


VOLUME 2

FALL 1988

# ARCTIC RESEARCH

OF THE UNITED STATES



INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

## About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee and in cooperation with 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.
- 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 non-technical audience. Al-

though 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 *United States 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." However, areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

The next two issues of the journal will report on Arctic topics and activities. Included will be additional 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. Contact the editor prior to submission for scheduling and additional information.

## Front Cover

*The U.S. Coast Guard icebreaker Northwind (foreground) escorting the R/V Polarbjorn during the deployment of the CEAREX program (see p. 44). The escort was completed at 82°43' north, the northernmost escort by a U.S. icebreaker. This was the final mission for Northwind, which is being decommissioned in January 1989 after 43 years of service. Northwind's list of accomplishments includes many "firsts." She assisted in the establishment of the facility at Thule, Greenland. By completing the first passage of McClure Strait from the Beaufort Sea to Melville Sound, she became the first ship to circumnavigate Banks Island. She was the first ship to survey the East Siberian, Kara and East Barents seas, and she made the westernmost penetration of the Laptev Sea by a U.S. ship. During the escort of the SS Manhattan through the Northwest Passage, she became the first ship to navigate the passage in both directions during the same season. At the other end of the world, Northwind assisted in the establishment of Little America on the Ross Ice Shelf, at the same time pioneering the use of helicopters for ice reconnaissance.*

# ARCTIC RESEARCH

OF THE UNITED STATES

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1987 and 1988 in Review	2
Department of Interior	
<i>Minerals Management Service</i>	5
<i>Geological Survey</i>	9
<i>Fish and Wildlife Service</i>	15
<i>Bureau of Land Management</i>	21
<i>National Park Service</i>	24
<i>Bureau of Mines</i>	27
National Science Foundation	29
Department of Defense	40
Department of Commerce	51
National Aeronautics and Space Administration	60
Department of Energy	67
Department of Health and Human Services	70
Smithsonian Institution	74
Department of Transportation	78
Environmental Protection Agency	80
Department of State	82
Department of Agriculture	84
News in Brief	
<i>Voyage of the Akademik Korolev</i>	89
<i>Fifth International Conference on Permafrost</i>	90
<i>Arctic Research Consortium</i>	92
<i>Alaska Science and Technology Foundation</i>	92
<i>Arctic Environmental Data System</i>	93
<i>Twelfth Northern Libraries Colloquy</i>	94
<i>International Conference on Technology</i>	95
<i>Symposium on Snow and Glacier Research</i>	95
Reports of Meetings	97
Forthcoming Meetings	101
Contributors and IARPC Staff Representatives	102
Illustration Credits	

# 1987 and 1988 in Review

*Prepared by Jerry Brown,  
Arctic Research of the  
United States editor and  
Head, Arctic Staff, Na-  
tional Science Foundation.*

The first issue of this journal, published one year ago, presented reports from U.S. Government agencies for FY 86. This issue brings us up to date on current Federal programs and covers FY 87 and 88. The year 1988 may well prove to be the turning point for the U.S. in the development of its role as an Arctic research nation. The following highlights U.S. interagency and other major Arctic accomplishments.

The Interagency Arctic Research Policy Committee met on May 2, 1988, and instructed the staff to develop the draft biennial revision to the Arctic Research Plan in time for the final submission to the President in July 1989. The Committee urged that the revisions demonstrate several areas of coordinated programs.

The Arctic Research Commission issued its annual report in January 1988 entitled *Entering the Age of the Arctic*, followed by a special report on logistics. Logistics needs in decreasing order of priority are: an ice-capable research vessel, land-based support, upgrade of the U.S. rocket range, and Federal coordination.

An IARPC-sponsored data workshop resulted in a commitment to develop an Arctic Environmental Data Directory (see p. 93).

An IARPC working group on logistics chaired by Rear Admiral Moran, NOAA, agreed to develop plans for coordinating logistics, including a directory of Federal logistics; a summary will be published in the next issue of this journal.

An IARPC-sponsored international symposium on northern information resulted in the publication of a U.S. report and a vision statement for a polar information network.

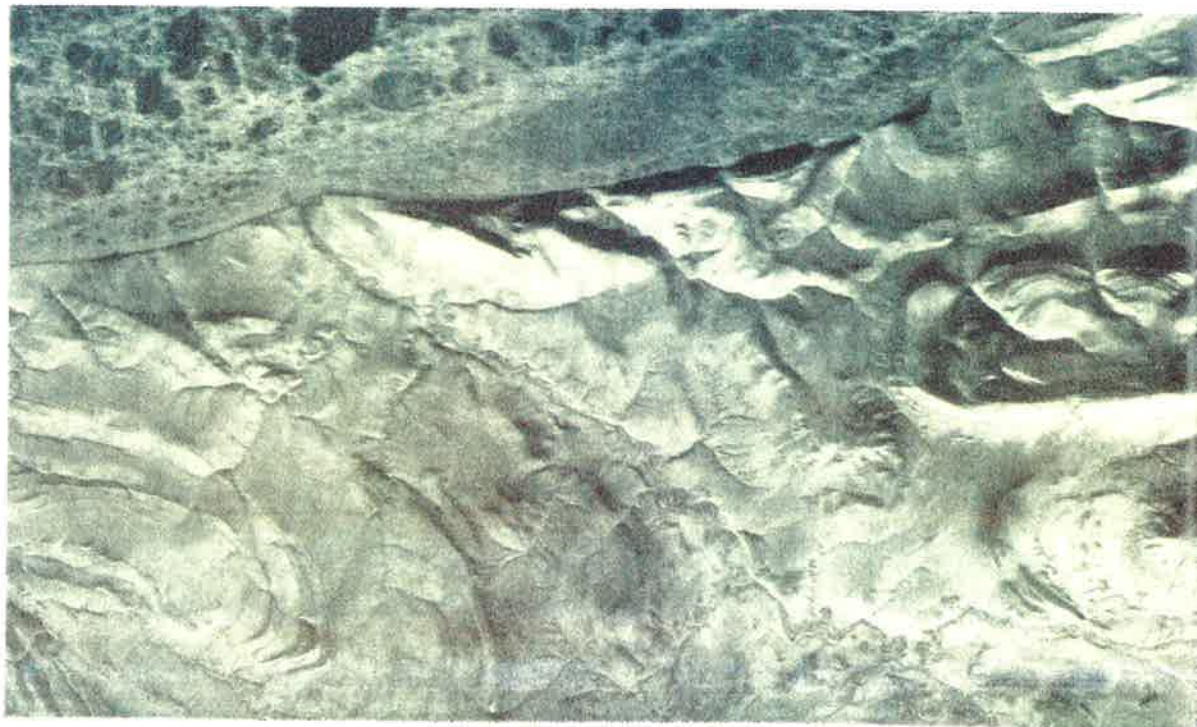
The State of Alaska created the Alaska Science and Technology Foundation. Its nine-member board is developing guidelines for administering an endowed grants program.

The Arctic Research Consortium of the United States was founded, with member institutions representing the majority of the U.S. universities involved in Arctic research.

After several years of preliminary discussions, a group of international Arctic scientists and administrators, including participants from the Commission and IARPC, met in Stockholm in March 1988. They recommended that an International Arctic Science Committee be established. The composition and functions of the IASC are under active discussion.

A major report was published on Arctic interactions, a potential contribution to global change programs.

*Side-Looking Airborne  
Radar (SLAR) image  
collected by the U.S.  
Geological Survey. This  
image of the De Long  
Mountains and the Arctic  
Ocean shows the Dugout  
Syncline, the Coke Basin  
(Smiling Eskimo Syncline)  
and the Igloo Mountain  
Syncline.*





The IARPC continued to coordinate information on Federal funding devoted to Arctic research and related activities. The FY 86-88 retrospective of U.S. Arctic research expenditures is given below. The revised FY 89 and estimated FY 90 funding will be presented in the Spring 1989 issue.

Agency	Actual 1986	Actual 1987	Actual 1988
(Thousands of dollars)			
Department of Interior	24,116	23,952	23,813
Department of Defense	26,636	25,043	23,856
National Science Foundation	18,144	21,894	23,118
National Aeronautics and Space Administration	7,999	13,423	16,850
National Oceanic and Atmospheric Administration	5,197	4,555	5,060
Department of Energy	5,436	3,610	2,927
Department of Health and Human Services	1,756	1,461	922
Smithsonian Institution	519	519	664
Department of Transportation	410	655	575
Environmental Protection Agency	400	300	0
Department of State	16	8	4
Department of Agriculture	850	860	867
Totals	91,479	96,280	98,656

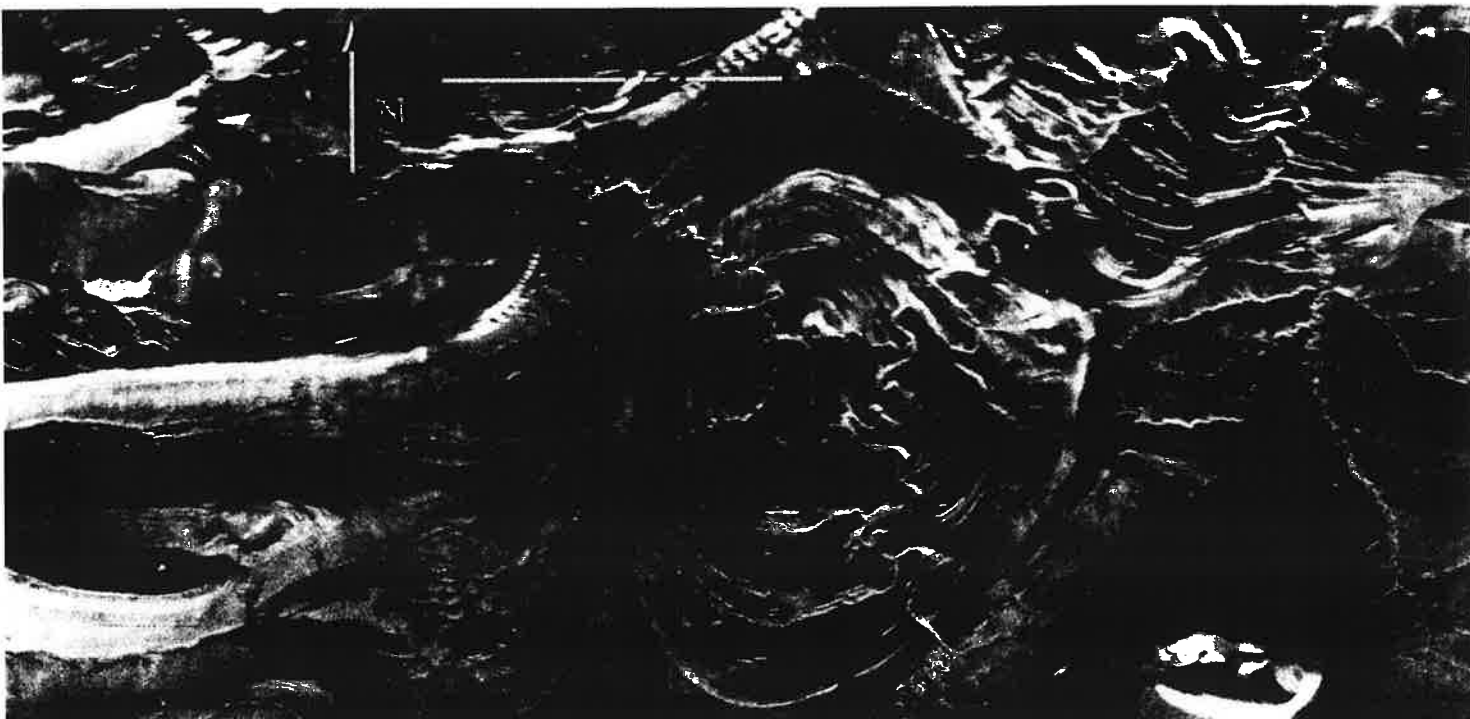
Readers may obtain further information on some of these activities from the following publications:

*Report of the Arctic environmental data workshop, March 21-24, 1988.* Available from Office of International and Intergovernmental Liaison Staff, NOAA, Room 4811 (LA4), 14th and Constitution Ave. NW, Washington, D.C. 20230.

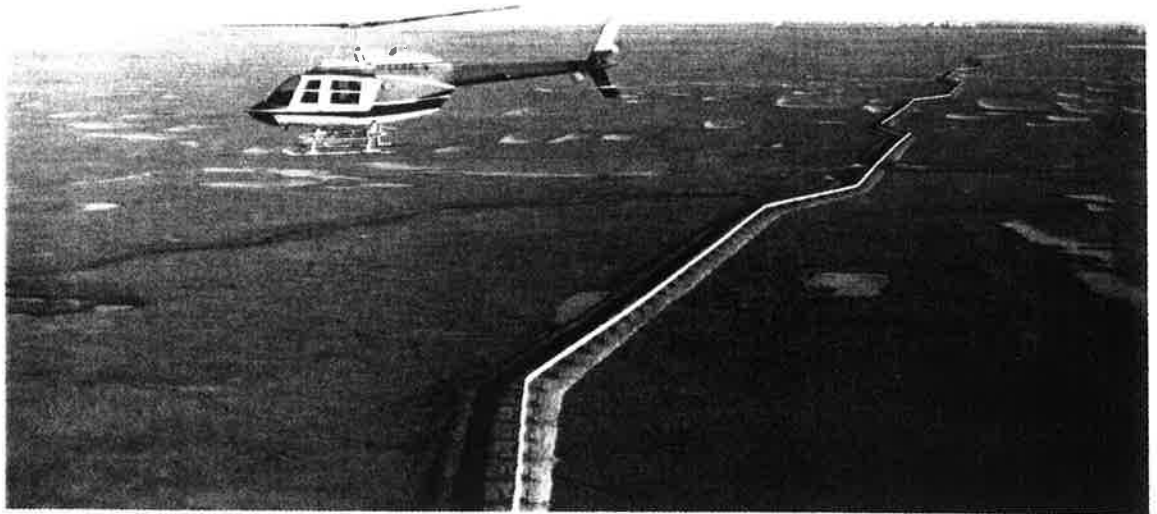
*Arctic interactions: Recommendations for an Arctic component in the IGBP.* Available from Office for Interdisciplinary Earth Studies, UCAR, P.O. Box 3000, Boulder, Colorado 80307.

*Twelfth Northern Libraries Colloquy, 5-9 June 1988.* Glaciological Data Report GD 22 and INSTAAR Special Publication. Available from WDC-A for Glaciology, CIRES, Campus Box 449, University of Colorado, Boulder, Colorado 80309-0449.

*Entering the age of the Arctic: Opportunities and obligations of an Arctic nation and Logistic support of Arctic research: Findings and recommendations of the U.S. Arctic Research Commission.* Available from U.S. Arctic Research Commission, Interstate Commerce Commission Bldg., Suite 6333, 12th and Constitution Ave. NW, Washington, DC 20423.



*Helicopter-supported research and monitoring activities of the Department of Interior over the trans-Alaska pipeline heading south from Prudhoe Bay.*



*M/V Tiglax, a state-of-the-art research vessel used by the Alaska Fish and Wildlife Research Center for studies of oceanography and seabird distribution.*



# Department of Interior

*The Department conducts research, mapping and monitoring programs throughout Alaska and its offshore regions and manages lands established under the Alaska National Interest Lands Conservation Act. These activities are performed by six services or bureaus, each with administrative and technical offices located in Alaska. In FY 87, a total of \$24.0 million was identified in support of these activities, and in FY 88, \$23.8 million was expended.*

## Minerals Management Service

The Minerals Management Service regulates the leasing, exploration and development of oil and gas in the Federal waters of the U.S. Outer Continental Shelf/Exclusive Economic Zone (OCS/EEZ). The MMS is required by law to assure that operations are safe and pollution-free and that the "best available and safest technologies" are used in the development of oil and gas. Also, the MMS must determine the environmental cost and possible multiple-use conflict in support of leasing and subsequent development and production activities in the OCS/EEZ. Arctic research and environmental studies are conducted under the Technology Assessment and Research Program (TA&R) and the Alaska Environmental Studies Program respectively. These studies are conducted in concert with universities, private companies, the states, and other Federal agencies. An annual summary of Alaska OCS activities is available from MMS OCS Information Program, 1951 Kidwell Drive, Suite 601, Vienna, Virginia 22180.

*Installing instruments in an ice rubble field to measure ice loads.*



	MMS FUNDING (thousands)		
	FY86	FY87	FY88
Offshore Minerals	288	219	121
Environmental Studies	10,340	8,343	7,128

## Technology Assessment and Research Program

The TA&R Program is responsible for assessing and evaluating technology, equipment, industry procedures and internal procedures relevant to the post-lease exploration, development and production of minerals on the OCS/EEZ; applying engineering and research approaches to mitigate identified hazardous conditions; and transferring the resulting information to MMS regulatory personnel. MMS regulators use this information in making regulatory decisions, issuing permits and reviewing applications to install structures, pipelines or other equipment, to drill for oil, gas or other minerals, and to produce these minerals. The TA&R Program has projects in the following areas: exhaust emission control; oil spill containment and cleanup; well control; risk, reliability and inspection; and structures, pipelines and ice mechanics. TA&R Program projects exclusively pertinent to Arctic and Subarctic OCS/EEZ waters include ice loads on structures and ice-structure interaction, design criteria and structural materials, oil transport and oil spill containment, and technology transfer.

Because research in the Arctic and Subarctic is expensive, most of the projects are performed jointly with other interested Federal agencies, Canada, offshore industry and universities. All projects are accomplished by

contract, and a small administrative staff is maintained to ensure the maximum application of research funds to a variety of projects.

### *Ice Loads on Structures and Ice-Structure Interaction*

Ice in its various forms is a basic hindrance to Arctic offshore oil, gas and other mineral operations. The forms of Arctic ice include seabed permafrost, land-fast ice, pack ice, icebergs and other moving ice floes, and spray ice. In a continuing effort to provide better engineering information relevant to ice resistance requirements, the TA&R Program funded the following projects in FY 87 and 88:

- Ice stress measurements at the Canadian platform "Molikpaq;"
- Verification of ice forces against Arctic structures;
- Impact of annual ice with a cable-moored platform; and
- Numerical modeling of ice-structure interactions.

### *Design Criteria and Structural Materials*

Structural design criteria and structural material information were developed for land-based operations, and their application was extended for use offshore. With the implementation of limit-state design, probabilistic-based design criteria and partial safety factors, the applicability and limitations of current structural design criteria and structural material information for offshore applications needs further evaluation. To provide a basis for this evaluation for offshore Arctic applications, the TA&R Program funded projects in FY 87 and 88 on probability-based design criteria for ice loads on fixed structures in the Beaufort Sea, and the punching shear resistance of concrete offshore structures for the Arctic.

*Icebreaker wake in the Beaufort Sea.*



### *Oil Transport and Oil Spill Containment*

As indicated by the recent OCS oil and gas lease sale in the Chukchi Sea, the remoteness and severe environmental conditions of the Arctic and the past failures to locate commercial quantities of oil and gas on the Alaska OCS have not daunted the interest of the oil and gas industry. Should hydrocarbons be found, economical and safe methods of transporting these hydrocarbons to shore must be developed. Also, any accidental spills must be cleaned up in all possible conditions, for example, when there is open water, broken ice or a solid ice cover. To ensure that adequate information will be available to regulate the development of Arctic OCS leases, the TA&R Program funded the following projects in FY 87 and 88:

- Feasibility of Chukchi Sea transportation;
- Evaluation of waterjet barriers for containing oil in the presence of broken ice; and
- Field test for burning oil on open water.

### *Technology Transfer*

Information about the problems of the users of current technologies must be communicated to researchers. Also, information about new technologies must be communicated to users. In FY 87 and 88, to encourage orderly technology transfer, the TA&R Program provided funds for the Ninth International Conference on Port and Ocean Engineering Under Arctic Conditions and the International Workshop on Oil Spill Response.

For further information, see *Technology Assessment and Research Program for Offshore Minerals Operations, 1988 Report*. This report is available from the Department of the Interior, Minerals Management Service, 12203 Sunrise Valley Drive, Mail Stop 647, Reston, Virginia 22091.

### *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 in-



formation requirements. The detailed rationale for the Alaska OCS Region's program can be found in the Alaska Regional Study Plan (RSP), which is prepared annually.

A portion of the Alaska Environmental Studies Program (ESP) is managed for the MMS through an interagency agreement with the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Other environmental studies and all social and economic studies are administered and contracted directly from the MMS Regional Office in Anchorage.

*Bowhead whale in the Beaufort Sea.*



### *Endangered Species*

The bowhead whale, an endangered marine mammal that is of key 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 (now conducted by MMS personnel) and a study of the behavior of the Davis Strait stock of bowhead whales. Also during FY 88, preparation of an authoritative book on bowhead whales and a study of the effect of production activities on Arctic whales were begun. A study examining the prediction of site-specific interaction of acoustic stimuli and endangered whales was completed. MMS has made several attempts to implant satellite tags on whales. The most successful involved attaching a satellite tag to a pilot whale that was being released from the New England Aquarium. The tag functioned for 95 days and provided 479 locations over a 7600-km path. This is the first successful long-term application of a satellite tag on a whale.

### *Living Resources*

The Marine Mammal Protection Act of 1972 established a national policy to protect marine mammal populations and to encour-

age their preservation to the greatest extent feasible. Seabirds, waterfowl and commercial fish species also are protected under various international agreements.

MMS studies are focusing on the vulnerability of marine mammals to noise disturbance. Other studies are modeling the population response of potentially sensitive marine mammals, including sea otters and fur seals, to hypothetical oil spills. Surveys of seabirds and mammals using Unimak Pass continued, including the first dedicated research effort on bird habitat use in Unimak Pass during the fall and winter. Approximately 275 conductivity, temperature and density (CTD) casts were taken during the seasonal surveys of Unimak Pass, which will provide a description of the major ecological processes affecting the seasonal occurrence of regional seabird groups.

The potential effects of offshore oil and gas operations on fisheries continue to be a major focus of studies. A study of Arctic fish sensitivities and habitats continued. A major effort to better define the coastal fisheries and related environment in the southern Bering Sea, particularly in the North Aleutian Basin, also



*Plankton tow gear being deployed in the Beaufort Sea.*

continued. This work includes investigations of the life stages and sensitivities of salmon, king crab and herring, as well as the near-shore physical oceanographic environment that constitutes the habitat of these commercially important species.

### *Environmental Monitoring*

The MMS Alaska OCS Region has completed a three-year program that monitored the long-term effects of oil and gas discharges in the Beaufort Sea; a comprehensive report summarizing the results is now available. Monitoring continued on densities and distribution patterns of ringed seals. The final report on three years of aerial surveys of ringed seals was issued in FY 88. Seabirds also continue to be monitored.

A multiyear study is underway to acquire, curate and analyze marine mammal tissues. The study is documenting baseline levels of chemical contaminants in tissues in order to monitor any increases potentially associated with future oil and gas drilling and production.

### *Pollutant Transport*

Potential oil spills are a major focus of the environmental assessments for Alaska OCS lease sales. A computer model for circulation and oil-spill trajectories is being used to predict the movement and dispersal of spilled oil. Another model for predicting the transport of oil into and along a beach is also being developed. A complementary study to describe the motion and distribution of oil droplets due to turbulent action in the water column was completed.

Efforts continued to improve knowledge of actual circulation for model-confirmation purposes. Fieldwork for the Beaufort Sea Mesoscale Circulation Study was completed, and the final report is due in FY 89. Data collection continued under MMS support to the Arctic Ocean Buoy Program (ice-drifting buoys). The results of this work will allow MMS to increase the accuracy of the Oil Spill Risk Analysis, which is a part of all offshore lease sales.

### *Ecosystems*

The purpose of ecosystem studies is to learn about habitats and biological and physical processes that support important species. Ecological studies were completed in three areas: the Chukchi Sea, the Yukon River delta and the North Aleutian Shelf lease area along the Alaska Peninsula. An MMS-funded study, in coordination with the NSF Inter-Shelf Trans-

port and Recycling Program, will attempt to determine the processes responsible for inter-annual variability in primary productivity, nutrient recycling and habitat utilization for the northern Bering Sea and the central Chukchi Sea. Fieldwork is completed for the Yukon Delta Ecosystem Processes Study, which focused on the movement of saltwater into the delta, juvenile fish use of the delta habitats, and seabird uses of the delta front. The Alaska Peninsula Coastal Ecosystem Study focused on major ecological processes and biotic relationships, particularly fish, birds and mammals, their trophic relationships, and sources of organic carbon.

### *Oil Spill Fates and Effects*

Laboratory and field studies sponsored by MMS have shown that there may be long residence times and extended recovery periods for Arctic and Subarctic biological and physical components and processes affected by hydrocarbons. A predictive oil-weathering model is in use that describes the physical and chemical changes of oil spilled in open seas or in the presence of sea ice.

Another project investigated the effect of the water-soluble fraction of Alaska North Slope crude oil on the chemosensory function of adult coho salmon; the results suggest that coho salmon can detect the presence of dissolved petroleum hydrocarbons at several orders of magnitude below the levels seen (or predicted) to cover large areas during oil spills. In FY 88, a field experiment in Alaskan waters investigated the effect of hydrocarbon exposure on the behavior of salmon returning to their natal stream.

### *Hazards*

Hazards are physical processes that may adversely affect exploration and development structures. Active surface and near-surface faulting are examples that have been studied extensively in the past. In recent years, studies that focused on sea ice mechanics and forces were funded at a moderate level through the MMS Technology Assessment and Research Program (TARP). Recent ESP studies have focused on possible constraints to oil and development activities imposed by meteorological or oceanographic conditions such as sea ice movement, storm surges and extreme winds and waves.

### *Social and Economic Studies*

The Alaska OCS Region's Social and Economic Studies are unique within MMS. Be-

cause subsistence activities are important in the culture of the Natives of coastal Alaska, the study of the effects of offshore petroleum development goes beyond conventional economic considerations. Case studies and socio-cultural and socioeconomic update studies define the social environment and describe the variables that may change with new OCS activities.

Recently completed studies have examined the effects of development on institutions in Barrow, Nome and the Pribilof Islands. During FY 87 the program began the first year of a four-year field study to track social changes to Bering Sea and North Slope inhabitants due to OCS exploration and development activities.

Several socioeconomic studies began in FY 87 in Point Hope and other Alaska communities. Two fisheries studies were begun, one to obtain current and historical commercial fishing data in the Bering Sea for the Northwest and Alaska Fisheries Center, and the other to use the data from previous studies to prepare a model that would allow MMS to project future fishing harvests in the Bering Sea.

### *Environmental Information Management*

The Alaska ESP for FY 87 and 88 included approximately 40 studies in nine subject

areas, covering the three Alaska leasing regions. The size and scope of this program necessitates mechanisms to integrate study results.

Information Update Meetings are scheduled for each planning area to allow recent multidisciplinary data from social and natural sciences to be integrated into the environmental assessment process. The results of these efforts are published by OCSEAP and are also used in environmental impact statements. An Information Update Report was published for the Chukchi Sea (Sale 109) in June 1987. In November 1987 an Arctic Information Transfer Meeting was held in Anchorage, Alaska, and was attended by more than 150 scientists, administrators, agency personnel and other interested parties. In April 1988 MMS sponsored a workshop on the technical objectives for fisheries oceanography in the Arctic.

The OCSEAP maintains an on-line bibliography of project-related reports. MMS maintains lists of direct-contracted studies, including endangered species, monitoring, oil-spill modeling, and social and economic studies. In 1987 OCSEAP published eight volumes containing 28 final reports. MMS has also funded the preparation of several books; the book *The Gulf of Alaska: Physical Environment and Biological Resources* was published in 1987.

## *U.S. Geological Survey*

The U.S. Geological Survey (USGS) conducts both terrestrial and marine research in the Arctic in a number of disciplines. Among these are energy and minerals, natural hazards, ice and climate, glaciology and Quaternary geology, deep continental studies, the magnetosphere and mapping.

### *Energy and Minerals*

Energy and minerals research in the Arctic is conducted both onshore and offshore to systematically describe and understand the geological settings where energy and mineral resources may occur and to provide quantitative assessments of the energy and mineral resources of the Arctic for land use planning and national need. The USGS carries on its

#### USGS FUNDING (thousands)

	FY86	FY87	FY88
Energy and Minerals	2,800	2,411	2,494
Natural Hazards	285	919	1,209
Ice and Climate	240	350	350
Hydrology	0	310	310
Glaciology and Quaternary	250	200	200
Marine Geology	400	985	692
Magnetosphere	25	25	25
Mapping	2,300	625	1,405

work in Alaska through several programs, the most significant being the Alaska Mineral Resources Assessment Program (AMRAP).

AMRAP provides an assessment of "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," as directed by Section 1010 of the Alaska National Interest Lands Conservation Act (ANILCA). Other active USGS energy and mineral programs are



*USGS survey project  
in the Arctic Ocean  
using the Coast Guard  
Cutter Polar Star.*



- The Geologic Framework Program, involving both general and specialized research on the regional geology of the state;
- The Development of Assessment Techniques Program, whose goal is improvement of the ability to identify and evaluate mineral resources;
- The Critical and Strategic Minerals Program, which identifies the potential of these resources to meet national military and economic needs;
- The Evolution of Sedimentary Basins Program, which studies depositional, structural, diagenetic and thermal processes to predict and evaluate water, mineral and petroleum resources;
- The Marine Geology-Exclusive Economic Zone (EEZ) Program, which evaluates the morphology and mineral potential of the continental margin and which has sponsored research cruises in the Bering Sea that systematically imaged the seafloor using Geologic Long Range Inclined Asdic (GLORIA) sonar surveys;
- The Gas-Hydrate Program, which attempts to determine the distribution, quantity and environment of methane hydrate; and
- The Geothermal Investigations Program, which focuses on studies of the nature, distribution and energy potential of geothermal resources and which is now investigating Mt.

Spurr, Mt. Edgecumbe and Emmons Lake caldera.

In September 1988, USGS conducted a geological and geophysical investigation of the southern end of the Northwind Ridge of the Arctic Ocean's Amerasian Basin. Using the Coast Guard Cutter *Polar Star*, data were obtained to 75°N latitude. Among the data collected were 9 box cores, 24 gravity cores, 9 piston cores, 1 dart core, 2925 km of bathymetry, 151 km of single-channel seismic reflection data, and 20 sonobuoy reflection profiles. One of the cores recovered by the expedition was taken about 250 miles north of Point Barrow, where the ocean is about 2.5 miles deep. This core is apparently the longest ever collected from the Canada Basin or the submerged mountain ranges that surround it.

A major study of the petroleum geology of the Arctic National Wildlife Refuge (ANWR) was released in late 1987. The study (USGS Bulletin 1778) contains 23 technical papers summarizing available information on the geochemistry, geology, structure and petroleum potential of the ANWR area. Other petroleum studies are investigating the oil and gas potential of the Yukon-Kandik basin, the Nenana basin, the Killik River and Chandler Lake quadrangle, the North Slope and the eastern Brooks Range.

A new Arctic publication, *The National*

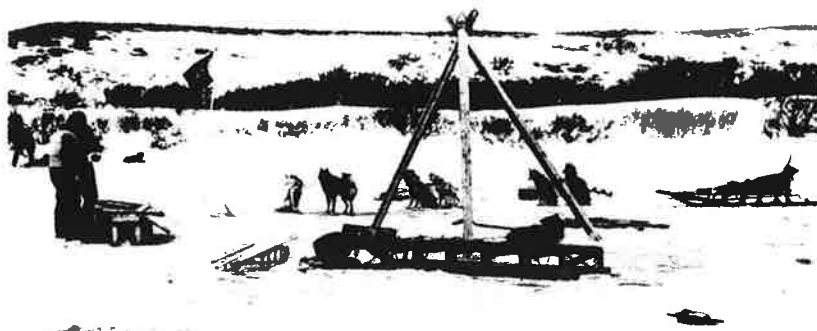


*Petroleum Reserve in Alaska, 1974-1982* (USGS Professional Paper 1899), is in press and will be available for general distribution in early 1989. This 956-page volume includes 39 papers on a wide range of research studies that were part of the recent exploration program mandated by the Naval Petroleum Reserves Production Act of 1976. The papers address exploration history, resource assessment, geologic framework, geochemistry, geophysics, paleontology, reservoir rocks and special studies. These subjects were investigated in response to several mandates of the act, including continuation of exploration drilling and a resource assessment of the entire reserve. The report includes maps and illustrations, as well as summary tables of the 28 new exploratory wells.

The quantity and quality of coal were assessed from numerous sites in the central and eastern portion of the Alaskan North Slope, including Sagwon Bluffs along the Sagavanirktok River, Juniper Creek and the Shaviovik River. A study of the thickest known Alaskan Arctic coal bed, a 55-m-thick, Eocene coal bed in the Death Valley area of the Seward Peninsula, was also conducted. Coal is known to exist in the offshore Alaskan Arctic, and preliminary studies indicate potentially large quantities. Investigations have been made of the regional geochemistry, diagenesis, stratigraphy, sedimentology, tectonic framework, mineral potential and geologic processes of Alaska North Slope basins.

Minerals being investigated include chromite, tin, placer and lode gold, tungsten, platinum, sulfides, lead and zinc. Environmental geologic studies were made of coastal erosion, sediment budgets and ice gouging in the Alaskan and Canadian Beaufort Sea, as well as the offshore stratigraphy of the Chukchi Sea.

*Collecting a 40,000-year-old sediment core from a lake on Saint Michael Island in Norton Sound.*



*Inspecting beds containing dinosaur bones along the Colville River.*

## *Natural Hazards*

The primary objective of USGS research on Arctic natural hazards (earthquakes, volcanoes and landslides) is to mitigate losses by providing data and evaluations essential for land use planning. Research focuses on hazards related to offshore lease areas, engineering design and emergency preparedness decisions. Three programs are actively investigating natural hazards:

- 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 assessing, reducing and predicting volcanic hazards; and
- The Landslide Hazards Reduction Program, which includes studies on assessing, reducing and predicting landslides.

Ongoing studies are resolving geologic elements and seismogenic processes throughout Alaska, with the goal of estimating long-term earthquake potential, particularly in the Yakutat, Shumagin and Unalaska seismic gaps. Regional and global seismographic stations are being operated. Engineering geologic maps

have been completed for many 1:250,000-scale quadrangles, including eight in the National Petroleum Reserve in Alaska (NPRA). The coastal plain portion of ANWR has also been mapped. Other work includes studies of the distribution, character and thermal regime of permafrost, including a new evaluation of the role of discontinuous permafrost in the Anchorage area.

### *Ice and Climate*

Ice and climate research is primarily conducted by the Water Resources Division, through its Ice and Climate Program. Its purpose is to

- Investigate the role of all forms of surface ice (sea ice, ice sheets, snow and glaciers) and polar oceans in the variation of meso-scale, regional and global climate;
- Develop aircraft and satellite techniques with passive and active microwave to observe surface ice and polar ocean phenomena in any weather and at any time of day at time scales ranging from daily to interannual;
- Develop numerical models for sea ice dynamics and thermodynamics, ice sheet flow and glacier flow; and
- Investigate the interaction of the upper ocean and sea ice, especially in the marginal ice zone.

Much work is conducted at the international level in the Arctic, primarily through long-standing joint programs with NASA and the French Space Agency (CNES). Studies are using satellite, aircraft and surface sensors to make simultaneous observations of sea ice, ice sheets, snow and oceans. The USGS role has been both in the design of microwave sensors for satellite missions and in the subsequent analysis and use of the satellite data. For example, the results of ten years of observation of variations in sea ice cover as observed with the Nimbus-7 multichannel microwave radiometer were reported in a joint USGS-NASA publication in October 1988. USGS researchers continue to participate in planning and carrying out aircraft remote sensing missions in conjunction with the satellite missions and in surface-truth experiments on drifting ice stations, ships and ice sheets. USGS investigators are involved in the ongoing marginal ice zone experiments being conducted in the Fram Strait and East Greenland Sea. A joint USGS-NASA study of the upper Colorado River basin snowpack using Nimbus-7 SMMR observations to measure snow water equivalents is now entering its seventh snow season. USGS researchers have developed numerical models for sea ice dynamics and thermodynamics in cooperation with other agencies, particularly the Goddard Space Flight Center of NASA. USGS-developed numerical models

*Terminus of an iceberg-calving tidewater glacier.*



of glacier flow and ice sheet flow are being used in conjunction with remote sensing data from surface-based radar sounders and aircraft and satellite radars.

## *Glaciology and Quaternary Geology*

The goals of glaciology and Quaternary geology research are to

- Understand the complete cycle of glacier behavior;
- Provide advice on specific glacial and engineering geological hazards;
- Assess glaciers as a resource;
- Develop and use methods for predicting glacier behavior;
- Interpret Quaternary geological environments and climate by reading the record of events recorded in loess, permafrost, glacial deposits, and marine and lacustrine sediments; and
- Assess the importance of Alaskan glaciers for interpreting climate.

Individual aspects of this project are conducted by the Geologic and the Water Resources Divisions.

Instrumentation is maintained at several glaciers, including the Hubbard Glacier, in different climatic areas to measure high-altitude climate, snow and ice balance, and glacier flow. Current projects are analyzing these baseline data, developing new techniques in glaciology and studying surging glaciers, ice-dammed lakes and calving glaciers, both to obtain new knowledge of these hazards and to learn more about glaciological principles and processes. A computer model relating climate data from long-term weather stations to mountain climate, glacier snow and ice storage, and glacier runoff was developed for the Columbia Glacier, Alaska, predicting its retreat. Studies of the post-breakout effects of Russell Fjord and Hubbard Glacier continue. A 1988 publication (USGS Circular 1018) documents the recent activities of Hubbard Glacier.

Numerous detailed studies of late-Tertiary and Quaternary marine, lacustrine, eolian and glacial sediments and permafrost of the North Slope and interior basins of Arctic Alaska continue. These include assessments of the depositional environment of the Flaxman member of the Gubik Formation; studies of Late Wisconsin eolian activity and alluviation of the Kobuk River valley; and thermal analyses of the permafrost and hydrate stability zones of the Kuparuk and Prudhoe Bay oil fields.

## *Deep Continental Studies*

Deep continental research involves multidisciplinary studies of the continental lithosphere, with an emphasis on deep crustal environments and processes that control or influence near-surface geology. The goal of deep continental studies is to obtain information about the composition, structure and dynamics of the Earth's crust and upper mantle in order to understand the occurrence of energy and mineral resources and the processes associated with major geologic hazards such as earthquakes and volcanic eruptions.

In the Arctic, deep continental studies are conducted as part of the Trans-Alaska Crustal Transect (TACT) Program. The TACT program applies 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 Investigations (TALI), which utilizes earth scientists from the Alaska Division of Geological and Geophysical Surveys, the University of Alaska, other universities and private industry. The TACT program, which is entering its fifth year, is a major, integrated multidisciplinary program designed to investigate the geology, tectonics and deep crustal structure along a north-south corridor following the route of the trans-Alaska pipeline and extending offshore across the Pacific and Arctic continental margins.

TALI studies proposed for the next several years will examine

- The ongoing processes of subduction and accretion, key processes in the evolution of Alaska and western North America;
- The deep configuration and history of rifting of the Beaufort margin and the relation of rifting to events in the Brooks Range and Canada Basin;
- The configuration and history of the Denali fault system, a late Mesozoic collision suture reactivated as a major Cenozoic strike-slip fault;
- The thickness, structures, roots and histories of the many terranes recognized between the Alaskan Range and the Brooks Range;
- The configuration and history of the Kaltag-Tintina fault system, which borders and disrupts a collage of crustal slices on the north margin of the Yukon-Tanana Upland; and
- The nature of the crust beneath the Yukon-Koyukuk Basin and the basin's structural history.

Recent TACT program accomplishments in-



*The Trans-Alaska Pipeline System haul road, the route of the Trans-Alaska Crustal Transect Program deep continental study.*

clude the completion of deep crustal seismic refraction surveys across the Alaska Range and Tanana River basins. Geologic mapping (1:63,360 scale) and specialized geologic studies have been extended to the Yukon River, resulting in a completed geologic strip map that covers the southern three-fifths of Alaska along the transect. Other activities include completion of magnetotelluric surveys from the Gulf of Alaska to the northern Alaska Range, extension of gravity and aeromagnetic modeling to the northern Alaska Range, and completion of an aeromagnetic survey in the Middleton Island region of the Gulf of Alaska.

### *Other Activities*

The magnetosphere and mapping activities remain essentially the same as presented in the FY 86 report (see *Arctic Research of the United States*, Fall 1987, p. 23).

The USGS operates three magnetic observatories in Alaska, one of which is located at Barrow on the Arctic coast. This station is particularly important because it is the only source of geomagnetic data close to the geomagnetic pole. It is at the geomagnetic pole where charged particles following magnetic field lines enter and leave the Earth. Geomag-

netic data are critical to our understanding of how sunspots affect communications and how the Earth's internal magnetic field and the atmospheric magnetic field are related.

The goals of the National Mapping Program with respect to Arctic Alaska include preparing and maintaining a variety of high-quality multipurpose base maps and digital cartographic data bases to meet specific national priorities, including the requirements of Federal and State agencies, Congress and others. Additional information on Arctic Alaska mapping activities may be obtained from the National Cartographic Information Center, U.S. Geological Survey, 4230 University Drive, Anchorage, Alaska 99508-4664.

### *Publications*

Readers may obtain further information on some of the research described in this article and other USGS activities from the following publications:

*Geologic studies in Alaska by the U.S. Geological Survey during 1987:* USGS Circular 1016, Branch of Alaskan Geology, 4200 University Drive, Anchorage, Alaska 99508-4667.

*Annual report of the U.S. Geological Survey:* USGS, Reston, Virginia 22092.



## Fish and Wildlife Service

The Alaska Fish and Wildlife Research Center addresses a wide variety of Arctic and Subarctic research problems of national and international scope, involving anadromous fisheries; land and marine mammals; seabirds, shorebirds and waterfowl; and the development and application of new methodologies to study fish and wildlife populations and their habitats. Much of this research is focused on minimizing the impact of resource development on fish and wildlife on National Wildlife Refuges (NWRs) across Alaska. The Fish and Wildlife Service (FWS) Arctic research is conducted under five broad topics: migratory birds, marine mammals, terrestrial ecology, fisheries and cooperative research.

### Migratory Birds

Alaska's migratory bird population is large and diverse. Over 40 million seabirds of 30 species use pelagic and coastal areas of Alaska year-round. Millions of migratory shorebirds nest in northern and western Alaska. Alaska habitats support more than 70,000 swans, 1 million geese and 12 million ducks that winter in all four North American

#### FWS FUNDING (thousands)

	FY86	FY87	FY88
Marine Mammals	1,300	1,400	1,250
Migratory Birds	900	1,300	1,700
Fisheries Research	241	375	375
Cooperative Research	250	300	325
Terrestrial Ecology	600	525	1,125

flyways. The Center's migratory bird studies have focused on the ecology and population dynamics of these seabirds, shorebirds and waterfowl.

### Seabirds

Black-legged kittiwakes have experienced complete reproductive failures at colonies throughout Alaska with alarming frequency in recent years. In 1987, research was begun on Middleton Island, in the north-central Gulf of Alaska, to identify the specific causes of these failures, which appear to be related to the birds' food supply. Studies are underway to estimate the means and variability in the annual survival of adult kittiwakes on Middleton Island.

The M/V *Tiglex*, a 120-foot research and refuge support vessel, entered its first year of service with a christening ceremony in Homer, Alaska, on July 2, 1987. With the cooperation of the Alaska Maritime NWR, Center personnel conducted studies of seabird distributions and oceanography near colonies at the west end of St. Lawrence Island in the Bering Sea. This research is designed to identify environmental factors (particularly oceanographic and prey factors) responsible for offshore aggregations of seabirds and to determine whether the times and locations of these feeding aggregations were consistent.

### Shorebirds

Personnel from the Yukon Delta NWR completed the third year of study of nesting bristle-thighed curlews, which are considered depleted. Their study site at Curlew Lake is at the most southerly portion of the breeding range, which appears to extend north along Norton Sound and onto the Seward Peninsula. Aside from the Nulato Hills of the north Yukon River delta, the only other area where bristle-thighed curlews are known to nest is on the Seward Peninsula. Employing a combination of Landsat imagery, existing habitat mapping and recent knowledge of habitats used by curlews nesting on the Yukon delta, Center personnel extensively sampled the Seward Peninsula to determine the distribution and number of curlews nesting in this area during 1988.



*Evaluating the effect of controlled burning on wetland vegetation and response by waterfowl at the Yukon River Flats.*

Both Laysan and Christmas islands have a history of hosting large numbers of bristle-thighed curlews during their northward migration. Upon completion of a three-month field effort on Laysan Island this fall, the Center will have investigated all aspects of the curlew's life cycle throughout its entire range in the same year.

### *Waterfowl*

The Yukon Flats region is Alaska's most significant waterfowl nesting area, with an estimated population of 1.5 million ducks, geese and swans. The Yukon Flats is also considered one of the most productive waterfowl habitats in North America. The prairie pot-hole and aspen parkland regions of the U.S. and Canada have higher densities of waterfowl on an annual basis, but the Yukon Flats has a higher sustained rate of production.

Despite the importance of the Yukon Flats to the continental waterfowl population, there is a large void in our understanding of northern wetland habitats. Historical information provides strong evidence that fire was an integral part of the natural system of the Yukon Flats. A long-term project to determine the influence of fire in forming, expanding and maintaining interior wetlands on Yukon Flats NWR was initiated in 1987. The purpose of this research is to determine changes in wetland vegetation composition and biomass following a controlled burn.

A cooperative effort between the Center, the Canadian Wildlife Service and the Washington Department of Game was initiated in 1987 to better understand the timing of migration and the habitat use of staging Pacific black brant and the origin of populations wintering in the Puget Sound area. Backpack radio transmitters were attached to brant from nesting colonies in western Alaska and the Canadian Arctic. This was part of an intensive radio-tracking study of these birds at Izembek Lagoon in southwestern Alaska, where nearly the entire population of Pacific black brant stage during their spring and fall migrations. Several thousand radio contacts with Canadian and Alaskan birds revealed segregation of the high-Arctic, light-bellied brant from those that were marked on Victoria Island and the Mackenzie delta, Canada, and the Yukon-Kuskokwim delta.

A study of the potential impacts of aircraft overflights on the distribution, habitat use, behavior and condition of molting brant was initiated in 1987. The major molting area consists of about 100 large, shallow basins in the

Teshukpuk Lake area a few kilometers inland from the Beaufort Sea. In some years, up to 32,000 brant (about 20% of the Pacific population) congregate on these lakes to molt during July, August and September. Banding studies indicate that these brant come from nesting colonies in the Canadian High Arctic, Wrangel Island and the Soviet mainland, and the Yukon-Kuskokwim delta in western Alaska. Aircraft flights near molting geese have been shown to elicit escape behavior, but the significance of these disturbances is unknown. The Center is addressing this problem through behavioral, energetic and habitat studies.

### *Marine Mammals*

The majority of the Center's research on marine mammals is issue-oriented, applied in nature, international in scope, and in the case of polar bears, sea otters and Pacific walrus, Congressionally mandated. Two objectives guide most of this research:

- Assessment and mitigation of the impacts of ongoing and proposed resource exploitation on marine (and terrestrial) mammals and their habitats; and
- Development of techniques and collection of information relevant to the needs of State, Federal and international management authorities.

### *Pacific Walrus*

Research on Pacific walrus continues to increase the reliability of population and trend estimates conducted by Soviet and U.S. biologists. Although Pacific walrus have been counted by aerial surveys many times, biases associated with their distribution limit the usefulness of these data. New satellite tracking systems to collect data on location and haul-out behavior were necessary to quantify some of these biases. Pressure housings for satellite telemetry transmitters were designed and evaluated. The new immobilizing drug Telezol was evaluated, and three methods of drug delivery were tested during the first field season at Round Island, Alaska. The locations of the walrus wearing the prototype transmitter are being studied, and haul-out data will be analyzed in conjunction with environmental conditions to investigate factors affecting haul-out patterns.

Under the Marine Mammal Project of the U.S.-U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection, and in



*Releasing a sea otter  
after surgical implantation  
of a radio transmitter.*

cooperation with the University of Alaska and the National Marine Fisheries Service, Center personnel participated in a walrus research expedition to the Chukchi Sea aboard a Soviet ship. In the summer of 1988, two Soviet scientists participated in field studies at Round Island, Alaska, with Center personnel. Data were collected on body size and condition, reproduction, food habits, and the age and sex composition of groups hauled out onto the ice. Samples were collected for mitochondrial DNA and virological analyses and for developing indirect methods to determine age.

### *Sea Otter*

Development of the coastal zone, increasing conflicts between shellfish resources, and legal and illegal killing has justified continued research on sea otters in Alaska. The eventual goal is a zonal management program. Included in this work are the development and analyses of data bases on tourism and commercial fisheries. Research focused on three locations in Alaska where management problems already exist or are likely to occur: Kodiak Island, Prince William Sound and southeastern Alaska.

Research at Kodiak Island continues to emphasize the movements of radio-marked sea otters, their feeding habits and the effects of their foraging on subtidal benthic communities. Center biologists documented an unusual die-off of sea otters at Kodiak Island during

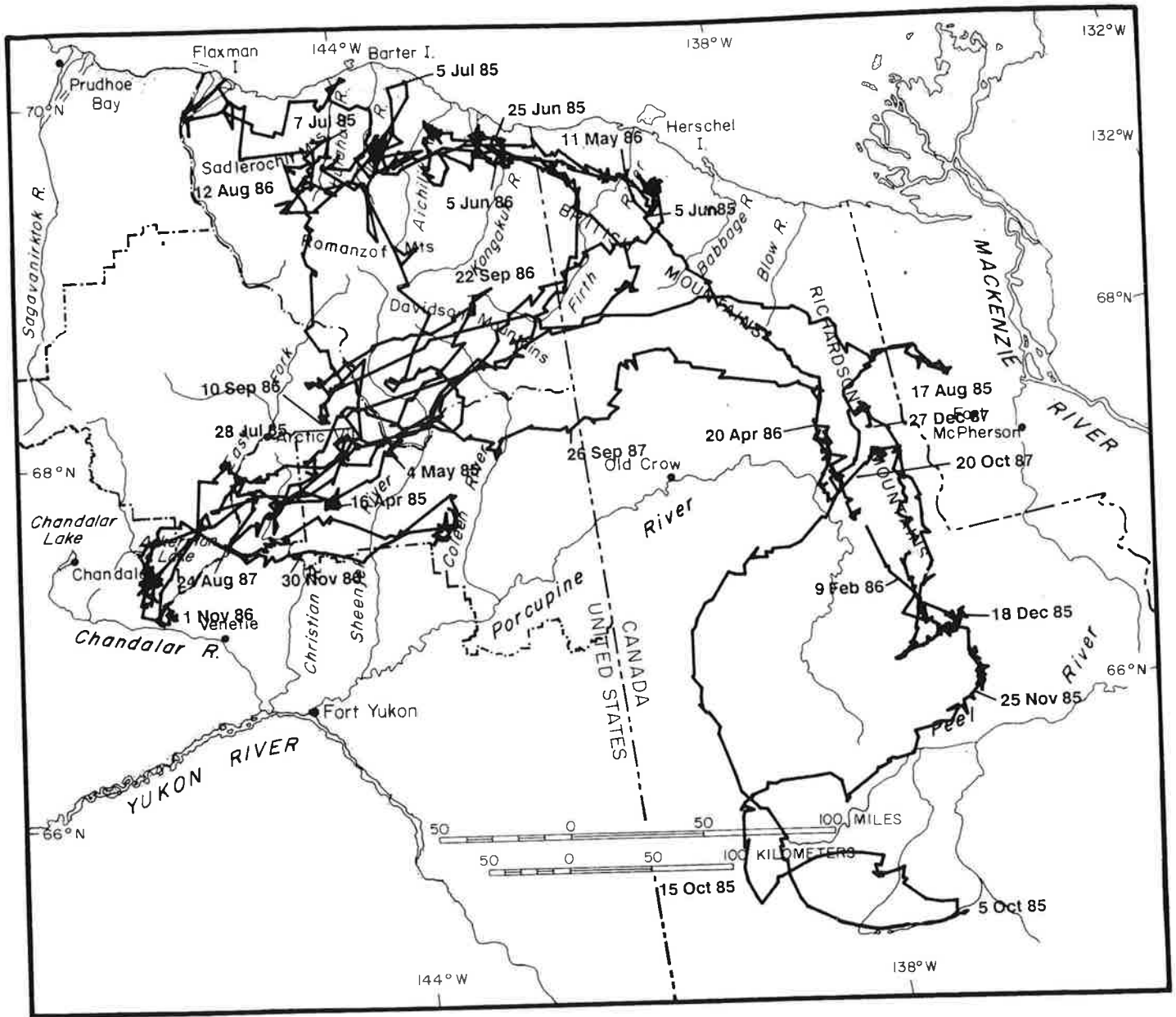
the summer of 1987. The cause of the die-off is not known, but paralytic shellfish poisoning has been hypothesized as a likely agent.

Researchers from the University of Minnesota, in conjunction with the Center, initiated a study of the movements, reproduction and mating systems of sea otters in Prince William Sound. Sixty animals have been radio-marked so far, and preliminary results confirm that sea otters move in and out of sheltered waters seasonally. A new, small radio transmitter that attaches to flipper tags was tested at Kodiak Island and Prince William Sound. The new tag shows promise as a relatively non-intrusive, short-term mark for sea otters.

### *Polar Bears*

Natives along the Alaskan Arctic coast can harvest polar bears without restriction. At the same time the habitats of polar bears in northern Alaska are increasingly being altered by petroleum-related developments. The potential combined effects of harvest and development provide the driving force behind ongoing polar bear research in Alaska. It has been hypothesized that there are separate northern and western polar bear populations in Alaska, and a major research objective is to determine the size and status of the populations that seasonally occupy coastal waters adjacent to Alaska.

The use of satellite telemetry on polar bears in Alaska has continued during FY 87 and 88.



*Satellite track of a female caribou from the Porcupine herd, April 1985 to December 1987.*

Telemetry data indicate that polar bears in the Bering and Chukchi seas are seasonal residents from November through March but retreat northward with the pack ice during April and May. Bears with radio transmitters have remained in the northern and northwestern Chukchi Sea adjacent to the Soviet coastline from June through October. To date, no polar bear marked in either northern or western Alaska has permanently moved from one area to another.

Four female polar bears marked in the Chukchi Sea apparently denned in the vicinity of Wrangel Island in Soviet territory during the fall of 1987, as indicated by satellite telemetry data. These data corroborated two trends observed in past years: the majority of polar bears in the Beaufort Sea establish ma-

ternity dens in the drifting pack ice, and the Arctic National Wildlife Refuge (ANWR) is the only significant land denning area in Alaska. Preliminary analysis of den success data for the Beaufort Sea have suggested that the production of cubs from land dens is significantly greater than that from dens on the sea ice.

### *Terrestrial Ecology*

The focus of this program is on wildlife ecology on FWS lands, where the FWS has shared responsibilities with the State of Alaska for the well-being of resident wildlife. FY 88 marked a major increase in Congressional appropriations related to the ANWR,



For further information on the ANWR studies, contact the 1002 Study Coordinator, Region 7, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99509.

particularly the evaluation of the refuge's coastal plain for potential oil and gas development (referred to as "1002," after Section 1002H of the Alaska Lands Act of 1980). These new studies, following up on information needs identified in the 1002 Report to Congress, are conducted by both the Center and the FWS Regional Office in Anchorage.

### *Caribou*

The Center continues to play a central role in determining the importance of the 1002 area to the Porcupine Caribou Herd (PCH), which migrates yearly to calve on the Arctic coastal plain. The Center works closely with biologists from ANWR, as well as from the Alaska Department of Fish and Game, the Alaska Cooperative Wildlife Research Unit, the Institute of Arctic Biology (University of Alaska), the Yukon Department of Natural Resources, and the Canadian Wildlife Service to understand why certain areas are used repeatedly by the herd. Additional work on predicting the potential impacts of oil development on caribou in ANWR is being carried out on the Central Arctic Herd (CAH), portions of which live in the areas now under petroleum development.

Satellite telemetry has uncovered several new aspects of caribou ecology. For example,

the average daily distance traveled was the same within a season for both herds, with the greatest movements in July and the shortest movements in February. Mean total distances traveled were only slightly greater for the highly migratory PCH animals than for the resident CAH animals. It has often been assumed that caribou are essentially sedentary from late fall until they embark on their spring migration. However, recent satellite telemetry data suggest that PCH animals often continue moving until well into December, occasionally switching from one traditionally used wintering area to another, before finally becoming sedentary for the remainder of the winter. Multi-year monitoring of individuals has revealed little fidelity to specific winter ranges.

Little is known about why pregnant caribou cows calve precisely where they do. Cows often continue moving until just before parturition, and they continue their movements only a week or two later, so the exact birth site can be difficult to determine. Recent results from the activity sensors attached to satellite collars suggest that this short "pause" for calving can be detected remotely, allowing researchers to pinpoint calving sites.

### *Other Arctic Mammals*

Biologists at the Center, working in cooperation with the FWS Alaska Regional Office, the U.S. Geological Survey/Earth Resources Observation Systems Field Office (Anchorage), the North Slope Borough and private industry, have incorporated numerous environmental base maps, across several study areas, into a geographic information system (GIS) archive. Within the GIS, each point location has been associated with several attribute variables such as telemetry data (animal identification, date and time). A primary focus of the Center's analyses has been assessing and mitigating the impacts of proposed gas and oil development on wildlife inhabiting the coastal plain of the ANWR. GIS graphics and analyses contributed substantially to the biological sections in the Coastal Plain Resource Assessment and Final Environmental Impact Statement completed in 1987.

The Center continues to build its biological data bases through ongoing satellite and radio telemetry studies of caribou, polar bear, muskoxen, brown bear, wolf and Dall sheep. New environmental data bases from satellites are being investigated, such as application of Landsat thematic and SPOT data for more highly resolved vegetative classifications, and



Caribou fitted with satellite telemetry collar.

*Investigating developmental stage of early- and late-run chinook salmon being incubated at different temperature regimes.*



AVHRR and SAR data for mapping snow and pack ice distribution. In addition to their primary function of providing animal locations, satellite collars can be useful in determining activity patterns without having to physically observe the animal. Center biologists, in cooperation with other agencies, have continued the process of calibrating collar-based activity indices with the known behavior of captive animals. Other studies using satellite collars include habitat use and foraging activity of muskoxen in Greenland, Dall sheep in the central Brooks Range, wolves in Alaska, and moose in south-central Alaska.

## *Fisheries*

The Center continues research on salmon that reproduce on the Kodiak and Kenai National Wildlife Refuges in Alaska. The Kodiak study addresses predator-prey, competition and trophic relationships as possible mechanisms for a marked decline in a population of sockeye salmon at Karluk Lake. The Kenai study is primarily a laboratory experiment designed to determine if temperature characteristics of different spawning areas are related to the timing of spawning by chinook salmon. Both studies have immediate application for managers because salmon are a heavily used natural resource that is intensively managed in Alaska.

New genetic studies on fish of the Yukon River, Bristol Bay and the North Slope were initiated. The Yukon River salmon study is designed to provide new data for international negotiators on the origins and distribution of salmon in that drainage. The Bristol Bay research is designed to investigate the genetic origins of salmon in areas where oil and gas exploration is proposed. Finally, North Slope studies are investigating genetic differences among char populations so that managers can ascertain the degree of similarity between

stocks and their possible vulnerability to oil and gas development. The North Slope char investigation is in its second year. The results to date suggest that char should be managed as discrete stocks because they apparently do not interbreed. Genetic stock identification appears useful in determining the percent composition of mixed stocks of char in offshore waters subject to oil and gas exploration.

## *Cooperative Research*

The FWS has a national program of cooperative research on fish and wildlife, in conjunction with state natural resource agencies and land grant universities. The University of Alaska-Fairbanks houses both the Alaska Cooperative Fishery Research Unit (CFU) and the Alaska Cooperative Wildlife Research Unit (CWU). A primary goal of the cooperative research program is to provide graduate- and postgraduate-level training for fish and wildlife biologists. This is accomplished through individual research projects of faculty and graduate students; the FWS program funds the administrative costs of the units. Support for individual projects at the Alaska units comes from a wide variety of sources: Alaska Department of Fish and Game; Canadian Wildlife Service; other Interior agencies including U.S. Geological Survey, National Park Service and Bureau of Land Management; other Federal agencies including National Science Foundation, U.S. Department of Agriculture-Forest Service and Environmental Protection Agency; and other FWS organizations, primarily the Alaska Fish and Wildlife Research Center and the FWS Regional Office in Anchorage.

During the past year the CFU completed four studies and conducted 15 continuing studies. The CWU was involved in 18 ongoing studies this past year, of which eight were completed. A booklet was published on threatened and endangered plants of Alaska. An evaluation of Pacific walrus subsistence harvest monitoring procedures enabled the sampling protocol to be modified to adjust for the timing and intensity of harvest for different villages. A study of vegetation use by muskoxen in the ANWR concluded that preferred vegetation types occurred throughout the drainages of the Refuge; the muskoxen occupied areas with higher proportions of preferred cover types. Continuing projects include several studies of caribou, muskoxen and migratory birds in Arctic Alaska.

For more information on cooperative research, contact the Director, Cooperative Fish and Wildlife Center, Region 8, U.S. Fish and Wildlife Service, Washington, D.C. 20240.

## Publications

Readers may obtain further information on some of the research described in this article from the following publications:

*Polar bear, Ursus maritimus*, by S.C. Amstrup and D.P. DeMaster: in *Selected marine mammals of Alaska: Species accounts with research and management recommendations* (J.W. Lentfer, Ed.), Marine Mammal Commission, Washington, D.C., 1988.

*Satellite telemetry: A new tool for wildlife research and management*, by S.G. Fancy,

L.F. Pank, D.C. Douglas, C.H. Curby, G.W. Garner, S.L. Amstrup and W.L. Regelin: U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 172, 1988.

*Did the 1982-1983 El Nino-southern oscillation affect seabirds in Alaska?*, by S.A.

Hatch: Wilson Bulletin, vol. 99, p. 468-474.

*Trophic levels and trophic relationships of seabirds in the Gulf of Alaska*, by G.A.

Sanger: in *Seabirds: Feeding biology and role in marine ecosystems* (J.P. Croxall, Ed.), Cambridge University Press.

Additional details (including technical publications) related to the migratory bird, marine mammal, terrestrial ecology and fisheries research are available from the Alaska Fish and Wildlife Research Center Director, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, Alaska 99509.

## Bureau of Land Management

The Bureau of Land Management's (BLM) Arctic research program consists primarily of inventory, monitoring and applied research activities focused on energy, minerals and renewable resources. These activities cover over 32 million acres of surface and subsurface lands and are performed entirely in terrestrial and freshwater environments. The Bureau has no marine or offshore responsibilities.

The Bureau's Arctic research activities are conducted under the authority of the Federal Land Management and Policy Act and the Petroleum Reserve Production Act. BLM also has responsibility for developing plans for managing the public lands and their resources. These plans take various forms, the most common of which are resource management plans (RMP) and habitat management plans

(HMP). Two of the most recent RMPs developed by the Bureau in its Arctic District are for the Teshekpuk Lake Special Area and the Utility Corridor. The Teshekpuk Lake area, in the northeastern portion of the National Petroleum Reserve in Alaska (NPPRA), is home to a wide variety of waterfowl and shorebirds. The area provides critical habitat for black brant geese during the breeding and molting periods each year, and it is also potentially important as a transportation corridor for North Slope oil and gas development activities. The Utility Corridor is a north-south strip of land of critical importance for transportation of people, materials, petroleum and perhaps, in the future, other mineral resources. The RMP for the Utility Corridor, initiated in FY 86, has required a continuing process of research, data collection and analysis, and development and evaluation of alternative management plans. It is a multi-disciplined study of resource values on over 15 million acres of BLM-managed land in northern Alaska. The final RMP, expected to be published in FY 89, will address the multiple-use issues of land disposal, development nodes, mining, recreation, access and wilderness.

In association with development of the Utility Corridor RMP, BLM has been conducting an interdisciplinary study required under Section 1001 of the Alaska National Interest Lands Conservation Act (ANILCA) for lands

BLM FUNDING (Thousands)			
	FY86	FY87	FY88
National Wildlife Refuge	305	325	350
Wildlife - Arctic District	165	145	224
Wildlife - ANILCA District	235	175	200
Wildlife - Management District	175	175	175
Wildlife - Conservation	350	350	350
Wildlife - Research	100	105	204
Wildlife - Management	0	105	155
Minerals/Mining	150	300	300

in the Central Arctic Management Area (CAMA), located north of the Brooks Range approximately 400 miles north of Fairbanks. The study has provided important information on wilderness and wildlife values, oil and gas resource potential, and oil and gas transportation within the CAMA. The study has also provided a significant amount of specialized data that will help define guidelines for management of the public lands within the CAMA. The ANILCA 1001 Study, or CAMA Report, will be completed and presented to Congress by December 1988. An associated document, the CAMA Wilderness Recommendation and Final Environmental Impact Statement, was published in October 1988.

The Bureau's Kobuk District in northwest Alaska has recently completed an aquatic HMP for the Norton Sound vicinity. This HMP inventoried anadromous fish habitat and identified habitat enhancement opportunities. The Kobuk District also completed HMPs for two Areas of Critical Environmental Concern (ACEC) in 1988. These plans established management actions for evaluating development on 200,000 acres of land in the Ray Mountains and near Galena. Sections of both these HMPs are concerned with monitoring caribou herds in the area of the ACECs.

During FY 88 and 89 the Bureau is preparing an HMP for the Colville River. This area

has one of the largest concentrations of cliff-nesting raptors in the world, with the most common species being peregrine falcons, gyrfalcons and rough-legged hawks. The primary objectives of this HMP are to assess the birds of prey and their habitats and to evaluate the suitability of the river for designation as a special birds of prey area.

The Bureau's renewable resources program in Arctic Alaska includes several ongoing wildlife habitat management programs. The Arctic District inventories, monitors and collects data on peregrine falcons, grizzly bear, Dall sheep, caribou and fish, including recreational opportunities for sport fishing. BLM cooperates with the National Park Service and the Alaska Department of Fish and Game in monitoring caribou and grizzly bear populations.

Radio collars attached to representative animals are very effective in monitoring the movements and population fluctuations of these species. During FY 88, fishery resources and recreational opportunities were studied along accessible rivers along the Dalton Highway. This area is within a few hours' drive of Fairbanks, and the demand for recreational use is expected to increase dramatically in the future. Additional inventory and monitoring efforts for fish and recreational fishing opportunities are planned for the Utility Corridor in 1989, 1990 and beyond.

The Bureau is particularly concerned with the protection and continued recovery of the Arctic peregrine falcon along the Sagavanirktok and Colville rivers. Although this falcon has been removed from the endangered list, it remains on the threatened species list. Recent surveys indicate that the population is increasing, with more breeding pairs returning to the Arctic each summer. Another important project for the District is the proposed introduction of the muskox into the central Arctic area. The idea developed during the Utility Corridor/CAMA planning process, and the project was initiated in 1988. An extensive environmental assessment effort, including public meetings in several North Slope villages where there is considerable interest in the re-introduction, is nearly complete. If the decision is to go ahead with the introduction, the Bureau expects to complete transplant operations in FY 89 or 90.

The Bureau's Arctic District, in cooperation with the U.S. Fish and Wildlife Service (FWS) and the Minerals Management Service, initiated an important research effort in the Teshkepuke Lake area during 1987. This area provides habitat for a variety of waterfowl and

*Gathering information on peregrine falcon chicks.*





*Traveling a newly marked easement on the treeless, snow-covered North Slope.*

shorebirds, including black brant geese, which use the area for breeding and molting each year. The region is also potentially important as a transportation corridor for North Slope oil and gas development activities. The current research effort is focused on the black brant, the energetic requirements of this sensitive species, and how development activities might interfere with these requirements. The project is planned to continue for five years, and the data are expected to provide important information for the Bureau to use in making management decisions in the Teshekpuk Lake area and other areas within the Arctic where waterfowl habitat and development activities may conflict.

In the Kobuk District, a number of inventory and monitoring projects have been completed, and others are planned for FY 89. Among the species being monitored are reindeer, caribou, moose and anadromous fish. The Bureau, in cooperation with the Alaska Department of Fish and Game (ADF&G), FWS and NPS, is investigating the movements of the western Arctic caribou herd and its interactions with domestic reindeer populations. Grizzly bear populations and habitat use on the Seward Peninsula are being studied in cooperation with the ADF&G and the NPS, and a multi-year inventory effort is planned with the FWS and ADF&G to evaluate moose habitat and opportunities for habitat improvement through the use of wildfire.

Monitoring of established oil and gas leases in the NPRA is an important activity in the Arctic District. Although no lease sales have

been held during the last three years because of the oil price decline and lack of interest by industry, the BLM continues to monitor those oil activities that are in operation or have been "mothballed" pending a change in current economic conditions. Geophysical activities also continue to be monitored to assure protection of other resource values. Under the Bureau's oil and gas program the potential for surface and subsurface land exchanges with the State of Alaska and Native corporations continues to be investigated in an effort to facilitate the development of the area's mineral resources and consolidate blocks of land for better management of NPRA's wildlife, cultural and other unique values.

The Bureau also recently completed the environmental impact statement for the Trans-Alaska Gas System (TAGS) pipeline and related facilities. A grant for the right-of-way is expected to be issued late in 1988. This will clear the way for construction of a gasline that will export North Slope gas to the Pacific Rim countries.

Gold mining continues to be an active program in northern Alaska. Under the authority of the FLPMA and in accordance with the 1872 Mining Law, the Bureau monitors gold mining activities and surface mining activities associated with the development of locatable mineral resources. Monitoring the extraction of gravel and other kinds of mineral materials important in Arctic construction and oil and gas exploration and development activities is also an important activity for the Bureau's Arctic District.

In other activities, the Arctic District has been involved in an identification and on-the-ground staking program of easements and over-land trails on the North Slope since 1984. This program is required by the ANILCA, Sec. 17(b). Approximately 350 miles of marked easements and trails, whose locations are determined in conjunction with the Bureau of Indian Affairs, the North Slope Borough, concerned Native groups, and local residents, are now in place. The trails, selected to minimize impacts to habitat, provide safe and sure transportation routes between Barrow, Wainwright, Atkasuk and the Kogru River northwest of Nuiqsut. The District expects to stake an additional 125 miles of easements and trails in FY 89. To the west, in the Kobuk District, inventories of cultural and historical values are being continued in the mountains near Nome and are expected to continue for several more years. Historical values in this area are primarily related to the gold rush days.



## National Park Service

The National Park Service conducts research in all of the areas it manages in Arctic Alaska: Noatak National Preserve (6,560,000 acres), Gates of the Arctic National Park and Preserve (8,440,000 acres), Bering Land Bridge National Preserve (2,770,000 acres), Cape Krusenstern National Monument (660,000 acres) and Kobuk Valley National Park (1,750,000 acres).

As units of the National Park System, these areas are managed to conserve the scenic, natural and cultural resources they contain for the use of present and future generations of people. Portions of Gates of the Arctic, Noatak and Kobuk are included in the National Wilderness Preservation System for the purpose of preserving their wilderness character. The principal uses of these units of the National Park System are for resource preservation, recreation and inspiration. In addition, they furnish a limited harvest of plant and animal resources for customary and traditional subsistence uses by rural residents, and, in the Preserves, for sport hunting.

In managing these areas to conserve scenery and resources while providing for nonconsumptive and consumptive uses, the National Park Service conducts applied research on topics identified in park resource management plans. This research may include the physical, biological, socioeconomic and cultural sciences, depending on the nature of the management need. The research may be conducted by Park Service scientists, by contractors, by co-operators or by independent scientists. To meet the most pressing and immediate

*Inspecting the teeth of an immobilized wolf in Gates of the Arctic National Park.*



### NPS FUNDING (thousands)

	FY86	FY87	FY88
Natural ecology			
Aniakchak	—	65	65
Bering Land Bridge	241	120	120
Denali	258	398	398
Gates of the Arctic	174	311	311
Cape Krusenstern	—	120	120
Noatak	205	79	78
Yukon-Charley Rivers	49	120	120
Cultural Resources			
Bering Land Bridge	—	65	75
Cape Krusenstern	—	150	149
Lake Clark	—	70	40
Interagency and International Cooperation	—	10	20

mandates for management, the natural resource research emphasizes data-gathering on resources that are consumed. Where possible this research also focuses on other natural resources, the processes that influence them, and the changes over time. The cultural resource research similarly focuses on resources that most directly relate to park mandates for management, to resources at risk of being lost due to natural or other causes, or to collection of baseline information.

### Natural Resource Research

FY 87 and 88 natural resource research focused on species-oriented studies and surveys. Wolf studies were conducted at Gates of the Arctic and Noatak in cooperation with the Alaska Department of Fish and Game. At Gates of the Arctic the activities of 16 packs were examined by tracking wolves with radio collars. The results show the wolves to be maintaining a stable land tenure system even though they are using a highly migratory caribou herd as an important prey base. The results also suggest that subsistence harvests were not excessive during the period of study. The methodology of the Noatak study is important because the wolves were monitored by satellite-tracked radio collars, which may increase the amount of data while eliminating aircraft risks during winter darkness. Moreover, both of these studies, as well as other studies and surveys of resources important for subsistence (including moose, Dall sheep, salmon and other fish, muskox, reindeer, brown bear and effects of all-terrain vehicles on tundra) that are being conducted in the northwestern park areas, have added importance because of the ongoing development of the Red Dog zinc mine site. A first report on all-terrain vehicle effects at Gates of the Arctic



*Archeological mapping along the Chukchi Sea coast in the Bering Land Bridge National Preserve.*

was published by the Cold Regions Research and Engineering Laboratory.

Studies of wolves at Denali National Park and Preserve, which is closely related ecologically to the Arctic, have monitored 10 packs in close coordination with studies of caribou, moose, Dall sheep and brown bears. Of 261 caribou calves radio-collared from 1984 through 1988, 40% died in May, with 47% of the dead caribou killed by brown bears and 29% killed by wolves. These studies at Denali of unmanaged animal populations are valuable not only for park management purposes, but also for the information they provide as a comparison for studies of similar animal systems in other areas where the animal populations are subject to harvest by humans.

Basic resource inventory projects were initiated at Aniakchak National Monument and Preserve the Bering Land Bridge National Preserve, and, to a lesser degree, several other parks in or near the Arctic. The Aniakchak work included a detailed limnological and fishery survey of Surprise Lake, which lies within the 6-mile-wide caldera but is connected to the Pacific Ocean by the 27-mile-long Aniakchak River that flows through a

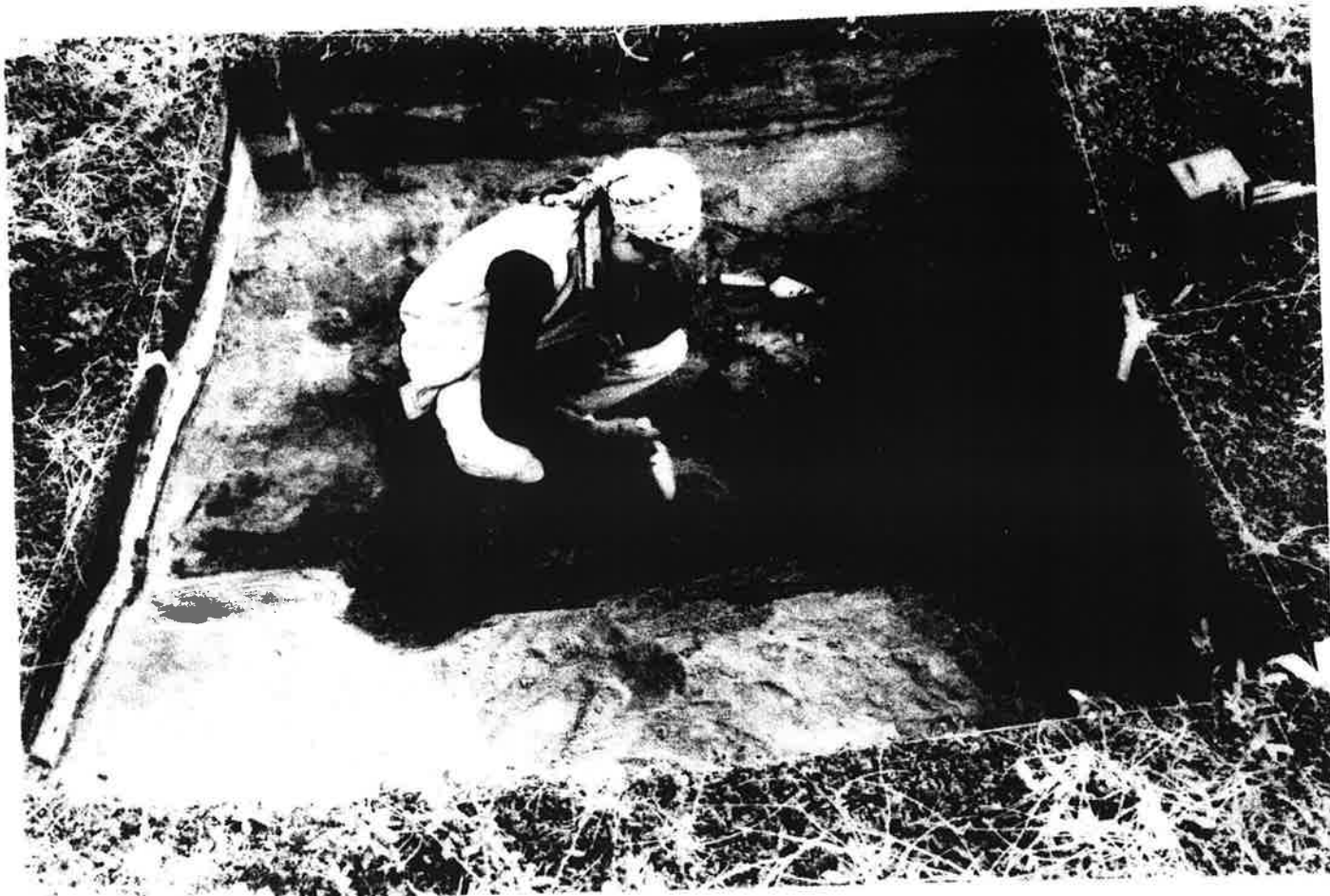
deep gash in the east side of the caldera wall. Other work included baseline water resource inventories at Bering Land Bridge and Denali, and development of plans to conduct such work in the Noatak in 1989. In addition, limited air quality monitoring was initiated in several of the northern parks.

The Regional Office continued development of its region-wide geographic information system (GIS) by acquiring needed staff and equipment. The GIS will be used in fire management, mining and minerals management, and basic cultural resource and ecological inventory and monitoring.

## ***Cultural Research***

Cultural research conducted by the National Park Service during the past several years focused on both cultural anthropology and archeology. A four-year study of past and present life patterns of the Dena'ina Indians of southwestern Alaska started in 1985 in Lake Clark National Park and Preserve and neared completion in 1988. This study, which approaches the Dena'ina from a holistic perspective by covering demography, resource use, social and political organization, world view and religion, has produced an ethnobotany of the Dena'ina and an archival-interpretive videotape of traditional Dena'ina fish storage techniques. The project has involved close cooperation between the National Park Service and the Dena'ina community, resulting in an ethnography being coauthored by a Dena'ina elder who also is a park ranger. The National Park Service has awarded a contract for a similar project to be conducted in the northwest parks between 1988 and 1991.

The Service conducted reconnaissance-level archeological surveys in the interior portion of the Bering Land Bridge National Preserve in 1985 and along the preserve's coastal lands adjacent to the Bering Strait, Chukchi Sea and Kotzebue Sound in 1986. These surveys, which encompassed about 24,000 acres (less than 1% of the preserve), documented 60 sites in the interior area of the preserve representing cultural occupations from the Denbigh Flint Complex (about 4200 years BP) to the Historic Inupiat period (about 50 years BP) and over 160 sites in coastal areas of the preserve representing Denbigh Flint Complex, Choris, Norton/Near Ipiutak, Kotzebue and Historic Inupiat occupations. The majority of archeological sites now known to occur in the



*Excavation of late Prehistoric house at Cape Espenberg in the Bering Land Bridge National Preserve.*

preserve appear to represent the last 1000 years of the regional cultural sequence. In conjunction with these archeological surveys, research was conducted in Bering Land Bridge on thaw lakes as repositories of paleoenvironmental information, on synthesizing data regarding the volcanic history of the Espenberg-Devil Mountain maars, on barrier island erosion and on sand ridge geomorphology. A report of the Bering Land Bridge work to date was published in 1988.

In 1988 the National Park Service also initiated an excavation project in Bering Land Bridge to investigate the extent and time depth of prehistoric occupations of the Cape Espenberg area adjacent to Kotzebue Sound and to recover information from eroding beach ridges. Information from this first of four years of work indicates that the beach ridge area was used intermittently in Arctic Small Tool and Ipiutak times and heavily from the Kotzebue Period through the late prehistoric.

At Cape Krusenstern National Monument the Park Service in 1988 completed the second year of a three-year archeological reconnaissance survey. The survey has identified 144

sites in addition to the beach ridge sites previously investigated.

The National Park Service also developed interagency and international cultural resource programs during 1988. In January it sponsored the first meeting of the Alaska Interagency Archeological Group for the purpose of increasing professional communication and sharing of information among Federal and State archeologists in Alaska. Topics addressed in this and subsequent meetings included how to improve the Federal archeology program, new technology in archeology, the U.S. Arctic Research Plan and Federally funded research in the Arctic, and research questions that can be addressed with data from Pleistocene megafauna remains found in placer deposits.

The Park Service's international activities included hosting two Soviet preservationists under terms of Area IV of the U.S.-U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection to work on projects in Sitka, Kodiak and Anchorage. In addition the Park Service extended an invitation for a Soviet archeologist to participate in a project in the Bering Land Bridge National Preserve in the summer of 1989. For more information

on the Alaska Interagency Archeological Group, contact Susan Morton, National Park Service, Anchorage, at (907) 257-2559. For more information on the Park Service's involvement in the U.S.-U.S.S.R. agreement, see the Spring 1988 issue of *Arctic Research of the United States* or contact Leslie Starr Hart, National Park Service, Anchorage, at (907) 257-2668.

## Publications

Readers may obtain further information on some of the research described in this article from the following publications:

*Nuvendaltun Quht'ana: The people of Nondalton*, by L. Ellanna and A. Balluta: in press.

*Beachridge archeology of Cape Krusenstern: Eskimo and pre-Eskimo settlements around Kotzebue Sound, Alaska*, by J.L. Giddings and D. D. Anderson: Publications in Archeology 20. National Park Service, Washington, D.C.

*Tanaina plantlore: Dena'ina K'et'una*, by P. Kari: Alaska Natural History Association, Anchorage, 1987.

*Effects of all-terrain vehicle traffic on tundra terrain near Anaktuvuk Pass, Alaska*, by C.H. Racine and L.A. Johnson: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H., Special Report 88-17, 1988.

*The Bering Land Bridge National Preserve: An archeological survey*, by J. Schaaf: Research/Resources Management Report No. 14, National Park Service, Anchorage.

## Bureau of Mines

The Bureau of Mines conducts mineral studies to provide information on mineral endowments and the potential for mineral resource development. These activities include evaluating the mineral reserve potential of mineralized areas, estimating the inferred reserve base at specific deposits, and sampling ores, especially for critical and strategic minerals. These programs are conducted and managed through the Information and Analysis Directorate in the Bureau of Mines. The information is used by Federal policymakers, land management and planning agencies, and Congress, who make land use and policy decisions that affect the availability, economics and long-term supply of domestically produced minerals.

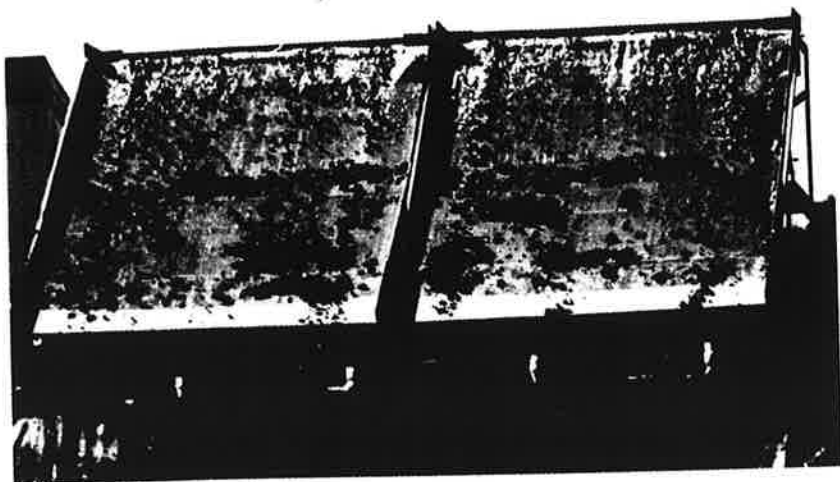
The Bureau's Arctic program is composed primarily of two activities: mining district studies in Alaska and site-specific investigations on Federal lands to identify strategic and critical minerals. Both programs are carried out by the Alaska Field Operations Center of the Bureau. The mining district studies systematically identify and estimate mineral reserves, characteristics of economic mineralization, mineral extraction methods, metal-

lurgical treatment methods, and production potential, including relationships to known mineral supplies. Bulk samples are collected for chemical analysis and metallurgical testing. The objective is to determine the mineral endowment of Alaska and the potential for economic development by private enterprise with an emphasis on critical and strategic minerals. A typical mining district study requires four years. Site-specific investigations follow up on favorable results from the mining district work.

The Bureau has developed a statistical method for estimating the economic potential of mineral resources. This method is being used in the Juneau Mining District and the Valdez Creek Mining District. The Bureau of Mines is providing the Bureau of Land Management with an economic impact analysis of the Steese-White Mountain area for their land use planning.

A future project of the Bureau of Mines in Alaska is a multi-year statewide assessment of strategic and critical minerals. This program will use a comprehensive geologic and engineering approach employing modern technologies in remote sensing, mapping, geophysical, geological and geochemical techniques, many of which were unavailable during previous investigations. The Bureau also intends to evaluate innovative methods being developed by Bureau research centers to resolve mining and environmental problems. Proposed projects include less intrusive mining methods for

	FUNDING (thousands)		
	FY86	FY87	FY88
Minerals	1,550	2,400	1,950



*Demonstration project using polyethylene oxide to clarify placer wash water, Livengood, Alaska.*

deposit definition and bulk sampling, in-situ and magnetic methods for mineral separation, and reclamation of waste disposal areas.

To help the placer mining industry of Alaska comply with Alaska environmental regulations, the Bureau of Mines' Tuscaloosa Research Center has conducted a series of demonstration projects in Alaska. These were designed to test the applicability of technologies to improve discharge water quality and to de-water slurries from mineral processing operations. Using the polymer polyethylene oxide, placer discharge waters are treated to reduce turbidity so that they conform to State of Alaska standards. The flocculated material is deposited in a disposal pit.

Heap leaching accounts for about a third of the gold produced in the U.S. but has not been extensively adopted in Alaska, which has many small or low-grade deposits suited to heap leaching. A problem that hampers heap leaching in cold climates is that operations must shut down during the winter because solutions freeze and percolation through the heaps cannot be maintained. There is great interest in the process, and research has been conducted on modifying heap leaching so that it can be used in the Arctic and Subarctic.

An approach that was tried in Canada was to build a heated building over the heap, but this is practical only if there is a source of waste heat. With a large heap this is not practical, especially if additional lifts are added to the heap each year. In the colder parts of Nevada, the leach solution is heated before it is applied to the heaps, allowing a longer operating season before freeze-up. The cost of heating the solution must be considered in terms of the total economics of the project. Another operation uses a drip irrigation system, with the hosing under about two feet of heaped ore in winter.

The U.S. Bureau of Mines is proposing a research program to address these and other cold weather problems. The program will investigate the addition of antifreeze, antiscalants or catalysts that enhance reaction rates. If the research is successful, small or low-grade properties in the northern climates that cannot afford the cost of conventional cyanidation plants may be brought into operation.



# National Science Foundation

*NSF 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 scientific disciplines: atmospheric sciences, ocean sciences, biological sciences, earth sciences, glaciology, engineering and education. The total expenditures for FY 87 were \$21.9 million and for FY 88 were \$23.1 million.*

For several decades the National Science Foundation has had a visible commitment to Arctic research. Since 1970 it has sponsored a formal Arctic Research Program assigned to the Division of Polar Programs. A number of other divisions and programs throughout NSF, primarily in the Directorate for Geosciences and the Division of Biotic Systems and Resources, support research in and on the Arctic as part of their overall funding. This dual funding approach within NSF offers multiple sources of support to researchers interested in the Arctic. Research grants are provided on the basis of unsolicited proposals and are peer-reviewed.

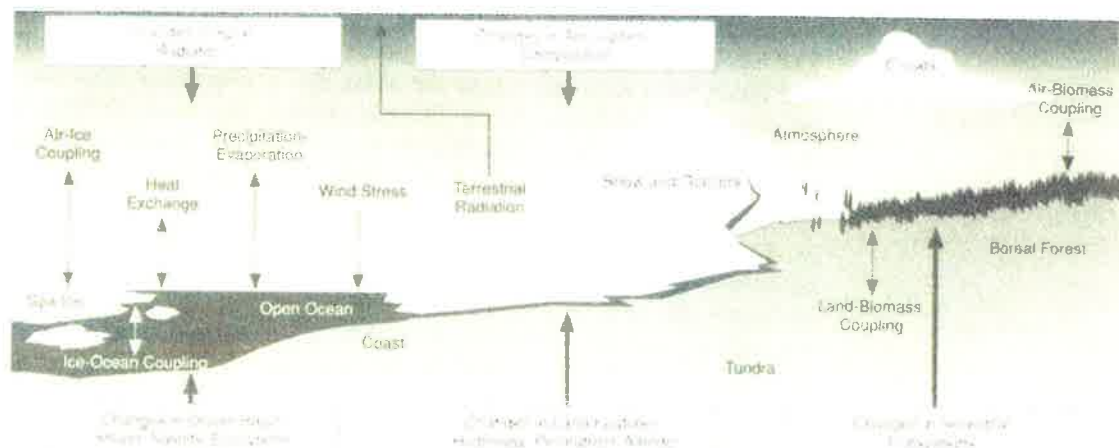
Because of the increasing prominence of polar research and the NSF's related responsibilities, the Chairman of the NSF's National Science Board established a special committee in June 1986 to review the role of the NSF in polar regions and to prepare a report of its findings and recommendations for consideration by the Board in June 1987. The purpose of the study was to provide guidance to the Board in shaping the most effective programs to meet the opportunities in polar research and thereby to enhance the contributions of

	FUNDING (thousands)		
	FY86	FY87	FY88
Atmospheric Sciences	5,759	5,972	7,544
Ocean Sciences/Ship Support	3,860	6,765	7,224
Biological Sciences	2,823	2,706	2,686
Glaciology	2,476	2,824	2,120
Earth Sciences	1,935	1,851	1,563
Engineering	663	746	897
Education	0	324	351
Coordination	340	237	258
Arctic Research Commission	286	465	480

polar research to national objectives and scientific understanding.

The Board's report, titled *The Role of the National Science Foundation in Polar Regions*, was published by NSF in June 1987 (as NSF publication NSB 87-128). The report recommended a doubling of NSF funding of polar research over a three-year period and increased emphasis for social sciences and engineering research related to the Arctic.

NSF has begun to implement the Board's recommendations. The first major initiative, Arctic Systems Science (ARCSS), will include studies of recent Arctic processes and interactions affecting global climate, and examinations of paleoclimate and past ecological conditions and responses.



*Arctic processes and interactions affecting global climate.*

In FY 87 and 88 NSF awarded funds for Arctic research to 88 institutions in 30 states and the District of Columbia. There were 206 research projects in 1987 and 210 in 1988. NSF's support of Arctic research, including facilities support and other field operations, over the past several years is shown below (in thousands of dollars):

	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88
Arctic Program (DPP)	5,887	6,209	7,344	7,947	8,005	8,095	8,211
Other NSF programs	8,650	6,732	9,191	11,482	10,139	13,799	14,907
Total	14,537	12,941	16,535	19,429	18,144	21,894	23,118

Complete details on NSF Arctic funding may be found in the publication *Arctic Science, Engineering, and Education Awards: FY 1987 and FY 1988*, available from Polar Coordination and Information, Division of Polar Programs, National Science Foundation, Washington, D.C. 20550.

## Atmospheric Sciences

NSF expenditures in the atmospheric sciences were \$6 million in FY 87 and \$7.5 million in FY 88 and averaged 62 projects per year. NSF supports Arctic atmospheric research in meteorology, climate dynamics, tropospheric chemistry, aeronomy, magnetospheric physics and solar-terrestrial physics. Within these disciplines, research involves studies of Arctic stratus clouds, Arctic haze, long-range transport of aerosols and trace gases over the Arctic Basin, precipitation and dry deposition on glaciers and ice sheets, magnetosphere-ionosphere interactions, very-low-frequency waves, auroras, and precipitation of energetic particles from the magnetosphere by VLF waves and magnetic pulsations.

These major research questions naturally concentrate on the unique polar environment. The Earth's magnetic field focuses particles and fields from near space into the polar upper atmosphere and ionosphere. There is, therefore, a complex, polar, high-altitude boundary where the sun, magnetosphere, ionosphere and atmosphere tightly couple together. The Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) program addresses this area by remote sensing in the atmosphere and mesosphere regions, which are difficult to assess by satellites, balloons or rockets. CEDAR is an approved program of the NSF Global Geosciences initiative. Similarly, a magnetosphere program is being

planned: Geospace Environment Modeling (GEM), which addresses the magnetosphere's inputs to the polar atmosphere. Both of these programs rely heavily on observation stations in Alaska, Canada and Greenland. Instruments are being upgraded and installed in places such as Fairbanks (Alaska), Svalbard (Spitsbergen) and Sondrestromfjord (Greenland). The overall aim is to have a comprehensive view of the Arctic atmosphere suitable for the interdisciplinary research objective of "Global Geosciences."

Over the past few years it has become evident that unique and important chemical reactions may occur in the polar stratosphere that influence the global-scale composition of the middle atmosphere. Much scientific interest and debate has been stimulated by the finding that a "hole" exists in the stratospheric ozone layer over Antarctica during the austral spring, and that this hole has apparently been enlarging during the past decade. Current evidence suggests the need for more complete examination of the chemical reactions that might occur in the polar night stratosphere. The scientific data available suggest that more information about the chemistry of the stratosphere over the Arctic may provide new insights about the importance of the polar regions in influencing stratospheric composition on the global scale.

To study stratospheric ozone chemistry in the Arctic, NSF supported research at the University of Michigan and cooperated with NOAA (see p. 52) to conduct exploratory studies relating to the chemistry of the polar night stratosphere. The objective was to measure key constituents of the Arctic stratosphere from a ground-based site in Thule, Greenland, during January and February 1988. These studies provided the first evidence that ozone-destroying forms of chlorine found in the Antarctic stratosphere also form over the Arctic during the winter.

The chemistry of auroral processes, including the production of nitric oxide and its transport to lower altitudes, is also a concern of aeronomy research. Auroral research by optical techniques is concentrated at Fairbanks, Alaska, for the nighttime aurora and at Spitsbergen for the daytime aurora. The dynamics of the mesosphere and thermosphere are investigated using spectroscopy of airglow emissions and interferometric observations of upper atmosphere neutral and ion wind velocities.

This work led to new discoveries of atmospheric stratification in the mesosphere and

*Principal regions of geospace to be investigated by the GEM program.*

*I: Magnetopause, boundary layer and cusp.*

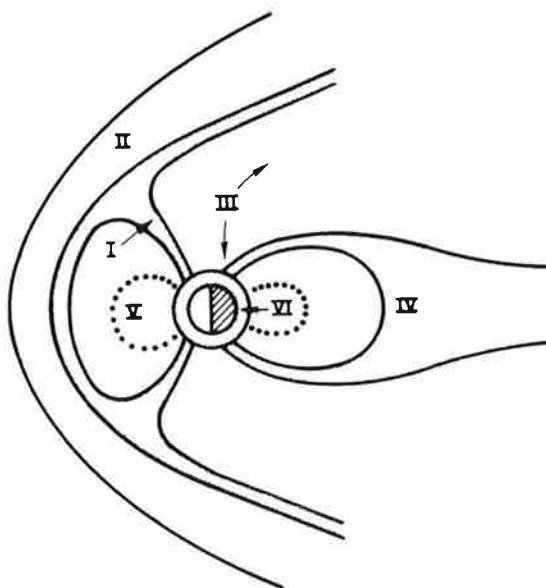
*II: Magnetosheath.*

*III: Polar cap and magnetotail.*

*IV: Plasma sheet and sub-storm region.*

*V: Plasmasphere.*

*VI: Middle atmosphere.*



lower thermosphere. Similar layers 1–2 km thick with up to an order of magnitude enhancement above ambient have been observed (but not simultaneously) for sodium abundance, electron density, polar mesospheric cloud particles, noctilucent cloud particles and auroral luminosity, and they are drawing increased research activity. Theories about this layering involve wave–particle interactions from above and below in both the neutral and ionized constituents.

Combined rocket, radar and optical studies have shown that high-resolution, ground-based optical techniques are feasible for determining the height variability in atomic oxygen abundance above the mesopause in the auroral region. This measurement is one of the most critical needs in understanding the many auroral and airglow emissions and the ozone chemistry of that region.

Modeling, radar and optical studies have improved an ionospheric–neutral coupled global thermospheric circulation model. The highlights of these studies were establishing the importance of the orientation of the interplanetary magnetic field, demonstrating the truly global impact on the circulation of polar magnetic disturbances, and determining the configuration of the ion convection pattern at the polar cap.

Meteorology research is carried out in Greenland (both along the coast and on the ice sheet), over the Arctic Basin by aircraft and ships, and at ground stations around the perimeter of the basin. Efforts are directed at examining trace deposition of pollutants that originate at mid-latitudes and studying the radiative heat balance as it is affected by

clouds. Analysis of data from the 1983 and 1986 Arctic Gas and Aerosol Sampling Project (AGASP) over Alaska, Canada and Greenland continues. A NOAA program is planned for the eastern Arctic in spring 1989 (see p. 52).

A major research program in upper atmosphere physics, involving many investigators, is a study of ULF wave–particle interactions. There is a concentration of ionospheric, magnetospheric and ULF instrumentation located in the Roberval–Lake Mistissini, Quebec, area. In addition, ionospheric and auroral instrumentation is maintained at Frobisher Bay, N.W.T., and Sondrestromfjord, Greenland, which are conjugate to similar equipment in Antarctica.

A special program for upper atmospheric facilities provides support for four large atmospheric observatories, including the incoherent scatter radar facility at Sondrestromfjord. This facility is dedicated to providing a better understanding of high-latitude magnetosphere–ionosphere–atmosphere coupling phenomena and atmospheric dynamics. It is the northernmost station in a chain of upper atmosphere observatories reaching from Greenland to the magnetic equator. These facilities are operated simultaneously to allow scientists to investigate global-scale upper atmosphere phenomena. Current research carried out by staff and users of this facility includes investigations into global modifications of the ionosphere and thermosphere triggered by energy deposition into the polar ionosphere, joint NSF–NASA–Air Force radar and sounding rocket experiments of high-latitude ionosphere irregularities, and joint radar and airglow experiments of the high-latitude thermosphere.

The largest and perhaps most fruitful of these experiments was the Coordinated Observations of Polar Electrodynamics (COPE) rocket campaign conducted in 1985 and 1987. Eighteen sounding rockets were successfully launched from Sondrestromfjord. Real-time diagnostics from the Sondrestromfjord radar were used as the basis for many of the launch decisions. The phenomena investigated spanned magnetospheric, ionospheric and plasma physics, as well as coupling to the neutral atmosphere. The radar's function went beyond simply diagnosing launch conditions for the chemical release rockets; for example, the radar was used to specify the magnetospheric forcing function to which the neutral atmosphere responds. For the triple rocket salvo in 1987, which measured the spatial correlation of electric- and magnetic-field fluctuations, the radar specified the two-dimensional spa-

tial variations in conductivity along the magnetic field lines traversed by the rockets. Such a complete experiment could not have been performed without the ground-based facilities mentioned above.

## Ocean Sciences

NSF expenditures in oceanography were \$6.8 million in FY 87 and \$7.2 million in FY 88 and averaged 29 projects each year. The high-latitude oceanic environment is an integral part of the global climate system. The polar oceans are comparatively small but are well defined and make a unique imprint on processes that have far-reaching importance. The cold surface waters of the polar oceans allow the deep ventilation and vertical exchange that produce the intermediate and bottom water masses of the global ocean. The atmospheric energy advection and exchange processes that form the polar heat sink are helping determine global climate variability. All aspects of the global atmospheric and oceanic circulation have their high-latitude expressions, modulated by the quasi-permanent sea ice cover of the Arctic Ocean.

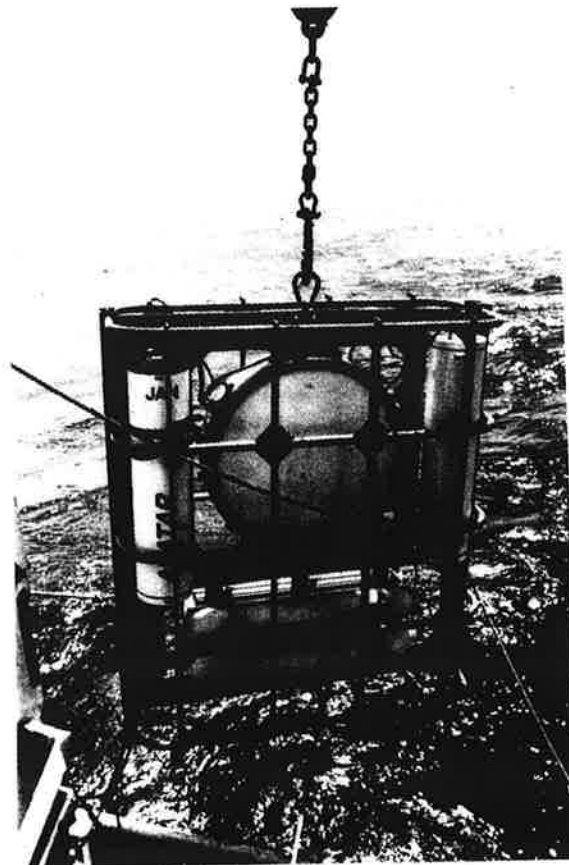
A study of the three-dimensional kinematics of the Greenland Sea with a moored acoustic

array, together with supporting hydrographic information, is the major NSF-sponsored contribution to the Greenland Sea Project. The array, in the form of a pentagon with a central mooring at approximately 75°N, 2°W, was emplaced in the summer of 1988 and is scheduled for recovery in September 1989. Supporting hydrographic data were obtained on three cruises: *Valdivia* in June 1988, *Polarstern* in June 1988 and *Haakon Mosby* in July 1988.

In the Greenland Sea, one of the major unresolved questions is the degree to which the water mass spins up in autumn and winter, bringing deep isopycnals closer to the surface, destabilizing the water column, and providing the environmental conditions for deep convective events to take place. The acoustic array is expected to define regionally coherent circulation features and detect the convective events themselves. The acoustic data provide a "snapshot" of the actual ocean circulation every four hours; the continuity of the roughly 2000 snapshots that will be obtained can produce a precise description of the evolving circulation. The horizontal resolution of the array will be limited by the low number of source-receiver pairs, but the resolution of the vertical structure, averaged over horizontal planes, is expected to be good. Additionally, observations on reciprocal paths around the triangles that form the subunits of the array will provide integrated circulation information on a relatively small geographic scale.

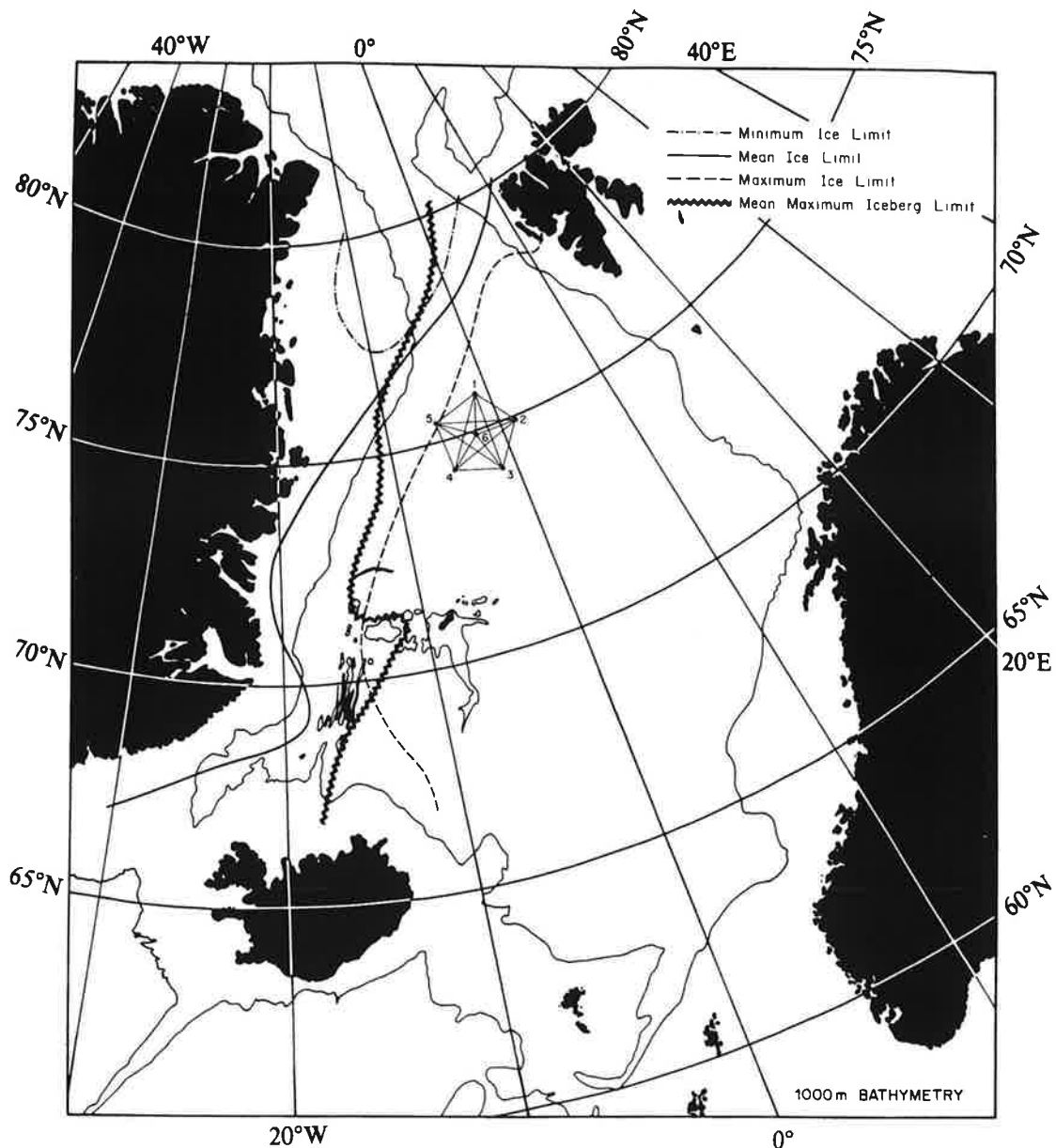
During the deployment cruise the feasibility of moving ship tomography was also tested. As the ship circumnavigated the array, it lowered vertical receiving equipment at four-hour intervals to record the signals transmitted by the moored sources. The number of ray paths was many times larger than the number of available source-receiver pairs, and the sound-speed field obtained over the approximately nine days of circumnavigation had a much higher resolution. The fidelity with which the inverted acoustic data represent the actual oceanic circulation field can be tested with the simultaneously obtained current meter and acoustic Doppler profiler data.

The multi-investigator program ISHTAR (Inner Shelf Transfer and Recycling) in the Bering and Chukchi seas continued to study the seasonal and interannual variation in the northward transport of water and its influence on biological processes. A total of 1194 oceanographic stations using over 200 ship-days and four research vessels were employed. In addition, 29 instrument moorings were de-



Acoustic transceiver  
being deployed in  
the Greenland Sea.

Location of the Greenland Sea Tomography Experiment, with five acoustic transceivers deployed in the form of an equilateral pentagon and a sixth in the center.



ployed and recovered, several of which remained deployed during the winter. A program with Japan's National Polar Research Institute resulted in the deployment of sediment traps on several 1987 cruises.

Other projects studied the phytoplankton blooms at the retreating ice edge to identify the fate of the resulting organic material and its utilization by consumer communities and to compare production and carbon flux processes with those at lower latitudes. Evidence suggests that a considerably larger fraction of the organic material in Arctic waters reaches the sediments without being grazed by zooplankton. In the Chirikov Sea, for example, this material is grazed by benthic gammarid amphipods, which appear to be a major component of the diet of the gray whale. Radio-

nuclides (from early atmospheric bomb-testing and from leaks from the Windscale and Chernobyl nuclear power plants) can be used to identify the movement of water masses with time in order to develop a more accurate picture of the flow into and out of the two major deep Arctic basins. A 1987 cruise aboard the German research ship *Polarstern* identified "young" inflowing Atlantic water by its Chernobyl signature, which may be followed as it circulates through the Arctic over the next few years.

Over the past several years the University-National Oceanographic Research Laboratory System (UNOLS) ships operated in the Arctic in support of NSF-funded projects. For the western Arctic these included the *Alpha Helix* (the only NSF ice-strengthened ship, operated



by the University of Alaska), the *Thomas G. Thompson* (University of Washington) and the *Thomas Washington* (Scripps Institution of Oceanography). Projects supported by these ships included ISHTAR, amphipod production, sea bird population dynamics, gray whale feeding, sea otter foraging, and geological and geophysical studies. In the eastern Arctic the *Endeavor* (University of Rhode Island) and the *Knorr* (Woods Hole Oceanographic Institution) supported studies on the ecology and population dynamics of gelatinous zooplankton, the deployment of experimental current meters, and the acoustic tomography project; several of these are joint studies with the Office of Naval Research. The NSF Division of Ocean Sciences manages and provides funding for these ship operations, which in FY 87 was an estimated \$2.3 million and in FY 88, because of an increase in the number of cruises, was estimated to be \$3.0 million. These increases in direct science support are reflected in the overall increased funding of NSF Arctic research during FY 87 and 88.

### *Biological Sciences*

NSF expenditures in the biological sciences were \$2.7 million in both FY 87 and 88 and averaged 21 projects per year. Noteworthy major activities in terrestrial biology were the establishment of two Long-Term Ecological Research (LTER) projects in Alaska, one in

boreal forest (taiga) and one in tundra. The first site, Bonanza Creek Experimental Forest, is 15 miles west of Fairbanks (lat. 64°45'N) and lies within the zone of discontinuous permafrost. Building upon a decade of intensive ecosystem research, the new LTER studies deal with both primary successional processes in the flood plain of the Tanana River and secondary succession in the uplands.

The Arctic tundra LTER site (lat. 68°38'N) is in the area of Toolik Lake at an elevation of 2500 ft in the northern foothills of the Brooks Range. Over the past decade the University of Alaska's research camp at Toolik Lake has emerged as a major center of ecological research in northern Alaska. This site, 360 miles north of Fairbanks, is accessible year-round by an all-weather road, although the operations normally are limited to May through September.

Funding for the Arctic LTER program amounts to \$450,000 per year and comes from the Division of Biotic Systems and Resources through their Ecosystem Studies Program. The LTER program is coordinating a number of other ecological research projects, including a major aquatic research program funded by the Division of Polar Programs. Additional research on the biogeochemistry of the terrestrial landscape is also supported by the Ecosystem Studies Program.

Long-term aquatic research at Toolik Lake began in 1975, with terrestrial ecologists starting experiments and observations there in 1976. Since then, about 25-30 senior investi-



*Typical diversity of ecosystems near the LTER site at Toolik Lake.*



*Experimentally divided lake near the Toolik LTER site.*

gators and many more students and technicians from institutions in the United States and Europe have conducted research at Toolik Lake. The Arctic LTER program at Toolik Lake is designed to build on this extensive research base, to provide core funding for ongoing, long-term experiments, and to link terrestrial, lake and stream studies more explicitly than has been possible in the past. The program includes 15 principal investigators from seven institutions, including the Universities of Alaska, Cincinnati, Kansas, Massachusetts and Minnesota. The lead institution is the Marine Biological Laboratory, Woods Hole, Massachusetts.

The heart of the program is a series of parallel, whole-ecosystem experiments in lakes, streams and the major terrestrial ecosystems. The experiments are of two kinds: "top-down" manipulations of herbivores or predators, and "bottom-up" manipulations of nutrient availability. The overall goal is to separate the roles of animal consumers from the plant and nutrient responses as controls over terrestrial and aquatic ecosystems.

Manipulation produces major changes in productivity and species composition within trophic levels or guilds, and its effects can often be traced clearly through several trophic levels. For example, phosphorus fertilization of the local river changed the entire basis of the food web from heterotrophy to autotrophy by stimulating algae growth. It also changed the structure of the insect community by favoring grazers over filter feeders, and it

sharply increased the growth of larval and adult fish. An important reason for continuing these experiments in the long term is that not all species respond at the same rate, and there is much to be learned by observing the sequence of changes and interpreting its causes.

A second major goal of the Arctic LTER program is to advance understanding of how mineral nutrients move over the Arctic landscape, from terrestrial to aquatic ecosystems. This goal is especially important in the context of human disturbance, because we know that the structure and productivity of terrestrial ecosystems is strongly nutrient-limited, and that disturbance in general tends to increase nutrient cycling rates and overall nutrient availability. We also know that aquatic ecosystems are strongly dependent on nutrient inputs from the surrounding tundra. The research is focusing on developing a model of nutrient transport and using stable isotopes as tracers to identify major sources, sinks and pathways of element cycling. The evidence collected to date suggests that primary productivity in some sites may depend on nitrogen inputs from adjacent ecosystems for as much as 10–20% of their annual nitrogen requirement.

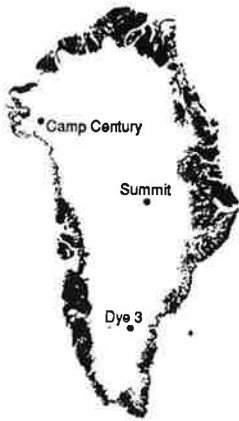
The biological and ecological research programs also support individual projects on a variety of topics, including soil and plant development, microtine population dynamics, tree growth responses and marine mammals.

Renewed interest in the Arctic social sciences, partly in response to the National Sciences Board report, resulted in funding several projects in cultural, social and physical anthropology and archeology.

## *Glaciology*

NSF expenditures in glaciology were \$2.8 million in FY 87 and \$2.1 million in FY 88 and averaged 26 projects per year. Glaciological research yields information about the paleoenvironment over periods as long as hundreds of thousands of years. NSF and the glaciological research community have formulated a glaciology research strategy to integrate glaciological research with other global change programs.

NSF supports a broad multi-disciplinary glaciological research program that involves the physics of glacier flow; mathematical modeling of glaciers, ice streams and the Greenland ice sheet; and the chemistry of ice



cores as indicators of long-term climate change. The program supports research on new methods of studying glaciers and ice sheets, including development of improved remote sensing capabilities, drilling methods and methods for analyzing ice cores.

The principal thrust of the glaciological research program is the deep drilling program in Greenland, GISP II (Greenland Ice Sheet Project II). GISP II and a corresponding European effort (GRIP, the Greenland Icecore Program) plan to retrieve ice cores to the base of the central Greenland ice sheet (a depth in excess of 3000 m). Conditions at the proposed drill site are such that the resolution of seasonal layers in the ice will be possible back to approximately 10,000 years, and the total record could include the last 200,000 years. During 1987, glaciologists and geophysicists focused on the choice of drilling sites at Summit in north-central Greenland. Because an ice sheet is a dynamic, deforming medium, detailed knowledge of the ice flow is necessary for dating the deep ice. Even with independent dating techniques, it is necessary to understand how, and from where, the ice has flowed throughout the time span covered by the ice cores.

Other research and planning studies have been concerned with developing equipment and procedures for handling the ice cores once they are recovered and the protocols for sampling and analyzing ice cores, including whether the analysis should be done in the field or in the laboratory. These studies are the necessary prelude to the full-scale GISP II program, which is expected to begin in 1989

and continue for five years. In preparation for GISP II, a test coring program at DYE-3 in southeast Greenland was conducted during the summer of 1988. The first increment of funding (\$2 million) for the polar ice coring program is contained in the FY 89 budget of the Division of Polar Programs and is considered the startup of the Arctic Systems Science (ARCSS) program.

Other locations, such as Alaska and China, are important sites for recovering ice core records. These sites provide documentation of the remote atmosphere and major atmospheric circulation patterns.

In China, the Dundee ice cap at 38°N is in a location where conventional long-term climatic data are virtually nonexistent. A joint project between the Ohio State University and the People's Republic of China successfully recovered ice cores drilled to bedrock. These cores are expected to yield information on general environmental conditions over at least the last 3000 years. Preliminary analysis of data from these cores also indicate that each ice core contains 10–13 m of Wisconsin glacial stage ice. This is the first glacial stage ice to be recovered from a nonpolar location.

In Alaska, researchers are investigating the sudden surge of the West Fork (Susitna River) Glacier after a quiescent period of about 40 years. Glacial motion is strongly influenced by liquid water at its bed, among other factors. Observation programs at both the West Fork Glacier and the Fels and Black River glaciers in the Alaska Range are using time-lapse photography and seismicity data from the glacier.



*Surface of the West Fork Glacier, Alaska.*

## Earth Sciences

NSF expenditures in the earth sciences were \$1.9 million in FY 87 and \$1.6 million in FY 88 and averaged 35 projects per year. Geological, geophysical and Quaternary research is supported throughout much of the Arctic. Projects seek to understand the tectonic evolution and geologic history of the Arctic Basin and to answer regional and local geologic questions. Arctic regions demonstrate wider swings in climate through geologic time than temperate and tropical regions. Studies of the paleoclimate are therefore not only significant for understanding the geologic history of the Arctic, but they yield important data on global climatic history. Evidence of the paleoclimate of the past 12,000 years is particularly well preserved in the lake sediments and paleosoils. Studies of shallow-water sediments and terrestrial deposits are important for establishing a detailed chronology of paleoclimatic and paleoecologic events. A workshop was held at the University of Colorado in May 1987 to define the scientific questions and techniques needed to extract additional paleoenvironmental information from high-latitude lake sediments and their surrounding environment.

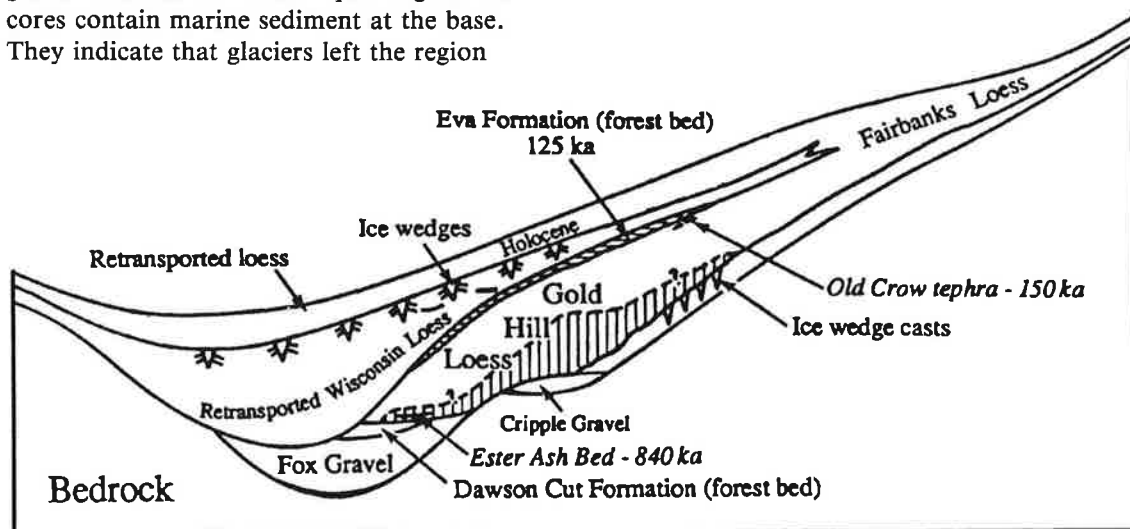
Several glacial, marine geology, and periglacial and soils projects continue in Svalbard. Despite its small size and geographic isolation, the Svalbard Archipelago is an extremely sensitive indicator of climatic changes. The interaction between atmospheric circulation, oceanic temperature and glacier activity has been a focus of research for several years. In a collaborative research program between the University of Colorado and the University of Bergen, a series of 14 piston cores up to 14 m long were recovered from a glacier-fed lake in western Spitsbergen. The cores contain marine sediment at the base. They indicate that glaciers left the region

more than 10,000 years ago and that the regrowth of local glaciers began about 4,000 years ago, although only within the last few centuries were conditions severe enough to establish glaciers in the lowest cirques.

Several projects are examining the depositional history of interior Alaska. A detailed geologic record of the past two million years is preserved in the nonglacial sediments of the Fairbanks area. Perennially frozen gravel, loess and retransported loess with several interbedded tephra layers preserve a rich floral and faunal history and record climatic changes in a periglacial Quaternary environment only tens of kilometers from the glaciated Alaska Range. The long-studied loess succession is one of the oldest and thickest in North America (100 m). With geochemical and petrographic identification and isothermal plateau fission-track dating of tephra, paleomagnetic studies of loess, thermoluminescence dating of loess and tephra, and examination of new vertebrate fossil localities, the record has become greatly refined and confirms an interglacial age of Eva Creek Forest Bed (125,000 years) and the Wisconsin age of the overlying Goldstream Loess. A basal tephra may be older than 840,000 years.

A project on the vegetational and climatic history of southwestern Alaska is exploring the relationship of modern pollen to modern vegetation and climate. It involves collecting and analyzing fossil pollen from lake sites to describe the paleovegetation and paleoclimate. These data, combined with previous palynological data, will enhance our understanding of the late-Quaternary climate and vegetation in northwestern North America.

In northern Alaska a study of Late Cretaceous vertebrate fauna suggests that Alaska



Stratigraphic relationships of Quaternary deposits in a creek valley near Fairbanks, Alaska.



*Ice wedges exposed in silty permafrost at a placer mining operation on Eva Creek near Fairbanks, Alaska.*

was part of an intercontinental route of dispersal and that it supported a diverse fauna. The discovery of concentrations of dinosaur bones on the Alaskan North Slope opens the possibility for the first assessment of the composition of this Cretaceous fauna. The U.S. Geological Survey is investigating the invertebrate paleontology, paleobotany, tephrochronology and magnetostratigraphy of this geological section. The site is yielding information on the tolerances of some dinosaurs to extremes in temperature and light regime. This is important in assessing current hypotheses concerning dinosaurian extinction, most of which invoke either catastrophic or gradual environmental change as the causal factor.

## *Engineering*

NSF expenditures in engineering were \$750,000 in FY 87 and \$900,000 in FY 88. An average of 12 projects were supported each year. Support in engineering, material sciences

and permafrost are provided from the Engineering, Geosciences, Material Sciences and Small Business Innovative Research (SBIR) programs. Research includes studies of the mechanical properties of ice, the hydraulic conductivity of frozen soils, metamorphism of dry snowpacks, three-dimensional analyses of ice, and permafrost. Support is also provided for international conferences. A workshop to further define priorities in cold regions engineering was held in Hanover, New Hampshire, in December 1988. The results will be reported in a forthcoming issue of this journal.

Permafrost research in the U.S. is primarily centered in Alaska, where extensive areas are underlain by perennially frozen ground. In addition, considerable areas of the Beaufort Sea continental shelf are underlain by subsea permafrost. Research continues on the distribution and origin of frozen sediments, ground ice and its properties, and recent climate changes as recorded in ground temperatures. The seafloor has significant engineering importance in the production and transmission of oil and gas. Basic research on terrestrial permafrost has yielded significant data on paleoclimate, recent changes in climate, and engineering geology in areas with potential energy and mineral resources. Of particular interest will be conclusions from several projects that are studying permafrost-climate relationships in the more southerly discontinuous permafrost zone. It is here where a warming of several degrees could create severe environmental and engineering problems as thawing of the ground accelerates.

Other engineering projects funded by NSF include a study of the effects of building heating and solar heating on snow deposition on roofs and a study of ice accretion rates and icing loads for an array of simple structural elements, including standard power transmission cables. Mathematical models of the creep of polycrystalline ice are being used to predict ice motion. Several materials engineering projects involve studies of the physical properties of ice. The results of these projects will aid in predicting the load-carrying capacity of ice and the ice loading of structures such as bridges.

NSF sponsors a program for science-based and high-technology small business firms, the Small Business Innovative Research (SBIR) program. 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 87 and 88, NSF funded research in the



Arctic under the SBIR program in the following areas:

- The prediction of the effects of freeze-thaw on materials and construction design;
- Geophysical techniques to determine frozen ground masses and the presence and configuration of buried and surface masses of ice;
- Sea ice profiling based on geophysical data; and
- Cold climate clothing and protection.

## Education

NSF expenditures in science and engineering education were \$320,000 in FY 87 and \$350,000 in FY 88 and averaged eight projects per year. Several programs in the Directorate for Science and Engineering Education (SEE) focus on improving science teaching and increasing interest in science and engineering careers among Native Americans. A grant under the Young Scholars Program and several supplements to research projects provided Alaska Natives pre-college and undergraduate opportunities to become involved with summer research experiences. Other projects at the University of Alaska are focusing on the teaching of science and mathematics in predominantly Native schools. One project will

develop, test and disseminate chemistry and physics laboratory courses for prospective Native Alaskan elementary school teachers. In addition, support was provided for a special teacher's workshop held in Fairbanks as part of the AAAS Arctic Science Conference in October 1988. In its continuing nationwide program to reward excellence in science and mathematics teaching, the Presidential awards program recognized, in 1987 and 1988, four Alaskan teachers from Kotzebue, Anchorage and Fairbanks.

Within the Geosciences Directorate and in support of interagency Arctic coordination, several other activities are focusing on Native involvement in research. A pilot project to present research approaches and results to local residents was undertaken in 1988. There is additional interagency coordination of on-the-job experiences in natural sciences and resources. Portions of the Arctic Research Plan are being translated into Inupiat. Several undergraduate awards were made in support of glaciology and atmospheric sciences.

## Coordination

NSF expenditures for information, planning and advisory services and for the Arctic Research Commission were \$700,000 in FY 87 and \$740,000 in FY 88. NSF supports a program of polar information and advisory services, provides support for the Interagency Arctic Research Policy Committee, provides funds for the Arctic Research Commission in its annual budget, partially supports the National Academy of Sciences Polar Research Board (PRB), and supports workshops and studies to further develop and implement Arctic research planning and policy.

A study is underway at the PRB, sponsored by NSF and several other agencies, to develop recommendations for an Arctic Social Sciences Program. A workshop on research opportunities on federally protected lands in Alaska was held in October 1987 and is resulting in recommendations for the types of research needed and the ways in which scientists, residents of the Arctic and agencies can work together on these lands. A June 1988 conference of northern librarians resulted in recommendations and plans for a polar information network. A proceedings volume is available (Glaciological Data Report GD 22) from CIRES, University of Colorado, Boulder, Colorado 80309.

*Barrow high school student working with a researcher on a study of thaw lakes.*



# Department of Defense

*Arctic research is conducted by all three services and includes virtually all environmental sciences, engineering and health disciplines. A total of \$25 million was devoted to basic research and related testing in FY 87, and \$23.9 million was expended in FY 88.*

The Arctic research program of the Department of Defense is designed to develop the knowledge, understanding and capability to conduct military operations in the Arctic as the defense needs of the nation require. The scope of current research ranges from human performance in Arctic environments to Arctic engineering to oceanography to atmospheric and ionospheric research at high latitudes.

Because of their specific missions, the different armed services have different research goals. The Army is strongly driven by requirements to understand the character and behavior of Arctic terrain, cold-weather human performance and Arctic engineering. The Navy's Arctic interest is obviously oceanographic, but it also includes low-level weather conditions over polar ice and their impact on ice behavior and naval operations. The Air Force's primary interest in the Arctic is the impact of ionospheric processes on communications, navigation and surveillance systems.

The Army's concern with the Arctic stems primarily from its troop units and installations located in northern regions. Three major bases are located in Alaska. Forts Wainwright and Richardson are home to the new 6th Light Infantry Division, while Ft. Greely is home to the Cold Regions Test Center and the Northern Warfare Training Center. The Alaska District of the Army Corps of Engineers, located on Elmendorf Air Force Base and Ft. Richardson, has responsibilities in military construction, water resources and environmental impact permits. Additionally, the 10th Mountain Division at Fort Drum, New York, must be capable of operating in winter terrain.

Both nationally and internationally the Corps of Engineers is called upon to provide construction and engineering services at cold weather sites. These include Army bases in Korea, Europe and the northern tier of the U.S., as well as Air Force sites in Canada, Greenland, Iceland and Norway. The Army's Arctic research focuses on troop and engineering support for these northern environments.

	FUNDING (thousands)		
	FY86	FY87	FY88
Arctic Engineering	5,596	849	2,111
Frozen ground and geology	1,306	1,138	1,538
Snow, ice and hydrology	2,257	2,191	2,287
Oceanography	7,191	11,247	9,235
Lower atmosphere	2,799	1,600	1,848
Upper atmosphere	4,523	5,300	4,700
Medical and human engineering	2,964	2,636	2,057

There are five U.S. Army organizations involved in Arctic research: the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire; the Cold Regions Test Center, Ft. Greely, Alaska; the Natick Research, Development and Engineering Center, Natick, Massachusetts; the Army Research Office (ARO), Research Triangle Park, North Carolina; and the Medical Research and Development Command, Ft. Detrick, Maryland. The mission of CRREL is to study the characteristics of cold regions and to use this knowledge to solve the cold regions problems of the Army and other Federal and State agencies. CRREL conducts the largest share of the Army's Arctic-related research, concentrating on snow and ice, and Arctic engineering, and it sponsors the Cold Regions Science and Technology Bibliography at the Library of Congress, which included over 4500 citations each year for 1987 and 1988. Natick conducts research on cold regions clothing, equipment and rations, while the Medical R&D Command investigates basic cold physiology and cold stress adaptation. ARO sponsors Arctic-related basic research in snow, ice, atmospheric propagation of near-millimeter waves (NMMW) in adverse weather including snow, and NMMW backscatter from snow surfaces. The ARO program provides support to CRREL and other Army cold regions research and development activities and is executed largely through grants and contracts to the university research community.

The Army Cold Regions Test Center at Ft. Greely, Alaska, is a test and evaluation activity focusing on cold weather operations; it

*Troops of the Army's  
6th Light Infantry  
Division training near  
Ft. Wainwright.*



does not conduct research. It performs technical testing for the Army Materiel Command developers and for other DOD agencies and services, government agencies such as NASA, and industry. Its support facilities, instrumentation and firing ranges allow it to test a variety of military equipment and weapons.

Air Force efforts over the past several years have concentrated on the high-latitude ionosphere, thermosphere and magnetosphere and the coupling processes that take place there. The objectives of the Air Force Arctic research program are to develop the basic understanding necessary for comprehensive models and real-time support for DOD systems affected by ionospheric processes and to develop predictive models that depend on solar wind parameters. The program uses multi-technique observations from a number of high-latitude locations. The Air Force does not maintain permanent facilities purely for research.

The Navy's Arctic and other high-latitude activities range from basic environmental investigations to applied work. The Office of Naval Research in Arlington, Virginia, supports basic, multidisciplinary efforts through contracts, primarily with academic institutions. The Naval Ocean Research and Development Activity at Bay St. Louis, Mississippi; the Naval Environmental Prediction Research Facility in Monterey, California; and the Naval Research Laboratory in Washington, D.C., perform both basic and applied research, with an emphasis on acoustics, numerical modeling and remote sensing. The Office of Naval Technology in Arlington, Virginia, together with a number of specific laboratories (the Naval Underwater Systems Center in New London, Connecticut; the Naval Ocean Systems Center in San Diego, California; the Naval Surface Weapons Center in Silver Springs, Maryland; and the Naval Civil Engineering Laboratory in Port Hueneme, Cali-

fornia), are involved principally in applied research and development.

The goal of Navy research in the Arctic is to provide accurate knowledge of the environment for naval operations. In pursuing this goal the Navy performs theoretical and experimental basic research on a range of Arctic processes and phenomena. This research requires a multidisciplinary perspective to permit a full understanding of the phenomena and processes, their statistics and dynamics. Contributing disciplines in order of decreasing emphasis include physical oceanography, acoustics, ice dynamics, biological oceanography, meteorology, geological oceanography, chemical oceanography and geophysics.

Specific phenomena and processes of current interest include mesoscale eddies, fine structure and turbulence, ambient noise generation, acoustic propagation and attenuation, air-ice-ocean stress, interaction of electromagnetic energy and ice, biomass productivity, lead development, deep convection, particle flux, ice-sediment interaction and high-latitude frontal zones. Specific regions of focus include the marginal ice zones, Fram Strait, the Greenland and Norwegian seas, the Bering and Chukchi seas, the Barents Sea and the central Arctic.

Investigations for which additional funding has been formally identified within the Office of Naval Research are termed Accelerated Research Initiatives (ARIs). ARIs are five-year studies with fixed funding, established on the basis of scientific merit, technical feasibility, timelines and Navy relevance. Recent ARIs within the ONR Arctic Sciences Program include the Marginal Ice Zone Experiment (MIZEX), Remote Sensing, Arctic Acoustics, Real-Time Environmental Arctic Monitoring (R-TEAM), Arctic Oceanography and Arctic Leads.

In addition there is a program supported by direct Congressional appropriation termed the University Research Initiative (URI). The Arctic URI focuses on Ice Mesoscale Modeling and Remote Sensing at Dartmouth College and the University of Colorado.

Logistics support for the Navy's basic research program in the Arctic is contracted to the University of Washington, which is responsible for establishing ice camps with the required supporting planes and ships, establishing remote staging facilities, and supporting (and renting if necessary) at-sea platforms for work in open water. Ships or planes are chartered as necessary. They perform all these services with a permanent staff of three.

## Arctic Engineering

DOD efforts in Arctic engineering are primarily carried out by the Army's Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, and Fairbanks, Alaska. The research focuses on the development of cost-effective facilities responsive to the Army's mission in cold regions. The emphasis in this area has increased because of the establishment of the Army's 10th Mountain Division at Ft. Drum, New York. Specific areas of interest include the design, construction, operation and maintenance of buildings, foundations, and water and wastewater systems, as well as roads and airfields in cold environments.



*Winter construction activities at Ft. Drum.*

At Ft. Drum the Army is spending \$750 million on new facilities to support the troops stationed there. During the design process, CRREL provided data on snow loads for building design as well as cost-effective pavement designs. The snow load criteria were recently incorporated in Corps of Engineers and American National Standards Institute standards for building design. Improved pavement designs were adopted that will reduce the life-cycle costs by minimizing low-temperature cracking, a major cause of pavement failure in cold climates.

Other pavement-related research has included cold regions pavement design validation in CRREL's Frost Effects Research Facility (FERF). The 29,000-square-foot FERF provides a unique opportunity for full-scale evaluation of pavement designs. Full-size construction equipment is used to build test sections. The facility's ability to rapidly freeze

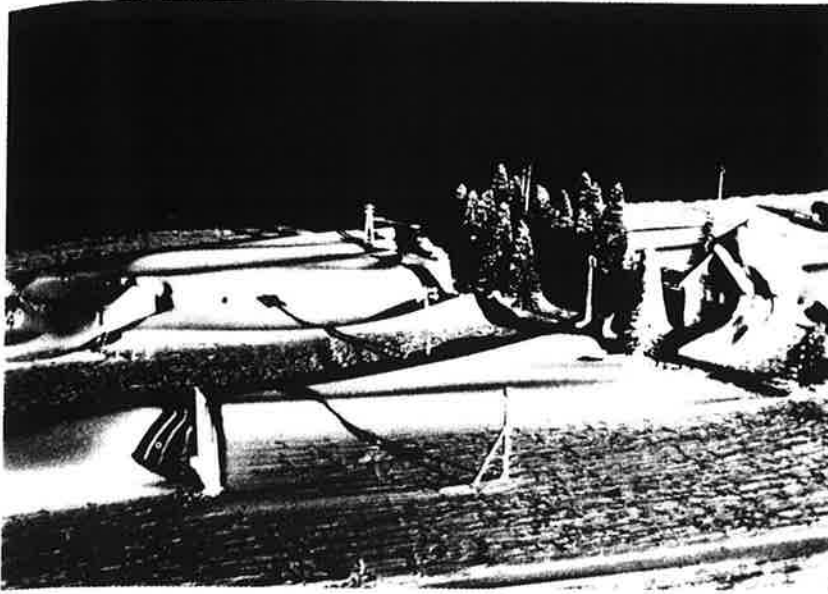
and thaw soils can provide several winters' worth of data in a few months. In Alaska this past summer, CRREL and other researchers from the Corps of Engineers and Federal Highway Administration conducted a field evaluation of procedures for classifying unsurfaced roads that should improve maintenance management.

In a recent environmental engineering project, a sludge freezing bed process was developed that can be used on all sludges produced by water and wastewater treatment plants in cold regions. The bed works on the principal that natural freezing separates the solid and liquid fractions of the sludge. During spring thawing, the liquid drains away, leaving a dry, odorless material that is easily handled with mechanical equipment. Approximately 60% of the total cost of waste treatment is associated with sludge dewatering, so this new procedure should have a major impact on treatment costs.

Other efforts have focused on the development of standard procedures and test equipment to assist in designing, constructing and operating facilities in cold regions. An infrared survey system has been established to diagnose potential roofing problems during the construction warranty period. Procedures to measure heat loss in building walls were recently approved by the American Society for Testing and Materials (ASTM), and a new test to evaluate the frost heave potential of soils has been submitted for ASTM's consideration. The new frost susceptibility test reduces evaluation time from two weeks to two days. CRREL has constructed and calibrated a snow-drift wind tunnel to conduct scale-model studies of snow and ice build-up on and around structures. The facility simulates snow with activated clay. By varying the humidity in the air stream, the precipitation build-up can be varied from dry powder to wet snow or icing conditions.

## *Permafrost, Frozen Ground and Geology*

DOD research on permafrost and frozen ground focuses on design data and criteria for construction of facilities in cold regions. A major goal is the development of geophysical subsurface exploration technology. Other projects include hazardous waste movement and control in frozen soil, and the operation of construction equipment such as augers in frozen ground. Basic research is conducted to as-



*Scale-model study of snow drifts in CRREL's wind tunnel.*

sess and predict the disturbance and recovery of permafrost terrain following natural and man-induced change. The Army Research Office (ARO) and CRREL are the two principal DOD organizations involved in this research.

Current progress has included borehole studies to determine the dielectric and thermal properties of frozen silt and alluvium; this is providing fundamental data that are useful in mapping permafrost distributions. Another project in subsurface mapping has been the evaluation of a galvanic resistivity technique for mapping subsea permafrost. Other research has developed a technique to determine water movement through unsaturated frozen soils. This effort is applicable to both modeling the frost susceptibility of soils and studying the transport of hazardous chemicals in frozen ground. Related work has looked at volatile organic movement in freezing soils.

Three auger bits were evaluated to compare their performance in both frozen soil and concrete pavements. The augers used a bit developed by CRREL for frozen soil, a commercially available bit, and a bit developed for use on a Canadian Army engineer vehicle. The commercially available bit performed the best in both frozen soil and concrete. Associated efforts have led to the development of light-weight drills and augers for collecting research samples of frozen soils.

## *Snow, Ice and Hydrology*

CRREL and (to a limited extent) ARO are the primary DOD agencies conducting or sponsoring research on snow, ice and hydrology.

The research focuses on identifying the types, directions, magnitudes and processes of natural and human-induced changes in cold regions environments, determining their impact on military and civilian systems and facilities, and providing the solutions necessary for effective operations in those cold environments. The scope of this effort ranges from fundamental research on the physical properties of snow and ice to closely focused, applied research on the operation of military systems in winter. Other applied research includes the development of engineering solutions to ice jam flooding on our nation's waterways.

Critical to this research is the development of techniques and instrumentation to accurately characterize the cold regions environment. For the past several years CRREL has conducted major field experiments studying the effect of winter conditions on electro-optical phenomena. As part of this effort an extensive array of snow and ice characterization techniques and instrumentation has been developed. A recent winter field experiment specifically focused on the thermal and millimeter-wave response of winter backgrounds.

The Corps of Engineers conducts an extensive research program focused on water resources planning and engineering. One of the tools of this research is remote sensing technology, using available satellite information from systems such as SPOT and Landsat in combination with ground truth data provided by hydrologic instrumentation such as snow triangles and soil moisture sensors.

The ability to rapidly measure ice thickness is important for military activities such as ice bridging and naval operations. Several experimental electromagnetic ice profiling systems have been developed and evaluated. Impulse radar systems have proven to be effective in measuring the thickness of regular freshwater ice, which is relatively nonconductive. Frazil ice, which forms in rapidly moving water, often collects in slushy accumulations in areas of slower water and can effectively block streams, causing flooding and erosion problems. Because of its higher conductivity, frazil ice cannot be profiled well using impulse radar. Recent studies have shown that magnetic induction, a method of measuring ground electrical conductivity, can be effective for profiling frazil ice accumulations.

In addition to profiling frazil ice, techniques have been developed to control its build-up and prevent ice jam flooding. Wilmington, Illinois, has experienced ice jam floods



on the lower reaches of the Kankakee River. In 1982 an ice jam caused \$9 million in damages. During the winter of 1987–88 CRREL demonstrated a water distribution system that took warm water from a power plant cooling pond and mixed it with the river flow, where it melted frazil ice build-up in the river, reducing the ice jam threat.

The establishment of the Army's new 6th Light Infantry Division (6th ID) in Alaska has heightened interest in Arctic research that affects military operations. Water supply is a key element for supporting troops in the field. A major project was initiated in 1988 to provide expedient methods for locating water in the Arctic. The major goal of this research has been to determine the feasibility of using various radars, including microwave systems, to locate unfrozen water under ice covers on lakes and rivers. Terrain features such as frost mounds and ice pressure ridges on rivers are potential source indicators. Research is also being conducted to assure that Army water purification units can operate effectively in winter environments.

Another military capability of interest to the 6th ID is tactical bridging in winter. Research in this area has focused on the development of improved ice bridging techniques using geotextiles for reinforcement, and the evaluation of tactical bridging systems in winter. In January 1987 several methods for rapidly clearing a river ice cover to permit launching of an Army floating tactical bridge were demonstrated on the Imjin River in Korea. A combination of explosives, chain saws, bulldozers and bridge boats were used to develop an open channel in the river into which the floating bridge sections could be launched.

*Tactical bridging exercise on the Imjin River in Korea.*



## *Oceanography*

Results from the Marginal Ice Zone Experiments (MIZEX) continue to be published. A comprehensive census of mesoscale eddies in the Fram Strait MIZ has established that they range in scale from 10 to 50 km radius, with 15 km typical. Possible generation mechanisms include flow instabilities enhanced by the divergence in the wind stress at the ice edge and topographic steering of the larger-scale circulation. A striking instability mechanism produces a local off-ice jet that develops into two counter-rotating (cyclonic–anticyclonic) eddies or a vortex pair. Synthetic aperture radar (SAR) data show that a characteristic length scale of vortex pairs along the ice edge is 30 km, with persistence of several days or more. In general the cyclonic eddies have interior density structure with upward vertical displacement at the center, often resulting in a weakening of the stratification. The cooling of the intermediate water elevated to the surface may be sufficient to initiate deep convection. Ice edge frontogenesis may also effectively reduce stratification, preconditioning deep convection initiated by surface layer cooling. During high-resolution MIZ transects, several narrow, well-mixed, “chimney-like” features have been observed with widths of 5–10 km and vertical extents of more than 250 m. Evidence of deep vertical mixing has also been suggested by the uniform distribution of phytoplankton biomass and photosynthetic parameters. An important global consideration is the role of such processes in the ventilation of Greenland Sea intermediate and deep water.

Overall, ocean dynamics seems to determine the location of the ice edge, while atmospheric dynamics determine the ice concentration and the rate of ice advection toward the edge. Existing data document MIZ scales of variability and define specific states of the system useful for model diagnosis but are limited in their ability to address dynamical evolution. Planned experiments during the Coordinated Eastern Arctic Experiment (CEAREX) will build on these results for sampling design and feature tracking.

The accuracy of remote sensing of the MIZ using passive microwave sensors has been refined through specific emissivity signatures extended to 90 GHz and through the study of multiyear floe processes. The interaction of snow-laden multiyear floes and surface gravity waves that can penetrate more than 10 km into the pack at the MIZ results in seawater



infiltration and enhancement of the brine volume at the snow-ice interface and in the snow itself. This effect may be of major importance in explaining the discrepancy between the low multiyear ice fraction derived from satellite SMMR and the high concentrations reported by direct observations.

With respect to water column particle flux, the entire Nordic Seas and at least the southern Arctic Ocean (Yermak Plateau area) are now established to be carbonaceous, dominated by coccoliths, rather than silicious as in the southern oceans. The carbon-to-silicon ratio for new sediment in this region consistently exceeds 1.0, in contrast to 0.03 in the Weddell Sea. The implied large capacity of the Nordic Seas for fixing carbon dioxide and storing it in the seabed may be an important component of the global carbon budget. The high correlation between biogenic carbon and the fine lithogenic fraction supports the hypothesis that accelerated settling of aggregated fine particles is the major mechanism of vertical sedimentation in the eastern Arctic.

In the central Greenland Sea and along the Barents Sea shelf, the particle flux maximum near the bottom occurs during late fall or early winter, offset by three months from the time of maximum primary productivity in the surface water. Concentrations during the fall-winter peak exceed amounts during other seasons by two orders of magnitude. Along the continental margin, this flux maximum is associated with an energetic shelf-to-basin transport of carbon-rich sediment. Such processes may have implications in locating hydrocarbon deposits. The timing and vigor of the near-bottom sediment transport peak is hypothesized to result from convectively driven

circulation during active freezing conditions interacting with residual settled summer biomass. Plans are to investigate these processes further as part of a future shelf-basin interaction study.

To expand understanding of multidisciplinary processes in the eastern central Arctic, a number of investigations are underway. On August 4, 1987, an advanced amphibious oceanographic buoy, the Arctic Environmental Drifting Buoy (AEDB), was deployed at 86°N, 22°E from R/V *Polarstern* through a 1-m hole bored through 6 m of ice using a newly designed steam jet auger. The AEDB drifted about 2500 km southward through Fram Strait with the ice and currents to where it was retrieved off Iceland in April 1988. This transect provided measurements of a number of variables within the ice and upper ocean through several distinct regimes over a range of seasons. The platform consisted of a vertical array of sensors, 125 m long in this case, tethered to a 1.5-m-diameter steel and composite sphere. The sphere housed satellite locating and data telemetering transmitters, temperature sensors and strain gauges, with external interface to a 60-level ice temperature profiler. The vertical array included temperature and conductivity sensors, fluorometers, transmissometers, electromagnetic and downward-looking acoustic doppler (ADCP) current meters, a sediment trap and an automated seawater filtration device. The ADCP alone yielded over 10,000 velocity profiles (16-m resolution) through the upper 200–300 m of the water column, enabling an unprecedented characterization of the Arctic internal wave environment. Analyses of both the ice and ocean data sets and the engineering performance during MIZEX continues.

Many of the distinctive biogenic and sedimentological features, as well as the ice distribution and movement in the eastern Arctic, are related to the presence of relatively warm water advected northward from the Atlantic into the Arctic Ocean through Fram Strait and the Barents Sea. The objectives of CEAREX are to understand the structure and function of mesoscale and small-scale (10 km to 1 m) processes in this Arctic Ocean exchange of momentum, heat and biomass and to understand the associated acoustic coherence and ambient noise fields. From September 1988 through May 1989, a number of coordinated investigations will be staged from ships, ice camps and aircraft.

During Phase 1 the sampling base was the *Polarbjorn* frozen into the central pack ice

north of Svalbard during fall and early winter. Phase 2 will further investigate the open water of Whaler's Bay in this region during mid-winter from the *Polarbjorn*, having recently drifted out of the ice pack. In Phase 3 the *Polarbjorn* will be joined by the R/V *Hakon Mosby* and SAR-equipped aircraft to study the Barents and northern Greenland sea marginal ice zones. Finally in Phase 4 oceanography and acoustics ice camps, as well as aircraft with SAR and meteorological sensors, will be deployed north of Fram Strait while the *Polarbjorn* pursues eddy tracking in the Fram Strait MIZ.

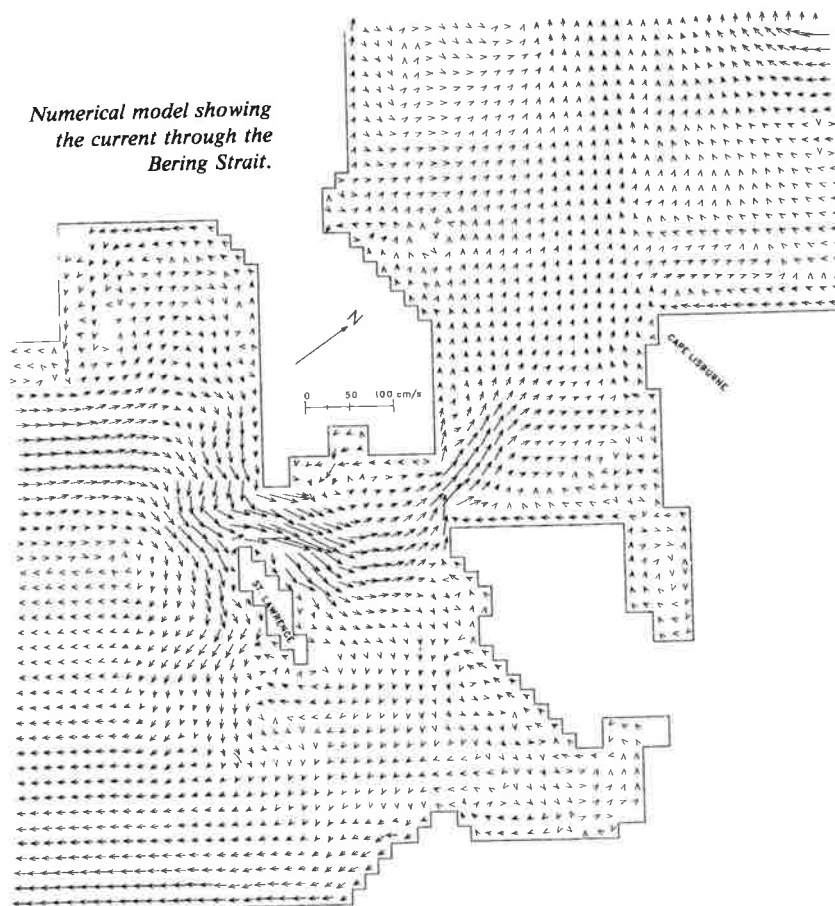
Building on the MIZEX results, the evolving dynamics of MIZ and subice eddies will be addressed, including their role in the mean circulation and in net seasonal biological productivity. Air-ice-ocean momentum flux will be studied through detailed measurement of atmospheric and oceanic boundary layer structure, together with ice floe stress and deformation fields. Below the boundary layer the partition of energy in the upper ocean among internal waves, mixing and dissipation will be investigated. Mechanisms of ambient noise generation in interior pack ice will be isolated, and causes of temporal and spatial

variability in low-frequency coherence will be evaluated.

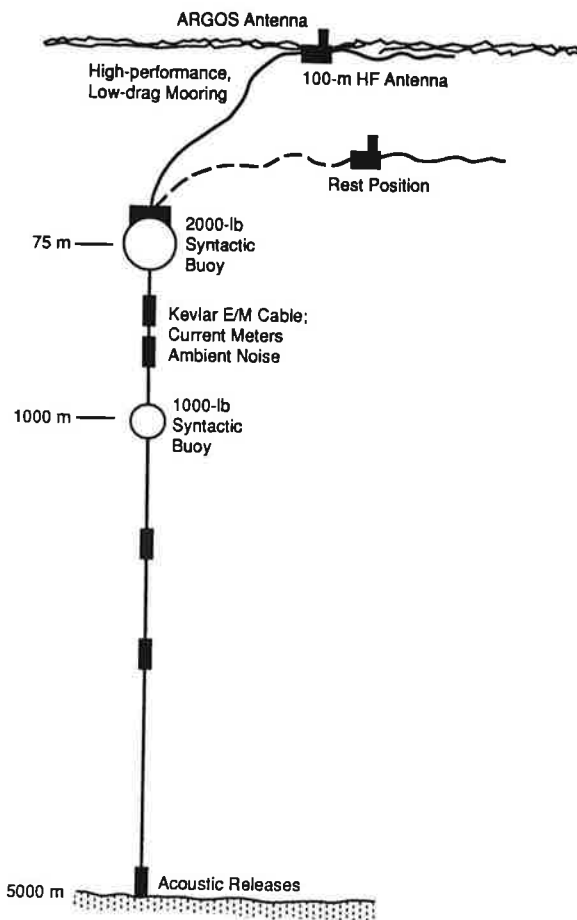
A net effect of operative ice mechanics and thermodynamics is reflected in the complex geometry of the upper and lower surfaces. The form and composition of these surfaces is also critical for scattering and absorption of electromagnetic and acoustic energy, central for both the radiation budget and remote sensing techniques. The inaccessibility of the lower surface and an uncertain correlation between surfaces has limited advances in understanding ice deformation and acoustic interaction. To address these issues, joint imaging experiments have been undertaken during spring 1987 and 1988 using coordinated submarines and aircraft. In 1987 the submarine obtained over 6000 km of upward-looking sonar data, 3000 km of side-scan profile and 4500 km of upward-looking video record. Simultaneously over segments of these transects a commercial Cessna and a NASA P-3 obtained X-band SAR and scanning passive microwave imagery and radiometer measurements. The precise correlation in space and time between surface and subsurface platforms as well as the two-dimensional side-scan perspective makes this a unique data set. An initial result is the clear discrimination of first-year and multiyear ice by the texture of the lower surface. Analysis continues on roughness parameters, SAR and passive microwave validation, intersurface coherence and optimal multisensor techniques.

In the western Arctic, cooperative studies with NOAA continue to address the relative importance of synoptic meteorology, ocean advection and local cooling and surface divergence in controlling fall ice cover in the Bering Sea. Hydrographic data from cruises, moored current meter measurements, and a data set from a small-scale process study off Nome are currently being analyzed to test regional numerical models of Bering and Chukchi circulation and local analytical models of coastal polynya maintenance. In a cooperative field expedition with USGS to discover the unknown origin of the Chukchi Cap, mesozoic siltstones were recovered from the base of the Chukchi Plateau, suggesting a continental origin for this feature. Further westward the extent and persistence of a seasonal winter polynya in the Sea of Okhotsk have been determined from satellite data. Modeling has indicated that this polynya may be a major source of Pacific intermediate and deep water.

Numerical and laboratory modeling have



Numerical model showing the current through the Bering Strait.



*RTEAM mooring em-  
planted in Fram Strait.*

provided insight into specific processes. Under-ice oceanic boundary layer models have been refined to include distinctly different parameterizations for momentum and heat fluxes. Medium-resolution (20-km) Barents Sea and Bering Sea limited area models have incorporated more realistic boundary conditions. Basin-scale models have improved ice rheology physics using a granular media approach. Laboratory modeling has established the critical height of a developing mixed layer when a stable salinity gradient is heated from below, analogous to the water mass within the Arctic halocline, and has characterized the effect of internal waves excited by mixed layer turbulence, applicable to stratified (meltwater) near-surface conditions in summer. Scale modeling of acoustic interaction in a plate-water system, similar to the ice-ocean interface region, has demonstrated the importance of plate discontinuities in redistributing acoustic energy.

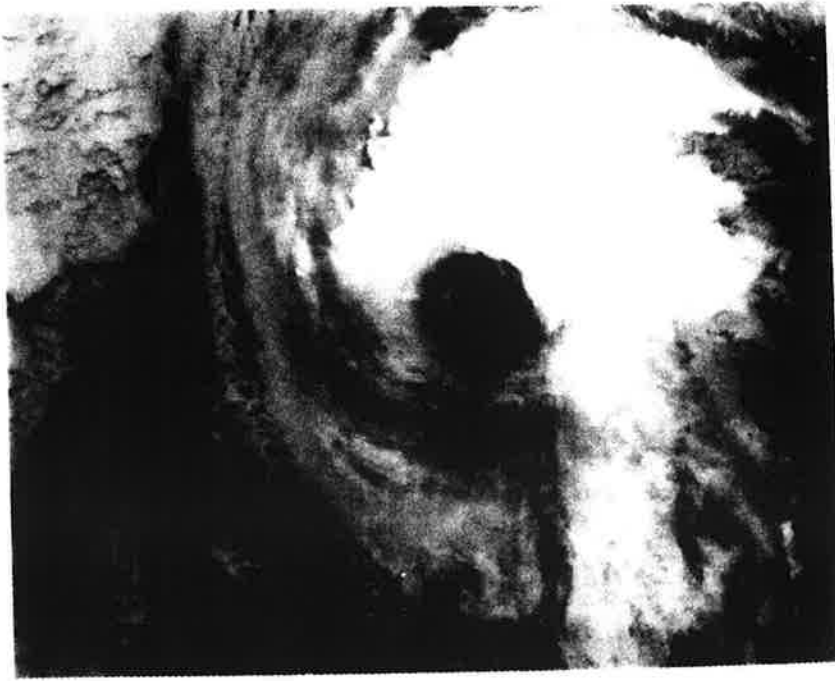
A number of new instrument systems are in advanced stages of development and testing. For ocean sampling, a light-weight (7-kg), compact (1.3-m-long) autonomous vehicle for under-ice temperature and conductivity transects has been field tested. Arctic-modified

(80 Hz) SOFAR floats have been developed and deployed, with further deployments scheduled for spring 1989. A subsurface fixed mooring system (RTEAM), designed to telemeter data from a remote, vertical array in near-real time for a year, has passed the prototype stage and has been deployed in Fram Strait. A precise tomography array of six subsurface transceiver moorings on a four-hour transmission schedule is in place for one year (1988–1989) in the Greenland Sea to study water mass structure, convective overturn, circulation and large-scale vorticity. A test of enhanced resolution has been performed by circumnavigating the transceiver array with a ship-suspended hydrophone array (moving ship tomography). For ice sampling, stress sensor arrays for floe-scale strain measurement are being evaluated in situ for consistency and stability. Side-scan sonar for mapping the lower ice surface has been implemented, and its performance is being assessed. For acoustic data acquisition, the Arctic Remote Autonomous Measurement Platform (ARAMP) has been field tested, and six units are in production for deployment in CEAREX (spring 1989). ARAMP has been designed to simultaneously measure a related set of atmospheric, oceanic and acoustic variables with both high-capacity internal data logging (laser disk) and telemetry options. The sensor type and distribution are flexible, and the system configuration can be modified to meet specific sampling objectives. Technological innovations are incorporated in a large-aperture (30-km) acoustic array. Ice-mounted array elements necessitate precise tracking and data transmission systems, which are now operational.

## *Lower Atmosphere Research*

The Office of Naval Research is conducting a variety of polar atmosphere studies. The objectives of the tropospheric and atmospheric boundary layer research are to define the causes of severe Arctic storms known as Arctic lows and to understand the origin of Arctic haze and aerosols.

The research on Arctic lows involves aircraft and satellite measurements to define the likely conditions for the genesis of these storms. The theoretical efforts include defining the generating mechanisms and improving understanding of the physics of the storms. The ultimate objective is to develop reliable predictive models using satellite and other



*Infrared image of a typical Arctic low.*

available data. The definition of these storms has been advanced, and promising predictive models are being developed. Field work from ships has focused on the boundary layer dynamics of the ice, ocean and atmosphere, as well as the relationship to the development of Arctic lows.

Tropospheric aerosols are monitored by the ground station at Fairbanks, Alaska, and in the recent past by the AGASP (Arctic Gas and Aerosol Sampling Project) in cooperation with NOAA. Aircraft data have shown that convection over Arctic leads can transport aerosols up to 4 km in altitude. The mechanisms for the production of these aerosols are being studied, and the origin of haze and aerosols measured over this Arctic region are being determined.

Reflecting the lack of knowledge about the evolution of the low-level Arctic atmosphere, a new effort is being started by ONR to study and understand the change in the boundary layer as it moves out over the polar ice cap.

### *Upper Atmosphere Research*

For the past several years there has been a strong basic research program at the Air Force Geophysics Laboratory (AFGL). This program has concentrated on high-altitude polar-cap ionosphere, thermosphere and magnetosphere studies and the coupling processes that take place there. The program, which combines multi-technique observations from a number of high-latitude locations with

a strong theoretical modeling capability, has provided a much improved understanding of polar-cap ionospheric features (e.g. polar cap "patches" and polar cap arcs), thermospheric dynamics, and satellite drag and magnetospheric energy transfer processes. Understanding the basic coupling processes and being able to explain high-latitude features is important in its own right, but it also helps mitigate potential problems for Air Force systems that operate in the region.

Within the high-latitude polar-cap ionosphere, convection transport velocities play an important role in determining plasma density variations. Models of the convection pattern, which have been developed recently, provide these velocities for different interplanetary magnetic field configurations. When these patterns are incorporated into AFGL-developed theoretical models in the polar-cap ionosphere, the resulting calculated densities quantitatively demonstrate that polar cap "patches" of enhanced ionization are produced by solar ultraviolet radiation rather than by precipitating energetic electrons and that their "patchiness" is caused by the time variation in the convection patterns themselves. Another ionospheric feature, sub-visual polar cap arcs, on the other hand, are produced by energetic particle precipitation and are collocated with convection shear reversal boundaries. These two features are now fairly well understood as a result of several Air Force-sponsored rocket, satellite and ground-based coordinated campaigns using optical photometers and imagers and coherent and incoherent scatter radar facilities.

Both of these features are responsible for producing severe radio scintillation activity that adversely affects Air Force communications and space track radar systems. In the case of polar cap arcs, the processes involved in generating plasma instabilities are associated with plasma velocity shears and have been identified and verified quantitatively. This work explains why scintillation activity and sub-visual polar cap arcs are observed together.

In addition to the high-latitude plasma density and transport observations, neutral wind velocities have been measured simultaneously from both ground-based and satellite-borne Fabry-Perot interferometers; the pattern that emerges is that very strong coupling between high-speed plasma drifts and the neutral atmosphere causes the neutral wind pattern to mimic plasma flow under most conditions when the Interplanetary Magnetic Field is characterized by a southward vector.



Another important basic research area has involved satellite drag. AFGL analysis of neutral-atmospheric empirical models used to forecast satellite drag revealed that the largest errors occur at high latitudes and increase with geomagnetic activity. Further, the accuracy of empirical models has not improved significantly over the past two decades. The Thermospheric General Circulation Model (TGCM) developed at the National Center for Atmospheric Research was examined as a potential means for making models more accurate. Realistic three-dimensional time-dependent parameterizations for the auroral and magnetospheric convection models that are incorporated within the TGCM were used to simulate thermospheric winds and density response during a major geomagnetic storm. The simulations showed that the polar and auroral thermosphere is a dynamical region with large variations caused by auroral forcing. The region is characterized by the generation and propagation of large- and medium-scale disturbances, with the response depending on altitude and local time.

The TGCM results were compared to empirical models and to data obtained by Air Force satellite density and wind sensors. These data and the TGCM fields show there is considerably more density structure associated with local regions of intense heating and wave propagation that are not accounted for in the empirical models. Neutral winds predictions (not available in empirical models) also reproduce features in magnitude and direction that agree with measurements. A statistical comparison of TGCM representation of atmospheric variability, using a larger data base, has demonstrated the advantages of this approach. During FY 87, plans were developed to create an operational version of the TGCM for satellite drag forecasting.

The polar regions of the ionosphere focus the effects of energy-transfer processes occurring over vast areas of the magnetosphere. Operational space particle and field sensors developed for the Defense Meteorological Satellite Program (DMSP) continuously monitor energy transfer from the magnetosphere as well as in-situ plasma properties. These satellites have begun the first continuous monitoring of the magnetospheric electric field. A portion of this research is being modified for operational use as a specification and forecasting tool for defining regions where spacecraft charging is probable and predicting energy deposition into the polar regions.

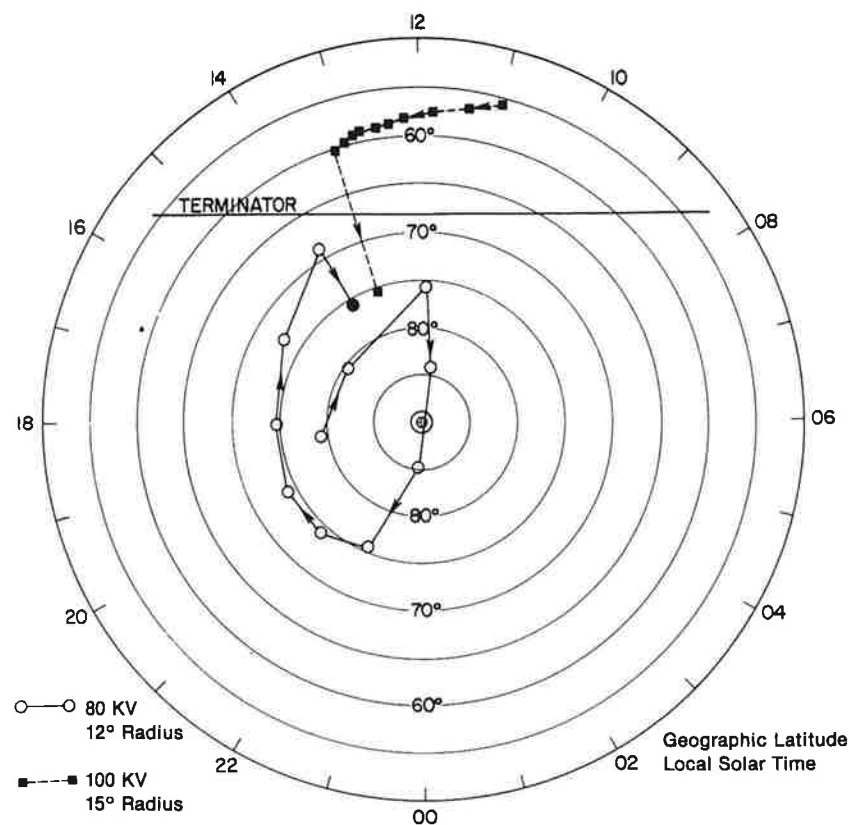
Single-event upsets and radiation damage

from the energetic particles in the magnetosphere are a major hazard to reliable and survivable satellite operations. The evolution of the radiation belts will be quantified with the CRRES satellite to be launched in 1990. The most comprehensive set of particle and field instruments planned or flown to attack the radiation problem has been developed and integrated into the CRRES satellite. In addition, codes for predicting energetic solar proton events have been modified for operational use for the Air Weather Service (AWS).

The close coupling between magnetospheric, ionospheric and thermospheric processes has been and continues to be the focus of programs in the high-latitude polar-cap regions sponsored by the AFGL and the Air Force Office of Scientific Research (AFOSR). The programs focus not only on understanding the physical mechanisms, but also on being able to provide better high-latitude specification models that can be used by the Air Force. AFGL, with AWS support, is developing real-time magnetospheric, ionospheric and thermospheric specification models; AWS will use these models as part of their Space Environment operational models, which will use real-time data from a network of ground-based and satellite-borne instruments.

AFGL, under AFOSR sponsorship, has completed the initial version of an infrared Auroral Atmospheric Radiance Code (AARC). The basis for the code is data for infrared atmospheric processes derived from the analysis of auroral rocket probe experiments as well as AFOSR-supported laboratory investigations of infrared atmospheric radiative processes. The model includes results from experimental facilities at AFGL as well as universities and other institutions supported directly by AFOSR. The auroral infrared radiance model presents the dominant spectral emissions in the wavelength region from 2 to 7  $\mu\text{m}$  for essentially any altitude profile of electron deposition, electron dosing level or auroral spatial configuration. Special radiance is computed for each rotational line in a given vibrational transition, and the effects of radiation transport are included. The model will be extended and revised to include additional auroral infrared emissions as additional information becomes available.

The Office of Naval Research operates a worldwide array of eight extra-low- and very-low-frequency radiometers to gather digital and analog data on electromagnetic noise. One is located in Antarctica, two are located in Greenland (Søndrestromfjord and Thule)



*Two plasma trajectories that reach Thule, Greenland, at 1400 LT under different polar cap conditions; one enters the sunlit region and one does not.*

and one is located in New Hampshire. The latter three stations are of particular interest because they lie approximately along the same magnetic field line and because one is in the polar cap, one is in the auroral zone, and one is in the sub-auroral area. This allows study of the changes in noise signal propagation into or through these areas. Each radiometer has 16 channels for reception at frequencies from 10 Hz to 32 kHz, with a bandwidth of 5% of the center frequency of each band. The radiometer at Thule also covers additional center frequencies up to 60 kHz. This expansion of coverage at Thule was done at the request of, and with funding from, the Air Force Geophysics Laboratory. Over a year's worth of data has been taken at each station, with at least a year of simultaneous coverage for all stations. Data processing and analysis are automated, and data are being prepared in standard radio noise format.

DOD is also involved in research on the stratosphere and mesosphere. The objective of this high-atmosphere research is to define the clouds and aerosols believed to exist at these altitudes, particularly their variability and physical characteristics. The circulation dynamics of the region is also being modeled in an attempt to understand why, when and where summer polar mesospheric clouds (85 km) and winter stratospheric clouds (25 km) form.

Stratospheric aerosols will be measured by an instrument package to be placed on the next French SPOT satellite. The nine-channel instrument will measure ozone, aerosols, nitrous oxide and water vapor.

The propagation and breaking of atmospheric gravity waves over the Arctic are being described and modeled. A stratospheric planetary-wave circulation model is being developed which implies a dynamic relationship to the "ozone hole."

## ***Medical and Human Engineering***

Arctic-related medical and human engineering research is conducted by the Army's Natick Research, Development and Engineering Center and the Research Institute of Environmental Medicine, both located in Natick, Massachusetts, and the Medical Research and Development Command at Ft. Detrick, Maryland. The objective of this work is to identify and resolve the major health and human engineering problems caused by the Arctic environment. DOD is focusing research on cold injuries, cold physiology, cold stress adaptation and the development of clothing, equipment and rations for troops in cold regions.

As part of the research on cold regions clothing and equipment, work has been completed on a new field backpack to replace the large Alice pack. The new pack has two components, a large main pack and a combination patrol pack. Also, an extreme-cold-weather sleeping system has been developed that allows sleep or rest at temperatures down to -80°F. The new system is 100% synthetic and is 30% lighter and less bulky than the current system. The new system is entering production and will be available for field use within 18-24 months. A mountain equipment kit for special military mountaineering forces is now available. The kit includes skis, boots, snowshoes and other equipment necessary to traverse ice- and snow-covered terrain.

Two areas of medical research have been the reduction of human sensitivity to cold through training and the development of an understanding of the significance of unstable blood pressure in hypothermia victims. Research has shown that blood pressure monitoring is necessary long after the body temperature has been stabilized at normal levels. The cold sensitivity training has focused on psychological training techniques to teach the body to increase blood flow in the hands and feet during cold exposure.

# Department of Commerce

## National Oceanic and Atmospheric Administration

NOAA performs research in the high-latitude regions of the planet in connection of its environmental monitoring and prediction responsibilities. Individual research programs focus on scientific questions addressing the Arctic environment and its relation to our global environment. NOAA also conducts research in support of services it performs, such as weather forecasting and fisheries management. Expenditures totaled \$4.6 million in FY 87 and \$5.1 million in FY 88.

### Meteorology, Climate and Air Quality

#### Geophysical Monitoring at Remote Polar Sites

At the Geophysical Monitoring for Climatic Change (GMCC) observatories of NOAA's Air Resources Laboratory (Boulder, Colorado), measurements of atmospheric trace constituents are made to elucidate their impact on global climate. At four baseline observatories located at remote sites (including Barrow, Alaska), continuous and discrete measurements are made of the concentrations of atmospheric trace constituents. Regularly monitored constituents include carbon dioxide, total column ozone, vertical profiles of ozone, surface ozone, stratospheric water vapor, chlorofluorocarbons, nitrous oxide, stratospheric aerosols, methane, volumetric aerosol scattering coefficient, condensation nuclei concentration, solar radiation, meteorological variables and precipitation chemistry.

Recent accomplishments include

- Hosting and participating in the NASA-sponsored Arctic Boundary Layer Experiment (ABLE), with an emphasis on methane fluxes from the Arctic tundra (see p. 65);
- Interpreting the historical record of surface ozone and solar radiation measurements from Barrow to investigate the impact of bromine compounds on ozone; and
- Analyzing carbon dioxide and methane data covariance as an indicator of correspondence between anthropogenic and natural sources and sinks of the two compounds.

NOAA FUNDING  
(thousands)

	FY86	FY87	FY88
Arctic Haze	477	100	150
Atmospheric Trace Constituents	170	180	180
Climate Modeling	200	200	200
Environmental Prediction	350	350	350
Fisheries Assessment	2,000	2,000	2,000
Bowhead Whale	1,000	1,100	1,300
Fur Seal Research	500	300	400
Sea Grant	200	200	355
Strategic Assessment	300	125	125

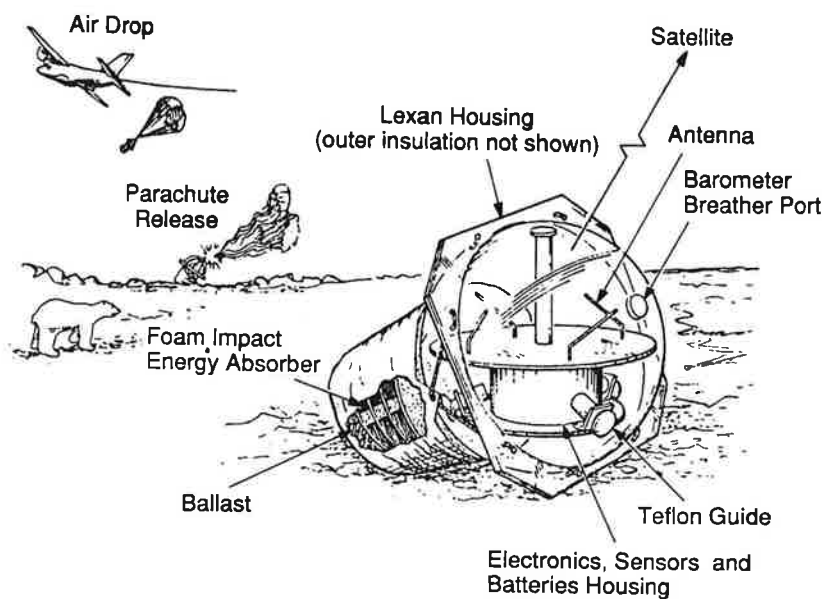
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#### Cooperative Arctic Buoy Program

The Cooperative Arctic Buoy Program is managed by NOAA's Office of Climate and Atmospheric Research (OCAR), Rockville, Maryland, with contributions from the Canadian Atmospheric Environment Service, the Norwegian government, the Department of Interior and NOAA. The program seeks to

- Measure and archive the pressure field, the ice velocity and their year-to-year variations;
- Investigate the relationships between atmospheric variables and ice behavior;
- Determine ice export from the Arctic Basin; and
- Improve real-time high-latitude pressure maps and forecasts of weather and ice conditions.

The U.S. Navy operational buoy program is conducted in conjunction with, and expands on, the Cooperative Arctic Buoy Program. Ice forecasters at the Navy/NOAA Joint Ice Center are kept informed so that they can derive position data from these important indicators of sea ice motion. Since the initial deployments during POLEX in 1979, the buoy



*Air-deployable automatic data buoy for use in the Arctic.*

network has grown from 15 to nearly 50 in 1988. It is expected that this program will continue at least through 1989. The data from these buoys are transmitted via the French ARGOS data collection and platform location system on the NOAA polar-orbiting satellites and are available on the Global Telecommunications System.

### *Cryosphere-Ocean-Atmosphere Modeling*

At NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey, researchers have developed cryosphere-ocean-atmosphere models to test the influence of ice sheets on the sensitivity of climate to anticipated changes in radiatively active gases such as carbon dioxide. Such models are used to study a wide variety of scientific problems, including polar ocean circulation and mixing.

### *Arctic Boundary Layer*

NOAA researchers are applying observational results and modeling techniques to improve our understanding of the Arctic atmospheric boundary layer. NOAA analyzed several aircraft data sets collected during 1982 and 1983 over the Bering and Beaufort seas.

Flights over the St. Lawrence polynya in the Bering Sea in February 1982 and 1983 by the NOAA P-3 aircraft measured the turbulent transport of heat and momentum across the polynya. The February 1983 flight was carried out over three different ice regimes: frazil ice, gray young ice and white young ice.

Turbulence data were also collected by the NOAA P-3 aircraft over the Arctic ice pack in the Beaufort Sea in February 1982 during

stable planetary boundary layer (PBL) conditions. These data are being analyzed to study the structure and dynamics of the stable Arctic boundary layer with emphasis on the processes responsible for the maintenance of the PBL model being developed at NOAA's Pacific Marine Environmental Laboratory (Seattle, Washington) for use in Arctic ice prediction studies.

### *Arctic Gas and Aerosol Sampling Project*

The Arctic Gas and Aerosol Sampling Project (AGASP) is a multifaceted cooperative research program designed to determine the distribution, transport, chemistry, aerosol physics and radiative effects of the polar air-pollution phenomenon known as Arctic haze. Conceived, organized and directed by NOAA, the project involved participants from the United States, Canada, Norway, Sweden, the Federal Republic of Germany and Denmark during two intensive field programs, March-April 1983 (AGASP-I) and 1986 (AGASP-II), using research aircraft. The flights were coordinated with ground-based measurements at baseline stations at Barrow, Alaska; Alert, Canada; and Ny-Alesund, Svalbard. The research has shown that the Arctic troposphere contains high concentrations of anthropogenic gases and aerosols, mainly from Eurasian and Soviet origins. These constituents are advected across the Arctic in distinct layers, on time scales of 10 days or less, and the haze layers have an appreciable impact on the flux of solar radiation reaching the ground in the high Arctic.

A third field program (AGASP-III) will be conducted in March-April 1989, focusing on the finer details of the Arctic radiation budget and how it is influenced by anthropogenic gases and aerosols. Further, an aerosol lidar and cloud physics instruments will be used to determine the role of ice crystals in the visibility reduction associated with the haze.

### *Arctic Observations of Stratospheric Chemistry*

The substantial depletion of Antarctic ozone over about the past ten years has focused attention on stratospheric photochemistry in polar regions. Scientists from NOAA's Aeronomy Laboratory participated in airborne and ground-based campaigns that have demonstrated that photochemical reactions involving chlorine-containing species are largely responsible for the depletion of Antarctic

ozone. These studies have also shown that the dynamical conditions of Antarctica have a critical effect on the unusually high sensitivity of ozone to increasing chlorine levels in that region. This raises the question of whether similar phenomena can take place in the Arctic stratosphere, where the dynamical conditions are highly variable and generally warmer than those in Antarctica.

A team of scientists from the NOAA Aeronomy Laboratory and the Cooperative Institute for Research in Environmental Science (CIRES) carried out a series of measurements of stratospheric constituents in Thule, Greenland (76.5°N), during January and February 1988. The same instruments employed at McMurdo Station, Antarctica (77.8°S), were used to probe the stratosphere above Greenland. Observed column abundances of chlorine dioxide were about ten times greater than theoretical predictions but about five times smaller than those obtained in Antarctica in late August. These data, along with simultaneous observations of nitrogen dioxide, provide evidence that the Arctic stratosphere undergoes some of the same chemical transformations that led to the Antarctic ozone hole, albeit to a much lesser extent. In FY 89, NOAA's Aeronomy Laboratory scientists will participate in an interagency campaign to measure a broad range of stratospheric species from aircraft platforms based at Stavanger, Norway (see p. 64).

## *Marine Observation and Prediction*

### *The Freeze Experiment*

Throughout the polar regions, there are oceanic areas that remain nearly ice free when temperature conditions would favor an ice cover. These ice-free areas, called polynyas, typically occur along Arctic coasts because offshore winds or currents continually remove the ice as it is formed.

Researchers from NOAA's Pacific Marine Environmental Laboratory, in cooperation with several investigators from other institutions, conducted the Freeze experiment along the west coast of Alaska in the northern Bering and Chukchi seas during the autumns of 1987 and 1988. This experiment was a follow-up to the Arctic Polynya Experiment conducted along St. Lawrence Island in the northern Bering Sea during the winter of 1984-85. The purpose of Freeze was to investigate physical processes in the atmosphere, sea ice and ocean

to observe the fine-scale interaction of ice formation with regional dynamics and thermodynamics. Because ice excludes salt as it forms, continual freezing in a polynya can increase the brine content considerably, which may affect the local water density structure and current field as the brine is mixed and advected beyond the polynya.

During the Freeze experiment, ten current-meter and pressure-gauge moorings were deployed for overwintering at key locations over the shelves. Four ARGOS ice buoys were also deployed (by helicopter) to trace the advancing ice edge and to map the heat and salt budgets for two distinct periods. The initial data analysis suggests that in light to moderate winds there is little structure to the ice crystal formation and brine rejection. However, in higher wind situations the freezing is organized into rows, which are probably formed by secondary circulations driven by Langmuir mechanics. This understanding is an important step for defining the external parameters for predictive modeling of ice formation.



*Frazil ice in windrows over a polynya.*

### *The Beaufort Sea Mesoscale Circulation Study*

The Beaufort Sea Mesoscale Circulation Study was initiated in the autumn of 1986 and has included measurements of currents, winds and ice velocities as well as observations of state variables and nutrient distributions in the ocean and state variables in the polar atmosphere, principally between Barrow and Demarcation Point along the Alaskan Beaufort Sea shelf. The study has involved ship (USCGC *Polar Star*) and helicopter operations. Data resulting from this study include wind velocity, air pressure and temperature records recovered continuously through 1987; ARGOS ice buoy tracks through 1987; and surface weather maps analyzed for the first



year of the experiment. Data collection continued through April 1988, when the remaining current-meter moorings were recovered through the ice and the coastal anemometers were dismantled.

From October 1986 to April 1987 the near-surface currents over the Beaufort Sea continental shelf were westward. The Beaufort Undercurrent, with its eastward flow, began at a depth of 60–90 m, much deeper than in some previous observations. There were several flow reversals of the undercurrent, which may have driven an upwelling of warm, saline water onto the shelf. The autumns of 1986 and 1987 had anomalously high air temperatures, and more storms than average passed along the Beaufort coast. The total data set is extraordinary in the temporal and spatial extent of its synoptic coverage and in the variety of its constituent measurements. The data set is also extremely large, and its full reduction and analysis will provide an exceptional opportunity for improving our understanding of the shelf circulation and its forcing, as well as conditions important to the marine ecology of the area.

### *Investigations in the Greenland Sea*

As a major site of deep water formation, the Greenland Sea is a window of the deep world ocean through which must pass both indicators and agents of climatic change. The long-term goal of NOAA's work in the Greenland Sea is to understand its role in the global climate and the large-scale dynamics of the atmosphere and ocean. NOAA's Pacific Marine Environmental Laboratory conducted hydrographic and circulation investigations from the *Polarstern* in the summers of 1987 and 1988, the *Valdivia* in summer 1988 and the *Knorr* in fall 1988. This work, part of the Greenland Sea Project, is a cooperative project with a number of institutions in Europe and North America. In addition NOAA has contributed to an instrumented United Kingdom array to study the overflow through Denmark Strait.

Analysis of the first hydrographic data set sheds new light on the recently discovered outflow into the Greenland Sea of saline Arctic Ocean deep water and on the formation of Norwegian Sea deep water. The results show that

- High-salinity water in the Greenland Sea originates at mid-depth (1600–1700 m) in the Arctic Ocean;

- This water flows southward along the Greenland slope until the bathymetry forces a divergence in the southwestern Greenland Basin, with the most saline water continuing southward into the Iceland Sea rather than flowing into the Norwegian Sea through gaps in the Mohn Rise;
- Within the Greenland Sea, the saline Arctic Ocean water is mixed with Greenland Sea deep water in an approximately 3:7 ratio to produce Norwegian Sea deep water; and
- The production of new deep water with Norwegian Sea properties is on the order of 2 Sv; this corresponds to a replacement time of about a decade, less than half that calculated from recent tracer box models, suggesting that not all of the new deep water moves into the Norwegian Sea but rather that a significant portion remains in the Greenland Sea.

### *Sea Ice Forecasts and Modeling*

A sea ice, barotropic-ocean model was developed to investigate the coupling of ice motion to wind-driven coastal currents. The model emphasizes the relationship of ice thickness to strength on downwind coasts and resolves the oceanic boundary layers for finite depth situations through the use of vertical structure functions. The model clearly shows that the feedback between ice thickness and motion is important on scales less than 10 km and that the relation of ice velocity to wind stress in coastal seas is variable because the ocean slope current responds only to the along-shore component of the wind. This is a major step in providing quality forecasts of coastal ice motion.

### *Vessel Icing*

NOAA's Pacific Marine Environmental Laboratory has an ongoing interest in improved vessel icing forecasts. The new algorithm developed during 1985 and 1986 has undergone extensive testing at NOAA's National Meteorological Center and Canadian and U.S. Navy equivalent groups. This algorithm is now being used for hemispheric forecasts of vessel icing potential by NOAA's National Weather Service. The Pacific Marine Environmental Laboratory and collaborating investigators from Canada are working on improving estimates of wave- and wind-generated spray during icing conditions.

## *Fisheries*

### *Bering Sea Resource Assessment*

NOAA's National Marine Fisheries Service (NMFS) in Seattle, Washington, assesses stock condition for crabs and groundfish in the Gulf of Alaska and the Bering Sea. These assessments provide measures of abundance independent of those derived from analyses of fisheries statistics, and they cover conditions of the multispecies community as a whole. The data serve multispecies and multidisciplinary purposes (fish/fish, fish/mammal, fish/bird, fish/environment). Combined with information from the fishery itself (catch, effort, size, age, location, etc.), they result in analyses of stock condition and recommendations for management of both the fishery and its environment. The information includes stock unit identification, estimates of potential yield, contemporary condition of stocks, short-term (1-3 year) prediction of change, interaction of the separate species and groups, and response to environmental change. Populations are sampled at sea aboard NOAA ships, chartered fishing vessels and cooperating foreign research vessels. Major surveys occur every three years in the eastern Bering Sea, the Gulf of Alaska and the Aleutian Islands. Annual surveys are made for critical species such as pollock, cod, yellowfin sole, and king and Tanner crab. Special-purpose surveys are made to reconnoiter new areas and to study processes that affect predictions.

Survey methods include bottom trawls for crabs and demersal fish; hydroacoustic and midwater trawls for semipelagic fish; and

special-purpose sampling for eggs, larval and juvenile fish, and shellfish. Trawl and acoustic surveys are used to estimate minimum biomass and are analyzed to define community structure; biological samples are taken to examine variability in growth, mortality and recruitment of the stock. Recruitment indices and processes that result in variations in abundance are studied to improve prediction. To increase the accuracy and precision of these assessments, NMFS conducts biological research to define recruitment processes, develops computer models to simulate the interactions and dynamics of population change, and supports contract research to improve methods and survey designs.

In 1988 a major fisheries survey was completed of the entire eastern Bering Sea from the Alaska Peninsula up to and including Norton Sound and out to the International Dateline. The abundance and structure of pollock stocks in the deep Aleutian Basin were surveyed in conjunction with scientists from Japan and the Soviet Union.

### *Arctic Marine Mammals*

NOAA's National Marine Fisheries Service is conducting bowhead whale research that is aimed at assessing the population growth of the species and the impact of the native take. The program's main emphasis is on collecting comparative data on recruitment rates, as well as more accurately determining the life history, primarily by aerial photogrammetry and photo identification. Initial results suggest that recruitment may be associated with changes in habitat, such as food availability and ice formation.

Significant changes in the Bering Sea and North Pacific ecosystem may have occurred, reflected in the recent declines in northern fur seal and Stellar sea lion populations that breed on islands in the eastern North Pacific and Bering Sea. Scientists from NOAA's National Marine Mammal Laboratory are studying changes in recruitment, foraging behavior, diseases, incidental take in fisheries and entanglement in marine debris. Initial evidence suggests that entanglement was a prime cause in the fur seal decline; however, current recruitment may have leveled off. Synergistic but as yet unidentified environmental and anthropogenic factors are believed to be operating in the Bering Sea ecosystem, which may account for the variety of significant changes that have occurred in community composition and population ecology of birds, fishes and mammals.

*Northern fur seal  
tangled in a fishing net on  
St. George Island.*



## Ocean Assessment

### Outer Continental Shelf

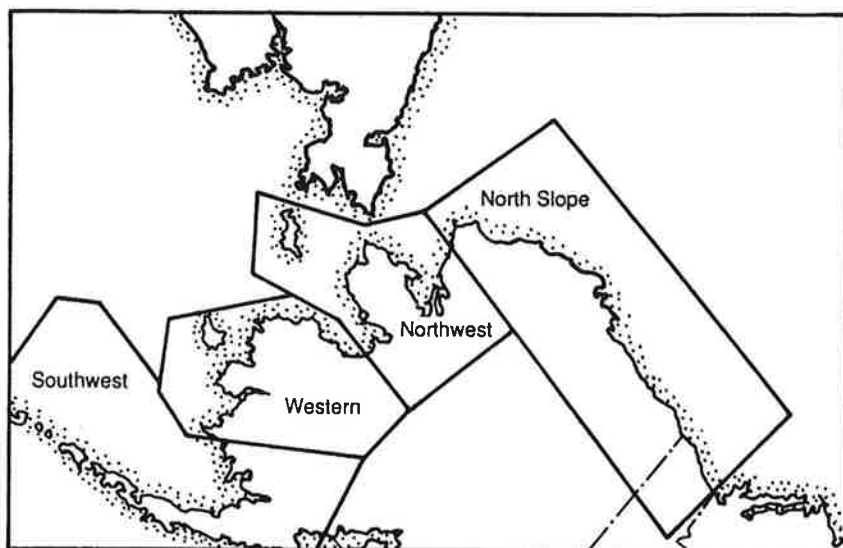
#### Environmental Assessment Program

The Outer Continental Shelf Environmental Assessment Program (OCSEAP) was established through an interagency agreement between the Minerals Management Service (MMS), the Department of Interior and NOAA. OCSEAP is a multidisciplinary environmental studies program that provides MMS and other agencies with environmental data and results of original research, as well as data synthesis reports, to help them formulate leasing decisions and develop management strategies to obviate or mitigate undesirable effects of outer continental shelf oil and gas development. Studies are performed on a cooperative basis between NOAA, agencies and universities.

OCSEAP studies are underway to improve the definition of offshore circulation and large-scale ice movements in the Beaufort and Chukchi seas. In cooperation with the University of Alaska, interdisciplinary studies have been conducted on the Chukchi Sea benthos. OCSEAP has also undertaken a series of interrelated studies of early life histories and habitat relationships for major Bering Sea finfish and shellfish species. Initial efforts have focused on larval and juvenile red king crab, salmon and Pacific herring. A study has begun to define the migratory behavior of Arctic char and Arctic cisco using genetic stock identification techniques.

A recently published comprehensive Alaskan bibliography of some 5000 publications is available for the Ocean Assessment Division, Box 56, Anchorage, Alaska 99513.

Example of information in the BCB atlas: Subsistence regions in the study area, and timing of subsistence harvest.

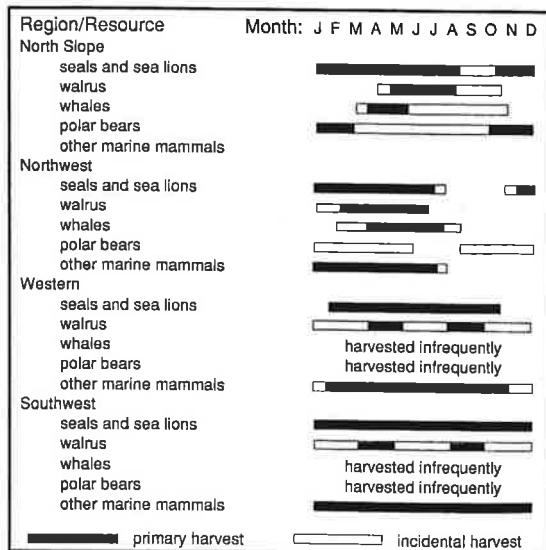


### Strategic Assessments

Regional strategic assessment data atlases are designed to communicate diverse and often complex information about the U.S. coastal zone in a spatial format that will support informed coastal resource management decisions. The atlases consolidate information on a series of identical base maps for six general themes: physical environments, biotic environments, living marine resources, economic activities, environmental quality, and jurisdictions.

A prepublication edition of the *Bering, Chukchi, and Beaufort Seas Strategic Assessment Data Atlas* (BCB), printed at one-half size, was published in late 1987, and the final full-size edition will appear in January 1989. The final *West Coast of North America Strategic Assessment Data Atlas* (approximately 150 maps) will be published in 1989 and will complete atlas coverage for the U.S. coastal ocean. A preliminary edition of this atlas with 36 representative maps was published in February 1988. A series of "pre-publication" editions of selected subsections are being developed. For example, the pre-publication edition of the marine mammal section (21 maps) was distributed in late 1988.

The BCB atlas, which contains 107 maps, includes three map plates describing Native subsistence activities that are an integral part of the Native culture and the economic base of Native villages. These maps are the first to synthesize information on subsistence activities for the entire region and are based on the results of intensive research conducted since 1979 by the Alaska Department of Fish and Game. They incorporate information from detailed field studies of the subsistence activities of over 35,000 people in 112 Native communities within the coastal areas of the Bering,



Chukchi and Beaufort seas. The BCB atlas also emphasizes living marine resources, with over 80 detailed maps in this category. For more information, contact Strategic Assessment Branch (N/OMA31), Ocean Assessments Division, Office of Oceanography and Marine Assessment, National Oceanic and Atmospheric Administration, 11400 Rockville Pike, Rockville, Maryland 20852.

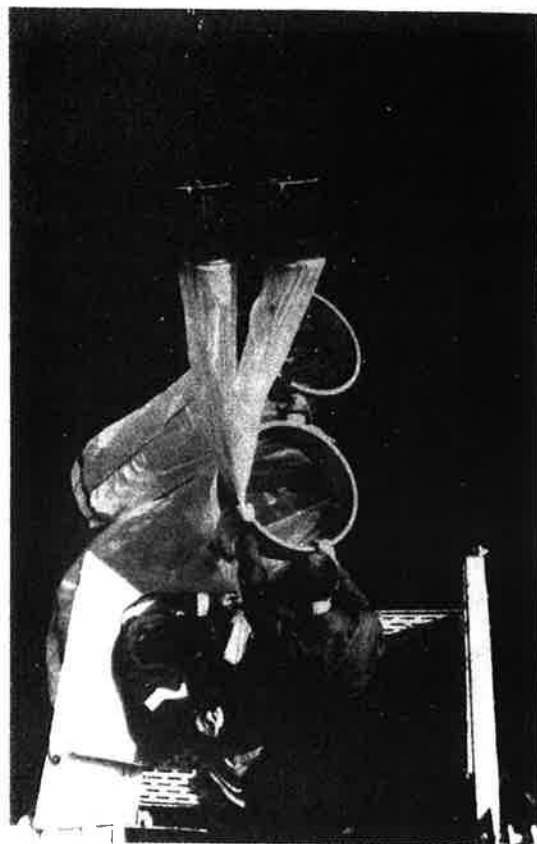
A detailed data base describing the relative abundance and spatial distribution of marine species over time, space and life-history function is now operational for many of the U.S. coastal oceanic regions. These data are based primarily on the regional atlas maps. The Computer Mapping and Analysis System for living marine resources is a microcomputer-based, interactive and user-friendly system that enables a wide range of users to access and use the information developed originally for the strategic assessment data atlas series. This year, over 1000 digital maps were added to the data base to capture the life history and distributional characteristics of 91 species of fish, invertebrates, marine mammals, and birds for the Bering, Chukchi and Beaufort seas region.

## *Related Programs*

### *Fisheries-Oceanography Coordinated Investigations*

Fisheries-Oceanography Coordinated Investigations (FOCI) is an effort by NOAA scientists at the Pacific Marine Environmental Laboratory and the Northwest and Alaska Fisheries Center (NAFAC) to understand the processes leading to recruitment variability of commercially valuable fish and shellfish stocks in the Gulf of Alaska and Bering Sea. The goal of FOCI is to understand environmental processes that lead to enhanced or failed recruitment. This information will be used to improve predictions of year-class strength. Impacts on survival during early life stages, particularly the larval stage, while the fish are transported from spawning grounds to nursery areas, are believed to be the most important factors in determining recruitment.

The major FOCI program for FY 86-90 is a study of the physical and biological environment of the pollock fishery in the western Gulf of Alaska. The FOCI hypothesis is that survival of pollock less than a year old is enhanced by remaining in the coastal region as opposed to being transported to the offshore Alaska Stream current. FOCI research has



*FOCI scientists deploying a net to sample for pollock eggs and larvae.*

been organized on three scales. A climate-scale approach examines the meteorological, oceanographic and biological conditions that correlate with historical year-class success. Interannual variations in transport and larval concentrations are being studied via annual field surveys and environmental time series. Both field and laboratory studies of transport, mixing, food availability, growth and predation investigate the intra-annual processes that affect mortality.

Preliminary results show that there are large year-to-year changes in larval abundances that are accompanied by changes in the physical environment. Interannual variations in the abiotic environment do not account for all the fluctuations in year-class strength. Biotic factors such as food, growth and predation, particularly during the early life stages, are necessarily considered. It is unlikely that any single factor in the biotic or abiotic environment would account for all or even most of the variability, or that any factor has the same impact every year. The long-term goal of FOCI is to establish environmental indices that can be monitored and interpreted for providing useful recruitment forecasts.

### *The APRISE Study*

The Assessment of Productivity and Recruitment in Subarctic Ecosystems (APRISE) study is testing the hypothesis that environmental variables trigger phytoplankton productivity, which affects the feeding regimes and then the recruitment of fish. APRISE is being conducted in Auke Bay, Alaska, with the goal of developing the ability to predict fish larval recruitment. It is a collaborative effort between NMFS, the University of Alaska and the Oceanic Institute of Hawaii.

### *National Sea Grant College Program*

NOAA's National Sea Grant College Program sponsors various fisheries-related research projects within the University of Alaska system. Those projects funded in FY 88 will study

- The interannual variability of the physical environment and fisheries of the Bering Sea;
- The size at maturity for Alaskan red king crab;
- The otolith microstructure of Pacific halibut;
- The energetics of halibut, yellowfin sole and flathead sole;
- The control of surimi functionality through modification of protein composition;
- A low-cost autonomous vehicle for research and exploration; and
- The recruitment fisheries oceanography of walleye pollock in the eastern Bering Sea.

### *Solar-Terrestrial Services and Research*

The beautiful visual displays of the aurora borealis are caused by intense episodes of electron and ion precipitation into the high-latitude upper atmosphere. These precipitating particles also provide a direct heat source at high altitudes that often exceeds the local input from ultraviolet and extreme-ultraviolet radiation. As a consequence the temperature and composition of the earth's thermosphere are affected, and through ionization of the neutral atmosphere, so are the ion density and conductivity.

Agencies and commercial interests affected by the consequences of these precipitating particles and also by the fluctuating geomagnetic fields that accompany these episodes include military and civilian radio communications and radars, low-earth-orbiting satellite operation units (such as NASA and agencies operating some navigational satellites) that

must contend with increased frictional drag caused by a heated atmosphere, geophysical exploration teams that prospect for oil or minerals by mapping the geomagnetic terrain, and pipeline and powerline companies adversely affected by currents induced by the fluctuating fields. These operational concerns, and also university and national research teams studying the causes and consequences of auroral activity, are served by the Space Environment Services Center (SESC), a joint operation of NOAA's Space Environment Laboratory and the U.S. Air Force Air Weather Service. The SESC provides around-the-clock, real-time forecasts and warnings of solar and space disturbances, and the laboratory conducts research to support these services. The SESC also collects an extensive national real-time space environment data base that accepts and integrates diverse observational data and serves as a focal point for international space environment data exchange programs.

### *Operational Weather, Hydrological and Ice Services*

#### *Navy/NOAA Joint Ice Center*

The Navy/NOAA Joint Ice Center (JIC) is the only organization in the free 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.

Satellite image products are the primary source of sea ice data at the JIC. Images are received from NOAA polar-orbiting series satellites and from the Defense Meteorological Satellite Program series satellites. Sea ice information is also derived from passive microwave sensors aboard various satellites. Accurate information on the location of the sea ice edge is derived from the GEOSAT satellite. The JIC also receives first-hand observations from aerial reconnaissance missions, ships and shore stations. Buoy drift tracks provide ice motion data on scales that cannot be easily resolved by satellites.

Workstation technology developed by NOAA's Program for Regional Observing and Forecasting Services (PROFS) was being introduced for sea ice analysis and forecasting operations during 1988. NOAA satellite image products and most meteorological fields from the National Meteorological Center and the





*Sea ice near Prince of Wales Island in southeastern Alaska.*

Fleet Numerical Oceanography Center are being assimilated, displayed and overlayed by the JIC's Digital Ice Forecasting and Analysis System (DIFAS). The JIC is participating in the development of more accurate sea ice algorithms for the SSMI instrument to be flown on the Defense Meteorological Satellite Program satellites. At least a portion of this expertise will carry over to the passive microwave instrument designed for the future NOAA polar-orbiting satellites. These all-weather sensors promise to be the mainstay of global sea ice work until the advent of an operational Synthetic Aperture Radar (SAR) system.

The JIC is working with NOAA, NASA and the Alaska SAR facility to obtain SAR image products collected by the research satellites to be launched by the European Space Agency (ERS-1) and the National Space Development Agency of Japan (JERS-1). The products will be used in a demonstration of the ability of SAR to improve the sea ice analysis capabilities of the JIC in the Alaskan

region. This work will form the basis for the application of Polar-Platform SAR data to sea ice analysis.

Numerical modeling of sea ice continues to advance, and the JIC stands to be the primary beneficiary of work being done by NOAA and Navy researchers. Dynamic models, including ice mechanics and statistical models, are under development for use at regional and global scales. NOAA's Pacific Marine Environmental Laboratory is currently developing their second-generation model for the Alaskan region, and the Naval Oceanographic Research and Development Activity is working on other regional models. These efforts should greatly enhance the JIC's short-term ice forecasting capabilities.

### *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 user needs; and providing specialized data analyses and interpretations. As part of this overall responsibility, NESDIS collects and maintains a variety of Arctic and Antarctic environmental data sets. Another center that is of particular relevance to the Arctic is the National Geophysical Data Center in Boulder, which includes World Data Center-A for Glaciology (Snow and Ice).

A valuable source of high-latitude data is the Advanced Very High Resolution Radiometer on NOAA's polar-orbiting TIROS satellites. Magnetic tape and hard-copy prints of the AVHRR data are archived by the NESDIS National Climatic Data Center. The Navy/NOAA Joint Ice Center in Suitland, Maryland, is the largest single user of AVHRR imagery.

NESDIS also operates the Satellite Search and Rescue System (SARSAT) using emergency position location instruments on the polar-orbiting spacecraft. The international program became operational in 1982, saving over 1000 lives in its first five years.

# National Aeronautics and Space Administration

*NASA supports a variety of research programs in the Arctic that emphasize the application of air- and space-borne remote sensing to studies in the earth and space sciences. Of particular interest are Arctic processes that influence or are influenced by the behavior of the overall earth system. These programs, which include the study of oceans and ice sheets, atmospheric chemistry, space plasma physics and land processes, were funded for a total of \$13.4 million in FY 87 and \$16.9 million in FY 88.*

## *Polar Oceans and Ice Sheets*

This program continues to focus on the utilization of space-borne sensors to determine the characteristics of the polar ice cover and to understand how polar ice influences and is influenced by the overlying atmosphere and the underlying ocean. Specific long-range scientific goals include determining the energy flux between the ocean and the atmosphere at high latitudes, identifying the processes that control the formation of intermediate and deep ocean water, understanding the processes that control the growth, drift and decay of sea ice, measuring the boundaries and mass balance of the world's great ice sheets and shelves, and generally advancing current capabilities for extracting geophysical information from remote sensing data collected over snow- and ice-covered regions.

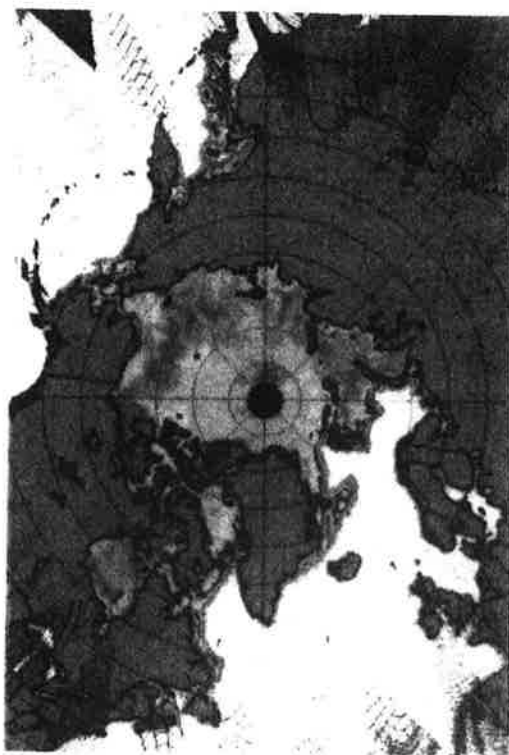
The program concentrates on remote sensing techniques that operate in the microwave portion of the electromagnetic spectrum; these methods are not constrained by either darkness or clouds, which commonly limit Arctic observations. Sensors operating in this frequency region permit the acquisition of the consistent time series of observations that are required by most geophysical problems. Particular emphasis has been placed on methods for extracting geophysical information from these data sets and for validating the results. This focus is particularly apt because of the 1987 launch of the SSM/I passive microwave system as part of the Defense Meteorological Satellite Program (DMSP) and the impending launch in 1990 by the European Space Agency (ESA) of the European Remote Sensing satellite (ERS-1). ERS-1 is the first of a series of satellites that will be in polar orbit and will carry synthetic aperture radar (SAR) systems.

	FUNDING (thousands)		
	FY86	FY87	FY88
Polar Ocean/Ice Sheets	2,727	7,600	9,600
Land Processes	623	665	760
Atmospheric Sciences	200	200	2,700
Sounding Rocket Program	858	950	950
Dynamics Explorer	2,900	3,000	1,700
Space Plasma Research	614	714	770
Solar Terrestrial Theory	77	294	370

Passive microwave studies continue to validate and refine existing algorithms for estimating the ice concentration in polynyas in the Bering and Okhotsk seas where new ice types are continually being formed during the growth season. Similar studies have also been undertaken in areas of heavy multiyear ice in the Chukchi and Greenland seas. When possible the remote sensing activities have been coupled with field observations of ice type and properties. In related efforts, considerable time has been devoted to improving field-portable equipment for determining the microwave characteristics of sea ice and snow, because quality data here will be useful in developing more realistic models. Progress has also been made in improving algorithms for making weather corrections to apply during the analysis of these data sets.

Of particular interest to users of passive microwave data from the polar oceans is the NASA program at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, which archives gridded brightness temperatures and derived products based on data from the SSM/I system deployed on the DMSP satellite launched in 1987 (see *Arctic Research of the United States*, Spring 1988, p. 32). Access to this data set is now possible since NSIDC has been established as a node on the NASA Ocean Data System (NODS) developed by the Jet Propulsion Laboratory.

*DMSP-SSM/I products  
used to determine winter  
sea ice concentration.*



The earlier passive microwave data collected by the ESMR and SMMR systems are also available via the same system. This data set is being calibrated and validated using data collected during an underflight of the SSM/I satellite by the NASA DC-8 aircraft during March 1988. Groups active in passive microwave research relative to the polar oceans include the Environmental Research Institute of Michigan (ERIM), the Goddard Space Flight Center (GSFC) and the Universities of Colorado, Massachusetts and Washington.

Research on applying active microwave remote sensing techniques to Arctic ocean and ice areas is being carried out in two directions. The first is a relatively small continuing program focused on applying the radar altimeter data from the GEOSAT satellite to the study of the topographic variations of the Greenland Ice Sheet. Developing benchmark elevations and general topographic analysis capabilities is essential for studying the future contributions of the ice caps (in particular Greenland and Antarctica) to anticipated rises in sea level. The altimeter data are also useful for locating the edge of the pack ice precisely.

The second, and much larger, active microwave research effort relates to studies of the polar regions using data from satellite-borne SAR systems. The rather intense activity in this field is tied to the coming launches of ERS-1 in 1990, J-ERS-1 in 1992 and RADARSAT in 1994, all satellites carrying SAR sys-

tems, and to the establishment of the Alaska SAR Facility (ASF) at the University of Alaska-Fairbanks, which will acquire, analyze and distribute these data. The following are activities that are part of this larger effort.

First, a continuing effort has been underway to collect field observations on the nature of radar returns from a variety of sea ice types and to model these changes in terms of observed changes in frequency, angle of incidence, polarization, crystal structure, brine and gas content, ice wetness, ice type, snow cover and wetness, and surface roughness. These measurements have recently been carried out in a near-laboratory setting using artificial sea ice grown on a pond at the Cold Regions Research and Engineering Laboratory (CRREL) in New Hampshire as part of a continuing program jointly supported by the Office of Naval Research.

Other recent activities include studies of the multi-frequency, multi-polarization data set acquired by the JPL SAR system flown as part of the instrument package on the NASA DC-8 on its deployment to Alaska during March 1988. Other remote sensing aircraft participating in this experiment were two Navy P-3 aircraft, one carrying a scanning microwave imager and the other carrying a second multi-channel SAR. Particularly interesting data were obtained over the ice pack in both the Bering and Chukchi seas. Observations were also made on the structure, chemistry and ridging of the brackish water ice occurring in the northern Bay of Bothnia as part of the U.S. participation in BEPERS (Bothnian Experiment in Preparation for ERS-1). BEPERS was jointly organized by the Finnish Institute for Marine Research and the Swedish Meteorological and Hydrological Institute.

Another area of research related to the coming operation of ASF is the complex problem of extracting meaningful geophysical information from the SAR data without extensive operator-system interaction. To date, attention has focused on the development of algorithms for tracking the motion of ice floes in successive SAR images and has resulted in several working procedures. Interest is now shifting to the problem of classifying ice types in SAR images. Groups involved in the active microwave research program are located at CRREL, ERIM, GSFC, JPL, Stanford University and the Universities of Alaska and Washington.

Considerable progress has been made on the Alaska SAR Facility during the past year.

*New SAR antenna at the  
Geophysical Institute,  
University of  
Alaska-Fairbanks.*



The construction of the new facility has just been completed, providing over 1600 square feet of additional floor space including a meeting room, six offices, three analysis rooms, a machine room, an archive and a 16-by 30-foot steel-reinforced concrete antenna support pad located on the roof of the Geophysical Institute (see back cover). The construction and installation of the 10-m antenna by Scientific Atlanta has also been completed. The other systems that will be necessary for station operation are being developed at JPL, with delivery to Alaska scheduled for the fall of 1989 and the spring of 1990. The SAR Processor System is being designed for a throughput of 1:10 (6 minutes of raw data transmission will be processed in 1 hour). Also under development is a data transmission system that will provide near-real-time, quick-look, low-resolution images to the NOAA National Ice Center within minutes after the satellite pass.

The Pre-launch Science Working Team (PSWT) completed their final input to the ASF Science Plan in August 1988 at their second meeting. They hope to release this document during the winter of 1988-89. During 1988, panels from the PSWT have been active in deciding which floe-tracking algorithms should be initially implemented in the Geophysical Products System (GPS) and in organizing the overall effort to produce reliable al-

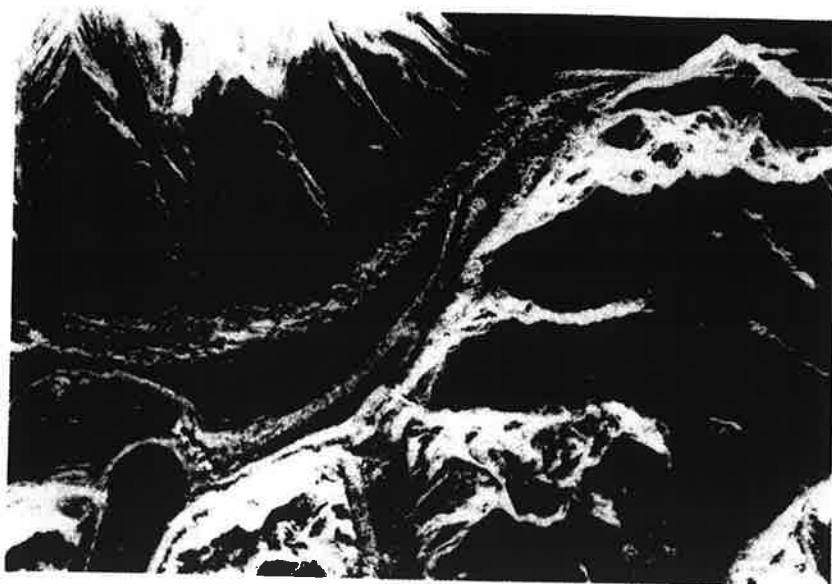
gorithms that generate ice classification and ocean wave information. The agreement between the Japanese government and NASA for the acquisition of real-time SAR data at ASF has been concluded, so the next major task confronting the PSWT is to update and expand the science program so that it deals effectively with the nearly simultaneous collection of both C-band data (from ERS-1) and L-band data (from J-ERS-1). Also associated with the development of the overall science program has been a careful review of the conceptual basis for the software for the Archive and Operations System (AOS). Another interesting development has been the acquisition of the major components of the Interactive Image Analysis System (IIAS). This system is designed for off-line image analysis requiring nonroutine interactive procedures. Ultimately, image analysis software developed and tested on the IIAS will be transferred to the GPS if the results are of sufficient general interest to warrant the development of a routine data product.

### *Aircraft SAR Studies of Terrestrial Processes in Alaska*

In March 1988, when the NASA DC-8 was deployed to Alaska in support of NASA's sea ice program, several Land Processes Branch investigators were able to obtain SAR coverage and ground measurements over their field areas. The following paragraphs describe some of their experiments.

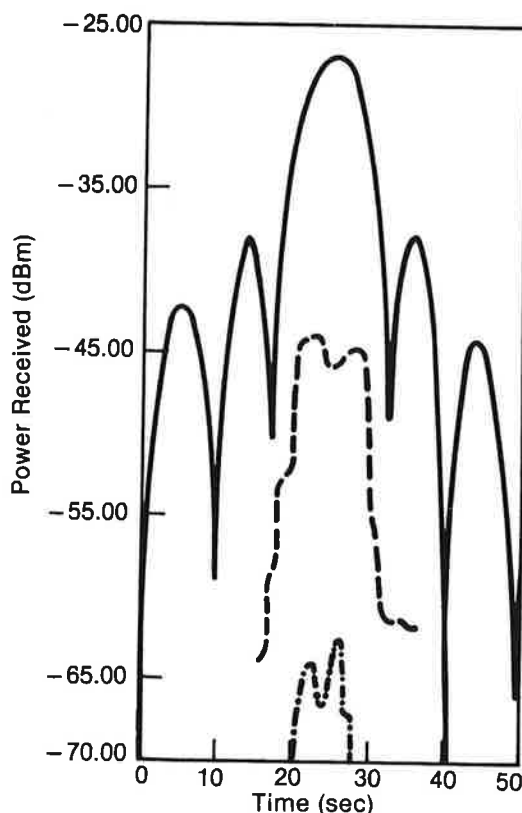
The utility of SAR for studying permafrost characteristics was examined. Because permafrost is typically an inhomogeneous mixture of water, ice, rocks and organic material, its physical properties may vary widely with location and season. The first field effort used ground receivers buried at various depths within the permafrost as well as on the permafrost surface. The receivers measured the aircraft SAR signal during an overpass so that scattering, boundary layer reflection, and attenuation and scattering by buried material could be determined.

An international team of ERS-1 investigators collected ground truth and SAR calibration data in the forests along Bonanza Creek, Alaska. Their research objectives were to further the development of microwave scattering models of forests under different environments and phenological conditions and to develop means for incorporating radar data into ecosystems models.



*SAR image of intersecting glaciers in the Black Rapids area of the Alaska Range.*

The vast cemented deposit of volcanic ash flow produced by Mt. Katmai in the Aleutian Arc occupies a large glacial valley, called the Valley of Ten Thousand Smokes because of its active geological state. The active volcanism and seismicity of the Aleutians reflects their relationship to the subduction of the oceanic Pacific Plate beneath the North American Plate. SAR data will be used to search for structural features related to the velocity field existing when the ash flow formed, as well as to estimate the volume and emplacement velocity of the ash flow.



*Received power as a function of time during an aircraft overpass for three receivers buried at different depths in permafrost.*

An innovative approach to the study of forest ecosystem dynamics involved the use of soil gradients and forest successional stages left in the wake of a rapidly receding glacier at Glacier Bay National Monument as a natural test bed for ecosystem process models. C-band data will be examined for information useful in ecosystem models, and specific model parameters will be inferred from C-band data and used to check the performance of the models' algorithms.

## *Particle and Magnetospheric Processes*

The aurora seen at high latitudes is the most visible interaction of the solar wind with the magnetosphere of the Earth. Two large-scale programs are now underway to understand the physics of the auroral displays. The first program is the NASA Solar Terrestrial Theory Program (STTP), whose goal is to understand the processes of energy transfer from the sun to the Earth's upper atmosphere. The STTP, which has an annual budget of almost \$4 million, has made significant progress in understanding the processes deep in the magnetosphere that power the aurora. The second program is the Global Geospace Science (GGS) component of NASA's International Solar Terrestrial Program (ISTP). The GGS program has a theory component, funded at about \$1 million per year, that will promote the interaction of theorists with the experimenters on the ISTP spacecraft, slated for launch in the 1990s. The theoretical effort will help in understanding the satellite observations of auroral and high-latitude plasma processes, which frequently occur in the upper atmosphere of the Arctic but which have their origins tens of thousands of kilometers deep in space in the Earth's magnetosphere, where the satellites will be making direct observations.

The Dynamics Explorer-1 (DE-1) spacecraft continues to provide data on ionosphere-magnetosphere interactions and auroral morphology, as well as on global air glow and ozone. Campaigns were conducted with the Siple, Antarctica, transmitter at the beginning and end of the year, as well as with sounding rockets. In June the GISMOS experiments coordinated a worldwide array of incoherent scatter radars as well as other geophysical monitoring stations. The orbital configuration was optimal for imaging of the aurora borealis during the latter part of the year. The



global auroral images, which are revealing the temporal and spatial morphology of auroral activity, are being successfully used to place in-situ measurements of plasma and upper atmospheric properties into a global context. The polar ionosphere is found to be a major, and perhaps dominant, source of plasma for the magnetosphere, with a dependence on the solar cycle. On the other hand, the geoelectric field of the magnetosphere plays a dominant role in driving high-altitude neutral winds over the polar cap from momentum exchange with ionospheric ions convecting in the field.

Northern auroral imaging continued into the first part of 1988. The experiments with DE-1 and the Siple, Antarctica, transmitter resumed for the austral winter and will again occur late in the year during the austral summer. Collaborations with radars continued under the CEDAR (Coupling, Energetics and Dynamics of the Atmosphere Region) international campaign.

Preparations are being made for several spacecraft missions involving active experiments in which physical phenomena will be studied by creating them artificially, rather than by observing them passively in their natural forms. In some of these missions, although the spacecraft will be orbiting at relatively low latitudes, the subjects of study will be plasma phenomena that occur naturally at high latitudes, in the auroral zone. In other future missions the spacecraft will orbit up to high latitudes and will study the plasma of the auroral zone directly.

The Combined Release and Radiation Effects Satellite (CRRES) program was originally planned around a single large satellite, to be launched from the Shuttle, carrying 48 canisters for releasing chemicals in space. After the Challenger accident, NASA decided to distribute these experiments over a mixed fleet of launch vehicles. The main satellite will now carry about half the original number of canisters and will be launched by an Atlas Centaur rocket into an eccentric orbit with its highest point at approximately six Earth radii. Some of the other planned releases will be made from two smaller satellites launched by Scout rockets into low Earth orbits, and the rest will be made from seven sounding-rocket payloads. Two of the experiments on the main satellite will attempt to create artificial auroras by releasing clouds of lithium vapor near the highest in the orbit; after becoming ionized by sunlight, the lithium is expected to stimulate plasma instabilities, leading to the precipitation of energetic electrons and pro-

tons, which should produce light when they strike the atmosphere at auroral altitudes. One of the two smaller satellites will orbit up to high latitudes, where it will release clouds of barium or lithium to act as tracers for auroral electric fields; it will also carry instruments to study plasma irregularities in the auroral ionosphere.

## *Upper Atmospheric Research*

The NASA Upper Atmosphere Research Program continues to conduct a comprehensive program of research aimed at expanding our knowledge of the physical, chemical and meteorological processes that control atmospheric ozone. In August and September 1987 a major airborne measurement campaign studied the sudden and unanticipated decrease in the abundance of ozone over Antarctica during the austral spring. The results from that study have directly implicated man-made chemicals in the enormous ozone depletion. To continue the study of production and loss mechanisms for ozone in the polar stratosphere and to assess man's growing influence on his environment, NASA is planning a similar extensive aircraft mission for January-February 1989 in the Arctic. The motivation for this experiment was provided by the recent findings of NASA's Ozone Trends Panel, which concluded that over the last 17 years, total column ozone has undergone a statistically significant decrease during the winter months at high northern latitudes. This change is outside the range of natural geophysical variability and is larger than the mean change predicted by model calculations of the effects of the increased atmospheric abundance of trace gases.

The 1989 aircraft mission based in Stavananger, Norway, will examine the chemical role of polar stratospheric clouds (PSCs) in the Arctic to determine what parallels (if any) exist with the new chemical findings over the Antarctic. The experiment will involve NASA's ER-2 and DC-8 aircraft in closely coordinated deployments using both in-situ and remote sampling instruments to measure a variety of chemical and meteorological variables. Flights will be conducted when PSC formation is statistically most active and will focus on air parcels processed through the polar vortex. A network of balloon ozone-sondes will provide complementary measurements for this mission.



In 1985 NASA initiated an Interdisciplinary Research Program in Earth Science aimed at advancing research on complex questions of global change. One of three topics selected for inclusion in this program and managed under NASA's Upper Atmosphere Research Program is atmospheric methane. This research is directed at understanding the origins and consequences of the increasing atmospheric concentrations of methane. Investigators are actively monitoring the fluxes, isotopic composition and seasonal variations in methane from northern wetlands and forests, as well as measuring oxidation rates from various ecosystems. These studies will play an important role in assessing the role of atmospheric methane in future climate modifications.

### *Global Tropospheric Experiment*

The goals of NASA's Tropospheric Chemistry Program are to understand global tropospheric chemistry and assess the susceptibility of the global atmosphere to chemical change. A major component of the program is the Global Tropospheric Experiment (GTE), which consists of a series of field expeditions to evaluate the performance of instrumentation under development, as well as specific field measurement issues.

Atmospheric boundary layer experiments, known as GTE/ABLE, consist of a series of expeditions with the following general scientific objectives:

- Understanding the processes that regulate the uptake and release of trace gases by sur-

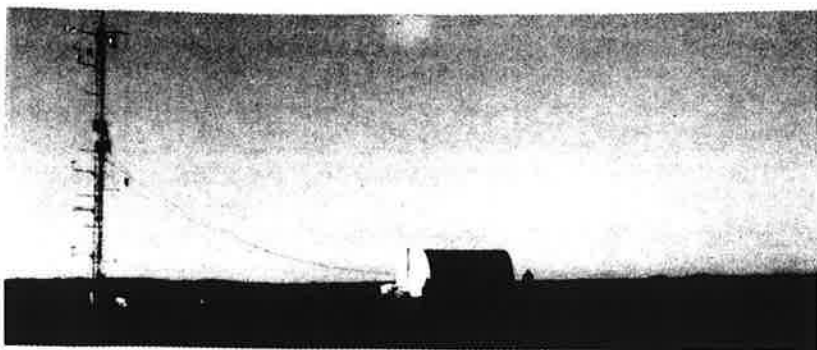
face ecosystems, particularly the factors that influence tropospheric trace gas budgets at the global scale;

- Determining the distributions of photochemically active atmospheric gases in relation to both source and sink characteristics and the meteorological transport processes in regions that have high priority for understanding global tropospheric chemistry;
- Developing new approaches for using airborne measurements, integrated with ground and satellite support data, to move toward quantifying atmospheric chemical processes at increasingly larger scales.

ABLE-1 was an investigation over the tropical Atlantic Ocean, and ABLE-2A and 2B were expeditions over the tropical rain forests of the Amazon Basin of Brazil during dry and wet seasons, respectively. ABLE-3 is investigating biosphere-atmosphere gas exchange processes in Arctic tundra and Subarctic boreal environments, as well as the atmospheric photochemical and transport processes that couple these environments to the global tropospheric chemical system. The project is focused on high-latitude (50°N) Northern Hemisphere regions that have been shown to be especially sensitive to climatic change. The research is specifically focused on the sources, sinks and distributions of methane, CO, carbon dioxide, NO, NO<sub>2</sub>, other nitrogen gases, HNO<sub>3</sub>, PAN, ozone, selected non-methane hydrocarbons and organic acids.

ABLE-3 experiments include aircraft survey measurements, airborne- and tower-based determinations of vertical fluxes for selected trace species, and ground-based measurements of surface exchange processes. ABLE-3 is also studying the potential role of soil carbon in Arctic and boreal peatlands as a source or sink for methane and carbon dioxide under present and future climatic conditions. It will also assess the factors that influence atmospheric photochemical processes in the high latitudes during summer.

The initial expedition, GTE/ABLE-3A, was conducted in Alaska during July and August 1988. Airborne measurements were conducted out of Barrow and Bethel, Alaska, on the NASA Electra research aircraft, a four-engine turboprop specially fitted for tropospheric chemistry investigations. The aircraft provides access to the range of peatland environments typical of the northern high latitudes: the coastal wet tundra north of the Brooks Range from Point Barrow and the Subarctic deltaic and interior peatlands of the Yukon delta from Bethel. Extensive ground-based meas-



*GTE/ABLE-3A ground-based measurement site near Bethel, Alaska.*

urements were conducted at a remote site northwest of Bethel. Initial efforts are underway in formulating a joint U.S.-Canadian follow-up expedition, ABLE-3B, for the summer of 1990, for similar studies in the boreal forest and Subarctic peatlands of Canada. The following were specific science objectives for ABLE-3A:

- Surface-atmosphere gas exchange studies focusing on three subjects: the Subarctic and Arctic peatlands as significant sources of atmospheric methane, the high-latitude biosphere and ocean as a source or sink for atmospheric carbon dioxide, and open water and vegetated terrestrial surfaces as sources or sinks for ozone, NO, NO<sub>2</sub>, NO<sub>y</sub> and other photochemically active molecules;
- Studies of trace gas distributions focusing on two subjects: the exchange of gases between surface sources and sinks, the mixed layer, and the free troposphere; and the role of long-distance transport as a source of ozone, or ozone precursors, to the Arctic troposphere, particularly external sources of pollution during summer conditions.

One study explored trace gas variability in the atmospheric boundary layer related to major Arctic surface types with measurements across coastal wet tundra, open Arctic Ocean, and polar ice-pack boundaries. Another project studied the chemical characteristics of atmospheric haze layers resulting from biomass burning.

There were two major components of the ABLE-3A ground studies: flux measurements using chamber techniques, and flux and ambient concentration measurements using a micrometeorological tower. The chamber methods give information on the smallest scales to identify the climatological factors that influence emission and deposition rates. The micrometeorological techniques provide flux information for larger areas.

The ground-based enclosure studies and associated ecological measurements were partially supported by the NASA Global Biospher-

ics, Interdisciplinary, and Terrestrial Ecosystems programs. These studies complement ongoing research sponsored by the National Science Foundation at Long-Term Ecological Research sites in Alaska.

The airborne measurements focused on photochemical and surface exchange processes over major Arctic and Subarctic wetland regions and on land-ocean-ice gradient studies. Atmospheric photochemical processes, involving active species like CO, NO, NO<sub>2</sub>, NO<sub>y</sub>, HNO<sub>3</sub>, and ozone, were investigated on all flights. These missions also used continuous lidar remote sensing of aerosol and ozone distributions above and below the aircraft to identify specific atmospheric structures. Missions to study surface exchange processes, conducted during clear weather, had two primary sampling strategies. The characteristics of sources and sinks and the transport of gases from the surface to the free troposphere were investigated with repeated vertical soundings from 150 m to 5 km in altitude over the complete research area.

In addition to measurements over peatlands during surface exchange studies, other missions documented the chemical characteristics of major air masses originating over the north Pacific Ocean and over the Arctic. These flights used detailed meteorological data to document the dynamical evolution of the air masses selected for chemical characterization. Studies of these relatively pristine air masses prior to their transit over the industrialized regions of North America complemented studies of sources and impacts of regional pollution in North America.

ABLE-3A transit flights between Wallops Island, Virginia, and Alaska were used to characterize latitudinal and longitudinal gradients in the distribution of trace gases in the free troposphere. In addition, remote sensing of aerosol and ozone above and below the aircraft provided a continuous two-dimensional view of chemical-dynamical interactions in the entire tropospheric column along the flight path. Transit flight data documented trace gas chemistry across a major pollution gradient from eastern North America to the Arctic. Also, because the biospheric carbon dioxide sinks and methane sources were near maximum during the ABLE-3A transit flights, the flights were designed to test the predictions for carbon dioxide and methane distributions made using a NASA three-dimensional model.

The results of the ABLE-3A studies will be reported at the spring 1989 AGU meetings.

# Department of Energy

*DOE Arctic research efforts included studies of the effects of landscape disturbance and carbon dioxide enrichment of the atmosphere, seismotectonics, magnetic field annihilation in the magnetosphere, energy data base management, and unconventional gas recovery methods. Funding totaled \$3.6 million in FY 87 and \$2.9 million in FY 88.*

## *Integrated Research on Tundra Ecosystems*

Tussock tundra covers about 80% of the 220,000 square kilometers of Alaskan Arctic tundra. It is the dominant type of vegetation in the North Slope foothills region, including the Arctic National Wildlife Refuge. Because the development of energy resources in Arctic tundra regions has caused (and will continue to cause) various types of disturbances to the landscape, the Ecological Research Division of the Office of Health and Environmental Research sponsors research on Response, Resistance and Resilience to, and Recovery from, Disturbance in Arctic Ecosystems. Known as the R4D program, it is the largest integrated terrestrial ecology program being conducted in Arctic Alaska over the last four years.

The long-term objectives for the R4D program are to determine the effects of disturbances and to develop models based on ecosystem disturbances so that appropriate, cost-effective measures can be used to minimize harmful disturbances. Another goal is to extend the results to other Arctic and alpine areas that are likely to be affected by energy development. While the long-term goals are to develop practical management tools, the means to these ends are through basic research.

Understanding the processes that control tussock tundra ecosystems, particularly the mechanisms by which water and nutrient availability regulate plant and ecosystem function, is a more immediate goal. Improved understanding of mechanisms and processes are being formalized in models operating at scales ranging from square-meter plots to hill slopes and watersheds. Linear arrays of slopes (such as along roads) and landscapes of many square kilometers are long-term targets of the modeling effort.

Working out of the Toolik Lake research

	FUNDING (thousands)		
	FY86	FY87	FY88
Ecosystem Response	1,400	1,400	1,400
Response to Carbon Dioxide	300	300	265
Arctic Offshore Research	1,550	495	372
Gas Hydrates	1,700	927	400
Aurora	126	128	130
Aleutian Seismicity	360	360	360

camp operated by the Institute for Arctic Biology, University of Alaska-Fairbanks, ten principal investigators from six universities are cooperating in an integrated study of the controls on nutrient movement and plant production in tundra ecosystems. The research program is being carried out along the Dalton Highway in the Imnavait Creek watershed, a tributary of the Sagavanirktok River 150 miles south of Prudhoe Bay. This is adjacent to the National Science Foundation's Long-Term Ecological Research site at Toolik Lake, and a number of cooperative links have been forged between the two programs (see p. 34).

The R4D program has produced a detailed record of stream geochemistry and its relationship to the landscape in the Arctic. Hydrologic and aquatic chemistry studies were begun in the upper reaches of Imnavait Creek in 1985. Snowmelt water has been collected at calibrated weirs with stage recorders and automated water sampling systems at first-order water tracks in the intensive study site and on Imnavait Creek. Sample collection includes the first meltwater in the spring and the last runoff prior to freeze-up in the fall. This combination of sampling and monitoring permits the water chemistry to be tied to stage and discharge records so that mass flux budgets for nutrients and major ions can be determined. This information will be used in evaluating the performance of models under development that will estimate mass flux from water tracks and from the Imnavait watershed.

The challenge of extrapolating the results of

these models over various scales, from small patch studies to the landscape, for example, is being met by linking process, transport and landscape models of differing spatial and temporal scales.

Because a system for spatially locating the ecosystem elements being modeled is essential to the success of this effort, the R4D program is developing a series of maps describing terrain features, vegetative cover, soils and hydrology for the intensive study area and its surrounding region. The scales of these maps range from 1:600 to 1:24,000. The maps and all of the other spatially discrete data are digitized in the R4D Arctic Geographic Information System (R4D/AGIS).

The information from these maps and from other sources can be layered via R4D/AGIS, allowing many layers of spatial information obtained over large land areas to be manipulated rapidly to identify source areas. Furthermore, through the use of correlative models, R4D/AGIS may provide the important initial conditions necessary for running a general Arctic ecosystem model at different locations, for example, estimates of biomass and leaf area index as functions of remotely sensed vegetation indices. This ability to manipulate spatial data and provide inputs to ecosystem models will provide a powerful tool for testing terrain sensitivity and analyzing hypotheses.

The feasibility of using advanced remote sensing and digital data processing techniques

to identify and measure landscape components important in land disturbance processes is being determined. Spatial relationships between landform geometry and ecologically important factors such as snow distribution, wind direction, solar inputs, soil type and plant biomass are being established and quantified. Multispectral image data with 10-m resolution have been obtained from the French SPOT satellite and are being used with R4D/AGIS for distinguishing vegetation classes. However, R4D/AGIS is structured to take advantage of data that will be obtained by the newest generation of NASA remote sensing satellites. R4D investigators will develop the ground-truth signatures for landscape features observable using an array of new satellite observation capabilities.

## Carbon Dioxide Research

The Carbon Dioxide Research Division is supporting research on the effects of increased CO<sub>2</sub> and climate change in the Arctic. Under this program two major projects are being funded: the response of tundra ecosystems to elevated atmospheric CO<sub>2</sub> and the projection of future sea-level changes caused by ice wastage.

The goals of the first of these projects are

- To determine the effects of changes in CO<sub>2</sub> and climate on growth enhancement, species population dynamics and the community carbon balance of tussock tundra; and
- To use existing data and ecological models of the tundra to analyze the short- and long-term response of the tundra ecosystem to changing CO<sub>2</sub> and climate.

The project emphasizes data analysis, modeling and interpretation of the results obtained over the past five years. The information contributes to modeling approaches under development by the San Diego Systems Ecology Research Group. The results are producing definitive statements of what is known and what is not known about tundra responses to varying CO<sub>2</sub> and climate conditions, including documentation of the need for further experimental work with the tundra ecosystem. A summary of four years of experimental results is being completed and will be followed by a report describing the data that will contribute to defining the parameters of a tundra ecosystem model.

A complementary activity is underway through the Oak Ridge National Laboratory to assess the relative importance of boreal and tundra regions in the global carbon cycle.

*Pit studies of superimposed ice on the Greenland Ice Sheet as part of a program to estimate the runoff from ice caps in a warmer future climate.*





The second project funded by the Carbon Dioxide Research Division seeks to understand and predict how the runoff from the world's largest glacier (exclusive of Antarctica) will respond in the next century to a changed climate caused by increased atmospheric CO<sub>2</sub>. The expected results include

- An understanding of the heat and mass flow into subfreezing snow and firn in order to model the evolution of the temperature distribution and the infiltration rates through the firn;
- An understanding of the relationship of changes in climate, as given by general circulation model predictions, to changes in the surface mass and energy balances of glaciers; and
- An analysis of the effects of changes in surface mass and energy balances on the flow of meltwater through snow and firn, and on runoff from these glaciers, in a CO<sub>2</sub>-affected climate.

Laboratory investigations will provide a qualitative understanding of the physical processes associated with mass and heat transfer within the sub-freezing snow mass; a conceptual model will be developed from these observations. Natural snow and firn will be carefully measured in the field before, during and after the melt season. The final step will be a numerical analysis. The project will require the compilation of results of general circulation models (GCMs) to develop a consensus for how climate is likely to change in the next century. Simple mass and energy balance models will translate the changes in climate into their effects on glacier surfaces for certain representative areas selected for this work. Analyzing the results will involve applying the mass and energy balance models to GCM estimates of present climatic environments and checking against known data. Then the models will be applied to the changed environments caused by a doubled concentration of CO<sub>2</sub>. The estimated amount of meltwater will be routed through the snow and firn to estimate the runoff and its evolution with time. These results, when integrated for the major ice masses of the world exclusive of Antarctica, can then be interpreted as the effect that these glaciers will have on the global sea level.

### *Other DOE Activities*

Other Department of Energy activities reported in the Fall 1987 issue of *Arctic Re-*

*search of the United States* remain unchanged. They include projects in fossil fuel technology, gas hydrates as a potential fuel source, plasmas in the magnetosphere, and the seismotectonics of the eastern Aleutian Arc.

DOE is active in research that advances the technology for recovering Arctic fossil fuels. The Arctic Offshore Research Information System (AORIS), a technology data base, has been developed to make available the information needed for fossil energy development in the Arctic. AORIS has two parts: a bibliographic and management information system containing references and abstracts, and a scientific and engineering technology information system containing quantitative data and descriptions of analytical models. The initial products of AORIS are now accessible. DOE is also involved in research on critical environmental factors for Arctic offshore energy development, such as ice accretion, ice impacts on stationary structures and seafloor stability.

DOE's work on gas hydrates is designed to evaluate their potential as a future supply of gas. The research plan is to identify and quantify the resource and to develop the exploration and production technology to demonstrate its feasibility. Computer simulations have been developed for the extraction process for hydrates, and field tests using industry-drilled wells on Alaska's North Slope have measured gas hydrate characteristics.

The Geophysical Institute of the University of Alaska-Fairbanks is researching the basic characteristics of the plasma of the magnetosphere. They are also studying energy-related geophysical problems of the Arctic, such as electric currents in power lines and pipelines induced by auroral activity.

Another DOE project, conducted by the Lamont-Doherty Geophysical Observatory at Columbia University, studies the geophysical processes of subduction and arc-magnetism. The purpose is to understand and assess the seismic risk to future energy projects in an active zone. Seismotectonic data are collected from 14 remote stations along a 300-km-long arc segment in the Shumagin Islands in the eastern Aleutians. These data are used to help understand the basic mechanisms of the convergence of the North American plate with the Pacific slab. These studies will be useful in assessing the geothermal energy potential of the Aleutian Arc and the seismic, volcanic and tsunami hazards to offshore oil-lease-sale areas directly adjacent to the Shumagin seismic gap.

# Department of Health and Human Services

*Arctic health research supported by DHHS is conducted primarily by the Centers for Disease Control and the National Institutes of Health through grants and contracts. Collaborative studies are performed with other health care providers including the Indian Health Service, the Alaska Department of Health and Social Services, and the University of Alaska. Funding totaled \$1.5 million in FY 87 and \$920,000 in FY 88.*

The Arctic region is recognized as a natural laboratory and, as such, a region where health research may have broad implications and applications. Key concerns in health and health research include social and behavioral aspects, disease trends and transmission, native diet, and human adaptation to extreme environmental and occupational challenges. The health-culture-socioeconomic component is important in addressing the complex issues being faced in the Arctic.

There are health problems that are unique to the Arctic. They may occur as a result of the particular physical and biologic environment, the social and cultural practices, the genetic-immune make-up of the people, or the interaction of these factors. Many diseases do not occur exclusively in the Arctic but occur at greatly increased rates. These diseases may be significant health problems in the rest of the United States (e.g. infant morbidity and mortality, including fetal alcohol syndrome and sudden infant death syndrome, childhood respiratory diseases, meningitis and otitis media), or they may be significant health problems internationally (hepatitis and respiratory and diarrheal diseases). Other disease conditions are important to study because they were once thought to be rare in Arctic populations but are now rapidly increasing in frequency (cancer, heart disease, dental disease, diabetes, obesity).

A major portion of Federal Arctic health research is conducted by the Arctic Investigations Laboratory (AIL) of the Centers for Disease Control. This facility, located in Anchorage, Alaska, maintains affiliation with the Alaska Area Native Health Service of the Indian Health Service (IHS). The AIL is staffed by personnel with epidemiological, statistical and laboratory expertise. Their mission is to reduce disease morbidity and mortality among Arctic residents, including Alaskan Natives

	FUNDING (thousands)		
	FY86	FY87	FY88
Disease prevention and control	828	471	400
Cancer in Alaskan natives	138	188	242
Vaccine evaluation	790	802	190
U.S. extramural research	—	334	351

(Eskimos, Indians and Aleuts). The research unit investigates the causes of disease, evaluates disease control programs, provides epidemiologic, statistical and laboratory consultation, assists in training personnel in Arctic health research, and provides support services for studies conducted by other agencies. Extensive work has been done in infectious diseases, once the major cause of disease in Alaskan Natives. More recent studies have concentrated on hepatitis, pneumonia, botulism, echinococcus (a parasitic infection of the liver) and meningitis.

## *Disease Prevention and Control*

The IHS, in collaboration with the AIL and the State of Alaska, is completing a three-year effort to eradicate hepatitis B (HBV) infection. In addition to causing acute hepatitis, long-term infection with HBV can lead to liver cancer. Alaskan Natives are at increased risk for both diseases. During the past three years, over 50,000 Alaskan Natives have been tested for evidence of infection with HBV, and those who had not been infected, as well as all newborn Native babies, are being immunized. The rates of acute infection have declined dramatically. Those who received some of the first doses of HBV vaccine are being followed annually to determine whether a booster shot may be necessary. Persons chronically infected with HBV are over 200 times more likely to develop liver cancer, which has had a fatality rate of nearly 100%.

Over 1500 persons chronically infected with HBV are being tested for a tumor marker (alpha-fetoprotein) to detect cancer at an early treatable stage. Liver cancer mortality has been cut in half.

Both upper and lower respiratory infections take their toll on health in Alaska. At least 20% of pneumonias are thought to be due to the bacteria *Streptococcus pneumoniae*. A statewide laboratory-based surveillance system has been initiated to identify all cases of culture-positive pneumococcal disease. The rates of disease are as much as 50 times higher in certain age groups of Alaskan Natives than in other U.S. populations. A vac-



Moving supplies into a health clinic during a village field trip for hepatitis B immunization studies.

cine is recommended for persons over age 65 and those with certain chronic conditions. A project is underway in the Native health corporation service areas to assure that all persons for whom vaccine is recommended have received their shot and to determine whether other groups of people in these high-risk areas would benefit from vaccination.

Botulism continues to be a problem in Alaska, resulting from the consumption of specially prepared Alaskan foods. Despite rapid treatment, botulism can be fatal, and one death resulted from botulism in 1988, the first in six years. Studies are in progress to determine the optimal amount of antitoxin to be used in treatment and to develop new laboratory tests to detect the presence of botulism toxin in the blood of patients with symptoms of the disease.

*Echinococcus multilocularis* (EM) is a tapeworm found most commonly in dogs and other animals. Humans, who may become infected incidentally by contact with dog or fox excreta, develop a large cancer-like lesion in the liver, which can eventually prove fatal. Residents of northwest coastal Alaska are at particularly high risk for this disease, which can be cured only with surgical removal of liver lesions when they are small. By the time pa-

tients are aware of symptoms from the disease, many lesions are already inoperable. A new blood test appears to be useful in screening asymptomatic persons in the high-risk areas for early lesions. Serosurveys are being conducted, and persons positive for the antibody to EM are evaluated for liver disease.

IHS studies of current dietary intake include attempts to identify and describe current food consumption practices of Alaskan Native adults from different regions in order to promote healthful dietary habits. They are also trying to establish an ongoing diet monitoring system in Alaska.

Population-based statistics on blindness rates and causes or the incidence of major eye diseases are nonexistent for Alaska. This IHS study seeks to examine two existing data sets from earlier ophthalmic surveys among Alaskan Natives. The study proposes to consolidate the information gathered in these surveys and present summary statistics on the prevalence and causes of blindness in Alaskan Natives.

A survey of the oral health status of the children of Nome, Alaska, will be conducted now and in five years to determine whether the addition of fluoride to the community water system helps prevent dental caries. This survey will establish baseline information on the prevalence of dental caries in the 3- to 18-year age group and will determine the prevalence and treatment needs of periodontal disease in children 12-13 years old.

*Haemophilus influenzae* type b (Hib) is the leading cause of meningitis in the United States. The population with the highest known incidence of invasive Hib disease is Alaskan Eskimos.

A licensed polysaccharide Hib vaccine has been administered to over 10 million children 2-5 years of age. Five case-control studies show a range of efficacy from 69 to 88%. However, the vaccine is ineffective in children less than 18 months of age, where the most serious disease occurs. This situation prompted the development of protein-polysaccharide conjugate Hib vaccines. These vaccines stimulate T-cells to produce excellent immune responses in young children and infants. A double-blind, randomized, placebo-controlled efficacy trial to evaluate one of these conjugate vaccines has now been completed in a high-risk group of Alaska Native infants. Approximately 2100 two-month-old infants received up to three doses of either vaccine or a saline placebo given on alternating months. The incidence of local and systemic reactions

was not statistically different between vaccine and placebo groups regardless of the number of doses provided. Trial subjects will be followed for an additional year to obtain more information on safety and efficacy. Because the trial is now into a surveillance or follow-up phase, fewer dollars are needed to support this effort.

Overall, the efficacy data were disappointing and indicated that the lot of vaccine used in this study population did not provide significant protection against disease. Studies in this population with other more potent Hib conjugate vaccines are under consideration in addition to studies with conjugate vaccines effective against pneumococcal pneumonia, which also causes a high degree of morbidity among Alaskan natives.

### *Cancer in Alaskan Natives*

For the past 13 years the Centers for Disease Control and Indian Health Service have collaborated on a statewide Native cancer surveillance project to identify all Alaskan Natives who have been diagnosed with cancer since 1969. Colorectal cancer was the most frequently diagnosed invasive cancer among Alaskan Natives between 1969 and 1983. It accounted for 260 of 1475 total cases and occurred in nearly equal numbers of men (127) and women (133). The age-specific rates are similar to those seen in other U.S. populations, and when adjustments are made for age, the rates of colorectal cancer among Natives are at least as high as those among U.S. whites. Of the 1475 invasive cancers diagnosed among Natives in 15 years, 199 were in young people. The most frequently diagnosed cancers were testis and blood cancer for the male population and cervical, breast and thyroid cancer for the female population.

In 1988, studies were initiated to determine the prevalence of human cervical and esophageal papilloma virus infections in Alaskan Natives and their role in cancers that develop at these sites. Human papilloma virus (HPV) has been implicated in both primary and metastatic human genital cancer, especially carcinoma of the uterine cervix. The in-vivo transformation and tumor development of human cervical tissue with HPV when transplanted into immunodeficient mice adds to the evidence for a viral etiology of the disease. In women, infections seem to parallel the presence of cervical dysplasia, and case reports suggest a relatively short time between detect-

able infection and invasive cervical cancer. Little is known about the natural history of genital HPV infection in men. However, smears of penile epidermis have revealed an increase of HPV in male sexual partners of women with HPV infections and cervical dysplasia, and HPV genomes have been identified as integrated DNA in penile cancer tissue. Although cervical cancer rates for U.S. Caucasians have been declining over the past 25 years, clinical encounters for genital HPV infections have increased severalfold. Age-adjusted invasive cervical cancer rates in Alaskan Native women during 1969-1983 were 28 per 100,000. These are over twice the U.S. rates, and the rates increased 23% during the time period. No data on genital HPV infections in Alaskan Natives are available.

Recently HPV has been suspected in human esophageal disease. HPV histologic changes have been reported in 17% of benign esophageal lesions and one third of esophageal cancers from a region hyperendemic for esophageal cancer. HPV DNA has been hybridized from paraffin-embedded tissue of half the esophageal carcinomas examined from a low-risk area. Age-adjusted rates for esophageal cancer in Eskimo and Aleut men and women during 1955-1981 were calculated to be 11 and 8 per 100,000 respectively, two and six times the rates in U.S. Caucasian men and women. The majority of Alaskan Natives who develop esophageal cancer reside in one area of Alaska.

### *Community Support Programs and Services*

The Alcohol, Drug Abuse, and Mental Health Administration has several Arctic-related health activities, which are generally supported through grant-in-aid programs. Allotments are made to the State of Alaska or regional and local governments for developing plans for establishing and implementing an organized comprehensive community-based system of care, activities and services (treatment and education) for persons who are homeless or have severe and persistent mental illness, alcohol and drug abuse problems and suicide tendencies. This also includes severely emotionally disturbed children, adolescents, other high-risk individuals, and underserved populations. Many of the programs are designed to develop the social, physical and intellectual competency of Native Alaskan youths, which meets the cultural needs of the

community while providing a regional economic development initiative. Much of the support also goes into improving the availability, distribution, competence and appropriate utilization of personnel who provide the mental health services to the severely mentally ill population. Finally, funds are earmarked for programs and related opportunities that are appropriate for Alaskan Natives and address a number of mental health needs and other areas related to how Alaskan Natives cope with rapid life transitions. FY 87 expenditures were \$2.76 million, and FY 88 expenditures totaled \$3.85 million. However, since these activities are not considered for research, the funds are not being reported for present purposes as DHHS research.

### *Extramural Related Research*

NIH provides additional support for Arctic research through grant and contract mechanisms in areas outside Alaska, such as Sweden, Norway, Finland and Canada. The research emphasis is more basic in scope and includes studies on immune effector mechanisms in

cancer patients, the genetic control and role of natural killer cells, nutrition and cancer, cellular and molecular mechanisms of brain damage caused by stroke and other cerebrovascular disorders, endocrine responsiveness in heterothermic mammals, and control of reproduction and fertility under extremes of body temperature.

In addition to the basic studies, a large NIH-sponsored field trial recently conducted in Sweden showed that two acellular pertussis vaccines for infants were safe and efficacious. This was the first well-controlled study demonstrating that acellular pertussis vaccines can effectively prevent pertussis. However, the trial was unable to demonstrate the serum correlates of immunity, that is, which antibodies confer protection. Subsequent pertussis vaccine trials are therefore needed to address many of the remaining unanswered questions. Sweden is one of several countries that is currently under consideration for follow-up studies, which are planned to begin by the end of 1988. The total cost for NIH-supported basic research and clinical studies in other Arctic and Nordic countries is approximately \$2.5 million annually in both FY 87 and 88.



# Smithsonian Institution

*The Smithsonian's activities span the entire area of the North American Arctic, from Labrador and Greenland to the Pacific coast, and include the circumpolar regions of Arctic Eurasia as well. A total of \$520,000 was devoted to these Arctic activities in FY 87, and \$665,000 was expended in FY 88.*

During the past year the Smithsonian Institution's Arctic programs received a major boost with new funding for an Arctic studies program in anthropology, biology and museum studies. The year was capped by the presentation of a major international exhibition, "Crossroads of Continents," prepared in cooperation with the Soviet Union, and the opening of the European tour of "Inua: Spirit World of the Bering Sea Eskimo." These and other activities are part of a revitalization of the Smithsonian's long-standing involvement in the Arctic, a process that is expected to see further development during the coming decade.

## *"Crossroads of Continents" Exhibition*

On September 22, 1988, the Smithsonian Institution opened a major special exhibition titled "Crossroads of Continents: Cultures of Siberia and Alaska" in the Evans Gallery of

	FUNDING (thousands)		
	FY86	FY87	FY88
Anthropology	463	463	578
Arctic Biology	56	56	86

the Museum of Natural History. Crossroads brings together, for the first time, the great early collections of the United States and the Soviet Union in a panoramic view of the history, culture and art of the North Pacific and Bering Sea, from the Amur River in Siberia to Vancouver Island in British Columbia, from Paleolithic times to the modern day.

Ten years in the making, Crossroads emerged from discussions in 1977 between anthropologists from the Smithsonian and ethnographers from the Institute of Ethnography of the U.S.S.R. Academy of Sciences, sponsored by the International Research and Exchanges Board (IREX), the operating arm of the American Council of Learned Societies. The exhibition, curated under the direction of William Fitzhugh, makes history of its own as the first fully integrated, jointly researched



*King Island Dancers performing at "Crossroads of Continents" opening.*



*Chukchi (left) and Alaskan (right) Eskimo families trading seal oil along the Bering Strait in the 1860s.*

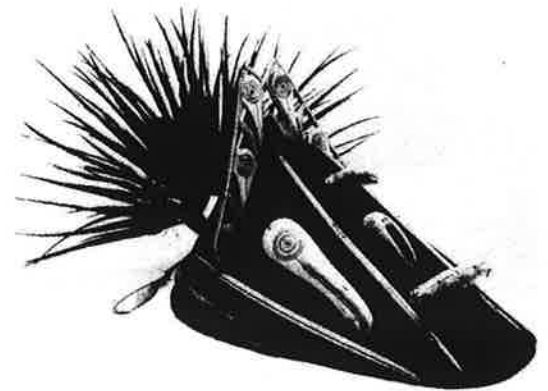
and curated Soviet-American exhibition. Showing in Washington until April 1, 1989, its tour includes major cities in the United States, Canada and the Soviet Union.

Crossroads explores traditional cultures of the North Pacific and Bering Sea from 18,000 years ago to the present. Archeological artifacts are used to present the prehistoric cultures of Siberia and Alaska leading to the formation of the region's historic peoples. The latter are seen through the works of 18th and 19th century artists and photographers but are primarily represented by ethnographic specimens collected by early explorers and scientists. These objects and images have existed for years on display and in storage in museums of the United States, Canada and the Soviet Union but have never been exhibited as a group.

During the Russian-America period, Russian ethnographers made extensive collections of Aleut, Eskimo, Athapaskan and Tlingit artifacts from the Aleutians to central California. Most of these collections came to reside at the Museum of Anthropology and Ethnography in St. Petersburg (Leningrad) founded by Peter the Great in 1714. Conversely the most important early Siberian artifacts were gathered by the American Museum of Natural History's Jesup Expedition, directed by Franz Boas between 1897 and 1903, and were sent to New York. Alaska's Bering and Chukchi sea Eskimo cultures are represented by Smithsonian collections gathered by Ross, Dall,

Nelson, Swan, Murdoch and others between 1855 and 1900.

For most of the 20th century these important collections have existed behind political barriers, inaccessible to the peoples and scholars of their lands of origin. None of the objects included have been seen outside their current custodian's borders, and few have ever been exhibited. The joining of these collections into a single exhibition permits the cultures of the North Pacific to be seen as they never have before—as part of an interrelated and complex North Pacific world whose cultures shared ideas, oral traditions, complex technology and art, and were linked across the Bering Strait by trade, migrations and warfare.



*Bering Sea Eskimo hunting hat collected by a Russian in the 1840s.*



*Tlingit Indians of the Sitka region, painted by Mikhail Tikhonov in 1817.*

Crossroads of Continents reaffirms and explores these ancient connections at the Arctic gateway between Eurasia and North America. The exhibit dramatically changes the view that North American Native cultures have been isolated from Old World cultural and historical developments. In fact, the Crossroads message tells of at least 14,000 years of Siberian and Alaskan contacts.

The exhibition also has a modern message. In an era of heightened strategic importance, the cultures and history of the North Pacific region needed to be better understood. Siberia and Alaska, though geographically remote from Moscow and Washington, hold important keys to the security and economic health of both nations. If relations between the United States and the Soviet Union are to improve, cooperation in research, economic development and policies toward Native peoples in the region where our nations are separated by only 56 miles is a goal worth pursuing. Thus Crossroads is not just a concept for past cultural relations; it highlights a program for the future. It is hoped that the exhibition, which will tour in North America, Canada and the Soviet Union, will foster a better understanding of North Pacific peoples and will contribute to increased scientific contacts and new cooperative research programs.

### *Crossroads Programs*

A variety of scholarly and educational programs accompanied the Crossroads exhibition. The most important of these was an international scientific meeting held at the Natural History Museum, September 22-23, 1988, at which Soviet, American and Canadian schol-

ars presented papers to a large audience of anthropologists, historians, art historians and natural scientists. Subjects ranged from the peopling of North America to discussions of modern environmental and cultural policy. The papers are currently being edited for publication by Smithsonian Press and will be available late in 1989. A second symposium on September 24 presented Crossroads exhibition themes to a public audience. The opening activities resulted in expansion of personal contacts between scientists and government officials of both countries, and discussions were held on expanding research contacts and exchanges.

The 20th century history of Siberian and Alaskan cultures is treated in the exhibition in a film produced by American filmmaker Ted Timreck and Latvian (U.S.S.R.) Andres Slapins of Riga Film Studio. Assembled from footage of Siberian and Alaskan native cultures, this film explores economic, political and cultural developments in Siberia and Alaska and compares both divergent and convergent aspects of these regions during the recent past. An hour-long version is being prepared for national television audiences in the Soviet Union and North America.

Other educational programs associated with Crossroads includes ethnographic film presentations, magazine articles and a teaching guide. Lecture and seminar programs will continue as the exhibition tours North America. In addition, Soviet scientists and museum specialists will accompany the North American tour, and American scientists will reciprocate during the Soviet tour.

### *Inua Exhibition*

The Smithsonian's previous exhibition, "Inua: Spirit World of the Bering Sea Eskimo," saw new life this year with the beginning of a European tour sponsored by the Smithsonian and the Arts America Program of the United States Information Agency. Opening in Zagreb at the International Congress of Anthropological and Ethnological Sciences in July, the exhibit of 200 objects and photographs curated by Susan Rowley will travel to Belgrade, Warsaw, Wroclaw, Luxembourg, Berlin, Tromsø and Reykjavik.

### *Sochi Conference*

During the past year, Earthwatch, a Boston-based field research organization, has been holding discussions with the Soviet Academy of Sciences to develop a program of scientific

*Sea lion battle helmet of the Tlingit Indians.*





Bronze plaque of a double-headed eagle, symbol of the Russian Czar, excavated from a 19th century Indian site on the Columbia River.

exchanges for United States and Soviet scholars. This initiative led, in the summer of 1988, to collaborative biological and limnological studies in Soviet central Asia and Lake Baikal. Expanding upon these successes, Earthwatch personnel and scientists from other institutions, including the Smithsonian, met in Sochi, U.S.S.R., in October with representatives of institutes of the Academy of Sciences of the Soviet Union. In addition to hearing reports of current projects, the group considered proposals for new field studies, including ones in Arctic regions. A draft protocol was prepared and was discussed in Moscow with officials from the Academy's institutions. The Earthwatch initiative provides a new private channel for scholarly exchange, augmenting existing government exchanges. A feature of the Earthwatch exchange is to promote participation of young Soviet scholars through private travel grants.

Proposals for research in Arctic regions should be forwarded to Brian Rosborough, Earthwatch, 680 Mount Auburn Street, Watertown, Massachusetts 02272. Copies of proposals for Arctic social science research should be forwarded to William W. Fitzhugh, Department of Anthropology, Smithsonian Institution, Washington, D.C. 20560.

## Arctic Education

This summer saw the Smithsonian expand its activities in the North in an unexpected direction—tourism. The Contributing Membership travel program sub-chartered Society Expedition's *World Discoverer* for a two-week cruise through the eastern Arctic. Smithsonian scientists Robert Hoffmann (mammals and birds), Stanwyn Shetler (plants and birds), Jeffrey Post (geology) and Susan Rowley (archeology and anthropology) accompanied the cruise as study leaders. Traveling with inflatable watercraft support provided unparalleled opportunities to visit remote locations and view wildlife from the departure point at Churchill, Manitoba, to the final destination in Iceland. Field calls were made at many locations in Hudson Bay, Baffin Island, the Button Islands and southern Greenland, and visits were paid to six Inuit communities, providing a cross section of current life in the Canadian Arctic.

## Arctic Studies Program

Last November the Smithsonian, as well as the community of Arctic scholars worldwide,

was saddened by the death of Curator Emeritus Henry Bascom Collins (1899–1987). Dr. Collins spent his life as a Smithsonian curator working on problems of Eskimo prehistory and anthropology. Known as the “dean” of Arctic anthropology, Collins’ research on the origins of Alaskan Eskimo culture and Canadian Arctic prehistory laid the foundation for our current understanding of Eskimo origins.

Building on Collins’ research and more than a century of Arctic studies and collecting, the Smithsonian proposed and received Congressional support for formalizing these achievements through the creation of a center for Arctic research. Initially planned to emphasize anthropology, archeology and museum studies, the program has been expanded to include a biological component. Plans call for continuing archeological research in eastern Canada and developing, over the next several years, field programs in Alaska and other circumpolar regions. Staffing plans call for hiring an Arctic ethnologist, an Arctic anthropologist and museum studies specialist, a western Arctic archeologist, and support personnel. In addition to research and publication, the program will include Native research and museum training and development of exhibitions in cooperation with other northern museums and institutions. In addition to providing support for the Crossroads exhibition, the program supported an entomological collecting program in Arctic Canada this past summer.

## Publications

Readers may obtain further information on some of the research described in this article from the following publications:

*Ethnological Results of the Point Barrow Expedition*, by John Murdoch: 1988 reprint of the 1892 edition published in the Ninth Annual Report of the Bureau of American Ethnology, with an introduction and new appendices by William W. Fitzhugh, Smithsonian Institution Press.

*Crossroads of Continents: Cultures of Siberia and Alaska*, by William W. Fitzhugh and Aron Crowell: Smithsonian Institution Press.

*Inua: Spirit World of the Bering Sea Eskimo*, by Susan Rowley: Catalog of the European tour, Smithsonian Institution and Arts America Program of the United States Information Agency.

# Department of Transportation

*The Department of Transportation conducts polar marine transportation research. Coast Guard icebreakers support governmental and nongovernmental research, both in the eastern and western Arctic, and perform sea ice and iceberg reconnaissance. A total of \$660,000 in direct research funding was expended in FY 87, and \$580,000 was expended in FY 88.*

## U.S. Coast Guard

The U.S. Coast Guard performs a variety of its traditional missions in the Arctic, including search and rescue, promotion of marine safety, enforcement of laws and treaties, environmental protection, and support of the national defense. In addition the Coast Guard provides icebreaker services in support of the missions of other agencies.

### Polar Icebreaker Operations

During FY 87 and 88 the U.S. polar icebreaker fleet was employed in all routine polar operating areas: the Antarctic, the western Arctic and the eastern Arctic.

There was one deployment to the western Arctic. U.S. Coast Guard Cutter *Polar Star's* summer 1988 operations in the Chukchi Sea under U.S. Geological Survey sponsorship started in August and continued into October. They entailed bottom coring and dredging operations, and a seismic array was towed through heavy ice cover for the first time. This project also tested the new coring and other scientific equipment installed aboard the *Polar Star* during the summer (an investment of \$1 million). In addition the Coast Guard conducted the first operational evaluation of the HH-65A helicopter in the polar environment.

In both years the annual icebreaker support for the Greenland resupply was provided by USCGC *Northwind*. During the FY 88 deployment the *Northwind* also collected high-frequency environmental acoustic measurements in the marginal ice zone for the U.S. Navy and collected ground truth information for an evaluation of the iceberg detection capabilities of side-looking airborne radar (SLAR). During the final project of the FY88 deployment, *Northwind* escorted the research

	FUNDING (thousands)		
	FY86	FY87	FY88
International Ice Patrol	0	200	180
Test and Evaluation	—	—	340
Arctic Pollution	200	350	0
Extramural Support	—	55	55
Marine Transport	210	50	0

vessel *Polarbjorn* deep into the polar ice pack and assisted in the deployment of a meteorological, ice and oceanographic network around *Polarbjorn*. The U.S. Navy sponsored this project. Throughout the deployment, data were being collected for the Naval Ocean Systems Center's VLF/LF radio reception survey.

In future years only the two Polar-class icebreakers will be operational. To make the best use of these vessels, further improvements will be made in their scientific support capabilities. These upgrades should be completed by the end of FY 91 at an estimated cost of \$7 million.

Funding of icebreaker time is a major factor in deployment planning. There are three cost categories to the user: transit costs, operating costs and surcharges (for ship maintenance and helicopters). All dedicated-time users during a given deployment share transit costs. Operating several projects simultaneously allows operating costs and surcharges to be shared as well. The average 1988 costs of icebreaker time are provided below:

Class	Avg daily fuel consumption (gal.)		Daily surcharge costs	
	Transit to project area	Operating in project area	Maint.	Helicopters
Polar	13,400	11,500	\$4670	\$1525
Wind	6,000	4,250	\$3530	\$1525

It should be noted that heavy icebreaking increases the operating fuel consumption. (FY 88 government fuel price is \$0.65/gal.)



icebergs took place in March 1987 in conjunction with the Canada-U.S. Labrador Ice Margin Experiment (LIMEX-87) in the Labrador Sea.

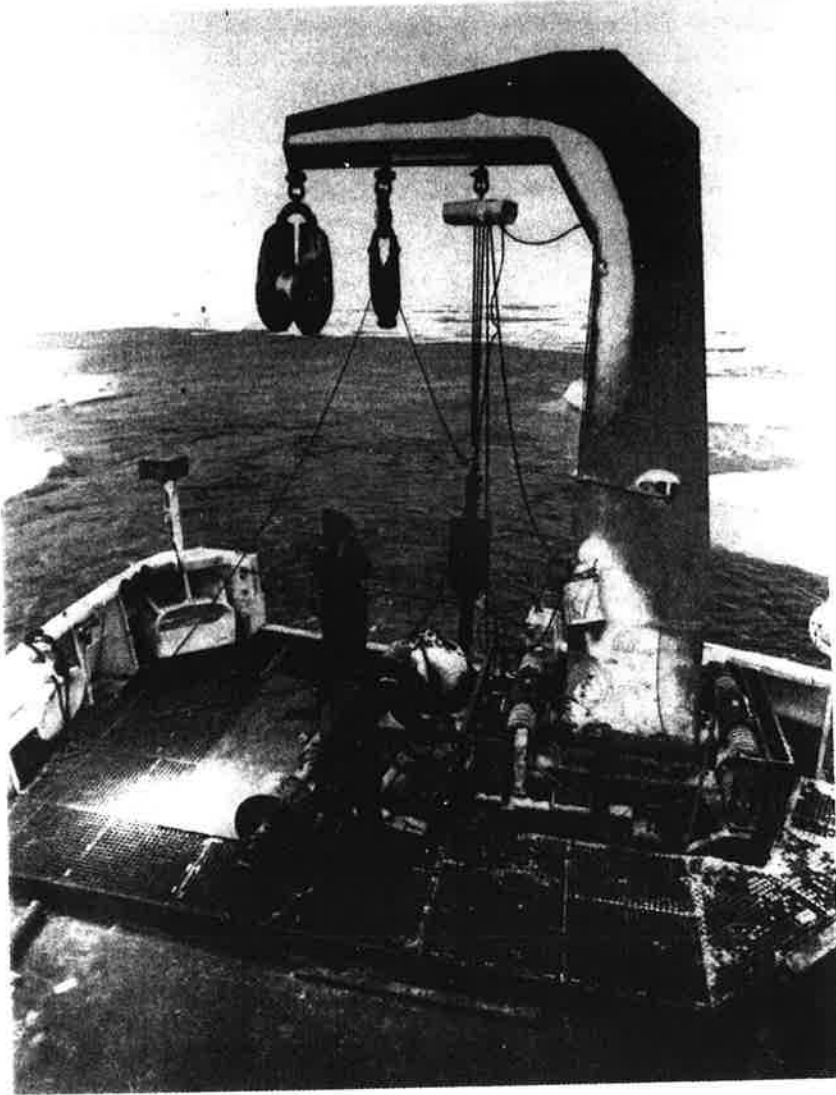
## *Maritime Administration*

The Maritime Administration was the lead government agency for commercial Arctic marine transportation research between 1979 and 1987. This program was carried out with the cooperation of the U.S. Coast Guard, several other government agencies, and industry. It focused on the development of new technology for the design and operation of commercial icebreaking ships. The Maritime Administration's Arctic marine transportation program, along with all other Arctic activities, was concluded during FY 88.

## *Strategic Highway Research Program*

The 1987 Surface Transportation and Uniform Relocation Assistance Act of 1987 established the Strategic Highway Research Program (SHRP) by designating 0.25% of major Federal-aid highway funds for a five-year research program concentrating on six areas: asphalt, long-term pavement performance, maintenance effectiveness, protection of bridge components, cement and concrete, and snow and ice control. The \$30 million-per-year program is carried out through cooperative agreements with the National Research Council of the National Academy of Sciences with guidance from the Federal Highway Administration and the American Association of State Highway and Transportation officials.

Projects related to the Arctic and other cold regions have included studies of the bond structure between ice and pavements, evaluations of deicing chemicals including the evaluation of techniques for reducing or eliminating the corrosive effects of salt, and the development of improved displacement plows and improved methods for controlling blowing snow. Other studies are examining the mechanisms of frost action on concrete. Annual funding levels are approximately \$1.0 million.



*Newly installed J-frame  
for coring and trawling  
operations on the USCGC  
Polar Star.*

## *Iceberg Reconnaissance and Prediction*

The U.S. Coast Guard's International Ice Patrol sponsored two oceanographic cruises in FY 87. USCGC *Bittersweet* investigated a warm core eddy near the conjunction of the Labrador Current and the North Atlantic Current. USCGC *Tamoroa* made measurements of iceberg drift and deterioration. During FY 88 the International Ice Patrol sponsored one cruise aboard USCGC *Northwind*. This project evaluated the viability of using SLAR during the annual iceberg season operations. Additional studies on the detection of

# Environmental Protection Agency

*EPA Cold Climate Research covers the spectrum of environmental problems, including treatment control technology, human health, air pollution effects, water pollution effects, and solid waste disposal. In FY 87 the program was funded at \$300,000, with no additional funds in FY 88.*

## *Cold Climate Research Program*

The Environmental Protection Agency's Cold Climate Research Program is an entirely extramural program of the Office of Research and Development (ORD). The program is managed out of ORD's Environmental Research Laboratory at Corvallis, Oregon. The emphasis is on environmental research that relates to cold climates. The research primarily concerns environmental problems in Alaska, but other cold regions of the U.S. can benefit. The scope of this research covers the spectrum of environmental problems, including treatment control technology, human health, air pollution effects, water pollution effects, and solid waste disposal.

The Corvallis Laboratory works directly with the EPA Region X Alaska Operations Office in Anchorage to coordinate ongoing research projects and to develop priorities for future studies. The Operations Office does not engage in research; its primary function is to coordinate EPA's regulatory responsibility with the State of Alaska. However, it provides the primary link to the State of Alaska interests and works with them and ORD in developing research priorities. Because of the variety of environmental research, the Corvallis laboratory calls upon other ORD laboratories to provide project officers for research that falls outside the expertise available at Corvallis. During FY 87 and 88 there were four active research projects, all of which have been completed or will be completed by the end of FY 88.

### *Impact of Oil Development on Coastal Tundra Wetlands*

Three studies were supported. The first resulted in a guide to the effects of gravel placement on wetlands and waterbirds. Gravel is the material of choice for the construction of oil development platforms and connecting roads along Alaska's North Slope. Its mining, transportation, placement and secondary ef-

	FUNDING (thousands)		
	FY86	FY87	FY88
Cold Climate Research	400	300	0

fects result in one of the major environmental impacts from oil and gas development in the area. The primary impact is on waterbirds and their habitat. The second study assessed seepage of oil drilling fluids from storage pits. The chemistry and toxicity of storage pit contents and concentrations found in surrounding wetland water and sediments were determined. Bioassay results indicated that drilling fluids are toxic to aquatic life. The third study evaluated the use of a geographic information system (GIS) to characterize waterbird habitat, density and distribution in the Colville River delta, a North Slope wetland environment. Field studies were used to assess the accuracy of the GIS characterizations and the relationship of bird sightings to landcover classifications. A value ranking of waterbird habitat was developed. The techniques will be useful in identifying areas vulnerable to dredge-and-fill activities. Identification of such areas is required by the Clean Water Act (40CFR, Sect. 230.80).

### *Ecosystem Impacts of Placer Mining*

Placer mining for gold in Alaska results in increased turbidity and sedimentation in downstream waters. This project assessed the impact on Arctic grayling. The findings indicate that juvenile grayling can tolerate short-term exposure of placer mining sediments with no apparent physical damage. However, when even small amounts of sediment reach spawning and rearing areas, particularly during low-flow periods, grayling are adversely impacted. Sac fry are not able to survive short-term exposure to mining effluents. This work supports the need to retain the State of Alaska's water quality standard for turbidity.

## Urban Air Pollution

Wood stoves are used extensively in Alaska. This project assessed the potential health impacts in an urban area near Juneau. Findings from this study were compared with similar studies conducted in other high-woodsmoke-impacted residential areas studied by EPA's Integrated Air Cancer Project. The relationship between ambient air mutagenicity and fine particle concentration was found to be similar to that found in Albuquerque, New Mexico, and Raleigh, North Carolina. Ambient air mutagenicity was similar in all three areas. This finding is of interest because it was thought that sunlight would affect mutagenicity levels.

## Air Models of Industrial Pollutants

Development of oil and gas along Alaska's North Slope has led to the installation of many gas-fired generators that have given rise to predictions of NO<sub>x</sub> levels in excess of EPA's air quality standards. Existing mathematical models are inadequate for confirming or refuting these predictions. A consortium of oil companies has been evaluating the downwash problem through wind tunnel studies. EPA has focused its attention on developing and improving of predictive models for atmospheric dispersion. Because field data under Arctic conditions were lacking, a winter field study was undertaken. An almost 90% data capture rate resulted from this work, an exceptional accomplishment in the severe weather conditions experienced. Data analysis has been completed, and assessment of pre-

dictive models will be completed by the end of 1988.

## Publications

Readers may obtain further information on some of the research described in this article from the following publications:

*Oil development in northern Alaska: A guide to the effects of gravel placement on wetlands and waterbirds*, by R. Meehan: U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency, 1988.

*Characterization and value ranking of waterbird habitat on the Colville River delta, Alaska*, by R. Meehan and T.W. Jennings: U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency, 1988.

*Effects of placer mining sedimentation on Arctic grayling of interior Alaska*, by J.B. Reynolds, R.C. Simons and A.R. Burkholder: Water Resources Bulletin, 1988.

*Cumulative impacts of oil fields on northern Alaskan landscape*, by D.A. Walker et al.: Science, no. 238, p. 757-761, 1987.

*Woodsmoke impacted air: Mutagenicity and chemical analysis of ambient air in a residential area of Juneau, Alaska*, by R.R. Watts et al.: Journal of Air Pollution Control Technology, vol. 38, no. 5, p. 652-660, 1988.

*Drilling fluids and the Arctic tundra of Alaska: Assessing contamination of wetlands habitat and the toxicity to aquatic invertebrates and fish*, by D.F. Woodward et al.: Archives of Environmental Contamination and Toxicology, vol.17, p. 683-697.

# Department of State

*The Department has responsibilities for international policy issues related to the Arctic, chairs the Interagency Arctic Policy Group, organizes joint meetings with Canada and Denmark and administers the Man and The Biosphere Program. Direct support for MAB was \$8000 in FY 87 and \$4000 in FY 88.*

The Interagency Arctic Policy Group (IAPG) has overall responsibility for establishing and coordinating Arctic policy. The IAPG also coordinates intergovernmental Arctic-related meetings. The Department of State's Office of Oceans and Polar Affairs within the Bureau of Oceans and International Environmental and Scientific Affairs (OES/OPA) is responsible for coordinating day-to-day international activities concerning the Arctic. The Office is responsible for U.S. foreign policy issues in the Arctic.

The Department has taken an active role in discussions concerning the possible formation of an International Arctic Science Committee (IASC). Through the IAPG the Department coordinated the development of an interagency position on the proposal. The Department worked closely with the National Science Foundation to develop background information for the U.S. representative, who has met with representatives of other countries. The Department has consulted regularly with the Arctic Research Commission on the proposal.

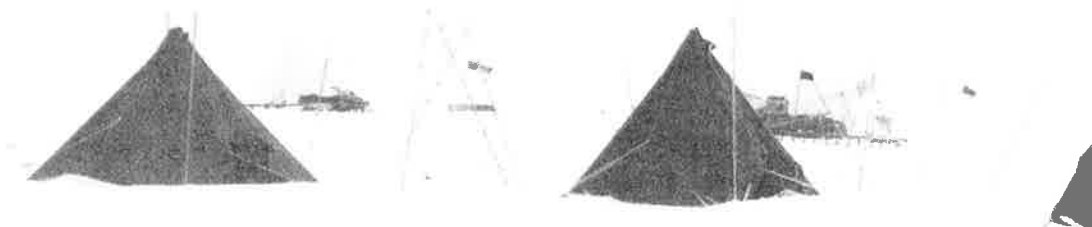
Representatives from the eight Arctic Circle countries (Canada, the U.S., the U.S.S.R., Norway, Sweden, Denmark/Greenland, Fin-

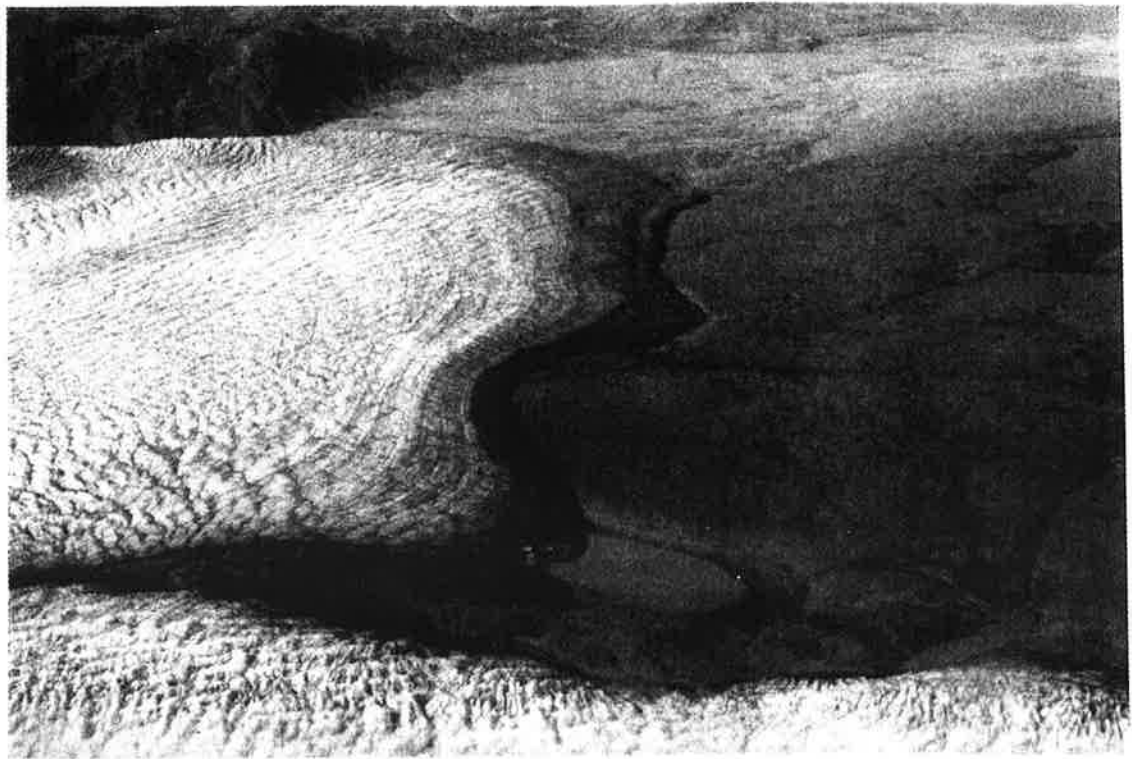
	FUNDING (thousands)		
	FY86	FY87	FY88
MAB Arctic Directorate	16	8	4

land and Iceland) met in Stockholm in March 1988 (see *Arctic Research of the United States*, Spring 1988, p. 46). The next working group meeting of representatives of the eight Arctic Circle countries is planned for December 1988 in the Soviet Union. It is hoped that it will be possible to agree on several outstanding issues, the most significant of which is participation within the IASC of non-Arctic countries that conduct scientific research in the Arctic.

The Department of State collects and collates proposals each year from U.S. scientists who wish to conduct research in Greenland. These proposals are due in OES/OPA each December so that they may be forwarded to the Danish Commission for Scientific Research in Greenland. The Commission organizes a meeting each April between U.S. representatives, led by the Department of State, and Danish authorities and scientists. The proposals are formally presented at this an-

*Research camp at Dye-3  
in Greenland.*





*Edge of the ice cap  
in Greenland.*

nual meeting. The number of U.S. research projects in Greenland in 1988 rose to 32 from 28 the previous year.

The Department also organizes, jointly with representatives from the Canadian Ministry of External Affairs, the annual review of environmental issues related to hydrocarbon development in the Beaufort Sea (see *Arctic Research of the United States*, Spring 1988, p. 55). The talks provide for the bilateral exchange of information on this topic, focusing on environmental concerns. The next review is planned for the spring of 1989.

The Arctic Directorate of the Man and the Biosphere program is the only program of Arctic research directly funded by the Department of State. The Arctic Directorate currently supports research on taiga-tundra ecotones and the northern boreal forest treeline. It is anticipated that high-latitude treelines will provide sensitive indicators of postulated global climatic warming. The Arctic Directorate has also provided modest support for a large-mammal (musk ox and takin) research exchange program between the University of

Alaska and an institution in China, a study of brown bear nurseries and human interactions in Denali National Park, a study of interactions between indigenous peoples and the management of national parks in Scandinavia and Alaska, and for continuation of work on vegetation classification in Alaska. In collaboration with other sectors of the Man and the Biosphere program, Arctic Directorate members have participated in conferences and research programs concerning forest hydrology research in China and sustainable development policy in high-latitude North America.

The Arctic Directorate represents the United States in the Northern Science Network (NSN). As reported in the Spring 1988 issue of this journal, there was a meeting of the NSN in Helsinki in March 1988 to evaluate and consider new directions for the Network. A recent NSN newsletter reports on current U.S., Canadian, Nordic and Soviet activities. In the U.S., copies may be obtained by contacting Arctic MAB Directorate, c/o Institute of Northern Forestry, 308 Tanana Drive, Fairbanks, Alaska 99775-5500.



# Department of Agriculture

*Although the Department of Agriculture is not a member of the Interagency Committee, representatives of its several Alaska-based services were invited to participate in the research planning process and review. An estimated \$860,000 was devoted to USDA support of Arctic research on forests, rangelands, soils and snow in Alaska in FY 87, and \$870,000 was expended in FY 88.*

## U.S. Forest Service

The 250 million acres of taiga in Alaska, all within the zone of discontinuous permafrost, include 106 million acres of spruce-birch-aspen forest. About 30% of this taiga forest is located within the ARPA-defined Arctic; much of the remaining taiga forest is on sites having a combination of elevation, slope and aspect that result in climatic conditions equivalent to the Arctic. Forest composition in the taiga is primarily controlled by soil temperature, drainage and fire history. Warmer, more productive sites are occupied by white spruce, aspen, paper birch and balsam poplar. Less productive forests, often overlying permafrost, are dominated by black spruce and occasionally tamarack.

Alaska's taiga forests include settings considered particularly sensitive to the temperature changes that are postulated to result from global climatic change. The discontinuous permafrost of central Alaska's taiga is "warm,"  $-0.5^{\circ}$  to  $-1.5^{\circ}\text{C}$ , and is thus especially susceptible to thaw caused by slight

*Experimental controlled burn in a black spruce forest at Washington Creek Fire Study Area, Alaska.*



FUNDING  
(thousands)

	FY86	FY87	FY88
Forest Service	650	800	800
Soil Conservation Service	200	60	67

warming trends. Warming and thawing could have rapid consequences for slope stability, soil movement into streams, forest growth rates, forest flora and fauna species composition, and landscape ecology. Alaska's elevational and latitudinal treelines are also expected to be sensitive indicators of global climatic change, as are terrestrial-aquatic ecotones. The taiga is thus particularly appropriate for consideration in designing national and international research programs to monitor environmental processes and rates important in evaluating possible climatic alterations. Forest Service research sites in the taiga, with documented research histories and long-term site integrity, should be useful in research on national and circumpolar global change.

## Research Facilities

The USDA Forest Service, Pacific Northwest Research Station, conducts research in Arctic areas of Alaska from the Forest Sciences Laboratory (FSL) at Anchorage and the Institute of Northern Forestry (INF) at Fairbanks. Research needs are identified in cooperation with Federal, State and private managers of forest and related renewable resources. The mission of FSL is to develop a multi-resource vegetation assessment for Alaska taiga forest and rangelands, and to assess the economic opportunities for increasing the use of renewable resources on these lands. The mission of INF is to develop a sound understanding of disturbed and undisturbed taiga and associated environments to use for their protection and management.

## *Vegetation Classification*

The final version of the Alaska Vegetation Classification System is in the last stages of preparation. This version contains keys, photos of vegetation types, a glossary and complete descriptions of vegetation units at the series level. Vegetation and site information is being collected to develop guidelines for managing the vegetation types of interior Alaska.

## *Fire Ecology*

The Bonanza Creek Experimental Forest near Fairbanks was selected as a Long-Term Ecological Research (LTER) site by the National Science Foundation. As a result, long-term ecological research study sites were established in cooperation with the University of Alaska to investigate natural environmental controls over successional processes leading to white spruce climax. Research on the effects of a wildfire in the Bonanza Creek Experimental Forest was continued. In addition to monitoring vegetation, soils and environmental characteristics over a long period of time, research is also underway to investigate the effects of nutrient controls over successional processes.

Research on the effects of wildfires on vegetation and permafrost in tundra ecosystems was carried out between 1977 and 1983 in three areas of northwestern Alaska. A model has been developed to relate the survival and succession of tundra plants to the timing and severity of burning. Within five to six years following tundra wildfires, plant cover can increase from 50 to 100% of the original vegetation on most sites, with the slowest recovery on northernmost sites. Most tundra plants appear to be well adapted to fire, since postfire increases in soil thaw in tussock tundra appear to stabilize or return to prefire levels within five to six years after burning.

## *Silviculture*

Research on the regeneration of white spruce on riverbottom sites in interior Alaska indicates that there is little or no difference in survival or height growth of seedlings between clearcutting and shelterwood methods but that significant differences exist for different regeneration and site preparation methods. Almost all the containerized seedlings survived, while survival of seedlings from direct seeding was less than 65%. Planted seedlings grew



*Log truck on an ice bridge over the Tanana River, Alaska.*

almost ten times higher on scarified sites than did natural seedlings germinating on-site.

Another study suggests that soil temperature and soil profile characteristics are more important than above-ground competition in determining the initial growth of planted seedlings. Seedling growth was highest following a significant reduction of the organic layer by site preparation with broadcast-burn or mechanical scarification.

## *Forest Entomology*

Methodology was developed for using conventional trap trees to trap spruce beetles in right-of-way clearings through spruce forests in south-central Alaska. Recommendations were also developed for the suppression of *Ips* engraver beetles in white spruce stands of interior and south-central Alaska. Methods were developed to reduce populations of *Ips* beetles in 1) pre- and post-logging situations by using conventional and lethal trap trees baited with the sex pheromone ipsdienol, 2) post-logging situations and fringe areas of stands burned by wildfires by using Lindgren funnel traps baited with ipsdienol, and 3) post-logging situations by treating trap trees and log decks with diesel oil or an aqueous solution of 2% carbaryl.

Results from a field test comparing a new formulation of spruce beetle sex pheromone developed by the University of Calgary with another formulation now used in Alaska indicate that the new formulation caught 80% more beetles.

## *Wildland Hydrology*

Field work was completed for an analysis of the hydrologic and geomorphic regime of

ice-cored upthrust features (pingos) in Caribou-Poker Creeks Research Watershed, with major support from the Center for Field Research. Topography was re-surveyed, and water discharge and quality, which are markedly different from the chemical composition of a nearby stream, were monitored through the 1988 summer. The hydrologic relationships and thermokarst terrain development associated with ice-related land forms are significant for land use planning in the taiga.



*Aufeis in the Caribou-Poker Creeks Research Watershed, Alaska.*

Because the Chugach National Forest management is concerned about placer mining and stream quality, INF and Chugach National Forest personnel developed a stream quality monitoring program to determine sediment-turbidity relationships and sediment characteristics. Sample analysis is conducted at INF. Placer mining consequences for stream quality remains a volatile public issue in central Alaska; in cooperation with EPA, INF scientists continued to monitor the water quality of taiga streams subject to placer mining, concurrently with measurements of unmined "control" streams in the Caribou-Poker Creeks Research Watershed.

A study of the consequences of fire-line explosives (FLE) in permafrost terrain, initiated in 1987 in cooperation with the Alaska Fire Service, Bureau of Land Management, continued. Replicated FLE lines on level terrain at Bonanza Creek Experiment Forest and on sloping terrain at Caribou-Poker Creeks Research Watershed are monitored to determine erosion, sediment production, permafrost thaw and effectiveness of rehabilitation measures. Sediment production following the Rosie Creek fire is also being monitored; erosion and sedi-

ment production directly resulting from wild-fire (as contrasted to that produced by improper road drainage or cat lines) is not significant in that setting.

INF continues to monitor the hydrogeochemical stream and catchment system of forested permafrost-free and permafrost-dominated landscapes in the Caribou-Poker Creeks Research Watershed. Streamflow and quality data for a second summer season was acquired for a subdrainage slated for major landscape perturbation experiments (whole-catchment timber harvest and fire).

## *Wildlife*

In 1988, data were collected on the survival, traditional use of rutting areas, mate selection, antler breakage and population characteristics of moose populations in mountainous areas of Denali National Park in interior Alaska. Summer activity and time budgets, important parameters of foraging ecology research, will provide data for bioenergetic models of moose. Ninety-five percent of the summer diet of moose inhabiting mountainous areas consists of leaves, twigs and bark of trees and shrubs, primarily willows, aspen and dwarf birch. The daily activity during the summer is about twice that in winter.

Data were also collected on winter movement patterns and habitat use of radio-collared moose in the Copper River delta, a riparian habitat in south-central Alaska. This moose population consists of two subpopulations occupying opposite sides of the Copper River. Moose occupied the wetlands throughout the year and used habitats ranging from dense spruce forests to intertidal mudflats; however, the inland willow sites were used most of the time. Calving areas were primarily in the willow-alder sites. Climatic conditions, which differ between the east and west sides of the Copper River, influenced where moose wintered and when they left the winter range.

## *Forest Pathology*

Work is now in progress to determine the identity and frequency of root and butt rot fungi associated with conifers within some of the major forest types of south-central Alaska. This research addresses two major questions: is pathogen activity related to stand composition, and does pathogen activity influence spruce beetle activity? The first ques-



*Winter logging on Willow Island in the Tanana River, Alaska.*

tion addresses intra-regional variation in root and butt rot incidence from a classical synecological perspective, an approach that has been lacking in forest pathology. The second question is fundamental to effective spruce beetle management since management plans that ignore the effects of pathogens may be less than optimal.

Inventory data from the Kenai Peninsula have been summarized and analyzed for development of a spruce beetle risk rating model. This research identified site and stand characteristics associated with high risk of beetle attack and can be used by forest managers to establish stand treatment priorities based on easily applied assessment criteria. Related research is also underway to determine the kinds, pathogenicities and frequency of blue stain species associated with the spruce beetle in south-central Alaska. The results of this research will provide essential baseline information for more detailed studies on the physiology of host-pathogen interactions.

### *Forest Inventory*

Current activities concentrated on inventorying forests of the Copper River basin, including the portion within the Chugach Na-

tional Forest in the Prince William Sound area. The inventory design used was the Alaska Integrated Resource Inventory System (AIRIS), previously used in the Tanana River basin and in southeast Alaska. This design involves using small- and large-scale (1:60,000 and 1:7,000) color infrared photo as sampling frame bases and then sampling a subset of the remotely sensed sample points on the ground. The inventory results will be used by Federal, State and local land planners and managers for multi-resource planning purposes.

### *Biological Diversity*

The taiga in interior Alaska is a mosaic of vegetation types that has resulted from fires and the characteristics of aspect, slope, elevation, drainage and parent material. The distribution of terrestrial vertebrates and invertebrates depends on plant species and the distribution of the plants within communities. Research at the INF has focused on the structure and function of the taiga ecosystem, primarily how natural and artificial disturbances affect forests and habitats and thus the diversity of plant and animal species that inhabit the taiga.

### *Long-Term Site Productivity*

The long-term productivity of forests in interior Alaska is an emerging question for natural resource managers. Long-term productivity is determined by the cumulative effects of biota, climate, soil, land management practices, time and their interactions, which may all be influenced by changes in atmospheric chemistry. The long-term productivity is being estimated from short-term monitoring of sites, but the actual productivity is still unknown. Studies of the effects of land management, forestry practices or natural processes other than fire on long-term productivity and biological diversity were initiated in FY 87 and 88. Programs to monitor long-term productivity on unmanaged forest, harvested forest lands, and land burned by prescribed fire were established in white spruce, black spruce, riparian, mixed spruce-hardwood and treeline stands in Bonanza Creek Experimental Forest and Caribou-Poker Research Watershed. INF has monitored the long-term effects of climatic changes and wildfire on the taiga ecosystem of interior Alaska at selected sites over the past 20 years.

## *Forest Analysis by Synthetic Aperture Radar*

An interdisciplinary effort was begun to explore the use of synthetic aperture radar (SAR) imagery, to be acquired from the Earth Resources Satellite (ERS-1), for analyzing global forests. In March 1988 SAR data (C, L and X-band radar) were acquired during an overflight of Bonanza Creek Experimental Forest by a NASA DC-8, a surrogate for the ERS-1 platform (see p. 62). Concurrent on-site data acquisition in selected flood-plain forest stands included stem and canopy measurements; moisture content and dielectric constant measurements of twigs, needles, stems and boles; snow-pack depth, density and dielectric constant; and ambient environmental conditions. The Bonanza Creek Experimental Forest is the first field site in a global array that will eventually include representative forest stands in Michigan, Virginia, Germany and Australia.

## *The Copper River Institute*

The Copper River Institute is a consortium of Federal, State and private organizations

that will provide a forum for study and management of the ecosystems of the Copper River delta. The Institute is dedicated to basic and applied research, technology development, and education and interpretation. The role of the Institute will be to

- Develop partnerships to expand the base of research participation and to support management programs;
- Provide facilities and logistical support for researchers.
- Provide a forum for informed debate among researchers
- Provide a forum to link research with management programs; and
- Identify research priorities and provide coordination to ensure that resources are used efficiently.

The Pacific Northwest Research Station and the Alaska Region (R10) of the Forest Service are providing the leadership necessary for establishing the institute. Membership is open to all organizations having an interest in research and management activities on the Copper River delta, including universities, interpretive associations, commercial and trade associations, conservation groups and Alaska Native corporations.

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## *Soil Conservation Service*

The Soil Conservation Service's (SCS) major emphasis in the Arctic has been to provide sound conservation technical assistance to land managers. The major research efforts have been directed at assessing the biomass of tundra and taiga areas being grazed by reindeer and muskoxen. SCS is cooperating with the University of Alaska through the Alaska Soil and Water Conservation District.

The Hagemester Island Range Survey has been completed. As previously suspected, this 67,000-acre range has been overgrazed, and the land manager is attempting to resolve the problem. In another project, lichen samples were collected on the Seward Peninsula reindeer ranges and analyzed by the EPA for radioactive contamination that may have resulted from the accident at the Chernobyl nuclear power plant.

SCS and the University of Alaska continue to collect data throughout all Alaska reindeer ranges that substantiate concerns about their ecological status. Overgrazing and wildfires

have depleted lichen production on many areas. A major task ahead is to identify the extent of these areas and develop a range recovery program.

Cooperative research is being conducted to provide SCS conservationists with information for coordinated resource management plans (CRMPs). The 16.4-million-acre range and soil survey on the Seward Peninsula continues to be used by reindeer herders and land managers for directing land planning decisions. SCS has been working with State and Federal land managers and regional and village land owners to develop CRMPs. One CRMP has been developed, and two more are being developed.

The Snow Survey Program in 1988 consisted of 195 data collection sites. Of these, 51 provide continuous temperature data and 19 are radio-telemetered. Data collected at the automated sites include snow water content, precipitation, air and soil temperatures, and wind speed and direction. Seven of the 16 Wyoming wind-shielded precipitation gauges are on the North Slope.



### *Voyage of the Akademik Korolev*

The Third American-Soviet Joint Expedition to the Bering and Chukchi seas represented a major international undertaking. The U.S. Fish and Wildlife Service (FWS) office in Washington, D.C., organized and coordinated the U.S. side in accordance with the memorandum of the 11th meeting of the U.S.-U.S.S.R. Joint Committee on Environmental Protection (Moscow, U.S.S.R., February 1988), the recommendation of the Soviet-American Conference on the Ecology of the Bering Sea and the plan of the joint bilateral activity of 02.07-2101. Titled "Comprehensive Analysis of Marine Ecosystems and Ecological Problems of the World Ocean," the expedition was held between July 16 and September 2, 1988, on board the Soviet research vessel *Akademik Korolev*. The delegation was headed by Professor Alla V. Tsyban, Goskomgidromet and U.S.S.R. Academy of Sciences, and Harold J. O'Connor, FWS.

The Soviets were represented on the cruise by participants from the U.S.S.R. State Committee for Hydrometeorology and Control of Natural Environment; the Academy of Sciences from the U.S.S.R.; and the Academies of Sciences from Ukraine, Belyorussia and Estonia. The Americans were represented by participants from FWS, University of Texas, Texas A&M University, University of Alaska, University of Maine, University of Washington, University of South Carolina, Skidaway Institute of Oceanography and Lamont-Doherty Geological Observatory.

*R/V Akademik Korolev in Dutch Harbor, with the R/V T.G. Thompson tied alongside.*



The research vessel, with the Soviet participants on board, arrived in Dutch Harbor in the Aleutian Islands on July 24, 1988. During three days in port the U.S. specialists and their scientific equipment were taken on board.

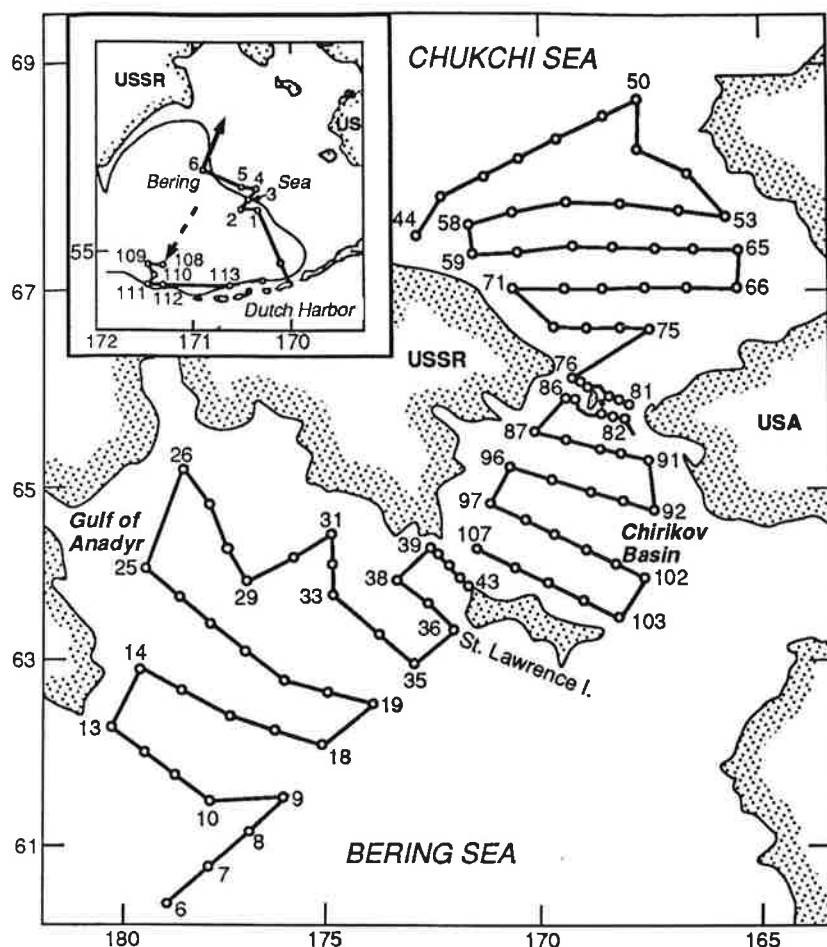
The principal objective of the expedition was to characterize the condition of the fundamental oceanographic, hydrochemical and hydrobiological parameters of marine ecosystems and to assess their capacity for assimilating marine pollution. This research was undertaken both in areas of long-term investigations and in new areas of the Bering Sea (the Gulf of Anadyr, the Chirikov Basin and the Bering Strait) and the southern portion of the Chukchi Sea.

The main scientific tasks were to

- Collect fundamental biological, chemical and physical data to provide a comprehensive ecological and oceanographic profile of the Bering and Chukchi seas;
- Study the physiological and ecological characteristics of plankton organisms; and
- Assess the ecological health of the Bering Sea.

The complex ecological investigations in the Bering and Chukchi seas, conducted at 113 stations along transects in three polygons (east, north and south), were accomplished in four stages. In the first stage, work was started in the east polygon (Stations 1-6) and was completed in the Gulf of Anadyr (Stations 6-43). The next stage studied the area of the southern Chukchi Sea (Stations 44-81) and included a transect of the Bering Strait. After a port call at Nome, Alaska, on August 17 and 18, investigations continued in the Chirikov Basin from the Bering Strait to St. Lawrence Island. The final stage of the expedition consisted of six stations (109-113) including the south polygon. The expedition ended on September 2 in Dutch Harbor.

The research was undertaken in five ecosystems in the Bering and Chukchi seas. Two ecosystems, situated in the eastern and southern regions, have the characteristics of deep-water ecosystems. Three ecosystems were in shallow areas of the Bering Sea (Gulf of Anadyr, Bering Strait and Chirikov Basin)



Cruise track and station locations of the expedition aboard the Akademik Korolev.

and the Chukchi Sea (southern portion) and were typical shelf ecosystems.

The structure of the water mass on the east polygon consisted of the shelf's boundary and was influenced greatly by the Bering Current flowing along the slope of the continental shelf. Analysis of the distribution of temperatures revealed the existence of two water layers. The minimum temperature was at a depth of 150–250 m (the boundary of the shelf water of the Bering Current), and the maximum temperature was at 400–500 m (the intermediate water of the Bering Sea).

The distribution of nutrients on the east polygon was typical for a shelf slope region. In the surface layers the nutrient concentrations were low; their concentration increased slowly below 100 m.

The ecosystems of the Gulf of Anadyr and

the Chukchi Sea are some of the most productive in the world. High concentrations of nutrients in the water masses are responsible for the high primary productivity. The water mass is enriched with nutrients transported from the Gulf of Anadyr through the Chirikov Basin and the Bering Strait to the southern area of the Chukchi Sea. This constant flow fuels the increase of phytoplankton numbers and production that occurs at the boundaries of these water masses.

The lowest temperature ( $-1.6^{\circ}\text{C}$ ) was discovered in the Gulf of Anadyr. Such low temperatures have not been observed here during the last 20 years. In spite of this, the phytoplankton biomass was significant.

The southern area of the Chukchi Sea, being influenced by Bering Sea waters, was rich in nutrients. This area had never been studied. The function of the ecosystems of the Chukchi Sea is determined by at least two currents. High-salinity water masses enriched with nutrients are transported from south to north. They are carried by a flow that exits from the Gulf of Anadyr, crosses the Chirikov Basin, flows through the Bering Strait and ends in the Chukchi Sea. Another current, formed from the cold and relatively high salinity coastal Siberian waters and also enriched with nutrients, flows from northwest to southeast.

The biological productivity is high in the Bering Sea and higher still in the Chukchi Sea. An array of anthropogenic organic contaminants (polychlorinated biphenyls, hexachlorocyclohexane, chlordane and DDT) were found in the surface waters of these seas. The chlorinated hydrocarbons were probably transported by global atmospheric processes.

At the end of the expedition on board, there was an exchange of preliminary data. American and Soviet scientists will exchange joint data analysis on March 1, June 1 and October 1, 1989. Both sides considered it useful to prepare and publish the joint manuscript containing the final analysis of the American-Soviet research.

For additional information, contact Steven Kohl, U.S. Fish and Wildlife Service, Office of International Affairs, Room 2058, Department of Interior, Washington, D.C. 20240.

## Fifth International Conference on Permafrost

International Permafrost Conferences are held every five years; the U.S. organized the Fourth Conference held in Alaska in 1983, and during August 2–5, 1988, Norway hosted

the Fifth Conference in Trondheim. Pre- and post-conference excursions to Svalbard and northern Scandinavia continued the tradition of field trips to examine permafrost and peri-

glacial features and engineering problems and solutions. The Chinese delegation, headed by Cheng Guodong of the Lanzhou Institute of Glaciology and Geocryology, offered to hold the Sixth Conference in China in 1993 with field trips to northeast China, the Tibet Plateau and the Tien Shen Mountains. The newly organized International Permafrost Association (IPA) held its second council meeting during the conference, elected a new slate of officers and established a number of working groups and administrative committees to develop and carry out its programs.

The conference, held at the Norwegian Institute of Technology, was organized by a 14-member committee chaired by Kaare Flaate of the Norwegian Road Research Laboratory. Three hundred scientists and engineers from 18 countries participated. The U.S. had the largest number of attendees (89), followed by Canada (54), Norway (35), China (27), the United Kingdom (13), U.S.S.R. (12), Japan (12), Sweden (11), FRG (10), Finland (10), Belgium, Denmark, France, Israel, Italy, the Netherlands, Poland and Switzerland. A two-volume publication containing 288 peer-reviewed papers was available at the conference and is being sold by Tapir Publishers (N-7079, Flataasen, Norway). The vast majority of the papers were prepared by the U.S.S.R. (79), U.S. (64), China (45) and Canada (42). In addition, the Soviets produced a separate 193-page volume containing 30 papers in Russian. The U.S. participation was coordinated by the National Research Council's U.S. Committee for the International Permafrost Association (USC/IPA) and its staff consultant, William Petrie. The USC/IPA was responsible for the review of the U.S.-authored manuscripts.

Both the proceedings volumes and the conference sessions were arranged according to science and engineering themes. The five scientific topics included climate and geothermal regimes, regional permafrost, physics and chemistry of frozen ground and frost heave, hydrology and ecology of natural and disturbed terrain, and periglacial phenomena. The four engineering topics included site investigations, terrain analysis and subsea permafrost; geotechnical properties and frost heave parameters; geotechnical engineering and pipeline construction; and other engineering including petroleum, mining and municipal. A third post-conference proceedings volume is planned and will contain invited papers of three special sessions that emphasized topics of current interest: climate change

and permafrost, coastal processes, and transportation. In addition, a workshop reflecting interests in global change and the need to archive data on permafrost was organized by Roger Barry of the World Data Center-A for Glaciology in Boulder, Colorado. The second, five-year *Permafrost Bibliography Update* was prepared by the Data Center and was distributed at the conference. Over 3300 new citations are presented. The bibliography is available as Glaciology Data Report 21 (ISSN 0149-1776).

The 16-member Council of the International Permafrost Association held its second meeting during the conference. The first order of business at Trondheim was election of a new Executive Committee. Troy L. Péwé (U.S.) replaces P.I. Melnikov (U.S.S.R.) as President; the new Vice Presidents are Cheng Guodong (China) and Vladimir Melnikov (U.S.S.R.). J. Ross Mackay (Canada) remains on as Secretary General. The council reaffirmed its desire to affiliate with both the International Union of Geological Sciences and the World Federation of Engineering Organizations. To conduct and sustain the activities of the council between conferences and provide advice to the Executive Committee, three standing committees and six working groups were established. The standing committees are to provide advice on finance, working groups and editorial policies. Working groups will organize on the following topics: mountain permafrost, terminology, foundations, global change and permafrost, frost-action environments, and permafrost. Additional information on IPA activities and committees are reported in an *IPA Newsletter* available in each country (for U.S. readers, contact USC/IPA, MH 460, National Research Council, 2101 Constitution Avenue NW, Washington, D.C. 20418). In a significant advance in periglacial and permafrost terminology, the Canadians announced the availability of this recently published glossary of permafrost and related ground-ice terms (National Research Council of Canada, Technical Memorandum 142). The Soviets announced plans to begin publishing a new quarterly journal in 1989 with an English edition for foreign sales.

Field excursions were organized by Johan Ludvig Sollid, Geografisk Institutt, Oslo University, and his colleagues from Norway, Sweden and Finland. The 430-km-long pre-conference bus trip from Narvik to Tromsø traversed typical fjord and inland landscapes, comprising moraine systems dated from Younger Dryas time (10,000–11,000 years BP), numerous

rock glaciers, and vast inland palsa bogs with local occurrences of permafrost. Road construction and maintenance problems associated with differential thaw settlement, frost heave, erosion and slope instability were observed. The pre- and post-conference excursions to Svalbard included a comprehensive visit to the Norwegian coal-mining town of Longyearbyen and a four-day boat trip to Sveagruva, Ny-Alesund and several stops along Isfjorden, including a visit to the Soviet mining town of Barentsburg. Permafrost occurs in the coal mines and influences the con-

struction of buildings, utilities, roads and air-fields in much the same ways as in Canada, Siberia and Alaska. Permafrost ranges in thickness up to 200 m or more in ice-free areas. Splendid examples of sorted circles, polygons, rock glaciers, chaotic push moraines and karst topography were viewed and discussed. Following the conference a special Arctic seminar included lectures on the Arctic and an overnight return flight to Svalbard. A limited edition of the revised field guidebooks will be available for purchase from Professor Sollid.

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## *Arctic Research Consortium*

The Arctic Research Consortium of the United States (ARCUS), a new organization of universities and non-profit institutions, was inaugurated and held its first annual meeting in Fairbanks, Alaska, on October 9, 1988 (See *Arctic Research of the United States*, Spring 1988, p. 58). Its mission is to strengthen and advance Arctic research to meet national needs. ARCUS consists of educational and non-profit institutions that have a direct interest in research and education in the Arctic. The Consortium is designed to improve the exchange of information and ideas with Federal, State and regional agencies that support research in the Arctic.

Representatives of 31 universities and other institutions attended the Fairbanks meeting. Dr. Al Johnson, from San Diego State University and a member of the Consortium's Exec-

utive Committee, inaugurated ARCUS, stating, "It is my pleasure, on behalf of the Executive Committee and the members of ARCUS, to now declare that the Arctic Research Consortium of the United States exists as described in the bylaws of the Consortium and to inaugurate it in keeping with its stated missions, goals and functions." ARCUS will be supported by dues contributed by member institutions, together with grants. Dr. Luis Proenza, Vice Chancellor of Research at the University of Alaska-Fairbanks, was designated President of the new organization. Donald (Chris) Shepherd, Louisville, Colorado, will serve as Executive Director of ARCUS.

For further information contact Dr. Proenza at (907) 474-7314 or Chris Shepherd at (303) 492-8830.

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## *Alaska Science and Technology Foundation*

Alaska Governor Steve Cowper named the nine directors of the new Alaska Science and Technology Foundation in September 1988 and opened a two-day session of its first meeting on October 11, 1988, in Anchorage (see *Arctic Research of the United States*, Spring 1988, p. 3, for background on the AS&TF). The Alaskan directors are Anchorage engineer Ed Clinton, Juneau anthropologist Lynn Wallen, Ketchikan fisheries biologist Gary Freitag, Native corporation officer Perry Eaton of Anchorage, Alaska Power

Authority Executive Director Bob LeResche, Director of the Institute of Arctic Biology Francis Williamson, and Director of Centers for Disease Control Ann Lanier. The two non-Alaskans are the Manager of Michigan's Centers of Excellence Program James Kenworthy of Ann Arbor, and venture capital expert George Kozmetsky of Austin, Texas.

For more information on the Board and its activities, contact Stephen Cole, Office of the Governor, Box A, Juneau, Alaska 99811.

# Arctic Environmental Data System

*Based on material prepared by Douglas R. Posson, U.S. Geological Survey, and Chairman of the newly formed Arctic Environmental Data Directory Working Group. His address is 801 National Center, Reston, Virginia 22092.*

An Arctic Environmental Data Workshop was convened on behalf of the IARPC in March 1988 at Boulder, Colorado, by NASA, NOAA, NSF and USGS (*Arctic Research of the United States*, Spring 1988, p. 59). Attended by representatives of 24 organizations, the workshop included presentations on the current activities of agencies that collect and manage Arctic data and the needs of users of Arctic data for mesoscale studies. Ensuing discussions addressed whether there is a need for an Arctic Environmental Data System (AEDS), outlined the salient features of a useful AEDS, and recommended a course of action. Tom Laughlin (NOAA), chairman of the workshop, prepared and distributed the final report in August 1988. The primary recommendation was that work should begin immediately on an Arctic environmental data directory (AEDD) in coordination with, and as a prototype for, studies of global change.

This work has begun. The May 2, 1988, meeting of the Interagency Arctic Research Policy Committee approved a plan with four elements, based on the recommendations from the workshop:

- Coordinate the development of the AEDD with the Interagency Working Group on Data Management for Global Change;
- Establish a multi-organizational working group to guide the establishment of the AEDD;
- Provide for data exchange across changing technologies; and
- Identify key Arctic environmental variables needed to detect, measure and understand Arctic mesoscale change and global change.

## Arctic Environmental Data Directory

The development of an Arctic Environmental Data Directory (AEDD) should be coordinated with the ad hoc Interagency Working Group on Data Management for Global Change and should use existing resources to the greatest possible extent. This working group was formed by the President's Office on Science and Technology Policy's Committee on Earth Science in June 1987. Participating agencies are NASA, NOAA, NSF, USGS and the Departments of Agriculture, Energy, Navy and State. Its goal is to create a national data system for global change research by 1995 that is consistent across agencies and involves and

supports universities and other user communities. The Arctic information collected for the AEDD will be used to help test an interagency directory for global change data. Because the directories share references in a standard format, a user in one agency will know about the contents of the data directories in the other agencies. The purpose of linking AEDD activities with those of the Interagency Working Group is that some Arctic processes affect the global climate, and some global climate processes affect the Arctic. In addition, the Arctic data represents a tremendous source of historical information about conditions in a relatively pristine environment. Users of each type of data benefit by knowledge of and access to both types of data.

## Arctic Environmental Data Directory Work Group

The Arctic Environmental Data Directory Working Group (AEDDWG) was formed in August 1988 with members from both governmental and nongovernmental institutions. By March 1989 the AEDDWG will coordinate the entry of references to at least 12 Arctic data sets from each member's organization into AEDD.

Also by March 1989 the AEDDWG will identify other institutions that hold Arctic data, contact them, inform them of the purpose of AEDD, and encourage them to enter references to their data holdings into AEDD. During the same time the group will define what is needed to establish mechanisms for user feedback. These might include training courses in the use of AEDD, workshops to promote the use of AEDD for Arctic studies, articles about AEDD in various newsletters, or presentations on AEDD at seminars attended by users of Arctic data. Clearly, it is important to keep the purpose, contents and use of AEDD relevant to the needs of the Arctic research community.

As a near-term objective, the AEDDWG will support the coordination with the activities of the Interagency Working Group on Data Management for Global Change. The principal members of the Interagency Working Group enthusiastically endorsed the joint activities at their meeting in June 1988. The USGS will assist in entering the references to Arctic data sets. The USGS Earth Science Data Directory (ESDD) will be used for the initial entry of the references. Because ESDD



is being used as the data directory of the USGS in the design of the Interagency Working Group's directory, ESDD will provide the gateway for sharing the Arctic data references with all users of the national data system for global change.

The AEDDWG will also coordinate with any similar bodies that might be created in Canada. Nancy Cutler, Director of the Centre Climatologique Canadien, will be the initial link in the AEDDWG to allow the Canadian Arctic data community to take advantage of the group's activities and the AEDDWG to benefit from similar activities in Canada.

### *Data Standards*

The AEDDWG will establish a small group to address technical issues such as data standards. Standard technology should be used wherever possible to make future generations of AEDS easier. While it is not the intent of AEDS to generate new standards, Arctic data organizations will be establishing standards when they select exchange media, instrumentation for data collection, computer operating systems and telecommunications protocols. Thus, the group will focus on the use of a Structured Query Language (SQL) for constructing data retrieval software, a Standard Generalized Mark-up Language (SGML) for introducing text such as professional papers and technical literature into digital systems, and a standard portable operating system based on UNIX, such as POSIX, to facilitate uniform computing when using different types of computers.

Adopting standards such as these is important because the actual Arctic data sets reside at many computer centers. The mix of technologies, including very large computers, minicomputers and many types of microcomputers, as well as vastly different software for data management, can be a difficult problem for scientists interested in accessing the data. The use of standards can help overcome problems introduced by unlike technologies.

The goal of the standards activities is to define and use technology in such a way that the Arctic data are preserved for future use even though the technologies containing and manipulating the data may have changed sev-

eral times. Thus, a data migration methodology needs to be put in place at the beginning of the system's construction.

Compact disk read-only memory (CDROM) is an example of a technology where standards have been developed that might be useful for disseminating Arctic data. The capacity of CDROM is 660 megabytes of digital data. A CDROM disk is inexpensive to produce and transport, has a long shelf life, and can be read on all sizes and models of computers using standard readers similar in size and cost to audio compact disk players. The AEDDWG will look into sponsoring a subscription series of CDROMs that could periodically distribute not only the complete AEDD index, but also hundreds of megabytes of key Arctic environmental data on each CDROM.

### *Environmental Variables*

One goal of the workshop was to facilitate the work of those dealing with the environmental data in support of studies of global change. Long-term monitoring of key environmental variables is useful for Arctic meso-scale studies, many of these variables may also be important in studies of global change. A list of monitoring variables is contained in *Earth System Science: A Program for Global Change—A Closer View*. This list represents the disciplines of the workshop's attendees and is subject to change; the categories are atmospheric, oceanic, hydrospheric, biospheric and solid earth variables. A lexicon would need to be developed before the list could be used to guide a data collection program.

### *Publications*

Readers may obtain further information on some of the research described in this article from the following publications:

*Earth System Science: A Program for Global Change—A Closer View* (F. Bretherton, Ed.), Report of the Earth System Sciences Committee to the NASA Advisory Council, p. 141-151, January 1988.

*Report of the Arctic Environmental Data Workshop, Boulder, Colorado, March 21-24, 1988*, by T.L. Laughlin, Report to the Interagency Arctic Research Policy Committee, 1988.

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## *Twelfth Northern Libraries Colloquy*

*Prepared by colloquy  
co-organizer Martha  
Andrews, Institute of  
Arctic and Alpine Research,  
University of Colorado*

The Twelfth Northern Libraries Colloquy was held in Boulder, Colorado, June 5-9, 1988, under the auspices of the University of

Colorado, Institute of Arctic and Alpine Research, and the World Data Center-A for Glaciology. Nearly 100 people attended from

11 countries with interests in Arctic, polar and cold regions. The conference consisted of papers, panel discussions, posters, demonstrations, a business meeting and field trips to the Rocky Mountain National Park, the University of Colorado Mountain Research Station, and the National Center for Atmospheric Research.

The Northern Libraries Colloquy is an international forum for exchanging information and ideas among the polar bibliographic community. The group pursues closer cooperation among information providers by exchanging information on library collections and methods of information processing, and coordinating information systems.

The Northern Libraries Colloquy first met at the Boreal Institute of Northern Studies, University of Alaska in 1971. A biennial schedule of meetings evolved, alternating between Europe and North America.

The Twelfth Northern Libraries Colloquy was planned around the theme *Northern Information—The Global Connection*. This theme was chosen to reflect the intent of the Arctic Research and Policy Act of 1984 (PL 87-373) and to extend its objectives to an in-

ternational level. The act recognized the need to support Arctic research efforts by increasing the efficiency of access to data and information.

Three recommendations were approved. The first supported the establishment of a Canadian Polar Information System. The second will result in a name change for the colloquy to Polar Libraries Colloquy in order to more accurately reflect the representation of the group. The third, and major, recommendation is a proposed plan of action for participants of the Northern Libraries Colloquy. This recommendation is designed to coordinate, through a working group, several tasks for formalizing a Polar Information Network.

Papers presented at the colloquy are available in the publication *Glaciological Data Report GD-22*, CIRES, University of Colorado, Boulder, Colorado 80309. The next colloquy will be held in Rovaniemi, Finland, in 1990 under the auspices of the Lapland University Library, the Rovaniemi City Library and the Arctic Centre. For more information, contact Juhani Lillberg, Administrative Director, Arctic Centre, University of Lapland, P.O. Box 122, 96101 Rovaniemi, Finland.

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## *International Conference on Technology for Polar Areas*

*Prepared by John F. Spletstoesser, Minnesota Geological Survey.*

Polartech '88, the second International Conference on Technology for Polar Areas, was held at the Norwegian Institute of Technology, Trondheim, Norway, on June 15-17, 1988. About 140 persons from 12 countries registered for the conference. The first Polartech conference had been held in Helsinki in 1986. The second included 55 technical papers, plus 10 invited speakers who addressed topics of vital importance for future activities in the Arctic.

Session topics included ship transport (5

papers), ice-structure interaction (11), land-based activities (5), exploratory drilling (6), ice drift and management (7), oil and gas production systems (9), ice properties (7), performance in cold climates (1) and materials (4). Technical excursions were made to three facilities belonging to the Norwegian Institute of Technology and SINTEF, two of the conference sponsors. Fifty-one of the technical papers and seven of the invited papers were printed in two volumes and are available from Tapir Publishers N-7079, Flataasen, Norway.

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## *Symposium on Snow and Glacier Research Relating to Human Living Conditions*

*Prepared by Hilda Richardson, Secretary General, International Glaciological Society.*

The International Glaciology Society Symposium was held in Lom, Norway, September 4-9, 1988. One hundred participants attended from 15 countries. Eighty papers were presented, in sessions entitled Glacier Hazards, Drift and

Creep Snow, Avalanches, Glacier Sediments, and Glaciers. The papers, after review and editing, will be published in *Annals of Glaciology*, vol. 13, June 1989. Orders for this issue be placed with Hilda Richardson, Secre-

tary General, International Glaciology Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom.

A half-day tour showed participants the Norwegian Geotechnical Institute's avalanche research station in the Stryn Mountains, with facilities for measuring snow-creep pressure and avalanche impacts on structures. The construction involved in building the all-seasons mountain road connecting eastern and western Norway were examined, and various glacial and hydrological problems and pro-

cesses described around the Jostedal glacier.

Two post-symposium tours were well attended. One tour concentrated on avalanche hazards and protective measures in the Geiranger Fjord, Hjørundfjord and Loen Valley areas. The other tour studied glacio-hydrological processes around the northern end of Jostedalsglaci and linked up with the first tour at Fjærland. Both groups hiked to Flatbreen to see a regenerated glacier, a glacier-dammed lake, and active glacier processes.



*One of three gray whales trapped in the ice off Barrow, Alaska, in October 1988. Local residents cut breathing holes, and two whales were eventually freed by Soviet icebreaking ships. For more information, see the current issue of UINIQ, The Open Lead, published by the North Slope Borough.*



# United States Arctic Research Commission

### *Fourteenth Meeting: May 2-3, 1988*

Commission Members Present: Juan G. Roederer, Chairman; A. Lincoln Washburn; Erich Bloch, Member Ex-Officio; Lyle D. Perrigo, Acting Executive Director. Observers: Victor G. Bradley, Government of Canada; Robert W. Corell, Peter Wilkniss, John Talmadge, Charles Myers and Jerry Brown, National Science Foundation; W. Timothy Hushen, Polar Research Board; Eric Laschever, Alaska Governor's Office, Washington, D.C.; Helen McCammon, Department of Energy; Thomas K. Newbury, Minerals Management Service; Nancy Gale.

The Arctic Research Commission held its fourteenth meeting in conjunction with the Interagency Arctic Research Policy Committee's meeting on May 2-3 (see *Arctic Research of the United States*, Spring 1988, p. 65). Chairman Roederer noted that this was the Commission's first meeting in the Washington, D.C., office.

### *Interagency Arctic Research Policy Committee Activities*

Erich Bloch, Director of the National Science Foundation, began by pointing out that the Commission can play a prominent role in enlisting the active cooperation of the private sector in fostering Arctic research. Following his opening remarks, discussion focused on

- The merits of a logistics coordination system;
- Including engineering research in the international initiative;
- Acquiring, processing and disseminating data and information;
- Stimulating science education programs for Native Alaskans;
- Research ethics, specifically Native involvement in scientific work, including the publication in layman's terms of results of research performed in Native communities, and perhaps a science fair; and
- Evaluating Prudhoe Bay data.

Discussion concluded with the Commission proposing to meet in Washington, D.C., in conjunction with the IARPC Seniors Meeting in the spring of 1989.

### *International Cooperation*

Robert Corell, Assistant Director for Geosciences, National Science Foundation, reported on the March 24-26, 1988, meeting in Stockholm (see *Arctic Research of the United States*, Spring 1988, p. 46). Chairman Roederer represented the Commission. Attendees from Canada, Denmark/Greenland, Finland, Iceland, Norway, the Soviet Union, Sweden

and the United States unanimously agreed that an International Arctic Science Committee should be established with an appropriate non-governmental organizational framework. Participation by Arctic scientists from non-polar rim nations is desired. Follow-up is expected at a planning session in July 1988 for a meeting in Leningrad in late fall of 1988, with a possible ratification in early to mid-1989.

### *Arctic Data and Information Systems*

The Environmental Data Workshop held in Boulder was discussed and the following issues raised (see *Arctic Research of the United States*, Spring 1988, p. 59; p. 93, this issue):

- The difficulty of assessing data in older computer systems or formats;
- The structure and preparation of data bank directories;
- The lack of information on medicine/health and social science needs; and
- The physical degeneration of information.

Draft statements from the workshop are expected in late summer or early fall, with revisions to be prepared for the March IARPC meeting. Chairman Roederer, Lincoln Washburn and Lyle Perrigo remarked that young university scientists may need prompting to put data and information into national repositories. A principal workshop recommendation called for the preparation of an Arctic directory of environmental data sets.

### *Logistics*

The Commission's report, *Logistic Support of Arctic Research*, was reintroduced as revised from the Juneau meeting and subsequently approved with minor changes and the inclusion of a foreword by Chairman Roederer outlining the purpose of the new series of documents and the Commission interest in logistics. (The report was published in July and is available from the Commission.)

### *Administrative Activities*

In executive session the Commission agreed that Chairman Roederer should select the new Executive Director from the list of three finalists. (Dr. Philip L. Johnson began work on June 1, 1988.) Additionally, it was agreed

Detailed minutes of Commission meetings and hearings are available directly from the U.S. Arctic Research Commission Office, Interstate Commerce Commission Building, Suite 6333, 12th and Constitution Avenue N.W., Washington, D.C. 20423.

that the new Executive Director should explore the possibility of securing legal counsel for the Commission. Other matters considered included the clarification of interactions with the IARPC and members of Congress, and the appointment of new Commissioners and Advisors. The Commission focused on the following issues: the international initiative, logistics, data and information, defense-related research, education, engineering research, ANWR-related research, and large-scale ecosystems research.

## ***Fifteenth Meeting: September 1-2, 1988***

*Commission Members*  
Present: Juan G. Roederer, Chairman, Ben C. Gerwick, University of California; Elmer E. Rasmuson, John H. Steele (nominee for vacancy on the Commission); Charles Myers representing Erich Bloch.  
*Commission Advisory Group Member:*  
David M. Hickok.  
*Staff:* Philip L. Johnson, Executive Director; Lyle D. Perrigo, Staff Officer; Karen E. Ford, Alaska Stenotype Reporter.  
*Observers:* Syun Akasofu, University of Alaska-Fairbanks; Vera Alexander, University of Alaska-Fairbanks; Eddie Bernard, Pacific Marine Environment Laboratory, NOAA; Max Brewer, U.S. Geological Survey; Henry Cole, State of Alaska, Office of the Governor; David Garman, Office of Senator Frank Murkowski; George F. Martin, U.S. Coast Guard Headquarters; Donald E. Packer, Alaska Science and Engineering Advisory Commission; Richard Jordan, University of Alaska-Fairbanks; James M. Posey, Arco Alaska, Inc.; Frank Williamson, Institute of Arctic Biology, University of Alaska-Fairbanks.

The Arctic Research Commission held its fifteenth meeting on September 1-2, 1988. This was the Commission's fourth meeting in Anchorage. This included a public session on September 1 in Anchorage and was preceded by a public meeting in Dutch Harbor on August 30, 1988.

### ***Interagency Arctic Research Policy Committee Activities***

Charles Myers called attention to the recently introduced journal, *Arctic Research of the United States*, published by the National Science Foundation on behalf of the IARPC and in cooperation with the Commission. This non-technically oriented journal summarizes results and activities of U.S. Arctic research.

### ***Comments from Congress***

David Garman, representing Senator Frank H. Murkowski, stated that the Congress is beginning to appreciate the importance of research, partially due to the high visibility of issues such as global warming and acid rain. The new journal has been helpful in alerting the public and the Congress regarding scientific work in the Arctic.

### ***Comments from the Governor***

Henry Cole discussed activities of the Alaska Science and Engineering Advisory Commission and the establishment of the Alaska Science and Technology Foundation.

### ***Logistics***

Lyle Perrigo noted the Commission's publication of *Logistic Support of Arctic Research*. Charles Myers briefed the Commission on activities of the newly formed IARPC Working Group on Logistics. More information on lo-

gistics coordination will appear in the forthcoming biennial review of the Arctic Research Plan.

Captain George Martin spoke on the acquisition of a third icebreaker. He saw no conflicts of purpose between the Coast Guard and the scientific community's need for an ice-capable research vessel dedicated to the Arctic. Discussion followed regarding the goals of both entities and possible follow-up action for the Commission.

### ***Arctic Data and Information Systems***

Charles Myers reported on the Arctic Environmental Data Workshop in Boulder last March and noted the formation of an IARPC working group to address data management issues as they relate to the Arctic Research Plan (see p. 93). Ben Gerwick pointed out that linking data and information systems should encompass non-governmental and international repositories as well as Federal agencies.

### ***Role of Sea Ice in Marine Ecosystems***

E. Bernard described a well-reviewed proposal to examine the role of the ice edge on marine productivity in the Bering Sea. This proposed research is compatible with the Commission's goal of a better understanding of the Arctic Ocean.

### ***International Cooperation***

Chairman Roederer gave a brief description of the background events leading up to the December 1988 meeting to be hosted by the Soviets in Leningrad. Topics for discussion coincide with those identified by both the Commission and the IARPC Arctic Research Plan. Chairman Roederer hopes that the U.S. Academy of Sciences will join the Commission, the IARPC and the Interagency Arctic Policy Group in developing international scientific cooperation in the Arctic. The formation of an International Arctic Science Committee could be a model for such efforts, functioning as the framework in which scientists of interested nations could work together on problems of mutual interest.

### ***Biennial Revision of Arctic Research Plan***

Charles Myers outlined the approach, objectives and schedule of the biennial revision of the Arctic Research Plan. Chairman Roederer discussed the review role of the Commis-



sion, and it was agreed that the Commission's Group of Advisors would review chapters relevant to their areas of expertise.

### *New Initiatives*

Ben Gerwick stated the need for new engineering research for the Arctic, particularly in the areas of Arctic construction, technology and coastal engineering. The Commission agreed to emphasize engineering research and call attention to work needed in this area.

Following up on concepts introduced at prior meetings, Chairman Roederer reintroduced the initiative of encouraging science education programs for Native Alaskans at the primary and secondary grade levels. A Federal/State task force may be one vehicle for accomplishing this goal.

A new initiative considered was the proposal by Alaska State Senator Arlis Sturgulewski and Unalaska Mayor Paul Fuhs, which calls for a broad-based, interdisciplinary research program on the Bering Sea fishery. This corresponds to the Commission's top priority of research to understand the workings of the Arctic Ocean and adjacent seas.

### *Other Business*

By mid-December the Commission staff will prepare the Annual Report and a statement of goals and objectives to guide the Interagency Arctic Research Policy Committee. The question of a policy for cosponsorship was raised with reference to the request from the Climate Institute for Commission cosponsorship of an upcoming workshop on "Climate Change in the Arctic." The staff is preparing a draft policy statement for responding to such requests which will be reviewed at the next Commission meeting.

In Executive Session the Commission adopted budget guidance for FY 89, approved 24 appointments to the Group of Advisors for two-year terms, considered minor amendments to the Arctic and Research Policy Act of 1984, approved procurement of legal services, and considered meeting dates for 1989.

### *Dutch Harbor Public Meeting*

Mayor Paul Fuhs introduced Chairman Roederer and the Commission and its staff to the public attending a meeting in Unalaska High School on August 30, 1988. Chairman Roederer spoke briefly on the enabling legislation of the Commission and its accomplishments and activities. Federal and State agency officials provided background information

about their respective responsibilities, perspectives and interests in fisheries and fisheries research. Visiting representatives included: William Aron, Director, Northwest and Alaska Fisheries Center, NOAA; Vera Alexander, Acting Dean, School of Fisheries and Ocean Science, University of Alaska-Fairbanks; Clarence Pautzke, Executive Director, North Pacific Fisheries Management Council; Brian Allee, Director, Division of Fisheries Rehabilitation, Enhancement and Development, Alaska Department of Fish and Game; William Woolf, Fisheries Specialist, Senator Frank Murkowski's Office; and Henry Cole, Science Advisor to Alaska Governor Steve Cowper.

After these overview presentations, the Commission received testimony and comments from the public. Alaska State Senator Arliss Sturgulewski and Mayor Fuhs presented a thoughtful proposal outlining research they believe should be undertaken to better understand and preserve the fisheries of the Bering Sea. Their proposal calls for a major study to enumerate management systems for the national and international waters of the Bering Sea. Loss of life, economic value, and opportunity have attended depletion of fishery stock elsewhere. The goal proposed is to obtain the information to assure the protection and enhancement of the Bering Sea fishery.

Additional presentations were also given by Jack Anderson of Anchorage, Kathy Grimnes of Ounalashka Corporation, Glen Bonovich of Unalaska City Council, and Abie Dixon and Tim Honan, Unalaska residents. Generally the testimony emphasized the goal of prudent management for the area's fisheries and natural resources.

### *Anchorage Public Meeting*

Chairman Roederer called the public meeting to order at the Loussac Library in Anchorage on September 1, 1988. Generally the recurring themes of the testimony presented in Anchorage were the collection and management of data and information, and logistics coordination. Areas emphasized by witnesses included the Bering Sea ecosystem, environmental problems, medical research, archeology and icebreakers.

The following is a chronological listing of the people making presentations, their affiliations and the essence of their input.

Michael J. Penfold, Director, Alaska Division of the Bureau of Land Management (BLM): BLM interests in research, data and

*Copies of the transcripts providing details on the various statements made before the Commission may be found in Commission offices in Anchorage or Washington, D.C.*

information, and science education for Native children.

Anne Lanier, Director, Alaska Center for Disease Control: health and medical research needs in the Arctic.

Captain George Martin, U.S. Coast Guard Headquarters: the need for one or more new icebreakers and the general mission of the U.S. Coast Guard.

Captain Rene Roussel, Safety Office Coordinator-Western Alaska, U.S. Coast Guard, Alaska: the activities of his office.

Leslie Starr Hart, Chief, Division of Cultural Resources, Alaska Region, U.S. National Park Service: her office's research interests and efforts to develop cooperative projects with Soviet scientists.

Judith Bittner, Chief, History and Archeology Section, Alaska Department of Natural Resources: archeology and anthropology work needed in northern Alaska.

John Kelley, Chairman, Science Advisory Committee, North Slope Borough: the interests of the borough in science and the operations of this committee.

Debra K. Slaybaugh, Supervisor, Special Studies, Standard Alaska Production Company: SAPC-sponsored research in northern Alaska and interest in sharing computerized

fisheries and oceanographic data acquired as a result of permit development studies.

Barbara Sokolov, Acting Director, Arctic Environmental Data and Information Center: efforts to better define data and information acquisition, storage and dissemination problems.

Martha Shepard, Director, Alaska Resources Library, Department of the Interior: the need to collect and manage environmental information generated in Alaska.

Richard Jordan, Chairman, Department of Anthropology, University of Alaska-Fairbanks: recent activities of his department.

Frank Williamson, Director, Institute of Arctic Biology, University of Alaska-Fairbanks: biomedical and allied research interests of his institute.

Walter B. Parker, President, Alaska Academy of Engineering and Sciences: AAES efforts to foster a conference on what was learned in the construction of the trans-Alaska pipeline and other activities of the Academy.

Harold Sparck, Bering Sea Fishermen's Association: research needed on variables affecting the productivity of the Bering Sea.

Sigfried G.B. Coady, veterinarian: proposal to collect samples showing the cardiovascular condition of marine and terrestrial mammals in Alaska.

## Forthcoming Meetings

*Listed here is a compilation of some 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 J. Brown, Arctic Research, National Science Foundation, Room 620, 1800 G St., NW, Washington, D.C. 20550.*

### **Second National Student Conference on Northern Studies**

**24-25 November 1988, Conference Centre, Ottawa, Ontario, Canada**

Contact: National Student Conference on Northern Studies, Association of Canadian Universities for Northern Studies, 130 Albert Street, Suite 1915, Ottawa, Ontario, Canada K1P 5G4  
Phone: (613) 238-3525

### **Second Arctic Policy Conference**

**1-3 December 1988, Montreal, Canada**

Contact: Centre for Northern Studies and Research, McGill University, 550 Sherbrooke Street, NW, Suite 460, Montreal H3A 1B9, Quebec, Canada

### **American Geophysical Union**

**5-9 December 1988, San Francisco, California**

Special Session: Research Challenges in the Arctic, 5-6 December

Contact: AGU, 2000 Florida Avenue NW, Washington, D.C. 20009

### **Conference of Arctic and Nordic Countries on Cooperation of Research in the Arctic**

**12-15 December 1988, Leningrad, U.S.S.R.**

Contact: Secretary General V.M. Kotlyakov, Institute of Geography, U.S.S.R. Academy of Sciences, Staromonetny per., 29, Moscow 109017, U.S.S.R.

Cable: 109017 Moscow, Geography

### **American Association for the Advancement of Science**

**14-19 January 1989, San Francisco, California**

Special Session: The Arctic—A Key to World Climate and Resources, 19 January 1989

Contact: AAAS, 1333 H Street NW, Washington, D.C. 20005

### **Civil Engineering in a Winter Environment: Building and Maintaining Infrastructure Fifth International Cold Regions Engineering Speciality Conference**

**6-8 February 1989, St. Paul, Minnesota**

Contact: Tom Krzewinski, Conference Chairman, Lakehead Testing Laboratory, Inc., 226 North Central Avenue, Duluth, Minnesota, 55807, U.S.A.  
Phone: (218) 628-2295

### **Arctic Technology and Economy: Present Situation and Problems, Future Issues**

**15-17 February 1989**

Contact: Sylvie Devers, Centre d'Etudes Arctiques, 19, rue Amelie, 75007 Paris, France  
Phone: 33(1) 45-50-29-83(84)

### **Frost in Geotechnical Engineering**

**13-15 March 1989, Saariselkia, Finland**

Contact: Secretary General H. Rathmayer, Technical Research Center of Finland, SF-02150 ESP00, Finland  
Phone: INT +358 0 4561  
Telex: 12 2972 VTTHA SF  
Fax: INT +3580 467 927

### **8th (1989) International Conference on Offshore Mechanics and Arctic Engineering**

**19-23 March 1989, The Hague**

Contact: Jin S. Chung, Colorado School of Mines, 1500 Illinois Street, Golden, Colorado 80401  
Phone: (303) 273-3573, 420-8114  
Telex: (910) 934-0190 CSM GLDN  
Fax: (303) 273-3283

### **18th Annual Arctic Workshop**

**Global Environmental Change in the Arctic 13-15 April 1989**

Contact: Dr. Robert Rogerson, University of Lethbridge, Lethbridge T1K 3M4, Alberta, Canada  
Tel: 403-329-2240

### **Eastern Snow Conference**

**8-9 June 1989, Chateau Frontenac, Quebec, Canada**

Contact: Gerald Jones, INRS-Eau, C.P. 7500 2700 rue Einstein, Sainte-Foy, Quebec, Canada G1V 4C7  
Phone: (418) 654-2533

### **Tenth International Conference on Port and Ocean Engineering Under Arctic Conditions (POAC 89)**

**12-16 June 1989, Lulea, Sweden**

Contact: Kena Karbin, S-951 87 Lulea, Sweden  
Phone: +46 920 917 75  
Telex: 80207 Centek S  
Fax: 2 +46 920 997 26

### **American Society of Limnology and Oceanography**

**18-23 June 1989, Fairbanks, Alaska, U.S.A.**

Contact: John Goering, Institute of Marine Sciences, University of Alaska, Fairbanks, Alaska 99775-1080  
Phone: (907) 474-7895, 7797

### **International Symposium on Mining in the Arctic 17-19 July 1989, Fairbanks, Alaska**

Contact: Dr. Sukumar Bandopadhyay, 108 Brooks Building, University of Alaska, Fairbanks, Alaska 99775-1190  
Phone: (907) 474-6876

### **Inuit Circumpolar Conference**

**24-28 July 1989, Sisiniut, Greenland**

U.S. Contact: Dalee Sambo, ICC, 429 D Street, Suite 211, Anchorage, Alaska 99501  
Phone: (907) 258-6917

### **International Association of Meteorology and Atmospheric Physics—Symposium on the Influence of Polar Regions on Global Climate 31 July-12 August 1989**

Contact: Ross Reynolds, IAMAP 89, University of Reading, Reading RG6 2AU, United Kingdom  
Phone: (0734) 318956  
Telex: 847813  
Fax (0734) 314404

**Institute of Circumpolar Studies**  
**31 July–18 August 1989, Fairbanks, Alaska**  
Contact: Nancy Bachner, Conferences and Institutes, 1176 Eielson Building, University of Alaska, Fairbanks, Alaska 99775  
Phone: (907) 474-7800

**Circum-Pacific Prehistory Conference**  
**2–6 August 1989, Seattle, Washington**  
Contact: Dale R. Crowes, The Seattle Center, 1001 4th Avenue Plaza, Seattle, Washington 98154-1101  
Phone: (206) 464-6580  
Telex: 6838153 BSC SEA  
Fax: (206) 382-9648

**Symposium on Ice and Climate**  
**21–25 August 1989, Seattle, Washington**  
Contact: Charles Raymond, University of Washington, AK-50, Seattle, Washington 98195  
Phone: (206) 543-8020

**Arctic Science Conference, AAAS Global Change**  
**14–16 September 1989, Fairbanks, Alaska**  
Contact: Frank Williamson, Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska 99775  
Phone: (907) 474-7648

**International Congress on Circumpolar Health: Community Health—Problems and Solutions in the North**  
**20–25 May 1990, Whitehorse, Yukon, Canada**  
Contact: 8th International Congress on Circumpolar Health, 801-750 Jewis Street, Vancouver, V6E 2A9, British Columbia, Canada  
Telex: 04-352848 VCR

**Northern Libraries Colloquy 13**  
**June 1990, Rovaniemi, Finland**  
Contact: Juhani Lillberg, Arktesen Keskuksen Saatio, Maakuntakatu 4, SF-96100 Rovaniemi, Finland

**Fifth Canadian Permafrost Conference**  
**6–8 June 1990, Quebec City, Canada**  
Contact: Mike Boroczki, Fifth Canadian Permafrost Conference, National Research Council of Canada, Ottawa, K1A 0R6, Ontario, Canada  
Phone: (613) 993-9009  
Telex: 053-3145  
Fax: (613) 952-7928

**International Conference on the Role of the Polar Regions in Global Change**  
**11–15 June 1990, Fairbanks, Alaska**  
Contact: Gunter Weller, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775  
Phone: (907) 474-7371  
Fax: (907) 474-7290

**XIII INQUA Congress**  
**2–9 August 1991, Beijing, China**  
Contact: Secretariat, XIII INQUA Congress, Chinese Academy of Sciences, 52 Sanlike, Beijing 100864, China  
Phone: 863062, 868361-336,568  
Cable: Beijing SINICADEMY  
Telex: 22474 ASCHICN  
Fax: 8011095

**6th International Symposium on Ground Freezing**  
**September 1991, Beijing, China**  
Contact: Hans Jessberger, Ruhr-University Bochum, P.O. Box 102148, D4630 Bochum 1, Federal Republic of Germany  
Phone: 02 341700-6135  
Telex: 0 825 860 UNIBO D

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## Back Cover

*New synthetic aperture radar (SAR) antenna being installed on the roof of the Geophysical Institute at the University of Alaska-Fairbanks. The installation of this 10-m antenna was a key step in the construction of the Alaska SAR Facility (see p. 61).*

