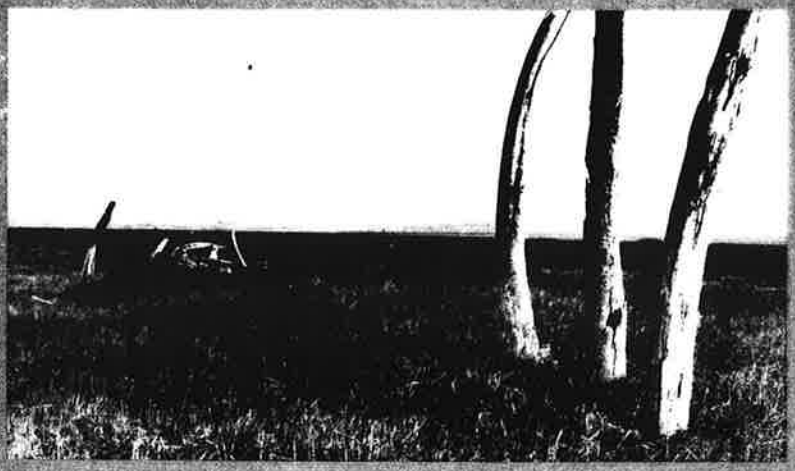
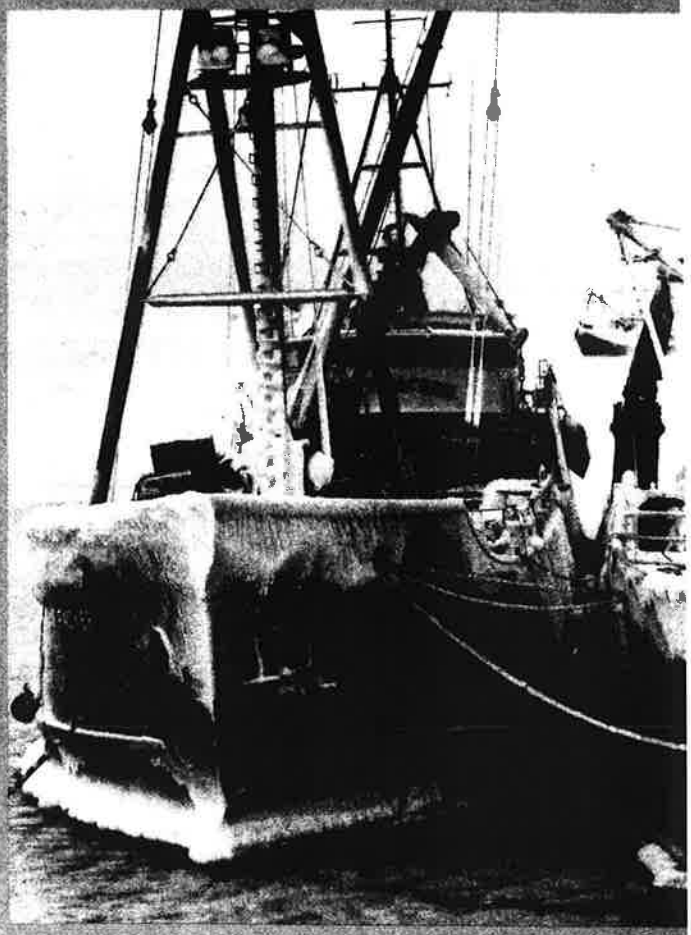
VOLUME 5 SPRING 1991

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
Volume 4, Spring 1990
Volume 4, Fall 1990

Address correspondence to Editor, *Arctic Research*, Division of Polar Programs, Rm 620, National Science Foundation, Washington, D.C. 20550.

Front Cover

Counterclockwise from upper right:
Icing on fishing trawler (photo by Arctic Alaska Fisheries Corporation).
Beringian archeological site (illustration by Richard Giamberdine, National Park Service).
Bedrock exposure and seabird rookery along the Bering Sea (photo by U.S. Fish and Wildlife Service).
Polar bears on Chukchi Sea ice (photo by U.S. Fish and Wildlife Service).

VOLUME 5 SPRING 1991

ARCTIC RESEARCH

OF THE UNITED STATES

U.S. Arctic Research Plan
Second Biennial Revision: 1992–1993

NATIONAL SCIENCE FOUNDATION
WASHINGTON D C 20550

OFFICE OF THE
DIRECTOR

June 18, 1991

The President
The White House
Washington, D.C. 20500

Dear Mr. President:

In response to the requirements of the Arctic Research and Policy Act of 1984, and on behalf of the Interagency Arctic Research Policy Committee (IARPC), I am pleased to transmit the second biennial revision to the United States Arctic Research Plan.

This revision contains accomplishments and updates to agencies' Arctic programs, and reflects current and ongoing U.S. activities and national concerns for Arctic research. It includes recommendations for several interagency programs and the initial results of an Arctic Social Science program. It describes the status of cross-cutting activities including logistics and data, which support and enhance U.S. capabilities for conducting an integrated national program of Arctic research. These revisions have been coordinated with and are responsive to guidance provided by the Presidentially-appointed Arctic Research Commission.

The Act, through the Interagency Committee and Commission activities, has stimulated increased awareness that the U.S. is an Arctic nation. Implementation of the Plan can ensure that adequate resources are maintained to address important related issues including ocean research, which serves our Nation's economic vitality and security interests. The Plan seeks to coordinate a number of agency programs. As a major step in addressing this challenge, the IARPC is undertaking an interagency initiative concerned with the Western Arctic.

On behalf of the IARPC, I hope that this second biennial revision to the Arctic Research Plan will provide a sound information basis to assist the Administration and the Congress in the evaluation and implementation of our Nation's commitment to and support for Arctic research.

Sincerely,

Walter E. Massey
Director

Enclosure: Biennial Revision to United States Arctic Research Plan

Executive Summary

1. Background

As required by the Arctic Research and Policy Act of 1984 (Public Law 98-373),* a comprehensive Arctic research plan was prepared by the Interagency Arctic Research Policy Committee (IARPC 1987) and submitted to the President, who transmitted it to Congress in July 1987. Section 109(a) of the Act requires a biennial revision to the Plan. The first revision was submitted on August 1, 1989. This document, the second biennial revision to the Arctic Research Plan, updates the previous two documents and elaborates on requirements of Section 109(a).

United States research in the Arctic and for this biennial revision is governed by the goals and objectives agreed upon by the Interagency Committee on February 3, 1986, and by the guidance provided by the Arctic Research Commission (ARC 1991a). These include supporting research to implement national policy for protecting national security interests, promoting rational development while minimizing adverse effects, contributing to the knowledge of the environment best studied in the Arctic, and contributing to mutually beneficial international cooperation.

The Act did not provide separate additional funding for Arctic research. Agencies are expected to request and justify funds as part of their normal budgetary processes. It was anticipated in the 1987 Plan that agencies would provide levels of funding consistent with the Plan's recommendations and existing programs during the intervening period. FY 1992 expenditures for Arctic research in the twelve Federal agencies is estimated at $146 million.

The Arctic Research and Policy Act requires cooperation among agencies of the U.S. Government that have missions and programs relevant to the Arctic. The Interagency Committee is providing the mechanism for developing and coordinating overall U.S. Arctic research activities. This biennial revision to the U.S. Arctic Research Plan serves as guidance for planning by individual agencies and for coordinating and implementing mutually beneficial national and international research programs. The document includes two major sections: the Strategy for Integrated U.S. Arctic Research Programs; and revisions to Research Mission Components. The Strategy is new to the Plan and provides another step in implementing the intent of the Arctic Research and Policy Act. It represents Federal agencies' efforts to plan and implement research involving a number of agencies and to cooperate in the international scientific arena on research related to the U.S. Arctic. The Research Mission Components consist of six major topics important to Arctic research and conducted as part of individual missions of twelve Federal agencies.

Over the past two years there has been an increasing amount of international activity, both on the governmental and nongovernmental levels. An intergovernmental agreement on protecting the Arctic environment was agreed to in June 1991 in Finland. The nongovernmental International Arctic Science Committee was agreed upon in 1990 and has begun its work on an international agenda related to global change.

2. Strategy for Integrated Research Programs

IARPC agencies agree to develop, starting in 1992, an integrated interagency program sufficient for meeting national needs

The Interagency Committee, at its meeting on June 28, 1990, agreed upon the following policy:

> The IARPC agrees that a more comprehensive approach to funding of research and baseline programs is required to ensure a long-term, viable research and development presence in the Arctic. This presence will ensure support of the national needs, which include renewable and nonrenewable resource development, environmental protection, and partnerships with the private sector and residents of the Arctic. It will complement other national and international scientific programs, such as Global Change. To this end the IARPC agencies agree to develop, starting in 1992, an integrated interagency program sufficient for meeting national needs.

Subsequently the IARPC agencies examined Arctic research from an interagency perspective and concluded that the following four programs were ready for immediate attention as multiagency focused efforts:

- *Western Arctic Ocean Circulation and Productivity*

  Goal: Understand the processes controlling physical and biogeochemical variability and productivity of the marine western Arctic.

* Amended on November 16, 1990 (Public Law 101-609).

- *Geodynamics of the Arctic Basin and its Margins*
  Goal: Determine the climatic, paleo-oceanographic and tectonic evolution of the Arctic and their effects on global change.
- *Arctic Monitoring*
  Goal: Establish baseline values and monitor trends in key environmental variables across a national and international network of sites.
- *Bering Land Bridge*
  Goal: Determine human responses and adaptations to changing climate and environment.

The FY 1991 funding for these four programs across eleven agencies is estimated at $51.3 million. The FY 1992 budget is proposed at a level of $57.3 million.

Another area of cooperation already underway involves data and information. Interagency activities have been initiated to develop an Arctic Environmental Data Directory and to automate, integrate and exchange Arctic bibliographic references. An interagency effort is underway to facilitate the exchange of Arctic data and published literature, not only within the U.S. but on an international basis. The initial products are the Arctic Environmental Data Directory and several CD-ROMs, including prototypes of the Arctic Data Interactive and bibliographic citations.

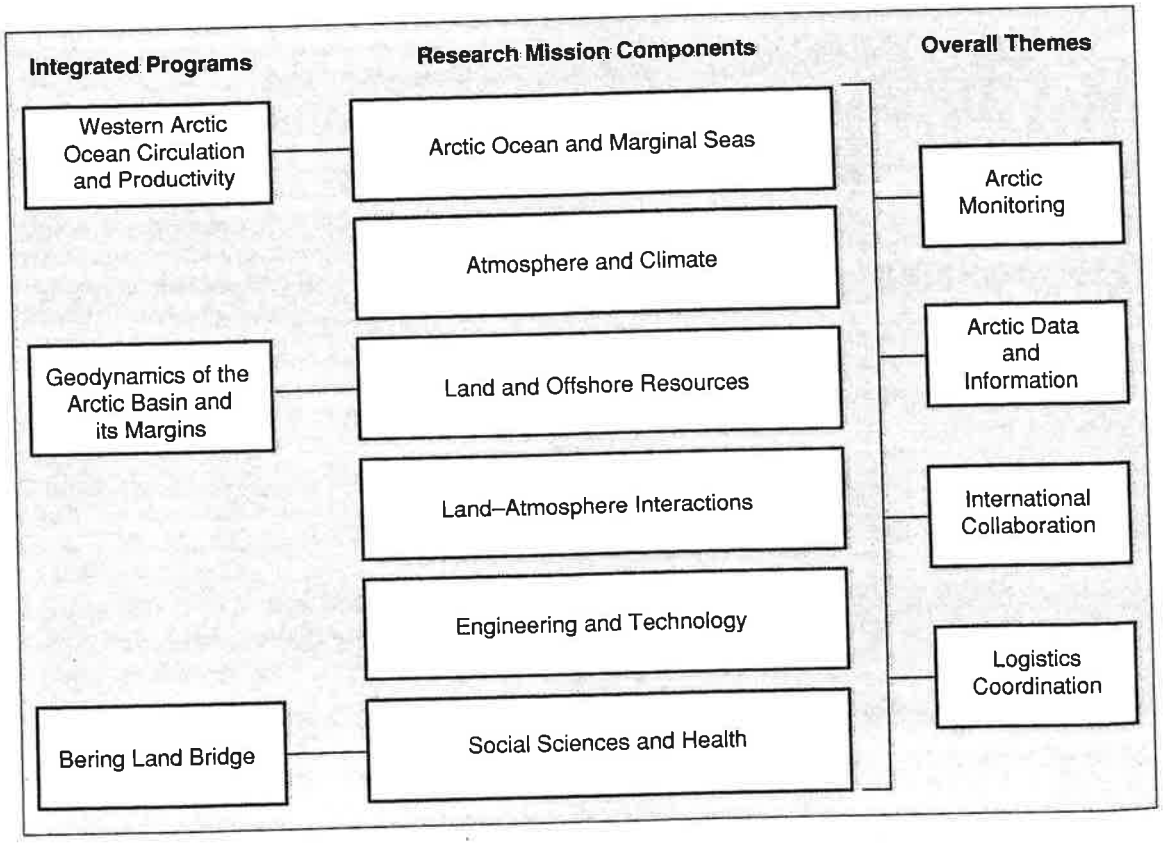
3. Research Mission Components

Under this section of the Plan, recent accomplishments and ongoing and planned activities of Federal agencies (1992–1993) are briefly described under the following subjects and scopes. To focus attention on recent accomplishments and plans within each agency, a Federal Arctic Research Workshop was held in Alaska in March 1991. All Federal agencies involved in the following activities participated or were represented.

Arctic Ocean and Marginal Seas

Ice Dynamics and Oceanography

Research in this area is important to advance our understanding of Arctic Ocean dynamics and air–sea heat and gas exchange. A systematic program of oceanographic measurements is urgently needed to support the objectives of interagency and individual agency programs.



Ocean and Coastal Ecosystems and Living Resources

Arctic marine ecosystems are dominated by sea ice, and coastal ecosystems are influenced by freshwater input and seasonal sediment loads. There is a need to quantify the influence of physical processes on the variability of marine living resources through long-term and well-designed interdisciplinary research.

Marine Geology and Geophysics

The Arctic continental margin and deep ocean basin constitute one of the world's least understood geological regions. A better understanding of the tectonic history, geologic structure, sediment processes and distribution, and climatic and glacial history of the deeper basins will require extensive geophysical and geological research and the integration of newly collected data on an international scale.

Atmosphere and Climate

Upper Atmosphere and Near-Earth Space Physics

The goal of this research is to trace the flow of energy, momentum and mass from the sun to the Earth, and to understand their interaction. Arctic-based studies of this energy flow are necessary to help develop and verify theoretical models needed for future predictions.

Climate and Weather

The Arctic climate has global implications as well as local and regional importance. Research is needed to address Arctic weather problems occurring on a variety of spatial and temporal scales that range from microscale to global. There is a need to relate Arctic atmospheric circulation to midlatitude weather and to measure and understand phenomena that may be linked to potential global warming.

Tropospheric and Stratospheric Chemistry

The chemistry of the Arctic atmosphere is dynamic, changing in response to natural and man-induced disturbances. Ozone depletion is a bipolar process. Expected warming trends could have a significant influence on biosphere–atmosphere interactions, trace gas emissions and retention, and atmospheric photochemical processes.

Land and Offshore Resources

Energy and Minerals

The geologic framework of the Arctic is poorly known because of its complexity, its remoteness and its relative lack of exploration. Information is necessary for discovery, assessment and mapping of new and dependable sources of oil, gas, coal and strategic minerals.

Coastal and Shelf Processes

Erosion rates are extremely high along the Alaskan Arctic coast, where sea ice and permafrost degradation are dominant geomorphic agents. Specific questions about where to locate causeways, man-made islands and other structures require studies of coastal erosion and sediment transport and an understanding of the long-term history of coastal areas.

Terrestrial and Freshwater Species and Habitats

The Arctic supports many unique species of birds, mammals, fish and plants that are important resources to the Nation, as well as to Alaskan Natives. To assure that biological resources are protected for future generations, management agencies must have adequate data and information on the biology and ecology of these species, as well as on environmental factors of importance to vital processes (e.g. feeding, breeding).

Forestry, Agriculture and Grazing

Increased knowledge of the current and potential productivity of Arctic and Subarctic forests and soils will lead to improved management practices for increased productivity of renewable resources.

Land–Atmosphere Interactions

Glaciology and Hydrology

Documentation of seasonal, interannual and long-term trends in the physical environment of the Arctic requires attention to the special features of seasonal and perennial snow and ice covers and glaciers, especially as they relate to and record climatic change. Reliable long-term information is needed on surface water quality and quantity.

Permafrost, Landscape and Paleoclimate

Geologic processes that are responsible for the present morphology and land surface are to a large degree a function of the underlying permafrost. Additional knowledge is needed about the temperature, distribution, thickness and depth of permafrost throughout all geomorphic provinces of the Arctic, including the continental shelf.

Ecosystem Structure, Function and Response

Global Circulation Models (GCMs) indicate that the Arctic will be sensitive to the effects of possible climatic changes resulting from green-

house warming. Research is needed to improve understanding of the influence of climate on land and freshwater processes, including heat balance relationships and landscape alteration. This should include the identification of biological indicators of change, long-term trends in biological diversity, and management strategies for living resources.

Engineering and Technology

Further development of Alaskan resources economically and in an environmentally sound manner requires improved designs and new technologies. Research is required to improve methods and systems for protecting the environment, including oil spill prevention technology and innovative containment and cleanup operations for ice-infested waters and permafrost terrain. Research is also needed for improving human habitability, including waste disposal and air pollution control, power generation and energy storage, and transportation systems.

Social Sciences and Health

Cultural Resources and Historical Processes

Long records of cultural and environmental change, when combined with the proxy records of ethnography and history, make the study of Arctic cultures critical for modeling human responses to global climatic and environmental change. Additional research is needed on the prehistory and history of Arctic cultures, on their interactions with other Native and Western peoples, and on their relationships with past and present environments.

Social Change

Rapid economic, social and political changes have resulted in the emergence of human problems that, while not unique to the Arctic, are nevertheless accentuated by economic development in this environment. Most prominent among them are human–environmental relationships, community viability and social reorientation. Unprecedented opportunities exist for basic and applied social and behavioral science research in Arctic regions.

Health

The Arctic is a region where health research has broad implications and applications. Key concerns in health and health research include social and behavioral problems, disease trends and transmission, nutrition, bioaccumulation, and human adaptation to extreme environmental and occupational challenges. The health–culture–socioeconomic component is important in the attempt to address the complex issues being faced in the Arctic.

4. Operational Support

Since the passage of the Act, the Interagency Committee, the Arctic Research Commission and the State of Alaska have addressed issues related to logistics support for Arctic research. In 1988 the Interagency Committee established a working group on Arctic logistics to deal with Arctic operational needs and to compile information on Federal Arctic logistics capabilities. This interagency effort produced an electronic directory of Federal Arctic logistics capabilities. In September 1989 a workshop was convened to address new technologies available to facilitate Arctic operations and logistics. The Interagency Committee continues to endorse the need for an icebreaker fleet for logistics and research and a more centralized approach for Federal logistics information and scheduling.

1. Introduction

As required by the Arctic Research and Policy Act of 1984 (Public Law 98-373),* a comprehensive Arctic Research Plan was prepared by the Interagency Arctic Research Policy Committee (IARPC 1987) and submitted to the President, who transmitted it to Congress in July 1987. Section 109(a) of the Act requires a biennial revision to the Plan. The first revision was submitted on August 1, 1989 (IARPC 1989). This document, the second biennial revision to the Arctic Research Plan, updates the previous two documents and elaborates on requirements of Section 109(a) (see Appendix F).

The Plan presented a detailed agenda for United States Arctic research and was the result of an extensive process of planning, consultation and revision. The biennial revisions build on the published Plan but are more restricted in scope, and they focus on what might be accomplished in the succeeding two-year periods (1990–91, 1992–93 etc.). In addition to the individual agency research activities (described in Section 3), this revision presents several integrated, interagency research programs (Section 2) as requested by the Interagency Committee at its June 1990 meeting. These cooperative efforts should be initiated in the 1992–93 period, and continue into 1994 and beyond. Each represents ongoing or planned programs of more than three Federal departments and has direct relation to economic, social and international developments in the Arctic and scientific questions related to regional and global processes.

This revision to the Plan was provided for review to all the groups identified in the Act (the Arctic Research Commission, the State of Alaska, residents of the Arctic, the private sector and public interest groups), as well as the participating Federal agencies, the Polar Research Board of the U.S. National Academy of Sciences, and individual scientists and engineers.

1.1 Goals and Objectives

United States research in the Arctic and this biennial revision are governed by national interests and Arctic research goals and objectives agreed upon by the Interagency Committee on February 3, 1986, and guidance provided by the Arctic Research Commission (ARC 1991a).

U.S. Interests

It is in the national interest of the United States to support scientific and engineering research to implement its national policy of protecting essential security interests, promoting rational development of the Arctic region while minimizing adverse environmental effects, and contributing to the knowledge of the Arctic environment or to aspects of science that are most advantageously studied in the Arctic. Where appropriate this research should be coordinated with the efforts of state and local government and the private sector. The research should be carried out in a manner that benefits from and contributes to international cooperation. Arctic research policy is subject to periodic review and revision.

U.S. Goals and Objectives in Arctic Research

Arctic research shall be aimed at resolving scientific and technological problems concerning the physical and biological components of the Arctic and the interactive processes that govern the behavior of these components. The objectives include addressing the needs for increased knowledge in such issues as the Arctic as a natural laboratory, national defense, natural hazards, global climate and weather, energy and minerals, transportation, communications, renewable resources, pollution, environmental protection, health, adaptation and Native cultures.

More specific long-term goals have been developed by the Interagency Committee to further guide the revision of the Plan:

- Pursue integrated, interagency research programs;
- Continue to develop and maintain U.S. scientific and operational capabilities to perform research in the Arctic;
- Promote the improvement of environmental protection and mitigation technology and the enhancement of ecologically compatible resource exploitation technology;
- Develop an understanding of the role of the Arctic in predicting global environmental changes and perform research to reveal early signals and to determine the significance of global changes in the Arctic;
- Contribute to the understanding of the relationship between Arctic residents and subsis-

* Amended on November 16, 1990 (Public Law 101-609); see Appendix F.

tence use of wildlife and how this relationship might be affected by global climate change and transported contaminants;
- Include Arctic residents in planning and conducting the research and report results to the individuals and communities involved in the research;
- Continue to document and understand the role of permafrost in environmental activities;
- Advance knowledge of the Arctic geologic framework and paleoenvironments;
- Develop the scientific basis for responding to social changes and the health needs of Arctic people;
- Contribute to the understanding of upper atmospheric and outer space phenomena;
- Develop and maintain data bases and data and information networks;
- Promote mutually beneficial international research programs and cooperation; and
- Develop and maintain a strong technological base to support national security needs in the Arctic.

In addition to these goals and objectives for Arctic research developed by the Interagency Committee, the Arctic Research Commission has provided further guidance for U.S. Arctic research (ARC 1991a) and recommendations for improvements in logistics for support of Arctic research (ARC 1988b) and for focused research on the Bering Sea as an Arctic marine ecosystem (ARC 1988a), on data and information (ARC 1989) and on engineering (ARC 1990a). This revision of the Plan is consistent with many of these Commission recommendations.

Table 1. Arctic research budgets by individual Federal agencies (in thousands of dollars).*

Agency	FY 85–89 Average	FY 90 Actual	FY 91 Estimated	FY 92 Proposed
NSF	21,503	24,088	27,567	29,805
DOI	24,497	25,213	27,693	30,465
DOD	23,109	24,540	25,200	28,090
NASA	12,232	17,350	18,030	23,315
DOC	4,894	8,528	12,866	15,614
DHHS	1,311	8,001	9,268	9,561
DA	689	3,962	4,152	4,183
DOE	3,271	2,429	2,082	1,884
SI	568	630	705	705
EPA	225	500	500	1,250
DOT	472	305	305	735
DOS	10	20	60	60
Total	92,781	115,566	128,428	145,667

* Capital facilities are not included in these estimates.

Table 2. Arctic research by major categories (in millions of dollars).*

	1991 enacted	1992 proposed	Dollar change	Percent change
Resource development†	49	56	+7	+14
Arctic as laboratory**	48	50	+2	+4
National security††	25	28	+3	+12
Total	122	134	+12	+10

* As published in the President's FY 1992 budget (see Appendix D).
† Includes DOI, DOC, DA, DOE, DOT, DOS and EPA.
** Includes DHHS, NASA, NSF and SI.
†† Includes DOD.

1.2 Budgetary Considerations

The Act did not provide separate additional funding for Arctic research. Agencies were expected to request and justify funds for these activities as part of their normal budgetary processes. It was anticipated in the 1987 Plan (p. 17) that agencies would provide levels of funding consistent with the Plan's recommendations and existing programs. Table 1 presents a summary of each agency's funding for the period of the Act (1985–1991). The total interagency Arctic budget estimate for FY 1991 is $128 million; for FY 1992 it is $146 million. In Table 2 Arctic funding is presented organized according to the three major policy objectives described above, and as reported for 1992 in the President's budget request. Categories on resource development and the Arctic as a laboratory include activities directly related to environmental protection and monitoring. See Sections 2 and 3 for details. Early increases in the national security and resource development funding were in part due to modifications in reporting procedures within some agencies as the programs became better defined. The estimated increases between the sums in Tables 1 and 2 represent changes in agency budgets made subsequent to publication of the President's FY 1992 budget. Appendix E contains agency budgets broken down by major sub-elements and cross referenced to the policy objectives. The Arctic Research Commission analysis of funding trends in U.S. Arctic research suggests that in terms of constant 1986 dollars, the total funding has remained nearly level at about $90 million (ARC 1991a).

1.3 Interagency Coordination

The Arctic Research and Policy Act (Appendix F) requires cooperation among agencies of the U.S. Government having missions and programs relevant to the Arctic. It established the Interagency Arctic Research Policy Committee to "promote Federal interagency coordination of all Arctic research activities" [Section 108(a)(9)]. The Interagency Committee, under the chairmanship of the Director of the National Science Foundation (NSF), continues to provide the mechanism for developing and coordinating U.S. Arctic research activities. The biennial revisions of the U.S. Arctic Research Plan serve as guidance for planning by individual agencies and for coordinating and implementing mutually beneficial national and international research programs.

A workshop on Federal research information exchange was held in Anchorage, Alaska, in March 1991 to facilitate coordination and the exchange of information

Although the two-year period since the last revision of the Plan was submitted has not been long enough to fully organize and implement all its recommendations, significant progress has been made and accomplishments continue to be identified. These include activities of the Interagency Committee and the Arctic Research Commission, the formation of the IARPC Social Science Task Force, the development by IARPC of a statement on principles for the conduct of research in the Arctic (Appendix G), and interagency data activities and the development of a related data directory and products. Selected accomplishments over the past two years for Federal agencies are summarized under each of the appropriate research mission components in Section 3. Additional information can be found in the journal *Arctic Research of the United States* (Volumes 2–4), published by NSF on behalf of the IARPC.

The Act mandates specific requirements for implementing a coordinated U.S. Arctic research program. Mechanisms for appropriate levels of coordination are still evolving. Three levels of coordination and cooperation are needed for an effective national Arctic research program:

- Specific research conducted in the Alaskan Arctic;
- National coordination; and
- International collaboration.

Each element requires a mechanism for internal program development, review and implementation, and each needs to be linked to the other two. The national effort is performed through the Interagency Committee. A staff oversight group of the Interagency Committee provides coordination, assisted by working groups representing specific agency programs. The Working Group on Arctic Ocean/Atmosphere has developed specific program strategies, as has the recently formed Social Science Task Force. Data, information and logistics groups are pursuing a number of interagency activities. These are reported in the subsequent sections.

Many interagency agreements and planning and coordinating activities already exist in Alaska. A workshop on Federal research information exchange was held in Anchorage, Alaska, in March 1991 to facilitate coordination and the exchange of information. This activity will continue in Alaska under the direction of an ad hoc coordinating group. Coordination with global change programs is an integral part of Arctic program development and implementation. Improved communication at all levels through existing newsletters and journals will be encouraged.

1.4 International Collaboration

The Arctic is becoming an arena for scientific research that transcends national boundaries and interests. Over the past two years there has been an increasing amount of activity involving international cooperation in the Arctic. Prior to this time, Arctic cooperation was confined to bilateral or regional arrangements. The growing willingness of the Soviet Union to cooperate in international forums has facilitated these discussions on circumarctic cooperation.

In August 1990 the International Arctic Science Committee (IASC) was formalized (*Arctic Research of the United States*, Fall 1990, p. 65). This nongovernmental body includes representatives of all eight Arctic rim nations and other nations with a significant capability in Arctic research (recent members are France, Germany, the United Kingdom, Japan, Poland and the Netherlands). The functioning of the IASC will facilitate cooperative regional research, unprecedented access to Arctic Ocean continental shelves, and the use of platforms and logistical bases not possible in unilater-

al efforts. The National Academy of Sciences is the designated U.S. representative. An International Arctic Social Sciences Association was also formed in August 1990 (*Arctic Research of the United States*, Fall 1990, p. 75).

Environmental concerns in the Arctic are being addressed at the intergovernmental level as a result of the Arctic Environmental Protection Strategy. A series of meetings were held in preparation for the full ministerial meeting held in Rovaniemi, Finland, in June 1991. Among the results are a statement of Arctic environmental principles, a strategy for Arctic environmental protection, elaboration of an international Arctic monitoring program, measures on the protection of the Arctic marine environment and on emergency response, and exchange of information on the conservation of Arctic flora and fauna.

Environmental concerns in the Arctic are being addressed at the intergovernmental level as a result of the Arctic Environmental Protection Strategy

The U.S. Man and the Biosphere (MAB) Program, through its High Latitudes Directorate, is participating in the UNESCO MAB Northern Sciences Network, located at the Arctic Center, Rovaniemi, Finland. The NSN focuses on protected areas, sustainable development and subarctic birch forests. US-MAB is supporting a senior fellowship to work with the Network secretariat in developing and implementing international plans. MAB also contributed to the development of an International Tundra Experiment (ITEX) to monitor the impact of global change on specific flora and fauna.

Among several bilateral efforts, the new U.S.–U.S.S.R. Oceans Studies Agreement has identified a number of Arctic scientific research proposals that may be developed into joint projects and thereby offer access to the Arctic Ocean region. The U.S.–U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection continues several major Arctic activities related to climate, flora, fauna, ecosystems and pollution. The increasing pace of Arctic research sponsored by the European community is evident in the proposed International Arctic Ocean Expedition–1991 (IAOE–1991), the Nansen Arctic Drilling (NAD) program and the Norwegian Nansen Drift Program. Japan is also expanding its Arctic research efforts in a number of areas, including buoy technology.

The Arctic Ocean Sciences Board (AOSB), a nongovernmental body that coordinates selected Arctic ocean research, has been successful in defining and organizing international research efforts such as the Greenland Sea Project. AOSB attention is now directed at an International Arctic Polynya Program, proposing comparative investigations of polynyas in the Bering Sea, the Greenland Sea and Baffin Bay.

The North Pacific Marine Science Organizations (known as PICES) was established in December 1990 to promote and coordinate marine scientific knowledge in the subarctic region of the north Pacific Ocean, including the Bering Sea. Studies of the ocean environment and its role in and response to global weather and climate change, uses and resources, and impacts from human activities are all envisioned as projects PICES will undertake.

The governor of Alaska convened the Northern Forum in September 1990 to agree upon regional approaches to economic and environmental cooperation (State of Alaska 1990). Plans to house a permanent secretariat in Anchorage are well underway.

1.5 Revision to the Plan

This second revision to the 1987 United States Arctic Research Plan includes two major sections:

- Section 2. Strategy for Integrated Research Plans
- Section 3. Research Mission Components

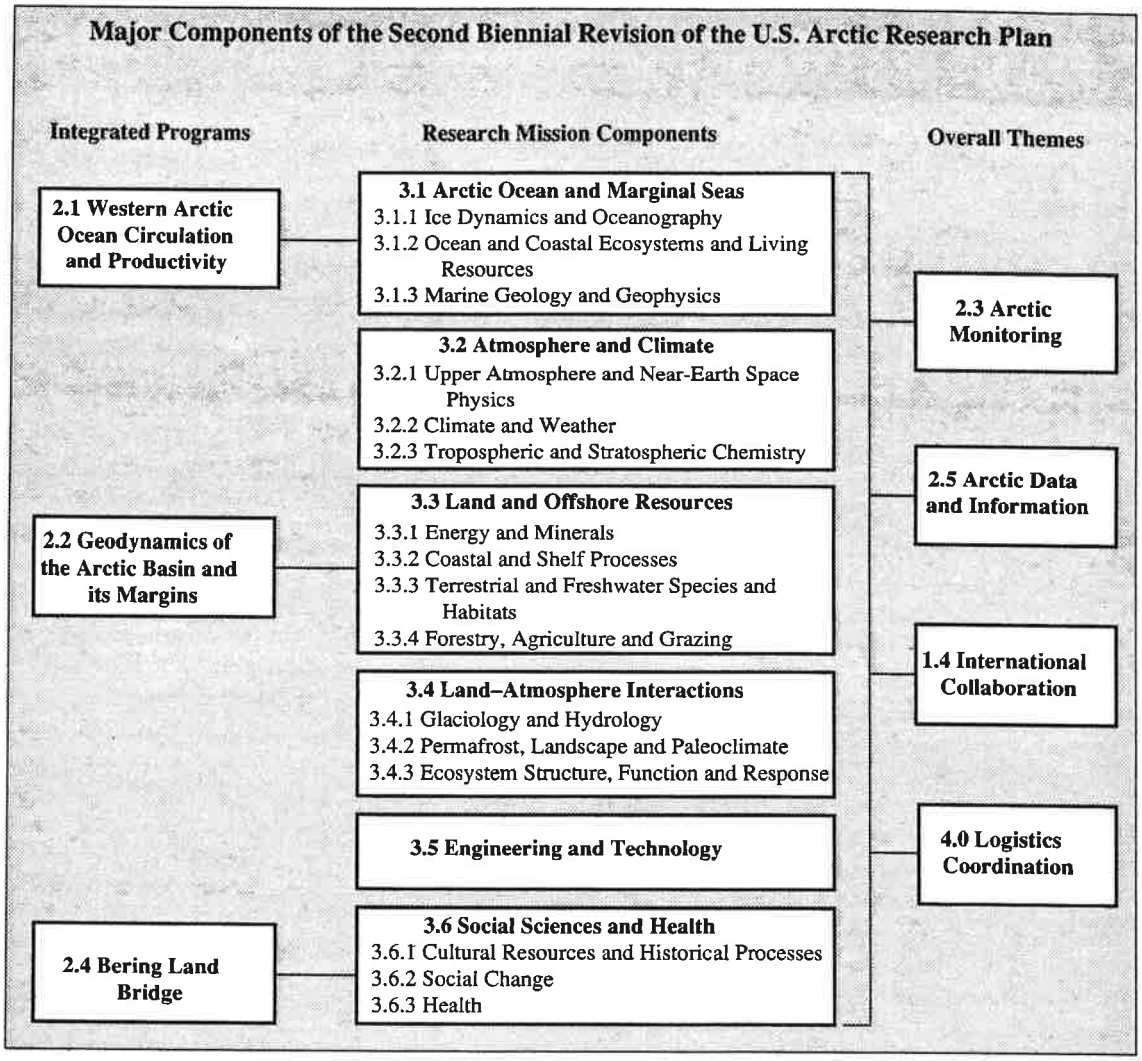
As an initial step an interagency program and budget crosscut for the proposed Arctic Ocean Research Strategy program was released in January 1990 at the time of the President's FY 1991 budget submission to Congress (IARPC 1990). The *Strategy for Integrated U.S. Arctic Research Programs*, published in February 1991, builds on earlier suggestions for proposed interagency programs and the Arctic Oceans strategy presented in the 1990–1991 revision. They represent another step in implementing the intent of the Arctic Research and Policy Act. The programs present Federal agency interests in coordinating Arctic programs that involve several agencies and furthering cooperation in the international scientific arena. These cooperative efforts build on existing programs, funding and activities; contribute to the emerging global change programs; and include interagency data and information activities (CEES 1991).

The Research Mission Components represent the individual agency programs and responsibilities. They are presented in six major categories and where common activities exist they are presented as collective activities. The listing does not include every program or project of each agency but represents the major activities and directions. The com-

plementarity of the integrated programs and the research missions is shown in the following figure. Several overall themes transcend essentially all integrated and research mission components.

Section 4 presents current activities related to field operational support necessary for implementation of the proposed interagency programs and research mission activities.

At its meeting on June 5, 1991, the Interagency Committee agreed to specific implementation tasks for this Revision to the U.S. Arctic Research Plan (see p. 91, summary of IARPC meeting for details).



2. Strategy for Integrated Research Plans

During its meeting of June 28, 1990, the Interagency Committee agreed on the following policy:

> The IARPC agrees that a more comprehensive approach to funding of research and baseline programs is required to ensure a long-term, viable research and development presence in the Arctic. This presence will ensure support of the national needs, which include renewable and nonrenewable resource development, environmental protection, and partnerships with the private sector and residents of the Arctic. It will complement other national and international scientific programs, such as Global Change. To this end the IARPC agencies agree to develop, starting in 1992, an integrated interagency program sufficient for meeting national needs.

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- Geodynamics of the Arctic Basin and its Margins;
- Arctic Monitoring; and
- Bering Land Bridge.

The U.S. has a substantial economic, strategic and environmental stake in the Arctic. Domestic energy reserves and the explosive growth in Bering Sea fisheries harvests are two examples of our dependence on Arctic resources. Sound management decisions for safe development of Arctic resources hinge on enhanced understanding of the environment, leading to better forecasts. In addition, there is a strong international commitment to collaborate.

Benefits to the Nation from Arctic research includes improved:

- Knowledge of fishery resources and controlling dynamics;
- Models and data for assessing global change and its effects;
- Understanding of past climates;
- International cooperation in a strategic region;
- Forecasts of weather, ice and ocean conditions;
- Protection of the Arctic environment;
- Understanding of causes and effects of air and water pollution; and
- Protection and understanding of historic cultural resources.

These coordinated, multiagency programs are being designed to:

- Focus research activities in concert with national needs and Global Change Research Program plans;
- Build on individual agency efforts in reconnaissance, monitoring, process studies and modeling;
- Facilitate research and logistics coordination through regionally focused programs;
- Take maximum advantage of remote sensing and new technologies;
- Strengthen interagency data and information management;
- Draw on the strengths of the academic, industrial and government research communities in planning and implementing programs;
- Support and enhance programs to acquire long-term measurements of key parameters and environments; and
- Enhance international research collaboration.

The role of the Arctic in meeting national needs and addressing key policy issues is further highlighted below.

Nonrenewable Resources

Currently the U.S. imports approximately 50% of its hydrocarbon needs. Twenty-five percent of our domestic production comes via the Trans-Alaska Pipeline System from Prudhoe Bay, Alaska. The best estimates are that at least 20% of the Nation's future reserves lie on the northern Alaskan coastal plain and adjacent continental shelf. Also, 12% of the Nation's gas reserves lie in the same region, and there are plans for a gas pipeline to transport this resource south. Gas hydrate reserves have been estimated to range from 10^{11} to 10^{14} cubic meters in Alaska and its offshore region.

The Arctic shelves also contain mineral deposits. At least one offshore tin placer has been brought into production in the Soviet Union. Gold placers are being commercially mined near Nome. Dredging for sand and gravel on the Arctic Ocean shelves supports hydrocarbon development and other large coastal and offshore construction projects.

Renewable Resources

Arctic waters support some of the most productive fisheries in the world. The Bering Sea supplies nearly one-tenth of the world's fishery products. An estimated 7 million metric tons of 43 commercial species are caught every year by fishermen from the United States, the Soviet Union, Japan and other nations. Since the passage of the Magnuson Fishery Conservation and Management Act in 1976, American groundfish operations in Alaska have developed into an industry with an annual product value estimated at $2.2 billion. In 1989, Alaska pollock, with landings of 1.1 million metric tons, was the most important U.S. fish in quantity, amounting to 28% of the U.S. commercial landings. This amount is an 88% increase over landings in 1988 and more than a five-fold increase over the 1984–1988 five-year average. Dutch Harbor–Unalaska, Alaska, was the leading U.S. port in the quantity of commercial fish landings. Alaska leads all states in both total volume and total value of fish landings.

Dramatic and unexplained fluctuations have occurred in the catch of groundfish and shellfish and the stocks of marine mammals. There is considerable concern that walleye pollock population will "crash" as others have in the past. Managing sustainable yields requires further research.

The impact on the coastal economy of Alaska and other northwestern U.S. states is magnified by substantial capitalization in vessels and processing plants and related income to a broad sector of the economy. A sustainable, predictable fishery stock is fundamental to the viability of this sector of the U.S. economy. Research on this marine ecosystem is essential for understanding and managing the resources.

Global climate models suggest that the amount of warming may be significantly greater in northern high-latitude regions than in lower latitudes

Global Change

High latitudes may experience the earliest unambiguous onset of global warming if a "greenhouse effect" occurs on Earth. Global climate models suggest that the amount of warming may be significantly greater in northern high-latitude regions than in lower latitudes, but the models do not agree well on the relative amount of warming to be expected at high latitudes.

Furthermore, there is growing evidence that the polar regions play a key role in the physical processes responsible for global climate fluctuations and in some circumstances may be a prime agent of such fluctuations. For example, North Atlantic deep water formation may be affected by a delicate balancing in the amount of fresh water that is exported from the Arctic Basin and that flows from the East Greenland Current into the region of deep vertical convection in the North Atlantic. Heat flux through the variable ice cover of the Arctic Ocean may have a profound effect on the surface heat budget and the global climate.

High-latitude warming may disturb the equilibrium of Arctic ice masses and hence global sea levels. Such events are well preserved in the geologic record, and polar regions are a natural repository of information about past climatic fluctuations. Additional data may shed light on the causes and effects of both catastrophic and evolutionary global change. Arctic research applies to virtually every science element in the U.S. Global Change Research Program Priority Framework.

Social and Environmental Issues

Arctic culture is part of, and highly dependent on, terrestrial and marine ecosystems. Northern indigenous communities numbering over 100 in the Alaskan Arctic, with a total population of 50,000, depend on hunting, trapping and fishing. Evidence increases of exposure to contaminants from lower latitudes. Samples of fish tissue and sediments thus far do not show contamination levels as high as in seriously contaminated urban areas in the lower forty-eight states, but they are not as pristine as might have been expected. Recent studies have found that concentrations of carbon dioxide and methane in Arctic haze layers are elevated with respect to background levels. Concentrations of these two gases are correlated, suggesting a common anthropogenic source (fossil fuel combustion) and subsequent transport into the Arctic. Soot carbon has been traced for thousands of kilometers across the Arctic, where it remains suspended in a dry, stable atmosphere. Ozone depletion in the polar vortex has enormous health implications to the people of the Northern Hemisphere.

Opportunities for Arctic Research in the 1990s

Remote Sensing

High-latitude satellite coverage and related data processing will reach a new level of capability in

the 1990s. For example, gridded microwave brightness temperatures from both the Nimbus and DMSP satellites, providing low-resolution (50-km) information on sea ice type and distribution, will be available on CD-ROMs through the National Snow and Ice Data Center (NSIDC).

Other satellite data that will be available in the 1990s include ocean color from SeaWiFS (U.S.) and ADEOS (Japan), surface topography from altimeters on ERS-1 (ESA) and TOPEX/Poseidon (U.S. and France), and low-resolution sea ice type and distribution from advanced microwave sounding units on NOAA K, L and M satellites (U.S.). High-resolution (30-m) synthetic aperture radar (SAR) imagery from ERS-1, JERS-1 and RADARSAT satellites (Europe, Japan and Canada), providing ice motion as well as detailed ice type and distribution, will be available from the Alaska SAR Facility (ASF) beginning in 1991. Use of the planned SAR satellites demonstrates the important international dimension of the projected activities. Over the longer term, this capability may be sustained by sensors aboard the planned Earth Observing System (EOS) spacecraft. The prospect of systematic, regional satellite coverage makes major, basin-wide investigations in the Arctic feasible for the first time.

In-situ Sensing

Air–ice–ocean sampling is being revolutionized by emerging new technologies. Precision navigation from portable, low-power receivers will soon be possible continuously from the satellite-based Global Positioning System now being deployed. A number of options for data telemetry are evolving, including specialized communication micro-satellites, an ionospheric-path HF radio frequency with digital packet switching, and a ground-plane MF radio frequency over ice. Advances in low-power microprocessors and mass storage media (optical disk, digital audio tape, video tape) have provided a new generation of programmable, high-capacity data loggers for field experiments. Innovative sensors and signal processing techniques based on acoustic and optical propagation have opened up new dimensions in probing the structure of the atmosphere, ice and ocean. New materials and high-density energy sources have spawned a new generation of remote platforms such as buoys and autonomous undersea vehicles. Instruments based on such new technology will enable radically new adaptable and interactive observational strategies for process studies, as well as provide the means for long-term, real-time monitoring of primary variables at remote sites.

Fisheries Management

Bering Sea stocks cannot be fished indiscriminately without irreversible changes in the population structure and yield. Agreements between the Presidents of the U.S. and the U.S.S.R. reflect the heightened consciousness regarding the rich fishery, wildlife, mineral and heritage resources of the Bering Sea region.

Representatives of the State of Alaska have called for a study of the Bering Sea aimed at understanding the fisheries dynamics and devising

Bering Sea stocks cannot be fished indiscriminately without irreversible changes in the population structure and yield

appropriate management options. The Arctic Research Commission has concurred with these concerns and has recommended a multiagency study of the Bering Sea as an ecosystem (U.S. Arctic Research Commission 1991). The existence of long-term fishery and climatic records for this region also helps in investigating fluctuations. PICES (see Section 1.4) is beginning its international activities.

Cultural Exchange

The June 1990 Bush–Gorbachev summit meeting reached a historic agreement on the feasibility of establishing a Soviet–United States International Park in the region of the Bering Strait. At the signing ceremony, President Bush said,

> This park will preserve the unique natural, environmental and cultural heritage of the Bering Sea region of Alaska and Siberia. Just as a bridge of land once joined our two continents, so let a bridge of hope now reach across the water to join our two peoples in this spirit of peaceful cooperation.

Planning for the International Park is proceeding based on a reconnaissance study prepared by the two nations in 1989 (*Arctic Research of the United States*, Fall 1990, p. 13) and a series of joint meetings and planning activities in 1990 and 1991.

Data

Common to all programs is the need for a data management program within the Federal agencies. An Arctic Environmental Data Directory (AEDD) is currently under development. The National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, has a long history of archiving cryospheric data and has recently produced several CD-ROM products of satellite and large experiment data sets. Other national archives hold a variety of data sets.

Estimated funds allocated to the integrated research programs* for the interagency Arctic programs (in millions of dollars).

Agency	*FY 1990*	*FY 1991*		*FY 1992*	
DOC/NOAA	6.9	9.9	(0.3)	12.1	(0.5)
NASA	5.7	9.0	(9.0)	10.5	(10.5)
NSF	7.0	9.0	(1.5)	11.0	(2.5)
DOD	6.8	6.5	(0)	7.3	(4.2)
DOI	8.0	10.0	(2.0)	10.0	(2.0)
EPA	0.5	0.5	(0.2)	1.3	(0.3)
DOE	2.3	1.9	(0.4)	1.7	(0.4)
USDA	1.7	1.8	(0.2)	1.9	(0.2)
SI	0.6	0.7	(0.3)	0.7	(0.3)
DOT	0.3	1.9	(0)	0.7	(0)
DOS	0.06	0.06	(0)	0.06	(0)
Total	39.9	51.3	(13.9)	57.3	(20.9)

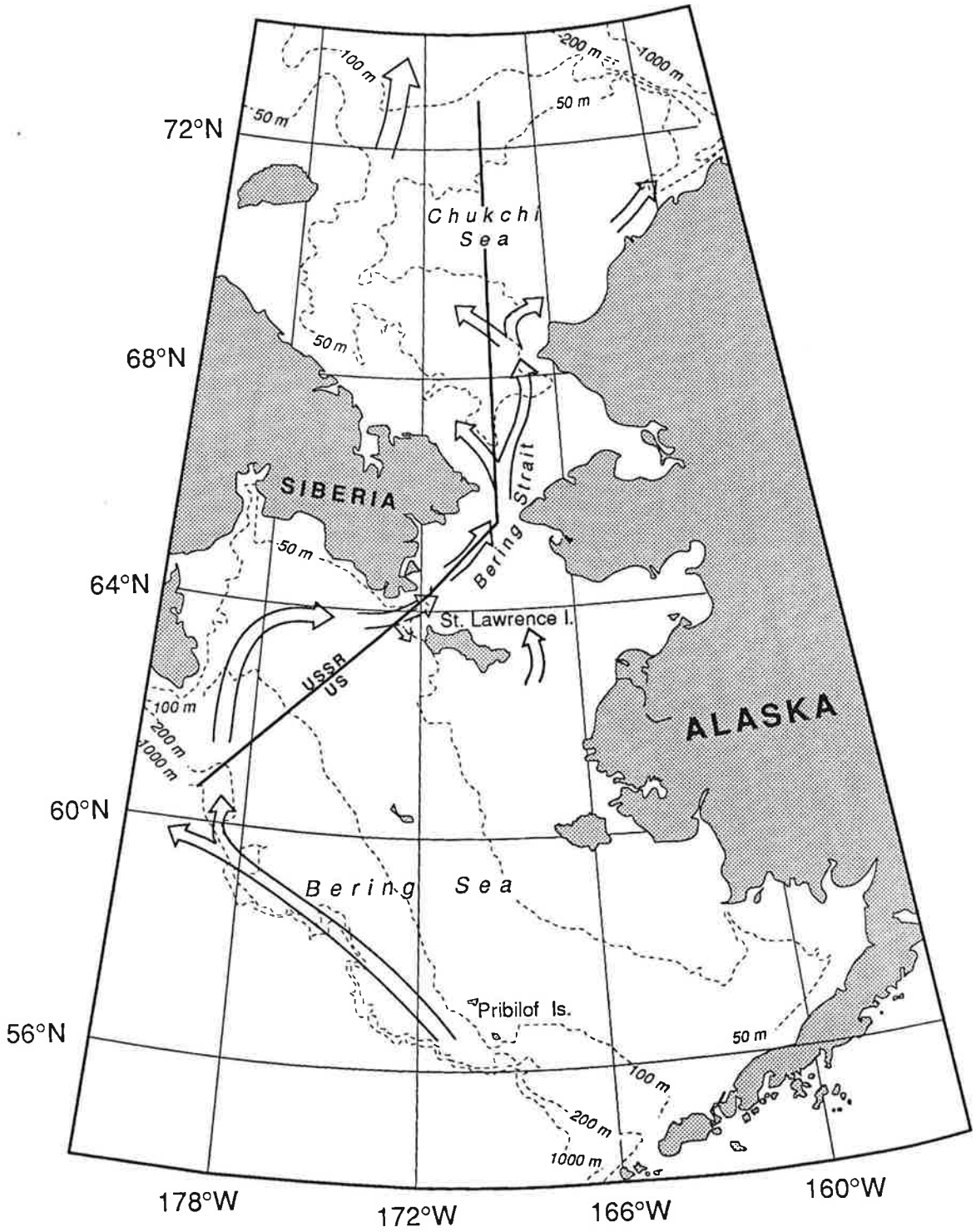
* Includes Western Arctic Ocean Circulation, Geodynamics, Monitoring, Bering Land Bridge and Data. These funds are contained in the line items presented in Appendix E. Estimates for the global change contributions to the total budget in the FY 1991 and 1992 totals are shown in parentheses.

A plan to integrate data archiving activities into an effective and coordinated activity will be developed and implemented over several years. A major Alaska-based bibliographic project (Polar PAC) is producing and updating a CD-ROM that includes listings of all Federal agencies' Arctic reports. Both the data and bibliographic activities will be a continuing effort to support the U.S. participation in an international Arctic Monitoring and Assessment Program.

Budget Analysis

As indicated earlier (Section 1.2), Arctic research budgets within most agencies are not defined as discrete programs or on a regional basis. The same is true for logistics support. The present budget analysis for the integrated programs is subject to the same uncertainties, and it takes into account regional allocations within given programs and the emerging global change programs applicable to the Arctic.

The FY 1991 estimate of $51.3 million for the four programs described in this report represents approximately 40% of the total anticipated interagency Arctic research and logistics budget. Included in this total is approximately $6.5 million in FY 1991 (USCG, NOAA and NSF) for large logistics support (ship support) and for data and information. The FY 1992 estimate is $57.3 million. Approximately 27% and 36% in FY 1991 and FY 1992, respectively, are estimated from global change programs. Descriptions of individual and multiagency activities are provided in the following sections.


72°N
68°N
64°N
60°N
56°N
178°W
172°W
166°W
160°W
Chukchi Sea
Bering Strait
SIBERIA
ALASKA
St. Lawrence I.
USSR
US
Bering Sea
Pribilof Is.
50 m
100 m
200 m
1000 m

2.1 Western Arctic Ocean Circulation and Productivity

Goal: To understand the processes controlling the physical and biogeochemical variability and the productivity of the marine western Arctic and thus improve both short- and long-term environmental forecasting capabilities.

Background

Both the physical and biological characteristics of the Arctic marine environment are determined by balances between local processes and exchanges with the Atlantic and Pacific oceans. Within the western Arctic region, the Bering Sea, the Northern Bering/Chukchi Shelf and the Arctic Ocean (extending from the shelf approximately to the Lomonosov Ridge) are three coupled yet distinct physical and biogeochemical regimes.

The Pacific source waters for the western Arctic are derived from flow through the Bering Sea, a large portion being nutrient-rich waters that upwell onto the shelf. Upwelling is particularly effective in the northwestern Bering Sea, where it fuels remarkably high biological productivity over the shelf, extending northward to Bering Strait. In contrast, the waters of lower salinity transiting the Bering Shelf farther eastward carry reduced nutrients with correspondingly lower productivity.

From the northern Bering Sea, the Pacific waters continue through Bering Strait into the Chukchi Sea, where, aided by nutrients recycled in winter, they support another extremely productive ecosystem. The carbon production in this region may supply 50% of the respiration demands within the Arctic Basin. Hence, the variability in production and the fate of the carbon are important inputs for calculating the oceanic carbon budget as it pertains to global change. Both the western inflow and the fresher waters entering through eastern Bering Strait are significantly altered in the Chukchi Sea by mixing and by interaction with the atmosphere, the ice cover and the sea floor as they circulate on the shelf. Modified but distinct Pacific waters eventually drain off the Chukchi Shelf into the deep Arctic Ocean. Within the Arctic Ocean the modified Pacific waters spread throughout the Canadian Basin, where they form a distinct layer between the surface ice cover and the warmer water below derived from the Atlantic inflow in the eastern Arctic. In this way the Pacific inflow insulates the enormous sea ice canopy of the western Arctic from melting and at the same time fertilizes the upper ocean with nutrients originally upwelled across the Bering slope. The stability of this system is critical in maintaining the Arctic climate. There are very few long-term current records for the Arctic Ocean and no hydrographic transects from which to understand the large-scale circulation or water column structure.

Freezing and melting of sea ice in the Bering Sea and on the Arctic Ocean shelves are critical in the process of water mass formation and biological productivity

Freezing and melting of sea ice in the Bering Sea and on the Arctic Ocean shelves are critical in the process of water mass formation and biological productivity. Ice mechanics also plays a direct role in the transport of energy between the atmosphere and the ocean. Seasonal and interannual variability is extremely large in this system, much of it associated with wind. This region could be critical for future U.S. activity in offshore oil exploration and production. Our ability to proceed with these commercial activities is seriously constrained by the lack of sufficiently accurate forecasts of weather and the strength and movement of the pack ice.

Improving both short- and long-term environmental forecasting capabilities for the western Arctic requires understanding of the role of atmospheric forcing, ice dynamics and the Pacific inflow. What controls the ocean transport and pathways from the deep Bering Sea onto the shelves? What are the principal patterns and scales of the shelf circulation? How does this circulation control production? What are the principal interactions between the variable ice cover and the shelf waters? How are the chemical and biological properties of the northward-moving waters redistributed? How are these waters modified in crossing the vast Arctic shelves? What controls the transport of the shelf-modified waters into the Arctic Ocean and their subsequent spreading? Recommendations contained in *Arctic System Science: Ocean–Atmosphere–Ice Interactions* (Joint Oceanographic Institutions Inc. 1990) and *Priorities in Arctic Marine Science* (National Research Council 1988) will be considered in implementing the program.

Objectives

- Define the principal pathways, rates and variability of Pacific waters through the western Arctic and the dynamics governing the flow;

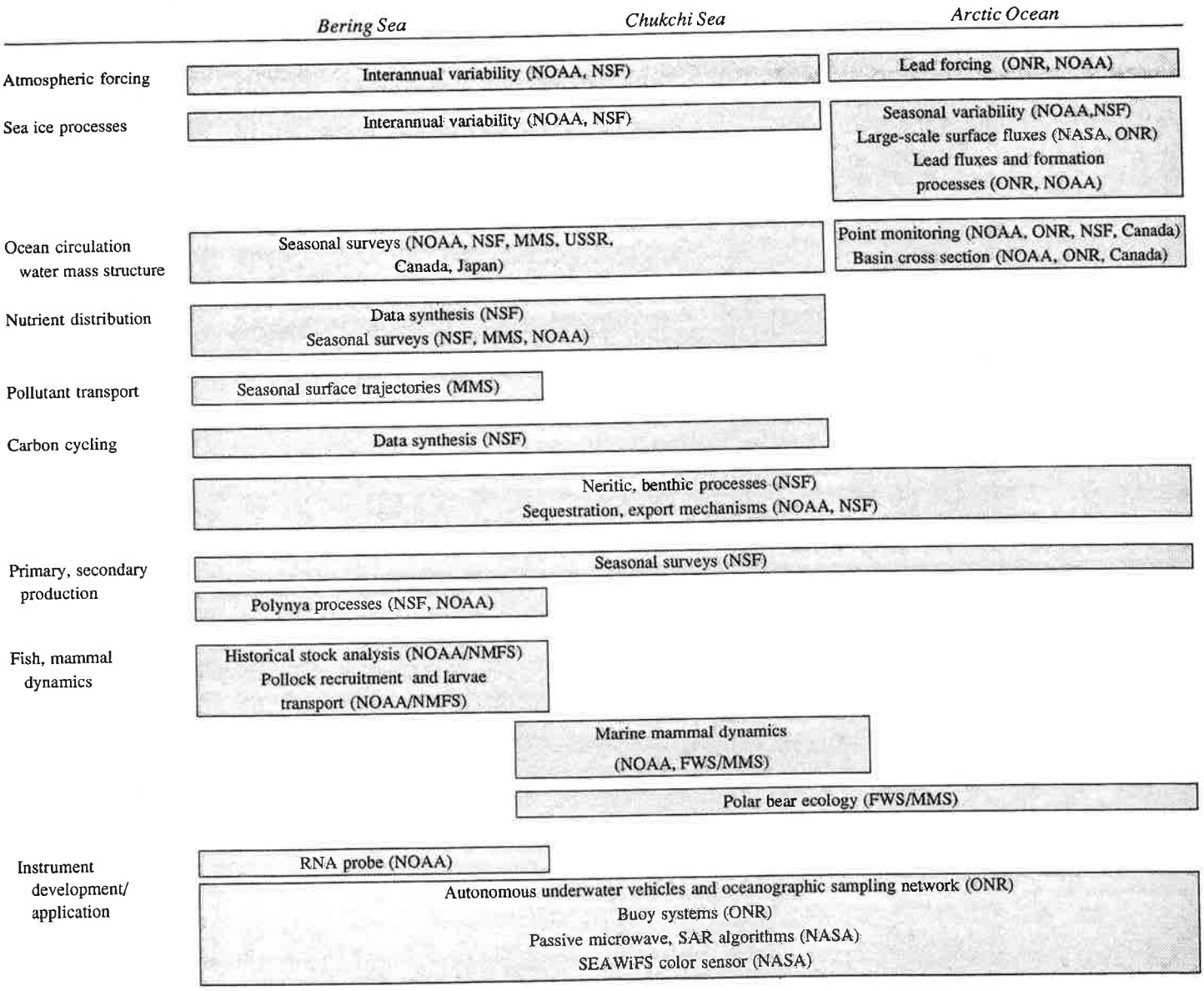
- Define the distribution of discrete stocks of important fish, shellfish and marine mammals, and the relationship of these distributions to physical, chemical and biological factors;
- Determine biological production rates and dynamics on the shelves of the western Arctic and assess their susceptibility to change;
- Relate sea ice dynamics to atmospheric forcing and determine the consequences for ocean circulation and biological production;
- Develop an accurate, high-resolution sea ice forecasting system with defined limits of predictability;
- Quantify the relative magnitude and sensitivity of fluxes contributing to the surface heat budget;
- Define the mechanisms and time scales of principal biogeochemical cycles in the western Arctic; and
- Determine the transfer of energy between trophic levels and the sequestration or loss of carbon from the shelf system.

Implementation

Implementation will proceed in phases designed to build data bases and modeling capabilities sufficient to guide the formulation and testing of hypotheses:

Phase I: Reconnaissance site surveys, synthesis of historical data bases, initial model development, interagency and international linkages for collaborative efforts.

Summary of existing and planned contributions to the Western Arctic Ocean Circulation and Productivity program.



Phase II: Multidisciplinary field experiments and process studies with interagency and international collaboration, data assimilation into high-resolution predictive models and long-term observational systems.

Most agencies are prepared to implement a limited Phase I effort with existing resources; several studies were initiated in FY 1990. Phase II represents a significant enhancement with a higher level of coordination. Programs listed under "Future Cooperative Program Elements" have been identified as critical needs that require additional funding for implementation.

Appendix B contains descriptions of specific existing, planned and future cooperative interagency program elements. Activities in Sections 3.1.1, 3.1.2 and 3.3.2 detail specific agency and multiagency plans that contribute to this integrated program. The diagram on p. 18 is a summary of the overall program.

Future Cooperative Program Elements

Bering Sea

- Expansion of field surveys sufficient to define the spatial and temporal variability in circulation;
- Regional climatology to determine the principal atmospheric and oceanographic forcing of the variable circulation in the Bering Sea;
- Primary and secondary production and its relationship to sea ice dynamics;
- Processes controlling the transfer of energy between trophic levels and the sequestration or export of carbon from the Bering Shelf;
- Coupled modeling of physical dynamics and ecosystem interactions.

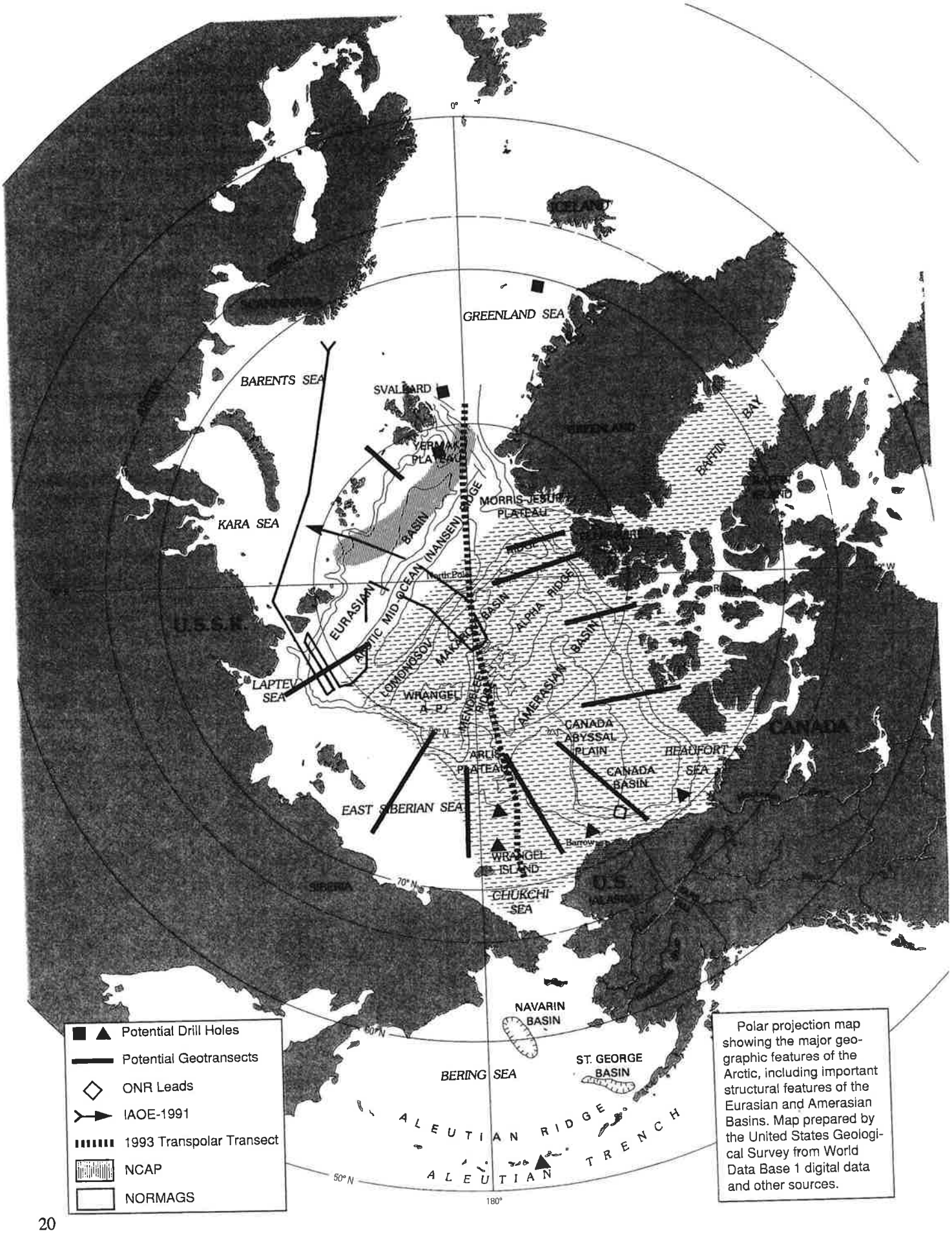
Northern Bering/Chukchi Shelf

- Shelf-basin exchange, including plume dynamics, export of carbon and nutrients;
- Expansion of biological sampling and measurements of primary production to define spatial and temporal variability and off-shelf components;
- Monitoring of ice thickness and ice deformation;
- Process studies of ice thermodynamics;
- Integration of SAR data into regional ice models;
- Higher-trophic-level dynamics.

Arctic Ocean

- Proposed coordinated transpolar expedition in the summer of 1993 with a U.S. Coast Guard icebreaker and the Canadian icebreaker *Louis St. Laurent* to obtain oceanographic and geophysical sections across the Arctic Ocean;
- Process studies of circulation dynamics on the continental slope;
- Continuous ocean and ice monitoring for spatial and temporal variability in ice thickness, upper ocean structure, circulation and water column sediment flux;
- Determination of the implications of Leads process studies for the western Arctic (on a regional scale), particularly the consequences for mixed-layer, atmospheric circulation;
- Coupled air–ice–ocean circulation modeling to look at coupling between higher and lower latitudes.

Under the integrated program, agencies will coordinate announcements of research opportunities and will align current research with the goals of the interagency effort. An interagency science steering committee will assure the continuity and integrity of the overall program.



Polar projection map showing the major geographic features of the Arctic, including important structural features of the Eurasian and Amerasian Basins. Map prepared by the United States Geological Survey from World Data Base 1 digital data and other sources.

2.2 Geodynamics of the Arctic Basin and Its Margins

Goal: To determine the climatic, paleo-oceanographic and tectonic evolution of the Arctic region and their effects on global climate, the biosphere and the dynamics of world oceans and atmosphere.

Background

The origin of the Arctic Basin is linked to the evolution of adjacent ocean basins and continents. Understanding past and present plate movements in the Arctic is necessary before a complete model of plate motions and paleogeography in the Northern Hemisphere can be constructed. The Cenozoic tectonic history (the past 67 million years) of the Eurasian Basin is relatively well known, since the Eurasian Plate and the North American Plate have been studied extensively to the south. The basin also contains a well-documented and decipherable magnetic lineation history. Little is known about much of the rest of the Arctic Ocean margin system. The evolution of the Amerasian Basin is a major unresolved problem. Rotation of the Arctic-Alaska Plate away from the Canadian NWT during the Cretaceous (prior to 65 million years ago) is consistent with geology of the Canadian Arctic Islands and Alaska. However, interrelationships with the Markarov Basin are unknown.

One of the major unsolved questions in earth sciences is the paleo-oceanographic and paleoclimatic evolution of the north polar deep-sea basins

One of the major unsolved questions in earth sciences is the paleo-oceanographic and paleoclimatic evolution of the north polar deep-sea basins. Identification of greenhouse warming within historical records requires quantifying the magnitudes, frequencies and rates of natural climate change. Of hundreds of samples collected in the Arctic Ocean, only four contain sediments that predate the onset of cold climatic conditions. The oldest black muds (about 80 million years old—Campanian age) and siliceous oozes (about 67 million years old—uppermost Cretaceous and earliest Paleocene) indicate that at least part of the Arctic Ocean was a relatively warm, productive, deep-sea basin prior to 40 million years ago. Three recent cores by the USGS may also record Cretaceous sediments. All other sediment cores from the Arctic Basin contain younger sediment, deposited in a cold, at least partially ice-covered, deep-sea regime. The record documents periods when iceberg-transported, terrigenous sediment was deposited on the basin floor. There are no marine data from 5 to 40 million years ago when the Arctic climate cooled, and thus no information is available to decipher the forcing functions or time of onset of glacial conditions. Today, dense, cold, Arctic surface waters sink and flow southward, filling the deep basins of the Atlantic and Pacific oceans. This circulation in the past may have been substantially different, with consequent climatic implications. The Alpha and Lomonosov ridges in the past were a greater barrier to circulation than at present; their rates of subsidence are unknown. Understanding the history of the ridges and the basins is critical for reconstructing past climate. Sixty-five million years ago (late Cretaceous), Alpha Ridge may have been a volcanic oceanic plateau. Lomonosov Ridge is probably a sliver of the Barents Sea margin. The geodynamic forces responsible for the origin of the Alpha and Lomonosov slides are unknown.

Twenty-five percent of the Nation's production of hydrocarbons comes from the Alaskan coastal plain, and 20% of reserves are estimated to be within the continental margin. Understanding the geologic history and structure of the Arctic margin is necessary for further development and management of these nonrenewable resources. In permafrost regions in the Northern Hemisphere, both onshore and offshore, considerable quantities of methane in the form of a hydrate are contained within and beneath the permafrost layer. Because global climate warming is postulated to be magnified in the Arctic, accelerated thawing of permafrost may occur, possibly releasing methane into the atmosphere. Continental shelves are potentially rich in gas from suspected frozen methane (clathrate) deposits.

Unlike temperate regions, where water is the only medium of energy exchange with the sea floor, the Arctic continental margin is a unique environmental domain involving not only the water column but also the interaction of two solids: ice and the sea floor. The surfaces of these solids are variable in form, both temporally and spatially, and the dynamics of their interaction results in ever-changing conditions. Erosion rates are extremely high along the low-lying Arctic coastlines, where sea ice and permafrost are common. Specific questions about where to build causeways, man-made islands and other structures can only be answered after basic process information is collected and interpreted. Knowledge of erosion and

sediment transport in the Arctic is essential for intelligently managing the coastal region.

The tectonic and paleoclimatic history of the Arctic Ocean margin system needs to be addressed at a minimum of six time ranges:

- The last few hundred years: How precisely do the sediments record the history of the Little Ice Age and the influence of man on the global system?
- 12,000–18,000 years ago: What changes occurred at the end of the Pleistocene that triggered the decay of the major ice sheets?
- 125,000 years ago: What were the conditions during the last major interglacial period?
- The last 2 million years: What is the timing, magnitude and periodicity of high-amplitude, late-Cenozoic climate oscillations and resultant ice sheets, both continental and marine?
- About 25 million years ago: What conditions triggered the initial Arctic climatic cooling, the formation of sea-ice cover and the earliest glaciations?
- About 67–85 million years ago: What was the climate at the end of the Cretaceous? How can we characterize the preglacial Arctic deep-sea paleoenvironment?

A general question that can be asked for each time range is: What were the paleo-oceanographic and paleontologic (both faunal and floral) responses to climate change, warm–cold oscillations and changes in the depth and width of ocean corridors linking the Arctic with the global ocean?

Objectives

- Determine the tectonic and geologic history of major structural elements of the Arctic Ocean margin system;
- Determine the climatic and paleo-oceanographic evolution and their effects on global climate;
- Understand coastal processes unique to high-latitude shelves;
- Estimate the volume of methane in permafrost regions and how rapidly it would be released by various degrees of warming; and
- Establish the tectonics and sea level oscillations of the Bering land bridge in order to understand the fauna and flora migrations.

Implementation

Implementation is designed to take advantage of planned and proposed international programs, including those of the International Arctic Science Committee and the Arctic Ocean Sciences Board. The initial activities are primarily exploratory. Multi-year programs involve major additional operational support. Sections 3.1.3 and 3.3.2 present specific agency and multiagency plans that contribute to this integrated program.

Future Cooperative Program Elements

Joint U.S./Canadian Traverse of the Arctic Basin

The geologic component will include a geophysical transect of the Chukchi borderland to obtain seismic refraction and reflection data to define Arctic continental margins. A super corer and gatling gun drill may be used to sample the geologic structure and obtain paleo-oceanographic data.

Northern Magnetic and Gravity Surveys

Detailed aeromagnetic and aerogravity surveys of the Amerasian Basin and continental margins will be required and will provide the basis for a series of up to twelve geophysical and sampling transects. It is anticipated that the Geological Survey of Canada will participate in NORMAGS.

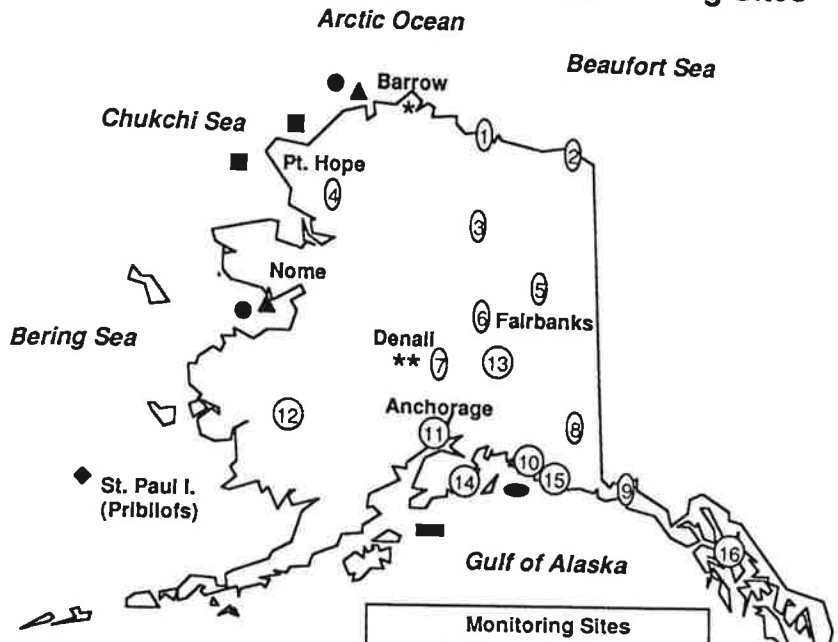
Arctic Gateway Drilling

The Ocean Drilling Program is based on paleo-oceanographic and tectonic objectives and recommendations of thematic panels and will consider Arctic drilling sites.

Nansen Centennial Arctic Program (NCAP)

Norwegian scientists plan to commemorate the Nansen "Fram" drift of 1883–1886 with a freeze-in of an ice-strengthened vessel for a two-year drift, probably starting in the Laptev Sea. The geological objectives are to elucidate the structure and evolution of the Arctic continental margins; the structure and evolution of the marginal plateaus and the Lomonosov Ridge; the structure of the lithosphere and the junction of the Arctic Mid-Ocean Ridge and the Laptev Sea margin; the preglacial Arctic Ocean; the timing and characteristics of initial climatic cooling and glaciation; the timing, magnitude and periodicity of high-amplitude late-Cenozoic oscillations, with emphasis on the late interglacial–glacial cycle; the development of deep circulation adaptations of marine biota to a cold hydrosphere; and sediment flux and carbon cycling in the Arctic Basin.

Selected Alaskan Research and Monitoring Sites



Tissue Sample Sites
▲ Ringed Seal
● Bearded Seal
■ Beluga Whale
◆ Northern Fur Seal
▬ Harbor Seal
⬬ Northern Sea Lion

Monitoring Sites	
*	CMDL/Seismic Observatories
**	Denali NADP/NTN
1	Colville
2	ANWR
3	Toolik Lake LTER
4	Noatak
5	Yukon Flats
6	Bonanza LTER
7	Denali/Black Rapids Glacier
8	Wrangell/St. Elias
9	Hubbard/Malaspina
10	Copper River
11	Susitna
12	Kusko/Bethel
13	Gulkana Glacier
14	Wolverine Glacier
15	Bering Glacier
16	Mendenhall Terminus

2.3 Arctic Monitoring

Goal: Building on existing sites and data bases, to participate in a coordinated international network of long-term atmospheric, terrestrial and oceanographic monitoring stations and to facilitate analysis, storage and dissemination of acquired data.

Background

Public, scientific and intergovernmental concerns for the well-being and protection of the Arctic are increasing. It is often difficult to distinguish between changes in the environment due to human-induced activities and those resulting from natural variability. Furthermore, the Arctic is being exposed to increasing inputs or effects of contaminants from lower latitudes due to atmospheric, marine and riverine transport. The spatial and temporal variability of contaminants, their fates and effects, and the overall status and trends in the quality of the Arctic environment and the condition of the biota are generally not well known.

Within the last ten years the governments of the circumpolar states have become increasingly aware of the need, and their responsibility, to combat these threats to the Arctic ecosystem. The June 1990 Bush–Gorbachev joint statement on the environment emphasized the importance of coordination of global atmospheric, terrestrial and ocean monitoring systems.

As indicated in Section 1.4, the Arctic Environment Protection Strategy includes an international Arctic Monitoring and Assessment Program (AMAP), whose primary objective is to measure the levels of anthropogenic pollutants and assess their effects in relevant components of the environment, focusing on pertinent organic contaminants and selected heavy metals and radionuclides.

The U.S. agencies, in accord with national and international programs and agreements, propose to develop their contribution to this international Arctic Monitoring and Assessment Program. The U.S. activities include monitoring chemical, biological and physical conditions and conducting environmental process research. Included are assessments of the nature and degree of contamination, the effects of contamination and other forms of human disturbance on the biota and ecosystems, and variations of physical parameters of the environment. Monitoring the physical parameters of the environment or the cryosphere (sea ice, permafrost, snow cover, glaciers etc.) is identified and also is being addressed in more detail in the U.S. Global Change Research Program.

Monitoring and related research in the Arctic is important for:

- Establishing a quantitative baseline against which natural variability and future changes can be evaluated;
- Detecting food chain contamination in ecosystems and humans;
- Detecting early signals of biological and physical changes in the environment;
- Determining sources and persistence of natural and anthropogenic contaminants;
- Determining sources and effects of natural and anthropogenic disturbances;
- Serving as a basis for management, mitigation and preservation of biodiversity (flora, fauna and habitats); and
- Developing more accurate predictive models of Arctic variables and establishing the information to initiate these models.

Existing chemical, ecological and cryospheric research- and monitoring-related activities within agencies.

Atmosphere	
Climate	DOC/NOAA
Chemical	DOC/NOAA, DOE, DOI/NPS, EPA, NASA, NSF
Oceans	
Physical	DOC/NOAA, DOD/ONR, DOI/MMS, NSF
Ice	DOC/NOAA, DOD/ONR, DOI/USGS, DOT/USCG, NASA, NSF
Chemical	DOC/NOAA, DOI/MMS, NSF
Biological	DOC/NOAA, DOI/MMS/FWS, NSF
Geological	DOI/USGS, NSF
Terrestrial Environments	
Freshwater	DOC/NOAA, DOI/FWS/USGS/NPS, EPA, NSF, USDA/FS/SCS
Land	DOI/BLM/NPS/FWS/USGS, NSF, EPA, DOE, USDA/FS
Snow/Glaciers/Permafrost	DOD/CRREL, DOI/USGS/NPS, NASA, NSF, USDA/FS/SCS
Social	
Socioeconomic	DOC/NOAA, DOI/MMS/BIA
Cultural	DOI/BIA/NPS/MMS, NOAA, NSF, SI

Deficiencies in existing national and international Arctic programs include:

- The minimal amount of baseline data from which to establish trends;
- The lack of a comprehensive network of environmentally appropriate sites;
- The lack of standardized strategies and protocols for gathering data across existing sites;
- The lack of a long-term commitment to coordinated, interagency observational programs;
- The lack of systematic storage, access and analyses of Arctic environmental data; and
- The lack of adequate international coordination.

The goals and objectives for program design and data management are to:

- Design a national and cooperative international sampling network and protocols, and provide for intercalibration of instruments and methods;
- Extend baseline measurements at selected U.S. sites and along transects (CMDL, LTER, NADP, parks and refuges, ALERT sites);
- Provide international harmonization of standards for measuring key pollutants and ecosystem health;
- Conduct satellite-based atmospheric observations and marine expeditions and cruises to document transport processes and rates of change;
- Develop habitat indices and inventories of species, populations and communities for assessing impacts and monitoring change;
- Conduct research on the fate and effects of chemical contaminants;
- Further develop centers for the international storage, exchanges and analyses of environmental data; and
- Identify data sets for input to the Arctic Environmental Data Directory (AEDD) and the Arctic Data Interactive (ADI) CD-ROM.

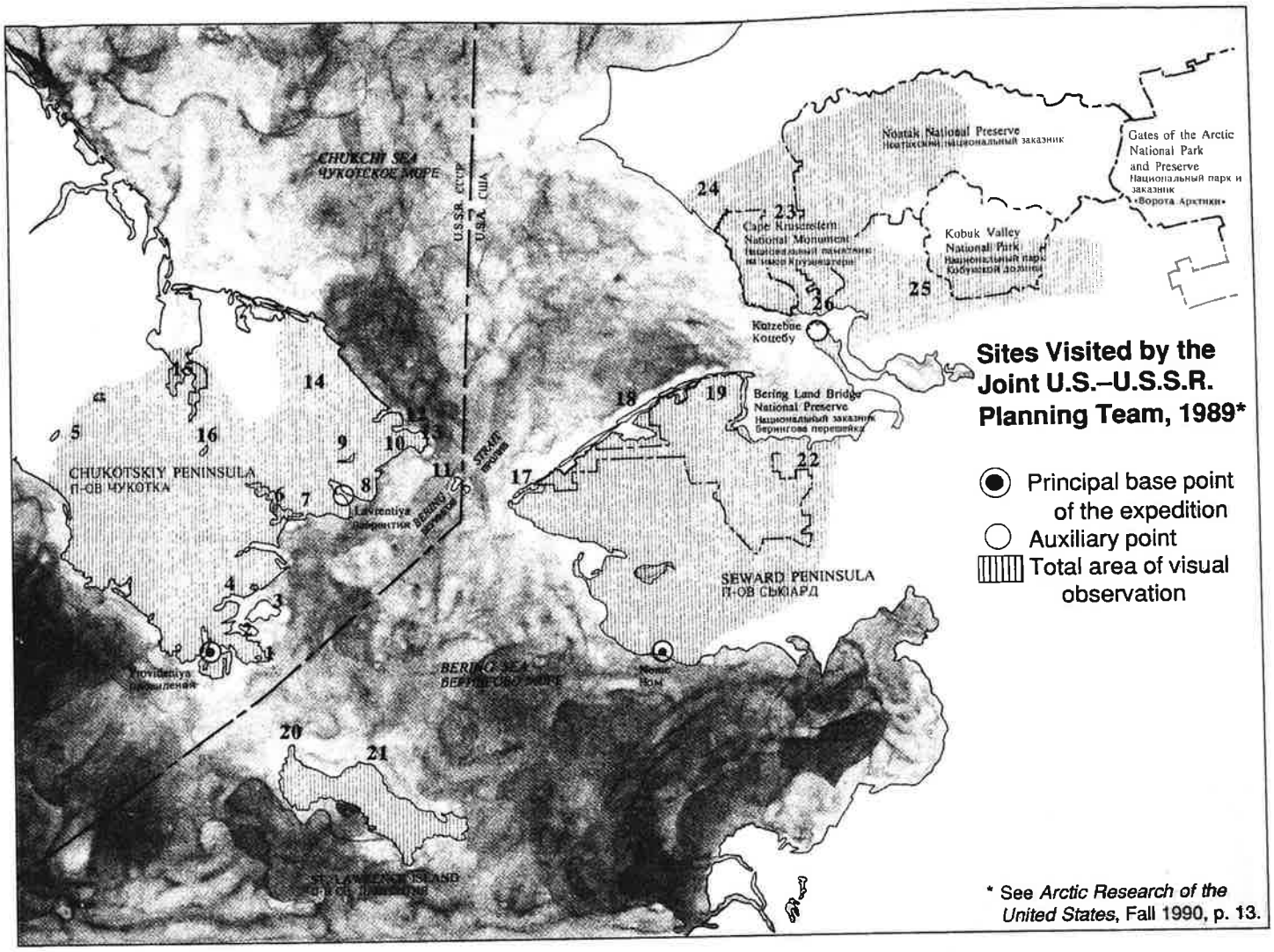
Implementation

The U.S monitoring activities will be conducted, in part, on a network of long-term terrestrial and oceanographic stations generally situated along transects and environmental gradients. One component, the Arctic Long-term Environmental Research Transects (ALERT), will consist of monitoring, assessment and research activities on physical, chemical and biological properties and processes. ALERT sites will be coordinated with circumpolar sites and other major U.S. and international programs (LTER, NADP, IGBP, UNESCO-MAB, IHP etc.) and expeditionary programs such as AGASP and routine satellite and oceans monitoring programs. Workshops are planned to design the sampling and monitoring approaches. EPA proposes to convene an international symposium on research and sampling designs to assess the status of, and changes in, the Arctic environment. These activities will be coordinated with AMAP, IASC and other international programs that have provisions for long-term monitoring (IGBP, MAB etc.). Essentially all mission research components presented in Section 3 of this Plan contain monitoring activities as illustrated below. See Appendix B for further details.

Future Cooperative Program Elements

- Design a monitoring program as part of an international Arctic Monitoring and Assessment Program, expand the AEDD and participate in workshops and symposia;
- Further develop appropriate methodologies for assessing the extent and magnitude of pollution in Arctic ecosystems caused by airborne contaminants; lichens and mosses will be sampled using a regional, probability-based sampling frame that will result in quantitative contaminant estimates for the U.S. Arctic; sediments will be analyzed from lakes throughout the Arctic to determine the source and timing of contaminants; additional studies will provide information on the levels of bioaccumulation of contaminants by various components of the terrestrial Arctic food webs (EPA);

- Under an expanded Arctic Studies Center, renew the Smithsonian Institution's basic systematic, evolutionary and ecological research on the Arctic biota in several key areas: inventory of the plant and animal species in both the terrestrial and marine environments, distribution and ecology of species, systematics and evolution of Arctic taxa, life history and environmental adaptation, and questions relating to the conservation of biodiversity (SI).
- Develop plans for upgrades to the ASF to accommodate SAR data from the Canadian Radarsat, which would offer the first opportunity to obtain weekly synoptic SAR coverage of the entire Arctic ice-covered oceans; together with other satellite and in-situ data, such observations would enable estimates of energy fluxes between the ocean and atmosphere at high latitudes (NASA);
- Develop a quantitative classification system for snow covers based on a broad range of physical properties (DOD/CRREL);
- Establish an Arctic data office to control data quality, promote data exchange, and link data and information; establish a real-time coastal ocean monitoring and analysis capability in the Arctic within NOAA's Coastal Ocean Program; develop and distribute data on coastal oceanography and fisheries in a CD-ROM, based on a compilation of Beaufort Sea studies (DOC/NOAA);
- Conduct cooperative long-term ecosystem monitoring along two transects: a circumpolar transect in the boreal and Arctic climatic zones, and a Pacific transect from Alaska to Tierra del Fuego; monitor total carbon loading, vegetation vigor and health, employing research tools such as GIS/remote sensing modeling and dendrochronological techniques (USDA/FS);
- As part of the Northwest Alaska Biogeographic Area global change program, centered on the MAB-designated Noatak National Preserve, establish a monitoring and research program that contributes plant, animal and environmental data to the circumpolar long-term monitoring program, including Soviet Arctic preserves (DOI/NPS);
- Undertake a five-year program on contaminants in Arctic fish and wildlife to sample tissues and to establish baseline levels for determining seasonal, annual and individual variations, identifying species or groups of species as contaminant sinks, determining their potential vulnerability to contaminant effects, and identifying the relationship of contaminants to patterns of habitat use and movement known from ongoing satellite telemetry and molecular stock identification studies (DOI/FWS);
- Monitor the effects of subsistence usage on populations and the effects of subsistence on regional ecology (DOI/BLM/NPS);
- Conduct studies related to global climate change (DOI/BLM/NPS);
- Enhance regional glacier monitoring through the establishment of north–south and east–west transects of "benchmark" maritime and continental glacier basins in North America and further develop sea ice, snow, hydrologic, permafrost and trace gas monitoring programs under the Global Climate Change Program (DOI/GS/NPS); and
- Develop a network of comparative research sites to determine the impacts on tundra ecosystems disturbed 5 years to several decades ago to better predict temporary or long-lasting changes in moisture, permafrost, vegetation and microbial populations, gas flux and soil composition (DOE/ER).



Sites on Chukotka—Area of Interest

1 Chaplino—Ethnography, Archeology
2 Whalebone Alley—Archeology
3 Arakamchechen Island—Archeology, Walrus Haulout Area
4 Korgan and Pestsovoi River Valleys—Hot Springs
5 Erguveyem River Valley—Hot Springs
6 Mechigmen Inlet—Archeology, Bird Nesting Area
7 Lorino—Hot Springs
8 Nunyamo—Archeology
9 Lake Koolen—Natural Phenomena, Fish, Migratory Bird Resting Area
10 Dezhnev—Archeology
11 Big Diomede Island—Archeology, Walrus Haulout Area
12 Cape Dezhnev, near Uelen—Archeology, Ethnography, Ivory Carving
13 Naukan—Archeology
14 Chegitun River Valley—Scenic Views, Rich Flora and Fauna
15 Kolyuchinskaya Inlet—Rare Fish Species, Migratory Bird Resting Area
16 Lake Ioni—Rare Fish Species, Migratory Bird Resting Area

Sites in Alaska—Area of Interest

17 Wales—Coastal Subsistence Lifestyle, Archeology, Ethnography, Reindeer Herding
18 Sishmaref—Coastal Subsistence Lifestyle, Archeology, Marine Mammals, Lagoons
19 White Fish Lake and Bering Land Bridge National Preserve—Archeology, Geology
20 Gambell—Island Subsistence Lifestyle, Ivory Carving, Archeology, Ethnography
21 Savoonga—Island Subsistence Lifestyle
22 Deering—Coastal Subsistence Lifestyle
23 Noatak—Interior Subsistence Lifestyle, Ethnography
24 Kivalina—Coastal Subsistence Lifestyle, Ethnography
25 Kiana—Interior Subsistence Lifestyle, Archeology, Ethnography
26 Kotzebue—Subsistence Lifestyle, Ethnography

2.4 Bering Land Bridge Program

Goal: To promote the understanding of the common heritage of Beringia and improve our knowledge of human adaptation and the paleo-environments of the region during and since the last glaciation.

Background

The ecologically rich Beringian region has long been seen as the birthplace of New World Arctic cultures and the center from which these cultures spread into other regions of the New World and nearby Asia. Geographically the region is crucial to any understanding of North Pacific and Arctic prehistory. This region saw the first migrations of humans into the New World, has been a center of Eskimo development, and has been an important conduit for Asian–American cultural exchanges for at least the past 15,000 years. The long history of human occupation of the Beringian region provides an unparalleled record of human adaptation to changing climatic, environmental and sociocultural conditions. Today the ecologically diverse and resource-rich Beringian region is home to numerous native groups, whose participation in political and economic development is essential. Archaeological excavations in the Bering region provide long-term data on faunal changes in both marine and terrestrial mammals, as well as changes in invertebrates, plants and soil chemistry. Coastal settlements correlate with changes in sea level and reflect the influences of these changes on local and regional animal and plant populations. Pollen and macrofossil samples from cores and stratigraphy from settlements and sediments can be closely correlated with human activities and environmental change. These data can provide the time depth necessary to construct predictive and testable models of relevance to all aspects of global change research.

The proposed Beringian Heritage International Park offers a concrete focus for interagency and international social and natural sciences research coordination and implementation

The Bering region provides exceptional conditions for research cooperation in the Arctic. Recent political and scientific developments provide research opportunities that have not existed for more than half a century. This program proposes multi-agency research with a strong interdisciplinary and international focus. Among the most important research topics that can be addressed in the Bering region are the peopling of the New World, adaptations and the dynamics of Arctic social and cultural change, the paleoecology of the region, and contemporary cultural, social, psychological and health issues.

In 1989 a joint Soviet–American planning team proposed the creation of a Beringian Heritage International Park and outlined a strategy for its creation. The principal goals would be to promote scientific cooperation, preserve natural and cultural sites, and provide opportunities for coordinating resources.

The proposed Beringian Heritage International Park offers a concrete focus for interagency and international social and natural sciences research coordination and implementation in the Arctic (*Arctic Research of the United States*, Fall 1990, p. 13).

The social sciences (archeology, anthropology etc.) provide the core of this integrated initiative, which involves collaboration with natural sciences, including paleoecology, geology and biology. The research program provides both time depth and a multidisciplinary analysis of human adaptation in the Arctic. Knowledge will be gained about circumarctic cultural development, past and present, and models formulated for human-ecosystem dynamics and demographic change.

Cultural resource management is a mission of numerous Federal agencies. In this regard the Department of the Interior (particularly the National Park Service, the Bureau of Land Management and the Bureau of Indian Affairs), the Smithsonian Institution and the National Science Foundation are important partners in research and surveys having to do with prehistoric and historic sites as well as indigenous cultures of today. Cooperative scientific investigations on Federal lands must be undertaken to accurately document and manage cultural resources. Without accurate documentation, preservation policies cannot be properly assessed. The same is true regarding modern indigenous socioeconomics and health concerns, and collaboration with the Department of Health and Human Services and its Indian Health Service, NOAA's Sea Grant Program, local governments, and Native councils and organizations in Alaska.

The program is presented at two levels: the overall Bering Land Bridge region and the specific proposed Beringian Heritage International Park. Related recommendations contained in the report *Science in Northwest Alaska: Research Needs and Opportunities on Federally Protected Lands* (D.M. Hopkins et al. 1990) will be considered in implementing this program.

Goals and Objectives

Goals

- Increase baseline documentation of Beringian cultures and archeological sites in relation to sea level change;
- Increase baseline information on the ethnography, linguistics and history of Beringian peoples and cultures;
- Document human responses and adaptation to changing climatic, environmental and sociocultural conditions; and
- Reconstruct paleoenvironments and distributions of flora and fauna in Beringia.

Objectives

- Conduct geological and archeological surveys of coastal regions to establish relationships between prehistoric settlements and sea levels;
- Monitor the effects of coastal erosion on prehistoric and historic sites in the Beringian region;
- Conduct paleoecological studies (e.g. palynology, paleontology, geology) of coastal regions and correlate the results with archeological data;
- Conduct ethnographic, linguistic and oral history surveys to determine key research problems and areas;
- Conduct socioeconomic and cultural studies to minimize the disruption caused by development; and
- Establish resource profiles of coastal regions.

Goals and Objectives of the Proposed Beringian Heritage International Park

- Promote the understanding of the common heritage of Beringia;
- Preserve and protect for research a portion of the 1000-mile-wide land link that intermittently connected Asia and North America between 14,000 and 25,000 years ago;
- Establish joint programs for the benefit of the international park and the preservation of the Beringian heritage;
- Establish a joint center (or centers) to work on projects relevant to resources of the common heritage and to provide scientific support for the international park; and
- Act as a catalyst for research efforts by encouraging international and interdisciplinary research.

Implementation

This focused social and natural sciences initiative will be undertaken within the framework of interagency cooperation. Using cooperative agreements, an interagency working group composed of representatives from Alaska- and Washington, D.C.-based agencies will develop and implement existing and required new programs as described below. Programs under the U.S.–U.S.S.R. Agreement on Cooperation in the Field of Environmental Protection will be utilized to facilitate the international aspects of the bilateral research (Working Groups IV, V, VIII, X, XI).

Missions and research specialties unique to individual agencies are to be combined into a coordinated plan. Each agency will support specific activities: NPS through contract and in-house studies on park lands; NSF through peer-reviewed projects; and the Smithsonian Institution through in-house programs and academic collaborators. Coordination on Federal lands will be through the land managers (NPS, BLM, FWS etc.). These activities will be coordinated with nongovernmental programs of the National Audubon Society, The Nature Conservancy and others. Logistics in Alaska will be coordinated with the National Park Service and cooperating agencies. Sections 3.3.2 and 3.5.1 and Appendix B detail specific agency and multiagency plans that contribute to this integrated program.

Existing and Planned Agency Contributions

Agencies and academic collaborators will use 1991 to coordinate ongoing activities and plan specific scientific investigations on both sides of the Bering Sea. The opening of the Smithsonian's *Crossroads of the Continents* exhibit in Alaska in April 1991 and associated visits of Soviet scholars has provided a focus for such activities. Quaternary scientists having active research programs in the Far East and Alaska are meeting in Alaska in 1991 to reexamine existing hypotheses and evidence of the paleoecology of Beringia and to plan future activities.

Joint U.S.–Soviet meetings were held during 1991 in Moscow, Leningrad, Denver and Alaska to discuss more specific program details and steps required to formally establish the proposed international park. Additional exchange visits are underway, and a joint seminar is planned for August 1991 in Provideniya. A status report on progress and future plans of the international park is in preparation.

A series of joint U.S.–U.S.S.R. field programs in Chukotka, the Heritage Park and northwest Alaska will be carried out over a three-year period.

U.S. participation will be planned by the interagency working group and will include major research themes on environmental archaeology, global change, and sociocultural and ethnohistorical research. The summer of 1991 will be the start-up for the U.S. research program in the existing Bering Land Bridge National Preserve. A series of projects identified by the NPS in collaboration with the research community will be initiated. Major conferences and publications will be undertaken to disseminate information on research results and ongoing programs. A series of symposia are planned for 1992.

Funding will be required to strengthen Federal programs relating to Arctic cultural–historical baseline studies in archaeology, geology, anthropology, oral history and subsistence. Data base development and coordination within Alaska and between U.S. and Soviet programs are important parts of the research and will greatly enhance the use of existing research knowledge and data. Specifically needed are:

- Compilation and coordination of cultural and natural resource data for the Bering region in the U.S. and U.S.S.R.;
- Archaeological, ethnographic and ethnohistorical investigations; exhibitions and educational programs; mapping in connection with geomorphic, paleoecological and archaeological surveys; and documentation of the people, wildlife, flora and landscape of Beringia;
- Scientific workshops in conjunction with the planned research centers and infrastructure development;
- Continued research relating to the peopling of the New World;
- Documentation of northern maritime cultural adaptations; and
- Academic research grants for disciplinary and multidisciplinary Bering projects relating to global change, stratigraphy, paleoecology and human adaptation.

2.5 Arctic Data and Information

Goal: To facilitate Arctic research by identifying and developing methods to improve the aquisition, storage and dissemination of Arctic data and information.

Two major activities are underway: development of the Arctic Environmental Data Directory (AEDD) and its associated Arctic Data Interactive system (ADI); and the Arctic Bibliographic Information Network. The IARPC requested that funds be made available from each agency to support the AEDD and ADI at the U.S. Geological Survey. Seven agencies are currently contributing direct funds to this effort.

Arctic Data

The area of Arctic data has been active in recent years, and there have been several significant interagency accomplishments.

The Arctic Environmental Data Directory, developed by the USGS with assistance from all agencies, now contains over 350 references to Arctic data bases maintained by government, academic and other organizations in the United States (including Alaska state and local governments), Canada, the Soviet Union, Finland, Norway and Iceland. Coverage is being extended to include the social sciences.

The Council on Northern Resources Information Management (CONRIM) established an AEDD Subcommittee in Alaska to identify additional data entries from state and local government agencies, Alaska-based Federal agencies and other Alaska-based organizations.

The AEDD Working Group coordinated its activities with the Interagency Working Group (IWG) on Data Management for Global Change, the Polar Research Board and the Arctic information sciences community. The IWG sponsored development of the Arctic Data Interactive (ADI) prototype CD-ROM to package and distribute the AEDD, together with selected data sets, scientific reports and bibliographic information. The first CD-ROM containing the AEDD and examples of specific Arctic data sets, which can run on both Macintosh and IBM-PC compatible desktop computers, was issued in the spring of 1991. The USGS was the lead agency for this project.

DOE has developed a user-friendly, menu-driven data base containing fossil-energy-related information on the Arctic (the Arctic and Offshore Research Information System, or AORIS). It consists of a directory of 85 data bases containing Arctic fossil-energy-related information; over 8000 references and abstracts on fossil-energy-related research; and scientific and engineering information containing over 800 data sets on sea ice characteristics. AORIS is available to the public through DOE's Morgantown Energy Technology Center computer system and the National Energy Software Center.

NOAA has produced the Alaska Marine Contaminants Database on a CD-ROM as a demon-

stration product that compiled existing data into a single data base and made it accessible to scientific users.

Objective

- Have the AEDD become *the* source of information on who has what data and information in the Arctic community.

Planned Interagency Activities

- Over the next two years, increase the number of entries from Alaska-based organizations, expand activities in the social and health sciences, continue to acquire data from other Arctic nations, and implement a process to update and review entries periodically to ensure that the directory remains current;
- Develop an interface with the international Arctic Monitoring and Assessment Program;
- Continue to merge digitized and bibliographic data bases and activities into a common national and international information network;
- Integrate the data activities with geographic information systems (GISs) and provide for ease of modification of the data system as computers and storage technologies change;
- Support the data handling requirements of Arctic marine and terrestrial mesoscale ecosystem programs (e.g. Bering Sea) and other integrated U.S. Arctic programs;
- Develop the ADI as a serial publication containing Arctic data and metadata; and
- Establish formal relationships between the AEDD and other related directories, such as the Global Change Data Directory and the directory activities of the Antarctic research community.

Arctic Bibliographies

Literature and bibliographies supporting Arctic research exist in a number of U.S. library collections and smaller agency libraries, as well as in Canadian and other international collections. Many additional reports accumulate as "gray" literature, uncataloged in organized collections. To avoid duplication of research and to improve access to existing results, it is necessary to provide mechanisms for integrating these resources. Ways of automating, integrating and exchanging Arctic bibliographic references are being developed, in cooperation with the related efforts on Arctic data, to increase the efficiency of access to both digital data and bibliographic information.

The National Science Foundation has supported the creation of an electronic bulletin board on OMNET to facilitate information flow, particularly among libraries (POLAR.LIT).

Several CD-ROM bibliographic products (Polar Pac, NISC and AORIS) were produced and evaluated both within the U.S. and internationally. These products were developed by DOD/CRREL, DOE/FE and NSF.

The Polar Library Colloquy, at their meeting in Rovaniemi, Finland, in June 1990, agreed to develop a process of shared resources for cataloging and disseminating information on polar literature. A U.S.-sponsored group met at Dartmouth College in Hanover, N.H., in April 1991 to review progress on networking and sharing bibliographic information and activities.

Objectives

- Promote regular exchanges of information on northern collections, new acquisitions and methods of information processing, including the social science disciplines;
- Develop a network of northern libraries to promote dissemination of all Arctic bibliographic information; and
- Provide user-friendly computer searching of global polar-related bibliographic data bases.

Planned Interagency Activities

- Continue to develop and distribute CD-ROM bibliographic products and on-line access for searching Arctic bibliographic data bases;
- Complete the final agreement on the first phase of the shared resources for acquisition and cataloging of polar information during the Polar Libraries Colloquy meeting in Columbus, Ohio, in May 1992; and
- In conjunction with the AEDD activities, continue to improve the networking of digital and bibliographic sources of national and international information on the Arctic.

3. Research Mission Components

3.1 Arctic Ocean and Marginal Seas

3.1.1 Ice Dynamics and Oceanography

A singular feature of the Arctic Ocean is the permanent, dynamic ice cover. This marine cryosphere significantly impacts the environment on all scales, from climatic to molecular. Critical processes governing this impact occur in the atmosphere and oceanic boundary layers above and below the ice. A major priority is the development of the next generation of operational ice forecasting models. A systematic program of oceanographic, cryosphere and atmospheric measurements by conventional technologies, as well as new technologies such as Autonomous Underwater Vehicles (AUVs), is needed to support the objectives of this mission element and the interagency program (see Section 2.1 of the Strategy Programs).

Selected Activities and Accomplishments

Acquired the first complete set of ice stress measurements for the initiation and formation of a pressure ridge in the open Arctic ice pack; fracture occurs several minutes after the peak force, indicating large-scale creep behavior previously unknown (DOD/ONR);

The marine cryosphere significantly impacts the environment on all scales, from climatic to molecular

Acquired the most comprehensive air–ice exchange data set to date during the nine months of the Coordinated Eastern Arctic Experiment (CEAREX); this will form the basis of improved synoptic and climatological models through better understanding of boundary layer physics; indications are that microscopic ice crystals may be critical to the surface radiation balance even with a clear sky (DOC/NOAA/OAR, DOD/ONR);

Discovered a preconditioning mechanism for deep convection associated with mesoscale eddy dynamics by using a high-resolution numerical model formulated for the Greenland Sea marginal ice zone; surface cooling in phase with the secondary circulation of a cyclonic eddy triggers penetrative vertical motion (DOD/ONR);

Successfully deployed an autonomous underwater vehicle for measuring upper-ocean water properties under ice during CEAREX; this highly portable platform traversed preprogrammed courses before returning to a homing beacon suspended beneath the entry hole; temperature and salinity profiles recorded onboard defined the directional wave number of internal waves at the base of the mixed layer (DOD/ONR);

Completed initial experiments showing the feasibility of imaging the internal structure of ice using high-frequency acoustic tomographic inversions; determining the evolution of this structure over time will provide insight into the mechanics and thermodynamics of ice in response to forcing (DOD/ONR);

Developed new statistical techniques for characterizing ice floes in satellite imagery, which will enable ice data from SAR satellites to be efficiently assimilated into numerical forecast models (DOD/ONR);

Deployed fourteen satellite-tracked drifting buoys on the Arctic sea ice in 1990; twelve more will be deployed in 1991; these buoys are used to derive ice drift velocity vectors and to report meteorological variables (air temperature and barometric pressure) through the Global Telecommunications System (DOC/NOAA, DOD/ONR/OCEANAV);

Completed an analysis of the Arctic sea ice observations from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) during 1978–1987; the SMMR record, which reveals the complexities of the morphology and dynamics of the Arctic sea ice cover in great detail, serves as a unique baseline for future research on the role sea ice plays in global change (DOI/GS);

Declared the Digital Ice Forecasting and Analysis System (DIFAS) to be operational for Alaskan ice analysis, and designated the Joint Ice Center as coordinating office for the Arctic Drifting Buoy Program (DOD/DOC/JIC);

Selected a sea ice algorithm (originally developed for the SMMR) for operational use by the Fleet Numerical Oceanography Center, Monterey, California, for the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) (DOD/OCEANAV);

Delivered all components necessary for analysis of ERS-1 Advanced Microwave Instrument (AMI) Synthetic Aperture Radar (SAR) data to the NASA-sponsored Alaska SAR Facility (ASF) for testing; ERS-1 will launch in 1991, and the ASF will perform processing, archiving and geophysical analyses of these data (NASA);

Released a research announcement soliciting investigations that will use the ASF facilities; 25 investigations were selected representing a wide range of scientific interests, including studies of the oceans, ice and land cover in the Arctic (NASA);

Published an ice atlas based on imagery from the Scanning Multichannel Microwave Radiometer; the atlas covers a nine-year period, from 1978 to 1987; all digital data associated with the atlas will be archived at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado (NASA);

Completed the validation of ice products derived from the Special Sensor Microwave/Imager and continued to archive these data products in the NSIDC (NASA);

Procured hardware to augment the Alaska SAR Facility, which will allow the capture and storage of high- and low-resolution SAR data, data compression for high-resolution data, and the communication of SAR data via the NOAA polar domestic satellite (DOMSAT) communications system to the Joint Ice Center; every orbit of low-resolution (4-km) data from the afternoon polar satellite, and occasional readouts of high-resolution (1.1-km) data, are being mapped for the Arctic and Antarctic (DOC/NOAA/NESDIS);

Completed the analysis of recent measurements in Barrow Canyon and supporting oceanographic and meteorological time series (DOC/NOAA/OAR);

Recovered two instrumented moorings and deployed a new one in the recirculation region of the southern Greenland Sea to assess the supply of buoyancy by the western boundary current to the interior region of the Greenland Sea; continued analysis of recent data sets related to the contribution of saline sources to the deep mixing regime (DOC/NOAA/OAR);

Initiated a joint U.S.–U.S.S.R. field investigation of the shelf circulation from Bering Strait northward with two cruises during the latter part of the 1990 field season; deployed 16 instrumented moorings for a year to provide a detailed time history of currents, sea surface elevation, temperature and salinity; conducted extensive mapping of water properties, including nutrients and dissolved oxygen and a number of trace substances such as chlorinated organics and stable isotopes; used satellite-tracked surface buoys to determine ice drift and meteorological forcing (DOC/NOAA/OAR);

Completed the Arctic Ocean Buoy Study in 1990 (DOI/MMS);

Completed Remote Sensing Data Acquisition and Analysis for the northern Bering Sea and Beaufort Sea (DOI/MMS);

Completed the integration of OSCEAP/ISHTAR data (DOI/MMS); and

Completed performance and compatibility analyses of oil-weathering and transport-related models for use in environmental assessment of the Alaskan OCS (DOI/MMS).

Objectives

- Determine the processes, dynamics and mechanisms of ice production, deformation, advection and decay;
- Determine the processes of renewal and mixing of Arctic and Subarctic water masses from large to small scales;
- Determine the large-scale circulation of the Arctic Ocean, its variability and its dynamics, including the role of shelf seas, boundary currents and exchanges with adjoining seas;
- Continue to develop advanced methods of unmanned environmental monitoring such as buoys and AUVs; and
- Determine the mean and natural range of variability of currents and hydrographic features in the nearshore region of the Bering, Chukchi and eastern U.S. Beaufort seas.

Ongoing and Planned Activities

Make long-term systematic observations of ocean, atmosphere and sea ice variables in the Arctic Ocean and adjacent seas (DOC/NOAA, DOD/ONR/OCEANAV, DOI/GS, NASA, NSF);

Continue improvements at the ASF, including upgrades for processing, archiving and analyzing data from the Japanese ERS-1 SAR (NASA);

Continue to process and archive Special Sensor Microwave/ Imager data and analyze these data in Arctic investigations (NASA);

Support science teams who continue research and analyze data and data products derived from the ASF (NASA);

Augment existing observation systems with more capable instruments to be developed over the next five years (DOC/NOAA, DOD/ONR, NASA, NSF);

Use observational data bases to validate and refine ocean–ice–atmosphere coupled models (DOC/NOAA, DOD/ONR/OCEANAV, NASA, NSF);

Conduct biophysical research focused on changes in nutrient cycling associated with upwelling and downwelling (DOC/NOAA, DOD/ONR, NSF);

Study Arctic Ocean circulation and water mass, conservative tracer movement, and variations and causes of variable transports (DOC/NOAA, DOD/ONR, NASA, NSF);

Coordinate international programs to address global change, including atmospheric input to water and ice surfaces (DOC/NOAA, DOD/ONR, DOI/GS, NASA, NSF).

Initiate and continue projects under Arctic System Science and its Oceans–Atmosphere–Ice Interactions program to understand the role of sea ice, atmosphere forcing and ocean circulation in global processes (NSF);

Conduct field work to quantify air–sea–ice fluxes from upper water layers to the troposphere associated with Arctic leads (DOC/NOAA, DOD/ONR, NASA);

Begin high-resolution modeling to refine a sampling strategy for shelf processes (DOD/ONR);

Conduct field and laboratory measurements to determine mechanical responses of sea ice to variable stress fields so that ice-floe-scale responses to synoptic-scale forcing can be integrated into regional models (DOC/NOAA, DOD/ONR, NASA);

Initiate a five-year program on sea ice mechanics starting in FY 1992 (DOD/ONR);

Maintain an Arctic Ocean climate monitoring station and expand the program to include a second site; begin measuring ice and freshwater discharge from the Arctic Ocean in a study of Atlantic climate change; conduct a U.S.–Canada oceanographic section across the Arctic Ocean in 1993 (DOC/NOAA/OAR);

Establish and maintain a series of sampling stations along the Chukchi–Beaufort sea coast to record oceanographic and meteorologic data (DOC/NOAA/NOS);

Increase satellite data sources for DIFAS (i.e. AVHRR/LAC, SSM/I); demonstrate the operational capability of SAR data for ice analysis; plan to increase the number of drifting buoys in the Arctic to improve ice forecasting models (DOD/DOC/JIC);

Conduct a pilot study of the ventilation of deep waters in the Greenland–Norwegian seas using CFCs and other tracers (DOC/NOAA/OAR);

As part of the Atlantic Climate Change Program, begin monitoring the freshwater flux from the Arctic Ocean through Fram Strait (DOC/NOAA/OAR);

Complete the first set of cruises in the Chukchi Sea in support of the joint U.S.–U.S.S.R. circulation study; calibrate and process the resulting hydrographic data sets (DOC/NOAA/OAR);

Obtain and analyze synoptic oceanographic and meteorological data to determine the magnitude and temporal and spatial variations of circulation along the Bering Sea continental shelf edge (DOI/MMS);

Complete modifications to a three-dimensional, variable-scale circulation model and a companion stochastic oil-spill-trajectory model for the Alaskan OCS (DOI/MMS);

Continue remote sensing and data acquisition and analysis for Alaskan OCS areas (DOI/MMS);

Acquire and analyze remote sensing data for the Bering and Beaufort seas (DOI/MMS); and

Revise the Alaska OCS oil-weathering model (DOI/MMS).

3.1.2 Ocean and Coastal Ecosystems and Living Resources

The biota of marine and coastal ecosystems are influenced by physical processes, including seasonal extremes of light and temperature. Arctic marine ecosystems are dominated by sea ice, while coastal ecosystems are influenced by freshwater input and seasonal sediment loads, as well as by seasonal sea ice. There is a need to quantify the resulting variability in the rates of biological production of marine living resources through long-term and well-designed interdisciplinary research (see Section 2.1 of the Strategy Programs).

There is a need to quantify the variability in the rates of biological production of marine living resources

Selected Activities and Accomplishments

Used radio-tracking of female polar bears to discover 41 additional maternity dens, bringing the number found in ongoing studies to well over 100; only 35 dens had been located in all previous studies; monitored survival and reproductive success in 46 radioed female polar bears as part of ongoing efforts to more fully understand the population dynamics of the species (DOI/FWS);

Conducted cooperative walrus surveys by U.S. and U.S.S.R. scientists, resulting in the development of a formal sampling protocol; solved problems with radio transmitter attachment and function; observations of radioed walruses are expected to lead to information that will increase the accuracy of aerial surveys (DOI/FWS);

Continued research on the use of biochemical techniques for defining stocks of polar bears to measure and predict the effects of harvest (DOI/FWS);

Continued research on species of salmon to provide information needed for the U.S./Canada Pacific Treaty negotiations (DOI/FWS);

Tracked white-fronted geese breeding in Bristol Bay, Alaska, through stopover sites in the Klamath Basin, California, to wintering areas in the interior highlands of Mexico; overwinter survival is 78% (DOI/FWS);

Processed radar imagery from the Soviet satellite Cosmos-1500, which showed promise of providing a systematic data base of seasonal pack ice distribution in the Bering and Chukchi seas for use in ecological studies of polar bear and walrus (DOI/FWS);

Collected tissue samples from Arctic marine mammals taken in native subsistence hunts and archived them, through the Alaska Marine Mammal Tissue Archival Project (AMMTAP), for future retrospective analysis for environmental contaminants; determined levels of environmental toxicants in Arctic marine mammals through analyses of tissue samples collected by the AMMTAP; determined the distribution and temporal trends of selected global micropollutants in biotic and nonbiotic compartments of major western Arctic coastal areas; established a set of permanent stations on the Arctic coast of the U.S. to monitor environmental conditions (DOC/NOAA/NOS, DOI/MMS);

Long-term studies of northern fur seals on the Pribilof Islands show that the total population may have stabilized, but pup production on St. George Island continues to decline

Described the mortality, dispersion and transport of larval king crabs and Pacific herring in the Port Moller region (Bering Sea) and determined the distribution and relative abundances of juvenile and adult life stages and their habitat requirements; described the seasonal abundances and distributional patterns, population characteristics and life histories of the fishery resources of the southeastern Chukchi Sea (DOC/NOAA/NOS, DOI/MMS);

Described natural processes affecting the concentration and fluxes of nutrients from the Yukon River and the influence of the river effluent on coastal ocean productivity (DOC/NOAA/NOS, DOI/MMS);

Initiated a comparative study of Arctic coastal ecosystems to describe their relative productivities, community structures and vulnerabilities to environmental alterations (DOC/NOAA/NOS, DOI/MMS);

Planned and conducted a Bering-Sea-wide acoustic study of the distribution and abundance of pollock (a multinational study that included Japan, the U.S.S.R. and the U.S.) and conducted a binational study (U.S. and U.S.S.R.) of bottom fish and shellfish resources of the eastern and western Bering Sea; U.S. efforts amounted to approximately 6000 trackline miles and 27 midwinter trawls to examine and enumerate spawning pollock aggregations (DOC/NOAA/NMFS);

Completed the third year of research to better understand the consequences of intense unregulated fishing for walleye pollock in the international zone of the Bering Sea (DOC/NOAA);

Completed histopathology work for 1212 fish and crab samples collected from the eastern Bering Sea, blood analysis from 1500 tanner crab samples to determine the distribution of bitter crab disease, and tissue analysis on 15 marine mammals (DOC/NOAA);

Continued to update the stock assessment of all commercial bottom and shell fish resources of the eastern Bering Sea (DOC/NOAA/NMFS);

Placed U.S. observers on domestic commercial fishery vessels that target bottom fish resources in the Bering Sea (DOC/NOAA/NMFS);

Continued long-term studies of the population dynamics and trends in numbers of the depleted northern fur seals on the Pribilof Islands, Bering Sea, showing that the total population may have stabilized at around 40% of its peak population size as recorded in the 1950s; pup production on St. George Island continues to decline; a conservation plan has been written outlining research and management needed to assess the status and recovery of the population (DOC/NOAA/NMFS).

Carried out a range-wide survey of northern (or Steller) sea lions in Alaska; the severity of the decline observed between 1985 and 1989 was not seen, although overall the population continues to decline in Alaska; in the southern Bering Sea the species has declined by over 90% since around 1970; in the western Gulf of Alaska the population declined by 63% between 1985 and 1989; in November 1990 the northern sea lion was declared a threatened species under the Endangered Species Act (DOC/NOAA/NMFS);

Completed six major exchanges as part of the U.S.–U.S.S.R. Marine Mammal Project, a cooperative research program to study the biology, ecology and population dynamics of marine mammal species of interest to both countries; exchanges included the second joint sea otter workshop and a series of joint walrus studies (DOC/NOAA, DOI/FWS);

Continued studies to measure lengths and to identify individual bowhead whales to help determine calf production, calving intervals, juvenile survival and population abundance of whales migrating past Barrow, Alaska, into the Chukchi and

Beaufort seas; new results show that the population is composed of about 40% adult animals (>13 m in length); annual calf production varies greatly, from 3 to 12%; and the calving intervals of three individually identified adult females ranged from 4 to 7 years (DOC/NOAA/NMFS);

Measurements and identification of individual bowhead whales help to determine calf production, calving intervals, juvenile survival and population abundance of whales migrating past Barrow, Alaska

Continued the Fisheries Oceanography Coordinated Investigation (FOCI) to understand the processes that lead to variations in recruitment of commercially valuable stocks of pollock in Alaskan waters; developed a model of the time dependency of larval dispersion and used it to simulate observations (DOC/NOAA/OAR);

Under FOCI, began to implement a new data management and analysis system, known as Extensive PMEL Information Collection (EPIC), allowing efficient access to many forms of data, including traditional physical oceanographic observations and less standard biological observations; EPIC also permits easy implementation and use of modern analysis programs and display routines (DOC/NOAA/OAR);

Through the National Status and Trends Program, continued to monitor the levels of toxic contaminants at several reference sites in the Arctic and Subarctic during 1990 and 1991; collected and analyzed samples for the levels of 70 toxic contaminants in bivalve molluscs at two sites in both years (DOC/NOAA/NOS);

Established OSCURS (Ocean Surface Current Simulations) numerical model as a new tool for describing ocean variability as part of an ecosystems modeling task by using it as part of variability studies in the Gulf of Alaska and the Bering Sea (DOC/NOAA);

Synthesized information on the effects of noise and disturbance on major haulout concentrations of Bering Sea pinnipeds (DOI/MMS);

Developed a method for monitoring the productivity, survivorship and recruitment of the Pacific walrus population (DOI/MMS);

Analyzed and ranked the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska (DOI/MMS);

Radio-tagged northern fur seal pups to determine migration routes through the Bering Sea and North Pacific Ocean (DOC/NOAA/OAR, DOI/MMS);

Linked a whale migration model with an oil-spill trajectory model to estimate the number of whale encounters for any size spill at any site in the Alaskan OCS (DOI/MMS);

Linked whale behavior models and acoustic transmission loss models to predict ranges of reaction of bowhead and gray whales at various sites in the Beaufort Sea (DOI/MMS); and

Modeled the effects of oil spills on the population dynamics of sea otters in the southeastern Bering Sea (DOI/MMS).

Objectives

- Determine status and trends of fish, birds and marine mammals and identify their habitat requirements;
- Monitor coastal ecosystems to detect and quantify temporal changes in nutrient and energy exchange and their effect on biota;
- Determine the magnitude and variation of marine productivity in Arctic areas through studies of the structure, dynamics and natural variability of the ecosystems;
- Consider the influence of ice on the environment and of human activities on both the biotic and abiotic environment;
- Study the influence of Arctic marine productivity on the global cycling of biologically active materials, including carbon and nitrogen; and
- Understand the physical and biological processes that affect fisheries recruitment in the U.S. waters of the Bering, Chukchi and Beaufort seas.

Ongoing and Planned Activities

Establish a capability to monitor ocean productivity in Arctic regions using a satellite ocean-color imager (NASA);

Extend Bering Sea biological research into the Chukchi and Beaufort seas to trace carbon and other nutrients, especially along leads, polynyas and ice edges (DOC/NOAA, DOD/ONR, NSF);

Study how polynyas form and develop, how they influence the migration, distribution and abundance of marine mammals and birds, and how recurring polynyas can be protected (DOC/NOAA, DOI/FWS/MMS, NSF);

Determine production rates of, and transfer of energy between, trophic levels on Arctic continental shelves; clarify the differences in ecosystem structure and function that influence the population dynamics of marine mammals and birds; design models to evaluate the impact of human activities on ecosystem processes (DOC/NOAA, DOI/FWS/MMS/NPS, SI);

Develop and conduct periodic monitoring programs to assess contaminant loads for higher-tro-

phic-level animals (DOC/NOAA, DOI/FWS/MMS);

Determine the stream origins of anadromous fish species that occur in the coastal waters of the Beaufort Sea; determine the relative abundance and population characteristics of fish in the near-shore coastal waters of the Arctic National Wildlife Refuge; identify the habitats they utilize (DOC/NOAA, DOI/FWS);

Investigate shelf-slope exchange processes in the Bering Sea as they affect the transport and recruitment of larval pollock into U.S. fisheries (DOC/NOAA);

Initiate and continue projects under Arctic System Science and its Oceans–Atmosphere–Ice Interactions program to understand the role of biogeochemical processes, nutrient regimes and productivity (NSF);

Begin to develop products for Alaska under CoastWatch, a theme within the NOAA Coastal Ocean Program, which has as its goal the development and delivery of environmental data and products for near-real-time monitoring of U.S. coastal waters to support environmental science and decision making (DOC/NOAA/NESDIS);

Continue programs on pollock, bottom and shell fish in the Bering Sea (DOC/NOAA/NMFS);

Begin the Bering Sea FOCI Program; identify the number of spawning stocks of pollock and the controlling oceanographic factors; describe and model the general circulation over the basin; conduct a cruise jointly with Soviet scientists to provide the first synoptic view of the major transport features and flow through the deep western passages and to obtain detailed data on nutrient distributions (DOC/NOAA/OAR/NMFS);

Continue long-term FOCI observations, including water properties, currents and pollock eggs and larvae; continue to acquire and process satellite images (DOC/NOAA/OAR/NMFS);

Use satellite tags to study the movements and habitat use patterns of northern fur seals and northern sea lions in the Bering Sea, not only the location and time of surfacing by each animals, but also the depth of dive and dive profiles needed to assess total activity patterns and energy budgets (DOC/NOAA/NMFS);

Study the status and trends of Pacific harbor seals in the eastern Bering Sea, where they are undergoing significant population changes; study the population dynamics of harbor seals in FY 1992–93, with the primary objective of determining minimum population size and, in the long-term, determining trends in abundance and status of stock assessment (DOC/NOAA/NMFS);

Conduct a complete review and synthesis of the life history and ecology of bowhead whales in FY 1992–93 using data collected since 1974 by NMML scientists and others from ice-based studies, aerial surveys and biological studies of harvested animals; field studies may be terminated for lack of funds (DOC/NOAA/NMFS);

Continue the National Status and Trends Program monitoring contaminants in the Arctic; measure levels of contaminants in 1992 at sites that were initially sampled in 1986 or 1988 (DOC/NOAA/NOS);

Study the coastal fisheries oceanography of the southern Bering Sea and the North Aleutian Basin to determine stock identity, timing, habitat use and environmental controlling mechanisms of juvenile salmon along the Alaska Peninsula, as well as factors affecting the development, survival and recruitment of larval and juvenile king crab and Pacific herring (DOC/NOAA/NOS, DOI/MMS);

Study the fisheries oceanography in the Chukchi and Beaufort seas to examine the habitat requirements and trophic relationships of anadromous and marine fish species (DOC/NOAA/NOS, DOI/MMS);

Continue delineation, faunal composition and repeated-use studies of benthic feeding areas of walrus and gray whales in the northeastern Chukchi Sea (DOI/MMS);

Coastal fisheries oceanography studies of the southern Bering Sea and the North Aleutian Basin will determine stock identity, timing, habitat use and environmental controlling mechanisms of juvenile salmon along the Alaska Peninsula

Determine the effects of oil and gas production activities (sound characteristics in spring lead systems) on bowhead and beluga whales (DOI/MMS);

Determine the location and timing of bowhead whale feeding, as well as the age of whales, using stable isotope analysis of prey species and whale tissues (DOI/MMS);

Compare the behavior of bowhead whales in Davis Strait, where there is little industrial development activity, to the behavior of whales in the western Arctic, where there has been industrial activity (DOI/MMS);

Refine the use of satellite tags for tracking right and bowhead whales (DOI/MMS);

Develop a baseline method to evaluate chemo-biological interaction involving cetaceans (DOI/MMS);

Compile the literature on bowhead whales and publish a book (DOI/MMS);

Study the use of satellite tags to determine pelagic areas important to declining populations of fur seals (DOI/MMS);

Develop guidelines for OCS operations in polar bear habitats (DOI/MMS);

Determine the importance of leads to bowhead whales, determine the potential influence of environmental and industrial factors on bowhead whale hunting, and verify the model of site-specific interactions of acoustic stimuli and whale behavior (DOI/MMS);

Monitor seabird colonies in the Bering and Chukchi seas to determine population numbers, productivity and feeding habits (DOI/FWS/MMS);

Monitor waterfowl and seabirds in the Beaufort Sea (DOI/MMS);

Monitor the distribution of whales in the Chukchi and Beaufort seas (DOI/MMS);

Determine the use of Kasogaluk Lagoon by marine birds and mammals (DOI/MMS);

Monitor levels of hydrocarbons and trace metals in Beaufort Sea sediments and organisms (DOI/MMS);

Monitor marine mammals, seabirds and waterfowl in the Alaskan OCS area (DOI/MMS); and

Study physical processes and ecosystems of the Alaskan OCS area (DOI/MMS).

3.1.3 Marine Geology and Geophysics

The Arctic continental margin and deep ocean basin constitute one of the least understood geological regions of the world, partly because much of the offshore area is covered with sea ice. A better understanding of the tectonic history, geologic structure, sediment processes and distribution, and climatic and glacial history of the deeper basin will require extensive geophysical and geological research and the integration of newly collected data on an international scale (see Section 2.2 of the Strategy Programs).

Selected Activities and Accomplishments

Confirmed that two major sea ice sources can be distinguished in the eastern Arctic through their sediment load: the East Siberian Sea and the Laptev Sea; sedimentation rates in the eastern Arctic are highly variable in time; during glacial periods they were 2–3 cm/ky, whereas in interglacials they were below 1 cm/ky; based on sediment core analysis during times of maximum glaciation, the ice flow in the Norwegian Sea apparently reversed to flow northward (DOI/GS);

Successfully recovered two heavily instrumented time-series trap moorings from the Barents Sea after one year of deployment; data indicate major cross-shelf transport of up to 800 mg/m^2-day of sediment with high current velocities (DOD/ONR);

Recovered sediment cores, geophysical data and ice sediment load data during two cruises; the cores contain a Quaternary sediment and climate record extending back more than one million years (DOI/GS);

The Arctic continental margin and deep ocean basin constitute one of the least understood geological regions of the world

Prepared a science plan for Arctic drilling (DOD/ONR); and

Convened a workshop on Arctic marine geology and prepared a report recommending a decade of U.S. research on the Arctic Basin (NSF).

Objectives

- Develop and perfect new techniques for deployment of instruments in the harsh Arctic environment (e.g. seismic tomography, geophysical arrays, hydraulic piston coring, scientific deep drilling);
- Initiate Arctic marine geological and geophysical studies to provide information on past and present climate change, support rational development of natural resources, and address fundamental questions of global geologic history and regional tectonic development;
- Define the geologic framework, deep structure and tectonic history and development of the Bering Sea region;
- Develop the capability for systematic and comprehensive collection of geologic data in the ice-covered offshore regions using remote sensing and other technologies; and
- Determine the modern sediment transport by sea ice, icebergs and other processes; characterize the seafloor sediments by coring and reflection methods; and establish a well-dated stratigraphy.

Ongoing and Planned Activities

Compile all existing U.S. and international sediment and geophysical data on the Arctic Ocean Basin for use in a geographic information system that would combine and index data (DOC/NOAA, DOI/GS/MMS);

Institute a combined marine and airborne research program for the collection of geological and geophysical data on the continental margins and Arctic and Bering basins using aircraft, ships and ice islands to maximize data collection (DOD/ONR, DOE, DOI/GS, NSF);

Complete geophysical and sediment coring transects across the northern Alaskan margin including the Chukchi, Beaufort and Bering seas, combining U.S. with Soviet and Canadian data (DOC/NOAA, DOD/ONR, DOI/GS, NSF);

Evaluate the need for additional stations and obtain additional international support for onshore digital, broad-band seismographic networks; data can be modeled with new methods in seismic tomography (DOI/GS, NSF);

Plans will begin for a sampling program to determine the paleoclimatic and paleo-oceanographic history of the Arctic Basin and margins

Conduct site surveys of areas of geologic and paleoclimatic interest using the same sensors as for transects and polygons; thoroughly analyze data to pinpoint possible drilling sites (DOI/GS);

Plan a sampling program to determine the paleoclimatic and paleo-oceanographic history of the Arctic Basin and margins as well as the Aleutian Basin of the Bering Sea and the stratigraphy and in-situ geotechnical properties of the surrounding shelves; initiate a U.S.–Canadian drilling project in the Yukon Flats–Old Crow Basin area (see 2.1) (DOI/GS, NSF);

Collect marine geophysical data in the Beringian and Aleutian areas to verify and understand results of GLORIA data collection (DOI/GS);

Conduct deep geophysical sounding in the Bering Sea to determine the fundamental tectonic processes that produced the geologic features of the upper crust and generate velocity amplitude anomalies (VAMPs) (DOI/GS, NSF);

Continue geologic investigations in the Shumagin Basin, Gulf of Alaska and lower Cook Inlet as part of the mission responsibility to assess petroleum and nonenergy mineral potential of the Outer Continental Shelf (DOI/MMS);

Plan to commence in 1993 a program for collecting geological and geophysical data on the continental margins and the Arctic and Bering basins using aircraft and ships (DOD/ONR, DOI/GS, NSF);

Conduct a three-nation (Sweden, Germany, U.S.) deep Arctic Basin expedition to collect extensive sediment cores and geophysics in the Laptev Sea, Eurasia and Makarov basins in 1991; investigate biogeochemical processes by inserting two time-series sediment traps (DOD/ONR, Sweden, Germany, Japan);

Conduct a joint U.S.–Norwegian program to investigate the sedimentary province of the Barents Sea and its controlling processes (DOD/ONR, Norway);

Conduct a joint U.S.–Canadian program in Kangerlussuak Fjord, East Greenland, to investigate sedimentary processes within a fjord and out across the continental shelf (DOD/ONR, NSF, Canada);

Install sediment trap(s) in the Bering Sea to monitor biogeochemical fluxes and compare the results to those from the eastern Arctic (DOC/NOAA/OAR, DOD/ONR);

Assess the oil and gas resources for onshore and offshore areas of Alaska; the USGS will assess onshore and Alaska waters extending three miles from shore, and MMS will assess offshore Alaska from the three-mile limit to approximately 200 nautical miles seaward (DOI/GS/MMS); and

Update the Chukchi, Beaufort and Bering sea geological reports and prepare a Hope Basin geological report (DOI/MMS).

3.2. Atmosphere and Climate

3.2.1 Upper Atmosphere and Near-Earth Space Physics

The goals of this research are to trace the flow of energy, momentum and mass from the sun to the Earth and to understand the interaction within and between the intervening regions. The impact of most of the variable components of the flow is funneled by the Earth's magnetic field into the polar regions. Arctic studies of this energy flow through the atmosphere help to develop and verify predictive models. Our understanding of the basic phenomena of the coupling processes, and the dramatic consequences across the full optical, radio and particle spectrum, is far from complete.

There is great interest in understanding and separating anthropogenic effects (such as greenhouse gases) and natural variability (such as decadal temperature swings) in the troposphere. Recent evidence suggests that some of the latter is due to solar-induced effects, especially in polar latitudes. It is expected that the coupling of the sun to the troposphere (and the rest of the atmosphere) will become a major topic of study in the next five years. This will be supported partially under the U.S. Glo-

bal Change Research Program (USGCRP) and will naturally focus on high latitudes, given the way in which the geomagnetic field focuses some forms of solar energy.

There is great interest in understanding and separating anthropogenic effects and natural variability in the troposphere

Selected Activities and Accomplishments

Continued the Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) program, which is aimed at a better understanding of the upper atmosphere using observations from ground-based radio and optical instruments (NSF);

Initiated the Geospace Environment Modeling (GEM) program, which is aimed at understanding the ionosphere and magnetosphere using a well-planned schedule of theory and experiments (NSF);

Conducted a jointly sponsored field campaign in Greenland in early 1990 to observe the ionospheric signatures of geospace disturbances; the Geophysics Laboratory flew the instrumented Airborne Ionosphere Observatory to make synoptic observations of the dark cusp and cleft dynamics; NSF supported the complementary ground-based measurements, data analysis and workshop; Japanese, NASA and AF satellites provided other data (DOD/AFGL, NSF);

Demonstrated the impact of greenhouse gases on the state of the upper atmosphere; the particle inputs in polar regions and the sensitivity to photochemistry, e.g. the ozone hole, make this an especially important issue for the polar upper atmosphere; research performed at the National Center for Atmospheric Research (NCAR) showed that the thermosphere cools by about 50 K when carbon dioxide and methane are doubled; the stratopause temperature decreases by 17 K; this sensitivity offers the possibility of monitoring global change (NSF);

Estimated the Earth's reconnection electric field from radar measurements taken at the Sondrestrom Radar Observatory; this variable is important because it describes the rate of transfer of solar wind energy to the closed field-line region of the magnetosphere; such ionospheric measurements represent the first estimates of the reconnection electric field in the ionosphere;

Conducted experiments at Sondrestrom that exploit simultaneous radar and optical measurements; these studies encompass aeronomical processes within auroral arcs, plasma flow near polar cap arcs and drift of plasma patches from the polar cap toward the auroral cap;

Developed a world-wide atmospheric noise prediction model for the first time for ELF/VLF/LF, including high latitudes; completed three years of ionospheric heating experiments at the Alaskan HIPAS facility;

Found an inverse relationship between the speed of the solar wind at Earth and the divergence rate of magnetic field lines in the sun's corona using ground-based solar magnetic field measurements; this relationship has important applications in forecasting the geomagnetic and auroral activities that affect communications, navigation and surveillance;

Provided the first clear demonstrations of the long-term conjugate nature of auroral activity at these high latitudes using the new Imaging Riometer for Ionospheric Studies (IRIS) at Sondrestrom, Greenland, working in conjunction with an identical IRIS at South Pole, Antarctica (DOC/NOAA, NSF);

Conducted a study that showed that considerable mesoscale order exists in the polar ionospheric flow, previously perceived as being chaotic. The electrodynamic forces driving these flow patterns provide a new source of polar thermospheric heating that may be of significance to global thermospheric circulation (DOC/NOAA, DOD/AFGL);

Conducted three-dimensional simulations suggesting that the geometry of the reconnected field lines is much more complicated than anticipated (DOE);

Launched one sounding rocket mission in FY 1991 to study a variety of phenomena in the areas of auroral and upper atmosphere physics; seven additional sounding rocket missions in these scientific areas are planned for the remainder of FY 1991; FAST, a small explorer satellite for studying the plasma microphysics of the aurora, was approved for a new start in 1990 and is scheduled for launch in 1994 (NASA); and

Continued research at the Space Environment Laboratory (SEL) to monitor solar activity and its effects on the space environment near Earth and on man's activities; the most dramatic effects on and above Earth occur in the polar regions, where the geomagnetic field lines pass through the upper atmosphere vertically (DOC/NOAA).

Objectives

- Observe the global-scale response of the polar regions through a coordinated program involving a polar network of ground-based optical, radio and magnetic observatories and space-based measurements;
- Develop special research tools to address key problems, including setting up a coordinated rocket program, promoting the use of special

facilities and making use of research aircraft;
- Maintain active theoretical programs and promote the evolution of models to describe the unique physics of the atmosphere and ionosphere in Arctic regions;
- Understand solar phenomena that affect Earth's environment;
- Understand electromagnetic waves, fields and particles in near-earth space; and
- Develop an understanding and the ability to make long-term predictions of radio propagation in and through Earth's ionosphere.

Ongoing and Planned Activities

Continue the placement of remote sensing facilities in the polar cusp region as part of the CEDAR program (NSF);

Expand the GEM program into a more comprehensive theory and observation program; implement the first stage of GEM, which is to understand the ionospheric signatures of near-space processes induced by the sun (DOC/NOAA, NASA, NSF);

Expand Interplanetary Magnetic Field (IMF) data collection to maximum full-time coverage by establishing receiving stations, encircling the Earth, for existing satellites and deploying a libration-point solar-wind satellite (DOC/NOAA, DOD/AF, NASA);

Augment particle measurements by high-inclination satellites at appropriate altitudes with simultaneous electric field and current measurements and UV imaging to facilitate long-term monitoring of electromagnetic and particle energy fluxes into the upper atmosphere and develop management procedures to ensure readily accessible data (DOC/NOAA, DOD/AF, NASA, NSF);

Establish optical, radio, magnetic and plasma drift diagnostics and HF doppler sounding ground-truth stations at a complement of polar cap sites to define the dynamic state of the polar cap and cusp environment (DOD/AFGL/AFOSR, DOI/GS, NASA, NSF);

Assess, upgrade and operate state-of-the-art diagnostic capabilities in existing Arctic facilities, including optical observatories, for studying auroral and other ionospheric and atmospheric phenomena (DOD/AFGL/AFOSR/NRL, NSF);

Implement data exchange among magnetometer, radar and other monitoring stations (DOC/NOAA, DOD/AFGL, DOI/GS, NSF);

Establish a multiagency study of thermal, electrical and chemical effects on the neutral upper atmosphere at high latitudes, including vertical coupling between atmospheric regions (DOC/NOAA, DOD, NASA, NSF);

Maintain a coordinated national sounding rocket program at auroral (Poker Flat, Alaska) and polar cap (Thule and Sondrestrom, Greenland) sites (DNA, DOC/NOAA, DOD/AF/N, NASA);

Coordinate the availability of existing research aircraft to support research campaigns in otherwise inaccessible Arctic regions (DOC/NOAA, DOD/AFGL, NASA, NSF) (see Section 4);

Expand efforts during the sunspot maximum by completing the necessary set of transpolar observing sites (DOD/AFGL, NSF);

Coordinate U.S. national (Max '91) and international (Flares 22) campaigns of intense observations of solar and geomagnetic activity during the maximum of the solar cycle under the auspices of the Solar–Terrestrial Energy Program (STEP) (DOC/NOAA, NASA, NSF);

Upgrade polar cusp incoherent scatter radars; establish a polar cap incoherent scatter observatory including radar and optical instruments, emphasizing coordinated ground-based and satellite studies (DOD/AF, NASA, NSF);

Establish an Arctic ionospheric active auroral research capability using a high-power HF facility supported by field experiments and theory (DOD/AFGL/ONR/NRL);

Continue collecting trapped energetic particles aboard the CRRES spacecraft for improved modeling of the Van Allen Radiation Belts (DOD/AFGL/ONR/NRL, NASA);

Expand a long-wave atmospheric noise model to include the ability to predict noise from magnetospheric and auroral sources and from high-altitude nuclear effects (DNA, DOD/ONR/NOSC/NUSC);

Launch the Maxie-I x-ray satellite in 1991 to measure the precipitation of energetic particles into the high-latitude and polar regions of the ionosphere (NASA, DOD/ONR);

Continue the sounding rocket program utilizing ranges at Poker Flat, Alaska; Andoya, Norway; and Kiruna, Sweden, to study auroral and upper-atmosphere space physics (NASA);

Launch the POLAR spacecraft (a component of NASA's Global Geospace Science and the International Solar Terrestrial Physics Programs) in June 1993; POLAR will conduct magnetospheric particle and fields observations, with particular attention to the interrelationship between the visible aurora and the magnetosphere (NASA);

Launch the Wind satellite (a second component in the GGS and ISTP Programs) in December 1992 to assist in understanding the energy inputs to the magnetosphere (NASA);

Participate in the major upgrade of the launch and science support facilities at the Poker Flat Research Range in order to improve NASA's sounding rocket capabilities at that site (DOD, NASA); and

Continue SEL's solar monitoring and predicting activities and plan an initiative to "modernize" these activities (DOC/NOAA).

3.2.2 Climate and Weather

The outstanding characteristic of the Arctic climate and weather is its dramatic variability in clouds, radiation and surface heat exchange. It is necessary to address Arctic weather problems occurring on a variety of spatial and temporal scales that range from microscale to global. A major need is for accurate regional and local weather forecasts, especially to predict hazardous weather, such as Arctic lows, storm surges, icing conditions and fog, which can affect human activities. The Arctic climate has critical global implications.

There is a need to relate Arctic atmospheric circulation to midlatitude weather and to measure and understand long-term temperature trends and the variability of the Arctic heat sink, which may be linked to global warming

Selected Activities and Accomplishments

Acquired remote sensing data indicating that major air–sea heat exchanges penetrate through the troposphere on an intermittent basis; this suggests that both tropospheric and stratospheric chemistry are linked to sea ice lead dynamics (DOC/NOAA/OAR, DOD/ONR);

Completed plans for and acquisition of new technologies for Alaska: a Doppler wind profiler was installed in Homer, Alaska; a satellite downlink and processing system was installed in Anchorage, Alaska; a C-band radar was installed in Kenai, Alaska; and a new-technologies data base is being archived for operational research studies (DOC/NOAA/NWS);

Completed a study of meridional transport of sea ice in the Bering Sea; began development of an Arctic component to the World Climate Research Program as part of an international planning effort; deployed the first Arctic Ocean climate monitoring station in joint U.S.–Canada effort (DOC/NOAA/OAR);

Discovered an important climate change signal in Nimbus-7 satellite microwave observations of Arctic sea ice during 1978–1987: a robust statistical analysis of the ice extent data for every two days of the 8.8-year record indicates a decline of $2.1 \pm 0.9\%$ at the 93% level of confidence; during the same period the Antarctic ice extent had no statistically significant trend (DOI/GS); and

Developed an improved method for predicting vessel icing (DOC/NOAA/OAR).

Objectives

- Develop an Arctic Climate Studies Program as part of the National Climate Program, including studies of climate effects on biological resources and a systematic program of observations and modeling of the Arctic radiation balance and cloud cover, and their effects on climate;
- Understand the extent to which Arctic climate variations are amplified signals derived from elsewhere or are generated locally as a result of the sensitivities of the regional environment;
- Understand whether, how and with what result Arctic climate anomalies propagate to middle and lower latitudes;
- Quantify sea ice feedback mechanisms that amplify climate change at high latitudes, quantify high-latitude terrestrial ice and snow changes, and consider their effects; and
- Quantify the air–sea–ice momentum and heat exchanges and quantify the role of air–sea interactions in imparting mesoscale tropospheric and stratospheric dynamics.

Ongoing and Planned Activities

Develop dynamically coupled meteorological models for weather prediction on both regional and local scales, assimilating satellite, aircraft and buoy data (DOC/NOAA, DOD/ONR/OCEANAV/NEPERF, NASA, NSF);

Assemble existing data from the instrumental record on Arctic climate to enable study of the salient features of climate change, to document observable patterns and to test theories and models (DOC/NOAA);

Parameterize the effects of physical processes (eddies, upwelling, wave–ice interaction) for use in large-scale models without excessive computations (DOC/NOAA, DOD/ONR/OCEANAV, NSF);

Study the interactions between the atmosphere and snow cover, glaciers and freshwater ice bodies on land to improve models of the atmosphere with specified lower boundary conditions and to determine the effect of anomalous snow conditions on the polar heat sink and atmospheric circulation (DOC/NOAA, DOI/GS, NASA, NSF);

Increase linkages among the broader GCM community, encourage use of multiple GCMs in Arctic parameterization experiments, and develop studies of polar radiation, clouds, albedo feedback and high-latitude atmospheric model performance (DOC/NOAA, DOE, NSF);

Develop a ten-year time series of sea ice cover and seasonal snow cover from SMMR satellite measurements and extend these time series into the future using SMM/I data (NASA);

Systematically analyze the first-year and multiyear sea ice fractions in the Arctic Basin and Greenland Sea from SMMR and SAR data, including ice, paleoclimate and cryospheric parameters (DOD/ONR, DOI/GS, NASA, NSF);

Develop plans for an Arctic Climate Studies Program and assess the effects of climate change on biological resources, including humans (DOC/NOAA/NCP, DOI/GS, NSF);

Analyze existing models and data on "Arctic low" development and evolution to improve the ability to predict Arctic low storms (DOD/ONR);

Investigate the meteorology of synoptic and mesoscale cyclogenesis over Arctic ice (DOC/NOAA);

Quantify air–sea heat exchanges of mesoscale tropospheric and stratospheric dynamics during the Leads field program (DOC/NOAA, DOD/ONR);

Study the Arctic front over Alaska to improve operational forecasting using new technologies, university resources and NWS regional data bases (DOC/NOAA/NWS);

Expand the data base of sea ice climatology for both Northern and Southern Hemispheres (DOD/DOC/JIC);

Continue to develop the Arctic Climate Systems (ACSYS) component of the World Climate Research Program (DOC/NOAA/OAR); and

Initiate the Atmospheric Radiation Measurement (ARM) program site selection on the North Slope of Alaska for the field program that is planned to begin in 1994 or 1995 as part of the U.S. Global Change Research Program (DOE).

3.2.3 Tropospheric and Stratospheric Chemistry

The chemistry of the Arctic atmosphere is dynamic, changing in response to natural and man-induced disturbances. Stratospheric ozone depletion is a global process accentuated at the poles. Ice core chemistry reveals current and historic trends in global gas and aerosol concentrations. Expected warming trends could have a significant influence on biosphere–atmosphere interactions, trace gas emissions and retention, and atmospheric photochemical processes. In addition, an average of 1.7 million acres of wildfire annually in Alaska has an impact on airborne particulates and chemistry.

Selected Accomplishments and Activities

Launched a series of balloons from Alert, NWT, and Heiss Island, U.S.S.R. as part of a collaborative research project with scientists from the University of Wyoming, Environment Canada and the U.S.S.R.; balloon soundings inside the winter polar vortex and at the latitude of the solar terminator showed a 20% ozone loss at the altitude of observed polar stratospheric clouds (NASA, NSF);

Conducted ABLE-3A in the Arctic to assess the flux of greenhouse gases, including CH_4, NO_x, NO_y and O_3, between the land surface and the troposphere and reported the results in a special issue of the *Journal of Geophysical Research* (NASA);

The chemistry of the Arctic atmosphere is dynamic, changing in response to natural and man-induced disturbances; stratospheric ozone depletion is a global process accentuated at the poles

Completed a major reprocessing of Nimbus-7 TOMS data, which identified a drop in stratospheric ozone in the Arctic and mid-to-upper northern latitudes that was more severe than previously reported (NASA);

Obtained aircraft measurements of polar stratospheric clouds during the Airborne Arctic Stratosphere Expedition (AASE), along with observations of chemical species including chlorine monoxide, a key player in photochemical ozone destruction; provided the first in-situ evidence supporting the view that important heterogeneous reactions previously identified only in laboratory and theoretical studies do take place in the lower stratosphere (DOC/NOAA/OAR, NASA);

Continued monitoring by the Climate Monitoring and Diagnostic Laboratory (CMDL), formerly Geophysical Monitoring for Climatic Change (GMCC), of the background atmosphere at Barrow, Alaska, and other non-Arctic sites (DOC/NOAA/OAR);

Continued to analyze data from the 1983, 1986 and 1989 Arctic Gas and Aerosol Sampling Program (AGASP) (DOC/NOAA/OAR);

Expanded the Arctic radiosonde data archive activity by successfully acquiring a nearly complete series of soundings from the Soviet ice stations and completing the digitizing of the U.S. Ptarmigan dropwindsonde files; the archive now numbers approximately one million soundings dating back to the 1930s (DOC/NOAA/OAR);

Calculated monthly mean tropospheric temperatures from the thickness of the 850/700 and 700/

500 mb layers for each of 1977 grid points in an octagonal grid centered on the North Pole for the period 1960–1989 as part of an ongoing study of Arctic climatology; estimated temperature trends by comparing mean values between the first and last 13-year periods of the record (DOC/NOAA/OAR);

Continued to sample and analyze Antarctic and Arctic phytoplankton for bromine production to document further results of the bromine ozone destruction phenomenon in both polar regions (DOC/NOAA/OAR); and

Continued sampling and analysis at the National Atmospheric Deposition Program site at Denali National Park (DOI/NPS).

Objectives

- Establish the correlation between the chemistry of polar stratospheric clouds in the Arctic and the ozone concentration at northern mid-latitudes;
- Develop a data base for determining long-term regional trends in climate and air chemistry, including solar radiation levels, across the circumpolar regions of the globe;
- Conduct periodic sampling of the Arctic stratosphere and troposphere to understand ozone depletion, atmospheric transport phenomena and the role of anthropogenic airborne pollutants in the Arctic; and
- Establish regional and seasonal variations in sources and sinks of carbon, nitrogen and sulfur, atmospheric gases and aerosol species and assess the importance of local emissions.

Ongoing and Planned Activities

Establish and maintain an appropriate number of sampling stations for air quality, atmosphere deposition and climate across the U.S. Arctic (DOC/NOAA, DOE, DOI/NPS/BLM, NASA, NSF);

Continue to monitor surface-level gases, aerosols and radiation at high-Arctic locations (e.g., Barrow, Alert, Ny Alesund) (DOC/NOAA);

Install Arctic-based, upward-looking lidars to measure gas and aerosol distributions in both the troposphere and stratosphere (DOC/NOAA, NASA, NSF);

Develop an extensive Arctic radiation balance program to determine early signals of climate change (DOC/NOAA, DOE, NASA, NSF);

Accelerate programs to validate satellite measurements of surface and atmospheric parameters in the Arctic (DOC/NOAA, NASA, NSF);

Continue periodic Arctic-wide aircraft programs to provide continuity with past measurements and deploy new sensors at and develop new research methods for specific Arctic locations (DOC/NOAA, DOD/ONR, DOE, NASA, NSF);

Conduct necessary follow-up to the 1989 Arctic Ozone Program and AGASP (DOC/NOAA, DOE, NASA, NSF);

Conduct long-range transport studies of nitrous oxides, trace metals and sulfate aerosols including Processing of Emissions by Clouds and Precipitation (PRECP) (DOE);

Conduct the second Airborne Arctic Stratospheric Expedition (AASE-II), a six-month program (October 1991 through March 1992) of aircraft data collection for studying stratospheric chemistry and dynamics, covering the Arctic and midnorthern latitudes throughout the duration of the Arctic vortex (DOC/NOAA/OAR, NASA);

Continue laboratory investigations into the role of polar stratospheric clouds and sulfate aerosols in modifying the chemistry of the stratosphere in the Arctic and high northern latitudes (DOC/NOAA/OAR, NASA);

Evaluate the impact of supersonic aircraft transportation on stratospheric chemistry via a program of modeling plus laboratory and field measurements (NASA);

Provide ground-level instrumentation, science teams and management support for the Network for the Detection of Stratospheric Change (NDSC), which will measure trace gases at sites stationed in Resolute and Alert, Canada; Thule, Greenland; and Kiruna, Sweden (DOC/NOAA, NASA);

Launch the Upper Atmosphere Research Satellite (UARS) (November 1991), which measures stratospheric chemistry in north and south latitudes up to 80° with its limb-observing instruments, and conduct correlative measurements in the Arctic (DOC/NOAA/OAR, NASA);

Support modeling and data analysis of stratospheric chemistry and ozone dynamics in the Arctic (DOC/NOAA/OAR, NASA);

Continue observational and theoretical studies related to the airborne stratospheric studies (DOC/NOAA/OAR);

Continue CMDL research at the Barrow site by continuing the long-term baseline measurements, continuing to support cooperative projects by university and other-agency scientists, and potentially adding several tasks to the long-term program, including measurements of other trace gases (e.g. CFC-113, CFC-114 and halons), more detailed ozone measurements, and ultraviolet radiation and regional energy budget measurements (DOC/NOAA/OAR);

Use a NOAA WP-3D, with support from AGASP scientists, as part of the ONR Leads Experiment (LEADEX) in the Arctic Ocean basin

north of Alaska, which will study the role leads play in the Arctic energy budget; the Wave Propagation Laboratory (WPL) in cooperation with NOARL is planning an Arctic boundary layer and lead plume study as part of LEADEX; a follow-on AGASP flight program will be planned for 1995 (DOC/NOAA/OAR);

Conduct a stratospheric–tropospheric exchange study, including mesoscale numerical model simulations and predictions, and aircraft-based chemical lidar measurements of trace constituents, air motions and the associated vertical fluxes of constituents across the Arctic tropopause (DOC/NOAA/OAR);

Plan further studies on the Arctic stratosphere within the next five years to examine the detailed structure and extent of Arctic ozone decline and to examine the implications for lower latitudes throughout the Northern Hemisphere (DOC/NOAA/OAR); and

Develop the Network for the Detection of Stratospheric Change (NDSC), a multi-agency international effort that will consist of five to six stations operated world-wide by the mid-1990s for long-term measurements of ozone and the chemical constituents that influence it; the goal of the network is to provide the earliest possible detection of stratospheric ozone changes and the means to understand their origin; there will be one or two sites in the Arctic (probably Thule, Greenland, and Resolute, Canada) (DOC/NOAA/OAR).

3.3 Land and Offshore Resources

3.3.1 Energy and Minerals

The geologic framework of the Arctic is very poorly known because of the complexities of its geologic setting, its remoteness and its relative lack of exploration. The remote frozen environment requires long lead times for energy and mineral development. Additional information is necessary to allow the discovery, assessment and mapping of new and dependable sources of oil, gas, coal and strategic minerals. These resources are important for national security and independence, as well as for local use and economics (see Sections 3.1.3 and 2.2 of the Strategy Program for related activities).

Selected Activities and Accomplishments

Continued the Alaska Mineral Resources Assessment Program (AMRAP) with studies in six distinct areas; also continued an analysis of the tectonics and thermal maturity of Arctic margin basin formations (DOI/GS);

Analyzed the structure of the Brooks Range as part of the TransAlaska Crustal Transect (TACT) study, which will be continued to complete the transect into the Beaufort Sea (DOI/GS);

The geologic framework of the Arctic is very poorly known because of the complexities of its geologic setting, its remoteness and its relative lack of exploration

Developed a Seafloor Earthquake Measurement System (SEMS) designed to gather seafloor motion data to provide seismic characterizations of offshore oil and gas leasing regions (DOE);

Identified gas hydrates in 50 exploratory and production wells, with the volume of gas within the hydrates estimated to be twice that of conventional gas in the Prudhoe Bay Field (DOE, DOI/GS);

Collected and reviewed seismic profiles to develop a base map for studies aimed at accurately estimating the total amount of clathrate deposits containing natural gas within a formation or reservoir (DOI/GS);

Completed field studies in the Arctic National Wildlife Refuge to identify environmental information and knowledge of the carbonaceous rock in the region (DOE);

Concluded a four-year study of the 5.7-million-acre Valdez Creek Mining District in south-central Alaska, resulting in the identification of 19 previously unreported mineral occurrences, including placer gold, combinations of gold, silver, platinum, chromium, nickel, cobalt, molybdenum and zinc, and economic quantities of industrial minerals such as limestone, perlite, zeolite, sand and gravel, and stone (DOI/BOM);

Began planning and logistics arrangements for a four-year study of the approximately two-million-acre Colville Mining District in north-central Alaska (DOI/BOM/BLM/GS);

Completed a report on tin and rare-earth placer deposits in the Ray River watershed, north-central Alaska, with preliminary resource estimates of contained tin in recent alluvium of 62–172 million pounds of tin in 300 million cubic yards of gravel; most of the occurrences are considered sub-economic inferred resources (DOI/BOM); and

Completed oil and gas reservoir quality studies in NPRA and ANWR and petrologic–petrophysical–engineering studies of selected wells near ANWR;

extracted geochemistry and biological marker compounds from sediments of the Bulge, northern Alaska and the Yukon Territory (DOI/BLM).

Objectives

- Continue systematic mineral appraisal activities and expand programs to provide for periodic assessment of the undiscovered oil and gas and strategic mineral resources in the Arctic on both broad and local scales;
- Evaluate unconventional energy resources (e.g. heavy oil, tar sands, gas hydrates);
- Identify energy and mineral resources for local use; and
- Use new technologies to develop a more modern, complete geologic data base, increase geologic mapping, expand modeling efforts and design derivative maps to address broader earth science questions.

Ongoing and Planned Activities

Expand efforts in site-specific drilling, geologic mapping and related analytical techniques for bedrock and surficial deposits, especially at medium and large scales, including geological and geophysical mapping correlation across the U.S.–Canadian Arctic boundary (DOI/BLM/BOM/GS/MMS);

Assess resources included in unconventional energy forms, including oil shale, heavy oil, tar sands, tight-gas sand, geopressured methane, coalbed methane and offshore gas hydrates (DOE, DOI/BLM/BOM/GS/MMS);

Increase the use of new and improved technologies, including geographic information systems and remote sensing, to produce geologic maps of critical Arctic onshore regions and continental margins and to combine geologic map data with other earth science and geographic data bases to produce derivative maps that address specific earth science questions (DOI/BLM/GS/MMS);

Continue research activities such as BLM's Resource Management Planning Effort and MMS's Resource Evaluation Program that aid in evaluating local energy resources (DOI/BLM/GS/MMS);

Make additional comprehensive, detailed onshore and offshore transects in northeastern and northwestern Alaska (e.g. TACT) to evaluate the potential for mineral and energy resources, as well as geologic hazards to development (DOE, DOI/GS/MMS, NSF);

Assess the nonenergy minerals lease sale proposed for 1991 in the Norton Sound area (DOI/MMS);

Conduct studies using geological modeling of subsurface resources, coupled with time-lapse modeling of subsurface impacts of mineral extraction and reclamation, to determine long-term cultural and environmental impacts (DOI/BLM/BOM);

Continue to analyze geological and formational characteristics of Alaskan North Slope fields by studying well data to improve the knowledge base of gas hydrate deposits (DOE);

Assess the production characteristics and economic potential of gas hydrates in northern Alaska and determine the relation between in-situ gas hydrate destabilization and global climate change (DOE, DOI/GS);

Initiate cooperative research efforts to assess the extent of the gas hydrate resources found in Alaska (DOE);

Study parameters for the design and development of a production well to recover methane from gas hydrate deposits on Alaska's North Slope (DOE);

Better define the extent of the deep gas resource base in the North Slope using field, laboratory and modeling activities to improve our understanding of the formation, migration and entrapment of this resource (DOE);

Characterize Arctic hydrocarbon reservoirs in terms of their reserves, physical and chemical properties, geologic configuration, structure and development potential (DOE, University of Alaska);

Continue the Colville Mining District study through FY 1994 by examining in detail sites identified from field reconnaissance sampling to delineate the extent, grade and type of mineralization and to determine the potential for development (DOI/BOM);

Continue to develop a minerals GIS/data base for microcomputers that allows extraction of current lease, well and oil and gas assessment information in text or map overlay format (DOI/BLM); and

Continue a detailed oil and gas study of the Utukok Special Management Area of the NPRA, petroleum geology and geochemistry studies in ANWR, and a bedrock geology study of the northernmost bulge of the Rocky Mountain Cordillera (DOI/BLM).

3.3.2 Coastal and Shelf Processes

Erosion rates are extremely high along the Alaskan Arctic coast, where sea ice and permafrost are common. Specific questions about where to build causeways, man-made islands and other structures can only be answered after basic process information is collected, interpreted and analyzed carefully. Studies of coastal erosion and sediment transport in the Arctic are needed to un-

derstand the long-term history of the coastal area in order to intelligently manage the coastal region (see Sections 2.2 and 2.4 of the Strategy Program for related activities).

Selected Accomplishments and Activities

Developed and released a National Coastal Geology Program, which addresses erosion and other coastal hazards and in future years will focus on the role of ice and freeze–thaw processes in causing erosion in Arctic Alaska (DOI/GS); and

Studies of coastal erosion and sediment transport in the Arctic are needed to understand the long-term history of the coastal area in order to intelligently manage the coastal region

Developed a coastline and surf-zone smear model and a handbook of smear model input variables, on a shoreline segment-by-segment basis, for the Alaskan OCS in 1989; the model will be used interactively to make probabilistic predictions of the physical and chemical state, amount and location of spilled oil after it contacts a beach; it accounts for deposition, beach substrate and slope, resuspension, weathering and along-shore transport of spilled oil (DOI/MMS).

Objectives

- Map beach, littoral and nearshore sediment and subsea permafrost and determine their associated physical and chemical properties;
- Define the processes controlling the formation and degradation of the seasonally frozen sea floor;
- Implement long-term measurements of tides, winds, waves, storm surges, nearshore currents and sediment distribution patterns to understand coastal erosion and sediment transport processes; and
- Investigate the direct and indirect effects of ice on coastal erosion (the influence on waves and currents) and on sediment transport (contact with beach sediments, keel gouging, entrainment in frazil ice).

Ongoing and Planned Activities

Investigate the volume of sediment and water transported by rivers (DOI/GS);

Expand the use of remote sensing technologies and other photographic processes as a source of coastal erosion and sediment transport data (DOC/NOAA, DOI/GS, NASA);

Investigate innovative techniques, such as archaeological surveys, as a means of gauging shoreline stability and measuring rates and amounts of coastal erosion and delta or coastal lowland submergence (DOI/GS, NASA, NSF, SI);

Develop and implement cooperative studies to sample and assess coastal beaches, bluffs and shore faces (DOC/NOAA, DOE, DOI/GS/MMS);

Plan and conduct icebreaker-supported programs in coastal areas (DOC/NOAA, DOI/GS/MMS);

Maintain gauging of three U.S. Arctic rivers to determine sediment type, mineralogy, petrology, provenance and grain size, and exchange data with other Arctic Rim nations to understand ancient and modern Arctic stream sediment supply histories (DOI/GS); and

Collect data on the thaw settlement of subsea permafrost and the engineering properties of frozen sediment; establish long-term investigations on thermal and oceanographic variables of the seafloor and frozen sediment (DOD/CRREL, DOE, DOI/GS).

3.3.3 Terrestrial and Freshwater Species and Habitats

The Arctic supports many unique species of birds, mammals, fish and plants, which are important resources to the Nation, as well as to Alaska Natives. Some of these resources are harvested commercially or for subsistence purposes (e.g. food, shelter, fuel, clothing and tools), and others provide recreation. To assure that biological resources are protected for future generations, management agencies must have adequate data and information on the biology and ecology of these species, as well as information on environmental parameters of importance to vital processes (e.g. feeding, breeding).

Selected Activities and Accomplishments

Instituted a Veterinary Science Program at the University of Alaska Agricultural Experiment Station, in collaboration with the Institute of Arctic Biology and the Alaska Department of Fish and Game, to study diseases, parasites and toxicology in wildlife; conducted field investigations and captive-animal research on many animals, including musk oxen, caribou, reindeer, wolves, arctic foxes, lynx, mink and sea otters, with special emphasis on brucellosis, rabies and oilspill toxicology (DA/CSRS);

Continued studies of wolves at Denali, Gates of the Arctic and Noatak; muskox at Gates of the Arctic and Bering Land Bridge; caribou, merlins, golden eagles, dall sheep and air quality at Denali;

reindeer at Bering Land Bridge; steppe vegetation at Yukon-Charley Rivers; vegetation inventory at Bering Land Bridge; and brown bears and water resources at Noatak (DOI/NPS);

Completed baseline fish and limnological studies at Gates of the Arctic, Surprise Lake in the Aniakchak Caldera, Yukon-Charley Rivers and Lake Clark (DOI/NPS);

Evaluated issues related to northern Pacific salmonid enhancement on the Noatak River (DOI/NPS);

Continued studies evaluating the potential effects of resource development, either by developing baseline information on resources that may be at risk or by measuring the effects of ongoing development on populations of selected species, giving special attention to caribou, musk oxen and species of waterfowl, primarily geese, believed vulnerable to disturbance (DOI/FWS);

Conducted studies of snow geese on the Arctic National Wildlife Refuge, emphasizing essential habitats and documenting types of vegetation used for food in order to predict the consequences of displacement of the geese from these habitats by development (DOI/FWS);

Continued research on black brant geese in the Teshekpuk Lake area; about 80% of the time spent there is devoted to feeding in a narrow strip of grasses and sedges along the shorelines of large, shallow, low-relief water bodies; molting brant are sensitive to a wide array of man-caused disturbances (DOI/BLM/FWS/MMS);

Radiomarked 53 Pacific black brant in the Soviet Union, western Alaska and Canada and later detected 33 of them staging at Izembek Lagoon, along with 276 banded individuals (DOI/FWS);

Studied the behavior and energetics of Pacific black brant and other geese in response to aircraft overflights at Izembek Lagoon, Alaska (DOI/FWS/MMS);

Showed that a reduction of the population of Arctic foxes improves the nesting success of cackling Canada geese somewhat in years when voles, the primary prey of the foxes, are abundant but has little or no effect in years when voles are scarce (DOI/FWS);

To assure that biological resources are protected for future generations, management agencies must have adequate data and information

Continued to monitor the population status of musk oxen, which were reintroduced to the Arctic National Wildlife Refuge in 1969; the population appears to have stabilized within a range of 350–400 individuals (DOI/FWS);

Determined that the survival of nesting female emperor geese on Alaska's Yukon–Kuskokwim Delta varies from 44 to 66% annually and is strongly correlated with nesting; females that nest are apparently less vulnerable to spring and summer subsistence hunting (DOI/FWS);

Completed the Utility Corridor Resource Management Plan, covering more than 15 million acres of BLM-managed land in northern Alaska along the Trans-Alaska Pipeline System between the Yukon River and the Brooks Range; conducted an integrated resource data collection effort within the Utility Corridor (DOI/BLM);

Completed an interdisciplinary report for lands in the Central Arctic Management Area; continued to implement the Norton Sound Habitat Management Plan; continued to monitor habitat management plans covering Areas of Critical Environmental Concern (DOI/BLM); and

Started several riparian enhancement and restoration projects on the Seward Peninsula in cooperation with the Alaska Departments of Fish and Game and Transportation (DOI/BLM).

Objectives

- Determine the abundance and distribution of fish and wildlife populations and identify their habitat requirements;
- Develop new techniques and technologies for studying and managing biological resources in the often-remote and cold-dominated Arctic environments, including recovery of ecosystems damaged by wildfires and other natural and human-induced causes; and
- Improve methods for detecting and determining the effects of human activities on the environment and identify measures to mitigate the declines of Arctic biological resources and the destruction of habitats.

Ongoing and Planned Activities

Measure the transmittance of photosynthetically available radiation through various ice types, including snow-covered ice, on large lakes and the biological productivity (phytoplankton and zooplankton) that occurs beneath these surfaces (DOC/NOAA);

Characterize the under-ice surface of lakes as a habitat for planktonic and benthic flora and fauna (DOC/NOAA);

Examine the role of sediment floc on the under-ice surface of lakes in nutrient and contaminant dynamics (DOC/NOAA);

Study the influence of the Slave River on the productivity and contaminant loading of Great Slave Lake (in Canada's Northwest Territories) including the potential for adverse effects of in-

creased watershed development and possible effects of climatic warming (DOC/NOAA);

Direct more emphasis on long-term ecological research and monitoring programs to study terrestrial and aquatic habitats and the resident and migratory species they support; differentiate naturally occurring changes from those related to human activity and identify linkages with coastal and marine ecosystems (DA/CSRS, DOI/BLM/FWS/NPS, NSF);

Increase the involvement of Alaska Native residents and organizations in research programs and decisions affecting fish and wildlife and other renewable land-based ecosystem resources (DA/CSRS, DOI/BLM/FWS/NPS, NSF);

Investigate the trophic relationships between higher vertebrate predators and consumers (e.g. seasonal predation rates, prey switching and habitat overlap) (DOI/BLM/FWS/NPS);

Continue interagency participation in multidisciplinary research efforts, including studies of Teshekpuk Lake waterfowl ecology and the Arctic National Wildlife Refuge (DA/CSRS, DOI/BLM/FWS/ MMS/NPS);

Determine spawning escapement and distribution of Pacific salmon in selected tributaries of the Yukon River (DOI/FWS);

Determine abundance characteristics, life stage distribution and population characteristics of fish species on the North Slope drainages of ANWR and the extent to which they utilize aquatic habitats (DOI/FWS);

Investigate the nature, extent and control of parasite and disease problems in wildlife (DA/CSRS);

Establish criteria for cultivating and propagating selected Alaska native plants (DA/CSRS);

Determine methods for treating abandoned gravel pads and roads in Arctic Alaska wetlands to improve their suitability for wildlife habitat by vegetating such sites with indigenous plants, with special reference to Prudhoe Bay and the surrounding oil fields (DA/CSRS);

Determine the influence of oil hydrocarbons on reproduction in mink (DA/CSRS/SAES);

Evaluate the effects of jet boats on salmon and trout egg and fry survival at Katmai and Lake Clark (DOI/NPS);

Continue studies of the relationship of bears to the Red Dog Mine at Noatak, bears and hunting at Aniakchak, merlins and pesticides at Denali, wildlife and road use at Denali, furbearers and trapping at Gates of the Arctic, and fire and wildlife in northwest Alaska (DOI/NPS); and

Begin studies of fire and wildlife in interior Alaska; moose and brown bears at Bering Land Bridge; river ecology and use, and stream fish genetics at Noatak; water resources at Gates of the Arctic; lichens at Noatak; wetlands at Yukon-Charley Rivers and coastal resources at Cape Krusenstern (DOI/NPS).

3.3.4 Forestry, Agriculture and Grazing

Increased knowledge of the current and potential productivity of Arctic and Subarctic forests and soils will lead to improved management practices for increasing the productivity of renewable resources. The goals are to promote self-sufficiency among local inhabitants and to accrue economic benefits.

Selected Activities and Accomplishments

Completed a risk rating system for Lutz and white spruce stands that incorporates plant community associations as an index to stand risk from attack by spruce beetles (DA/FS);

Developed a moose habitat enhancement plan for the Copper River Delta and continued data collection on moose habitat preference in riparian areas of the Copper River Delta and in mountainous areas of Denali National Park (DA/FS);

Began studies of plant succession focused on natural colonization of artificial gravel deposits created from petroleum exploration and production, revealing that 75 species from 19 families were colonizing gravel pads that were 5 to more than 15 years old; proposed a revision of revegetation methods to facilitate use of indigenous species for gravel pad rehabilitation (DA/CSRS);

Examined patterns of nitrogen cycling within primary successional soils associated with open shrub, alder and white spruce stands on the Tanana River flood plain near Fairbanks; alder forest floors had the highest nitrogen-fixing rates: 163 kg of fixed nitrogen per year (DA/CSRS);

Isolated over 56 cold-tolerant *Trichoderma* and over 400 cold-tolerant bacteria from Alaska soils; *Trichoderma* species were found to be capable of controlling damping-off, snow mold and many economically important soilborne diseases, as well as promoting plant growth and development (DA/CSRS);

Studied selenium supplementation of beef cattle; small amounts of feedstuffs containing adequate Se and monthly injections, or injections every two months, will supply adequate Se (DA/CSRS);

Studied safety and nutritional content of reindeer field-harvested during a spring 1989 handling; low total fat content results in a saturated fat content that approximates that of poultry and fish (DA/CSRS);

Attempted to control brucellosis disease in reindeer herds by treating approximately 15,000 rein-

deer with a vaccine that has been approved for use in Alaska, with initial results indicating that field protection was provided (DA/CSRS);

Initiated a five-year strategy for reindeer grazing on the Seward Peninsula (DOI/BLM);

Continued research on movements and reproductive success of caribou, with emphasis on the interaction of weather and other factors with habitat utilization during critical parts of the life cycle and the consequent influence of habitat availability on populations (DOI/FWS); and

Used Landsat-TM data as part of a project to study the use of remote sensing for identifying tundra vegetation (DOI/FWS).

Increased knowledge of the current and potential productivity of Arctic and Subarctic forests and soils will lead to improved management practices

Objectives

- Continue and extend forest resource research throughout the underutilized taiga forests, focusing on applying ecological information in sustained-yield management and protection of forest types for subsistence and economic use;
- Enhance soil and crop science research to develop effective management practices under conditions of permafrost, low temperatures, wildfire and development impacts; and
- Improve techniques and technologies for research on reindeer management systems, including health, habitat and forage.

Ongoing and Planned Activities

Acquire long-term baseline data describing taiga forests, including productivity, human occupancy, total carbon production and sequestering, and the vigor and health of key vegetation communities and species including ecotones, employing permanent research sites, GIS and remote sensing, integrative modeling and dendrochronological techniques (DA/CSRS/FS/SCS, DOI/BLM/NPS);

Addressed remaining problems in distinguishing vegetation classes while using Landsat-TM data to identify tundra vegetation (DOI/FWS);

Determine the human and environmental impact, including the effects of fire, insects and diseases, on forest and park resources for use in developing more effective management and protection systems and for supporting subsistence, wildlife habitat and protection of streams and fisheries (DA/CSRS/FS, DOI/BLM/FWS/NPS);

Monitor climate conditions in areas where soils have the potential for agriculture to determine their suitability for crop production, focusing on the effects of permafrost, erosion and short growing seasons (DA/ARS/CSRS/SCS, DOI/BLM/NPS);

Develop plant varieties that perform under severe Arctic conditions for use in rehabilitating disturbed environments (DA/ARS/CSRS, DOI/BLM/NPS);

Collect data on lichens, including nutrient value, sensitivity to disturbance and recovery from overgrazing (DA/SCS, DOE, DOI/BLM/NPS);

Study the influence of snow cover on the availability of winter range forages, and the interactions and competition of caribou and reindeer on tundra range in western Alaska (DA/SCS, DOI/BLM/NPS);

Monitor the levels of forest pests in interior Alaska forests (DA/FS/ARS, DOI/NPS/BLM);

Determine the impact of timber harvests on snowmelt and runoff rates from a boreal forest watershed (DA/CSRS/FS);

Determine after-fire plant succession on boreal zone rangeland disturbed by oil drilling activities (DA/CSRS);

Determine methods for treating abandoned gravel pads and roads in arctic Alaska wetlands to improve their suitability for wildlife habitat by vegetating such sites with indigenous plants, with special reference to Prudhoe Bay and surrounding oil fields (DA/CSRS);

Determine soil nitrogen supplies in relation to forest productivity and successional patterns (DA/CSRS);

Identify organisms that have a potential for suppressing specific soil-borne plant pathogens and determine the mode of action of these biocontrol agents (DA/CSRS);

Investigate seleniferous feeds and injectable liquid selenium as supplements to selenium-deficient beef cattle diets (DA/CSRS);

Study reindeer herding at Bering Land Bridge (DOI/NPS);

Determine the quality of Alaskan reindeer meat, handled and harvested under existing conditions, as a potentially important market product for Native people (DA/CSRS); and

Continue development of an effective control program for brucellosis in reindeer herds (DA/CSRS).

3.4 Land–Atmosphere Interactions

3.4.1 Glaciology and Hydrology

Documentation of seasonal, interannual and long-term trends in the physical environment of the

Arctic requires attention to the special features of seasonal and perennial snow and ice cover and glaciers, especially as they relate to and record climatic change. Reliable information is also needed on surface water quality and quantity. Collection of this information will provide a climatic and hydrologic baseline for the Arctic.

Selected Activities and Accomplishments

Combined field observations with Synthetic Aperture Radar and ice-penetrating radar measurements of the Malaspina and Bering glaciers to show that both glaciers occupy deep fjord basins extending several hundred meters below present sea level; in both instances the basins extend more than 50 km behind the present ice margins (DOI/GS);

Long-term trends in the physical environment of the Arctic require attention to the special features of seasonal and perennial snow and ice cover and glaciers, especially as they relate to and record climatic change

Determined that the recent acceleration in the rate of retreat of the Mendenhall Glacier is not related to global warming but is a function of changes in the drainage system associated with the glacier (DOI/GS);

Determined that between 1977 and 1988 the Wolverine Glacier thickened by as much as 8.1 m, caused by unusually warm winters accompanied by high amounts of snow precipitation; the climate during the post-1977 period of observations has become warmer and wetter (DOI/GS);

Continued the Greenland Ice Sheet Project; the major thrust of the GISP II project is to drill and recover ice cores from the entire thickness of the Greenland Ice Sheet, over 3000 m, in order to reconstruct the history of atmospheric chemistry and climate for the Northern Hemisphere over the past 200,000 years (NSF);

Continued to reprocess Geosat altimeter data, with results suggesting that part of the Greenland ice sheet thickened significantly in the nine-year interval between the Seasat and Geosat altimeter missions (NASA);

Tracked coarse (gravel) sediments in glacially fed rivers via radio transmitters, providing a major breakthrough for understanding sediment transport regimes in gravel-bed rivers by providing the first comprehensive data on both rates of movement and transport sequences correlated to specific flow events (DOD/CRREL);

Tested high-resolution ground-penetrating radar's ability to locate and define highly localized sources of water in permafrost at several sites in Alaska; located water conduits at depths between 5 and 25 m below the basal ice layer at the margin of the Matanuska Glacier in southeastern Alaska (DOD/CRREL);

Developed a model (following field and laboratory studies) to predict the development of impermeable firn (and consequent runoff and discharge to the ocean) in response to predicted future climate change (DOE); and

Convened an interagency workshop on glacier monitoring in Alaska and developed plans for long-term monitoring (DOI/GS/NPS).

Objectives

- Continue to develop paleoenvironmental records from ice caps, ice sheets and mountain glaciers; conduct research on processes by which gases and aerosols are incorporated into the snow and ice; and correlate these records with adjacent records for other sources and proxy records;
- Document the cause-and-effect relationships between glaciers, sea ice and global hydrology, including the relationship to world sea-level changes and climatic fluctuations, both long-term and short-term, regional and global, and continue to develop models for glacier mechanisms;
- Determine the consequences of specific renewable and nonrenewable resource development and harvest practices on ground and surface water, and develop predictive models for stream flow and water quality;
- Forecast future sea-level change caused by "greenhouse"-induced changes in runoff from polar glaciers and ice caps; and
- Establish the role of land–water interactions in the control of nutrient cycling.

Ongoing and Planned Activities

Expand systematic programs of ocean–atmosphere–glacier interaction, coupled with field studies to monitor short- and long-term changes in glaciers caused by flow dynamics and climate (DOD/CRREL, DOI/GS, NASA, NSF);

Expand the use of innovative research techniques, including remotely sensed data collection from microwave satellites and aircraft (DOC/NOAA, DOD/CRREL, DOI/GS, NASA);

Continue important studies of mass balance and dynamics of representative Alaskan glaciers and expand studies to other glaciers (DA/FS, DOD/CRREL, DOI/GS, NSF);

Implement national and international coopera-

tive agreements to augment monitoring networks to study glacier mass balance, glacier fluctuations, stream quality and river behavior across the Arctic, and increase the use of regional facilities for long-term monitoring (DOD/CRREL, DOI/GS, NASA);

Develop theoretical models for determining the quantity of precipitation and snow distribution by wind drifting, and for forecasting snowmelt and precipitation runoff in glacierized and unglacierized basins in permafrost regions (DOC/NOAA, DOE, DOI/GS, NASA, NSF/NCAR);

Gauge the quantity and monitor the water quality of Arctic streams to determine discharge cycles (DOI/GS);

Complete the acquisition of the 3000-m-deep ice core in Greenland, continue analyses of the ice for paleoclimatic and atmospheric chemistry conditions, and conduct ancillary surface studies on depositional regimes (NSF);

Develop projects under Arctic System Science (ARCSS) to understand the role of hydrologic processes and nutrient cycling in long-term changes of the Arctic (NSF);

Monitor Alaskan glaciers as an indicator of global climate change (DOI/NPS/GS);

Use the CRREL Sleepers River Research Watershed, Vermont, as a cold regions research site for the DOI/USGS Water, Energy and Biogeochemical Budgets program (DOD/CRREL, DOI/GS);

Conduct transect studies of the glaciers of North America using historic photography and maps to establish a retrospective baseline; extend this baseline to the future using field observations and remote sensing (DOI/GS/NPS);

Conduct an airborne SAR and laser altimeter investigation over Greenland during the summer of 1991, with the goal of applying data from these instruments to a variety of geophysical investigations (NASA);

Complete the reprocessing of Geosat altimeter data and begin to process and analyze ERS-1 Advanced Microwave Instrument altimeter data (NASA);

Continue to develop and validate regional-scale snow runoff models for estimating future sea-level changes (DOE);

Continue to evaluate the influence of various wind shields on snowfall catches on precipitation gauges in the Arctic (DA/SCS, DOC/NOAA/CMDL);

Continue to monitor and expand to an appropriate sample density the network of Wyoming-shielded precipitation gauges (DA/SCS); and

Observe precipitation variations over the Greenland ice sheet (DOC/NOAA).

3.4.2 Permafrost, Landscape and Paleoclimate

Additional knowledge is needed about the temperature, distribution, thickness and depth of permafrost throughout all geomorphic provinces of the Arctic, including the continental shelf. Modern geologic processes that are responsible for the present morphology and land surface need to be better understood.

Selected Activities and Accomplishments

Investigated the concept that variations in the surface concentration of radon gas could indicate the permafrost distribution at depth and provide a rapid means of performing preliminary site investigations for planning and design of facilities (DOD/CRREL);

Developed a preliminary model to predict heat transfer in the active layer overlying permafrost (DOD/ARO/CRREL);

Determined continuous vegetation histories from lake deposits in Alaska and the Soviet Far East, providing the first comparisons of events of the late Glacial and Holocene records on both sides of the Bering Sea (NSF);

Assessed the impact of climate change on permafrost distribution (NSF, DOI/GS); and

Supported the International Permafrost Association, which began publishing a semiannual news bulletin and began preparing a circumpolar permafrost map at 1:7,500,000 in cooperation with government agencies (DOD/CRREL, DOI/GS, NSF).

Additional knowledge is needed about the temperature, distribution, thickness and depth of permafrost throughout all geomorphic provinces of the Arctic, including the continental shelf

Objectives

- Undertake a comprehensive program to extract paleoclimatic records from permafrost terrains;
- Understand how geologic processes affecting Arctic morphology and land surfaces have responded to changes in the past, and conversely, how these land surfaces and their constituent sediments document the history of past climate;

- Improve the ability to assess and predict the degree and rate of disturbance and recovery of permafrost terrain following natural or human-induced changes;
- Develop results leading to the ability to predict future climate-induced changes to the Arctic landscape; and
- Reconstruct the late Glacial and Holocene climate history in the Arctic.

Ongoing and Planned Activities

Conduct integrated studies of modern geologic processes and landforms, relict landforms, and changes in climate-controlled geologic processes with time (DOD/CRREL, DOI/GS, NSF);

Systematically investigate the temperature characteristics, areal extent, depth structure and response to climate change of Arctic permafrost by implementing a systematic long-term observational network of stations in Alaska designed for active layer and temperature measurements (DOD/CRREL, DOE, DOI/GS/MMS, NASA, NSF);

Continue to determine and map the character, horizontal distribution and depth of terrestrial and subsea permafrost (DOD/CRREL, DOE, DOI/GS, NASA, NSF);

Continue projects to recover paleoenvironmental histories from lake sediments, Quaternary deposits and permafrost terrain (NSF);

Monitor geothermal boreholes in northern Alaska for climate reconstruction (DOI/GS); and

Revise the permafrost map of Alaska and participate in the preparation of a circumpolar permafrost map (DOI/GS, NSF).

3.4.3 Ecosystem Structure, Function and Response

The Arctic is expected to be especially sensitive to the effects of possible global changes, including possible greenhouse warming on terrestrial, atmosphere and marine environments, as well as contaminant transport and deposition. Research is needed to improve our understanding of the influence of climate on land and freshwater processes and vice versa. Topics of particular importance include heat balance relationships, landscape alteration, impacts of wildfire, identification of biological indicators of change, current contaminant levels, sources and sinks of carbon and trace gases, and long-term trends in biological diversity (see Sections 3.3.3 and 2.3 of the Strategy Programs for related activities).

Selected Activities and Accomplishments

Continued research at the NSF Long Term Ecological Research (LTER) site at Bonanza Creek to determine the effects of resource limitations such as moisture and sucrose on ecosystem productivity and resiliency, and to study how the addition of sucrose and sawdust to experimental sites alters the carbon–nutrient balance (DA/FS, NSF);

Installed climatic monitoring stations on an upland and flood plain area in the Bonanza Creek LTER site for measuring snow load and water content, temperatures of the soil profile, monthly depth of freeze and photosynthetic active radiation (DA/FS, NSF);

Measured the partial pressure of CO_2 in 29 aquatic ecosystems across Arctic Alaska, showing that in most cases (27 of 29) CO_2 was released to the atmosphere; this CO_2 probably originates in terrestrial environments; if this mechanism is typical of that of other tundra areas, then current estimates of the Arctic terrestrial sink for atmospheric CO_2 may be 20% too high (NSF);

Determined that tussock tundra vegetation near Toolik Lake, Alaska, is losing carbon to the atmosphere, possibly in response to recent climatic and environmental conditions; given the very large pools of soil carbon in northern ecosystems (390 GT), there is a potential for significant impact on atmospheric CO_2 should a sizeable portion of the stored soil carbon be released to the atmosphere (DOE);

As part of the LTER lake study, showed that primary production is seasonally dependent on river flow and nutrient inputs, which varies annually, and that sediments act as a strong nutrient sink with no cycling of nutrients (NSF);

Research is needed to improve our understanding of the influence of climate on land and freshwater processes and vice versa

Used remote sensing studies to develop new and more accurate estimates of methane flux in the North American Arctic tundra (NASA);

Developed an experiment plan and selected candidate sites for the Boreal Ecosystem–Atmosphere Study (BOREAS); the proposed experiment sites are in Prince Albert National Park, Saskatchewan, and Nelson Home, Manitoba (NASA);

Found 1960s fallout radionuclide of cesium within 10 cm from the ground surface, showing how strongly it is retained on the organic mat (DOE);

Found that beryllium 7, a naturally occurring radionuclide, moves downslope to the riparian zone

in tundra, with very little leakage into streams, suggesting that metals that behave similarly to beryllium (e.g. iron, zinc, cobalt and lead) would tend to concentrate in the riparian zone as well (DOE);

Developed particle trajectory models (of road dust) to predict alteration of drainage, thaw depth and effects of different ecosystems (DOE);

Current estimates of the Arctic terrestrial sink for atmospheric CO_2 may be 20% too high

Developed models to investigate climate change effects and modifications of surface energy balance and calibrated them with gas and water flux measurements (DOE);

Implemented a field pilot study, the Arctic Accumulation of Air Toxics Project, across the North Slope of the Brooks Range to evaluate the use of lichens and mosses as environmental surrogates for inorganic and organic contamination (EPA);

Convened an international workshop to exchange information on experimental approaches and methodologies for evaluating Arctic air toxins; cooperated with a visiting Estonian scientist on sampling protocols and approaches; and shared resources and research information with NPS, USFWS and NSF (EPA); and

Determined levels of trace metals and hydrocarbons in sediments and organisms of the Beaufort Sea as part of a continuing monitoring study to determine if oil and gas activities are altering environmental chemistry (DOI/MMS).

Objectives

- Distinguish ecological changes due to natural causes from changes due to human activities and evaluate management techniques for the conservation and restoration of ecosystems;
- Identify and evaluate the responses of key biological populations and ecological processes to increased CO_2 and to different climatic conditions; monitor the changes in ecotone boundaries, which might serve as integrative indicators of change; and select biological indicators for use in a monitoring program designed to detect, measure and predict the extent of change;
- Expand the number of Long-Term Ecological Research sites and biological observatories into representative Arctic sites under LTER, MAB and ANILCA activities;
- Identify factors contributing to reductions in regional and global biological diversity;
- Integrate process, community, ecosystem and landscape features into a dynamic description that is realistically linked to both finer and coarser scales of resolution;
- Determine the CO_2 flux from tundra and the responses of vegetation to elevated levels of CO_2; and
- Determine the environmental factors controlling methane fluxes.

Ongoing and Planned Activities

Develop and implement techniques for detecting, minimizing and monitoring changes in terrestrial and aquatic systems caused by human activities and environmental factors (DA/FS/SCS, DOE, DOI/BLM/FWS/MMS/GS/NPS, EPA, NSF);

Institute multiagency planning to establish ecological hypotheses to be tested by field and laboratory research (DA/FS, DOE, DOI/BLM/NPS/MMS, NASA, NSF, SI);

Conduct studies to determine the most appropriate sites for biospheric observations and transects (DA/FS, DOE, DOI/BLM/GS/NPS, NASA, NSF, SI);

Conduct studies to evaluate the effects of human activities on the genetic integrity of wild populations of fish, wildlife and vegetation (DA/FS, DOE, DOI/BLM/FWS/NPS/MMS, NSF, SI);

Expand the use of satellite remote sensing and other technologies (DOC/NOAA, DOE, DOI/BLM/FWS/GS/NPS/MMS, NASA, NSF);

Conduct multiagency symposia on terrestrial ecosystems and ecological research, including postseason review meetings (DA/FS, DOE, DOI/BLM/FWS/NPS, NASA, NSF, SI);

Link biosphere reserves and other protected lands to the NSF-sponsored Long-Term Ecological Research program; expand northern LTER candidate sites to include Noatak Preserve and ANWR (DA/FS, DOI/FWS/NPS, NSF, SI);

Through the U.S. Arctic Directorate of MAB, continue to implement the Northern Sciences Network (DA/FS, DOE, DOI/FWS/ NPS, NSF, SI).

Initiate the first phase of the Arctic System Science program Land–Atmosphere–Ice Interactions; continue the Fairbanks and Toolik Lake LTER program and related terrestrial and aquatic ecosystem projects (NSF);

Continue interdisciplinary methane investigations to measure methane flux in situ and to understand ecological processes leading to methane flux in the Arctic (DA/FS, DOC/NOAA, DOE, EPA, NASA, NSF);

Develop direct measurements of integrated soil production and consumption of methane, carbon dioxide, nitrous oxide and carbon monoxide using a technique based on soil fluxes and profiles of radon (222) (EPA);

Continue investigations to classify and stratify

ground cover types for developing statistical estimates of methane flux for the Arctic tundra and taiga (NASA);

Develop radiative transfer models for synthetic aperture radar to measure structural properties of high-latitude forests (NASA);

Continue planning for the Boreal Ecosystem–Atmosphere Study (BOREAS), which will be conducted jointly with several Canadian agencies; solicitations for proposals will be released in late 1991; automated data collection will take place from 1992 through the intensive field campaigns planned for 1994 (NASA);

Investigate the potential effects of global change on the Alaskan boreal forest and regeneration of boreal tree species (DA/CSRS/FS);

Expand the impact and recovery program to use existing disturbed sites for measuring changes in important ecosystem parameters (DOE);

Initiate the development of a circumpolar network for investigating disturbed sites in other regions exposed to different energy-related disturbances (DOE); and

Assess the risk, in terms of character, magnitude and timing of changes, to Arctic biological systems from atmospherically deposited contaminants (EPA).

3.5 Engineering and Technology

Three recent reports identify research needs in polar engineering. The National Science Board, in its report on the Role of the National Science Foundation in the Polar Regions (NSB 1987), identified research needs in polar engineering.

The Arctic Research Commission (ARC 1990a) undertook an examination of the state of Arctic engineering and technology research to identify possible gaps and weaknesses and make appropriate recommendation. The Commission stated that a strong engineering research program is necessary to improve design and construction techniques, equipment, materials and components to make engineering practices more effective under Arctic conditions. The Commission concluded that, in order to satisfy the basic principles of U.S. Arctic Policy and to achieve the desired national competitiveness in the Arctic, it is necessary to significantly improve the nation's Arctic engineering capabilities through a balanced, sustained and coordinated program of Federal support of cold regions engineering research at universities and national laboratories.

A strong engineering research program is necessary to improve design and construction techniques, equipment, materials and components to make engineering practices more effective under Arctic condition (ARC 1990a)

Based on its findings the Commission recommended that the U.S. Interagency Arctic Research Policy Committee develop an Arctic engineering research plan with special emphasis on the following priority items:

- Oil spill prevention technology, including innovative containment and cleanup operations in ice-infested waters and permafrost terrain;
- Waste disposal and air pollution control;
- Power generation and energy storage;
- Improved Arctic construction techniques;
- Transportation systems for Arctic conditions; and
- Materials and processes suitable for Arctic operations.

In addition to these topics, priority areas of scientific research whose results are of crucial importance and areas of important technology transfer were recommended to be included in the Arctic engineering research plan:

- Physical properties of ice and snow;
- Physical and chemical behavior of Arctic soils;
- More extensive communications and cooperation to be developed between the various government agencies and the professional societies, conferences with specialized Arctic engineering activities, and more effective mechanisms for technology transfer between government, academia and private industry; and
- New engineering courses and programs specializing in Arctic engineering topics.

A workshop on Cold Regions Engineering Research Needs (Carlson et al. 1989), sponsored by NSF, identified a number of specific research needs:

- Analysis of how current construction procedures, material equipment and personnel performance in Arctic environments can be improved;
- Analysis of building and utility systems for Arctic regions to ensure that they are appropriately based on the nature and constraints imposed by unique environmental conditions;
- Improved comprehensive understanding of ice processes, the effect of ice on structures and the effect of structures on ice;
- Determination of the effects on frozen seabed

and permafrost of structures for energy and other development activities; and
- Improved methods and systems for protecting the environment and for improving human habitability.

Selected Activities and Accomplishments

Conducted in-situ experiments on extending the service lives of grounded spray ice islands into warm weather, on the mechanical properties of saline ice, and on mechanisms that comprise the forces generated by sea–ice–structure interaction (DOI/MMS);

Continued oil spill response technology research for open water and broken ice fields, largely focusing on the burning of crude oil on water, the use of chemical treating agents, the remote sensing of slicks, and the development of a water jet boom for ice-infested areas (DOI/MMS);

Acquired and refurbished the now-closed Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility (DOI/MMS);

Continued to evaluate technologies for reducing engine emissions resulting from OCS operations (DOI/MMS);

Submitted a patent application for a device to measure the impact of pressure on the internal friction and creep of ice (DOD/CRREL);

Completed studies on the use of insulation under pavements to reduce frost effects and on the use of scrap rubber from tires in asphalt concrete to reduce the retention of ice on roadways; developed a thermal stress device to test the susceptibility of pavements to low-temperature cracking; developed new methods for interpreting nondestructive test data obtained from falling weight deflectometer tests on frozen and thawing pavements; and fabricated a refrigerated test chamber to measure the drainage of water through pavement structures during freezing and thawing (DOD/CRREL);

Evaluated a unique dual-energy gamma device to nondestructively characterize the performance of insulation subjected to harsh environments (DOD/CRREL);

Evaluated a commercial icebreaker design, including towed resistance, propulsion and ramming tests of a scale-model icebreaker (DOD/CRREL);

Developed and tested a hybrid thermosyphon system in support of the USAF Alaskan Over-the-Horizon-Radar project; the concept combines horizontally placed passive thermal piles with backup active refrigeration to stabilize ice-rich, warm permafrost (DOD/CRREL);

Tested a model hydropower intake trash rack incorporating a new concept in trash rack heating in the CRREL refrigerated flume (DOD/CRREL);

Reassessed the long-term effects of oil spills on permafrost, vegetation and soil chemical and biological properties at an experimental crude oil spill site established in the late 1970s (DOD/CRREL);

Showed that solvent mixed with steam further improves the recovery of heavy oil deposits (DOE, University of Alaska); and

Reached an agreement to share the costs of a coal-fired cogeneration demonstration plant in Healy, Alaska (DOE, State of Alaska).

Objectives

- Develop the extraction technology necessary to recover the Arctic reserves of crude oil, natural gas, heavy oil, methane hydrates and other fossil fuel resources;
- Support technology transfer to the private sector of fossil energy resource recovery and conversion technology, and the environmental impact of such recovery;
- Analyze how current construction procedures, material, equipment and personnel performance in Arctic environments can be improved;
- Ensure that building and utility systems for Arctic regions are more appropriately based on the nature and constraints imposed by unique environmental conditions;
- Improve on the comprehensive understanding of ice processes, the effect of ice on structures and the effect of structures on ice;
- Determine the effects of placement of structures for energy development and other types of developmental activities on frozen seabed and permafrost;
- Develop expeditious, economic and environmentally sound techniques for developing and transporting Alaskan Arctic oil, gas and other fossil fuel and mineral deposits; and
- Improve methods and systems for protecting the environment and improving habitability.

Ongoing and Planned Activities

Monitor sea ice and stream ice motion, concentration, floe size and ice type (DOD/COE/OCEANAV, DOI/GS/MMS, NASA, NSF);

Develop techniques and methods for remotely monitoring and measuring ice, including distribution, frequency and annual occurrence of pressure ridges and rubble field systems (DOD/COE/OCEANAV/ONR, DOI/GS/MMS, NASA, NSF);

Develop ice erosion control measures (DOD/COE, DOI/MMS);

Develop the technology for recovering unconventional fossil energy resources such as heavy oil, tar sands, oil shale, tight-gas sand, geopressured methane and gas hydrates (DOE/FE, DOI/GS/MMS);

Evaluate and promote improved oil transportation technology and oil spill prevention and clean-up systems suitable for Arctic conditions (DOI/MMS);

Improve equipment and machinery operation in cold regions (DOD/COE);

Undertake studies of snow physics, drifting and traction on snow and ice (DOD/COE, DOT);

Improve ice adhesion technologies (DOD/ONR, DOI/MMS, DOT/CG/SHRP);

Develop and validate improved models of frost heave and thaw weakening for pavement systems (DOD/COE, DOT);

Develop new materials and designs for lighter structures and improve the durability and performance of building materials for low-temperature applications (DOD/COE, DOI/MMS, NSF);

Develop innovative water supply and waste treatment systems for remote Arctic areas (DHHS/PHS, DOD/COE);

Develop technologies to control ice jam formation and to predict ice forces on structures (DOD/CRREL, DOI/MMS);

Investigate approaches for converting methane to higher hydrocarbons (i.e. syncrude), which can then be easily transported in the existing trans-Alaska crude oil pipeline (DOE);

Continue to investigate offshore safety, pollution prevention and oil spill response research technologies for open ocean and ice-infested regions (DOI/MMS); and

Evaluate new technologies to reduce engine emissions and improve hazardous materials management and transportation systems (DOI/MMS);

A series of studies are planned or underway as part of cooperative oil spill response research programs for Arctic waters, including the following:

- The use of aircraft sensing capabilities for oil thickness measurement;
- Development of a water-jet boom for use in broken ice fields;
- Oil slick recovery techniques;
- Chemical treating agents and dispersants;
- Air pollution effects on in-situ burning of spilled oil;
- Development of high-strength contaminant booms for use in ice;
- Development of under-ice oil detector systems;
- The use of ice floes as a means of containing oil spills; and
- Development of mechanical devices that operate in ice fields for separating oil from ice and water.

3.6 Social Sciences and Health

The importance of the North is clearly recognized by the Arctic Research and Policy Act of 1984 and the 1989 National Academy of Sciences report *Arctic Social Sciences: An Agenda for Action*. The following builds on the recommendations of the 1989 revision. The long-range goal of the plan is:

> To investigate the human dimensions of global, regional and local change through the study of past and present northern cultures and societies, and to gain an understanding of human–environment interactions relating to health and well-being.

In accordance with this goal and the recommendations of the IARPC (June 1, 1989), the following actions have been implemented:

- An Interagency Arctic Social Science Task Force was established and Terms of Reference specified and subsequently approved by the IARPC;
- The Arctic Social Science Task Force drafted a Statement of Principles for the Conduct of Research in the Arctic, which was reviewed externally and subsequently approved by the IARPC (Appendix G);
- The NSF has established and funded a multidisciplinary Arctic Social Sciences Program within the Division of Polar Programs; and
- The Polar Research Board's Arctic Social Science Committee prepared a report entitled *Contributions of Arctic Social Sciences to the Social Science Community*.

Coordination and Infrastructure

The Interagency Arctic Social Science Task Force, chaired by the National Science Foundation, meets periodically and consists of representatives from Agriculture (USFS), Commerce (NOAA, NMFS, Sea Grant), Health and Human Services (IHS, NIH, CDC), Environmental Protection Agency, Interior (MMS, BIA, BLM, NPS, FWS), Defense, State (OES), the Smithsonian Institution, the Council on Environmental Quality, the U.S. Arctic Research Commission and the National Academy of Sciences (Polar Research Board).

Included within the mandate are the following:

- Prepare Arctic social science and health research and budget crosscuts;
- Facilitate coordination between social science, health, medical and environmental research in the Arctic;

- Promote educational and training opportunities in the Arctic; and
- Advance public understanding of Arctic social science research.

Principles for the Conduct of Research in the Arctic

All scientific investigations in the Arctic should be assessed in terms of potential human impact and interest. 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. This 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. The principles (Appendix G) have been formulated to provide guidance for researchers in the physical, biological, behavioral, health, economic, political and social sciences, as well as the humanities. Following approval by the senior representatives of IARPC, each agency has been asked to implement these principles in the management of research under their jurisdiction. The statement has been announced in the *Federal Register* and published in the journal *Arctic Research of the United States* (Spring and Fall, 1990).

All scientific investigations in the Arctic should be assessed in terms of potential human impact and interest

Interagency Arctic Social Science Task Force

The Task Force focuses on defining science priorities in three areas: cultural resources and historical processes, social change, and health. These three priorities can be divided into numerous subject areas and two historical dimensions. One dimension, covered by archaeology, ethnography and history, is the long-range cultural historical perspective. The second dimension, addressed by the health sciences, ethnography, sociology and economics, encompasses contemporary issues and problems that are highly correlated with the interactions of northern indigenous and Western cultures, and the consequences for northern communities, subsistence, health and well-being. Because of the unique physical conditions that define the Arctic as a region, the main integrating theme for this research is human–environment interaction.

Numerous government agencies have mandates, missions, research interests and programs relating to these science priorities. Coordination and programs among the agencies will increase their effectiveness in this regard and better serve the people of the North.

Resources Management

Cultural and natural resources management is a mission of numerous Federal and state agencies. Cooperative scientific investigations on public lands must be undertaken to accurately document and monitor prehistoric and historic artifacts, sites, structures and landscapes. Effectively formulating, implementing and evaluating resource protection policies requires, first, accurate documentation of baseline data. Equally important are data bases on contemporary indigenous communities and their subsistence and systems of natural resource management. Not only should there be better coordination between agencies, but scientifically motivated research should be encouraged on public lands (Hopkins et al. 1990). Collaboration with local governments, Native councils and organizations should also be encouraged. Such partnerships can be facilitated by specialized groups such as the Alaska Interagency Archaeology Working Group or through integrating projects such as the Beringian Heritage International Park and the Bering Land Bridge Research Program. The NSF Arctic Social Sciences program provides a new source of university funding for research of this kind in Alaska.

Training and Education

The cadre of Arctic researchers in the U.S. is relatively small, and greater efforts must be undertaken to encourage science in the North. This is especially true regarding Native involvement in higher education. It is almost impossible to obtain graduate instruction outside of the major urban centers in Alaska. For these reasons, individual scientists working in the Arctic have been encouraged to involve local communities in planning and implementing scientific projects. Young people can participate in research projects through programs such as the Research Experience for Undergraduates (REU) program at NSF. Other agency programs are the Resource Apprenticeship Pro-

The cadre of Arctic researchers in the U.S. is relatively small, and greater efforts must be undertaken to encourage science in the North

Human–Environment Interactions

Cultural Resources and Historic Processes	Social Change
	Acculturation
Prehistoric and Historic	Demographic change
Archaeology	Community viability
History	Technological impacts
Ethnohistory	Political–administrative dynamics
Paleoenvironments	Education and training
Sea level changes and adaptive strategies	
Cultural resources management	DOI, NSF, SI
DOI, NOAA, NSF, SI	**Health**
	Mental and physical well-being
Contemporary	Environmental interactions
Cultural, social and economic impacts of environmental change	Epidemiology
	Infectious diseases
Adaptive strategies	Cancer research
Land and marine resource uses	Substance abuse
Subsistence	Accidents and suicide
Natural and cultural resources management	Health-care delivery and engineering
DOI, EPA, NOAA, NSF, SI	CDC, IHS, NIH, DOD

gram for Students (RAPS) of BLM, NPS and FWS, which provides summer jobs for Native Alaska students.

Alaska Native Commission

On August 18, 1990, the President signed the Indian Law Enforcement Reform Act (Public Law 101-379), which authorizes the establishment of the Joint Federal–State Commission on Policies and Programs Affecting Alaska Natives. The Congress found that there is a growing social and economic crisis among Alaska Natives in spite of recent laws and policies intended to protect and encourage traditional culture and economic self-sufficiency. The Congress further found that it was timely and necessary to review all policies and programs designed to serve Alaska Natives and to determine specific actions that would help assure that public policy goals for Alaska Natives were being achieved.

The Commission will have 14 members, 7 appointed by the President and 7 appointed by the Alaska Governor. The Commission will hold hearings and make specific recommendations to Congress to help ensure that Alaska Natives have comparable life opportunities and that their needs are addressed. These recommendations will respect the traditional and cultural uniqueness and special status of Alaska Natives, as well as cultural differences. The Commission will report to Congress with its recommendations and will make its report available to Alaska Natives, the State of Alaska and the President.

3.6.1 Cultural Resources and Historical Processes

The Arctic affords unique opportunities for studying cultural adaptation and change. It provides an ideal laboratory for research into the interaction of humans with their environment. The ability of humans to adapt to changing conditions is the key to human survival. To predict the effects of environmental change on human populations, it is necessary to have an understanding of both long-term and short-term processes. Studies are needed in archaeology, anthropology and history. These can provide a time depth of at least 15,000 years in Alaska. Paleoecological, zoological and physical anthropological studies provide information about changing environmental and subsistence conditions. Because of the enormous importance of coastal resources and the changing shorelines of the last 10,000 years, sea-level changes are central to northern cultural and historical research. Focusing on the processes of historical change makes Arctic research relevant to the most fundamental issues facing humankind today.

The NSF Arctic Social Sciences program encompasses archaeology; cultural, physical and social anthropology; ethnology; history; geography; sociology; psychology; linguistics; political science; law; economics and related subjects. Interdisciplinary research themes of particular concern are rapid social change, community viability and human–environment interactions, including issues relating to subsistence, sustainable development and global change.

Contemporary issues of paramount importance are the cultural, social and economic impacts of environmental change. These range from the immediate effects of oil spills to global climate change. The melting of the polar ice caps will likely have dramatic impacts on contemporary civilization and on many major urban areas of the planet. For northern indigenous people, the viability of the northern habitat and adaptation to change will largely determine whether or not they can maintain traditional lifeways and survive in their homelands. On a global scale the management of land and marine resources, along with the indirect effects of industrial development, is the core issue of environmental protection.

Both the cultural–historical and contemporary socioeconomic perspectives are needed to formulate predictive and explanatory models for understanding the human dimensions of global change. The Arctic is a region of great scientific relevance to global issues and an area of particular concern in its own right.

Selected Activities and Accomplishments

Showed the exhibit *Inua: Spirit World of the Bering Sea Eskimo* in Iceland (SI);

Carried out archaeological investigations on Frobisher Bay in Canada documenting the Martin Frobisher expedition (1576–1578), as well as Eskimo sites in the region (SI);

Completed studies of deglaciation, land–sea interface changes and paleobotanical changes over the past 8000 years for the Labrador coast (SI);

Proceeded with research in connection with the Beringian Heritage International Park and in the Beringian region (DOI/NPS);

Both the cultural–historical and contemporary socio-economic perspectives are needed to formulate predictive and explanatory models for understanding the human dimensions of global change

Published archaeological data from Cape Krusenstern, Cape Espenberg, the Kobuk valley and the Noatak region (DOI/NPS);

Completed the Alaska version of the National Archaeological Data Base (DOI/NPS);

Undertook resource ethnographies in the northwest areas (DOI/NPS);

Investigated 172 Native allotments since 1989 for cultural resource and archeological clearances; during 1989 and 1990, 130 field investigations were completed on sites of historical, cultural and archaeological significance for conveyance under ANSCA, more than half in the Aleutians; over 1400 taped interviews were conducted with Native elders (DOI/BIA);

Funded grants for subsistence data gathering and to support the Eskimo Walrus Commission, the Alaska Eskimo Whaling Commission, and the Sea Otter Commission; in addition, special grants were made to study and deal with the impact of the Exxon Valdez oil spill; much of this cultural resources inventory and subsistence-related program research addresses the overall study themes of rapid social change, community viability and human–environment interactions (DOI/BIA);

Collected extensive information on kinship, cultural history, subsistence etc. from Point Lay and similar comparative information from Point Hope; the impact of schools, resettlement and, for example, the construction of the DEW line site, was explored with data starting in the 1880s (DOI/MMS);

Developed and funded research on obsidian hydration dating on archeological sites in northern Alaska (DOI/BLM);

Documented 20 prehistoric and historic sites during an inventory of about 6300 acres in the Utility Corridor near Coldfoot by cultural resource specialists; other sites north of the Brooks Range and in NPRA were also studied (DOI/BLM);

Tested an early contact period whaling site at Nanagiatchuk (DOI/BLM);

Collected descriptive material, including maps and photographs of the Gold Rush-era "Wild Goose" Pipeline near Nome (DOI/BLM);

Excavated four sites undergoing river erosion in the Unalakleet drainage (DOI/BLM);

Discovered a skull of a pachyrhinosaurus along the Colville River; the University of Alaska Museum continued work at this site and revealed new insights into the late Cretaceous dinosaurs of Alaska (DOI/BLM); and

Funded Arctic and northern research projects through the Man and the Biosphere Program High Latitude Directorate, including work on northern ecosystems and northern peoples; the High Latitude Directorate has also provided support for a fellowship position at the Northern Sciences Network Secretariat in Rovaniemi, Finland (DOS).

Objectives

- Document and analyze the origins and transformations of Arctic cultural systems, ethnic groups and languages;
- Research paleoenvironmental changes, including ancient sea levels, in concert with cultural historical investigations;
- Study and analyze traditional knowledge systems, resource uses and subsistence against the background of contemporary technological changes and the development of state and Federal natural and cultural resource management policies; and
- Develop explanatory and predictive models relating Arctic societies and cultural systems to issues of regional and global environmental change.

Ongoing and Planned Activities

Conduct baseline cultural historical and environmental documentation and research focusing on the proposed Beringian Heritage International Park and the Beringian region, with special attention on paleoecology, environmental and sea level changes, the earliest settlement of the New World, and the ethnography, linguistics and history of Beringian peoples and cultural systems; the Smithsonian's Arctic Studies Center is preparing, with the NPS, the University of Alaska and other state organizations, a new joint Soviet–U.S. exhibition called *Beringia: Arctic Mediterranean* for tour in Alaska and Siberia in 1992–1994, as well as workshops and training opportunities for Native stu-

dents interested in anthropology and social sciences (DOI/NPS/BIA/BLM/GS, DOS, NSF, SI);

Through Phase One of the Beringian Heritage Program, beginning in 1991, support the production of a Russian–English archeological dictionary; prepare a traveling mini-Crossroads exhibit; and initiate an ethnographic and ethnoarcheological study in the Bering Land Bridge National Preserve (DOI/NPS);

Continue Archeological Overviews and Assessments for Gates of the Arctic National Park and Preserve and Noatak National Preserve (DOI/NPS);

Inventory data bases; develop management plans for preservation and research; train Native researchers; and enhance Native collaboration in research process (DA, DOC/NOAA, DOI/BIA/BLM/FWS/NPS, NSF, SI);

Conduct a Traditional Land Use Inventory (TLUI) and a GIS analysis of cultural resources in Alaska (not yet funded) (DOI/BLM);

Continue to fund multidisciplinary research and provide support for dissertation-level and undergraduate students through the Arctic Social Sciences Program (NSF);

Fund research on small-group interaction, stress and adaptation, and cognition and performance through the Joint NASA/NSF Research in Human Factors and Human Physiology in the Arctic and Antarctic program; of special interest for the Arctic are studies on social and cultural adaptation, with research sites possible at facilities in Barrow and Kotzebue, along with international collaboration (NASA, NSF);

Continue cultural resource inventory data gathering and analysis throughout the Arctic (DOI/NPS/BIA);

Promote cooperative grants to study the subsistence use of resources (DA/FS, DOI/FWS/BIA/NPS/BLM); and

Examine subsistence resource harvest practices in the Bristol Bay region along with analyses of the key political, economic, social and cultural factors that affect subsistence pursuits (DOI/MMS).

3.6.2 Social Change

Acculturation, the interaction of Native and Western values and cultures, is an ongoing problem of Indian and Inuit (Eskimo) peoples in the Arctic. The technological and economic impacts affect all aspects of traditional lifeways. Whole communities are threatened, as is the organizational control of land, resources and social systems. Such changes alter demographic patterns as well as local, regional and statewide politics. The question of local control is a major concern of northern people. Two areas of special importance in this regard are education and health care.

Selected Activities and Accomplishments

Continued to support fisheries studies involving management regimes, accident rates, commercial vs recreational fishing, and dynamic economic models of halibut fisheries (DOC/NOAA);

Provided economic information and assistance to the Pacific and North Pacific Fishery Management Councils, industry, NMFS and other agencies, including preparing reports and publications, participating on council plan teams in preparing draft regulatory impact reviews of fishery management plan amendments, and preparing and reviewing research proposals and programs (DOC/NOAA);

Supported education and training for Native Alaska students through the Resource Apprenticeship Program for Students (RAPS); the NOAA Sea Grant and Cooperative Education programs have also supported students in Alaska; this Alaska program is being expanded nationwide (DOC/NOAA, DOI);

Funded the establishment of a Clearinghouse on Circumpolar Education with representatives throughout Alaska (NSF);

Provided dissertation research support for Native students (NSF);

Acculturation, the interaction of Native and Western values and cultures, is an ongoing problem of Indian and Inuit (Eskimo) peoples in the Arctic

Received and reviewed over 30 proposals in the first year of the new Arctic Social Sciences Program (NSF);

Sponsored a social and economic study on the population, economy, sociocultural institutions and infrastructures of all communities of the North Slope Borough; the NSB has emerged as the dominant entity in the region leading to an inevitable cultural homogenization among North Slope communities (DOI/MMS); and

Initiated the Social Indicators project in 1989 to document changes in the human environment resulting from major actions in the Outer Continental Shelf; interviews have occurred in 31 sample communities from Kaktovik in the northeast to Atka in the southwest; results will be available beginning in 1992 (DOI/MMS).

Objectives

- Gain insight into the short-term and long-term effects of rapid social change on Arctic cultures and societies;
- Determine ecological thresholds relating to economic development and community viability;
- Develop practical applications of social and behavioral science to benefit Arctic residents;
- Develop culturally relevant educational programs; and
- Develop linkages between cultural behavior and health.

Ongoing and Planned Activities

Continue economic and social impact assessments of harvest allocations between offshore catcher–processor fleets and local, Alaskan-community-based fisherman and processors, including community profiles and the development of regional economic models; studies of the economic and social effects of privatizing and/or limiting access to the commercial fisheries of the Exclusive Economic Zone are also in progress (DOC/NOAA);

Fund a project on the effects of privatizing some fishery resources and examine the way fishermen make fishing area decisions in current open access areas (DOC/NOAA);

Study the economic and social dimensions of fishery and marine mammal conservation, harvest and management; recent amendments to the Magnuson Fishery Conservation and Management Act will require additional fishery impact studies to be developed in the near future; amendments to the Marine Mammal Protection Act have required new environmental impact studies to be conducted; forecasted major effects on commercial fishing and subsistence harvests are being studied (DOC/NMFS); and

Continue to provide long-term support for research in sociology, psychology, community development, economics and education (NSF).

3.6.3 Health

Health is physical, mental, social and spiritual well-being. Unique cross-cultural interactions and social interdependencies due to harsh environmental conditions in the Arctic highlight this definition of health. Therefore, all Arctic health research must take into account complex human and environmental interactions.

Health research in the Arctic includes the study of the effects of cultural change on Native populations, epidemiology of disease, adaptation of humans to extreme environmental conditions, environmental health risks, contamination, and health care delivery in remote and isolated Arctic communities. Health concerns in the Arctic are often related to international health issues. Western culture (and potentially Asian culture) impacts Native people adversely by introducing lifestyle and dietary changes and new infectious agents. Research designed to study these effects and techniques for disease prevention is urgently needed. Funding by DHHS is showing a dramatic increase (see Appendix E).

Selected Activities and Accomplishments

Completed studies comparing the immunogenicity of three *Haemophilus influenzae* type b conjugate vaccines, administered to Alaska Native infants; three new conjugate vaccines have been tested, two of which proved highly immunogenic in Alaska Native infants (DHHS/CDC/IHS);

Completed a study of the level of protection against Hepatitis B virus infection seven years after administration of Hepatitis B vaccine; over 50,000 Alaska Natives were vaccinated, leading to a dramatic decline in illness (DHHS/CDC/IHS);

Continued revaccinations with pneumococcal vaccines in northwest Alaska; bacterial pneumonia is the fourth leading cause of hospitalization and sixth of death among Alaska Natives (DHHS/CDC/IHS);

Completed studies to determine the prevalence of Human Papilloma Virus in selected Alaska Native populations; cancer among Alaska Natives differs markedly from the general U.S. population; studies have focused on cancers that appear to be related to specific viral infections: nasopharynx, cervix, esophagus and liver (DHHS/CDC/IHS);

Completed a year-long study examining the effects of prolonged Antarctic residence, resulting in the description of a new syndrome of human physiology and balance called the "Polar T 3 Syndrome;" all indications suggest that extended high-latitude Arctic residence should induce a similar constellation of human adaptation (DOD/NMRI, NSF);

Undertook research on the bioaccumulation of methylmercury in the food chain associated with dredging; tests of water from Norton Sound determined that mercury levels were an order of magnitude below EPA limits, and tests of human hair samples from Nome showed that mercury did not exceed established EPA criteria (DOI/MMS);

Undertook research to establish the utility of rewarming hypothermic humans with a microwave-emitting vest and suggested its practical application (DOD);

Funded a study to evaluate physiological and

psychological impairments of human performance in cold-stressed subjects (DOD/MRDC);

Completed initial work on developing electrically heated gloves for use by aircrew personnel, which will provide protection to –80°F while having a minimal impact on dexterity and tactility (DOD/NRDEC); and

Arctic health research must take into account complex human and environmental interactions

Supported research and programs on the prevention of cervical cancer in Alaska Native women, tobacco-use prevention, cancer data bases, sleep apnea, physiology in cold regions, and fractures of the skull and face among Alaska Natives (DHHS/NIH).

Objectives

Health research in the Arctic is done, individually or collaboratively, by the Arctic Investigations Program (AIP) of the Centers for Disease Control (CDC), the Indian Health Service (IHS), the National Institutes of Health (NIH), the Alcohol, Drug Abuse and Mental Health Administration (ADAMHA), the Department of Defense (DOD) and the Division of Public Health, State of Alaska. These agencies conduct Arctic research with the following objectives:

- Establish and support basic and applied scientific inquiry for the purpose of improving human health through biomedical and behavioral research programs; and
- Disseminate new information derived from basic and applied research into studies of the etiology, pathogenicity, prevention, diagnosis and treatment of human biomedical disorders and studies of the psychosocial factors associated with poor health status or associated with environmental contaminants.

Ongoing and Planned Activities

Undertake studies on the sustained levels of immunity and vaccine efficacy ten years following vaccination against Hepatitis B virus (HBV) infection and vaccine efficacy in infants; continue studies of responses to new Hepatitis A vaccines through 1992 (DHHS/CDC/IHS);

Continue studies on the effectiveness of alfafetoprotein screening of Hepatitis B virus carriers in prevention of the morbidity and mortality of primary hepatocellular carcinoma (DHHS/CDC/IHS);

Continue to evaluate strategies for preventing invasive *Haemophilus influenzae* type b (Hib) disease and pneumococcal disease among Alaska Natives (DHHS/CDC/IHS);

Continue studies of Fetal Alcohol Syndrome among Alaska Natives, including a joint FAS prevention project for research and training designed to counteract this fully preventable problem (DHHS/CDC/IHS);

Continue studies by the National Institute for Occupational Safety and Health and the Center for Environmental Health in collaboration with the State of Alaska on the epidemiology, risk factors and prevention strategies for occupational injuries in Alaska communities (DHHS/CDC/IHS, State of Alaska);

Continue evaluation of strategies in the prevention of cervical dysplasia in Alaska Native women (DHHS/CDC/IHS);

Continue epidemiologic studies of spondyloarthropathy in circumpolar populations; these rheumatic diseases are prevalent in Native populations; parallel studies are being carried out by the Soviet Institute of Rheumatology (DHHS/NIH/IHS);

Continue investigations on the incidence and survival among Alaska Natives with cancer; a five-year surveillance project and the establishment of a data base are part of this project (DHHS/NIH/IHS);

Expand studies of the Polar T Syndrome for Arctic residents (DOD);

Begin investigations of the mechanisms of middle-latitude circannual seasonal patterns in energy balance and expenditure to better understand polar physiology (DOD);

Continue studies on cold-associated amnesia, peripheral cold injury, management of hypothermia and improving cold weather clothing and rations (DOD);

Assess the accumulation of pollutants at the base of the human food chain (EPA);

Establish an American Indian and Alaska Native Mental Research Center for promoting excellence in mental health research in Native populations (DHHS/ADAMHA);

Continue research on suicide among Alaska Native youths (DHHS/ADAMHA); and

Enhance data collection on alcohol and substance abuse in Alaska (DHHS/ADAMHA, State of Alaska).

4. Operational Support

The following is the status of facility-related operational support. The IARPC has agreed to develop specific logistics plans as part of this Second Biennial Revision (see p. 91, IARPC meeting summary).

Ships and Ice Platforms

Vessels supporting research in ice-covered areas fall into two categories, based on their ice-going capability. The categories are:

- Icebreakers operated by the Coast Guard; and
- Ice-capable and ice-strengthened vessels for research and survey purposes.

The Federal Oceanographic Fleet Coordinating Council (FOFCC) 1990 report supports the need for the Coast Guard to maintain and operate a fleet of icebreakers for polar ice escort, logistic support and research support. It reaffirms that an ice-capable research ship be operated as a national facility for both the Federal and academic communities.

The Arctic Research and Policy Act (ARPA) confirms the Coast Guard's role as manager of the nation's icebreaker fleet to serve the nation's interests in the heavy ice regions of the Arctic. This includes security, economic and environmental interests. Research in support of those interests is specified in ARPA. Coast Guard icebreakers support research in these regions in two general ways: on dedicated science deployments and, as opportunities arise, in conjunction with other missions. Central management of the icebreaker fleet, given adequate resources, permits the interchangeability of ships to ensure mission accomplishment. The Coast Guard has two icebreakers and is acquiring a third.

Ice-going vessels of lesser capability than icebreakers are more economical, and they permit access to the marginal ice zone and other areas of less rigorous ice conditions. The requirement for research in these areas of lesser ice conditions has increased recently. Aside from the USGS research vessel RV *S.P. Lee*, a geological and geophysical vessel that occasionally works in the Arctic, no suitable dedicated U.S. vessel exists to fulfill that need. The UNOLS Fleet Improvement Committee approved a report *Science Mission for an Intermediate Ice Capable Research Vessel*. There is a need for specific identification of research vessels to collect seismic reflection profiles, geopotential data, sediment samples and seismic-refraction profiles in the Bering Sea, Arctic Ocean and Chukchi Sea, and to conduct winter research in the Bering Sea polynyas. NSF plans include the construction of an Arctic ice-capable research ship. The conceptual design has been completed and is undergoing community review (Glosten Associates 1991).

Coast Guard icebreakers are available to users on a reimburseable basis. Daily fuel costs and maintenance surcharges are charged to users or paid by researchers. Average costs are $13,000 per day.

Drift stations and other ice platforms including Soviet and Canadian opportunities will be utilized as research dictates.

Land-Based Facilities

The Polar Ice Coring Office (NSF) provides logistics support for research in Greenland, with emphasis on the Greenland Ice Coring program.

U.S. investigators have access, on a cooperative or reimbursable basis or both, to land-based facilities in Canada and Nordic countries. Cooperative arrangements with the Polar Continental Shelf Project Office in Canada provide for logistics support in the Canadian High Arctic. Facilities in Svalbard are available through the Norwegian Polar Institute, Norwegian universities and other national programs.

Small seasonal camps are maintained in the Alaskan Arctic by individual agencies or groups of agencies to support field programs. The Toolik Lake camp operated by the University of Alaska, and the privately operated facilities at Barrow and Prudhoe Bay, provide fixed bases for land-based research (DOC/NOAA, DOE, DOI/FWS/NPS/GS, NSF).

DOC/NOAA maintains a warehouse building, located at Elmendorf Air Force Base, for storing and maintaining field equipment, scientific instruments, and Arctic gear. The building provides nearly 7000 square feet of heated space (DOC/NOAA/NOS).

Atmospheric Facilities and Platforms

Poker Flat Rocket Range, Alaska, is being upgraded to state-of-the-art upper-atmosphere research capability so that it can support coordinated rocket and atmospheric monitoring programs.

Subject to the agreement of the Danish authorities, periodic rocket launches take place from Thule and Sondrestrom, Greenland. The U.S. incoherent-scatter radar facility at Sondrestrom is used by several agencies. The U.S. Air Force will terminate operations at Sondrestrom Air Base by

the fall of 1992. Science programs that formerly relied on the Air Force for logistics support will be required to seek new means of support.

Central Coordination and Logistics Information Clearinghouse

Several agencies compiled a directory of Federal Arctic research logistics capabilities. The State of Alaska has published a complementary inventory of Arctic logistics capabilities. Federal agencies participated in a logistics planning workshop in September 1989 at the Arctic Science Conference, Fairbanks; a workshop report was published (Kelley et al. 1990). The Department of the Interior supports an Alaska Office of Aircraft Services (OAS), which coordinates aircraft services on a reimbursable basis.

An electronic bulletin board on OMNET is available for posting currently available logistics information (ARCTIC.LOGISTICS).

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Appendix A: Glossary of Acronyms

AASE	Airborne Arctic Stratospheric Expedition
AASE-II	Airborne Arctic Stratospheric Expedition-II
ABLE	Arctic Boundary Layer Expeditions
ACSYS	Arctic Climate Systems
ADEOS	Advanced Earth Observation System
ADI	Arctic Data Interactive
AEDD	Arctic Environmental Data Directory
AF	Air Force
AFGL	Air Force Geophysical Laboratory
AFN	Alaska Federation of Natives
AFOSR	Air Force Office of Scientific Research
AGASP	Arctic Gas and Aerosol Sampling Program
AIP	Arctic Investigations Program
ALERT	Arctic Long-term Environmental Research Transects
AMAP	Arctic Monitoring and Assessment Program
AMI	Advanced Microwave Instrument
AMMTAP	Alaska Marine Mammal Tissue Archival Project
AMRAP	Alaska Mineral Resource Assessment Program
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
ANWR	Arctic National Wildlife Refuge
AORIS	Arctic Offshore Research Information System
AOSB	Arctic Ocean Science Board
APOA	Arctic Petroleum Operators Association
ARC	Arctic Research Commission
ARCSS	Arctic Systems Science
ARM	Atmospheric Radiation Measurement program
ARO	Army Research Office
ARPA	Arctic Research and Policy Act
ARS	Agricultural Research Service
ASF	Alaska SAR Facility
AUV	Autonomous Underwater Vehicles
AVHRR	Advanced Very High Resolution Radiometer
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BOM	Bureau of Mines
BOREAS	Boreal Ecosystem–Atmosphere Study
CDC	Centers for Disease Control
CD-ROM	Compact Disk-Read-only Memory
CEAREX	Coordinated Eastern Arctic Experiment
CEDAR	Coupling, Energetics and Dynamics of Atmospheric Regions
CES	Committee on Earth Sciences
CFC	Chlorofluorocarbon
CIRES	Cooperative Institute for Research in Environmental Sciences
CMDL	Climate Monitoring and Diagnostic Laboratory (formerly GMCC)
COE	Corps of Engineers
CONRIM	Council on Northern Resources Information Management
CRREL	Cold Regions Research and Engineering Laboratory
CRRES	Combined Release and Radiation Effects Satellite
CSRS	Cooperative State Research Service
DEW	Distant Early Warming
DHHS	Department of Health and Human Services
DIFAS	Digital Ice Forecasting and Analysis System
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOMSAT	Domestic Satellite
DOS	Department of State
DOT	Department of Transportation
ELF	Extremely Low Frequency
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPIC	Extensive PMEL Information Collection
ERL	Environmental Research Laboratory
ERS-1	European Remote Sensing (Satellite)
FAST	Fast Auroral Snapshot
FE	Fossil Energy
FOCI	Fisheries Oceanography Coordinated Investigation
FOFCC	Federal Oceanographic Fleet Coordinating Council
FS	Forest Service
FWS	Fish and Wildlife Service
FY	Fiscal Year
GCM	General Circulation Model

GEM	Geospace Environment Modeling
GGS	Global Geospace Science
GIS	Geographic Information System
GISP II	Greenland Ice Sheet Project II
GLORIA	Geologic Long Range Inclined Asdic
GMCC	Geophysical Monitoring for Climatic Change (now CMDL)
GS	Geological Survey
HBV	Hepatitis B virus
HF	High Frequency
HIPAS	High-Power Auroral Stimulation
IAOE–1991	International Arctic Ocean Expedition–1991
IARPC	Interagency Arctic Research Policy Committee
IASC	International Arctic Science Committee
IGBP	International Geosphere-Biosphere Program
IHP	International Hydrological Program
IHS	Indian Health Service
IMF	Interplanetary Magnetic Field
IPHC	International Pacific Halibut Commission
IRIS	Imaging Riometer for Ionospheric Studies
ISHTAR	Inner Shelf Transfer and Recycling
ISTP	International Solar-Terrestrial Program
ITEX	International Tundra Experiment
IWG	Interagency Working Group
JERS-1	Japanese ERS-1
JIC	Joint Ice Center
JPL	Jet Propulsion Laboratory
LEADEX	Leads Experiment
LF	Low Frequency
LTER	Long-Term Ecological Research
MAB	Man and the Biosphere
MF	Medium Frequency
MMS	Minerals Management Service
MRDC	Medical Research and Development Command (Navy)
NAD	Nansen Arctic Drilling program
NADP/NTN	National Atmospheric Deposition Program/National Trends Network
NARL–UIC	NARL–Ukpeagvik Inupiat Corporation
NASA	National Aeronautics and Space Administration
NCAP	Nansen Centennial Arctic Program
NCAR	National Center for Atmospheric Research
NCP	National Climate Program
NDSC	Network for the Detection of Stratospheric Change
NEPERF	Naval Environmental Prediction Research Facility
NESDIS	National Environmental Satellite Data and Information Service
NIH	National Institutes of Health
NISC	National Information Services Corporation
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NMRI	Naval Medical Research Institute
NOAA	National Oceanic and Atmospheric Administration
NOARL	Naval Oceanographic and Atmospheric Research Laboratory
NORMAGS	Northern Magnetic and Gravity Surveys
NOS	National Oceanographic Service (NOAA)
NOSC	Naval Ocean Systems Center
NPRA	National Petroleum Reserve-Alaska
NPS	National Park Service
NRDEC	Natick Research, Development and Engineering Center (Army)
NSB	National Science Board
NSB	North Slope Borough
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSN	Northern Sciences Network
NUSC	Naval Underwater Systems Center
NWS	National Weather Service
NWT	Northwest Territories
OAR	Office of Oceanic and Atmospheric Research
OAS	Office of Aircraft Services
OCEANAV	Oceanographer of the Navy
OCS	Outer Continental Shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OES	Bureau of Oceans and International Environmental and Scientific Affairs (Department of State)
OHMSETT	Oil and Hazardous Materials Simulated Environmental Test Tank
OIES	Office of Interdisciplinary Earth Sciences
OMB	Office of Management and Budget
ONR	Office of Naval Research
OSCURS	Ocean Surface Current Simulations
PHS	Public Health Service
PICES	Pacific International Council for the Exploration of the Sea
PMEL	Pacific Marine Environmental Laboratory (NOAA)
PRECP	Processing of Emissions by Clouds and Precipitation

RADARSAT	Radar Remote Sensing Satellite
RAPS	Resource Apprenticeship Program for Students
REU	Research Experience for Undergraduates program
SAES	State Agricultural Experiment Stations
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
Sea-WiFS	Sea-Viewing Wide-Field Sensor
SEL	Space Environment Laboratory
SEMS	Seafloor Earthquake Measurement System
SI	Smithsonian Institution
SMMR	Scanning Multichannel Microwave Radiometer
SSM/I	Special Sensor Microwave/Imager
STEP	Solar-Terrestrial Energy Program
TACT	Trans-Alaska Crustal Transect
TLUI	Traditional Land Use Inventory
TM	Thematic Mapper
TOMS	Total Ozone Mapping Spectrometer
TOPEX	Poseiden Ocean Topography Experiment
UCAR	University Corporation for Atmospheric Research
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOLS	University National Oceanographic Laboratory System
USAF	United States Air Force
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UV	Ultraviolet
VAMP	Velocity Amplitude Anomalies
VLBI	Very Long Baseline Interferometry
VLF	Very Low Frequency
WPL	Wave Propagation Laboratory

Appendix B: Strategy for Integrated U.S. Arctic Research Programs

Western Arctic Ocean Circulation and Productivity

Phase I:.Existing and Planned Agency Contributions

Bering Sea

DOC/NOAA:

Initial surveys of the circulation and hydrographic structure of the deep Bering Sea and its shelves in relation to wind forcing

- Bering Fisheries Oceanography Coordinated Investigations (FOCI) initiated in FY 1991 under the NOAA Coastal Ocean Program with emphasis on the role of cross-shelf transport of pollock larvae from the deep Bering basin to the U.S. continental shelf in enhancing recruitment to U.S. fishery.
- Initial surveys of the eastern Bering shelf in cooperation with MMS during cruises in FY 1990.
- FY 1991 cruises with the Soviets will define the seasonal variability in the ocean response to wind by conducting hydrographic transects extending from the deep basin onto the shelf in all directions.

Synthesis, analysis and modeling of historical data on bottomfish, shellfish and marine mammal (Steller sea lion, bowhead whale, northern fur seal) stocks (NOAA/NMFS)

Development of techniques such as RNA probe for fishery stock identification

- FOCI

NSF:

Synthesis of primary productivity and biogeochemical data sets

- ARCSS (Arctic System Science).

Field studies to evaluate spatial and temporal variations in primary and secondary production and biogeochemistry

- Follow the modification of seawater as it transits the Bering Sea (ARCSS).

DOI/MMS:

Building on previous investigations, undertake studies of pollutant transport and living resources and long-term monitoring of key species

Continue reconnaissance of fur seal and sea lion feeding areas

DOI/FWS:

Dynamics of marine mammal population

- Ongoing research on polar bears examines local and large-scale movements of satellite-telemetered individuals, location and productivity of maternity dens, and biochemical and genetic indicators of subpopulations. Enhanced cooperation with Soviet scientists in FY 1990 and FY 1991 allows investigations of maternity sites in Soviet territory.

Northern Bering/Chukchi Shelf

DOC/NOAA:

Initial surveys of circulation and water properties on the Chukchi shelf including Soviet territorial waters

- Ice Edge Ecosystem (ICE) study to be initiated under NOAA Coastal Ocean Program in FY 1991.
- Build on joint cruises with the U.S.S.R. begun in FY 1990 including deployment of long-term moorings, land meteorological stations, ice drifters, surveys of nutrients and chlorinated organics to acquire the data base for interannual variability of atmospheric forcing, sea-ice processes and ocean transport, mixing and nutrient distributions, and the resultant distribution and magnitude of production. U.S.S.R., Canada, Japan and NSF will collaborate.

Modeling of ocean-ice coupled circulation

- ICE

Preliminary analysis of historical data set for atmospheric variability

NSF:

Synthesis of historical data

- Under ARCSS, continue synthesis of previous oceanographic studies, especially ISHTAR.

Pilot studies of primary productivity and biogeochemical cycling

- Under ARCSS, focus on sub-ice, neritic and benthic communities within the annual ice edge zone.
- Coordinated moored sensors and regional studies and transects to extend measurements into the Soviet region of the Bering and Chukchi seas.

NASA:

Processing and distribution of passive-microwave data (at NSIDC) and of SAR data on ice type distribution and motion (at the Alaska SAR Facility)

- Initial emphasis will be on refining algorithms and supporting research to demonstrate and verify applications of the SAR data.

DOI/MMS:

Field surveys and refinement of circulation model of the eastern Bering shelf

DOI/FWS:

Distribution and productivity of polar bears

- Distribution relative to ice movement and ringed seal abundance, as well as to physical and biological factors, including factors contributing to reproductive success.

Distribution of walrus

- Ongoing studies of walrus population distributions and behavior.

Arctic Ocean

DOC/NOAA:

Initial measurements of ice thickness, currents, sedimentation and hydrography off Beaufort Sea shelf

- Established single Arctic Ocean climate monitoring station (long-term fixed mooring) in FY 1990 in conjunction with IOS/Canada.
- Observations will be continued in FY 1991.

DOD/ONR:

Field studies of winter leads

- Under the DOD/ONR Leads program initiated in FY 1990, examine the mechanics and patterns of lead formation in response to applied stress fields, the atmospheric and oceanic dynamics associated with individual leads, and the properties and structure of recently generated ice.

NSF:

Field and analysis program on atmospheric, sea ice and oceanographic variations and controls in the Basin

- Conduct joint U.S.–U.S.S.R. transpolar cruise.
- Participate in IAOE–1991; physical and chemical oceanography.

NASA:

Processing and distribution of passive-microwave data (at NSIDC) and of SAR data on ice type, distribution and motion at the Alaska SAR Facility

Research to estimate energy mass and salt fluxes at the ocean/ice/atmosphere interfaces, develop realistic models to describe these fluxes, and incorporate these models into GCMs

DOI/MMS:

Continued monitoring of whale migrations and assessment of leads to bowheads; continued monitoring of Beaufort Sea waterfowl and marine birds; study polar bear densities around oil and gas facilities

DOI/FWS:

Distribution of polar bears

- Track polar bears in the Arctic Ocean to examine the long-term exchange of individuals with populations in the Chukchi and Bering seas.

Phase II: Planned Agency Contributions

Bering Sea

DOC/NOAA: *Continuation of FOCI with field surveys; application of biological and chemical techniques to determine spawning origin, mixing and recruitment success of pollock populations from the central Bering; analysis and integration of biological and physical data to determine factors affecting recruitment success*

NSF: *Participation in polynya and other oceanographic research based on funding of peer-reviewed proposals*

NASA: *Planned launch of SeaWiFS to provide an opportunity to acquire synoptic estimates of ocean productivity*

DOI/MMS: *Continuation of Phase I studies*

DOI/FWS: *Continuation of development and evaluation of census methods for walrus*

- Enhanced cooperation with Soviet scientists seeks to standardize survey methods and data handling to provide more comprehensive information on regional populations and trends.

Continuation of investigations of movements and subpopulations of polar bears

- Collection of additional data on long-term movements and further development of biochemical and genetic indicators of subpopulations will enable better assessment of information needed for managing populations.

Future Cooperative Program Elements:

Expansion of field surveys sufficient to define the spatial and temporal variability in circulation
Regional climatology to determine the principal atmospheric and oceanographic forcing of the variable circulation in the Bering
Primary and secondary production and its relationship to sea ice dynamics
Processes controlling the transfer of energy between trophic levels and the sequestration/export of carbon from the Bering shelf
Coupled modeling of physical dynamics and ecosystem interactions

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Northern Bering/Chukchi Shelf

DOC/NOAA: *Field surveys of physical parameters and circulation on the Chukchi shelf*

- Intensive spring and summer field campaigns under ICE, collaborative with the U.S.S.R.

Modeling of sea ice physics

- Continuation under ICE, with application of SAR data.

NSF: *Expansion of field measurements of particle flux, chlorophyll and chemical parameters with emphasis on Bering Sea–Chukchi Sea transition*

- ARCSS will support moored arrays and expanded cruise transects to examine temporal and spatial variability of biogeochemical processes and variables.

Development and improvement of coupled models

- ARCSS

NASA: *Processing and distribution of passive-microwave and SAR data on ice type distribution and motion*

DOI/MMS: *Continuation of studies of sea ice, pollutant transport, living resources, endangered species, oil-spill and transportation effects, and marine and anadromous fisheries*

DOI/FWS: *Expansion of polar bear and sea bird studies along Soviet coasts*

- Access to Soviet coastal areas to examine reproductive success of polar bears to provide information needed for managing regional populations; access to important breeding or stopover sites for shared geese populations and data sharing with Soviet scientists to provide important information on resources needed by these populations.

Expansion of biological sampling and measurements of primary production to define spatial and temporal variability and off-shelf component
Monitoring of ice thickness and ice deformation
Process studies of ice thermodynamics
Integration of SAR data into regional ice models
Higher trophic level dynamics

Arctic Ocean

DOC/NOAA: *Field studies of atmospheric variability and effects on ice deformation*
- Participate in DOD/ONR Leads program to examine the mechanics and patterns of lead formation in response to atmospheric stress, and the effect of leads on atmospheric dynamics and the flux of heat and momentum.

DOD/ONR: *Process studies of atmosphere–ocean exchange associated with leads*
- Leads

NSF: *Extension of ARCSS studies of atmosphere–ice–ocean processes and related modeling*

NASA: *Processing and distribution of passive-microwave and SAR data on ice type, distribution and motion*
Research to estimate energy, mass and salt fluxes at the ocean/ice/atmosphere interfaces, develop realistic models to describe these fluxes, and incorporate these models into GCMs

DOI/MMS *Continuation of long-term observational studies and ecosystem studies in Kasegaluk Lagoon and the Beaufort Sea; continuation of studies of Arctic marine and anadromous fisheries*

DOI/FWS: *Extension of polar bear studies*
- Enhance the base of information on Arctic Ocean populations to help determine the relative contributions of land- and ice-based maternity dens to recruitment; expected increases in the longitudinal data base on movements to aid in quantifying mixing between Arctic Ocean and other populations.

Multiagency: *Monitoring of ice movement and surface pressure field*
- Support of Arctic drifting ice buoy network with international collaboration.

Future Cooperative Program Elements:
Proposed coordinated transpolar expedition in the summer of 1993 with a U.S. Coast Guard icebreaker and the Canadian icebreaker Louis St. Laurent *to obtain oceanographic and geophysical sections across the Arctic Ocean*
Process studies of circulation dynamics on the continental slope
Continuous ocean and ice monitoring for spatial and temporal variability in ice thickness, upper ocean structure, circulation, water column sediment flux
Determination of the implication of Leads process studies for the western Arctic (regional scale)—the consequences for mixed layer, atmospheric circulation
Coupled air–ice–ocean circulation modeling to look at coupling between higher and lower latitudes

Arctic Monitoring

Existing and Planned Agency Contributions

EPA: An Alaskan pilot program initiated in summer 1990 will continue to evaluate the nature, extent and effects of exposure of Arctic ecosystems on a regional scale to atmospheric contaminants.

NSF: Activities include long-term observations at the Fairbanks and Toolik LTER sites in Alaska, specific process-related research including development of research contributing to the International Tundra Experiment (ITEX), and oceanographic measurements (ARCSS and related programs).

USDA/FS: Activities include long-term monitoring of regional snow and stream conditions; physical and chemical environment, vegetation and soil parameters on the Bonanza Creek Experimental Forest LTER site; monitoring of timber harvest and placer mining effects, prescribed fire effects on hydrologic regimes, and stream sedimentation on water quality on Caribou–Poker Creeks Research Watershed; and further development of inventories of total carbon storage and vegetation vigor and health.

DOE: Ongoing activities include radionuclide monitoring at Barrow, Alaska, and Thule and Constable Point, Greenland; plant effects from CO_2 enhancement; and dynamics of disturbed ecosystems (R4D program) covering biogeochemical cycling in atmosphere and streams into tundra vegetation and soils.

DOC/NOAA: Within the National Status and Trends network, triennial sampling of sediments, fish and shellfish is conducted along the Bering, Chukchi and Beaufort sea coasts to determine trends in contaminant concentrations. The marine mammal tissue archive program extant in Alaska, sponsored by MMS and carried out by NOAA OCSEAP, is maintained in conjunction with the National Institute of Standards and Technology to provide a baseline for tissue contaminant concentration. Annual, triennial and special-purpose surveys of marine mammals and Bering Sea groundfish and shellfish are conducted. The GMCC atmospheric monitoring station at Barrow, Alaska, measures carbon dioxide, ozone, CFCs, nitrous oxide, methane and other trace constituents. NOAA collects, archives, processes and distributes data from operational earth-observing satellites and supports the National Geophysical Data Center activities to maintain and distribute snow and ice data sets and products. In conjunction with the DOD/Navy, models and work station technology are developed to improve sea ice analysis and forecasting by the Joint Ice Center (JIC). A SAR communications link is being established to bring ERS-1, JERS-1 and Canadian RADARSAT data in near-real time to the JIC. A tide station is operated at Prudhoe Bay, and new technology for measuring tides in polar regions is being developed. Support is provided along with other agencies for the international Arctic drifting ice buoy network.

NASA: Activities include continuing development of data systems at the NSIDC, using passive-microwave data to measure sea-ice extent and concentration; at Goddard Space Flight Center, using radar-altimetry data to measure ice-sheet surface topography and changes in surface elevation; and at the Alaska SAR Facility using SAR data to determine detailed characteristics of the ice and land surface, including sea-ice concentration, type and motion.

DOD/NAVY: The Department of the Navy (Oceanographer of the Navy) continues to modernize and improve its sea ice analysis and forecasting capabilities at the Navy/NOAA Joint Ice Center through the development of the Digital Ice Forecasting and Analysis System (DIFAS), the Polar Ice Prediction System (PIPS) ice forecasting model, and a communications link between the U.S. and Canadian ice centers for the routine exchange of sea ice and iceberg data and products. Data are obtained to measure sea ice extent, elevation and drift using the Defense Meteorological Satellite Program, Special Sensor Microwave/Imager (SSM/I), Geosat follow-on and TOPEX/Poseidon, and Arctic drifting buoys.

DOD/CRREL: Data are acquired from selected northern locations on climate, snow and vegetation covers, hydrologic balance and permafrost.

DOI/NPS: A program of inventory and monitoring is being implemented for Alaskan parks, including population dynamics of selected animal species, occurrence and nature of natural fires, characteristics of soil thaw, water and air quality, wet and dry deposition of airborne contaminants, and climatic parameters.

DOI/FWS: Activities include baseline contaminants studies along the Arctic coastline and on northern Alaska wildlife refuges, including trace metals, organochlorine pesticides and hydrocarbons in sediments, water, invertebrates, birds and Arctic foxes; contaminants studies at reserve pits and on offshore discharge in the Prudhoe Bay area; and studies of terrestrial mammals, waterfowl, fishery resources, other wildlife, and habitat interrelationships.

DOI/MMS: Several multiyear, multidisciplinary projects monitor the marine and coastal ecosystems and the human environment to detect changes resulting from offshore oil and gas development activities, including monitoring seabird, whale and ringed seal populations in the Beaufort and Chukchi seas, periodic sampling and chemical analysis (heavy metals and petroleum hydrocarbons) of marine sediments and organisms in the Beaufort Sea, and monitoring socioeconomic and sociocultural changes in selected Alaskan communities.

DOI/USGS: Activities include monitoring surface and ground water quality and quantity; monitoring representative Alaskan glaciers and permafrost ground temperature at selected stations; operating the seismic observatory (Barrow); conducting mineral assessments and studies on earthquakes and volcanoes; and maintaining the AEDD and numerous map and photographic inventories.

DOI/BLM: Existing monitoring activities include impacts of human activities on public lands, changes in these impacts due to mitigation measures imposed by management, and changes in habitats of various wildlife and fisheries species.

Bering Land Bridge Program

Existing and Planned Agency Contributions

DOI/NPS: The National Park Service is the lead agency for the Beringian Heritage International Park and cultural resource management in this region. NPS archaeologists, anthropologists and natural scientists will collaborate with university researchers in the U.S. and institutions in the U.S.S.R. Support is available for Native heritage studies, museum development and exchange of personnel.

NSF: The National Science Foundation's Arctic Social Sciences program can support university-based research in archaeology, anthropology, ethnography and related subjects. NSF can also promote multidisciplinary projects involving human–environmental interactions, earth sciences, ecology and global change.

SI: The Smithsonian Institution's Arctic Studies Program can focus resources on the Bering region through field projects, archival and museum collections and exhibits such as *Crossroads of the Continents*. Coordination with other SI programs in paleobotany, geology and natural history is central to the Bering research program.

DOI/BIA: The Bureau of Indian Affairs input focuses on education, communication and Native programs. Support is also provided for archaeological and anthropological research.

DOI/MMS: The Minerals Management Service has had a major commitment to baseline studies and research on the socioeconomic impacts of offshore gas and oil development on contemporary societies in this region of Arctic Alaska.

DOI/BLM: The Bureau of Land Management, like the NPS, is concerned with cultural resource management and cultural historical analysis through archaeology and anthropology, as well as subsistence studies.

DOC/NOAA: The National Oceanic and Atmospheric Administration supports research on social and cultural change relating to marine resources, economic policies and maritime communities. The Bering region is an area of special interest because of the rich fish and sea mammal resources, which still are a major basis for settlement. Sea Grant programs support state and university research.

Appendix C: Third Biennial Report of the Interagency Arctic Research Policy Committee to the Congress

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.

IV.C. ENHANCING RESEARCH AND EXPANDING THE HUMAN FRONTIER

Reprint of pages Two–35 through Two–76 of the *Budget of the United States Government, Fiscal Year 1992*

One area that has received special emphasis is Arctic research, though U.S. activities in the Arctic go beyond the range of programs included in the USGCRP.

U.S. policy in the Arctic consists of four elements: protection of essential security interests; support for sound, rational development of the region; promotion of scientific research contributing to knowledge about the Arctic; and promotion of mutually beneficial international cooperation in the Arctic. Federal Arctic research is guided by a 5-year research plan developed by the Interagency Arctic Research Policy Committee (IARPC) (in consultation with the Presidentially-appointed Arctic Research Commission and other interested groups) and updated biennially.

The budget includes $134 million for Arctic research, an increase of about $12 million over the 1991 level. Activities included in the USGCRP account for approximately 50 percent of this increase. Within the total for 1992, $60 million is proposed to implement the four integrated programs covering the western Arctic: oceans research, geodynamics, studies of the Bering Sea and land mass, and monitoring and data collection activities. Approximately $6 million of this amount is for ship and aircraft support in five agencies, NSF, Transportation, NOAA, Interior, and DOD/Navy. These programs support bilateral and multilateral environmental, space, oceans, and social science agreements and cooperative activities.

Table C–17. **UNDERSTANDING THE ARCTIC**

(Dollar amounts in millions)

Category	Budget Authority			
	1991 Enacted	1992 Proposed	Dollar change	Percent change
Resource development[1]	49	56	+7	+14
Arctic as laboratory[2]	48	50	+2	+4
National security[3]	25	28	+3	+12
Total	122	134	+12	+10

[1]Includes the Departments of Interior, Commerce, Agriculture, Energy, Transportation, State, and the Environmental Protection Agency.

[2]Includes the Department of Health and Human Services, and the National Aeronautics and Space Administration, the National Science Foundation, and the Smithsonian Institution.

[3]Includes the Department of Defense. The 1991 enacted level includes a one-time increase for Defense of about $13 million specifically for upper atmosphere research and associated facilities, including the High Frequency Active Auroral Research Program (HAARP). For the purposes of comparison with 1992 levels, this funding has been excluded.

Appendix E: Arctic Research Budgets of Federal Agencies

Dept/ Agency	Program Name	CAT	ELEMENT C	FY90 actual	FY91 estimate	FY92 proposed
				(thousands of dollars)		
DOD	Arctic Engineering	S	L	3,510	3,980	3,530
DOD	Permafrost/Frozen Ground	S	L	1,300	1,370	1,400
DOD	Snow and Ice Hydrology	S	L	3,370	3,680	3,480
DOD	Oceanography	S	O	9,760	10,160	12,590
DOD	Lower Atmosphere	S	A	1,630	1,610	1,480
DOD	Upper Atmosphere	S	A	3,800	3,630	4,220
DOD	Medical and Human Engr	S	H	1,170	770	1,390
	total.....			24,540	25,200	28,090
DOI/MMS	Technology Assessment/Research	R	O	1,700	2,100	4,400
DOI/MMS	Environmental Studies	R	O	5,200	5,200	5,200
DOI/USGS	Energy and Minerals	R	L	2,534	2,534	2,534
DOI/USGS	Natural Hazards	R	L	1,209	1,209	1,209
DOI/USGS	Ice and Climate	R	L	350	1,500	1,000
DOI/USGS	Hydrology	R	L	310	150	200
DOI/USGS	Glaciology and Quaternary	R	L	150	1,150	1,150
DOI/USGS	Marine Geology	R	O	980	500	500
DOI/USGS	Magnetosphere	R	A	25	25	25
DOI/USGS	Mapping	R	L	915	1,070	1,070
DOI/FWS	Marine Mammals	R	O	1,330	1,340	1,700
DOI/FWS	Migratory Birds	R	L/O	1,900	1,900	1,900
DOI/FWS	Fisheries Research	R	L	375	375	375
DOI/FWS	Cooperative Research	R	L	350	350	350
DOI/FWS	Terrestrial Ecology	R	L	1,075	1,075	1,100
DOI/BLM	National Wildlife Refuge	R	L	100	50	50
DOI/BLM	Habitat-Arctic	R	L	348	276	200
DOI/BLM	Habitat-Kobuk	R	L	372	259	409
DOI/BLM	Pipeline Studies	R	L	175	175	175
DOI/BLM	Fire Control	R	L	350	350	350
DOI/BLM	Nat Petro Reserve/Alaska	R	L	112	181	200
DOI/BLM	Minerals/Mining	R	L	360	456	500
DOI/BLM	Global Change	R	L	0	50	50
DOI/NPS	Cultural Resources	R	H	337	590	790
DOI/NPS	Natural Ecology	R	L	1,100	1,350	1,550
DOI/BIA	Cultural	R	H	1,700	1,700	1,700
DOI/BIA	Subsistence	R	H	1,075	750	750
DOI/BOM	Minerals	R	L	781	1,028	1,028
	total.....			25,213	27,693	30,465
NSF	Atmospheric Sciences (a)	L	A	7,264	7,400	7,400
NSF	Ocean Sciences/Ship Support (a)	L	O	3,134	3,200	3,300
NSF	Biological Sciences	L	L/O	1,988	2,000	2,100
NSF	Glaciology (a)	L	L	2,000	2,100	2,100
NSF	Earth Sciences	L	L	2,094	2,500	2,600
NSF	Arctic Systems Science (a)	L	O/L	5,300	7,600	9,400
NSF	Engineering	L	L	613	600	600
NSF	Social Science/Education	L	H	964	1,400	1,500
NSF	Coordination	L	C	247	270	270
NSF	Arctic Research Commission	L	C	485	497	535
	total.....			24,088	27,567	29,805

(a) includes major operational support $ 5.5 million/yr (avg)

Dept/ Agency	Program Name	CAT	ELEMENT	FY90	FY91	FY92
NASA	Polar Ocean/Ice Sheets	R	O	7,800	8,500	9,000
NASA	Land Processes	R	L	800	1,100	1,600
NASA	Solid Earth Science	R	L	1,200	1,200	1,200
NASA	Atmospheric Sciences	R	A	3,000	1,000	1,000
NASA	Arctic Ozone	R	A	1,000	2,500	7,500
NASA	Sounding Rocket Program	R	A	1,000	1,050	1,100
NASA	Dynamics Explorer	R	A	1,300	1,365	600
NASA	Space Plasma Research	R	A	850	895	895
NASA	Solar Terrestrial Theory	R	A	400	420	420
	total.....			17,350	18,030	23,315
DOC/NOAA	Arctic Haze	R	A	200	100	100
DOC/NOAA	Solar Terrestrial	R	A	250	250	250
DOC/NOAA	Atmos Trace Constituents	R	A	180	180	180
DOC/NOAA	Climate Modeling	R	A	300	300	300
DOC/NOAA	Environmental Prediction	R	A	735	810	1,065
DOC/NOAA	Fisheries Assessment	R	O	1,900	1,900	2,400
DOC/NOAA	Marine Mammal Assessment	R	O	1,200	1,200	1,200
DOC/NOAA	Sea Grant	R	O	150	260	170
DOC/NOAA	Ocean Assessment	R	O	150	150	160
DOC/NOAA	Stratospheric Ozone	R	A	400	400	1,000
DOC/NOAA	Arctic Ecosystems	R	O	390	1,890	1,890
DOC/NOAA	Data Management	R	O	437	1,161	1,415
DOC/NOAA	Human Resources	R	H	366	619	679
DOC/NOAA	Aircraft/Vessels	R	O	1,102	1,928	2,805
DOC/NOAA	Global Change	R	A/O	768	1,718	2,000
	total.....	R		8,528	12,866	15,614
DOE	Ecosystem Response	R	L	1,574	1,298	1,300
DOE	Response to Carbon Dioxide	R	L	532	444	444
DOE/FE	Gas Hydrates	R	L	183	200	0
DOE	Aurora	R	A	140	140	140
	total.....			2,429	2,082	1,884
DHHS	Indian Health Service	L	H	250	250	250
DHHS	National Institutes of Health	L	H	1,770	1,850	1,850
DHHS	Communicable Disease Con. Ctr.	L	H	3,010	4,023	4,130
DHHS	ADAMHA	L	H	2,971	3,145	3,331
	total.....			8,001	9,268	9,561
SMITHSONIAN	Anthropology	L	H	555	630	630
SMITHSONIAN	Arctic Biology	L	L	75	75	75
	total.....			630	705	705
DOT/USCG	Int'l Ice Patrol	R	O	250	250	250
DOT/USCG	Test and Evaluation	R	O	0	0	430
DOT/USCG	Extramural Support	R	O	55	55	55
	total.....			305	305	735
EPA	Arctic Research Program (ALERT)	R	L	250	250	1,000
EPA	High Latitude Methane	R	L	250	250	250
	total.....			500	500	1,250
AGRICULTURE	Forest Service	R	L	1,013	1,147	1,150
AGRICULTURE	Agricultural Research Service	R	L	778	778	778
AGRICULTURE	Cooperative State Res Service	R	L	1,197	1,247	1,275
AGRICULTURE	Soil Conservation Service	R	L	974	980	980
	total.....	R		3,962	4,152	4,183
STATE	MAB: Arctic Directorate	R	L	20	60	60
GRAND TOTALS	----------			115,566	128,428	145,667

CAT: S=National Security, R=Resource Development, L=Arctic as Laboratory

Appendix F: Arctic Research and Policy Act, As Amended

PUBLIC LAW 98-373 - July 31, 1984; amended as
PUBLIC LAW 101-609 - November 16, 1990

An Act

To provide for a comprehensive national policy dealing with national research needs and objectives in the Arctic, for a National Critical Materials Council, for development of a continuing and comprehensive national materials policy, for programs necessary to carry out that policy, including Federal programs of advanced materials research and technology, and for innovation in basic materials industries, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:

TITLE 1-ARCTIC RESEARCH AND POLICY

SHORT TITLE

SEC. 101. This title may be cited as the "Arctic Research and Policy Act of 1984, as amended".

FINDINGS AND PURPOSES

SEC. 102.(a) The Congress finds and declares that--

(1) the Arctic, onshore and offshore, contains vital energy resources that can reduce the Nation's dependence on foreign oil and improve the national balance of payments;

(2) as the Nation's only common border with the Soviet Union, the Arctic is critical to national defense;

(3) the renewable resources of the Arctic, specifically fish and other seafood, represent one of the Nation's greatest commercial assets;

(4) Arctic conditions directly affect global weather patterns and must be understood in order to promote better agricultural management throughout the United States;

(5) industrial pollution not originating in the Arctic region collects in the polar air mass, has the potential to disrupt global weather patterns, and must be controlled through international cooperation and consultation;

(6) the Arctic is a natural laboratory for research into human health and adaptation, physical and psychological, to climates of extreme cold and isolation and may provide information crucial for future defense needs;

(7) atmospheric conditions peculiar to the Arctic make the Arctic a unique testing ground for research into high latitude communications, which is likely to be crucial for future defense needs;

(8) Arctic marine technology is critical to cost-effective recovery, and transportation of energy resources and to the national defense;

(9) the United States has important security, economic, and environmental interests in developing and maintaining a fleet of icebreaking vessels capable of operating effectively in the heavy ice regions of the Arctic;

(10) most Arctic-rim countries, particularly the Soviet Union, possess Arctic technologies far more advanced than those currently available in the United States;

(11) Federal Arctic research is fragmented and uncoordinated at the present time, leading to the neglect of certain areas of research and to unnecessary duplication of effort in other areas of research;

(12) improved logistical coordination and support for Arctic research and better dissemination of research data and information is necessary to increase the efficiency and utility of national Arctic research efforts;

(13) a comprehensive national policy and program plan to organize and fund currently neglected scientific research with respect to the Arctic is necessary to fulfill national objectives in Arctic research;

(14) the Federal Government, in cooperation with State and local governments, should focus its efforts on the collection and characterization of basic data related to biological, materials, geophysical, social, and behavioral phenomena in the Arctic;

(15) research into the long-range health, environmental, and social effects of development in the Arctic is necessary to mitigate the adverse consequences of that development to the land and its residents;

(16) Arctic research expands knowledge of the Arctic, which can enhance the lives of Arctic residents, increase opportunities for international cooperation among Arctic-rim countries, and facilitate the formulation of national policy for the Arctic; and

(17) the Alaskan Arctic provides an essential habitat for marine mammals, migratory waterfowl, and other forms of wildlife which are important to the Nation and which are essential to Arctic residents.

(b) The purposes of this title are--

(1) to establish national policy, priorities, and goals and to provide a Federal program plan for basic and applied scientific research with respect to the Arctic, including natural resources and materials, physical, biological and health sciences, and social and behavioral sciences;

(2) to establish an Arctic Research Commission to promote Arctic research and to recommend Arctic research policy;

(3) to designate the National Science Foundation as the lead agency responsible for implementing Arctic research policy; and

(4) to establish an Interagency Arctic Research Policy Committee to develop a national Arctic research policy and a five year plan to implement that policy.

ARCTIC RESEARCH COMMISSION

SEC. 103. (a) The President shall establish an Arctic Research Commission (hereinafter referred to as the "Commission").

(b)(1) The Commission shall be composed of seven members appointed by the President, with the Director of the National Science Foundation serving as a nonvoting, ex officio member. The members appointed by the President shall include--

(A) four members appointed from among individuals from academic or other research institutions with expertise in areas of research relating to the Arctic, including the physical, biological, health, environmental, social and behavioral sciences;

(B) one member appointed from among indigenous residents of the Arctic who are representative of the needs and interests of

Arctic residents and who live in areas directly affected by Arctic resource development; and

(C) two members appointed from among individuals familiar with the Arctic and representative of the needs and interests of private industry undertaking resource development in the Arctic.

(2) The President shall designate one of the appointed members of the Commission to be chairperson of the Commission.

(c)(1) Except as provided in paragraph (2) of this subsection, the term of office of each member of the Commission appointed under subsection (b)(1) shall be four years.

(2) Of the members of the Commission originally appointed under subsection (b)(1)--

(A) one shall be appointed for a term of two years;

(B) two shall be appointed for a term of three years; and

(C) two shall be appointed for a term of four years.

(3) Any vacancy occurring in the membership of the Commission shall be filled, after notice of the vacancy is published in the Federal Register, in the manner provided by the preceding provisions of this section, for the remainder of the unexpired term.

(4) A member may serve after the expiration of the member's term of office until the President appoints a successor.

(5) A member may serve consecutive terms beyond the member's original appointment.

(d)(1) Members of the Commission may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code. A member of the Commission not presently employed for compensation shall be compensated at a rate equal to the daily equivalent of the rate for GS-18 of the General Schedule under section 5332 of title 5, United States Code, for each day the member is engaged in the actual performance of his duties as a member of the Commission, not to exceed 90 days of service each year. Except for the purposes of chapter 81 of title 5 (relating to compensation for work injuries) and chapter 171 of title 28 (relating to tort claims), a member of the Commission shall not be considered an employee of the United States for any purpose.

(2) The Commission shall meet at the call of its Chairman or a majority of its members.

(3) Each Federal agency referred to in section 107(b) may designate a representative to participate as an observer with the Commission. These representatives shall report to and advise the Commission on the activities relating to Arctic research of their agencies.

(4) The Commission shall conduct at least one public meeting in the State of Alaska annually.

DUTIES OF THE COMMISSION

SEC. 104. (a) The Commission shall--

(1) develop and recommend an integrated national Arctic research policy;

(2) in cooperation with the Interagency Arctic Research Policy Committee established under section 107, assist in establishing a national Arctic research program plan to implement the Arctic research policy;

(3) facilitate cooperation between the Federal Government and State and local governments with respect to Arctic research;

(4) review Federal research programs in the Arctic and recommend improvements in coordination among programs;

(5) recommend methods to improve logistical planning and support for Arctic research as may be appropriate and in accordance with the findings and purposes of this title;

(6) recommend methods for improving efficient sharing and dissemination of data and information on the Arctic among interested public and private institutions;

(7) offer other recommendations and advice to the Interagency Committee established under section 107 as it may find appropriate;

(8) cooperate with the Governor of the State of Alaska and with agencies and organizations of that State which the Governor may designate with respect to the formulation of Arctic research policy;

(9) recommend to the Interagency Committee the means for developing international scientific cooperation in the Arctic; and

(10) not later than January 31, 1991, and every 2 years thereafter, publish a statement of goals and objectives with respect to Arctic research to guide the Interagency Committee established under section 107 in the performance of its duties.

(b) Not later than January 31 of each year, the Commission shall submit to the President and to the Congress a report describing the activities and accomplishments of the Commission during the immediately preceding fiscal year.

COOPERATION WITH THE COMMISSION

SEC. 105. (a)(1) The Commission may acquire from the head of any Federal agency unclassified data, reports, and other nonproprietary information with respect to Arctic research in the possession of the agency which the Commission considers useful in the discharge of its duties.

(2) Each agency shall cooperate with the Commission and furnish all data, reports, and other information requested by the Commission to the extent permitted by law; except that no agency need furnish any information which it is permitted to withhold under section 522 of title 5, United States Code.

(b) With the consent of the appropriate agency head, the Commission may utilize the facilities and services of any Federal agency to the extent that the facilities and services are needed for the establishment and development of an Arctic research policy, upon reimbursement to be agreed upon by the Commission and the agency head and taking every feasible step to avoid duplication of effort.

(c) All Federal agencies shall consult with the Commission before undertaking major Federal actions relating to Arctic research.

ADMINISTRATION OF THE COMMISSION

SEC. 106. The Commission may--

(1) in accordance with the civil service laws and subchapter III of chapter 53 of title 5, United States Code, appoint and fix the compensation of an Executive Director and necessary additional staff personnel, but not to exceed a total of seven compensated personnel;

(2) procure temporary and intermittent services as authorized by section 3109 of title 5, United States Code;

(3) enter into contracts and procure supplies, services and personal property;

(4) enter into agreements with the General Services Administration for the procurement of necessary financial and administrative services, for which payment shall be made by reimbursement from funds of the Commission in amounts to be agreed upon by the Commission and the Administrator of the General Services Administration; and

(5) appoint, and accept without compensation the services of, scientists and engineering specialists to be advisors to the

Commission. Each advisor may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code. Except for the purposes of chapter 81 of title 5 (relating to compensation for work injuries) and chapter 171 of title 28 (relating to tort claims) of the United States Code, an advisor appointed under this paragraph shall not be considered an employee of the United States for any purpose.

LEAD AGENCY AND INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

SEC. 107. (a) The National Science Foundation is designated as the lead agency responsible for implementing Arctic research policy, and the Director of the National Science Foundation shall insure that the requirements of section 108 are fulfilled.

(b)(1) The President shall establish an Interagency Arctic Research Policy Committee (hereinafter referred to as the "Interagency Committee").

(2) The Interagency Committee shall be composed of representatives of the following Federal agencies or offices:

(A) the National Science Foundation;
(B) the Department of Commerce;
(C) the Department of Defense;
(D) the Department of Energy;
(E) the Department of the Interior;
(F) the Department of State;
(G) the Department of Transportation;
(H) the Department of Health and Human Services;
(I) the National Aeronautics and Space Administration;
(J) the Environmental Protection Agency; and
(K) any other agency or office deemed appropriate.

(3) The representative of the National Science Foundation shall serve as the Chairperson of the Interagency Committee.

DUTIES OF THE INTERAGENCY COMMITTEE

SEC. 108. (a) The Interagency Committee shall--

(1) survey Arctic research conducted by Federal State, and local agencies, universities, and other public and private institutions to help determine priorities for future Arctic research, including natural resources and materials, physical and biological sciences, and social and behavioral sciences;

(2) work with the Commission to develop and establish an integrated national Arctic research policy that will guide Federal agencies in developing and implementing their research programs in the Arctic;

(3) consult with the Commission on-

(A) the development of the national Arctic research policy and the 5-year plan implementing the policy;

(B) Arctic research programs of Federal agencies;

(C) recommendations of the Commission on future Arctic research; and

(D) guidelines for Federal agencies for awarding and administering Arctic research grants;

(4) develop a 5-year plan to implement the national policy, as provided in section 109;

(5) provide the necessary coordination, data, and assistance for the preparation of a single integrated, coherent, and multiagency budget request for Arctic research as provided for in section 110;

(6) facilitate cooperation between the Federal Government and State and local governments in Arctic research, and recommend the undertaking of neglected areas of research in accordance with the findings and purposes of this title;

(7) coordinate and promote cooperative Arctic scientific research programs with other nations, subject to the foreign policy guidance of the Secretary of State;

(8) cooperate with the Governor of the State of Alaska in fulfilling its responsibilities under this title;

(9) promote Federal interagency coordination of all Arctic research activities, including-

(A) logistical planning and coordination; and

(B) the sharing of data and information associated with Arctic research, subject to section 552 of title 5, United States Code; and

(10) provide public notice of its meetings and an opportunity for the public to participate in the development and implementation of national Arctic research policy.

(b) Not later than January 31, 1986, and biennially thereafter, the Interagency Committee shall submit to the Congress through the President, a brief, concise report containing-

(1) a statement of the activities and accomplishments of the Interagency Committee since its last report; and

(2) a statement detailing with particularity the recommendations of the Commission with respect to Federal interagency activities in Arctic research and the disposition and responses to those recommendations.

5-YEAR ARCTIC RESEARCH PLAN

SEC. 109. (a) The Interagency Committee, in consultation with the Commission, the Governor of the State of Alaska, the residents of the Arctic, the private sector, and public interest groups, shall prepare a comprehensive 5-year program plan (hereinafter referred to as the "Plan") for the overall Federal effort in Arctic research. The Plan shall be prepared and submitted to the President for transmittal to the Congress within one year after the enactment of this Act and shall be revised biennially thereafter.

(b) The Plan shall contain but need not be limited to the following elements:

(1) an assessment of national needs and problems regarding the Arctic and the research necessary to address those needs or problems;

(2) a statement of the goals and objectives of the Interagency Committee for national Arctic research;

(3) a detailed listing of all existing Federal programs relating to Arctic research, including the existing goals, funding levels for each of the 5 following fiscal years, and the funds currently being expended to conduct the programs;

(4) recommendations for necessary program changes and other proposals to meet the requirements of the policy and goals as set forth by the Commission and in the Plan as currently in effect; and

(5) a description of the actions taken by the Interagency Committee to coordinate the budget review process in order to ensure interagency coordination and cooperation in (A) carrying out Federal Arctic research programs, and (B) eliminating unnecessary duplication of effort among these programs.

COORDINATION AND REVIEW OF BUDGET REQUESTS

SEC. 110. (a) The Office of Science and Technology Policy shall--

(1) review all agency and department budget requests related to the Arctic transmitted pursuant to section 108(a)(5), in accordance with the national Arctic research policy and the 5-year program under section 108(a)(2) and section 109, respectively; and

(2) consult closely with the Interagency Committee and the Commission to guide the Office of Technology Policy's efforts.

(b)(1) The Office of Management and Budget shall consider all Federal agency requests for research related to the Arctic as one integrated, coherent, and multiagency request, which shall be reviewed by the Office of Management and Budget prior to submission of the President's annual budget request for its adherence to the Plan. The Commission shall, after submission of the President's annual budget request, review the request and report to Congress on adherence to the Plan.

(2) The Office of Management and Budget shall seek to facilitate planning for the design, procurement, maintenance, deployment and operations of icebreakers needed to provide a platform for Arctic research by allocating all funds necessary to support icebreaking operations, except for recurring incremental costs associated with specific projects, to the Coast Guard.

AUTHORIZATION OF APPROPRIATIONS; NEW SPENDING AUTHORITY

SEC. 111. (a) There are authorized to be appropriated such sums as may be necessary for carrying out this title.

(b) Any new spending authority (within the meaning of section 401 of the Congressional Budget Act of 1974) which is provided under this title shall be effective for any fiscal year only to such extent or in such amounts as may be provided in appropriation Acts.

DEFINITION

SEC. 112. As used in this title, the term "Arctic" means 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.

Appendix G: Principles for the Conduct of Research in the Arctic

Prepared for the Social Science Task Force of the U.S. Interagency Arctic Research Policy Committee and approved by the Polar Research Board on June 15, 1988

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

Ninth Meeting
June 5, 1991

Committee Members or Agency Representatives Present: Walter E. Massey, Chairman, NSF; Eldon W. Ross, Department of Agriculture; Ned A. Ostenso, Department of Commerce; Grant Aufderhaar, Department of Defense; Helen McCammon, Department of Energy; W. Craig Vanderwagen, Department of Health and Human Services; Harlan Watson, Department of Interior; Curtis Bohlen, Department of State; Erich W. Bretthauer, Environmental Protection Agency; Norine J. Noonan, Office of Management and Budget; William Fitzhugh, Smithsonian Institution.

Chairman Walter Massey convened this open meeting at 3:30 pm. He noted that he has reviewed the activities of the Committee and its progress in planning and coordinating Arctic research. He stated that as the new Director of NSF he is looking forward to chairing the Committee and serving on the Arctic Research Commission.

He reported on his meeting with Dr. Juan Roederer, Chairman of the Arctic Research Commission, on May 29 and that he (Dr. Massey) plans to participate in the Commission meeting in Alaska in August. After introductions of agency representatives, Dr. Massey began the meeting with a brief information item.

Senator Kerry, joined by Senators Stevens, Murkowski and Gore held an Arctic hearing on April 24, and Senator Gore held a related hearing on May 13. On May 16 a $20-million fund for Arctic research was introduced as part of the National Energy Security Act of 1991. After seven years since passage of ARPA, Congress is again showing active interest in the status of Federal Arctic research activities. The Interagency Committee should have a central role in these new developments.

The first formal agenda item was a report by Assistant Secretary of State Curtis Bohlen on the Arctic Environmental Protection Strategy, which is scheduled for approval in Finland the week of June 10, 1991. Mr. Bohlen described the negotiations leading up to the Strategy. It was concluded that IARPC agencies, which ultimately will be responsible for implementing many of the environmental protection and monitoring activities, should provide a formal statement of support for the Arctic Environmental Protection Strategy. The following statement was agreed to:

> IARPC recognizes the importance of the Arctic Environmental Protection Strategy. IARPC encourages agencies to support the Strategy's principles and related research and monitoring activities. The Committee agrees to coordinate the development of specific plans for U.S. participation during the next year.

After discussion and approval, Dr. Massey thanked Mr. Bohlen and his staff for their outstanding efforts in developing the U.S. position.

Report prepared by Charlie Myers, OPP.

Shere Abbott, Polar Research Board, presented a status report on the International Arctic Science Committee and its first Council meeting held in Oslo, Norway, in January 1991.

The review and approval of the Second Biennial Revision to the U.S. Arctic Research Plan was next on the agenda. The revision consists of two major sections: excerpts from the Strategy report and descriptions of the research missions of each agency. The Interagency Strategy Report had recently been transmitted to a number of Congressional committees. The major elements of these integrated programs are now incorporated into the Revision. The Revision is circulating within each agency for official approval. A final copy is required at the White House by late June in order to permit sufficient time for clearance and transmittal to Congress by July 31.

Prior to approval of the Revision, an addition to the U.S. Arctic Research Policy, originally formulated by this Committee in 1986, was agreed upon by adding "and transported contaminants" to the U.S. goals and objectives (see p. 7–8 of this issue).

The Committee approved the document in principle and the staff was authorized to make final editorial changes. (The full text of the Revision is presented in this issue of the journal.)

The section on Integrated Programs calls for the establishment of several implementation groups. Based on presentations of these groups, the Committee agreed on the scope of each major activity and provided specific instructions to the responsible groups as follows:

Robert Corell, NSF, reported for the Arctic Oceans/Atmosphere Working Group and presented plans to develop coordinated multiagency programs for the Bering–Chukchi–Beaufort Sea, including initial steps for an Arctic Basin geodynamics program and coordinate with PICES, a newly proposed Intergovernmental North Pacific Fisheries Program. The group will also establish an Arctic Logistics Plan.

Eric Bretthauer, EPA, discussed establishment of a working group on monitoring in support of the newly developed international Arctic Monitoring and Assessment Program to be cochaired initially by EPA and NOAA. Eldon Ross, Department of Agriculture, endorsed the need for the monitoring.

Harlan Watson, Department of Interior, dis-

cussed data and information activities and asked Doug Posson to report on the Arctic Environmental Data Directory (AEDD), CD-ROM and plans to integrate activities with the polar libraries. The Committee's request of June 1990 for interagency funding resulted in seven agencies contributing direct funding for the AEDD and CD-ROM activities of approximately $200,000 and includes EPA, Health and Human Services, Interior, NSF, Energy, Agriculture and Smithsonian. NOAA, NASA and Defense, although not contributing direct funding, are making available on-going data projects. These activities are to continue in 1992.

William Fitzhugh of the Smithsonian reported on behalf of the Social Science Task Force and specific Bering Land Bridge plans, including a 1992 symposium to be co-organized by the National Park Service, NSF and Smithsonian.

Dr. Massey requested that each working group report in writing to the Committee by December 1991. Summaries of these reports are to be included in the Committee's report to the President and Congress in January 1992.

Dr. Juan Roederer addressed the Committee on activities of the Arctic Research Commission. After Dr. Roederer's report, Dr. Massey thanked him for his dedicated efforts over the past $3^1/_2$ years in chairing the Commission and developing the guidance for U.S. Arctic research.

There had been no written requests from members of the public to make statements at this meeting. The meeting adjourned at 5:00 pm.

Arctic Research Commission

Commission Members Present: *Juan G. Roederer, Chairman, Jona H. Steele, Vice Chairman, Ben C. Gerwick; Oliver Leavitt; Elmer Rasmuson; Peter Wilkniss, representing the Ex-Officio Member*
Staff: *Philip L. Johnson, Executive Director; and Lyle D. Perrigo, Head, Alaska Office*
Commission Advisory Group: *Thomas F. Albert, David Hickok and Howard Thomas*
Visitors present: *Ruth Bean, Alaska Pacific University; Jerry Brown, National Science Foundation; Sal Cuccarese, AEIDC, University of Alaska; John Cook, Bureau of Land Management, DOI; Michael Crone, NOAA/NESDIS; Charlie Edwardson, Anchorage, Alaska; Victor Fischer, University of Alaska Anchorage; Patrick Flood, ARCO Alaska, Inc.; Doug Ford, Anchorage Times; Jerry Imm, Minerals Management Service, DOI; Norman Ingram, Alaska Clean Seas; Paul L. Lowry, Minerals Management Service, DOI; Bruce McKenzie, Alaska Clean Seas; Melvin Monsen, Jr., Alaska Fisheries Development Foundation; Ron Morriss, NOAA; Tom Murrell, Minerals Management Service, DOI; Bill Palmisano, U.S. Fish and Wildlife Service; Walt Parker, Parker Associates, Inc., Anchorage; Luis Proenza, President, ARCUS; Loren Rasmussen, Alaska Dept. of Transportation; Satoru Suzuki, Shimizu Corp., Tokyo, Japan; Marnie Sweet, Anchorage, Alaska; Dale Taylor, National Park Service; Randall Weiner, Trustees for Alaska*

Twenty-Second Meeting October 15–16, 1990

The Arctic Research Commission held its meeting in Anchorage, Alaska. Chairman Roederer reported on Commission activities since the previous meeting. He noted publication of three reports, *Arctic Engineering Research: Initial Findings; International Agreements for Research, Logistics and Access Concerning the Arctic* and *Corrosion of the Trans Alaska Pipeline System and Research Needs.* Roederer said he and the Executive Director conducted a very useful site visit to major U.S. research activities in Greenland in July.

Interagency Arctic Research Policy Committee (IARPC)

Peter Wilkniss observed that Erich Bloch's retirement as NSF Director was a loss to Arctic science. He noted that the Commission's 1986 initiative in San Diego had led to the creation of the International Arctic Science Committee in August 1990. Ted DeLaca has been assigned responsibility within NSF for the Arctic System Science program. Wilkniss stated that the pending closure of the U.S. Air Force base at Sondrestrom in Greenland is likely to double the cost of U.S. research there but may force more international cooperation. He also described his voyage to the North Pole in August aboard the Soviet nuclear icebreaker *Rossiya.*

Jerry Brown reported that IARPC has decided to develop an expanded budget crosscut analysis of the Arctic research programs and has defined four areas of multiagency collaboration as the focus of this analysis: 1) the Arctic Ocean with emphasis on the western Arctic; 2) Arctic Basin geodynamics; 3) environmental monitoring and data management, building on the Arctic Environmental Data Directory with agency cost-sharing; and 4) the Beringian Heritage International Park. Brown reported that IARPC renewed the Social Science Task Force and adopted the Principles for the Conduct of Research in the Arctic. Brown acknowledged the loss of enthusiasm for Arctic research among some Federal agencies without funding increases for research, and the Commission discussed several ideas for research collaboration. Elmer Rasmuson and Oliver Leavitt suggested contacting the Alaska Federation of Natives for their ideas on research needs.

Alaska Congressional Delegation

Bruce Evans of Senator Murkowski's office reported on amendments to ARPA and noted the final bill included two significant changes from the original draft: a text change to include reporting requirement language agreed upon by IARPC, and deletion of the Commission's Advisor's exemption from the provisions of the Federal Advisory Committee Act. The amended ARPA legislation provides for appointment of two additional Commissioners, one from an academic or other research institution with expertise in areas of Arctic-related research and one from among individuals familiar with the Arctic and representative of the needs and interests of private industry undertaking resource development in the Arctic. Bruce Evans' report further noted that it is intended that ANWR be included in the Administration's national energy strategy. (P.L. 101-609 was signed by the President on November 16, 1990.)

Alaska Governor's Office

Lyle Perrigo reported that the Alaska Science and Engineering Advisory Commission is preparing a strategic plan for the State of Alaska for research and development,which will assist economic development.

Arctic Research Consortium of the United States (ARCUS)

Luis Proenza reported that the 21-member Consortium is planning to build a community of scientists for Arctic research. ARCUS proposes a two-phase program: phase 1 for data collection and interpretation tasks, and phase 2 for addressing assessment, planning and implementation needs defined in phase 1. Current thinking envisions a "university without walls."

Status of International Activities

Chairman Roederer reviewed activities leading to the signing of the Founding Articles for the International Arctic Science Committee (IASC) in Resolute, Canada, in August 1990. An invitation was made in Resolute for the U.S. to host the first Arctic Science Conference. A general discussion

followed addressing the need for an IASC budget and its oversight and how the Polar Research Board would coordinate with the broad scientific community. Phil Smith, in a conference call, said he thought the best coordination would occur on very specific ideas. Ben Gerwick urged that Arctic engineering research be included in IASC programs, pointing out the need to consider the adverse effects of many human activities.

Research and Development for Alaska's Commercial Fishery

Melvin Monsen, Alaska Fisheries Development Foundation, reported on private industry funding of research to improve the commercial fishing industry. He estimated that about $1 million of research activity was sponsored through AFDF, of which $300,000 represented direct cost sharing by industry.

Commission Goals Report

Chairman Roederer emphasized the importance of reviewing Arctic research priorities because of the changes that have occurred in the last two years. He suggested that the Commission formulate recommendations recognizing economic as well as environmental values. Peter Wilkniss said NSF had focused on doubling the amount of research funds available and succeeded in expanding Arctic research support from $8 million to $16 million over the past three years.

Chairman Roederer reviewed the recommendations and status of the environmental impact statement process. Elmer Rasmuson emphasized the importance of the Commission's recommendations to improve the EIS process to all development projects in Alaska and especially to oil exploration and production. Roederer discussed new priority research, including potential utilization of North Slope natural gas. He noted two important research issues regarding conversion of natural gas to electricity are 1) disposal of CO_2 and 2) the large quantities of heat produced at the generation plant. Chairman Roederer discussed the need for long-term environmental monitoring using modern technology. The need for monitoring biological populations and ecosystems was also noted.

Ben Gerwick asked that the oil spill engineering recommendation be given highest priority and visibility over other engineering recommendations. Tom Albert observed that the public hearing on October 15, 1990, demonstrated that several groups involved in oil spill investigations are not coordinated.

Public Meeting

A public meeting was convened to discuss research needs attending interactions among resource development, the economy and the environment. Expert witnesses reported on the following topics as the basis for the discussion:

Oil development plans—Patrick Flood, ARCO

Oil spill clean-up in ice-infested waters—Bruce McKenzie, Alaska Clean Seas; Tom Murrell and Jerry Imm, U.S. Minerals Management Service; Randall Weiner, Trustees for Alaska; Walter Parker, Alaska Oil Spill Commission; Charles Edwardson, Helo Corp.

Research on infrastructure degradation in the Arctic—Howard Thomas, American Society of Civil Engineers; Loran Rasmussen, Alaska Department of Transportation.

Alaska–Soviet research cooperation—Dale Taylor, National Park Service; Bill Palmissano, U.S. Fish and Wildlife Service.

Twenty-Third Meeting February 20–21, 1991

The Arctic Research Commission held its meeting in Washington, D.C. Chairman Roederer updated Commission activities since the October 1990 meeting, noting the transfer of administrative support services from the University of Alaska to the General Services Administration and the transfer of staff to Federal Civil Service. The Arctic Research and Policy Act amendment (P. L. 101-609) was signed by the President on November 16, 1990. The Commission published three reports during this period—*Logistic Support of United States Research in Greenland: Current Situation and Prospects; Goals, Objectives and Priorities to Guide United States Arctic Research* and the *1991 Annual Report to the President and the Congress*.

Alaska Congressional Delegation

Blair Thomas, office of Senator Frank Murkowski, stated the Senator was working with the White House on Presidential appointments to the Commission. Regarding the Arctic National Wildlife Refuge (ANWR), he was pursuing leasing options, an energy strategy and conservation measures with other members of the Senate. Chairman Roederer noted that the Commission's position, if asked, was that it would make recommendations on research needs or research-related

Commission Members Present: Juan C. Roederer, Chairman, John H. Steele, Vice Chairman, Ben C. Gerwick, Elmer Rasmuson, Peter Wilkniss, representing the Ex-Officio Member Staff: Philip L. Johnson, Executive Director, Lyle D. Perrigo, Head, Alaska Office, and Jennifer Lopocaro, Administrative Officer. Commission Advisory Group: George Newton and Luis Proenza. Visitors Present: Shere Abbott, Polar Research Board, NRC; Ray Arnaudo, OES/OPA, U.S. Department of State; Richard Brandt, Office of Naval Research; Jeffrey Beard, American Society of Civil Engineers; George Brenneman, Indian Health Service, HHS; Lawson Brigham, U.S. Coast Guard; John Bozwin, Ocean Science News; David Cline, National Audubon Society; Eric Corens, Friends of the Earth; Ned Cyr, NOAA/OAS; Ted DeLaca, National Science Foundation; Jim Devine, U.S. Geological Survey; Pam Dunn, Forest Service, U.S. Dept. of Agriculture; Denis P. Galvin, National Park Service; Duane Gibson, U.S. Senator Ted Stevens' office; Ozzie Girard, U.S. Geological Survey; Robert Hampson, National Aeronautics and Space Administration; Richard Hines, U.S. Navy; William Hoi, U.S. Coast Guard; Elizabeth Leighton, OES/OPA, U.S. Department of State; Will Marnin, The Wilderness Society; Donald O'Dowd, Former President, University of Alaska; Ned Ostenso, National Oceanic & Atmospheric Administration; Douglas Posson, U.S. Geological Survey; Carol Richardson, Office of the Oceanographer of the Navy; Paul Ringold, U.S. Environmental Protection Agency; Pam Rooney, American Society of Mechanical Engineers; Fred Singer, Washington Institute for Values in Public Policy; Randy Shanny and Ben Sussman, ARCO Power Technologies, Inc.; Jack Talmadge, National Science Foundation; Blair Thomas, U.S. Senator Frank Murkowski's Office

aspects, but there would be no political statements.

Duane Gibson, office of Senator Ted Stevens, stated some of the Senator's work dealt with the supercomputer at the University of Alaska–Fairbanks, studies of the aurora borealis, the HAARP project, and the facilities upgrade at Poker Flat.

Alaska Governor's Office

Luis Proenza, reported that Governor Hickel is considering how to approach science and technology issues in his administration. The Science Advisor was asked to resign and the Governor plans to phase out the Alaska Science and Engineering Advisory Commission. He will ask the University of Alaska–Fairbanks to represent Alaska science and technology along with the Alaska Science Technology Foundation. Proenza reported that the Governor has great interest in the work of the Commission and has assigned Commissioner Glenn Olds to interface with the Commission. (Note: Governor Hickel designated L. Proenza as his Science and Technology Policy Advisor in April 1991.) Elmer Rasmuson encouraged the Governor's efforts but warned against the university becoming entangled in politics, noting the primary mission of the university is education.

Interagency Arctic Research Policy Committee

Jack Talmadge, NSF Division of Polar Programs, representing the IARPC, emphasized U.S. Arctic research strategic planning programs and summarized the main goals of *Strategy for Integrated U.S. Arctic Research Programs*. He noted that in June 1991 the IARPC Seniors Meeting will review the Biennial Revision of the Arctic Research Plan and in December 1991 another report will include responses to the Commission's recommendations as required by ARPA.

International Arctic Policy Working Group

Ray Arnaudo, Head of the Division of Polar Affairs in the Department of State, and Chair, IAPWG, addressed the IASC, the Finnish Initiative and the North Pacific Marine Science Organization, indicating growing interest in cooperation in the Arctic. A final ministerial meeting on environmental protection, pollution and future meetings will be held in Rovaniemi in June 1991. Arnaudo mentioned the establishment of the North Pacific Marine Science Organization (PICES) consisting of the U.S., U.S.S.R., Japan, China and Canada and noted talks are continuing with the Canadians regarding fishing, environment, science and technical issues on the Beaufort Sea. John Steele asked whether boundaries for PICES include the Bering Sea. Arnaudo responded that the boundaries included the Bering Sea but the focus would be on the North Pacific. In response to Steele's request to differentiate between the role of IASC and the Finnish Initiative, Arnaudo indicated that the precise relationship was not formalized, but IASC will address scientific issues in the Arctic and the Finnish intuitive will focus more on environmental policy issues. Shere Abbott said the IASC will pursue its own initiatives on basic science separate from policy and political issues.

Elmer Rasmuson indicated concern that there is an abundance of groups working on international issues resulting in a diffusion of funds and talents. He suggested that the international community establish priorities and address new challenges rather than form new organizations. Jack Talmadge stated that the abundance of groups is not excessive due to the changing focus of Arctic research from national defense to more of an economic strategy.

Beringian Heritage International Park

Dennis Galvin, National Park Service, discussed U.S.–U.S.S.R. ongoing national park projects, including the proposed Beringian Park. Legislation will be proposed that allows the President to proclaim existing parks as the U.S. component. The U.S.S.R. is advancing a similar proposal. Galvin said the Soviets desire a strong marine component but the U.S. unit is entirely terrestrial due to legal restrictions.

National Research Council

Gunter Weller reported in a conference call with the Commission that the IASC is proceeding with a specific international polar and interdisciplinary focus, and aims to play an active role in coordinating and implementing Arctic system research. The January Oslo Council meeting addressed the direction of IASC, funding and the Regional Board. John Steele asked how IASC will deal with areas of national concern, such as health, environment or sociology, and asked what role the Commission should play. Gunter Weller said that while the Commission and the Polar Research Board have a role to play, the mechanism for involvement is as yet unclear.

fice; Robert Thomas, National Aeronautics and Space Administration; Christine Wegman, House Committee on Science and Technology

National Oceanic and Atmospheric Administration

Ned Ostenso discussed NOAA Arctic research. John Steele asked if there was definitive evidence that global warming has occurred and inquired about the status of the NOAA budget. Ostenso said such information was only a model and NOAA is monitoring factors of global warming. He said that budget prospects are not stable. Elmer Rasmuson asked about research on ice edge ecosystems and Ostenso answered that research started last year.

National Aeronautics and Space Administration

Robert Thomas summarized NASA's research on the troposphere, the use of satellites and remote sensing programs, including its goal to evaluate the role of the Arctic in global climate change. Tools include commissioning the Synthetic Aperture Radar facility at the University of Alaska–Fairbanks, passive microwave data, ocean color data from satellites, altimetry regarding Arctic ice sheets and airborne synthetic aperture radar. NASA is attempting to coordinate these large amounts of data into systems for greater public access.

Robert Hampson discussed NASA research projects on ozone levels, CFCs and related research. In response to John Steele's question as to whether methane levels had been determined, Hampson said methane flux is a key indicator but it is not possible to state conclusions about the Arctic at this time.

Office of Naval Research, High Frequency Active Auroral Research Program (HAARP)

Richard Brandt discussed the HAARP program, which was begun in 1990 and is jointly administered by the Navy and the Geophysics Laboratory of the Air Force. The main goal of the program, which has both defense and civilian applications, is to establish new research capabilities in the auroral field for doing ionospheric modifications. Don O'Dowd asked if there were public concerns about electromagnetic waves, and Brandt responded these concerns would be addressed in the environmental impact statement.

Military–Civilian Research Opportunities

George Newton reported that the Navy is forthcoming with information about Arctic sea ice obtained from submarines in spite of ensuring national security needs. He said recent events in the Soviet Union have increased opportunities for military and civilian application of Arctic research.

National Science Foundation, Arctic System Science (ARCSS) Initiative

Ted DeLaca described ARCSS within the framework of other NSF programs but noted that it is a regional program focused on directed research in an effort to answer fundamental questions on the role of the Arctic in global change. ARCSS can also function as a test bed for the International Geosphere–Biosphere Program (IGBP). Chairman Roederer asked about specific funding levels and whether there were plans for expanding ARCSS to the outer-atmosphere Arctic environment. Ted DeLaca summarized the funding levels and noted expansion was limited by lack of funds.

Arctic Oil Spill Response

Captain Holt, U.S. Coast Guard, summarized the National Response System, noting the main principle of the plan is that the polluter pays for the damages. He described the role of the Coast Guard in terms of national response, coordination and support. He noted the shortcomings resulting from the *Exxon Valdez* spill were addressed last year by the Oil Spill Pollution Act of 1990. Ben Gerwick asked for comment on USCG research activities dealing with advanced clean-up methods in Arctic waters. Holt responded with a list of projects in which the USCG is involved jointly with other agencies.

Innovative Concepts in Arctic Energy and Environmental Research

Ramy Shanny, President of ARCO Power Technologies, described ARCO's project to work on low-cost, high-altitude continuous measurements of concentrations of chemical elements in the ionosphere and troposphere with Skylink (a drone airplane powered from the ground) and a microwave probing system with extended communication applications. Chairman Roederer commended Shanny on this concept.

David Cline said the National Audubon Society believes environmental and economic problems in the Arctic require multifaceted international research effort and stressed the danger of overharvesting natural resources. Future plans for the Society include interest in a Biosphere Reserve, in the Bering Sea and in monitoring Arctic environmental pollution.

Fred Singer, Washington Institute for Values in Public Policy, discussed environmental issues related to Arctic energy development. He said that models agree that the Arctic is warming, and additional research is needed on greenhouse gases and the role of the polar night. He noted there is need for global observations from satellites to monitor sea level rise and melting or rise of the Greenland ice cap. Singer suggested that opening ANWR is a vital part of a balanced energy strategy and that the U.S. should continue to develop what it can produce domestically as well as concentrate on conservation.

Research Requirements Attending Arctic Energy Programs

Chairman Roederer asked what the Commission can do as an advisory body to identify research needs related to economic aspects of the Arctic. He stressed the importance of scientific research in an objective atmosphere. Jack Talmadge discussed decreased security as contributing to this atmosphere and the increasingly timely policy of rational development. Elmer Rasmuson noted that the Commission's recommendations on the EIS process have not been acted upon. He urged reactivation because current activities of agencies fall short, given the increased emphasis on environmental issues and policy. Rasmuson stated that if future recommendations were assessed more pragmatically in terms of implementation, the Commission would be more effective. Chairman Roederer agreed that support from the Congressional delegation was a key factor in obtaining response.

John Steele noted the importance of research on renewable resources, stating that value judgements often override technical details when there is inadequate research. Ben Gerwick noted that U.S. research often operates in a "crisis mode," whereas the Canadians are more advanced in oil spill research. He said a controlled, large-scale oil spill experiment in ice-infested waters, as suggested by Chairman Roederer, would be an opportunity for joint research with Canada.

Forthcoming Meetings

Listed here is a compilation of recent and forthcoming meetings, workshops and conferences on Arctic or northern topics and activities. Readers are invited to submit information on upcoming meetings, as well as reports on national or international meetings attended, to Editor, Arctic Research, National Science Foundation, Room 620, 1800 G St., NW, Washington, D.C. 20550.

1991

Nordic Conference on Cold
30 January–2 February 1991, Trömso, Norway
Contact: Nordic Council for Arctic Medical Research, Aapistie 3, SF90220, Oulu, Finland
Phone: 358-81-334202
Fax: 358-81-334765

Okhotsk Sea and Sea Ice: 6th International Symposium on Okhotsk Sea and Sea Ice
3–5 February 1991, Hokkaido, Japan
Contact: Masaaki Aota/Kunio Shirasawa, Secretariat, Scientific Program Committee, Okhotsk Sea and Cold Ocean Research Association, Sea Ice Research Laboratory, Hokkaido University, Minamigaoka 6-4-10, Mombetsu, Hokkaido 094 Japan
Phone: 01582-3-3722
Fax: 01582-3-5319

Cold Weather '91—Exposition and Conference
12–13 February 1991, Arlington (Crystal City), Virginia
Contact: Coordinator, Cold Weather '91, 25 South Quaker Lane, Suite 24, Alexandria, Virginia 22314
Phone: (703) 823-2333
Fax: (703) 823-2813

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

Seventh International Hypoxia Symposium
26 February–2 March 1991, Lake Louise, Alberta, Canada
Contact: Conference Coordinator 1M10, McMaster University, 1200 Main Street West, Hamilton, Ontario, Canada L8N 3Z5
Phone: (416) 525-9140, ext. 2182

20th Arctic Workshop—Mesoscale Modeling
16–18 May 1991, Fairbanks, Alaska
Contact: Craig Gerlach, Alaska Quaternary Center, University of Alaska, Fairbanks, Alaska 99775-1200
Phone: (907) 474-7817
Fax: (907) 474-5469
Bitnet: FYAQC@ALASKA

42nd AAAS Arctic Science Conference—Circumpolar Modeling
22–24 May 1991, Fairbanks, Alaska
Contact: Neal Brown, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775
Phone: (907) 474-7999

International Arctic Technology Conference
29–31 May 1991, Anchorage, Alaska
Contact: Society of Petroleum Engineers, P.O. Box 833836, Richardson, Texas 75083-3836
Phone: (214) 669-3377
Fax: (214) 669-0135
Telex: 730989 SPEDAL

Third International Symposium on Cold Regions Heat Transfer
12–14 June 1991, Fairbanks, Alaska
Contact: Stephanie Faussett, Institute of Northern Engineering, University of Alaska, Fairbanks, Alaska 99775-0660
Phone: (907) 474-6113
Fax: (907) 474-6087

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

Tenth International Conference on Offshore Mechanics and Arctic Engineering
23–28 June 1991, Stavanger, Norway
Contact: Nirmalk Sinha, OMAE/ASME, National Research Council of Canada, Ottawa, Ontario, Canada K1A 0R6

Industrial Development of the North and the Problem of Biological Recultivation
July 1991, Syktyvkar, Komi Republic, U.S.S.R.
Contact: Inna B. Archegova, Institute of Biology, Komi Scientific Center, Ural Division of the U.S.S.R. Academy of Sciences, 28 Kommunisticheskaya St., Syktyvkar 167610, Komi S.S.R., U.S.S.R.
Phone: 124-60-00

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

First (1991) International Offshore and Polar Engineering Conference
11–15 August 1991, Edinburgh, United Kingdom
Contact: ISOPE-91, Box 1107, Golden, Colorado 80402-1107
Phone: (303) 273-3673
Fax: (303) 420-3760

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

International Conference on Ground Ice and Cryomorphogenesis
18–25 August 1991, Anadyr, U.S.S.R.
Contact: B.D. Ershov, Department of Geocryology, Moscow State University, 119899, Moscow, U.S.S.R.
Fax: 7 095 939 0126
Telex: 411 483 MGU 54

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

3rd International Muskox Symposium
3–8 September 1991, Nuuk, Greenland
Contact: Danish Polar Center, 3 Hausergrade DK-1128, Copenhagen K, Denmark
Phone: 45-33-158666
Fax: 45-33-134976

6th International Symposium on Frozen Ground
10–12 September 1991, Beijing, China
Contact: ISGF91, Central Coal Mining Research Institute, Hepingli, Beijing 100013, Peoples Republic of China
Phone: 421 4931
Fax: 421 9234
Telex: 22504 CCMRI CN

2nd WMO Operational Ice Remote Sensing Workshop
10–13 September 1991, Ottawa, Canada
Contact: Ice Center Environment Canada (ICED), 373 Sussex Drive, LaSalle Academy, Block E, Ottawa K1A 0H3, Canada
Phone: (613) 996-4214
Fax: (613) 563-8480

POAC 91, 11th Conference on Port and Ocean Engineering Under Arctic Conditions
23–27 September, St. John's, Newfoundland
Contact: Derek B. Muggeridge, Director, Ocean Engineering Research, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X5, Canada
Phone: (907) 737-8804
Fax: (907) 73704042
Telex: 016-4101

Canadian Arctic Global Change Research
24–25 October 1991, Ottawa, Canada
Contact: Association of Canadian Universities for Northern Studies, 130 Albert Street, Suite 201, Ottawa, Ontario K1P 5G4, Canada
Phone: (613) 238-3525
Fax: (613) 238-6012

First International Design for Extreme Environments Assembly
12–15 November 1991
Contact: IDEAA One Program Office, College of Architecture, University of Houston, 4800 Calhoun, Houston, Texas 77204-4431
Phone: (713) 749-1181
Fax: (713) 747-6230

1992

Polartech '92, International Conference on Development and Commercial Utilisation of Polar Technologies in Polar Regions
22–25 January 1992, Montreal, Canada
Contact: Marianne Stenbaek, Centre for Northern Studies and Research, McGill University, Burnside Hall 720, 805 Sherbrooke St. West, Montreal, H3A 2K6, Canada
Phone: (514) 398-6052
Fax: (514) 398-8364
Telex: 05-268510

Symposium on Remote Sensing in Glaciology III
17–22 May 1992, Boulder, Colorado
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +223 355974
Fax: +233 336543

Second (1992) International Offshore and Polar Engineering Conference
14–19 June 1992, San Francisco, California, U.S.A.
Contact: ISOPE-92, P.O.Box 1107, Golden, Colorado 80402-1107
Phone: (303) 273-3673
Fax: (303) 420-3760

27th Congress of the International Geographical Union
9–14 August 1992, Washington, D.C.
Contact: IGU Congress Secretariat, 1145 17th and M Street NW, Washington, D.C. 20036
Phone: (202) 828-6688

29th International Geological Congress
24 August–3 September 1992
Contact: Secretary General, IGC-92, P.O. Box 65, Tsukuba, Ibaraki 305, Japan
Phone: 82-298-54-3627
Fax: 81-298-54-3629

Symposium on Snow and Snow-Related Problems (part of an International Forum on Snow Areas)
14–18 September 1992, Nagaoka, Japan
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: +223 355974
Fax: +223 336543

Eighth Inuit Studies Conference
and
First International Arctic Social Sciences Conference
25–28 October 1992, Quebec City, Canada
Contact (Inuit): Louis-Jacque Dorais, Dept of Anthropology, Laval University, Quebec G1K 7P4, Canada
Phone: (418) 656-7827
Fax: (418) 656-3023
Contact (IASSC): Ludger Müller-Wille, Department of Geography, McGill University, 805 Sherbrooke St. W, Montreal H3A 2K6, Canada
Phone: (514) 398-4960
Fax: (514) 398-7437

1993

VI International Conference on Permafrost
5–9 July 1993, Beijing, China
Contact: G.D. Cheng, Lanzhou Institute of Glaciology and Geocryology, Academia Sinica, Lanzhou, China
Phone: 26726-385
Telex: 72008 IGGAS CN

International Cryosols Tour: Classification, Correlation, and Management of Permafrost Soils
Late July 1993, Northwest Canada and Alaska
Contact: John Kimble, USDA-SCS, Federal Building, Room 152, 100 Centennial Mall North, Lincoln, Nebraska 68508-3866

Third International Conference on Geomorphology
23–29 August 1993, Hamilton, Canada
Contact: McMaster University, Hamilton, Ontario, Canada L85 4K1
Phone: (416) 546-9140 ext. 4535
Fax: (416) 546-0463
Telex: 061-8347

Back Cover *Eskimo stone markers rising above the tundra landscape, Bering Land Bridge National Preserve, Alaska. (Photograph courtesy of National Park Service, Anchorage, Alaska.)*

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