Responding to Arctic Environmental Change

TRANSLATING OUR GROWING UNDERSTANDING INTO A RESEARCH AGENDA FOR ACTION

An International Study of Arctic Change (ISAC) Workshop
30 January – 1 February 2012
Queen's University, Kingston, Canada

ISAC

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ACKNOWLEDGEMENTS

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ISAC

ISAC is an open-ended, international, interdisciplinary arctic environmental change program. ISAC encompasses pan-Arctic, system-scale, multidisciplinary observations, synthesis and modeling to provide an integrated understanding of arctic change and projections of future change. The ISAC Science Plan provides a vision for integrating research among diverse fields and varied users and stakeholders.

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INTRODUCTION

The International Study of Arctic Change (ISAC) is an ongoing, international, interdisciplinary arctic environmental change research program. ISAC encompasses pan-Arctic, system-level, cross-disciplinary observations, synthesis and modeling to provide an integrated understanding of arctic change and projections of future change. The ISAC Science Plan (Murray et al. 2010) provides a vision for integrating research among diverse fields and varied users and stakeholders while outlining a framework for collaborative, international, and interdisciplinary research about the arctic system. This program of research is framed within a context of observing, understanding and responding to environmental change in the Arctic.

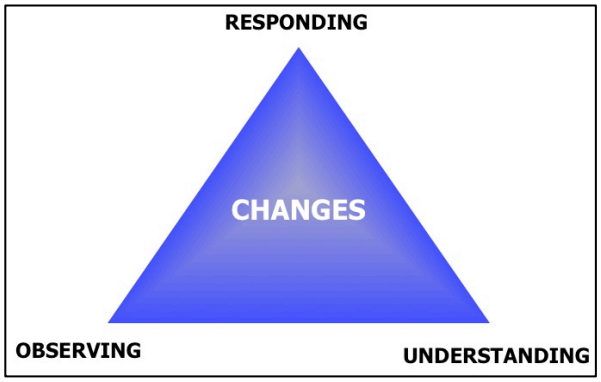

Figure 1. ISAC components: responding, observing and understanding.

Working with scientists and stakeholders to scope and design effective responses to arctic environmental change is key to ISAC, with one goal to drive forward observational and understanding activities and research objectives that are significant for science and meaningful to society.

This workshop report details the first phase of implementation of the Responding to Change (RtoC) component of the ISAC program and provides the necessary background on workshop development including planning meetings, topical considerations, and broader needs of the research community. The report further outlines a common reference framework for RtoC and identifies fundamental research activities necessary to implement RtoC while simultaneously providing a pathway for RtoC to inform ongoing arctic system observing initiatives.

BACKGROUND

ISAC is not the only arctic change research program to include, explicitly or implicitly, the three ambitions of observing change, understanding change,

and responding to change, (e.g. SEARCH 2005, ACCESS, ArcticNet[1]). Over the past decade many research activities directed towards observing and understanding have developed, including many which result from the recent International Polar Year (IPY) 2007-08. Yet, despite what appears to be an overall trend toward increased engagement of researchers with issues of relevance to RtoC, the integration of RtoC research into the mainstream has been slow in coming to fruition. There remains a distinct lack of progress in defining and implementing a collaborative and coordinated international RtoC research agenda, with the reasons for this being complex and multidimensional.

RtoC pushes traditional scientific enquiry into the domain of practice, which presents new challenges, not the least of which includes the full integration of stakeholders into the science planning process. The people who will ultimately implement proposals for the effective adaptation, management and mitigation of change must first actively engage with the processes that define research. This involvement has only recently become a top priority across a broad spectrum of the research community (see for example Pearce et al. 2009). Delay in the implementation of RtoC programs has had a negative impact on the research community's ability to offer solutions for coping with change, and now is also impacting the design optimization of a pan-Arctic, multi-domain, multi-purpose observing system. An observing system that can simultaneously serve stakeholder and research needs is urgently needed as are more detailed and improved projections of future changes, yet shortcomings also exist for the development of a comprehensive Understanding Change component. Both observing and understanding activities should be informed by scientific and stakeholder needs and the first ISAC RtoC workshop was an initial step in that direction.

WORKSHOP PREPARATION

In the preparation phase for this workshop, two open planning meetings[2]

[1] A brief description of each of the programs mentioned here is located at the end of this report.

[2] Planning meeting reports are available at www.arcticchange.org. The first meeting was held at

were held in an effort to define what kinds of RtoC activities the international research community might embrace and which of the many issues should be the subject of a first RtoC workshop. It is clear that before any large, coordinated effort at RtoC research may occur, there is a pressing need to develop a common understanding of what RtoC actually means for arctic research and for all arctic stakeholders, and more broadly, how and under what conditions does the agenda connect to global change research. Planning meeting participants agreed that RtoC in the Arctic is now more important and necessary than ever before, but also that the lack of conceptual clarity as related to definition and implementation of RtoC is a hindrance in moving forward.

There was also agreement around the need to assess the extent to which science research priorities align with stakeholder information priorities including, but not limited to, those relevant to observational and modeling initiatives developed during the last decade and over the course of the IPY 2007-08. In the absence of a framework that can be used to define and address priorities and emerging issues at the pan-Arctic scale, scientific and stakeholder collaboration on the relevant research remains the challenge.

WORKSHOP QUESTIONNAIRE

Prior to convening the RtoC workshop, all registered participants were asked to participate in a survey designed to determine areas of expertise, breadth of experience with stakeholder or scientific partners, familiarity with different arctic research initiatives, resonance of the term Responding to Change, and an overview of perceived scientific and social challenges and needed information for responding.

RESULTS

There was a 42% response rate to the questionnaire. Several respondents were, in the end, unable to participate in the workshop, but their input through the survey is included here. Examples of responses to questions 5-7 are included in the appendix to this report.

the Oslo 2009 International Polar Year Conference and the second at the 2010 Annual Meeting of the American Geophysical Union in San Francisco.

Responding to Arctic Environmental Change: Workshop Questionnaire

1. What is your primary area of expertise?

2. If you are an academic or university/college-based researcher have you worked with northern stakeholder groups (northern residents, agencies, industry, etc.) and in what capacity (generally)?

3. If you are a representative of a stakeholder community what is your primary connection, if any, to the arctic research community?

4. With which, if any, national and/or international programs of arctic environmental change research are you familiar and in what capacity (e.g. as a participant, a partner, passing knowledge, etc.)?

5. Does the term Responding to Change resonate with you, and if so how would you define it? If not, why not?

6. What are the biggest scientific and societal challenges facing us as a result of arctic environmental change?

7. What information from the scientific community would you find useful or necessary to support your own activities or to support sustainable use of the Arctic (e.g. forecasts (for what), monitoring (of which parameters), analysis of system dynamics (e.g. ecosystem, physical system, commercial activities, etc.). In which form would you prefer to obtain such output (e.g. data center access, scientific papers, summaries, etc.)?

Questionnaire respondents generally converged on a definition of RtoC that encompassed the whole of human action taken in recognition of climatic, social and ecological change, with the scale of action ranging from that of the individual, to the community level, be it arctic communities or the research community, and to national and global-scale entities that could make decisions that will facilitate mitigation of
change. Several respondents mentioned that effective scientific response should include both a changed research agenda and directed efforts in capacity building and bridge building across disciplines, across basic and applied science agendas, among stakeholder groups and across the science/policy interface. Most respondents included some discussion of adaptation, with the broadest possible scope including adaption of people and non-human biota, and/or the response of non-human biota and of the physical components of the arctic system to ongoing changes.

In the context of the workshop, the results of the questionnaire were useful for developing an organizing framework, and for laying the groundwork for

productive discussion, including an agreed-upon working definition of RtoC.

WORKSHOP STRUCTURE

The workshop was organized around four questions critical to RtoC. These questions emerged as key in discussions held at the workshop planning meetings in 2009 and 2010. Workshop participants addressed these questions in a variety of ways: first through participation in the pre-workshop questionnaire discussed above, and then at the workshop itself through formal, keynote presentations, in breakout groups, and in plenary discussions.

Organizing Questions

Q1. What is meant by responding to arctic environmental change?

Q2. What research questions align with stakeholder needs for information? Which are tractable in the short term and which need to be addressed over the longer term?

Q3. How well do established arctic observing initiatives align with stakeholder needs for information and how can this alignment be improved?

Q4. What is needed to advance science/stakeholder partnerships, and to improve communication between these diverse communities?

Two keynote speakers, who presented either a stakeholder or a research perspective on the issue, initially tackled each question. There were eight keynote speakers in total. Breakout groups were charged with consideration of these same questions, and plenary discussions followed reports from the breakout sessions.

TOWARDS A COMMON REFERENCE FRAMEWORK

Deriving a working definition of RtoC was an important objective of the workshop. This is necessary for the identification of relevant research questions and for establishing a research agenda that fosters partnerships among stakeholders and scientific programs. Such research will address questions that achieve a balance between the scientific motivations to understand the fundamental behavior of the arctic system and stakeholder concerns (Stokes 1997). A working definition of RtoC is also necessary for the alignment of ongoing observing activities with diverse needs for information; stakeholder needs extend beyond those of the scientific community and in this instance refer to

specific services or benefits that groups derive from the Arctic. Improved alignment also requires agreement and understanding as to what data and information are of the greatest mutual value. RtoC encompasses a consideration of who is responding to what, when, and where, why and how with our working definition stated as follows:

"Given the dynamic nature of the arctic system RtoC means actors jointly developing an iterative and integrative process and tools for responding to change." This definition is further elaborated in figure 2. It illustrates an example of relationships among actors, action(s), and response within a dynamic system as embedded in RtoC.

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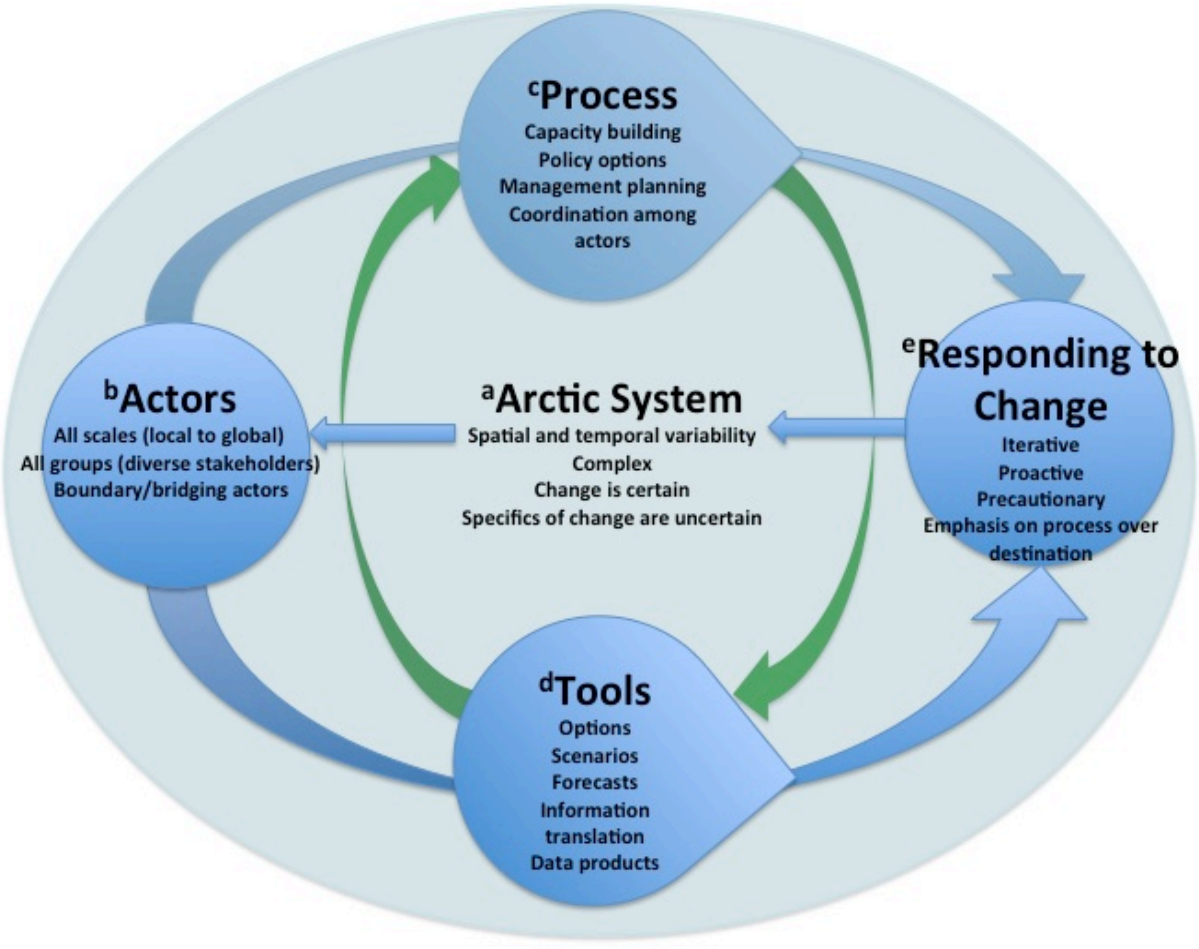

Figure 2. Given the dynamic nature of the arctic system[a,] RtoC means actors[b] jointly developing and iterative and integrative process[c] and tools[d] for responding to change[e]

A RESEARCH AGENDA FOR ACTION

Flexibility is required when working within a framework driven by diverse stakeholder considerations as this diversity enables innumerable, and in some cases complex and incompatible research avenues. Yet while there are calls to manage arctic change using theoretical frameworks such as resilience as a guiding principle, and calls for sweeping top-down policy changes (see for example Chapin et al. 2006), there are few well-developed, thoroughly scoped arctic research programs specifically designed for RtoC as described here (see however, ArcticNet www.arcticnet.ulaval.ca). Activities situated within specific projects have generally been more successful for the purposes of RtoC (see for example Gearheard et al. 2011, Eicken et al. 2011, Loring and Gerlach 2010) but such projects may not be well integrated into larger national and international programs.

At the programmatic level, there is an acknowledgment that much basic research on the arctic system remains to be done (SEARCH 2005, Bowden et al., 2006, Murray et al. 2010, Roberts et al. 2010, Wegner et al. 2012 to cite just a few examples). This is entirely compatible with the goals of RtoC, goals that are sometimes framed within a context of "applied research." However the distinction between basic and applied research is an artifact of the past and not particularly meaningful (Reagan 1967), especially in the context of RtoC outlined here. As Pielke and Byerly (1998:44) note "few problems have purely scientific solutions," and stakeholder integration is a process that can both inform and improve the scientific endeavor by identifying not just new needs, but also by bringing new sets of problem solving skills to the table. Relevance to scientific and societal needs or use-inspired, dual-purpose science with stakeholder engagement from the outset more accurately describes RtoC than the term 'applied.'

As knowledge transmission and knowledge translation are not unidirectional, the potential for capacity building in a program with stakeholder integration exceeds that of a program

without. Transcending the boundaries between basic and applied research, and between scientist and stakeholder, can enable research to settle on themes identified as deserving of urgent attention and facilitate collaborative means for addressing the 'wicked problem' (Weber and Khademian 2008) of arctic change. In light of this, it is worth considering RtoC activities within a hierarchy of different levels of integration that enable individuals and programs to find a best fit within the overarching conceptual structure.

ARCTIC SYSTEM SERVICES

The concept of ecosystem services, as defined in the Millennium Ecosystem Assessment and elsewhere (Costanza et al. 1997, de Groot et al. 2002, MA 2005), has been fruitful for improved communication among scientists and stakeholders but less so with respect to the development of "user-inspired and user-useful research" (Cowling et al. 2008). The MA and related work considered ecosystem services almost exclusively in terms of ecosystem functions involving the biosphere and valuation assessments of these services (i.e. Costanza et al. 1997, Kinzig et al. 2011). Here we take a broader approach, building on work that has cast specific research questions in terms of the interactions among or between any set of components of the arctic system (physical, biological chemical or human), that provide services to stakeholders, services that stakeholders need and services that stakeholders will use (e.g., Huntington et al. 2007, Eicken et al 2009, Francis et al., 2009). This is schematically outlined in Figure 3, illustrating how the concept of Arctic System Services informs research and learning approaches. This illustration does not show how the arctic system functions in and of itself, and this distinction is important; the nature and behavior of the arctic system is still very much a focus of emerging research approaches (Overland et al. 2004, Overpeck et al. 2005, Wookey et al 2009, Rawlins et al. 2010, Streever et al. 2011, to cite just a few examples).

The conceptual framework sketched in Figure 3 illustrates a major challenge that research and mutual learning in the RtoC context can help overcome. Most stakeholder groups are often two or more

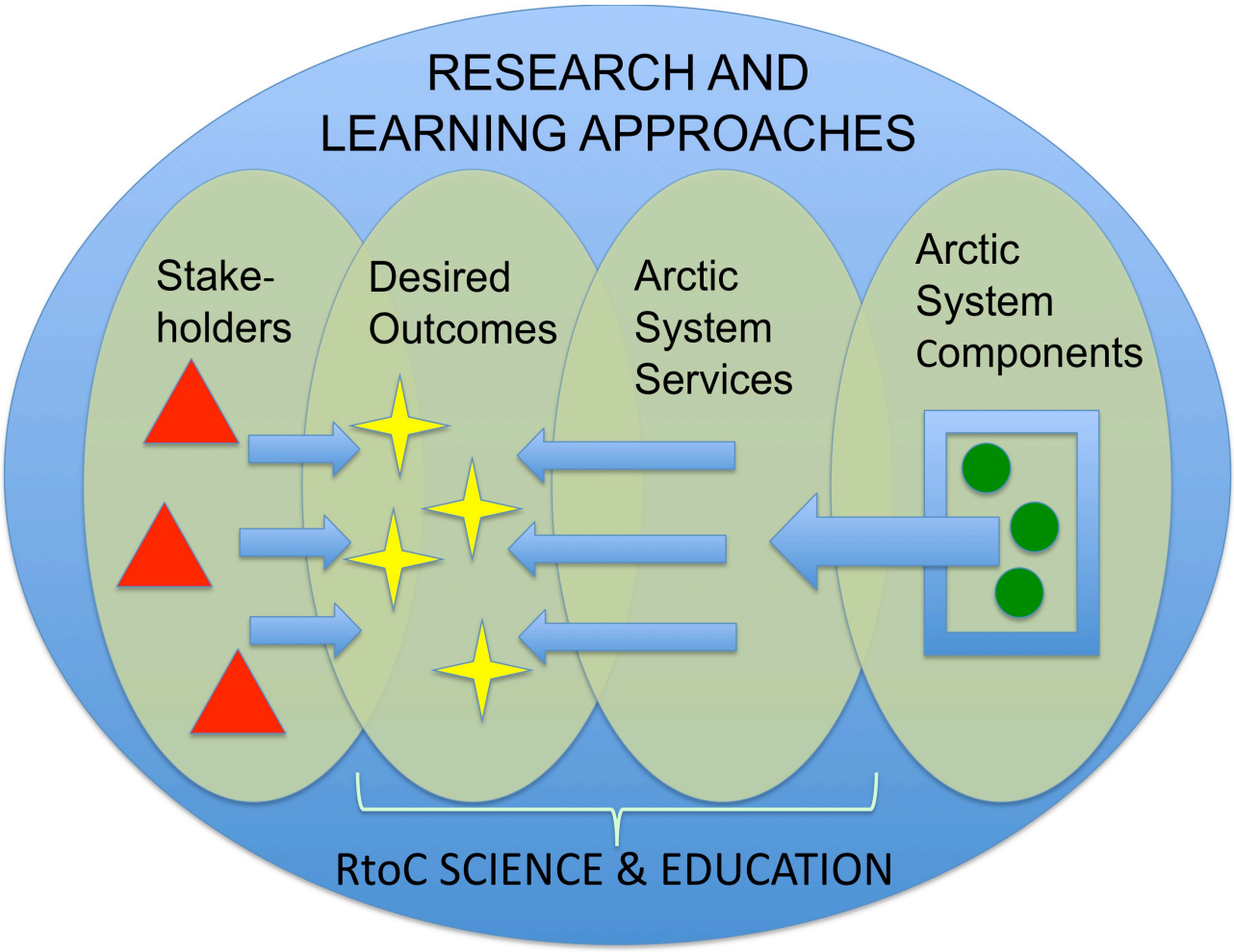

Figure 3. Schematic representation of a reference framework for research and learning approaches related to RtoC. This illustrates how specific arctic system components and processes, associated with variables that relate to the state and dynamics of the system, translate into specific ***Arctic System Services*** *of interest to stakeholders. Such services are key in assessing or shaping outcomes seen as desirable by different stakeholder groups. In this sense, the realms of desired outcomes and arctic system services bridge stakeholders and broader, fundamental scientific interests.*

steps removed from any research pertaining to improved understanding of the arctic system and its change over time. Equally, many scientists are two or more steps removed from desired outcomes. Resolving the separation and differences between classic earth system science, the social and human sciences, and the questions and focused information needs underlying stakeholder concerns, with integration across domains, requires innovative approaches that will promote multi-purpose, use-inspired research capable of meeting the challenges of a changing arctic.

In the past, much arctic research was confined to the separate, rather than the integrated, study of arctic system components (Figure 3, right), with analysis of the system as a whole only becoming more important in recent years. Most long-term observing programs (e.g., SEARCH, DAMOCLES, ArcticROOS, etc.) have focused on tracking physical variables that describe some portion of the system and that are presumed to be relevant to assessing trajectories toward potential future states. Fewer studies have focused on biological (i.e., primary production) or human variables (i.e., demography) that might also be relevant to system-scale change. In marine research there has been an emphasis on tracking the large-scale heat and freshwater budget of the Arctic and fluxes of these through major Arctic Ocean gateways (Dixon 2008, SEARCH 2005). On land, assessing the budgets of heat, freshwater, and key components of the carbon cycle has taken precedence (White et al. 2007, SEARCH 2005, Francis et al. 2009).

Such research may include elements of potential interest to stakeholders, but this information must be communicated in meaningful and understandable ways. The identification and development of commonalities requires joint assessments of information needs and existing programs. Central to this is the need to identify specific processes and mechanisms through which Arctic System Services link the system to desired outcomes determined by stakeholders. Here desired outcomes refer to ways in which stakeholders can take advantage of present and future opportunities **and** overcome challenges posed by a rapidly changing Arctic. It is important to note that Arctic System Services might not always have a positive impact on desired outcomes – this potential is illustrated below in Example 1.

As described by Figure 3, RtoC science and education can be thought of as the two bridging elements enabling stakeholders to connect to and impact research devoted to improved understanding of the arctic system and its components. RtoC activities can be understood as, e.g., research, education, or communication that serves to link stakeholders and scientists of all

persuasions with the aim to build multi-purpose, use-inspired research programs. At the same time, this schematic also serves as a conceptual roadmap to different research activities and stakeholder interests. The overarching framework provides a means to connect research that is planned in isolation and is presently disconnected from stakeholder interests, with desired outcomes. The formulation of desired outcomes and their linkage to Arctic System Services can foster improved information exchange and joint planning among groups that are currently not in direct exchange. Below we present several simplified examples to further illustrate these concepts.

1. HUMAN HEALTH

A clearly stated desired outcome for arctic residents is minimized risk to human health from the spread of infectious disease resulting from environmental change. Hantavirus (Genus *Hantavirus*, Family *Bunyaviridae*) is a virus that is spread to humans through contact with rodent urine, and that is potentially life threatening. The virus is commonly associated with old and new world rats and mice, but it is also carried by the Arvicolenae – pan-Arctic voles and lemmings (Mills 2004).

The spread of the variant Puumulavirus in the north of Europe is to a large extent conditioned by winter survival of high densities of voles; they depend critically on the soil-snow interface temperatures. Early and deep winter snow enhances reproduction and survival and areas with deeper snowpack show increased density of nests (Reid et al. 2011). However, a low snowpack will expose the voles for predators and they will then seek shelter in housing thus coming into closer contact with humans. The virus can then be more easily transmitted to humans (Olsen et al. 2010). Hence the Arctic System Service that links state variables and processes to desired outcomes (minimized spread of Hantavirus) would be either low snowpack depth and low winter minimum air temperatures promoting low soil/snow interface temperatures and low densities of Arvicolenae in the vicinity of human habitation(s) or the opposite. Research to establish critical limits remains to be carried out.

Importantly however, these Arctic System Services are directly linked to state variables (snow depth, air temperature) that are already monitored by existing observing networks (i.e., SnowNet www.ipysnow.net/).

2. PARK MANAGEMENT IN NORTHERN CANADA

In this example from the workshop, some key desired outcomes for the management of national parks are identified. These include maintenance of dynamic ecological integrity, sustaining land-based lifestyles, and continued provision of rewarding outdoor and educational experiences for the public. These outcomes reflect the needs and desires of local (park managers, aboriginal peoples, visitors), regional (northerners), and national (all Canadians) stakeholders.

The Arctic Systems Services necessary to achieve and sustain these outcomes are partially identified as a tolerable rate of climate change, sustained ecosystem productivity, the availability of healthy habitat components, and healthy trophic systems (predator/prey relationships, including those involving people). These services are linked to all components of the arctic system and to a wide range of state variables many of which are already being monitored (radiation, precipitation, temperature, evaporation etc.). However, the extent to which the data derived from such monitoring activities is organized in such a way as to facilitate the potential desired outcomes is still not clear. In this example, an observing program probably also needs to capture key variables within the human component of the system such as public perspectives on parks, public use of parks, policy changes, and more.

One avenue to take for an RtoC research agenda aiming at these desired outcomes is to focus on the need to manage future landscape-level shifts in ecosystem distribution and structure (Prowse et al. 2009). Issues to tackle could include how to evolve observing programs towards providing more useful and or

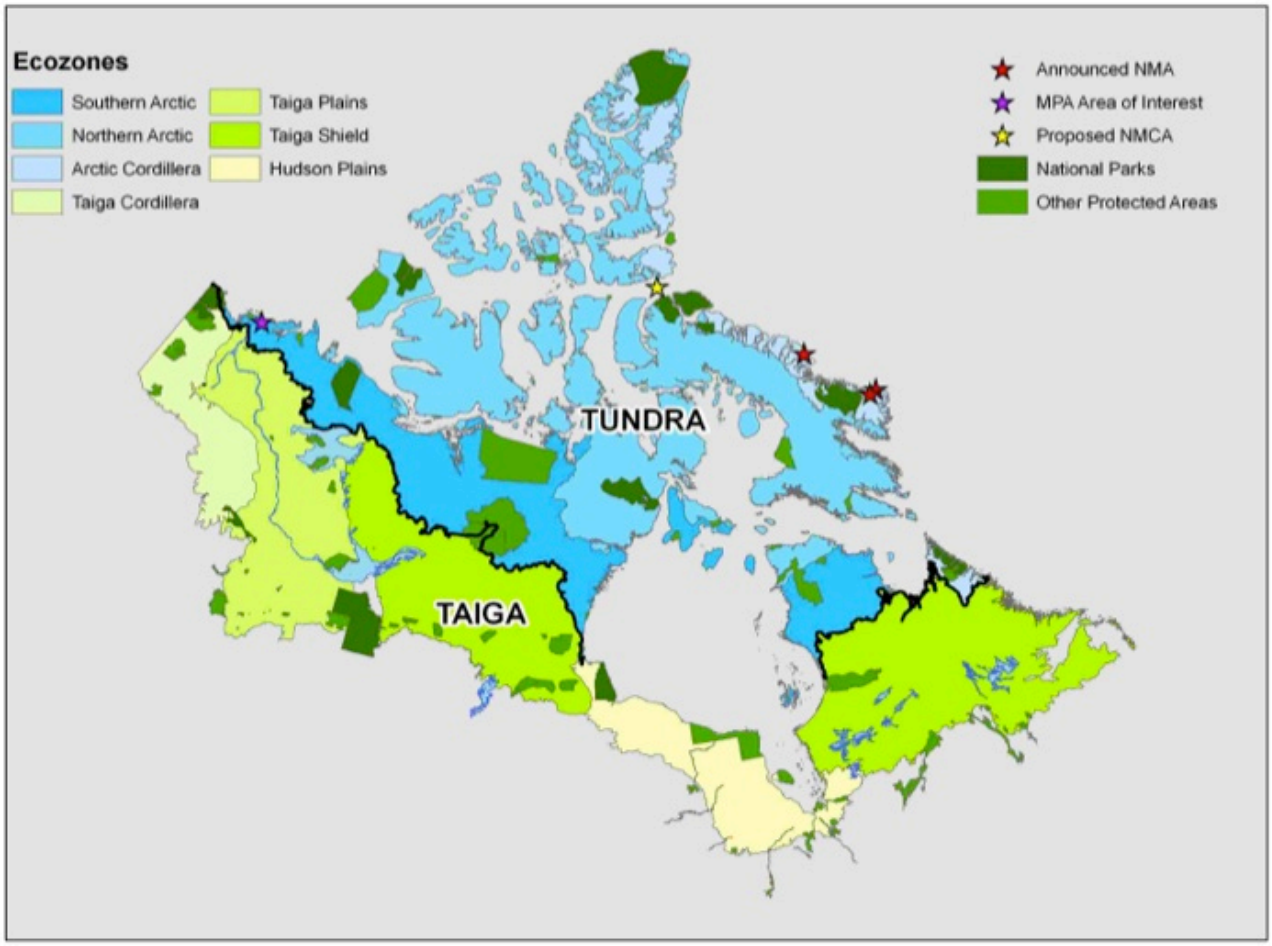

Figure 3. Map of northern Canada illustrating ecological zones, location of national parks, protected areas and other areas of interest. Illustration courtesy D. McLennan, Parks Canada.

comprehensive indicators of projected changes, and the development of ways to utilize those measures in planning for uncertainty while striving to achieve the outcomes described above.

3. FOOD SECURITY

In this example stakeholders are identified as subsistence and country food users for whom a desired outcome is access to sufficient quantity of high quality wild food resources, both plant and animal, marine and terrestrial. Here we consider some of the Arctic System Services that provide for terrestrial subsistence resources. Among these are habitat, snow cover, freshwater, forage, pollination, resistance to disease, resistance to invasive species, maintenance of biodiversity, and the economic capacity to purchase and service subsistence technologies,

including but not limited to boats, motors, snow machines and fuel. The arctic system components that provide these services include the hydrological system, the climate and weather system, the cryosphere, the biosphere, and the socio-economic system.

System variables to be observed might include vegetation growth, snow depth, lake depth, timing of breakup, freezeup, and greenup, species biogeography, price and availability of fuel, among others. It is expected that the observational data needed will vary from place to place and with respect to subsistence species of interest. Stakeholders are key to determining these observational needs and to the identification of gaps in current observing and understanding (modeling and similar) activities that can project future system states that might impact access to and quality of subsistence resources.

DISCUSSION AND RECOMMENDATIONS

The initial challenge of RtoC is bringing together researchers and stakeholders in a meaningful way and bridging barriers across language, knowledge and cultural divides. Research questions have to be defined with stakeholders, not in isolation from them. Stakeholders should be motivated to engage with research and to identify where and when information needs to be provided at spatial and temporal scales that differ from those commonly utilized by the scientific community – and this applies across the board from the individual to intergovernmental organizations.

Communication can be improved if there are multiple points of entry into the research process and likewise into the responding process. New tools are needed to facilitate partnerships, and for translating scientific data into information usable for risk assessments, problem solving, and decision-making to cite just a few examples.

Here workshop participants clearly articulated a new way of approaching the development of science and research that transcends the level of the principal investigator, with the bidirectional flow of information as the key. Science and

stakeholder interests meet at the nexus of Arctic System Services. RtoC is different than adaptation and mitigation because it is explicitly linked to implementation through development of tools for decision support, engagement, and science development. The larger challenge here is how to effect cooperation and coordination at levels from those of individuals to that of the international and the inter-governmental. It may be that partnerships with entities such as the Sustaining Arctic Observing Network (SAON) initiative of the Arctic Council, and with non-governmental organizations (NGOs) will facilitate implementation as envisioned below.

RECOMMENDATION 1

A key recommendation from the RtoC workshop is the development of an interactive, widely accessible, stakeholder engagement tool that can be used to develop new research priorities and research questions. Whether designed as an interactive website, a simple registry or even a discussion board, such an instrument could initially be tested by communicating the results of this workshop in a different venue and format with the explicit purpose of soliciting comments and improving the framework for RtoC. This tool or toolkit could be accessed through the ISAC website and maintained by the ISAC IPO. One model to consider might be comparable to that developed by Timberland Voices of Challenge http://responsibility.timberland.com/. Here in addition to corporate information about climate initiatives, products, factories and services, there is also an interactive discussion board, a blog, opportunities to listen to podcasts, and a host of social media communication venues with which stakeholders (customers, clients. etc.) can engage. Such engagement tools are common in industry, and increasingly used by local and regional governments. Where entities provide a service or information that stakeholders want and/or need, engagement levels are high.

RECOMMENDATION 2.

The framework for RtoC outlined here should be used to help align the international arctic observing system and the Arctic Observing Summit (AOS) (Murray et al. 2011) with stakeholder

desired outcomes. The AOS is planned as a SAON task, with ISAC in the lead. It is intended as a biannual event that will bring together entities that collect and/or use Arctic observations, and will engage basic research and mission-oriented communities, academia, governmental and non-governmental agencies, industry and arctic stakeholders. Aligning observing activities with stakeholder desired outcomes will require advance preparation and there should be a prior and recurring process that assesses this alignment in preparation for each AOS.

RECOMMENDATION 3.

A follow-up workshop that focuses on science/stakeholder research development should take place within the next 12-16 months. Support for implementation activities like the second RtoC Workshop should enable some of these activities to be located in areas where stakeholders are immediately vested in the outcome (i.e., northern communities).

RECOMMENDATION 4.

Existing arctic research programs should consider expansion of scheduled activities to include regular participation in stakeholder driven events such as the Polar Shipping Summit, meetings of groups like the International Whaling Commission, and the Indigenous Peoples Secretariat, as well as broader engagement with other non-governmental organizations, perhaps through entities such as the Arctic NGO Forum (www.arcticngoforum.org).

RECOMMENDATION 5.

For RtoC implementation to be successful missing research capacity must be entrained. This includes more comprehensive integration of the engineering, the social science and the health sciences research communities into existing and developing arctic research programs. The interactive stakeholder engagement tool (Recommendation 1) can positively contribute towards this, as can the second RtoC workshop and other implementation activities that will be planned in conjunction with this and with the forthcoming Arctic Observing Summit.

ACTION ITEMS AND CONCLUSIONS

Workshop participants identified a series of action items designed to disseminate the results to a broad audience and to further RtoC implementation over the coming year. These include, in addition to implementation of Recommendations 1-5 above, preparation of a presentation for both the Planet Under Pressure Conference, London March 2012 and the Montreal IPY 2012 Conference: From Knowledge to Action in April 2012. The poster from the Planet Under Pressure Conference is included at the back of this report. In addition other planned dissemination material includes this workshop report, and peer-reviewed publication of the major workshop output.

Successful implementation of RtoC, especially within the context of an international program will require accountability of all actors engaged in RtoC and new institutional arrangements that can foster creativity and novel partnerships. The development of the interactive stakeholder engagement tool can be the first step in this process.

Greenland. Photo M.S. Murray

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PROGRAMS NOTED IN THE TEXT

ACCESS – Arctic Climate Change, Economy and Society www.access-eu.org

ACCESS is an European Project supported within the Ocean of Tomorrow call of the European Commission Seventh Framework Programme. The main objective is to assess climatic change impacts on marine transportation (including tourism), fisheries, marine mammals and the extraction of oil and gas in the Arctic Ocean. ACCESS is also focusing on Arctic governance and strategic policy options.

ArcticNet Network of Centres of Excellence Canada www.arcticnet.ulaval.ca

ArcticNet brings together scientists and managers in the natural, human health and social sciences with their partners from Inuit organizations, northern communities, federal and provincial agencies and the private sector to study the impacts of climate change in the coastal Canadian Arctic. The central objective of ArcticNet is to contribute to the development and dissemination of the knowledge needed to formulate adaptation strategies and national policies to help Canadians face the impacts and opportunities of climate change and globalization in the Arctic.

Arctic ROOS – Arctic Regional Ocean Observing System http://arctic-roos.org

The Arctic Regional Ocean Observing System **(**Arctic ROOS) was established by a group of 14 member institutions from nine European countries working actively with ocean observation and modeling systems for the Arctic Ocean and adjacent seas. Arctic ROOS promotes, develops and maintains operational monitoring and forecasting of ocean circulation, water masses, ocean surface conditions, sea ice and biological/chemical constituents.

DAMOCLES – Developing Arctic Modeling and Observing Capabilities for Long-term Environmental Studies www.damocles-ec.org

DAMOCLES (2007-2010) was an integrated ice-atmosphere-ocean monitoring and forecasting system designed for observing, understanding and quantifying climate changes in the Arctic. DAMOCLES was concerned with the potential for a significantly reduced sea ice cover, and the impacts this might have on the environment and on human activities, regionally and globally.

SEARCH – Study of Environmental Arctic Change www.arcus.org/search

SEARCH is a U.S. interagency system-scale, cross-disciplinary, long-term arctic research program. The core aim of SEARCH is to understand the recent and ongoing complex of interrelated pan-arctic changes. These changes are affecting ecosystems, living resources,

and the human population, and are impacting local and global economic activities. SEARCH science spans across arctic terrestrial, oceanic, atmospheric, and social systems.

QUESTIONNAIRE RESPONSES: QUESTIONS 5, 6, AND 7

Question 5. Does the term Responding to Change resonate with you, and if so, how would you define it? If not, why not?

1. "This is a challenging term because it can mean lots of things, if it is not specifically defined. It can be cut in different ways. First, we can think of Responding to Change in terms of the scientific community responding to a changing arctic with a research agenda that focuses specifically on the ways in which the Arctic is changing and what are the likely consequences of these changes. Second is the point of view of the stakeholders, but there are many of these in a variety of forms, so we need to split these out again (I can think of at least four ways). 1) We can think of Responding to Change in terms of indigenous peoples altering their lifestyles to adapt to a changing arctic environment, 2) We can think of the arctic nations (U.S., Canada, Denmark, Norway, Russia, Iceland) and how their governance, policies, and objectives will change as a result of a changing Arctic, 3) We can think of industry stakeholders, such as energy development, shipping, etc. that may need to change their operations or have new opportunities as a result of change, 4) We can think of every part of the Earth that could ultimately be affected by the changing Arctic in terms of reduced sea-ice extent, ocean circulation, sea-level rise, fisheries dynamics, tourism, charismatic megafauna, etc."

2. "The term resonates with me in a very practical way as an Arctic resident (more so than in my scientific life perhaps). The Arctic is constantly changing, not only environmentally, but socially, economically, politically and I see my community having to respond all the time. There are matters of scale, time, topic... It is not easily defined in the international environmental research context, but in my personal context, it means doing what you need to do in order to lead the life that you want to have. At the level of an individual living in an Arctic community, sometimes it comes down to just that."

3. "I strongly respect that decision support, mitigation and adaptation are viewed as relevant and legitimate lines of inquiry within environmental change research. My critique of the apparatus of Observing-Understanding-Responding is that it reads as too based in the ""pipeline"" model of scientific knowledge production and application. The validity of this model has been debunked by the Science and Technology Policy research community for decades. These analyses have demonstrated time and again that decision-making and response is rarely science-based, even when the science is well understood (references include Pielke's /Honest Broker/). In light of that, the overall apparatus of Observing-Understanding-Responding seems too coherent and idealized relative to observed behavior of agents who may or may not be influenced by improved understanding of environmental change. This framework could prove limiting. In practice, I think

of Responding to Change activities as capacity building across many sectors: bringing broader and more nuanced questions to the science community, bridging practices between science and engineering, elevating decision support, increasing resilience in at risk communities. I think the success of these activities will be best served by breaking down disciplinary boundaries and creating iterative and integrated communities of practice."

4. "Yes. Too long an answer to write here, but simple answer is doing something when faced with evidence of change. Doing 'what' is the question... in any case, important to implement approaches that are (i) based on the precautionary principle and (ii) implemented by way of an adaptive management framework."

5. "EEA is an institution which has been set up to provide policymakers and the general public a better understanding of the state of the environment as well as the changes and outlooks for the environment. Not least the changes are vital and a number of core indicators has been established in order to guide policy makers in adjusting or implementing new regulations to safeguard the environment. Fire of the EEA member countries are Arctic states, and EEA therefore has a responsibility to ensure that there is a good understanding amongst Europeans of the environmental changes occurring in the Arctic, their underlying causes and the policy changes needed to address them. This also applies to environment and health issues arising from e.g. European sources and affecting the Arctic population and the environment. A good understanding of the environmental changes, the integrated and temporal inter-linkages as well as ecosystem resilience and potential tipping points are all vital topics to master in order to give the best advice to policy makers on how to respond to change."

6. " I would define it as scenarios for how northern residents and biota may function in the face of near certain changes to the climate system. At a broader scale, I would like to think that it could encapsulate a GLOBAL response to these expected changes. This is the scale where meaningful changes can be made to help mitigate changes in climate. But in the absence of this, Adaptation is essential, and the question is "How will these adaptations occur."

7. "I think this term perfect to represent and summarize the final goal of all our efforts. To my opinion it should indicate the whole of actions that will able a sustainable economical and societal development of the Arctic, preserving as much as possible the precious and fragile Arctic ecosystem (where ecosystem include also the human element)."

8. "I would define it as scenarios for how northern residents and biota may function in the face of near certain changes to the climate system. At a broader scale, I would like to think that it could encapsulate a GLOBAL response to these expected changes. This is the scale where meaningful changes can be made to help mitigate changes in climate. But in the absence of this, Adaptation is essential, and the question is "How will these adaptations occur."

9. "I define responding to change as any human action taken in light of the recognition of anthropogenic climate change, with a recognition that such response will be done in an

environment of uncertainty both with respect to what we are responding to, and the outcome of response actions. Responses primarily take the form of reducing the magnitude of the change via greenhouse gas reductions (aka mitigation) or adaptation. Adaptation in turn can take the form of enhancing our capacity to adapt (via economic development, governance change, technological innovation, empowerment etc.) or actual adaptation implementation (the deployment of technologies, behavioural changes etc.)."

10. "Responding to Change resonates as a call for both mitigation and adaptation policies to address environmental change. Arctic environmental change will come with a social, economic, and environmental price tag for Canada, which will only increase with inaction. Mitigation policies are therefore necessary but they do not provide immediate gains, and as such, adaptation policies need also be implemented."

Question 6. What are the biggest scientific and societal challenges facing us as a result of arctic environmental change?

1.The scientific challenges are many and they are related to feedbacks. How will reduced sea-ice alter regional and global climate, ocean circulation patterns, coastal dynamics, marine productivity, marine wildlife? How will the changing arctic tundra vegetation feed back to affect regional climate, permafrost dynamics, plant-herbivore interactions? What will be the fate of permafrost and the carbon stored in frozen ground? From a societal perspective - how will indigenous people respond to changes in their subsistence environments (coastal marine-life, inland reindeer/caribou)? What will be the trajectory of oil and gas development and production throughout the Arctic? Will shipping through arctic waters become more prevalent, and what will be the consequences?

2. Rights of Arctic residents and indigenous peoples to maintain their livelihoods and lifestyles, differences in national, regional priorities (e.g. oil and gas exploration), funding and keeping Arctic science as a priority…

3. Within the Arctic, I think that globalization needs to be more strongly and explicitly integrated into this question. It feels like environmental and global change are becoming inseparable. The impact of increased activity in a fragile ecosystem is a leading concern. Examples include shipping, fishing and oil extraction. Globally, the leading concern is the impact of melting ice sheets on sea level rise and ocean circulation.

4. "Biggest scientific challenge is long-term data collection and monitoring. Efforts to collect long-term data sets via standardized monitoring are few and frequently not maintained. However, these are critical for adaptive approaches since monitoring is the key feedback into planning and decision making. Biggest societal challenge is adaptation to the change and setting into motion actions that will help in the future."

5. “At the moment most of the focus is directed at the immediate effects of climate change such as sea-level rise, coastal erosion and loss of iconic species like polar bears. But the more hidden effects like ecosystem disruption, loss of ecosystem resilience, ocean acidification, invasive species and tipping points has been less addressed by the media and policy makers. The long-term and often irreversible effects need to be explored and debated. The linkages between the Arctic and the global system, like ocean currents, heat transport, sink of pollutants and storage of GHG (methane, CO2 in permafrost and dissolved in the ocean) also needs to be understood better and the consequences explained to policymakers & public. Long term outlooks/scenarios need to be developed, not only for sea-level rise but also for potential collapse of ecosystem services. Finally security implications of climate change and access to resources are also areas which need to be addressed.”

6. “From a scientific point of view, to provide instruments suitable to realistically represent future scenarios and evaluate consequences of human actions. from a societal point of view, found way to conjugate economical development (pressure will be to strong to avoid it) and Arctic ecosystem (in the extensive sense indicated above).”

7. “Biggest scientific challenge is to both predict changes to the region in response to climate change, but also to predict how these changes will create feedback processes that further influence the climate system (and changes in this region). For society, the key is to start thinking about Adaptation (regionally) while the rest of the society tries to grapple with climate change mitigation. Climate change could drastically change the lives of those living in the north, in some cases causing known (at this time scale) ancestral traditions to no longer be viable.”

8. “To me, the biggest challenges revolve around a) adapting to climate change in light of an existing "adaptation deficit" - i.e. there is no stable baseline; b) communication of scientific information which is so overwhelmingly negative that it can introduce a defeatist stance; c) the politics surrounding self-determination, economic dependence, and attribution of climate change.”

9. “Average temperature changes, changes in biological diversity, potential security problems among states and non-state actors, increased public spending on mitigation and adaptation programs, etc.”

Question 7. What information from the scientific community would you find useful or necessary to support your activities or to support sustainable use of the Arctic (e.g. forecasts (for what), monitoring (of which parameters), analysis of system dynamics (e.g. ecosystem, physical system, commercial activities, etc.). In which form would you prefer to obtain such output (e.g. data center access, scientific papers, summaries, etc.)?

1. “This is a tough question. Much of the information that we presently have on arctic systems comes from only a few locations. I think we need a much broader monitoring network throughout

the Arctic in terms vegetation, wildlife, biodiversity, climate, carbon fluxes, water fluxes, energy budgets, etc. Scientific papers and summaries are often useful for site-specific projects, but when we get down to doing arctic-wide syntheses, data center access is crucial, but of course you can only get out what gets put in."

2. "I think it would be very useful to study to what extent agents are integrating environmental information in their decision making. To understand the overall context of decision making and how better information really impacts better decision making. I think there will be a spectrum of results ranging from "hardly at all" to "a great deal"". An example is the case of oil extraction. Given such a high profit, high risk industry, to what extent will scientific information hold sway over other factors. Versus the case of sea ice forecasts and shipping traffic."

3. "The IPY provided – and still provides - a lot of new and useful information. In my view however, there is a need to continue more long-term observation/monitoring of key indicators/parameters and not to spread ourselves (funders) to wide in new areas. Although new research/science is continuously needed to identify knowledge gaps, more long-term observations are required to confirm trends and changes in the Arctic. More and better use of remote sensing is also called for. Better coordination of efforts through observation networks or funding strategies can also help minimise overlap and more efficient use of resources/efforts. Merging information/data from various sources into a few hubs is also needed to give a better overview of the arctic information available (e.g. the Eye on Earth platform in EEA). Access to information gathered by industry (shipping or oil/gas companies) would also be useful. Use of traditional knowledge and community based monitoring would also need to be 'harvested' in the current financial climate where 'new' money is less likely to be spent on arctic research/monitoring."

4. I think there is a TREMENDOUS need for a coordinated monitoring effort in the Arctic, PARTICULARLY in the vast regions of Canadian and Eurasian Arctic. There is also a tremendous need to both expand and better integrate the scientific community. So little research has been done in these areas (above) compared to parts of Alaska – it is not clear that what we know about the Arctic based on Alaskan research applies to the broader Arctic or not. There is a need to try and better integrate site-specific work with both modeling and remote sensing to scale up results both in space and time. This is the only way we can start to make forecasts for the future. To go along with this effort, there needs to be a better network of routine (i.e. meteorological data) data collection to support modeling efforts. If a systematic data collection/modeling effort could be deployed at a range of sites (similar to what ITEX has done), it would provide invaluable data from which to both develop and test process-based models. These models can be used both to forecast climate impacts, but also to predict future changes in climate based on the development of biogeochemical feedbacks. Monitoring efforts also need to be sustained for longer time periods. I think the ITEX network has started to demonstrate the time scales over which SOME vegetation changes are likely to occur. There needs to be at least a 20-year time horizon for any monitoring

efforts. If this workshop (and others) can help to create this sort of integrate effort, it would have tremendous value!!"

5. ""I think the science itself is excellent, and the only aspect that is lacking is a plan for communication which builds cooperation among relevant stakeholders.

WORKSHOP PARTICPANTS

Nikolaj Bock
European Environment Agency
Kongens Nytorv 6, 1050 Copenhagen K,
Denmark
Email: Nikolaj.bock@eea.europa.eu
Web: www.eea.europe.eu

Hajo Eicken
Geophysical Institute
University of Alaska Fairbanks
P.O. Box 757320,
Fairbanks, AK, 99775-7320, USA
Email: hajo.eicken@gi.alaska.edu
Web:
www.seaice.alaska.edu/gi/people/eicken

Howard Epstein
Department of Environmental Sciences,
University of Virginia, Clark Hall 291
McCormick Road P.O. Box
400123 Charlottesville, VA 22904-4123, USA
Email: hee2b@virginia.edu
Web: www.evsc.virginia.edu/faculty/epstein-howard-e/

Birgitta Evengård,
Departments of Clinical Microbiology and Infectious Diseases, Umeå University
SE-901 85 Umeå, Sweden
Email: Birgitta.Evengard@climi.umu.se
Web:
www.inchr.com/researcher%20Evengard.html

Shari Gearheard
National Snow and Ice Data Center
Cooperative Institute for Research in Environmental Sciences
University of Colorado at Boulder
P.O. Box 241 Clyde River, Nunavut, X0A 0E0
Canada
Email: shari.gearheard@nsidc.org
Web: http://nsidc.org

S. Craig Gerlach
Center for Cross Cultural Studies
University of Alaska Fairbanks
124 Bunnell, P.O. Box 756730
Fairbanks, AK 99775-6730, USA
Email: sgerlach@alaska.edu

Sari Graben
School of Policy Studies
Robert Sutherland Hall 138 Union Street,
Room 217
Queen's University,
Kingston, Ontario, K7L 3N6, Canada
Email: sari.graben@queensu.ca
Web:
www.queensu.ca/sps/facultyresearch/postdoctoralfellows/grabens.html

Bryan Grimwood
Department of Recreation and Leisure Studies
Burt Matthews Hall
University of Waterloo
200 University Ave. W.
Waterloo ON N2L 3G1, Canada
Email: bgrimwood@uwaterloo.ca
Web:
www.ahs.uwaterloo.ca/rec/research/facbio.html#grimwood

Cedric Juillet
Department of Environmental Resource Studies and Sciences
1600 West Bank Drive
Trent University,
Peterborough, ON K9J 7B8, Canada
Email: cedric.juillet@gmail.com

Michael Karcher
O.A.Sys - Ocean Atmosphere Systems GmbH,
Lerchenstrasse 28a, 22767 Hamburg,
Germany
Email: michael@oasys-research.de
Web: www.oasys-research.de

Daniele Labonte
School of Policy Studies
Robert Sutherland Hall 138 Union Street,
Room 217, Queen's University,
Kingston, Ontario, K7L 3N6, Canada
Email: labonted@queensu.ca
Web IPY 2012:
www.ipy2012montreal.ca/index.php

Melissa Lafreniere
Department of Geography
Mackintosh-Corry Hall, Room D201
Kingston, Ontario, K7L 3N6, Canada
Email: melissa.lafreniere@queensu.ca
Web: geog.queensu.ca/faculty/lafreniere.asp

Donald McLennan
Parks Canada Agency/Agence Parcs Canada
National Monitoring Biologist/Biologiste
Surveillance Nationale
25 Eddy St (25-S-4), Hull, Quebec, K1A 0M5,
Canada
Email: donald.mclennan@pc.gc.ca

Maribeth S. Murray
International Arctic Research Center
930 Koyukuk Drive
PO 757340, University of Alaska Fairbanks,
Fairbanks, Alaska, 99775-7340, USA
Email: msmurray@alaska.edu
Email: murray@arcticchange.org
Web: www.arcticchange.org

Heather Nicol
Department of Geography
1600 West Bank Drive
Trent University
Peterborough, Ontario, K9J 7B8, Canada
Email: heathernicol@trentu.ca
Web:
www.trentu.ca/geography/faculty_nicol.php

Karen Pletnikoff
Community Services Department
Aleutian/Pribilof Islands Association, Inc.
1131 East International Airport Road
Anchorage, AK 99518, USA
Email: karenp@apiai.org

Peter Schlosser
The Earth Institute,
Columbia University 405 Low Library,
MC 4335 535 West 116th Street
New York, NY 10027, USA
Email: schlosser@ldeo.columbia.edu
Web:
www.earth.columbia.edu/articles/view/2253

Neil Scott
Department of Geography,
Mackintosh-Corry Hall, Room D201
Kingston, Ontario, K7L 3N6, Canada
Email: scottn@queensu.ca
Web: www.geog.queens.ca/fabrecc

Martin Sommerkorn
WWF Global Arctic Program
P.O. Box 6784, St. Olavs Plass, 0130 Oslo,
Norway
Email: msommerkorn@wwf.no
Web: www.panda.org/arctic

Sandy Starkweather
Earth System Research Laboratory
National Oceanic and Atmospheric
Administration (NOAA)
325 Broadway Boulder, CO 80305, USA
Email: sandy.starkweather@noaa.gov
Web:
http://sciencepolicy.colorado.edu/stcert/students/sandra_starkweather/index.html

Mark Vardy
Department of Sociology
D431 Mackintosh-Corry
Queen's University
Kingston, Ontario, K7L 3N6, Canada
Email: mark.vardy@queensu.ca
Web:
www.queensu.ca/sociology/people/graduatestudents/phdstudents/vardy.html

Vito Vitale
Institute of Atmospheric Sciences and Climate (ISAC)
National Research Council
Via Gobetti 101, 40129 Bologna, ItalyEmail: v.vitale@isac.cnr.it
Web: www.isac.cnr.it/~radiclim/

Ioan Wagner
Department of Geography
Queen's University
Mackintosh-Corry Hall, Room D201
Kingston, Ontario, K7L 3N6, Canada
Email: wagneri@queensu.ca
Web:
http://geog.queensu.ca/faculty/Wagner.asp

Johanna Wandel
Department of Geography and Environmental Management
Environment Building 1, Room 105
University of Waterloo
200 University Avenue West Waterloo, Ontario, N2L 3G1, Canada
Email: jwandel@uwaterloo.ca
Web:www.ic3.uwaterloo.ca/cms/en/faculty/JohannaWandel.aspx

PLANET UNDER PRESSURE CONFERENCE – RTOC POSTER

Science for Society in the Arctic and Beyond

Responding to Arctic Environmental Change

Maribeth S. Murray[1] (msmurray@alaska.edu) , Hajo Eicken[2] Nicolaj Bock[3], Howard Epstein[4] Birgitta Evengård[5], Shari Gearheard[6] S. Craig Gerlach[7] Sari Graben[8], Bryan Grimwood[9], Cedric Juillet[10], Michael Karcher[11], Danièle Laberte[6] Donald McLennan[12], Karen Pletnikoff[13], Peter Schlosser[14], Neil Scott[15], Martin Sommerkorn[16], Sandy Starkweather[17] ,Mark Vardy[18], Vito Vitale[19], Ioan Wagner[15] and Johanna Wendel[20]

[1]International Arctic Research Center and Northern Studies Program, University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA, [2]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, USA, [3]European Environment Agency, Copenhagen, Denmark, [4]Dept. of Environmental Sciences, University of Virginia, USA, [5]Depts. of Clinical Microbiology and Infectious Diseases, Umeå University, Sweden, [6]National Snow and Ice Data Center, CIRES, University of Colorado at Boulder, USA, [7]Center for Cross Cultural Studies, University of Alaska Fairbanks, USA [8]School of Policy Studies, Queen's University, Canada, [9]Dept. of Recreation and Leisure Studies, University of Waterloo, Canada, [10]Association of Polar Early Career Scientists (APECS), [11]U.A.Eye – Ocean Atmosphere Systems GmbH, Hamburg, Germany, [12]Parks Canada Agency/Agence Parcs Canada, Canada, [13]Community Services Deptt., Aleutian/Pribilof Islands Assoc., Anchorage, USA, [14]The Earth Institute, Columbia University, USA, [15]Dept. of Geography, Queens University, Canada,[16]WWF Global Arctic Program, Oslo, Norway, [17]Center for Science and Technology Policy Research, CIRES, University of Colorado Boulder, USA, [18]Dept. of Sociology, Queen's University, Canada, [19]Institute of Atmospheric Sciences and Climate (ISAC), National Research Council of Italy, Italy, [20]Dept. of Geography and Environmental Management, University of Waterloo, Canada

INTRODUCTION

What does responding to environmental change (RtoC) in the Arctic really mean? Is it the human response to change or is it more broadly defined as the response(s) of all Arctic System components? There is no agreement, yet there is recognition that the scientific community should provide information useful for a wide range of needs. Alignment among science and stakeholder research priorities is needed but absent a framework for defining and addressing these, and for addressing emerging issues, collaboration is slow coming to fruition. Here, we report on recent efforts to address the following questions:

Q1. What is meant by responding to arctic environmental change? **Q2.** What research questions align with stakeholder needs for information? Which are tractable in the short term and which can be addressed over the longer term? **Q3.** How well do established arctic research initiatives align with stakeholder needs for information; how can this be improved? **Q4.** What is needed to advance science/stakeholder partnerships and to improve communication among these diverse communities?

Responding to Change

Figure 1. Given the dynamic nature of the arctic system[c] RtoC means actors[a] jointly developing an iterative and integrative process[c] and tools[d] for responding to change[e].

A working definition of RtoC is important to the identification of relevant research questions and to a research agenda that fosters partnerships between stakeholders and scientific programs.

A RtoC research program should address questions that achieve a balance between the scientific motivation to understand the fundamental behavior of the Arctic System and stakeholder concerns (Stokes 1997).

A workable definition of RtoC will enable alignment of ongoing research activities with diverse needs for information. This requires agreement and understanding as to what data and information are of the greatest mutual value for science and for society.

Beyond Ecosystem Services

RtoC encompasses a consideration of who is responding to what, when and where, why and how. Stakeholder needs extend beyond those of the scientific community and in this instance refer to specific services or benefits that groups derive from the Arctic. We conceive of these as Arctic System Services – this concept both encompasses the more familiar ecosystem services (MEA 2005), and transcends it, incorporating as it does, the services provided by all components of the arctic system, including the human component.

The Arctic System comprises all of the Arctic land surface, ice, oceans, atmosphere, and its people, and all of the physical, chemical, biological, and social interactions and controls (Murray et al 2010), and the services provided. It is a regional component in, and an integral part of the Earth System.

Figure 2. One view of the Arctic System and some ecosystem and human services (HARC 2007), or Arctic System Services.

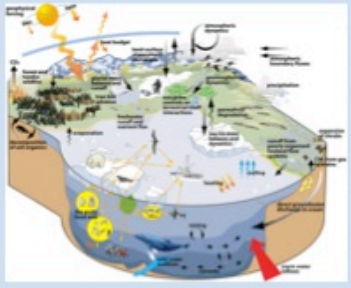

Figure 3. The Arctic System here is represented by a complex network of process interactions, interdependent feedbacks and dramatic thresholds (Study of Environmental Change [SEARCH, 2005]).

This schematic demonstrates the interconnections among components and emphasizes that changes in one component may influence numerous other parts of the system. Importantly, it leaves out the human component – integration of the human component into system analysis remains problematic.

Dual Purpose Science and Desired Outcomes

The concept of Arctic System Services builds on work that has cast specific research questions in terms of how interactions between any set of components (physical, biological chemical or human) of the arctic system provide services to stakeholders. This is schematically outlined in Figure 4 which illustrates how the concept informs research and learning approaches not how the arctic system functions in and of itself (shown in Figure 3). This distinction is important as the question of the nature and behavior of the arctic system is still very much a focus of emerging research (Overpeck et al. 2005, Huntington et al. 2007, Murray et al. 2010).

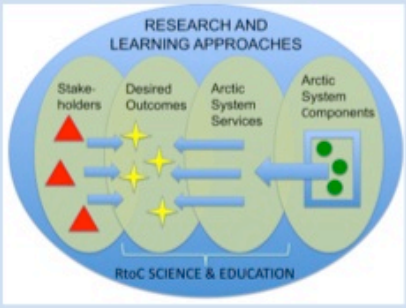

Figure 4. Schematic representation of a reference framework for research and learning approaches related to RtoC. This diagram illustrates how specific arctic system components and processes, associated with variables that relate to the state and dynamics of the system, translate into specific Arctic System Services of interest to stakeholders. Such services are key in assessing or shaping outcomes seen as desirable by different stakeholder groups. In this sense, the realms of desired outcomes and arctic system services bridge stakeholders and broader, fundamental scientific research interests.

CONCLUSIONS

The conceptual framework shown in Figure 4 describes a major challenge that research and mutual learning in a RtoC context can help overcome. Most stakeholder groups are two steps removed from any research pertaining to improved understanding of the arctic system and its change over time. Equally, many scientists are two steps removed from desired outcomes. Resolving the separation and differences between classic earth system science/social science and the questions and focused information needs underlying stakeholder concerns requires innovative approaches that will promote dual-purpose, use inspired research capable of meeting the challenges of a changing arctic.

Identification and development of commonalities requires joint assessments of information needs and existing programs. Central is the need to identify specific processes and mechanisms through which Arctic System Services link the system itself to desired outcomes determined by stakeholders. Here desired outcomes refer to ways in which stakeholders can take advantage of present and future opportunities and overcome challenges. RtoC science and education are two bridging elements enabling stakeholders to connect to and impact research on improved understanding of the Arctic System and its components. Given the rapid pace of change in the Arctic and its regional and global repercussions, implementation of RtoC activities is clearly urgent.

THE INTERNATIONAL STUDY OF ARCTIC CHANGE www.arcticchange.org

The International Study of Arctic Change is an open ended, international, interdisciplinary arctic environmental change research program. ISAC encompasses pan-Arctic, system-scale, multidisciplinary observations, synthesis and modeling to provide an integrated understanding of arctic change and projections of future change. The ISAC Science Plan (Murray et al. 2010) provides a vision for integrating research among diverse fields and varied users and stakeholders while outlining a framework for collaborative, international, and interdisciplinary research on the Arctic System. This program of research is framed with respect to observing, understanding and responding to environmental change in the arctic, with RtoC driving program ambitions.

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