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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 in-

tended 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.

Front Cover

Polar bears on sea ice off the Arctic coast of Alaska. (Photograph courtesy of U.S. Fish and Wildlife Service, Anchorage, Alaska.)

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OF THE UNITED STATES

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United States Arctic Research Plan

Biennial Revision: 1990–1991

Letter of Transmittal	2
Executive Summary	3
1. Introduction	6
1.1 Goals and objectives	6
1.2 Budgetary considerations	7
1.3 Interagency coordination	8
1.4 Revision to the Plan	9
2. Proposed Interagency Programs	11
2.1 Arctic ocean / marginal seas interactions	12
2.2 Biosphere / atmosphere interactions	18
2.3 Arctic data and information networks	22
3. Research Mission Components	26
3.1 Arctic ocean and marginal seas	26
3.2 Atmosphere and climate	29
3.3 Land and offshore resources	32
3.4 Land / atmosphere interactions	36
3.5 Engineering and technology	39
3.6 People and health	40
4. Operational Support	47
5. Bibliography	49
Appendix A: Glossary of Acronyms	50
Appendix B: IARPC-Related Organizations and Activities	53
Appendix C: Highlights of Interagency and Related Activity	54
Appendix D: IARPC Biennial Report to the Congress	55
Appendix E: 1990 Budget of the U.S.: Special Analysis J	58
Appendix F: Arctic Research Budgets of Federal Agencies	60
Appendix G: Arctic Research and Policy Act of 1984	62
News in Brief	66
Reports of Meetings	68
Forthcoming Meetings	70

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United States Arctic Research Plan

Biennial Revision: 1990-1991

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550



OFFICE OF THE
DIRECTOR

August 1, 1989

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 first 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 new interagency programs and the initial steps for an Arctic Social Science program. Finally, it provides status reports on 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 Arctic Research Commission, appointed by President Reagan in January 1985.

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 first step in addressing this challenge, the IARPC is undertaking an interagency cross-cut of the proposed oceans program for FY 1991.

On behalf of the IARPC, I hope that this first 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,

Erich Bloch
Director

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. This document is the mandated biennial revision.

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, which include supporting research to implement national policy of protecting security interests, promoting rational development while minimizing adverse effects, and contributing to the knowledge of the environment best studied in the Arctic.

<i>Proposed Interagency Programs</i>	<i>Research Mission Components</i>
Arctic Ocean/Marginal Seas Interactions	Arctic Ocean and Marginal Seas Atmosphere and Climate
Biosphere/Atmosphere Interactions	Land and Offshore Resources Land/Atmosphere Interactions
	Engineering and Technology
	People and Health
Data and Information Networks (Including Remote Sensing)	

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. The total expenditure for Federal Arctic research appears to have leveled off at approximately \$96 million per year.

The Arctic Research and Policy Act of 1984 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 coordination and implementation of mutually beneficial national and international research programs. The revision includes two major sections: The Proposed Interagency Programs are new to the Plan and provide another step in implementing the intent of the Arctic Re-

search and Policy Act of 1984. They represent 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 are six major topics important to Arctic research.

2. Proposed Interagency Programs

The Interagency Committee, during its May 1988 meeting, requested that several short- to long-term interagency research programs be established to demonstrate the ability to plan and implement cooperative research. The scope of these programs was to address complex problems of either regional or global scale. In this context, several interdisciplinary and multi-agency activities are proposed: 1) Arctic Ocean/Marginal Seas Interactions, 2) Biosphere/Atmosphere Interactions, and 3) Arctic Data and Information Networks. They address several broad national questions: What is the role of the Arctic in global processes and change? What are the early signals of global change that are best observed in the Arctic? At its March 1989 meeting, the Interagency Committee further resolved that a budget analysis be developed for those programs and activities related to Arctic Ocean/Marginal Seas Interactions. This cross-cut will be employed in the 1991 budgetary process.

The goals of the Arctic Ocean/Marginal Seas Interactions program are:

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

An initial goal of the Biosphere/Atmosphere Interactions program is to define and understand the role of northern terrains and ecosystems in global carbon dynamics and biogeochemical cycles.

This revision to the Plan was reviewed by all the groups identified in the Act, as well as Federal agencies and the Polar Research Board of the U.S. National Academy of Sciences, and their comments have been considered in the final version of the Plan.

Interagency working groups will be convened in 1989/1990 to develop coordinated plans, schedule activities, and identify gaps in resources and operational capabilities. Annual meetings of investigators representing different agencies' programs will be convened to exchange the prior season's results and to plan follow-up activities. Residents of the Arctic and industry and state and local government representatives will be included in consultation, planning, and participation.

The Arctic Data and Information Networks program has as its goal the development of a common network of accessionable systems which will integrate data and information bases by 1991. Efforts have begun to develop an Arctic Environmental Data System. Activities to automate, integrate and exchange Arctic bibliographic references are underway. Over the next five years there will be an increase, by several orders of magnitude, in the amount of information acquired by satellites over the polar regions. To ensure that these data are used effectively, this Plan addresses the need for archives that provide easy access to the data.

3. Research Mission Components

Under this section of the Plan, objectives, accomplishments, and ongoing and planned activities of Federal agencies are briefly described, focusing on the period covered by this revision (1990–1991).

Arctic Ocean and Marginal Seas

Ice Dynamics and Oceanography: Research in the area of ice dynamics and oceanography 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: 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 understand their interaction. Many of the physical processes involved in the sun–earth interaction are observable from high latitudes. Arctic-based studies of this energy flow are necessary to help develop and verify theoretical models needed for future predictions. Our understanding of the basic phenomena of the coupling processes involved, and the dramatic sequences across the full optical, radio, and particle spectrum, is far from complete.

Climate and Weather: It is necessary to address Arctic weather problems occurring on a variety of spatial and temporal scales that range from micro-scale to global. Arctic climate has global implications. There is a need to relate Arctic atmospheric circulation to mid-latitude weather, and to measure and understand phenomena which may be linked to 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 the complexities of its geologic setting, its remoteness, and its relative lack of exploration. Information is necessary to allow the 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 are common. 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 which are important resources to the Nation, as well as to Alaska

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 parameters 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: 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.

Ecosystem Structure, Function and Response: The Arctic is likely to be sensitive to the effects of possible climatic changes resulting from greenhouse warming. Research is needed to improve understanding of the influence of climate on land and freshwater processes, including heat balance relationships, landscape alteration, the identification of biological indicators of change, and long-term trends in biological diversity, as well as managing living resources.

Engineering and Technology

To further develop Alaskan resources economically and in an environmentally sound manner require improved designs and new technologies. Construction costs in the Arctic are at least two or more times higher than in most major non-Arctic areas. Most criteria for building and materials in the Arctic have been borrowed from more temperate regions. Low temperatures often result in increased deterioration of typical materials. Sea ice, permafrost, and river ice jams are major hazards to structures and create engineering challenges. Ice-structure interactions are fundamental for addressing engineering problems in environments affected by freshwater and sea ice.

People and Health

Cultural Resources and Historical Processes: Research is needed on the prehistory and history of Arctic cultures, on their interactions with other Native and Western peoples, and their relationships with past and present environments. 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 response to global climatic and environmental change.

Rapid Social Change and Human Environmental Relationships: 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 rapid social change. Unprecedented opportunities exist for basic and applied social and behavioral science research in Arctic regions.

People and Their Health: The Arctic is a region where health research may have broad implications and applications. Key concerns in health and health research include social and behavioral aspects, disease trends and transmission, Native diet, and human adaptation to extreme environmental and occupational challenges. The health-culture-socioeconomic component is important in the attempt to address the complex issues currently being faced in the Arctic.

4. Operational Support

Over the past two years, the Interagency Committee, the Arctic Research Commission, and the State of Alaska have addressed issues related to the logistic support of 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 is producing a directory of Federal Arctic logistics capabilities and identifies those available in Alaska. The Plan endorses the need for a four-icebreaker fleet, the acquisition of an ice-capable research vessel, upgrading of the Alaskan rocket launching facility, and a central approach for Federal logistics planning and information.

1. Introduction

Public Law 98-373, 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.*

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. This document fulfills the mandated requirement.

The Plan presented a detailed agenda for United States Arctic research and was the result of an extensive process of planning, consultation, and revision. This biennial revision builds on the published Plan, but is more restricted in scope and focuses on what might be accomplished in the next two years (1990-1991). In addition to these individual agency research activities (described in Section 3.), this revision presents, for the first time, several focused, interagency programs (Section 2.) as requested by the Interagency Committee at its May 1988 meeting. These cooperative efforts may be initiated in the 1990-91 period, and continue to 1993 and beyond. Each represents ongoing or planned programs of three to five Federal departments and has direct relation to economic and social developments in the Arctic, scientific questions related to regional and global processes, and national security interests.

This revision to the Plan has undergone review by all the groups identified in the Act (Arctic Research Commission, State of Alaska, residents of the Arctic, private sector, and public interest groups), as well as Federal agencies, and the Polar Research Board of the U.S. National Academy of Sciences.

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:

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 which 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 which benefits from and contributes to mutually beneficial 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.

To achieve these goals and objectives, research and its support will focus on:

National Security

Environmental phenomena and processes relating to defense;

Human health and biology in the Arctic;

High-latitude communications; and

Arctic marine technology

Rational Development with Minimal Environmental or Adverse Social Impact

Arctic marine technology relating to transportation systems and offshore operations;

Collection and long-term monitoring of baseline data on relevant parameters for cumulative environmental impacts;

Environmental, health, behavioral, and societal aspects of development;

Sea state, ice reporting and weather forecasting.

Scientific Research on Arctic Phenomena and Processes and Aspects of Science Best Studied in the Arctic

Systematic collection of basic data related to physical, biological, materials, social, cultural, health and behavioral phenomena and the establishment of an Arctic data and information system;

Effects of Arctic conditions on global climate and weather;

Effects of pollution on global climate and weather patterns, and their mitigation; and

Preserving and conserving wildlife and essential habitats

In addition to these goals and objectives for Arctic research developed by the Interagency

Committee, the Arctic Research Commission has also developed goals and objectives to guide U.S. Arctic research (ARC 1988c), recommendations for improvements in logistics for support of Arctic research (ARC 1988b), and recommendations for focused research on the Bering Sea as an Arctic marine ecosystem, and on health research in Alaska (ARC 1988a). This revision of the Plan is consistent with many of these Commission recommendations.

In addition to the goals and objectives referred to above, more specific long-term goals have been developed by the Interagency Committee to further guide the revision of the Plan:

- Continue to develop and maintain overall 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 determine the significance of global changes in the Arctic.
- Contribute to the understanding of the relationship between Arctic residents and subsistence use of wildlife and how this relationship might be affected by global climate change.
- Include Arctic residents in the planning and conduct of the research and report results to the individuals and communities involved in the research.
- Pursue an integrated research program on marine ecosystems, living resources, and ice edge processes.

- Continue to document and understand the role of permafrost in environmental activities.
- Advance knowledge of Arctic geologic framework and paleoenvironments.
- Develop the scientific basis for responding to social changes and 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.
- Develop and maintain a strong technological base to support national security needs in the Arctic.

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 (1985–1990).

The trends in Arctic funding are given in Table 2, organized according to the three major policy objectives described above, and as reported for 1990 in the President's Budget Request (Special

Table 1. Expenditures on Arctic Research (thousands of dollars).

Agency	Actual				Estimated	
	FY85	FY86	FY87	FY88	FY89	FY90
Department of Defense	22624	26636	21580	22452	22254	20009
Department of Interior	26450	24116	23952	24263	23706	23571
National Science Foundation	19429	18144	21894	23118	24930	27480
National Aeronautics and Space Administration	7229	7999	13423	16850	15660	14650
National Oceanic and Atmospheric Administration	5548	5197	4355	4735	3635	4585
Department of Energy	2815	5076	3250	2567	2647	2235
Health and Human Services	1493	1756	1461	922	922	922
Smithsonian	507	519	519	664	630	630
Department of Transportation	565	410	655	575	155	160
Environmental Protection Agency	400	400	300	0	25	250
Department of State	16	16	8	4	4	4
Department of Agriculture	NA	850	860	867	870	870
Total	87076	91119	92257	97017	96438	95366

Table 2. Trends in Federal Arctic Funding (thousands of dollars).

<i>Arctic Policy Objectives</i>	<i>Actual</i>				<i>Estimated</i>	
	<i>FY85</i>	<i>FY86</i>	<i>FY87</i>	<i>FY88</i>	<i>FY89</i>	<i>FY90</i>
National security	22,624	26,636	21,580	22,452	22,254	20,009
Rational development	35,794	36,065	33,380	33,011	32,042	31,675
Natural laboratory	28,658	28,418	37,297	41,554	42,142	43,682
Total	87,076	91,119	92,257	97,017	96,438	95,366

Analysis J, see Appendix E). Early increases in the security and development funding were in part due to modifications in reporting procedures within some agencies as the definition of programs took place. The total expenditure for the period of the Act (actual and estimated) seems to have leveled off at between \$95 and \$97 million per year. Appendix F contains agency budgets broken down by major sub-elements and cross referenced to the policy objectives.

1.3 Interagency Coordination

The Arctic Research and Policy Act of 1984 (see Appendix G) 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, National Science Foundation (NSF), is providing the mechanism for developing and coordinating overall U.S. Arctic research activities. The biennial revision of the U.S. Arctic Research Plan serves as guidance for planning by individual agencies and for coordination and implementation of mutually beneficial national and international research programs.

Although 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:

- Arctic Alaska-specific research and related programs
- National coordination
- 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 well underway through the Interagency Committee. A staff oversight group of the Interagency Committee provides day-to-day coordination and has been assisted by working groups representing specific agency programs for 1) ocean/atmosphere, 2) land resources and interactions, 3) social science and health, 4) data and information, and 5) operational support. The Interagency Committee has met three times since the original Plan was approved and submitted in 1987 (May 2, 1988; March 27, 1989; June 1, 1989).

Many interagency agreements and planning and coordinating activities already exist in Alaska. An Alaskan oversight mechanism which could bring together the needs and views of Federal, state, and local governments, the private sector, and the public is being discussed. The needs for improved, peer-reviewed research design and quality control are issues deserving further attention. At the international level, bilateral and multi-lateral programs are in place. The proposed development of an International Arctic Science Committee could serve to formulate additional planning and coordination of research across the Arctic. Improved communication through existing newsletters and journals should be encouraged. Appendix B lists principal interagency organizations and international activities with which the Interagency Committee and/or its member agencies are actively participating.

Although the two-year period since submission of the Plan has not been long enough to fully organize and implement the hundreds of recommendations, significant progress has been made and accomplishments can be identified. These include activities of the Interagency Committee, the Arctic Research Commission, and ongoing and new activities of Federal agencies and State and other groups named in the Act. Highlights of selected interagency and related activities are listed in Appendix C. Selected accomplishments for Federal agencies are summarized under each of the appropriate research mission components in Section 3. Additional information can be found in issues of *Arctic Research of the United States*, published by the IARPC.

1.4 Revision to the Plan

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

2. Proposed Interagency Programs
3. Research Mission Components

The Proposed Interagency Programs are a new element of the Plan and represent another step in implementing the intent of the Arctic Research and Policy Act of 1984. They present recent Federal agency efforts to plan and implement Arctic programs involving several agencies and to further cooperate in the international scientific arena on research related to the U.S. Arctic. These cooperative efforts build on existing programs and activities, and contribute to the newly emerging global

The Proposed Interagency Programs are a new element of the Plan and represent another step in implementing the intent of the Arctic Research and Policy Act of 1984

change programs (CES 1989). An interagency program and budget cross-cut for the proposed Arctic Ocean/ Marginal Seas Interactions program is underway, and is similar to the Committee on Earth Sciences process for global change program planning. The pilot cross-cut will be available as part of the FY 1991 budget justification.

Working groups of the Interagency Committee have reviewed the three major research sections of the 1987 Plan (Oceans-Atmosphere, Land, and People) and provided revised summaries for each of the specific research elements in Section 3. For each element, selected accomplishments and research objectives are highlighted, and the major activities that are ongoing or planned by Federal agencies are listed, focusing on, though not necessarily limited to, 1990-91. The intent of these summaries is to focus on needs and actions within and among agencies and not to rewrite in detail the existing Plan. The background for each summary can be found on the pages indicated in the Plan (see Table 3). In some cases, several original elements have been combined, where objectives and actions were found to be similar or overlapping. Responsible agencies are listed (alphabetically by department followed by specific service, bureau or other major organizational unit) for each action. These designations indicate existing mission responsibilities and reflect individual ongoing and planned

agency programs. Summaries of these activities are found in the FY 86, FY 87, and FY 88 agency reports (*Arctic Research of the United States*, Fall 1987 and 1988 issues). Research conducted under these elements can be characterized as being conducted by single agencies, bureaus or services, or by several agencies working together on a cooperative and generally reimbursable basis. These mission elements complement the Proposed Interagency Programs and, where appropriate, are integrated and coordinated with the multiagency programs. Elements are presented separately to emphasize the individual agencies' responsibilities, particularly in the absence of interagency initiatives.

Section 3.6, People and Health, is a significant revision to the 1987 Plan and restates future directions. During the period 1988-1989, the Polar Research Board of the National Academy of Sciences undertook a study of Arctic social science, partly at the request of several Federal agencies in response to recommendations of the Arctic Research Commission. A report was issued in early 1989 entitled, "Arctic Social Science: An Agenda for Action" (NRC, 1989). In response to the report's recommendations, the Interagency Committee, at its March 1989 meeting, formed a Task Force to develop a common interagency position which reaffirms many of the report's recommendations. The social science subsection of this revision focuses on research directed at two interlinked themes: history and cultural resources and rapid social change and environmental relationships. The result is a more unified and coherent plan that reviews recent accomplishments, presents research themes, and highlights organizational issues needing attention during the next two years. Included in the latter are issues of data and publication, training and education, research ethics, and information exchange. The people and health subsection stresses social and behavioral aspects, disease trends and transmission, diet, and human adaptation to extreme environmental conditions. Together, the social science-health program will contribute importantly to understanding the complex problems being faced by humans in the Arctic in the late 20th century. Involvement of Arctic residents in the planning and conduct of the research remains a high priority in all aspects of Arctic research. Furthermore, the establishment of regional research and resource centers will enhance the interaction between local people and researchers and improve exchange of information.

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

Table 3. Guide to Revisions to the 1987 U.S. Arctic Research Plan.

<i>1987 Plan</i>	<i>Proposed Interagency Programs (1989 revision)</i>	<i>Research Mission Components and Elements (1989 revision)</i>
Atmosphere and Oceans (31)*	Arctic Ocean/Marginal Seas Interactions [12]	Arctic Ocean and Marginal Seas Ice Dynamics and Oceanography (43,49) [26] Ocean and Coastal Ecosystems and Living Resources (77,184) [27] Marine Geology and Geophysics (135) [28] Atmosphere and Climate Upper Atmosphere and Near-Earth Space Physics (38) [29] Climate and Weather (43,63) [30] Tropospheric and Stratospheric Chemistry (172) [31]
Land—Its Resources and Environmental Interactions (121)	Biosphere/Atmosphere Interactions [18]	Land and Offshore Resources Energy and Minerals (134,143) [32] Coastal and Shelf Processes (178) [33] Terrestrial and Freshwater Species and Habitats (149) [34] Forestry, Agriculture and Grazing (153) [35] Land/Atmosphere Interactions Glaciology and Hydrology (159) [36] Permafrost, Landscape and Paleoclimate (163) [37] Ecosystem Structure, Function and Response (167) [38]
		Engineering and Technology (186,232) [39]
People (213)		People and Health Cultural Resources and Historical Processes (250–260, 267) [41] Rapid Social Change and Human Environ- mental Relationships (262, 269–280) [42] People and Their Health (218) [45]
	Arctic Data and Information Networks (207,281) [22] Remote Sensing (69, 201) [24]	

* () numbers refer to pages in the *United States Arctic Research Plan* (1987)

[] numbers refer to pages in this revision (1989)

2. Proposed Interagency Programs

Contributions to Understanding of Regional and Global Processes

During its May 1988 meeting, the Interagency Committee resolved that several short- to long-term interagency research programs should be established to demonstrate agencies' ability to plan and implement cooperative programs. The scope of these programs was to address complex problems of either regional or global scale. In this context, several interdisciplinary and multi-agency programs and activities are proposed, which address broad questions: What is the role of the Arctic in global processes and change? What are the early signals of regional and/or global change that are best observed in the Arctic? The questions address policy goals and objectives for resource development with minimal environmental impact, the use of the Arctic as a natural laboratory, and national security. Furthermore, they complement and reinforce emerging national and international programs on global change, including those involving the human dimension (CES 1989).

An important research theme is the role played by the polar regions in global climate and climate change. Nearly all high-latitude ocean and ice research has direct relevance to climate, as do aspects of biology and earth science, such as methane production, ocean productivity, tectonic history, glacial geology, and paleoclimatology from glaciers, seabeds and lake sediment cores. At present, we do not know the solar radiation balance at high latitudes; we do not know the magnitude of methane production or of carbon sequestration in polar regions; we do not understand what controls deep-water formation, nor how rapidly changes in these controls affect conditions far from the polar regions; we do not know the reasons for large, long-period changes in sea-ice extent, nor what effect these changes have on climate or on marine biological productivity; we do not know even whether the ice sheets of Greenland and Antarctica are growing larger or smaller, and we cannot accurately predict what their influence will be on sea level in a warmer climate. The need to include the human dimension when considering regional and global change is receiving increased awareness, both nationally and internationally. The Arctic provides local and regional environments in which to examine past, present and future social, economic, and adaptive processes.

A major goal of the research described here is an improved understanding of Arctic regional and global processes. These processes can be summarized briefly as:

- The effect of sea ice and seasonal snow cover on the global radiation budget, and their role on feedback processes that amplify the climate signal.
- Methane production in Arctic and Subarctic peatland, and its contribution to the growing levels of greenhouse gases in the atmosphere.
- Sequestration of carbon dioxide (the principal greenhouse gas) from the atmosphere by high biological productivity in Arctic and Subarctic terrains and waters and net transfer to the deep ocean via deep-water formation.
- Intensive heat transfer from ocean to atmosphere in the Arctic, and cooling of the global ocean via the slow thermohaline circulation which links the world's oceans.
- The change in mass balance of polar and sub-polar glaciers and ice sheets and its effect on global sea level.
- Tectonic history of the ocean basins and its impact on paleoclimate and development of hydrocarbons and mineral resources.
- Social and cultural processes related to historical and environmental changes.

By studying these processes, we will also improve our ability to forecast environmental conditions such as weather, sea-ice behavior, and ocean characteristics, which will enhance living and working conditions for local peoples, and will benefit national security interests and developmental activities such as agriculture, fishing, shipping, mining, and oil and gas drilling and production.

It is timely for the Federal agencies involved in the Arctic to coordinate a long-term, sustained program of research utilizing both in-situ and satellite observations to answer these and related questions. Many of the component parts of this program already exist or are planned, although some increases in resources are required. The most urgent needs are for a clear statement of the required research and a commitment from the research community and the mission and funding agencies to its implementation. These proposed interagency programs are a first step in this process and complement and build on the process started under the Committee on Earth Sciences.

For the proposed programs discussed here, planning is underway and initial implementation will occur over the next two years:

- 2.1. Arctic Ocean/Marginal Seas Interactions
- 2.2. Biosphere/Atmosphere Interactions

2.3. Arctic Data and Information Networks, Including Remote Sensing

In addition to interest in understanding the role of the Arctic in global change, increasing regional, national and international attention is focusing on the management of Arctic ecosystems and their protection from the adverse environmental effects of human activities both within and outside the Arctic. Some problems of particular concern are the causes and effects of: long-distance and local transport of atmospheric and marine contaminants; the accumulation and biomagnification of heavy metals and other toxins in Arctic food chains; drift net fisheries on populations of fish, marine mammals and birds; stratospheric ozone depletion; and Arctic haze. Also, environmental pollution events, such as the recent oil spill in Prince William Sound, provide scientific opportunities to study the short- and long-term effects of hydrocarbon spills on the terrestrial, intertidal, freshwater, and marine biological and human communities. To meet these compelling and expanding research needs, it is anticipated that over the next two years greater emphasis on interagency programs, including mechanisms for coordination, will be required to build on existing U.S. Arctic programs and related international activities.

2.1 Arctic Ocean / Marginal Seas Interactions

Role of the Arctic Ocean—Atmosphere and Adjacent Seas in Global Climate and Biological Productivity

Program Goal. Agencies represented on the Interagency Arctic Research Policy Committee are planning and propose to implement a research program with the following goals:

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

These three goals capture what the Interagency Committee considers to be important and immediate scientific questions in Arctic oceanography. They closely parallel the highest research priorities recommended by the Polar Research Board (1988) and the top research priority identified by the Arctic Research Commission (1988). These goals also bear directly on the responsibilities of the participating Federal agencies related to managing the harvest of living marine resources, developing our offshore energy and mineral reserves, and understanding and predicting processes critical to global climate change. These goals can be considered Arctic-related subelements of the broad science elements defined by the Committee on Earth Sciences. The first goal includes both Biogeochemical Dynamics and Ecological Systems and Dynamics. The second goal is included within Climatic and Hydrologic System. The third goal is directly related to Earth System History.

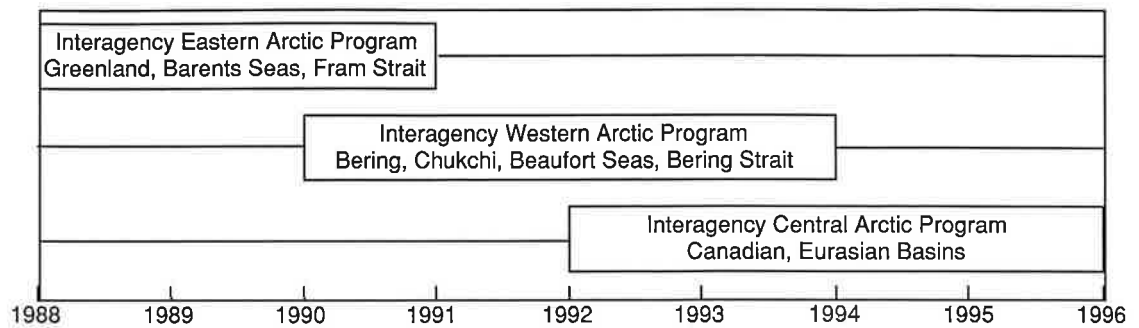
A number of complementary research activities are now being planned by various Federal agencies. The Interagency Committee recognizes that linking these activities offers an opportunity to maximize the scientific output while minimizing the logistical costs for each agency. This research plan for Arctic Ocean/Marginal Seas Interactions was developed from this base of projected complementary agency activities and represents a starting point for further planning and involvement of the broader research community.

To accomplish the research, new focused interagency programs will be carried out in the western Arctic (including the Bering Sea, Chukchi Sea, and Beaufort Sea), and then in the central Arctic Basin. The Coordinated Eastern Arctic Experiment (CEAREX) and the Greenland Sea Project are underway now and will continue as these other programs are initiated. The illustration at the top of the next page shows the timing of these geographically focused, interagency research programs.

The interagency western Arctic research program provides a much-needed opportunity to examine and compare the seasonal ice edge, polynyas, and leads in terms of the thermodynamic processes that are active and the overall contribution of each of these unique air-ice-ocean environments to the total heat flux, biological productivity and carbon flux of the Arctic Ocean and its adjacent seas.

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

Background. The Arctic marine environment is



distinguished by a permanently ice-covered region in the central Arctic Ocean and the presence of a seasonal ice cover in the shelf regions and adjacent seas. This ice cover is a key factor in mediating and controlling the biological, physical, chemical, and geological processes that are unique to this marine environment.

The Arctic Ocean has the largest shelf-to-deep basin areal ratio of any sea in the world. Within this basin the water mass properties and distribution, the circulation structure, and the geology and geomorphology are poorly known. The dynamics governing the water motion and sediment dynamics have been crudely modeled, but sparse data prohibits verification of the results. The contribution of the Arctic system to the production of North Atlantic deep water is significant, and such Arctic water properties may be extremely sensitive indicators of trends in climate change.

The U.S. Arctic, particularly the Bering and Chukchi Sea shelves, contains some of the richest commercial fisheries in the world. Large populations of birds and marine mammals, including many migratory species, inhabit these waters. Sea ice acts as a platform and habitat for marine mammals and a substrate for the plants that form the base of the food chain supporting birds, shellfish, fish, and marine mammals. The ice meltwater stabilizes the water column and allows a strong seasonal pulse of production. The Northern Bering Sea has recently been shown to have the world's highest primary production rates. However, there have been dramatic and unexplained fluctuations in some of the key harvestable fish and shellfish species and some marine mammal populations. Greater understanding of the natural ecosystem structure and functioning is necessary to predict these fluctuations and identify the most appropriate management strategies to mitigate the effects of any human activities on the environment.

2.1.1 Air-Ice-Ocean Interaction

Of all the possible interactions within the Arctic system, vertical fluxes between the atmosphere and ocean through the ice are of central and widespread importance. The mechanics of the air-ice-

ocean system involves the coupling of two fluids which deform continuously under the action of shear forces to a solid which can statically sustain a rate of strain. The mismatch between fluid and solid response to strain as well as heterogeneities in the ice properties and surface geometry make it difficult to accurately predict regional scale (50 km) effects by integrating ice floe scale (1 km) responses to synoptic scale forcing (10-km ocean; 200-km atmosphere).

Air-ice-ocean interaction results in an evolving field of ridges, leads and polynyas in the ice cover. Although leads and polynyas cover only a few percent of the surface area at any given time, they likely account for most of the air-ocean heat and moisture fluxes in ice-covered regions. Such fluxes may have a significant impact on global climate. The relationship of ridge and lead patterns in the ice to air and ocean stress fields needs further study. Mechanisms maintaining polynyas have been hypothesized. Field experiments are needed to verify flux estimates, test hypotheses and determine net biological and physical effects.

Secular changes in ice cover thickness, resulting in changes in the insulating separation between water and air, may also account for substantial variation in the vertical heat flux in the Arctic system. Increased solar radiation in the summer may result in increased ice melting with no discernible change in ocean or atmospheric temperature because the heat is being used to melt the ice. However, in the winter this thinner ice cover can result in a greater loss of heat from the ocean to the atmosphere. The impact of this process on the surface heat budget of the Arctic Ocean and its effect on global climate have not been assessed. Long-time scale data, including seasonal inter-comparisons, are needed to quantify and validate the role of this process.

Prediction of ice-air-ocean flux is complicated by the effect of ocean density stratification. Changes in density are related both to heat flux and to mass flux (brine rejected in freezing and fresh water produced in melting). Increased stratification increases the tendency for energy input to the surface layer to radiate as internal waves.

Internal waves can also be generated by the motion of ice keels and smaller scale roughness elements. A central problem is how to represent the three-dimensional structure of the evolving ice cover with its abrupt topography and discontinuities, such as keels and leads. Besides affecting mechanical stress, the ice geometry effectively separates the scales of heat and salt flux from those of momentum flux. Coupled air-ice-ocean models are virtually unavailable now, yet are crucial to all predictions concerning the Arctic and global climate change. Also, boundary layer models must be coupled to the interior dynamics of the system. There is increasing evidence that processes within the Arctic Ocean affect the deep water mass structure of the Greenland/Norwegian Seas and subsequently the formation of deep water throughout the North Atlantic Ocean. The significance of this contribution needs to be defined.

2.1.1.1 Marginal Ice Zone Processes

The marginal ice zone (the seasonal ice edge at its southern extreme and the ice edge that develops episodically along the coastline) represents a unique mechanical and thermodynamic boundary where interacting physical and biological processes have important consequences for the overall biological productivity of a region.

The marginal ice zone is a discontinuity in the exchange of momentum and heat between the atmosphere and ocean. Wind stress and heat flux in this zone can drive vertical motion over a great depth range. Deep vertical convection is enhanced in the winter by decreased stability of the water column due to surface cooling, mixing and freezing, and mid-depth lateral convection. When winds are strong and persistent from a favorable direction relative to the marginal ice zone orientation, the oceanic density gradients can evolve into frontal systems with complex cross-front circulation cells and strong along-front jets. Variability in the wind forcing as well as frontal instability mechanisms result in the generation of eddies. The eddies can entrain ice, increasing melting and thereby increasing stratification and stability. The dynamics and feedback mechanisms of all these processes need to be understood to allow predictive modeling of the ice dynamics as they relate to the biology of the system.

2.1.1.2 Ecosystem and Biogeochemical Dynamics

Physical processes such as frontogenesis and eddy formation induce upwelling of nutrient-rich waters into the photic zone. Melting ice traps nutrients in the stratified surface layers, providing the basis for intense phytoplankton blooms. The ecosystems of the Bering Sea depend on fronts

and tidal mixing, ice dynamics, and the seasonal retreat of the ice-edge through the Bering and Chukchi Seas, an area equal in size to that from Texas to the Canadian border and the Rocky Mountains to the Mississippi River. In the Greenland Sea, year-round recruitment of ice from the Arctic Ocean to the ice-edge area of Fram Strait leads to a distinctly prolonged season of productivity in the marginal ice zone. Biomass depends critically on initial timing of phytoplankton blooms and the subsequent phasing, level, and extent of zooplankton grazing. The roles of biological mechanisms and mesoscale physics in initiating and regulating productivity are yet to be determined. High surface concentrations of plankton may affect ice melting and near-surface stratification by increased absorption of solar radiation, thus creating one of several dynamic feedbacks still to be evaluated. These processes and interactions control critical pathways of energy flow from producers to consumers, e.g., from phytoplankton to bottom organisms, to commercial fisheries, and to marine mammals. At present we do not understand why animal populations fluctuate widely on an interannual to decadal time scale, or how carbon produced is sequestered and moved through the world ocean.

2.1.1.3 Lead and Polynya Dynamics

Polynyas, recurring mesoscale areas of open water in sea-ice-covered regions, are special cases of the marginal ice zone. Although polynyas cover only 3–4% of the surface area of the Arctic, together with leads in the sea ice they may be responsible for up to 50% of its ocean and atmospheric heat transfer. Polynyas differ with respect to the processes that maintain them; some are maintained as open areas by the vertical flux of heat, others are maintained by wind stress. These differences can affect not only the size and duration of a polynya, but also the level of enhanced biological activity. Some polynyas seem to recur in the same places year after year. Polynyas also are important areas for marine mammals and may be important for other biological resources. The relationships between the physics and biology are not well understood. These processes need to be understood in order to predict the ultimate export of organic material from the immediate area and the full extent of the biological enhancement.

2.1.1.4 Arctic Basin Circulation

In the Central Arctic Basin, three principal elements of the water mass structure are a cold, low-salinity surface mixed layer in the upper 50 m, cold halocline water between 50 and 200 m, and a layer of warm Atlantic water with a core between

300 and 500 m. The halocline is also a well-defined pycnocline, which effectively decouples the warm Atlantic water from mechanical mixing with the surface layer and therefore insulates the surface ice cover from this large subsurface heat source. The persistence and extent of the Arctic ice pack depend on this structure, thereby making this a critical issue for ocean climate. The effectiveness of the decoupling/insulation is directly related to the thickness of the pycnocline layer. A current hypothesis is that the cold, upper halocline is maintained by lateral advection of dense water from the broad continental shelves that border the Polar Basin. The dynamics governing the production of this dense shelf water and its transport across the shelf are not well understood (see section 2.1.2.2).

The dynamics governing the production of dense water over the broad continental shelves that border the Polar Basin and its transport across the shelves are not well understood

Another climate-related issue in which the Arctic appears to play an important role is the export of dense water from the Arctic Basin and the deep ventilation of the Norwegian Sea and Greenland Sea. Recent observations show that an outflow of water through Fram Strait may be occurring at all depths and that deep water formation occurs in Fram Strait. Water exchanges also occur at Bering Strait, the Barents Sea, and the Canadian Archipelago. The total flux, the mechanisms controlling the exchange, and the role in both the circulation of the Arctic Ocean and deep water formation in the North Atlantic need to be resolved.

2.1.1.5 Objectives

Marginal Ice Zone Dynamics

- Develop an understanding of the physical processes governing the extent and dynamics of the seasonal sea ice. This includes transport of ice by ocean currents, differentiating the role of heat advection by currents versus local vertical heat flux in ice melt-back, and understanding the relation of atmospheric circulation to interannual variations of ice cover.

Ecosystem and Biogeochemical Dynamics

- Examine the dynamics of primary production, nutrient recycling, community structure, and material fluxes to determine how they relate to physical processes at ice-edges, in polynyas, and in leads, and characterize and quantify the vertical flux of particulate material

from the surface waters and its effect on the tropho-dynamics of the pelagic and benthic ecosystems.

- Quantify annual and seasonal cycles in productivity and flux and their variability at ice-free times and in ice-free regions of the Chukchi, Bering, Greenland, Norwegian, and Barents Seas.
- Quantify the effect of freshwater input and other unique shelf processes on biological productivity, seasonal cycles in growth and biomass, nutrient cycling, carbon deposition, denitrification, and community structure of Arctic shelf ecosystems.
- Understand the mechanisms of biological productivity and biogeochemical cycling in the highly seasonal, often cold and dark, waters of the Arctic Ocean basin including food chain dynamics, special adaptations of organisms, growth cycles, community structure, carbon deposition, and nutrient cycling.

Lead and Polynya Dynamics

- Understand the local physics of momentum and buoyancy fluxes in the oceanic and atmospheric boundary layers associated with leads and polynyas.
- Determine stress/rate of strain relationships, horizontal scale interactions, and fracture mechanisms in the sea ice cover.
- Determine the regional effects on air–ice–ocean interaction of discontinuities in the ice cover.
- Understand the maintenance mechanisms in polynyas.

Basin Circulation and Dynamics

- Determine the dynamic coupling and exchange of the Arctic Ocean with its marginal seas and its role in global ventilation and deep water formation.
- Understand the structure and driving mechanisms of the principal currents within the central Arctic Ocean.
- Develop coupled air–ice–ocean models with improved physics for use in General Circulation Models (GCMs).

2.1.2 Ocean Margin–Basin Interaction

2.1.2.1 Paleoclimate

The Arctic Ocean has played, and continues to play, a critical role in the evolution of global climate and oceanography. Today's polar oceans represent unique environments because of their cold hydrospheres and because of the presence of ice caps on adjacent land masses. These environments are the result of long-term climate change and recurring climate shifts between late Cenozoic

glacial and interglacial climatic modes. Studies of the marine depositional environments and sediments of the polar oceans which record this evolution have provided important but fragmentary data to describe the onset of the cold polar climate since late Eocene/Oligocene time and the response of fauna and flora to cold temperatures.

Biogenic and terrigenous sediment deposited on the floor of the Arctic Ocean and its marginal seas can be analyzed to provide information about the climate, environment, and ocean conditions at the time of deposition. Specifically, the following types of climatic (paleoclimatic) and environmental information can be determined from sediment and fossil analyses: water depth, water temperature, water chemistry, availability of nutrients, presence or absence of ice cover, and the existence of glaciations at the time of deposition. Analysis of pollen deposited in the sediment reveals information about the extent of glaciations and type and extent of vegetation on the adjacent terrestrial margin.

Methane hydrate present in shelf sediments formed under climatic conditions significantly different from present conditions. The mapping of these hydrates (extent, thickness, and depth) and the determination of their chemistry will provide details about the climate at the time of their formation. Sediment sampling and high resolution geophysics to provide information on lateral extent of specific climatic units is required.

The evolution of the cold polar oceans has also had a tremendous impact on the hydrography of the world's oceans because as the waters of the polar oceans cool, they sink and flow equatorward to fill major deep-sea basins. Thus, climatic evolution in the polar regions is global in its impact, for both the responses and dynamics of the world's oceans and atmosphere and for the biosphere.

2.1.2.2 Shelf Dynamics

The dynamics governing the production of dense shelf water are related to the thermodynamics of ice formation and the mechanics of sea-ice divergence. Where open water is maintained through divergence mechanisms, mainly in coastal zones, continuous freezing provides cold, dense water through the process of brine rejection. Once formed, relatively dense water driven by gravity tends to flow across and off the Arctic shelves toward deeper water of similar density. The dominant transport may occur throughout the water column, constrained in relatively narrow cross-shelf troughs, and/or broadly within the bottom boundary layer. The relative importance of the different cross-shelf transport mechanisms has not been determined. The extent to which this water is modi-

fied by entrainment during transport, the nature of the spreading within the halocline, and penetration to levels greater than the halocline is unknown.

Unlike temperate regions where water is the only medium of energy exchange with the seafloor, 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 seafloor. The surfaces of these solids are variable in form, both temporally and spatially, and the dynamics of their interaction results in an ever-changing geologic condition.

The processes responsible for the geologic character of the Arctic continental margin differ markedly from those processes encountered in areas where the forcing is exclusively water-driven. The effects of Arctic seasonality, which translates into a continually varying ice canopy, alters the forcing functions on Arctic shelves. The presence of this ice may limit the use of the non-linear wave current interaction theory and its related models, which are presently driving state-of-the-art, sediment dynamics research. A second major difference is in the very nature of the high latitude sediments themselves. Due to the major role played by ice in their origin, transport, and deposition, these sediments are texturally heterogeneous, both temporally and spatially. Their fine fractions are composed not of the chemically active hydrous aluminosilicate minerals found in other environments, but of chemically inert clay-sized components derived by ice-dominated comminution processes. The effects of ice on both the forcing functions and nature of high latitude sediment will require changes in the parameterization of the momentum equations and sediment suspension equations used in the study of sediment dynamics.

The physical interaction of the ice on both the coast and seafloor is important in eroding and transporting sediments. The sediment budget of the Arctic Ocean Basin needs to be defined.

2.1.2.3 Objectives

Paleoclimate

- Characterize the pre-glacial Arctic deep-sea paleoenvironment.
- Determine timing and characteristics of initial climatic cooling and glaciation.
- Determine timing, magnitude, and periodicity of high amplitude late Cenozoic climatic oscillations and resultant ice sheets, both continental and marine.
- Determine the paleo-oceanographic and paleontologic (both fauna and flora) response to climatic change, warm-cold oscillations and changes in the depth and width of ocean cor-

ridors linking Arctic and global oceans.

- Characterize changes in silica and carbonate fluxes and their budgets and atmospheric CO₂ levels.
- Determine distribution and chemistry of methane hydrate and assess climatic conditions operational at time of formation.

Shelf Dynamics

- Understand the dynamics of inner shelf mixing and cross-shelf transport that create and modify dense shelf water and advect it off-shelf.
- Determine the net effect of shelf processes on the maintenance of water masses and circulation within the central Arctic Ocean.

A final component critical to the success of this effort is year-round access by researchers to the ice-covered seas via suitable ships and aircraft

- Determine the impact, if any, the ice canopy has on the forcing functions (turbulence, waves, currents, etc.) affecting sediment transport. Assess the importance of saline flow. Determine how the canopy affects upper mixed layer/bottom boundary layer interaction.
- Understand how bottom stress varies due to differences in the bottom roughness caused by both variations in sediment texture and ice scour.
- Evaluate how resuspended sediment settling rates are affected by non-aggregating particles.
- Determine how high latitude sediment dynamics processes contrast with temperate, ice-free, wave-dominated continental shelves.

See Section 2.3 and Mission Elements 3.1.1, 3.1.2, 3.1.3, 3.2.2, 3.2.3, 3.3.2 for complementary activities.

2.1.3 Planning and Coordination

Interdisciplinary research will be necessary to move beyond the purely descriptive phase of Arctic science in order to understand the interactive processes on multiple time and spatial scales. This concerted research approach is feasible in part because of the anticipated increase in remotely sensed data for this region (e.g., the Alaska SAR facility due to begin operation in 1991) and the commitment to development of instrumentation capable of long-term in-situ measurements. A final component critical to the success of this ef-

fort is year-round access by researchers to the ice-covered seas via suitable ships and aircraft.

An interagency working group consisting of agency program managers will be convened late in 1989 to develop the coordinated plans, schedule activities and identify gaps in resources and operational capabilities. Additional workshops will be convened both to further refine the scientific implementation plans and to identify and develop additional priority areas for research. Annual meetings of investigators representing different agencies' programs will be convened to exchange the prior season's results and to plan follow-up activities. Residents of the Arctic and industry and state and local government representatives will be included through consultation, planning, and participation.

There will be continued cooperation and participation in ongoing and planned international research programs. Under the auspices of the Arctic Ocean Sciences Board, the Greenland Sea Project was developed and conducted an intensive field program from summer 1988 through 1989. At least ten countries are contributing to the effort to increase our understanding of the role of the Greenland Sea in climate-related processes and of the relationship between seasonal and interannual sea ice variations and the large-scale dynamics of the atmosphere and ocean. Some measurements are being made within Fram Strait to monitor fluxes into and out of the Greenland Sea.

The Arctic Ocean Sciences Board is now considering the initiation of the International Arctic Polynya Program. Research plans are being developed for the St. Lawrence Island polynya in the Bering Sea (SLIP), the Northeast Water on the Greenland Sea Shelf (NEW), and the North Water polynya in Baffin Bay (NOW).

Specific agency programs and projects that have been identified as potential components of the Arctic Ocean/Marginal Seas Interactions program follow.

DOC

NOAA has ongoing research to understand the population dynamics of marine mammals, particularly the bowhead whale, Stellar sea lion, and northern fur seal. A planned fisheries oceanography investigation focused on pollock will complement the ongoing effort to assess the stock condition of crabs and groundfish in the Bering Sea. NOAA's proposed Ice Edge Ecosystem Study is at the core of the marginal ice zone research program. The Ice Edge Ecosystem Study will test whether the interannual variation of maximum ice extent and seasonal ice retreat account for the major year-to-year variability in the biological

productivity of the Bering and Chukchi Seas. This builds on NOAA's ongoing research to model and understand the Arctic atmospheric boundary layer and to understand the fine-scale interaction of ice formation with regional dynamics and thermodynamics (with DOD/ONR). NOAA will continue its participation in the Greenland Sea Project. Data analysis of the oceanographic and meteorological data set from the Beaufort Sea Mesoscale Circulation Study (supported by DOI/MMS) will continue as a basis for a future effort to examine cross-shelf dynamics and the circulation of the Arctic Ocean. Resource atlases and data syntheses by NOAA's Strategic Assessment Program and other NOAA data and monitoring programs will also contribute to the information base for agencies to plan and coordinate programs.

DOD

The ONR program includes research in both the eastern and western Arctic, such as CEAREX, the new Leads program, and high latitude shelf-sediment dynamics. Analysis of data from CEAREX (with DOC/NOAA and NASA), from the Greenland Sea (with DOC/NOAA, NASA, and NSF), and from the Chukchi Borderland/Cap (with DOI/GS), and analysis of remotely sensed ice surfaces (with NASA) will all contribute to this program. ONR plans to continue mooring arrays in the Greenland Sea (with DOC/NOAA and NSF) and Bering/Chukchi Seas (with NOAA), as well as to deploy Bering Sea sediment traps for flux studies (with DOC/NOAA). ONR plans to refine sediment flux measurements from Barents to Greenland Seas, lead pilot experiments in the Beaufort Sea (with DOC/NOAA), and initiate a western Arctic lead data base using SAR (with NASA). Instrumentation development is planned for lead/polynya studies (with DOC/NOAA and NSF). ONR interagency workshops will be sponsored on Mesoscale Modeling and Prediction, and Shelf-Basin interaction. ONR will initiate a new program in FY 90 on Arctic shelf dynamics.

DOI

The ongoing programs under FWS for assessing the status of and managing marine mammals, birds, fisheries, and habitats, the MMS environmental studies program, Arctic Basin marine geology and geophysics program, GLORIA image mapping, shelf surveys, gas hydrate studies, and coastal studies are all contributions to this interagency program. A gas hydrate workshop will be organized at the Fall 1989 AGU.

NASA

The Polar Oceanography program includes

specific emphasis on science planned for the Alaska SAR Facility, establishment of a data system at NSIDC to process, archive, and distribute daily estimates of sea-ice cover and seasonal snow cover from SMMR and SSM/I passive microwave data, and the analyses of high latitude Ocean Color Imager Data (Sea WiFS; See Section 2.3.3 for more details).

NSF

Polar and Ocean Sciences programs include ISHTAR, Greenland Sea tomography, sediment flux studies, an ocean-atmospheric coordinated effort under Arctic Systems Science (ARCSS), and coordination with GOFS, JGOFS, and WOCE. UNOLS ship support is included. NSF will sponsor a workshop focused on Arctic Basin marine geology and geophysics.

2.2 Biosphere/Atmosphere Interactions

Role of Northern Land Regions in Global Carbon Dynamics and Biogeochemical Cycles

Program Goal. Agencies represented on the Interagency Committee are planning and propose to implement an interagency research program with the following goal:

- To define and understand the role of northern terrains and ecosystems in global climate changes and biogeochemical cycles and the effects of human perturbations on these processes.

Northern terrains and ecosystems are among the most sensitive of the earth, and global climate changes could be greatest in the North. Northern regions are likely to show the largest and earliest effects of global greenhouse warming. These lands and ecosystems are not just passive indicators of change in the dynamic earth system but play important active roles in global processes. The global atmospheric circulation patterns are determined by Arctic boundary conditions through pole-equator temperature differences. High latitude climate-hydrology-ocean interactions play an important role in determining ocean circulation and rates of CO₂ gas exchange between the global oceans and atmosphere. Northern ecosystem / terrain-atmosphere interactions, particularly those including peatlands and permafrost, involve potentially important sources and sinks of greenhouse gases and other elements key to biological processes.

One of the highest priorities identified by the

NAS Committee on Global Change and the IGBP is to determine the relationships between the atmospheric/hydrospheric and biosphere systems in global change. The Arctic system must be a primary consideration in these relationships. Monitoring, process studies, and model development in the Arctic are to a limited extent being carried out at the present time. Focusing and enhancing the level of effort of the agencies in the Arctic terrains toward the above stated goal will provide the critical information necessary in pinpointing the role of the Arctic in global change, as well as provide improved understanding needed for rational development of natural resources.

Most Federal agencies involved in biogeochemical cycling, climate research, and modeling

CH₄ are known to have varied between glacial and interglacial periods. The predicted rise in global methane release is similar to the measured increase at the end of the last glacial period, suggesting several hypotheses for control of global methane releases from peatlands and the degassing of deglaciated landscapes. Another question to be addressed is how past carbon accumulation varied with changing carbon dioxide, climate, and nutrient conditions.

Objectives:

- Determine sources and sinks of CO₂, CH₄, and other radiatively active trace gases (and their magnitude and flux rates) in northern ecosystems and terrains and their response to potential climate–landscape–permafrost changes.
- Refine estimates of contemporary and historical rates of change in organic terrains (e.g., carbon loss or gain) and correlate these with ice core, sedimentary, paleoclimatic, and permafrost records and observations.
- Incorporate results into general circulation models (GCM) and further refine experimental designs.

To define and understand the role of northern terrains and ecosystems in global climate changes and biogeochemical cycles and the effects of human perturbations on these processes

have ongoing research related to carbon dynamics in northern regions. Planning, implementation, and early communication of results among agencies will enhance scientific progress in refining answers to how northern terrain will respond and contribute to global climate change. Components of the Program Goal are outlined here for development and coordination during 1990–1991.

2.2.1. Role of Carbon Cycling in Northern Terrains and Ecosystems in Global Change

Northern ecosystems are estimated to contain 27% of global soil carbon. Permafrost terrain contains additional frozen organics and methane hydrates, as do the shallow seas surrounding the Arctic Basin. Response of tundra, bogs, and boreal ecosystems and buried methane hydrates to future climate change is expected to be significant, as these landscapes and geologic units may emit both CO₂ and CH₄. An improved understanding of sources, sinks and fluxes of these chemical species in present-day, atmosphere–biosphere interactions is required to refine prediction of the response of northern terrains to climate change. The partitioning of the flux of carbon from these cold soils between CO₂ (dry, aerobic) and CH₄ (wet, anaerobic) depends on local soil moisture. Answers to how these fluxes vary seasonally and across subtle changes in vegetation, relief, and water tables are required. Finally, the concentrations of CO₂ and

2.2.2 Atmospheric, Hydrologic, and Biospheric Interactions in Northern Terrains

Northern terrains and ecosystems constitute a complex mosaic of interacting landscape elements. In many cases, the response of one landscape element to regional or global change will depend on the response of neighboring units. This is particularly true in peatlands and areas with continuous and discontinuous permafrost, where ecosystem processes are regulated by local to regional hydrological characteristics. Integration of the response of separate ecosystems will require consideration of each landscape element, associated terrain, and relationships among these elements and ecosystem characteristics in a regional landscape.

Northern terrains and ecosystem processes also show a sensitivity to interannual variations in climate and soil moisture regimes. An improved understanding of the relationship of these systems to global change will require repeated or continuous measurements and integration over time to evaluate their responses.

Objectives:

- Develop and apply methods that take into account topography, hydrology, geomorphic gradients, and fluxes among landscape elements in projecting measures of ecosystem processes from site-specific studies to regional responses.

- Utilize existing sites and establish new sites in a network of long-term research sites to examine temporal trends and interannual variability in terrestrial-atmosphere interactions.
- Develop a multi-site monitoring program for measurement of CO₂ and other trace gases directed at determining regional fluxes between terrestrial systems and the atmosphere.
- Develop a capability to use remotely sensed imagery data in measuring ecosystem and terrain processes on a regional basis.

See Section 2.3 and Mission Elements 3.2.3, 3.4.2, and 3.4.3 for complementary activities.

2.2.3 Implementation

To achieve the objectives of this program, four principal and concurrent thrusts are required: 1) long-term observational programs, 2) process research, 3) intact ecosystem experiments, and 4) model development, testing and applications. The following outlines proposed approaches in each of these four areas. In the monitoring studies, remote sensing, telemetry and in-situ studies will be emphasized; in the process research, coupling between the hydrosphere, atmosphere and biosphere will be emphasized; the intact ecosystem experiments will provide "reality tests" for the developed models. Models will serve as dynamic syntheses of available information, serving both to identify areas of additional data needs and to extrapolate beyond studied sites.

Long-Term Observations and Monitoring

- For the hydrosphere the goal is to obtain baseline data sets of stream and groundwater hydrology. Currently, there is lack of knowledge of the relationship of environmental variables to seasonal, annual, and long-term hydrologic regimes and ability to predict hydrologic consequences of both regional and global anthropogenic changes.
- A more extensive meteorological monitoring program is required to obtain baseline data sets of air quality and meteorological conditions (airflows, precipitation, evaporation, temperatures, etc.). Also monitoring needs to be established to measure solar reflectance under different atmospheric conditions, including Arctic haze.
- An ecological monitoring program is required to obtain baseline data over decades in order to understand linkages between the abiotic and biotic components of the Arctic ecosystem. These include ultraviolet radiation effects at long-term sites such as on the LTER and MAB Biosphere Reserves and along broad geographical transects.

- Satellite monitoring using visible and near-infrared sensors (AVHRR, Landsat if available, and SPOT) to document spatial patterns and vegetation attributes on the regional landscape will be continued. This will be augmented in 1990 and beyond with radar data from the European Space Agency's ERS-1 satellite. Limited aircraft and remote sensing observations will be acquired at selected sites. A more systematic strategy for acquiring and archiving these data will be required.

Process Research

- Particle flux and gas exchange measurements need to be made for different terrains to understand their influences on soil, plant, air, water, and disturbance conditions. Emphasis is required on transients occurring after soil and plant disruption, differences between natural and disturbed landscapes, and correlation and integration with climate models.
- Examination of the influences of soil, plant, topographic, hydrologic, and meteorologic conditions on albedo, photosynthesis, evapotranspiration, respiration, and sensible heat fluxes emphasizing spatial and temporal variability are necessary to determine mechanistic responses of ecosystems and landscapes to changes in these factors.
- Extrapolation of leaf and plant processes (and driving factors) to vegetation community dynamics and on to relevant landscape "average values" is required to predict ecological responses to local disturbances as well as global changes.
- Dynamics of the water cycle in the Arctic will require coupling measurements and models for the atmosphere, hydrosphere, and biosphere components, including components of evapotranspiration and permafrost dynamics.
- The fluxes, sources and sinks of chemicals in and through the atmosphere, hydrosphere and biosphere will need to be determined.
- Definitions of patterns and controls of primary production and organic matter accumulation, energy fluxes, nutrient mineralization rates, spatial and temporal distribution of populations, and ecosystem response to natural stresses need to be addressed. Studies would be integrated with the hydrological and chemical studies.
- Study sites are required at Barrow, Toolik, Fairbanks, and other areas to establish adequate representation of specific regions.

Intact Ecosystem Experiments

- Controlled, intact ecosystem experiments can

be conducted to test hypotheses and develop models of ecosystem functions. However, the complexity of larger-scale intact ecosystems is generally substantial and few experiments can be performed. Consequently, experiments of opportunity will be used initially, where the disturbance is supplied by some natural transient (such as a fire or drought) or by some development activity such as the exploration with its associated disturbances. For these experiments of opportunity, the cost of creating the disturbance is avoided, but it is still necessary to invest in defining baselines and control test sites. Controlled experiments will be designed and subsequently conducted.

Residents of the Arctic, members of industry, and state and local government representatives will be included, through consultation, planning, and participation

Model Development, Testing and Applications

- Simultaneously with the development of process models for the hydrosphere, atmosphere, and biosphere, coupling of the media will be achieved through modeling of energy flux and chemicals (including water), which is similar to the procedure proposed for the International Geosphere-Biosphere Program (IGBP). Thus, model development can be viewed as a contribution to the major thrust of the IGBP and both endeavors will profit from frequent communications.
- In contrast to the IGBP, however, these activities will develop models at a variety of temporal and spatial scales, including the specific as well as regional sites. Models applicable at a variety of spatial scales have the important advantage that parameterizations of processes for use at larger time and spatial grid scales can then be tested with model results obtained from the smaller-scale problems. Thus, "reality checks" will be available for the coarse-grid models.
- Model testing will be performed via intact ecosystem experiments. In addition, in conjunction with sensitivity tests of the models, the models will be used to suggest specific field studies and to define measurement protocols.

International Collaboration

- Plan research and utilize long-term monitoring and research sites in collaboration with

northern Canada, Greenland, Svalbard, Iceland, Scandinavia, Denmark, the Soviet Arctic, and the MAB Northern Sciences Network.

2.2.4 Planning and Coordination

An interagency working group consisting of agency program managers will be convened in 1989 to develop a coordinated plan, schedule activities, and identify gaps in research, resources and operational capabilities.

Questions related to long-term, on-site measurements at existing and additional research sites will be addressed, as well as additional expeditionary programs. Annual meetings of investigators from different agencies' programs will be convened to exchange the prior season's results and to plan follow-up activities. The first will be scheduled for early 1990 and will encourage participation from other countries, particularly where existing bilateral agreements or projects are already active (USSR, Canada, Norway). Residents of the Arctic, members of industry, and state and local government representatives will be included, through consultation, planning, and participation.

Specific agency programs and projects that are identified as components of this coordinated effort follow:

DA

Forest Service is responsible for development of the Forest/ Atmosphere Interaction Research Program and use of test sites including the LTER site in Fairbanks, Alaska.

DOC/NOAA

GMCC Program includes year-round monitoring of trace gases at Barrow, Alaska, observatory and cooperative projects. The international methane project, proposed under Area VIII of the US/ USSR Environmental Protection Agreement, plans to measure the flux of methane from wetland environments, survey the extent of methane hydrate deposits in terrestrial permafrost and submarine environments, maintain an atmospheric measurement station network, and develop a cooperative carbon cycling model.

DOE

Carbon Dioxide and Global Carbon Cycle programs are preparing a report on potential changes in carbon cycle gas emissions from Arctic, boreal peatland, and boreal upland ecosystems in response to CO₂-induced climate change and conducting studies on glacier and sea levels and General Circulation Models. Research includes studies of direct effects of CO₂ and the influence of climate change on high-latitude ecosystems.

The Ecological Research program continues to focus on tussock tundra response to disturbance and integrates remote sensing studies, multilayered GIS digital databases, and a variety of laboratory and field experiments with synthetic model development. Plant physiology, basin and plot hydrology, geochemistry, precipitation chemistry, and snow accumulation patterns are among system attributes being examined to provide an understanding of the mechanisms driving ecosystem dynamics. Remote sensing and digital data management techniques are used to establish spatial relationships between physical and biological characteristics of these ecosystems and mathematical models are developed to help synthesize information, to present a framework for simulating large and small scale responses to perturbations, and to permit analyses involving extrapolation in time and space.

DOI

Geological Survey programs include mapping, measurements, and history of the lateral and areal extent of gas hydrates and permafrost to assess permafrost and gas hydrates as sinks and sources of methane, and studies of the climatic history of Arctic regions.

Park Service manages Biosphere Reserves and parks in Alaska which may be used for long-term research and monitoring.

EPA

Global Change program will assess the influences of climatic change on feedback mechanisms controlling biogenic emissions of methane in high-latitude regions.

NASA

Global Tropospheric Experiment program is preparing results of summer 1988 aircraft-ground ABLE 3A studies in Alaska, including 1) peatlands as sources of CH₄, 2) CO₂ exchange-biosphere/ocean, and 3) role of open water and vegetation as source/sink of photochemically active molecules. Planning is ongoing for 1990 expedition to Hudson Bay lowlands (ABLE 3B).

Upper Atmosphere Research and Interdisciplinary programs are considering regional studies of trace gas exchange coupling hydrology and development of global data sets starting in 1989 and continuing for up to three years.

Terrestrial Ecosystems program is conducting research to use remotely sensed landscape patterns to extrapolate point measurements of methane flux to regional scales. Planning for follow-up to First ISLSCP Field Experiment (FIFE) Boreal Forest field site is underway.

Biosphere Research: Emissions from Wetlands (BREW) is preparing results of field measurements conducted in Alaska in summer 1988, including studies of 1) fluxes of CO₂, CH₄, Rn²²² and biogenic sulfur gases, and 2) relationships to remotely sensed variables. Planning for ABLE 3B and boreal and wetland flux studies is underway.

The Alaska SAR Facility Science Plan includes phenological assessments of terrestrial ecosystems.

NSF

Arctic Systems Science (ARCSS) is a new program initiated in FY 89 to investigate air-land-ocean interactions, including a five-year Greenland Ice Coring Program to understand paleoenvironments and the linkages between the cryosphere and the high-latitude oceans and land masses. Individual grants support permafrost, lake sediment, and other paleoenvironmental research related to the accumulation and transport of organic matter. Long-Term Ecological Research (LTER) sites at Toolik Lake and Fairbanks serve as core areas for studies of ecosystem-landscape aquatic interactions.

2.3 Arctic Data and Information Networks, Including Remote Sensing

Program Goal: Agencies represented on the Interagency Committee are planning and propose to implement an interagency research program with the following goal:

- To develop a common network of accessible systems combining data and information bases by 1991.

2.3.1 Arctic Environmental Data System (AEDS)

In order to facilitate the Arctic research recommended in this Plan, it is necessary to identify and develop methods to improve the management and dissemination of Arctic data. Following an interagency workshop in 1988, initial efforts focused on the development of an Arctic Environmental Data System.

Objectives

- Coordinate and contribute to the establishment of a distributed national data system to support national and international programs related to global environmental change.

- Support the data handling requirements of Arctic marine and terrestrial mesoscale ecosystem programs (e.g., Bering Sea).
- Develop a data system useful to Arctic scientists, residents, and resource managers, which could be integrated with geographic information systems (GIS).
- Provide for ease of modification of the data system as computers and storage technologies change.

Ongoing and Planned Activities

- Develop an Arctic Environmental Data Directory (AEDD), and obtain representative references on Arctic data sets from institutions that hold Arctic data (DOC/NOAA, DOD/NOAA/ Joint Ice Center, DOE, DOI/GS, NASA, NSF, SI).

To avoid duplication of research, and improve access to existing results, it is necessary to provide some mechanism for integration of Arctic information resources

- Develop a list of key Arctic environmental variables needed to detect, measure, and understand Arctic mesoscale changes, especially in relation to global change, and in cooperation with the Alaska Science and Engineering Advisory Commission pursue its recommendation to establish and collect data from a statewide monitoring program for climate change in Alaska (DOC/NOAA, DOE, DOI/GS, NASA, NSF, SI).
- Define requirements to establish mechanisms for user training and evaluation of the AEDS, including directory publication, presentations, workshops (DOC/NOAA, DOE, DOI/GS, NASA, NSF, SI).
- Determine whether to sponsor a digital data subscription series, using compact disc read-only memory (CD ROM) technology, containing the AEDD index to Arctic data sets, and eventually key Arctic environmental data (DOC/NOAA, DOE, DOI/GS, NASA, NSF).
- Coordinate AEDD activities with the Inter-agency Working Group on Data Management for Global Change, and with related Canadian data activities (DOC/NOAA, DOE, DOI/GS, NASA, NSF).
- Establish small working groups to address technical issues (e.g., data standards, query and retrieval language, standard portable operating system) (DOC/NOAA, DOD/NOAA/

Joint Ice Center, DOE, DOI/GS, NASA, NSF).

2.3.2 Arctic Information Network

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, uncatalogued in organized collections. To avoid duplication of research, and improve access to existing results, it is necessary to provide some mechanism for integration of these Arctic information resources. Ways to automate, integrate and exchange 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.

Objectives

- Promote the regular exchange 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.
- Provide user friendly computer searching of global polar-related bibliographic data bases.

Ongoing and Planned Activities

- Formalize a U.S. working group of northern libraries, from the Northern Libraries Colloquy (NLC), to plan and coordinate implementation of a Northern Information Network, linking Federal and University bibliographic holdings (DA/FS, DOC/NOAA, DOI/BLM/ FWS/GS/MMS, NSF, SI, with university libraries).
- Develop and encourage more effective mechanisms to catalogue and disseminate "gray" literature and have it represented in bibliographic data bases through coordinated efforts and provide mechanisms to measure effectiveness (DA/FS, DOC/NOAA, DOI/BLM/ FWS/GS/MMS, NSF, SI, with university libraries).
- Develop and encourage use of an electronic mail network (e.g., Bitnet, Omnet, SciNet) among U.S. and other polar libraries to promote resource sharing and cooperation (DA/FS, DOC/NOAA, DOI/GS, NSF, SI, with university libraries).
- Encourage polar libraries to become members of one of the existing national bibliographic utilities (e.g., WLN, OCLC) (NSF).

- Improve access to existing on-line information retrieval systems containing Arctic bibliographic data bases by developing products available on optical disk (e.g., CD-ROM) (DA/FS, DOC/NOAA, DOI/GS, NOAA, NSF, SI, with university libraries).
- Increase frequency and distribution of the Northern Libraries newsletter to users (NSF, with university libraries).
- Design and develop a gateway or computer network to link the several existing polar information resources, working toward a common data base structure (DA/FS, DOC/NOAA, DOI/GS, NSF, with university libraries).

2.3.3 Remote Sensing and Telemetry

Over the next five years there will be an increase, by several orders of magnitude, in the amount of information that will be acquired by satellites over the polar regions. To ensure that these data are used effectively we shall need "friendly" archives that provide easy access to parameters derived from the data, a clear understanding of the accuracy and limitations of these derived parameters, a capability to extract the temporal and spatial information contained in long-term, global data sets, and an ability to incorporate these data sets in the development of large-scale theoretical models, and in their initiation and updating (see 2.4.1).

Objectives

Satellite capabilities that are and/or will be available for Arctic research include (listed in order of increasing spatial resolution):

- Coarse-resolution passive-microwave imagery available since 1973 from NASA's ESMR and SMMR, and currently being acquired by DOD's SSM/I. These data are used to compile global daily estimates of the extent and characteristics of sea-ice cover and of seasonal snow cover.
- Coarse-resolution measurements of radar backscatter for the open ocean obtained by radar scatterometers that will operate aboard the European ERS-1 and the Japanese ADEOS in the early 1990s. These provide estimates of sea-surface wind vectors.
- Medium-resolution visible and infrared imagery, such as that acquired by NOAA's polar-orbiting weather satellites and by NASA's CZCS. These data are used to monitor cloud cover, sea ice conditions, surface temperatures, and ocean color (to provide estimates of near-surface chlorophyll concentrations). NASA and EOSAT are planning to

fly an ocean color imager, Sea-WiFS, in 1991. Sea-WiFS will provide global coverage, cloud conditions permitting, on a daily or every-two-days basis, including coverage of the Arctic. Global data will be processed and archived at Goddard Space Flight Center. Also, Sea-WiFS will continuously broadcast high resolution data (HRPT format). An HRPT ground station in Alaska will provide AVHRR (sea surface temperature) and Sea-WiFS (chlorophyll) imagery for the Bering Sea and Gulf of Alaska.

- High-resolution radar imagery from Synthetic Aperture Radars (SARs) to be flown aboard the European and Japanese ERS-1 satellites and the Canadian Radarsat in the early and mid-1990s will permit detailed mapping of sea-ice conditions and ocean waves. NASA established the Alaska SAR Facility (ASF) to develop capabilities during 1989–1991 to receive, process, archive and distribute SAR data from all these satellites within the framework of memoranda of understanding negotiated with ESA, NASDA and CCRS.

In addition, high-resolution images from Landsat are useful for regional studies, and for validating estimates of surface conditions obtained by other sensors. Radar-altimeter measurements over the ocean can be used to measure wave height, wind speed, eddy intensity and position of the sea-ice margin, and to reconstruct the geoid as represented by the ocean surface, which gives proxy information on seabed topography. Most of these techniques provide almost total and frequent coverage of the polar regions. In addition, airborne surveys provide detailed measurements, not yet possible from spacecraft, of magnetic and gravity fields, both indicative of local geology; and atmospheric parameters, such as profiles of humidity, particulates and trace gases.

Ongoing and Planned Activities

- Complete development of the SSM/I Data System and its implementation at the NSIDC, and work with NOAA to maintain this data system on a permanent basis (NASA).
- Complete development of the ASF with full capability to be upgraded for acquisition of SAR and other (optical, ocean color, etc.) data from all planned missions into the Eos time frame. NSF, NOAA, and Navy should take an active role in ASF planning and in developing associated research programs (DOC/NOAA, DOD/Navy, NASA, NSF).
- Focus on radiative transfer studies with practical application to developing algorithms for the rapid extraction of useful information

from remotely sensed data. Intensive validation campaigns should yield clear, user-oriented assessments of sensor and algorithm performance (DOD/Navy, NASA).

- All agencies cooperate to encourage application of remotely sensed data to research problems. NSF and NASA promote the application of remotely sensed data to postgraduate research in the polar regions to ensure that we have the human resources available to make use of the data acquired in the 1990s. USGS should provide GIS and related mapping and remote sensing expertise to facilitate development and exchange of research results.
- Develop a broad bipolar capability for airborne remote sensing with the major goals of validation of satellite measurements, intensive studies of specific regions, and acquisition of data not obtainable from spacecraft (DOC/

NOAA, DOD/Navy, DOI/GS, NASA, NSF) .

- Develop instrumentation for acquisition of in-situ oceanographic and biological data at remote locations for transmission to investigators via satellite (DOD/Navy, NSF).
 - Position location and navigational capability is of particular importance in the Arctic Ocean with its drifting ice cover, and should be made fully and continuously available for use of unmanned sensors on the ice, for work stations and research programs on the ice, and for major manned platforms, such as for drilling for scientific programs and for logistic support.
 - Develop an accessible archive of remotely sensed data for analysis, integration and synergistic merging of time series data sets for climatological analysis (DOC/NOAA, DOI/GS, NASA, NSF) (see section 2.4.1).
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3. Research Mission Components

This section of the revision to the Plan covers the six major components and their individual mission elements. For each element, *Selected Activities and Accomplishments* by Federal agencies are highlighted, generally covering the period since the Plan was published (1987–1989); *Objectives* and *Ongoing and Planned Activities* of Federal agencies are briefly described, focusing on the period covered by this revision (1990–1991).

3.1 Arctic Ocean and Marginal Seas

3.1.1 Ice Dynamics and Oceanography

Research in the area of ice dynamics and oceanography is important to advance our understanding of Arctic Ocean dynamics and air–sea heat and gas exchange. A major priority is the development of the next generation of operational ice forecasting models for Arctic regions. A systematic program of oceanographic measurements is urgently needed to support the objectives of this mission element and the interagency program (see 2.1 for related activities).

Selected Activities and Accomplishments

ONR planned and conducted the international Coordinated Eastern Arctic Experiment (CEAREX) to improve understanding of how atmospheric structure controls the transfer processes between the atmosphere and the underlying ocean and ice. NOAA contributed the NOAA P-3 aircraft and conducted studies of heat flux between the atmosphere and ocean, effects of Arctic haze, and development of Arctic storms.

The ONR Accelerated Research Initiative (ARI) and University Research Initiative (URI) programs addressed heat flux balances and ice formation associated with Arctic leads, effects on oceanic and

stitute, of historic data on recurring polynyas in the northern Bering and Chukchi seas, and performed analysis of meteorological factors affecting their size and persistence.

ONR, NSF, NOAA, and NASA participated in the international Greenland Sea Project.

NOAA, with support through OCSEAP, completed the Beaufort Sea Mesoscale Circulation Study to improve understanding of shelf circulation and its forcing. An extensive data set including meteorological parameters, ocean currents, ice velocities, water column nutrient, salinity, and temperature distributions was collected for the shelf region between Barrow and Demarcation Point.

NOAA developed a new sea-ice, barotropic–ocean model with a grid spacing of 2–10 km to investigate the coupling of ice motion to wind-driven coastal currents on the Bering Sea and Alaskan continental shelves.

NOAA and ONR conducted the Freeze Experiment in the northern Bering and Chukchi Seas to observe the fine-scale interaction of ice formation with regional dynamics and thermodynamics.

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 scale.
- 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.

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).

Augment existing observing systems with more capable instrument systems 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 intermass, conservative tracer movement, and variations and

Research in the area of ice dynamics and oceanography is important to advance our understanding of Arctic Ocean dynamics and air–sea heat and gas exchange

atmospheric circulation, and the mechanical characteristics of ice and rheology, coupled with remote sensing.

NASA established the Alaska Synthetic Aperture Radar (SAR) Facility (ASF) in Fairbanks, and developed the related science plan.

NASA implemented a sea-ice data system at NOAA's National Snow and Ice Data Center in Boulder, Colorado, and initiated a multisensor aircraft remote sensing program over the Bering, Beaufort and Chukchi Seas.

NOAA/OCSEAP sponsored a review completed by the University of Alaska, Geophysical In-

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).

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. Marine ecosystems are dominated by sea ice, while coastal ecosystems are influenced by freshwater input and seasonal sediment loads, as well as by season

There is a need to quantify the influence of physical processes on population abundance and resulting variability in rates of biological production

al sea ice. There is a need to quantify the influence of physical processes on population abundance and resulting variability in rates of biological production of marine living resources through long-term and well-designed interdisciplinary research (see 2.1 for related activities).

Selected Activities and Accomplishments

NOAA's Strategic Assessment Program issued atlases of living resources of the Bering, Chukchi and Beaufort Seas.

NSF continued the Inner Shelf Transport and Recycling (ISHTAR) program in the Bering and Chukchi seas, while a joint US/USSR cruise in summer 1988 complemented ongoing marine ecosystem programs. Planning in 1988 under the NSF Arctic Systems Science (ARCSS) program includes an ocean-atmosphere interaction component related to marine ecosystems.

The Minerals Management Service, with NOAA/Ocean Assessment Division, completed ecosystem studies and published scientific literature reviews for the Chukchi Sea (in cooperation with NSF/ISHTAR), Yukon River Delta, and the North Aleutian Shelf along the Alaska Peninsula. NOAA also completed a literature review on natural petroleum seeps in Alaskan marine environment.

The Minerals Management Service, Alaska Environmental Studies program, in cooperation with NOAA, published the results of an Arctic Information Transfer Meeting in 1988, followed by a

report on an interagency workshop on Arctic fisheries and oceanography.

NOAA's OCS Environmental Assessment Program (OCSEAP) started a collection program for Alaskan marine mammal tissues for contaminant analysis. Field collections of tissues are made in cooperation with Native subsistence hunters. The tissues are preserved and archived at a specimen bank at DOC's National Institute of Standards and Technology.

NOAA's OCSEAP coordinated studies with the Fish and Wildlife Service concerning salmon genetic stock identification in the southeastern Bering Sea, and Arctic char habitat use and stock inter-mixing in the Beaufort Sea.

The Fish and Wildlife Service continued to assess polar bear population status and habitat relationships in the Bering and Chukchi seas, and walrus populations in the Chukchi Sea, using satellite telemetry.

Reports were produced by Federal agency-supported activities, including the Polar Research Board's report, *Priorities in Arctic Marine Science*, which sets forth a major research agenda. The Arctic Ocean Science Board proposed an International Arctic Polynya Project.

NOAA/National Marine Fisheries Service continued programs to: provide an opportunity for St. Paul residents to participate in collecting data from the 1988 northern fur seal harvest; assess the recovery of the bowhead whale population; identify the nature of declines of northern fur seal and northern sea lion populations; synthesize data on marine mammal populations for model development; and manage an observer program for studying the effects of incidental take of Dall's porpoise in high seas driftnet fisheries on porpoise populations.

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 study of the structure, dynamics, and natural variability of the ecosystems, and 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.
- Understand the physical and biological pro-

cesses that affect fisheries recruitment in U.S. waters of the Bering Sea.

Ongoing and Planned Activities

Establish a capability to monitor ocean productivity in Arctic regions using 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 the formation and development of polynyas, how they influence the migration, distribution, and abundance of marine mammals and birds, and ways that 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, and 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 trophic level animals (DOC/NOAA, DOI/FWS/MMS).

Determine stream origin of anadromous fish species that occur in the coastal waters of the Beaufort Sea and determine relative abundance and population characteristics of fish in the near-shore coastal waters of the Arctic National Wildlife Refuge and 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).

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 2.1).

Selected Activities and Accomplishments

In 1988, the Geological Survey completed a geophysical transect across Alaska, crossing into

the Beaufort Sea.

In September 1987, the Geological Survey, aboard the Coast Guard icebreaker *Polar Star*, collected sediment samples and geophysical data at the Chukchi Cap.

The Geological Survey Geomagnetic Observatory program continued to operate its magnetic observatory at Barrow, Alaska, the northernmost facility in the U.S., which continues to provide baseline data on the earth's geomagnetic field.

During 1986–1988, the Geological Survey conducted GLORIA (sidescan sonar system) surveys and reconnaissance studies in the Bering Sea and Gulf of Alaska.

The Minerals Management Service completed and published geologic reports on the Chukchi and Beaufort Sea basins, North Aleutian Shelf and the Kodiak region.

In 1986–1989, Federal agencies participated in international coordination planning meetings, which continued to define approaches to unraveling the history of the Arctic Basin through geophysical methods and direct sampling.

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.

Ongoing and Planned Activities

Develop a detailed plan for a multi-agency Arctic Ocean Basin geology and geophysics program (DOD/ONR, DOI/GS/MMS, NSF).

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 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).

Conduct site surveys of potential deep drilling sites, using the same sensors as for transects and

energy, momentum, and mass from the sun to the earth, and understand the interactions 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 theoretical models needed for future predictions. Our understanding of the basic phenomena of the coupling processes involved, and the dramatic sequences across the full optical, radio, and particle spectrum, is far from complete.

Selected Activities and Accomplishments

NASA's WIND spacecraft, in an orbit that will allow 95% solar wind coverage, and POLAR spacecraft, with auroral imaging, were approved in the 1988 budget for launch in 1992.

A number of spacecraft, including those operated by NASA, NOAA, and DOD, made UV images to better define two-dimensional energy input into the upper atmosphere by auroral and Polar Cap precipitating particles.

NSF initiated 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 defined the Geospace Environment Modeling (GEM) program, which is aimed at understanding the ionosphere and magnetosphere using a well-planned schedule of theory and experimental approach.

Using a sodium lidar, NSF discovered that a dramatic depletion of the 90-km height sodium layer occurs each summer in the Arctic.

At its Millstone Hill incoherent scatter radar NSF has found that there are plasma instabilities at 1000-km altitudes over the Arctic, the motion of which can mimic satellites and missiles.

NSF- and Air Force-funded research using the Sondrestrom and Millstone Hill incoherent scatter radars found and confirmed that there is a significant change from season to season in the high latitude ionospheric electric field.

NOAA's Geostationary Operational Environmental Satellite (GOES) program, which collects magnetometer and riometer data from 15 locations in the U.S. and Canada, is being expanded. Additional data are also available from several other countries. Open scientific access is available to near-real-time data collected by NOAA satellites.

A program sponsored by NSF and NCAR found that atmospheric temperatures over the North Pole are closely correlated with solar activity and the direction of equatorial stratospheric winds (called the phase of the quasi biennial oscillation).

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

polygons. Thoroughly analyze data to pinpoint drilling sites (DOI/GS, DOT/CG).

Plan a drilling 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. In support of ocean/margin-basin interactions (see 2.1), initiate a U.S.-Canada drilling project in the Yukon Flats-Old Crow Basin area (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 (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 non-energy mineral potential of the Outer Continental Shelf (DOI/MMS).

3.2. Atmosphere and Climate

3.2.1. Upper Atmosphere and Near-Earth Space Physics

The goal of this research is to trace the flow of

lation). This is the first statistically convincing correlation between solar activity and weather, and even though the mechanism is not understood, the effect is already being used by NOAA in making long-term atmospheric forecasts.

The Air Force Geophysics Laboratory, having determined two states of the polar ionosphere, further determined the physical basis for each state, thus dramatically changing both scientific and application-oriented views of the Polar Cap.

Objectives

- Collect continuous data on the solar wind and interplanetary scintillation, or external forcing terms, through deployment and maintenance of low earth orbiting Arctic inclination satellites, solar and magnetospheric monitors in synchronous orbit, and spacecraft.

The goal of this research is to trace the flow of energy, momentum, and mass from the sun to the earth, and understand the interactions within and between the intervening regions

- Observe the global scale response of the polar region 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 use of special facilities, and making use of research aircraft available.
- Maintain active theoretical programs and promote evolution of models to describe unique physics of the atmosphere and ionosphere in Arctic regions.

Ongoing and Planned Activities

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 or implement, and operate state of the art diagnostic capabilities in existing Arctic facilities, including optical observatories, for the study of 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).

Expand efforts during the imminent sunspot maximum by completing necessary set of transpolar observing sites (DNA, DOD/AFGL/NRL, 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 Sondre Stromfjord, Greenland) sites (DNA, DOC/NOAA, DOD/AF/N, NASA).

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

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

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).

3.2.2 Climate and Weather

The outstanding characteristic of Arctic climate and weather is its variability. 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. Arctic climate also has global implications. There is a need to relate Arctic atmospheric circulation to mid-latitude weather.

er, and to measure and understand long-term temperature trends and the variability of the Arctic heat sink, which may be linked to global warming (see 3.4.1 for related paleo-activities).

Selected Activities and Accomplishments

NOAA participated in the ONR-CEAREX program with two successful P-3 flights to document the structure and evolution of polar lows in the Norwegian Sea.

Understanding of the physics of Polar Lows has led to predictive models. A report on Polar Lows is being published based on a conference held in Madison, Wisconsin, March 1988.

Objectives

- Develop an Arctic Climate Studies Program as part of the National Climate Program, including climate effects on biological resources, and a systematic program of observations and modeling of the Arctic radiation balance and cloud cover, and their effect on climate.
- Understand to what extent Arctic climate variations are amplified signals derived from elsewhere, or 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, and quantify high latitude terrestrial ice and snow changes, and consider their effects.

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

Ongoing and Planned Activities

Develop dynamically coupled meteorologic 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 of 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 GCM's in Arctic parameterization experiments, and develop studies of polar radiation, clouds, albedo feedback, and high latitude atmospheric model performance (DOC/NOAA, DOE, NSF).

Develop 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).

Undertake systematic analysis of the first-year and multi-year 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/NCOP, DOI/GS, NOAA, NSF).

Undertake analyses of existing models and data on "Arctic low" development and evolution in order to develop improved predictive capabilities of Arctic low storms (DOD/ONR/OCEANAV).

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

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 impact on airborne particulates and chemistry (see 2.2 for related activities).

Selected Activities and Accomplishments

Major NASA and NOAA expeditions (ABLE 3A summer 1988, Ozone winter 1989, and AGASP spring 1989) involving surface, aircraft and satellite measurements helped determine processes controlling both tropospheric and strato-

spheric ozone chemistry, the potential impact of large-scale pollution events, and the role of the biosphere as a source and sink for atmospheric gases and aerosols.

NOAA's Geophysical Monitoring for Climatic Change (GMCC) program continued to maintain and operate the observatory at Barrow, Alaska, as a baseline monitoring facility, which has provided 15 years of data used to interpret trace gas species.

NSF and NOAA sponsored collaborative research with scientists from the University of Wyoming, Environment Canada and the USSR, and launched a series of balloons from Alert, NWT, and Heiss Island, USSR, to study polar stratospheric clouds and the role that they play in the catalytic destruction of ozone by chlorine derived from chlorofluorocarbons.

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

NSF-sponsored scientists studying ice cores demonstrated a direct chronological record of rapid variation of atmospheric composition and climate.

DOE and ONR measurements and analyses of Arctic haze revealed a relationship between radiative balance and carbon particle concentration.

Objectives

- 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.
- 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/PS, NASA, NSF).

Continue monitoring of 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 on 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).

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 2.1.2 and 2.2 for related activities).

Selected Activities and Accomplishments

The Department of Interior undertook new studies and completed publications on the Arctic National Wildlife Refuge (ANWR), including a final report on Coastal Plain Resource Assessment by the FWS (wildlife) and BLM/GS (oil and gas). The GS published a separate and more detailed report on the joint BLM/GS oil and gas assessment, as well as geographic information system maps. NOAA's Ocean Assessments Division established a cooperative agreement with the FWS for fisheries-oceanography research along the coastal plain of the Arctic National Wildlife Refuge.

The Geological Survey's Alaska Mineral Re-

source Assessment Program (AMRAP) continued to provide data to aid in evaluating local energy and mineral resources, including strategic and critical minerals.

USGS Professional Paper 1399, published in 1988, reports on all aspects of the 1974–1982 NPRA exploration program, including archeology, environmental assessment, engineering, geology, geophysics, drilling program, and resource assessment.

The Minerals Management Service conducted assessments of the petroleum and non-energy mineral potential of the Outer Continental Shelf, including Beaufort, Chukchi, North Aleutian and Kodiak shelves; updated estimates of undiscovered oil and gas resources are being published.

BLM prepared a Resource Management Plan for the Utility Corridor addressing multiple-use issues, published results from the Central Arctic Management Area (CAMA) study, and completed an EIS on the Trans-Alaska Gas System (TAGS) pipeline to clear the way for construction of a gas line to export North Slope gas to the Pacific Rim countries.

Objectives

- 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.

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

- 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 analytic 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 to address specific earth science questions (DOI/BLM/GS/MMS).

Continue the Alaska Mineral Resource Assessment Program (AMRAP) and related research activities such as BLM's Resource Management Planning Effort and MMS's Resource Evaluation Program, that aid in the evaluation of local energy resources (DOI/BLM/GS/MMS).

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

Prepare assessments for non-energy minerals lease sale proposed for 1990 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 the long-term cultural and environmental impacts (DOI/BLM/BOM/GS).

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 and interpreted, and the results are analyzed carefully. 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 (see 2.1 for related activities).

Selected Activities and Accomplishments

Department of Interior studies of the Beaufort and Chukchi Seas by the Geological Survey and the Minerals Management Service were presented in government reports, scientific journals and books, as well as several special Arctic symposia (e.g., AGU in December 1988 and AAAS in January 1989).

Objectives

- Map beach, littoral, and nearshore sediment and subsea permafrost. 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 in order to understand coastal erosion and sediment transport processes.
- Investigate the direct and indirect effects of ice on coastal erosion (influence on waves and currents), and on sediment transport (contact with beach sediments, keel gouging, entrainment in frazil ice).

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

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, for example 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, DOT/CG).

Increase stream gauging of 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).

Collect data on thaw settlement of subsea permafrost and the engineering properties of frozen sediment. Establish long-term investigations on thermal and oceanographic parameters 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 Alaska Natives. Some of these resources are harvested commercially or for subsistence purposes (e.g., food, shelter, fuel, clothing, and tools); and others provide for 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

Fish and Wildlife Service monitored selected resident and migratory fish and wildlife species to construct population models, making use of technologies such as satellite-based tracking systems and geographic information systems. New telemetry transmitters were developed and are undergoing testing. The Alaska Fish and Wildlife Research Center continued to study the Porcupine and Central Arctic caribou herds in relation to North Slope oil and gas development and proposed development in ANWR. Recent results are available from satellite telemetry on caribou yearly range of travel, location of calving sites, and day-to-day movement patterns.

Bureau of Land Management began a study of fisheries resources and recreational opportunities on accessible rivers along the Dalton Highway. The BLM's protection and recovery program shows apparent increase in the population of the threatened peregrine falcon. Assessment of the feasibility of reintroduction of muskox in the Oolamnavok River region was completed. Cooperative efforts with the Alaska Department of Fish and Game on caribou movements in the Teshekpuk Lake Special Area and with the Park Service on North Slope grizzly bears were performed.

The Department of Interior initiated a multi-year study of waterfowl and shorebirds, including black brant (geese), at Teshekpuk Lake. The Alaska Fish and Wildlife Research Center of the FWS conducts this project, in cooperation with BLM and MMS, to investigate habitat in this potential North Slope transportation corridor.

The FWS monitored spawning escapement of fall chum salmon in the Chandalar River in support of U.S.-Canada Yukon salmon negotiations, and conducted fisheries and habitat investigations on rivers of the ANWR.

Studies by the National Park Service included

using satellite-tracked radio collars on wolves in Noatak, examining the effects of all-terrain vehicles in the Gates of the Arctic National Preserve, multi-species monitoring studies at Denali National Park and Preserve, baseline water resource inventories at Denali and Bering Land Bridge, effects of fish hatcheries on genetic integrity of temperate and Arctic salmon stocks, and vegetation mapping.

The National Park Service, Alaska Region, designed and proposed a comprehensive science program for the Region to offer balanced science staffing for the parks, research centers, and regional office.

Department of Energy research at Toolik Lake (R4D), based on the occurrences of natural isotope abundances in various invertebrates, fish, and birds, suggests that some freshwater food chains are seasonally dependent on inputs of carbon from terrestrial peat deposits and are, in essence, being subsidized by the input of this sub-fossil carbon.

Objectives

- Determine 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.

Management agencies must have adequate data and information on the biology and ecology of birds, mammals, fish and plants

- 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

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 (DOI/BLM/FWS/NPS, NSF).

Increase the involvement of Alaska Native resi-

dents and organizations in research programs and decisions affecting fish and wildlife and other renewable land-based ecosystem resources (DOI/BLM/FWS/NPS, NSF).

Investigate the trophic relationships between higher vertebrate predators/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 (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).

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 increased productivity of renewable resources. The goals are to promote self-sufficiency among local inhabitants and to accrue economic benefits.

Selected Activities and Accomplishments

The Forest Service completed the final version of the Alaska Vegetation Classification System.

Sponsored by NSF's Long-Term Ecological Research (LTER) program, the Forest Service established long-term sites in cooperation with the University of Alaska, to investigate natural environment and nutrient controls over ecological succession processes.

The Forest Service developed a model for evaluating the effects of wildfire on vegetation and permafrost in tundra ecosystems. Studies were also completed on silviculture, forest entomology, wildland hydrology, and forest pathology.

The Forest Service collected data on moose populations in mountainous areas of Denali National Park as input to bioenergetic models.

The Soil Conservation Service completed the Hagemeister Island Range Survey on grazing, and continues to collect data with the University of Alaska on reindeer ranges throughout Alaska.

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.
- 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 forest conditions, productivity, and human occupancy (DA/FS/SCS, DOI/BLM/NPS).

Increased knowledge of the productivity of Arctic and Subarctic forests and soils will lead to sounder management practices and help local inhabitants gain self-sufficiency and economic benefits

Determine human and environmental impacts, including the effects of fire, on forest and park resources for use in development of more effective management and protection systems, and to support subsistence, wildlife habitat, and protection of streams and fisheries (DA/FS, DOI/FWS/NPS).

Monitor climate conditions in areas where soils have the potential for agriculture to determine suitability for crop production, with focus on the effects of permafrost, erosion, and short growing season (DA/ARS/SCS, DOI/BLM/NPS).

Develop plant varieties that perform under severe Arctic conditions for use in rehabilitation of disturbed environments (DA/ARS, DOI/BLM/FWS/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 availability of winter range forages, and the interactions and competition of caribou and reindeer on tundra range in western Alaska (DA/SCS, DOI/BLM/FWS/NPS).

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

The Geological Survey conducted remote sensing of Alaskan glaciers using airborne radar. Between 1986 and 1989 this produced new information on bottom topography and glacier sediments. The Satellite Image Atlas of the Glaciers of the World is using remotely sensed imagery to prepare the initial regional volumes covering the Arctic.

The role of glaciers in global sea level change was addressed by several DOE, DOI/GS, NASA and NSF programs.

TNSF-sponsored scientists selected drilling sites for the Greenland Ice Sheet Project GISP II. Several programs were conducted in summer 1988 to test coring equipment and techniques and to assess surface and near-surface snow and ice for regional gradients of chemical constituents.

During the 87/88 winter, CRREL conducted research on water detection using 500 MHz radar and in-situ verification of unfrozen water beneath several rivers and lakes in the Arctic National Wildlife Refuge.

Glaciologists conducted a major field program on the Columbia Glacier in Alaska to establish the role of water pressure in basal sliding velocity. This program contributes to the determination of the world's ice-budget.

Objectives

- Continue to develop paleoenvironmental records from ice caps, ice sheets and mountain glaciers and to conduct research on processes by which gases and aerosols are incorporated into the snow and ice. Correlate these records with adjacent records for other sources and proxy records.
- Document the cause-and-effect relationships of glaciers to world sea level changes and climatic fluctuations, both long-term and short-term, regional and global, and continue the development of 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.

Ongoing and Planned Activities

Increase shallow, intermediate and deep ice core collections and analysis from Greenland ice sheet and on northern glaciers in order to understand and predict regional and global climate changes. With the consent of the Danish Commission for Scientific Research in Greenland, acquire 3,000-meter ice core from Greenland (DOD/CRREL, DOI/GS, NSF).

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

Expand the use of new and innovative research techniques, including remotely sensed data collec-

Reliable information on seasonal and perennial snow and ice cover, glaciers, and surface water will provide a climatic and hydrologic baseline for the Arctic

tion 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 (AG/FS, DOD/CRREL, DOI/GS, NSF).

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

Develop theoretical models to determine the quantity of precipitation and snow distribution by wind drifting, and to forecast snow melt and precipitation runoff in glacierized and unglacierized basins in permafrost regions (DOC/NOAA, DOE, DOI/GS, NASA, NSF/NCAR).

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

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 (see 2.2 for related activities).

Selected Activities and Accomplishments

The Geological Survey continued to find signs of past climate changes as evidenced by:

Geothermal measurements in continuous permafrost to assess short-term climate change in Arctic Alaska and to substantiate general warming at the top of permafrost over the past century.

Discovery of four periods of contrasting seasonal climate in the Alaskan Arctic over the past 40,000 years that ranged from colder and drier to warmer and drier than the present climate.

Delineation of historic debris flows in the Arctic Foothills and determination that they occur during exceptionally warm, wet summers.

Confirmation that the Arctic Coastal Plain was a polar desert during some late Cenozoic glacial episodes.

Presence of unusually deep thermokarst basins in the Arctic Foothills of Alaska formed as a result of the melting of ice wedges that were more than 20 m deep. These exceptionally deep ice wedges developed because they were able to grow upwards as rapidly as wind-blown silt was deposited during the last glacial cycle.

Trees that no longer grow as far north as Alaska growing north of the Brooks Range during one late Cenozoic warm period. Permafrost and perennial Arctic Ocean sea ice probably were not present at this time.

NSF continued sponsorship of projects to reconstruct paleoenvironments from lake sediments, pollen, and glacial geology, and monitor recent changes in permafrost temperatures.

CRREL conducted borehole studies to determine the dielectric and thermal properties of frozen silt and alluvium relevant to mapping permafrost distribution and demonstrated the utility of using floating DC galvanic resistivity surveys to map sub-sea permafrost.

Objectives

- Undertake a comprehensive program to extract paleoclimatic records from permafrost terrains.
- Understand how geologic processes affecting Arctic morphology and land surface 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.

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, aerial extent, depth structure, and response to climate change of Arctic permafrost, through implementation of 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).

Prepare maps of mean annual air temperature, and develop models to predict ground temperature based on surface factors (DOC/NOAA, DOD/CRREL, DOE, DOI/GS, EPA, NASA, NSF).

Modern geologic processes that are responsible for the present morphology and land surface need to be better understood

Determine and map the character, horizontal distribution, and depth of terrestrial and subsea permafrost (DOD/CRREL, DOE, DOI/GS, NASA, NSF).

3.4.3 Ecosystem Structure, Function and Response

The Arctic is expected to be especially sensitive to the effects of possible climatic changes resulting from possible greenhouse warming on terrestrial, atmosphere, and marine environments. Research is needed to improve 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, the identification of biological indicators of change, and long-term trends in biological diversity (see 2.2 and 3.3.3 for related activities).

Selected Activities and Accomplishments

Arctic tundra research of the NSF Long-Term Ecological Research (LTER) program and the DOE Response, Resistance, Resilience, and Recovery from Disturbance (R4D) program continues in the Toolik Lake area. Both programs concern the long-term dynamics of freshwater and terrestrial ecosystems and have complementary goals, including understanding the control and movement of nutrients in Arctic ecosystems, the

response of the ecosystems to disturbance, and the development of methods for regional extrapolation. The programs develop and share climate, geographic information, and remotely sensed data bases.

A recent DOE/R4D study of natural isotope abundances shows that some inland tundra ecosystems are experiencing a net loss of carbon, i.e., carbon is being mineralized faster than fixed. Initial results suggest that at least some freshwater food chains are seasonally dependent on inputs of subfossil organic carbon derived from terrestrial peat deposits.

At the DOE/R4D site, disturbance treatments of increased water flow and nutrient additions resulted in increased leaf area and production. Additions of trace nutrients suggested that low iron and molybdenum availability may limit photosynthesis of some species. The most important factor limiting Sphagnum moss production appears to be exposure to bright light, with high production occurring under the shade of shrub canopies and low production in open tussock tundra.

Objectives

- Distinguish ecological changes due to natural causes from changes due to human activities and evaluate management techniques for conservation and restoration of ecosystems.
- Identify and evaluate the responses of key biological populations and ecological processes to increased CO₂ and to different climatic conditions. Monitor the changes in ecotone boundaries, which might serve as integrative indicators of change. 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.

Ongoing and Planned Activities

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

Institute multi-agency planning to establish ecological hypotheses to be tested by field and

laboratory research (DA/FS, DOE, DOI/BLM/NPS, 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, NSF, SI).

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

Conduct multi-agency symposia on terrestrial ecosystems and ecological research, including post-season review meetings (DA/FS, DOE, DOI/BLM/FWS/NPS, NASA, NSF, SI).

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

Link biosphere reserves and other protected lands to 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, implement the Northern Sciences Network and the development of an action plan for northern biosphere reserves (DA/FS, DOE, DOI/FWS/NPS, NSF, SI).

3.5 Engineering and Technology

Construction costs in the Arctic are at least two or more times higher than in most major non-Arctic areas. Most criteria for building and materials in the Arctic have been borrowed from more temperate regions. Low temperatures often result in increased deterioration of typical construction materials and the need for special handling of human waste and hazardous materials. Sea ice, permafrost, and river ice jams are major hazards to structures and create engineering challenges. Ice-structure interactions are fundamental for addressing engineering problems in environments affected by freshwater and sea ice. Arctic Alaskan oil and gas deposits, both onshore and offshore, are potentially the largest undeveloped source of oil

and gas remaining in the U.S. To develop this resource economically and in an environmentally sound manner will require new technologies.

Selected Activities and Accomplishments

CRREL developed a new test to evaluate a soil's frost heave potential and developed a pulse modulated radar unit for identification of subsurface features.

CRREL completed small-scale tests on dynamic ice-structure interaction during continuous crushing, continued development of design data for structures in Alaska, particularly on guidance for selection of design snow loading, and developed an underwater frazil ice detector and field tested it.

CRREL completed an evaluation of methods for upgrading the performance of water supply alternatives for cold regions.

Minerals Management Service evaluated oil spill containment and cleanup procedures and equipment for open water and broken ice conditions, conducted a workshop on Arctic Offshore Oil Spill Response Technology (December 1988), and entered into an agreement with Canada to jointly fund and participate in Arctic oil and containment research.

Strategic Highway Research Program (DOT) determined the mechanism by which entrained air in portland cement concrete affects its resistance to damage by freezing and thawing.

Department of Energy (FE), in cooperation with the U.S. Coast Guard and the U.S. Navy, determined the bond strength of sea-spray ice to various structural and protective materials. DOE/FE research was completed on a cathodic corrosion technique for protecting offshore steel structures from marine corrosion.

The DOE/FE Morgantown Energy Technology Center placed the Arctic Offshore Research Information System (AORIS) in operation. The system incorporates a directory of 85 Arctic databases, a bibliographic component of over 9,000 citations on Arctic energy research, and a data component of over 1,100 data sets in tabular and graphical format on sea ice characteristics.

The DOE/FE completed preliminary simulation of ice island drift trajectories, which indicate that ice islands in the Arctic Ocean have a ten-year recurrence area along the Alaskan Beaufort Sea coast. This simulation study indicates that engineering designs in the Alaskan Beaufort Sea offshore areas need to include interactions with ice islands.

Objectives

- 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 upon the nature and constraints imposed by unique environmental conditions.
- Improve upon the comprehensive understanding of ice processes, the effect of ice on structures, and the effect of structures on ice.
- Determine 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 development

Ice-structure interactions are fundamental for addressing engineering problems in environments affected by freshwater and sea ice

and transportation of Alaskan Arctic oil, gas, and other fossil fuel and mineral deposits.

- Improve methods and systems for protection of the environment and for improved 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, DOT/CG, NASA, NSF).

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

Develop technology for recovery of 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, DOT/CG).

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).

Evaluate new technologies to reduce engine emissions and improve hazardous material man-

agement and transportation systems (DOD/COE, DOI/MMS).

Develop a new icebreaker design (DOD/COE, DOT/CG).

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, DOD/NAVY, DOI/MMS, DOT/CG, 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).

3.6 People and Health

3.6.1 Adaptation and Change: Human Society and Ecology in the Arctic

The *United States Arctic Research Plan* (1987) proposed a set of common themes and disciplinary research needed to understand social science problems in the North. The present revision seeks to further define and focus interagency research under the following long-range goal:

To understand the human dimensions of global, regional, and local change in the North by using studies of past and present northern societies to develop protocols and models of human/environmental interactions.

Arctic societies have responded and continue to respond to global as well as to local and regional processes (NRC, 1989, p. 13–15). What is not clear is the relative influence of global versus local environmental and historical/ social forces. Research is needed to investigate these factors among Arctic peoples, past and present.

The circumpolar North is ideally suited for studies of human responses to environmental and socio-cultural change. In general, these studies follow two closely interlinked paths. One is historical and seeks understandings on the development and environmental relationships of Arctic cultures, peoples, and languages from their origins through the modern day. The second investigates contemporary conditions of Arctic peoples and

draws upon a broad array of social, behavioral, and medical sciences to understand and solve contemporary human problems. Both tracks are interdependent and neither can be researched and understood without reference to the other.

It is expected that social and environmental problems will continue and that coordinated studies of human adaptation and change, and of the effects of anthropogenic change, will assist in developing rational policies for Arctic peoples and regions. Two interrelated programs should be pursued:

3.6.2 Cultural Resources and Historical Processes

Selected Activities and Accomplishments

The Smithsonian Institution opened a major special exhibition in cooperation with the U.S.S.R., "Crossroads of Continents: Cultures of Siberia and Alaska," with related programs including an international scientific meeting among American, Canadian, European and Soviet scholars, as well as films, seminars, publications, and performances.

The National Park Service conducted archeological research along the coastal lands of the Bering Land Bridge National Preserve adjacent to the Bering Strait, Chukchi Sea and Kotzebue Sound, implemented an interagency archeological coordination process in Alaska, and provided educational and archeological assistance. The Service also completed a four-year study of the past and

climatology, as well as ethnography, linguistics, physical anthropology, and history. The goal is to achieve an integrated, inter-disciplinary understanding of the origins and development of Arctic peoples. These data are particularly important for understanding the heritage of northern peoples and for developing a global perspective on the history of human/environmental interactions.

Research is needed on prehistory and history of Arctic cultures and peoples, on their interactions with other Native and Western groups, and on relationships with past and present environments. Archeological and historical evidence provide a record of human adaptations to changing Arctic regions and conditions for more than 15,000 years. These data are unique in containing evidence on the history of cultures in relation to environmental change. In addition to providing evidence on the history and interactions of Arctic cultures, archeological sites contain data on the history of temperature regimes, sea levels, floral and faunal changes, and other paleo-records. This long record of cultural and environmental change, when combined with proxy records of ethnography and history, makes the study of Arctic cultures critical for modeling human response to global climatic and environmental change. The following elements are included.

Survey and Cultural Resource Management. Responsible agencies will continue to survey and develop databases on paleontological, archeological and historical sites, will maintain records, conduct mitigation, provide resource management services, will protect archeological and historical resources, will coordinate databases, publications, and preservation work, and will integrate inter-agency planning and community involvement where appropriate.

Research. Research will be conducted on terrestrial, aquatic and marine biological resources, paleoecological conditions, and archeological, ethnographic, historical, and linguistic subjects to increase understanding of cultural and environmental history, identify processes of change, and develop explanatory models with regional and global orientation. Priority should be given to endangered sites and resources and to research that contributes most to studies of global change. Sites with important paleoecological and cultural records and in climatically sensitive geographic or ecological regions, such as along the forest-tundra fringe and in the trans-Beringian region, should receive attention, as should those with potential for solving long-standing research problems.

International. The current political climate favors development of trans-Beringian research programs with Soviet scientists. In addition, agen-

Research is needed on prehistory and history of Arctic cultures and peoples, on their interactions with other Native and Western groups, and on relationships with past and present environments

present life patterns of the Dena-ina Indians of southwestern Alaska in Lake Clark National Park and Preserve.

Within the Department of Interior, the Bureau of Indian Affairs conducted archeological and anthropological surveys.

Background

The historical basis for Arctic environmental and culture change is investigated by researching the history of Arctic cultures, their interactions with other native Arctic and Western cultures, and their environmental interactions. These studies include archeology, paleoecology, geology, paleo-

cies should participate in the growing network of northern museums, cultural centers, research institutions, organizations, and scholarly societies.

Interpretation and Education. Agency capabilities should be developed to educate the public on the importance of historical sites, monuments, and other data sources relevant to their mission. Agencies will disseminate information on research and help develop database and publication lists.

Objectives

- Develop predictive models and protocols of the response of Arctic peoples and cultures to global and regional climatic, environmental, and social change.
- Research origins, development, and interrelationships of Arctic cultures, languages, and people.
- Establish environmental parameters for human ecology and demography with paleo and modern resource data.
- Seek understanding of factors resulting in cultural change in Arctic regions.
- Involve northern residents in research processes and ensure results serve local needs in addition to advancing science.

Ongoing and Planned Activities

Expand inventory of archeological and ethnographic data with special attention to critical endangered data sources and trans-Beringian ties (DOI/BIA/BLM/FWS/NPS, DOS, NSF, SI).

Research contact-period sites and sources to determine relationship between prehistoric and ethnographic cultures (DOI/NPS, DOS, NSF, SI).

Develop evidence of trade and contacts, especially between cultures of the trans-Beringian region (DOI/NPS, DOS, NSF, SI).

Document and analyze Native languages and oral history, and expand study of ethnohistory and ethnosience (DOI/BLM/NPS, NSF, SI).

Expand studies exploring linkages between culture and biological resources (DA/FS, DOC/NOAA, DOI/BLM/FWS/NPS, NSF, SI).

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

3.6.3 Rapid Social Change and Human Environmental Relationships

Selected Activities and Accomplishments

The Polar Research Board published a special report, "Arctic Social Science: An Agenda for Ac-

tion," which recommended future directions for social science research.

The National Park Service completed a four-year study of the past and present life patterns of the Dena-ina Indians of southwestern Alaska in Lake Clark National Park and Preserve.

NOAA Sea Grant supported fisheries studies involving relationships between fisheries management regimes and accident rates, relationships between commercial and recreational fisheries, and development of dynamic economic models of halibut fisheries.

The Department of Interior participated actively in the Resource Apprenticeship Program for Students (RAPS) with the BLM, NPS, and FWS, providing summer jobs for Native Alaskan students to gain training in natural resources. Several NSF programs, including a Young Scholars Project, provided summer jobs for pre-college and undergraduate students and teacher enhancement opportunities.

The Minerals Management Service conducted social and economic analyses of coastal communities.

Background

The study of contemporary change in northern societies is the least developed in the Federal research system, and yet in terms of human impact, research in these areas should have high priority (IARPC, 1987, p. 242–243). Rapid economic, social, and political changes have resulted in the emergence of human problems that, while not unique to the Arctic, are nevertheless accentuated in this environment. Most prominent among these problems are human–environmental relationships, community viability, and rapid social change. These problems have been documented in several recent reports (NRC, 1989; AFN, 1989). The expected results will contribute to a wide range of scholarly disciplines, to theory of social change, and to better government and national security, and will be of practical benefit to Arctic residents and the larger society.

The following topics enumerated from the recommendations of the U.S. Academy of Sciences' report are appropriate research themes and problems. Under the theme of human–environmental relationships, research should be performed on basic and applied problems relating to subsistence economy, human impacts on the natural environment, human response to habitat change, and models of global climatic change. In the area of community viability, studies are needed on the relationship between community survival and cultural survival, and on problems involving economic diversification, psychosocial adjustment, and other

obstacles to community survival. Finally, problems relating to rapid social change, including social specialization, education, cognitive attitudes and coping mechanisms and their applied aspects, should receive attention.

Objectives

- Develop models on impact of environmental change, including climate change, on human life and subsistence activities.
- Determine ecological thresholds relating to economic development and community viability.
- Seek understandings about the effects of rapid social change on Arctic residents, cultures, and society.

Rapid economic, social, and political changes have resulted in the emergence of human problems that, while not unique to the Arctic, are nevertheless accentuated in this environment

- Develop practical applications of social and behavioral science to benefit Arctic residents and society.
- Develop research linkages between social and behavioral aspects of health (cf. AFN report, 1989).
- Examine the effects of development and research activities on the subsistence lifestyles of Alaskan Native people.

Ongoing and Planned Activities

Initiate studies leading to the development of predictive models on the impact of environmental change on Arctic biological resources and human societies (DOC/NOAA, DOI/FWS/MMS/NPS, NSF, SI).

Determine levels of human activities that threaten the stability of natural systems and sustainability of human life (DA/FS, DOC/NOAA, DOI/BLM/FWS/MMS/NPS, NSF, SI).

Conduct research on resource management regimes and on problems of resource allocation and methods of conflict resolution (DA/FS, DOC/NOAA, DOI/FWS/MMS/NPS, DOS, NSF, SI).

Conduct research on economic aspects of community viability and on the relationship between community and cultural survival (DA/FS, DOC/NOAA, DOE, DOI/BLM/FWS/MMS/NPS, NSF, SI).

Study the relationship between social change and physical and mental health and the cognitive and emotional limits of people's ability to cope

with rapid social change (DHHS/ADAMHA/CDC/NIH/NIMH, DOI/BIA/MMS, NSF, SI).

Promote educational needs for participation of Arctic residents in a modern, rapidly changing, multi-cultural world (DHHS/CDC/NIH/NIMH, DOC, DOED, DOI, NSF, SI).

3.6.4 Coordination and Infrastructure

The Academy report (NRC 1989) identifies basic and applied research problems, most of which are being addressed in some fashion by Federal agencies. Nevertheless, all need stronger support and better interagency coordination. This task has been taken up by the Interagency Committee's Social Science Working Group, which is composed of agency representatives and is developing plans to coordinate programs in Washington and at regional offices in Alaska. Following the Academy's recommendations, this working group was upgraded to "task force" status. We recognize the need to increase coordination and information flow within the many DOI agencies involved in "people" issues. Some areas the Social Science Working Group identified for interagency coordination include:

Culture and History. Many agencies share responsibilities in research on archeology, history, and Native culture (BIA, NPS, NSF, SI). These studies would benefit from coordinated agency planning that pool resources and expertise in support of mutually defined goals.

Cultural Resource Management. Federal and state land-holding agencies share responsibilities in the management of renewable (biological) and non-renewable (mineral, historical/archeological/paleontological) resources. The fact that many agencies conduct management activities that have similar professional, administrative, and legal requirements and functions suggests that opportunities exist for interagency coordination and cooperation leading to improved management at lower cost. The success of the Alaska-based Interagency Archeology Working Group, which includes Federal and State agencies, indicates the promise of coordination in this area. Similar promise has been demonstrated by the growth of local wildlife management organizations like the Alaskan Eskimo Whaling Commission and the Eskimo Walrus Commission.

Social, Economic, and Behavioral Research. Problems of people living in the Arctic are of concern to all government agencies. These agencies have specialized roles, such as delivery of health, social, or economic services and protection of natural resources. Coordination across disciplinary

lines, for instance, in sociocultural aspects of health or cultural restraints to economic development, and encouragement of research that integrates natural resources and social science concerns are likely to result in gains that could not be achieved by individual agencies or disciplines acting alone.

In addition to interagency coordination, the Social Science Working Group has targeted the following topics:

Publication Directory. IARPC workshops and hearings have repeatedly heard of the need for a central information system for Arctic research. A serious problem is the absence of a central index of publically available social science reports and publications issued by government agencies. A

Northern residents desire to learn about results not only of social science research, but of all types of scientific research conducted in the North, especially in their immediate environs

central directory would facilitate the dissemination of existing research and should be included as part of the information networks proposed elsewhere in this Plan (see section 2.3.2).

Training and Education. Numerically, the number of Arctic social science specialists is very small, perhaps not more than a few hundred U.S. scholars, and among this group there are only a few Native Americans or others who grew up in Arctic communities. This pool of researchers is too small to meet the needs of society. Support for education and training is therefore an extremely high priority for furthering the goals of Arctic social science. Special emphasis should be placed on identifying and training northern residents to be aware of science and to become scientists themselves. Encouraging support and development of research centers, local museums and culture centers would aid interaction between scientists and Arctic residents and promote local science training.

Research Ethics. Federal agencies require a set of ethical guidelines for the conduct of social science research whether or not this is conducted in or outside the Arctic. Procedures exist for handling breaches of this code of conduct, and as a result, agencies receive few specific complaints of researcher misconduct. Nevertheless, because research conduct remains a continuing concern of northern residents and is noted in the Arctic Research Commission publications, ethical guidelines for the northern researcher should be formal-

ly adopted. In the coming year consideration of modifying or adopting such guidelines as those issued by the Alaska State Department of Fish and Game (1984) or the Association of Canadian Universities for Northern Studies (ACUNS) ("Ethical Principles for Northern Research," 1982) will be an action item for the IARPC Social Science Task Force.

Public Information and Communication. One of the most serious information gaps in northern research is in the transmission of research results to northern communities. Scientific information is a valuable commodity to northern peoples and one which directly affects their well-being and even their survival. Northern residents desire to learn about results not only of social science research, but of all types of scientific research conducted in the North, especially in their immediate environs. Need for Arctic resident participation in the design of the research is equally important.

No easy solution has been devised to handle this problem, but several efforts are underway. The NSF funded a pilot project in 1988 to evaluate methods of transferring research results to Arctic residents; NASA is working closely with local communities to explain its 1988 expeditionary program to Alaska; and such activities as the NPS interpretive centers and the Smithsonian's Crossroads of Continents exhibition outreach programs present opportunities for local education. Nevertheless, these programs do not address the need for individual investigators to pass results back to local communities. Few publications or media systems are geared to interpret and publish such results, and scientists themselves are frequently not ideal public interpreters. Scientists, agencies, and associations of Native and northern residents need to collaborate to find an appropriate solution to this important information issue.

Implementation. At its June 1, 1989, meeting, the IARPC approved initial implementation activities for Arctic Social Science. Over the next two years the following steps will be initiated to complement ongoing activities:

- 1) The Task Force will meet regularly to improve coordination amongst agencies and establish guiding principles for the conduct of research. Participating agencies will designate single points of contact for each agency.

- 2) NSF will establish an Arctic Social Science Program Officer position and seek an appropriate level of funding in FY 1991 to support a high quality, academically based research program.

- 3) Several workshops will be convened to coordinate and plan research programs, development of standards for cultural resource research, and training and post-graduate opportunities.

4) Agencies will encourage and cooperate with the Polar Research Board in its continued oversight review of the status of U.S. Arctic Social Science.

5) Additional international collaboration will be developed on a circumarctic basis.

3.6.5 People and Their Health

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

Selected Activities and Accomplishments

The Arctic Investigations Laboratory (CDC), in collaboration with the Indian Health Service and Alaska Division of Public Health, completed a 3-year program to protect Alaska Natives from hepatitis B infection.

The AIL completed a 7-year study of the long-term immunogenicity and protection provided by hepatitis B vaccine.

Through support of NIH and in collaboration with Harbor–UCLA Medical Center, AIL completed a 4-year study of the efficacy of a new conjugate Hib vaccine.

The Arctic region is recognized as a natural laboratory and, as such, a region where health research may have broad implications and applications

The first Siberian–U.S. agreement in medical research was signed between the University of Alaska and the Soviet Academy of Medical Sciences. The agreement facilitates the exchange of medical information and researchers concerned with health in the North.

Objectives

- Establish and support basic and applied scientific inquiry for the purpose of improving human health through biomedical and behavioral research programs.
- Translate new information derived from basic and applied research into studies of the etiol-

ogy, pathogenicity, prevention, diagnosis and treatment of infectious diseases, nutrition-related disorders, and other biological conditions and their complications.

- Continue support of the fundamental biological processes of growth, development, and aging in addition to the biological effects of the environment.
- Evaluate and disseminate new information about medicine and health; construct and provide new biomedical research facilities and research resources and improve biomedical communications.
- Plan and conduct research programs directed toward the development, evaluation and promotion of cancer and chronic disease prevention, detection, diagnosis, and treatment. (This research includes the identification of persons at increased risk of disease, methods of screening and detection of disease, intervention aimed at reducing disease risk, and development and evaluation of new therapeutic agents and strategies for treatment of these diseases.)
- Identify and resolve major health and human engineering problems that derive from the distinctive characteristics of the Arctic environment (cold sensitivity and adaptation).
- Plan and conduct research programs directed toward understanding, preventing, and reducing the effects of intentional and unintentional injuries.
- Support and conduct epidemiological, social, environmental, and behavioral studies of heart, vascular, pulmonary, metabolic, neoplastic and blood diseases in both general and special populations.

Ongoing and Planned Activities

Decrease the annual incidence of specific infectious diseases through evaluating and implementing various prevention strategies and technologies, including the use of new vaccines and immunoglobulins. Specific diseases targeted for prevention efforts include hepatitis B, hepatocellular carcinoma, hepatitis A, pneumococcal disease, Hib disease (particularly in infants), echinococcal disease, and human papilloma virus (DHHS/CDC/NIAD/NIH).

Develop and evaluate new technologies for the rapid identification of specific infectious diseases, including botulism, Hib disease, pneumococcal disease, hepatocellular carcinoma, non-A non-B hepatitis, and echinococcal disease (DHHS/CDC/NIAD/NIH).

Examine and conduct ophthalmic and oral health surveys to gather information and deter-

mine the prevalence and cause of blindness and dental caries in Alaskan Natives (DHHS/IHS).

Continue surveillance of cancer, diabetes, and arthritis in the Alaskan Native population in support of efforts to identify risk factors for these diseases and to develop and evaluate prevention strategies (DHHS/CDC).

Describe current food consumption practices among Alaskan Natives and establish a dietary monitoring system in Alaska (DHHS/HRSA/IHS).

Expand comprehensive community-based social programs with emphasis on prevention of alcoholism and drug abuse in youths. These programs will attempt to modify and adapt youth activities to meet local community needs and culture values. Additional research programs will identify various mental health needs and other problem-oriented areas which deal with how Alaskan Natives cope with rapid life transitions (DHHS/ADAMHA/NIH).

Continue to conduct cold-related research stud-

ies in areas of hypothermia and cold injuries. New specific areas of focus involve cold physiology, cold stress adaptation, and the development of clothing, equipment, and rations for troops in cold regions (DOD/DA).

Support development of injury surveillance systems for gathering and integrating information as to the numbers and characteristics of people injured and the factors that influence injury causation. Injury research should focus on the role of alcohol in nonfatal as well as fatal events, and on both short-term and long-term studies (DHHS/CDC/IHS).

Expand efforts to develop chronic disease research strategies in the Alaskan Native population and to design, implement, and evaluate coordinated initiatives to strengthen the multi-disciplinary approach to diabetes, arthritis, cancer, and heart disease, and to intensify preventive services (DHHS/CDC/IHS/NIH).

4. Operational Support

Over the past two years, both the Interagency Committee and the Arctic Research Commission have addressed issues related to the logistic support of 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. Also in 1988, the Commission published a report on Arctic research logistics and recommended that the U.S.: 1) acquire an Arctic research vessel with icebreaking capabilities; 2) continue support for existing land-based logistics support centers; 3) upgrade the U.S. high-latitude sounding rocket launch facility; and 4) establish a central office for logistic coordination and a clearinghouse for logistic information.

The following is the status of facility-related operational support.

4.1 Ships

Research in the ice-covered areas of the Arctic takes place under conditions that are defined by a number of variables that determine vessel requirements, such as location, time of year, present environmental conditions, past conditions, etc. Ice conditions in the same location can vary dramatically from year to year, season to season, and even day to day. An area of open water or widely spaced ice floes can become impenetrable and hazardous to ill-equipped vessels in a matter of hours with a change in wind direction. Research that is possible from a minimally ice-capable vessel in the warmer season might require a fully capable icebreaker at other times of the year. 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
- Ice-capable/ice-strengthened vessels for research and survey purposes

The Federal Oceanographic Fleet Coordinating Council (FOFCC) 1988 report on high latitude vessel requirements supports the need for the Coast Guard to maintain and operate a fleet of four icebreakers for polar ice escort, logistic support, and research support. It endorses the Coast Guard plans to upgrade science support capabilities of the existing Polar Class vessels. Furthermore it reaffirms that an ice-capable research ship

be operated as a national facility for both the Federal and academic communities.

4.1.1 Icebreakers

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. When a dedicated science mission is assigned, that is the ship's highest priority; it would only be diverted for an emergency. Opportunistic science support is the most efficient and economic use of the ship, but subjects a particular project to uncertainty, depending on the other missions assigned. Central management of the icebreaker fleet, given adequate resources, permits the interchangeability of ships to assure mission accomplishment. The Coast Guard presently has only two icebreakers. The President's budget request to Congress for FY 1990 includes funding for a third polar icebreaker for the Coast Guard. The Polar class icebreakers are undergoing substantial upgrade of their research support capabilities.

4.1.2 Ice-capable and ice-strengthened vessels

Ice-going vessels of lesser capability than icebreakers are more economical, and 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, and no suitable U.S. vessel presently exists to fulfill that need. The UNOLS Fleet Improvement Committee has recently 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. Long-range budget plans for FY 1992-95 by the Navy and NSF include funds for Arctic ice-capable research ships.

4.2 Land-based Facilities

The Polar Ice Coring Office (NSF) provides logistics support for research on the Greenland Ice Cap.

U.S. investigators have access, on a cooperative and/or reimbursable basis, 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 (DOC/NOAA, DOE, DOI/FWS, DOI/NPS, NSF).

The Alaska Science and Engineering Advisory Commission, in its 1988 Annual Report, supports the recommendations in the 1987 Arctic Research Plan for the establishment of regional science and logistics centers in northwest Alaska.

4.3 Atmospheric Facilities and Platforms

There is a need to upgrade the Poker Flat Rocket Range, Alaska, to state-of-the-art upper atmosphere research capability and to support coordinated rocket and atmospheric monitoring programs.

Subject to the agreement of the Danish authorities, periodic launches into the polar cap from Thule and Sondre Stromfjord, Greenland, should include middle atmospheric (emphasis on ozone problem, including aircraft coordination), ionospheric, and thermospheric-ionospheric—magnetospheric interaction studies (DOC/NOAA, DOD/AF, NASA).

There is a need to maintain state-of-the-art capability and support active use of the U.S. incoherent-scatter radar facility at Sondre Stromfjord, Greenland (DOD/AF, NASA [overflight coordination], NSF).

There is a need to expand coordination of available aircraft to support research operations in otherwise inaccessible Arctic regions. This requires commitment to ensure that the national resource represented by the present number of research aircraft remains secure rather than subject to risks of year-to-year fluctuations in funding (DOC/NOAA, DOD, NASA and NSF each have aircraft).

4.4 Central Coordination and Logistics Information Clearinghouse

Agencies recommend a central approach for logistics planning and information. The combined Federal-State logistics directory is a first step toward a logistics information clearinghouse.

The following interagency activities are underway or completed:

Agencies compiled a directory of Federal Arctic research logistics capabilities. The State of Alaska inventory of Arctic logistics capabilities is being integrated with the Federal directory.

Agencies will participate in a logistics planning workshop in September 1989 at the Arctic Science Conference, Fairbanks, and an international logistics conference in 1990.

Agencies have initiated planning and scheduling of Arctic ship needs and capabilities.

The Department of the Interior supports an Alaska Office of Aircraft Services (OAS), which coordinates aircraft services on a reimbursable basis. Coordination with the Airborne Geosciences Working Group has been initiated to enable aircraft scheduling for Arctic programs.

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Appendix A: Glossary of Acronyms

AAAS	American Association for the Advancement of Science	ARC	Arctic Research Commission
ABLE	Arctic Boundary Layer Expeditions	ARCSS	Arctic Systems Science
ABSORB	Arctic Beaufort Sea Oilspill Research Body	ARCUS	Arctic Research Consortium of the United States
ACUNS	Association of Canadian Universities for Northern Studies	ARI	Accelerated Research Initiative
ADAMHA	Alcohol, Drug Abuse and Mental Health Administration	ARP	Arctic Research Plan
ADEOS	Advanced Earth Observation System	ARPA	Arctic Research and Policy Act
ADFG	Alaska Department of Fish and Game	ARS	Agricultural Research Service
ADGGS	Alaska Division of Geological and Geophysical Surveys	ASCE	American Society of Civil Engineers
AEDD	Arctic Environmental Data Directory	ASF	Alaska SAR Facility
AEDS	Arctic Environmental Data System	ASME	American Society of Mechanical Engineers
AEIDC	Arctic Environmental Information and Data Center	AVHRR	Advanced Very High Resolution Radiometer
AEWC	Alaska Eskimo Whaling Commission	AVIRIS	Advanced Visible and Infrared Imaging Spectrometer
AF	Air Force	AWARE	Alaska Water Resources Evaluation
AFGL	Air Force Geophysical Laboratory	BIA	Bureau of Indian Affairs
AFN	Alaska Federation of Natives	BLM	Bureau of Land Management
AFOSR	Air Force Office of Scientific Research	BOM	Bureau of Mines
AFP	Alpha-Fetoprotein	BREW	Biosphere Research: Emissions from Wetlands
AFWRC	Alaska Fish and Wildlife Research Center	CAMA	Central Arctic Management Area
AG	Agriculture	CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
AGASP	Arctic Gas and Aerosol Sampling Program	CCRS	Canadian Center for Remote Sensing
AGU	American Geophysical Union	CDC	Centers for Disease Control
AHAP	Alaska High Altitude Photography	CD ROM	Compact Disk-Read-only Memory
AHD	Alveolar Hydatid Disease	CEDAR	Coupling, Energetics and Dynamics of Atmospheric Regions
AIDJEX	Arctic Ice Dynamics Joint Experiment	CEAREX	Coordinated Eastern Arctic Experiment
AIL	Arctic Investigations Laboratory	CES	Committee on Earth Sciences
AIS	Airborne Imaging Spectrometer	CG	Coast Guard
AIWEX	Arctic Internal Wave Experiment	CIA	Central Intelligence Agency
ALASKA	Arctic Lands and Shelves-Key Assessments	CID	Center for Infectious Diseases
AMLR	Antarctic Marine Living Resources	CIR	Color Infrared
AMPTE	Active Magnetospheric Plasma Tracer Explorers	CIRES	Cooperative Institute for Research in Environmental Sciences
AMRAP	Alaska Mineral Resource Assessment Program	COE	Corps of Engineers
ANCSA	Alaska Native Claims Settlement Act	CONRIM	Council on Northern Resources Information Management
ANILCA	Alaska National Interest Lands Conservation Act	COOSRA	Canadian Offshore Oil Spill Research Association
ANWR	Arctic National Wildlife Refuge	CRREL	Cold Regions Research and Engineering Laboratory
AOGA	Alaska Oil and Gas Association	CTD	Conductivity, Temperature and Depth
AOR	Arctic and Offshore Research	CZCS	Coastal Zone Color Scanner
AORIS	Arctic Offshore Research Information System	DA	Department of Army or Department of Agriculture
AOSB	Arctic Ocean Science Board	DC	Direct Current
APEX	Arctic Polynya Experiment	DE	Dynamics Explorer
APOA	Arctic Petroleum Operators Association	DEW	Distant Early Warning
		DHHS	Department of Health and Human Services

DMSP	Defense Meteorological Satellite Program	ICES	Group International Council for the Exploration of the Sea
DNA	Defense Nuclear Agency	IGBP	International Geosphere–Biosphere Program
DOC	Department of Commerce	IHP	International Hydrological Program
DOD	Department of Defense	IHS	Indian Health Service
DOE	Department of Energy	IMF	Interplanetary Magnetic Field
DOED	Department of Education	IPA	International Permafrost Association
DOI	Department of Interior	IR	Infrared
DOS	Department of State	ISHTAR	Inner Shelf Transfer and Recycling
DOT	Department of Transportation	ISLSCP	International Satellite Land Surface Climatology Program
DPP	Division of Polar Programs	ISTP	International Solar–Terrestrial Program
EBV	Epstein–Barr Virus	IUCH	International Union of Circumpolar Health
EEZ	Exclusive Economic Zone	IWC	International Whaling Commission
EIS	Environmental Impact Statement	JGOFS	Joint Global Ocean Flux Study
EM	Electromagnetic	JRS	Japanese Remote Sensing (Satellite)
Eos	Earth Observing System	LME	Large Marine Ecosystem
EOSAT	Earth Observation Satellite	LRV	Low Resolution Visible
EPA	Environmental Protection Agency	LTER	Long-Term Ecological Research
ERS	European Remote Sensing (Satellite)	MAB	Man and the Biosphere
ESA	European Space Agency	MAP	Middle Atmosphere Program
ESMR	Electrically Scanning Microwave Radiometer	MARAD	Marine Administration
FCCSET	Federal Coordinating Council for Science, Engineering and Technology	MIZ	Marginal Ice Zone
FCZ	Fisheries Conservation Zone	MIZEX	Marginal Ice Zone Experiment
FE	Fossil Energy	MMS	Minerals Management Service
FIFE	First ISLSCP Field Experiment	MOS	Model Output Statistics
FOFCC	Federal Oceanographic Fleet Coordinating Council	MOU	Memorandum of Understanding
FS	Forest Service	MSS	Multispectral Scanner
FWS	Fish and Wildlife Service	NAS	National Academy of Sciences
GCM	General Circulation Model	NASA	National Aeronautics and Space Administration
GEM	Geospace Environment Modeling	NASDA	National Space Development Agency
GEOSAT	Geostationary Satellite	NCAR	National Center for Atmospheric Research
GIS	Geographic Information System	NCP	National Climate Program
GISP II	Greenland Ice Sheet Project II	NEPERF	Naval Environmental Prediction Research Facility
GLORIA	Geologic Long Range Inclined Asdic	NEW	Northeast Water (Polynya)
GMCC	Geophysical Monitoring for Climatic Change	NGO	Non-Governmental Organization
GOES	Geostationary Operational Environmental Satellite	NIAID	National Institute of Allergies and Infectious Diseases
GOFs	Global Ocean Flux Study	NIH	National Institutes of Health
GS	Geological Survey	NIMH	National Institute of Mental Health
GTF	Governor's Task Force	NIST	National Institute of Standards and Technology
HF	High Frequency	NLC	Northern Libraries Colloquy
HIRIS	High-Resolution Imaging Spectrometer	NMC	National Meteorological Center
HRPT	High-Resolution Picture Transmission	NMFS	National Marine Fisheries Service
HRSA	Health Resources and Services Administration	NMML	National Marine Mammal Laboratory
HRV	High-Resolution Visible	NOAA	National Oceanic and Atmospheric Administration
IAPG	Interagency Arctic Policy Group	NOGAPS	Naval Operational Global Atmospheric Prediction System
IARPC	Interagency Arctic Research Policy Committee	NOW	North Water (Polynya)
IASC	International Arctic Science Committee		
IAWG	Interagency Archeology Working		

NPC	Nasopharyngeal Cancer		Research
NPFSC	Interim Convention on Conservation of North Pacific Fur Seals	SCAT	Scatterometer
		SCOR	Scientific Committee for Ocean Research
NPOC	Naval Polar Oceanography Center		
NPRA	National Petroleum Reserve—Alaska	SCS	Soil Conservation Service
NPS	National Park Service	Sea-WiFS	Wide-Field Sensor
NRC	National Research Council	SGC	Salivary Gland Cancer
NRL	Naval Research Laboratory	SHPO	State Historical Preservation Office
NSDD	National Security Decision Directive	SHRP	Strategic Highway Research Program
NSF	National Science Foundation		
NSIDC	National Snow and Ice Data Center	SI	Smithsonian Institution
NS&T	National Statutes and Trends	SISEX	Shuttle Imaging Spectrometer Experiment
OAR	Oceans and Atmospheric Research		
OAS	Office of Aircraft Services	SLAR	Side-Looking Airborne Radar
OCEANAV	Oceanographer of the Navy	SLIP	St. Lawrence Island Polynya
OCI	Ocean Color Imager	SME	Solar Mesospheric Explorer
OCLC	Online Computer Library Center (Formerly Ohio College Library Center)	SMMR	Scanning Multichannel Microwave Radiometer
		SPOT	Système Probatoire d'Observation de la Terre
OCS	Outer Continental Shelf		
OCSEAP	Outer Continental Shelf Environmental Assessment Program	SSM/I	Special Sensor Microwave/Imager
		SSWG	Social Science Working Group
OIES	Office of Interdisciplinary Earth Sciences	STEP	Solar—Terrestrial Energy Program
		TACT	Trans-Alaska Crustal Transect
OMAE	Offshore Mechanics and Arctic Engineering	TAGS	Trans-Alaska Gas System
		TALI	Trans-Alaska Lithosphere Investigation
ONR	Office of Naval Research		
OSTP	Office of Science and Technology Policy	TA&R	Technology Assessment and Research
PICES	Pacific International Council for the Exploration of the Sea	TM	Thematic Mapper
		UARS	Upper Atmosphere Research Satellite
PICO	Polar Ice Coring Office		
PIPOR	Programs for International Polar Oceans Research	UCAR	University Corporation for Atmospheric Research
PIPS	Polar Ice Prediction System	UNESCO	United Nations Educational, Scientific and Cultural Organization
PM	Passive Microwave		
POAC	Port and Ocean Engineering Under Arctic Conditions	UNOLS	University National Oceanographic Laboratory System
PRB	Polar Research Board	URI	University Research Initiative
PRECP	Processing of Emissions by Clouds and Precipitation	USCG	United States Coast Guard
		USDA	United States Department of Agriculture
PROBES	Processes and Resources of the Bering Sea Shelf		
		USGS	United States Geological Survey
PYK	Porcupine—Yukon—Kuskokwim	UV	Ultraviolet
RAPS	Resource Apprenticeship Program for Students	VHRR	Very High Resolution Radiometer
		WINE	Winter in Northern Europe
R4D	Response, Resistance, Resilience and Recovery from Disturbance	WLN	Western Libraries Network
		WOCE	World Ocean Circulation Experiment
ROV	Remotely Operated Vehicle		
SAD	Seasonal Affective Disorder	WP	Weather Plane
SAR	Synthetic Aperture Radar	YPLL	Years of Potential Life Lost
SCAR	Scientific Committee on Antarctic		

Appendix B: IARPC-Related Organizations and Activities

Federal

Arctic Research Commission
 Interagency Arctic Policy Group (Department of State)
 National Climate Program Office (Department of Commerce)
 Committee on Earth Sciences (Federal Coordinating Council for Science, Engineering and Technology)
 Federal Oceanographic Fleet Coordination Council
 Marine Mammal Commission
 North Pacific Fishery Management Council
 National Ocean Pollution Policy Board

State/Local Government

Alaska Science & Engineering Advisory Commission
 Alaska Science and Technology Foundation
 North Slope Borough
 Northwest Borough
 Cities of Unalaska, Bethel (NOAA, NASA)

Federal-State

Alaska Land Use Council
 Interagency Hydrology Committee of Alaska

Universities

Arctic Research Consortium of the United States

Residents

Alaska Federation of Natives
 Arctic Slope Regional Corporation
 NANA Regional Corporation
 Association of Village Council Presidents
 Other Corporations and Councils

Private/Public

National Research Council/Polar Research Board
 Alaska Oil and Gas Association
 Standard Alaska Production Company
 ARCO Alaska, Inc.

International

Man and the Biosphere - Northern Sciences Network (UNESCO)
 Arctic Ocean Sciences Board (non-governmental)
 ICES/PICES (preorganizational working group)
 Working Group on Arctic International Relations (non-governmental)
 Inuit Circumpolar Conference
 International Arctic Science Committee (preorganizational working group)
 Alaska-Siberian Medical Research Program
 U.S. Bilaterals/Agreements/Treaties/Consultations
 U.S.-USSR Cooperation in the Field of Environmental Protection
 U.S.-USSR World Ocean Agreement
 U.S.-USSR Basic Science Agreement
 U.S.-Canada Geosciences Agreement
 U.S.-Canada Beaufort Sea Talks
 U.S.-Canada Arctic Fisheries and Marine Mammal Coordination Workshop
 U.S.-Canada Porcupine Caribou Herd Treaty
 U.S.-Canada Yukon River Salmon Negotiations (Pacific Salmon Treaty)

Appendix C: Highlights of Interagency and Related Activity

- Workshop and report on research on Federally Protected Lands (Sept. 1987)
- Participation with the Interagency Arctic Policy Group in U.S.–Canadian Beaufort Sea Talks and research coordination (November 1987, Ottawa; April 1989, Seattle)
- Publication of first three issues of the journal, *Arctic Research of the United States* (Fall 1987; Spring and Fall 1988)
- Workshop report on the development of an Arctic Environmental Data System and initial implementation of an Arctic Environmental Data Directory (March 1988)
- Workshop on Arctic Science Education, AAAS, Fairbanks, Alaska (October 1988)
- Pilot project on science transfer to resident communities, University of Alaska, Anchorage
- Translation of the 1987 Plan into Inupiat, North Slope Borough
- Conference and report on Northern Information (June 1988)
- Smithsonian joint U.S./Canada/U.S.S.R. exhibition, *Crossroads of Continents: Cultures of Siberia and Alaska*, and symposium (September 1988, four-year U.S.–Canada tour and three-year Soviet tour)
- Workshop on the Role of the Arctic in Global Climate Change and report, *Arctic Interactions*, Boulder, Colorado (October 1988)
- Issuance by the State of Alaska of a Native Policy Statement (October 1988)
- Workshop and report on Arctic Engineering, Hanover, New Hampshire (November 1988)
- Establishment of Alaska Interagency Archeological Group by Department of Interior, Anchorage
- U.S.–Canadian Arctic Fisheries and Marine Mammal Coordination Workshop (January 1989)
- National Academy of Sciences report on Arctic Marine Science (January 1989)
- National Academy of Sciences report on Arctic Social Science (February 1989)
- Joint U.S.–Canadian workshop on Trans-Border Research, Chena Hot Springs, Alaska (February 1989)
- Workshop on Long-Term Monitoring in Alaska Parks, Chena Hot Springs, Alaska (February 1989)
- Development of Federal Arctic Logistics Directory (March 1989)
- Assistance to the Interagency Arctic Policy Group on policy guidance for an International Arctic Science Committee
- Establishment by the State of Alaska of its Alaska Science and Technology Foundation
- Directory of land-based logistics published by the Alaska Science and Engineering Advisory Commission

Appendix D: IARPC Biennial Report to the Congress (January 1988)

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550



OFFICE OF THE
DIRECTOR

January 29, 1988

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 your Executive Order 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

SECOND BIENNIAL REPORT OF THE
INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE
(FEBRUARY 1, 1986 TO JANUARY 31, 1988)

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 dated January 28, 1985.

Since the first report covering the period to January 31, 1986, the Interagency Arctic Research Policy Committee has:

- o Prepared and published the U.S. Arctic Research Plan, as required by Section 108(a)(4) of the Act. The Plan was submitted to the President on June 23, 1987. The President transmitted the Plan to Congress on July 31, 1987;
- o Initiated publication of a new journal, Arctic Research of the United States. The first issue reviews all Federal agency Arctic research for FY 1986 and includes summaries of the IARPC and Commission activities (attached);
- o Consulted with the Commission on policy and program matters described in Section 108(a)(3), and was represented at all meetings of the Commission;
- o Provided input to an integrated budget analysis for Arctic research, which identified \$90.5 million in Federal support for fiscal year 1986 and \$91.1 million in fiscal year 1987;
- o Continued the processes of cooperation and coordination required under Section 108(a)(6), (7), (8) and (9);
- o Provided for public participation as required in Section 108(a)(10), which culminated in active public involvement in the development of the recommendations and the Plan in November 1986 at a consultative meeting in Anchorage, Alaska;
- o Approved and initiated implementation of an Arctic Research Policy; and
- o Completed a study of an Arctic information center.

In addition to two meetings of the Committee (February 3, 1986 and March 23, 1987), other meetings organized and sponsored by the Interagency Arctic Research Policy Committee (IARPC) over the past two years included:

- o Land and Cultural Resources Workshop: Anchorage, Alaska, and Marine Ecosystems Workshop: Boulder, Colorado (March 1986)

- o Energy and Minerals Resources Workshop: Anchorage, Alaska (May 1986)
- o U.S. Arctic Resident Review Workshop: Barrow, Alaska (October 1986)
- o Consultative Workshop: Anchorage, Alaska (November 1986)
- o Social Science Workshop: Washington, D.C. (January 1987)

All of these activities have served to increase awareness of Arctic research, both within and outside the Federal government. These activities have provided unprecedented opportunities for outside involvement in the establishment of Arctic research policy and research plans.

The Arctic Research Commission met four times in fiscal year 1986 and four times in fiscal year 1987. The Commission published its second and third annual reports in January 1987 and January 1988, respectively, and prepared and distributed three issues of its newsletter, "U.S. on the Arctic Rim."

The Chairman of the Arctic Research Commission, James Zumberge, submitted his resignation to the President in July 1987; Juan Roederer, Vice Chairman of the Commission, was appointed Chairman by the President on December 2, 1987, following the President's acceptance of Chairman Zumberge's resignation.

This second biennial report on activities under the Arctic Research and Policy Act demonstrates that considerable progress has been made in coordinating the activities of the Federal agencies. A spirit of cooperation pervades the activities of the Interagency Committee. The continuation of that spirit will assure future national and international achievements under the Arctic Research and Policy Act.

Appendix E: 1990 Budget of the U.S. Government: Extract from Special Analysis J

RESEARCH AND DEVELOPMENT

**Reprint of Pages J-1 Through J-16 From Special Analyses,
Budget of the United States Government, 1990**

Note.—All years referred to are fiscal years, unless otherwise noted. Details in the tables, text, and charts of this booklet may not add to totals because of rounding.

**OFFICE OF MANAGEMENT AND BUDGET
EXECUTIVE OFFICE OF THE PRESIDENT
January 1989**

PART III: CROSSCUTTING R&D ACTIVITIES

There are a number of R&D activities with a common theme and purpose that are supported by a number of Federal agencies. Although this R&D is done primarily to meet each agency's mission needs, in a number of instances, Federal agencies coordinate these activities in order to realize maximum benefits from their expenditures. This new section of the Special Analysis will describe these crosscutting R&D efforts in a number of areas: arctic research, global change research, research in superconducting materials, semiconductors, and fiber optics. This section will also report on the technology transfer activities of the Federal Government.

ARCTIC RESEARCH

Two complementary policy documents currently govern U.S. Arctic research policy. The Arctic Research and Policy Act of 1984 (Public Law 98-373) requires an "... integrated, coherent, and multiagency request . . ." for research in the Arctic as part of the President's annual budget request to Congress. National Security Decision Directive 90 (NSDD 90, April 14, 1983) identifies four basic elements of U.S. Arctic Policy:

- protection of essential security interests in the Arctic region;
- support for sound, rational development in the Arctic region, while minimizing adverse effects on the environment;
- promotion of scientific research in fields which contribute knowledge about the Arctic; and
- promotion of mutually beneficial international cooperation in the Arctic.

In response to these directives, the Interagency Arctic Research Policy Committee (established by Public Law 98-373) compiled a detailed listing of agency programs in Arctic research, including budgetary estimates, and has grouped them into three major categories of national concern: national security, rational development, and the Arctic as a natural laboratory.

Based on current activities and future needs, the Interagency Committee, in consultation with the Arctic Research Commission, the Governor of the State of Alaska, the Arctic residents, the private sector, and public interest groups, prepared a comprehensive plan for the overall Federal effort in Arctic research. This U.S. Arctic Research Plan was transmitted to the President on June 23, 1987. The President sent the Plan to Congress on July 31, 1987.

The mandated biennial revision of the Plan is scheduled for submission to the President in July 1989 and will describe several interagency cooperative programs on sea/ice ecosystem and land/atmosphere interactions. The Arctic Research Commission continues to issue annual and special reports containing guidance and recommendations to agencies.

Table J-5 provides a summary of Federal support for Arctic research integrated by major category. These estimates are subsumed within agency totals for the conduct of research and development.

Table J-5. FEDERAL SUPPORT FOR ARCTIC RESEARCH ¹

(Obligations in thousands of dollars)

Category	1988 actual	1989 estimate	1990 estimate
National security	23,856	22,420	21,690
Rational development	33,246	32,507	32,342
Natural laboratory	41,554	42,142	43,682
Total	98,656	97,069	97,714

¹ Includes the Departments of Defense, Energy, Health and Human Services, Interior, Commerce, Agriculture, and Transportation, the National Science Foundation, the National Aeronautics and Space Administration, the Environmental Protection Agency, and the Smithsonian Institution.

Appendix F: Arctic Research Budgets of Federal Agencies

ARCTIC RESEARCH BUDGETS OF FEDERAL AGENCIES					(JULY 1989)		
Dept/ Agency	Program Name	CAT	FY86 act	FY87 act	FY88 act	FY89 est	FY90 est
			(thousands of dollars)				
DOD	Arctic Engineering	S	5,596	1,049	2,111	2,161	2,210
DOD	Permafrost/Frozen Ground	S	1,306	933	1,638	1,642	1,780
DOD	Snow and Ice Hydrology	S	2,257	2,394	2,267	1,944	1,920
DOD	Oceanography	S	7,191	8,339	8,895	9,531	8,284
DOD	Lower Atmosphere	S	2,799	884	792	493	365
DOD	Upper Atmosphere	S	4,523	5,351	4,692	4,100	2,900
DOD	Medical and Human Engr	S	2,964	2,630	2,057	2,383	2,550
	DOD Total.....		26,636	21,580	22,452	22,254	20,009
DOI/MMS	Offshore Minerals	R	288	219	171	225	200
DOI/MMS	Environmental Studies	R	10,340	8,343	7,128	6,911	6,911
DOI/USGS	Energy and Minerals	R	2,800	2,411	2,494	2,534	2,534
DOI/USGS	Natural Hazards	R	285	919	1,209	1,209	1,209
DOI/USGS	Ice and Climate	R	240	350	350	350	350
DOI/USGS	Hydrology	R	0	310	310	310	310
DOI/USGS	Glaciology and Quaternary	R	250	200	200	200	150
DOI/USGS	Marine Geology	R	400	985	692	1,285	980
DOI/USGS	Magnetosphere	R	25	25	25	25	25
DOI/USGS	Mapping	R	2,300	625	1,405	995	1,710
DOI/FWS	Marine Mammals	R	1,300	1,400	1,650	1,380	680
DOI/FWS	Migratory Birds	R	900	1,300	1,700	1,850	1,900
DOI/FWS	Fisheries Research	R	241	375	375	375	375
DOI/FWS	Cooperative Research	R	250	300	325	350	350
DOI/FWS	Terrestrial Ecology	R	600	525	1,125	1,075	1,075
DOI/BLM	National Wildlife Refuge	R	305	305	150	150	300
DOI/BLM	Habitat-Arctic District	R	105	195	224	230	260
DOI/BLM	Habitat-NW District	R	235	172	200	200	200
DOI/BLM	Pipeline Studies	R	175	175	175	175	175
DOI/BLM	Fire Control	R	350	350	350	350	350
DOI/BLM	Nat Petro Reserve/Alaska	R	100	195	204	200	200
DOI/BLM	Central Arctic Management	R	0	166	155	0	0
DOI/BLM	Minerals/Mining	R	150	200	200	200	200
DOI/NPS	Cultural Resources	R	-	295	284	284	284
DOI/NPS	Natural Ecology	R	927	1,212	1,212	927	927
DOI/BOM	Minerals	R	1,550	2,400	1,950	1,916	1,916
	DOI Total.....		24,116	23,952	24,263	23,706	23,571
NSF	Atmospheric Sciences	L	5,759	5,972	7,544	7,500	7,500
NSF	Ocean Sciences/Ship Support	L	3,860	6,765	7,224	7,000	7,000
NSF	Biological Sciences	L	2,823	2,706	2,688	2,700	2,700
NSF	Glaciology	L	2,478	2,824	2,123	2,200	2,200
NSF	Earth Sciences	L	1,935	1,853	1,553	1,600	1,600
NSF	Arctic Systems Science	L	-	-	-	2,030	4,530
NSF	Engineering	L	663	748	897	800	800
NSF	Education	L	0	324	351	350	400
NSF	Coordination	L	340	237	258	250	250
NSF	Arctic Research Commission	L	286	465	480	500	500
	NSF Total.....		18,144	21,894	23,118	24,930	27,480

CAT: S=National Security, R=Resource Development, L=Arctic as Laboratory

Dept/ Agency	Program Name	CAT	FY86	FY87	FY88	FY89	FY90
			(thousands of dollars)				
NASA	Polar Ocean/Ice Sheets	L	2,727	7,600	9,600	7,300	6,500
NASA	Land Processes	L	623	665	760	490	600
NASA	Atmospheric Sciences	L	200	200	2,700	900	3,000
NASA	Sounding Rocket Program	L	858	950	950	975	1,000
NASA	Dynamics Explorer	L	2,900	3,000	1,700	1,300	1,300
NASA	Space Plasma Research	L	614	714	770	805	850
NASA	Arctic Ozone	L	-	-	-	3,500	1,000
NASA	Solar Terrestrial Theory	L	77	294	370	390	400
NASA	NASA Total.....		7,999	13,423	16,850	15,660	14,650
DOC/NOAA	Arctic Haze	R	477	100	150	200	200
DOC/NOAA	Atmos Trace Constituents	R	170	180	180	180	180
DOC/NOAA	Climate Modeling	R	200	200	200	200	200
DOC/NOAA	Environmental Prediction	R	350	350	350	350	350
DOC/NOAA	Fisheries Assessment	R	2,000	2,000	2,000	2,000	2,000
DOC/NOAA	Marine Mammal Assessment	R	1,500	1,200	1,200	1,200	1,200
DOC/NOAA	Sea Grant	R	200	200	355	355	355
DOC/NOAA	Strategic Assessment	R	300	125	300	150	100
DOC/NOAA	DOC/NOAA Total.....	R	5,197	4,355	4,735	4,635	4,585
DOE	Ecosystem Response	R	1,400	1,400	1,400	1,400	1,400
DOE	Response to Carbon Dioxide	R	300	300	265	265	265
DOE/FE	Arctic Offshore Research	R	1,550	495	372	452	0
DOE/FE	Gas Hydrates	R	1,700	927	400	400	400
DOE	Aurora	R	126	128	130	130	130
DOE/FE	Aleutian Seismicity	R	0	0	0	0	40
DOE/FE	DOE Total.....		5,076	3,250	2,567	2,647	2,235
DHHS/CDC	Disease Control	L	828	471	490	490	490
DHHS/NIH	Cancer in Alaska Natives	L	138	188	242	242	242
DHHS/NIH	Vaccine Evaluation	L	790	802	190	190	190
DHHS/NIH	U. S. Research Grants	L	-	334	351	351	351
DHHS/NIH	DHHS Total.....		1,756	1,461	922	922	922
SMITHSONIAN	Anthropology	L	463	463	578	555	555
SMITHSONIAN	Arctic Biology	L	56	56	86	75	75
SMITHSONIAN	Smithsonian Total.....		519	519	664	630	630
DOT/USCG	Int'l Ice Patrol	R	0	200	180	100	105
DOT/USCG	Test and Evaluation	R	-	-	340	0	0
DOT/USCG	Arctic Pollution	R	200	350	0	0	0
DOT/USCG	Extramural Support	R	-	55	55	55	55
DOT/MARAD	Marine Transport	R	210	50	0	0	0
DOT/MARAD	DOT Total.....		410	655	575	155	160
EPA	Cold Climate	R	400	300	0	0	0
EPA	High Latitude Methane	R	-	-	-	25	250
AGRICULTURE	Forest Service	R	650	800	800	800	800
AGRICULTURE	Soil Conservation Service	R	200	60	67	70	70
AGRICULTURE	Total.....	R	850	860	867	870	870
STATE	MAB: Arctic Directorate	R	16	8	4	4	4
GRAND TOTAL	-----		91,119	92,257	97,017	96,438	95,366

CAT: S=National Security, R=Resource Development, L=Arctic as Laboratory

Public Law 98-373
98th Congress

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 I—ARCTIC RESEARCH AND POLICY

SHORT TITLE

SEC. 101. This title may be cited as the "Arctic Research and Policy Act of 1984".

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;

Arctic Research
and Policy Act of
1984.

15 USC 4101
note.

15 USC 4101.

(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 (hereafter referred to as the "Commission").

(b)(1) The Commission shall be composed of five 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) three 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;

Establishment.

15 USC 4102.

(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) one member 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.

(a)(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-16 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.

Public meeting.

DUTIES OF 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 suggest 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) suggest 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; and

(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.

(b) Not later than January 31 of each year, the Commission shall—

(1) 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; and

(2) submit to the President and to the Congress a report describing the activities and accomplishments of the Commission during the immediately preceding fiscal year.

Report.

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 552 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.

5 USC 8101 et seq.

28 USC 2671 et seq.

15 USC 4104.

Confidentiality.

15 USC 4103.

15 USC 4105.

5 USC 5331.

- (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; and
- (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.

LEAD AGENCY AND INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

15 USC 4106.

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.

Establishment

(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

15 USC 4107.

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 for in section 109;

(5) provide the necessary coordination, data, and assistance for the preparation of a single integrated, coherent, and multi-agency 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 description of the activities of the Commission, detailing with particularity the recommendations of the Commission with respect to Federal activities in Arctic research.

5-YEAR ARCTIC RESEARCH PLAN

15 USC 4108.

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

Public
information.

Report.

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

15 USC 4109.

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 Science and 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.

Report.

(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 ice-breaking operations, except for recurring incremental costs associated with specific projects, to the Coast Guard.

AUTHORIZATION OF APPROPRIATIONS; NEW SPENDING AUTHORITY

15 USC 4110.

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.

2 USC 651.

DEFINITION

15 USC 4111.

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.

Arctic Ocean Sciences Board Activities During 1989

This report on AOSB activities during 1989 was presented to the Scientific Committee on Oceanic Research in October 1989.

The Arctic Ocean Sciences Board held its eighth meeting in February 1989 in Washington, D.C., under the Chairmanship of Prof. G. Hempel (Federal Republic of Germany), during the course of which it considered a broad range of Arctic Ocean science issues.

Discussions of the initial results of the first intensive field studies under the Greenland Sea Project (GSP) indicated that there is substantial inter-annual variability in oceanographic conditions in the Greenland Sea. Accordingly, it was agreed that: 1) long time-series measurements are necessary to determine the extent of this variability; 2) it is essential to determine the interaction of surface and intermediate layer convection and deep-water formation; and 3) additional studies are needed of small-scale frontal systems, eddies, and sea ice. The Board strongly endorsed continuation of the project and requested the GSP Steering Committee to develop plans for a second intensive field study to be conducted when the ERS-1 satellite is operational.

The Board accepted the recommendations it had received from two AOSB-sponsored workshops to initiate a comprehensive study of polynyas. It adopted the International Arctic Polynya Project (IAPP) and established a Science Coordinating Group under the Chairmanship of Dr. Louis Legendre of Canada to provide coordination and oversight for this project.

It was agreed that initial IAPP studies should focus on three polynyas: the Northeast Water in the Greenland Sea (NEW), the North Water in Baffin Bay (NOW), and the St. Lawrence Island Polynya in the Bering Sea (SLIP). Small planning

groups were set up for each of these studies. The NEW group was to meet on 27–29 September in Bremerhaven. Planning has advanced most rapidly for North Water, in particular to overwinter a vessel at the Carey Islands during the winter of 1990–1991. The SLIP group met in August in Seattle; it is aiming for a SLIP field program in 1991–1992.

Reports on a possible FRAM Commemorative Drift Program and Arctic Ocean drilling were presented to the Board, which decided to further explore options in both areas. The Board will thus revisit both of these items at its next meeting. The Norwegian Committee for the Nansen Centennial Arctic Program has prepared a draft interdisciplinary scientific plan for such a program that will soon undergo internal review in Norway. If approved, it may well be open to international participation.

The Board will also consider the establishment of a data base on Arctic research operations as a possible initial step in developing improved coordination of such operations in the future.

The Board received a series of presentations from staff of the U.S. National Aeronautics and Space Administration (NASA) on applications of remote sensing to Arctic research and held a roundtable discussion on this topic.

Prof. Hempel was elected as Chairman and Dr. John Bowman (U.K.) was elected as Vice-Chairman, both for a one-year period.

The AOSB will hold its ninth meeting on 15–17 January 1990. This meeting will be hosted by the Scott Polar Research Institute in Cambridge, U.K.

Alaska Science and Technology Foundation

Board Members of the ASTF:

Edward R. Clinton,
Chairman, ASTF;
Dowland-Bach Corp.;
John Sibert, Executive
Director, ASTF;
Perry R. Eaton, Community
Enterprise Development
Corporation;
Gary R. Freitag, Southern
Southeast Regional
Aquaculture Association;
Anne P. Lanier, Center
for Infectious Disease;
Robert E. LeReache, Alaska
Power Authority;
James Kenworthy, Michigan
Strategic Fund;
George Kozmetsky,
University of Texas System;
Lynn A. Wallen,
Anthropologist;
Francis S.L. Williamson,
University of Alaska

The Foundation was created by the State in 1988 with a \$6 million appropriation and this year received \$34 million in its endowment. In August 1989 the first ten awards were announced. They totaled \$721,598 and were matched by \$658,204 from other public and private organizations. These initial projects for up to three years were selected

from 105 submitted proposals. Five projects are intended to contribute to the fishing industry, two to the forest industry, one to the mining industry, one to the energy industry, and one for development of an economical data log instrument. Additional awards will be released when negotiations are completed.

Project	Investigator
Alaska-based Seafood Processing Tool Development	Larry Smith, Innerspace Technologies of Alaska, Sitka
Applicability of Siberian Placer Mining Technology in Alaska	Dr. Frank Skudrzyk, Professor of Mining Engineering, University of Alaska-Fairbanks
Remote Data Logger	James E. Dryden, Dryden and LaRue Instruments, Anchorage
Studies on Growth and Quality of Spruce Complex in Coastal Alaska	Dr. John Alden, Institute of Northern Forestry, Fairbanks
Low-cost Hydroturbine	David Pahl, Haines
Alaska Shellfish Hatchery Development	W. Michael Kaill, Alaska Department of Fish & Game, FRED Division
Genetic Stock Identification of Important Commercial Fish in the Bering Sea	Dr. Gerald Shields, Professor of Biology, University of Alaska-Fairbanks
Study of Terminal Area Troll Chinook Harvesting	Lonnie L. Haughton, F/V China Cove, Ketchikan
Forest Products from Alaskan Native Trees	Dr. Edmond C. Packee, Agriculture and Forestry Experiment Station, Fairbanks
Commercial Utilization of Arrowtooth Flounder	McIlvin J. Monsen, Alaska Fisheries Development Foundation, Inc.

Alaska Science and Engineering Advisory Commission

Commission Members:

Brian J. Allee, Alaska
Department of
Fish and Game;
Henry Cole (Chairman),
Governor's Office;
Aurora Hovland;
Erwin Long, Arctic
Foundations, Inc.;
Peter McRoy,
University of Alaska;
Donald E. Pickering, MD;
Paul B. Reichardt,
University of Alaska;
John Sibert, Executive
Director, Alaska Science &
Technology Foundation

ASEAC was established through legislative appropriation in August 1987, with the mandate to formulate state research policy, to provide counsel to the Governor and the Legislature, and to assist in the management of research activities throughout the state (see *Arctic Research of the United States*, Spring 1988). The Commission is responsible for the review and development of policy related to science and engineering, including health issues, and renewable and nonrenewable resources.

In September 1989, the Commission published a directory, *Alaska Research Sites* (available from Henry Cole, Governor's Office, State of Alaska, Box AD, Juneau, Alaska 99811). It provides brief

information and points of contact for Federal, State, university and selected private sites and facilities. Appended is information on cabins of the Alaska Department of Fish and Game, Alaskan harbors, airports, telecommunication facilities and emergency services throughout the State. A fold-out location map accompanies the report.

The Commission is soon to release reports resulting from workshops on research needs in engineering, fisheries, and use of rare earths. These reports are directed toward strategic considerations in setting research priorities for the State of Alaska. The Commission encourages close collaboration with the ASTF, the ARC and the IARPC.

Arctic Research Commission

Eighteenth Meeting June 27, 1989

Commission members and staff Present: Juan G. Roederer, Chairman; John H. Steele, Vice Chairman; Oliver L. Leavitt; Carol A. Roberts, representing ex-officio member Erich Bloch; Philip L. Johnson, Executive Director, and Lyle D. Perrigo, Head, Anchorage office. Group of Advisors: Thomas F. Albert, North Slope Borough; Roger Herrera, BP Exploration (Alaska), and David Hickok. Speakers: Al Ewing, U.S. Environmental Protection Agency; Jim Hemming, Dames and Moore; Roger Herrera, BP Exploration (Alaska); John Kelley, North Slope Borough Science Advisory Committee; Denby Lloyd, Office of the Governor; John Rogers, Alaska Regional Office, U.S. Fish and Wildlife Service; John Schindler, Minerals Management Service, DOI; Jeffrey K. Towner, U.S. Army Corps of Engineers; Mark A. Tunee, North Slope Borough Science Advisory Commission. Visitors: Ted Birkedal, National Park Service; Juli Braund-Allen, Arctic Environmental Information and Data Center, University of Alaska-Anchorage; Jerry Brown, National Science Foundation; Judy Gotlieb, Minerals Management Service, DOI; Ray Jaknbnzak, BP Exploration (Alaska); Luis Proenza, University of Alaska Fairbanks; Hild Sandstede, Greenpeace; Barbara Sokolov, Arctic Environmental Information and Data Center, University of Alaska-Anchorage; Dale Taylor, National Park Service; Howard Thomas, Harding Lawson Associates.

The Arctic Research Commission held its 18th meeting in Anchorage, Alaska, on June 27, 1989. Chairman Roederer announced that the Commission's report on data and information problems as they affect Arctic research, as well as a brochure on Arctic research and the Commission, would be published by mid-summer. A principal focus of this meeting was to receive testimony on improvements to the scientific methodology and analysis in environmental impact statement procedures.

Federal Environmental Impact Statement Procedures

As a continuation of the efforts to analyze environmental assessment procedures as they are required by the National Environmental Policy Act (NEPA) and applied in the Arctic, a public hearing was conducted to receive testimony from Alaskan representatives of the private sector, involved Federal agencies, and state and local government. Witnesses were invited to address three basic issues: quality of data and analysis, participation, and timing in preparing environmental assessments and impact statements.

The presentations of witnesses were thoughtful considerations of options to improve the scientific information in environmental analyses. A majority indicated that: 1) the law and regulations need not be changed, but that 2) improvements might be achieved by use of third party peer review of the technical content, particularly the methods used to collect the data cited and the analysis used to support the conclusions.

A scoping phase is intended to define the questions to be addressed in an EIS. It was suggested that impartial review of the lead agencies' plans for scoping would lead to more appropriately framed questions and therefore a more effective process.

Some decisions based on environmental impact statements stipulate a monitoring program as part of the project. Peer review of the design of the monitoring activities will help assure sound and usable results.

It was well recognized that inordinate delay of a project due to environmental litigation adds

enormously to its cost. It was also clear that added time for further review of environmental impact statements would not be welcome.

The Commission will formulate its findings and conclusions at future meetings.

Interagency Arctic Research Policy Committee

Carol Roberts, representing Erich Bloch, Chairman IARPC, noted that the biennial revision of the U.S. Arctic Research Plan had been completed, approved by 12 member agencies, and forwarded to the White House for acceptance. A budgetary crosscut technique similar to the one employed for the Global Change Program is being used for the Ocean components of the Arctic Research Plan, and will be included as part of the FY 1991 budget submission.

Progress was reported on preparation of an Arctic data directory by USGS. Over 250 data sets are now entered into the directory. It was also announced that the National Science Foundation will initiate a program for basic research in Arctic social sciences and plans to recruit a program director.

State of Alaska Activities

The Commission was updated by Henry Cole, Science Advisor to the Governor, on the science implications of the enormous efforts being made to cope with the crude oil spill in Prince William Sound. One of the state actions was to establish the *Exxon Valdez* Oil Spill Commission to gather information. Its report is due in January 1990, and is to address: 1) containment and cleanup actions; 2) steps needed in the future to ensure proper management, handling, and transportation of crude oil; 3) changes in industrial and government practices needed to minimize the potential for future spills; and 4) legislative proposals to encourage and fund prevention, response, cleanup, and mitigation of future oil discharges.

The Governor also established the Oil Spill Coordination Office to handle legal issues and economic recovery activities associated with this nearly 11 million gallon oil spill.

The Alaska Science and Engineering Advisory Commission expects to publish this summer an inventory of logistic sites in Alaska suitable for

research. The Governor has indicated a need to build a scientific research infrastructure that will aid economic development and diversification.

Dr. John Sibert has been named Executive Director of the Alaska Science and Technology Foundation. The Foundation plans to announce the first awards later this summer.

Other Business

In executive session the Commission adopted a budget for its operations in FY 1990, and added two members to its Group of Advisors: Mr. George B. Newton, Manager, Advanced Systems and Technology, Department of Analysis and Technology, Inc., Arlington, Virginia; and Mr. Howard P. Thomas, Director of Geotechnical Services, Harding Lawson Associates, Anchorage, Alaska.

Forthcoming Meetings

Listed here is a compilation of forthcoming meetings, workshops and conferences on Arctic or northern topics and activities. Readers are invited to submit information on upcoming meetings, as well as reports on national or international meetings attended, to J. Brown, Arctic Research, National Science Foundation, Room 620, 1800 G St., NW, Washington, D.C. 20550.

Symposium on the Arctic and Global Change
25–27 October 1989, Ottawa, Ontario, Canada
Contact: Climate Institute, Suite 403,
316 Pennsylvania Ave., SE, Washington, D.C.
20003

The Role of Circumpolar Universities in Northern Development
24–26 November 1989, Thunder Bay, Ontario, Canada

Contact: Paul Watts, Director, Centre for Northern Studies, Lakehead University, Thunder Bay, Ontario, Canada P7B 5E1
Phone: 807-343-8360
Fax: 807-343-8023

AGU, Snow, Ice and Permafrost Sessions:
5–9 December 1989, San Francisco, California
Contact: American Geophysical Union, 2000 Florida Avenue, NW, Washington, D.C. 20081

Circumpolar Ecosystems in Winter: First International Symposium and Workshop
16–23 February 1990, Churchill, Manitoba, Canada
Contact: Dennis Macknak, Churchill Northern Studies Center, P.O. Box 610, Churchill, Manitoba, Canada R0B 0E0

Fourth International Ice Tech Symposium
20–23 March 1990, Calgary, Alberta
Arctic Section of the Society of Naval Architects and Marine Engineers
Contact: J. Wainwright, c/o Arctic Transportation Ltd., Suite 800, Eau Claire 2, Calgary, Alberta, Canada T2P 3T3.

First Circumpolar Symposium on Remote Sensing of Arctic Environments
1–3 May 1990, Yellowknife, Northwest Territories
Contact: Steven Matthews/Helmut Epp, N.W.T. Remote Sensing Centre, Government of the Northwest Territories, P.O. Box 1320, Yellowknife, N.W.T., Canada X1A 2L9
Phone: (403) 920-3329
Telex: 034-45528
Fax: (403) 873-0221

PRO MARE, Symposium on Polar Marine Ecology
12–16 May 1990, Trondheim, Norway
Contact: Egil Sakskaug, Trondheim Biological Station, Byenesveien 46, N-7018 Trondheim, Norway
Phone: +47-7-513260
Fax: +47-7-509034

International Congress on Circumpolar Health: Community Health—Problems and Solutions in the North
20–25 May 1990, Whitehorse, Yukon Territory, Canada
Contact: 8th International Congress on Circumpolar Health, 801-750 Jewis Street, Vancouver, British Columbia, Canada V6E 2A9
Telex: 04-352848 VCR

IAHR Regional Conference on Circumpolar and Northern Religion—Interpreting Shamanism and Folk Religion in Arctic and Subarctic Regions

13–19 May 1990, Helsinki, Finland
Contact: Juha Y. Pentikainen, University of Helsinki, Department of Comparative Religion, Luotsikatu 4 A 1, 00160 Helsinki, Finland
Phone: 19241

Sixth International Conference on Hunting and Gathering Societies—CHAGS 6, University of Alaska—Fairbanks

28 May–1 June 1990
Contact: Linda Ellanna, Department of Anthropology, University of Alaska—Fairbanks, Fairbanks, Alaska 99775-0160
Phone: (907) 474-6751 or 474-7288
Fax: (907) 474-7720
BITNET: FFLJE@ALASKA

CANQUA/AMQUA—Rapid Change in the Quaternary Record
4–6 June 1990, Waterloo, Ontario, Canada
Contact: Alan V. Morgan, WATERLOO 1990, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
Phone: (519) 885-1211 (x3231)
Fax: (519) 746-2543, (519) 888-4521

Fifth Canadian Permafrost Conference
6–8 June 1990, Quebec City, Quebec, Canada
Contact: Mike Boroczki, Fifth Canadian Permafrost Conference, National Research Council of Canada, Ottawa, Ontario, Canada KIA OR6
Phone: (613) 993-9009
Telex: 053-3145
Fax: (613) 952-7928

13th Polar Libraries Colloquy
10–14 June 1990, Rovaniemi, Finland
Contact: Liisa Kurppa, Arctic Center, University of Lapland, P.O. Box 122, 96101 Rovaniemi, Finland
Phone: +358-60 324-275
Telex: 19205519
Fax: +350-60 324-270

International Conference on the Role of the Polar Regions in Global Change
11–15 June 1990, Fairbanks, Alaska
Contact: Gunter Weller, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775
Phone: (907) 474-7371
Telex: 35414
Fax: (907) 474-7290

Polar Tech '90
14–16 August 1990, Copenhagen, Denmark
Contact: Conference Secretariat, Danish Hydraulic Institute, Agern Alle 5, DK-2970 Horsholm, Denmark
Phone: +45 42 86 80 33
Telex: 37402 DHICPH DK
Fax: +45 42 86 79 51

Arctic Geology and Petroleum Potential
15–17 August 1990, Tromsø, Norway
Contact: Norwegian Petroleum Society, Box 1897,
Vika, 0124 Oslo 1, Norway
Phone: 47 2207025
Telex: 77 322 NOPETN
Fax: 47 2830547

**Seventh Inuit Studies Conference, Looking to the
Future: Arctic 2000**
19–23 August 1990, Fairbanks, Alaska
Contact: Dr. Lydia Black, Department of Anthropology,
University of Alaska, Fairbanks, Alaska 99775.
Phone: 907-474-6760 or 474-7288
Fax: 907-474-7720
BITNET: FFLTB@ALASKA

10th IAHR Symposium on Ice
20–23 August 1990, Helsinki, Finland
Contact: Mauri Maattanen, Helsinki University of
Technology, Otakaari 1, SF02150, Espoo, Finland

Symposium on Ice–Ocean Dynamics and Mechanics
27–31 August 1990, Hanover, New Hampshire
Contact: Secretary General, International Glaciological
Society, Lensfield Road, Cambridge CB2 1ER,
United Kingdom
Phone: +233 355974
Fax: +223 336543

Second International Conference on Ice Technology
18–20 September 1990, Cambridge, United Kingdom
Contact: C.A. Brebbia, Computational Mechanics
Institute, Ashurst Lodge, Ashurst, Southampton SO4
2AA, United Kingdom
Phone: 0 42129 3223
Telex: 47388 ATTN COMPMECH
Fax: 042129 2853

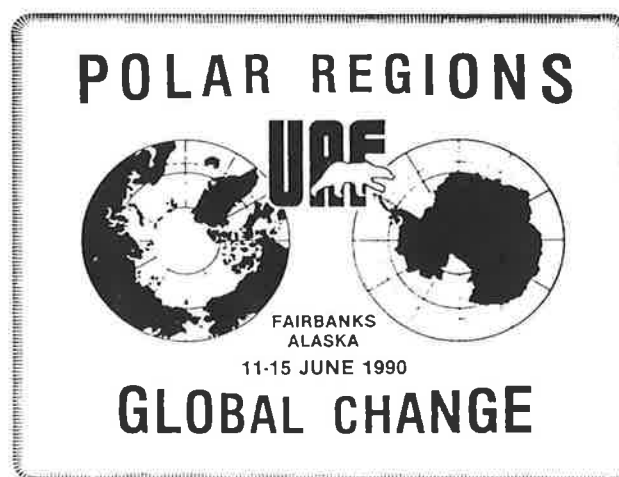
**AAAS Arctic Science Conference–Circumarctic
Perspectives**
8–10 October 1990, Anchorage, Alaska
Contact: Thomas Newbury, Conference Chair,
c/o Minerals Management Service, 949 E. 36th Ave.
(Room 110), Anchorage, Alaska 99508-4302
Phone: (907) 261-4604

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

Mountain Glaciology—Relation to Human Activities
26–30 August 1991, Lanzhou, China
Contact: Secretary General, International Glaciological
Society, Lensfield Road, Cambridge CB2 1ER,
United Kingdom
Phone: +233 355974
Fax: +223 336543

Symposium on the Physics and Chemistry of Ice
1–6 September 1991, Sapporo, Japan
Contact: Norikazu Maeno, Institute of Low Tempera-
ture Science, Hokkaido University, Sapporo, 060, Japan

6th International Symposium on Ground Freezing
September 1991, Beijing, China
Contact: Hans Jessberger, Ruhr-University
Bochum, P.O. Box 102148, D4630 Bochum 1,
Federal Republic of Germany
Phone: 02 341700-6135
Telex: 0 825 860 UNIBO D



Contact: Cindy Wilson, Conference Coordinator
Geophysical Institute, University of Alaska–Fairbanks
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Phone: (907) 474-7954
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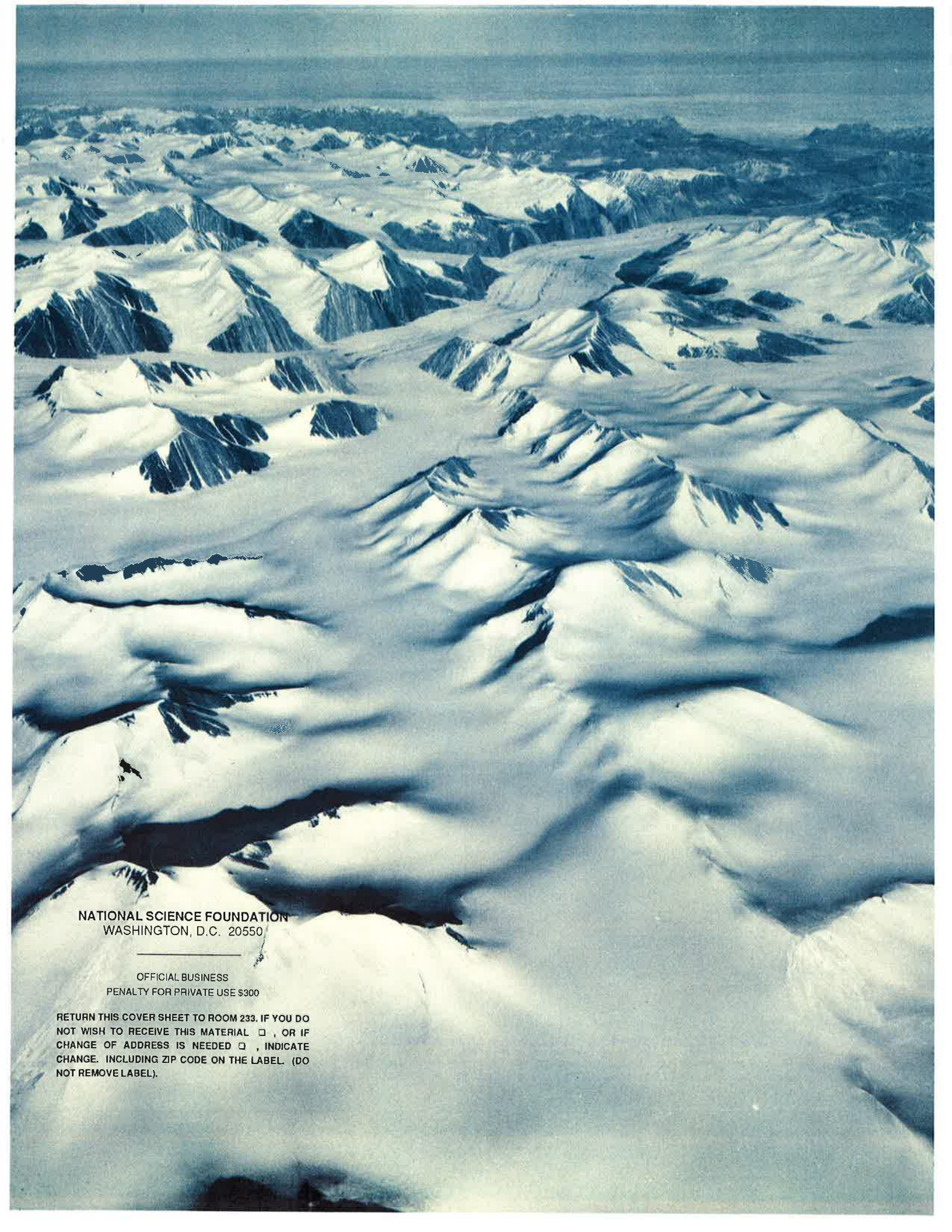
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Back Cover

*An ice field in the Victoria and Albert Mountains on the eastern part of Ellesmere Island in the Queen Elizabeth Islands area, Northwest Territories, Canada. Photo T400L-201, National Air Photo Library (Canada). From illustration on p. 545 of Williams, R.S., Jr., 1986, *Glaciers and glacial landforms*. In *Geomorphology from Space. A Global Overview of Regional Landforms* (N.M. Short and R.W. Blair, Jr., Ed.). NASA Special Publication SP-486, p. 521–596.*



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