitude marginal seas, surface divergence forced by wind stress gradients can affect vertical motion over a great depth range. The potential for deep vertical convection increases in winter due to the often-close-to-neutral stability of the water column. This potential decreases in summer due to stratification from surface heating and ice melting. The marginal ice zone often plays a significant role in the dynamics. Surface wind stress can change by a factor of five in this

zone, depending on the concentration and roughness of ice. Horizontal variability in wind stress magnitude drives both horizontal shear flow and vertical motion through Ekman transport divergence in the surface layer. If the water column is stratified, interior geostrophic adjustment results in a vertical shear in the steady downwind current. Thus jet-like flows (horizontal and vertical shear) develop in response to wind forcing. When winds are strong and persistent from a favorable direction, the oceanic density gradients evolve into frontal systems with complex cross-front circulation cells and strong along-front jets. Such frontogenesis is governed by nonlinear dynamics including mixing, and its predictability is uncertain. Variability in the wind forcing (such as the passage of polar low systems) as well as frontal instabilities lead to the production of eddies. Eddies can also be generated and rectified by the interaction of flow with bottom topography.

Jets, eddies, dipole vortices and chimneys, as well as smaller-scale structures, have been documented. Understanding the nonlinear instability mechanisms remains a major challenge. Details of eddy interaction and dissipation are unknown, although eddies have been observed to propagate into and beneath the ice cover. A number of complex feedback paths in the dynamics need to be evaluated. For example, because of the large-scale water mass structure, cyclonic eddies in the Nordic Seas often have warm cores. Such eddies often entrain ice floes in spiral bands, accelerating melting. The exact role of eddies in maintaining an equilibrium ice edge is unclear. The redistribution of ice, as well as the melting and subsequent stratification, changes the surface wind stress field, which, in turn, alters the dynamic balances and the flow field advecting the ice. In addition, the change in ice concentration alters the pattern of energy dissipation from the spectrum of incident surface gravity waves. The synoptic-scale wind stress field itself may be sensitive to local air-ice-ocean interaction, and the extent to which atmospheric cyclogenesis, such as polar low development, is triggered by local conditions is uncertain.

A series of comprehensive process studies is required to test model dynamics with field observations and determine the order of importance of specific feedback mechanisms. Current plans call for field experiments in the Labrador Sea during February 1997 and February 1998 to observe and characterize ocean deep convection. This experiment will rely heavily on data collected by unmanned autonomous surface and subsurface floats, moorings and satellites.

Ice Electromagnetics

Ice properties important for electromagnetic interaction are the dielectric constant permittivity, the porosity and the surface morphology. These are affected by a number of physical processes. Upward expulsion of brine during new ice formation produces a surface ice layer of very high salinity and patches of liquid brine. The dielectric properties of this surface layer are poorly known and are complicated by salt or frost flowers that often form on new ice. This salty, low-density layer of ice crystals can produce strong backscatter, particularly at microwave frequencies. Salt flower formation is expected to strongly affect the metamorphosis of snow cover on the ice sheet. Evolution of the briny snow-ice interface and development of layering in the snow (due to melt-thaw cycles) produce strong frequency and polarization effects. Temporal data on snow cover metamorphosis and its effect on electromagnetic emission and attenuation under Arctic conditions have only recently been acquired. For new ice such as frazil, congelation and pancake, the emitted spectrum reflects its history of development. The surface of frozen pancake ice is much rougher than that of congelation ice. Only pancake ice has sufficient small-scale roughness to affect emission and backscatter in microwave bands. The brine pocket/ice crystal structure differs considerably between pancake and congelation ice, suggesting that brine wicking, and thus snow cover evolution, will proceed differently. To relate the thermodynamics of snow and ice to electromagnetic energy scattering (partitioning between surface and volume) and emission in the infrared and microwave bands requires greater understanding of these physical processes.

Short-wave (ultraviolet, visible and near-infrared) radiation is a major factor in the heat and mass balance of the ice pack, the thermohaline structure of the upper ocean, and biological activity in and beneath the ice. At present the full spectral radiation field in the ice and water is difficult to predict. Vertical variability in optical properties, transmission and absorption through the air-snow-ice-ocean system is related to thermally induced changes in the structure and chemistry of the ice, brine crystallization and drainage, and algae growth. Coupling of variables complicates the analysis of transmission spectra. Ice growth not only increases the optical thickness but also produces changes in the temperature and salinity distribution, which alter the optical properties. A change in air temperature can also affect light levels beneath the ice without a change in

thickness or incident radiation. A detailed understanding of scattering and absorption mechanisms related to the structure and composition of the evolving ice cover is needed. The inverse problem can then be addressed using a high-resolution radiative transfer model with appropriate attenuation physics.

Both the local spectrum and the integral spectrum over larger spatial scales are important. For example, models of lead systems will depend critically for input on the form of such systems sensed remotely with electromagnetic energy. Understanding the relation of lead systems to fields of ice motion, ice stress and atmospheric-oceanic forcing, and the net effect of such systems on large-scale surface heat, salt and moisture fluxes, requires a synthesis of air-ice-ocean modeling, high-resolution remote imagery and selected in-situ observations. Electromagnetic sensing limits and sensitivities need to be understood in the context of flux estimation and ice dynamics. Surface temperatures, albedo and cloud cover must be incorporated in radiative transfer models to accurately determine integral radiation spectra, a critical component of the high-latitude heat budget. This work is an integral part of the planned SHEBA program.

Space and Ionospheric Research

A major DOD program in upper atmosphere and ionospheric research is conducted by the U.S. Air Force Phillips Laboratory (PL) and the Air Force Office of Scientific Research in a coordinated effort to understand the effects of space weather on systems. The goals of this comprehensive research program are to understand the basic physical and chemical processes that control the large-, medium- and small-scale structure and dynamics of the polar ionosphere. The main objectives of this effort are to specify, predict and mitigate disruptions to DOD communications, navigation and surveillance systems that are affected by poorly understood variations in the plasma density within the polar ionosphere. These processes include plasma physics, ion chemistry, ion-neutral coupling and electrical coupling to the distant magnetosphere. All of these processes act simultaneously to influence the structure and dynamics of the polar ionosphere. In addition, all of these processes exhibit variations over time periods ranging from minutes to diurnal, seasonal and ultimately the solar cycle.

The research effort is a combination of experiments to determine specific physical processes,

first-principles numerical modeling and theoretical research to actively pursue and maintain a well-rounded program. A wide range of ground-based radio, radar and optical diagnostics are employed to perform the needed measurements. These are conducted from Nord, Qanaq, Thule, Sondrestrom and Narssarssuaq, Greenland (in cooperation with the Danish Meteorological Institute); Ny Alesund, Longyearbyen (Spitsbergen) and Tromso, Norway (in cooperation with the University of Oslo, Norway); and Goose Bay, Labrador (Canada). Many of these state-of-the-art instruments are developed and tested for field deployment under this effort. Measurements are obtained through routine operation of ground stations for long-term variations and during dedicated campaigns by the deployment of a variety of sensors performing coordinated, multi-technique observations. The ground-based measurements are often complemented by measurements from instruments on sounding rockets and polar-orbiting satellites. From this understanding, numerical models to specify and ultimately to predict the behavior of this complex region are being developed. The models are updated using real-time data from a variety of ground-based and satellite sensors. Development, calibration and validation of these sensors is an important aspect of this effort.

This research and model development is needed for real-time support to DOD communications, navigation and surveillance systems, since radio-wave propagation is severely affected by large-scale gradients and small-scale irregularities in the ionospheric F-layer plasma density. Ionospheric density gradients, irregularities and density fluctuations cause unacceptable fading of satellite communications and navigation signals, as well as clutter on ground-based, long-range, high-frequency communications links and surveillance radars. This research effort also includes studies to quantify the effect of ionospheric disturbances on actual system performance, leading to development and deployment of ground-based sensors for operational systems support.

Electrodynamics of Sun-Aligned and Auroral Arcs

The PL all-sky imaging photometer (ASIP) at Qanaq, Greenland, has been fundamental in the study of sun-aligned arcs in the central polar cap. Operating every Arctic winter since 1983-84, this sensitive instrument has documented polar cap arcs and F-layer patches over an entire solar cycle. Several studies using this rich data set have advanced our understanding of polar cap

arcs, in particular the control that the interplanetary magnetic field (IMF) exerts over their formation, orientation, location, drift and disappearance. For example, the growth and decay of polar cap arcs may be related directly to the change in the polar ionospheric convection pattern following a reversal in the north-south component of the IMF.

Experiments were conducted at Sondrestrom, Greenland, to investigate the electrodynamic circuitry and plasma flow in the vicinity of auroral arcs. The experiments involved real-time measurements of auroral arcs using the PL ASIP to determine the location and orientation of one or more arcs. This information was then used to position the scan pattern of the Sondrestrom incoherent scatter radar to optimize measurements of the plasma density and line-of-sight ion velocities in the vicinity of the arc. The combined measurements led to a complete description of plasma flow, electric fields and currents near auroral arcs.

Analysis of these experiments is continuing, with detailed plasma flow patterns around the auroral arcs being derived from the incoherent scatter radar measurements. These determine the electric fields, which, when combined with measured electrical conductivity, allow a detailed calculation of the horizontal and field-aligned currents flowing into and out of the ionosphere. Also, the measurements allow detailed calculation of the Poynting flux associated with the arcs.

Plasma Convection and Patches

Nearly a decade ago, PL launched an intensive study of the polar ionosphere using the newly developed ASIP, digital ionospheric sounding system and satellite beacon receivers, as a consequence of PL's observations of outages of satellite communication links within the polar cap. This research led to the PL's remarkable discovery of the two states of the polar ionosphere, one characterized by the presence of discrete patches of enhanced ionization that convect in the anti-sunward direction and are highly structured to cause intense scintillations of satellite signals and the other state characterized by sun-aligned polar cap arcs. By integrating these measurements with those provided by the incoherent scatter radar and satellite in-situ probes, the initial framework has been much refined, resulting in a better understanding of the coupling between the ionosphere, the overlying magnetosphere and the underlying thermosphere, leading to the isolation of source functions that control the structure and dynamics of the complex polar ionosphere.

The formation of patches has been simulated

using a first-principles model. The model was run for an entire year and for 24 hours per day. A strong seasonal (summer minimum) and Universal Time variation was predicted by the model results. These were compared with one full year of digital ionosonde and UHF satellite scintillation measurements. The results show excellent agreement. The measured and modeled F-layer plasma densities agree. Also, the occurrence of scintillation, which is related to plasma density irregularities within the patches, shows the same behavior within the central polar cap. These results indicate that the behavior and variations of the F-layer within the central polar cap can be explained by plasma transport and that the IMF, which controls convection, exerts strong control over the polar cap ionosphere.

Drift data from several high-latitude stations are being used to determine polar convection patterns. The measurements are used to fit a Heelis or Heppner–Maynard pattern, with excellent agreement. The technique, called the Polar Convection Monitor (PCM), yields quantitative representations of the large-scale convection pattern. The use of multiple stations greatly improves the accuracy of the pattern. Comparison with convection patterns determined from Defense Meteorological Satellite Program (DMSP) measurements has recently begun. Inclusion of the DMSP data in this technique may also allow higher temporal and spatial resolution of the PCM.

Electron Content and Scintillation

A network of UHF and L-band satellite observing stations is maintained at high latitudes to continuously record radio signals from Air Force communication and navigation satellites. In the presence of ionospheric irregularities, fluctuations of amplitude and phase (scintillations) of radio signals occur, degrading the quality of satellite communication links and the operational perfor-

mance of UHF surveillance radars. Monitoring and measurement of ionospheric scintillation continue at Thule and Sondrestrom, Greenland.

High-Frequency Active Auroral Research Program

As part of a Joint Service (Air Force–Navy) research effort, entitled the High-Frequency Active Auroral Research Program (HAARP), a unique, high-power, HF ionospheric heating facility is under construction in Gakona, Alaska. The heater will be capable of providing sufficient energy densities in the ionosphere to enable investigations to be conducted on the modulation of auroral currents to generate ELF/VLF waves, the acceleration of electrons to produce optical emissions, the production of field-aligned ionization to scatter radio waves, and other phenomena triggered by the interactions of very-high-power radio waves in the ionosphere. The ground-based heating instrument will have an effective radiated power in excess of 1 gW, with HF tuning over the 2.8–12 MHz band and rapid beam-steering agility. The facility will also include a wide variety of ionospheric diagnostic instruments, including ELF/VLF/HF receivers, HF ionospheric sounders, HF/VHF radars, UHF scintillation receivers, optical and infrared cameras and an incoherent scatter radar. Installation of a 360-kW development prototype transmitter, consisting of a 48-element (6×8) antenna array, was completed in the spring of 1995. The prototype will be used during 1996 to test and validate the overall engineering design and performance characteristics of the planned full-scale HF transmitting array (12×15). Experimental research using the prototype will begin in the fall of 1996. The transmitting array will be increased incrementally, leading to a full-scale operational facility (including installation of all diagnostics, a power plant and an operations center) by 2002.

National Aeronautics and Space Administration

As part of its Mission to Planet Earth, NASA supports various research programs in the Arctic that emphasize applications of airborne and space remote sensing to studies of the earth and space sciences. Of particular interest is the role of Arctic processes in global climate and climate change.

Polar Exchange at the Sea Surface

Polar Exchange at the Sea Surface (POLES) is a NASA Earth Observing System (EOS) interdisciplinary project investigating the exchange of mass and energy at the air–ice–ocean interface in the polar regions. The effects of global warming are likely to be seen first at the POLES, because computer models of climate and general circulation predict that the greatest response to an increased concentration of atmospheric carbon dioxide, a major component of the so-called greenhouse gases, will occur in polar regions. The accuracy of these models is uncertain but can be improved through better use of satellite observations.

POLES is one of a number of investigations within EOS, a NASA program with the primary goal of advancing the scientific understanding of the entire Earth system. Working with both national and international scientific communities, NASA seeks to develop a deeper understanding of the components of the global climate system, the interactions between these components, and the changes occurring within the system.

The goal of POLES is to understand what the Arctic air–ice–ocean system is doing right now. To accomplish this, NASA has focused on the assimilation of satellite and other data into coupled models. This philosophy is distinct from most Arctic modeling studies, which have generally ignored these data or used them only cursorily for validation. Such studies are driven only by solar input and are thus free to represent coupled air–ice–ocean processes completely internally. In POLES, on the other hand, the models are constrained by as many observations as possible. These models are used to advance the study and understanding of polar processes on the time scales determined by satellite data availability, that is, the present era. With the deeper understanding thus gained, NASA can learn how to better simulate future climates as well.

NASA wants to utilize data—especially satellite data—to show the present state of the polar climate and how it works. The essential ingredient for progress in polar climate studies is data. Data

	Funding (thousands)	
	FY 94	FY 95
Polar oceans/ice sheets	6,500	6,000
Land processes	2,700	6,850
Solid earth science	1,200	500
Atmospheric sciences	1,000	0
Arctic ozone	1,500	950
Sounding rocket program	6,750	3,750
Op/maint Poker Flat Range	1,500	1,500
Poker Flat upgrades	5,000	0
Suborbital science	1,400	1,250
Ionospheric/mesosphere research	1,290	1,300
FAST auroral snapshot	800	800
Magnetosphere research	1,000	1,000
Solar terrestrial theory	420	420
Arctic data systems	16,400	14,500
Total	31,060	38,820

are required for all aspects of modeling: setting boundary and initial conditions, assimilation and model testing. Data are required for diagnosing processes and for establishing a baseline against which to assess climate change. NASA’s science and modeling objectives require high-quality data sets of a host of variables, many of which are observed by polar-orbiting satellites.

POLES has produced a number of data sets and data processing tools:

- Improved polar algorithms for the TIROS-N operational vertical sounder (TOVS) and for the advanced very high resolution radiometer (AVHRR);
- STREAMER, a flexible radiative transfer model;
- CASPR, the Cloud and Surface Parameter Retrieval System for polar AVHRR data;
- Surface radiative flux data sets from the International Satellite Cloud Climatology Program (ISCCP);
- Ice-motion data from synthetic aperture radar (SAR) satellites and the International Arctic Buoy Program;
- Monthly Arctic snow depth distribution data set;
- Gridded 2-m air temperature data set; and
- Surface salt fluxes to the Arctic Ocean, 1979–1985.

Some of these are described below in more detail.

Data required for POLES air-ice-ocean interaction studies.	
Radiation "inputs"	Cloud fraction, cloud top and bottom height, cloud optical depth, cloud effective particle size, temperature and humidity profiles, surface temperature and albedo
Radiative fluxes	Down and upwelling short- and long-wave radiative fluxes at surface and top of atmosphere
Atmospheric dynamics	Temperature, humidity and wind profiles, surface pressure, geostrophic wind
Turbulent fluxes	Wind stress, geostrophic wind, stratification, surface roughness
Sea ice properties	Ice type concentrations, ice thickness distribution, ice motion, snow thickness
Oceanographic data	Salinity, temperature and current profiles, mixed-layer stability and depth, ocean surface stress, surface salinity and temperature forcing
Other data	River runoff, precipitation

Surface Heat Balance

The polar regions are the heat sinks of the global climate system. Atmospheric advection of sensible heat from lower latitudes supplies about 100 W/m^2 , which is then radiated to space. The radiative balance is in turn crucially dependent on clouds, temperature and humidity fields, and the surface albedo. In winter a surplus of long-wave radiation is lost to space and the surface cools, leading to sea ice growth. In summer an excess of solar radiation is absorbed by the surface, especially in low albedo areas such as melt ponds and cracks, or leads, in the pack ice. The result is melting. Clouds play a crucial role. In fact, they reduce both ice growth and melt. In winter they increase the downwelling long-wave radiation above clear-sky values by roughly 80 W/m^2 , thus slowing sea ice growth. In summer they decrease the net radiation balance by about 40 W/m^2 , thus slowing melt.

To get a first look at the real spatial and inter-annual variability of Arctic surface radiation, NASA analyzed available ISCCP atmospheric and cloud data from AVHRR. When they compared these fields with older climatologies computed from station data, there were discrepancies: NASA's downwelling fluxes are lower and their short-wave fluxes are greater. These differences can be traced to the ISCCP cloud-detection algorithm, which gives lower cloud amounts compared with climatologies based on visual surface observations. With this data set NASA has analyzed cloud forcing, finding that the effect of clouds on these radiation balances is the opposite of that in lower latitudes. In the Arctic, clouds have a net warming effect on the surface—positive "cloud forcing."

To make better use of satellite data NASA has pursued a course of rigorous reinvention of TOVS and AVHRR algorithms for radiation "input" vari-

ables in polar conditions—atmospheric profiles and cloud and surface properties—and are producing new and better data sets. En route they have produced software tools for radiation modeling (STREAMER) and for cloud and surface algorithms (CASPR).

AVHRR provides complete Arctic coverage several times a day at a resolution of up to 1.1 km. Its short-wave and long-wave bands can be used for estimating clear-sky surface temperature and albedo, cloud amount, cloud optical depth, and particle effective radius, and—with profile data from TOVS, radiosondes or models—cloud top temperature and pressure. These geophysical parameters are fundamental for calculating the surface radiation balance and are needed for better modeling.

Pending the validation of individual components of the retrieval process, in-situ measured fluxes provide suitable validation. For instance, the downwelling surface short-wave flux estimates from CASPR are very good, with a bias of -4 W/m^2 and an rms error of 32 W/m^2 compared with in-situ observations. Cloud optical depth and particle effective radius retrievals are being compared to aircraft measurements collected during the Beaufort and Arctic Storms Experiment (BASE) that took place during the fall of 1994. Wintertime retrievals will not be validated until aircraft data become available, probably from the SHEBA (Surface Heat Budget of the Arctic Ocean) field experiment in 1997-98.

TOVS has flown continuously on NOAA polar-orbiting satellites since 1978, generating one of the longest and most complete satellite data sets available. It observes radiances in 24 channels in the visible, IR and microwave bands. Cooperating with the Laboratoire Meteorologie Dynamique, NASA has significantly reduced errors in polar retrievals by accounting for the unique physical characteris-

POLES investigators at five institutions specialize in meteorology, oceanography, glaciology and remote sensing. They include Roger Buess, University of Colorado; Frank Curvey, Jet Propulsion Laboratory, Jennifer Francis, Rutgers, The State University of New Jersey; Jeff Josselyn, Boston University; and Robert A. Brown, Scott Martin, Drew Rothrock, Axel Schweinger, Michael Steele, Don Vassilius and Jindan Zhang, all at the University of Washington. Information about the POLES project, access to its data sets, and links to other relevant sites are available on the World Wide Web at <http://psc.apd.washington.edu/POLES/> or contact the principal investigator, Drew Rothrock, Polar Science Center, Box 355640, University of Washington, Seattle WA 98195 (rothrock@apd.washington.edu).

tics of sea-ice-covered regions. At a horizontal resolution of approximately 100 km, NASA's TOVS processing algorithms can now provide estimates of an impressive list of geophysical variables, including vertical temperature profiles, layer-average water vapor content, cloud height and fraction, surface temperature, and microwave emissivity over sea ice. TOVS provides many of the quantities needed for air-ice-ocean modeling and climate process studies.

With the "polar-proofed" satellite retrievals, NASA has computed surface radiation and the advection of heat into the Arctic and shown the convergence of heat in particular regions, such as north of eastern Siberia, where heat is continually pumped by the Aleutian low-pressure system. With an imminent 15-year TOVS Polar Pathfinder data set, NASA will quantify the interannual and long-term change in the Arctic heat balance and quantify individual contributions of northward advection, surface heat exchange and radiation to space.

Surface Temperature

Near-surface temperature data are needed both as model input and for climate change analyses. While the development of surface temperature algorithms and data set production from satellite data have been underway, NASA has generated a multiyear, gridded, twice-daily temperature data set for the Arctic Basin, from 1979 to the present, using surface observations. It is unique in that it is based on the optimal interpolation of all available sources of surface data, including the Arctic drifting buoys (whose deployment began in 1979), the Soviet North Pole series of drift stations, and coastal weather stations. NASA's values have a mean error of about 2°C. The National Meteorological Center surface temperatures (which include no direct surface observations, only radiosondes) are biased warm by 5°C. NASA is analyzing this data set for interannual variability and any trend that would indicate global warming.

Ice-Ocean Modeling

Development of an ice-ocean model that uses observed ice motion data and satellite ice concentration data has produced exciting results. NASA has examined the freshwater budget of the Arctic Ocean from autumn 1979 to autumn 1985. The ice model uses data from drifting buoys to determine the velocity field and data from passive microwave satellites to determine the ice concentration field. The resulting fluxes of momentum and salt are then used to drive the ocean model. The model "grid" consists of seven broad regional cells where average quantities such as salinity profiles are computed to a depth of 200 m.

The model shows interannual variations of roughly 100% in the sea ice and fresh water exported through Fram Strait. The mid-1980s was a period of low freshwater export through Fram Strait into the Greenland Sea; this corresponds with a low-salinity anomaly in the Greenland Sea seen in analyses of ocean cruise records. These anomalous periods are believed to repress deep convection in the Greenland Sea and act as a control on the global thermohaline circulation in which the Greenland Sea is a crucial link. The freshwater exports through Fram Strait and through the Canadian Archipelago appear to be out of phase, suggesting that intermittent deep convection in the Greenland Sea and the Labrador Sea may also be out of phase.

The ice model results show that a surprising amount of ice is old and ridged. The Arctic ice cover consists primarily of multiyear ice, 60% by area and 82% by volume. The average ice thickness is 2.7 m, with a seasonal variation of 30% and an interannual variation of 10%. The ice export through Fram Strait varies from 1100 to 3000 km³, primarily because of varying ice velocity.

Program for Arctic Regional Climate Assessment

In 1991 NASA began an airborne program over the Greenland ice sheet to assess the accuracy of laser altimetry over ice. Early results indicated that ice-surface elevations could be measured to an accuracy of 20 cm or better along flight lines of several hundred kilometers. Consequently, during 1993 and 1994, all major drainage basins on the ice sheet were surveyed to yield a baseline data set for comparison with later airborne surveys and with data from the planned NASA satellite Geoscience Laser Altimeter System (GLAS), scheduled for launch in 2002. Comparison of these measurements with earlier satellite Doppler surveys in southern Greenland suggest thickening in the southwest of up to 2 m between 1980 and 1993. Annual surveys of a flight line along Jacobshavn Glacier and another along the EGIG line revealed thickening at about 1 m/yr over parts of the Jacobshavn Glacier but negligible change farther inland.

From the start this project included a surface program to validate the aircraft measurements and to help interpret satellite microwave data. This program provided an opportunity to obtain additional measurements needed to assess the significance of observed changes in surface elevation. This aspect of the field program now has the highest priority, the validation and microwave-interpretation components having largely met their objectives. Conse-

quently in 1995 NASA initiated the Program for Arctic Regional Climate Assessment (PARCA), which has the prime goal of measuring and understanding the mass balance of the Greenland ice sheet. The main components of this program are:

- Periodic airborne laser-altimetry surveys along precise repeat tracks across all major ice drainage basins;
- Ice-thickness measurements along the same flight lines;
- Monitoring of various surface characteristics of the ice sheet using satellite radar altimetry, SAR, passive-microwave, AVHRR and scatterometer data;
- Surface-based measurements of ice motion at 30-km intervals along the 2000-m contour completely around the ice sheet, with interpolation of local relative ice motion using interferometric SAR;
- Shallow ice cores (10–200 m) at many locations to infer recent climate history, atmospheric chemistry and interannual variability of snow accumulation rates and to measure temperature and vertical ice motion at various depths;
- Investigations of surface energy balance and factors affecting snow accumulation and surface ablation (this program is a collaborative effort with NSF and includes the installation of automatic weather stations at the deeper drill-hole sites);
- Estimation of snow accumulation rates by model analysis of column water vapor obtained from radiosondes and TOVS data;
- Detailed investigations of individual glaciers and ice streams responsible for much of the outflow from the ice sheet; and
- Development of a thermal probe to measure various ice characteristics at selected depths in the ice sheet.

This program is expected to continue through at least the next five years, with resurvey of the laser-

altimeter flight lines in 1998–99. By then NASA should have estimates of ice velocity across the entire 2000-m contour line, results from 150- to 200-m ice cores at approximately 500-km intervals along the same route, energy-balance investigations plus automatic weather stations at most of these sites, and significant improvements in our knowledge of snow-accumulation rates, surface melting and glacier discharge. NASA will also have compiled time series of surface and near-surface characteristics derived from satellite SAR, passive-microwave, AVHRR and scatterometer data.

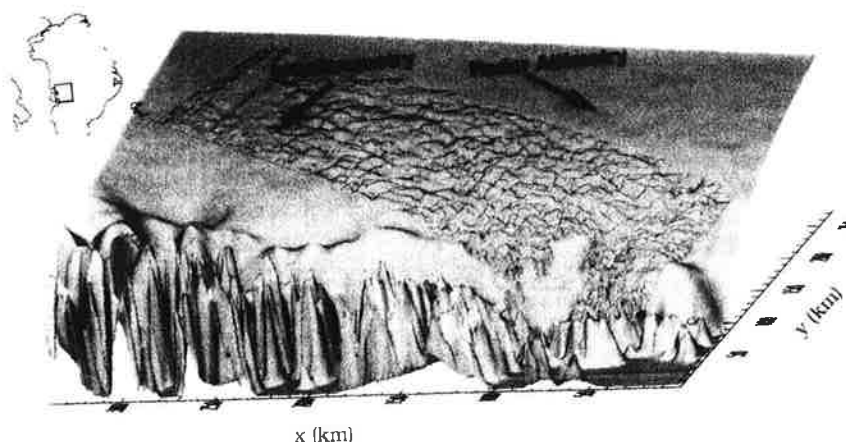
SAR Interferometry over the Greenland Ice Sheet

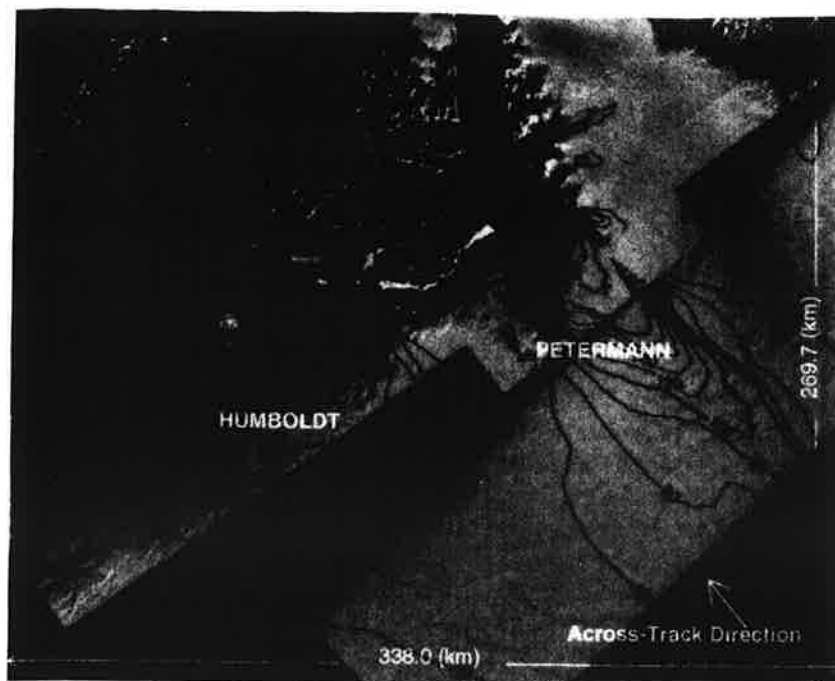
The ice sheets of Greenland and Antarctica play an important role in the Earth's climatic balance. Of particular importance is the possibility of a significant rise in sea level brought on by a change in the mass balance of, or collapse of, a large ice sheet. Accurate topographic and ice-flow velocity data are essential for improving estimates of mass balance and for gaining a better understanding of ice dynamics. Despite this importance, relatively little topographic or velocity information has been collected for the ice sheets. Radar altimeters have measured topography but without the fine horizontal resolution necessary for many applications. Velocity data are sparse due to the logistical difficulty and expense of making ground-based measurements. Ice-flow velocities have been measured from the displacement of features observed in pairs of visible or SAR images, but these methods do not work well for the large, featureless areas that comprise much of the ice sheets.

Since the launch of the ERS-1 SAR several researchers have demonstrated that satellite radar interferometry is capable of accurately measuring ice velocity and surface topography. This technique uses the phase difference between coherently interfered pairs of complex SAR images, which form an interferogram. When the images are acquired at different times from nearly-repeating orbits, the interferogram is affected by both topography and surface displacement. As a result, two interferograms are required to separate the combined topographic and motion information.

This technique has been used to study the movement of the Humboldt and Petermann Glaciers in northwest Greenland. The interferometer is sensitive to surface displacement that is directed toward or away from the radar. Thus, the observed displacement is affected by both horizontal movement normal to the satellite track (across track) and vertical movement of the ice. The effect of vertical

Comparison between interferometric and radar altimetric elevation models. The interferometric data covers a 100- × 300-km strip northeast of the terminus of Jacobshavn Glacier in western Greenland. The increase in detail provided by interferometry is striking. Comparison of the interferometric data with airborne laser altimeter data (10-cm scale accuracy) from a 76-km long profile yielded estimates of 4-m absolute accuracy and 2.6-m relative accuracy.





Contour map of velocity for the Petermann and Humboldt Glaciers in northwest Greenland.

displacement was canceled using interferometrically determined surface slope information and the result scaled to estimate the across-track component of horizontal velocity. To estimate the along-track component of velocity, not-yet-acquired data from a different (ideally orthogonal) satellite-track is needed. In this example, the across-track direction is nearly aligned with the primary direction of flow so that the contours are a reasonable approximation of ice speed. No other method offers the ability to create such accurate, high-resolution (80 m) maps of velocity over such a wide area.

The velocity maps indicate that, although the Humboldt and Petermann are adjacent to each other, they have quite different flow patterns. The Petermann Glacier is a fast-moving outlet glacier that is channeled by a well-developed fiord that extends back under the ice. The flow is strongly convergent, with peak speeds of nearly 1000 m/yr near the grounding line. The Humboldt Glacier discharges a similar volume of ice across a much wider calving face, exhibiting weakly convergent flow with much slower flow speeds than the Petermann Glacier.

With its ability to provide detailed velocity and topographic data, interferometry is proving to be a powerful new remote-sensing technique for glaciological studies. One area in particular where interferometry may prove useful is in the improvement of estimates of ice discharge flux, which are poorly known. In conjunction with ice thickness data from sensors such as the University of Kansas airborne radar-echo sounder, high-resolution interferometric velocity data can be used to estimate the

discharge flux of outlet glaciers. Application of this method to the major outlet glaciers of Greenland and Antarctica would yield much improved estimates of ice discharge, leading to better mass balance estimates.

Terrestrial Ecology

NASA's Terrestrial Ecology Program focuses on the function of global terrestrial ecosystems and their interactions with the atmosphere and hydrosphere. Particular emphasis is placed on carbon cycling, land-atmosphere interactions and remote sensing. Specific objectives are directed toward understanding the factors controlling ecosystem function, land-cover patterns and processes, the response of ecosystems to change, and exchanges with the atmosphere related to biogeochemical cycling and the physical climate system. Airborne and spaceborne remote-sensing measurements are used extensively to achieve these objectives and to extend small-scale process understanding to regional and global contexts. Ecological modeling is also a major component of the program.

With respect to the Arctic, the Terrestrial Ecology Program supports a few remote-sensing research studies to characterize the Arctic and boreal landscapes (using both active and passive microwave sensors) and a few process studies to understand carbon dynamics and trace gas fluxes in the region. In addition, a major interdisciplinary field campaign, the Boreal Ecosystem-Atmosphere Study (BOREAS), which technically is confined to the boreal forest biome, conducts research relevant to the Arctic.

BOREAS is a major, international remote-sensing and field observational project to improve our understanding of interactions between the boreal forest biome and the atmosphere. It is being sponsored jointly by several U.S. and Canadian government agencies, with NASA as the lead. The primary scientific focus of BOREAS is on understanding the boreal region's response to and influence on climate. This is accomplished through intensive observations of exchanges of radiative energy, heat, water, carbon dioxide and trace gases and through improvement of computer simulation models of the processes controlling these exchanges. It is important to focus on this region because the boreal forest is one of the Earth's largest biomes and plays a significant role in the Earth's carbon cycle and energy balance. Its soils are a major storehouse for organic carbon.

The intensive field observational component of BOREAS was conducted from August 1993 through September 1994 in central Canada. A con-

tinuous set of monitoring measurements—meteorology, hydrology and satellite remote sensing—were gathered over the 1000- × 1000-km BOREAS study region that covers most of Saskatchewan and Manitoba, Canada. This monitoring program was punctuated by six campaigns that saw the deployment of over 300 scientists and air crew into the field, supported by 11 research aircraft. The participants included primarily scientists from U.S. and Canadian research institutions, but important contributions also came from scientists from France, the United Kingdom and Russia. The field campaigns lasted for 123 days and resulted in the compilation of a comprehensive surface-atmosphere flux data set supported by ecological, trace gas, hydrological and remote-sensing observations. The surface-atmosphere fluxes of sensible heat, latent heat, carbon dioxide and momentum were measured using eddy correlation equipment mounted on a surface network of 10 towers complemented by four flux-measurement aircraft. Seven aircraft carrying advanced remote-sensing imaging instruments (for example, radar, hyperspectral, multi-angle optical, laser and multi-polarization equipment) flew during four intensive observational periods throughout the annual cycle. Over 350 airborne missions, including eddy correlation and remote-sensing observations, were flown during the 1994 field year.

Preliminary analyses of the data indicate, as expected, that the area-averaged photosynthetic capacity of the boreal forest is much less than that of the temperate forests to the south. This is reflected in very low photosynthetic and carbon draw-down rates, which in turn are associated with low transpiration rates (less than 2 mm per day over the growing season for coniferous species in the area). The strong sensible heat fluxes generated as a result of this often lead to the development of a deep, dry planetary boundary layer over the forest, particularly during the spring and early summer. The effects of frozen soils and the strong physiological control of evapotranspiration in the biome do not seem to be well represented in most operational general circulation models (GCMs) of the atmosphere. Already these results have led to the improvement of land surface parameterizations in GCMs.

BOREAS scientists will return to the field in 1996 to resolve a few issues and fill data gaps from 1994. The field phase of this study will end in 1996, although Canadian institutions are exploring mechanisms to continue some of the monitoring measurements and to exploit the future research potential of these sites. Analyses of the data will continue through the year 2000.

Arctic Ozone

NASA's Upper Atmosphere Research Program (UARP) and Atmospheric Chemistry Modeling and Analysis Program (ACMAP) support a number of tasks related to measuring and understanding chemical and dynamic processes in the Arctic atmosphere from the upper troposphere through the stratosphere and lower mesosphere. Such studies include the measurements and subsequent data analysis using space-, aircraft-, balloon- and ground-based instruments. A particular area of emphasis involves the mechanisms whereby polar and midlatitude exchange occurs in the upper atmosphere.

Since air inside the winter polar vortices typically has very different chemical composition from air outside the vortex, significant transport and exchange of air could have important implications for midlatitude ozone amounts. Both observations and modeling efforts during 1994-95 have shown strong evidence that air inside the vortex is well isolated from the air outside through most of the stratosphere and that the isolation of the Arctic vortex is much less complete in December and March (corresponding to vortex spin-up and breakdown, respectively) than it is in January and February.

The Vortex Ozone Transport Experiment (VOTE), based in Fairbanks, Alaska, was conducted from December 1995 to February 1996 using the NASA DC-8 aircraft as a research vehicle. The scientific purpose of this mission was to examine small-scale features (filaments) in ozone and methane, which are believed responsible for the exchange of trace gases between the polar regions and midlatitudes. Other goals included testing the accuracy of forecasts of the appearance of these features, determining ozone loss rates in the Arctic winter polar vortex by measurements of ozone/methane ratios as a function of time, and determining if heterogeneous reactions might be taking place on high cold cirrus in a manner similar to that on polar stratospheric clouds (PSCs). Sharp gradients in ozone were seen outside the vortex as the DC-8 crossed polar vortex filaments during flights out of Fairbanks and during a transit to Iceland. The location of these filaments agreed well with predictions. There was also some evidence of midlatitude intrusions into the vortex, again in agreement with forecasts. The DC-8 underflew the coldest part of the vortex, where temperatures were low enough to form nitric acid trihydrate (a form of PSC) but no particles were observed.

Measurements of trace chemical species in the Arctic stratosphere are made regularly using the

Upper Atmosphere Research Satellite (UARS). A particularly important set of measurements are those of the microwave limb sounder (MLS) instrument, which measures O_3 and ClO . MLS measurements have been very useful in pointing out the abundance of high levels of ClO in the Arctic. Record high ClO and low ozone values were recorded at high northern latitudes in 1995. MLS measurements of HNO_3 made during the VOTE mission showed the vortex to be denitrified, which would explain the absence of PSCs at that time. Because of slightly higher temperatures and less persistent confinement, Arctic ozone losses have not been as severe as in the Antarctic. Interannual variability in the dynamical conditions of the Arctic vortex is in general greater than in the Antarctic, and ozone distributions in the winter and spring will therefore have much greater interannual variation than in the Antarctic. A slight cooling of the stratosphere due to increasing concentrations of radiatively active gases has the potential to exacerbate ozone depletion in the Arctic through the formation of increased amounts of polar stratospheric clouds.

A unique set of measurements was obtained at high northern latitudes in April 1993 as part of the second flight of the Atmospheric Laboratory for Applications and Science (ATLAS) on the Space Shuttle. Extensive analysis during 1994 and 1995 of the data obtained by the atmospheric trace molecule spectroscopy (ATMOS) instrument has revealed details about the partitioning among the major components of stratospheric chlorine-containing molecules inside and outside of the remnant Arctic vortex. Another study using ATMOS data has looked at distributions of long-lived tracer species such as CH_4 , N_2O and HF , which give information on transport effects that have occurred during the winter and provide a dynamical context for analyses of the chemistry of reactive chlorine and nitrogen species during the erosion of the vortex in the spring. They infer average winter descent

rates for vortex air and observe that some of the barrier to transport persists at least until mid-April.

Ground-based Fourier transform spectrometer (FTS) measurements at Sondre Stromfjord, Greenland, have been made by researchers from the National Center for Atmospheric Research from October 1994 to April 1995. Conducted under UARP support, these measurements are a component of the international Network for Detection of Stratospheric Change (NDSC) and have yielded column abundances for HCl , HF , O_3 , HNO_3 and N_2O . The results have been compared with similar observations made during the Second European Stratospheric Arctic and Midlatitude Experiment (SESAME) and will be presented in a special issue of the *Journal of Atmospheric Chemistry* later this summer. In parallel with the observations from Sondre Stromfjord, a new FTS instrument is being installed at the NDSC site in Thule, Greenland, with operations scheduled to begin in late 1996.

During the winters of 1994 and 1995 a number of balloon-borne instruments were flown out of Kiruna, Sweden, by UARP investigators in collaboration with the SESAME campaign. The instrument suite included the submillimeter limb sounder (SLS) and an ultraviolet ozone absorption photometer from the Jet Propulsion Laboratory and a ClO/BrO detection system from the University of California at Irvine. The observations were also compared with UARS MLS and Halogen Occultation Experiment (HALOE) instrument retrievals.

NASA's UARP and ACPMAP programs continue to support measurements and multidimensional models for atmospheric chemistry and transport needed to study the global atmosphere. The mission results presented above underscore the necessity to include the full range of dynamical, radiative and chemical processes in models that are used to predict future ozone losses given prescribed scenarios for emission of CFCs, their substitutes and other chlorine- and bromine-containing compounds.

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. Individual research programs focus on scientific questions addressing the Arctic environment and its relation to the global environment. NOAA also conducts research in support of services it performs, such as weather forecasting and fisheries management.

Arctic Marine Mammals

The Protected Resources Management Division and the National Marine Mammal Laboratory (NMML) of NOAA's National Marine Fisheries Service (NMFS), both in Alaska, are responsible for the protection, management and research for 22 species of marine mammals that occur commonly in that state, including five endangered species (bowhead, fin, humpback, northern right and sperm whales), one threatened species (Steller sea lion) and one depleted species (northern fur seal). Protection involves implementation of recovery plans for the Steller sea lion and the humpback whale, the implementation of the Northern Fur Seal Conservation Plan, the development and implementation of a conservation plan for the harbor seal, and cooperation with the International Whaling Commission regarding subsistence takes of bowhead whales. In 1994 Congress amended the Marine Mammal Protection Act (MMPA), adding several new sections, including one pertaining to cooperative agreements in Alaska. The amended MMPA notes that "the Secretary may enter into cooperative agreements with Alaska Native organizations to conserve marine mammals and provide co-management of subsistence use by Alaska Natives." The amendments specifically provide NMFS with the authority to provide grants to Alaska Native organizations to:

- Collect and analyze data on marine mammal populations;
- Monitor the harvest of marine mammals for subsistence use;
- Participate in marine mammal research; and
- Develop co-management structures with Federal and State agencies.

The NMFS's Alaska Regional Office (AKR) has recently received concurrence from Alaska Native groups to develop a program to determine subsistence takes of Steller sea lions, harbor seals

	Funding (thousands)	
	FY 94	FY 95
Arctic haze	50	0
Solar terrestrial	201	700
Atmospheric trace constituents	185	328
Environmental prediction	950	287
Fisheries assessment/management	2,478	5,786
Marine mammal assessment	1,200	1,962
Coastal hazards	42	50
Ocean assessment	112	115
Stratospheric ozone	150	235
Satellites/data management	800	703
Human resources	589	0
Aircraft/vessels	2,500	1,756
Climate and global change	784	801
Arctic ice	315	35
Remote sensing	0	300
Total	10,336	12,815

and beluga whales. Through contracts with the Alaska Department of Fish and Game and with the Cook Inlet Marine Mammal Council, comprehensive data on levels of subsistence taken in recent years have been collected. These data are critical to the successful co-management of these species. Further, the AKR has supported, and partially funded, the development of Alaska Native Harbor Seal and Steller Seal Lion Commissions and has worked with the Indigenous People's Council for Marine Mammals, the Pribilof Islands Joint Management Board, the Alaska Beluga Whale Committee and several other groups to further conservation of marine mammals taken for subsistence. One such successful program developed in cooperation with Native organizations was the systematic collection of tissue samples from Steller sea lions, harbor seals and beluga whales in Alaska to determine whether contaminant levels in tissues intended for human consumption are at acceptable levels. The AKR has also been instrumental in spearheading efforts to try to overcome the negative impacts of development on the Pribilof Islands by working with the Coast Guard, EPA, Corp of

Engineers, Alaska State agencies, and the residents and governments on St. Paul and St. George Islands. Finally, the AKR has been working with Russian and American marine scientists to support additional research on local problems and on the health of the overall Bering Sea ecosystem.

Some of the changes to the MMPA in 1994 significantly affected research on marine mammals in Alaska. In addition, the general trend to downsize programs within the Federal government has eroded support for several long-term research projects. For example, NMML's bowhead research program has been terminated. One of the primary accomplishments of NMML scientists in recent years was the summarization of the status of all of the stocks of marine mammals that occur in the waters off Alaska. This volume, titled "Alaska Marine Mammal Stock Assessments 1995," is available at no cost and includes summaries for each species on the following topics: stock definition, population size, minimum abundance, current trends in abundance, maximum productivity, potential biological removal levels, human-caused mortality and status.

Field research at the NMML on marine mammals in waters off central and northern Alaska has concentrated on five species in recent years: Steller sea lions, harbor seals, northern fur seals, beluga whales and gray whales. Below are summaries of field work on the Steller sea lion, beluga whale and gray whale.

The breeding range of the Steller sea lion extends from the Kuril Islands and Okhotsk Sea, eastward through the Aleutian Islands and Gulf of Alaska, and then south to central California. The number of sea lions throughout the range has declined by over 66% from about 300,000 in the 1960s to 116,000 in 1989, the first range-wide survey. The second range-wide survey in 1994 coordinated by the NMML indicated a further decline. At present the area from southeastern Alaska through Oregon is the only region where the number of animals is not declining. Counts of animals on rookeries and haulout sites within most of Alaska declined rapidly between the 1970s and 1989 and have continued to decline (but at a slower rate) from 1989 to 1995. As yet, the cause(s) for the decline have not been identified.

Steller sea lions disperse widely throughout the range after their breeding season. Thus, sea lions incidentally taken in Alaskan fisheries from July to May could be from declining or stable populations. At present, Steller sea lions in the United States are managed as a single population, regardless of their geographic derivation because when Steller sea lions were being considered for listing under the U.S. Endangered Species Act in

the late 1980s, there was no evidence of geographic stock separation. Consequently the species was listed as threatened throughout its range even though populations in some areas were not at low levels or declining. Recent research by the NMFS has addressed the hypothesis that the Steller sea lions in Alaska are composed of at least two stocks.

The strongest evidence for stock separation is genetic studies that suggests that an eastern and a western stock exist, with the division at about Prince William Sound. Differences observed in population dynamics and site groupings resulting from an analytical technique called cluster analysis further support the notion of limited gene flow among rookeries (and stocks). Tagging and branding studies show that Steller sea lions are reproductively faithful to their birth sites and that fewer than 10% emigrate. Large amounts of mixing away from rookeries during the nonbreeding season is potentially confounding but may not result in interbreeding between animals from the two areas. Differences among sea lions found in other studies, such as pup weights and blood parameters, are tantalizing and suggests the need to continue with these studies. NMML biologists recommend that Steller sea lions be managed as two stocks, an eastern stock that includes all animals east of Cape Suckling, Alaska (144°W longitude) and a western stock that includes all animals at and west of Cape Suckling. When sufficient data are available, particularly on the genotype of Steller sea lions in the Kuril Islands, recognition of additional stocks may be appropriate.

Beluga whale research has taken place annually over the last three years. The primary focus of NMML-supported beluga whale surveys has been in the Cook Inlet Region. Here, in cooperation with the Alaska Beluga Whale Committee, the Cook Inlet Marine Mammal Council, the Alaska Department of Fish and Game and the AKR, NMML scientists have attempted to determine the abundance of a relatively small and isolated population. Aerial surveys have indicated an abundance of whales, on the order of 1000 animals. Research has also been directed toward catching and radio-tagging animals to determine movement patterns and correction factors for aerial surveys. Efforts are underway to determine if the number of animals in Cook Inlet is sufficient to support recent subsistence harvests of approximately 50 animals per year.

In the past 10 years, NOAA funding to support research on ice seals has generally not been available. At present, reliable estimates of abundance for ringed, bearded, ribbon and spotted seals are not available, although the current level

of subsistence use of these animals is thought to number in the thousands annually. Therefore, the NMFS is tentatively planning on initiating surveys to determine abundance for these species in 1998. These surveys will be done in cooperation with the Alaska Department of Fish and Game, Native organizations, local residents and the AKR.

The Marine Mammal Health and Stranding Response Program (MMHSRP) was established in 1992 to facilitate the collection and dissemination of data on the health of marine mammals and health trends in marine mammal populations in the wild, to correlate these trends with available data on physical, chemical and biological environmental parameters and to coordinate effective responses to unusual marine mammal mortalities. In 1987 the Minerals Management Service provided funds to NOAA to establish and conduct the Alaska Marine Mammal Tissue Archival Project (AMMTAP) for the collection and long-term storage of tissues from Alaska marine mammals. AMMTAP continues now in conjunction with the MMHSRP with funding provided from DOI's National Biological Service and the NMFS. The program involves the participation and cooperation of Federal agencies, state organizations, international agencies, universities and Native American organizations. Samples continue to be collected to determine the levels of contaminants in Alaskan marine mammals, to determine the health of populations, and to examine correlations between health parameters and contaminant levels. In addition, the data are being used by public health organizations to examine circum-polar patterns of chlorinated hydrocarbon concentrations and the potential risk to people who eat marine mammals as subsistence foods.

MMHSRP has involved the evaluation of health and contaminant issues through the analysis and banking of marine mammal tissues from subsistence hunting activities. The NMFS's Environmental Conservation Division has spearheaded the analyses of these tissues for contaminants as part of the monitoring component. These analyses have provided baseline data on the levels of contaminants in Alaskan marine mammals. In 1995 over 420 samples were collected or analyzed for chlorinated hydrocarbon levels. Preliminary evaluations indicate that the patterns of congeners of PCBs from Alaskan marine mammals exhibit different patterns of accumulation than those of tissues from marine mammals from other geographic areas.

The Department of Commerce's National Institute of Standards and Technology (NIST) serves as the depository for the archived tissues

from these animals. These tissues are frozen and stored for future analyses as needed when new methods are developed or new questions are asked. Currently the tissue bank contains tissues from 87 pinnipeds and 54 cetaceans from Alaska. Analyses have been performed on selected portions of these tissues by the NIST, NMFS and collaborating researchers to establish baseline levels of trace elements (including heavy metals), PCBs and chlorinated pesticides in species of particular interest due to their subsistence value. A quality assurance component spearheaded by the NIST monitors the collection and analyses of these samples to ensure consistency and accuracy of the data.

Finally, health issues in these marine mammal populations are addressed through cooperation with the Armed Forces Institute of Pathology and the Department of Agriculture. Tissues from these animals are being analyzed for evidence of disease and will be stored for future analyses as needed. Sera from these animals have been banked for future studies of the presence of antibodies to specific diseases. In addition, specific analyses are being performed to monitor the presence of diseases of current concern.

All of the data collected are centralized into a database that can be accessed by researchers and managers. The information collected will help managers make risk assessment and impact decisions regarding marine mammal populations in the Arctic. In addition, these data will contribute to our current state of knowledge about the presence and possible effects of anthropogenic contaminants present in this fragile ecosystem.

Marine Fisheries

Fisheries Assessment

NOAA's NMFS continued its long-standing commitment to assessment studies of U.S. living marine resources (LMRs) in the Bering Sea and Aleutian Islands during 1994 and 1995. This effort includes 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 (EEZ).

The Alaska Fisheries Science Center (AFSC) in Seattle continues to annually assess the stock condition for most species of marine finfish and

shellfish having commercial, recreational or ecological significance in western U.S. Arctic waters (the Bering Sea and Aleutian Islands). These assessments provide measures of population abundance independent of those derived from analyses of fisheries statistics, and they also address the status and health of the marine ecosystem as a whole. Information syntheses incorporate identification of stock units, short-term prediction of abundance trends, biological interaction of species and species groups, and general ecosystem response to environmental change. When combined with data from the commercial fleet (that is, fishing effort, location, catch composition, fish size/age, etc.) collected through the AFSC's Observer Program, AFSC stock assessments provide recommendations for managing the fisheries and conserving the supporting resource base.

LMR populations are sampled at sea aboard NOAA ships, chartered fishing vessels and cooperating foreign research vessels. Significant area-extensive survey effort rotates every three years between the eastern Bering Sea, the Gulf of Alaska and the Aleutian Islands. During intervening years, standardized AFSC assessment surveys are conducted within each region. Annual estimates of stock abundance are completed for commercially important species, such as walleye pollock, Pacific cod, sablefish, yellowfin sole and king and Tanner crabs. Dedicated scientific cruises are also conducted to study biological and physical processes that affect stock assessments.

The principal survey methods include bottom trawls for demersal fish and crabs, hydroacoustic and midwater trawls for semipelagic fish, and special-purpose nets for eggs, larvae and juvenile fish and shellfish. Trawl and acoustic surveys are used to estimate biomass and define community structure; biological collections are taken to examine variability in growth, mortality and stock recruitment. In 1994 the AFSC conducted comprehensive bottom-trawl surveys of Bering Sea and Aleutian Islands finfish and shellfish and an echo integrational/midwater trawl survey of Bering Sea pollock as a continuation of annual and triennial survey efforts begun in the Bering Sea in the mid-1970s. In 1995 the AFSC continued the annual survey effort in the Bering Sea with a bottom trawl survey of finfish and shellfish on the eastern Bering Sea shelf. Recruitment indices and processes that generate variations in abundance are studied to improve prediction through the Fisheries-Oceanography Coordinated Investigations (FOCI). FOCI is a cooperative program between the AFSC and NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle. To increase the accuracy and precision of these

assessments, AFSC scientists conduct biological research to define recruitment processes, develop computer models to simulate interactions and dynamics of population change, and conduct or collaborate in extramural studies to improve sampling methods and survey designs.

Bering Sea Fisheries Oceanography Coordinated Investigations

As of September 1995, Bering Sea FOCI completed four years of a six-year program to develop an improved understanding of the ecological processes affecting population distribution and size for walleye pollock, which is the largest, single-species fishery in the world. This project is funded by NOAA's Coastal Ocean Program and managed by PMEL. Bering Sea FOCI research provides information to resource agencies such as the International Convention on Conservation and Management of Pollock Resources and the U.S. North Pacific Fishery Management Council. Bering Sea FOCI has already established a basis of understanding of recruitment and populations and has developed tools and methods to learn more. The project has made advances toward defining the stock structure of Bering Sea pollock by determining basin circulation, analyzing recent and historical survey data, and developing genetic testing methods. The research is on the verge of being able to say whether there are repeatable, significant differences in genetic structure between fish from the eastern and western portions of the Bering Sea. The overall goal of Bering Sea FOCI remains to reduce uncertainty in resource management decisions through ecological research on pollock recruitment and stock structure in the Bering Sea. During FY 95, Bering Sea FOCI completed components to contribute to the realization of the goal and to perform seed research for future years.

In 1996 the Coastal Ocean Program will be initiating a new regional ecosystem study in the Bering Sea. The goal of this new study, Southeast Bering Sea Carrying Capacity (SEBSCC), is to study the southeastern Bering Sea ecosystem and the role of juvenile pollock in it, including the factors that affect their survival.

Ocean Assessment

The occurrence of contaminants, including artificial radionuclides, in the Arctic environment and biota has been documented for nearly 30 years. However, during the past two decades, such occurrences have become better document-

ed and include a wide spectrum of anthropogenic contaminants, including chlorinated industrial chemicals and pesticides, toxic metals, organo-metallic compounds, petroleum hydrocarbons and radionuclides. It is generally believed that due to prevailing global atmospheric circulation and the propensity of many persistent organic compounds for successive revolatilization, the Arctic has received and accumulated contaminants from lower latitudes for several decades—the “global fractionation” or “cold trapping” hypothesis. These concepts remain unproven because of a lack of adequate data on the sources, transport and fate of environmentally persistent contaminants in the Arctic, notably the U.S. Arctic.

The Office of Ocean Resources Conservation and Assessment (ORCA), of the National Ocean Service (NOS), is addressing Arctic ocean assessment issues in the following projects.

Arctic Pollution from Petroleum Development and Associated Contaminants

The Coastal Monitoring and Bioeffects Assessment Division (CMBAD) of ORCA recently completed a review of data from the U.S. Arctic on levels of petroleum hydrocarbons in water, sediment and biota. The review includes assessment of reconnaissance data that were obtained during the 1975–1980 period and more specific regional studies that were carried out in Norton Sound, the Chukchi Sea and coastal areas of the Beaufort Sea. In addition, the review incorporates new data, based on samples collected in 1993, on the amounts and distribution of polycyclic aromatic hydrocarbons in the sediment and biota of the Beaufort Sea continental shelf and deep waters of the Canadian Basin. This review is part of an Arctic-wide assessment of oil pollution that will be included as a chapter in the “State of the Arctic Environment” monograph to be published under the auspices of the Arctic Monitoring and Assessment Program (AMAP).

Radionuclides in the Arctic Environment and Biota

Since 1993, CMBAD/ORCA has taken the lead in establishing a quality-controlled data set on the spatial distribution and scales of contamination from radionuclides in the surficial sediment and selected biota. The purposes of this study are to describe the current extent of environmental contamination; establish a baseline to determine temporal trends in the future; and develop a strategy for establishing a long-term monitoring program in the U.S. Arctic. A second objective, contingent upon the results of detailed radiochemical analyses, is to characterize the type, chemical form and

source(s) of the radionuclides analyzed and to describe their probable transport and exposure pathways in the Arctic marine environment and biota. At selected sites the radionuclide data are being augmented with data on concentrations of persistent organic pollutants and toxic metals to provide a more comprehensive assessment of environmental contamination.

The principal approach for the study is to use NOAA’s in-house expertise and to establish cooperative efforts with other agencies and organizations in the collection of samples, radiochemical analyses and interpretation of study results. To date, field samples have been obtained in cooperation with NOAA’s National Marine Fisheries Service, the National Biological Service, the U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game, the North Slope Borough and the University of Alaska. Collection sites include continental shelf and oceanic areas of the Beaufort Sea; coastal sites off Barrow, Alaska; Wrangel Island; Talon Island; and coastal streams in Alaska and Siberia (for anadromous fish).

NOAA has also provided funding for a student intern at the North Slope Borough to develop a background report on regional issues relating to environmental contamination and to assist NOAA in collecting samples, reporting data and interpreting results. In this effort, particular emphasis is being placed on the occurrence of radionuclides in animals used for subsistence by local residents. This underscores NOAA’s commitment to involve the Arctic indigenous people in resource management and other decisions that affect them.

Study results obtained to date show that the concentration of artificial radionuclides in sediment and biota are very low, and cesium-137 was the only anthropogenic radionuclide detected by high-resolution gamma-ray spectroscopy. Cesium-137 activity in surficial sediment in the Beaufort Sea was between 1 and 12 Bq/kg (Bequerel per kg dry weight; 1 Bequerel corresponds to one nuclear transformation per second); it was between 5 and 7 Bq/kg for Wrangel Island and between 1 and 2 Bq/kg off Talon Island. In comparison, cesium-137 activity in Kara Sea sediment is 20–50 Bq/kg, and much higher, exceeding 150 Bq/kg, in Chernaya Bay, a fjord of Nova Zemlya, where a series of underground and atmospheric nuclear weapons tests have been carried out. In animals collected from the sea bottom, cesium-137 activity was barely detectable, most values being less than 1 Bq/kg; in anadromous fish, such as Arctic char, broad whitefish, Arctic cisco and Pacific salmon, collected from the U.S. Arctic waters, cesium-137 ranged from undetectable to 4

Bq/kg. Cesium-137 activity in liver, lung and blubber tissue of the bowhead whale and in the muscle and bone samples of king eider was extremely low as well.

The plutonium-240:239 atomic ratio in sediment samples, ranging from 0.15 to 0.24 but predominantly approximately 0.19, is indicative of global fallout as the radionuclide source. In general, the global fallout ratio (resulting from atmospheric nuclear tests) is between 0.175 and 0.190, and that resulting in weapons-grade plutonium is approximately 0.05. Chemical analyses of samples from the Bering Sea have recently been completed. Analyses are underway for a number of biological samples (whole animals) and specific tissue samples from subsistence species.

Atmospheric Research

Stratospheric Ozone

Stratospheric ozone plays an essential role in the Earth's ecology because of its absorption of ultraviolet radiation. The total ozone abundance over Antarctica has decreased dramatically during the austral spring seasons of the past decade, and this is now known to be caused by a combination of anthropogenically released chlorine and the special conditions of the polar climate.

In the Antarctic, virtually all of the ozone is removed each spring over the altitude range where polar stratospheric clouds exist. It is difficult to see the Antarctic ozone depletion becoming very much deeper (although it appears to be increasing in horizontal extent). In contrast, the Arctic is nowhere near this limit. Northern Hemisphere ozone depletion (on the order of 10–30%) was observed in 1993. Even if current international control measures are followed, chlorofluorocarbons (CFCs) will continue to increase, reaching their expected peak around the year 2000. During this period the Arctic ozone depletion will likely worsen.

NOAA's Aeronomy Laboratory (AL) is making long-term measurements in the Arctic (similar to those made in the Antarctic) of ozone, nitrogen dioxide, chlorine dioxide and bromine monoxide to monitor them and to increase our understanding of the seasonal, diurnal and long-term behavior of stratospheric ozone. Kangerlussuaq (Søndre Strømfjord), Greenland, is an ideal site for this purpose for two reasons:

- Its proximity to the Arctic Circle allows year-round twilight measurements (which afford the greatest instrument sensitivity); and
- It is near the (usual) center of the winter polar vortex, where the largest effects are expected.

A spectroscopic instrument, similar to the one that has been in use at McMurdo Station in Antarctica, was installed at the incoherent scattering radar site near Kangerlussuaq in late September 1994, after almost nine months of developmental work. The technique used is UV-visible absorption spectroscopy, using scattered sky light as the light source. The data give total column measurements of NO₂, O₃, and OClO or BrO, depending on the wavelength range chosen (visible or near-UV). These are key molecules involved in ozone-depletion chemistry. The instrument is operated by remote computer control and enables scientists to monitor the trace gases with very little on-site operator attention. This instrument is the only atmospheric chemistry experiment at the site, although other agencies and institutions measure dynamic and electrical atmospheric parameters.

Also, in 1994, collaboration with the Danish Meteorological Institute (DMI) began, prompted by the need for cooperation and logistics coordination for the installation of the AL instrument in Greenland. That initial collaboration was followed by the development of a mutual scientific interest in the phenomenon of spring surface ozone loss that has been observed in Greenland. Further collaboration with DMI resulted in the visit of a Danish graduate student to the laboratory in summer of 1995 for six months. This student worked on improving the DMI data analysis procedures and on modeling DMI data with the model developed by the laboratory. A paper on that work is forthcoming in 1996.

During the first quarter of 1995, scientists from the AL conducted a field visit to Kangerlussuaq, which involved additional chemical measurements during the spring period to try to understand the phenomenon of spring ground-level ozone loss. Additional chemical species were measured (bromine monoxide, in particular) by operating two spectrographs. Also, a surface ozone spectrometer was added for the campaign. Several events occurred in March and April 1995 in which surface ozone suddenly decreased to less than 10 ppbv. At least one of those events was associated with increased BrO and OClO levels.

Atmospheric Trace Constituents

NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL), located in Boulder, CO, has operated a background atmospheric monitoring observatory at Barrow, Alaska, since 1972. The Observatory is part of a larger four-observatory network with other stations at Mauna Loa, Hawaii; American Samoa; and the South Pole. Continuous

and discrete measurements of atmospheric trace constituents are taken to study their impact on global climate. Moreover, these measurements provide a long-term documentation of specific quantities representing the background state and composition of the atmosphere. The Barrow station is a vital component of the network representing Arctic background conditions.

The program mission at Barrow, as at the other three NOAA/CMDL observatories, is focused on research related to those atmospheric constituents capable of forcing change in the Earth's climate through modification of the atmospheric radiative environment and those that may cause depletion of the global ozone layer. The mission is accomplished primarily through long-term measurements of trace atmospheric species such as carbon dioxide, carbon monoxide, methane, nitrous oxide, surface and stratospheric ozone, halogenated compounds including CFC replacements, aerosols, and solar and infrared radiation at baseline observatories and other sites spanning the globe. These measurements document global changes in the key atmospheric species, which are all affected by mankind, and identify causes of interannual variability. The resulting data are used to assess climate forcing and ozone depletion, to develop and test predictive models, and to keep scientists, policymakers and the public abreast of the current state of our chemical and radiative atmosphere.

A primary objective of CMDL is to determine regional-scale sources and sinks of several primary trace species. Toward this objective, a global network of flask sampling is undertaken at more than 40 sites. The Arctic sites of this network are at Alert and Mould Bay, Canada; Cold Bay and Shemya, Alaska; Ocean Station "M"; Iceland; and Spitsbergen. Once per week, ambient air is collected in a pair of flasks for analysis of carbon dioxide and nitrous oxide. The resulting data from this array of measurements are analyzed, in conjunction with two- and three-dimensional transport-diffusion model results, for insight into the global and regional carbon cycle. For example, a distinct slowdown of the global carbon dioxide growth rate during 1992-93 has been shown to be linked to an abnormally strong terrestrial biospheric sink in the temperate latitudes of the Northern Hemisphere.

Atmosphere-Ice Interactions

Over the last five years, NOAA's Environmental Technology Laboratory (ETL) has developed an extensive capability for polar measurements for the Arctic Leads Experiment (LEADEx), which took

place in March and April 1992 under the auspices of the Office of Naval Research (ONR). The objectives of this program were:

- To develop new remote sensing methods for Arctic boundary layer research and apply them to field studies of Arctic boundary layer phenomena;
- To improve our understanding of the physical processes dominating the dynamics of the persistent, stably stratified Arctic atmospheric boundary layer with emphasis on transitory phenomena, including interactions with internal waves and Arctic leads; and
- To use the data collected during field studies to improve air-sea-ice flux parameterizations and to improve parameterizations and algorithms in numerical models used to forecast weather in the Arctic.

The efforts of ETL for the Arctic Leads Accelerated Research Initiative (ARI) have produced significant results, both technologically and scientifically. The technological results include the development of a portable minisodar, which was useful in the Arctic and which will undoubtedly be useful for other research and for providing data on the response obtained from profilers and ceilometers in the exceptionally cold and dry Arctic climate. The scientific results include useful measurements near two leads and a fairly complete and unique atmospheric data set from the base camp, characterizing the pack-ice background springtime atmospheric structure. The lead data have provided some in-situ verification for large eddy simulations of leads, and it has also shown that the problem is more complex than initially thought because of the rapid and spatially varying refreezing of the leads and because of the varying background lower tropospheric structure. The base camp data have shown surprisingly large diurnal cycles of the near-surface atmospheric structure and significant impact of radiative and subsurface fluxes on the surface heat budget. In FY 94 and FY 95, analyses of this data set have provided descriptions of springtime atmospheric processes in a climatologically important region where data are scarce, and the data set is being or will be used for initializing and verifying a one-dimensional boundary layer model, a one-dimensional radiation model, three-dimensional mesoscale models, or surface parameterizations used in global climate models.

The observational results from LEADEx will provide important information for the planning of the Surface Heat Energy Budget of the Arctic (SHEBA) field program, which is sponsored by the Arctic System Science (ARCSS) program of NSF. An 8- to 12-month deployment is planned several hundred kilometers north of Prudhoe Bay, Alaska,

beginning in fall 1997 or spring 1998. SHEBA will be an investigation of the physics of the surface balance of the ice sheet, with a focus on ice albedo and cloud feedback mechanisms. SHEBA will have an extensive set of surface in-situ sensors and surface-based remote sensors for measurements of the ocean, the ice and the atmosphere. The NASA-sponsored third deployment of the First ISCCP (International Satellite Cloud Climatology Program) Regional Experiment (FIRE-III) will be conducted in the summer of 1998 in close coordination with SHEBA; FIRE-III will be investigating Arctic clouds and their impact on climate. SHEBA is also collaborating closely with the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) program, which is a long-term study of atmospheric radiative transfer processes. The overall goal of these studies is to advance the fundamental state of knowledge of these complex processes and to provide a comprehensive set of data that can be used to improve models and satellite observations of the surface and atmosphere. ETL participates in these programs with support from NSF, NASA, NOAA/Office of Global Programs and ETL base funds. Based on its experience and general expertise in remote sensing, ETL won two SHEBA awards in FY 95 to develop, construct and test a Doppler cloud radar, a lidar and a Doppler wind profiler for future deployment in the main ice camp of SHEBA. A prototype wind-profiler system has already been successfully tested in FY 95, and a prototype lidar system will be deployed on a ship in March 1996. Components for the Arctic ruggedized versions will be ordered following the field tests. Construction of the Doppler cloud radar is in progress. This radar is a close copy of the cloud radars that ETL is building for the other DOE ARM sites.

Meteorological, Ice and Data Services

Solar-Terrestrial Services and Research

The Space Environment Center (SEC) continues to monitor solar activity and its effects on the space environment near Earth and on man's activities. The real-time monitoring and forecasting service provided by SEC's Space Environment Forecast Center, in collaboration with the U.S. Air Force Air Weather Service, serves the needs of Federal agencies and nongovernment users. The most dramatic effects on and above Earth occur in Arctic and Antarctic regions, where the geomagnetic field lines pass vertically through the upper atmosphere.

NOAA has space environment monitor (SEM) packages on each of the polar-orbiting satellites. They measure the total power input to the upper atmosphere due to particles entering the atmosphere from the magnetosphere. They routinely monitor the response of the particles to high-latitude disturbances. As of late 1995 the SEM on board NOAA-12 continues to operate with no degradation. The last of the original SEMs was launched on NOAA-14 and turned on in January 1995. The operational geostationary SEM systems onboard the GOES spacecraft continue to monitor the charged particle environment, the local magnetic field and the solar X-ray flux. GOES 6 SEM data ceased after November 1994 as new data became available, first from GOES 8, which was launched in April 1994, and then from GOES 9, launched in May 1995. GOES 8 and 9 are the current operational satellites. Some SEM instrument modifications were made on the new series of three-axis stabilized platforms that began with GOES 8. Among these changes are a shift in the X-ray instrument dynamic range to higher levels and the addition of two energetic electron channels. NOAA/SEC is working with the U.S. Air Force and NASA to build and fly a solar X-ray imager on a future GOES spacecraft. Delivery of the instrument is scheduled for 1996, with an expected launch around the turn of the century.

Satellite and Data Management

NOAA's National Environmental Satellite, Data and Information Service (NESDIS) in Suitland, MD, manages the U.S. civil operational Earth-observing satellite systems. NESDIS also has the basic responsibility for collecting, archiving, processing and disseminating environmental data; developing analytical and descriptive products to meet user needs; and providing specialized data analyses and interpretations. As part of this overall responsibility, NESDIS maintains a variety of Arctic environmental data sets. The data holdings of the National Geophysical Data Center (NGDC) in Boulder, CO, which includes the World Data Center-A for Glaciology (Snow and Ice), are of particular relevance to Arctic studies. Information on those activities are provided under the National Snow and Ice Data Center (NSIDC) below.

Instruments carried on NOAA's polar-orbiting environmental satellites are a valuable source of Arctic environmental data. These include:

- The TIROS operational vertical sounder (TOVS), which provides vertical temperature and moisture atmospheric soundings for Arctic weather analyses;
- The solar backscatter ultraviolet spectral radi-

ometer, which produces total ozone measurements and ozone profiles;

- The space environment monitor, which determines the energy deposited by solar particles in the upper atmosphere and provides a solar warning system;
- The ARGOS data collection system, which collects environmental information from in-situ platforms such as the Arctic ice buoys; and
- The advanced very high resolution radiometer (AVHRR), which is used by the National Ice Center (NIC) for generating ice analyses and forecasts by interactive analysis of digital infrared and visible imagery.

These satellite data sets, available since 1979, are archived by the NESDIS National Climatic Data Center (NCDC) in Asheville, NC, and copies can be obtained on magnetic tapes. Since 1994, AVHRR data have also been available on-line electronically to users via the NESDIS Satellite Active Archive (SAA). TOVS data will be added to the SAA in 1996.

NESDIS, in partnership with the Navy, began in 1995 to implement a near-real-time processing, communications and access system for synthetic aperture radar (SAR) data. These data will become available operationally from the Canadian RADARSAT satellite in 1996. SAR data, which are high-resolution active radar backscatter measurements, are particularly useful for determining ice age, ice concentration and the location of leads and polynyas. Arctic data from the Alaska SAR Facility (ASF) at the University of Alaska Fairbanks and the Tromsø, Norway, readout station will be processed in near real time at the respective readout stations and sent electronically to NESDIS and the NIC for use in ice analysis and other applications of interest to U.S. government agencies. Demonstrations of applications have been conducted at the NIC since 1992 with SAR data from the European Remote Sensing (ERS-1) satellite, so that NIC personnel are ready to apply SAR data operationally from RADARSAT. NESDIS will handle the communications for SAR data from the ASF and will provide U.S. government access via the SAA. Arctic data from the passive-microwave special sensor microwave/imager (SSM/I) and the visible and infrared operational linescan system (OLS) instruments flown on Defense Meteorological Satellite Program (DMSP) satellites are also used by the NIC in ice analyses and forecasts. The NCDC archives the SSM/I sensor data, and the World Data Center-A for Glaciology archives mapped SSM/I data for the polar regions and provides software to convert these data to maps of ice concentrations. The

SSM/I sensor data and derived products such as ice concentration, ice age and ice edge are now received by NESDIS on a near-real-time basis from the Navy Fleet Numerical Meteorological and Oceanographic Center in Monterey, CA, over the Shared Processing Network linking the Nation's operational environmental processing centers.

NESDIS also participates in the Search and Rescue Satellite System, an international program using emergency position location instruments on polar-orbiting spacecraft to detect distress signals from emergency locator transmitters on aircraft and emergency position-indicating radio beacons on boats and ships. Emergency signals are relayed by the satellites to local user terminals (LUTs) in participating countries. Search-and-rescue coverage of part of the Arctic is provided by LUTs in Norway, Canada, the United Kingdom, Russia and Alaska.

National Snow and Ice Data Center

The NSIDC was established by NOAA in 1982. It is operated under the auspices of NESDIS/National Geophysical Data Center (NGDC) through a cooperative agreement between NOAA and the University of Colorado. Except where noted, the following activities, conducted in FY 94 through FY 95, were funded through NOAA's Environmental Services Data and Information Management (ESDIM) program, NOAA's Climate and Global Change Program, and NOAA support of the World Data Center-A for Glaciology.

The Eurasian Glacier Inventory. The mass balance of the world's glaciers is an important topic to the global change research community. The Eurasian Glacier Inventory contains information for over 35,000 glaciers within the former Soviet Union (FSU) and the People's Republic of China. Inventory parameters include geographic location, area, length, orientation, elevation and classification of morphological type and moraines. These data are the digital version of thousands of handwritten records from the Institute of Geography in Moscow and the World Data Center-D for Glaciology in Lanzhou, China. Data are distributed both on diskette and electronically. This data set is important because it provides easy access to extensive records that would otherwise be unavailable to many glaciologists and climate researchers. The data set will be extended beyond its current geographical boundaries as new acquisitions allow.

Russian Sea Ice Data and the Global Digital Sea Ice Data Bank. Sea ice parameters for the period 1967-1990 from the Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia, are now available electronically. The data were provided to NSIDC as part of a data exchange pro-

Data products, documentation and publications can be viewed or requested through NSIDC's User Services pages at URL <http://www.nsidc.colorado.edu/> on the World Wide Web. User Services may also be reached by calling 303-492-6199.

gram sponsored by the World Meteorological Organization (WMO). The WMO is committed to developing a Global Digital Sea Ice Data Bank (GDSIDB) in the interests of the World Climate Research Program (WCRP). Other nations besides Russia and the U.S. that have agreed to contribute data to the GDSIDB are Canada, Denmark, Japan, Germany, Finland and Sweden. Initial funding for NSIDC's involvement came from WMO; recently, additional support was received from the ESDIM program.

The AARI data were digitized from charts of the Eurasian Arctic produced using aircraft and satellite observations acquired over ten-day periods. Sea-ice parameters include total concentration, stage of development (age) and ice form (for example, pancake ice). The data are currently available in Sea Ice Grid (SIGRID) format, a standard adopted by the WMO Commission for Marine Meteorology for the archival and exchange of digital sea-ice data. However, NSIDC will integrate AARI data and data from the National Ice Center (NIC) in Suitland, MD, (also available in SIGRID format) to produce a CD-ROM containing data from both sources. Software has been developed to convert data from the SIGRID format to maps of ice parameters on a standard grid to make the data easier to use. In general, it is expected that the AARI data will be more accurate and detailed for seas adjacent to the FSU, while NIC data will cover areas adjacent to Alaska, Canada and Greenland. A combined data set, therefore, potentially offers two decades of the most complete, detailed and accurate representation of Arctic ice conditions possible. However, differences in temporal and spatial sampling for the two data sets complicates combining them. Exploration of these issues, along with results of a comparison of AARI and NIC analyses, where those analyses overlap, will be included in the data set documentation. A prototype combined product can be viewed through NSIDC's home page.

The AARI data set provides hitherto inaccessible information on ice conditions and their spatio-temporal variations in the Eurasian Arctic. In addition to use for basic research on trends in ice extent and concentration, the combined AARI/NIC data set will be useful as an ancillary data set with which to compare estimates of ice concentration from satellite passive microwave data.

The Historical Arctic Rawinsonde Archive. The Historical Arctic Rawinsonde Archive (HARA) contains over 1.2 million vertical soundings of temperature, pressure, humidity and wind. It represents all available rawinsonde ascents from Arctic land stations poleward of 65°N from the beginning of records through 1991. For most

stations the record begins in 1958. Coverage is relatively uniform around the Arctic, except in the interior of Greenland. Sounding data were obtained from the National Center for Atmospheric Research (NCAR), Boulder, CO, and the NOAA/National Climatic Data Center (NCDC) in Asheville, NC. The data set is available on four CD-ROM volumes.

The HARA data set has been used in several NSF- and NOAA-supported studies of atmospheric water vapor characteristics. Basic features of vertical and longitudinal variations in vapor flux have been outlined. These results were obtainable due to the extensive coverage of HARA. Variables including temperature and meridional winds were analyzed as well. Moisture transport into the Arctic and its interannual variability are primarily determined by North Atlantic cyclone tracks. Estimates of precipitation minus evaporation for the area north of 70°N were found to peak in September and to be larger than previous estimates by 36%. The September peak occurs due to a circulation shift, yielding poleward fluxes along a broad zone from near the prime meridian to 150°E. Water vapor influences the energetics of the atmosphere; variations in Arctic water vapor are likely to play a direct role in climate change.

DMSP Archive User Services. In 1995 the NOAA/NGDC Defense Meteorological Satellite Program (DMSP) Digital Archive became fully operational. NSIDC provided services to users of this archive (mainly from the cryospheric community) and developed the DMSP Operational Linescan System Geolocation, Image Display and Graphical Orbit Mapping Tool, which is software with which multi-discipline users can search and order visible and infrared imagery.

Cryospheric Indices. NSIDC's project to develop cryospheric indices for NOAA's Global Climate Perspective System recognizes the need for data sets that enhance skill in detecting climate change and applying climate models. The initial focus for this project is on snow cover and sea ice extent, because of the importance to modelers of the positive temperature-albedo feedback mechanism regulated by these variables. Regionally complete data sets are needed to provide essential snow and ice boundary conditions and ultimately to understand how model output compares with observed changes in climate. Two cryospheric products have thus far been produced from data acquired for the project. The first, "Historical Soviet Daily Snow Depth 1874–1984," contains data from 280 stations as well as monthly climatologies. The original data were provided to NSIDC by NCDC via a NOAA bilateral agreement with the USSR. The second

product, "Combined Northern Hemisphere Weekly Snow Cover and Sea Ice Extent, 1978–1994," provides critical input for climate model boundary conditions and validation studies. This product was created by mapping weekly NOAA snow charts from visible-band imagery and NSIDC ice extent estimates from passive microwave data to the same grid. Quality-checking includes direct comparison with surface station data.

Beyond integrating these and additional planned data sets (including snow water equivalent and ice concentration) into the Global Climate Perspectives System, the cryospheric indices project has an additional objective. Variations in the response of commonly used descriptors of snow cover (such as total area covered or maximum depths) are being evaluated to determine the optimal ones for change detection. The initial results are described in current publications.

Improved Data Access and Data Rescue.

NSIDC is continuing efforts, under the ESDIM program, to transfer data to new media and to bring them under NGDC archival standards for ensuring the survival of data sets or for easier and wider dissemination of data products. Recent data sets archived in this manner include four years of Arctic Ocean drifting buoy data, Rand Corporation global monthly snow cover data, and weekly sea ice data from the National Ice Center.

Permafrost. Two international workshops on permafrost were held in 1994 and 1995. Conclusions from the workshops were published in *Glaciological Data* and in the *Frozen Ground* newsletter, which were distributed to more than 1000 individuals and organizations. These workshops established priorities for acquiring permafrost data according to their use for detecting global change, modeling and engineering design. Priorities for data rescue were set as well. Russian data at risk were targeted, and an inventory of Russian maps of permafrost data and a list of Russian organizations holding permafrost data were included in the workshop report to *Glaciological Data*.

Arctic Contamination. A bibliography on contamination by radionuclides, persistent organics, trace metals and hydrocarbons was prepared for the Interagency Arctic Research Policy Committee's (IARPC) Workshop on Arctic Contamination held in Anchorage, AK, in May 1993. The bibliography, available on diskette, comprises approximately 750 citations. It addresses the need, identified at the workshop, for a survey of existing sources of information and data on Arctic contamination that will serve as a resource for scientists and those forming U.S. policy on Arctic contamination.

National Ice Center

The National Ice Center (NIC) was established as a cooperative, interagency organization responsible for performing global sea ice and Antarctic iceberg analysis and forecasting. The NIC includes the Naval Ice Center, the U.S. Coast Guard and NOAA's NOS, NESDIS and NWS. In September 1995, oversight responsibility of the NIC was transferred from NOS to NESDIS. The primary mission of the NIC is to produce global, regional and tactical-scale analyses and forecasts for sea ice in the Arctic and Antarctic and for freshwater ice of the Great Lakes and Chesapeake Bay.

These analyses and forecasts are available to customers through a variety of communications pathways. Approximately 90% of the data used to produce these products are satellite-derived imagery. The largest sources of satellite data are the advanced very high resolution radiometer (AVHRR) aboard the TIROS-N series of satellites and the OLS aboard the Defense Meteorological Satellite Program (DMSP). Although the horizontal resolutions for the AVHRR and OLS are adequate (1 and 0.6 km, respectively), both sensors operate in the visible and infrared wavelengths, limiting their capability for ice detection due to clouds.

During the past two years the NIC has been receiving, on a limited basis, SAR imagery from the ERS-1 satellite. SAR is the only high-resolution, remote sensing data source capable of penetrating the perpetual cloud cover and restricted illumination conditions characteristic of the polar regions. The NIC has been conducting an operational demonstration of the SAR data for its use in depicting ice cover. In demonstration studies, SAR imagery has proven extremely useful for depicting the important boundary between first-year ice and multiyear ice, the formation of new ice and the concentration of ice.

An important source of surface meteorological data and ice drift information in the Arctic is drifting buoys. The NIC manages the U.S. Interagency Arctic Buoy Program (USIABP), whose mission is to establish and maintain a network of drifting meteorological buoys in the Arctic. An optimal sampling array of buoys for both operations and research is a spacing of not greater than 400 km over a square grid. Thus, at least 40 buoys should be operating in the Arctic basin to meet this criteria. In the early years of the buoy program (1991–1992), fewer than 25 buoys were gathering meteorological data, with 72% reporting on the Global Telecommunications System (GTS). During 1994 between 40 and 50 buoys were situated in the Arctic Ocean, with over 95% reporting on the GTS.

A second aspect of the buoy program has been the evaluation of the meteorological data collected by the buoys, which includes surface atmospheric pressure and surface air temperature. During 1994 and 1995 a buoy performance field test was conducted at NOAA's Climate Monitoring and Diagnostics Laboratory in Barrow, AK. The objective of the Barrow field test was to conduct a dynamic long-term evaluation of the ability of unattended drifting buoys to measure meteorological parameters with sufficient accuracy to satisfy operational and research requirements. Emphasis was placed on the accuracy of the surface air temperature measurements, as most thermistors had been placed inside the buoy. Meteorological data from five drifting buoy designs presently in use were tested against the Barrow standards. All five buoys demonstrated a similar accurate performance in the measurement of surface atmospheric pressure, but there was a dramatic improvement in the accuracy of surface air temperature for the buoys with external thermistors. Buoys will continue to be tested at Barrow, especially as new technology produces better designs.

National Weather Service

The Alaska Region of the National Weather Service (NWS) continues to conduct applications research in support of its operational forecasting programs in the Arctic. Research topics fall into the following program areas: meteorology; satellites/data management; environmental prediction; and Arctic ice. Budgeting for these projects is broken down into three categories: external funding, internal funding and cooperative funding.

The major source of external funding for the following research activities has come from the Cooperative Program for Operational Meteorology, Education, and Training (COMET), a division of University Corporation for Atmospheric Research (UCAR); and other government agencies.

During FY 94 and 95 the NWS Alaska Region and other scientists continued to work on a study to determine methods to monitor, detect and track airborne volcanic ash using remote sensing techniques to protect lives and property, especially aviation. Accomplishments under this project included the provision of multispectral algorithms for detecting volcanic ash using NOAA polar-orbiting satellite imagery (now used as a standard technique among involved NOAA agencies). These multispectral techniques have been used in the Anchorage Weather Service Forecast Office (WSFO) on 21 volcanic eruptions since implementation, with high success. In addition, an International Center for Volcanic Ash Research

has been established at the Anchorage WSFO, funded in part by the NWS, which allows a visiting scientist to conduct research using unique NWS data sets and allows access to forecasters for collaborative efforts, test and evaluation, and operational implementation of research results.

Another study involved the characterization and prediction of volcanic cloud movement. The purpose of this study is to use multi-satellite data to characterize the conditions in an airborne volcanic ash cloud, including the horizontal and vertical extent of the cloud and ash concentration and size. To date, a technique using vertical sounding channel data from the polar-orbiting NOAA and DMSP satellites has been developed and is being tested for validation.

Studies of the location and important weather associated with the meteorology of the Alaska Arctic front continued. A published report indicates that the precipitation generated by the Arctic front is two-and-one-half times greater than previously reported based on using new technology, the WSR-88D Doppler radar. A forecast technique has been integrated into the forecaster workstation at the WSFO in Anchorage for operational use.

A study of Bering Sea storms and their associated storm surges on Nome, Alaska, is ongoing. The purpose is to determine characteristics of storms that produce major storm surges so as to generate a forecast scheme from the common meteorological patterns to provide timely and accurate forecasts. A checklist of critical meteorological and oceanographic parameters in the generation of storm surges in the Bering Sea has been provided to forecasters, and a joint effort with the NWS Techniques Development Laboratory resulted in an operational Bering Sea storm surge prediction model. The results from this COMET-funded project has supported the development and implementation of a storm surge/wave forecast model for the Bering Sea, which has been funded by the NWS Office of Meteorology. An operational forecast model has been implemented, and model products are routinely delivered for access by forecast offices in Alaska and Nome. Successful forecasts were made of the Bering Sea coastal flooding event, which occurred in October 1995.

In cooperation with the Federal Aviation Administration (FAA) and NASA, the NWS Alaska Region is working on a project of investigating volcanic hazards and upper winds using the total ozone mapping spectrometer (TOMS) satellite data. The purpose of this real-time capture, processing and distribution of the TOMS satellite data to meet operational FAA and NWS

forecast needs is to monitor, track and predict the distribution and concentration of sulfur dioxide associated with a volcanic eruption and to estimate the upper winds at commercial flight level over the northern Pacific Ocean from the gradient concentration of ozone. A TOMS downlink site was established at the Anchorage WSFO in December 1995, and communications for transfer of products to the FAA was established in January 1996.

Cooperative Institute for Arctic Research

With the creation of the CIFAR in 1995, research projects focusing on the Arctic have been initiated. Most of this new research started in 1995, and the studies fall under five program areas: Arctic haze, stratospheric ozone, Arctic ice, ocean assessment and coastal hazards.

Arctic Haze

Airborne measurements of black carbon and aerosol pollutants over the Arctic were carried out during March and April 1995 as part of an international experiment on a Russian Ilyushin-98 research aircraft flying around the North Pole. An aetholometer for determining the black carbon content of the pollution and a nephelometer for measuring the single-body scattering coefficient were included in the instrument package. Both are important parameters for understanding the importance of Arctic haze on the Arctic climate. The analyses clearly showed high levels of pollutants originating within the former Soviet Union. The physical morphology and chemical analysis of the haze layers will provide some of the most comprehensive measurements ever taken of this important pollution phenomenon.

Stratospheric Ozone

Observational and modeling studies of Arctic stratospheric chemistry were carried out by scientists from the University of Alaska and NOAA's Aeronomy Laboratory. They installed and began measurements with a solar Fourier transform infrared (FTIR) spectrometer at the Poker Flat Research Range in Fairbanks. They also incorporated "non-zonal" chemistry and low-sun photochemistry into the two-dimensional model of NCAR, making it effectively three-dimensional.

Arctic Ice

Analysis of the regional deformation of sea ice was carried out between the University of Alaska and NOAA's Pacific Marine Environmental Lab

(PMEL) as part of the Sea Ice Mechanics Initiative (SIMI) experiment. Data used include processed SAR images and ice trajectory information from the Geophysical Processor System of the Alaska SAR Facility at the University of Alaska and AVHRR images. Preliminary results indicate that there is an observable correlation between the ice camp data on the >1- to 10-km scale, the SAR data on the >1- to 100-km scale and the AVHRR data at the >10- to 500-km scale. The results also indicate the existence of convergence waves in the ice, denoting internal ice stress propagating from the coast. These occurred on scales of about 100 km over 3–5 days during steady wind conditions. The geometry and orientation of the basin and the compactness of the ice cover play a major role in determining ice stress fields.

Ocean Assessment

Bering Sea ecosystem studies were conducted in which scientists from the University of Alaska and NOAA's PMEL have been able to realistically simulate spring phytoplankton blooms in both open water and at the edge of the ice and to illustrate the various roles in which the physical conditions control aspects of the blooms, such as stratification and mixing. An existing numerical model was modified to realistically model the accelerated downward flux of biogenic material through the aggregation of phytoplankton cells into clumps and chains, such as the so-called biological pump. This is a mechanism that apparently allows carbon to get to the bottom of the shelf quickly and to feed the benthic fisheries in the Bering Sea.

The Bering Sea green belt, including shelf-edge processes and ecosystem production, was also investigated. Observations suggest that processes in the region of the shelf edge are important to the prodigious biomass yield at numerous trophic levels in the Bering Sea. The physical basis for the green belt appears to be a combination of tidally induced upwelling at the shelf edge and vertical stratification and stabilization of the water column by the shelf break front. Tides and tidally induced circulation play a major role in the formation of the Bering Sea hydrological regime and high biological productivity of the area. Investigations in this process depict a trapped motion around islands. Simple numerical investigations reveal that this trapped motion is due, at least in part, to tidal current rectification over shallow topography. Both diurnal and semi-diurnal tidal oscillations generate clockwise eddies around islands. In the diurnal band of oscillations, the enhanced currents occur also at the shelf slope, where tidal waves generate shelf waves because

of resonance interaction of the tidal wave and topography. Further research here is very important because this is a source region and the pathway for the elevated primary production throughout the spring, summer and fall.

Coastal Hazards

In the area of coastal hazard research between the University of Alaska and NOAA's PMEL, investigations of tsunami runup along Alaska's coastlines were conducted. The focus of this research is on possible sources of volcanogenic tsunamis in Cook Inlet. There are five active volcanoes on the western shore of Cook Inlet, two of which have generated debris flows into the sea. The model used has fine-resolution spatial grids from 900 m in the deep areas to about 60 m in the nearshore domains. Maximum wave height plots for Cook Inlet from hypothetical landslide sources of Cook Inlet volcanoes show relatively large amplitudes and concentrations of radiated energy on the Kenai Peninsula and Kalgin Island. Not much energy penetrates into Upper Cook Inlet beyond the Kenai Foreland, where a large number of oil platforms and the municipality of Anchorage are located.

The intent of another tsunami project was to develop the ability to perform routine moment tensor inversions for earthquakes in Alaska and the Aleutian Islands, based on the regional and local broadband seismograms now available and being continuously recorded by the Alaska Earthquake Information Center. As an initial step, scientists obtained, installed and tested several of the moment tensor inversion codes that are currently available. They are in the process of determining a broad range of earthquake source parameters, including location, depth, moment, focal mechanism, duration (area) and displacements in near real time, which are particularly important for estimating the likelihood of tsunami generation.

Coastal Programs

Coastal Change Analysis Program

Quantifying changes in the areal extent of wetlands and adjacent uplands is critical for linking both natural phenomena and land-based human activities to coastal ocean productivity. The NOAA Coastal Change Analysis Program (C-CAP) uses satellite imagery and aerial photography to monitor areal extent, functional status and change in these critical habitats. C-CAP has developed a standard, nationally accepted protocol for mapping submerged aquatic vegetation,

emergent coastal wetlands and adjacent uplands. Change detection projects have been conducted in over a dozen states, including Alaska.

An analysis of change in coastal land cover between 1986 and 1993 was initiated in the Yakutat Bay region of southeast Alaska. Researchers from NOAA's National Marine Fisheries Service (NMFS) Auke Bay Laboratory (AK), NMFS Beaufort Laboratory (NC), and Oak Ridge National Laboratory (TN) are using Landsat thematic mapper imagery and the C-CAP protocol to classify land cover and detect change in the coastal habitat of Russell Fjord and Hubbard Glacier. Map products based on the analysis of 1986 imagery are available through the NMFS Beaufort Laboratory. The final product will be the analytical comparison of imagery from 1986 and 1993. The analysis will quantify land cover changes resulting from natural phenomena (such as coastal erosion, flooding and the advancement and retreat of Hubbard Glacier) and anthropogenic activities (such as logging and coastal development). A CD-ROM should become available by the end of 1996.

Interest in the applications of this change detection analysis has been expressed by the Sealaska Timber Corporation for guiding their logging strategies and identifying salmon habitat, the U.S. Forest Service for augmenting their wetlands survey, and the city of Yakutat to guide their stream restoration project.

NOAA CoastWatch

Coastal managers, decisionmakers and researchers require accurate and immediate information concerning environmental processes and events that could affect the health and stability of coastal resources. The NOAA CoastWatch program supports those information needs by providing rapid dissemination of satellite and other data and information for the entire coastal U.S. through a network of regional nodes. Between 1990 and 1994 eight regional nodes were established and began distributing near-real-time satellite imagery and other environmental information products to over 200 users. The Alaskan coastal region is served by the Alaska CoastWatch node located at the National Weather Service's Alaska Region Office in Anchorage.

Early support for the establishment of CoastWatch was provided by the Coastal Ocean Program (COP). In FY 94 CoastWatch was incorporated into the operations of the National Environmental Satellite, Data, and Information Service (NESDIS). CoastWatch continues to be a collaborative effort, with participation by NESDIS, the National Marine Fisheries Service, Oceanic and

Atmospheric Research, the National Weather Service and the National Ocean Service. COP continues its participation by supporting research to enhance the utility of CoastWatch data products and advance the applications of remote sensing technology to coastal monitoring, prediction and management. A three-year project to investigate the applications of current and future satellite data streams in the analysis of mesoscale oceanic processes in Alaskan coastal waters and the Bering Sea will begin in 1996.

Global Climate Change

NOAA's Climate and Global Change Program maintains a small programmatic effort in the Arctic, driven primarily by scientific questions regarding the Arctic's role in global climate change. Coupled ocean-atmosphere models in the U.S. and in Europe have suggested that the planet's response to increased greenhouse forcing will fundamentally involve changes in the thermohaline circulation of the ocean, popularly described as the "conveyor belt." In the modern ocean, dense water is formed in very limited areas of the global ocean, with the Greenland/Norwegian and Labrador Seas being the predominant Northern Hemisphere regions of deep water formation. As northward-flowing surface water in the Atlantic cools, it releases heat (thus warming northern Europe) and sinks to form a deep water mass identifiable throughout the global ocean. The rate of this thermohaline circulation varies dramatically in models with different scenarios of greenhouse gas forcing. These model runs are given some credence by observations from the paleoclimate record, which indicate strong thermohaline variability as recent as 10,000 years ago. The strongest control on the thermohaline circulation is the amount of fresh water coming into the North Atlantic from the Arctic Ocean.

The Arctic interests of the Climate and Global

Change Program have thus been driven by the desire to observe and model these hypothesized Arctic-Atlantic interactions. An array of instruments to measure the flux of fresh water from the Arctic, including sea ice, has been deployed in Fram Strait since 1991, in cooperation with European investigators. Downstream in the Greenland Sea, annual measurements of salinity and transient tracers have provided a time series of deep water formation in this region, demonstrating the response of deep convection to changes in freshwater input. Several atmosphere-ocean-ice modeling efforts on varying scales are being used to examine the mechanisms at work in the long-term variability of this component of the climate system.

Logistics

NOAA operates, maintains and supports a core fleet of ships and aircraft used to accomplish many of NOAA's missions in the Arctic. NOAA's highly skilled and experienced ship and aircraft fleet employees work closely with personnel from NOAA's line organizations and program offices as well as other Federal agencies to assure success of all program missions. The Office of NOAA Corp Operations (NC) serves NOAA and the Nation by providing high-quality and cost-effective scientific, engineering and technical services, ships and aircraft research platforms, and personnel in support of missions that lead to comprehensive understanding of the environment.

In addition to some of the programs identified in previous sections, in which NC participated, NOAA helicopters also provided platform support for three Arctic projects during FY 94 only:

- A study of the population size of polar bears, conducted by the U.S. Fish and Wildlife Service;
- A bowhead whale survey, conducted by the Minerals Management Service; and
- Deployment of Navy ice buoys, sponsored by the Naval Research Laboratory.

Department of Agriculture

The Department of Agriculture supports and conducts research to improve understanding, use and management of renewable 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.

Forest Service

The northern boreal forest of Alaska—the taiga—lies in the zone of discontinuous permafrost. The more than 100 million acres of Alaska's northern boreal forest is a heterogeneous mix of warm, productive sites supporting white spruce, paper birch, aspen and balsam poplar stands, intermingled with permafrost-underlain black spruce stands and shrub, riparian and wetland vegetation. About one-third of Alaska's taiga lies within the Arctic as defined by the Arctic Research and Policy Act; some two-thirds occupies sites that, by virtue of elevation, slope and aspect, have climatic conditions equivalent to those of the Arctic.

The Forest Service's Pacific Northwest Research Station (PNW) is responsible for boreal forest research in Alaska. This research is directed toward improving the understanding, use and management of Alaska's natural resources and especially the northern boreal forest. Forest Service PNW scientists have been stationed at the PNW Station's laboratory in Fairbanks and the Forestry Sciences Laboratory in Anchorage. These scientists can also call on the expertise of Forest Service research personnel in Oregon and Washington as necessary and as funding permits.

The PNW Ecosystems Processes research program is directed toward improving understanding of biological, physical and ecological processes and components of terrestrial ecosystems. PNW scientists stationed at Fairbanks have been actively involved in research into forest succession on highly productive forest lands—floodplains and warm slopes—and on cooler, less-productive permafrost terrain. Research efforts are aimed at safeguarding the Long-Term Ecological Research (LTER) programs. Programs in entomology, forest genetics, silviculture, harvesting and sustainable development are being discontinued.

Ecosystems Processes scientists will continue to play a leading role in the LTER program, funded by the National Science Foundation. This work is centered on the 5000-ha Bonanza Creek Experimental Forest (BCEF) near Fairbanks. BCEF-LTER

	Funding (thousands)	
	FY 94	FY 95
Forest Service—environment	959	912
Forest Service—climate change	441	488
Agricultural Research Service	730	0
Cooperative State Res—environment	722	725
Cooperative State Res—food/safety	790	793
Natural Res Con S—environment	1,102	1,040
Natural Res Con S—climate	276	260
Total	5,020	4,218

is led by co-principal investigators from the Institute of Northern Forestry and the University of Alaska Fairbanks. The primary areas of research in BCEF-LTER include:

- Patterns and controls of primary production;
- Spatial and temporal distribution of populations;



Forest Service technician changing a pollen slide at an LTER weather station on the floodplain of the Tanana River in the Bonanza Creek Experimental Forest.



Forest Service crew probing for permafrost on a burned area at an LTER site in interior Alaska.

- Patterns and controls of organic matter accumulation;
- Inorganic contributions and transport of nutrients through soils, groundwater and surface waters; and
- Patterns and frequency of disturbance in Alaskan ecosystems.

Current LTER research in BCEF addresses vegetation succession in floodplains and uplands, herbivory, and resource availability to specific vegetation communities in relation to climate, nutrient availability and biogeochemical processes. The research program is undergoing a thorough re-examination of long-term goals to provide for the development of new paradigms of boreal forest successional dynamics. A research cooperative is being established between PNW and the University of Alaska Fairbanks to integrate this research with the aquatic research described below.

PNW Aquatic/Land Interactions scientists at the Institute of Northern Forestry have been terminated. The research addressed landscape-scale pro-

cesses affecting watershed stability, streamflow patterns, stream quality, stream productivity and ecological relationships in Alaska's boreal forests. Research centered on the 10,400-ha Caribou-Poker Creeks Research Watershed (CPCRW) near Fairbanks will be integrated into the LTER program shared between the University of Alaska Fairbanks and the Institute of Northern Forestry research Coop Unit. The composite BCEF/CPCRW LTER site encompasses 150+ km² and includes environmental settings varying from highly productive floodplain forests and permafrost-free coniferous and hardwood forests stands on south-facing slopes to low-productivity coniferous woodlands underlain by permafrost on north-facing slopes and in cold valley settings. Research includes determining the effects of permafrost on the catchment hydrologic regime and analyzing the hydrologic behavior of periglacial land forms. Included are studies of the ecological relationships of headwaters streams and the linkage between landscape (catchment slopes), riparian zone and stream channel. Hydrogeochemical monitoring of headwaters streams in CPCRW provides the foundation for process research, which has already documented the influences of permafrost on streamflow patterns, stream biota and sub-Arctic hydrologic phenomena including auffs and pingos. This work furnishes a basis for assessing terrestrial/aquatic (watershed) ecosystem change in response to changing climate or environmental contamination. It is anticipated that the National Atmospheric Deposition Program (NADP) in Caribou-Poker Creeks Research Watershed will continue. The water quality of first- and second-order streams in CPCRW has been monitored for more than a decade and will continue. The broad objectives of continuing research at CPCRW are to develop an understanding of hydrologic, climatologic and environmental relationships of taiga ecosystems, to support catchment-scale experimentation on the effects of resource management practices on these relationships, and to support multi-disciplinary long-term environmental monitoring of the stream/landscape biological and physical system.

Climate change predicted by many general circulation models indicates that regions north of 60° latitude might be subjected to major warming in coming decades, increasing permafrost thaw, altering vegetation distribution, biological productivity and the wildfire regime, and perhaps releasing large quantities of stored organic carbon into the global carbon cycle. Soils in the taiga are rich in organic carbon, much of which is currently stored in permafrost. If central Alaska were to experience 4–8°C of warming over the next century, much of the permafrost (currently at –0.5 to –2°C) would thaw, potentially releasing large amounts of carbon to the

atmosphere and hydrosphere. An ongoing experiment is testing the effects of elevated atmospheric CO₂ concentration and +4°C soil temperatures on the carbon and nitrogen balance of a model white spruce ecosystem.

Wildfire is a major determinant of boreal forest pattern and productivity in central Alaska. Research at the Institute of Northern Forestry is continuing into fire ecology and fire effects on ecosystem processes, forest succession in relation to wildfire, and forest productivity, including the stability and productivity of forest streams affected by fire. Pre-burn and post-burn research has continued in the Yukon Flats National Wildlife Refuge, at the 1988 Selawik fire site in northwest Alaska, and at the sites of the 1950 and 1985 Porcupine River fires, providing pioneering information on the long-term consequences of wildfire in Alaska's boreal forest. Detailed studies of wildfire history have been initiated at BCEF and CPRW in support of the expanding LTER program.

Ecosystem Processes studies by scientists at the Forestry Sciences Laboratory in Anchorage are continuing on the population dynamics of moose in the Copper River Delta and in Denali National Park. The Copper River Delta research is concentrating on defining basic seasonal movement patterns and seasonal use patterns in relation to habitat, determining seasonal foraging habits, defining sexual activity and reproduction, and determining winter habitat and possibilities for habitat enhancement. Research at Denali focuses on foraging strategies and long-term population trends in relation to habitat. Monitoring of radio-collared animals is a valuable research tool used in both areas.

Forest Service efforts in the Environmental Health and Protection Research program in the Arctic will be terminated. This program developed management practices that reduce the impact of pest insects on biodiversity, wildlife and fish habitat and water quality while promoting the diversity of beneficial insects in Alaskan forest ecosystems.

PNW Inventory and Economics Research scientists at the Forestry Sciences Laboratory in Anchorage are responsible for inventories and analysis of the boreal forests of Alaska. A state-wide cooperative soils and vegetation inventory was initiated in 1981 and is continuing. Satellite imagery and aerial photography are used in classifying land cover types; analysis addresses timber, understory vegetation, biomass, soils and wildlife habitat. The project has completed inventorying nearly two thirds of the state and has produced numerous resource bulletins describing the resources. Additional scientific papers covering wildlife, biomass, forest products and inventory techniques have also been published.

Cooperative State Research Education and Extension Service

The Cooperative State Research Education and Extension Service funds research projects at the University of Alaska's Agriculture and Forestry Experiment Station (AFES). AFES research projects are aimed at solving problems related to agriculture, forestry and the environment. The AFES research objectives are to provide new information for managing renewable resources at high latitudes and to improve technology for enhancing economic well-being and quality of life at high latitudes. AFES is part of the School of Agriculture and Land Resources Management at the University of Alaska Fairbanks. This association provides a direct link between research and teaching in forestry, agriculture and natural resources. Scientists who conduct research at the experiment station also teach, sharing their expertise with both undergraduate and graduate students.

In identifying local Alaskan research needs, experiment station scientists regularly meet with land managers, foresters and farmers from throughout the state to discuss specific needs and problems. AFES researchers also work directly with producers through farm forums, agricultural field days, greenhouse workshops, vegetable conferences, reindeer herder workshops and forestry workshops. Because of these contacts, most AFES research projects in the plant and animal sciences program have been in response to producer requests.

Research completed at AFES is published in scientific journals as well as experiment station bulletins, circulars, conference proceedings, books and the station's own journal, *Agroborealis*. Experiment station scientists disseminate their findings through conferences, professional journals, workshops and other public information programs. Subjects range from greenhouse operations to potato production, from reindeer herding to forest productivity, and from mine soil reclamation to the management of outdoor recreation.

During FY 94 and 95 one project has focused on the classification and interpretation of permafrost soils in Alaska. Research has been centered on the morphology, classification and land use interpretations of permafrost soils. The cryogenic structures and morphological properties of permafrost soils were studied in the sub-Arctic regions of Alaska, northeast Russia and northwest Canada with the cooperation of the Russian Academy of Sciences, Agriculture Canada and the USDA-NRCS. Soil horizons within the active layers generally contain sublimation, segregation and

injected ice. Fine and thin ice lenses are common, and massive ice occurs occasionally. Cryogenic structures of the permafrost layer usually differ from those of the active layer. Identifying the cryogenic structures can help to establish the true active layer depth, which is sensitive to climatic changes. The morphology of ice-cemented permafrost soils is usually characterized by ruptured organic horizons, distorted mineral horizons and frost-churned humus within the mineral horizons, with the exception of recently formed alluvial or tidal marsh soils. Granular structures are common in the A horizons, platy structures are common in the B horizons, and massive and blocky structures are common in the BC horizons. The upper permafrost layers usually consist of ice-rich horizons or massive ice.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) cooperates and coordinates with state, village, regional and Federal land owners, NRCS field office personnel in Alaska and other agencies in Alaska to provide technical resource planning and application assistance to these various land-owners users and planners. Coordinated resource management plans, allotment management plans or interim plans are developed. Soil maps are made of Native lands along with other private and government lands in Alaska.

Soils Activities

The NRCS has continued to work in conjunction with the University of Alaska Fairbanks and Agriculture Canada to measure soil moisture and temperature along several transects in areas going from non-permafrost zones to areas of intermittent permafrost to areas in the north where there is continuous permafrost. Studies are also being conducted on the active layer in the permafrost zone. The information gathered from these transects and similar ones in Canada and Russia has allowed a group to develop a proposal for a new soil order in soil taxonomy: Gelisols. The final touches are being put on this proposal, and its implementation will greatly help in mapping and interpreting soils in Alaska and other parts of the world where there is permafrost. This will allow transfer of technology from region to region.

The NRCS is also actively working with the National Science Foundation's Arctic Systems Science (ARCSS) program on the North Slope of

Alaska, where greenhouse gas fluxes and changes to carbon sequestration may be subject to potential changes from global climate change. This work has added more sensors for soil moisture and temperature south of Deadhorse along the Haul Road and also at Barrow. Sites have been sampled in conjunction with scientists from the University of Alaska Fairbanks. Complete characterization is being run on these samples in the laboratory in Lincoln, Nebraska. The information gathered from this sampling and others will help develop a much larger soil database for Alaska. Preliminary work has shown 30% or more carbon storage in the sensitive permafrost area than was previously thought to occur. The data from these and other samplings will be used in many soil process models being developed. These areas in the Arctic may be either sources or sinks of carbon if there is global warming. Estimates of the amounts and possible changes cannot be made by modelers, however, until the baseline information is gathered.

The NRCS, with the University of Alaska and in cooperation with the Forest Service and Park Service, has established some new sites to study soil processes in wetlands. The same parameters that have been monitored at the sites established several years ago will be measured (soil temperature, moisture, redox properties, depth of the water table etc.). Wetlands are a major component of soils in Alaska, and this work will help the NRCS and others better understand, identify and manage these critical areas. Selected sites will be sampled in the summer of 1996 to look at the effects of biological activities. This is part of a broad NRCS project to look at wetland sites from the warm south (Texas) to cold northern areas (Alaska).

A joint cooperative activity has been established between cryopedologists from the NRCS, University of Alaska, Agriculture Canada and the International Permafrost Association and many other scientists from the United States and Europe to produce a joint circumpolar map showing the soils within the limits of the northern discontinuous permafrost. The map will be in a GIS environment at a scale of 1:10,000,000. The map units will carry the classifications of the United States, Russia and Canada. There will be a supporting database that will include polygon identification, percentage of each component in the polygon, parent material, drainage, local surface form, soil classification, texture, vegetation and soil code. Other items could include carbon and nitrogen contents and particle size distribution. A variety of maps can be made from this information to help understand and manage areas containing continuous permafrost. A test map of Alaska and the Yukon will be complete by June 1996. This will be

compared to a map being made for the area east of longitude 125° in Russia.

The NRCS completed digital and attribute data files for the "Exploratory Soil Survey of Alaska" during 1994–1995 at a scale of 1:1,000,000. This product provides general-level soil survey coverage for the entire state and is available in a GIS format. Detailed soil survey coverage was completed on over 2,500,000 acres of land (Fort Richardson, Kobuk area, Gates of the Arctic National Park, Gerstle River area, Lower Kenai area, Matanuska–Susitna Valley area and Tuxedni Wilderness) during the same period. Each of these surveys includes inventory data on both soils and vegetation and provides interpretations for most use and management concerns. Preliminary data are available for these areas, and complete spatial data and attribute files will be available in the near future.

The proceedings of the International Meeting on Permafrost-Affected Soils were published in 1995, and the publication is available by writing to John M. Kimble, NSSC-NRCS-USDA, Federal Building, Room 152, MS 36, 100 Centennial Mall North, Lincoln, NE 68508-3866 (email kimble@nssc1000.nssc.nrcs.usda.gov). This publication contains the papers that were presented at the meeting in 1993.

Range Activities

A major part of the range management program involves areas grazed by 36,500 reindeer. The present tundra monitoring program involves conducting utilization checks in selected reindeer grazing permit areas. Exclosure monitoring has involved evaluating plant treatment response and plant succession. The exclosures are located in Adak, Hagemeister and Nunivak Islands; there are also eight on the Seward Peninsula. Exclosure data, organization, standardization and maintenance are needed. A cooperative study with the University of Alaska Anchorage and the Fish and Wildlife Service has resulted in the establishment

of ten long-term vegetation trend monitoring plots on Nunivak Island in 1990. Data from the Nunivak study will be completely automated and made available. A study by the University of Alaska Anchorage and the NRCS (1991–1994) will evaluate lichen growth rates relative to grazing, fire and other treatments and make other ecological and physiological assessments of reindeer and caribou habitats.

Snow, Climatological and Water Supply Activities

The NRCS collects and maintains a database of snow precipitation and temperature (air and soil) from specific remote locations throughout Alaska. The information in 1995 came from 164 snow courses giving monthly snow depth and water content, 23 snow pillow sites giving daily snow water content, and 47 precipitation gages giving 36 daily records and 11 monthly records. Maximum, minimum and average temperatures are recorded at 19 radiotelemetry sites.

The Alaska Snow Survey Program will be expanding its services to Soil and Water Conservation Districts and NRCS personnel. This will be accomplished by providing greater assistance in interpreting climate data and disseminating information from the National Water and Climate Center (WCC). This effort with the WCC will result in an annual precipitation map for the state.

The snow survey information is currently used in the Arctic for:

- Calculating 19 streamflow snowmelt runoff volume forecasts and 15 snowmelt runoff indexes (SRIs);
- Determining freshwater availability, hydroelectric power generation, and river and sea ice breakup timing;
- Engineering and development;
- Blowing snow control;
- Studying reindeer movements;
- Wildlife winter severity indexes; and
- Various climate studies and research.

Department of Energy

The Department of Energy has responsibility for providing for the long-term energy security of the United States. To carry out this responsibility, DOE's Arctic activities seek to expand our understanding for predicting the regional and global consequences of continued dependence on fossil fuels and quantifying long-term migration pathways of specific energy-related contaminants.

DOE's Arctic research studies include investigating the role of Arctic ecosystems in the global flux of carbon, measuring greenhouse gases, developing a research site on the North Slope of Alaska for studying the influence of clouds on radiation transport, and measuring radionuclides in the Arctic atmosphere and deposition. DOE researchers also collaborate with other Federal agencies in investigations of the sources and levels of energy-related contaminants in the Arctic environment.

Cloud and Radiation Testbed Site

The Atmospheric Radiation Measurements (ARM) program addresses the major problem with the predictions of global and regional greenhouse warming: the predictions are based on general circulation models (GCMs) in which we do not yet have complete confidence. To develop greater confidence in the model predictions, the GCMs must be improved. 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.

The ARM approach is to create a number of long-term, highly instrumented climate research sites in carefully selected locations around the world. The site locations proposed and under development were selected primarily on the basis of what needs to be learned about clouds and radiation to improve the models, but secondarily on the basis of cost and logistics. Three locations for Cloud and Radiation Testbed (CART) sites are planned. The first CART site, in the southern Great Plains of the U.S. north of Oklahoma City, began operations during 1992. The second CART site is planned for the tropical western Pacific and is scheduled to begin operations in 1996. The third CART site is planned for the North Slope of Alaska (NSA) and adjacent Arctic Ocean (AAO) and is expected to begin a

	Funding (thousands)	
	FY 94	FY 95
Environmental monitoring/assessment	1,150	0
Environmental measurements	20	40
Nat Inst Global Env Change	300	144
Response to carbon dioxide	60	0
Atmos radiation/planning	500	2,612
Magnetosphere research	140	0
Carbon balance/tundra ecosystem	0	132
Total	2,170	2,928

phased deployment in conjunction with the SHEBA (Surface Heat Budget of the Arctic) program.

The CART sites have a planned life of ten years. The rationale for their long duration is that virtually all process-focused meteorological and climatological efforts to date have been based on short-term field efforts (a few weeks to a few months). During these brief periods, particular meteorological phenomena of interest occur at most a few times. This restricts these efforts to one or two case studies, which, while they produce important qualitative understanding, are limited by the statistics of small numbers in the accuracy and precision with which the relevant phenomena can be quantitatively described. With all of its potential economic and other societal impacts, global climate change is nevertheless the result of small radiative effects—a difference of a few watts per square meter in the energy balance out of an average energy flow of several hundred. To improve our ability to predict climate change, the physical effects that must be measured and accurately modeled are small. Doing this requires the statistics of large numbers—many cases, not just a few.

On the other hand, climate monitoring efforts have been ongoing for decades. However, these efforts focus on measuring a few important climate-related parameters, not the full range of parameters needed for the process studies necessary to improve the GCMs. The ARM program fills the critical gap between field campaigns and monitoring. For the NSA/AAO CART site the central facility is proposed to be adjacent to the National Oceanic and Atmospheric Administration's (NOAA) high-latitude climate monitoring facility near Barrow so

The general point of contact for the ARM program is Peter Egan, Manager, Atmospheric Radiation Measurements Program, Environmental Sciences Division, ER-74, U.S. Department of Energy, Washington, DC 20585. Tel: 202-481-4812. For the North Slope of Alaska, adjacent Arctic Ocean, ARM site, the point of contact is Richard Lyle, ARM Site Manager, Arctic Ocean National Laboratories, P.O. Box 5000, Fairbanks, AK 99707-5000. Tel: 907-457-1000. For the tropical western Pacific, the point of contact is Richard Lyle, ARM Site Manager, National Oceanic and Atmospheric Administration, P.O. Box 5000, Fairbanks, AK 99707-5000. Tel: 907-457-1000.

as to take advantage of NOAA instrumentation already in place and avoid unnecessary duplication.

A generic, fully developed CART site includes facilities spread over a large area. On the North Slope, an area of roughly 200 km² in size is being considered. The central facility will have the largest concentration of instrumentation, which will rely heavily on upward-looking remote sensors to determine the characteristics of the clouds, winds and atmosphere as a whole above the site on a continuous basis. Around the central facility, two to four auxiliary stations are planned at a distance of one to a few kilometers for characterizing the cloud field over the central facility. The larger area surrounding the central facility and the auxiliary stations (the extended CART site) will eventually be instrumented with a sparse network of automated surface weather stations similar to those used at many small airports but augmented with radiometric instrumentation and systems for measuring surface fluxes of water vapor and sensible heat. For about 16 months, one of the NSA/AAO boundary facilities will likely be the ice island in the Arctic Ocean perennial ice pack, to be instrumented as part of the SHEBA project.

In addition to ground-based instrumentation for characterizing the atmosphere and the Earth's surface, it will also be necessary to make occasional instrumented aircraft flights to measure conditions aloft, primarily over the central facility, and to depend heavily on data from polar-orbiting satellites. Coordination with the National Aeronautics and Space Administration (NASA), NOAA and other agencies regarding both the aircraft and satellite components is underway through FIRE (First ISCCP [International Satellite Cloud Climatology Program] Regional Experiment) and other programs. The achievements to date of the NSA/AAO CART effort have been developmental. Extensive on-site surveys have been conducted, preliminary site designs and schedules have been produced, discussions have been initiated with virtually all of the potentially interested local, regional, state and Federal agencies, and interagency and international scientific collaborations have been forged with many of the programs, projects and individual investigators active in the Arctic. The specific design of Arctic-qualified instrument shelters, the preliminary site design and the formal environmental assessment were completed in FY 94. The spring 1997 schedule for initial NSA/AAO CART operations was chosen to be in concert with the schedule for the SHEBA project, in which the ARM program will play a significant role, together with NSF, ONR, NASA and NOAA.

As part of the commitment to involve the local community, ongoing discussions have been taking

place with North Slope leaders, with the village corporations and with several elements of the North Slope Borough, and public information meetings have been held. The North Slope Borough Wildlife Management Department will play a major role in assessing the potential environmental impacts of the project. Barrow Technical Services (a subsidiary of the Ukepeagvik Inupiat Corporation) has been contracted to provide continuing liaison with the North Slope community.

Responses to Carbon Dioxide and Concomitant Climate Change

High-latitude ecosystems (Arctic, boreal forest and northern bogs) contain vast stores of carbon—about 500 Gt, mostly in the soil active layer and upper permafrost. This is equivalent to about two-thirds of the carbon now in the atmosphere. Arctic ecosystems alone contain about 180 Gt of soil carbon, or 12% of the global soil carbon pool, even though they make up only 6% of the total land area.

General warming of the Arctic over the last few decades has been clearly documented from several sites. Higher temperatures could increase the depth of the soil active layer and lower the water table, resulting in greater soil aeration and higher rates of soil decomposition. If soil decomposition increases more rapidly than primary production, the Arctic could represent a significant source of carbon to the global atmosphere. Alternatively, nutrient mineralization rates could increase due to enhanced soil decomposition, resulting in greater plant growth and ecosystem productivity. Under this scenario, ecosystem productivity could increase more rapidly than soil decomposition, with the system becoming a net sink for atmospheric carbon.

DOE-sponsored research on ecosystem responses to carbon dioxide (CO₂) and concomitant climate change is designed to determine the combined effects on ecosystem function of elevated levels of atmospheric carbon dioxide and likely changes in other environmental variables. The effort includes documentation of the current net ecosystem carbon dioxide flux, comparison with values from the historic and recent geologic past (Holocene), and development of an experimental base for predicting future fluxes.

During the period of interest, DOE-supported researchers obtained the following significant results related to the seasonal patterns of CO₂ flux from the major Siberian ecosystems, emphasizing winter CO₂ efflux and the role of ancient Pleistocene peat deposits. Siberian forest tundra was found to be a consistent CO₂ source to the atmosphere, including 89 gC/m²-yr during winter. This

winter flux was approximately half the annual CO₂ efflux from the site. If these effluxes are typical of boreal needle-leaved forests, this would be a winter efflux of 1.1 GT/yr, equivalent to 42% of the observed annual fluctuation in atmospheric CO₂ north of 66°N. These effluxes, if broadly representative of needle-leaved boreal forest, are a globally significant CO₂ source. This large winter efflux could account for much of the large seasonal fluctuations observed in atmospheric CO₂ at high latitudes. If this phenomenon is widespread, it suggests that the large seasonal amplitude of atmospheric CO₂ at high latitudes is due more to a substantial CO₂ efflux in winter rather than to high productivity in summer. The winter efflux appeared to be more a consequence of winter respiration than of outgassing of CO₂ that accumulated in soils during summer. Winter respiration increased in response to addition of carbon substrates and was closely correlated with winter temperature.

Global Measurements of Radionuclides in the Atmosphere and Deposition

For the Natural and Anthropogenic Radionuclides in the Environment Program, the point of contact is Richard Lorton, Environmental Sciences Division, U.S. Department of Energy, Environmental Measurements Laboratory, 376 Hudson Street, NY, NY 10014, 212-626-3324.

The objective of the program is to characterize natural and anthropogenic radionuclides deposited on the Earth's surface, quantify them, model their environmental pathways, and evaluate their environmental and human health impacts on regional and global scales. A component of this program is the operation of a high-quality global radioactivity sampling network by DOE's Environmental Measurements Laboratory (EML), which includes stations in the Arctic and sub-Arctic (Alaska, Canada, Greenland, Iceland and Norway). Through the global network, DOE is continuously poised to react instantly to any new introduction of atmospheric radioactivity.

On April 6, 1993, an accident at a reprocessing plant in the Tomsk-7 military nuclear complex 16 km north of the Siberian city of Tomsk released about 40 curies (Ci) (1.5 teraBecquerel [TBq]) of beta-gamma radionuclides into the atmosphere. Following notification of the accident, EML responded to determine the extent of possible contamination of the atmosphere with radioactivity. A three-dimensional trajectory model was used to calculate possible transport paths of the radionuclides released during the accident. Week-long high-volume air filter samples collected at Barrow, Alaska, the northernmost site in the United States, were analyzed for gamma-ray-emitting isotopes. The fission products niobium-95 (⁹⁵Nb) and ruthenium-106 (¹⁰⁶Ru) were first detected in the sample collected from April 15 to 21. The surface

air concentrations of these isotopes inferred from this sample were 2.2 and 15 μBq/m³, respectively, at the midpoint of collection. In the sample collected from April 21 to 30, zirconium-95 (⁹⁵Zr) and ruthenium-103 (¹⁰³Ru) were detected in addition to ⁹⁵Nb and ¹⁰⁶Ru. The surface air concentrations of ⁹⁵Zr, ¹⁰³Ru, ⁹⁵Nb and ¹⁰⁶Ru inferred from this sample were 1.2, 0.8, 2.8 and 16 μBq, respectively. No fission products were detected in the sample collected from April 30 to May 8th. The activity at Barrow of ⁹⁵Nb, the most prominent isotope present in these samples, was approximately 1/1000th the activity of the naturally occurring radioisotope beryllium-7 (⁷Be). The concentrations of these fission products were extremely low and of no dosimetric significance to the residents of Barrow. EML also detected minute traces of Tomsk-7 debris at the network sites located at Moosonee, Canada, and Thule, Greenland.

Organic Contaminants in the Alaskan Arctic and Siberia

Through scientific collaboration with the U.S. Environmental Protection Agency's (EPA) Arctic Contaminants Research Project, DOE's Environmental Measurements Laboratory (EML) has been involved in determining the presence and chronological record of atmospheric deposition, combustion-produced, potentially toxic and/or carcinogenic organic contaminants such as polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) and polycyclic aromatic hydrocarbons (PAH) in the North Slope of Alaska and the Taimyr Peninsula, Siberia, Russia. Although most of the peninsula is wilderness tundra, a sizable industrial city, Norilsk (population 250,000), is located at its southern extent. Norilsk is a significant source of contaminants to the surrounding region because of its mining and smelting operations.

Lake sediment coring is used for reconstructing the historical deposition of contaminants in the watersheds of lakes. Soil sampling is used to provide contaminant inventories. Lichen and moss are collected for use as surrogates of deposition since they may accumulate contaminants directly from the atmosphere or from materials deposited on them. During this activity period, lake sediments were collected from ten lakes in Alaska and three from the Taimyr Peninsula. Representative samples of soils and/or lichens and moss were also collected. Results of measurements for this reporting period are available for sediment from Wonder Lake in Denali National Park, AK. Two kinds of PAH were found: parental PAH produced from combustion and biogenic PAH derived from natural precursors.

Collecting sediment cores from the surface of the ice at Cascade Lake, North Slope Borough, Alaska, in the spring of 1994.



For the Organic Contaminants in the Alaskan Arctic and Siberia project, the points of contact are Matthew Monette, Environmental Sciences Division, U.S. Department of Energy, Environmental Measurements Laboratory, 376 Hudson Street, NY, NY 10014, 212 650 3625, and Yuhai Yin, Quality Assurance and Metrology Division, U.S. Department of Energy, Environmental Measurements Laboratory, 376 Hudson Street, NY, NY 10014, 212 650 3467.

The composition of combustion-produced parental PAH resembles those observed in other environmental samples, but the levels were two to three orders of magnitude lower than those found in sediments from other lakes in the contiguous U.S. The concentrations of biogenic PAH were one to three orders of magnitude higher than those of combustion-produced PAH. PCDD/F levels were very low, with only trace amounts of 1,2,3,4,6,7,8-hepta-chlorinated-dibenzofuran (HpCDF) and octa-chlorinated-dibenzofuran (OCDF) detected in the sediment. Since HpCDF and OCDF are recognized as primarily combustion-produced PCDD/F, these data suggest that some natural pyrolysis process may have occurred. These results also support the hypothesis of De Novo synthesis, which suggests that PCDD/F can be formed from a variety of chemically unrelated precursors, not necessarily man-made chlorinated aromatics, but also natural precursors, together with a chlorine donor.

Arctic Waste Assessment Program

This program concerns research on the occurrence of selected radionuclides in water, sediment and biota collected from the Arctic Ocean basin. These investigations are part of a larger U.S. effort to determine if radioactive waste management practices of the former Soviet Union (FSU) have poten-

tially compromised fisheries resources in the Arctic Ocean or, in any way, have led to radioactivity levels of concern in this ecosystem. The program is under the direction and sponsorship of the Office of Naval Research and will continue through FY 96. Collaborating with DOE's Environmental Measurements Laboratory is a consortium consisting of the IsoTrace Laboratory of the University of Toronto and several DOE laboratories: Oak Ridge National Laboratory, Argonne National Laboratory and Pacific-Northwest National Laboratories.

The objective is to perform radionuclide measurements in water, biota and sediments to determine whether or not the Arctic Ocean has been compromised by radioactivity releases from the FSU. The radionuclides being measured include technetium-99 (^{99}Tc), iodine-129 (^{129}I), neptunium-237 (^{237}Np) and plutonium-239+240 ($^{239,240}\text{Pu}$). ^{129}I is measured using accelerator mass spectrometry techniques, while the remaining isotopes are measured using thermal ionization mass spectrometry techniques. Geographic sampling is principally focused in the western Arctic Ocean (Bering, Chukchi and Beaufort Seas), although samples from the Laptev and East Siberian Seas are being analyzed for comparison with data collected elsewhere.

The results of measurements made by the consortium in 1994 and 1995 have led to the following conclusions. ^{129}I concentrations in the western

For the Earth Collection, contact the Office of Arctic Research, Department of Energy, Environmental Measurements Laboratory, 376 Hudson Street, NY, NY 10014, 212 650 3467.

For the EML Ob River project, the point of contact is Matthew Monetti, Environmental Sciences Division, U.S. Department of Energy, Environmental Measurements Laboratory, 376 Hudson Street, NY, NY 10014, 212-620-3625.

For EnviroTRADE, the points of contact are Susan W. Johnson, EM-544 Information For Decisions (IFD) Program Manager, Department of Energy, Cloverleaf Building, 20400 Century Boulevard, Germantown, MD, 20878, 301-903-7930, and Mark Harrington, Technical Support, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87115, 505-844-4221.

Arctic Ocean are generally 5–10 times lower than concentrations seen in the Barents and Kara Seas. Sellafield-derived ^{129}I has been advected into the Laptev Sea, and there is increasing evidence of its transport to the Beaufort Sea at depths between 200 and 400 m. There is evidence from sediment analyses that ^{237}Np , in excess of that expected from global fallout, has entered the Arctic Ocean. It is likely that the mechanism for import was via the Ob and Yenisei Rivers. Preliminary measurements of ^{237}Np in a small suite of seawater samples collected from the Beaufort Sea show easily measurable concentrations of this radionuclide at levels that exceed those expected from global fallout input. Sediments raised from the Canadian Basin show the presence of fuel reprocessing plutonium whose release date to the environment approximates 1957, the date of the large chemical explosion at the Mayak Complex, which released high-level radioactive waste over more than 20,000 km². The pathway by which this material reached the Beaufort Sea is still being investigated.

Personnel from the Environmental Measurements Laboratory (EML) also participated in a complementary sampling excursion on the lower reaches of the Ob River and its estuary in which sediment cores

were obtained from 15 stations. The initial results performed by colleagues at the Woods Hole Oceanographic Institution, and confirmed by EML, indicated that several of these cores can be used to identify the chronological record of radionuclide contamination.

Other Relevant DOE Activities

The EnviroTRADE Information System is under development for the DOE Environmental Restoration and Waste Management (EM) Office of Science and Technology (OST). This program provides the architecture for managing a large quantity of data on environmental waste sites and associated remediation technology development within a single database compatible with, or structured by, a geographical information system. During the period of interest, at the request of DOE, the EnviroTRADE project also coordinated the development of a database on FSU radioactive and other hazardous contamination in the Arctic. The EnviroTRADE project also established nodes in the FSU providing Russian scientists the ability to input data and make use of the EnviroTRADE technology in their own remediation efforts.

Department of Health and Human Services

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

Centers for Disease Control and Prevention

Arctic research programs of the Centers for Disease Control and Prevention (CDC) are conducted by the National Center for Infectious Diseases (NCID), the National Center for Environmental Health, the National Center for Injury Control and Prevention and the National Institutes of Occupational Safety and Health. These programs represent excellent focused interagency cooperation and collaboration with the State of Alaska Division of Public Health, the Alaska Native Medical Center of the Indian Health Service (IHS), the Alaska Area Native Health Service (AANHS) and other Alaska agencies and organizations.

Infectious Diseases

The Arctic Investigations Program (AIP), NCID, located in Anchorage, Alaska, is an integrated epidemiologic and laboratory-based research program for the prevention and control of infectious diseases among residents of the Arctic and sub-Arctic, especially Alaska Natives (Eskimos, Aleuts and Indians). The program emphasizes applied epidemiology and laboratory research in a widely scattered, sparsely distributed population. Activities include disease surveillance, investigations of the etiology of disease, analytic and descriptive epidemiologic studies, development of laboratory methods, evaluation of intervention strategies, dissemination of information, logistics support for research efforts by other agencies and organizations, and training in research, epidemiology and public health.

Central to the AIP mission is the maintenance of infectious disease surveillance capacity, which allows trends in disease incidence and organism characteristics to be monitored and provides baseline incidences from which disease reduction can be measured following implementation of a preventive strategy. Currently the AIP laboratory maintains a statewide surveillance system of all invasive disease caused by *Streptococcus pneumoniae* and *Haemophilus influenzae*.

The statewide epidemiologic and laboratory surveillance of invasive pneumococcal and *H. in-*

	Funding (thousands)	
	FY 94	FY 95
Indian Health Service	250	0
National Institutes of Health	3,932	3,524
Centers for Disease Control/Prevent	2,057	2,986
Health Care Financing Admin	200	0
Total	6,439	6,510

fluenzae diseases was established at AIP in 1982 and involves 23 of 26 hospitals, laboratories and clinics. Basic demographic and clinical information is collected, and information is verified by chart review. The surveillance system is evaluated annually to determine completeness. Verification of all meningitis caused by either *H. influenzae* or *S. pneumoniae* is determined by searching all discharge diagnoses records and by matching these records against laboratory-culture-confirmed meningitis captured by the surveillance system. Annual reports, including antimicrobial sensitivity patterns, are provided to each participating laboratory.

Statewide surveillance of *H. influenzae* and *S. pneumoniae* allows annual monitoring of disease rates and trends in emerging antimicrobial resistance. Identification of high rates of *H. influenzae* resistant to ampicillin, and a pneumococcal strain now resistant to penicillin, erythromycin and trimethoprim sulfamethoxazole, raises concerns about antibiotics usage.

Hepatitis B in Alaska Natives. Hepatitis B virus (HBV) infection is a serious public health problem in many areas of the world. In some regions of Asia, Africa and the South Pacific, the prevalence of hepatitis B surface antigen (HBsAg) exceeds 10%. In many of these areas, HBV-associated hepatocellular carcinoma (HCC) is a leading cause of death from cancer.

Since 1972 the AIP and the Alaska Area Native Health Service (AANHS) have conducted epidemiological surveys of the prevalence, incidence, transmission and sequelae of HBV infection among the Eskimos living in the Yukon-Kuskokwim Delta of southwest Alaska. The prevalence of HBsAg was 6.4%, with considerable village-to-village variation. The incidence of new HBV infection was high, especially in children less than two years old and in household contacts of HBsAg-positive persons. Transmission was highest between children

positive for hepatitis Be antigen (HBeAg) and those negative for all HBV seromarkers. Children had a significantly higher risk of becoming chronic carriers of HBsAg when infected than did adults. Although 4.5% of prenatal women were HBsAg positive, only 24% of these were also HBeAg positive, indicating that perinatal transmission played a much smaller role than children-to-children transmission in the spread of infection in this population. In adults, HBV infection was probably acquired both from HBeAg-positive children and through heterosexual contact. HBV infection seemed to spread first among household contacts, then to other villagers, and finally from village to village.

The rate of HBsAg-associated sequelae among Alaska Natives was also high. The annual incidence of HBsAg-positive necrotizing vasculitis was 15 cases per 100,000 population. The annual incidence of HCC in Alaskan Eskimo males was 11.2 cases per 100,000, five times that of white males in the U.S. Studies of HBsAg-positive HCC patients have shown that serum alpha-fetoprotein (AFP) was raised as early as two years before clinical presentation of a tumor and that twice-yearly AFP screening of HBsAg carriers could detect HCC at a resectable and potentially curable stage.

In 1981 a hepatitis B vaccine demonstration project conducted in the Yukon-Kuskokwim Delta among 1600 Alaska Natives showed that in 95% of the study participants, antibodies to HBsAg developed after three doses of hepatitis B vaccine.

In March 1983 a statewide hepatitis B control program was instituted with the cooperative efforts of the AANHS, AIP and the State of Alaska Division of Public Health. The objective was to immunize all serosusceptible Alaska Natives to eliminate new HBV infection. An ongoing maintenance phase includes immunization of all newborn Alaska Natives and, in addition, administration of hepatitis B immune globulin to those born of HBsAg-positive mothers.

Serologic testing to determine HBV status prior to immunization allowed identification of all HBV carriers. These patients are being carefully followed and tested for AFP in addition to HBV markers.

In FY 94 and 95, long-term studies of the protection provided by hepatitis B vaccine in Alaska Native infants and adults continued. The immunization program has protected the population to the extent that no symptomatic cases of hepatitis B infection were reported in the area having the highest incidence of disease (215/100,000) prior to the control program.

In collaboration with the Hepatitis Branch, Division of Viral and Rickettsial Diseases, a sero-

survey was completed in the Bristol Bay region of southwest Alaska to determine the protection provided by hepatitis B immunization in the under-30-year-old population.

The cooperative hepatitis B control program in Alaska has significantly decreased the incidence of acute hepatitis B. It is likely that the long-term sequelae will also decline in Alaska Natives over time. Information gathered in this program is of national and international interest. The strategy used in the control program has been integrated into control programs in other countries. The information gathered on the long-term efficacy and safety of the hepatitis B vaccine is being used to develop policy for revaccination schedules. The AFP screening program is a model for HCC control in other parts of the U.S. and in other countries.

Pneumococcal Infections in Alaska Natives. *Streptococcus pneumoniae* remains a major cause of pneumonia, meningitis, sepsis and otitis media worldwide. In the U.S. it is estimated to be responsible for at least one-fourth of all community-acquired pneumonia. Despite the existence of a capsular polysaccharide vaccine for 23 of the most common 83 serotypes with an estimated efficacy of 60–80% in adults, no more than 10% of those at high risk in the U.S. have been vaccinated. A progressive increase in antimicrobial resistance, particularly penicillin and more recently erythromycin, has been observed worldwide but less commonly in the U.S.

To date, the highest reported invasive pneumococcal disease rates in infants exist in Alaska Native (Yupik Eskimo) infants from western Alaska, where one in every 40 infants is diagnosed with the disease during the infants' first two years of life (1,235 per 100,000 per year), and many more are undiagnosed due to inaccessibility to culture before empiric antibiotic administration.

Pneumococcal meningitis rates in this infant population are 37 times higher than other U.S. rates similarly derived. An elevated prevalence of moderate penicillin resistance (14%) has been observed only in one region of Alaska, together with an increase in isolates multiply resistant to two or more antibiotics. Statewide surveillance for invasive pneumococcal disease in Alaska reveals rates of invasive disease in Alaska Natives 40–54 years of age that are eight times higher than non-Native rates; Native infant disease rates statewide are four times higher than rates in a benchmark U.S. community. Alaska Natives have an age-adjusted mortality rate from invasive pneumococcal disease that is five times higher than non-Native Alaskans. By age 75 at least one in 15 Alaska Natives will have experienced one episode

of invasive pneumococcal disease, compared to 1 in 53 non-Natives. In Alaska, invasive pneumococcal disease occurs in Natives with AIDS over 100 times more frequently than those without AIDS; however, no co-infections have been reported in Natives to date. The universal problems of preventing and managing this disease are:

- The absence of an accurate rapid nonbacteriologic diagnostic test;
- No effective means for monitoring or controlling the development of antimicrobial resistance;
- The absence of an immunogenic vaccine for use in infants;
- The failure to deliver the currently available 23-valent vaccine to high-risk adults;
- The lack of adequate data on the duration and strength of antibody response of adults with chronic disease to both primary vaccination and revaccination with this vaccine; and
- A continuing controversy over the efficacy of this vaccine in those for whom it is intended.

Studies at AIP focus on:

- Maintaining a statewide surveillance system for invasive pneumococcal disease and reporting the descriptive epidemiology of the disease;
- Elaborating the descriptive epidemiology and suppurative sequelae still common in Alaska Natives;
- Developing nonbacteriologic detection systems for diagnosing pneumococcal infections;
- Establishing a standard system for measuring serotype-specific, class-specific antibodies;
- Examining the immunogenicity and efficacy of current and new pneumococcal vaccines; and
- Developing and evaluating guidelines and programs for improving immunization of adults.

In FY 94 and 95, statewide surveillance was continued for invasive pneumococcal disease, as well as monitoring for a regional increase in antimicrobial resistance of pneumococcal isolates (serotype 6B) to penicillin, erythromycin and trimethoprim sulfamethoxazole.

Rates were summarized and reported for invasive pneumococcal disease in Alaska from 1986 to 1990. The age-adjusted annual incidence was 74 per 100,000 for Natives and 16 per 100,000 for non-Natives. The annual incidence in Alaska Native children less than 2 years of age was 624 per 100,000 for invasive pneumococcal disease, 84 per 100,000 for meningitis and 290 per 100,000 for bacteremic pneumonia.

In FY 94 and 95, AIP summarized and reported the serotype distribution and antimicrobial resis-

tance patterns of invasive pneumococcal isolates recovered from Alaska patients between 1986 and 1990. Moderate penicillin resistance was found in 3.4% of the isolates. A regional increase in antibiotic resistance was seen in the Yukon-Kuskokwim Delta, where 16.0% were moderately resistant to penicillin, 10.8% were resistant to erythromycin and 6.2% were resistant to trimethoprim sulfamethoxazole.

Together with the Respiratory Disease Branch of the Division of Bacterial and Mycotic Diseases, AIP completed a summary and reported the analysis of a nasopharyngeal carriage study among Alaska Native infants and children to determine the carriage rate and risk factors for carriage of *Streptococcus pneumoniae* resistant to antibiotics. The carriage rate in children less than 5 years of age was 50%. The pattern of antimicrobial resistance among nasopharyngeal isolates resemble patterns found among invasive isolates recovered from patients living in the same geographic area.

AIP recovered the first Alaskan pneumococcal isolate that was multiply resistant to penicillin, erythromycin, trimethoprim sulfamethoxazole, cefaclor, ceftriaxone and cefotaxime. Together with the State of Alaska Section of Epidemiology, AIP issued an Epidemiology Bulletin alerting health care providers in the state of the presence of multiply resistant pneumococcal strains and recommended screening of all invasive pneumococcal isolates for penicillin resistance.

AIP continued to evaluate the long-term immunogenicity of the 23-valent pneumococcal vaccine in persons who received a primary immunization and those receiving re-immunization in a cohort of adults with documented chronic "high-risk" illnesses. Previous studies have showed that the immune response of reimmunization closely resembles the primary vaccination experience with no adverse side effects. Furthermore, the revaccination of patients may improve their response over that resulting from primary vaccination.

AIP also summarized and presented the analysis of a case-control study of the efficacy of both the 14- and 23-valent pneumococcal polysaccharide vaccines in Alaska Native adults. When vaccine use in 184 cases and control patients was compared, the overall efficacy was 79%. In those less than 65 years of age, the efficacy was 60%; for non-alcoholics it was 89% and for alcoholics, 75%. Another continuing study evaluated the long-term immunogenicity of the 23-valent pneumococcal polysaccharide vaccine in alcoholics.

An immunogenicity study of a heptavalent pneumococcal conjugate vaccine in Alaska Native infants up to 24 months of age was initiated. Together with collaborators at John Hopkins Uni-

versity Center for Native American Health, AIP initiated a review of all reports of pneumococcal disease in American Indians and Alaska Native infants.

The population-based surveillance of invasive pneumococcal disease in Alaska permits the calculation of rates for specific disease manifestations (indicating the magnitude of their excess) and provides important data that will be necessary for the development and testing of new pneumococcal vaccines for both infants and adults. The surveillance system also provides a platform for monitoring the emergence of antimicrobial resistance and disease reduction or re-emergence after implementation of a preventive strategy.

The statewide surveillance in Alaska has allowed the early detection of emerging antimicrobial resistance among serotype 6B isolates in the Yukon-Kuskokwim Delta region, where 70% are now moderately resistant to penicillin and at least one other antibiotic (erythromycin or trimethoprim sulfamethoxazole). The arrival of pneumococcal strains in Alaska now fully resistant to penicillin and third-generation cephalosporins is of great concern to the health care community since these antibiotics are used empirically in rural Alaska for treatment of infection. Carriage studies indicate that 50% of children less than 5 years of age carry pneumococcal isolates and 74% are serotype 5B and are multiply resistant. Carriage of drug-resistant pneumococcal isolates are associated with children less than 2 years and with day-care attendance. Prevention efforts should include the use of the heptavalent conjugate vaccine, which includes serotype 6B, and, if it proves effective, should target this age group in day-care settings.

The continued evaluation of vaccine efficacy and immunogenicity in adults with well-defined chronic disease both from primary and repeat vaccination will have direct implications for recommendations for vaccination of high-risk individuals and populations elsewhere.

Iron Deficiency Anemia and Helicobacter Pylori in Alaska Natives. Iron deficiency anemia has long been recognized as a common nutritional problem among Alaska Natives. Most early studies in Alaska have focused on the detection of iron deficiency anemia in infants and small children. Over the years the Arctic Investigations Program has participated in many studies and surveys of iron deficiency and anemia in the Alaska Native population.

The cause of iron deficiency in this population is unknown. A usual cause of iron deficiency in most populations is a reduced intake of dietary iron. The traditional Native Alaskan diet generally contains many iron-rich items such as meat (land

and marine mammals) and cold-water fish, and a recent nutrition survey among Alaska Native adults has shown that the intake of dietary iron in this population exceeds that of a similar general U.S. population. A recently published study of the diet of Bristol Bay Alaska Natives described a high consumption of iron (especially heme iron) and vitamin C, foods that should optimize iron stores. Inhibitors of iron absorption have not been systematically studied in this population but are unlikely to affect heme iron absorption. Increased loss of iron through gastrointestinal blood loss is supported by evidence of a high prevalence of elevated stool heme content in a study of 140 healthy Eskimo adults from southwestern Alaska. Subsequent endoscopy of 70 of 84 with the highest stool blood loss had biopsy-confirmed chronic active gastritis due to *Helicobacter pylori* in all but one. Why *H. pylori* disease appears to be present in this population with blood loss and anemia is not known. It may be related to high levels of omega-3 polyunsaturated fatty acids, found in the plasma of Alaska Natives consuming a largely subsistence diet of marine fish, mammals and other cold-water fish. High levels of plasma omega-3 fatty acids have been related to decreased platelet aggregation and increased bleeding times in other non-Alaska Eskimo populations.

The objective of this collaborative AIP study with the Indian Health Service and the Center for Chronic Disease Prevention and Health Promotion is to determine the prevalence of iron deficiency and iron deficiency anemia in the Alaska Native population, to determine the relationship between this anemia and *H. pylori* infection and other host factors, and to develop and evaluate a strategy to prevent *H. pylori* infection in the Alaska Native population.

In FY 94 and 95 an investigation of gastrointestinal blood loss in Alaska Natives was reported. This collaborative study between the Mayo Clinic, YK Health Corporation, IHS and AIP concluded that fecal blood loss was pandemic and that the florid *H. pylori* gastritis probably accounts for the blood loss. A working group of national and local experts in *H. pylori* disease was convened by AIP with the collaboration of IHS. This conference resulted in developing strategies for further investigation of *H. pylori* disease in Alaska Natives. A statewide serosurvey of Alaska Natives was also completed, and it indicated that 75% of the Alaska Native population have serologic evidence of *H. pylori* infections.

The apparent association of *H. pylori* disease with blood loss is a breakthrough in defining a possible etiology for the high prevalence of anemia among Alaska Natives documented over the past

40 years. Years of study of thousands of Alaska Natives has failed to define the etiology of the anemia until now. The presentation of *H. pylori* disease as anemia in a population is unique. Dietary cofactors such as omega-3 fatty acids may be associated with this unique presentation.

Respiratory Syncytial Virus. Respiratory syncytial virus (RSV) illness is a significant cause of morbidity in Alaska Native infants. A review of discharge diagnoses in four Alaska Native Health Service hospitals in western Alaska from 1986 through 1992 showed rising hospitalization rates due to bronchiolitis and RSV pneumonia. The estimated rates of hospitalization for RSV-infected infants under one year of age increased in these four regions from 55 per 1000 in 1988 to 87 per 1000 in 1992. Most U.S. studies report rates ranging from 1 to 14 per 1000. A careful retrospective review in the two largest hospitals in western Alaska was conducted covering the period from October 1, 1991, to September 30, 1993. The hospitalization rate for Native infants in Anchorage, Alaska, was 33 per 1000, while the rate for those in the Yukon-Kuskokwim Delta region was 100 per 1000. The highest previously reported rate of RSV hospitalization was 20 per 1000 in Tyneside, England.

A hospital-based surveillance program is being conducted at the Yukon-Kuskokwim Delta Regional Hospital, the Alaska Native Medical Center and the Providence Hospital for infants from the Yukon-Kuskokwim Delta hospitalized with RSV disease. Cord bloods are obtained for RSV neutralizing antibodies. Nasal aspirates of acute respiratory illness admissions under three years of age are obtained for viral culture and RSV detection. The hospitalized infants are compared in a case-controlled study to infants matched by age and region. The aims of the study are to confirm the rates of RSV hospitalization, to compare the severity of illness with other populations, to determine the seasonality of infections, to determine if cord blood RSV neutralizing titer has a protective effect, and to identify risk factors for RSV hospitalization.

In FY 94 and 95 a retrospective review of two years of hospitalizations for RSV-infected infants in Yukon-Kuskokwim Delta Regional Hospital was completed. In collaboration with the Johns Hopkins University and IHS, one year of a proposed three-year laboratory surveillance study of acute respiratory illness in infants in the Yukon-Kuskokwim Delta region has been completed. Case controls, cord bloods and severity of illness clinical information is also being collected on infants under the age of three years hospitalized at the Yukon-Kuskokwim Delta hospital.

Fetal Alcohol Syndrome

Since 1991 the National Center for Environmental Health of the CDC has collaborated with the IHS and the State of Alaska Department of Health and Social Services (DHSS) to obtain relevant epidemiologic data for guiding the development and evaluation of fetal alcohol syndrome (FAS) prevention and surveillance efforts in Alaska. Through formal agreements the three participants established the Alaska Fetal Alcohol Syndrome Prevention Project. The project's goals are to:

- Provide technical and programmatic review of IHS FAS programs and data and to analyze and evaluate programs;
- Assist the State of Alaska in developing and implementing FAS surveillance systems to capture data from program services currently being provided by the State and IHS; and
- Develop model surveillance, data analysis and program evaluation methods that can be used by other states or circumpolar nations and by indigenous peoples of the Arctic.

In 1993, CDC, IHS and DHSS staff presented the project's findings at the IXth Congress of the International Union for Circumpolar Health in Reykjavik, Iceland. The Congress generated interest in FAS, which led to the formation of a working group. FAS will be one of the six working groups of the Xth Congress to be held in Anchorage during May 1996.

Since 1993 the project has further explored the value of existing databases and programs in surveillance of FAS and has further defined the magnitude of maternal risk factors through both the Behavioral Risk Factor Surveillance System and the Pregnancy Risk Monitoring System. The project used 16 data sources in identifying potential FAS cases born between 1977 and 1992. Researchers were able to review the medical charts of 568 of the 630 potential cases identified. They used a five-criteria case definition to ascertain FAS cases. The findings indicate a high prevalence of FAS in Alaska, particularly among Alaska Natives; the rates for 1978-1992 were 2.1 per 1000.

In analyzing data on potential cases identified through an IHS case file, a pediatric practice case file and Medicaid claims from private providers, project staff established an observed prevalence rate of chart-verified FAS of 3.1 per 1000 live births for Alaska Native children born between 1986 and 1989. This analysis, which used capture-recapture methodology, found that the IHS case file ascertained a greater percentage of cases during a period when it conducted active case-finding surveillance among Alaska's 12 Native Regional Health Corporations.

The project also assessed the general public's

awareness and knowledge of FAS and surveyed health care providers not only to ascertain each profession's knowledge, attitudes, beliefs and behaviors concerning alcohol abuse and FAS, but also to identify training and resource needs of the state's health-care providers. Project staff have worked with the Nordic Council to survey health-care providers in Greenland to assess their knowledge of the diagnostic features of FAS.

Researchers found substantial under-reporting of FAS in each of the 16 data sources examined, indicating that multiple data sources and active screening programs are needed to enhance case ascertainment. To improve case ascertainment among circumpolar nations, the FAS Working Group, through a grant from CDC, plans to offer a workshop on diagnosing FAS to participants in the Xth Congress.

National Institutes of Health

National Institute on Alcohol Abuse and Alcoholism

The National Institute on Alcohol Abuse and Alcoholism (NIAAA) is the lead Federal agency responsible for supporting and conducting biomedical and behavioral research on the causes, consequences, treatment and prevention of alcohol-related problems affecting the Nation's health. The NIAAA supports two active research projects in Alaska. In 1994 a grant was awarded to the University of Connecticut Health Center to conduct a five-year collaborative study with the University of Alaska Anchorage to examine the genetic, biological and behavioral characteristics of Native Alaskans receiving treatment for alcoholism. Well underway in its second year, the project has met several objectives. Research assistants, including Alaska Natives, have been trained in procedures using standardized methods to obtain clinical assessment and laboratory data on 250 men and 250 women. To date, 100 subjects have been recruited into the study.

The research has important implications. This study will provide the first comprehensive clinical description of Native Alaskans in treatment for alcohol dependence using a standardized assessment protocol and will enhance understanding of the nature of alcohol dependence among Native Alaskans, determine the importance of gender differences with respect to the course, severity and risk factors associated with alcohol problems, and determine if there are Native Alaskan subtypes of alcoholism as has been described for the majority population.

The clinical assessment battery used in this

study is identical to that used in the Collaborative Study on the Genetics of Alcoholism (COGA), which will contain a large sample of approximately 10,000 subjects collected at six sites in the continental U.S. The COGA sample represents a range of alcohol problems and contains a sufficient number of Hispanic and African-American subjects for comparison across different ethnic groups. Comparisons with the sample of Native Alaskans can identify specific cultural differences in the development of alcohol problems.

The study lays the groundwork for subsequent studies. For example, the identification of possible cultural differences between alcohol-dependent Native Alaskans and the majority population may suggest avenues for approaches to improve Native Alaskan treatment outcomes.

A second study is supported by a grant awarded to the University of Alaska in 1994 that seeks to determine whether and by how much community alcohol control can reduce the risk of violent death by homicide, suicide and accidents among Native Alaskans. The subject population consists of all Alaska Native residents of Alaska communities with at least 25 Native residents in 1990. About 80,000, or around 94% of the state's Native population, lived in these communities in 1990. The study employs statistical analyses of death certificate data provided by the Alaska Bureau of Vital Statistics over the 1980-1990 period. Nearing the end of its second year, the investigator expects to report findings in late 1996.

In 1995 NIAAA sponsored a conference with the University of Alaska Anchorage and the Alaska Native Alcoholism Recovery Center, Cook Inlet Tribal Council, held in Anchorage. With the recognition that solving problems affecting communities requires active involvement of community residents, a primary goal of the meeting was to bring service providers, researchers, policymakers and Alaska Native leaders together to share existing information about alcohol abuse and alcoholism, to assess what kind of additional information is needed, and to explore ways to develop appropriate treatment and prevention programs. Over 100 scientists, students, clinicians, service program directors and community members attended and participated in lively, focused sessions. An important outcome has been the beginning of ongoing dialogue among alcohol researchers, practitioners and alcoholism service providers and the planning of collaborative research focusing specifically on the needs of Alaska Natives.

National Institute of Child Health and Human Development

The National Institute of Child Health and Hu-

man Development (NICHD) continues to support research at the Institute of Arctic Biology, University of Alaska, on the role of the endocrine system in hibernating mammals and on mechanisms by which Arctic ground squirrels spontaneously adopt subzero body temperatures without freezing. Investigations have shown that Arctic ground squirrels, as well as other hibernating species, stop hibernating and resume sustained euthermia when plasma androgen is artificially increased. Current work seeks to identify the central nervous system sites that are sensitive to androgen inhibition of hibernation. Other work is focused on the role of the suprachiasmatic nucleus in seasonal timing and patterns of hibernation and on the seasonal changes of plasma androgens, gonadotropins and glucocorticoids in a natural population of Arctic ground squirrels.

In FY 94, NICHD sponsored a two-day conference on the endocrinology of Arctic birds and mammals. The purpose of the symposium was to review the endocrine mechanisms that regulate seasonal reproduction, migration and premigration activities, hibernation, and responses to stress in Arctic birds and mammals and to compare these mechanisms and strategies to those of species in temperate climates.

National Library of Medicine

The mission of the National Library of Medicine (NLM) is to aid the advancement of medicine and to improve public health through effective dissemination of the results of research. As part of this broad mission, NLM indexes and catalogs the published reports of health-related Arctic research, provides easy access to these reports and other health-related literature needed by researchers and practitioners in Arctic Alaska via on-line database services and the National Network of Libraries of Medicine, and undertakes special outreach projects to ensure that rural and isolated health professionals know about these services and can take advantage of them. The Alaska Health Science Information Service in Anchorage is an active participant in the National Network of Libraries of Medicine, with a history of service to rural health professionals throughout Alaska, including the Arctic region, as well as to the Institute of Circumpolar Health Studies in Anchorage.

From FY 94 to FY 95, NLM funded the Alaska Rural Health Information Access Project, which allowed the Alaska Health Sciences Information Service to enhance its systems for serving remote practitioners, including those in the Arctic. As part of another NLM-funded project, the University of Washington Health Sciences Library, which is the Regional Medical Library for the Pacific

Northwest, is helping the Alaska Health Science Information Service to arrange Internet connections for rural health professionals in Alaska. Internet connections will improve access to on-line information services and will also help remote practitioners and researchers to communicate with colleagues throughout the region, the country and the world.

National Institute on Drug Abuse

NIDA is the lead Federal agency responsible for supporting research on behavioral, psychological, biological, medical and sociological factors that may be causes of drug abuse and addiction, and the correlates and consequences of drug abuse, such as HIV and other infectious diseases, violence and crime.

NIDA has sponsored a cooperative agreement with the University of Alaska Anchorage as part of its AIDS community-based outreach/intervention research program. The objectives of this ongoing research project, which began in July 1991, are to monitor the HIV status of injecting drug users and crack cocaine users in Alaska and to evaluate the effectiveness of an innovative, culturally sensitive program in reducing AIDS risk behaviors among Alaska Natives relative to the NIDA standard intervention. This project extends beyond HIV and includes other medical conditions such as hepatitis and pneumonia. Approximately 80–85% of current injectors in the project are positive for hepatitis C, and extensive research is being undertaken to develop interventions to prevent the spread of this debilitating and costly disease among drug users in Alaska.

The project is also studying *Streptococcus pneumoniae*, which can cause pneumonia and meningitis. Drug users are at high risk for *S. pneumoniae*, as well as HIV. If they can be encouraged to take *S. pneumoniae* vaccine, this can greatly reduce the chances of this becoming an opportunistic infection if the drug user contracts AIDS. It can also prevent *S. pneumoniae* in non-HIV-positive drug users.

As part of the NIDA-supported work involving *S. pneumoniae*, an initiative of major significance incorporates telemedical techniques. In a demonstration project involving telemicrobiology in culturing and identification of *S. pneumoniae*, a consultant will be able to observe and instruct a technician using a computer screen. The technician will be at a University of Alaska field station, and the consultants will be at remote locations, including sites in the mainland U.S.

In July 1995, NIDA also initiated an Alaska State Epidemiology Work Group in conjunction with the University of Alaska Anchorage and the

Alaska State Department of Health. This project is modeled after NIDA's Community Epidemiology Work Group (CEWG). The CEWG is a community-based network of researchers from 20 major metropolitan areas of the U.S. and around the world who meet semiannually to report on patterns and trends of drug abuse, vulnerable populations, risk factors and negative health and social consequences of drug abuse.

With both the NIDA-supported research at the University of Alaska and the NIDA-initiated Alaska State Epidemiology Work Group, the University of Alaska Anchorage's Telemedicine Project has been incorporated to bridge the great geographic expanse of Alaska in a series of "research at a distance" projects. These projects use desktop video teleconferencing technology to investigate the transformation of epidemiological and health-related research from a model based on physical proximity to one that can be shared over great distances. In collaboration with the NIDA-supported research, the Telemedicine Project will continue to explore the uses of narrow-band telecommunications and information technology to improve the delivery of health care to all citizens of Alaska.

National Institute of Mental Health

The NIMH supported a variety of research projects that have an impact on Arctic populations. The Institute's goals and objectives include support of health and mental health services research as they relate to Arctic, ethnic, minority and other rural populations. Many of the Arctic health research activities supported by NIMH are part of general American Indian and Alaska Native programs. They include the following:

- Continued support of an American Indian and Alaskan Mental Health Research Center;
- Support of a five-year, large-scale assessment of the prevalence rates for major mental disorders among Native Americans, their mental health service utilization patterns, the impact on psychiatric morbidity of selected risk factors, and the cross-cultural generalizability of the results;
- The D/ART (Depression/Awareness, Recognition and Treatment) program; and
- Program announcements on Research on Mental Disorders in Rural Populations; and American Indian, Alaska Natives and Native Hawaiian Mental Health Research.

The D/ART program, a public and professional education campaign sponsored by NIMH in collaboration with private organizations and citizens, is based on over forty years of research on the diagnosis and treatment of depressive disorders. Its goals include the alleviation of symptoms through early

intervention and effective treatment for individuals who suffer from depressive disorders. The program was presented to over 10,000 Alaskans through conferences, workshops and public-speaking engagements to various audiences such as clergy, educators, nurse practitioners and a Native American tribal council. Other FY 94 activities included a health fair in Seward, Alaska, and presentations to the U.S. Army Corps of Engineers, the Municipality of Anchorage employees, University of Alaska students and various church-related family services. Graduate students in psychology from Alaska Pacific University continue to facilitate five weekly depression self-help groups. Referrals for these groups come through word-of-mouth as well as from doctors, hospitals, newspaper ads and community mental health centers.

National Heart, Lung, and Blood Institute

Pulmonary Vascular Disease. In FY 91 the National Heart, Lung, and Blood Institute (NHLBI) initiated a program to address problems that prevent the rapid and effective application of new developments in the medical diagnosis and care of patients with diseases such as pulmonary hypertension, pulmonary vasculitis and pulmonary thromboembolism. In FY 93 a five-year program began to develop a curriculum to meet the needs of physicians practicing in the rural Washington-Alaska-Montana-Idaho region. University and community physicians are developing local clinical practice guidelines for evaluation and care of patients with primary pulmonary hypertension and pulmonary hypertension secondary to airflow obstruction, and for prevention, evaluation and treatment of pulmonary thromboembolism. Education programs are directed toward housestaff and fellowship trainees at affiliated hospitals and community physicians throughout the Washington-Alaska-Montana-Idaho region. A regional newsletter is distributed emphasizing progress in pulmonary vascular science and current patient management issues. Communication is increased among individuals conducting clinical and basic research relating to pulmonary vascular disease from several disciplines and affiliated institutions. In March 1994 the Pulmonary Vascular Disease Clinic was established, to which patients with known or suspected pulmonary vascular disease are referred from the Washington-Alaska-Montana-Idaho regions. A registry of patients evaluated at the clinic has also been established.

Sleep Apnea. Sleep apnea is a major sleep disorder affecting more than three million adults in the U.S. Patients with the disorder experience fragmented sleep due to periods of apnea (absence of breathing) that result in low blood oxygen levels.

The hallmark of the syndrome is excessive daytime sleepiness. Sudden infant death syndrome (SIDS), cardiac arrhythmias, systemic and pulmonary hypertension, coronary heart disease and congestive heart failure have also been associated with sleep apnea.

NHLBI continues to support a project to train personnel in the methods of cardiac modeling and to obtain the research necessary to apply the methods to cardiopulmonary patterns during sleep apnea in seal pups. Alaskan seal pups are capable of withstanding sleep apnea of up to 14 minutes duration, a condition that would prove lethal to terrestrial mammals. Sleep apnea in seal pups is central, repetitive, under developmental influence and, most important, normal and non-pathogenic. During these periods, seals exhibit a suite of physiological and metabolic events that include heart rate changes, significant circulatory oxygen desaturation and dramatic hematocrit and peripheral circulatory flow alterations. The heart rate patterns appear to be similar to those of children who are at risk for SIDS.

National Institute on Aging

The National Institute on Aging (NIA) provided a no-cost extension to complete a Small Business Innovation Research project at the Mary Conrad Center, a nursing home in Anchorage. This research developed an automated system to reduce urinary incontinence among residents, a major concern for elders in long-term care. Phase 2 of the study extended the program to the Our Lady of Compassion Home, Fairbanks, to investigate profiles, causes and treatment responses between Alaska Native and non-Native nursing home residents. Differences in urinary incontinence between other U.S. minority populations and the majority population have been found in prior research and are important issues for designing the most effective treatment approaches.

National Cancer Institute

Breast Cancer in Alaska Natives. Recent studies have shown an association between breast cancer and elevated levels of organochlorines, such as DDT and PCBs, in adipose tissue and serum. Alaska Natives may be at increased risk of exposure because their diets are disproportionately high in protein and fat from marine sources having high concentrations of organochlorines. The Alaska Native population is covered by a cancer registry, and serum has been collected and banked since 1967. In collaboration with the Centers for Disease Control and Prevention and the Indian Health Service (IHS), the National Cancer Institute (NCI) is conducting a pilot study to determine the avail-

ability of banked serum for breast cancer cases and controls to assess the variability of organochlorine levels in the serum, as well as to assess the extent and quality of data in the INS medical records on known breast cancer risk factors. Consideration is being given to the possibility of a full-scale study of breast cancer in Alaska Natives in subsequent years.

Preventing Cervical Cancer in Alaska Native Women. This project targets Alaska Native women age 18 and over in two locations: at the Alaska Native Medical Center, Anchorage, and in rural St. Paul Island in the Pribilof Islands. In Anchorage, 500 women were enrolled from a random sample of the 5000 eligible Native residents of the area. In St. Paul, all adult women (approximately 125) were eligible to participate. Intervention strategies were implemented following enrollment in the project. One intervention was a special demonstration women's health clinic. This women's clinic includes extended evening hours, hour-long appointments, staffing by women providers and nurse practitioners, comprehensive health surveillance for women of all ages, Pap smear tracking services, individual patient education, mammography services and tobacco cessation classes.

Data-Based Cancer Intervention Research in Alaska. The Alaska Department of Health and Social Services receives support from the NCI for developing a project that will serve as a model of data use for planning and evaluating statewide cancer prevention and control interventions. Upon analysis of existing data, the two interventions that have been chosen are regional cancer data profiles and tobacco use reduction.

For the first intervention, 13 separate cancer profiles will be developed. Each profile will be regionally specific as defined by the census areas/boroughs located within the boundaries of the 12 Alaska Native Health Corporations and the Municipality of Anchorage. Each profile will focus on all cancers in general and, more specifically, lung, colorectal, breast and cervical cancer. Information will be provided on risk factors, prevention and early detection, as well as interpretation of the findings and recommendations for cancer prevention and control to health and public policymakers within Alaska. This information will then be given to health professionals and educators. The profiles will provide the first complete review on cancer in Alaska. The expected outcome of the profiles' influence is a change in local ordinances and appropriations for cancer prevention and control programs.

The second intervention, tobacco use reduction, will focus on a legislative excise tax initiative accompanied by a media/grassroots campaign to

increase public awareness of the harmful effects and to decrease the social acceptability of tobacco use. If successful, the intervention is expected to have the greatest impact on youth and those with low income.

Community Clinical Oncology Program. The Community Clinical Oncology Program Cooperative Agreement with the Virginia Mason Research Center in Seattle includes a component in Anchorage and an affiliate in Fairbanks, Alaska. This program provides communities that are not served by university hospitals with access to clinical treatment and prevention trials. Most notably this has provided Alaskans with the opportunity to participate in trials in the prevention of cancers of the prostate and colon as well as studies involving treatment of a number of cancers significant to this population. This program serves as continuing medical education for health care givers and accelerates dissemination of the state-of-the-art care technologies.

Etiology of Cancer in Alaska Natives. In collaboration with the IHS, the NCI is conducting studies of familial risk factors for nasopharyngeal carcinoma and primary hepatocellular carcinoma among Alaska Natives.

Evaluation of Virus-Associated Tumors. This effort utilizes the Alaskan Native American Cancer Registry to investigate the molecular epidemiology of several virus-associated malignancies, such as lymphoma and liver cancer, in Alaska Natives.

Hepatic Changes in Primary Hepatocellular Carcinoma. The goal of this study is to determine whether genetic factors are of clinical importance in primary hepatocellular carcinoma (PHC). Several Alaska Native families that include members with early onset of PHC are being studied. Unlike liver cancer in high incidence areas of the world, mutations in the p53 tumor suppressor gene are rare in the Native Alaskan population. In addition, a molecular genetic karyotype is being derived for a collection of approximately 20 PHC tumors, some of which are being provided by the IHS and may include tumors from Native Alaskan patients.

National Network for Cancer Control Research among American Indian and Alaska Native Populations. The purpose of this network is to reduce preventable cancer morbidity and mortality to the lowest possible levels and improve cancer survival to the greatest possible extent. The network comprises individuals from reservations, tribal organizations, urban organizations and the IHS, and it includes service providers, academicians, clinic directors, researchers and organization leaders.

One accomplishment of the network was the development of a National Strategic Plan for Cancer Prevention and Control to benefit the overall

health of American Indians and Alaska Natives (AI/AN). The purpose of the plan is to enhance awareness in Federal agencies, other organizations and individuals about the problems of cancer among AI/AN populations. Consistent with the Year 2000 objectives, this document suggests strategies to reduce cancer morbidity and mortality and to increase survival among AI/AN populations. The network will provide an addendum to the plan each fiscal year.

Reduction of Cancer in American Indian and Alaska Native Populations. The Native American Women's Cancer Initiative (NAWCI) began in FY 93. This research will determine the effectiveness and efficacy of cancer control and prevention strategies that are designed to focus on one of the following objectives:

- Address the barriers to culturally appropriate quality cancer control services, including screening, appropriate follow-up, diagnosis, treatment and rehabilitation programs for cancers that are common and/or disproportionately elevated within indigenous women;
- Reduce cancer risk behaviors in Native American women, such as high dietary fat intake, tobacco use and alcohol consumption; and
- Provide technical assistance to improve Native American women's research skills and eventually increase the number of Native American women in key research positions, such as principal investigators.

The Native American Monograph No. 1, "Documentation of the Cancer Research Needs of American Indians and Alaska Natives," has been developed. Its purpose is to provide a resource to assist in formulating culturally acceptable cancer prevention and control research projects or programs. It is a brief overview of the cancer problem among AI/AN people living in urban, rural, reservation and village sites and is primarily designed for use by Native and non-Native cancer researchers.

Five-Year Cancer Surveillance of Alaska Natives. The NCI has two intra-agency agreements with the IHS. The objective of the first is to provide accurate cancer incidence, mortality and survival data for Alaska Natives. The program is collected in a format that meets the criteria and standards of the Surveillance, Epidemiology and End Results (SEER) program of the NCI, which enables comparisons of cancer patterns in the Alaska Native population to those in other U.S. population. There has been follow-up of incident cases and survival rates for 1969–1983. Efforts have also been made to update follow-up data to 1992. The cancer registry is updated as new cases of death are received and certified.

For the second intra-agency agreement, work

was completed on describing the burden of illnesses due to cancer in the AI/AN populations and defining the variation in cancer incidence and prevalence among the relevant populations (by geography, ethnicity, cultural and behavioral patterns) and analyzing the determinants of variations as a basis for developing testable hypotheses of etiologic and risk factors as well as prevention and control interventions. Researchers have identified areas for further study, with particular emphasis on design, methodology, development and pilot testing of intervention studies of the effectiveness of prevention and control strategies for cancers shown to be of particular importance in the AI/AN populations. The intra-agency agreement has demonstrated productive, collaborative work between the IHS and SEER centers in geographic areas with relatively large AI/AN populations.

Organochlorine Exposure and Breast Cancer Risk in Alaska Native Females. A new study funded under the National Action Plan on Breast Cancer (NAPBC) will evaluate the relationship between exposure to exogenous organochlorines

and the development of breast cancer in Alaska Native women by prospectively collecting tissue samples from all women undergoing breast biopsy and analyzing these samples for organochlorines (such as DDE, BCD and PBB). The study builds on collaborations between the Indian Health Service and the Centers for Disease Control and Prevention and has the approval of the Anchorage Tribal Health Council. The investigators will interview all participating women to identify potentially confounding risk factors for breast cancer, including parity and family history. The laboratory and interview data will be analyzed to determine if the amount of organochlorine chemicals in the serum and adipose tissue increases the risk for developing malignant breast disease. This study was approved for funding by the NAPBC because of the historically low incidence of breast cancer in Alaska Native women and their potentially high exposure to organochlorides through a diet high in fish and marine mammals. As such, this population provides a unique opportunity for the study of the potential role of environmental chemicals in breast cancer risk.

Smithsonian Institution

The Smithsonian Institution's mission in Alaska is primarily carried out through the Arctic Studies Center, which opened an office in Alaska in 1993 and which has produced a wide range of programs serving both the northern research community and Native interests.

The 150th anniversary of the Smithsonian produces a new birthday of its own: a new office in Alaska for partnerships in research, collection sharing and museum training. Birthdays like the United States Quincentennial and the Smithsonian's 150th are a time of reflection and renewal. Two years ago the Columbian Quincentennial gave the Nation a chance to reassess its past. Unlike previous celebrations that emphasized New World discovery, European expansion and the development of new resources and technologies, the 1996 Quincentennial offered the vision of a new social compact between American society and its Native peoples. For the first time a national anniversary carried a strain of reflection that tempered the concept of Columbian era "progress" with recognition of the trials experienced by America's first citizens during and after the Columbian era.

New opportunities were also recognized. The founding of the National Museum of the American Indian, passage of the Native American Graves Protection Act (NAGPRA) and increased awareness of Native American culture and history had a profound effect on redefining past and present. By extension, these programs called also for a new relationship with many rural communities, including those in Alaska, that rarely have access to centralized cultural resources and programs. As a leading center of cultural experience and learning, the Smithsonian can play a major role in redefining America in this multicultural age. An increasingly important part of that mission concerns peoples, cultures and environments of the Arctic, especially in Alaska.

Reinventing the Smithsonian

Established in 1846 by the bequest of Englishman James Smithson to found an institution "for the increase and diffusion of knowledge," the Smithsonian is one of the oldest and most revered agencies of U.S. Government. This year the Smithsonian celebrates its 150th birthday on the 8th of August. The anniversary is being marked by a major traveling exhibition, "America's Smithsonian," and by conferences, symposia and special

	Funding (thousands)	
	FY 94	FY 95
Anthropology	630	500
Arctic biology	75	50
Total	705	550

publications. The event also marks a departure from the Institution's previous stance as self-appointed collector, interpreter and presenter of the Nation's culture and history in Washington. In future years the Smithsonian intends to open its doors wider, reaching out with Internet and other electronic tools to provide access to resources for regional audiences who cannot visit the Washington facilities in person.

Access has emerged as a keyword at the same time that the Smithsonian has loomed larger as a national icon and sometimes cultural battlefield. Among the questions raised by the public and politicians are the proper public role of a national institution dedicated to research and education. Controversy over the *Enola Gay* exhibit, over interpretation of art of the Western Frontier, over repatriation of Indian remains and artifacts, and over the Smithsonian's concentration in Washington have sparked debate. How are we to achieve our goals in a time of rapid social change when many sectors of society wish to claim ownership in presenting "their" part of our national legacy?

These questions have been considered by a Commission chartered to explore the Smithsonian's role in the coming century. As one of the oldest research museums in the country, the Smithsonian has assembled unique resources and presentation skills, and it needs to consider how best to serve the whole society as well as regional and ethnic interests. Especially we need to find ways to bring the Nation's large, irreplaceable collections and archives to a wider public. In the case of Alaska, these resources are among the oldest in the Americas.

The Smithsonian's Commission on the Future has suggested the following directions:

- Emphasize education both in Washington and across the country through electronic means, traveling and collaborative exhibitions, and public programs;

- Build collaborative partnerships with other museums, research centers and educational institutions throughout the Nation; and
- Develop approaches to collections, research, education and exhibitions that will be inclusive of the diversity of the American people.

The capability for fulfilling the Smithsonian's mission in Alaska, and with those living elsewhere who have interests in the Arctic, lies principally with the Arctic Studies Center (ASC), which was established in 1988 by Congressional appropriation to foster research and education on the history, cultures and environment of Arctic regions. Located in the National Museum of Natural History (NMNH), the ASC has access to large repositories of cultural and biological collections and archival documents from the circumpolar world, especially from Alaska. Other Smithsonian units, including the National Museum of the American Indian (NMAI) and the Folklife Center, also hold Alaskan resources in ethnology, art, science and history.

Alaska Office Programs

In 1993 the ASC established an office in Alaska in partnership with the Anchorage Museum of History and Art and the Municipality of Anchorage. The Alaska office provides facilities to develop programs with greater participation of Alaskan residents, and it serves as an important conduit for facilitating access by Alaskan residents to Smithsonian collections and expertise in Washington. The Anchorage office has been directed by anthropologist Aron Crowell since April 1994. An education coordinator was added to the staff in 1996 with funding from NMAI.

The creation of the Alaska office revitalizes the Smithsonian's long connection to Alaska, where immense, systematic collections of Arctic and sub-Arctic ethnology, archeology and natural history were acquired during the 1800s and the first half of the 20th century. The significance of these resources grows apace with new concerns for understanding long-term changes in northern environments and human adaptations, and with expanding opportunities for collaborative cultural research and education.

National Park Service Partnership

Since 1993, agreements with the National Park Service (NPS) have supported interdisciplinary studies of prehistoric settlement and population growth along the resource-rich coast of the Gulf of Alaska. This region is the present and ancestral home of the Alutiiq, Dena'ina and Tlingit peoples. Five national parks (Katmai, Lake Clark, Kenai

Fjords, Wrangel-St. Elias and Glacier Bay) are situated along the Gulf coast, providing a set of study areas that sample cultural, biological and physical diversity over a distance of some 1000 miles. Coordinated archeological and geological surveys in the parks are designed to examine how human populations have been affected by climatic shifts, repeated glacial advances, earthquakes, volcanic eruptions and dramatic changes in sea level and shorelines. Throughout the Holocene, these recurring events have impacted people, the coastal biome and the archeological record.

Preliminary results include evidence for a very large earthquake that rocked the entire Gulf region about 1070 A.D. Like Alaska's great earthquake of 1964, this earlier event caused some sections of the coast to be rapidly uplifted. Other areas subsided into the sea, causing the destruction of coastal villages and archeological sites. Because similar earth movements have occurred many times, parts of the Gulf coast have well-preserved archeological records extending back more than 7000 years, while others have been periodically wiped clean of human traces. Glaciers have also figured prominently in the natural and cultural history of the region. The growth of glaciers during the Little Ice Age, which reached its maximum at about 1750 A.D., forced the abandonment of villages that were in the path of advancing ice. Portions of the coast were flooded as the weight of the ice depressed the elastic crust of the earth, altering the coastal ecology and requiring substantial adjustments on the part of hunting and fishing cultures.

These processes were documented during 1995 ASC/NPS fieldwork in Glacier Bay National Park. The project was coordinated with the Hoonah Indian Association, including student participation in surveys and excavations. As originally noted by Frederica De Laguna, Little Ice Age glacial advances and flooding are remembered through Tlingit oral traditions that add a rich dimension of local knowledge to the search for old village and camp sites in this region.

Museum Study Programs

In the area of museum work the ASC is currently involved in the study, exhibition and publication of the William J. Fisher collection, which has been curated at the NMNH in Washington D.C. The Fisher collection is a diverse and well-documented assemblage of ethnographic materials from southern Alaska dating to the period 1879-1894. The centerpiece of the project is an exhibition titled "Looking Both Ways: Alutiiq History, Culture, and Modern Identity" that is being developed with the Alutiiq Museum on Kodiak Island.

"Looking Both Ways" will focus on the Alutiiq



*Excavations at Hooknoowoo
Fort, a Tlingit refuge
settlement in Glacier Bay
National Park.*

cultural revitalization movement and highlight recent research, including a variety of collaborative projects involving anthropologists, Alutiiq communities and Native cultural experts. The Kodiak Area Native Association and Alutiiq Museum have used cooperative, community-based approaches in archeology, oral history, language and arts programs, and this model is being applied to the production of the exhibition itself. Alutiiq consultants and advisors are helping to shape the content of the show, and the Alutiiq Museum is contributing staff, collections and financial support. On the research side a group of 17 museum studies students, instructors and Native artists traveled recently to Washington, D.C., to examine the Fisher collection and interpret materials and techniques seen on the 19th-century pieces. Some items in the Fisher collection, including a highly decorated man's parka made of ground squirrel, sea otter, caribou, weasel

and mink, will be replicated by traditional artists for the permanent collection at the Alutiiq Museum. An exhibition catalog, a CD-ROM catalog, educational programs for the public schools, and a conference on Alutiiq identity issues are all being produced in conjunction with "Looking Both Ways," which is scheduled to open in Kodiak in 1998. Research and planning funds for the project have been awarded by the Smithsonian and the National Endowment for the Humanities.

The ASC is involved in other study and training initiatives designed to benefit Alaska's rapidly expanding network of community museums and cultural centers. Through the combined sponsorship and participation of the Arctic Sivuunum Ilisagvik College (ASIC), the University of Alaska Museum (Fairbanks), the ASC and the Pew Charitable Trusts, students in Alaskan cities and rural communities are now able to take college courses toward an accredited Minor in Museum Studies. Participants meet each week at museums, cultural centers and tribal offices in Barrow, Unalaska, Yakutat, Kodiak, Fairbanks, Anchorage and other locations, joining the class by conference call from their home sites. The weekly seminars cover a wide range of topics, from exhibitions to education, collections, conservation, funding and administration. Participants agree that one of the most exciting aspects of the "distance delivery" format is the chance to network each week with colleagues and peers around the state and to hear updates on new museum projects, upcoming conferences and special opportunities. Subsidized student travel to Washington, Fairbanks, Barrow and museums in the Sonoran Desert has helped participants to broaden their skills, perspectives and contacts in the museum world.

To provide opportunities for professional development in more specialized museum skills, the Alaska Native Human Resource Development Program and the ASC are cosponsoring a series of workshops in subjects such as collections management, object conservation and exhibition development for small museums. Modeled on national programs conducted by the Smithsonian's Center for Museum Studies and its American Indian Museum Studies program, the Alaska workshop series will enable a much higher level of participation on the state level. Opportunities for Smithsonian internships, fellowships and community scholar awards are available for students, traditional artists, museum personnel and others with cultural research and preservation interests.

Plans call for long-term loans of selected Smithsonian collections to the Anchorage facility for use in exhibitions and as research and reference materials for material culture studies, teaching and pro-

jects by indigenous scholars and artists. The Anchorage Museum of History and Art and the Municipality of Anchorage have generously committed to assisting the ASC in its physical expansion to include additional office and collections storage space.

"Crossroads Alaska" Exhibition

During the past two years a small version of the Center's North American "Crossroads" exhibition designed for tour to rural regions has traveled to 15 cities and regional centers in Alaska. This project has been supported by grants from the National Science Foundation, the NPS, the Department of State's Man and the Biosphere program, the Smithsonian and other sources. Curated by Valerie Chaussonnet and produced by the Smithsonian's Office of Exhibits Central, "Crossroads Alaska" brought treasures of Alaska Native culture and themes of North Pacific cultural exchange to regions of Alaska that have never before seen large exhibitions. A special attraction, in addition to viewing high-quality craft and artworks of other Native Alaskan cultures outside their regions, was the presence of more than 100 specimens selected from museums of the Russian Far East, representing the Siberian Eskimo, Chukchi, Even, Koryak and Amur tribes.

"Crossroads Alaska" was the culmination of a three-year planning effort by Valerie Chaussonnet and William Fitzhugh, assisted by curators from Alaskan and Siberian museums and universities, and Native specialists, throughout the North Pacific region. In addition to nearly 300 specimens organized by cross-cultural themes that integrated archeological, ethnographic and contemporary art, the exhibit included a 40-tape video library assembled by Leonard Kammerling, a series of photographic notebooks on each culture group prepared by James Barker, and superb educational materials developed by the University of Alaska Museum staff with teachers from throughout Alaska. An elegant catalog prepared by Valerie Chaussonnet, including essays by Native authors, provides a fresh model with Native authorship.

The exhibition tour was the opening exhibition in several newly built culture centers and museums, such as the Kodiak Museum. Skills in exhibition presentation, conservation, education and local promotion were transferred to local museums, helping these institutions to develop their own resources in ways that will provide cultural and economic benefits in the future. In every venue the show attracted crowds that exceeded previous exhibitions, primarily as a result of expert promotion and support by Alaska tour coordinator Jean Flanagan Carlo.

A unique feature of the tour was an education program that applied exhibition materials and concepts to local cultural interests and resources. Programming was designed to draw elders, local culture experts and children into innovative learning situations. Rather than using the exhibition as a mute, bounded universe of learning, the program used the exhibit as a stimulus for adjunct community-based learning that matched hunters who imparted animal lore to young men; older seamstresses who demonstrated skin-sewing techniques to young enthusiasts; and the same with dancers, carvers and singers. The effects were startling and were captured by careful documentation of the learning process at each venue by museum officials and teachers. The show's data forms, comment sheets, videotapes and photographic records provide a body of research data on how Native and rural Alaskan people respond to informal, museum-based learning experience. These materials will be analyzed to improve information delivery in future rural exhibitions. The success of the show was summed up by one elementary school student: "You made my brain learn lots!"

"Crossroads" finished its Alaskan tour in November 1995 and begins its Russian tour in Khabarovsk in November 1996. Here it will become the first exhibition to travel regionally in the Russian Far East, visiting Magadan, Petropavlovsk, Uzhno-Sakhalinsk, Vladivostok, Blagovashensk and possibly Yakutsk and Novosibirsk during the next two years. Finally we have found a way for this Russian-American cultural marathon to be seen on the Asian side of the Bering Strait. Support for the Asian tour is from U.S. Information Agency, the Russian Ministry of Culture, local administrations and museums of the Russian Far East, the Smithsonian Institution and the Trust for Mutual Understanding.

"Living Yamal" Program

Beyond the North Pacific, the ASC's research in Alaska is part of a larger study of the history of Arctic peoples in general. From a circumpolar perspective, one of the major issues in northern studies has been the search for the origins of Eskimo cultures. Originally Eskimo origins were thought to be related to Samoyedic peoples of the central Russian Arctic, who moved west into Scandinavia, becoming Saame (formerly known as Lapps), and from there to Greenland and Arctic Canada. Later theories called for movements in the opposite direction, from the Russian Arctic across Bering Strait into Canada. In either case, the Russian North seemed to play a role.

In the 1930s Russian origin theories surfaced



Nenets family in Yamal tundra near Yuribei River looking at Polaroid pictures presented to them by a visiting researcher (August 1995).

again with the discovery of strong Siberian influences at the Ipiutak site at Point Hope in north-western Alaska. Here archeologists Helge Larsen and Froelich Rainey identified shamanistic elements that seemed closely tied to ancient sea mammal hunting cultures of western Siberia, on the lower Ob River and Yamal Peninsula. Their views were influenced by excavations of Valerie Chernetsov, a Russian archeologist who discovered remains of an ancient sea mammal hunting culture in the Yamal in 1928. Later the locations of these sites were lost and their collections were misplaced. In the absence of new research the question remained: Could the Yamal have been a proto-Eskimo homeland?

For the past two years the Arctic Studies Center has investigated this and other questions of archeology and history in the Yamal region. An immense Arctic lowland in western Siberia, the Yamal is occupied by 8000 reindeer-herding Nenets, whose culture is one of the most traditional of any northern people today. At the same time, Yamal holds one of the largest deposits of natural gas in the world, and the region is scheduled for production by Nadymgasprom in the near future. The inevitability of development in one of the most pristine areas of the Arctic has stimulated the need for new research in this little-known region.

“Living Yamal” is dedicated to research on regional history and culture that will enhance cultural survival and minimize the negative effects of development. The project is directed by the ASC and Russian colleagues, with support from Amoco Eurasia Corporation, Nadymgasprom and local administration.

Unlike mitigation studies designed to address the specific impacts of development on archeological resources or on local socioeconomic conditions, “Living Yamal” has a broad cultural, historical and educational focus. In addition to documenting cultural history and modern ethnographic life, a principal goal is to bring historical and cultural information to the attention of all actors involved in the area: Native people, Russian immigrants, industry representatives and government officials. With knowledge of modern and past land use, industry may avoid accidental damage to sacred sites and crucial pasture lands and can make more informed decisions about field operations and infrastructure development. Most important, because every development program carries a cost in rapid cultural change, heritage programs can help people understand and preserve cultural legacies and make more informed decisions about their interests and priorities.

The results of the program range across a broad interdisciplinary front. Archeological surveys pro-

vide support for theories suggesting that modern intensive reindeer nomadism as practiced by today's Nenets peoples is a relatively recent phenomenon, probably beginning about 1750 A.D. at the end of the Little Ice Age, when conditions for tundra growth improved. Previous to this, settlement is documented in a variety of ecological niches, at locales favoring marine mammal hunting, fishing and wild reindeer hunting, between 500 and 1200 A.D. These sites contain more diverse fauna, shamanistic materials are present, and ceramics and ritual bronze castings indicate contacts with the greater Uralic and possibly the White Sea-Scandinavian trade zones. Winter residence by small groups in the Yamal may have been part of the more diverse economy of these times.

Our work demonstrates that Chernetsov's view of an early proto-Eskimo or Eskimo-like maritime hunting culture on the Yamal is erroneous. Not only are the characteristics of Eskimo culture missing from these sites, it also appears that intensive maritime adaptations were not possible under the relatively unproductive ecological conditions of the eastern Kara Sea.

Our research also identified the importance of local archival resources for the reconstruction of Yamal population history. Early 20th-century census records contain information on family history and migration routes, wintering and summering locales of clan groups, group size, and numbers of reindeer owned by group leaders. Early photographs of Nenets people have been discovered and prepared for exhibition in local museums. An ethnoarcheological program has been initiated to explore modern Nenets subsistence patterns and ritual use of the landscape. Ethnographic films have been prepared, and publications have been assembled for dissemination in English and Russian. The results of these and other projects have been presented at regional centers in the Yamal and have stimulated interest in expanding local documentation projects.

As a collaborative project, "Living Yamal" has generated valuable new information on Yamal culture at a critical time in the history of this region. Two thousand years of occupation by reindeer hunting and herding peoples have been documented, and early anthropological data and archeological sites have been assessed and reinterpreted. The project has also served as a model of community-based research on indigenous cultures in the North. Awareness of cultural heritage provides Native peoples with an important defense against rapid culture loss at the same time that it educates industry and local government about values indigenous people wish to preserve, but too often lose, in the rush to bring northern industry "on line." While the

documentation achieved in this program will enrich Arctic studies generally, the community-based research models developed should be applied in other regions where industrial development continues with little regard to social and cultural issues. The bottom line so far achieved is that culture and history, like animals and environment, require consideration in any development plan for the North.

Community Anthropology on Nunivak Island

In Alaska many Native villages still retain a strong community identity based on tradition, hunting and fishing subsistence economies, and an ideology of reverence for elders who retain traditional knowledge and a spiritual relationship with the land and animals on whom life depends. These sentiments are leading communities throughout Alaska to develop their own cultural preservation programs involving 19th-century material culture, much of which now resides in museums throughout the world.

The Arctic Studies Center embraces the tripartite mandate of the Smithsonian's contributions to knowledge through research, exhibition and educational outreach. All three agendas are realized by the ASC commitment to "community anthropology," which combines staff museum expertise, Smithsonian collections and archival data, and Native community interests and expertise. The result is a new generation of scholarship that advances knowledge while also meeting the needs and interests of indigenous northern communities.

Community anthropology is a natural outgrowth of exhibition programs like "Inua" and "Crossroads," which brought historic collections from 19th-century Alaska previously hidden in the attic of the National Museum of Natural History into public view outside Washington for the first time. The greatest impact of these programs was, of course, in Alaska, where they transformed Native perceptions of local cultural heritage. Cultural treasures that had been known previously only to a few scholars suddenly received the wide public audience they rightly deserved. Images of objects from these exhibitions are now seen as recurring motifs in Alaskan commercial art and have promoted a resurgence of interest in traditional material culture, clothing and ceremonial regalia. These exhibitions, the smaller versions that traveled to rural locations, and their catalogs and accompanying educational programs have played a major role in the resurgence in cultural revival programs.

In the 1990s these interests merged with a growing sentiment for the physical return of museum materials that had been improperly alien-

ated from Native peoples. With the passage of the National American Graves Protection Act (NAGPRA) and the foundation of the National Museum of the American Indian at the Smithsonian, a mechanism for repatriation was established and the return of knowledge and awareness of museum objects to Native communities that produced them began.

The first step in developing "community anthropology" in Alaska was taken in September 1995 when the ASC's Stephen Loring, assisted by Bureau of Indian Affairs anthropologist Ken Pratt, visited the Cup'ig village of Mekoryuk on Nunivak Island to acquaint them with collections that had been made for the Smithsonian there in 1927 by Henry Collins and T. Dale Stewart. Long forgotten in the Museum's attic, the Nunivak collections were never published and had been gathering dust for years. Surprisingly, while scholars showed little interest in the Nunivak collections, the people of Nunivak became excited with the prospect of "re-excavating" these collections in the museum, and a joint project emerged.

In 1927 Collins considered the Inuit of Nunivak to be among the most "traditional" of all Alaskan Native people and thought this region might hold clues in his search for the earliest Eskimo cultures in Alaska. Although these early materials eluded him, he and Stewart compiled a large collection of artifacts and human remains from late prehistoric and historic period sites, and these materials were later shipped to Washington. The collections contain 1430 artifact records and skeletal remains of at least 230 individuals.

The Collins-Stewart collections have never been properly examined and described. They include artifacts purchased from Nunivak villagers, objects collected from houses in abandoned communities or from excavated sites, and artifacts collected from burial scaffolds. The latter clearly fall under the terms that require repatriation. Interestingly, while in many cases identical objects were recovered from three or four collecting contexts, only those from burial sites are subject to repatriation.

Meetings with village elders centered on the identification of sites, people and activities represented in photographs taken by Collins, now in the National Anthropological Archives. Discussions of one set of artifacts revealed that the "wooden dishes" with paintings of loons and seals collected by Collins from stone-lined pits were recognized by the elders as ritual dishes used to offer drinks of fresh water to seals immediately after they had been caught. Similar discoveries made community members enthusiastic about studying the Stewart-Collins photographs, artifacts and documentation,

which they felt could be further documented by their own traditional knowledge and oral history, and they agreed to collaborate on a publication that would be of historic interest to their home community.

In February 1996 a delegation of Nunivak elders visited the Smithsonian to assist museum anthropologists in making a full assessment of the Nunivak collections. As the objects were studied, piece by piece, together with Collins' and Stewart's notes, insights on identification, object name, function and even anecdotes were recorded, greatly increasing the research potential of what had previously been an assemblage of objects divorced from their cultural and social setting. More important, the Nunivak community now has a personal bond with ASC staff that ensures collaboration in future research and educational programs. The next step in the process may be collaboration on joint excavation and exhibition projects, and the return to the community of collections and skeletal materials from burial sites.

Repatriation, as practiced by the Arctic Studies Center, uses Smithsonian resources to fulfill a broader mandate than specified in NAGPRA and the NMAI Act. In this sense the return of "ancestors" is only part of a process of re-engagement with Native people that, in the past, too often ended when the anthropologists and collectors returned collections to the museum. Most of these collections were never seen again by their home communities, and many were never published or exhibited. The re-opening of collections and archives to local donor communities revolutionizes the concept of museum anthropology as it has been practiced nearly universally for more than two centuries.

Today these methods are unacceptable. A new relationship has to be forged and new responsibilities need to be recognized. Research and curation can no longer proceed in isolation of interested local communities. The reflexive style of operation being practiced by the Arctic Studies Center as exhibited by its educational programs, field studies like "Living Yamal" and community anthropology projects like those on Nunivak Island offers new models for the museum anthropology of the 21st century. It is a labor-intensive effort, but its rewards are our best hope for the preservation of cultural legacies that enrich human life and are of particular importance to the Native peoples and others that populate Arctic regions. It is also a good way to do business. We are discovering that while anthropologists in the universities continue to be caught up in debates about whether anthropology as an academic discipline "is dead," it is very much alive in museums that have reconnected their staffs and collections with their original sponsors.

Environmental Protection Agency

The Environmental Protection Agency's Arctic research focuses on ecosystem protection, primarily in the areas of contamination, global climate change, risk assessment and environmental technology.

The EPA's Arctic research activities in FY 94 and FY 95 had the following broad goals:

- To estimate the extent of Arctic ecosystem contamination brought about by atmospheric transport of pollutants and to investigate the introduction of pollutants into Arctic food webs (Arctic Contaminants Research Program);
- To clarify the potential global and local impacts of climate change in the Arctic (Climate Change Program);
- To support the transfer of risk-based information to state environmental programs to improve strategic planning (Comparative Risk Assessment program); and
- To develop plans for estimating the condition of two northwestern Alaska estuaries using the scientific methods developed by the multiagency Environmental Monitoring and Assessment Program (Regional-Environmental Monitoring and Assessment Program).

Arctic Contaminants Research Program scientists extract blood for steroid hormone analysis from a lake trout prior to collecting muscle and liver samples for contaminant analyses.

Arctic Contaminants

A growing body of international literature suggests that the Arctic is becoming a repository for various environmental contaminants. Also, the literature suggests that these contaminants have been,

	Funding (thousands)	
	FY 94	FY 95
Arctic contaminants	925	0
Climate change	200	0
Comparative risk assessment	75	0
Regional EMAP	0	250
Total	1,200	250

and are being, released by industrial and agricultural practices undertaken not only in the Arctic but at lower latitudes. The Arctic Contaminants Research Program (ACRP) focused on assessing the extent of contamination of Arctic ecosystems by atmospherically transported pollutants. Also, this work investigated the potential consequences of pollutant introduction into Arctic food webs. The specific objectives of the ACRP were to:

- Document levels of various Arctic contaminants in Arctic biota and environmental media;
- Evaluate the recent history of contaminant transport and deposition and identify possible sources of contaminants;
- Determine the possible effects or consequences of food web uptake of Arctic contaminants; and
- Interpret the results of monitoring efforts from an international perspective.

The ACRP was completed in FY 94. One of the key activities during this year was organizing and convening the International Symposium on the Ecological Effects of Arctic Airborne Contaminants in Reykjavik, Iceland. This symposium was attended by 200 scientists and was financially supported by a broad range of Arctic agencies throughout the world. The scientific papers resulting from this symposium are published in *The Science of the Total Environment*, volumes 160 and 161 (1995).

In FY 94 organic and inorganic contaminant analyses continued in Arctic Alaska on sample matrices consisting of lake sediments, soils, lichens, mosses, freshwater fish and ground squirrels. Synthesis of these data has begun and initial papers have been published. Scientists from the EPA (Western Ecology Division, Corvallis, Oregon) and the Far North Agricultural Research Institute (Norilsk, Russia) cooperated on a joint field expedition to evaluate airborne contaminants in the Taimyr Peninsula of Arctic Siberia. Samples identical to those collected in Alaska were obtained





Researchers from Oregon State University and the Far North Agricultural Research Institute, participants in the joint U.S.-Russian expedition, don latex gloves before sampling lichen and moss at a remote site in northern Taimyr, Arctic Siberia.

along a 900-km transect northeast of Norilsk, as well as from sites selected using a probability-based sampling framework on the Taimyr Peninsula. Contaminant concentrations in the samples were compared to those from Alaska, and the initial results suggest that evidence for airborne metal contaminants in these two locations is similar and relatively low when compared to Arctic regions closer to regional population centers.

Freshwater fish and small mammals in the U.S. and Russian Arctic have detectable concentrations of both organic and inorganic pollutants, but these levels are not elevated relative to temperate systems. Based on sediment core analyses, concentrations of heavy metals, such as mercury and lead, in lake trout from the U.S. Arctic and burbot from the Russian Arctic do not appear to be elevated as a result of long-range atmospheric transport but rather represent naturally occurring sources. Organochlorine pesticides and polychlorinated biphenyl (PCB) concentrations in freshwater fish from the U.S. and Russian Arctic were similar to values reported for freshwater fish from the Canadian and Scandinavian Arctic, typically 20 orders of magnitude lower than in Arctic marine mammals.

Climate Change

The overall goal of the Climate Change Program is to clarify the potential impact of global climate change in the Arctic. Most projections of future climate suggest that the most dramatic changes in temperature and other climate variables will occur at high latitudes. Research is being conducted to clarify the impact of potential changes and to consider the nature of possible feedbacks to the control of the climate system. Studies include

estimating the effects of climate change on the release of carbon-containing greenhouse gases from the large reservoir of organic matter in high-latitude ecosystems.

Research activities have addressed the source and sink dynamics of greenhouse gases through both field and laboratory experiments. These experiments defined baseline conditions, developed flux data sets and investigated how selected high-latitude ecosystems interact with climate-related factors such as temperature, moisture, the level of perennially frozen soil (permafrost level) and nutrient availability in Arctic soils. Data are being incorporated into models to estimate fluxes of greenhouse gas emissions into the atmosphere.

Studies were conducted at the Bonanza Creek Long-Term Ecological Research area near Fairbanks, Alaska. The research examined processes that control methane oxidation and carbon dioxide emissions and the temperature and moisture sensitivity of methane oxidation and soil respiration. This research determined that methane oxidation within the soil prevents a substantial fraction of the methane produced by anaerobic microorganisms from escaping to the atmosphere. The methane oxidation process becomes increasingly important as the water table drops in response to decreases in precipitation and levels of permafrost in the soils. However, warming generally increases soil respiration, the release of carbon dioxide from soil organic matter. Thus, the composition of the carbon greenhouse gases emitted from Arctic soils may be highly responsive to changes in soil moisture and temperature associated with global climate change.

Other studies indicated that carbon isotopic composition of soil methane and carbon dioxide is strongly affected by oxidation processes within the soils. This result is relevant to models that use isotopic composition to constrain the magnitudes of various greenhouse gas sources.

Comparative Risk Assessment

This program is designed to strengthen state capabilities in strategic planning for managing human health and ecological risk. The EPA is providing support to the Alaska Department of Conservation (DEC) to help this agency incorporate reliable risk-based information while planning and evaluating its environmental programs. This work will assist the DEC in assessing and prioritizing problems comprehensively and from a risk-based perspective. The effort is similar to projects that have been undertaken in over 30 other states.

The EPA is supporting the DEC in accomplishing objectives that include:

- Conducting a statewide comparative risk analysis to develop a more accurate understanding of the environmental risks posed to Alaskans;
- Ranking environmental concerns according to the levels of health risk they pose to Alaskans and the ecological risk these concerns pose to the environmental quality of Alaska's environments;
- Involving the public in discussions to ensure that they understand and support the established priorities;
- Developing a strategic plan to achieve maximum human health and ecological risk reduction; and
- Linking the strategic planning processes of the EPA and Alaska for more effective coordination and reliability in environmental decision making.

Regional-Environmental Monitoring and Assessment Program

Resources were obligated in FY 95 to conduct a Regional-Environmental Monitoring and Assessment Program (REMAP) project in Arctic Alaska. REMAP applies the scientific concepts, methods and technologies developed by the multi-agency Environmental Monitoring and Assessment Program (EMAP) to help resolve priority environmental problems identified by the EPA's regional offices. The plans for this REMAP project are to use techniques developed by EMAP-Estuarines to obtain baseline data that will be used to estimate the condition of two northwestern Alaska estuaries.

Department of Transportation

DOT supports Arctic research through the U.S. Coast Guard and the Federal Highway Administration. The U.S. Coast Guard operates polar icebreakers as national polar research assets for Arctic oceanographic expeditions of both government and nongovernment researchers. The Federal Highway Administration is studying a variety of highway problems in the Arctic.

U.S. Coast Guard

The two Polar-class icebreakers operated by the U.S. Coast Guard, the *Polar Star* and the *Polar Sea*, provide support for Arctic science as high-latitude research platforms. Built in the late 1970s, these ships were designed to provide military logistics services, including the ice escort of vessels resupplying military or research bases in the Arctic and Antarctic regions. As the polar icebreaker's role shifted to that of a polar research platform, design deficiencies became evident. This role as a research platform expanded, and larger research projects requiring larger science teams exacerbated the problem.

The need to improve these capabilities was identified, and in 1987 upgrades were implemented through the Polar Science Upgrade program. This five-year project, costing over \$14 million, was successfully completed at the end of FY 93. Dedicated-science living and working spaces were expanded on the ships. The addition of a senior scientist stateroom and other improvements now make it possible to support up to 32 scientists and technicians of both sexes. Upgraded oceanographic winches, new cargo and science gear handling systems, expanded lab spaces, new oceanographic instrumentation, new communication equipment and modern, high-resolution, direct-downlink, environmental satellite receiving systems improved the research capabilities of these platforms. The Coast Guard established a permanent civilian science liaison position to support polar icebreaker expedition planning. The scientific liaison officer is located with the icebreaker operations staff in Alameda, CA. His primary duty is to assist icebreaker users with planning, coordinating and implementing polar science projects. Polar scientific research support continues to be the primary mission of Coast Guard polar icebreakers.

USCGC *Polar Sea* and CCGS *Louis S. St-Laurent* conducted Arctic Ocean Section 1994 (AOS-94), a U.S. and Canadian cooperative sci-

	FY 94	FY 95
Test and evaluation	800	800
Arctic science support equipment	602	602
Extramural support	35	35
Arctic logistics support	14,400	14,400
Total	15,837	15,837

ence cruise that crossed the Arctic from west to east through the North Pole. AOS-94 was the result of an intense four-year planning period, involving over 25 scientific institutions and Federal agencies from the U.S. and Canada. Knut Aagaard of the University of Washington was the Expedition Leader, and Art Grantz of the U.S. Geological Survey and Ed Carmack of the Institute of Ocean Sciences in Sidney, BC, were the Senior Embarked Scientists aboard USCGC *Polar Sea* and CCGS *Louis S. St-Laurent*, respectively. The U.S. funding agencies for this expedition were the National Science Foundation, the Office of Naval Research and the U.S. Geologic Survey; the Canadian funding agencies were the Department of Fisheries and Oceans, the Department of Indian and Northern Affairs, and the Department of Environment.

This mission's extensive science program was carried out by an international team of 65 researchers, 30 embarked in *Polar Sea* and 35 in *Louis S. St-Laurent*, representing:

- The University of Washington;
- The Institute of Ocean Sciences (Sidney, British Columbia);
- The Microwave Group (Dunrobin, Ontario);
- The U.S. Army Cold Regions Research and Engineering Laboratory;
- The University of Saskatchewan;
- Oregon State University;
- The U.S. Geological Survey;
- Woods Hole Oceanographic Institute;
- The University Of California (San Diego);
- Dalhousie University (Nova Scotia);
- Bigelow Laboratory (Boothbay, Maine);
- North Carolina State University;
- East Carolina University;



The Yamal, Louis S. St-Laurent and Polar Sea leaving the North Pole together.

- The Lamont-Doherty Earth Observatory; and
- The University of Quebec.

The *Polar Sea* and *Louis S. St-Laurent* left Victoria, British Columbia, on 17 July. They reached the ice edge off Point Barrow on 26 July, and the ships completed 34 science stations before seeing open water again. The programs included extensive geological observations, studies of ocean circulation, ice studies, oceanographic and atmospheric chemistry, and the first comprehensive study of polar bears in the central Arctic.

The science stations included:

- 28 oceanographic casts;
- 92 macrobiological net tows;
- 54 biological and geological cores;
- 23 on-ice coring and sampling operations;
- 20 science support dives (under-ice biology and ice studies);
- Continuous measurements of atmospheric chemistry to determine the extent of volatile organic chemical dispersion (and the extent of the "greenhouse effect") on the Arctic atmosphere; and
- 42 helicopter sorties to conduct ice studies.

The *Polar Sea* and *Louis S. St-Laurent* recorded several interesting "firsts" during this expedition, including:

- Becoming the first U.S. and Canadian surface ships to reach the North Pole, on 22 August;
- Becoming the first ships ever to reach the North Pole from the Pacific Ocean; and
- Becoming the first ships ever to completely circumnavigate the North American continent.

The trip plan originally called for the ships to return to the Alaska area after making the Lomonosov Ridge/North Pole area, but the *Polar Sea* lost a blade from her starboard wing propeller just prior to making the Pole. Although not a

"show stopper," it did degrade the icebreaking capability of the ship enough to drive the decision to return to open water on the Atlantic Ocean side. Here, the ice edge is much farther north due to the influence of the Gulf Stream. This change had minimal impact to the science program and actually proved beneficial to several disciplines.

The *Polar Sea* spent 81 days on this deployment, transited 2,313 nautical miles of ice-covered ocean and steamed a total of 15,294 nautical miles before reaching Seattle on the 6th of October. The *Polar Sea* was commanded by Captain Lawson Brigham; the *Louis S. St-Laurent* was commanded by Captain Phillip O. Grandy.

This cooperative mission was a resounding success, demonstrating the capacity of U.S.-Canadian international partnering to achieve unprecedented ice navigation and Arctic science goals, even with both partners under the constraints of reduced budgets. It also illustrates the fraternity among Arctic mariners, as a chance meeting at the North Pole elicited a spontaneous international celebration by the crews of U.S., Canadian and Russian icebreakers when the AOS-94 ships met the Russian icebreaker *Yamal* unexpectedly at the North Pole. While conducting science operations at the Pole, the captains of the *Polar Sea* and *Louis S. St-Laurent* were invited by the captain of the Russian icebreaker *Yamal* to rendezvous and exchange visits. The three ships met 26 miles south of the pole on the 23rd of August (the following day), and all three held open houses in position 89°41.3'N, 012°13.3'E. Tours were conducted, a softball game was played and a picnic held for all three ships. Leaving the North Pole, the three ships transited together until the *Polar Sea* and *Louis S. St-Laurent* returned to doing science stations.

Despite constantly overcast conditions, a high-resolution environmental satellite imagery receiver allowed the *Polar Sea* to downlink special sensor microwave imager (SSM/I) images from Defense Meteorological Satellite Program (DMSP) satellites. This supported strategic trackline planning with a comprehensive picture of polar ice concentration. This recent addition now gives Polar-class icebreakers the capability of receiving National Oceanographic and Atmospheric Administration (NOAA) and DMSP images. With facsimile reception usually poor at extremely high latitudes, frequent NOAA and DMSP satellite passes provide more reliable and timely updates of surrounding ice and weather conditions.

The Coast Guard has contracted for a third polar icebreaker, the *Healy*, with Avondale Shipyard in New Orleans. In the initial stages of construction now, the *Healy* is being built from the keel up with science support in mind.

Healy characteristics

Length: 420 ft Beam: 82 ft
 Draft: 29 ft Displacement: 16,303 tons
 Speed: 12.5 kt
 Icebreaking: 4.5-ft-thick ice at 3 kt
 Propulsion: diesel/electric
 Shaft: two shafts at 30,000 shp each
 Range: 16,000 nautical miles/180 days

Accommodations

Scientists: up to 50
 Crew and other support personnel: 75

Schedule

Start construction: 18 March 1996
 Keel laying: 16 September 1996
 Delivery: 15 June 1998
 Launch: 12 July 1997

Key figures in the U.S. Arctic science community have been solicited for input in both the design and staffing stages of this project. The Coast Guard has expanded communications with its Arctic science partners by forming a Polar Icebreaker Policy Liaison Group with the National Science Foundation (NSF) and by funding the establishment of a Polar Icebreaker Science Advisory Committee of the University National Oceanographic Laboratory System (UNOLS) Council. These initiatives are expressions of the Coast Guard's goal to operate the most capable deep-polar research vessels available and will help keep the United States a primary player in polar research well into the next century.

Federal Highway Administration

The objectives of the FHWA in the Arctic are to develop and maintain cost-effective and safe surface transportation facilities, primarily for highways and highway vehicles, just as anywhere else in the U.S. In the Arctic, however, there is a need to assure that highways are compatible with severe constraints imposed by weather conditions and the fragile ecology of the area, as well as other normal environmental compatibility concerns.

The FHWA has been monitoring and conducting research in the Arctic for many years; in addition the numerous investigations conducted elsewhere in the U.S. are often relevant to highway problems in the Arctic. These projects have been primarily in collaboration with the various state highway agencies, especially Alaska and the states with more severe winter conditions. Together with the state highway agencies, the FHWA sponsors, collaborates with and monitors work done under the auspices of the National Academies of Science and Engineering through the Transportation Research Board's National Cooperative Highway Research Program (NCHRP). Some of this work includes funding for and collaboration with other agencies such as the U.S. Geological Survey and the Corps of Engineers (CRREL) and university and private consultant contractors.

Stream Crossing and Hydraulic Problems

Arctic streams typically have highly variable discharges and flood levels and are plagued by floating and blocking ice. Measurements are com-

	Funding (thousands)	
	FY 94	FY 95
Stream crossing/hydrological	375	757
Pavement problems	1,000	950
Soils/subbases (permafrost)	80	70
Weather monitoring/storm forecast	90	260
Snow control/pavement treatment	374	336
Air/water quality impacts	0	1,111
Total	1,919	3,484

plicated by permafrost and water flows under and above ice layers. To deal with these conditions the USGS has for decades and during this period of interest been contracted to measure the varying water discharge rates and the flood stages of numerous representative streams. The results of these measurements and estimates have been used in structural and hydraulic designs of bridges and culverts and in estimates of floods and risk analyses related to stream flows.

Alaska has a program to study stream channel stability and scour at bridges. Scour problems depend on the bed loads and the highly variable runoffs and sources of sediment loads within their watersheds. Both aggrading and degrading streams may occur at bridge sites. Many riverbeds have highly erodible silts.

Arctic streams can have heavy debris loads of loose ice, brush, trash and even trees, usually during the late spring and summer. Studies dealing with sources of debris and debris loads on bridges were completed in 1995, and the results are being disseminated.

There have been studies that have led to revised design requirements for fish passage through highway culverts and for the use of culverts in lieu of bridges. In the Arctic regions of Alaska the requirements of the fish have to be considered. The blockage of culverts by ice or the reduction of culvert capacity by heavy silt deposits also have to

be considered. Various culvert modifications have been used to enhance fish passage. Efforts are being made to increase the versatility of the Fish-pass program to consider more fish species.

Soils and Pavement Subbases

Investigations dealing with soil conditions for roads are a continuing effort. Studies are being done to increase the compatibility of the highways to permafrost and reduce pavement damage from loss of permafrost. Insulation layers underneath and adjacent to the paved surfaces are being tested. For highways on filled sections, increases of the width of unpaved shoulders have been found to be useful. Evaluations are being made of the long-term benefits of embankment reinforcements, insulated layers, air-cooled ducts, thermosyphons and snow sheds for controlling permafrost thaw-related roadway distress.

In the Alaska Permafrost Database Update study there are continuing efforts to measure temperatures and settlement observations at selected instrumentation sites on Alaska's highway system. Significant conclusions will be reported.

In the Alaska Permafrost Stabilization study there will be monitoring of movements of selected typical distressed permafrost embankments through the installation of surface and subsurface movement sensors. Control features have been installed on project sites.

An experimental project has been planned for a site near Fairbanks, Alaska, to evaluate the performance of a highly porous air-convection embankment fill that prevents thaw-degradation of underlying permafrost soils by natural convection of cold air during the winter. Treated and control sections, each 200 ft long, will be monitored for temperature changes, entombed shoulder failures, severe longitudinal cracking, roadway surface conditions and thaw pits.

Planning was done for using thermosyphons in an experimental highway feature near Fairbanks, Alaska, to be installed in FY 96. Thermosyphons have been well tested in laboratories and have been successfully used for building foundations and supports for petroleum pipelines. They are intended to remove heat from the ground and thence maintain permafrost close to stable ambient conditions.

Pavement Studies

The main efforts dealing with pavement performances under Arctic conditions are now being done by the Pavement Performance Division of the

Office of Engineering Research and Development. An initial thrust in the large effort to evaluate long-term pavement performance occurred under the Strategic Highway Research Program (SHRP).

Both portland cement and asphalt concrete test sections have been placed. Various mix designs, thicknesses and base conditions are being used at 51 sites that are in the colder climatic zones of the U.S. or at Canadian sites established under collaborative cooperative agreements. Observations of the behavior of the surface conditions, distresses and integrity of the pavement sections will continue for a prolonged period. This includes deflections, rideability and surface defects such as spalling. For the same pavement site locations the heat transfers and temperature changes from the surface to depths are being measured and evaluated, revealing seasonal changes of heat content and temperature with time and with local ambient air temperatures and deep ground temperatures.

Considerations include the temporal pavement responses (diurnal, seasonal and annual) due to the separate and combined effects of moisture and temperature variations. Models of pavement behavior and responses being developed and validated with the data obtained on the limited number of sections studied in the seasonal monitoring program are expected to be applicable to other similar test sections of the SHRP.

The Alaska Department of Transportation, in collaboration with the FHWA, has been involved in studies directed toward Arctic conditions. One study will use the Thermally Stressed Restrained Specimen Test paving mix test equipment to evaluate the thermal cracking potentials of compacted mixes at optimum modified asphalt contents with typical aggregate gradations. It will be determined how the cracking resistance of Alaska's typical pavement can be improved and which asphalt modifier types will optimize results. The use of finely ground tire rubber has shown benefits and will be included in the evaluation. Another study will use the SHRP Level 1 paving mix test equipment to evaluate the properties of compacted mixes and to select optimum asphalt contents and aggregate gradations for rut resistance. A study of studded tire traction will measure the benefits of using regular and lightweight studs on ice- and snow-covered pavements. These benefits will be compared to the documented damage to pavements, which includes the majority of pavement rutting. A study of rutting of Alaskan pavements is evaluating the contributions of displacement and wear on rut development by:

- Investigating the effects of gradation and fracture levels on Marshall stability and the dynamic creep behavior of paving mixes

prepared at different asphalt contents and voids;

- Measuring the studded-tire wear resistance of different mixes from tests on both field- and laboratory-mixed samples with different gradations and aggregates;
- Measuring winter and summer wear rates at various locations along with the studded-tire use percentages;
- Promoting awareness of the damaging effects of studded tires; and
- Increasing enforcement.

Weather Monitoring and Storm Forecasting

A system being field tested in several states to improve weather guidance for highway maintenance operations will allow a strategic and timely response to problems resulting from ice and snow storms. The overall system of combining road conditions and pavement and ground conditions, particularly the temperatures and potentials for heat transfer, the timely communications of such conditions, and near-term and intermediate-term weather forecasts for road maintenance managers is now termed Roadway Weather Information Systems (RWIS). These systems, together with more exact and timely local weather forecasts, are being rapidly deployed in most pertinent states.

The goals of these investigations are improved weather information for the more strategic, economic, timely and properly sized highway maintenance responses to snow and ice storms. Expected cost savings come from smaller or more timely responses to storms. Weather monitoring and storm forecasting systems are also being used to help with decisions to close or not close travel on highway sections.

Snow Control and Pavement Treatments for Snow and Ice

Short test sections of snow fences based on designs developed during the SHRP study are being evaluated in several states. Snow plow improvements primarily developed under the SHRP are also being field tested in several states.

Implementation of anti-icing technology has been completed, with 27 states participating in new anti-icing activities. This investigation involves using prewetted salt applications and liquid snow and ice control chemicals for their anti-icing effects. The objectives of this anti-icing study were to allow states to gain hands-on experience

in using efficient and effective procedures for snow removal and ice control. Anti-icing strategies, including various material types and improved material spreader equipment, have been expanded to also consider the use of RWIS, weather forecasting and friction measuring. Field tests and evaluations were done for the winters of 1993-94 and 1994-95 to determine the effectiveness of these strategies over a range of traffic, environmental and climatological conditions.

Investigations for developing methods for manufacturing calcium magnesium acetate (CMA) at lower production cost are continuing. These studies have been considering the laboratory conversion of waste materials such as sewage sludge and cheese whey permeate to CMA using high-yield anaerobic bacteria and the determination of yields and purities of the products based on their processes, the costs for the commercialization of the products, and the market strategy and industry interest to bring their processes into commercialization. Phase I studies for these CMA materials based on acetic acid being produced at lower costs have shown that the projected costs can be competitive with other snow and ice control chemicals. CMA would not cause the corrosion or environmental impacts that the more common snow and ice control chemicals cause. Phase II pilot-plant studies for alternate CMA production are now underway.

Heating systems involving various heat sources and heat distribution systems are being installed on a selection of highway bridges to minimize deck icing problems. Evaluations of the performances, costs and practicality of these installations are underway in Oregon, Texas, California, Nebraska and Virginia. The problems related to reductions of icing of pavements and bridge decks are being evaluated in other states, such as Alaska and Ohio.

Air and Water Quality Impacts of Highways and their Operations

In the U.S. there have been on-going studies of the sources of PM 10 (very fine dust and aerosols) for which there are air quality standards to protect public health. One source of these air pollutants is abrasives used on roads to increase traction for vehicles traveling on snow and ice. A primary source of the particulates is pavement and vehicle wear and exhaust. Studded tires commonly used in Alaska increase the pavement wear particles. A secondary source is the resuspension of fine particulates by moving vehicles.

Alaska has been trying to identify sources and control measures for the Anchorage area. In addi-

tion to PM 10 sources more common elsewhere in the U.S., some parts of Alaska receive more pavement wear materials due to studded tires, volcanic ash and fines from glacial flour deposited in flood plains, which are readily entrained by winds after being dried. PM 10 violations can be enhanced by strong temperature inversions, which can limit dispersal of air contaminants. Efforts for unpaved roads are intended to stabilize the road surfaces and use dust palliatives to both preserve the road surface and reduce the air pollution impacts from dust from highways during periods of low precipitation.

The Clean Air Act requires the use of oxygenated fuel for localities not attaining the clean air standard for carbon monoxide concentrations in the ambient air. Anchorage and Fairbanks are such locations. The state conducted test during the winters of 1993-94 and 1994-95 to determine whether ethanol could be used as an additive instead of MBTE as a substitute for 10% of the gasoline. Vehicle

driveability and emission performances were evaluated.

The water quality impacts of winter maintenance materials, primarily salts, to surface water and ground water have been and are being investigated. Massachusetts, Ohio and Indiana have been especially concerned about the impacts of salts and other contaminants to ground water. Other U.S. highway investigations are directed toward attenuating or removing water contaminants that could come from highway runoff or construction and repair materials used in highways.

Alaska is currently obtaining and evaluating representative samples of runoff and leftover debris resulting from snow storage operations from streets and highways in different regions of the state. These samples will be analyzed for their chemical composition and possible water contamination potential in relation to assumptions by regulatory agencies.

Department of State

The Department of State continues its involvement in several multilateral and bilateral activities related to environmental protection and scientific research in the Arctic. The most significant of these are the Arctic Environmental Protection Strategy, needs assessment of and assistance to the Russian Arctic, and the U.S. Man and the Biosphere program.

Arctic Environmental Protection Strategy

The Arctic Environmental Protection Strategy (AEPS), established in 1991, is an organization of eight Arctic countries devoted to regional action on environmental issues of common concern. AEPS has four working groups:

- Arctic Monitoring and Assessment Program (AMAP);
- Protection of the Arctic Marine Environment (PAME);
- Conservation of Arctic Flora and Fauna (CAFF); and
- Emergency Prevention, Preparedness and Response (EPPR).

The State Department provided support to the National Oceanic and Atmospheric Agency (NOAA) for AMAP's data collection and reporting of basic scientific research on Arctic contaminants. NOAA is the lead U.S. agency contributing to the AMAP report. In FY 95 NOAA also received support for a PAME project to develop a risk assessment methodology. The State Department also provided funds to the U.S. Fish and Wildlife Service, which is the lead U.S. agency in the CAFF working group; the money was forwarded to the CAFF Secretariat in Canada as the U.S. contribution to operating expenses.

Facilitating the participation of Alaska indigenous people, nongovernmental organizations (NGOs) and others in Arctic policy discussions is also a priority of the State Department. Support was provided to the following groups:

- The Inuit Circumpolar Conference (ICC), for AEPS meeting expenses and for drafting the section of the AMAP report to Ministers dealing with the dangers to human health caused by environmental contaminants, especially the impact of heavy metals on Arctic indigenous people;
- The Environmental Protection Agency (EPA), to pay for travel expenses of six Russian governmental officials to attend an EPPR seminar on radioactive waste held in Alaska in June 1994;

	Funding (thousands)	
	FY 94	FY 95
Arctic environmental research	500	639
Man and the Biosphere	200	100
Total	700	739

- The U.S. Arctic Network, an Alaskan NGO representing both environmental NGOs and Native points of view in AEPS deliberations; and
- The U.S. Marine Mammal Commission, to defray expenses involved in the negotiation of a Bearing/Chukchi Seas polar bear conservation agreement between U.S. and Russian indigenous people.

Russian Arctic

Natural resource protection and environmental cleanup of the Russian Arctic are significant areas of concern to the State Department. In FY 94 the State Department provided funding for four projects relating to Russia, totaling \$99,500. The Steelhead Committee of the Federation of Fly Fishers received funds towards the cost of completing a joint U.S.–Russian survey of the fishery resources of the Kamchatka Peninsula. Funds went to the EPA for use in the Murmansk upgrade project for the treatment of low-level liquid radioactive waste. The World Wildlife Fund received a grant for an Amur (Siberian) tiger conservation program that featured an anti-poaching team. A grant was provided to three Russian scientists to work on U.S. ships and one American to work on a Russian ship to conduct studies regarding the stock structure and area of origin of Bering Sea pollock.

In FY 95, funding for projects related to the Russian Arctic was increased to \$109,000. The International Whaling Commission (IWC) received funds to conduct two whale population studies: a study of the endangered bowhead and grey whales in the Sea of Okhotsk, and a detailed study of Arctic beluga whales, including their reactions to modern human activities such as offshore drilling and icebreaker traffic. The State

Department contributed funds to the U.S. Marine Mammal Commission to help establish a new Russian Marine Mammal Commission; this effort had also been supported by NGOs, which had already raised \$100,000. An NGO called the Endangered Species Project received a grant for another Siberian tiger sanctuary; the 1994 project had been very successful, and this was seen as an appropriate expansion of the effort. Another NGO, Wild Salmon Center, Inc., from Washington, received funding to collect additional samples of adult steelhead salmon on the Kamchatka Peninsula.

Arctic Seas Assessment Program

The International Atomic Energy Agency (IAEA) is the international agency charged with promoting the safe use of nuclear energy and preventing radioactive contamination from such use. The Arctic Seas Assessment (ASA) program was established by the IAEA in 1992 for the purpose of responding to reports of significant dumping of radioactive waste at sea by the Former Soviet Union. ASA conducted exploratory cruises to the Barents and Kara Seas areas in 1992, 1993 and 1994 to assess the potential for risks to human health and the environment and to evaluate the need for remedial action. The State Department contributed to ASA from funds designated to support international organizations and has also provided the expert services of U.S. scientists to the ASA's Marine Environmental Laboratory. It is widely recognized that the U.S. contribution made this program possible. The ASA reports that there are no significant regional or global effects at present from the dumped waste but that future contamination of the marine food chain might occur as the result of gradual deterioration of the barrier materials used to contain the waste.

In FY 94, \$135,000 was spent on ASA to cover the expenses of collecting samples and for laboratory analysis and reporting. In FY 95 the State Department contributed \$115,000 to the ASA program to pay the expenses of a scientific expert at the IAEA lab in Monaco to work on the radionuclide analysis. This program was continued in FY 96 at a cost of \$111,000.

Man and the Biosphere Program

The U.S. Department of State also receives funds annually for the administration of the U.S. Man and the Biosphere (MAB) program. The administration of this program is conducted through a MAB Secretariat located in the Depart-

ment. Via the U.S. MAB program, the U.S. contributed an additional total of \$105,000 in FY 94 and \$79,000 in FY 95 to Arctic-related programs.

The principal Arctic-related MAB program funded in FY 94 through the State Department was a continuation of the core project of the MAB High Latitude Ecosystems Directorate. The project, begun in 1992, was a comparative study of Alaskan and Canadian resource management systems for caribou herds. By 1994 most of the data for the study had been collected, and funding was used to support the compilation of data and drafting of the report. FY 95 funds covered finalization and distribution of the report. The major findings of the study, which was based primarily on surveys of traditional caribou users and government managers, were:

- The use of a management board composed of both users and government managers results in the managers becoming more sensitive to the needs of the users.
- User participation on the management board does not make it more likely that villagers will cooperate with the board's decisions.
- Managers' participation in the community was more effective in generating user compliance with management policies than user participation on management boards.

State Department funds were provided to the High Latitude Ecosystem Directorate to support the Arctic Ungulate Conference in Alaska in August 1995, where the results of the caribou management study were presented and discussed. U.S. MAB also supported the participation of four MAB members at the scientific symposium of the EuroMAB V Conference in Kangerlussuaq, Greenland, in September 1995; the results of the caribou study were also presented at this symposium.

In addition, the U.S. continued its contribution to the Northern Sciences Network (NSN) of MAB. NSN, which is also supported by six other Arctic countries and the U.K., publishes a newsletter twice a year. Through its secretariat in the Danish Polar Center, the NSN collects and distributes information relating to Arctic environmental issues, operates an international advisory board and provides operational support for international MAB conferences. In 1995 all country assessments were raised to cover additional expenses related to the International Tundra Experiment (ITEX). ITEX and NSN, both MAB programs, merged secretariats at the end of 1994.

In 1995, MAB funded two new Arctic projects:

- The Alaskan Glacier Bay Ecosystem Initiative received a grant to support a workshop on scientific data needs assessment and studies planning for the Glacier Bay and Admiralty

Island Biosphere Reserve.

- The Rural Alaska Community Action Program was awarded a grant to collect information on the history of local residents' use of marine resources within the Aleutian Islands National Wildlife Refuge area.

Other Arctic Projects

State Department funding was spent to support Federal agency participation in conferences and seminars relating to the Arctic, including support to the U.S. Marine Mammal Commission for an international conservation workshop and to the EPA to assure publication of the proceedings of an international Arctic Airborne Contaminants Symposium.

The State Department also donated funds to the Smithsonian Institution to support the tour of the

special exhibit "Crossroads Alaska/Siberia" to the Russian Far East.

The largest individual award for Arctic environmental activities in 1995 went to the joint Canada-U.S. Pacific Salmon Commission to begin a salmon restoration project on the Yukon River. This project was to improve habitat for, and management of, chum and chinook salmon that spawn in the Canadian section of the river.

The State Department also contributed to two health-related programs. The Centers for Disease Control received support that allowed a group of 15 scientists and indigenous people to meet three times to review existing data and make recommendations concerning health hazards. The American Society for Circumpolar Health received a grant to pay for the travel expenses of 10 Native Americans to attend preparatory meetings for an international conference to be held in 1996.

Selected Meetings of Interest

Listed here is a compilation of recent and forthcoming meetings, workshops and conferences on Arctic or northern topics and regions. Readers are invited to submit information on upcoming meetings, as well as reports on national or international meetings attended, to Editor Arctic Research Alert, Reviews and Polar Studies Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22204.

1996

Workshop on Arctic Tourism Guidelines 19–22 January 1996, Longyearbyen, Svalbard, Norway [By invitation only]

Contact: WWF-Arctic Programme
Fax: 47 22 20 06 66
E-mail: wwfp@oslonett.no

The 11th International Symposium on Okhotsk Sea and Sea Ice: Workshop on International Multidisciplinary Plans in the Sea of Okhotsk 25–28 February 1996, Mombetsu, Hokkaido, Japan

Contact: Mr. Soshi Hamaoka, Secretariat of 11th
International Symposium on Okhotsk Sea and Sea Ice,
c/o Department of Planning and Coordination,
Mombetsu Municipal Office, Saiwai-2, Mombetsu,
Hokkaido, 094 Japan
Tel: 81 1582 4 2111; Fax: 81 1582 3 1833
E-mail: kunio@lt.hines.hokudai.ac.jp

International Workshop on the Okhotsk Sea and Arctic: The Physics and Biogeochemistry Implied to the Global Cycles

29 February–1 March 1996, Tokyo, Japan
Contact: Takatoshi Takizawa, Ocean Research
Department, JAMSTEC, 2-15 Natsushima, Yokosuka,
Japan 237
Tel: 0468-67-5571; Fax: 0468-65-3202
E-mail: takizawat@jamstec.go.jp

26th Arctic Workshop 14–16 March 1996, Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado, USA

Contact: Cynthia Ocken-Roberts, INSTAAR,
University of Colorado, Boulder, CO 80309-0450, USA
E-mail: ocken_c@cubldr.colorado.edu

International Union of Circumpolar Health Meeting

Third week of May 1996, Anchorage, Alaska, USA

Contact: Tom Bender, International Union for
Circumpolar Health, P.O. Box 212001, Anchorage,
Alaska 99521-2001 USA
Fax: 1-907-786-4353

International Conference for Polar Snow-Ice and Global Change 15–20 April 1996, Lanzhou, China

Contact: Dr. Li Shize and Dr. Li Shongqin, Lanzhou
Institute of Glaciology and Geography (LIGG), 730000
Lanzhou, China
Tel: 86 0931 88 25 815; Fax: 86 0931 88 85 241

The 1996 IASC Annual Meeting 24–25 April, 1996, Bremerhaven, Germany [By invitation only]

Contact: Odd Rogne, The IASC Secretariat, P.O. Box
5072, Majorstua, 0301 Oslo, Norway
Fax: 47-22 95 96 01
E-mail: iasc@npolar.no

Climate Change, Water Resources and Energy Production in the Nordic Countries

26–28 April 1996, Reykjavik, Iceland
Contact: Kristinn Einarsson, Orkustofnun, Grensasvegi
9, IS-108 Reykjavik, Iceland
Fax: +354 568 8896
E-mail: ke@os.is

Seventh ITEX Workshop 26–29 April 1996, Copenhagen, Denmark

For scientific/technical matters contact: Preben Gud-
mandsen, Technical University of Denmark, Building
348, DK-2800 Lyngby, Denmark
Tel: 45 45 25 37 88; Fax: 45 45 93 16 34
E-mail: pg@emi.dtu.dk
For organizational matters contact: Mrs Iris Madsen,
The Danish Polar Center, Strandgade 100 H, Dk-1401,
Copenhagen K, Denmark
Tel: 45 32 88 01 00; Fax: 45 32 88 01 01
E-mail: im@pops.dpc.min.dk

The Fourth Circumpolar Symposium on Remote Sensing of Polar Environments 26 April–1 May 1996, Copenhagen/Lyngby, Denmark

For scientific/technical matters contact: Preben
Gudmandsen, Technical University of Denmark,
Building 348, DK-2800 Lyngby, Denmark
Tel: 45 45 25 37 88; Fax: 45 45 93 16 34
E-mail: pg@emi.dtu.dk
For organizational matters contact: Mrs Iris Madsen,
The Danish Polar Center, Strandgade 100 H, DK-1401
Copenhagen K, Denmark
Tel: 45 32 88 01 00; Fax: 45 32 88 01 01
E-mail: im@pops.dpc.min.dk

Xth International Congress on Circumpolar Health

19–24 May 1996, Anchorage, Alaska, USA
Contact: Michele A Hansen, Xth ICCH Coordinator,
c/o American Society for Circumpolar Health, P.O. Box
242822 Anchorage, Alaska 99524-2822 USA
Tel: 1-907-561-4406; Fax: 1-907-562-7802
E-mail: icch@epi.hss.state.ak.us

The International Arctic Science Committee has established a new service to the Arctic research community: an Arctic meetings listing available via the Internet. Called SAM (Survey of Arctic Meetings), it contains information on international Arctic meetings, as well as major national meetings with international participation. The World Wide Web address for SAM is <http://www.npolar.no/iasc/sam.htm>.

ISOPE '96-Offshore and Polar Engineering Conference

26-31 May 1996, Los Angeles, California, USA
Contact: Jin S. Chung, Chairman, ISOPE-96, Box 1107, Golden, Colorado 80402-1107, USA
Tel: 1-303-273-367; Fax: 1-303-420-3760

Second International Conference on Cryopedology

June 1996, Syktyvkar, Russia
Contact: David Gilichinsky, Institute of Soil Science and Photosynthesis, Pushchino, Moscow Region, Russia
Tel: 7 095 923 1887
E-mail: gilichin@issp.serpukhov.su

16th Polar Libraries Colloquy
16-21 June 1996, University of Alaska, Anchorage, USA

Contact: Barbara Sokolov, Director, UAA Consortium Library, University of Alaska Anchorage, 3211 Providence Drive, Anchorage, AK-99508-8178, USA
Tel: 1-907-786-1825; Fax: 1-907-786-6050
E-mail: anbjs@orion.alaska.edu

Second International Scientific Conference on the Global Energy and Water Cycle

17-21 June 1996, Washington, DC, USA
Contact: Meetings Division (Judy Cole), 101 Research Drive, Hampton, Virginia 23666-1340, USA
E-mail: cole@cais.com.

Changing Glaciers: Revisiting Themes and Field Sites of Classical Glaciology

24-26 June 1996, Norwegian Glacier Centre, Fjarland, Sognefjord, Norway
Contact: Elisabeth Isaksson, Norwegian Polar Institute - Brekontoret, P.O. Box 5072, Majorstua, N-0301 Oslo, Norway
Tel: 47 22 95 95 00; Fax: 47 22 85 95 01
E-mail: elii@npolar.no

Interpraevent 1996: Protection of Habitat Against Floods, Debris Flows and Avalanches
24-28 June 1995, Garmisch-Partenkirchen, Germany

Contact: Interpraevent 1996, c/o Bayerisches, Landesamt für Wasserwirtschaft, Lazarettstr. 67, D-806365 Munich, Germany

International Symposium/Workshop on Polar Desert Ecosystems

1-4 July 1996, Christchurch, New Zealand
Contact: The Secretary, National Institute of Water and Atmospheric Research, Ltd., P.O. Box 8602 Riccarton, Christchurch, New Zealand

The Oceanography Society (TOS) Meeting on Marine Environment and the Global Change Programs

8-11 July 1996, Amsterdam, The Netherlands
Contact: TOS, 4052 Timber Ridge Drive, Virginia Beach, Virginia, USA
Tel: 1-804-464-0131; Fax: 1-804-464-1759
E-mail: jrhodes@ccpo.odu.edu

VI International Symposium on Cold Hardiness in Animals and Plants

14-19 July 1996, Copenhagen, Denmark
Contact: Hans Ramliv, Chemical Institute, lab.III, H C Ørsted Institute, Universitetsparken 5, DK-2100 Copenhagen 1, Denmark
E-mail: hans@kiku.dk

or

Iris Madsen, Danish Polar Center, Strandgade 100 H, DK-1401 Copenhagen K, Denmark
Tel: 45 32 88 01 00; Fax: 45 32 88 01 01
E-mail: im@pops.dpc.min.dk

International Symposium/Workshop on Polar Desert Ecosystems

1-4 July 1996, Christchurch, New Zealand.

Contact: The Secretary
National Institute of Water and Atmospheric Research, Ltd., P.O. Box 8602, Riccarton, Christchurch, New Zealand

High Arctic Field Meeting, Ellesmere, Axel Heiberg, and Cornwallis Islands

8-17 July 1996, Ottawa, Ontario Canada
Contact: Antoni G Lewkowicz, Department of Geography, University of Ottawa, Ottawa, Ontario, Canada K1N 6N5
Tel: 1-613-562-5704; Fax: 1-613-562-5145
E-mail: alewkowi@acadvm1.uottawa.ca

30th International Geological Congress
4-14 August 1996, Beijing, China

Contact: Professor Zhao Xun, 30th International Geological Congress, P.O. Box 823, Beijing 100037, China
Tel: 86 1 8327772; Fax: 86 1 8328928

International Symposium on Representation of the Cryosphere in Climate and Hydrological Models
12-15 August 1996, Victoria, B.C., Canada

Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge, CB2 1ER, United Kingdom
Tel: 44-1223 355974; Fax: 44-1223 336543
E-mail: 100751.1667@compuserve.com
WWW site: <http://www.dow.on.doe.ca/crysis/igs96.html>

8th International Cold Regions Engineering Conference

12-17 August 1996, Fairbanks, Alaska, USA
Contact: Larry Bennett, School of Engineering, University of Alaska, Fairbanks, Alaska 99775, USA
Tel: 1-907-474-6121; Fax: 1-907-474-6087

First International Congress on Northern Agronomy
15-17 August, 1996, Yakutsk, Russia

Contact: Nikolay Popov, Vice-Director of the Scientific Amalgamation "Yakutskoje," Congress Organizing Committee, Yakutsk, Scientific Amalgamation "Yakutskjoe," Kalandarashvily Street, 5, Republic of Sakha (Yakutia), Russia
Tel: 6-45-77, 6-02-08, 6-20-40, 3-59-07
Fax: 7-095 230 29 19, (41122) 6 45 77, (41122) 6 02 08
Telex: 135 136 JOL RU
E-mail: ivan@poykt.yacc.yakutia.su

**Traditional Knowledge and the Contemporary World—The 10th Inuit Studies Conference
15–18 August 1996**

Contact: Irene Mazurkewich, Department of Linguistics, Memorial University, St. John's NF A1B 3X9, Canada
Tel: 1-709-737-8299; Fax: 1-709-737-2548
E-mail: imazurk@kean.uccs.mun.ca

**IX International Symposium on the Physics and Chemistry of Ice
27–31 August 1996, Hanover, New Hampshire, USA**

Contact: Victor Petrenko, 8000 Cummings Hall, Dartmouth College, Hanover, New Hampshire 03755-8000, USA

**International Conference on Oil, Gas and Ecology of the Earth Cryosphere
September 1996, Nizhnevartovsk, Tumen**

Contact: Vladimir Melnikov
Tel: 34 52 24 3649; Fax: 34 52 22 3380
E-mail: root@ikz.tyumen.su

**4th International Symposium on Glacier Caves and Cryokarts in Polar and High Mountain Regions
1–7 September 1996, Alpine Centre**

Rudolfshütte, Uttendorf, Salzburg, Austria
Contact: Univ. Prof. Dr. Heinz Slupetzky, c/o Institut für Geographie, Universität Salzburg Austria
Tel: +43 (0) 662 8044 525

Images of the North Through Prism of Science and Tourism

10–12 September 1996, Geological Institute, Econord, Khibiny Co., Nordic Study Centre, Royal Academy of Sciences

Contact: Mikhail Torokhov, Fersman str., 14, Apatity, Murmansk Reg., 184200 Russia
Fax: +47-78914153 from all countries
Fax: +7 512 9514153 only from Norway and Finland
E-mail: mitor@ksc-gi.murmansk.su

NAFO Symposium "Visioning Sustainable Harvests from the Northwest Atlantic in the Twenty-First Century"

10–12 September 1996, St John's, Newfoundland, Canada

Contact: Hans Lassen, Danish Institute for Fisheries Research, Charlottenlund Slot, DK-2920 Charlottenlund, Denmark
Tel: 4533-96-3300; Fax: 4533-96-3333
E-mail: hi@dfu.min.dk
or
Tissa Amaratunga, NAFO Secretariat, P.O. Box 638, Nova Scotia B2Y 3Y9, Canada
Tel: 902-469-9105; Fax: 902-469-5729

Polartech '96

24–26 September 1996, St Petersburg, Russia

Contact: Boris Polonsky
Fax: 7 812 127 95 95
E-mail: krylspb@sovam.com

Arctic Contaminants Conference

8–10 October 1996, Iqaluit, N.W.T., Canada

Contact: Alan Saunders, Canadian Polar Commission Suite 1710-360 Albert Street, Ottawa, Ontario, Canada K1R 7X7
Tel: 1-613-943-8605; Fax: 1-613-943-8607
E-mail: saunders@polarcom.gc.ca

PICES 5th Annual Meeting

14–20 October 1996, Nanaimo B.C., Canada

Contact: PICES Secretariat, c/o Institute of Ocean Sciences, P.O. Box 6000, Sidney BC, Canada V8L 4B2
Tel: 1-604-363-6366; Fax: 1-604-363-6827
E-mail: pices@ios.bc.ca

1997

8th International Symposium on Ground Freezing and 3rd International Symposium on Frost in Geotechnical Engineering

14–17 April 1997, Luleå, Sweden

**International Symposium on Snow and Avalanches
26–30 May 1997, Chamonix Mont-Blanc, France**

Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Tel: 44 1223-355974; Fax: 44 1223-336543
E-mail: 100751.1667@compuserve.com

Fifth Circumpolar Universities Cooperation Conference

10–12 June 1997, Luleå, Sweden

Contact: Paula Wennberg, Conference Coordinator, Luleå University, S-971 87, Luleå, Sweden
Fax: 46 920 721 60
E-mail: cucc@ies.luth.se

**International Symposium on Physics, Chemistry, and Ecology of Seasonally Frozen Soils
10–12 June 1997, University of Alaska, Fairbanks, Fairbanks, Alaska**

Contact: Dr Pieter Groenevelt, Program Chair, Department of Land Resource Science, University of Guelph, Guelph, Ontario N1G 2W1, Canada
For information about the symposium program contact: Brenton Sharratt
Tel: 1-612-589-3411
E-mail: bsharratt@mail.mrsars.usda.gov
or

Jerry Radke
Tel: 1-515-294-0213
E-mail: jkradke@iastate.edu

For symposium logistics contact: Conferences and Special Events

Tel: 1-907-474-7800
E-mail: fyci@aurora.alaska.edu

ISCORD 1997 International Symposium on Cold Regions Development

16–19 June 1997, Anchorage, Alaska, USA

Contact: Ted Vinson, Department of Civil Engineering, Oregon State University, Corvallis, Oregon 97331-2302, USA
Tel: 1-503-753-0725; Fax: 1-503-753-3052
E-mail: vinsont@ccmail.orst.edu

**International Symposium on Antarctica and
Global Change**

**14–18 July 1997, University of Tasmania,
Hobart, Australia**

Contact: Secretary General, International Glaciological
Society, Lensfield Road, Cambridge CB2 1ER, United
Kingdom

Tel: 44 1223 355974; Fax: 44 1223 336543

E-mail: 100751-1667@compuserve.com

**8th Meeting of the Canadian Quaternary
Association (CANQUA) (held jointly with the
Canadian Polar Commission)**

**August, 1997, Kuujuaq, Nouveau-Quebec
(with Field Trips in Ungava)**

Contact: Michel A Bouchard, Albert Haller Department
of Geology, Canadian Polar Commission, Université
de Montreal, 1710-360 Albert Street, P.O. Box 6128,
Station Centre Ville, Montreal, Quebec K1R 7X7,
Canada

Tel: 1-514-343-6821; Fax: 1-514-343-5782

E-mail: bouchami@ere.umontreal.ca

**Naval Arctic Research Laboratory's
50th Anniversary Celebration**

1–9 August 1997, Barrow, Alaska, USA

Contact: Glenn W Sheehan, Executive Director,
Barrow Arctic Science Consortium (BASC), P.O. Box
955, Barrow, AK 99723, USA

Tel: 1-907-852-4881; Fax: 1-907-852-8213

**Second International Conference on Cryopedology
5–8 August 1997, Syktyvkar, Russia**

Contact: Prof. I V Zaboeva, Institute of Biology,
Komi Center, Russian Academy of Sciences, 167610
Syktyvkar, Komi Republic, Russia

Tel: 7-821-22-25213; Fax: 7-821-22-25231

E-mail: gilichin@issp.serpukhov.su

**IV International Geomorphology Conference
and IPA Executive Committee Meeting
(and pre- and post-conference permafrost excursions)**

28 August–3 September 1997, Bologna, Italy

Contact: M Panizza, University Degli Studi di Moden,
59-41100 Modena, Italy

Tel: 059 23 0394; Fax: 059 21 8326

**NAFO Symposium "Visioning Sustainable
Harvests from the Northwest Atlantic in the
Twenty-First Century"**

**10–12 September 1997, St John's,
Newfoundland, Canada**

Contact: Hans Lassen, Danish Institute for Fisheries
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Denmark

Tel: 45 - 33 96 33 00; Fax: 45 33 96 33 33

E-mail: hl@dfu.min.dk

or

Tissa Amaratunga, NAFO Secretariat, P.O. Box 638,
Dartmouth, Nova Scotia, Canada B2Y 3Y9

Tel: 1-902-469-9105; Fax: 1-902-469-5729

**International Symposium on Fishery Stock
Assessment Models for the 21st Century:
Combining Multiple Information Sources**

8–11 October 1997, Anchorage, Alaska, USA

Contact: Brenda Baxter, Alaska Sea Grant College
Program, University of Alaska Fairbanks, Fairbanks,
USA

E-mail: FNBRB@aurora.alaska.edu

1998

**Seventh International Conference on
Permafrost**

27–31 July 1998, Yellowknife, Canada

Contact: J.A. Heginbottom, Geological Survey of
Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8,
Canada

Tel: 1-613-992-7813; Fax: 1-613-992-2468

E-mail: heginbottom@gsc.emr.ca

**IASC/SCAR Symposium on Global Changes in the
Polar Regions - Results and
Challenges from Bipolar Science**

August/September 1998, Tromsø, Norway.

Contact: Executive Secretary, IASC, Secretariat, P.O.
Box 5072, Majorstua, 0301 Majorstua, Oslo, Norway

Tel: 47 22 95 96 00

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***Back
Cover*** *Headwaters of the Noatak River. From its source in the Gates of the Arctic National Park in the central Brooks Range, Alaska, the Noatak River flows west, then south through the Noatak National Preserve, for over 400 miles, to its outfall in the Chukchi Sea.*

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