3. Agency Programs

3.1 Selected New Opportunities for Arctic Research

The following sections describe some new opportunities for Arctic research. The focus is on selected new agency programs and is not intended to be a comprehensive listing of all programs in a given research area.

3.1.1 U.S. and 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 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 are providing 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

NOAA has supported a temporal and spatial study of Alaskan clouds based on the use of a ground infrared imager. Measurement of clouds is fundamentally important to studies of Arctic climate variability and change. The infrared cloud imager records calibrated images of sky radiance. This project is a first step toward studying the relationship between the Arctic Oscillation and cloudiness at various Arctic locations.

3.1.4 Fisheries Management

NOAA is also undertaking studies of the development of physical, chemical, and plankton databases for the Bering and Chukchi Seas. In addition, NOAA is carrying out an analysis of physical and ecosystem model outputs in relation to changing populations of Stellar's sea lions. NOAA also funds programs that focus on traditional ecological knowledge addressing scientific and coastal communities informational needs.

3.1.5 Cultural Exchange

Work continues on the Russia–United States International Beringian Park in the Bering Strait region. This park would preserve the unique environmental and cultural heritage of 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 U.S.–Russia Collaboration

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 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. Many agencies have taken the initiative to develop their own contacts and programs in Russia.

In 2003, NOAA and the Russian Academy of Sciences signed a Memorandum of Understanding on World Ocean and Polar Region Studies. This MOU resides under the Russian–U.S. Science and Technology Agreement. Because the U.S. and Russia have the opportunity to display leadership in identifying and conducting collaborative scientific activities to better explain and anticipate the types of changes that will occur in the Arctic over the coming decades, several collaborative projects have already started, and others are needed. The NEESPI project has already established the Joint Cold Land Processes and Arctic Coastal Studies based at the International Arctic Research Center, University of Alaska Fairbanks. It is anticipated that the center will provide coordination and foster further collaboration in studies over the entire Russian Arctic. NOAA has also initiated negotiations that may lead to the establishment of a sophisticated atmospheric observatory in the Russian North to complement other observatories in North America. It is anticipated that the International Polar Year will provide much needed thrust to the strengthening of Russian–U.S. scientific collaboration in the Arctic.

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 (available at http://nsidc.org/data/ewg/index.html) 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.

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.

3.1.7 Oil Pollution Control

Title V of the Oil Pollution Act of 1990 established the Prince William Sound Oil Spill Recovery Institute (OSRI), with interagency participation led by NOAA and including the Department of the Interior, the Department of Transportation, and three state agencies (Fish and Game, Environmental Conservation, and Natural Resources). During the 1990s the State of Alaska coordinated with OSRI in developing an Arctic–subarctic oil spill research plan. OSRI's programs are funded through the approximately $1 million in annual interest earnings it receives from a $22.5 million fund dedicated for OSRI and maintained within the Oil Spill Liability Trust Fund. In 2002, Congress approved extension of OSRI through September 2012, with its funding to continue from the interest earnings as described above. OSRI programs are detailed at their web site (www.pws-osri.org). OSRI is located in Cordova, Alaska, and is administered through the Prince William Sound Science Center (www.pwssc.gen.ak.us), a non-profit research organization founded in 1989 to facilitate and encourage ecosystem studies in the greater Prince William Sound region.

3.1.8 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 for the infrastructure.

Permafrost degradation is not a hypothesized outcome of global warming; engineers have been dealing with the effects of permafrost degradation for some time. 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. The degradation process may result in an increase in the mobility of methane 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 issue of permafrost degradation impacts virtually all elements of the existing infrastructure and future Arctic building programs, land use, and contaminant mobility, and it 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.

3.1.9 Contaminant Behavior and Impact in Northern Polar Regions

NOAA is involved in several contaminant behavior programs that are examining the deposition flux rates and fate of atmospheric mercury at Barrow, Alaska, and tracing persistent organic and trace element pollutants in the Alaskan Arctic. The latter is the Alaskan component of a larger effort entitled "Study of Atmospheric Deposition in the Arctic; A Paired Study of a Site in Alaska and a Site in the Russian Far East." The scientific objectives are to gain insight into the sources, occurrence, and environmental fate of persistent organic pollutants, to contrast the occurrence of persistent organic pollutants and trace elements in this region with other Arctic airsheds, and to provide data in a form compatible with existing AMAP data to be used in assessing the potential risks to the environment and human inhabitants in the Arctic.

The Climate Monitoring and Diagnostics Laboratory's clean air sector at Barrow, Alaska, is also involved in monitoring gaseous elemental mercury in the Arctic environment. This is a byproduct of coal combustion, waste incineration, and certain types of manufacturing. Mercury concentrations in certain Arctic mammals are the highest in the North American Arctic (Arctic Monitoring and Assessment Program 1997). A reduction in atmospheric mercury occurs when there are sunlight, low temperatures (less than 20°C), and an underlying snowpack. The concentrations of bioavailable mercury in the Barrow snowpack are the highest ever measured anywhere in the world. If the mercury events found at Barrow are prevalent throughout the coastal Arctic, this region would represent a deposition zone for mercury air pollution.

3.2 Arctic Ocean and Marginal Seas

3.2.1 Ice Dynamics and Oceanography

Recent studies indicate that the sea ice cover is undergoing significant climate-induced changes, affecting both its extent and thickness. For instance, satellite-derived estimates of maximum ice extent suggest a net reduction between 1978 and 1996, at an average rate of –3% per decade (Parkinson et al. 1999). A recent report by Comiso (2003) indicates an even more rapid reduction in the perennial sea ice cover: –9% per decade. Data on the ice thickness, derived from submarine-based upward-looking sonar, also suggest a net thinning of the sea ice cover since 1958 (Rothrock et al. 1999, Wadhams and Davis 2000, Tucker et al. 2001). NOAA is continuing to monitor these changes to improve the fundamental understanding of the role of the sea ice cover in the global climate system and to take advantage of the sensitivity of the sea ice cover as an early indicator of the magnitude and impact of climate change.

Until satellite imagery can be used to monitor ice thickness, we must rely on measurements made from submarines, aircraft, seafloor moorings, and drifting buoys. As determined at the recent SEARCH Workshop on Large-Scale Atmospheric/Cryospheric Observations (Overland et al. 2002), this is most effectively done through a coordinated effort to establish a large-scale sea ice observing system. It is also necessary to disseminate the data collected from the various components of this system to the scientific community in a timely and consistent fashion. Once available, the data can be used to gain insight on the relationship between the characteristics of the sea ice cover and climatic forcing. Specific emphasis should be placed on efforts to work in tandem with those developing satellite-based assets designed to measure ice thickness. Data from the ice-based observing system can play a central role in assuring an optimal approach for obtaining accurate satellite-based measurements. Together, these platforms can provide an effective means of assessing the state of the sea ice cover over the entire Arctic basin.

NOAA, NSF, NASA, and DOD work cooperatively to carry out observations and modeling of the freshwater dynamics connecting the Arctic and the Atlantic. Concentrated activity occurs where the Arctic and Atlantic Oceans meet and interact. Improved observations of water masses and fluxes of water, salt, ice, and tracers between the Arctic and the Atlantic will help us understand this changing state and anticipate its future.

NOAA is continuing to study the variability of thermohaline circulation and freshwater storage in the Arctic Ocean. The Arctic Ocean and its marginal seas are key areas for understanding the Arctic climate system and its change through time. Changes in the freshwater balance would influence the extent of sea ice cover; changes in the surface albedo, energy balance, temperature, and salinity of water masses; and biological processes in the Arctic. (Also see Section 2.1.)

3.2.2 Ocean and Coastal Ecosystems and Living Resources

NOAA has undertaken several programs focusing on ocean ecosystems, including analyses in the Bering Sea region to study climate variability and its impacts on ecosystems and a study of the trophic pathways on the Chukchi–Beaufort shelf. Microalgae grow on the undersurface of sea ice as well as within the sea ice matrix and are a well-known feature of Arctic ecosystems. They contribute a poorly known proportion of the total primary production in Arctic seas. Ice algae are important to microbial food webs and the dissolved and particulate carbon and nitrogen pools of the Arctic Ocean. Novel techniques to quantitatively trace carbon fixed by ice algae and water column phytoplankton through pelagic and benthic food webs using conservative fatty acid signatures are being used. The results of this work will help us understand trophic dependencies and carbon budgets in Arctic food webs and predict the effects of environmental change caused by global warming and further reductions in sea ice.

NOAA's Arctic Research Office has supported projects to examine possible connections between Arctic climate and oceanic change and the declining Steller's sea lion population. The areas of interest include impacts of climate change on the Bering Sea ecosystem over the past 500 years, retrospective studies of climate impacts on Alaska Steller's sea lions, the nature of North Pacific regime shifts and their impacts on Steller's sea lions, ocean climate variability as a potential influence on Steller's sea lion populations, North Pacific climate variability and Steller's sea lion ecology, interannual variability of biophysical linkages between the basin and shelf in the Bering Sea, and climate-related processes and killer whale abundance as factors in Steller's sea lion population trends in the Aleutian Islands. The National Marine Mammal Laboratory's Alaska Regional Office and the Protected Resources Management Division are responsible for research on the management of 22 species of marine mammals that commonly occur in Alaska, including Steller's sea lions.

NOAA's Resource Assessment and Conservation Engineering Division and Resource Ecology and Fisheries Management Division is promoting a full-scale program to provide information on the run characteristics of Yukon River chinook salmon. Over 1100 fish will be radio-tagged near the river's mouth and tracked to upriver spawning areas in order to provide information on stock composition and timing, nation of origin, migration patterns, and locations of previously undocumented spawning areas.

NOAA's Pacific Marine Environmental laboratory (PMEL) conducts fisheries oceanography and ecosystem studies in the Bering Sea and the western Gulf of Alaska. Fisheries–Oceanography Coordinated Investigations (FOCI) is a cooperative program among PMEL, NMFS's Alaska Fisheries Science Center, NOS's Coastal Ocean Program, and the University of Alaska. FOCI's goals are to increase understanding of the Alaskan marine ecosystem, to document the role of walleye pollock in the ecosystem, to determine factors that affect pollock survival, and to develop and test annual indices of pre-recruit pollock abundance. FOCI is also investigating decadal variability and climate change of the North Pacific and western Arctic, particularly in light of the declining Steller's sea lion population. (Also see Section 2.1.)

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. In addition, the Arctic seafloor north of Alaska and on the Chukchi Plateau and Northwind Ridge remain poorly mapped. Several missions from NOAA have begun to carry out multibeam mapping operations in this ice-covered region of the U.S. Exclusive Economic Zone (EEZ) to create detailed bathymetric maps.

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

In 2002 NOAA funded the development of an ROV, the *Global Explorer*, to investigate life under the ice, in the water column, and on the seafloor of the deep Canada Basin and the Northwind Ridge. This program, called Arctic 2002, was a collaboration between NOAA's Ocean Exploration Office and Arctic Research Office, the Canadian Department of Fisheries and Oceans, JAMSTEC, and institutes in China. The major goal of this expedition was to take censuses of marine life in the unexplored regions of the Arctic. NOAA's Office of Ocean Exploration will continue to support exploration in the Canada Basin during the summer of 2005.

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. 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 climate variability and change. Warming of the atmosphere at lower altitudes is occurring 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. These effects are being studied intensively as part of the U.S. Global Change Research Program. (See Chapter 12, p. 260 of the Strategic Plan for the U.S. Climate Change Science 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 radiowave propagation in and through Earth's ionosphere.

3.3.2 Climate and Weather

NOAA is currently supporting a program to study the recent changes in sea ice and snow cover and their impact on the Arctic Oscillation. Changes are occurring in the Arctic that appear to have begun in the late 1960s and increased in the 1990s. These include tropospheric warming, reduction in ice extent, and increased variability in snow cover (Moritz et al. 2002). Much scientific interest has focused on the Arctic Oscillation (AO). A paradox is that the main shifts in the AO are seen in mid-winter, while many of the surface changes are seen in spring and summer. A second issue is whether the reductions in sea ice and snow cover in the western Arctic actually have an impact on the atmosphere. The goal of this project is to determine the impact of the Arctic Oscillation on low-level wind and temperature fields in spring in the Arctic and to evaluate the magnitude of feedback from sea ice and snow anomalies to the atmosphere in spring and summer.

The recently released Arctic Climate Impact Assessment (ACIA) was a four-year project of the Arctic Council and the International Arctic Science Committee that started in 2001; the overview report was released in November 2004. The larger science report is scheduled to be available in the summer of 2005. Funding for ACIA was from the eight Arctic-rim nations, with the U.S. (through NSF and NOAA's Arctic Research Office) being the lead country for the assessment. The goal of the ACIA was to examine the possible impacts of climate change on the environment and its living resources, on human health, and on relevant economic sectors. About 180 authors were selected for the assessment from all Arctic countries. An ACIA Symposium was held in Iceland in November 2004, and briefings have been held in many countries, including to Scandinavian parliaments and the U.S. Congress. Further information on ACIA can be found on its web page at http://www.acia.uaf.edu/.

The Arctic Council is developing a scientific response to the ACIA that would be undertaken by its various working groups. A summary of the recommendations from the ACIA science report is being prepared for release at the same time as the science report itself. Because of the drastic changes in high latitudes foreseen by the ACIA, joint work between the Arctic countries is warranted.

The Arctic Climate Impact Assessment (ACIA) is a four-year project of the Arctic Council and the International Arctic Science Committee that started in 2001 and will be completed by the end of 2004. Funding for ACIA is from the eight Arctic-rim nations, with the United States (through NSF and NOAA's Arctic Research Office) being the lead country for the assessment. The goal of the ACIA is to examine the possible impacts of climate change on the environment and its living resources, on human health, and on relevant economic sectors. About 180 authors have been selected for the assessment from all Arctic countries. Further information on ACIA can be found on its web page at http://www.acia.uaf.edu/.

In addition, the ARM (Atmospheric Radiation Measurement) Program, DOE's principal climate change research effort, seeks to resolve scientific uncertainties about global climate change with a specific focus on improving the performance of general circulation models (GCMs) used for climate research and prediction. The ARM program focuses on one critical feature of the GCMs: the transport of solar and thermal radiation (sunlight and radiant heat) through the earth's atmosphere to and from the earth's surface. Within this area the greatest uncertainties are associated with clouds: their formation, quantitative description, behavior, and optical characteristics as influenced by atmospheric and underlying surface conditions.

ARM created a number of long-term, highly instrumented climate research sites in carefully selected locations around the world. The site locations were selected primarily on the basis of what needs to be learned about clouds and radiation to improve the models, but secondarily on the basis of cost and logistics. Three Cloud and Radiation Testbed (CART) sites now exist, each with facilities at more than one location. In addition, an ARM Mobile Facility (AMF) is currently being developed. In spring 2003, the three ARM CART sites taken together were designated a National User Facility: the ARM Climate Research Facility (ACRF). The ARM Mobile Facility will become part of the ACRF as soon as it is deployable.

A generic, fully developed ACRF site includes facilities spread over a large area. The central facility at Barrow has the largest concentration of instrumentation at the North Slope of Alaska site. It relies heavily on upward-looking remote sensors (radars, lidars, and radiometers of several kinds) to determine the characteristics of the clouds, winds, and atmosphere as a whole above the site on a continuous basis. The inland facility at Atqasuk has a subset of the instrumentation deployed at Barrow. A temporary-use facility at Oliktok Point to the east of Barrow is available for field campaigns using instrumented tethered balloons that cannot be accommodated at Barrow because of Federal Aviation Administration constraints.

In addition to ground-based instrumentation for characterizing the atmosphere and the earth's surface, it is also necessary to make occasional instrumented aircraft flights for measuring conditions aloft and also to depend heavily on data from polar-orbiting satellites. Because of the proximity of the NSA ACRF site to the North Pole, polar orbiters view the NSA site much more frequently than sites at lower latitudes. A major field campaign called the Mixed-Phase Arctic Cloud Experiment (M-PACE), utilizing research aircraft, satellite remote sensors, and instrumentation at Barrow, Atqasuk, Oliktok Point, and Toolik Lake Field Station, was recently completed. This is one of many field campaigns that have taken place at the North Slope ACRF site.

The NSA/AAO site provides data about cloud and radiative processes at high latitudes and, by extension, about cold and dry regions of the atmosphere in general. These data will be used to refine models and parameterizations for high-latitude regions and for the upper atmosphere. The ACRF goal is to provide a high-quality legacy data set for these purposes through continuous quality improvement. ARM also periodically solicits and funds proposals utilizing ARM data to achieve ARM goals. The issues of principal interest as they apply to cold regions are as follows:

- Atmospheric radiative transfer;
- Ice and mixed-phase cloud formation, evolution, and dissipation;

- Behavior of surface radiative characteristics;
- Direct and indirect aerosol radiative effects; and
- Development and testing of satellite remote sensing algorithms.

It should be noted that because the NSA/AAO is an element of a National User Facility, other agencies, academic institutions, and even foreign researchers and organizations can apply to use the NSA/AAO facilities to address climate-related or other issues of their own choosing. Provided that certain criteria are met, facility use can be granted on a non-interference basis (http://www.db.arm. gov/cgi-bin/IOP/iops.pl). If the only need is for existing data streams, no application or approval is necessary. The data are publicly available through the ARM data archive (http://www.arm.gov/data/).

3.3.3 Tropospheric and Stratospheric Chemistry and Dynamics

NOAA scientists from the Aeronomy Laboratory and the Climate Monitoring and Diagnostics Laboratory play prominent roles in the international scientific assessment of the ozone layer.

NOAA scientists from the Climate Monitoring and Diagnostics Laboratory (CMDL) conduct monitoring and research of atmospheric constituents that are capable of forcing change in the climate of the earth and atmospheric constituents that may cause depletion of the global ozone layer. The programs consist primarily of long-term measurements of solar radiation and atmospheric trace gases such as carbon dioxide, methane, carbon monoxide, halogenated compounds, nitrous oxide, surface and stratospheric ozone, and aerosols, and at sites remote from local and regional air pollution. The long-term measurements are supplemented by field campaigns using aircraft, ships, and even trains traveling the Trans-Siberian Railroad.

Global measurements show that atmospheric concentrations of chlorofluorocarbon-12 and the bromine-containing halons are continuing to increase in spite of the Montreal Protocol. Industrial production of CFC-12 ended in 1995 in the “developed” countries, but production in economically developing countries (for example, Russia and China) will continue until 2010.

3.4 Land and Offshore Resources

3.4.1 Energy and Minerals

The geologic framework of the Arctic is very poorly understood because of the complexities of its geology, 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

- Reinstate 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, gas hydrates);
- 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

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. The 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 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.

3.4.4 Forestry, Agriculture, and Grazing

Enhanced knowledge of Arctic and subarctic 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

- Conduct research 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, permafrost, 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, Greenland, Germany, Norway, Sweden, and Finland and with the Joint Cryosol Committee of the International Permafrost Association and the International Union of Soil Science;
- 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

NOAA has supported a program to study the hydrologic response of Siberian major rivers to climate change and variation (Yang et al. 2002). Arctic rivers are an important component in global ocean and climate systems, and these studies have shown changes in the hydrologic regimes of the major rivers in Siberia over the past several decades. This project, at the University of Alaska Fairbanks, is a comprehensive assessment of change and variability in Siberian river systems and their connections to surface climate and atmospheric circulation.

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 in 2000, 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, analysis of 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 (Davis et al. 2000). Some areas, however, appear to be undergoing thinning in excess of 1 m/yr, 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 (Krabill et al. 2000, Abdalati et al. 2001, Thomas et al. 2001).

Future PARCA research will address these issues, focusing on near-coastal snowfall and ablation and on the dynamics of thinning outlet glaciers. 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.

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, which was launched on January 12, 2003. ICESat is a three-year mission (five-year goal) to measure elevation changes on the earth's great ice sheets to an accuracy of approximately 2 cm. These data will greatly enhance our ability to ascertain where the Greenland ice sheet is growing and where it is shrinking. These data will be combined with ancillary data to investigate the mechanisms for that shrinkage.

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. The level of thinning is consistent with what has been observed in the more temperate regions of the Greenland ice sheet but don't show a strong dynamic component.

3.5.2 Permafrost, Landscape, and Paleoclimate

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

Objectives

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

3.5.3 Ecosystem Structure, Function, and Response

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 advances 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 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 and future Arctic building programs, including roads, pipelines, buildings, airfields, and hazardous material storage tanks.

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 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 exploiting 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 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? How can traditional knowledge enhance scientific understanding of the Arctic environment? 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* (see Appendix F), 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 United States 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 (ANSC), an organization that provides essential linkages between researchers and local communities, facilitating communication and cooperation.

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.

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. Their traditional and local knowledge base can provide long-term information about northern ecosystems and wildlife, of considerable value in resource management.

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.

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 passage of NAGPRA (Native American Graves Protection and Repatriation 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 have been concurrent changes in traditional cultural values. Chronic unemployment, family violence, substance abuse, and societal breakdown in general have reached epidemic proportions.

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 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. 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. Research Experience for Undergraduate (REU) supplements and sites provide on-site research training to college and university students.

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 NSF Office of Polar Programs (OPP) has begun a new postdoctoral fellowship program supporting independent postdoctoral research at a U.S. host institution for up to three years. The program goals are to support innovative research in any area of science supported by OPP, to foster the next generation of polar scientists, and to broaden participation in polar science. In addition to support for salary, health insurance, and a modest research budget, the fellowship also supports fieldwork in the Arctic and the Antarctic through the Arctic Research Support and Logistics program and the U.S. Antarctic Program.