VOLUME 11 FALL/WINTER 1997

ARCTIC RESEARCH

OF THE UNITED STATES

INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

About the Journal

The journal *Arctic Research of the United States* is for people and organizations interested in learning about U.S. Government-financed Arctic research activities. It is published semi-annually (spring and fall) by the National Science Foundation on behalf of the Interagency Arctic Research Policy Committee and the Arctic Research Commission. Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act of 1984 (PL 98-373) and established by Executive Order 12501 (January 28, 1985). Publication of the journal has been approved by the Office of Management and Budget.

Arctic Research contains

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

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

As indicated in the U.S. Arctic Research Plan, research is defined differently by different agencies. It may include basic and applied research, monitoring efforts, and other information-gathering activities. The definition of Arctic according to the ARPA is "all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering, and Chukchi Seas; and the Aleutian chain." Areas outside of the boundary are discussed in the journal when considered relevant to the broader scope of Arctic research.

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

Address correspondence to Editor, *Arctic Research*, Arctic Research and Policy Staff, Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington VA 22203.

Cover

Satellite synthetic aperture radar (SAR) interferogram of the Malaspina Glacier, a large surge-type glacier on the coast of south-central Alaska. It is fed primarily by the Seward Glacier, which descends from the St. Elias Mountains at the top-center. The distance across the image from left to right (west to east) is about 54 km; the distance from top to bottom (north to south) is about 68 km. The colored fringes represent the component of glacier motion in the radar line-of-sight direction, which is from the right and into the surface at an incidence angle of 23°. The closely spaced fringes at top-center, for instance, represent primarily the rapid motion of ice discharging from the Seward Glacier, while the decreasing fringe spacing near the bottom of the image represents primarily the effect of increasing surface slopes near the glacier margin. The SAR images used to synthesize the interferogram were acquired on 22 and 23 January 1996 during the ERS-1 and -2 Tandem Mission. The baseline was 169 m. The interferogram was furnished courtesy of D.R. Fatland and E.N. Troshina of the Geophysical Institute, University of Alaska Fairbanks. This work has been supported by a NASA grant to C.S. Lingle and an Alaska SAR Facility research assistantship. The SAR images are copyright ESA, 1996.

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ARCTIC RESEARCH

OF THE UNITED STATES

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U.S. Arctic Research Plan
Biennial Revision: 1998–2002

Executive summary 2

1. Introduction 4
   - *1.1 National needs, goals and objectives* 4
   - *1.2 Budgetary considerations* 7
   - *1.3 Interagency coordination* 7
   - *1.4 International cooperation* 8
   - *1.5 Revision to the plan* 10

2. Special Focus Multiagency Research Programs 11
   - *2.1 Assessment of risks to environments and people in the Arctic* 11
   - *2.2 Surface Heat Budget of the Arctic Ocean* 18
   - *2.3 Beringian systems studies* 23
   - *2.4 Arctic data and information* 27

3. Agency Programs 32
   - *3.1 New opportunities for Arctic research* 32
   - *3.2 Arctic Ocean and marginal seas* 34
   - *3.3 Atmosphere and climate* 35
   - *3.4 Land and offshore resources* 38
   - *3.5 Land–atmosphere–water interactions* 39
   - *3.6 Engineering and technology* 41
   - *3.7 Social sciences* 42
   - *3.8 Health* 46

4. Logistics and Operational Support 47

5. Bibliography 51

Appendix A: Glossary of Acronyms 52
Appendix B: Sixth Biennial Report of the Interagency Arctic Research Policy Committee to the Congress 54
Appendix C: Arctic Research Budgets of Federal Agencies 56
Appendix D: Federal Arctic Research Program Descriptions 59
Appendix E: Arctic Research and Policy Act, As Amended 65
Appendix F: Principles for the Conduct of Research in the Arctic 69
Appendix G: U.S. National Arctic Policy Statement 71

Selected Meetings of Interest 73
Interagency Arctic Research Policy Committee Staff 75

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OFFICE OF THE
DIRECTOR

May 30, 1997

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

Dear Mr. President:

I am pleased to transmit through you to the Congress the enclosed Biennial Revision: 1998-2002 to the United States Arctic Research Plan. This Plan is required under Public Law 98-373, as amended by Public Law 101-609, the Arctic Research and Policy Act.

The Plan describes scientific and engineering research to support implementation of U.S. national policy objectives in the Arctic. It also includes research initiatives that relate to understanding and protecting the Arctic environment. It is submitted on behalf of the Interagency Arctic Research Policy Committee for which the National Science Foundation serves as chair agency.

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,

Neal Lane

Neal Lane
Director

Enclosure

United States Arctic Research Plan

Biennial Revision: 1998–2002

Executive Summary

Background

The United States has substantial economic, scientific, strategic and environmental interests in the Arctic. As required by the Arctic Research and Policy Act of 1984 (Public Law 98-373),* a comprehensive Arctic Research Plan is prepared by the Interagency Arctic Research Policy Committee and submitted to the President, who transmits it to Congress. Section 109(a) of the Act requires a biennial revision to the Plan. This document, the fifth biennial revision to the Arctic Research Plan, updates the plan and elaborates on requirements of Section 109(a).

United States research in the Arctic and this biennial revision are governed by U.S. national policy on the Arctic, research goals and objectives agreed upon by the Interagency Committee, and guidance provided by the Arctic Research Commission.

It is in the national interest of the United States to support scientific and engineering research to implement its national policy objectives, including:

- Protecting the Arctic environment and conserving its living resources;
- Promoting environmentally sustainable natural resource management and economic development in the region;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involving the indigenous people of the Arctic in decisions that affect them;
- Enhancing scientific monitoring and research on local, regional and environmental issues (including their assessment); and
- Meeting post-Cold-War national security and defense needs.

The Arctic Research and Policy Act requires cooperation among agencies of the U.S. Government having missions and programs relevant to the Arctic. It established the Interagency Arctic Research Policy Committee to "promote Federal interagency coordination of all Arctic research activities" [Section 108(a)(9)]. The Interagency Committee, under the chairmanship of the Director of the National Science Foundation (NSF), continues to provide the mechanism for developing and coordinating U.S. Arctic research activities

Revision to the Plan

This fifth revision to the United States Arctic Research Plan includes two major sections. The first of these presents the Special Focus Multiagency Research Programs. For this biennial revision of the plan, agencies agreed that the following four programs are ready for immediate attention as multiagency focused efforts:

- Assessment of Risks to Environments and People in the Arctic
- Surface Heat Budget of the Arctic Ocean
- Beringian Systems Studies
- Arctic Data and Information.

The second major section is the Agency Programs, which represent the objectives of Federal agencies, focusing on the period covered by this revision (1998–2002). They are presented in six major categories, and where common activities exist they are presented as collective programs:

- Arctic Ocean and Marginal Seas
- Atmosphere and Climate
- Land and Offshore Resources
- Land–Atmosphere–Water Interactions
- Engineering and Technology
- Social Sciences and Health.

Since the passage of the Act, the Interagency Committee, the Arctic Research Commission and the State of Alaska have addressed issues related to logistics support for Arctic research. This revision considers issues related to surface ships, submarines and ice platforms; land-based and atmospheric facilities and platforms; coordination; and data facilities.

Budgetary Consideration

Appendix C presents a summary of each agency's funding for the 1996–1998 period. The total interagency Arctic budget estimate for FY 97 is $172.0 million; for FY 98 it is $156.2 million. For some agencies, budgets for Arctic research are projected to decrease. Program descriptions may be assumed to reflect the general direction of agency programs.

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

1. Introduction

The United States has substantial economic, scientific, strategic, and environmental interests in the Arctic. The Arctic is defined by the Arctic Research and Policy Act (ARPA) to include "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, Chukchi Seas; and the Aleutian chain."

Our recognition of the value of the Arctic has matured dramatically in recent years. We now appreciate more fully its economic and strategic significance to our nation. More than 50% of the U.S. continental shelf and coastline lies within Alaska, with much of it in the Arctic.

The Arctic shelves contain some of the richest commercial fisheries in the world, as well as large populations of birds and marine mammals. Contaminant accumulation in the food chain may have a direct impact on the global human population. For example, the U.S. pollock fishery in the Gulf of Alaska and Bering Sea is estimated to be a $2 billion industry, yet there is insufficient information about contaminants in the Bering Sea ecosystem for the long-range planning necessary to assure that this fishery and others will remain free of influence from Arctic contaminants.

Increased resource development and use of the Arctic Ocean as a transportation corridor present additional risks to the Arctic environment. A better understanding of Arctic systems, including biological, atmospheric, oceanic, ice and sediment-transport dynamics, is necessary to effectively respond to catastrophic events. Expanded safety and environmental protection measures and services must be preceded by baseline research activity and impact modeling to identify appropriate service and response levels.

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, the fifth biennial revision to the Arctic Research Plan, updates the previous documents and elaborates on requirements of Section 109(a) (see Appendix E).

The Plan presents a detailed agenda for United States Arctic research and is the result of an extensive process of planning, consultation and revision. In addition to the individual agency research activities (described in Section 3), this revision presents several focused multiagency research programs (Section 2). These cooperative efforts will continue into 1998 and beyond. Each represents ongoing or planned programs of more than three Federal departments and has direct relation to economic, social and international developments in the Arctic and scientific questions related to regional and global processes.

1.1 National Needs, Goals and Objectives

United States research in the Arctic and this biennial revision are governed by U.S. national policy on the Arctic (announced by the U.S. Department of State, September 1994), the Declaration on Establishment of the Arctic Council (announced by the U.S. Department of State, September 1996), research goals and objectives agreed upon by the Interagency Committee, and guidance provided by the Arctic Research Commission.

National Needs and Problems

The national interest of the United States requires support of scientific and engineering research to implement its national policy objectives, including:

- Protecting the Arctic environment and conserving its biological resources;
- Assuring that natural resource management and economic development in the region are environmentally sustainable;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involving the Arctic's indigenous people in decisions that affect them;

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

- Enhancing scientific monitoring and research on, and assessment of, local, regional and global environmental issues on Earth and in near-Earth space; and
- Meeting post-Cold-War national security and defense needs.

Where appropriate this research should be coordinated with the efforts of state and local governments and the private sector. The research should be carried out in a manner that benefits from and contributes to international cooperation. Arctic research policy is subject to periodic review and revision. The role of the Arctic in meeting national needs and addressing key policy issues is further highlighted below.

Nonrenewable Resources

The U.S. imports approximately 50% of its hydrocarbon needs. Twenty-five percent of our domestic production comes via the Trans-Alaska Pipeline System from Prudhoe Bay, Alaska. The best estimates are that at least 20% of the Nation's future reserves lie on the northern Alaskan coastal plain and adjacent continental shelf. Also, 12% of the Nation's gas reserves lie in the same region, and there are plans for a gas pipeline to transport this resource south. Gas hydrate reserves have been estimated to range from 10^{11} to 10^{14} cubic meters in Alaska and its offshore region. In addition to oil and gas, the Arctic has large coal and peat resources. The U.S. Arctic has been estimated to contain about as much coal as the remainder of the U.S. However, U.S. Arctic coal production will be limited until the energy needs of Alaska grow substantially or the Pacific Rim countries provide sufficient impetus for further coal development.

Minerals are also important Arctic resources. The Red Dog lead–zinc–silver mine, north of the Arctic Circle, is one of the largest zinc-producing mines in the world, producing 60% of the U.S. zinc output. The Arctic shelves also contain mineral deposits. At least one offshore tin mine has been brought into production in Russia. Dredging for sand and gravel on the Arctic Ocean shelves supports hydrocarbon development and other large coastal and offshore construction projects.

Renewable Resources

Arctic and Bering Sea waters support some of the most productive fisheries in the world. The Bering Sea supplies nearly 5% of the world's fishery products. An estimated 4 million metric tons of 43 commercial species are caught every year by fishermen from the United States, Russia, Japan and other nations. Since the passage of the Magnuson Fishery Conservation and Management Act in 1976, American groundfish operations in Alaska have developed into an industry with an annual product value estimated at $2.2 billion. Dutch Harbor–Unalaska, Alaska, is the leading U.S. port in the quantity of commercial fish landings. Alaska leads all states in both total volume and total value of fish landings. The 1994 catch of Alaska pollock was 1.4 million metric tons, and this catch has not changed markedly over the past five years (average value: 1.3 million metric tons).

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

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

Global Change

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

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

Arctic biological processes can also affect global processes and result in positive feedback on CO_2 increase and warming. Ecosystems may function as either sources or sinks for atmospheric CO_2. It remains unclear whether Arctic ecosystems

are functioning as sources or sinks for excess CO_2. For example, a shift in vegetation from tundra to trees could have significant effects on regional climate.

High-latitude warming may disturb the equilibrium of Arctic ice masses and hence global sea levels. Such events are preserved in the geologic record, and polar regions are a natural repository of information about past climatic fluctuations.

Arctic regions display significant ozone decreases. These are expected to deepen over the next decade, as atmospheric chlorine and bromine reach high levels because of previous releases. Their causes and implications will continue to be a subject of research. Additional data may shed light on the causes and effects of both catastrophic and evolutionary global change. Arctic research provides a critical component of virtually every science element in the U.S. Global Change Research Program.

Social and Environmental Issues

Arctic culture is part of, and is dependent on, terrestrial and marine ecosystems. Northern indigenous communities, numbering over 100 in the Alaskan Arctic with a total population of 50,000, are supported partially by hunting, trapping and fishing. Evidence shows increased exposure in these communities to contaminants from lower latitudes. Much of the population of the Arctic is dependent on the health of the region's ecosystems. Samples of fish tissue and sediments thus far do not show contamination levels as high as in seriously contaminated urban areas in the lower 48 states, but they are not as uncontaminated as might have been expected.

Recent studies have found that concentrations of carbon dioxide and methane in Arctic haze layers are elevated with respect to background levels. Concentrations of these two gases are correlated, suggesting a common anthropogenic source (fossil fuel combustion) and subsequent transport into the Arctic. Soot carbon has been traced for thousands of kilometers across the Arctic, where it remains suspended in a dry, stable atmosphere. Ozone depletion in the polar vortex has enormous health implications for the people of the entire Northern Hemisphere.

High latitudes are also particularly susceptible to adverse conditions in the space environment, which can cause disruption of satellite operations, communications, navigation and electric power distribution grids, leading to a variety of socio-economic losses. These space environment effects, generally referred to as "space weather," are often associated with transient phenomena on the sun that may cause geomagnetic storms on Earth, with the occurrence of bright, dynamic auroral displays and the development of intense ionospheric currents. These induced currents can cause massive network failures in electric power distribution systems and permanent damage to multi-million-dollar equipment in power generation plants.

U.S. Goals and Objectives in Arctic Research

Arctic research is aimed at resolving scientific, sociological 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 on such issues as using the Arctic as a natural laboratory, national defense, natural hazards, global climate and weather, energy and minerals, transportation, communications, renewable resources, contaminants, environmental protection, health, adaptation and Native cultures.

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

- Pursue integrated, interagency and international research and risk assessment programs for the purpose of managing Arctic risks;
- Continue to develop and maintain U.S. scientific and operational capabilities to perform research in the Arctic;
- Promote the improvement of environmental protection and mitigation technology and the enhancement of ecologically compatible resource use technology;
- Develop an understanding of the role of the Arctic in predicting global environmental changes and perform research to reveal early signals of global changes in the Arctic and determine their significance;
- Develop the scientific basis for responding to social changes and the health needs of Arctic people;
- Contribute to the understanding of the relationship between Arctic residents and use of wildlife and how this relationship might be affected by global climate change and transported contaminants;
- Engage Arctic residents, scientists and engineers in planning and conducting the research and report results to these individuals and the public;

- Continue to document and understand the role of permafrost in environmental activities;
- Advance knowledge of the Arctic geologic framework and paleoenvironments;
- Contribute to the understanding of upper atmospheric and outer space phenomena, particularly their effects on space-borne and ground-based technological systems;
- Develop and maintain databases and data and information networks; and
- Develop and maintain a strong technological base to support national security needs in the Arctic.

In addition to these goals and objectives for Arctic research developed by the Interagency Committee, the Arctic Research Commission has provided further guidance for U.S. Arctic research. This revision of the Plan is consistent with these Commission recommendations.

1.2 Budgetary Considerations

The Act does not provide separate additional funding for Arctic research. Agencies are expected to request and justify funds for these activities as part of the budget process. Table 1 presents a summary of each agency's funding for the 1996–1998 period. The total interagency Arctic budget estimate for FY 97 is $172.0 million; for FY 98 it is $156.2 million. Appendix C contains a detailed listing of existing Federal agency programs and budgets, divided by major subelements. The plan contains the detailed agency budgets through FY 98. For some agencies, budgets for Arctic research are projected to decrease. These decreases reflect the competitive budget environment. However, program descriptions may be assumed to reflect the general direction of agency programs.

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

Agency	*FY 96 Actual*	*FY 97 Budget*	*FY 98 Proposed*
DOD	30.5	24.5	13.1
DOI	32.7	27.9	27.3
NSF	46.2	47.8	49.8
NASA	38.0	38.2	33.7
NOAA	13.7	12.8	11.5
DOE	4.2	4.2	4.2
HHS	6.4	6.5	6.5
SI	0.5	0.5	0.5
DOT	6.9	6.3	6.3
EPA	0.8	0.5	0.5
DA	2.8	2.8	2.8
DOS	0.1	0.1	0.1
Total	182.7	172.0	156.2

* Capital facilities and icebreaker support costs are not included in these estimates.

1.3 Interagency Coordination

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

Since the last revision of the Plan, significant progress in implementing recommendations has been made and accomplishments continue to be identified. These include activities of the Interagency Committee and the Arctic Research Commission. Additional information can be found in the journal *Arctic Research of the United States* (Volume 10, Spring/Summer 1996), published by NSF on behalf of the IARPC.

The Act mandates a requirement for implementing a coordinated U.S. Arctic research program. Mechanisms for appropriate levels of coordination continue to evolve. Three levels of coordination and cooperation are needed for an effective national Arctic research program:

- Individual agency, and independent investigator, research programs;
- National coordination; and

• International collaboration.

Each element requires a mechanism for internal program development, review and implementation, and each needs to be linked to the other two. The national effort is performed through the Interagency Committee. A staff oversight group of the Interagency Committee provides coordination, assisted by working groups representing specific agency programs. A data and information group and a logistics and operational support group are pursuing a number of interagency activities. These are reported in the subsequent sections. The Environmental Monitoring and Assessment Working Group prepared the Arctic contamination research and assessment plan (see Section 2, p. 11).

Many interagency agreements and planning and coordinating activities already exist. Coordination with global change programs is an integral part of Arctic program development and implementation. Improved communication at all levels through existing newsletters and journals is encouraged.

1.4 International Cooperation

On September 19, 1996, the U. S. signed a declaration establishing the Arctic Council, an eight nation forum designed to bring together in a senior policy setting the environmental conservation elements of the Arctic Environmental Protection Strategy (AEPS) and broader issues of common concern related to sustainable development. In addition to the eight nations (Canada, Denmark/Greenland, Finland, Iceland, Norway, the Russian Federation, Sweden and the U.S.), the region's indigenous communities are recognized as Permanent Participants of the Arctic Council. Canada is the chair of the Arctic Council until September 1998, at which time the United States has indicated an interest in assuming the chair.

The Arctic Council is entirely consistent with the objectives articulated in the U. S. Arctic Policy Statement of 1994 and offers an important vehicle for pursuing them. These policy objectives include:

- Protecting the Arctic environment and conserving its living resources;
- Promoting environmentally sustainable natural resource management and economic development in the region;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involving the indigenous people of the Arctic in decisions that affect them;
- Enhancing scientific monitoring and research on local, regional and environmental issues; and
- Meeting post-Cold-War national security and defense needs.

The United States has been an Arctic nation, with important interests in the region, since the purchase of Alaska over a century ago. National security, economic development, human rights and scientific research remain cornerstones of these interests. At the same time, the pace of change in the region—particularly political and technological developments—continues to accelerate, creating interdependent challenges and opportunities for policy makers in Arctic regions.

U.S. Arctic policy reflects these elements of continuity and change. It emphasizes environmental protection, sustainable development and the role of indigenous people, while recognizing U.S. national security requirements in a post-Cold-War world. It also is concerned with the need for scientific research, particularly in understanding the role of the Arctic in global environmental processes, and the importance of international cooperation in achieving Arctic objectives.

The U.S. works in consultation with the State of Alaska, Alaskan indigenous people and Alaskan non-governmental organizations (NGOs) on Arctic issues and policy making. Federal agencies continue to give careful consideration to local Alaskan needs, including the unique health, social, cultural and environmental concerns of indigenous people when developing Arctic plans and policies. Representatives of the State of Alaska, Alaskan indigenous people and Alaskan NGOs will continue to be included as appropriate on U.S. delegations to Arctic-related international meetings. The U.S. has also set as a high-priority goal gaining on-par representation for its Athabascan and Aleut populations in Alaska as Permanent Participants on the Arctic Council.

Arctic Environmental Protection Strategy

The U.S. expanded its international cooperation under the Arctic Environmental Protection Strategy (AEPS). Beginning in 1989, the eight Arctic

countries began discussions on improving Arctic cooperation. In 1991, in Rovaniemi, Finland, they reached agreement on AEPS. This nonbinding effort has primarily operated through four working groups to address environmental issues relevant to the circumpolar area:

- *Arctic Monitoring and Assessment Program (AMAP):* Assesses the health and ecological risks associated with contamination from radioactive waste, heavy metals, persistent organics and other contaminants. Recommends targeted monitoring to collect current data from areas of special concern.
- *Conservation of Arctic Flora and Fauna (CAFF):* Studies the adequacy of habitat protection and ways to strengthen wildlife protection through an international network of protected areas and more effective conservation practices.
- *Protection of the Arctic Marine Environment (PAME):* Creates international guidelines for offshore oil and gas development in the Arctic, organizes and promotes the drafting of a regional action plan for control of land-based sources of Arctic marine pollution, and collects information on Arctic shipping activities.
- *Emergency Prevention, Preparedness and Response (EPPR):* Develops and refines an environmental disaster "risk assessment" for the Arctic, reviews emergency notification systems, conducts spill response exercises, recommends cleanup and other response measures.

Sustainable Development and Environmental Protection

A basic premise of U.S. Arctic policy is that the work of the Arctic Council, particularly in the field of sustainable development, needs to build on the environmental protection considerations of AEPS, which is now an integral part of the Council. The Arctic Council Declaration describes sustainable development as "including economic and social development, improved health conditions and cultural well-being." Further, the concept of sustainability is reflected in its description of environmental protection, which refers to "the health of the Arctic ecosystems, maintenance of biodiversity in the Arctic region and conservation and sustainable use of natural resources." Terms of Reference for the Council's sustainable development efforts are currently being negotiated between the eight Arctic governments with the participation of the region's indigenous communities. A process has begun to identify, from a U.S. perspective, issues within the arena of Arctic sustainable development upon which circumpolar attention might reasonably be directed either in the form of a high-level discussion at biennial meetings of the Council itself or implementation of specific cooperative activities.

Scientific Research

The United States continues to plan to further international scientific research through development of an increasingly integrated national Arctic research program. This includes support for international cooperation in monitoring, assessment and environmental research.

The Interagency Arctic Research Policy Committee, with advice from the U.S. Arctic Research Commission, coordinates Federal efforts to produce an integrated national program of research, monitoring, assessments and priority setting that most effectively uses available resources. U.S. Arctic policy recognizes that cooperation among Arctic nations, including coordination of priorities, can make essential contributions to research in the region. To this end the results of the AMAP assessment on the state of the Arctic environment is an important tool in influencing future research priorities.

Conservation

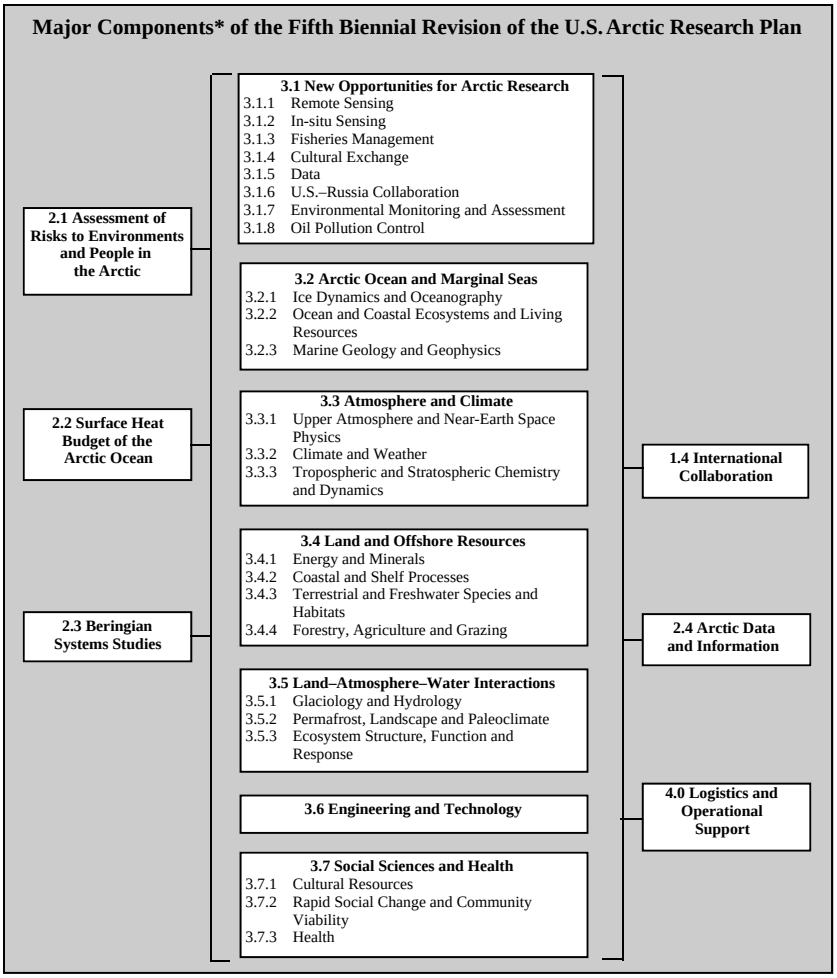
The United States works both nationally and internationally to improve efforts to conserve Arctic wildlife and protect habitat, with particular attention to polar bears, walruses, seals, caribou, migratory birds and boreal forests.

Consistent with the Agreement on Conservation of Polar Bears, the U.S. is discussing ways to improve conservation of polar bear populations whose range extends to Russia and the United States. The U.S. also works to better implement existing measures, such as the 1916 Migratory Bird Treaty, to conserve populations of migratory species of birds that breed in the Arctic.

Cooperation with Russia and Other Nations

The United States engages the Russian Federation on Arctic environmental issues on a bilateral and multilateral basis. The U.S.–Russian Joint Commission on Economic and Technological Cooperation (commonly known as the Gore–Chernomyrdin Commission or GCC) remains the principal venue for a bilateral dialogue on environmental issues, including species conservation and antipoaching campaigns. In addition to

the broad-based cooperation within the Arctic Council, and its predecessor the AEPS, which, inter alia, aid in establishing a more effective environmental regulatory infrastructure in Russia, other multilateral fora now exist to address specialized concerns. Through NATO, the U.S. engages the Russian military on defense-related environmental issues. On a trilateral basis, with Norway, the U.S. focuses on cleanup and consolidation of waste generated from military activities through the Arctic Military Environmental Cooperation (AMEC) process. U.S. support of the International Atomic Energy Agency's International Arctic Seas Assessment Program also has provided a conduit for monitoring and assessing radioactive contaminants in the seas adjacent to the Russian Arctic.



* Numbers refer to descriptions of components within the Plan.

1.5 Revision to the Plan

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

- Section 2. Special Focus Multiagency Research Programs; and
- Section 3. Agency Programs.

The Agency Programs represent the objectives of Federal agencies, focusing on the period covered by this revision (1998–2002). They are presented in six major categories, and where common activities exist they are presented as collective activities. Individual agency mission accomplishments were discussed in the Spring/Summer 1996 issue of *Arctic Research of the United States* and will be updated in 1998. The complementarity of the interagency programs and the agency programs is shown in the figure on this page. Several overall themes transcend essentially all integrated and research mission components.

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

2. Special Focus Multiagency Research Programs

In 1990 the Interagency Committee agreed on the following policy:

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

Subsequently the IARPC agencies examined Arctic research from an interagency perspective. For this biennial revision of the plan, agencies agreed that the following four programs are ready for immediate attention as multiagency focused efforts:

- Assessment of Risks to Environments and People in the Arctic;
- Surface Heat Budget of the Arctic Ocean;
- Beringian Systems Studies; and
- Arctic Data and Information.

These coordinated, multiagency programs are being designed to:

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

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

Benefits to the Nation from Arctic research include improvements in:

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

2.1 Assessment of Risks to Environments and People in the Arctic

Introduction

Increasingly, there is recognition that the Arctic regions are more than remote, sparsely inhabited and undisturbed environments. The scientific and environmental communities, as well as the inhabitants (that is, indigenous and newly resident) and private sector interests, recognize that the Arctic is actually a concentration area for locally and globally generated contaminants and pollutants. Two examples of the Arctic's potential as a materials sink are the high environmental and body burden levels of synthetic compounds that are known to mimic certain hormones (that is, endocrine disruptors), and Arctic haze, the seasonal build-up of atmospheric pollution.

For the situation of endocrine mimics, atmospheric and marine system transport can lead to unusual concentrations of polychlorinated biphenyls, among other foreign substances, in polar bears as well as in the umbilical cord blood of Inuit

Flensing a whale along Alaska's north coast. Traditional diets may pose a nutritional risk to some Alaskan Natives because of the concentration of contaminants in marine vertebrates. Most of these contaminants originate from industrial activities in temperate latitudes far to the south and are transported to the Arctic by natural physical and chemical processes. (Photo by Kimberlee Beckmen, NOAA/NMFS.)

newborns. For Arctic haze, the unique seasonal stability of the Arctic regions' air mass promotes this phenomenon and also contributes to polar ozone depletion by transporting contaminants over the polar region and into North America. Had the Chernobyl nuclear reactor accident occurred only a few weeks earlier than it did, before the seasonally stable Arctic haze air mass had dissipated, dangerous levels of radioactive contaminants would have been concentrated over Alaska and northern Canada.

Arctic contaminants include not only those noted above but also persistent organic compounds, trace and heavy metals, radionuclides and chronic hydrocarbon contaminants. Many of these contaminants are transported through the marine and terrestrial environments, as well as the atmosphere. The potential impacts on human health, ecosystems and economic vitality of the presence of these contaminants in Arctic ecological systems are poorly studied and understood, as yet.

To provide the basis for informed policy decisions with respect to short- as well as long-term risks of and responses to this contamination, there is an immediate need for focused continuing multidisciplinary research and a well-defined risk assessment and risk management program that provides an integrated and more comprehensive basis for and approach to understanding the complex issues of Arctic contamination. Components of such an integrative program must include baseline characterization activities and monitoring of contaminant dispersal, exposure and effect, coupled with the results of social and economic analyses. Specific program elements must include data and information management, data rescue and data synthesis; observation; process-oriented research; and model development.

The programs of the IARPC's member agencies are strategically focused to fulfill these needs. The IARPC is structured to capitalize on the strengths of these agency programs so as to build a national program capability for an innovative, multidisciplinary approach for the United States to begin to systematically understand the complexities of Arctic phenomena that impact on our society.

This program of Assessment of Risks to Environments and People of the Arctic has been developed in response to an IARPC Policy Statement on Arctic Contamination and its Agenda for Action, the substance of U.S. policy in the Arctic (Appendix G) and the results of an IARPC Workshop, several agency programs and workshops on Arctic contamination.

For example, the Arctic Nuclear Waste Assessment Program (ANWAP), a Congressionally mandated program, has focused on evaluating the impact of former Soviet Union nuclear waste discarded into the Arctic Ocean and possibly entering the Arctic marine environment from diverse land-based sources. This program has provided about $30.0 million in support of over 80 domestic and international research projects. It will provide a unique human and ecological radiological dose assessment for the Alaskan marine environment, with applicability to the entire Arctic Basin in 1997 (Office of Naval Research 1995, 1996, in prep.).

ANWAP and its report are supplemented by the findings of 15 years of applied and integrated research by the Nuclear Energy Agency's Coordinated Research and Environmental Surveillance Program (CRESP) under the Organization for Economic Cooperation and Development (OECD). The risk assessment framework of the CRESP has been used to define the transport and fate of past radioactive materials disposed of in the northeastern Atlantic Ocean by the European community (OECD 1996). ANWAP built upon the coordinated risk assessment approach of CRESP to conduct its Arctic assessment of marine radioactivity, and together they serve as the models for the proposed IARPC risk assessment initiative for multiple contaminants. Much progress has been made on radiological issues, and this progress will lead to understanding of processes affecting other contaminants.

NOAA's National Status and Trends (NS&T) program was initiated in 1984 to determine the status of, and to detect changes in, the environmental quality of the Nation's coastal waters. The program's activities focus on two long-term goals:

- Assess the status and trends of environmental quality in relation to levels and effects of toxic contaminants, radionuclides and other sources of contamination in U.S. marine, estuarine and Great Lakes environments; and
- Develop diagnostic and predictive capabilities to determine the effects of toxic contaminants, radionuclides and other sources of environmental degradation on coastal and marine resources and human uses of these resources.

Among other activities, the program measures pollutants from a nationwide network of 240 sites. Biological effects of contaminants are evaluated on the basis of sediment toxicity assessments, biomarker responses and changes in benthic community structure. In 1997, sampling will be conducted at eight coastal sites in the U.S. Arctic, extending from Nome to Barter Island.

The Alaska Marine Mammal Tissue Archival Project (AMMTAP) is now managed under the Marine Mammal Health and Stranding Response Program (MMHSRP) of NOAA/National Marine Fisheries Service (NMFS) and is jointly funded by the Office of Protected Resources (NOAA/NMFS), the National Institute of Standards and Technology (NIST) and the Outer Continental Shelf program (DOI/Biological Resources Division and Minerals Management Service). The program collects and analyzes tissues and sera from marine mammals in order to assess marine mammal health, including tissue contaminant levels. The program involves research to develop better techniques and tools to assess health and to assess the impacts of contaminants and other stressors on health. Analyses of marine mammal tissues are conducted through collaborative efforts of several national (primarily the NMFS/Northwest Fisheries Science Center/ Environmental Conservation Division) and international (Germany, Austria and Canada) labs. The overall program coordinates with and has provided information on contaminants to many organizations including other Federal, state, international and Native organizations.

In August 1996 the Office of Naval Research and the U.S. Environmental Protection Agency sponsored the U.S. Arctic Contaminant Research Planning Workshop. The major goals of this workshop included the capture of insights into the feasibility of broadening the research activities of the ANWAP, informing (with respect to the Arctic) the human health, environmental and ecological research priority setting of the U.S. Environmental Protection Agency and judging the relevance of any proposals that might be received by the EPA.

A central feature in the conduct of this research planning workshop was its focus on the use of the risk assessment/risk management paradigm. Efforts at the workshop were bounded by the understanding that there should be an effort to integrate the conduct as well as the findings of risk assessments (that is, human health and ecological risk assessments) and that such risk assessments may:

- Be quantitative or qualitative;
- Be either predictive or retrospective;
- Focus on environmental or human health stressors, or on physical, chemical or biological phenomena or processes; and
- Be designed to link sources of impact, stressors and effects.

The risk assessment model presented at the workshop was that currently in use by the EPA for all of its human health and ecological risk assessment exercises and is characterized by four stages:

- Problem formulation (for example, the purpose of the workshop);
- Analysis (that is, the illustration of exposure to stressors, and their effects);
- Risk characterization (that is, the clear and explicit description of the details of risk assessment process undertaken in any given instance, and of its results); and
- Risk management (that is, those actions taken as a result of the assessment to address, resolve, prevent or mitigate the expected risk).

For this workshop the question of the nature of the appropriate criteria for research in support of Arctic human health and ecological risk assessment and risk management remains.

An important—and as yet unresolved—concern voiced throughout the workshop focused on input to the research planning process by the indigenous people of the Arctic. This concern takes on heightened significance in light of the establishment of the Arctic Council. The U.S. acceded to the *Declaration on the Establishment of the Arctic Council* in September 1996. The Declaration affirms the commitment of the nations of the Arctic Environmental Protection Strategy "...to the well-being of the inhabitants of the Arctic, including recognition of the special relationship and unique contributions to the Arctic of indigenous people and their communities." Further, it lays a foundation for "recognizing the traditional knowledge of the indigenous people of the Arctic and their communities and taking note of its importance and that of Arctic science and research to the collective understanding of the circumpolar Arctic; and, …to pro-

vide a means for promoting cooperative activities, and to ensure full consultation with and the full involvement of indigenous people and their communities and other inhabitants of the Arctic." The intent of the Declaration comports directly with the National Science and Technology Council's initiative to focus attention on promoting interagency human health and environmental research, and risk assessment and risk management activities, on Human Dimensions.

While all IARPC agencies are in some manner involved in the elucidation of contamination problems in the Arctic, the key Federal agencies for this initiative are the Department of Energy (DOE), the Department of Defense (DOD), the Department of Interior (DOI), the Department of State (DOS), the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF) and the Department of Health and Human Services (HHS).

Contamination and the Arctic Environment

During the past several years, a number of independent sources, including a special Russian Federation Commission, the Yablokov Commission, established by Russian Federation President Boris Yeltsin, have reported and documented a multiyear, post-World-War-II history of dumping of nuclear and toxic waste materials by the former Soviet Union (FSU) into the Arctic Ocean, its marginal seas and many of the larger river systems of the adjacent land masses.

While the Yablokov Commission's disclosures were instrumental in bringing attention to the problems of Arctic radionuclide pollution, radionuclides are just one aspect of Arctic contamination. Other pollutants, including persistent organic compounds, trace and heavy metals and hydrocarbons, may also pose serious threats to Arctic ecosystems and populations. In addition to direct discharge, contaminants are transported to the North through streams and rivers, ocean currents and atmospheric circulation.

The Arctic contamination issue is far more complicated than just discharge of contaminants from the FSU. Internationally, resource development, mining and petroleum production have been long-term sources introducing contaminants into the Arctic. Among the contaminants accumulating in the Arctic are persistent organic compounds from North America, Asia and Europe, coal combustion products from Europe and Asia, and other types of contaminants, such as pesticides, with a global origin. Detectable quantities of radioactivity from nuclear plants at Sellafield, United Kingdom, and Cap de La Hague, France, are found entering the Barents Sea from the west. In Alaska alone the Defense Environmental Restoration Program identified more than 150 sites that require some level of environmental cleanup.

Regarding radioactivity, the Yablokov Commission Report of 1993 identified that the FSU dumped (in violation of international law), or lost in the marine environment, radionuclide materials totaling more than 2,500,000 curies of radioactivity. Most of this was in the Arctic. This quantity of dumped materials represents twice as much material as has been disposed of in the Atlantic and Pacific Oceans by all other nations combined. Included in this total are large volumes of liquid radioactive waste, sealed barrels of solid radioactive waste, fueled nuclear submarines and more than one dozen intact nuclear reactors.

Other reports indicated that substantially larger quantities of radioactive and toxic waste products are stored in temporary impoundments or have been dumped into lakes and rivers that are tributaries to the Arctic Ocean, including the Ob, Lena and Yenisey Rivers. One example, Lake Karachai, a small lake in the southern Urals, may have received more than 100 million curies of plutonium waste.

Nuclear reactor accidents, such as Chernobyl in 1986, Myak in 1957 and Tomsk in 1993, as well as a multiyear history of atmospheric, surface and subsurface nuclear weapons testing, especially in the Novaya Zemlya region, have produced radioactive atmospheric fallout over much of the Arctic. The presence of other nuclear reactors throughout the Russian Federation and eastern Europe, similar in design to those of Chernobyl, poses a continuing threat with uncertain consequences.

In March 1993 the Russian Federation also identified the existence of radioactive waste dump sites in the northwesternmost Pacific Ocean. No information exists about the impact of these wastes on the adjacent Bering Sea.

In the United States, aside from the IARPC, activities of the Arctic Research Commission (ARC) and Senate Select Committee on Intelligence directed national attention to the Arctic radiological contamination issue. The ARC determined by discussions with the Commission on Arctic Research of the Russian Academy of Sciences that Russian scientists were interested in and able to join assessment efforts to establish the

dimensions of broad pollution problems and risks to Arctic nations and people. Such cooperation with the Russian scientific community has benefited ANWAP.

IARPC Involvement in Arctic Contamination

The IARPC, through its *Policy Statement on Arctic Contamination*, its *Agenda for Action* and its 1993 Workshop on Arctic Contamination has taken the lead U.S. role in clarifying the Arctic contamination issue. Using presently available, limited resources, the IARPC has begun to compile existing data and analyses concerning types and distribution of contaminants, as well as field studies to determine contaminant movement and distribution.

Linkages

International

The proposed IARPC Initiative on Assessment of Risks to Environments and People in the Arctic is primarily focused on contaminant risk to U.S. lands, waters and people. The results of the U.S. program would be shared with the Arctic Council members.

The Russian Federation is a major scientific entity in the Arctic Basin. Traditionally it has resisted research cooperation because of security and territorial interests. In the past three years this position has dramatically changed, and Russia is now cooperating openly in many respects and is providing scientific information about Arctic contamination and logistics support for studying the Arctic. There has been much open sharing and discussion between U.S. and Russian scientists on many aspects of the Arctic contamination issue.

Linkages also will be (or already are being) forged with the International Atomic Energy Agency (IAEA), the International Arctic Science Committee (IASC), the International Institute for Applied Systems Analysis (IIASA) and the Organization for Economic Cooperation and Development's (OECD) Nuclear Energy Agency (NEA).

National

The risk from contaminants to Alaskan lands, waters and people is a vital concern to the State of Alaska. The State has many ongoing relevant programs within its Department of Environmental Conservation, Department of Natural Resources, and Department of Health and Social Services. The IARPC Initiative on Assessment of Risks to Environments and People in the Arctic will coordinate with the State of Alaska government and its programs to maximize utilization of available resources.

The indigenous people of Alaska have a great knowledge of the Arctic. They also have the highest risk of potential impact from Arctic contamination. The participation of Alaskan Natives in contaminant research is a goal of the IARPC. Organizations such as the Native regional corporations, the Inuit Circumpolar Conference, the Alaska Federation of Natives and governmental and nongovernmental entities within the North Slope Borough (i.e., the North Slope Borough Fish and Game Management Committee) will serve as forums for Native involvement in the IARPC Initiative. Additionally the IARPC Initiative will coordinate its plans and activities with ongoing Federal activities.

Elements of IARPC's Initiative on Assessment of Risks to Environments and People in the Arctic

This Initiative on Assessment of Risks to Environments and People in the Arctic recognizes the need to achieve an integrated multidisciplinary approach to understanding Arctic contamination and the likelihood of its impacts on ecosystems and human health. This approach involves development of an integrated, comprehensive assessment, including:

- Data and information identification and management, coupled with data rescue and synthesis;
- Observation;
- Process-oriented research;
- Model development; and
- Implementation of the various stages of the risk assessment and risk management paradigm mentioned above.

Increasing the comprehensiveness of assessments of the Arctic contamination issue are fraught with unknowns and hindered by minimal information. For the IARPC to begin to understand the potential impacts and consequences from a broad range of contaminants released or accumulating in the Arctic, three major types of information will be needed following the example of ANWAP for the nuclear contaminants. The first is relevant and credible information about the type, chemistry, quantity, distribution and packaging of each type of contaminant released into or accumulating within the Arctic. The second is process information about each contaminant; specifically, how it accu-

mulates, how it is transported, how it enters the food chain (its biological uptake) and what its effects are on human and ecosystem health. The third—and probably most problematic and data-poor—involves information and understanding on the Human Dimensions (that is, the social, behavioral and economic aspects of the issue pertinent to the Arctic context).

Environmental contaminants do not respect boundaries, be they physical (air, snow, ocean, biota) or political (national). As a consequence the fate and effects of contaminants in the Arctic must be assessed over wide spatial and temporal scales and political and cultural dimensions. Such assessments can be done with observational and monitoring data. The cost to assess all media and all such dimensions at all scales, however, would be prohibitive. To compensate for this dilemma, human health and environmental risk assessment and risk management programs must strive to understand the sources, transport processes, fates and effects (as well as the identifiable and measurable factors of Human Dimensions) of contaminants and to develop models that allow for an understanding of the present situation in question, as well as for the extrapolation of this information.

For this Initiative on Assessment of Risks to Environments and People in the Arctic to be productive, defensible and credible, it must include:

- Historical studies of past environmental conditions and pollutant baselines and their distribution.
- A strategic research planning and problem formulation effort. This initial and critical part of the activity would investigate the state of our understanding of past and present major Arctic human health and ecological stressors (inclusive of such elements as toxic chemicals, persistent organic pollutants, metals, radioactivity, and changes in land use, land cover, habitat, biodioversity, and Arctic human lifestyles).
- A risk-assessment and risk-management-based activity that has as its intent to go beyond the indication of the "presence" of the above-mentioned human health and environmental stressors in the Arctic to a critical analysis of the likely consequences of the "presence" to human health and to the condition of the ecological resources that make the Arctic unique.
- An in-depth analysis component to provide heretofore unavailable information related to the Human Dimensions of health and ecological risk in the Arctic.

Part of the Human Dimensions analysis component is currently in progress through Native Alaskan review. The Alaska Native Science Commission agreed to serve as the primary link between Arctic scientists, government officials and nongovernment entities to assure that tribal concerns and knowledge are factored into scientific research and interagency agreements.

Information Management, Data Rescue and Data Synthesis

There is a need to identify and manage data and information that has application to the assessment of Arctic contamination, specifically data and information related to the health and ecosystems that Alaskan residents and indigenous peoples depend on for recreation, subsistence and commerce. There is also a need for common data formats for this information, and a need to perform the necessary data conversions and connections. Associated with each data set should be its "metadata," that is, information about the data, such as instrument characteristics, processing information, peculiarities in collecting or processing the data, known problems that have been solved, and comments from scientists who have used the data.

Data rescue is urgently needed to prevent the permanent loss of certain data that are essential for assessing the human health and ecosystem risks posed by contaminants in the Arctic. As found by ANWAP, in Russia, as well as throughout the entire Arctic scientific community, much of the data and information is unknown to the scientific community, exist in formats or files that are not easily accessed, or is being lost to the scientific community. Part of the problem is the lack of coordination in the collection, storage, quality assurance, archiving, communication and retrieval of pertinent information.

Once existing data sets are rescued and assembled, an information synthesis is required that assesses the available data with respect to quality control and quality assurance criteria, analyzes the information for implications, and identifies any data gaps for planning subsequent data collection efforts.

Observation

Observation is necessary to:

- Document temporal and spatial patterns of contaminants and the health of the biota or ecosystem;
- Document indicators (including markers) of their presence;

- Identify processes that transport and transform them; and
- Produce information on the likely and potential effects of these contaminants.

This information is essential for estimating the current toxic risks to ecosystems and to people and for evaluating models that may predict future risks.

Heightened concerns for the protection of the Arctic environment and biological resources during the past decade have greatly accentuated the need for more comprehensive and multidisciplinary observations on the extent and severity of contamination from different sources. Such observations are essential for describing potential threats to Arctic ecosystems and human residents from anthropogenic contaminants, including radionuclides.

Internationally, accessibility of data generated in the former Soviet Union is a major drawback. When accessible, data often lack quality assurance provisions, limiting their use in Arctic-wide environmental assessments. A number of bilateral and multinational collaborative environmental monitoring and research projects between Russia and western countries, including the United States, and preparation of an Arctic-wide environmental assessment report under the auspices of the Arctic Monitoring and Assessment Program, have alleviated this problem. It is anticipated that future environmental data and reporting will be more consistent and satisfy quality assurance requirements in field sampling and chemical analysis procedures.

Process-Oriented Research

Process-oriented research is an essential precursor to the development of useful models and to accurate predictions of risks and impacts. This research must include experiments that test hypotheses dealing with:

- Time-varying source functions for Arctic contaminants;
- Transport of contaminants by ice, water and air;
- Natural sources of contamination;
- Transport of contaminants by biota;
- Bioaccumulation of contaminants;
- Accumulation of contaminants in water, soil and sediment; and
- Uptake by high trophic levels, including human consumption.

Without such studies it will not be possible to determine those key processes that must be included in models and risk assessments and to predict how these terms will change with time. Examples of such studies include experiments that determine bioaccumulation factors for contaminants by Arctic organisms, determine unique Arctic contaminant transport mechanisms for contaminants such as those associated with ice formation and transport, and determine how Arctic processes can transform contaminants into forms that differ significantly from their initial state.

Model Development

With the rapid increase in the power and technology of supercomputing and the attendant advances in numerical physics research, there is a new opportunity to do high-resolution, complex computer simulations of coupled dynamic processes in the ocean–atmosphere system. These computer models can be used in four ways:

- They can be compared with natural systems to evaluate their accuracy.
- They can be used to assist (and may be the only way to succeed) in interpreting and integrating the large data sets that will be collected.
- Their results can be used as valuable input for planning observational programs.
- As a result of their success in the first three modes, researchers may have enough confidence to use them for prediction.

Higher-order paradigms take on increasing complexity. Furthermore, researchers must communicate the purpose, the result and its associated confidence to the eventual users of the information. Obviously the choice of the appropriate paradigm or model is critical to this process.

Impact and Risk Analysis and Determination and Management of Risks

The most serious limitations arise from our lack of understanding of physical, chemical, biological and geologic processes and their natural variability and interactions with a broad range of Arctic contaminants. A clear understanding of the Arctic contaminant issue and its interrelationship with the global environment will require sophisticated and sustained interdisciplinary studies.

As has been accomplished for radioactivity under ANWAP, assessing impacts and risk to humankind and the environment from contaminants involves linking the exposure to or dosage from a particular substance with an expected response. Health, ecological and economic impacts should be considered individually, realizing that a particular contaminant may produce high health risks, for example, but low ecological impact or vice versa. When calculating impacts to humans, from the

standpoint of environmental equity, the distribution of risk is an important factor for impacts to Native Arctic peoples. Rural Native communities with low population densities may not appear to have a high population risk, but unique factors related to foods and lifestyle may expose these groups to unknown risks. Therefore, an understanding of food chain interactions and contaminant concentration factors is important for calculating the risk to biota and to humans. The time dimension is also important, since environmental threats may have a long latency period.

Assessing exposures, doses and impacts involves a thorough understanding of transport processes, including physical, chemical, geochemical and biological factors, and actual environmental levels of contaminants of concern. These factors are all integrated through the modeling process by which exposure and dose estimates can be made. Research and modeling should proceed in an iterative manner, utilizing as much site-specific data as possible. The models will predict contaminant distributions in time and space, which will then be coupled to information on concentration factors and also acute and chronic biological effects data.

Assessments of exposure and impacts may proceed from a rough calculation utilizing maximizing assumptions and very little site-specific characterization to a very data-intensive program, as the situation warrants.

2.2 Surface Heat Budget of the Arctic Ocean

Introduction

Climate is arguably the most pervasive and influential factor that defines the "Arctic." There is scarcely any aspect of the Arctic system, including the human and natural components, that is unaffected by climate. Both historical records and paleoclimatic proxy indicators depict the Arctic as a highly variable and sensitive region in the global climate system. Much of our knowledge of the fundamental physics of Arctic climate and its interaction with the global system comes from simulations performed with general circulation models (GCMs). These simulations indicate that physical processes occurring in the Arctic ocean–atmosphere–ice (OAI) system produce climate feedback mechanisms involving the sea ice, snow cover and Arctic clouds. These mechanisms influence many features of Arctic climate, especially its high sensitivity to perturbations, such as changing concentrations of atmospheric CO_2 and aerosol. This high sensitivity also extends the influence of Arctic climate processes to hemispheric and global scales.

The consequences of the climatic changes simulated by GCMs in response to an anthropogenic doubling of atmospheric greenhouse gas loading over the next 70 years would be enormous, both within and outside the Arctic. Therefore, in looking to the future environment, it is of the utmost importance to understand both the potential climatic implications of policies and practices that may affect climate, and the reliability of the projections of future climate scenarios. The high sensitivity of Arctic climate is also manifest in wide disagreements between the climate simulations of different GCMs. To a great extent these differences arise from different model formulations of the interactive OAI processes that determine two critical climate feedback mechanisms: the ice–albedo feedback and the cloud–radiation feedback.

A coordinated multiagency project called SHEBA (Surface Heat Budget of the Arctic Ocean) is being implemented during 1995–2002 to enhance our ability to understand and predict how the Arctic climate system changes on time scales of 10 to 100 years, including both natural variability and response to anthropogenic forcing.

Planning and Development

The uncertainties surrounding Arctic climate sensitivity and projections of future Arctic climate have been prominent in the planning of the Ocean–Atmosphere–Ice Interactions (OAII) component of Arctic System Science (ARCSS). Studies of the surface energy balance, atmospheric radiation and clouds over the Arctic Ocean were recommended as one of six science priorities for ARCSS–OAII.

A workshop, and subsequent discussions in the scientific community, resulted in the concept for a project called "SHEBA: Surface Heat Budget of the Arctic Ocean" to address the key uncertainties that now limit our ability to document, understand and predict Arctic climate. The workshop produced consensus that the highest priority be placed on acquiring an accurate, comprehensive data set documenting the physical processes in an ocean–atmosphere–ice column that affect ice–albedo

feedback and cloud–radiation feedback, over a full annual cycle and on a horizontal scale that approximates the resolution of current and projected GCMs.

A consensus also emerged that the best way to obtain the needed in-situ data is to deploy a coordinated measurement program on the drifting pack ice of the Arctic Ocean, sampling in detail the OAI column from the base of the oceanic mixed layer through the top of the atmospheric planetary boundary layer, over the course of a full annual cycle. In this approach the experiment can follow the evolution of the ice cover, including its mass balance and radiative properties, as an element that responds to and interacts with the two boundary layers.

With inputs from the ARCSS workshops and many other sources, the Arctic Research Commission (ARC) has recommended as one of four priorities for the U.S. Arctic Research Program to "conduct research to understand the Arctic Ocean and how the ocean and the atmosphere operate as coupled components" (ARC 1993). The ARC report recommends a five-year, multiagency attack on this priority area. SHEBA constitutes a major element of research in this broad priority area.

Following the Orlando workshop, the ARCSS–OAII Science Steering Committee established a Science Working Group (SWG) to further develop the scientific planning and coordination of SHEBA and recommended that NSF/ARCSS, together with relevant agency partners in the Interagency Arctic Research Policy Committee (IARPC), issue a sequence of program announcements. In response the lead agencies (NSF and ONR) have identified three phases for SHEBA:

- Phase I (1995–1996) focused on activities that must precede the field experiment, including analysis of existing data sets, modeling studies to refine measurement priorities, and the development of measurement technology to be applied during the field experiment.
- Phase II (1997–1999) encompasses the field experiment itself, and the initial analysis and interpretation of the resulting data, including detailed process modeling studies and initial OAI column applications.
- Phase III (2000–2002) will focus on the application of the data sets to GCMs, including single-column modeling, parameterization development and simulations with improved GCMs.

Some 16 Phase I projects are currently underway. In July 1996 NSF and ONR issued a joint announcement of opportunity for Phase II research, including participation in the SHEBA field experiment, which is scheduled to begin in late September 1997. Current plans call for publication of a SHEBA Phase III announcement of opportunity in the summer of 1999.

SHEBA Goals, Objectives and Rationale

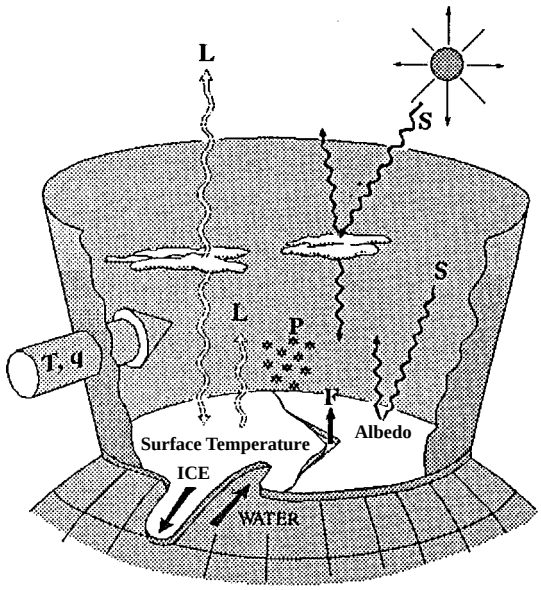
The SHEBA prospectus lays out a scientific rationale for a systematic attack on understanding how the Arctic ocean–atmosphere–ice system affects the climate of the Arctic and the globe. Two main problem sets are highlighted: ice–albedo feedback and cloud–radiation feedback. Within each of these problem areas, as in all facets of the U.S. Global Change Research Program, the overall goals are to document, understand and predict how the relevant portion of the climate system works.

The two primary goals of SHEBA are:

- To develop, test and implement models of Arctic air–sea–ice processes that demonstrably improve GCM simulations of the present-day Arctic climate, including its variability; and
- To improve the interpretation of satellite remote sensing data in the Arctic so that satellites can assist effectively in interpreting the Arctic climate system and provide reliable data for model input, model validation and climate monitoring.

The key interactive components of the system to be studied by SHEBA are shown in the figure on p. 20. This figure is useful as a schematic for average conditions over the oceanic portion of the north polar cap, and for the processes occurring within a single Arctic column of a coupled, ocean–atmosphere–ice climate model. In the latter case the base of the column may be thought of as coinciding with an area of the Arctic Ocean centered on the SHEBA drifting research station. The energy balance of the system inside the shaded boundaries is driven by two external forcing functions: S, the solar radiation at the top of the atmosphere, and T,q, the horizontal advection of sensible and latent heat by the atmosphere. The primary energy sink for the system is the outgoing longwave radiation (OLR) L at the top of the atmosphere.

The sources and sinks of energy depend on the state of the system inside the column. For example, the fraction of sunlight reflected back to space



Schematic energy balance of the Arctic ocean–atmosphere–ice column. The arrow labeled T,q *represents the net advection of moist static energy into the Arctic atmosphere by eddy and mean motion. The solar and thermal infrared radiation fluxes are labeled* S *and* L. *The turbulent heat transfer through openings in the ice is labeled* F. *The stars labeled* P *represent precipitation, consisting of about 10–15 cm of water equivalent in the form of snow, an unknown amount of ice crystal precipitation, and a small amount of rain in summer. The tongues of ice and warm water symbolize the net advection of ice water into the column. In a single Arctic column of a global climate model, the horizontal advection of* T,q, *ice and water would appear as flux divergence terms. (Figure provided by N. Untersteiner.)*

varies with the cloud cover and the surface albedo. The surface albedo depends in turn on the state of the ice cover, such as the area covered by open water, melt ponds, and ice and snow of different thicknesses and physical properties. This surface state is related in a complicated way to surface temperature variations over the annual ice cycle of accretion and ablation. The OLR depends on the surface temperature, as well as the vertical distribution and temperature of clouds and greenhouse gases in the Arctic atmosphere. The vertical transport of heat near the surface is affected significantly in winter by turbulent fluxes *F* through open leads and by suspended ice crystal precipitation *P* that is not recorded in routine observations of "cloud," but which nevertheless affects the absorption and emission of *L*.

The transformations of thermodynamic energy in the OAI column affect the mass balance of the sea ice and snow cover, the formation of clouds and the radiative properties of the surface. The nature of these effects exerts strong influences on the Arctic climate sensitivity exhibited by GCMs. The resulting changes in the mean annual cycle of surface temperature are part of the coupled response of the entire OAI column to changes in the forcing functions *S, T* and *q,* in addition to any anthropogenic forcing such as changes in the concentrations of greenhouse gas and aerosol in the column.

The questions that SHEBA is addressing can be phrased simply with reference to the state of the system in the column depicted in the diagram to the left. For example,

- Given the observations of *S, T* and *q,* how accurately do our models reproduce the observed state of the column, as it varies over the annual cycle, using physical formulations for the processes that represent the present "state of the art?"
- How sensitive is the state of the column to the physical formulations that produce the wide variations among different GCMs?
- How much of the uncertainty in climate sensitivity of the column is due solely to the formulation of processes within the column, versus changes in the "external" forcing *T,q* that may also react to variations in the state of the column during a climate change?

SHEBA aims to acquire a data set of unprecedented accuracy, comprehensiveness and duration with which to address these and many related questions.

The surface energy balance at the atmosphere–ice and atmosphere–ocean interfaces is the key to coupling between the surface state (for example, temperature, albedo, open water area and ice thickness) and the atmospheric processes that determine the overall energy balance of the ocean–atmosphere–ice column. Moreover, it is here at the atmosphere–ice–ocean interface that one finds both the widest variations in treatment of physical processes by different climate models and the most powerful ice–albedo feedback that amplifies climate sensitivity.

The response of such a heterogeneous system to the radiative and turbulent fluxes that force it has never been documented comprehensively and accurately over a full annual cycle and over a region containing variable ice types, snow cover, melt ponds and leads. The primary objective of SHEBA Phase II is to provide this comprehensive documentation and to analyze the individual processes associated with subsets of the complete set of variables in the OAI column.

Cloud–radiation feedback is also characterized by the interplay between energy balance and mass balance. Over the Arctic Ocean, diabatic, and espe-

cially radiative, cooling appear to play a more important role in cloud formation and maintenance than at lower latitudes. The water balance is coupled to the energy balance through the large change in atmospheric emissivity that accompanies cloud formation, the cloud tops serving as sites of relatively large cooling rates. Because of the short lifetime of individual cloud elements, and the time scales of physical processes governing cloud–radiation interactions, in-situ observations relevant to the detailed microphysical processes affecting cloud-radiation feedback will be acquired on a short-term campaign basis, in coordination with the NASA FIRE-III Arctic stratus project. A major objective of the FIRE/SHEBA field activities is to document the key physical, chemical and radiative processes related to cloud–radiation feedback, with the aid of intensive campaigns with research aircraft.

The centerpiece of the SHEBA field program will be a drifting research station on the sea ice of the Arctic Ocean, at which the surface energy and mass balance, and the processes in the adjacent boundary layers, will be documented over a thirteen-month period. The surface observations will be combined with aircraft campaigns, analysis of satellite observations and modeling. The observational program will emphasize the interactions of the surface radiation balance, mass changes of the sea ice, the storage and retrieval of energy and salt in the mixed layer of the ocean, the formation and radiative properties of clouds and their interplay with the radiation balance, and the relationships between the air–sea–ice system and the signals received by satellite-borne remote sensors. Special emphasis will be placed on the use of modern surface-based technology. Dedicated aircraft will conduct regular surveys of the surface conditions and take a variety of measurements in the cloudy atmospheric boundary layer. Observations at the ice camp will be augmented by a number of strategically placed automatic data acquisition systems. To realize the scientific objectives of SHEBA requires coordination of science planning, logistics, in-situ measurement programs, data management, modeling, data analysis and remote sensing activities. The following section describes the plans for implementation that aim to achieve the necessary coordination and integration of the project.

Implementation

SHEBA established a project office at the Polar Science Center, University of Washington, as a Phase I project. The project office is responsible for project-wide communications and information, data management, liaison with collaborating projects, and other aspects of the infrastructure. A logistics support project was also established at the Polar Science Center, University of Washington, as a Phase I project. The logistics project is responsible for establishing and maintaining logistics support for the research station. Information about all aspects of SHEBA is available on the SHEBA home page, maintained by the project office. The address is http://sheba.apl.washington.edu.

The SHEBA field experiment is scheduled to begin in late September 1997 and continue until October 1998. The timing and duration of the experiment are dictated by the science priorities: it is essential to follow the evolution of the ice cover, and its relation to the surface energy balance, over at least one full annual cycle through freeze-up, with special emphasis placed on the spring–summer transition and the summer melting season. Based on existing climate models and Phase I results, the ocean–atmosphere–ice interactive processes occurring during spring and summer appear to be the most influential and the least understood in terms of their contributions to ice–albedo feedback and cloud–radiation feedback.

The in-situ measurements will be staged from and distributed around a research station on the surface of a multiyear ice floe in the Beaufort Sea. The pack ice in this region normally exhibits the generic features that SHEBA aims to study, such as sea ice of varying thickness and age, leads, melt ponds and ridges. A drifting ice floe is the best platform for SHEBA because:

- The scientific approach is based on documenting interactive processes in an element of sea ice of sufficient size and variability to contain numerous surface features that vary in horizontal area and physical properties over the course of the experiment, and
- Long experience with scientific camps on the pack ice addressing other science issues (ice dynamics, internal waves, oceanography of leads in winter, ice mechanics) shows that such a platform optimizes the science support within the constraints of safety and cost.

Current plans call for the research station to be based around an ice-strengthened ship, frozen into the drifting pack ice. The station will be deployed by sailing into the pack with icebreaker escort in late summer or early autumn. Logistics and research flights to the camp will be staged from

The Quicksilver GT500 aircraft system used by the NOAA Atmospheric Turbulence and Diffusion Division (ATDD) as a low-cost instrumented research aircraft. This aircraft will be operated from an icebreaker during SHEBA. The GT500 is the smallest aircraft in the NOAA ATDD measurement aircraft fleet and is primarily intended for surface–atmosphere flux determinations in small regions. It is equipped with the mobile flux platform instrumentation cluster designed and fabricated by NOAA ATDD. The GT500 has removable wings and is shipped in its container to the field site. (Photo courtesy of Steven Brooks, NOAA.)

airports in Alaska and Canada. Flights by short-range aircraft can be staged from locations near the coast, such as Barrow, Prudhoe Bay, Barter Island and Tuktoyaktuk. An icebreaker will probably be used again to escort the SHEBA ship out of the pack ice at the end of the experiment.

Concurrent with the in-situ measurements, satellite remote sensors will acquire repeated coverage of the SHEBA column, sampling in the visible, thermal infrared, passive microwave and radar wave bands, and the resulting digital and image data will be obtained for SHEBA investigators. Sensors planned to be operational at this time include AVHRR, TOVS, SSM/I, and Radarsat SCANSAR.

Coordination

In an effort to maximize the efficiency and scientific payoff from SHEBA, the SWG has actively pursued appropriate interagency cooperation between ARCSS and other programs. During 1993 the SHEBA SWG formally requested that IARPC form an Interagency Group (IAG) to look after the implementation and support of SHEBA in the context of the multiagency Federal environment and the U.S. Arctic Research Plan.

The interagency cooperation for SHEBA has been productive on a number of fronts. NSF/ARCSS and ONR have jointly issued the SHEBA Phase I and Phase II program announcements, including joint panel reviews. Partly as a result of the development of SHEBA, NASA has identified studies of Arctic stratus clouds as a priority for Phase III of the First ISCCP Regional Experiment (FIRE-III). ISCCP stands for International Satellite Cloud Climatology Program. The FIRE-III program announcement, published in the summer of 1994, solicited proposals to participate in a research aircraft campaign over the Arctic pack ice during the spring of 1997. Through coordination between SHEBA and the FIRE science team, plans call for this campaign to take place over the SHEBA drifting research camp and to take advantage of the surface-based measurements to be acquired there.

The Department of Energy (DOE) has established its Atmospheric Radiation Measurement (ARM) program as a major contribution to U.S. global change research. This program is focused on improving the understanding of radiative transfer, including the effects of clouds, as a contribution to narrowing the uncertainty in climate projections. ARM observations are to be conducted over a period of about ten years, at specially instrumented Cloud and Radiation Testbed (CART) sites. One of three CART sites now identified by ARM is the North Slope of Alaska (NSA) site to be established near Barrow. The other CART sites are in the Great Plains of the U.S. and the tropical western Pacific Ocean.

The SHEBA project office and the office of the ARM technical director have established a Participation Agreement (PA) that defines the mutual commitments, rights and responsibilities of the two projects. ARM has extended the NSA CART concept to include participation in SHEBA, with the extended title ARM NSA/AAO (Adjacent Arctic Ocean). Under the SHEBA/ARM PA, ARM will provide state-of-the-art instrumentation for measuring radiation and cloud properties at the SHEBA camp, and SHEBA will provide logistics support and personnel to assist with the operation of the ARM instrumentation. Each project will provide its data sets to the other. ARM benefits from the acquisition of a data set in the moving pack ice, which will provide valuable context for the longer-term land-based measurements at Barrow. SHEBA will benefit from access to the high-quality ARM measurements. The SHEBA/ARM PA is available on the SHEBA home page.

The SHEBA project office has established a second PA with the Radarsat Geophysical Processor System Science Working Group (RGPS SWG). This PA, also available on the SHEBA home page, provides for SHEBA to obtain accurate information on meso- and large-scale ice deformation, including changes in open water area and the ice thickness distribution. In return, RGPS scientists will have access to the SHEBA data sets. The project office is currently engaged in developing a third PA with the NASA FIRE III Arctic Stratus project.

To facilitate the application of SHEBA data to

climate model improvements, the SHEBA project office is participating in the Polar Working Group of the Climate System Modeling (CSM) project of the National Center for Atmospheric Research (NCAR). The developing plans of the CSM Polar Working Group place a high priority on the use of SHEBA data sets with column models of the Arctic OAI physics as represented by CSM. SHEBA has been recognized as an essential contribution by the Arctic Climate System Study (ACSYS) of the World Climate Research Program.

2.3 Beringian Systems Studies

Background

Beringia, the region surrounding Bering Strait including the Chukchi and Bering Seas and adjacent portions of the North Pacific, Siberia and Alaska, is situated at a geographic crossroads and international border. Although the region has been recognized as a key location for scientific research for more than a century, its remote northern location and frontier status have discouraged research. Today, with a more favorable political climate and improved access, and with economic, conservation and Native interests at stake, Beringia is emerging as a major international arena for interdisciplinary study of scientific issues and global change with historical and modern perspectives.

The Beringian Systems Studies fill a crucial gap in knowledge needed for understanding broader global systems that cannot be attained without solid regional databases and syntheses. As one of the least known but most dynamic areas of the northern hemisphere, studies of the greater Beringian region will be important for regional and global science policy formation.

Interest in Beringia comes from many sectors. For more than 150 years scientists have seen Beringia as crucial for understanding geological history and the evolution and relationships of Asian and American biota and cultures. At the same time, Native peoples are concerned about sustaining traditional life and renewable resources. Equally concerned are resource managers and industries exploiting Beringia's rich fisheries, timber, mineral resources and potential oil and gas fields, which are needed by the wider world. For these and other reasons, Beringia requires a comprehensive integrated plan.

The rationale for this plan is based on the need for information required for proper management of Beringian resources as much as it is on the need for scientific understanding. In addition to its diverse geography and natural history, Beringia is characterized by a diversity of cultures, languages, belief systems, and economic and political systems. Yet it remains a distinct environmental, biotic and cultural region and is a natural geographic focus for study. Its marine and terrestrial ecosystems are the most productive of any northern region; its minerals and fisheries have enormous economic value; and its historical and living resources for scientific study of the Beringian world are extensive. Despite remaining differences in political systems, population trends and other cultural and socioeconomic factors on both sides of Bering Strait, the region is a distinct, integrated environmental system and needs to be studied as a whole.

The study of global change has special importance for the Beringian region because of its location, history and structure. Of special significance is that its northern geography has restricted human impacts that have radically changed the environments and ecology of most other regions of the globe. But in Beringia since the appearance of Europeans 250 years ago, few regional species have been driven to extinction, and while fisheries have altered the marine system, ecosystem viability has not been radically changed. On the other hand, natural change, including cataclysmic earthquakes, vulcanism, climatic change, raising and lowering of sea levels, forest fires and other powerful forces, have been a major force in shaping natural and human history. The latter have also been strongly influenced by cultural and historical forces that impinged from the outside. In Beringia the close articulation between physical, biological and human systems can be studied in an unbroken sequence over thousands of years.

Federal agencies have mandates to protect these regions from pollution and resource depletion in order to ensure a future for the region's residents, many of whom are Native peoples who have or claim special traditional rights. Many of these resources are also shared with and administrated jointly by Canada, Russia, Japan and other North Pacific nations. Many of the biological resources (birds, marine mammals, fisheries) are

migratory and require transnational management programs to ensure their continued availability to local peoples and world markets.

For these reasons Beringian research is important in the wider context of the global change program. As research in other areas of the globe advances, Beringian research has hardly begun and is emerging as a major gap in knowledge. Research is needed especially for baseline data and monitoring; on historical and evolutionary systems; and on physical, biological and cultural processes and interrelationships. Information from the Beringian region is now recognized as crucial for understanding wider global issues, including ocean circulation models, paths of contaminant flows, sea ice distribution, ocean productivity, weather patterns and climatic change. Beringian studies have high priority in both regional and global contexts.

Recent political events have greatly facilitated the development of joint Beringian research programs. For more than half a century Beringia was an aggressively defended political frontier, and little scientific communication across Bering Strait was possible. As a result, despite many unifying features, much of the region remains unexplored and is known largely from national perspectives. During the past decade, political moderation has produced international research partnerships that serve as foundations for integrated programs. Collaboration with Russia continues to mature, and research ties with Japan, China and Canada offer opportunities to promote scientific understanding of a region that is rapidly becoming an important zone of joint scientific and economic enterprise. In a world increasingly short of resources for research, interagency, interinstitutional and international collaboration in Beringia offers tangible benefits across the scientific spectrum.

As a regionally focused plan the Beringian systems initiative draws on existing programs conducted by Federal, state and university sectors. The plan links existing research into a geographically focused and thematically integrated network.

The Beringian plan proposes integrated studies of Beringian environments, ecosystems, processes, climate, culture and history. A primary thrust will be to develop knowledge on human–environmental interactions and impacts at regional and global scales for use in developing policy for maximal environmental productivity and protection. Relevance to issues important to Natives and northern residents will help guide research, and community participation will be encouraged.

Research Themes

Research needs in the Beringian zone include a wide variety of scientific disciplines ranging from historical studies and investigation of modern processes to issues of health and safe industrial practice. The basic themes have been incorporated in current governmental programs, including the National Science Foundation's Arctic System Science, Paleoclimates from Lakes and Estuaries (PALE), and Arctic shelf–coast interactions programs; the Smithsonian Crossroads and Jesup II programs; the National Park Service's International Beringian Park and regional resource inventory programs; and the proposed Bering Sea Impact Study (BESIS).

Three themes dominate these programs: environmental history and evolution; human history, culture and human–environmental interactions; and modern processes and human and environmental health. A fourth cross-cuts all others: climate impacts and global change. Developing understanding in each thematic area requires discipline-based science at various time and spatial scales. Integration requires team science and coordination across disciplinary fields through a variety of mechanisms. A ten-year program duration is proposed for achieving a synthesis plateau for this effort.

Research Programs

NSF has defined the central science issues for an integrated program of Arctic research of which the Beringian program serves as an ideal regional application. Certain regions of the northern hemisphere still remain so poorly known as to be considered "black holes" where data and systemic studies are so weak that even their fragmentary data cannot be evaluated or used effectively for broader applications. The Barents, Laptev and Bering/Chukchi Seas and coastal regions fall into these categories. Of these the greater Beringian system is the most important. Current plans include the following research programs.

Bering Sea Impact Study

Regional assessments of impacts due to global climate change are a high priority on the international agenda of the International Geosphere–Biosphere Program (IGBP), the World Climate Research Program (WCRP) and the Human Dimensions Program of Global Change (HDP). Impact assessments provide an excellent means of interdisciplinary analysis and synthesis. In the end it is the importance of addressing societal responses to regional climatic change that underlies fundamen-

tal concern about global change. The International Geosphere–Biosphere Program provides a rationale for a regional emphasis (IGBP 1991):

> First, the research needed to develop a global perspective demands that regional differences in characteristics such as biogeography and climate be taken into consideration. Second, the goal of a practical predictive capability for global environmental change makes it necessary that this capacity be developed for distinct subcontinental regions. Global change predictions will be of greatest value to decision makers on a regional basis, and if scientists from throughout the region are involved from the start in the processes through which change is generated.

No comprehensive Arctic regional impact assessments have been attempted to date, possibly excepting the Canadian Mackenzie Basin Impact Study (MBIS 1990–1996; Cohen 1996) and efforts by Peterson and Johnson (1995). Synthesis efforts to assess regional impacts in the Arctic have begun under the auspices of the International Arctic Science Committee (IASC). Two areas of particular interest were chosen: the Barents Sea area and the Western Arctic/Bering Sea region (IASC 1995).

The Bering Sea Impact Study (BESIS) plan has already identified a broad agenda of ocean-based, coastal and watershed research designed to measure and predict the impact of global change on regional systems. Building from baseline studies, the plan calls for increasing integration at higher levels across disciplines to understand the basic processes controlling productivity of the Beringian ecosystem including impacts on human systems. Its goals include:

- Assess the nature and magnitude of changes in the Western Arctic/Bering Sea region as a consequence of global change;
- Predict/assess the consequences of these changes on the physical, biological and socioeconomic systems in the region;
- Determine the cumulative impacts of these changes on the region, including assessment of past impacts; and
- Investigate possible policy options to mitigate these cumulative impacts.

BESIS plans call for a loose consortium of independent research projects coordinated by a directorate at the Center for Studies of Global Change at the University of Alaska. American, Canadian, Russian, Japanese and Chinese participation has been established. Integration will be encouraged through cooperative planning, workshops and review procedures, using existing funding mechanisms. Native and community input will be important. Disciplinary involvement ranges across the spectrum of physical, biological and human sciences.

Pollution and Environmental Health

Because of the enormous importance of Beringian biological resources for local and global economies, scientific studies of direct and indirect effects of human intrusions must be considered one of the highest priorities of a Beringian systems plan.

Jesup II

In 1997 the field of museum studies and anthropology celebrates the centennial of the Morris Jesup North Pacific Expedition (JNPE) conducted by the American Museum of Natural History in 1897–1903. The JNPE explored the history and cultures of the Beringian–North Pacific region with Russian and German collaboration, but the research momentum it created had to be abandoned at the descriptive level due to the onset of political rivalries. The Smithsonian's Jesup II program will coordinate a new generation of human, cultural and environmental studies in a region that has been occupied by humans for at least 15,000 years. In addition to historical and anthropological studies, research on modern cultures and peoples, enhancement of heritage and cultural survival, and their responses to contemporary processes and problems will be emphasized.

Education

Education is a necessary component of a Beringian research plan. Beringia is a unique and largely American national resource that needs to be better known and appreciated by the nation at large, both for its remarkable geographic, environmental, cultural and historical features and for its economic importance. Because Beringian studies directly concern local populations, educational programs must be planned with participation of Arctic residents.

Management

An important objective of any Beringian research effort must be to develop supporting data and policy recommendations useful for government officials with management responsibilities over the region's resources. The vast majority of Beringia is public domain and falls under the control of Federal or state management, either Russian or American. Foreign interests also have a major stake in Beringian fisheries, and local communities derive a major portion of their economies and sus-

tenance from renewable resources. Finally, because Beringia is of importance to the wider world, management of its resources and scientific studies have international policy involvement.

Goals and Objectives

- Assess the magnitude of changes in the Beringian system as a consequence of global change;
- Assess and predict the consequences of these changes on the physical, biological and socioeconomic systems in the region and determine the cumulative impacts of these changes on the region, including assessment of past impacts;
- Promote studies addressing the modern socioeconomic conditions of Beringia's rural residents and in particular problems of environmental quality, education and human health;
- Increase baseline documentation and synthesis on Beringian paleoenvironments and landscape history and distributions of marine and terrestrial flora and fauna for use in global change modeling;
- Develop baseline documentation of cultural, biological and linguistic variation in historical and modern times, and inventory and assess the status of these resources;
- Develop integrated syntheses of human–environmental interactions with regional and global perspectives;
- Establish baseline documentation on pollutants and their pathways in Beringian food chains and their environmental, health, and economic impacts;
- Develop modeling capabilities and relate the results of regional Beringian studies to larger global patterns of climatic and environmental interactions and change; and
- Develop coordination and infrastructure by enhancing regional research centers, by promoting the spread of scientific knowledge and by encouraging cooperative and international research and education programs that include representation of northern residents and communities.

Planned Elements

Substantial progress has been made during the past decade in developing the planning and infrastructure for Beringian area studies by agencies with relevant on-going programs. BESIS provides a strong focus for scientific planning and coordination. BESIS and Jesup II both are organized as a consortium of independently funded research and educational programs coordinated by a series of workshops, communication networks and interagency activities. Among the proposed activities are:

- NSF: Support of cumulative impacts assessments of global change in the Beringian System through ARCSS and other programs; of science planning and coordination workshops; and of activities in education that communicate scientific knowledge gained to regional and national audiences;
- NOAA: Support research in climatology, meteorology, oceanography, marine food chains and fisheries and provide assistance in logistics and data management;
- NPS: Maintain heritage, research and educational programs associated with the Beringian International Park, including archeological and ethnographic studies, geomorphology, paleoecology and landscape history; facilitate cultural and archeological preservation and training programs; identify cultural landscapes; support international contacts and exchanges and field programs in existing parks; and continue existing documentation, education and cultural resource inventory programs;
- Smithsonian: Integrate Jesup II programs with BESIS plans and build capabilities and collections of the Anchorage regional office at the Anchorage Museum; conduct research on culture, history, art and contemporary issues; conduct museum-based training in artifact conservation and exhibition; develop Beringian exhibit projects with Native collaboration; maintain Russian area studies program and support the Crossroads tour in the Russian Far East.
- Fish and Wildlife Service: Continue biological studies of Beringian fauna and provide logistics assistance in accordance with existing operations and research plans;
- DOS: Assist in supporting international planning and facilitate international contacts and exchanges, especially in terms of environmental protection and Native issues, Beringian aspects of IASC, AEPS, MAB and other ongoing activities;
- EPA: With other agencies, provide coordination and support for AEPS and conduct research and assessment studies on pollution, pathways, water quality and health-related environmental issues in the Beringian region;
- HHS: Provide assistance in studying the impacts of modern socioeconomic and environmental change on nutrition, health and

related issues, and conduct medical training and exchange programs with Russian partners;
- DOD: Provide funding for pollution research and logistic support for field activities consistent with current mission objectives, and
- DOT: In concordance with existing missions, provide logistic support for research activities of other agencies and groups.

Implementation

The Beringian Systems plan has seen a major development during previous cycles of this plan. While once restricted to independent activities of a few agencies (NPS, SI, NSF), the plan now has a growing base of support in government and the international science community. The emergence of the BASIS and BESIS as comparative programs in little-known Arctic maritime and coastal regions in the Barents and Bering Sea regions provides important impetus for development of a coordinated international effort across the scientific spectrum. With support of U.S. agencies in an area of great importance to United States interests, studies of Beringia can achieve important regional results and will play an important role in the refinement of broader global change issues.

Through mechanisms of cooperative agreements and interagency coordination and planning teams, major progress is being made on implementing this plan. International aspects of the research being conducted under bilateral and multilateral agreements are already underway with Russian, Canadian, Japanese and Chinese partners. Circumpolar communication is being facilitated by IASC and other groups. Workshops currently being planned will continue to provide integrating mechanisms.

As in former versions of this plan, where relevant and feasible, mission and research specialties unique to individual agencies are being combined into a coordinated plan. BESIS is one outcome of this effort. Agencies are expected to develop plans concordant with existing missions, but with greater emphasis on joint planning, shared benefits and international activities. Coordination with other agencies will be developed to enhance mutual goals and the overall program. Coordination on Federal lands will be through the land managers. All activities will be coordinated with nongovernmental organizations, universities, research centers and Native and community organizations.

2.4 Arctic Data and Information

Arctic Data

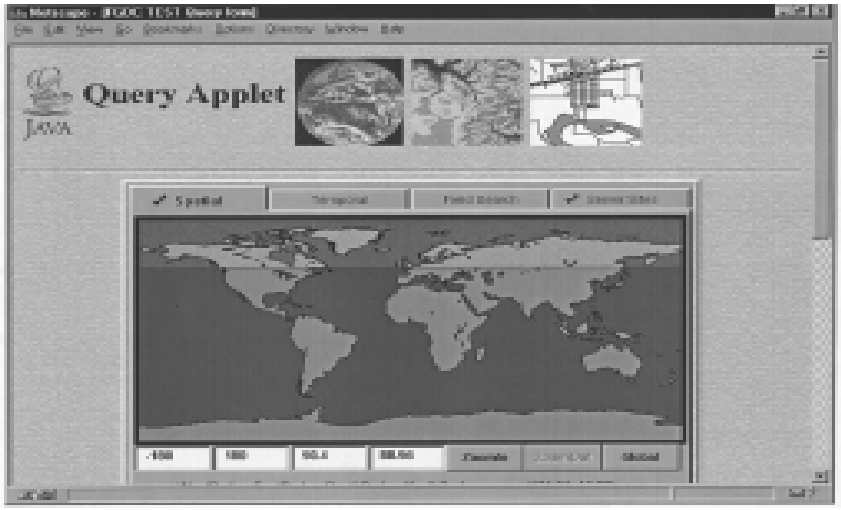
The Arctic Environmental Data Directory (AEDD) is a collection of information that describes the major Arctic data holdings of the IARPC agencies. With more than 350 entries, AEDD also identifies selected Arctic data sets managed by the state and local agencies in Alaska, various universities and a few other Arctic nations. AEDD is managed by the U.S. Geological Survey (USGS) on behalf of IARPC science agencies. All data-set descriptions in AEDD are reviewed prior to entry for completeness, consistency and accuracy. AEDD resides on a World Wide Web (WWW) server in offices of the USGS in Anchorage, Alaska, and is accessible over the Internet using standard WWW search and browsing tools and the Wide Area Information Service (WAIS). The complete collection of on-line U.S. and international Arctic data and information is indexed worldwide by commercial services.

AEDD has taken advantage of recent developments and technology, most notably the WWW. During 1995–1996, AEDD has established a WWW home page (see <http://www.ak.wr.usgs. gov/aedd/aedd. html>) that provides powerful tools to explore all data and information in the AEDD and ADD (the U.S. and international directories). As a service the AEDD home page also links directly to more than 50 other Arctic data and information sources on the WWW. Because this cross-reference tool is frequently updated, a researcher may connect to virtually every known Arctic data and information resource in the world from the AEDD home page with the click of a mouse.

The Arctic Research Consortium of the U.S. (ARCUS) is working with the NSF Arctic System Science (ARCSS) program to identify and explore the human dimensions of Arctic science (HARC). AEDD has participated in two workshops sponsored by HARC to help guide social scientists into the use of AEDD as their metadata repository for socioeconomic data and information.

International Arctic Data

The IARPC challenged the AEDD Working Group to make the directory circumpolar in scope,



World Wide Web page for the Arctic Environmental Data Directory. The AEDD uses state-of-the-art graphical search tools to access Arctic databases. (Courtesy of Douglas Posson, USGS.)

including descriptions for data sets residing in all Arctic nations. To this end the AEDD Working Group has formed an effective working relationship with the United Nations Environment Program (UNEP) Global Resources Information Database (GRID) office in Arendal, Norway. The two groups sponsored a series of workshops with circumpolar participation with the objective of establishing contacts in all countries with Arctic science programs to create an international Arctic Data Directory (ADD). Participants from all of the Arctic countries, plus several other countries, the European Community and international organizations with significant Arctic science programs, have agreed in concept to assemble compatible directories with the idea that, using the WWW, researchers can access all of the directories as if they were one directory.

Based on the model that AEDD initiated, an ADD node was established at UNEP/GRID–Arendal in 1994. This directory holds information about Arctic data for the Nordic countries and portions of western Russia. ADD is a network cooperation between major Arctic environmental data holders. This cooperation is making Arctic data available to circum-Arctic users. ADD assesses the quality and reliability of data set descriptions by means of a set of internationally agreed-upon criteria. ADD provides worldwide access to Arctic environmental data via the Internet. ADD identifies and works actively to form working relationships with institutions holding Arctic environmental data. ADD's network cooperation ensures feedback mechanisms to establish and maintain its relevance by addressing key environmental issues.

Through the ADD workshops the AEDD Working Group has also established contacts within Denmark, Germany, Italy, Japan, the Netherlands, New Zealand, Poland and the United Kingdom. Each of these countries is being encouraged to consider sponsoring a node of ADD. Eventually ADD will contain, and make available to the research community, descriptions of all major Arctic data holdings worldwide.

At a workshop in Moscow in September 1995, Russia agreed to initiate a Russian ADD node that will contain information about the Russian Arctic. The Russian node will be affiliated with the UNEP/GRID. All three nodes have agreed to identify and use certain standards that will make it easier for researchers to use the directory. For example, the structure and content of all ADD nodes is based on the Directory Interchange Format (DIF), which is used by the Global Change Master Directory, the Master Directory of the International Geosphere–Biosphere Programme, the Antarctic Data Directory, and the NASA Master Directory. The use of DIF simplifies the task of researchers who must access many data sources. All ADD nodes will use the WWW as their primary means of access, with obvious benefits to the research community. All ADD nodes will use Netscape Navigator (or equivalent WWW browsers) and standard search engines such as WAIS as primary search and retrieval mechanisms.

ADD has also taken advantage of the new technology available on the WWW. The ADD home page is maintained by UNEP/GRID–Arendal. In its second generation of design, it is incorporating the concept of "Gateway to the Arctic Environment" as part of the ADD support to the international Arctic Council. The AEDD and ADD home pages are closely linked and share considerable content. Together they provide a state-of-the-art and very complete guide to Arctic data and information in support of Arctic research. Because these directories are linked electronically, users can search on a specific theme to gain information on how to obtain relevant data sets worldwide.

The AEDD Working Group and UNEP/GRID–Arendal are working closely with the Russian State Committee on Environment Protection (SCEP) to establish the third ADD node in Moscow, Russia. Changes in the organization of the former Ministry of Environment Protection and Natural Resources have slowed the process of establishing the UNEP/GRID–Moscow node, but progress has been made. The objective is to facilitate the process of making information about Russian Arctic data more readily known and available to researchers in all countries. More than 80 Russian institutes holding Arctic data

and information have already been identified. A quick schedule to establish the node by 1996 has led to the preliminary identification and documentation of 40 Russian institutions. The Moscow node, though not yet operational, has found a home at the Center for International Projects (CIP) at Moscow State University, with sponsorship by the SCEP. This endeavor requires close cooperation between scientists in Western nations and those in the Russian Federation and a commitment to apply equivalent review and quality standards to the data set descriptions from all sources.

Arctic Contamination Data

Issues of Arctic contamination are of great concern in the international community, but there is little knowledge of the sources or content of data sets that might help in understanding these issues. The Japan Foreign Ministry participated as an observer at the ADD Steering Council meeting in Arendal in November 1996. Negotiations are underway to explore establishing an ADD node in Japan, sponsored by the Japan Foreign Ministry or other interested Japanese agencies or universities, perhaps beginning in 1997, to house and manage environmental contamination data from the marginal seas of the Russian Far East. Russian participants have offered to host a workshop in the Primorsky Kray, near Vladivostok, during 1997–1998 to further explore these environmentally sensitive areas and to begin cooperation and data sharing.

With headquarters in Oslo, Norway, AMAP is identifying and using data sets from the Arctic nations. AEDD and ADD are both being used as key resources to be accessed and used by AMAP researchers. The USGS, as the AMAP data manager for North American data, is supporting AMAP activities with AEDD. In this regard an effort is being made to add descriptions of data sets that relate to Arctic contamination and to incorporate links to data sources of others. Data sets that measure contaminants in the marine and freshwater environments, on land surfaces, in the atmosphere and in the flora and fauna will be added to AEDD. Of particular interest will be HARC data sets on medicine, human health, marine biology, socioeconomic information, demographics and the physical measurements of radionuclides, persistent organics and heavy metals in the Arctic environment.

National Snow and Ice Data Center

The National Snow and Ice Data Center (NSIDC), University of Colorado at Boulder, is funded by NSF to archive and disseminate data and information generated through the Arctic System Science (ARCSS) and Arctic Natural Sciences programs. The ARCSS Data Coordination Center (ADCC) at NSIDC has expanded its efforts to provide the most up-to-date means of data accessibility to the scientific community. Current ADCC activities focus on integrating communication among the ocean-based, land-based, ice core, paleoclimate and human dimension communities. Developing ways to archive and disseminate data and information in a timely and consistent manner, maintaining and expanding user clientele, and providing access to existing data necessary for research by all investigators are other functions of the ADCC. The ADCC endeavors to be a catalyst for system science and integration within ARCSS.

An ARCSS World Wide Web home page <http://arcss.colorado.edu/> developed at ADCC for access to data and information has become a tool for integration within ARCSS. Direct accessibility is the fundamental feature of this service, where data and information can be downloaded easily. Contact information for each ARCSS investigator, NSF ARCSS managers and staff, upcoming meetings and proposal deadlines, and information on each ARCSS component are included. A list-server provides electronic mail and information access to the ARCSS component communities and for each component working group and advisory committee.

CD-ROM development is actively underway with the release of the GISP2/GRIP CD-ROM in 1997 (in conjunction with the *Journal of Geophysical Research* special issue on ice cores). Other forthcoming CD-ROMs include an Arctic-wide downwelling radiation climatology CD-ROM and two ocean-related CD-ROMs scheduled for production before the fall of 1997.

To ensure that data collected are available on a long-term basis, the ADCC maintains a complete copy and backup of each data set and data product. Existing national data centers may be identified as additional dissemination sites for particular data types, in which case a copy of the appropriate data and metadata will be deposited at that center. Connections between NSIDC and other national and international data centers provide added exposure for data. Another ADCC coordination role is to provide a published record of the ARCSS program through a data catalog. Information about each data set is included in the NSIDC data catalog, with a reference to the ARCSS project attached to each ARCSS data set.

NSIDC's data holdings include a wide range of data sets funded by NASA and NOAA in addition to

those funded by NSF. NSIDC operates as a Distributed Active Archive Center for cryospheric data for the NASA EOSDIS program. NSIDC also holds many in-situ data sets that are maintained through NOAA funding. The NOAA Environmental Services Data and Information Management (ESDIM) program in particular has been responsible for the rescue and development of numerous data sets from the former Soviet Union.

The continuing increase in the very large volume of satellite data acquired over high latitudes has led NASA to establish two major Distributed Active Archive Centers for polar data. The Alaska Synthetic Aperture Radar (SAR) Facility (ASF) in Fairbanks, Alaska, is responsible for receiving, archiving, processing and distributing data from the many SAR satellites and for scheduling data-acquisition requests. NSIDC is primarily responsible for polar data from other instruments. A major NASA emphasis has been towards extracting information from the large volume of satellite data in a form that is both useful and intelligible to a broad community. As data volume grows, user-friendly data facilities consume an increasing proportion of available rescues, stressing the need to seek innovative approaches to data management. Data managed by these facilities are referenced in AEDD.

Nongovernmental Organizations

AEDD is also working with nongovernmental organizations that have mutual interest in Arctic environmental data and information. For example, the International Permafrost Association (IPA) is working to identify and rescue frozen-ground data that may be at risk of being lost by agencies in various countries including the U.S. As organizations succeed in building data sets of interest, whether in the U.S., Russia or other countries, they are using AEDD and the international ADD to document the results. Through associations with such organizations, descriptions in the international ADD of larger numbers of Arctic data sets will be realized with minimum cost and effort to the AEDD working group.

The AEDD will continue to work closely with nongovernmental organizations to compile extensive new collections of Arctic data and information. For example, the IPA Data and Information Working Group, as a subset of the Global Geocryological Database (GGD) project is developing a CD-ROM, "Circumpolar Active-layer Permafrost System (CAPS)" for the June 1998 7th International Conference on Permafrost at Yellowknife, N.W.T.

Planned Interagency and International Data Activities

- Increase the value-added content of AEDD by increasing the number of entries and WWW links in AEDD, with an increased focus on Arctic contamination issues and socioeconomic data and information related to Arctic inhabitants;
- Improve access to AEDD by continuing to adopt up-to-date tools on the WWW, including expansion of the WWW home page and compatibility with commercial browsers and standards-based search engines;
- Work with IARPC agencies to support the Arctic Council and its programs, including AMAP and the Conservation of Arctic Flora and Fauna, to provide information about and access to Arctic data of the U.S.;
- Seek expansion of international member and nonmember participation in ADD, with near-term potential for a new node in Japan and longer-term plans for Canada, Germany, the United Kingdom, Denmark and perhaps Poland;
- Continue to work with UNEP/GRID to establish and populate the international ADD node in Russia to document and provide access to greater amounts of Russian Arctic data and information;
- Investigate new technologies that will make it as easy as possible to identify and use Arctic data sets while maintaining the high quality and reliability of AEDD and its contents and links;
- Help identify, rescue and document Arctic data sets at risk of being lost, in conjunction with other organizations that share common interests; for example, the National Climate Data Center is cooperating with Russia in data exchange to help identify, rescue and document the extensive set of precipitation data at risk of being lost, including data for north of the Arctic Circle.
- Develop and distribute tools that will help scientists and data managers document Arctic data sets properly, such as a "DIF template on a diskette" for use on desktop computers;
- Conduct workshops in conjunction with the Japanese scientific community to develop Japanese cooperation and an ADD node in Japan; and
- Expand cooperation with the Antarctic data and information communities through links to ICAIR and related organizations.

Arctic Information

The U.S. Polar Information Working Group (USPIWG) is an independent body of U.S. polar information specialists associated with the international Polar Libraries Colloquy. The objective of USPIWG is to offer a single service to the U.S. Arctic and Antarctic scientific communities for matching information resources with information needs in a user-based context. Institutions and organizations currently represented are:

- University of Alaska Fairbanks;
- University of Alaska Anchorage (UAA);
- Environment and Natural Resources Institute of UAA;
- Alaska State Library;
- Arctic Research Consortium of the U.S. (ARCUS);
- International Permafrost Association;
- World Data Center A for Glaciology and the Institute of Arctic and Alpine Research at the University of Colorado at Boulder;
- Byrd Polar Research Center at the Ohio State University;
- Dartmouth College;
- U.S. Army Cold Regions Research and Engineering Laboratory; and
- Cold Regions Bibliography Project at the Library of Congress.

Ongoing and Planned USPIWG Activities

The second edition of *Arctic Information and Data: A Guide to Selected Resources* was published in 1996. The updated version expands upon the earlier brief descriptions and contact information for libraries, data centers, directory services (such as the Global Change Master Directory and the Arctic Environmental Data Directory), journals and newsletters, CD-ROM and printed indices, and other sources of information or data relating to the Arctic. New sections have been added, one on non-governmental organizations and another on Internet services. This edition is currently being prepared for the Internet, where it will have selected links that will be monitored for currency and quality.

The amount of duplicate indexing among the databases published on the PolarPac and Arctic and Antarctic Regions CD-ROMs is being reduced through distribution of responsibilities for indexing between the Cold Regions Bibliography Project and the Scott Polar Research Institute. The plans are for this cooperation to expand.

Two members of USPIWG serve on the Polar Libraries Colloquy Steering Committee. A U.S. initiative on that committee has led to a joint meeting being organized for 1998 in Reykjavik, Iceland, with the International Association of Aquatic and Marine Science Libraries and Information Centers.

Electronic Access to Polar Information Resources on CD-ROM

PolarPac version 4, the CD-ROM database of international polar regions bibliographic information, was published in 1996 by WLN. New additions included several Russian library indexes and the Inuit Health Bibliography.

Arctic and Antarctic Regions, NISC's CD-ROM suite of polar regions reference databases from around the world, in its March 1996 version, has approximately 750,000 records, mostly of journal articles. Reference databases from the U.S., U.K. and Canada are globally searchable. A major recent addition to this CD-ROM is the library catalog of Indian and Northern Affairs Canada.

The two CD-ROMs complement each other to a great extent and include coverage of all cold regions and document types such as monographs, serial analytics and technical reports. Both library catalogs and reference databases are included on the disks.

Internet

A polar Web site has been established and is being managed at the Arctic Centre, University of Lapland, Finland. The Polar Libraries Colloquy Web site is linked to it. A menu of several sections points the user to a variety of information types, including libraries, databases, meetings and news. Both the guide (*Arctic Information and Data: A Guide to Selected Resources,* Second Edition) and the directory (*Polar and Cold Regions Library Resources: A Directory*) appear here in full text but without full search capability. See the polar Web site, Polar Libraries Colloquy, at <http://www.calgary.ca/~tull/polar/plcmain.htm>.

3. Agency Programs

3.1 New Opportunities for Arctic Research

3.1.1 Remote Sensing

High-latitude satellite coverage and related data processing has reached a new level of capability in the 1990s. Satellite visible, infrared, microwave and synthetic aperture radar data are analyzed for polar sea ice mapping by the National Ice Center (NIC). Large portions of the imagery used by NIC are archived at the NOAA/ NESDIS Satellite Active Archive (http://www.saa.noaa.gov). NASA is using gridded microwave brightness temperatures from the Defense Meteorological Satellite Program (DMSP) satellites to produce low-resolution (50 km) information on sea ice type and distribution. With the launch of ERS-1 and -2 (Europe) in 1991 and 1995, JERS-1 (Japan) in 1992 and Radarsat (Canada) in 1995, high-resolution (30 m) synthetic aperture radar (SAR) data have become available on a routine basis for research purposes. The radar imagery provides a greatly enhanced capability to detect leads and ridges, ice type and ice motion. NASA and NOAA are working with Canada to obtain ice coverage every six days for both operational and research applications.

Major advances in the applications of SAR data have been made recently through the interferometric analysis of time-separated pairs of SAR images that were obtained from approximately identical satellite locations. This approach yields estimates of surface topography (to an accuracy of a few meters) at high spatial resolution, and it detects very small changes that have occurred during the interim between the two image acquisitions. Examples of such changes include volcanic swelling prior to an eruption, crustal shear across earthquake faults, and glacier motion. This is an area of rapid development and promises to revolutionize our ability to monitor important polar phenomena.

In addition to SAR image data, the ERS satellites also provide routine measurements of ocean surface winds, wave spectra and surface topography. Ocean winds can also be inferred from radar backscatter measurements made by NASA's NSCAT, aboard the Japanese ADEOS spacecraft.

More precise and less ambiguous estimates of ice thickness change over all slopes should be provided by the Geoscience Laser Altimeter System (GLAS) with an orbit reaching 86°N (covering all of Greenland), due to be launched in 2001/2002. GLAS is one of the Earth Observing System (EOS) suite of instruments. Others, planned for launch as early as 1998, will provide enhanced capability to acquire visible, infrared and microwave data, leading to an improvement in our ability to monitor various characteristics of the polar land, ice and ocean surfaces, as well as the atmosphere. One important example is the advanced microwave scanning radiometers (AMSRs) scheduled for launch in 1999 and 2000 on the ADEOS II and EOS PM satellites, respectively. The data from these instruments will provide polar information on continental snow cover distributions and thicknesses, land surface wetness, sea surface temperatures, and sea ice concentrations, types and temperatures. Resolutions will be higher than those from the current DMSP satellites, although still relatively coarse (for example, about 20 km for sea ice concentrations) compared to visible and infrared imagery.

Other satellite data that will be routinely available include ocean color from SeaWiFS (U.S.) and ADEOS (Japan), surface topography from TOPEX/ Poseidon (U.S. and France) and GEOSAT (U.S.), and low-resolution sea ice type and distribution from the advanced microwave sounding units on the NOAA-K, L and M satellites (U.S.).

There has been, and will continue to be, substantial international cooperation in the polar-orbiting satellite programs of those nations with major space programs. Sharing of data from satellites of different nations makes possible systematic regional satellite coverage of the Arctic to support major basin-wide investigations.

Major advances in space sciences are afforded by the recently launched fleet of spacecraft that are part of the International Solar Terrestrial Physics (ISTP) program. In addition, the satellites launched as part of the Mission to Planet Earth will offer an unprecedented opportunity to understand and monitor the environment close to Earth.

3.1.2 In-situ Sensing

Ground-based observations are being revolutionized by emerging new technologies. Precision navigation from portable, low-power receivers will soon be possible from the satellite-based global positioning systems. A number of options for data telemetry are evolving, including specialized communication micro-satellites, an ionospheric-path HF radio frequency with digital packet switching,

and a ground-plane MF radio frequency over ice. Advances in low-power microprocessors and mass storage media (optical disk, digital audio tape, video tape) have provided a new generation of programmable, high-capacity dataloggers for field experiments. Innovative sensors and signal processing techniques based on acoustic and optical propagation have opened up new dimensions in probing the structure of the atmosphere, ice and ocean. New materials and high-density energy sources have spawned a new generation of remote platforms such as buoys and autonomous detectors. Instruments based on such new technology will enable radically new adaptable and interactive observational strategies for process studies, as well as provide the means for long-term, real-time monitoring of primary variables at remote sites.

3.1.3 Fisheries Management

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

Representatives of the State of Alaska have called for a study of the Bering Sea aimed at understanding the fishery dynamics and devising appropriate management options. The Arctic Research Commission has concurred with these concerns and has recommended a multiagency study of the Bering Sea as an ecosystem. (See Section 2.3 for the proposed Beringian Systems Studies Program.)

The NOAA/National Marine Fisheries Service (NMFS) conducts an extensive program of ecological and stock assessment research in support of its fisheries and marine mammals conservation mandates. These research programs include biological oceanography to understand how environmental changes affect resource production, stock assessments to determine resource status, and recruitment research to understand and forecast new entrants to fisheries and mammal populations. This information is used to set harvest levels and to allow wise use of the resources.

3.1.4 Cultural Exchange

The June 1990 summit meeting reached a historic agreement on the feasibility of establishing a Russia–United States International Park in the region of the Bering Strait. This proposed park would preserve the unique natural, environmental and cultural heritage of the Bering Sea region of Alaska and Siberia.

The Smithsonian Institution continues to provide cultural exchange throughout the circumpolar region through various research, exhibition, training and Internet programs, including its current Crossroads exhibition touring in the Russian Far East.

3.1.5 Data

Common to all programs is the need for consistent data management among the Federal agencies. The Arctic Data and Information Program (Section 2.4) describes this activity.

3.1.6 U.S.–Russia Collaboration

The ending of the Cold War and the opening of relations with the former Soviet Union offer an unprecedented opportunity to develop bilateral research programs on Arctic scientific issues of common concern to the U.S. and Russia. Several bilateral agreements already exist to promote cooperative efforts in the areas of environmental protection, oceans research, basic science, fisheries management and energy technology. An extensive amount of data has been exchanged with the former Soviet Union and now Russia over the last several years, which include data north of the Arctic circle. These data are distributed among the U.S. national data centers. A steady stream of Russian scientists and science officials have visited the U.S., offering plans and proposals for collaborative work. Proposals for specific projects with Federal agencies have resulted. Many agencies have taken the initiative to develop their own contacts and programs in Russia. Revelations about environmental contamination in the Russian Arctic and efforts to “rescue” scientific data from the former Soviet Union have been the principal motivations behind much of this activity.

Studies of Russian, U.S. and Canadian Arctic history continue to demonstrate the ties that have linked Arctic peoples, cultures and regions for the past 15,000 years.

3.1.7 Oil Pollution Control

Title V of the Oil Pollution Act of 1990 established the Prince William Sound Oil Spill Recovery Institute (OSRI), with broad interagency participation led by NOAA and including the Department of Interior, Department of Defense, Department of Transportation and Environmental Protection Agency. The State of Alaska is working to coordinate with OSRI’s development of an Arctic–Subarctic oil spill research plan. The plan has $5 million in research support from the State of Alaska and authority to receive up to $23 million from an account to be established in the National Pollution Fund.

3.2 Arctic Ocean and Marginal Seas

3.2.1 Ice Dynamics and Oceanography

A prominent feature of the Arctic Ocean is its permanent, dynamic ice cover. This marine cryosphere significantly impacts the environment on all scales, from climatic to molecular. Critical processes governing this impact occur in the atmosphere and oceanic boundary layers above and below the ice. A major priority is the development of the next generation of operational ice forecasting tools and models. A systematic program of oceanographic, cryospheric and atmospheric measurements by such conventional technologies, as well as new technologies such as autonomous underwater vehicles (AUVs), is needed to support the objectives of this research and the interagency program.

The Arctic Ocean is being explored using Navy nuclear submarines, under the aegis of a multiagency program funded by the Office of Naval Research (ONR) and NSF. The aim of this unclassified, basic-research mission, called SCICEX, is to increase our fundamental understanding of processes in the Arctic Ocean. Research areas of interest fall into six broad categories:

- Air–ice–ocean interaction;
- Ocean circulation;
- Ocean biology and chemistry;
- Ice–acoustic interaction;
- Ice–electromagnetic interaction; and
- Marine geology and geophysics.

Among the specific SCICEX studies are investigations of the water masses operating in the Arctic, including inputs from and interactions between Atlantic and Pacific waters, fronts, eddies, shelf processes, riverine inputs, and overall water mass movements. Many of the water mass studies will examine the pollution content of Arctic waters, either as their principal area of concern or as a tracer for water mass movements. Additional studies will be aimed at examining pollution levels in the ice pack and on the ocean bottom. Coordinated experiments to study issues related to the virus/bacterioplankton cycle in Arctic waters are also being conducted. Included in these experiments is an examination of bacterioplankton and viral abundance, community composition, community metabolic capabilities, and interactions. The structure, distribution and draft of the ice pack over large portions of the Arctic are analyzed to investigate the properties of the ice and predict ice thickness distribution. Detailed bathymetric data collection is also part of the SCICEX program. Bathymetry of the Arctic Ocean has been difficult until the advent of SCICEX, and the new and planned observations will add to the bathymetric database throughout the Arctic Basin, with special emphasis on the Mid-Ocean and Lomonosov Ridges and the Chukchi Borderland region. In particular, a portable swath bathymetric imaging system, now being built, promises to revolutionize our knowledge of the geology of the Arctic Ocean.

Objectives

- Determine the processes, history, dynamics and mechanisms of ice production, deformation, advection and decay;
- Determine the processes of renewal and mixing of Arctic and Subarctic water masses from large to small scales;
- Determine the large-scale circulation of the Arctic Ocean, and circulation variability and dynamics, including the role of shelf seas, boundary currents and exchanges with adjoining seas; and
- Determine the mean and natural range of variability of currents and hydrographic features in the nearshore region of the Bering, Chukchi and eastern U.S. Beaufort Seas.

3.2.2 Ocean and Coastal Ecosystems and Living Resources

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

Objectives

- Determine the status and trends of fish, bird and marine mammal populations and identify their habitat requirements;
- Monitor coastal ecosystems to detect and quantify temporal changes in nutrient and energy exchange and their effect on biota;
- Determine the magnitude and variation of marine productivity in Arctic areas through studies of the structure, dynamics and natural variability of the ecosystems;

- Consider the influence of ice and human activities on both the biotic and abiotic components of the Arctic environment;
- Study the influence of Arctic marine productivity on the global cycling of biologically active materials, including carbon and nitrogen; and
- Understand the physical and biological processes that affect fisheries recruitment in the U.S. waters of the Bering, Chukchi and Beaufort Seas.

3.2.3 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.

Objectives

- Develop and perfect new techniques for deployment of instruments in the harsh Arctic environment (for example, seismic tomography, geophysical arrays, hydraulic piston coring and scientific deep drilling);
- Initiate Arctic marine geological and geophysical studies to provide information on past and present climate change and the history of the ice cover, 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 such as the nuclear submarine; and
- Determine modern sediment transport by sea ice, icebergs and other processes; characterize the seafloor sediments by coring and reflection methods; and establish a well-dated stratigraphy.

3.3 Atmosphere and Climate

3.3.1 Upper Atmosphere and Near-Earth Space Physics

The goals of this research are to trace the flow of energy, momentum and mass from the sun to the Earth and to understand the interaction within and between the intervening regions. The upper atmosphere, the ionosphere and the magnetosphere comprise these intermediate regions. Most of the magnetosphere—the outer part of the Earth plasma environment—is connected to the polar regions through the converging magnetic field lines, and thus a large fraction of the energy that goes through the magnetosphere is deposited in the polar upper atmosphere, with dramatic consequences across the full optical, radio and particle spectra. Our understanding of these coupling processes is far from complete due to the sparsity of measurements in the Arctic regions.

There is great interest in understanding and separating anthropogenic effects (for example, 20th century increased emissions of greenhouse gases) and natural variability (for example, decadal temperature swings) in the upper atmosphere. Recent evidence suggests that some of the latter is due to solar-induced effects, especially at polar latitudes. It is expected that the coupling of the sun to the upper atmosphere will become a major topic of study in the next five years. This research will be supported partially under the U.S. Global Change Research Program (USGCRP) and, because of the Arctic's high sensitivity to climate change, will focus on high latitudes.

Plans are underway for a Polar Cap Observatory (PCO) near the Earth's geomagnetic pole at Resolute Bay on Cornwallis Island in the Northwest Territories of Canada. Construction is planned to begin in FY 98, with a planned start for the facility in December 2000 to coincide with the upcoming solar maximum. The scientific requirements for the PCO have been identified by a series of workshops that brought together leading upper-atmosphere researchers. Two chains of incoherent scatter radar facilities, one in North America and one emerging in Europe, currently provide measurements of ionospheric electron content, plasma drifts, electron and ion temperatures and a variety of other atmospheric parameters that are derived from these quantities. The Polar Cap Observatory

would constitute an apex of both of these chains. The plans call for the main component of the PCO to be a state-of-the-art incoherent scatter radar consisting of a high-power transmitter and a large steerable antenna that allows atmospheric properties to be measured over a large portion of the polar cap. Also included would be a suite of smaller optical and radio-wave devices for remotely sensing atmospheric parameters not measured by the incoherent scatter radar. This arrangement would constitute a comprehensive set of polar cap diagnostic instruments, capable of producing data for many scientists in the national and international research communities.

The state of the space environment near Earth and its response to solar inputs has come to be known as "space weather." At present there is a multiagency program, known as the National Space Weather Program (NSWP), to coordinate research and model development in this area, with the goal of enabling improved space forecasting abilities. The major agencies involved are NSF, NOAA, DOD, NASA, DOE and DOI, and they are committed to providing timely, accurate and reliable space environment observations, specifications and forecasts within the next 10 years.

A major component of the NSWP is the DOD program in upper atmosphere and ionospheric research, conducted by the U.S. Air Force Phillips Laboratory (PL) and the Air Force Office of Scientific Research (AFOSR) in a coordinated effort to understand the effects of space weather on systems. The goals of this comprehensive research program are to understand the basic physical and chemical processes that control the large-, medium- and small-scale structure and dynamics of the polar ionosphere. The main objectives of this effort are to specify, predict and mitigate disruptions to DOD communications, navigation and surveillance systems that are affected by poorly understood variations in the plasma density within the polar ionosphere. These processes include plasma physics, ion chemistry, ion-neutral coupling and electrical coupling to the distant magnetosphere. All of these processes act simultaneously to influence the structure and dynamics of the polar ionosphere. In addition, all of these processes exhibit variations over time periods ranging from minutes to diurnal, seasonal and ultimately solar cycle. The research effort is a combination of experimental measurements to determine specific physical processes combined with first-principles numerical modeling efforts and a strong connection to ongoing theoretical research supported by other agencies to actively pursue and maintain a well-rounded program.

A wide range of ground-based radio, radar and optical diagnostics are employed to perform the needed measurements. These are conducted from Nord, Qanaq, Thule, Sondrestrom and Narssarssuaq, Greenland (in cooperation with the Danish Meteorological Institute); Ny Alesund, Longyearbyen (Spitsburgen) and Tromso, Norway (in cooperation with the University of Oslo, Norway); and Goose Bay, Labrador (Canada). Many of these state-of-the-art instruments are developed and tested for field deployment under this effort. Measurements are obtained through routine operation of ground stations for long-term variations and during dedicated campaigns by the deployment of a variety of sensors performing coordinated, multitechnique observations. The ground-based measurements are often complemented by measurements from instruments on sounding rockets and polar-orbiting satellites. From this understanding, numerical models to specify and ultimately predict the behavior of this complex region are being developed. The models are updated using real-time data from a variety of ground-based and satellite sensors. Development, calibration and validation of these sensors is an important aspect of this effort.

This research and model development is needed for real-time support to DOD communications, navigation and surveillance systems, since radiowave propagation is severely affected by large-scale gradients and small-scale irregularities in the ionospheric F-layer plasma density. Disruption is caused by ionospheric density gradients, irregularities and density fluctuations, which cause unacceptable fading of satellite communications and navigation signals, and clutter on ground-based, long-range, high-frequency (HF) communications links and to surveillance radars. This research effort also includes studies to quantify the effect of ionospheric disturbances on actual system performance leading to development and deployment of ground-based sensors for operational systems support.

As part of a Joint Service (Air Force–Navy) research effort, entitled High Frequency Active Auroral Research Program (HAARP), a unique, high-power, HF ionospheric heating facility is being constructed in Alaska. The heater will be capable of providing sufficient energy densities in the ionosphere to enable investigations to be conducted on the modulation of auroral currents to generate ELF/VLF waves, the acceleration of electrons to produce optical emissions, the production of field-aligned ionization to scatter radio waves,

and other phenomena triggered by the interactions of very-high-power radio waves in the ionosphere. A ground-based heating instrument is planned. In addition a wide variety of diagnostic instrumentation has been acquired. Plans for an incoherent scatter radar are being actively pursued.

Objectives

- Observe the global-scale response of the polar regions through a coordinated program involving a polar network of ground-based optical, radio and magnetic observatories and space-based measurements;
- Develop special research tools to address key problems, including establishing a Polar Cap Observatory and upgrading the existing incoherent scatter radars, the array of HF radars in the Arctic, and the arrays of optical, radio and magnetic remote sensors, and also including establishing a coordinated rocket program, promoting the use of special facilities and making use of research aircraft;
- Maintain active theoretical programs and promote the evolution of models to describe the unique physics of the atmosphere and ionosphere in Arctic regions;
- Understand solar phenomena that affect the Earth's environment;
- Understand electromagnetic waves, fields and particles in near-Earth space; and
- Develop an understanding and the ability to make long-term predictions of radio-wave propagation in and through the Earth's ionosphere.

Year-round measurement site near Prudhoe Bay, Alaska. Insulation, Teflon shells, resistance heaters and wind/thermo-electric generators keep this tower running through the Arctic winter. The tower monitors surface-to-atmosphere heat and carbon exchange. The tower is linked by cellular telephone and provides daily data and self diagnostics. (Photo courtesy of Steven Brooks, NOAA.)

3.3.2 Climate and Weather

The outstanding characteristic of the Arctic climate and weather is its dramatic variability in clouds, radiation and surface heat exchange. Most projections of future climate change suggest that high-latitude regions will incur the greatest temperature fluctuations. Research is needed to clarify the impact of potential change and 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 such hazardous weather phenomena as Arctic lows, storm surges, icing conditions and fog, which can affect human activities.

Objectives

- Develop an Integrated Arctic Climate Studies Program as part of the USGCRP, including studies of climate effects on Arctic indigenous peoples and biological resources, and a systematic program of intercomparison between observations and modeling results, focused on the Arctic radiative balance, cloud processes and their effects on local, regional and global climate;
- Understand the extent to which Arctic climate variations are amplified signals derived from elsewhere or are generated locally as a result of the sensitivities of the regional environment;
- Understand whether, how and with what result Arctic climate anomalies propagate to middle and lower latitudes;
- Quantify snow cover and ice feedback mechanisms that amplify climate change at high latitudes, quantify high-latitude terrestrial ice and snow changes, and consider their effects;
- Quantify land and sea surface–atmosphere

momentum and both sensible and latent heat exchanges, and model the role of surface–atmosphere interactions in influencing mesoscale tropospheric and stratospheric dynamics; and
- Develop a "testbed site" on the North Slope of Alaska for making atmospheric radiation measurements to improve mathematical simulations of cloud and radiative transfer processes in general circulation models (GCMs) as part of the USGCRP.

3.3.3 Tropospheric and Stratospheric Chemistry and Dynamics

The chemistry of the Arctic atmosphere is dynamic, changing in response to natural and human-induced disturbances. Stratospheric ozone depletion is a global process accentuated at the poles. Ice core chemistry reveals current and historic trends in global natural and anthropogenic 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 annual average of 1.7 million acres of wildfire in Alaska has an impact on airborne particulates and atmospheric chemistry.

Objectives

- Establish the correlation, if any, among the chemistry of polar stratospheric clouds in the Arctic, the ozone concentration at northern midlatitudes and the incident ultraviolet radiation reaching the Earth's surface;
- Develop a database for determining long-term regional trends in climate and air chemistry, including solar radiation levels and anthropogenic contaminant levels (organics, metals, radionuclides, greenhouse gases and ozone-depleting gases), 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;
- Conduct theoretical and experimental research to understand the chemical and dynamical processes that deplete stratospheric ozone in the Arctic region; and
- Establish regional and seasonal variations in sources and sinks of carbon, nitrogen and sulfur, atmospheric gases and aerosol species and assess the importance of local emissions.

3.4 Land and Offshore Resources

3.4.1 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 Section 3.1.3 for related activities).

Objectives

- Continue systematic mineral appraisal activities and expand programs to provide periodic assessments of the undiscovered oil and gas and strategic mineral resources in the Arctic on both broad and local scales;
- Evaluate unconventional energy resources (for example, heavy oil, tar sands, gas hydrates, solar and wind);
- Identify energy and mineral resources for local use;
- Use new technologies to develop a more modern and complete geologic database, increase geologic mapping, expand modeling efforts and design derivative maps to address broader earth-science questions; and
- Evaluate the economic, environmental, cultural and social implications of resource extraction and transport.

3.4.2 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 be answered only after basic pro-

cess information is collected, interpreted and 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. Study of archeological sites can provide important information on the history of coastal platforms, erosion rates and land–shelf interactions.

Objectives

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

3.4.3 Terrestrial and Freshwater Species and Habitats

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

Objectives

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

3.4.4 Forestry, Agriculture and Grazing

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

Objectives

- Continue and enhance a sustained program of research into ecosystem processes of northern boreal forest ecosystems, focusing on issues of forest landscape and stream ecosystem sustainability and productivity over long time periods; ecosystem stability in the face of episodic disturbance and global climate change; and interactions among atmosphere, landscape, forest and stream ecosystems and ecosystem management for societal goals;
- Enhance soil and crop science research to develop effective management practices under conditions of permafrost, low temperatures, wildfire and development impacts;
- Prepare coordinated soil resource information (maps and databases) of the Arctic circumpolar region; and
- Provide technology for enhancing the economic well-being and quality of life at high latitudes.

3.5 Land–Atmosphere–Water Interactions

3.5.1 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. Also, reliable information is needed on surface water quality and quantity. Collection

of this information will help provide a climatic and hydrologic baseline for the Arctic. The Arctic is expected to be especially sensitive to the effects of possible global changes, including possible greenhouse warming, on terrestrial, atmosphere and marine environments.

Objectives

- Continue to develop paleoenvironmental records from ice caps, ice sheets and mountain glaciers; conduct research on the incorporation of global, hemispheric and regional climate signals in snow and ice records; conduct research on the processes by which gases, aerosols and particulates are incorporated into the snow and ice; and support interpretation of results from existing records and correlation of these records with adjacent records from other sources and proxy records;
- Document the relationships between glaciers, sea ice and global hydrology, including the relationship to world sea-level changes and climatic fluctuations, and continue to develop models for glacier mechanisms;
- Determine the consequences of specific renewable and nonrenewable resource development and harvest practices on ground and surface water, and develop predictive models for stream flow and water quality;
- Forecast future sea-level fluctuations attributable to greenhouse-gas-induced changes in polar glaciers and ice caps;
- Establish the role of land–water interactions in the control of nutrient cycling; and
- Investigate the hydrology and biogeochemistry of the Arctic drainage basin from a systems perspective, and study linkages between the land and water components of the Arctic system, with emphasis on the water resources in this system (water quality, bioaccumulation, sediment and dissolved material pathways and flux rates).

Colville River, Alaska, near Sentinel Hill. The Colville River cuts into the permafrost and actively erodes the banks as it approaches its outfall in the Arctic Ocean on Alaska's North Slope. (Photo courtesy of John Haugh, BLM.)

3.5.2 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.

Objectives

- Undertake a comprehensive program to extract paleoclimatic records from permafrost terrains and lake sediments;
- Reconstruct the late Glacial and Holocene climate history in the Arctic via borehole monitoring and other technology;
- Improve the ability to assess and predict the degree and rate of disturbance and recovery of permafrost terrain following natural or human-induced changes;
- Improve our understanding of the effects of thawing of permafrost on the hydrology, ecosystem characteristics and productivity of boreal forest ecosystems;
- Model the response of the hydrologic and thermal regimes of the active layer and permafrost to greenhouse-gas-induced warming in the Arctic and Subarctic at different locations;
- Provide information on the moisture and thermal regime of the active layer and on degradation of permafrost due to climate warming;
- Develop results leading to the ability to predict future climate-induced changes to the Arctic landscape;
- Understand how possible climate-induced alterations to permafrost systems may influence carbon metabolism, turnover and storage; and
- Reconstruct the late Glacial and Holocene climate history in the Arctic.

3.5.3 Ecosystem Structure, Function and Response

The Arctic is expected to be especially sensitive to the effects of possible global changes and con-

taminant transport and deposition on terrestrial, freshwater, marine and atmosphere environments. Research is needed to improve our understanding of the influence of climate on land and freshwater processes and vice versa. Resource managers and decision makers need reliable environmental impact and health risk assessments.

Topics of particular importance include heat balance relationships, landscape alteration, impacts of wildfire, identification of biological indicators of change, development of a basis for, and clarification of, current and recent contaminant levels, sources and sinks of carbon and trace gases, and long-term trends in biological diversity.

Objectives

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

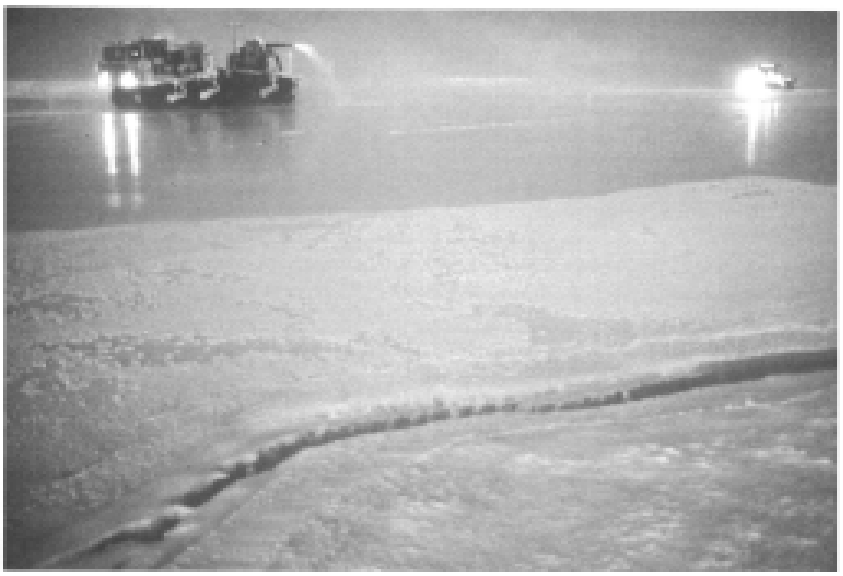
3.6 Engineering and Technology

Engineering and technology provide one of the best and possibly most direct avenues for improving and extending the infrastructure so critical to quality of life in the Arctic. In addition, enhanced engineering capabilities and advanced technologies can make crucial contributions to addressing environmental quality challenges and achieving environmentally sustainable development of natural resources. The harsh and unique environment of the Arctic makes advancement in these areas particularly difficult and limits the ability to simply borrow or evolve the engineering and technology advances developed for nonpolar conditions. Only concentrated, specific efforts will produce the advanced technical capabilities the Arctic requires. Engineering and technology development programs that address the priority Arctic engineering research needs are necessary to support these efforts.

In this time of scarce resources, cooperation between government agencies, academia and the private sector provides an excellent opportunity to leverage resources and assure that the advanced technologies developed by government and academia can be practically and effectively applied. Development of goals that meet both commercial and technological interests will help assure that technologies developed will move rapidly into the marketplace.

The January 1993 biennial statement of the Arctic Research Commission, *Goals and Priorities to Guide United States Arctic Research,* provides clear priorities for Arctic engineering and technology. In this document the Commission found that to achieve the basic principles of the U.S. Arctic policy and to achieve the desired national competitiveness in the Arctic, the Nation's Arctic engineering capabilities must be improved through a balanced and coordinated continuing program of cold-regions engineering research at universities and national laboratories. The Commission recommended that the IARPC develop an Arctic engineering research plan with special emphasis on the following items:

- Improved methods for the continued performance of existing transportation and public facilities in cold regions;
- New and more cost-effective construction technologies and materials for Arctic purposes;
- Design of maintainable and affordable rural sanitation facilities for Arctic villages;
- Capabilities for testing the performance of outdoor material and equipment;



Ice road construction on Alaska's North Slope. The construction of ice roads and ice drilling pads allow oil and gas exploration to be accomplished during the Arctic winter. When these structures melt in the spring, they disappear, leaving little or no trace on the tundra of the previous winter's activities. [Photo by David Predeger, courtesy of BP Exploration (Alaska) Inc.]

- Methods for waste disposal and local air pollution control under Arctic conditions; and
- Small-scale power generation and energy storage technologies.

The Commission also recommended that the Interagency Coordinating Committee on Oil Pollution Research support research for an adequate and thoroughly tested oil spill prevention technology and response capability for the Arctic. Three specific types of research were recommended: perfection of in-situ burning techniques, development of alternatives to combustion, and policy analysis and information transfer activities related to testing and accepting new pollution abatement processes.

The recommendations given above are consistent with those presented in the April 1990 *Findings and Recommendations of the Arctic Research Commission, Arctic Engineering Research: Initial Findings and Recommendations.* The 1990 report of the Commission also recognized the following critical areas of scientific research, the results of which are of major importance and will be crucial for successful technology development and transfer:

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

Objectives

- Develop engineering data and criteria for building, operating and maintaining strategic and operational facilities in the Arctic;
- Provide the capability to conduct logistics operations in the Arctic;
- Develop environmentally compatible engineering technologies for the Arctic;
- Provide design criteria for ship operations in ice-infested waters;
- Provide engineering data and criteria for water resources activities and environmental impact permitting;
- Ensure that future outer-continental-shelf oil and gas development operations are safe and pollution-free;
- Ensure that the best available and safest technologies are used in the development of oil and gas in the Arctic;
- Develop methods for mining and mine closure that are environmentally compatible in Arctic environments;
- Advance the technology for recovering fossil fuels in the Arctic, including onshore extraction and production methods;
- Prevent the discharge of oil, chemicals and other hazardous materials into the marine environment;
- Ensure the quick, effective detection and cleanup of pollution discharges;
- Evaluate enhanced marine transportation for resupply of coastal and Arctic villages;
- Develop and maintain effective surface transportation facilities in the Arctic; and
- Develop mechanisms for technology transfer between government, academia and private industry.

3.7 Social Sciences

The Arctic Research and Policy Act of 1984 makes explicit reference to the importance of the social, behavioral and health sciences (Section 102b). Following recommendations by the National Science Board, an Arctic Social Sciences Program was established within the Office of Polar Programs at the National Science Foundation. In addition, an Interagency Arctic Social Sciences Task Force was established within IARPC. As one of its first activities, the Task Force implemented a

Statement of Principles for the Conduct of Research in the Arctic, which addresses the need for improved communication and increased collaboration between Arctic researchers and northern peoples (see Appendix F).

The Arctic Social Sciences Task Force

The Interagency Social Science Task Force consists of agency representatives. Included within its mandate are the following:

- Prepare Arctic social science and health research budget;
- Facilitate coordination between social science, health, medical and environmental research in the Arctic;
- Promote educational and training opportunities in the Arctic; and
- Advance public understanding of Arctic social science research.

International Arctic Social Science and Health Research

A number of international scientific organizations have incorporated the social and health sciences into their programs, including the International Arctic Social Sciences Association (IASSA), the International Arctic Science Committee (IASC), the Arctic Environmental Protection Strategy (AEPS) and the International Union for Circumpolar Health (IUCH). The IASSA was also formed in 1990 to represent the social sciences in IASC, as well as to emphasize the need for research partnerships with Native people. Three themes of importance are sustainable use of living resources of high value to Arctic residents, environmental and social impacts of industrialization on the Arctic, and rapid cultural change. The U.S. has actively participated in and supported these organizations.

The U.S. Man and the Biosphere Program (MAB) and the Northern Sciences Network (NSN)

The international coordination of ecological research in the Arctic has been facilitated by the Secretariat of the NSN, which is now based at the Danish Polar Center in Copenhagen. U.S. support of the NSN is made possible through the Department of State. The MAB High Latitude Directorate, together with NSF, has supported a study of joint management of the Alaskan/Canadian Porcupine Caribou Herd. The MAB program is facing new challenges with respect to biosphere reserves. Two important new themes with respect to the social sciences are the development of a global vision of the human/nature relationship, and the need to increase efforts to involve local communities, elected officials and all the stakeholders in developing the biosphere reserve program.

Social and Health Sciences

NSF continues to provide support for peer-reviewed research projects dealing with decision, risk and management frameworks, risk and health perceptions, co-management of resources, and collaborative research with indigenous communities.

Support is provided by NSF for an Alaska Native Science Commission (ANSC). The goal of the ANSC is to improve communication between the scientific community and Native people in Alaska, to facilitate the documentation and use of traditional and local Native knowledge and experience, and to better coordinate and regulate the access and logistics interests of researchers in Alaska. The ANSC, based at the University of Alaska Anchorage, is a unique institution in the Arctic and has the potential to greatly advance understanding of indigenous knowledge and develop common goals with the scientific community.

Human Dimensions of Global Change

The NSF supports opportunities for research on the Human Dimensions of Global Change (HDGC). HDGC research focuses on the interactions between human and natural systems, with an emphasis on the social and behavioral processes that shape and influence those interactions.

Among the general themes that especially relate to the Arctic are:

- Resource use and management, including land use, land cover and land use technologies; and
- Institutions and governance, including socio-legal dimensions of global phenomena.

The HDGC Policy Sciences Program has a strong focus on interdisciplinary approaches and is particularly concerned with basic research on environmental policies, including:

- The impacts of environmental policies on environmental attitudes;
- Research on risk and uncertainty;
- Societal values and environmental justice; and
- International environmental monitoring and compliance regimes.

In addition to the NSF, other agencies such as NOAA and the Smithsonian Institution's Arctic Studies Program support research on the HDGC.

The Beringian Systems Program

Regional interdisciplinary assessments of impacts due to global change are a high priority on

the international global change agenda. Two programs of special interest are being developed: the Bering Sea Impact Study (BESIS) and the Barents Sea Impact Study (BASIS) (see Section 2.3).

Training and Education

The numbers of researchers working in the North are small, and it has long been recognized that this situation requires special attention. Arctic research is costly for established scholars and can be prohibitive for younger academics and graduate students. The lack of graduate education in the North has also made it difficult for Native students to pursue academic careers in science and education. For these reasons the NSF and Federal agencies in Alaska bear special responsibilities for supporting science, not only through research grants but through training and educational programs.

The NSF CAREER program supports research and curriculum development by younger academics. In addition, the NSF is planning to expand the Research Experiences for High School Teachers and Students Program. Other forms of support are the NSF Research Experience for Undergraduate (REU) supplements, which provide training through participation on research projects, and dissertation improvement grants. The Alaska Federation of Natives, with NSF support, is developing a statewide Rural Systemic Initiative designed to develop educational curriculums using Native knowledge and experience.

The RAPS (Resource Apprenticeship Program) of the Department of Interior has provided summer jobs for Alaska Natives through the NPS, BLM and FWS. Other programs, such as the Co-op Ed Program and the NOAA Sea Grant Program, also support students in Alaska. The BLM Heritage Education National Program is developing materials on archaeological and historical places in Alaska to support education of America's children and to foster a sense of stewardship of cultural heritage. The USDA Forest Service has participated in an increasing number of programs within the region to promote Alaska Archaeology Week activities (lectures, field trips) and other opportunities for education that foster stewardship and the conservation of heritage resources. The USDA Forest Service is continuing a comprehensive program of cultural resource presentations, subsistence awareness sessions, and site monitoring and protection, in cooperation with the University of Alaska Southeast, Ketchikan Campus. The USDA/FS will continue to sponsor multicultural educational opportunities involving Native and local communities and National Forest visitors. The SI conducts educational programs in the North Pacific and Russian Far East and provides museum and exhibit training in Washington, D.C., Anchorage and Fairbanks.

Resources Management

Over 66% of the area of Alaska is managed by Federal agencies. Cultural and natural resources are protected by law, and good management can only be built on accurate baseline data. Although cultural resources, historic and prehistoric sites, artifacts and landscapes require documentation and protection, renewable resources, especially fish and game, are also culturally defined through subsistence needs. In 1989, Alaska State subsistence laws were declared unconstitutional because they discriminated against non-rural residents. As a result, Federal land management agencies assumed responsibility for subsistence management on Federal lands. The DOI Fish and Wildlife Service (and its Office of Subsistence Management) is the lead Federal agency in this responsibility. Subsistence is defined as fulfilling both household economic needs and cultural needs, including social communication, food sharing and maintenance of cultural knowledge and identity. Management of marine resources, such as fish and most species of marine mammals, is led by the DOC National Marine Fisheries Service. It is increasingly necessary that Federal agencies coordinate their activities and collaborate with Native, university, private and state research interests.

3.7.1 Cultural Resources

The Arctic is a major repository of human experience. Archaeological remains go back some 15,000 years, providing a record of human adaptation to environmental change of unparalleled richness. The Arctic is also home to numerous indigenous cultures, some of which are rapidly losing their traditional lifeways, languages and cultural heritage. This traditional and local knowledge base can provide long-term information about northern ecosystems and wildlife, of considerable value in resource management.

The fact that many agencies have similar administrative and management structures and mandates suggests that excellent opportunities exist for interagency cooperation. The opening of the Smithsonian's Arctic Center office in Anchorage offers possibilities for cooperation between land-managing agencies and the Smithsonian in a wide variety of research and programmatic activities. The National Park Service and the Smithsonian

have been working together in Anchorage for several years on regional archeological assessments, and NSF–SI cooperation in education and exhibition has begun. With tighter budget restraints, interagency collaboration is not only preferable but will increasingly become necessary.

A number of agencies support research on archaeology, history and Native culture (BIA, BLM, USFS, NPS, SI, NSF). Finds of artifacts and bones give evidence of past economies and baseline data for pollution monitoring, and historical and ethnographic descriptions tell of more recent conditions. Coastal resources (fish, seals, walruses, whales) supported the largest human populations in Alaska, and changing shorelines and maritime conditions are reflected by these sites.

To maximize the effectiveness of research sponsored by Federal agencies, there needs to be increased initial planning and coordination of projects, pooling of technical resources and use of existing databases. The results of such research should also be made public through popular publications, and special efforts should be made to make results accessible to residents potentially affected by the research.

Objectives

- Document and analyze the origins and transformations of Arctic cultural systems, ethnic groups and languages;
- Study and analyze traditional knowledge systems, resource uses and subsistence economics;
- Research paleoenvironmental changes, including ancient sea levels, in concert with cultural historical investigations; and
- Help develop explanatory models integrating cultural systems with local, regional and global environmental changes.

Repatriation

Repatriation has become a major priority for museums and research institutes since the passage of NAGPRA (Native American Graves Protection Act) in 1990. This act requires Federal agencies to document Native American human remains, associated grave goods and items of "cultural patrimony." Agencies must report their holdings of such materials to Native American groups and consult about their repatriation. The National Park Service has a major role in NAGPRA for coordination and guidance at the national level. It can be expected that repatriation will be a major effort for at least a decade.

Repatriation of Alaskan collections at the Smithsonian has led to several major collection returns during the past several years, with more to follow in the future. Consultation in this process has opened new channels of communication between the Smithsonian and Alaska Native peoples that offer potential for future program development in research, education and exhibition development.

3.7.2 Rapid Social Change and Community Viability

The impacts of technological and economic development on northern societies, both Native and non-Native, have been profound. While standards of living have often been improved, there has been a concurrent loss of traditional cultural values. Chronic unemployment, family violence, substance abuse and societal breakdown in general have reached epidemic proportions. One key to recovery is the facilitation of increased local control of land, resources, social institutions and education. All across the Arctic, including Alaska, there are demands for greater political autonomy. While this will add greatly to northern community empowerment, success will ultimately depend on economic viability and the balancing of development with ecologically sound policies. Within these contexts, subsistence hunting and fishing is a major factor in northern socioeconomics.

Objectives

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

3.8 Health

Health can be defined as a combination of physical, psychological, social and spiritual well-being. Unique cross-cultural interactions and social interdependencies due to harsh environmental condi-

tions in the Arctic highlight this definition. Consequently Arctic health research must take into account complex human and environmental interactions.

Health research in the Arctic includes basic and applied biomedical research (such as molecular biology and genetics), the study of the effects of cultural change on Native populations, epidemiology of disease, adaptation of humans to extreme environmental conditions, environmental health risks, contamination and health care delivery in remote and isolated communities. Health concerns in the Arctic are often related to international health issues. Western culture (and potentially Asian culture) can impact Native people adversely by introducing lifestyle and dietary changes and new infectious agents. Research designed to study these effects and techniques for disease prevention is urgently needed. Health research in the Arctic is done, individually or collaboratively, by the Arctic Investigations Program of the Centers for Disease Control and Prevention, the Indian Health Service, the National Institutes of Health, the Substance Abuse and Mental Health Services Administration, the Department of Defense and the Division of Public Health, State of Alaska. Nonclinical research on social and behavioral aspects of health is supported by the National Science Foundation's Arctic Social Sciences Program.

Among the ongoing and planned activities in Arctic health research is the continuation of studies of fetal alcohol syndrome among Alaska Natives, including projects for research and training designed to counteract this fully preventable problem. The National Institute for Occupational Safety and Health and the Center for Environmental Health, in collaboration with the State of Alaska, will continue studies on the epidemiology, risk factors and prevention strategies for occupational injuries in Alaska communities. Investigations will continue on the incidence of Alaska Natives with cancer; a five-year surveillance project and the establishment of a database are part of this project. Other areas of focus are research on suicide among Alaska Native youth, alcohol and substance abuse, and mental health with the goal of establishing an American Indian and Alaska Native Mental Research Center.

The National Institute on Drug Abuse (NIDA) has initiated a program of community-based research at the University of Alaska Anchorage dealing with the relationship of substance abuse in active drug users to infectious diseases, including human immune-deficiency virus (HIV), hepatitis B and C, and pneumonia. NIDA plans to expand these efforts. Part of this expansion includes the development of telemedicine.

NIDA also will work to continue an Alaska State Epidemiology Work Group in conjunction with the University of Alaska Anchorage and the Alaska State Department of Health.

With both the NIDA-supported research at the University of Alaska and the NIDA-initiated Alaska State Epidemiology Work Group, the University of Alaska Anchorage's Telemedicine Project has been incorporated to bridge the great geographic expanse of Alaska in a series of "research at a distance" projects.

Research on the accumulation of pollutants at the base of the human food chain and potential health risks due to nuclear contamination are the subject of both U.S. and international efforts in connection with the AEPS.

The DOD will continue to study the Polar T Syndrome for Arctic residents, seasonal patterns in energy balance, cold injury and cold weather clothing and rations. The National Science Foundation's Arctic Social Sciences Program is supporting research on childbearing practices and Native perceptions of environmental risk, as well as a comparative multidimensional Alaskan–Siberian study of Native health status and rapid social change.

Objectives

- Establish and support basic and applied scientific inquiry for the purpose of improving health through biomedical and behavioral research programs;
- Disseminate new information derived from basic and applied research into studies of the etiology, pathogenicity, prevention, diagnosis and treatment of human biomedical disorders and studies of the psychosocial factors associated with poor health status or associated with environmental contaminants;
- Establish and support epidemiologic monitoring systems in the Arctic that can guide research and assist in the development of timely interventions;
- Study individual populations for underlying connections between substance abuse, infectious diseases, accidents, and sociocultural and economic conditions; and
- Make Arctic health data and information more accessible to the public.

4. Logistics and Operational Support

Ships and Ice Platforms

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

- Icebreakers operated by the Coast Guard;
- Ice-capable and ice-strengthened vessels for research and survey purposes;
- Nuclear submarines provided by the U.S. Navy;
- Manned drifting ice stations; and
- NOAA's National Undersea Research Program (NURP) capabilities and expertise with unmanned deep-diving vehicles.

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

The Arctic Research and Policy Act (ARPA) confirms the Coast Guard's role as manager of the Nation's icebreaker fleet to serve the Nation's interests in the heavy ice regions of the Arctic. This includes security, economic and environmental interests. Research in support of those interests is specified in ARPA. Coast Guard icebreakers support research in these regions in two general ways: on dedicated science deployments and, as opportunities arise, in conjunction with other missions. The Coast Guard has two icebreakers and is acquiring a third. A design and construction contract was awarded to Avondale Industries, Inc., of New Orleans in July 1993. The vessel is scheduled to be delivered in FY 98 and operational in FY 99. Coast Guard icebreakers are available to users on a partial-reimbursable basis. Daily fuel costs and a portion of the helicopter and ship maintenance costs are charged to users, as mandated by OMB.

A research vessel providing all-season access to the Arctic region is essential for many research requirements. The University National Oceanographic Laboratory System (UNOLS) published updated Scientific Mission Requirements for the Arctic Research Vessel in 1993 and completed the Arctic Research Vessel Preliminary Design Report in 1994.

As part of the planning process, the National Academy of Sciences conducted a review and evaluation of the scientific requirements for an Arctic research vessel in the context of national research needs in the Arctic ocean regions. The study included an assessment and update of past studies, a comprehensive analysis of all Arctic facilities and their roles in meeting research requirements, and recommendations for national planning and coordination. An Arctic Icebreaker Coordinating Committee (AICC) was established in 1996 to coordinate science community and Coast Guard planning for science missions.

Drift stations and other ice platforms including Russian and Canadian opportunities will be utilized as research needs dictate. A manned drifting ice station, SHEBA (Surface Heat Budget of the Arctic), is planned for the fall of 1997. It is anticipated that SHEBA will drift for 14 months, making it the first U.S. year-round ice station since AIDJEX in 1975–76.

In late 1994 the U.S. Arctic Research Commission assisted in drafting and implementing a Memorandum of Agreement (MOA) that lays the foundation for a series of annual nuclear submarine cruises dedicated to science in the Arctic Ocean, starting in the spring of 1995. This new series of science cruises is a follow-on to the very successful proof-of-concept deployment of the USS *Pargo* in the summer of 1993. The 1995 cruise was on the USS *Cavella* and the 1996 cruise was on the USS *Pogy*. During these cruises the principal mission of the submarines is to conduct unclassified experiments selected from competitive proposals. The submarines spend 40–60 days each year collecting data in the Arctic, with the costs being shared by the U.S. Navy (which will provide the Arctic-capable submarine at no cost to the science community) and the participating science agencies (who will fund the experiment and the unique data collection systems to be installed). Each cruise will be supported by the Naval Undersea Warfare Center's Arctic Submarine Laboratory, which has coordinated all the Navy's Submarine Arctic Exercises for the past 40 years. Scientists conducting key experiments may be able to accompany the ship on the cruises.

The unique opportunities for collecting comprehensive data in areas of the Arctic Ocean, many of which are routinely accessible only by submarine, are significant, particularly because the Navy intends to declassify all data and make it available to the world science community. Some of the types of data to be collected include:

- Water samples at various depths;
- Depth and roughness of the ice canopy;
- Meteorological observations;
- Topographic, bathymetric and gravity profiling; and
- Studies of Arctic Basin water masses, their sources and circulation.

Measurements will be taken while underway and submerged, when surfaced through the ice, or by the deployment of automatic buoys, which can provide continuous data via satellite long after the submarine has departed.

In addition to these purely scientific benefits, the knowledge gained during these cruises will assist policymakers in making decisions regarding environmental protection, fisheries management, natural resource distribution, and exploitation and management of the Arctic Ocean and adjoining coasts.

The Arctic Science Submarine Cruise MOA is the product of several years of effort and negotiation among numerous agencies through the Arctic Research Commission. The MOA was signed by the National Science Foundation, the National Oceanographic and Atmospheric Administration, the U.S. Geological Survey, the Chief of Naval Research, the Director of the Submarine Warfare Division in the Office of the Chief of Naval Operations, and the Commanders of both the Atlantic and Pacific Submarine Forces. It is a significant document that demonstrates a unique interagency partnership established to address national and global issues for the benefit of all, while using available resources. The resultant availability of submarines provides a new source and level of operational support for research and will both expand and improve the quality of data sets from the central Arctic Ocean.

The NOAA National Undersea Research Program has extensive expertise and experience in conducting deep-diving efforts in all types of aquatic environments. NURP is assessing the possible application of their expertise and capabilities to studies focusing on the contamination of the Arctic, particularly contamination associated with the practices of the former Soviet Union. The National Undersea Research Center in Fairbanks, Alaska, can provide vehicles for seafloor exploration or experiments, The center can also work through the ice with ROVs as was done in Antarctica.

National Ice Center

The U.S. Navy/NOAA/Coast Guard National Ice Center (NIC) provides worldwide sea ice, Great Lakes ice and Chesapeake Bay ice information to the U.S. armed forces, U.S. government and international agencies, and civil interests. NIC staffing and fiscal resources are provided through a cooperative agreement between the Department of the Navy, the Department of Commerce (NOAA) and the Department of Transportation (U.S. Coast Guard). Weekly global and regional-scale ice extent and coverage products are produced in support of mission planning, vessel operations and scientific research. More frequently produced tactical-scale ice analyses and forecasts are tailored to customer-specified spatial and temporal requirements. Sea ice features of most frequent interest to operations include ice edge position, ice thickness, ice concentration, areas of compression or heavy deformation, and the location/orientation of open water or thin-ice-covered leads and polynyas. All NIC ice extent and coverage products are derived from a blend of remotely sensed and in-situ oceanographic and meteorological data.

Routine data sources for ice analyses include RADARSAT synthetic aperture radar (SAR), ERS-2 SAR, DMSP operational linescan system (OLS) fine visible/infrared imagery, NOAA TIROS advanced very high resolution radiometer (AVHRR) local area coverage (LAC) visible/infrared imagery, DMSP special sensor microwave/imager (SSM/I) passive microwave data, aerial reconnaissance visual and side-looking airborne radar (SLAR) observations, drifting buoy observations and ship/shore reports.

NIC ice analyses are crucial to both the safety of navigation in ice-covered waters and as a U.S. contribution to international global climate and ocean observing systems. Real-time NIC analog and digitally formatted ice products are distributed via a facsimile auto-polling system and a World Wide Web (WWW) home page (http:/www.natice.noaa. gov), respectively. NIC historical (1972–1994) Arctic and Antarctic ice information are available on CD-ROM in the international sea ice archival (SIGRID) format from the World Data Center-A and the National Snow and Ice Data Center (NSIDC). These data are also available in a geographic information system (GIS) compatible format from the NIC. Monthly multiyear ice climatologies of median ice concentration and maximum, median and minimum ice extents are also available on the NIC WWW home page. The U.S. Interagency Arctic Buoy Program (USIABP), managed by the NIC, collects and distributes surface meteorological and ice drift data. A historical quality-controlled archive of these data is available for the World Data Center-A or via the Internet

(http://iabp.apl.washington.edu) from the Applied Physics Laboratory of the University of Washington.

Land-Based Facilities

The Polar Ice Coring Office provides logistics support for research in Greenland. The logistics support for the NSF facilities in Sondrestrom have changed dramatically since Greenland was granted Home Rule and since September 1992 when the U.S. Air Force terminated operations at Sondrestrom. The logistics support, which was provided by the Air Force, is now done through arrangements negotiated with the Greenland Home Rule Government.

The Polar Ice Coring Office (PICO) provides logistics support as required for NSF in Kangerlussuaq (formerly Sondrestrom AB), Greenland. The New York Air National Guard ski-equipped LC-130s operate from Thule AB and will also operate from Kangerlussuaq when appropriate.

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

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

DOC/NOAA has available hangar facilities for two H-1N helicopters at Fort Richardson, Anchorage, Alaska. These facilities have some additional space for field equipment, scientific instruments and Arctic gear. NOAA fleet ships have previously worked above latitude 60°N, ice and weather permitting. NOAA aircraft have flown Arctic research projects while basing out of Elmendorf AFB, Eielson AFB and Thule AFB. NSF, ONR and the New York Air National Guard are taking over the SPAWAR Arctic Logistics infrastructure at Thule AB.

Atmospheric Facilities and Platforms

Poker Flat Rocket Range, Alaska, was upgraded with DOD funds ($10 million in FY 92) to state-of-the-art upper-atmosphere research capability so that it can support coordinated rocket and atmospheric monitoring programs.

Subject to the agreement of the Danish authorities, periodic rocket launches take place from Thule and Kangerlussuaq, Greenland. The U.S. incoherent-scatter radar facility at Sondrestrom is used by several agencies. The U.S. Air Force terminated operations at Kangerlussuaq Air Base on September 30, 1992. Science programs that formerly relied on the Air Force for logistics support are now supported by sponsoring agencies.

NSF has also sponsored the construction of a building at Resolute Bay, Northwest Territories, Canada, to house a variety of instruments for upper atmospheric and space research. Referred to as the Early Polar Cap Observatory, this facility will become a focal point for a major experimental facility known as the Polar Cap Observatory, with construction planned to begin in FY 98. This will provide a unique cluster of an incoherent scatter radar, radio and optical equipment for future space physics experiments within the polar cap.

NASA is establishing a Network for Detection of Stratospheric Change (NDSC) program at Thule and Sondrestrom, Greenland, to provide long-term data on a variety of stratospheric constituents.

Central Coordination and Logistics Information Clearinghouse

The State of Alaska has published a complementary inventory of Arctic logistics capabilities. Federal agencies participated in a logistics planning workshop at the Arctic Science Conference, Fairbanks; a workshop report was published. The Department of the Interior supports an Alaska Office of Aircraft Services (OAS), which coordinates aircraft services on a reimbursable basis.

An electronic bulletin board, ALIAS, was updated for use on the Internet (http://www.nsf. gov: 80/od/opp/arctic/logistic/start.htm). The IARPC Logistics and Operational Support Working Group and NSF are coordinating this effort.

Data Facilities

Archiving and distribution functions for data required in support of Arctic research are distributed among all the U.S. national data centers. Disciplinary data for the Arctic are held in global archives at the National Climatic Data Center (climatology and meteorology), at the National Oceanographic Data Center (oceanography), at the National Geophysical Data Center (seismology, geomagnetism, marine geology and geophysics, solar and iono-

spheric studies, ecosystems, topography and paleoclimatology) and at the National Center for Atmospheric Research (upper atmosphere and ionospheric studies). Global satellite data archives for polar-orbiting satellites are held by NOAA/NESDIS/National Climatic Data Center (NCDC) in Asheville, NC. Included in these archives are:

- Global infrared and visible digital imagery from the advanced very-high-resolution radiometer (AVHRR) instruments;
- Atmospheric temperature and moisture data and derived soundings from the high-resolution infrared radiation sounder (HIRS) instruments; and
- Global passive microwave data from the special sensor microwave/imager (SSM/I).

Electronic access to recent AVHRR and HIRS data is available through the NESDIS Satellite Active Archive (http://www.saa.noaa.gov). Global satellite data archives for the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) data are held by the National Geophysical Data Center. The National Oceanographic Data Center (NODC)/World Data Center-A for Oceanography (WDC-A) is the lead agency in the United National Intergovernmental Oceanographic Commission (IOC) Global Oceanographic Data Archaeology and Rescue Project (GODAR). The goal of this project is to locate and rescue historical oceanographic data that are in jeopardy of being lost, including Arctic oceanographic data.

There is a particular Arctic focus at two facilities, the National Snow and Ice Data Center (NSIDC) at the University of Colorado at Boulder and the Alaska SAR Facility at the Geophysical Institute at the University of Alaska Fairbanks. The NSIDC provides access to cryospheric data for both northern and southern hemispheres, with the present emphasis on the Arctic. NSIDC is chartered and funded by NOAA, through the Cooperative Institute for Research in Environmental Sciences (CIRES), to provide snow and ice data services. The center is under contract to the NASA Earth Observation System Data and Information System (EOSDIS) project as a Distributed Active Archive Center (DAAC), providing data services for snow and ice, including products from passive microwave remote sensing instruments, such as SSM/I and SMMR, and in-situ data.

The Alaska SAR Facility (ASF) also operates a DAAC under contract to NASA/EOSDIS. The facility receives and processes polar imagery from synthetic aperture radar (SAR) instruments onboard European (ERS-2), Japanese (JERS-1) and Canadian (Radarsat) satellites. Higher-level data products derived from the SAR data include sea ice classification and motion and ocean wave spectra. Other data sets maintained at ASF, with an Alaska regional emphasis, include Landsat and AVHRR imagery, and the 1978–1986 Alaska High-Altitude Photography (AHAP).

Without archives, Arctic data would in time be lost. Without a method to locate data in the archives, scientists would have no access to the data required for Arctic and other research. Both the Arctic Environmental Data Directory (AEDD), with its Arctic focus, and the Global Change Master Directory (GCMD) and NOAA Environmental Services Data Directory (NESDD), each having a broader mandate, are vital windows into the U.S. national data archives, providing a means for scientists to locate the data they require.

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Appendix A: Glossary of Acronyms

AAO	Adjacent Arctic Ocean
ACSYS	Arctic Climate System Study
ADCC	ARCSS Data Coordination Center
ADD	Arctic Data Directory
ADEOS	Advanced Earth Observation System
AEDD	Arctic Environmental Data Directory
AEPS	Arctic Environmental Protection Strategy
AFN	Alaska Federation of Natives
AFOSR	Air Force Office of Scientific Research
AGASP	Arctic Gas and Aerosol Sampling Program
AICC	Arctic Icebreaker Coordinating Committee
AMAP	Arctic Monitoring and Assessment Program
AMEC	Arctic Military Environment Cooperation
AMMTAP	Alaska Marine Mammal Tissue Archival Project
AMSR	Advanced microwave scanning radiometers
ANILCA	Alaska National Interest Lands Conservation Act
ANSC	Alaska Native Science Commission
ANWAP	Arctic Nuclear Waste Assessment Program
AOSB	Arctic Ocean Science Board
ARC	Arctic Research Commission
ARCSS	Arctic System Science
ARCUS	Arctic Research Consortium of the United States
ARM	Atmospheric Radiation Measurement
ARPA	Arctic Research and Policy Act
ASF	Alaska SAR Facility
AUV	Autonomous underwater vehicles
AVHRR	Advanced very high resolution radiometer
BASIS	Barents Sea Impact Study
BESIS	Bering Sea Impact Study
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CAFF	Conservation of Arctic Flora and Fauna
CAPS	Circumpolar Active-layer Permafrost System
CART	Cloud and Radiation Testbed
CDC	Centers for Disease Control
CD-ROM	Compact disk–read-only memory
CIP	Center for International Projects
CIRES	Cooperative Institute for Research in Environmental Sciences
CRESP	Coordinated Research and Environmental Surveillance Program
CRREL	Cold Regions Research and Engineering Laboratory
CSM	Climate system modeling
CSRS	Cooperative State Research Service
DA	Department of Agriculture
DAAC	Distributed Active Archive Center
DIF	Directory interchange format
DMSP	Defense Meteorological Satellite Program
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
DOT	Department of Transportation
EOS	Earth Observing System
EOSDIS	Earth Observation System Data and Information System
EPA	Environmental Protection Agency
EPPR	Emergency Prevention, Preparedness and Response
ESDIM	Environmental Services Data and Information Management
FAS	Fetal alcohol syndrome
ERS-1	European Remote-sensing Satellite
FHWA	Federal Highway Administration
FIRE	First ISCCP Regional Experiment
FOFCC	Federal Oceanographic Fleet Coordinating Council
FSU	Former Soviet Union
FWS	Fish and Wildlife Service
FY	Fiscal year
GCC	Gore–Chernomyrdin Commission
GCM	General circulation model
GCMD	Global Change Master Directory
GGD	Global Geocryological Database
GIS	Geographic information system
GLAS	Geoscience Laser Altimeter System
GODAR	Global Oceanographic Data Archeology and Rescue Project
HAARP	High Frequency Active Auroral Research Program
HDGC	Human Dimensions of Global Change
HF	High frequency
HHS	Department of Health and Human Services
HIRS	High-resolution infrared radiation sounder

HIV	Human immuno-deficiency virus
IAEA	International Atomic Energy Agency
IAG	Interagency group
IARPC	Interagency Arctic Research Policy Committee
IASC	International Arctic Science Committee
IASSA	International Arctic Social Sciences Association
IGBP	International Geosphere–Biosphere Program
IHS	Indian Health Service
IIASA	International Institute for Applied Systems Analysis
IOC	Intergovernmental Oceanographic Commission
IPA	International Permafrost Association
ISCCP	International Satellite Cloud Climatology Program
ISTP	International Solar Terrestrial Physics
ITEX	International Tundra Experiment
IUCH	International Union for Circumpolar Health
JERS-1	Japanese Earth Resources Satellite
JNPE	Jesup North Pacific Expedition
LAC	Local area coverage
LTER	Long-Term Ecological Research
MAB	Man and the Biosphere
MF	Medium frequency
MMHSRP	Marine Mammal Health and Stranding Response Program
MMS	Minerals Management Service
MOA	Memorandum of understanding
NAGPRA	Native American Graves Protection Act
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NDSC	Network for Detection of Stratospheric Change
NEA	Nuclear Energy Agency
NESDD	NOAA Environmental Services Data Directory
NESDIS	National Environmental Satellite Data and Information Service
NGDC	National Geophysical Data Center
NGO	Non-governmental organization
NIC	National Ice Center
NIDA	National Institute on Drug Abuse
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NS&T	National Status and Trends
NSA	North Slope of Alaska
NSB	National Science Board
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSN	Northern Sciences Network
NSWP	National Space Weather Program
NURP	National Undersea Research Program (NOAA)
OAI	Ocean–atmosphere–ice
OAII	Ocean–Atmosphere–Ice Interactions
OAR	Office of Oceanic and Atmospheric Research
OAS	Office of Aircraft Services
OECD	Organization for Economic Cooperation and Development
OLR	Outgoing long-wave radiation
OLS	Operational linescan system
OMB	Office of Management and Budget
ONR	Office of Naval Research
OPP	Office of Polar Programs
OSRI	Oil Spill Recovery Institute
PA	Participation agreement
PALE	Paleoclimates from Arctic Lakes and Estuaries
PAME	Protection of the Arctic Marine Environment
PCO	Polar Cap Observatory
PICO	Polar Ice Coring Office
PL	Phillips Laboratory
PMEL	Pacific Marine Environmental Laboratory
PICES	Pacific International Council for the Exploration of the Sea
PRB	Polar Research Board
Radarsat	Canada's imaging satellite
RAPS	Rural Apprenticeship Program
REU	Research Experience for Undergraduates
RGPS	Radarsat Geophysical Processor System
SAR	Synthetic aperture radar
SCS	Soil Conservation Service
SCEP	State Committee on Environmental Protection (Russian)
SeaWiFS	Sea-viewing wide-field sensor
SHEBA	Surface Heat Budget of the Arctic Ocean
SI	Smithsonian Institution
SLAR	Side-looking airborne radar
SMMR	Scanning multichannel microwave radiometer

SSM/I	Special sensor microwave/imager
SWG	Science working group
TOPEX	Poseiden Ocean Topography Experiment
UAA	University of Alaska Anchorage
UCAR	University Corporation for Atmospheric Research
UNEP/GRID	United Nations Environmental Program/Global Resources Information Database
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOLS	University National Oceanographic Laboratory System
USAIBP	United States Interagency Arctic Buoy Program
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
USPIWG	United States Polar Information Working Group
WAIS	Wide area information server
WCRP	World Climate Research Program
WWW	World Wide Web

Appendix B: Sixth Biennial Report of the Interagency Arctic Research Policy Committee to the Congress

February 1, 1994, to January 31, 1996

Background

Section 108(b) of Public Law 98-373, as amended by Public Law 101-609, the Arctic Research and Policy Act, 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 IARPC. The IARPC was authorized by the Act and was established by Executive Order 12501, dated January 28, 1985.

Section 108(b)(2) of Public Law 98-373, as amended by Public Law 101-609, directs the IARPC to submit to Congress, through the President, as part of its biennial report, a statement "dealing with particularity the recommendations of the Arctic Research Commission with respect to Federal interagency activities in Arctic research and the disposition and responses to those recommendations." In response to this requirement, the IARPC has examined all recommendations of the Arctic Research Commission since February 1994. The required statement appears in Appendix A.

Activities and Accomplishments

During the period February 1, 1994, to January 31, 1996, the IARPC has:

- Prepared and published the fourth biennial revision to the United States Arctic Research Plan, as required by Section 108(a)(4) of the Act. The President transmitted the Plan to Congress on July 14, 1995.
- Published and distributed four issues of the journal *Arctic Research of the United States*. The journal reviewed all Federal agency Arctic research accomplishments for FY 92 and 93 and included summaries of the IARPC and Arctic Research Commission meetings and activities. The Spring 1995 issue contained the full text of the fourth biennial revision of the U.S. Arctic Research Plan.
- Consulted with the Arctic Research Commission on policy and program matters described in Section 108(a)(3), was represented at all meetings of the Commission, and responded to Commission reports and recommendations on Arctic Ocean and Bering Sea studies, land–atmosphere interactions, upper atmosphere and space studies, engineering, people and health, natural resources, the environment, long-term studies, education, research infrastructure (including logistics) and data and information (Appendix A).
- Continued the processes of interagency cooperation required under Section 108(a)(6), (7), (8) and (9).
- Provided input to an integrated budget analysis and crosscut for Arctic research for the President's budget, which estimated $191 million in Federal support for FY 94 and $175 million in FY 95.
- Arranged for public participation in the development of the fourth biennial revision to the U.S. Arctic Research Plan as required in Section 108(a)(10).
- Converted the Arctic Environmental Data Directory (AEDD), which now contains information on over 400 Arctic data sets, to make it available from Alaska as a resource on the World Wide Web on the Internet.
- Continued the activities of an Interagency Social Sciences Task Force, including participation in an Arctic Health Seminar. Of special concern is research on the health of indigenous peoples and research on the Arctic as a unique environment for studying human environmental adaptation and sociocultural change.
- Assisted in the establishment of an Alaska regional office of the Smithsonian's Arctic Studies Center in cooperation with the Anchorage Historical Museum to facilitate education and cultural access programs for Alaska residents.
- Supported continued U.S. participation in the non-governmental International Arctic Science Committee and U.S. participation in the Committee's International Conference on

Arctic Research Planning held in Hanover, New Hampshire, in December 1995.

- Participated in the National Security Council review of U.S. policy in the Arctic. This review resulted in a new U.S. policy for the Arctic that expanded the focus of U.S. Arctic policy to include greater emphasis on science and environmental protection.
- Participated in policy formulation for the development of the Arctic Environmental Protection Strategy. This strategy contains a set of principles and objectives for the protection of the Arctic environment. IARPC's Arctic Monitoring Working Group serves as a U.S. focal point for the Arctic Monitoring and Assessment Program (AMAP) and coordinates domestic monitoring efforts.
- Focused attention within the U.S. Government on the dumping of nuclear waste and other toxic waste materials by the former Soviet Union on land and into the Arctic Ocean, seas and rivers; also provided assistance to the Department of Defense Arctic Nuclear Waste Assessment Program (ANWAP).
- Approved a coordinated Federal agency research initiative on Arctic contamination at its June 1994 meeting. The initiative augments individual agency mission-related programs and expertise to address the key unanswered questions about Arctic contamination. The initiative is intended to help guide internal agency planning. The goal of the IARPC Arctic contamination research initiative is to assess the sources, transport, fate, effects and risks of contaminants directly disposed of in the Arctic, as well as contaminants accumulating in the Arctic from non-Arctic sources, in relation to human health and ecosystems in Alaska, the remainder of the Arctic and the Earth as a whole. This initiative proposes the development of an integrated, comprehensive assessment including: 1) data rescue and synthesis; 2) observations; 3) process-oriented research; 4) model development; 5) impacts analysis and determination of risk; and 6) information management. Funding for the initiative should be included in agency budget submissions if the initiative is of sufficiently high priority to each agency.
- Convened two formal meetings of the Committee, in June 1994 and May 1995, and twenty-six meetings of IARPC staff committees, working groups and task forces to accomplish the above items.

Appendix C: Arctic Research Budgets of Federal Agencies

		Budget (dollars in thousands)		
Dept/Bureau	*Program name*	*FY 96 actual*	*FY 97 planned*	*FY 98 proposed*
DOD	Arctic Engineering	2,369	2,245	1,697
DOD	Permafrost/Frozen Ground	1,562	844	841
DOD	Snow and Ice Hydrology	1,910	2,585	2,538
DOD	Oceanography	8,988	6,808	4,194
DOD	Lower Atmosphere	168	160	150
DOD	Upper Atmosphere	2,000	3,100	3,100
DOD	High-Freq Active Auroral Prog	13,000	7,500	0
DOD	Medical and Human Engr	489	1,221	566
	DOD TOTAL	30,486	24,463	13,086
DOI/MMS	Technology Assessment/Research	3,320	3,000	3,000
DOI/MMS	Environmental Studies	1,810	1,095	500
DOI/USGS	Energy and Minerals	4,500	3,500	3,500
DOI/USGS	Natural Hazards	3,500	3,500	3,500
DOI/USGS	Global Change	2,500	1,000	1,000
DOI/USGS	Marine and Coastal Geology	1,000	250	250
DOI/USGS	Geomagnetism	250	250	250
DOI/USGS	Ice and Climate	480	250	250
DOI/USGS	Hydrology	130	130	130
DOI/USGS	Mapping	1,070	750	750
DOI/USGS/BRD	Marine Mammals	1,660	1,660	1,660
DOI/USGS/BRD	Migratory Birds	2,390	2,390	2,390
DOI/USGS/BRD	Fisheries Research	360	360	360
DOI/USGS/BRD	Cooperative Research	330	330	330
DOI/USGS/BRD	Terrestrial Ecology	1,130	1,130	1,130
DOI/USGS/BRD	Park Research	1,140	1,140	1,140
DOI/BLM	Natural Ecology	1,500	1,500	1,500
DOI/BLM	Cultural Resources	250	250	250
DOI/BLM	Pipeline Monitoring	500	500	500
DOI/BLM	Fire Control	350	350	350
DOI/BLM	Mining Administration	250	250	250
DOI/NPS	Cultural Resources	790	790	790
DOI/NPS	Natural Ecology	1,650	1,650	1,650
DOI/BIA	Cultural	600	600	600
DOI/BIA	Subsistence	1,250	1,250	1,250
	DOI TOTAL	32,710	27,875	27,280

Dept/Bureau	Program name	Budget (dollars in thousands) FY 96 actual	FY 97 planned	FY 98 proposed
NSF/OPP	Arctic Nat Science Program	10,382	10,880	11,501
NSF/OPP	Arctic System Science Prog	15,539	16,285	17,213
NSF/OPP	Arctic Social Sciences Prog	1,861	1,954	2,065
NSF/OPP	Arctic Research Support	639	525	555
NSF/OPP	Arctic Data/Info/Coord	339	356	366
NSF/OPP	Arctic Research Commission	500	500	500
NSF/OPP	Subtotal	29,260	30,500	32,200
NSF	Other Sciences	13,969	14,248	14,533
NSF	Engineering	260	265	271
NSF	Education	2,730	2,785	2,840
	NSF TOTAL	46,219	47,798	49,844
NASA	Polar Ice Interactions	5,500	5,500	5,500
NASA	Ecology	6,400	2,200	2,000
NASA	Solid Earth Science	500	500	500
NASA	Arctic Ozone	1,000	5,000	1,000
NASA	Clouds and Radiation	1,100	1,200	4,000
NASA	Sub-orbital Science	700	700	700
NASA	Iono/Thermo/Mesospheric SR&T	600	600	600
NASA	FAST Auroral Snapshot	5,200	4,800	4,100
NASA	Magnetospheric SR&T	1,000	1,000	1,000
NASA	Solar Terrestrial Theory	400	400	400
NASA	Arctic Data Systems	14,600	14,700	13,100
NASA	Sounding Rocket Program	1,000	1,600	800
	NASA TOTAL	38,000	38,200	33,700
DOC/NOAA	Atmos Trace Constituents	423	220	210
DOC/NOAA	Fisheries Assessment/Management	7,145	7,106	6,770
DOC/NOAA	Marine Mammal Assessment	2,318	2,200	2,200
DOC/NOAA	Coastal Hazards	78	0	0
DOC/NOAA	Ocean Assessment	154	30	30
DOC/NOAA	Stratospheric Ozone	92	30	0
DOC/NOAA	Satellites/Data Management	749	285	285
DOC/NOAA	Remote Sensing	449	530	530
DOC/NOAA	Aircraft/Vessels	1,606	468	468
DOC/NOAA	Climate and Global Change	409	395	395
DOC/NOAA	Arctic Ice	57	350	415
DOC/NOAA	Weather Research	256	235	235
DOC/NOAA	Western Arctic/Bering Sea Ecosystem	0	1,000	0
	DOC TOTAL	13,736	12,849	11,538
DOE/EML	Environmental Measurements	40	40	40
DOE/ER	Nat Inst Global Env Change	186	186	186
DOE/ER	Carbon Balance/Tundra Ecosystem	132	132	132
DOE/ER	Atmos Radiation/Planning	3,812	3,812	3,812
	DOE TOTAL	4,170	4,170	4,170
DHHS	National Institutes of Health	3,576	3,539	3,539
DHHS	Centers for Disease Control/Prevent	2,851	2,922	2,922
	DHHS TOTAL	6,427	6,461	6,461

Dept/Bureau	Program name	Budget (dollars in thousands) FY 96 actual	FY 97 planned	FY 98 proposed
SMITHSONIAN	Anthropology	450	450	450
SMITHSONIAN	Arctic Biology	50	50	50
	SMITHSONIAN TOTAL	500	500	500
DOT/USCG	Test and Evaluation	3,445	3,400	3,400
DOT/USCG	Extramural Science Support	10	30	30
DOT/FHA	Stream Crossings/Hydrological	783	700	700
DOT/FHA	Pavement Problems	898	900	900
DOT/FHA	Soils/Subbases (Permafrost)	428	200	200
DOT/FHA	Weather Monitoring/Storm Forecasting	100	100	100
DOT/FHA	Air/Water Quality Impacts	1,000	700	700
DOT/FHA	Snow Control/Pavement Treatment	229	300	300
	DOT TOTAL*	6,893	6,330	6,330
EPA	Research and Development	517	300	300
EPA	Regional Activities	327	80	80
EPA	International Activities	0	100	100
	EPA TOTAL	754	480	480
USDA/FS	Forest Service - Environment	700	700	700
USDA/CSRE&ES	Cooperative State Res - Environ	725	725	725
USDA/CSRE&ES	Cooperative State Res - Food/Saf	793	793	793
USDA/NRCS	Natural Resources Conservation Svc	560	560	560
	USDA TOTAL	2,778	2,778	2,778
STATE	MAB: Arctic Directorate	61	56	51
	STATE TOTAL	61	56	51
	GRAND TOTALS	182,734	171,960	156,218

* The Coast Guard maintains polar-class icebreakers that provide research support in the Arctic. The costs for this support are not included in these totals.

Appendix D. Federal Arctic Research Program Descriptions

Department of Defense

- Arctic Engineering: The study and development of technologies for construction and maintenance of facilities and equipment in Arctic environments.
- Permafrost/Frozen Ground: The study of the formation, structure, characteristics and dynamics of permafrost and frozen ground.
- Snow and Ice Hydrology: The study of the snow pack and river, lake and sea ice, their formation, structure and dynamics.
- Oceanography: The study of Arctic Ocean features and processes including sea ice dynamics.
- Lower Atmosphere: The study of Arctic weather with an emphasis on heat budget.
- Upper Atmosphere: The study of the structure and physical and chemical processes in the polar ionosphere and their effects on communications and navigation.
- High-Frequency Active Auroral Research Program (HAARP): The use of radio wave energy to study basic physical response and composition of the ionosphere and upper atmosphere.
- Medical and Human Engineering: The study of human response to cold climates and methods to mitigate those effects.

Department of the Interior

Minerals Management Service

- Technology Assessment and Research Program: Research to support Minerals Management Service offshore operations. Studies address operational needs for permitting of drilling and production operations, safety and pollution inspections, enforcement action, accident investigations, and well control training requirements.
- Environmental Studies Program: Research to provide information needed for prediction, assessment and management of impacts from offshore natural gas and oil and mineral development activities on human, marine and coastal environments of Alaska.

U.S. Geological Survey

- Energy and Minerals: Research to assess the distribution, quantity and quality of energy and mineral resources with an increasing emphasis on characterizing the environmental impact of resource occurrence and use. This information assists the Nation in managing its land, formulating environmental policies and ensuring stable and safe supplies of resources.
- Natural Hazards: Research to forecast and delineate hazards from earthquakes, volcanoes, landslides and related phenomena. Losses from future natural hazard events can be significantly reduced through studies of past and potential events applied to disaster mitigation and response planning.
- Global Change: Research to investigate the impact that potential global change, such as global warming, would have on our planet. This is part of the U.S. Global Change Research Program, which provides the scientific basis for developing policy relating to natural and human-induced changes in the global Earth system.
- Marine and Coastal: Research to address issues of national, regional and local concern that involve marine and coastal geology. These issues involve natural hazards, natural resources, and environmental quality and restoration; they span the full continuum from coastal wetlands and seashores to the deep ocean.
- Geomagnetism: Research to measure, map and model the Earth's magnetic field within various time scales and to publish and disseminate this information for use in navigation and orientation by Federal, state, local and international groups. Eleven magnetic observatories are operated and repeat magnetic field surveys are performed to determine how and how fast the Earth's magnetic field is changing.
- Ice and Climate: Research to understand the causes, characteristics and effects of changes in glacier conditions over annual to decadal time scales, as well as of changes in snow conditions in mountainous areas over monthly to seasonal time scales.

- Hydrology: Research to monitor and assess the sensitivity of surface water and wetland hydrology to variations and changes in climate.
- Mapping: Program to develop geologic and environmental maps of Arctic Alaska.

U.S. Geological Survey–Biological Resources Division

- Marine Mammals: Research on marine mammals to provide information needed for the Department to fulfill its stewardship responsibilities under the Marine Mammal Protection Act.
- Migratory Birds: Research on migratory birds to provide basic biological information needed for responsible implementation of the Migratory Bird Treaty Act.
- Fisheries: Research related to land management responsibilities on National Wildlife Refuges and National Parks, or focusing on treaty issues involving the U.S. and Canada.
- Cooperative Research: Research addressing issues relating to short-term or site-specific resource management issues.
- Terrestrial Ecology: Research related to land management, emphasizing potential effects of resource development on National Wildlife Refuges.
- Park Research: Research related to land management, emphasizing issues specific to National Parks.

Bureau of Land Management

- Natural Ecology: Inventorying and monitoring of the quantity and status of waters, soils, vegetation, fish and wildlife populations, and habitats in Arctic Alaska. This is a major effort to support lands and resources management in this unique area.
- Cultural Resources: Studies of man's prehistoric activities in the Arctic. Recent findings in northern Alaska have helped in understanding man's migration into North America.
- Pipeline Monitoring: Program to ascertain that permittees are in compliance with the agreement and grant right-of-way for the Trans-Alaska Pipeline in Arctic Alaska. There is constant monitoring of pipeline integrity and status of the natural resources in and adjacent to the right-of-way.
- Fire Control: Studies of fuels, ignition, burning, fire spreading and methods of control of wildfires in the Arctic. A network of remote automatic weather stations has been established. The primary purpose of this network is to help understand the influence of weather on wildfires.
- Mining Administration: Monitoring of placer mining on public lands in Arctic Alaska. The goal is to assure compliance with the approved plan of operations and minimize the impact of mining on the riparian-wetland resource.

National Park Service

- Cultural Resources: Research and investigation of cultural resources as they pertain to historic places in National Parks. The Shared Beringian Heritage Program promotes international cooperation in multidisciplinary studies of Beringia.
- Natural Ecology: Research to monitor and understand natural resources in National Parks.

Bureau of Indian Affairs

- Cultural: Research and investigation of learned and shared behaviors as they pertain to historic places and cemetery sites applied for under the provisions of the Alaska Native Claims Settlement Act (P.L. 92-203).
- Subsistence: Research on the customary and traditional uses of fish, game and plant resources.

National Science Foundation

- Arctic Natural Sciences: Research in atmospheric, space, ocean, biological, earth sciences and glaciology that is primarily investigator-initiated; this is basic research that is concerned with processes and phenomena in the entire Arctic region, including Alaska, Canada, Greenland, Svalbard, Russia, the Arctic Ocean and adjacent seas, and the upper atmosphere and near space.
- Arctic System Science (ARCSS): An interdisciplinary program that examines the interactions within and between the climatic, geologic, biologic and socioeconomic subsystems of the Arctic. ARCSS is a regional component within the U.S. Global Change Research Program.
- Arctic Social Science: A multidisciplinary and interdisciplinary program focused on issues of human–environment interactions, rapid social change and community viability.
- Arctic Science Support: Support for Intergovernmental Personnel Act (IPA) personnel

assigned to the Arctic Sciences Section of the Office of Polar Programs (OPP), and scientific meeting, panel and publication support.
- Arctic Data and Information, and Advisory and Coordination: Support for a program of Arctic data and information research and advisory services, including support for the Interagency Arctic Research Policy Committee, and conferences, workshops and studies to further develop and implement Arctic research planning and policy.
- Arctic Research Commission: Support for the Commission staff and members. Funding for the Arctic Research Commission is included in the NSF budget for administrative convenience.
- Other Sciences: Research supported in divisions and programs outside the Office of Polar Programs (OPP) in atmospheric, ocean, biological, earth sciences and glaciology that is primarily investigator-initiated, basic research.
- Engineering: Engineering research that is related to the Arctic.
- Education: Education research that is related to the Arctic.

National Aeronautics and Space Administration

- Polar Ice Interactions: Program focuses on Arctic ice cover and its interactions with the oceans and atmosphere. Long-range goals are significant improvement in our ability to represent high-latitude processes in models of global climate and climate change, and implementation of a program to monitor important high-latitude phenomena that are likely to respond to climate change, with particular emphasis on the mass balance of the Greenland ice sheet and its effect on sea level.
- Ecology: Program focused on the function of high-latitude terrestrial ecosystems and their interactions with the atmosphere and hydrosphere, with particular emphasis on carbon cycling and land–atmosphere interactions.
- Solid Earth Science: Program focused on improving our understanding of the Earth gravity field, oscillations in the length of day and tilting of the axis of rotation. It also contributes to other polar studies by providing a frame of reference with which to monitor changes, such as the volume of the ice sheets.
- Arctic Ozone Studies: Program supporting a number of tasks related to measuring and understanding chemical and dynamical processes in the Arctic stratosphere in order to measure and understand changes in Arctic stratospheric ozone.
- Arctic Data Systems: Support for two Distributed Active Archive Systems (DAACs) for high-latitude data: one at the National Snow and Ice Data Center (NSIDC) in Boulder, Colorado, and one at the Alaska SAR Facility (ASF), in Fairbanks, Alaska. The ASF is responsible for the acquisition, processing, archiving and distribution of synthetic aperture radar (SAR) data from several non-U.S. spacecraft, and the NSIDC handles most other satellite data over high latitudes. In addition, NASA supports the development of several high-latitude "Pathfinder" data sets, comprising higher-level information derived from various satellite data.
- Space Physics Division: Support for a vigorous program of experimental and theoretical studies of the upper atmosphere of the Arctic regions, including the ionosphere, thermosphere, magnetosphere and the Aurora Borealis. It includes these programs listed in the NASA budget table: Sounding Rocket Program, Suborbital Science, Iono/Thermo/Mesospheric Science and Technology, Clouds and Radiation, FAST Auroral Snapshot, Magnetospheric Science and Technology, and Solar Terrestrial Theory.

Department of Commerce

National Oceanic and Atmospheric Administration

- Atmospheric Trace Constituents: Continuous and discreet measurements of atmospheric trace constituents (for example, greenhouse gases) that are important to understanding global change.
- Marine Fisheries Assessment: Assessment by the National Marine Fisheries Service (NMFS) of U.S. living marine resources in Arctic waters.
- Marine Mammal Assessment: Long-term research by NMFS's National Marine Mammal Laboratory on the population biology and ecology of Arctic marine mammals. NMFS also participates in the Marine Mammal Health and Stranding Response Program, which oversees the Arctic Marine Mammal

Tissue Archival Program (AMMTAP) in collaboration with Department of Interior (FWS, BRD and MMS) and the National Institute of Standards and Technology (NIST). The AMMTAP collects, analyzes and archives tissues for contaminants and health indices to provide a database on contaminants and health in marine mammal populations in the Arctic.
- Coastal Hazards: Activities directed towards developing a better understanding of the effects of tsunami propagation and run-up.
- Ocean Assessment: A cooperative effort between NOAA and NIST to collect and archive tissue samples from Alaskan marine mammals; part of these are analyzed to develop a database on contaminant levels. Ocean assessment also includes the National Status and Trends Program whose objective is to describe spatial distribution and determine long-term trends of contaminant concentrations in coastal areas.
- Stratospheric Ozone: Program that is developing an understanding of the dynamics and chemistry of the potential for Arctic ozone depletion, as part of activities directed to understanding the global depletion of stratospheric ozone.
- Satellites/Data Management: Research addressing NOAA's responsibilities for collecting, archiving, processing and disseminating environmental data, and providing specialized data analyses and interpretations.
- Remote Sensing: A substantial program (jointly with NSF and DOE) for developing, testing and using ground-based remote sensors for Arctic meteorological research. The emphasis is on prototypes for future operational systems that can operate in the Arctic environment with a minimum of attention. The scientific issues include boundary layer turbulence and structure, cloud macro- and micro-physical properties, and cloud-radiative coupling relevant to Arctic climate.
- Aircraft/Vessels: Program to account for the platforms needed to conduct the research and observations associated with NOAA's Arctic research program.
- Climate and Global Change: Studies that are assessing Arctic processes as forcing functions of climate and global change and as "barometers" of global change.
- Arctic Ice: Support of NOAA's Pacific Marine Environmental Laboratory (PMEL) investigations of the influence of sea ice on weather and climate systems, oceanographic stratification and marine biota. The National Ice Center, jointly operated by NOAA, the U.S. Navy and the U.S. Coast Guard, provides analyses and forecasts of ice conditions in all seas of the polar regions, the Great Lakes and Chesapeake Bay. The National Snow and Ice Data Center (NSIDC), affiliated with NOAA's National Geophysical Data Center (NGDC), archives many new and rescued ice data sets.
- Arctic Weather: Research primarily addressing two forecast problems: detection of the Arctic front, and the effect of the Arctic front on local weather.

Department of Energy

- Environmental Measurements: Measurements of long-term levels and trends of anthropogenic and natural radionuclides in the Arctic atmosphere. Investigations of the use of radionuclides as atmospheric tracers.
- National Institute of Global Environmental Change: Multiple projects that relate to the measurement of carbon fluxes and "greenhouse" gases.
- Carbon Balance/Tundra Ecosystems: Investigation of the response of tundra ecosystems to changes in the levels of elemental CO_2.
- Atmospheric Radiation Planning: Development of an Atmospheric Radiation Measurement (ARM) research site on the North Slope of Alaska to investigate and model the influence of clouds on radiation transport related to climate change.

Department of Health and Human Services

National Institutes of Health
- Basic and applied research that relates primarily in the areas of rheumatic diseases, cancer, drug abuse, and coronary heart disease that affect Arctic residents.

Centers for Disease Control and Prevention
- An infectious disease prevention and control program designed to evaluate infectious disease prevention strategies in the Alaska Native population.
- An occupational injury research program focusing on the Nation's geographic area with

the highest risk of occupational-related injury.
- A program to provide technical assistance to the State of Alaska to develop a surveillance system for Fetal Alcohol Syndrome (FAS) and to develop and evaluate model programs for FAS prevention.

Smithsonian Institution

- Anthropology: Research and interpretation of Arctic cultures and natural history. Training of Arctic residents and Natives in museum studies, collections care, conservation and cultural heritage programs. Studies of the origin and history of northern cultures and their interactions with their environment and with European cultures are central features of this research.
- Arctic Biology: Basic research on biological and evolutionary studies in botany, zoology and other natural history fields. Interactions of Arctic flora and fauna with human cultures are emphasized.

Department of Transportation

U.S. Coast Guard

- Arctic Science/Logistics Support: The costs of providing and maintaining polar icebreakers for use in the Arctic.
- Test and Evaluation: The cost of tests designed to evaluate polar icebreakers in the performance of Arctic missions. (Previously, unreimbursed Arctic science mission costs were included in this category.)
- Extramural Science Support: Funding provided to other agencies for Arctic science studies, research or vessel availability studies.

Federal Highway Administration

- Stream Crossing/Hydrological: Investigations directed toward dealing with highway stream crossings, bridges and covered culverts; anomalies found in Arctic conditions, including frozen ground and related subfreezing conditions and permafrost, can cause icing blockages and highly variable stream discharges.
- Pavement Studies: Investigations of the effects of the Arctic and its extremely low and highly variable temperatures on behaviors of portland cement and asphalt concrete pavements.
- Soils/Sub-bases (Permafrost): Investigations dealing with the control of unpaved road surfaces and appropriate measures to attain stable road conditions in Arctic areas typified by poor drainage conditions and permafrost.
- Weather Monitoring/Storm Forecast: Investigations directed toward detecting the presence of ice or snow or cold conditions on highway pavement and bridge deck areas and integrating these determinations with improved weather forecasting to improve the timing strategies and sizing of highway maintenance efforts to deal with possible or expected occurrences of snow and ice on highways.
- Air/Water Quality Impacts: Investigations directed toward forecasting the environmental impacts of highway construction.
- Snow Control/Pavement Treatment: Investigations dealing with the interception and diversion of snow and ice; the disbonding from pavements and removal of snow and ice from pavements; the prevention of snow and ice covering and melting of snow and ice by chemical (salt) applications; and the covering of ice and snow on pavements by abrasive materials such as coarse angular sands to improve traction by vehicles on pavements.

Environmental Protection Agency

- Research and Development: Intramural and extramural basic and applied research based on the risk assessment/risk management paradigm. EPA research interests in the Arctic include air quality, land use, habitat, bioremediation and environmental engineering and social science research.
- Regional Activities: Activities of EPA's Region 10 (Pacific Northwest and Alaska office) conducted with the State of Alaska and local communities, Alaskan indigenous peoples and others to resolve specific Arctic environmental issues.

Department of Agriculture

Forest Service

- Research directed toward improving the understanding, use and management of Alaska's natural resources, especially the northern boreal forest. Research centers on the dynamics of mixed stands and the cumulative effects of management activities on hydrology, soils,

vegetation, wildlife, carbon reserves, insects and fire in boreal ecosystems.

Cooperative State Research Education and Extension Service

- Research in plant sciences emphasizing propagating and cultivating Alaska native plants and domestic crops.
- Research in animal sciences investigating genetic parameters for growth and reproduction of pink salmon and the chemical composition, nutritional value and utilization of animal feeds.
- Research in natural resources and forestry addressing forest floor organic matter reserves, ecosystem sustainability, soil classification, wildlife habitat, quantifying timber productivity and disturbance revegetation in wetlands.

Natural Resources Conservation Service

- Research in support of the National Cooperative Soil Survey and the Snow Survey programs addressing soil cryogenic processes, soil reduction and oxidation properties, temperature, water status and gas flux in wetlands, reindeer and caribou grazing needs, vegetation trends, and vegetation, landform and carbon sequestration relationships. Snowfall measurement techniques are being studied to support the snow survey which continues to be used to predict snowmelt, water availability, river break-up timing and wildlife movements.

Department of State

- Man and the Biosphere Program: Research as part of the U.S. Man and the Biosphere Program. Working with indigenous communities, the program seeks to ensure sound management of key renewable resources such as caribou and salmon.

Appendix E: Arctic Research and Policy Act, As Amended

PUBLIC LAW 98-373 - July 31,1984; amended as
PUBLIC LAW 101-609 - November 16, 1990

An Act

To provide for a comprehensive national policy dealing with national research needs and objectives in the Arctic, for a National Critical Materials Council, for development of a continuing and comprehensive national materials policy, for programs necessary to carry out that policy, including Federal programs of advanced materials research and technology, and for innovation in basic materials industries, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:

TITLE 1-ARCTIC RESEARCH AND POLICY

SHORT TITLE

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

FINDINGS AND PURPOSES

SEC. 102.(a) The Congress finds and declares that—

(1) the Arctic, onshore and offshore, contains vital energy resources that can reduce the Nation's dependence on foreign oil and improve the national balance of payments;

(2) as the Nation's only common border with the Soviet Union, the Arctic is critical to national defense;

(3) the renewable resources of the Arctic, specifically fish and other seafood, represent one of the Nation's greatest commercial assets;

(4) Arctic conditions directly affect global weather patterns and must be understood in order to promote better agricultural management throughout the United States;

(5) industrial pollution not originating in the Arctic region collects in the polar air mass, has the potential to disrupt global weather patterns, and must be controlled through international cooperation and consultation;

(6) the Arctic is a natural laboratory for research into human health and adaptation, physical and psychological, to climates of extreme cold and isolation and may provide information crucial for future defense needs;

(7) atmospheric conditions peculiar to the Arctic make the Arctic a unique testing ground for research into high latitude communications, which is likely to be crucial for future defense needs;

(8) Arctic marine technology is critical to cost-effective recovery, and transportation of energy resources and to the national defense;

(9) the United States has important security, economic, and environmental interests in developing and maintaining a fleet of icebreaking vessels capable of operating effectively in the heavy ice regions of the Arctic;

(10) most Arctic-rim countries, particularly the Soviet Union, possess Arctic technologies far more advanced than those currently available in the United States;

(11) Federal Arctic research is fragmented and uncoordinated at the present time, leading to the neglect of certain areas of research and to unnecessary duplication of effort in other areas of research;

(12) improved logistical coordination and support for Arctic research and better dissemination of research data and information is necessary to increase the efficiency and utility of national Arctic research efforts;

(13) a comprehensive national policy and program plan to organize and fund currently neglected scientific research with respect to the Arctic is necessary to fulfill national objectives in Arctic research;

(14) the Federal Government, in cooperation with State and local governments, should focus its efforts on the collection and characterization of basic data related to biological, materials, geophysical, social, and behavioral phenomena in the Arctic;

(15) research into the long-range health, environmental, and social effects of development in the Arctic is necessary to mitigate the adverse consequences of that development to the land and its residents;

(16) Arctic research expands knowledge of the Arctic, which can enhance the lives of Arctic residents, increase opportunities for international cooperation among Arctic-rim countries, and facilitate the formulation of national policy for the Arctic; and

(17) the Alaskan Arctic provides an essential habitat for marine mammals, migratory waterfowl, and other forms of wildlife which are important to the Nation and which are essential to Arctic residents.

(b) The purposes of this title are—

(1) to establish national policy, priorities, and goals and to provide a Federal program plan for basic and applied scientific research with respect to the Arctic, including natural resources and materials, physical, biological and health sciences, and social and behavioral sciences;

(2) to establish an Arctic Research Commission to promote Arctic research and to recommend Arctic research policy,

(3) to designate the National Science Foundation as the lead agency responsible for implementing Arctic research policy, and

(4) to establish an Interagency Arctic Research Policy Committee to develop a national Arctic research policy and a five year plan to implement that policy.

ARCTIC RESEARCH COMMISSION

SEC. 103. (a) The President shall establish an Arctic Research Commission (hereinafter referred to as the "Commission").

(b)(1) The Commission shall be composed of seven members appointed by the President, with the Director of the National Science Foundation serving as a nonvoting, ex officio member. The members appointed by the President shall include—

(A) four members appointed from among individuals from academic or other research institutions with expertise in areas of research relating to the Arctic, including the physical, biological, health, environmental, social and behavioral sciences;

(B) one member appointed from among indigenous residents of the Arctic who are representative of the needs and interests of Arctic residents and who live in areas directly affected by Arctic resource development; and

(C) two members appointed from among individuals familiar with the Arctic and representative of the needs and interests of private industry undertaking resource development in the Arctic.

(2) The President shall designate one of the appointed members of the Commission to be chairperson of the Commission.

(c)(1) Except as provided in paragraph (2) of this subsection, the term of office of each member of the Commission appointed under subsection (b)(1) shall be four years.

(2) Of the members of the Commission originally appointed under subsection (b)(1)—

(A) one shall be appointed for a term of two years;

(B) two shall be appointed for a term of three years; and

(C) two shall be appointed for a term of four years.

(3) Any vacancy occurring in the membership of the Commission shall be filled, after notice of the vacancy is published in the Federal Register, in the manner provided by the preceding provisions of this section, for the remainder of the unexpired term.

(4) A member may serve after the expiration of the member's term of office until the President appoints a successor.

(5) A member may serve consecutive terms beyond the member's original appointment.

(d)(1) Members of the Commission may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code. A member of the Commission not presently employed for compensation shall be compensated at a rate equal to the daily equivalent of the rate for GS-18 of the General Schedule under section 5332 of title 5, United States Code, for each day the member is engaged in the actual performance of his duties as a member of the Commission, not to exceed 90 days of service each year. Except for the purposes of chapter 81 of title 5 (relating to compensation for work injuries) and chapter 171 of title 28 (relating to tort claims), a member of the Commission shall not be considered an employee of the United States for any purpose.

(2) The Commission shall meet at the call of its Chairman or a majority of its members.

(3) Each Federal agency referred to in section 107(b) may designate a representative to participate as an observer with the Commission. These representatives shall report to and advise the Commission on the activities relating to Arctic research of their agencies.

(4) The Commission shall conduct at least one public meeting in the State of Alaska annually.

DUTIES OF THE COMMISSION

SEC. 104. (a) The Commission shall—

(1) develop and recommend an integrated national Arctic research policy;

(2) in cooperation with the Interagency Arctic Research Policy Committee established under section 107, assist in establishing a national Arctic research program plan to implement the Arctic research policy;

(3) facilitate cooperation between the Federal Government and State and local governments with respect to Arctic research;

(4) review Federal research programs in the Arctic and recommend improvements in coordination among programs;

(5) recommend methods to improve logistical planning and support for Arctic research as may be appropriate and in accordance with the findings and purposes of this title;

(6) recommend methods for improving efficient sharing and dissemination of data and information on the Arctic among interested public and private institutions;

(7) offer other recommendations and advice to the Interagency Committee established under section 107 as it may find appropriate;

(8) cooperate with the Governor of the State of Alaska and with agencies and organizations of that State which the Governor may designate with respect to the formulation of Arctic research policy;

(9) recommend to the Interagency Committee the means for developing international scientific cooperation in the Arctic; and

(10) not later than January 31,1991, and every 2 years thereafter, publish a statement of goals and objectives with respect to Arctic research to guide the Interagency Committee established under section 107 in the performance of its duties.

(b) Not later than January 31 of each year, the Commission shall submit to the President and to the Congress a report describing the activities and accomplishments of the Commission during the immediately preceding fiscal year.

COOPERATION WITH THE COMMISSION

SEC. 105. (a)(1) The Commission may acquire from the head of any Federal agency unclassified data, reports, and other nonproprietary information with respect to Arctic

research in the possession of the agency which the Commission considers useful in the discharge of its duties.

(2) Each agency shall cooperate with the Commission and furnish all data, reports, and other information requested by the Commission to the extent permitted by law; except that no agency need furnish any information which it is permitted to withhold under section 522 of title 5, United States Code.

(b) With the consent of the appropriate agency head, the Commission may utilize the facilities and services of any Federal agency to the extent that the facilities and services are needed for the establishment and development of an Arctic research policy, upon reimbursement to be agreed upon by the Commission and the agency head and taking every feasible step to avoid duplication of effort.

(c) All Federal agencies shall consult with the Commission before undertaking major Federal actions relating to Arctic research.

ADMINISTRATION OF THE COMMISSION

SEC. 106. The Commission may—

(1) in accordance with the civil service laws and subchapter III of chapter 53 of title 5, United States Code, appoint and fix the compensation of an Executive Director and necessary additional staff personnel, but not to exceed a total of seven compensated personnel;

(2) procure temporary and intermittent services as authorized by section 3109 of title 5, United States Code;

(3) enter into contracts and procure supplies, services and personal property;

(4) enter into agreements with the General Services Administration for the procurement of necessary financial and administrative services, for which payment shall be made by reimbursement from funds of the Commission in amounts to be agreed upon by the Commission and the Administrator of the General Services Administration; and

(5) appoint, and accept without compensation the services of, scientists and engineering specialists to be advisors to the Commission. Each advisor may be allowed travel expenses, including per diem in lieu of subsistence, as authorized by section 5703 of title 5, United States Code. Except for the purposes of chapter 81 of title 5 (relating to compensation for work injuries) and chapter 171 of title 28 (relating to tort claims) of the United States Code, an advisor appointed under this paragraph shall not be considered an employee of the United States for any purpose.

LEAD AGENCY AND INTERAGENCY ARCTIC RESEARCH POLICY COMMITTEE

SEC. 107. (a) The National Science Foundation is designated as the lead agency responsible for implementing Arctic research policy, and the Director of the National Science Foundation shall insure that the requirements of section 108 are fulfilled.

(b)(1) The President shall establish an Interagency Arctic Research Policy Committee (hereinafter referred to as the "Interagency Committee").

(2) The Interagency Committee shall be composed of representatives of the following Federal agencies or offices:

(A) the National Science Foundation;

(B) the Department of Commerce;

(C) the Department of Defense;

(D) the Department of Energy;

(E) the Department of the Interior;

(F) the Department of State;

(G) the Department of Transportation;

(H) the Department of Health and Human Services;

(I) the National Aeronautics and Space Administration;

(J) the Environmental Protection Agency; and

(K) any other agency or office deemed appropriate.

(3) The representative of the National Science Foundation shall serve as the Chairperson of the Interagency Committee.

DUTIES OF THE INTERAGENCY COMMITTEE

SEC. 108. (a) The Interagency Committee shall—

(1) survey Arctic research conducted by Federal State, and local agencies, universities, and other public and private institutions to help determine priorities for future Arctic research, including natural resources and materials, physical and biological sciences, and social and behavioral sciences;

(2) work with the Commission to develop and establish an integrated national Arctic research policy that will guide Federal agencies in developing and implementing their research programs in the Arctic;

(3) consult with the Commission on-

(A) the development of the national Arctic research policy and the 5-year plan implementing the policy;

(B) Arctic research programs of Federal agencies;

(C) recommendations of the Commission on future Arctic research; and

(D) guidelines for Federal agencies for awarding and administering Arctic research grants;

(4) develop a 5-year plan to implement the national policy, as provided in section 109;

(5) provide the necessary coordination, data, and assistance for the preparation of a single integrated, coherent, and multiagency budget request for Arctic research as provided for in section 110;

(6) facilitate cooperation between the Federal Government and State and local governments in Arctic research, and recommend the undertaking of neglected areas of research in accordance with the findings and purposes of this title;

(7) coordinate and promote cooperative Arctic scientific research programs with other nations, subject to the foreign policy guidance of the Secretary of State;

(8) cooperate with the Governor of the State of Alaska in fulfilling its responsibilities under this title;

(9) promote Federal interagency coordination of all Arctic research activities, including-

(A) logistical planning and coordination; and

(B) the sharing of data and information associated with Arctic research, subject to section 552 of title 5, United States Code; and

(10) provide public notice of its meetings and an opportunity for the public to participate in the development and implementation of national Arctic research policy.

(b) Not later than January 31, 1986, and biennially thereafter, the Interagency Committee shall submit to the Congress through the President, a brief, concise report containing-

(1) a statement of the activities and accomplishments of the Interagency Committee since its last report; and

(2) a statement detailing with particularity the recommendations of the Commission with respect to Federal interagency activities in Arctic research and the disposition and responses to those recommendations.

5-YEAR ARCTIC RESEARCH PLAN

SEC. 109. (a) The Interagency Committee, in consultation with the Commission, the Governor of the State of Alaska, the residents of the Arctic, the private sector, and public interest groups, shall prepare a comprehensive 5-year program plan (hereinafter referred to as the "Plan") for the overall Federal effort in Arctic research. The Plan shall be prepared and submitted to the President for transmittal to the Congress within one year after the enactment of this Act and shall be revised biennially thereafter.

(b) The Plan shall contain but need not be limited to the following elements:

(1) an assessment of national needs and problems regarding the Arctic and the research necessary to address those needs or problems;

(2) a statement of the goals and objectives of the Interagency Committee for national Arctic research;

(3) a detailed listing of all existing Federal programs relating to Arctic research, including the existing goals, funding levels for each of the 5 following fiscal years, and the funds currently being expended to conduct the programs;

(4) recommendations for necessary program changes and other proposals to meet the requirements of the policy and goals as set forth by the Commission and in the Plan as currently in effect; and

(5) a description of the actions taken by the Interagency Committee to coordinate the budget review process in order to ensure interagency coordination and cooperation in (A) carrying out Federal Arctic research programs, and (B) eliminating unnecessary duplication of effort among these programs.

COORDINATION AND REVIEW OF BUDGET REQUESTS

SEC. 110. (a) The Office of Science and Technology Policy shall—

(1) review all agency and department budget requests related to the Arctic transmitted pursuant to section 108(a)(5), in accordance with the national Arctic research policy and the 5-year program under section 108(a)(2) and section 109, respectively; and

(2) consult closely with the Interagency Committee and the Commission to guide the Office of Technology Policy's efforts.

(b)(1) The Office of Management and Budget shall consider all Federal agency requests for research related to the Arctic as one integrated, coherent, and multiagency request, which shall be reviewed by the Office of Management and Budget prior to submission of the President's annual budget request for its adherence to the Plan. The Commission shall, after submission of the President's annual budget request, review the request and report to Congress on adherence to the Plan.

(2) The Office of Management and Budget shall seek to facilitate planning for the design, procurement, maintenance, deployment and operations of icebreakers needed to provide a platform for Arctic research by allocating all funds necessary to support icebreaking operations, except for recurring incremental costs associated with specific projects, to the Coast Guard.

AUTHORIZATION OF APPROPRIATIONS; NEW SPENDING AUTHORITY

SEC. 111. (a) There are authorized to be appropriated such sums as may be necessary for carrying out this title.

(b) Any new spending authority (within the meaning of section 401 of the Congressional Budget Act of 1974) which is provided under this title shall be effective for any fiscal year only to such extent or in such amounts as may be provided in appropriation Acts.

DEFINITION

SEC. 112. As used in this title, the term "Arctic" means all United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering and Chukchi Seas; and the Aleutian chain.

Appendix F: Principles for the Conduct of Research in the Arctic

Introduction

All researchers working in the North have an ethical responsibility toward the people of the North, their cultures, and the environment. The following principles have been formulated to provide guidance for researchers in the physical, biological, behavioral, health, economic, political, and social sciences and in the humanities. These principles are to be observed when carrying out or sponsoring research in Arctic and northern regions or when applying the results of this research.

This statement addresses the need to promote mutual respect and communication between scientists and northern residents. Cooperation is needed at all stages of research planning and implementation in projects that directly affect northern people. Cooperation will contribute to a better understanding of the potential benefits of Arctic research for northern residents and will contribute to the development of northern science through traditional knowledge and experience.

These "Principles for the Conduct of Research in the Arctic" were prepared by the Interagency Social Science Task Force in response to a recommendation by the Polar Research Board of the National Academy of Sciences and at the direction of the Interagency Arctic Research Policy Committee. This statement is not intended to replace other existing Federal, State, or professional guidelines, but rather to emphasize their relevance for the whole scientific community. Examples of similar guidelines used by professional organizations and agencies in the United States and in other countries are listed in the publications.

Implementation

All scientific investigations in the Arctic should be assessed in terms of potential human impact and interest. Social science research, particularly studies of human subjects, requires special consideration, as do studies of resources of economic, cultural, and social value to Native people. In all instances, it is the responsibility of the principal investigator on each project to implement the following recommendations:

1. The researcher should inform appropriate community authorities of planned research on lands, waters, or territories used or occupied by them. Research directly involving northern people or communities should not proceed without their clear and informed consent. When informing the community and/or obtaining informed consent, the researcher should identify—
   a. all sponsors and sources of financial support;
   b. the person in charge and all investigators involved in the research, as well as any anticipated need for consultants, guides, or interpreters;
   c. the purposes, goals, and time frame of the research;
   d. data-gathering techniques (tape and video recordings, photographs, physiological measurements, and so on) and the uses to which they will be put; and
   e. foreseeable positive and negative implications and impacts of the research.
2. The duty of researchers to inform communities continues after approval has been obtained. Ongoing projects should be explained in terms understandable to the local community.
3. Researchers should consult with and, where applicable, include northern communities in project planning and implementation. Reasonable opportunities should be provided for the communities to express their interests and to participate in the research.
4. Research results should be explained in nontechnical terms and, where feasible, should be communicated by means of study materials that can be used by local teachers or displays that can be shown in local community centers or museums.
5. Copies of research reports, data descriptions, and other relevant materials should be provided to the local community. Special efforts must be made to communicate results that are responsive to local concerns.
6. Subject to the requirements for anonymity, publications should always refer to the informed consent of participants and give credit to those contributing to the research project.
7. The researcher must respect local cultural traditions, languages, and values. The researcher

should, where practicable, incorporate the following elements in the research design:

a. Use of local and traditional knowledge and experience.
b. Use of the languages of the local people.
c. Translation of research results, particularly those of local concern, into the languages of the people affected by the research.

8. When possible, research projects should anticipate and provide meaningful experience and training for young people.
9. In cases where individuals or groups provide information of a confidential nature, their anonymity must be guaranteed in both the original use of data and in its deposition for future use.
10. Research on humans should only be undertaken in a manner that respects their privacy and dignity:
    a. Research subjects must remain anonymous unless they have agreed to be identified. If anonymity cannot be guaranteed, the subjects must be informed of the possible consequences of becoming involved in the research.
    b. In cases where individuals or groups provide information of a confidential or personal nature, this confidentiality must be guaranteed in both the original use of data and in its deposition for future use.
    c. The rights of children must be respected. All research involving children must be fully justified in terms of goals and objectives and never undertaken without the consent of the children and their parents or legal guardians.
    d. Participation of subjects, including the use of photography in research, should always be based on informed consent.
    e. The use and disposition of human tissue samples should always be based on the informed consent of the subjects or next of kin.
11. The researcher is accountable for all project decisions that affect the community, including decisions made by subordinates.
12. All relevant Federal, State, and local regulations and policies pertaining to cultural, environmental, and health protection must be strictly observed.
13. Sacred sites, cultural materials, and cultural property cannot be disturbed or removed without community and/or individual consent and in accordance with Federal and State laws and regulations.

In implementing these principles, researchers may find additional guidance in the publications listed below. In addition, a number of Alaska Native and municipal organizations can be contacted for general information, obtaining informed consent, and matters relating to research proposals and coordination with Native and local interests. A separate list is available from NSF's Office of Polar Programs.

Publications

Arctic Social Science: An Agenda for Action. National Academy of Sciences, Washington, D.C., 1989.

Draft Principles for an Arctic Policy. Inuit Circumpolar Conference, Kotzebue, 1986.

Ethics. Social Sciences and Humanities Research Council of Canada, Ottawa, 1977.

Nordic Statement of Principles and Priorities in Arctic Research. Center for Arctic Cultural Research, Umeä, Sweden, 1989.

Policy on Research Ethics. Alaska Department of Fish and Game, Juneau, 1984.

Principles of Professional Responsibility. Council of the American Anthropological Association, Washington, D.C., 1971, rev. 1989.

The Ethical Principles for the Conduct of Research in the North. The Canadian Universities for Northern Studies, Ottawa, 1982.

The National Arctic Health Science Policy. American Public Health Association, Washington, D.C., 1984.

Protocol for Centers for Disease Control/Indian Health Service Serum Bank. Prepared by Arctic Investigations Program (CDC) and Alaska Area Native Health Service, 1990. (Available through Alaska Area Native Health Service, 255 Gambell Street, Anchorage, AK 99501.)

Indian Health Manual. Indian Health Service, U.S. Public Health Service, Rockville, Maryland, 1987.

Human Experimentation. Code of Ethics of the World Medical Association (Declaration of Helsinki). Published in *British Medical Journal,* 2:177, 1964.

Protection of Human Subjects. Code of Federal Regulations 45 CFR 46, 1974, rev. 1983.

Appendix G: U.S. National Arctic Policy Statement

On September 19, 1996, the United States signed the Declaration establishing the Arctic Council, an eight nation forum designed to bring together in a senior policy setting the environmental conservation elements of the Arctic Environmental Protection Strategy (AEPS) and broader issues of common concern related to sustainable development. In addition to the eight nations: Canada, Denmark/Greenland, Finland, Iceland, Norway, the Russian Federation, Sweden and the U.S., the region's indigenous communities are recognized as Permanent Participants of the Arctic Council. Canada is the chair of the Arctic Council until September 1998, at which time the United States has indicated an interest in assuming the chair. During this time, Rules of Procedure for the Council will be adopted.

The Arctic Council is entirely consistent with the objectives articulated in the U.S. Arctic Policy Statement of 1994 and offers an important vehicle for pursuing them. These policy objectives include:

- Protecting the Arctic environment and conservation of its living resources;
- Promoting environmentally sustainable natural resource management and economic development in the region;
- Strengthening institutions for cooperation among the eight Arctic nations;
- Involvement of the indigenous people of the Arctic in decisions that affect them;
- Enhancing scientific monitoring and research on local, regional and environmental issues, and
- Meeting post-Cold-War national security and defense needs.

Background

The United States has been an Arctic nation, with important interests in the region, since the purchase of Alaska over a century ago. National security, economic development and scientific research remain cornerstones of these interests. At the same time, the pace of change in the region—particularly political and technological developments—continues to accelerate, creating added interdependence and new challenges and opportunities for policy makers in Arctic nations.

U.S. Arctic policy reflects these elements of continuity and change. It emphasizes environmental protection, environmentally sustainable development, human rights and the role of indigenous people, while recognizing U.S. national security requirements in a post-Cold-War world. It also is concerned with the need for scientific research, particularly in understanding the role of the Arctic in global environmental processes, and the importance of international cooperation in achieving Arctic objectives.

The U.S. works in consultation with the State of Alaska, Alaskan indigenous people and Alaskan non-governmental organizations (NGOs) on Arctic issues and policy making. Federal agencies will continue to give careful consideration to local Alaskan needs, including the unique health, cultural and environmental concerns of indigenous people when developing Arctic plans and policies. Representatives of the State of Alaska, Alaskan indigenous people and Alaskan NGOs will continue to be included as appropriate on U.S. delegations to Arctic-related international meetings. The U.S., also, has set as a high-priority goal gaining on-par representation for its Athabascan and Aleut populations in Alaska as Permanent Participants on the Arctic Council.

Arctic Environmental Protection Strategy

The U.S. expanded its international cooperation under the Arctic Environmental Protection Strategy (AEPS).

Beginning in 1989, the eight Arctic countries—United States, Canada, Denmark, Finland, Iceland, Norway, Russia and Sweden—began discussions on improving Arctic cooperation. In 1991, in Rovaniemi, Finland, they reached agreement on the Arctic Environmental Protection Strategy (AEPS). The AEPS has primarily operated through four working groups to address environmental issues relevant to the circumpolar area.

Sustainable Development and Environmental Protection

A basic premise of U.S. Arctic policy is that the work of the Arctic Council, particularly in the field of sustainable development, needs to build on the environmental protection considerations of the Arctic Environmental Protection Strategy (AEPS), which is now an integral part of the Council. The

Arctic Council Declaration describes sustainable development as "including economic and social development, improved health conditions and cultural well-being." Further, the concept of sustainability is reflected in its description of environmental protection which refers to "the health of the Arctic ecosystems, maintenance of biodiversity in the Arctic region and conservation and sustainable use of natural resources." Terms of Reference for the Council's sustainable development efforts are currently being negotiated between the eight Arctic governments with the participation of the region's indigenous communities. And a process has begun to identify, from a U.S. perspective, issues within the arena of Arctic sustainable development upon which circumpolar attention might reasonably be directed either in the form of a high-level discussion at biennial meetings of the Council itself or implementation of specific cooperative activities.

Scientific Research

The United States plans to further scientific research through development of an integrated national Arctic research program. This would include support for international cooperation in monitoring, assessment and environmental research.

The Interagency Arctic Research Policy Committee, with advice from the U.S. Arctic Research Commission, coordinates Federal efforts to produce an integrated national program of research, monitoring, assessments and priority-setting that most effectively uses available resources. U.S. Arctic policy recognizes that cooperation among Arctic nations, including coordination of priorities, can make essential contributions to research in the region. To this end the results of the AMAP assessment on the state of the Arctic environment should be an important tool in determining research priorities for the future.

AEPS Implementing Working Groups

Arctic Monitoring and Assessment Program (AMAP): Assesses the health and ecological risks associated with contamination from radioactive waste, heavy metals, persistent organics and other contaminants. Recommends targeted monitoring to collect current data from areas of special concern.

Conservation of Arctic Flora and Fauna (CAFF): Studies the adequacy of habitat protection and ways to strengthen wildlife protection through an international network of protected areas and more effective conservation practices.

Protection of the Arctic Marine Environment (PAME): Creates international guidelines for the offshore oil and gas development in the Arctic, organizes and promotes the drafting of a regional action plan for control of land-based sources of Arctic marine pollution, and collects information on Arctic shipping activities.

Emergency Prevention, Preparedness and Response (EPPR): Develops and refines an environmental disaster "risk assessment" for the Arctic, reviews emergency notification systems, conducts spill response exercises, recommends cleanup and other response measures.

Conservation

The United States works, both nationally and internationally, to improve efforts to conserve Arctic wildlife and protect habitat, with particular attention to polar bears, walruses, seals, caribou, migratory birds and boreal forests. Consistent with the Agreement on the Conservation of Polar Bears, the U.S. is discussing ways to improve conservation of polar bear populations whose range extends to Russia and the United States. The U.S. also works to better implement existing measures, such as the 1916 Migratory Bird Treaty, to conserve populations of migratory species of birds that breed in the Arctic.

Cooperation with Russia and Other Nations

The United States engages the Russian Federation on Arctic environmental issues on a bilateral and multilateral basis. The U.S.–Russian Joint Commission on Economic and Technological Cooperation (commonly known as the Gore–Chernomyrdin Commission or GCC) remains the principal venue for a bilateral dialogue on environmental issues, including species conservation and anti-poaching campaigns. In addition to the broad-based cooperation within the Arctic Council, and its predecessor, the AEPS which, inter alia, aid in establishing a more effective environmental regulatory infrastructure in Russia, other multilateral fora now exist to address specialized concerns. Through NATO, we engage the Russian military on defense-related environmental issues. On a trilateral basis, with Norway, we focus on cleanup and consolidation of waste generated from military activities through the Arctic Military Environmental Cooperation (AMEC) process. Our continued support of the International Atomic Energy Agency's International Arctic Seas Assessment Program also provides a conduit for monitoring and assessing radioactive contaminants in the seas adjacent to the Russian Arctic.

Selected Meetings of Interest

Listed here is a compilation of recent and forthcoming meetings, workshops and conferences on Arctic or northern topics and activities. Readers are invited to submit information on upcoming meetings, as well as reports on national or international meetings attended, to Editor, Arctic Research, *Arctic Research and Policy Staff, Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22203.*

1997

Polar Processes and Global Climate
3–6 November 1997, Rosario Resort, Orcas Island, Washington, USA
Contact: Roger Colony, Director, IAPO, P.O. Box 5072, Majorstua, N-0301 Oslo, Norway
E-mail: acsys@npolar.no
or
The Scientific Organizing Committee:
Knut Aagard: aagard@apl.washington.edu
Dennis Hartman: dennis@atmois.washington.edu
Vladimir Kattsov: kattsov@mgo.spb.su
Ron Steward: rstewart@dow.on.doe.ca
Andrew Weaver: weaver@ocean.seos.uvic.ca

Problems with Cold Work
16–20 November 1997, Stockholm, Sweden
Contact: Professor Ingvar Holmér, National Institute for Working Life, Department of Ergonomics, S-171 84 Solna, Sweden
Phone: 46 8 730 9100
Fax: 46 8 730 1967
E-mail: iholmer@niwl.se
Web site: http://www.niwl.se/foprog/climate/climate.htm

Sealing—The Future; International Conference and Exhibition
25–27 November 1997, St. John's, Newfoundland, Canada
Contact: NAMCO–North American Marine Mammal Commission, c/o University of Tromsø, N-8037 Tromsø, Norway
Phone: 47 77 64 59 08
Fax: 47 77 64 59 05
E-mail: nammco-sec@nammco.no

XX Symposium on Polar Biology
4–5 December 1997, National Institute of Polar Research, Tokyo, Japan
Contact: Secretariat, XX Symposium on Polar Biology, National Institute of Polar Research, 9-10 Kaga 1-chome, Itabashi-ku, Tokyo 173, Japan
Phone: +813-3962-4569
Fax: +813-3962-5743
E-mail: iwao@nipr.ac.jp

1998

1st European Cold Conference
7th National Symposium on Cold
11–16 January 1998, Kiruna and Jukkasjärvi, Lapland, Sweden
16–18 January 1998, Satellite symposium in Archangelsk, Russia
Contact: Pär Granlund
Phone: +46 920 75 085
Fax: +46 920 75 084
E-mail: granlund.dol@interact.se

International Symposium on Okhotsk Sea and Sea Ice
1–5 February 1998, Mombetsu, Hokkaido, Japan
Contact: Mr. Soshi Hamaoka, Secretariat of the Okhotsk Sea and Cold Ocean Research Association, Okhotsk Sea Ice Science Research Co., 25-2 Motomombetsu, Mombetsu, Hokkaido, 094 Japan
Phone: 81 1582 3 1100
Fax: 81 1582 3 1514
or
Dr. Kunio Shirasawa, Chair of Program Committee
E-mail: kunio@pop.lowtem.hokudai.ac.jp

Third International Congress for Arctic Social Sciences: Changes in the Circumpolar North. Culture, Ethics and Self-Determination
21–23 May 1998, Copenhagen, Denmark
Contact: Frank Sejersen, Coordinator, IASSA Secretariat, c/o Dept. of Eskimology, Strandgade 100 H, DK-1401 Copenhagen K, Denmark
Phone: 45 32 88 01 67
Fax: 45 32 88 01 61
E-mail:iassa@coco.ihi.ku.dk

ISOPE-98: 8th International Offshore and Polar Engineering Conference
24–29 May 1998, Montreal, Canada
Contact: Jin S. Chung, ISOPE, PB 1107, Golden, Colorado 80402-1107, USA
Phone: 1-303-273-3673
Fax: 1-303-420-3760

5th International Symposium on Mining in the Arctic
14–17 June 1998, Yellowknife, N.W.T., Canada
Contact: Symposium Secretariat, Canadian Institute of Mining, Metallurgy and Petroleum, Xerox Tower, 1210-3400 de Maisonneuve Boulevard West, Montreal, Quebec, Canada H3Z 3B8
Phone: 1-514-939-2710
Fax: 1-514-939-2714

Seventh International Conference on Permafrost and IPA Council Meeting
23–27 June 1998, Yellowknife, N.W.T., Canada
Contact: J.A. Heginbottom, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8
Phone: 1-613-992-7813
Fax: 1-613-992-2468
E-mail: permafrost.conference@gsc.emr.ca
Web sites: http://www.nrcan.gc.ca/gsc/permaf_e.html (English)
http://www.nrcan.gc.ca/gsc/permaf_f-html (French)

The International Arctic Science Committee has established a new service to the Arctic research community: an Arctic meetings listing available via the Internet. Called SAM (Survey of Arctic Meetings), it contains information on international Arctic meetings, as well as major national meetings with international participation. The World Wide Web address for SAM is http://www.npolar.no/iasc/sam.htm.

International Congress on the History of the Arctic and Sub-Arctic Region
18–21 June, 1998, Reykjavik, Iceland
Papers and other contributions by 31 October 1997 to:
Professor Ingi Sigurdsson, Institute of History, University of Iceland, IS-101, Reykjavik, Iceland
Phone: 354.525 4426
Fax: 354.525 4242
E-mail: ingi@rhi.hi.is
Information/registration:
International Congress on the History of the Arctic and Sub-Arctic Region, Iceland Tourist Bureau, ITB-Congrex, Skógarhlid 18, IS-101 Reykjavik, Iceland
Phone: 354-562 3300
Fax: 354-562 3345/562 5895
E-mail: congrex@itb.is

Fifth Circumpolar Remote Sensing Symposium
22–26 June 1998, University of Dundee, Scotland
Deadline for abstracts: 31 March 1998.
Contact: Miss S. K. Newcombe, Fifth Circumpolar Remote Sensing Symposium, Dundee Centre for Coastal Zones Research, Department of Applied Physics and Electronic and Mechanical Engineering, University of Dundee, Dundee DD1 4HN, Scotland, UK
Phone: +44 1382 344933
Fax: +44 1382 345415
E-mail: s.k.newcombe@dundee.ac.uk

International Society of Soil Science Congress–Cryosols
8–17 July 1998, Montpellier, France
Contact: David Gilchinsky, Institute of Soil Science and Photosynthesis, Russian Academy of Sciences, 124292 Pushchino, Moscow Region, Russia
Phone: 7 095 923 3558 (Moscow)
Phone: 7 095 923 1887 (Pushchino)
E-mail: gilchin@issp.serpukhov.su

14th International Symposium on Ice
27–31 July 1998, Clarkson University, Potsdam, NY, USA
Contact: Eileen Winters, 14th Ice Symposium, CEE Department, P.O. Box 5710
Clarkson University, Potsdam, NY 13699-5710, USA
Phone: 1-315-268-3856
Fax: 1-315-268-7985 or 7636
E-mail: eileen@draco.clarkson.edu
Web site: http://www.clarkson.edu/~htshen/icesyp.html

IASC/SCAR Symposium on Global Changes in the Polar Regions–Results and Challenges from Bipolar Science
August/September 1998, Tromsø, Norway
Contact: Executive Secretary, IASC, Secretariat, P.O. Box 5072, Majorstua, 0301 Majorstua, Oslo, Norway
Phone: 47 22 95 96 00
Fax: 47 22 95 96 01
E-mail: iasc@npolar.no

International Symposium on Glaciers and the Glaciated Landscapes
17–20 August 1998, Kiruna, Sweden
Contact: Secretary General, International Glaciological Society, Lensfield Road, Cambridge CB2 1ER, United Kingdom
Phone: 44 1223 355974
Fax: 44 1223 336543
E-mail: 100751-1667@compuserve.com

International Symposium on Polar Aspects of Global Change and Field Trip to Svalbard
24–28 August 1998, Tromsø, Norway
Contact: International Symposium on Polar Aspects of Global Change, c/o Norwegian Polar Institute, N-9005 Tromsoe, Norway
E-mail: jaklin@tromso.npolar.no

17th Polar Library Colloquy
Autumn 1998, Reykjavik, Iceland
Contact: Eirikur Einarsson, Marine Research Institute, P.O. Box 1390, 121 Reykjavik, Iceland
Phone: 354 552 0240
Fax: 354 562 3790
E-mail: eirkur@hafro.is

International Conference on Snow Hydrology: The Integration of Physical, Chemical and Biological Systems
6–9 October 1998, near Windsor, Vermont, USA
Contact: Janet Hardy, Chair, Snow Hydrology Conference, Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, NH 03755, USA
Phone: 1-603-646-4306
Fax: 1-603-646-4397
E-mail: jhardy@crrel.usace.army.mil

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Back Cover

Tanana River in interior Alaska. Large rivers are major geologic features of interior Alaska. The rivers, and the active nature of their channels, are of major ecological importance in the Alaskan taiga. (Photo by John Haugh, BLM.)

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