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

Repatriation 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.