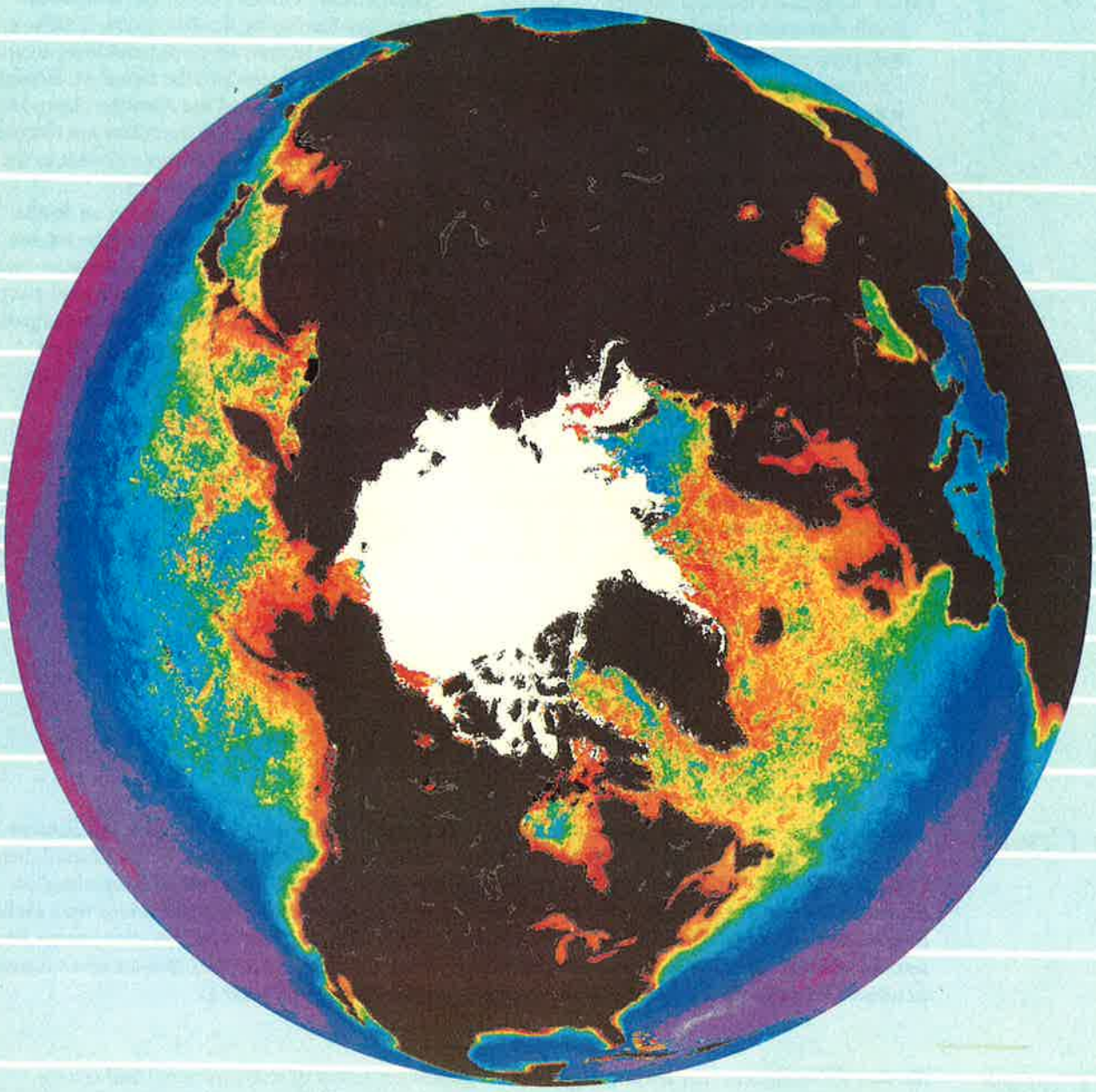
VOLUME 4

SPRING 1990

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 the Arctic Research Commission. Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

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

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

As indicated in the 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.

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

Prior issues:
Volume 1, Fall 1987
Volume 2, Spring 1988
Volume 2, Fall 1988
Volume 3, Spring 1989
Volume 3, Fall 1989

Front Cover

Northern Hemisphere Phytoplankton Distribution. Phytoplankton pigment concentration and summer minimum (September) sea-ice cover in the Arctic, derived from measurements obtained by the Coastal Zone Color Scanner (CZCS) and the Scanning Multichannel Microwave Radiometer (SMMR) operated on board the Nimbus-7 satellite from 1978 to 1987. The phytoplankton pigment concentrations were derived from a composite of all the CZCS data acquired during 1978–1982; pigment concentrations range from less than 0.1 mg/cubic meter of sea water (purple) to 30 mg/cubic meter (orange). Sea-ice cover is shown as white. (Image produced by Gene Feldman of Goddard Space Flight Center.)

Back Cover

Northern Hemisphere Sea Ice and Snow Cover. Maximum extent of seasonal snow and sea ice (February-March) in the Arctic as derived from the Scanning Multichannel Microwave Radiometer (SMMR). Sea ice is shown as white, and seasonal snow in three depth ranges: shallow snow (dark blue) from about 1 to 10 cm; moderately deep snow (medium blue) from about 11 to 33 cm; deep snow (light blue) greater than 33 cm. Permanent ice caps are shown in purple. (Image produced by Gene Feldman of Goddard Space Flight Center, using data provided by Dorothy Hall and Don Cavalieri, also of GSFC.)

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OF THE UNITED STATES

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The ARPA Mandate

The intent of the Congress as expressed in the Arctic Research and Policy Act in 1984 is to provide for a comprehensive policy and programs dealing with national research needs and objectives in the Arctic. In recent years the importance of the Arctic as part of the global system of air, land, and ocean processes has gained international attention and has stimulated Arctic scientists throughout the circumpolar nations. To be an Arctic Nation entails obligations as well as opportunities to devise ways to reconcile the wise use of Arctic resources with the preservation of environmental values and Native cultures. Science is therefore challenged to provide basic understanding of how the Arctic system works as a component of our planet and concurrently solve practical problems posed by man's presence in the Arctic.

The past year marked the fifth anniversary of the Arctic Research and Policy Act (ARPA). Steady progress by the Interagency Arctic Research Policy Committee and the Arctic Research Commission has fulfilled the intent of ARPA. One of the most important mandates of the Act is the preparation of a comprehensive 5-year Arctic Research Plan, to be revised biennially. The Plan is based in part on goals and objectives to guide Arctic research formulated by the Commission, on recommendations by the National Academy of Sciences, and on information gained from extensive public, private, and Arctic resident participation. The Interagency Committee completed the first Biennial Revision of the U.S. Arctic Research Plan and transmitted it to the President in July 1989.

The lead article in this issue of *Arctic Research of the United States* reflects the importance of the Arctic Ocean and its marginal seas to U.S. national interests, including the fisheries industry, the oil and gas industries, defense, and the study of global climate change processes. Research on these subjects is the top priority of the Commission. The Interagency Committee has developed an interagency Arctic Oceans Research strategy that includes a consolidated budget for the five agencies directly involved. It was released on January 29, 1990, following the President's submission of the FY 1991 budget to the Congress. It reflects an increasingly integrated and coordinated Federal research program in the Arctic. To follow this pilot effort for the Arctic Oceans component, 5-year forward planning of research budgets for major Arctic activities now appears feasible for the first time.

In the 5 years since the passage of ARPA, the Federal agencies are well on their way to fulfilling the principal stipulations of the Act. The next 5 years will see many beneficial changes in scope and content of U.S. Arctic research, stimulated by both national and international cooperation. The Interagency Committee and the Commission will continue contributing vigorously to the planning of interagency research and the further implementation of U.S. Arctic research policy.

Arctic Oceans Research

Strategy for Fiscal Year 1991 U.S. Program

This article is based on a report published in January 1990. It was prepared by the Arctic Ocean-Atmosphere Working Group of IARPC, chaired by Robert Corell, Assistant Director for Geosciences, National Science Foundation. Working group staff who participated in the development of this report are Marcia Lagerloef, DOC/NOAA; Thomas Curtin and Leonard Johnson, DOD/ONR; Bruce Molnia, DOI/USGS; Robert Thomas, NASA; Jerry Brown, Ted DeLaca, Charles Meyers, Michael Reeve, and Sharon Smith, NSF.

THE ARCTIC is a unique area of the Earth. It is characterized by harsh climate, extreme variations in seasonal sunlight, and a permanently ice-covered deep ocean basin, surrounded by seasonally ice-covered marginal seas. The Arctic is a treasure chest of renewable and nonrenewable resources. The sensitivity of its environment may provide one of the earliest responses to global change; in turn, anthropogenic impacts there may propagate over the entire globe.

The report that follows presents the initial strategy, goals, science elements, and a Federal budget crosscut for a coordinated U.S. Arctic Oceans Research Program. The overall goal of this program is to establish the scientific basis for developing national and international policy for managing our Arctic resources, understanding the impact of the Arctic on the remainder of the Earth, and coping with the impacts of global change.

The Arctic Oceans Research Program has been formulated to meet the primary deficiencies in existing U.S. Arctic oceans research and follows guidelines published in the 1989 revision of the U.S. Arctic Research Plan. The three goals of the Arctic Oceans Research Program are—

- To understand the physical dynamics of the atmosphere-ice-ocean interaction, water mass formation, and ice extent and motion and their impact on global climate conditions.
- To understand the marine ecosystem and biogeochemical dynamics of the Arctic shelves, the Arctic Basin, and the marginal ice zones and these systems' roles in Arctic productivity, global carbon flux, and marine population dynamics.
- To understand the geologic processes and the evolution of the Arctic Basin and continental margins and their roles in recording, indicating, and influencing global climate.

The Arctic Oceans Research Program emphasizes a multidisciplinary approach to understanding the complex interactions that drive the Arctic. Integrated Federal agency participation is necessary to utilize all of the essential research expertise within the Government and academic science communities and to provide a mechanism for coordinated planning and support of logistics for research operations.

The research effort consists of six primary science elements:

- Arctic Basin Circulation
- Ecosystem and Biogeochemical Dynamics
- Lead and Polynya Dynamics
- Marginal Ice Zone Dynamics
- Paleoclimate
- Shelf Dynamics

The program's goals and objectives follow the guidelines and closely parallel the research priorities formulated by the Interagency Arctic Research Policy Committee, the Arctic Research Commission, the Polar Research Board of the National Academy of Sciences, and the workshop *Arctic Interactions: Recommendations for an Arctic Component in the International Geosphere-Biosphere Programme.*

In FY 90, funding for the U.S. Arctic Oceans Research Program is planned at $37.7 million. The FY 91 budget is proposed at a level of $43.8 million.

Public Law 98-373, the Arctic Research and Policy Act of 1984 (ARPA), was enacted "to provide for a comprehensive national policy dealing with national research needs and objectives in the Arctic." ARPA also established an Interagency Arctic Research Policy Committee (IARPC) and authorized it to work with the Arctic Research Commission (ARC) to develop a national Arctic research policy and a 5-year plan to implement that policy. The first United States Arctic Research Plan was submitted to the President and Congress in July 1987, and the first revision was submitted in July 1989.

The ARPA also directed IARPC to provide the necessary coordination, data, and assistance for the preparation of a single integrated, coherent, multiagency budget request for Arctic research. This U.S. Arctic Oceans Research Program represents the first attempt by IARPC to meet these ARPA guidelines.

Introduction

The Marine Arctic

The Arctic is defined by the Arctic Research and Policy Act to mean "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." The Arctic also includes the Barents Sea, East Siberian Sea, Greenland Sea, Norwegian Sea, Baffin Bay, Kara Sea, White Sea, and Laptev Sea. In this article the phrase "Arctic oceans" refers to all the marine areas of the Arctic.

The marine Arctic is a unique environment, characterized by a deep, permanently ice-covered central ocean basin, surrounded by seasonally ice-covered shelves and marginal seas. At the North Pole, a few meters of sea ice float on more than 4 km of marine waters.

Leads (cracks in the ice), polynyas (perennially ice-free areas), and the ice edge are areas where the ocean and atmosphere interact, influencing global climate, ocean circulation, heat and radiation exchange, and the global atmospheric gas budget. Sediments on the floors of the Arctic Ocean and its marginal seas contain detailed records of past climate, extent and duration of glaciations and sea ice cover, paleo-oceanography, and paleo-environmental history.

The Arctic is a particularly sensitive indicator of global change and greenhouse warming. Global circulation models predict that the most dramatic impacts of global change will be observed first in the polar latitudes, particularly the Arctic.

Marginal seas, such as the Bering and Chukchi, contain abundant marine organisms and support robust food webs, including some of the richest commercial fisheries in the world. Little is known about the mineral resources of the marine Arctic, but nearby onshore petroleum fields, such as those near Prudhoe Bay, Alaska, are among the largest in the world.

As a consequence of the importance and uniqueness of the Arctic oceans environment, an integrated, multiagency Arctic Oceans Research Program strategy and budget crosscut have been formulated. Arctic oceans research is necessary to provide a sound scientific basis for developing national and international policy for managing our Arctic resources, understanding the impact of the Arctic on the remainder of the Earth, and coping with the impacts of global change.

The most severe limitation to the success of this research program is the limited access to the ice-covered Arctic Ocean and seasonally ice-covered marginal seas. The U.S. research fleet has no dedicated Arctic research vessels (ice-reinforced, ice-strengthened, or ice-breaking).

The next 5 years will bring a massive increase in satellite remote sensing data over polar regions, representing a major opportunity to obtain long-term, regular estimates of many characteristics of the Arctic ice cover and surrounding oceans. Rigorous application of these data to Arctic oceans research problems is an important priority within the proposed program strategy.

The most severe limitation to the success of this research program is the limited access to the ice-covered Arctic Ocean and seasonally ice-covered marginal seas. The U.S. research fleet has no dedicated Arctic research vessels (ice-reinforced, ice-strengthened, or ice-breaking).

The United States shares a common Arctic boundary with seven other nations. The Soviet Union is by far the dominant scientific entity in the Arctic Basin but has traditionally resisted research cooperation there because of security and territorial interests. In 1988 this position dramatically changed, and the Soviet Union is now cooperating in forming the nongovernmental International Arctic Science Committee. Accordingly, it is now imperative that the United States pursue a national and international agenda of research in the Arctic oceans.

The Research Program

This article describes—

- Key research goals and objectives for a coordinated Arctic Oceans Research Program following the guidance provided in the U.S. Arctic Research Plan (revised 1989)
- A Federal budget crosscut for the agencies that will initially participate in that program: Department of Commerce (DOC), Department of Defense (DOD), Department of Interior (DOI), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF)

The budget crosscut provides information on FY 89 and FY 90 (base) and FY 91 (proposed) support for Arctic oceans research broken out by (1) science element, (2) agency, (3) type of activity, and (4) Federal budget function. Descriptions of the science elements, the relevant agency programs (base and proposed), and the types of activities (research, long-term observations, operations, data management) are included. This report is an initial attempt to develop a crosscut for the Arctic and only covers Arctic oceans research. A budget crosscut of the full U.S. Arctic program, including scientific priorities, is being developed in 1990.

During FY 90 this initial strategy document for the Arctic Oceans Research Program will be expanded into a more detailed program plan for research through FY 96. A plan for coordinated logistics will accompany the research plan.

The crosscut performed by the Committee on Earth Sciences (CES) in 1989 for the U.S. Global Change Research Program was used as a model for the process and format for developing this crosscut. One of the science elements (ecosystem and biogeochemical dynamics) is similar in both programs; however, the other elements are

different because this program was formulated to provide answers to questions unique to the Arctic.

The planning process undertaken with the development of the U.S. Arctic Research Plan and this program strategy and budget crosscut are intended to foster a coordinated Federal research effort, one that maximizes how individual agency mission-related programs and expertise are applied to address the key unanswered questions about the Arctic system. These documents should help guide internal agency planning and assist in budget deliberations of the Congress.

Why Is It Important to Increase Our Understanding of the Arctic?

Knowledge of the Arctic has matured dramatically in recent years. We now appreciate more fully not only its economic and strategic significance to the Nation but also the global import of the interactions that take place within the Arctic environment.

- The environmental sensitivity of the Arctic may provide us with one of the earliest indicators of global climate change.

Polar oceanic processes play a dominant role in formation of the deep and bottom water of the world ocean and thus the circulation of the world ocean.

Global circulation models predict that with a doubling of atmospheric carbon dioxide, the surface air temperature of the Arctic could increase by as much as 4°C. The projected surface temperature change in high latitudes of the Southern Hemisphere is much less.

Global warming can result in melting of the glacier ice and marked changes in the extent of sea ice, with major societal and environmental consequences.

- Polar oceanic processes play a dominant role in formation of the deep and bottom water of the world ocean and thus the circulation of the world ocean.

Heat energy, the amount of oxygen and carbon, and other characteristics of these deep reservoirs are acquired in areas of deep thermohaline convection.

Research suggests that key processes controlling this deep convection involve sea ice and take place in the Arctic Ocean, on the continental shelves around its margins, and in the Norwegian and Greenland Seas.

- The Arctic shelves contain some of the richest commercial fisheries in the world as well as large populations of birds and marine mammals.

Primary productivity in a portion of the northern Bering and southern Chukchi Seas has been measured at 400 to 500 g C/m^2-yr, among the world's highest.

The U.S. pollock fishery in the Gulf of Alaska and Bering Sea is estimated to be a $2 billion industry, yet there is insufficient information about the Bering Sea ecosystem for long-range planning to assure that this fishery does not experience a dramatic crash similar to that of the King and Tanner crab harvests.

- The natural resources of the Arctic are poorly known. But even with our limited knowledge, some of the largest mineral and petroleum resources on Earth have been found there.

Why Now?

There is broad scientific and political consensus on both the environmental importance of the Arctic, as described above, and the key scientific issues. The program goals and objectives set forth in this report are drawn from a large body of workshop reports, National Academy of Sciences reports, and deliberations of other advisory committees.

The potential avenues for national and international collaborative effort are opening up. The Arctic Ocean Sciences Board, which coordinated and encouraged the international Greenland Sea Project, is now turning its attention to a major study of polynyas in three separate Arctic environments. Formation of the International Arctic Science Committee is proceeding. Additionally, the Soviet Union, long in control of some of the key areas of the Arctic Basin, is opening up its boundaries and proposing both access and ice-capable ship support for international research investigations in waters adjacent to its territories.

Major advances in the technology available to study the Arctic are coming on line. Long-term, in-situ observing systems are being developed and deployed to measure the full suite of physical, meteorological, chemical, and biological parameters. Remote sensing with real-time data transmission is key to achieving a spatial and temporal coverage of the Arctic that is logistically impossible using only surface vessels. Three satellites with synthetic aperture radar (SAR) sensors, due for launch in 1991, 1992, and 1994, will

for the first time provide us with continuous all-weather remote sensing of sea ice type and extent.

The Program

The overall goal of the Arctic Oceans Research Program is to provide a sound scientific basis for developing national and international policy for managing our Arctic resources, understanding the impact of the Arctic on the remainder of the Earth, and coping with the impacts of global change.

In order to better understand the role of the Arctic oceans in global and regional processes, the IARPC proposes that three groups of key scientific questions be addressed:

The natural resources of the Arctic are poorly known. But even with our limited knowledge, some of the largest mineral and petroleum resources on Earth have been found there.

1. What are the physical dynamics of atmosphere-ice-ocean interaction and what is their relationship to water mass formation, ice extent and motion, and heat and momentum flux?

How are these physical, biological, and chemical processes impacted by, and how do they affect, global climate?

2. What are the dynamics of the marine ecosystem (especially fisheries) and what is its relationship to physical processes on the Arctic shelves, in the marginal ice zones, and in the Arctic Basin?

What is the nature and magnitude of biogeochemical fluxes among and between trophic levels in the Arctic oceans, and between these oceans and the global ocean?

What are the roles of the Arctic shelves, the marginal ice zones, and the Arctic Basin in Arctic productivity, population dynamics of critical marine species, and global carbon flux?

3. What is the relationship of the geologic evolution of the Arctic continental margins and Basin to the presence and extent of natural resources?

What record of global paleoclimate and global climate change is recorded in the sediments of the Arctic continental margins and Basin?

What can we learn about future climate change from understanding the paleoclimate record of, and geological processes active in, the Arctic continental margins and Basin?

Implementation Strategy

The Arctic Oceans Research Program implementation strategy includes (1) identification of objectives; (2) identification of six interdisciplinary science elements; and (3) integration of the program with agency missions, programs, and international activities. As an integrated program plan is developed, objectives for each science element will be identified to elucidate the following aspects:

Monitoring. Baseline data are required to allow us to understand the Arctic environment and predict changes in it. Knowledge of the past is essential to understanding the present and the future. Data on past climates, CO_2 levels, and circulation patterns are recorded in marine and lake sediments and in glacier ice. Observations of changing oceanographic, ice, and atmospheric variables are required to define seasonal and annual variability and changes over decades. The successful monitoring of CO_2 and methane is an example of the value of this type of data. In the Arctic, unmanned and remote measurements by satellites will be invaluable for determining changes in ocean, ice, and atmosphere variables.

Understanding. Arctic processes are only beginning to be understood. For example: quantitative estimates of heat flux through both water and ice are in their infancy; the broad features of Arctic surface circulation are known, but subsurface circulation is almost totally unknown. The effect of the ubiquitous Arctic stratus clouds on heat exchange is poorly known, as is biologic productivity with its dependency on the physical environment and feedbacks. It is uncertain whether the Arctic is a source or sink of global carbon. Knowledge of the past climatic history of the Arctic too is fragmentary; we do not even know when glacial conditions commenced. Both the history and the knowledge of the interactive processes are required before reliable models can be developed. A clear understanding of the Arctic environment will require sophisticated and sustained interdisciplinary studies.

Predicting. While scientific understanding is increasing, there remains much to be done if truly integrated models of the Arctic are to be developed. The most serious limitations arise from our lack of understanding of physical, chemical, biologic, and geologic processes and their natural variability and interactions to form coupled systems. The effect of human activities on the Arctic environment, such as Arctic haze

and marine pollution, cannot be predicted without understanding the natural systems.

Science Elements

The Arctic Oceans Research Program recognizes the need to achieve an integrated multidisciplinary approach to Arctic science. Multidisciplinary programs are a necessary step in improving the knowledge base and obtaining a better predictive capability. To facilitate the integration process, the program focuses on the following six interdisciplinary science elements:

1. *Arctic Basin Circulation.* Determine principal currents, their dynamic coupling and exchange with marginal seas, and their role in global ventilation and deep water formation. Apply this information to develop realistic coupled atmosphere-ice-ocean models for use in General Circulation Models (GCMs).

2. *Ecosystem and Biogeochemical Dynamics.* Understand and quantify the dynamics of primary production, pelagic and benthic trophic dynamics, biogeochemical cycling, and material fluxes to determine how they relate to variations in the physical processes and how they affect population dynamics of fish, birds, and marine mammals and the global carbon budget.

3. *Lead and Polynya Dynamics.* Determine the local physics of momentum and buoyancy fluxes in the oceanic and atmospheric boundary layers associated with leads and polynyas and their regional effects, as well as related ice dynamics and thermodynamics.

4. *Marginal Ice Zone Processes.* Develop an understanding of the physical processes governing extent and dynamics of seasonal sea ice.

5. *Paleoclimate.* Determine the timing, extent, number, and duration of high-amplitude late Cenozoic (and earlier) climatic oscillations, the resultant ice sheets and glaciations, and the accompanying changes in the global ocean circulation and hydrographic features. Understand the importance of geologic processes in influencing past, present, and future climate.

6. *Shelf Dynamics.* Identify and understand the processes active in and controlling production of dense shelf waters, shelf ice dynamics, and water-sediment interactions and determine the effect of shelf processes on circulation within the central Arctic.

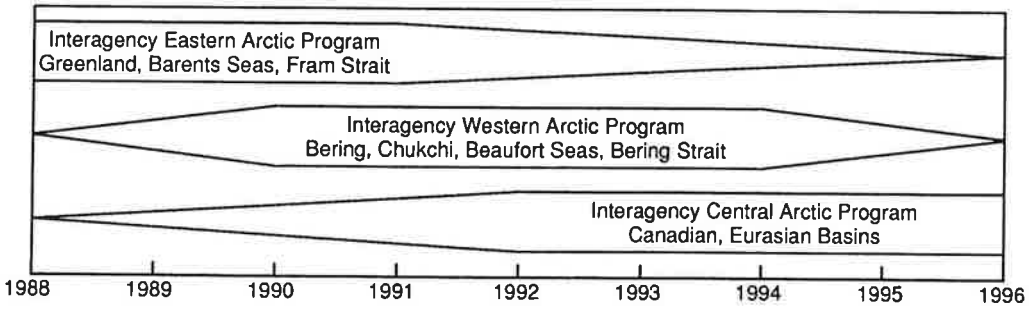
These six elements are complementary in that they are interdependent and cannot be pursued in isolation. For instance, an understanding of "Ecosystem and Biogeochemical Dynamics" requires information resulting from most, if not all, of the other elements. The science elements and relevant agency programs are discussed in more detail starting on page 8.

Integration With National and International Activities

These six science elements capture what the Interagency Committee considers to be important and immediate scientific questions in Arctic science. They closely parallel the highest research priorities recommended in the U.S. Arctic Research Plan (1987) and its biennial revision (1989), by the Polar Research Board (1988) and by the Arctic Research Commission (1988). These elements also bear directly on the responsibilities of the participating Federal agencies related to managing the harvest of living marine resources, developing our offshore energy and mineral reserves, and understanding and predicting processes critical to global climate change.

A number of complementary research activities are either under way or being planned by various Federal agencies. Linking these activities offers an opportunity to maximize the scientific output while minimizing the logistical costs for each agency. This research program represents a starting point for further planning and involvement of the broader research community.

Regionally focused interagency programs are one means of accomplishing this research agenda. The Coordinated Eastern Arctic Experiment (CEAREX) conducted in FY 89 and the Greenland Sea Project are examples of how this has been effective in the eastern Arctic. In the western Arctic, the Leads and Ice Edge Ecosystem Study and elements of the Arctic System Sciences Initiative and International Arctic Polynya Program are



proposed in FY 91 to coincide with the launch of ERS-1 and the data available through the Alaska SAR Facility. The diagram on page 7 illustrates the proposed timing of these geographically focused, interagency research programs.

There is an overlap of scientific elements between the different regional research programs that is both necessary and desirable because of the heterogeneity of the Arctic environment and the specific mission mandates of each agency.

The Budget

The FY 90 and FY 91 budget analysis is derived from planning and analysis activities mandated under the Arctic Research and Policy Act of 1984. A detailed agency-by-agency budget listing has been prepared and published since 1985 by the Interagency Arctic Research Policy Committee. The Office of Management and Budget has prepared a Special Analysis for Research, including the Arctic, as part of the Annual Budget of the United States Government. That analysis provides a crosscut by category of national concern (national security, rational development, natural laboratory). The following budget analysis for the first time provides a crosscut by science element and type of activity. It is based on the research conducted in FY 89 and the FY 90 and FY 91 proposed research.

Budget by Science Element

From a scientific perspective, the best way to understand the Arctic oceans research budget is to examine it by the major science elements:

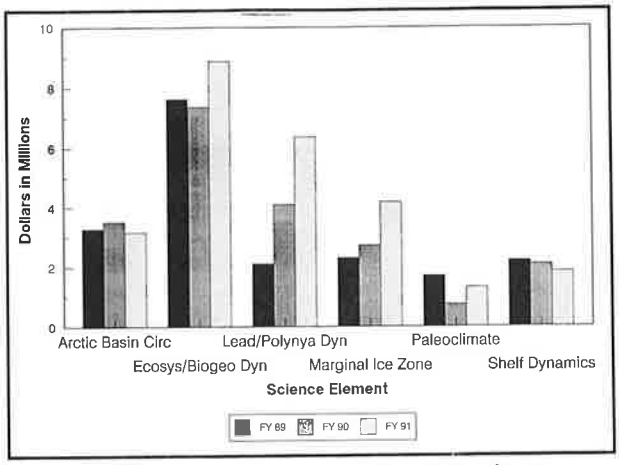
- Arctic Basin Circulation: The FY 90 budget proposes $3.53 million for this element and the FY 91 budget proposes $3.18 million.
- Ecosystem and Biogeochemical Dynamics: The FY 90 budget proposes $7.36 million for this element and the FY 91 budget proposes $8.88 million.
- Lead and Polynya Dynamics: The FY 90 budget proposes $4.10 million for this element and the FY 91 budget proposes $6.36 million.
- Marginal Ice Zone Processes: The FY 90 budget proposes $2.72 million for this element and the FY 91 budget proposes $4.18 million.
- Paleoclimate: The FY 90 budget proposes $0.75 million for this element and the FY 91 budget proposes $1.32 million.
- Shelf Dynamics: The FY 90 budget proposes $2.10 million for this element and the FY 91 budget proposes $1.85 million.

Budget by Agency

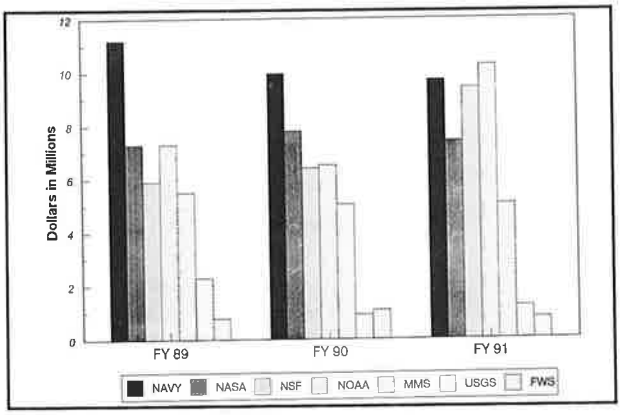
The individual agency efforts reflect their particular missions and build upon their scientific and technical strengths. The following identifies the role of each agency in the six

U.S. Arctic Oceans Research Program Budget (dollars in millions).

Elements	Total budget			NSF			Navy	
	FY89	FY90	FY91	FY89	FY90	FY91	FY89	FY90
Research Components*								
Arctic Basin Circulation	3.29	3.53	3.18	0.70	0.70	0.70	1.65	1.90
Ecosystem/Biogeochem Dynamics	7.63	7.36	8.88	1.90	1.80	2.20	0.83	0.74
Lead and Polynya Dynamics	2.12	4.10	6.36	0.10	1.00	2.00	1.73	2.28
Marginal Ice Zone Processes	2.31	2.72	4.18	0.20	0.30	0.80	1.57	1.52
Paleoclimate	1.71	0.75	1.32	0.50	0.20	0.50	0.04	0.04
Shelf Dynamics	2.21	2.10	1.85	0.30	0.30	0.20	0.85	0.90
Research Components Subtotal	19.26	20.55	25.77	3.70	4.30	6.40	6.66	7.37
Data Management	3.47	4.08	4.47	0.00	0.10	0.40	0.46	1.58
Long-Term Observations	4.23	3.30	3.50	0.00	0.00	0.00	0.50	0.10
Operations†								
Aircraft	0.84	0.80	1.22	0.00	0.00	0.00	0.35	0.05
Ships	5.28	3.25	5.02	2.20	2.00	2.60	0.90	0.05
Stations, Miscellaneous	7.21	5.70	3.77	0.00	0.00	0.00	2.34	0.80
Operations Subtotal	13.33	9.75	10.01	2.20	2.00	2.60	3.59	0.90
TOTAL	40.29	37.68	43.75	5.90	6.40	9.40	11.21	9.95



U.S. Arctic Oceans Research Program budget by science element.



U.S. Arctic Oceans Research Program budget by agency.

science elements and the FY 90 and FY 91 proposed expenditures.

National Science Foundation (NSF): NSF primarily supports university-based basic research and related ship time. Both the Division of Polar Programs and the Division of Ocean Sciences are actively involved. Currently funded programs include a nutrient/primary productivity program in the Bering Sea (ISHTAR) and physical and biological oceanography of the Greenland Sea. Future research programs will be integrated under the Arctic Systems Science (ARCSS) initiative. Funds are included for the design of an ice-capable research vessel. NSF's efforts encompass all six science elements. The FY 90 budget proposes $6.40 million and the FY 91 budget proposes $9.40 million.

Department of the Interior (DOI): DOI programs include the U.S. Geological Survey (USGS), the Fish and Wildlife Service (FWS), and the Minerals Management Service (MMS). USGS carries out research in paleoclimate, shelf dynamics, and marginal ice zone processes. The FY 90 USGS budget proposes $0.91 million and the FY 91 budget proposes $1.21 million. MMS has responsibility for managing the Nation's offshore mineral resources and funds research to best develop these resources and to predict, assess, and manage potential effects of development on the human, marine, and coastal ecosystems. The FY 90 MMS budget proposes $5.04 million and the FY 91 budget proposes $5.04 million. FWS conducts studies on the

	NASA			NOAA			MMS			USGS			FWS		
FY91	FY89	FY90	FY91	FY89	FY90	FY91	FY89	FY90	FY91	FY89	FY90	FY91	FY89	FY90	FY91
0.50	0.25	0.30	0.60	0.25	0.25	1.00	0.44	0.38	0.38	0.00	0.00	0.00	0.00	0.00	0.00
0.60	0.10	0.10	0.10	0.73	0.64	2.11	3.50	3.30	3.30	0.00	0.00	0.00	0.57	0.78	0.57
3.21	0.10	0.40	0.70	0.00	0.23	0.26	0.19	0.19	0.19	0.00	0.00	0.00	0.00	0.00	0.00
1.43	0.20	0.30	0.60	0.22	0.48	1.21	0.00	0.00	0.00	0.12	0.12	0.14	0.00	0.00	0.00
0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.51	0.72	0.00	0.00	0.00
0.90	0.15	0.30	0.50	0.08	0.40	0.05	0.00	0.20	0.20	0.83	0.00	0.00	0.00	0.00	0.00
6.74	0.80	1.40	2.50	1.28	2.00	4.63	4.13	4.07	4.07	2.12	0.63	0.86	0.57	0.78	0.57
0.75	1.70	1.30	1.80	0.42	0.31	0.69	0.65	0.42	0.42	0.18	0.28	0.35	0.06	0.09	0.06
0.40	0.00	0.00	0.00	3.35	3.00	2.90	0.38	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
0.30	0.00	0.30	0.50	0.07	0.00	0.00	0.35	0.35	0.35	0.00	0.00	0.00	0.07	0.10	0.07
0.40	0.00	0.00	0.00	2.18	1.20	2.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.10	4.80	4.80	2.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.10	0.07
1.80	4.80	5.10	3.10	2.25	1.20	2.02	0.35	0.35	0.35	0.00	0.00	0.00	0.14	0.20	0.14
9.69	7.30	7.80	7.40	7.30	6.51	10.24	5.51	5.04	5.04	2.30	0.91	1.21	0.77	1.07	0.77

* Figures represent approximations since programs often address more than one science element but are not broken down accordingly in agency budgets.

† Agencies calculate Arctic logistics costs in different ways. When this table was compiled, a standardized methodology had not been worked out.

status and trends of populations of marine mammals, fish, and birds and their habitats. The FWS budget proposes $1.07 million for FY 90 and $0.77 million for FY 91.

National Aeronautics and Space Administration (NASA): NASA's principal activities in polar oceans research are the development of data systems for Synthetic Aperture Radar (SAR) and passive microwave data and application of these data to the study of ice-covered waters. In addition, measurements of ocean color are used to investigate biological productivity in the polar oceans. NASA's program contributes to all of the science elements except paleoclimate. Currently, development of the Alaska SAR Facility (ASF) and preparation for the Program for International Polar Ocean Research (PIPOR) are major elements of the program. The NASA budget proposes $7.80 million for FY 90 and $7.40 million for FY 91.

Department of Commerce/National Oceanic and Atmospheric Administration (DOC/NOAA): NOAA conducts research, monitors, and archives and disseminates data on the Arctic environment to support its mission responsibilities for environmental prediction and management of living marine resources. NOAA's research programs are focused on marginal ice zone processes, ecosystems and biogeochemical dynamics, Arctic Basin circulation, and shelf dynamics. NOAA's Climate and Global Change Program and Coastal Ocean Program will include key Arctic components in FY 91. The NOAA budget proposes $6.51 million for FY 90 and $10.24 million for FY 91.

Department of Defense/Navy: The Office of Naval Research conducts research in support of the Navy's mission. Several large multidisciplinary and multi-institutional programs are under way or planned, including CEAREX in the eastern Arctic and Leads. The Oceanographer of the Navy supports program elements related to physical oceanography, remote sensing of ice dynamics, sea ice modeling, and data management. The Navy budget proposes $9.95 million for FY 90 and $9.69 million for FY 91.

Budget by Type of Activity

The program is divided into four types of activities: research, data management, long-term observations, and operations and facilities. The FY 90 budget proposes $20.55 million for research and the FY 91 budget $25.77 million; $4.08 million is budgeted for data management in FY 90 and $4.47 million in FY 91; $3.30 million is budgeted for long-term observations in FY 90 and $3.50 million in FY 91; and $9.75 million is budgeted for operations and facilities in FY 90 and $10.01 million in FY 91.

Funds have been included for future observing systems, including ships, data management needs, and associated facilities. However, these funds do not adequately cover the ship support required to conduct the proposed research. These planning efforts and program coordination mechanisms, established under the IARPC and its working groups on logistics and data, will

Types of Activities

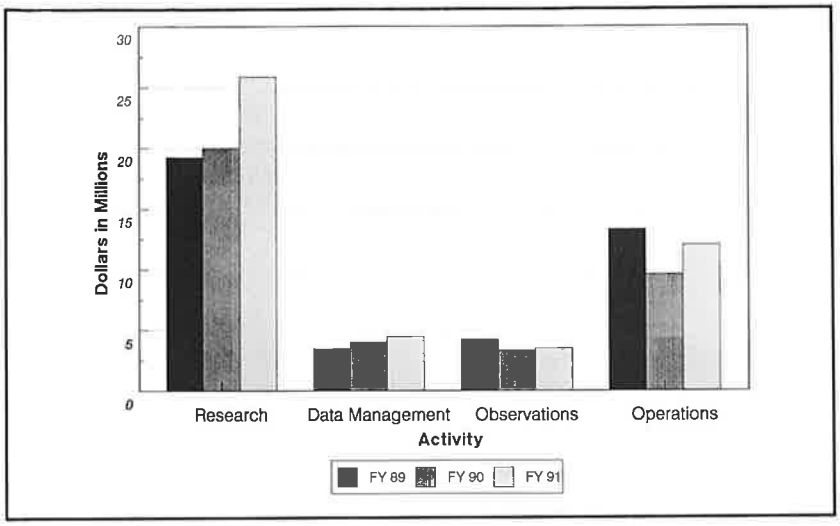
Successful understanding of the six science elements of the U.S. Arctic Oceans Research Program is contingent on the integration of a series of activities, each of which provides different types of input for analysis and interpretation. These activities are research, data management, long-term observations, and facilities and operations.

1. Research. Basic and applied science, theory, analysis, modeling, prediction, and assessment, which are fundamental to understanding the dynamics of the Arctic, its resources, and its importance in shaping global climate and responding to global change.

2. Data Management. Organizing, archiving, preserving, and making available data from Arctic oceans research. Archived data must be maintained for extended periods, perhaps 100 years or more, to be useful in retrospective comparisons. An interagency Arctic Environmental Data Directory is under development.

3. Long-term Observations. Observations made periodically or continuously over 3 years or more. They are essential to documenting the physical dynamics of the Arctic, its resources, and its importance in shaping global climate and responding to global change. A major portion of the existing effort is devoted to monitoring stocks of living marine resources.

4. Facilities and Operations. Some activities may require major investments in logistics or facilities (i.e., satellites, research vessels, supercomputers, etc.) that are essential to the success of a program. An interagency Arctic working group will develop implementation plans in conjunction with the specific science requirements. An electronic bulletin board now lists Federal capabilities available for logistics support in the Arctic.



U.S. Arctic Oceans Research Program budget by activity.

ensure the most efficient use of these capital investments.

Budget by Federal Budget Function

The following table presents the funding level according to the Federal budget functions that encompass the scientific, technological, resource, and environmental elements of the crosscut. In FY 90, $14.20 million is proposed for function 250; and $16.80 million is proposed for FY 91. For function 300, $13.53 million is proposed for FY 90 and $17.26 million for FY 91.

1989–1991 U.S. Arctic Oceans Research Program Budget by Federal Budget Function. (Dollars in Millions)

Budget No.and Function	1989	1990	1991
TOTAL	40.29	37.68	43.75
250: General Science, Space and Technology	13.20	14.20	16.80
NASA	7.30	7.80	7.40
NSF	5.90	6.40	9.40
300: Natural Resources and Environment	15.88	13.53	17.26
DOI	8.58	7.02	7.02
DOC/NOAA	7.30	6.51	10.24
Defense (Navy)	11.21	9.95	9.69

Descriptions of Science Elements and Relevant Agency Programs

This section contains brief descriptions of the state of our knowledge for each of the six science elements as well as the remote sensing activities of the U.S. Arctic Oceans Research Program. A short statement describing ongoing agency projects and additional areas of emphasis for FY 91 is also presented. The agency's project descriptions highlight the primary activities related to the budget crosscut and may not include all relevant agency activities.

1. Arctic Basin Circulation

The top few hundred meters of the water column in the central Arctic Basin are stratified in three layers: a cold, low-salinity, surface-mixed layer (upper 50 m); a cold halocline (seawater with a steep downward increase in salinity) middle water layer (50–200 m); and a lower layer of warm Atlantic water (extending below 200 m). The middle layer is also a well-defined density boundary, effectively preventing the lower, warm Atlantic water from mixing with the surface layer. This barrier also insulates the surface ice cover from the warming effects of the Atlantic water subsurface heat source, protecting the ice cover from melting. The relationship of these three water mass components is a critical issue for ocean climate. A current hypothesis is that the cold upper halocline is maintained by lateral advection (horizontal addition) of dense water produced on the continental shelves that surround the basin. The formation of this dense, cold shelf water and its transport across the shelf to the deep basin are not well understood.

A second related issue is the transport or export of Arctic Basin dense water and the deep ventilation (gas exchange) of the Norwegian and Greenland Seas. The total flux (quantity), the mechanism controlling the exchange, and the role of this mixing in both the circulation of the Arctic Ocean and deep water formation in the North Atlantic Ocean need to be understood.

Agency Programs

FY 89–90

Greenland Sea Project. During the summer of 1988, the U.S. component of this international program placed a moored acoustic tomography array for a 1-year period, performed hydrographic surveys, and moored current meters. The results of this experiment will provide a detailed "snapshot" of ocean circulation, designed to document the deep convection that may occur in autumn and winter. Data analyses continue into FY 90 (ONR, NOAA, NSF).

Cryosphere-Ocean-Atmosphere Model. A model is being developed to test the influence of ice sheets on climate sensitivity as it relates to anticipated changes in radiatively active gases such as carbon dioxide. This is part of a larger effort to

develop a realistic coupled global ocean-atmosphere general circulation model (NOAA).

Experiments and models, hydrographic surveys, and underwater floats were placed and tracer analyses were performed in the Nansen Basin to examine eastern Arctic Ocean water mass formation. Model studies were able to duplicate the observed "chimney process" for the formation of Greenland Sea bottom water (ONR).

FY 91

ARCSS. This NSF initiative will be composed of integrated interdisciplinary studies to evaluate the role of the Arctic Ocean in global change. Circulation of the Arctic Ocean and adjacent seas will be studied through experimentation and modeling.

Atlantic Climate Change Program. This is a study of climate variability related to thermohaline processes in the Atlantic Ocean. It is a joint undertaking by atmospheric scientists and oceanographers, based on modeling, examination of data sets, and long-term measurements of thermohaline processes in the Atlantic Ocean (NOAA).

TRAPOLEX. A proposed European cruise (with U.S. participation) to the central Arctic Basin may collect water mass stratification and circulation data in the Amundsen and Makarov Basins (ONR).

2. *Ecosystem and Biogeochemical Dynamics*

Biologically, Arctic continental shelves are highly productive, supporting some of the world's major fisheries. In the southeast Bering Sea, as well as at other locations, physical processes, such as upwelling at the ice edge and associated with stationary fronts or eddies, introduce nutrient-rich waters into the photic zone. This provides the basis for intense phytoplankton blooms. Polynyas (recurring open-water areas in ice-covered regions) create unique habitats for birds and mammals with potentially significant offsite export of organic material.

The dynamics of these various physical systems, their role in conjunction with biological mechanisms in initiating and regulating biological production, the transfer of energy between trophic levels, and the effect of interannual environmental variability on these processes are uncertain and need to be determined.

Ultimately, the extent of fisheries biomass may depend critically on the initial timing of phytoplankton blooms and the subsequent phasing and extent of zooplankton grazing. Our present understanding of the factors that cause fluctuations of populations of fish and marine mammals on interannual to decade scales is inadequate. The downward transport of organic material and the processes that move it offshore need to be quantified to determine the role of the Arctic in ocean carbon sequestration (removal and storage).

Agency Programs

FY 89–90

Coordinated Eastern Arctic Experiment (CEAREX). This experiment defines biomass dynamics associated with the ice edge. Field investigations in Fram Strait during FY 89 studied the ecosystem associated with ice edge eddies during early spring bloom conditions and looked at the biophysical interactions controlling productivity. Under-ice plankton and bacterial distributions were also investigated (ONR).

Inner Shelf Transfer and Recycling Experiment (ISHTAR). This project examines seasonal and interannual variation in the northward transport of Pacific Ocean water and the impact of variability in this transport on biological processes and on the ecosystem in the Bering Sea, as well as deposition and mineralization of particulate organic materials in the Bering and Chukchi Seas (NSF).

Fisheries Recruitment Oceanography. Field and laboratory studies are conducted to examine biological and environmental factors that affect variations in growth and recruitment of fish and shellfish (NOAA, MMS).

Ecosystem Modeling. Models are developed to predict the effects of environmental factors, fishing effort, and predator-prey interactions on year-to-year population fluctuations and on the availability of fish stocks in the Bering Sea ecosystem (NOAA, MMS).

Marine Mammal Populations. Field surveys are conducted in an attempt to understand and predict the dynamics of certain marine mammal species in the Bering, Chukchi, and Beaufort Seas (NOAA, MMS). Studies are conducted on distribution and movements of polar bears (using satellite telemetry) and on polar bear reproductive success. Survey methods for walrus are being standardized with Soviet specialists (FWS).

FY 91

ARCSS. Studies include carbon sequestration, ecosystem dynamics, and the effects (and interactions) of energy exchange on Arctic oceans water column structure. Data analyses and syntheses will continue from previously funded field programs and will be integrated into future studies (NSF).

Ice Edge Ecosystem Study. This study will test the hypothesis that interannual variation in

the maximum sea ice extent and seasonal ice retreat account for the major year-to-year variability in the biological productivity of the Bering and Chukchi Seas. The program will include use of coupled sea ice and ocean models, process-oriented investigations of how abundant biological environments are maintained through the combination of oceanic and atmospheric mechanisms, and examination of the relation of ice edge primary production to nutrient recycling and the occurrence and timing of secondary production (NOAA).

Bering Sea Fisheries-Oceanography Coordinated Investigations. Walleye pollock in the Bering Sea will be studied to test the hypothesis that transport of larval pollock from the deep Aleutian Basin to the continental shelf contributes to recruitment for the U.S. fishery (NOAA).

3. *Lead and Polynya Dynamics*

In addition to cooling the global ocean by the slow export of cold, dense water through the thermohaline circulation cells that link the world's oceans, the Arctic oceans transfer a substantial amount of heat to the cold Arctic atmosphere. Ice leads and polynyas, which may cover only a small percentage of the surface area of the Arctic at any one time, likely account for most of this atmospheric heat flux. The mechanisms that result in the formation of these openings in the ice and what determines their size and duration are not well understood. Similarly, the annual changes occurring in the three-dimensional structure of the Arctic oceans ice cover are not sufficiently understood to accurately predict the response of the system to atmospheric and oceanic forcing. An understanding of the interior dynamics of the Arctic oceans is needed to provide a coupling to the atmosphere-ice-ocean boundary model. Finally, there is a need to determine the high-latitude radiation balance, which may be responsible for secular changes in ocean ice-cover thickness. This change may have a profound impact on the Arctic Ocean's surface heat budget and on global climate. The area of an individual recurring polynya may be thousands of square kilometers.

Agency Programs

FY 89–90

Leads. Leads is a program to obtain a fundamental understanding of the factors controlling Arctic lead pattern development, atmosphere boundary layer dynamics, and local dynamics (ONR).

ARCSS. This NSF initiative includes coordinated interdisciplinary investigations on the role of sea ice fluctuations in ecosystem structure and function and heat and gas exchange. Investigations will use experimentation, remote sensing, and modeling.

Ice and Climate Project. This project assesses the response of Arctic ice to atmosphere and ocean forcing processes (DOI/USGS, French Space Agency).

FY 91

International Arctic Polynya Program. A comprehensive international, interdisciplinary program is being planned to simultaneously study three Arctic polynyas: Northwest Water (East Greenland Shelf), North Water (Baffin Bay), and the Saint Lawrence Island Polynya (Bering Sea) (NSF, NOAA, ONR, NASA).

4. *Marginal Ice Zone Dynamics*

The marginal ice zone is the seasonal ice edge at the southern limit of the Arctic pack and the ice edge that develops episodically along the coastline. The marginal ice zone is a unique mechanical and thermodynamic boundary where physical and biological processes interact, producing important consequences for the overall biological productivity of the region. Wind stress and heat flux in this zone can affect the vertical motion of the water column over a great depth. Variability in the winds coupled with instabilities at the ice front can result in the generation of eddies. These eddies can entrain ice, resulting in increased melting and thereby in increased stratification and stability. There is not a sufficient understanding of these processes to allow predictive modeling of ice dynamics, and consequently the implications of ice dynamics for biological activity. The relative roles of heat advection by currents and local surface heat flux and radiation balance in the melt of ice have not been resolved. The reasons for large, long-period changes in the extent and position of sea ice and the effect these changes have on climate and biological productivity are not known. The ecological influence of the marginal ice zone is incompletely understood.

Agency Programs

FY 89–90

Ice and Climate Project. This project assesses the response of Arctic ice to atmosphere and ocean forcing processes (DOI/USGS, French Space Agency).

FREEZE. Field and modeling studies have been conducted to determine the relative importance of synoptic meteorology, ocean advection, and local cooling and surface divergence in controlling fall ice cover in the Bering Sea (NOAA, ONR).

Ice Mechanics and Growth Experiment. Factors leading to changes in the marginal ice zone are analyzed (NSF).

Sea Ice Modeling. Models are developed to predict sea ice extent, movement, and growth for operational forecasts (OCEANAV).

FY 91

Ice Edge Ecosystem Study (see FY 91 Ecosystem and Biogeochemical Dynamics). Models of the dynamics of the permanent and marginal ice zones will be developed (NOAA).

NSF will continue to fund basic research related to changes in the marginal ice zone and its effects on ecosystem dynamics. The ARCSS initiative will include coordinated interdisciplinary programs to investigate the effects of seasonal ice margins on gas exchange, biogeochemical cycles, and ecosystem dynamics.

5. *Paleoclimate*

The sediment and fossils of the Arctic oceans record a detailed paleoclimatic, paleoenvironmental, and structural history of the past few hundred million years. Marine geological and geophysical studies are needed to unravel this record. Examples of the types of paleoclimatic and paleoenvironmental information that can be extracted include presence and extent of ice cover, water temperature and depth, water chemistry and nutrient availability, glacial history, and paleocirculation. Analysis of ice-rafted sediment provides insights into the extent and duration of continental glaciations. Methane hydrate (gas clathrates) is present in sediments underlying parts of the Arctic oceans. Mapping the extent, thickness, and depth of these hydrates, as well as determining their geochemistry, will provide details about climate at the time of their formation.

Agency Programs

FY 89–90

Sedimentology. Deep sea cores from the eastern Arctic Basin and shelves were collected and are being analyzed for sediment type, rate of accumulation, physical properties, and age (ONR, NSF).

Bering Sea-Chukchi Framework Studies. Studies are being conducted to provide a detailed look at the thickness, age, and distribution of sedimentary bodies that contain a long-term climate record of the Arctic Ocean (DOI/USGS).

Gas Hydrate Studies. The distribution of gas hydrates, both onshore and offshore, is being mapped in the Arctic Ocean. The geochemistry of the hydrates is being studied onshore (DOI/USGS).

Arctic Ocean Sediments. In FY 90, a study is to be initiated to examine the stratigraphic record contained in Arctic oceans sediment cores to provide information on paleotemperature, faunal assemblages, glacial history, and water mass history (NSF).

FY 91

The DOI/USGS, in cooperation with the Geological Survey of Canada, is planning stratigraphic drill holes in the Yukon and Old Crow Basins to investigate the late Cenozoic paleoenvironment. These terrestrial holes would then be linked with proposed offshore stratigraphic holes to be drilled by the Nansen Arctic Drilling Project (NAD). NAD is an international project designed to sample the marine sedimentary record of the Arctic for paleoclimatic and structural purposes.

The DOI/USGS will continue studies on the distribution and geochemistry of gas hydrates, both onshore and offshore. Attention will also focus on methane released from hydrates and its influence on climate.

The DOI/USGS in cooperation with Lamont is planning to study the crustal and stratigraphic framework from the Arctic Ocean to the North Pacific Ocean.

NSF will focus on projects relating to the history of the Arctic Basin and its adjacent seas. The ARCSS initiative will include funding for coordinated multidisciplinary programs to examine processes of sediment transport across the land/sea interface and marine geology and geophysics of the Arctic Basin.

6. *Shelf Dynamics*

Shelf dynamics pertain to the oceanographic and meteorological factors controlling the production of dense shelf waters, shelf ice dynamics and thermodynamics, water-sediment interactions, and the mechanics of sea ice formation. Where areas of open water are maintained in coastal zones, continuous freezing of near-shore waters results in the formation of cold, dense waters through brine rejection.

Unlike temperate regions, where liquid water is the only medium of energy exchange, the Arctic continental margin is a unique environment involving not only the water column, but also the interaction of sea ice and the sea floor. The effect of Arctic seasonality, with its continuously varying ice canopy, varies the processes that force activities on the Arctic shelves. Sediment entrained in fast ice during freeze-up may account for the majority of

sediment transported from the shoreline and shallow shelf zone into the deeper Arctic Basin. The nature of high-latitude sediment is also substantially different. Due to the major role played by ice in sediment origin, transport, and deposition, Arctic sediments are surprisingly more heterogeneous, both temporally and spatially, than sediments elsewhere in the world ocean. Little information exists on the total sediment budget of the Arctic oceans.

Agency Programs

FY 89–90

Barents Sea Shelf Study. In FY 90, a SEA MARC (wide swath bathymetry) survey of the western Svalbard margin is to be made. Additionally, data on bottom roughness, type, thickness, and acoustic stratigraphy will be collected in the Barents Sea. Current meters will also be deployed (ONR).

Beaufort Sea Mesoscale Circulation Study. To better understand shelf circulation and its driving (forcing) mechanisms, this study has collected and is analyzing 3 years of current, wind, ice velocity, hydrographic, and meteorological data between Barrow and Demarcation Point (DOI/MMS, NOAA).

U.S./U.S.S.R. Bering/Chukchi Seas Circulation Study. Hydrographic surveys and year-long moorings will be used to determine the time-dependent western Arctic shelf circulation, with particular emphasis on the northward transport of nutrients and salt in the Bering and Chukchi Seas (NOAA).

Bering Sea Sediment. Samples were collected and analyses performed to determine the sediment composition, trace metal component, and hydrocarbon content in sediment and benthic organisms (DOI/MMS).

Bering Sea GLORIA Studies. GLORIA (Geological Long Range Inclined Asdic, a wide swath side-looking sonar device) surveys in the Bering Sea were conducted to provide a detailed look at the morphology of the sea floor, especially defining sediment sources, sediment sinks, and transport pathways. In FY 90, a Bering Sea GLORIA atlas will be released (DOI/USGS).

Coastal Processes. The processes responsible for sediment transport and erosion on the shelf and along the coast are being evaluated (DOI/USGS).

NSF continues to fund basic research related to coastal erosion, subsea permafrost, and bottom water formation.

FY 91

Arctic Sediment-Ice Study. In FY 91, a new study will address the impact of the ice canopy on the forcing functions affecting sediment transport, bottom stress variations, particle settling rates, and high-latitude sediment dynamics (ONR).

NSF plans to continue funding unsolicited proposals on shelf sediment water processes.

Remote Sensing

Remote sensing is inherent throughout the science elements and is presented as a separate subject here to summarize recent activities. Full use of remote sensing is particularly important in the Arctic, where in-situ measurements are difficult and costly to obtain and can at best provide only a localized picture. Moreover, satellite remote sensing data have the potential of providing the long, stable time series of data needed to detect changes that might be occurring in the Arctic environment.

All science elements make use of remotely sensed data, and these are acquired by instruments aboard buoys, ships, aircraft, and satellites. Measurements from aircraft and satellites yield estimates of sea ice extent, concentration, and type; sea-surface temperatures, winds, and waves; and ocean color.

A major goal of NASA's oceans program is to compile long-term, well-documented data sets derived from the satellite instruments. The principal activities relevant to the Arctic Oceans Research Program are

1. The data system being implemented at the National Snow and Ice Data Center for processing, archiving, and distributing sea ice products derived from passive-microwave data obtained by NASA's ESMR and SMMR instruments and from the DOD's SSM/I. The Oceanographer of the Navy is funding the development of SSM/I algorithms for sea ice classification.

2. The Archive and Operations System that will be implemented at the Alaska SAR Facility (ASF). The Oceanographer of the Navy and NOAA are jointly developing a SARCOM link to allow selective transmission of SAR data from the ASF to the Navy/NOAA Joint Ice Center in Suitland, Maryland, for use in ice forecasting and analysis products. SARs will operate aboard a series of foreign satellites: the European Space Agency's first remote sensing mission (ERS-1), to be launched in 1990/91; the first Japanese Earth Resources Satellite (JERS-1), to be launched in 1992; and the Canadian Radarsat, to be launched in 1994. NASA has memorandums of understanding (MOUs) that will permit acquisition of SAR data from ERS-1 and JERS-1 at the ASF, which is being established at the

University of Alaska-Fairbanks. A similar MOU is under negotiation for acquisition of Radarsat data. SAR data from these missions will be received, processed, archived, and distributed by the ASF. In order to facilitate application of the SAR data to these investigations, NASA, ONR, NOAA, NSF, and USGS are discussing a joint research announcement for proposals that includes the application of ASF data to specific research objectives. The objectives are presented in the Science Plan from the ASF Program (JPL 1989).

3. NASA is also exploring options for launch of the Compact Wide Field Sensor (SeaWiFS) to obtain ocean-color data for estimating ocean biological productivity.

Over the next 5 years, these several instruments will provide a massive increase in remotely sensed data at high latitudes, representing a fundamental element of the proposed Arctic Oceans Research Program. Toward the end of the 1990s, the international Earth Observing System of polar-orbiting satellites will further increase the availability of remotely sensed data, with measurements extending over a period of 15 years or more.

A program for an International Polar Ocean Research (PIPOR) project of satellite remote sensing, in-situ observations, and numerical modeling is planned for the period 1990 to 1996 and will make full use of several appropriate satellite missions.

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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 Fiscal Year 1989 were $23.7 million.

The National Science Foundation (NSF) supports a formal Arctic research program assigned to the Division of Polar Programs (DPP). 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. Research grants are provided on the basis of unsolicited proposals and are peer reviewed.

In FY 89, NSF awarded funds for Arctic research to 77 institutions in 29 states and the District of Columbia, representing 210 projects. NSF's support of Arctic research, including facilities support and field operations, over the past several years is shown below (in thousands of dollars).

	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89
DPP	6209	7344	7947	8005	8095	8211	10175
Other NSF programs	6732	9191	11482	10139	13799	14907	13556
Total	12941	16535	19429	18144	21894	23118	23731

The following sections present highlights of several major programs and selected projects. A complete listing of NSF Arctic funded projects is given in the publication *Arctic Science, Engineering, and Education Awards: FY 1989,* available from Polar Coordination and Information, Division of Polar Programs, National Science Foundation, Washington, DC 20550.

Arctic Systems Science

A major new initiative across NSF, Arctic Systems Science (ARCSS), is being implemented. The goal of ARCSS is to understand the physical, geological, chemical, and biological processes of the Arctic system that interact with the total earth system and thus contribute to or are influenced by global change. The elements of this initiative have been divided into two principal areas of endeavor—reconstruction of paleoenvironments and process studies of present-day environmental interactions. Included is an evaluation of the atmospheric and paleoenvironmental records contained in glacial ice and in lake and marine sediments, which document changes in the earth's past. These coordinated interdisciplinary activities are being accomplished through observation, experimentation, analysis, and modeling. Two ARCSS workshops were conducted in early 1990 to develop detailed scientific plans for air-ocean and air-land interactions and to focus on the role the Arctic plays in global change processes.

FY 89 FUNDING (thousands)

Glaciology	2173
Atmospheric Sciences	7154
Ocean Sciences	5524
Biological Sciences	3347
Earth Sciences	1436
Arctic Systems Science	2500
Engineering and Technology	559
Social Science and Education	302
Coordination and Commission	736

Glaciology

NSF funded 34 projects in glaciology (including Arctic Systems Science) totaling $4.7 million in FY 89. Research supports the study of all forms of naturally occurring ice and its history under a broad multidisciplinary glaciological research program that is currently focused on the physics of fast glacier flow, numerical modeling of glaciers and their interactions with the atmosphere and oceans, the chemistry of ice cores as indicators of paleoatmospheric chemistry and long-term climate change, and modern glacial geological process and the geological history of glaciers. 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.

A major thrust of the glaciological research program in the Arctic is the deep ice coring and analysis program in Greenland, called the second Greenland Ice Sheet Project (GISP 2). GISP 2, an ARCSS initiative, and a corresponding European effort, the Greenland Icecore Program (GRIP), plan to retrieve ice cores to the base of the central Greenland ice sheet (a depth in excess of 3000 m). GISP 2 is a major component of the NSF Global Geosciences initiative and, as the first major program under ARCSS, is projected to extend over a 5-year period.

The establishment of a remote field camp in May 1989 in the summit region of central Greenland (latitude 72°34.79'N, longitude 38°27.11'W, elevation 3203 m) marked the beginning of the most ambitious U.S. ice coring program to date. Over the next 5 years, GISP 2 plans to collect ice cores to the base of the Greenland ice sheet to retrieve a high-resolution, 200,000-year record of earth's environmental history, spanning two glacial and two interglacial periods, the longest such record available from the Northern Hemisphere. Particular attention will be paid to the Little Ice Age, the Climatic Optimum, the Younger Dryas oscillation, glacial-interglacial transitions, and other rapid climate transitions. In addition, detailed time series analyses will be performed in search of climate cycling and for comparison with proxy climate data sets from other media and latitudes. A parallel ice core project is being conducted 30 km to the east by European ice core researchers. Comparison of U.S. and European results will ensure that both the dating of the environmental signals and the interpretations of these signals are unambiguous.

Snowpit samplers in clean garments.

Properties to be studied in the GISP 2 core include the composition of occluded gases, particles, stable isotopes in ice and gases, major and trace element chemistry of ice, electrical conductivity, and physical properties. Specific goals of GISP 2 include the following:

- Retrieval of a high-resolution record of Holocene and pre-Holocene climate (temperature, precipitation rate, air mass sources, humidity, wind strength) and atmospheric chemistry (gases and soluble and insoluble constituents).
- Documentation of the production and exchange rates for anthropogenic, volcanic, biogenic, oceanic, terrestrial, and cosmogenic sources of atmospheric constituents.
- Investigation of timing and forcing dependency as revealed by correlation of climatic parameters (such as temperature and precipitation), radiatively important gases (such as CO_2 and CH_4), aerosols, and other system boundaries such as ocean characteristics, sea ice extent, ice volume, volcanic activity, and atmospheric turbidity.
- Development of accurate dating techniques and flow modeling for pre-Holocene ice, with particular attention to the identification of global stratigraphic markers such as isotopic ratios, cosmogenic events, and volcanic events.

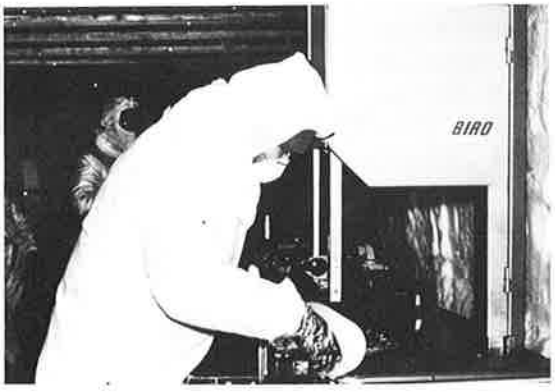
Field activities in 1989 were largely devoted to preparing for the deep drilling component of the program, which begins in May 1990. Several scientific experiments were completed that will be important to the interpretation of the deep record. For example, snowpits were sampled locally and within a 150-km radius of the drill site to provide additional tests of the spatial representativeness of the drill site. Automatic weather stations were installed to provide year-round records as a basis for developing atmosphere-ice transfer functions. Atmospheric sampling was undertaken at a solar-powered clean air facility situated 28 km upwind from the main camp to assess air-snow fractionation. Fresh and aged snow and vapor sampling was conducted to identify precipitation sources and postdepositional controls. Processes controlling gas entrapment were studied, and intercalibration of ice core properties to be examined in the deep core was initiated on several shallow (90-m to 200-m) cores recovered during the field season. The deepest of these first-year cores provides a 750-year record that will be analyzed over the coming year.

Preliminary field investigation of these cores using electroconductivity has already allowed the identification of volcanic events and seasonal chronology. In addition to the scientific program conducted this season, significant progress was made on the construction of a semipermanent station for the forthcoming field activities and on the testing and operation of the drill to be used in drilling and coring the deep ice.

The University of New Hampshire is coordinating GISP 2 scientific activities through its GISP 2 Science Management Office. Logistical and drilling support is provided by the Polar Ice Coring Office at the University of Alaska, Fairbanks. Permission to work in Greenland is generously provided by the Commission for Scientific Research in Greenland and the governments of Denmark and Greenland. The 109th TAG Air National Guard, Schenectady, New York, and the U.S. Air Force Military Airlift Command from McGuire Air Force Base in New Jersey provide transport. Support at Sondrestromfjord Air Base in Greenland is provided by the U.S. Air Force Space Command. Scientists from 15 academic institutions and Federal agencies are participating in GISP 2.

Atmospheric Sciences

NSF funded 78 projects in the Arctic atmospheric sciences, totaling $7.2 million in FY 89. Funding supports atmospheric research in meteorology, climate dynamics, tropospheric and stratospheric 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, polar stratosphere clouds and stratospheric chemistry related to ozone depletion, magnetosphere-ionosphere interactions, very-low-frequency (VLF) waves, auroras, and precipitation of energetic particles from the magnetosphere by VLF waves and magnetic pulsations.



Scientists in trench workstations wearing clean garments.

A recent study of a phenomenon well known in northern latitudes, namely, bright, high-altitude (85-km) noctilucent clouds seen typically around sunset and sunrise, has found that these clouds are absent from the historical record prior to 1885. It has been hypothesized that the increasing number and brightness of these events could be due to the large amount of water vapor reaching the mesopause, where the clouds are formed. This increased water vapor may be the result of oxidation of excess methane in the stratosphere, the methane being due to industrialization, land use, and ever-growing human and animal populations. The initial brightness enhancement was probably brought on by the large stratospheric injection of water from the Krakatoa volcanic eruption in 1883. Scientists conclude that the brightness, distribution, and frequency of occurrence of these clouds will continue to increase in the immediate future and could be a useful monitor of the methane additions.

Under NSF sponsorship, the geospace research community has developed the Geospace Environment Modeling (GEM) program to organize the multifaceted measurement techniques needed for geospace imaging into coordinated, ground-based observing campaigns. The GEM program breaks new ground in scientific organization by introducing the concept of coordinating theory campaigns with observing campaigns to enhance rapid interpretation and application of the results. GEM campaigns will first image large areas of the magnetosphere (for example, the polar ionosphere) where phenomena occur that are critical to the understanding of geospace dynamics. The program will also develop the capability to image the entire area. Geospace scientists will then be able to view the domain the way atmospheric scientists now view satellite images of global weather.

The GEM program has community support beyond NSF-funded scientists in that it is one of three U.S. programs in the international Solar-Terrestrial Energy Program. Accordingly, the GEM precampaign workshops have had broad international attendance. National Aeronautics and Space Administration and Department of Defense funded scientists plan to participate in GEM campaigns, thus complementing NSF-supported programs with additional scientific personnel, measurement hardware, satellite data, data processing, archiving services, and logistic support for the campaigns.

In other space programs a comprehensive set of coordinated observations of electric field, electron density, auroral precipitation, and currents was made from the Sondrestromfjord radar and the Greenland magnetometer chain.

NSF participated in the support of the National Oceanic and Atmospheric Administration's Arctic Radiation and Chemistry Experiment, a follow-on in March and April 1989 to earlier Arctic Gas and Aerosol Sampling Programs (AGASP I and II) (see *Arctic Research of the United States*, Volume 2, Spring 1988, page 39). Arctic Radiation and Chemistry Experiment was an investigation of physical processes that determine

the structure of the Arctic planetary boundary layer, the relationship of the atmospheric structure to the underlying surface, and the interaction of the Arctic with lower latitudes. The principal scientific objectives of the expedition were to determine the Arctic radiation budget in spring with particular emphasis on surface reflectance, air chemistry, and aerosol physics under cloudy and cloud-free conditions; to measure directly the properties of Arctic aerosols; and to understand the sensitivity of surface fluxes to changes in surface properties sufficiently well to model regional air-ice-ocean interactions. The range of observed conditions is a prerequisite for determining the influence of atmospheric forcing on ocean and ice processes in Arctic regions. Of particular concern is that, although the various contributions to the radiation budget are a major influence on Arctic climate, the magnitude of those contributions is still relatively unknown.

Conclusions from the study negate the importance of nutrient inputs from the Yukon River on shelf biology and ecosystem dynamics and emphasize the importance of the Anadyr Stream. Flowing from the Gulf of Anadyr to the Arctic Ocean, the Anadyr Stream is a major driving force of productivity and biogeochemical dynamics on the north Bering Sea shelf.

Three NSF-supported projects made use of an instrumented NOAA P3 meteorological research aircraft in the vicinity of Fram Strait, with complementary environmental observations from a drifting ship and two ice camps maintained as part of the Office of Naval Research's Coordinated Eastern Arctic Experiment (CEAREX).

In another international activity, scientists from several U.S. universities conducted joint field studies with Soviet scientists to develop histories of climatic change in Siberia and Alaska. A principal achievement was the collection of sediment cores from six lakes in eastern Siberia spanning 85 m of sediment from 23 cores. The longest core, 16 m, is from a tectonically formed lake in a nonglaciated region. The sediments are estimated by Soviet geologists to span the past 70,000 years or more. Other cores are from a suite of periods of the last glacial cycle. Together these cores will allow the first intensive study of the climatic history of eastern Siberia. Tree-ring data, spanning the past 300 years, were collected from stands of *Larix*, and access was obtained to local weather records for cross calibration. The scientific participants from the North-East Complex Scientific Research Institute in Magadan and the Institute of Geography in Moscow were oriented to U.S. methods for lake coring and palynological procedures. The Soviet scientists provided plans for future collaboration in Chukotka and other paleoclimatologically unexplored regions of Siberia. A joint Soviet-American report was prepared, describing the results of field work and outlining the next phase of collaborative research.

Ocean Sciences

NSF funded 22 projects in Arctic oceanography totaling $5.5 million in FY 89. 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 have far-reaching effects. For example, 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 global atmospheric and oceanic circulation have their high-latitude expressions, modulated by the quasi-permanent sea ice cover of the Arctic Ocean.

A long-term goal of one study, the Bering Sea ice edge, is to understand the effects of interannual variation in sea ice on annual primary production and its allocation to higher trophic levels. The 1987 and 1988 cruise results have confirmed and expanded earlier findings that show a close relationship between physical processes and the spring bloom at the Bering Sea ice edge. New findings include qualification of a modest but significant role for urea as a source for the bloom, evidence that the microbial process is an important source of ammonium in the euphoric zone, and marked variations in bacterial productivity corresponding to variations in the concentrations of dissolved amino acids.

An ecosystem program called Inner Shelf Transfer and Recycling (ISHTAR) is concerned with nutrient input, transfer, recycling, and deposition on the north Bering and Chukchi sea shelves. The program focuses on the effects of interannual changes in atmospheric forcing on water transport through several regional straits leading to the Arctic Ocean. Conclusions from the study negate the importance of nutrient inputs from the Yukon River on shelf biology and ecosystem dynamics and emphasize the importance of the

Anadyr Stream. Flowing from the Gulf of Anadyr to the Arctic Ocean, the Anadyr Stream is a major driving force of productivity and biogeochemical dynamics on the north Bering Sea shelf. In 1988 the third Soviet-American research cruise aboard the *Akademik Korolev* reported several scientific advances on the oceanography of the western Bering and Chukchi seas. New information confirmed southeastern transport of Siberian coastal water, high pelagic and benthic productivity at the convergence of the Anadyr and Siberian streams in the Chukchi Sea, and possible sequestration of global carbon in the Arctic Ocean. Future efforts of U.S. and Soviet scientists will emphasize the Chukchi Sea as an important carbon and nitrogen reservoir. A U.S.-U.S.S.R. symposium on the Ecology of the Bering and Chukchi seas was held at the meeting of the American Society of Limnology and Oceanography in Fairbanks, Alaska. Soviet and American scientists agreed to meet in April 1990 in the Soviet Union to plan the fourth joint cruise in 1991. The Department of Interior's Fish and Wildlife Service is the lead organization for these joint Soviet-American studies.

Acceptance of the Toolik Lake site into the LTER program allows long-term planning for Arctic research.

In the Gulf of Alaska a program was completed to measure changes in circulation through use of hydrography, current meter deployments, and drifters. One drifter traveled the entire length of the Aleutian Island Arc and into the Eastern Hemisphere. There is evidence that the Alaska current has shifted. Although the cause is uncertain, the smoothed wind stress direction of the Gulf of Alaska current indicates a severe 4- to 6-year fluctuation, with increasing velocity in the last year.

In the Greenland Sea, six acoustic transceiver moorings were recovered in late 1989 after a year-long deployment in a project of Scripps Institution of Oceanography and Woods Hole Oceanographic Institution. The experiment measured travel times of sound pulses to infer density (temperature) and currents within the 200-km array, with the expectation that deep convective events (called chimneys) could be recognized. Observations by the Norwegian Meteorological Service showed that sea ice moved over the array and retreated during the winter and that the mixed layer deepened rapidly, reaching a depth of 1800 m and indicating a preconditioned environment for the formation of chimneys. The data are being processed to produce the sound speed field, which will be merged with hydrographic data to infer kinematic and temperature structure of the water.

Biological Sciences

NSF supported 20 projects in biological sciences totaling $3.3 million in FY 89. Included are long-term studies that are particularly valuable in ecosystem-level research, for two major reasons. One is that ecosystem processes are often highly variable from year to year, and it may take many years of data collection before a pattern can be distinguished and its causes clearly defined. Second, the response time of whole ecosystems to disturbance, climate change, or experimental manipulation may be measured in decades, or even centuries, rather than the 2- to 5-year duration of the typical research project. The Toolik Lake area became part of NSF's Long-Term Ecological Research (LTER) program in 1987 and is under the direction of the Ecosystems Center in Woods Hole, Massachusetts. The three principal components of the program are lake studies, river studies, and terrestrial landscape studies. In each of these three areas, long-term monitoring of ecosystem processes (such as primary production) is conducted to document natural variability and to detect trends. Research in each area also includes the monitoring of long-term experiments designed to help elucidate how major ecosystem processes are controlled.

Acceptance of the Toolik Lake site into the LTER program allows long-term planning for Arctic research. The number and variety of long-term experiments are being expanded, as is the monitoring program. The accumulated data base and the availability of these experiments for research by others should serve to attract new researchers with new ideas to Toolik Lake. Another important goal has been to integrate the Toolik Lake and Kuparuk River watershed studies to compare their hydrology and geology. To this end, a Geographic Information System for these watersheds is being developed.

Another means of integrating terrestrial and aquatic research is through the use of stable isotopes as tracers. The question is whether terrestrial plants or lake phytoplankton is the important food resource in a small Arctic lake. Lakes are often considered self-contained ecosystems because they have discrete, easily defined boundaries. But lakes receive nutrients, dissolved

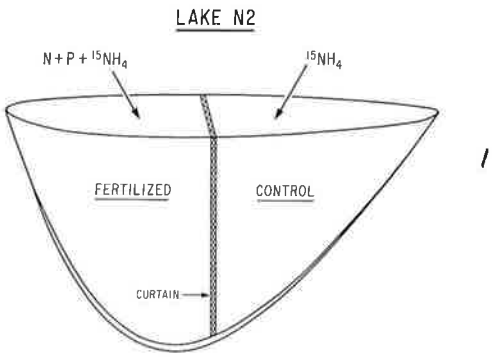
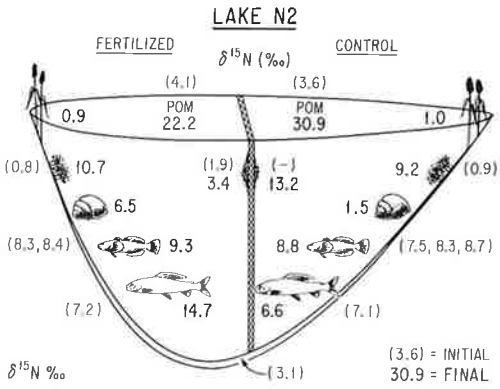


Diagram showing results of additions of nutrients and tracer amounts of ^{15}N into the divided Arctic lake.



The largest increases in ^{15}N content occurred in phytoplankton (POM) and submerged mosses; grayling and snails in the fertilized side had higher values than those in the control side, suggesting a faster transfer of nitrogen through the food chain caused by nutrient enrichment. (See MBL report for further details.)

organic compounds, and decaying plant litter from surrounding watersheds. Thus the food required for growth of fish and other consumers may originate from within the lake, or it may be transported to the lake from the watershed.

The lake studied had previously been divided with a plastic curtain into control and experimental sections (see *Arctic Research of the United States*, Volume 2, Fall, p. 35). Small amounts of the stable isotope ^{15}N were added to both sides of the lake to label phytoplankton with a nitrogen tracer. Terrestrial plants were unlabeled. The experimental side of the lake was also fertilized with nitrogen and phosphorus to stimulate algal growth. The ^{15}N label appeared in the algae and zooplankton consumers almost immediately, and their ^{15}N content increased steadily with time. By the end of the experiment, zooplankton in both the control and fertilized sides had ^{15}N contents similar to those of phytoplankton. This similarity in ^{15}N content suggests a food web based on algae rather than on terrestrial plants. In contrast to the planktonic community, there was a much smaller enrichment of ^{15}N in animals of the benthic food web. The ^{15}N content of snails and sculpin increased only slightly over the summer, indicating a time lag of at least one growing season in the incorporation of new phytoplankton production into the benthic food chain.

There was also evidence that grayling and the snail *Lymnea* accumulated more ^{15}N in the fertilized side than in the control side over the summer. This suggests that nutrient enrichment enhances the rate at which nitrogen cycles through the food web. This project demonstrated that significant progress can be made, at relatively little additional cost, if long-term experiments are already "up and running" and available to ecologists. Future experiments are planned with the tracer ^{13}C to help understand the carbon cycle as well.

Another activity, the Flora of North America project, is a cooperative enterprise by plant taxonomists in 22 academic institutions and museums in the United States and Canada. The project is designed to catalog in printed and computer data base formats a complete inventory of the estimated 17,000 species of flowering plants, ferns, and conifers of the continent, north of Mexico. The University of Alaska's Museum and Herbarium is one of the cooperating institutions. Coverage for the flora includes Alaska, Canada, and Greenland, with an estimated 400 to 800 species not found farther south in the continental United States. Authoritative classification of all species, descriptive information on morphology, chromosome numbers, economic uses, vernacular names, geographical ranges, and identification keys are some of the products of this multi-institutional endeavor. The FNA project is anticipated to take 12 to 15 years to complete the printed volumes, with ongoing development and maintenance of searchable data bases on the plants of North America. These data bases will be integrated with others covering the floras of China, Europe, and, eventually, the U.S.S.R.

Earth Sciences

NSF funded 25 projects in Arctic earth sciences totaling $1.4 million in FY 89. Geological, geophysical, and Quaternary research throughout much of the Arctic region is supported. Projects seek to understand the tectonic evolution and geologic history of the Arctic Basin and its margins and to answer local and regional geologic questions. Arctic regions have demonstrated wider swings in climate through

geologic time than have 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. Studies of shallow water sediments and terrestrial deposits are important for establishing a detailed chronology of paleoclimatic and paleoecologic events.

During the Late Cretaceous the North Slope of Alaska was populated by diverse assemblages of dinosaurs and other terrestrial and freshwater vertebrates. Discovery of these high-latitude faunas raises questions concerning the nature of the Late Cretaceous environments and the range of tolerance of some species of dinosaurs and other extinct vertebrate lineages. Paleontologists from the University of California Museum of Paleontology (Berkeley) and the University of Alaska Museum (Fairbanks) continued field and laboratory studies of Late Cretaceous (Maastrichtian) terrestrial vertebrates found in exposures of the Kogosukruk Tongue, Prince Creek Formation, west of Deadhorse (Prudhoe Bay).

Main quarry area along river bluff.

Fossils at the bottom of the bone bed.

In this area, duck-billed dinosaurs (hadrosaurids) are abundantly represented in an extensive bone bed, and their remains are frequently preserved at other stratigraphic levels. Systematic analyses indicate that these specimens are referable to the species *Edmontosaurus saskatchewanensis* first described from southern Alberta.

A channel lag deposit yielded the remains of several kinds of freshwater fishes and mammals. The latter include abundant specimens of the marsupial *Pediomys*, at least two kinds of multituberculates (rodentlike mammals), and a rare placental mammal.

Intriguingly, no remains of turtles, crocodilians, or champsosaurs, common members of contemporaneous faunas in Alberta, Montana, Wyoming, and areas farther south, have been discovered. The collection is now large enough to warrant the hypothesis that the lack of remains of these animals reflects their absence or rarity in the local faunas and is not an artifact of small sample size.

Paleobotanical research on the local floras of the Prince Creek and adjacent formations suggests that during the latest Cretaceous the climate of the North Slope was becoming cooler and more seasonal. By the end of the Cretaceous, winter temperatures occasionally could have fallen to freezing, and permanent accumulations of ice might have developed in the mountains.

This reconstruction of the environment provides the intriguing possibility for assessing the difference between the ranges of tolerance of juvenile and adult members of several species of dinosaurs and mammals found on the North Slope and those of contemporaneous species of turtles, crocodilians, and champsosaurs. Also, it provides an opportunity to test the hypothesis advanced in other quarters that a short period of cold temperatures caused the extinction of the dinosaurs. To the south, where latest Cretaceous and early Paleocene faunas are much better known, the end of the Cretaceous was marked by the extinction of the dinosaurs, but most lineages of turtles, crocodilians, champsosaurs, and mammals survived.

Late Triassic tetrapod faunas are significantly different from those of the Early Jurassic; nonetheless, during the Late Triassic, representatives of diverse groups (mammals, dinosaurs, crocodilians, turtles) first appeared and continued to diversify through the remainder of the Mesozoic.

Knowledge of these Late Triassic forms is extremely important to understanding the evolutionary transitions that gave rise to such major groups as mammals and dinosaurs, and for this reason a research team from Harvard University designed a program to investigate various formations of the Scoresby Land Group, Greenland, for evidence relating to this critical period in the history of life.

Using screening techniques at a site from which fragmentary dinosaur vertebrae were collected last year, the team discovered an entire prosauropod dinosaur in situ. This is believed to be the first dinosaur known from Greenland. Also recovered were a number of amphibian and reptilian specimens that are evidence of a varied tetrapod fauna. Among these are a large amphibian (skull length estimated at 90 cm), a

A geodesic dome allows a drift-free zone to surround it. This dome is currently buried under 5 m of snow. Window glass in the frame has not cracked. The dome is a 10-m 3-frequency Daystar.

reptile (dinosaur or thecodont), and other partial tetrapod skulls or skeletons that require laboratory preparation for positive identification. Two dinosaur skeletons were also discovered but had to be left in place for future collecting because their size exceeded the expedition's logistical capabilities.

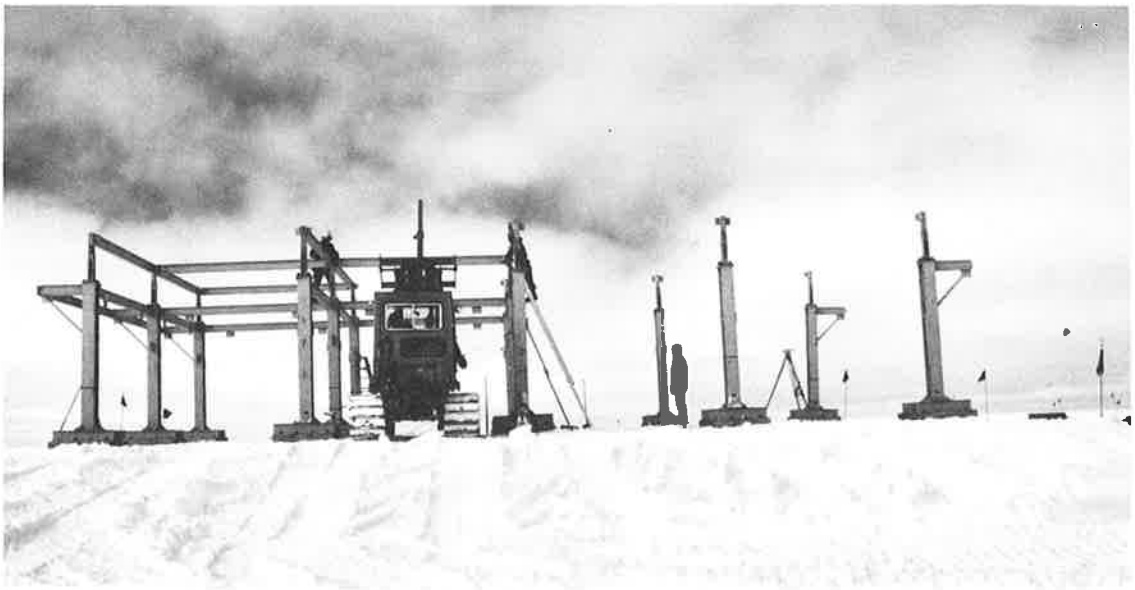
Engineering and Technology

NSF funded nine projects in Arctic engineering and technology, totaling $559,000 in FY 89. Support in engineering, material sciences, and permafrost is provided by the Engineering, Geosciences, Materials Research, 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. A workshop to further define priorities in cold region engineering was held in Hanover, New Hampshire, in December 1988. Highlights of recommendations included design guidelines for offshore Arctic structures, structures in watersheds and coastal areas, facilities infrastructure, and transportation infrastructure technology. A report of the workshop was published in the *Journal of Cold Regions Engineering*, volume 3, no. 4, December 1989.

NSF sponsors a program for science-based and high-technology small business firms, the 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 89 the SBIR program funded projects on geophysical techniques to determine frozen ground masses and the presence and configuration of buried and surface masses of ice, optimum waste treatment operations for the polar environment, and cold climate clothing and protection.

Social Science and Education

During FY 89, and in accordance with the recommendations of the National Science Board and the Polar Research Board of the National Academy of Sciences, initial steps were taken to begin a new Arctic social sciences program. The program proposes to address both disciplinary and interdisciplinary research questions. Five projects totaling $155,000 were already under way in FY 89. The Iceland Paleoeconomy project, begun in 1986, continued a series of archeological and ethnographic investigations in Iceland. Analyses on major animal bone and



Summer 1989 construction of GISP 2 camp facility.

artifact collections document more than 800 years of occupation in this climatically marginal region. Impacts of "little ice age" cooling are evident in reduced use of cattle and sheep and an increase in seal hunting.

NSF funded eight projects relating to northern science and engineering education, totaling $302,000 in FY 89. Several programs in the Directorate for Education and Human Resources focus on improving the teaching of science and increasing the interest in careers among Native Americans. Several research projects provided Alaska Natives precollege and undergraduate opportunities to become more involved in training and research experiences.

In its continuing nationwide program to reward excellence in teaching of science and mathematics, the Presidential awards program recognized, in 1989, two science teachers from Bethel and Thorne Bay, Alaska.

Coordination

NSF expenditures for information, planning, and advisory services and for the Arctic Research Commission were $736,000 in FY 89, which served to fund 10 different projects. 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 Polar Research Board, and supports conferences, workshops, and studies to further develop and implement Arctic research planning and policy. A bibliographic project was funded to ensure efficient access and retrieval of Arctic literature.

Publications

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

GISP II, by M. Morrison: Eos, Transactions of the American Geophysical Union, vol. 70, October 31, 1989.

Relation between increasing methane and the presence of ice clouds at the mesopause, by G. E. Thomas et al.: Nature, vol. 338, no. 6215, pp. 490–492, April 6, 1989.

The Ecosystems Center, 1988–1989 Annual Report. Marine Biological Laboratory, Woods Hole, MA.

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 seven services or bureaus, each with administrative and technical offices located in Alaska. In Fiscal Year 1989, a total of $26.6 million was identified in support of these activities.

Minerals Management Service

The Minerals Management Service (MMS) 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 conflicts in leasing and subsequent development and production activities in the OCS/EEZ. Arctic research is conducted under the Technology Assessment and Research (TA&R) Program, and environmental studies are conducted under the Alaska Environmental Studies Program (ESP). These studies are conducted with universities, private companies, the States, and other Federal agencies. An annual summary of Alaska OCS activities is available from MMS's OCS Information Program, M5-642, 381 Elden Street, Herndon, VA 22070.

Technology Assessment and Research Program

The TA&R Program assesses and evaluates technology, equipment, industry procedures, and internal procedures relevant to the post-lease exploration, development, and production of minerals on the OCS/EEZ; applies engineering and research approaches to mitigate hazardous conditions; and transfers resulting information to MMS regulatory personnel. The MMS regulators use this information to make regulatory decisions and to issue permits and review 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

FY 89 FUNDING (thousands)

Offshore Minerals	900
Environmental Studies	7700

has projects in the following areas: engine exhaust emission control; oil-spill containment and cleanup; well control; risk, reliability, and inspection; and structures, pipelines, and ice mechanics. TA&R Program projects that pertain to Arctic and Subarctic OCS/EEZ waters include ice loads on structures and ice-structure interaction, design criteria, structural materials, and oil spill containment and cleanup.

Because research in the Arctic and Subarctic is expensive, most projects are performed jointly with other interested Federal agencies, the Canadian Department of the Environment, the offshore industry, and universities. Projects are accomplished by contract, and a small administrative staff is maintained to manage the program.

The MMS has expanded its oil-spill response technology program since the spill in Prince Edward Sound. This program is striving to attain significant technological improvements or milestones within 5 years. A major area of emphasis is the burning of oil in place on the ocean surface. Researchers have measured high-burn efficiencies on both fresh and weathered crudes of various types under laboratory conditions. The project will be pursued on a larger scale, and an at-sea experiment is planned. The products of combustion, together with the fate of these products, is under investigation. The program is also investigating reformulation of existing dispersants, formulation and tests of oil-treating agents to enhance collection or burning, mechanical recovery systems, and spill detection systems.

Arctic offshore exploration activities have been hampered more by the lack of commercially valuable discoveries than by technology. Sea ice in its various forms is the most severe environnmental risk in the Arctic, creating potential hazards much greater than those for

Horned puffin observed during field studies on the Pribilof Islands.

open-ocean operations. Such hazards include the forces that moving sea ice exerts against offshore structures; icing of structures resulting from freezing spray; gouging of the seafloor, which can interfere with buried pipelines; and interference with locating or cleaning up oil spills. Engineering data for these hazards will become increasingly more important as operations move from exploration to production and as structures are considered for deeper water, especially within the shear zone or in pack ice. The TA&R Program is funding projects in the following areas to develop a better understanding of the engineering constraints for operating in the Arctic:

- The Nipterk spray ice island experiment is a joint program with industry participants and the Canadian Oil and Gas Lands Administration to assess ways to extend the use of exploration spray ice platforms through ice breakup and into the summer.
- A joint industry-Government study is evaluating the influence of crushed ice between a structure and the moving ice floe on the load distribution on the structure.
- Research is being conducted to determine the ice loads and motions likely to be experienced by a cable-moored platform subjected to a moving ice floe or field of rubble ice.
- A joint university-industry-Government consortium is investigating the structure-property relationships that govern the mechanical properties of sea ice.
- A joint industry study is assessing the uncertainties related to the complex modeling of the ice-structure interaction process.

Research sponsored by the TA&R Program is presented in reports, seminars, and workshops. In addition, workshops are conducted on pertinent areas of technology. In 1989, the TA&R Program sponsored its biennial seminar on its research program for the public; the International Well Control Symposium/Workshop, administered by Louisiana State University; and the Offshore Oil Spill Response Technology Seminar. The biennial report, *Technology Assessment and Research Program for Offshore Minerals Operations— 1988 Report*, is available without charge from the TA&R Program, Minerals Management Service, M5-647, 381 Elden Street, Herndon, VA 22070-4817.

Alaska Environmental Studies Program

As the managing agency for the MMS OCS leasing program in Alaska, the Alaska OCS Region has conducted environmental, social, and economic studies to obtain information needed to make sound leasing decisions as well as to monitor human, marine, and coastal environments. In anticipation of shifts in information needs, the program has increased studies to meet post-lease and monitoring information requirements. The detailed rationale for the Alaska OCS Region's program can be found in the Alaska Regional Study Plan (RSP), which is prepared biennially. A portion of the Alaska Environmental Studies Program (ESP) is conducted for the MMS through an interagency agreement with the National Oceanic and Atmospheric Administration 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.

Endangered Species

The bowhead whale, an endangered marine mammal of importance to Native culture, makes extensive annual migrations through six OCS planning areas. Efforts to define the habitat and migrations of endangered whales and the potential effects of offshore operations on these species continued. These studies included on going aerial monitoring of bowhead whales in the Arctic; a comparison of the behavior of the Davis Strait and Bering Sea stock of bowhead whales; and an analysis of the stable isotopes of bowhead whale and zooplankton tissues. Also during FY 89, preparation of an authoritative book on bowhead whales and a study of the

effect of production activities on Arctic whales were ongoing. A study of 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 free-ranging right whale off Nova Scotia. The tag functioned for 22 days and provided 71 locations over a 1523-km path. This is the first successful long-term application of a satellite tag on a free-ranging baleen whale.

Living Resources

The Marine Mammal Protection Act of 1972 established a national policy to protect marine mammal populations and to encourage their preservation to the greatest extent feasible. Seabirds, waterfowl, and commercial fish species also are protected under various international agreements.

MMS studies of non-endangered marine mammals (other than monitoring studies) have focused on the vulnerability of marine mammals to noise disturbance and their use of specific geographic areas where OCS development might occur.

Noise disturbance studies included field-testing of the potential responses of beluga whales to OCS production sounds (in conjunction with similar research on bowhead whales); literature research and ranking of haulout sites used by four species of Bering Sea pinnipeds (including Pacific walrus) according to their potential sensitivity to human disturbance; and a general comparison (based on computer modeling of acoustic transmission) of the sensitivity of all species of marine mammals to various types of noise in Alaskan waters.

Steller sea lions along the Kenai peninsula.

Research scientists tagging a ribbon seal in the Bering Sea.

Habitat utilization of specific marine areas by both marine mammals and avifauna has been studied in the areas of Unimak Pass and Kasegaluk Lagoon. Study in the Unimak Pass included extensive oceanographic sampling to describe major ecological processes affecting seasonal occurrence of regional seabird groups. A study at Kasegaluk Lagoon, begun in FY 89, is focused primarily on the use of this area by beluga whales, spotted seals, and migratory waterfowl. The potential effects of aircraft overflights on black brant and other geese is being studied on the Izembeck National Wildlife Refuge and near Teshekpuk Lake on the Arctic coast.

The potential effects of offshore oil and gas operations on fisheries continue to be a major focus of the ESP. A study of fisheries oceanography in areas of potential oil and gas activities was initiated in 1989 to determine the fisheries resources at risk in the central Chukchi Sea. A study of Arctic fish sensitivities and habitats in the Beaufort Sea continued. A major effort to better define the coastal fisheries and related environment in the southern Being Sea, particularly in the North Aleutian Basin, also continued. This work includes investigations of the life stages and sensitivities of salmon, king crab, and herring, as well as the nearshore physical oceanographic environment that constitutes the habitat of these commercially important species.

Environmental Monitoring

The MMS Alaska OCS Region initiated a program in 1984 to monitor the long-term effects of oil and gas discharge in the Beaufort Sea. The initial 3-year sampling and analysis study was completed in 1986, and a comprehensive report summarizing the results is available. Monitoring is planned to continue every 3 years. Field sampling took place again in 1989. Analyses and the report should be completed in 1990.

Baseline monitoring of the densities and distribution patterns of ringed seals was completed. The final report on 3 years of aerial surveys of ringed seals was issued in FY 88.

Seabirds continue to be monitored through an intra-agency agreement with the U.S. Fish and Wildlife Service. Beginning in FY 89, several Bering Sea and Chukchi Sea seabird colonies are being monitored each summer using standardized monitoring protocols developed by both agencies. Parameters monitored include numbers of birds on preestablished plots, reproductive success, and feeding habits.

A multiyear project to acquire, curate, and analyze marine mammal tissues continues. The study is archiving tissues for future analysis and is sampling baseline levels of chemical contaminants in tissues to monitor any increases that may be 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. An improved three-dimensional numerical computer model for simulation of circulation and of oil-spill trajectories is being tested to predict the movement and dispersal of spilled oil. Another model for predicting the transport of oil into and along a beach was developed recently, and input data from the coastal environment of Alaska are now being assembled.

Efforts to improve knowledge of actual circulation for model-confirmation purposes continued. The final report for the Beaufort Sea Mesoscale Circulation Report was completed. The report reflects 18 months of continuous data from the Beaufort Sea Shelf, an important advance in observations and understanding of that area. Work also began on collection of field data for the Bering Sea Continental Shelf Edge Cross-Shelf Transport Study. Data collection continued on 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 recently in four areas: the Chukchi Sea, the Yukon River delta, the North

Researchers deploying a plankton tow near the Pribilof Islands.

Minerals Management Service scientific committee visiting the Seward, Alaska, sea otter rehabilitation center constructed following the Exxon Valdez *oil spill.*

Aleutian Shelf along the Alaska Peninsula, and the Unimak Pass lease area. An MMS-funded study, in coordination with the NSF Inter-Shelf Transport and Recycling Program (ISHTAR), has just been completed to assist in determining the processes responsible for interannual variability in primary productivity, nutrient recycling, and habitat utilization for Kotzebue Sound and near Hope Basin. The Yukon Delta Ecosystem Processes Study 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. The Unimak Pass Study focused on higher trophic use of the pass area and the processes that sustain this use. At present, Kasegaluk Lagoon on the Chukchi Sea coastline is being modeled for ecosystem processes and primarily marine bird and mammal use.

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; results suggest that coho salmon can detect the presence of dissolved petroleum hydrocarbons at several orders of magnitude below the levels 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. The results indicated that migrating adult pink salmon do not appear to avoid oil-contaminated waters with hydrocarbon concentrations ranging from 1 to 10 ppb, but they appear to become temporarily disoriented. Disorientation did not prevent the test animals' eventual return to the home stream. The final report from this study is now available.

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, dynamics, and superstructure icing were funded through the MMS TA&R Program. Recent 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. Because 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 sociocultural 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 the communities of the North Slope Borough, described the sociocultural and socioeconomic characteristics of Point Lay and Point Hope, and provided important data on the extent of subsistence activities in Barrow and Wainwright. A study of the Bering Sea commercial fisheries will be completed in 1990 that will describe the importance of the fishing industry to several local communities in western Alaska. A similar study of the Gulf of Alaska was initiated during 1989 and will build on the information acquired for the Bering Sea study.

Environmental Information Management

During FY 88 and FY 89 the ESP included approximately 40 studies in nine subject areas cover ing the three Alaska leasing regions. The size and scope of this program call for 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 and referenced in environmental impact statements. An Information Update Report was published for the Chukchi Sea in June 1987 and one for the Beaufort Sea in 1988. In November 1987 an Arctic Information Transfer Meeting in Anchorage was attended by more than 150 scientists, administrators, agency personnel, and other interested parties. Another ITM was scheduled for late January 1990. In 1988 MMS sponsored workshops on the technical objectives for fisheries oceanography in the Arctic and on mercury in the marine environment. In 1989 MMS sponsored a workshop on synthesis of environmental information on causeways in the nearshore Beaufort Sea and one to assist in the design of baseline monitoring studies in support of the MMS mining program in Norton Sound.

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. During 1987–89, OCSEAP published 17 volumes containing 58 final reports. MMS has also funded the preparation of two books: *The Gulf of Alaska: Physical Environment and Biological Resources* and *The Eastern Bering Sea Shelf: Oceanography and Resources.*

Fish and Wildlife Service

FY 89 FUNDING (thousands)

Marine Mammals	1380
Migratory Birds	1850
Fisheries Research	375
Cooperative Research	350
Terrestrial Ecology	1075

Most Arctic research conducted by the U.S. Fish and Wildlife Service (FWS) is performed by its Alaska Fish and Wildlife Research Center in Anchorage and by its Cooperative Fishery and Wildlife Research Units at the University of Alaska–Fairbanks. These organizations are part of and supported by the scientific resources of 12 Service research centers and over 30 cooperative research units nationwide. The primary focus of their research is on animal species for which the Federal Government, through the Fish and Wildlife Service, has management responsibility under law or treaty. These species include migratory birds, anadromous fish, marine mammals, and all fish and wildlife species inhabiting components of the National Wildlife Refuge System. The primary goal of the research is to gain a better understanding of fish and wildlife ecology in the Arctic, enabling the Service to make informed decisions on the management of living resources and to prevent threats and conflicts as other resources of the Arctic are developed and utilized. A secondary goal is to improve methods available to conservation biologists by applying innovative technologies to the difficult problems of studying free-living animals in the Arctic.

Migratory Birds

The populations and diversity of Alaska's migratory bird fauna are great. More than 40 million seabirds of 30 species use pelagic and nearshore areas of Alaska year-round. Millions of migratory shorebirds breed in northern and western Alaska. Its habitats support more than 70,000 swans, 1 million geese, and 12 million ducks that winter in all four North American flyways. The focus of Service studies has been on the ecology and population dynamics of waterfowl, seabirds, and shorebirds.

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 pothole and aspen parkland regions of the United States and Canada have higher densities of breeding waterfowl, but the Yukon Flats has a higher sustained rate of production, presumably because it is less susceptible to periodic drought. However, the ecology of Arctic wetlands, as exemplified by the Yukon Flats, is poorly understood. Evidence shows that occasional reduction of vegetation by fire is necessary to maintain the productivity of these wetlands. Long-term studies investigating the role of fire in wetland ecology have continued on the Yukon Flats National Wildlife Refuge. A 900-acre experimental burn conducted in FY 89 was

too small and not intense enough to have the desired effects.

In contrast to most other species of waterfowl, continental populations of many species of geese have been stable or have increased in recent years. Populations of cackling Canada geese, dusky Canada geese, emperor geese, white-fronted geese, and black brant that nest in Alaska have declined seriously, however. Continuing studies examine the roles of habitat features, weather, predation, disturbance, and harvest in the numbers and breeding success of nesting geese. Arctic foxes have been an important cause of nesting mortality in some years. Results indicate that the severity of losses to fox predation is related to population cycles in microtine rodents, with relatively low predation on waterfowl when tundra vole are abundant. Several species of geese are being studied to predict the effects of development in traditional staging areas. Among game ducks, pintails have significant breeding populations in Alaska. New work on pintails examines breeding biology in an attempt to explain the dramatic declines in populations that have occurred across the continent in recent years. Hen pintails nesting on the Yukon Flats National Wildlife Refuge were equipped with radio transmitters to assess their survival, nesting success, and survival of broods accompanying the hens after leaving nests. In addition, aerial surveys were conducted in other areas to locate breeding pintails. Staff of the Northern Prairie Wildlife Research Center field station in Dixon, California, will attempt to locate the radiomarked hens on their wintering grounds in the Central Valley of California.

Reproduction in 1989 was extremely poor, with loss of hens, eggs, and broods to predators; poor weather also contributed to losses. New studies initiated by the Northern Prairie Wildlife Research Center in Jamestown, North Dakota, are investigating the biology of tundra swans on the breeding grounds on Alaska's Colville Delta, during migration in North Dakota, and on wintering grounds in Maryland.

Continuing studies of seabirds and their prey base are examining potential competition between Alaska's 100 million seabirds of 50 species and its expanding commercial and recreational fisheries. A pattern of considerable geographic variation in prey availability and seabird foraging patterns indicates the need for regionalized management. Detailed studies are investigating feeding by tufted puffins to determine their potential competition with commercial fisheries for walleye pollock. Research to date has shown that the puffins select prey that are too small for commercial take and the fishery removes adults that may prey on smaller

Long-term satellite telemetry studies.

fish; consequently the birds and the fishery seem to have a beneficial or at least neutral relationship.

Data analysis was completed on studies of murres and black-legged kittiwakes at Cape Thompson. These studies were part of a long-term effort to relate the unstable populations of these birds with environmental factors, including the highly unpredictable Arctic weather. Black-legged kittiwakes in Alaska have one-fourth to one-third the overall reproductive success of kittiwakes in Britain. Estimated mortality in Alaska colonies was much lower than expected based on studies conducted elsewhere, but it is doubtful that even low mortality can compensate for chronic reproductive failure. Factors suspected, but not implicated, in poor breeding success include collapse of the food supply and predation on eggs and nestlings by gulls.

Long-term investigations of shorebirds seek to develop basic information on their population dynamics that will provide baseline data for use in assessing impacts of petroleum pollution. During 1989, information developed on black turnstones on the Yukon-Kuskokwim Delta was used to assess impacts from the Exxon *Valdez* spill in Prince William Sound. Some Alaskan shorebird populations are shared with the Soviet Union, and joint U.S.-U.S.S.R. studies have been proposed for 1990. Continuing investigations of the bristle-thighed curlew, a species with a total population of only about 7000, extended to all parts of its far-flung range. It breeds on the Seward Peninsula, stages on the Yukon-Kuskokwim Delta, and winters on Laysan Island. Studies on the breeding range have attempted to define habitat needs and reproductive success so that lands important to the species can be more accurately identified. Similar investigations seek to delineate important habitat features and conditions for staging birds.

Marine Mammals

Research on marine mammals seeks to achieve a better understanding of their ecology to address conflicts and threats involving energy development and production, commercial and sport fisheries, and regulated and subsistence harvests. Since populations of some marine mammals, most importantly walrus and polar bear, are shared with the Soviet Union, marine mammal research is an important area of cooperation between the two nations.

Research on polar bear reproduction continues, with most effort directed toward discovering denning sites and relating site characteristics to reproductive success. Research to date indicates that dens on land are significantly more successful than those on drifting ice and that barrier islands off the Arctic National Wildlife Refuge are particularly important sites for polar bear reproduction. The effective size of polar bear breeding populations is an important consideration in assessing their ability to withstand losses. To determine the effective size of breeding populations, researchers must learn whether subpopulations are reproductively isolated from one another or whether they interbreed over wide areas of the Arctic. Satellite radiotelemetry is used to study movements, and mitochondrial DNA analysis and stable carbon/nitrogen ratios are used to assess genetic continuity among polar bears from different parts of the geographic range. Data indicate that individual bears have less stable home ranges than previously thought. Tissue analysis for indicators of relationship is still under development, with efforts so far devoted to analyzing and controlling for sources of variation among individuals, localities, and seasons. Long-term monitoring of radioed cohorts seeks the answers to outstanding questions regarding the balance between recruitment and mortality. Studies of bear distribution with respect to ice movement and ringed seal abundance investigate the influence of these factors on polar bear ecology.

Continued increases in the sea otter population in Alaska have resulted in increasing conflicts with man over shellfish resources.

Pacific walrus populations are believed to be declining, influenced perhaps by disturbance from hydrocarbon exploration and development and from commercial fisheries. Assessment of population status relies on surveys of hauled-out animals, but estimates derived from these surveys are suspect because of their failure to account for walrus in the water. The Service, in cooperation with biologists from the Soviet Union, is attempting to improve the accuracy of survey data in several ways. Survey design has been investigated to develop more appropriate censuses, high-resolution video imagery is being used to improve the accuracy of counts, and conventional and satellite telemetry is used to investigate the behavior of walrus, particularly the portions of time spent in and out of the water. Problems with transmitter reliability have impeded behavioral studies. Planned cooperative studies with scientists from the Soviet Union were scaled back in the face of fund shortfalls and unfavorable ice conditions. The full range of activities is expected to resume in FY 90.

Research on sea otters continues, with emphasis on recovery of populations in the Aleutian Archipelago and southeast Alaska. Conflicts are emerging between burgeoning sea otter populations and commercial fisheries, including a growing mariculture industry directly affected by sea otters. As part of the ongoing studies, sea otters were equipped with radio transmitters in the vicinity of Kodiak Island and in eastern Prince William Sound. Tagged animals in Prince William Sound were not directly affected by the Exxon *Valdez* oil spill, but having operations in the area permitted Alaska Fish and Wildlife Research Center staff to quickly begin monitoring

Techniques have been developed to accurately estimate variations in the patterns of movement of walruses and ice.

sea otters in affected areas. Radio transmitters were implanted in oiled sea otters that had been rescued, rehabilitated in treatment centers, and released. The objective of this research was to determine the efficacy of different types of rehabilitation and the overall effectiveness of rehabilitation in improving the chances for survival. Animals in areas affected by spilled oil were also equipped with radio transmitters to determine the long-term effects on use of habitats, survival, and reproduction.

Wildlife Ecology

The Fish and Wildlife Service has shared responsibility with the State of Alaska in managing resident wildlife populations occurring on Service lands. Research in this area focuses primarily on large mammals that require extensive areas of undisturbed habitat and, consequently, are highly sensitive to disturbance from a variety of human activities. Also, owing to the isolation of much of their habitat, the great distances that may be covered by individuals, and the severity of the climate, conventional means of conducting ecological studies are inadequate. This problem has required the development and application of technological aids, including integrated satellite telemetry, satellite imagery, and geographic information systems. This new technology has permitted biologists to begin in-depth studies of habitat conditions and habitat use by wildlife. For example, timing of snow melt and emergence of forage plants can be determined remotely and correlated with the phenology of wildlife movements.

The proposed opening of the Arctic National Wildlife Refuge to petroleum development has raised concerns about the impact on wildlife, particularly caribou. The area is used by the Porcupine caribou herd, a migratory herd that occupies Canada during part of the year and that is distinct from the less migratory Central Arctic herd that is found primarily to its west. The focus of the study is the "1002 Area," the portion of the refuge proposed for drilling. A major increase in congressional appropriations related to evaluation of potential impacts of oil and gas development was received in FY 88 continued in FY 89. Objectives include determining habitat use by the Porcupine herd in relation to migrations and events in the annual cycle and the effects of existing oil production on the Central Arctic herd. Because of a late snow melt, only 22 percent of pregnant females in the Porcupine herd calved in the 1002 Area, but survival was better there than on other areas, and by the end of June all cows and surviving calves had moved into the 1002

Calf production, distribution, and movements of the Central Arctic caribou herd monitored by FWS.

Area. Overall, productivity in 1989 was lower than the long-term mean. Cows of the Central Arctic herd had lower productivity in areas with oil production than in adjacent areas, but the causes for the difference are unknown. Investigations with similar objectives are under way on musk ox; preliminary results have indicated that satellite telemetry is far superior to aerial sighting to determine the location of musk ox herds.

Fishery Research

Emphasis is on anadromous fish, several species of salmon, and Arctic char inhabiting streams on Service land that may be affected by petroleum development. Chum and Chinook salmon harvested in the lower Yukon River are the result of stock originating in both U.S. and Canadian portions of the river system. To negotiate a treaty allocating portions of the catch to each country, it is necessary to assess the contributions of spawning grounds in each country to the harvest. Studies on genetic characterization of stock from different breeding areas, on timing and composition of runs, and on composition of the harvest are nearing successful completion. Research on coho salmon occupying the Kodiak National Wildlife Refuge initiated in FY 89

examines their ability to maintain populations in the face of expanding commercial harvest. An activity completed in FY 89 was the testing, validation, and improvement of the Habitat Suitability Index model for the Arctic grayling. These models provide habitat information that is useful for impact assessment and habitat management. Each model contains a number of variables, some or all of which may be affected by disturbances resulting from development. Research information is used to evaluate and validate the variables in the model and, in this instance, to suggest additional variables to make the model more useful.

New Technologies

Difficulties encountered in conducting research on Arctic fish and wildlife can often be overcome through developing and applying new technological tools. Such tools include remote sensing and satellite telemetry, both now routinely used in studies of wildlife and their habitats. Studies of mitochondrial DNA and other molecular techniques are used to develop information on geographic variation within animal populations, relatedness of subpopulations, geographic affinities of migrants, genetic variability in individuals, and the integrity of population units. All of the attributes measured by these techniques are of interest to fish and wildlife managers in one or more common situations related to conservation. The Alaska Fish and Wildlife Research Center has extended its capabilities by developing specialized laboratory facilities, purchasing equipment, and recruiting staff devoted to molecular applications in conservation biology. New investigations are in the planning process.

Cooperative Research

The Service is involved in a national program of cooperative fish and wildlife research that also includes State fish and wildlife agencies, land-grant universities, and, in some instances, the Wildlife Management Institute. The cooperative units are organized within the Service as a single research center headquartered in Washington, D.C., but units have traditionally had a great deal of latitude in their ability to respond to local issues and needs. The major goal of the cooperative research program is to provide graduate-level training for fish and wildlife biologists. This training is usually provided by joint participation in research projects by faculty and students. The Service funds salaries and some administrative costs, but project funding is usually obtained elsewhere on a project-by-project basis. Research funding for the Alaska units comes from the Alaska Department of Fish and Game; the Canadian Wildlife Service; other bureaus of the Department of the Interior, including the U.S. Geological Survey, the National Park Service, and the Bureau of Land Management; and other Federal agencies, including the National Science Foundation, the U.S. Forest Service, and the Environmental Protection Agency.

The Alaska Wildlife Unit has 12 research projects under way. One area of emphasis is to develop information on the ecological requirements of caribou. The Delta caribou herd has grown from about 2500 animals in 1975 to the current level of more than 8000 and has significantly changed its seasonal distribution pattern. Findings indicate that lichen depletion on the traditional winter range may be influencing the expansion of the winter range of the Delta herd. Other facts, including snow patterns, which can aid predators in detecting and killing caribou, proximity to calving grounds, and historical use patterns may override the availability of forage in determining movements in late winter. Studies of movement patterns of the Porcupine caribou herd indicate that weather events may play only a minor role in determining distribution, compared with factors such as rutting activity, forage availability, and harassment by predators. Changes in habitat use patterns associated with insect harassment during the summer mosquito season need additional clarification. Researchers are now investigating these changes in the Kuparuk Oil Field area.

The unit is currently carrying out two musk ox investigations. One is yielding information on the foraging relationships and activity of musk ox in Perry Land, Greenland, and the other is investigating habitat characteristics in potential release areas of the Arctic National Wildlife Refuge. Information from the Greenland study will be useful in understanding habitat requirements and will provide insights on habitat sites suitable for released animals. Depth and hardness of snow cover are being measured because these are important factors for feeding musk ox.

The Alaska Fisheries Unit was involved in 13 research projects in FY 89. Studies of seasonal movements of northern pike in Minto Flat, Alaska, indicated that the pike move from the flats into streams such as the Chatinika River for overwinter habitat. The concentration of fish in these small streams makes them highly vulnerable to harvest, and findings indicate that allowing winter fishing in the area could result in severe overharvest of the population. Minto Flats is an important wetland area supporting both fish and waterfowl production. The basis for its high

productivity is poorly understood and crucial to rational habitat protection. The unit is undertaking limnological investigations to better understand energy flow through this important habitat.

Extensive work on the behavioral ecology of Arctic grayling in small Alaskan streams is providing precise information on the distribution of these fish. The findings will permit the development of predictive models of use to managers. Studies of the population dynamics of Arctic grayling at Ugashik Lakes, Alaska, are providing some new insights into the ecology of the Bristol Bay area, where the largest Arctic grayling in Alaska are produced. The growing sport fishery in the area may be cause for alarm, owing to the apparently low replenishment of grayling.

Additional details (including copies of technical publications) related to the migratory bird, marine mammal, wildlife ecology, and fisheries research are available from the Alaska Fish and Wildlife Research Center, U.S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99509. For further information on the Alaska National Wildlife Refuge studies, contact the 1002 Study Coordinator, Region 7, see address above. Additional information on cooperative research can be obtained from the Director, Cooperative Fish and Wildlife Units Research Center, Region 8, U.S. Fish and Wildlife Service, Washington, DC 20240.

National Park Service

The National Park Service is mandated to preserve undisturbed ecosystems and cultural resources while providing opportunities for a variety of recreational activities and to ensure protection of subsistence ways of life for local rural residents. To accomplish this mission requires information that must come through research.

General Management Plans are completed for each of the five areas the National Park Service manages in Arctic Alaska. Resource Management Plans, which guide the identification of research needs, are being rewritten in accordance with new guidelines. The Alaska Region has made a commitment to develop and use a Geographic Information System (GIS) and is allocating funding and staffing for that purpose. The GIS was operational only in the Alaska regional office during the year, but eventually field units will have onsite systems.

FY 89 FUNDING (thousands)

Cultural Resources	
Bering Land Bridge	90
Cape Krusenstern	65
Denali	50
Gates of the Arctic	55
Katmai	20
Klondike	20
Northwest Areas	80
Wrangell-Saint Elias	15
Natural Resources	
Noatak	145
Gates of the Arctic	256
Bering Land Bridge	40
Denali	376

National Park Service areas are available for compatible forms of research by independently funded scientists, offering sites and resources protected from unnatural disturbances. Independent research is encouraged, and area staffs can at times provide limited logistical support. Each natural area or natural area cluster has one or two resource management specialists on site who are familiar with research opportunities and problems.

Natural Resource Research

The Alaska Region has a small natural resources research staff, and most projects are carried out cooperatively with other Federal agencies, State agencies, and universities. Of special importance are studies and surveys of natural resources that are used consumptively for recreation, such as sport hunting (in preserves) and fishing, or for subsistence. Basic inventories of natural resources are emphasized to provide baselines from which to monitor changes such as those caused by use or by influences such as global climate warming. The natural resources scientific program for the Alaska Region is administered by the Regional Director in Anchorage through the Division of Natural Resources.

Highlights of the most important natural resource research projects conducted in Arctic Alaska by the National Park Service during FY 89 are discussed in the following paragraphs. Of major scientific interest are interrelated studies of wolves, brown bears, and caribou along with other prey species including Dall sheep and moose at Denali National Park and Preserve. These studies involve radio tracking and are scheduled to continue for

another 4 years. They are already producing valuable basic information about the interactions of those predator-prey species in this mostly protected area. The wolf study is being carried out with the U.S. Fish and Wildlife Service (FWS). Brown bear and wolf studies are also in progress in Noatak National Preserve and Kobuk Valley National Park, respectively, in cooperation with the Alaska Department of Fish and Game (ADF&G). Part of the impetus behind the brown bear study is to determine the possibility of impacts from the developing Red Dog Mine and its road to the sea, which passes through Cape Krusenstern National Monument.

Field work for a baseline limnological study of isolated Surprise Lake in the Aniakchak Caldera, Aniakchak National Monument and Preserve, was completed by staff of the Cooperative Park Studies Unit (CPSU) at Oregon State University. At Gates of the Arctic National Park and Preserve, studies of wolves (with ADF&G), lake fish (with FWS), furbearers, and all-terrain vehicle use were carried out. Baseline ecological data gathering continued at Bering Land Bridge National Preserve along with reindeer studies and a cooperative study of musk ox with ADF&G. Initial surveys for a water resources baseline study in Noatak were conducted.

Limited air quality monitoring was carried out in several units, with major monitoring at Denali, a Class I area. An important brown bear study in the Brooks range by ADF&G was supported, as was a musk ox study at Gates of the Arctic and a Dall sheep study at Denali conducted by University of Alaska students through FWS's Cooperative Wildlife Research Unit. Two raptor studies at Denali were conducted, one by a University of Alaska student and one in cooperation with FWS. A study of wildlife and road relationships was continued with cooperation from bus drivers at Denali. A visitor study was completed at Denali, conducted through the CPSU at Idaho State University. A major survey of vegetation was continued at Gates of the Arctic and Noatak as part of fire management studies.

Cultural resource site at Mechigmen.

During the year, an internal inventory and monitoring workshop was held at Chena Hot Springs near Fairbanks through the Institute of Northern Forestry, the U.S. Forest Service, and the University of Alaska. Speakers came from Alaska and several other States.

The prospect of cooperative research on paired Biosphere Reserves in the United States and the Soviet Union has been enhanced by recent exchange visits. Two Soviet scientists, Dr. Yuri Chernov and Dr. Nadya Matveyeva (of the Institute of Evolution, Ecology, and Morphology of Animals, U.S.S.R. Academy of Sciences, Moscow; and the Komarov Botanical Institute, U.S.S.R. Academy of Sciences, Leningrad, respectively) visited Alaska in July 1989. A major objective of the visit was to compare Noatak National Preserve with potential sites in the Soviet Far East and Siberia and evaluate potential for long-term collaboration in taiga and tundra research between the United States and the Soviet Union.

A group of U.S. National Park Service and Soviet specialists visited the Chukotka Peninsula in the Soviet Union (September 7-18, 1989) and

Visiting Soviet scientists with Clemson University scientist at Barrow, Alaska.

the Seward Peninsula and other regions in Alaska (September 18–25, 1989). The group became acquainted with the natural and cultural richness of the regions and acquired a great deal of scientific and practical knowledge. They also consulted with local officials and citizens regarding the development of an official proposal for an international park. A report was distributed during the 12th session of the joint Soviet-American Commission Collaborating on Environmental Protection, in January 1990 in Washington, D.C.

First cousins Tommy Autoghamy, Savoonga, Alaska, and Soviet archeologist and ethnographer, Tasyan Tein, who met for the first time on the International Park expedition.

Cultural Resource Research

The Cultural Resources Division of the Alaska Region continued an active Arctic research program including several ongoing and new studies in history, archeology, and cultural anthropology.

A 3-year ethnographic baseline study was initiated this year in the region around the three Northwest Alaska park areas (Cape Krusenstern National Monument, Kobuk Valley National Park, and Noatak National Preserve). This project of the University of Alaska–Fairbanks is a comprehensive study of resource use including traditional land use, place names, and ethnohistory.

Archeological sites dating from Denbigh times (4200 years) to early historic times located at Cape Espenberg and along the Bering Strait coast were tested during the second year of the Bering Land Bridge Data Recovery project. A considerable variety of artifacts was recovered, including lithic, ivory, antler, wood, and bone objects; trade beads; iron; and ceramics.

A multiyear, interdisciplinary Cultural Resources Inventory for Gates of the Arctic National Park and Preserve has culminated in the publication of a two-volume historic resources study entitled *Gaunt Beauty ... Tenuous Life* by William E. Brown, National Park Service. The final report of the Gates of the Arctic Archeological Site Inventory has also been prepared and is ready for publication. Other completed projects with manuscripts in press are the Cape Krusenstern Cultural Resources Inventory, an archeological overview and assessment for Denali National Park and Preserve, and an overall history of mining in Alaska with special attention to mining in Alaska National Parks.

The Archeological Assistance Unit in the Alaska Region conducted an interagency research project with the U.S. Navy and the U.S. Fish and Wildlife Service in the Aleutian Islands in September 1989. Interdisciplinary teams of National Park Service and Navy divers located and documented submerged shipwrecks in Kiska Harbor associated with the Japanese occupation of Kiska Island during World War II. The project located 10 submerged wrecks, including a Japanese RO 65 submarine, two Japanese subchasers, and an airplane that may be an

Cultural resource sites on Yttigran Island, U.S.S.R.

American B-17. A second season is planned for July 1990.

The Archeological Assistance Unit has also completed the collection of the first 5000 bibliographic records for the Alaska version of the National Archeological Data Base (NADB). The data base is now available for use on a microcomputer at the Alaska Regional Office of the National Park Service and will be available shortly at the Alaska State Historic Preservation Office.

The Alaska Region initiated testing of the prototype Archeological Resources Inventory (ARI) component of the Cultural Sites Inventory (CSI), a computerized data base system for registering park archeological resources. Archeological data from four Alaska park areas (Bering Land Bridge and Yukon-Charley National Preserves, Cape Krusenstern National Monument, and Gates of the Arctic National Park and Preserve) were used in this pilot study. The CSI will have integral links to other data bases such as specific research programs, Geographic Information Systems (GISs), and National Register programs.

Research projects in history currently under way include an historic resources study of Wrangell-Saint Elias National Park and Preserve and administrative histories of Katmai National Park and Preserve and Klondike Gold Rush National Historic Park.

Under the U.S.-U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection (1972), a team of National Park Service and Soviet specialists conducted a field study and developed a proposal to establish an international park in Beringia with units on both sides of the Bering Strait. At a meeting in Moscow in July 1989, additional exchange projects were planned focusing on the Russian-American heritage of Alaska. Projects discussed include loan of exhibit materials from the Soviet Union to Sitka National Historic Park, the joint preparation of a bilingual publication on the life of Bishop Innocent (Veniaminov), planning, interpretation, and collections management.

Bureau of Land Management

The Bureau of Land Management (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. BLM has no marine or offshore responsibilities.

BLM'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 develops plans for managing the public lands and their resources. These plans include resource management plans (RMPs), which establish management direction for large areas, and activity plans, which address how an RMP will be accomplished in specific areas by activity.

The Proposed Resource Management Plan and Final Environmental Impact Statement for the Utility Corridor was signed by the State Director in FY 89. This RMP, initiated in FY 86, covers more than 15 million acres of BLM-managed land in northern Alaska along the Alaska Oil Pipeline between the Yukon River and the crest of the Brooks Range, an area of critical importance for transporting people, materials, petroleum, and perhaps, in the future, other mineral resources. This plan addresses multiple-use issues such as

FY 89 FUNDING (thousands)

National Wildlife Refuge	150
Habitat-Arctic District	230
Habitat-NW District	200
Pipeline Studies	175
Fire Control	350
National Petro Reserve/Alaska	200
Minerals/Mining	200

During the summer of 1989, BLM biologists conducted an intensive fisheries, minerals, and recreation inventory of public lands in the Utility Corridor.

land disposal, development nodes, mining, recreation, wildlife and fisheries, and access.

As a result of this planning effort, and to prepare for more detailed activity planning, BLM conducted an integrated resource data collection effort within the Utility Corridor during FY 89. Data were collected on 18 streams covering approximately 230 miles for fisheries habitat, recreation potential, riparian resources, and water quality. Wildlife efforts included identifying 3 sheep salt licks and 21 raptor nesting sites, inventorying 6300 acres for cultural resources, and identifying 14 prehistoric and 18 historic sites. Sixty sites were identified for potential development for recreation purposes, with preliminary surveys being made on 5 campground locations, 30 wayside/trailhead locations, and 8 picnic sites. Approximately 150 miles of existing and potential off-road vehicle trails and 80 miles of hiking trails were inventoried, along with 75 sites for potential mineral collecting. In addition, 3000 acres of commercial timber were mapped.

The data will be analyzed and used to develop a recreation activity management plan for the Utility Corridor in FY 90 and in other activity plans in subsequent years. This area is accessible via the Dalton Highway, which runs the full length of the Utility Corridor, and its southern portion is within a few hours' drive of Fairbanks. The demand for recreational use is expected to increase dramatically in the future.

In association with developing the Utility Corridor RMP, BLM conducted an interdisciplinary study required under Section 1001 of the Alaska National Interest Lands Conservation Act (ANILCA) for lands in the Central Arctic Management Area (CAMA), located north of the Brooks Range approximately 400 miles north of Fairbanks. The resulting document, referred to as the CAMA Report, was submitted to Congress in December 1988.

A 5-year research program seeks to identify the impacts of increasing recreation use on nesting bald eagles. Birds are monitored by radio signal.

Renewable Resources

BLM's renewable resources program in Arctic Alaska includes several ongoing wildlife and fisheries habitat management programs. During FY 89, work continued on implementing the Norton Sound Habitat Management Plan, including inventorying anadromous fisheries habitats, measuring levels of subsistence usage, and identifying habitat enhancement opportunities. BLM has started initial project designs for several riparian enhancement and restoration projects in cooperation with the Alaska Departments of Fish and Game and Transportation. BLM also continued to monitor efforts related to habitat management plans covering two Areas of Critical Environmental Concern (ACEC).

BLM is particularly concerned with the protection and continued recovery of the Arctic peregrine falcon. Monitoring studies continued along the Sagavanirktok and Colville rivers in conjunction with the U.S. Fish and Wildlife Service and the recovery plan. Surveys continue to indicate that the Arctic peregrine population is increasing.

The Bureau, with financial assistance from the U.S. Fish and Wildlife Service and the Minerals Management Service, continued the research effort in the Teshekpuk Lake area. FY 89 was the third year of this 5-year project, which is conducted through an interagency agreement with Region 8 of the U.S. Fish and Wildlife Service. This effort focuses on black brant geese, the energy requirements of this sensitive species, and how development activities might interfere with these requirements. This region is potentially important as a transportation corridor for North Slope oil and gas development and lies in the National Petroleum Resource-Alaska (NPRA). The information resulting from this study will be used by the Bureau to make management

decisions in the Teshekpuk Lake area and other areas within the Arctic where development activities may affect waterfowl habitats.

Several other inventory and monitoring projects were conducted in cooperation with other agencies, including the Alaska Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Park Service. Among the species monitored were reindeer, caribou, moose, Dall sheep, grizzly bear, and anadromous fish. Alaska's Board of Game approved reintroduction of musk oxen into the central Arctic area by BLM. This transplant of musk oxen, taken from Nunivak Island, will occur in FY 90 or FY 91.

Oil and Gas Leases

BLM also monitors established oil and gas leases in the NPRA. Although no lease sales have been held during the last 4 years because of the oil price decline and lack of industry interest, BLM continues to monitor oil activities in operation and those that have been "mothballed" pending a change in economic conditions. Geophysical activities also continue to be monitored to assure protection of other resource values. Under its oil and gas program, BLM continues to investigate the potential for surface and subsurface land exchanges with the State of Alaska and Native corporations 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.

BLM, upon completion of the environmental impact statement for the Trans-Alaska Gas System (TAGS) pipeline and related facilities, issued a grant for right-of-way. This clears the way for future construction of a gas line that will export North Slope gas to the Pacific Rim countries.

Monitoring nesting bald eagles, Paxson River, Alaska.

Gold Mining

Gold mining continues to be an active program in northern Alaska. Under the authority of the Federal Land Policy and Management Act and in accordance with the 1872 Mining Law, BLM monitors gold mining activities and surface mining activities associated with the development of locatable mineral resources. BLM also monitors the extraction of gravel and other kinds of mineral materials important in Arctic construction and oil and gas exploration and development activities.

Trails

Another ongoing program is the identification and on-the-ground staking of easements and overland trails. This effort was begun in 1984 under the Alaska National Interest Lands Conservation Act, Section 17(b). Trail locations are determined in conjunction with the Bureau of Indian Affairs, the North Slope Borough, concerned Native groups, and local residents. To date, more than 400 miles of trails and easements have been marked.

Resource Apprenticeship

The Resource Apprenticeship Program for Students (RAPS) combines the efforts of Federal and State land-managing agencies, the Alaska school system (both secondary and university), and private industry to provide worthwhile employment and education opportunities for rural Alaskan students seeking careers in natural resource management.

RAPS links a potential labor pool with a demonstrated employment need. By participating in the program students get on-the-job training in natural resource management. They can also qualify for tuition waivers in natural resource management programs at the University of Alaska-Fairbanks to continue their education after high school.

Alaska Natives are among the largest private landowners in the world. The Alaska Native Claims Settlement Act (ANCSA), passed in 1971, provided Alaskan Natives with a land settlement of 44 million acres. As a result, they now manage a diverse ecosystem.

In 1980, one in four Natives dropped out of high school. Only 3.5 percent completed college. Young Alaskan Natives, many coming from

RAPS student Kourak Nakah of Kotzebue helps a fisheries biologist stock fish.

remote areas, find competing for entry-level positions very difficult, and suicide and alcoholism rates among youth in rural communities are high.

The RAPS program was piloted by the BLM's Arctic District in 1987 to provide natural resource management exposure to Native high school students. A high school junior from Barrow and another from Point Hope helped archaeologists excavate historic sites, worked with recreation specialists on river patrols, and helped biologists conduct wildlife studies. BLM and the Bureau of Indian Affairs paid the costs.

BLM expanded the program in 1988 to include 10 students placed in three BLM districts plus two students in the National Park Service (NPS) and two in the Fish and Wildlife Service (FWS).

In 1989, 30 students were involved in RAPS. Participating organizations went from three in 1988 to seven in 1989. Continued expansion of agencies and students is foreseen for 1990 with the addition of the Universities of Alaska at Fairbanks and Anchorage, Northwest Alaska Native Association, and Sealaska Regional Corporation. Students live with host families near their summer jobs, which exposes them to the cultural differences of larger cities. The host families receive a small reimbursement for food and transportation costs and are an extremely important part of the program.

At the end of the summer, students are required to write a paper on their experiences. Follow-up with the student's parents and school continues in the fall and winter, and students are encouraged to return to the agency for additional experience through their college years. Every effort is made to place them in a job following graduation, either in a sponsoring State or Federal agency or in a private agency or Native corporation.

The program has been widely publicized and well accepted. More students apply than can be accommodated, and additional agencies want to join the program.

The RAPS program operates under the philosophy that it is better to offer a quality experience to a small number of students than to offer "make work" projects to a larger number of students.

Migrant Education funding in the amount of $22,000 has been obtained for 1990 through a grant from the Alaska Department of Education. A Request for Proposal is being prepared for submission to the Private Industry Council in Fairbanks to fund students under the Job Training Partnership Act.

BLM has obtained a Volunteers In Service to America (VISTA) Action Grant, the first VISTA program approved for a Federal agency in Alaska and a first for BLM nationwide, to support the RAPS program.

In March 1990, BLM's former Arctic District Manager Tom Dean and RAPS Program Coordinator Robert Jones were awarded the Secretary of Interior's Stewardship Award for their extensive efforts in launching the RAPS program. RAPS will be expanded to BLM nationwide in 1991.

BLM will continued to serve as the lead coordinating agency in the interagency effort. RAPS has been endorsed by the Alaska Department of Education and the Alaska Association of School Administrators.

Geological Survey

FY 89 FUNDING (thousands)

Energy and Minerals	2,534
Natural Hazards	1,209
Ice and Climate	350
Hydrology	310
Glaciology and Quaternary	200
Marine Geology	1,285
Magnetosphere	25
Mapping	1,025

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, Quaternary geology, deep continental studies, the magnetosphere, and mapping. A number of these activities are highlighted or summarized in two recent publications: *1989 Annual Report on Alaska's Mineral Resources* and the currently available report on *Geologic Studies in Alaska.*

International cooperative activities highlighted the U.S. Geological Survey's Arctic activities in 1989.

In January, USGS organized a workshop at the meeting of the American Association for the Advancement of Science in San Francisco. The workshop theme was "The Arctic: A Key to World Climate and Resources." Results of the workshop emphasized the importance of understanding the history (past, present, and future) of Arctic climate and the need for these investigations to hold top priority. Recommended for Arctic programs were more paleoenvironmental-paleontological investigations, an international program in Arctic drilling, improved and expanded weather and climate monitoring, and increased satellite coverage of the polar regions.

Representatives from USGS and the Geological Survey of Canada (GSC) met in January and identified five Arctic topics of mutual concern that could benefit from joint investigations:

1. Arctic basin and margin geophysics,
2. Terrestrial borehole drilling in the Yukon Flats and Old Crow Basins,
3. Arctic coastal processes,
4. Beaufort Sea post-Oligocene biostratigraphy, and
5. Brooks Range mapping across the international border.

Mineral resource lecture to Glaciological Institute participants, Lemon Glacier, Juneau Icefield, July 1987.

In November and December, workshops were held on the first two topics. The geophysics workshop uncovered a strong desire on the part of its participants to commence a regional aerogravity and aeromagnetic survey of the western Arctic Ocean and strong interest to conduct an onshore-offshore seismic experiment. With respect to borehole drilling, a 3-year program was outlined that would visit and evaluate potential drill sites in Canada and Alaska during the first year (1990), drill in the Yukon Flats, Alaska, area during the second year (1991), and drill in the Old Crow Basin, Canada, area during the third (1992). The goals of the project are to collect, by coring, a long, continuous terrestrial climatic record that would extend back to the Tertiary, correlate the histories contained in the sediments, and finally, in future years, extend the correlation to the offshore.

In April, a workshop was held to discuss climate monitoring and precision temperature measurement in permafrost. Attending were specialists from Canada, the U.S.S.R., and the United States. Discussions focused on (a) determination of what parameters are most critical for coupling observations made of permafrost temperature with surface and near-surface air temperature and (b) methodologies for standardization of precision borehole temperature measurements.

In July, the USGS Arctic Research Committee sponsored a workshop at the International Geological Congress in Washington, D.C., on Arctic Geological Processes and Global Change. Topics included northern observatories and global change monitoring; whether global warming will result in sea-level rise; sea level, gas hydrate composition, and the stability of the Beaufort continental shelf; methane hydrate and global change; Bennett Island atmospheric plumes; Arctic Ocean ice-cover variations; glacier growth and climatic warming; remote sensing of snow cover; radar analysis of Arctic glacial features; and Arctic data management.

In August, a joint USGS-GSC expedition investigated the Beaufort Sea continental margin, north of Barter Island. The expedition mapped and sampled a series of exposed Cenozoic thrust folds and sampled Quaternary outcrops to

provide a paleoenvironmental record of the Beaufort margin. The expedition was conducted from the U.S. Coast Guard icebreaker *Polar Star*, which provided excellent support for the project.

USGS, in cooperation with the University of Idaho, has designed a 6-week field-training program to introduce members of the scientific community to high-latitude earth science. The course, Polar and Alpine Geosciences, will be offered on the Juneau Icefield, Alaska, from July 20–September 1, 1990. For information, contact the Office of International Geology, 917 National Center, Reston, VA 22092.

Publications

Readers may obtain further information of the USGS activities from the following publications:

Geologic Studies in Alaska, by the U.S. Geological Survey, 1988, USGS Bulletin 1903, J. H. Dover and J. P. Galloway, eds.

1989 Annual Report on Alaska's Mineral Resources, USGS Circular 1040, J. L. Schneider, ed.

Annual Report of the U.S. Geological Survey, USGS, Reston, VA 22092.

Bureau of Mines

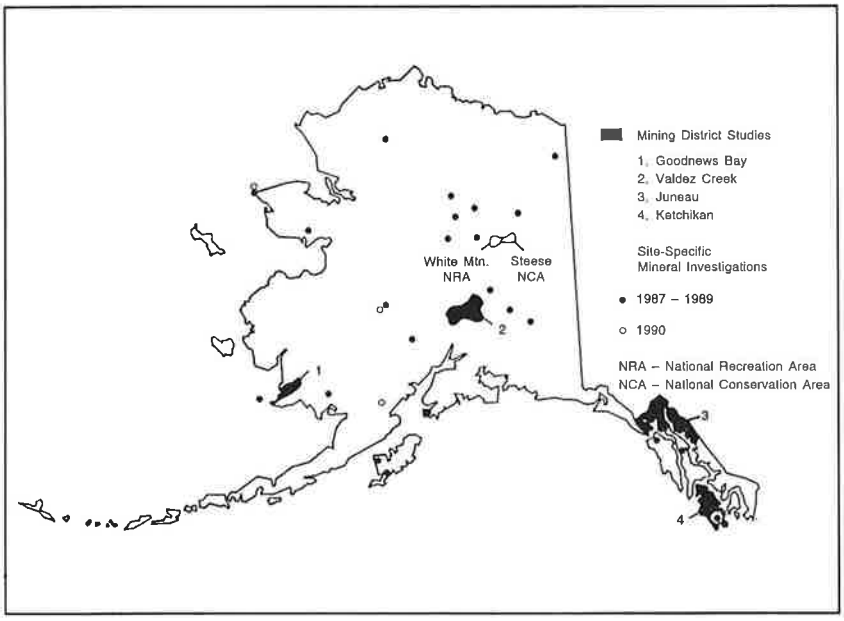
FY 89 FUNDING (thousands)

Minerals	857

The Bureau of Mines (BOM) is a primary source of information on mineral production in the United States and throughout the world. BOM assesses the worldwide availability of minerals, giving highest priority to deposits under U.S. control. It analyzes the impact of Government policies, economic conditions, and political events on the mineral sector of the economy and the Nation's mineral supplies.

Activities include evaluating mineral reserve potential of mineralized areas, estimating the inferred reserve base at specific deposits, and identifying the major sources of supply for critical and strategic minerals. These programs are conducted and managed by BOM's Information and Analysis Directorate. The information is used by Federal policymakers, land planning agencies, and the Congress, all of which make land use and policy decisions that affect the availability, economics, and long-term supply of domestically produced minerals. BOM's program in Alaska consists primarily of mining district studies, site-specific investigations on Federal lands, and potential supply analyses. The program provides for a systematic investigation of mining districts to include identification and estimation of mineral reserves, characteristics of economic mineralization, mineral extraction methods, metallurgical treatment methods, and evaluation of the production potential.

Locations of assessments of potential mineral supply from selected regions of Alaska.



Alaska has the highest potential for critical and strategic mineral deposits in North America. BOM, in its Alaska Strategic and Critical Minerals program, locates and assesses the resource development potential of deposits in these mineral terranes. This effort provides timely, comprehensive strategic and critical mineral data required by Federal and State agencies to make well-informed economic, policy, and land-use decisions; it will also encourage industry involvement in the exploration and development of strategic and critical minerals in Alaska. The Bureau of Mines is not funded to do primary or secondary research in Alaska. Therefore, the Alaska appropriated funds are Arctic-related but are not designated specifically as research funds.

In response to the President's National Materials and Mineral Program Plan of 1982, BOM's Inventory of Land-Use Restraints Program (ILURP) was initiated for Alaska. This program details studies showing the relationship

between public land restrictions and mineral exploration and development. The program provides information on the minerals located on public lands and the cumulative impact of legislative and discretionary withdrawals on the availability of public land for use in the land-use decisionmaking process and for use by the private sector in mineral development planning. In Alaska, about 68 percent of land is public land, and only 15 percent of public land in Alaska is available to mineral entry.

The ILURP information is used by the Bureau of Land Management and the U.S. Forest Service in making land-use decisions, by the private sector, and by BOM's Potential Mineral Supply Analysis System in assessing the economic values of mineral resources in selected regions. The Potential Mineral Supply Analysis System statistically estimates the supply of discovered and undiscovered resources from designated regions. BOM's Mineral Land Assessment Program provides field-oriented geologic data related to known resources, mining district studies, and site-specific mineral investigations. Joint assessments by the State of Alaska and BOM of the Kuskokwim and northwest regions in Alaska were completed in FY 87. In response to a request from the Bureau of Land Management, BOM conducted an assessment of Alaska's Steese/White Mountain Region. The work was completed in FY 88.

The Mining District Studies in Alaska are designed to assist land management agencies in land-use decisions and to reduce the dependency of the United States on foreign sources for strategic and critical minerals. The Anti-Apartheid Act of 1986, P.L. 99-440, mandates that the United States decrease its import reliance on South African supplies of platinum-group metals, chromium, manganese, cobalt, and selected other minerals. The Mining District Studies, conducted in cooperation with the State of Alaska, provide detailed information on the identified mineral resources on Federal and State lands and the potential for their economic development. Emphasis is also placed on developing more extensive quantitative information on potentially economic mineral resources, especially of critical and strategic minerals.

At the request of the Congress, and in cooperation with the Alaska State Division of Geological and Geophysical Surveys (ADGGS), BOM began the 4-year Juneau Mining study in FY 85. Field work was completed in four subdistricts, and in FY 88 an analysis of undiscovered economic deposits occurring in the district was conducted. The final report will be published in FY 90.

The 5.7 million-acre Valdez Creek District, which includes the largest producing placer gold mine in Alaska, has potential for a significant increase in mineral development. The 4-year study, begun in FY 87, included cooperative work with the ADGGS. In FY 88 and FY 89, the feasibility of underground mining at the Valdez Creek placer mine was investigated. BOM studied a low-grade gold deposit to examine the feasibility of mining it, developed a deposit model for use in exploring for other undiscovered occurrences, and conducted geophysical examinations and subsurface sampling at sites that were previously identified as having mineral potential. In FY 88, BOM discovered mineralization near the McCallie Creek glacier. Work in FY 89 consisted of mapping and sampling that discovery, doing new work on areas that showed anomalous gold values in previous sampling, and examining the remote central part of the district. Final field work and a draft of the final report on the Valdez Creek District study will be completed in FY 90.

Geographic Positioning System: Antenna and receiver in use on Juneau Icefield, August 1989.

Site-specific mineral investigations provide detailed data on small areas of Federal lands that have a high potential for important minerals. The

program began in 1981 in Alaska and grew out of mineral land assessment studies conducted in the 1970s that examined important metals like chromium, tin, and cobalt. By 1987, platinum, columbium, tantalum, yttrium, gallium, germanium, and rare-earth elements had been added to this relatively limited program. BOM conducts these investigations at widely distributed sites in Alaska. Site selections in Alaska have been coordinated with BOM's metallurgical research program. Bulk samples are provided for mineral characterization and benefication studies at BOM research centers.

Since FY 85, the principal commodities evaluated have been platinum-group metals, chromium, base metals, rare-earth elements, tungsten, uranium, and gold. BOM identified significant occurrences of chromium, massive metallic sulfides, columbium, and gold. Further evaluation is needed, however, to determine the economic potential of these occurrences. New studies will concentrate on geologic terranes that extend into Canada and the Soviet Union, where exploration and development far exceed that in the same terranes in Alaska.

If the mineral industry is to identify and develop promising new domestic mineral resources, important mineralized areas on public lands must remain open to exploration and development. Problems in planning decisions often arise because decisionmakers lack either the necessary mineral information and the resources to acquire it or the expertise to analyze minerals information and to develop alternatives that are less restrictive to mineral exploration and development. Therefore, to ensure that mineral resource development can compete with more easily identifiable alternative land uses, BOM represents the national interest by promoting access to minerals on public lands. It strives to ensure that mineral considerations are an integral part of land-use decisions.

Bureau of Indian Affairs

FY 89 FUNDING (thousands)	
Anthropology and Cultural Resources	1780
Subsistence	700

The Bureau of Indian Affairs (BIA) in Alaska provides a wide variety of traditional technical and program services to the Alaska Native people, their lands, and resources. In addition to its traditional responsibilities, BIA in Alaska performs functions called for by special statutes applicable to Alaska or that have special provisions for Alaska Natives.

BIA's mission is to meet the special unmet non-health-related social, economic, cultural, and natural resource protection needs of Alaska Natives resulting from their status as Indians. The BIA's role is to create the environment that will help the Alaska Natives to achieve economic self-sufficiency and self-determination; provide services necessary to meet otherwise unmet needs; and fulfill unique statutory requirements relating to the Alaska Natives or their resources.

While direct research is not specifically within the BIA's mission in Alaska, most programs require some research to determine level of need, gather data, or prepare reports on accomplishments. In the past 10 years the types of studies conducted by the BIA have been far-reaching. A few examples are determining the social and economic impact of oil and gas drilling on communities; studying the cultural and subsistence needs of the Eskimo to take bowhead whale; studying the extent and effect of subsistence take of various species by Alaska Natives; studying the need for freight service to the western coastal villages; inventorying the cultural resources on Native allotments and townsites; and investigating the historical, cultural, and archeological significance of Native cemetery sites and historical places for conveyance under the Alaska Native Claims Settlement Act (ANCSA).

These examples reveal that most of the BIA's research is in two broad, often overlapping areas: anthropological and cultural resources and subsistence use of natural resources. This is the first year BIA is reporting under ARPA. Funding in FY 89 totaled $2.4 million.

Anthropological and Cultural Resources

The BIA has been conducting two major efforts involving data gathering, analyzing, and reporting in this area. One effort is to investigate the historical, cultural, and archeological significance of Native cemetery sites and historical places for conveyance under the ANCSA. The other effort is to inventory, and mitigate, where necessary, archeological and historic sites on trust properties or where BIA anticipates action.

The ANCSA Projects Office

Under section 14 of ANCSA, the Native regional corporations could select existing

Alaid Island site, part of the Semichi Islands of the Near Island group of the Aleutian Islands.

cemetery sites and historical places for conveyance to them. The BIA established the ANCSA Projects Office in Anchorage, Alaska, in 1978. Since inception, the ANCSA Projects Office has investigated nearly 2000 separate cemetery sites and historical places applied for by the regional corporations. Reports are complete on about 1200 of these sites and detail the data found and the archeological, anthropological, and historical significance of the sites to Alaska Natives.

In 1989 and again in 1990, the field efforts will concentrate on the Aleutian Chain sites. The BIA investigated 87 sites in 1989, with 53 of them on the chain and 17 that were reinvestigations because of new information. The plan for 1990 is to accomplish 93 investigations, of which 54 are in the Aleutians. The Aleutian investigations will be done again this year by sharing the Fish and Wildlife Service vessel, the *Tiglax.*

Cultural Resources Inventory and Management

This area includes all necessary archeological inventories for compliance with section 106 of the National Historic Preservation Action on Alaska Native Allotments. These inventories are done according to an agreement with the Bureau of Land Management and the Advisory Council on Historic Preservation. It also includes section 106 compliance and environmental assessment work for locations throughout Alaska, where BIA anticipates actions such as road or housing improvement projects.

This function also includes the inventory, and mitigation if necessary, of all cultural, archeological, anthropological, or historic resources on Alaska Native allotments and Alaska Native townsites. Because of limited budgets, this function is done only before approval of any transactions affecting these trust and restricted properties. These sites are located throughout Alaska, but the majority are on the coastline and the rivers.

Old John Lake site in the Doyon Region.

Adak Island site in the Andreanof Island group in the Central Aleutian Islands.

In 1988 and 1989, the BIA inventoried about 120 locations each year. The BIA also conducted one mitigation data recovery project each year. In 1989, the office established its own laboratory for limited analysis and storage of artifacts. The BIA makes and files with the State Historic Preservation Office a section 106 compliance report for each site. If eligible, BIA also prepares a determination report for potential nomination to the National Register of Historic Places. The office also has established a special relationship with the Alaska Native owners of properties and the elders and has been active in cooperative efforts and professional organizations.

Subsistence Use of Natural Resources

Efforts in this broad area enable and help Alaska Native individuals and organizations to protect and enhance their special use and preference rights for subsistence take of natural resources. It includes special exemptions or preference rights such as those in the Marine Mammal Protection Act and in title VIII of the Alaska National Interest Lands Conservation Act (ANILCA). Generally, BIA has issued small grants or contracts to Alaska Native tribes or tribal organizations to gather data and to participate in organizations, management planning, advisory committees, and councils.

Subsistence use of natural resources is an important concern of the Alaska Natives, so the BIA uses funding from natural resources, fish and wildlife, and rights protection programs for this function. Most efforts also include coordination and cooperation with other Federal and State agencies and Alaska Native organizations. Additional funding for Alaska Native involvement in the subsistence studies made necessary by the Exxon *Valdez* tanker incident may continue to be available. In 1989, subsistence support was a part of the Tanana Chiefs Conference's contract and a joint contract with Alaska Village Council Presidents and Kuskokwim Native Association and included collecting and verifying subsistence use data, information and education sharing with the communities, subsistence advocacy, and representation on advisory councils and boards.

Other efforts in 1989 included a small cooperative study with the State of Alaska to determine if a group of rural residents of Wrangell were eligible for subsistence preference under ANILCA. BIA also participated in a joint effort in previous years (1986 to 1988) with the National Park Service, the North Slope Borough, and the U.S. Army Cold Regions Research and Engineering Laboratory. This study was on the effect of the all-terrain vehicle traffic of subsistence activities on tundra terrain near Anaktuvuk Pass.

Four separate grants and agreements involved The North Pacific Rim (TNPR). One was a cooperative agreement with the Alaska Department of Fish and Game on a study to rehabilitate the sockeye salmon in the English Bay-Port Graham area. Another was a continued and expanded (because of the oil spill) subsistence use study of Tatitlek Natives, done in cooperation with the State of Alaska. A third was to provide support through TNPR for the formation of an

ANCSA archeologist conducting an on-site interview with Native elder, Kobuk River Delta, Northwest Alaska.

Alaska Sea Otter Commission to work in cooperation with the Fish and Wildlife Service on the use and management of the sea otter. The last was a study on the social, economic, cultural resource, and subsistence impact of the oil spill on the seven villages in TNPR.

The BIA did additional research with the Alaska Eskimo Whaling Commission on quota needs and harvest strategies, including the acquisition and testing of penthrite projectiles. Next year, the BIA intends to study the Little Diomede Natives' historical use of and cultural and sustenance need for bowhead whales. The BIA cooperated with the North Slope Borough in support of the Inuvialuit beluga whale committee to help in collection of harvest information, use, and availability. The BIA also funded the collection of subsistence resource harvest data and the monitoring of subsistence activities for walrus through the Eskimo Walrus Commission.

Department of Defense

Arctic research is conducted by all three services and includes virtually all environmental sciences, engineering, and health disciplines. A total of $23.1 million was devoted to basic research and related testing in Fiscal Year 1989.

The Department of Defense (DOD) conducts Arctic research to ensure the development of the knowledge, understanding, and capability to meet national defense needs in the Arctic. The range of military requirements extends from Army ground operations to Arctic engineering, logistics, health, oceanography, and atmospheric research. Within the broad scope of current research are such topics as human adaptability to cold, auroral and ionospheric phenomena, deep ocean water formation, and construction in permafrost regions.

The military services conduct Arctic research to address specific needs stemming from the identified requirements of each service. The Army is strongly driven by requirements to understand the Arctic terrain and its impact on ground operations and equipment performance; to understand the performance of troops in the field under adverse conditions; and to understand the constraints imposed by the Arctic environment on construction, roads, buildings, and support systems, such as waste water. The Navy focuses largely on Arctic oceanography, but also conducts research on high-latitude communications, Arctic storms, and the response of sea ice to atmospheric and oceanographic forcing. The Air Force's primary interest is the impact of ionospheric processes and phenomena on communications, navigation, and surveillance systems.

The Army must be sure of its capability to conduct combat operations in northern regions. The recent stationing of the 6th Light Infantry Division in Alaska has focused Army attention on the special environmental conditions of the Arctic.

Three major bases are located in Alaska. Ft. Wainwright and Ft. Richardson are the locations of the 6th Light Infantry Division, and Ft. Greely is the home of the Cold Regions Test Center (CRTC) and the Northern Warfare Training Center. The Alaska District of the Corps of Engineers is located on Elmendorf Air Force Base and at Ft. Richardson. In addition, the 10th Mountain Division at Ft. Drum, New York, must be capable of operation in winter terrain.

The Army Corps of Engineers has responsibilities for military construction, water resources, and environmental impact permits. Both nationally and internationally, the Corps is called on to provide construction and engineering services at cold-weather sites. These include Army bases in Korea, Europe, and the northern tier of the United States, as well as Air Force sites in Canada, Greenland, Iceland, and Norway.

FY 89 FUNDING (thousands)

Arctic Engineering	1802
Permafrost/Frozen Ground	1281
Snow and Ice Hydrology	3172
Oceanography	9119
Lower Atmosphere	1172
Upper Atmosphere	5100
Medical and Human Engineering	1259

Five U.S. Army organizations are involved in Arctic research and development: the Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire; the CRTC, 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. CRREL is a national center of excellence in cold regions research and technology. The mission of CRREL is to study and understand the characteristics of cold regions and to use this knowledge to solve 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, ice, frozen ground, and cold weather engineering. It sponsors the Cold Regions Bibliography at the Library of Congress, which includes over 140,000 citations and is available both on-line and on CD-ROM. Natick conducts research on cold regions clothing, equipment, and rations, while the Medical Research and Development Command investigates basic cold physiology and cold stress adaptation. ARO sponsors Arctic-related research in snow and ice, atmospheric propagation of near-millimeter waves (NMMWs) 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 CRTC at Ft. Greely is a test and evaluation activity focusing on cold weather operations. CRTC does not conduct research but performs technical testing for the Army Materiel Command, other DOD agencies and services, Government agencies such as the

Ship-track and ice-camp trajectories during CEAREX, September 1988 through May 1989.

National Aeronautics and Space Administration (NASA), and industry. Its support facilities, instrumentation, and firing ranges allow it to test a variety of military equipment and weapons.

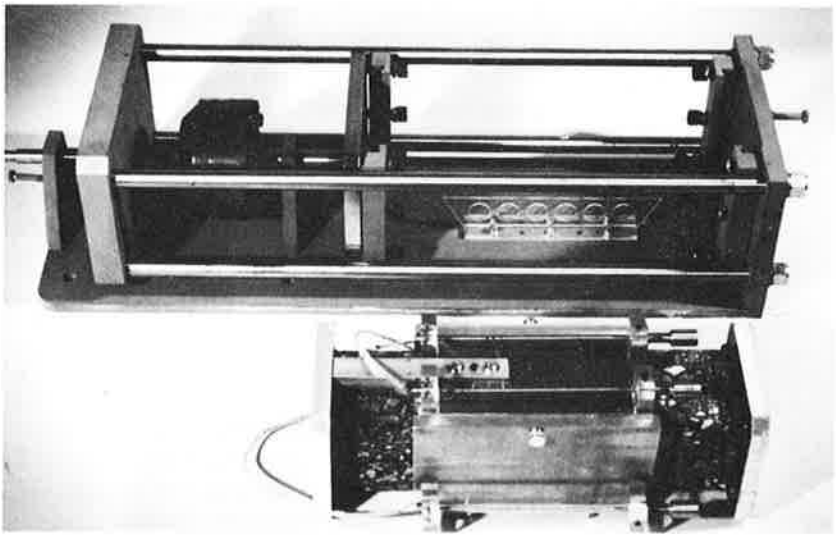
Air Force efforts over the past several years have concentrated on the high-latitude ionosphere, thermosphere, and magnetosphere and the coupling processes that take place there. The objectives of the Air Force Arctic research program are to develop the fundamental understanding necessary for comprehensive models and real-time support for DOD systems affected by ionospheric processes and to develop predictive models that depend on ground-based and satellite measurements. The program uses multitechnique observations from a number of high-latitude locations.

The Navy's Arctic-related activities range from basic environmental investigations to applied research associated with operational systems. These activities are pursued within a number of organizations. The Office of Naval Research (ONR, Arlington, Virginia) supports basic multidisciplinary efforts through grants and contracts, primarily with academic institutions. The former Naval Ocean Research and Development Activity (NORDA, Bay Saint Louis, Mississippi) and the former Naval Environmental Prediction Research Facility (NEPRF, Monterey, California) have been consolidated into one organizational unit, the Naval Oceanographic and Atmospheric Research Laboratory (NOARL). The locations of the component activities remain unchanged. NOARL and the Naval Research Laboratory (NRL, Washington, D.C.) perform basic and applied research with emphasis on acoustics, numerical modeling, and remote sensing. The Office of Naval Technology (ONT, Arlington, Virginia) supports applied research and development through specific Navy laboratories such as the Naval Underwater Systems Center (NUSC, New London, Connecticut), the Naval Ocean Systems Center (NOSC, San Diego, California), the Naval Surface Warfare Center (NSWC, Silver Spring, Maryland), and the Naval Civil Engineering Laboratory (NCEL, Port Hueneme, California). ONR and ONT form the core of the Chief of Naval Research Command, which addresses broad, basic research issues and the initial transition of useful results to fleet applications. More focused applications occur under the Chief of Naval Operations through the Space and Naval Warfare Systems (SPAWAR) Command.

The overall goal of the Navy's research in the Arctic sciences is to provide an accurate knowledge of the environment for naval operations. In pursuit of this goal, the Navy funds comprehensive theoretical and experimental research on a range of high-latitude processes and phenomena. A multidisciplinary perspective is necessary for a full understanding of the inherent interactions. Contributing disciplines, in order of relative emphasis, are acoustics, physical oceanography, meteorology, ice dynamics, biological oceanography, geological oceanography, chemical oceanography, and geophysics. Within each discipline, insight is pursued through both observation and modeling. Observation includes remote and in-situ sensing with the strategy of determining optimal sampling distributions in time and space. Modeling includes analytical, numerical, and physical analogs with the strategy of formulating essential governing dynamics and estimating the limits of predictability. Across disciplines, some infrastructure (for example, platforms, data management

systems) is common and supported to ensure adequate expertise and capability when necessary. For example, logistics for the Arctic basic research program (ONR) is contracted to the Polar Science Center at the University of Washington. Ice camps, aircraft, ice-strengthened vessels, and remote staging facilities are deployed regularly and effectively with a permanent staff of three. No ships or planes are owned but rather are chartered as necessary to support specific science experiments.

Investigations for which enhanced funding has been formally identified within ONR are termed Accelerated Research Initiatives (ARIs). ARIs are typically of 5 years' duration and are established on the basis of scientific merit, technical feasibility, timeliness, and naval relevance. Current ARIs within the ONR Arctic Sciences Program are Real Time Environmental Arctic Monitoring (RTEAM), Arctic Oceanography, and Arctic Lead Dynamics. In addition, a University Research Initiative (URI) program focused on laboratory ice mechanics, geophysical scale ice dynamics, and remote sensing continues.



Thermal stress measurement device for determining material behavior at temperature ranges of +20°C to -40°C.

Arctic Engineering

The Army's Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, and Fairbanks, Alaska, has primary responsibility for DOD efforts in Arctic engineering. The research focuses on the development of cost-effective facilities responsive to the Army's mission in cold regions. The establishment of the Army's 6th Light Infantry Division at Ft. Wainwright, Alaska, and the 10th Mountain Division at Ft. Drum, New York, has increased the emphasis in this area. Specific cold environment areas of interest include the design, construction, operation, and maintenance of roads, airfields, buildings, foundations, and water and wastewater systems.

At Ft. Drum, the Army has spent more than $750 million on new facilities to support the troops stationed there. CRREL provided data on snow loads for building design as well as effective roof designs. Improved pavement designs were adopted that will reduce the lifecycle costs by minimizing low-temperature cracking, a major cause of pavement failure in cold climates. Technical assistance was also provided during the construction process. Similar support efforts are planned for future construction efforts at Ft. Wainwright.

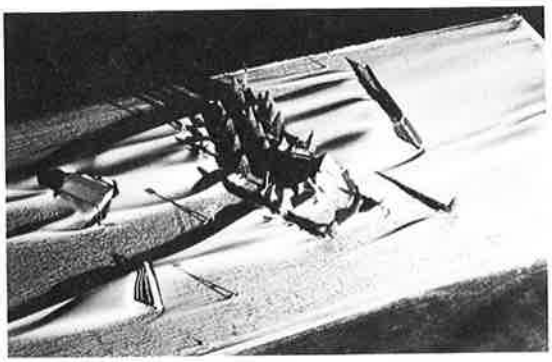
Pavement-related research has included cold regions pavement design validation in CRREL's Frost Effects Research Facility (FERF). The 29,000-square-foot FERF provides a unique opportunity for full-scale evaluation of pavement designs. The facility can rapidly freeze and thaw soils, yielding several winters' worth of data in a few months. During 1989, tests of asphalt concrete pavements built on highly plastic clay and silt subgrades were conducted in the FERF.

Trafficability tests carried out on the clay subgrade test sections will lead to revision of design criteria for pavement built over these frost-susceptible soils.

Other research in the FERF concerned a study of the performance of buried utility systems in cold regions to reduce the incidence of accidental freezing of buried water and wastewater lines and to develop guidance for frost shielding and insulation of water and wastewater lines and heat-distribution lines. A pipe loop was constructed in the FERF to obtain experimental data on losses from buried conduits of heat-distribution systems. Current design procedures are based on assumptions of ground conditions, some of which may not be valid for specific applications. Evaluation of heat losses in the FERF provides a controlled environment in which losses can be measured accurately and conditions such as ground-water, moisture level in the conduit, and frozen ground temperature can be monitored and controlled.

CRREL has a snow-drift wind tunnel that is used to conduct scale-model studies of snow and ice build-up on and around structures. The facility simulates snow with a special activated clay. By varying the humidity in the airstream, the simulated precipitation build-up can be varied from dry powder snow to wet snow or icing conditions. Recent efforts include an evaluation of snow-drift impact on modifications to the South Pole station in Antarctica.

Winter engineering is another active research area at CRREL. Winter engineering activities focus on development of procedures and equipment



Wind tunnel to simulate snowdrift accumulation.

for efficient combat engineering in Alaska, Korea, Western Europe, and mountain regions. Problems studied include creation of gaps and barriers (for example, craters, ditches, and ice covers on rivers); construction of protective emplacements where excavation, drilling, and blasting are required; and building of expedient landing areas, runways, and roads. Much of this research has direct application to Arctic construction activities. Recent efforts have involved evaluation of a frozen-soil ripping bucket for small excavation equipment, documentation of blasting and blast effects in frozen ground materials, and development of an effective, economical tie-down anchor for expedient aircraft landing mats.

Permafrost, Frozen Ground, and Geology

DOD research on permafrost and frozen ground is primarily conducted and supported by two agencies, CRREL and ARO. This research provides design data and criteria for construction and operation of facilities in cold regions. Other efforts include studies of toxic and hazardous waste movement and control in frozen soils. Basic research is conducted to assess and predict the disturbance and recovery of permafrost terrain following natural and human-induced changes.

ARO supports both laboratory and field programs that study the physical mechanisms controlling processes in frozen ground. An experimental program is examining physical mechanisms that control the strength of frozen soils to develop rational constituent relationships. Field programs are under way to measure heat and mass flow of water and salts through a full annual cycle in permafrost and to develop physically based models of the processes responsible for patterning in periglacial soils.

Subsurface exploration is a key element in the design and construction of facilities on permafrost. CRREL researchers are working to improve electromagnetic exploration methods (for example, galvanic and magnetic induction systems and ground-penetrating radars) that have proved effective for ground-based use. The CRREL effort is focusing on modifying, developing, and testing these systems in aquatic and airborne modes to explore bedrock and subsea permafrost, river brash and frazil ice, soil properties and distribution, and water tables. Evaluations with direct current (DC) towed arrays have proved effective in profiling subsea permafrost. In 1989 an automated galvanic survey system was assembled and tested over a bedrock site.

Other fundamental research at CRREL has examined the effects of pressure and temperature on moisture migration in frozen soil. This involves subjecting highly frost-susceptible silts to concentration and temperature gradients while characterizing moisture movement. Fundamental studies are under way to examine the effect of soil properties and environmental conditions on the chemical, biological, and

Bridge on White River, Vermont, collapsed during January 1990 thaw.

Locating unfrozen water in the Arctic.

physical processes that govern the persistence, transport, and fate of natural and manufactured compounds. Work is continuing on evaluation of freezing as a decontamination and containment strategy for hazardous chemicals.

Snow and Ice Hydrology

DOD research on snow and ice hydrology is focused on identifying the types, directions, magnitudes, and processes of human-induced and natural changes in cold regions environments. Research is in progress to quantify the effect of snow and ice on military and civilian systems and facilities and to quantify snow properties, including depth, density, stratigraphy, grain size, and crystal type. This work is also evaluating the general climatic and topographic controls that determine local snow types. The result will be a generalized distribution map of specific snow properties that will provide baseline data for future satellite sensors. Current efforts have involved establishment of instrumentation sites from Valdez to Prudhoe Bay in Alaska. In cooperation with NASA, initial analysis of snow data from the transect has been compared with passive microwave data (37 GHz) from aircraft and satellite sources.

The ability to measure ice thickness rapidly is important for military activities such as ice bridging and naval operations. Several experimental electromagnetic ice-profiling systems have been developed and evaluated. Pulsed radar systems have been effective in measuring the thickness of regular freshwater ice. Application of the radar signal-processing to river depth and other data, obtained using software developed for ice surveys, revealed previously unobtainable data.

Frazil ice, which forms in rapidly moving water, often collects as slush in areas of slower water and can effectively block streams and cause flooding and erosion problems. Because of its higher conductivity, frazil ice cannot be profiled well using pulsed radar. Recent studies have shown that magnetic induction, another method that depends on ground electrical conductivity, can be effective for profiling frazil ice accumulations.

Other ice research at CRREL concerns determination of the mechanical properties of freshwater and sea ice. These data are used to develop design criteria for ice forces on structures for both military and civilian applications. Recently a reverse/direct stress-testing device was developed for uniaxial tension, compression, and cyclic loading of ice samples. The device grips ice specimens rigidly without introducing any loads or bending moments as a result of the clamping effort. This technique makes it possible to study damping and deformation mechanisms, modulus variations, and cyclic stress-induced damage under loading paths—measurements that cannot be obtained by other experimental methods. A patent application has been filed for this device.

The establishment of the Army's 6th Light Infantry Division in Alaska has heightened interest in Arctic conditions that affect 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 ensure that Army water purification units can operate effectively in winter environments.

Mapping top of subsea permafrost in shallow coastal waters near Prudhoe Bay, Alaska.

Snow characterization and data collection site at Prudhoe Bay, Alaska.

Oceanography

Many of the distinctive hydrographic, biogenic, and sedimentological features observed throughout the Arctic Ocean 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. A number of current investigations are addressing the mechanisms controlling this transport and distributing the associated heat. Observational efforts have been organized into the Coordinated Eastern Arctic Experiment (CEAREX). The objectives of CEAREX are to understand the structure and function of mesoscale and small-scale (10 km to 1 m) processes in the 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 series of field studies were staged from ships, ice camps, and aircraft. Building on the Marginal Ice Zone Experiment (MIZEX) results, the evolving dynamics of Marginal Ice Zone (MIZ) and underice eddies were addressed, including their role in the mean circulation, in governing the location of the MIZ, in conditioning deep winter convection, and in seasonal biological productivity. Air-ice-ocean momentum flux was studied through detailed measurement of atmospheric and oceanic boundary layer structure. Other measurements included ice floe stress, strain, and deformation fields. Below the boundary layer, the partition of energy in the upper ocean among internal waves, mixing, and dissipation was investigated using arrays of hydrographic and current sensors. Ambient noise generation in interior pack ice was measured to isolate event physics, and temporal and spatial variability in low-frequency coherence was determined using a large aperture array of hydrophones. The scattering and emissivity of snow and ice in the microwave band were also studied, particularly during the fall-winter evolution. The complex, 9-month CEAREX, including the unusual operations in fall and winter, was completed successfully largely because of the expertise of the logistics support group and the experience of the chief scientists. A comprehensive workshop to review results, facilitate interdisciplinary analyses, and plan publications was held in February 1990.

Regionally complementing CEAREX, the Greenland Sea Project (GSP) completed its intensive field year, addressing circulation and water mass formation. High-precision, seasonal hydrographic cruises, tomography, moored current meter arrays, and remote sensing were used. The synthesis of data from CEAREX, GSP, the French Arctic Marginal Ice Zone (ARCTEMIZ) Program, the NATO Greenland-Iceland-Norwegian Seas (GIN Seas) investigation, and ongoing Norwegian efforts including the Seasonal Ice Zone Experiment (SIZEX) will provide the most comprehensive data set yet available in the Nordic Sea region. A centralized hydrographic data base is being implemented.

Preliminary planning and commitments have been completed for cooperative work with Japanese scientists in the Sea of Okhotsk. Moorings will be deployed in the spring to measure water properties, currents, and particle concentrations north of Hokkaido. In collaboration with the National Oceanic and Atmospheric Administration (NOAA), long-term moorings have also been deployed on the Chukchi shelf to examine exchange processes north of Bering Strait. In the central Arctic, objective methods of detecting and quantifying regional-scale lead patterns from remote-sensing imagery are being addressed, as is the coherence and feedback of such patterns with and on synoptic-scale atmospheric systems. The net effect of leads on the Arctic heat budget will be examined. Options for establishing a statistically robust data base for lead distribution are being assessed.

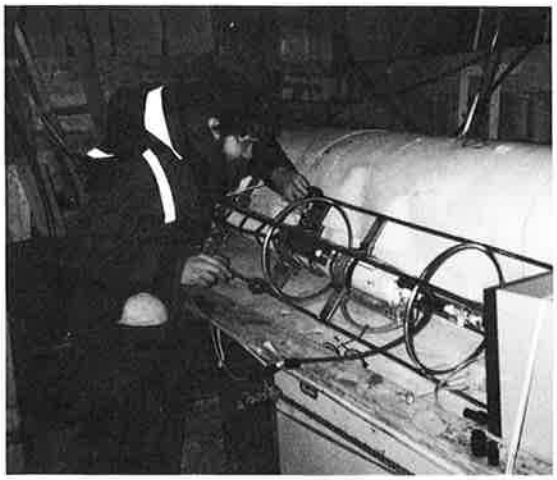
The effects of ice mechanical and thermodynamical processes are reflected in the complex geometries of the upper and lower surfaces. The form and composition of these surfaces is also critical for scattering and absorption of electromagnetic and acoustic energy, central for both the radiation budget and remote-sensing techniques. The inaccessibility of the lower surface has meant limited advances in understanding ice-ocean interaction and acoustic scattering. Results from joint imaging experiments, undertaken during spring 1987 and 1988 with coordinated submarine and aircraft measurements, are

being analyzed. In 1987, submarine sensors obtained thousands of kilometers of narrow-beam upward-looking sonar, sidescan sonar, and upward-looking video data. Simultaneously over segments of these transects, X-band synthetic aperture radar (SAR) and passive microwave data, laser profiles, visual imagery, and radiometer measurements were obtained. The precise correlation in space and time between surface and subsurface platforms, as well as the two-dimensional sidescan perspective, makes this a unique data set. With joint support from NASA, analysis continues on roughness parameterizations, passive microwave signatures, and inter-surface coherence. The complete data set will be achieved in 1990 and will be available for further analysis by approved investigators.

Ice stress/mass balance measurement site on ice floe north of Svalbard during fall-winter.

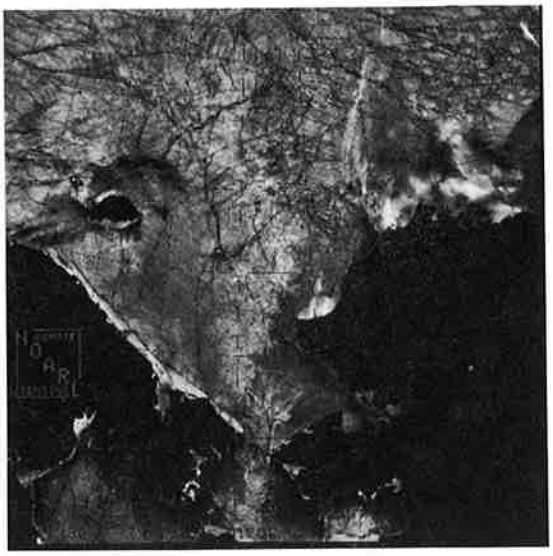
Numerical and laboratory modeling has provided insight into specific processes. Oceanic boundary-layer models, previously refined to differentiate momentum and heat fluxes, are being expanded to include the effects of the lateral melting of ice floes. Atmospheric boundary-layer models are being formulated to incorporate the heat and moisture fluxes associated with winter leads in the central Arctic. Barents Sea and Bering Sea limited-area models (20-km resolution) are being tested with more realistic boundary conditions. Basin-scale models are being improved through coupling to more accurate gyre-scale ocean models. Laboratory modeling has established the mechanisms governing the evolution of steplike structure in ocean thermal gradients and has provided a framework for interpretation of related field observations. Preparations are under way to simulate line sources of buoyancy flux as part of the new lead dynamics study. In addition, laboratory studies of frazil ice production, properties, and behavior are being initiated. Scale modeling of acoustic interaction in a plate-water system, similar to the ice-ocean interface region, has demonstrated the importance of plate cracks and edges in redistributing acoustic energy, as well as the critical nature of keels in dissipating low-frequency acoustic energy by transformation to plate waves. The latter result has also been demonstrated in numerical simulations.

New instrument systems continue to be developed and tested. For ocean sampling, a lightweight (7 kg), compact (1.3 m long), autonomous vehicle for underice temperature and conductivity transects was field-tested successfully during CEAREX. Further navigational refinements are under way. Arctic-modified (80 Hz) SOFAR floats were deployed during CEAREX and are being tracked by an array of moored listening stations. The subsurface mooring (RTEAM) designed to telemeter data from a vertical array through an ice cover for relay by satellite in near-real time has been deployed and redeployed in Fram Strait. A precise tomography array of six subsurface transceiver moorings, on a 4-hour transmission schedule in the Greenland Sea to study water mass structure, convective overturn, circulation, and large-scale vorticity, was successfully retrieved after 1 year, in working order with good data. The testing of enhanced resolution appears promising. This is performed by circumnavigating the transceiver array with a ship-suspended hydrophone array (moving ship tomography). A second-generation Arctic Environmental Drifting Buoy (AEDB) is being designed for deployment of multiple sensors in particularly rugged environments such as the MIZ. Summer testing is planned from a U.S. Coast Guard icebreaker off Greenland. For high-volume data acquisition, the Arctic Remote



Microstructure profiling during CEAREX.

Autonomous Measurement Platform (ARAMP) was field-tested in CEAREX. ARAMP, designed to measure a set of atmospheric, oceanic, and acoustic variables, has both high-capacity internal data logging (laser disk) and telemetry options. A number of ARAMP problems were uncovered and solved in the field; performance



Infrared image of the Chukchi Sea region showing patterns of leads and thin ice.

of the CD WORM drive at low temperature remains an issue and is being addressed. For ice sampling, stress sensor arrays for floe-scale force measurement are being evaluated based on their successful deployment in CEAREX. In-situ performance tests have been established. A narrow-beam (formed by an acoustic lens), upward-looking sonar—designed for long-term sensing of ice thickness (together with a pressure sensor) from a mooring—has been successfully

Autonomous underwater vehicle deployed beneath ice.

field-tested in the Arctic in a 1-year deployment. Additional improvements are being incorporated. In preparation for the atmospheric boundary-layer investigations during the lead dynamics experiments, a new-generation, portable, surface-based sound direction and ranging (sodar) and an improved airborne light direction and ranging (lidar) are being developed for high-resolution density anomaly and aerosol profiling. For the oceanic boundary-layer work, a new heat flux buoy and multibeam acoustic doppler sound navigation and ranging (sonar) for velocity profiling are being designed. An amphibious sampling platform for lead transects is also under development.

Lower Atmosphere

Lower Arctic atmosphere research is primarily done through the combined efforts of ONR and the Atmospheric Directorate (formerly NEPRF) of the Navy Oceanographic and Atmospheric Research Laboratory (NOARL).

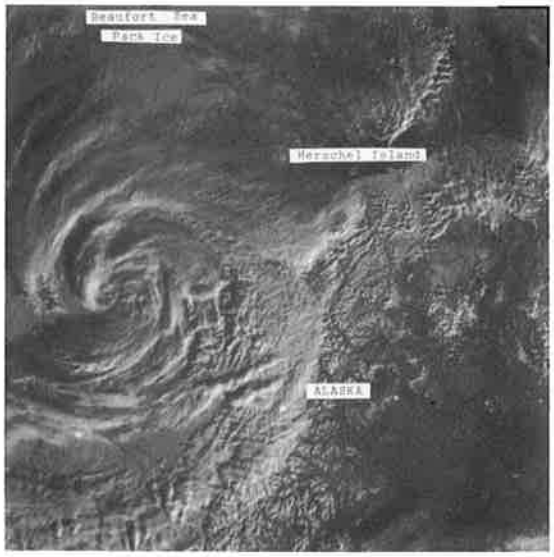
The Arctic atmosphere research effort at NOARL ranges from synoptic studies of Arctic phenomena for *Forecaster's Handbooks*, to remote-sensing studies of the Arctic through a variety of satellite sensors, and to regional and mesoscale modeling for improved Arctic weather forecasts. Specific phenomena of current interest include polar lows, Arctic fog, Arctic fronts, jet-stream interrelationships with cyclogenesis, mountain waves, air-sea interaction effects, meteorological causes for lead and polynya development, and barrier effects in the Arctic. The MIZs and nearby waters are currently areas of increased attention. The loss of several ships each year in the Norwegian and Alaskan regions because of severe winds, sea state, and accompanying structural shipboard icing also draws special attention.

Over the past several years, parts of the MIZEX and CEAREX experiments have been atmosphere-related and have focused on satellite remote sensing. The Atmospheric Directorate of NOARL is exercising a leading role in the Accelerated Research Initiative (ARI) on Arctic Leads commencing in FY 90. Although Arctic leads typically occupy only a small fraction of the ice-covered surface, they account for a considerable percentage of the heat, moisture, and momentum transfer between the surface and the Arctic atmosphere. Buoyant plumes develop over the exposed water in the leads because the water's surface temperature generally is much warmer than the air. Thus, an understanding of atmospheric boundary-layer models is being used. These include Large Eddy Simulations (LESs) which, although very intensive users of computer time, directly resolve the majority of energetic eddies in a turbulent flow field. The LES results can then be used to evaluate simpler atmospheric models and improve them.

The field phase of the ARI on Arctic Leads will involve a pilot study in 1991 and a major experimental study in 1992. These studies will

provide atmospheric data from aircraft, satellite and ground-based remote sensors, and special research on the ice, as well as conventional data sources. Considerable effort is being made to ensure that these experiments are well coordinated with the needs of the modelers and to determine whether the models can aid in designing the nature of the experiment.

On the mesoscale and the synoptic scale, the focus switches to evaluation of the net effect of a field of leads rather than the behavior of a single lead. There is work in progress to parameterize this net effect in mesoscale and regional atmospheric models and thereby improve model forecasts in the Arctic. This work has important ramifications well beyond



NOAA-9 visible channel image showing a polar low with center over the ice pack near Barter Island, Alaska, on 15 October 1985 at 0451 GMT.

the meteorological questions involved. Improvement in the mesoscale model depiction of the Arctic boundary layer will lead directly to improvement in the forcing terms in ice models. A major forcing term in such ice models is the atmospheric surface stress provided by the atmospheric model.

Aside from the Leads Experiment, NEPRF/NOARL is continuing a variety of atmospheric studies concerning Arctic or polar lows and Arctic aerosols and haze. Satellite documentation of a polar low in Alaskan waters was obtained for the first time, and a method was developed to predict such storms on a 24-hour basis with satellite data. Showing the importance of such phenomena, the polar low mentioned previously paid a surprise visit to the U.S. Coast Guard icebreaker *Polar Sea*, which was suddenly struck by 75-knot winds on a day when only light southerly winds were forecast.

Upper Atmosphere

The upper atmospheric research program within DOD is largely concentrated in research programs at the Air Force Geophysics Laboratory (AFGL) and in the contract research program of the Air Force Office of Scientific Research (AFOSR). Research on high-latitude electromagnetic noise is being sponsored by the Office of Naval Research to determine the effects of high-latitude environment on communications systems.

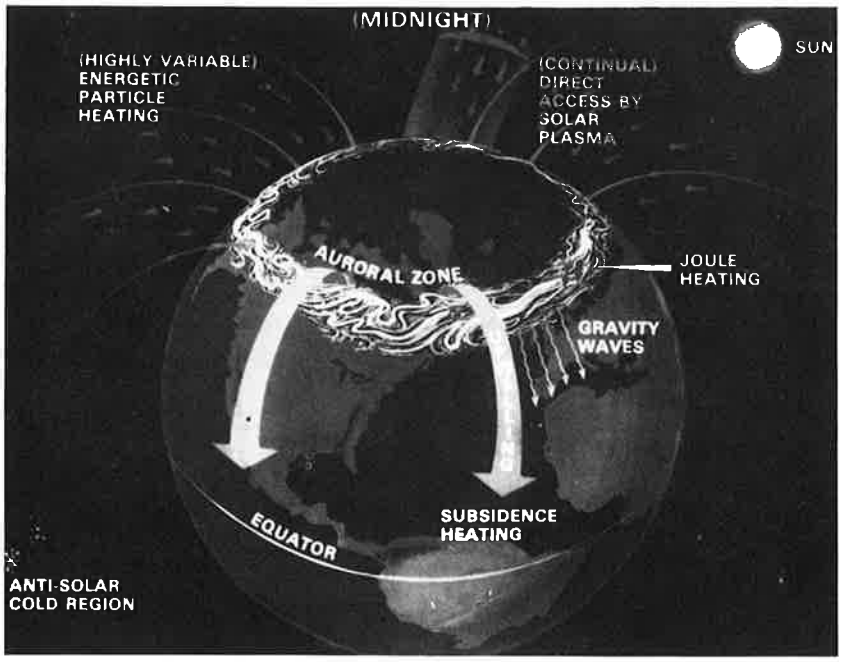
The AFGL research program in upper atmospheric research continues to place strong emphasis on identifying and understanding the role of polar and high-latitude processes in controlling the global dynamics of the thermosphere and ionosphere.

In 1989, work was completed at AFGL on a major campaign designed to understand the global upper atmospheric response to variable high-latitude forcing. The effort involved 30 researchers, several funding agencies such as AFOSR, NSF, NOAA, NASA, Defense Nuclear Agency (DNA), ONR, and several research organizations, using six major research radars, six polar orbiting satellites, and a global net of ground-based sensors. The results are summarized in a special issue of the *Journal of Geophysical Research* (December 1989) devoted to "The Equinox Transition Study." That collection of 14 interlocking papers provides a benchmark of the state of the science in global upper atmospheric modeling in 1989—how far scientific understanding has come and where scientific effort is headed. This work is of considerable significance to the realism with which the upper atmospheric environment can be specified as it modulates satellite drag, density, and radio frequency propagation conditions in the Arctic and globally.

The Equinox Transition Study (ETS) was a highly successful, coordinated campaign. The experimental design resulted in high-quality data that were comprehensive both in the completeness of measurements and in coverage that was global rather than mesoscale. Nature cooperated in providing a calibrated geophysical scale over an extreme dynamic range of disturbance. The 8-day period involved the most disturbed day of the year and a day half as disturbed, separated and preceded by quiet days. The ETS data set was thus unique among campaigns of this nature. The broad scientific aim of ETS was to understand the electromechanical response of the thermosphere-ionosphere system to variable high-latitude forcing. ETS has led to the identification of important new couplings among the mesosphere, lower thermosphere, upper thermosphere,

ionosphere, and magnetosphere through a variety of mechanisms ranging from mechanical to chemical to electrical.

A primary ETS objective was to compare the measured parameters with those predicted by the Thermospheric General Circulation Model (TGCM) of the National Center for Atmospheric Research (NCAR) to assess (and upgrade as appropriate) the current state of physical understanding and modeling. The ETS demonstrated that theoretical models have progressed beyond statistically good representation of thermospheric-ionospheric dynamics to a point at which time-dependent modeling of events over a large dynamic range for numerous sites is conceivable. This study constituted the first serious effort to reduce the number of free-input parameters in the NCAR TGCM and then to accurately simulate conditions at many locations simultaneously. Substantial improvements follow from the use of more realistic inputs in place of the standard input parameterizations. In particular, the relative placement of ionospheric conductivity boundaries with respect to electric field boundaries is especially important to global thermosphere-ionosphere modeling, as well as specification and prediction.



Global view of thermosphere-ionosphere dynamics.

The definition of high-latitude inputs still has no satisfactory solution. Priority should be given to resolving this problem in the near future. The simplest method of specifying the high-latitude inputs is to use various geophysical indices. For the ETS study, new techniques had to be developed to specify the auroral particle precipitation more accurately by reference to orbit-by-orbit satellite data. High-latitude convection was specified by a new assimilative mapping of the ionospheric electrodynamics (AMIE) technique, which provided a best-fit potential pattern to a variety of ionospheric data. The effect of these new procedures was more startling than expected because the auroral oval and high-latitude convection locations could differ from their parameterized locations by hundreds of kilometers. These new inputs generated differences in the TGCM predictions, including neutral wind reversals and changes of several hundred degrees in the calculated exospheric temperatures. With the high-latitude inputs described in this more realistic fashion, directed by measurements, the resulting thermospheric simulation for the September 19, 1984, storm and September 17-24, 1984, ETS period became substantially more realistic; many features of the storm period were accurately reproduced.

Modeling studies also revealed that neutral winds predicted at midlatitudes are very sensitive to changes in high-latitude forcing. Joule heating is the mechanism that generates the strong equatorward wind surges often observed during storms. The cause of enhanced storm-time temperatures observed at upper midlatitudes is air parcel transport. Air parcels are subject to Joule heating as they pass through the auroral zone and are then deposited at lower latitudes. Storm-time parcel trajectories are very different from quiet-time trajectories because of changes in the convection pattern.

A persistent, previously unknown, high-density polar bulge was discovered in this more realistic model simulation and was confirmed by direct satellite observations. In addition, it was discovered from the model results that there remains an unidentified, additional substantial high-latitude heat source.

The ETS modeling studies have also revealed two missing processes in the NCAR TGCM. First, the neutral temperature response and post-storm thermospheric recovery in temperature composition are crucially dependent on cooling by nitrous oxide (NO) in the lower thermosphere. The radiative cooling by nitrous oxide was not included in the TGCM, and the model thermosphere was unable to recover. Second, the equatorward neutral winds predicted by the TGCM are smaller than the measured winds. This is consistent with model temperature gradients and density enhancements that are too small, suggesting that a high-latitude energy source is missing. Both of these processes have now been included in an updated version of the TGCM.

The comprehensive data set obtained from the ETS campaign allowed a variety of scientific

problems to be addressed. The scope of the studies under the ETS umbrella, as well as the diversity of participants, led to several synergistic relationships, further emphasizing the benefits of collaborative studies in multi-instrument campaigns.

In another area, sun-aligned polar-cap arcs are the subject of active research. Discovered 20 years ago, these optical features were thought to be a curiosity, present only rarely. Ten years ago, during research in the polar cap related to command, control, communications, and intelligence requirements, AFGL discovered that these features are present as often as half the time. AFGL has since played a lead role in determining and modeling the optical and radiofrequency-related properties of polar-cap arcs. In 1989, AFGL extended the understanding of these areas to a comprehensive electrodynamics, thermal, and energy-budget characterization, with important implications for the structure and dynamics of the upper atmospheric polar cap.

In another area, sun-aligned polar-cap arcs are the subject of active research. Discovered 20 years ago, these optical features were thought to be a curiosity, present only rarely.

This work confirmed for the first time that the arcs have the anticipated simple arc electrodynamics. Further, it led to several important new discoveries:

- The high-velocity edge of the arc marks the location of strong, persistent, downward Poynting flux.
- This Poynting flux can bring in electromagnetic energy at a rate well exceeding the net particle energy deposited by the ionizing energetic electron flux.
- This heating is a substantial source of heat for the polar thermosphere, which helps to resolve the problem of the missing polar thermosphere heat source(s).
- Finally, a reasonably simple yet self-consistent, accurate, and comprehensive representation of stable, intense sun-aligned arcs is presented, including their electrodynamic, thermal, and energetic character.

These findings are of particular interest to the extent they define processes that apply at least within the polar cap on half of all nights, when the interplanetary magnetic field is northward.

The close coupling among 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 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 Air Weather Service (AWS) support, is developing real-time magnetospheric, ionospheric, and thermospheric specification models; AWS will use these models as part of its Space Environment operational models, which will use real-time data from a network of ground-based and satellite-borne instruments. Physical coupling of these models in an Integrated Space Environment Model is now beginning.

ONR operates a worldwide array of extra-low-frequency and very-low-frequency radiometers to gather digital and analog data on electromagnetic noise. One is located in Antarctica (at Byrd Station), and two are located in Greenland (Sondrestromfjord and Thule). The latter two stations are of interest because they lie approximately along the same magnetic field line and because one is in the polar cap and the other is in the auroral zone. 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 percent of the center frequency of each band. The radiometer at Thule also covers additional center frequencies up to 60 KHz.

During the period 1986-1989, ONR continued its ionospheric modification research at the High Power Auroral Stimulation (HIPAS) facility located in the auroral zone near Fairbanks, Alaska. This research concentrated on generalization of ELF radiation in the ionosphere and was conducted by a team of scientists from Pennsylvania State University, the University of California, Los Angeles, and SAIC. In the auroral region near HIPAS, modulation of the powerful auroral electrojet current by ionospheric heating can lead to easily detectable amounts of radiation, as originally demonstrated in experiments in Tromso, Norway. The ONR-supported research has been investigating ways of increasing the efficiency of exciting ELF radiation. If the efficiency can be increased by several orders of magnitude over what was originally demonstrated, then this approach of radiating ELF from a virtual antenna in the ionosphere becomes attractive for potential application in submarine communication systems. In 1989, initial experiments were conducted to test some novel ideas for increasing excitation efficiency. The approach involves rapid steering ("painting") of the heater beam to excite a much larger area of the ionosphere. The painting must be accomplished on a time scale

such that the entire patch radiates coherently. The initial experiments, performed with a beam-forming time of 20 μs, served to confirm the theory, but the expected major increase in excitation depends on more rapid beam steering than was available at the time.

Medical and Human Engineering

Arctic-related medical and human performance and engineering research is conducted principally by the Army's Natick Research, Development and Engineering Center, and the Research Institute of Environmental Medicine, both located in Natick, Massachusetts, and the Naval Medical Research Institute, Bethesda, Maryland; Naval Health Research Center, San Diego, California; and Naval Aerospace Medical Research Laboratory, Pensacola, Florida. The primary objective of this research is the identification and resolution of medical and human performance and engineering problems common to operations conducted in cold climates. DOD is focusing research on the human physiologic response to cold, the pathophysiology and management of cold injury, the acquisition of human cold adaptation, and the improvement of performance in the cold by adjusting cold weather clothing and rations.

The experiments in climate-controlled chambers in Natick and Bethesda have helped expand understanding of the human response to cold. Experiments in these chambers have shown that, characteristically, energy use increases 50 percent within 30 min exposure to cold air, skin blood flow and skin temperature rapidly decline, and blood pressure increases. The ability to match similar visual patterns, while exposed to cold air, is associated with a much higher error rate compared with the same test conducted in a warm room. Based on these characteristic features of cold exposure, testing of drugs to modify these responses is being considered and screening tests to identify cold-sensitive individuals are being studied.

Research is active in the area of cold injury involving freezing and nonfreezing cold injury, as well as hypothermia. Investigators at Natick have participated in followup studies of cold injury developed in the Falkland Islands War. Models are being developed to study nonfreezing cold injury at Bethesda. Resuscitation from mild and severe hypothermia is of major concern to military persons operating in cold climates. The Navy has recently published results of the first human trials using microwave rewarming of mild hypothermia. Models are used to determine the best sequence of fluid and heat administration in rewarming hypothermic victims to minimize cardiac rhythm disturbances and to decrease morbidity.

In another effort, USARIEM scientists performed hand blood-flow studies on members of the Joint U.S.-Soviet Expedition on Bering

U.S. team entering Providenya.

Bridge. A finding was that long-term cold exposure of hands increased blood flow even in persons with prior high exposure. In another related study, peripheral blood flow in military-age blacks and whites from three geographic regions was measured after cold challenge. Rewarming rates and patterns were compared after cold water immersion of the hands. Blacks had a significantly colder hand skin temperature at room temperature and a blunted rewarming response. Caucasians had a lower heart rate, lower systolic blood pressure, and reduced sympathic response to cold stress. A third effort characterized the importance of dehydration relative to cold injury susceptibility. Dehydration of 4.6 percent of body weight was found to produce significantly colder hand temperature after cold challenge testing.

The Navy has recently reported that high-latitude operations in Antarctica are associated with a new condition of thyroid hormone status. These hormone alterations may also be present in similar circumpolar Arctic latitudes. The production and tissue storage of triiodothyronine (T_3), the most active of the thyroid hormones, are more than doubled after 5 months in Antarctica and remain doubled for up to 1 year of residence on the continent. Why and how these changes take place are being studied.

Nutrition and hydration studies in cold climates are conducted by both Army and Navy laboratories; these studies provide excellent standards for balanced intake when working in

polar environments. Cold-weather-clothing research continues in efforts to provide an ensemble with maximum cold-weather protection and minimum constraint of mobility. Initial work has been completed on development of electrically heated gloves for use by aircrew personnel. The gloves are components of the cold-weather-clothing system for aircrew and will provide protection to -60° F while having minimal impact on dexterity and tactility. Also, a multipurpose lightweight overboot (MULO) is being developed. The new boot will provide protection from the environment and chemical attack, replacing two items currently in the inventory, a wet-weather vinyl overshoe and a footwear cover for protection against chemical agents. Work is also under way to develop a cold-weather feeding system that will provide improved equipment and rations. This system will be specifically designed to support and maintain the performance, morale, and effectiveness of troops operating in cold environments.

National Aeronautics and Space Administration

NASA supports a wide variety of research programs in the Arctic that emphasize the application of air- and space-borne remote sensing. These programs include the study of oceans and ice sheets, atmospheric chemistry, space plasma physics, and land and solid earth processes. In Fiscal Year 1989 these programs were funded for a total of $15.7 million.

Alaska SAR Facility

The primary purpose of the Alaska SAR (synthetic aperture radar) Facility (ASF) is to advance man's understanding of oceanic processes in the polar regions. The station will also contribute data useful in studies of glaciology, geology, permafrost, hydrology, and vegetation science. The considerable interest in this program results from several factors: the all-weather high-resolution capabilities of SAR; the complementary nature of SAR data to passive microwave (SSM/I) data, particularly when applied to investigations of the world's sea ice covers; and the innovative approach taken by the ASF program to deal with the problems involved in timely SAR analysis. Of particular interest are the problems of rapidly extracting useful geophysical information from the data stream, combining this information with ancillary data obtained by other remote sensing and surface-based systems, and efficiently archiving this information so that the results are available to a variety of users in diverse locations. ASF provides an effective approach to efficient use of SAR data in conjunction with the output of the numerous sensors envisioned for the Eos program, which is planned for the latter half of the 1990s.

The specific SAR satellites that will provide data to the ASF receiving station at the Geophysical Institute, University of Alaska–Fairbanks are the ESA ERS-1 (launch in spring 1991), the Japanese ERS-1 (launch in 1992), and the Canadian Radarsat (launch in 1994).

The following ASF projects have been conducted since the last report in this journal:

- The receiving ground station component of the ASF was successfully tested under a wide range of environmental conditions, including temperatures down to -52°C. One result of this testing has been an effective delineation of the station mask based on the reception of transmissions from existing satellites orbiting at comparable altitudes.
- The ASF Science Plan was completed; copies can be obtained by writing to the Director, ASF, Geophysical Institute/UAF, Fairbanks, AK 99775-0800.
- Final software and interface testing of the SAR Processor System (SPS) and the Archive and Operations System (AOS) is in progress at the Jet Propulsion Laboratory, with shipment to ASF expected during the early spring of 1990.
- A critical design review of the Geophysical Processor System (GPS) has been completed, as have extensive discussions between the GPS team and a group representing the scientific user community. Delivery of the GPS to Alaska is currently anticipated for the early fall of 1990.
- The primary components of the Interactive Image Analysis System (IIAS) have been installed at ASF and are currently receiving heavy use in a variety of image analysis tasks, including studies of the Exxon *Valdez* oil spill in Prince William Sound. This system is essentially a clone of the GPS and is designed to provide offline analysis and software testing during routine operational use of the GPS.

At launch, the GPS will consist of the following subsystems:

1. An ice-motion tracker capable of a minimum throughput of 10 low-resolution image pairs per day. Ice motions will be sampled on the

FY 89 FUNDING (thousands)

Polar Ocean/Ice Sheets	7300
Land Processes	490
Solid Earth Science	1100
Atmospheric Sciences	900
Arctic Ozone	3500
Sounding Rocket Program	975
Dynamics Explorer	1300
Space Plasma Research	805
Solar Terrestrial Theory	390

SSM/I grid with a 5-km spacing. The registration accuracy is anticipated to be 300 m or better, with between 90 and 95 percent correct matches of the motion vectors. The initial search for matching floes will be aided by ice drift estimates based on empirical correlations with the velocity of the geostrophic wind. Testing of the code is currently in progress using both aircraft (C-band) and Seasat (L-band) imagery.

2. An ice classification procedure capable of a minimum throughput of 20 low-resolution image pairs per day. Again, the classification and ice concentration map will utilize the SSM/I grid with a 5-km spacing.

3. A wave spectra analyzer capable of a minimum throughput of 25 512 x 512 pixel subscenes per day taken from one high-resolution (1-look) image. The smoothed spectra will be used to calculate the wave direction and the wavelength of wave peaks. Pre-launch verification of the procedure will be made by using Seasat and SIR-B data, which, in turn, have been verified with buoy data.

All GPS products initially will be provided to the user as unverified products. A quantitative verification of the correctness of the output of the procedures will be the first priority after the launch of ERS-1.

In summary, the development of both the station and the science plan have proceeded well, and it is anticipated that the station will be fully operational by the launch date of ERS-1. (For further information, contact the Director, Alaska SAR Facility, Geophysical Institute, University of Alaska-Fairbanks, AK 99775-0800.)

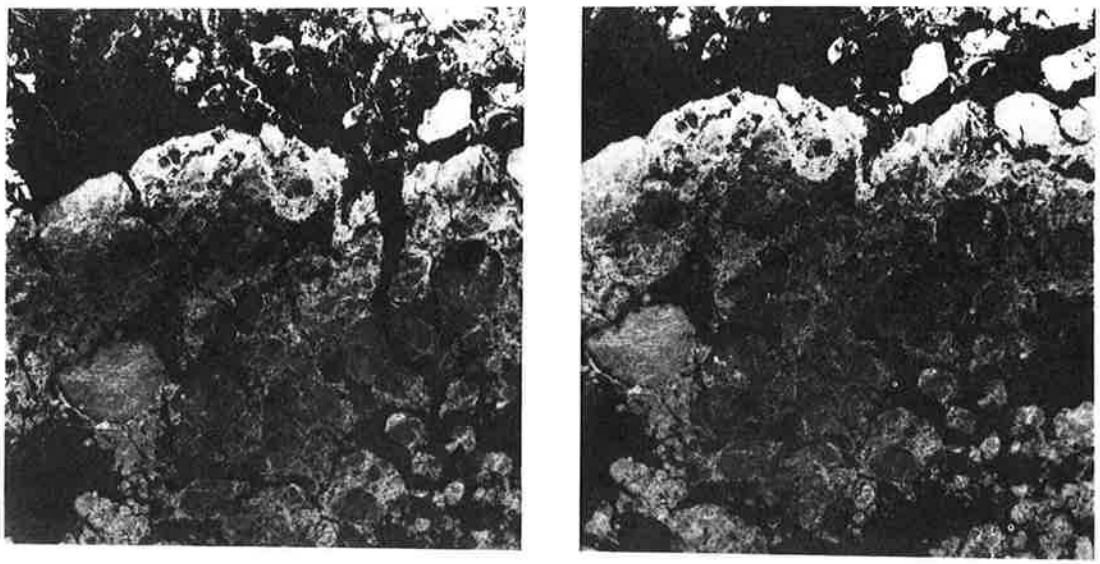
Radar Altimetry of Greenland Ice Sheet

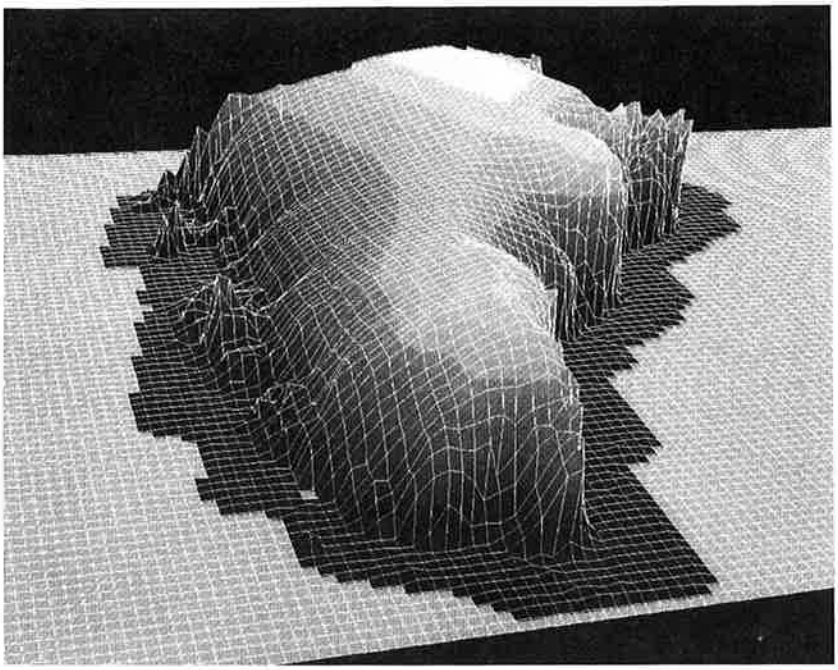
The program of processing radar altimeter data collected over the Greenland ice sheet by Geosat, Seasat, and Geos-3 has produced detailed maps of surface topography south of 72°N and information for studies of the ice sheet mass balance. Digital georeferenced data bases of all corrected elevations from Seasat and Geosat and gridded elevations on a 20-km grid are available on magnetic tape from NSIDC and NSSDC. The detailed surface topography defines the directions of ice flow and delineates the various drainage basins. Measurement of elevation change by satellite altimetry also offers a unique method of determining changes in ice volume and therefore the mass balance.

The mass balance of the Greenland and Antarctic ice sheets is of particular interest because of its direct relationship to global sea level and the possibility of enhanced ice-sheet melting in a warmer climate. At present, global sea level appears to be rising by 2.4 ± 0.9 mm/yr. Although both thermal expansion of the ocean and melting of small glaciers contribute to sea-level rise, the major source of water for the projected sea-level rise is often assumed to be the polar ice sheets.

Analysis of the ice-sheet elevations from Geos-3, Seasat, and the first 18 months of Geosat show that the southern 40 percent of Greenland has been growing. Vertical velocities of the surface are determined from measured changes in surface elevations at 256,694 intersections between paths of Geosat

Time-sequential image pair (separated by 3 days) acquired by Seasat during revolutions 1409 and 1452.





Three-dimensional surface elevation map of southern Greenland (60° N to 72° N) from Geosat radar altimetry. Surface slope indicates the direction of glacier flow.

during a 548-day period in 1985 and 1986, and from 5096 intersections between Geosat paths in 1985 and Seasat paths in 1978. Although the standard error at a single crossover is about 1.4 m, the error of the mean regional difference is only a few centimeters. The average of all measurements between 60°N and 72°N shows an increase of 0.20 ± 0.08 m a year from 1978 to 1985 and 0.27 ± 0.02 m a year during 1985 to 1986. Analysis by elevation bands indicates that the surface elevation increased in both the area of net annual ablation below about 1200 m and the area of net annual accumulation at higher elevations. For both periods, the spatially averaged increase in surface elevation is 0.23 ± 0.04 m a year. The results in sea-level equivalent are a global sea-level depletion of 0.2 to 0.4 mm a year.

Polar Microwave Brightness Temperatures

The National Snow and Ice Data Center (NSIDC) is distributing the NIMBUS-7 Scanning Multichannel Microwave Radiometer (SMMR) brightness temperature grids for the North Polar region on CD-ROM. The first CD-ROM in the series contains grids for the period October 29, 1978, through January 31, 1980. Approximately five subsequent CD-ROMs will contain the Northern Hemisphere grids for February 1, 1980, through mid-August 1987, when the SMMR became inoperative. Following completion of the North Polar region series, South Polar region grids will be mastered on CD-ROM as well.

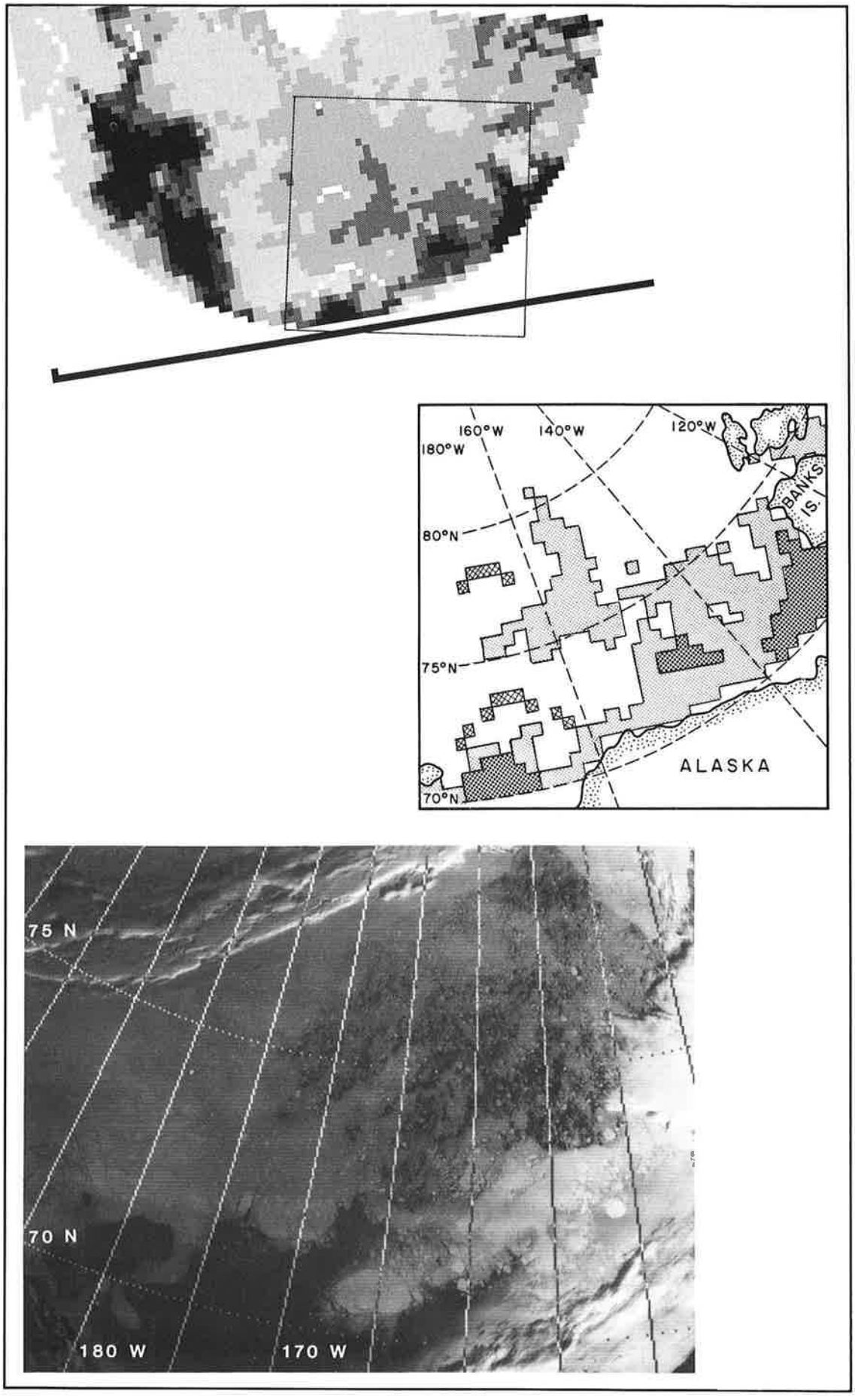
In addition to the brightness temperatures from each of the five dual-polarized SMMR channels, the CD-ROM contains a landmark, a coastal outline map, latitude and longitude pairs which provide georeference for each SMMR grid cell, sensor and grid documentation, and bibliographic references. Two floppy diskettes accompany the CD-ROM distribution. The diskettes contain a suite of software designed to extract individual channels from the archive files residing on the CD-ROM and to derive daily ice concentration grids. They also contain an image display package, IMDISP, designed by NASA's Planetary Data System. IMDISP is used on personal computers and supports CGA, EGA, and VGA graphics adapters.

NSIDC has been funded by the NASA Polar Oceans Program to develop a computer-based Cryospheric Data Management System (CDMS). The CDMS design aims to provide a single focal point for snow and ice data sets. It is an enhanced version of the NASA Jet Propulsion Laboratory's (JPL's) NASA Ocean Data System (NODS) designed for archiving of SSM/I data and production of cryospheric data sets.

In June 1987, the Defense Meteorological Satellite Program (DMSP) successfully launched the Special Sensor Microwave Imager (SSM/I). The SSM/I is a high-resolution microwave imager that will provide near real-time microwave data on sea ice, atmospheric moisture and precipitation, soil moisture, and ocean parameters. The instrument operates at four frequencies: 19.3, 22.2, 37.0, and 85.5 GHz. Vertical and horizontal polarizations are provided for each frequency except the 22.2 GHz channel, which has only vertical polarization. The resolution of the SSM/I sensor footprint ranges from a coarse 70 x 45 km for the 19.3 GHz channel to a high of 16 x 14 km for the 85.5 GHz channel. The satellite orbital characteristics permit daily global coverage with repeat coverage possible every 12 hours because of the orbital overlap.

SSM/I orbital swath data are being gridded into brightness temperature grids for the polar regions. NODS has processed SSM/I data for the period June 20, 1987, through May 15, 1988. NSIDC has assumed responsibility for the archiving and production of the gridded data for the polar regions for the period after May 15, 1988. The two archives were merged into a single archive at NSIDC in September 1989. In addition to delivering the processed SSM/I data, NODS representatives delivered the final version (3.6) of the NODS software.

Quality control became an important component of the SSM/I archival operations at NSIDC in 1989. Geolocation has been an enigma to users of SSM/I passive microwave data. The



Low ice concentrations in the Canada Basin shown by SSM/I data. At top left is a mean SSM/I ice concentration field from 78–84° N and 90° E eastward to 90° W based on data for 1, 3, 5, and 7 September 1988. The five gray levels from black to the lightest indicate ice concentrations from 0 to 20 percent (mostly open water) through 80 to 100 percent, with unshaded areas indicating missing data. An extensive area with ice concentrations less than 60 percent is depicted in the Canada Basin. Low concentration area is shown in the visible-band DMSP OLS scene for 2 September 1988 (bottom left).

NASA SSM/I Sea Ice Algorithm Working Group (SSIAWG) agreed to accept the corrections proposed by Dr. Calvin T. Swift at the University of Massachusetts. The corrections assume the geolocation error is associated with an error in the attitude of the DMSP spacecraft. Coefficients, which are latitude- and time-dependent, are derived using 15 islands at various latitudes to locate the SSM/I pixels. The derived coefficients are then used to derive the small angle approximations for both cross-scan and along-scan shifts due to pitch, roll, and yaw of the spacecraft. These adjustments are applied to the SSM/I prior to gridding the orbital data for the polar regions. Another quality control measure is to filter data from the archive where values are determined to be unrealistic. Erroneous SSM/I TB values range from 0 to 650 Kelvins. (For further information contact Ron Weaver, NSIDC, Campus Box 449, University of Colorado, Boulder, CO 80309. Phone: (303) 492-7624.)

Solid Earth Science

Each summer since 1984, the NASA Crustal Dynamics Project (CDP) has performed a series of geodetic measurements in Alaska and western Canada to better understand the subduction of the Pacific plate underneath the North American plate on the southern coast of Alaska and in the Aleutian Islands. For these measurements, the CDP has used the radio astronomy technique known as Very Long Baseline Interferometry (VLBI). VLBI measurements require radiotelescopes and sophisticated electronics to record wideband noise emitted continuously by quasars at the far reaches of the universe. When this noise is received simultaneously at each of the telescopes, timing data accurate to about 30 picoseconds (the time it takes light to travel one centimeter) can be derived. Such timing data acquired over a day can in turn be used to measure the baseline between the telescopes to an accuracy of about 1 cm, even when the telescopes are separated by thousands of kilometers.

The VLBI data for these locations show that significant crustal motions (measured with respect to Fairbanks in the Alaska interior) are occurring, indicating the buildup of strain to be released in earthquakes.

The CDP's Alaska/Canada VLBI measurement program uses a large (25-m diameter) radiotelescope located near Fairbanks and a smaller (3-m diameter) mobile VLBI system, which has been taken to several sites of geophysical interest. Two of these sites (Sand Point in the Shumagin Islands and Cape Yakataga in the southern coast of the Alaskan mainland) are in seismic gaps—areas that are long overdue for a major earthquake. A site on Kodiak Island is in the area that saw massive damage from the magnitude 8.3 earthquake in 1963. All three locations are in the subduction zone where the North American plate is overthrusting the Pacific plate. The VLBI data for these locations show that significant crustal motions (measured with respect to Fairbanks in the Alaska interior) are occurring, indicating the buildup of strain to be released in earthquakes.

The southern part of Alaska has been built up over millions of years by plate tectonics; the motion of the Pacific plate has carried islands and continental "slivers" (known as terranes) northward and built hundreds of kilometers of Alaska. The VLBI site at Cape Yakataga is on the Yakutat terrane, which is now being "plastered" onto Alaska. At this site, VLBI has measured motions of 34 mm a year (two-thirds the total rate of Pacific plate motion). Two magnitude 7.6 earthquakes occurred in the Gulf of Alaska about 100 km south of Cape Yakataga in the winter of 1987-88. VLBI measurements the following two summers showed that the earthquakes had caused the terrane to deform elastically, amounting to 8 cm of motion at Cape Yakataga.

In addition to the coastal sites, the mobile VLBI system has made similar measurements at three interior locations—Nome and Sourdough in Alaska and Whitehorse in the Yukon. Since these three sites plus the Fairbanks base station are far from the subduction region and active faults, they provide geodetic control information to define the "stable" interior of Alaska.

Atmospheric Chemistry

Trace Gas Fluxes

In 1989, NASA selected a second round of projects to advance research on complex questions of global change under its Interdisciplinary Research Program. One of the three topic areas solicited was trace gas fluxes from ecosystems and their fate in the troposphere. This topic was selected to continue and expand the highly successful methane program initiated in the first

round of interdisciplinary research. The new research is directed at understanding the origins and consequences of increasing atmospheric concentrations of radiative trace gases, particularly methane and nitrous oxide. Several studies focusing on emissions from northern and Arctic ecosystems were selected. Investigators are measuring fluxes from wetlands and forests to monitor seasonal variations in methane fluxes. Others are studying the controls on trace gas emissions. One study is using remote sensing and a stratified sampling approach to calculate regional methane inputs to the atmosphere. These studies will be important in assessing the role of atmospheric methane in future climate modifications.

The chemical composition of the Arctic winter stratosphere was found to be highly perturbed in a manner very similar to that found in the Antarctic, with highly elevated abundances of active chlorine (CIO) and significant reductions in inactive chlorine reservoir compounds.

Arctic Ozone

The NASA Upper Atmosphere Research Program continues to conduct a comprehensive program of research aimed at expanding knowledge about the chemistry and meteorology of the Earth's stratosphere, with an emphasis on processes that control the distribution of stratospheric ozone. As reported previously (*Arctic Research of the United States*, Volume 3, Spring 1989, p. 61), in January and February 1989, a major airborne measurement campaign was conducted from Sola Airfield, Norway, to examine the Arctic winter stratosphere. The goal was to establish whether the processes that contribute to the springtime Antarctic ozone depletion are operative in the Northern Hemisphere. The Airborne Arctic Stratospheric Expedition (AASE) was carried out in part because of the findings of NASA's Ozone Trends Panel, which concluded that over the 17-year period from 1969 to 1986, total column ozone at high latitudes had undergone a statistically significant decrease during the winter months. This change was outside the range of natural geophysical variability and was larger than predicted by model calculations of the effects of increased atmospheric abundance of trace gases.

NASA's DC-8 and ER-2 aircraft each made 14 flights into the Arctic vortex, during which 23 instruments monitored chemical and meteorological variables. The aircraft measurements were complemented by balloon-sonde ozone and temperature data at several different Arctic locations throughout the mission. Key findings from this field campaign have contributed to a better understanding of the interplay between chemistry and dynamics in the Arctic polar stratosphere. In short, the chemical composition of the Arctic winter stratosphere was found to be highly perturbed in a manner very similar to that found in the Antarctic, with highly elevated abundances of active chlorine (CIO) and significant reductions in inactive chlorine reservoir compounds. The observations indicate the importance of heterogeneous chemistry occurring on the surfaces of polar stratospheric clouds (PSCs) in both hemispheres. No unambiguous evidence for chlorine-catalyzed ozone loss has yet been identified for the Arctic winter of 1989. Readily detectable ozone reductions would be expected to occur only if high concentrations of CIO were maintained for sufficiently long periods in cold illuminated air. Vortex dynamics during the 1989 winter probably limited these conditions and are likely to do so in most Northern Hemisphere winter and spring seasons. Thus, the Northern Hemisphere ozone trends cannot be unambiguously identified with PSC chemistry, although the observations are qualitatively consistent with such an explanation.

Department of Commerce

National Oceanic and Atmospheric Administration

NOAA performs research in the high-latitude regions of the planet in connection with its environmental monitoring and prediction responsibilities. Individual research programs focus on scientific questions addressing the Arctic environment and its relation to the global environment. NOAA also conducts research in support of services it performs, such as weather forecasting and fisheries management. Funding totaled $9.8 million in Fiscal Year 1989.

Meteorology, Climate, and Air Quality

Geophysical Monitoring at Remote Polar Sites

At the Geophysical Monitoring for Climatic Change (GMCC) observatories of NOAA's Climate Monitoring and Diagnostics Laboratory (Boulder, Colorado), measurements of atmospheric trace constituents are taken to identify 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 studies indicate that concentrations of CO_2 and CH_4 in Arctic haze layers are elevated with respect to background levels. Carbon dioxide and CH_4 concentrations are highly correlated throughout the Arctic atmosphere. The high correlation and the association with haze layers suggest a common anthropogenic source for these gases and subsequent transport into the Arctic. The CH_4/CO_2 ratios may provide a method for estimating the as-yet poorly quantified fossil fuel CH_4 source.

FY 89 FUNDING (thousands)

Arctic Haze	400
Atmospheric Trace Constituents	180
Climate Modeling	200
Environmental Prediction	260
Fisheries Assessment	2100
Marine Mammal Assessment	1200
Sea Grant	263
Ocean Assessment	70
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Analysis of concurrent measurements of CO_2, CH_4, and aerosol black carbon at Barrow, Alaska, revealed periods, not influenced by local activities, when concentrations of all three species are elevated and highly correlated. The black carbon/CO_2 ratios are consistent with fossil fuel combustion, providing further evidence for transport of anthropogenic effluents from lower latitudes into the Arctic. The CH_4/CO_2 ratios are consistent with those found throughout the Arctic by aircraft sampling and suggest a fossil fuel source of CH_4 to the Arctic.

Cooperative Arctic Buoy Program

The Cooperative Arctic Buoy Program is managed by NOAA's Office of Climate and Atmospheric Research (OCAR), in Silver Spring, Maryland, with contributions from the Canadian Atmospheric Environment Service, the Norwegian government, the U.S. Department of Interior, and

NOAA. The program seeks to accomplish the following.

- Measure and archive the pressure field, ice velocity, and their year-to-year variations;
- Investigate the relationships between the 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 (JIC) 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 network has grown from 15 to nearly 50 in 1988 and 1989, the last year of the program. Although further funding is in question, some buoys will continue to operate perhaps into 1991. 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.

Climate and Global Change

OCAR is responsible for coordinating and implementing the focused NOAA activities within the U.S. Global Change Research Program, including all U.S. activities in the Tropical Oceans/ Global Atmosphere Program. OCAR develops, manages, and coordinates projects of atmospheric, oceanographic, and climatic research that are largely interagency or international in scope.

In FY 89, OCAR provided support for researchers from the University of Colorado to acquire, assimilate, and analyze a historical Arctic data set including temperature, moisture, and wind-sounding data northward of 65°N. A major product of this research will be an evaluation of temperature trends over the past 30 to 50 years throughout the Arctic troposphere and lower stratosphere.

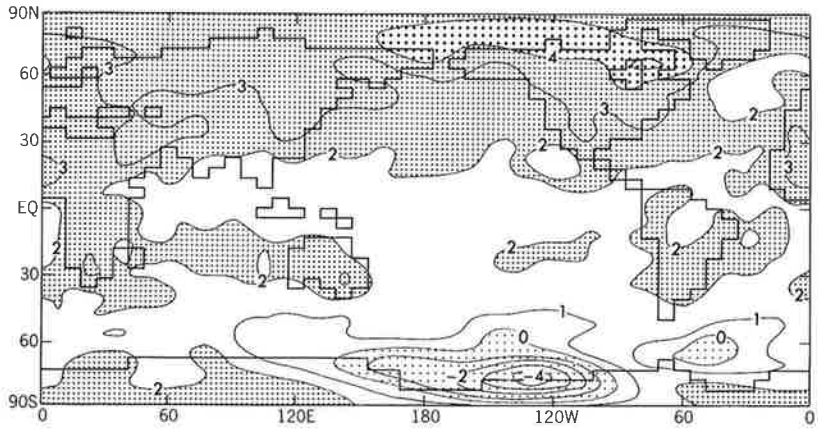
Another project supported by OCAR in 1989 focused on developing a capability at the National Snow and Ice Data Center of the University of Colorado for researchers to access the data stream from the Digital Ice Forecasting Analysis System (DIFAS) of the JIC. The DIFAS system for the first time electronically combines satellite imagery and National Weather Service observed and forecast atmospheric fields with various other ice and oceanographic data fields. Researchers will use these data to improve modeling and prediction of changes in ice-atmosphere interactions. An initial project will be to analyze Arctic sea ice variability since 1953, its relation to atmospheric and oceanic forcing, and its potential effects on ocean deep water formation through brine rejection and ocean stability.

Climate Modeling

A new-generation climate model at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) has been used to examine the influence of ocean currents on the response of the climate to gradually increasing greenhouse gases. With worldwide interest in this problem increasing, this is the first model to address the problem in this manner.

Of particular relevance for higher latitudes, the new GFDL model indicates the possibility of a major north-south asymmetry in the climate warming response. Specifically, the model predicts that, over the next century or so, the higher latitudes of the Northern Hemisphere are expected to experience a surface warming to exceed that of the global average by a factor of 2 or more. This result is generally consistent with previous "no-ocean" models.

The new model indicates that the higher latitudes of the Southern Hemisphere will not warm in any significant way over the next century, owing to upwelling and intense vertical mixing in the Antarctic circumpolar ocean. These processes act to dilute the greenhouse signal by distributing it through a significant depth of the ocean thermal reservoir. This model result raises new sets of questions on details of high-latitude responses to increasing greenhouse gases.



Output from new-generation climate model developed by NOAA's Geophysical Fluid Dynamics Laboratory shows projected surface temperature changes with an increased concentration of atmospheric CO_2.

Arctic Boundary Layer

NOAA researchers are applying observational results and modeling techniques to improve the

understanding of the atmospheric boundary layer. The objective of the NOAA effort in the Coordinated Eastern Arctic Experiment (CEAREX) during 1988-89 was to collect a comprehensive high-Arctic meteorological data set covering fall through spring. The regional pressure gradient was determined from drifting buoys, while radiation, atmospheric soundings, and near-surface wind and temperature profiles were measured from a drifting ship and ice camp. During spring 1989, two flights were made over the ice camp with the NOAA P3 research aircraft, providing detailed observations of the vertical variation of turbulence, wind, and temperature.

A regional atmospheric model is being developed, capable of improving ice forecasting and climate models by including the low-level temperature inversion structure found in the Arctic in winter. This inversion structure can almost decouple ice motions from atmospheric motions during clear sky conditions.

Arctic Gas and Aerosol Sampling

The third field campaign of the Arctic Gas and Aerosol Sampling Program (AGASP), involving intensive airborne research, was successfully conducted in the Norwegian Arctic, March-April 1989. Representing five countries, the participants came from three NOAA labs, three national labs, nineteen universities, and NASA. The NOAA WP-3D aircraft was flown from Bodo, Norway, to study two separate Polar Low systems that developed in the Greenland Sea, the transfer of energy from the atmosphere to the ice over permanent pack ice north of Spitsbergen, the transfer of wind and heat energy along the ice edge, and Arctic haze (air pollution) and solar radiation distributions east of Spitsbergen. The flights were coordinated with surface measurements at the Ny-Alesund (Norwegian) baseline station on Spitsbergen and the Office of Naval Research (ONR) CEAREX "O" and "A" ice camps northwest of Svalbard.

AGASP scientists continued their study of the photolytic destruction of tropospheric ozone in the Arctic spring boundary layer. One finding suggests that the bromine molecule involved in the ozone destruction reaction may originate under the ice and be released to the atmosphere as bromoform and bromodichloromethane. A marine or ice alga may be responsible.

From aircraft data on these flights, it was observed that the ozone destruction phenomenon may be capped by a temperature inversion as small as 0.2°C. Ozone destruction was not observed in the marine boundary layer over open water, even on days when such destruction was observed 100 km further north over the Arctic ice pack.

Along with scientists from NOAA's Wave Propagation Laboratory (WPL), the University of Washington, the Naval Postgraduate School, and ONR, AGASP scientists are actively planning for a major ONR-supported Arctic research program in spring 1992, namely, the Arctic Leads Experiment (LEADEX). The objectives

AGASP—Polar Lows—CEAREX crew and scientists from the NOAA WP-3D aircraft, Bodo, Norway, April 1989.

of the LEADEX program are to understand winter leads in the central Arctic in terms of the dynamics of the coupled atmospheric-oceanic boundary layers, including local ice production processes, the relationship and scale dependence between external stress fields and the deformation and fracture of ice, and the net effect of leads on regional atmospheric-oceanic properties. Field and laboratory experiments will be used to determine relevant dynamics and refine models.

Although no unequivocal signature of photochemical loss of Arctic ozone was identified by the end of the mission, a considerable portion of the vortex air was "primed" for ozone destruction.

AGASP scientists will be involved in surface gas and aerosol measurements around the leads, energy flux measurements over the leads, and an airborne program to determine the synoptic-scale aspects of lead-atmosphere-ice interactions.

Arctic Observations of Stratospheric Chemistry

The substantial depletion of Antarctic ozone over about the past 10 years has focused attention on stratospheric photochemistry in polar regions. Scientists from NOAA's Aeronomy Laboratory participated in airborne and ground-based campaigns that demonstrated how photochemical reactions involving chlorine-containing species are largely responsible for the depletion of Antarctic ozone. Following a ground-based stratospheric sampling program in the Arctic in 1988, the multiagency (NOAA, NASA, National Science Foundation, Chemical Manufacturers' Association) international Airborne Arctic Stratospheric Expedition was conducted in 1989 to establish whether the processes that contribute to the Antarctic ozone depletion are operative in the Northern Hemisphere (see the NASA article, p. 63). The specific goals were to study the production and loss mechanisms of ozone in the north polar and subpolar stratospheric environment and study the effect on ozone distribution of the Arctic polar vortex and of the cold temperatures associated with the formation of polar stratospheric clouds.

The campaign was based in Stavanger, Norway, and used two aircraft: a high-altitude ER-2 and a modified DC-8, both equipped with state-of-the-art instrumentation for determining the chemical composition and physical state of the atmosphere. Twenty-eight flights, as far north as the Pole and as far as the west coast of Greenland, were flown during the Arctic winter in January–February 1989.

Data from the expedition are still being analyzed, but preliminary findings indicate that the chemical composition of the Arctic polar stratosphere was highly perturbed: chlorine monoxide and chlorine dioxide abundances were elevated, the inactive chlorine reservoir was decreased, and nitrogen compounds were reduced. These perturbations occurred over a wide range of altitudes in the stratosphere and, because the meteorological conditions were not grossly unusual, they are expected to occur in most years. Although no unequivocal signature of photochemical loss of Arctic ozone was identified by the end of the mission, a considerable portion of the vortex air was "primed" for ozone destruction.

The first formal refereed publications from the Airborne Arctic Stratospheric Expedition are in the March 1990 special issue of *Geophysical Research Letters.*

Marine Observation and Prediction

The Freeze Experiment

The Freeze Experiment was begun in the autumn of 1987 to investigate the finescale and mesoscale processes associated with ice formation over the western Arctic shelves and their relation to the regional dynamics and thermodynamics. A combination of current meter and pressure gauge moorings is being used to estimate dynamical effects; drifting ice buoys to trace ice motion and ice edge advance; and conductivity, temperature, and depth (CTD) surveys to map heat and salt distributions prior to and during initial fall freeze-up. *Autumn 1988 proved notable for its extreme ice extent, the greatest in the 35 years of modern observations.* Together with the measurements from the anomalously warm 1987–88 season, the recent surveys provide an unparalleled view of modern western Arctic ice extremes. In 1989, instruments moored the previous year were recovered, and the hydrography of the eastern Bering Sea shelf was extensively surveyed with CTD stations.

Beaufort Sea Mesoscale Circulation

The study of circulation in the Beaufort Sea, sponsored by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) and

conducted by NOAA's Pacific Marine Environmental Laboratory, has been completed. Approximately 40-50 m below the ocean surface the major circulation feature of the outer shelf and slope is the Beaufort Undercurrent, a strong flow generally directed eastward but subject to frequent reversals toward the west. These reversals are normally accompanied by upwelling onto the outer shelf. The undercurrent is very likely part of a basin-scale circulation within the Arctic Ocean.

While the influence of wind on subsurface flow in the southern Beaufort Sea is statistically significant, it generally accounts for less than 25 percent of the flow variance below 60 m. Therefore, below the mixed layer, circulation on the relatively narrow Beaufort shelf is primarily forced by the ocean and not by the local wind.

There are large changes in wind variance with season, the largest variance occurring in late summer and early autumn. January also shows large variance because blocking atmospheric pressure ridges in the North Pacific shift the storm track westward over the west coast of Alaska and across the North Slope. Despite the seasonally varying wind field and the large seasonal differences in the upper ocean temperature and salinity fields, there is no evidence for seasonal variability in the subsurface circulation. This situation contrasts with that in the Bering Strait,

While the influence of wind on subsurface flow in the southern Beaufort Sea is statistically significant, it generally accounts for less than 25 percent of the flow variance below 60 m. Therefore, below the mixed layer, circulation on the relatively narrow Beaufort shelf is primarily forced by the ocean and not by the local wind.

and probably also in much of the Chukchi Sea, where a seasonal wind-driven cycle in the transport is readily apparent.

During 1986-87, the Beaufort Undercurrent appears to have been anomalously deeper by 30 to 40 m. The consequences of such anomalies are significant for the upper ocean velocity structure and transport. Both 1986 and 1987 were warmer than normal, with less coastal ice in the summer and autumn and more storms passing along the west coast of Alaska and across the North Slope. These climatological near-minimum ice years were followed in 1988 by the heaviest summer ice along the Chukchi coast since 1975.

Greenland Sea

As a major site of deep water formation, the Greenland Sea is a window on the deep world ocean through which must pass both indicators and agents of climatic change. Vertical circulation (convection) and water mass transformation in the Greenland Sea are being studied by NOAA's Pacific Marine Environmental Laboratory as part of the International Greenland Sea Project.

During 1988-89 the laboratory deployed long-term moored instrumented arrays and also participated in seasonally repeated hydrographic censuses that were highly accurate. Preliminary examination of the hydrographic data suggests that during 1988-89 the upper 2 km of the ocean were successfully ventilated, following several years of little, if any, deep convection.

Two new instrumented arrays were deployed in 1989 to monitor the southwestern part of the Greenland Sea, where recirculation from the East Greenland Current appears to provide fresh water to the convective gyre. This is significant because the gyre is apparently rather delicately poised with respect to its ability to sustain convection, so that small variations in the freshwater supply can alter or stop the convection.

Sea Ice Forecasts and Modeling

As a major step in improving forecasts of coastal sea ice motion around Alaska, Pacific Marine Environmental Laboratory scientists are expanding the existing one-dimensional coastal sea ice-barotropic ocean model to two dimensions, conforming with the topography of the western Arctic shelves. The new model has nominal 18-km grid spacing, employs the ice thickness and strength relation developed for the one-dimensional model, and retains both the barotropic and wind-driven forcing critical to ice motion on these shelves.

The effects of different lateral boundary conditions are being examined, and a sensitivity study of the various model parameters is being performed. The model is expected to lead to a full forecasting capability for the Navy-NOAA Joint Ice Center (JIC) in 2 to 3 years.

Vessel Icing

At high latitudes, spray generated by ships in heavy seas can freeze to vessel structures, producing an extreme hazard. The NOAA vessel icing forecast algorithm has been evaluated against current understanding of the icing process and

against recent operational experience. The NOAA algorithm showed excellent results when compared with a new cold-weather data set from the Labrador Sea and provided excellent forecasts to more than 140 fishing vessels in Alaskan waters during January 1989, the worst icing episode of the decade.

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Ocean Assessment

Outer Continental Shelf Environmental Assessment Program

OCSEAP was established by means of an interagency agreement between the Minerals Management Service (MMS) of the Department of Interior and NOAA. OCSEAP is a multidisciplinary environmental studies program that provides MMS and other agencies with scientific data. The agencies can then formulate leasing decisions and develop management strategies to avoid potentially undesirable environmental effects of oil and gas development on Alaska's outer continental shelf. In addition, field studies provide needed new information, and existing information is synthesized so that it can be applied more effectively to assessment and management needs.

In recent years, major OCSEAP studies have been designed to describe ocean circulation and cross-shelf exchange of properties along the continental shelf break in the eastern Bering Sea, to determine the effect of the Exxon *Valdez* oil spill on the viability of eggs and larvae of Pacific herring in Prince William Sound, to describe early life histories and habitat relationships for major finfish and shellfish in the southeastern Bering Sea, to document behavioral responses of Pacific salmon during spawning migration to very low (parts per billion) concentrations of the water-soluble fraction of petroleum, to assess fishery resources of the northeastern Chukchi Sea, to formulate numerical models of lagoonal ecosystems in the Arctic, and to delineate migratory corridors and stock composition of Arctic char and Arctic cisco along the Beaufort Sea coast.

In 1989, OCSEAP, with contributions from other agencies, produced a three-volume climatic atlas of the seas around Alaska. The atlas provides tabular and graphical presentation of data on 23 different climatologic and oceanographic properties and derived parameters.

OCSEAP maintains an extensive marine environmental data base, encompassing more than 15 years of multidisciplinary research on the Alaska outer continental shelf. Recently published synthesis reports have summarized information from OCSEAP-supported studies (and other sources) for the Chukchi and Beaufort seas. A regularly updated bibliography of about 5000 OCSEAP-supported publications is also available (Alaska Office, NOAA Ocean Assessments Division, P.O. Box 56, Anchorage, AK 99513).

Marine Mammal Tissue Archive

NOAA, in collaboration with the National Institute for Standards and Technology (NIST), has designed and implemented a protocol to collect and preserve tissue samples from Alaskan marine mammals. These samples are stored at the National Biomonitoring Specimen Bank as reference material for use as a contaminant baseline for analysis in the future. Samples are collected from animals harvested by Alaskan natives for subsistence use. Liver, blood, fat, kidney, and bile samples have been collected from northern fur seals, ringed seals, bearded seals, and beluga whales. A fraction of the preserved material is occasionally analyzed for selected contaminants (metals, pesticides, PCBs, and aromatic hydrocarbons) to ensure that the materials are adequately preserved and stored.

National Status and Trends

The National Status and Trends Program for Marine Environmental Quality was formed in 1984 to monitor spatial distributions and long-term temporal trends of contaminant concentrations in U.S. coastal and estuarine regions and biological responses to that contamination. A broad suite of contaminants is measured periodically in sediments, bivalve mollusk, and fish tissue samples from selected stations around the U.S. coast. As of 1989, nine Alaskan sites had been sampled, including five in the Bering, Chukchi, and Beaufort seas.

The sediments and tissue samples are analyzed for polynuclear aromatic hydrocarbons (PAHs), PCBs and other chlorinated hydrocarbons, and toxic metals. Fish tissues have also been examined for petroleum-metabolizing

enzymes (aryl-hydrocarbon hydroxylase), petroleum metabolites in bile, pollutant adducts of DNA in liver tissue, and histopathological conditions. These procedures are carried out according to documented requirements for quality assurance of sampling and chemical analysis. Repeated sampling at these and other Alaskan coastal sites will allow comparisons of Arctic marine environmental quality with other U.S. coastal sites and evaluation of long-term trends in marine environmental quality in Arctic coastal areas.

Strategic Assessments

Regional strategic assessment atlases have been designed to summarize and communicate diverse and often complex information about the U.S. coastal zone to support informed coastal resource management decisions. The *Bering, Chukchi, and Beaufort Seas Data Atlas* (BCB Atlas), with 107 maps, appeared early in 1989, the third in a series. The atlases present information on six general themes: physical environments, biotic environments, living marine resources, economic activities, environmental quality, and jurisdictions. The atlases include regional maps that illustrate patterns of distribution, abundance, and use for coastal resources; descriptive text on selected themes; and graphic illustrations that summarize important data trends and patterns. The BCB Atlas emphasizes living marine resources of the Arctic, with over 80 detailed maps in this category.

The BCB Atlas was designed and formatted from its inception to be placed in digital form for computer mapping and analysis. The data are evaluated, interpreted, and compiled in a series of data bases organized so that comprehensive analyses can be made on specific estuarine, coastal, oceanic issues, and related assessment products concerning environmental quality and use of resources.

A detailed data base describing the relative abundance and distribution of marine species over time, space, and life history is now operational for many U.S. coastal regions, including the Bering, Chukchi, and Beaufort seas. The information can be accessed through the Computer Mapping and Analysis System for Living Marine Resources (Cmas). Cmas allows rapid, user-friendly manipulation and synthesis of the data base to provide comparisons and statistical analyses of the characteristic seasonal habitats and behaviors of marine species. The Bering, Chukchi, Beaufort seas module contains information on 102 marine species: 37 invertebrates, 21 fishes, 31 birds, and 13 mammals. For more information, contact the Strategic Assessment Branch (N/OMA31), Ocean Assessments Division, NOAA, Rockville, MD 20852.

Fisheries

Arctic Marine Mammals

NOAA's National Marine Mammal Laboratory at the Alaska Fisheries Science Center in Seattle, Washington, is conducting long-term research on the population biology and ecology of Steller sea lions, northern fur seals, and bowhead whales in the western North American Arctic. Research in 1989 was conducted jointly with the Soviet Union under the U.S.-U.S.S.R. Environmental Protection Agreement (Project V—Marine Mammals) on Steller sea lions, and with Japan on northern fur seals.

During the past two decades, significant changes have been observed in the numeric composition of several vertebrate populations (birds, fishes, and marine mammals) in the eastern North Pacific and Bering Sea ecosystems. Apex predators such as the Steller sea lion and Pacific harbor seal have declined significantly, and the northern fur seal population on the Pribilof

Northern fur seals on Reef Rookery, St. Paul Island, Bering Sea, Alaska, July 12, 1988.

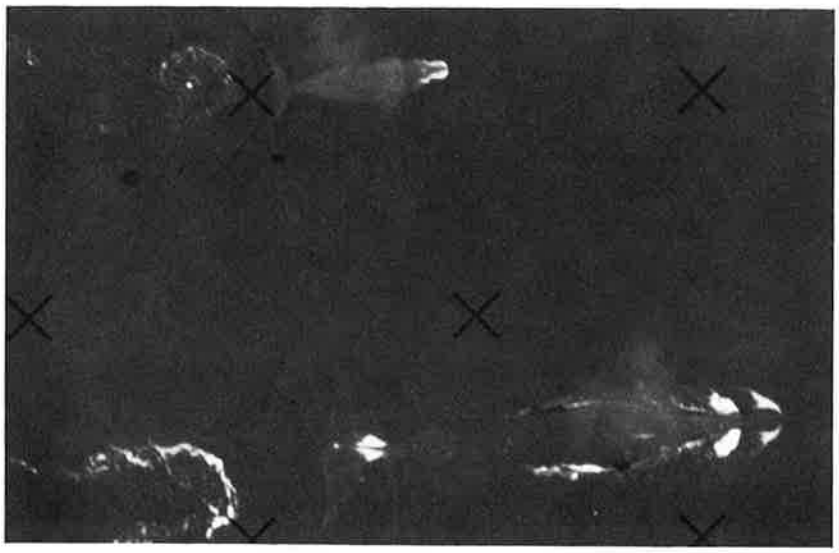
Adult Steller sea lion fitted with radio receiver for studies of feeding behavior and movements during breeding season.

Islands has declined by 60 percent since the 1950s. The causes for these declines have not been clearly identified, although the synergistic effects of commercial fisheries and changes in oceanographic and atmospheric conditions (for example, water temperature and storms) appear to be important.

The Steller sea lion population, from the western Gulf of Alaska to the western Aleutian Islands including the Bering Sea, where more than 70 percent of the species resides, has declined 63 percent in just 4 years; from 67,617 animals observed on land in 1985 to 24,953 in 1989—a reduction of 16 percent per year. Furthermore, since 1960, the population has declined 82 percent, a result of increased mortality of all sex and age classes and a reduction in pup production. Mass emigration is not a factor in the decline of the population in Alaska, because the number of sea lions in Soviet waters has also declined since about 1970, and no significant increase in the population has occurred in other areas of the species' range. Further work is needed to identify the locations and causes of mortality once the animals leave the summer breeding rookeries to feed at sea. The decline of the Steller sea lion throughout most of its range is significant because of the potential effect that human activities, including competition for available food resources, may be having. Because the species has declined to a fraction of its former size, the population has recently been listed as threatened under the Endangered Species Act of 1973.

Research on bowhead whales is conducted to assess the recovery of the population by studying recruitment, other life history events, and the catch by Alaska Eskimos. Recent modeling and sensitivity analyses of the catch history suggest that the current population is 24 to 66 percent of its initial size of 13,000 to 27,000 whales in 1848 (prior to commercial whaling).

Adult bowhead whale with calf off Point Barrow, Alaska. "X"s help standardize measurements of individual animals.



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 landings 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.), these data 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 3 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 mid-water trawls for semipelagic fish, and special-purpose sampling for eggs, larval and juvenile fish, and shellfish. Trawl and acoustics 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.

Results to date show large year-to-year changes in larval abundances and fisheries year-class strengths.

In 1989, the annual NMFS survey of the eastern Bering Sea from the Alaska Peninsula to 61°N latitude and out to the International Dateline was completed. The abundance and structure of pollock stocks in the deep Aleutian Basin were surveyed in conjunction with scientists from Japan and the Soviet Union.

Related Programs

Fisheries-Oceanography Coordinated Investigations

The Fisheries-Oceanography Coordinated Investigations (FOCI) program is an effort by NOAA scientists at the Pacific Marine Environmental Laboratory and the Northwest and Alaska Fisheries Center 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 to FY 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 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.

Results to date show large year-to-year changes in larval abundances and fisheries year-class strengths. In 1986 and 1987 the main larval patch remained in the coastal zone along the Alaskan peninsula, yet these fisheries year-classes will probably be poor. Mortality factors other than transport were critical. In 1985 and possibly 1988, both with strong fisheries year-classes, a stronger than normal estuarine flow kept the larvae in the vicinity of Kodiak Island. Larval mortality is approximately 10 percent per day. Analysis of data from 1988 and 1989 is addressing causes for mortality and whether there are critical life points for the larvae such as the time of first feeding.

During 1989 a numerical model was developed to examine the time-dependent dispersion of larvae. The model is used as a method of quantitatively combining physical oceanographic information from satellites and in-situ data with biological information on feeding and predation.

National Sea Grant College Program

NOAA's National Sea Grant College Program sponsors various fisheries and policy-related research and education projects within the university systems of Alaska and Washington. Arctic projects funded in FY 89 included

- The size at maturity of Alaskan red king crab;
- Relationships between otolith microstructure and important life history events of Pacific halibut;
- Ecology of yellowfin and flathead sole information, important to fisheries management;

- Recruitment fisheries oceanography of walleye pollock in the eastern Bering Sea;
- Long-term variation in growth and abundance of Bristol Bay sockeye salmon;
- Analysis of national fisheries management practices of major nations since the 1982 Convention on Law of the Sea, with attention given to conservation of shared stocks (for example, pollock in the Bering Sea) and jurisdiction over anadromous species that range beyond any single nation's exclusive economic zone (for example, North Pacific salmon); and
- As part of the McKernan Lectures in Marine Affairs at the University of Washington, a lecture and publication, *The Arctic in World Affairs*, by Oran R. Young, director of the Dartmouth Institute for Arctic Studies.

The APPRISE Study

The Association of Primary Production and Recruitment in Subarctic Ecosystems (APPRISE) program is a collaborative effort between the National Marine Fisheries Service, the Juneau Center for Fisheries and Ocean Science (University of Alaska), the Institute of Marine Science (University of Alaska), and the Oceanic Institute. APPRISE focuses on the association between primary production and the recruitment of commercially important species in a Subarctic ecosystem. The cooperating institutions have the technical ability to monitor the standing stock, rate processes, and other variables related to the dynamic process of larval survival. APPRISE seeks to define relationships between environmental factors and primary and secondary production as they affect the prey regime for recruitment of selected larval fish and shellfish. APPRISE is designed as a 5-year effort that will describe the association between various planktonic rate processes and optimal larval recruitment, the interannual variability of these associations, and how these associations relate to the physical characteristics of the environment in any given year. These definitions will provide a basis for predicting recruitment in a given year based on assessment of the measurable physical and planktonic conditions prevailing during critical periods. Such a predictive basis could apply to more extensive and less accessible Subarctic fisheries areas.

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-altitude upper atmosphere. These accompanying and higher energy 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, conductivity, and chemical composition.

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 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 monitoring 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 JIC is the only organization in the western world that provides global sea ice analyses and forecasts. Standard weekly analyses of Arctic and Antarctic sea ice conditions are distributed to government, military, university, research, private industry, and foreign interests.

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 Satel-

lite 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 was derived from the GEOSAT satellite until the sensor failed in late 1989. 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.

Bottom pressure recorders are located in 4000 m of water, approximately 200 miles (322 km) off the coast of Kodiak Island, and small tsunamis have been detected in 1987, 1988, and 1989.

Workstation technology developed by NOAA's Program for Regional Observing and Forecasting Services was introduced at the JIC in 1989. NOAA satellite image products and most meteorological fields from the National Meteorological Center and the Fleet Numerical Oceanography Center are being assimilated, displayed, and overlaid by the JIC's DIFAS. At present, the DIFAS is operating in a demonstration mode. The JIC is participating in the development of more accurate sea ice algorithms for the Special Sensor Microwave/Imager (SSMI) instrument, which is 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, along with the Advanced Very High Resolution Radiometer (AVHRR) aboard TIROS-N, 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 data to improve the sea ice analysis capabilities of the JIC in the Alaskan region (see the NASA article, p. 63).

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 the 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.

Tsunami Information

To provide timely and effective tsunami information and warnings to Pacific communities, the National Weather Service operates the Tsunami Warning System program. Seismograph and tide stations participate in the program. The Alaska Tsunami Warning Center in Palmer, Alaska, is operated for the protection of Alaska.

A research program is in place to monitor the Shumagin seismic gap for tsunami generation. Bottom pressure recorders are located in 4000 m of water, approximately 200 miles (322 km) off the coast of Kodiak Island, and small tsunamis have been detected in 1987, 1988, and 1989. These data are being used by academic scientists for model verification and development.

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 maintains a variety of Arctic and Antarctic environmental data sets. 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 AVHRR 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 JIC in Suitland, Maryland, is the largest single user of AVHRR imagery. NESDIS also recently began operational processing of the Defense Meteorological Satellite Program SSMI instrument data and will develop prototype ice edge products for the JIC.

NESDIS also operates the Satellite Search and Rescue System using emergency position location

instruments on the polar-orbiting spacecraft. The international program became operational in 1982 and saved more than 1000 lives in its first 5 years.

Publications

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

Carbon dioxide and methane in the Arctic atmosphere by T. J. Conway and L.P. Steele: Journal of Atmospheric Chemistry, no. 9, pp. 81-100, 1989.

Correlations among combustion effluent species at Barrow, Alaska: Aerosol black carbon, carbon dioxide, and methane," by A.D.A. Hansen, et al. Journal of Atmospheric Chemistry. no. 9, pp. 283-300.

Bulletin of the Ecological Society of America, vol. 70, no. 1, pp. 21-25, 1989; and *Polar Record*, first issue of 1990.

Summary Report 1988: Geophysical Monitoring for Climate Change, by J. W. Elkins and R. M. Rosson, eds.: Air Resources Laboratory, no.17, 1989.

Department of Agriculture

The U.S. Department of Agriculture was formally accepted as a member of the Interagency Arctic Research Policy Committee in 1989. The Department is reporting for the first time on research activities of four USDA agencies conducted in Alaska and responsible for funding of $3.9 million.

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 percent of this taiga forest is within the Arctic as defined by the Arctic Research and Policy Act (ARPA). Much of the remaining taiga forest is on sites with 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 interior Alaska's taiga is "warm," - 0.5 ^{o}C to -1.5 ^{o}C, and is thus especially susceptible to thaw caused by slight warming trends. Warming and thawing could have rapid consequences for slope stability, soil movement into streams, forest growth rates, species composition, forest flora and fauna, and landscape ecology. Alaska's elevational and latitudinal treelines also are expected to be sensitive indicators of global climatic change, as are terrestrial-aquatic ecotones and areas exposed by receding glaciers caused by global warming. The taiga is thus particularly appropriate for consideration in developing national and international research programs to monitor the environmental processes and rates that are important in evaluating possible climatic alterations. Forest Service research sites in the taiga, with documented research histories and long-term site integrity, should contribute useful research on national and circumarctic global change.

FY 89 FUNDING (thousands)

Forest Service	910
Agricultural Research Service	800
Cooperative State Research Service	1165
Soil Conservation Service	1033

Research Facilities

The Forest Service's Pacific Northwest Research Station conducts research in Arctic areas of Alaska from the Forestry 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. FSL's mission is to develop a multiresource 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 the protection and management of both disturbed and undisturbed taiga and associated environments.

Vegetation Classification

Work is nearly complete on a 10-year project, the Alaska Vegetation Classification System. The major objective of this project is to provide a common classification system to be used by all agencies and groups involved with vegetation inventory in Alaska. It already has received wide use. The system includes 75 color photographs, keys, descriptions of 169 vegetation types at the series level, and a listing of approximately 450 plant communities within the series. The final publication also will include a complete bibliography of related Alaskan reports, both published and unpublished. Support for this project and testing of preliminary versions has come from the Alaska Department of Natural Resources, the U.S. Fish and Wildlife Service, the Bureau of Land Management, and the National Park Service. In addition, many other resource agencies in Alaska have provided support and cooperation.

Long-Term Ecological Research

In the fall of 1987, an interdisciplinary group of University of Alaska-Fairbanks (UAF) and INF scientists received funding from the National Science Foundation to establish a long-term ecological research site in Bonanza Creek Experimental Forest (BCEF). This is one of 17 sites in the United States. Besides long-term monitoring of environmental, vegetation, and soil parameters, the BCEF project is investigating controls of forest succession on sites leading to productive stands of white spruce. This project continues the long-term INF research on floodplain succession on the Tanana River floodplain and upland succession studies following the 1983 Rosie Creek fire. The first summer's work (in 1988) concentrated on establishing two permanent weather stations in BCEF—in the upland and on the floodplain. Researchers also established research sites in four stages of succession of the floodplain and three in the upland, each replicated three times for a total of 21 research sites. In addition, baseline data on soils and vegetation were obtained at most of the sites. Activity in 1989 was concentrated on establishing one environmental monitoring site at each stage (7 sites), setting up experimental treatment studies at each site, and finishing enclosures at several floodplain sites. These 21 research sites and two weather stations will provide a good base for proposed Forest Service studies in global climate change and long-term site productivity.

Researchers are also studying revegetation following four wildfires and nine experimental burns of varying ages.

Plant Succession

From 1985 to 1988, with UAF scientists, INF conducted a study of the effects of salt crust formation on the succession on the Tanana River. Most sites of this research have become long-term ecological research sites, and related research is continuing. Results will be published in a special issue of the *Canadian Journal of Forest Research.*

With the installation of the synthetic aperture radar (SAR) facility at UAF, there has been considerable interest in uses of SAR imagery for measuring ecosystem parameters in the boreal forest. In the spring of 1988, the floodplain area of BCEF was imaged using SAR mounted in National Aeronautics and Space Administration (NASA) aircraft. Scientists at INF are cooperating with a group of international scientists in obtaining ground-truth data to use in interpreting the SAR images. Additional funding is being sought for more detailed research when the first SAR satellite is launched in 1991.

Fire Effects

Fire research in Alaska is now the responsibility of the fire research unit in Seattle. Fire-effects research continues on a low-priority basis, and new work is undertaken when requested. Current activities include pre- and post-fire management work in the Yukon Flats National Wildlife Refuge (YFNWR). Prefire vegetation and woody fuels have been studied in two of the resource units. When the YFNWR has successfully burned these areas, INF will assess the initial impact of the fire and follow the revegetation process through time.

Post-wildfire research on the 1988 Selawik Fire has just begun. INF will assess the initial and long-term effects of this tundra/taiga fire on lichens and other vegetation, especially plants consumed by migrating caribou. Little is known about the role of fire in the ecology of lichens and their habitats.

Post-wildfire studies continue in the area burned by the 1950 and 1985 Porcupine fires. INF is resurveying existing vegetation plots, establishing new plots in the areas burned by both fires and in areas affected by active mudslides following the 1985 fire. This is the only area in interior Alaska where changes in vegetation have been followed through one complete interfire cycle.

Study of the consequences of fireline explosives (FLE) in permafrost terrain has been initiated. Use of fireline explosives is much less expensive than handline construction and is increasingly employed in fire control in central Alaska. Replicated FLE lines were installed on level terrain at BCEF and on sloping terrain at Caribou-Poker Creeks Research Watershed, following pretreatment documentation of physical, vegetation, and permafrost thaw conditions. INF scientists are monitoring these installations to ascertain vegetation succession, erosion, sediment production, permafrost thaw, and effectiveness of FLE rehabilitation measures.

INF researchers are also studying revegetation following four wildfires and nine experimental burns of varying ages. The wildfires are the Chicken (1966), Wickersham (1971), Grenac Road (1977), and Rosie Creek (1983) fires. Experimental fires include seven experimental

burns (1978) in Washington Creek and two Willow Island site-preparation burns (1983). Vegetation on most of these burns has now progressed into the next stage of succession. This research contributes to an understanding of the long-term effects of fire and is useful to area land managers.

Regeneration and Genetics

Provenance planting trials of white spruce, Sitka spruce, and lodgepole pine at geographical locations from the Aleutians to Fairbanks are under way. Results will provide resource

Spruce provenance tests being conducted on Adak Island in the Aleutians to determine the western range of this species.

managers with information on seed sources and specific genotypes to use for reforestation on specific sites. This information may be particularly important in the study of global warming.

Research on the effects of microsite on growth of planted white spruce seedlings suggests that white spruce plantation establishment and early growth on floodplain sites can be modeled more precisely with the inclusion of microsite factors. These factors include associated vegetation, soil profile characteristics, and site-preparation methods.

Silviculture

Research on the effects of site preparation and silvicultural systems on artificial regeneration of white spruce on Willow Island near BCEF suggests superior survival and growth 5 years after seedlings were planted. Little is known of seed dispersal patterns in wild stands other than the cyclic nature of seed production. Seed dispersal was correlated with wind speed and direction from August 1986 through May 1989. This information can be used to predict seed rain and optimum cutting-unit size and orientation.

Information is lacking on the structure and dynamics of young, mixed stands on upland sites in interior Alaska. Information is needed on the vertical and horizontal stratification of young, white spruce-hardwood stands or growth-increment and stand-development patterns. Reconnaissance plots are being established throughout the Tanana River basin for intensive sampling of these mixed stands. Detailed stem mapping and stem growth analysis will provide a basis for describing stand-development processes. This research will also help predict a range of stand structure and compositions of managed stands for maintaining productivity.

Forest Insects and Disease

Research is under way to develop different forest management prescriptions for spruce stands to protect them from attack by spruce beetles in south-central and interior Alaska and to develop strategies for managing populations of spruce beetles. Studies on host suitability and susceptibility indicate that white spruce is less resistant to attack, but infested Lutz spruce produces more beetle brood. Fast-growing trees with basal areas of 60–120 square feet per acre and annual growth of more than 1 mm per year are also more resistant to attack. Resistance can be increased by stand manipulation through selective cutting and fertilization. Soil moisture deficits and low temperatures in early summer, during the period of beetle flight, cause reduced water potential within trees. This limits cambial growth and increases the trees' susceptibility to attack by beetles. Stands of mixed spruce and paper birch, in which the major species of spruce are white and Lutz spruce, are at greatest risk of attack by spruce beetles. Stands with open canopies were at greater risk than were stands with closed canopies, and increased elevation was associated with increased risk of attack. An expert-systems model is being developed for short- and long-term risk of beetle outbreaks in stands of spruce in south-central Alaska.

Host resistance also can be correlated with increased levels of myrcene, limonene, and beta-phellandrene. Host terpene levels are regulated by site and weather factors and by minor disturbances to the physiology of the trees' water and nutrient transportation systems such as the phloem.

Researchers study wood-boring insects to determine their impact on the quality and value of Alaskan timber.

Beetle populations can be managed through several strategies: pheromone-baited traps, pheromone-baited lethal trap trees, antiaggregation pheromones, protective chemicals such as carbaryl, and remedial chemicals such as permethrin. Strategies have also been developed to reduce the impact of *Ips* engraver beetles in stands of white spruce in interior Alaska. These strategies use some of the same beetle-management methods developed for the spruce beetle. The Alaska Division of Forestry has applied this information in its timber-harvest activities in the Tanana Valley State Forest.

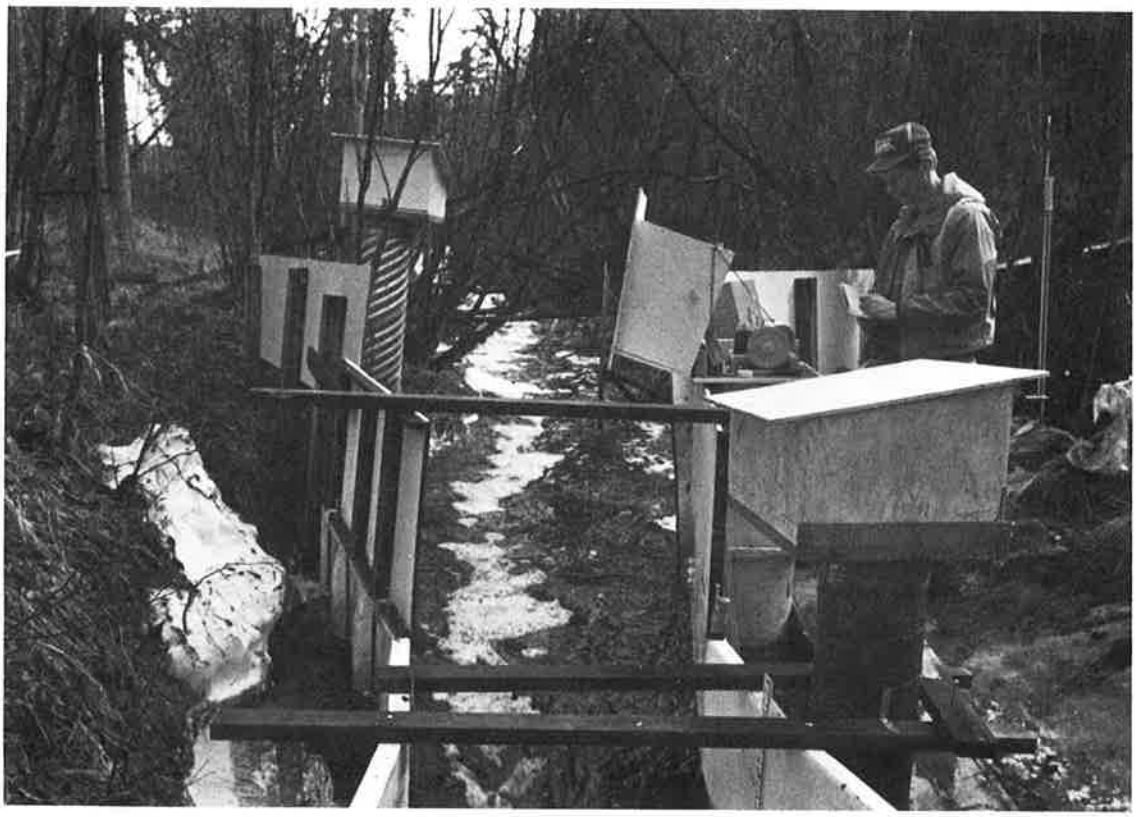
Scientists studying the effect of wetlands disturbance on water quality and stream sedimentation monitor aquatic insect populations.

Water Quality and Sedimentation

Research is under way into hydrologic and water-quality regimes of subarctic stream and catchment systems. Work is concentrated in the 104-km^2 Caribou-Poker Creeks Research Watershed (CPCRW), 40 km north of Fairbanks. The consequences of riparian vegetation clearing in a headwaters valley have been studied in collaboration with University of Alaska scientists. Treatment effects are limited to alteration of litter and leaf fall and solar radiation energy sources for in-stream primary production. This specific treatment (hand clearing, without heavy equipment crossing the stream course) did not have significant influence on stream sediment load or physical and chemical parameters.

Research has begun on the hydrologic and geomorphic regime of a permafrost-related land form—ice-cored upthrust features termed pingos—in CPCRW. Topographic and vegetation field mapping was completed for two major pingos. Currently one pingo is thermally and physically degrading and is contributing meltwater (of markedly different chemical composition from stream baseflow) to Caribou Creek. Water discharge and quality were monitored from 1987 to the present. The hydrologic relationships and thermokarst terrain development associated with such ice-related land forms can be regionally significant to land-use planning in the taiga.

Hydrogeochemical stream-system monitoring of both permafrost-free and permafrost-dominated catchments continues in CPCRW. Strong influence of permafrost on flood regime and total water yield has been conclusively documented. This stream-system monitoring anticipates major experiments in landscape



USDA researchers monitor spring runoff at Spinach Creek watershed near Fairbanks, Alaska, to develop ways of predicting spring runoff patterns in relation to topography, climate, and land use.

Moose habitat research being conducted by USDA scientists in mountainous areas of Denali National Park.

perturbation (whole-catchment timber harvest and fire).

Water quality monitoring is also being completed for streams subject to placer mining for gold, concurrently with measurements of unmined "control" streams in CPCRW. While affecting relatively little land area, placer mining can have severe water quality effects and remains a volatile public issue in central Alaska. INF scientists are also cooperating with Chugach National Forest personnel in monitoring placer mining sites in south-central Alaska.

Sediment production following wildfire was monitored in connection with the Rosie Creek fire studies. Erosion and sediment production directly resulting from wildfire (as contrasted to that produced by improper road drainage or cat lines) has not been significant in that setting.

Wildlife

Since 1980, moose habitat research has been conducted at Denali National Park, 120 miles south of Fairbanks. The park has a naturally regulated population of moose that exploits treeline habitats typical of moose in mountainous portions of south-central and interior Alaska. Summer and winter studies have focused on foraging strategies at Denali and Isle Royale National Parks. INF scientists continue to gather data on long-term population trends of moose as they relate to habitat conditions. INF is also investigating several ancillary topics, including long-term changes in traditional use of rutting habitats, nutrition, antler breakage, and social behavior during the rut. Monitoring of mortality in radio-collared animals continues, including some that have been collared since 1980.

In 1987 research was initiated to determine major winter habitat use by moose on the Copper River Delta. Objectives were to gather baseline data on movements, foraging ecology, and use of important winter ranges and to determine range condition and trends. The Cordova Ranger District plans to manipulate the winter range of moose to enhance the populations of these animals on the west Copper River Delta. Data have been collected for the past two and a half winters. Field studies are in progress in summer to sample vegetation in key wintering areas, estimate forage production and consumption, and establish a long-term transect to monitor range condition.

Agricultural Research Service

The Fairbanks office of the Agricultural Research Service (ARS) conducts research on conservation tillage and water quality management for subarctic soils. Current research studies include the following determinations:

- The vulnerability of weeds growing in Subarctic conditions to tillage and chemicals, to develop effective systems of weed control.
- Herbicide efficacy and rate of decomposition under Subarctic conditions to decide which herbicides are effective and environmentally safe.
- Nutritional optima for nitrogen, phosphorus, sulfur, and boron under tilled and no-till conditions.
- Effects of tillage and crop-residue management on soil temperature.
- The effects of soil temperature on the length of the growing season, which is vital to production in the Subarctic region.

A USDA veterinarian draws blood from a brucellosis-infected reindeer.

Cooperative State Research Service

The Cooperative State Research Service (CSRS) funds research projects at the University of Alaska's Agriculture and Forestry Experiment Station. Research is under way on a broad range of topics.

Wildlife Diseases

Musk-oxen were originally native to Alaska, but became extinct to the area in the 1800s. A small group of animals was reintroduced to Alaska from Greenland in the 1930s. These musk oxen multiplied, and there are now several hundred animals in several locations. Various diseases have been a problem in these herds and are under investigation.

Reindeer were introduced to Alaska from Siberia in the late 1800s to serve as a food source for starving Native populations along the Northwest Coast of Alaska. They are classified as domestic animals and currently serve as a major food source in several areas. Some meat is inspected and shipped to other States to be marketed as an exotic food. Major diseases under investigation in reindeer are brucellosis, internal parasites, warbles, and nasal bots. The serologic response of reindeer to natural brucellosis infection and experimental vaccination is being determined. Standard methods will be adapted and used to detect the presence of humoral antibodies. The effects of long-term brucellosis infection in reindeer will be documented.

Several species of wild and domestic animals are maintained in captivity at the UAF campus. Researchers monitor the health of these animals and investigate various disease processes. The research laboratories that handle the specimens are located on campus and coordinate sample analysis from throughout Alaska. The Veterinary Science Program at UAF responds at times to reports from the field on wildlife disease outbreaks. A primary objective is to conduct disease investigations to determine proper diagnosis of any wildlife disease outbreak.

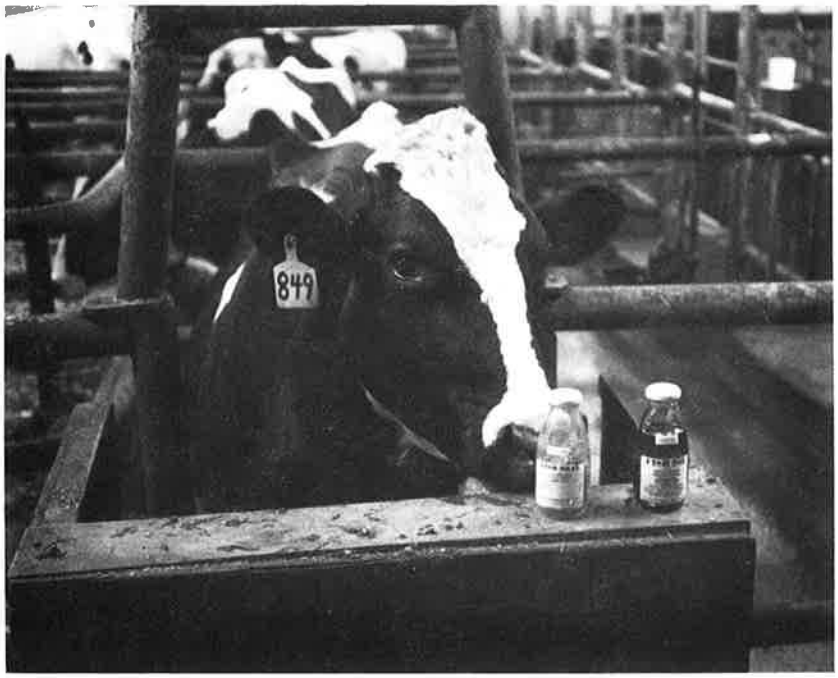
Crops

CSRS is supporting a program to study the farming "system" of grain-based agriculture in Alaska. The objective is to identify areas in which predominant agricultural enterprises are small-grain and livestock oriented. These areas are described in terms of climate and soil; infrastructure; and economic, political, and social characteristics and constraints.

Alaska CSRS, as part of a national germ plasm program, is participating in programs to explore foreign and domestic areas for rare plant germ stock. This program involves the documentation of the performance of introduced plant germ plasm and its use in reducing genetic vulnerability.

In other programs, researchers are comparing nitrogen sources applied at different rates and times on field-grown lettuce. They are studying the onset and development of tipburn. Lettuce transplant and fall seeding procedures are also being evaluated. A study on the application rates and disposal techniques of dairy manure on oat forage grown in a Subarctic environment is under way. The amount of nitrogen fertilizer, from each of 3 years of application, that remains in the soil root zone in successive years is being measured to determine crop uptake of residual nitrogen.

USDA researchers have extensively tested vegetable varieties under Alaska's unique conditions of colder soils, long photoperiods, and a short growing season.



USDA scientists have developed livestock diets substituting processed fish wastes for imported plant proteins in swine, beef, and dairy cattle feeds.

The study will determine the limiting concentration levels of dairy manure that, when applied to the cropping systems on oats, cause detrimental effects on surface and ground water within the Point MacKenzie project area. Storage practices for dairy waste under northern latitude climatic conditions are being evaluated.

Domestic Animals

A total system for forage and beef production in Alaska is being developed and tested by CSRS. The beef cattle rate of growth, their consumption of the forage, and changes in annual and perennial forages are being evaluated. Research will validate and test the animal submodel of the BEEF program for applicability of the logic and coefficients that are part of the model. A companion project is defining limiting parameters for use of barley straw and salmon meal in lactation rations for dairy cows. Possible synergistic interactions between soybean and salmon meals and between form of roughage and concentrate formulation are being considered. Consumer acceptance of milk produced by cows fed salmon meal is being evaluated.

Selenium deficiency is a common problem in cattle diets in Alaska. Seleniferous feeds and injectable liquid selenium as supplements to selenium-deficient beef cattle diets are being investigated. Possible microbial advantages with ingested seleniferous feeds are being explored. Objective evaluation of seleniferous feeds, inorganic injection, and microbial response will lead to more accurate supplementation guidelines.

In other studies, researchers are determining the physical and chemical characteristics of barley cultivars and their relationship to feeding value for swine. They are also determining the chemical characteristics and feeding value of western-produced protein supplements for swine.

USDA employees monitor this mature white spruce forest where the trees are more than 180 years old. These researchers will develop growth and yield models and determine methods to improve forest productivity.

Forestry

CSRS researchers at the University Alaska are developing growth and yield models to quantify timber productivity in interior Alaska and provide managers with appropriate equations and derived tables essential for timber management decisionmaking. Models will allow for various conditions and will model the number of years for each tree species to reach breast height. Researchers will develop polymorphic site index curves for each species, establish levels of growing stock studies to model stand density effects on mortality and growth, and determine correct BTU values for each species. Studies will also test existing individual tree-volume tables and develop new tables as needed; develop natural stand yield tables; and select practical yield-prediction models for interior Alaska.

Soil nitrogen supply in relation to forest productivity and successional patterns is being investigated for interior Alaska. This work is based on flux estimates for nitrogen obtained from past research. Current research estimates the impact of different system disturbances on potential nitrogen mineralization in various vegetation types across successional sequences in relation to temperature, moisture, and substrate quality. The relationship between nitrogen mineralization, seasonal growth of dominant site trees, and site quality will be used to refine estimates of the flow and storage of nitrogen. Laboratory tracer techniques will be used to develop a stress test to

Soil profiles of an alluvial floodplain reveal a series of deposits from floods of the past.

assess nitrogen supply and demand by forest trees. It also will develop a predictive model of nitrogen dynamics in relation to tree growth. The model will incorporate the soil dynamics and plant uptake of nitrogen and the control process across successional sequences in uplands and floodplains of the Tanana River. This will give researchers the ability to assess and predict the impact of perturbations on nitrogen dynamics.

Streamflow from a boreal forest watershed is being measured during the spring break-up season. The data are being used to test the snowmelt algorithm of a watershed model. The studies are being done on the Spinach Creek watershed.

Soil Conservation Service

The Soil Conservation Service (SCS) provides technical assistance in interior Alaska in areas of land use for agriculture, forestry, settlement, recreation, and wildlife habitat management. State, borough, local, and private contributions help support SCS conservation activities. SCS assistance, principally resource information needed for land management decisions, provides a basis for response to the Alaska Native Claims Settlement Act, which provides for the conveyance of Federal land to private Native corporations. About 35.1 million acres of land had been conveyed by the beginning of FY 89, and another 9 million acres of land will be conveyed over the next 5 to 10 years.

Annual soil surveys are conducted on up to 400,000 acres, providing data for soil and water conservation, natural resource surveys, and community resource protection and management. Currently, emphasis is placed on remapping and updating old surveys in response to urban development. In addition, SCS provides technical assistance for soil survey work conducted by the USDA Forest Service.

River basin surveys and investigation programs describe problems and pose solutions on between 2 and 3 million acres of watersheds in any given year. The studies delineate floodplains; compile flood profiles; and determine water, land, and related resource availability and potential for forest-based industries and municipal and industrial water needs. Assistance is currently being provided to solve streambank erodibility, sedimentation, and other problems on the Kenai River, the Kuskokwim River, and the Copper River.

Statewide snow survey and water-supply forecasting activities acquire data on snowpack, soil temperature, solar radiation, windspeed and direction, relative humidity, and barometric pressure. These data are used to estimate the timing of spring break-up, to determine the accessibility of agricultural field equipment under heavy snow conditions, to predict snowmelt runoff for placer mining, to assist in fisheries management, and to contribute to the design of snowdrift and avalanche-control structures.

Department of Energy

DOE Arctic research efforts include 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 $2.3 million in Fiscal Year 1989.

Integrated Research on Tundra Ecosystems

FY 89 FUNDING (thousands)

Ecosystem Response	1268
Response to Carbon Dioxide	265
Arctic Offshore Research	452
Gas Hydrates	202
Aurora	130

Tussock tundra covers about 80 percent of the 220,000 km^2 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 (R4D).

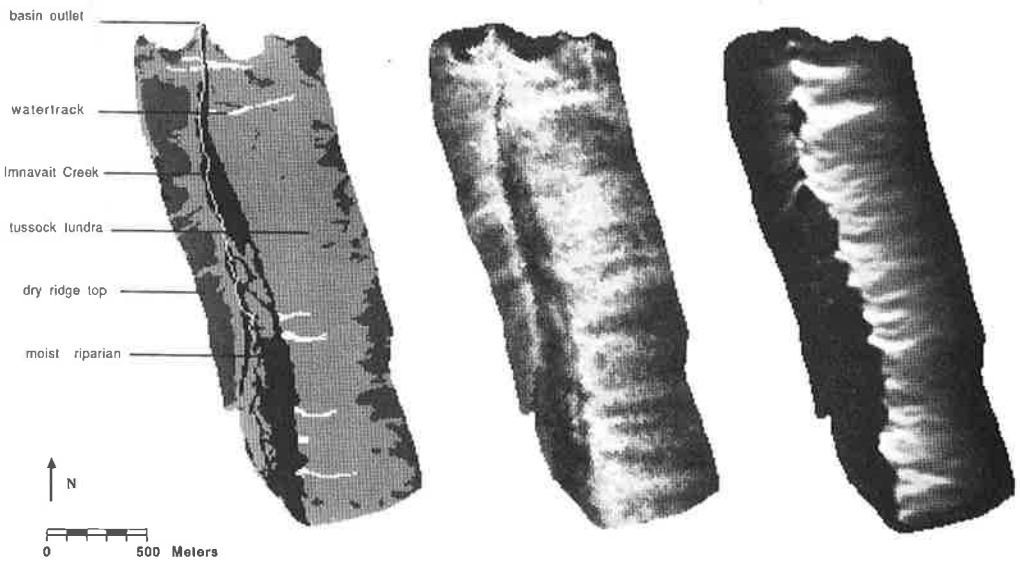
Working out of the Toolik Lake research camp operated by the Institute for Arctic Biology, University of Alaska–Fairbanks, 10 principal investigators from 6 universities are cooperating in the R4D program. The research program is being carried out in the Imnavait Creek watershed, a tributary of the Sagavanirktok River, and is adjacent to the National Science Foundation's Long-Term Ecological Research (LTER) site at Toolik Lake, and a number of cooperative links have been forged between the two programs (see p. 21).

The long-term objectives for the R4D program are to determine the effects of ecosystem disturbances, to develop models, and to use appropriate, cost-effective measures to minimize harmful disturbances. Another goal is to extend the results to other Arctic 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.

A more immediate goal is to understand the processes that control tussock tundra ecosystems, particularly the mechanisms by which water and nutrient availability regulate plant and ecosystem function. Improved understanding of mechanisms and processes is being formalized in a general Arctic simulation model that operates 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. 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.

Plant process studies are being summarized in simulation models of plant growth and gas exchange. These models are developed with a generalized format to work in different types of plant communities, such as dry ridgetop, tussock tundra, and moist riparian. Plant growth and nutrient uptake are currently based on studies of *Eriophorum vaginatum*, a dominant sedge responsible for the "tussocks" of the tundra. Initial versions of the gas exchange model define conditions under which the tundra acts as a net source or sink for carbon dioxide. Initial results suggest that the growth of another important tundra plant, *Sphagnum* moss, is apparently inhibited when it is exposed to high light conditions. Thus, soil thermal properties, net ecosystem gas exchange, and nutrient trapping by the moss layer in lower slope and riparian communities are strongly influenced by the distribution of dense vascular plant canopies that shade the moss layer.

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



Three views of the Imnavait Creek watershed in northern Alaska: (1) simplified vegetation map, (2) vegetation index based on a SPOT satellite, (3) drainage pattern map based on a digital elevation model.

water has been collected at calibrated weirs with stage recorders and automated water sampling systems at first-order water traces 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. Winter snow contains substantial amounts of nitrate, sulfate, and calcium ions. Spring snowmelt is responsible for a major loss of nutrients from the ecosystem, with lowest pH and maximum concentrations of ions, suspended solids, and dissolved organic carbon occurring with peak flow from the watershed. Strong summer rains that result in surface runoff contribute to transport of carbon from the watershed. This release of organic acids is particularly pronounced when rains follow a prolonged dry period. Similar release of inorganic ions to the stream system does not occur during summer rains. This information will be used in evaluating the performance of models, now under development, that will estimate mass flux from water tracks and from the Imnavait watershed.

A basin hydrologic model has been validated against hydrographs for small collecting areas that drain the slopes via "water tracks," as well as for the entire watershed. This model operates on a daily time step and provides information on depth of thaw and soil water content in each contributing field. Analytical and field work is designed to provide advanced versions of a hydrologic model that more realistically describe subsurface flow and material transport (for example, nutrients) within the ecosystem. This approach requires the interfacing of hydrologic, decomposition, and plant growth models. Validation of the nutrient transport model will be made with data from coordinated studies of soil solution and flowing water chemistry, spatial patterning in the water table of the basin through time after storm events, hydrographs of water tracks and the valley bottom stream, and transport of tracers within and across boundaries of the different vegetation types present. It is hypothesized that dry ridgetop communities are a source of nutrients, that slope communities act to trap nutrients, and that riparian communities are the major contributors of solutes to the stream system during the summer, when subsurface flow predominates. Field studies of seasonal development of the "active" plant surfaces (leaf area and fine root area) allow development of a simulation model describing the nutrient-trapping interface between plants and soil.

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). 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.

The information from these maps and from other sources can be layered via R4D/AGIS, allowing spatial information obtained over large land areas to be manipulated rapidly. Furthermore, through the use of correlative models, R4D/AGIS may provide the important initial conditions necessary for running the general Arctic simulation 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 supply 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, obtained from the French SPOT satellite, are being used with R4D/AGIS for distinguishing vegetation classes. Using SPOT images, it is possible to recognize spatial patterning in dry ridgetop, moist riparian, and tussock tundra slope plant communities in the Imnavait Creek research watershed.

Carbon Dioxide

The Carbon Dioxide Research Division is supporting research on the effects of increased CO_2 and climate change in the Arctic. Under this program, two major projects are being funded: the response of tundra ecosystems to elevated atmospheric CO_2, and the projection of future sea-level changes caused by the ice wastage (see *Arctic Research of the United States*, Volume 2, Spring 1988, page 68).

Ice wedges found throughout much of Alaska have an impact on road building, agriculture, construction, and other developmental activities

The goals of the first project are

- To determine how changes in CO_2 and climate affect 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_2 and climate.

Recent activities emphasize data reduction and analysis of previous experiments, in which atmospheric CO_2 and temperature were manipulated in the tussock tundra at Toolik Lake. Contrary to previous thinking, which indicated carbon accumulation in tussock tundra, these recent analyses illustrate that carbon is currently being lost from the tussock tundra in this region. If findings at Toolik Lake are representative of all circumpolar tussock tundra, carbon loss from tussock tundra may be on the order of 0.1–0.2 gigatons per year (Gty^{-1}), and net carbon sequestering of all Arctic tundra may be 0.2–0.3 Gty^{-1} less than previously thought. However, these findings and projections should be viewed in perspective, since they reflect what has been observed at a single location in a vast expanse of circumpolar tundra extending across three continents. DOE investigators will examine other tundra locations in Alaska to gain further insight into the extent of this observed phenomenon and to assess the validity of these preliminary extrapolations.

It is possible that the tussock tundra may have recently changed from a carbon sink to a carbon source because of increases in surface temperature during the past century and concomitant climate change. Warmer, drier soil conditions should cause an increase in soil decomposition. This trend, if general and continuing, could result in massive amounts of carbon being liberated from soil organic matter as CO_2.

The second project funded by the Carbon Dioxide Research Division seeks to understand and predict how runoff from the world's largest glacier (exclusive of Antarctica) will respond in the next century to a climate changed by increased atmospheric CO_2. 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_2-affected climate.

It has been widely speculated that sea-level rise will be a major consequence of greenhouse warming, and current models suggest that wastage of land ice will be the cause. Meltwater generated at the surface of a cold ice cap or glacier will not run off immediately but will refreeze until the snow is warmed and pathways are developed. The time scale of this process may be the largest uncertainty in predicting future sea-level change. Natural and artificial melt experiments conducted on Arctic ice caps show that a critical element is the development of ice layers that could permit more rapid lateral runoff. Detailed field measurements (before and after) were made of snow temperature, structure, and hydraulic properties for use in computer models. An initial computer model of water flow in cold snow successfully simulated some aspects of this flow, but an advanced model, now under development, is needed to cope with the sharp discontinuities in snow that cause ice layers. This advanced model, which couples heat flow and water flow equations, links a meltwater generating zone (at 0°C), a nonequilibrium zone with water flowing between subfreezing ice grains, and a cold zone with no liquid water present.

Other DOE Activities

Other Department of Energy activities reported previously include projects in fossil fuel technology, gas hydrates as a potential fuel source, and plasmas in the magnetosphere.

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, makes 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 AORIS is being made available in the microcomputer version (PC-AORIS) and is provided on CD-ROM format (available from the National Energy Software Center, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439, telephone (312) 972-7250). The completed AORIS was demonstrated on January 4, 1990, and a draft final report and user manual are currently undergoing review. The AORIS is expected to be available in 1990.

DOE's work on gas hydrates is part of an unconventional gas recovery program. Comparatively little is known about gas hydrates, but early estimates of gas in place are on the order of quadrillions of cubic feet. The research plan is to identify and quantify the resource, to develop the exploration and production technology, and to demonstrate its feasibility. Computer simulations have already 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. Laboratory experimentation on natural and synthetic gas hydrates has provided basic data for developing reservoir and production models. Data from analyses of onshore well logs and offshore seismic records have provided geological information for further refinement of the reservoir and production models, and reservoir simulations have helped to develop feasible extraction and production models and to identify remaining gaps in the data.

Objectives for the current fiscal year include determining the chemical and physical properties for both natural and synthetic gas hydrates under laboratory conditions; completing the geologic characterization, developing geologic models for the formation of both onshore and offshore gas hydrates, and developing resource estimates for them; developing diagnostic techniques for measuring in-place characteristics of both onshore and offshore gas hydrates; and developing reservoir and simulation models and preliminary economics for gas hydrates production.

The Geophysical Institute of the University of Alaska-Fairbanks is researching the basic characteristics of the plasma of the magnetosphere and studying energy-related geophysical problems of the Arctic, such as electric currents in power lines and pipelines induced by auroral activity. The results from this magnetosphere study are also applicable to plasma research in other fields such as thermonuclear fusion research, solar physics, and astrophysics. Advances have recently been made in the theory of plasma behavior with confirmation through observation of the plasma in the region that produces auroras. Advances have also been made in understanding the effects of the aurora on energy facilities such as pipelines.

Department of Health and Human Services

Arctic health research supported by DHHS is conducted directly by the Centers for Disease Control and the Indian Health Service. Additional Arctic health research is supported by the National Institutes of Health through grants and contracts. Collaborative studies are performed by other health-care organizations, including the Alaska Department of Health and Social Services, the University of Alaska, and various Alaska Native health corporations. Funding totaled $1.8 million in Fiscal Year 1989.

Federally funded Arctic health research continues to be carried out cooperatively by several Federal agencies in Alaska. Direct research is primarily conducted by two agencies of the U.S. Public Health Service with facilities in Alaska: the Arctic Investigations Program (AIP) (formerly Laboratory) of the Centers for Disease Control (CDC), and the Alaska Native Health Service (ANHS) of the Indian Health Service (IHS). The projects described here either are conducted in Alaska or involve Alaska residents as participants in the studies. Generally, either CDC or IHS has the lead responsibility for a particular research project, but in almost every case the success of a research project depends on the coordinated support of both agencies. Collaborative research by the CDC and IHS has focused on prevention and control of viral hepatitis, bacterial meningitis in children, pneumococcal disease, botulism, and echinococcus (a parasitic infection primarily involving the lungs and liver).

In addition, Federal support was reinstituted or made available to new projects in cancer, arthritis, and cardiovascular disease with support from three of the institutes of the National Institutes of Health (NIH). The cancer and arthritis funds are provided to the IHS by the National Institute for Arthritis and Musculoskeletal Disorders and the National Cancer Institute. The cardiovascular disease project funds are from the National Heart, Lung, and Blood Institute to Louisiana State University and the State of Alaska, Department of Health and Social Services, Section of Epidemiology.

FY 1989 FUNDING (thousands)

Centers for Disease Control (CDC)	998
Indian Health Service (IHS)	246
Grants and Research (NIH)	590

Centers for Disease Control

The following research projects are primarily funded by CDC and conducted by CDC investigators who are located in Anchorage in the AIP facility. There is a close interaction between the CDC and other Federal agencies and Native organizations in conducting these research projects.

Meningitis

Hemophilus influenza type b (Hib) is the leading cause of meningitis in children. Infection can lead to death, severe neurologic damage and hearing loss. Rates of disease in Alaska Native children are at least four times greater than in non-Native Alaskan children, and the disease occurs earlier in life, peaking at ages 6 to 7 months. The currently available vaccines (made of the outer capsule of the bacteria) induce antibodies only in older children and are licensed for use only in children over 17 months old. Because of the early onset of the disease, this vaccine cannot significantly affect Native disease rates. A major vaccine trial using a conjugated vaccine administered at the same time as routine well baby immunizations was completed in FY 89. Although this vaccine was found to be highly effective in a trial in Finland, vaccine efficacy was disappointingly low (37 percent) in the Alaska trial, and only low levels of antibody were stimulated by the vaccine.

Since the initiation of the Alaska trial, three new conjugate vaccines have been developed and are undergoing efficacy trials in the United States and elsewhere. Immunogenicity studies are being conducted in Alaska to compare the antibody responses of all four vaccines. In addition, a demonstration project is being conducted in the Alaska region at highest risk for Hib disease. The

project involves administering four shots of bacterial polysaccharide immune globulin (BPIG) especially prepared to provide high levels of antibody against Hib and two other bacteria. Future efforts on Hib are dependent on the outcome of the immunogenicity studies ongoing in Alaska and the three major vaccine trials elsewhere.

Hepatitis

In the past, Alaska Natives suffered excessive rates of hepatitis B (HBV), a viral infection that can cause acute hepatitis as well as cirrhosis and cancer many years after the initial infection. Persons chronically infected with hepatitis B are nearly 200 times more likely to develop liver cancer, which is usually fatal. About 3 percent of the Alaska Native population is chronically infected, and up to 7 percent in some regions. The IHS, State of Alaska Division of Public Health, and AIP joined in a statewide effort in 1983 to test all Alaska Natives for HBV infection and immunize—with hepatitis B vaccine—all persons not previously infected. The first phase of this program has been completed: the vaccination series has been administered to more than 50,000 Alaska Natives, and there has been a dramatic decline in illness from hepatitis B. The second phase of the program requires immunization of all newborn Alaska Natives. Persons immunized with the first licensed vaccine available in 1981 are being followed up to determine how long protection will last after an initial three-shot vaccination series. After 7 years, 74 percent of persons immunized have protective antibody levels, and no hepatitis B surface antigen positive infection has occurred. The Alaskan study is the only study in the United States designed to address the question of the need or timing of a booster dose of hepatitis B vaccine.

Pneumonia is the fourth leading cause of hospital discharges in the IHS in Alaska and ranks sixth among causes of death among Alaska Natives.

Approximately 1400 people chronically infected with hepatitis B are tested twice a year to determine their current viral status and test their blood for alpha-fetoprotein (AFP), a marker for liver tumor. Six patients have had tumor detected at an early stage, and five have lived as long as 7 years after surgery. AFP testing will be continued. Because the hepatitis carriers are widely dispersed throughout Alaska, laboratory efforts are directed toward developing a test for AFP that can be performed by the village health aide. In September 1989, an international meeting was held in Anchorage to review work in AFP screening being carried out worldwide. Participants made recommendations for screening of hepatitis B carriers and future research needs on AFP and liver cancer.

In addition to hepatitis B, periodic epidemics of hepatitis A infection have occurred about every 15 years. Surveillance documented an increase in cases reported in Alaska in 1985. Vaccines for hepatitis A are just becoming available. Studies of antibody responses of Alaskans to the new vaccines and an efficacy trial are under discussion.

Pneumonia

Pneumonia is the fourth leading cause of hospital discharges in the IHS in Alaska and ranks sixth among causes of death among Alaska Natives. Upper respiratory problems and otitis media rank third and fourth among leading causes of outpatient visits. Streptococcus pneumonia, a leading cause of bacterial meningitis in adults, is responsible for about 20 percent of all pneumonia.

Statewide laboratory-based surveillance for confirmed cultures from normally sterile body fluids of *S. pneumoniae* document increased rates in Alaska Natives. Rates overall are 6 times greater in Alaska Natives than non-Natives and as high as 10 times greater in certain age groups.

A vaccine is available that produces antibodies in persons over age 2 and is recommended largely for persons over age 65 and those with serious heart and lung conditions and diabetes. Pneumococcal vaccine has not been optimally used in the Alaska Native population. A project has been under way in one northwest region of Alaska to immunize all persons in the region at increased risk and revaccinate those whose primary immunizations were given more than 6 years previously. Laboratory work is directed toward characterizing the serotype and antibiotic resistance patterns of the isolates, developing rapid diagnostic tests for pneumococcal disease, and developing immunoglobulin class-specific and serotype-specific antibody assays.

Botulism

Botulism continues to be an important problem in Alaska. In some years, half of all cases of food-borne botulism reported to CDC are from Alaska. The problem continues to occur from the consumption of specially prepared traditional Alaskan foods. One death occurred in FY 88 and one in FY 89 from consumption of foods contaminated by botulinum toxin. A dietary survey appended questions to assess the level of use of frequently implicated foods among the popula-

tions. Laboratory studies focused on methods of rapid detection of toxin in body fluids of patients; these methods could replace lengthy and expensive mouse bioassays.

Echinococcus multilocularis

Alveolar hydatid disease (AHD) is a disease primarily of the liver. AHD is caused by inadvertent infection of humans by a dog or fox tapeworm, *Echinococcus multilocularis* (EM). Untreated, lesions on the liver result in severe, prolonged, chronic liver disease and eventual death. AHD is a problem in Arctic and Subarctic populations, including residents of Northwestern Alaska. Cure can be complete only by surgical resection of small lesions, although benzinadazole compounds may be helpful. In 1985, new serologic tests became available, and serosurveys were performed annually. In 1988, ultrasound examinations were performed in conjunction with the serosurveys in two villages. Thirteen new patients were identified during the surveys, three with active lesions. Ongoing research is directed toward (1) identification of new EM-specific antigens for use in serologic testing and standardization of laboratory tests; (2) studies of voles to assess the prevalence of infection in the intermediate host, and vole assays to assess the viability of tissues removed surgically from patients; and (3) treatment of nonresectable patients with benzinadazole compounds. An international meeting scheduled for June 1990 on AHD will include representatives from all areas with hyperendemic regions: Europe, the U.S.S.R., China, Japan, Alaska, and Canada. Maximizing strategies for prevention and control and identifying needed areas for research are key agenda items.

Iron deficiency has long been recognized as a problem among Alaska Native children, and an iron supplementation project in the 1970s resulted in improvement in mean hemoglobin level. Recent efforts have focused on improvement in health education regarding nutrition, to enhance use of iron-rich foods available in the traditional Alaska Native diet.

Arthritis

Clinicians in the Alaska IHS have consistently commented on high rates of arthritis, although studies of rheumatoid arthritis have failed to document an excess. Increased rates appear to result from conditions classified as reactive arthritides. The National Institute of Arthritis and Musculoskeletal Disorders has entered into an agreement with the IHS to assess the prevalence of the various syndromes that are grouped as spondyloarthropathies and reactive arthritis among two groups of Eskimos in Alaska. The project will determine the natural history of these conditions over a 5-year period, the spectrum of disease that comprises these syndromes, and the role of genetics, primarily Human Leukocyte Antigen (HLA) and environmental factors.

Anemia

Iron deficiency has long been recognized as a problem among Alaska Native children, and an iron supplementation project in the 1970s resulted in improvement in mean hemoglobin level. Recent efforts have focused on improvement in health education regarding nutrition, to enhance use of iron-rich foods available in the traditional Alaska Native diet. Iron deficiency is now known to affect immunologic defenses; therefore, study of iron deficiency, especially in populations at high risk for infection, is important.

A variety of small surveys has been conducted over the past few years in conjunction with other serosurveys among the Alaska Native populations. Prevalence of anemia (defined by CDC age and sex-specific hemoglobin values) and iron deficiency (serum ferritin ≤12 ng/ml) were determined and found to be generally low, although the magnitude of the deficiencies varied by region, age, and sex. Anemia rates were as high as 23 percent in school-age children, 86 percent in adolescents, and 35 percent in adults. Iron deficiency was documented in up to 65 percent, 86 percent, and 72 percent, respectively, of the three groups. Blood loss, as well as insufficient intake or absorption of iron, may play a role. Plans for FY 90 include testing of a random sample of blood from a statewide serosurvey for ferritin to assess the prevalence among Alaska Natives of iron deficiency anemia by region, village, age, and sex.

Cancer

Previous research by the CDC and IHS, with support from the National Cancer Institute, documented that cancer patterns among Alaska Natives differed markedly from those of the general U.S. population and even from those of Native Americans residing outside Alaska. Studies and programs have focused on cancers that occur in excess: nasopharynx, cervix, esophagus, gallbladder, and liver (see the earlier paragraph on "Hepatitis"). Human papilloma virus (HPV) had been implicated in cervical and esophageal cancer.

Studies are under way to examine the presence and specific genotypes of HPV in cervical specimens of Alaska Native women among several patient groups using IHS health care. A new project will allow the determination of the prevalence of infection of several sexually transmitted diseases—HPV, chlamydia, gonorrhea, and syphilis— among women in the general population in one region of Alaska. Another project will examine pap-smear histories of women who developed invasive cervical cancer, compare screening techniques for examining the cervix (pap smear, cervicograph, and HPV tests), and conduct followup studies of women, particularly those who are HPV-positive with no cytologic abnormalities.

Injury Surveillance and Control

The Center for Environmental Health and Injury Control (CEHIC), in collaboration with IHS, has developed an Injury Surveillance System that is currently being used by IHS in Native villages and the IHS regional office in Anchorage. The objectives of this system are to provide routinely collected data on injury that can help to identify priority injury problems, determine trends, and evaluate interventions. This system is being used routinely as part of the IHS injury prevention program in Alaska.

CEHIC has recently awarded the Alaska Department of Health and Social Services two grants to support work in injuries that affect rural Alaskans. The first, a grant in Applied Methods in Injury Surveillance, will be used to establish a statewide system to conduct surveillance of head and spinal-cord injuries that can serve as a model for the conduct of surveillance on head and spinal-cord injuries in other States. In addition, the Alaska Department of Health and Social Services has been awarded a grant for the development of a State-based Injury Control Program that will establish a statewide injury control focus. The department, through an established Emergency Medical Services Unit, will focus on intentional and unintentional injuries. This unit will help provide services to 70 percent of Alaska Natives dispersed among 175 villages as well as 70 rural towns with primarily non-Native populations.

International Activities

The circumpolar nations continue to collaborate on programs and research in health. The International Union for Circumpolar Health sponsored two workshops: one in Yellowknife, Northwest Territories, Canada, on tobacco and health problems, and the other in Greenland on AIDS and sexually transmitted disease. Both workshops focused on particular Arctic needs in these areas.

The Eighth International Congress of Circumpolar Health (ICCH), a meeting held every third year in a different circumpolar area, will be held in Whitehorse, Yukon Territory, Canada, in May 1990, with scientific sessions and workshops scheduled in all health areas.

Two international workshops, one on liver cancer and another on AHD, will focus on particular problems of the North. The arthritis project team has collaborated with researchers in the U.S.S.R. to coordinate and standardize study protocols as much as possible. A project will be conducted in Chukotka region similar to the Alaskan study. Persons in circumpolar nations will collaborate to develop a monograph on cancer in Eskimos to include input from Alaska, Canada, and Siberia.

The Alcohol, Drug Abuse, and Mental Health Administration

Substance Abuse Program

Through a series of interviews, the Alcohol, Drug Abuse, and Mental Health Administration will conduct an evaluation to assess a variety of clients' functioning, including demographic data, drinking and drug-taking behavior, social and psychological functioning, economic and occupational information, and criminal behavior. The evaluation will include a followup study with a matched control group. Evaluation instruments are being designed to take into account the cultural differences of the Alaska Native people who will make up a significant proportion of program clients.

American Indian and Alaska Native Mental Health Research

The Research Center (Tucson Area Indian Health Service) is designed to facilitate the accomplishment of a comprehensive research program and related research training opportunities that address a number of mental health needs among American Indians and Alaska Natives. The specific aims include the following:

1. Promoting excellence in mental health research and research training appropriate for American Indians and Alaska Natives.

2. Assisting others in planning and implementing mental health research that is programmatically relevant to American Indians and Alaska Natives.

3. Disseminating information through a professionally refereed journal, an annual monograph series, and a computerized bibliographic information retrieval system that will guide the design, conduct, and interpretation of future mental health research pertaining to American Indians and Alaska Natives.

4. Planning and carrying out an interdisciplinary, problem-oriented research program that focuses on how American Indians and Alaskan Natives cope with rapid life transition. This program studies the epidemiologic patterns of the mental health consequences of such transitions, the effectiveness of the systems of care that have emerged in response to these consequences, and methods of preventing and/or ameliorating the effects of stressful transitions on identifiably high-risk groups across the developmental life span.

5. Structuring research training as part of the center program.

The mission of IHS is to raise the health of American Indians and Alaska Natives to the highest possible level. Thus, IHS efforts and funding are primarily dedicated to the provision of direct health-care services.

Two major studies conducted by the Center specifically focused on the Alaska Native.

- "Coping Processes During Stressful Life Transitions Among American Indian and Alaska Native College Students." This study entails annual surveys of approximately 1200 Indian or Native students and 600 non-Indian or Native students across seven major universities. Its purpose is to identify the stressors that Indian or Native students experience upon transition to institutions of higher education, the consequences of such stress in terms of risk for ADM disorders, and mediating forces such as social support, cognitive/behavioral coping strategies, and various personality factors. Extensive analyses of collected data are under way.
- "Epidemiology of Inupiaq Mental Health Problems." This involves extensive ethnographic interviews of representative samples of both adolescent and adult members of two Northwest Alaska Native Association Region Alaska Native villages, Noorvik and Kiana. The purpose of this study is to identify the kind and frequency of mental health problems experienced by this special population, to elicit Inupiaq models for understanding these problems, and to develop orientation and instructional materials for training local mental health aides.

Alaska Mental Health Statistics Improvement Project Grant

The State of Alaska plans to set up a revised management information system that will address problems observed in the State's current system. The Alaska project lists the following goals and objectives:

- To develop and administer programs that are responsive to the mental health needs of the citizens of Alaska and to provide ongoing efforts to improve the health of these individuals.
- To improve the statewide management of mental health service.
- To improve Alaska's capacity to engage in evaluation and research activities related to topics of substantial importance to the State.

Indian Health Service

The mission of IHS is to raise the health of American Indians and Alaska Natives to the highest possible level. Thus, IHS efforts and funding are primarily dedicated to the provision of direct health-care services.

The IHS is funded primarily to provide health care services to American Indians and Alaska Natives. Very little funding is used for research. Additional research by IHS is through collaboration with other research-funded organizations.

In addition, the IHS funds and conducts some Arctic research projects. Although IHS staff are the principal investigators in these projects, all research efforts involve close cooperation, support, and involvement of other organizations, including the State of Alaska, Federal agencies, and Alaska Native groups.

The IHS and the State of Alaska cooperated in a statewide survey, using a questionnaire designed by the University of Minnesota Adolescent Health Program, of more than 1500 Alaska Native and 4000 non-Native adolescents 12 to 18 years of age. The data from this project will be used to develop programs that target more effectively the special health needs of adolescents in Alaska.

In 1989, a selected population of high-risk Alaska Native infants began to receive bacterial polysaccharide immune globulin (BPIG) to

demonstrate the feasibility of using an immune globulin as a public health measure to prevent Hib invasive disease (see the "Centers for Disease Control" section). Earlier efficacy studies in a population of Apache Indian infants demonstrated the effectiveness of BPIG in preventing Hib disease.

Other areas of Arctic research being conducted by the IHS include:

- Epidemiological investigations of eye disease in Alaska Natives.
- Programs to reduce infection by *Echinococcus multilocularis.*
- Assessments of current dietary intake of Alaska Native adults.
- Evaluations of long-term immunity of pneumococcal polysaccharide vaccine, hepatitis B vaccine, and diphtheria-tetanus toxoid in Alaska Native alcoholic patients.
- Fetal Alcohol Syndrome (FAS) studies: evaluation of a screening tool to identify women at risk for producing children with alcohol-related birth defects and prospective case-control study of the development of children who are exposed to alcohol while in utero.
- Study of spondyloarthropathy in Alaska Natives: a 5-year study funded by NIH through an interagency agreement with IHS.

The National Institutes of Health

Preventing Tobacco Use Among Native American Adolescents

NIH will conduct a randomized 5-year study to test personal and environmental interventions to prevent smokeless and smoked tobacco use among Alaska Native and American Indian (Native American) youth in Alaska, Idaho, Montana, and Washington. The content of personal interventions, involving groups of Native youth, will include reinforcement of ethnic pride and values, health, and positive self-image, as well as the development of problem-solving, coping, and communication skills. Environmental intervention, to include Native youth, families, and peers, will develop social and situational supports to prevent tobacco use. Subjects will be 3584 Native American females and males, 11 to 13 years of age at the time of initial involvement. Recruited from 28 sites, consenting subjects will be pretested and, by site, randomly divided into four conditions. Subjects in three conditions will receive either personal intervention or environmental intervention or both interventions; subjects in one condition will receive no intervention. All subjects will be posted, then followed every 6 months. Semiannually, intervention-condition subjects will receive pairs of booster sessions. Outcome measures will quantify subjects' smokeless and smoked tobacco use and will assess variables associated with tobacco use. The study is supported by Native tribal, reservation, and public schools in Alaska, Idaho, Montana, and Washington.

Cancer Surveillance

The overall objective of this proposal is to provide accurate cancer incidence, mortality, and survival data for Alaska Native (Eskimo, Indian, and Aleut) residents of Alaska. The data will be obtained in a format that meets the criteria and standards of the SEER program of the National Cancer Institute. This will allow the inclusion of this information into the SEER data base and a comparison of cancer patterns in the Alaska Native population with those of other U.S. populations, including other Native Americans. The project will provide baseline data to identify cancer sites that should be targeted for intervention and against which the results of prevention and control programs can be measured. The information will also be collected in a manner that will make it useful and readily available to IHS, AANHS, and Alaska Native Health Corporation health care providers to provide optimal followup care of cancer patients and serve in planning future health facilities and health services relative to cancer.

Cancer Mortality

The objectives of this project are as follows:

- To describe the burden of illness from cancer in the American Indian and Alaska Native populations.
- To describe the variation in cancer incidence and prevalence among the relevant populations (by geographical, ethnic, cultural, and behavioral patterns) and analyze the determinants of variation as a basis for generating testable hypotheses of etiologic and risk factors, as well as prevention and control interventions.
- To describe the variation in cancer mortality among different service populations of IHS and analyze variation to identify remediable deficiencies in the patterns of care and care-seeking behavior.
- To describe the prevalence of known behavioral risk factors for cancer, particularly

those related to diet and use of tobacco products.

- To describe the patterns of care received American Indian and Alaska Native populations at risk, and analyze the obstacles to early diagnosis and adequate treatment that are attributable to the system of care.
- To identify areas for further study, with particular emphasis on design, methods development, and pilot testing of intervention studies, of the effectiveness of prevention and control strategies for cancers shown to be of particular importance in the Indian and Native populations of Alaska.
- To demonstrate productive, collaborative work between the IHS and SEER centers in geographic areas with relatively large Indian and Alaska Native populations (e.g., the New Mexico Tumor Registry and the Fred Hutchinson Cancer Research Center) as one means for accomplishing these objectives.

Alaskan Oil Spill

The National Institute of Environmental Health Sciences (NIEHS), the National Institute for Occupational Safety and Health, the University of Washington School of Public Health, the U.S. Environmental Protection Agency, and the Agency for Toxic Substances and Disease Registry sponsored a conference in July 1989 to bring together participants from various organizations involved with the oil spill from the Exxon *Valdez* tanker, the spill cleanup, and the assessment of the impact of the spill on environmental, public, and occupational health. The NIEHS is using the results of this conference in planning biomedical research to address health-related issues secondary to oil spills and their cleanup.

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 $630,000 was expended in Fiscal Year 1989.

Anthropological Research

FY 89 FUNDING (thousands)

Anthropology	555
Arctic Biology	75

The past year has seen the further development of the Smithsonian's Arctic Studies Center, a program that began with special Congressional funding in 1988. Dedicated to a broad spectrum of Arctic research and education, the program follows the Smithsonian's mandate for "the increase and diffusion of knowledge"—to include, specifically, studies of Arctic and Subarctic cultures, peoples, and environments from the Ice Ages to the present. The Center conducts research on northern ethnology, archeology, and natural history; curates Arctic collections; produces publications and exhibitions on Arctic subjects; and provides training opportunities in field research, material culture studies, and museum anthropology.

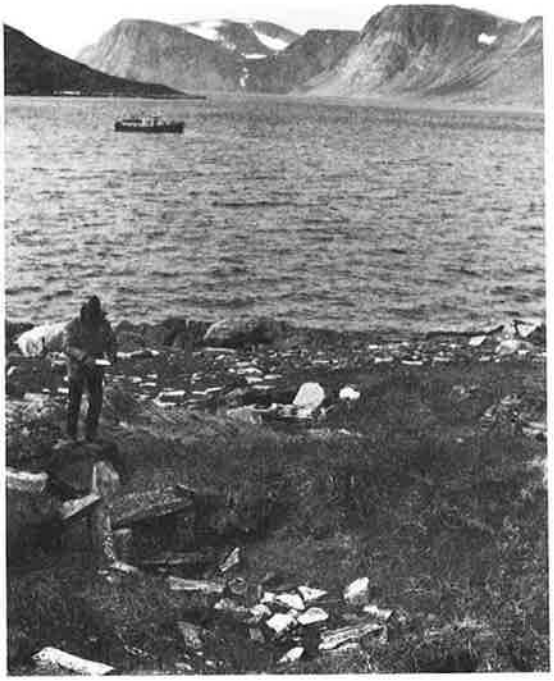
The program was formed in response to compelling needs for a museum-based research center devoted to the study of Arctic regions. By the 1980s, the danger signals were abundantly clear. Industrialization and urbanization were having a serious negative impact on northern societies and environments; global climatic and environmental change threatened disruption of Arctic ecosystems; knowledge of traditional culture and language was being lost at a rapid rate; and archeological sites were being lost to erosion and vandalism. At the same time, political developments, including land claims settlements, organization of the Inuit Circumpolar Conference, and growing recognition of the importance of Arctic regions in world affairs, contributed an urgency to a renaissance in Arctic studies. In leading this renaissance, northern peoples, scholars, and Congress have called for more responsiveness on the part of government and the private sector. The creation of the Smithsonian's Arctic program is part of that response.

The focus of the Arctic Research Program is on the history, prehistory, and current conditions of northern peoples, as well as the study of biota and ecosystems. Special attention will be given to archeological, ethnographic, and historical studies, interpretation of material culture, and studies of modern Arctic and Subarctic cultures and languages. The program goals lie in three general areas: research, museum studies, and education.

In the area of research, primary attention will be directed at social and economic change; cultural history and ethnohistory; circumpolar ethnology and archeology; and natural history, paleoecology, material culture, and museum studies. The geographic scope of these studies will be circumpolar, but owing to the focus of the Smithsonian's unique collections of ethnographic, archeological, physical anthropological, photographic, and archival resources, the program will emphasize North American Arctic and Subarctic regions, including Greenland.

The Arctic Center program will also have a strong emphasis on museum anthropology and natural history. One of the most critical needs in the present era is for development of museum training programs for Arctic peoples and institutions and providing access to information and collections in southern institutions. The Arctic Center program, in cooperation with other Smithsonian offices, will offer assistance in museum training for northern peoples in areas of collection building, data systems, conservation, program development, publications, and exhibitions.

In this way the program will function to facilitate and increase the flow of information from centers of research and training to the larger society, with special attention to northern peoples and organizations, academic institutes, cultural centers, and museums. International programs will be an important activity. Collaborative research and training in Arctic anthropological studies will be undertaken with other northern nations. Special exhibitions and traveling exhibit programs will be mounted for southern and northern audiences. The program will thus be an active instrument in fulfilling the Smithsonian's historic mandate for research and education.



Mapping a 12th–14th century A.D. Thule culture ceremonial house at Staffe Island, extreme northern Labrador.

In pursuing these goals, the Center will coordinate activities with government agencies and nongovernmental organizations involved with Arctic research, including the Interagency Arctic Research Policy Committee (IARPC), the National Science Foundation, the Polar Research Board, and other committees and international organizations active in Arctic research and affairs.

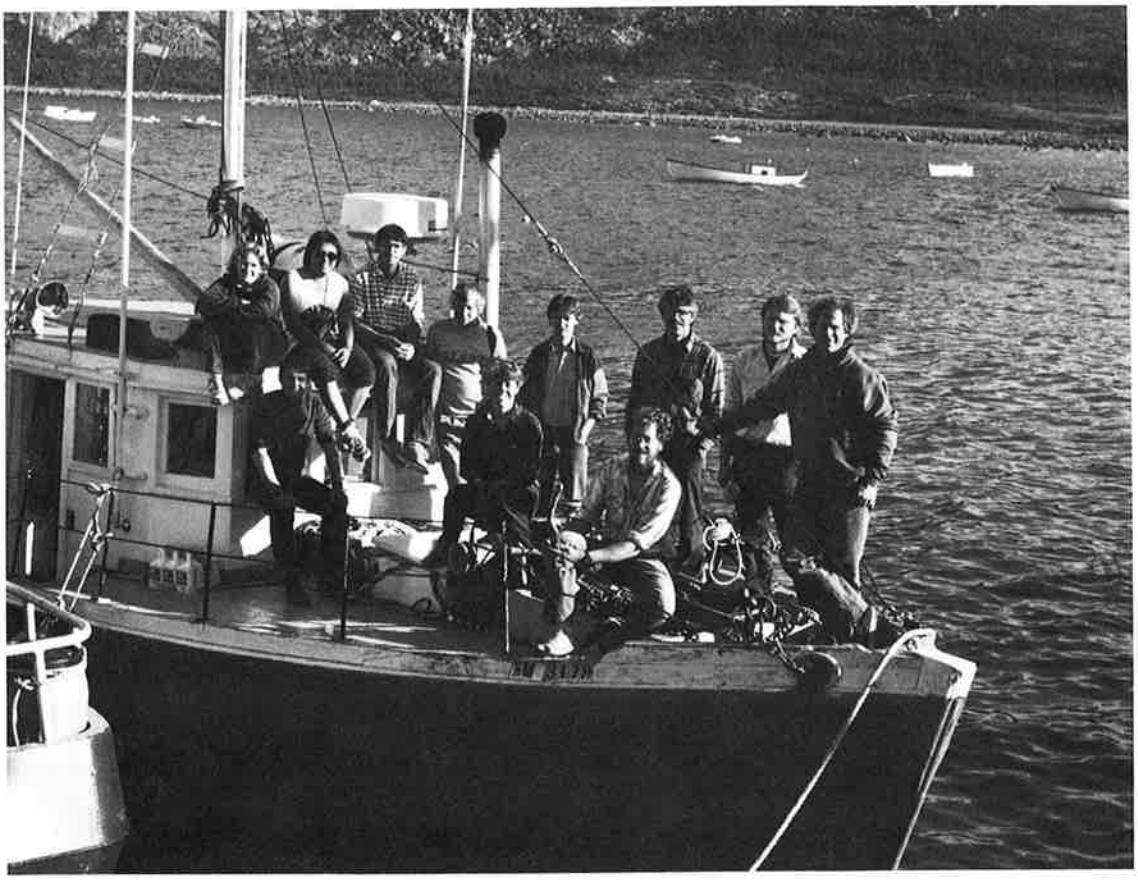
Research Projects

The Smithsonian is currently conducting a variety of research projects. Longstanding research on the prehistory and paleoecology of the Labrador coast, now entering its third decade of study, includes the analysis of collections and the preparation of six monographs on the results of the Torngat Research Project and other projects in Labrador. The Center also is studying early Alaskan Eskimo art and iconography, Siberia–Alaska contacts and exchange, and circumpolar cultural trends. In addition, new studies on the archeology of Frobisher Voyages are being planned (see the next section, "Conferences"). Contract research is being conducted on a variety of special topics: archeometric studies of Labrador Maritime Archaic and Dorset culture lithics and Dorset culture-exchange patterns; a monograph on social, economic, and cultural aspects of the North Alaska whaling complex; and a study of Arctic literature.

Conferences

- *Leningrad Arctic Science Coordination*—Smithsonian scientists participated in the Leningrad conference in December 1988, and presented a paper on global issues in circumpolar studies in an exciting and tumultuous

Field team aboard R.V. Pitsiulak *in Nain, Labrador.*



social science session. This session brought into contact for the first time an international group of Arctic social science researchers with a broad array of Soviet specialists in northern economics, sociology, geography, and ethnology. The conference also included representatives of various ethnic groups. An important result of the meeting was the development of a plan to organize an international, scholarly network of northern social scientists, a task now under way.

- *Frobisher Conference*—In November 1989, an international group of archeologists, ethnologists, historians, metallurgists, geologists, physicists, and other scholars met at the Smithsonian Institution to discuss research results and plan publications for the 1981 Smithsonian expedition exploring the archeology of the Martin Frobisher voyages (1576-78) in Frobisher Bay, Baffin Island. As the earliest English settlement in the New World, Frobisher's mining colony on Kodlunarn Island is an important unexplored source of data on the Frobisher voyages and Elizabethan-era technology. For example, an analysis of iron "blooms" (smelter masses) from the Kodlunarn Island sites produced a series of 12th–13th-century radiocarbon dates, whose surprisingly early ages raise questions warranting further exploration. In addition, the escalating erosion of this historically important site raises concern among researchers. These preliminary findings have given impetus to plans for an archeological survey of English, Norse, and Inuit sites and an ecological survey of the impact of the Little Ice Age on Eastern Arctic cultures, animals, and glaciers, scheduled for the 1990–94 period.

Koryak native from Kamchatka, performing with Siberian dancers and folk musicians at the "Crossroads of Continents" exhibition.

Exhibits

Crossroads of Continents: Cultures of Siberia and Alaska—"Crossroads of Continents" is the first major exhibit presented by the Arctic Research Program at the Smithsonian. The exhibit opened in Washington, D.C., in September 1988 and then moved to Seattle and New York. Detailing the cultural history of the peoples of the North Pacific, including the Bering and Chukchi Seas, from Paleolithic times to the present, this exhibit presents a sweeping chronological and geographic panorama beginning with the peopling of the New World and the development of prehistoric cultures of the North Pacific. After the showing at the American Museum of Natural History in New York, the exhibit will travel to Indianapolis, Los Angeles, Anchorage, and Ottawa, and from there to the U.S.S.R.

Inua: Spirit World of the Bering Sea Eskimo—This exhibit presents the art, technology, and ethnography of the 1877-81 Yupik-speaking peoples of Alaska's Bering Sea coast before major European influence. The exhibit has been reorganized, following its North American tour, and is currently touring Europe with the U.S. Information Agency's Arts America Program. The exhibit has received highly favorable reviews in Eastern Europe and is currently on view in Tromso, Norway.

Prehistory of Beringia—The Smithsonian's Arctic Program and the University of Alaska are collaborating with Soviet archeologists on an exhibit of the ancient cultures of the Beringian region from Paleolithic times to the historical period. Now under development, the exhibit is planned to open in Siberia in 1992 when "Crossroads of Continents" opens in the western U.S.S.R. "Early Beringians" will tour at local northeast Siberian museums and, after 1993, in local Alaskan museums and cultural centers. This exhibit, the first joint museum enterprise to unite Siberian and Alaskan institutions, will offer important opportunities for scholarship, general education at the village level, and cultural exchange.

Film Projects

Crossroads of Continents: Cultures of Siberia and Alaska—This film, now in production with co-direction from American and Latvian filmmakers, features "Crossroads" project themes, artifacts, Siberian dancers, 20th-century cultural developments, and scholars involved in this ground-breaking exhibition.

Early Cultures of the Far Northeast—Also in production, with co-direction from American and Latvian filmmakers, this film features the results of Smithsonian archeological research on the cultures of Labrador from the Ice Ages to the modern day.

Biological Research

In the past, Smithsonian biologists have been extremely active in Arctic research, but in recent years the attention of most of the Institution's biologists has focused on the tropics. After a hiatus of some years, however, the quiescence in Arctic research is beginning to change. In December 1988, the Smithsonian participated in an international conference in Leningrad on the coordination of research in the Arctic. Smithsonian scholars presented a paper proposing cooperative research on mammals. Researchers have been active during the year in negotiating a bilateral research proposal within the framework of the agreement between the U.S.S.R. Academy of Sciences and the National Academy of Sciences of the United States. In 1989, the Smithsonian supported a 2-week field visit to Subarctic Western Siberia in conjunction with a botanical conference.

Also in 1989, the Smithsonian supported a museum zoologist specializing in meiofauna to conduct 3 weeks of research on the systematics and zoogeography of coastal Alaskan Kinorhyncha and associated meiofauna. Extensive collections were made from Friday Harbor, Washington, northward to Subarctic Yakutat, Alaska.

Federal programs have been attempting to assess the long-term effects of the Exxon *Valdez* oil spill. Before the spill, few baseline data on meiofauna were available. Because meiofauna are exclusively endobenthic or mesobenthic within sediments, such studies may be very important in the assessment process. Smithsonian scientists are participating in the identification of meiofauna collected by the multiagency assessment teams that have taken samples in the area of the oil spill. In the summer of 1990, the Smithsonian expects to make field collections from adjacent unaffected areas to derive comparative data.

Preliminary plans for 1990 call for expanding museum research in Arctic and Subarctic areas of North America, including new algal studies by two phycologists.

Environmental Protection Agency

EPA research covers the spectrum of environmental problems, including treatment control technology, human health, air pollution effects, water pollution effects, and solid waste disposal. In Fiscal Year 1989 a new program was funded at an initial $25,000.

The Cold Climate Research Program, an extramural program of the Office of Research and Development (ORD), was officially concluded in FY 87. The research primarily concerned environmental problems in Alaska, including treatment control technology, human health, air pollution effects, water pollution effects, and solid waste disposal. The Corvallis Laboratory worked directly with the EPA Region X Alaska Operations Office in Anchorage to coordinate ongoing research 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.

During FY 89 the U.S. Environmental Protection Agency, as part of its Global Change Research Program, funded a planning effort for Arctic laboratory and field investigations. The objectives of the research are to elucidate physical, chemical, and biological processes controlling the net fluxes of radiatively important trace gases (RITGs), especially methane, nitrous oxide, and nitric oxide, associated with carbon and nitrogen cycling in high-latitude environments (tundra, taiga, boreal forest, wetlands). The proposed research would emphasize (1) the modification of an existing field site, or the establishment of a new site, for RITG research; (2) the collection of baseline flux measurements in the field; and (3) studies in support of the development and testing of quantitative approaches to predicting effects of environmental factors on RITG fluxes. The laboratory studies will emphasize biofeedback processes, such as wet-dry cycles, changes in nutrient input, changes in temperature, changes in pH, as well as others. The field studies will be structured such that RITG fluxes can be determined as a function of site characteristics. Process model development will encompass mathematical algorithms describing key processes and feedbacks.

A major international activity involves chairship, coordination, and implementation of the U.S.–U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection. A number of major activities related to the Arctic took place in FY 89. In addition, preparation was begun for the Twelfth Meeting of the U.S.–U.S.S.R. Joint Committee, which took place in Washington, D.C., on January 9–12, 1990. Of the 11 technical areas of the agreement, six areas focus significant activities on the Arctic (Areas IV, V, VI, VII, VIII, X, and XI). The following paragraphs highlight some of these activities.

FY 89 FUNDING (thousands)	
High Latitude Methane	25

Under the National Park Service's leadership (Area IV), a joint group of Soviet and American specialists conducted field investigations on either side of the Bering Strait in preparation for the designation of an international park.

Under the Fish and Wildlife Service's leadership (Area V), joint expeditions and visits to study polar bear, sea lions, black brant, and other Arctic fauna and flora took place as well as discussions on research on northern Biosphere Reserves and protected areas.

Under Area VI, the Coast Guard negotiated a cooperative agreement of mutual assistance in the event of an accidental spill in the Bering and Chukchi seas, as well as a joint oil spill contingency plan.

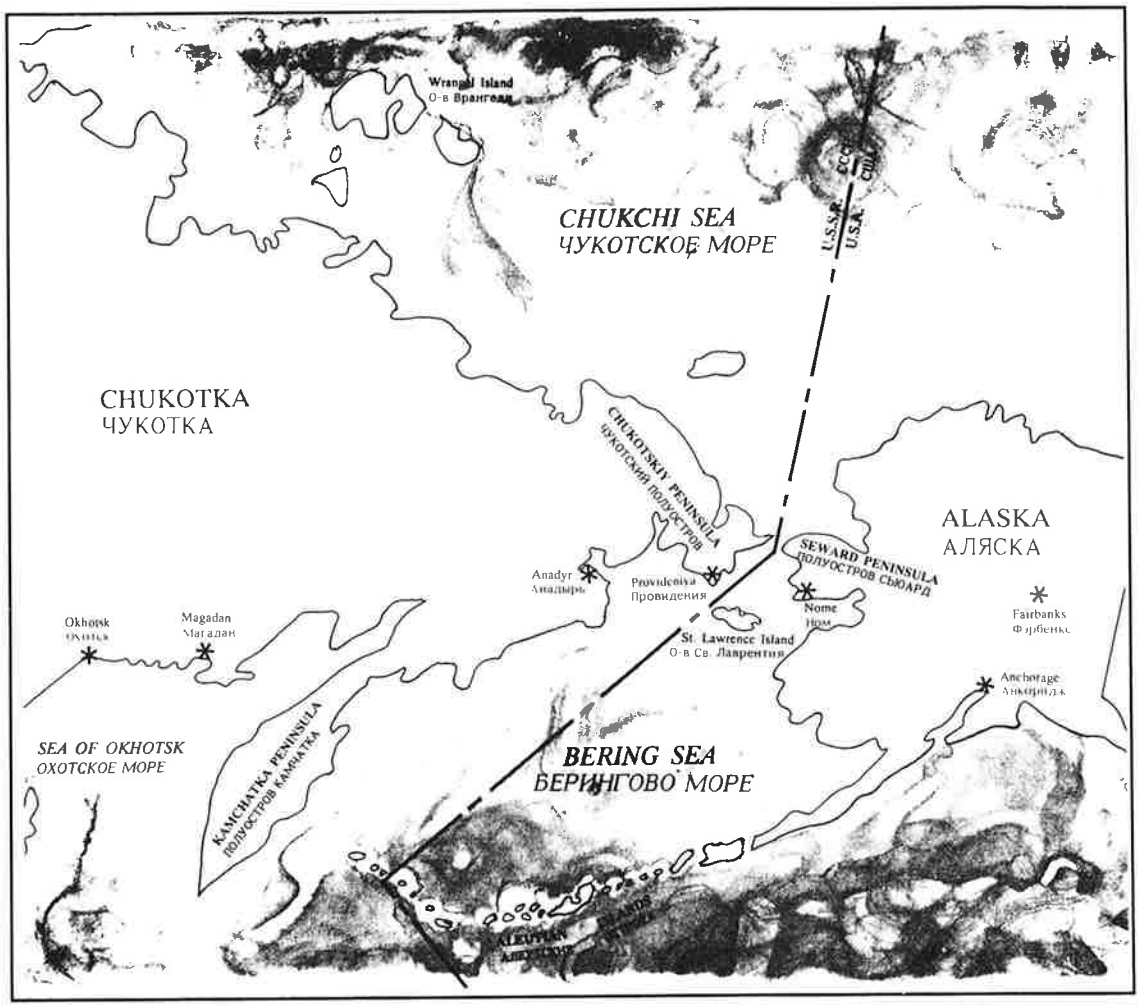
Under Area VII, long-term U.S.–Soviet research in the Bering and Chukchi seas continued with completion of a joint cruise, a symposium, and preparation of joint publications.

Area VIII, under the National Climate Program Office auspices, facilitated projects on the influence of climate change on permafrost, acquisition of lake cores for paleoclimate reconstruction in the Magadan region, and for a methane sampling program.

Activities under Area X, cochaired by the National Science Foundation and the U.S. Geological Survey on Arctic and Subarctic Ecosystems, were initiated by a visit of U.S. specialists to West Siberia gas fields and Soviet ecologists to tundra sites in Alaska, Colorado, and Washington.

Area XI, under the leadership of the Council on Environmental Quality, developed plans for a symposium on legal measures for protection and management of living resources of the Bering Sea.

A report on the Implementation of the Agreement for the period February 1988–December 1989 provides additional details and is available from the International Office, EPA Headquarters, Washington, D.C.



Numerous scientific exchanges are taking place under the U.S.–U.S.S.R. Agreement (map courtesy of National Park Service).

Department of Transportation

The U.S. Coast Guard icebreakers support government and nongovernment research, both in the eastern and western Arctic, and perform sea ice and iceberg reconnaissance.

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 maritime safety, enforcement of laws and treaties, environmental protection, and support of national defense. The Coast Guard's major role in the Arctic is to provide icebreaker services to other agencies and to meet needs in research support and logistics and resupply.

FY 89 FUNDING (thousands)

International Ice Patrol	79
Extramural Support	55

Polar Icebreaker Operations

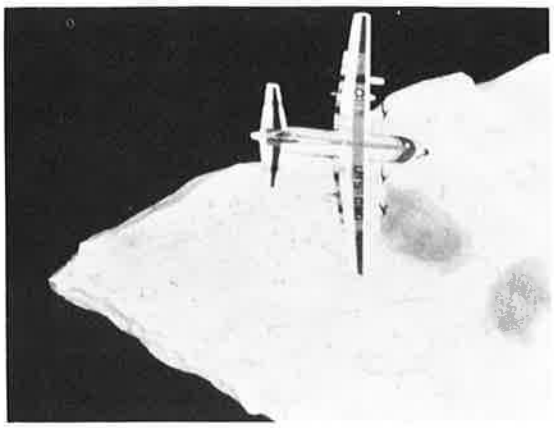
During Fiscal Year 89, the U.S. polar icebreaker fleet was employed in all routine polar-operating areas: the Antarctic and the western and eastern Arctic. FY 89 began with an easterly Northwest Passage transit, during which two projects were carried out: in-situ measurements by the Naval Research and Development Activity of microwave brightness temperature of sea ice and snow, and an investigation by University of Alaska researchers of phytoplankton populations and nutrients in the passage. In August, following the annual Greenland resupply, the U.S. Coast Guard cutter *Polar Star* journeyed through the Northwest Passage to support research projects in the western Arctic. During the Northwest Passage transit, a U.S. Geological Survey (USGS) sea ice sampling and observation project took place. The major scientific effort of the cruise was a joint geological project, with researchers from the USGS, the Geological Survey of Canada, and Woods Hole Oceanographic Institution. Six different geological investigations were carried out in an area north of Barter Island, looking at sediment transport, sediments, and underlying structures of the east Beaufort Sea. This project was a repeat of the previous year's successful USGS cruise, making use of the expanded coring and trawling capability of the *Polar Star*. The coring and trawling equipment is the first stage of a two-phase upgrading of scientific facilities on board the *Polar Star* and *Polar Sea*. The new facilities will provide researchers with expanded geological and oceanographic lab facilities, new oceanographic and coring and trawling winches, a PC-based winch control system, an uncontaminated seawater system, additional services and spaces for vans, and a subbottom echosounder. The entire upgrading project will be completed on both vessels by the end of FY 91.

The acquisition of a new 460 foot (140 m) research icebreaker has been approved for the Coast Guard for FY 90. Funded for $329 million through the Department of Defense, this vessel will offer most of the facilities of a large, open-water research vessel. Scheduled completion is set for 1995.

Funding of icebreaker time continues to be an impediment to conducting research from Coast Guard icebreakers. Reimbursable costs to researchers occur from a combination of fuel consumed, surcharges for ship maintenance, and helicopters. These costs are shared by all dedicated time users, paid both for operating time and transit time. Operating area cost during the Beaufort Sea project was approximately $13,000 per day.

Iceberg Reconnaissance and Prediction

The U.S. Coast Guard's International Ice Patrol participated in the Canada–U.S. Labrador Ice Margin Experiment (LIMEX 89). In addition to providing aircraft remote sensing of sea ice for LIMEX, the International Ice Patrol cooperated with Canada's Bedford Institute of Oceanography and Atmospheric Environment Service in tracking the drift of icebergs in sea ice, using ARGOS-tracked drifters placed on icebergs and sea ice. International Ice Patrol also operationally deploys ARGOS-tracked drifting buoys in the Labrador and northeast Atlantic to predict iceberg drift. Starting in FY 89, some of these buoys were equipped with barometric sensors.



Ice-breaking and ice patrol operations.

DOT-Sponsored Highway Research

The Strategic Highway Research Program (SHRP) was established as part of the 1987 Highway Act. It is a 5-year, $150 million program administered by the National Research Council. Some of the research activities of SHRP are related to cold-weather construction and maintenance of highways and bridges. The research covers resistance of concrete to freezing and thawing, prevention of ice-pavement bonding, and how to break established bonds. Other research projects undertaken by SHRP may prove to have cold-weather applications. This is especially true of the wide-ranging research into pavements. Approximately $2.0 million was devoted to cold regions projects in FY 89.

Department of State

The Department of State has responsibilities for international policy issues related to the Arctic and chairs the Interagency Arctic Policy Working Group, which oversees U.S. Arctic policy.

The Department is involved with two major initiatives for Arctic cooperation: the consultative process on protection of the Arctic environment and the establishment of the International Arctic Science Committee.

The Finnish Government hosted an international conference in September 1989 in Rovaniemi, Finland, to discuss the unique environmental problems of the Arctic regions. Representatives of the eight Arctic countries (Norway, Finland, Sweden, Iceland, Soviet Union, Canada, Denmark, and United States) attended.

At the Rovaniemi meeting, two working groups were established, one to review the state of the environment in the Arctic, the second to consider existing international arrangements and future cooperation. The environmental issues of concern outlined in the Rovaniemi report (acids, heavy metals, noise, oil, organic contaminants, and radioactivity) are undergoing review in both scientific and legal papers. Reports concerning Arctic environmental monitoring and emergency response strategies are also under review. The Second Consultative Meeting on Protection of the Arctic Environment was held in Yellowknife, Northwest Territories, Canada, on April 18-23, 1990, and included observers from the Federal Republic of Germany and Great Britain and a nongovernmental organization, the Inuit Circumpolar Conference.

The Yellowknife meeting continued work begun in Rovaniemi on outlining a strategy for Arctic environmental protection, analyzed legal instruments, and reviewed reports on the state of the Arctic environment. No specific proposals for cooperation were approved at this meeting, although the need for coordination of Arctic environmental monitoring or joint contingency planning for emergencies, such as oil spills, was discussed. Sweden will host a third preparatory meeting in early 1991, leading to the eventual goal of a high-level meeting of Arctic countries in the spring of 1991 in Finland.

There was general agreement that the idea of continuing cooperation is of common benefit to the Arctic countries. The United States shares the concerns expressed at both meetings for the protection of the Arctic environment and will undertake a comprehensive review of all papers in preparation for further meetings.

FY 89 FUNDING (thousands)	
MAB: Arctic Directorate	4

The second initiative involving the Department is the imminent establishment of the International Arctic Science Committee (IASC). IASC is a nongovernmental scientific organization designed to encourage and facilitate international consultation and cooperation for Arctic scientific research. Since the last report in the spring 1989 *Arctic Research of the United States,* the drafting committee has met on several occasions, and the Founding Articles are in the final stages of editing.

As structured in the Founding Articles, the IASC would develop guidelines for cooperative scientific Arctic research, periodically organize an Arctic Science Conference, and establish working groups to develop scientific programs. Participation in IASC would be open to the scientific organizations of the eight Arctic countries, as well as those of other countries engaged in significant Arctic scientific research. A regional board would be established to consider general regional aspects of scientific cooperation.

It is anticipated that the IASC Founding Articles will be signed within the next few months, establishing IASC.

The Department of State also administers the U.S. Man and the Biosphere Program. The U.S. Man and the Biosphere Program (MAB) Secretariat is located in the Department of State. The High-Latitude Ecosystem Directorate is one of five U.S. Directorates that receive funding from MAB. The level of support depends on the number and quality of proposals awarded for these Directorates in any given year (grants average $30,000 each). The State Department, along with several other agencies, contributes to the funding of MAB. In 1989 the overall U.S. MAB program was funded at over $600,000 with State contributing $395,000. In 1990, the total was increased to $900,000.

The High-Latitude Ecosystem Directorate aims to enhance the understanding and rational management of resources and ecosystems in the high-latitude regions of the United States and other circumpolar northern lands. This is to be accomplished through support of cooperative international endeavors; through fostering integrated research in biological, physical, and social sciences in applying scientific advances to societal needs, including those of multicultural residents and indigenous peoples; and through support of informed policy formulation on societal issues, including sustainable development, global climatic change, and maintenance of biological diversity and stability in high-latitude ecosystems.

The Directorate currently supports a study of existing circumpolar northern research sites in the context of global change research. The Directorate represents the United States in the MAB Northern Sciences Network. The Northern Sciences Network secretariat is now located at the Arctic Centre, University of Lapland, P.O. Box 122, SF-96101, Rovaniemi, Finland. Copies of the MAB Northern Sciences Network newsletter may be obtained from the secretariat.

In addition to these activities, the Department of State coordinates two annual events. First, under the umbrella of the 1951 U.S.-Denmark Defense Agreement, The Office of Oceans and Polar Affairs collates and prepares a list of all U.S. scientific research proposals for Greenland. A U.S. delegation attends an annual meeting in Copenhagen with the Danish Commission for Scientific Research in Greenland, at which time the proposals are formally presented.

Second, the Department of State and its counterpart in the Canadian Ministry of External Affairs annually organize a 1- or 2-day discussion of topics concerning environmental issues surrounding hydrocarbon development and related topics in the Beaufort Sea.

Principles for the Conduct of Research in the Arctic

Prepared by the Social Science Task Force of the U.S. Interagency Arctic Research Policy Committee

Introduction

All researchers working in the North have an ethical responsibility toward the people of the North, their cultures, and the environment. The following principles have been formulated to provide guidance for researchers in the physical, biological, behavioral, health, economic, political, and social sciences and in the humanities. These principles are to be observed when carrying out or sponsoring research in Arctic and northern regions or when applying the results of this research.

This statement addresses the need to promote mutual respect and communication between scientists and northern residents. Cooperation is needed at all stages of research planning and implementation in projects that directly affect northern people. Cooperation will contribute to a better understanding of the potential benefits of Arctic research for northern residents and will contribute to the development of northern science through traditional knowledge and experience.

These "Principles for the Conduct of Research in the Arctic" were prepared by the Interagency Social Science Task Force in response to a recommendation by the Polar Research Board of the National Academy of Sciences and at the direction of the Interagency Arctic Research Policy Committee. This statement is not intended to replace other existing Federal, State, or professional guidelines, but rather to emphasize their relevance for the whole scientific community. Examples of similar guidelines used by professional organizations and agencies in the United States and in other countries are listed in the publications.

These principles are to be observed when carrying out or sponsoring research in Arctic and northern regions or when applying the results of this research.

Implementation

All scientific investigations in the Arctic should be assessed in terms of potential human impact and interest. Social science research, particularly studies of human subjects, requires special consideration, as do studies of resources of economic, cultural, and social value to Native people. In all instances, it is the responsibility of the principal investigator on each project to implement the following recommendations.

1. The researcher should inform appropriate community authorities of planned research on lands, waters, or territories used or occupied by them. Research directly involving northern people or communities should not proceed without their clear and informed consent. When informing the community and/or obtaining informed consent, the researcher should identify—

a. all sponsors and sources of financial support;

b. the person in charge and all investigators involved in the research, as well as any anticipated need for consultants, guides, or interpreters;

c. the purposes, goals, and time frame of the research;

d. data-gathering techniques (tape and video recordings, photographs, physiological measurements, and so on) and the uses to which they will be put; and

e. foreseeable positive and negative implications and impacts of the research.

2. The duty of researchers to inform communities continues after approval has been obtained. Ongoing projects should be explained in terms understandable to the local community.

3. Researchers should consult with and, where applicable, include northern communities in project planning and implementation. Reasonable opportunities should be provided for the communities to express their interests and to participate in the research.

4. Research results should be explained in nontechnical terms and, where feasible, should be communicated by means of study materials that can be used by local teachers or displays that can be shown in local community centers or museums.

5. Copies of research reports, data descriptions, and other relevant materials should be provided to the local community. Special efforts must be made to communicate results that are responsive to local concerns.

6. Subject to the requirements for anonymity, publications should always refer to the informed consent of participants and give credit to those contributing to the research project.

7. The researcher must respect local cultural traditions, languages, and values. The researcher should, where practicable, incorporate the following elements in the research design:

a. Use of local and traditional knowledge and experience.

b. Use of the languages of the local people.

c. Translation of research results, particularly those of local concern, into the languages of the people affected by the research.

8. When possible, research projects should anticipate and provide meaningful experience and training for young people.

9. In cases where individuals or groups provide information of a confidential nature, their anonymity must be guaranteed in both the original use of data and in its deposition for future use.

10. Research on humans should only be undertaken in a manner that respects their privacy and dignity:

a. Research subjects must remain anonymous unless they have agreed to be identified. If anonymity cannot be guaranteed, the subjects must be informed of the possible consequences of becoming involved in the research.

b. In cases where individuals or groups provide information of a confidential or personal nature, this confidentiality must be guaranteed in both the original use of data and in its deposition for future use.

c. The rights of children must be respected. All research involving children must be fully justified in terms of goals and objectives and never undertaken without the consent of the children and their parents or legal guardians.

d. Participation of subjects, including the use of photography in research, should always be based on informed consent.

e. The use and disposition of human tissue samples should always be based on the informed consent of the subjects or next of kin.

11. The researcher is accountable for all project decisions that affect the community, including decisions made by subordinates.

12. All relevant Federal, State, and local regulations and policies pertaining to cultural, environmental, and health protection must be strictly observed.

13. Sacred sites, cultural materials, and cultural property cannot be disturbed or removed without community and/or individual consent and in accordance with Federal and State laws and regulations.

In implementing these principles, researchers may find additional guidance in the publications listed below. In addition, a number of Alaska Native and municipal organizations can be contacted for general information, obtaining informed consent, and matters relating to research proposals and coordination with Native and local interests. A separate list is available from NSF's Division of Polar Programs.

Publications

Arctic Social Science: An Agenda for Action. National Academy of Sciences, Washington, D.C., 1989.

Draft Principles for an Arctic Policy. Inuit Circumpolar Conference, Kotzebue, 1986.

Ethics. Social Sciences and Humanities Research Council of Canada, Ottawa, 1977.

Nordic Statement of Principles and Priorities in Arctic Research. Center for Arctic Cultural Research, Umea, Sweden, 1989.

Policy on Research Ethics. Alaska Department of Fish and Game, Juneau, 1984.

Principles of Professional Responsibility. Council of the American Anthropological Association, Washington, D.C., 1971, rev. 1989.

The Ethical Principles for the Conduct of Research in the North. The Canadian Universities for Northern Studies, Ottawa, 1982.

The National Arctic Health Science Policy. American Public Health Association, Washington, D.C., 1984.

Protocol for Centers for Disease Control/ Indian Health Service Serum Bank. Prepared by Arctic Investigations Program (CDC) and Alaska Area Native Health Service, 1990. (Available through Alaska Area Native Health Service, 255 Gambell Street, Anchorage, AK 99501.)

Indian Health Manual. Indian Health Service, U.S. Public Health Service, Rockville, Maryland, 1987.

Human Experimentation. Code of Ethics of the World Medical Association (Declaration of Helsinki). Published in *British Medical Journal* 2:177, 1964.

Protection of Human Subjects. Code of Federal Regulations 45 CFR 46, 1974, rev. 1983.

Interagency Arctic Research Policy Committee

Committee Members or Agency Representatives Present:
Erich Bloch, Chairman, NSF; Peter deVos, Department of State; Ned Ostenso, Department of Commerce; Eric Bretthauer, Environmental Protection Agency; Helen McCammon, Department of Energy; Harlan Watson, Department of Interior; Robert Knisely, Department of Transportation; Thomas Hamilton, Department of Agriculture; David Klein, Department of Health and Human Services; Shelby Tilford, NASA; Ted Cress, Department of Defense; Jack Fellows, Office of Management and Budget; Stan Shetler, Smithsonian Institution.

Seventh Meeting
November 6, 1989

Chairman Erich Bloch convened the meeting. He reviewed recent Committee activities, the publication of the first biennial revision to the U.S. Arctic Research Plan, and a meeting of committee staff with Office of Management and Budget (OMB) examiners to review FY 91 budget proposals for Arctic research. This was the first interagency dialogue with OMB on Arctic research. He noted that the Interagency Committee had cosponsored a workshop on Arctic logistics in Fairbanks, Alaska, in September 1989. He also noted that agencies are participating in Small Business Innovation Research Seminars in Los Angeles and Washington to encourage private-sector interest in solving Arctic and cold regions problems. Mr. Bloch commented on the importance of data and information for all Arctic research activities and reminded the agencies of his request that they provide comments to Douglas Posson of the U.S. Geological Survey regarding the Arctic Research Commission's report on data and information. The Committee then heard reports from several agencies on their environmental research related to the oil spill near Valdez, Alaska.

Mr. Bloch next turned to a discussion of the biennial report to the President, which is required under the Arctic Research and Policy Act. He stated that the staff had prepared an outline for the report. He requested that agencies provide comments on the outline so that the staff could prepare the report for final clearance. (See following Appendix.)

Robert Corell, Assistant Director for Geosciences, NSF, then reported on the development of the Arctic Oceans Research Program, a multi-agency coordinated effort. NSF, Navy, Interior, and NASA participated in the development of this program, which is budgeted at about $44 million for FY 91.

Peter deVos, Deputy Assistant Secretary for Oceans and Environment and Scientific Affairs in the Department of State, reported on an initiative of the Finnish Government to develop cooperative activities in Arctic environmental protection. A consultative meeting was held in Finland in September 1989, with a second consultative meeting in Canada in April 1990.

Dr. Corell then discussed activities related to establishing an International Arctic Science Committee (IASC). He reported that negotiations are continuing aimed at resolving differences among the participating countries and that he was optimistic that the IASC would be established.

Luis Proenza, President of the Arctic Research Consortium of the United States (ARCUS), discussed the history, mission, and accomplishments of ARCUS and its future plans. He invited those present to attend the ARCUS annual meeting in Washington in December 1989. Mr. Bloch then adjourned the open session of the committee meeting.

The Committee reconvened in closed session to discuss coordination and budgetary issues. Dr. Corell discussed the Arctic oceans crosscut process in depth and the efforts to build integrated programs, not simply combinations of individual agency programs. He noted that as a result of this effort, OMB suggested that a crosscut exercise be extended over a 5-year period, for FY 92-96, to cover the entire Arctic program. The agencies then agreed to develop the FY 92-96 overall Arctic program crosscut.

The following Committee members or Agency Representatives attended the Sixth Meeting on June 1, 1989. Their names were inadvertently omitted from the Spring 1989 issue of Arctic Research.

Erich Bloch, Chairman, National Science Foundation; Mel Peterson, Department of Commerce; Robert Worrest, Environmental Protection Agency; James Decker, Department of Energy; Vernon Wiggins, Department of Interior; Jocelyn Stevenson, Department of Transportation; Paul Dunn, Department of Agriculture; David Klein, Department of Health and Human Services; Wes Huntress, National Aeronautics and Space Administration; Ted Cress, Department of Defense; Fred Bernthal, Department of State; Paul Dunn, Department of Agriculture; Jack Fellows, Office of Management and Budget; William Fitzhugh, Smithsonian Institution.

Appendix

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICE OF THE
DIRECTOR

January 26, 1990

The President
The White House
Washington, D.C. 20500

Dear Mr. President:

I am pleased to transmit through you to the Congress the enclosed report required under Public Law 98-373, the Arctic Research and Policy Act of 1984.

This report is submitted on behalf of the Interagency Arctic Research Policy Committee for which the National Science Foundation serves as chair agency. The report lists activities and accomplishments of the Interagency Committee and describes the activities of the Arctic Research Commission. Both entities are authorized by the Act and were established by Executive Order 12501 of January 28, 1985.

It is a distinct honor for the member agencies to serve on the Interagency Committee and for the National Science Foundation to chair it.

Sincerely,

Erich Bloch
Director

Enclosure: Biennial Report

THIRD BIENNIAL REPORT OF THE INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE TO THE CONGRESS (FEBRUARY 1, 1988 TO JANUARY 31, 1990)

Prepared by the National Science Foundation
on behalf of the Interagency Arctic Research Policy Committee

Section 108(b) of Public Law 98-373, the Arctic Research and Policy Act of 1984, directs the Interagency Arctic Research Policy Committee (IARPC) to submit to Congress, through the President, a biennial report containing a statement of the activities and accomplishments of the Interagency Arctic Research Policy Committee and a description of the activities of the Arctic Research Commission. Both the Interagency Committee and the Commission are authorized by the Act and were established by Executive Order 12501 dated January 28, 1985.

During the period February 1, 1988 to January 31, 1990, the Interagency Arctic Research Policy Committee has:

- Prepared and published the first biennial revision to the United States Arctic Research Plan, as required by Section 108(a)(4) of the Act. The revised Plan was formally submitted to the President on August 1, 1989, and the President transmitted the Plan to Congress on August 2, 1989.

- Published and distributed four issues of the journal Arctic Research of the United States. The issues reviewed all Federal agency arctic research for FY 1987 and 1988 and included summaries of the IARPC and Commission meetings and activities. The fall 1989 issue contained the full text of the biennial revision to the U.S. Arctic Research Plan.

- Consulted with the Commission on policy and program matters described in Section 108(a)(3), was represented at all meetings of the Commission, and responded to Commission reports on goals and objectives, logistics and data.

- Continued the processes of cooperation and coordination required under Section 108(a)(6), (7), (8) and (9);

- Provided input to an integrated budget analysis for arctic research for the President's budget, which identified $97.0 million in Federal support for fiscal year 1988, and $106.0 million in fiscal year 1989.

- Provided for public participation as required in Section108(a)(10),which culminated in active public involvement in the development of the recommendations and the biennial revision to the Plan at consultative meetings in Anchorage, Barrow, and Kotzebue, Alaska, in March 1989;

- Prepared a strategy report, published in January 1990, for an FY 1991 interagency Arctic Oceans Research Program which identified six key science elements for future research.

- Developed the Arctic Environmental Data Directory, which now contains information on 250 arctic data sets, and developed a demonstration model for a prototype CD ROM (compact disc - read only memory) containing arctic environmental data and information.

- Conducted a formal interagency review of the National Academy of Sciences report on development of an Arctic Social Science Program, and formally supported establishment of an arctic social sciences research program at the National Science Foundation. The program has now been established.

- Participated in discussions on the development of a non-governmental International Arctic Science Committee.

In addition to four meetings of the Committee (May 2, 1988; March 27, 1989; June 1, 1989; and November 6, 1989), other meetings were organized and sponsored by the Interagency Arctic Research Policy Committee (IARPC) over the past two years and included:

- Social Science Workshops: Fairbanks, Alaska (September 1988) and Washington, D.C. (January 1989)

- Data Workshops: Boulder, Colorado (March 1988 and June 1989)

- Logistics Workshop: Fairbanks, Alaska (September 1989)

All of these activities have served to increase awareness of arctic research, both within and outside the Federal government. These activities have provided opportunities for outside involvement in the establishment of arctic research policy and research plans.

During this period, the U.S. Arctic Research Commission meet eight times and:

- Published a Statement of Goals and Objectives to Guide United States Arctic Research (December 1988). The report addresses guiding principles, priority research areas, support and management as well as new opportunities for research. This guidance was used by the Interagency Arctic Research Policy Committee in preparing the biennial revision of the United States Arctic Research Plan.

- Published a comprehensive report, Arctic Data and Information: Issues and Goals (June 1989), which addresses a series of specific issues concerning arctic data and information including policy considerations, and recommends steps to implement a comprehensive national policy and an Arctic Data and Information System.

- Reviewed the environmental impact statement (EIS) process and developed recommendations for its improvement in the Arctic with emphasis on the need for external scientific and technical review at all stages in the process.

- Prepared an explanatory brochure on the Arctic Research Commission, its basic objectives, principal duties, and the priority areas of arctic research.

United States Arctic Research Commission

Commission Members Present: Juan G. Roederer, Chairman; John H. Steele, Vice Chairman; Ben C. Gerwick; Oliver Leavitt; Elmer E. Rasmuson; Jerry Brown and Peter Wilkniss, representing ex-officio member Erich Bloch. Staff: Philip L. Johnson, Executive Director, Lyle D. Perrigo, Head, Anchorage office. Commission Advisory Members: *Thomas F. Albert, North Slope Borough; George B. Newton, Analysis and Technology; Robert B. Weeden, University of Alaska–Fairbanks.* Visitors: *Vera Alexander, UAF; Brian Allee, Alaska Department of Fish and Game; Patricia Anderson, NSF; Bob Carlson, UAF; Henry Cole; Office of the Governor of Alaska; Jack Colonell, Hunter Environmental Services; Paul Dunn, U.S. Forest Service; Bruce Evans and David Garman, Senator Murkowski's office; Joe Fletcher, NOAA; Jay Jakubczak, BP Exploration (Alaska); Tom Newbury, Minerals Management Service; Walt Parker, Alaska Oil Spill Commission; Charles Slaughter, Institute of Northern Forestry, USDA; Barbara Sokolov, University of Alaska–Anchorage.*

Nineteenth Meeting September 12–13, 1989

The Arctic Research Commission held its meeting at the Elmer E. Rasmuson Library in Fairbanks, Alaska, on September 12-13, 1989. Chairman Roederer opened the meeting, noting the publication of the third issue of the Commission's *Findings and Recommendations* series, "Arctic Data and Information: Issues and Goals," and a brochure showing the goals, objectives, and priorities of Arctic research.

Interagency Arctic Research Policy Committee (IARPC)

Jerry Brown stated that the Biennial Revision of the U.S. Arctic Research Plan was formally transmitted to the President and to the Congress on August 1 and would be published in the fall issue of the journal *Arctic Research of the United States*. Dr. Brown summarized the implementation of the Commission's early recommendations for research priority on the Arctic Ocean and marginal seas in the interagency "crosscut" budget. He added that IARPC is also focusing on the long-term issues and goals addressed in the Commission's *Data and Information* report.

Dr. Brown noted that the proceedings of an NSF-sponsored workshop on Cold Regions Engineering were to be distributed in September 1989. He reported on the signing of a U.S.-Soviet bilateral scientific agreement and stated that the United States continues to be optimistic about agreement on the formation and operation of an International Arctic Science Committee (IASC).

Alaska Congressional Delegation

David Garman announced his planned departure from Senator Murkowski's staff and introduced Bruce Evans as the staff member responsible for Arctic issues and the point of contact for the Commission.

Alaska Governor's Office

Henry Cole, Science Advisor to the Governor, reported that the Alaska Science and Technology Foundation (ASTF) announced its first grants in August. He discussed the role of the Alaska Science and Engineering Advisory Commission (ASEAC) as strategic planner for scientific and engineering issues affecting economic development. He also announced the publication of the ASEAC report on logistic sites in Alaska in response to a request from Commission Chairman James H. Zumberge in 1987.

Polar Research Board

Gunter Weller, of the Polar Research Board (PRB), discussed the PRB's "Strategic Series" of reports covering the Antarctic, the Arctic, and bipolar interests. The Board has been requested by NSF to develop a report on bipolar research. Dr. Weller described the identity and relationships of key organizations involved in U.S. Arctic research, pointing out specific roles of the Commission and the PRB.

Alaska Science and Technology Foundation

Francis Williamson, a member of the ASTF Board of Directors, described the history of the Foundation and the recent set of initial grants. The purpose of ASTF is to fund applied research that may have a near-term, favorable impact on the Alaska economy.

Arctic Research Consortium of the United States (ARCUS)

Luis Proenza, President of ARCUS, described the purpose, functions, composition, and plans of the organization. The mission of the organization is to strengthen and advance Arctic research to meet national needs. He reported that ARCUS consists of 20 institutions and an additional seven international corresponding members.

Assessment of Commission Initiatives

Chairman Roederer opened discussion of the Commission's health initiative, which began with the establishment of a State-Federal task force based on a joint resolution of the Governor of Alaska and the chairman of the Commission. In 1987, the joint task force recommended research on injury control, cancer, diet and atherosclerosis, and infectious diseases. These recommendations were endorsed by the Commission. Discussion followed on the state of Arctic health research in Washington, D.C., and Alaska, and it was decided that the Commission would examine the current position of the task force with regard to the earlier recommendations.

The Commission's ice edge initiative also began with a joint State-Federal task force. Following the report of the task force in FY 87 and endorsement by the Commission, the National Oceanic and Atmospheric Administration

(NOAA) developed a program proposal but has since failed to receive support from the Office of Management and Budget (OMB). Joe Fletcher, Director of NOAA's Environmental Laboratories, reported that the ice edge proposal was not in the FY 90 budget but has been resubmitted for FY 91.

Regarding the Bering Sea proposal, which was made to the Commission by Unalaska Mayor Paul Fuhs and Alaska State Senator Arliss Sturgulewski, Philip Johnson noted that encouraging activity is under way that relates to the Commission's highest priority, research to understand the Arctic Ocean. Five agencies and the Office of Management and Budget are preparing a budget plan for integrated research on the Arctic oceans including the Bering Sea.

Dr. Johnson reviewed the current status of efforts to secure an adequate Arctic research vessel with icebreaking capability, referring to the Commission's publication, *Logistic Support of Arctic Research*. The Administration's request for an icebreaker was removed from the House budget, but funds remain in the House appropriations bill for science upgrades. Specifications for an ice-capable research vessel are being developed by a University National Oceanographic Laboratory System planning committee, but this vessel would not be able to operate without icebreaker escort in the central Arctic Ocean. Other options were discussed, and Dr. Roederer noted that the Commission would continue to support its recommendation for an Arctic research vessel.

Dr. Johnson reported that there were no new developments on the Commission's recommendation for baseline support for existing land-based logistic centers in the Arctic.

Dr. Brown reported that the Commission's recommendation to establish a central office for logistic coordination was being responded to by Federal agencies. A listing of their logistic assets has been compiled and is posted and updated on an electronic bulletin board.

Chairman Roederer reported on the third Commission recommendation on logistics, which calls for an upgrade of the sounding rocket launch facility at Poker Flat. Plans have been formulated to install a new radar system and other upgrades. Mr. Garman reported that Congress is deliberating on the amount of support for the Poker Flat upgrade.

Dr. Roederer reported that the Commission's report, *Arctic Data and Information: Issues and Goals*, had been sent to IARPC. Barbara Sokolov reported on a workshop in Juneau in August at which the Commission's recommendations were summarized by Chairman Roederer. Dr. Brown noted that the IARPC working group is focusing on merging the data directory and bibliographic sources.

With respect to the Commission's interest in international cooperation, Dr. Johnson reported on the compilation of research agreements that relate to Arctic research. The Commission decided to review the list of proposed science research topics from the December 1988 Leningrad meeting to propose priorities for future research.

Environmental Impact Statements

The Commission discussed the draft document, *Improvements to the Scientific Content of Environmental Analysis in Environmental Impact Statements,* and agreed to certain modifications.

New Initiatives

The Commission discussed issues to be considered in the coming year, including Arctic engineering research needs. Walt Parker, Chairman of the Alaska Oil Spill Commission, made a presentation regarding the Exxon *Valdez* oil spill. Brian Allee, Alaska Department of Fish and Game, outlined mariculture programs. A possible Commission meeting in the Siberian Far East was also discussed.

Bipolar Research

Chairman Roederer noted current NSF and PRB involvement in bipolar research and encouraged similar Commission interest. Common problems of both poles were discussed. Dr. Wilkniss commented on NSF's position with respect to both the Antarctic and the Arctic, noting similarities and differences in budget process, logistics, and policy.

Roles of ASTF and ASEAC

The Commission considered the initial efforts of ASTF and its role compared to that of ASEAC. Members agreed that the Commission supports and encourages the efforts of both organizations.

Commission members present: *Juan G. Roederer, Chairman; John H. Steele, Vice Chairman; Ben C. Gerwick; Elmer E. Rasmuson; Jerry Brown and Jack Talmadge, representing ex-officio member Erich Bloch.* Staff: *Philip L. Johnson, Executive Director; Lyle D. Perrigo, Head, Alaska Office.* Commission Advisory Group: *John Middaugh, Department of Health and Social Services Alaska; George B. Newton, Analysis and Technology; Norbert Untersteiner, University of Washington.* Visitors: *Knut Aagaard, William Aron, Eddie Bernard, Linda Jones, Jim Overland, Carol Pease, and Gary Stauffer, NOAA; Don Bevins, Larry Bliss, Linda Brubaker, Greg Dash, Peter Grudis, Bernard Hallett, Steve Porter, Richard Reed, Minze Stuiver, Fio Ugolini, Lincoln Washburn, and Edward Wenk, University of Washington; Vera Alexander, University of Alaska–Fairbanks; Bruce Evans, Senator Murkowski's office; Vince Fitzpatrick, Geosafe Corporation; Roy F. Hooley, Failure Analysis Associates; James H. Jarrett, Battelle Pacific Marine Laboratory.*

Twentieth Meeting December 11–12, 1989

The Arctic Research Commission held its twentieth meeting on December 11–12, 1989, with the business sessions held at NOAA's Pacific Marine Environmental Laboratory (PMEL) in Seattle and the public meeting held at the University of Washington.

Chairman Roederer reported on recent meetings with Allan Bromley, Science Advisor to the President, and Dinah Bear, General Counsel, Council on Environmental Quality (CEQ). CEQ agreed with the findings of the draft report, *Improvements to the Scientific Content of the Environmental Impact Statement Process,* and is expected to implement the recommendations. Philip Johnson reported on a conference in Knoxville, Tennessee; a conference on the Arctic environment in Rovaniemi, Finland; and a Navy conference on Arctic-cold weather operations and support. Lyle Perrigo reported on the second group of awards from the Alaska Science and Technology Foundation (ASTF).

Interagency Arctic Research Policy Committee (IARPC)

Jack Talmadge, National Science Foundation (NSF), commented on the mutually beneficial relationship between the Commission and IARPC. He stressed the need to protect or expand Arctic programs in domestic budgets. Jerry Brown, NSF, reviewed a number of activities of the Interagency Committee, including the Biennial Revision of the U.S. Arctic Research Plan and an Arctic Ocean and adjacent seas multiagency crosscut budget submitted to OMB in September. Dr. Brown reported favorable comments on the Commission's report, Arctic Data and Information and announced several international activities, including a program announcement as a result of the agreement on U.S.-U.S.S.R. Cooperation in the Field of Basic Scientific Research signed in May 1989.

Alaska Congressional Delegation

Bruce Evans, from Senator Murkowski's office, reported slow progress with regard to the ARPA amendments and offered to help expand Commission congressional contacts.

NOAA Arctic Science

William Aron, Alaska Region, National Marine Fisheries Service, discussed activities and issues of his laboratory in the Arctic. He emphasized the close working relationship with PMEL, illustrated issues of commercial interests and native needs, and commented on various fish population dynamics in the Bering Sea. He noted the importance of the international "donut hole" fishery in the middle of the Bering Sea.

Knut Aagaard, PMEL, reviewed PMEL's Arctic research programs. He emphasized the importance of research on sea ice in the Arctic and its relevance to the Arctic biology, global ocean circulation, and world climate.

Revitalized Health Initiative

John Middaugh, Alaska State epidemiologist, provided a progress report and recommended further initiatives to augment Arctic health research. He pointed out the substantial reduction in deaths due to infectious diseases since the 1950s in both Native and nonnative populations. Dr. Middaugh described various Federal agencies and noted that the Arctic Investigations Program (AIP), part of the Centers for Disease Control (CDC), is the only Federal health research element in Alaska and that there is no suitable mechanism for coordinating Arctic health activities among agencies. He reported on various efforts to focus Arctic health research and defined the next steps of a continuing strategy on Arctic health needs.

Philip Johnson reported on a meeting on October 24 in Washington with Myra Munson, Commissioner of Alaska Health and Social Services, and senior officials of eight health agencies. Discussion centered on the lack of a central repository or point of coordination among State and Federal agencies in addition to the need for a broadened mission for the AIP in Anchorage. Dr. Johnson also reported on a meeting with CDC in Washington regarding consideration of the Commission's recommendations.

Arctic Engineering Research

Ben Gerwick described the statement prepared for the meeting recognizing the need for Arctic engineering research in many areas. Dr. Roederer noted some additional engineering research in the Arctic, and it was agreed that the Commission would communicate its recommendations on Arctic engineering research to the chairman of IARPC and selected professional engineering societies.

Executive Session

In executive session, the Commission discussed an addition to the group of advisors, following the resignation of George Reid. David J. Hofmann, Department of Physics and Astronomy, University of Wyoming, was

selected as an advisor. The Commission also discussed the budget and future Commission field trips and meetings.

Public Meeting

A public meeting was convened on the campus of the University of Washington on the afternoon of December 11, 1989, to receive presentations on the needs and objectives of future research in the Arctic. About 35 people attended, and 14 scientists and engineers reported on the status of their research and suggested areas for future emphasis.

Forthcoming Meetings

Listed here is a compilation of 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.

1990

First Circumpolar Symposium on Remote Sensing of Arctic Environments
1–3 May 1990, Yellowknife, Northwest Territories
Contact: Steven Matthews/Helmut Epp, N.W.T. Remote Sensing Centre, Government of the Northwest Territories, P.O. Box 1320, Yellowknife, N.W.T., Canada X1A 2L9
Phone: (403) 920-3329
Telex: 034-45528
Fax: (403) 873-0221

Ice-Covered Seas and Ice Edges: Physical, Chemical and Biological Processes and Interactions 22nd International Liège Colloquium on Ocean Hydrodynamics
7–11 May 1990, Liège, Belgium
Contact: Anne-Marie Schoenaerts, Modelenvironment, University of Liège, B5, Sart Tilman, B-4000 Liège, Belgium
Phone: +32 (41) 56.33.55
Fax: +32 (41) 56.23.55

PRO MARE, Symposium on Polar Marine Ecology
12–16 May 1990, Trondheim, Norway
Contact: Egil Sakskaug, Trondheim Biological Station, Bynesveren 46, N-7018 Trondheim, Norway
Phone: +47-7-513260
Fax: +47-7-509034

IAHR Regional Conference on Circumpolar and Northern Religion—Interpreting Shamanism and Folk Religion in Arctic and Subarctic Regions
13–19 May 1990, Helsinki, Finland
Contact: Juha Y. Pentikainen, University of Helsinki, Department of Comparative Religion, Luotsikatu 4 A 1, 00160 Helsinki, Finland
Phone: 19241

International Congress on Circumpolar Health: Community Health—Problems and Solutions in the North
20–25 May 1990, Whitehorse, Yukon Territory, Canada
Contact: 8th International Congress on Circumpolar Health, 801-750 Jewis Street, Vancouver, British Columbia, Canada V6E 2A9
Telex: 04-352848 VCR

Sixth International Conference on Hunting and Gathering Societies—CHAGS 6, University of Alaska–Fairbanks
28 May–1 June 1990
Contact: Linda Ellanna, Department of Anthropology, University of Alaska–Fairbanks, Fairbanks, Alaska 99775-0160
Phone: (907) 474-6751 or 474-7288
Fax: (907) 474-7720
BITNET: FFLJE@ALASKA

CANQUA/AMQUA—Rapid Change in the Quaternary Record
4–6 June 1990, Waterloo, Ontario, Canada
Contact: Alan V. Morgan, WATERLOO 1990, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
Phone: (519) 885-1211 (x3231)
Fax: (519) 746-2543, (519) 888-4521

Conference on the Shared Living Resources of the Bering Sea Region
5–7 June 1990, University of Alaska–Fairbanks
Contact: Dinah Bear, Council on Environmental Quality, 722 Jackson Place, NW, Washington, D.C. 20503
Phone: (202) 395-5754

Fifth Canadian Permafrost Conference
6–8 June 1990, Quebec City, Quebec, Canada
Contact: Mike Boroczki, Fifth Canadian Permafrost Conference, National Research Council of Canada, Ottawa, Ontario, Canada KIA OR6
Phone: (613) 993-9009
Telex: 053-3145
Fax: (613) 952-7928

13th Polar Libraries Colloquy
10–14 June 1990, Rovaniemi, Finland
Contact: Liisa Kurppa, Arctic Center, University of Lapland, P.O. Box 122, 96101 Rovaniemi, Finland
Phone: +358-60 324-275
Telex: 19205519
Fax: +350-60 324-270

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
Telex: 35414
Fax: (907) 474-7290

Northern Hydrology Symposium
10–12 July 1990, Saskatoon, Saskatchewan, Canada
Contact: Terry Prowse or Simon Ommanney, Scientific Information Division, National Hydrology Research Institute, 11 Innovation Boulevard, Saskatoon, Saskatchewan, Canada S7N 3H5
Phone: (306) 975-5735 (Prowse) or (306) 975-5751 (Ommanney)

Polar Tech '90
14–16 August 1990, Copenhagen, Denmark
Contact: Conference Secretariat, Danish Hydraulic Institute, Agern Alle 5, DK-2970 Horsholm, Denmark
Phone: +45 42 86 80 33
Telex: 37402 DHICPH DK
Fax: +45 42 86 79 51

Arctic Geology and Petroleum Potential
15–17 August 1990, Tromso, Norway
Contact: Norwegian Petroleum Society, Box 1897, Vika, 0124 Oslo 1, Norway
Phone: 47 2207025
Telex: 77 322 NOPETN
Fax: 47 2830547

Seventh Inuit Studies Conference, Looking to the Future: Arctic 2000
19–23 August 1990, Fairbanks, Alaska
Contact: Lydia Black, Department of Anthropology, University of Alaska, Fairbanks, Alaska 99775
Phone: (907) 474-6760 or 474-7288
Fax: (907) 474-7720
BITNET: FFLTB @ALASKA

10th IAHR Symposium on Ice
20–23 August 1990, Helsinki, Finland
Contact: Mauri Maattanen, Helsinki University of Technology, Otakaari I, Sf02150, Espoo, Finland

Symposium on Ice–Ocean Dynamics and Mechanics
27–31 August 1990, Hanover, New Hampshire
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +233 355974
Fax: +223 336543

Third Northern Regions Conference: Cooperation in a Changing World
16–20 September 1990, Anchorage, Alaska
Contact: Ginna Brelsford, Governor's Office of International Trade, 3601 C Street, Suite 798, Anchorage, Alaska 99503
Phone: (907) 561-2260
Fax: (907) 561-4577
Telex: 25-278 SOAGOIT AHG

Second International Conference on Ice Technology
18–20 September 1990, Cambridge, United Kingdom
Contact: C.A. Brebbia, Computational Mechanics Institute, Ashurst Lodge, Ashurst, Southampton SO4 2AA, United Kingdom
Phone: 0 42129 3223
Telex: 47388 ATTN COMPMECH
Fax: 042129 2853

International Symposium on Glaciers–Oceans–Atmosphere Interactions
24–29 September 1990
Contact: V.M. Kotlyakov, Institute of Geography, U.S.S.R. Academy of Sciences, Staronometry per 29, Moscow 109017, U.S.S.R.
Phone 238-1845
Telex 411781 GLOBESU

AAAS Arctic Science Conference—Circumarctic Perspectives
8–10 October 1990, Anchorage, Alaska
Contact: Thomas Newbury, Conference Chair, c/o Minerals Management Service, 949 E. 36th Ave. (Room 110), Anchorage, Alaska 99508-4302
Phone: (907) 261-4604

IWAIS 90: 5th International Workshop on Atmospheric Icing of Structures
29–31 October 1990, Tokyo, Japan
Contact: Japanese Society of Snow and Ice (IWAIS '90), c/o Inter Group Corporation, Akasaka Minato-ku, Tokyo 107, Japan

1991

Sixth International Conference on Cold Regions: Cold Regions Engineering Technology in the 21st Century
26–28 February 1991, Hanover, New Hampshire
Contact: Devinder Sodhi, USACRREL, 72 Lyme Road, Hanover, NH 03755-1290
Phone: (603) 646-4100
Fax: (603) 646-4278

International Arctic Technology Conference
29–31 May 1991, Anchorage, Alaska
Contact: Society of Petroleum Engineers

Circumpolar Sustainable Development Conference
3–8 June 1991, Surgut, Siberia
Contact: Dr. Marianne Stenbaek, Director, Centre for Northern Studies and Research, McGill University, 805 Sherbrooke St. W., Montreal, Quebec, Canada H3A2K6
Phone: (514) 398-6052

ISCORD 91, International Symposium on Cold Region Development
16–21 June 1991, Edmonton, Alberta, Canada
Contact: ISCORD 91, P.O. Box 8330, Postal station 'F,' Edmonton, Alberta, Canada T6H 5X2
Phone: (403) 450-5218
Fax: (403) 450-5198
Telex: 0372147

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

XX General Assembly IUGG
11–24 August 1991, Vienna, Austria
Contact: F. Nobilis, Hydrographisches Zentralburo, Marxergrasse 2, A-1030 Vienna, Austria
Phone +43 222 71100 Ext. 6944
Fax: +43 222 7139311

Glaciology Relating to Human Activities
26–30 August 1991, Lanzhou, China
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +223 355974
Fax: +223 336543

Symposium on the Physics and Chemistry of Ice
1–6 September 1991, Sapporo, Japan
Contact: Norikazu Maeno, Institute of Low Temperature Science, Hokkaido University, Sapporo, 060, Japan

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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- National Park Service—John Dennis
- Bureau of Mines—Priscilla Young and Martin Cognac
- Bureau of Indian Affairs—Joseph Donahue

National Science Foundation—*Jerry Brown* (Staff Chairman) and *Charles E. Myers*
- Atmospheric Sciences—Dennis Peacock

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Department of Commerce—*Marcia Lagerloef*
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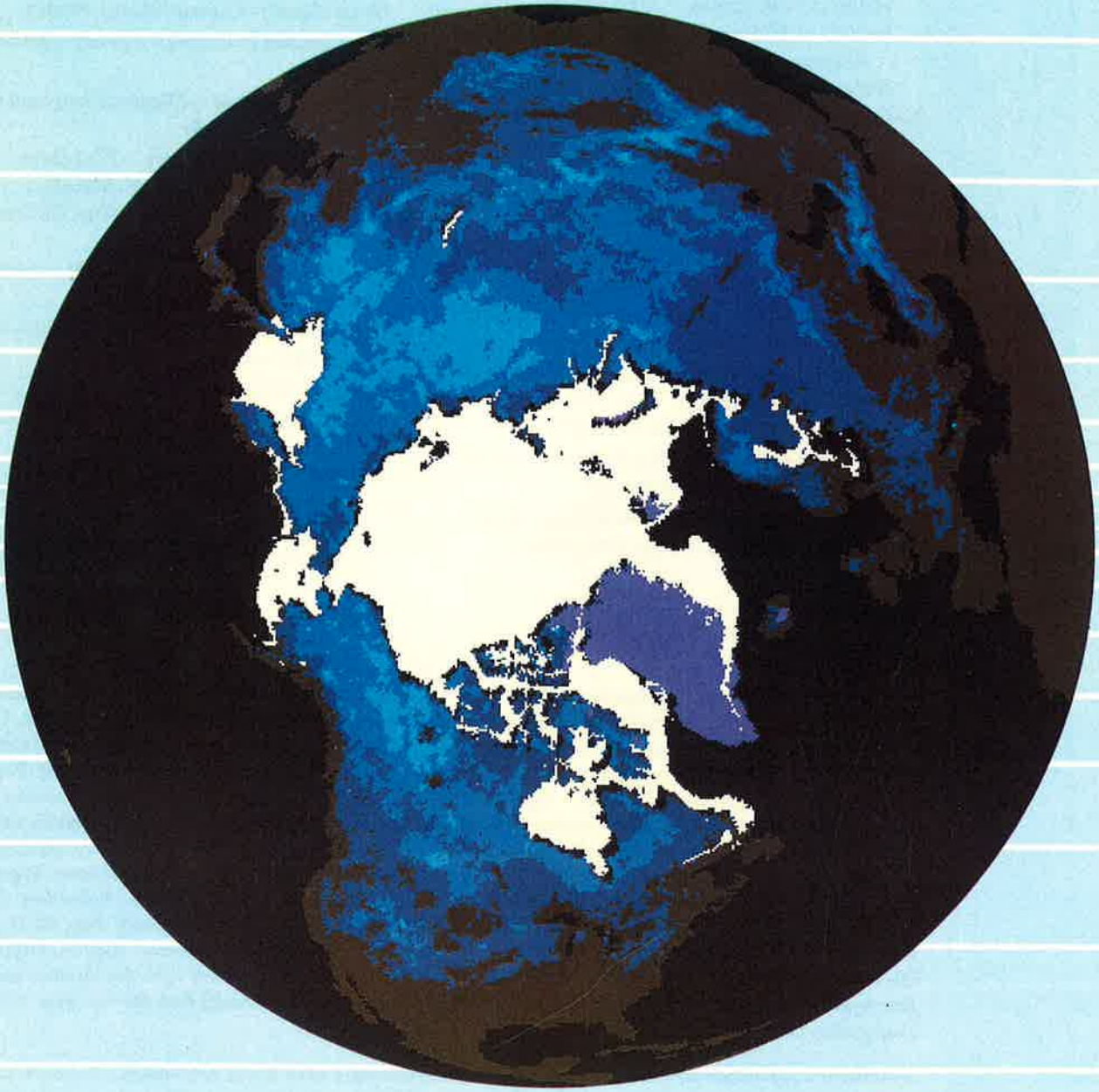

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