

Arctic Research

A GLOBAL RESPONSIBILITY

**An Overview of the Second International
Conference on Arctic Research Planning**

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*ICARP II - 2nd International Conference
on Arctic Research Planning*

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ICARP II

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The Working Lead Authors were selected by the Conference Steering Group, based on nominations submitted by organizations and individuals responding to an invitation advertised widely. The Working Group members, then, were appointed by the Conference Steering Group in cooperation with the Working Group Chairs and Liaisons, based on nominations from the Conference Sponsors and their networks. The working groups are intra-disciplinary, have a good geographical distribution and focus on young scientists. The Working Group reports, after an open review and the November ICARP II Conference, were finalized as the chapters contained herein.

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The Context for Long-Range Arctic Research Planning

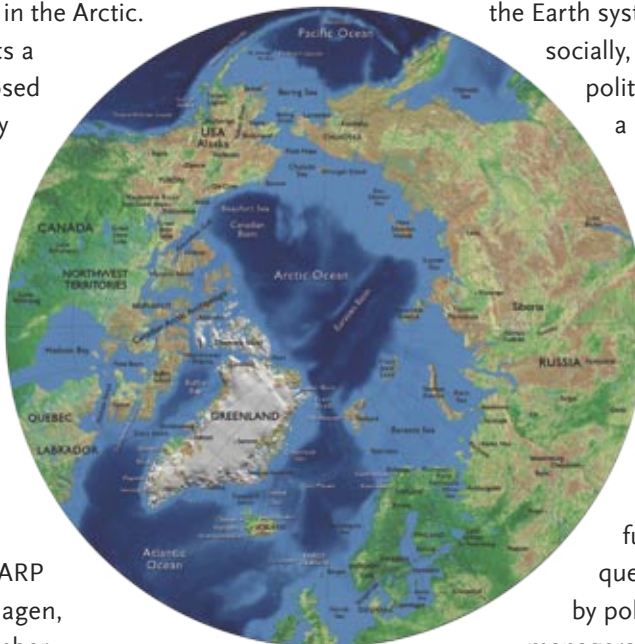
The Arctic is of special importance to the world and it is changing rapidly. It is thus essential that decision makers have the latest and best data and information available regarding ongoing and projected changes in the Arctic.

This document presents a brief overview of proposed science plans set out by leading researchers to improve our understanding of this vital region, how it is changing, and how those changes will affect the Arctic and the world.

The Second International Conference on Arctic Research Planning (ICARP II) was held in Copenhagen, Denmark, 10-12 November 2005. It brought together scientists, policy makers, research managers, Indigenous Peoples, and others interested in and concerned about the future of Arctic research. Conference participants concluded that since the first International Conference on Arctic Research Planning held in 1995 in New Hampshire, there has been a paradigm shift to a holistic and multidimensional perspective in the Arctic. This holistic perspective integrally includes the

human dimension, Indigenous insights, and a more complete integration of Arctic processes in the Earth system.

The Arctic is a unique and important part of the Earth system, environmentally, socially, economically and politically. It surrounds a northern polar sea strategically positioned between two continents and bridging eastern and western societies. How the Arctic system works, how it is changing, and what it will be like in the future, are important questions being asked by policy makers, land use managers, and people who reside in the Arctic. ICARP II put voice to these questions and developed plans to address them. The science plans on the enclosed CD, which are highlighted in this brief overview, represent the culmination of the ICARP II process.





context

Setting a Context for a Set of Overarching Research Themes

There has been a dramatic increase in recent years in both ongoing research and assessments, and in the planning for future research directions that are focused on the Arctic. These efforts follow a long tradition of research fostered by over 20 national governments, the coming International Polar Year (IPY), the International Arctic Sciences Committee (IASC), the Arctic Ocean Sciences Board (AOSB), the Working Groups of the Arctic Council, the World Climate Research Programme (WCRP), the International Arctic Social Sciences Association (IASSA), and many others.

The scientific community, its governments, and non-governmental organizations have a long tradition of assessing the state of scientific understanding and, based on that knowledge assesses the needs for future research. Driven both by the science itself and by the needs of society, thoughtful projections of future research needs are prepared by organizations such as IASC¹, the Arctic Council² through its various Working Groups, national scientific funding agencies and other scientific organizations (e.g., Arctic Research Commission, European Polar Board, Polar Research Board of the U.S. National Academy of Sciences, AOSB, WCRP), and special planning entities such as the Russian sponsored Conference on Arctic Research Planning in 1988, International Conference on Arctic Research Planning (ICARP I), the recommendations for future research derived from the Arctic Climate Impact Assessment (ACIA), and the

comprehensive processes associated with the IPY. These perspectives have been synthesized by the three-year planning process of the International Conference on Arctic Research Planning II (ICARP II).

Research findings of substantial relevance to society in recent years have stimulated a remarkable range of ideas, framings, and conceptual perspectives on future research for the Arctic. While the scientific community has articulated such in scientific journal articles, newsletters, and media outlets, these perspectives have been synthesized primarily through four international efforts to detailed long range planning for research across a range of challenges that the Arctic poses; e.g., changes in the landscape and environs, evolving societal conditions, globalization and other factors affecting the region and its peoples. Inherent in all of these planning efforts is both a major engagement of the Indigenous communities' perspective and the marked increase in the integration and focused efforts from the social sciences community. In virtually all these efforts, the perspectives of the Indigenous community and others living in the Arctic are increasingly evident. These four approaches to framing research initiatives follow:

The ACIA, as an ongoing process throughout its implementation, identified research derived during the analysis and conduct of the assessment. The ACIA recommendations for future research were derived from the eighteen

¹ IASC is a non-governmental organization whose aim is to encourage and facilitate cooperation in all aspects of Arctic research, in all countries engaged in Arctic research and in all areas of the Arctic. IASC was established in 1990 and today comprises 18 member countries whose Academies of Science appoint members to the Council that determines the programs and activities of IASC.

² The Arctic Council is an intergovernmental forum for addressing many of the common concerns and challenges faced by the Arctic states; Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, the Russian Federation, Sweden and the United States. The Council is a unique forum for co-operation between national governments and indigenous peoples. Six international organizations representing many Arctic Indigenous communities have the status of Permanent Participants of the Arctic Council and are involved in the work of the Council in full consultation with governments. The Indigenous populations in the Arctic are represented by: Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Conference, the Russian Association of Indigenous Peoples of the North, and the Saami Council.

scientific chapters and the ten Key Findings of the assessment as the highest priority areas for future research.

Three major topics were suggested as future priorities by the ACIA authors: (1) studies focused on sub-regional impacts, (2) evaluating socioeconomic impacts, and (3) assessing the vulnerabilities of human and natural systems.

Sub-regional Impacts: There is a need to balance coarse-grain and fine-grain climate impact research and assessments. The initial ACIA assessment largely focused on Arctic-wide impacts, which will provide context for future fine-grain studies. While additional circum-Arctic studies will continue to provide answers to a broad set of highly relevant issues facing society, additional fine-grain studies are also needed for more precise questions, often of direct relevance and utility for local residents.

Socioeconomic Impacts: Important economic sectors in the Arctic include oil and gas production, mining, transportation, fisheries, forestry, tourism and the consequences for local communities and residents. Most of these sectors will experience direct and indirect impacts due to climate change, but in most cases, only qualitative information on economic impacts is presently available.

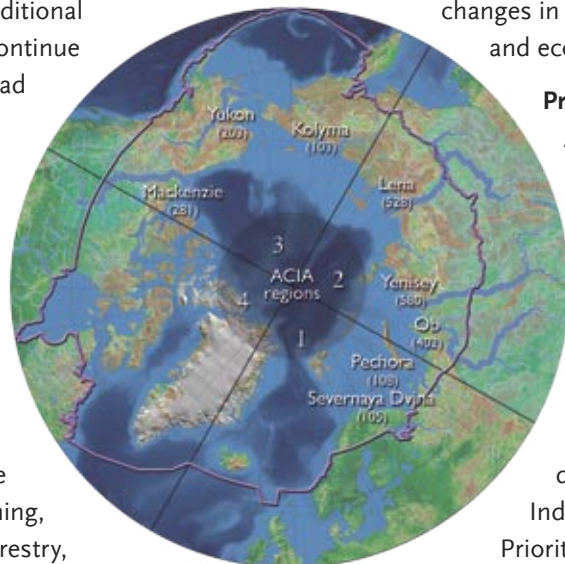
Assessing Vulnerabilities: Vulnerability is the degree to which a system is susceptible to adverse effects of multiple interacting stresses. Assessing the vulnerabilities of human institutions and natural systems involves knowledge not just of the consequences of stresses and their interactions, but also of the capacity of the systems to adapt.

To address these three high-priority research and future assessment agendas, the ACIA team recommended that there is a suite of necessary improvements in long-term monitoring, process studies, climate modeling, and analyses of impacts on society.

Long-Term Monitoring: Long-term time series of climate and climate-related parameters are available from only a few locations in the Arctic. Continuation of long-term records is crucial, along with upgrading and expanding the observing systems that monitor snow and ice features, runoff from major rivers, ocean parameters, and changes in vegetation, biodiversity, and ecosystem processes.

Process Studies: Many Arctic processes that control conditions within the Arctic require further study, both through scientific investigations and through more detailed and systematic documentation of Indigenous knowledge. Priorities include collection and interpretation of data related to climate and the physical environment, and studies of the rates and ranges of change for plants, animals, and ecosystem function. Such studies often involve linking climate models with models of ecosystem processes and other elements of the Arctic system.

Modeling: Improvements in modeling Arctic climate and its impacts are needed, including in the representation of ocean mixing and linkages to sea ice, permafrost-soil-vegetation interactions, important feedback processes, melting rates of glaciers and ice sheets and extreme events.





context

Model refinement and validation is required for models within scientific disciplines, and there is also a need to link and integrate models across disciplines. Developing, verifying, and applying very high-resolution coupled regional models to improve projections of regional changes in climate would also help provide more useful information to local decision-makers.

Analysis of Impacts on Society: Improving projections of the consequences of climate change on society will depend in part on the advances in climate modeling mentioned above as well as on generating improved scenarios of population and economic development in the Arctic, developing and applying impact scenarios, forging improved links between scientific and Indigenous knowledge, and more thoroughly identifying and evaluating potential measures to mitigate and adapt to climate change.

The international social sciences community has long sought to articulate research needs that both underpin fundamental social science questions and issues within an Arctic context and integrate the socioeconomic perspectives

with those of the natural sciences to better understand the total human/natural environmental system. The International Arctic Social Sciences Association, among others, has sought to articulate these perspectives. One of the most important and comprehensive efforts to both describe current states of knowledge and to identify important long range planning perspectives has been the Arctic Human Development Report (AHDR), conducted under Arctic Council. The AHDR suggests the following major areas of research for the coming decade or so:

Cultures and Societies: A better understanding of the effects of cumulative changes on cultural and social well-being in the Arctic is needed.

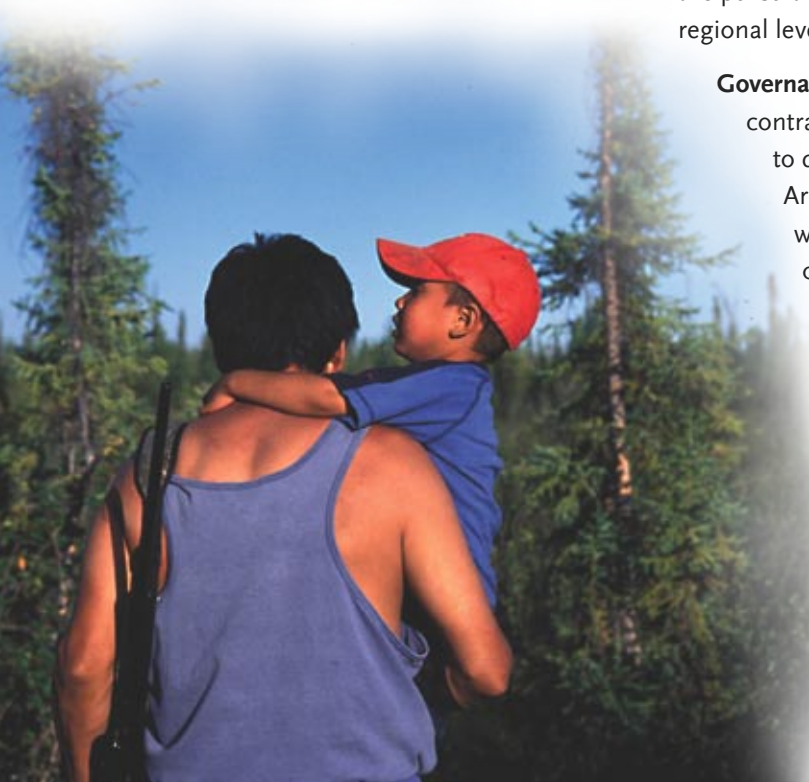
Demography: Collect more and better information on the Arctic's residents using common data protocols.

Settlers: Learn more about the experiences of recent settlers in the Arctic and their interactions with the region's Indigenous peoples.

Industry: Improve our understanding of the roles that modern industrial activities play in the pursuit of sustainable development at the regional level.

Governance: Do more to compare and contrast new institutions in the Arctic and to distil lessons relevant not only to the Arctic itself but also to other areas of the world characterized by an abundance of natural resources and sparse and culturally diverse populations.

The International Polar Year 2007-2008 has structured its research programs, organized from the perspective of our current understanding of the most pressing research nested within five major research themes. The five IPY themes are:



Status: To determine the present environmental status of the polar regions by quantifying their spatial and temporal variability.

Change: To quantify, and understand, past and present environmental and human change in the polar regions in order to improve predictions.

Global Linkages: To advance our understanding of polar - global interactions by studying teleconnections on all scales.

New Frontiers: To investigate the unknowns at the frontiers of science in the polar regions.

Vantage Point: To use the unique vantage point of the polar regions to develop and enhance observatories studying the Earth's inner core, the Earth's magnetic field, geospace, the Sun and beyond.

Human Dimensions: To investigate the cultural, historical, and social processes that shape the resilience and sustainability of circumpolar human societies, and to identify their unique contributions to global cultural diversity and citizenship.

These planning efforts have provided a rich set of insights concerning the needs for and the directions for research in the coming years, particularly of over the next 10 -15 years. Each has an appropriate framing of their research directions. Building upon these and other sources, the ICARP II planning teams structured their analysis of research needs around twelve major areas of potential research needs, each of which has been lead by an international team of scientists and other experts (e.g., elders and other leaders in the Indigenous communities of the North). This process led to the analyses and recommendations, the results of which are documented in eleven Science Plans and a Background Paper on Contaminants. The following eleven Science Plans and the Background Paper, the full versions of which are



contained in the CD attached at the end of this document:

Sustainability Issues: Sustainable Development and Arctic Economies

Indigenous Residents: Indigenous Peoples and Change in the Arctic

Coastal: Arctic Coastal Processes

Central Basin: Deep Central Basin of the Arctic Ocean

Margins: Arctic Ocean Margins and Gateways

Shelf Seas: Arctic Shelf Seas

Cryo/Hydrosphere: Terrestrial Cryospheric and Hydrologic Processes and Systems

Biosphere: Terrestrial and Freshwater Biosphere and Biodiversity

Modeling: Modeling and Predicting Arctic Weather, Climate and Ecosystems

Vulnerabilities: Resilience, Vulnerability and Rapid Change

Science & Public Issues: Science in the Public Interest

Contaminants: Presence and Fate of Heavy Metals, Persistent Organic Pollutants (POPs), Petroleum Hydrocarbons and Radionuclides.



Overarching Research Themes derived from the ICARP II Process

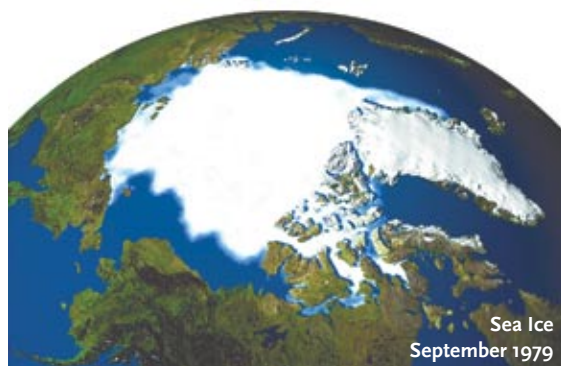
From a very broad perspective, the following overarching research themes reflect the research priorities that have emerged from the ICARP II planning process as well as the long-range planning processes of other major Arctic research programmes and meetings. The material discussed in these themes is drawn from the ICARP II Science Plans, which can be found on the CD in the back of this document, in addition to the ICARP II Conference and other consultations.

Understanding Climate Change and other Major Environmental Regimes of the Arctic Region

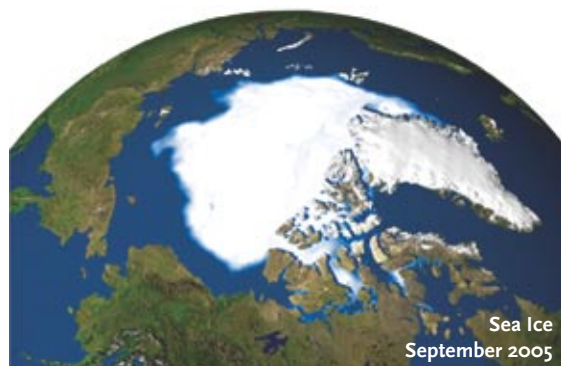
Recent scientific assessments document the urgency to deepen our understanding of past, present and potential future conditions of the climate system and other environmental regimes as they relate to the Arctic. Central to this is the need to extend our understanding of those fundamental processes that govern the state of these systems in the Arctic, e.g., the origins and transport of mass and energy in the hydrological system, including the melting (or accretion where appropriate) of sea ice, glaciers, ice sheets, and snow. Similarly, scientific assessments have documented a critical need to better understand the role of and the capabilities to project the transport and pathways of contaminants that are currently having a substantial impact within the Arctic, such as persistent organic pollutants (POPs), heavy metal contaminants (e.g., mercury, cadmium) organochlorine compounds, radionuclides, and in some cases hydrocarbons.

Current capabilities are inadequate to model,

with sufficient resolution and detail, the behavior and states of some important aspects of regional climate and, particularly, those important characteristics of the socio-natural system that govern the overall environmental state of the Arctic. For example, the ice flow dynamics and melt rates of the Greenland Ice Sheet, the potential release of methane from bogs and permafrost of the high north, and the connections of processes in the Arctic that interact with global scale processes (e.g., atmospheric circulation, heat and mass transport via thermohaline circulation or contaminant transport and pathways) all present major research challenges for the decade ahead. Modeling capabilities at regional scales will require finer resolution and detail and further extension of downscaling capabilities. In summary, extending the capabilities and skill to project future conditions across the Arctic and connections to global systems is a high priority research objective for the decade ahead.



Sea Ice
September 1979



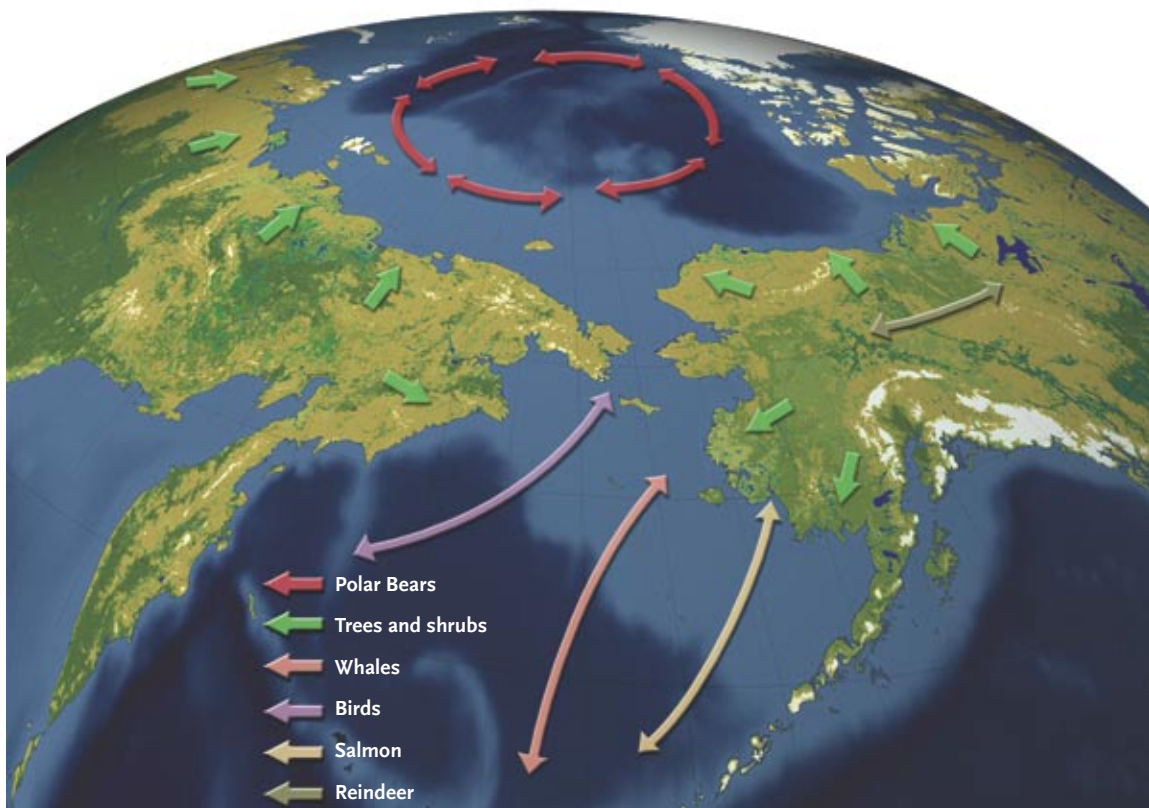
Sea Ice
September 2005

Source: NASA and NSIDC

Understanding the Processes that Govern Changes in Arctic Terrestrial and Marine Ecological Systems

Ecosystem structure, function, and composition are already changing in the Arctic and are projected to change still further in response to changes in the Arctic's climate and other environmental factors. Improved understanding of the multi-scale processes that control Arctic terrestrial and marine ecosystems is an essential research objective for the decade ahead as these processes are the foundation upon which to project future shifts, transformations, and behavior of species impacted by the changing environment. Climate change and related processes are already substantially altering the ecological niches for Arctic flora and fauna,

impacting species such as polar bears, seals, walrus, reindeer/caribou, birds, fish, insects, trees, and plants. While climate change plays a substantial role in Arctic ecological systems, companion processes (e.g., natural resource uses and management strategies, pollution and legal regimes) must be integrated into the research agenda. In summary, it is essential to (2) extend and deepen our understanding of Arctic terrestrial and marine ecosystems and the services they provide, and (2) expand our capacity and skill to model essential terrestrial and marine ecological processes in order to assess potential future impacts of societal importance.





themes

Understanding the Character and Cumulative Changes in Societal-Environment Interactions

Research that seeks to understand the processes (e.g., societal and natural system resiliencies, human behavior, and cultural values) that govern human well being and environmental health is of central importance as these systems are increasingly subjected to globalization, and rapid social and environmental change. Understanding the coupled nature of societal-environment interactions is a fundamental challenge for the research community and is a critical issue to be addressed in the coming decades. For example, while Arctic peoples and cultures have proven resilient enough to sustain themselves when faced with conditions considered by outsiders as extreme and unforgiving, these communities now report that current environmental and climatic conditions are far outside their experience. Some

indicate that they have no feasible alternatives to sustain their cultures or the capacity to cope. Arctic communities and residents are closely linked to their environments and to the economic, political, and social development of their regions. Therefore, research that addresses these complex linkages across Arctic economies and issues of human well being is now needed and should, among other things, address three factors: (1) sustaining economic stability in a context of environmental stewardship, (2) maintaining a sense of individual and cultural identity, and (3) enabling the capacity, for many communities, to live close to and rely on natural resources. While it is expected that a wide range of individuals, communities, and organizations will be partners in the research, a special effort will be made to

engage Indigenous communities and their perspectives in the research. Further, and most importantly, there should be a marked increase in the engagement of the social sciences community. Research of this nature is seen as a foundation to ensure a sustainable future for Arctic communities and natural ecological systems.





Adapting to and Coping with Change in the Arctic

In the case of climate change, policy responses to the challenge of a changing climate will involve two aspects, (1) mitigation strategies and policies designed to reduce atmospheric concentrations of greenhouse gases, and (2) adaptation actions by society that seek adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects. The decision/policy communities frequently note that research that addresses directly adaptation and/or coping strategies is woefully inadequate to address the challenges of climate change. Research to more fully develop effective adaptation strategies, methodologies, and best practices will require an integrative approach that includes costs and benefits of policy changes. Several research approaches are needed: (1) *active anticipatory* approaches, where policy actions help reduce climate change damage before the effects are felt, (2) *reactive* approaches would seek to reduce effects once they are more clearly delineated and the costs of

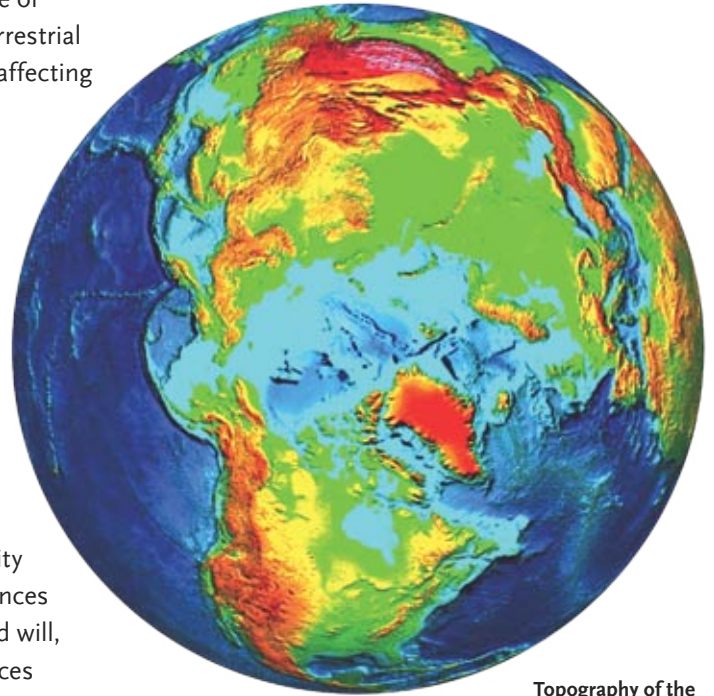
inaction are better known, and (3) analyses that seek to elucidate the consequences of *passive approaches* where policy developers refrain from implementing any policy measures. Taken together, these broad areas of research have the potential to provide society with serious near-term strategies/knowledge to cope with a changing climate, while mitigation strategies seek to reduce long-term warming. Research that addresses these challenges will need to do so in a culture of science and scholarly inquiry that seeks to maintain intellectual integrity and objectivity while at the same time increasingly enabling the public at large and decision makers to move knowledge and understanding to action for the common good. In short, the ICARP II analyses indicate that research on the issues of adaptation and coping strategies should address fundamental issues (e.g., option and risk analyses or “what if” studies) that elucidate effective methodologies and best practices rather than advocating specific adaptation strategies.



themes

Understand the Tectonic History of the Central Arctic Ocean Basin

All evidence indicates that a complex suite of interrelated atmospheric, oceanic, and terrestrial changes are now underway in the Arctic, affecting every part of the polar environment. An expanded research program is essential to more fully understand and clarify the interconnections among tectonic processes, climatic variability and change, climate history, and the importance of these processes within the deep Arctic oceanic basin. It is now clear that there are accelerating changes across the high latitudes, as revealed by changing sea ice thickness and extent, water temperatures, vegetation distribution, and storm intensity which have already had serious consequences for human habitation at high latitudes and will, as they progress, have further consequences for humans worldwide. The entire system – from terrestrial land masses to the deep basins – is projected to be severely stressed by changing ice and water conditions, varying primary production and food availability to faunal communities, an increase in contaminants, and



Topography of the Arctic basin and surrounding area



Cleveland Volcano
Aleutian Islands

possibly increased ultraviolet radiation. As these environmental changes reach rates and levels that are beyond the adaptive capacity of some Arctic populations and ecosystems, research will be essential to understand habitat niches, the changing nature of ecosystem structures and functions, and community stability and well being. Understanding the role played by the central Arctic Oceanic basin in the total system is especially critical. The tectonic origins, geophysical processes, and paleoclimatic/ environmental record of this basin, and its connections to the global scale are not adequately understood aspects of the geophysical world. Extending and deepening that understanding is an essential next step toward a comprehensive understanding of the Arctic.

Documenting, Understanding the Importance of Knowledge, and Communicating the Science that Addresses the Challenges of Change

The Arctic has become the bellwether of the Earth's changing climate and other environmental changes, such as marked increases in the transport, fate and impacts of contaminants that already impact human and animal life in the Arctic. To support and facilitate the research agenda posed by the ICARP II process, three essential elements need to be substantially expanded: **(1) Documenting:** There is a need to document the key scientific data that accurately depict the state of change through an expanded program to monitor, archive, and make widely accessible essential data and information concerning the Arctic to support decision-making/policy development and the research program. It is recommended that this initiative goes well beyond classical data and information perspectives to include the power of the web and future web-based systems. **(2) Understanding Foundations upon which Knowledge supports Policy:** Research that seeks to more fully understand the ways scientific knowledge becomes ingrained and forms a basis for both understanding and taking action is posited as an essential area of scientific inquiry. A more robust understanding of the relationship between science and the public interest requires fundamental research that expands insights of the ways social, historical, cultural, economic, and political forces drive the foundations for public understanding and decision-making/policy development. The research suggested in this Overarching Theme is founded on a hypothesis that decisions and policy choices are likely to be assisted by deepening our understanding of three interrelated processes: (a) ways of more adequately defining the challenges being addressed, (b) deepening our insight concerning the strategies and methodologies that

characterize the conduct of research, and (c) the assumptions and approaches for communicating the results of the effort to take knowledge to policy formation and decision-making. Research that brings the expertise of psychology, marketing, economics, communication, risk perception, and an understanding of what motivates behavioral change together with natural sciences which can explain the dynamics and implications of climate change is an example of a research approach to this issue. **(3) Communicating the Science that Addresses the Challenges of Change:** Effective approaches to communicating insights gained through scientific research to the public and the policy community have been lacking and will need substantial development in the coming years. Strategies and institutional arrangements are needed that effectively communicate the results of research that elucidates the causes, impacts, and implications of climate and environmental change, the risks associated with those changes, and the array of possible solutions and their implications in ways that are scientifically credible and meaningfully understood by decision makers and the lay public. This should be done through the use of the best science, a sound understanding of the associated risks, and the best of modern communications technologies and approaches. During the ICARP II process, virtually every community involved or consulted indicated the need for a serious and comprehensive communication and outreach program, including the education of our youth.



plans

Introductions to the Research Plans

AN INTRODUCTION TO

Science Plan 1: Arctic Economies and Sustainable Development³

Arctic peoples are the ones most dependent on the future of the Arctic. Cultures found only in the Arctic simply have no feasible alternatives to their homelands if they are to sustain their cultures. They are thus the most vulnerable members of society with respect to events in the Arctic. In addition, Arctic communities and residents are closely linked to their environments and to the economic, political, and social development of their regions. This ICARP II science plan begins with a focal question stressing the complex problem of linking Arctic economies to sustainable development.

How do Arctic economies work and how are they linked to issues related to sustainable development in general and to human development of Arctic residents and communities in particular?

Seven key scientific questions are explored under three main headings:

- The meaning of sustainable development
- Influences on sustainable development
- What sustainable development implies

The questions are intended to challenge common assumptions about the Arctic and about sustainable development, leading to a better understanding of if and how the concept of sustainable development can be usefully applied in the Arctic. Next, there is a reflection on the significance of research into sustainable development, from the point of view of an Indigenous Arctic resident. Finally, the science plan describes how this vision for a research program links to other work underway in the Arctic, what outcomes it is likely to produce, how it can be carried out, and in general terms what funding is required.

Among many important areas of discussion in the plan, one involves a look at the social and economic costs implied in sustainable development. Achieving sustainable development requires making changes from current practices. Such changes involve costs and benefits, just as current practices do. Assessing the short- and long-term costs and benefits of sustainable development will help identify the primary obstacles to and opportunities from such changes.



³The full text of each of the science plans is contained in the enclosed CD in a pdf file.



AN INTRODUCTION TO

Science Plan 2:

Indigenous Peoples and Change in the Arctic: Adaptation, Adjustment and Empowerment

Arctic peoples and cultures have proven resilient enough to make a living out of natural conditions considered by outsiders as extreme and unforgiving. Peoples of the Arctic consider three issues as key factors in their lives: controlling one's own destiny, maintaining cultural identity, and living close to nature. Such issues should be reflected in future research priorities.

Four key thematic issues are addressed in this science plan, with key scientific questions pertaining to:

- a. culture and education;
- b. well-being and health;
- c. economic models; and
- d. Indigenous peoples and the state.

Within each of these themes gaps in knowledge are identified that are considered necessary to address in future research planning. Despite the significant amount of research into problems of Arctic societies and communities, this science plan gives first priority to issues that reflect gaps in knowledge, but also takes as a point of departure for further discussion areas where Arctic knowledge can make a difference, not just in the Arctic, but globally.

Among its many important discussions, this plan looks at the forces, both positive and negative, impacting Indigenous peoples. For example, in recent years the assertion of Indigenous rights, along with the concomitant growth of Indigenous political power leading, variously, to the negotiation of land claims, increased autonomy and self-representation, and even home rule have afforded significant opportunities for cultural recovery and



revitalization. These political gains have been largely founded on the conviction that culture, and by extension heritage, language, values, and life-skills, are central to the continuity of individual and collective Indigenous identities. In response there has been a blossoming of initiatives in the cultural, linguistic, and educational fields.

Along with these initiatives, however, new threats and challenges to Indigenous social and cultural sustainability have appeared, most fuelling (or fuelled by) an increasingly rapid pace of externally forced, disruptive social change. These include, but are not limited to, globalization, urbanization, exposure to mass media, population growth, demographic shifts, a widening "generation gap", and withdrawal from traditional hunting, fishing or herding economies.



plans

AN INTRODUCTION TO Science Plan 3: Arctic Coastal Processes

The Arctic coastal zone is the interface through which land-ocean exchanges in the Arctic are mediated and is the site of concentrated human settlement and activity that occurs at high latitudes. This Science Plan is formulated from three major systemic perspectives – physical, ecological, and social – in order to devise measures for identifying changing impacts on the *physical environment* (including possible linkages to the global system, e.g., greenhouse gas emission, organic carbon), *biodiversity* (including coastal ecosystems, distinctive areas, habitats, and species), and *human activities* at different scales (such as local and regional resource use to globalization in terms of renewable resources, quality of the environment, industrial activities and contaminants).

A linked series of physical, ecological, and social science questions and assessment measures are outlined, promoting a multi-scale,

interdisciplinary approach to Arctic coastal zone research and management. Examples of key science questions include:

- How does high-frequency environmental forcing (atmospheric and oceanographic, sea-level change) control Arctic coastal dynamics?
- Where are the unique and special biodiversity features, why are they there, and what are the underlying ecological processes for these features?
- How do humans interact with coastal environments in the Arctic, and how do these human-environment relationships change between different coastal regions in the north?

To provide answers to the key science questions for the Arctic coastal zone, the Science Plan advocates a series of sites for high-resolution studies within a broader eco- and socio-regional frame of reference. Critical elements

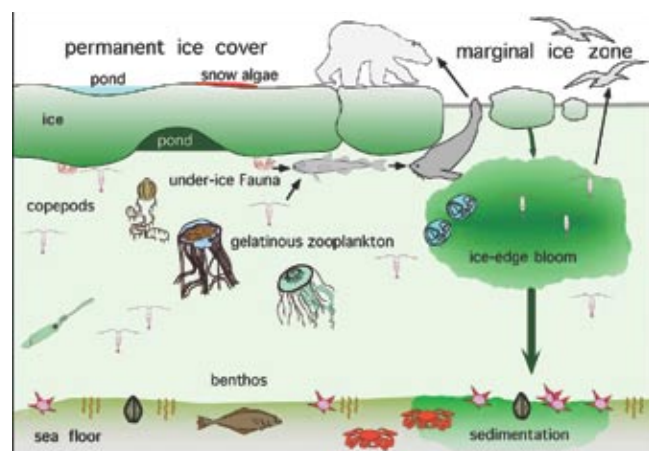
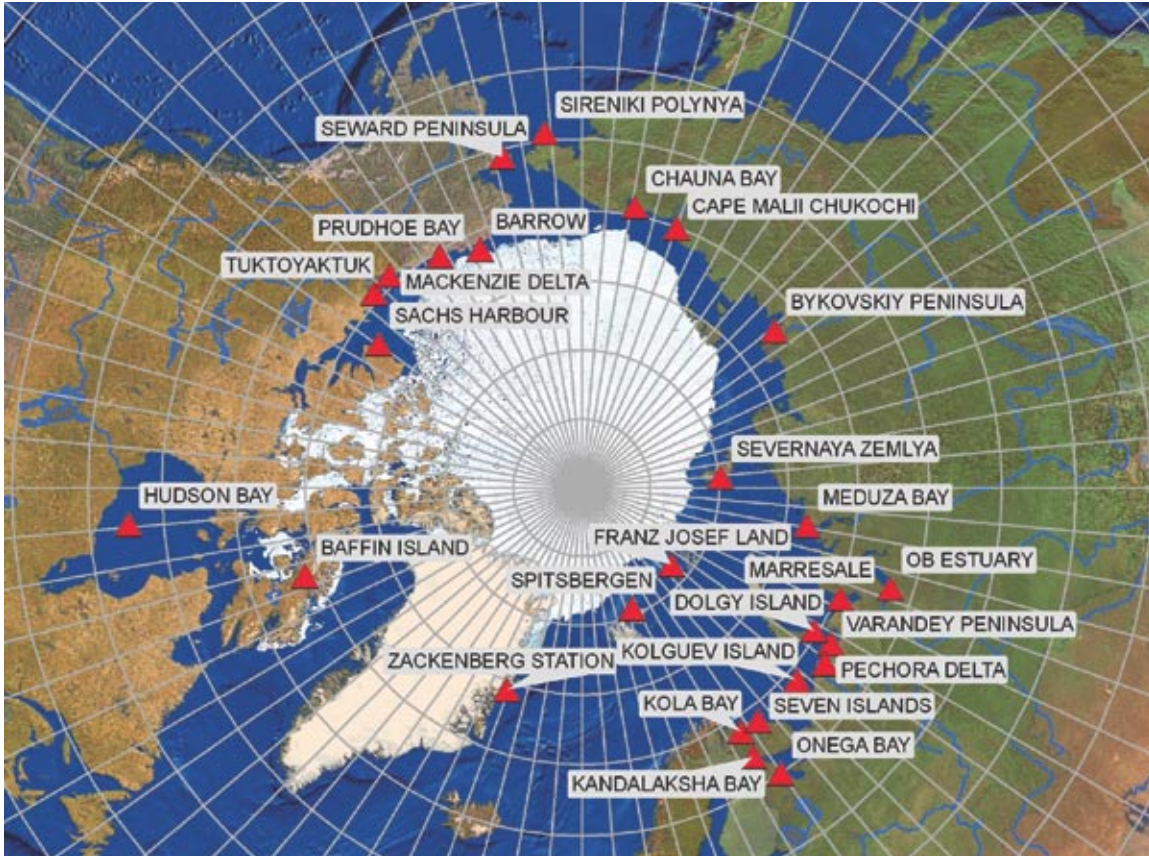


Figure 3.1. Schematic representation of the Arctic coastal marine ecosystem and typical interacting species (Gradinger et al., 2004).



of this research include a network of coastal observatories (both on and off-shore), and a broad-scale physical, environmental, and social circum-Arctic characterization to provide context. Empowering these studies are data management and information systems that include a particular emphasis on data synthesis, and cyber infrastructure and sensor technologies at multiple spatial and temporal scales.

Anticipated outcomes of this research include:

- Decreased uncertainty about the functioning of biological and physical processes and resulting possible impacts on ecological and social systems.
- Data supply and support for ecoregion-based management.
- Scientific and traditional knowledge support for sustainable development.

Figure 3.2. Potential focal areas for a network of physical, ecological, and social observatory sites in the Arctic coastal zone. Each site – at its own particular spatial scale - is a fine grain complement to the coarser grain circum-Arctic characterization research. With this multi-scale complementarity, synergies between sites and between sites and the ecoregional context are promoted.



plans

AN INTRODUCTION TO

Science Plan 4: Deep Central Basin of the Arctic Ocean

It is not possible to understand the Earth as a series of isolated fragments. All evidence indicates that a complex suite of interrelated changes is underway, affecting every part of the environment. Tectonic and climatic processes connect remote regions of the globe across great distances. Truly global understanding of tectonics, climate, and climate history awaits aggressive study of the deep Arctic Ocean. Two complementary approaches are necessary to achieve this goal: contemporary process studies and historical studies.

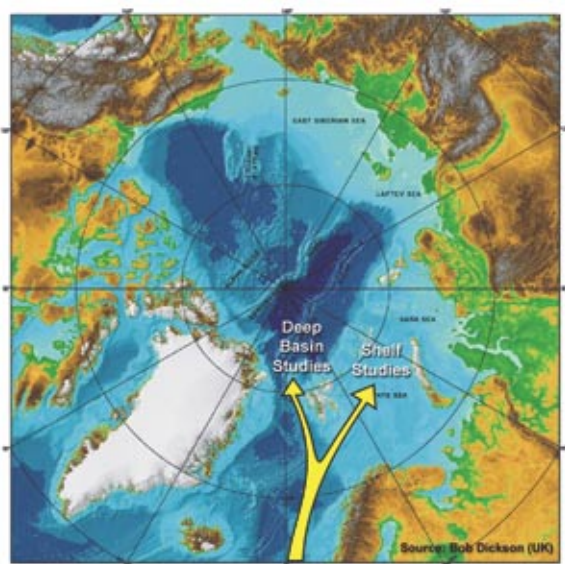
While the basin form is fairly well known today, exploration of the Arctic Ocean is ongoing. Our view of the basin is focused by the bathymetry, gravity, and seismic reflection data that have been collected and released by the U.S. Navy over the last decade, but our understanding of the basin's sub-seafloor structure and history is incomplete. Acquiring more multi-channel seismic reflection data will be necessary to map the structures

and select sites for scientific drilling. Drilling is the only way to date events and structures in the basin and collect the records of ancient climates preserved beneath the seafloor. The initial focus for drilling should be the condensed sections on the basin highs to

obtain complete, long-term records of the basin history, including the Mesozoic history of the Amerasian Basin, which is almost completely unknown. In the short term, these objectives may best be served by drilling on the Chukchi Plateau.

Arctic science depends on access. Despite rapidly declining sea-ice extent observed over the last two decades, there are regions that are not accessible by icebreakers in any season. Other areas are seasonally accessible. Study of the complex, heterogeneous, variable processes in this basin requires continuous access to the water column, the ice surface and the seabed. Autonomous data acquisition is the only way to acquire data of sufficient density in the critical regions. The current push for real-time observations (e.g., Study of Arctic Environmental Change [SEARCH] and Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies [DAMOCLES]) will build understanding of the contemporary environment and augment the few locations with relatively long land-based records, providing context to these historical studies.

While this is necessary, the only way to reconstruct the history of the Arctic Ocean, spanning a transition from the nearly unknown history of the Early Mesozoic to near tropical conditions in the late Cretaceous to Pleistocene glaciation to the present conditions of rapid change, is to recover the long records preserved in the sediments below the seafloor. A coupled program to collect geophysical data and to drill into the sedimentary section would make it possible to recover the records of the climate experiments the unobserved Earth has conducted since the Mesozoic.



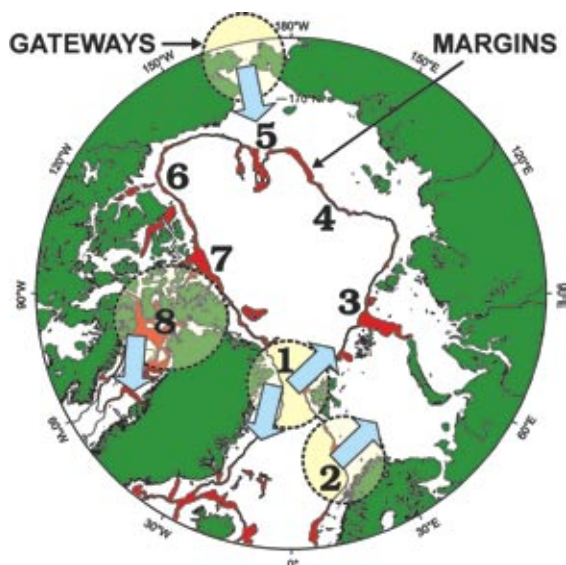


AN INTRODUCTION TO Science Plan 5: Arctic Margins and Gateways

The gateways in and out of the Arctic act as key regulators of forcing factors for the Arctic and the global climate system, while the margins are the active transformation sites along oceanic boundary pathways and the locations of water, carbon and sediment transport from the shelves to the deep basins. A fundamental objective of this science plan is to understand how Arctic margins and gateways regulate the physical and biogeochemical processes in the Arctic that are linked to sea-ice dynamics, air-sea interactions, the freshwater balance, and associated ecosystem dynamics. The shelf-break is a key site for studying ecosystem responses to climate change as it is a focal zone for evaluating system responses in terms of changing sea-ice cover, boundary current dynamics, and shelf-basin exchange.

This science plan proposes a coordinated, international research strategy to include contemporary oceanographic and biological studies along select section lines across the slope

as well as mooring emplacements in key Arctic regional areas (see Figure 5.1). Longer-term paleo-oceanographic studies should also be collected at select sites, including geophysical aspects to establish the detailed tectonic, geodynamic, sedimentary and paleo-topographic histories of the margins and gateways. These field campaigns require coordination with high-resolution process and large scale modeling studies to optimize observations and enable synthesis of data to understand Arctic Ocean variability across broad time scales. Time-series data collections (autonomous and ship-based) will enable us to evaluate the role of gateways and slope regions in climate change and the associated ecosystem response. This proposed framework would also leverage ongoing and planned field operations in order for emplacement of a long-term observatory network of measurements tracking key processes at the margins and gateways that are both influencing and responding to Arctic environmental change.



Regional Areas:

Margins and Gateways

1. Fram Strait Complex (gateway)
2. Western Barents Sea (gateway)
3. Santa Anna Trough (margin)
4. Kara/Laptev/East Siberian Sea (margin)
5. Bering Strait Complex (gateway)
6. Beaufort Sea (margin)
7. Northern Canada (margin)
8. Canadian Arctic Archipelago Complex (gateway)

Figure 5.1. Distribution of eight regional areas for margin and gateways studies within the ICARP II science plan 5 (figure courtesy of Eddy Carmack).



plans

AN INTRODUCTION TO Science Plan 6: Arctic Shelf Seas

Arctic shelf seas represent about half the Arctic Ocean and 25% of the entire World Ocean shelves. They are vitally important for coastal Arctic communities since shelf seas provide most of the living resources necessary for subsistence and commercial harvest. For example, the Barents Sea and the Bering Sea are among the most productive oceanic areas on Earth. Considering the importance of the Arctic and sub-Arctic seas for global fisheries and the harvesting of other marine resources, the projected changes in Arctic climate will have major repercussions at the ecosystem level that will extend throughout various economic and societal sectors.

The Arctic shelf seas encompass the seasonal sea-ice zone (which is partly ice free during the summer), and thus are expected in the near future to offer important waterways for major world transportation of goods and natural resources as well as for oil and gas development (Figure 6.1). Arctic shelf seas receive 10% of the global freshwater discharge, including all the freshwater from Siberian and Canadian rivers, and transport it to the deep Arctic Basin. The resulting 100 to 200 m thick layer of low-saline water covers the entire Arctic Ocean and serves a major role in sea-ice formation during freezing periods.

Over the past decade, evidence has accumulated that the Arctic is undergoing significant and sweeping changes, including rapidly rising temperatures; reduced sea-ice cover; destabilization of land-fast ice; and increased coastal erosion due to degradation of permafrost, increased wave action, sediment transport by sea ice, and sea-level rise. These changes are already directly manifested on shelf environments. If they continue, as implied by climate models, they will

have major implications for circum-Arctic ecology and human activities. Although the mechanisms amplifying or damping these potential changes are not well understood, they are essential for understanding and modeling the entire system across disciplines over the next decades and to project their influence over global climate.

With respect to increasing levels of shipping, resource exploitation, and traditional subsistence activities in Arctic shelf seas, research focusing on six scientific issues is essential and strongly required to predict changes and improve future assessments.

1. Changes in shelf-ocean dynamics and brine production
2. Changes in cross-shelf transport
3. Ecosystem alteration and its impact on marine resources
4. Phenology of key ecosystem events
5. Arctic polynyas in response to climate change
6. Evaluations of the paleo-record in developing future scenarios

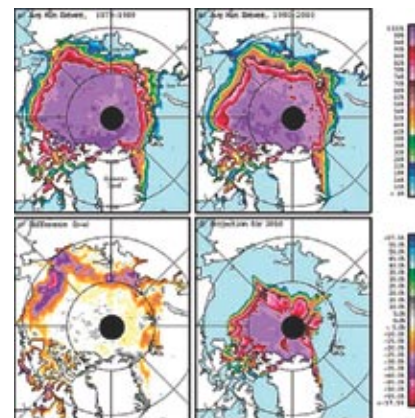


Figure 6.1. Reduction in summer minimum ice extent between 1979 and 2000. Note in particular how ice has retreated from shelves (c). Projection for 2050 is based on linear trend derived for 1980s and 1990s (d).



AN INTRODUCTION TO

Science Plan 7:

Terrestrial Cryospheric & Hydrologic Processes and Systems

The cryosphere is an especially important part of the global climate system. Significant changes have been observed in hydrologic and cryospheric systems over the last half-century, and more pronounced changes are forecast as climate continues to change as a result of global greenhouse gas emissions resulting from human activities. International scientific consensus is building that the Arctic is moving towards a new seasonally ice-free state, accompanied by major intra-Arctic changes to biogeophysical and socioeconomic systems of special importance to northern residents and also producing some extra-Arctic effects that will have global consequences.

As the Arctic system moves towards a new state, concern has been expressed about how changing cryospheric/hydrologic systems will affect major global climate feedbacks, biological productivity and biodiversity, and human and economic systems. The broad scientific questions addressed by this science plan include:

- How will ongoing and predicted future changes to the inter-annual variability of Arctic terrestrial cryospheric and hydrologic processes affect global and regional feedbacks to the climate system (e.g., radiative feedbacks and feedbacks via the thermohaline circulation), and global sea level?
- How will ongoing and predicted future changes in the cryospheric and hydrologic systems affect terrestrial and freshwater aquatic ecosystem productivity and biodiversity?
- How will ongoing and predicted future changes in the hydrologic system impact humans?

This science plan thus outlines a program based on a phased approach that includes (1)

process studies, (2) modeling and prediction, and (3) long-term observations that will allow short-term progress in a number of areas outlined in the scientific questions above, while ensuring that gaps in long-term observations are addressed. The intent is that, by the end of the program, these new observations will make it possible to address aspects of the science questions that are critically dependent

on long-term observations. Further, the approach includes near-term actions that will permit many of the science questions to be addressed in the short term, using existing observations, and/or measurements that are currently being acquired. Given the current state of knowledge and large unstudied parts of the Arctic, a three-pronged approach is recommended:

- Filling of existing knowledge gaps through process research in well-studied regions;
- Initiation of new research programs in regions that are currently unrepresented by previous field programs; and
- Extrapolation of understanding gained through process studies and modeling analyses throughout the pan-Arctic basin. To enable such extrapolation, it is essential to conduct verification and validation studies in carefully selected sites in under-studied regions.

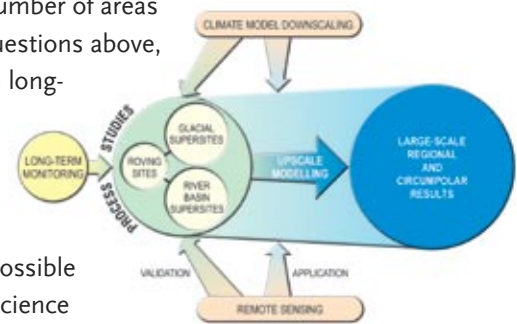


Figure 7.1 is a schematic outlining the ICARP II process of integrating field-based monitoring at supersites with modeling and remote-sensing applications to permit broad-scale upscaling of results.

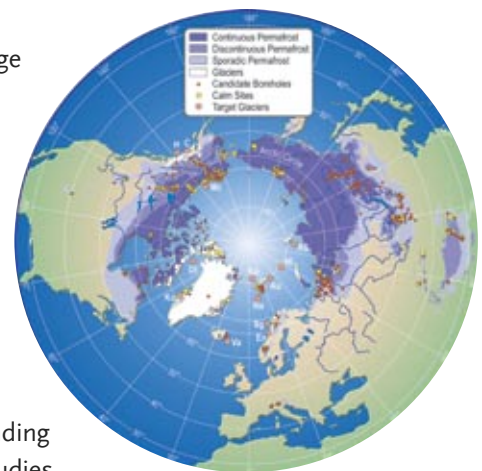


Figure 7.2. Location of permafrost candidate boreholes, active-layer monitoring sites (after International Permafrost Association) and GLACIODYN target glaciers.



plans



AN INTRODUCTION TO

Science Plan 8:

Terrestrial and Freshwater Biosphere and Biodiversity

Ecosystem structure and function are already changing in the Arctic and are projected to change still further in response to changes in the Arctic's climate and other environmental factors. For example, permafrost is widespread in Arctic regions and thawing could result in very rapid changes to physical aspects of the landscape and ecosystem function. Assessments of these changes were made recently within the Arctic Climate Impact Assessment, the Millennium Ecosystem Assessment, and the Fourth Assessment of the Intergovernmental Panel on Climate Change Working Group 2.

Although there is therefore, a good knowledge

of many aspects of the responses of Arctic ecosystems to climate change, some key uncertainties and gaps remain and further field-based research and development of predictive models is a major necessity for allowing more detailed and comprehensive projections of change. Particular challenges include improved understanding of key processes and transient responses to climate change, upscaling from point measurements to regional scales, and the integration of climate feedback effects (net radiative forcing) at the landscape level (including interactions between ecosystems). This science plan focuses on how the scientific community can



improve its ability to identify, attribute, and project the impacts of climate change on terrestrial and freshwater ecosystems of the Arctic.

Ecosystem function and ecosystem structure are the two major focal points for this science plan. In practice, these topics are interlinked. Both are likely to respond to multiple drivers of change including the dominant climate drivers of change, such as temperature, precipitation, radiation and disturbance, and other drivers such as the wetting and drying of soils, permafrost changes, erosion, and deposition of dust.

Understanding and predicting biospheric feedbacks with the atmosphere is the main issue

related to ecosystem function for the near future. Two types of biospheric feedback are likely to have significant impacts on the atmosphere and climate at both local and global scales: impacts of biogenic trace gases, aerosols and dust, and exchanges of energy and water between the biosphere, hydrosphere, and atmosphere. The main focus relating to ecosystem structure is to gain better data on current and past changes in terrestrial and freshwater biodiversity, an improved understanding of the processes causing these changes, an ability to predict future changes, and a better understanding of the consequences of change for resource use and ecosystem function.

AN INTRODUCTION TO

Science Plan 9:

Modeling and Predicting Arctic Weather, Climate and Ecosystems

This science plan addresses modeling and prediction of past, present, and future weather and climate on timescales ranging from days to a couple thousand years, with an emphasis on the likely evolution of climate over the next 100 years. It is also important to study the processes behind the large climatic variations that have occurred in the past as they may be of relevance in relation to current and future human-induced global warming. In general, this science plan covers those processes and components that are expected to provide a first order feedback on the rest of the climate system on timescales up to about 100 years.

Selected key questions addressed in this plan include: What is the robustness of the Arctic climate and the key feedback processes behind the large-scale variations? How does Arctic climate interact with global climate? How will Arctic sea ice evolve? How will Arctic glaciers change? How may stratospheric processes influence Arctic climate? How will changes in land and permafrost affect climate?

Arctic climate model projections for 2025-2035 and until 2100 will likely be improved by means of process studies, upscaling and observing system development, and by the development of a high-resolution, new-generation coupled regional model of the Arctic for simulating regional atmospheric-sea ice feedbacks. Special attention needs to be given to the following aspects: the influence of improved representation of Arctic processes and feedbacks in regional and global climate models; observation-based quantitative metrics for climate model evaluation in an ensemble approach; regional downscaling

of climate projections for applications of societal importance; and bridging hydrological models and regional climate models.

Another important advance would result from the development of new dynamically adaptive Arctic climate models with dynamically adaptive cores that can be easily implemented within Earth system models. Comprehensive Earth system models with resolved atmospheric dynamics are recommended, and should include representation of the evolution of the Greenland Ice Sheet, essential cryospheric feedbacks, a predictive carbon cycle, and biogeochemical feedbacks in the ocean.

An integrated observation and data-management system, incorporating all relevant disciplines, scales and observing platforms, is paramount and will make use of polar reference stations, so called “supersites,” and will include an inventory of Arctic observing platforms. The main aim is to develop a data and information management system that is based on existing approaches to enable multidisciplinary Arctic studies, and include the historical data rescue.

All suggested plans require coordination of observations and modeling ensuring the same domains for modeling and observational work. Nested domains need to be defined based on

2010 - 2030



geo-morphological, cryospheric, hydrological, and biogeochemical considerations, which should effectively enable upscaling and downscaling of climate and allow much more realistic hydrological and biogeochemical modeling. This approach will facilitate integration of model output and observations, and should lead to the production of high quality datasets representing the variability of essential parameters at dominant temporal and spatial scales.

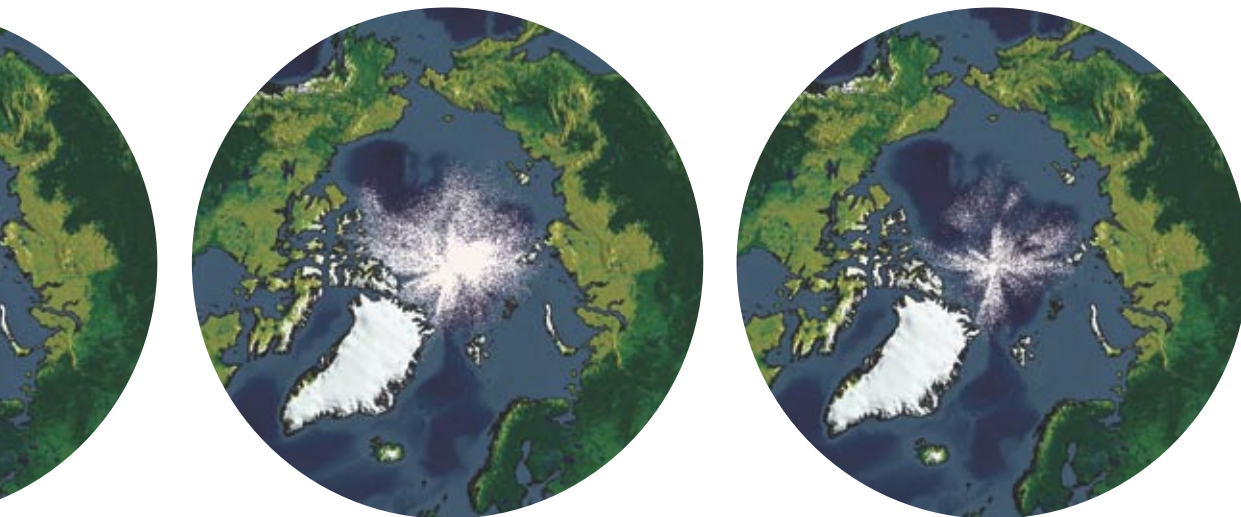
There are several important cross-cutting science issues addressed in this plan: freshwater and energy balance of the Greenland Ice Sheet, Arctic sea ice, precipitation minus evaporation, hydrology, permafrost, glaciers and snow,



biogeochemistry, and extreme events with their natural and social implications. An urgent remaining problem to be addressed is the inadequate knowledge of precipitation, including its solid part. This should be addressed by means of observations, validation and calibration campaigns, observing system development, and modeling. In addition, key components of the Arctic hydrological budget, river runoff, glacial melt, and sea ice would benefit from enhanced *in situ* observational monitoring programs.

2040 - 2060

2070 - 2090



September sea-ice extent, already declining markedly, is projected to decline even more rapidly in the future. These three images show the average of five climate models' projections, all using the same moderate emissions scenario, for three future time periods. As the century progresses, sea ice is projected to move further and further from the coasts of arctic land masses, retreating to the central Arctic Ocean. Some models project the virtually complete loss of summer sea ice to occur sometime in this century.

©2004, ACIA / Map ©Clifford Grabhorn



plans

AN INTRODUCTION TO

Science Plan 10:

Rapid Change, Resilience and Vulnerability in Social-Ecological Systems of the Arctic

Recent assessments have concluded that the Arctic is undergoing a period of rapid change. For example, Arctic climate trends show warming that exceeds the global average and can be double that of other regions of the world, causing thawing of permafrost, melting of glaciers, changes in hydrological processes, shifts in species, increasing coastal erosion, more wildfires, and shrinking sea ice. Meanwhile, continued interest in exploitation of northern resources is bringing an increase in human infrastructure and an expansion of the human footprint.

The Arctic is closely coupled to the external (non-Arctic) environment and is highly dynamic. External processes have been the dominant

drivers of change in the Arctic. However, as globalization and changes in land use proceeds, internal drivers and feedbacks of change are emerging. Thus, rapid change in the Arctic raises questions about how the various forces for change may interact and affect the capacity for human adaptation. These conditions also highlight questions regarding which variables ultimately govern the fundamental properties of the Arctic System and what is the potential of humans and or climate change to modify those processes in an environment of low biological diversity, sparse social and material resources, and limited political and economic autonomy. As the ACIA and the recent 2007 IPCC reports



document, the accelerating changes across the Arctic in the decades ahead are very likely and there will be increased needs to understand more complete adaptation risks (and in some cases opportunities) for the region.

While Arctic Indigenous peoples have historically been very resilient, it is important to recognize that the types and rate of change in the Arctic today are unprecedented. This suggests the need to move away from the view of Indigenous northern people with inherently adaptive capabilities, and towards a focus on the co-evolution of social and ecological systems within and among these cultures. Addressing these problems requires that ecological, economic, and social dimensions be considered in an integrated fashion.

To achieve an integrated analysis of rapid change, this science plan proposes that *social-ecological systems* serve as a primary unit of analysis, on which an interdisciplinary program of northern research can build on recent developments in theories of resilience, vulnerability, and complexity, and proposes research that considers the linkages of change across various scales of time and space. This approach calls for an understanding of the emergence and behavior of complex adaptive systems, and a need to identify the feedbacks between and among social and ecological aspects of the system. Finally, there is a need to understand the properties that govern these processes to appreciate better the implications of rapid change and its novel conditions to human wellbeing.

To focus this research, this science plan identifies a set of five general research questions.

- How do we best characterize patterns of rapid social-ecological change in the Arctic?
- What are the attributes of social-ecological sub-systems and their linkages to the Arctic System that are vulnerable or resilient to rapid change?



- What are the critical thresholds of change, domains of attraction, and recurring patterns?
- What are the factors that account for variance in systems and subsystems?
- How should the study of resilience and vulnerability integrate multiple sources of knowledge (e.g. science, traditional and local knowledge) to inform public policy?

The approach is highly interdisciplinary, ensures meaningful involvement of Arctic residents, Indigenous peoples, agency management practitioners, and academic researchers, and has direct links to decision makers.

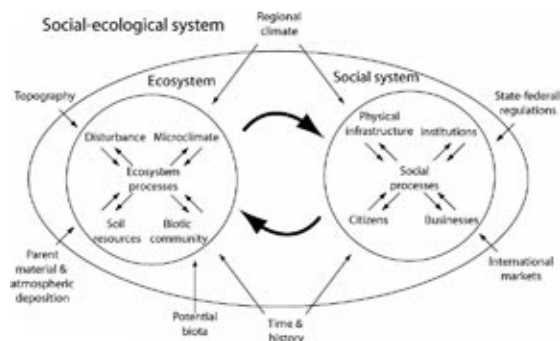


Figure 10.1. A social-ecological system consists of ecological and social subsystems that strongly influence one another at local and regional scales. For each subsystem there are external factors (e.g., regional climate and international markets) that are not influenced by local conditions (known as state factors by ecologists) and internal factors (e.g., institutions or disturbances), which respond to external factors and which both affect, and are affected by local processes (known as interactive controls by ecologists) (Whiteman et al., 2004).



plans

AN INTRODUCTION TO

Science Plan 11: Arctic Science in the Public Interest

The goal of this research plan is to understand better the driving forces behind Arctic science and its relationship to the public interest. The past becomes crucial to understanding present and future possibilities. A proper understanding of the relationship between Arctic science and the public interest requires an understanding of the social, historical, cultural, economic, and political forces that drive Arctic science. There are as many “publics,” as there are different “sciences,” and their relations are multidimensional. A continuum is assumed from the value base on which all decisions and choices are based, through the three related research processes of defining the issues, conducting the work, and communicating the results, to an analysis of the work’s impact. Based on this perspective of the research continuum, five key headings are identified for discussion:

- Understanding the image of the Arctic and of Arctic science
- The construction of research questions
- The conduct of research in the Arctic
- The control and communication of knowledge (ownership/sharing)
- The impacts and relevance of research

Research is funded for a reason. Social forces shape the research questions that drive Arctic science. They are constructed to serve several purposes. Issues like sovereignty, national interest, the large resource economy, local rights, access to jobs, and simply a genuine search for knowledge are all important drivers. It is often suggested that what might be called the “dominant societies” or as some have called it “western science” have for the most part driven Arctic science and related scholarship. However,

it is increasingly likely that other views and forms of knowledge, such as societies and cultures with oral traditions, will become foundations for additional insights and new understandings, and hence will enhanced scholarship concerning the Arctic region.

Independent of whether or not this view is correct, it is time to have a closer look at how the research questions are shaped, whether they get addressed, and if there are questions that never get asked. Thus, five main issues under which questions can be formulated are: Who asks? Why ask? What is researched? What is not asked? What could be changed? Answering questions developed within this framework requires an integration of the history, sociology and politics of Arctic science.





AN INTRODUCTION TO

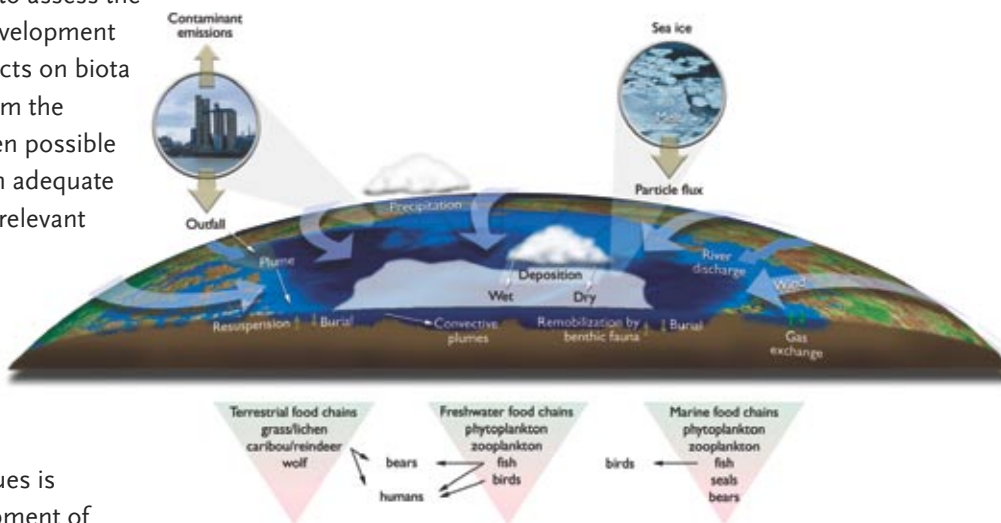
Science Plan 12:

The Fate and Implications of Contaminants in the Arctic

One of the most serious multiple stresses on the Arctic is that of the contamination that affects ecosystems and Arctic human populations, particularly Indigenous peoples of the region. The links between contaminants (heavy metals, persistent organic pollutants, petroleum hydrocarbons, and radionuclides) and threats to the health and well-being of both animal populations and human populations in the Arctic clearly demonstrate the relevance of this issue to residents and communities of the north. The influence of climate change on contaminants illustrates the connections to global processes that may, in the near future, lead to significant changes for both the Arctic and other parts of the world, that are as yet poorly understood. The focus of contaminant research in the Arctic is an understanding of the mechanisms by which contaminants are transported to and within the Arctic, and knowledge of the fate and implications of Arctic contamination for the region's environment and ecosystems, including human populations in the Arctic. Our ability to assess the extent of Arctic contamination, its development over time (temporal trends), and effects on biota at different levels of organization (from the molecular level to population and even possible ecosystem responses) depends on an adequate base of knowledge regarding (many) relevant scientific disciplines.

Potential human health effects of contaminants are a key concern, in particular for Indigenous peoples of the Arctic. Research (and monitoring) aimed at improving understanding of Arctic pollution issues is an integral component in the development of

sound science-based policy recommendations to reduce Arctic contamination and its impacts. This key feedback in terms of policy relevance is facilitated largely through the Arctic Council, and the work of the Arctic Monitoring and Assessment Programme. Information on contamination of the Arctic played a key role in the development of international agreements such as the Stockholm Convention on Persistent Organic Pollutants, and the UN ECE Convention on Long-range Transboundary Air Pollution and its related protocols, and is also an important component in the reviews of the effectiveness and sufficiency of such agreements. Recently, increasing attention has been paid to the issue of Arctic climate change, and the many ways in which future climate change has the potential to alter the pathways of contamination and the environmental fate and effects of contaminants in the Arctic – including possible feedbacks relevant for assessing contamination issues at lower latitudes.





issues

Emerging Issues

ICARP II employed a consultative process that engaged a wide range of scientific organizations, institutions, and individual scientists and other experts to establish the working groups that produced the twelve science plans outlined in the previous section and available as complete long range plans on the enclosed CD. As an adjunct to the ICARP II Conference in Copenhagen, the Steering Committee invited the submission of additional contributions as “Emerging Issues.” These “Emerging Issues” were presented to the Copenhagen Conference and are included herein as introductions to the issues of the full papers presented at the conference. They include:

- Emerging Issues in Arctic Human Health Research
- The Response and Role of Permafrost on a Warming Planet
- Human Security in the Arctic
- Education and Outreach
- Major Observational Programs of Importance to Arctic Research
- Emerging Issues of Importance to Arctic Research Infrastructure



Emerging Issues in Arctic Human Health Research

A common theme across the Arctic is the rapid pace of change presenting new challenges to the health and well-being of Arctic residents; this calls for additional health research. Living conditions have changed and continue to change from an economy based on subsistence hunting and gathering to a cash-based economy. Across the circumpolar north there is increasing activity towards sustainable development



via local resource development and widening involvement in the global economy. The influence of such changes on the physical health of Arctic residents has, in some measures, been positive: improved housing conditions, stable food supply, increased access to western goods, and decreases in illness and death due to infectious diseases.

But these changes in lifestyle brought about by the move away from traditional subsistence hunting and gathering and the societal changes brought on by modernization in general have also resulted in an increased prevalence of chronic diseases such as diabetes, hypertension, obesity, and cardiovascular diseases. In addition, child abuse, alcohol and drug abuse, domestic violence, suicide, and unintentional injury are also connected to rapid cultural change and the associated loss of cultural identity and self esteem. Globalization has meant improvements in the transportation infrastructure. Many communities are thus no longer isolated. Consequently these communities are now vulnerable to the many infectious diseases.

Contaminants such as mercury, other heavy metals, polychlorinated biphenyls (PCBs), DDT, and dioxins have migrated to the Arctic and become bio-magnified in Arctic food webs. Their

presence in subsistence foods is of great concern to Arctic residents. Potential human health effects include damage to the developing brain, and the endocrine and immune systems. A new concern is the role of mercury on cardiovascular diseases. Research is needed to identify the levels and human health effects of these contaminants in Arctic residents, particularly the very young, and to use research to provide guidance on both the risks and benefits of consuming traditional foods.

Climate change has presented a new set of health challenges to Arctic residents. It is likely that the most vulnerable will be those living close to the land in remote communities and those already facing health-related changes. Health-related impacts may include injuries related to unpredictable ice and weather conditions and heat stress in summer. Additional impacts could result from changes in vector-borne diseases, zoonotic infectious diseases, access to safe water supplies, wildlife migration patterns and traditional food supply, and thawing permafrost and resulting damage to sanitation infrastructure. Research in these areas is needed to identify climate sensitive indicators that will improve prediction of health impacts and enhance development of mitigation strategies.



issues

The Response and Role of Permafrost on a Warming Planet

Permafrost degradation affects most components of the Arctic system and requires integrated, crosscutting approaches to research planning and policy formulation. In turn, an integrated permafrost focus would (1) provide more direct connections to end users, including others in the Arctic research community; (2) assist in developing a holistic and hemispheric approach to the state and fate of the cryosphere; (3) provide more efficient use of established activities and related coordination; and (4) utilize more effectively the international permafrost community and its collective expertise. Though permafrost has been and is being addressed in a wide variety of activities, what is missing is a well-organized, coordinated and forward looking plan for more completely understanding the regional and global changes in permafrost regions under a warming climate, their connections to the hydrologic and carbon cycles, and to provide

validation of models at different spatial and temporal scales.



The map shows hazard potential by risk level (high risk, moderate risk, low risk, and stable) for buildings, roads and other infrastructure due to permafrost thaw by the middle of this century under a moderate emissions scenario.



Human Security in the Arctic

Viewing human security broadly, as “freedom from fear and freedom from want,” it covers many aspects of security: economic, health, food, personal, political, community, and environmental security. Human security in the Arctic context is often grounded on the nexus between the ecosystem and social system. Human security complements and strengthens a number of concepts discussed in the ICARP II science plans, particularly notions of knowledge production,

sustainable development, and vulnerability, resilience and adaptation, whereby, for example, vulnerability can be equated to negative security (relationship to threats) and resilience and adaptation to positive security (relationship to enabling). Given the concept’s wide scope, from personal to environmental security, it facilitates an interdisciplinary approach that allows for connections between the diverse working group plans.

Education and Outreach in Arctic Research

It is important to engage people in Arctic scientific discovery in order to provide them with a deeper understanding of the Arctic regions and their role in global systems. Doing so will lead to a well-informed citizenry capable of influencing policy decisions in and about the North. This will also help develop the next generation of Arctic researchers, professionals and leaders as well as help ensure that future research is relevant to and addresses major needs of people as well as the Earth system. Global change has increased the urgency of engaging the public in Arctic science issues. The Arctic is changing, and these changes have wide-ranging implications not only for the Arctic, but also for the global environment and population. The more people throughout the world know about and understand these issues, the more they will be able to influence their political leaders to respond appropriately.

Education and outreach has traditionally been

regarded as an “end of pipe” activity. When the scientist has found “the truth”, it is transferred to next generations through education, and to the masses via media, museums, and the like. The discussions at the ICARP II conference made it clear that Arctic science needs to relate to the public, not only to get support to sustain itself, but also to gain new insights, questions and perspectives through interaction with the public. Thus, there are mutual benefits from a good interaction between science and the public. Education and outreach are important components of, and integral to research.

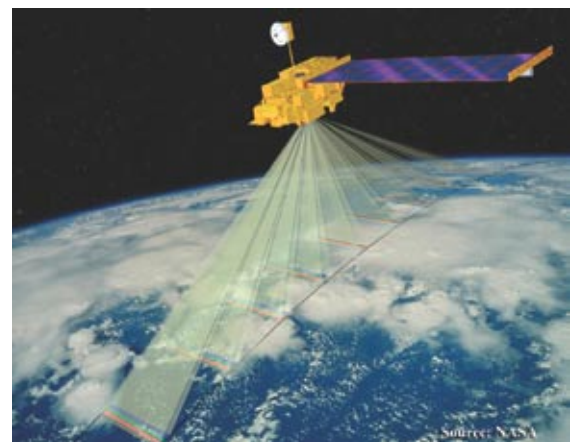
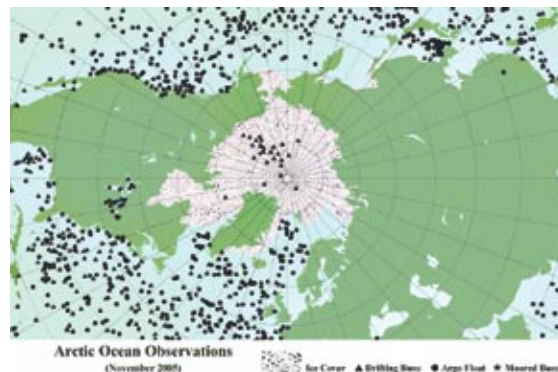
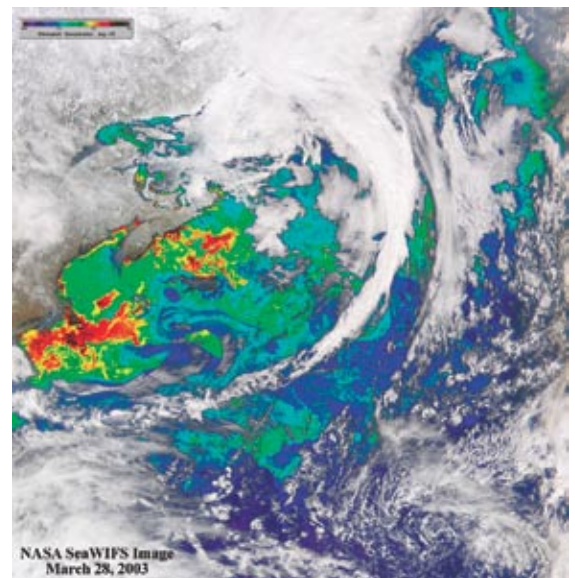




Major Observational Programs of Importance to Arctic Research

Many of the observational needs for ongoing monitoring of the Arctic environment are and will be met through global observing systems. An overview of major global observing programs focused on the World Meteorological Organization (WMO) Observing System, the Global Climate Observing System (GCOS), the Global Earth Observing System of Systems (GEOSS), and satellite remote sensing.

It is recommended that an observation strategy be developed that integrates remote sensing, in situ observations/monitoring data, and modeling from the beginning, and enables feedbacks among them. This would involve development of calibration/validation strategies and effective sampling strategies, use models to inform observations and data to initialize, validate and improve models. There is a need to take advantage of the planned missions. There is a need to clearly identify needs and priorities for observations and models: What are the most important issues? What are the barriers to progress? How can they best be overcome? Where will investments have the greatest return? The overarching challenge is integrating the strengths of remote sensing with complementary observations and models to describe how the Arctic system works, how it is changing and what those changes mean for the future. IPY and ICARP II activities can address this challenge.

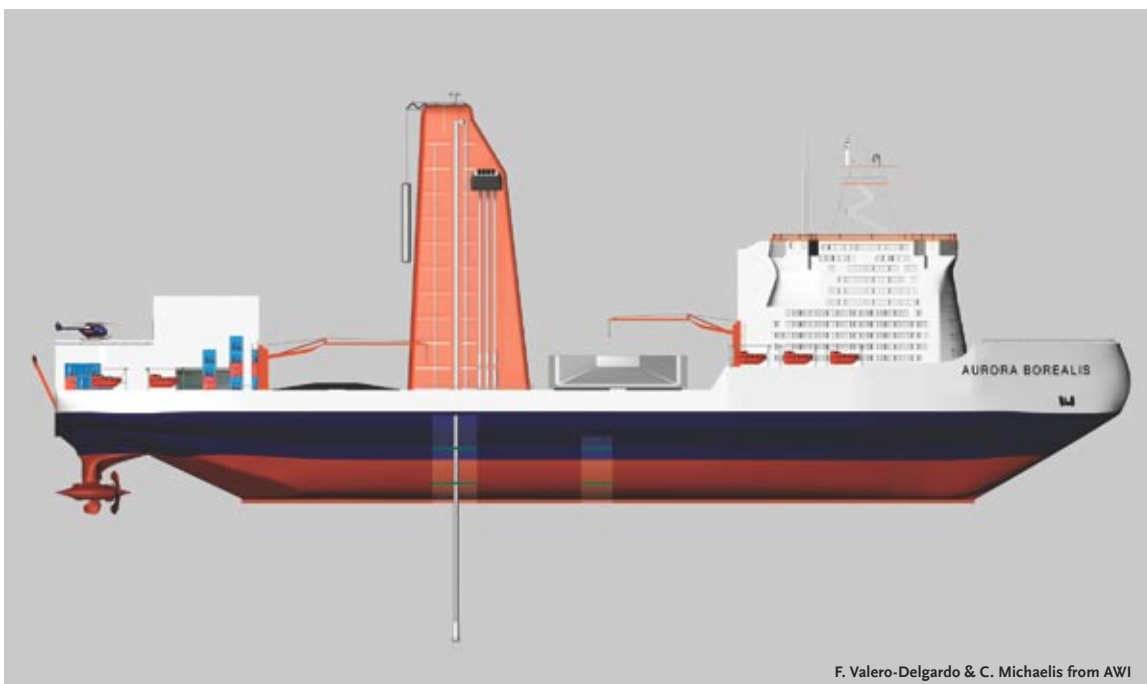


Emerging Issues of Importance to Arctic Research Infrastructure

Arctic research on land and sea requires state-of-the-art technologies and infrastructure. In addition we have an obligation to equip the upcoming generation of polar researchers with the most modern and safest research platforms the 21st century can provide. This effort will require major investments, both in terms of generating new tools and maintaining and renovating existing infrastructure. The IPY, with its attempts to coordinate and foster cooperation on an international level in an unprecedented way therefore offers a unique chance for a leap of progress in our understanding of Arctic processes and their dynamics with their influence on the adjacent continents and the global environment.

Among the areas with deficits in infrastructure are unmanned observational systems (marine and terrestrial), polar stations on the circum-Arctic land areas, drifting stations, ships (mainly ice-breakers), airplanes, and satellites. Many of these

major infrastructure items are too expensive, complicated and/or technically demanding to be run as national facilities. International consortia of various kinds will need to be formed to generate, manage and efficiently use large-scale international Arctic research infrastructure.



F. Valero-Delgado & C. Michaelis from AWI

Sketch of an initial design for the new research icebreaker AURORA BOREALIS

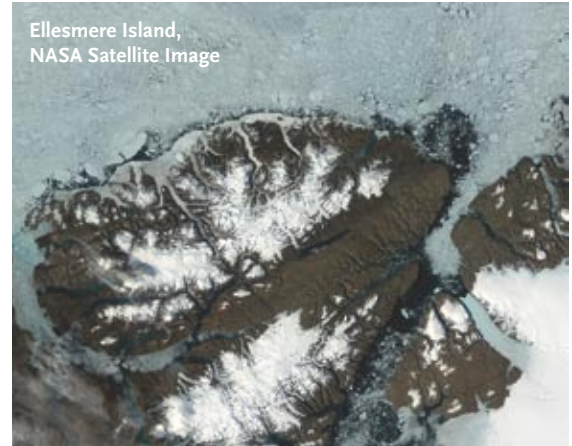


Concluding Thoughts

The Arctic is a unique and important part of the Earth system: environmentally, socially, economically, and politically. It is now experiencing some of the most rapid changes on the planet, from severe changes in its climate to impacts from globalization and other socioeconomic issues. The Arctic surrounds a northern polar sea strategically positioned between two continents and bridging eastern and western societies. How the Arctic system works, how it is changing, and what it will be like in the future are important questions being asked by policy makers, land use managers, and people who reside in the Arctic.

The range of questions, issues, and gaps in understanding identified during the ICARP II process provided the underpinning for the Science Plans and for framing research perspective for the decade or two ahead. The challenges and opportunities for scholarship and research of importance to society, governments, and individuals across the Arctic and around the world are manifold, with questions such as these driving the future of inquiry and analyses:

- How do Arctic economies work and how are they linked to issues related to sustainable development in general and to human

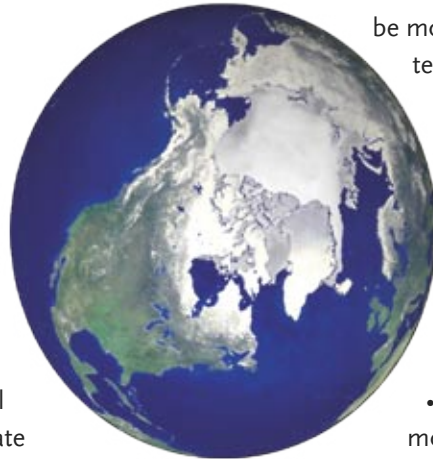


development of Arctic residents and communities in particular?

- How do Indigenous peoples of the Arctic maintain control of their own destiny, cultural identity and reliance on nature given climate change, contaminants, and other challenges to their well-being?
- Where are the unique and special biodiversity features, why are they there, and what are the underlying ecological processes for these features?
- How does the freshwater discharge into the Arctic basin affect the stability of halocline processes, sea-ice formation and primary production?
- How do Arctic margins and gateways regulate the physical and biogeochemical processes in the Arctic and in what ways are they linked to sea-ice dynamics, air-sea interactions, the freshwater balance, and associated ecosystem dynamics?
- How do the processes within and across the Arctic shelf seas (which represent about half the Arctic Ocean and 25% of the entire World Ocean shelves) control fish and other living marine stocks for subsistence and commercial harvest?
- How will ongoing and predicted future changes in the cryospheric and hydrologic systems affect terrestrial and freshwater

aquatic ecosystem productivity and biodiversity?

- What are the dominant responses of Arctic ecosystems to climate change and can predictive models provide more detailed and comprehensive projections of change?
- How does Arctic climate interact with global climate and how will Arctic sea ice evolve?
- Can an understanding (i.e., scientific, traditional and local knowledge) of the resilience and vulnerability of Arctic natural and human systems to climate and other changes across the Arctic facilitate better public policy?
- What are the critical and controlling links between contaminants (heavy metals, POPs, petroleum hydrocarbons and radionuclides) and the threats to the human health and well-being for populations living in the Arctic?



- What are the more detailed regional changes in permafrost evolution and distribution under a warming climate and their connections to the hydrologic and carbon cycles (e.g., methane releases) and can these processes be modeled at relevant spatial and temporal scales?
- How can science more effectively engage people in the scientific discovery process in order to provide them with a deeper understanding of the Arctic regions and their role in global systems?
- How can observations and monitoring strategies be developed that more effectively integrate remote sensing and in situ data across the Arctic and with international initiatives such as GEOSS?



The ICARP II planning process put voice to these questions and has developed detailed scientific research plans to address them. The International Polar Year (2007-2008) will provide a unique opportunity to enhance and deepen our understanding of questions such as these and provide a foundation for the decades ahead which will continue to be characterized by rapid change across the Arctic. The research perspectives from the ICARP II planning process will be essential to fostering the opportunities and addressing challenges faced by this unique and special place on planet Earth. It is in this spirit that the ICARP II Team and its Steering Committee offer these research perspectives for the decade or two ahead.

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The Arctic is a unique and important part of the Earth system, and it is now experiencing some of the most rapid changes on the planet. How the Arctic is changing and what it will be like in the future are important questions being asked by policy makers, land use managers, and people who reside in the Arctic. ICARP II put voice to these questions and developed scientific research plans to address them. The decades ahead will continue to be characterized by rapid change in the Arctic, and the research perspectives from this ICARP II process will be essential to fostering opportunities and addressing challenges faced by this unique and special place on planet Earth.

