Study of Environmental Arctic Change:

Plans for Implementation During the International Polar Year and Beyond

SEARCH
Study of Environmental Arctic Change

Report of the SEARCH Implementation Workshop
May 23–25, 2005

Cover Photo: Coastal erosion due to thawing permafrost and increased wave action threatens several arctic communities, including Shishmaref, Alaska. Coastal dynamics, driven by a combination of natural and anthropogenic factors and occurring at the interface of land, ocean, and human activities, provides a salient example of the complexity of arctic change. Examples such as this underscore the need for a multi-disciplinary approach to understanding arctic change, as exemplified by SEARCH. Photo © Native Village of Shishmaref. Courtesy of Luci Eningowuk.

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Foreword

Development of the SEARCH program began in the late 1990s, in response to observations revealing changes in arctic ocean and atmospheric conditions. An open letter was circulated to the scientific community proposing a program to track and understand these seemingly widespread and rapid changes. By April 1997, 40 scientists from 25 institutions had signed the letter, which called for an international effort initially called the "Study of Arctic Change" to investigate those changes through measurement, data analysis, and modeling. A workshop in November 1997 gathered more than 70 scientists who reported on recent changes in the Arctic, supporting the premise of a related suite of changes that were occurring arctic-wide.

As the scientific effort developed to a broad initiative involving several federal agencies, its name changed to the Study of Environmental ARctic CHange (SEARCH). At a 1999 workshop, 39 researchers began to draft the SEARCH Science Plan. Published in 2001, the Science Plan summarizes observed changes; presents the SEARCH hypotheses, objectives, and strategies; and recommends a broad interdisciplinary program aimed at understanding the interrelated arctic changes and their implications. In 1999, the Interagency Arctic Research Policy Committee (IARPC) included SEARCH as "ready for immediate attention" in the U.S. Arctic Research Plan, and a SEARCH Interagency Working Group (IWG), now the Interagency Program Management Committee (IPMC), was established. The IPMC consists of the eight federal agencies responsible for scientific research in the Arctic that have agreed to work together on implementing SEARCH:

- National Science Foundation (NSF, current IPMC chair)
- National Oceanic and Atmospheric Administration (NOAA)
- National Aeronautics and Space Administration (NASA)
- U.S. Department of Defense (DOD)
- U.S. Department of Energy (DOE)
- U.S. Department of the Interior (DOI)
- Smithsonian Institution
- U.S. Department of Agriculture (USDA)

In close cooperation with the IPMC, the SEARCH Science Steering Committee developed an implementation strategy outlining activities for coordinated implementation to address the science questions posed in the Science Plan. Published in 2003, the Implementation Strategy clearly demonstrated that SEARCH activities transcend the intellectual, infrastructural, and fiscal resources of any single nation, strongly suggesting that an international program is needed to realize SEARCH goals.

The research community and agencies responded to this need during the SEARCH Open Science Meeting, held in October 2003 in Seattle, Washington. During this meeting over 440 researchers from around the world presented and discussed progress in understanding and new observations of the rapid environmental change in the Arctic. The OSM included over 280 oral and poster presentations, attesting to the significant interest of the research community to advance our understanding of arctic change. The scientific sessions were followed by an international implementation workshop during which participants requested that the International Arctic Science Committee (IASC) and Arctic Ocean Sciences Board (AOSB) start the formation of an international effort on arctic change. Both organizations responded positively and initiated the International Study of Arctic Change (ISAC)

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program, the international umbrella under which SEARCH will be a national component.

Initial SEARCH projects have been implemented with contributions from several U.S. funding agencies, including the NSF, NOAA, and NASA. In addition, SEARCH continues to develop cooperative relationships with many of the pertinent arctic science programs sponsored by other nations and international groups. Recent developments, including the creation of ISAC and the upcoming International Polar Year 2007–2008 (IPY), offer opportunities for accelerated implementation of SEARCH. In recognition of these opportunities, the SEARCH Science Steering Committee (SSC) organized a SEARCH Implementation Workshop to update the 2003 Implementation Strategy and to align the implementation priorities with the evolving thinking in the SEARCH and ISAC communities, as well as the arctic community-at-large.

The main goal of the workshop was to provide recommendations for prioritized implementation of SEARCH during the period of the upcoming IPY 2007–2008, with a view beyond this near-term time line. Held 23–25 May 2005 at the National Conference Center in Lansdowne, Virginia, the SEARCH Implementation Workshop was attended by over 80 scientists, including members of the SEARCH SSC, the three SEARCH Panels (Observing Change Panel, Understanding Change Panel, and Responding to Change Panel), the IPMC, and scientists from the wider research community. This report summarizes the results from deliberations held before, during, and after the SEARCH Implementation Workshop. The draft of this report was circulated for broad community review and has subsequently undergone several additional iterations of review by the three SEARCH implementation panels and the more than 80 scientists that participated in the workshop.

On behalf of the SEARCH Science Steering Committee, we would like to acknowledge the contributions from the arctic research community that have improved each successive draft of this report. We would also like to thank the SEARCH Implementation Panels and the Science Steering Committee for the insight and guidance they have provided, as well as the work of the members of the workshop organizing committee who led the development of this report.

The SEARCH Science Management Office at ARCUS was essential to the successful workshop process and the production of this report. We would like to thank Wendy Warnick and Helen Wiggins for their skillful guidance of the report's content development and editorial process, and Sarah Behr, Alison York, and Birte Horn-Hanssen for graphics, layout, and editorial contributions at various stages. The entire staff of ARCUS contributed to the success of the implementation workshop through excellent planning, organization, and hard work. Finally, on behalf of the arctic research community, we thank the National Science Foundation and the Interagency Program Management Committee for the opportunity provided to the arctic research community to participate in this planning and implementation process.

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Executive Summary

The overall goal of the Study of Environmental Arctic Change (SEARCH) is to understand the nature, extent, and future development of the system-scale changes presently observed in the Arctic. These changes include, for example, increasing average annual surface air temperatures, decreasing summer sea ice extent and sea ice mass, changing ocean circulation, northward movement of tree lines and vegetation zones, thawing glacial ice masses and permafrost, and changing socioeconomic dynamics. The initial objectives of SEARCH have been documented in the SEARCH Science Plan (SEARCH, 2001) and Implementation Strategy (SEARCH, 2003) and include:

- Documenting the nature and extent of the present changes in the Arctic;
- Determining if such changes occurred in the past;
- Following the evolution of past and present changes;
- Understanding the forcing mechanisms and feedbacks that control system changes;
- Understanding the interaction between changes in the physical/chemical, biological, and human domains; and
- Illuminating system interactions between the Arctic and the lower latitudes.

Initial SEARCH projects have been implemented largely on an opportunistic basis with contributions from several U.S. funding agencies, including the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA), among others. Recent developments, including the creation of the International Study of Arctic Change (ISAC) as the international umbrella for SEARCH and the upcoming International Polar Year 2007–2008 (IPY), offer opportunities for accelerated implementation of SEARCH. In recognition of these opportunities, the SEARCH Science Steering Committee (SSC) organized a SEARCH Implementation Workshop to update the 2003 Implementation Strategy and to align the implementation priorities with the evolving thinking in the SEARCH and ISAC communities, as well as the arctic community-at-large. The main goal of the workshop was to provide recommendations for prioritized implementation of SEARCH during the period of the upcoming IPY 2007–2008, with a view beyond this near-term time line.

Held 23–25 May 2005 at the National Conference Center in Lansdowne, Virginia, the SEARCH Implementation Workshop was attended by over 80 scientists, including members of the SEARCH SSC, the three SEARCH Panels (Observing Change Panel, Understanding Change Panel, and Responding to Change Panel), the Interagency Program Management Committee (IPMC), and scientists from the wider research community.

Discussions at the workshop were facilitated by three position papers outlining implementation priorities for SEARCH Observing, Understanding, and Responding activities—the general categories of activities and related panel structure outlined in the SEARCH Implementation Strategy (2003). The three SEARCH panels—convened to work with the SEARCH SSC to plan and coordinate the broad spectrum of SEARCH activities—drafted the position papers that were distributed for community input before the workshop.

The workshop was organized to include a combination of plenary discussions and breakout sessions. Breakout sessions alternated between the panel-focused themes (Observing, Understanding, and Responding) and smaller working groups organized around several specific topical areas (e.g.,

terrestrial ecosystems, distributed marine observations, human dimensions, etc.) that were identified by the SSC as requiring specific attention.

This report summarizes the results from deliberations held before, during, and after the SEARCH Implementation Workshop. The draft of this report was posted for additional community input on the SEARCH website (http://www.arcus.org/SEARCH/index.php).

The priorities detailed in this report for the next steps of SEARCH are guided by the need to understand the complex of pan-arctic change. Workshop participants identified the following set of scientific questions that build on the hypotheses presented in the 2001 SEARCH Science Plan and lie at the heart of the SEARCH program:

1. Is the arctic system moving to a new state?
2. To what extent is the arctic system predictable (i.e., what are the potential accuracies and/or uncertainties in predictions of relevant arctic variables over different timescales)?
3. To what extent can recent and ongoing climate changes in the Arctic be attributed to anthropogenic forcing, rather than to natural modes of variability?
4. What is the direction and relative importance of system feedbacks?
5. How are terrestrial and marine ecosystems and ecosystem services (i.e., processes by which the environment produces resources that support human life) affected by environmental change and its interaction with human activities?
6. How do cultural and socioeconomic systems interact with arctic environmental change?
7. What are the most consequential links between the arctic and the earth systems?

Priority activities and major recommendations for implementation were developed to address the science questions and are summarized in tabular form (Table 1). The criteria used to prioritize activities included: importance to meeting SEARCH science objectives, fit with international activities, and readiness for implementation. Details of the scientific objectives and proposed activities are further described in Section 4 of this report (Meeting the SEARCH Objectives).

Under each science question listed in the table, SEARCH implementation activities are grouped by Observing, Understanding, and Responding activities, characterized in general terms as follows:

Observing Activities - Types of activities include: data rescue; improvement of observation density, co-location, and integration; improvement of coverage to close observation gaps; development of optimal observation and sampling strategies; observations of key processes and studies of feedbacks; acquisition of paleo-data over critical time periods; development of networks; development of data archival and distribution systems; and utilization of innovative and effective technology.

Understanding Activities - Types of activities include: model-based assimilation of available observations; improvement and expansion of model capabilities; model simulations for forecasting and for guiding observing system design; development and use of proxy records; paleo reconstructions; diagnostic analyses of synthesized observations and paleo reconstructions; and studies of interactions between arctic environmental, socioeconomic and cultural changes.

Responding Activities - Types of activities include: stakeholder-driven guidance of observations and identification of useful predictions; interpretation of modeling/analysis results in the context of local knowledge; assessment of the responsiveness and effectiveness of institutions in addressing social and economic concerns about climate change; and development of community-based networks and cooperatives to facilitate the above activities.

In addition to the grouping of activities according to the seven key science questions, the table contains two additional overarching groups of activities: Data Management Strategy and Education and Outreach.

Efficient progress within the SEARCH program requires continuous exchange of results and iterative development of the research activities outlined in the Observing, Understanding, and Responding categories. Activities within the three major categories must be closely coordinated, and activities from each simultaneously initiated.

Additionally, whereas the priorities outlined in this report generally focus on U.S. and Canadian sectors of the Arctic, predictive understanding of arctic change will require research throughout the pan-arctic system. Internationally coordinated and non-U.S. programs will lead activities in many regions of the Arctic; under the international umbrella of ISAC, SEARCH will coordinate U.S. participation in international programs and projects as appropriate.

With input from a broad representation of arctic researchers, the priorities and activities summarized in this report cut across disciplinary and geographic boundaries to guide the science community and agencies in SEARCH implementation, including that for the upcoming International Polar Year. Implementation of the SEARCH Observing, Understanding, and Responding activities will further our knowledge of the extent and future development of the system-scale change presently observed in the Arctic and the implications for the global community.

Table 1. Overview of SEARCH Priority Activities. *The first column, "Activity," lists the proposed activities organized by science question. The second column, "Priority/Phasing," rates the activity (1–3, with 1 representing highest priority) in terms of importance to SEARCH science objectives, fit with international activities, and readiness for implementation. The third column, "Additional Questions," references additional key science questions addressed by the activity, as described in Section 3 of the report. The fourth column lists the section(s) in the report that can be consulted for further information.*

Activity	Priority/ Phasing	Additional Questions	Section
1. Is the arctic system moving to a new state?			
Observing Activities (Page 9):			
(a) Construct a high-resolution (10^0–10^1 year) multiproxy spatial and temporal paleoclimate network extending back 2,000 years	1	2, 3, 5, 7	4.1.6
(b) Enhance and stabilize the distribution and continuity of the upper-air, surface climatology, and weather observation networks, including integration of cryospheric, hydrologic, and oceanic variables	1	2, 3, 4	4.1.1
(c) On land, initiate at least one intensive site for integrated time series measurements that include climate, surface energy balance, hydrology, glaciology, trace gases, permafrost/active layer, C/N/P budgets, species composition, vegetation structure, and contaminant compounds; apply new technology, numerical analyses, and remote sensing to extrapolate field measurements to high quality circumarctic gridded datasets	1	3, 4, 5, 7	4.1.4
(d) Develop an integrated observation network for identification and long-term monitoring of social and economic indicators of human subsystem changes that drive and/or feed back to arctic physical and biological system changes	1	2, 3, 4, 5, 6	4.1.5
(e) Implement automated monitoring in the ocean and for sea ice of key biological and chemical parameters coincident with physical observations (including key energy balance terms and fluxes) over annual cycles at critical representative locations	1	2, 4, 5	4.1.2
(f) Determine pan-arctic and regional mass budget parameters for sea ice and overlying snow (including key snow/ice properties) from remote sensing, surveys, and buoys, with adequate attention to both seasonal and perennial sea ice zones	1	2, 4, 5	4.1.2
(g) Determine water balance components in flagship research watersheds, key benchmark glaciers, and on the Greenland Ice Sheet through field measurements, remote sensing and modeling	1	2, 4, 7	4.1.3
(h) Determine the degree to which people across the Arctic are observing environmental change that exceeds the bounds of understood experience	2	2, 5, 6	4.1.5
Understanding Activities (Page 36):			
(i) Synthesize existing observations from the past several decades by an Integrative Data Assimilation for the Arctic System (IDAAS), producing a gridded database with maximum homogeneity for detection and attribution of arctic change	1	3, 4, 5	4.2.1
(j) Conduct observing system sensitivity experiments with models, drawing upon enhanced observations from the IPY, to design optimal observing networks and sampling strategies for monitoring the arctic system in the post-IPY period	1	5	4.2.1
(k) Synthesize human dimensions data on a pan-arctic scale, including data on resident socioeconomic changes, human perceptions (local, regional, and non-arctic) of arctic change, and on local and global-scale development and industrial activities	1	5, 6, 7	4.2.1

Responding Activities (Page 43):			
(l) Identify specific ways to improve knowledge of arctic environmental change such that people are enabled to make better-informed decisions	1	2, 3, 4, 5, 6, 7	4.3.1
(m) Determine and assess the ways in which stakeholder and residents' perceptions of an arctic state change affects responses to change	3	6	4.3.1
2. To what extent is the arctic system predictable (i.e., what are the potential accuracies and/or uncertainties in predictions of relevant arctic variables over different timescales)?			
Observing Activities (Page 9):			
(a) Repeat hydrographic sections across major frontal features of the Arctic Ocean; build on international programs and collaborations and use remote sensing to provide broader spatial coverage	1	1, 3, 4, 5, 7	4.1.2
(b) Determine spatial variation and temporal patterns of permafrost degradation, glacier ablation, and changing water resources	1	1, 4, 5, 6	4.1.3
Understanding Activities (Page 36):			
(c) Perform coordinated sets of model experiments targeted at understanding arctic change and reducing uncertainty in projections of future arctic change; include ensembles of simulations, process sensitivity studies, and downscaling to local information	2	1, 3, 4, 7	4.2.2
(d) Develop and conduct experiments with linked social-ecological models to assess the predictability of associated ecosystem changes and human adaptations	2	4, 5, 6	4.2.2
(e) Process climate datasets quickly enough to be useful for short-term forecasting, and calibrate and archive weather datasets for use in climate studies	3	6	4.2.2
Responding Activities (Page 43):			
(f) Identify predictions that will be most useful to stakeholder groups planning for and responding to change in areas such as fisheries, marine transportation and development, and renewable resource use/subsistence harvests	1	6	4.3.2
(g) Quantify and communicate the uncertainties in forecasts of changes in key variables in the arctic system	1	5, 6, 7	4.3.1
(h) Evaluate the effectiveness of different methods of expressing uncertainty in facilitating adaptive responses to change	3	6	4.3.1
3. To what extent can recent and ongoing climate changes in the Arctic be attributed to anthropogenic forcing, rather than to natural modes of variability?			
Observing Activities (Page 9):			
(a) Construct decadal-resolution multiproxy records from earlier warmer periods, particularly the early Holocene thermal maximum and Last Interglaciation	2	1, 3, 5, 7	4.1.6
(b) Coordinate atmosphere, ocean, and sea ice observation efforts to significantly enhance understanding of regional differences	2	1, 2	4.1.1, 4.1.2
(c) Improve quantification of essential paleo-proxies (sea ice, precipitation, temperature) through sampling and proxy measurements co-sited with terrestrial and marine instrumental observatories	3	1, 5	4.1.6
Understanding Activities (Page 36):			
(d) Conduct experiments and sensitivity tests with updated models to determine the portion of the recent changes in the Arctic attributable to increased greenhouse gas concentrations and aerosols relative to other large-scale drivers	1	1, 2, 4, 7	4.2.3

(e) Integrate observations of terrestrial, marine, and atmospheric variables from diverse sources into readily accessible databases suitable for integrated (across-variable) assessments of change, especially in the context of large-scale drivers such as the Arctic Oscillation, Pacific Decadal Oscillation, and greenhouse forcing	2	1, 4, 5, 6, 7	4.2.3
Responding Activities (Page 43):			
(f) Translate modeling results aimed at understanding the causes of climate change into a form useful to the many different groups of stakeholders	2	4	4.3.4
(g) Assess the effect of understanding the role of anthropogenic forcing on climate change in shaping responses to change	3	6	4.3.1
4. What is the direction and relative importance of system feedbacks?			
Observing Activities (Page 9):			
(a) Characterize permafrost and hydrological controls on vegetation change and quantify the resultant impact of ecosystem change on freshwater fluxes and biogeochemistry	2	2, 5, 6	4.1.3, 4.1.4
Understanding Activities (Page 36):			
(b) Improve and expand capabilities of models used for arctic simulations by enhancing formulations of key arctic processes (surface energy budget, clouds, vegetative effects, ocean/ice transports, and land and water use changes)	2	2, 3	4.2.4
Responding Activities (Page 43):			
(c) Assess the interaction of stakeholder responses to change with the direction and relative importance of system feedbacks	3	6	4.3.1
5. How are terrestrial and marine ecosystems and ecosystem services (i.e., processes by which the environment produces resources that support human life) affected by environmental change and its interaction with human activities?			
Observing Activities (Page 9):			
(a) Determine abundance and distribution of marine animals and pelagic/benthic communities, including measurements of key biophysical ocean and sea ice variables	2	6	4.1.2
(b) Work with stakeholders and resource managers to organize local ecological monitoring networks to collect and share data on regional ecological changes, including near-real time observations relevant to ecosystems and ecosystem services	2	1, 2, 6	4.1.5
(c) Integrate hydrology and glacier measurements with ecosystem dynamics	3	1, 2, 4, 6	4.1.3, 4.1.4
Understanding Activities (Page 36):			
(d) Synthesize information and modeling on ecosystem components and their interactions, assessment of freshwater flux, and marine ecosystem modeling, including the contribution of resource harvests and other human activities	2	6	4.2.5
(e) Develop an understanding of how to scale process and mechanistic knowledge in space and time, initially through focused studies on key variables and interactions (e.g., surface energy balance, trace gases, land vegetation cover); requires multi-scale observations, pan-arctic comparisons, modeling, and remote sensing	2	1, 2, 4, 6, 7	4.1.5

Responding Activities (Page 43):			
(f) Assess how human responses interact with changes in ecosystems and ecosystem services	3	6	4.3.1
6. How do cultural and socioeconomic systems interact with arctic environmental change?			
Observing Activities (Page 9):			
(a) Establish data outlets for near-real time observations relevant to stakeholder groups	1	1, 2, 4, 5, 7	4.1.5, 4.3.3
(b) Develop a pan-arctic database of key human dimensions indicators of population, employment, and subsistence	1	5	4.1.5
(c) Develop a coastal ocean-ice-atmosphere observation network providing data relevant to stakeholders (e.g., subsistence hunt safety, navigational hazards, storm surges, threats to coastal infrastructure, etc.)	2	5, 7	4.2.6
(d) Determine abundance and distribution of key commercial and subsistence species and integrate into database coupled with relevant environmental data	2	5	4.3.2
(e) Compile coastal dynamics and long-term tide and storm surge data	3	2, 5	4.1.2
Understanding Activities (Page 36):			
(f) Develop socioeconomic models incorporating ecosystem services; conduct qualitative and quantitative research on resilience of social-ecological systems	1	5	4.2.6
Responding Activities (Page 43):			
(g) Establish or identify community/industry networks and cooperatives, focusing on a variety of activities, including data gathering, identifying relevant predictions of change, and interpreting results in context of local and scientific knowledge	1	1, 2, 4, 5, 7	4.3.4
(h) Characterize the ongoing and potential effects on infrastructure resulting from permafrost degradation	2	5	4.1.3
(i) Assess the responsiveness and effectiveness of local, regional, and national institutions in addressing societal concerns about climate change in the context of other forces for change	3	5	4.3.2
7. What are the most consequential links between the arctic and the earth systems?			
Observing Activities (Page 9):			
(a) Enhance observations of heat, salt, and volume fluxes through straits connecting the Arctic with the north Pacific and Atlantic Oceans	2	1, 2, 3, 4, 5	4.1.2
(b) Monitor perceptions of temperate zone residents on arctic climate change and its consequences	2	6	4.1.5
(c) Integrate glacier and ice sheet mass balance measurements with observations of climate dynamics	2	1, 2, 4	4.1.3
Understanding Activities (Page 36):			
(d) Conduct controlled model experiments to understand global-arctic linkages focused on key physical linkages, effects of arctic warming on global sea level, and effects of hydrological changes on the North Atlantic	2	4	4.2.7
Responding Activities (Page 43):			
(e) Identify long-term effects of reduction in sea ice and sea level changes on arctic shipping, resource development and harvests, global markets, and international security	3	5	4.3.1

8. Data Management Strategy (Page 47)			
(a) Form a SEARCH Data Management Advisory Group:	1	All	5.3
Develop SEARCH Data Policy	1	All	5.3
Develop comprehensive SEARCH Data Management Plan	1	All	5.3
Develop SEARCH Data Inventory	1	All	5.3
Establish data management requirements for SEARCH investigators	1	All	5.3
Create a central SEARCH Data and Information Coordination Service	1	All	5.3
(b) Rescue and incorporate relevant historical data	2	All	5.3
9. Education and Outreach (Page 53)			
(a) Develop education and outreach sections and activities on SEARCH website, including K–12 and educational content, press links, and community-relevant content	1	All	6.4
(b) Develop comprehensive guide with information on ways in which individual SEARCH researchers and projects can participate in education and outreach efforts	1	All	6.4
(c) Implement a SEARCH-focused multi-agency Research Experience for Teachers program	2	All	6.4
(d) Initiate SEARCH-focused, student-centered informal science education programs integrated with community monitoring network activities, field research programs, and use of SEARCH datasets	2	All	6.4