Summaries of projects supported by the FY2001 Arctic Research Initiative competition

<u>Daqing Yang et al., Hydrologic Response of Siberian Major Rivers to Climate Change and Variation</u>

Arctic rivers are an important component in global ocean and climate systems. Recent studies have shown remarkable changes in hydrologic regimes of the major rivers in Siberia (Lena, Ob and Yenisei) over the past several decades. This project will support a comprehensive assessment of change and variability in Siberian river systems and their connections to surface climate and atmospheric circulation. The investigators will examine the observational evidence of associations between river discharge and atmospheric and terrestrial variables, such as air temperature, precipitation, snow cover, soil moisture, timing and duration of the active layer depth, shallow ground water storage, ice thickness, and the Arctic Oscillation index.

The primary product of this project will be a better understanding of Siberian hydrologic and climatic dynamics. The resulting data set, characterized by the most detailed and up-to-date regional information, will be a valuable addition to existing global climatic databases.

<u>Peter B. Rhines, Observation and Modeling of the Fresh-Water Dynamics connecting the Arctic and Atlantic: A Feasibility Study</u>

The region where the Arctic and Atlantic Oceans meet and interact is of particular importance to global climate. Concentrated activity occurs there in both ocean and atmosphere, and recent measurements indicate that it is a region of substantial and ongoing change. Increasing amounts of fresh water have been pouring out of the Arctic in recent years and, in combination with intensified winds, have visibly altered the circulation of the Atlantic. Existing observational networks are inadequate to chart these changes or even to establish a baseline upon which changes occur. Improved observations of water masses and fluxes of water, salt, ice and tracers between the Arctic and the Atlantic must be established if we are to understand this changing state and anticipate its future.

The investigator on this project will study observational and modeling methods relevant to the intense flows linking the Arctic and Atlantic Oceans. He will examine the feasibility of an affordable but adequate long-term measurement program in the Canadian Archipelago and Davis Strait, the Labrador Sea and Labrador continental shelf. He will also examine existing numerical circulation and coarser resolution climate models to summarize the current state of their treatment of fresh-water balance and flow through high-latitude passages.

Andrey Proshutinsky et al., 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. The present state of the Arctic Ocean itself and its influence on the global climate system strongly depend on the Arctic Ocean freshwater budget. Changes in the freshwater balance would influence the extent of sea-ice cover, changes in surface albedo, energy balance, temperature and salinity of water masses, and biological processes in the Arctic.

Freshwater storage in the Arctic Ocean results in a persistent salinity anomaly (minimum salinity at depths from 5 m through 400 m) in the center of the Beaufort Gyre that drives the thermohaline circulation of the Arctic Ocean anticyclonically. The freshwater budget of the Arctic Ocean and freshwater output to the North Atlantic depend significantly on the intensity of this salinity anomaly, the direction of the thermohaline circulation, and the availability of freshwater from the Beaufort Gyre.

In this project, the investigators will use data accumulated in U.S. and Russian research institutions, together with existing numerical ocean models, to examine the origin of the salinity anomaly in the Beaufort Gyre and investigate its variability.

Rosanne D'Arrigo et al., Paleoclimatic Reconstructions of the Arctic Oscillation

The Arctic Oscillation (AO), defined as the leading mode of Northern Hemisphere sea-level pressure variability, is believed to represent the surface signature of the polar vortex; and as such it may be one of the key factors impacting climate at northern latitudes. In the positive phase of the AO, pressure tends to drop over the polar cap and to rise around 55 degrees N, strengthening the westerlies and steering ocean storms in a more northerly direction. When high-latitude tropospheric winds are strong, there is increased warmth in northern Canada and Eurasia. Thus, the AO may be a partial cause of the enhanced extratropical winter warming trend of recent decades, perhaps in concert with greenhouse warming.

The investigators will extend the available instrumental record for the AO by several hundreds of years into the past using tree rings and other high-resolution records. Key hypotheses they will test include whether the recent increase in the AO in the past few decades is unusual relative to its behavior over the past several centuries.

Jennifer Francis, Jeffrey Key and Steven Ackerman, Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties

The circulation of the Arctic atmosphere has undergone change during recent decades. It is unclear, however, how this change is related to other variables such as the magnitudes and pathways of horizontally advected heat and moisture into the Arctic as well as changes in cloud properties there. Conventional meteorological data are sparse over the Arctic Ocean; and, other than surface pressure fields and temperatures, we have had relatively little ammunition to investigate these issues in an Arctic-wide sense.

Newly available satellite-derived data sets from the NOAA/NASA Pathfinder Program offer an unprecedented opportunity to observe the Arctic climate by providing measurements of atmospheric quantities spanning two decades. The investigators in this project will use these new data sets to analyze poleward transport of sensible heat and water vapor from low latitudes into and within the Arctic region and examine how these quantities are related to cloud properties and the Arctic Oscillation.

John E. Walsh, An Arctic Archive of Model Output and Application to SEARCH

Recent environmental changes in the Arctic are well documented. These changes have motivated the interagency program known as SEARCH (Study of Environmental Arctic Change) whose objective is a predictive understanding of recent, ongoing and future environmental changes in the Arctic. In addition to observational and process studies, the SEARCH Science Plan includes modeling to test ideas about the coupling between the different components of Arctic change, and to predict its future course.

The investigator will develop a web-accessible archive containing the Arctic output from state-of-the-art global climate models. This archive of present-day and 21^{st}-century (projected) Arctic climate will be made available to other SEARCH projects and to the Arctic Climate Impact Assessment. Another component of the project will be an assessment of the extent to which state-of-the-art climate models reproduce the characteristics of the Arctic Oscillation and the North Atlantic Oscillation in simulations of present-day climate. A third component will be an evaluation of changes in the Arctic Oscillation projected by the models in their greenhouse simulations of 21^{st}-century climate.

John W. Weatherly, Connections between Arctic-Subarctic Ocean Fluxes and the Arctic Oscillation

The goal of this project is to investigate the relationship between the Arctic Oscillation and the variability of ocean and sea ice fluxes between the Arctic Ocean and adjacent seas. This will be done using a coupled, global atmosphere-ocean-ice general circulation model. The results of the research are expected to contribute to our understanding of how the Arctic Oscillation influences ice and ocean variability and how sea ice export, water mass exchange, and thermohaline circulation interact on time scales longer than our present observational records.

Joseph A. Shaw, Temporal and Spatial Variability of Alaskan Clouds Studied with a Ground-Based Infrared Cloud Imager

Measurement of clouds is fundamentally important to studies of climate variability and change in the Arctic. The Arctic radiation balance is especially sensitive to clouds because of a combination of the high thermal emissivity of clouds, the small input of solar radiation during winter, the high visible reflectivity and high thermal emissivity of snow and ice, and the low water vapor content of the Arctic atmosphere. Understanding the Arctic climate system, therefore, requires a quantitative knowledge of Arctic clouds, including their spatial and temporal distributions and their thermal radiative properties.

The investigator will deploy a newly developed Infrared Cloud Imager (ICI) in Alaska for determining spatial and temporal cloud statistics from radiance emitted in the 8-12 µm wavelength region. The ICI instrument records calibrated images of sky radiance, assigning a brightness temperature value to each pixel in an image. These values will be used to classify the pixels in terms of cloud existence and cloud type (e.g. clear sky, cirrus, mid-level cloud, stratus). ICI will be deployed first at the Department of Energy's Atmospheric Radiation Measurement Program site near Barrow, Alaska, where ICI data will be compared with cloud statistics from existing equipment there. Subsequently, the ICI instrument will moved to the Poker Flat Research Range near Fairbanks, Alaska for similar comparison with existing equipment. The project will be a first step toward studying the relationship between the Arctic Oscillation and cloudiness at various Arctic locations.

James E. Overland et al., Do Recent Changes in Sea Ice and Snow Cover Impact 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. Ecological impacts of these changes are already being noted. Much scientific interest has focused on the Arctic's leading mode of variability, the Arctic Oscillation (AO). The AO represents an Arctic-wide increase in upper atmospheric winds and a decrease in sea level pressure. 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 AO 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 study will be based primarily on observational data and analyses from three newly available sources.

Igor Belkin, Ocean Fronts of the Bering, Chukchi and Beaufort Seas

The goals of this project are (1) to describe qualitatively and quantitatively the ocean fronts of the Bering, Chukchi and Beaufort seas and (2) to investigate possible links between the fronts' characteristics (location, cross-frontal ranges and gradients) and the environment (bottom topography, sea ice cover, air temperature, river runoff, Bering Sea transport and wind stress).

The investigator will use both satellite and *in situ* data to derive, map and analyze the ocean fronts. Seasonal and interannual variability of the frontal patterns and individual fronts in each sea will be explored. Possible relations between the frontal patterns and parameters, on one hand, and various environmental parameters, on the other hand, will be elucidated on a variety of scales, from seasonal to interannual to decadal.

Alan M. Springer et al., Trophic Pathways on the Chukchi-Beaufort Shelf: Where do the Ice Algae Go?

Microalgae grow on the undersurface of sea ice as well as within the sea ice matrix, and are a conspicuous, well-known feature of Arctic ecosystems. They contribute a poorly-known proportion of the total primary production in Arctic seas, and recent studies suggest that ice algal primary production has been greatly underestimated. Ice algae are important to microbial food webs and the dissolved and particulate carbon and nitrogen pools of the Arctic Ocean, and they contribute to food webs leading to numerous species of marine birds and mammals of importance in regional subsistence economies. The importance of ice algae to production budgets at higher trophic levels is uncertain, but likely varies greatly across the Bering/Chukchi/Beaufort shelf because of physical oceanographic processes originating in the Bering Sea.

The investigators will employ a novel technique to quantitatively trace carbon fixed by ice algae and water column phytoplankton through pelagic and benthic food webs using conservative fatty acid signatures derived originally from ice algae and phytoplankton. The results will help us to understand trophic dependencies and carbon budgets in Arctic food webs and to predict effects of environmental change caused by global warming and further reductions in sea ice.

Steven B. Brooks, Steven E. Lindberg et al., Deposition Flux Rates and Fate of Atmospheric Mercury at Barrow, Alaska

The objective of this project is to expand the existing mercury measurement program at Barrow, Alaska, to include direct mercury flux measurements, particulate mercury monitoring, additional snowpack Hg analysis, and atmospheric halogen chemistry.

Leonard A. Barrie, Gregory W. Patton et al., Persistent Organic and Trace Element Pollutants in the Alaskan Arctic

This project is the Alaskan component of a larger effort entitled "Study of Atmospheric Deposition of Contaminants in the Arctic: A Paired Study of a Site in Alaska and a Site in the Russian Far East." The component in the Russian Far East will be supported separately by the Environmental Diplomacy Fund.

The scientific objectives of the project are (1) to gain insight into the sources, occurrence and environmental fate of persistent organic pollutants (POPs) and aerosol trace elements in the atmosphere of the Alaskan Arctic, (2) to contrast the occurrence of POPs and trace elements in this region with other Arctic air sheds, and (3) 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 due to POPs.

For one year at NOAA's Climate Monitoring and Diagnostics Laboratory in Barrow, the atmospheric concentrations of 90 polychlorinated biphenyl compounds, 40 organochlorine pesticides/herbicides or their metabolites, and 14 PAHs will be measured. Observed POPs and trace aerosol concentrations will be used to estimate atmospheric inputs of these substances to the Arctic. Collaboration with Canadian laboratories in this research ensures access to a set of similar observations with current observations being made in the Canadian and Russian Arctic.