International Study of Arctic Change – International Project Office, Phase 1
A proposal under the auspices of international cooperative scientific programs.

Program Description

Background

During the past two decades a set of interrelated changes has been detected and documented in the Arctic system (Lachenbruch and Marshall 1986, Morrison et al. 2001, Overpeck et al., 1997, Peterson et al. 2002, Serreze et al. 2000,). These changes, of greater and lesser magnitudes, occurred across all domains (biological, chemical, ecological, human and physical) and have already had an impact on life in the Arctic (Briffa et al., 1998, Hamilton et al., 2003, Rühland et al. 2003). The International Study of Arctic Change (ISAC) is a long-term, international, cross-disciplinary pan-arctic program that is concerned with "arctic change due to enhanced greenhouse warming and other anthropogenic 'interferences' and the effects of natural variability on the Arctic system" (http://www.iasc.se/isac.htm). ISAC will be designed to further document and track arctic changes, understand their causes, nature and connectivities, and to study socioeconomic, political, and cultural responses and feedbacks in order to minimize and mitigate negative effects. Climate models suggest future changes will be substantial (Holland et al., 2006, Serreze and Francis 2006) and have profound impact globally through climatic teleconnections (McLean et al. 2001, Osvaldo et al. 2000). As a long-term program, ISAC will provide the underpinning for an expanded knowledge base and lead to improved assessments of the impacts of environmental change (including climate change, abrupt or otherwise) in the Arctic.

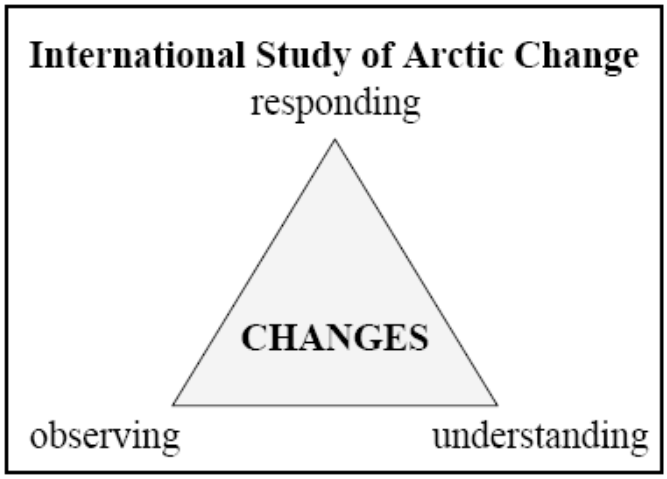

Figure 1. (from ISAC Science Overview Document, January 2005).

The three cornerstones of ISAC are observing past, present and future arctic changes, understanding their causes and effects, and examining responses on regional to global scales.

ISAC was initiated in 2003 under the umbrella of the International Arctic Science Committee (IASC) (http://www.iasc.se/about_iasc.htm) and the Arctic Ocean Sciences Board (AOSB) (http://www.aosb.org/). An Interim Science Planning Group (ISPG) was formed in 2004. In January 2005 the ISPG published the ISAC Science Overview Document in which the scientific rationale for the program, the theoretical framework, overarching goals, and some guiding objectives and hypotheses are outlined. Future assessments of the Arctic system (cf. ACIA 2004, AHDR 2004, IPCC 2007) will rely on

an increased and integrated knowledge of all components, including the human domain. This requires understanding the behavior of the Arctic system – past, present and future, understanding the role of the Arctic as a component of the global system, and including society as an integral part (NSF 03-574 www.nsf.gov/pubs/2004/nsf04587/nsf04587.pdf).

Scientists, policy makers and stakeholders need to be prepared for the possibility that the Arctic system is moving toward or has already moved to a new state (Overpeck et al. 2005) and focus attention on changes that affect the arctic regions and for which social and ecological systems may be unprepared for or incapable of adapting to either locally, regionally or globally (Alley et al. 2003). ISAC provides a venue for guiding and developing system-level research on a pan-arctic scale that is relevant to assessment and policy needs, even as these evolve and change in the context of a changing Arctic and a changing Earth system.

Reaching ISAC Objectives

ISAC is based on the Study of Environmental Arctic Change (SEARCH) initiative, a U.S.-based interagency effort to effort to "understand the nature, extent, and future development of the system-scale change presently seen in the Arctic (www.arcus.org/SEARCH/index.php). ISAC is guided by four principle hypotheses:

(1) The complex of interconnected changes is driven by global change but also influenced by regional Arctic feedbacks.

(2) Amplification of climate signals in high latitudes, especially in the Arctic, lead to amplitudes of observed changes that are larger than those observed in lower latitudes.

(3) The observed changes are expected to continue and possibly accelerate in the future.

(4) The observed changes in the Arctic have large impacts on ecosystems and societies (ISAC SOD 2005:8)

These hypotheses are testable through a sustained program of fundamental research on the Arctic as a system (Figure 2). Such a program is designed to address specific questions on the atmosphere, the cryosphere, the oceans, ecosystems, the human dimension and the couplings among these different components, and to further consider the predictability of system variability and change (ISAC SOD 2005). Importantly ISAC will build upon the impact assessments and outcomes presented in the AHDR (2004) and

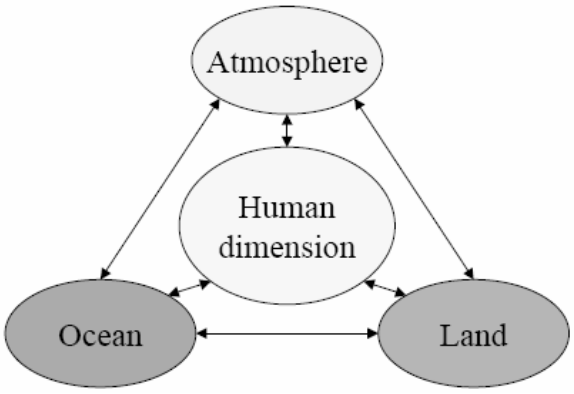

Figure 2. Processes and their relations within the Earth System compartments as well as their interactions with the human dimension (ISAC SOD 2005:8).

the ACIA (2005) and others described by AMAP (2002a, b 2003) to improve future assessments. This requires close collaboration with other national and international arctic research programs and organizations including but not limited to those supported by the European Science Foundation, the U.S. National Science Foundation, and those linked to the International Arctic Science Committee (http://www.iasc.se/about_iasc.htm), the Arctic Ocean Sciences Board (http://www.aosb.org/), the International Arctic Social Sciences Association (http://www.iassa.gl/about.htm), and the Arctic Council (http://www.arctic-council.org/), including the Indigenous Peoples Secretariat (http://www.arcticpeoples.org/).

Observing Change

Critical to achieving ISAC objectives is the documentation of arctic change at multiple spatial and temporal scales, and across system components. This requires a multi-national commitment to long-term, multi-disciplinary, system-scale observation platforms to record past, present, and future changes. Such platforms must be sustained in order to establish meaningful time series, and be flexible enough to respond to changing scientific requirements, new insights and shifting theoretical, methodological and political frameworks. They must be designed to accommodate multiple and varied datasets and build upon efforts initiated prior to and in the context of the International Polar Year (NRC:2004) including the European Integrative Project "Developing Arctic Modeling and Observing Capabilities for Long-Term Environmental Studies" (DAMOCLES, http://www.damocles-eu.org/index.shtml), and the U.S. National Science Foundation's Arctic Observing Network (AON) http://www.nsf.gov/news/news_summ.jsp?cntn_id=109687 . The rational for the latter is laid out in the Polar Research Board of the National Academies of Science report, *A U.S. Vision for the International Polar Year (IPY)* (PRB 2004) and in the SEARCH initiative's *Plans for Implementation During the International Polar Year* (SEARCH SSC 2005).

Understanding Change

Understanding change is a key component in predicting future conditions. There is a need to understand the Arctic system as both a "functioning unit, and as a set of interacting parts" (Ritchey 1991). This requires incorporating observations and analysis into synthesis and modeling activities for the Arctic and for the Earth systems, and critically, must include integration of multiple and diverse datasets drawn from the human component (Huntington et al. 2007). Moving beyond coordinated observation efforts to coordinated synthesis (cf. Fisher et al. 2000, McGuire et al. 2002) and a new generation of coordinated modeling activities (Allen and Ingram 2002, Rastetter et al. 2003) is necessary. Syntheses must acknowledge and account for the myriad different processes that operate within the arctic system, whether these are atmospheric, hydrological, or social processes. Without synthesis, observational information is unsuitable for planning effective response to change (cf. Fisher et al. 2000). Among others, modeling can include community integrated systems models (those that synthesis knowledge from disparate domains), that can provide a unified and coherent framework for thinking about causal relationships and possible system responses (Nicolson et al. 2002). Fundamentally,

observation, analysis, synthesis and modeling are all required if we are to understand the complex interactions among the different components of the Arctic system and teleconnections to the Earth system.

Responding to Change

Integrated analysis of multiple time series of atmospheric and climate indices, sea ice, oceanographic and terrestrial physical variables, and biotic data strongly suggest that the Arctic is responding to change over the past thirty years in a "temporally and geographically coherent manner" (Overland et al 2004: 318). Assessing, responding to, and mitigating arctic change impacts on ecosystems and societies effectively rests on the development of multi-disciplinary observational, synthesis, and modeling activities that are relevant to societal needs, to the science plans and priorities established by the ISAC Scientific Steering Group (SSG), and to those established by other groups and acknowledged by the ISAC SSG. For example the impacts of global warming on the northern oceans and seas include increased sea-level and sea-surface temperature, decreased sea-ice cover, and changes in salinity, alkalinity, wave climate and ocean circulation with feedbacks occurring through changes in ocean mixing, deep water production and coastal upwelling (McClean et al. 2001). Combined with direct anthropogenic influences from fisheries, pollution, and increased coastal and offshore development (SEARCH 2005) these changes will have certain impact on marine ecosystem sustainability, biodiversity and productivity. Such impacts are already reflected in the collapse of the Atlantic Cod (*Gadus morhua*) fisheries in the north Atlantic (Hamilton et al. 2003) and in the declining productivity of the cod fisheries of the North Sea through the 1990s (O'Brien et al., 2000). Coping with and responding to these kind of system-wide changes requires "improved understanding of the full range of possible changes, through sustained observation, collection and study of [a range of] data, improved statistical techniques, simulations with a hierarchy of models, and impacts assessments [that are] of value to policy-makers seeking to promulgate effective responses" (Alley et al. 2003).

Program Implementation and the ISAC International Project Office

There are varying structural and cultural characteristics among disciplines, institutions, and countries that influence the way in which research and research partnerships develop and which, in turn, influence the capacity for scientific observation, synthesis and modeling and all that flows from that (Hollingsworth and Hollingsworth 2000). Important to the successful implementation and success of ISAC as an integrated international system science effort is a strategic vision for integrating diverse areas and constituents and providing focused research on arctic change. The development of a science plan that guides decision-making about the kinds of observations, (whether these be existing, those embedded in ongoing programs, or new observations made during the International Polar Year), that are best suited for addressing ISAC scientific hypotheses is the first step. New efforts to accumulate observational data must be relevant to addressing system level questions about arctic change. Long-range science planning should develop within a framework structured to provide an expanded knowledge base about all components of

the arctic system with the goal of leading to improved assessments of the impacts of environmental change. Of crucial importance is the integration of human dimensions data in its' various forms, including that related to adaptation (Tol et al. 1998); this requires careful thinking about the means by which such data can facilitate system studies, and system-level understanding.

Also necessary is the ability to secure funding to implement the research and related activities detailed in the science plan. Both the creation of a science plan and an implementation strategy requires the recruitment of personnel from diverse disciplines and subspecialties with research experience in different paradigms in order to foster interdisciplinarity and integration of activities across specialties, research problems, and institutional and national frameworks. Cutting across disciplinary, institutional and national boundaries is critical for the expansion and deepening of knowledge about the Arctic system and its connections to the wider Earth system. For example, the documentation of changes in freshwater input to the Arctic Ocean (Peterson et al., 2002) required synthesis of drainage discharge data at a pan-arctic scale that involved collaboration among multiple scientists across four institutions in three nations. While such collaborations are not necessarily new, the scale of these is increasing as scientific questions become more sophisticated and system-oriented and the societal relevance of scientific inquiry more pressing. Intense and frequent interactions among scientists with diverse perspectives within a setting that enables a creative and productive environment all the while framed by rigorous standards of review and scholarship is a key characteristic of research organizations with repeated successes and discoveries of merit (cf. Hollingsworth and Hollingsworth 2000:222). ISAC will foster a community of arctic researchers and research programs that are united in efforts to remove obstacles to observation, synthesis, modeling, and understanding. The ISAC International Project Office should provide such opportunities for interaction at the pan-arctic level where possible through various initiatives beginning with the development of the community-created science and implementations plans in partnership with the SSG and the ISAC Council.

A successful international research program requires creating scientific and stakeholder partnerships at the outset. There must be collaboration throughout and issues of data management, integration, access and availability are critical. Flexibility in decision-making and significant community input to the development of research plans and priorities and to relevant funding and government agencies are necessary. Success is contingent upon collaborators investing in problem definition from the start (Nicolson et al. 2000) and recognition that the processes of observation, modeling and synthesis are subordinate to the common tasks (Peilke and Conont 2003). For ISAC these include advancing system-scale knowledge, establishing relevance to societal needs, and enabling assessment and response. In a similar vein, the scientific community must become increasingly engaged in conveying information to the public, to policy makers, and to resource managers and other stakeholders. This communication is necessary so that it is clear what changes may mitigated, what changes may not and how best to accomplish mitigation when it is an option (see for example recommended actions for coping with and mitigating changing biodiversity in Chapin et al., 2000). Linkages to similar

programs considering Arctic and Global change issues are necessary and the development of best practices for communicating models results, and predictions (and error ranges) in aid of decision making is critical (Pielke and Conant 2003).

The ISAC International Project Office (IPO) - Specific Tasks and Related Outcomes

Within the overall ISAC structure, the IPO will provide staff support for the SSG and future panels or working groups, and carry out the activities identified by the SSG. Top priorities include:

1) Develop the ISAC management structure.

Since the completion of the Science Overview Document a Scientific Steering Committee (Figure 3) has been appointed, and an ISAC Council formed. The council consists of eight working groups/panels reflecting eight different components of the Arctic system. There is one member of the SSG in each group/panel and the remaining members must be appointed over the coming months.

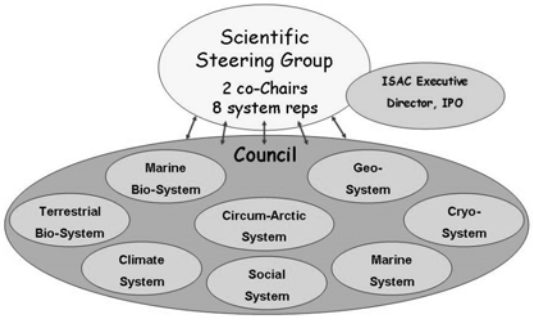

Figure 3. ISAC management structure.

2) In collaboration with the SSG facilitate the development of the ISAC Science Plan.

The development and completion the ISAC Science plan should proceed even as ISAC council seats are being filled. The science plan should present in detail the central science questions of ISAC and the major approaches and priorities for addressing these within the context of hypothesis driven research. This will require face to face meetings of the SSG, solicitation of scientific and stakeholder input through both workshop and working group activities, preparing of a draft document, community comment and review and publication. This process is envisioned as similar to that by which the SEARCH Science Plan (Morrison et al. 2001), the SEARCH Implementation Plan (SEARCH SSC 2003) and the Report of the SEARCH Implementation Workshop (SEARCH 2005) were developed.

3) Build and maintain a web accessible catalogue of ISAC projects that will be used to guide the program and co-ordinate ISAC projects.

4) With the guidance of the SSG, keep other arctic programs informed of scientific progress made within the ISAC program and provide a source of information to interested parties and stakeholders.

As the ISAC IPO develops it will increasingly function as a venue for providing information to scientists, arctic residents, and the broader public. Information should be circulated to the scientific community through the both conventional and electronic media and should include the maintenance of a web site, regular publication of a

newsletter and the development of a listserve and forum for discussion. The ISAC Project Office will work with ISAC researchers to co-ordinate and communicate results to policy makers and the public via communications to the popular media a variety of formats including print (cf. Sturm et al., 2003), press briefings (see for example http://www.arcus.org/ARCUS/media/downloads/AGU_Arctic_Press_Briefing_2006_121106.pdf), and government briefings (http://www.arcus.org/federal/2007_briefing.html) as appropriate.

5) Provide a forum for discussion of establishing scientific standards or norms; sharing of such information between organizations and best practices for communication of scientific information, model outputs, predictions and assessments to a wide range of stakeholders.

6) Foster cooperation and communication among ongoing initiatives and activities.

7) Identify important data gaps in research and monitoring and foster synthesis.

This can begin immediately through participation in the upcoming IPY workshop on sustaining arctic observing networks (http://www.arcticobserving.org/index.php?option=com_frontpage&Itemid=1) and through established collaboration with major national efforts including in the United States, AON and SEARCH, and in Europe DAMOCLES. Over the longer term the IPO should work with the SSG and the ISAC Council to plan an international "Arctic Change" meeting that facilitates reporting on results generated from IPY research and that is designed to advance international arctic system science beyond the IPY through discussion of key science questions, observational data, and future planning.

8) Ensure appropriate data dissemination.

9) Engage in capacity building.

The ISAC IPO will work with the SSG, the Council and others to identify promising young scholars. Among other activities the ISAC IPO can assist in partnering new investigators with established researchers, and facilitate international scientific and scholarly exchange through connection to the University of the Arctic and a wide range of national and international educational and research institutes affiliated with ISAC through PI participation in the national programs that fall under the ISAC umbrella. The IPO should work with IASC, AOSB and others to develop a dedicated pool of funds for young scientist support and create an international internship opportunity in the ISAC IPO. Entrainment is the surest way to establish a legacy for a collaborative, multi and interdisciplinary systems approach to the study of arctic change.

Phase I – October 1 2007-May 31, 2008

In this proposal funds are sought for Phase I activities of IPO. This will include promoting ISAC and informing relevant groups of its objectives, activities and plans

through participation in a series of meetings over the next twelve months that include but are not limited to:

1) SEARCH Science Steering Committee Meeting, Washington DC. 5-7 November 2007
2) Sustaining Arctic Observing Networks Workshop, Stockholm, 12-14 November, 2007
3) DAMOCLES Meeting, 26-28 November, Paris
4) Arctic Science Summit Week, Syktyvkar, March 2008

During this period the IPO will also work to develop and complete the ISAC Science Plan in collaboration with the ISAC SSC and with input from the broad community of international arctic scientists, policy makers and stakeholders. Other major objectives are to fill the roster of ISAC Council members and to transition the IPO to Stockholm (Phase II) and the Swedish Polar Research Secretariat (SPRS). Prior to the transition the IPO will work with the SPRS and the IASC Secretariat and the Arctic Research Consortium of the United States (ARCUS) to develop the ISAC website and begin to build the catalog of ISAC projects and related links.

Intellectual Merit and Broader Impacts

Understanding the interactions of human and environmental domains in the context of arctic change and the effects of these interactions on the globe are a major focus of ISAC. Understanding how the Arctic evolves as a system and how the Arctic relates to the Earth system is critical. ISAC is motivated by changes that are already affecting the lives of arctic residents and arctic ecosystems. These changes are projected to continue and to have global impacts through climatic teleconnections. The recent documentation of maximum summer sea ice retreat (http://arctic.atmos.uiuc.edu/cryosphere/) in the northern hemisphere with all attendant implications for the socio/economic/and ecological components of the Arctic system underscores the need to better understand, assess, and predict component and system changes, and to build the partnerships needed to do so sooner rather than later. ISAC and the ISAC IPO provide a forum for international scientific planning, and for co-ordination of scientific effort within a common hypothesis driven, research oriented framework. Arctic change is not limited to the boundaries of any one state, research institution, or research program and a strong international, interdisciplinary collaboration is a powerful means by which ensure that pan-arctic societally-relevant scientific progress can be made. Building upon existing efforts like SEARCH and DAMOCLES, the ISAC IPO will facilitate regular and coordinated interaction among scientists and stakeholders to advance knowledge. Through capacity building the IPO will ensure that the ISAC initiative includes an ever-broadening constituency and the IPO will work with the SSG to ensure that arctic change research efforts are connected to one another, that they inform efforts to respond to a changing world, and that ISAC science continues to evolve. The implementation of ISAC should ultimately change the way the international arctic research community frames its scientific questions and implements research programs. It should enable arctic system science to sit at the forefront of global change research through innovative collaborations among natural and social scientists and others.

Results from Prior NSF Support

Murray, M.S., A.C. Hirons, and L.K. Duffy, 2005-2007 Agents of Change: Subsistence Choices, Mercury Bioaccumulation, and Ecosystem Change: A Long-term View from the Gulf of Alaska. NSF Award 0525278

This two-year exploratory program of collaborative interdisciplinary research on societal adaptation and agents of change from the mid-Holocene to the present in the Gulf of Alaska (GOA) was focused on the links among subsistence choices and health in the face of mercury bioaccumulation and changes in the marine food web. Using archaeological datasets as a starting point, the primary goals were to: 1) assess whether human subsistence choices change in concert with or are independent of local marine ecosystem changes; and 2) evaluate the impact of changes in subsistence on past human health as indicated by the levels of mercury recovered from archaeological faunal samples. We considered the connections between marine vertebrate exploitation, food web length, ocean production, and mercury bioaccumulation using multiple methods drawn from archaeology, biochemistry and oceanography.

Preliminary results of zooarchaeological analysis indicate that people exploited a broad spectrum of marine resources, including a variety of fish and marine mammals and that the species exploited varied over time and seasonally. Biogeochemical analysis indicated a long-term decline in total mercury values in Pacific Cod (*Gadus macrocephalus*), Sea Otter (*Enhydra lutris*) and Harbor Seal (*Phoca vitulina*) while the ratios of stable carbons and nitrogen from the bone collagen of these same species indicates changes in local marine productivity. In combination the data suggest that variability and trends in human diet and marine ecosystem structure and function through the mid and late Holocene were closely linked to the large shift in sea-level and flooding of Beringia associated with deglaciation at the end of the Pleistocene. Through an expanded program of research, we are now testing the possibility that we may have derived new proxy measures for local-scale flooding and shelf-expansions that are indicative of other documented climate change episodes in the regions and considering how these fed into decision making, especially as regards settlement and subsistence and local sea-ice conditions.

Publications:

In preparation Prehistoric Pacific Cod Fisheries Shed Light on Climate and Ecosystem Changes through the Holocene. **M.S. Murray**, H. McKinney, L.K,. Duffy, A.C. Hirons, P. McRoy, and J. M Schaafe. For submission as a letter to *Nature*, August 2007.

In press* Zooarchaeology and Arctic Marine Mammal Biogeography, Conservation, and Management *Ecological Applications*, **M.S. Murray** (Accepted February 07)

2006* An Exploratory Study of Total Mercury Levels in Archaeological Caribou Fur from Northwest Alaska, *Chemosphere* 65: 1909-1914. S. C.Gerlach, L. K. Duffy**, M.S. Murray**, P. M. Bowers & R.Adam

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