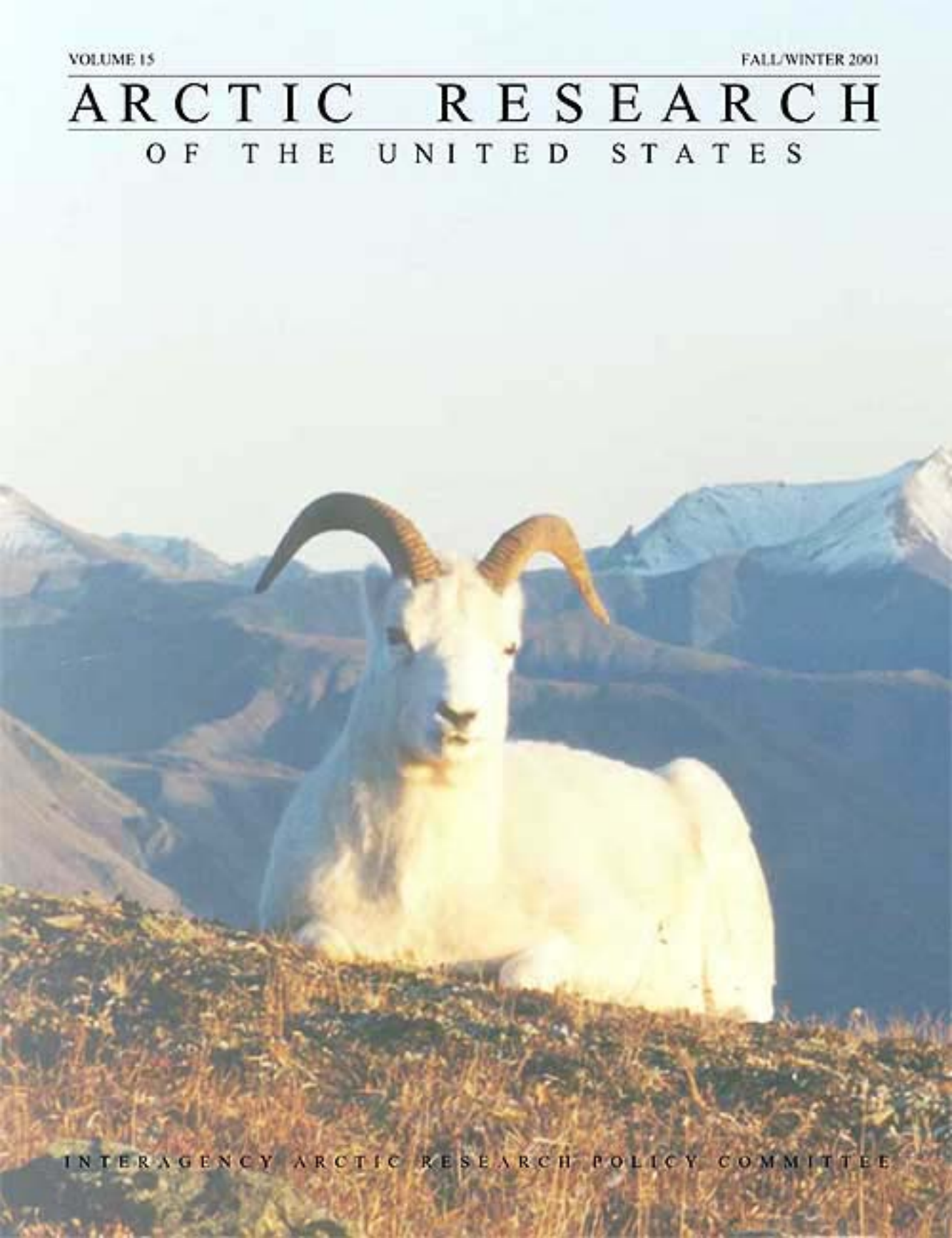
VOLUME 15 FALL/WINTER 2001

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 (IARPC) and the Arctic Research Commission (ARC). Both the Interagency Committee and the Commission were authorized under the Arctic Research and Policy Act (ARPA) 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; and
- Summaries of other current and planned Arctic research, including that of the State of Alaska, local governments, the private sector, and other nations.

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.

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Cover

Dall ram at Denali National Park. (Copyright 2000 by Tony Reynolds; used by permission.)

VOLUME 15 FALL/WINTER 2001

ARCTIC RESEARCH

OF THE UNITED STATES

United States Arctic Research Plan

Biennial Revision: 2002–2006

Introduction

The United States Arctic Research Plan was prepared by the Interagency Arctic Research Policy Committee (IARPC). The Plan is a consensus document that reflects the views of twelve IARPC agencies. It responds to recommendations of the U.S. Arctic Research Commission and to recommendations of scientists who provided advice to the IARPC agencies.

The Plan includes three special focus multiagency research programs agreed to by the Federal agencies and includes multiagency cross-cutting issues such as research support and logistics, facilities, international activities, and data and information. The Plan describes high-priority research needs of the agencies but does not include every possible Arctic research idea that might be suggested. The Plan also responds to environmental and strategic objectives of U.S. Arctic policy.

The Plan is a living document. In accordance with the Arctic Research and Policy Act, it is revised every two years.

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 updates the Plan and elaborates on the 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, chaired by the National Science Foundation (NSF), continues to provide the mechanism for developing and coordinating U.S. Arctic research activities.

Revision to the Plan

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

- Study of Environmental Arctic Change (SEARCH)
- Bering Sea Research
- Arctic Health Research.

The second major section is the Agency Programs, which represent the objectives of Federal agencies, focusing on the period covered by this revision (2002–2006). They are presented in seven 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
- 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 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 2000–2002 period. The total interagency Arctic budget estimate for FY 01 is $240 million; for FY 02 it is $233 million. Program descriptions may be assumed to reflect the general direction of agency programs.

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

1. Introduction

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), the Declaration on Establishment of the Arctic Council (announced by the U.S. Department of State), research goals and objectives agreed upon by the Interagency Committee, and guidance provided by the Arctic Research Commission.

1.1.1 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;
- 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.

U.S. Arctic research uses the northern polar region as a natural laboratory to study processes that also occur at lower latitudes. 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.

1.1.2 Nonrenewable Resources

The U.S. imports approximately 50% of its petroleum needs. About 17% of our domestic oil production comes via the Trans-Alaska Pipeline System from the Prudhoe Bay region in Arctic Alaska. The Department of the Interior (USGS and MMS) estimates that at least 36% of the Nation's future reserves (undiscovered resources) of oil and natural gas liquids lie beneath northern Alaskan and the adjacent offshore areas. The State of Alaska reports that northern Alaska contains known gas reserves of 30.9 trillion cubic feet (tcf), which is about 18% of the Nation's gas reserve; currently plans are being discussed for a gas pipeline to transport this resource south. Additionally the Department of the Interior reports that there are approximately 160 tcf of undiscovered natural gas in northern Alaska and offshore, which is approximately 30% of the Nation's undiscovered natural gas. Gas hydrate resources of Arctic Alaska have been estimated by the USGS to range from 0 to 119,000 tcf (at 95 and 5% probabilities), with a mean estimate of 32,894 tcf. The USGS estimates that 98% of these resources occur under Federal waters in the Beaufort Sea.

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.

1.1.3 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

fishing fleets 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.

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. A number of other important fish and non-fish species are declining in North Pacific and Bering Sea coastal systems as well. For example, Pacific salmon runs have been at all-time lows in several major western Alaska watersheds over the past few years. Sea otters in the western Aleutians have declined dramatically. There are concerns that walruses may be experiencing population changes because of shifts in ice distribution. Populations of terrestrial and marine birds exhibiting significant declines include loons; sea ducks such as the threatened Steller's and spectacled eiders, and at-risk species such as black scoter, long-tailed duck, and common eider; seabirds such as red-legged kittiwakes and common murres; and several shorebirds including bristle-thighed curlews and buff-breasted sandpipers. Importantly, for most of these species there is little known about their life history, population dynamics, and habitat requirements, thus complicating the identification of factors that may be limiting their recovery to former levels of abundance. Additionally, Alaska Natives living in many coastal villages near the North Pacific and Bering Sea depend on these species for subsistence. Changes in their distribution and abundance would be devastating to the villages.

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.

1.1.4 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. 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.

The Arctic ozone layer has exhibited significant changes—concentrations are decreasing. 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.

1.1.5 Social and Environmental Issues

Arctic populations live in close contact with their environment and are highly dependent on marine and terrestrial ecosystems. Contaminants pose a potential threat to the health of Arctic residents who rely on subsistence foods (fish, marine mammals, moose, and caribou). Heavy metals, organochlorines, soot, and other pollutants accumulate at high latitudes because of atmospheric and oceanic circulation patterns and subsequent concentration in food

chains and organic soils. The effects of environmental change, including climate changes, can have enormous impacts on Arctic ecosystems, on the response of wildlife to ecosystem productivity, and on the human use of wildlife.

Other issues of importance to Arctic residents include social and economic changes such as those resulting from large-scale development and population influx. Many of these changes are positive, such as increased educational and employment opportunities, better medical care, and the use of modern technology. Other changes, such as social and cultural disruption, have been a cause for concern. Research addressing the phenomena of rapid social change, human–environment interactions, and the viability of small subsistence-dependent communities sheds light on the complex relationships between environment, economy, culture, and society.

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

High latitudes are also particularly susceptible to adverse conditions in the space environment, which can disrupt satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic 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, which bring bright, dynamic auroral displays and 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.

1.1.6 U.S. Goals and Objectives for 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 their 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 Arctic research funding for the 2000–2002 period. The total interagency Arctic expenditure for FY 00 was $242 million; for FY 01 it is $240 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 02. 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 00 Actual*	*FY 01 Actual*	*FY 02 Proposed*
DOD	23.3	20.4	8.6
DOI	43.9	43.9	43.0
NSF	67.5	74.2	76.6
NASA	46.6	34.2	38.5
NOAA	29.7	30.7	32.8
DOE	4.7	4.2	4.0
DHHS	13.8	15.9	16.0
SI	0.5	0.5	0.5
DOT	6.3	10.9	7.9
EPA	0.7	0.7	0.4
DA	4.8	4.9	4.9
DOS	0.0	0.0	0.0
Total	241.9	240.4	233.3

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, chaired by 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 14, Spring/Summer 2000), published by NSF on behalf of the IARPC.

The Act mandates coordination of U.S. Arctic research programs. 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. These are reported in the subsequent sections.

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 October 13, 2000, in Barrow, Alaska, the U.S. Department of State completed its two-year chairmanship of the Arctic Council and handed the gavel to Finland for the 2000–2002 period. The Arctic Council is an eight-nation forum established in 1996 to bring together in a senior policy

setting the environmental conservation elements of the Arctic Environmental Protection Strategy (AEPS) and 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 United States), many of the Arctic's indigenous communities are recognized as Permanent Participants of the Arctic Council.

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 in 1867. 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 Department of State works in close consultation with the State of Alaska, Alaskan indigenous people, and Alaskan nongovernmental 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 communities, when developing Arctic programs and policies. Alaskans will continue to be included as appropriate on U.S. delegations to Arctic-related meetings. U.S. Inuit, Aleut, Gwich'in, and Athabaskan populations are now represented as Permanent Participants on the Arctic Council, the Gwich'in and Athabaskans as a result of a ministerial decision in October 2000 in Barrow, Alaska. The Council now has six Permanent Participants.

The Arctic Council today includes five observer nations (Germany, France, the Netherlands, Poland, and the United Kingdom) with Arctic research and environmental interests. These nations have contributed to the environmental working groups of the Council and, at the Barrow Ministerial meeting, stated that they were interested in taking a more active role in the Council's work. The U.S. welcomed the offer by the United Kingdom to host a preparatory meeting of the Senior Arctic Officials in London prior to the Ministerial meeting in Barrow.

1.4.1 Environmental Protection

The U.S. expanded its international cooperation during the U.S. Chairmanship beyond the scope of the Arctic Environmental Protection Strategy (AEPS).

The United States is fully engaged in the Arctic Council Action Plan to Eliminate Pollution in the Arctic (ACAP). The Environmental Protection Agency has provided leadership for an ACAP program to prevent production and remediate the effects of persistent organic pollutants in the Russian Federation. The U.S. also supports implementation of other projects to eliminate dioxins and obsolete pesticides from the Arctic.

The National Science Foundation and NOAA provide crucial leadership for the Arctic Climate Impact Assessment (ACIA), in cooperation with the Arctic Monitoring and Assessment Program, and for the Conservation of Arctic Flora and Fauna (CAFF) Working Group, in cooperation with the International Arctic Science Committee. The U.S. is financing a substantial portion of the ACIA Secretariat, among other contributions.

U.S. engagement in prevention and remediation activities follows a decade of international cooperation to monitor and assess the levels of environmental pollution. Beginning in 1989 the eight Arctic countries first discussed the need for international cooperation to address environmen-

tal protection. In 1991 in Rovaniemi, Finland, they reached agreement on AEPS. In 1996 in Ottawa, Canada, the Arctic Council was created to address issues of sustainable development in the Arctic and to oversee and coordinate the programs established under 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 Preparedness and Response (EPPR):* Provides a forum in which participants work to better prevent, prepare for, and respond to the threat of environmental emergencies in the Arctic. Activities include risk assessment and recommendation of response measures.

Arctic Council Ministers approved the recommendation that the Senior Arctic Officials, under the leadership of the Finnish Chair, review the allocation of environmental work among the four working groups (AMAP, CAFF, PAME, EPPR) to remedy gaps and duplication, if any.

1.4.2 Sustainable Development

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 the 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."

At the Barrow Ministerial meeting in October 2000, Ministers endorsed and adopted the Arctic Council's Sustainable Development Framework Document, which forms a basis for continuing cooperation on sustainable development in the Arctic. The Framework Document, consistent with the Terms of Reference and Iqaluit Ministerial Declaration, identifies sustainable development projects, cooperative activities, and priorities for the Council's consideration.

In 1998, Ministers approved several sustainable development project proposals. In Barrow, Ministers welcomed the work accomplished during the 1998–2000 period. The U.S., with leadership from the Institute for Circumpolar Health Studies at the University of Alaska Anchorage, completed its report on Arctic telemedicine. Alaska's Department of Community and Economic Development has a network of private, nongovernmental, and Arctic Council member states in support of its Arctic ecological and cultural tourism project. Ministers at Barrow approved a project of the Arctic Investigations Program of the U.S. Centers for Disease Control and Prevention (CDC) to establish an integrated infectious disease–International Circumpolar Surveillance (ICS) system through a network of hospital and public health laboratory authorities in the Arctic.

1.4.3 Scientific Research

The United States continues to plan to further international scientific research through development of an increasingly integrated national Arctic research program. During the U.S. Chairmanship the U.S. took steps to support international cooperation in monitoring, assessment, and environmental research, as well as social science research related to sustainable development. U.S. support for the Arctic Climate Impact Assessment is a key example of promoting international collaborative research in the environmental sciences and in social science related to sustainable development.

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 Framework Document on Sustainable Development, support for the Survey of Living Conditions in the Arctic, and the

AMAP assessment on the state of the Arctic environment provide an important tool in influencing future research priorities.

1.4.4 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. and Russia signed an agreement in October 2000 to improve conservation of their shared population of polar bears. Several official studies are ongoing, including a study of pollution contamination of seals around two villages in northern Alaska. The U.S. also works to better implement existing measures, such as the 1916 Migratory Bird Treaty and other conservation measures, to mitigate seabird bycatch by commercial fishing vessels.

1.4.5 Cooperation with the Russian Federation and Other Nations

Via the Department of State's Environmental Diplomacy Funds (EDF), the U.S. is supporting international projects that assess pollutants in Russia for the benefit of the entire Arctic region. In FY 00, EDF contributed to an Arctic-Council-led project on Persistent Toxic Substances, Food Security, and Indigenous Peoples of the Russian Far North. The project will establish an air quality monitoring station in the Russian Far East to gather high-quality, comprehensive data on pollutants in the Russian Arctic. This project will also assess local pollution sources that affect the traditional foods of Natives in Russia. In FY 01, EDF will help support the Swedish-led Evaluation of Dioxins and Furans in the Russian Federation. The findings of these projects will have relevance not only in Russia, but in the entire Arctic region. U.S. financial and resource contributions to these projects ensure a strong international presence on issues that ultimately affect our own Arctic inhabitants and ecosystems.

In addition to the broad-based cooperation within the Arctic Council, which, among other things, aids in establishing a more effective environmental regulatory infrastructure in Russia, other multilateral forums 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 the cleanup and consolidation of waste generated from military activities through the Arctic Military Environmental Cooperation (AMEC) process. Our 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.

The former Soviet Union (FSU) had an extensive nuclear power program with numerous supporting waste management activities that involved ad hoc storage of low- and intermediate-level radioactive wastes by shallow land burial and in surface water impoundments, as well as storage of high-level wastes. The Mayak, Tomsk, and Krasnoyarsk sites all lie within a few kilometers of the edge of the West Siberian Plain and Basin. Past and continuing disposal of wastes at Mayak, Tomsk, and Krasnoyarsk to surface waters (for example, the Ob and Yenisey Rivers) and surface water impoundments, and by deep well injections at Tomsk and Krasnoyarsk, have the potential for contaminating the Arctic Ocean, the western Siberian oil and gas fields, and the regional water resources.

1.5 Revision to the Plan

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

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

The Agency Programs represent the objectives of Federal agencies, focusing on the period covered by this revision (2002–2006). They are presented in eight major categories, and where common activities exist they are presented as collective activities. Individual agency mission accomplishments were discussed in the Spring/Summer 2000 issue of *Arctic Research of the United States* and will be updated in 2002. 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
Interagency 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 three programs are ready for immediate attention as multiagency focused efforts:

- Study of Environmental Arctic Change (SEARCH)
- Bering Sea Research
- Arctic Health Research.

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 of the causes, effects, and limits of air and water pollution; and
- Protection and understanding of cultures and cultural resources.

2.1 The Study of Environmental Arctic Change (SEARCH)

The Arctic Ocean and the surrounding lands and seas are seemingly remote areas for most of us, yet ongoing changes in this area may have profound impacts not only on the people and economies of the region, but also on residents throughout the Northern Hemisphere and beyond. Native subsistence hunters and others with a keen sense of observation have noted substantive changes in the physical environment and in the behavior of wildlife.

"Last spring we only got six walrus because of the weather and ice moving out too quick. I talked to elders about the weather. A long time ago it used to be real nice for weeks and even sometimes for months. Now we only have a day or two of good weather. And a lot of times it is real windy now. They don't know what is causing that either. And the hunters that I talked with about the ice conditions say it is getting a lot thinner. It is going out too quick. Maybe it is because of the weather. Maybe it is because of that global warming."

Herman Toolie, Savoonga, St Lawrence Island, 2000

"My people hunted beaver in Hay Slough for over 100 years, and in one house we had 32 beaver. Because a lot of our lakes don't freeze as deep. We are having more warmer winters than usual on a consecutive basis. What's happening is that because the winters are warmer, the lakes don't freeze all the way down and more of the young beavers survive. We now have more beaver than ever in this slough because of warm winters that give the beaver the most favorable conditions to survive. The beaver then proceed to dam and tier off the sloughs so resident species of fish, which again provides the Indians with a very viable source of food, cannot reach their spawning ground to provide the next generation of food for the Indians of the Interior."

Paul Erhart, Fairbanks, 2000

Scientists are documenting concurrent large-scale changes in the Arctic,* of which these local fluctuations are a reflection. There is strong observational evidence consistent with thinning of the Arctic ice pack and a decrease over time of the maximum extent of the sea ice cover. The state of the Arctic atmosphere has changed over the past few decades, changing temperature and wind patterns and causing ice to circulate differently in the Arctic Ocean. Warm Atlantic water has intruded unusually far into the eastern Arctic Ocean. Surface air temperatures throughout much of the Arctic are increasing, especially in winter and spring, leading to thawing of permafrost and earlier ice melting. Stratospheric ozone over the Arctic is diminishing in the spring, leading to elevated UV levels reaching the surface.

These physical changes are leading to changes in the biosphere. Canadian studies demonstrated that polar bears are malnourished because of a shortened hunting season caused by earlier retreat of shorefast ice. Walrus are finding fewer sturdy ice floes to serve as haulout areas. The tree line is advancing, consistent with the milder winters. Beavers are flourishing in the milder climate, causing increased damming of rivers that reduces the return of salmon to spawning grounds.

In the Arctic itself, these physical and biological changes have social and cultural consequences for the Native communities and lifestyle and economic consequences for all Arctic residents. Because these changes in the Arctic environment make it difficult to predict what tomorrow may bring, the entire complex of changes has been given the name "Onami," which is derived from the Yup'ik word for "tomorrow."

The dramatic environmental changes seen in the Arctic over the past few decades will almost certainly create daunting environmental and socioeconomic challenges (or, perhaps, new economic or social opportunities?) in the Arctic region itself, but can these changes affect a much larger portion of the earth? For the most part, the observed changes relate to the physical environment and are thought to be linked to climate variability or change. Whether the processes at work are entirely natural or are being caused or strengthened by human activities, impacts to a much larger area can occur in at least two major ways: via the atmosphere and via the oceans.

Evidence is mounting that the state of the Arctic atmosphere, as characterized by the Arctic Oscillation index,† strongly influences seasonal weather patterns over the U.S. The Arctic Oscillation was only recently described, and our understanding of its influence on weather and climate is at an early stage. In a preliminary finding the National Weather Service has stated that for the eastern third of the U.S., "the AO is the single most important factor in wintertime seasonal temperature variability." They also stated that at this time it is the most difficult factor to forecast seasonally with skill.

While connections through the atmosphere can influence weather and climate outside the Arctic on seasonal and interannual scales, connections through the oceans operate over time scales of up

* The areal extent of the "Arctic" for the Study of Environmental Arctic Change includes not only all areas north of the Arctic Circle, but also the entire Bering Sea, the Labrador Sea, the far North Atlantic, the entire permafrost zone on land, and watersheds that drain into the Arctic Ocean.

† The Arctic Oscillation index is defined as the first empirical orthogonal function of the Northern Hemisphere winter sea level pressure field. The AO can be thought of as the difference between the weighted average of sea level pressure over the entire midlatitude belt centered near 45°N and the weighted average of sea level over the entire Arctic basin. The AO has been in a strong positive state for the past decade.

to several decades. The global thermohaline circulation (THC), in concert with the Gulf Stream, carries a significant amount of heat north and east across the North Atlantic to northern Europe and Scandinavia. Processes in the North Atlantic and Arctic strongly influence the rate at which the THC transports water. It is theoretically possible that increases in the flux of fresh water from the Arctic can decrease the rate of the THC and cause a significant cooling effect in Northern Europe and Scandinavia and perhaps even trigger an increase in glaciation over much of the Northern Hemisphere. There is evidence that such changes have occurred in the past, perhaps even over short time scales of about 10 years. The National Academy of Sciences has begun a study of "abrupt climate change" that will consider the scientific evidence regarding the causes and probabilities of such events.

The U.S. agencies that conduct or sponsor scientific activities in the Arctic have agreed that greater attention must be given to Arctic environmental processes and their potential impacts on the biosphere, including human social and economic well being. Many of these agencies have joined together to support the Study of Environmental Arctic Change (SEARCH). The SEARCH program will consist of research, monitoring, and analysis activities to track and quantify environmental changes in the Arctic, distinguish causative factors, assess environmental and socioeconomic impacts, provide an analysis of the changes that may be expected in the future, and provide outreach to policy makers and the public.

2.1.1 Evidence for Climate Variability and Change in the Arctic

The earth's climate is not constant. There are climate cycles that vary over seasonal to centennial scales, and sudden climate changes can be induced by rare events (such as meteor impacts or volcanism). Now there is a new worry—that human activities may cause climate change. The primary cause of this worry is the undeniable build-up of carbon dioxide in the atmosphere as a result of a century of accelerating combustion of fossil fuels. Most worrisome is the recognition that the use of fossil fuels will continue to increase for decades to come, resulting in concentrations of carbon dioxide in the atmosphere that may exceed the pre-industrial level by four times or more. Already, there is solid evidence of significant increase of surface temperatures on a global basis and of increased storage of heat in the global oceans.

In the Arctic the increase in surface temperature has been quite dramatic over the past 30 years, leading to changes in a number of environmental parameters sensitive to temperature. The temperature changes seen in the Arctic are consistent with the output of global climate models forced with increasing concentrations of atmospheric carbon dioxide. Many studies have been reported over the past decade that argue that the Arctic may be a sensitive indicator of global change. Models show that under a representative global warming scenario, temperature increases will be amplified in the Arctic, and the upper Arctic Ocean salinity will decrease because of enhanced precipitation at high latitudes. Archaeological studies have shown that human cultures have been drastically affected by such terrestrial and ocean-based changes. For example, studies have demonstrated a dramatic expansion of Vikings across the North Atlantic and their settlement of Iceland and Greenland during a warm climatic period, followed by their subsequent extinction from Greenland during the early part of the Little Ice Age. Similar human impacts have been documented in the archaeological records for virtually every area of the circumpolar region and are especially well known in Labrador and the eastern North American Arctic.

Recent Changes

Even though science cannot at present provide irrefutable arguments regarding the cause(s) of the recent observed global and Arctic warming, studies have proven that these changes are unprecedented over at least the last 400 years, although the Arctic has experienced more significant changes during the past 8000 years. The rapid changes that have occurred in the last decades provide the motivation for SEARCH, and it is useful to review a few of these key findings.

In the ocean the warming influence of Atlantic water appears to have started in the late 1980s and has persisted through the 1990s. Data collected during several cruises in 1993–1995 indicate that the boundary between the eastern and western halocline types has shifted from over the Lomonosov Ridge to roughly parallel to the Alpha and Mendeleyev Ridges. In terms of longitudinal coverage, this means that the area occupied by the eastern, Atlantic water types is nearly 20% greater than previously observed. This distribution has persisted well into 1999, although the Atlantic water temperature appears to have ceased to increase in 1998.

The observed shift in ocean frontal positions is associated with changes in ice drift and atmospheric pressure patterns. The ice drift and pressure fields for the 1990s are shifted counterclockwise 40°–60° from the 1979–1992 pattern, just as the upper ocean circulation pattern derived from the hydrographic data is shifted relative to climatology. This change is consistent with the findings that the annual mean sea level atmospheric pressure over the central Arctic basin is decreasing and has been below the 1970–1995 mean in every year since 1988. This change in atmospheric pressure is part of the recent large change in atmospheric circulation of the Northern Hemisphere as captured by the AO index.

There have been changes in terrestrial variables as well. Increased air temperature has been attended by reductions in spring snow cover since the mid-1980s. Arctic glaciers have exhibited negative mass balances, paralleling a global tendency. Other studies point to increased plant growth, northward advances of the tree line, increased fire frequency, and thawing and warming of permafrost.

Long-Term Trends

There is evidence for multi-decadal and longer trends in several key Arctic variables. There has been pronounced warming over northern Eurasian and North American land areas since the early 1970s, particularly during winter and spring, partly compensated for by cooling over northeastern North America. Temperatures have also increased over the Arctic Ocean in spring and summer. These changes are in general agreement with those depicted in model anthropogenic change experiments. Reconstructions based on proxy sources indicate that late-20th-century Arctic temperatures are the highest in at least the past 400 years. Statistical analysis of this time series against records of known forcing mechanisms suggests that the recent warming has an anthropogenic component. Available observations point to long-term and recently augmented reductions in sea ice cover.

These physical changes coincide with a shift in the Arctic budget for biogenic carbon. Recent data suggest that past carbon accumulation in Arctic tundra has changed to a pattern of net loss, with growing season releases of up to 150 g m^{-2} yr^{-1}. The Arctic has been an overall significant sink for carbon over historic and recent geologic time scales, resulting in large stores of soil carbon of perhaps 300 gigatons. Present conditions appear to represent significant deviations from historic and Holocene carbon fluxes and indicate the potential for a positive feedback on global change through losses of CO_2 to the atmosphere of up to 0.7 Gt C yr^{-1} (about 12% of the total emission from fossil fuel use). These soil emissions augment the anthropogenic impact.

Links between the Arctic and the Global System

The Arctic is one of two primary sinks for solar energy, which enters the earth climate system most strongly in the equatorial regions; the other sink is the Antarctic. The observed changes impact the efficiency with which the Arctic can act as a heat sink. First, the Arctic Ocean's stratification and ice cover provide a control on the surface heat and mass budgets of the north polar region and thereby on the global heat sink. If the distribution of Arctic sea ice were to continue its present decrease, the altered surface fluxes would affect both the atmosphere and the ocean and would likely have significant consequences for regional and global climate.

Second, the export of low-salinity waters, whether liquid or in the form of desalinated sea ice, has the potential to influence the overturning cell of the global ocean through control of convection in the subpolar gyres. For example, recent suggestions that North Atlantic and Eurasian climate variability may be predictable on decadal time scales rest in part on the variability of such upstream forcing in the Greenland Sea.

Third, sea ice, nutrient availability, and water density condition Arctic marine life. Changes in these factors may impact marine ecosystems and biogeochemical cycling of essential nutrients and dissolved organic matter. Changes in the terrestrial hydrologic cycle may alter soil moisture, impacting plant communities and their grazers. If Arctic soils have shifted from a sink to a source of carbon dioxide and methane as indicated earlier, this would be a strong connection between Arctic processes and global climate.

Finally, the atmospheric circulation of the Northern Hemisphere has been changing as part of a pole-centered pattern, termed the Arctic Oscillation (AO). Recent modeling studies suggest that the AO is a fundamental mode of atmospheric change that has impact well beyond the Arctic. Other studies suggest that the positive trend seen in recent decades may be symptomatic of anthropogenic climate change.

2.1.2 The Human Dimension

There is a strong human dimension to the environmental changes of recent years. These have direct effects on the residents of the Arctic

because many of them live so close to the environment. Moreover, the changes seem to be having farther-reaching effects that touch society in sub-Arctic and even temperate regions through fisheries and transportation. For example, Canadian grain is being shipped through Churchill, on Hudson Bay, for the first time because of decreased ice cover in the Canadian Arctic.

Local and Regional Effects

The environmental changes discussed above affect the residents of the Arctic that subsist wholly or in part on Arctic flora or fauna. Indeed, the hunters and fishers of the north have made many of the observations of environmental change. They have recounted recent declines in abundance of a variety of fish species as well as marine mammals and seabirds. They have reported changes in the terrestrial environment, such as drying of lakes and wetlands, drying of summer vegetation, and thawing of discontinuous permafrost. Indigenous people are uniquely prepared to note the increased variability and decreased predictability of the physical environment. Examples of their reports of sea ice conditions, storm patterns, sea level, weather changes, snow, rain, and water temperatures and their effects on plant and animal food sources show remarkable connections to the changes cited in the scientific literature.

Changes in the physical and biotic environment have impacts beyond the local village and community scales. Changes in the duration and extent of pack ice cover influence the abundance of polar bears and seals; changes in seawater temperature in Baffin Bay have a profound impact on the West Greenland and Baffin cod and halibut fisheries; and changes in temperature and snow cover influence the population sizes of caribou, muskox, and small fur-bearers that northern residents depend on for food, clothing, and income. The presence or absence of polynias and open ice leads influences the availability of sea mammals to hunters, and the amount of stormy weather can determine whether hunters can reach their prey even when game is present. Modern Arctic residents confirm these and many other climatic and environmental changes that influence the distribution of Arctic resources important to humans in the north.

Large-Scale Effects

There is growing concern that the Arctic is a final destination for airborne contamination from the rest of the Northern Hemisphere. This is a major concern of the indigenous population. Further, the recent changes in the Arctic environment seem to have a connection with changes in the fisheries of the North Atlantic, the Bering Sea, the Barents Sea, and the Yukon River. These have resulted in regional economic change and a redistribution of income in many areas.

It is a mistake to think of the Arctic Ocean as being pristine. The recent report of the Arctic Monitoring and Assessment Program makes this abundantly clear. One reason is the atmospheric transport of semivolatile organic pollutants (DDT, PCBs, etc.) and mercury that enter the atmosphere in lower latitude regions and condense in the Arctic. Through this mechanism, we find concentrations of pollutants such as PCBs in Arctic fauna. In addition, there is local atmospheric pollution. The largest Arctic rivers drain some heavily industrialized zones, including portions of the former Soviet Union that were used heavily for the production and processing of radionuclides. Finally, there has been direct dumping of pollutants into the Arctic Ocean and toxic chemicals left behind after closure of former defense sites. It is difficult to predict what the future holds for the transport of pollutants into the Arctic, except to say that it is likely to change and that for some pollutants such as organochlorines and mercury there is legitimate concern. There is also concern that, just as the rising AO enhanced the northward heat flux, it may also be responsible for an increase in the northward flux of contaminants. These concerns have given rise to a lack of confidence in the safety of Native foods.

Over the past decade, large-scale ecological changes have impacted fishery-dependent societies around the world. Fishing pressure has been one driver for these changes, but often the changes have coincided with climatic variations as well. Economically critical groundfish populations, for example, exhibited steep declines or collapses off Norway, the Faeroe Islands, Iceland, West Greenland, Newfoundland, and New England during the late 1980s or early 1990s. The collapse of Newfoundland's northern cod fishery in 1991-92 occurred in conjunction with unusual ice conditions and a broadening of the cold intermediate layer of the Labrador Current during a Northwest Atlantic cooling phase of the NAO. Norway's cod fishery was partially recovering from its own crises (1989) during the same years, assisted by a Northeast Atlantic warming phase. West Greenland's cod fishery first developed as the warm Irminger Current extended northwards around 1920 but later declined and eventually collapsed (1992) as fishing increased and waters cooled.

Climate and ocean circulation variations direct-

ly affect commercial fish populations (particularly their reproduction, larvae, and food webs) through variables such as water temperature, salinity anomalies, vertical mixing, and currents. Moreover, fishing itself can increase the vulnerability of target populations to climatic change by altering age structure (for example, removing most of the robust and high-fertility older individuals) and densities among predatory fish populations and reducing the populations of food fish. Human adaptive efforts, in response to these ecological changes, include technological intensification, shifts to alternative species, economic diversification, government subsidies, and out-migration. Fishery-dependent communities throughout the northern Atlantic have experienced population losses during the past decade.

In the North Pacific a physical regime shift took place in the mid-1970s with an intensification of the Aleutian low-pressure system. Among the many changes associated with that shift were increased Alaskan salmon catches and a change from shrimp to groundfish dominance in the Gulf of Alaska. Similarities have been observed among the effects on fisheries of ecological changes in the Bering Sea, along the Newfoundland coast, and in the Barents Sea. The groundfish stocks associated with these areas have historically contributed to relatively stable fisheries over fairly long periods of time until recently. The cod and pollock fisheries seem to be drawing down mature age classes at rates that exceed recruitment in most years. Periodically, however, a good year provides exceptional juvenile survival, which builds the fishable stocks back up several years later as the young fish mature. We are uncertain of the ecosystem changes that are causing this. Both the Barents Sea fishery and the Canadian Atlantic fisheries saw a rapid increase in the industrial fishery in the 1950s and 1960s, combined with boundary disputes that frustrated fishery managers. It seems that when the natural fluctuations in productivity of the marine ecosystem are large, "normal fishing pressure" can be enough to deplete stocks beyond recovery in just a few years if oceanographic changes cause the good years to become less frequent. These fisheries, which are among the world's largest, may be extremely vulnerable to climate change.

An example of the potential interaction of climate and fisheries management is the recent collapse of some western Alaska salmon stocks and the curtailment of groundfish operations in the Bering Sea because of declines in the western populations of the Steller sea lion and northern fur seal. These are significant current management issues. The basic science problem with resource management is that fisheries agencies with responsibility over stocks important for human harvest are driven toward solving narrowly focused, short-term problems. For productive fisheries management, we need to understand how the whole system works, from climate influences to ocean circulation to ecosystem productivity to specific species that are important to humans.

These recent changes in sea ice conditions and weather have impacted local transportation. The changes may be most far reaching for their effect on the Northern Sea Route (NSR) along the Russian Arctic coast. The NSR has been a primary concern of Russian polar scientists for many years. Much of their research was done with the aim of improving predictions of shipping conditions along their Arctic Ocean coast. Now several nations, notably Japan and Russia (there are Alaskan interests as well), are examining the new potential of the NSR for trade. If the Arctic change affects navigability, this may change shipping patterns between Asia and northern Europe, altering the world economic significance of the Arctic Ocean. Impacts are likely, as well, on the use of the Northwest Passage through the Canadian Archipelago and on shipping into the Alaskan and Canadian North Slope. As noted above, light ice conditions in Hudson Bay now allow the use of Churchill as a shipping port.

2.1.3 Science Hypotheses

A complex suite of related atmospheric, oceanic, and terrestrial changes have dominated the Arctic in the last several decades. Because they have made it harder for those who live in the north to predict what the future may bring, this complex of recent changes has been termed "Onami," derived from the Yup'ik for "tomorrow." Onami is characterized among other things by:

- A decline in central Arctic sea level atmospheric pressure;
- Increased surface air temperatures in Northern Europe, the Russian Arctic, and western North America, with cooling over eastern North America and Greenland;
- Alterations in terrestrial precipitation and changes in vegetation;
- Cyclonic ocean circulation and rising coastal sea level;
- Increased temperature of Atlantic waters in the Arctic;

• Decreased sea ice cover; and
• Decreased Beaufort Sea surface salinity.

Learning the full scope of Onami will be an ongoing goal of SEARCH. However, a working definition based on present knowledge is useful. For this we define Onami as the recent and ongoing, decadal (3–50 year), pan-Arctic complex of intertwined changes in the Arctic system. These changes encompass the physical processes listed above, as well as resultant changes in ecosystems and living resources and consequent impacts to the human population. Four key working hypotheses have been developed to help guide SEARCH.

The first hypothesis is that Onami is related to the Arctic Oscillation. Associations between the AO and changes in many environmental parameters, such as air temperature and ocean circulation, have been documented. A key goal of SEARCH is to test this hypothesis by quantitatively assessing the interactions among the atmosphere, ocean, and land. It will tell us much about how Onami is tied to the global atmospheric system.

A second hypothesis is that Onami may be a component of anthropogenic climate change. The AO is a fundamental mode of atmospheric variability, and the increasing dominance of its positive mode may be tied to the anthropogenic component of climate change. Thus, Onami may be tied to climate change through the AO as well as through other large-scale patterns of atmospheric variability. Testing this hypothesis bears directly on the goal of understanding how Onami fits into the larger picture of global climate change.

A third hypothesis is that feedbacks among the ocean, land, ice, and atmosphere are critical to Onami. These feedbacks could determine whether the Onami, and therefore the Arctic, play critical roles in global climate change. For example, a decrease in sea ice and snow cover forced by higher temperatures could lead to further warming because of the reduction in albedo (the well-known ice–albedo feedback). This could in turn alter patterns of atmospheric circulation, further impacting Onami and snow and sea ice. A second example is albedo and sensible heat flux feedback through reductions or expansion in sea ice extent in marginal seas. The Barents, East Siberian, and Labrador Seas are especially sensitive to such change.

The final hypothesis is that the physical changes of Onami have large impacts on the Arctic ecosystems and society. This is true whether Onami is tied to either natural or anthropogenic climate change or is the result of other factors, including human activity. The key issues growing from this idea are that we must describe (and ultimately attempt to predict) the ecosystem and societal impacts of Onami, and we must distinguish between the changes associated with the large-scale physical Onami phenomenon and the changes caused by other human activity. Archaeological and paleoenvironmental studies can assist such investigations by presenting data sets from before periods of modern human impacts.

2.1.4 Objectives

The overarching goal of SEARCH is to understand Onami. This requires that we address the following objectives:

- Determining if Onami has happened before;
- Determining if Onami is continuing; and
- Understanding the forcing mechanisms and feedbacks that control Onami.

From this understanding the SEARCH Program will derive the ability to:

- Assess the predictability of Onami and, to the extent possible, develop a capability to predict the course of Onami;
- Assess and predict the impact of Onami on ecosystems and society; and
- Provide information of societal relevance in a timely way.

These objectives must be approached differently when dealing with different components of the Arctic system. For example, Onami relationships are perhaps most readily apparent in atmospheric and oceanographic data, such that research to understand processes and feedbacks can proceed without delay. Initial assessment is still needed in the biological realm, and in the human dimension the separation of effects of environmental change from those of society's actions remains a challenge.

2.1.5 SEARCH Organization and Interagency and International Coordination

SEARCH was conceived initially as a physical oceanography program, because recent changes in the Arctic environment were most readily apparent in the ocean and sea ice. It has rapidly become clear, however, that recent Arctic changes go well beyond the marine environment into the terrestrial environment and the atmosphere. Consequently SEARCH has been broadened into a thematic program extending across many scientific disciplines. It has become apparent that SEARCH must

include a long-term observation program, an international dimension, and a remote-sensing component. Because of this breadth, SEARCH requires support by multiple U.S. agencies, as well as international collaboration. Organizational efforts have been directed, to date, at developing an interagency effort for SEARCH and for making SEARCH part of the World Climate Research Program's International Program on Climate Variability and Predictability (CLIVAR).

IARPC and the Interagency Working Group for SEARCH

In the previous edition of the U.S. Arctic Research Plan (*Arctic Research of the United States*, Fall/Winter 1999), Arctic Environmental Change was one of the proposed research initiatives. In March 2000 the full IARPC met and, after a discussion of the SEARCH goals, formally established the Interagency Working Group for SEARCH and directed that it prepare an Interagency Research Plan for SEARCH. An initial interagency implementation plan was prepared in June 2000 to cover FY 01 activities related to SEARCH. In April 2001 the working group was given direction by the full IARPC to prepare similar implementation plans for FY 02 and FY 03.

SEARCH Organization in the Scientific Community

The SEARCH program will obtain scientific guidance through a Science Steering Committee (SSC) supported through a Project Office structure. The membership of the SSC consists primarily of scientists from U.S. academic institutions but includes representatives from government and international organizations. The present SEARCH SSC was formed to write the initial Science Plan. A new committee will be formed for the implementation phase of SEARCH and will have the responsibility for interpretation and implementation of the Science Plan in the principal investigator community.

Data archival will be a major task for SEARCH because of the heavy emphasis on long-term observations. Here, various data archival facilities with experience editing, storing, and displaying the wide variety of data types might be used, but their data must be centrally available. It should be possible with the use of the World Wide Web to create a distributed data bank that appears to the user as a centralized site. A similar paradigm should work to some extent for information dissemination.

National and International Coordination of SEARCH

The organizers of the SEARCH Program are taking steps to ensure proper coordination with Arctic science activities conducted by other groups and countries. The World Climate Research Program (WCRP) is the primary international activity for global climate research. It is the parent of two activities of relevance to SEARCH: CLIVAR and CLIC.

The Climate Variability and Predictability (CLIVAR) program is a major driver for U.S. research on climate. "Panels" represent the main efforts within the U.S. CLIVAR program. There are three CLIVAR panels: the Atlantic Panel, the Pacific Panel, and the Pan-American Panel. The panels are equally represented on the CLIVAR Science Steering Committee (SSC), which is also responsible for providing oversight of the panels. An interagency team representing NSF, NOAA, DOE, and NASA set up the SSC. These panels enable the program to provide a critical mass of resources, ensure coordination and communication between climate research activities (both within the U.S. and internationally), ensure a proper program balance by identifying and filling crucial gaps in the program, and strengthen the multiagency support for high-priority climate research in the U.S. In November 1999, SEARCH was proposed to the U.S. CLIVAR Scientific Steering Committee as a component of the U.S. CLIVAR program. The CLIVAR SSC response was positive, and SEARCH is now recognized as a component of CLIVAR.

The SEARCH SSC has been encouraged to establish close ties with other international programs, such as the Climate and Cryosphere (CLIC) program. Like CLIVAR, such programs operate under the WCRP and have received significant support in Europe. Other interactions are developing with the Norway–U.K. joint climate program, activities supported by the European Union, and activities supported by the Japanese Frontier program in the Arctic.

2.1.6 Recommendations for the Future

The SEARCH SSC needs to ensure that its science plan is comprehensive and has been generally accepted by the scientific community. Further, the SSC should develop a set of science-based priorities within each subset of the science plan. SEARCH must move forward in all areas and not be limited to only the "most comfortable" areas, while leaving the complex issues for an undefined future time.

2.2 Integrated Assessment for a Sustainable Bering Sea

The Bering Sea, located between the Aleutian Archipelago and Bering Strait, is a marginal sea that connects the North Pacific and Arctic Oceans. It is the world's third-largest semi-enclosed sea and includes a wide eastern shelf encompassing about half its total area.

The Bering Sea region supports one of the world's richest assemblages of seabirds and marine mammals and large stocks of commercially valuable fish and shellfish. Its multiple habitats are ideal as homes to a rich variety of biological resources, including the world's most extensive eelgrass beds; at least 450 species of fish, crustaceans, and mollusks; 50 species of seabirds; and 25 species of marine mammals.

This rich, abundant, and ecologically diverse system has attracted and supported aboriginal cultures for millennia. Today, Bering Sea resources continue to support the economic survival, subsistence, and cultural foundation for a majority of the 227 federally recognized tribes of Alaska. In addition, the U.S. Bering Sea fishery contributes over half of the nation's fishery production, with an annual product value estimated at $2.2 billion. Walleye pollock comprise much of the fish landings, Bristol Bay supports the world's largest sockeye salmon fishery, and snow crab landings represent the largest crustacean fishery in the U.S. In addition to supporting commercial fisheries, the Bering Sea also supports 80% of the U.S. seabird population, comprising 36 million birds. Many unique and endemic species breed in the Bering Sea. The importance of the region is reflected in a variety of recent agreements, adopted by the U.S., other nations, and international organizations, designed to protect Bering Sea marine mammals, birds, and fish resources.

During the 1970s, 1980s, and 1990s, rapid changes in the physical and biological characteristics of the Bering Sea raised significant concern among resource managers, Native communities, commercial interests, and conservationists, among many others. While change is a natural characteristic of all ecosystems, and animal and plant communities are adapted to natural environmental rhythms, some natural changes or anthropogenic pressures can be too great or too sudden for biota to adjust, resulting in die-offs within species and shifts in community composition. Observed changes in the fish and mammal populations of the Bering Sea region suggest that current environmental and human pressures are too great. For example, over the last 20 plus years, Bering Sea Steller sea lion populations declined 50–80% and are now listed as "endangered." Northern fur seals are listed as "depleted" under the Marine Mammal Protection Act. Bering Sea populations of common murres, thick-billed murres, and red and black-legged kittiwakes declined up to 90%. In 1999 the collapse of the salmon fishery in Bristol Bay led the State of Alaska to consider the region an economic disaster area. Natural and anthropogenic forces are likely combining to cause rapid changes in the physical environment and biological communities of the Bering Sea region. Although considered among the most productive of high-latitude seas in the world today, the Bering Sea is at risk.

Significant changes occurring in the oceanographic and atmospheric Arctic environment, targeted under SEARCH (Study of Environmental Arctic Change, see Section 2.1), are powerful influences in the Bering Sea region. As in other Arctic regions, the Bering Sea is likely responding to these forces of change. The Bering Sea integrated assessment will benefit from work completed under SEARCH. At the same time, work completed as part of the Bering Sea integrated assessment will contribute to SEARCH, serving as a case study sub-ecosystem.

2.2.1 Arctic Research Commission Charge

The Arctic Research Commission, in its 2001 Report to Congress, targeted integrated research and assessment of the Bering Sea as a key research priority. The Commission observed that concern about the Bering Sea has engendered large and intense research synthesis and planning efforts with significant research and financial investment. These efforts share a commitment by scientists from diverse disciplines and organizations to come together to define the most important research needs and share research results. The quality of past and current research is unquestioned. However, while significant research efforts have produced important results, our understanding of how and why those changes are occurring remains elusive. Based on meetings it held during 1999, the Commission concluded:

- There is insufficient integration among key Bering Sea research programs.

- Current research does not enable managers to predict ecological responses to management decisions implemented within the Bering Sea region.

As the Commission noted, for example, connections must be made between research efforts on different populations of the same species to allow for comparisons. Basic oceanographic data collection and analyses should be integrated with studies of population effects in species at higher trophic levels, such as marine mammals, birds, and fish. Further, scientists must process data in such a way that predictions about changes in the Bering Sea ecosystem can be made, particularly on the population dynamics of higher trophic organisms.

The Commission found that data analysis is now *post hoc*, and management decisions are primarily based on historical records of system behavior rather than on predictions about ecological responses to new management decisions. Managers need the type of scientific information that will allow them to prevent negative effects and avoid crisis management. While there are ecological, social, and financial risks associated with making incorrect predictions, predictions with carefully stated confidence limits are essential for effective resource management and protection of the Bering Sea.

2.2.2 Building an Iterative Bering Sea Research Strategy

While continued research is critical to better elucidate the mechanisms and processes of change in the Bering Sea as well as the Arctic, ensuring that all essential scientific questions are well directed and investigated to answer key management concerns is a challenge. To meet the needs for an integrated assessment in the Bering Sea, Federal partners are implementing a strategic plan to clarify and connect scientific questions to management needs, as well as identify key goals. Since natural ecosystems, science, and management are all dynamic systems, an iterative process will be established to ensure linkages among needed management decisions, research, and ongoing system changes.

Components of Strategic Integrated Research

The Bering Sea Research Strategy will include four key components, each of which influences the others in an iterative framework. They include:

- Common Vision and Goals: Based on dialogue among interested parties of the Bering Sea, key concerns, common interests, and desired outcomes from management actions will be defined. In this process, diverse interests establish agreement on key ecological and human values of concern to provide the necessary framework around which to structure integrated assessments.
- Conceptual Synthesis: Existing data will be integrated to identify potential relationships among forcing functions, ecosystems changes, sources of stress, and ecological endpoints of concern identified in the goals. The process is interactive, iterative, and interdisciplinary, transforming diverse data into a set of conceptual models and predictive testable hypotheses about the influences of multiple natural and human stressors on ecological and human systems. The purpose is to learn more from existing data, generate multiple working hypotheses about likely causal relationships, and define essential research needs.
- Research Plan: Based on the conceptual synthesis and resulting conceptual models, a research plan will be developed that identifies key questions, information gaps, and conceptual links. A superimposed guiding framework for integrating research and interpreting results can then be used to generate an integrated interagency research plan among Federal agencies and other research organizations that capitalizes on existing research efforts and encourages strategic new research.
- Research Implementation: New research will be initiated to evaluate predictive relationships among natural and human influences on key values of concern. The research will investigate processes, trends, and effects, as well as monitor the impacts of management decisions. Information will be fed back into goal setting, synthesis, and planning for re-evaluation of goals, refinement of conceptual models, and development of updated research plans.

Goal development, conceptual synthesis, research planning, and implementation each provide feedback to all other components. As a result the strategy is inherently iterative, involving an interplay among research findings and environmental observations, desired management outcomes, goal setting, and new insights that lead to new research.

Chapter Organization

To provide background about the Bering Sea, Section 2.2.3 describes some of the basic charac-

teristics of the region and the forces influencing it. Section 2.2.4 provides an outline of recommended research, giving priorities for current research needs. To build a more comprehensive integrated research strategy in the future, Section 2.2.5 describes the process planned to establish unified goals, conceptual syntheses, and research planning to achieve strategic research of integrated assessments.

2.2.3 The Bering Sea Region

The larger Bering Sea region includes the waters and coastal regions of the Bering Sea situated between Alaska and Russia. The southern extent includes currents from the North Pacific flowing through the Aleutian Chain and waters flowing north through the Bering Strait to the Chukchi Sea and Arctic Ocean. A large terrestrial component is part of the region that includes watersheds in Alaska and Russia discharging into the Bering Sea, such as the Yukon and Kuskokwim watersheds covering the majority of Alaska.

Characteristics

In the early 1980s, scientists working under the Processes and Resources of the Bering Sea Shelf (PROBES) project defined specific hydrographic regimes for the southeastern Bering Sea: the coastal or inner shelf domain, the middle shelf domain, the outer shelf domain, the continental slope, and the transitional areas or fronts between them. Each of these domains represents a different marine habitat.

Time series data collected in Bering Strait on salinity and temperature confirm that Alaskan coastal waters are relatively warm, have low salinity, and flow through the eastern channel of the strait. Bering Shelf water is of higher salinity. The eastern Bering Sea consists of an oceanic and shelf regime. Within the broad (>500 km) shelf regime, three distinct domains exist, characterized by contrasts in water column structure, currents, and biota. The balance between mixing (tidal and wind) and buoyancy flux (freshwater discharge, ice melt, and solar radiation) generates the domains. A system of three hydrological zones exists over the western shelf that is somewhat analogous to the system of hydrological zones on the eastern shelf. The coastal, transition, and oceanic zones are easily distinguished by their temperature–salinity characteristics and vertical structure. As with the eastern shelf, atmospheric processes that regulate the heat balance and result in the formation of ice are primary features of the environment that dictate oceanographic conditions of the western shelf. Ice typically covers the entire western shelf in winter.

North of approximately 62°N, changes in topography, tidal energy, and river discharge from the Yukon modify boundaries between domains. South of St. Lawrence Island, three water masses exist across the shelf: Alaskan Coastal, Bering Shelf, and Anadyr. North of St. Lawrence, all three water masses are present and can be identified as they flow northward through Bering Strait. Over the western shelf, the dominant circulation feature is the Anadyr Current, a coastal flow extending from the Gulf of Anadyr westward past Cape Navarin.

The status of living marine resources in the Bering Sea ecosystem is largely confined to commercially important fish and invertebrates and birds and mammals readily observed from land or air. Data on forage fishes are largely confined to the Pacific herring, which is dominated by the Togiak stock. Knowledge of invertebrates is largely restricted to crabs. Eastern Bering Sea salmon abundance was generally high during the 1980s and 1990s, although specific runs, such as chinook and chum in western Alaska, have been poor. Several marine mammal and seabird populations have undergone major changes in abundance. Patterns of change for marine birds has varied among species, locations, and decades over the past 20–30 years. Changes in many bird and mammal populations are most likely related to prey abundance and availability. Changes in oceanographic conditions can affect the geographic distribution and availability of species. One of the more important anthropogenic influences on the Bering Sea ecosystem is commercial fishing.

Forces of Change

Observations and historical analyses supported by NOAA and NSF over the last six years show that the Bering Sea ecosystem is influenced by hemispheric processes that many believe explain recent biotic declines. Observed changes in biota have also been linked with a long history of natural resource exploitation that has spanned two centuries but that has increased dramatically within the last few decades. There is rising evidence of increased loading of pollutants being transported to and sequestered in Arctic oceanic, atmospheric, and terrestrial environments and biota. Alterations of the ocean floor from industrial fishing and changes in terrestrial habitats caused by develop-

ment activities have also occurred and cannot be excluded as factors in these declines. The natural changes and human influences are likely altering the biocomplexity of the Bering Sea in ways not yet understood. Quantifying the relative importance of natural and human-induced variations in explaining upper-trophic-level ecosystem change is a key management issue for the Bering Sea. The cause of biotic fluctuations, while still unknown, is likely a reflection of natural, climate-related, and other human-induced pressures.

Oceanographic and Atmospheric Influences

The Bering Sea responds to two dominant climate patterns in the region: the Pacific Decadal Oscillation (PDO) and the Arctic Oscillation (AO). The PDO has a 40- to 50-year cycle with principal impact on the southern Bering Sea. This was reflected in lower sea surface temperatures in the North Pacific from 1925 to 1947 and from 1977 to 1998, with reverse conditions occurring in 1899–1924 and 1948–1976. The Arctic Oscillation is associated with the spin-up of the polar vortex and has influence from the sea surface to the stratosphere and from the Arctic to midlatitudes.

The highly varying sea ice cover of the Bering Sea has a profound influence on the physical and biological ocean environment. Sea ice in its most extensive years arrives in January and remains to May, coincident with negative values of the PDO (for example, in the early 1970s there was extensive winter ice cover before the 1977 shift in the PDO and, to some extent, the AO). The late 1970s and 1980 were warmer years with reduced ice cover. In the 1990s winter ice has again become more common after a 1989 shift in the AO, although not to the extent observed in the early 1970s. A key Arctic change that impacts the Bering Sea and Alaska is a shift toward higher temperatures in April.

Resource Extraction

The Bering Sea ecosystem has been impacted by significant human activity. Many believe that the ecosystem has been damaged as a result of these impacts. These beliefs are based on (1) significant increases in levels of human activity, especially commercial fishing, since the 1960s, and (2) unexpected and unexplained changes in important components of the ecosystem (for example, some pinnipeds and seabirds). The removal of biomass from the Bering Sea has been very large (for example, more that a million tons of pollock per year plus large landings of salmon, crab, and other commercial species). Biomass removal of this magnitude will likely cause both direct and indirect effects on many other species within the ecosystem, including predators, competitors, and prey, as well as change in the proportions of various species within the ecosystem.

Extraction of arsenic, lead, zinc, and oil within the Bering Sea region may also be contributing to the loadings of contaminants now increasingly found within Bering Sea resources. Local sources could be combining with long-range transport of contaminants to play an important role in the health and distribution of biological resources as well as humans living in the region.

Contaminants

In 1998 the Arctic Monitoring and Assessment Program (AMAP), under the Arctic Council, published *The AMAP Assessment Report: Arctic Pollution Issues*. The principal conclusions in this report were that in comparison with most other areas of the world, the Arctic remains a relatively clean environment. However, characteristics of the Arctic environment place Arctic ecosystems at risk:

- The Arctic is a focus for major atmospheric, riverine, and marine pathways, resulting in long-range transport of contaminants to and within the Arctic, where it enters the food web and biomagnifies.
- Low temperatures, extreme seasonal variations in light, and lack of nutrients are some of the physical and chemical characteristics that cause environmental stress to organisms, limit productivity of Arctic ecosystems, and make them potentially more vulnerable to environmental contaminants.
- Several groups of people in the Arctic are highly exposed to environmental contaminants. Persistent contaminants, derived from long-range transport and local sources, accumulate in animals that are used as traditional foods.
- The combination of long-range transport processes, climatic conditions, and physical, chemical and biological properties results in the accumulation of some contaminants in traditional subsistence foods at levels higher than found outside of the Arctic.

Habitat Alteration

Habitat is critical to all living organisms, whether fish, invertebrates, mammals, birds, or

primary producers. Habitat characteristics influence survival, growth, and reproduction. Habitat encompasses the physical, chemical, and biological environment within which an organism lives. At different life stages, habitat requirements may differ significantly for a particular species at birth or spawning, during early life stages, and as an adult. Thus, to understanding the habitat requirements for a particular species requires a significant understanding of its life history characteristics. Unfortunately our understanding of the life history and habitat requirements for most species depending on Bering Sea ecosystems is limited at best, making it a significant challenge to understand the ramifications of activities causing habitat alteration within watersheds, wetlands, coastal regions, and the domains of the Bering Sea.

2.2.4 Bering Sea Research Plan

Interagency integrated Bering Sea research will be implemented in stages. Ongoing research programs will continue to gather important information and may benefit from the research recommendations provided below, which outline research topics of particular importance. Concurrent with ongoing research, interagency efforts to develop an integrated research strategy will begin and run concurrently. Both efforts will revolve around four questions central to ensuring future integration:

- What array of factors (stressors or forcing functions) are influencing change in the Bering Sea, over what time scales and spatial characteristics?
- How are these factors (anthropogenic and natural) interacting to effect change on priority components and processes of Bering Sea ecosystems?
- What feedback mechanisms are operating within the Bering Sea systems that will impact the course of change?
- What and where is change most likely to occur within Bering Sea ecosystems, given alternative scenarios of natural forces and human influences?

The relative importance of natural cycles and human factors in explaining variability in abundance in the Bering Sea is a key management issue. In addition to perturbations created by human activities, environmental factors are seldom stable and are subject to large-scale fluctuations. It is clear that the production of new organic matter, which provides the basis for exploitable fish populations and all other higher-trophic-level animals, is greatly affected by both human actions and environmental factors. Questions remain, however, concerning the ecosystem dynamics of the vast Bering Sea shelf that supports this high productivity. An integrated assessment for the Bering Sea must include questions that investigate the interplay of human and natural processes.

Research Recommendations

To promote integrated interpretations of data, studies in general should be collaborative and multi-disciplinary and should include standard physical and chemical measures as well as a suite of biological measures. Biological measures recommended include primary production, zooplankton biomass and production, zooplankton grazing, grazing by larval and juvenile fishes and the abundance of forage species, and the diets of marine birds and mammals. Specific ongoing research activities recommended include the following:

1. Maintain long-term time series data collection important for integrating and indicating ecosystem change in the eastern Bering Sea. These include:

- Four biophysical moorings maintained by the National Oceanic and Atmospheric Administration (NOAA) to collect vital information on winds, sea ice, water column structure, currents, nutrients, and chlorophyll concentrations across the eastern shelf.
- National Marine Fisheries Service (NMFS) data on northern fur seal pup production and diet samples in the Pribilof Islands and Bogoslof Island.
- NMFS surveys of Steller sea lions in the Aleutian Islands and Bering Sea.
- U.S. Fish and Wildlife Service (UFWS) surveys of seabird population dynamics and diet samples from colonies around the Bering Sea and Pribilof Islands.

2. Conduct comprehensive research on the connections between climate change and ecosystem function to evaluate and predict the effects of climate change on the structure and function of biotic communities in the eastern Bering Sea, asking questions such as:

- What is the influence of the timing and magnitude of spring primary production on the characteristics and ecological relationships within the biotic community? How has summertime warming of waters over the shelf during the past three decades impacted or created a northward shift in ecosystem properties required for successful pollock production?

- How have changes in the timing of the spring bloom altered the transfer of energy from phytoplankton to zooplankton, and what are the implications for the food web?
- What similarities and differences in physical properties exist between the southeastern and northeastern Bering Sea now, and how has the southeastern Bering Sea changed since the region was evaluated under PROBES?
- How does wind stress and heating of the upper mixed layer during summer influence summertime primary production? How does this summertime production influence zooplankton biomass and lipid content (food value) in the upper water column? How does zooplankton abundance and quality affect the condition of small forage fish in late summer and the survival of juvenile fish during the following winter?

3. Conduct studies to evaluate the effect of spring and summertime cross-shelf flux in determining ecosystem function and trophic transfer of energy to apex predators. A key question to ask is:

- What is the influence of the interannual variation of on-shelf flow of nutrient- and zooplankton-rich slope water on new production and zooplankton populations on the outer shelf?

4. Evaluate how decreased cross-shelf flux may lead to decreased production in zooplankton for planktivorous birds, and in small fishes for piscivorous birds and mammals. Hypotheses to evaluate include:

- On-shelf transport of slope water advects oceanic copepods onto the shelf and supplies nutrients that enhance new production, which alters production and supports the zooplankton on which forage fish feed.
- Increases in forage fish would in turn influence seabird and fur seal foraging success on the Pribilof Islands by virtue of variability in the magnitude and pathways of on-shelf flow, with enhanced reproductive success associated with moderate to strong on-shelf flow and lower success during weak on-shelf flow. This enhanced reproductive success may result from bottom-up processes caused by the introduction of nutrient- and zooplankton-rich slope waters.
- On-shelf flow and tides create areas of convergence at the shelf edge, where birds feed on small fish attracted to concentrations of neuston.

In addition, based on research recommendations made by the Bering Sea research community, the following four categories of research are recommended.

Monitoring

- Maintain and enhance time series from moored biophysical buoys and discrete shipboard samples across the southeast Bering Sea, Bering Strait, Aleutian North Slope current, and Unimak Pass. This includes weather, temperature, salinity, primary production, and zooplankton sampling.
- Strengthen existing surveys of groundfish, crabs, birds, and mammals and add information on benthos, forage fish, and predator species.
- Archive, in a geographically registered format, all available remote sensing for sea ice, SST, and ocean color in near-real-time.

Retrospective Analyses

- Characterize the space/time structure of climate forcing.
- Establish baseline conditions, including variability, of key physical and biological indicators.
- Survey archaeological middens and sediment cores to look at species abundance and change.
- Evaluate the relative impacts of anthropogenic versus natural factors on patterns of biological change.
- Produce a unified database for the Bering Sea.

Modeling

- Use downscaling techniques to relate the results from global general circulation models to changes forcing the Bering Sea.
- Implement high-resolution physical/biological models that include zooplankton dynamics and individual-based models for nodal and commercially valuable species.
- Conduct statistical and explicit model building to investigate changes in trophic-level structure in response to physical changes.
- Model the effects of alternate natural resource management strategies.

Process Studies

- Examine mechanisms of nutrient replenishment onto the continental shelves.
- Determine the role of the physical environment on the critical life stages of key species.

- Evaluate the cause of changes in trophic interactions.
- Use telemetry to define marine mammal and apex predator feeding areas.
- Evaluate experimental management strategies, including fish removals, on local prey abundance and distribution.

2.2.5 Strategic Research for Integrated Assessments

While continued research is critical to better elucidate the mechanisms and processes of change in the Bering Sea as well as the Arctic, ensuring that the essential scientific questions are well directed and investigated to answer key management concerns is a challenge. To meet the needs for an integrated assessment in the Bering Sea, Federal partners are developing a strategic plan to clarify and connect scientific questions to management needs as well as identify key goals.

Since natural ecosystems, science, and management are all dynamic systems, an iterative process will be established to ensure linkages among decisions that need to be made, new knowledge that will be obtained, and ongoing changes that will influence outcomes. The importance of this process was reflected in 1996 when the Polar Research Board of the National Research Council published a study on the Bering Sea ecosystem, which included a set of recommendations emphasizing the vital link between science and management including:

- Adopting a broad ecosystem perspective for scientific research and resource management;
- Adopting an adaptive management approach for Bering Sea resources;
- Evaluating how well management and research institutions are able to address emerging problems;
- Providing appropriate management solutions; and
- Developing research programs to help policy makers solve short- and long-term ecological problems.

Building an Iterative Bering Sea Research Strategy

The Bering Sea Research Strategy will include four key elements. Each element will be linked to the others through clearly defined feedback loops within an iterative framework. They include the following:

- Unifying vision and goals: Through dialogue among parties interested in the Bering Sea, identify key concerns, common interests, and desired outcomes of management actions and agree on key ecological and human values of concern. This will provide the necessary framework around which to structure integrated assessments and help ensure scientific advances and adaptive and predictive management.
- Conceptual synthesis: Assess and integrate available information within an interactive, iterative, interdisciplinary process to transform current data into a set of conceptual models characterizing predictive testable hypotheses about the influences of multiple natural and human stressors on ecological and human systems. For best success, the process will generate multiple working hypotheses about potential causal relationships.
- Research planning: Based on the conceptual synthesis, define the essential research needs and a research plan designed to produce integrated research and assessments. The expected outcome is a proposed research program among Federal agencies and others that capitalizes on existing research efforts and defines new research within a structured framework for integrating research activity and interpreting results.
- Research implementation: Initiate new research designed to test potential causal relationships among natural and human influences impacting key values of concern. New findings would be used to refine the conceptual links established during conceptual syntheses to derive new knowledge about processes, effects, trends, and relationships, as well as to assess the influence of management decisions on ecosystem change.

Each of these elements is iterative. Successful implementation results in feedback among elements to create an interplay between research findings and environmental observations, desired management outcomes, goal setting, and new insights that lead to new cutting edge research.

Implementation of the Strategy

In April 2001 the Interagency Arctic Research Policy Committee authorized the establishment of an Interagency Working Group (IWG) for the Bering Sea. The IWG was charged to develop a coordinated approach to implementing an integrated assessment for a sustainable Bering Sea. Over the next year the IWG will organize and develop a plan for implementing an assessment.

Questions managers and scientists answer during early dialogues.

Managers answer

- What are the ecological and human values of concern and what outcomes are desired?
- What are the management goals and decisions needed and how will an integrated assessment help?
- At what scale must it be addressed?
- What are the policy considerations?
- What precedents have been set through previous decisions?
- What is the context of this assessment?
- What resources are available?
- What level of uncertainty is acceptable?

Scientists define

- What are the spatial and temporal boundaries of the problem?
- What information is already available, compared to what is needed?
- What practicalities constrain data collection?
- Can decisions be based on assessments of a small area evaluated in depth or a large-scale assessment at lesser detail?
- What are the critical ecological endpoints and key ecosystem and receptor characteristics?
- What are the likelihood and duration of system recovery?
- What is the nature of the problem now, compared to the past and the future?
- What are the current state of knowledge, the available data, and the type of analyses?
- What are the constraints?

Defining a Vision and Goals

Federal efforts to establish a vision began with dialogue among interested parties in the Bering Sea region between 1998 and 2000. Interviews were conducted with Federal and state officials, and commercial and environmental interests, among others. The results from these interviews generated several common themes:

- Current management regimes and institutional structures need to be enhanced to achieve a coordinated ecosystem-wide approach to management.
- A common vision and agreement on a desired future condition for the Bering Sea is needed. The vision should be as specific as possible to guide managers.
- A common understanding of the threats to the Bering Sea ecosystem is essential. Given insufficient science, there must be agreement on scientific priorities to answer fundamental questions about what is happening in the ecosystem.

As follow-up to these findings, the U.S. Environmental Protection Agency (EPA) is serving as a catalyst for organizing a Bering Sea Summit to be held in Anchorage in April 2002 through implementation of the Bering Sea Regional Geographic Initiative (RGI). EPA is serving as a lead Federal organizer based on EPA's broad mandate (protect human health and safeguard the natural environment), the absence of specific resource management responsibilities in the Bering Sea (a "disinterested" Federal partner), and substantial experience with community-based environmental protection and predictive risk assessment. EPA is working in partnership with Federal and state agencies, tribes, and environmental and industry groups, among others, to convene the Summit, which is being designed to foster dialogue among the diverse organizations, management agencies, and communities in the Bering Sea region. The expected outcome is a multi-party strategic vision for protecting, investigating, and utilizing Bering Sea resources in a sustainable way. A principal goal for the Summit is to develop an implementation strategy with local, regional, national, and international components.

Conceptual Synthesis and Research Planning

A Federal effort for promoting conceptual synthesis and research planning for a Bering Sea integrated assessment will be developed based in part on the results of the Bering Sea Summit 2002 and efforts by a newly formed Federal Bering Sea Interagency Working Group, a partnership among Federal agencies and other interagency management organizations including efforts under SEARCH. National efforts will be linked to international activities, including work by the Arctic Council and the United Nations Environmental Programme (UNEP) Global International Waters Assessment.

Strategy development will progress concurrently with ongoing research efforts. The outcome over the next several years will be the completion of goal setting, conceptual synthesis, and a first-stage integrated assessment and research plan.

Early conceptual synthesis will be based on available information on all aspects of the system of concern (for example, ecosystem characteris-

tics, natural and anthropogenic forces influencing the ecosystem, exposure to potential stressors, and observed changes). This initial synthesis will provide the basis for developing preliminary conceptual models, which generally lead scientists to seek other types of data and information not previously recognized as needed. The conceptual models include written descriptions and visual representations of predicted relationships among ecological values and factors potentially influencing them. They are valuable as learning and communication tools, are easily modified in response to new information, highlight what is known and not known, and provide a framework for prediction.

A research plan will be generated from a careful evaluation of conceptual synthesis. Planning normally results in a delineation of an integrated assessment design, data needs, and measures and methods for conducting analyses for an integrated assessment. This is directly linked to conceptual models and includes the rationale for selecting priorities.

Strategy development, integrated assessments, and research planning and implementation will remain an iterative process that can be used, modified, and used again as new understanding and new questions emerge for the Bering Sea.

2.3 Arctic Health

Arctic health research encompasses two major subdivisions: environmental health and public health. The former includes the topics of environmental contaminants, the effects of climate change (Arctic Climate Impact Assessment), and radioactive nuclides. The latter includes infectious diseases, occupational injuries, chronic diseases, behavior, delivery of health care, capacity building, and the elimination of health disparities between the Alaska Native and non-Native populations.

2.3.1 Environmental Health

The occurrence of artificial radionuclides and pesticides in the environment and biota has been documented for over 30 years and has since remained a matter of scientific and public concern. This concern was heightened considerably in 1990s, first by an increased awareness of the unexpectedly high levels of contamination in the Arctic that led to the adoption of the Arctic Environmental Protection Strategy in 1991 by the eight Arctic countries, including the U.S. Soon thereafter, in 1992, there was a major disclosure of widespread dumping of nuclear reactors and wastes into the Arctic and northwest Pacific Ocean by the former Soviet Union. Later in the same year, it was reported that 15,000 pounds of soil contaminated with radioactive material, including fallout material collected from an atom bomb test in Nevada, was buried 30 years ago near Cape Thompson, Alaska.

In recent years it has become increasingly clear that many contaminants found in the Arctic, particularly certain pesticides and industrial chemicals, originate in areas far removed from the Arctic but that those chemicals tend to persist and accumulate in the Arctic environment and food chains, including human residents. Because of their reliance on local fauna for subsistence and preserving their cultural heritage, Alaska Natives have become increasingly apprehensive about the quality of their traditional food resources and the health of Arctic ecosystems. The paucity of scientific data on the nature and severity of environmental contamination on human health and renewable biological resources has prompted the Interagency Arctic Research Policy Committee (IARPC) to begin planning for a focused, interagency research program emphasizing health concerns in the U.S. Arctic, including its environmental aspects.

Radionuclides in the Environment and Subsistence Foods

Global fallout from atmospheric testing of thermonuclear devices is the principal environmental source of artificial radionuclides in the U.S. Arctic. Even though the ground deposition of fallout radionuclides is quite pervasive, its distribution is greatly influenced by patterns of mean annual precipitation. Thus, portions of southeastern Alaska (which is not part of the U.S. Arctic) are estimated to have orders-of-magnitude higher activity of the radionuclide cesium-137 than, for example, the North Slope of Alaska. However, proportionately high consumption of caribou, freshwater fish, berries, bowhead whales, and other subsistence foods in the U.S. Arctic is often considered an important

means of radionuclide exposure to humans.

The National Oceanic and Atmospheric Administration (NOAA) in collaboration with the Los Alamos National Laboratory (LANL) have measured activities of anthropogenic and naturally occurring radionuclides in coastal sediments and a number of faunal species that are used for subsistence in the U.S. Arctic. The study, supported in part by the Office of Naval Research (ONR), showed that typical yearly consumption of caribou meat by an adult resident of Barrow added a very small amount (0.0045 mSv) to the average effective dose equivalent of ionizing radiation. This value should be viewed in relation to the average radiation dose to humans from natural sources (3.0 mSv)*, such as exposure to radon and cosmic radiation, and other anthropogenic sources (0.6 mSv), such as consumer goods, medical x-rays, and air travel. Subsistence foods derived from marine food chains accounted for a much smaller, and perhaps negligible, dose.

It is generally concluded that human health and ecological risks from projected releases from nuclear waste dump sites in the Arctic are likely to be inconsequential. However, a summary of ONR-funded studies has noted the need to consider other known sources and potential transport pathways for radionuclides in the Arctic. For example, major Siberian rivers may potentially contribute significant amounts of radionuclides from nuclear power plants and weapons factories in Russia, amounts that could pose as much or greater risks than the materials dumped directly into the Arctic Ocean.

Contaminants in Species of Subsistence, Commercial, and Aesthetic Value

The presence of persistent organic contaminants in Arctic wildlife has been documented for more than 30 years. For example, specimens of gyrfalcons collected from the Seward Peninsula in 1970 had highly variable levels of DDE (a metabolite of DDT that is most often related to adverse biological effects in the field) and PCBs in their tissues, but in some cases the levels exceeded 200 ppm. The peregrine falcon in the Amchitka region was considered a highly vulnerable species as early as 1970, when DDE residue in members of that population were associated with thinning of eggshells. Since then, relatively high levels of these and other contaminants, such as hexachlorocyclohexane (HCH), have been reported in liver and fatty tissues of many species of fish and wildlife, including marine mammals. Some marine mammals, such as the Pacific walrus, have relatively high concentrations of potentially toxic metals in their tissues.

Both NOAA and the U.S. Fish and Wildlife Service (FWS) have ongoing programs to determine the contaminant levels and their biological effects in protected and threatened species under the Marine Mammals Protection Act and the Endangered Species Act. Nearly all marine mammal tissue collected for contaminant analyses in these programs were from animals harvested by Alaska Natives, often in consultation with statewide Native organizations and cooperatives, such as the Alaska Eskimo Walrus Commission. This results in a broad geographic distribution of samples and cooperative efforts with subsistence hunters. Examples of contaminant-related studies on selected Arctic faunal species are noted below.

The polar bear biomonitoring program of the FWS was initiated in 1995 to determine if contaminant levels in polar bears from the two Alaskan population stocks were of concern. The Chukchi/Bering Seas and southern Beaufort Sea population stocks in Alaska are shared with Russia and Canada, respectively. Levels of PCBs in adult male polar bears from Alaska analyzed to date are relatively low compared to the high levels found in polar bears in eastern Hudson Bay, Canada, and Norway. Average levels of HCH in Alaskan bears are among the highest reported in the Arctic. Little is known, however, about the potential impacts that these relatively high HCH levels may have on the health of polar bears, human consumers, and the Arctic ecosystem. To date, samples have been obtained from approximately 28 bears. Sampling for this project will continue through FY 02, when a final report will be prepared. Polar bears have been identified as a sentinel species under the Arctic Monitoring and Assessment Program (AMAP) for monitoring environmental contamination in the Arctic ecosystem because of their wide distribution, position at the top of the Arctic marine food chain, and value to Native subsistence users.

Tissue samples have also been collected for long-term storage by the Alaskan Marine Mammal Tissue Archival Project (AMMTAP) for use in

* Sievert (Sv) is a measure of absorbed radiation dose per unit mass, often expressed as millisievert (mSv). A 1-mSv yearly dose is often equated to an increased risk of cancer in one person out of 20,000, and a dose of 0.01 mSv is generally considered negligible in terms of potential risk to individuals.

future analyses as analytical techniques improve and for assisting in the development of spatial and temporal trends of contaminant levels in the Arctic. AMMTAP is a cooperative interagency program supported by the U.S. Geological Survey (USGS), NOAA, and the National Institute of Standards and Technology (NIST). Standardization of quality assurance and quality control procedures will help reduce past limitations that have hindered making meaningful comparisons among various data sets. The contaminant data collected from the polar bear biomonitoring program have been used for inter-laboratory comparisons, as well as for physiological studies on contaminant accumulation and effects on polar bears.

The FWS studies of organochlorine pesticides and industrial chemicals, hydrocarbons, and heavy metals in walrus tissues over the past two decades have shown only extremely low levels of organic contaminants in walrus blubber collected from coastal and offshore sites in the Bering Sea. However, these studies have documented high levels of cadmium in the kidney and liver tissues of walrus in the Bering and Chukchi Seas. In several instances, cadmium concentrations in kidney tissues were higher than the level thought to interfere with organ function in some mammals. A positive correlation between cadmium and age was found in both liver and kidney. Similar relationships were found between age and concentrations of zinc (kidney) and arsenic (liver and kidney). Histopathological examination of samples from 170 animals collected from Gambell and Diomede indicated that the metals present in the kidneys and livers did not appear to cause injury to the tissues. Data on heavy metal contamination in the walrus tissues are being synthesized for publication. Although data are few and from disparate sources, high levels of cadmium in bowhead whale kidney tissues have also been reported.

Concentrations of persistent organic pollutants (POPs) in blubber, and heavy metals in liver and kidney, have been determined for two stocks of Alaskan Arctic beluga whales (Beaufort Sea and Eastern Chukchi Sea stocks) from the Bering Sea population and for beluga whales from the sub-Arctic Cook Inlet population. Generally the sub-Arctic Cook Inlet animals appear to be substantially different from the two Alaskan Arctic stocks, having lower concentrations of POPs and metals (except for copper). The two Alaskan Arctic stocks have concentrations of POPs that are similar to levels reported for beluga populations across the North American Arctic; however, certain metal concentrations are substantially different. Hepatic total mercury concentrations are higher and cadmium concentrations are lower in these Alaskan belugas than what has been reported for belugas farther east in the Canadian Arctic.

In recent years, FWS has made organochlorine and heavy metals measurements in livers and kidneys from 66 sea otters that were collected in coastal waters throughout Alaska. Preliminary results have identified several otters with low levels of PCBs, beta-BHC, pp-DDE, and dieldrin. Given a rather sparse sampling coverage, the source of these contaminants is unclear, and the physiological effects of contaminants on sea otters can only be speculated.

Mercury is a naturally occurring element that is present in rocks and ores. It is also released into the atmosphere by degassing of the earth's crust and oceans in large amounts; an approximately equal amount is released by way of human activities, such as burning of household and industrial wastes and waste discharge from certain industries. Its presence in food chains, particularly large predator fish such as sharks, swordfish, and large species of tuna, has been well documented. In recent years, the presence of mercury in coastal and freshwater fish has become a matter of great concern, prompting many states to issue fish consumption advisories. Although extensive data are available on mercury concentration in fish tissues in the Arctic, data from the U.S. Arctic are scant. Few data have recently been obtained on total mercury and methylmercury in the muscle and liver tissues and eggs of Pacific salmon species from the Yukon, Kuskokwim, Nugashak, and Kvichak Rivers. The higher concentration of mercury in chinook salmon could be because of its longer life span in ocean waters and its higher trophic level. Analysis of these data continues. It is not clear whether mercury in natal streams and lakes is further recycled by freshwater fauna or whether there is further bioaccumulation through freshwater and terrestrial food chains.

Comparisons of hepatic total mercury concentrations in beluga whales across the North American Arctic indicate that the highest concentrations may be found in the Beaufort Sea and Chukchi Sea stocks of the Alaska Bering Sea population (averaging around 50 mg/kg ww); these levels are within the range reported for the St. Lawrence Estuary population. Although levels of total mercury in the Cook Inlet animals have been found to be much lower (averaging 5 mg/kg ww) than con-

centrations in the other Alaskan belugas, the hepatic concentrations of methyl mercury are similar among all three Alaskan groups (0.3–2 mg/kg ww).

FWS has determined concentrations of organochlorine pesticides, including toxaphene, in burbot collected from three National Wildlife Refuges in interior Alaska and the Tanana River near Fairbanks, Alaska. In general, there were greater contaminant concentrations from sites below Fairbanks and within the Yukon Flats Refuge than at Tetlin and Kanuti refuges. There were greater concentrations of DDT and its metabolites at Fairbanks, probably reflecting the historical use of that pesticide within the city of Fairbanks and at nearby military bases. Concentrations of DDT and metabolites from Fairbanks were up to two orders of magnitude greater than in burbot from five studies in Canada. The range of PCB concentrations were similar to those from four of six Canadian studies and were generally less than laboratory-derived effects values. Toxaphene concentrations were generally low. Because this was an initial assessment and sample sizes were low, further studies would illuminate whether the concentrations found at Fairbanks and Yukon Flats are of concern to fish and wildlife resources. This report will be finalized in FY 01.

Personnel from the Alaska Maritime NWR collected bald eagle carcasses from Adak Island between 1994 and 1998. Tissues were collected for contaminants analysis, and data from the 1994–1996 samples were reported in a technical report entitled "Contaminant residues in bald eagles (*Heliaeetus leucocephalus*) from Adak Island, Alaska" (WAES-TR-97-02). Additional funding in FY 99 allowed for analysis of the remaining samples collected after 1996. Data from all birds have been combined, compared, and drafted into a manuscript, which will be submitted to a peer-reviewed scientific journal in FY 01.

The number of red-throated loons breeding in Alaska declined 53% from 1977 to 1993. Aerial population surveys in Alaska have produced rigorous trend data for red-throated loons, but despite this, only fragmentary knowledge exists about the natural history of this species. In 1998, FWS identified red-throated loons as a "species at risk" in Alaska and identified four specific data needs: demographic parameters, distribution among wintering areas and links to breeding areas, subsistence bycatch in fishing nets, and exposure to contaminants. This work will continue during FY 01.

The Agency for Toxic Substances and Disease Registry (ATSDR) has initiated the Alaska Native Subsistence and Dietary Contaminants Program to study contaminants in the environment, subsistence resources, and people in Alaska Native populations. Working with other Federal, tribal, state, and local governments, ATSDR will focus on research and public health activities necessary to empower Alaska subsistence diet users to make informed dietary decisions while incorporating traditional and western scientific information. The primary goals and activities for this program are to:

- Identify Alaska Native traditional subsistence diets and characterize human exposure to dietary contaminants;
- Characterize and analyze human health risks and nutritional benefits of the Alaska Native subsistence lifestyle;
- Evaluate human health effects in the Alaska Native population that may be associated with contaminants found to be part of the subsistence lifestyle;
- In partnership with the affected Alaska Native communities, provide communication and education to assist in culturally appropriate decisions on risks and benefits of the diet; and
- Develop and implement interventions that are culturally appropriate and based on the defined needs of the Alaska Native population.

Ecosystems at Risk

The U.S. Arctic ecosystems are quite varied in their complexity and biological productivity. In the marine environment, they include some the world's most productive, for example, the southeastern Bering Sea and Chirikov Basin ecosystems, which support important commercial fisheries and an extraordinary feeding habitat for wildlife. In contrast, oceanic waters of the Canadian Basin have low biological productivity, although they may contain faunal assemblages that are unique, consisting of species of both the Atlantic and Pacific Oceans, or species that have survived through the ages (certain sponges and bryozoans). On land the U.S. Arctic is dominated by wet and alpine tundra, both of which are critical to thousands of migratory birds, caribou, and other species. The spruce–poplar forests are extensive and highly productive, but they occupy a relatively small portion of the U.S. Arctic lands.

Irrespective of their location, all Arctic ecosys-

tems are highly cyclic (because of large seasonal changes in light levels, nutrient input, and temperature) and have low species diversity. On an annual or decadal cycle, they are also affected by weather and climatic changes, such as those caused by the presence, intensity, and movement of the Aleutian Low Pressure System in the northern North Pacific Ocean. In the marine environment, the location of the ice edge, as well as continental shelf-slope exchange of materials, is also critically important to both the onset and sustenance of primary productivity and ultimately to food chains culminating in fish and wildlife species, many of which have considerable commercial, subsistence, and aesthetic value.

The structure and dynamics of the U.S. Arctic ecosystems have been studied for nearly 30 years with primary funding support from a number of Federal agencies, such as DOD/ONR, NSF, DOC/NOAA, DOI/MMS and others. Programs such as the Outer Continental Shelf Environmental Assessment Program, 1975–1992, provided a strong foundation for multidisciplinary scientific studies of coastal and continental shelf waters around Alaska. Many concurrent and follow-up studies, such as PROBES, ISHTAR, and SHEBA funded by the National Science Foundation and the Fisheries–Oceanography Cooperative Investigations (FOCI) funded by NOAA, have greatly advanced the scientific database and understanding of Arctic ecosystems. New studies and programs, as well as budget initiatives, will continue to shed new light on ecosystem dynamics, particularly in relation to climatic changes, shelf-slope exchange of energy and materials, and factors controlling the deposition and environmental fate of contaminants.

Both NOAA and the Minerals Management Service (MMS), U.S. Department of the Interior are continuing congressionally mandated studies of the Arctic environment and resources, notably those relating to fisheries and wildlife. In the case of MMS, the primary purpose is assessment of impacts from oil and gas activities along the North Slope of Alaska. The USGS will be conducting studies over the next five years (2001–2005) to examine the impacts of climatic change and atmospheric transport of contaminants in the Yukon River basin. The studies will be designed to characterize water quality parameters, identify contaminant sources, and assess the effects of contaminants on regional biota and ecosystems.

There are sixteen National Wildlife Refuges in Alaska, encompassing approximately 92,000,000 acres. Lands within the National Wildlife Refuge system in Alaska have had a varied and interesting history. While large tracts remain in near-pristine condition, past uses of refuge lands have also included oil exploration and drilling, mining, establishment of runways and support facilities for aircraft, and use by the military for various operations including military installations, staging areas, supply depots, training grounds, and historic battlefields. After these operations ceased, sites were often abandoned. At other sites, hazardous materials were spilled with no subsequent cleanup. The total number of formerly used defense sites (FUDS) in Alaska is 648. Most of them have undergone preliminary assessment for the nature of contamination and clean-up needs. A number of sites are currently scheduled for remediation by the U.S. Army Corps of Engineers, the Department of the Navy, or the Department of the Air Force. The FWS has also conducted numerous studies on contamination in refuges within the Arctic, establishing baseline conditions or investigating impacts on trust species. These investigations are needed to determine significant changes through time; the need will continue as new issues are identified.

EPA has been evaluating the Polar Sunrise Effect on atmospheric mercury in Barrow, Alaska, since 1999. Research has confirmed that mercury is depleted in the atmosphere during the month following Arctic sunrise. Preliminary results support the hypothesis that mercury is transformed from elemental mercury in the atmosphere to reactive gaseous mercury. Mercury may then become bioavailable in the terrestrial and aquatic environments following Arctic sunrise coincident with onset of the breeding season of Arctic wildlife.

2.3.2 Public Health

Infectious Diseases

The CDC's National Center for Infectious Diseases, Arctic Investigations Program (NCID/AIP), together with Health Canada's Laboratory Centres for Disease Control, Bureau of Infectious Diseases, has initiated an International Circumpolar Surveillance (ICS) system linking existing public health laboratories and facilities in the Arctic to address emerging infectious disease problems. This initiative follows U.S. government interagency recommendations established by the Committee on International Science Engineering and Technology (CISET) and the CDC's Global Health Strategy. In 2002–2006 ICS participant

countries will include the U.S., Canada, Greenland/Denmark, Iceland, Norway, and Sweden with planned linkage with public health laboratories in the Barents Sea regions of the Russian Federation. The current focus of ICS is on population-based surveillance of invasive bacterial diseases caused by *Streptococcus pneumoniae, Haemophilus influenzae, Neissera meningitidis*, Group A & B *Streptococcus* in aboriginal and non-aboriginal peoples residing in Arctic regions. Outcomes will include descriptions of diseases rates, epidemiologic factors, bacterial agent characteristics including antimicrobial susceptibility profiles, and collaborative approaches for prevention and control. Extending the ICS to include other infectious disease problems of Arctic countries is planned. Tuberculosis, particularly multi-drug-resistant tuberculosis, is once again becoming a threat to human health in many Arctic communities. Tuberculosis is expected to be included in the ICS in 2002–2006. NCID/AIP will continue research focusing on the prevention and control of infectious disease problems in the U.S. Arctic. These include viral infections caused by respiratory syncytial virus; hepatitis A, B, and C; and diseases caused by bacteria now commonly resistant to antibiotics (*Streptococcus pneumoniae*, *Staphylococcus aureus*, and *Helicobacter pylori*). Together with the Alaska Native Tribal Health Consortium, NCID/AIP will conduct projects to evaluate the immunogenicity of a new 7-valent pneumococcal conjugate vaccine in Alaska Native children and study the effectiveness of the current 23-valent pneumococcal vaccine in Alaska Native elders. *Helicobacter pylori* infection is commonly associated with gastric ulcers. Recent studies conducted by CDC's National Center for Chronic Disease Prevention and Health Promotion's Division of Nutrition and Physical Activity, the Yukon Kuskokwim Delta Health Corporation, the State of Alaska Division of Public Health, and NCID/AIP have shown an association between *Helicobacter pylori* infection and iron deficiency anemia in Alaska Natives. Additional studies are needed to assess the validity of this association, as well as the development and evaluation of effective prevention and control strategies.

Occupational Injuries

The CDC's National Institute for Occupational Safety and Health, Division of Safety Research Alaska Field Station (NIOSH/DSR/AFS), in collaboration with the Indian Health Service, the State of Alaska, the Alaska Native Tribal Health Consortium, and the Alaska Native Health Board, will continue studies on the epidemiology, risk factors, and prevention strategies for occupational injuries in Alaskan communities. The NIOSH/DSR/AFS will continue to coordinate the development of an integrated surveillance system for disease and injury in the Arctic, linking the existing NCID/AIP-initiated International Circumpolar Surveillance (ICS) system for infectious diseases with nascent systems for injuries and birth defects, eventually monitoring chronic diseases and malignancies, behavioral risk factors, and a broader spectrum of injury events. It will provide a more seamless picture of the current health status and trends by partnering with the Alaska Division of Public Health, the Alaska Native Medical Center, and the Alaska Native Health Board's Epidemiology Center.

The NIOSH/DSR Alaska Field Station is mounting two other initiatives in Arctic research. Surveillance for work-related injuries has identified the commercial fishing industry as contributing high numbers of fatal and severe non-fatal injuries. A new project will address the problems of vessel stability in the fishing fleet, the hazards posed by machinery and fishing equipment, and the physical design and layout of fishing vessels and will develop feasible interventions to prevent injuries among fishermen. Vessel stability and the deck environment surrounding the deployment and retrieval systems of fishing equipment (including the use of cranes, winches, lines, nets, crab pots, and crab pot launchers) will be examined from a mechanical and safety engineering perspective. Through effective industry focus groups and application and promotion of new technological innovations and interventions, the number of fatal and non-fatal injuries in this industry should decrease.

Alaska experienced an overall downward trend in occupational fatalities since 1990 (from 78 in 1990 to 42 in 1999, a decrease of 46%), but occupational aviation fatalities continue to be a problem. In response the U.S. Congress supported a Federal initiative to reduce aviation-related injuries and fatalities and to promote aviation safety in cooperation with the air transportation industry in Alaska. The initiative is a three-year partnership of four Federal agencies: the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), the National Weather Service (NWS), and the National Institute for Occupational Safety and Health (NIOSH). The goal is to reduce the number of aircraft

crashes and injuries in Alaska by at least 50% by the end of 2009.

Chronic Diseases

The CDC's National Center for Environmental Health, Division of Environmental Hazards and Health Effects (NCEH/EHH), will continue studies on the relationship between exposure to environmental organochlorines and development of breast cancer in Alaska Native women. This will be assessed by collecting biological samples from women undergoing breast biopsy or surgery at the Alaska Native Medical Center and analyzing these samples for endocrine-disrupting chemicals (for example, DDE, PCB, and PBB). Interviews are being conducted to identify potentially confounding risk factors for breast cancer (such as parity and family history) and to collect dietary information.

The Alaska Native Tumor Registry (ANTR) was initiated in 1974 in collaboration with the National Cancer Institute (NCI), NIH, and the Centers for Disease Control and Prevention (CDC). From the outset of registry efforts, the procedures and policies followed were those of the NCI Surveillance, Epidemiology and End Results (SEER) Program. The registry takes an active role in management and follow-up care of cancer patients. All patients are tracked and notified of recommended follow-up appointments. Accurate information on the unique cancer patterns occurring in this population is useful for provider education and training, program planning, studies of cancer etiology, evaluation of screening programs, interventions to improve patient care, and programs for cancer prevention and risk reduction.

ANTR completed the "Alaska Native Cancer Survival Report," and several scientific articles have been published based on ANTR data. The registry will provide an update of cancer incidence for Alaska Natives statewide and by service unit. Discussions are underway with the Army Corp of Engineers and the Air Force to study contaminants at military sites and cancer patterns. Research studies in progress include:

- Serum PCB levels in breast cancer patients and controls;
- Prospective study of breast cancer and organochlorines in serum and fat tissue in the breast;
- *Helicobacter pylori* and cancer and other diseases of the stomach;
- Prevalence of colorectal cancer genes in (formalin fixed) tissue among colorectal cancer patients;
- Familial aggregation of nasopharyngeal cancer; and
- Biomarkers expressed in tumor tissue of Alaska Native breast cancer patients.

The Genetics of Coronary Artery Disease in Alaska Natives (GOCADAN) Study is a five-year project that is focusing on a family study of 1200 individuals comprising 40 families of adults and children over the age of 18, primarily from two villages near Nome, Alaska. This project is a partnership with Norton Sound Health Corporation, a subcontractor to the Indian Health Service, to study the etiology of heart disease in Alaska Natives using the protocol and many investigators from the Strong Heart Study, an NHLBI-funded 12-year study of cardiovascular disease in American Indians. The study will also include a cardiology center at Cornell Medical School, a genetics center at Southwest Foundation for Biomedical Research, a coagulation laboratory at the University of Vermont, a central laboratory at Medlantic Research Institute, and investigators located at the University of Alaska. Examinations began in October 2000. A ten-centiMorgan genetic scan will be used to identify significant linkages between markers and risk factors and disease.

Three projects are being reviewed or have been approved for funding during the coming year. The Age, Gene/Environment Susceptibility (AGES) study is funded from 2001 to 2008 by the National Institute on Aging. NIA is seeking additional funding to expand this study to an existing cohort of approximately 12,000 members to identify genetic and other new risk factors for selected diseases and conditions including atherosclerosis and stroke and to characterize phenotypes for these diseases and conditions, in relation to genetic susceptibility, gene function, and genetic/environmental contributions to disease. Improvement in the measurement of quantitative traits as phenotypes will result from the use of prior longitudinal data and more recent non-invasive imaging techniques. These include calcium scoring of the coronary arteries by computerized tomography (CT) and hippocampal volume by magnetic resonance imaging (MRI).

The second proposed project is an intervention study entitled Stroke Prevention in Alaska. The intervention will focus on dietary counseling of Alaska Natives to modify and reduce fat intake, improve weight control, and increase physical activity. The study will include 600 adults over

the age of 24 from four Alaska villages, including two Siberian Yup'ik villages, one central Yup'ik village, and one Inupiaq village. Protocols for data collection will follow those for the Strong Heart Study. Data collection will include dietary assessments, cardiovascular disease risk factors, and ultrasound carotid artery measures, as well as extensive laboratory measures and lifestyle surveys.

The third proposed project is focused on Alaska villages below the Arctic Circle. It will expand, facilitate, and stimulate biomedical research, including multiple components focused on disease surveillance; survey systems for genetic, environmental, and behavioral risk factors; high-throughput genotyping; and cultural/behavioral research.

National Eye Institute (NEI) staff are engaged in discussions with investigators in the Department of Ophthalmology of the Alaska Native Medical Center regarding a proposed epidemiological study of refractive error in Alaskan children, adopting a protocol used successfully in China, Nepal, and Chile under WHO/NEI sponsorship. The Bethel area of Alaska is under consideration. With the increasing significance of refractive error as a public health problem in children, a study in a Native American population would be of high potential interest.

Alcoholism is a long-term, progressive disease that can lead to compromised workplace performance; disrupted families; long-term health complications including cirrhosis, heart disease, and cognitive impairment; and injuries and death from accidents or violence. Research into the causes, prevention, and treatment of alcoholism, including approaches that can serve the far northern environment in particular, is central to reducing the consequences of excessive alcohol use. Research supported by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) in Alaska is aimed at the nature of alcoholism in this population, approaches to treatment, and the impact of public policy on drinking. The research addresses features particular to the Alaskan environment, including the sparse population in a remote landscape with a significant Native American population.

One study is the first comprehensive clinical description of Native Alaskans in treatment for alcohol dependence using a standardized assessment protocol, identical to that used in NIAAA's multi-center Collaborative Study of the Genetics of Alcoholism (COGA), making comparison across different ethnic groups possible. In particular, identification of possible ethnic and cultural differences is likely to have implications for improved treatment outcomes for Native Alaskans.

NIAAA-supported investigators also recently looked at local policy changes in Barrow, Alaska, and their effects on alcohol consumption. During a 33-month period, referenda passed by the citizens at first imposed, then withdrew, and finally re-imposed a total ban on alcohol sales. Research findings indicated significant decreases in emergency room visits (including those for assaults) when alcohol was banned, increases to levels of the pre-ban period when the ban was lifted, and significant declines again when the ban was re-imposed by Barrow voters. The contrasts between periods when the policy was in force and periods when it was suspended makes this a revealing study of the effects of public policy on drinking.

Looking ahead, NIAAA and the National Institute of Child Health and Human Development are preparing to collaborate in studying the role of prenatal alcohol exposure in sudden infant death syndrome (SIDS). Recent findings suggest a strong relationship between alcohol use during pregnancy and SIDS, adding to the established risks of fetal alcohol syndrome and alcohol-related neurodevelopmental disorder. The high incidence of both alcohol problems and SIDS in Alaska lends itself to such research.

Another study is designed to understand how Alaska Natives maintain or achieve sobriety, such as factors that protect individuals from alcohol dependence and facilitate recovery. Spirituality is thought to be a critical element in the recovery process, and investigators will explore its role in promoting resiliency to abusive drinking behaviors.

The National Institute on Aging (NIA) continues to fund the Native Elder Research Center, located within the Division of American Indian and Alaska Native Programs of the Department of Psychiatry, School of Medicine, and University of Colorado Health Sciences Center in Denver. The Center coordinates a research career development program targeted at American Indian (AI) and Alaska Native (AN) investigators, focusing on aging, health, and culture. The Center augments ongoing partnerships with AI/AN communities to ensure involvement of elders, their families, and local systems of care in aging research. The aim is to increase the pool of talented investigators committed to research.

The Alaska Native maternal and newborn blood monitoring program will measure persistent organic pollutants, heavy metals, and micronutri-

ents in the blood of women entering prenatal care and in the umbilical cord blood of their newborn infants.

The program was developed at the request of Alaska Native communities to provide data on human tissue levels of contaminants that are transported to the Arctic from lower latitudes, entering the food chain of subsistence species, and being ingested by rural Alaska Natives pursuing their traditional diet.

The data will be utilized for several purposes:

- It will be used to provide trend data on human tissue levels over time.
- It will allow, over time, for examination of health outcome data, to see whether correlations with contaminant levels exist.
- Combined with a subsistence dietary history in each woman and micronutrient levels, the data will be examined for correlation of subsistence food intake with micronutrient levels and examined for positive health outcomes in women and infants.
- Communities will be able to perform their own risk-benefit assessment and formulate community-specific strategies to reduce exposure and maintain the traditional diet.
- The data will be shared with state and Federal agencies with responsibilities for contaminant risk assessment, and reduction of pollutant release.
- The data will be shared with the other Arctic countries as part of the AMAP protocol.

At present the monitoring program covers approximately 75 villages along the Arctic Ocean and Bering Sea, as well as the Yukon and Kuskokwim Rivers. The monitoring program is funded by the EPA, the Alaska Native Tribal Health Consortium, the CDC National Center for Environmental Health, and the State of Alaska.

Behavioral Aspects

Supported by a grant from the National Science Foundation, a researcher at the Food and Drug Administration is investigating cognitive performance related to extended residence in Antarctica and seasonal mood alterations. The project has two specific objectives. The first is to determine whether long-term exposure to low temperatures and/or dim light, both characteristic of polar winters in high-latitude environments, are associated with significant changes in cognitive performance and emotional well-being. The second objective is to determine whether decrements to mood and cognitive performance can be effectively prevented or minimized through the administration of pharmacological interventions and/or phototherapy.

The National Institute of Mental Health, NIH, is expanding its portfolio of research on the prevention of suicide in response to the recent Surgeon General's report on suicide. Included in these efforts are attempts to reach out to traditionally underserved populations such as Alaska Natives.

The National Institute on Drug Abuse, NIH, supports evaluation of the benefits of needle exchange programs (NEPs) and/or pharmacy distribution of syringes by intervening with injection drug users to reduce hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV); this research has been underway at the University of Alaska Anchorage (UAA) since 1996. Data being monitored include results of urine testing for amphetamines, cocaine metabolites, and morphine, as well as serological testing for HBV, HCV, and HIV. An objective is to refer drug injectors recruited into the study for a free HBV vaccination series, with success in enrolling over half of the active drug users participating. The subject population includes Alaska Natives, whites, African Americans, and Hispanics. NIDA anticipates that such efforts will continue in the future, with the possibility of cooperation with other countries (Canada and Russia) holding Arctic territory adjacent to Alaska.

A First Independent Research Support and Transition (FIRST) Award (1997–2001) at the University of Alaska Anchorage (UAA) is identifying subgroups of women and their risk behaviors and potential for diseases relative to use of drugs and condoms. The study uses individual level predictors, contextual variables related to sexual decision making, psychosocial constructs, and selected demographic variables to develop subtypes of women and to better understand their pattern of drug-using and sexual behaviors (particularly among Alaska Native women) that put them at risk for sexually transmitted and other blood-borne infectious diseases. Plans include expansion into full-fledged research aimed at expanding knowledge of drug use, sexual risk, and infectious disease risk of Alaska Native women.

In May 2000, NIDA staff co-organized the Eighth International Conference on AIDS, Cancer, and Related Problems in St. Petersburg, Russia, and co-chaired sessions devoted to drug abuse and AIDS epidemiology and prevention/intervention,

with participants from Siberia, the Russian Far East, and the Arctic. A large symposium is planned for May 2001 in St. Petersburg.

Delivery of Health Care

The National Institute of Mental Health, NIH, currently supports a number of telemedicine grants that are testing the delivery of mental health interventions through this technology. The NIDA-supported extramural research initiatives at the UAA have benefited from UAA's Telemedicine Project that helps to bridge the geographic expanse of Alaska in a series of "research at a distance" projects using desktop video teleconferencing technology. In collaboration with the NIDA-supported research, the Telemedicine Project is continuing to explore the uses of narrow-band telecommunications and information technology to improve the delivery of health care to all citizens of Alaska. It is anticipated that these efforts will be expanded to include countries with Arctic territory adjoining that of the U.S. (Canada and Russia).

Capacity Building/Health Disparities

The National Institute of Neurological Diseases and Stroke is funding a Specialized Neuroscience Research Program at the University of Alaska Fairbanks (UAF) that establishes an Alaskan Basic Neuroscience Program (ABNP) to expand, facilitate, and stimulate neuroscience research, to facilitate the collaborative research, and to stimulate the active participation of Alaska Native students. The ABNP will carry out interdisciplinary research to study mechanisms of neuroprotective adaptations via four specific aims: 1) develop an administrative core directly under the Provost that will provide the most effective environment, 2) develop a research program around the theme of neuroprotective adaptations and increase collaborations with other neuroscientists, 3) develop an emphasis on neuroscience graduate education, and 4) upgrade an existing tissue culture/imaging facility to state-of-the-art standards. The proposed research focuses on neuroprotective adaptations associated with hibernation and signal transduction in the control of cell death, neuronal regeneration, circadian rhythms, and thermoregulation.

The National Library of Medicine (NLM), NIH, has in the last two years created several Web-based information services that serve the public directly. MEDLINEplus and ClinicalTrials.gov are two notable resources that together are receiving more than 50 million page hits per year. NLM is prominently featuring outreach to minority and underserved communities so they may make maximum use of these services. For the Native American communities in Alaska and the Pacific Northwest, these activities are centered at the Regional Medical Library in Seattle at the University of Washington. "Tribal Connections in the Pacific Northwest" (www.tribalconnections.org) connects American Indian/Alaska Native communities to health resources on the Internet, including MEDLINEplus. This highly successful program is connecting hospitals, clinics, libraries, and remote villages via the Internet and thus reducing the isolation from quality health information and health care of this vulnerable population. Related to the Tribal Connections program is a series of telemedicine projects in rural Alaska that collectively is serving as a testbed strategy for cost containment and for raising the quality of health care for a minority population that is scattered across a vast area.

The National Cancer Institute (NCI), NIH, through its Surveillance Research Program, Division of Cancer Control and Population Sciences, supports the Network for Cancer Control Research among American Indian and Alaska Native Populations. Established in 1990, this network of researchers working among American Indians and Alaska Natives developed a National Strategic Plan for Cancer Prevention and Control Research in FY 92. The NCI shares support for Network meetings with the Mayo Comprehensive Cancer Center, Rochester, MN. With additional NCI support, the Network has convened three national conferences to discuss research and training and to disseminate results.

In 1997, NCI assisted the Network and Mayo in establishing the Native CIRCLE, a clearinghouse for information and resources developed through research (http://www.mayo.edu/nativecircle). Many useful, culturally sensitive materials, including school curricula, videos, pamphlets, and survey instruments, are catalogued and made available to researchers and communities for application in areas of smoking prevention, cancer screening, and dietary change.

Ongoing efforts for the Network include collaborative efforts with the Indian Health Service and the Centers for Disease Control and Prevention, expansion of cancer surveillance among American Indian populations, and pursuit of new studies in patterns of care and cancer survivorship. Members successfully competed to become

one of NCI's new Special Population Networks. This large, five-year project will address comprehensive tribal cancer control using partnerships between populations, tribes, multiple cancer centers, the NCI, and the American Cancer Society and will also develop, assess, and implement cancer education among community members.

The NCI supports the Native American Student Research Program, a cancer control research training program for American Indian and Alaska Native graduate and post-doctoral students. Spanning six years, the program has provided training to 53 trainees of diverse Native groups, including Alaska Natives. A substantial proportion of the trainees have been awarded NCI funds (17 of 43 eligible, or 40%) to carry out community-based cancer control activities among Native groups. The training program has been awarded another five-year grant. The projects require implementation of a research plan within an established timetable and a report utilizing analytical skills.

The Office of Intramural Research, Office of the Director, NIH, is pursuing an initiative called the Arctic Health Disparities Research Dissemination Network (AHDRDN), envisioned as a central point of recognizance for U.S. human health efforts, including research, surveillance, education and training, communications, and outreach activities, particularly aimed at the Native populations. A starting point for the Network is the new Arctic Health Information web site, currently under development by the Specialized Information Services Division of the National Library of Medicine, NIH. The AHDRDN could be proposed to the Arctic Council as a new project under its Sustainable Development Working Group (SDWG).

The U.S. Department of State will continue to promote international cooperation on health issues in the Arctic Council. The Arctic Council is an intergovernmental forum for the eight Arctic nations and six indigenous organizations representing Arctic communities concerned with environmental protection and sustainable development. The U.S. raised the profile of Arctic health issues during its 1998–2000 Chairmanship of the Arctic Council. The U.S. initiated projects on telemedicine and infectious disease, featured presentations by U.S. experts at Council meetings, and hosted the May 2000 International Conference on Arctic Development, Pollution and Biomarkers of Human Health. The U.S. also contributed to the Council's Human Health Effects Program in the Arctic Monitoring and Assessment Program (AMAP) and helped fund a new assessment of contaminants in the food supply of Russian indigenous communities in the Arctic.

At the Second Ministerial Meeting of the Arctic Council in Barrow, Alaska, in October 2000, Ministers welcomed and approved the report on Telemedicine in the Arctic prepared by the Institute for Circumpolar Health Studies and the proposal by the CDC's Arctic Investigations Program to develop an International Circumpolar Surveillance System (ICS) for infectious diseases.

The Arctic Investigations Program worked closely with Canada and Denmark/Greenland in setting up the ICS for *Streptococcus pneumoniae*. As a follow-on initiative, the Office for the Advancement of Telehealth at the U.S. Health Resources and Services Administration (HRSA) will work with Sweden and Norway to organize an international workshop to develop elements of a common methodology for evaluating the varied telehealth programs in the Arctic.

The Department of State will facilitate U.S. participation as appropriate in all the health activities of the Arctic Council. Canada's program on Children and Youth, for example, will focus on data collection and analysis of health indicators by developing pilot projects in the four broad areas of health (socio-economic-cultural, health services, psychosocial well-being, and biophysical health). The U.S. has supported the Russian Indigenous Peoples of the North (RAIPON) proposal to monitor and assess the levels of contaminants in the indigenous food eaten by residents of the Russian Arctic. RAIPON has funding from the Global Environment Facility (GEF) for this research project.

3. Agency Programs

3.1 New Opportunities for Arctic Research

3.1.1 U.S. Chairmanship of the Arctic Council

U.S. agencies are continuing to examine how best to contribute data to ongoing research programs being conducted through the Arctic Council's working groups and also whether there is scope for new research on issues relating to environmental contaminants, pollution, human health, and biodiversity. Given the Council's mandate with respect to sustainable development, there is also scope for renewed emphasis on research in the social sciences.

3.1.2 Remote Sensing

NASA has completed a major re-survey of the Greenland ice sheet, through its Program for Arctic Regional Climate Assessment (PARCA), resulting in the completion of a wide range of remote-sensing-based data sets covering the ice sheet. These are in the process of being made available, with coordination from the National Snow and Ice Data Center (see Section 3.5.1 for details about PARCA). Data sets include surface topography derived from satellite radar and airborne laser observations, meteorological observations from automatic weather stations, ice thickness from radar sounding, surface accumulation from ice cores, and passive-microwave-derived estimates of surface melt. This combined data set represents a new benchmark for the current state of the Greenland ice sheet.

NASA also supports the development of geophysical "pathfinder" data sets that will be useful to a broad community of scientists. Following a re-competition of NASA's Pathfinder program, the following projects with Arctic interests were selected. These projects include the development of a historical synthesis (1978–2000) of snow cover data from microwave and optical instruments, to be used for modeling purposes; a pilot study of Alaskan glacier extent measurements to quantify global warming impacts using satellite high-resolution optical and infrared data sets (the Global Land Ice Measurements from Space project, or GLIMS, led by USGS); and the development of snow and ice cover products for polar research applications using NASA's scatterometer data.

NASA has entered a new data-rich era of satellite observations of the Arctic, with the launch of the Earth Observing System suite of sensors. ICESAT will make observations of cloud and ice surface heights, the latter being comparable with airborne laser altimeter observations of Greenland, one of the goals being to determine whether the rapid thinning of many parts of the margin of the Greenland ice sheet is continuing. The NASA satellites TERRA and AQUA will each provide a wide range of data types that will enrich our capability to understand Arctic processes. Two examples are AMSR, which is an advanced passive microwave sensor of high potential value for sea ice studies, and MODIS, which is a high-spectral-resolution visible and infrared imaging sensor that will enhance our ability to observe surface albedo and temperature in polar regions.

3.1.3 In-situ Sensing

NASA has supported the development of the Greenland Climate Network (GC-Net), which currently consists of 20 stations with a widely distributed coverage over the Greenland ice sheet. Four stations are located on top of the ice sheet (in the 3000-m elevation range) along the north–south direction, ten stations are located along the 2000-m contour line, and four stations were positioned in the ablation region at around 300 m in elevation. GC-Net automatic weather stations (AWSs) are equipped with instruments to measure surface energy and mass balance. So far the GC-NET archive contains more than 50 station-years of measurements. These data have been quality controlled and calibrated.

3.1.4 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 study of the Bering Sea as an ecosystem. (See Section 2.2.)

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 fisheries 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.

The agency and the groundfish industry carry out large-scale observer programs to monitor at-sea catch and bycatch of the fleet. This information is used to set harvest levels and to allow wise use of the resources.

3.1.5 Cultural Exchange

Work continues on planning for the Russia–United States International Beringian Park in the Bering Straits region. This park would preserve the unique environmental and cultural heritage adjacent regions of Alaska and Siberia. Current plans call for continuing the highly successful past efforts on research, cultural exchanges, and publication projects.

3.1.6 Data

Common to all programs is the need for consistent data management among the Federal agencies. The Arctic Data and Information Program describes this activity (see Section 4.2).

3.1.7 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 from 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 preserve and disseminate 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 people, cultures, and regions for the past 15,000 years.

Under the Environmental Working Group (EWG) of the U.S.–Russian Joint Commission on Economic and Technological Cooperation, the U.S. and Russia have developed methods and procedures for using national security data for environmental problems of mutual interest. A key success of the EWG has been the creation of a series of Arctic climatology atlases using information derived from both Russian and U.S. national security data. Four CD-ROM atlases covering winter and summer oceanography, ice, and meteorology have been released with 40-year gridded time-histories. The oceanographic atlases have more than doubled the Arctic oceanographic information available to the world's scientific community.

3.1.8 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–sub-Arctic 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.

3.1.9 Permafrost Degradation

Renewed concern for the potential damage to infrastructure and the environment due to permafrost degradation has been sparked by ongoing

initiatives to provide access to the National Petroleum Reserve in Alaska (NPR–A) for nonrenewable resource development, as well as increased DOD interest for potential National Missile Defense facilities in Alaska and other Arctic regions.

Roads, airfields, buildings, and pipelines founded on permafrost are at risk of damage when the ground warms or thaws. This degradation causes frozen ground to lose its strength, with consequences ranging from a reduced service life to outright structural failure. The thawing of ice-rich permafrost produces irregular settlement and slope instabilities that permanently alter the terrain and have catastrophic consequences on the infrastructure.

Significantly, permafrost degradation is not a hypothesized outcome of global warming: engineers have been dealing with the effects of permafrost degradation for some time, and there are documented cases of the resulting damage to the infrastructure. Although a link with global climate change is intuitive, factors such as microclimate, local hydrology, glacial history, geomorphology and materials, and increased snow depth can promote, and in some cases control, degradation at specific sites.

In addition to the impact to infrastructure, permafrost warming and thawing have dramatic effects on vegetation, topography, and hydrologic processes, which in turn have serious ecological and land use implications. Warming may increase the release of trapped methane and CO_2 as a greenhouse gas. The degradation process may result in a dramatic increase in the mobility of contaminants locked in existing permafrost deposits. The impact is initially localized and is highly dependent on the nature of the contaminants and the geological and hydrological conditions of the site. The contaminants become more widespread as warming proceeds, increasing the probability of their introduction into the food chain and large-scale groundwater contamination.

The issue of permafrost degradation impacts virtually all elements of the existing infrastructure and future Arctic building programs, land use, and contaminant mobility, and raises concerns regarding the exposure of other cold-regions nations to this threat. Although this problem has been recognized by the engineering community, knowledge of the extent of permafrost areas at risk, predictions of the rate of degradation and the resultant damage to specific structures, and a strategy for dealing with progressive damage are all lacking.

3.1.10 Contaminant Behavior and Impact in Northern Polar Regions

This new program of the National Science Foundation has as its goal to encourage research on the physical and biological routes, rates, and reservoirs of Arctic contaminants to develop baselines for natural systems. This research will provide a better understanding of the behavior of contaminants among the Arctic's atmospheric, marine, terrestrial, and estuarine systems and their impacts on human populations and ecosystems.

3.2 Arctic Ocean and Marginal Seas

3.2.1 Ice Dynamics and Oceanography

NASA has developed the Radarsat Geophysical Processor System (RGPS) to produce estimates of the motion, deformation, and seasonal thickness of the Arctic Ocean ice cover from time-sequential synthetic aperture radar imagery. This system has provided, for the first time, accurate, large-scale measurements of the spatial variability of the area ice cover. The seasonal ice is important because it contains the crucial thickness range that produces the most ice growth, the most turbulent heat flux to the atmosphere, and the most salt flux to the ocean. The ultimate objective is to compile, from long-term, high-resolution observations, basin-scale estimates of geophysical fields that are suitable for process studies, model parameterization and validation, and climatological studies. From the area and thickness estimates, the RGPS can be used to compute the deformation of the ice cover and the volume stored in seasonal ice as a result of the nonuniform motion of the ice cover.

NASA has continued to investigate the large-scale changes in the Arctic sea ice cover since late 1978, using satellite passive-microwave data from NASA's Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) and the Defense Meteorological Satellite Program's Special Sensor Microwave Imagers (SSMIs). The satellite data

allow calculation of sea ice concentrations (the percentage of area covered by ice) and, through use of the concentrations, ice extents and length of the sea ice season (the number of days per year with ice coverage). Analysis of how the ice concentrations, ice extents, and length of the sea ice season have changed since 1978 contribute to our understanding of Arctic climate variability, which is the first step in establishing its role in climate.

Results of the analysis for the satellite data from late 1978 through the end of 1996 reveal considerable spatial and interannual variability within the Arctic ice cover but also some clear overall trends. Most prominently the Arctic sea ice extents exhibited an overall trend toward less sea ice, at an average rate of 34,300 ± 3,700 square kilometers per year, or 2.8% per decade. The largest decreases were in the Kara and Barents Seas and the Seas of Okhotsk and Japan. Increases occurred in the Bering Sea, Baffin Bay/Labrador Sea, and the Gulf of St. Lawrence, although only those in the Gulf of St. Lawrence were statistically significant.

Greater spatial detail in the patterns of Arctic sea ice cover change has been revealed by mapping trends in the length of the sea ice season. The central Greenland Sea and most of the ice-covered region of the eastern hemisphere all display shortening sea ice seasons, with the strongest trends being in the eastern Barents Sea, just north of far western Russia. The Bering Sea, northern and eastern Baffin Bay, the Labrador Sea, and the Gulf of St. Lawrence all experienced lengthening sea ice seasons instead. Overall, a much larger area experienced a shortening in the sea ice season than a lengthening, corresponding well with the overall ice extent decreases over the same period found through the same satellite data and with the thinning of the ice cover found through submarine data.

To provide explanations for the observed hemispheric and regional trends in sea ice coverage, NASA is also funding investigations that model the role of sea ice in Arctic climate. The recent changes of reduced Northern Hemisphere sea ice coverage and thickness have raised the issues of whether they are indeed trends or part of natural variability and whether the observed trend could be the result of an anthropogenic process. One of the most robust projections of global circulation models in response to increasing anthropogenic trace gases is a decrease in Northern Hemisphere sea ice. Is the decrease of 2.8% per decade over the 40 years, and the noticeable thinning of ice throughout the region, the expected beginning of this anthropogenically driven process? If so, it has strong implications for high-latitude warming and a positive sea ice–albedo feedback.

Modeling carried out at NASA's Goddard Institute for Space Studies (GISS) indicates that the change in phase of the North Atlantic Oscillation associated with recent changes in Arctic sea ice primarily arises from the impact of increasing trace gases on the zonal wind structure in the upper troposphere/stratosphere and the corresponding alteration in planetary wave propagation. At the same time, increasing trace gases lead to a freshening of the North Atlantic, a reduction in North Atlantic Deep Water production, and cooling in the high North Atlantic, also decreasing the sea level pressure in this region. In this model, future sea ice decreases result primarily from thermodynamic factors associated with global warming, rather than sea ice advection. Once sea ice decreases, the effect on the atmosphere is to promote more cyclonicity, enhancing the removal of sea ice from the Arctic. The important conclusion, based on the GISS model analysis, is that the observed change in sea ice in the Arctic appears to be arising from increasing atmospheric greenhouse gases, but acting primarily through atmospheric and oceanic dynamical changes; however, future Arctic sea ice decreases may be more associated with global warming than with advection changes, a result that needs to be explored with a coupled ocean–troposphere–middle atmosphere model.

The goal of NASA's Polar Exchange at the Sea Surface (POLES) project is to refine knowledge of the Arctic climate system using satellite and other observations and models. The POLES piece of the climate system puzzle includes the heat and moisture balance of the polar atmosphere, the amounts and radiative effects of polar clouds, the surface heat and moisture balance, and the transport of heat and moisture into the polar atmosphere from the midlatitudes. With a good knowledge of these variables, it is possible to determine the history and forcing mechanisms of climatic change in Arctic sea ice cover, the freshwater balance of the Arctic Ocean, and its interaction with subpolar oceans.

New Arctic Ocean ice thickness data from U.S. Navy submarines show a striking thinning over the past several decades, a change that mirrors decreasing ice extent seen by satellites. A sea ice model shows similar changes and has the advantage of allowing a diagnosis of model forcing and

About half of the ice thinning over the past 35 years is apparently caused by a slow, continual warming of Arctic surface temperatures. The other half of the modeled thinning is caused by a change in surface wind patterns; it is more abrupt and appears strongly in the 1990s.

The POLES program will continue under a project called The Role of Polar Oceans in Contemporary Climate Change. The focus shifts somewhat to assimilating a variety of observed data sets into model simulations to provide the best possible estimate of the Arctic climate record for the past 50 years. The first step is to determine the optimal methods for utilizing satellite-based estimates of forcing variables and for assimilating satellite and ground-based measurements of ice motion and ice concentration into our ice–ocean model. Global climate models tend to use very elementary physics to represent sea ice; this can contribute to poor representation of all Arctic climate processes in longer-term climate hindcasts and predictions. The sea ice model, with its more sophisticated ice physics, is being modularized, so that it will be readily accessible for these GCMs.

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.

3.2.4 Underwater Research

Marine scientists working in the Arctic are severely limited by vessel capability and other logistical problems. The development of submersible technology, especially remotely operated

vehicles (ROVs) and autonomous underwater vehicles (AUVs), may significantly improve our ability to study and understand the physical and biological processes of the polar seas. The increased U.S. policy interest in the Arctic and the biological and physical data accumulating about it challenge undersea technology.

NOAA's National Undersea Research Program's (NURP) West Coast and Polar (WC&P) Center, located at the University of Alaska Fairbanks, has supported many projects in recent years, including studies of beluga whale feeding habitats in the Arctic and benthic response to early season deposition of algae in the Chukchi Sea. During the Chukchi Sea expedition the Coast Guard Cutter *Polar Sea* cut a path through the Arctic ice and provided openings so that an ROV provided by WC&P could obtain seafloor samples. The underside of the ice pack was found to be home to dense mats of algae that fall to the bottom and feed a thriving seafloor community. Bacteria were collected in a search for new drugs. Water, biota, and ice samples provided data on carbon dioxide sea–air exchange to help understand the global carbon cycle and climate change.

Objectives

- Increase our understanding of the relationship of finfish and shellfish to particular habitats and improve population estimates;
- Study shelf and slope ecology, particularly important biological processes and the physical and biogeochemical processes that accompany them;
- Study tectonic environments, such as hot spot effects, fracture zones, and propagating rifts, including the ecology and chemical characteristics;
- Study the fishery potential of seamounts, where unique biological communities have developed due to a combination of isolation, bathymetry, and ocean current regime, and search for clues to the causes of intra- and interannual variability of fish stocks; and
- Using acoustic propagation, perform physical oceanographic studies of biological activity under the ice in the Arctic, particularly light and chlorophyll studies, coupled with studies of the biological communities and ecosystem dynamics under ice and in areas covered seasonally by ice.

3.3 Atmosphere and Climate

3.3.1 Upper Atmosphere and Near-Earth Space Physics

The goal of this research is to study upper atmospheric and near-Earth space phenomena unique to the Arctic regions. These include the aurora, particle precipitation, auroral convection and currents, polar mesospheric clouds, Joule heating, and geomagnetic storms and substorms. These phenomena are intimately linked to the Arctic environment and culture, particularly as Arctic inhabitants become more dependent on modern technology and the Arctic economy becomes more firmly planted in technical systems.

Many of these phenomena are driven by particles and fields originating on the sun. Particles from the sun impact Earth's magnetosphere, which is connected to the upper atmosphere and ionosphere through magnetic field lines that converge in the polar regions. A large fraction of the energy entering the magnetosphere is deposited in the polar upper atmosphere with dramatic consequences. Strong currents can disrupt electrical power systems and cause accelerated erosion in oil pipelines. Magnetic perturbations jeopardize the accuracy of mining exploration technology. Arctic ionospheric disturbances interrupt the performance of GPS navigation systems, surveillance systems, and high-frequency radiowave propagation.

The state of the space environment near Earth and its response to solar inputs has come to be known as space weather. The study of Arctic phenomena represents a critical element in understanding the way the space weather system works.

The Arctic region is also extremely sensitive to atmospheric changes associated with global warming. Ongoing research is showing that the sensitivity of the Arctic upper atmosphere to climate change provides an effective means to monitor long-term variations of the atmosphere. Warming of the atmosphere at lower altitudes occurs in conjunction with cooling of the upper atmosphere, a change that is believed to be manifested in the increasing occurrence rate of polar mesospheric clouds. Changes in the thermal structure of the upper atmosphere have also produced a

measurable change in the height of ionospheric layers. These effects are being studied intensively as part of the U.S. Global Change Research Program.

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 Relocatable Atmospheric 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 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 Earth's ionosphere.

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 people 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 Upper Atmosphere Research Program (UARP) and the Atmospheric Chemistry Modeling and Analysis Program (ACMAP) are the experimental and modeling components, respectively, of NASA's research program to study the upper atmosphere. Together, they aim at expanding our scientific understanding so as to permit both the quantitative analysis of current perturbations as well as the assessment of possible future changes in this important region of our environment.

With respect to the Arctic, UARP and ACMAP strive to understand the greater frequency of substantial stratospheric ozone loss in recent winter/spring seasons and thereby develop a prognostic ability to assess the likelihood of continuing erosion of ozone in the Arctic stratosphere over future decades. Research studies within any one winter are designed to explore avenues of distinct T, Cl_x, NO_y, DO_x embedded in the Arctic vortex

that are representative of the different Arctic winter conditions that are likely to occur during the next decade or two of peak vulnerability of stratospheric ozone to destruction catalyzed by halogen chemistry. Such exploration will enable us to define the response of the chemical system to changing boundary conditions of T, H_2O, etc., thereby projecting the longer-term response of Arctic stratospheric ozone to climate change forcings.

Within the next year, two additional satellite instruments will be launched that have a primary objective of continuing trends quality data for both the total ozone column and the ozone profile. SAGE III is a fourth-generation instrument and a crucial element in NASA's Earth Observing System (EOS). The first of three flights of the SAGE III instrument currently planned will be a flight aboard a Russian Meteor-3M platform in early 2001. SAGE III/Meteor will be in a sun-synchronous polar orbit that provides primarily high-latitude measurements via solar occultation. The primary scientific objective of the three SAGE III missions is to obtain high-quality global measurements of key components of atmospheric composition. Its mission is to enhance our understanding of natural and human-derived atmospheric processes by providing accurate long-term measurements of the vertical structure of aerosols, ozone, water vapor, and other important trace gases in the upper troposphere and stratosphere. These measurements are vital inputs to the global scientific community for improved our understanding of climate, climate change, and human-induced ozone trends.

The QuikTOMS mission (also planned for launch in 2001) is designed to continue daily mapping of the global distribution of the earth's total column of atmospheric ozone with Total Ozone Mapping Spectrometer Flight Model 5 (TOMS-5). TOMS-5 was scheduled to be launched in the year 2000 aboard the Russian satellite Meteor-3M (2), but the Meteor-3M (2)/TOMS-5 mission was terminated in April 1999. Because of the timeliness requirement of ozone monitoring, NASA had to formulate a new mission to fly TOMS-5 in a short time. The continuous observation of the global ozone past the year 2000 is critical for monitoring the expected recovery of ozone as levels of chlorofluorocarbons (CFCs) decrease from their current maximum as a result of the Montreal Protocol limits. Thus, it will play a critical role in tracking the annual changes of ozone in the Arctic stratosphere.

Objectives

- Understand the chemical, physical, and transport processes of the upper troposphere and the stratosphere and their control on the distribution of atmospheric species such as ozone;
- Assess possible perturbations to the composition of the atmosphere caused by human activities and natural phenomena (with specific emphasis on trace gas geographical distributions, sources, and sinks and the role of trace gases in defining the chemical composition of the upper troposphere and the stratosphere);
- Understand the processes affecting the distribution of radiatively active species in the atmosphere and the importance of chemical–radiative–dynamical feedbacks on the meteorology and climatology of the stratosphere and troposphere;
- Understand ozone production, loss, and recovery in an atmosphere with increased abundances of greenhouse gases; and
- Conduct modeling analyses and observations to understand the influence of Northern Hemisphere boreal forest fires on the Arctic atmosphere.

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.

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 hydrate, 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 process 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, and 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

Enhanced knowledge of Arctic and sub-Arctic ecosystems, their controlling processes, and productivity will lead to improved forest, cropland, and soil management practices for sustaining renewable resource productivity. The goals are to promote self-sufficiency and economic benefits for local inhabitants.

Objectives

- Sustain a research program covering northern boreal forest ecosystems and their controlling processes, focusing on forest landscape and stream ecosystem sustainability and long-term productivity in the face of episodic disturbance, global change, and atmosphere, landscape, forest, stream, and management interactions;
- Conduct soil and plant science research to enhance management practices in the face of development and low-temperature, perma-

frost, and wildfire impacts;
- Prepare coordinated soil resource information (maps and databases) of the Arctic circumpolar region and continue to coordinate this effort with China, Russia, Canada, and Finland;
- Conduct animal science research focused on integrated pest management and Holarctic ruminant parasites; 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

The Program for Arctic Regional Climate Assessment (PARCA) is a NASA project with the goal of measuring and understanding the mass balance of the Greenland ice sheet. Primarily remotely sensed data have been used in the project, complemented by targeted in-situ measurements, primarily on ice cores and at automatic weather stations (AWS).

Before PARCA, we could not determine whether the ice sheet was increasing or decreasing in volume, and mass-balance errors were equivalent to a thickness change of about ±10 cm/yr for the entire ice sheet. Since then, repeat surveys by satellite radar altimeter (1978–1988 and 1992–1999) and by aircraft laser altimeter (1994–1999), and volume-balance estimates from comparison of total snow accumulation with total ice discharge, all show that the entire region of the ice sheet above about 2000 m in elevation has been close to in balance (within 1 cm/yr) for at least the past few decades but with smaller areas of quite rapid change that can largely be explained by temporal variability in snow accumulation rates. Some areas, however, appear to be undergoing large changes, which may be ongoing adjustments to events since the last glacial maximum or they may indicate changes that began only recently. In particular, most surveyed outlet glaciers are thinning in their lower reaches, and a large area of ice sheet in the southeast has also thinned significantly over the past few decades, at rates that increase to more than 1 m/yr near the coast. Only part of this thinning can be explained by increased melting associated with recent warmer summers, indicating that ice discharge velocities must also have increased.

Future PARCA research will address these issues, focusing on near-coastal snowfall and ablation and on the dynamics of thinning outlet glaciers. This work will also help prepare for the interpretation of future measurements of elevation change by the Geoscience Laser Altimeter System (GLAS) aboard NASA's ICESAT, to be launched early in 2002. For example, in addition to understanding coastal thinning, a major goal of future PARCA research will be the development of models that reliably hindcast temporal variability in snowfall and surface ablation over the ice sheet, using analyses from operational weather-forecasting models to provide ongoing maps of accumulation and ablation rates over both polar ice sheets. This will best be achieved by developing appropriate capabilities for Greenland, where the existing database is far richer than for Antarctica and where the acquisition of new data can be both rapid and at low cost.

NASA has also supported an assessment of the current state of balance of major Canadian ice caps. This makes use of survey work from the mid-1990s, from which changes in surface topography can be assessed. Initial results indicate that all of the ice caps for which analyses have been completed show some signs of thinning, primarily at the edges. Not all data from each of the ice caps have been analyzed yet, but the level of thinning is consistent with what has been observed in the more temperate regions of the Greenland ice sheet.

Future NASA plans for research on the Canadian ice caps include continued analysis of elevation change characteristics, an examination of the temperature and accumulation history of the last several decades using coastal and in-situ data, and a determination of the level of imbalance of the ice caps as a whole.

The effect of the northwest North American glacier system covering Alaska and western Canada on sea level remains poorly know. NASA has been estimating the mass balance of the largest glaciers and icefields bordering the Gulf of Alaska using SAR imagery, combined with small-aircraft laser altimetry and a digital elevation model of Alaska. The study has also involved simulating the mass balance of these glaciers over the longest

time scales for which low-altitude temperature and precipitation data are available from nearby coastal communities, using a precipitation–temperature–area–altitude (PTAA) mass balance model calibrated with the altimetry results. There has also been a simulation of the freshwater runoff into the Gulf of Alaska from these glaciers and the changes in runoff through time, from early in the 20th century to the present. The results to date indicate that the Seward–Malaspina glacier system alone accounted for about 0.4% of the mean global sea-level rise (1.8 mm/yr) observed during this time period. The long-term goal of this project is to estimate the increases in the freshwater contributions to the Alaska Coastal Current caused by negative glacier mass balances around the entire Gulf of Alaska, as well as the contribution to rising sea level caused by melting and thinning of these glaciers and icefields.

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 sub-Arctic 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 contaminant 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.

Recent concerns of Arctic infrastructure damage due to permafrost degradation have highlighted the inability of current engineering and technology design criteria to address changes in the permafrost foundation over the life cycle of these structures. These deficiencies impact the existing infrastructure in Alaska (where warming is occurring at a faster than expected pace), and future Arctic building programs, including structures such as roads, pipelines, buildings, airfields, and hazardous material storage tanks. These same concerns have been raised regarding the exposure of other cold-regions nations to this threat, particularly in the former Soviet-block countries.

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.

Objectives

- Develop engineering data and criteria for building, operating, and maintaining strategic and operational facilities and infrastructure in the Arctic, including the effects of permafrost degradation;
- Ensure that current engineering practices include assessment of potential impacts of warming climate on permafrost and other Arctic systems commensurate with the design life of the projects;
- Provide the capability to conduct logistics operations and research support and development in the Arctic;
- Undertake assessment of the potential impact of weather changes associated with climate warming on transportation and maintenance of lines of communications;
- Develop environmentally compatible engineering technologies for the Arctic;
- Develop enhanced understanding of cold-regions performance of new structural materials and systems;
- Provide design criteria for ship operations in ice-infested waters;
- Provide mapping and prediction of ice conditions, along with GIS-based monitoring systems, for port and harbor management;
- Provide engineering data and criteria for water resources activities and environmental impact permitting;
- Provide GIS database and mapping capability for land use, water resources, and monitoring of environmental degradation;
- Ensure that the best available, safest, and pollution-free technologies are used in the development of oil and gas in the Arctic and outer continental shelf;
- Ensure, through technology transfer and retrospective case studies, that future resource exploration and development in the Arctic take advantage of both tried and proven methods, as well as incorporating innovative new technology with minimal environmental impact;
- Provide enhanced engineering criteria and techniques to use naturally occurring materials, such as snow and ice, for ice road and island construction, reducing costs and minimizing environmental impacts;
- 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;
- Develop criteria for exploitation of frozen ground conditions to minimize environmental

impact (tundra snow and ice roads) and enhance system performance (for example, ground-penetrating radar);
- Prevent the discharge of oil, chemicals, and other hazardous materials into the marine environment;
- Ensure quick, effective detection and cleanup of pollution discharges;
- Provide the ability to predict and map movement of pollutants in ice-infested waters;
- Develop Arctic-appropriate cleanup technologies for contaminants and remediation of sites resulting from past military and resource development;
- Evaluate enhanced marine transportation for resupply of coastal and Arctic villages;
- Develop and maintain effective surface transportation and air support facilities in the Arctic; and
- Develop mechanisms for technology transfer between government, academia, and private industry.

3.7 Social Sciences

The historic, current, and future presence of human populations in the Arctic has made the social sciences a top priority and a valuable tool for Arctic research. How have various groups adapted to environmental, economic, and social change? What predictions about future adaptations can be made on the basis of the historic and prehistoric record? These are just a few examples of questions that arise when considering the role of societies in Arctic research. In addition, Arctic communities have themselves become active partners in research projects responding to local needs and concerns.

In an effort to coordinate research plans among Federal agencies, an Interagency Arctic Social Sciences Task Force was established within the Interagency Arctic Research Policy Committee (IARPC). The Task Force prepared and 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 people. The principles have fostered greater awareness of local concerns among Arctic researchers and have helped to place a high value on the full participation of Arctic residents in research and environmental issues.

International Arctic Social Science and Health Research

International scientific organizations that have recognized the importance of Arctic social sciences include the International Arctic Social Sciences Association (IASSA), the International Arctic Science Committee (IASC), and the International Union for Circumpolar Health (IUCH). The U.S. has actively participated in these organizations.

The Arctic Council also admitted two new indigenous groups, the Arctic Athabaskan Council and the Gwich'in Council International, as Permanent Participants. They join the Aleut International Association, the Inuit Circumpolar Conference, the Saami Council, and the Russian Association of Indigenous Peoples of the North (RAIPON), bringing the number of Permanent Participants on the Council to six. RAIPON was elected to replace the Saami Council as chair of the Board of the Indigenous Peoples' Secretariat in November 2000.

The program of the Arctic Council's Sustainable Development working group depends in part on the work of social science research. Research is at the heart of the Survey of Living Conditions in the Arctic: Inuit, Saami and the Indigenous Peoples of Chukotka. The Arctic Telemedicine project, the International Circumpolar Surveillance project on infectious diseases in the Arctic, and the project on Arctic Children and Youth all depended, in part, on the contributions of social science research. The Council anticipates that additional projects underway on timberline forests, capacity building, reindeer husbandry, and ecological and cultural tourism will benefit from the contributions of social science research.

Social science research is also a significant contributor to the environmental protection agenda of the Arctic Council. Social science research, for example, is an integral component of the new Arctic Climate Impact Assessment (ACIA) and an element of the monitoring programs for toxic pollutants under AMAP's subgroup on Human Health.

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. Arctic social scientists work with Arctic communities in a collaborative fashion. For example, NSF's Arctic Social Sciences Program contributed to the establishment of the Alaska Native Science Commission, an organization that provides essential linkages between researchers and local communities, facilitating communication and cooperation. The Arctic Social Sciences Program has partnered with the Arctic Research Support and Logistics Program to support a long-term data collection and archive project by the Calista Elders' Council focusing on traditional Yup'ik knowledge and culture.

NSF plans to continue to emphasize the partnership approach in the Arctic through enhanced outreach to Arctic communities, recognizing that cooperative community relations and education form a central tenet of responsible research conduct.

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 emphasis on the social and behavioral processes that shape and influence those interactions. NOAA's Economics and Human Dimensions program supports research investigating human responses to variations in the climate system. The program currently focuses on the potential use and constraints to the use of climate forecast information for decision making across a range of sectors. Although NOAA's Economics and Human Dimensions program does not focus on any particular region, the role of indigenous knowledge and how it might interact with newly developed climate forecast information, as well as the ways in which Native communities adapt to their regional climate, is of interest to the program. The Human Dimensions of the Arctic System (HARC) initiative, launched under the NSF Arctic System Science program, will focus on the dynamics of linkages between human populations and the biological and physical environment of the Arctic, at scales ranging from local to global. HARC research examines current and potential impacts on human activity that may be expected to occur in response to global change.

Education, Training, and Outreach

NSF and Federal agencies are committed to training young scientists and to developing educational components that link social scientists with students and other members of Arctic communities. The Smithsonian Institution conducts research and education programs in the North Pacific, Russia, Canada, and the North Atlantic region and provides museum and exhibit training in Washington, D.C., and Anchorage, Alaska. In the summer of 2001 a new exhibition on Alutiiq culture of Kodiak Island will open in Alaska and tour for two years. Finally, the massive millennium exhibition, "Vikings: the North Atlantic Sagas," which opened in Washington in mid-2000, has traveled to New York and will tour to Denver, Houston, Los Angeles, Ottawa, and Minneapolis through 2003. In addition to catalogues for these exhibitions, a new Arctic Studies Center publication series, *Contributions to Circumpolar Anthropology*, has been initiated and will include an English translation of a material culture atlas of Siberia, a Native history of the Bering Strait region, and archival studies of the Jesup North Pacific Expedition and works on the Yamal, Siberian archaeology, and the history of Eastern Arctic archaeology.

Programs such as NSF's Faculty Early Career Development (CAREER) program support innovative research and teaching by junior faculty members. Dissertation Improvement Grants, available through NSF's Arctic Social Sciences Program, support graduate students in their Ph.D. research projects. Research Experience for Undergraduate (REU) supplements and sites provide on-site research training to college and university students. The Teachers Experiencing the Arctic (TEA) program links secondary school teachers with Arctic scientists to form research teams and bring Arctic research experiences into the secondary school classroom.

NSF encourages community outreach and education through supplements to visit local communities and schools, develop and share instructional materials, involve students in research projects, and disseminate research results to a large audience. Small Grants for Exploratory Research (SGER) can be used for exploratory or high-risk projects that require community endorsement before researchers can make definite plans.

The RAPS (Resource Apprenticeship Program) of the Department of the Interior has provided summer jobs for Alaska Natives through the NPS, BLM, and FWS. Other programs, such as the

Cooperative Education 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 and field trips) and other opportunities for education that foster stewardship and the conservation of heritage resources. The Forest Service is continuing a comprehensive program of cultural resource presentations, subsistence awareness sessions, and site monitoring and protection. The Forest Service will continue to sponsor multicultural educational opportunities involving Native and local communities, as well as the diverse range of National Forest visitors.

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's 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.

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 Smithsonian's Arctic Center office in Anchorage has produced cooperation with several other government agencies in a 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 SI cooperation with NSF and NEH has resulted in several important exhibitions and publications. 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, walrus, whales) supported the largest human populations in Alaska, and changing shorelines and maritime conditions are reflected by these sites. An example of one such site that is changing our view of human–environment interactions in the Arctic is found on Zhokov Island in the northern Laptev Sea. This 8000-year-old site is being excavated by Smithsonian and Russian scientists. The island seems to have been an early Holocene thermal "oasis" that supported early human life and a biota warmer than that of the present day, at a time when much of the Arctic was still buried under continental ice.

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 also become a major priority for museums and research institutes since the pas-

sage 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 at the Smithsonian has resulted in returns of most of its collections of human remains from Alaska, and consultations are beginning with regard to cultural objects. At the same time a new program, the Smithsonian Alaska Collection Project, has been initiated by the Arctic Studies Center. The project will involve consultation with various groups of Alaska Natives over cultural materials they would like to see brought to the Arctic Studies Center office in Anchorage for study, exhibition, and publication on the Internet.

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.

One of the recent losses contributing to community instability lies in the area of historical knowledge. While the elders remain important in transmitting knowledge, much information on the past two centuries of community history lies in museums and archives far from northern villages. With NSF assistance, the Smithsonian has been pioneering new methods of "knowledge repatriation" on St. Lawrence Island, through collaborative identification, publication, and local dissemination of historical community records that have never before been available to village residents.

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 interdependencies due to harsh environmental conditions in the Arctic highlight this definition. Consequently Arctic health research must take into account complex human and environmental interactions.

Health research in the Arctic focuses on basic and applied biomedical topics (such as molecular biology and genetics), the effects of cultural change on Native populations, the epidemiology of disease, adaptations 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 intimately linked to international health issues. Western 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 Centers for Disease Control and Prevention, the Indian Health Service, the National Institutes of Health, and the Department of Defense. Nonclinical research on social and behavioral aspects of health is supported by the National Science Foundation's Arctic Social Sciences Program. (For more information, see Section 2.3.)

Objectives

- Ensure interagency communication and coordination in health research priority setting, resource management, infrastructure, and program development to ensure that health research translates into prevention and control activities that benefit all Arctic people;
- Establish, enhance, and maintain surveillance systems of health events impacting Arctic populations to allow timely and focused interventions and the monitoring of intervention effectiveness;
- Establish, enhance, and support basic and applied research for the purpose of improving health through biomedical and behavioral research programs; and
- Establish, enhance, and maintain health communication systems to facilitate timely dissemination of basic and applied research information on the etiology, pathogenicity, diagnosis, prevention, and treatment of diseases of concern to people of the Arctic.

4. Research Support, Logistics, Facilities, Data, and Information

4.1 Research Support and Logistics

IARPC will use new resources targeted for Arctic logistics to enhance the leadership role of the U.S. in Arctic research. The focus on logistics entails:

- Establishment, development, and maintenance of national Environmental Observatories;
- Technology and instrument development;
- Expansion of marine platforms and aircraft support capabilities;
- Integration of research, education, and Arctic community interests; and
- Further international collaboration in the support of research.

The use of the new resources will be guided by the Arctic Research Commission's report *Logistics Recommendations for an Improved U.S. Arctic Research Capability*. The general recommendations of the report are:

- Ensure access to the Arctic over the entire year;
- Increase availability and use of remote/autonomous instruments;
- Protect the health and safety of people conducting research in the Arctic;
- Improve communications and collaboration between Arctic people and the research community; and
- Seek interagency, international, and bilateral logistics arrangements.

Planning will be done in partnership with Native groups and other advisory bodies and will respond to merit-reviewed proposals.

The development of additional Environmental Observatories (EOs) is a major component of the proposed plan for logistics enhancement and is also an identifiable component of the NSF theme "Biocomplexity." Candidates for Arctic Environmental Observatories include:

- Toolik Lake, Alaska, an NSF LTER site where the agency has already supported upgrades;
- Barrow, Alaska, Environmental Observatory, where NSF has initiated a cooperative agreement with the Barrow Arctic Science Consortium; and
- Summit, Greenland, a site for which NSF is exploring joint year-round operations with Denmark and other European countries.

As proposals are received for these sites, they will provide the core of an Arctic network for use in distance learning programs, science projects, and related logistics support. By working through the International Arctic Science Committee (IASC), the U.S. hopes to link its EOs with those of other countries (for example, Abisko, Sweden; Svalbard, Norway; and Zackenburg, Kangerlussuaq, Denmark/Greenland) to assure that scientists have access to the full range of Arctic environments and to promote distance learning on an international scale.

The NOAA/CMDL Barrow Observatory, a manned atmospheric baseline facility located six miles northeast of Barrow, has been in continuous operation since 1973. The Barrow Observatory focuses on research relating to atmospheric constituents that are capable of forcing change in the climate of the earth through modification of the atmospheric radiative environment, as well as those that may cause depletion of the ozone layer. This facility conducts scores of continuous monitoring activities, including hosting 21 cooperative programs with universities and other government agencies. NOAA operates a three-station network of solar UV measurements with sites at Barrow, St. Paul Island, and Nome. The Barrow Observatory has expanded its research activities over its lifetime and expects to be monitoring climate change in the Arctic through the next century. Information on CMDL and the Barrow Observatory can be found at http://www.cmdl.noaa.gov.

In response to concerns about Arctic ozone loss and increased UV-B radiation, NSF is considering establishing increased UV measurement projects at the same three EO sites. Also, the atmospheric and space weather observatories at existing U.S. facilities at the Sondrestrom Radar (Greenland) and Spitsbergen may be upgraded.

Research applications of aerosondes (drone aircraft) also will be examined.

Another major logistics issue in the Arctic is developing full access and capability to conduct research on all aspects of the Arctic Ocean. The U.S. plans to facilitate this by funding:

- Research use of the new USCGC *Healy*;
- Tomographic arrays; and
- Improved sensors for the Arctic drifting buoy program, moorings, and autonomous underwater vehicles.

For both marine and terrestrial research the U.S. will improve basic health and safety by providing access to a pool of emergency beacons, satellite phones, and GPS receivers. There is also a need to better integrate traditional knowledge of Arctic residents with research to broaden our capability in the Arctic. The U.S. plans to increase the duration of measurements (especially during the winter) by providing remotely operated instruments linked with individual researchers in their labs, with other Environmental Observatories, and with distance learning centers at community colleges and elementary schools involved with the Alaska Rural Systemic Initiative and the College of Rural Alaska.

4.1.1 Ships and Ice Platforms

Vessels supporting research in ice-covered areas fall into four categories, based on their ice-going capability:

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

The Coast Guard maintains icebreaking facilities with due regard to national defense and for icebreaker support to other Federal agencies pursuant to interagency agreements. 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. 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 three icebreakers, which 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. The Arctic Icebreaker Coordinating Committee (AICC) of UNOLS, the University–National Oceanic Laboratory System, coordinates science community and Coast Guard planning for science missions.

Drift stations and other ice platforms including international opportunities will be utilized as research needs dictate.

The NOAA National Undersea Research Program has extensive expertise and experience in conducting deep-diving efforts in all types of aquatic environments. 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.

4.1.2 National Ice Center

The National Ice Center (NIC) is a unique interagency organization with oversight from the Department of Defense (DOD), Department of Commerce (DOC), and Department of Transportation (DOT) and responds to both Defense and U.S. national interests as outlined in Annex II to the 1995 Navy–NOAA Umbrella Memorandum of Agreement (MOA). The Naval Ice Center (NAVICE) comprises the largest component of NIC and represents the Naval Meteorology and Oceanography Command through the Naval Oceanographic Office. The second leg of the triad, DOC, is represented under the National Oceanic and Atmospheric Administration's (NOAA) Office of Satellite Data Processing and Distribution. The U.S. Coast Guard's (USCG) Director of Operations Policy represents the third member of the triad, DOT.

NIC's mission is to provide the highest quality operational global, regional, and tactical-scale sea ice analyses and forecasts, tailored to meet the requirements of U.S. national interests. It provides this support to U.S. armed forces, U.S. government and international agencies, academic and scientific institutions, and civil interests.

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 and 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.

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 raster and digital ice products are distributed via the Internet using the NIC home page (http://www.natice.noaa.gov) and over military networks comprising the Defense Information Infrastructure. The NIC's climatological data atlas, developed under the auspices of the Environmental Working Group (EWG) of the U.S.–Russian Binational Commission on Economic and Technological Cooperation, features climatologies of sea ice chart data from Russian and U.S. ice centers. It is based on individual observations collected over the period 1950 through 1994 from U.S. and Russian satellite data, ice stations, icebreakers, and airborne ice surveys. Additionally, U.S. submarines operating in the Arctic over the period from 1977 through 1993 collected data used for a previously classified ice climatology. The atlas is available from the National Snow and Ice Data Center.

NIC legacy (1972–1994) Arctic ice information is available on CD-ROM in digital geographic information system (GIS) -compatible format from the World Data Center for Glaciology–Boulder and the National Snow and Ice Data Center. Arctic ice information for 1995–1996 and Antarctic ice information (1972–1997) are available as of 2001. More-recent Arctic and Antarctic sea ice data sets (1997 to present) are in digital format and available via the NIC web page. NIC has a program in place to finish the conversion of the remaining legacy Arctic and Antarctic information into ARC/INFO GIS format in the 2000–2002 time frame.

The U.S. Interagency Arctic Buoy Program (USIABP), managed by 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.

The NIC science program, operating with fiscal support from ONR, NOAA, and NASA, is aimed at expanding the use of NIC's products within the science community and providing a route for migration of scientific techniques (such as algorithms) into the operational environment but was recently expanded to include five post-doctoral fellows. The NIC Science Plan (available at http://www.natice.noaa.gov) summarizes the activities, interests, and goals of this polar science program. Current areas of in-house research include improvements to the next generation of ice forecast models, study of Antarctic hydrography, evaluation of passive and active microwave remote sensing algorithms, refinement of data assimilation techniques, and improvements to long-term sea ice forecasting techniques. The science program also involves oversight of external activities, such as the University of Colorado's work to improve the MODIS sea ice algorithm and the Jet Propulsion Lab's work to develop a sea ice-mapping algorithm for ENVISAT. Other areas of applied research include the improvement of SSM/I-derived ice concentration products, implementation of 85-GHz ice motion products, improved ice forecast models, and ice detection using data from new satellite sensors like the TERRA Moderate Resolution Imaging Spectrometer (MODIS), the ENVISAT dual-polarized SAR, and the QuikSCAT SEAWINDS scatterometer.

4.1.3 Land-Based Facilities

Under contract to NSF, the VECO Polar Resources (VPR) provides logistics support for research in Greenland. By arrangement with NSF, other agencies can also use the services of VPR. The logistics support for the NSF facilities in Kangerlusuaq have changed dramatically since Greenland was granted Home Rule and since September 1992, when the U.S. Air Force terminated operations at Sondrestrom AFB. The logistics support, which was provided by the Air Force, is now done through arrangements negotiated with the Greenland Home Rule Government and the Danish Polar Center.

The VPR provides logistics support as required for NSF in Kangerlussuaq, Greenland. The New York Air National Guard ski-equipped LC-130s operate from Kangerlussuaq principally to Summit.

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 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 Field Station, operated by the University of Alaska and now being upgraded with NSF/VPR support, and the NSF-funded facilities operated by the Barrow Arctic Science Consortium (BASC) at Barrow and facilities at Prudhoe Bay operated by VPR 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 have taken over the SPAWAR Arctic Logistics infrastructure at Thule AB.

A memorandum of understanding between the National Science Foundation and the U.S. Army Corps of Engineers has been implemented which allows NSF-supported engineering and scientific researchers to use USACE laboratory facilities. Many of these state-of-the-art facilities are dedicated to cold-regions research and engineering thrusts and are described below.

An aggregation of unique facilities that are nationally and internationally recognized exists at the Cold Regions Research and Engineering Laboratory (CRREL). The main complex is in Hanover, New Hampshire. In addition, a permafrost research tunnel and additional coldrooms are located near Fairbanks, Alaska. Industry and academia often use CRREL's unique experimental facilities. This is evidenced by the high number (80) of cooperative research and development agreements that the laboratory has put in place over the last seven years.

At the Hanover campus the main laboratory houses 24 low-temperature research laboratories capable of achieving temperatures as low as –50°F, special-purpose ice test facilities, cleanrooms, a chemical laboratory, and two specialty low-temperature materials laboratories. The Material Evaluation Facility can simulate snow and icing conditions and can simulate static and cycling temperatures ranging from –50° to 120°F and has the capability to conduct full-scale tests on automotive vehicles. The High Performance Materials Laboratory is used for strength and thermal testing of many types of materials, including construction, road, bridge, and composite materials. Specialized testing machines, such as the Split Hopkinson Pressure Bar, enable low-temperature, high-strain materials evaluation to temperatures as low as –80°C. Other equipment includes thermal cycling chambers that allow for thermal cycling from –100° to 100°C and a specially fabricated UV–radiometry system for exposing testing materials to controlled doses of radiation.

The 73,000-square-foot Ice Engineering Facility has three special-purpose research areas: a large low-temperature towing tank, a 100-foot-long refrigerated flume for modeling rivers, and a large hydraulic-model room for studying ice effects on civil works facilities, primarily locks and dams. The Ice Engineering Facility also houses a snowdrift wind tunnel.

The Frost Effects Research Facility (FERF) allows full-scale research on the impact of freeze–thaw cycles on pavements, foundations, and utility systems. This 29,000-square-foot facility contains a 182- by 75-ft soil testing area that can be maintained at temperatures below 30°F and 12 large test cells where soil can be frozen and thawed at temperatures ranging from as low as –35°F to as high as 120°F. Six to eight natural freeze–thaw cycles can be simulated in a single year. The newest addition to the CRREL's experimental capability, the Heavy Vehicle Simulator (HVS), is housed in this facility. The HVS can simulate the effect of heavy vehicles on roads and pavements.

At the Alaska campus in Fairbanks, CRREL has a research permafrost tunnel and maintains a 133-acre permafrost research site. The CRREL facilities in Alaska include two coldrooms capable of –30°F temperatures, a heavy equipment maintenance shop, a woodworking shop, a soils laboratory, a shock laboratory, and several Small Unit Support Vehicles (SUSVs) used as research vehicles.

The Technical Information Analysis Center (TIAC) serves DOD and the Nation as the most comprehensive source of cold-regions information in the world. The 24,000-square-foot TIAC provides a gateway to the world's information and research resources for cold-regions science and engineering. The Cold Regions Science and Technology Information Analysis Center (CRSTIAC) serves as the Nation's corporate repository for cold-regions science and engineering data. This center houses the CRREL library, which contains 30,000 books, 160,000

reports, 450 journals, 450 rolls of microfilm, 250,000 pieces of microfiche, 40 CD-ROM reference titles, and topographic maps of all 50 states. The Bibliography on Cold Regions Science and Technology, comprising 53 volumes dating from 1951, is prepared for CRREL by the Library of Congress and contains approximately 250,000 citations, including cumulative author and subject indexes.

4.1.4 Atmospheric Facilities and Platforms

Because of the strategic location of the Arctic for observing space-related phenomena, an extensive infrastructure has been established over the past four decades to observe the Arctic upper atmosphere and ionosphere. The Arctic is the site of many ground-based radio, radar magnetic, and optical observing sites. These sites and many other smaller facilities have been an important aspect of the Arctic social structure, providing economic benefits in remote regions and educational opportunities for indigenous people.

Among the major upper atmospheric research facilities in the Arctic are the Sondrestrom Radar in Greenland, the High Frequency Active Auroral Research Program (HAARP) radar in Alaska, the Poker Flat Rocket and Research facility near Fairbanks, the Resolute Bay Observatory in Canada, the Longyearbyen Optical Station in Norway, and the SuperDARN radar network with sites spanning the Western Hemisphere Arctic. These and other smaller sites are operated in collaboration with international partners, including academic and research institutions in Canada, Denmark, Norway, and Japan.

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.

NASA and NSF cooperated in a program called the Program for Arctic Regional Climate Assessment (PARCA). This involved satellite and airborne surveys of different regions of the ice sheet to establish patterns of ice sheet thickening and thinning, along with ground-based surveys to establish reference data for interpreting airborne and satellite observations. Ground observations included the deployment of automatic weather stations and the analysis of shallow snow pits and deep ice cores. The results have, for the first time, shown clear regional patterns in the mass balance of the ice sheet.

4.1.5 Central Coordination and Logistics Information Clearinghouse

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, is being developed on the Internet (http://www.arcus.org/ALIAS/index.html) to provide information on logistics resources throughout the Arctic.

4.1.6 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 ionospheric studies, ecosystems, topography, and paleoclimatology), and at the National Center for Atmospheric Research (upper atmosphere and ionospheric studies). Data sets for a vast array of cryosphere-specific variables in the Arctic (sea ice, snow cover, permafrost, etc.), are archived and distributed through the National Snow and Ice Data Center (NSIDC) and the World Data Center–A (WDC–A) for Glaciology in Boulder, Colorado. These include satellite-derived measurements, in-situ observations, and ancillary information that have been supported by NASA, NOAA, and NSF. 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)/WDC–A is the lead agency in the United Nations 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.

The Alaska SAR Facility (ASF) also operates a DAAC under contract to NASA/EOSDIS. The facility receives and processes polar imagery from SARs onboard Canadian (Radarsat) and European (ERS-2) satellites. The ASF also carries out a range of tasks in support of the data, including calibration and the development of data analysis tools. A major data analysis project underway at the ASF involves implementation of the Radarsat geophysical processor system (RGPS), which is designed to generate high-level products from Radarsat, including ice drift, ice deformation, and ice thickness histograms using a novel Lagrangian tracking system.

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. NOAA's Environmental Services Data Directory (NESDD) is a vital windows into the U.S. national data archives, providing a means for scientists to locate the data they require.

4.2 Arctic Data and Information

4.2.1 Arctic Data

This year completes a decade of service to the polar science community at the Alaska SAR Facility (ASF), NASA's facility for archiving and distributing SAR data.

Some of the major projects served this year include the second joint U.S.–Canadian Applications Development Research Opportunity (ADRO-2, see section 3.1.2); the Radarsat Geophysical Processing System project (section 3.2.1); operational support with near-real-time data (averaging less than three hours turnaround) for the National Ice Center; and the NOAA Coast Watch and Alaska Demonstration projects. Sub-Arctic research projects supported include the Alaskan Volcano Observatory and the Boreal Forest Mapping Mission. In addition to these projects, ASF supports other projects, which together represent an estimated user community of 1400 individual PIs and co-PIs.

ASF has facilitated research and applications development through involvement with the science community, participating in workshops, attending conferences, and producing and distributing new products. This year ASF hosted a visiting scientist, continued participation in NASA's ESIP Federation, and participated in IGARSS, AGU, and other meetings.

With the recently signed U.S.–Canadian IMOU extending the relationship between NASA and CSA to acquire and exploit Radarsat data, ASF plans to increase the user community by a minimum of 5% and provide continuity of the data record needed by the polar research scientists in order to track the ongoing global changes in the earth system. ASF also plans to continue reception of ESA's ERS-2 SAR data and to negotiate with ESA and NASA to participate in the reception, archive, and distribution segments of their future missions (Envisat, CryoSat, ALOS). ASF will also continue to stand ready for the launch of ADEOS-2. ASF plans to expand near-real-time services to the operational communities to support business-as-usual requirements, disaster mitigation protocols, and the commercial applications community for aid in effective and responsible policy decisions at the state and local level. ASF is also working to produce a public CD-ROM with an ERS-1 SAR mosaic of Alaska.

The National Snow and Ice Data Center (NSIDC) Distributed Active Archive Center (DAAC) provides access to cryospheric data for both northern and southern hemispheres, with the present emphasis on the Arctic. NSIDC is chartered and partially 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 NASA's Earth Observation System Data and Information System (EOSDIS) project as a DAAC, providing snow and ice data and information services. The DAAC processes, archives, and distributes sea ice and snow cover data from visible, infrared, and passive microwave sensors, in particular from the special sensor microwave imager (SSM/I), the moderate resolution imaging

spectrometer (MODIS), and advanced very high resolution radiometer (AVHRR) sensors and related in-situ data. The DAAC's passive microwave data sets include a 20-plus-year time series of sea ice extent and concentration for both polar regions.

The EOS TERRA satellite was launched in late 1999, and snow products from the MODIS instrument were released to the general scientific community in mid-October 2000. Sea ice products from the MODIS instrument are expected to be released in early 2001. In addition to the MODIS snow and ice products from the TERRA and AQUA satellites (to be launched in mid-2001), the DAAC will ingest and distribute all passive microwave products from the advanced microwave scanning radiometer on AQUA. Altimetry and aerosol data sets from the Geoscience Laser Altimeter System (GLAS) instrument on ICESat will also be distributed by the NSIDC DAAC. ICESat is scheduled for launch in late 2001.

Non-EOS satellite data include the Near Real Time Ice and Snow in EASE grid (NISE) daily product, gridded passive microwave brightness temperatures and sea ice data on CD-ROM, AVHRR polar subsets at 1.25- and 5-km grids, and other in-situ data. Information on all NSIDC DAAC data sets may be found at http://www.nsidc.org/.

The National Snow and Ice Data Center (NSIDC) was chartered by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) in 1982 to provide a focus for cryospheric data management activities. NSIDC operates under a cooperative agreement between NOAA and the University of Colorado's Cooperative Institute for Research in Environmental Sciences. Within NOAA, NSIDC is affiliated with the NESDIS National Geophysical Data Center. NSIDC is also the home of the World Data Center for Glaciology, Boulder. At present the majority of funding for NSIDC data management activities comes from NASA for operating a Distributed Active Archive Center (DAAC) for cryospheric data collected by the Earth Observing System (EOS) program.

The NSIDC DAAC provides access to EOS satellite data, as well as ancillary in-situ measurements, baseline data, model results, and algorithms relating to cryospheric and polar processes. These activities are evolving from existing practices at NSIDC DAAC to permit a smooth implementation of the EOS Core System Version 2 and beyond. NSIDC archives and distributes snow and ice products from the moderate resolution imaging spectroradiometer (MODIS) instrument aboard the NASA TERRA satellite. MODIS snow cover extent, sea ice extent, and sea ice surface temperature products are available in orbital and gridded formats. These products extend the existing 30-year record of passive-microwave-derived snow and sea ice products at greatly improved spatial and spectral resolution. Other DAAC products are the Near Real Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent, and global brightness temperatures from the Defense Meteorological Satellite Program's special sensor microwave imager. In addition to work with data sets, NSIDC compiles the DAAC Yearbook, a collection of articles on applications of DAAC data, written for the general public.

As part of a larger joint NOAA/NASA program, NSIDC works closely with NOAA's NESDIS Long Term Archive team to develop a prototype long-term archive of snow and ice data, metadata, and products from EOS satellites. This effort will determine the resource requirements for a level of service to the user community that is comparable to the current level of service provided by NSIDC for EOS cryospheric data and by the National Geophysical Data Center for Defense Meteorological Satellite Program data and products.

The Arctic System Science (ARCSS) Data Coordination Center (ADCC) at NSIDC will provide ARCSS data and information to the scientific community well into the 21st century. The ADCC is the permanent archive and access point for data collected by investigators in the National Science Foundation's ARCSS program and serves as a catalyst for ARCSS integration through data and information management. Of note is ADCC's work to develop an automated system for climate model output data requests. ADCC averages well over 600 megabytes of data and information downloaded per month. These data sets are mostly in-situ and small data groupings rather than NSIDC's more typical large, multisensor collections.

Funding from the Environmental Services Data and Information Management program has resulted in the publication of over 30 snow, glacier, and sea ice data sets that had been in danger of loss. Many of these are from the former Soviet Union. NSIDC's participation in the joint U.S.–Russian Environmental Working Group's Arctic Climatology Subgroup to produce Arctic Atlases on CD-ROMs has strengthened connection to data repositories in Russia.

The User Services staff responds to inquiries made to NSIDC and its subsidiary data centers. Examples include students requesting information for school projects and reports, media and textbook publishers requesting photographs and interviews, and science researchers requiring information about data holdings, processing, formats, and science algorithms. Educational and research users represent more than half of all users, with the remainder split among government, commercial, and the general public. The rising number of requests for information from the general public has led NSIDC to develop educational "theme pages" on subjects such as glaciers and snow.

Investigators associated with NSIDC bring a polar scientist's perspective to data management. Work is being conducted under approximately 30 grants at any time, and topics range from studying variation in the timing and extent of snowmelt on the Greenland and Antarctic ice sheets with passive microwave data to documenting Inuit knowledge of climate change. NSIDC also seeks to synthesize and interpret research for the general public. For example, "State of the Cryosphere" web pages present aspects of snow cover, sea ice, glaciers, and sea level changes as they relate to climate change.

NSIDC served as co-chair of a World Climate Research Programme (WCRP) Task Group to develop a Climate and Cryosphere (CliC) Science and Coordination Plan. The plan, which lays a path for the coordination of the cryospheric elements of existing projects of the WCRP, was adopted in March 2000, and a joint Arctic Climate System (ACSYS) –CliC Science Steering Group was established. The CliC project addresses interactions among all land and oceanic components of the cryosphere (snow cover, glaciers, ice sheets, permafrost and seasonally frozen ground, freshwater ice, and sea ice) and the climate system, as well as the role of the cryosphere as a climatic indicator for monitoring. Significant questions concern the contribution of glacier melt to sea level rise, the effects of changes in snow and ice cover on water resources, and the impacts of climate change on polar sea ice and on frozen ground. The text of the CliC plan is available at http://www.npolar.no/acsys/CLIC/clic_may.pdf.

4.2.2 Arctic Information

Arctic and Antarctic Regions is available for Windows, DOS, and Internet use from NISC. Comprehensive polar coverage on this CD offers over 800,000 records compiled by the major polar regions research organizations in the U.S., Canada, and the U.K.

A Polar web site, a collaborative project of the Polar Libraries Colloquy and others, provides a guide to Internet resources. The address is http://www.urova.fi:80/home/arktinen/polarweb/polarweb.htm.

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Appendix A: Glossary of Acronyms

ABNP	Alaskan Basic Neuroscience Program
ACAP	Arctic Council Action Plan to Eliminate Pollution in the Arctic
ACIA	Arctic Climate Impact Assessment
ACMAP	Atmospheric Chemistry Modeling and Analysis Program
ACSYS	Arctic Climate System Study
ADCC	ARCSS Data Coordination Center
ADEOS	Advanced Earth Observation System
ADRO	Applications Development Research Opportunity
AEDD	Arctic Environmental Data Directory
AEPS	Arctic Environmental Protection Strategy
AFB	Air Force Base
AFSC	Alaska Fisheries Science Center
AGES	Age, Gene/Environment Susceptibility study
AHDRN	Arctic Health Disparities Research Dissemination Network
AICC	Arctic Icebreaker Coordination Committee
AIP	Arctic Investigations Program
AMAP	Arctic Monitoring and Assessment Program
AMEC	Arctic Military Environmental Cooperation
AMMTAP	Alaska Marine Mammal Tissue Archival Project
AMSR	Advanced microwave radiometer sensor
ANTR	Alaska Native Tumor Registry
AO	Arctic Oscillation
ARC	Arctic Research Commission
ARCSS	Arctic System Science
ARCUS	Arctic Research Consortium of the United States
ARM	Atmospheric Radiation Measurement program (DOE)
ARPA	Arctic Research and Policy Act
ASF	Alaska SAR Facility
ATSDR	Agency for Toxic Substances and Disease Registry
AUV	Autonomous underwater vehicles
AVHRR	Advanced very high resolution radiometer
AWS	Automatic weather station
BASC	Barrow Arctic Science Consortium
BLM	Bureau of Land Management
BRD	Biological Resources Division (USGS)
CAFF	Conservation of Arctic Flora and Fauna
CAREER	Faculty Early Career Development program (NSF)
CDC	Centers for Disease Control and Prevention
CFC	Chloroflourocarbon
CIRES	Cooperative Institute for Research in Environmental Sciences
CISET	Committee on International Science Engineering and Technology
CLIC	Climate and Cryosphere program
CLIVAR	Climate Variability and Predictability program
CMDL	Climate Monitoring and Diagnostic Laboratory (NOAA)
COGA	Collaborative Study of the Genetics of Alcoholism
CRREL	Cold Regions Research and Engineering Laboratory
CRSTIAC	Cold Regions Science and Technology Information Analysis Center
CT	Computerized tomography
DAAC	Distributed Active Archive Center
DHHS	Department of Health and Human Services
DMSP	Defense Meteorological Satellite Program
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
EDF	Environmental Diplomacy Funds
EO	Environmental Observatory
EOS	Earth Observing System
EOSDIS	Earth Observation System Data and Information System
EPA	Environmental Protection Agency
EPPR	Emergency Prevention, Preparedness and Response
ERS	European Remote-sensing Satellite
EWG	Environmental Working Group
FAA	Federal Aviation Administration
FERF	Frost Effects Research Facility

FOCI	Fisheries–Oceanography Cooperative Investigations
FSU	Former Soviet Union
FUDS	Formerly used defense sites
FWS	Fish and Wildlife Service
FY	Fiscal year
GCM	General circulation model
GC-Net	Greenland Climate Network
GEF	Global Environment Facility
GIS	Geographic information system
GISS	Goddard Institute for Space Studies
GLAS	Geoscience laser altimeter system
GLIMS	Global Land Ice Measurements from Space
GOCADAN	Genetics of Coronary Artery Disease in Alaska Natives study
GODAR	Global Oceanographic Data Archaeology and Rescue Project
GPS	Global positioning system
HAARP	High Frequency Active Auroral Research Program
HARC	Human Dimensions of the Arctic System (NSF)
HBV	Hepatitis B virus
HCH	Hexachlorocyclohexane
HCV	Hepatitis C virus
HDGC	Human Dimensions of Global Change program
HF	High frequency
HIRS	High-resolution infrared radiation sounder
HIV	Human immunodeficiency virus
HRSA	Health Resources Services Administration
HVS	Heavy vehicle simulator
IARPC	Interagency Arctic Research Policy Committee
IASC	International Arctic Science Committee
IASSA	International Arctic Social Sciences Association
ICS	International Circumpolar Surveillance
IOC	Intergovernmental Oceanographic Commission
IPA	Intergovernmental Personnel Act
IUCH	International Union for Circumpolar Health
IWG	Interagency Working Group
JCCEM	Joint Coordinating Committee for Environmental Management
LANL	Los Alamos National Laboratory
LTER	Long-Term Ecological Research
MAB	Man and the Biosphere
MMS	Minerals Management Service
MOA	Memorandum of agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MRI	Magnetic resonance imaging
NAGPRA	Native American Graves Protection Act
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVICE	Naval Ice Center
NCCOS	National Centers for Coastal Ocean Science
NCDC	National Climate Data Center
NCEH	National Center for Environmental Health
NCI	National Cancer Institute
NCID	National Center for Infectious Diseases
NDSC	Network for Detection of Stratospheric Change
NEI	National Eye Institute
NEP	Needle exchange program
NESDD	NOAA's Environmental Services Data Directory
NESDIS	National Environmental Satellite Data and Information Service
NEWNET	Neighborhood Environmental Watch Network
NGDC	National Geophysical Data Center
NGO	Non-governmental organization
NIA	National Institute on Aging
NIAAA	National Institute on Alcohol Abuse and Alcoholism
NIC	National Ice Center
NIDA	National Institute on Drug Abuse
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NISC	National Information Services Corporation
NISE	Near Real Time Ice and Snow in EASE grid
NIST	National Institute of Standards and Technology
NLM	National Library of Medicine
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NPR–A	National Petroleum Reserve–Alaska
NPS	National Park Service
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center

NSR	Northern Sea Route
NTS	Nevada Test Site
NTSB	National Transportation Safety Board
NURP	National Undersea Research Program (NOAA)
NWR	National Wildlife Refuge
NWS	National Weather Service (NOAA)
OAS	Office of Aircraft Services
OLS	Operational linescan system
OMAO	Office of Marine and Aviation Operations (NOAA)
OMB	Office of Management and Budget
ONR	Office of Naval Research
OPP	Office of Polar Programs (NSF)
OSRI	Oil Spill Recovery Institute
PAME	Protection of the Arctic Marine Environment
PARCA	Program for Arctic Regional Climate Assessment
PCB	Polychlorinated biphenyls
PDO	Pacific Decadal Oscillation
PMEL	Pacific Marine Environmental Laboratory (NOAA)
POLES	Polar Exchange at the Sea Surface
POP	Persistent organic pollutants
PROBES	Processes and Resources of the Bering Sea Shelf
RAIPON	Russian Indigenous Peoples of the North
RAPS	Resource Apprenticeship Program (DOI)
REU	Research Experience for Undergraduates program
RGI	Regional Geographic Initiative (EPA)
RGPS	Radarsat Geophysical Processor System
ROV	Remotely operated vehicle
SAR	Synthetic aperture radar
SBI	Western Arctic Shelf Basin Interaction program (NSF)
SDWG	Sustainable Development Working Group
SEARCH	Study of Environmental Arctic Change
SEER	Surveillance, Epidemiology, and End Results program (NCI)
SGER	Small Grants for Exploratory Research (NSF)
SHEBA	Surface Heat Budget of the Arctic Ocean program
SI	Smithsonian Institution
SIDS	Sudden infant death syndrome
SMMR	Scanning multichannel microwave radiometer
SPAWAR	Space and Naval Warfare Systems Command
SSC	Scientific steering committee
SSM/I	Special sensor microwave/imager
SUSV	Small unit support vehicle
TEA	Teachers Experiencing the Arctic program (NSF)
THC	Thermhaline circulation
TIAC	Technical Information Analysis Center
UAA	University of Alaska Anchorage
UAF	University of Alaska Fairbanks
UNEP	United Nations Environmental Program
UNOLS	University National Oceanographic Laboratory System
USACE	United States Army Corps of Engineers
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
USIABP	United States Interagency Arctic Buoy Program
UV	Ultraviolet
VPR	VECO Polar Resources
WC&P	West Coast and Polar Center (NOAA)
WCRP	World Climate Research Program
WDC	World Data Center
WHO	World Health Organization

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

February 1, 1998, to January 31, 2000

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 "detailing 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 1998. The required statement appears in Appendix A.

Activities and Accomplishments

During the period February 1, 1998, to January 31, 2000, the IARPC has:

- Prepared and published the fifth biennial revision to the United States Arctic Research Plan, as required by Section 108(a)(4) of the Act. The Plan was sent to the President on July 7, 1999.
- Published and distributed four issues of the journal *Arctic Research of the United States*. These issues reviewed all Federal agency Arctic research accomplishments for FY 96 and 97 and included summaries of the IARPC and Arctic Research Commission meetings and activities. The Fall/Winter 1999 issue contained the full text of the sixth 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 meetings of the Commission, and responded to Commission reports and Recommendations (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 for Arctic research, which estimated $185.7 million in Federal support for FY 98 and $221.5 million in FY 99.
- Arranged for public participation in the development of the fifth biennial revision to the U.S. Arctic Research Plan as required in Section 108(a)(10).
- Continued to maintain the Arctic Environmental Data Directory (AEDD), which now contains information on over 400 Arctic data sets. AEDD is available on the World Wide Web.
- Continued the activities of an Interagency Social Sciences Task Force. 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.
- Continued to support 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, via the National Research Council.
- Participated in the continuing National Security Council/U.S. Department of State implementation of U.S. policy for the Arctic. U.S. policy for the Arctic now includes an expanded focus on science and environmental protection and on the valued input of Arctic

residents in research and environmental management issues.

- Participated in policy formulation for the ongoing development of the Arctic Council. This Council incorporates a set of principles and objectives for the protection of the Arctic environment and for promoting sustainable development. IARPC supports the contributions being made to projects under the Council's Arctic Monitoring and Assessment Program (AMAP) by a number of Federal and State of Alaska agencies. IARPC's Arctic Monitoring Working Group serves as a U.S. focal point for AMAP.
- Approved four coordinated Federal agency research initiatives on Arctic Environmental Change, Arctic Monitoring and Assessment, Assessment of Risks to Environments and People in the Arctic, and Marine Science in the Arctic. These initiatives are designed to augment individual agency mission-related programs and expertise and to promote the resolution of key unanswered questions in Arctic research and environmental protection. The initiatives are intended to help guide internal agency research planning and priority setting. It is expected that funding for the initiatives will be included in agency budget submissions, as the objectives and potential value are of high relevance to the mission and responsibilities of IARPC agencies.
- Convened formal meetings of the Committee and its working groups, staff committees, and task forces to accomplish the above.

Appendix C: Arctic Research Budgets of Federal Agencies

		Budget (dollars in thousands)		
Dept/Bureau	*Program name*	*FY 00 actual*	*FY 01 planned*	*FY 02 proposed*
DOD	Arctic Engineering	2,583	2,670	2,750
DOD	Permafrost/Frozen Ground	350	350	430
DOD	Snow and Ice Hydrology	1,385	1,455	1,485
DOD	Oceanography	3,000	3,000	3,030
DOD	Lower Atmosphere	140	100	100
DOD	Upper Atmosphere	0	0	0
DOD	High-Freq Active Auroral Prog	15,000	12,000	0
DOD	Medical and Human Engr	901	850	863
	DOD TOTAL	23,359	20,425	8,658
DOI/MMS	Technology Assessment/Research	3,200	3,200	3,200
DOI/MMS	Environmental Studies	3,800	3,800	3,800
DOI/USGS	Energy and Minerals	3,500	3,500	3,500
DOI/USGS	Natural Hazards	3,500	3,500	3,500
DOI/USGS	Global Change	1,000	1,000	1,000
DOI/USGS	Marine and Coastal Geology	250	250	250
DOI/USGS	Geomagnetism	250	250	250
DOI/USGS	Ice and Climate	250	250	250
DOI/USGS	Hydrology	130	130	130
DOI/USGS	Mapping	750	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	2,900	2,900	2,000
DOI/BLM	Minerals Research	115	115	115
DOI/BLM	Cultural Resources	200	200	200
DOI/BLM	Pipeline Monitoring	550	550	550
DOI/BLM	Fire Control	380	380	380
DOI/BLM	Mining Administration	300	300	350
DOI/NPS	Cultural Resources	1,400	1,400	1,400
DOI/NPS	Natural Ecology	2,486	2,486	2,486
DOI/BIA	Cultural Resources	600	600	600
DOI/BIA	Subsistence Studies	1,250	1,250	1,250

Dept/Bureau	Program name	Budget (dollars in thousands) FY 00 actual	FY 01 planned	FY 02 proposed
DOI/FWS	Migratory Birds	3,884	3,884	3,884
DOI/FWS	Fisheries	4,068	4,068	4,068
DOI/FWS	Marine Mammals	1,768	1,768	1,768
DOI/FWS	Conservation of Flora and Fauna (CAFF)	200	200	200
DOI/FWS	U.S. Russia Environmental Agreement	150	150	150
	DOI TOTAL	43,891	43,891	43,041
NSF/OPP	Arctic Natural Science	9,988	11,187	11,589
NSF/OPP	Arctic System Science Prog	14,351	15,930	16,503
NSF/OPP	Arctic Social Sciences Prog	1,459	1,619	1,684
NSF/OPP	Arctic Education research	225	250	260
NSF/OPP	Arctic Research Support	151	168	174
NSF/OPP	Arctic Data/Info/Coord	88	98	102
NSF/OPP	Arctic Research Commission	700	1,000	1,028
NSF/OPP	Arctic Logistics/Instrumentation	23,230	25,785	26,765
NSF/OPP	Sub-total OPP	50,192	56,036	58,105
NSF	Other NSF Science Programs	17,295	18,160	18,523
	NSF TOTAL	67,487	74,196	76,628
NASA	Polar Ice Interactions	4,000	4,000	4,000
NASA	Ecology	2,371	619	535
NASA	Solid Earth Science	1,300	2,000	5,000
NASA	Arctic Ozone	12,700	6,440	6,500
NASA	Clouds and Radiation	1,500	750	750
NASA	Sub-orbital Science	3,300	900	2,500
NASA	Iono/Thermo/Mesospheric	1,502	1,500	1,500
NASA	Magnetospheric SR&T	400	292	200
NASA	Geospace Sciences	2,065	2,100	2,100
NASA	FAST Auroral Snapshot	1,500	1,500	1,300
NASA	Solar Terrestrial Theory	400	400	400
NASA	Arctic Data Systems	13,908	12,100	12,600
NASA	Research Balloon Program	750	750	0
NASA	Sounding Rocket Program	950	800	1,100
	NASA TOTAL	46,646	34,151	38,485
DOC/NOAA	Atmos Trace Constituents	40	250	800
DOC/NOAA	Fisheries Assessment/Management	18,100	16,600	18,900
DOC/NOAA	Marine Mammal Assessment	2,600	3,900	3,900
DOC/NOAA	Ocean Assessment	15	30	15
DOC/NOAA	Stratospheric Ozone	205	250	250
DOC/NOAA	Satellites/Data Management	418	325	325
DOC/NOAA	Remote Sensing	465	456	300
DOC/NOAA	Aircraft/Vessels	1,946	1,976	2,053
DOC/NOAA	Climate and Global Change	268	90	90
DOC/NOAA	Weather Research	40	125	125
DOC/NOAA	Western Arctic/Bering Sea Ecosystem	2,997	3,845	2,782
DOC/NOAA	Barrow Observatory	790	1,200	1,600
DOC/NOAA	Undersea Research	205	30	0
DOC/NOAA	Arctic Research Initiative	1,650	1,650	1,650
	DOC/NOAA TOTAL	29,739	30,727	32,790

		Budget (dollars in thousands)		
Dept/Bureau	*Program name*	*FY 00 actual*	*FY 01 planned*	*FY 02 proposed*
DOE/SC	Nat Inst Global Env Change	186	186	186
DOE/SC	Atmos Radiation/Planning	3,200	3,200	3,200
DOE/FE	Alaska Hydrate Characterization	70	N.A.	N.A.
DOE/FE	Hydrate Test Well Participation	339	N.A.	N.A.
DOE/EE	Wind Activities in Alaska	380	270	75
DOE/EM	JCCEM/Arctic Transport Studies	550	570	570
	DOE TOTAL	4,725	4,226	4,031
DHHS	National Institutes of Health	9,844	10,702	11,164
DHHS	Centers for Disease Control/Prevent.	3,990	5,151	4,787
	DHHS TOTAL	13,834	15,853	15,951
SMITHSONIAN	Anthropology	400	400	400
SMITHSONIAN	Arctic Biology	50	50	50
	SMITHSONIAN TOTAL	450	450	450
DOT/USCG	Test and Evaluation	3,750	500	0
DOT/USCG	Arctic Science Support	2,530	10,330	7,870
DOT/USCG	Extramural Science Support	30	30	30
	DOT Total	6,310	10,860	7,900
EPA	Research and Development	365	360	200
EPA	Regional Activities	250	220	100
EPA	International Activities	93	75	100
	EPA TOTAL	708	655	400
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	964	964
USDA/NRCS	Natural Resources Cons Svc S - Global	560	560	560
USDA/ARS	Agricultural Research Service	2,000	2,000	2,000
	USDA TOTAL	4,778	4,949	4,949
STATE	MAB: Arctic Directorate	20	20	20
	STATE TOTAL	20	20	20
	GRAND TOTALS	241,947	240,403	233,303

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 snowpack 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 physical processes in the thermosphere, ionosphere and magnetosphere. Studies also include applied research to investigate, predict, and assess the impacts from the thermosphere, ionosphere, and magnetosphere to communication, navigation, surveillance, and satellite systems.
- High-Frequency Active Auroral Research Program (HAARP): The use of radiowave 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 hydrol-

ogy 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 USGS 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 the 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 wild fires 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 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

- Cryosphere: This program is focused on the Arctic ice cover and its interactions with the oceans and atmosphere. The long-range goals are to significantly improve our ability to represent high-latitude processes in models of global climate and climate change and to understand the current and likely impact of changes in ice mass on sea level.
- Ecology: This program is 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 and Natural Hazards Science: This program is focused on improving our understanding of the earth's gravity field, oscillations in the length of day and tilting of the axis of rotation, geodesy to determine the rate of past-glacial rebound of the lithosphere for ice mass and structuralstudies, the earth's magnetic field to determine crustal structure, and topography and topographic change of the Arctic and Antarctic regions. The program 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: This program is supporting a number of tasks related to chemical and dynamical processes in the Arctic stratosphere, with the aim of measuring and understanding changes in Arctic stratospheric ozone in an atmosphere with increasing abundances of greenhouse gases.
- Arctic Data Systems: NASA provides 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 acquiring, processing, archiving, and distributing synthetic aperture radar (SAR) data from several non-U.S. spacecraft, and the NSIDC handles most other satellite data over the high latitudes. In addition, NASA supports the development of several high-latitude "Pathfinder" data sets, comprising higher-level information derived from various satellite data.
- Clouds and Radiation: NASA supports comprehensive studies of the impact of Arctic clouds and aerosols on the the Arctic radiation balance and its impact on the global radiative balance. Studies supported include modeling and analysis of satellite cloud and aerosol data obtained over the polar regions. In addition, NASA supports missions to the Arctic (e.g. FIRE-ACE) that include ground, ship, and airborne sensors coordinated with satellite observations to study the processes that contribute to the evolution of cloud and aerosol distributions.
- Geospace Physics: NASA provides support for a vigorous program of experimental and theoretical studies of geospace phenomena originating in or affecting Arctic regions, including the mesosphere, thermosphere, ionosphere, and magnetosphere. It includes these programs listed in the NASA budget table: Sun-Earth Connection Theory Program, Fast Auroral SnapshoT Explorer spacecraft, Geospace Low Cost Access to Space (sub-orbital) program, and the Geospace Sciences Supporting Research and Technology program.

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 Fisheries Research: NOAA's Pacific Marine Environmental Laboratory (PMEL) and Alaska Fisheries Science Center (AFSC) conduct the Fisheries Oceanography Coordinated Investigations (FOCI) program in the Bering Sea and North Pacific. FOCI is concerned with

understanding and predicting the impacts of interannual variability and decade-scale climate change on commercially valuable fish species.

- 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 wide range of programs and activities directed toward NOAA's environmental stewardship responsibilities, including environmental monitoring and assessment, technology transfer, and education and outreach. Ocean assessment includes the National Status and Trends Program, the Coastal Ocean Program, and other pertinent activities of the recently formed National Centers for Coastal Ocean Science (NCCOS), National Ocean Service.
- Stratospheric Ozone: A 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 with minimal attention. The scientific issues include boundary layer turbulence and structure, cloud macro- and microphysical properties, and cloud-radiative coupling relevant to Arctic climate.
- Aircraft/Vessels: Platform support from the Office of Marine and Aviation Operations (OMAO) 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. NOAA's Arctic Research Office chairs the Interagency Working Group on the Study of Environmental Arctic Change (SEARCH).
- Arctic Ice: 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.
- Boreal Forest Fires and the Arctic: Modeling, research, and observations to understand the influence of Northern Hemisphere boreal forest fires on atmospheric chemistry in the Arctic, especially focusing on the production of surface-level ozone and other pollutants and the atmospheric and climate effects of the input of soot.
- Arctic Research Initiative: Program supporting research, monitoring, and assessment projects to study natural variability and anthropogenic influences on Western Arctic/Bering Sea ecosystems. These activities are a U.S. contribution to the Arctic Council's Arctic Monitoring and Assessment Program. Projects supported by this program are expected to lead to better understanding of Arctic contaminants and their pathways, the effects of climate change including increased ultraviolet radiation, and the combined effects of stresses from climate change and various contaminants.

Department of Energy

- Climate-Related Atmospheric Radiation Research: Continued operation of an Atmospheric Radiation Measurement (ARM) research ("testbed") site on the North Slope of Alaska to improve mathematical simulations of cloud and radiative transfer processes in general circulation models (GCMs).

- Environmental Measurements of Radioactivity in the Atmosphere: Continuous measurements of long-term levels and trends of anthropogenic and natural radionuclides in the Arctic atmosphere. Sites include Alaska, Greenland, and northernmost Canada and Norway.
- Neighborhood Environmental Watch Network (NEWNET): Continued operation of an Alaskan network (Fairbanks, Kotzebue, Nome, Point Hope, and Seward) of public-accessible environmental gamma-radioactivity monitoring stations and data storage/processing systems, based on concepts developed by the DOE for the Community Monitoring Program at the Nevada Test Site (NTS) Nuclear Testing Facility.
- Joint Coordinating Committee for Environmental Management (JCCEM) Contaminant Transport Studies: Continuing assessment of the hydro-geologic framework and radioactivity contamination status of the West Siberian Basin from past and ongoing releases of commercial and defense-related nuclear and hazardous waste disposal operations at the former Soviet Union Mayak, Tomsk, and Krasnoyarsk sites.
- North Slope of Alaska Methane Hydrate Resource Assessment: DOE continues to assist the U.S. Geological Survey (USGS) in an assessment of the recoverability and production characteristics of permafrost-associated methane hydrates and related free-gas accumulations in the Prudhoe Bay–Kuparuk River area of the North Slope of Alaska.
- Wind Electricity Generation Activities in Alaska: To better understand the role that wind energy can play, the DOE's Wind Energy Program continues to be engaged in collaborative efforts with Alaskan organizations at the state and local levels to explore ways in which wind can make a greater contribution in the production of electric power. Efforts are particularly focused on smaller rural communities, where the cost of diesel-generated electricity is very high. Current Alaskan locations include Kotzebue, Wales, Nome, Nightmute, Nunapitchuk, Selawik, and Unalakleet.

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 and alcohol abuse, and coronary heart disease that affect Arctic residents.

Centers for Disease Control and Prevention

- A research program designed to evaluate infectious disease prevention and control strategies in the Arctic and sub-Arctic, with a special focus on diseases of high incidence and concern among the indigenous peoples of the circumpolar region.
- An occupational injury research program focusing on the Nation's geographic area with the highest risk of occupational-related injury.
- Research on human exposure to environmental persistent organic pollutants in the Arctic.

Agency for Toxic Substances and Disease Registry

- A research program to identify and reduce risks from exposure to environmental contaminants while maintaining the benefits of the subsistence lifestyle.

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.

Environmental Protection Agency

- Research and Development: Intramural and extramural basic and applied research founded on the risk assessment and risk management paradigm. EPA research interests in the Arctic

include water quality, watershed cumulative effects, air quality, land use, bioremediation and the combined impact of contaminants, climate change, and resource use on freshwater and marine ecosystems. Research efforts address issues of long-range transport and transformation of contaminants to the Arctic and the status and trends of contaminants such as persistent organic pollutants and heavy metals within the Arctic environment. Research and Development is working closely in partnership with Region 10 on forwarding an integrated assessment of human health and ecological risks in subsistence communities with the Bering Sea watershed.
- Regional Activities: Activities of EPA's Region 10 (Pacific Northwest and Alaska office) are conducted in partnership with tribes, the state, and local communities to resolve key issues in rural sanitation, clean drinking water, clean-up of formerly used defense sites, regulation of local industry, and other issues key to protecting human health and the unique Arctic and sub-Arctic environments.

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.
- Important portions of the boreal ecosystems research are conducted at the Bonanza Creek Long-Term Ecological Research Site near Fairbanks, AK.

Cooperative State Research, Education and Extension Service
- Research in plant sciences emphasizing propagating and cultivating Alaskan 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, quantification of timber productivity, and disturbance revegetation in wetlands.

Natural Resources Conservation Service
- Research in support of the National Cooperative Soil Survey program addressing permafrost, soil cryogenic processes, soil reduction and oxidation properties, temperature, water status and gas flux in wetlands, reindeer and caribou grazing needs, and vegetation trends.
- Research on vegetation, landform, and carbon sequestration relationships in support of the Global Change Research Program.
- Research in support of the snow survey program. Snowfall measurement techniques are being studied to support the snow survey, which is used to predict snowmelt, water availability, river breakup timing, and wildlife movements.

Agricultural Research Service
- Research on plant sciences emphasizing germplasm preservation to protect native and Russian plant species with emphasis on medicinal value and utility for erosion control.
- Research in animal sciences to investigate Alaska fisheries byproduct use (especially for feed stocks), integrated pest management for grasshopper control in Alaska's central basin, and the biosystematics of Holarctic ruminant parasites to assess pathogen distribution in food resources of northern communities.

Department of State
- Coordination of U.S. involvement in the Arctic Council and its working groups, including the Arctic Monitoring and Assessment Program; Conservation of Arctic Flora and Fauna, of which the U.S. is the vice-chair; Emergency Prevention, Preparedness, and Response; Protection of the Arctic Marine Environment, which the U.S. chairs; Sustainable Development; and the Arctic Council Action Plan to Eliminate Pollution of the Arctic.
- Chairmanship of regular meetings of the interagency Arctic Policy Group and overall responsibility for the coordination and formulation of U.S. policy in the Arctic.
- Direction of Environmental Diplomacy Funds (EDF) to international pollution assessment projects. The State Department has contributed to the project on Persistent Toxic Substances, Food Security, and Indigenous Peoples of the Russian Far North. The project will monitor both air quality in the Russian Arctic and toxics in the traditional foods of Natives in Russia. State EDF support is also planned for the Evaluation of Dioxins and Furans in the Russian Federation.

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, Umea, Sweden, 1989.

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

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

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

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

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

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

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

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

Appendix G: Acknowledgments

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