The Interagency Program For the Study of Environmental Arctic Change (SEARCH)

An Implementation Framework With Specific Plans for FY2002 and FY2003

The recent changes seen in the Arctic are very severe, and there is a strong possibility that these changes will continue into the future and cause consequences throughout the Northern Hemisphere. The SEARCH Program is focused on understanding the reasons for the changes seen to date, extrapolating the course of change into the future, and preparing society to adjust to future changes.

Prepared by the Interagency Working Group for the
Study of Environmental Arctic Change
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Members of the Interagency Working Group for the Study of Environmental Arctic Change

Name		Affiliation	Contact Information
Abdalati	Waleed	NASA	202-358-0746 wabdalat@hq.nasa.gov
Brass	Garry	Arctic Research Commission	703-525-0111 gbrass@arctic.gov
Calder	John	NOAA	301-713-2518, ext. 288 John.Calder@noaa.gov
Fitzhugh	William	SI	202-357-2682 fitzhugh.william@nmnh.si.edu
Muench	Robin	DOD	703-588-2902 muenchr@onr.navy.mil
Heit	Merrill	DOE	212-620-3623 merrill.heit@science.doe.gov
Ledbetter	Mike	NSF	703-292-8029 mledbett@nsf.gov
Marcy	Suzanne	EPA	907-271-2895 marcy.suzanne@epamail.epa.gov
Nelson	Gordon	DOI	907-786-7100 glnelson@usgs.gov
Shafer	Steve	DOA	301-504-4644 srs@ars.usda.gov

Acronyms Used in This Report

Acronym	Expansion
ACIA	Arctic Climate Impact Assessment
AO	Arctic Oscillation
ASOF	Arctic/Sub-Arctic Ocean Fluxes
DOA	Department of Agriculture
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
EPA	Environmental Protection Agency
IARPC	Interagency Arctic Research Policy Committee
IPCC	Intergovernmental Panel on Climate Change
IPMC	Interagency Program Management Committee
IWG	Interagency Working Group
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
ONR	Office of Naval Research
SEARCH	Study of Environmental Arctic Change
SI	Smithsonian Institution
SSC	Science Steering Committee
THC	Thermohaline Circulation

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Global warming could well have serious adverse societal and ecological impacts by the end of this century, especially if globally-averaged temperature increases approach the upper end of the IPCC projections. Even in the more conservative scenarios, the models project temperatures and sea-levels that continue to increase well beyond the end of this century, suggesting that assessments that examine only the next 100 years may well underestimate the magnitude of the eventual impacts[1]*.*

Introduction

Significant changes in the atmosphere, oceans, and on land in the Arctic are affecting virtually every part of the Arctic and are now having both direct and indirect repercussions on human society. Because of the interplay of natural and human-caused factors, we do not know if the recent complex of changes is part of a pattern of natural variability or the beginning of a long-term shift. We also do not know what

[1] From Climate Change Science: An Analysis of Some Key Questions, National Academies of Science, June, 2001.

climate and ecosystem processes may be involved, or what the long term impacts may be. We do know that major environmental changes in the Arctic can affect – or at least anticipate – major changes in other global systems. An interagency program, the Study of Environmental Arctic Change, is being developed to understand the complex suite of significant atmospheric, oceanic, terrestrial and human changes that has occurred in the Arctic in recent decades[2].

Arctic Oscillation

There is evidence that many of these changes are strongly connected with the Arctic Oscillation (AO), which is apparently a natural mode of atmospheric variation. There is evidence that the AO itself may be strengthened by the anthropogenic (human-caused) rise in greenhouse gases, thus suggesting a human cause for some of the recent changes in the Arctic.

While climate change seems the most likely explanation for the observed environmental changes, there are other potential mechanisms for large-scale human influence on the Arctic, such as long-range transport of contaminants, and industrial-scale fishing. We cannot now separate the natural and anthropogenic factors that are causing the observed changes, so do not know if the recent complex of changes is part of a cyclic pattern of natural variability or the beginning of a long-term shift. We also do not know if these changes can themselves reinforce or slow environmental change.

Goals

SEARCH is a broad, interdisciplinary, multi-scale interagency program with a core goal of understanding the complex of recent and ongoing intertwined changes, with a view toward prediction. In addition to understanding how changes in the Arctic are interrelated to each other, SEARCH will investigate the links between Arctic change and global climate change and will assess the impacts that Arctic change may have throughout the northern hemisphere. SEARCH will evaluate the possibility that changes in the Arctic can anticipate changes elsewhere on the globe.

To be most effective in understanding the Arctic's many systems and their interplay, many resources and kinds of expertise must be brought together. SEARCH is the first interagency effort to combine funding sources, disciplines and knowledge from across the U.S. and around the world to address an issue of this type. The effort is designed to remove redundancy and bring researchers together to share knowledge and learn from one another. It is unique, and given the complexity of the Arctic environment, absolutely essential.

Critical Science Questions

The recent changes seen in the Arctic are very severe, and there is a strong possibility that these changes will continue into the future and cause consequences throughout the Northern Hemisphere. The

[2]Text adapted from the SEARCH Science Plan, developed by the SEARCH Science Steering Committee. Visit the SEARCH Web Site at http://psc.apl.washington.edu/search/

SEARCH Program is focused on understanding the reasons for the changes seen to date, extrapolating the course of change into the future, and preparing society to adjust to future changes. A set of key science questions will guide the efforts of SEARCH:

1. Are the changes seen in recent decades in the Arctic climate system consistent with natural variability, or are such changes at least partially attributable to human activity?
2. What is the interplay among atmospheric circulation, ozone loss, and UV radiation?
3. Can climate changes in the Arctic be predicted or assigned a probability?
4. How will hemispheric or global climate, affect or be affected by changes in the Arctic?
5. How will seasonal weather patterns in the Arctic and mid-latitudes be affected by changes in the Arctic?
6. What are the likely effects and consequences of environmental Arctic change on the health and well being of Arctic residents?
7. What are the likely effects and consequences of environmental Arctic change on ecosystems and key species of the Arctic?
8. How might Arctic-driven environmental changes affect societies and U.S. national security?

Major Activities

SEARCH includes four major types of activities:

- A long-term observational program to detect and track the environmental changes;
- A modeling program to synthesize observations, test ideas about the coupling between the different environmental changes observed, and to predict their future course;
- Studies to test hypotheses about critical forcing and feedback processes; and
- An application component to understand the ultimate impact of the physical changes on ecosystems and societies, and to distinguish between climate-related changes and changes due to other factors such as resource utilization, pollution, economic development and population growth.

To achieve the goals of SEARCH, the agencies supporting it will have to invest not only in the four areas described above, but also in "infrastructure" activities such as:

- development of new observing technologies;
- creation of new computer-based models;
- management and rescue of environmental data; and
- construction and maintenance of field facilities.

Observing and Modelling

A widely agreed need is the deployment of a comprehensive and sustained Arctic environmental observing system. This system will require remote and in situ systems focused on land, sea, air and ice. It must provide the critical information on the physical and biotic environment needed to meet the needs of SEARCH. The observing system must be strongly coupled to modeling and data assimilation efforts to ensure the system's data is useful and used. This comprehensive system must be sustained throughout the 21st century, recognizing that it will evolve to meet new requirements, comply with new strategies, and incorporate new technologies. Once new observing technologies have been developed and proven in the field, a pathway to transition these technologies to operational status will be needed. This pathway must include consideration of funding requirements, data quality and continuity, and data application.

The observing system and models have to provide useful information at different geographic scales from local to regional to global. The use of satellite-based remote sensing is critical for providing the large-

scale overview and finer-scale information when possible. Locally intensive observations will rely more heavily on in situ observations. Whenever possible, these should be made with autonomous sensors or samplers. Continuous use of in situ data for calibration or validation of remotely sensed data is essential and will require a multi-agency approach.

Summary of Agency Participation

Each participating agency will contribute to SEARCH in ways consistent with its mandates, strategies, and scientific capabilities. Each will undertake specific parts of SEARCH, and share data, information, and understanding to achieve the overall SEARCH goals. Results from SEARCH and other programs will provide the scientific underpinning for Arctic regional and global assessments of climate variability and change and associated impacts. Table 1 below describes the major types of activity that each agency expects to undertake to support SEARCH. Table 2 lists specific priorities for 2003 and currently known agency funding requests.

Table 1. Agency activity areas

National Science Foundation	Environmental processes research and observation, model development, observing technology development, social sciences research, Native-led observatories
National Aeronautics and Space Administration	Space-based and airborne measurements of atmospheric and land/ocean surface processes; model-based research
Department of Commerce/National Oceanic and Atmospheric Administration	Sustained in situ ocean and atmospheric observations, data- and model-based analyses, forecast services, impact assessments
Department of Defense/Office of Naval Research, Cold Regions Research and Engineering Laboratory	Research and technology development leading to predictive capability for environmental conditions that affect defense operations and the state of human society
Department of Energy/Atmospheric Radiation Measurement Program – North Slope of Alaska/Adjacent Arctic Ocean Site	Research on atmospheric processes, quantification of surface radiation budgets, environmental modeling

Department of Interior/Bureau of Land Management, Fish and Wildlife Service, National Park Service, US Geological Survey, Minerals Management Service	Use of protected and managed land areas for long-term terrestrial in situ observations; assessment of impacts of environmental change on glaciers, vegetation, fish, and wildlife; development of best management practices,
Department of Agriculture/Agricultural Research Service, Natural Resource Conservation Service, Forest Service	Impacts of high latitude environmental change on plant germplasm, agricultural pests, soil quality, and boreal forests; assessments of environmental change on agricultural potential and forest resources
Environmental Protection Agency	Regional assessments focused on human and ecological health, cultural values, and economic parameters
Smithsonian Institution	Research to understand current and past responses of society to environmental change, and development of inter-agency outreach program
Department of Transportation/US Coast Guard	Logistics support for ocean and sea ice research and observations
All	Integrated modeling or assessment efforts, joint studies, collaborative publications

Table 2. Agency priorities and funding

Agency	**Priorities**	**FY2003 Funding Request**
National Science Foundation	Field measurement programs for improving models and understanding processes; develop new technologies; implement environmental observatories (facilities for making measurements, with a changing mix of measurements); develop new models and data assimilation techniques; lead the interagency effort on human dimensions research	Request $40.5 million in new funds.
National Aeronautics and Space Administration	Provide the perspective from space under the NASA Earth Science Enterprise; evolve from observation only to include modeling and data assimilation; re-calibrate existing sensors for use in the Arctic; build long-term, consistent data sets and support data management and rescue efforts; in future, aim for more analysis and modeling with targeted in situ field campaigns to support existing or already planned satellites	Funding request is to be determined.
Department of Commerce/National Oceanic and Atmospheric Administration	Focus on sustained observations of atmosphere, sea ice, ocean and marine biota; undertake related data management and data rescue efforts; support modeling and data assimilation; develop applications and products for the public and policy/decision-makers	Request $2.0 million in new funds.

Department of Defense/Office of Naval Research, Cold Regions Research and Engineering Laboratory	Continue DOD mission-focused research with secondary objective of supporting SEARCH when possible; continue tracking and modeling sea ice and snow; analyze historical Arctic Ocean and terrestrial data and recent Arctic atmospheric and hydrological data; develop new observing technologies; continue observations in the Bering Strait region; evaluate future DOD missions under possible future environmental conditions in the Arctic and globally.	Will use existing funds to begin.
Department of Energy/Atmospheric Radiation Measurement Program – North Slope of Alaska/Adjacent Arctic Ocean Site	Continue Atmospheric Radiation Measurement Program at the North Slope/Adjacent Arctic Ocean site; investigate flux of thermal and solar radiation through the atmosphere with emphasis on the role of clouds; build and maintain data base; apply knowledge to climate models; maintain facilities at Barrow and Atqasuk; complete original site design to include Barrow, Atqasuk and Oliktok Point as funds permit.	Will use existing funds to begin.
Department of Interior/Bureau of Land Management, Fish and Wildlife Service, National Park Service, US Geological Survey, Minerals Management Service	Conduct studies to understand impacts of environmental change on the lands and resources managed by DOI; discriminate natural from anthropogenic causes and determine need for management actions; provide protected locations and facilities for establishment of environmental observing sites; continue research on conservation of trust species under conditions of a changing Arctic; undertake long-term ecological observations; perform associated data management and rescue tasks.	Will use existing funds to begin.
Department of Agriculture/Agricultural Research Service, Natural Resource Conservation Service, Forest Service	Conduct research on environmental changes occurring in high latitudes that may affect the sustainable production of food, fiber, and other renewable resources; contribute information concerning impacts on these resources and resource use to interagency human dimensions research.	Will use existing funds to begin.
Environmental Protection Agency	Undertake SEARCH-related activities within its mission to protect human health and safeguard the natural environment; catalyze integration of data and understanding to understand effects of multiple stressors; link human health and cultural impacts with environmental change; facilitate an integrated assessment of the Bering Sea region	Will use existing funds to begin.
Smithsonian Institution	Develop mechanisms to present the SEARCH program and results to a broad national audience, communicate scientific discoveries and understanding, advertise needs and capacities to the public; enhance existing programs and activities to include Arctic science elements; entrain commercial and charitable organizations to develop educational and outreach materials.	Will use existing funds, donations, and contributions from other agencies to begin.
Department of Transportation/US Coast Guard	Provide icebreaker, helicopter and other logistic support for SEARCH scientific activities in the Arctic.	Will use existing funds.

Major Programs to be Conducted Under the Auspices of SEARCH

Meeting the goals of SEARCH and providing answers to the critical science questions will require the coordinated application of the capabilities and resources of all of the participating agencies. A simple representation of the interactions of agencies and themes of activity is shown in Table 3. In addition, collaboration with organizations and scientists from other countries will be required to deal with the pan-Arctic nature of these questions.

Table 3. Matrix of agency involvement in different thematic areas

Research Theme/Agency	NSF	NASA	DOC	DOD	DOE	DOI	DOA	EPA	SI
Human Society	X					X		X	X
Marine/Terrestrial Biosphere	X	X	X	X		X	X		
Atmosphere and Cryosphere	X	X	X	X	X	X			
Ocean	X	X	X	X		X			
Integrated projects, models, assessment	X	X	X	X	X	X	X	X	X

The SEARCH Science Plan defines a comprehensive, multi-disciplinary approach to understanding environmental change in the Arctic and its connections to other regions. The complexity of the overall plan requires that it be divided into smaller thematic areas suitable for effective implementation. A series of "programs" are to be developed that include efforts in one or more of the four thematic areas (ocean, atmosphere-cryosphere, biosphere, human society) included under SEARCH. These programs will develop in their own way with expert scientists preparing the scientific approach and agency managers developing implementation and funding mechanisms. Details on the current state of planning for these programs can be found in Appendix I.

Ocean Thematic Area

The first program to be identified under SEARCH is the Arctic/Sub-Arctic Ocean Fluxes (ASOF) Program, which has had a year of intense planning and coordination at national and international levels.

The descent of cold, dense waters across the Greenland-Scotland Ridge and in the Labrador Sea is a principal means by which the deep ocean is ventilated and renewed. . Most projections of greenhouse gas induced climate change anticipate a weakening of the thermohaline circulation (THC) in the North Atlantic in response to increased freshening and warming in the sub-polar seas. The thermohaline circulation is a global process that transports warm surface water from the equator to the higher latitudes and returns cold deep water. A reduction in upper-ocean density at high northern latitudes may reduce the rate at which water sinks and thus may weaken the THC and possibly change the climate of eastern North America and western Europe. The ASOF program is focused on response of the ocean's

thermohaline circulation to changes in flux of Arctic ice or fresh water to the north Atlantic. ASOF is designed to detect changes in freshwater flux and in thermohaline circulation and assess the potential for resultant climate change.

In FY2003, NSF, NASA, NOAA, and DOD/ONR will support ASOF, as will several international collaborators.

Atmosphere/Cryosphere Thematic Area

In late 2001, the agencies are planning to hold a major science workshop that will develop the purpose and scope of a proposed new program, now titled "Atmospheric and Cryospheric Change in the Arctic" (ACCA). The Arctic atmosphere and cryosphere have undergone significant changes during the last thirty years, but our present level of knowledge is inadequate to understand, quantify or predict the interactions among these changes. These changes have become increasingly apparent over the past decade and have resulted in shifts in the Icelandic and Aleutian low mid-latitude weather systems with corresponding far-reaching impacts on northern hemisphere climate.

Central Arctic pack ice cover has decreased in thickness by more than one third in some areas, and marginal sea ice extent has decreased by 20% in response to these atmospheric changes. The subsurface layers of the Arctic Ocean have warmed by more than 0.5 degrees Celsius, which from an oceanographic viewpoint is both unusual and highly significant with respect to regional oceanographic and sea ice processes. Corresponding changes are impacting permafrost, seasonal snow cover, associated ecosystems and high latitude human communities.

The ACCA program will seek to improve understanding of these interactions, leading to formulation of effective strategies to minimize the impacts of climate change on the global population and economy.

In FY2003, NSF, NASA, NOAA, DOE, and DOD will provide support for the ACCA program.

Biosphere Thematic Area

The SEARCH Science Steering Committee (SSC) is developing a framework for a science program focused on environmental change and associated impacts on marine and terrestrial biota. An initial planning workshop was held in June 2001. Key objectives of the biospheric component of SEARCH will be to understand how climate variability and change affects ecosystems and key species, and to understand how human management and use of living resources may have to adapt.

In 2002, EPA and other agencies will conduct a Bering Sea Summit in Anchorage. The Summit will provide common ground for all parties with interests in the larger Bering

Sea region, which includes the Beaufort and Chukchi Seas. Participants will discuss how environmental change will affect each party, how each is likely to respond, and what can be done to minimize conflict. These discussions will embrace ecologic, economic, human health, and socio-cultural themes. The SEARCH SSC will update the SEARCH Science Plan in response to these planning activities.

In 2003, the NSF, NOAA and DOI will develop and undertake an implementation plan that will coordinate and enhance biospheric research in the Bering Sea. Simultaneously, NSF, NOAA, DOI, and NASA will evaluate how to transform existing terrestrial ecological monitoring sites, e.g. an existing north-south transect in the Alaska National Wildlife Refuge, into more comprehensive terrestrial environmental change monitoring sites.

Human Society Thematic Area

To assess the effects of environmental change on indigenous people and other residents, a research program examining the dynamics of linkages between human populations and the biological and physical environment of the Arctic is required. Under SEARCH, experts in the social and economic sciences are leading a dialogue with physical and biological scientists to develop the needed research effort. During 2002, the NSF, Smithsonian Institution, EPA and others, in conjunction with the SEARCH SSC, will organize a social sciences workshop to create an implementation plan for 2003. In addition, the NSF will support research activities in two areas: study of societal conflicts that arise when “common pool” Arctic resources are affected by major environmental changes; and pilot projects to involve networks of local residents in performing and documenting environmental change observations.

Synthesis, Integration and Outreach Activities

In 2003, the agencies that comprise SEARCH will begin what will become a continuing set of activities designed to address the complex goals of SEARCH. By bringing together the data, information and understanding that each has achieved, the inherently multi-disciplinary SEARCH hypotheses and science questions can be addressed. The precise nature of these activities will be developed over the next year. One possibility is a multi-agency SEARCH Symposium, perhaps held in conjunction with the regular meeting of a scientific society. Another possibility is development of a report to the public that describes current understanding of one or more critical issues. The Smithsonian Institution will organize and lead an interagency task team that will develop outreach activities based on information supplied by the various agencies.

Currently, the U.S., through both NOAA and the National Science Foundation, is providing leadership and financial support to the Arctic Climate Impact Assessment (ACIA), a whole-Arctic activity under the auspices of the Arctic Council. SEARCH will support the ACIA assessment to be completed in 2004, and also will participate in future

assessments undertaken by the Intergovernmental Panel on Climate Change (IPCC) in 2005 and beyond.

Resource Requirements for Full Implementation of SEARCH

The SEARCH program is planned as a long-term effort to document and understand environmental change and associated impacts. Given this long-term perspective, SEARCH can be successful even though all activities do not begin at the same time. Agency planning processes are complex and require coordination within the Administration and concurrence by the Congress. Over the next several years, the participating agencies will define further their individual roles in SEARCH and seek to obtain the resources needed to implement those roles. At the present time, based on agency views of what is needed and possible, an annual funding level of $118 million will be required to undertake all of SEARCH. This funding level is distributed as shown in Table 4. The agencies will work to refine these numbers and build them into their future budget requests.

Table 4. Annual funding required for full implementation of SEARCH

Agency and Program Office	**Annual SEARCH Funding at Full Implementation**
National Science Foundation – Office of Polar Programs, Arctic Sciences Section	$50,000K
National Oceanic and Atmospheric Administration - Arctic Research Office	$26,000K
National Aeronautics and Space Administration – Cryospheric Sciences Program	$15,000K*
Department of Defense – Office of Naval Research and Army Corps of Engineers/Cold Regions Research and Engineering Laboratory	$8,500K*
Department of Energy – Atmospheric Radiation Measurement Program/Alaska Site	$3,000K*
Department of Interior – National Park Service, Fish and Wildlife Service, Geological Survey, Bureau of Land Management	$10,000K*
Smithsonian Institution – National Museum of Natural History	$2,000K*

US Environmental Protection Agency –Arctic Program	$1,500K*
Department of Agriculture – Forest Service, Natural Resources Conservation Service, Agricultural Research Service	$2,000K*
Total funding required by all participating agencies	$118,000K

* These numbers were not reported by the agencies, but are estimates based on the scope and scale of the activities they are considering for future action.

Interagency Management of the SEARCH Program

From its inception in the spring of 2000, the Interagency Working Group (IWG) has been responsible for developing the SEARCH program within the agencies. It seems natural that the IWG should retain a leadership role as SEARCH becomes an active program.

In FY2002, the IWG will propose to the Interagency Arctic Research Policy Committee (IARPC) that it is renamed the Interagency Program Management Committee (IPMC) for SEARCH. A draft "terms of reference" for the IPMC will be prepared for IARPC review by December 2001. This will include statements on the role and responsibility of the IPMC, and on procedures that the IPMC will follow to implement SEARCH across all of the participating agencies. One objective of the IPMC will be to coordinate with related agency programs, in particular the U.S. Global Change Research Program. The IPMC will require the continued existence and functioning of the SEARCH Science Steering Committee.

For the IPMC to function, it will need more resources than the IWG has required. Like the IWG, the members of the IPMC will provide a portion of their time for SEARCH-related activities. However, once SEARCH becomes active, there will be need for greater communication, coordination, record keeping, and reporting. Therefore, the IPMC will need the full-time services of an Executive Secretary (scientist) and of an administrative assistant. The IPMC will need funds to conduct planning meetings, prepare reports, and undertake other SEARCH-wide, non-science functions. The IWG recognizes and accepts these future requirements and will seek guidance from the IARPC for meeting them.

The SEARCH Scientific Steering Committee (SSC) will continue to provide scientific planning. In particular, it will develop the scientific bases for the thematic programs to be implemented under SEARCH and will be instrumental in devising means for synthesis and integration of the diverse information that SEARCH will generate. The SSC will provide scientific liaison to international science groups and aid the IPMC's efforts to achieve international implementation mechanisms.

APPENDIX I: Focused Programs to be Conducted as Part of SEARCH

This Appendix contains three sections. The first, Arctic/Sub-Arctic Ocean Fluxes, describes a well-developed program with active international collaboration. The second section, Atmospheric and Cryospheric Changes in the Arctic, describes a program under development based in interagency consultations over the past several months. The final section describes areas for which scientific programs are in the initial consultation phase. It is anticipated that all of the program areas described will be ready for implementation in 2003.

1. Arctic/Sub-Arctic Ocean Fluxes (ASOF)

Bob Dickson, CEFAS, Lowestoft, UK, Chair, International Science Steering Group (ISSG) for ASOF

1.1. Background

Most projections of greenhouse gas induced climate change anticipate a weakening of the thermohaline circulation (THC) in the North Atlantic in response to increased freshening and warming in the sub-polar seas. Since the overflow and descent of cold, dense waters across the Greenland-Scotland Ridge is a principal means by which the deep ocean is ventilated and renewed, the suggestion is that a reduction in upper-ocean density at high northern latitudes will weaken the THC.

Unfortunately, our models do not yet deal adequately with many of the mechanisms believed to control the THC, and our observations cannot yet supply many of the numbers they need. For example our present observations of this large scale overturning circulation (in the North Atlantic or anywhere else) are insufficient to detect whether or not it is changing: we have no measurements of the freshwater flux between the Arctic Ocean and Atlantic by either of its two main pathways; we have no measurements of the variability of the heat and salt flux to the Arctic Ocean; we have a growing knowledge of the long-term variability of dense overflows which “drive” the THC but only embryonic ideas as to their causes. Understandably then, we take the view that these key mechanisms and processes are too crudely represented in the present generation of climate models. Paleoclimate records, however, show that massive and abrupt climate change has occurred in the Northern Hemisphere, especially during and just after the last Ice Age, with THC change as the most plausible driver. Both paleo-climate records and models suggest that the changes in the strength of the THC may occur rapidly, in a few decades. Further, in our admittedly-short modern records of ocean variability, we have growing evidence that hydrographic changes of decadal scale in the Arctic and sub-arctic seas are able to feed south across the deep northern overflows to cause hydrographic changes in the deep and abyssal layers of the Labrador Sea. These variations are large and long sustained though we don’t yet know enough about process to determine their climatic significance.

1.2. Present state of ASOF planning

Plans have advanced to the point of designing a prototype array (Figure 1) and establishing an International Science Steering Group (ISSG) to carry the concept through to implementation.

Table 1. Current membership of ASOF ISSG

Bob Dickson, CEFAS, Chair	
Jens Meincke (IFMH), Deputy Chair (E)	Peter Rhines (U.W) Deputy Chair (W)
E. Fahrbach, (A-W-I)	Mark Johnson (UAF)
Jochem Marotzke (SOC)/ [Harry Bryden (SOC)]	Simon Prinsenberg (BIO)/ [Eddy Carmack (IOS)]
Peter Haugan (Geophys Inst, UIB)/ [Harald Loeng (IMR)]	Mike McCartney/ [Cecilie Mauritzen (WHOI)]
Bill Turrell, (FRS) / [Bogi Hansen (FL of Faroes)]	Peter Schlosser LDEO/ [Tom Haine (JHU)]
Richard Wood (Hadley)/ [Michael Karcher (A-W-I)]	Sergey Pryamikov (AARI)
Edmond Hansen (Norsk Polar Institute)	Japan tbd
Ian Vassie (Proudman Oceanographic Lab)	Rich Pawlowicz (UBC)/ [Craig Lee (UW-APL)]
	Tom Pyle (NSF)/ [John Calder (NOAA)]

The intention is to establish a co-ordinated, circum-Arctic system of ocean flux measurements with decadal 'stamina' to cover all of the gateways that connect the Arctic Ocean with sub-arctic seas. These space-time requirements are easily justified. Recent studies provide clear evidence that recent changes in the marine climate of the Arctic Ocean are decadal and pan-arctic in scale and ---at least in part---- reflect a changing balance between Atlantic and Pacific influences. And coupled with the fact that the most advanced models now suggest that ocean fluxes through different Arctic gateways may be linked in their time-dependence, it makes sense to make these measurements at the same time

We cannot entirely restrict our attention to "Arctic gateways" however. In a program concerned with the slowdown or shutdown of the THC, some part of our observing system must be directed at measuring the rate of the meridional overturning circulation of the North Atlantic south of the Greenland-Scotland Ridge. Thus the proposed ASOF observing system extends south to 25ºN (see Figure 1). It would be myopic also to ignore the Labrador Sea as the site through which all the deep and bottom waters that "drive" the THC must pass, and we devote a considerable observing effort to that site. At least initially, the appropriate emphasis in making our long observational series is seen to lie in "keeping pace with" change rather than its prediction, while generating the data sets and time-series needed to develop the predictive skill of climate models.

1.3. Next steps

Though the membership of the ISSG covers the full geographical spread of the array, we intend to organise the SSG under two Deputy Chairs (DC) ---Jens Meincke of the University of Hamburg as DC (E) and Peter Rhines of the University of Washington as DC (W) ---to permit the western and eastern groups of the SSG to meet with greater flexibility and greater frequency than could the whole group. The ASOF Chair and two Deputy Chair (W) met in April 2001 to plan the mix of design studies and equipment trials.

The business of the full Group prior to implementation will be to progress the ASOF Science Plan including links to national programmes, to prepare progress reports, to debate means of international co-ordination in both science and funding, and to receive the collective advice of Arctic operators on unresolved issues. Once per year in the fall, it is planned that the full ISSG will meet, beginning in fall 2001 in Washington DC and continuing in (probably) Hamburg in fall 2002, probably as a Euroconference.

The initial discussion phase is all but ended. The work to implementation is beginning. Progress can be tracked on SEARCH and Norsk Polarinstitutt websites.

Figure 1. Distribution of the observing sites that make up the prototype ASOF Array. The justification for each is described in the Strawman-3 document on the SEARCH website (http://psc.apl.washington.edu/search/).

2. Atmospheric and Cryospheric Change in the Arctic (ACCA)

Robin Muench, Jim Overland, Bernie Zak, Kim Partington - SEARCH Task Team for ACCA

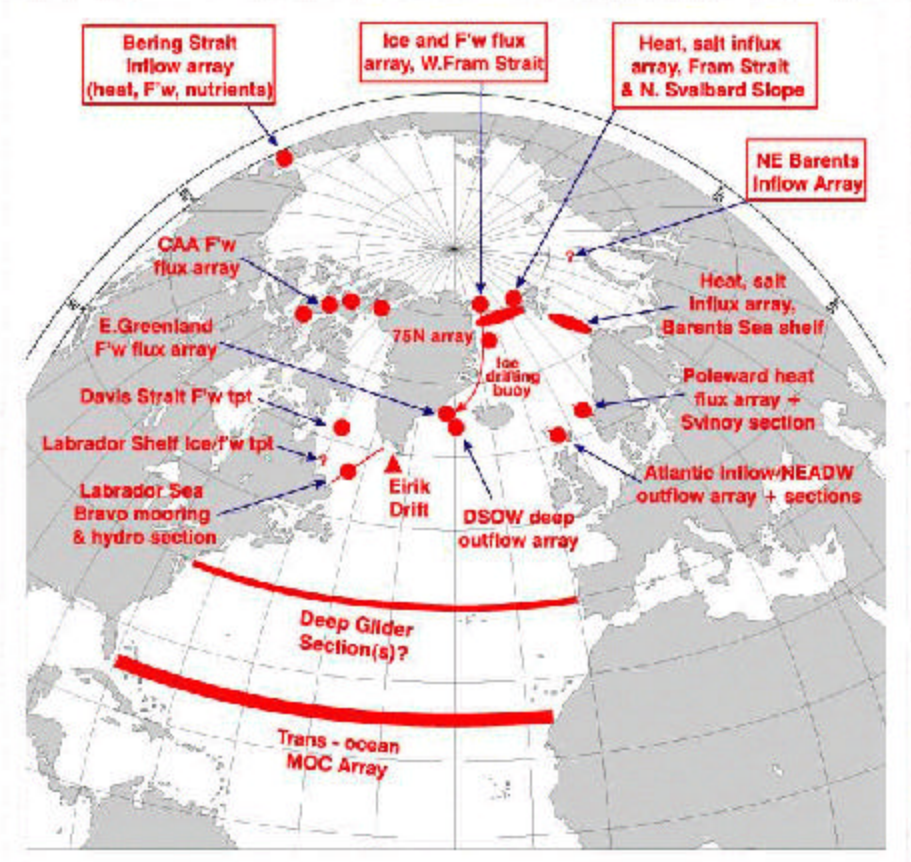

Figure 1. Configuration of prototype ASOF Array.

2.1. Purpose and Rationale

This document proposes a strategy for coordinating individual agency approaches to the study of Atmospheric and Cryospheric Change in the Arctic (ACCA). ACCA is an integral part of the interagency Study of Environmental Arctic Change (SEARCH). Coordination will be essential from the projected program start date in FY02 onward, and will focus on integrating the following three topics:

- Improved predictive understanding of Arctic atmospheric

and cryospheric processes through continued model development and data assimilation;
- Coordination, maintenance and enhancement of Arctic climate and radiation measurement networks; and,
- Variations in the fluxes of heat, freshwater, and climate-impacting contaminants into and within the Arctic and sub-arctic regions.

ACCA is motivated by the need to understand the accelerated climate change that has been observed in the Arctic and to identify the impacts that this change may have on the global climate system. The primary means for addressing the need will be through model development. The data needed for model validation require establishment and maintenance of field measurement networks adequate to assess regional meteorological and radiation parameters and to detect variations in the regional fluxes of heat, water vapor, freshwater, and climatically active atmospheric contaminants. The models and measurement systems are inherently linked, inasmuch as each system drives the others. Hence, coordination will be essential and is addressed in this document.

2.2. Background

The Arctic atmosphere and cryosphere have undergone significant changes during the last thirty years. These changes have become increasingly apparent over the past decade and have resulted in shifts in the Icelandic and Aleutian low mid-latitude weather systems with corresponding far-reaching impacts on northern hemisphere climate. Central Arctic pack ice cover has decreased in thickness by one third, and marginal sea ice extent has decreased by 20%, in response to these atmospheric changes. The subsurface layers of the Arctic Ocean have warmed by more than 0.5 degrees Celsius, which from an oceanographic viewpoint is both unusual and highly significant with respect to regional oceanographic and sea ice processes. Corresponding changes are impacting permafrost, seasonal snow cover, associated ecosystems and high latitude human communities.
Our present level of knowledge is inadequate to understand, quantify or predict the interactions among these changes. To provide just one of many possible examples, existing global climate models predict that persistent change will be particularly evident in high northern latitudes. These models suggest, however, that sea ice changes will be greater in winter rather than in summer-as actually observed. Improved understanding of these interactions will be an essential contribution toward the formulation of effective strategies to minimize the impacts of climate change on the global population and economy.

2.3. Science drivers

ACCA will address the above concerns by focusing research on the following key climate-related questions.
- Which of the atmospheric and cryospheric changes that have occurred in the Arctic during recent decades reflect long-term, as compared to interannual or decadal, changes?

- Which of these changes reflect significant teleconnections with lower latitude climate?
- What mechanisms have driven the recent and ongoing atmospheric and cryospheric changes?
- What are some future Arctic climate change scenarios and their probabilities of occurrence?
- What are possible, or probable, impacts of Arctic climate change on the global ocean and on lower latitude climate?

2.4. Strategy

An integrated approach based on enhancement of observational systems, field-based process studies, numerical modeling and data assimilation will be necessary in order to address these issues. Before assessing future change, we must demonstrate that our models can simulate past and present conditions. This requires assimilation of long-term datasets into the models, and an improved understanding of the relevant processes. Presently ongoing climate change can only be documented and characterized through real-world observations obtained over decadal time periods and large geographical regions. A minimal strategy to accomplish this will require the following.

Distributed observation network to obtain long-term observations of sufficient quality and continuity to address questions of climate. This includes satellite observations and distributed networks of climate and radiation measurements.
Modeling and data analyses using climate models that adequately represent Arctic processes, coupled with assimilation techniques that optimize the integrated information return from models and observations.
Process studies that are based on field data and assess processes that impact climate and whose understanding is essential to successful development and application of climate models.
Coordination activities to maintain a focus on key issues and to ensure that policymakers and the public are informed in timely fashion about key findings.

These topics can be grouped into general categories falling under observation network, and modeling and data analyses.

2.4.1. Distributed observation network

Reliable long-term measurements are limited in the Arctic. Technological advances now make it possible to greatly enhance new data acquisition using existing facilities, such as drifting and land-based remote stations, through use of telemetry. New technologies also allow use of satellites in enhanced data acquisition. Several such facilities exist in the Arctic.

1. The International Arctic drifting Buoy Program (IABP) provides measurements of sea level pressure, ice drift and surface temperature.
2. The Barrow Alaska Environmental Observatory (NOAA Climate Monitoring and Diagnostics Laboratory, DOE Atmospheric Radiation Measurement Program, and NSF Arctic System Science

Program) measures UV, visible and IR radiation, cloud cover and height distribution, aerosols, heat and water vapor fluxes, CO_2 and other air chemistry parameters.
3. The Greenland Climate Network assesses climate and glaciological parameters across the Greenland ice sheet.
4. The North Pole Environmental Observatory, a five-year remote drifting station, measures meteorological, snow, sea ice and upper ocean parameters.
5. Manned and autonomous surface and upper air stations measure a broad variety of atmospheric parameters.
6. Satellite monitoring documents vertical structure of the atmosphere (*e.g.,* TOVS) in addition to snow and ice cover (SSM/I and others).
7. The Network for the Detection of Stratospheric Change (NDSC) measures stratospheric parameters.

These facilities need to be expanded and coordinated, and the measurements prioritized, in order to support a set of core Arctic measurements. The following activities provide examples of candidates for support within ACCA:

1. Support development of new observational technologies through long-term agency support motivated by well defined science requirements such as, for instance, the need for statistically robust sea ice thickness and snow cover observations.
2. Replacement of the historical, predominantly Russian, drifting ice camps by an array of remote autonomous drifting stations to monitor atmospheric, sea ice and upper ocean conditions.
3. Augment the existing IABP program to include surface meteorological observations and flux measurements.
4. Augmentation or reestablishment of recently downgraded or closed weather and hydrologic stations, especially those in Russia and on the Arctic coast of North America, and addition of atmospheric profiling systems at critical locations.
5. Integration of existing regional weather network,s such as the Greenland climate network, into an Arctic-wide network.
6. Submarine and autonomous underwater vehicle (AUV) cruises and moored upward looking sonars (ULSs) to monitor ice thickness in key areas where advection or thermodynamic processes are thought to be important.
7. Coordinated use of satellite sensors to improve the coverage, range and quality of observations and to provide data in a quality controlled, well documented, easily accessible, comprehensive and coherent gridded format.
8. Coordination or integration of existing solar radiation monitoring networks and adjustment of these networks to meet the needs of data assimilation for models.

2.4.2. Modeling and data analyses

Understanding Arctic climate sufficiently to allow prediction depends on use of climate models. These depend in turn on the availability of observations for model validation. Establishment of data priorities for assimilation into models is essential. The following issues will be paramount in ACCA.

1. Application of statistical techniques to datasets in order to test hypotheses concerning high latitude climate processes.
2. Inclusion of realistic cryospheric behavior, including sea ice rheologies and cloud radiation feedback, in climate models.

3. Development of optimal techniques for data assimilation into models.
4. Quantitative intercomparisons of the existing ocean-ice-atmosphere models.
5. Evaluation of the role of air chemistry in Arctic change, with an emphasis on aerosols, CO_2 and ozone.

2.4.3. Process studies

These address deficiencies in our modeling of large-scale climate processes, and should be selected based both on model deficiences and on observed conditions. These studies are likely to involve a combination of field observations and theoretical research, and require well-defined strategies for assimilation of results into models. Cloud radiation feedback mechanisms and upper ocean turbulent heat fluxes, neither of which are well documented in the Arctic but both of which are crucial to understanding climate, are examples of such processes.

3. Potential Future Programs

3.1. Terrestrial Biotic Systems

Background: Dramatic changes have occurred in non-glaciated terrestrial systems in response to a predominately warmer physical environment during the past decade. Those changes are by no means monolithic but trends of environmental variables over most of the Arctic demonstrate a clear picture of cryospheric, hydrologic, and ecosystem response consistent with regional warming. Permafrost temperatures have warmed resulting in disappearance of some southern permafrost zones with northern permafrost zones thawing earlier, deeper, and remaining thawed later in the season. Hydrologic changes include decreased snow cover and depth, increased precipitation, and significant seasonally and spatially variable changes in runoff. The ecosystem response to changes in the physical environment resulted in changed tundra species composition, northern migration of tree line, increased abundance of shrubs, and a change within tundra regions from a sink to a source for carbon dioxide.

The changes in terrestrial environmental variables are by no means a simple direct response to regionally warming atmospheric temperature trends. Indeed, some areas of the Arctic are cooling and the terrestrial systems have responded accordingly. The predominant pan-Arctic trend, however, is one of a response consistent with environmental warming. If nothing else is clear about the changes in terrestrial systems it is the high degree of biocomplexity inherent in the myriad direct and indirect climate, hydrologic, soil, ecosystem feedback mechanisms. Increased understanding of the vulnerability of arctic terrestrial systems to projected continued warming is important to the management of renewable natural resources, decisions concerning changes in land use, maintenance of existing/future infrastructure, mitigation of environmental impacts, and the sustainability of arctic communities, particularly those depending on a subsistence lifestyle.

Approach: A central question arises from the recent trend of climate warming and terrestrial system change: Are the changes related and are they part of a natural cycle or anthropologically induced? There have been cycles of atmospheric temperature change for thousands of years and fluctuations in terrestrial systems on the same time scale. The degree of warming in high-latitudes observed in the past few decades occurred in the 1930/40s and repeatedly in the paleoclimate record of the past millennia. The difficulty in making connections is twofold: correlating the most recent warming trend to observed changes in terrestrial systems and tying either the warming or the terrestrial changes to anthropological causes. The data simply do not exist and the understanding of the feedback processes is too insufficient to produce reliable evidence of either relationship. Having admitted that the problem is unsolvable at present does not exclude the possibility that it can be solved with a coordinated approach using available techniques and in a reasonable time frame. SEARCH provides the framework for accomplishing that goal because it allows coordinated observations of changes within the system while taking a system-level view of the biocomplexity of the Arctic on a sufficiently long time-scale to begin to identify feedback processes acting in response to both natural and anthropogenic causes/effects.

While many research projects have been funded by Federal agencies that address aspects of terrestrial system response to climate change, the agency efforts have not been coordinated to maximize a system-level understanding of causes/effects. SEARCH will facilitate the needed coordination to produce a research outcome that builds on the earlier efforts and take advantage of those results to design an interagency research program that seeks a system-level understanding of the environmental processes. The research program will include:

1. long-term data collection from environments shown to be sensitive to climate change on the decadal time-scale, e.g., existing ecological monitoring sites in the Alaska National Wildlife Refuge (DOI/FWS)
2. limited manipulative experiments to induce changes in terrestrial processes in response to climate change, and
3. modeling studies designed to integrate knowledge about processes and feedbacks in order to build a predictive capability.

3.2. Marine Biotic Systems

Background: The Bering Sea ecosystem is among the most productive of high latitude seas. It is a rich, abundant, and ecologically diverse system that has attracted and supported aboriginal cultures across millennia. A kaleidoscope of oceanographic, geophysical, biochemical, economic, and cultural forces, shapes the ecosystems of the Bering Sea region. Over the last two decades changes in Bering Sea resources have been profound. Steller's sea lions declined 50 to 80 percent and are now listed as "endangered". Northern fur seals are listed as "depleted" under the Marine Mammal Protection Act. Bering Sea populations of common murres, thick-billed murres, and red

and black-legged kittiwakes declined up to 90 percent. In 1999 the collapse of the salmon fishery in Bristol Bay led the State to declare the region an economic disaster.

Concurrent with biotic declines, there are significant changes in the oceanographic and atmospheric Arctic environment. Observations and historical analysis made over the last six years show that the Bering Sea ecosystem experiences large inter-annual climate variability. Observations point to the influence of hemispheric processes on Bering Sea resources, explaining, many believe the observed biotic declines. However, observed changes in biota have also been linked with a long history of natural resource exploitation spanning two centuries, but which has increased dramatically within the last few decades. There is rising evidence of increased loadings of pollutants being transported to and sequestered in Arctic oceanic, atmospheric, and terrestrial environments, and biota. Alteration of the ocean floor from industrial fishing and change in terrestrial habitats caused by development activities has also occurred during the period of biotic declines, and cannot be excluded as factors in these declines. This suite of natural change and human influences are likely altering the biocomplexity of the Bering Sea in ways not yet understood. Quantifying the relative importance of natural and human-induced variations in explaining upper trophic level ecosystem change is a key management issue for the Bering Sea.

Concern about the Bering Sea has engendered large and intense research synthesis and planning efforts; it is a region of significant research investment. These efforts share a commitment by scientists from diverse disciplines and organizations to come together to define the most important research needs and share research results. The quality of past and current research is unquestioned. Yet our understanding of changes occurring in the Bering Sea and its biocomplexity remain elusive. This prompted the Arctic Research Commission to target an integrated assessment of the Bering Sea as one of its priorities. Ecosystems in the Bering Sea region provide an opportunity to test all four of the SEARCH hypotheses as they relate to biological change. Results will provide new insight on the causes of the biotic changes occurring in the Bering Sea and provide an estimate of what the future may hold for native people and commercial enterprises dependent on the Bering Sea's riches.

Approach: The approach to implementing the marine biotic systems research effort will focus on three principal tasks:

1. Build an inter-disciplinary, integrated observation and knowledge base for the Bering Sea region
2. Synthesize available information into conceptual models that identify potential linkages among natural and human induced stressors to achieve new insights and guide future research
3. Perform integrated ecosystem-level assessments for the Bering Sea region that link ecological, cultural, economic, and health challenges to physical change in the environment, recognizing both natural phenomena and human activities that impact marine ecosystems and indigenous populations.

3.3. Human Social and Economic Systems

Background: Where researchers have studied evidence of past and contemporary cultures, it is clear that survival in the Arctic has depended upon adaptability. Changes in the Arctic have been tied historically to both local and global processes. In addition to change driven by seasonal extremes and variability, human activity within the region has caused significant environmental, economic, social, and cultural change (e.g., colonization, marine mammal hunting, fur trade, gold rush, urbanization). Arctic residents today have the capacity to foster or discourage some of the most extensive and precipitous changes in the region (e.g., large-scale oil development, logging, alteration of fire regimes, redirection of freshwater flow to the Arctic Basin).

Change has also come from human activity outside the Arctic (e.g. animal domestication, high-seas fishing; transport of ozone, greenhouse gases, and nuclear waste to the region; the hunting of birds and mammals in southern portions of their migratory route). Because humans are a catalyst of change on global and regional as well as local scales, it is essential to incorporate the human dimensions in any study of the arctic system. The human capacity to adapt to change in the Arctic will be further tested, as the polar regions are expected to sustain the early and significant changes associated with contemporary global change. It is not just the Arctic that will be affected, however. Some physical changes that originate in the Arctic could propagate to lower latitudes, changing air and sea temperatures, and affect economies. For example, major Atlantic and Pacific fisheries could depend on ocean conditions that are influenced by arctic processes affected, in turn, by changes in climate. Ten percent of U.S. oil supplies come from arctic petroleum developments that are designed to perform under current conditions. For these reasons and others, the Arctic is seen as an early warning system for emerging global changes that will ultimately affect other areas as well. The experience of arctic peoples is, thus, instructive for humans elsewhere in the world who are striving to accommodate exacerbated fluctuations and accelerating rates of change in their respective natural and social environments.

The Arctic is extremely vulnerable to climate change and its impacts. The special report on regional impacts of climate change by Working Group II of the Intergovernmental Panel on Climate Change (IPCC) noted that over the period of IPCC assessment, climate change will contribute to major physical, ecological, sociological, and economic changes already begun in the Arctic. A considerable interdisciplinary effort is needed to collect and analyze information on the implications of these environmental changes for human populations.

The environment dominates many aspects of daily life in the Arctic; environmental changes are likely to have immediate, important consequences to arctic peoples. Human activities themselves may be a cause of environmental changes in the Arctic. For example, archaeologists have found evidence of prey overkill by prehistoric hunters and fishers, followed in some instances by local population declines and site abandonments. More contemporary versions of this dynamic include boom-and-bust

cycles of Russian and Canadian fur trades, gold-rush mining, and oil-field development. In addition to consuming resources, settlements may generate contamination on scales ranging from local to regional. Such problems may alter the trophic dynamics of the arctic system, affecting the abundance and safety of terrestrial and marine food resources upon which many arctic peoples depend.

The greatest potential for arctic environmental change, however, may originate from outside the Arctic. Long-range transportation of contaminants, the global build-up of greenhouse gases, and stratospheric ozone depletion all have the potential to alter environments. Arctic ecosystems are particularly sensitive to such alteration and may see relatively early and substantial changes. The natural variability and vulnerability of arctic biophysical systems, combined with humans' close dependence on those systems, magnify the potential importance of global change for arctic residents. Accurate predictions of future impacts require the inclusion of a human component (socio-economic and health aspects) as critical elements in the arctic system.

Approach: To assess the effects of environmental change on indigenous people and other residents, a research program examining the dynamics of linkages between human populations and the biological and physical environment of the Arctic is required. That research program should incorporate an integrative, interdisciplinary approach including the following:

1. The biophysical basis for future human impacts on the functioning of the Arctic system;
2. Recent and past patterns of habitat use (including land, water, and ice) and resource use (including subsistence, land tenure, domestication, farming, fishing, and resource extraction) where human consequences of global change are expected;
3. Patterns of human response and adaptation to environmental change (including settlement decisions, shifts in resource use, migration, diversification, impacts of environmental change on human health, and economic transitions);
4. The basis for sustainability, viability, resilience, and vulnerability in future interactions between humans and their environment; and
5. Development and implementation of an educational framework that offers feedback and learning opportunities for local stakeholders, scientists, and decision-makers.

II-1: National Science Foundation

The SEARCH Science Plan (www.psc.apl.washington.edu/search/) has been used by the Interagency Arctic Research Policy Committee to develop a coordinated budget initiative. The cost has been estimated at greater than $100M per year for all agencies of which NSF requires on the order of $50M. While this number may be unrealistic in the current budget environment, there are components of SEARCH which are clearly defined and which are ready to proceed:

A. ATMOSPHERE AND OCEAN DRIVERS

The physical changes encompassed by SEARCH include, among other things, a decline in sea level atmospheric pressure, an increase in surface air temperature, cyclonic ocean circulation, and a decrease in sea ice cover. These changes are in turn driving changes in the ecosystems and living resources and thus affecting the human population. Given a change in the strength of the polar vortex, perhaps as indicated by a rise in the Arctic Oscillation index, SEARCH hypothesizes impacts in the form of changes in: 1) subarctic ecosystems, 2) social values through changes in the marine and terrestrial environments, 3) biogeochemical fluxes in the marine and terrestrial environments. Each of these impacts will be explored in various components of OPP's SEARCH effort, but all are linked to the underlying physical drivers of the system.

1) Modeling Atmospheric Change (MAC)

Changes in the Arctic Oscillation are hypothesized to be the underlying driver for arctic change. Long term measurements and observations are critical to parameterization and validation of more sophisticated atmospheric-ice-biosphere coupled models. The activities needed include:

- Land-based measurements. In situ measurements of atmospheric and surface energy budget parameters are essential. Numerous high latitude stations have closed, degrading the arctic terrestrial observing network at a crucial time. An effort is needed to place autonomous stations that record variables such as surface air temperature, pressure, radiation and moisture flux, cloudiness, type of precipitation and visibility.
- Sea-based measurements. In the marine environment there is a need to augment buoy based measurements and deploy autonomous instruments that can provide reliable aspirated measurements of the air temperature over sea ice. To understand the linkages between atmospheric variability driven by the Arctic Oscillation and its impact on the ocean and sea-ice cover, it is important to establish the coupling between the atmosphere and the ice surface that controls

the seasonal cycle of ice albedo, a key component of one of the feedback processes affecting the arctic system.

- Remote sensing will be used to collect data on atmospheric moisture transport; cloudiness, river and lake thaw cycles, and seasonal cycles of sea ice formation and disintegration.
- Modeling is a key component of this effort, and further models of the AO, its mechanism of driving the arctic system, and its relation to the rest of the global atmospheric circulation are needed.

New instrumentation is needed to support these activities. Autonomous observatories, autonomous air vehicles and sounders plus ocean moorings are needed to establish a network of stations gathering synoptic measurements of atmospheric variables that drive climate. The data will enhance regional and global models used to forecast environmental responses to changing climate conditions.

Science: $2,500,000	
Environmental Observatories, (US, Greenland, Svalbard, Russia)	$2,000,000
Logistics: $1,250,000	
Instrumentation:	
Autonomous Air Vehicles (AAV)	$1,000,000
Ocean moorings and drifters (including ULS), hydrology	$1,500,000
Atmospheric Sounders (radars, lidars)	$2,000,000

2) Arctic/Subarctic Ocean Fluxes (ASOF). [We hope to initiate in FY 2002 with development of new autonomous instruments, limited hydrologic measurements, and emplacement of current moorings in Bering Strait.]

Global oceanic and atmospheric circulation controls climate and is, in turn, strongly influenced by ice cover, ocean temperature, and fresh water input to the Arctic Ocean. Continued warming of the Arctic is expected to slow or stop the “oceanic conveyor belt” that controls Northern Hemisphere weather patterns. ASOF is an international effort to monitor the valves in the arctic ocean circulation system to determine the water, energy, and salt balance between all of the inputs, outputs, and regions of water-mass transformation in the Arctic that drive global circulation patterns. The US part of a measurement program should include time-series measurements of:

- Variability of current flow using moorings in the Bering Strait and Canadian Archipelago in conjunction with international efforts at other choke points;
- Variability of fresh-water input to the Arctic Ocean using a hydrologic network in the major river systems;
- Processes driving transformation of surface water subduction that drives deep circulation using moorings and direct or autonomous measurements;
- Interactions and feedbacks of atmospheric variables influencing

atmospheric pressure and radiation;
- Variability of ice thickness measurements using remote, autonomous instruments; and
- Variability of ice cover distribution using remote sensing methods.

New instrumentation, including autonomous vehicles, oceanographic moorings,and ice buoys, must be used to establish a network of stations gathering synoptic measurements of ocean, hydrologic, and atmospheric variables that drive climate. The data will be used to enhance regional and global models used to forecast environmental responses to changing climate conditions.

Science costs: $2,000,000
Logistics: $1,250,000
Instrument costs:

Autonomous Underwater Vehicles (AUV)	$2,000,000
Ocean moorings and drifters	$1,500,000
Acoustic tomography	$5,000,000

B. ENVIRONMENTAL RESPONSES

1) Flux of Greenhouse Gases (FOGG)

The biocomplexity of environmental controls on seasonal to decadal biogeochemical cycles in areas of frozen soils are too poorly known to assess accurately the potential impacts of continued climate warming. The processes controlling large-scale and long-term variability of greenhouse gases, energy, and pollution in the Arctic are poorly known due to the scarcity of full annual cycle measurements of relevant environmental variables. Time-series measurements that resolve the seasonal cycle are critical to differentiate between “natural” variability and the effect of long-term climate change. Key sites where spatial variability has been observed must be instrumented for time-series measurements of:

- Environmental variables controlling the annual cycle of greenhouse gas flux by soils, water, and plants;
- Estimated volume of methane release through erosion of methane-rich soils in terrestrial peat beds and near-shore methane hydrates;
- Paleoenvironmental record of peat formation and vegetation changes that provide evidence of long-term natural variability; and
- Magnitude, impacts, and processes controlling DMS release caused by dramatic recent change in productivity in the Bering Sea.

A long-term circumarctic terrestrial field program is required to separate interannual variability from long-term climate-induced changes. Remote, autonomous instruments

must be developed and deployed in a wide range of environments to assess the impact of the arctic warming on global climate. Coupled ecological and biogeochemical model development will be critical for forecasting the effects of continued climate warming on release of greenhouse gases adding to the burgeoning anthropogenic greenhouse gas load.

Science: $2,000,000
Environmental Observatories: $2,000,000
Logistics: $1,500,000
Instrumentation: Autonomous flux towers (distributed network) $500,000
Aircraft measurement systems $500,000

2) **<u>Bering Sea Ecosystem Changes Study</u> (BSECS)**

The Bering Sea is among the most productive of high latitude marine ecosystems, supporting one of the world's richest assemblages of seabirds and marine mammals and large stocks of commercially valuable fish and shellfish. Approximately one half of all US fish and shellfish landings come from the Bering Sea. The broad eastern Bering Sea shelf and shelf slope are also important because they modify the heat, salt, nutrient content and particulate carbon load of water passing from the North Pacific Ocean to the Arctic.

A combination of natural change and human influences has been altering the Bering Sea ecosystem in ways not yet understood. Quantifying the relative importance of natural and human-induced variations in explaining upper trophic level ecosystem change is a key to the long-term sustainability of exploitation of the marine ecosystem of the Bering Sea.

<u>Observed climate-related changes include:</u>
- a marked reduction in the duration and extent of winter ice-cover,
- a longer, calmer and warmer summer season, and
- a possible long term warming trend in summertime sea surface temperature.

<u>Biological changes include:</u>
- large and persistent summer blooms of coccolithophores (1997-2000);
- marked changes in the species composition of meso-zooplankton;
- a major increase in the biomass of large jellyfish over the shelf;
- major declines in the abundance of forage fishes in the southern portion of the shelf;
- a northward shift in the distribution of both adult and juvenile pollock;
- marked decreases in the number of returning salmon;
- emaciation of migrant shearwaters in 1997 and 1998, with a massive die-off in 1997;
- 40-50% decreases in piscivorous seabirds at the Pribilof Islands since 1976;
- major declines in northern fur seal populations at the Pribilofs;

- a 50 to 80% decline in populations of Steller sea lions, but strong comeback of endangered large baleen whales on the eastern Bering Sea shelf.

There are three major areas of interdisciplinary process-oriented research that need to be enhanced in order to improve our ability to understand and possibly predict the effects of climate change on the structure and productivity of the eastern Bering Sea. These are examination of:

- the influence of the timing and magnitude of spring primary production on its fate.
- the impact of climate change on the fate of summer and fall production;
- the role of spring and summertime cross-shelf flux in determining ecosystem function and trophic transfer to apex predators.

In addition to field process studies, in order to address some of the above concerns, a number of currently-maintained time-series need to be extended, and some new time series established. These would probably include moorings deployed in partnership with NOAA/PMEL to gather information on winds, sea ice, water column structure, currents, nutrients, and chlorophyll concentrations across the eastern shelf, as well as various assessments of animal populations done in collaboration with the National Marine Mammal Laboratory and the U.S. Fish and Wildlife Service.

Science: $3,000,000
Logistics: $2,000,000
Instrumentation: Ocean moorings $1,000,000

3) <u>Mass Balance of Ice (MBI)</u> Mountain glaciers and small ice caps comprise only about 4% of the area on the earth, but they are unusually sensitive indicators of climate change. A sustained increase of 1^{o} K in temperature causes a decrease in length of 15-20% for typical glaciers in northwestern North America. Small mountain glaciers could have a large effect on sea level. Over the last century, sea level has been rising and the rate is expected to increase due to CO_2 -induced climatic warming. Recent model predictions indicate a 49-cm increase in sea level by the year 2100 in which most of this increase is believed to be due to thermal expansion of the oceans and to the melting of mountain glaciers and small ice caps. Up to one-third of this increase is predicted to be from mountain glaciers alone.

The mass balance of a glacier or large ice sheet is extremely difficult to measure. The US component of a comprehensive glacier mass balance study would include:

- Defining the regional trends in glacier mass balance in Alaska and neighboring regions because they are direct indicators of climate change in arctic regions;
- Identifying the contribution of these mountain glaciers to the ongoing sea level rise.
- Comparison of the present average balances with those measured during previous studies to examine mass balance trends from in the last half of the twentieth century

as a consequence of increased climatic warming in the Arctic;
- Instrument development to refine the mass balance measurements of valley glaciers.

Science costs: $1,000,000
Logistics: $500,000
Instrumentation: Airborne lasers and imagery $1,000,000

C. HUMAN IMPACTS

The human impacts of environmental changes in the Arctic are mediated through other dynamic systems of change, resulting in complex secondary and tertiary effects. Modeling the interaction of the multiple scale decision frameworks and the variety of societal and economic constructs that define the Arctic human system, in conjunction with observed and predicted environmental changes, poses an unprecedented interdisciplinary opportunity to understand the primary, secondary, and tertiary impacts of the physical environmental processes.

1) Common Pool Arctic Resources (CPAR)

Of particular concern to both Arctic residents and non-Arctic populations is the future of fisheries. As interdisciplinary teams of social scientists, biologists, and climatologists have shown, dramatic declines of northern species (e.g., cod) have had multiple causes and feedback effects. Contemporary societal conflicts over marine mammal preservation, large-scale and small-scale fisheries, and the future of fragile coastal environments have demonstrated the need for an integrative, predictive and policy-relevant analysis, affecting common pool marine resources. The interdisciplinary SEARCH initiative on the Common Pool Arctic Resources (CPAR) will involve biologists, economists, geographers, sociologists, and political scientists in a circumarctic comparison of North Atlantic and Bering Sea fisheries in coordination with the BSECS program (item B2).

Science costs: $1,000,000
Logistics: $500,000

2) Local Environmental Observatories (LEO)

The involvement of Arctic residents themselves is essential for the overall SEARCH initiative. Not only do Arctic residents possess first-hand knowledge of environmental change, but also they have a direct stake in the effects of change on their ways of life. Social scientists have been working collaboratively with Arctic residents on documenting systems of traditional knowledge. The complex methodologies, both quantitative and qualitative, developed from these path-breaking collaborations will be used to document local observations and assist in the integration of education and environmental science

for the younger generations of Arctic residents. The development of Native-operated environmental observatories across the Arctic will involve interdisciplinary teams of science educators, anthropologists, linguists, and cognitive science experts in human-computer interactions working with Native organizations (village councils, regional associations, regional governments, hunters & trappers associations, reindeer herding associations, etc.) to set up observation systems, "*Local Environmental Observatories*," (LEO) in addition to data storage and retrieval mechanisms. Because of the complexity involved in working across cultural, political, and linguistic boundaries, this initiative should be both long-term and international, drawing up on the resources already identified and contributing to the current circumarctic study of living conditions among indigenous populations.

Science: $1,000,000
Environmental Observatories: $500,000
Logistics: $500,000

II-2: National Aeronautics and Space Administration

NASA is uniquely poised to support SEARCH through extensive space-based measurements and modeling and analysis capabilities. NASA is currently in the midst of deploying a comprehensive suite of Earth Observing System (EOS) sensors, each designed to study various components of the Earth System. Some that are best-suited for Arctic research are scheduled for launch in the late 2001 - early 2002 time frame, so their timing for SEARCH is ideal. These include Ice Cloud and land Elevation Satellite (ICESat), which is specifically designed to maximize high-latitude coverage for ice and atmospheric observations, Gravity Recovery and Climate Experiment (GRACE), and the Advanced Microwave Sounding Radiometer on the Aqua satellite. Remote sensing measurements from these and other missions, including those of our international partners, along with complementary modeling and analysis activities, will address a wide spectrum of Arctic applications.

These observations and the studies that translate them into meaningful interpretation of the relevant processes will provide unprecedented advances of our understanding of the Arctic system. More realistic incorporation of the relevant processes into global climate models will better describe the interactions between the Arctic and the rest of the global climate system, thus advancing the understanding of how changes in the Arctic affect the rest of the world and vice versa.

NASA has recognized the importance of the Arctic in the global climate system for many years and has supported a vigorous research program in terms of both satellite missions and research and analysis. We have also encouraged interagency collaboration and anticipate productive collaboration with our agency partners through SEARCH, but existing resources are limited. Present support is at a level that is appropriate for the current Earth Science Enterprise budget, and without additional funds, no increase in activity is planned. However, with additional resources, NASA can take greater advantage of its sophisticated observational and analysis capabilities to advance our understanding of important Arctic processes and their feedbacks and interactions with other parts of the global climate system.

In FY-2003, NASA's currently planned efforts that are consistent with SEARCH will be directed toward:

- Investigating the role of Arctic sea ice in thermohaline circulation through continued observations and improvements to ice/atmosphere/ocean models
- Making initial estimates of sea ice thickness using remotely sensed data
- Examining freeze/thaw processes and their relationship to Boreal/Arctic Biogeochemistry.
- Monitoring changes in Arctic glaciers and ice caps and the Greenland ice sheet, and

working toward assessing the stability of the Greenland ice sheet
- Investigation of pan-Arctic Hydrology
- Assessing changes in stratospheric ozone in the Arctic in light of recent reduction of ozone-destroying chemicals
- Improvement of surface temperature and albedo retrievals for energy balance calculations.
- Measurement of aerosol distribution in the Arctic
- Detection and analysis of Arctic cloud cover
- Investigating the changes in biomass of the boreal forests and primary productivity in marine environments

The current budget for Research and Analysis activities in the Arctic is nearly $40 million. This includes our current investment in data archive and distribution centers (the National Snow and Ice Data Center and the Alaska SAR Facility), which will be well situated to manage data sets associated with SEARCH. The funding for space-based measurements in support of these activities such as algorithm development, calibration/validation, etc.) is considerably larger, and is not included in this $40 million estimate. The SEARCH initiative is not expected to fund new satellite missions, but information acquired through SEARCH may feed into future mission plans.

If additional resources were to be acquired through SEARCH, these research and analysis activities would be pursued more vigorously, and important new investigations would be supported, as recommended in the just-released National Research Council report “Enhancing NASA’s Contribution to Polar Science”. New activities facilitated by SEARCH would include:

- More rigorous “Arctic-specific” validation of satellite data
- Improved space-based measurements of sea ice thickness for understanding its role in ocean circulation and ocean/ice/atmosphere energy exchanges
- quantification of snow cover on sea ice for understanding ocean/ice/atmosphere energy exchanges
- enhanced monitoring and analysis of processes relevant to the formation and destruction of stratospheric ozone
- determination of atmosphere/surface chemical fluxes at ice edges
- analysis of cloud/surface radiative exchanges
- investigations into Arctic precipitation retrievals from satellites and models
- comprehensive assessment of surface energy parameters (temperature, albedo, turbulent fluxes, etc.)
- observations of ocean salinity
- studies of permafrost extent and variability, sensitivity to climate change, and role in the carbon cycle
- extensive measurements of changes in Arctic glaciers and their implications for near-term sea level rise

- Further development of long-term consistent data sets

These observations and analysis would be ongoing, and would evolve over time to quantitative assessments and understanding of the relevant processes. The longer-term objective would be to predict the future changes in these characteristics in a changing environment, and assess the implications for life on Earth.

The overall costs for these additional activities, many of which would involve comprehensive field components, are still to be determined. The costs will take into consideration the variation in field activities from year to year, and the need to maintain a balance between observation, modeling, and analysis.

The NASA Policy Official for matters related to SEARCH is Dr. Ghassem Asrar, Associate Administrator, Office of Earth Science at NASA Headquarters. Specific questions on the details of NASA's plans within SEARCH should be directed to:

Dr. Waleed Abdalati
Manager, Cryospheric Sciences Program
NASA Headquarters
Code YS
300 E Street SW (202) 358 - 0746
Washington, DC 20546 wabdalat@hq.nasa.gov

NOAA's Vision for SEARCH

The Strategic Plan for the National Oceanic and Atmospheric Administration (NOAA) contains goals that guide the agency to understand and predict climate variability and change and to provide stewardship for marine living resources and coastal environments. These strategic goals are consistent with the SEARCH objectives of providing early detection of environmental change in the Arctic, understanding the causes of these changes, understanding their connection to the rest of the Earth, and of assessing impacts of these changes in the Arctic and at lower latitudes.

NOAA's Role Over a Ten-Year Horizon

NOAA will participate in SEARCH by undertaking activities that will address a series of key questions that are consistent with NOAA's goals:

- Are the changes seen in recent decades in the Arctic climate system consistent with natural variability, or are such changes at least partially attributable to human activity?
- What is the interplay among atmospheric circulation, ozone loss, and UV radiation?
- Can climate changes in the Arctic be predicted or assigned a probability?
- How will anticipated climate variability or change affect marine ecosystems?
- How will seasonal weather patterns in the Arctic and mid-latitudes be affected by changes in the Arctic?
- How will hemispheric and global climate be affected by changes in the Arctic?

NOAA will build on its traditional strengths and focus on a few types of activities in dealing with these complex questions. NOAA will rely on other SEARCH participants for complementary information. NOAA's efforts will focus on:

1. Sustained observations of the atmosphere, ocean, and marine biosphere
2. Diagnostic analysis, including cross-disciplinary analyses
3. Development and delivery of products and services, e.g. assessments; better regional forecasts for climate, marine ecosystem productivity, and atmospheric transport of substances; information for public and policy use
4. Data management and data rescue

The undertaking of sustained observations will be the central core of NOAA's activities, on which other activities will be based. NOAA plans that its observational activities will focus on four major areas:

T Physical ocean observations - focused on the flux of freshwater, heat, nutrients

T Biological ocean observations - emphasizing impacts of environmental change on ecosystems, carbon/aerosol flux rates, and on dynamics of exploited/protected species in response to climate and ocean variability

T Observations of the physical atmosphere and air/surface interactions - including radiation, surface heat budgets, ice cover, hydrology

T Observations of chemical atmospheric constituents - climate forcing, contaminant transport, air/sea and air/land fluxes of green house gases

Current NOAA Programs Relating to SEARCH

NOAA, along with its partner agencies, began preliminary implementation of SEARCH in FY2001. Interagency and international planning workshops were held for the Arctic/Sub-Arctic Ocean Fluxes program. In FY2002, NOAA will begin initial implementation of this program. In addition, NOAA and its partners are making significant effort to design atmospheric and cryospheric observation and research programs specifically to meet the goals of SEARCH. NOAA's ongoing Arctic Research focuses on analysis of existing data and on limited new fieldwork to provide the underpinnings for the activities of SEARCH in FY2003 and beyond.

NOAA's Top Priorities for Future Activities Relating to SEARCH

NOAA will join with interagency and international partners to create an ocean observing system throughout the Arctic Ocean and adjacent Seas of sufficient density and diversity of observations to provide the data needed to drive a variety of forecast models and support essential assessments and services. In particular, observations will focus on fluxes of freshwater, heat and nutrients to and from the Arctic, and on physical and chemical factors controlling biological productivity in the Bering Sea.

NOAA will join with its partners to support a circum-Arctic atmospheric observation program focused on climate, weather, and transport of contaminants. This program will include intensive long-term observation sites such as Barrow, Alaska and Alert, Canada. It will also include distributed observation networks such as the Arctic Buoy Program and short term intensive field campaigns based on use of aircraft, ice camps or other appropriate logistic support.

NOAA will support data analysis, diagnostics and assessments designed to aid in describing and understanding the time-varying state of the Arctic Ocean, adjacent seas, and atmosphere. NOAA will create data sets and archives to ensure availability of its data to the broader community.

NOAA will develop, produce and disseminate various products and services that make use of its observational remote and in situ data and analyses for the benefit of the public, and policy- and decision-makers in government and business.

NOAA's FY2003 SEARCH Activities

<u>Continuing Activities:</u>

NOAA's pilot effort on Arctic/Sub-Arctic Ocean Fluxes will continue in FY2003. The Arctic Research Initiative will focus on summary and synthesis of prior SEARCH-related work and publication of results in peer-reviewed journals.

New Activities:

A suite of new ground based remote sensing tools has recently become available that offer the advantages of high frequency measurements of many different attributes of the atmosphere and of unattended operation for large periods of time. NOAA proposes to take advantage of these advances in the early stages of its SEARCH-related activities and begin operation of these tools at Barrow, Alert, and in the Russian Far East. Payoff: New understanding of factors controlling the Arctic vortex and ozone loss and improved representation of Arctic atmospheric processes in forecast models.

NOAA and other national and international partners are supporting the International Arctic Buoy Program. This program provides the only reliable in situ data on ice drift and surface atmospheric temperature and pressure over the central Arctic basin. NOAA will enhance this fleet of buoys to improve the accuracy of the temperature measurements so that long-term temperature change can be more confidently detected. Also, NOAA will add capability to this program for direct measurement of ice thickness. This critical value is needed to determine if the volume of Arctic sea ice is changing as many models predict. Payoff: Climate-quality surface air temperature data will allow more reliable detection of climate change in the high Arctic and measurement of ice thickness will confirm or deny model predictions of Arctic ice loss over the coming decades.

NOAA will undertake an “Arctic reanalysis” to provide a robust set of data to describe the evolution of the Arctic environment over the past 40 years. Available in situ and satellite data will be assimilated into models to provide a smoothed description of the Arctic environment that will form the basis for future analyses of Arctic climate variability and change. Also, diagnostic work will begin on studies of the effect of Arctic variability on mid-latitude seasonal variations. Payoff: A solid multi-decadal baseline of environmental conditions in the Arctic will be available against which future changes can be measured with confidence.

NOAA will join with other national and international collaborators to implement a circum-Arctic program to measure and evaluate the fluxes of freshwater, heat, and nutrients to and from the Arctic Ocean. This program, Arctic/Sub-Arctic Ocean Fluxes (ASOF), is being planned by an international science steering group to ensure that the resources available from several countries are utilized in the most efficient way. NOAA’s contribution to this effort will focus on the critical deep water formation area in the Labrador Sea, one of two places in the Arctic where cold water sinks to great depths and provides a driving energy for the global thermohaline circulation. While no additional resources are requested in 2003, work initiated in 2002 will provide the first new NOAA data on this project. Payoff: NOAA and its partners will begin building the data record to assess actual changes in ocean circulation to refine model projections of a 20-50% slowdown in thermohaline circulation during this century.

FY2003 Budget Target

Current Activities:

Arctic Research Initiative (SEARCH-related portion)	$ 350,000
Arctic Ocean observations (FY02 request)	$ 450,000

New Activities:

NOAA intends to initiate its role in SEARCH in the following four areas:

Atmospheric Intensive Sites	$1,000,000
International Arctic Buoy Program	$ 600,000
Arctic Reanalysis/diagnostics	$ 400,000
Arctic/Sub-Arctic Ocean Observations	$ [450,000]

In FY2003, NOAA will allocate $2,000,000 from its climate research increase request and $450,000 of continuing funds to undertake dedicated activities under SEARCH, with an emphasis on Arctic environmental observations and data analysis.

Program Evolution and Budget Projection

NOAA will develop the activities described earlier under "NOAA's role over a ten-year horizon" and anticipates an ultimate level of effort of $26,000,000 per year will be required to implement the full program of observations, analysis and services.

Policy-level Contact Point: Dr. David L. Evans, Assistant Administrator for Research
David.Evans@noaa.gov
301-713-2458

Staff-level Contact Point: Dr. John A. Calder, Director
NOAA Arctic Research Office
John.Calder@noaa.gov
301-713-2518

Agency Vision

SEARCH is a climate change initiative whose overarching objective is to understand the sequence of rapid environmental changes that have impacted the Arctic regions over the past few decades. A corollary goal is the ability to predict these changes and to assess their likely impacts on the environment and on society. DoD mission-focused research efforts contribute to this latter goal while enhancing military sustainability, operational performance and readiness. DoD's primary interest in global climate change is focused on the effects that this change may have on Defense mission areas. DoD Science and Technology investments are focused on maximizing combat effectiveness while minimizing total platform life cycle costs. These investments in many cases nicely complement the defined objectives of SEARCH. Examples of such investment include the broad range of DoD programs that focus on prediction of the battlespace environments. In the case of the ocean, predictions include sea ice, atmospheric and acoustic conditions over daily to interannual timescales. For the terrestrial environment, predictions include land, snow and atmospheric boundary layer conditions over daily to interannual timescales. An additional concern is the prediction and mitigation of environmental and societal impacts, including population and economic shifts that are likely to impact the strategic geography and related military missions.

Agency Role over Coming Decade

The DoD role in SEARCH over the coming decade is unlikely to change significantly from the present. Essentially, DoD mission-focused research efforts will contribute to SEARCH goals while focussing on enhancing military sustainability, operational performance and readiness. The projected environmental changes will result in evolution of the program priorities for best accomplishing the DoD mission.

Current SEARCH-Related Activities

Current DoD activities that contribute to the overall agency mission are heavily focused on development and validation of predictive models of the battlespace environments. To this end, a primary ongoing activity is development of numerical modeling techniques for predicting pack ice distribution and thickness. This model development is focussed strongly on locations of the marginal ice zones and location and orientation of lead fields. A multiyear program to measure inflow of Pacific Ocean water to the Arctic through Bering Strait will continue, as this flow provides a primary input of heat and low salinity water to the Arctic and has significant consequences for the internal structure and pack ice cover of the Arctic Ocean. The long-term deployment of satellite-tracked buoys (the International Arctic Buoy Program, or IABP) used to track basin-scale pack ice motion and to measure atmospheric parameters

relevant to weather prediction, continues. Atmospheric data from these buoys are used to drive the models, and measured ice trajectories are used to validate predicted ice motions. Ocean temperature, salinity and acoustic data obtained from the central Arctic basin over the past decade are presently being analyzed with the goal of describing and better understanding the internal dynamical processes associated with the dramatic mid-depth warming that has taken place. This understanding will contribute to model development and to understanding the longer-term changes that are occurring. Analyses are underway of an intensive, year-long set of atmospheric measurements anticipated to greatly improve our climatological prediction capability at high latitudes and over an ice cover. Data on the ice conditions in the Northern Hemisphere continue to be collected and analyzed, providing a climatological atlas of ice conditions. Research is being done to improve the use of remote sensing to determine ice conditions. Finally, efforts are underway to develop autonomous underwater vehicles that can be used to measure a broad spectrum of sea ice and ocean parameters over large distances and beneath a pack ice cover.

Terrestrial models attempt to predict land conditions, including the state of the ground, rivers, lakes, and coastal environments. A particular emphasis is placed on the interactions between the terrain and the atmospheric boundary layer. Fundamental to the development of terrestrial models is a continuing basic and applied research program to investigate the physical, biological, chemical, and electromagnetic properties and processes of snow, ice, and frozen ground. These programs include the measurements of selected land, snow, ice, and atmospheric parameters, to determine and characteristic their impact on key terrestrial processes. Currently, focus areas include the degradation of permafrost, changes in the vegetative cover, snowmelt hydrology, energy exchange between the Earth's surface and lower atmosphere, and environmental restoration. An overarching programmatic objective is to optimally employ available remote sensing platforms to assess the state of the ground and monitor changes. This work includes satellite sensors as well as the development of autonomous ground-based sensors, which can provide information to more accurately interpret and augment the satellite-sensed data with information that is of a higher spatial and temporal resolution. In the area of risk assessment, work is being done to establish techniques to translate global and regional predictions of environmental change into information that can be used in the design, maintenance, and operation of infrastructure systems.

Top Priorities for Future Activities

DoD future priorities will continue to be centered upon those tenets summarized above under "Agency Vision". To the extent that oceanic, sea ice, terrestrial and atmospheric conditions change over the coming years, research programs that address these changes will evolve in such as way as to best support the DoD mission. Specific programs cannot be defined, inasmuch as we cannot predict with certainty the future environmental changes that will impact, to an extent, the DoD mission. It seems

certain, however, that future research activities will continue to measure selected environmental parameters within the context of studies that address environmental features, such as sea ice and permafrost, or processes, such as generation of oceanic deep and bottom waters, formation of the intense storms associated with so-called "polar lows", changes in the pattern of snowmelt and river runoff, and microbial fluctuations. Development and testing of general circulation models (GCMs) that will include climate change prediction among their capabilities is anticipated to continue for the foreseeable future. Field measurements will continue of parameters that are needed to validate these GCMs, and increasing development and use of autonomous vehicles is likely. Work will also continue in the area of risk assessment, to better understand the implication of future environmental change on the human dimension. Emphasis is likely to be on evolution and redirection of present activities rather than on development of new activities.

FY2003 SEARCH-Related Activities

Development of pack ice prediction models will continue, as will the multiyear suite of water transport observations in Bering Strait and the drifting buoy deployments. The Bering Strait measurements will become a contributing part of the ASOF program, previously described in Appendix I. It is anticipated that fieldwork will be initiated, as part of a separate project, to address dense water formation and transport associated with the continental shelves north of Bering Strait. These processes are highly climate-relevant inasmuch as they can be expected to vary in intensity depending on climate conditions and because they impact the maintenance of the Arctic pack ice cover. Basic and applied research on the properties and processes associated with the terrestrial environment will continue, providing a growing database to assess environmental change and its impact on infrastructure systems. Work in the area of environmental restoration will continue, including basic research to determine the effects of permafrost on contaminant transport processes and to better predict the fate and transport of contaminants as a function of changing environmental conditions. Emphasis on the application of remote sensing tools to determine the state of the ground will grow, as will, the development of risk assessment techniques. Development will continue of autonomous vehicles, both for the oceanic and terrestrial environments.

FY2003 Budget Target

Given the priority of DoD mission objectives, DoD does not anticipate fielding program elements dedicated to SEARCH. Therefore, DoD will not request a budget increase that can be specifically associated with the SEARCH effort. However, DoD does anticipate continued research in areas that will provide valuable supporting information that will be available to the SEARCH community. The DoD budget for efforts that can contribute to SEARCH is approximately $8.5 mil.

Policy level Contact:

CAPT Frank W. Garcia, Jr.
Assistant for Battlespace Environments
Office of the Deputy Under Secretary of Defense
(Science & Technology)
1777 N. Kent St. Suite 9030
Rosslyn, VA 22209
Tel: 703-588-7411
FAX: 703-588-7560
Email: frank.garcia@osd.mil

II-5: Department of Energy

There are several compelling scientific reasons to study climatic change at high latitudes such as the Arctic. Examples include:

? Ice (including snow) is the predominant form of condensed water most of the year, both in the air and on the surface. Ice and snow scatter, transmit, and absorb sunlight and radiant heat much differently than water.

? There is very little water vapor in the atmosphere, changing the impact of the atmosphere on the propagation of radiant energy, particularly radiant energy propagating upwards from the surface, and on the performance of some atmospheric remote sensing instruments.

? The major "pumps" for the global ocean currents are at high latitudes, and there is good reason to believe that those pumps will be affected by climate-related changes in the atmosphere.

? High latitude atmospheric processes over both land and sea must be characterized for incorporation into global climate models.

DOE's role in the study of climatic change in the arctic is through it's Atmospheric Radiation Measurements (ARM) Program, and specifically through research conducted at the North Slope of Alaska/ Adjacent Arctic Ocean site (NSA/AAO). As such, all anticipated Departmental participation in SEARCH must be intrinsically related or synergistic to the goals and needs of ARM/NSA/AAO.

ARM is part of DOE's effort 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.

The ARM approach is to create a number of long-term, highly instrumented climate research installations in carefully selected locations around the world known as "Cloud And Radiation Testbeds," or CART sites. The CART sites have a planned life of ten years. The rationale for their long duration is that virtually all process-focused meteorological and climatological efforts to date have been based on short-term field efforts (a few weeks to a few months). The longer time frame produces many case studies of diverse meteorological phenomena, and these statistics provide improved

accuracy and precision with which the relevant phenomena can be quantitatively described. With all of its potential economic and other societal impacts, global climate change is nevertheless the result of small radiative effects- a difference of a few watts per square meter in the energy balance out of an average energy flow of several hundred. To improve our ability to predict climate change, the physical effects that must be measured and accurately modeled are small. Doing this requires the statistics of large numbers - many cases, not just a few. On the other hand, climate-monitoring efforts have been ongoing for decades. However, these efforts focus on measuring a few important climate-related parameters, not the full range of parameters needed for the process studies necessary to improve the GCMs. The ARM Program fills the critical gap between field campaigns and monitoring.

The ARM NSA/AAO CART site has become a focal point for atmospheric and ecological research activity on the North Slope. It is of particular significance to the needs of SEARCH, especially for a better understanding of the interconnections of the atmosphere-ocean climate system. The NSA/AAO CART site is in close proximity to the National Oceanic and Atmospheric Administration's (NOAA) high-latitude climate monitoring facility near Barrow, AK (N 71 deg 19.378'; W 156 deg 36.934') and Atqasuk:, AK (N 70 deg 28.329'; W 157 deg 24.467'). This placement allows ARM to take advantage of NOAA instrumentation already in place and avoid unnecessary duplication.

Specifically, the NSA/AAO site is providing data about cloud and radiative processes at high latitudes. These data are being used to refine models and parameterizations as they relate to the Arctic. NSA/AAO currently includes a 130 ft meteorological tower, a 40 ft long instrument shelter, and three instrumentation decks, all on pilings (because of the permafrost). Laboratory and office space are also located in the former Naval Arctic Research Laboratory (NARL) complex a mile from the NOAA Barrow site. The site data system (NANUQ: polar bear) is also located at NARL. The extensive instrumentation suite is detailed at www.arm.gov.

Scientific objectives for the NSA/AAO site that are directly related to the needs of SEARCH include:

- Providing the comprehensive data sets necessary to develop and test continually improved algorithms for GCMs to describe radiative transfer and cloud processes at high latitudes;
- Specifically focusing on development of algorithms to describe;
    1. Radiative transfer within both the clear and cloudy atmosphere, especially at low temperatures;
    2. Physical and optical behavior of water (ice) and land surfaces, both bare and snow-covered, especially during transitions from winter to summer and back;
    3. Physical and optical behavior of ice and mixed phase clouds;

- Important near-term priorities include:
    1. Infrared radiative transfer under cloudless skies for very cold, dry conditions. This issue pertains to both high latitudes and high altitudes.
    2. Influence of stratus clouds on solar radiative transfer near the surface.
    3. Influence of stratus clouds on infrared radiative transfer near the surface.
    4. Solar radiative transfer to the surface under cloudless conditions.
    5. Interactions of surface albedo and related optical and physical factors with surface heating.
    6. The effect of proximity to the coast on the formation and properties of stratus clouds.
    7. Stratus cloud formation and evolution processes on GCM grid cell scales.

FY 2003 DOE SEARCH Budget Target:

- Current Activities
    - Projected ARM activities at the NSA/AAO: = $3.2M
- New Activities
    - TBD : As deemed appropriate for ARM NSA/AAO.

The general point of contact for the ARM program and it's relationship to SEARCH is: Dr. Wanda R. Ferrell, Manager, Atmospheric Radiation Measurement Program, Office of Biological and Environmental Research (OBER), Environmental Sciences Division, SC-74, U.S. Department of Energy, Washington, DC 20585, (301) 903-0043. For the NSA/AAO the point of contact is Dr. Bernard Zak, NSA/AAO, Sandia National Laboratories, PO Box 5800, Albuquerque, NM 87185 0755, (505) 845-8631. For more information about NSA/AAO, visit the web at http://www.arm.gov/docs/sites/nsa/nsaaao.html.

II-6: Department of Interior

As stewards of our nation's lands and waters, the Department of the Interior is committed to protecting our natural resources from any potential adverse impacts from climate change. The Department realizes that to meet this challenge, we need dynamic management strategies that reflect the changing environment in which we live. Therefore, DOI is engaged in scientific efforts to learn about potential impacts of climate change, energy conservation activities, and educational information for visitors.

The Department of the Interior manages much of the land and outer continental shelf in the U. S. Arctic and conducts research both in support of management decisions and to achieve a global understanding of physical and biological processes. Departmental managers also have a trust responsibility to Alaska Natives to ensure that Native lands and subsistence resources are protected. In order to make management decisions, the Department conducts research to understand where and when changes are occurring, whether changes are natural or anthropogenic, and whether changes can or should be mitigated. The Bureau of Land Management, National Park Service, Minerals Management Service, U. S. Fish and Wildlife Service, Bureau of Indian Affairs, and U. S. Geological Survey conduct environmental monitoring and interpretation to detect and understand changes.

Much of DOI's Arctic research focuses on the impacts of development, particularly related to the exploration and production of oil and gas. Changes brought about by development, however, are superimposed on changes related to long-term variation in the Arctic climate. Failure to understand the natural, long-term changes may lead to incorrect identification of causative factors. Each of the Department's bureaus has a slightly different need for information, but all Bureaus seek to understand the fundamental causes of change.

The National Park Service (NPS) preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. NPS protects, restores and maintains natural and cultural resources and associated values. They are managed within the broad ecosystem and global context. The NPS cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world. NPS collaborates with federal, state, tribal, international and local governments, private organizations, academia, and businesses to work toward common goals.

NPS incorporates research findings and new technologies to improve work practices, products, and services and shares technical information and expertise with public and private land managers. NPS is able to host research and contribute to knowledge about natural and cultural resources and their associated values. The National parks in Alaska contain strategic locations for climate research, including the Kobuk and Noatak areas, where land cover is anticipated to undergo significant modification as the climate warms. Management decisions about resources and visitors are based on adequate scholarly and scientific studies, as well as local knowledge and information. In particular, NPS is embarking on an Inventory and Monitoring Program that will help measure relatively undisturbed environments and assess changes in the Arctic.

The Bureau of Land Management (BLM) manages the western third of the north slope of Alaska, as well as other large tracts in northern Alaska. These lands and water bodies are managed for multiple uses, ranging from extraction of oil, gas, and minerals to preservation as wilderness, including wild and scenic rivers. Although the BLM does not have a specific research mandate, it actively seeks and supports research that will aid management decisions and help the BLM to achieve its mission to "sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations." In 2001, BLM created a science strategy for BLM lands in the Nation and in Alaska. The plan calls for identifying science needs and communicating those needs to science providers and the public. BLM focuses on applied science that is directly applicable to management decisions rather than on basic research. Expansions of BLM research in Alaska is likely to be oriented toward the National Petroleum Reserve, pipeline and transportation corridors, and Wild and Scenic Rivers, where BLM has specific mandates. Much of this research will be conducted under existing programs or under modest additions to existing programs.

The U. S. Fish and Wildlife Service conducts research, including inventory and monitoring, in support of their responsibilities for the conservation of migratory birds, certain marine mammals, endangered species, anadromous fish, and all biota in National Wildlife Refuges. USF&WS also participates in international circumpolar monitoring through Conservation of Arctic Flora and Fauna (CAFF) and Arctic Monitoring and Assessment Programme (AMAP). USF&WS anticipates continued strong efforts that support the goals of SEARCH.

FWS activities undertaken as part of the SEARCH program will address a series of key conservation and management issues that are consistent with FWS's mission. FWS information needs specifically address life in the Arctic; namely, how change and variability of abiotic factors influencing the Arctic effect the biotic components of terrestrial and marine Arctic ecosystems. Not only is FWS concerned about impacts on fish, wildlife and their habitats, we must also ensure that healthy populations of these species remain available for traditional human subsistence and commercial consumption. Some key questions facing FWS include:

C How does variability in sea ice extent and thickness affect the distribution, population, and productivity of our marine trust species -Pacific walrus and polar bear, and their prey?

- Do oceanic regime shifts affect seabird, anadromous fish and marine mammal populations?
- How does climate change affect diversity and productivity of Arctic plants and what are the subsequent impacts to keystone vertebrate species (herbivores and carnivores)?
- If there are changes in seasonal weather patterns, how will these affect terrestrial and

coastal marine ecosystems?

FWS will use several different methods for addressing these complex questions, and will rely on other SEARCH agencies for complimentary or supporting information. FWS efforts will focus on:

1. Sustained observations and designation of long-term ecological monitoring sites at National Wildlife Refuges throughout the Arctic.

2. New methodologies to monitor long-term trends in animal populations.

3. Cooperative monitoring studies with subsistence hunters to assess changes in abundance and population demographics of subsistence species.

4. Modeling, especially to develop best management strategies for species of special concern.

5. Development and delivery of information products and services - assessments and information for use of public, resource managers, and policy makers.

6. Data management and data rescue.

7. Collaboration- national, international (through the Arctic Council and bilateral conservation agreements with both Russia and Canada), and local (through involvement of communities in monitoring and education activities to enhance community understanding of local and large scale implications of their changing environment).

Development and implementation of refuge-based, long-term ecological observations will be the basis of FWS's activities, on which other studies will be based. FWS plans that observations will focus on three primary areas:

1. Terrestrial vegetation observations - emphasizing relations to wildlife use, forage availability, fuel development and fire frequency.

2. Offshore ice, near shore and coastal lagoon observations - focused on habitat change, nutrient flow, and availability of essential habitat and forage foods for marine mammals, shorebirds, waterfowl, and anadromous fishes.

3. Observations of abundance and productivity of species of concern- focusing on species of international importance and keystone subsistence species.

For FY2003, FWS envisions coordinating with national and international partners to advance work in measuring the influence of climate change and variability on populations of important, and often high visibility species for which the American public cares a great deal. New initiatives, however, have not yet been identified.

The Minerals Management Service also anticipates continued SEARCH-related research, primarily under the Outer Continental Shelf Program. This program supports research in the Chukchi and Bering Seas and Arctic Ocean. Much of this research

relates to the impact of energy development, but climate change is an integral part of many of the studies. MMS expects a continuation of the current level of research.

The U. S. Geological Survey has SEARCH-related activities within numerous programs that evaluate biological, geological, and water resources of Alaska. Through the National Mapping Program, USGS also provides maps and geographic information systems data that are used by many in the community of SEARCH researchers. In 2002 and 2003, USGS anticipates that the Administration will request new programs that relate to Arctic energy development and the effects of this development on the environment. The anticipated studies will doubtless have relevance to understanding the response of terrestrial ecosystems to climate-induced changes. Understanding these responses, in turn, will help understand the impacts on indigenous people brought about by changes in subsistence resources. USGS also anticipates continued research related to mountain glaciers in Alaska.

Staff Level Contact: Gordon L. Nelson
USGS, Anchorage
907-786-7100
glnelson@usgs.gov

II-7: Department of Agriculture

The mission of the US Department of Agriculture is to enhance the quality of life for the American people by supporting production of agriculture: ensuring a safe, affordable, nutritious, and accessible food supply; caring for agricultural, forest, and range lands; supporting sound development of rural communities; providing economic opportunities for farm and rural residents; expanding global markets for agricultural and forest products and services; and working to reduce hunger in America and throughout the world. All aspects of this mission may be impacted by environmental change in the Arctic. Some changes in the Arctic environment might appear at first glance to be far removed from food production and economic opportunities in rural communities, particularly in the contiguous 48 states, or from global agricultural market forces. However, projected environmental changes in the Arctic have the potential to affect agricultural and forestry related resources in Alaska, as well as weather and climate in lower latitudes, which may impact production and shipping of food and fiber products. Thus, although USDA conducts limited global change research in the Arctic, much of the Department's research is relevant to the goals of SEARCH.

Agricultural Research Service (ARS) - ARS is USDA's principal in-house research agency. ARS works to provide the scientific knowledge and technologies needed to ensure the viability of American agriculture. It conducts research to address agricultural problems of high National priority and aggressively works to transfer research results to the marketplace, where they serve the needs of a wide range of users. Several ARS projects are relevant to SEARCH goals.

Arctic Germplasm - The ARS plant germplasm management effort in Alaska is co-located with the Alaska Plant Materials Center, Alaska Department of Natural Resources, Division of Agriculture, at Palmer. The newly established National Plant Germplasm System (NPGS) collection for high latitude germplasm is administered from the ARS Western Plant Introduction Station in Pullman, WA. Activities of these units include research, preservation, evaluation, regeneration, and storage of disease-free plant germplasm adapted to high latitudes. Research includes studies of plant pathogens that might impede high-latitude germplasm management, reduce agricultural productivity in high latitudes, and interfere with revegetation of disturbed arctic sites with native or introduced germplasm. The NPGS has supported plant explorations in the Falkland and South Georgia islands, where collections included native grasses with potential utility for revegetating disturbed Alaskan landscapes.

Grasshoppers and Integrated Pest Management - Research is being conducted on integrated pest management (IPM) for grasshopper control in the Delta Junction region of Alaska. Grasshoppers are the most important insects affecting Alaskan agriculture, with estimates of potential crop loss exceeding 50 percent. Due to recent changes in plant communities caused land-use change in

the Delta agricultural area, grasshopper population explosions have become frequent and a threat to agriculture. Grasshoppers in Alaska are unique because they require 2 years to complete egg development. Research on the life history and population dynamics of the Alaskan delta population of grasshoppers is needed to determine the factors regulating population outbreaks and to be able to predict explosions. There is some belief that grasshoppers may adapt to a 1-year diapause, which has implications for environmental change. Research will provide the knowledge that should enable population prediction and allow land managers to prepare for grasshopper problems in even-numbered years. A grasshopper-specific fungus has recently appeared in some grasshopper populations. Fundamental studies will be conducted to determine its impact and potential use. Also, research on microbial pesticides in sensitive areas will enable non-chemical control and will be of benefit in other geographical areas.

Parasitic Fauna of Arctic Ruminants - Across the Arctic, ruminants (particularly caribou, muskoxen and wild sheep) are keystones for maintenance of remote communities as sources of food and as the focus of economic activity. Although much is understood about the biology of high-latitude ruminants, knowledge of their parasite fauna is poor. Biodiversity for helminth parasites in arctic ruminants is poorly known, and there are major unresolved issues for identity, taxonomy and distribution of pathogenic parasites that occur in the muscles, digestive, and pulmonary systems of Arctic ruminants. Research focuses on understanding disease processes in these animals, factors associated with parasites as potential regulators of host populations, and the biotic and abiotic parameters that may control the geographic distribution and emergence of various parasite species are directly linked to accurate documentation of faunal diversity. In rapidly changing northern environments, such critical knowledge is vital as it allows us to understand a poorly documented facet of biocomplexity in the Arctic, the role of parasitism and disease in natural systems and the potential exchange of parasites and pathogens at the interface of agricultural and wild ecosystems.

Natural Resource Conservation Service (NRCS) - NRCS provides National leadership in a partnership effort to help people conserve, improve, and sustain America's natural resources and environment. NRCS provides leadership for conservation activities on the Nation's 1.6 billion acres of private and other non_Federal land. This agency provides technical assistance and information to individuals; communities; tribal governments; Federal, State and local agencies; and others. The NRCS staff partners with staff of the local conservation district and state agencies and with volunteers. NRCS also offers financial assistance, surveys the Nation's soils, inventories natural resources conditions and use, provides water supply forecasts for Western States, and develops technical guidance for conservation planning.

Arctic Soil Survey - Scientists from the NRCS National Soil Survey Center, along with collaborators, have been investigating the effects of climate on soil temperature and moisture levels in tundra and frozen soils in high latitudes around the globe. They are especially interested in how higher temperature might be a catalyst for the release of large amounts of carbon stored in cold soils. The effect of releasing this stored carbon would be an increase in the most prevalent greenhouse gas, carbon dioxide, in the atmosphere. NRCS is also mapping and describing soils in the arctic through the Cooperative Soil Survey Program, other US agencies and international collaborators. The Soil Survey is the primary resource for soil and vegetation information for a wide variety of land managers.

Forest Service - The Forest Service is a Federal agency that manages public lands in national forests and grasslands. The Forest Service is also the largest forestry research organization in the world, and provides technical and financial assistance to State and private forestry agencies. The phrase, "Caring for the land and serving people" captures the Forest Service mission: to achieve quality land management under the sustainable multiple-use management concept to meet the diverse needs of people.

Ecosystem Research - The Forest Service cooperates with the University of Alaska, Fairbanks in supporting the Bonanza Creek LTER and conducts silviculture and plant ecological studies. Hydrologic studies and precipitation chemistry monitoring in association with the LTER are conducted at the Caribou-Poker Creek Research Watershed.

Policy-Level Contact:
Dr. Barbara C. Weber
Associate Deputy Chief for Research
USDA Forest Service
PO Box 96090
Washington, DC 20090-6090

Science Contacts:
Dr. Richard Cline
USDA Forest Service
Research and Development (WFWAR)
201 14th St. SW
P.O. Box 96090
Washington, DC 20090-6090
Phone: 202-205-1524
Fax: 202-205-1530
E-mail: rcline@fs.fed.us

Dr. Steven R. Shafer
USDA Agricultural Research Service
National Program Staff
5601 Sunnyside Ave.
Room 4-2280
Beltsville, MD 20705-5140
Phone: 301-504-4644

Fax: 301-504-6231
E-mail: srs@ars.usda.gov

II-8: Smithsonian Institution

1. The Smithsonian SEARCH mission

The SEARCH program now being developed by a consortium of government agencies explores the role of ongoing changes in Arctic environment and its impacts on human societies. The Smithsonian Institution - through the National Museum of Natural History (NMNH) - sees its primary role in developing mechanisms to present the SEARCH agenda to a broad national audience, to communicate scientific processes and major discoveries, and to advertise the program's needs and capacities to the public. The Smithsonian Institution has unique capabilities in fulfilling this mission on behalf of the entire consortium of SEARCH participants.

2. The Smithsonian SEARCH Initiative

The Smithsonian NMNH proposes a multi-tiered outreach effort to educate the public about the dynamic nature of arctic systems and their impacts on our lives. We envision at least ***seven*** levels of programming over the period of five years, beginning in FY02:

- a multi-staged web site linked to the Smithsonian's popular address;
- an Arctic feature in the Smithsonian's forthcoming *Global Links* electronic exhibition;
- 'state-of-the-field' workshop and publication;
- a SEARCH exhibit to be presented as part of NMNH's existing *Forces of Change* program;
- a smaller traveling SEARCH exhibit;
- an educational documentary film on arctic environmental change for national distribution;
- educational curricula for museum and school use

3. Smithsonian Resources and Ongoing Activities Related to the SEARCH Agenda

The NMNH's ***Arctic Studies Center*** (ASC) has been researching interrelationships between arctic climate, environmental, and cultural change for many years and has a reputation for excellent scholarship, public programs, and exhibitions. These staff resources, supported by a unique Smithsonian collection of northern artifacts and documentary materials (including archival photographs and audiovisual records) would be used to develop the scientific content and display sources for a *SEARCH*-based exhibit, outreach, and educational program, in cooperation with other *SEARCH*-participating agencies, institutions, and private donors.

The NMNH already has a ***Forces of Change*** educational program featuring the dynamics of global change and exploring the connections among the physical, biological, and cultural forces that shape our world. It includes: (1) a 6,000 square foot permanent exhibit at the NMNH on the Mall; (2) a set of smaller exhibits traveling to museums, science centers, and libraries across the country; (3) films, lectures, and symposia; (4) interactive computer products for home and school distribution; (5) curriculum materials for elementary and secondary schools; and (6) a web site. ***Forces of Change*** is already working with federal agencies (i.e. US Department of Agriculture's Sustainable Agriculture and Research Education Program) to interpret

their research and educational messages for the public. Another successful agency-partnered collaboration, *Global Links*, is currently under development with NASA's Office of Earth Sciences. Through a series of changing 'case studies,' this exhibit capitalizes on the unique capability of space-based imagery to present a global perspective of the Earth. Museum collections provide ground-truth and tangible evidence of the Earth's dynamics and history. Recent advances in understanding global climate change through ground-based observations, satellite imaging, and atmospheric and oceanographic research in the Arctic would make an excellent *Global Links* case study for a national audience.

4. Smithsonian SEARCH Action Plan

(a) WEB SITE. The quickest way to begin promoting the SEARCH agenda is to develop a web site overview of the SEARCH initiative, its principle documents, contributing agency programs, and selected research needs, efforts, and results. The site should be informative, non-technical and graphic and should be developed in phases by an interagency team as the scope and complexity of the SEARCH program develops. The popular Arctic Studies Center web site www.nmnh.si.edu/arctic offers a potential model for such a web presence, which could be developed to provide links to *SEARCH* program during Fall 2001-Winter 2002.

(b) *GLOBAL LINKS.* A SEARCH-based *Global Links* program featuring Arctic change could be developed quickly since the required display and computer infrastructure will already be in place in the Museum by late 2001. This format would present *SEARCH* science in electronic media through computer consoles in the Smithsonian's NMNH and in other museums wishing to offer the program. The program could be developed and installed by spring of 2003.

(c) STATE-OF-THE-FIELD Workshop and a follow-up report covering the current frontiers of Arctic social sciences critical to the SEARCH Agenda could be produced by the Arctic Studies Center researchers during 2002 (in about 12-15 months), and a 200-page illustrated report could be published in 2003.

(d) SEARCH EXHIBIT at the NMNH. An exhibit for the general public featuring SEARCH themes would take two years to develop and could best be presented in conjunction with the current Antarctic exhibition planned for the existing NMNH *Forces of Change* program for 2004. We envision the exhibit primarily as a dynamic combination of modern media and display elements, including large-size color photos, illustrative panels, artifacts, models, and interactive computer installations. Subject matter presentations would explore the field from five to eight specific case studies from various arctic regions. Each story would also feature a specific type of scientific research and monitoring operation being supported by governmental agencies or inter-agency groups. The exhibit is to premiere at NMNH in 2004 and will then travel to between 10 and 15 museums across the country over four years.

(e) SEARCH EDUCATIONAL DOCUMENTARY would be a natural outgrowth of the scholarly work done to prepare other components of the program. It could be produced in collaboration with NOVA, Discovery, or other network channels, to present SEARCH efforts to a broad national audience. Presentation date should be 2004.

(f) TRAVELING SEARCH. Once prepared, the main SEARCH exhibit could be re-formatted into a smaller traveling exhibit that could be made available in multiple copies to many locations in the United States and Canada. Such a show would be especially interesting for local museums and public libraries in cities and rural regions in Alaska. The preparation of the travelling exhibit could be scheduled for 2004-05.

(g) EDUCATIONAL MATERIALS could also be developed for school curricula and other formats for museum and classroom use. The Smithsonian has extensive experience in collaboration with teachers and publishers to produce educational kits and print media educational materials. This can be done in conjunction with the preparation of the main *SEARCH* exhibit in 2003-04.

5. Smithsonian Budget Contribution to *SEARCH*: FY03 and Beyond

The Smithsonian's major contribution will be in the dedication of its fundraising capabilities to a substantial portion of this budget. It is also expected that contributions to this proposal will come from various agencies through their SEARCH or regular budgets.

FY02 Activity

Pending the overall SEARCH budget outline approval by the inter-agency committee, Smithsonian activity could start in FY02 with a series of inter-agency meetings that result in a preliminary *Global Links* Arctic SEARCH exhibit concept (component a) and a preliminary educational SEARCH Web presence (component b).

Smithsonian contribution: Staff time and materials, as well as writing, design, programming, and other services, can be estimated at $40K.

FY03 Activity

Research, design development, and installation of the *Global Links* Arctic *SEARCH* exhibit (component b) and the educational SEARCH Web site (component a). Organization of State-of-the-Field workshop and publication of follow-up report (component c).

FY03 SEARCH budget for components (a) and (b): $330K

Smithsonian contribution: Staff time and materials, as well as editing, fabrication, and other services, for components (a) and (b) can be estimated at $50K. The State-of-the-Field workshop and publication (component c) is estimated at **$**250K,

to be raised from grants and contributions.

FY04 Activity

Production of a major traveling exhibit based on polar research (component d); a smaller version of the exhibit designed for small museums, libraries and community centers (component f); educational materials (component g), and a documentary film (component e).

Funds needed from various sources total $3-5M. These will be sought from the FY04 budget from SI and beyond, through inter-agency contributions under the overall SEARCH initiative, and from private sponsors. The documentary film is estimated at $400K and is expected to be funded from grants and contributions and by networks.

Beyond the Smithsonian contributions noted above, this proposal is contingent upon the receipt of sufficient funds from outside sources.

EPA Mission

EPA's Mission is to "protect human health and safeguard the natural environment-air, land, and water-upon which all life depends". This mission is met through specific goals to ensure clean air, clean water, and safe food, to prevent pollution and reduce risk locally in our communities and ecosystems and globally from cross-border environmental risks. Current rapid change is compromising EPA's ability to achieve its mission in the Arctic.

EPA Vision for SEARCH

Profound changes occurring in the Arctic-Subarctic regions led the Interagency Arctic Research Policy Committee (IARPC) to develop a FY03 interagency research initiative called Study of Environmental Arctic Change (SEARCH). EPA's unique mission among federal agencies, and scientific capabilities can, and should, play a key role in SEARCH. These include EPA's ability to: (1) analytically integrate the functioning of ecosystems with human health risks; (2) synthesize inter-disciplinary research into comprehensive, integrated risk assessments across multiple scales; (3) evaluate the interactive non-linear effects of diverse multiple stressors; and (4) connect science to public policy concerns.

EPA's Role:

SEARCH has targeted the important influence of the Arctic Oscillation on climate and other environmental change occurring in the Arctic. These influences are likely interacting with multiple forces that are both dependent and independent of atmospheric influences. EPA's key role in SEARCH will be to:

- Serve as a catalyst for integrating available multi-disciplinary data and new research generated under SEARCH and other programs to better understand the combined effects of multiple environmental forces impacting the Arctic and likely causing change.
- Clarify the linkage of human health and cultural impacts with environmental changes in the physical and biological environments, and
- Facilitate an integrated assessment within a key Arctic region, the Bering Sea, to elucidate the complex interplay of ecological, health, cultural and economic forces causing observed changes directly influenced by atmospheric processes.

Why This Emphasis Is Important:

Alaska is a national treasure, but its unique mosaic of cultures and ecosystems is highly vulnerable to irreversible change. The risk to Arctic and Subarctic ecosystems and cultures is immediate. A fuller understanding of the forces of change is needed to inform complex intra- and inter-agency management decisions. Current research and management activities are not adequate to protect human health or to safeguard this environmental and cultural treasure. EPA has a uniquely important role to play in addressing key issues related to SEARCH. Contaminants transported long distances by the atmosphere and surface waters collect in the cold Arctic environment. Distribution of these toxins, now collecting in the fat and tissue of marine birds, mammals, fish and humans will be directly impacted by changes in atmospheric processes.

- Native Alaskans, comprising half of all US Tribes (227), are at high risk from ecosystem changes and contaminants because they depend on subsistence for their health, livelihood and culture. Fear of contaminated subsistence foods is already seriously impacting Native health. Changing

environments can be linked to decreased abundance and availability of subsistence prey. Managing change requires innovative and integrative multi-disciplinary research completed in partnership with Native Alaskans that incorporates their traditional knowledge.

The Bering Sea is our nation's "fish basket" supplying 56% of all fishery products consumed by Americans. Changing climate, heavy fishing, and increasing contaminant levels in combination could decimate this highly productive ecosystem that currently supports a multi-billion dollar industry.

Proposed Products:

Under SEARCH, EPA propose an Arctic-Subarctic research initiative to integrate across human health and ecological issues and address the:

influence of global change on trends in contaminant transport, transformation, storage, and the effects of exposure on human, marine and terrestrial communities;
risk to human health and ecosystems in the Bering Sea region from the combined effects of diverse anthropogenic and natural stressors; and
close inter-dependence of ecological, health, economic and cultural viability within subsistence communities under stress from rapid environmental change.

This research supports key goals under SEARCH by addressing the complex dynamic, multi-stressor relationships characteristic of the close coupling of human and environmental systems in Alaska. Expected research outcomes include:

! Models and assessments that elucidate transport pathways and storage processes operating in the Arctic particularly for future projections of climate change, alteration of food webs, resource development and international growth;
! Synthesis of interdisciplinary data to create prospective assessments, integrated at the regional scale, to guide resource managers and research planning for the Bering Sea by addressing the resilience of ecosystems and human cultures to the combined effects of climate change, fishing pressure, land use, contaminants and other stressors;
! Creative partnerships with Alaska Tribes in the design and conduct of research to address critical questions about the value and risk of eating subsistence foods, innovative ways to ensure clean water supply and waste management, and alternative approaches for predicting and managing change in Alaska bush communities;
! Enhanced understanding of how to guide future development in light of rapid environmental change and along paths that are sustainable for ecosystems and compatible with key cultural values;
! Risk communication and management tools that would more sharply focus on the public health concerns of Alaskan communities at risk.

Relationship to Interagency Initiatives:

Complements:

! IARPC's April 2001 resolution for an "Integrated Assessment for a Sustainable Bering Sea" and EPA's role as chair of the interagency working group;
! Federal, state, and Tribal call for action on contaminants in Alaska.
! US partnerships with the international community (1) Arctic Council (2) US-Canada Boundary Waters Treaty (3) International Geosphere-Biosphere Programme, (4) UNEP Global Environmental Waters Assessment