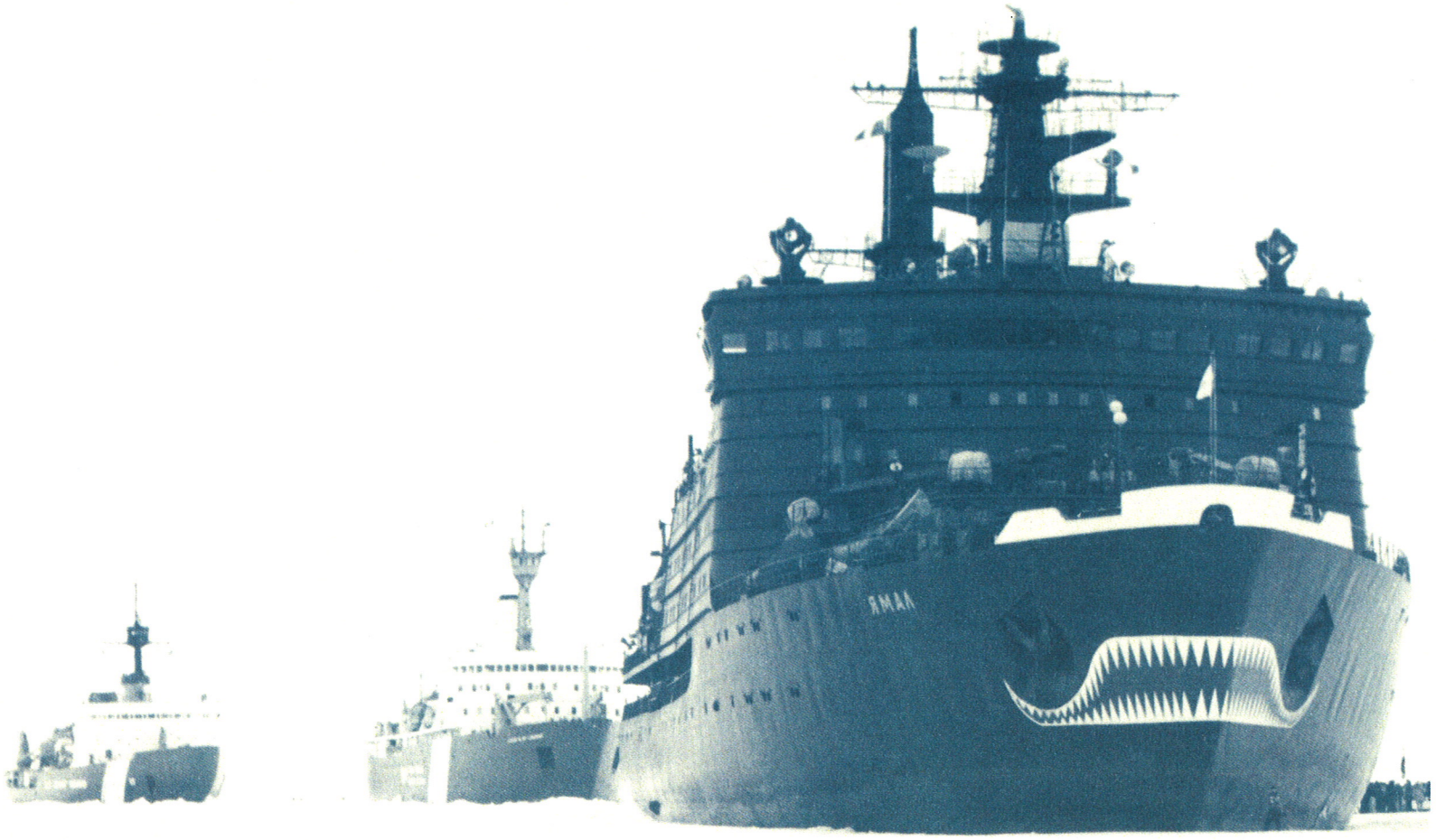
VOLUME 8 FALL 1994

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.

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Front Cover

U.S. Coast Guard icebreaker Polar Sea, *Canadian icebreaker* Louis S. St. Laurent *and Russian icebreaker* Yamal *rendezvous near the North Pole in late August 1994. The U.S. and Canadian ships carried 70 scientists to the high Arctic to participate in the Arctic Ocean Section, a scientific expedition to increase our understanding of the role of the Arctic in global change, study Arctic pollution, observe Arctic wildlife and map the ocean floor. Research support was provided by the National Science Foundation's Arctic System Science Program; the Office of Naval Research; the Canadian Departments of Fisheries and Oceans, Indian and Northern Affairs, and Environment; the U.S. Geological Survey; the Canadian Coast Guard; and the U.S. Coast Guard.*

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ARCTIC RESEARCH OF THE UNITED STATES

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Donna R. Valliere, Production Assistant

This issue of *Arctic Research of the United States* presents highlights and results of major fiscal year 1992 and 1993 Arctic research programs and selected projects of the Federal agencies. For more information, you may contact the agency staff representatives listed on page 144.

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, and the upper atmosphere and near space. Research falls principally within seven major disciplines: atmospheric science, ocean science, biology, earth science, glaciology, engineering and education.

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

In FY 93, NSF awarded funds for Arctic research to 114 institutions in 39 states and the District of Columbia, representing 269 projects. NSF's support of Arctic research, including facilities support and field operations, over the past several years is shown below (in thousands of dollars).

	FY 87	FY 88	FY 89	FY 90	FY 91	FY 92	FY 93
OPP	8,095	8,211	10,175	12,310	14,696	20,638	22,072
Other NSF programs	13,801	14,906	13,549	11,778	12,455	14,308	13,779
Total	21,896	23,117	23,724	24,088	27,151	34,946	35,851

The following sections present highlights of several major programs and selected projects. A complete listing of NSF Arctic funded projects is given in the publication *Arctic Science, Engineering, and Education Awards: FY 1993*, available from the Office of Polar Programs, National Science Foundation, Arlington, VA 22230.

Arctic System Science

The National Science Foundation established the Arctic System Science (ARCSS) program in 1986. 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, the divisions of the Geosciences Directorate and other components of NSF as appropriate. ARCSS is coordinated by the Office of Polar Programs. Through a series of workshops and interactions with a broad scientific community, ARCSS has refined its goals and mandates. These are 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 supported 65 projects totaling $12.56 million in FY 93.

	Funding (thousands)	
	FY 92	FY 93
Arctic System Science	11,638	12,560
Glaciology	2,070	3,007
Atmospheric Sciences	6,606	6,670
Ocean Sciences	3,270	3,045
Biological Sciences	5,410	5,533
Earth Sciences	3,105	2,397
Engineering and Technology	204	143
Social Science and Education	1,896	1,683
Coordination	747	813
Total	34,946	35,851

ARCSS has four linked components:

- The Greenland Ice Sheet Project (GISP2);
- Paleoclimates from Lakes and Estuaries (PALE);
- Ocean/Atmosphere/Ice Interactions (OAII); and
- Land/Atmosphere/Ice Interactions (LAII).

It is a phased, long-term program; GISP2 was initiated in 1989 and will end in 1997, PALE and OAII began in 1990, with LAII beginning in 1993 and a new program, Synthesis, Integration and Modeling (SIM), being established in 1994.

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 Integration and Coordination Panel. The

panel includes representatives from each SSC, plus a few others to enhance the scientific breadth and experience of the group.

In 1993 a report entitled *Arctic Systems Science: An Integration and Planning Report* was published. This and other workshop reports, science plans and further information on the Science Steering Committees and Integration and Coordination Panel are available from ARCSS.

NSF/ARCSS has been particularly successful at establishing partnerships with other Federal agencies. In 1992 and 1993 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 and predicting future dynamics.

The overall goal of GISP2 is 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. Some of the exciting results from GISP2 are reported below under Glaciology.

The overall goal of PALE is to construct paleoclimatic history from the sediments of Arctic and subarctic bogs, lakes and seas. A variety of proxy indicators (for example, pollen, diatoms, sediment chemistry and grain size) in the sediments yield 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. Initial analyses of this network have established that the Arctic climate is not in phase around its perimeter. PALE has been accepted by PAGES (PAst Global changES) of the International Geological Biological Project as a core project. In January 1994 a workshop attended by PALE investigators led to the publication of a volume of 36 extended abstracts. One report confirmed that varved lakes could provide regional chronologies with absolute time intervals of approximately 50 years for the entire Arctic. Next year a new project will be launched in which PALE and GISP data will be combined with written historical and archaeological data. The project will focus on the Greenlandic and Icelandic sectors of the Arctic and will bring entirely new insights into the issue of sustaining human settlements during the medieval warm period and the Little Ice Age in these extreme environments.

Contemporary and Process Studies

OAII and LAII are process oriented and rely more on experiment and less on description than GISP2 and PALE. An important goal of OAII 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. OAII achievements are described below under Ocean Sciences.

An objective of the major LAII study, called LAII-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. LAII will also assess the effect of changing temperature and snow regimes on critical terrestrial organisms and their communities. LAII-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 has 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. LAII has joined ITEX (International Tundra Experiment of the Man and the Biosphere Program), which is a study of the effects of climate warming on circumpolar plant species and community dynamics.

LAII is testing, among other things, the following three hypotheses:

- Greenhouse-induced changes in temperature and moisture are large enough to trigger changes in trace gas fluxes from Arctic land areas.
- Climate change and the related oxidation of soil organic matter will increase the nutrient flux to streams, lakes and the Arctic Ocean.
- Arctic trace gas feedbacks will be sufficient to affect climate beyond the Arctic.

In response to requests by Alaska Native organizations, LAII will expand to study the effect of global change on food organisms such as geese and caribou.

Glaciology

The Glaciology Program supported 24 projects totaling $2.07 million in FY 92 and 33 projects totaling $3.01 million in FY 93. The research that was supported includes the study of all forms of naturally occurring ice and its history under a broad multidisciplinary glaciology research program. 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, Arctic Russia, Sweden and Washington state. However, some funding supports research in high-altitude regions of the midlatitudes and low latitudes 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 were funded this biennium. These include studies of liquid-like 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), was completed and began operations during this biennium. 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, among other variables that can be measured in boreholes in the ice at various places on the glacier.

Scientists from the University of Washington and the University of Alaska are examining the structural changes in the basal zone of the Black Rapids Glacier during a seasonal pulse in velocity that occurs each year. Current theories of glacier motion presume that water-pressure-induced changes in the structure of cavities behind bedrock bumps and/or properties of soft bed material cause seasonal velocity changes by altering the speed of the ice over the bed of the glacier. This work provides new information about the detailed form of seasonal velocity variation and the relation to water inputs and outputs.

The Bering Glacier in Alaska is the longest (191 km) and largest (5173.5 km^2) glacier in North America and is the largest surging glacier on Earth. Surging is defined as periodic, very rapid movements of large quantities of ice within a glacier, alternating with much longer periods of near stagnation. The current surge was first detected in the spring of 1993 and is still continuing. Scientists from the U.S. Geological Survey, the University of Alaska, the State University of New York-Oneonta and the University of Wyoming were supported through NSF's rapid response program—Small Grants for Exploratory Research (SGER)—to study the ongoing surge of the Bering Glacier.

The work on the Bering Glacier funded by the Arctic Glaciology program involves analysis of synthetic aperture radar imagery, vertical aerial photography, time-lapse photography and stream gauge monitoring. Oblique-view aerial photographs of certain portions of the glacier are being taken periodically to document glacier activity throughout the year. Automated observations of water and suspended and dissolved loads from glacial outlets will monitor the subglacial hydraulics, which, according to present understanding, controls the propagation of surges.

Glacial Geological Studies

One of the largest uncertainties in ice volume changes during the late Quaternary are the areal and vertical extents of ice sheets over Franz Josef Land, Novaya Zemlya and the adjacent seas (Barents/Kara). Deglaciation of Franz Josef Land and the northern Barents Sea occurred surprisingly early, according to glacial geologists from The Ohio State University and the University of Colorado-Boulder funded by the Arctic Glaciology program. Radiocarbon dating of driftwood and shells at the marine limit and forams from adjacent marine sediments indicate that glacier retreat began on Franz Josef Land prior to 10,200 years ago. Deglaciation of the Barents/Kara Sea ice sheet may have been initiated by a rapid global sea-level rise 13,000 years ago. The sea-level rise would have destabilized this marine-based ice sheet, particularly in the deep troughs bordering the Russian Arctic seas.

Researchers from Northern Illinois University and Appalachian State University are studying the

sedimentary record in Glacier Bay, Alaska, the site of the largest documented marine deglaciation in the world, in order to better understand marine glacier terminus stability with changing climate and marine conditions. The study is using the R/V *Alpha Helix* for collecting data by seismic reflection profiling, side-scan sonar, and piston and gravity coring. A cruise in 1993 collected over 880 km of high-resolution seismic lines, 71 sediment cores and 22 surface sediment grab samples. One major finding from the preliminary shipboard core descriptions is a repeated bedding style that appears to be cyclic and may represent annual depositional events. If so, the dating control on these cores will be greatly enhanced.

Greenland Ice Sheet Project Two

On 1 July 1993, after five years of drilling, the GISP2 program reached bedrock at a depth of 3053.44 m, after drilling several meters of silty ice. Shortly thereafter 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.

The depth–age relationships for the GISP2 core have been developed from a variety of core variables, including annual layers of visual stratigraphy, electrical conductivity, laser light scattering of dust, stable isotopes, major anions and cations, insoluble particles, lead-210, total beta activity and carbon-14 from occluded carbon dioxide in air bubbles in the ice, plus ice dynamics modeling. Annual layer counting (based on visual stratigraphy, electrical conductivity and laser-light scattering) appears to provide a viable dating tool to a depth of at least 2600 m (about 65,000 years ago), as suggested by observations during the 1993 field season. The age at the bottom of the GISP2 core is still unknown, but it could represent as much as 250,000 years of the Earth's history.

One of the most dramatic climate events observed in marine and ice core records is the Younger Dryas, a return to near-glacial conditions that punctuated the last glaciation. Multiparameter annual layer counting of the GISP2 core has provided a high-resolution view of this event. The end of the Younger Dryas is characterized by a doubling of accumulation at GISP2 in perhaps one to three years; the onset of this event is also characterized by a large and abrupt change in accumulation rate. Fluctuations in the electrical conductivity of GISP2 ice on the scale of less than five to twenty years have been used to reveal rapid changes in the dust content of the atmosphere during the last glaciation. These rapid changes appear to reflect a type of "flickering" between preferred states of the atmosphere, which provides a new view of climate change.

A comparison of the Holocene and glacial portions of the GISP2 record indicates that sulfate concentrations were low during the Holocene and markedly higher during cold periods, reflecting increased input of terrigenous dust to the glacial atmosphere. In contrast, sulfur from marine biogenic sources, in the form of methane sulfonic acid, is higher in concentration during warm periods and lower during glacial conditions. This suggests a reduced contribution of oceanic sulfur to the Arctic atmosphere during glacial climates. This trend is dramatically different from that observed in the Vostok ice core in East Antarctica, where high-latitude oceanic sulfur emissions apparently increased during glacial periods.

Several other climatic events, such as the Little Ice Age, which appears to span the period AD 1350 or 1450 to about AD 1900, have been studied in detail. GISP2 temperatures modeled from oxygen isotopes reveal a relatively subdued temperature effect at this site during the Little Ice Age, and accumulation is slightly lower than during the previous Medieval Warm Period. Carbon dioxide values may dip slightly during the Little Ice Age, whereas dust (as indicated by insoluble particles, calcium, magnesium and potassium) and marine sources (as indicated by sodium, chloride and methane sulfonic acid) either increased in the atmosphere or were transported more efficiently to the site during this period.

In addition to providing a remarkable paleoenvironmental record, the GISP2 core provides our first view of the basal conditions (clear ice into silty ice into bedrock) beneath the central region of a polar ice sheet. Analysis of the basal materials (both the silt in the ice and the 1.55 m of bedrock) will also provide information useful to those studying the geology of Greenland. Preliminary observations in the field indicate that the upper 10–15 cm are a weathered "schist-like" rock that grades into a very fresh "granite gneiss" below.

Drilling operations in 1992 collected core from a depth of 1510 m to a depth of 2252 m. The ice drilled in 1992 included samples from the last glacial–interglacial transition, and preliminary results collected in the field revealed details of climate change with a resolution and quality not seen before in ice core drilling. Core processing was continued in the field, as in previous seasons, which allowed results, in the form of prepared ice samples, water samples, filters and various forms

of data that were collected, to be returned from the field directly to various laboratories at the end of the season without additional handling of the core. These included samples for isotopes of hydrogen and oxygen, particulates, major ions, physical properties, isotopes of occluded gases, isotopes of helium, cosmogenic radionuclides and methane sulfonic acid (MSA). Analyses performed directly in the field included electrical conductivity (ECM), visual stratigraphy, major ions, physical properties and laser light scattering (both solid and liquid measurements).

The atmospheric sampling camp—a remote, solar-powered, clean sampling site—also operated throughout the 1992 and 1993 seasons, with the collection of aerosol samples, samples of fresh and aging snow and other specialized samples. Limited results are available so far for reactive gaseous species, such as hydrochloric acid, nitric acid and hydrogen peroxide, but the 1993 season has yielded continuous records of hydrogen peroxide and high-resolution, short-duration records of concentrations of gaseous acids in surface-level air. The importance of ice fog and dry deposition in the delivery of atmospheric constituents to the snow surface has been suggested and is the focus of continued sampling. The six automatic weather stations installed in the Summit region continued to operate during the 1992 and 1993 seasons. Each is equipped to monitor a variety of meteorological parameters (for example, temperature, barometric pressure, wind speed, wind direction, global short-wave radiation, humidity and snow depth) and relay the output to the ARGOS system.

Atmospheric Sciences

NSF Atmospheric Sciences programs supported 60 projects totaling $6.61 million in FY 92 and 48 projects totaling $6.67 million in FY 93. The Division of Atmospheric Sciences supports a broad spectrum of research activities encompassing meteorology, climate dynamics, tropospheric and stratospheric chemistry, aeronomy, ionospheric physics, magnetospheric physics and solar physics. Lower atmospheric phenomena that are studied include Arctic stratus clouds, Arctic haze, long-range transport of aerosols and trace gases over the Arctic Basin, polar stratospheric clouds and stratospheric chemistry related to ozone depletion. Upper atmospheric processes studied in the Arctic include polar mesospheric clouds, auroral excitation and emissions, ionization production and loss, auroral current systems and magnetic storms. Because Earth's magnetic field guides magnetospheric and solar wind particles into the polar regions, the Arctic is the ideal location for studying solar wind–magnetosphere interactions and their influence on the near-Earth space environment.

Upper atmospheric research in the Arctic includes work supported under two Global Change programs. The CEDAR (Coupling, Energetics, and Dynamics of Atmospheric Regions) program is focused on the study of coupling between atmospheric layers from the mesosphere to the exosphere. CEDAR emphasizes support for developing and deploying advanced instrumentation and facilities and establishing and maintaining a comprehensive database containing up-to-date atmospheric measurements. The Geospace Environment Modeling (GEM) program uses a combination of theory and observations in a systematic effort to study the magnetosphere and how it interacts with Earth's ionosphere and the solar wind. A general circulation model for the magnetosphere, comparable to and inspired by general circulation models used for the lower atmosphere, is being developed by GEM scientists. This model can be considered one of the final products of the GEM effort. The NSF-funded instruments in the Arctic regions play an essential role in developing and validating this model.

Much of the upper atmospheric research in the Arctic is enabled through the establishment and continued support of observational facilities. The Sondrestrom Radar Facility, located on the southwest coast of Greenland and operated by SRI International, is NSF's largest permanent base north of the Arctic Circle and is a major hub of upper atmospheric and solar–terrestrial research. The principal instrument is an incoherent scatter radar with a 33-m-diameter parabolic antenna. This radar is capable of measuring electron densities, electron and ion temperatures, and Doppler velocities over a large field of view at all ionospheric heights. To further the scientific capabilities and usefulness of the radar, the Sondrestrom facility also contains a wide range of instruments (mostly university-owned), including spectrometers, imagers, interferometers, magnetometers, ionosondes and riometers. In FY 93 a recently developed Rayleigh–aerosol lidar began making measurements at Sondrestrom, allowing studies of polar stratospheric clouds and middle atmospheric densities and temperatures. Another recent addition to the instrumentation at Sondrestrom is a dual-frequency radar system that provides coverage of atmospheric winds at altitudes of 60–120 km. This will enable studies of the effects of gravity waves and tides in the polar regions.

A particularly exciting development is the selection of the Sondrestrom Radar Facility as a testbed for a project to demonstrate the feasibility

of national "collaboratories," a concept where emerging computer technology is used to enable scientists from all over the world to view data and actively participate in real-time experiments. The collaboratory reduces many of the logistical complexities involved with performing experiments in remote locations such as the Arctic. The project is jointly funded by the Division of Atmospheric Science and the Division of Information, Robotics, and Intelligent Systems. Experiments that have been conducted in the last year have demonstrated the effectiveness of the system in enabling scientists in widely separated geographic locations to collaborate, exchange information and modify experiments in real time. The collaboratory has the potential of becoming an important teaching tool as well by encouraging student participation in remote experiments.

In addition to the instruments deployed at Sondrestrom, a number of other instruments for upper atmospheric research have been deployed in the Arctic. For example, NSF has contributed with other agencies to develop a chain of HF radar facilities that now stretches longitudinally from central Canada to Europe. These instruments measure the two-dimensional distribution of plasma convection over the polar regions, allowing studies of auroral electrodynamics and coupling processes to the solar wind and magnetosphere. Another continuing Arctic observatory is located in Longyearbyen, Norway, containing optical instrumentation for studies of auroral emissions and atmospheric winds. NSF has continued to support the operation of magnetometers and VLF transmitters, all of which are used to determine the distribution of high-latitude ionospheric current systems. Many of these Arctic instruments were supported with funds provided by the CEDAR and GEM programs.

Location of the prototype upper atmosphere research facility at Resolute Bay, Northwest Territories.

In FY 93 a prototype observing facility was constructed for upper atmospheric research at Resolute Bay in the Northwest Territories. The facility includes laboratory work space and living quarters for visiting scientists. Funding for the facility was provided by the CEDAR program and the Office of Polar Programs. The facility presently includes an all-sky imager and a spaced-antenna drift instrument. Canadian scientists have also contributed instruments to the facility. This facility is the first phase of a proposed Polar Cap Observatory, which will include an incoherent scatter radar. Because of the very high latitude of the site, this prototype facility is expected to provide measurements of many unique polar phenomena, including the polar vortex, Arctic noctilucent clouds, the polar cap aurora, cross-polar cap convection and polar cap ionization patches. Many of these observations have direct relevance to the monitoring and diagnosis of global change phenomena.

The Polar Aeronomy and Astrophysics Program in the Office of Polar Programs provides approximately $1 million per year to support research on Arctic stratospheric ozone and to support upper atmospheric studies that are coordinated with magnetically conjugate projects in Antarctica.

Two separate groups from the University of Wyoming are flying instruments on balloons to study the role that aerosols and stratospheric clouds play in the chemical destruction of ozone. One of those groups is developing long-duration (several days) ballooning techniques so the chemical and physical properties of a stratospheric air mass can be continuously monitored as it circulates around the North Pole in the wintertime polar vortex. This development is being undertaken in collaboration with scientists from the Russian Central Aerological Institute. The other Wyoming group is flying balloonsondes from Kiruna, Sweden, in collaboration with several European investigators.

A group from the University of Denver has established a high-resolution infrared Fourier transform spectrometer in Eureka, NWT, Canada, to measure trace atmospheric species. The principal motivation is to track the chemistry causing ozone destruction in the stratosphere.

The University of Maryland has now installed imaging riometers (relative ionospheric opacity

meters) called IRISes at both Sondestromfjord, Greenland, and Iqaluit, NWT, Canada, as well as the original IRIS at South Pole, Antarctica. This array can, for the first time, be used to study the auroral morphology in both hemispheres at any time of year or in any weather. NSF continues to support magnetometers at several sites and to provide funds for data analysis to several groups.

Ocean Sciences

NSF Ocean Sciences programs supported 25 projects totaling $3.27 million in FY 92 and 19 projects totaling $3.04 million in FY 93. Much of the NSF Division of Ocean Sciences (OCE) funding for Arctic research during these years was channeled through the activities of ship support of the R/V *Alpha Helix*, a study for a new replacement Arctic research vessel and cosponsorship of several Arctic Systems Science (ARCSS) research projects with OPP/OAII. The ARCSS research primarily involved two collaborative projects: Investigating the Western Arctic and the Northeast Water Polynya project. In 1993 the Ocean Drilling Program undertook two legs within Arctic waters, which accounted for most of the OCE funding for that year.

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. The *Alpha Helix* is becoming marginally adequate to support major multidisciplinary research projects in Arctic waters, and a major study has been undertaken to plan for a potential replacement vessel. During 1992 and 1993, the *Alpha Helix* spent approximately 150 days each year at sea in support of eight to ten research projects spanning several scientific disciplines.

One project involved an ongoing investigation of the transport and water properties in the Bering Strait and over the Chukchi Shelf. The goal of this research is to study the circulation and water mass transformation processes on the Chukchi Shelf and to measure the Pacific inflow to the Arctic, its modification on the shelf and its influence on shelf productivity and sea ice. Emphases are on the Chukchi Shelf and water masses entering through the Bering Strait. Core measurements involve deploying current meter moorings to obtain time-series measurements of temperature, conductivity, current velocity and sea-ice thickness, and conducting shipborne, basin-wide CTD (conductivity, temperature, depth) and acoustic Doppler current profiler (ADCP) surveys. The initial sampling program was carried out during a fall 1993 cruise on the *Alpha Helix*. A total of 122 CTD stations were occupied, and vertical profiles of horizontal current velocity were collected continuously along cruise tracks with the vessel-mounted ADCP.

Concurrent with these activities, a number of discreet water samples were taken throughout sea-going operations for the analysis of dissolved oxygen, oxygen isotopes, nutrients, helium, tritium and dissolved barium. Ship support was also used for studying marine mammal distributions in the Chukchi Sea, relative zooplankton biomass in profiles and spatially discreet samples, brine production and transport from the polynyas of the northern Bering and Chukchi Seas, the variability of sea ice draft distribution, causes and consequences of this variability, and the role of ice cover in maintaining climate. Future work funded through OCE will contribute to continued deployment and recovery of current array moorings, reoccupation of CTD grids, continued chemical sampling, marine mammal observations, the study of zooplankton biomass, and continued data analysis and processing.

The second major Arctic program partially funded by OCE through ARCSS/OAII is the North East Water Polynya (NEWP) project. Although polynyas (open bodies of water in sea ice) may represent only a small part of the Arctic region, they may account for large fractions of the midwinter energy exchange between the atmosphere and the ocean. They are believed to be sites of enhanced biologi-cal activity and dense-waterformation.

In 1992 and 1993 the NEWP project undertook two highly successful research cruises onboard the USCG icebreaker *Polar Sea*. Samples were collected at 81 locations in the first year and 103 during the second off the coast of Greenland. Studies focused on physics, meteorology, tracers, particle chemistry, pelagic and benthic biology, hydrography, currents, air–sea fluxes, sedimentology and remote sensing. The extensive field program collected data for physical, hydrographic, meteorological and current studies using ADCP arrays, surface-drifter buoys, sediment traps, current meter moorings and CTD casts throughout the cruise track. Several moorings deployed during the 1992 cruise were recovered during 1993, and the data are being analyzed. These data will help validate and test hypotheses of polynya formation and preservation, as well as help clarify the roles of geostrophic flow, upwelling, internal waves, currents and tides in polynya phenomena.

To determine carbon flow, nutrient dynamics and particle import–export within the polynya region, a wide array of chemical and tracer experimentation was completed in 1992 and 1993. Nutri-

ents (NO_3, NO_2 PO_4, SiO_4, NH_3), oxygen, ^3H, ^3He, halocarbons, radionuclides (^{234}Th and ^{210}Pb), suspended particles, CO_2 and deposited sediments were measured at selected stations along the cruise track. These measurements will help further define the role of "new" biological production within the polynya, the importance of particle sinking rates, gas exchange across the air–sea interface, and the spatial and temporal variations in particle fluxes within the region. In addition, a large effort has also been expended on understanding the biological processes that influence production, respiration and the trophic dynamics associated with polynya phenomena. Data are currently being analyzed, and the results will be published in upcoming journals and workshops.

The OCE-sponsored Ocean Drilling Program (ODP) undertook two legs (151 and 152) in Arctic waters during FY 93. Leg 151, 30 July through 24 September 1993, focused on four partly ice-covered sites: the Northern Gateway region (Yermak Plateau and Fram Strait), the East Greenland Margin, the Greenland–Norway transect and the Iceland Plateau. A series of drillings were conducted to obtain cores for use in reconstructing the temporal and spatial variability in oceanic heat budgets and for studies of oceanic chemistry. In addition, this leg served as a platform for studies of circulation patterns in a preglacial, relatively warm polar and subpolar ocean and the mechanisms of climatic change in a predominately ice-free climatic system. Cores containing records of biogenic fluxes ($CaCO_3$, opal and organic carbon) and stable carbon and oxygen isotopes were collected for studies of carbon cycle dynamics, productivity and facies evolution and for biogeochemical comparisons with other depositional environments.

Sites for drilling were arrayed as either broad transects to monitor spatial paleoclimatic variability or closely spaced suites across a range of depths to monitor vertical variability. Deep drilling sites were chosen for specific purposes, such as to constrain the time of opening of the Fram Strait or to monitor downstream sedimentological effects of deep flow through narrow gateway constrictions. In addition, sites were chosen to address the age and nature of basement rocks in the Northern Gateway region.

From 29 September to 24 November 1993, leg 152 continued as the second in an eight-leg program proposed by the North Atlantic Rifted Margin Detailed Planning Group (NARM-DPG) to investigate rifted margins. The group has planned studies of both volcanic and nonvolcanic margins; leg 152 (63°N, Greenland transect) falls into the latter category. The drilling sites are located approximately 550 km south of the original center of the Iceland hotspot, chosen for its apparent structural simplicity and relatively well understood plate kinematic history. Four sites were chosen to constrain a number of features, including the timing of breakup, the nature of the lithospheric deformation, magmatic processes, flexural deformation rates, emplacement mechanisms, geochemical and volumetric trends in the magmatism, spreading rates prior to the formation of the first oceanic magnetic isochrons, syn- and post-constructional subsidence of the volcanic carapace, and the post-breakup subsidence of the spreading ridge.

Biological Sciences

NSF Biological Sciences programs supported 33 projects totaling $5.41 million in FY 92 and 27 projects totaling $5.53 million in FY 93. These programs support research in all aspects of Arctic biology, including biological oceanography and marine ecology, terrestrial and freshwater ecology, and solar irradiance monitoring (UV-B) at Point Barrow, Alaska. While research topics span a broad range of biological disciplines, such as microbiology, zoology and botany, several projects are multidisciplinary and interdisciplinary.

A major interdisciplinary project continues in the foothills on the North Slope of Alaska. This 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 since the mid-1970s. In conjunction with the Long-Term Ecological Research (LTER) program, this project has developed a multidisciplinary team approach to ecosystem studies over the years. These 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. One such change has been the virtual extinction of two species of zooplankton in Toolik Lake. 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.

Arctic lakes and streams proved to be ideal for long-term experimental manipulations of the system. Results have shown, for example, that stream fertilization can change a stream from heterotrophy to autotrophy and that it can return to prefertilization conditions when grazing insect populations catch up with the new algal production. Other manipulations of the lakes and rivers, such as removing a top predator from the system, have shown top-

down effects on the ecosystem. For example, adult trout force yearlings into suboptimal habitats, where the growth of yearlings is stunted compared to those in the experimental river or lake. This effect also cascades down several trophic levels, where the increase in zooplanktivorous young trout moved the structure of the zooplankton population towards smaller sizes. Studies on manipulating planktonic communities using field enclosures have also allowed scientists to understand various steps in the microbial loop that regulates bacterial biomass. Concerning land–water interaction, studies have indicated a previously unmeasured pathway where carbon dioxide from soil respiration moves into streams and lakes and then into the atmosphere. In wet tundra this process may account for as much as 20–50% of the primary production, in contrast to temperate terrestrial systems, where communities assimilate, recycle and bury most of the fixed carbon in the system.

In Arctic terrestrial systems, several disciplinary or small multidisciplinary projects are also supported. These projects focus on a wide range of questions that address terrestrial communities and populations ranging from soil microbes to mammals and birds. A multidisciplinary terrestrial project is focusing on the interactive role of soil development on plant and algal establishment in circumpolar deserts in the Canadian High Arctic. The results so far have shown that landscape patterns, soil climate and nitrogen-fixing cyanobacteria in nutrient-poor soil are critical to the establishment of plant communities in high-latitude desert ecosystems. Studies on the metabolic adaptation of polar bears during food shortages have shown why these animals are so successful in fasting for long periods of time. These bears possess a unique ability at any time of year to preserve body mass through nitrogenous waste recycling. No other mammal has been reported to possess this ability. Research continues on the adaptations of Arctic breeding birds to the extreme environmental conditions and the brief high-latitude summer. Arctic birds have evolved novel and rapid neuroendocrine and endocrine mechanisms to allow adaptation to changing reproductive conditions. This is unlike many species breeding at lower latitudes.

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. Investigations on the photo-adaptation of large macroalgae or kelp in the Beaufort Sea have shown that during the extended summer light period *Laminaria solidungula* stores most of its fixed carbon and delays new frond tissue production until winter nutrients are more abundant under the sea ice. This unique photo-adaptation of reallocating carbon reserves from the previous season allows the alga to utilize winter nutrient inputs for growth, even in a low-light environment. A multidisciplinary research project on the foraging ecology of planktivorous seabirds, particularly small auklets, in the western Aleutian Islands, has shown that physical processes and hydrographic structure influence the distribution and foraging behavior of these seabirds. Physical processes in the system are important conduits for delivering subsurface zooplankton prey into surface waters for avian predation. Related oceanographic studies are also focusing on 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. A research project focusing on primary and secondary productivity of Arctic marginal seas has shown that carbon cycling in cold seas is largely the result of an interactive response by the bacteria to low temperatures and substrate concentrations. These observations suggest that during the onset of spring phytoplankton blooms, when temperatures are near zero or below, components of the microbial loop may be uncoupled from primary production, resulting in a potential net export of high-latitude shelf carbon to the deep ocean basin.

The two largest projects supported by the Biological Sciences Program during FY 92 and 93 were the ongoing Long-Term Ecological Research (LTER) projects on tundra, lake and taiga ecosystems in Alaska. The Arctic and Bonanza Creek LTER projects have been described in some detail in earlier issues of this publication. Both projects continue the successful pursuit of their individual project objectives and their participation in the 18-project 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 and who see productive advantage in performing comparative and synthesis-oriented projects.

Two other ecosystem-scale projects were supported in subarctic Russia during FY 92 and 93. One project focused on using dendro-ecological (tree ring) data to reconstruct the multicentury, regional-scale forest-fire and climate histories of taiga forests in Siberia. These reconstructed records are being used to assess the temporal and spatial changes and trends in fire activity that have occurred in response to changes in climate and land use. The patterns are being compared with

similar records from the western U.S. These data are being used to develop models of future changes in forest ecosystems in response to global climate change and human land-use practices.

A second project in subarctic Russia focused on the role played by dead and dying trees in the global carbon cycle. Preliminary estimates indicate that tree mortality contributes significantly to the global carbon flow and that dead wood is a major component of the global pool of stored carbon. If these estimates are correct, it is important that models of the global carbon budgets be modified to include the dead-wood components.

The Biological Programs supported a neuroendocrinological project on photoperiodic responses of Arctic birds. Although photoperiodic responses are critical in many organisms, from plants to humans, the location, sensitivity and neural connectors of the photoreceptors in the vertebrate brain are not known. Immunological techniques are being used to locate in the brain the cell bodies and neural terminals that are involved in photoperiodic modification of circadian rhythms. New insights into how changing the light periods affects the nervous system and influences the timing of biological events could lead to the development of treatments for photoperiodic disorders in humans, such as midwinter depression at high latitudes, jet lag and disorders created by changes in work shifts.

Other research supported by the Biological Programs included continued work on the Arctic and subarctic components of the Flora of North America project, on thermoregulation by Arctic bumble bees and on Arctic tundra response to elevated temperatures and global climate change. An ongoing project receiving support was the role of carbon–nitrogen interactions in Arctic ecosystem response to disturbance and global climate change.

Funding was provided during FY 92 and 93 for improvements in the collection of Arctic and subarctic mammals housed at the University of Alaska Museum. This is the only reference and voucher collection in the state and provides an invaluable resource for scientists and managers working with Arctic mammal species. The funds will allow improved cataloging and database management and allow expansion of the frozen tissue collection (essential to those doing molecular studies on Arctic mammals).

The Biological Programs provided funds for one symposium and one workshop in Arctic biology. The symposium was on the endocrinology of Arctic birds and mammals and was held in Los Angeles. The workshop was on the biodiversity and ecosystem consequences of climate change and was held in Oppdal, Norway.

Earth Sciences

NSF Earth Sciences programs supported 54 projects totaling $3.10 million in FY 92 and 35 projects totaling $2.40 million in FY 93. The Polar Earth Sciences Program supports research in a wide variety 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 surficial processes in the Arctic. Many projects receive support through split-funding agreements with other NSF programs (ATM, EAR, INT) and other agencies (NPS, NRL). Some projects involve collaboration with foreign research programs (Canadian and Russian, in particular). 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: western Alaska and eastern Siberia, the eastern continental shelf of Greenland, the Hudson Strait, and the Kara and Barents Seas.

Geologists from the Universities of Massachusetts and Alaska, working with Russian colleagues on the coasts of the Chukchi and Bering Seas, are undertaking an extensive revision of the Pleistocene stratigraphy of the Chukchi Peninsula in an effort to reconcile glaciomarine sedimentary records from Siberia and Alaska. In a separate but related project, geologists from the Institute of Arctic and Alpine Research (INSTAAR) at the University of Colorado are examining cores from the bottom of the Bering Strait to determine paleoenvironmental conditions and constrain the timing of inundation of the Bering Land Bridge. This work has important ramifications for the timing of human migration into North America, a topic that is particularly relevant in light of recently discovered archeological sites in western Alaska.

Geologists from INSTAAR, collaborating with Canadian geologists on two separate projects, are investigating the glaciomarine sedimentary record of East Greenland and the Hudson Strait. The sedimentary record from continental shelf sediments of

East Greenland help to constrain the history of the Greenland Ice Sheet and are particularly important in conjunction with ongoing paleoclimate studies of the ice cores from the GISP2 and GRIP sites. Work in the Hudson Strait is focused on determining the nature, timing and periodicity of ice movements in the strait, which is the major pathway for icebergs from the Laurentian ice sheet during its existence and disintegration.

Geologists and paleontologists from Woods Hole Oceanographic Institution and the Ohio State University, working with Russian colleagues, are studying sediment cores and grab samples from the Kara and Barents Seas in an attempt to constrain the extent and history of an ice sheet thought to have been centered on the Kara Sea during the last ice age. This work has particular relevance to the problem of a full and accurate accounting of the water that was required to produce the change in sea level since the end of the last ice age.

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, northeastern Siberia and the Arctic Ocean, whereas tectonic and petrogenetic studies of the geologic record have focused on Greenland and Svalbard.

Geologists from the University of Minnesota, in collaboration with European geologists in an ongoing study, are determining the thermal history recorded in the rocks of central Spitsbergen. This information places constraints on tectonic models for both mid-Paleozoic collisions associated with Pangaea assembly and rifting associated with the opening of the Norwegian Sea and the separation of Greenland and Scandinavia.

Geologists from Lamont Doherty Earth Observatory, along with many oceanographers from several U.S. institutions, participated in a unique opportunity to study the Arctic Ocean basin from a U.S. Navy nuclear submarine, the USS *Pargo*. The LDEO group measured gravity variations along the cruise track, which included several crossings of the Lomonosov–Alpha Ridge complex. The data appear to be of very high quality and will prove useful to interpretations of the crustal structure beneath the Arctic Ocean. In addition, NSF is contributing to ongoing efforts of the Naval Research Laboratory for aerogeophysical investigations of the Arctic Ocean basin.

Completion of the ice core at Summit, Greenland, by the GISP2 project yielded a substantial bonus to geologists interested in the bedrock underneath the ice sheet. A 1.55-m-long core of rock was recovered with a special drill developed by the Polar Ice Coring Office, with joint support from NSF and the European GRIP project office, to penetrate rock at the bottom of the ice core hole. The core consists of schistose rock in the upper part and granitic rock in the lower part, separated by a breccia zone. Research is underway on this core, which will be quite useful to constrain the extent of crustal provinces identified from coastal outcrops, but more significantly this technology opens the way for direct studies of the sub-ice lithosphere.

Engineering and Technology

NSF Engineering supported five projects totaling $204,000 in FY 92 and three projects totaling $143,000 in FY93. Support in engineering, material sciences and permafrost are 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 93 the SBIR program funded projects on the use of microcellular thermoplastic foams as construction materials for polar regions and on fuel cells for a portable remote power supply in the polar regions.

Social Science

NSF Social Science programs supported 40 projects totaling $1.90 million in FY 92 and 34 projects totaling $1.68 million in FY 93. The Arctic Social Sciences Program is part of the Office of Polar Programs. The primary goal of the program is to stimulate and support Arctic and northern research within all social science disciplines. The Arctic Social Sciences Program encompasses research in cultural, social and physical anthropology, archaeology, ethnology, history, geography, sociology, psychology, linguistics, political science, law, economics and related subjects. In addi-

tion, the program is designed to encourage cross-disciplinary research and collaboration with indigenous people and northern residents.

Following the recommendations of the National Academy of Sciences/Polar Research Board (PRB) report *Arctic Social Sciences: An Agenda for Action* (1989), three overarching research themes were identified for the program: community viability, rapid social change and human–environment relations. These priorities refer to issues being faced by northern residents and indigenous people throughout the North and past and future conditions relating to human adaptation and environmental change.

Although the Arctic is a geographically delimited region, research proposals relating to Arctic or northern conditions or issues may be submitted to the program. The Arctic is viewed as an integrated part of global environmental and human systems. Projects that are international (circumpolar) in focus are especially encouraged.

The Arctic Social Sciences Program has assumed special responsibilities towards northern residents, particularly the indigenous people of the North. All projects must obtain the informed consent of subjects and relevant local organizations before fieldwork can be undertaken. A statement of "Principles for the Conduct of Research in the Arctic" was prepared by the Interagency Arctic Social Sciences Task Force and serves as a guide for all principal investigators wishing to do research in Arctic regions.

In 1992 the Arctic Social Sciences Program received 37 research proposals from 25 institutions in 18 states, and in 1993, 44 proposals from 27 institutions in 20 states. During these two years, awards totaling $4.04 million were made. These figures include commitments for projects of up to five years' duration. The awards comprise 13 doctoral dissertations, 21 research projects and project supplements and 4 workshops or conferences. The proposal subject matter reflects the multidisciplinary and cross-disciplinary character of the program. Awards in FY 92 and 93 encompass physical, social and cultural anthropology, visual anthropology, archaeology, sociology, political science, demography, linguistics, oral history and science education.

The individual studies focus, for example, on climate change and human adaptation in the North Atlantic region and Alaska, community involvement in natural resources management, prevention of fetal alcohol syndrome, preservation of and access to Native oral histories, documentation and recording of Native languages, the impact of northern industrial development on adolescents, comparisons of Alaskan and Siberian Native welfare, and decision and risk science relating to resource development and Arctic contamination in both regions.

The Arctic Social Sciences Program is in a unique position within NSF to address the human dimensions of global change. This multidisciplinary social sciences program is incorporated within the natural sciences framework of the Office of Polar Programs, in particular the Arctic Systems Science Program. Seven archaeological projects, including three dissertations, were supported in these two fiscal years, and they best demonstrate the productive linkages between the social and natural sciences. A multiyear North Atlantic Bioarchaeology (NABO) project is being jointly supported by the Human Dimensions of Global Change Program, the ARCSS Program and the Arctic Social Sciences Program. Information aboutboth marine and terrestrial ecosystems is being recovered from archaeological sites in Canada, Greenland, Iceland, the British Isles and Scandinavia. Other archaeological projects are being carried out in Labrador, Alaska (including Kodiak and the Aleutian islands) and Siberia.

The PRB has called on NSF to develop research related to societal needs. The Arctic Social Sciences Program was conceived of as addressing specific concerns: health and well being, community-based economic viability, and the effects of rapid social change on Native minorities. An example of an ongoing effort is the four-year project, Comparative Analysis of Social Transition in the North. This study is integrating social and health statistics in Alaska and Siberia in order to define relationships between society and health using a cross-cultural perspective. Three Native Alaskans working with northern education have received dissertation grants, and a three-year grant for research on childrearing practices has been awarded to the Northwest Alaska Borough. Future commitments of this kind will help to sustain the program and guarantee the involvement of Native minorities in science, education and economic growth.

Coordination

NSF Arctic coordination and information programs supported seven projects totaling $747,000 in FY 92 and five projects totaling $813,000 in FY 93. 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.

Department of the Interior

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

Minerals Management Service

The adequacy of technology for use in areas that have yet to yield a potential resource (but may in the future) is an elusive concept. It is difficult to demonstrate adequacy before there is a specific need for the technology or before there is significant experience with the technology to develop a useful database. The petroleum industry has shown in the past, as the search for oil and gas moved farther offshore and into the hostile regions of the Arctic, that it has the ability to conduct operations in a safe and reliable manner. Economics, not limitations on technology, has usually determined when a field can be produced. However, the development of petroleum basins in ice-infested waters will involve new concepts and technologies that will be used for the first time. Various aspects of these new technologies remain to be proven, and considerable research and development funds are being expended to develop safe and reliable concepts.

The Minerals Management Service (MMS) assesses the nature, extent, recoverability and value of leasable minerals on the Outer Continental Shelf (OCS). Within this framework, MMS has the statutory authority to regulate the exploration and development of oil, gas and mineral resources on the OCS. A major part of this effort is to ensure that such developments are safe and pollution-free. The MMS conducts a research program to determine the engineering constraints to offshore operations and to provide a formal technology base for MMS operations personnel at a time when the oil and gas industry is moving into more hostile frontier environments in search of resources.

The contact person for the TA&R program is Dr. Charles E. Smith, Research Program Manager, Technology Assessment and Research Branch, Minerals Management Service, 381 Elden Street, MS-4700, Herndon, Virginia 22070-4817.

Technology Assessment and Research Program

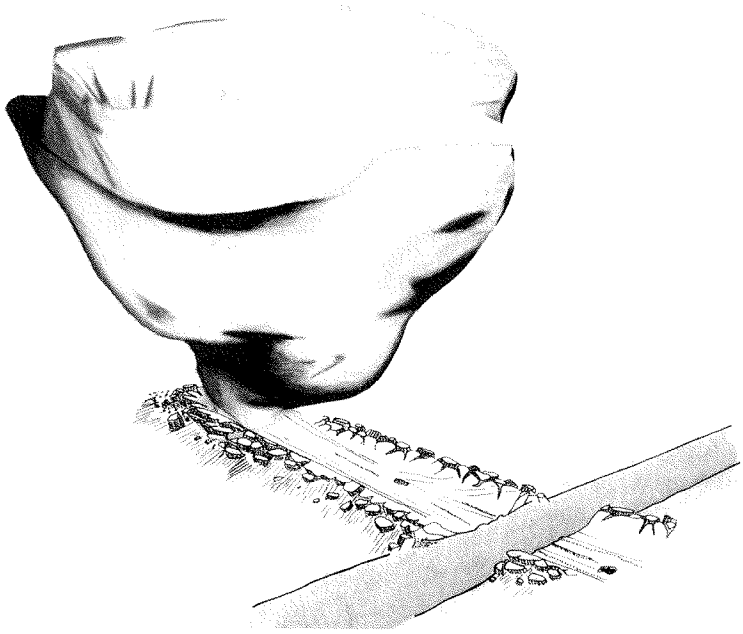
The Technology Assessment and Research (TA&R) program is a contract research program; that is, the research is not performed within the agency but is conducted by academic institutions, private industry and government laboratories. Studies are performed in cooperation with the offshore industry or with 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 allows us to understand each other's needs and eliminates 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.

	Funding (thousands)	
	FY 92	FY 93
Technology Assessment and Research	3250	3090
Environmental Studies	2165	1722
Total	5415	4812

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 much 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 seafloor 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 is funding a variety of projects to develop a better understanding of the engi-



Ice scouring of the seafloor.

neering constraints for operating in the ice-infested Arctic.

The most likely transportation mode for commercial development of oil and gas prospects in the Arctic and subarctic offshore regions will be by 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 that occur periodically through 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 the trenching and trench backfill requirements. This question arises due to an incomplete understanding of the ice below the incision scour depth. The TA&R program is funding a pressure ridge ice scour experiment, which is designed to increase knowledge of the scouring process and specifically of subscour deformation processes. This integrated, multidisciplinary approach includes:

- Selection and development of theoretical and numerical models;
- Corroboration of these models with results of small-scale, high-gravity centrifuge modeling;
- Validation of model results with full-scale observations; and
- Development of an industry-accepted design tool (a field-verified, finite-element model) complete with a set of specific design guidelines.

The TA&R program is also funding a project to develop a comprehensive report on the current state of the practice for spray-ice technology. Spray-ice technology is relatively new, and no comprehensive source of information exists on designing and building engineering structures with spray ice. Much of the information on spray ice is proprietary within a number of oil companies that have invested in the research and development of this technology. To a lesser extent, information on spray ice resides with individuals in private consulting companies who carried out some of the research for the oil companies. Over the past several years, a number of papers have been published for engineering meetings and in scientific journals on various aspects of spray-ice development and its application. This project will make a comprehensive review of the state of the art in spray ice developments and combine this information into a single publication that can be used as a guide for future considerations by the verification of designs submitted by the industry.

Another TA&R project is designed 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, engineers must address this aspect. This is particularly true for existing marine systems, where there have been dramatically increased pressures for environmentally safe and economically sound operations. It is also very important for 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.

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.

The TA&R program is also funding a project to carry out theoretical research on the fundamental mechanisms governing the deformation and

failure of sea ice, including the effects of its heterogeneous microstructure, and to develop physically based constitutive models to represent that knowledge. The theory developed from this program will provide a rational basis for addressing complex and important problems in ice mechanics, such as predicting the material and structural scale interactions during indentation and penetration that are not now amenable to analysis. The multiple crack interaction problem will be analyzed by generalizing recent theories that are capable of modeling a given population of strongly interacting "straight" cracks of specified length at different locations. In particular, the theory to be developed should be capable of describing the micromechanics of growing and winged microcracks, whose presence in compressed ice is now gaining acceptance.

Oil-Spill Research

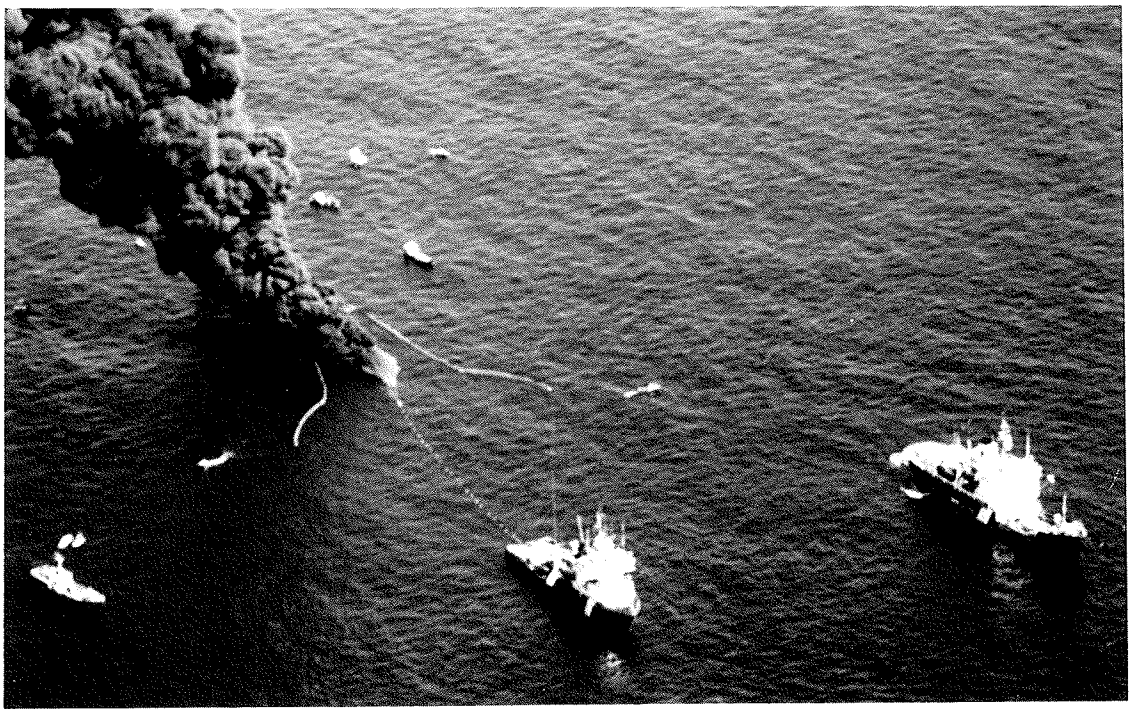
The MMS is expanding its oil-spill response technology program in view of the recent spill in Prince William Sound, Alaska. The TA&R program is striving to attain significant technological improvements or milestones in five years. Much emphasis is being placed on the burning of oil in place on the ocean surface. High burn efficiencies have been measured on both fresh and weathered crudes of various types under laboratory conditions. The TA&R program is funding several projects to develop a better understanding of the technologies required to clean up spills.

One project will:

- Continue laboratory and field evaluations of in-situ burning of spilled oil with an emphasis on the quantities and behavior of airborne and waterborne pollutants, using burning and non-burning conditions for comparisons;
- Provide field verification and mesoscale findings, with an emphasis on health and safety issues;
- Investigate the efficiencies of in-situ burning with a wide range of crude oils and products (laboratory scale); and
- Investigate and improve the efficiencies of burning emulsions in realistic wave conditions.

Two full-scale experimental burns were conducted offshore St. John's, Newfoundland, in August 1993. Participating in the experiment were 234 scientists and observers, plus ship and aircraft crews, eleven major vessels, eleven smaller vessels, three helicopters, two fixed-wing aircraft, four radio-controlled helicopters, four remote-controlled sampling boats, a tethered blimp and a remotely operated submersible. An experimental fireboom was tested to destruction, and oil was successfully burned in an unconfined mode. The burns were monitored with over 200 samplers and sensors, and 120% of the planned samples were taken. Sampling has yielded data on over 2000 parameters and substances. Data analysis and verification continues.

An In-Situ Burning Oil Spill Workshop was conducted in January 1994 in Lake Buena Vista, Florida, to present the current state of knowledge and to determine future research needs required to improve our understanding of in-situ burning. Response managers who have recently used this



Newfoundland Offshore Burn Experiment, conducted in August 1993, offshore St. John's, Newfoundland.

technique described their experiences. Two panels were convened: Environmental, Health and Safety, and Operational Implications. The panels examined the existing information and identified specific research needs that have not been met. The results of the workshop will be used by MMS to refine future research efforts to address the highest-priority issues.

The TA&R program provided funds for the operation and maintenance of the Ohmsett National Oil Spill Response Test Center. Work will continue there to define the state of the art for various oil-spill response equipment and to improve innovative oil-spill response strategies. The MMS sponsored the refurbishment of the facility, and testing resumed in June 1992. During FY 93, testing of three oil-spill containment booms and skimmer systems and one temporary storage device was completed. Final reports and videos are available.

A TA&R project is developing an airborne fluoroscanner, which is a remote airborne surveillance system that can discriminate between spilled oil and spurious targets that appear as oil to existing sensors. The system should generate a real- or near-real-time display for rapid dissemination to the responder. The current experimental system was built using a dual laser system and was extensively tested in the laboratory. Field testing is underway. This system does not have a scanning capability, which is required for operational feasibility, nor does it have all-weather capabilities, as laser energy attenuates in atmospheric moisture. It is, however, a major breakthrough in remote oil detection and identification. The nonscanning laser system was successfully flight tested at a specially constructed facility at the Canadian Coast Guard Base Petewawa in May 1993. Future work will consist of completing the development of the scanning operational prototype, which was begun in June 1993. This year's work will consist of designing a new-generation unit to include capabilities to scan and image the slick area, constructing a prototype unit to incorporate these new features, and testing portions of the prototype in the laboratory.

The TA&R program is also developing an airborne thickness sensor, which will quantify and map the thickness of oil slicks on the surface of the water. Slick thickness can vary by four orders of magnitude, with 90% of the oil occupying only 10% of the space. A spill response can be substantially increased if efforts can be concentrated on thicker portions of the slick. A laboratory instrument was altered to allow it to fly in a DC-3 aircraft. It was flight tested at a specially constructed facility at the Canadian Coast Guard Base Petewawa in May 1993. The instrument worked well on the ground, but it failed to function when it was flown. The problem was analyzed in depth and found to be the microphonics of the instrument and the nonlinearity of the laser beams (vibrations caused the lasers not to fire). Work has started to upgrade the sensor to eliminate the problems caused by vibration of the aircraft. The reconfigured prototype will again be mounted in an airplane and flight tested. Once operational problems are overcome, design work will begin on an actual airborne operational unit.

To develop an accurate understanding of the behavior and fate of spilled oil, the TA&R program is funding a study that addresses oil weathering, evaporation, water-in-oil emulsification, dissolution and photooxidation. This project will continue to study spilled oil to acquire an understanding of the long-term behavior and to develop models to predict this behavior.

A study of oil-spill chemical treating agents consists of four parts:

- Study of dispersant action mechanisms;
- Development of tests for new categories of spill-treating agents;
- Testing of new spill-treating agents; and
- Testing of new dispersant concepts.

Work will continue to develop standard-test protocols for evaluating the performance for 11 categories of chemical treating agents, to evaluate existing agents, including dispersants, and to continue the development of new oil-spill dispersants and chemical treating agents.

Alaska Environmental Studies Program

As the managing agency for the MMS OCS leasing program in Alaska, the Alaska OCS Region 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 program has increased studies to meet post-lease and monitoring information requirements. In 1993 the MMS established its second 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 will focus on environmental and socioeconomic studies that are relevant to OCS oil and gas and marine 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.

Satellite tag on a bowhead whale in the Beaufort Sea.

Endangered Species

The bowhead whale, an endangered marine mammal of importance to Native culture, makes extensive annual migrations through six OCS planning areas. Efforts to define the habitat and migrations of endangered whales and the potential effects of offshore operations on these species continued. These studies included ongoing aerial monitoring of bowhead whales in the Arctic. An annual survey report is available for the fall 1992 observations. Also, a comprehensive scientific text on bowhead whales was published in 1993. Field work for the study of the effects of production activities on Arctic whales was rescheduled from 1993 until 1994. MMS has sponsored the development and field testing of satellite tags on whales for several years. Bowhead whale tagging efforts in the Arctic in 1992 were successful; the principal investigators are analyzing data and preparing manuscripts for peer-reviewed scientific journals. A study to develop an improved biopsy technique for cetaceans was completed in 1993. The study developed a method to evaluate the transport of toxins in integumentary tissue and established baseline measures of tissue contamination in free-ranging endangered whales. It also assessed the possible ability of humpback whales to metabolize man-made chemicals and petroleum hydrocarbons that may contaminate their tissues.

Living Resources

The Marine Mammal Protection Act of 1972 established a national policy to protect marine mammal populations and to encourage their preservation to the greatest extent feasible. Seabirds, waterfowl and commercial fish species also are protected under various international agreements. A two-year study completed in 1993 utilized satellite tags applied to male northern fur seals and northern sea lions in an effort to better understand their pelagic distributions, particularly during the winter. Also, a field manual designed to minimize the effects of human–polar bear encounters near gas and oil industry activities was published in 1993.

In 1992 a report was received that detailed a multiyear, multiagency study of Kasegaluk Lagoon. The study, based on a series of low-level aerial surveys, determined the summer distribution, habitat utilization and relative densities of selected waterfowl and other avifauna. A marine mammal portion of the study focused primarily on the use of this area by beluga whales and spotted seals.

Environmental Monitoring

A cooperative agreement was established with the Environment and Natural Resources Institute at the University of Alaska Anchorage in 1993 to perform a water quality study in Cook Inlet. The preliminary results from two field sampling efforts in June and August 1993 suggest that Cook Inlet is still a relatively pristine body of water, notwithstanding its 32-year history of oil exploration, development and production. The results of this survey are comparable to those of the Cook Inlet Regional Citizens Advisory Council, which performed a similar, but less comprehensive, study in 1992.

Seabirds continue to be monitored through an intra-agency agreement with the U.S. Fish and Wildlife Service. Several Bering Sea and Chukchi Sea seabird colonies are being monitored each summer using standardized monitoring protocols developed by both agencies. Parameters monitored include numbers of birds on pre-established plots, reproductive success and feeding habits. Seabird colonies at the Diomede Islands and Cape Lisbourne were studied in 1992, along with pelagic surveys of seabirds in the Barren Islands area.

A multiyear, multiagency project to acquire, curate and analyze marine mammal tissues continued through 1993. The study archives tissues for future analyses and is sampling baseline levels of chemical contaminants in tissues to monitor any increases that might be associated with future oil and gas drilling and production.

Social and Economic Studies

The Alaska OCS Region's social and economic studies are unique within MMS. Because subsistence activities are important to many aspects of Native societies in Alaska, the study of the effects of offshore petroleum development goes beyond conventional economic considerations. Case studies and sociocultural and socioeconomic update studies define the social environment and describe

the variables that may change with new OCS activities. Recently completed studies have documented the importance of subsistence activities in the Bristol Bay region and on the North Slope. A recently released report on the NANA region describes the economic importance of mining to the region and shows the structure of the negotiated agreements on issues such as local hire and subsistence activities between a regional Native corporation and a multinational mining corporation. A great deal of research has been conducted on the consequences of the *Exxon Valdez* oil spill for communities in the Gulf of Alaska region as part of MMS's social indicators study. Several volumes of results have been published. In addition, the MMS is engaged in a cooperative agreement with the Subsistence Division of the Alaska Department of Fish and Game to study the long-term subsistence, social and cultural consequences of the spill for a sample of 19 communities in Alaska.

Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) conducts research in the Arctic in order to generate information that will help it 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. Research addresses the effects of development, disturbance, hunter harvest and natural environmental cycles on 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 the conservation of living resources. 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 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 early 1993 Fish and Wildlife Service research programs were proposed for transfer to the National Biological Survey (NBS), a new bureau constituted by combining the biological research functions of a number of Interior Department bureaus. This transfer became effective with passage of the FY 94 Appropriations Act in November 1993. All FWS research activities reported here have been transferred to the NBS, together with a few research-related activities formerly performed by operational units of the FWS. Future reports will reflect these changes.

Biological research in the Arctic is difficult, given the harsh conditions, frequently inaccessible habitats and often wide-ranging movements of Arctic biota. Since it has often been necessary to develop new methods of obtaining information, some of the most advanced technologies have been developed for, or first applied to, research in the Arctic. Satellite-linked biotelemetry and 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.

	Funding (thousands)	
	FY 92	FY 93
Migratory Birds	1970	1970
Marine Mammals	1450	1459
Wildlife Ecology	1100	1100
Fisheries Research	388	389
Cooperative Research	350	350
Total	5258	5268

Additional details (including copies of technical publications) related to the migratory bird, marine mammal, wildlife ecology and fisheries research programs are available from the Alaska Fish and Wildlife Research Center, National Biological Survey, 1011 East Tudor Road, Anchorage, Alaska 99509. For further information on the Arctic National Wildlife Refuge studies, contact the 1002 Study Coordinator, U.S. Fish and Wildlife Service, Region 7, 1011 East Tudor Road, Anchorage, Alaska 99509. Additional information on cooperative research can be obtained from the Division of Cooperative Research Units, National Biological Survey, 1849 C Street, N.W., Washington, DC 20240.

Migratory Birds

Migratory birds of the Arctic regions of Alaska include substantial populations of Arctic-nesting geese and swans, large populations of several species of ducks, several populations of shorebirds and some of the greatest known concentrations of breeding seabirds. The focus of FWS research is to learn more about the dynamics of these populations and to assess the effects of various human activities on them. A few populations of migratory birds in the U.S. Arctic have declined to levels that cause concern, while others remain abundant. Certain species that remain abundant in the Arctic have become depleted in temperate regions. Special attention may be paid to populations that are of concern, either locally or on a continental basis, but research attention is directed to all populations of migratory birds. For those for which precarious or declining populations do not cause immediate concern, effort is directed toward predicting the effects of known or anticipated changes. The primary factors affecting geese, swans and ducks are

Rock sandpipers at Izembek Lagoon on the Alaska Peninsula.

believed to be harvest, losses to predator populations that may have been abetted by human activities, and disturbance on staging areas. Shorebirds breed and stage in tundra habitats that are extremely vulnerable to disturbance of land and vegetation. The huge seabird populations depend on both nearshore and offshore marine fishes, which vary greatly in abundance in response to changes in ocean currents and other factors. Depletion of fish stocks by commercial fishing may alter the delicate balance between need and availability of food for any of the 40 species of seabirds occurring in Alaska.

The Pacific black brant is a small Arctic-nesting goose that has shown long-term population declines. Continuing banding studies have shown that most birds captured in Alaska come from breeding colonies on Wrangel Island, Russia, or from northern Canada. Satellite imagery was used to distinguish habitats of high value to migrating brant. Helicopter flights associated with oil production activities pose a potential disturbance to resting brant, and research continued on the kinds and degrees of disturbance resulting when concentrations of resting brant are flushed by helicopters.

Satellite telemetry permitted the identification of important wintering areas for Arctic-nesting white-fronted geese in Mexico, and a series of related studies examined issues surrounding the conservation of the Laguna Babicora and other important Mexican wetlands that may be essential for maintaining populations of these geese.

Lesser snow geese feed on tundra vegetation on the Arctic National Wildlife Refuge, and research continued to determine the kinds and amounts of tundra necessary to meet snow goose habitat requirements. Observations of feeding on vegetation and the distribution of preferred foods provided data used in a model of habitat requirements. The limited distribution of preferred foods, the high calculated food requirements (2,900 tons for 300,000 geese) and the time (more than two years) required for regeneration of vegetation after feeding form the basis for determining the overall habitat needs for the population.

The northern pintail is known as one of the most abundant species of dabbling ducks and one of the most sought-after by hunters. The breeding range includes most of the northwestern quarter of the North American continent, with the prairie potholes of Canada being the most productive breeding area. Populations have declined seriously: continental breeding populations have declined by more than 60% over the past 35 years. Part of the decline is believed to result from permanent changes in the central prairie regions of the U.S. and Canada, including wetland drainage and intensified agriculture. Also contributing to recent declines has been a prolonged drought affecting much of the same area through the late 1980s. By 1990 it was believed that there was no significant reproduction of prairie-breeding pintails; northward-migrating ducks proceeded all the way to the Arctic, having failed to find suitable breeding areas along the way. Arriving later than their normal time to initiate nesting and failing to find suitable habitats, they appear to remain, without breeding, in Arctic regions until it is time to begin the southward migration. It is believed that the only significant breeding of pintails during the late 1980s and early 1990s occurred in Alaska. Research on pintails breeding in Alaska was considered essential to explain factors that might be affecting populations in other areas.

That research has indicated that ducks arrive in the Alaska breeding areas with good fat reserves, indicating that food resources along migration routes are important for the initiation of nesting. It appears that large percentages of breeding attempts in Alaska pintails may be balanced somewhat by declining nesting success, keeping the overall productivity relatively constant. Survival of adults appeared to be good. Related research conducted by the Northern Prairie Wildlife Research Center in Jamestown, North Dakota, and Dixon, California; the National Wetlands Research Center in Lafayette, Louisiana; and the Patuxent Wildlife Research Center in Laurel, Maryland, examines breeding biology in the prairies, wintering ecology and movements of pintails in a coordinated attempt to understand the remarkable decline of this species on a continent-wide basis.

A relatively large portion of past research on shorebird populations focused on the ecology of the bristle-thighed curlew, a large species of

sandpiper in a group that includes several rare and elusive species. The world population of bristle-thighed curlews appears to be less than 7000 individuals, and the habitats they occupy are vulnerable to disturbance. Historical population levels are unknown, but reports from wintering islands in the tropical Pacific suggest either significant declines or major shifts in winter distribution. The population that was studied breeds on the Seward Peninsula, stages on the Yukon Flats, and may winter on any of a number of Pacific islands. Birds were banded on the breeding grounds, and studies of habitat use, food availability, timing of migration and proportion of young in the population were examined on breeding and staging areas. Detailed studies on nesting examined territoriality, the roles of parents, the behavior of the young and major causes of nest loss. The abundance of various fruits used by curlews on staging areas were tracked seasonally to determine the role of food availability in the timing of migration. Wintering-ground studies were conducted on Laysan Island in the Hawaiian Archipelago, where a marked population of about 250 birds was monitored.

Breeding studies indicated that the nesting area is restricted to the west-central portion of the Seward Peninsula. There were high rates (approximately 90%) of returning birds banded the previous year, indicating good overwinter survival, at least in the portion of the population studied on the breeding grounds. Blood samples were taken to assess the genetic homogeneity of birds nesting on the Seward Peninsula and another area in the Andreafsky Wilderness. Birds marked on breeding areas in the northern Seward Peninsula were not found on Laysan Island; those marked as wintering birds on Laysan were discovered to breed in the southern part of the breeding range. It is believed that the breeding birds under study winter on islands farther south. Population estimates have been refined, and there were estimated to be 3400 breeding pairs in 1991. There is concern that birds undergoing the flightless molting period in winter may be vulnerable to predation on those islands where there are populations of introduced predators. Work in the Pacific Islands was completed and awaits final analysis of the data.

Polar bear tagged for radio-telemetry tracking.

Marine Mammals

The FWS 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 necessary 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 development on areas that may be essential for the stability of populations.

Studies of polar bear movements have been undertaken for several years, using conventional and satellite-linked radiotelemetry. The objective of this research has been to determine the extent to which local populations may be isolated from one another or may mix with larger regional populations. If populations are isolated and relatively distinct, overexploitation or excessive losses from other causes might have permanent consequences in the area affected. If, on the other hand, polar bears undertake long movements and mix freely over large areas, local depletion might be less important, but any effects could have international consequences. Results indicate that polar bears followed over relatively short periods tend to stay in reasonably distinct areas, but those tracked over the longer term may travel great distances. Bears first located in the Beaufort Sea may move to the Chukchi or even the Bering Seas, indicating that there is mixing of populations; 80% of female polar bears that were in the Chukchi Sea when they had transmitters attached have been found to den in Siberia. A growing base of data on polar bear movements has tended to support the conclusion that movements of bears are extensive and there is considerable mixing of populations. Examination of a variety of molecular and biochemical indicators has attempted to detect the existence of distinct subpopulations, without success; these results are not taken

as definitive, however, because additional development and refinement of techniques is judged to be necessary.

Long-term research on polar bear reproduction seeks to understand recruitment in polar bear populations and to relate reproductive success to environmental factors. Female bears are fitted with radio collars and followed to denning sites. Observations during and following occupancy of dens, including re-sighting bears that may be accompanied by cubs, become part of a growing base of information on polar bear reproduction. Observations of well over 100 polar bear dens have documented denning sites on drifting pack ice, on shorefast ice and on land, primarily offshore islands. Only a minority of dens are located on land, but there are increasing indications that these sites are more productive than other sites. Moreover, bears that den on any one type of substratum in one year tend to select the same type of substratum for subsequent dennings. This information may be useful in developing safeguards should coastal areas be affected by petroleum exploration or development. One instance in which a female bear had a den close to an ice road used in petroleum production indicated an unexpected tolerance for the closeness of human activity.

Research on the Pacific walrus seeks to develop reliable methods of census that can be used by U.S. and Russian biologists to monitor population status. Walruses are normally observed when hauled out on land, and aerial surveys are used to count hauled-out walruses over large areas. The portion of the population that may be hauled out at any given time is not known, however, and any accurate census must account for animals that are in the water and therefore not recorded in censuses. A major goal of cooperative U.S.–Russian research has been to standardize existing census methods and to evaluate their ability to provide population trend information. Recent studies have sought to:

- Develop effective doses of immobilizing chemicals to use in tagging walruses;
- Understand haul-out behavior to better relate aerial counts of hauled-out animals to total population estimates;
- Develop models that relate the proportion of hauled-out walruses to environmental factors, such as barometric pressure, tides and wind; and
- Develop models that relate ice-resting walruses in the Chuckchi Sea to water mass, water depth, sediment loads and ice cover.

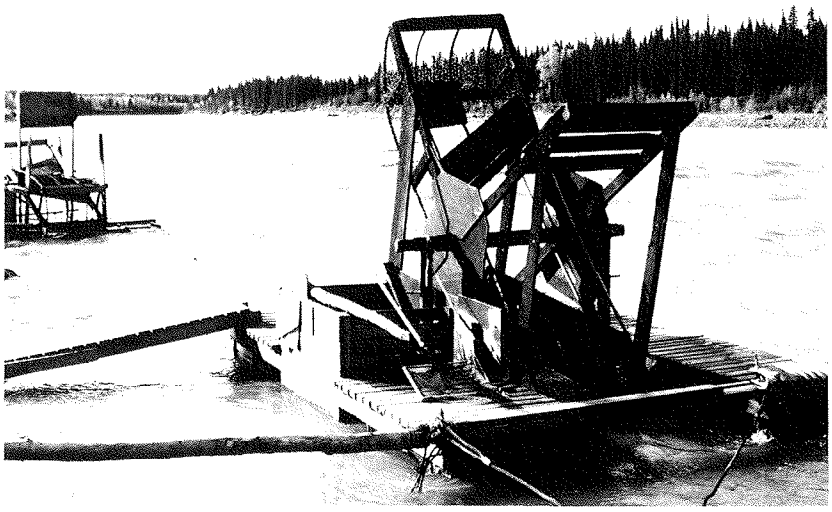
Basic techniques for conducting studies have been successfully worked out, but correlations of walrus behavior with environmental factors have not proven sufficient to provide precise population estimates.

Walruses hauled out on shore, northern Alaska.

Wildlife Ecology

Research on wildlife ecology on FWS lands centers on the Arctic National Wildlife Refuge and a variety of other National Wildlife Refuges on which there are management issues. Basic information on the ecology of species of management concern and specialized information on the effects of development are sought to understand and predict the effects of potential petroleum exploration and development. 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 open to potential petroleum exploration. Other 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, ample forage for calves 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 are ideal on the Arctic coastal plain, where predators are not abundant. Also, they are thought to be safer there, because the flat, open topography permits the caribou to sight predators at relatively great distances. Forage is also generally good, but its quality and abundance depends on the timing of annual weather



Salmon wheel on the Yukon River.

events. 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 migrate toward the coast to seek relief from insects, which reach great abundance in the short summer. The use of specific areas by the PCH have been documented, with the intent of evaluating the use of the 1002 Area and its 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 studied is lower than that observed in the PCH, but the reasons for this are still unknown. Also, the CAH has shown a period of growth despite apparently poorer reproduction; the population was estimated to be 13,000 in 1983 and 19,000 in 1991.

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 seems to have stabilized at 300–400 adults. Continuing research focuses on movements, habitat utilization and status of the population.

Fisheries Research

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 research has been to determine what portion of harvested populations are of U.S. and Canadian origin, as a basis for allocating the harvest. Because the U.S. harvest is of spawners ascending the river, 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 different species and for fish populations spawning in different parts of the system. At any given time the salmon run at a particular point will be composed of different proportions of different stocks. Using a variety of biochemical and molecular techniques (including mitochondrial and nuclear DNA techniques) to distinguish stocks, studies were undertaken to determine the composition of salmon stocks at different times and places. As a result of those studies, it is now possible to estimate the percentage of chum salmon stocks that originate from U.S. and Canadian waters. Techniques that permit discrimination of chinook salmon stocks are still under development. 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 December 1991. Continuing research has tended to verify and increase the precision of earlier estimates.

Cooperative Research

The FWS 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 as a single research center headquartered in Washington, D.C., but units have traditionally had a great deal of latitude to respond to local issues and needs in choosing research projects. The major goal of the cooperative research program is to provide specialized graduate-level training for fish and wildlife biologists. This training is usually provided by joint participation in research projects by faculty and students. The FWS 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 units, for example, comes from the Alaska Department of Fish and Game, the Canadian Wildlife Service, other bureaus of the Department of the Interior (including the U.S. 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 with 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 survival rates of peregrine falcons in Alaska and of the status and ecology of an island species of vole proposed for listing. Waterfowl investigations included studies of brant, lesser snow geese and pintails that were conducted in cooperation with related studies at the Alaska Fish and Wildlife Research Center. Research on mammals also included work related to Alaska Fish and Wildlife Research Center studies of muskoxen, caribou and walrus, as well as unrelated studies of black bears in interior Alaska and reindeer in the Beringian Heritage International Park. Research on nongame mammals included the development of a small-mammal monitoring program at Denali National Park.

National Park Service

The National Park Service (NPS) manages areas under its administration to ensure the continuation of geological and biological processes unimpaired by adverse human activity and also the continuation of many human activities, including sport hunting and subsistence harvest, which can potentially impair these resources and processes. The areas are also vulnerable to influences originating outside them, such as air pollution, oil spills and consumptive uses, including reindeer grazing, mining and commercial fishing.

Although the parks and preserves are relatively large, they still fail to protect complete ecosystems, and as a result they require management intervention. Park management depends on the availability of resource information obtained through research and monitoring. The goals of natural resource research are to:

- Identify and quantify the natural resources at risk;
- Examine and understand basic ecological processes and interactions; and
- Determine and evaluate influences from human activities.

The goals of cultural resource research are to:

- Acquire and maintain an accurate park information base;
- Identify and evaluate cultural resources;
- Develop strategies for treating, protecting and interpreting cultural resources;
- Involve park-associated Native groups in research and resource management;
- Foster international and interagency coordinated research of Beringian natural and cultural resources; and
- Develop ethnographically sensitive approaches to cultural and natural resource management.

The goals of monitoring are to detect and measure the results of natural and anthropogenic causes of change.

	Funding (thousands)	
	FY 92	FY 93
Natural resources	1065	1373
Cultural resources	1300	1305
Total	2365	2678

Natural Resources

A major study effort for several years in Alaska has been research on large predator–prey relationships. One of these studies, which has been ongoing in Denali National Park and Preserve since 1987, is 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. During the study period the wolf population increased from 4 per 1000 km^2 to about 7 per 1000 km^2 and then declined to 6.2 per 1000 km^2. The caribou herd declined from 3500 in 1987 to 1700 in 1993. Calf recruitment has been very low for five years in a row, and in 1993 only two calves out of 40 born to radio-collared cows survived.

Also in Denali National Park and Preserve there is a related study of grizzly bear home range and movement patterns. The objectives are to determine the bears' annual home range and movement patterns, the habitat used by bears, the amount of time spent in caribou calving areas, foraging behavior during the calving season, and alternative motivation for male bear movements. Radio transmitters were placed on 30 bears in 1991 and 1992. Females comprised 62% of the adults and 31% of the independent subadults. The average adult female age was 17 and ranged from 7 to 24. The mean adult male age was 15. The average litter size was 2.4 cubs at the time of den emergence. All

females remained at higher elevations than the males during the caribou calving period. The old-age structure of this population is unique, probably because of an extended period of high subadult mortality.

Another study related to predator–prey relationships was initiated in the 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. Factors influencing the survival of caribou calves will be examined by testing whether calving distribution, habitat selection and calf condition influence cause-specific mortality rates of calves. In the winter of 1993, radio-collared caribou were widely and atypically dispersed, but cows returned to historic calving grounds in the Wrangell Mountains in the spring. A total of 65% of 431 cows examined during parturition surveys indicated pregnancy, and 26 of 37 radio-collared cows produced calves in 1993. A total of 38 of 39 radio-collared calves died between 25 June and 16 July. The herd composition averaged 8.8 calves per 100 cows in late June and 3.6 calves and 38 bulls per 100 cows in late September.

Since 1988, NPS has been investigating reproduction of the golden eagle population in Denali National Park. Annually, 60–80 nesting pairs were monitored to evaluate patterns in reproductive performance and determine sources of annual variation. Fledgling success varied nearly four-fold, from 0.23 fledglings per nesting area surveyed in 1992 to 0.88 in 1988. Most of the variation in reproductive performance in this population can be attributed to changes in the proportion of territorial pairs that successfully reared broods, with the number of young per brood accounting for the remainder of the variation. Relationships between weather patterns and prey abundance are being investigated as explanations for the changes in productivity that were observed.

Examining female wolves by ultrasound for pregnancy and number of fetuses at Yukon–Charley Rivers National Preserve, Alaska.

A study is being conducted in Yukon–Charley Rivers National Preserve to determine the abundance, population structure and effects of harvest on marten populations. Marten account for the largest single contribution to fur production in Alaska, with harvests yielding approximately $3 million annually. Because most marten studies in Alaska and the Yukon Territories of Canada have not focused on marten population biology, the objectives of this three-year study were to determine the summer population density and structure annually and to evaluate the effects of trapline spacing on the vulnerability of marten to harvest. The methods included mark–recapture estimates of radio-collared marten, used to determine the summer population density and structure, and necropsies on nearly 1000 carcasses collected from trappers over the study period, used to determine the sex–age structure of the harvest and fecundity patterns.

The NPS, in cooperation with the Fish and Wildlife Cooperative Research Unit at the University of Alaska Fairbanks, is studying the spawning characteristics of Dolly Varden char in the Kugururok River, Noatak National Preserve. This three-year study was initiated in 1993 to provide some answers to the complex life history of the northern form of Dolly Varden, which will allow agencies to better understand and manage this unique and important resource. Partial weirs captured 136 upstream-migrating char, of which 39 were considered fall spawners and 5 were recaptures from this study. A preliminary report has been made but without complete data analysis.

An inventory and monitoring project was conducted on the water quality in 10 lakes in Gates of the Arctic National Park and Preserve in mid-July 1992 and 12 lakes in July 1993. Each lake was visited for about two hours, and sampling was conducted from the pontoons of an anchored float plane. Standard limnological measurements were made, along with reactive phosphorus, nitrate and nitrite nitrogen, ammonium nitrogen, sulfate, chloride, alkalinity and turbidity. Samples were analyzed for trace metals, chlorophyll *a* as an estimate of biomass, and zooplankton. Data analysis to date is only provisional.

Research to develop long-term inventory and monitoring protocols for national parks characteristic of the Arctic and subarctic was initiated in 1992 in Denali National Park and Preserve. Pilot efforts are focusing on experimental design questions regarding areal stratification and monitoring technologies. A watershed–ecosystem approach has been expanded beyond hydrological and depo-

sitional considerations to include a suite of integrated measures linking key aquatic and terrestrial biota, environmental variables or defined ecological processes to detect and track environmental change. A core measurement program embraces principles of the hydrological cycle, hypotheses surrounding global climate change and biological interactions of organisms occupying intermediate, but poorly studied, positions in Alaskan food webs. Monitoring activities are centered on data collection in or nearby permanent vegetation plots located in habitats defined by their plant cover and soil characteristics.

In 1989 a research project was initiated to develop and test methods to promote the restoration of streams and riparian plant communities that have been disturbed by placer mining. This project, being conducted in Denali National Park and Preserve, addresses a serious problem throughout Alaska where the structure and function of riparian ecosystems have been severely disturbed. In 1988, spoil outside the stream channel was recontoured with heavy equipment, and mining debris was removed. In 1989, experimental planting of alder and willow was initiated with various experimental designs and treatments. After five years the rate and pattern of natural succession varied among different types of regraded spoil. The total nitrogen and the proportion of sand relative to silt and clay were major soil factors related to the rate of succession. The alder plantings had over 90% survival and were vigorous even on harsh sites. Alder promoted the recovery of riparian plant communities and stimulated the growth of feltleafed willow.

The role of Arctic ecosystems as sources or sinks of carbon dioxide, and their rate of sequestration or loss, may be affected by interagency fire management strategies in Alaska. A study being conducted in Bering Land Bridge National Preserve is examining whether the interagency fire management strategies are increasing atmospheric carbon dioxide or whether there are compensating mechanisms that minimize the effect of fire management policies on the release of carbon to the atmosphere. Data reduction to date indicates that the youngest stands lose approximately 180 g C/m^2 each season, decreasing to 115 for stands that are 22 years old and somewhat less for stands of unknown age. Past work showed that with respect to new growth, recently burned tundra stands were much more productive. However, the large areas of intertussock tundra that are completely denuded of plant material, a change in albedo (and therefore an increase in soil temperature) and the large amount of dead material resulting from the fire all result in high rates of respiration for recently burned stands, resulting in a loss of carbon. For all stands measured, the largest loss of carbon was from the intertussock areas, and this loss was the greatest in the recently burned stands. The magnitude of carbon loss compares favorably with extensive measurements made on the North Slope of Alaska, where tussock tundra was found to lose 155 g C/m^2 each season. Daily carbon flux values on the Seward Peninsula compare with values measured in Iceland, four sites in western Siberia, and six sites in the Kolyma Lowlands of the Far Eastern part of Russia.

Cultural Resources

In recognition of the important role that humans have played and continue to play in Alaska's ecological systems, and to preserve and foster the appreciation of the cultural resources in its custody through appropriate programs of research, treatment, protection and interpretation, the National Park Service has built a strong program in the social sciences. This program includes archeological, historical and ethnographic studies. The latter discipline reflects the Service's growing awareness that almost all park areas are part of the homelands of living Native Americans. The links between particular park areas and Native American groups is often strong; this is especially the case in Alaska, where subsistence and other traditional uses of park lands and resources are everyday activities for one of the largest Native populations in North America. Research projects helping to achieve these goals include:

- Ethnographic and archeological overviews and assessments that compile and evaluate existing cultural resources information and expose critical research and resource management needs;
- Development of computerized databases and GIS capabilities;
- Cultural resource identification and evaluation studies that help build park information bases, define the significance of resources and recover information from threatened and impacted resources;
- Integrated, multidisciplinary research that provides understanding of past and present human–land–resource relationships and supplies information essential for sound management decisions in both cultural and natural resources;
- Research that includes active Native participation and involvement that enables development of inventories of ethnographic sites, Native Alaskan place names, and traditional and current resource use, and ensures that

NPS plans reflect the concerns and needs of park-associated Native groups; and
- The Shared Beringian Heritage Program, which promotes interagency and international cooperation in multidisciplinary Beringian studies.

Shared Beringian Heritage Program

The multiyear, multidisciplinary Shared Beringian Heritage Program focuses on bilateral U.S. and Russian studies in ethnography, archeology, historical architecture, geology, ecology, paleoecology, paleogeography and wildlife biology in the Bering Strait area. This integrated research has both interagency and international participation and has been stimulated by planning for the proposed Beringian Heritage International Park. The research involves close collaboration between cultural and natural scientists in both the U.S. and Russia as well as northern Native people from both nations. The second and third phases of the program continued in 1992 and 1993 in the Bering Land Bridge National Preserve.

Archeological site that is subject to destructive erosion from the river and from oceanic storm surges, Bering Land Bridge National Preserve, Alaska.

One project, in its fourth and final year, integrates studies of the human ecology, ethnohistory, ethnoarcheology and historic architecture of early 20th century Inupiat reindeer herders in the Bering Land Bridge National Preserve. Investigations of historic sites associated with the Barr family, who acquired reindeer in 1905, examine how the reindeer herding economy was integrated with the subsistence economy of the early 1900s. Archeological research has focused on four historic sites utilized by the Barr family: a winter village, a fall fishing site, a summer camp and a reindeer corral. Historic architectural research has been centered on cache and semisubterranean house structures at the winter village. Gideon Barr's detailed knowledge of construction techniques, village layout, occupants and their relationships, and site activities, coupled with ethnoarcheological data, enabled the production of reconstructive drawings of the village. This documentation represents the first detailed application of NPS Historic American Buildings Survey standards for recording historic Native architecture in Alaska.

Archeological excavations conducted at the circa 1800 A.D. eroding village site known as Killak are extremely important because sites representing this time period are largely absent from the coast because of erosion. This time period is especially significant in studying precontact culture and culture change because it represents the time before the caribou collapse of the late 1800s, before the introduction of reindeer herding, before commercial whaling in the Bering Strait (and the subsequent decline of sea mammals), and before the widespread availability of European manufactured goods. The archeological investigations at Killak and the ethnoarcheological excavations at reindeer herding sites are providing material data that will enable the application of direct historic analogy in archeological investigations of successively earlier sites linked to the Barr family and their ancestors.

Several projects have emphasized Native partnerships. A six-week science and teaching laboratory was established in Shishmaref to interest and train local people in the Beringian research program. A program to encourage village-initiated social and natural science research conceived, designed, conducted and completed by village residents includes an oral history of community duck and seal hunting, food preparation and Eskimo games (Shishmaref Native Corporation); an oral history project on place names and place name legends (Wales Native Corporation); video documentation of the construction of a traditional ugruk (bearded seal) hunting boat, directed by elders (Kivalina IRA Council); an oral history documentation of winter hunting techniques, particularly on sea ice (Diomede IRA Council); and an oral history project on plants, animals, tools and place names (Brevig Mission Traditional Council). The goals of the proposed Beringian Heritage International Park and the scientific research conducted under the Heritage Program are being documented for a popular audience in a videotape and a book, *Quamani; Up the Coast, In My Mind, In My Heart*, co-authored with a Shishmaref resident.

Several Russian–American collaborative research projects are underway. A comparative anthropological study initiated in FY 93 is docu-

menting early 20th century linguistic, social, ethnic and cultural networks between Native people of the northern Seward Peninsula and the northern Chukotka Peninsula. Another project is compiling species lists of birds, mammals, fish, vascular plants, lichens, mosses and liverworts in Russian, English, Siberian Yupik and Inupiaq from field data and publications as a foundation for comparing Central Beringian biota. The Russian–American International Panarctic Biota initiative conducted extensive botanical research in the northern Seward Peninsula for a third year; the primary objectives include a botanical database in a standardized format for use in parks; a checklist for taxa; complete monographic descriptions of flora for comparison on a continental scale; complete definitions of geographic ranges; systems of biodiversity monitoring; a standard geographical basis for the analysis of Arctic biota; identification of areas for inventory and monitoring; and guidelines for database organization and analysis of floristic data. The Shared Beringian Heritage Program contributed funding to an NSF-supported study of the late Cenozoic history of the Bering Strait region, a collaborative Russian–American three-year effort to correlate the maritime transgressive and glacial events recorded on both sides of the Strait. Joint field research was conducted on the Chukotka Peninsula, Nome, the Baldwin Peninsula, Barrow and St. Lawrence Island by scientists from the Complex Scientific Research Institute, the Geological Institute of the Russian Academy of Science, the Pacific Institute of Geography–Russian Academy of Sciences, the University of Alaska Fairbanks and the University of Massachusetts. The Shared Beringian Heritage Program also contributed support to the Smithsonian Institution for three years to develop "Crossroads Alaska," a traveling exhibit of 300 artifacts from the Smithsonian, Alaska and Siberian museums. Finally, the process of designing and producing a Russian–English dictionary of archeological terms was begun in 1991 by a committee of archeologists from the University of Alaska Anchorage, the Alaska–Siberia Research Center, the University of Pennsylvania, Washington State University, the Russian Academy of Sciences and the NPS.

Northwest Alaska has been the scene of dramatic climatic changes over the past several million years, such as the emergence and submergence of a land bridge that extended over 1000 km at its maximum. The landscape history component of the Shared Beringian Heritage Program has five major projects. Tephrochronology research has centered on the development of a comprehensive stratigraphic, chronologic and geochemical database on the tephras occurring in the Bering Land Bridge National Preserve from 7,000 to 200,000 years ago. A second project is investigating the paleoenvironment of the land bridge during the last glacial period by excavating the 17,000-year-old ground surface preserved under the Devil Mountain tephra. Surficial geologic mapping of the Bering Land Bridge National Preserve has been undertaken in order to understand the evolution of the landscape, providing the context needed to understand the distribution of archeological, paleontological and modern biotic communities across the landscape. A third project is focusing on the geomorphology of the dynamic coastline of the northern Seward Peninsula, which is a proxy record of sea level and climate history and has been the subject of intensive geomorphological and geoarcheological research for several years. Finally, studies of thaw lakes and freshwater wetlands have been undertaken in order to understand thaw lake deposits, which are rich in well-preserved organic remains dating from as early as 100,000 years ago through the Holocene and are exposed in the coastal bluffs and other areas of the Bering Land Bridge National Preserve.

The Shared Beringian Heritage Program also supports research on reindeer and gyrfalcons. A three-year study of the productive dynamics of range vegetation and related reindeer productivity is closely tied to the ethnoarcheological study of the history and human ecology of reindeer herding on the Seward Peninsula. The objective of the project was to define and develop techniques that will enable description of critical habitat requirements of reindeer on both the Seward and Chukotka Peninsulas and to relate this to animal productivity. This research has been conducted in close cooperation with the Native Reindeer Herders Association, Nome, Alaska, and with individual herders as participants. Gyrfalcon research, entering its third year of funding under the Shared Beringian Heritage Program, is focusing on monitoring radio-tagged gyrfalcons and will include molecular genetic studies to examine the genetic interaction between Alaska and Siberian populations.

National Archeological Survey Initiative

A separate major program, funded under the National Archeological Survey Initiative, is also illustrative of a broad interdisciplinary and cooperative approach. The Survey Initiative is a 20-year, system-wide program designed to inventory, document and evaluate archeological resources on park service land. In FY 92 the Alaska Region began the first year of a five-year archeological survey project funded under this initiative, focused on the coastal lands in southcentral and southeastern Alaska National Parks. The first year of the

project began a cooperative effort between the NPS and the U.S. Geological Survey with emphasis on compiling and assessing existing archeological, ethnographic, geomorphological and paleoenvironmental information for Kenai Fjords National Park. A separate component of this project began in FY 92 in Sitka National Historic Park, where archeologists enlisted the combined assistance of the Sitka Tlingit tribe, ethnographers, archival historians and historical landscape architects to gather and interpret evidence relevant to the land use history of the park area. In FY 93, researchers from the NPS and the U.S. Geological Survey documented the cultural resources, coastal geomorphology and Late Holocene glacial history of the eastern Kenai Fjords National Park.

Noatak Geology and Archeology

The National Park Service has initiated a reconnaissance survey of the 6.6-million-acre Noatak National Preserve. In 1992 the survey focused on geomorphological features relating to the late Pleistocene "Glacial Lake Noatak," and over 100 new archeological sites were discovered.

Archeological Overviews and Assessments

Archeological overviews and assessments were initiated for Wrangell–Saint Elias National Park and Preserve and completed and published for Katmai National Park and Preserve. The results of these projects are the publication of a document that compiles, reviews and evaluates all existing archeological data for a park and its immediate vicinity. The results include an up-to-date park resource information base, as well as recommendations and directions for future research and management of the resource.

Cultural Resources Mining and Monitoring Program

Now in its seventh year, the Cultural Resources Mining and Monitoring (CRMIM) program has documented well over 300 sites in Alaska's National Parks. The program was originally established to inventory and evaluate archaeological sites on all valid mining claims within Denali National Park and Preserve, Wrangell–St. Elias National Park and Preserve, and Yukon–Charley Rivers National Preserve. Since 1989, when the initial inventory phase of the project was completed, the duties of the program have been expanded to include a number of other mining-related activities on park lands, as well as coverage of five other parks and preserves in the region, including Gates of the Arctic, Bering Land Bridge, Kenai Fjords, Katmai and Lake Clark. Each field season, multi-disciplinary crews of archaeologists, historians and architects survey, record and monitor sites on and around mining claims and abandoned mineral lands. Crew leaders compile detailed site reports, complete with photographs, slides, maps and frequently architectural drawings. A comprehensive, four-volume CRMIM report is currently being written.

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 Survey, which will be responsible for most of the Department's biological research (including BLM's).

	Funding (thousands)	
	FY 92	FY 93
Minerals (ANWR)	10	10
Natural Ecology	1020	1175
Cultural Resources	289	168
Pipeline Monitoring	350	500
Fire Control	350	350
Mining Administration	260	250
Total	2279	2453

Waterfowl and Other Birds

The relationship between 20 limnological characteristics and waterfowl brood use was observed on 104 wetlands in the Lower Innoko River area in Alaska in 1990 and 1991. The work was in cooperation with the University of Alaska Fairbanks

and was completed in FY 93. It tested whether wetland morphology, hydrochemical characteristics, primary productivity and aquatic invertebrate concentrations affected the density of duck broods found on wetlands. The results suggested that brood use by all species of ducks was influenced by wetland temperature, potassium concentration and shoreline length. Use by dabbling duck broods alone was related to water color, temperature and shoreline length. Concentrations of chlorophyll *a*, biomass of aquatic invertebrates and shoreline length were associated with diving duck broods alone. On a density basis (broods per meter of shoreline), total phosphorous and chlorophyll *a* concentrations most strongly influenced brood use. These associations suggest that large, productive, darkly stained wetlands with low to moderate salinity and abundant aquatic invertebrates are used most by duck broods.

Similar observations of wetlands surrounding the drainages of the Kvichak and Alagnak Rivers of Bristol Bay compared the same 20 wetland characteristics to waterfowl and brood use in 1992 and 1993. The final results from 153 wetlands are not yet available, but preliminary analyses suggest a relationship between wetland pH, conductivity and water color. Large, shallow wetlands with abundant emergent and submergent aquatic vegetation along shorelines were most attractive to waterfowl.

Waterfowl brood surveys were conducted on public lands in the interior region of the Seward Peninsula, Alaska, during 1989–1993. Production was monitored for four consecutive years on McCarthy's Marsh and for three consecutive years in the Upper Kuzitrin River Basin. The Bering Land Bridge National Preserve provided field assistance in the Kuzitrin River study area. The estimated production in McCarthy's Marsh was 4691 ± 516 ducks in 1992. The estimated production in the Kuzitrin Flats was 3992 ± 559 in 1992 and 4888 ± 1857 in 1993. Northern pintails and greater scaup were the most common breeders. The results from 1992 were published as a progress report, and a final report is in press.

Waterfowl brood surveys were conducted in the Pah River Flats, Alaska, during July 1993. Although spring flooding was extensive, duck production was greater than estimates from 1989. A large portion of the study area had burned in a lightning-caused wildfire in the summer of 1992. Some features of waterfowl production and aquatic vegetation in burned and unburned ponds were compared, and a brief review of some effects of fire on waterfowl were discussed in an open-file report.

The Kobuk District established two breeding bird survey routes along the Elliot Highway between Livengood and Manley Hot Springs in June 1993. A total of 26 species were recorded, including alder flycatcher, Swainson's thrush, orange-crowned warbler and slate-colored juncos as the most abundant species. An olive-sided flycatcher, a species recently listed as a candidate species, was also recorded. In addition to the two survey routes, a 12-station, off-road, point-count route along hiking trails at the Kobuk District Office's Blixt Public Use Cabin, south of Livengood, was instituted. These off-road data will be compiled for the Alaska Partners In Flight Working Group Off-Road Point Count Pilot Study. Survey efforts will continue on an annual basis to contribute to the statewide efforts to monitor long-term trends of neotropical migratory bird populations.

The Arctic District has been monitoring the Arctic peregrine falcon along the Colville River for the past two years. The monitoring is in accordance with the Falcon Recovery Plan for Alaska, administered by the U.S. Fish and Wildlife Service. All data collected are collated by the Fish and Wildlife Service's Endangered Species Office in Anchorage.

Mammals

Working with the U.S. Fish and Wildlife Service (lead agency) and the Alaska Department of Fish and Game (ADF&G), the BLM has used radiotelemetry to track the movements and calving success of the Galena Mountain caribou herd near the village of Galena in interior Alaska since the mid-1980s. The herd summers on BLM lands and winters on Koyukuk National Wildlife Refuge lands. Twenty new radio collars were placed on the herd in April 1992, and the BLM assisted the Fish and Wildlife Service in radio-tracking efforts in May 1993.

The BLM and the ADF&G cooperated in an aerial moose census in the Fish and Niukluk River drainages on the Seward Peninsula in March 1992. Four aircraft took four days to complete the survey. The technique used was stratified random sampling. The overall average density was 2.1 moose per square kilometer (0.8 per square mile), near the average for interior Alaska. However, the moose population in the area had declined by 40% since the previous survey five years ago.

A moose census was conducted in the Squirrel River drainage in cooperation with the ADF&G in November 1992. Data on population age and sex composition, estimated population size, and relative moose densities were obtained. The census area encompassed 1440 square miles, including riverine, forested upland and tussock tundra habi-

tats. The population estimate was 1372 moose ± 23.4%, with an overall density of 0.95 moose per square mile. Twenty-eight percent of the cows were observed with calves, and the calf:cow ratio was estimated at 32:100. The overall sex ratio was estimated at 37 bulls:100 cows. Declining bull:cow moose ratios and increasing sport harvest in northwestern Alaska have caused concern among state and Federal managers responsible for managing moose populations and their habitats. The census will be repeated at five-year intervals to monitor moose population trends relative to increasing harvests and recreational uses in the Squirrel River drainage.

A computerized spatial analysis of remotely sensed habitat variables was correlated with moose density in northcentral Alaska. Much of the data were obtained with cooperation of the Fish and Wildlife Service, Koyukuk Refuge. Models for moose density were developed using subsets of habitat variables. Macrohabitat factors explained 60–70% of the variation in November moose densities, according to a regression model. A logistic regression allowed correct classification of greater than 90% of the sample units into high or low moose density categories, based solely on habitat characteristics. Fire was less important to the model than expected, whereas river riparian zones were extremely important. Models based on habitat alone may be useful for predicting moose density classes for some management purposes.

A population census and the first stage of muskox habitat monitoring in the Seward Peninsula were completed in 1992. The BLM participated in an interagency effort with the ADF&G and the National Park Service to conduct a range-wide muskox population aerial census in April 1992. The BLM subsequently established vegetation transects at nine sites where muskoxen were observed in late winter (early April) and visited the transects by helicopter in July. Ecosite, vegetation type and composition, slope and aspect were recorded on 500-m transects. A variety of habitat types were used by muskox, although certain ecosites predominated in this small sample.

In a cooperative project with the Soil Conservation Service, the BLM studied reindeer forage utilization and range conditions in the Seward Peninsula. This monitoring project was designed to prevent overuse of lichen forage and inventory and to determine grazing capacity and stocking rates for domestic reindeer. On selected allotments, winter reindeer grazing locations were delineated, and those areas were examined in the summer using a modified grazed class method for utilization determination and a weight estimate method for range condition.

Reindeer roundup on the Seward Peninsula.

Fisheries

Coho salmon escapement was monitored on Boston Creek, a small river located in the central part of the Seward Peninsula, Alaska, during August 1992. A weir placed in the river forced fish to pass within view of a 7-m scaffolding tower erected on the riverbank. Observers in the tower recorded a net upriver movement of 324 coho salmon. The expanded escapement estimate for the project period was 674 coho, with the total escapement for the year estimated between 802 and 1202 fish. In conjunction with the tower count, a helicopter survey was conducted and compared to the expanded weir count. Basic water chemistry information and stream flow measurements were gathered, and an inventory of aquatic habitat was conducted within the lower 37 km of the main channel. Six habitat types covering 963,418 m^2 were identified. Water turbulence and deep pools were found to be the dominant in-stream cover types, with overhanging vegetation and small woody debris providing important secondary cover types. The availability of overwintering habitat was considered to be most limiting to coho salmon production within the system.

Hoosier Creek, a small third-order stream located about six miles south of the village of Rampart, Alaska, was surveyed during the summers of 1992 and 1993. The objective of the work was to document fishery and aquatic habitat val-

ues and to compare differences in channel geometry before and after mining. Standard survey techniques were employed to measure the right and left edges of water, top and bottom of riffles, right and left bankfull widths, right and left flood-prone widths, and stream gradients in both mined and undisturbed sections of the stream. The bed material particle size distribution was obtained, and the dominant particle size was determined by plotting the cumulative percentage against the particle size. Fisheries values were determined by electrofishing the undisturbed and mined stream segments using a three-pass capture–removal procedure. Aquatic habitat was also quantified. Hoosier Creek was found to provide important rearing habitat for chinook salmon, Arctic grayling, Dolly Varden and slimy sculpin. The aquatic habitat had a greater complexity through the undisturbed section, with a variety of pool, riffle and glide habitat types, and in-stream cover of undercut bank and woody debris. The overall pool:riffle ratio was 1:2 through this segment. In comparison the mined segment was almost 100% riffle habitat, with in-stream cover limited to water turbulence and cobble edge. The streambank erosion potential was rated high in the undisturbed segment and extreme in the mined segment, with the primary controlling factor being streambank vegetation. Values for other stream channel variables were also determined.

Hydrology

As partial implementation of the Hogatza and Indian River Area of Critical Environmental Concern (ACEC) Habitat Management Plans, five segments of stream along Indian River, Clear Creek and Aloha Creek were topographically surveyed. The purpose of the surveys was to document the natural geomorphology of the streams and provide data useful for channel design and reclamation in the event future mining takes place. Standard survey techniques were employed to measure the right and left edges of water, top and bottom of riffles, right and left bankfull widths, right and left flood-prone widths, and stream gradients. The bed material particle size distribution was examined, and the dominant particle size was determined. Survey data will be plotted to show plan, cross-section and longitudinal views, and values for entrenchment, width:depth ratio, sinuosity, slope, belt width and meander width ratio will be calculated. In addition, information concerning species occurrence and habitat use will be presented.

The BLM continues to participate in the interagency snow survey in the Arctic. During the last two years, 13 stations have been observed four times each year.

Flowering Plants

A baseline inventory of flowering plants was conducted at 10 sites in 1992–1993 along the Squirrel River in northwestern Alaska to identify the botanical values within the riparian corridor. The Squirrel River is under study for designation as a Wild and Scenic River, and transect sites were selected based on the potential localized impact from recreational users. More than 140 plant species were identified and cataloged, including several species found beyond their previously known range.

Cultural Resources

The Kobuk District continued its program of baseline reconnaissance inventory for cultural resources in FY 92, with extensive surveys in the eastern Seward Peninsula and adjacent areas. With the use of helicopters, reconnaissance inventory was conducted in the Shaktoolik, Ungalik, Koyuk, Mangoak and Buckland River drainages over a two-week period in July and August. The results of the work were mostly negative, although two previously unknown historic sites were recorded, including a compound of several structures on the Mangoak River. The Kobuk District also continued its work on the history of mining in the district, with archival results relating to the Seward Peninsula, Ruby and Manley areas.

The Arctic District Office continued its work at the Mesa cultural resource site. Excavations at this site in Arctic Alaska provide evidence for a Paleoindian occupation of Beringia, the region adjacent to the Bering Strait. Eleven carbon-14 dates on hearths associated with Paleoindian projectile points place humans at the site between 9,730 and 11,660 radiocarbon years ago. The presence of Paleoindians in Beringia at these times challenges the notion that Paleoindian cultures arose exclusively in midcontinental North America. The age span of Paleoindians at the Mesa site overlaps with dates from two other cultural complexes in interior Alaska. A hiatus in the record of human occupation occurs between 10,300 and 11,000 years B.P. Late-glacial climate fluctuations may have made northern Alaska temporarily unfavorable for humans and spurred their southward dispersal.

U.S. Geological Survey

The U.S. Geological Survey (USGS) conducts both terrestrial and marine investigations in the Arctic and in Alaska. In addition to traditional geological studies, many studies are focused on sediment and water transport, water quality, environmental hazards, remote sensing and global change. As the Nation's principal conservation agency, the Department of the Interior, the parent agency of the USGS, has responsibility for most of our nationally owned public lands and natural resources. In recent years this responsibility has been expanded to include many aspects of the U.S. Exclusive Economic Zone (EEZ). USGS investigations on these public lands, many in partnership with other Federal, state and nongovernmental organizations, have been useful for fostering sound use of our land and water resources and preserving environmental and cultural values.

USGS Alaska and Arctic programs include:

- The Earthquake Hazards Reduction Program, which seeks to mitigate earthquake losses by providing data and evaluations for land-use planning, engineering and emergency preparations;
- The Volcano Hazards Program, which includes studies on the assessment, reduction and prediction of volcanic hazards and helps fund the Alaska Volcano Observatory;
- The Deep Continental Studies Program, which investigated the geology and geophysics of the volcanic eruption of 1912, and the resulting vent and Novarupta dome, in Katmai National Park; and
- The Geologic Framework Program, involving both general and specialized research on the regional geology of Alaska.

In addition, the Trans-Alaska Crustal Transect (TACT) program is a multidisciplinary approach to study the Earth's crust along a corridor from the Pacific Ocean to the Arctic Ocean. This program is coordinated with the Trans-Alaska Lithosphere Investigation, which involves earth scientists from the Alaska Division of Geological and Geophysical Surveys, the University of Alaska, other universities and private industry.

As directed by Section 1010 of the Alaska National Interest Lands Conservation Act, the Secretary of the Interior is required to assess "the oil, gas, and other 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." During the 1992-93 period of concern, the Alaska Mineral Resources Assessment Program (AMRAP) was one of the major responses of the USGS to this legislation. The goal of this program

	Funding (thousands)	
	FY 92	FY 93
Energy and minerals	2850	2850
Natural hazards	3700	3700
Ice and climate	750	675
Hydrology	150	130
Glaciology and Quarternary	175	165
Marine geology	500	500
Mapping	1000	1000
Total	9125	9020

is a systematic investigation of the state's mineral resources through four progressively more detailed levels of study. Geologic studies at level I cover the whole state, and at level II they cover large areas. Studies at level III draw on many geologic disciplines to produce resource assessments at scales of 1:250,000 and 1:125,000. Level IV research focuses on detailed studies of specific mining districts, mineral deposits or topics relating to the genesis of mineral deposits. In 1992, level III studies were underway in 25 quadrangles, and 27 level IV studies were in progress. Similar activities continued in 1993.

USGS AMRAP publications are a key source of information about Alaska's geology and resource potential. AMRAP studies are essential for determining the distribution and potential of national mineral and energy endowments, for formulating public policy affecting resource and land management, and for improving resource-assessment technology for minimizing potential impacts from development. These studies, which develop the concepts, models and techniques needed to identify new mineral deposits, are vital to the minerals exploration industry.

The USGS performs its resource assessment work in Alaska through several programs in addition to AMRAP. Among the programs active in 1992 and 1993 were:

- Studies of mineral resources on public lands;
- The Development of Assessment Techniques Program, which has a goal of improving the ability to identify and evaluate mineral resources;
- The Strategic and Critical Minerals Program, which identifies the potential of these resources to meet national military and economic needs; and
- The Oil and Gas Investigations Program, which focuses on studies of petroleum-forming processes and potential source regions in order to produce reliable estimates of undiscovered petroleum resources.

Information for mineral deposits and occurrences in the United States and worldwide is available through computerized files of the USGS Mineral Resources Data System (MRDS). For Alaska

Ice margin of the surging Bering Glacier, which has bulldozed the surface sediment and soil in its path.

there are more than 4000 records in 100 1:250,000-scale quadrangles throughout the state. Data in these files include up to 200 entries related to record identification, location, geology, deposit type, exploration and development, mine workings, commodity, production, reserves, resources and references.

In the field of glacial geology and glaciology, one of the most significant events in decades is the surge of the Bering Glacier, which began in late spring 1993. By the end of 1993, more than half of the 5175-km^2 surface area of the glacier displayed a variety of surge-generated features, including deeply crevassed bulges and pressure ridges, extensional fractures with intricate patterns of intersecting crevasses, tear faults, ephemeral lakes, grabens and a myriad of other stress-generated features. Surging is defined as periodic, very rapid movements of large quantities of ice within a glacier, alternating with much longer periods of near-stagnation. Surging is frequently accompanied by major advances of the glacier's terminus.

The displacement of the Bering's terminus began in late August 1993, when a 5-km-wide tongue of the central terminus of the piedmont lobe began moving across Vitus Lake, advancing at nearly 100 m per day. This advance was accompanied by a substantial increase in iceberg production. By October 5, 1993, icebergs and brash ice were filling about 50% of the entire lake. By the end of 1993, the terminus had advanced more than 3.5 km.

Bureau of Mines

The U.S. Bureau of Mines (USBM) is a primary source of mineral information in the U.S and throughout the world. The USBM assesses the worldwide availability of minerals, giving highest priority to deposits in the U.S. It makes mineral resource assessments as part of land-use planning on Federal lands, it conducts basic mining and mineral processing research of benefit to the mineral industry, and it analyzes the impact of government policies, economic conditions and political events on the mineral sector of the economy and the Nation's mineral supplies.

Since the USBM was established in Alaska in 1911, it has continued to accomplish the overall mission of the Bureau: to help ensure that the United States maintains an adequate, dependable supply of minerals and materials necessary to meet its national security and economic needs at acceptable social, environmental and economic costs. This mission is accomplished, in part, by providing mineral resource information to Federal agencies for use in land-use planning and management, addressing environmental issues by providing objective information and analysis regarding the impact of mining in Alaska, and identifying and assessing costs, technical feasibility and economic impacts that proposed rules may have on the supply, availability and use of minerals.

	Funding (thousands)	
	FY 92	FY93
Mineral Land Assessment	2809	2762
Regulatory Analysis	326	519
Technology Research	1295	1860
Total	4430	5141

The USBM research program also contributes to the mission by developing the scientific basis for technology to help meet the Nation's mineral and material needs and mitigate associated economic, human and environmental costs. In Alaska the USBM is conducting research to develop environmentally sound technologies for surface, underground and borehole slurry mining; tailings disposal in permafrost regions; and reclamation and mine closure technology.

Mineral Land Assessments

The goal of mineral land assessments in Alaska is to improve the availability of mineral data and its analysis for Federal land-use decision making. The USBM conducted studies of mineral resources and inventories of abandoned-mine-site hazards on the Tongass and Chugach National Forests and other public lands at the request of the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) for use in their land-planning processes.

A cooperative minerals investigation involving the USBM, the U.S. Geological Survey (USGS) and the Alaska Division of Geological and Geophysical Surveys was completed in the Colville Mining District in northern Alaska. The 7-million-hectare study area is of interest to the BLM, the National Park Service (NPS), the State of Alaska and Native corporations. The district was being evaluated because the BLM requested minerals information for consideration as part of its land-planning process, and some public land could be opened to mineral exploration. Coal and barite resources have been defined. Significant occurrences of lead, zinc, silver, copper, manganese, fluorite and phosphate are also present. Mineral reports have been published on the district, and a final report will be available at the end of FY 94.

A five-year mineral study of the Ketchikan Mining District (KMD), southeastern Alaska, was completed for the USFS, which is revising its management plan for the Tongass National Forest. The KMD is endowed with base metals, gold, silver, molybdenum, platinum-group metals (PGM), tungsten, rare-earth metals, limestone and gravel. The Alaska Division of Geological and Geophysical Surveys, under a cooperative contract, engaged in regional mapping activities in the Helm Bay and Hyder areas. The USBM defined a highly anomalous platinum area on Mt. Burnett, discovered porphyry molybdenum mineralization in Ketchikan, and found banded sulfides in the Hyder area. The type of molybdenum mineralization found in Ketchikan is similar to that of the world-class Quartz Hill deposit in Alaska. Banded sulfides in the Hyder area are similar in character and age to those found at the nearby, highly productive Premier Gold Mine in British Columbia, Canada.

The USFS is currently planning the revision of the management plan for the Chugach National Forest, which will be completed by FY 98. Possible designations of Wilderness Areas and Wild and Scenic Rivers will affect potential mineral development. The USFS requested the USBM to provide information on minerals and mine-site hazards in support of forest planning efforts in an area of the Chugach National Forest between Unakwik Inlet and Columbia Glacier in Prince William Sound.

The BLM asked the USBM to evaluate mineral resources and abandoned-mine-site hazards in the Fortymile River and Black River planning units, which are BLM's highest-priority planning units in Alaska. The information will be included in the Resource Management Plans for the units. The study of about 1.6 million hectares in the eastern part of Alaska will take three years to complete.

Regulatory Impact Analysis

Regulations promulgated or under development by other government agencies have become an increasingly significant factor affecting the minerals sector of the economy. The USBM provides information on the costs, technical feasibility and economic impacts that proposed rules and promulgated regulations may have on minerals availability, supplies and uses.

Because the Department of the Interior is developing ecosystem-based management approaches to land management, the USBM studied the effects that ecosystem management concepts have had on the mine permitting process in Alaska. Reports have been released on current ecosystem management practices in Alaska and on a geographic information system (GIS) model of the ecosystem surrounding the Greens Creek Mine that allowed evaluation of the impacts of the mine development on wildlife habitat, both with and without impact mitigation measures. The model shows that measures taken by the Forest Service and the mining company to minimize the impacts of the mine road significantly reduced the adverse impacts on sensitive species in the ecosystem. Discussions are underway with the Annette Island Tribal Council and the Bureau of Indian Affairs about analyzing the potential economic and environmental impacts of mine development on Annette Island in southeast Alaska.

Although currently prohibited by EPA regulations, the USFS, the BLM and the Corps of Engineers believe that submarine tailings disposal (STD) may be environmentally the best disposal method for some proposed mines in Alaska. The USBM has been examining this claim by investigating the technological, environmental and regulatory feasibility of deep ocean disposal of mill tailings from near-shore mines. Early results of this project indicated that there was not enough information on submarine disposal for an informed regulatory assessment of STD desirability. A key feature of this project has been the development of an organized and peer-reviewed data set for analyzing STD. Four reports have been released on the technical, environmental and regulatory aspects of submarine disposal, with two more to be released shortly. Additional studies are proposed to assess the long-term environmental consequences of instances of past tailings discharge into the marine environment, and to assess the effectiveness of marine modeling systems currently available for projecting short-term environmental effects of STD use.

As part of the USBM effort to estimate the impact that proposed Resource Conservation and

Recovery Act (RCRA) Subtitle D regulations may have on the U.S. mining industry, a study was undertaken to assess the impact of the proposed regulations on the mining industry in Alaska. USBM reports discuss tailings and waste rock management under the proposed regulations in the unique environmental conditions found in Alaska. General findings are that most of the proposed waste management regulations could be addressed by current engineering practices, although excessive use of liners could make large-scale disposal facilities prohibitively expensive.

Revision of the Tongass Land Management Plan by the USFS will affect the availability of land for mineral entry and development. For several years the USBM has assisted the USFS in this revision, and an innovative land management tool, the "minerals prescription," came out of this collaboration. A supporting study quantifies the economic impact of the minerals industry on southeast Alaska, including mineral activities in British Columbia supported from southeast Alaskan bases. This study found that the development of two mines currently proposed in southeast Alaska would raise mining employment levels in the area from the current 675 to about 2000.

The USBM initiated an inquiry into the effects of mine regulation on the initial mine permitting process. The objectives were to develop a detailed understanding of mine permitting processes by developing detailed case studies of mine permitting requirements and processes, and to conduct a comparative analysis of environmental regulatory structures and permitting required for mine development in Alaska and British Columbia.

Technology Research

A study of the western Arctic coal-deadfall syncline, a cooperative project between the Arctic Slope Consulting Group and the USBM, will determine environmentally sound technology for mining coal and reclaiming mined lands in the Arctic. In 1994, development of the Kuchiak Research Mine was initiated. The project will assess the existing technology and develop new technology leading to a design for environmentally sound mining of Arctic coal beds in northern Alaska. This technology will comply with State and Federal regulations for mine development, active operation and closure. This research will contribute to obtaining a post-mined setting that is both aesthetically pleasing and acceptable for secondary use.

The goal of another USBM research project has been the development of reclamation and closure technology for placer gold mines situated in fragile Arctic and alpine environments. The project concentrated on the field evaluation of emerging technologies and innovative methods developed by small mining operations, regulatory agencies and equipment entrepreneurs. Some of the techniques that were studied were stream di-

Preparing a shot for developing the ramp into the mine pit at the Western Arctic Coal-Deadfall Syncline Project. The temperature at the time was –38°F.

version technology, recontouring and revegetation of slopes and hillsides, habitat enhancement, and mining and processing methods that maximize resource recovery so that once an area is mined and reclaimed, the ground need not be disturbed in the future. This project is completed and the final reports are being written. The work was done in cooperation with the BLM, the USFS, the Alaska Division of Mining, the Montana Bureau of Mines, the Oregon Division of Geology and the Alaska Miner's Association.

A project on underground mining is evaluating new mine design technologies and applying these technologies to mining in Alaska. A key feature of resource recovery in Alaska is the difficulty in assessing alternative mining methods so that resource recovery can be maximized and wastes and associated environmental impacts can be minimized. Computer-generated mining simulations are being used in this project to evaluate mining options without the costly development and field testing that is normally required. Geotechnical data are currently being gathered from the Greens Creek Mine in southeast Alaska to verify the computer simulations. Ultimately these modeling techniques will be used to design mines that optimize resource recovery, worker's health and safety, and environmental impact.

Another project addresses the environmental feasibility of disposing of mine waste in natural waters. While most literature, as well as USBM research, indicates that oxidation of sulfide minerals and acid production are minimized, many other types of minerals can be sparingly yet unacceptably soluble. The environmental viability of subaqueous disposal is, therefore, very site-specific. Samples have been taken of tailings from which all sulfide minerals have been removed as part of the proposed beneficiation procedure. The samples were placed in aquariums in a manner that simulated submarine disposal and then were covered with seawater. The aquariums are being subjected to various physicochemical conditions. Some are toxic to simulate disposal in a shallow basin or an area subject to tidal current exchange. Some are kept anoxic by nitrogen purging to simulate disposal in a deep closed basin such as a fiord. With the exception of minor amounts of manganese, no contaminants appear to be released. During 1994 the pore water of these samples will be analyzed to determine the dissolved metal contents, and toxicity tests will be conducted. If no dissolved metals exist and no toxicity is observed, a site demonstration test may be conducted by placing similar samples on the ocean floor. Pore water chemistry, toxicity and recolonization characteristics will be monitored.

Another project strives to develop economical, safe and environmentally sound techniques for mining in permafrost. To study the behavior of underground openings in frozen ground, instruments were installed in a retreat room-and-pillar section of the Dome Creek drift mine, a small underground placer operation near Fairbanks. Preliminary results have demonstrated that the instruments and data acquisition system functioned properly despite the subfreezing temperatures. Vertical displacement of the mine roof depended on the span of the underground opening and the proximity to active mining. Significant stress changes were measured in permafrost gravel, even though this material has a low modulus of deformation and exhibits a creep-type behavior. Researchers are continuing to analyze the field data collected from these instruments.

Four precious metal ores from work performed in 1992 on Prince of Wales Island were evaluated for recovery of byproduct iron and copper. Commercial-grade magnetite concentrates (63% iron) were produced by magnetic separation, with iron recoveries of 90–94%. The copper mineral chalcopyrite was recoverable by conventional froth flotation. Two other samples from Prince of Wales Island were studied for amenability of gold and silver recovery by cyanidation.

The borehole placer miner that was tested in 1992 in a frozen placer at Tenderfoot Creek was redesigned and improved in 1993. The new design addressed the problem of slurry inlet clogging by cobbles. The 1992 field test revealed that this clogging problem had to be overcome to make progress toward commercial borehole mining of frozen placers. The newly designed borehole miner was tested in a new slurry test loop built at the USBM Twin Cities Research Center, Minnesota. Full-scale simulated mining tests in gold-bearing frozen gravel were conducted using this test loop.

Disposal of frozen tailings and waste rock as backfill material for an underground mining operation is being assessed. The chemical stability of the frozen fill material is important in evaluating its potential for long-term deposition. Freeze–thaw cyclic tests were conducted on frozen placer gravel samples to simulate seasonal temperature variations that could affect frozen backfill. The results showed minimal mobilization of the residual metals contained in the samples during the freeze–thaw cycles. Additional research revealed that the presence of dissolved salts in the saturation solution did not affect the freezing of the material or the solubilization of the metals. Continuing research will investigate the effect of acidity on the chemical stability of the frozen fill materials for long-term deposition in underground mines.

Processing of approximately 50 samples weighing 8 metric tons was completed as part of a multicenter, multiagency effort on titanium resources of Alaska. Three groups of beach sand samples were processed: Cape Yakataga, Yakutat, and the Gulf of Alaska from Cape Yakataga to Cape Spencer. The sample preparation, performed at the Salt Lake City, Utah, Research Center, included drying, splitting, concentrating by spiraling, and splitting of concentration products. A three-turn spiral was used for this work. Splits from the head and concentrate were sent for chemical analysis. Concentrate splits of selected samples are being mineralogically examined at the USBM Albany, Oregon, Research Center. Detailed characterization reveals that ilmenite, zircon and rutile grains in samples taken from the Cape Yakataga area contain intergrowths of calcium- and magnesium-bearing minerals that could interfere with chlorination of the concentrates. Current research is focused on the Yakutat area, where the heavy mineral content of the beach sand is higher and the beaches are broader than the Cape Yakataga area.

Mineral characterization and beneficiation studies were completed on samples from the Story Creek lead–zinc deposit in the Colville Mining District. Mineralogical studies completed on the Ivotuk Hills phosphate samples showed that the rock may contain as much as 30.7% P_2O_5. Vanadium tends to concentrate in earthy-appearing areas of ooliths and in dolomitic calcite, both between and within the phosphatic ooliths.

Bureau of Indian Affairs

The Bureau of Indian Affairs (BIA) in Alaska is organized under the Juneau Area Office and includes five regional branches: the Anchorage, Fairbanks, Bethel, Nome and Southeast agencies. The BIA Central Office in Washington, D.C., has oversight responsibilities for the Bureau's Alaska operations.

	Funding (thousands)	
	FY 92	FY 93
Archeology	180	195
ANSCA 14(h)(1)	1477	1477
Subsistance	291	372
Fisheries/aquaculture	120	142
Total	2068	2186

BIA Archeology Program

The BIA maintains an archeology program responsible for ensuring that Bureau undertakings comply with Section 106 of the 1966 National Historic Preservation Act and other Federal cultural resource laws. This program primarily relates to the Bureau's administration of Native allotments and town sites and is conducted under a 1988 agreement with the Bureau of Land Management, the Alaska State Historic Preservation Office and the Advisory Council on Historic Preservation. Under the agreement, Bureau archeologists consult with external agencies and conduct surveys and mitigation projects to avoid or reduce impacts to cultural resources on restricted Native properties.

Although the BIA has inventoried over 1,200 allotment parcels, about 10,000 remain unexamined. Experience suggests that some 1,500 unrecorded historic properties may exist on unexamined allotments. It will be years before BIA's small archeology staff completes its work, but the program's long-term contributions to the inventory, management and study of Alaskan cultural resources promise to be highly significant.

ANCSA 14(h)(1) Program

The Alaska Native Claims Settlement Act (ANCSA) (Public Law 92-203) granted Alaska Natives fee-simple title to 40 million acres of land in Alaska and extinguished aboriginal title to any additional lands. Section 14(h)(1) of this act allowed ANCSA-created Alaska Native regional corporations to receive a portion of their acreage entitlements as historical places and cemetery sites. The BIA ANCSA Office was established in 1978 to conduct Section 14(h)(1) site investigations, and this program has become the BIA's largest social science endeavor.

The BIA ANCSA Office was not created to conduct "pure" research but rather to determine if selected tracts are eligible for conveyance as ANCSA14(h)(1) sites. Site eligibility criteria are modeled after those of the National Register of Historic Places but differ in significant ways.

Since 1978, more than 2200 investigations have been completed. Investigations are tailored to help determine site eligibility under the 14(h)(1) criteria and include a reconnaissance-level archeological survey at each site. Because the emphasis is on surface indications of cultural activity, detailed site maps are prepared. These maps typically include scale drawings of all identified surface cultural fea-

tures (such as house remains) and their distribution. No excavations are performed, and only limited subsurface tests are conducted. A literature search is made for data pertinent to the site or the general area. Also, because many of the sites are relatively recent and poorly represented in the literature, there has been an emphasis on gathering oral history data.

The oral history collection contains over 1400 taped interviews with Alaska Native elders and is the most valuable body of the 14(h)(1) data. Roughly a third of these taped interviews have been completely transcribed and translated. The major reason for conducting these interviews is to collect site-specific data, but they have yielded information on a wide range of related subjects, including subsistence and land use patterns, social organization, religious and ceremonial life, culture change, language and ethnogeography. Since the published literature contains meager information about many of these subjects, the value of the oral history collection for preserving Alaska Native traditional knowledge is unparalleled.

Except for a few "overview" reports based on multiple site investigations, each investigation results in a 30- to 50-page-long report. Copies of all final reports are maintained in the files of the BIA ANCSA Office and at the Alaska State Office of the BLM. Also, one report copy is submitted to the applicant regional Native corporation and one to the Federal agency having jurisdiction over the lands on which the site is located. Besides the BLM, Alaska-based agencies that receive 14(h)(1) site reports include the Fish and Wildlife Service, the Forest Service and the National Park Service.

Other Research

The BIA funds a wide variety of other programs in Alaska, some of which involve research. For instance, BIA funding of the Alaska Eskimo Whaling Commission has supported several studies of contemporary bowhead and beluga whaling. The BIA has also funded the Sea Otter Commission and the Eskimo Walrus Commission, which has received between $25,000 and $70,000 per year from the BIA since 1979. Additionally, about $600,000 of BIA money went to oil-spill-impacted villages following the 1989 *Exxon Valdez* disaster, and another $250,000 was given to the villages of English Bay and Port Graham in 1992 for a similar purpose. Some of this money has indirectly supported social science research.

Most of the BIA-funded programs are carried out by Alaska Native organizations and concern either natural resources or Native "rights protection." Many use monies allocated in compliance with Title VIII of the Alaska National Interest Lands Conservation Act (ANILCA). In both 1992 and 1993 the BIA received about $420,000 of ANILCA funds, but there is not a direct correlation between the annual level of ANILCA funding received by the BIA and the amount of research it supports.

Department of Defense

DOD conducts Arctic research to ensure the development of knowledge, understanding and capability to meet national defense needs in the Arctic. Research is conducted by all three services and includes virtually all environmental sciences, engineering and health disciplines.

The Department of Defense (DOD) 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 predicting the growth and movement of Arctic sea ice, 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. These research efforts are performed by a wide range of DOD facilities. The Army concentrates on terrain, frozen soils and engineering problems. The Navy's efforts focus primarily on oceanography, meteorology and sea ice predictions. 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 Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, is the only facility that focuses solely on Arctic and cold regions problems; CRREL is internationally recognized as a center of excellence in Arctic research. The Army Research Office (ARO) in Research Triangle Park, North Carolina, supports a wide spectrum of Arctic basic research through grants and contracts, primarily to colleges and universities. The Natick Research, Development and Engineering Center in Natick, Massachusetts, is responsible for investigations in food, clothing and textiles, as well as cold weather equipment, while human physiological response to cold exposure is explored at the Army Medical Research and Development Command at Fort Detrick, Maryland. The Army also operates the Cold Regions Test Center at Fort Greely, Alaska; this facility does not conduct research but serves as a test and evaluation facility for the Army and other government agencies.

	Funding (thousands)	
	FY 92	FY 93
Arctic contamination	0	10,000
Arctic engineering	2,615	2,819
Permafrost/frozen ground	1,139	915
Snow and ice	4,589	7,706
Oceanography	8,920	9,592
Lower atmosphere	1,715	506
Upper atmosphere	3,650	3,400
Medical and human engineering	601	3,023
Total	23,229	37,961

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 (formerly the Naval Civil Engineering Laboratory) 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 Radionuclides

It was revealed in 1991 and confirmed in 1993 that the former Soviet Union (FSU) dumped 16 nuclear reactors (six of them with fuel) and over 10,000 containers of lower-level radioactive waste

Number of stations and samples collected as part of the ONR-sponsored research to determine the degree of threat posed by the radioactivity dumped into the Arctic Seas by the former Soviet Union.

Cruise	*Location*	*No. of stations*	*No. of samples*		
			Sediment	*Water*	*Biota*
Alpha Helix *	Bering and Chukchi Seas	196	500	4700	250
G. Fersman	Kara Sea (dump site)	66	1000	50	
Mendeleev†	Kara Sea and Ob River	30	300	300	100
Okean	Bering and Chukchi Seas	64	1000	300	500
E. Ovsyn	Ob and Yenisey Rivers Kara Sea	77	450	400	500
Polar Star	North American Arctic	62	200	200	12 trawls
Polarstern	Laptev Sea		22	24	
USS *Pargo*	Arctic Ocean	15		150	
D. Zelensky	Barents Sea Kara Sea	7	100		
H. Larsen	Chukchi Sea	66		100	
Various**	Laptev, E. Siberian, Chukchi, Beaufort and Bering Seas		400		

* Some samples collected from the *Alpha Helix* in the Chukchi Sea during 1992 will also be analyzed by this program.

† Many samples obtained by the Shirshov Institute of Oceanography from the *Mendeleev* will be measured.

** Sediment samples collected with U.S. Navy sponsorship in the 1960s and 1970s.

into the Arctic Seas. It is also known that the large Ob and Yenisey Rivers are draining terrestrial radioactivity into the Kara Sea from FSU nuclear fuel reprocessing plants and from weapons development activities. This information naturally caused concern in the U.S., particularly in Alaska, as well as in other Arctic countries. The Department of Defense was given responsibility for assessing the actual or potential risks, with particular emphasis on resources and human populations in Alaska.

The Office of Naval Research in 1993 launched a broad-based program that exploited existing academic, industrial and governmental capabilities. The primary objective of this program is to determine with a high level of confidence whether or not the radioactivity dumped in the Arctic Seas by the FSU presents a threat to the Arctic environment. Water, sediment and biological samples were collected by five ships in the eastern Arctic near the dump sites and major river estuaries and by five ships in the western Arctic near Alaska. Over 11,000 samples were obtained from 600 stations in order to assess the background radiation levels from fallout and other sources and to search for elevated radiation levels associated with FSU nuclear waste that has been deposited in Arctic Seas. Additional data from the Russian–Norwegian cruises in the Kara and Barents Seas and the fjords of Novaya Zemlya are now available.

Analyses of the measurements and samples returned for the Arctic have just begun. Previously available information and the limited data obtained so far from materials collected by this program indicate that there is no imminent danger to the Arctic from the dumped materials or river effluent. Data from localized regions in the Kara Sea do show radionuclide concentrations that suggest an influence of inputs from local nuclear bomb tests, dumping or discharge from the Ob and Yenisey Rivers. However, concentrations in the Kara Sea are often less than those in other areas, such as the Irish Sea, into which radioactivity has been discharged from a reprocessing facility in the U.K. Additional funds were appropriated by Congress in 1994 and 1995 to continue this program.

Arctic Engineering

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. 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 Department of Defense 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. CRREL is the only laboratory within DOD whose primary mission is to address problems and opportunities unique to the world's cold regions and winter environments.

Research in cold regions science and engineering requires special equipment and expertise to operate at low temperatures and under extreme conditions. Such facilities are sophisticated and expensive, and the research staff must be highly specialized in the unique aspects of processes and interactions that dominate in cold environments.

Having a single-focus cold regions R&D organization to provide expertise to DOD and the Nation, with the ability to serve any Federal agency and the private sector when needed, is an investment strategy that results in an outstanding capability at a much reduced effective cost to all.

CRREL has conducted several research studies involving building technology. As a result of CRREL research, the American Society for Testing and Materials adopted a standard test method for determining air change to 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 conducted an extensive study that compared a low-temperature hot water (LTHW) system with a high-density polyethylene casing to a coated-steel-cased high-temperature hot water (HTHW) system. The LTHW piping has a polyurethane foam insulation rather than the calcium silicate or mineral wood insulation of the HTHW system. Polyurethane foam cannot be used with HTHW or steam because its upper temperature limit is about 250°F. The advantages of the LTHW system are the use of corrosion-resistant nonmetallic piping, improved joining capability, increased flexibility and lower cost. This study found that LTHW piping is advantageous over HTHW piping because there is a 50% savings in installation, a 65% savings in heat loss, and a longer, less problematic lifetime.

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. These findings were featured in the National Roofing Contractors Association publication series covering physical factors affecting metal roofs.

CRREL has developed and field-tested a portable asphalt stress and strain measuring device that allows on-site testing of asphalt samples to ensure that the asphalt concrete is of the proper composition for local environmental conditions. A U.S. patent has been received for this equipment.

A commercially available ripper tooth was installed on a tracked military vehicle at Fort Leonard Wood, Missouri, substantially improving the vehicle's hard-ground excavation capability, as it demonstrated by ripping an area paved with asphalt. This quickly installed device is a low-cost accessory (less than $1300) that can dramatically improve the excavation capability of existing military engineer vehicles.

CRREL, in cooperation with an international group from the Danish National Road Directorate, the Road and Traffic Laboratory of Finland and the Cornell University Local Roads Program, completed plans for a major research study for the Federal Highway Administration (FHWA). This effort will evaluate subgrade soils using accelerated loading and controlled climatic conditions to improve criteria for predicting shear deformation in pavements, taking into account the subgrade soil type and representative moisture conditions.

Another research program with the FHWA involves the implementation of anti-icing technology on highways. The application of a chemical freezing-point depressant on a pavement prior to, or soon after the start of, ice or snow precipitation either prevents the formation of a bonded ice sheer or minimizes the bond strength. A successful anti-icing program is expected to demonstrate that the amount of chemicals needed for snow and ice control can be significantly reduced. CRREL has developed a field test program to be conducted by 15 state highway agencies. Anti-icing chemicals will be placed in test areas, while conventional de-icing practice will be followed in control areas.

At Sloulin Field in Williston, North Dakota, CRREL is helping the Federal Aviation Administration (FAA) evaluate the possibility of allowing larger, heavier aircraft to use the airport when the pavement structure is frozen and potentially stronger. Instrumentation for measuring subsurface temperatures and moisture contents has been installed; subsequent data will be tied to a computer-based expert system to determine if a particular aircraft can use the airport at different times during the winter. It is expected that the results of this study will provide guidance on winter load adjustments at other small commuter airports.

In cooperation with the town of Richmond, Maine, and the Department of Civil Engineering at the University of Maine, CRREL is monitoring the performance of a gravel road that incorporates a layer of chunk tire chips used as an insulating layer to restrict the depth of frozen penetration in the roadway. 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 1993-94. 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.

Among CRREL's extensive technical assistance with the assessment, remediation and cleanup of contaminated sites in Alaska, 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. 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.

In continuing studies addressing the problem of waterfowl mortality due to white phosphorus contamination of the Eagle River Flats wetlands in Alaska, the feasibility of remediation or removal was examined, together with the techniques of covering the sediments with material placed on the winter ice cover or removing and landfarming the sediments to oxidize the white phosphorus. Progress was also made in elucidating the chemistry of white phosphorus and related processes of wetlands.

Permafrost, Frozen Ground and Geology

DOD research on permafrost and frozen ground is primarily conducted by two agencies: CRREL and the Army Research Office (ARO). This research 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.

ARO efforts related to permafrost and frozen ground are primarily directed toward understanding their physical behavior, the movement and control of toxic and hazardous substances in frozen ground, and the acquisition of experimental data that will lead to the formulation of constitutive models. Such information is important for improving the design of structures for use in cold regions and in remediating contaminated sites. Experimental studies related to material strength and behavior are being conducted at the Massachusetts Institute of Technology, the University of Maryland, the University of Texas at El Paso and Rensselaer Polytechnic Institute. Theoretical studies related to frost heaving and contaminant transport are underway at Purdue University, and the Geophysical Institute of the University of Alaska is engaged in a field program to determine water and salt movement in permafrost and in the active layer.

Knowledge about the behavior of water at the freezing front of frozen soil and during thawing, at the molecular level, is the basis for understanding frost heave, ice lens formation and material transport. ARO activity in this area continued with the thermodynamic characterization of solutions in the interface region between an ice lens and host soil grains and through the development of computer simulations of model interface fluids. Simulations of a pore-phase film between two soil grain "walls" have shown that the solution near the solid surface may be either solid, liquid or gas (that is, ice, water or vapor), depending on the separation distance, the shear stress and the dipole moment. This finding further illustrates the importance of the influence of the molecular structure of the walls on the confined fluid. Saline permafrost is widespread in Arctic regions and is of interest because the salt can produce significant changes in the permafrost's physical properties and because it is possible for the salt to become mobile under potential energy gradients. A field study has been completed in which in-situ vertical profiles of water content, salt concentration and temperature in the permafrost layer and the overlying active layer have been measured for a variety of soil and permafrost types over a full annual climatic cycle at several sites in Alaska.

ARO geotechnical research has concentrated on laboratory experimental studies aimed at better characterizing and understanding the behavior of cold-climate materials. Construction in and on frozen earth poses difficult design problems because the time-dependent strength deformation properties of frozen soils are the most variable and complex of all geomaterials to understand and model. Even the simplest form of frozen soil (sand with ice-filled pores) entails a highly complex interaction between the solid skeleton and the pore matrix, composed of ice and unfrozen water that changes continuously with time as a function of temperature and stress–strain level. A new computer-automated triaxial cell has been developed to first consolidate an unfrozen sand specimen to a desired effective confining stress and then freeze the specimen while maintaining the confining stress. Using this apparatus the stress–strain behavior of frozen sand as a function of density, confining pressure, strain rate, temperature and time has been measured. Analysis of the results is underway to identify the physical mechanisms controlling behavior and to develop a physically based constitutive model. Centrifuge experiments are also being conducted to ascertain whether scaling laws for freeze–thaw can be established for use in modeling frost heave phenomena. Initially two soils are being tested by freezing the soil from the upper surface at different accelerations to examine the influence of gravitational acceleration on the vertical displacement of frost heave, as well as the changes in void ratios and water content of the soil, during freezing. The behavior of the active zone within a frozen soil profile in response to dynamic loading during freeze–thaw cycling and the effects of freeze–thaw on the permeability of compacted clay landfill covers are also being investigated. These studies are important in the context of the performance of pavements and road surfaces and the performance of landfills in cold climates.

ARO is planning to develop a series of workshops on permafrost and frozen ground. Potential topics include the computational chemistry of freezing soils, the strength and deformation properties of frozen soils, the effect of microstructures on physical and thermal properties of snow and the macroscopic properties and behavior of snow. The results of these sessions will help to decide areas of emphasis in the terrestrial sciences.

CRREL provided assistance to the Office of Naval Research/USAF Geophysical Lab study involving the foundation design and construction of a prototype antenna array in Gulkana, Alaska. The project involves a High-Frequency Active Auroral Research Program (HAARP), with antennas being placed on relatively warm, ice-rich permafrost subsoils. CRREL also completed an operating manual for the hybrid thermosyphons installed beneath the power plant planned to be used at the HAARP facility.

In 1993 CRREL, with partial funding from the Department of Energy, demonstrated under laboratory conditions that frozen soils can be used as a barrier to prevent the transport of heavy metals, volatile organics and solvents. Ground freezing has been used for at least 100 years for groundwater seepage control, particularly in sinking shafts, tunneling and responding to environmental emergencies. During ground freezing, ice between soil particles increases the soil's strength and decreases the soil's permeability. Ground freezing is advantageous because no additives are placed in the soil, the technology has already been proven in industry for purposes other than hazardous waste containment, the process may be turned on or off during an emergency if cooling coils are incorporated, and the thickness can be controlled by adjusting the temperature. This technology is being demonstrated at the Oak Ridge National Laboratory, where a tritium-contaminated waste disposal trench has been completely surrounded with a frozen barrier 2–5 ft thick. This will contain the tritium-contaminated groundwater and prevent uncontaminated groundwater outside the barrier from getting into the trench, thus immobilizing the tritium-contaminated groundwater long enough to allow for its radioactive decay. Also in 1993 CRREL began pilot-scale treatability studies to determine the soil properties and unfrozen water content of native soils and initiated studies to determine the diffusion coefficients of tritium and strontium in frozen soils from the site. These pilot-scale studies will be followed by full-scale field demonstrations.

A thermodynamic model of permafrost has been developed that takes into account conduction heat flow and variable subsurface thermal properties. The model can predict the future effects of surface climate change, but more importantly it can be used to calculate past climates at specific locations. This requires a model that is rigorous enough to be used in an inverse mode. The inverse thermodynamic model will be tested and used with data from the SERDP deep boreholes and a number of shallow holes already established at CRREL research sites in Alaska.

Cracking of the ground due to thermal contraction is a common annual process in permafrost regions, forming distinctive terrain and subsurface features. Another CRREL project is attempting to identify ground conditions that favor the formation of thermal contraction cracks in seasonally frozen soils and to relate the spatial extent and severity of cracking to site conditions and climatic factors to

understand the impact of cracking on engineered soil layers and covers used at waste disposal sites. Theoretical observations from permafrost areas along with data from an instrumented seasonal frost site will be used to help develop guidelines for constructing engineered soil structures used to control subsurface movements of water or contaminants. This information will directly contribute to industry concerned with the design of clay liners for waste site containment in areas that experience frost.

The paleoenvironmental analysis of permafrost was undertaken for interpreting paleotemperature trends from stable isotope analyses of ground ice and for providing paleoclimatic data required for regionalization of global change models to the Alaskan Arctic. This research provides a fundamental method for analyzing the paleoclimate of Arctic permafrost regions and developing a new, unique data source for the Alaskan Arctic, where there is a critical shortage of such data for assessing the impact of climate change. This information is needed to assess the impact of short- and long-term weather patterns on DOD strategic facilities and national assets, such as the Trans-Alaska Oil Pipeline, which is built on permafrost. The objective of developing a paleoenvironmental analysis of permafrost sequences was met, with substantial progress in obtaining paleoclimatic data for central Alaska. Current results suggest that climatic variability and response in the Alaskan Arctic may occur rapidly, as in Greenland; this response is critical to evaluating future climatic change impacts. This program will continue to examine and predict the impact of future climatic changes on permafrost stability and processes, as well as DOD infrastructure and operation in the Arctic.

In continuing studies addressing cost-effective means of delineating subsurface contamination and transport, extensive use was made of improved techniques of utilizing ground-penetrating radar. Among the spinoffs of this work was the first successful mapping of the total thickness of permafrost using this radar, with confirmation from the extensive drilling necessary to map the subsurface extents of contamination.

Snow and Ice

DOD research in snow and ice is primarily carried out by CRREL and ARO. The Office of Naval Research (ONR) also sponsors research on sea ice mechanics.

No standard method exists for measuring the bond strength of ice or the effectiveness of methods to reduce bonding and promote de-icing. This lack of standardization inhibits the development or ranking of materials to achieve low ice adhesion. Two devices have been designed at CRREL that measure the adhesive bonding strength of ice frozen to various surface materials and roughnesses. One device applies shear stresses to the interface, while the other applies tensile stresses. The objective is to develop a device that will produce a reliable measure of the adhesive bond so that a standard test procedure can be established. Also, there is no standard procedure for preparing ice samples. Because ice is notably sensitive to the way that it is grown, it is urgent that procedures be standardized.

Microwave and millimeter-wave interactions with a snowpack are of considerable interest for radar remote sensing applications in a winter environment. To predict or interpret radar signatures from a snow-covered terrain, surface and volume scattering processes from a snow cover need to be understood. Investigations have been conducted at CRREL to study the volume scattering loss in a snow cover at the radar frequencies. Based on these studies a simple snow extinction model that preserves the essential scattering physics has been developed and experimentally verified. Plans are in progress to develop and verify a simplified snow surface scattering model. Simple alternatives to the more complex scattering theories are required for practical applications.

In continuing studies addressing the processes that determine the thermal and microwave signatures of the snowpack, field measurements and numerical simulations of natural and forced snow ventilation were conducted, and the effects of slope, aspect and vegetation on snowmelt were examined. A modeling study of subsurface heating of snow revealed that subsurface melting can occur even when the snow surface is below freezing. In attempts to better characterize snow structure, stereology was found to be a useful technique for characterizing many basic phenomena occurring in the snowpack. Included was the finding that effective medium theory is able to describe many of the characteristics of snow needed for the application of radar interaction models for target detection. A detailed thermal model of the evolution and behavior of the snowpack, called SNTHERM, was improved and extended with the addition of a two-stream radiative transfer code and inclusion of capillary effects to better handle liquid water movement in response to textural changes. The model was tested against various data, including those obtained at Grayling, Michigan.

Millimeter wave studies continued, with analyses showing that changes in backscatter at 35, 95 and 225 GHz are highly sensitive to incidence angle, whether the snow is wet or dry; this information will guide prototype modeling to focus on

viewing geometry and terrain. Distributed modeling methodology was designed for "next-generation" capabilities to include the use of object-oriented modeling with moving solution areas as conditions change in response to environmental driving forces.

Basic research has unlocked the mystery of processes that control an important water quality factor that occurs during snowmelt. Metamorphosis (aging) can cause solute (impurity) redistribution from snow crystal interiors to their surfaces. If, as is assumed, all crystals have similar initial solute distributions, then as the snowpack ages and vapor is transferred from warmer to colder crystals, the concentration of impurities increases for the shrinking grains until they have completely disappeared, leaving their impurities on the surfaces of the mature grains. At the same time, the larger grains are growing, selectively rejecting chemical species within the newly developed layers of ice lattice. This rejection is energetically favorable because impurities located on ice grain surfaces or at disordered grain boundaries cause less strain than if they are located within the ice matrix itself. Of course, not all the small grains disappear completely, and at any given time the snowpack or column has a distribution of grain sizes and impurity concentrations. However, the overall trend is an exclusion of impurities from snow grain interiors to their surfaces. The resulting effect of this process is manifested during spring snowmelt. Since the more highly concentrated snow crystal surfaces melt first, the initial snow meltwater contains very high concentrations of solutes, including acids, which can lead to "acid shock" in stream water.

A new classification system for snow was derived and tested with data from across Alaska, with tundra, taiga and maritime snow distinguished. The new system divides seasonal snow covers into seven types (tundra, taiga, maritime, prairie, ephemeral, alpine and mountain), which are compatible with older classification systems but differ in that they are based on snow stratigraphy, texture and thermal attributes. Four of these snow types occur in Alaska as well as throughout the Northern Hemisphere, and extensive textural and thermal data have been collected on them. These data also consider the spatial variations of the snow cover rather than point characteristics. This is a major advance, making the classification system useful for remote sensing and surface activities such as mobility and snowmelt hydrology.

CRREL is working with the USDA Soil Conservation Service to collect similar data from the continental U.S. to verify the system in all snow types. It appears that a single parameter, the temperature of the snow–ground interface, is sufficient to determine the type of snow cover. The value of this classification system is that it associates the type of snow cover with ranges of specific physical attributes, making the classification system a much more powerful tool for estimating the types of conditions to be encountered in a region and the impact of the snow cover on activities in that area, as well as the general hydrology and water budget essential to life and economic well being in the region.

The mechanical properties of granular materials are closely linked to the material microstructure as well as to the properties of the matrix material that makes up the grains. ARO is sponsoring a detailed investigation of the microstructural changes that occur within snow during deformation using both natural snow samples and artificial snow made from spherical particles. Stereological studies are made of snow microstructure (pore size, grain size, bond diameter, neck length, neck shear deformation, three-dimensional coordination number, and free surface area per unit volume) for a range of strains, strain rates and temperatures. A portable, microprocessor-based, digital thermo-resistograph for the field collection of snow-cover strength data was developed and transferred to CRREL during the project. Another field-based project is aimed at understanding the thermal and mechanical response of snowpacks during melt or rain events in order to gain insight into avalanche release mechanisms and improve predictions of the timing and size of snow avalanches. The results have shown that the evolution of wetting within a snowpack is not homogeneous and is strongly influenced by the snowpack's internal stratigraphy as well as the temperature and rainfall rate. Together these studies indicate that metamorphic processes play an important role in the initial compaction of a snow profile and that snow cannot be physically modeled simply as a compressible, linear, viscoelastic material.

ARO is sponsoring several complementary studies in the area of ice mechanics. A systematic, experimental investigation of the ductile-to-brittle transition in freshwater polycrystalline ice under compression was conducted to evaluate the formation and propagation of wing cracks as a function of grain size, strain rate, temperature and stress state. The transition occurred when the conditions for crack-induced strain softening and for crack instability were met simultaneously. Crack nucleation in polycrystalline ice, with the emphasis on examining the origins of wing cracks in ice, is also being investigated. Polycrystalline ice samples subjected to dynamic, stress-controlled in-situ deformation are monitored using X-ray beam-line X-19C on the synchrotron at the Brookhaven

National Laboratory. The experiments demonstrate that the dislocation–grain boundary interaction mechanism depends on both geometrical parameters and temperature. The mechanism of crack nucleation in ice is also being studied, with particular interest in nucleation at high strain rates. Crack nucleation at high strain rates is thought to result from elastic anisotropy, which may lead to stress singularities at the edges and corner grains. Experimental work is exploring the effects of ice microstructure (crystal shapes, sizes and orientations), stress state and temperature. It is coupled with computer modeling to apply the treatment of stress singularities, resulting from elastic anisotropy, to the particular microstructures and elastic properties of freshwater ice. Ice fatigue may have an important role to play in a number of ice-failure situations, for example, the ablation of the Antarctic ice sheet by the calving of icebergs. A study of fatigue crack propagation in freshwater ice is underway to investigate the effect of applied load and temperature on the frequency and propagation rate of fatigue cracks in polycrystalline, randomly oriented aggregates of freshwater ice with a view to determining the controlling micromechanisms. Data obtained from these tests are being used to develop a micromechanical model of fatigue crack propagation in freshwater ice.

Ice physics is also an area of interest to ARO. ARO and CRREL are sponsoring the preparation of a series of monographs that will lead to a comprehensive, current and theoretically accurate volume on ice physics. Topics to be addressed by the 12 monographs to be published include: the structure of ordinary ice, the electrical properties of ice, the optical properties of ice, the electro-optical effects in ice, the thermal properties of ice, the elastic properties of ice and anelastic relaxation, the plastic properties of ice, the fracture of ice, the electromechanical effects of ice, the surface of ice, other forms of ice and their properties, ice in space, and ice laboratories.

ONR is sponsoring research designed to:

- Understand the stress–strain behavior of sea ice on scales from 1 cm to 1 km and establish constitutive equations related to the observed continuum behavior;
- Determine the scales and mechanisms governing fracture and develop modeling approaches to predict intermediate-scale behavior based on small-scale properties; and
- Understand the interaction of sea ice failure mechanisms with macro-scale stress fields as the basis for predicting peak loads on structures.

Geophysical-scale (10–100 km) continuum models simulate daily displacements to within about 3 km/day but are unable to reproduce locally realistic ice conditions and stresses. The effectiveness of new-generation, high-resolution numerical models will depend on improved understanding of subgrid-scale mechanical processes and their scale dependence. The unusual deformation and strength properties of natural sea ice are related to two major characteristics. Ice is a solid close to its melting point, thus exhibiting creep and temperature-dependent strength. Also ice is a highly flawed, anisotropic material through which cracks can propagate easily. Understanding of ice on a laboratory scale has advanced considerably over the past two decades. Difficulties remain in moving from the knowledge of small-scale ice properties to prediction of how ice behaves in a larger scale. There are no generally accepted and reliable methods for predicting ridge or lead formation or ice loads on structures. Ice strength is strongly scale dependent: average stresses at failure under small-scale laboratory conditions are on the order of 20 MPa, whereas measured average stresses during full-scale interaction with a structure are less than 1 MPa. Distinguishing between brittle and ductile behavior is critical. Although both are forms of failure, they are distinct processes with different scaling properties that must be addressed by different formalisms: continuum mechanics and fracture mechanics. The continuum behavior of granular and columnar ice has been described by uniaxial constitutive laws through the stages of transient creep, but long-term and oscillatory creep effects are not well understood. Also not understood and of fundamental importance are the spatial scales and stress conditions over which continuum mechanics is applicable. In the fracture mechanics of ice, crack nucleation and crack propagation under complex thermomechanical loading are mechanisms that are poorly understood. To address the fundamental question concerning the transition from continuum to discrete mechanisms requires much improved understanding of the scale interaction physics.

Methods for estimating global ice loads on offshore structures are based primarily on load-limiting scenarios that assume that crushing is the dominant failure mode. Observations of full-scale integrations suggest that floe splitting or fracture is a very frequent failure mechanism, whereas crushing occurs less than 10% of the time. The 100-year global ice load on a structure, for example, could be reduced if the statistics of floe splitting are included in the probabilistic load model. To address this problem, ONR-funded researchers participated with scientists from Amoco, Mobil and Canadian Marine Drilling Ltd. in designing and implementing an experimental program to

investigate the large-scale fracture properties of sea ice. Phase I, completed during January 1992 near Calgary, Canada, consisted of freshwater ice fracture tests in preparation for a more thorough set of experiments in sea ice (April 1993). The results of the experiments represent one of the finest data sets available. The largest fracture specimen of any material was tested and the broadest scale range (1:81) achieved. A newly designed servo-control system provided propagation of stable cracks in fracture geometries that are unstable without closed-loop control.

Successful initial experiments have shown the feasibility of imaging the internal structure of sea ice in the field using high-frequency acoustic tomographic inversions. Determining the seasonal evolution of this structure will provide insight into the mechanics and thermodynamics of the ice in response to forcing. The potential impact on the Navy is in better forecasting of Arctic sea ice properties, evolution and distribution. The potential impact on technology is in refining remote sensing algorithms, particularly for conditions of multiyear ice development.

Oceanography

For winter leads in the central Arctic, the objectives of DOD research are to:

- Understand the dynamics of the coupled atmospheric–oceanic boundary layers and the net effect of an ensemble of leads on regional air and water properties;
- Understand local ice production processes and their effects on air–sea flux variability; and
- Determine the relationship between stress fields and the development of deformation and lead patterns.

Winter leads are areas of rapid heat loss to the atmosphere, intense ice production and large buoyancy fluxes to the ocean. Model calculations indicate that essentially all the net ice production in the central Arctic takes place in refrozen winter leads. This ice production balances the ice export through Fram Strait and accounts annually for about 10% of the ice in the basin. Salt fluxes associated with ice production in the leads appear to control changes in the overall salinity and structure of the mixed layer during the fall and winter. Annual totals of turbulent heat exchange between ice and the atmosphere are more than an order of magnitude larger when winter leads are taken into account. The large-scale effects of winter leads are thus related to seasonal and annual changes in the state of the ice–ocean system. Current large-scale models that take into account open water and/or ice thickness distribution ignore most of the processes associated with leads and do not adequately simulate their overall effects on the system. Fundamental questions remain regarding the vertical exchange of heat and mass between the lead and underlying water, and the effects of variations in lead geometry. Theoretically, under normal winter conditions, salinity fluxes, ice growth rates and turbulent heat input to the atmospheric boundary layer will be about two orders of magnitude larger over a refreezing lead than over surrounding thicker ice. There have been no detailed studies of ice development in winter leads. Questions to be addressed include:

- What is the extent and structure of the forced convective circulation in the oceanic and atmospheric boundary layers at winter leads?
- Given the contributions from individual leads and the regional lead density and pattern, what is the net effect of lead processes on a regional scale?
- What characteristics of the applied stress field determine lead pattern development and evolution?
- What governs the rate and spatial structure of refreezing leads?
- What is the temporal and spatial evolution of the material properties of new ice in refrozen leads?

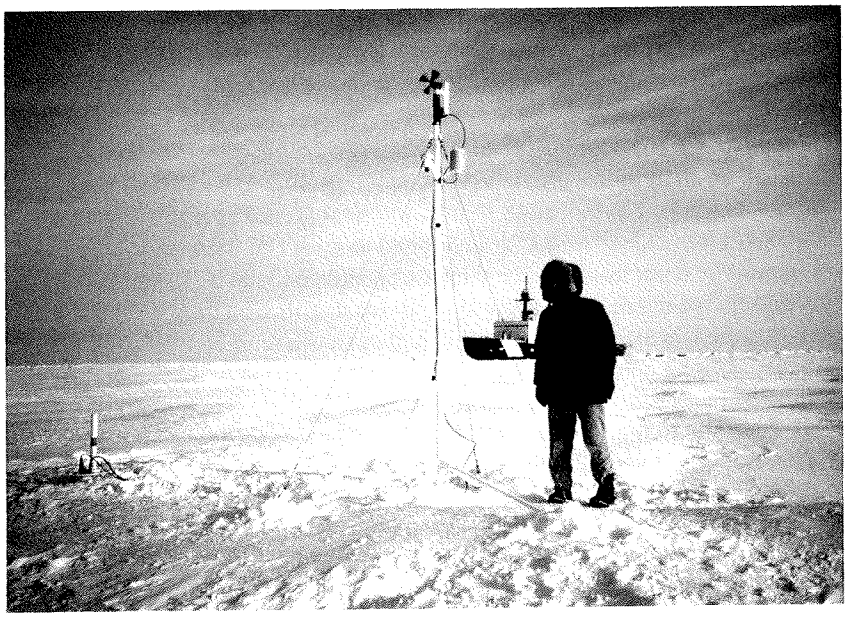
A major field experiment, LEADEX, was completed during the spring of 1992 in the Beaufort Sea. Atmospheric and oceanic boundary layer processes were measured in a number of active leads using newly developed logistics techniques, including rapid-response ice-camp-based helicopters, autonomous vehicles and several fixed-wing aircraft. Satellite databases are being compiled and analyzed for lead-related image resolution and structure. Atmospheric- and oceanic-boundary-layer numerical models have been formulated and run to guide the field sampling. Atmospheric temperature and humidity profiles from Soviet ice islands have been analyzed and are being used in a radiative transfer model to understand how atmospheric and surface conditions influence the detection of sea ice leads by satellite sensors with various spectral sensitivities and spatial resolutions. The observed lead width distribution at highest resolution (Landsat) has been determined to be negatively exponential. New techniques based on probability rather than cross correlation have been developed for compressing and tracking ice floes in satellite imagery. Floe outlines are modeled as closed principal curves around which ice edge pixels are clustered. For linear features such as leads, models based on morphological skeletons have been developed.

Laboratory studies of convective instability in

stratified fluids have documented the governing parameter regimes. The interaction between a surface line source of negative buoyancy (a laboratory-simulated winter lead) and the deflection of a density interface below is strongly dependent on the Richardson number. In the presence of ambient turbulence, the plume can either advance against the background turbulence or be destroyed by the turbulence.

In the first successful deployment of an autonomous underwater vehicle for measuring upper-ocean water properties under ice, temperature and salinity profiles recorded onboard defined the directional wave number of internal waves at the base of the mixed layer. A new freeze-in buoy to measure heat flux in refreezing leads has been deployed. Instruments for Arctic atmospheric boundary layer studies that have been developed and tested include a ruggedized sonic anemometer/thermometer, a 915-MHz radar wind profiler with a special clutter fence and an integrated Radio Acoustics Sounding System (RASS) to provide acoustic enhancement of the returns in very dry Arctic conditions, and a portable minisodar.

Deploying a drifting buoy containing a global positioning system as part of a sea ice mechanics experiment in the Beaufort Sea in September 1993.



Weather station on the sea ice mechanics experiment's main camp floe in the Beaufort Sea, September 1993. The Polar Star *is in the background.*

A new, self-contained, internally recorded, low-power ice draft/thickness sensor for deployment on subsurface moorings has produced an unprecedented year-long time series in both the Beaufort and the Greenland Seas. Tests of the prototype units, which use a narrow-beam sonar formed by an acoustic lens together with a pressure sensor, have demonstrated a new capability for long-term measurements of ice volume flux, a critical variable in air–ice–ocean interaction and interbasin exchange. This could result in better forecasting of Arctic sea ice distribution and in improved remote sensing algorithms, particularly for conditions of rapid ice deformation.

Another major ONR research program is designed to determine the temporal and spatial structure of mass, momentum and energy fields within the Arctic system; the structural components of the shelf basin; and the net flux of principal system constituents. The principal program thrusts are air–ice–ocean interaction, shelf-basin dynamics and structure, ice–acoustic interaction and ice–electromagnetic interaction. Infrastructure and instrumentation are also supported. Air–ice–ocean interaction objectives are to understand the vertical flux of momentum and buoyancy in oceanic and atmospheric boundary layers coupled through ice, the scale interaction governing stress–strain behavior in a floating ice plate of geophysical dimensions, local and regional causes and effects of discontinuities in ice covers, and high-latitude biological productivity. Shelf-basin dynamics and structure objectives are to understand the processes governing Arctic cross-shelf transport and the net effect of cross-shelf exchange on basin circulation, water mass and sediment distributions. Ice–acoustics interaction objectives are to understand the coupling of low-frequency (1–1000 Hz) acoustic waves with the ice plate, the scattering and absorption of high-frequency (1–10 kHz) acoustic energy incident on the complex lower ice surface, and the generation mechanisms and spectral content of ambient noise. Ice–electromagnetic interaction objectives are to understand the scattering and absorption of energy by, and the emissivity of, snow and ice distributions in the visible through microwave bands.

Models of internal waves, eddy interaction and deep ocean convection associated with mesoscale structure have been formulated and verified with

observations. The mean melt rate of ice in the East Greenland Current is 0.38 m per degree of latitude, providing a freshwater input to Greenland Sea surface waters of about 1.9 m per month. The analysis, based on submarine transects, quantifies the freshwater export from the Arctic Ocean. The upper water column (0–500 m) in the Eurasian Basin has been isolated from the atmosphere for 6–7 years based on ^{85}Kr–^{11}F and tritium–^{3}He ratios. The formation rate of Greenland Sea deep water has decreased significantly (80%) during the 1980s. A model of deep water exchange in Eastern Arctic Seas constrained by tritium–CFC-11 indicates that almost no deep water formation occurs in the Greenland Sea. Based on a uniformity of 0–18 in all water masses below the halocline in the Eurasian Basin, an upper limit for the shelf water contribution to the deep waters is about 2.5%. Two preconditioning mechanisms for deep convection in the Greenland Sea have been revealed by fully coupled ice–ocean numerical modeling. Where flow intersects topography producing upwelling or where cyclonic eddy decay dynamics coincide with surface cooling, deep convection occurs in about 10 days to depths of 1000 m. In the central gyre of the Greenland Sea, mixed-layer depths were observed to progress from 200 to over 1200 m in only four weeks in the winter of 1989. This deep ventilation created oxygen-enriched intermediate water, observed spreading from the central gyre the following summer. Such deep convective events are primarily forced by local air–sea fluxes, although advective contributions are still being assessed. The effect of sea ice cover on travel time variability in an acoustic tomographic array has been modeled. A comprehensive data set sufficient to test the model has been acquired during a year-long deployment in the Greenland Sea. Analyses to date have verified model results. Rotating tank experiments in the laboratory have shown that density-driven exchange through a broad strait, such as Fram Strait, is accomplished on short time scales by narrow boundary currents controlled by the deformation radius and on longer time scales by eddies generated in the cross-strait by baroclinic and barotropic instabilities. The relative importance of these two mechanisms, as well as wind-driven exchange, is being evaluated. During cold, heavy-ice years in the Sea of Okhotsk, upwelling associated with warm eddies creates holes in the ice cover, in turn cooling Okhotsk water that enters the Pacific Ocean.

Air–ice–ocean optical models accurately reproduce realistic spectral evolution; acoustic and electromagnetic ice-scattering mechanisms have been determined. Mechanisms by which radiative transfer (400–1000 nm) in sea ice is affected by temperature-dependent changes in brine volume and air bubble density and size distribution have been revealed by a four-stream, multilayer, thermo-optical model combined with laboratory studies. During cooling, transmissivity is unaffected by precipitation of magnesium chloride (–8°C) and sodium sulfate (–18°C) but decreases measurably during precipitation of sodium chloride in brine pockets (–26° to –30°C). The transmissivity decrease was discovered to be smaller than previously predicted, a result of salt crystals increasing more in size than in number as cooling progresses. Crystal size has been correlated with brine pocket size using electron microscopy. These effects are reversible with warming up to –10°C, where scattering and reflectivity increase because of the formation of air bubbles in the brine pockets. Model scattering is currently overestimated at this temperature. Irreversible changes in the structure and optical properties of the ice occur at –5°C, where brine pockets coalesce. An effective permittivity tensor related to the fractional volume of brine inclusions has been computed from ice cross-section correlation functions. A general mixing formula for discrete scatterers immersed in a host medium provides the effective permittivity of the medium. Backscattering coefficients are then obtained by applying radiative transfer theory to a composite model for volume and rough surface scattering. New sea ice scattering models based on radiative transfer theory with phase fluctuations for spherical- and needle-shaped scatterers have been formulated. Initial comparisons with observations have been favorable. A comparison of model results based on strong fluctuation theory with observations from CRREL experiments has identified interference phenomena apparently associated with surface layering. It may be possible to use such fringe effects to determine stages of ice or snow cover growth.

Heat flux through the ice is insufficient to maintain Arctic temperatures; northward heat advection by transient storms is required even at 81°N. Leads and thin ice (<0.8 m) contribute 12% to the winter tropospheric heat budget in the central Arctic. Fall ice distribution on the Chukchi Sea shelf is highly sensitive to vertical salinity stratification, which is related to the integrated wind field history. This improves on past theory, which held that winds alone were primarily responsible for the ice cover distribution. Two major sea ice sources can be clearly distinguished in the eastern Arctic Ocean based on sediment analysis: the East Siberian Sea and the Laptev Sea.

The annual 1989-90 average near-bottom (1200 m) particle flux in Bear Island Trough was about 800 mg/m^2 per day, the largest offshore flux

recorded in the world. The organic carbon component was large, indicating that the southwest Barents Sea is an important sink for fossil carbon.

Thermal ice stresses are largest on the surface of multiyear floes, often are of opposite sign deeper in the ice, and are not observed at all in first-year ice. The effective elastic modulus for sea ice at small strain rates is two to three times smaller than previously thought, based on a synthesis of observed under-ice noise fluctuations with a thermal stress model incorporating a creep rate formulation. The first complete set of ice measurements for the initiation and formation of a pressure ridge in the open Arctic ice pack have been acquired. Fracture occurs several minutes after the peak force, indicating large-scale creep behavior previously unknown. For the first time, unambiguous evidence has been obtained in the laboratory for the fundamental mechanism of brittle comprehensive fracture of ice. A frictional crack sliding model that includes three-dimensional effects (wing cracks) can explain comprehensive fracture.

Upper Atmosphere

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 (AFOSR) 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- (thousands of kilometers), medium- (hundreds of kilometers) and small-scale (tens of kilometers) 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 (electrons and positive and negative ions) 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 (that is, the electron density variation and motion) of the polar ionosphere. In addition, all of these processes exhibit variations over time periods ranging from minutes to diurnal, seasonal and ultimately solar cycles.

The research effort is a combination of experimental measurements to determine specific physical processes combined with first-principles numerical modeling efforts (as opposed to climatological table look-up modeling) and a strong connection to ongoing 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, Qaanaaq, 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 and Argentia, Newfoundland (Canada). Many of these state-of-the-art instruments are developed and tested for field deployment under this effort. Measurements are obtained through the routine operation of ground stations for long-term variations and during dedicated experimental campaigns by the deployment of a variety of sensors performing coordinated, multitechnique 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 are important aspects 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 fluctuations (or irregularities) in the plasma density of the ionospheric F layer (the region of the ionosphere located near 300 km). Disruption is caused by ionospheric density gradients, irregularities and density fluctuations, which cause unacceptable fading of satellite communications and navigation signals, as well as clutter on ground-based, long-range, high-frequency (HF) communications links and surveillance radars. This research effort also includes studies to quantify the effect of ionospheric disturbances on actual system performance, leading to the development and deployment of ground-based sensors for operational systems support.

Electrodynamics of Auroras

A series of experiments was conducted at Sondrestrom, Greenland, to investigate the electrodynamic circuitry and plasma flow in the vicinity of auroras. This led to a complete description of plasma flow, electric fields and currents near auroral arcs. The detailed results were only possible because of the high spatial and temporal resolution of

the measurements obtained by using a specialized observing mode with an all-sky imaging photometer and an incoherent scatter radar.

While initial studies concentrated on stationary arcs, more recent studies have focused on auroras that are first observed in the region known as the auroral oval and then drift poleward to become polar cap arcs. These arcs are observed in the post-midnight local time sector. These observations indicate that at times, oval arcs can drift and expand poleward in the post-midnight sector and evolve into sun-aligned polar cap arcs. These observations demonstrate the need for large-scale and continuous measurements to understand polar arc characteristics.

Plasma Motion and Patches

Nearly a decade ago, PL launched an intensive study of the polar ionosphere using the newly developed all-sky imaging photometer (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 PL's remarkable discovery of the two states of the polar ionosphere: one is characterized by the presence of discrete (>500 km) patches of enhanced ionization that move in the anti-sunward direction and are highly structured to cause intense scintillations of satellite signals; the other state is 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, leading to a better understanding of the relationships (coupling) between the ionosphere and the overlying magnetosphere and the underlying thermosphere.

The formation of patches has also been modeled by using PL's comprehensive time-dependent high-latitude ionospheric model. Patches have been simulated, establishing the feasibility of modeling space weather for operational systems support.

Two winter polar campaigns were performed in the Svalbard area during 1991-92 and 1992-93 when PL's ASIP, the digisonde and satellite scintillation systems were deployed. Because of the high latitude of the cusp (day-side auroral oval) in the Svalbard area, optical measurements can be performed during the magnetic noon period. This campaign was coordinated with the Space Physics group at the University of Oslo and was supported by the European Incoherent Scatter (EISCAT) radar observations of the cusp region. The generation mechanisms of auroras in the cusp and the dependence of their motion on the east–west component of the interplanetary magnetic field (IMF) have been studied in the context of magnetospheric boundaries. Scintillation measurements indicate moderate activity during the magnetic noon, which indicates a lower probability of encounter with patches and possible structuring of the low-density plasma by sheared flow patterns in the cusp.

The generation of patches was modeled using a first-principles ionospheric model together with the Heelis convection model. The result was the generation of a patch with a seven-fold increase in electron density, which could be tracked from the cusp to over Thule and farther into the polar cap. Other patch-generating mechanisms, such as flux transfer events, are under consideration.

Analysis of two years of plasma velocity (drift) data from the central polar cap (Qaanaaq) has been completed. Comparison of this drift data to the IMF has revealed consistent relationships between the drift and the IMF. Current efforts to monitor the polar cap convection involve using the Qaanaaq drift magnitude and direction to determine the sign of two components of the IMF. This effort has been largely successful. Limitations to the determination of the IMF using the convection from a single station have been observed. Current efforts involve using convection from multiple stations in the polar regions to resolve this ambiguity. The potential to specify the high-latitude convection pattern in near real time from the ensemble of the individual station drift measurements, together with satellite in-situ electric field measurements, at a central facility is being investigated.

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 or scintillations of satellite signals occur. Scintillations introduce signal fading and phase jitter in satellite signals, which degrade the quality of satellite communication links and introduce fluctuations of radar cross-section and coherent integration loss to impair the operation of UHF surveillance radars. Joint measurements performed by the Phillips Laboratory and the Wright Laboratory at Sondrestrom, Greenland, established that errors in messages received via the satellite can be predicted from the simultaneously recorded amplitude scintillations. The ionospheric structures responsible for scintillations were also identified by simultaneous incoherent scatter radar and all-sky imaging photometer observations. This study has led to the in-house development of a personal-

computer-based remote-access scintillation warning system, which receives signals from a satellite, performs on-line signal analysis and can be accessed on a telephone line to get automated voice message reports of scintillation activity. Such a unit has been deployed at Sondrestrom, Greenland, which has been remotely accessed by operational systems centers within the continental U.S. to receive voice message reports of scintillation activity in the Arctic.

High-latitude ionospheric total electron content (TEC), which indicates ionospheric range error for trans-ionospheric surveillance radars, and scintillation along the same line of sight, is monitored using navigation satellite signals. A station at Thule, Greenland, using passive reception of L-band signals from the global positioning system (GPS) satellites, has monitored TEC and L-band scintillation since the onset of the recent solar maximum. Air Weather Service, with PL technical assistance, plans to install a new, GPS-based monitor, the Trans-Ionospheric Sensing System (TISS), at Thule during 1994. TISS will continuously monitor TEC in up to ten directions simultaneously. These observations will continue during the decreasing phase of the solar cycle, when the effect of large magnetic storms may be observed. This data set will define the diurnal, seasonal and, to some extent, directional variation of these parameters at solar maximum and will serve as a basis for developing and validating polar cap models.

TEC and L-band scintillation from GPS signals have also been monitored throughout the recent solar maximum from Lerwick, U.K. In addition the Lerwick station obtained latitude profiles of TEC and both VHF and UHF scintillation from the Navy navigation (TRANSIT) satellite signals. Monitoring these satellites nearly to the horizon, these observations cover the midlatitude, trough and polar ionosphere. Dramatic directional variation in observed effects is evident, since north-looking observations can see into polar effects, while simultaneous south-looking observations data see midlatitude conditions. From these TRANSIT data, coupled with four-direction GPS data, three-dimensional maps of TEC vs. latitude vs. time have been developed, which together with the scintillation data show association of scintillations with geophysical features such as the trough wall. This data set is being analyzed for application to model validation and development for the U.K. region, with emphasis on the northerly sector.

Irregularity Generation Mechanisms

The scintillation recording systems are deployed at crucial locations, such as Ny Alesund (Svalbard) and Thule and Sondrestrom (Greenland), to investigate the generation of small-scale irregularities in the cusp, the polar cap and the night-side auroral zone. During magnetic noon, Ny Alesund and Sondrestrom occupy the cusp location, where the solar wind particles obtain direct access into the ionosphere along the Earth's magnetic field. Recent incoherent scatter radar observations performed by PL at Sondrestrom indicate that when the interplanetary magnetic field (IMF) is southward, patches of ionization interspersed by channels of highly sheared plasma flows move through the cusp into the polar cap. It is significant that the two instability mechanisms operate side by side in the cusp region during the southward orientation of the IMF. In contrast to the above, these two instability mechanisms operate within the polar cap under distinctly different IMF configurations. The gradient drift instability mechanism only operates to structure the convecting patches of ionization, and when the IMF is northward, collisional Kelvin Helmholtz instability operates to structure plasma associated with sun-aligned arcs in the polar cap. Scintillation and NASA's Dynamics Explorer 2 satellite in-situ measurements indicate that small-scale irregularities that cause scintillation are more efficiently generated in sheared flow regions.

High-Latitude Model

This project has focused on developing a comprehensive theoretical first-principles model of the high-latitude F region. The purpose of this model is to provide a theoretical framework for understanding observations as well as the means to assess quantitatively the various potential sources of high-latitude plasma structure. The model has been used for two types of studies. In one study, time-varying convection was used to simulate the creation of F-region patches. In particular, variations in the convection pattern that resulted from changing the B_y IMF component caused the tongue of ionization to be broken up into patches and blobs. While this study focused on testing a particular theoretical scenario, a second study is attempting to simulate specific digisonde and radar observations made at Sondrestrom. The initial phases of this study have shown that both a time-dependent global convection pattern and spatially localized regions of transient high-speed flow can play a role in structuring the F-region plasma. Further, when high-speed flows based on the specific radar observations are used, the simulated density structure is in reasonable agreement with the digisonde observations.

High-Frequency Active Auroral Research Program

As part of a Joint Service (Air Force–Navy) research effort, entitled High-Frequency Active Auroral Research Program (HAARP), a unique, high-power, HF ionospheric heating facility will be constructed in 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. A ground-based heating instrument having effective radiated powers in excess of 1 gW (90 dBW), with HF tuning over the 2.8–12 MHz band and beam steering agility, is planned. In addition a wide variety of diagnostic instrumentation will also be acquired, including: ELF/VLF/HF receivers, HF ionospheric sounders, HF/VHF radars, UHF scintillation receivers, optical and IR cameras, and an incoherent scatter radar. Construction of the facility is expected to begin in early 1994.

Meteor Scatter

The high-latitude meteor scatter propagation program was completed during 1993. The program was initiated in 1983 to provide data on the effects of severe polar cap absorption, as well as auroral absorption and scattering, which was required to develop a robust and survivable meteor burst communication system. The performance of a meteor communication system is a function of antenna deployment, transmitter power, modulation, coding, frequency, data rate and communication protocols, all of which depend on the propagation characteristics. The PL program included a range of theoretical and experimental investigations in Greenland to determine the propagation properties over the frequency range of 35–147 MHz using two diagnostic scatter links; one, between Sondrestrom Air Base and Thule Air Base, is entirely within the Polar Cap, while the second, between Sondrestrom Air Base and Narssarssuaq, crosses the auroral region. In addition, a scatter link was also operated for a short time between Thule and Station Nord. These links provided the source for the construction of extensive high-latitude propagation databases, which were used to develop propagation and communication system performance statistics. The statistics on seasonal and diurnal variability were presented in quarterly data bulletins. A series of special investigations was conducted to evaluate the effects of propagation along multiple paths (multipath) and naturally occurring polar cap and auroral absorption on the communication channel. In addition, measurements were made to develop statistics on fast and slow fading and frequency diversity as a fading mitigation technique. The PL program has greatly expanded the knowledge of meteor scatter propagation and its ability to support communication systems. The results have been presented in a series of Air Force customer reports, data bulletins, journal publications and conference proceedings. The information has been used by both government and industry in developing advanced adaptive communication systems.

Medical and Human Engineering

The Army Natick Research Development and Engineering Center (NRDEC) documented needed improvements for the ten-person Arctic shelter. Recommendations were made to update the fabrics and material, add a lace-in floor and improve the zipper design to allow easy replacement. A contract was awarded to fabricate modified ten-person Arctic tents. A commercially available tent was identified and ordered for testing.

Another NRDEC project on modeling heat transfer in tents validated a computer model of three-dimensional laminar flow around tents. In their work on the Multi-Fuel Yukon Heater, NRDEC procured a prototype Yukon heater for evaluation.

Phase I of a contract to develop electrically heated handwear was completed. A cold-chamber evaluation of dexterity, tactility and thermal resistance of prototype gloves was conducted.

The U.S. Army Research Institute of Environmental Medicine (USARIEM) conducts research to sustain and enhance the health and performance of military personnel in cold environments, including Arctic areas, through basic and applied biological and biophysical research. The Institute conducts basic research to elucidate mechanisms and sequela of environmental (cold, heat, high terrestrial altitude) stress and injury, and it performs applied research to provide preventative countermeasures to performance decrements, injuries and illnesses associated with military forces exposed to a wide spectrum of physical demands, material systems hazards, climatic conditions and combat stress. Also, USARIEM assists the U.S. Army Natick Research and Development and Engineering Center (USANRDEC) in developing personnel

clothing, equipment and rations by assessing the physiological impact of these items under climatic extremes.

USARIEM published and distributed a technical note reviewing how cold weather can affect soldier health and performance and providing recommendations for soldiers deployed in cold regions.

USARIEM also published the results of a study that examined whether cold exposure influences the adaptations resulting from endurance training. Soldiers performed daily physical training for eight weeks in either cold water (to blunt their increase in body temperature) or hot water (to exacerbate their increase in body temperature). This study found that physical training enhances the cutaneous vasoconstrictor response to cold and that this effect was equal in both groups. Thus, regardless of whether soldiers are stationed in warm or cool geographic regions, soldiers preparing to deploy to cold-weather regions can optimize their thermoregulatory response to cold by undertaking physical conditioning programs. Another finding was that physical training performed under conditions that prevented the normal body temperature increase during exercise was equally effective for improving physical fitness levels. Thus, military divers whose endurance training is often performed in cool water or soldiers whose training is performed in cold weather can obtain the fitness improvements benefits from physical training.

Prototype multifuel Yukon tent heater.

A study examined the effects of mild sunburn on the soldiers' ability to thermoregulate during exercise in the cold. Sunburn was found to impair the vasoconstrictor response to cold and result in greater heat loss. These adverse effects were still present one week after the sunburn at a time when the associated erythema had disappeared.

USARIEM examined the effects of acute and chronic pyridostigmine bromide (PB) administration on thermoregulatory and metabolic responses to exercise in cold air. Soldiers completed two 7-day trials in a double-blind, cross-over experimental design: during one trial they received PB and during the other trial they received a placebo. For each trial, subjects attempted four, 3-hour exercise tests on days 2–3 and again on days 6–7. The findings demonstrated that the PB dosage used by U.S. military personnel, as a pharmacological defense against nerve agent poisoning, should not cause any adverse thermoregulatory or metabolic effects for soldiers working in cold climates.

A retrospective cohort survey study on four company-size units within the 6th Infantry Division's brigade at Fort Wainwright, Alaska, was conducted. This study attempted to establish an epidemiological baseline for the study of disease and injury trends in soldiers at Arctic latitudes. Data are being analyzed to determine trends and factors that may be amenable to preventive intervention.

USARIEM has an ongoing study to examine the efficacy of using glycerol to hyperhydrate soldiers during cold-weather operations. It has long been recognized that soldiers dehydrate during cold-weather operations, which then reduces their work capabilities and increases their susceptibility to cold injury. In addition to enabling hyperhydration, glycerol will depress the freezing temperature and add caloric density to the canteen contents.

Another ongoing study is examining the influence of body fat on body fluid and cardiovascular responses to cold exposure. Preliminary data suggest that adiposity might have little effect on cardiovascular responses to cold exposure; however, lean subjects may have a greater fluid loss during cold exposure.

A comprehensive literature review was conducted on alcohol ingestion and human thermoregulation in the cold. It was found that:

- Alcohol causes a reduction in body temperature, with the magnitude of reduction proportional to blood alcohol concentration;
- The severity of cold and the person's body composition modify the thermoregulatory effects of alcohol; and
- Hypoglycemia greatly exacerbates the reduction in body temperature caused by alcohol ingestion.

Furthermore, the literature suggests that the mechanism by which alcohol ingestion exacerbates the fall in core temperature during cold exposure is by impairing metabolic heat production, rather than by increasing heat dissipation via vasodilation, as commonly believed.

USARIEM conducted a series of evaluations of the Army Field Feeding System (AFFS). Most recently the AFFS was evaluated with developmental cold-weather rations at Ft. Greely, Alaska, during the winter of 1991. A battalion-size unit was studied during a field training exercise. Overall the cold-weather rations of the AFFS were adequate; however, food consumption was lower than energy expenditure, and recommendations were made to the ration developer.

USARIEM performed a biophysical evaluation of the Interim Intermediate Cold-Wet Glove (IIMCWG) and six prototype test gloves for USANRDEC. Soldiers dressed in a complete Extended Cold Weather Clothing Ensemble evaluated the test handwear during 4-hour sedentary exposures to cold air at 0°C (gloves wetted) and –17.8°C (gloves dry). None of the test gloves could meet the requirement of 4 hours protection at –17.8°C. A few soldiers were able to endure 4 hours at 0°C with externally wetted gloves while wearing the IIMCWG (control) and three of the prototype test gloves.

Development continued on a cold-extremity heat transfer model. The limited natural ability of humans to cope with extreme cold stress by metabolic shivering and conservation of heat must be supplemented by auxiliary means, particularly for body extremities. Protection of the body surface by clothing and insulation specific to the hands and feet often is limited in many military operational situations. A computer model, based on axial temperature variations, was produced incorporating infinite-series solutions. Blood perfusion properties were simulated using a volumetric heat-generation algorithm. Successful predictions of cold-induced vasodilation to actual experimental data were included into the model's source code. Endurance times, as quantified by a drop in digit temperature down to 5°C, is now predicted adequately. In general, for the clothed finger, its length and diameter strongly influence endurance times and respective cooling curves.

In another ongoing effort, USARIEM has developed regression equations to predict shivering in soldiers as a function of core temperature and skin temperature responses (from existing USARIEM databases). An algorithm was written into a six-node thermoregulatory model predicting metabolic and other physiological responses to cold stress at various combinations of work and clothing systems.

USARIEM characterized the effects of hypothermia and early rewarming on clinical chemistry responses in the miniswine model. Arterial and venous blood samples were taken at timed intervals from anesthetized miniswine, which were cooled to a core temperature of 26–28°C and subsequently rewarmed to normothermia. During deep hypothermia, circulating levels of lactic acid dehydrogenase and creatine phosphokinase were increased, but most clinical chemistries were unaltered. This study indicated that hypothermia and rewarming had limited effects on clinical chemical variables.

An ongoing study suggests a possible role of endotoxemia due to an acute elevation of lipopolysaccharide during hypothermia and early rewarming. Preliminary data indicate that during hypothermia (a core temperature of 28°C) there occurs a sharp, transitory elevation in endogenous plasma lipopolysaccharide (LPS, endotoxin), which resolves with return to normothermia. These LPS endotoxin elevations might be contributing to the pathophysiology of hypothermia and rewarming shock.

A Cooperative Research and Development Agreement was established with Stanford University to analyze samples of human blood from hypothermic surgical patients. Blood samples will be collected by the surgical team at Stanford, quickly processed and frozen, and shipped to USARIEM for analyses of circulating endotoxin. This research will provide information on the role of endogenous endotoxin in the potential development of hypothermia and rewarming shock that develops in some humans. A protocol is being written at USARIEM for the conduct of this research.

USARIEM studied the role of hippocampal cholinergic neurons in acute cold stress. Using in-vivo microdialysis, changes in acetylcholine were monitored in cold-stressed rats and controls. Acetylcholine levels fell significantly during cold stress, then sharply rebounded to above-normal levels during recovery. Substantial decrements in learning and memory were present following cold stress. This information will be employed to design nutritional and pharmacologic strategies customized to alleviate the decrements in neurotransmission and behavior produced by cold stress.

Using a rat model of acute cold stress, it was determined that administration of sympathomimetic drugs increases the ability of tyrosine to protect against stress-induced behavioral decrements. Two sympathomimetic drugs—amphetamine, a controlled substance, and phenylpropanolamine, an over-the-counter drug—effectively increased the beneficial effect of tyrosine on coping behavior during cold stress. Animals pretreated with

tyrosine in combination with either drug were less adversely affected by exposure to cold stress. The combination of tyrosine with either drug produced greater benefits than the highest dose of tyrosine tested. These results demonstrate that a nutrient and over-the-counter drug combination may protect animals against the adverse effects of environmental and behavioral stress on their ability to cope with cold.

USARIEM used Living Skin Equivalent (LSE) to identify nonvascular aspects of freeze–thaw injury to human skin cells. Pairs of transwell cell culture inserts, containing LSE, were prepared and placed in two wells of a six-well assay tray (containing assay media). One specimen was maintained at room temperature and the other was cooled at 1°C/min to –15°C and rapidly rewarmed. Both specimens were incubated for 24 hours on fresh maintenance media at 37°C in a CO_2 incubator. Prostaglandin E_2 (PGE_2) and interleukin-1α (IL-1α) were measured in the assay medium, after the rewarming interval, and in the maintenance media after the 24-hour incubation. Specimens were then processed for electron microscopy. The data indicated that the process of freezing and rewarming LSE, at rates consistent with frostbite, produces significant release of PGE_2 and IL-1α from these cell types, which could influence the outcome of frostbite in vivo.

USARIEM's FY 94 plans include:

- Providing information to NASA on finger protection in severe cold environments;
- Evaluating the cold weather boot for the U.S. Army Natick Research, Development and Engineering Center;
- Conducting biophysical evaluations for the Navy;
- Completing a study on the influence of body fat on cardiovascular and fluid responses to cold exposure;
- Conducting a study on mechanisms of cold-induced diuresis and methods to achieve hyperhydration for cold-weather operations;
- Conducting a study on the effects of dehydration on thermoregulation in the cold;
- Continuing to study the effects of hypothermia and rewarming in the porcine model; and
- Continuing to used Living Skin Equivalent (LSE) to identify nonvascular aspects of freeze–thaw injury to human skin cells.

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 spaceborne remote sensing to studies in the earth and space sciences. Of particular interest is the role of Arctic processes in global climate and climate change.

Role of the Arctic in Global Climate

This program focuses on Arctic ice cover and its interactions with the oceans and atmosphere. Its long-range goals include:

- Significant improvement in our ability to represent high-latitude processes in models of global climate and climate change; and
- Development of the ability to monitor important high-latitude phenomena that are likely to respond to climate change.

Its specific objectives include:

- Derivation, from satellite data, of long-term, reliable time series of sea ice extent, concentration and motion, as well as surface temperature, albedo and atmospheric characteristics above the sea ice;
- Estimation, using these time series together with in-situ measurements from data buoys, of fluxes of energy, salt and water at the ocean–ice–atmosphere interfaces;
- Investigation of the impact of these fluxes on the overlying atmosphere and cloud cover, on ocean density structure and on high-latitude ocean circulation;
- Measurement, using satellite and aircraft data, of the mass balance of the Greenland Ice Sheet and of some of the factors affecting it—snow accumulation, summer melting and ice discharge down glaciers and ice streams; and
- Improved understanding of what determines snow accumulation rates and summer melting rates on the ice sheet.

The satellite data contributing to this effort include:

- Passive microwave (sea ice; snow cover; onset and extent of surface melting);
- Synthetic aperture radar (SAR) (sea ice characteristics, including motion; ice sheet mapping; glacier and ice stream motion and ice sheet surface characteristics);
- Scatterometer (sea ice; ice sheet surface characteristics);
- Medium-resolution visible and infrared (sea ice, including albedo and temperature; clouds; ice sheet morphology);
- Infrared and microwave sounding (atmospheric sounding; clouds);
- High-resolution visible and infrared (ice sheet and glacier mapping and motion);
- Radar altimeter (ice sheet surface topography and thickening–thinning rates; sea ice extent); and
- Laser altimeter (ice sheet surface topography and thickening–thinning rates; sea ice surface roughness).

	Funding (thousands)	
	FY 92	FY 93
Polar ocean/ice sheets	10,500	13,000
Land processes	1,600	1,500
Solid earth sciences	1,100	1,000
Atmospheric sciences	750	620
Arctic ozone	7,500	1,500
Sounding rocket program	1,100	2,250
Dynamics explorer	600	300
Space plasma	895	2,880
Solar terrestrial theory	420	420
Total	24,465	23,470

All the relevant satellite sensors, apart from the laser altimeter, are currently flying and will continue through the next decade. The radar altimeter does not make useful measurements over slopes greater than about 1:60, and there are problems with the interpretation of data over ice associated with the large radar footprint and with radar penetration into the surface snow. Consequently the Geoscience Laser Altimeter System (GLAS), planned for launch in 2002 as part of the Earth Observing System (EOS) program, has ice sheet mapping as its prime objective. Meanwhile, NASA has tested an aircraft laser altimeter, with precise airplane navigation from the global positioning system (GPS), in order to make an early start on measuring ice thickening and thinning rates over the Greenland Ice Sheet.

Some of the data sets listed above extend back to the 1970s, already providing us with long time series, and a major priority of the Polar Program has been to develop algorithms to convert these data into useful estimates of sea ice and ice sheet characteristics, to develop data systems for applying these algorithms and to distribute user-friendly

data to the research community. These data systems, at the National Snow and Ice Data Center (NSIDC) and the Alaska SAR Facility (ASF), have become the two EOSDIS Distributed Active Archive Centers (DAACs) that serve the polar community.

One of the NASA-supported EOS Interdisciplinary Projects has close relevance to the Polar Program: POLES, which has the prime objective of calculating energy and mass fluxes at the ocean–ice–atmosphere interfaces.

Important recent accomplishments of the Polar Program include:

- Time series of sea ice cover for 1972–1976 and 1978–present;
- Techniques for monitoring ice sheet summer melt zones over the same periods;
- Automated techniques for monitoring detailed sea ice characteristics and ice motion from SAR data;
- Significant progress towards monitoring ocean–ice–atmosphere energy fluxes from satellite and buoy data and investigating associated impacts on the ocean density structure;
- Techniques for mapping ice sheets and measuring ice stream motion from Landsat and SAR data;
- Most accurate available mapping of ice sheet topography, using satellite altimetry data, and associated detection of significant apparent thickening of the southern part of the Greenland Ice Sheet between 1978 and 1987;
- Linkage of GPS receivers to an aircraft autopilot to ensure that overflights are within tens of meters of a desired route;
- Initiation of a significant NASA program addressing Greenland Ice Sheet glaciology;
- Use of aircraft laser altimetry with GPS to provide the ability to measure surface elevations on grounded ice sheets to an accuracy of approximately 10 cm and to infer ice thickness statistics for floating sea ice;
- Development of three user-friendly data systems: the National Snow and Ice Data Center; the Alaska SAR Facility; and altimetry retracking at the Goddard Space Flight Center; and
- Publication of *Microwave Remote Sensing of Sea Ice,* an AGU Monograph summarizing the status of our understanding based largely on research supported by NASA and the Office of Naval Research.

Future activities will include:

- Modeling studies to assess GCM sensitivity to polar processes;
- Continued enhancement of expert systems to take advantage of multi-sensor data and time series information;
- Continued time series of sea ice cover;
- Convergence on "community algorithms" to establish new time series of snow cover on land, surface temperatures on sea ice and ice sheets, atmospheric profiles and cloud cover over ice, and summer melt zones on ice sheets;
- Progressive improvement in our ability to monitor ocean–ice–atmosphere energy, mass and momentum fluxes;
- Participation in an interagency Surface HEat Budget of the Arctic (SHEBA) experiment;
- Extension of ice-sheet altimetry retracked data sets to include ERS-1 data over ice sheets;
- Accurate mass-balance measurements by systematic surveys of Greenland Ice Sheet surface elevations and mapping of Arctic sea ice thickness, using airborne laser and GPS techniques; and
- First-ever SAR mapping of the Greenland Ice Sheet.

NASA traverse party in Greenland, measuring GPS locations on the ice sheet in support of the aircraft laser-altimetry survey.

Bering Glacier Surge

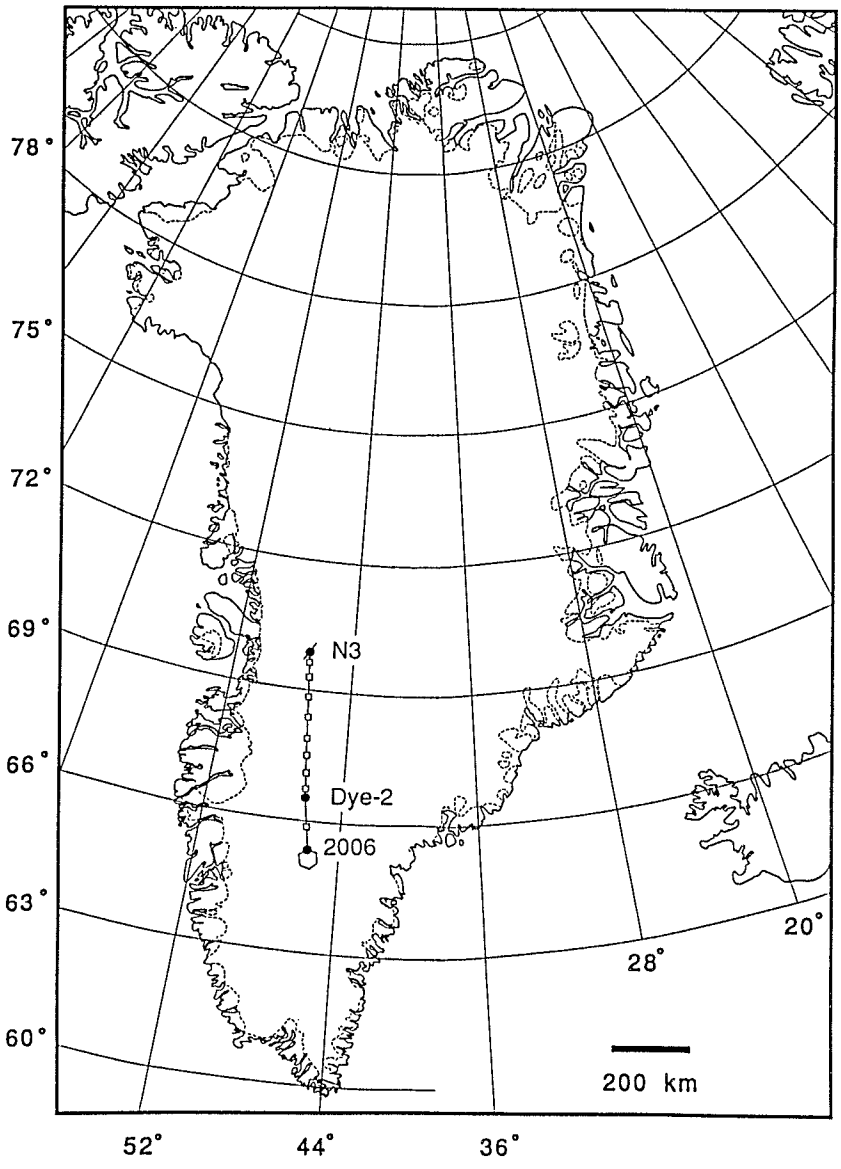
The continuing surge of the Bering Glacier has provided scientists at the University of Alaska's Geophysical Institute with an opportunity to monitor a major glacial event, using SAR from the ASF. Located in south-central Alaska, the Bering Glacier is the world's largest temperate-latitude glacier, covering 5200 km^2 and extending some 200 km west from its origin at a flow divide in the Bagley Icefield near the Alaska–Canada border. The Bering Glacier is unusually complex in that it is both a surge type and a tidewater glacier that is grounded below sea level for about 50 km upstream from its terminus. Historically it has surged approximately every 20 years, the last event taking place in 1965–1967. It was recently thought that the Ber-

ing Glacier might be susceptible to rapid and irreversible retreat following its last surge, particularly if the low-lying beach complex that separates proglacial Vitus Lake from the Pacific were to erode and expose the Bering terminus to the relatively warm waters of the Gulf of Alaska. Instead, however, the glacier began to surge in the spring of 1993.

Scientists from the Geophysical Institute have been tracking the surge with ERS-1 SAR. Specifically they have been using terrain-corrected, geocoded and coregistered SAR images to measure the propagation velocity of the surge, surface deformations and the rate of advance of the Bering Glacier following propagation of the surge to the terminus. A terrain correction procedure, developed at the EROS Data Center (EDC) and implemented on the ASF's Interactive Image Analysis System (IIAS), generates rectified images that are registered to the UTM map projection of the digital elevation model used to correct the SAR's geometric distortions. Measurements of the dimensions of ice bulges on the glacier surface and displacements associated with propagation of the surge front are obtained directly from the terrain-corrected images. An 11-frame sequence of these images has been animated to illustrate the dynamic behavior of the surging glacier. This is the first time that regularly repeated measurements of a surge have been made with satellite images through the clouds and winter darkness that tend to obscure the coastal regions of Alaska.

Ice velocity measurements during the Bering Glacier surge are also being made using complex ERS-1 images (forgoing any initial terrain correction). At high resolution this method relies on repeated identification of distinctive surface features such as crevasse patterns and medial moraines, which are observed to translate down-glacier in time-sequenced images. These velocity measurements also take advantage of the nearly identical imaging geometry resulting from coincident ERS-1 satellite orbital paths, which are repeated every 35 days during the interdisciplinary phase of the satellite mission. Because the surge is "seen" by several satellite passes within a 35-day interval, this analysis will produce a detailed spatial and temporal characterization of the glacier surface velocity during the course of the surge.

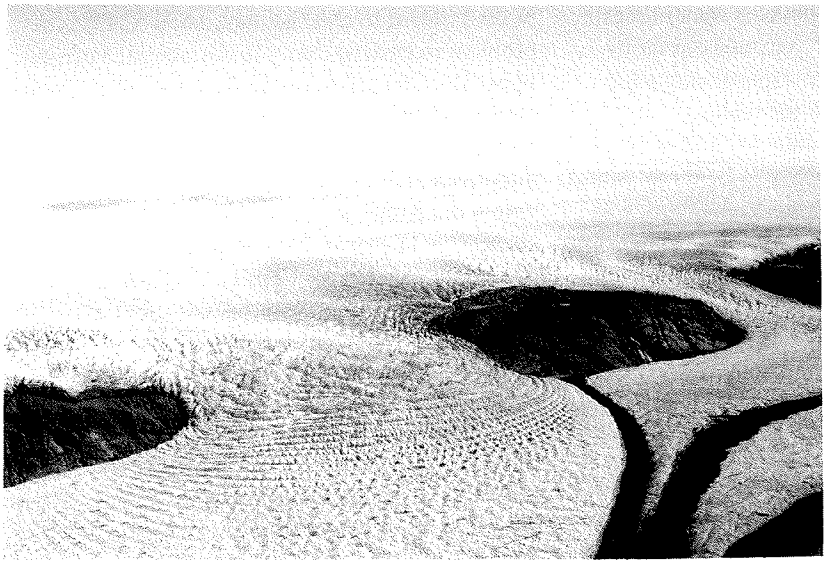
Also being measured are the presurge surface velocities of the upper Bering Glacier (Bagley Icefield), the Jefferies Glacier and other glaciers within the Chugach Mountains using spaceborne SAR interferometry. The initial results indicate that small surface translations can be measured over a three-day interval with accuracies on the order of centimeters per day in much of this region. Furthermore, observed slight variations in surface velocity are potentially strong indications of subglacial bed topography. In combining interferometry with more conventional techniques of SAR image analysis, and by validating their results via field measurements, the researchers at the Geophysical Institute hope to obtain a quantitative time sequence analysis of the Bering Glacier surge with unprecedented accuracy.



Greenland Ice Sheet, showing the traverse line from a camp occupied in 1992 (N3) through the 1993 camp (DYE-2) and ending at a remote field camp (2006). The filled circles show the location of 10-m cores; the open squares show locations where shallow pits were sampled.

Radar Backscatter Measurements on the Greenland Ice Sheet

Surface observations of microwave radar backscatter and firn physical properties were made during 1993 as part of a continuing NASA effort to interpret spaceborne remote sensing data collected



Greenland outlet glaciers.

over the Greenland Ice Sheet. Experiments in 1993 were fashioned to complement earlier observations, which were interpreted to show that high radar backscatter values (normalized radar cross sections of nearly 0 dB) measured on the flanks of the ice sheet are related to the percolation and refreezing of meltwater beneath the ice sheet surface.

The 1993 experiments included three new attributes. First, observations were made with a new, wide-band (2 GHz), 13.5-GHz radar, which offered excellent depth resolution and could profile along the surface. Second, observations were acquired before, during and after percolation events in an effort to better document the radar signature of this process for later application to ERS-1 data interpretation. Finally, firn physical property data were collected in shallow pits along a 500-km traverse line. The pit data will be used for comparison with coincident ERS-1 data that have been acquired along the traverse line.

Microwave radar data collected at 1-m intervals along a 100-m-long line were a highlight of the 1993 effort. The radar echograms show that the early development of ice layers is a discontinuous process. Later in the season and depending on the vigor of the melt process, the layers may become continuous over tens of meters or more. Along with providing insight into the spatial properties of the percolation process, interpretation of these data can be used to better understand seasonally acquired ERS-1 SAR data. Essentially the geometries of the ice layers and the surrounding metamorphosed firn are the primary sources of radar backscatter. The in-situ data also have implications for interpreting radar altimeter data. The continuity of the layers suggests that interaction between scattering from the ice sheet surface and from the first ice layer can complicate the shape of the leading edge of altimeter wave forms.

Terrestrial Ecology

NASA's Terrestrial Ecology Program focuses on the function of global terrestrial ecosystems and their interactions with the atmosphere and the 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, about a quarter of the research conducted under the Boreal Ecosystem–Atmosphere Study (BOREAS), which technically is confined to the boreal forest biome, is relevant to the Arctic.

BOREAS is a major, international remote sensing and field observational project to improve our understanding of the interactions between the boreal forest biome and the atmosphere. Its primary scientific focus is on understanding the boreal region's response to and influence on climate. 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.

BOREAS will be conducted at two approximately 600-km^2 sites located in and around Prince Albert National Park, Saskatchewan, and Nelson House, Manitoba, Canada. These sites were chosen to represent ecological conditions typical of the boreal forest biome's northern and southern limits. Studies at the northern site (at 56°N) should be particularly relevant to Arctic research. BOREAS observations of these sites from the surface, air and space will be used to improve our understanding of the biological and physical processes and states that govern the exchanges of energy, water, heat, carbon and trace gases between boreal forest ecosystems and the atmosphere, with particular reference to the region's carbon budget and those processes and states that may be sensitive to global change.

The study also will seek to develop remote sensing techniques that can be used to extend our understanding of boreal forest–atmosphere exchange processes from local to regional scales.

A pilot campaign was conducted in August 1993, and a series of five intensive field campaigns, each approximately three weeks in duration, was conducted in 1994. They consisted of a winter campaign (February), a spring thaw campaign (April-May) and three summer campaigns to span the growing season (May-June, July, August-September). Baseline meteorological and remote sensing monitoring started in early 1993 and will continue for at least a year after the 1994 field campaigns. Data analysis will continue through 1996, and a guest investigator program is planned for research beyond that time. The BOREAS Information System (BORIS) has been put in place to assemble all BOREAS data sets, assist investigators with quality assurance work, and distribute data within the BOREAS Science Team. When the data have been fully quality assured and documented, they will be transferred to the Oak Ridge National Laboratory's Earth Observing System Distributed Active Archive Center for archival and distribution to the broad research community. A series of BOREAS CD-ROMs are planned for release, starting in 1996.

Arctic Ozone

NASA's Upper Atmospheric 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 stratosphere. Studies underway include the measurements and analysis of data from space-, aircraft-, balloon- and ground-based instruments. A particular area of emphasis is how chemical processes occurring during the winter polar vortex affect the midlatitude stratosphere in both winter and spring.

A second Airborne Arctic Stratospheric Expedition (AASE II), based in Fairbanks, Alaska, and Bangor, Maine, was conducted from October 1991 through March 1992. These measurements, combined with satellite and meteorological data, have provided the first detailed picture of the factors that drive changes in the Arctic ozone layer from fall, through winter and into spring. The AASE II campaign, with extended seasonal coverage, new instrumentation and refined abilities to separate chemical and dynamic effects, has given a better understanding of ozone losses in the Arctic and northern latitudes.

Scientists have concluded that stratospheric ozone (O_3) is destroyed by chemical reactions when exposed to chlorine monoxide (ClO) and bromine monoxide (BrO) in the presence of sunlight. The ClO arises primarily from chlorofluorocarbons (CFCs), and the BrO is produced from both natural and anthropogenic CH_3Br and from man-made halons. The AASE II observations within the Arctic revealed how the ClO abundance changed with season. High levels of Arctic ClO can persist into the sunlit months of spring (February and March), depleting the ozone in the Arctic. The temperature records of the Arctic show that winters with the necessary low stratospheric temperatures in February are not uncommon.

During 1992 the Total Ozone Mapping Spectrometer (TOMS) measurements show that the hemispheric ozone average during January, February and most of March was lower than in any previous year in the TOMS record. Measurements of trace chemicals 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 consistent with the AASE II observations.

A unique set of measurements were obtained at high northern latitudes in April 1993 as part of the second flight of the Atmospheric Laboratory for Applications and Science (ATLAS) space shuttle flight. A nighttime launch of the shuttle allowed one instrument, the Atmospheric Trace Molecule Spectroscopy (ATMOS) instrument, to make sunrise measurements at these high northern latitudes. Given the very large number of molecules measured by the ATMOS instrument, results from this flight may be very useful in aiding in detailed process studies of chemistry and transport in this region of the stratosphere.

This past year saw the conclusion of measurements from the Stratosphere Aerosol Monitor II (SAM II) instrument aboard the Nimbus 7 satellite. This instrument measured aerosol extinction at high latitudes, both northern and southern, and has been critical to our determination of the distribution of polar stratospheric clouds (PSCs). Drift of the spacecraft orbit made it impossible as of the end of December 1993 for the instrument to acquire the sun at needed times for measurement.

NASA's UARP and ACMAP 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 such additional ozone-depleting processes in models that are used to pre-

dict the future ozone losses associated with regulatory strategies regarding CFCs, their substitutes, other chlorine-containing gases and the bromine-containing compounds.

Space Physics

The Space Physics Division of the Office of Space Science (OSS) supports a vigorous program of experimental and theoretical studies of the upper atmosphere of the Arctic regions, including the ionosphere, thermosphere and magnetosphere. The Arctic upper atmosphere is the source of many geophysical processes operating in the solar–terrestrial environment, with the most noticeable phenomenon being the aurora borealis.

There are two programs that are directly supported by the Space Physics Division in these areas of Arctic research. The Suborbital Program supports ongoing scientific research through the use of sounding rockets to directly study the aurora over the Arctic regions. These sounding rockets are launched from the Poker Flat Research Range near Fairbanks, Alaska, to probe the fine-scale details of thermospheric, ionospheric and auroral processes at altitudes and temporal resolutions unavailable from satellites. Conversely satellites offer morphological studies over the entire Arctic region of the energy inputs and outputs from the solar–terrestrial processes.

One of the new missions supported by the Space Physics Division in this research will be the Fast Auroral SnapshoT (FAST) Explorer mission, which is scheduled for launch in 1994. This satellite mission will investigate the plasma physics of various auroral phenomena at extremely high time and spatial resolutions, capturing auroral events "on the fly" and in great detail. The science objectives of FAST will be to examine the electrodynamic causes of intricately complex auroral displays. Of special importance will be an attempt to reveal how electric and magnetic forces guide and accelerate electrons, protons and other ions in the auroral regions. The secondary scientific objectives involve lower-resolution global measurements that can be used in studies undertaken in conjunction with other related space missions, which would include, for example, the multi-spacecraft International Solar–Terrestrial Physics (ISTP) program and experiments undertaken on nonorbital sounding-rocket research missions.

FAST is a small Explorer mission, which can be developed at relatively low cost in a relatively short time and launched on relatively inexpensive vehicles. The FAST satellite is to be launched on a Pegasus launch vehicle, a small, winged rocket designed to blast off from an airplane in flight, thus using less fuel and needing less weight than an Earth-based orbital launcher.

Through 1996 a flotilla of international spacecraft are to be launched by NASA, Japan's Institute for Space and Astronautical Science and the European Space Agency (ESA) under the International Solar–Terrestrial Physics (ISTP) science initiative, which comprises five dedicated science missions and eight spacecraft, including the Polar mission, due for launch late in 1994. This program will provide a global perspective of the Earth's magnetic and plasma environment and the way in which it responds to the changes in the solar wind.

The Polar spacecraft, which will carry 11 instruments, will measure the flow of plasma to and from the ionosphere along auroral magnetic field lines and will observe the precipitation of solar particles into the upper atmosphere. By imaging the northern (Arctic) aurora, NASA's Polar Mission will measure the entry of solar plasma into the magnetosphere over the Earth's magnetic poles and will study the ways in which this plasma impacts the Earth's uppermost atmosphere (in the ionosphere).

These experimental efforts are complemented by the Space Plasma Research (Supporting Research and Technology) and the Solar Terrestrial Theory programs. These programs of theory, modeling and data analysis are crucial to understanding the physics operating in the Arctic upper atmosphere and enabling the construction of global-scale models.

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.

Meteorology, Climate and Air Quality

Geophysical Monitoring at Remote Polar Sites

At the baseline observatories of NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL) (formerly Geophysical Monitoring for Climatic Change) headquartered in Boulder, Colorado, continuous and discrete measurements of atmospheric trace constituents are taken to study their impact on global climate. Four baseline observatories are located at remote global sites, including Barrow, Alaska. Regularly monitored variables include carbon dioxide, methane, carbon monoxide, total column ozone, surface ozone, chlorofluorocarbons, halons, nitrous oxide, aerosol scattering coefficient, condensation nuclei concentration, solar radiation, meteorological variables and precipitation chemistry. In addition, the NOAA observatories provide a facility for investigators from universities and other government agencies to conduct atmospheric research.

Carbon Cycle

In-situ monitoring of carbon dioxide (CO_2) continued at the four CMDL baseline observatories, as did monitoring of methane (CH_4) and carbon monoxide (CO) at Barrow and Mauna Loa. CO_2 and CH_4 were measured in flask samples from the global cooperative air-sampling network. Measurements of CO, made by CMDL, and measurements of carbon and oxygen stable isotopes of CO_2, made in collaboration with the University of Colorado, were obtained from a subset of the network. New air-sampling sites were added to the cooperative network; these included the Baltic Sea, in collaboration with the Polish Sea Fisheries Institute, and Iceland, in collaboration with the Icelandic Meteorological Service.

	Funding (thousands)	
	FY 92	FY 93
Arctic haze	100	50
Solar terrestrial research	250	201
Atmospheric trace constituents	180	180
Environmental prediction	1065	950
Fisheries assessment	2400	2400
Marine mammal assessment	1200	1200
Sea Grant	195	195
Ocean assessment	20	125
Stratospheric ozone	1000	0
Satellites/data management	1415	800
Human resources	679	500
Aircraft/vessels	2805	2500
Climate and global change	0	630
Arctic ice	1782	620
Arctic ecosystems	1890	1890
Arctic climate modeling	300	300
Total	15281	12541

Analysis of CH_4 data from the air-sampling network revealed near-zero growth in the Northern Hemisphere during 1992. The change may be due to decreased CH_4 emissions in the former Soviet Union and Eastern Europe, resulting from stabilization in the production of natural gas, repair of major leaks in the natural gas pipeline system, and a sharp reduction in coal production.

Nitrous Oxide and Halocarbons

Under NOAA's Radiatively Important Trace Species (RITS) program and Climate and Global Change Program (CGCP), CMDL is measuring these gases in the atmosphere using flasks collected at seven sites and shipped to Boulder for analysis, as well as in-situ gas chromatographs (GCs) at five remote sites, including Barrow.

The growth rates of a number of important ozone-depleting chemicals, including CFC-11,

CFC-12, CFC-113, methyl chloroform (CH_3CCl_3), carbon tetrachloride (CCl_4) and halons H-1211 and H-1301, continued to decrease over the past year as the result of both mandated and voluntary reductions in their emissions. Since 1987 the growth rate of $CHClF_2$, a substitute compound for CFC-12, was relatively constant at about 6.5 parts per trillion per year. Although most of the news on CFCs was encouraging, the growth rate of N_2O has been gradually increasing over the past decade.

Pairs of flasks were collected almost once a week from all four NOAA baseline observatories. Flasks were analyzed by electron-capture gas chromatography (EC-GC) using the original GC that was installed in 1977. A new automated EC-GC system was installed for measuring N_2O, CFC-12, CFC-11, CH_3CCl_3 and CCl_4 in flasks, and more flasks were added to the CMDL halocarbon flask network. A comparison of both EC-GC systems is under way. Larger-volume flasks (850 cm^3) were sampled at least once a month for atmospheric halons H-1211 and H-1301 using EC-GC and cryogenic trapping of a 100-cm^3 sample. From the same flasks, measurements of HCFC-22, HCFC-141b, HCFC-142b, CFC-114 and methyl bromide continued using gas chromatography/mass spectrometry (GC/MS) and cryo-trapping of a 200-cm^3 sample.

In addition to flask measurements, in-situ automated GCs continued sampling for atmospheric measurements of N_2O, CFC-12, CFC-11, CFC-113, CH_3CCl_3 and CCl_4 once an hour at all four CMDL baseline observatories. Trace gas standard work for N_2O, CFC-12, CFC-11, CFC-113, CH_3CCl_3, CCl_4, HCFC-22, HCFC-134a, HCFC-123 and halons H-1211 and H-1301 has continued, and many standards were remade to examine the stability of our primary standards.

Aerosols and Radiation

The aerosol monitoring program continued at the four CMDL baseline stations. Condensation nucleus concentration and aerosol scattering measurements have been made at Barrow since 1976. A springtime maximum in aerosol scattering at Barrow (sometimes called the Arctic haze) is caused by the transport of human-produced (anthropogenic) pollution materials from the midlatitudes. A study of the aerosol scattering coefficient and optical depth at Barrow showed a decrease by about a factor of two in the springtime Arctic haze event between 1982 and 1992. The trend is attributed to a steadily declining Soviet economy and the implementation of ever-stronger emission controls in the areas that contributed heavily to the existence of the haze initially.

The Arctic Gas and Aerosol Sampling Program (AGASP) is a multinational, cooperative research program focusing on understanding the phenomenon of Arctic air pollution known as Arctic haze. AGASP conducted major NOAA WP-3D field campaigns in 1983, 1986 and 1989. In 1986 the program fielded four aircraft from the U.S., Canada and Norway, and it conducted measurements from Alaska through the Canadian archipelago to Spitzbergen. In 1989 AGASP NOAA WP-3D activities were focused in the Greenland Sea–Spitzbergen region, partially in support of the ONR CEAREX research program at O and A ice camps located northwest of Spitzbergen.

AGASP-IV was conducted in 1992 in the Arctic off Barrow and Prudhoe Bay, Alaska, as part of the ONR Lead Experiment (LEADEX). In addition to the core AGASP objectives, AGASP scientists were involved in surface measurements from the Arctic baseline stations at Barrow, Alaska, and Alert, Northwest Territories, and in an associated NOAA WP-3D and University of Washington C-131 airborne program. The focus of the studies was to determine energy fluxes from leads and to study the synoptic-scale aspects of lead–atmosphere–ice interactions.

Processing continued on these data sets. This included the transfer and reformatting of the data from NOAA aircraft data tapes to personal computer diskettes. Software was written to facilitate the extraction and further processing of any of hundreds of parameters from the data set by PC-based database and spreadsheet programs. A NOAA technical memorandum is being prepared that discusses in detail the meteorological, atmospheric aerosol and trace gas, and radiometric conditions during the field experiment.

Special Projects and Observatory Programs

The four CMDL baseline observatories continue to constitute one of NOAA's primary efforts to monitor the composition of the atmosphere and to relate any changes in the composition to climate and global change. CMDL clean-air observatories have collected data since 1958 and continue to be a primary source of information for detecting, quantifying and assessing the buildup of greenhouse gases and aerosols in the atmosphere. The CMDL program also actively engages in monitoring and research through cooperative programs at the baseline stations and through CMDL's specialized monitoring programs with universities, institutes, other countries and other government agencies. This ongoing effort is one of the key connections that CMDL has with the broader research community in developing measurement instrumentation, monitoring techniques and research analyses related to atmospheric composition and climate change.

Climate and Global Change

The Office of Global Programs (OGP) has a number of studies that are assessing Arctic processes as forcing functions of climate and global change and as "barometers" of global change. A number of studies have been supported in FY 92 and 93, the results of which are still being analyzed.

The freshwater discharge from the Arctic Ocean through Fram Strait has been investigated to verify its magnitude, determine its variability and create an observational basis for predicting this variability. As part of the Atlantic Climate Change Program (ACCP), this monitoring of the freshwater flux will be continued until 1995, since both the freshwater forcing and the convective regime in the ventilating region of the Greenland Sea appear to have strong interannual variability. This work also complements ACCP efforts in transient tracer monitoring and ice modeling in the same area, and it is coordinated with related investigations by a number of European studies.

In a related effort OGP is supporting studies of the linkages between sea ice and seasonal-to-decadal variations of the North Atlantic climate system. This involves documenting the North Atlantic sea ice variations at about 100-km resolution and monthly intervals over the twentieth century. Drawing on existing digital data sets, this documentation will provide a historical sea ice data archive for the Atlantic Climate Change Program, and it will serve as a sea ice counterpart to the Comprehensive Ocean Atmosphere Data Set sea surface temperature data and to large-scale atmospheric data sets spanning the twentieth century. It includes not only the traditional sea ice variables (extent and concentration) but also derived estimates of the interannually varying outflow of sea ice from the Arctic Ocean to the North Atlantic. Diagnostic analyses will be performed to quantify the causes of North Atlantic sea ice variations and their relationships to subsequent surface anomalies in the North Atlantic subpolar seas.

OGP is supporting studies of Arctic ice thickness using a sounder system that detects the echo envelope of the underside of the ice above a submarine and calculates a distance, based on a preset assumed sound speed through the water, to the under-ice surface. The submarine depth is determined from the measured hydrostatic pressure. The resulting digital pulses, which represent ice draft, are then continuously recorded on digital magnetic tapes or personal computer diskettes. The digital signals are also fed to a continuously running analog strip-chart recorder, which provides a backup record of the profile data.

OGP is also supporting the development of a numerical model of the upper ocean and sea ice. The purpose is to simulate the evolution of oceanic surface properties on spatial scales from several hundred kilometers to the global scale and on time scales from several days to several years. It is intended for coupling to atmospheric general circulation models on comparable space and time scales in order to investigate the interactions of atmosphere and ocean in intra-decadal climate variations and to identify possible sources of climate drift in coupled models, which are a major impediment to studies of longer-term climate variations. The upper-ocean model includes the advection and mixing of temperature and salinity, in the presence of a velocity field diagnostically determined from a linear momentum balance. A significant part of the effort will be to assemble and compare observed surface and upper-ocean quantities with model solutions.

Ocean Assessment and Monitoring

Arctic Environmental Assessment Center

The Arctic Environmental Assessment Center of NOAA's Office of Ocean Resources Conservation and Assessment (ORCA) was closed in April 1992 due to lack of funding. Located in Anchorage, Alaska, the Center conducted research, synthesized information and disseminated data and information products to support management decisions affecting coastal and marine resources and environments in the U.S. Arctic. Most of the Center's projects were funded by the Minerals Management Service (MMS) of the Department of the Interior as part of its Environmental Studies Program to support oil and gas leasing decisions. In addition the Center conducted multidisciplinary studies on a cooperative basis with other agencies and provided scientific support to NOAA's programs and activities on environmental assessment and monitoring in the Arctic. Following are major activities or accomplishments of the Center in FY 92.

The movements of Arctic cisco and Dolly Varden char (formerly known as Arctic char) and their habitat preferences in Camden Bay in the eastern Beaufort Sea were monitored using the ultrasonic telemetry technique. It was shown that the directedness of movement varied between species and among individuals; most displayed an affinity for the shoreline. Arctic cisco recorded a net speed of 12–44 cm/s in a predominantly southwesterly direction, whereas the Dolly Varden's net speed was 10–64 cm/s with no particular prevalent direction.

These data are important in assessing the significance of the coastal plume of warm, brackish water in the Beaufort Sea to the feeding and growth of anadromous fish.

Two species of marine fish—Arctic cod and fourhorn sculpin—are fairly abundant and ubiquitous in the Beaufort and Chukchi Seas. There is no commercial catch of the species in this region, but both are important in marine food webs. On the basis of limited field sampling, the Center staff made the only available population and biomass estimates for young-of-the-year Arctic cod in the Camden Bay region of the Beaufort Sea; 84 million cod (with a biomass of 1.6 million kg) were estimated to occur in the upper 2 m of the bay during summer.

Site-intensive oceanographic and atmospheric field data, obtained in the coastal region off the Arctic National Wildlife Refuge during 1988–1991, were processed and analyzed. Reports describing the results of the 1988–1990 field work were published. The results showed that coastal currents in the eastern Beaufort Sea are generally weak and directed eastward, often showing reversals in response to changing winds. The dominant winds during summer are from the east-northeast or west-northwest, so that wind-driven currents tend to be along-shore and bimodal in direction. Cross-shelf flow episodes occur fairly often, with daily averages exceeding 5 cm/s and having durations of three days or more. Such flows are capable of transporting water-borne materials between the inner and outer continental shelf regions.

A simulation modeling study to describe the Kasegaluk Lagoon ecosystem, in the northeastern Chukchi Sea, was completed. Two models were constructed: a lagoon circulation model and an ecological simulation. The study relied on the synthesis and analysis of existing data in order to provide a conceptual framework for understanding the salient features of the ecosystem and on the model sensitivity to guide future research. The modeling results showed a significant mismatch in the energy flow between trophic levels; for example, primary productivity appears more than adequate to support the lagoon's heterotrophs, but the estimated fish production may be too low to support the feeding requirements of seals and other mammals that inhabit the lagoon on a seasonal basis. This suggests that the current database on the biomass and the understanding of the energy use patterns at different trophic levels are inadequate. The model documentation was completed in August 1992 and submitted to the MMS.

A review of scientific literature was initiated to define the rates and variability of biological productivity in the Arctic Ocean and to delineate its spatial patterns in relation to the nutrient content and flux of material in the inflowing water masses from the northern Bering Sea to the Chukchi and Beaufort Seas. If completed, the study results will be useful in designing a field sampling program to define the magnitude and pathways of energy transfer at lower trophic levels in these seas and for examining the possibility of sequestration of large amounts of organic matter on the Arctic continental shelves.

Compilation and digitization of fisheries data from the U.S. Arctic were completed to make these data available to other users in a consistent and usable format. A portion of the compiled data has been published on CD-ROM, and retrieval software for the data was recently produced under the sponsorship of the MMS. The data retrieval system employs a graphic user interface, enabling the user to select data on the basis of species, region or gear type.

The Center continued to maintain the Outer Continental Shelf Environmental Assessment Program (OCSEAP) bibliography and published the final report volumes for the program. The last of the final report volumes (volume 74) was published in the summer of 1992. The OCSEAP Bibliography, consisting of over 4000 citations, was transferred to the MMS.

Marine Mammal Tissue Archive

Established in 1987, the Alaska Marine Mammal Tissue Archival Project (AMMTAP) is a cooperative effort between NOAA and the National Institute of Standards and Technology (NIST) to collect and archive tissue samples from Alaskan marine mammals. This project, conducted over a period of several years, will develop a resource that can be used to determine baseline contaminant levels against which future contaminant measures can be compared. Past funding for AMMTAP has been provided directly by the MMS and is now being provided by the MMS through the National Biological Survey. AMMTAP is managed as a component of the Marine Mammal Health and Stranding Response Program of NOAA's National Marine Fisheries Service (NMFS).

Samples are collected from animals harvested by Alaska Natives for subsistence. Samples of liver, fat, kidney and occasionally other kinds of tissues (blood, brain, muscle, bile, teeth etc.) are collected using standard procedures and are cryogenically stored in the National Biomonitoring Specimen Bank at NIST. A fraction of the preserved material is occasionally analyzed for selected contaminants (metals and chlorinated hydrocar-

bons) in order to develop a database on initial contaminant levels and monitor sample changes during storage.

The AMMTAP has collected and archived tissue samples from marine mammals of the Arctic Ocean, Bering Sea and Gulf of Alaska, emphasizing species of subsistence value. Through collaborative arrangements with Alaska Native subsistence hunters and organizations, Federal and State agencies, AMMTAP has sampled ringed seals, spotted seals, harbor seals, bearded seals, Steller sea lions, northern fur seals, walruses, beluga whales and bowhead whales. During FY 92 and 93, sampling included seals and walruses from Norton Sound (in collaboration with Kawerak, Inc., the Eskimo Walrus Commission and the U.S. Fish and Wildlife Service), beluga from Cook Inlet (in collaboration with the NMFS Alaska Western Field Office) and bowhead whales from Barrow (in collaboration with the North Slope Borough Department of Wildlife Management). Arrangements were also made to obtain samples from Steller sea lions and harbor seals in cooperation with the Alaska Sea Grant Marine Advisory Program and the NMFS Alaska Regional Office.

The AMMTAP, in collaboration with the University of Ulm and the Nuclear Research Facility KFA, Germany, Department of Fisheries and Oceans Canada, NMFS's Northwest Fisheries Science Center and the North Slope Borough Department of Wildlife Management, reported through agency and journal publications on concentrations of selected trace elements and chlorinated hydrocarbons in tissues of pinnipeds from Norton Sound, belugas, bowheads and northern fur seals. This collaborative work is continuing and will develop a substantial database that can be used in determining the health and contaminant load in Arctic subsistence species.

National Status and Trends Program

NOAA's National Status and Trends (NS&T) program was formed in 1984 to describe the spatial distribution and determine the long-term trends of contaminant concentrations in the environment and biota in U.S. coastal and estuarine regions. The program consists of seven components:

- The Mussel Watch Project;
- The Benthic Surveillance Project;
- Bioeffect Surveys;
- Historical Trends;
- Coastal Contamination Assessments;
- The Quality Assurance Project; and
- Specimen Banking.

The program also evaluates new methods for assessing the biological and ecological effects of environmental contamination and develops subcellular, organismic and ecological indices or parameters to determine the nature and magnitude of the decline in environmental quality or impairment of coastal ecosystems.

The program encompasses nearly 300 sampling sites nationwide and measures the levels of about 70 contaminants in bottom sediments and tissues of bottom-dwelling mollusks and fish. The contaminants measured include 24 polycyclic aromatic hydrocarbons (PAHs), 20 congeners of polychlorinated biphenyls (PCBs), DDT and its breakdown products DDD and DDE, 9 other pesticides, butyltins, 4 major elements and 12 trace elements. Nine sampling locations, which are part of the Benthic Surveillance Project, are located in the U.S. Arctic: six in the Bering Sea, one in the Chukchi Sea and two in the Beaufort Sea. Due to funding constraints, the Arctic sites have not been sampled on a regular basis nor has it been possible to analyze all of the collected samples. The last field sampling in the Arctic was conducted in 1988, and the last sets of contaminant data are from 1986.

Radionuclides in the Arctic

NOAA is participating in a comprehensive program of studies to describe the sources, transport, biological accumulation and fate of radionuclides in the Arctic. The program, sponsored by the Office of Naval Research, was prompted by the disclosure of vast quantities of radionuclide waste, nuclear reactors and nuclear-powered vessels that were dumped or disposed off in the Arctic Ocean by the former Soviet Union. The objective of NOAA's study is to establish a quality-controlled data set on the spatial distribution and scales of contamination from radionuclides in the marine environment and selected biota of the U.S. Arctic in order to:

- Describe the magnitude and sources of radionuclide pollution;
- Establish a baseline to determine temporal trends; and
- Develop strategies for establishing a long-term monitoring program.

This is consistent with the purpose and scope of NOAA's NS&T Program, which recently completed a study of the occurrence of artificial radionuclides in bivalves collected from coastal waters of the coterminous United States.

In 1993 NOAA participated in field work in the northern Chukchi and Beaufort Seas to collect sediment and benthic invertebrate samples for radiochemical analyses. Also, samples of anadromous

and marine fish and tissues of marine mammals harvested for subsistence use by coastal inhabitants have been obtained. A 15-day cruise on board the NOAA ship *McArthur* has been scheduled for the summer of 1994 in the southeastern Bering Sea to increase sampling coverage and collect a variety of fauna to describe the extent and potential severity of radionuclide contamination in the U.S. Arctic.

Fisheries

Arctic Marine Mammals

NOAA's National Marine Mammal Laboratory (NMML) at the Alaska Fisheries Science Center in Seattle, Washington, is conducting long-term research on the population biology and ecology of Steller sea lions, northern fur seals, harbor seals, and bowhead, beluga and killer whales in the western North American Arctic. Research in 1993 was conducted jointly with Russia under the U.S.–Russia Environmental Protection Agreement (Area V, Project VI–Marine Mammals) on Steller sea lions and large seals, and with Japan on northern fur seals.

During the past decades, significant changes have been observed in the numeric composition of several vertebrate populations (birds, fishes and marine mammals) in the eastern North Pacific and Bering Sea ecosystems. Populations of apex predators such as the Steller sea lion and the northern fur seal on the Pribilof Islands have declined by 60% since the 1950s. The causes for these are synergistic effects of commercial fisheries and changes in oceanographic and atmospheric conditions (for example, water temperature and storms).

The Steller sea lion population, from the western Gulf of Alaska to the western Aleutian Islands including the Bering Sea, where the great majority of the species resides, has declined by over 80%, a result of increased mortality of all sex and age classes but primarily a result of reduced juvenile survivors. Mass emigration is not a factor in the decline of the population in Alaska, because the number of sea lions in Russian waters has also declined since about 1970, and no significant increase in the population has occurred in other areas of the species' range. Further work is needed to identify the locations and causes of mortality once the animals leave the summer breeding rookeries to feed at sea. The decline of the Steller sea lion throughout most of its range is significant because of the potential effect that human activities, including competition for available food resources, may be having. Because the species has declined to a fraction of its former size, the population has recently been listed as threatened under the Endangered Species Act of 1973.

NOAA's research on the endangered bowhead whale population has provided insights into critical life history parameters. These whales are photographed during their spring migration past Point Barrow, the northernmost tip of Alaska. By using calibrated camera systems installed in an aircraft, image lengths can be measured and well-marked individuals can be re-identified. Since 1984 there have been over 1700 bowhead whales measured and 1300 cataloged as identifiable in these aerial photographs. The results indicate that the population is composed of 41.8% sexually mature adults, 53.0% immature and 5.2% calves. This high proportion of immatures suggests that the population is increasing. The NMML photograph collection, including images from other research groups, now represents over 2500 bowhead whales with sufficient markings to allow for re-identification. Four pairs of adults were re-identified with calves more than once between years, indicating calving intervals of approximately four years.

Marine Fisheries Assessment

NOAA's National Marine Fisheries Service (NMFS) continued its long-standing commitment to assessment studies of U.S. living marine resources (LMRs). This effort includes fishery-independent resource surveys, 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.

The Alaska Fisheries Science Center (AFSC) in Seattle, Washington, 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. 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 (1- to 3-year) 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.), AFSC stock assessments provide recommenda-

tions 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 cruises are conducted within each region. Annual estimates 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 the biological and physical processes that affect stock assessments.

The principal survey methods include bottom trawls for crabs and demersal fish, hydroacoustic and mid-water 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. Recruitment indices and processes that generate variations in abundance are studied to improve prediction. To increase the accuracy and precision of these assessments, AFSC scientists conduct biological research to define recruitment processes, develop computer models to simulate the interactions and dynamics of population change, and conduct or collaborate in extramural studies to improve sampling methods and survey designs.

Related Programs

Fisheries–Oceanography Coordinated Investigations

The goal of Fisheries–Oceanography Coordinated Investigations (FOCI) is to understand the coupled physical and biological interactions that affect the survival of walleye pollock in Alaskan waters and ultimately lead to variations in recruitment. Recruitment is the process by which young fish are added to the adult or fished stock. Research has been conducted in support of the paradigm that such fluctuations largely are a result of events early in their life history. Our understanding of processes affecting recruitment has advanced to the degree that last year FOCI provided U.S. fishery management with recruitment information independent of that gathered from the commercial fishery for establishing pollock fishing quotas in the Gulf of Alaska. In the fall of 1993, FOCI again supplied estimates of pollock biomass for the Gulf of Alaska.

Since the inception of FOCI in 1985, an interdisciplinary team of scientists has focused its research on Shelikof Strait, which is the spawning locale for the commercially important Gulf of Alaska pollock. In FY 92 a Bering Sea component was added to FOCI under the auspices of NOAA's Coastal Ocean Program. Bering Sea research identifies the different aggregations of pollock, their relation to dominant circulation features of the Bering Sea, and the effects of basin, slope and shelf habitats on the early life stages of pollock.

FOCI made predictions in the fall of 1992 for the 1989, 1990, 1991 and 1992 year classes (the year when fish were spawned) of walleye pollock recruiting to the Shelikof Strait fishery. The preliminary prediction scheme used objective statistical analyses of spawner-recruit data and the FOCI-extended recruitment time series. Predictions were modified subjectively by researchers' knowledge of the environment. FOCI's predictions helped the Resource Ecology and Fisheries Management (REFM) division of NOAA's Alaska Fisheries Science Center define recruitment scenarios for their stock projection model. REFM analyzes stock projections and catch scenarios and recommends fishing quotas to the North Pacific Fishery Management Council.

Modeling studies are being used to help assess the impact of interannual changes in circulation on the survival of pollock larvae. The circulation model used is the Semispectral Primitive Equation Model (SPEM), modified for this region. The model is driven by daily wind stress, Fleet Numerical Meteorology and Oceanography Center (FNMOC) surface analyses adjusted for local topographic effects, and seasonal patterns of freshwater runoff. The model has a horizontal resolution of 4 km and nine vertical levels to replicate the observed current shear. The model code is designed to take advantage of vector-processing computer architecture.

The circulation model has been coupled with an individual-based model of egg and larval growth. This coupled model tracks large numbers of developing eggs and larvae as they migrate vertically and are advected by the circulation. The biological model is probabilistic; feeding and mortality are stochastic functions of time and the local physical environment. Our motivation for such an approach is the observation that wide variability exists within natural fish populations, and models of the "average" individual are likely to be misleading. As a result of tracking the unique spatial, temperature, salinity and feeding histories of representative individuals, more of the natural variance within the population can be reproduced. For example, analy-

ses of statistics from a coupled model experiment suggested how the unique spatial histories of different individuals can yield a bimodal distribution of weights and lengths within a single year class. In contrast, a model with no spatial information yielded a simple unimodal distribution.

Thus far, model runs have succeeded in reproducing the general spatial features of the circulation field as inferred from drifting buoy data and hydrographic surveys. A comparison of model output with moored current meter data for 1989 has yielded exceptional agreement. Model-generated spatial patterns of larval density on specific days in 1989 compare well with field surveys for that year. Such biophysical simulations suggest physical causes for part of the interannual variability in pollock survival. Potentially they will be used to help forecast recruitment success under changing physical conditions.

Currents and eddies in Shelikof Strait and its accompanying sea valley were examined. Analysis of the transport along the Alaskan coast has improved the understanding of the dynamics of the Alaska Coastal Current (ACC). Larval survival, at least in part, is related to the strength of the ACC. The ACC is forced not just in Shelikof Strait but also to the east. Physical conditions that retain larvae on the continental shelf, as opposed to transporting them into deeper waters, are believed to enhance the survival of pollock in Shelikof Strait. The formation of mesoscale eddies on the shelf helps to retain (on the shelf) larvae, plankton and nutrients associated with shelf waters in particular areas. Such processes vary from year to year as physical conditions change. A careful examination of the dynamics within an eddy observed in 1989 in the Shelikof region was completed. The 1989 eddy was associated with a larval patch, and apparently larval mortality was less within the eddy than outside. To discover how common these mesoscale eddies are, a census of the number of eddies in the Shelikof Sea valley was completed. Eddies were most common in the spring, when up to four occurred each month.

Bering Sea FOCI has acquired considerable knowledge of the basin-wide circulation in the Bering Sea. Prior to Bering Sea FOCI, barely more than anecdotal information existed. In August 1991, on a cruise conducted in both U.S. and Russian waters, operations included 112 CTD (conductivity, temperature, depth) casts, release of 25 satellite-tracked drifters and deployment of 3 current moorings in Near Strait, the wide opening between the Aleutian and Komandorski Islands. During this cruise, no Alaskan Stream water was flowing into the Bering Sea through Near Strait; furthermore, the Kamchatka Current outflow was only half its normal value. A year later, however, CTD and drifter data showed well-developed inflow through Near Strait, and current meters in Near Strait recorded the evolution of this inflow. Thus, a major, interannual variation in the inflow to the Bering Sea was documented. In other respects, however, circulation in the western and central Bering Sea seems more organized and simpler than in many historical schemes of circulation. Flows exist that connect the western, central and eastern basins. These results also are supported by use of the U.S. Navy ocean layer (one-eighth degree) model, which shows eddy variability in Near Strait and in the west-central Aleutian Basin but a more regular annual signal in the eastern basin.

FOCI studies in the eastern Bering Sea, mainly with drifters, have revealed distinct currents that may be relevant to pollock larval drift. Flow along the North Aleutian Slope appears capable of transporting larvae onto the eastern shelf in less than three weeks. A pathway across the northern basin has also been identified. This flow could transport larvae or immature fish to the Russian coast in about three months. Thus, a time-scale match exists between drift velocities and the potential requirement for pollock larvae to advect onto the shelf to have strong year classes. The water temperature north of the middle front on the Bering Sea shelf also may play a role in the rate of larval growth, which also contributes to survival and fisheries recruitment.

Eddies and high concentrations of pollock larvae often are coincident in Shelikof Strait, and a similar relationship exists in the eastern Bering Sea. Mesoscale (80- to 150-km-diameter) eddies are common in both circulation schemes and dynamic topographies of the oceanic waters of the eastern Bering Sea. The typical separation of CTD stations and the lack of adequate sea surface temperature gradients have left the smaller eddies unresolved. Between 1988 and 1993, 12 satellite-tracked buoys were deployed in four eddies in the southeastern Bering Sea basin. Our success in finding eddies resulted from placing buoys in high concentrations of pollock larvae. Similar biophysical processes may be occurring in both the Gulf of Alaska and the Bering Sea that increase the likelihood of larval survival within eddies.

A time-series mooring was placed north of the eastern Aleutian Islands during the spring and summer of 1992 and 1993 in an area of known pollock spawning. Meteorological measurements are wind, humidity, solar insolation, and air and sea temperature; oceanographic measurements are current, salinity, bio-optical properties and backscatter from zooplankton. For the first time, measurements have been obtained of the mixed-layer's development

and the hourly zooplankton abundance throughout the spring bloom. The steady trend of mixed-layer shoaling was punctuated by one strong storm event that deepened the mixed layer near the time of the pollock larval spawning. The data will be used to test the hypothesis that larvae are food-limited in the spawning grounds of the Aleutian basin and must be advected to the Bering Sea shelf to produce a strong year class.

Sea Ice–Troposphere Interaction

In FY 93, analyses were completed of oceanographic, meteorological and sea ice data obtained from the northern Bering Sea and Chukchi Sea region during the autumns of 1987 to 1991 in cooperation with Russian scientists. These data were acquired as part of a program designed to compare air, sea and ice conditions during the autumn in the western Arctic. The ice edge was significantly farther north in 1987 and in 1989–1991 than in 1988, when ice existed along the coastline from Barrow to Icy Cape. In 1987 the ice edge was anomalously far to the north as late as October, and the autumn ice-edge advance was later than in 1988–1991. Interannual variations were observed throughout the region but were greatest in the northern Chukchi Sea. There, surface oceanic isotherms and isohalines were shifted nearly 2° latitude farther south in 1988, coincident with the southward displacement of the ice edge. However, the subsurface water at 20 and 35 m deep in the same region was actually warmer in 1988 than in other years. From mid-August until mid-October 1988, the wind blew mainly from the north, averaging nearly 10 m/s across the Chukchi Sea. Although other years had northerly wind events that were as strong, the persistence of this pattern was striking. Also embedded in this northerly wind regime was a two-week period in September with westerly winds that caused the pack ice to be pinned against the beach along the northwest coast of Alaska, leading to the infamous media event of three trapped whales near Barrow. By contrast, other years had higher variances in the wind and significantly fewer instances of northwesterly winds than in 1988. There is no evidence for a sea-water temperature anomaly upstream, southward of the ice edge during 1988. Ice continually eroded along the southern front until the surface mixed layer reached a thermally quasi-stable state near the freezing point, which was the result, not the cause, of the extreme presence of ice in the Chukchi Sea in 1988.

A harmonic analysis of tidal and inertial motion was applied to observations of the positions of Argos buoys (buoys that transmit data via Argos, a satellite-based data telemetry and geolocation system) deployed on drifting multiyear sea ice in the Eastern Arctic–Barents Sea during the Coordinated Eastern Arctic Experiment (CEAREX) in 1988 and 1989. An Argos positioning-data screening protocol was developed, and a constrained least-squares algorithm was constructed for separately estimating mean tidal and inertial currents. This analysis provides estimates of individual tidal components at 15-day intervals along the sea ice buoy drift tracks. This technique shows a reasonable qualitative distinction between tidal and inertial oscillations at nearly semidiurnal frequencies. Estimates of errors due to sampling and colinearity are derived directly from model statistics. Estimates of velocity produced from the unequally time-based data are then used for interpolation to a regular time grid for spectral analysis and ice motion studies. Computed velocities of up to 70 cm/s for the principal lunar component of tidal motion over Spitsbergen Bank southeast of Svalbard are in reasonable agreement with the regional Norwegian tidal model.

A major multiyear research program, Coastal Observations and Simulations with Topography (COAST), was established in FY 92 and started in the fall of 1993. The objective of this program is to identify and understand the influence of terrain on coastal weather phenomena, with the ultimate goal of improving weather, wind and sea state forecasting in the coastal zone. It is sponsored by NOAA's Coastal Ocean Program and the Office of Naval Research and also involves ERL's Environmental Technology Laboratory (formerly Wave Propagation Laboratory), the National Weather Service (NWS) and various universities.

A case study was completed on an unanticipated coastal wind storm near Yakutat, Alaska. This study showed that intense winds were caused by a propagating pressure surge associated with damming of the onshore-directed flow by the coastal terrain. NWS is sponsoring a follow-up study of the climatology and dynamics of these events in collaboration with forecasters from Juneau and Anchorage, Alaska.

A remote-sensing wind and temperature profiler was obtained for the Puget Sound region by a consortium including NWS, PMEL, the Puget Sound Air Pollution Control Agency, the Washington State Department of Ecology, the Environmental Protection Agency and the University of Washington. This instrument will be used for climatological and mesoscale meteorological research in collaboration with the Seattle office of NWS.

These activities represent the beginning of a five-year program involving a blend of observational, modeling and theoretical work. COAST will address a fundamental research issue with

important implications for operational forecasting anywhere there is significant terrain.

Under-Ice Ecology

An under-ice ecology program was conducted on Great Slave Lake in the Canadian Northwest Territories involving the Environmental Sciences Division of the National Hydrology Institute of Environment Canada and the Great Lakes Environmental Research Laboratory of NOAA. A major goal of the 1992 field program was to determine the physiological condition of zooplankton under extreme conditions of food limitation during winter. Laboratory feeding experiments, lipid concentrations and reproductive state were used to determine whether the zooplankton from the western basin, as well as the very deep (614-m) ultraoligotrophic eastern arm, were physiologically active or in metabolic arrest. Both of the calanoid copepods *Limnocalanus* and *Diaptomus sicilis* had higher lipid concentrations in Great Slave Lake than in Lake Michigan, even though ovary development and egg carrying were high and about the same in both lakes. The feeding rate of *D. sicilis* in the ice-covered Great Slave Lake was lower than ever observed in the open or ice-covered Lake Michigan. Lowered feeding effort and low quality and concentration of the seston of Great Slave Lake were the reasons for the difference. Stored lipids must have been fueling much of the reproduction in Great Slave Lake. These results are giving us insights on how these copepods, important to large lake ecosystems from the Canadian Arctic down to the Laurentian Great Lakes, cope with winter. This information will be useful for designing future studies to evaluate the effects of climate change on these large lakes.

People and Health

Social and economic research was carried out jointly by the National Marine Fisheries Service and the North Pacific Fishery Management Council for fishery management planning for the groundfish and crab fisheries of the Bering Sea and Aleutian Islands (BSAI), the groundfish fisheries of the Gulf of Alaska (GOA), the BSAI and GOA scallop fisheries and the halibut fishery off Alaska. Most of the research focused on the issue of allocating catch and bycatch quotas among competing uses and user groups. The specific topics addressed included the following:

- The bycatch of crab, halibut, herring, and salmon in the groundfish fisheries;
- Allocation BSAI pollock and GOA pollock and Pacific cod quotas between catch for at-sea processing and onshore processing;
- Community development quotas for the BSAI pollock, halibut and sablefish fisheries to provide assistance to Native coastal communities in western Alaska;
- Allocation of the BSAI Pacific cod quota between the trawl and fixed-gear fisheries;
- Individual transferable quotas for the fixed-gear halibut and sablefish fisheries;
- A vessel moratorium for the BSAI groundfish and crab fisheries and the GOA groundfish fisheries;
- The use of user fees to fund the groundfish and crab fishery observer programs;
- Individual transferable quotas and license limitation for registration areas;
- Seasonal and area allocations of quotas;
- Gear restrictions, including minimum mesh size limits;
- Time and area closures to protect marine mammal populations;
- Methods for improving the accuracy and timeliness of catch and bycatch estimates; and
- Fishery management plans for the BSAI and GOA scallop fisheries.

National Marine Fisheries Service activities that were not in direct support of fishery management included the following:

- Preparation of the economic analysis associated with the Draft Legislative Environmental Impact Statement for the "Marine Mammal–Commercial Fisheries Interaction" proposal;
- Participation on the Economic Steering Committee for the *Exxon Valdez* Damage Assessment Program; and
- Preparation of regulations to implement the Oil Spill Act of 1991.

Operational Weather, Hydrological and Ice Services

Solar–Terrestrial Services and Research

The Space Environment Laboratory (SEL) of NOAA/OAR/ERL continued 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 SEL's Space Environment Forecast Center in collaboration with the USAF 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.

Navy–NOAA Joint Ice Center

The Navy–NOAA Joint Ice Center (JIC) is the only organization in the western world that provides global sea ice analyses and forecasts. Standard weekly analyses of Arctic and Antarctic sea ice conditions are distributed to government, military, university, research, private industry and foreign interests. The JIC has several activities that support research, although it is primarily an operational center producing sea ice analyses and forecasts on global, regional and local scales. The activities or programs that support research include the Digital Ice Forecasting and Analysis System, the Arctic Drifting Buoy Program and the Operational Demonstration of synthetic aperture radar (SAR) data. During FY 93 a draft annex to the Navy/NOAA MOA was written to change the name of the JIC to the National Ice Center (NIC) and to codify the U.S. Coast Guard as a full-time partner of the NIC.

The Digital Ice Forecasting and Analysis System (DIFAS) is workstation technology originally developed by NOAA's Program for Regional Observing and Forecasting Services. DIFAS has been upgraded during the past two fiscal years by installing five new workstations and writing new software. This upgrade has allowed the NIC to produce the Great Lakes ice analysis interactively. The immediate use of these analyses is for operational shipping in the Great Lakes. However, the product will ultimately be digitized and used for climatological studies. Eventually ice analyses of all the polar regions will be totally produced on the upgraded DIFAS using all sources of digital satellite imagery and reconnaissance data. These products, which are archived at the National Snow and Ice Data Center, should prove beneficial for climate change studies.

The NIC has the responsibility for coordinating and managing the U.S. Interagency Arctic Buoy Program (USIABP). Participants providing financial support to this program are the Navy, NOAA, NASA and NSF. The USIABP was formed to establish and maintain a baseline network of drifting buoys of sufficient spatial resolution and longevity to define surface synoptic-scale atmosphere pressure, air temperature and sea ice drift fields in the Arctic. At the beginning of FY 92, only 11 meteorological buoys were functional in the Arctic. By the end of FY 93, 42 meteorological buoys were reporting surface pressure and temperature data via the Global Telecommunications System (GTS). In an attempt to improve the accuracy of air temperature measurements, a buoy calibration and performance study was initiated during FY 93 in Barrow, Alaska. Three types of buoys were installed at Barrow to determine the most functional buoy design for measuring air temperatures. Two additional buoys will be installed in FY 94. The ultimate goal is to provide researchers with accurate air temperatures over the Arctic Ocean for global climate studies.

A workstation for processing and analyzing SAR data was installed at the NIC in FY 92 to conduct an operational demonstration of the utility of SAR data for ice analysis. This demonstration has occurred over the past two fiscal years. SAR data represent a high-resolution, all-weather data source for ice depiction. Although only small amounts of SAR data have been received, the NIC was able to provide near-real-time support to the Coast Guard's *Polar Star* during a scientific mission in the Chukchi Sea in September 1992. When SAR imagery has been available, the data have been incorporated into the NIC's operational analyses. SAR data were particularly useful for the Great Lakes ice analyses during the 1992-93 ice season. During the period of the demonstration, SAR imagery has proven very effective in several applications, such as multiyear boundary location, lead detection, ice motion measurements and new ice detection. As more SAR data become available, especially after the launch of Radarsat, and these data are integrated into the operational data stream, the quality and detail of the ice products should be much improved, benefiting the research community.

Meteorological Research

The Alaska Region of the National Weather Service conducts a number of Arctic meteorological research activities. The funding for much of the research comes from the Cooperative Program for Operational Meteorology, Education and Training (COMET), a division of UCAR.

Studies of the Arctic front over Alaska address two forecast problems: detection of the Arctic front and the effect of the Arctic front on local weather. The results to date show that there is more unusual weather associated with the front than anticipated. The new doppler radars and the automated surface observation system, along with polar satellite imagery, are being used to detect the front. A final report is due in the spring of 1995.

The project to use the Defense Meteorological Satellite Program (DMSP) special sensor micro-

wave/imager (SSM/I) data to assist forecasting in Alaska involves accessing real-time DMSP digital data and processing and distributing that data to NWS workstations. Regional algorithms for SSM/I are being generated for five climatological regions of Alaska to determine the areal extent and intensity of precipitation, cloud water content, integrated water vapor, land surface moisture and snow water equivalents. In addition, surface ocean wind speed is being derived.

A Taku windstorm and Arctic outbreak study attempts to understand what is needed to forecast these severe downslope events. Specific mesoscale features of these winds are being examined to help accurately forecast the intensity and duration of the windstorms.

An effort to improve the monitoring and forecasting of volcanic airborne debris is not only for those areas with active volcanos but also for regions downwind where airborne volcanic ash may travel. This research has resulted in operational multispectral techniques for detecting volcanic ash plumes in polar-orbiting imagery and in C-band radar reflectivity returns.

A lightning prediction study for interior Alaska involves a hybrid neural–expert system to assist forecasters. The system uses artificial intelligence and pattern recognition. An initial test of the system was done in 1993 and helped define the critical parameters in forecasting lightning. Further work continues to refine the system.

A study to predict storm surges and waves in the Bering Sea grew out of a storm that hit Nome, Alaska, on 5-6 October 1992. Over $14 million in damage occurred to the city and surrounding coastal roads. An analysis of past storms was conducted in 1993. Improved forecasting techniques are being developed and should be available to forecasters for the next storm season.

SAR data are being examined as a source of observations for ocean wave forecasting in the Gulf of Alaska and Bering Sea. An initial study shows the SAR observations to have an accuracy of within 0.75 m for waves greater than 2 m. Other satellites with SAR are due to be launched in polar orbit in the coming months, and this study will continue to determine their utility as a major source of open ocean observations of wave height.

Research on the surface winds in the eastern Gulf of Alaska attempts to forecast the intensity and duration of topographically forced high winds caused by landfalling storms. The eastern Gulf of Alaska has the highest coastal mountains in the world (greater than 3500 m). Winds in excess of 40 m/s are common with strong storms. This study is using the latest theories on barrier winds along with an analysis of past storms.

Satellite, Data and Information Services

NOAA's National Environmental Satellite, Data and Information Service (NESDIS) 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 use needs; and
- Providing specialized data analyses and interpretations.

As part of this overall responsibility, NESDIS maintains a variety of Arctic and Antarctic environmental data sets. The data holdings of the National Geophysical Data Center in Boulder, which include those of the World Data Center A for Glaciology (Snow and Ice), are of particular relevance to Arctic studies.

A valuable source of high-latitude data is the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's polar-orbiting environmental satellites. Magnetic tapes and hard-copy prints of the AVHRR data are archived by the NESDIS National Climatic Data Center. AVHRR data for the Arctic are routinely mapped for the National Ice Center (NIC) for use in generating ice analyses and forecasts by interactive analysis of digital satellite imagery.

A satellite communications system for rapidly transmitting SAR data from the Alaska SAR Facility at the University of Alaska Fairbanks to the NIC in Suitland, Maryland, has been used routinely since April 1992. This link, maintained by NESDIS, carries up to 10 ERS-1 SAR quick-look images of the Arctic per day. These data are analyzed by the NIC to evaluate the impact of using SAR data in ice analyses and forecasts. SAR data will become a prime source of remote sensing data for the NIC after the Canadian Radarsat is launched in 1995 and begins to provide SAR data on an operational basis.

Arctic data from the SSM/I flown on DMSP satellites are now being tested for utility in ice analyses and forecasts. The National Climate Center 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 concentration. The SSM/I sensor data and 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 over the Shared Processing Network linking the nation's operational environmental processing centers.

NESDIS is participating in an interagency program with the Air Force to fly a solar X-ray imager on the next series of NOAA's Geostationary Operational Environmental Satellites (GOES). The preliminary design review of the X-ray imager was held in November 1993. This instrument will be integrated on the GOES-M satellite with a launch around the turn of the century.

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 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.

Department of Agriculture

The Department 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

	Funding (thousands)	
	FY 92	FY 93
Forest Service	1243	1350
Cooperative State Research Service	1291	1290
Soil Conservation Service	1104	1148
Agricultural Research Service	778	717
Total	4416	4505

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, especially the northern boreal forest. PNW scientists are stationed at the Institute of Northern Forestry in Fairbanks and the Forestry Sciences Laboratories in Anchorage and Juneau. 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 Ecosystems Processes scientists stationed at the Institute of Northern Forestry are actively involved in research into forest succession on highly productive forest lands—floodplains and warm slopes—and on cooler, less-productive permafrost terrain. A major recent accomplishment is the publication of the Alaska Vegetation Classification system, a document now being widely used in natural resource management in Alaska.

Ecosystems Processes scientists are playing a leading role in the Long-Term Ecological Research (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 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;
- 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 emphasis is on the floodplain, where primary succession is initiated by periodic flooding, and on uplands, where secondary succession is strongly influenced by periodic wildfires.

Scientists of the PNW Aquatic/Land Interactions research program at the Institute of Northern Forestry are studying landscape-scale processes affecting watershed stability, streamflow patterns, stream quality, stream productivity and stream ecological relationships in Alaska's boreal forests. Their research is centered on the 10,400-ha Caribou–Poker Creeks Research Watershed (CPCRW) near Fairbanks, which was established in 1969 and is dedicated to research into hydrologic and environmental questions in the discontinuous-permafrost boreal forest (taiga) of the Yukon–Tanana Uplands of central Alaska. The broad objectives of

research at CPCRW are to develop an understanding of hydrologic, climatologic and environmental relationships in taiga ecosystems, to support catchment-scale experimentation on the effects of resource management practices on these relationships, and to support multidisciplinary long-term monitoring of the stream–landscape biological and physical system. CPCRW encompasses more than a dozen first-, second- and third-order subdrainages over an elevation range of 210–826 m, allowing analysis of a stream system continuum from headwaters through fourth-order streams.

PNW Aquatic/Land Interactions research at CPCRW includes determining the effects of permafrost on the catchment hydrologic regime and analyzing the hydrologic behavior of periglacial landforms. Increasing attention is being paid to the ecological relationships of headwater streams and to the linkage between the landscape (catchment slopes), the riparian zone and stream channels. Hydrogeochemical monitoring of headwaters streams in CPCRW provides the foundation for process research, which has already documented the influences of permafrost on streamflow patterns, steam biota and subarctic hydrologic phenomena including aufeis and pingos. This work concurrently furnishes a basis for assessing terrestrial–aquatic (watershed) ecosystem change in response to changing climate or environmental contamination. Scientists at the Institute of Northern Forestry recently established the northernmost site of the nationwide National Atmospheric Deposition Program (NADP) in CPCRW; precipitation chemistry is monitored in the Caribou Creek valley (at an elevation of 230 m). Beginning in September 1993 the NADP program in CPCRW was complemented by the operation at treeline (at an elevation of 762 m) of a remote aerometric station (in cooperation with the Environmental Science and Technology Center, National Biological Survey), which records standard climatic variables and monitors UV-B radiation. Continuous air samples are pumped through a filter pack, which is changed monthly and analyzed for airborne particulate chemistry. These inputs are being compared with measurements in streams draining the same landscape. The water quality of first- and second-order streams in CPCRW has been monitored for more than a decade.

Spruce provenance tests on Adak Island in the Aleutian Islands to determine the western range of climate warming in Alaska.

Ecosystems Processes and Aquatic/Land Interactions scientists pursue a common interest in boreal forest ecosystem productivity and functioning. LTER research opportunities offered by BCEF-LTER are significantly expanded through collaboration of the BCEF-LTER program with the CPCRW. Research monitoring in CPCRW relevant to LTER includes a basin-wide system of hydrologic and climatology stations, with many records dating back more than two decades. Ecosystem monitoring supports research into basic ecosystem processes, forest succession and the hydrologic regime and stream ecology in a first-order to fifth-order stream continuum. Four 25-ha Long-Term Forest Reserve Stands have been established in CPCRW specifically for baseline ecosystem monitoring in each of four major environmental settings: treeline; permafrost-underlain north-slope coniferous woodland; permafrost-underlain valley and riparian zone; and permafrost-free south-slope mixed deciduous–coniferous forest. These reserve stands, in which 0.25-ha subsamples have been permanently surveyed and intensively measured, complement a network of 24 LTER sites in BCEF established to study forest succession on floodplains and uplands.

The composite BCEF/CPCRW LTER site encompasses more than 150 km^2 and includes environmental settings varying from highly productive floodplain forests and permafrost-free coniferous and hardwood forest stands on south-facing slopes, to low-productivity permafrost-underlain coniferous woodlands on north-facing slopes and in poorly drained cold valley settings. The composite BCEF/CPCRW research site offers attractive opportunities for scaling ecosystem research from plot to slope to watershed under controlled conditions over an elevational gradient from floodplain to treeline and over a range of soil, vegetation and permafrost conditions. Several LTER cross-site stream ecology projects have been initiated that include CPCRW. These include a conservative tracer release investigation of how various hydrologic parameters (such as discharge, transient storage and lateral inflow) vary with location, a study

Research on the impact of wood-boring insects on wood quality and value.

to address carbon dynamics in aquatic ecosystems and an investigation of large-scale patterns in the distribution of microbial biomass in stream ecosystems. CPCRW complements BCEF and the LTER site at Toolik Lake in providing facilities for studying large-scale ecological patterns, providing a forested watershed system near the northern forest limit and within the discontinuous permafrost region.

Climate change predictions by many general circulation models indicate that regions north of 60° latitude may be subjected to major warming in coming decades, producing increased permafrost thaw, altered vegetation distribution, altered biological productivity, altered wildfire regime and perhaps the release of large quantities of stored organic carbon into the global carbon cycle. Soils in the taiga are rich in organic carbon, much of which is stored in permafrost. In the event that central Alaska were to experience warming of 4–8°C 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. The large, carefully documented forest stands in CPCRW and BCEF offer baselines and sites for evaluating ecosystem response to warming over the range of important taiga environmental settings. One planned study in CPCRW will monitor organic carbon dynamics in headwater streams having 3.5–55% of their contributing catchments underlain by permafrost. From these data it will be possible to construct a model of the effect of discontinuous permafrost on organic carbon dynamics in streams and attempt to predict the effects of global warming on the taiga.

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 Yukon Flats National Wildlife Refuge, in the 1988 Selawik fire in northwest Alaska and in 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 CPCRW in support of the expanding Long-Term Ecological Research program.

Ecosystem Processes scientists at the Forestry Sciences Laboratory, Anchorage, are continuing research on the population dynamics of moose in the Copper River Delta and Denali National Park. At the Copper River Delta, research is concentrating on defining basic seasonal movement and 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.

PNW Environmental Health and Protection Research scientists conduct research on forest health problems, research aimed at developing ecosystem 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 forest ecosystems in Alaska. This research covers a broad area of ecosystem activities, including the cause-and-effect relationship with global climate change, long-term site productivity, biodiversity and new perspectives in forestry. The primary goal is to determine the relationships between insects, diseases and the health of the vegetation at various levels of the forest community in a changing environment.

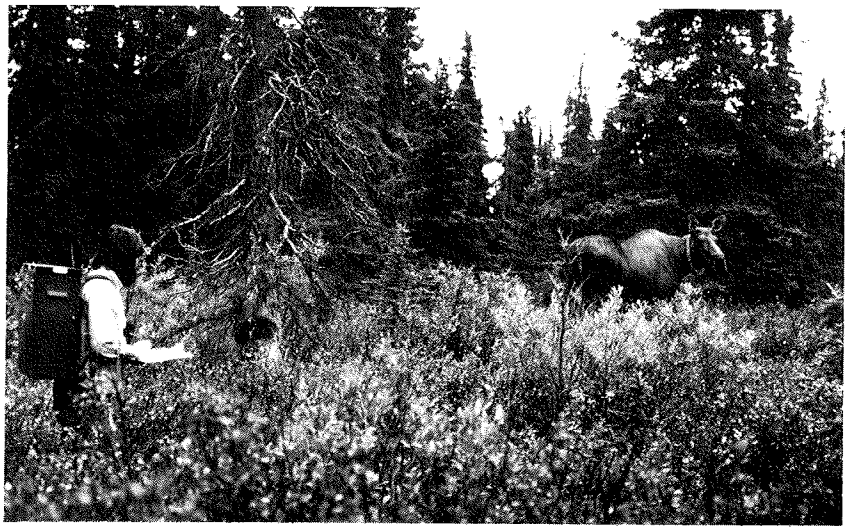
Current forest insect research is aimed at identifying physiological mechanisms and phytochemicals in various species of spruce in the boreal forests of circumpolar countries. This is a collaborative program between the Institute of Northern Forestry, the Forest Products Laboratory and the Finnish Forest Research Institute. The research includes investigations on the role of certain monoterpenes and stilbenes that enhance host resistance to attack by spruce-inhabiting bark beetles. Research on the host resistance of similar species of spruce that are indigenous to northern latitudes could result in the development of forest stand manipulations through silvicultural treatments that would increase the resistance in species of spruce

that are susceptible to attack by spruce bark beetles. The results of this research indicate that Sitka, white and hybrid Lutz spruce respond to mechanical wounding and wounding plus inoculation with blue stain fungi by forming an induced reaction zone around the wound sites. Beetles tended to deviate from this zone when constructing egg galleries; trees inoculated with fungi seemed to deter larval feeding.

An aggressive research effort is also underway on the development of technology to manipulate populations of spruce and *Ips* engraver beetles using behavior-modifying semiochemicals. The most promising tools for reducing losses to natural resource productivity from bark beetles in Alaska appear to involve the use of host- and insect-produced semiochemicals. Several operational use strategies utilizing semiochemicals have been successfully field tested, such as beetle trap out, spot baiting and diversion trapping using pheromone-baited traps and trap trees.

A cooperative study was developed with the National Park Service to establish long-term research sites for monitoring changes in populations of insects that inhabit riparian, upland and alpine sites in Denali National Park. Changes in the health of forest ecosystems and the effects of global climate change can be measured by changes in the density, species composition, range and behavior of terrestrial insect populations. This study plan was incorporated into the Long-Term Ecological Monitoring plan for Denali National Park in the summer of 1992 and is compatible with long-term studies being conducted in boreal ecosystems of other circumpolar countries. The purpose of this study is to monitor terrestrial insect populations in various ecological biomes over time, with an emphasis on species composition, density, host plant preference, distribution within the host, range with increased elevation and latitude, and the detrimental and beneficial effects of insects on host plants and other insects (primary and secondary consumers, pollinators and decomposers).

Moose habitat research at Denali National Park, Alaska.



Scientists at the Institute of Northern Forestry, as part of the PNW research program on Production of Goods and Services, have concluded a three-decade study addressing the cumulative effects of management alternatives on boreal forest productivity and on silvicultural techniques appropriate for boreal forest ecosystems. Completed research on the structure and dynamics of mixed-species forest stands and white spruce forest stands provides a basis for developing management prescriptions for sustainable forest utilization. Research into the genetic basis for tree improvement programs in Alaska's boreal forest has continued, with species provenance trials in place for white spruce, Sitka spruce and lodgepole pine.

PNW Inventory and Economics Research scientists at the Forestry Sciences Laboratory, Anchorage, are responsible for inventory 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. Forest Service scientists have particularly addressed the forest conditions on the Kenai Peninsula and in south-central Alaska in response to increasing forest insect problems; an infestation of spruce bark beetles is causing widespread forest mortality and impairment of forest productivity in those regions.

Cooperative State Research Service

The Cooperative State Research 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 of 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 direct linkage 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.

While AFES research results are used by foresters, farmers and land managers, all Alaskans directly benefit from the wise use of land resources. 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. Through these direct public contacts, they discover additional research needs.

Because of these contacts, most AFES research projects in the plant and animal sciences program were in response to producer requests. Research projects in the forest sciences and resources management program were developed in cooperation with industry, State and Federal agencies.

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.

Plant and Animal Sciences

Among the research projects in the plant and animal sciences is a study on the management of Alaskan beef cattle to maximize forage use. This study seeks to maximize the use of Alaskan forage for beef cattle through alternative management, by managing cattle on a fall calving scheme and by comparing animal survival, health and economic considerations with traditional spring calving methods. The beef cattle at Palmer have been bred in April and May so they would calve in late February and March; through the winter these cows were often overfed because of their efficient usage of feedstuffs. In this study the herd was shifted to fall calving, so that the cows begin their maximum lactation, requiring the most energy, in August. They are in excellent condition from being on pasture, and they lactate during the winter to take full advantage of nutrients in the harvested forage. The first fall calves were born in August 1991. Calves were weaned before going to pasture and grazed the duration of the summer. In early October they were placed in the feedlot and were ready for slaughter in December and January. This saved about 50% on grain from spring calving. The free-choice hay intake by beef cows for fall and spring calving is 2.5% of body weight, but fall-calving cows use winter forage more efficiently because they are also providing for calves and were not in over-condition for spring grazing.

Another study looked at the characteristics and feed value of barley and western protein supplements for swine. Two studies were conducted to determine the feeding value of three fish hydrolysates produced by the Bertullo Bio-Proteus Process (an aerobic proteolytic fermentation by a marine yeast, deboned, oil separated and hydrated) from cod processing wastes, whole pollock and halibut steaks. The products were low in oil and ash, with high protein contents of 73, 79 and 71% for cod, halibut and pollock hydrolysates, respectively. Hydrolysates from the cod waste and halibut steaks had equal growth and feeding value to the other test diets, but daily gains were lower with the pollock diet. The reduced daily gains were related to a poorer feed-to-grain ratio of 2.2 for the pollock diet compared to 1.8 for the other three diets.

The classification and interpretation of permafrost soils in Alaska is the focus of another project. Research has been centered on the morphology, classification and land use interpretations of permafrost soils in Alaska. The current definitions and taxonomic keys do not adequately address the cryogenic nature of the permafrost soils. Nearly 65% of the soils in northern Alaska can be covered by two subgroups. Based on field data, it is proposed to place the cryogenic formative element, pergelic, in the order level. Thus, a Gelisol order is proposed to include all permafrost-affected soils. Soils in the zone of discontinuous permafrost and those in the zone of continuous permafrost have different climatic zones, yet they are classified the same. It is proposed that the pergelic climatic zone corresponds to the zone of continuous permafrost and has a mean annual soil temperature (MAST) from –4 to –10°C, with a mean annual precipitation (MAP) of 12–50 cm. The cryic–pergelic climatic zone corresponds to the zone of continuous permafrost with a MAST of –4 to +2°C and a MAP of 30–45 cm. The redoximorphic features of some permafrost soils were studied to relate to the past environment. The active layers of some permafrost soils were studied for ice structure and water content as part of a global change research program.

In a study of the propagation and cultivation of Alaska native plants, ten species that were identified as having potential as ornamentals will be used in experiments to determine methods of commercial propagation. Standard seed germination

tests will be conducted, followed by experimentation with various pretreatments (scarification, stratification, etc.) should germination fail. Vegetative propagation techniques using root, rhizome and stem cuttings will be investigated to determine the timing of cutting collection, cutting age and growth regulator treatments. Once an appropriate propagation method has been established, greenhouse experiments will be conducted to evaluate vegetative growth on eight soil-based or soilless media and under all possible combinations of five levels of nitrogen, phosphorus and potassium fertilizers. Irrigated field plots of wild blueberries and lingonberries will be established to determine appropriate levels of fertilizer for seedling establishment and vegetative growth. Experiments will consist of all possible combinations of three amounts of nitrogen, phosphorus and potassium. During the 1992 growing season, evaluations were conducted on 18 tree species, 35 shrubs, 197 herbaceous perennial ornamentals, 238 annual flowers, 35 herbs and 156 vegetables in the Georgeson Botanical Garden. Ornamentals were evaluated for landscape potential, frost tolerance and winter hardiness. Vegetables and herbs were screened for suitability in Alaska's home gardens.

Another project is looking at vegetating man-made gravel structures within Arctic wetland plant communities. This research includes an array of studies aimed at identifying soil treatments and plant species useful in vegetating abandoned gravel fill in the Arctic tundra regions of northern Alaska. Gravel pads abandoned for a known period of time can provide valuable insight into the time required for plant colonization in this region. The National Petroleum Reserve in Alaska (NPRA) contains several of these types of gravel fill, representing sites abandoned approximately 10 years. In 1984 a preliminary evaluation of vascular plant colonization on the gravel fill in NPRA was begun. The second evaluation of four exploratory gravel pads in NPRA was conducted in 1991-92. One drilling pad, Umiat No. 5, used during the exploration of the reserve, was added to the study in July 1992, representing sites abandoned approximately 40 years ago. Researchers have identified more than 125 vascular plant species colonizing gravel fill in the Alaskan Arctic. Approximately 100 are worthy of closer examination for revegetation potential. Sixty-four indigenous vascular plant species were planted in rows at the botanical garden at BP Put River No. 1. This array includes 28 forb and half-shrubs, 23 grasses, 9 shrubs and 4 grasslike species planted over three years. Some grass specimens of the earliest planting developed sufficiently to begin sexual reproduction by the summer of 1992. Most of the forb and half-shrub specimens are quite small because of the slow development in the Arctic. The planting will provide material for phenological and seed production evaluations in a uniform garden for perhaps the largest collection of indigenous Arctic plants in Alaska.

Forest Sciences

A study in interior Alaska forests seeks to evaluate the importance of forest floor organic matter chemistry to microbial decomposer activity and the supply of nutrients for plant growth and to evaluate the feedback mechanisms between plant growth and nutrient supply. Net nitrogen mineralization in the forest floor and surface mineral soil of Tanana River floodplain ecosystems was four times greater in early successional alder and poplar than in later successional poplar and white spruce. Nitrate made up 84% of the average seasonal total mineral nitrogen produced in these soils, compared with 20% in the later successional soils. These differences were closely related to the lignin–nitrogen ratio of the forest floor and the carbon content of the mineral soil. The shift in net mineralization when poplar becomes the dominant forest type is related to the chemistry of poplar litter. Ether extracts of the forest floor contain organic chemicals that act as an energy source for the decomposer population, limiting the supply of ammonium for nitrifying microbes. Tannins in the organic matter may also inhibit nitrification in the later successional forest types.

Another study seeks to:

- Quantify the timber productivity of Alaska northern forest lands and provide managers with appropriate equations and tables essential for basic timber management decision-making and stand prescriptions;
- Develop appropriate polymorphic site index curves;
- Test existing volume tables or develop new tables;
- Describe the impact of moose browsing on early height growth of hardwoods;
- Develop a tree improvement program plan for Alaska;
- Continue and expand the levels of growing stock studies;
- Initiate the establishment of fixed-area, permanent sample plots for the construction of yield tables;
- Prepare a directory of forest inventories for Alaska; and
- Assess practical-yield prediction models for adaptation to Alaska.

In a study aimed at simulating climatological

input to forest hydrologic models, progress has been made toward developing a stochastic weather simulator from the daily climatological data for Fairbanks. The model works by generating a value for daily sky cover randomly based on the historical distribution of sky cover given the previous day's sky cover. Clear-sky solar radiation is calculated using a sinusoidal seasonal variation of atmospheric turbidity and then modified by the randomly generated sky cover to give daily global radiation. Next, depending on the current-day sky cover and whether the previous day was wet or dry, a determination is made as to whether the current day is wet or dry based on transition probabilities. If the current day is wet, the amount of precipitation is randomly generated from the monthly distribution of "precipitation per wet day." Daily maximum and minimum temperatures are generated from a knowledge of the previous day's temperature and the current and previous day's sky cover. Daily dew-point temperature is calculated based on the current day's minimum temperature and precipitation. Finally the daily average wind speed is generated independently as a function of the observed monthly distributions of daily wind speeds. Researchers are refining the mathematical and statistical relationships and completing professional and user-oriented products.

Resources Management

A historical overview of agricultural activities in selected areas of the circumpolar North provides a background for a development model set in the post-industrial period. Past research has focused on Alaska and is now expanding to include the clay belts of southeastern Canada, the Yukon Territory in Canada's northwest, Siberia and the Russian Far East. Resource frontiers are remotely located in difficult environments and are within political boundaries of core government and trade centers. The model proposes that frontier agriculture begins in disconnected nodes (Stage I: subsistence). As activity increases, the nodes expand (Stage II: commercial/local) and eventually interconnect (Stage III: regional product movement). Finally, regional production and international trade develop (Stage IV: regional/international agriculture). In Stage IV there is a reciprocal transport of products from the frontier to the core. None of the areas studied has an agriculture in Stage IV. Agricultural development in the circumpolar North has not been supported by post-industrial core governments. Cores have not required frontier agricultural resources to augment their economic base. To move into Stage IV, frontier regions must depend on their own resources.

Another project focuses on developing the criteria for selecting watchable wildlife sites in Alaska and the appropriate management strategies after selection. A statewide steering committee served as a panel of experts, and a modified Delphi technique was used to select the appropriate variables. Initially each committee member submitted a list of variables in choosing roadside watchable wildlife sites. These lists were consolidated and resubmitted to each member, who then rated the importance of each variable. A field evaluation form was developed based on the important variables the committee identified. Using the same technique the steering committee was surveyed to determine the appropriate minimum management program, regardless of the agency. The results were then incorporated into a master memorandum of understanding between Federal and State agencies and the Alaska Department of Fish and Game.

Soil Conservation Service

The Soil Conservation Service (SCS) cooperates and coordinates with state, village, regional and Federal land owners. SCS field office personnel in Alaska provide technical resource planning and application assistance to these various landowners and users. Coordinated resource management plans, allotment management plans or interim plans are developed.

Soils Activities

The SCS, in conjunction with the University of Alaska Fairbanks and Agriculture Canada, has established a transect of representative permafrost-affected soils in the Northwest Territories, Yukon Territory and Alaska. At these sites, measurements are being made of soil moisture and temperature, active-layer properties and atmospheric parameters. This information is being gathered to help explain cryogenic processes in soils and their influence on soil genesis and morphology. At all of the monitoring sites, soil profiles were sampled for complete characterization. These data will aid the process studies and will also support the development of an expanded database of soils information for this region.

The information gathered from these research sites in Canada and Alaska is being used to improve the classification of permafrost-affected soils. The studies will also increase our knowledge about the amount of carbon that is sequestered at the high latitudes. The information from these studies is being used in soil process models to further our understanding of cryogenic processes. These

sites have been established as long-term monitoring sites to help in understanding changes that may occur as a result of global climate change. Recent sites have been established along the Haul Road from Fairbanks to Prudhoe Bay.

Soil surveys are being conducted through the National Cooperative Soil Survey (NCSS). There is an ongoing soil survey in the Gulkana River area, where the permafrost is discontinuous. Work has been recently completed in the Gates of the Arctic National Park, where the soil survey is supplemented with studies of associated vegetation and landforms within this area of continuous permafrost. Work continues on the lower Kenai Peninsula in the permafrost-free zone.

The SCS, along with the University of Alaska Fairbanks, has also established a series of sites in Alaska to study soil processes in wetlands. At these sites, soil moisture and temperature, redox properties, depth of water tables and other properties are being measured. At selected sites, gas flux (methane, carbon dioxide and nitrous oxide) is measured. This work, which allows a better understanding of wetland processes at high latitudes, is a continuation of similar projects located in Texas, Louisiana, Oregon, North Dakota, Minnesota, Indiana and New Hampshire. Comparisons can be made to determine how soil processes are different or similar in these different areas.

The SCS, the University of Alaska Fairbanks and the National Park Service cooperated to establish a Long-Term Ecological Research (LTER) site in Denali National Park; initial soil survey activities were completed in the park in 1993.

The SCS, Agriculture Canada, the University of Alaska Fairbanks and the Alaska/Yukon Society of Professional Soil Scientists organized a tour and international meeting to discuss the genesis and classification of permafrost-affected soils. The trip, in July 1993, started in Inuvik, Northwest Territories, and ended in Fairbanks, Alaska. As a result of the conference, an international committee is developing a proposal for a new soil order (Gelisols). In 1994 a joint SCS and Agriculture Canada team will conduct field mapping in northern Siberia as part of an exchange with Russian soil scientists.

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 on 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 SCS (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.

River Basin Study Activities

The final reports for the Tanana and Copper River Basin studies were issued in 1991. Portions of the soils and land cover mapping have been digitized. Field work on the Kenai River Basin study was completed in 1991, including streambank inventory and designs for erosion control structures. Soils and land cover maps were digitized, and the final report was produced in 1993.

Snow, Climatological and Water Supply Activities

The SCS continues to collect snow and related climatological data. Of significant importance in the Arctic is the amount of annual snowfall the region receives. The true amount of snowfall reported for the Arctic coast varies considerably, according to the monitoring technique and gauge design. There appears to be a significant difference between the total snowfall catch of the NWS non-shielded or Alter-shielded precipitation gauge and the SCS Wyoming-shielded gauge. SCS currently coordinates data collection at seven North Slope Wyoming-shielded gauges. A non-shielded or Alter-shielded precipitation gauge may be providing inadequate shielding to allow an accurate catch of snowfall in the windy and exposed tundra environment. In July 1989, SCS established a study site at Barrow at the NOAA Climate Modeling and Diagnostic Laboratory (formerly Global Monitoring for Climatic Change), in which precipitation gauges with various kinds of wind shielding are located close to each other. The wind shields being evaluated are the Wyoming shield, the Canadian national standard Nipher shield, the Alter shield and the NWS standard (no shield). The results of total snowfall in 1993 show that the Nipher shield collected 88% of that of the Wyoming shield, the Alter shield collected 35% and the NWS standard collected 13%.

Snow survey data are used in the Arctic for cal-

culations of snowmelt runoff volumes in Arctic rivers, determinations of freshwater availability and augmentation, forecasts of river breakup timing, engineering and development, blowing snow control, studies of caribou movements and global warming modeling research.

Agricultural Research Service

The Subarctic Agricultural Research Unit of the USDA Agricultural Research Service located at Fairbanks, Alaska, cooperates with the University of Alaska and Agriculture Canada (Beaver Lodge, Alberta) on various aspects of agriculture at high latitudes. The research mission at Fairbanks is to determine the role of conservation tillage and fertilizer management in carbon sequestration and greenhouse gas fluxes and the effects of elevated atmospheric levels of CO_2 on plant growth, nutrient requirements and carbon allocation in plants.

Fairbanks is located at the northern edge of arable agriculture and offers a unique opportunity to test the limits of mechanistic models and observe ecosystem processes under their most limiting conditions. Research is being conducted to enhance and improve management of soil, water and air resources to optimize agricultural production and environmental quality. The 64°N latitude makes this location a unique place to study plant responses to elevated CO_2 because of the long days, moderate summer temperatures and low sun angles. In this environment the response of plants to elevated atmospheric CO_2 on plants' cold tolerance, their water stress tolerance and the ability of cold-adapted plants to respond to increases in atmospheric CO_2 are studied.

Current research programs include:

- Greenhouse gas fluxes in managed grassland;
- The effect of tillage and crop residue management on greenhouse gas fluxes;
- The effects of green manure and urea fertilizer on greenhouse gas fluxes;
- Microbial processes involved in short- or long-term inhibition of methane consumption in agricultural field soils; and
- Environmental factors affecting the consumption of methane and adaptation of soil organisms to climatic conditions.

The research emphasizes plant science, soil fertility, microbiology, soil physics and micrometeorology. This research was supported with $717,000 for FY 93 and $730,000 for FY 94. In response to instructions to reduce the agency budget, ARS proposed the termination of a number of programs, including the Arctic program at Fairbanks, for FY 95.

Collecting gas samples for a long-term tillage study.

Plant Sciences

Research on weed biology and control has been aimed at understanding the effects of the subarctic environment on weed seed longevity in soil and on the degradation and environmental fate of herbicides.

The longevity of 17 weed and native-colonizing seeds was investigated in the subarctic to determine those species that pose the greatest challenge in controlling. Eleven of the weed species had greater than 6% seed viability after being buried for seven years. The viability of shepherd's purse and Pennsylvania smartweed was retained longer in Alaska than at more southerly locations.

The degradation rates of metribuzin and linuron were studied at Fairbanks and Palmer, Alaska, because carryover from these herbicides could potentially injure subsequent crops. A subsequent crop of cabbage was killed by metribuzin that remained after one year from the time of application. However, linuron that remained after one year did not injure cabbage or lettuce.

Tillage management may alleviate injury from herbicide carryover. A study conducted at Fairbanks indicated that herbicide residues were deposited below a depth of 5 cm by moldboard plowing,

whereas residues were evenly distributed by rototilling and remained near the soil surface by chisel plowing. Subsequent crops were severely injured by herbicide residue when chisel plowing was used for seedbed preparation. Therefore, growers can minimize herbicide injury by using tillage methods that incorporate the residue in the soil, such as with moldboard plowing.

Soil temperature and organic matter content were studied as factors affecting the absorption of metribuzin and metolachlor. More metribuzin was absorbed at 5°C than at 28°C, while more metolachlor was absorbed at 28°C. However, temperatures accounted for less than 10% of the variation in absorption, while soil organic water content accounted for greater than 80% for both herbicides.

Leaching of pesticides and fertilizers is of concern on all agricultural lands, but little is known of the leaching potential of subarctic soils. The movement of metribuzin and metolachlor was studied in interior Alaska; preliminary data show that there was little or no movement below 15 cm over two years. These data will be used to determine the adequacy of models for predicting leaching in the subarctic.

The response of plants to changes in CO_2 concentration and other climate changes (temperature and water, for example) must be known to aid in forecasting future needs in food and fiber. Information is available that characterizes the response of temperate and tropical plants to changes in CO_2 concentration. However, little is known concerning the response of subarctic ecosystems to climatic change. Therefore, studies will be undertaken to ascertain the responses of subarctic plants to CO_2 temperature and photoperiod.

Soil Fertility and Microbiology

Newly cleared soils in interior Alaska are deficient in plant nutrients, and applications of nitrogen, potassium, phosphorus and sulfur are required to sustain plant productivity. The organic material on the forest floor is generally removed during the clearing operation to facilitate the use of agricultural machinery in tillage and planting. This material contains a significant portion of the plant nutrients in the forest. Field and laboratory studies have found that this material, when incorporated into the soil, decomposes rapidly. Inorganic nitrogen and potassium, both of which are required in large quantities by plants, are released during the decomposition process. Other studies have shown that barley straw placed on the soil decomposes much slower than when incorporated into the soil. Surface crop residues are therefore slower to release carbon and plant nutrients and may result in greater sequestration of carbon into dead plant material. Therefore, agronomic practices that allow placement of straw on the soil surface will help slow the increase in atmospheric CO_2.

Previous studies have shown that only a small portion of the nitrogen in green manure is taken up by subsequent crops. Research is being undertaken to determine the fate of nitrogen from green manures by comparing the rate of nitrogen released by decomposition of fall-incorporated green manure with that of barley uptake requirements. The effect of organic and mineral nitrogen on the flux of radiatively active gases (CO_2, CH_4 and NO_3) in soil will also be studied. Other locations cooperating on this study are Ft. Collins, Colorado, and Mayaguez, Puerto Rico.

Soil Physics and Micrometeorology

Soils of interior Alaska are very friable and are prone to erode during the dry, early spring. Tillage practices that affect the stability of the soil in the spring were evaluated near Delta Junction, Alaska. The stability of the soil was found to increase as the number of tillage operations decreased. Reduced tillage also provided a wetter seedbed environment, a factor important for seed germination in dryland cropping regions.

General circulation models predict that global warming in the next century will be accentuated at high latitudes. Climate warming could have a major impact on agriculture in Alaska. Analysis of temperature records for several locations in Alaska indicated that the growing season at half of the locations has lengthened over the last 70 years.

Soil surface slope and aspect and surface crop residues influence the absorption of solar radiation and thereby plant growth, but few studies have evaluated this relationship at high latitudes. Field studies at Fairbanks indicated that southerly ridges with a 40° slope absorbed 40% more radiation than east-facing or west-facing ridges and 90% more than north-facing ridges. Black barley straw was found to reflect less than 5% of the incident radiation, while natural-colored and white straw reflected 20 and 30%, respectively. Black straw resulted in an increase in soil temperature, as much as 2°C, compared to white or natural-colored straw. In addition, the soil thawed faster under black straw.

Clearing large tracts of native forest in the subarctic has the potential to influence the radiation balance and regional climates. Studies near Fairbanks are investigating the effect of clearing native forest on the radiation energy balance. This information is needed for predicting the effect of large-scale agricultural development at high latitudes on future climatic changes.

Department of Energy

DOE's Arctic studies includes modeling contaminant transport in the Western Siberian Basin, measuring radionuclides in the Arctic atmosphere and investigating plasma processes in the magnetosphere. In studies of global change, DOE is investigating the role of Arctic ecosystems in the global flux of carbon, measuring "greenhouse gases," assessing the use of natural radionuclides as atmospheric tracers and developing a research site on the North Slope of Alaska for studying the influence of clouds on radiation transport.

The Department of Energy (DOE) has responsibility for providing for the long-term energy security of the United States. To carry out this responsibility, DOE is heavily involved in the development of new energy technologies and the means of assessing and minimizing negative economic, environmental, safety and health impacts of both new and mature energy technologies. DOE's Arctic activities support the DOE mission by expanding our understanding of the response of Arctic ecosystems to disturbance associated with energy resource exploration and exploitation and by improved our capabilities for predicting the regional and global consequences of continued dependence on fossil fuels.

	Funding (thousands)	
	FY 92	FY 93
Gas hydrates	100	0
Contamination database	0	50
Monitoring and assessment	0	6450
Environmental measurements	212	415
Ecological response	717	700
Response to carbon dioxide	469	470
ARM planning	290	394
National institutes	0	300
Magnetosphere research	148	152
Total	1936	8931

Cloud and Radiation Testbed Site

The North Slope of Alaska/Adjacent Arctic Ocean (NSA/AAO) Cloud and Radiation Testbed (CART) site is the high-latitude element of DOE's Atmospheric Radiation Measurement (ARM) program, DOE's climate-process-focused contribution to the U.S. Global Change Research Program (USGCRP), to the World Climate Research Programme (WCRP) and to WCRP's evolving Arctic component, the Arctic Climate System Study (ACSYS).

The 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 cannot have complete confidence. Even the model simulations for the present state of the atmosphere differ in significant ways from each other and from what is observed. 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 learned about clouds and radiation to improve the models, but secondarily on the basis of cost and logistics. Three locations for 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 1995. The third CART site is proposed for the North Slope of Alaska and adjacent Arctic Ocean and has a 1997 start date.

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 phe-

The general point of contact for the ARM program is: Peter Lunn, Manager, Atmospheric Radiation Measurement Program, Environmental Sciences Division ER-74, U.S. Department of Energy, Washington, D.C. 20585, (301) 903-4819.

For the North Slope of Alaska/Adjacent Arctic Ocean CART site, the points of contact are: Bernard Zak, North Slope of Alaska/Adjacent Arctic Ocean CART Site Program Manager, Sandia National Laboratories, PO Box 5800, Albuquerque, NM 87185-0755, (505) 845-8631; and Knut Stamnes, North Slope of Alaska/Adjacent Arctic Ocean CART Onsite Scientist, Geophysical Institute, University of Alaska, Fairbanks, AK 99775-0800, (907) 474-7368.

nomena 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 NOAA's high-latitude climate monitoring facility near Barrow so 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 roughly 200 km 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 continual 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. On the boundaries of the extended CART site, small versions of the central facility are needed. 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 (Surface Heat Budget of the Arctic Ocean).

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 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 will all be initiated during 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 Ukpeagvik Inupiat Corporation) has been contracted to provide continuing liaison with the North Slope community.

Integrated Research on Tundra Ecosystems

The development of energy resources in tundra regions of Alaska has resulted in various types of disturbances to the fragile landscape. In addition, the burning of fossil fuels may result in changes to the global climate, with particularly dramatic impacts at the high latitudes. To better understand the consequences of these disturbances to Arctic ecosystems, the Environmental Sciences Division of the Office of Health and Environmental Research has sponsored basic ecological research on the response, resistance, resilience and recovery of Arctic ecosystems to disturbance (R4D).

During the last two years DOE's nine-year

For the R4D program, the point of contact is: Curtis Olsen, Environmental Sciences Division ER-74, U.S. Department of Energy, Washington, D.C. 20585, (301) 903-5329.

R4D program has largely met its short-term objectives, and a synthesis of the program's multidisciplinary results has been completed. This synthesis has integrated the field research and model-development activities of more than 20 investigators from 11 academic and DOE institutions. The DOE R4D program synthesis will soon be published by Springer-Verlag as a book entitled *Landscape Function: Implications for Ecosystem Response to Disturbance, A Case Study in Arctic Tundra.*

Responses to Carbon Dioxide and Concomitant Climate Change

For the Carbon Dioxide Program, the point of contact is: Roger Dahlman, Environmental Sciences Division ER-74, U.S. Department of Energy, Washington, D.C. 20585, (301) 903-4951.

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 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 have measured carbon dioxide flux over a north–south gradient on the North Slope of Alaska and at IBP (International Biological Program) sites and elsewhere in the U.S. and Russia. Measurements made at IBP site 2 near Barrow, Alaska, show that this area has changed from a sink for carbon dioxide (as measured in the early 1970s) to an atmospheric source for carbon dioxide now. The general pattern from all sites measured in the U.S. and Russia indicates a net loss of carbon from the surface to the atmosphere. Evidence from past decades had suggested that the Arctic as a whole was a sink for atmospheric carbon dioxide, accumulating approximately 0.1 Gt of carbon annually.

During July 1993, Russian research sites on the Taymir Peninsula that had been studied prior to 1975 were sampled to determine daily carbon flux, depth of thaw and plant chemistry. Each site has good baseline data for vegetation, biomass and, in most cases, soil and plant nutrient content and leaf photosynthesis and respiration rates. The research team was made up of Russian scientists from the Moscow State University and the Russian Academy of Sciences and American scientists from San Diego State University. Using vegetation maps and visual inspection, habitats measured were chosen to be those most representative of the general area.

The daily carbon flux (grams of carbon per m^2 per day) varied from –0.187 (sink) in a lowland habitat to +1.964 (source) for Arctic desert habitat at Ust Tareya. The upland sites were always sources of carbon dioxide to the atmosphere, while the lowland sites were either in balance or sinks. The habitat sampled at Pura was a slight sink at –0.242, while all other sites sampled were sources. Krestie showed a daily flux of 0.374 and Agapa, 0.781. These values are similar to those measured for Arctic tundra in Alaska. Measurements were also made along a 200-km east–west transect in the Kolyma Lowlands, including five different sites.

While the data from Russia are less complete than the data from Alaska, these measurements (Taymir and eastern Russia) indicate a current loss of carbon dioxide from the Russian tundra consistent with measured Alaska loss rates.

Other Relevant DOE Activities

The EnviroTRADE Information System, currently under development for DOE's Environmental Restoration and Waste Management (EM) Office of Technology Development, provides the architecture for managing a large quantity of data on environmental waste sites and associated site remediation technology development efforts within a single database featuring geographical information system (GIS) capabilities.

During the period of interest, at the request of DOE, the EnviroTRADE project incorporated the

For EnviroTRADE, the point of contact is: Susan Johnson, U.S. Department of Energy, EM-523, Washington, D.C. 20585, (301) 903-7930.

available database on former Soviet contamination of the Arctic with radioactive and other hazardous species. In connection with this project, an EnviroTRADE node was established in the former Soviet Union, giving Russian and other former Soviet scientists the ability to input data and make use of the technology in their own remediation efforts.

For the Project Chariot Site Assessment and Remedial Action, the point of contact is: Tom Gerusky, Office of Environmental Restoration EM-452, U.S. Department of Energy, Washington, D.C. 20585, (301) 903-8186.

During the summer of 1993, DOE undertook a site assessment and remedial action at an experimental site dating from the early 1960s at which a residue of radioactive-tracer-contaminated soil had been buried. The U.S. Geological Survey (USGS) experiment utilizing radioactive tracers was part of a U.S. Atomic Energy Commission study (Project Chariot) of the feasibility of using nuclear explosives to excavate a harbor near Cape Thompson, 32 miles from the village of Point Hope and 41 miles from the village of Kivalina. In late 1962, Project Chariot was terminated. No nuclear explosives were used at, or even transported to, the Chariot site. The tracer-contaminated soil resulting from the USGS experiment was buried under four feet of clean soil, forming a mound.

In response to public concern, during the summer of 1992, the Alaska Department of Environmental Conservation (ADEC) and the U.S. Army Corps of Engineers conducted an investigation of the Project Chariot site. A surface radioactivity survey indicated that the radioactive materials in the mound remained intact, since no readings above background levels were measured. The ADEC placed the site on the State Hazardous Waste Site List.

Subsequently a Site Assessment and Remediation Action Plan was prepared and implemented with the oversight of the U.S. Fish and Wildlife Service, the Alaska Department of Environmental Conservation, the Alaska Department of Natural Resources, representatives of the village of Point Hope and of the Native village of Point Hope, as well as representatives of the North Slope Borough.

Remediation consisted of removing the tracer-contaminated soil and disposing of it at the Nevada Test Site. The parallel assessment established that, because of the four-foot soil cover, even prior to the remediation action, there was no measurable radiation exposure above natural background at the mound. No contamination in the vegetation and small mammal samples was detected. However, some residual surface contamination was found at the sites of two of the USGS test plots. It was also removed. Past risk was concluded to have been essentially zero. Future risk is expected to be zero.

Department of Health and Human Services

In FY 92 and 93 five agencies of the U.S. Public Health Service of the Department of Health and Human Services supported or conducted Arctic health research. These agencies were the National Institutes of Health, the Centers for Disease Control and Prevention, the Substance Abuse and Mental Health Services Administration, the Health Care Financing Administration, and the Indian Health Service.

Substance Abuse and Mental Health Services Administration

The Substance Abuse and Mental Health Services Administration (SAMHSA) continues to support demonstration activities that relate to Alaska Natives. These projects are directed at:

- Improving and expanding the treatment of alcohol and drug abuse for Alaska Natives;
- Serving as effective models in preventing alcohol and other drug abuse problems among individuals and certain high-risk groups; and
- Serving as effective models of assessment and treatment interventions for severely mentally ill adults who are living apart from their community of origin and for homeless individuals who have a dual diagnosis of mental illness and substance abuse disorders.

SAMHSA, through a grant from the State of Alaska, is working to enhance its ability to collect data on mental health services through improved information systems and the development of standards of data content to ensure comparability of data across the entire mental health services delivery field. It also established a conference that provided a forum for rural providers of substance abuse prevention and intervention services to network and share information and prevention strategies relevant to both their own needs and to the cultural needs of the Alaska Native community.

Health Care Financing Administration

The Health Care Financing Administration (HCFA) research and demonstration program conducts studies whose goals are to assess the current health care delivery and financing section and to develop innovative ways to improve the quality and cost-effectiveness of health care programs. The principle objective of the research program is to stimulate, support and assist, through an active health services research and demonstration program, the resolution of major health care organization and financing issues. This assistance will serve a long-term and vital purpose by increasing the efficiency and effectiveness of the entire health care sector by improving the ways in which health care is financed and delivered.

HCFA is administering the Rural Health Care Transition Grants Program, which is designed to strengthen the capability of eligible small rural hospitals to provide high-quality care to Medicare beneficiaries. Under this program, non-Federal, nonprofit hospitals that have fewer than 100 beds and are being paid as a rural hospital under the Medicare hospital prospective payment system could request up to $50,000 per year for up to three years for a variety of developmental projects and service enhancements. This program has aided five hospitals in Alaska. Three hospitals received funding in FY 92: Seward General Hospital received $50,000 to provide basic acute care hospital services and emergency health services; Central Peninsula General Hospital received $50,000 to develop a patient care delivery model that emphasizes high-quality care while maintaining control over escalating

	Funding (thousands)	
	FY 92	FY 93
Substance Abuse and Mental Health Services Admin.	2,500	5,000
Health Care Financing Administration	150	250
Centers for Disease Control and Prevention	2,400	2,400
National Inst. of Health	5,784	3,773
Indian Health Service	750	750
Total	11,584	12,173

health care costs; and Valley Hospital received $50,000 to establish a Medicare-certified multidisciplinary hospital program to serve the community. In FY 93 each of these three hospital received an additional $50,000. Two new awards of $50,000 each were presented to Bartlett Memorial Hospital to provide health care to the outlying communities of Gustavus, Haines and Skagway, Alaska; and to South Peninsula Hospital to plan and implement a case management program.

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 Prevention Services (NCPS), the National Center for Environmental Health (NCEH), the National Center for Injury Control and Prevention (NCIPC) and the National Institutes of Occupational Safety and Health (NIOSH). The CDC 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.

Prevention and Control of Infectious Diseases

The Arctic Investigations Program (AIP) of 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 subarctic, 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, logistic support for research conducted 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 incidence from which disease reduction can be measured following implementation of a preventive strategy. The AIP laboratory maintains a statewide surveillance system of all invasive disease caused by *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Neisseria meningitidis* and *Streptococcus pyogenes*.

The statewide epidemiologic and laboratory surveillance of invasive pneumococcal and *H. influenzae* diseases was established at AIP in 1982 and involves 23 of 26 hospitals, laboratories and clinics. In 1991 the categories of *S. pyogenes* and *N. meningitidis* were added to the statewide surveillance system. Basic demographic and clinical information are collected on cases, 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*, *S. pneumoniae* or *N. meningitidis* 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 the pneumococcal strain now resistant to both erythromycin and trimethoprim-sulfamethoxazole, raises concerns about the use of antibiotics.

Viral Hepatitis

Hepatitis A virus (HAV) infection is a major disease problem for Alaska Natives. The disease typically recurs in a cyclic pattern. The latest statewide epidemic began in late 1986 and appears to have peaked in late 1988 or early 1989. By the end of 1990, the epidemic had included over 1100 documented cases of disease in Alaska Natives. During late 1992 and early 1993 increased levels of disease were observed in several areas throughout the state.

AIP's HAV program focused on understanding and describing the population of Alaska Natives susceptible to HAV infection and on testing candidate HAV vaccines in this population. In conjunction with the Indian Health Service, a safety and immunogenicity study of a candidate HAV vaccine was conducted among Alaska Native preschoolers and adults and non-Native adults. Accomplishments in 1992 and 1993 include:

- Publishing statewide serosurvey data, which reveal an increasing prevalence of antibody to

HAV with increasing age, but with vast differences between regions of the state (extrapolation of the survey results indicate that more than 50% of the Alaska Native population were probably susceptible to HAV infection at the start of the most recent statewide epidemic);
- Completing an immunogenicity investigation of hepatitis A vaccine, for which preliminary analyses indicate a very good response to the vaccine but with differences between vaccination schedules and a decreased response with increasing age; and
- Providing technical and scientific assistance to the State of Alaska and the IHS in their attempt to control the most recent outbreaks of hepatitis A using the unlicensed vaccine.

Hepatitis B virus (HBV) infection is a serious public health problem in many areas of the world, where the prevalence of hepatitis B surface antigen (HBsAg) exceeds 10% and HBV-associated hepatocellular carcinoma (HCC) is a leading cause of death. Since 1972 the AIP and the Alaska Area Native Health Service (AANHS) have conducted epidemiologic surveys of the prevalence, incidence, transmission and sequelae of HBV infection among the Eskimos living in the Yukon–Kuskokwim delta of southwest Alaska. The overall prevalence of HBsAg was 6.4%, with considerable village-to-village variation. The incidence of new HBV infection was high, especially in young children and in household contacts of HBsAg-positive persons. The rate of HBsAg-associated sequelae among Alaska Natives was also high. A hepatitis B vaccine demonstration project conducted in 1981 in the Yukon–Kuskokwim delta among 1600 Alaska Natives showed that 95% of the study participants developed antibodies to HBsAg after three doses of hepatitis B vaccine.

Accomplishments in 1992 and 1993 include:
- Completing more than 2000 screenings for serum alpha-fetoprotein (AFP) of the 1600 Alaska Native HBsAg carriers each year;
- Continuing long-term investigations of protection provided by hepatitis B vaccine in Alaska Native infants and adults;
- Maintaining a low incidence of acute symptomatic hepatitis B at 7/100,000 population in the area having the highest incidence of disease (215/100,000) prior to the control program;
- Completing a study of the side effects of hepatitis B vaccine in Alaska Natives; and
- Conducting a serosurvey 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 HBV infection. 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 in 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 a 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.

Since the discovery of the hepatitis C virus (HCV), several reports have indicated a high rate of antibody to hepatitis C virus (anti-HCV) in patients with HCC. Alaska Natives have a high prevalence of markers of HBV infection and a high incidence of HCC. With the development of technology to identify HCV virus serologically, an initial effort is being made to identify the role of HCV in non-A, non-B hepatitis and in HCC among Alaska Natives. In a population with a high rate of viral hepatitis and subsequent chronic liver disease, we have established that HCV is not associated with HCC in the Alaska Native population. This finding is important in determining priority efforts to control viral hepatitis.

Bacterial Infections

Haemophilus influenzae type b (Hib) has been the most common cause of bacterial meningitis and a leading cause of other invasive infections in children in the U.S. Despite antibiotic therapy, the mortality caused by Hib meningitis remains high (approximately 5%), and serious neurologic sequelae occur in as many as 10–25% of survivors of meningitis. Studies conducted at AIP have characterized the epidemiologic features of the disease in Alaska Natives and defined the epidemiology of Hib disease in all population groups in the state. The Native population represents only 16% of the population of Alaska but has 51% of all invasive Hib disease; for Alaska Natives the cumulative Hib disease risk for the first two years of life was approximately 4%. As part of continuing efforts to provide protection against invasive Hib disease, immunogenicity trials of four conjugate vaccines were conducted. Additional studies looked at a variety of dosing schedules of one of the licensed pediatric vaccines and a combined Hib/HBV vaccine preparation. Also, a demonstration project using human bacterial polysaccharide immune globulin (BPIG) was begun in July 1989 in the Yukon–Kuskokwim delta area. In 1992 and 1993, following the introduction of Hib vaccine, the number of cases of Hib disease among Alaska Native children less than 5 years of

age declined from 20–30 cases each year to 2–3 cases each year.

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 cases of community-acquired pneumonia. Despite the existence of a capsular polysaccharide vaccine for 23 of the most common among 83 different 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 to penicillin and more recently to erythromycin, has been observed in *S. pneumoniae* worldwide but less commonly in the U.S. The highest reported invasive pneumococcal disease rates in infants are found in Native infants from western Alaska; pneumococcal meningitis rates in this 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 that are resistant to two or more antibiotics. Statewide surveillance for invasive pneumococcal disease in Alaska reveals rates of invasive disease in Alaska Native adults 40–54 years of age that are eight times higher than non-Native rates and Native infant disease rates that 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.

Studies at AIP focus on:

- Maintaining a statewide surveillance system for invasive pneumococcal disease and reporting of the descriptive epidemiology of the disease;
- Elaborating the descriptive epidemiology and 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.

Accomplishments in 1992 and 1993 include:

- Continuing the statewide surveillance for invasive pneumococcal disease and monitoring a regional increase in antimicrobial resistance of pneumococcal isolates (serotype 6B) to penicillin, erythromycin and trimethoprim-sulfamethoxazole;
- Completing data collection and 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;
- Reporting a revaccination study of adults with documented chronic "high-risk" illnesses; analysis showed that the immune response of reimmunization closely resembles the primary vaccination experience with no adverse side effects;
- Reporting a study demonstrating that Alaska Native chronic alcoholics respond adequately to immunization with the 23-valent pneumococcal polysaccharide vaccine;
- Initiating an immunogenicity study of a heptavalent pneumococcal conjugate vaccine in Alaska Native infants less than 24 months of age; and
- Collaborating with Johns Hopkins University Center for Native American Health to initiate a review of all reports of pneumococcal disease in American Indian and Alaska Native infants.

The ability to quantitate pneumococcal antibody amounts and to compare the amounts measured by investigators in different laboratories is of fundamental importance for understanding the natural history of pneumococcal infection, immunity and response to vaccination. The standard assay for the measurement of antibody to *Streptococcus pneumoniae* is the radioprecipitation assay. The major limitations of this assay are that it is only performed in a few laboratories and that it measures total antibody, regardless of class, subclass or affinity for antigen. Because of these difficulties and the potential for measuring serotype-specific, class-specific or subclass-specific antibody, many laboratories have turned to enzyme immunoassay (EIA). There is, however, no universally accepted serum standard and no standard assay format that will allow interlaboratory comparison of assays. The objectives of AIP's program are to establish a reproducible quantitative EIA to measure serotype-specific, class-specific pneumococcal antibody, to assign weight-based units to a proposed universal serum standard, to compare these values with those of other laboratories, and to use this assay to evaluate of the immunogenicity of pneumococcal vaccine in Alaska Natives.

The evaluation of existing and alternative methods of detecting invasive pneumococcal disease is also a major objective of AIP. Rates are calculated from data generated by a statewide surveillance system based on cultures of *S. pneumoniae* from a normally sterile site (blood, cerebral spinal fluid, pleural fluid). Because cultures may not always be positive, particularly in a population with a high

empiric antibiotic usage, the rates of disease may underestimate the true incidence of disease in this high-risk population. An alternative to culture is the laboratory detection of pneumococcal antigens or other components in body fluids such as blood, urine or cerebral spinal fluid of patients with suspected invasive disease. Such methods also have the potential to rapidly detect disease in patients in the absence of viable organisms upon culture. The program involves collecting specimens of whole blood, serum, urine and cerebral spinal fluid from patients with invasive pneumococcal disease identified through the surveillance system, and evaluating the sensitivity and specificity of antigen or DNA detection systems for the detecting invasive pneumococcal disease.

Prevention and Control of Sexually Transmitted Diseases

As is the case with sexually transmitted diseases (STD) caused by other pathogens, the prevalence of STD due to *Chlamydia trachomatis* differs markedly in different areas of Alaska. Selective screening, diagnosis and treatment for chlamydia was introduced in Alaska's two Title X-funded family planning clinics in 1988. Expansion of screening activities into STD clinics began in four public health centers in November 1990 and in the municipal STD clinic in December 1992. Positive tests among women screened in these five STD services (each in a different area of the state) ranged from 4.6% to 13.6% in 1992, and from 5.2% to 11.7% in 1993. In December 1993 a shift to the widespread use of genetic DNA probes in the state laboratories made it possible to offer chlamydia screening through all interested providers currently participating in the statewide gonorrhea screening program. One hundred and seven sites participate in this expanded program.

Prevention and Control of Anemia

Iron deficiency anemia has long been recognized as a common nutritional problem among Alaska Native children. Most early investigations in Alaska have focused on the detection of iron deficiency anemia in infants and small children. Over the years the AIP laboratory has participated in many investigations 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 recent investigation of the diet of children in both Bristol Bay and the Yukon–Kuskokwim delta found a high consumption of non-Native food relatively low in dietary iron. It remains to be determined whether this lower intake of iron alone can explain the iron deficiency in children or whether other factors such as inhibitors of iron absorption or iron loss play important roles. Increased loss of iron through chronic idiopathic gastrointestinal blood loss is supported by a high rate of positivity of stool guaiac in stools from apparently healthy Alaska Natives from two villages from southwestern Alaska. This may be related to high plasma levels of omega-3 polyunsaturated fatty acids, found in the plasma of Alaska Natives who consume a largely subsistance 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 to increased bleeding times in other Eskimo populations outside Alaska.

The objective of this collaborative program is to determine the prevalence, by age, sex, community and region, of iron deficiency and iron deficiency anemia in the Alaska Native population. An additional goal is to examine the relationship of iron deficiency to the high incidence of infectious disease in this population.

Following research in 1988 and 1992, which found that 75% of stool samples from adults in five Yukon–Kuskokwim delta villages had elevated quantitative heme content, an endoscopic examination of 70 individuals, conducted in 1993, found that all but two individuals with elevated stool heme content had evidence of hemorrhagic gastritis. Evidence also suggested that infection with *Helicobacter pylori*, an organism emerging as a cause of chronic gastritis, may be the cause of the excessive bleeding and iron deficiency anemia in Alaska Native adults.

Prevention and Control of Fetal Alcohol Syndrome

A joint effort was developed among the CDC, the IHS and the State of Alaska to understand the magnitude of the fetal alcohol syndrome (FAS) problem through the Behavioral Risk Factor Surveillance System and to evaluate the effectiveness of programs designed to prevent FAS in the Alaska Native population.

Fetal alcohol syndrome is completely preventable, yet it is the most commonly known environ-

mental cause of birth defects and developmental disabilities. The rate of FAS is very high among Alaska Natives: 42 per 10,000 live births, compared with an estimated 6 per 10,000 in the general population of the U.S. The purpose of the joint FAS prevention project is to determine, through research and training (collaborative epidemiologic, operational, behavioral, evaluational and health education communication), better means of FAS prevention and intervention in Alaska and the other 49 states.

The project goals are to:

- Provide technical and programmatic review of IHS FAS programs and data, and actively 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 by IHS; and
- Develop model surveillance, data analysis and program evaluation methods that could be used to assist other states, communities and American Indian populations.

These goals are expected to optimize the potential for long-term statewide FAS surveillance systems.

In June 1993, representatives from the CDC, the Alaska Department of Health and Social Services and the IHS presented a profile on the Alaska Fetal Alcohol Syndrome Prevention Project at the IXth Congress of the International Union for Circumpolar Health in Reykjavik, Iceland. Interest in FAS during the conference led to the formation of a working group on FAS. One of the six topics of the Xth Congress of the International Union for Circumpolar Health will be FAS.

Prevention and Control of Injury

In 1992 the National Center for Injury Prevention and Control helped establish a permanent injury prevention and control program within the Alaska Department of Health and Human Services, Division of Public Health. The Alaska State and Community-Based Injury Control Program is committed to reducing the high incidence of morbidity and mortality due to injuries among the Native and non-Native populations. Alaska is developing programs to reduce drownings, motor-vehicle-related injuries, bicycle-related injuries and fire/burn injuries.

The State of Alaska has developed a comprehensive highway safety program and is implementing various interventions and programs, including seat belt use, infant/toddler car safety seat use, DUI prevention programs, and all-terrain-vehicle and snowmobile injury prevention.

The Alaska Marine Safety Education Association provides marine safety and boating education to a broad range of clients, including commercial fishermen, recreational boaters and youths in school settings. Other activities include:

- Developing and updating marine safety and survival course curricula;
- Providing instructor training and support of a statewide volunteer instructor network, resulting in over 100 trainers in 26 communities being supported with equipment loans, materials and technical assistance and 5,000 individuals being trained in marine safety and survival last year; and
- Assisting the Coast Guard in establishing national standards for marine instructors and marine safety procedures.

Bicycle safety programs in Anchorage and Juneau have been supported through the Safe Kids coalition. A survey of helmet use was implemented in Juneau in preparation for a bicycle safety campaign. Over 40,000 helmet discount coupons were distributed in Anchorage.

In 1992 the Alaska Injury Control program provided thermometers to check the settings of hot water heaters in a variety of sites in the state and assisted public health nurses in Sitka and Fairbanks in developing a program to have participants measure the temperature of their water and mail in the results. Follow-up was done to determine if participants turned the water heaters down to safe levels.

Through a CDC grant the Alaska Department of Health and Social Services is developing a statewide system to conduct surveillance of head and spinal cord injuries using the Alaska trauma registry and hospital discharge data. The objective of this project is to determine and describe factors associated with head and spinal cord injuries, including risk factors, cost of injury, disability and possible interventions to prevent head and spinal cord injuries. Approximately 90% of the population is covered by the surveillance system. The quality of the head and spinal cord injury data collected by the system is being assessed.

In addition, the National Institutes of Occupational Safety and Health (NIOSH) established the Alaska Activity in Anchorage to develop program activities focusing on occupational injury research and prevention in the Nation's geographic area of highest risk. This program was conducted in collaboration with the Alaska State Department of Health and Social Services, the Alaska Department of Labor, the Indian Health Service, other Federal agencies, industry, labor, communications media, health-care providers, universities and community colleges, and other

individuals and organizations in the private sector interested in public health. In 1992 NIOSH began providing technical and financial assistance through a cooperative agreement to the State of Alaska for the Fatality Assessment and Control Evaluation (FACE) program, which investigates traumatic injury deaths in the agriculture, forestry and fishing industries.

During FY 92 and FY 93, program accomplishments have included the following:

- Conducting an initial, in-depth study focused on identifying and reducing risks associated with commercial fishing, logging and air transport in Alaska;
- Compiling a comprehensive inventory and assessment of surveillance systems and agencies that ascertain the number of workers participating in high-risk industries;
- Assisting the Alaska Department of Health and Social Services, Occupational Injury Prevention Program, in developing a statewide occupational fatality surveillance system;
- Investigating all 233 occupational fatalities reported to the researchers for calendar years 1991–1993;
- Publishing 13 articles in scientific, public health and occupational safety and health journals and books, and giving 54 presentations in professional and public settings;
- Sponsoring a National Fishing Industry Safety and Health Workshop in Anchorage, Alaska, in 1992 to increase awareness, build cooperation, share information and experiences, and encourage action to prevent injury and disease that result from working in the commercial fishing industry;
- Hosting a visiting scientist from the Finnish Institute of Occupational Health, who accompanied an Alaska Activity researcher to several logging operations;
- Hosting the Unit Head for Occupational Health, Malaysian Ministry of Health, for the month of August 1993;
- Proposing specific interventions developed as a result of epidemiologic and process analysis of severe injury events, including technological innovations (such as log truck stake extensions and fishing vessel retrofit sponsons) and procedural innovations (such as redundant or fail-safe communications in logging transport operations and encouraging the wearing of personal flotation devices during commercial fishing operations) to improve worker safety in Alaskan industries; and
- Designing and implementing a comprehensive state surveillance system for severe occupational injuries.

National Institutes of Health

National Institute on Drug Abuse

The 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 use, abuse and dependence. 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 FY 91, are to monitor the HIV status of intravenous 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.

NIDA is also planning to initiate a State Epidemiology Work Group in Alaska in FY 95. This project will be 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. who meet semiannually to report on patterns and trends of drug abuse in their areas and to identify emerging drugs of abuse, vulnerable populations, risk factors and negative health and social consequences of drug abuse.

National Heart, Lung, and Blood Institute

In FY 92 the National Heart, Lung, and Blood Institute (NHLBI) supported two extramural projects related to Arctic research totaling $349,412, and in FY 93, five extramural projects at a total of $502,415.

Since 1987 the NHLBI has supported the first systematic study of apnea (absence of breathing) in a mammalian species that routinely experiences prolonged absence of breathing during sleep—the northern elephant seal. Sleep apnea, a sleep disorder affecting more than three million adults in the U.S., results in fragmented sleep due to periods of apnea that cause low blood oxygen levels. 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. The work with seal pups has shown that their heart rate patterns appear similar to children that are at risk

for SIDS. To compare these seal patterns with the human cardiac rhythm dynamics that occur during sleep apnea disorder and in children at risk for SIDS, sophisticated time-based analysis of heart rate is required. In FY 93 the NHLBI awarded a grant to train personnel in statistical modeling of time-based cardiac rhythm changes and to apply these methods to cardiopulmonary patterns during sleep apnea in seal pups.

Low death rates from atherosclerotic cardiovascular disease observed in Greenland Eskimos have been linked to their habitual dietary intake of large amounts of polyunsaturated omega-3 fatty acids present in fish oils. Most, if not all, of the reported investigations are epidemiological studies and studies of risk factors associated with atherosclerotic cardiovascular disease. The prevalence and extent of atherosclerotic lesions in either the coronary arteries or the aorta in Greenland, Canadian or Alaska Natives have not been established by objective, standardized scientific methods. In FY 89 the NHLBI awarded a five-year research project grant to characterize the prevalence and extent of atherosclerotic lesions in the coronary arteries and aorta of autopsied Alaska Natives (Aleuts, Indians and Eskimos) and in autopsied non-Natives, examine the relationship of omega-3 fatty acids and clinical risk factors to atherosclerosis in the two populations, and compare these findings with similar studies in other ethnic groups. By the end of FY 92, three pathologists, with extensive experience in visual evaluations of arterial lesions, and blinded to all data relating to each specimen, independently had finished quantitating fatty streaks and raised lesions for 103 Natives and 101 non-Native residents of Alaska. Findings from this study are expected to elucidate the nutritional benefits of fish oil for preventing coronary heart disease.

Since FY 87 the NHLBI has supported a study of the physiologic responses to chronic cold exposure, as commonly experienced in polar regions. The study has found that chronic exposure of rats to cold (5–6°C) induces hypertension, the first time a "naturally occurring" hypertension has been induced without surgical intervention, administration of excessive doses of hormones or drugs, or genetic manipulation. The overall objective is to assess potential mechanisms that may contribute to the development of cold-induced hypertension.

In FY 91 the NHLBI initiated a program of Academic Awards in Vascular Disease 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 researcher from the University of Washington in Seattle received a five-year award to develop a curriculum to meet the unique needs of physicians practicing in the rural areas of Washington, Alaska, Montana and Idaho. A comprehensive clinical program for the care of patients with primary and secondary pulmonary hypertension will be based at the University of Washington Medical Center with multispecialty care facilitated by a nurse coordinator. University and community physicians will develop 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. Educational programs will be directed toward housestaff and fellowship trainees at affiliated hospitals and community physicians. A regional newsletter will be distributed emphasizing progress in pulmonary vascular science and current patient management issues.

National Cancer Institute

Recent studies have shown associations 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 is further defined by banked serum collected 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 availability 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 IHS medical records on known breast cancer risk factors. The pilot study is expected to be completed in 1994. If the pilot study indicates that it would be feasible and likely to be informative, a full-scale study of breast cancer in Alaska Natives will be proposed.

A project aimed at preventing cervical cancer in Alaska Natives targets women age 18 and over and is located at the Alaska Native Medical Center, Anchorage, and 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 imple-

mented following enrollment in the project. One intervention was a special demonstration women's health clinic that includes extended evening hours, hour-long appointments, staffing by women providers and nurse practitioners, comprehensive health surveillance for women of all ages, pap tracking services, individual patient education, mammography services and tobacco cessation classes.

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. 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; they will be regionally specific for each of the census areas or boroughs within the 12 Alaska Native Health Corporations, plus the Municipality of Anchorage. Each profile will focus on all cancers in general and, more specifically, lung, colorectal, breast and cervical cancers. Information will be provided on risk factors, prevention and early detection, as well as interpretations of the findings and recommendations for cancer prevention and control. The target audience for this intervention is the health and public policy makers within Alaska; a second distribution wave will follow for 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 the environment, specifically 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 and 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 youths and those with low incomes.

A study is underway to isolate and identify new natural marine products from Arctic and other locations as leads for cancer chemotherapy by using assays that assess biochemical differences between tumor cells and their normal counterparts. This project has three aims:

- To demonstrate that natural products that inhibit specific biochemical targets will also exhibit antitumor activity;
- To confirm that the use of such target-directed assays will minimize the discovery of agents possessing already known mechanisms; and
- To provide anticancer drug leads from marine organisms that are structurally different from those obtained from terrestrial sources.

A screening schedule will be implemented that provides a rational network of natural products' chemistry and biochemistry assays to discover activity in crude extracts, guide the isolation of active principles, and provide adequate quantities of pure active compounds for in-vivo followup testing. Extracts of selected marine invertebrates, collected cyanobacteria, cultured microalgae and cultured anaerobic bacteria and fungi will be prepared and tested in the biochemical prescreens. Active leads will be tested further in whole cells and then in animal models.

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 a continuing medical education for health care givers and accelerates dissemination of state-of-the-art care technologies.

In collaboration with the IHS, the NCI is conducting studies of familial risk factors for nasopharyngeal carcinoma and primary hepatocellular carcinoma among Alaska Natives.

The NCI is conducting a study using 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.

Another study is trying 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.

A National Network for Cancer Control Research Among American Indian and Alaskan Native Populations has been set up 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 also 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. The purpose of the plan is to enhance awareness in Federal agencies, other organizations and individuals about the problems of cancer among these populations.

The Native American Women's Cancer Initiative (NAWCI) concept was approved in FY 93. This research will determine the effectiveness and efficacy of cancer control and prevention strategies that are designed to address one of the following objectives:

- Address the barriers to culturally appropriate quality cancer control services, including screening, appropriate followup, 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*, was developed. The purpose of this publication is to provide a resource and reference to assist in formulating culturally acceptable cancer prevention and control research projects or programs. It is a brief overview of the cancer problem among Native people living in urban, rural, reservation and village sites, primarily designed for use by Native and non-Native cancer researchers.

In 1992 the NCI developed a research training program entitled "Native American Research and Research Training Opportunities: Strategies for the Future." The program emphasized the development of technical skills, training in research methodology, and evaluation and proposal development. The workshop provided an opportunity for Native Americans and NCI-designated cancer centers to interact, discuss their own group's cancer research priorities, and identify potential collaborative efforts, both short and long term. The goals of the workshop focused on:

- Increasing the number of Native Americans participating in NCI-sponsored basic, clinical prevention and control research;
- Expanding cancer research and education activities that will reduce cancer incidence and mortality in Native American populations; and
- Increasing the number of Native Americans who are principal investigators and coinvestigators on research projects sponsored by the NCI.

The NCI has two intra-agency agreements with the IHS. The objective of the first intra-agency agreement, "Alaska Native Cancer Surveillance Project," 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. populations. There has been followup of incident cases and survival rates for 1969 to 1983. Efforts have also been made to update followup data to 1992. The cancer registry is updated as new cases of death are received and certified.

For the NCI's second intra-agency agreement, "Reducing the Available Cancer Mortality in American Indians and Alaskan Natives," work was completed on describing the burden of illnesses due to cancer in the Native populations, 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 the 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 Native populations.

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 91 to FY 93, 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 Allergy and Infectious Diseases

Among Alaska Natives *Haemophilus influenzae* type b (Hib) and streptococcal pneumonia disease incidence rates exceed those of the general U.S. population. NIAID-supported researchers have been instrumental in developing two generations of vaccines against Hib. The first generation of Hib vaccines became available in 1985, but early vaccines were not immunogenic in children under two years of age. A second generation of conjugate Hib vaccines, in which a bacterial antigen is linked to a protein carrier to induce a stronger immune response, is effective in children as young as two months of age. From 1988 to 1992, following licensing of Hib conjugate vaccines for older and then younger infants, there has been a significant reduction in the incidence of invasive Hib disease and its related morbidity and mortality. Focused surveillance data from 1992 and 1993 indicate that this trend is continuing, with virtual eradication of disease in some communities. In the U.S. *Streptococcus pneumonia* (also called pneumococcus) is a major cause of fatal meningitis and middle ear infections in infants and young children. It is also responsible for 20% of pneumonia cases in infants. A NIAID-supported pilot vaccine study was conducted in 117 toddler-aged children. Three bivalent conjugate pneumococcal vaccine models were assessed and compared to the currently licensed vaccine. The data indicate that at each dose tested, all conjugate vaccines were well tolerated, with no severe adverse reactions reported. Furthermore, all of the conjugate vaccines were immunogenic in the study population, and in each case the response to the higher dose of the vaccine was better. Additional studies are required to determine which of these vaccine models offers the greatest potential for success in the clinical setting. The NIAID-supported project that specifically targets Arctic populations supports surveillance studies to examine the incidence of streptococcal pneumonia in Alaska Natives.

National Institute of Child Health and Human Development

The National Institute of Child Health and Human 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 has sought 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.

National Institute of Arthritis and Musculoskeletal and Skin Diseases

The National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) conducts and supports basic and clinical research on many of the most debilitating diseases affecting the Nation's health, including the many forms of arthritis and diseases of the musculoskeletal system and the skin, as well as research on the normal function of joints, muscles, bones and skin.

NIAMS has been actively involved in a study of spondyloarthropathies in circumpolar populations since 1989. This study has been carried out with the Russian (formerly U.S.S.R.) Institute of Rheumatology in Moscow and the U.S. Indian Health Service (IHS), Alaska Native Health Service. The U.S.–Russian studies in circumpolar populations grew out of a shared interest in this group of diseases. The spondyloarthropathies are a group of related rheumatic disorders that encompass ankylosing spondylitis, Reiter's syndrome, reactive arthritis, arthritis associated with inflammatory bowel disease, and psoriatic spondylitis.

The etiology and pathogenesis of the spondyloarthropathies are incompletely understood, although it is clear that both genetic and environmental factors participate in causing the diseases. Spondyloarthropathies appear to be associated to a great degree with Class I histocompatibility antigen HLA B-27. However, the role of HLA B-27 has not been clarified. In addition, there are ample data indicating that there is significant involvement of infection or infective agents in the disease etiology. Despite the known association of spondyloarthropathies and HLA B-27, and the clear involvement of microbial triggers in some of the syndromes, the precise etiology of the spondyloarthropathies needs to be revealed. How and why these diseases are initiated in susceptible individuals remains unknown.

U.S. and Russian investigators independently became interested in the spondyloarthropathies in their circumpolar populations because both groups recognized a substantial burden of poorly understood and inadequately described rheumatic disease in populations with a high frequency of HLA B-27. North American Eskimo populations have been reported to have high HLA B-27 frequencies (in the range of 25–40%) compared to other racial or ethnic groups; it is found in 6–14% of U.S. whites. U.S. investigators from the NIAMS, in collaboration with investigators supported by the IHS in Alaska and Russian investigators from the Institute of Rheumatology in Moscow, agreed to carry out studies with shared objectives. However, it was decided that each country would carry out their studies independently. The combined study objectives of the project are:

- To determine the prevalence of spondyloarthropathic disorders in selected indigenous circumpolar populations of the U.S. and Russia;
- To describe the spectrum of spondyloarthropathic disease, including clinical manifestations, natural history, sequelae and severity of disease impact in the populations; and
- To lay the groundwork for investigation of the role of specific genetic and environmental factors in the pathogenesis and expression of the disease.

American and Russian scientists arriving in Novo Chaplino, Siberia, by "school bus" for a site visit. An all-terrain vehicle was necessary for traversing streambeds and tundra when the road disappeared.

The prevalence studies of spondyloarthropathies in the Alaskan and Siberian study regions have been completed. These data will provide the first nearly comprehensive description of the spondyloarthropathies disease spectrum in well-defined populations.

In addition to determining prevalence, these data are useful for defining disease aspects that require representative cases. This use was exemplified in a comparative study of disease in men and women. IHS investigators found that, contrary to the long-held clinical belief that spondyloarthropathies are primarily found in males, in their study population the ratio of male to female cases was close to parity. However, lack of recognition of spondyloarthropathies in women may result from a slightly milder disease, together with the clinical belief that spondyloarthropathies are rare among them.

NIAMS does not support the Russian component of the study but for the past four years has provided expenses for three or four Russian collaborators to meet annually with scientists working on the project in the U.S. under the auspices of the U.S./Russian Cooperative Program on Arthritis and Musculoskeletal Diseases. The project is ongoing.

National Institute on Aging

The National Institute on Aging (NIA) supported a Phase I Small Business Innovation Research (SBIR) 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 extends 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.

NIA has also developed a public information brochure for accidental hypothermia, a possible health threat to older Alaskan residents.

National Institute of Diabetes and Digestive and Kidney Diseases

A research project to determine to what extent intervention can decrease the prevalence of diabetes, hyperinsulinemia and cardiovascular risk fac-

tors among Yupik Eskimos living on St. Lawrence Island and the west coast of Alaska has been funded by the National Institute of Diabetes and Digestive and Kidney Diseases. This project also investigated dietary patterns, physical activity levels and anthropometric data in an attempt to correlate these variables with the occurrence of diabetes, cardiovascular risk factors, diabetes complications and insulin levels. As part of the ongoing Alaska–Siberia Medical Research Program, identical baseline data are currently being gathered in the population of Yupik Eskimos across the Bering Straits on the Chukotka Peninsula in Siberia.

As a result of this study it was determined that the age-adjusted prevalence of non-insulin-dependent diabetes mellitus (NIDDM) among Alaska's Eskimos, Indians and Aleuts overall increased 11% (from 15.7 to 17.4 per 1000) over the two-year period from 1985 to 1987. Rates in 1987 varied from 6.7 to 40.8 per 1000 in various Indian Health Service units in Alaska. These estimates are based only on clinically recognized cases. Comparing preliminary rates to Chukotka Natives 15 years and older, it was found that the St. Lawrence Island rate is 9.7 per 1000, while the Chukotka rate is 1 per 1000. Since Siberian Yupik Eskimos of Chukotka and Alaska are genetically closely related, the working hypothesis is that diet and lifestyle account for the difference in diabetes prevalence. This represents a unique opportunity for research since these populations were essentially one until 1948.

A survey of 800 subjects (both male and female) on St. Lawrence Island and western Alaska will be carried out using similar methodology to the ongoing Strong Heart Study among other non-Alaskan groups of Native Americans. The surveys will be followed by an intervention in which half of the participating villages will receive specific education about diet and risk factors and will be encouraged to eat more traditional foods, decrease foods with low nutrient density such as sugar, decrease intake of saturated fats and increase physical exercise. Additional interventions will be implemented based on recommendations and input from the community. During the fifth year of this grant the effectiveness of the interventions will be tested by a careful comparison of diabetes and cardiovascular risk factors, repeating the same survey as in year one of the study. Since the Alaskan Eskimos began abandoning traditional diets and lifestyles only recently, it is possible that the study might lead to a reversal in this trend by providing significant insights into the etiology of NIDDM and might lead to identification of the causative lifestyle factors that can be modified to prevent diabetes.

National Institute of Mental Health

The National Institute of Mental Health (NIMH) supported a variety of research projects that have an impact on Arctic populations. The institute's goals and objectives include support of mental health and mental health services research as they relate to diverse conditions, including the 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. Among activities funded by NIMH are the following:

- Continued support of an American Indian and Alaskan Native Mental Health Research Center;
- Publication of a major book summarizing current knowledge in regard to the epidemiology, precursors and prevention of suicide among American Indians and Alaska Natives;
- Programs announcements on Research on Mental Disorders in Rural Populations; and American Indian, Alaska Native, and Native Hawaiian Mental Health Research; and
- Continued support of three rural mental health research centers that have conditions similar to those in the Arctic: the Iowa Center for Family Research, the Arkansas Center for Rural Mental Health Care Research and the Virginia Southeastern Rural Mental Health Research Center.

Indian Health Service

The mission of the IHS is to raise the health status of American Indians and Alaska Natives to the highest possible level. Thus the IHS uses its resources primarily for providing direct curative and preventive health care. However, the IHS funds some clinical research and enters into collaborative relationships with other Federal agencies to study the effects of the hepatitis B vaccine on the incidence of hepatitis B and hepatocarcinomas in the Alaska Native population. These two diseases may be related and occur at very high rates in some Alaska Native populations. These collaborations are especially strong in Alaska and are enhanced by the proximity of the Alaska Native Medical Center to the AIP. Thirteen of the research worker assigned to the AIP are IHS personnel, and five IHS physicians collaborate as research associates with AIP investigators. In other Arctic research activities, the IHS collaborates with the NIH.

Smithsonian Institution

The first five years of the Smithsonian's Arctic Studies Center has produced a wide range of programs serving both the northern research community and Native interests.

In today's shrinking world, increasingly dependent on northern resources, a pressing need exists for scientific knowledge and education in areas of circumpolar cultures, society and ecosystems. Within the span of a single human generation since WWII, the industrialized world has established bridgeheads in formerly remote Arctic and subarctic regions. This incursion immediately and unalterably changed northern environments and traditional cultures, bringing them into the global system with astounding rapidity and with little preparation for effects and consequences. During this period, scientific advances have equipped researchers with new techniques for understanding northern environments, and momentous changes in international relations have enabled scientists and Native peoples across the circumpolar North to share and exchange information to an unprecedented degree.

In one way or another these changes have contributed to the development of a focused program of Arctic research at the Smithsonian. Now in its fifth year, the Arctic Studies Center of the Smithsonian's National Museum of Natural History has developed a wide range of programs in Arctic and subarctic anthropology and natural history.

	Funding (thousands)	
	FY 92	FY 93
Anthropology	600	600
Arctic biology	75	75
Total	675	675

Arctic Studies Center

As originally mandated by Congress, the Center was formed to provide a permanent national program for research and interpretation of Arctic cultures and natural history and for the development of educational programs benefiting the Nation at large and northern peoples specifically. In keeping with the Smithsonian's mandate for "the increase and diffusion of knowledge," the Center was charged with:

- Conducting research in Arctic anthropology and natural history;
- Curating the National Arctic Anthropological Collections;
- Preparing educational exhibitions, films and videos;
- Offering training in museum anthropology and community archeology;
- Publishing scientific research, catalogs and databases; and
- Providing professional assistance to government agencies and the public.

The Center builds on a long history of Smithsonian activity in the North. Soon after the founding of the Institution in 1846, Spencer F. Baird sent teams of naturalists, including Robert Kennicott, William Healy Dall, Henry W. Elliott and others, into the Yukon Territory and Alaska to make collections and gather geographic information. The results of these scientific missions were instrumental in influencing Congress's decision to purchase Alaska from Russia in 1867. They also led to an explosion of research conducted by a second generation of America's Alaska pioneer researchers, Edward W. Nelson, John Murdoch, Lucien Turner and others, who laid the foundations for our current understanding of Alaskan ethnology and natural history. Later, in the early 20th century, research shifted to discipline-based studies in physical anthropology, archeology, zoology and paleontology by today's "grandfather figures," Leonard Stejneger, Ales Hrdlicka, T. Dale Stewart and Henry Collins. In more recent decades, Smithsonian work in Alaska waned as biological interests shifted to the tropics and overseas, and the Institution's archeologists, first Henry Collins and then William W. Fitzhugh, explored the history of Native peoples and environments of the Canadian Arctic and Greenland.

Alaskan "Rediscovery"

The early 1980s saw a new phase of Smithsonian involvement in Alaska. Prompted by visits from Senator Ted Stevens and his then-wife, Anne Stevens, to inspect the Smithsonian's Alaskan collections, a plan was developed to get some of these materials back to Alaska as a special exhibition of ethnographic objects collected by Edward W. Nelson in western Alaska in 1877–1881.

In 1982, when the Smithsonian opened "Inua: Spirit World of the Bering Sea Eskimo," and sub-

sequently brought it to Anchorage, Juneau and Fairbanks, most Alaskans had little knowledge of the Institution or its Alaskan history. Alaskans who traveled to Washington, D.C., were surprised to discover treasures of their Alaskan heritage in exhibits on the Mall at the National Museum of Natural History. Gathered more than a century ago, these objects still evoked a powerful call on viewers, even in the nontraditional settings of the sparsely furnished Smithsonian galleries.

"Inua" was not alone in awakening Alaskan interest in Smithsonian collections. Several years earlier the National Gallery of Art's precedent-setting exhibition, "The Far North," had been shown to acclaim in Anchorage. In addition, during the "Inua" showing in Washington and Anchorage, Henry Collins returned to Alaska, for the first time since his Bering Straits work in the 1930s, creating both a media sensation and a revival of research interests in western Alaska.

The "Inua" exhibition was soon followed by a smaller traveling exhibition by the same name that toured widely to Native villages throughout the state. This "mini-Inua" exhibit was developed with the assistance of the Alaska State Museum, which managed the statewide tour and pioneered new techniques in traveling exhibition hardware. At the end of the Alaskan tour, "mini-Inua" traveled to the Canadian Arctic and Greenland, while a third version, produced through the ArtsAmerica Program of the USIA, went on to tour in Eastern and Northern Europe from 1987 to 1989.

During the same period a second major show was produced featuring the history, art and archeology of the Native cultures of the North Pacific. Produced jointly with Russian, Canadian and American curators, "Crossroads of Continents: Cultures of Siberia and Alaska" drew attention to the creativity and linked history of these people and the need for international scholarship and practical cooperation among governments sharing interests in this region. Recently, "Crossroads" itself has been succeeded by a smaller traveling exhibition, "Crossroads Alaska/Siberia," with strong local educational components, now touring in Alaska before being prepared for travel to the Russian Far East.

These exhibits have had a profound impact and have permanently changed Alaskan perceptions of their cultural heritage. The return of cultural treasures and the permanent record of these objects in widely distributed illustrated catalogs have not only rejuvenated interest in traditional Native arts, they have also created a revolution in commercial arts, invigorated the revival of masked dancing and the use of dance costume, and stimulated the development of curriculum materials. While the impact of "Inua" tapped latent knowledge and interest in Alaskan Eskimo cultures, "Crossroads," with its expanded ethnic and geographic scope, not only familiarized Alaskans with each others' Native history and arts but brought those of peoples of the wider North Pacific region into focus, exploring interrelationships and differences. These messages were dramatically enhanced by the collapse of the U.S.S.R., which brought new openness and tangible connections in travel and exchange between the Native peoples of the North Pacific.

Establishment of Alaska Office

These activities, and growing interest in collection repatriation stimulated by the passage of the Native American Graves and Repatriation Act, made it clear that a more permanent solution was needed to provide Alaska Natives and other Alaska residents with greater access to their heritage in the Smithsonian's collections. This interest was directed not only at ethnological and archeological collections, but also at the associated documentation and archived collections of photographs, films and historical materials. In 1992 the National Museum of Natural History decided to explore the possibility of opening an office of the Arctic Studies Center in Alaska.

In December 1993 the first major step was taken toward this end with the establishment of a Smithsonian Arctic Studies Center office at the Museum of History and Art in Anchorage to facilitate Smithsonian Alaska-based research and educational programs. The agreement, announced in Anchorage on December 15, 1993, calls for cooperation across a wide range of areas, including research, exhibit

William Fitzhugh, Patricia Wolf, Stan Shetler, Elmer Rasmuson and (front row) Mary Louise Rasmuson and Anchorage Mayor Tom Fink at the signing of the agreement between the Smithsonian's National Museum of Natural History, the Anchorage Museum of History and Art, and the Municipality of Anchorage, establishing the Center's new office in Anchorage, December 15, 1993.

development, museum training, publication and assistance to Alaska institutions and organizations. The term is for five years, renewable thereafter.

The creation of the ASC Anchorage office provides Alaskans with new opportunities in museum training, education, exhibition development, repatriation and collaborative research. A central feature of the new Smithsonian–Alaska relationship is grounded in principles of partnership and local consultation. The agreement is a practical first step in the reunification of Alaska with an important part of its cultural and natural resources legacy.

Smithsonian activities at the Anchorage office will include scholarly research, exhibition, publication and educational programs. The ASC Anchorage office will collaborate with other Alaskan institutions and agencies and will coordinate with the Smithsonian's Alaskan repatriation programs. The office will be involved in North Pacific area anthropological research projects and will collaborate with Alaskan universities and agency programs.

Projects underway and under consideration include exhibits on Yupik mask traditions, on Inupiat whaling, on Athapascan and Alutiiq material culture and on early Tlingit history and European contact. Each of these projects will be developed with the involvement of Alaskan scholarly and Native communities and will utilize Smithsonian collection and archival resources. The Smithsonian is particularly interested in working with the NMNH Repatriation Office and appropriate Native groups to help document collections destined for repatriation.

The ASC office will be staffed initially by a Smithsonian anthropologist and resident affiliated scholars. AMHA will provide administrative support until Smithsonian funding is available for staff expansion. Ultimately it is hoped that the ASC office will grow into a small-scale research, curation and educational center occupying permanent quarters in an enlarged Anchorage Museum facility. A five-year development program toward this end has been initiated. The ACS program will be advised by an Alaska-based advisory committee representing national and local constituencies.

The Anchorage office will also play an important role in coordinating and conducting research programs with the Washington office. Among the projects that are planned are the newly organized "Jesup 2" research program, surveys of archeological resources of Alaska's National Parks conducted jointly with the NPS, and oral history and film research projects such as that being conducted on the King Island film and visual archives collected by Father Bernard Hubbard in the 1930s.

Research Programs

The Jesup 2 North Pacific Initiative

The Smithsonian Institution, in association with other museums and universities, has begun a long-term study of the cultures, peoples and environments of the greater North Pacific and Beringian region. Named after the pioneering Jesup North Pacific Expedition (JNPE) of 1897–1903 led by Franz Boas of the American Museum of Natural History, the new North Pacific study will seek to integrate social and natural sciences in a region where scholarly communication has been blocked by political hostility and confrontation for most of the 20th century.

Motivated by the promising results of the original Jesup Expedition and by the recent "Crossroads of Continents" exhibition, the Smithsonian has developed a research program to investigate the history and current status of Native cultures of the Greater North Pacific Region (GNPR) as a centennial successor to "Jesup 1." In collaboration with a consortium of institutions and agencies in the U.S., Russia, Canada and Japan, Jesup 2 has begun to evaluate and reassess the results of the original Jesup Expedition and to coordinate a new study of the area in a multidisciplinary and international context.

Several dramatic changes have taken place in the North Pacific in the past century. The population of the GNPR has grown many times because of the arrival of outsiders; indigenous populations, though also growing rapidly, are now a minority in their homelands in all but a few locations. Native subsistence economies have changed under the pressure of modernization, commercial exploitation and governmental policies. A number of ethnic groups have become extinct as recognized entities, while the majority of Native languages are endangered and will seemingly not survive into the 21st century under the pressure of assimilation. Although Native populations are growing in most parts of the GNPR, the cultural diversity and integrity of the region is threatened. This situation creates an urgent need for social scientists to document conditions and record ongoing changes, to outline the fields of greatest concern and to contribute perspectives on cultural traditions and the survival of indigenous culture and language in the future.

At the start, emphasis is being placed on evaluating and publishing existing JNPE collections, data, archival sources and interpretations. Conferences and symposia have begun to reevaluate these data and the contexts under which they were gathered to provide a secure database for modern com-

Yupik Eskimo woman from Sireniki, Chukotka, Russia, assisting with reindeer butchering.

parative research. In several cases Jesup 1 data never reached synthesis, and some was never published. Concurrent with this starting phase the Smithsonian proposes a new field survey of the GNPR aimed at understanding cultural and environmental history and inventorying and assessing the current status of cultures and peoples of this region today.

The new program is exploring a detailed regional component of the larger subject of global cultural and environmental change. Unique features of the circumpolar environment make it particularly well suited for studying global change. Circumpolar land masses are geographically contiguous, their marine and terrestrial flora and fauna are closely related, and they share similar climates and environments. These conditions have promoted similarities in composition, structure and history of their biota. The pattern extends also to cultures and human history, as seen by the expansion of Arctic and subarctic cultures across thousands of miles, including across Bering Strait from North Siberia to Greenland and all along the insular zone of the North Pacific rim. This attests to the global nature of population movements, cultural diffusion and impetus of historical forces in the North Pacific region over a 40,000-year time span.

The GNPR, with its deep human history and biologically productive environments, is an ideal setting for multidisciplinary research on modeling long-term human–environmental interaction and culture change with a global, circumpolar perspective.

A major focus of Jesup 2 will be on contemporary issues affecting the cultures and peoples of the GNPR. As the world approaches the end of the 20th century and faces a new millennium, scholars and the public alike are concerned with the dramatic outcomes of the past century and the legacy it will leave to future generations. Environmental degradation, pollution, loss of species and ecosystem integrity are issues of major concern. A similar set of concerns is expressed by both the general public and social scientists regarding human cultural diversity and the rights of indigenous people. Paternalistic governmental policies, industrialization and the spread of consumerist values all have damaged indigenous subsistence and languages and distorted their cultural continuity and ethnic diversity.

While the issue of cultural survival is likely to become a major focus of social sciences for the next century, few if any efforts are underway to summarize the outcomes of a centennial-long cultural transformation in a broad regional perspective. An important research advantage of the Smithsonian project is that the GNPR already has available the unique baseline data set developed by the first Jesup Expedition. The goal of the proposed program is to produce a summary of indigenous survivals and losses during the 20th century in an area that has been highly influential in global ecological and political systems throughout the major part of the century because of its location at a sensitive geopolitical boundary.

As in the historical component of the program, comparative surveys will be an important method of research. During this century thousands of Siberian, Alaskan and Northwest Coast Natives abandoned their traditional lifestyles and joined the modern workforce in increasingly industrialized urban settings. Huge numbers of outsiders immigrated into their territories, bringing demographic, social and political change. Entrepreneurism, business interests and military policies made major impacts on both human and natural environments. While many groups continue to live in their homelands, most have lost their Native languages, have adopted imported religious beliefs, and rely on modern technology. The same is mostly true for Ainu people in northern Japan.

In Siberia equally dramatic changes have been experienced. State-controlled hierarchies have dictated policy; floods of recruited and imprisoned outsiders have arrived; some Native groups have been deprived of traditional livelihoods, while others involved in state-owned reindeer herding, pelt

farming and fishing have been artificially subsidized. Official policies of "russification" and relocation have reduced the viability of Native life and economy. State-controlled industrial development has had a devastating impact on land and resources over which Native people have had little control.

Despite differences in political systems, in many respects the results of 20th century developments in Siberia and northwest North America have produced surprisingly similar results. In both areas Native people have lost much of their ability to direct their own futures; languages have been weakened or lost; poverty has increased; subsistence economies have been weakened; and alcoholism and social disjunctions/disorders are serious problems. In both areas cultural and language survival, Native rights, education policy, and economic and political issues are looming as major problems in the future.

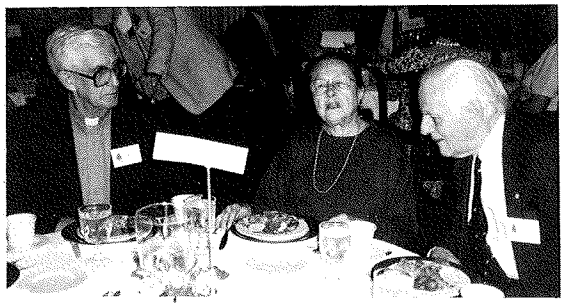
Jesup 2 is being conducted in cooperation with local Native groups and communities and with the aim of encouraging local education and professional development. Ethical considerations for such work are now respected practices in social research and are becoming more widespread in other fields. Implementation of special training programs, encouragement of local scholars, development of Native research resources, and cultural exchange among indigenous peoples of the area will be priorities for international and national efforts under the new Jesup 2 initiative. After five centuries of a dominant "Atlantic" perspective on world history and politics, we are entering an era in which Pacific resources and relations are assuming an important role in world affairs. The opportunity to develop a knowledge basis for North Pacific lands, peoples and cultures will provide immense benefits to science, to northern peoples and to public understanding of a little known but increasingly important part of the world.

With the recent relaxation of political controls, Russian scholars have been increasingly able to conduct joint research with their American, Japanese and Canadian colleagues. Botanists, geologists and other natural scientists have been able so far to develop several mutually beneficial collaborative programs. Although some progress has been made also in the social sciences, its pace of development has been slower than in the natural sciences. Russian social scholars are generally more interested in western library resources, technology and research methods, publication outlets, educational opportunities and financial support for their own field programs in Russia than in North American field opportunities. North Americans, on the other hand, are primarily eager to get access to formerly closed Russian collections and archives, field sites and Native populations.

Jesup 2 affords new opportunities for both sides and will bridge the gap resulting from decades of isolation and recent resource shortages. The program is facilitating broad-based international cooperation, which will achieve a new understanding and a new synthesis at this continental crossroads by 2002—the anniversary of the actual field completion of the JNPE. We hope that what eluded Boas and his partners—thematic synopsis and regional integration—might be possible today due to the more holistic approach to social processes and cultural change and to the larger body of data, methods and theory available to modern researchers.

Major milestones of the Jesup 2 program to date include:

- "Jesup 2: Survival, Continuity, and Culture Change in the North Pacific Region" (Quebec IASSA symposium, 1992);
- "Gateways to Jesup 2: Evaluating Archival Resources of the Jesup North Pacific Expedition, 1897-1902" (Washington AAA symposium, 1993);
- Exhibition of "Crossroads Alaska/Siberia";
- Publication of "Anthropology of the North Pacific Rim"; and
- Research development meetings by Russian, Canadian and Japanese project participants.



Father Marie-Rousseliere, Frederica deLaguna and Graham Rowley, among the many "elders" attending the Dartmouth conference on Eastern Arctic archeology in May 1993.

Elders Conference in Eastern Arctic Archeology

The occasion of Elmer Harp's 80th birthday became the focal point for a large gathering of Eastern Arctic archeologists at Dartmouth College in May 1993. Harp was instrumental in inspiring a generation of Arctic specialists at Dartmouth, many of whom attended the conference, together with 50 colleagues and students and fellow octogenarians Graham Rowley, Father Mary-Rousseliere and Frederica deLaguna. In addition to a round of social

Excavations proceeding at the Willows Island Dorset site in Countess of Warwick Sound, Frobisher Bay. Martin Frobisher's mines (1576–1578) lie at the far left, on Kodlunarn Island.

enterprises honoring our "elders," the program included two days of scholarly papers on the history, practice and future of archeology in the Eastern Arctic—subjects barely touched upon in existing literature. In addition to strong representation from Canadian, American and Danish archeologists, members of the Inuit community offered views on current and future research needs and the need for community-based archeology programs. A full video record of the conference was made, including interviews with the elders. The conference was organized by the Arctic Studies Center with the assistance of Dartmouth's Dickey Endowment and support from the National Science Foundation, the Social Science and Humanities Research Council of Canada, the Department of Indian and Northern Development, the Smithsonian, the Canadian Museum of Civilization and private donors Evelyn Nef and Mary Wesbrook. Papers will be published in collaboration with Dartmouth's Institute of Arctic Studies by the University Press of New England.

Archeology of Frobisher Bay

Southeast Baffin has been the locus of detailed archeological studies for the past four years under the auspices of the Canadian Meta Incognita Project. The MIP was organized to explore the archeology and history of the Frobisher Bay region, with special emphasis on the records and remains of the Frobisher voyages (1576–1578), Inuit oral history and Inuit archeology. Having completed studies of Frobisher's principal site on Kodlunarn Island in 1981, the Smithsonian portion of this program in 1990–1993 has been directed at locating "off-Kodlunarn" Frobisher sites, studying Inuit sites for evidence of European–Inuit contact and, in 1993, completing outer bay surveys and excavation of Dorset sites.

Highlights of the 1992 season include excavation of four historic-period Inuit winter houses and four fall/winter qarmats; regional surveys of Dorset, Thule and Frobisher mine sites; and various environmental studies. Unusually severe ice conditions made it impossible to carry out archeological surveys and driftwood collection projects in the outer bay region around Loks Land. The Inuit houses at Kamaiyuk, which was visited and described by George Best in 1577, contained Elizabethan artifacts such as roof tile, English flint pebbles, coal, English hardwoods and metal remains, indicating an occupation at or shortly after the Frobisher voyages. Most of the European materials had probably been obtained by scavenging the remains of Frobisher blacksmith and assay shops after their abandonment in 1578. Excavation at sites occupied during the intermediate period (17th–18th century) suggests that any European influence in eastern Baffin Island was remote during this period, possibly indicating the region's physical isolation from European vessels at the height of the Little Ice Age. Finally, excavations at late 19th century sites document the Inuit response to massive European contact during the whaling and trading eras. Important results were also obtained from several Dorset culture sites dating to the period A.D. 0–1400.

In 1993, the last year of the Frobisher field program, surveys were completed in the outer bay, and Dorset culture sites 800–2500 years old were excavated. The principal excavation work involved studies at an Early Dorset site on Willows (Opingivik) Island, which featured a frozen midden containing rare wood, ivory and bone artifacts. Early Dorset harpoons, leisters, sled and boat parts, tool handles, shafts, snowknives, toys, boxes and artwork were recovered. The new finds indicate that Early Dorset culture was well adjusted to Eastern Arctic conditions, having snowhouses and skin boats. A rich collection of faunal remains will provide a basis for reconstructing subsistence patterns and environment. A Late Dorset house floor dating about A.D. 1300 was also excavated.

In addition to compiling evidence on the Inuit response to 500 years of European contact, the Frobisher Bay surveys demonstrate that archeological sites in outer Frobisher Bay and Cyrus Field Bay are being severely damaged by coastal submergence and erosion. Damage is extensive at the Frobisher mining and workshop site at Kodlunarn Island and at most historic Inuit winter villages. Erosion of ancient sites is so extensive that most Pre-Dorset sites (2000–500 B.C.) have already been destroyed, and Dorset sites are seriously eroded. Even recent Inuit sites are eroding or endangered. Attention should be given to archeological

programs aimed at recovering or preserving these archeological resources before they are lost.

An important outcome of the Frobisher archeological program in 1993 was the publication of two volumes, "Archeology of the Frobisher Voyages" and "The Meta Incognita Project," in addition to reports and journal articles, detailing results of this large joint Smithsonian–Canadian Museum of Civilization program.

Nineteenth century model of an Aleut hunter wearing a hunting visor, from the collections of the Museum of Anthropology and Ethnography, St. Petersburg.

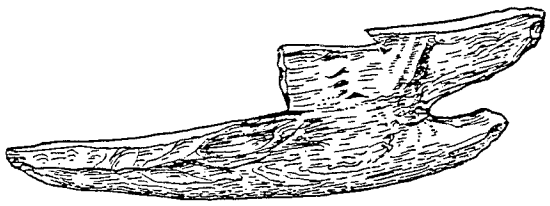
Archeology of the Western Aleutians

The Smithsonian has been involved in Aleutian studies for more than a century, beginning with Dall, followed by Stejneger and Hrdlicka. The National Museum of Natural History houses some of the largest and earliest ethnographic and archeological collections from the Aleutians. Continuing in this tradition, the Arctic Studies Center has spent three years collaborating in the Western Aleutian Human Paleoecology and Biodiversity Research Project.

This interdisciplinary and international research project, which also has an important USFWS component, is designed to pursue archeological, paleoclimatic and biogeographical research in the Western Aleutians. Project objectives include:

- Defining the culture history of the Western Aleutian archipelago;
- Reconstructing Aleut subsistence and settlement patterns;
- Providing data on site conservation and management status;
- Analyzing middens for paleobiological and paleoclimatic data on avian biogeography and population dynamics;
- Reexamining cultural and biological relationships between the Aleutian Islands and Asia; and
- Encouraging Aleut heritage and use of Smithsonian collections.

The project began in the summer of 1991 with a reconnaissance trip to Buildir Island, situated between the Rat and Near Islands. Previously Buildir had been archeological terra incognita. The research team located, mapped and tested an extraordinarily well-preserved Aleutian midden site. While the brief period of field work was not enough for complete excavation, enough material and information was recovered to justify an expanded study in the future.



Wooden bow element for a model Aleut baidarka (kayak) recovered from the midden on Buldir Island in the Western Aleutians, radiocarbon dated to 350 years B.P.

The Arctic Studies Center joined the project in 1992, beginning with a survey on Little Kiska, one of the western Rat Islands. The principal site consisted of a prominent midden mound containing thick layers of sea urchins mixed with faunal remains, including marine mammals, birds, fish and limpets. One of the many interesting finds was a whalebone-lined pit. Situated a meter and a half below surface, the pit contained a large number of bone artifacts, a stone lamp and a beach-cobble hammerstone. While no human remains were recovered, this pit is similar to a burial found by Hrdlicka on Amoknak in the 1930s. A radiocarbon date of 420±60 B.P. was obtained for this feature. Below the pit, deposits continued to a depth of 3.2 m, where shells dating to 2300±100 were recovered.

In 1993 the team returned to Buildir. The major site fronted an eroding beach and contained a nearly perfectly preserved midden more than a meter deep. Many of the wood and bone artifacts have been dated as early as 2000 B.P., while the

upper levels of the midden date to the early historic period, about 200 B.P., without any trace of European contact.

The Western Aleutian Project has demonstrated that many benefits accrue from interagency cooperation in research in remote regions. By pooling staff, funding and logistics resources (use of the USFWS research vessel *Tiglax*), the team has conducted a complex research program with minimal cost. Although final analysis remains for the future, the project has completed its principal research objectives. To date it has not produced evidence of cultural contacts with Kamchatka, the long-standing issue of Western Aleutian archeology.

Arctic Adaptations and Siberian Eskimo History

Russian visiting scientist Igor Krupnik published a major work, *Arctic Adaptations: Native Whalers and Reindeer Herders of Northern Eurasia*, in 1993. This work presents the results of a detailed comparative study of the subsistence economy, demography, and cultural and environmental adaptations of Native groups employing radically different adaptations to Arctic conditions—sea mammal hunting and reindeer herding—of the Russian North. Theories of culture change and comparisons with cultures of the American Arctic make this book a milestone in Arctic social science.

During the past two years Krupnik also made progress in completing a manuscript titled *Survival in Contact: Siberian Eskimo Transitions, 1900–1990*. Co-authored with Mikhail Clenov and supported in part by an NSF award, this book is the outcome of a long-term survey among the Siberian Eskimos of the Chukchi Peninsula during the 1970s and 1980s. The monograph, to be published by Smithsonian Press in late 1994, is the first and only detailed account of the traditional social system and contact history of the Eskimo people in Siberia and of their transformation during the 70 years of the Soviet regime.

Arctic Botanical Studies

A researcher from Moscow State University collaborating with Smithsonian Institution scientists recently completed a study of the genetic variability and evolution of lichens. Generally, scientists have considered lichens to be genetically uniform and an evolutionary dead end. However, using DNA extraction and new molecular markers, the researchers found the opposite to be true. After extracting and amplifying the DNA of the lichens of the genus *Umbilicaria* retrieved from glacial ice in Greenland (radiocarbon dated at 1550 B.P.), the researchers sequenced the DNA and compared it to samples of contemporary *Umbilicaria*. They found that while the DNA from the older samples resembled that of the more contemporary, it was not identical. These differences indicate that evolutionary processes have been acting upon lichens.

In addition to the specific results of this study, the work has important implications for both the analysis of other ancient DNAs and DNA preservation. DNA sequencing on a sample this old and a fragment this large is unprecedented. The extraction, amplification and sequencing techniques successfully used here may aid others studying DNA under glacial conditions.

Public Programs

Films

The 1993 annual film event memorializing the life of Latvian filmmaker Andris Slapins, who was killed by Soviet forces in the siege of Riga in 1991, featured films by the Inuit filmmaker, Zacharias Kunuk of Igloolik, N.W.T., Canada. Kunuk's films, which have received wide recognition during the past two years, present a Native view of "traditional" and "contemporary" Inuit ethnography. The 1994 Slapins Award was presented to Russian anthropologist–filmmaker Andrei Golovnev of the Institute of History and Archeology, Russian Academy of Sciences, Ekaterinburg, Russia. Golovnev has produced a remarkable series of films documenting the life of the Nenets, a traditional reindeer-herding culture of the Yamal Peninsula whose lives have been strongly impacted by oil development in the midst of their Native lands.

In other areas of film production, the ARC produced two film documentaries in 1994 in collaboration with Ted Timreck and WGBH/NOVA. The NOVA program, *Viking Contact*, documents the unexplored interaction of Vikings with American Indian and Inuit peoples in Greenland and the Eastern Canadian Arctic. *Frobisher Legacy* presents the history of Inuit peoples of Frobisher Bay from their first contacts with Europeans to the present day, a little-known chapter in the cultural history of the Eastern Arctic.

Crossroads Exhibition for Rural Alaska and Siberia

In September 1993 the Arctic Studies Center opened a small traveling version of its large special exhibition "Crossroads of Continents" at the University of Alaska Museum in Fairbanks. "Cross-

roads Alaska/Siberia" presents, through more than 300 archeological and ethnographic artifacts, 350 archival and contemporary photos, and 20 videos, Native cultures of Alaska and the Russian Far East. The cultures represented in the exhibition include Athapaskan, Tlingit, Haida, Inupiaq, Yupik and Aleut on the American side, and Asian Eskimo, Chukchi, Koryak, Itelmen, Yukaghir, Even, Amur River and Sakhalin Island Native cultures, Nanai, Ulchi, Oroch, Orok, Udegi, Negidal, Ainu and Nivkh on the Russian side. The exhibition, which includes teaching materials, spans from Paleolithic to contemporary times and covers almost every aspect of life, from cuisine to warfare.

The focus of the exhibition is the material and spiritual traditions, history and relationships of those cultures as parts of a rich North Pacific cultural area. The land bridge that physically linked the two continents during the ice ages is seen culturally today through similarities in technology, religion, social structure, art and ceremonial life.

The special mission of "Crossroads Alaska/ Siberia" is to bring materials home to peoples who created them but, because of the absence of museum facilities for large shows locally, have to travel to large centers to view exhibitions of their own heritage materials. With this in mind, the exhibition has been designed to travel to the rural and small community museums and cultural centers in Alaska and subsequently to Siberia. Historical photographs, videos and educational packages give the schools and general public a deeper understanding of the living cultures whose ancestors produced the artifacts on display. The exhibition was been created with grants from the NSF Science Education Program, Smithsonian Special Exhibition Funds, the National Park Service and USMAB. A catalog is available from the Arctic Studies Center.

Ainu Exhibition

A team of Japanese and American curators from the Smithsonian, the American Museum of Natural History and the Brooklyn Museum have begun planning a special exhibition on Ainu culture and history. The exhibition is being prepared from 3000 Ainu specimens, photographs, films and other documentation recently rediscovered in North American museums. Better documented and earlier than Japanese-held Ainu collections, the American material is an important new resource for Ainu people and Ainu scholars.

The Ainu are the southernmost of Asia's North Pacific peoples. A hunting and fishing culture, Ainu people became famous after their "discovery" by Europeans and Americans following the Meiji Restoration in 1868 and their presentation at the World's Columbian Exhibition in Chicago in 1892-93. Their elaborate material culture, spirituality and ritual (especially Ainu bear ceremonialism) captivated viewers, and the unusual Ainu physical type, with heavy facial hair, led some scholars to believe the Ainu were a remnant Caucasian group surrounded by a sea of Asian peoples. In addition to focusing on Ainu art, technology and religious beliefs (many of which demonstrate the influence of acculturation and contact with neighboring cultures), the exhibition will present a detailed view of Ainu history as a small Native people in the midst of powerful and competing nations—Japan, China and Russia—and will compare this history with that of a "sister culture," the Kwakiutl of British Columbia, which also faced serious threats to survival at the hands of expanding Euroamerican society.

After years of pressure to assimilate into the Japanese mainstream, the Ainu have been experiencing a significant cultural revival, a story that will be told in the exhibit with the assistance of Ainu consultants. The exhibit is timely in that it contributes to an Ainu celebration of an Ainu past and present. In short, the Ainu exhibit is a parable about cultural ethnicity and the formation and preservation of cultural values in a multicultural world. It will teach important lessons about history and anthropology, and it will also be a strikingly beautiful show.

Community Archeology Programs

One of the most important innovations of the Arctic Studies Center is its Community Archeology Program. Like many ASC initiatives, this program, serving as an outreach and educational activity for Native Alaskans and Canadians, grew out of a confluence of needs and opportunities. While the Smithsonian has included Native collaboration in its field and laboratory research projects for many years, the establishment of the Center has provided the means for establishing a stronger commitment to community outreach programs. Passage of the Native American Graves Protection and Repatriation Act, which requires museums to work with Native peoples and, under certain conditions, to return skeletal remains and cultural artifacts to them, has given further impetus to the Center's work. Although the ASC is not a direct player in the National Museum of Natural History's repatriation program, the Center works closely with northern Native groups in a broad array of "repatriation" issues, including educational outreach, increasing Native access to Smithsonian collections, staff and training opportunities, and the establishment of "in-the-field" archeology in their commu-

Innu (Indian) youths from Sheshatshit, Labrador, beginning excavations of an old trading site at the mouth of the Red Wine River on the Naskapi River, central Labrador, as part of an archeological training program.

nities. The major objectives of the community archeology program are to promote community interest in cultural heritage, greater involvement of communities in local anthropological research, and training of northerners and Natives in science and education.

The need for community-based research has become increasingly obvious in recent years. A frequent complaint of northern communities is directed at "hit-and-run anthropology," where researchers arrived at a remote northern location, excavated a site or interviewed people, and then returned with their collections and data to their southern institutions. Deprived of virtually all involvement in archeological or anthropological projects, many northern Native groups have come to resent the intrusions of scientists and the perceived loss of knowledge about their cultures.

The ASC's Community Archaeology Program (CAP), in which Native community members are encouraged to work with the Museum's collections, to suggest questions for study, and to collaborate in research, has proven highly effective in establishing a basis for a new relationship between local communities and academic institutions. Previous archeological projects began by informing communities of the research objects and methods. The CAP begins differently, by asking communities what they would like to know about the past and how they would like to go about finding that out. This is sometimes easier said than done. Some community leaders—confronted with pressing social problems arising in part from isolation, rural poverty and ongoing land claims—have been interested but could not put archaeological research at the top of their priority lists. Nevertheless, in the past two years the ASC has conducted two successful pilot programs in coastal villages in Labrador, where Smithsonian field workers have been conducting archeology for more than 20 years.

In the northern Inuit-Settler village of Nain, an ASC archeologist, working closely with an Inuit colleague from the Labrador Inuit Association's Torngasok Cultural Centre, spent a month excavating an old midden in the center of the town of Nain. In addition to training Inuit students in field archeology, the project is leading to a book on the history of Nain, which will include the analysis of the midden excavation, descriptions of the recovered artifacts, and historic drawings and photographs from museums and archives. In addition to missionary diary accounts, the study will include historical accounts and legends and stories contributed by Nain community elders. The result will be both a standard archaeological report and a history of the community for and by the people of Nain.

Another CAP program was conducted in the fall of 1993 in the Innu (Indian) village of Sheshatshit, Labrador. Unlike the Inuit, who live primarily off the sea, the Innu were traditionally caribou hunters. Only a single generation removed from this nomadic hunting lifestyle, the Innu are just beginning to develop an interest in their history. In this remote but historically rich land, archaeological digs are a source of possible employment for the Innu, so a six-week "job-training" course was arranged in which the ASC provided instruction and the Government of Newfoundland and Labrador provided student funding. Eight young men and women spent two weeks in the classroom, where they learned about the theory and methods of archaeology and the prehistory of Labrador. At the end of the program, the students set up a display in the town's parish hall and presented their work to the community. Program evaluation revealed that the Innu project generated interest in heritage programs that had previously been of interest only to the older generation. As a result of the project the community of Sheshatshit gained better understanding of their local heritage resources, learned techniques of heritage recovery and preservation, and felt better equipped to make informed decisions about the importance of culture and history in the future.

Collection Study Programs

In addition to field programs, the ASC provides community assistance in museum training and collection study. Studies of archeological and ethnological materials from local areas, assembly of local resource inventories, including archival and photographic holdings, and development of "tribal

Deanna Kingston interviews her uncle, Alex Muktoyuk, while working on the Father Bernard Hubbard Collection of motion picture film from Alaska, taken on King Island in the 1930s.

catalogs" have been found to be of great interest to northern communities. The ASC has opened dialogues with several Native groups in Alaska whose interests include the repatriation of skeletal and funerary remains but extend beyond this process to broader issues of cultural education and access to heritage resources held by the Smithsonian.

By advertising access to Smithsonian fellowships and other support programs, the ASC has been able to assist several groups of community scholars during the past two years. In 1992 an Aleut scholar from the Aleut Institute in Anchorage, Alaska, studied the Museum's collection with the support of a Native American Community Scholar's Award from the Smithsonian's Office of Fellowships and Grants.

Vivian Johnson, a Yupik Native from Bethel, Alaska, examines a beaded belt collected in the late 1870s from her home area by W. Edward Nelson.

Study projects involving Smithsonian archival photography and film holdings have provided other opportunities for northern Native peoples. The recent acquisition by the National Museum of Natural History's Human Studies Film Archive of about one million feet of motion picture footage shot in Alaska between the 1920s and 1960s by Father Bernard Hubbard (a Jesuit missionary known popularly as "The Glacier Priest") created the foundation for another type of local training and outreach. The Hubbard film includes more than 20 hours of footage shot in the 1930s on King Island, south of Bering Strait. Some 200 Inupiat Eskimos lived here until the early 1960s, when they were forced to move to the mainland. The Museum has copied the Hubbard King Island footage to videotape, so that King Islanders in Alaska will have access to it. In addition, an anthropologist whose mother is a King Islander is using the Hubbard footage to study King Island dance traditions and the continuing role of dance in maintaining King Island ethnicity and group identity. With support from the Smithsonian's Native American Community Scholar Program, she has created a guide to Hubbard's King Island footage, a task in which she was assisted by her uncle, who joined her to add detailed documentation.

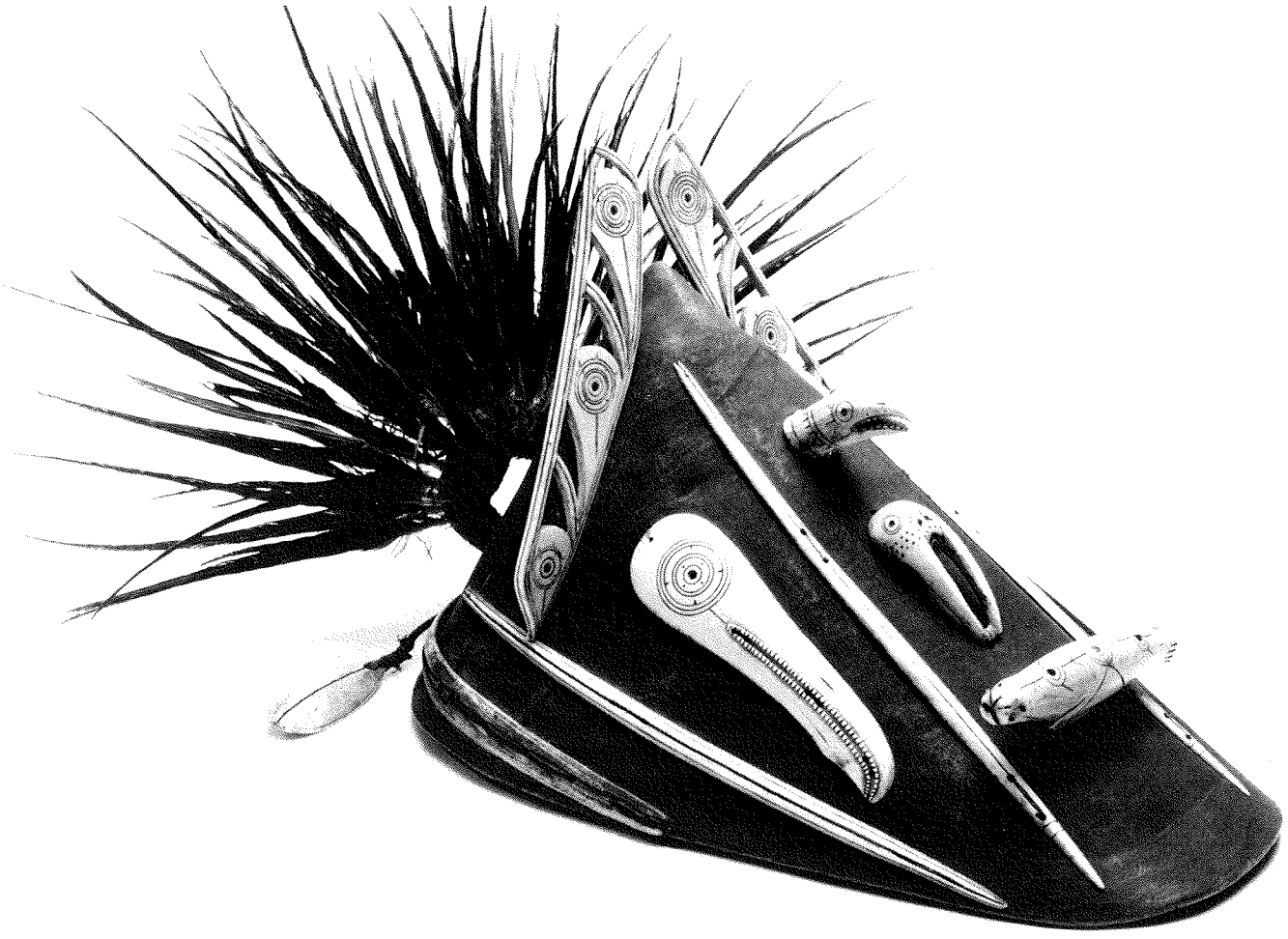
Future Programs

Since its founding in 1988 the Arctic Studies Center has developed a wide range of programs serving scholars and the public. Maintaining its long tradition of northern research that began virtually with the founding of the Smithsonian, the Center conducts archeological and ethnographic research throughout the circumpolar regions. Current research programs continue to study the environmental archeology and early history of Labrador, European–Inuit contact in Baffin Island and the archeology of Kodiak Island, southern Alaska and the western Aleutians. New projects have been organized with Russian collaboration on the archeology of Russia's Arctic coast. Through the Jesup 2 program, conferences and field work aimed at integrating North Pacific culture history and contemporary ethnology have begun with scientists from Russia, Japan and other nations, and a consortium of North American institutions is being formed to pool resources and documentation. Exhibition projects such as "Crossroads Alaska/Siberia" continue to be a source of inspiration for research and of ed-

ucational interest to the public, and methods have been developed to provide smaller exhibits to underserved rural areas of the North. At the same time, new projects like the Ainu exhibit provide opportunities to explore how anthropology can inform society about issues of racism, ethnicity and cultural survival, while also presenting magnificent unseen works of ethnographic art and culture.

Other programs currently in development include a survey of the history and cultural resources of the Yamal Peninsula of Arctic Russia. The Living Yamal Program, a cooperative project with Amoco Corporation, will be devoted to studies of ethnography, history and archeology of the Nenets people. In addition to its research goals, the project includes public programs in museum and film anthropology. A second program being developed with Russian collaboration involves archeological surveys of the Russian High Arctic islands, where Mesolithic sites containing remarkably well-preserved remains are being excavated in the New Siberian Islands, dating to 8000 years ago. The history of early human adaptations to this extreme northern regions, where mammoths have been found to have persisted as late as 4500 years ago, has important implications on the peopling of the New World and development of Eskimo cultures.

As the Arctic Studies Center moves into its second half-decade, it has made a credible start at fulfilling the goals established for it by a tradition of five generations of Smithsonian curators and researchers and by its new mission through its Alaska office. As the only Federal program specifically dedicated to cultural and natural history research in Arctic regions, the ASC has developed plans to utilize its holdings and experience to further knowledge of Arctic cultures, peoples and environments. Through its research and public programs, its publications and exhibitions, the ASC can serve both as a repository and as a laboratory for Arctic research as well as a public outreach and educational center. Through its Anchorage office the Center can now offer a wide range of new benefits to Alaska residents, can participate more fully in Alaska-based research and education and can promote the unrealized opportunity of the repatriation movement—the establishment of meaningful relationships between scientists, collections and communities having direct interest in utilizing heritage and research materials that have been inaccessible in the National Collections for far too long.



Bering Sea Eskimo hunting hat collected by I.G. Voznesenskii in the 1840s, from the collections of the Museum of Anthropology and Ethnology, St. Petersburg, featured in the "Crossroads of Continents" exhibition.

Environmental Protection Agency

EPA's Arctic research focuses on ecosystem protection. Monitoring activities address such issues as climate change phenomena; transport, fate and effects of contaminant such as radionuclides, heavy metals and persistent organic substances; and development of environmental technologies useful in environmental management and restoration.

The Environmental Protection Agency's Arctic research activities in FY 92 and 93 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 determine the potential for wetlands restoration in the environs of Prudhoe Bay, Alaska (Wetlands Restoration Program); and
- To support the transfer of risk-based information to state environmental programs to improve strategic planning (Comparative Risk Assessment Program).

	Funding (thousands)	
	FY 92	FY 93
Arctic Contaminants	906	837
Climate Change	272	425
Wetlands Restoration	0	125
Comparative Risk Assessment	0	75
Total	1178	1462

Arctic Contaminants

The goal of the Arctic Contaminants Research Program (ACRP) focuses on assessing the extent of contamination of Arctic ecosystems by atmospherically transported pollutants. Also, this work is investigating the potential consequences of pollutant introduction into Arctic food webs. Specific objectives of the ACRP are 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 goal and objectives of the program were established as a growing body of international literature suggests that the Arctic environment is becoming a repository for various environmental contaminants. Also, the literature suggests that these contaminants have been, and are being, released by industrial and agricultural practices, undertaken not only in the Arctic but at lower latitudes.

The EPA has supported this Arctic environmental contamination activity by monitoring for three field seasons in Arctic Alaska. This has provided samples and analytic data as well as the development of analytical methodologies. For instance, analytical methodologies for measuring the concentration of organic contaminants in lichens have been developed. Specifically the program is:

- Determining the status and extent of contaminants using regionally representative samples of lichens, mosses and soils;
- Ascertaining contaminant origin and chronology using lake sediment cores (cores will separate native contaminant contributions from long-range-transported contaminants, since lake sediment cores can distinguish between pre-industrial and post-industrial times);
- Studying squirrels and two species of fish for possible sublethal effects from the food web transport of pollutants, including analyses of biological stress indicators and bioaccumulation; and
- Cooperating with the seven other Arctic Monitoring and Assessment Program countries to develop standardized monitoring approaches and methods (two Russian expeditions have used EPA methods for sample collection), and evaluating the feasibility of using modifications of the Environmental Monitoring and Assessment Program (EMAP) sampling framework in remote Arctic locations.

Climate Change

The goal of the Climate Change Program is to clarify the potential impact of global climate change in the Arctic. The work focuses on determining the components of the Arctic ecological system that might be affected most by modifications in global climate. These studies are intended to provide decisionmakers with the information necessary to prompt regulatory actions that could mitigate adverse impacts.

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.

This program is multidisciplinary, with an approach designed to elucidate the mechanisms controlling greenhouse gas emissions from Arctic soils. Field and laboratory experiments are being conducted to determine the interaction of such environmental factors as temperature, moisture, the level of perennially frozen soil (permafrost level), and nutrient availability on Arctic soils. Data are being incorporated into models to estimate fluxes of greenhouse gas emissions into the atmosphere.

Wetlands Restoration

The goal of this effort is to determine and verify the potential for wetlands restoration in the environs of Prudhoe Bay, Alaska. The work focuses on investigating the dynamics of permafrost hydrology and vegetational growth and succession.

The work addresses the disturbance produced by more than 20 years of oil exploration and production at Prudhoe Bay. An extensive network of roads and drill pads was constructed by filling wetlands. These developments in the tundra have caused habitat fragmentation and other adverse effects on wildlife. Also, filling and removing material from wetlands has disturbed the permafrost hydrology. Restoring and revegetating abandoned roads and drill pads can be successful only if the hydrology of the area can be predicted reliably.

The feasibility of wetlands restoration is being investigated under a University of Alaska study of the dynamics and hydrology of the permafrost. The study will determine the factors that indicate the potential for wetlands restoration as well as the appropriate restoration approach for the Prudhoe Bay locality. The research includes mathematical modeling and field verification. One of the field test sites is an abandoned gravel pad now being revegetated in cooperation with ARCO Alaska. EPA scientists have transplanted tundra plugs from a donor site to the gravel site to examine the potential for propagation of the whole tundra plant community.

Temporary field camp set up on Elusive Lake in Arctic Alaska, April 1994, to obtain sediment cores for analyzing the chronology of contaminants in this basin. This lake serves as an integrated site for EPA's Arctic Contaminant Research Program; the ice is typically 2 m thick.

Comparative Risk Assessment

This program is designed to strengthen state capabilities in strategic planning for the management of 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 into the planning and evaluation of its environmental programs. This work—a comparative risk project in Alaska—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 decisionmaking.

Department of Transportation

DOT supports Arctic research through the U.S. Coast Guard, which provides icebreaking capability for government and nongovernment research and performs iceberg reconnaissance, and through the Federal Highway Administration, which is studying a variety of highway problems in the Arctic.

U.S. Coast Guard

	Funding (thousands)	
	FY 92	FY 93
Test and evaluation	814	920
Ice thickness sensor development	0	225
Arctic science support equipment	50	1037
Extramural support	0	35
Total	864	2217

The two Polar-class icebreakers operated by the U.S. Coast Guard, *Polar Star* and *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 and research bases in the Arctic and Antarctic. The polar icebreaker's primary role has since been changed to that of a polar research platform: scientific research support is now the primary mission of Coast Guard polar icebreakers. As this role was expanded, design deficiencies became evident, and larger research projects requiring larger science teams exacerbated the problem. In 1987 the need to improve these capabilities was identified, and upgrades were implemented through the Polar Science Upgrade (PSU) program. This five-year project, costing over 14 million dollars, was successfully completed at the end of FY 93.

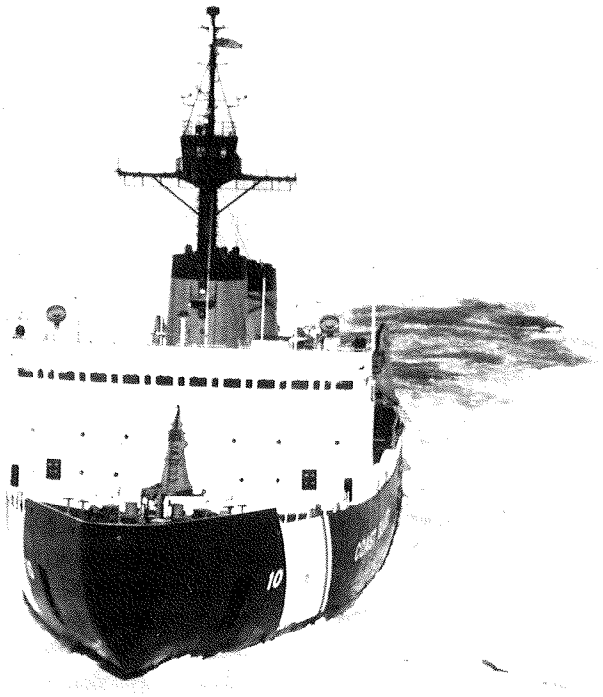
Associated with the PSU program, the Coast Guard established a permanent civilian science liaison position to support polar icebreaker expedition planning. The science liaison officer, located with the icebreakers in Seattle, has the primary duty to assist icebreaker users with planning, coordinating and implementing polar science projects. Also, science-dedicated living and working spaces have been expanded on both ships. The addition of a senior scientist stateroom and other initiatives now make it possible to support up to 32 scientists and technicians of both sexes, an increase of 12 berths. 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 have improved the research capabilities of these platforms.

From mid-July to October 1992, the *Polar Sea* was deployed in the eastern Arctic to support the first segment of the Northeast Water Polynya (NEWP) project, a large multidisciplinary investigation sponsored by the National Science Foundation. NEWP I involved researchers from 13 science institutions representing 5 countries. They embarked on an ambitious deployment that included 12 major projects and 81 separate science stations. During this challenging deployment, Polar Sea supported research projects in the following fields:

- Microbiology (with radioisotope analysis);
- Phytoplankton and zooplankton biology;
- Benthic biology and oceanography;
- Physical oceanography and hydrography;
- Chemical oceanography;
- Atmospheric physics and meteorology; and
- Zoology

The *Polar Star* was also deployed in the summer of 1992, working in the western Arctic on Arctic West Summer 1992 (AWS '92). Sponsored by the U.S. Geological Survey, this mission involved supporting a large multidisciplinary mission. This successful deployment carried research and technical personnel from five institutions from the U.S. and Canada. The *Polar Star* supported research associated with:

- The geology of the Chukchi borderland;
- The bathymetry and paleoclimatology of the Northwind Ridge region;
- Synthetic aperture radar signatures of autumn sea ice;
- The paleoclimatology and paleoceanography of the western Arctic;



U.S. Coast Guard icebreaker Polar Star *steaming through the ice.*

- The dropstone content in surface sediments of the Northwind Ridge;
- Rare-element chemistry water sampling; and
- Sea-ice-rafted sediment signals in the Arctic Basin.

From July to October 1993, the *Polar Sea* was again deployed to the eastern Arctic for the completion of NSF's Northeast Water Polynya project. Despite heavy ice conditions, NEWP II was a resounding success: an extensive sampling plan was successfully completed, four year-long moorings were successfully recovered, a first-ever transect of the Belgica Bank was made and other significant science experiments were completed.

The *Polar Star* was also deployed during the summer of 1993, returning to the western Arctic for Arctic West Summer 1993 (AWS '93). This was a major deployment sponsored by the Office of Naval Research and the U.S. Geological Survey. The *Polar Star* supported three distinct and independent science programs:

- Oak Ridge National Laboratory's Arctic Radionuclides (ARCRAD) study;
- A joint USGS–Canadian Geological Survey project; and
- Construction of an ice camp for the Office of Naval Research and the Applied Physics Lab of the University of Washington.

Participating in this ambitious and diverse deployment were 69 researchers, representing 20 institutions from 3 nations. This deployment included studies of:

- Radionuclide contamination in the Arctic and Canadian Basin ecosystems;
- Physical oceanography;
- Biological oceanography;
- The geology of the Amerasia Basin;
- Seismic refraction;
- The climatology of the western Arctic Basin;
- The oceanography of the Canada Basin and the Northwind Ridge;
- Ice physics;
- Sediment in sea ice;
- Paleoclimatology and paleoceanography;
- Sea ice mechanics;
- Technology development for autonomous underwater vehicles (AUVs); and
- Cadmium distributions in waters of the Chukchi Sea, the Bering Sea and the Gulf of Alaska.

These complex missions conducted aboard both ships were supported by newly installed Terascan satellite imagery receivers. This recent addition now gives Polar-class icebreakers the capability of receiving National Oceanographic and Atmospheric Administration (NOAA) and Defense Meteorological Satellite Program (DMSP) images. Frequent satellite passes provide almost hourly updates of NOAA and DMSP imagery, substantially improving navigation in ice. This gear allows the ships to save both time and fuel while transiting between sampling areas, and it also assisted the *Polar Star* in locating a suitable floe to set up the ice camp.

As reflected in several letters and messages from senior scientists, the Coast Guard is starting to see a return on its investment in upgrading these ships for scientific research. Reports of successful Coast Guard icebreaker-supported experiments are now appearing frequently in scientific newsletters and journals.

The Navy, on behalf of the Coast Guard, has also contracted for a third Polar icebreaker with Avondale Shipyard in New Orleans. In the design stages now, Coast Guard Icebreaker *Healy* is being built from the keel up with science support in mind. Many key figures in the U.S. Arctic science community have provided input in both the design and staffing stages of this project, and the Coast Guard intends to continue this close liaison with the scientific community.

The Coast Guard's goal of operating the most-capable high-latitude research vessels available will help keep the U.S. a primary player in polar research well into the next century.

Federal Highway Administration

The goals and objectives of the Federal Highway Administration (FHWA) in the Arctic are to develop and maintain cost-effective surface transportation facilities, primarily for highways and 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 United States are often relevant to highway problems in the Arctic. These projects have been primarily in collaboration with the various state highway agencies, especially in Alaska and the states with more severe winter conditions. Together with the state highway agencies, the FHWA sponsors, collaborates on 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 USGS and the Army Corps of Engineers Cold Regions Research and Engineering Laboratory, and university and private consultant contractors.

Hydraulic Problems at Stream Crossings

Arctic streams typically have highly variable discharges and flood levels and are plagued by erratic and highly variable floating and blocking ice. To deal with these conditions the USGS has for decades been contracted to measure the varying water discharge rates and the flood stages of the Yukon River and numerous other representative streams. The results of these measurements and estimates have been used in structural and hydraulic designs of bridges and culverts. Arctic streams can have heavy debris loads of loose ice, brush, trash and even trees, usually during the late spring and summer. During FY 93, studies dealing with sources of debris and debris loads on bridges have been continued and are expected to be completed during FY 94.

Soils and Pavement Subbases

Investigations dealing with soil conditions for roads are continuing. For unpaved roads, efforts are directed at stabilizing the road surfaces and using dust palliatives to both preserve the road surface and reduce the air pollution impacts from highway dust during periods of low precipitation. Studies are being done to increase the compatibility of the highway to permafrost and reduce the damage to highway pavements from the 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 insulated embankments, air-cooled ducts, thermal syphons and snow sheds for controlling permafrost-thaw-related roadway distress.

	Funding (thousands)	
	FY 92	FY 93
Stream crossings/Hydraulic problems	250	550
Pavement problems	1500	1000
Weather monitoring/Storm forecasting	40	80
Snow control/Plows/Fences Pavement treatment	140	530
Soils/Subbases (permafrost)/ Dust palliatives	0	80
Total	1930	2240

Pavement Studies

Since FY 87 there has been a high level of effort in pavement investigations of interest to the Arctic. The earlier investigations under the five-year-long Strategic Highway Research Program (SHRP) were largely completed by FY 92. The main efforts dealing with pavement performances under Arctic conditions are now being done by the Long-Term Pavement Performance Division, a new Division of the Office of Engineering and Highway Operations Research and Development.

Both Portland cement and asphalt concrete test sections of pavements have been placed in adequate lengths. Various mix designs, thicknesses and base conditions have been used or are proposed for 64 sites. Fifty-one of the sites are in 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 are being made and will continue for a prolonged period. This includes deflections, rideability and surface defects such as spalling. For these same pavement sites the heat transfers and temperature changes from the surface to depths are being measured and evaluated, revealing 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 behaviors 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 such as the longitudinal cracking investigation, which has been developing a scheme for using reinforcing materials in road embankments to limit longitudinal cracking caused by the lateral movements of the embankment.

Weather Monitoring and Storm Forecasting

Investigations started primarily in the SHRP to improve weather guidance to help highway maintenance operations in their response to problems resulting from ice and snow storms are being further field tested in several states, such as Colorado, Minnesota, New York, New Jersey and Pennsylvania. The studies are evaluating means to adequately and representatively sample road temperature conditions, current weather conditions at selected local highway sites and local regions (200–2000 square miles are typical for urban areas) and short-term weather forecasts, as well as methods to rapidly and reliably communicate these measurements and predictions. Short-term strategic predictions with adequate probabilities based on rapid computer calculations are then made available for highway maintenance decisions. Artificial intelligence based on meteorological principles and concepts and historical records of area storms are exploited to improve the predictive programs.

Colorado researchers are evaluating the Glenwood Canyon Ice Detector System. Ice detection equipment was installed during the summer of 1993.

The goals of these investigations are improved weather information for 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 storm threats. Weather monitoring and storm forecasting systems can also be used to help with decisions to close or not close travel on highway sections for storm conditions.

Snow Control and Pavement Treatments for Snow and Ice

Short test sections of snow fences based on designs developed during the SHRP study on snow fences and snow plows are being evaluated in several states, including Nebraska and New York. Snow plow improvements and a specially designed scoop attachment developed under the SHRP are being field tested in several states.

Implementation of anti-icing technology has begun, with 15 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 efforts. The objectives of this anti-icing study are to allow states to gain hands-on experience in using efficient and effective procedures for snow removal and ice control, such as anti-icing strategies, information provided by a road weather information system (RWIS), weather forecasting, friction measuring, various material types and improved material spreader equipment from field tests for an additional two winters (1993-94 and 1994-95), and to analyze anti-icing effectiveness over a range of traffic, environmental and climatological conditions. The Army's Cold Regions Research and Engineering Laboratory is the contractor for this study.

Investigations for developing methods for manufacturing calcium magnesium acetate (CMA) at lower cost have begun. These studies will consider the laboratory conversion of waste materials such as sewage sludge and cheese whey permeate to CMA using high-yield anaerobic bacteria and the determinations 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.

Colorado Department of Transportation is examining the use numerous materials as possible replacements or supplements for sodium chloride.

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 and costs of these installations will be undertaken.

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, the International Arctic Science Committee and the U.S. Man and the Biosphere program

Arctic Environmental Protection Strategy

	Funding (thousands)	
	FY 92	FY 93
Total	200	849

The AEPS was agreed to by the eight Arctic nations in June 1991. The State Department coordinates U.S. participation in the nonbinding legal agreement, which calls for cooperation in efforts to protect the Arctic environment. The AEPS document is based on State of the Arctic Environment reports prepared by the participants. The goals are preservation of environmental quality and natural resources, accommodation of environmental protection principles with the needs and traditions of Arctic Native peoples, monitoring of environmental conditions, and the reduction and eventual elimination of pollution in the Arctic environment.

The AEPS prescribes specific actions to control six types of pollutants: persistent organic contaminants, oil, heavy metals, noise, radioactivity and acidification. This is to be accomplished through cooperative steps in the following five areas: an Arctic Monitoring and Assessment Program (AMAP), protection of the marine environment, emergency preparedness and response, conservation of Arctic flora and fauna, and sustainable development.

Ambassador David Colson, Deputy Assistant Secretary for Oceans and Fisheries, led the U.S. delegation to the Second Ministerial AEPS meeting in Nuuk, Greenland, in September 1993. The meeting resulted in a declaration on environment and development in the Arctic and a report listing recent actions and steps to be taken to further implement the strategy. The U.S. urged ministers to address the issues of polar bear conservation, boreal forests, policy-level involvement in the Arctic Monitoring and Assessment Program, and coordination of national science programs.

The most recent AMAP meeting of experts was held in Tromsø, Norway, in February 1994. The meeting built on the framework established in 1991 to coordinate monitoring efforts and develop an Arctic data directory. The U.S. hosted the Second Conservation of Arctic Flora and Fauna (CAFF) meeting in Alaska in the spring of 1993, and Reykjavik is the site of the next meeting, which is planned for September. Sweden hosted an emergency preparedness meeting under the strategy. The State of Alaska held an international emergency response exercise under the auspices of the AEPS in June 1994.

Other agencies take responsibility for expert-level activities; for example, the National Oceanic and Atmospheric Administration covers AMAP, while the Fish and Wildlife Service is involved in flora and fauna protection. The State Department will contribute $130,000 to the AMAP program in FY 94.

International Arctic Science Committee

The State Department, working with the Polar Research Board, continues to follow the activities of the International Arctic Science Committee (IASC), a nongovernmental scientific organization that encourages and facilitates international consultation and cooperation in all aspects of Arctic research.

The IASC Secretariat was established in Oslo. The U.S. proposes to host an international IASC conference on research in the Arctic in late 1995. The conference will identify program elements for Arctic science that cannot be carried out without international cooperation, and it will work toward bringing the results of scientific research to bear on public issues relating to the Arctic.

The scientific program of IASC is set by the IASC Council, which has established a working group on Arctic global change studies, with instructions to conduct a small workshop and consider a regional program of global change research. Ad hoc working groups have been set up

to advise the Council on data systems, human and social sciences, and the possible uses of an inventory of Arctic research programs. In addition, IASC is investigating ways to cooperate in the execution of the Arctic Environmental Protection Strategy.

Man and the Biosphere Program

The Department of State also administers the U.S. Man and the Biosphere program, through a MAB secretariat located in the Department. In FY 92 the U.S. National Committee for the Man and the Biosphere Program approved the funding for a central core project of the U.S. MAB High Latitude Ecosystems Directorate entitled "Human–Environment Interactions and Institutional Frameworks: Alternative Caribou Management Systems in the Arctic." The U.S. MAB provided $300,000 of support for this project over FY 92 and 93.

The project addresses the central interest of enhancing the understanding and rational management of resources and ecosystems in the high-latitude regions of the U.S. and other circumpolar northern lands in order to sustain the region's biology and the welfare of its inhabitants. The directorate's core program will assess human–environment interactions and institutional frameworks in terms of their effect on the success of alternative caribou management systems in the Arctic in order to:

- Advance our understanding of the relationships between common property resource management structures and management effectiveness;
- Develop a sound empirical baseline on two Arctic management systems that may be severely stressed in the next five to ten years; and
- Apply quantitative scientific methods to comparisons of management systems and their effectiveness.

The directorate is testing hypothesized relationships between caribou management systems, perceptions of resource users and resource managers concerning the management system, and management effectiveness. They expect that management system effectiveness will, in part, depend on the degree to which resource users and managers share perceptions concerning herd population dynamics, the role of harvests in local economies, the relationships between harvest and consumption patterns, the relevance of various types of data to herd management, the degree of compliance with the herd management system, and the appropriateness of management system rules to local circumstances. In the directorate's research, they are developing cooperative working relationships with Native groups and government agencies by including local residents as members of their research team, involving both resource users and resource managers in interpreting the data generated by the study, and providing feedback of the study findings to affected communities, agencies and interested groups in both Alaska and Canada.

In FY 92 the U.S. MAB National Committee also approved $48,000 over a two-year period to support, as a research project complementary to the High Latitude Ecosystem's Directorate core project, a proposal entitled "Community Involvement in Cooperative Resource Management: The Case of the Porcupine Caribou." The Porcupine Caribou Herd (PCH) is the largest shared mammalian resource of the United States and Canada and an important resource to over 9000 Native and non-Native subsistence harvesters who live in communities within and just outside of the PCH's range. Such natural resources can pose special management problems that are often a result of the migratory nature of the resource, the jurisdictional coordination required in management, and the cultural disparity sometimes found between indigenous resource users and national government agencies. In Canada, government and Native PCH resource users have attempted to address these problems by entering into a "co-management" agreement that calls for user communities and government agencies to share in the authority and responsibility for Porcupine Caribou management. The objective for this research is to analyze and evaluate community involvement in caribou management decisionmaking, a critical component of Canada's approach to PCH management. Researching the role of community in cooperative management arrangement represents a critical step in understanding the performance and success of authority-sharing agreements between government and indigenous peoples in the management of natural resources.

In FY 92 the U.S. MAB program also allocated $15,000 to support a workshop in Anchorage, Alaska, for Biosphere Reserve Managers in the circumpolar North. This workshop established a working group for Circumpolar Biosphere Reserve Managers to stimulate cooperation among the circumpolar biosphere reserves of Europe, Russia and North America. A Steering Committee representing 15 existing and proposed Circumpolar Biosphere Reserves and two World Heritage Sites proposes to implement recommendations from that workshop. Circumpolar Biosphere Reserves have similar latitudes, vegetation types, species, subsis-

tence needs, threats from global change, and threats from development. Their differences lie in management strategies, stages of designation as a biosphere reserve, levels of information available to them, and levels of staffing, funding and equipment. The Steering Committee will conduct a series of short-term projects, and these differences and similarities can lead to future cooperative research such as comparative short-term biodiversity projects, global change research, long-term monitoring, and management of human use and activities within biosphere reserves.

In FY 93 the U.S. MAB National Committee approved as an additional project to complement the directorate's core activities a proposal entitled "Empowerment and Equity of Indigenous Peoples of North America: Emerging Cooperative Institutions for Fisheries Management." The Committee approved the sum of $49,000 to support this project over a two-year period. Indigenous fishers have historically been placed at the "end of the line" in receiving a share of the catch and were often limited or closed out due to concerns about the conservation of the salmon run. Cooperative management institutions emerged from this conflict in response to a variety of forces and mandates. This project will examine the contemporary relationship between the indigenous peoples of North America and their reliance on Pacific salmon. The essential question to be addressed is: Can co-management regimes lead to equitable and sustainable management and also maintain and promote the health of the ecosystem and the well-being of the Native peoples?

Other Activities

In addition to these activities, the State Department coordinates U.S. participation in an annual meeting in Copenhagen with the Danish Commission for Scientific Research in Greenland to review and approve proposals for research in Greenland by U.S. scientists. The Department's Division of Polar Affairs compiles the list of proposals and leads the U.S. delegation to the Commission meeting. This meeting is usually held in conjunction with a conference on Arctic issues. This year the focus is the biological effects of ozone depletion in the Arctic.

The Department of State participates in the efforts of the Interagency Arctic Research Policy Committee (IARPC) to develop a coordinated Federal response to the issue of radioactive contamination in the Russian Arctic and is involved in various bilateral and multilateral programs with Russia that could involve Arctic research. Examples of these are the U.S.–Russia Joint Environmental Agreement and the International Science and Technology Center established in Moscow.

The State Department's research budget is modest. Funds went towards the creation of an Arctic contaminants atlas, a workshop on radioactive waste, studies on pollution of the Chukchi, Beaufort and Bering Seas, support for IARPC and the Arctic Monitoring and Assessment Program, work on the conservation of flora and fauna, as well as funds to coordinate Native participation in AEPS meetings. State funds also went towards a successful symposium on Arctic airborne contaminants, held in Reykjavik.

Interagency Arctic Research Policy Committee

Twelfth Meeting
June 14, 1994

Committee members and staff representatives present: *Neal Lane, National Science Foundation, Chair; Raymond Arnaudo, Department of State; Sidney Draggan, Environmental Protection Agency; Carl Gerber, Environmental Protection Agency; Oswald Girard, Department of Interior; Peter Hartsock, Department of Health and Human Services; Sarah Horrigan, Office of Management and Budget; Charles Kennel, National Aeronautics and Space Administration; Debra Knopman, Department of Interior; Nancy Maynard, National Aeronautics and Space Administration; Bruce Molnia, U.S. Geological Survey; Charles Myers, National Science Foundation; Edward Myers, National Oceanic and Atmospheric Administration; George Newton, Arctic Research Commission; Ari Patrinos, Department of Energy; Douglas Posson, U.S. Geological Survey; Tucker Scully, Department of State; Bradley Smith, Department of Defense; James Stewart, Department of Agriculture; Alan Thomas, National Oceanic and Atmospheric Administration; Alan Walker, Coast Guard; Robert Watson, Office of Science and Technology Policy.*

The Interagency Arctic Research Policy Committee (IARPC) met Tuesday, June 14, 1994, at the National Science Foundation, 4201 Wilson Boulevard, Arlington, VA.

Dr. Neal Lane, Director, National Science Foundation and Chair, IARPC, called the meeting to order. Following introductions, including George Newton (representing Arctic Research Commission Chairman Donald O'Dowd) and David Garman, staff for Senator Murkowski (Alaska), Dr. Lane stated that the principal agenda item for the meeting was the question: what is the appropriate Federal agency research response to the problems of environmental protection and environmental monitoring in the Arctic.

Presidential Policy on the Arctic

Dr. Lane called on Tucker Scully to present a summary of the Department of State's review of U.S. policy related to the Arctic as outlined in a draft policy statement of May 1994. Mr. Scully reported that the review was conducted by the Interagency Working Group on Global and Environmental Affairs chaired by the Department of State and includes the principal Federal agencies.

U.S. Arctic Policy was reviewed in the context of the post-Cold War era. National security issues, an important element of the existing policy, have changed. In addition, other developments have influenced the context of the policy, such as:

- The increasing importance of the polar environment;
- The question of threats to the biological resources of the Arctic and the forms of conservation necessary to protect resources;
- New priorities and concerns for research and monitoring;
- The emergence of sustained efforts for institutional cooperation among Arctic countries for cooperation in an Arctic environmental protection strategy; and
- The emergence of more specifically focused research in cooperation with indigenous peoples.

Recommendations, following the review of the Interagency Working Group, include:

- Strengthening the Arctic Environmental Protection Strategy, with specific recommendations for environmentally sustainable development in the Arctic and a more formal mechanism for overseeing the implementation of the Arctic Environmental Protection Strategy;
- Strengthening the role of the IARPC in support of national and international scientific research, and working with the Office of Management and Budget and the Office of Science and Technology Policy to develop integrated, multiagency Arctic research budgets for the United States;
- Implementing conservation policies (including measures in the Arctic region to protect habitats and preserve Arctic wildlife reserves, boreal forests, polar bears and migratory birds) and reviewing efforts to protect the Bering Sea ecosystem; and
- Developing and coordinating strategies to deal with potential environmental disasters in the Arctic, and promoting international cooperation by supporting such programs as the Arctic Monitoring and Assessment Program (AMAP).

Specific bilateral aspects of U.S.–Russian relationships in the Arctic addressed in the review covered such areas as the cross-Bering Sea environment, scientific research, monitoring and contaminants risk assessment, issues relating to habitat identification and conservation, sustainable development, and promotion of cultural and social exchanges between the U.S. and Russia. The U.S. will be encouraging Russia to develop land-based storage facilities to eliminate radioactive dumping in the Arctic.

Dr. Lane suggested that the staff take on the responsibility for revising the Arctic Research Policy to reflect the new national policy. The Committee agreed to do this.

Arctic Environmental Protection Strategy and Arctic Monitoring and Assessment Program

Dr. Lane acknowledged support from the Department of State of $130,000 provided to the Committee to help manage environmental protection activities through the AMAP program. He expressed appreciation to the National Oceanic and

Atmospheric Administration, which has agreed to manage these funds for the IARPC.

Alan Thomas reported that there are two basic objectives in the AMAP program: assessment and data handling. The funding from the Department of State will be used to support data management activities in three main areas:

- Nationally, by funding the U.S. Geological Survey project in support of AMAP data management;
- Internationally, by supporting the AMAP Secretariat; and
- By supporting various assessment meetings and experts' participation as necessary.

In the assessment area the funding will be used to support studies of pathways and heavy metals. Efforts have focused on identifying experts to aid in writing and reviewing the required reports.

Dr. Lane called for comments. Sidney Draggan added that the AMAP Secretariat should be encouraged to work in a coordination function to help assure the comparability of methods and approaches taken by the various Arctic nations in their environmental monitoring and assessment programs. Raymond Arnaudo reminded the group that the funding provided by the Department of State was a one-time grant. Joint sharing of the Secretariat costs may be needed if there are to be future project efforts.

IARPC Arctic Contamination Initiative

Dr. Lane provided some background on the initiative. The IARPC approved a policy statement on Arctic contamination in 1992. The committee then convened a workshop on Arctic contamination in Anchorage, Alaska, in May 1993. At the last IARPC meeting the staff was directed to develop a research and assessment initiative. Debra Knopman acknowledged the contributions of Bruce Molnia in this area and turned to him for comments. Mr. Molnia reviewed the Arctic Contamination Research and Assessment Program report, which was provided to the committee members. The report presents recommendations for careful monitoring, international cooperation and data management. The Arctic Contamination Research and Assessment Program is an FY 96 interagency initiative. The purpose of the program is to assess the risk from Arctic contamination, first to Alaska, then to the Arctic as a whole, and finally to the Earth as a whole. It was prepared by an interagency technical committee consisting of representatives from various IARPC agencies.

The goals and objectives of the Arctic Contamination Research and Assessment Program closely follow the guidelines and research priorities formulated by the IARPC, the Arctic Research Commission, the Arctic Contamination Workshop, the National Arctic Policy and committees of the U.S. Congress. The structure of the initiative is based on a multidisciplinary integrated approach to understanding Arctic contamination issues and impacts on ecosystems and human health. Five key elements are contained in the program:

- Data and information management;
- Data rescue and synthesis;
- Observation and monitoring;
- Process-oriented research and development of models; and
- Impact analysis and determination of risk.

The goal of the Arctic Contamination Research and Assessment Program is to assess the sources, transport, fate and effects of contaminants and to determine the risks of contaminants directly dumped into the Arctic, as well as contaminants that accumulate in the Arctic from non-Arctic sources. The program builds on other existing programs and activities rather than being a totally separate activity. The initiative described is intended to aid in integrating isolated, unconnected programs and will lead to a systematic monitoring and scientific approach to understanding the Arctic contamination issues. The ultimate concern is the potential threat to U.S. health, ecosystems and fisheries.

To fund this initiative, a multiagency program is suggested. The budget presented for FY 96–99 requests annual funding for the National Oceanic and Atmospheric Administration, the Department of Interior, the Department of Energy, the Environmental Protection Agency and the National Science Foundation. Approximately $33 million in new funds would be needed to supplement the existing budget of the Federal agencies.

Dr. Lane thanked Mr. Molnia for his presentation and pointed out that the Arctic Research and Policy Act does not provide mechanisms for Arctic research funding. Therefore, funding would be an issue. He then requested the IARPC to authorize him to send a letter (a draft of which was provided to the committee) to the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP) to request funding.

Ms. Knopman commented that the Department of Interior was unable to fund this initiative from their base budget, and they do not have new money beyond what they are currently contributing. Sarah Horrigan supported Mr. Scully's mention of the legal requirement to develop an

interagency budget for Arctic research. She stated that OMB fully intends to work with the agencies to develop an integrated program in those areas.

Carl Gerber added that the Environmental Protection Agency lacked new money to fund this initiative. Peter Hartsock expressed the same concern but added that the National Institutes of Health's interest in this area is growing and the intention is to continue to make the Arctic a priority. Ms. Knopman addressed the OMB and OSTP representatives to add that partial funding would be better than none and a data-collection, management and monitoring activity would be an interim measure.

Robert Watson responded that the challenge before the various agencies was to review their priorities and make sure that the highest-priority programs are the ones being funded. Perhaps new, higher-priority programs would replace ones currently being funded. Dr. Lane asked for clarification that the Arctic activities were not necessarily excluded from the other key initiative areas (i.e., Global Change) of OMB and OSTP. Mr. Watson confirmed that they were not excluded. Alan Walker added that an integrated Arctic budget would be useful. OMB and OSTP are charged by law to work with the IARPC in this process. The establishment of an integrated budget is key (Mr. Watson and Ms. Horrigan agreed). Mr. Watson added that it may be possible to improve programs, even without additional monies, by improving cooperation and integration between the agencies. Improvements in interagency cooperation can lead to better programs.

Mr. Newton reinforced the statements that an integrated focus would make the best use of funds in the Arctic and would help to avoid duplication of effort. Ms. Horrigan responded that OMB is committed to doing that but the budget they put together is only as good as the input they receive from the participating agencies and only as good as the agencies' willingness to prioritize their programs.

Dr. Lane closed the discussion by suggesting that the letter in its current form be submitted to OMB and OSTP. This was agreed to without objection.

IARPC Data Activity

Douglas Posson presented an overview of the work of the Arctic Environmental Data Working Group on a variety of tasks, including the establishment of a prototype CD-ROM data system to distribute Arctic data sets and information. One resulting product was the Arctic Data Interactive (ADI) CD-ROM. Mr. Posson stated that the fundamental idea behind the project is that good science has to be backed by good data.

Another project of the group is the Arctic Environmental Data Directory (AEDD). The AEDD is a directory of agencies and organizations that have Arctic data. Over the past five years the directory has been developed and now contains approximately 400 entries. The peer review process has improved the reliability of the directory and is important for its continued use in the Arctic research community. The content, by discipline, of the directory was also reviewed. Some areas have relatively good coverage (earth science, oceanography, remote sensing, health and socioeconomics), while others had almost no data (contamination). This analysis of content helped to identify areas of research where more programs need to be supported to fill the data gaps.

The ADI CD-ROM is a "digital data journal" intended to provide data to a broader audience, beyond the research community, including educators, public interest groups and policymakers. The multimedia disk received the Design Achievement Award from President Clinton in 1994.

The group is also working on an international version of the directory. This directory is linked to other nations through the Internet. Each nation is to maintain its directory (in a standard format), which is linked to AEDD and other international science programs. Participating groups such as the United Nations Environment Program, the Norwegian Department of Interior, the Finnish Arctic Center, the Russian Ministry of Environmental Protection and the Canadian Polar Commission are part of the consortium. Mr. Posson presented plans for 1994–1995 for the expansion of the AEDD and its international counterpart. The group estimates that there are approximately 2000 data sets in the U.S. that can be identified and documented.

Dr. Lane concluded that it appears there has been good progress in the Arctic data directory areas, and the group will look forward to an update at the next meeting.

IARPC Biennial Revision to the U.S. Arctic Research Plan

Dr. Lane stated that the current IARPC biennial revision to the U.S. Arctic Research Plan is due to be submitted to the White House in June 1995 and to Congress by July 31, 1995. The plan has two major components: interagency initiatives and individual agency programs. Dr. Lane requested authorization from the Committee for the staff to proceed with this next revision. There was unanimous support.

Comments from the Arctic Research Commission

George Newton reported on four items from ARC:

- An Arctic health seminar was completed in February 1994 in cooperation with the Department of Health and Human Services.
- The Commission noted the progress made in the Arctic logistics area.
- The Arctic Science Submarine Program Plan is nearing completion and will allow for a minimum of one dedicated Arctic science deployment each year for the next five years. The first cruise is scheduled to take place in the spring of 1995.
- Philip Johnson, ARC Executive Director, will retire as of July 1994. Mr. Newton thanked Mr. Johnson for a job well done in support of the Nation's Arctic research efforts. Mr. Newton introduced Gary Brass, who has been appointed Executive Director of the Commission to replace Mr. Johnson.

International Conference on Arctic Research Planning

Robert Corell discussed the plans for the International Arctic Science Committee's International Conference on Arctic Research Planning, which will be hosted in Hanover, NH, by Dartmouth College and the U.S. Army Cold Regions Research and Engineering Laboratory. The conference is designed to look at fundamental areas in which there can be cooperative research among the Arctic nations. Collaborative international research activities will be explored, as well as mechanisms for funding. The conference anticipates 150 invited participants (to ensure representation by various disciplines). The International Arctic Science Committee represents a nongovernmental council of scientists and a governmental regional board made up of interested nations. The primary purpose of the Committee is to foster increased cooperation in research.

United States Arctic Research Commission

Thirty-Third Meeting
December 7–8, 1993

Commission Members Present: *Donald D. O'Dowd, Chairperson; James O. Campbell; Clifford J. Groh Sr., Charles H. Johnson; George B. Newton; Luis M. Proenza, Vice Chair; and Neal Lane, Ex-Officio Member.*

Staff: *Philip L. Johnson, Executive Director; and Lyle D. Perrigo, Head, Alaska Office.*

Commission Advisors: *Jerry Brown, Walter Bugno, William Fitzhugh, Imants Virsnieks and Oran Young.*

Visitors: *Tina Adler, Science News, Washington, DC; Tom Armbruster, Department of State, Washington, DC; Col. Archie Berberian, NY Air National Guard, 109th Airlift Group, Schenectady, NY; Fred Bernthal, Deputy Director, National Science Foundation, Arlington, VA; Noel Broadbent, National Science Foundation, Arlington, VA; Rex Brown, George Mason University, Fairfax, VA; Lou Codispoti, Office of Naval Research, Arlington, VA; Robert Corell, National Science Foundation, Arlington, VA; Kemp Conn, National Biological Survey, DOI, Washington, DC; Sam Davis, Rice University, Houston, TX; Ted DeLaca, University of Alaska, Fairbanks, AK; David Doniger, Office of Environmental Quality, The White House; George Doumani, Technical Assistance International Corp., Washington, DC; Lt. Jim Fallin, USN, Navy News, Washington, DC; Maj. Sherrie Fowlks, NY Air National Guard, 109th Airlift Group, Schenectady, NY; Dave Garman, Office of Sen. Murkowski, Washington, DC; Jeff Gossett, Arctic Submarine Laboratory, San Diego, CA; Stuart Gustafson, Alaska Oil*

The Arctic Research Commission convened its 33rd Meeting in the Conference Room of the National Science Foundation at 9:00 a.m.

Chairperson O'Dowd introduced Dr. Fred Bernthal, Deputy Director, NSF. Dr. Bernthal indicated that either the Director or Deputy Director would attend Commission meetings convened in the lower 48 states. Recent appointments in IARPC included Dr. Neal Lane as Chair, as well as a number of senior representatives in various agencies. Dr. Lane plans to visit Alaska, perhaps in August. IARPC has reestablished its Working Group on Logistics and is preparing a program initiative on Arctic contaminants. The issue of five-year budget projections has not been resolved. Dr. Lane joined the meeting in the afternoon. He welcomed the Commission to the new NSF building and commented on his initial enthusiasm for the mission and staff of NSF, although the Federal budget realities hint at difficult times ahead. He affirmed his desire to work with the Commission and to visit Alaska this summer.

Report of the Chair

Following the last meeting in Kotzebue, AK, on September 8–9, the Commission visited Red Dog Mine, and a trip report has been distributed. As a followup to actions taken in September, the Commission has written to the Congress recommending funding of a science submarine deployment and procurement of an Arctic research vessel. The Commission has also written to the appropriate committee chairmen recommending removal of barriers to collocation of Federal research units on university campuses. Noting that EPA is not continuing to co-chair the IARPC task force on Arctic contaminants and intends to eliminate its own $850,000 Arctic contaminants program, the Commission has written to the EPA Administrator requesting an explanation.

The Commission continues to be concerned with the full implementation of the provisions of the Arctic Research and Policy Act, particularly the requirement for the specified participation of OMB and OSTP. To further this process the Commission brought its concerns to the attention of Vice President Gore. The Department of Health and Human Services has responded to the Commission's request for Arctic health contacts in that agency. That agency has asked Dr. Gary Noble, Assistant Director for the Centers for Diseases Control and Prevention (Atlanta), to represent DHHS on IARPC. Dr. Jay Moskowitz of NIH will also assist IARPC coordination. The Executive Director and the Chairperson met with Dr. Moskowitz recently, and they jointly decided to organize an Arctic health seminar on February 24, 1994, in a Senate conference room.

On November 22, 1993, the Commission convened key Federal marine science leaders to discuss the future use of Navy submarines for Arctic science. After a brief review of the successful science submarine deployment this past August and September, the operating side of the U.S. Navy indicated that science planning could proceed with the assurance of submarine availability and that the costs would be less than $500,000/year (plus costs of science personnel) for about a 30-day cruise each year. As a result, ONR, NSF and NOAA will initiate planning with the research community. Leonard Johnson started this process by conducting the first planning session at the AGU meeting in San Francisco on December 6, 1993.

In early November the Chairperson attended part of the Polar Research Board meeting in Irvine, CA, and discussed current Commission activities. The Chairperson met with Dr. Neal Lane (NSF Director), Dr. Fred Bernthal and Dr. Neal Sullivan (Director, Office of Polar Programs) on November 22 and briefly reviewed the Commission's concerns. The following day Senator Murkowski held a meeting with Dr. Lane, Dr. Sullivan, Executive Director Johnson, Dave Garman (of Senator Murkowski's office) and the Chairperson. This set of meetings was the beginning of a continuing and frequent dialogue to better coordinate Arctic research.

Congressional Representatives

Senator Ted Stevens indicated dimmer prospects for an Arctic research vessel than in the last session of Congress, and he encouraged further use of submarines for civilian research. He reported discussing Arctic contaminants with A. Yablokov, environmental advisor to President Yeltsin, concerning Russian records on radioactive dumping. He prefers greater attention to Pacific areas and urged the Commission to monitor the ONR effort. He expects the radioactive waste dumping issue to be on the agenda of the January Clinton–Yeltsin

and Gas Association, Anchorage, AK; John Haugh, Bureau of Land Management, Washington, DC; C.E. Heuer, Exxon Production Research Co., Houston, TX; Leonard Johnson, Office of Naval Research, Arlington, VA; Maj. Virule Johnston, NY Air National Guard, 109th Airlift Group, Schenectady, NY; Stacey Joyce, States News Service, Washington, DC; Lt. Col. Mark Kalber, LC-130 Program Manager, The Pentagon, Washington, DC; Wesley Marquardt, U.S. Coast Guard, Washington, DC; Charles Myers, National Science Foundation, Arlington, VA; John Rosenberg, Rosenberg Associates, Alexandria, VA; Dale Perry, BSE Corp, Manchester, CT; Cpt. Bruce Scott, Arctic Submarine Laboratory, San Diego, CA; Loren Setlow, Polar Research Board, Washington, DC; Walt Spung, Mobile Research and Development Corp., Dallas, TX; Neal Sullivan, National Science Foundation, Arlington, VA; Lt. Col. Jim Toscano, NY Air National Guard, 109th Airlift Group Schenectady, NY; Capt. Alan F. Walker, U.S. Coast Guard, Washington, DC; Cdr. Brian Wegner, USS Pargo.

summit meeting. He also expressed concern for the continuing imbalance in Arctic–Antarctic programs.

Dave Garman, Senator Murkowski's office, reported that Senator Murkowski was en route from Vietnam. He reported that the Senator was concerned with EPA's plan to withdraw from Arctic research, especially with such high interest in Arctic contaminants. Senator Murkowski has offered to cohost (with the Commission) an Arctic health seminar in February for NIH officials.

Interagency Arctic Research Policy Committee

Charles Myers, NSF, reported that in addition to the changes in senior-level representatives to IARPC, up to 75 staff members across the Federal agencies were involved in various IARPC activities. He distributed copies of the IARPC draft report to Congress, which addresses responses to Commission recommendations since the last report in January 1992. This report's responses to Commission recommendations are more detailed than the 1992 version.

Mr. Myers indicated progress on a strategy for an integrated approach to assessing Arctic contaminants. He stated that the Commission resolution of August 1992 helped focus the agencies on this important issue. A multiagency program initiative is nearing completion. He reported that a total of $184 million is projected for Arctic research in FY 94, including a renewal of the $10 million for radioactive waste assessment by ONR.

Mr. Myers reported that $6.5 million in the NSF FY 94 budget request to begin procurement of an Arctic research vessel had been deleted without prejudice, and a GAO review of ship procurement practices for the academic fleet was requested by Congress.

Polar Research Board

Loren Setlow, Director, reported on the November meeting in Irvine, CA. The agenda was focused on reports of a number of Arctic meetings in Norway, Iceland and Greenland and a presentation of a SHEBA proposal (Surface Heat Budget of the Arctic Ocean), as well as a 35th anniversary celebration of the PRB. Two workshops in September and December were held by the Committee on the Bering Sea Ecosystem; a report is expected by the fall of 1994. A glaciology panel met in October to review ice coring research. Legislation by Senator Murkowski is expected to generate a study by the PRB and the National Academy of Medicine of I-131 studies on Natives in Alaska. The next PRB meeting will be in April in Washington, DC, and will have an international theme.

International Arctic Science Committee

Robert Corell, Assistant Director of Geosciences, NSF, and U.S. representative to the Regional Board, reviewed the origin and structure of the IASC and summarized the November Regional Board meeting held in Washington, DC. This meeting helped resolve ambiguities about the role of the Regional Board and its relation to the IASC Council. Three proposals were discussed:

- An international Arctic Science Conference in the U.S. in 1995;
- A Russian proposed task to create an Arctic encyclopedia; and
- Establishment of a Committee of Managers of National Arctic Science Programs (logistics managers).

Oran Young, Dartmouth College and U.S. representative to the IASC Council, reported that the next Executive Committee meeting would be in Oslo on December 20–21, and the next Council meeting would be in Greenland in the first week of May 1994. There followed a discussion of the need to better define responsibilities among Arctic organizations, which have proliferated in recent years.

Arctic Research Consortium of the United States

Oran Young, member of the ARCUS Board, reported on the status of ARCUS as an organization. Laura Lee McCauley departed on September 30, 1993, and the Board has since restructured and the staff downsized. ARCUS is seeking a president at 20% time, not necessarily to be located in Fairbanks, although the offices will remain there. A three-year cooperative agreement is under negotiation for funding at NSF. The 6th annual meeting is scheduled for the spring of 1994 in Washington as "Arctic Week." A more proactive board will seek funding from sources other than NSF and an expanded membership.

Status of Review of U.S. Arctic Policy

David Doniger, Office of Environmental Quality, Executive Office of the President, reported on behalf of the National Security Council (NSC) on the status of the Arctic policy review requested via the State Department as part of PRD/NSC 12. The Arctic review was sent to the NSC in early November. There are no current plans to release it

publicly, nor has the need to issue a new Arctic policy been resolved. Mr. Doniger indicated that some elements of Arctic policy need reaffirmation, while others may need to be refocused. National security remains an important element, but environmental concerns are also a high priority. Bilateral activities with Russia are being explored via the meetings between Vice President Gore and Prime Minister Chernomyrdin. He indicated the importance of Arctic wildlife and the Bering Sea fishery. He expects to encourage AMAP via IARPC, but budget support may be difficult to secure. In closing, he invited suggestions on Arctic policy and coordination. Clifford Groh asked if Mr. Doniger had read the ARPA law and understood the coordination specified in the law. Mr. Doniger replied that he had not but that national Arctic policy was broader than Arctic research policy. Mr. Groh stated that while he did not disagree individually with the recommendations in the report, he found it upsetting that there was substantial emphasis on preservation and none on sustainable economic development.

Luis Proenza asked if the six listed elements (environmental protection and biological diversity, international cooperation, national security, indigenous peoples, environmentally sustainable development, and scientific research) were intended as the basis for a revised policy statement? Mr. Doniger replied yes, in order to raise environmental issues to equal prominence with national security. Mr. Proenza agreed that many issues raised in the report were appropriate but that it was not a balanced set for national Arctic policy. Charles Johnson pointed out that Natives had not been involved in negotiating the polar bear agreement and should have been consulted. Dr. O'Dowd noted that the earlier drafts were more forcefully worded in support of science and that there were differences between the report and its summary.

Status and Direction of Polar Programs in NSF

Neal Sullivan, Director, Office of Polar Programs, NSF, stated that the presence of OPP in the Director's office was intended to give greater emphasis to polar research activities. He is considering a reorganization of OPP to improve the efficiency and clarity of Arctic focus. The new organization will be known by March. He also indicated an intent to revise an advisory structure for OPP to save funds and reduce redundancy. The largest Arctic program, Arctic System Science, is now directed by Patrick Webber. This program is multidisciplinary, with bridges to other NSF disciplinary units to avoid competition.

Dr. Proenza expressed concern about the balance in emphasis placed on research at the two geographic poles and the desire to use logistic technologies appropriately in both. Mr. Groh pointed out the responsibilities of the lead agency, NSF, under ARPA, particularly section 108a.

Science Submarines: Results and Plans

Jeffrey Gossett, Director of Operations, Arctic Submarine Laboratory, USN, briefly summarized the history of submarine operations in the Arctic. The science submarine deployment with the USS *Pargo* in August and September 1993 was guided by a science steering committee organized in February 1993. To assure that the data obtained were unclassified, the submarine operated above 400 feet and under 20 knots, outside exclusive economic zones in the central Arctic, and without tactical sensors. It was the fastest readying of an Arctic deployment yet experienced.

Commander Brian Wegner, USN, Commanding Officer of the USS *Pargo,* presented an illustrated debriefing of the science cruise. All objectives were completed to the satisfaction of the five scientists aboard and Navy personnel. Data obtained during the 20 days on task exceeded expectations.

Ted DeLaca, University of Alaska Fairbanks and chief scientist for the cruise, reported that 44 scientists from 17 institutions responded to an electronic advertisement and contributed to the cruise plan. The mission was not hypothesis-driven; rather it was an experiment to determine:

- The suitability of a Navy submarine for civilian science;
- The degree of Navy–civilian compatibility;
- The public release of the data; and
- The quality of the scientific data.

The first three objectives were fully satisfied, and analysis of the samples and interpretation of the data for chemical and physical parameters, ice features and geophysical measurements will determine the quality and utility of the results. Dr. DeLaca stated that the cruise was an unqualified success. It is now time to develop a multiple-year science plan for future science uses of submarines. It may be possible to develop specially tailored instruments and to coordinate data gathering with other platforms to achieve a more comprehensive research program.

George Newton commented that no parameter in the vast Arctic is sufficiently well known, so there is much to do and submarines open a new tool to proceed. He summarized a meeting convened to initiate planning for 1995–1999. So far we have overcome the bureaucratic resistance and shown that a willingness to succeed is essential.

Charles Johnson reported that the issue of a peace dividend to the cold war had arisen at an international meeting in Greenland in September 1993 and that the U.S. representative had announced that a U.S. Navy submarine was executing a civilian science mission in the Arctic at that moment. Luis Proenza moved that the Commission commend the U.S. Navy and its continued support of association with Arctic research. The motion was seconded and passed without objection.

Leonard Johnson, ONR, reported that ONR, NOAA and NSF were proceeding to initiate planning for future submarine deployments based on Adm. Ryan's assurance of availability in the period 1995–1999. A draft Memorandum of Agreement is being circulated. At the meeting on December 6 in San Francisco, as part of the meeting of the American Geophysical Union, 80 scientists attended an initial discussion. It is hoped that a multiagency announcement of opportunity can be issued as a basis for soliciting interest and writing a multiyear science plan. The Russian–USGS *Victor* project was also discussed in San Francisco.

Jim Devine, Assistant Director, USGS, prefaced a presentation on the *Victor* project by stating that it was complementary, not competitive, with the U.S. Navy submarine potential.

Dale Perry, BSE Corp., provided a handout and presentation that compared his views of the characteristics of a Russian submarine (*Victor*) proposal with his assumptions about a U.S. Navy submarine project. The *Victor* project is intended to mount a Sea Beam instrument for bathymetric mapping of the sea bottom. Following an initial trial deployment, the costs would then be $3 million per month. Loren Setlow and Alan Walker both expressed concern for funding trade-offs implied for this project.

Luis Proenza moved that the Commission adopt a Resolution of Appreciation in recognition of George Newton's guidance and dedicated service in achieving an Arctic science nuclear submarine cruise in 1993. The motion was seconded and adopted. A framed Resolution of Appreciation and the U.S. flag flown from the USS *Pargo* at the North Pole were presented to George Newton.

Trade-offs in Arctic Oil and Gas Decisions

Rex Brown, Research Professor, School of Information Technology and Engineering, George Mason University, presented an approach for assessing trade-offs among society's interests associated with public decisions to develop Arctic oil and gas. He suggested focusing on governmental permitting decisions. An analytic framework incorporating parameters of costs and benefits would then focus debate on the quantitative or qualitative values assignable for every included parameter leading to an objective basis for describing net impact. He illustrated his concept with assumed values for a hypothetical offshore oil lease sale.

Oran Young commented that the central purpose of such a framework was as a device to expose a full range of issues to public debate. Clifford Groh moved that this report be considered at the next meeting of the Commission and that industry be encouraged to comment on the report. The motion was seconded and adopted without objection.

Arctic Monitoring and Assessment

Charles Johnson reported on his attendance in Nuuk, Greenland, at the second Ministerial Conference on the Arctic Environmental Protection Strategy in September.

During international discussions of the Arctic Monitoring and Assessment Program (AMAP), concern was expressed for EPA's intent to pull out of Arctic research. The U.S. delegation moved to involve Native representatives in all working groups of the Arctic Environmental Protection Strategy and to establish a task force on sustainable development. Both motions were enthusiastically adopted. Iceland is to host a seminar in the fall of 1994 on Native knowledge. A report of the meeting and a list of participants were filed with the Commission. The 3rd Ministerial Conference will be hosted by Canada in 1995. Mr. Johnson also visited the Danish Polar Center in Copenhagen.

Charles Johnson next reported on his attendance at an international symposium on Ecological Effects of Arctic Airborne Contaminants in October in Iceland. A series of scientific papers were presented on pathways and distribution of Arctic contaminants, ecological responses and the relationship to climate change. There were only a few papers on human health issues. Abstracts, reprints and a list of participants were filed with the Commission. Chairperson O'Dowd expressed appreciation for Mr. Johnson's attendance and reports on these Arctic conferences.

Russian Nuclear Dumping and Assessment

Lou Codispodi, Program Manager, ONR, reported on the $10 million appropriated in FY 93 to assess radioactive waste dumping in the Russian marine environment. Some 10,000 samples obtained from eight cruises in the summer of 1993 are being analyzed. So far there is no evidence that

Russian radioactive wastes have moved beyond Russian territorial waters. In December a report will be sent to Congress on the results to date. An additional $10 million has been appropriated for FY 94 and will be used, in part, to obtain samples in waters of the Russian Far East and to consider contaminants discharged from Russian rivers.

IARPC Contaminants Plan

Charles Myers discussed the origin and status of IARPC's interagency program initiative Arctic Contamination Research and Assessment Program for FY 95–96. This initiative proposes an integrated multidisciplinary approach to understanding Arctic contamination and its impact on ecosystems and human health. Elements include:

- Data and information rescue, management and synthesis;
- Observations;
- Process-oriented research;
- Model development; and
- Impact analysis and determination of risk.

Such research may require 3–5 years of effort, and monitoring may be necessary for 20 years. This initiative is derived from the IARPC workshop convened in Anchorage last May and builds on the field observations supported by ONR. Seven or eight agencies may participate.

Discussion of budget implications indicated that agencies may be reluctant to budget for this initiative at the expense of current activities but that the plan was sufficiently modular to fit the funds that might be appropriated. The Commission may want to support this initiative as a response to a broadly recognized issue and as an example of interagency integration desired for the entire Arctic research program. Mr. Myers also reported that the U.S. is to host the international AMAP Task Force in the fall of 1994 and that NOAA is increasing its role in AMAP as EPA withdraws.

Status of Ski-Equipped LC-130 Fleet

Maj. Virle Johnson, Operations Officer, NY Air Guard, presented a briefing on the use of ski-equipped LC-130 planes in support of research in Greenland and Antarctica. The 109th Air Lift Group currently operates eight aircraft built in 1984, and two new planes will be delivered in 1995. In recent years these planes have operated in support of the ice core drilling program in central Greenland, as well as at the South Pole and in support of Navy exercises in the Arctic. The pilots and crew have many years of polar experience. Of 4100 annual flying hours by the unit, 600 were in the Arctic and 800 were in Antarctica. Each October there is a planning conference, with the participation of customers.

Lt. Col. Mark Kalber, Program Manager for LC-130, National Guard Bureau, expressed concern for the continued operation of this unique capability, as there is no wartime tasking at either pole. (All Air Guard units have wartime contingency tasking.) Under consideration is a proposal to unite the Air Guard fleet with the NSF fleet of seven planes operated by the Navy under a single point of management. Given the projected services at both poles, all requirements could be met with fewer planes; old planes could be retired, resulting in a more efficient operation.

Discussion revealed that in the Antarctic a DOD rate is charged per hour for flight service; the rate charged in the Arctic is about twice as high. The Commission may wish to examine the potential for a single national rate for such services.

National Biological Survey and Arctic Research

Kemp Conn, Acting Assistant Director for Inventory and Monitoring, National Biological Survey, discussed the intent and status of this new bureau in the Department of Interior. It is a science agency without regulatory or advocacy roles. Up to 1800 existing employees are being transferred within DOI to establish NBS based on an Executive Order (Sept.) and an appropriation (Nov.). Eugene Hestor, previously with the National Park Service, has been appointed Deputy Director. Recruitment is underway for a Director, four Assistant Directors and four Regional Directors. Alaska is part of the Western Region; there are 56 people and about $6 million in the state now assigned to NBS. About $181 million will be available in FY 94. It intends to create a strategic plan and to coordinate with many other Federal agencies. NBS will design a data directory and a status and trends report within a year. Criteria for targeting critical ecosystems are to be defined. An appropriate international role has not yet been resolved. He invited suggestions on critical issues for Alaskan species and ecosystems.

Discussion of Options for Reviewing Research Priorities for NSF

Philip Johnson summarized an options paper, before the Commission, prepared in response to discussion at the 32nd Meeting. NSF was asked to appoint and assemble six to ten panels to prepare recommendations on research priorities. The Com-

mission is to receive the panel reports and public presentations by the panel chairs and then to provide NSF with a report addressing the following for all panel recommendations:

- Relevance to ARC recommendations;
- Relevance to the national Arctic Research Plan;
- Appropriateness to stated NSF goals;
- Contribution and balance for advancing understanding of the Arctic; and
- Contribution to national needs.

Option 1 calls for a technical evaluation using experts to assist the scoring of recommendations within and among panels. Option 2 requires less technical verification but would rank the recommendations. Option 3 would decline to undertake the task for NSF.

Jack Talmadge, NSF, indicating that he had reviewed the options paper, stated that it captured the NSF suggestion and urged the Commission to adopt Option 1 or 2 as consistent with ARPA. Clifford Groh asked how much funding would be required for Option 1. Philip Johnson estimated that it would cost up to an additional $250,000 per year. Mr. Talmadge stated that zero additional funds were available and that the few additional days needed could be accommodated with the Commission funding. Donald O'Dowd asked what additional input beyond the panel report would be provided. Mr. Talmadge indicated none, saying that the Commission's past practices in conducting public meetings are sufficient. The process, including a report to NSF, should not exceed six months. Clifford Groh stated his concern for the amount of additional time he could devote to the Commission for such a review. Luis Proenza observed that NSF is the lead agency for Arctic research and that this task could help strengthen NSF leadership of IARPC as well as focus ARC efforts. Recognizing that it would be undertaken provisionally, Mr. Groh moved adoption of Option 2. James Campbell stated that he would vote against the motion because he felt that it would become an open-ended commitment of time and funds. Upon discussion, the motion was adopted on a vote of five in favor and one opposed.

Loren Setlow, PRB, commented that should NSF proceed with the review process proposed, he envisions no problem in working with the Commission, assuming an adequate core funding for the PRB.

Approval of Annual Report

A draft annual report of the Commission for FY 93, due January 31, 1994, was unanimously approved for completion of figures and printing.

Smithsonian Office in Alaska

William Fitzhugh, Director, Arctic Studies Program, Smithsonian Institution, announced the decision to sign an agreement on December 15, 1993, with the Anchorage Museum of History and Art to establish an office of the Arctic Studies Program in the spring of 1994. This small presence, the first for the Smithsonian in Alaska, will expand its role in Arctic research, education and cooperation with Native peoples as well as with local governmental agencies. It should also assist the repatriation of Alaskan artifacts now held in Smithsonian collections in a manner that will better assist the understanding and preservation of traditional Native cultures.

After discussion the Commission adopted a motion to send a letter of congratulations to the Smithsonian.

Interagency Coordination Mechanisms

Philip Johnson summarized an outline of various kinds of mechanisms and activities by which agencies coordinate in setting shared goals, plan and conduct research, evaluate results and transfer information to users and decision-making bodies. As the Commission is mandated to facilitate cooperation among agencies with respect to Arctic research, it would be valuable to determine specific successful examples of each type of mechanism in order to assess current and potential means of fostering a more coordinated and integrated Arctic research program. Such a staff study could be the basis of a Commission report of Findings and Recommendations. After brief discussion the Commission concurred.

Thirty-Fourth Meeting March 9-10, 1994

The Commission held its meeting at the Holiday Inn–Ballston in Arlington, VA, on March 9 and 10, 1994. Chairperson Donald O'Dowd summarized the previous meeting in December at NSF. The annual report for FY 93 has been completed and was distributed in February 1994. Following the December meeting, the Executive Director advised the Commission of his intent to retire from government service in May. Accordingly the Members have conferred by phone and have posted a vacancy announcement for a Senior Executive Service position, which closed on March 16, 1994. In Executive Session the Members met to prepare for the selection process in accord with procedures

Commission Members present: *Donald D. O'Dowd, Chairperson; James O. Campbell; Ben C. Gerwick Jr.; Clifford J. Groh Sr.; Charles H. Johnson; George B. Newton; Luis M. Proenza, Vice Chair; and Neal Lane, Ex-Officio Member.*

Staff: *Philip L. Johnson, Executive Director; and Lyle D. Perrigo, Head, Alaska Office.*

Commission Advisors: *Jerry Brown, William Fitzhugh and Imants Virsnieks.*

Visitors: *Tom Armbruster, Department of State, Washington, DC; Ray Arnaudo, Department of State, Washington, DC; Sherre Abbott, National Research Council, Washington, DC; Dinah Bear, Washington, DC; Noel Broadbent, National Science Foundation, Arlington, VA; Linda Brubaker, Univ. of Washington, Seattle, WA; Michael Champ, Texas A&M, College Station, TX; Thomas Curtin, Office of Naval Research, Arlington, VA; James Devine, Dept. of the Interior, USGS, Reston, VA; John Diamante, Environmental Protection Agency, Washington, DC; Bob Dyer, Environmental Protection Agency, Washington, DC; Robert Edison, Office of Naval Research, Arlington, VA; Dave Garman, Office of Senator Murkowski, Washington, DC; Ozzie Girard, Department of the Interior, USGS, Washington, DC; Larry Inouye, North Slope Borough, AK; Judy Rogers Johnson, Arlington, VA; Leonard Johnson, Office of Naval Research, Arlington, VA; Stacey Joyce, States News Service, Washington, DC; Tom Laughlin, National Oceanic and Atmospheric Administration, Washington, DC; Peter Lunn, Department of Energy, Germantown, MD; David McDougal, National Aeronautics and Space Agency, Hampton, VA; Paul Mayewski, University of New Hampshire, Durham, NH; Bruce Molnia, Department of the Interior, USGS, Reston, VA; Richard Moritz, University of*

of the Federal Civil Service. It is the Commission's expectation that a successful candidate will be identified and announced in early May.

On February 24 the Commission and Senator Murkowski cosponsored an Arctic Health Seminar for Federal health research program officials, primarily from the National Institutes of Health. The Executive Director and Jay Moskowitz, the NIH contact for the IARPC, helped organize the seminar presentations by a team of five Alaskans. The speakers, introduced by Luis Proenza, were: Senator Frank Murkowski; Julie Kitka, President, Alaska Federation of Natives; George Conway, Chief, Alaska Activity, NIOSH; Sven Ebbesson, President, Circumpolar Health Association and leader of the Alaska–Siberian Medical Research Program at the University of Alaska; Robert White, Institute of Arctic Biology, University of Alaska Fairbanks; and Dean Lee Gorsuch, School of Public Affairs, University of Alaska Anchorage. Senator Stevens offered a few remarks at the end of the afternoon. The seminar was convened in the Hart Senate Office Building, with a participation of about 30, which included representatives from 12 institutes and several other agencies.

In the process of organizing the Arctic Health Seminar, the Commission learned that the Alaska Activity, NIOSH, CDC, is scheduled for transfer and elimination within a year. This unit of six people and a budget of $520,000 was established in Anchorage, AK, in 1991 to study the high rates of occupational injury in Alaska and to recommend interventions. The Commission played a role in encouraging its establishment, and it has done, by all accounts, an excellent job so far.

Regarding the Commission's concern for the EPA's possible withdrawal from Arctic research, we now understand that a new representative to IARPC, Sidney Draggan, has been designated and that a reduced and refocused program of perhaps $250,000 per year is under consideration. The Commission continues to suggest that a larger effort by EPA is needed to support President Clinton's draft Presidential Decision Directive on Arctic policy.

Progress is underway to realize the continued availability of U.S. Navy submarines for civilian science. A second scientific conference (in addition to American Geophysical Union in December), held by the American Society for Limnology and Oceanography, was briefed in February and again evoked expressions of interest from the attending scientists. A Memorandum of Agreement has been drafted and is under review within a number of Federal agencies as a basis for developing and implementing a multiyear science plan using Navy submarines.

During the period February 14–18, the Chairperson visited a number of science and business leaders in Anchorage and Fairbanks, Alaska. It will be valuable for the Commission to track the impact on Arctic research of a number of separate and uncoordinated decisions to reduce the size of Federal agencies in Alaska.

Congressional Representatives

Dave Garman, Senator Murkowski's Office, reported that Senate Bill S-1758, which had been introduced and referred to committee, would facilitate the creation of a marine research endowment using funds from the Exxon Valdez Trust Fund. The bill does not designate an amount of funding but has left that decision to the Trustees.

Alaska Governor's Office

Mead Treadwell, Deputy Commissioner, Alaska Department of Environmental Conservation, provided a letter report that stated that Alaska continues to be concerned about potential radioactive contaminants from Russia. Therefore, Governor Hickel supports a ban on ocean dumping, and he has established working relationships with Russian officials. Discussions of long-term monitoring for airborne radiation material are underway with several Federal agencies. On June 29, 1994, in Anchorage, AK, a "tabletop" drill on responses to a peacetime nuclear incident by eight nations will occur.

With respect to Exxon Valdez/Oil Spill Research, the Exxon Valdez Trustees are allocating additional funds for ecological research, somewhat in response to the endowment proposals that have been made so far. Expansion of support for the Seward marine research facilities is a major initiative for research being addressed by the Exxon Valdez civil trustees. The trustees have recognized the need for a coordinated ecological model of Prince William Sound and the entire spill area. Meanwhile, the Oil Spill Recovery Institute, based in Cordova, is completing a draft of an Arctic/Subarctic Oil Spill Research Plan.

The State of Alaska supports the establishment of a Sustainable Development Working Group and anticipates terms of reference being prepared by Canada. Agreement was reached in the Second Conference of Environmental Ministers in Nuuk, Greenland, last September to establish such a group.

Interagency Arctic Research Policy Committee

Charles Myers, NSF, reported that the Fifth Biennial Report of IARPC was approved and sent

Washington, Seattle, WA; Charles Myers, National Science Foundation, Arlington, VA; Walter C. Oechel, San Diego State University, San Diego, CA; David Randall, Colorado State University, Fort Collins, CO; Jack Talmadge, National Science Foundation, Arlington, VA; Victor B. Serveiss, Environmental Protection Agency, Washington, DC; Loren Setlow, Polar Research Board, Washington, DC; Neal Sullivan, National Science Foundation, Arlington, VA; Larry Schultz, Columbia, MD; Alan F. Walker, U.S. Coast Guard, Washington, DC; Robert Watson, Office of Science and Technology Policy, Washington, DC; Patrick Webber, National Science Foundation, Arlington, VA; Bernard D. Zak, Sandia National Labs, Albuquerque, NM.

to Congress in early March. Donald O'Dowd indicated that this current report, whose Appendix reports on IARPC responses to recommendations of the Commission, is much better than earlier reports. Mr. Myers responded that about 75 people in 12 agencies contributed to IARPC activities and deserved credit for this report.

Mr. Myers indicated that the IARPC initiative on Arctic Contaminants Research and Assessment proposes up to $33 million of additional funding beginning in FY 96 and is, in part, a response to the Commission's recommendation adopted in August 1992. It is intended to build on the effort funded via ONR in FY 93 and again in FY 94. Donald O'Dowd stated that the Commission intended to endorse this IARPC initiative when the proposal is completed.

The proceedings of the Workshop on Arctic Contamination convened in Anchorage, AK, in May 1993 (314 p.) is at the printer and will be distributed as the spring issue of the journal *Arctic Research of the United States.*

Neal Lane, Director of NSF and Chair of IARPC, summarized the role and purpose of the National Science and Technology Council (NSTC) established by President Clinton. The Council, chaired by the President and including all science agencies, will be assisted by nine committees. Mr. Lane will co-chair with H. Varmus, Director of NIH, the Fundamental R&D Committee. Collectively the NSTC intends to coordinate the Federal investment of about $73 billion per year in research, of which about $15 billion is in basic research. The first objective is to provide general guidelines by April for formation of the FY 96 budget.

Because discretionary Federal spending is essentially level for the next five years, budgeting is now a zero sum game. Whereas the previous administrations were able to focus on only a limited set of new initiatives for new funds, NSTC is undertaking a serious priority-setting mission across all research. Committees of NSTC will consider a wide array of issues besides budgets, including intellectual property rights, indirect costs and linkages to policy.

Status of NSF Polar Programs Organization

Neal Sullivan, Director, Office of Polar Programs, stated that he was deeply interested in the Arctic and shared with the Commission a mutual interest in improving research in both polar regions. The new NSF Director, Neal Lane, has set forth an ambitious strategic planning process, and OPP is represented on the planning work group by Pat Webber. The focus of this agency-wide effort is to evaluate operations and management and define strategic program foci. A report to the June meeting of the National Science Board is planned.

The Office of Polar Programs is planning a reorganization, but it must be coordinated with NSF's strategic plan. The mission of OPP is to support world-class science on the polar regions. Dr. Sullivan recognized the need for more cohesion and visibility for Arctic research, and he wishes to reduce the perceived competition between Arctic and Antarctic efforts by emphasizing bipolar research.

Arctic System Science Program

Patrick Webber, OPP, NSF, Program Director for the Arctic System Science Program (ARCSS), stated that this program is an interagency partnership based on OPP funding of about $12.5 million and a similar amount from others but with collaboration with NASA and DOE as well as coordination with international investigators. The NSF program was developed with assistance from the Arctic Research Consortium of the U.S., and the priorities arose from the science community. ARCSS is part of the U.S. global change research program. The research to be implemented parallels four areas recommended by the Commission. The broad goals are to improve the prediction of consequences of climate change in the Arctic and to provide the scientific basis for policy formulation and management.

The present components are two programs studying past environments: the Greenland Ice Sheet Project (GISP) and the Paleoclimates of Arctic Lakes and Estuaries (PALE). Another two programs are studying the contemporary environment: Ocean/Atmosphere/Ice Interactions (OAII) and Land/Atmosphere/Ice Interactions (LAII). In the future, additional efforts on the social and human responses to climate change and on integration among components are planned.

Paul Mayewski, University of New Hampshire, summarized seven years of progress with 20 participating institutions to recover and evaluate an ice core through the Greenland Ice Cap. Known as the Greenland Ice Sheet Project, GISP views the ice core essentially as a "time machine." Forty-five parameters of gases, particulates, frozen solutions and electrical properties are measured. Thus, a high-resolution, verifiable climate record with annual markers extending back 105,000 years is emerging. The record shows a rise of 7–10°C in temperature over the past 20,000 years. It reveals temperature oscillations over just a few years, probably due to changes in atmospheric circulation.

This ice core record is likely to become the standard for comparing past climates from all over the world.

Linda Brubaker, University of Washington, reported on the status of PALE, a program component of ARCSS examining paleoenvironments in sediments. This set of NSF projects is focused primarily on three past periods: 2,000 years, 20,000 years and 150,000 years before present. Such information about past depositional and environmental histories will help determine climate controls on ice sheets and Arctic feedback affecting global climates. Modeling techniques will be used to interpret Arctic linkages to general atmospheric circulation models. Data analyzed so far indicate great temporal and spatial climate variability across the Arctic over the past 20,000 years.

Richard Moritz, APL, University of Washington, reported on progress in the OAII component toward understanding processes and predicting responses to climate change at the air–ice–ocean boundary. The marine environment of the Arctic is an interactive system. While enough is known to assert that the Arctic plays a large role in shaping global climate, important first-order features of the Arctic marine environment have still not been described adequately. Through a series of workshops and a Science Steering Committee, five priorities were defined:

- Surface energy budget, atmospheric radiation and clouds;
- Circulation of the Arctic Ocean;
- Hydrological cycle of the Arctic Ocean;
- Productivity and biogeochemical cycling; and
- Coupled air–sea ice modeling.

Data analyses so far suggest that 70% of the interannual variability in ice cover can be explained by atmospheric circulation of high and low pressure.

Walter Oechel, San Diego State University, reported on the LAII component of ARCSS. Significant research areas for Land/Atmosphere/Ice Interactions (LAII) identified by researchers for initial emphasis include Arctic feedback processes that may amplify global climate change, changes in Arctic hydrological and biogeochemical systems, changes in biotic communities, and the regional and global effects of all these changes.

Dr. Oechel emphasized the role of carbon flux in tundra and bog ecosystems. Recent data from several circumarctic locations suggest that these organic terrains are now net sources of carbon to the atmosphere rather than net storage systems. If permafrost melts and the albedo of tundra surfaces changes, the loss of carbon dioxide and methane to the atmosphere will accelerate.

Richard Moritz discussed a major program proposal, Surface Heat Budget of the Arctic Ocean, or SHEBA. The scientific plan anticipates occupying a drifting Arctic ice island for a year-long field experiment to record careful observations that would permit analyses of the ocean circulation, sea ice, snow, cloud and radiation budget. A 14-member Science Steering Committee exists to guide implementation of the research design. The results would greatly assist validation of global climate change simulations for the Arctic.

Peter Lunn, Department of Energy, indicated that his agency had changed their scheduled deployment of the Alaska Atmosphere Radiation Measurements (ARM) instrumentation array in order to collaborate with SHEBA. He then introduced Bernie Zak, Sandia Laboratory, NM, manager for the Cloud and Radiation Testbed site planned near Barrow, AK. This atmospheric radiation project is designed to study over a 10-year period the radiation transfer through the atmosphere and clouds as an observational basis for improving general atmosphere circulation models.

The Arctic atmosphere differs from other latitudes by retaining less moisture in the air column, by having a very cold surface and by having a high albedo of snow for much of the year. Data will be obtained over sea ice for a year in collaboration with SHEBA and over tundra in collaboration with the NOM station at Barrow, as well as at Atkasook, an inland site.

David McDougal, NASA program manager, introduced David Randall, Colorado State University, who reported on an Arctic component of First ISCCP Regional Experiments (FIRE). ISCCP is an abbreviation for International Satellite Cloud Climatology Project. NASA is the lead agency, but several Federal agencies participate, as well as a number of other nations. An eight- to ten-week campaign is planned in April–June 1997 using satellites, aircraft and modeling techniques to study Arctic stratus and marine cirrus clouds. A plan has been prepared, and the work will collaborate with SHEBA and ARM investigators.

International Activities

Ray Arnaudo, Chief, Arctic Affairs, Department of State, summarized a calendar of meetings scheduled by working groups of the Environmental Protection Strategy. He invited Commission representatives to attend as part of the U.S. delegations. The U.S. position regarding a Canadian proposal for an "Arctic Council" favors combining it in some appropriate way with the Arctic Environmental Protection Strategy. Such a merger would more efficiently focus limited resources for Arctic activities.

The meetings between Vice President Gore

and Prime Minister Chernomydin are scheduled to convene again this spring in Washington, DC. There is an environment subcommittee, chaired by the Administrator of EPA, that may consider a U.S.–Russia bilateral agreement regarding Arctic contaminants, but radioactive wastes are thought to be best considered in a multinational context.

Ray Arnaudo reported that his office had $5 million to support research proposals and encourages submission of requests. Mr. Arnaudo indicated that a Presidential Decision Directive was pending but that he did not know when it might be signed.

James Campbell asked about the status of the Bering Sea Study, and Loren Setlow, Polar Research Board, responded that two workshops had been held and that the Committee was starting to draft its report. A fall release by the National Academy of Sciences is anticipated.

Bruce Molnia, USGS, discussed plans for an International Environmental Data Directory based on the U.S. Environmental Data Directory initiated by IARPC via USGS in 1988, which now includes 400 U.S. data sets. A Steering Committee met in San Francisco in December 1993 to outline an action plan for 1994. All Arctic countries are urged to participate, and the Russian Ministry of Environment Protection has pledged to do so.

National Science and Technology Council

Robert Watson, Associate Director, Office of Science and Technology Policy, reviewed the President's Executive Order establishing a National Science and Technology Council and nine committees on research for:

- Health, safety and food;
- Information and communication;
- National security;
- Civilian industrial technology;
- Fundamental science;
- International science, engineering and technology;
- Environment and natural resources;
- Transportation; and
- Education and training.

The intent is to develop a mechanism to coordinate and manage all Federal research, about $73 billion per year, and to set priorities consistent with the President's policies. The committees are to develop a vision for research, define appropriate policy questions, and develop the facts needed to set strategies and priorities.

The Committee on Environment and Natural Resources has seven program subcommittees and three cross-program subcommittees. A forum is organized for March 28–30, 1994, sponsored by OSTP at the National Academy of Sciences, to review and recommend a set of strategies for each subcommittee. Robert Watson invited the Commission to send two participants to this forum. In April, OSTP expects to issue initial guidance to agencies on research to be included in the FY 96 budget. During the summer the subcommittee strategies and recommendations will be refined and integrated as well as iterated with agencies as they evolve their budget justifications. Mr. Watson invited the Commission to review and comment on the Arctic aspects of the strategy statements during the summer. He emphasized the need to overcome two criticisms of Federal research: that some projects are too short term and that some projects are too "blue sky" to be policy relevant. He stated that Federal research should be policy relevant, not policy driven.

Luis Proenza observed that the Commission represents a good model for NSTC because it had struggled for a number of years with many of the same issues of priorities, interagency coordination and private sector relations now before NSTC committees.

The Commission discussed the draft Presidential Decision Directive on Arctic and Antarctic Policy and decided to prepare comments for the National Security Council and OSTP.

Initial Analyses of Contaminants in the Kara Sea Region

Michael Champ, Senior Scientist, Geochemical and Environmental Research Group, Texas A&M University, discussed data obtained in the Kara Sea and the Ob and Yenisey Rivers, Russia, in 1993 and the measurements of radionuclide and pesticide concentrations. Concentrates of these contaminants were considered high, especially in the Yenisey River sediments. Estimates of the total amounts of toxicants in river and estuarine sediments that might be flushed into the World Ocean is very substantial but needs verification.

Dr. Champ then discussed a strategy for assessing environmental and human health risks in the Arctic. He and his coauthors conclude that:

- The degree and magnitude of environmental contamination and subsequent environmental and human health risks are unknown;
- Funding and leadership for U.S. Arctic research is distributed across many Federal agencies with diverse missions; and
- The U.S. needs a cost-effective and integrated Arctic environmental and public health assessment strategy.

He described elements of such a national strategy.

Progress Report on Interagency Coordination Mechanisms

Philip Johnson, Executive Director of the Commission, reported on initial insights from a task to assess interagency coordination and Arctic program integration. One of the major premises underlying the Arctic Research and Policy Act of 1984 is that better coordination and integration among the 12 Federal agencies that support Arctic research are needed and achievable. In an era of budget restraint, even contraction, it follows that greater effectiveness and return on research funds should be a shared aspiration among Federal Arctic programs. National research plans and program statements frequently call for "coordination" but do not describe specific mechanisms to foster and achieve the benefits suggested or implied. Often, however, protection of the status quo and agency traditional turf may prevail in practice.

Staff have requested responses from its Group of Advisors to help identify and critique successful examples of multiagency coordination. Those responding could name only a few, mostly different, examples. Staff have begun to interview Federal program officials in Alaska and in Washington. It appears that Federal program managers will identify many examples of interagency collaboration.

Such apparent dichotomy of views leads to some initial generalizations to be confirmed by further assessment:

- Agencies do more top-down coordinating than is generally recognized in the science community but usually seem to achieve only limited integration in the implementation phase.
- A designated lead agency with adequate funding may be a key element.
- Clear specification of project goals and objectives is essential for multiagency cooperation.
- A dedicated project office or similar means to fix responsibility for integration is important, either in an agency or by contract.
- Leadership within agencies to encourage and reward interagency cooperation would help.
- Scientists seem to be conscious primarily of the bottom-up integration realized in their personal experience.
- Large or expensive technology can be a forcing function for integration, for example, Arctic ships or sophisticated instrument arrays.

Discussion of these points revealed that coordination was relatively easy but that integration of research programs among agencies was difficult. Transfer of funds among agencies was also procedurally slow and difficult.

Consideration of a Resolution in Support of Arctic Occupational Injury Research

The Commission discussed the planned elimination within a year of the Alaska Activity of the National Institute of Occupational Safety and Health (NIOSH) in Anchorage. This research unit of six people and a budget of about $520,000 per year was established in 1991 with urging by the Commission. It is performing very well. A resolution was reviewed, moved and adopted.

Status of Coast Guard Initiatives

Alan Walker, Chief, Ice Operations, USCG, introduced and distributed remarks by RADM William Ecker, USCG. In December 1991, RADM Ecker announced a number of initiatives at the Commission meeting held in Monterey, CA, to improve icebreaker services for the polar research community. Substantial progress has been achieved, as evidenced by praise by user scientists aboard science deployments in 1992 and 1993. These improvements include:

- An icebreaker user council;
- A USCG internal working group to review operations;
- A new science liaison position to facilitate science planning and coordination;
- An exchange program with Canada to increase navigation experience on the ice for senior officers;
- Completion of $17 million worth of science upgrades on both icebreakers;
- Improvements in ship engine controls; and
- Installation of standard oceanographic gear and support equipment, including better inflatable small boats.

One of the more effective upgrades is the installation of Terascan satellite receivers for indirect access to sea ice imagery and weather information. A new, third icebreaker is under construction for delivery in September 1997; it will be 420 ft long and is designed to break 4 ft of sea ice at 3 knots. It will accommodate 35 scientists.

Rasmuson Fisheries Research Center

James Campbell reported that Elmer Rasmuson of Anchorage, a former Member of the Commission, had given $1 million to the University of Alaska Fairbanks to establish the Rasmuson Fisheries Research Center. Donald O'Dowd indicated that he would serve on the initial advisory committee, the first meeting of which is scheduled on March 24, 1994.

Selected Meetings of Interest

Listed here is a compilation of recent and forthcoming meetings, workshops and conferences on Arctic or northern topics and activities. Readers are invited to submit information on upcoming meetings, as well as reports on national or international meetings attended, to Editor, Arctic Research, *Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230.*

1994

International Conference on the Arctic and North Pacific: Bridges of Science Between North America and the Russian Far East
25 August–2 September 1994, Anchorage, Alaska, and Vladivostok, Russia
Contact: Dr. Gunter Weller, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775-0800
Fax: (907) 474-7290
E-mail: gunter@dino.gi.alaska.edu

10th International Symposium and Workshop Northern Research Basins
28 August–3 September 1994, Svalbard, Norway
Contact: Knut Sand, SINTEF, Norwegian Hydrotechnical Laboratory, N-7034, Trondheim, Norway
Phone: 47 7 592300
Fax: 47 7 592376

Symposium on Periglacial Slope Processes and Deposits, Past and Present
4–9 September 1994, France
Contact: Jean-Pierre Lautridou, Centre de Géomorphologie du CNRS, 24 rue des Tilleuls, 14000 Caen, France
Phone: 31 45 5718
Fax: 31 45 5757
E-mail: lautridou@geomorpho.unicaen.fr

International Conference on Arctic Margins
5–9 September 1994, Magadan, Russia
Contact: Kirill V. Simakov, North East Scientific Centre, 16 Portovaya Street, Magadan, 685000 Russia, or Dennis K. Thurston, U.S. Minerals Management Service, 949 E. 36th Avenue, Rm 605, Anchorage, Alaska 99508-4302
Phone: (907) 474-7219 (Kirill Simakov, U.S.)
(7-41) 3 223-0953 (Kirill Simakov, Russia)
(907) 271-6545 (Dennis Thurston)
Fax: (907) 271-6565
E-mail: ahdt1@acad2.alaska.edu

Symposium and Workshop on Time Domain Reflectometry
8–9 September 1994, Evanston, Illinois
Contact: Charles Dowding, Department of Civil Engineering, Northwestern University, Evanston, Illinois 60708
Phone: (708) 491-4338
Fax: (708) 491-4011

INQUA/GLOCOPH International Meeting
10–17 September 1994, Southampton, U.K.
Contact: J. Branson, GeoData Institute, University of Southampton, Southampton S09 5NH, United Kingdom

ATE '94—Arctic Town and Environment
11–16 September 1994, Vorkuta, Russia
Contact: A. Tashaev, Institute of Biology, Konii Scientific Centre, 167610 Syktyvkar, Russia
Phone: 7 821 22 25213
Fax: 7 821 22 20163

Arctic Opportunities Conference
12–15 September 1994, Rovaniemi, Finland
Contact: Mrs. Raija Kivilahti, Conference Secretary, P.O. Box 122, 96101 Rovaniemi, Finland
Phone: +358 60 324 778
Fax: +358 60 324 760
E-mail: rkivilah@levi.urova.fi

European Conference on Grand Challenges in Ocean and Polar Science
12–16 September 1994, Bremen, Germany
Contact: ECOPS Conference, Alfred Wegener Institute, P.O. Box 120 161, D-27515 Bremerhaven, Germany

100th Anniversary Symposium of the Commission Internationale des Glaciers: Glacier Mass Balances: Measurements and Reconstructions
14–16 September 1994, Innsbruck, Austria
Contact: M. Kuhn, Institute of Meteorology and Geophysics, University of Innsbruck, Innrain 52, A-6020 Innsbruck, Austria

Making Marine Mammal Management Work: Sustainability and Social Equity in the Coastal Zone
20–23 September 1994, Halifax, Nova Scotia, Canada
Contact: Oran Young, Institute of Arctic Studies, Dartmouth College, Hanover, New Hampshire 03755
Fax: (603) 646-1279 or
Milton Freeman, Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta T6G 2E2, Canada
Fax: (403) 492-5273

Snowsymp '94, International Symposium on Snow and Related Manifestations
26–28 September, Manali, India
Contact: Lt. Col. S.G. Nair, HQ Snow and Avalanche Study Establishment, Manali, Distt Kullu (HP), India

7th International Symposium on Ground Freezing
24–28 October 1994, Nancy, France
Contact: ISGF '94, LCPC, CNRS/UMR 1113, Cité Descartes, 2 allée Képler, 77420 Champs sur Marme, France
Phone: 33 1 40 43 54 40
Fax: 33 1 43 54 50

International Snow Science Workshop
30 October–3 November 1994, Snowbird, Utah
Contact: L. Fitzgerald, ISSW '94, P.O. Box 49, Snowbird, Utah 84092

3rd International Symposium on Glacier Caves and Cryokarst in Polar and High Mountain Regions
1–6 November 1994, Chamonix, France
Contact: M. Griselin, GDR Recherches Arctiques, 70150 Bonboillon, France

Conference on Dynamics of the Arctic Climate System
7–10 November 1994, Gøteborg, Sweden
Contact: Prof. Peter Lemke, Alfred Wegener Institute for Polar and Marine Research, P.O. Box 120161, D-27515 Bremerhaven, Germany
Phone: +49 471 4831 512
Fax: +49 471 4831 425

Symposium of Permafrost-Affected Soils
Soil Science Society of America Annual Meeting
13–18 November 1994, Seattle, Washington
Contact: J.G. Bockheim, Department of Soil Science, University of Wisconsin, Madison, Wisconsin 53706-1299
Phone: (608) 263-5403
Fax: (608) 265-2595

Fourth International Student Conference on Northern Studies (held in conjunction with the Association of Canadian Universities for Northern Studies 1994 Conference "Northern Science: Aboriginal and Non-Native Concerns")
26–28 November 1994, Ottawa, Ontario, Canada
Contact: 130 Albert Street, Suite 201, Ottawa, Ontario, K1P 5G4, Canada

XVII Symposium on Polar Biology—Sea Ice Ecology
7–9 December 1994, Tokyo, Japan
Contact: Secretariat XVII Symposium on Polar Biology, National Institute of Polar Research 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173, Japan
Phone: +813 3962 4711
Fax: +813 3962 5743
E-mail: fukuchi@nipr.ac.jp

International Conference on Northern Wilderness Areas: "Ecology, Sustainability, Values"
7–9 December 1994, Rovaniemi, Finland
Contact: Arctic Centre–Vilhontalo, University of Lapland, P.O. Box 122, FIN 96101, Rovaniemi, Finland
Phone: +358 60 324 758 or 778
Fax: +358 60 324 777
E-mail: asippola@roisrv.urova.fi

1995

Northern Parallels—4th Circumpolar Universities Cooperation Conference
23–25 February 1995, University of Northern British Columbia, Prince George, B.C., Canada
Contact: The Office of International Programmes, University of Northern British Columbia, P.O. Box 1950, Prince George, British Columbia V2L 5P2, Canada
Phone: (604) 960-5702
Fax: (604) 960-5793
E-mail: sheena@unbc.edu

5th Annual Common Property Conference: "Reinventing the Commons"
24–28 May 1995, Bodo, Norway
Contact: Associate Professor Audun Sandberg, Hogskolesenteret i Nordland, 8002 Bodo, Norway
Phone: 47 081 17310
Fax: 47 081 17369
E-mail: audun.sandberg@isv.hsn.no

2nd International Congress of Arctic Social Sciences (ICASS II): "Unity and Diversity in Arctic Societies"
28 May–4 June 1995, Rovaniemi, Finland and Kautokeino, Norway
Contact: IASSA Secretariat, Arctic Centre, University of Lapland, P.O. Box 122, FIN-96101 Rovaniemi, Finland
Phone: +358 60 324 759
Fax: +358 60 324 777
E-mail: mpretes@roisrv.urova.fi

ISOPE-95: 5th International Offshore and Polar Engineering Conference
11–16 June 1995, The Hague, The Netherlands
Contact: Technical Program Committee, Attn: Prof. Jin S. Chung, ISOPE, P.O. Box 1107, Golden, Colorado 80402-1107
Phone: (303) 273-3673
Fax: (303) 420-3760

Symposium on Biochemistry of Seasonally Snow-Covered Catchments (ICSI/ICWQ/ICT)
3–14 July 1995
Contact: K. Tonnessen, U.S. National Park Service, Air Quality Division, P.O. Box 25287, Denver, Colorado 80225-0287

IGS International Symposium on Glacial Erosion and Sedimentation
20–25 August 1995, Reykjavik, Iceland
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, U.K.
Phone: 0223 355974
Fax: 0223 336543

EISMINT International Symposium on Ice-Sheet Modeling
18–22 September 1995, Strasbourg, France
Contact: C.S.M. Doake, EISMINT, British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, U.K. or
P. Pirra, EISMINT, European Science Foundation, 1 quai Lezay Marnésia, F-67080 Strasbourg Cedex, France

International Conference for Arctic Research Planning
5–9 December 1995, Hanover, New Hampshire
Contact: Oran R. Young, Director, Institute of Arctic Studies, 6193 Murdough Center, Dartmouth College, Hanover, New Hampshire 03755
Fax: (603) 646-1279
E-mail: oran.r.young@dartmouth.edu

Monitoring of Permafrost and Frozen Soils: Implications for Studies of Periglacial Processes Under a Changing Climate (proposed)
American Geophysical Union Fall Meeting
11–15 December 1995, San Francisco, California
Contact: Bernard Hallet, Quaternary Research Center, AK-60, University of Washington, Seattle, Washington 98195
Phone: (206) 685-2409
Fax: (206) 543-3836
E-mail: hallet@u.washington.edu

1996

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

8th International Cold Regions Engineering Conference
1 August 1996, Fairbanks, Alaska

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
Phone: 86 1 8327772
Fax: 86 1 8328928

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

1997

IV International Geomorphology Conference
28 August–3 September 1997, Bologna, Italy
Contact: M. Panizza, Universita Degli Studi di Moden, 59-41100 Moden, Italy
Phone: 059 23 0394
Fax: 059 21 8326

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
Phone: (613) 992-7813
Fax: (613) 992-2468
E-mail: heginbottom@gsc.emr.ca

Revision of U.S. Arctic Research Plan

Readers of Arctic Research of the United States are invited to comment on the U.S. Arctic Research Plan and suggest improvements. The Third Biennial Revision of the Plan was published in this journal (Volume 7, Spring 1993).

The first U.S. Arctic Research Plan was published in 1987. In accordance with Section 109 of the Arctic Research and Policy Act, the next biennial revision of the Plan is to be prepared by July 1995, in consultation with the Arctic Research Commission, the Governor of Alaska, the residents of the Arctic, the private sector and public interest groups.

Please send your comments to Charles E. Myers, Head, Arctic Staff, Interagency Arctic Research Policy Committee, Office of Polar Programs, National Science Foundation, Arlington, VA 22230.

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Back Cover

The drill dome at the Greeland Ice Sheet Project Two (GISP2) site at Summit, Greenland. A 3053-m ice core was drilled, reaching bedrock in 1993. A 1.5-m core was also collected from the bedrock underlying the ice sheet. The purpose of the project is to obtain a paleoclimatic history of the northern hemisphere. Research support was provided by the National Science Foundation.

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