

Arctic Forum

Abstracts 2008

Tipping Points: The Arctic and Global Change



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Cover Photo: Telephone line and pole damage caused by melting permafrost near Barrow, Alaska, observed by Teachers and Researchers Exploring and Collaborating (TREC) teacher Misty Nikula (2004). Photo by Misty Nikula.

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Foreword

Sponsored by the National Science Foundation (NSF) and hosted by the Arctic Research Consortium of the U.S. (ARCUS), the Arctic Forum serves as an opportunity for community planning, collaboration, education, and outreach. The Forum is held in conjunction with the ARCUS Annual Meeting and gathers members of the arctic research community, key agency personnel, policy makers, educators, students, media, and the public in one of few interdisciplinary meetings focused on the Arctic. The Forum includes poster and paper sessions on a diverse array of topics in arctic science and offers scientists, students, the media, and the public an opportunity to discuss important science, policy, and education issues in a collaborative environment.

Now in its 14th year, the Arctic Forum continues to serve the community. The *Arctic Forum Abstracts* have been published by ARCUS since 1998; this publication marks the 11th edition. This year's meeting, "Tipping Points—The Arctic and Global Change," was held 13–15 May 2008, at the National Association of Home Builders, in Washington, DC. The prevailing discussion at this year's Forum was the rapidly changing Arctic. The leading concern voiced by Arctic Forum participants was how to successfully educate policy makers and the public at large about problems

and possible mitigation techniques brought on by global change. This edition of *Arctic Forum Abstracts* illustrates the nature of change occurring across the Arctic and the problems that scientists, policy makers, and the public face. Included are abstracts from the opening reception, hosted by the Finnish Embassy, a Congressional briefing, and a position paper by student scholarship winners.

As executive director of ARCUS, I appreciate the efforts of the many experts who shared their work, thoughts, and concerns with the community at the Arctic Forum. We thank Craig Fleener and Martin Miles for co-chairing the Forum, ARCUS staff members for managing the meeting, NSF for support, and the Finnish Embassy for hosting the reception. Alysa J. K. Loring, of ARCUS, was the managing editor for this abstract volume.



Wendy K. Warnick
Executive Director

Introduction

Tipping Points: The Arctic and Global Change

*Martin Miles, Environmental Systems Analysis Research Center
Craig Fleener, Gwich'in Council International (Arctic Forum Co-Chairs)*

The interconnectedness of the Arctic is demonstrated when a single change sends ripple effects throughout the arctic marine, terrestrial, atmospheric, socioeconomic, and global systems. Changes in arctic conditions present a number of problems for arctic life—wildlife, plant life, and socio-economic life. Although these problems immediately affect the Arctic, the complications are also bleeding over into the sub-arctic and farther south in ways not fully understood. In considering these problems, it is important to strengthen the bonds between education, research, indigenous cultures, and policy—we cannot hope to succeed if we do not work together. Better information-sharing structures need to be created, both to prevent duplication and to encourage collaboration. Everyone must be involved—educators, the media, the New York cabbie, the German farmer, the Russian coal-miner, and the Saami reindeer herder. If we as scientists are the only ones talking about the problems today, we will be the only ones talking about it tomorrow.

This year's Forum sessions included a diverse and international range of perspectives on gaps in our understanding, research priorities, and outreach priorities. Presentations and discussions focused on three thematic questions:

- How is climate change affecting the arctic environment?
- Do these changes represent tipping points to a new state of the arctic system?
- What are the possible future scenarios and connections to the globe?

Participants addressed these questions in a combination of plenary and poster presentations as well as moderated panel discussions. This volume of abstracts illustrates the interconnected nature of changes happening in the arctic system and points to these as possible “tipping points” that represent new, unknown, and potentially irreversible vanguards of arctic and global change. The abstracts underscore the importance of working collaboratively and enhancing education and outreach.

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Presentation Abstracts

Council Forum Roundtable Discussion: New Paradigms in Polar Research— Recommendations for Member Institution Actions to Overcome Obstacles to Interdisciplinary and International Research

Moderator: Vera Alexander, University of Alaska Fairbanks

Panelists: Jenny Baeseman; Lawson Brigham; Bruce C. Forbes; and Sean Topkok

In recent years, polar science has advanced beyond traditional, disciplinary-based research. Today's critical problems, like global climate change, require approaches that transcend disciplinary, geographic, and cultural boundaries to address system-level science. The Arctic is a truly multi-national arena and the science recognizes no borders. The challenges and barriers to successful international and interdisciplinary research have been discussed in numerous research community venues. These challenges range from individual researcher barriers (e.g., finding collaborators outside a discipline, publishing interdisciplinary papers in traditional journals, etc.) to national barriers (e.g., limited funding for international projects, governmental restrictions on multi-lateral collaborations, etc.).

As the accumulation of environmental, cultural, and economic changes cascade throughout the polar and global systems,

scientific research must change rapidly in order to address questions and challenges never before encountered—a paradigm shift is needed that exceeds the responsive capability of institutions and the scientific culture.

This roundtable discussion will focus on the institutional level (universities, research institutes, etc.) and will address the question, "How can our scientific institutions meet the challenge of supporting international and interdisciplinary research and invigorate research with new perspectives, approaches, and methods?" Short panel presentations and discussion amongst Council Forum participants will result in recommendations to ARCUS Member Institutions for realistic approaches to meet the challenge of these new paradigms in polar research.

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Arctic Climate Change: Where Reality Exceeds Expectations

Mark C. Serreze, University of Colorado Boulder (Keynote Speaker)

It was probably around the year 2000 when it became clear that the changes unfolding in the Arctic were too persistent and coherent among different parts of the system to be dismissed as natural climate fluctuations. The issue today is coming to grips with the rapidity of change. In many ways, it seems that reality has exceeded expectations, and that our vision of the Arctic's future is already upon us.

The most visually striking evidence of rapid change is the Arctic's shrinking sea ice cover. While climate models tell us that sea ice extent should already be declining in response to greenhouse gas loading, observed trends

are much steeper—we are perhaps 30 years ahead of schedule. Climate models also tell us that largely as a result of sea ice loss, arctic warming will be outsized compared to the rest of the Northern Hemisphere. This so-called arctic amplification, however, is already here and is growing. Permafrost is warming then thawing, and the Greenland Ice Sheet is stirring in ways quite unexpected ten years ago, with disturbing implications for sea level rise. Why is the Arctic changing so rapidly? What are the missing pieces of the puzzle? Are there potential tipping points in the arctic system? Have we already reached some?

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Arctic Sea Ice Now and in the Future

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In summer 2007, the arctic sea ice extent shrank by more than one and a half million km². Compared to sea ice conditions in the 1950s to 1970s, this loss represented a 50% reduction in the area of the Arctic Ocean covered by sea ice at the end of the melt season. The cause for decline appeared to be largely driven by a thin ice pack that decayed rapidly in response to the anomalously warm, sunny, and windy summer.

Climate model simulations have long predicted complete loss of the arctic summer ice cover with continued greenhouse gas emissions. An alarming result from simulations of the National Center for Atmospheric Research's Community Climate System Model

version 3 (NCAR CCSM3) is the possibility that once the ice pack thins sufficiently, natural variability could trigger abrupt ice loss. Estimates of ice thickness from the ICESat GLAS laser altimeter instrument indicate that the arctic ice is currently as thin (or thinner) as ice thickness distributions in NCAR CCSM3 simulations prior to these abrupt ice loss events in the model runs, raising concern that the Arctic may be on the verge of a rapid transition towards nearly ice-free arctic summers, possibly within a decade. Following the record ice losses in September 2007, the 2008 spring ice cover suggests the Arctic is vulnerable to yet another dramatic ice loss this summer.

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Marine Mammals and Diminishing Ice: Slow Science on a Faster Earth

Brendan P. Kelly, National Science Foundation

Continent-sized expanses of sea ice have structured marine mammal populations by adding three-dimensional complexity to the environment, providing refugia from predation, and erecting barriers to gene flow. Cetaceans and pinnipeds have adapted to specialized niches in seasonal sea ice, and the latter have achieved their greatest diversity in polar seas.

Adaptive responses to loss of sea ice will be limited by the rapid pace of that change relative to long generation times. Refuge from predation will diminish. Gene flow will increase within and between taxa and may lead to species loss through introgressive hybridization.

Recent advances in understanding the ecology and genetic structure of these populations are rapidly being overtaken by environmental change. The non-hierarchical structure of the research community maximizes productivity over long periods, but may be ineffective on short time scales. The pace at which scientific understanding translates into management practices also lags. The disparity between the pace of environmental change and the pace of societal responses adds potency to the sense that “the Earth is faster” now.

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Climate Change and Marine Mammal Conservation Policy

Timothy J. Ragen, Marine Mammal Commission

A tipping point can occur when the rate of change in one factor varies depending on a second, related factor. Although they can be defined in esoteric, mathematical terms, tipping points are common in virtually all aspects of our lives. Climate change can be viewed as a phenomenon with at least five major related elements (physical/chemical changes, biological/ecological changes, conservation law and policy, socioeconomic policy, and societal behavior), each of which is replete with relationships that contain tipping points.

With regard to marine mammal conservation and policy, perhaps the most important tipping point hinges on the goal set forth in the Marine Mammal Protection Act.

The primary objective of the Act with respect to marine mammal management is to “maintain the health and stability of the marine ecosystem.” Whether and to what extent we do so is entirely dependent upon our willingness to commit to that goal and act accordingly. We are teetering on the edge of abandonment of that goal. Should we choose to do so, our actions will lead to a devastating tipping point in the conservation of marine mammals. Avoiding such calamity will require re-examination of societal values and, indeed, ourselves as part of the natural world. Avoiding such calamity will require a clearer vision of the world we wish to pass to our children and grandchildren.

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Arctic Ocean Acidification: A Contemporary and Future View of Changes to the Marine Carbon Dioxide System

Richard G. J. Bellerby, University of Bergen

The oceanic inorganic carbon content is increasing due to partial equilibration with the anthropogenic increase in atmospheric carbon dioxide. Due to the slow turnover of the ocean, the greatest changes to marine carbonate chemistry are presently seen in the productive surface ocean. The high latitudes are regions with the greatest connectivity between the surface and intermediate-to-deep oceans and are thus sites where anthropogenic carbon is removed most effectively from the surface. They are also areas that are predicted to undergo the earliest and greatest changes to the carbonate system with the potential to modify ecological systems with associated climate feedbacks.

We have studied the processes conditioning the carbon biogeochemistry of the surface and intermediate waters of the Nordic and

Barents Seas. We will show the rates and regionality of anthropogenic carbon increases and ocean acidification determined from direct observations and data-based methods. We will also discuss future changes in arctic and North Atlantic acidification, derived from both simple ocean and more complex physical-biological coupled ecosystem models, providing tipping point predictions for selected ecosystems and species. These will be related to recent results from deliberate nutrient and carbon dioxide manipulation experiments on marine pelagic ecosystems and discussed with respect to potential future climate feedbacks from changes in carbon biogeochemistry.

Changes in Terrestrial Ecosystems in Response to a Decade of Warming

Mads C. Forchhammer, University of Aarhus

Over the past decade, pronounced and unprecedented changes in spring snow melt and summer temperature have been recorded in the high arctic ecosystem of Zackenberg, Northeast Greenland. In response, plants, insects, and birds displayed considerable plasticity in the annual timing of reproduction. On average, flowering of plants, emerging of insects, and birds' egg-laying advanced 14.6 days since 1995. However, there was considerable spatial variability in phenotypic plasticity within species, as well as between species. Diversity in the response to climate increased the complexity in community dynamics, suggesting increased vulnerability of consumer-resource dynamics to climate change. This example from Zackenberg is presented in the context of recently observed changes through the arctic terrestrial ecosystems.

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Panel Discussion: Environmental Tipping Points

Moderator: Joshua Schimel, University of California Santa Barbara

Panel Members: Caspar Ammann; Craig Fleener; Maribeth S. Murray; and Martin Sommerkorn

Moderated by Joshua Schimel, this panel presented various perspectives on tipping points—paleoecological, terrestrial, and socio-economic.

Serious questions face the science community as change in the Arctic becomes more dramatic and the public becomes more concerned and aware. Together, this panel raised some concerns on which the entire science community must reflect and consider in their research.

Short presentations from each panelist were followed by community discussion. Several important points were raised:

- Education needs to happen not only with students, but with colleagues, as well.
- It would behoove the science community to be policy prescriptive—the link between science and policy cannot be avoided.

- There is still some anxiety about getting into the area of applied work; researchers need to be able to get credit for doing “non-research” work, and interdisciplinary ties need to be strengthened.
- Unless a New York cab driver cares about climate change, there are not going to be any changes in policy.
- How are changes in climate going to affect people’s health? Maybe this is one way to get the general public and policy makers to care.
- One major problem is that the science community lets the media describe climate change—scientists need to be more active and vocal about what is known and what changes might come.

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- The science community should offer solutions as well as identify the problems.
- Does it make sense to manage for sustainability? How can policy changes be achieved? Scientists need to move toward managing for resilience rather than sustainability. The survival of the entire system needs to be ensured, rather than one perturbation of it.
- Education and communication are vital keys; if the science community is the only one talking about climate change today, they will be the only ones talking about it in the future, as well.

As illustrated by various presentations throughout the day, many agree that arctic change is happening, it is rapid, and it is dramatic. Scientists need to reach their *own* tipping point—to become vocal about what they observe happening, what they think the potential repercussions will be, and how they see possible solutions for mitigation. As scientists move forward with new research, it is crucial that these thoughts begin to play key roles in their research designs.

Well Adapted But Still Extinct: Norse Greenland in New Perspective

Thomas H. McGovern, City University of New York; Andrew P. Dugmore; Christian Keller; and Konrad Smiarowski

The end of the Norse Greenland settlement is widely associated with the climate changes of the “Little Ice Age,” environmental destruction, and an inability to adapt. However, new evidence presents a picture of Norse sustainable resource use and successful adaptation to climate change—successful adaptation, which may have become part of the long-term problem. Settlement choices made during the initial Norse colonization and settlement of Greenland, followed by a rising level of connection, intensification, and investment in fixed resource spaces, and social and material infrastructure, increased the effectiveness of adaptation but at a cost of reduced resilience in the face of variation. When confronted by rapid, natural, and cultural changes in the 14th century, Norse society in Greenland had to

choose between well-integrated, socially buffered, and well proven stability and chancy and socially expensive paths toward resilience. Their choice was both totally reasonable and completely fatal.

Norse Greenland is not a case of simple failure of adaptation or poor management of resources and available labor (Diamond 2005), but a case far more disturbing in a modern context. It is possible to creatively adapt to new environments, build up centuries of community-based managerial expertise, wisely conserve fragile resources for communal benefit, codify the results, maintain century-scale sustainable patterns of life and society—and yet still face ultimate collapse and extinction.

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Arctic Health and a Changing Physical Environment: New Perspectives on Increased UVB, Ozone Depletion, and Increased Warming

Edward C. De Fabo, George Washington University

Global climate change has two major components: global warming and stratospheric ozone depletion (SOD). While most current interest is on global warming the polar environments are also very sensitive to changes in SOD, more so than other regions. A common perception is that stratospheric ozone depletion is no longer a climate change problem. Evidence contradicting this is given by the appearance of the largest ozone “hole” to date in the Antarctic (winter 2006) and the fact that the Arctic has also experienced ozone depletion, though not to the same extent. The health concerns surrounding SOD are based on the physical fact that directly associated with ozone depletion is an increase in biologically damaging UVB radiation (290–320 nm). Consequently, human health effects associated with UVB radiation are at an increased

risk. The most well-known of these are skin cancers and eye cataracts. Less well known, however, are health effects associated with UVB-induced systemic immune suppression, such as loss of control on skin cancer development and independence to pigmentation.

This talk will focus on the role of UVB radiation in such health effects. While skin cancer in the indigenous population of the Arctic is not common at present, with regard to a “tipping point,” one might ask if this low incidence could change given increased UVB associated with ozone depletion. This question takes on greater significance given our recent experimental data showing that pigment appears to play a role in cutaneous malignant melanoma development. These and other effects will be discussed.

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Coming to Terms with the Future of Northern Food Systems

S. Craig Gerlach, University of Alaska Fairbanks; Philip A. Loring; and Tom Paragi

Alaska's communities, both rural and urban, are engaged in times of rapid social and ecological change, with changes driven by both extreme events (rapid change) and by cumulative effects (gradual change). The state is experiencing dramatic economic, cultural, and demographic restructuring. In a global context of rising food and fuel prices, the costs of living in "bush Alaska" are on the rise and rural-to-urban migration is undermining community stability and health. In this paper we use the Alaska food system as a framework for linking agents of change to impacts through downscale feedbacks and interactions. We also consider tipping points in terms of how the human dimension is responding to change through a balance of tradition and food system innovation.

The Alaska food system is strongly connected to climate, weather, ecosystems, cultures and economic systems, with complex and multifaceted responses to change in each dimension. Food choices are shaped by cultural preference and availability and by ecological opportunities and constraints. Social, political, and economic forces, often with origins mostly

outside of the state, largely determine which foods appear on the shelves of commercial stores and how much they cost, with diet-related health outcomes clearly linked to food choice and availability. Thus, Alaska's food links households, communities, and regional economies to larger economic and ecological landscapes through an array of functional connections and dependencies. Rural Alaska is linked to urban centers, which themselves are linked to the global marketplace through the distribution of food, fuel, and other commodities.

In this presentation we discuss the harvest of traditional foods, but expand beyond the narrow definition of subsistence to discuss the whole rural Alaska food system through examples from the Yukon and Tanana River watersheds. Country, or wild, food harvest opportunities are constrained today by climate related changes in seasonality, by lag time in response of federal and state regulatory frameworks to rapid social and ecological change, by a lack of public services, industrial and manufacturing infrastructure in many communities, and by the rising cost of

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transportation, food, and fuel. Food choice reflects availability and access, level of knowledge about the health benefits, and risks of nutritionally high and low quality foods, by an interest in where food is harvested or produced, and by intergenerational transfer of knowledge about the same. Through design or expedience, food choice also reflects the extent to which individuals and communities have personal and financial control over what they eat. Because local, regional, and global food systems are situated in social, cultural, economic, historical, political, and nutritional contexts, food system feedbacks and interactions influence community viability through diet and health. Where rural food systems depend heavily on external inputs for a secure food supply, described through an axis of vulnerability, or “over-connection,” of the rural to the urban, they are vulnerable to even the smallest changes in climate, weather, economics, transportation, and energy costs.

Local Opportunities and Challenges from Arctic Climate Change: A Saami Perspective

Rune Fjellheim, Arctic Council Indigenous People's Secretariat

The Saami, like other indigenous arctic groups, are confronting difficult challenges in the face of climate change. A main conclusion of the Arctic Climate Impact Assessment (ACIA) was that a warming Arctic is a more accessible Arctic. Yet, while it may be true that the Arctic holds substantial resources in energy, minerals, fishing, and forestry, access to these resources creates a significant strain on indigenous people. This talk will contextualize a specific challenge faced by Saami reindeer herders (rain) and will identify the biggest fear Saami people have in the face of climate change (that they will lose access to their lands).

As the climate warms, Saami reindeer herders are beginning to experience a new weather feature in the December, January, and February months—rain. On the surface, this may not seem like a problem, but, in fact, it creates several potentially disastrous issues for indigenous reindeer herders. Rain creates thick layers of ice on the ground, making it impossible for reindeer to reach plants for grazing. In addition, the warmer conditions inhibit strong ice development on lakes. As lake ice becomes less stable, the people and herds migrating across them are placed in danger. New scientific projections forecast

that rain and thinning lake ice will be more prominent at least one-third of the time in the future during these months. Consequently, it is becoming necessary for people to reevaluate their lifestyles and economic dependencies. Although poverty levels in the Arctic are high, the Arctic is not a poor area. On the contrary, it is a very wealthy region. The Arctic has abundant resources in energy, minerals, forestry, and fishing and is a substantial contributor to the world market. A serious concern of the Saami people, however, is that most of these resources exist on their lands. The Saami face many challenges in climate change, but they will adapt; nevertheless, the people are scared of the link between climate change and mitigation policies. Indigenous peoples want and need to be part of the process for finding solutions. They do not want to be part of the problem because climate change is greatly affecting them, as well. At the same time, however, they want to maintain sovereignty over their lands. Because the search for new energy solutions (hydroelectric, wind power, biofuel, and uranium) is so closely linked to the resources on Saami land, it is fundamental that governments include indigenous peoples in their quest for climate change mitigation.

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Future Marine Transportation in the Russian Maritime Arctic

Lawson W. Brigham, U.S. Arctic Research Commission

The Russian maritime Arctic includes the Barents Sea region and the Northern Sea Route (NSR) stretching from Kara Gate to Bering Strait. During the Soviet era, a huge fleet of icebreakers and icebreaking cargo carriers were built to service the entire Russian Arctic and to provide visible, sustained marine presence in this remote region of the globe. This extraordinary fleet of polar ships—some nuclear-powered—and remarkable ice navigation skills allowed the establishment of year-round navigation in 1978–79 to the port of Dudinka on the Yenisey River. The Noril'sk Nickel complex (serviced by Dudinka), the world's largest copper and nickel producer, is currently developing a fleet of icebreaking cargo carriers to maintain year-round navigation between Dudinka and Murmansk without icebreaker convoy support. Russian-flag icebreaking carriers are being built for service in the Barents and Pechora seas and in support of offshore gas development; this shuttle tanker system is soon to operate year-round between the Pechora Sea and Murmansk.

Additionally, the management of the Russian nuclear icebreaking fleet appears to be changing from the Murmansk Shipping Com-

pany (operator of these ships for 40 years) to Rosatom, the large Russian nuclear power company. How this decision will affect the use of the nuclear ships on tourist voyages to the North Pole and central Arctic Ocean, and their use in convoying, remains uncertain.

The challenges for Russia's future use of the length of the NSR remain significant: status and future investment in marine infrastructure, restructuring of NSR tariffs and navigation rules, continued arctic ship technological developments and movement to independent icebreaking carriers (without icebreaker convoy), the size and composition of the government and commercial icebreaker fleets, and seasonal use of the central Arctic Ocean by shippers rather than use of the NSR or the Northwest Passage. Despite increasing marine access along the Eurasian coast due to a retreat of arctic sea ice, the main driver for the future of the Russian maritime Arctic is the continued development of natural resources—a huge economic driver for the Russian Federation.

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Sovereignty and Security in the New Arctic: The Coming Blizzard

Robert Huebert, University of Calgary

The Arctic is transforming. The twin processes of climate change and resource development will fundamentally change the north. In addition, new geopolitical realities are rewriting the boundaries of the north. There are many opportunities that come with these developments, but there will also be great challenges. What security and sovereignty threats will develop in the Arctic as economic and geo-political activity intensifies?

This presentation will begin by considering what is meant by the term "Arctic Sovereignty and Security." The second task of the presentation will be to examine the current and developing threats to the Arctic.

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New Approaches to Linking Scientific Synthesis, Policy, and Education

Charles Vörösmarty, University of New Hampshire

The public and policy makers increasingly make more demands on the science community. We are now tasked with creating better answers to questions like:

- What are the perceived and actual threats to national security because of climate change?
- How will climate change affect our food resources?
- What infrastructure problems will climate change create?
- What does the future hold for coastal zones if there is a massive ice melt and sea level rise?

To address some of these complex issues the National Science Foundation Arctic System Science Program (ARCSS) community has embarked on an effort to characterize the state of the entire system through synthesis-focused science. There is a clear need for the development of a collaboratory—a network that spans distance, supports human interaction oriented to a common research goal, fosters contact between researchers who are known and unknown to each other, and provides access to data sources and tools that

are required to accomplish research tasks. A collaboratory of this scope would enable the science community to move toward synthesis of the science, and better inform the public and policy makers.

The notion of a collaboratory arose from several workshops (www.arcus.org/ARC-SS/2007_data/index.html), and is being further discussed through the fall of 2008 and into 2009. The Collaboratory notion is to create a four-pillar, computer-based entity that would enable the science community to better develop ideas and reach the public with important information. These four pillars include:

- collaborative "meeting grounds,"
- data and modeling cyberinfrastructure support services,
- education, outreach, and policy, and
- scientific professional development.

The public, now more than ever, needs accurate information for informed decision-making and to avoid sensationalism. But the issue is complex, and there are a plethora of potential biological impacts—we are really talking about a tipping bucket, rather than single tipping points, because of the intercon-

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nected nature of the system. The science community must do a better job of influencing the policy domain and informing the public, because non-scientists will make decisions with or without solid scientific information. In order to understand these global and interconnected tipping points, there has to be a mechanism—a collaboratory—that is accessible to all. This talk presents the collaboratory concept for the arctic research, education, and policy community, and identifies specific problems it would help to allay.

Development of Cyberinfrastructure During Rapid and Interconnected Change

Dan Lubin, National Science Foundation

The numerous challenges with researching and solving current problems in high latitude climate change include:

- requirements for effective communication and data sharing across a wide variety of disciplines,
- technical and sociological aspects of international collaboration, and
- the often highly disciplinary-focused nature of polar field work itself.

Nearly all aspects of cyberinfrastructure have a bearing on successful climate research in the Arctic. Cyberinfrastructure involves much more than new processors, storage hardware, and communication lines. To make cyberinfrastructure work for an interdisciplinary

research community, one must consider elements of computational thinking that include high performance computing, informatics, library science, sustainability and accessibility of digital archives, data visualization and interoperability, and the study of virtual organizations and laboratories.

This talk will introduce these diverse topics, and the National Science Foundation's investment in them via the Office of Cyberinfrastructure. The goals are to encourage all stakeholders to consider how cyberinfrastructure can best be configured to meet the community's needs, and to encourage researchers to consider forming partnerships with computational scientists that can result in transformational research in arctic climate change.

Tipping Points and the Media

Erika Engelhaupt, Environmental Science and Technology

The tipping point concept provides a useful case study of some of the pitfalls in media coverage of climate change. Scientists use the term “tipping point” in various ways to describe changes in climate, and others use it in entirely different ways to describe shifts in policy focus or media coverage.

Over the past year or two, media coverage of climate change has shifted in a way that might be described as passing a tipping point. One could argue that rapid changes in the Arctic have driven this shift, in large part by snapping a clear photograph of climate impacts in the form of vanishing sea ice and stranded

polar bears. The chief complaint of scientists about media coverage of climate was, until recently, a misplaced emphasis on journalistic balance that led editors to over-represent the views of a relatively small group of deniers of anthropogenic warming. Today, coverage has shifted in a way that still leaves some scientists uncomfortable. Reporters present climate change more often as real and human-caused, but they also appeal to emotion and a sense of impending danger in order to personalize climate stories. Has the media passed a tipping point on climate change and has it become overly alarmist? Or not alarmist enough?

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U.S. Arctic Research Program Response to a Changing Arctic: Current and Future Goals

Mead Treadwell, U.S. Arctic Research Commission

The U.S. Arctic Research Commission (USARC), established by the Arctic Research and Policy Act of 1984, reports on progress made across the U.S. government in responding to the Commission's 2007 Goals Report and seeks advice from the science community on changes that the Commission might make to the Goals Report, which is to be issued in 2009. Currently, the Interagency Arctic Research and Policy Committee (IARPC) has established a working group with agency leaders to pursue five thematic goals recommended by the Commission.

Establishment of an Arctic Observing Network to assist the Study of Environmental Arctic Change (SEARCH) and Bering Sea research programs is underway, domestically and in cooperation with a pan-Arctic Sustainable Arctic Observing Network (SAON). The National Science Foundation (NSF) is leading the effort. A thematic research program plan on arctic civil infrastructure, to include new initiatives in oil spill research, shipping, and civil infrastructure, is being led by the Department of Defense Army Corps of Engineers Cold Regions Research Laboratory. Cross-agency work plans for natural resource assessment and Earth science are being led by the Department of the Interior's U.S. Geologi-

cal Survey. The National Institutes of Health's (NIH) Fogarty International Center will soon help convene efforts to develop a better plan for arctic human health research and has reported to the Commission that more proposals from U.S. research institutions are needed in these fields of study. Finally, NSF, the Smithsonian Institution, the National Endowment for the Humanities, the Department of Education, and Commissioner Vera Metcalf of USARC are working to help develop a research plan on indigenous language, identity, and culture. The Commission welcomes input from ARCUS members and the public at large as goal recommendations are set for 2009.

National research platform needs, including new icebreakers, the proposed Alaska Region Research Vessel, laboratory facilities, and ocean observing systems, continue to be a focus of the Commission's work. Efforts to improve international cooperation will focus on Russia and Japan this calendar year. The Commission continues to raise concern about base budgets for science and urges Congress to advance the American Competitiveness Initiative, which would grow the NSF and NIH budgets significantly. Likewise, the Commission urges federal agencies to make greater, steady use of extra-mural, competitive research in meeting agency science needs.

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Panel Discussion: Priority Actions and Response Strategies

Moderator: Peter Schlosser, Lamont-Doherty Earth Observatory

Panel Members: Vera Alexander; Max Holmes; Robert Huebert; Anya Suslova; and Simon Stephenson

Serious questions face the arctic science community as change becomes more pervasive, and as the public demands more answers. This panel focused its discussion and comments on answering a central question: *What are the three highest priority actions—scientific, educational, management, or political—we should take to improve our ability to respond to these observed and predicted changes?*

As moderator, Peter Schlosser, challenged the panel to consider several questions:

- What do we mean by "response"?
- What are we responding to? Sea ice change? System-state changes?
- Are the present changes we see in the Arctic unique?
- Change is part of the Earth system. Are the changes we are seeing now similar to those that happened in the past?

- Present changes are driven by humans, but consider other constraints: Earth's carrying capacity, global-scale change, and the rapidity of change.

A key concern brought up by the panel was the relationship between policy and the public. Policy change requires public pressure, but the public cannot pressure decision makers if they do not understand the difference between science and ideology. This concern raised several key questions:

- How do scientific results filter into policy, media, and education?
- How do the values scientists have as researchers impact the earth systems they study and those who are affected by resulting policy?
- How can the public be educated, if not through the media?

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- The public needs to be educated on what science *is* and what it *is not*.
- Education seems like a priority—perhaps scientists need to also find a way to educate the press?
- It is important to talk to decision makers—if the science community does not define arctic science, others *will*.
- More emphasis must be placed on the synthesis of research (and less on the small, minor disagreements).
- One problem is that science is dynamic, whereas policy is static (once a law has been passed, the ‘problem’ is assumed to have been solved; whereas, in science, decisions can only be made based on what is known now, and that knowledge may change tomorrow). How can the two be mitigated?

A clear theme that emerged from the community discussions that followed the presentations was that scientists need to step out of their comfort zones and focus on ways to educate the public, media, and policy makers. Education is the key to solving problems—even if people do not become scientists, it gives them knowledge to draw on when forming policies and decisions. To avoid perpetuating the information gap, it is critical that scientists find ways to communicate clearly outside of academia.

Poster Abstracts

Millennial-Scale Paleoceanographic Variability in the Central Arctic Ocean Exemplified by a Late Quaternary Sediment Record from the Mendeleev Ridge

Ruth Adler, Byrd Polar Research Center (Student Scholarship Winner); Leonid Polyak; Darrell S. Kaufman; and Andréa Grottoli

The Arctic Ocean is one of the least understood regions in the world, despite the critical role it plays in modulating global climate change.

Here, we present data from a relatively high sedimentation rate core (HLY0503-08JPC) raised from the Mendeleev Ridge in the western Arctic Ocean that covers the climate record of the past ~150 kyr. The core was retrieved during the Healy-Oden Transarctic Expedition 2005 (HOTRAX'05) from an important location—the two major surface circulation systems in the Arctic shift over the core site. As a result, the sediment at the core site records changes in the Arctic Ocean circulation as well as in ice conditions with a temporal resolution of ~2 cm per thousand years.

One important question related to the ongoing ice loss in the Arctic is what the changes in ice extent were in the past, especially during the warm intervals such as the last interglacial ~120–130 kyr. We use planktonic foraminiferal abundance and stable-isotope data to characterize oceanographic conditions during this time interval. Preliminary results indicate that most pronounced changes were related to glacial/stadial cycles. The last interglacial appears to have had relatively restricted ventilation, which indicates a larger amount of freshwater in the Arctic Ocean in comparison with interstadial periods. The causes of this pattern are being discussed.

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Simulating MODIS Measurements of Snow Directional Reflectivity from Antarctic Plateau

Igor Appel, The Analysis Group (TAG), LLC; Changyong Cao; and Robert Iacovazzi

Different theoretical approaches—two-stream theory, Mie discrete scattering, and geometric optics—were expediently compared to assess their ability to calculate diffusive radiation from snow cover at a visible wavelength for the conditions at Dome Concordia on the Antarctic plateau. Various descriptions of absorption, transmission, reflectance, and multiple scattering are taken into consideration. It has been demonstrated

that only a means of geometric optics could describe angular dependencies related to bidirectional snow reflectance, and a simple asymptotic analytical model could be used to calculate bidirectional reflectance. An equation was developed that robustly simulates nadir Moderate-Resolution Imaging Spectroradiometer (MODIS) reflectance fraction measurements from Dome Concordia.

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Shaping the Future of Polar Research

Jenny L. Baeseman, Association of Polar Early Career Scientists; Kriss Rokkan Iversen; Narelle Baker; and Jose Xavier

The International Polar Year 2007–2008 (IPY) is advancing our fundamental understanding of the polar regions and the cryosphere as a whole. To ensure the legacy of these scientific advances, the next generation of polar scientists must be recruited, nurtured, educated, and mentored. To retain the current cohort of early career polar scientists and recruit the next generation of researchers, professional development and networking activities must be expanded to address difficulties in international and interdisciplinary collaborations, rapidly developing technologies, logistical requirements of field work, and the increasing need to disseminate science results to the public and policy makers.

The Association of Polar Early Career Scientists (APECS) is an international and interdisciplinary organization for undergraduate and graduate students, postdoctoral researchers, early faculty members, and educators with interests in polar regions and the cryosphere. By providing networking and career development opportunities, APECS activities aim to raise the profile of polar research, develop effective leaders in education and outreach, and

stimulate interdisciplinary and international research collaborations. APECS builds on extensive national and disciplinary networks to develop integrated research directions, meet career development needs, and communicate the urgencies of polar science to a worldwide audience. In addition to being a networking organization, APECS facilitates mentoring by and liaises with senior researchers. APECS' primary objective is to assist young researchers in addressing the challenges of polar research as they progress through the early stages of their careers. Education and outreach is a high priority of APECS members for a number of reasons, including the stimulation and engagement of the next generation of polar scientists that will be needed to meet growing scientific challenges. APECS' membership includes more than 1,000 early career researchers from every continent, ranging from undergraduate and graduate students and post-doctoral fellows to new faculty members and educators.

For more information, visit:
<http://arcticportal.org/apecs>.

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Lake Sediment Records of Holocene Climate Variability from the Lofoten Islands, Arctic Norway

*Nicholas L. Balascio, University of Massachusetts (Student Scholarship Winner); and
Raymond S. Bradley*

The Lofoten Archipelago, located off the northwestern coast of Norway (67–69°N), is a group of mountainous islands dissected by glacial valleys and fjords that extend into the Norwegian Sea. The Lofoten Islands are in an important location within the climate system of the North Atlantic region. The maritime climate is mild, despite this high latitude location, with a mean annual air temperature of ~4 °C and a mean annual precipitation of ~1,200 mm. These conditions are strongly regulated by the Norwegian Atlantic Current, an extension of the North Atlantic Drift that flows immediately west of the islands, and by atmospheric circulation linked to phases of the North Atlantic Oscillation. Holocene climate variability in this region is, therefore, directly associated with changes in major oceanic and atmospheric components of the climate system that act on

different timescales. Many proxy records have been compiled from the North Atlantic region that document broad-scale Holocene climate regimes, but there is a need for higher resolution records to examine the timing of shorter term trends, leads, and lags that exist among different reconstructions.

Here, we present results from the analysis of lake sediment cores of the Lofoten Islands. Sediment cores from two lakes, Bovatnet and Heimerdalsvatnet, provide records that span the last 4,700 and 7,800 cal yrs BP, respectively. Geochemical analyses of the sediment show changes in runoff and productivity related to climate and regional sea level fluctuations. Fit into the regional context of climate and environmental change, these records will increase our understanding of past climate variability.

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The Polar Archaeology Network: Illuminating Past Socio-Ecological Arctic Changes and Providing Data for Understanding and Responding to Present and Future Changes

Hans Peter Blankholm, University of Tromsø; Maribeth S. Murray; Bjarne Grønnow; Debora Zurro; and Mikkel Myrup

The archaeological study of past arctic changes is not inconsequential to resolving problems stemming from contemporary arctic change. Outside of the Arctic, archaeology has shown its potential for illuminating global and regional environmental change events and providing baseline data on ecosystems and human systems that are relevant to developing effective remediation, mitigation, and ecosystem restoration activities. There is a real need to include retrospective ecological, climatological, land-use, and ecosystem service data derived from archaeological sources of information in mitigation and adaptation strategies. Archaeological studies provide longitudinal frameworks for understanding possible alternative socio-ecological systems in a changing Arctic.

In the face of rapid change, however, archaeological sources of ecosystem and other data are increasingly threatened, especially by coastal erosion, permafrost thawing, industrial and urban development, and increased tour-

ism. The potentially massive loss of data holds repercussions not only for the scientific community and society at large, but especially for arctic peoples whose own history is recorded in these sites and who live in the rapidly changing north.

The Polar Archaeology Network (PAN) (<http://polararchaeologynetwork.blogg.no/>) was formed in the spring of 2007 to respond to the need of the polar archaeological research community for better engagement with broad interdisciplinary initiatives in polar science, a desire for stronger international collaboration, a desire to grow polar archaeological research capacity, the wish to develop more advanced field and analytical methods particular to polar archaeology, and to ensure continued access to potential datasets that may be environmentally and/or politically sensitive in the context of a changing arctic. PAN is endorsed by the International Arctic Science Committee (IASC) (www.arcticportal.org/iasc/) as an IASC Network.

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Included among the activities of PAN are:

- Development of an international circumpolar archaeological observing network that monitors and recovers data from archaeological sources increasingly threatened by arctic change;
- Identification and synthesis of existing retrospective datasets, identification and rescue of threatened data sets, integration of diverse data streams, and integration of relevant archaeological data and archaeological approaches into larger arctic change research programs;
- Collection of new circumpolar retrospective time series on arctic environmental change (especially change among the marine, terrestrial, and human components of the arctic system) and relevant proxies for past climate and environmental change episodes; and
- Development of scholarly exchange and capacity building opportunities among the polar archaeological research community.

PAN is forming appropriate working groups to develop recommended actions and best practices for accomplishing these goals. This poster presentation highlights the role of archaeological data in arctic change research and threats to data sources.

Nutrient Budget Investigation on the Chukchi Sea Shelf

Elena P. Bondareva, Arctic and Antarctic Research Institute (Student Scholarship Winner)

We have archived hydrological (temperature and salinity) and hydrochemical (nutrient and oxygen) data collected from Russian observations in the Chukchi Sea spanning the period from 1922 to the early 1990s. A major focus for research relates to understanding how the Pacific waters entering into the Chukchi Sea influence physical and biogeochemical processes and linkages to nutrient dynamics and budgets. Calculation of the nutrient budgets in the Chukchi Seas and assessment of arctic coastal systems' metabolisms has been done according to recommendations of the international program Land Ocean Interaction in the Coastal Zone (LOICZ).

The modeling approach proposed by the LOICZ has been adapted to the arctic system.

Additional nutrient fluxes related to ice formation and melting are included in the model. We have found that the Herald and Barrow Canyons are the key exchange sites for nutrient and carbon. Previous investigations show ecosystem changes on the shallow shelves of the Northern Bering and Chukchi Seas. Reduction in the extent and duration of sea ice, increased seawater temperature, and changing hydrographic conditions will directly impact carbon and nutrient export from the shelf region to the deep arctic basin. There is a need to compare Russian archived data and new data obtained in the Chukchi Sea during the last international expeditions.

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Determining Organic Matter Sources for Methane Production and Bubbling from Alaskan Lakes Using Stable Isotopes and Radiocarbon Ages

Laura S. Brosius, University of Alaska Fairbanks (Student Scholarship Winner); Katey M. Walter; and Dragos A. Vas

Methane (CH₄) ebullition from northern lakes has recently been recognized as a globally significant source of atmospheric CH₄, a potent greenhouse gas. This conclusion is based on the extrapolation of results from a few detailed studies of ebullition dynamics in lakes in Siberia, Scandinavia, and the Midwestern U.S. The magnitude, dominant pathway, and drivers of CH₄ production and ebullition in other northern regions, such as Alaska, are unknown. While organic matter availability has been identified as a key driver of CH₄ production in aquatic environments, the relative contribution of different organic matter sources has not yet been rigorously investigated. Among Alaskan lakes, organic matter sources include those released from thawing permafrost and modern terrestrial and aquatic ecosystems. Until now, crude assumptions have been made to attribute relative contributions of modern versus ancient organic substrates to methanogenesis in lake sediments. Understanding the magnitude, dominant pathway

and drivers of CH₄ production and ebullition in Alaskan lakes is important because projections of increased warming, permafrost thaw, and plant productivity in Alaska have implications for enhancing these emissions, thereby exacerbating climate change via mechanisms not yet accounted for in models.

The goal of my research is to determine, using natural-abundance isotopic mixing models of CH₄ and its precursors, the relative contributions of different organic matter sources (permafrost, terrestrial, and aquatic) to methanogenesis in lakes near Fairbanks, Denali National Park, and Toolik Field Station. Relative rates of production via two pathways (CO₂ reduction and acetate fermentation) will also be determined with respect to different organic matter substrates by calculation of an apparent carbon fractionation factor. Finally, assessment of substrate availability with ongoing climate warming may indicate future trends in CH₄ emission.

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Gateway to the Arctic: The University of Delaware's William S. Carlson International Polar Year Events

Tracey L. Bryant, University of Delaware

This poster highlights the University of Delaware's (UD) efforts to engage the public in learning more about the Arctic and Antarctic through the William S. Carlson International Polar Year Events. Launched in February 2008 at UD, the series is named after William S. Carlson, former president of UD from 1946–1950, and a distinguished polar explorer himself. UD's Research Communications Initiative has helped extend polar research and topics to the public, using traditional tools such as news articles, and simulcasts of presentations into the 3-D virtual world of Second Life.

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ARCUS Internet Media Archive (IMA): A Resource for Outreach and Education

Tina M. Buxbaum, Arctic Research Consortium of the U.S.; and Wendy K. Warnick

The ARCUS Internet Media Archive (IMA) is a collection of photos, graphics, videos, and presentations about the Arctic that are shared through the Internet. It provides the arctic research community and the public with a centralized location where images and video pertaining to polar research can be browsed and retrieved for a variety of uses. The IMA currently contains almost 6,500 publicly accessible photos, including 4,000 photos from the National Science Foundation funded Teachers and Researchers Exploring and Collaborating (TREC, now PolarTREC) program, an educational research experience in which K–12 teachers participate in arctic research as a pathway to improving science education. The IMA also includes 450 video files, 270 audio files, nearly 100 graphics and logos, 28 presentations, and approximately 10,000 additional resources that are being prepared for public access.

The contents of this archive are organized by file type, contributor's name, event, or by organization, with each photo or file accompanied by information on content, contributor source, and usage requirements. All the files are key-worded and all information, including file name and description, is completely searchable.

ARCUS plans to continue to improve and expand the IMA with a particular focus on providing graphics depicting key arctic research results and findings as well as edited video archives of relevant scientific community meetings.

To submit files or for more information and to view the ARCUS Internet Media Archive, please go to: <http://media.arcus.org> or email: photo@arcus.org.

How We Know What We Know About Our Changing Climate: Scientists and Kids Explore Global Warming

Lynne Cherry, children's author; and Gary Braasch

Across the nation, teachers, administrators, and parents are looking for age-appropriate materials that scientifically explain global warming and its effects to children. Renowned children's author Lynne Cherry and award-winning photojournalist Gary Braasch have written the book, *How We Know What We Know About Our Changing Climate: Scientists and Kids Explore Global Warming*, to empower children who will inherit a planet that is changing rapidly from the past. This book provides the education platform to help today's youth understand and effectively fight climate change and transform our world for the better.

Robert Coontz, deputy editor of *Science Magazine* wrote: "This beautiful and informative book fills a major gap in environmental writing for children. It covers a wide range of research, defining technical terms gracefully and naturally as they arise. The overall tone—urgent without being shrill, hopeful without being complacent—strikes me as just right. I happily recommend it." The book depicts scientists at work, teaches children the language, methods, and process of science, imparts knowledge of technological tools and data collection, provides methods and ideas for school

and home projects about weather and climate, and describes and encourages participation in citizen-science programs. In photographs, text, and graphic presentations, the book shows how children can immediately reduce their carbon footprint. It inspires them to do so by showing the effects of many kids learning about climate and working together, with examples of how some are already influencing their communities to change.

The book was published by Dawn Publications in 2008 for grades 4–9. A teacher guide is also available. More information is available at: www.howweknowclimatechange.com

Other Interesting and Related Material

Braasch, Gary. 2007. *Earth Under Fire: How Global Warming is Changing the World*. University of California Press.

This book was selected as one of the 50 most important environmental books—from John Muir to the present—by *Vanity Fair* (The Green Guide, April 2, 2008). An updated second printing will be in stores by summer 2008. The book is a 280-page large format book with dramatic photographs of climate change from around the world by environmental photojour-

nalist Gary Braasch. Braasch was awarded the Ansel Adams Award for Conservation Photography in 2006.

In a unique seven year documentation, Braasch followed scientists to research locations from polar areas to tropical rainforests and from mountain glaciers to coral reefs. He photographed people already affected by the changing climate and documented changing landscapes in dramatic before-and-after images. The book depicts the broad effects of climate change on the world and our civilization. The comprehensive text, written by Braasch, ends with a detailed call to action to limit global warming. This book also includes powerful essays by leading scientists, including Jonathan Overpeck on polar areas, Thomas Lovejoy on threats to biodiversity, and Stephen Schneider on the implications of current rates of warming.

"Braasch has told the story of climate change in a new way by bringing together startling and breathtaking imagery with personal accounts and the best available scientific evidence."—Martin Parry, Co-chair, IPCC Working Group 2, in *Nature Reports: Climate Change*, March 2008.

Assessing Knowledge, Resilience and Adaptation, and Policy Needs in Northern Russian Villages Experiencing Unprecedented Climate Change

Susan A. Crate, George Mason University

An urgent challenge of the 21st century is to understand levels of knowledge, resilience and adaptation, and policy needs in populations confronting the local effects of unprecedented Global Climate Change (GCC). This project represents a novel approach to these ends by advancing knowledge through partnering with rural native Viliui Sakha communities in northeastern Siberia to explore ways to effectively address the local issues of GCC. Research questions include:

- What local effects of GCC are Viliui Sakha communities witnessing, and how is it affecting their subsistence survival?
- What knowledge is there about how Viliui Sakha adapted in the past to climate perturbations, and how are contemporary Viliui Sakha adapting to the local effects of GCC?
- What knowledge and record is there about past local/regional climate perturbations, and what knowledge is being generated on the local, regional, and republic-wide level about contemporary global climate change?

- What information about GCC from other western scientific sources is both relevant and constructive for Viliui Sakha communities?
- What GCC policy exists at the local, regional, and national levels, how effective is it for rural Viliui Sakha communities, and how can it be made more effective?

The four-village, three-year study is a collaborative effort involving the active participation of the targeted communities, field assistants, native specialists, an in-country research team, and an international collaborator. The project is founded on the principal investigator's fifteen years of ongoing research and work with rural Viliui Sakha.

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Effects of Environmental Variations on the Spatial Distribution of Groundfish in the Northern Bering Sea

Xuehua (Sherry) Cui, University of Tennessee (Student Scholarship Winner); Jacqueline M. Grebmeier; Lee W. Cooper; James R. Lovvorn; Christopher A. North; and Jason M. Kolts

The Bering Sea is undergoing a northward biogeographical shift as a result of atmospheric and hydrographic forcing that may be climate related. Recent environmental change in the Arctic has been dramatic, and the most obvious evidence has been the reduced extent and earlier melting of seasonal pack ice. Bottom water temperature increases are thought to be influencing northward fish range expansion and altering fish community structure as seasonal sea ice becomes less prominent.

During two icebreaker cruises on the USCGC *Healy* (7 May–5 June 2006 and 16 May–18 June 2007), groundfish were collected at 43 stations in 2006 (59 otter trawls), and 52 stations in 2007 (72 beam and 17 otter trawls) in the Bering Sea north of St. Matthew Island. Arctic cod (*Boreogadus saida*), Bering flounder (*Hippoglossoides robustus*), and Snailfish (*Liparidae*) were the dominant fish in the sampling area.

Fish community patterns have been analyzed from each trawl collected during the two research cruises and converted to a standardized catch per unit effort (CPUE) for each fish taxon. We used regression models to convert otter trawl CPUE data in 2006 to quantitatively comparable beam trawl CPUE data.

This study is using multivariate analyses (cluster analysis, multidimensional scaling: MDS) to advance understanding of ecologically based relationships between environmental factors and fish community structure in the northern Bering Sea. The goal is to predict groundfish distribution under scenarios of increasing bottom water temperature in the Bering Sea. Initial results show that bottom water temperature and sediment grain size are the most useful predictors of fish distribution among 14 environmental variables analyzed. In addition, bottom water temperature exerts a significant ($p < 0.01$) influence on groundfish cluster groups.

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Influence of Environmental Conditions on the Community Structure of Eukaryotic Sea Ice Microbiota

Brian J. Eddie, Arizona State University; Christopher Krembs; Andrew Juhl; and Susanne Neuer

Sea ice microbial community structure affects carbon and nutrient cycling in polar seas, but its susceptibility to changing environmental conditions is not well understood. Here, we studied the eukaryotic microbial community in sea ice cores recovered from three locations near Point Barrow, Alaska, in May 2006, by documenting its diversity and composition in relation to vertical depth within the cores, as well as light availability (mainly as variable snow cover), and nutrient concentrations. We applied denaturing gradient gel electrophoresis (DGGE) of a section of the 18S rRNA gene in combination with epifluorescence microscopy to quantify and compare the community structure of the major eukaryotic microbial phylotypes in the ice.

We found that the community composition of the sea ice is more affected by the depth horizon in the sea ice than by light availability, although more light resulted in a greater biomass of phototrophs. This underscores the importance of snowfall and snow distribution on sea ice microbial community structure on scales of only meters. Evidence of protistan grazing upon diatoms was found, with implications for carbon and nutrient recycling in the ice. By combining molecular and microscopic techniques, this research is a first step toward gaining a new perspective of the microbial processes that are occurring in sea ice ecosystems and of its potential climate sensitivity.

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Tundra Vegetation Properties Along a Latitudinal Gradient of the Yamal Region of Russia

Howard E. Epstein, University of Virginia; Donald (Skip) A. Walker; Patrick Kuss; Elina Kaarlejavi; and George Matyshak

An understanding of land-atmosphere interactions and biogeochemical cycling in any system is predicated by knowledge of the spatial distribution of vegetation properties, and the capacity for vegetation to exchange carbon and water between the land and the atmosphere. In many regions of the Siberian arctic tundra, this baseline information on vegetation in a spatial context does not exist in any systematic fashion.

As part of a U.S. National Aeronautics and Space Administration and Northern Eurasian Earth Science Partnership Initiative Land Cover Land Use Change project, we analyzed in detail the vegetation properties of three tundra locations along a latitudinal gradient in forest tundra and arctic tundra east of the Ural Mountains, including the Yamal Peninsula. Our locations were situated near Nadym (65°18'N), Laborovaya (67°41'N), and Bovanenkova (70°17'N). At a minimum of two sites per location, using 50 m x 50 m grids, we systematically sampled leaf area index (LAI),

normalized difference vegetation index (NDVI), species composition, vegetation biomass, and foliar nutrient concentrations.

The LAI of vascular plants declined from an average of 1.08 at Nadym to 0.36 at Vaskiny Dachi along the 5° latitudinal transect. NDVI values of the tundra vegetation did not decline with latitude and were 0.60 for Nadym, 0.67 for Laborovaya, and 0.58 for Vaskiny Dachi. This is likely due to the contribution of non-vascular, understory vegetation to the NDVI signal. Related, average foliar nitrogen concentrations were greatest at Laborovaya, the site with the highest NDVI. A key result is that, even along this transect of approximately 500 km, the heterogeneity of vegetation properties within a location can be greater than that over the entire transect. This heterogeneity needs to be considered in estimations of biogeochemical cycling in the Yamal region. Our research plan is to continue sampling further north to encompass a broader arctic transect.

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Sustaining the Bering Ecosystem: A Social Science Research Plan

Ben Fitzhugh, University of Washington; Henry Huntington; Mary Pete; and Jennifer Sepez

The Bering Sea is changing from ice-dominated to an increasingly open water system. The over-arching goal of the NSF-supported Bering Ecosystem Study (BEST) is to understand the effects of climate variability and change on the Bering Sea ecosystem. To the people who are simultaneously a part of that ecosystem and rely on its productivity for life and work, climate change and its effects are among the top concerns. Sustaining the Bering Ecosystem articulates a vision and approaches for social science research as a component of the BEST Program (www.arcus.org/bering). This science plan seeks to initiate research to elucidate the dynamic relationship between the Bering Sea ecosystem and the humans who constitute an integral component of that system. The plan delineates a research program focused on three broad themes:

- Impacts on humans: how past, current, and possible future changes in the Bering Sea ecosystem affect the health and well-being of people living and depending on this region for subsistence, employment, and cultural survival.

- Human impacts: how changing human uses of the Bering Sea region affect the natural cycles of this ecosystem by moderating and/or accelerating systemic changes.
- Dynamics of human and non-human natural systems: how the human-environmental dynamic has changed through time and may change in the future due to internal and external opportunities and pressures.

These themes are developed in the context of a community-driven approach based on the concerns, goals, and interests of Bering Sea residents and other stakeholders of the region. This plan has been drafted through the collaboration of Bering Sea residents (primarily Alaska Natives) and non-resident stakeholders, social scientists, and natural scientists to focus efforts around research questions important to stakeholders, which in various ways center on issues of sustainability (of resources, economic opportunities, ways of life, and culture itself). The research envisioned by this plan will provide a foundation for resident communities, regional corporations and tribal

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councils, industry stakeholders, resource managers, and policy makers at various levels to plan for and face the future with less uncertainty. To accomplish this goal, research must be developed with attention to concrete and practical outcomes.

In this social science effort, and in the broader BEST study of which it is a part, synergies must be explored that harness the strengths of multiple disciplines toward common purposes. For this reason, the research anticipated in this plan will:

- generally involve interdisciplinary teams and projects that include a modeling component;
- may focus on more than one of the defined research themes; and
- require collaboration and partnership with native and non-native residents and stakeholders in the Bering Sea.

Designing a Database for the Archiving of Spectral Data Collected Using an Automated Tram System

Santonu Goswami, University of Texas El Paso; Kuldeep Matharasi; John Gamon; and Craig E. Tweedie

Ecologists and environmental scientists collect a huge amount of data from different field sites trying to answer a research question—they also face the challenge of properly archiving the data and making it available for researchers in the future.

Spectral data was collected as part of the biocomplexity experiment in Barrow, Alaska, for 2005, 2006, and 2007 using a robotic cart and a hyper-spectral spectrometer. The hyper-spectral spectrometer collects optical data in 256 bands along three 300 m-long transects

over a dry arctic lake bed. In one day, the cart system collects approximately 900 optical data files for the total length of 900 m, which totals to approximately 2,700 data files per week.

The amount of data collected for three years created strong challenges for effective data handling and processing, which led to the design of a database system using PostgreSQL. This system facilitated the ease of effectively accessing the data for the purpose of data processing and also improved the quality control of the data in a minimal time.

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The Future of the Arctic Council in View of the Incoming Climate Change

Waliul Hasanat, University of Lapland (Student Scholarship Winner)

Soft-law instruments have been developed over three decades, some of which have created permanent cooperation among states. The Arctic Council is a permanent forum of eight arctic states to promote environmental protection and sustainable development in the Arctic. Climate change, however, is seriously affecting the main objectives of the Council. Through the course of time, climate change has grown as an important issue under the Arctic Council. The Council provides noteworthy information to policy-makers and other actors so as to limit climate change and to address its impacts on arctic ecosystems and residents. Even with its institutional weaknesses for want of proper mechanisms, the Council functions through its various working groups and their programs. This poster shows a few proposals for reforming the structure of the Council to address incoming consequences of climate change.

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The U.S. Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facilities on the North Slope of Alaska

Mark D. Ivey, Sandia National Laboratories; Bernard D. Zak; and Jeffrey A. Zirzow

Since 1998, the Atmospheric Radiation Measurement (ARM) Climate Research Facility (ACRF) North Slope of Alaska (NSA) site, with instrumented facilities near the towns of Barrow and Atkasuk, has provided data about cloud and radiative processes at high latitudes. Campaign-scale atmospheric measurements in the Arctic for research activities funded by the U.S. Department of Energy's ARM Program began nearly a year earlier during the Surface Heat Budget of the Arctic (SHEBA) experiment. Currently, about 70 instruments are installed permanently at the NSA site. In 2004, the ACRF sites worldwide became a national user facility. The other fixed ACRF sites are in the tropical western Pacific and in the southern Great Plains of the U.S. In addition, ARM has a mobile facility, which is deployed for several months at a time at additional places of interest. It has been deployed on the California coast, sub-Saharan Africa, and Germany, and is now being deployed in China.

The user facility status means that researchers from other organizations are welcome both to use the ACRF data (available through a data archive), and, if appropriate, to use the facilities themselves to deploy additional instrumentation for field campaigns.

Within the ARM community, field campaigns are called "intensive operating periods," or IOPs. They range in length from weeks to years. At the North Slope site, there have been about two dozen such field campaigns. One is ongoing now: the Indirect and Semi-Direct Aerosol Campaign. In addition to many visitor instruments at Barrow, it also involves overflights by instrumented aircraft. Use of the facilities is managed through a proposal process. For more information, see www.arm.gov.

Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Department of Energy's National Nuclear Security Administration under contract: DE-AC04-94AL85000.

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Arctic Research Mapping Application (ARMAP): 2D Maps and 3D Globes Support Arctic Science

George W. Johnson, University of Texas El Paso; Allison G. Gaylord; Jerald Brady; Ryan Cody; Mike Dover; Diana Garcia-Lavigne; Roberta Score; William F. Manley; and Craig E. Tweedie

The Arctic Research Mapping Application (ARMAP) is a suite of interactive, online mapping programs for field-based scientific research in the Arctic. Users can navigate to areas of interest and explore hundreds of active research projects by location, year, funding program, investigator, discipline, keywords, and other variables. Project information is displayed within 2D maps and 3D globes, with links for additional details. Users can view:

- a variety of base maps (satellite imagery, topography, etc.);
- framework layers (cities, roads, lakes, placename gazetteer, etc.); and
- scientific data (sea ice extent, treeline, arctic vegetation, etc.).

Users can browse or search for projects, copy selected data, print or export maps for presentations or publications, and choose from a “map gallery” of predefined images of interest. An online help system and narrated demos are also provided. The gateway website can be found at <http://armap.org/>.

With special emphasis on the International Polar Year, ARMAP is designed for science planners, scientists, educators, and the general public. The online applications—ARMAP2D, ARMAP for Google Earth, and ARMAP3D—encompass projects funded by the National Science Foundation, National Oceanic and Atmospheric Administration, and the U.S. Geological Survey. ARMAP helps avoid duplicated effort, while providing tools for a variety of

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users. It follows cutting-edge “best practices” and community-based standards for data sharing, such as the Open Geospatial Consortium (OGC) Web Map Services (WMS).

In summary, ARMAP goes beyond visualization to coordination and synthesis of arctic research.

Lichen Recovery Following Heavy Grazing by Reindeer Delayed by Climate Warming

David R. Klein, University of Alaska Fairbanks; and Martha Shulski

Introduced reindeer, *Rangifer tarandus*, heavily exploited lichen-rich plant communities on St. Matthew Island in the Bering Sea. A die-off of the reindeer followed, exacerbated by extreme weather in 1964, resulting in extirpation of the reindeer. By 1985, two decades following the reindeer die-off, total lichen biomass was only 6% of that in similar plant communities on adjacent Hall Island, not reached by the reindeer. By 2005, 41 years after the reindeer die-off, lichen re-growth on St. Matthew was only 12% of lichen biomass in the Hall Island communities.

Analysis and modeling of weather patterns in recent decades in the Bering Sea region point to a warmer, drier climate with decreased fog, which has led to deterioration of conditions that favored lichen growth in the past on St. Matthew Island. A similar pattern of removal of lichens as major components of plant communities has occurred following introductions of reindeer to other islands at high latitudes and has been documented in association with climate warming in recent decades in the wintering grounds of the Western Arctic Caribou Herd.

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Landscape Change in the Russian Arctic: Ecological Implications of the Petroleum Industry to the Nenets Reindeer Herding on the Yamal Peninsula

*Timo Kumpula, University of Joensuu (Student Scholarship Winner); Bruce C. Forbes;
and Florian Stammer*

The aim of this research is to assess the capacity for satellite imagery in detecting different natural and anthropogenic land cover changes in the vicinity of a modern petroleum extraction development in the Russian Arctic.

The Yamal Peninsula, in northwest Siberia, contains some of the largest untapped deposits known in the world. It also serves as the homeland of the Yamal Nenets, who have exploited first wild, and then domestic, reindeer in the region for at least 1,000 years. Their annual migration from the treeline to the northern tundra brings them into contact with a number of impacts associated with gas exploration and production. These range widely and include physical obstructions from roads, railways, and pipelines, as well as direct and indirect ecological impacts, such as changes in vegetation, soils, and hydrology due to drilling, infrastructure development, and seismic surveys. Some of the effects are relatively small-scale, only a few meters across, while others cover several hectares. Nenets' perceptions of the spatial

aspects of their territories encompass changes in both quantity and quality of terrestrial habitats, rivers, lakes, and campsites that have been used seasonally for centuries.

Satellite imagery used was Landsat MSS/TM/ETM, SPOT, ASTER TERRA VNIR, and Quickbird-2. Even with the most high-resolution imagery, it was not possible to detect things like trash (rusted metal, broken glass), drilling mud, or petro-chemicals that can strongly affect the overall quality of reindeer pastures.

In the Bovanenkovo gas field, 450 km² have been affected by the gas field and about 33 km² of vegetation has been destroyed or has changed from its original state. Proper assessment of the overall ecological impacts of petroleum development requires a combination of state-of-the-art remote sensing coupled with detailed ground-truthing efforts that embrace both scientific and local knowledge from indigenous herders and non-indigenous gas field workers.

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Smithsonian at the Poles: Contributions to International Polar Year Science

Michael A. Lang, Smithsonian Institution; Igor Krupnik; and Scott E. Miller

The Smithsonian Institution convened a polar science symposium on 3–4 May 2007, as one of the inaugural U.S. contributions to celebrate the International Polar Year 2007–2008 (IPY). “Smithsonian at the Poles: Contributions to International Polar Year Science” presented research findings by Smithsonian scholars and their collaborators on arctic and Antarctic research, with particular attention to changes in polar systems past, present, and future, and their global impact. The symposium continued a tradition of polar science that began nearly 150 years ago and resulted in some of the world’s foremost collections and archives of arctic and Antarctic materials. The symposium featured an introductory plenary

session followed by concurrent sessions of invited papers and panel discussions, evening public and keynote lectures, and tours of collections.

Thirty papers are currently in press at Smithsonian Institution Scholarly Press with an anticipated 2008 publication date. The symposium volume encompasses the following themes: polar astronomy, systematics and biology of polar organisms, environmental change and polar marine ecosystems, IPY histories and legacies, methods and techniques of under-ice research, and cultural studies.

For symposium abstracts and speaker information please go to www.si.edu/ipy.

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Under-Ice Research: Results of the Svalbard International Polar Diving Workshop

Michael A. Lang, Smithsonian Institution; and Martin D. J. Sayer

Approximately four decades ago, scientists were first able to enter the undersea polar environment to make biological observations for a nominal period of time. Since those first ice dives in wetsuits, without buoyancy compensators, double-hose regulators, or submersible pressure gauges, technology has advanced. Today's scientific ice divers have the potential to extend their observational and experimental depths and times to limits never before available. Novel ice-diving techniques have expanded the working envelope based on scientific need to include use of dive computers, oxygen-enriched air, re-breather units, blue-water diving, and dry suit systems. With the advent of new technology, greater scientific productivity is achieved while maintaining the scientific diving community's exemplary safety record.

The basis for this diving safety research project was the 1991 Polar Diving Workshop (Lang and Stewart, eds., 1992, available online at www.si.edu/dive), supported by NSF, Smithsonian Institution, and the American Academy of Underwater Sciences. Fifteen years of experience later, we confronted the need to re-evaluate and update those 22 polar diving recommendations through the combined international, interdisciplinary expertise of participating polar diving scientists, manufacturers of dry suits and thermal protection, physiologists and decompression experts, and diving safety officers. In preparation for the International Polar Year, an increased level of attention was focused on the Arctic and Antarctic, and this project constituted a contribution from the international polar scientific diving community.

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The Role of Alaska Native Elders in the Cultural Resilience of Native Communities

Jordan Lewis, University of Alaska Fairbanks (Student Scholarship Winner)

Native communities are working towards strengthening their traditional cultures and values, whether through elders teaching in the classroom, or the inclusion of traditional knowledge in school-based curriculums. Efforts of this nature demonstrate the community's resiliency, or their ability to sustain themselves in a rapidly changing society. The key actors in passing down and sustaining traditional knowledge and values are the Alaska Native elders. Elders contribute to community resilience in native communities in several ways, including:

- Increasing the diversity of options of coping with change through their ideas, traditions, and experience that may not be in common use by the current community;
- Serving as a bridge between traditional and modern institutions; and
- Strengthening social-ecological linkages through their experiences with subsistence harvest.

Community resilience can be enhanced through reducing vulnerability to shocks and

perturbations by developing a community support system and engagement in active communication with younger people through teaching them in school.

Many Alaska Native elders have overcome various forms of adversity and yet still wish to remain in their own homes and community, passing down traditional knowledge and stories. The aspects of cultural and community resilience are complex and involve many factors, especially social and ecological factors. When looking at the social and ecological factors, it could be argued that Alaska Native elders possess the characteristics and life experiences that may contribute to cultural and community resilience. The role elders play in community resilience is the continued sharing of their knowledge and living their traditional lifestyle so that others may follow in their footsteps and understand the complex, yet interconnected, social-ecological systems.

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Large Scale Tipping Points, Small Scale Societies

Philip A. Loring, University of Alaska Fairbanks; and S. Craig Gerlach

Much has been made of the question of large-scale ecological tipping points in the arctic system, with important work being done to identify where they may have already been experienced, how they might be avoided, and to anticipate how they will impact arctic peoples. This last question, how ecological tipping points will affect the Arctic's small-scale communities, is complicated because socio-cultural, political, and economic systems can have tipping points of their own, and the interactions between these domains are many. Gradual ecological change, for instance, can accumulate over time and lead to abrupt cultural or economic change; conversely, many resilient social systems in the past have proven able to take abrupt ecological changes "in stride."

This poster explores these interactions of change and tipping points in Alaska. The communities of rural, "bush Alaska" are presently undergoing a dramatic period of economic, cultural, and demographic restructuring, with common patterns of rural-to-urban migration

occurring across the state. These transitions are complicated, driven by a mix of ecological, social, political, and economic drivers. Some of the major circumstances include: a significantly decreased ability to rely on wild, country foods as the result of climate variability and regulatory rigidity, an increased need/desire to participate in a cash economy, and the needs of elders to pursue quality healthcare services. Many communities are becoming locked-in to these transitions; the longer they continue, the harder it becomes for communities to reverse the trend. This begs the question of whether some socio-cultural or socio-economic tipping point, a point of no return, has been reached or exceeded for communities undergoing these transitions. If not, what are new designs for policy and resource management that can go towards reversing these destructive trends? And for those that have, what way forward as they experience the significant nutritional and social-cultural stresses, such as diabetes, depression, and alcoholism that appear to result?

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Offshore Leasing, Seismic Exploration, and Drilling in the Beaufort and Chukchi Seas, Arctic Ocean, Alaska, and Polar Bear Habitats: GIS Mapping for Public Policy Decisions

Pamela A. Miller, Northern Alaska Environmental Center; and Alan Baldivieso

Clear information about living marine resources and sources of potential impact from oil and gas activities like seismic exploration, drilling, pipelines, and ports is necessary for informed public policy. We have compiled existing and planned infrastructure and lease sales for Alaska's North Slope and overlaid this with sensitive habitat information in GIS maps to better educate the public, media, and decision-makers about cumulative industrialization in the Arctic.

Our poster presents two GIS maps:

- the Beaufort and Chukchi Sea population polar bear information derived from U.S. Geological Survey studies overlaid with Minerals Management Service (MMS) lease sale areas, and
- proposed offshore activities (seismic exploration, offshore drilling, and existing and planned lease sales) derived from a variety of public data sources in order to present a broad regional compilation that had not been done by applicants or agencies.

These GIS map examples elucidate the major expansion of the oil and gas industry into the Arctic Ocean off Alaska and sensitive wildlife resources at risk. There is major public concern about offshore oil development due to the high risks of devastating harm in the event of a major spill. Due to the "response gap," wherein oil spills most of the year in the Arctic Ocean cannot be cleaned up due to ineffective mechanical response, broken sea ice, and other weather conditions, the oil spill concern is further heightened in the Arctic.

Most of the Arctic Ocean off the coast of Alaska is open to offshore leasing, with over 60 million acres of federal outer continental shelf waters in the Beaufort and Chukchi Sea lease sale programs, which extend further north than ever before. Five lease sales are planned by the MMS in the next five years. In the first, the Chukchi Sea lease sale, 193 oil companies bid on 2.75 million acres out of the 29 million acres offered. When the Beaufort Sea area is added, a total of 4.1 million acres have been leased in federal Arctic Ocean waters. On land, 11 million acres in the National

Petroleum Reserve of Alaska, and 16 million acres of state of Alaska lands are available for oil and gas leasing across Alaska's Arctic today.

The Chukchi Sea lease sale was the first held in a decade, and the environmental impact statement contained major data gaps of key baseline ecological information necessary to adequately analyze oil exploration and development impacts of the proposed lease sale. While there had been a comprehensive ecological study program carried out by the National Oceanic and Atmospheric Administration roughly two decades ago, this program has ceased. It is largely unknown how the rapid loss of sea ice and other climate changes has affected wildlife populations and habitat use. Our map uses some of the best available science on polar bear habitat use for the Chukchi Sea, but the U.S. Fish and Wildlife Service said in 2007, "a reliable population estimate is not available for the Bering-Chukchi Sea polar bear stock." Crucial ecological baseline information should be collected and the oil spill "response gap" filled prior to any Chukchi Sea lease sales.

Linkages of onshore pipelines, ports and other facilities required for offshore development—often ignored in offshore leasing environmental impact reviews—are more easily made apparent through GIS maps. In light of rapidly increasing climate changes in the Arctic, which are already stressing wildlife habitats and resources crucial for subsistence, it is even more important that the cumulative impacts to fish, wildlife, and people be taken into account as the public evaluates new oil and gas industry proposals to greatly increase its drilling, shipping, and industrialization of the Arctic Ocean.

The International Study of Arctic Change (ISAC)

Maribeth S. Murray, International Study of Arctic Change; and Michael Tjernström

The International Study of Arctic Change (ISAC) is a long-term, international, interdisciplinary science program. ISAC will provide an integrated understanding of arctic change and projections for future change. Understanding the nature and extent of the system-scale change presently observed in all domains of the Arctic and facilitating projections of their future development requires the ability to untangle secular trends from anomalous changes. Scientists, policy makers, and stakeholders need to be prepared as the arctic system moves towards a new state and attention focuses on changes in the arctic regions for which social and ecological systems may be unprepared.

The goals of ISAC are to provide scientifically-based information for the development of response strategies to society and decision makers in the face of pan-arctic system-scale changes and to provide contributions to scientific assessments that address present and future needs. Toward this end, ISAC will engage in multidisciplinary observational, synthesis, and modeling activities. As a program, ISAC is open-ended and focused on observing, understanding, and responding to arctic change. ISAC provides the underpinning for an expanded scientific knowledge base and will lead to improved assessments of arctic change and elucidate linkages between the Arctic and the global systems.

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Arctic Science Discoveries

National Science Foundation

Our understanding of the Arctic has increased enormously over the past five decades of intense research, but much remains to be learned, and new discoveries await researchers who study this unique region. The Arctic Sciences Section of the National Science Foundation (NSF) funds basic research of the Arctic through the Arctic Natural Sciences, Arctic Social Sciences, and Arctic System Science (ARCSS) programs, with field research support from the Research Support and Logistics program. Some important research results are presented both as answers to important questions and leads to future research directions:

- **Studying Arctic Change: The Study of Environmental Arctic Change (SEARCH)** is an interagency, interdisciplinary, multi-scale program to study changes occurring in the Arctic and their potential impacts.
- **A look at Ringed Seal Migration: Working with Alaska Native hunters**, researchers captured a ringed seal and attached a satellite-tracking device to get the first-ever look at spring migration in this species as it moves northward with the melting ice of the Chukchi Sea.
- **Photochemistry in Greenland Snow:** Scientists have discovered that light-mediated chemical reactions (photochemistry) occur at the air-snow interface and significantly impact the chemical composition of air trapped in ice and of the air overlying the snow.
- **Small Streams on the Move:** Researchers have discovered that small streams contribute more to removing nutrients such as nitrogen from water than do their larger counterparts. The findings are based on data collected initially from streams in NSF's Arctic Tundra Long-Term Ecological Research site in Alaska and subsequently from 12 sites across the country.
- **Living Conditions in the Arctic:** This is an international effort involving a partnership of researchers and indigenous organizations across the Arctic. The purpose is to advance our understanding of changing living conditions among Inuit and Saami peoples and the indigenous peoples of Chukotka.
- **Life on the Gakkel Ridge:** The Gakkel Ridge is the slowest spreading center in the world, giving scientists the opportunity to explore

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the Earth's inner layers as the mantle spreads at about 1 cm per year onto the ocean floor near the North Pole.

- Understanding the Arctic Ocean: The Western Arctic Shelf Basin Interactions (SBI) project is investigating the impact of global change on physical, biological, and geochemical processes over the Chukchi and Beaufort Sea Shelf Basin in the western Arctic Ocean. Closely affiliated is the Chukchi Borderlands project to study the region where relatively cold, fresh, and nutrient-rich water from the Pacific Ocean meets warmer, saltier, and deeper water from the Atlantic Ocean over a bottom tortuously rife with slopes, ridges, and deep sea plateaus.

Discovery, Understanding, Teaching, Learning

National Science Foundation

NSF Commitment

The National Science Foundation seeks to advance learning and discovery in science and engineering, to nurture emerging fields, to prepare the next generation of scientific talent, and to ensure that all Americans understand what science and technology have to offer.

Community Involvement

The foundation's commitment to reaching beyond the traditional boundaries of science demands participation by the entire science community. Every proposal to NSF is required to address not only the intellectual merit but also the broader impacts of the research being proposed. Broader impacts might occur in any of five areas:

- promoting teaching, training, and learning;
- broadening participation of underrepresented groups;
- enhancing the research-education infrastructure;
- disseminating results broadly; and
- benefiting society.

Ideas

Earth's polar regions offer compelling opportunities to convey the broader impacts of research. The foundation's polar advisory committee—external scientists and educators—has made a list of ideas to help investigators explain in their proposals how their research would achieve broader impacts.

Examples

Many researchers, and others, who work in polar regions are advancing these ideas through traditional approaches—like involving students at the undergraduate level and beyond—and through innovative, community-oriented projects.

For further information, please go to: www.nsf.gov/od/opp/opp_advisory/oaccrit2.htm.

The International Polar Year

National Science Foundation

The International Polar Year 2007–2008 (IPY) is envisioned to be an intense, coordinated field campaign of polar observations, research, and analysis that will be multidisciplinary in scope and international in participation. IPY 2007–2008 will provide framework and impetus to undertake projects that normally could not be achieved by any single nation. The National Science Foundation was designated by the President's Office of Science and Technology to be the lead U.S. agency in organizing IPY activities.

Climate Change in High-Latitude Forests: Effects of Global Warming and CO₂ Fertilization on Natural Populations of Black and White Spruce

Elizabeth A. Nelson, University of Toronto (Student Scholarship Winner); and Sean C. Thomas

Global increases in temperature and atmospheric CO₂ concentration are predicted to enhance tree growth in the short term, but studies of current impacts of climate change on Canada's forests are limited. This study examined the effects of increasing temperature and atmospheric CO₂ concentration on tree ring growth in southeast Yukon, west-central Manitoba, and northern Ontario, sampling white spruce (*Picea glauca*) and black spruce (*Picea mariana*). Over 50 tree cores from each site were sampled, analyzed for ring-width, cross-dated, and averaged, generating a ~100 y chronology for each population.

We found a positive correlation between ring-width increment and spring temperatures (April: $p < 0.04$; May: $p < 0.002$) in Ontario. In Manitoba, we found a similar positive correlation between spring temperatures

and ring width (May: $p < 0.015$), but a negative correlation with summer temperatures (July: $p < 0.002$), likely due to summer water-limitation. In the Yukon, we found a negative relationship between ring width and spring temperatures (May: $p < 0.002$; June: $p < 0.01$), an indication of increased freeze-thaw damage under warmer conditions. We examined the residuals, following a regression with temperature for a positive trend over time, which has been interpreted in prior studies as evidence for a CO₂ fertilization effect. We detected an increase in ring width of 0.002 and 0.008 mm per year ($p < 0.001$; $p < 0.001$) in the Ontario and Manitoba populations, respectively, which was not explained by climate. These populations are more water-limited than the Yukon population, which had no evidence of a CO₂ fertilization effect.

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The Advancement of Exploration Along Scientific Lines: American Geographical Society Involvement in Arctic Research and Exploration

Frederick E. Nelson, University of Delaware

The American Geographical Society (AGS) has been closely involved in polar research and exploration since its inception in 1851, beginning with sponsorship of mid-19th century expeditions by Kane, Hayes, Schwatka, and others. The society played a major role in the expeditions of Admiral Robert Peary, who served as AGS President from 1903 to 1907. A signature characteristic of AGS sponsorship, even in the mid-19th century, was the society's requirement that its expeditions produce tangible scientific results. This quest for scientific achievement produced remarkable basic and technical developments in mapping and surveying, photogrammetry, geology, climatology, oceanography, glaciology, and strategic studies.

Several major institutions grew out of AGS programs in the Arctic, including the Arctic Institute of North America, the World Data

Center for Glaciology, the Juneau Icefield Research Program, and the Icefield Ranges Research Project. The society's primary journal, *Geographical Review* (and its predecessor titles), has been a major outlet for polar research for more than 150 years. Many luminaries of 20th century arctic science received their initial field experience on AGS expeditions. The society published many high-quality polar maps, including the 1:5,000,000 Map of the Arctic Region (1975), an innovative document compiled using satellite imagery, classified bathymetric data, and careful interpretation of deliberately falsified Soviet cartographic information. Today, AGS continues its polar involvement through several projects, including the W. S. Carlson International Polar Year Events.

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The Circumpolar Active Layer Monitoring Program (CALM II): Recent Initiatives and Results

Frederick E. Nelson, University of Delaware; Nikolay I. Shiklomanov; Dmitri A. Streletskiy; Kenneth M. Hinkel; and Jerry Brown

The Circumpolar Active Layer Monitoring Program (CALM), established in the early 1990s, is designed to observe temporal and spatial variability of the active layer, near-surface permafrost parameters, and their response to changes and variations in climatic conditions. The CALM network involves 14 participating countries and is comprised of 168 sites distributed throughout the Arctic, parts of Antarctica, and several mountain ranges of the mid-latitudes. Owing to historical circumstances and logistical constraints, the distribution of sites is not uniform within the permafrost regions. The majority of the sites are in arctic and subarctic lowlands.

At 77 sites, direct active-layer measurements are conducted on standard rectangular grids ranging from 10 m x 10 m to 1 km x 1 km. The locations of grids were selected to represent generalized surface and subsurface conditions characteristic of broad regions. The size of each grid reflects the level of local geographic variability. At 91 sites, active-layer values are inferred using soil temperature mea-

surements from boreholes of variable depth. Approximately 60 CALM sites have continuous active-layer records longer than five years, and 30 have ten-year records or longer. Auxiliary information includes air temperature, soil moisture, soil temperature at different depths, snow cover, soil composition, and landscape characterization. Metadata include detailed site descriptions and photographs of each site. Although the limited number of observational sites, their sparse distribution, and relatively short records preclude direct extrapolation of observations to the entire circum-arctic region, several groups of sites have been used to create regional maps of active-layer thickness.

Data obtained from the network are used widely in validation procedures for permafrost, hydrological, ecological, and climatic models, at a variety of geographic scales. Several sites have records of frost heave and thaw subsidence that are contributing to a re-conceptualization of the role of the active layer in global-change studies.

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The University of Delaware's W. S. Carlson International Polar Year Events: History, Scope, and Organization

Frederick E. Nelson, University of Delaware

The University of Delaware (UD) has maintained a strong presence in cold-regions research since the mid-1940s, when William Samuel Carlson, a highly accomplished arctic explorer, military strategist, and Earth scientist, was named 20th President (1946–1950) of the University. Carlson played leading roles in two of the University of Michigan's Greenland expeditions in the late 1920s and early 1930s. Later, as commanding officer of the Arctic, Desert, and Tropic Branch of the U.S. Army Air Forces Tactical Center during World War II, Colonel Carlson played a key role in developing several transportation routes through the Arctic that hastened defeat of the Axis powers. He authored many scientific and popular publications concerned with the Arctic, including the books *Greenland Lies North* (1940) and *Lifelines Through the Arctic* (1962). Carlson was a founding member of the Arctic Institute of North America.

Although the University of Delaware has maintained a vigorous and continuous program of polar research since Carlson's tenure, the faculty, staff, and students involved are diffused throughout the university's colleges and departments, without a clear institutional focal point. Consequently, although many of these

individuals are well known in their respective fields, until recently the institution had not been perceived widely as a center of polar-oriented research.

The Carlson IPY Events were developed to:

- create a sense of community among UD's diffuse polar-oriented researchers and educators;
- develop a distinctive and highly visible role for the university in the milieu of IPY activities;
- promote education about the polar regions in the state of Delaware;
- forge a close relationship between UD and the American Geographical Society, a national organization involved closely with IPY activities for more than a century; and
- create a new basis for development efforts on behalf of UD among public funding agencies, private foundations, and prominent Delaware corporations.

The Carlson IPY Events provide support for public lectures, departmental and interdisciplinary seminars, two major art exhibitions, a film series, and several other events focused

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on polar topics. The project is sponsored jointly by the University of Delaware's Center for International Studies, the Office of the Provost, all of the university's seven colleges, the UD library, UD museums, UD Office of Public Relations, and the American Geographical Society. The Carlson IPY Events are administered by a university-wide committee and are part of an ongoing series sponsored by the Center for International Studies under the title "UD and the Global Community."

NORSAGA: A Project for IPY

Astrid E. J. Ogilvie, University of Colorado Boulder; William P. Patterson; Ingibjörg Jónsdóttir; Niels Einarsson; and Oyvind Nordli

The project Northern Narratives: Social and Geographical Accounts from Norway, Iceland, and Canada (NORSAGA) is an international collaborative study, which brings together a blend of social and natural science skills contributed by a team of researchers from the U.S., Iceland, and Canada in response to the 2005 European Science Foundation BOREAS competition (www.esf.org; Klein et al., 2007). It is also an official National Science Foundation (NSF) International Polar Year project. NORSAGA comprises three individual projects focused on four geographical areas of research: Iceland, Labrador/Nunatsiavut, arctic Canada and Alaska, and Norway. The latter project falls under the auspices of NSF, while the Canadian and Icelandic components are funded by the Social Sciences and Humanities Research Council for Canada and by the Icelandic Centre for Research (RANNÍS).

The methods to be used for NORSAGA involve the study of traditional ecological knowl-

edge (TEK), as well as the documentation and analysis of social, geographical, and environmental movements, using narratives primarily in the form of historical documentary records. Standard methods of source and content analysis are used. The main time period covered is the past 300 years to the present. Data from the natural sciences, especially climate proxy data, are also used in NORSAGA.

The Labrador/Nunatsiavut component includes an analysis of tree-ring cellulose data. This will result in the highest resolution 300-year record of proxy climate that has yet been produced for Labrador. This detailed record, together with proxy climate data for Iceland, will be compared with documentary and TEK data in order to enhance understanding of perceptions of boreal environmental changes and climate impacts over the past 300 years. Data from arctic Canada and Alaska are taken primarily from the writings of the explorer Vilhjálmur Stefánsson (1889–1962).

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For Norway, the TEK study is centered on the Vestre Slidre region of Valdres in the Oppland district. The contemporary focus of this part of the project considers the pastoral practice of transhumance, which involves bringing cattle up to lush mountain pastures in the summer—a practice that is rapidly dying out. For the social and environmental history component of this part of the project, data are drawn from farmers' diaries as well as other historical sources and a winter-spring temperature reconstruction for southeastern Norway for the period 1758 to 2006 has already been published (Nordli et al., 2007).

Astrid Ogilvie's journey to Labrador in 2007 to discuss changes in the location and nature of sea ice led to an unexpected discovery. The community of Makkovik, with a population of 400 and a main focus of this part of the project, was settled in the 1890s by a Norwegian named Torstein Kvaerna Andersen. His home was in Begnadalen, a valley which happens to be located in the Norway study area. This link was not known to Ogilvie before her visit to Makkovik and makes comparison of the two locations especially interesting.

NORSAGA may be seen in the context of the long tradition in Western scholarship of seeking to understand interactions between humans and their environments. Not only is the project interdisciplinary and multidisciplinary, but, by blending a number of different data sets, its potential for an increase in

knowledge regarding social-environmental relationships is vast. Together, the three individual projects that comprise NORSAGA will yield data that will be of relevance to many different academic disciplines.

The general aims of NORSAGA reflect the BOREAS call, which noted that much arctic science has been dominated by natural science agendas, with inhabitants of the Arctic often seen merely as natural variables. A major long-term goal of NORSAGA is to begin to redress this balance and consider the cultural as well as the environmental processes that shape boreal affairs. NORSAGA may also be seen in the context of the global and regional impacts of the arctic climate system and its variability, with a special focus on establishing links between environmental change and human activity. The primary objective of NORSAGA is thus to explore particular instances of change in the past and present in order to document and understand the movements, narratives, and histories of humans within their environmental context.

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A Baseline Study for Long-Term Acoustic Monitoring in the Arctic Ocean: Ambient Noise Measurements, Environmental Correlates, and Bioacoustics North of Barrow, Alaska

Ethan H. Roth, University of California San Diego (Student Scholarship Winner); Josh Jones; John A. Hildebrand; and Sean M. Wiggins

Communities and researchers in the Arctic have observed drastic alterations in sea ice dynamics that have already begun to disturb the marine ecosystem. While the decline of sea ice will directly affect marine mammals and arctic native people, increases in ambient sound and changes in acoustic propagation could also have indirect consequences for the region. Recent work has shown how the global shipping trade in the Pacific Ocean has caused an increase in ambient noise levels of 3 dB per decade since the 1960s (McDonald, 2006). In a seasonally ice-free Arctic, increases in oil industry and shipping activities along the North Slope of Alaska will concentrate sources of anthropogenic noise in an area where relatively little man-made sound has been produced until recently. This study collects year-long baseline measurements in order to understand the contribution of environmental correlates, marine mammals, anthropogenic sound, and other noise-generating mechanisms to the sound spectrum.

In September 2006, two high-frequency acoustic recording packages were deployed to the seafloor north of Point Barrow, Alaska. Hydrophones continuously recorded sound in the underwater environment and stored data autonomously for nine months. During this time period, conditions included open water, sea ice formation and pressure ridging, a land-fast ice canopy, and breakup. Our analysis is concerned with defining the complex relationship and dependency that ambient noise has on sea ice and how this shifts over time until a seasonally ice-covered Arctic Ocean becomes reality.

The first year of data has been analyzed using spectral methods. Physical data is correlated with sea ice concentration data from the National Aeronautics and Space Administration AMSR-E satellite and wind speed data from a National Oceanic and Atmospheric Administration meteorological station in Barrow. In addition, several cetacean and pinniped species were recorded, including bowhead

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and beluga whales, ringed and bearded seals, and walrus. This bioacoustic data is compared with sea ice concentration data to determine relationships between sea ice dynamics and marine mammal presence or absence. Combined with ancillary data, long-term acoustic monitoring is effective in observing changing levels in ambient sound related to environmental and man made noise, while detecting the presence of marine mammals.

Elevation Change of Drangajökull Ice Cap, Iceland, from Cloud-Cleared ICESat Profiles and GPS Ground-Survey Data

Christopher A. Shuman, University of Maryland; Oddur Sigurðsson; Jóna Finndís Jónsdóttir; Richard S. Williams, Jr.; and Dorothy K. Hall

Located on the Vestfirðir (Northwest Fjords), Drangajökull is the northernmost ice cap in Iceland. Currently, the ice cap exceeds 900 m in elevation, has an area of ~146 km², has apparently decreased in area from about 160 km² a few decades ago, and has lost mass since the early 1900s. Drangajökull's size and relative accessibility for GPS surveys, as well as the availability of repeat satellite altimetry profiles since late 2003, make it an excellent subject for mass-balance/change-detection analysis.

The ice cap was surveyed by four GPS-equipped snowmobiles on 19–20 April 2005 and has been profiled in two places by Ice, Cloud, and Land Elevation Satellite (ICESat) "repeat tracks" 12 times from late 2003 to late 2007. Mean differences between the temporally closest ICESat elevations and the digital

elevation model (DEM) elevations from the ground-based GPS surveys (ICESat-DEM) vary from +0.72 to +1.08 m and have standard deviations of 3 to 4 m. The trend of the elevation difference data from 2003 to 2007 shows net negative 2.26 m a⁻¹ elevation changes where ICESat tracks 0046 and 0307 across Drangajökull. If representative of the whole ice cap, this elevation loss translates into -0.3 GT yr⁻¹ and a total loss over 2003–2007 of approximately 1.3 GT. This analysis suggests that ICESat-derived elevations can be used for multi-year change detection, but uncertainties remain because of ICESat laser energy declines and continuing cloud cover. Consequently, similar elevation change and mass-balance assessments may have similar uncertainties, especially on cloudy ice-sheet and ice-cap slopes.

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Water Stress at the Arctic Treeline: Importance of Parent Material Depth and Atmospheric Drought

Patrick Sullivan, University of Alaska Anchorage; and Bjartmar Sveinbjörnsson

The water relations of white spruce (*Picea glauca*) have been monitored during two contrasting growing seasons on a riverside terrace in Noatak National Preserve (67°29'N, 162°13'W). The terrace is capped with a layer of silt and sand, which grades from depths of 12 to 48 cm. White spruce trees ~2.5 m in height and ~4.0 cm in diameter are evenly distributed along the terrace. Precipitation during the 2007 growing season was almost exactly one-half of precipitation during summer of 2006.

The warm, dry 2007 growing season led to water stress in white spruce trees at the shallow end of the silt cap gradient, where the parent material is less than 30 cm thick. Water stress was observed when measurements were made in mid-July, but not during early June or late August. Water stress manifested as a complete shut-down of photosynthesis when measured at 2:00 p.m., 8:00 p.m., and 2:00 a.m. Net photosynthesis in water-stressed trees was only observed when measurements were made at 8:00 a.m., the time

during the diurnal cycle when the atmospheric vapor pressure deficit was lowest. Stem water potentials of -1.8 Mpa corresponded with the point at which trees closed their stomata and shut down photosynthesis.

Interestingly, soil water contents were very similar when the July and August dates were compared. In late August, the atmospheric vapor pressure deficit was lower than in July, suggesting that both dry soils and a dry atmosphere contributed to the water stress observed in July. Measurements of light saturated photosynthesis in June, July, and late August of 2007 revealed a major surprise. Photosynthetic rates in late August were more than double those observed in June and only slightly less than double those observed in July. While this observation may be specific to a dry growing season with depressed photosynthetic rates in July, it suggests that autumn may be an important and overlooked period of substantial carbon gain in treeline environments.

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Heterogeneity of Shrub Expansion in the Arctic

Ken Tape, University of Alaska Fairbanks

A multitude of evidence suggests that deciduous shrubs are replacing low-growing tundra vegetation in many regions of the Arctic, including Alaska. This shift in vegetation represents the major landscape change underway in the Arctic and is profoundly altering a host of ecosystem processes. Repeat photography shows that while some areas have changed radically, other areas remain unchanged.

The goal of this work is to identify diagnostic environmental and floristic properties of expanding versus stagnant shrub patches, by

sampling where repeat photography is available. Preliminary measurements from expanding and stagnant shrub patches suggest that such diagnostic properties exist. In the summer of 2008, the National Park Service is supporting fieldwork to measure environmental and floristic properties in expanding and stagnant shrub patches, as part of the long-term monitoring program. Other funding is supporting identical work on the North Slope. This sampling will add roughly 30 transects to the 4 initial transects, and all will be established as long-term monitoring sites.

The Causes of Greenland's Record Surface Melt in 2007

Marco Tedesco, City University of New York; Xavier Fettweis; and Mark C. Serreze

Observing snow melt extent and duration over the Greenland Ice Sheet is fundamental for understanding how Greenland is contributing to current sea level rise and affecting Earth's energy budget. Some of the liquid water from snowmelt flows into the ocean, directly contributing to sea level rise, while other water percolates at the bottom of the ice sheet. Melted snow absorbs and reflects the sun's irradiated energy differently than fresh snow; melted/refrozen snow absorbs up to four times more energy than fresh/unthawed snow. This strongly affects Earth's energy budget.

Analysis of passive microwave brightness temperatures from the space-borne Special Sensor Microwave Imager (SSM/I) documented a record surface snowmelt over high elevations of the Greenland Ice Sheet during summer of 2007. To interpret this record, results

from the SSM/I were examined in conjunction with atmospheric fields from the National Centers for Environmental Prediction and Atmospheric Research reanalysis, satellite-derived cloud fraction from the Moderate Resolution Imaging Spectro-Radiometer, and output from the Modèle Atmosphérique Regional (MAR) regional climate model. The pronounced surface melt was consistent with southerly airflow promoting persistent positive temperature anomalies through the summer season (June–August). Cloud radiative forcing appears to have played a lesser role, though available data were insufficient to draw firm conclusions. No significant trend was observed with respect to the shortwave incoming radiation. Positive (negative) anomalies of long-wave incoming radiation (albedo) suggest that these two components might have contributed to setting the melting record.

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PolarTREC—Teachers and Researchers Exploring and Collaborating: Innovative Science Education from the Poles to the World

Kristin M. F. Timm, Arctic Research Consortium of the U.S.; Janet Warburton; and Wendy K. Warnick

PolarTREC—Teachers and Researchers Exploring and Collaborating, a program of the Arctic Research Consortium of the U.S. (ARCUS), is a National Science Foundation-funded International Polar Year (IPY) project, in which K–12 teachers participate in polar research, working closely with scientists as a pathway to improving science education.

The PolarTREC conceptual model applies and advances best practices of teacher research experiences through intensive scientific content training, use of cutting-edge technology for field communications and outreach, the application of inquiry-based learning in all activities, a focus on sustained, long-term collaborations between educators, scientists, and students, and promotion of broad public interest and engagement in polar science and the IPY.

PolarTREC, currently in its second year, enables over 40 teachers to spend two to six weeks in the Arctic or Antarctica, working closely with researchers investigating a wide range of scientific topics, including sea ice dynamics, terrestrial ecology, marine biol-

ogy, atmospheric chemistry, long-term climate change, and others. While in the field, teachers and researchers communicate extensively with their colleagues, communities, and hundreds of students of all ages across the globe, using a variety of tools including satellite phones, online journals, podcasts, and interactive "Live from IPY!" calls and web-based seminars. The online outreach elements of the project convey these experiences to a broad audience far beyond the classrooms of the PolarTREC teachers. In addition to field research experiences, PolarTREC supports teacher professional development and a sustained community of teachers, scientists, and the public through workshops, Internet seminars, an e-mail listserve, and teacher peer groups. Teachers and researchers have connected with wide audiences before, during, and after the field research experiences that have transpired thus far. From the field, 31 "Live from IPY!" Events have reached 3,900 students and 1,161 teachers, researchers, and members of the community, and the teams have answered over 300 student and public

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questions about the life, work, and science of the polar regions. PolarTREC teachers and researchers have given over 100 presentations to schools, community groups, and professional organizations, and have been featured in radio and television news, as well as over 90 newspaper, magazine, and Internet articles. The PolarTREC website has 850 separate teacher journal entries, 1,700 "Ask the Team" questions, and 5,750 photos in the photo gallery. The online PolarTREC Learning Resources database currently contains 46 lessons and activities to aid educators in teaching polar science. The Connecting Arctic and Antarctic Researchers and Educators (CARE) Network, a professional development network that uses online web meetings to support the integration of science research experiences into classroom curriculum, will be holding its first meetings in the summer of 2008. A comprehensive program evaluation has been taking place since program inception, and preliminary results are forthcoming. Through these activities, PolarTREC advances and promotes broad public interest and engagement in polar science to provide a lasting legacy of the IPY.

To join the discovery, make global connections, and be part of the International Polar Year or for more information, visit the PolarTREC website at: www.polartrec.com, or contact ARCUS at: info@polartrec.com or 907-474-1600.

PolarTREC—Teachers and Researchers Exploring and Collaborating: Classroom Activities and Learning Resources

Kristin M. F. Timm, Arctic Research Consortium of the U.S.; Janet Warburton; and Wendy K. Warnick

This display highlights a variety of learning resources created by PolarTREC teachers, as well as classroom activities that students completed in conjunction with various PolarTREC expeditions. Projects include educational activities, artwork, songs, movies, and other student projects. Contributions come from:

- Hanna High School, Brownsville, Texas;
- Barrett Elementary School, Arlington, Virginia;
- Kalama Intermediate School, Makawao, Hawaii;
- Redd School, Houston, Texas;

- Bellaire High School, Houston, Texas;
- Blanco Middle School, Blanco, Texas;
- Chico Junior High, Chico, California;
- Chester-Andover Elementary School, Chester, Vermont; and
- Liverpool High School, Liverpool, New York.

To join the discovery, make global connections, and be part of the International Polar Year or for more information, see the PolarTREC abstract or visit the PolarTREC website at: www.polartrec.com, or contact ARCUS at: info@polartrec.com or 907-474-1600.

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PolarTREC—Teachers and Researchers Exploring and Collaborating: Classrooms and Communities Experience the Polar Regions—PolarTREC Outreach Success

Kristin M. F. Timm, Arctic Research Consortium of the U.S.; Janet Warburton; and Wendy K. Warnick

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Before, during, and after the field research experience, teachers and researchers communicate extensively with their colleagues, communities, and hundreds of students of all ages across the globe, using a variety of tools including online journals, photos, and an "Ask the Team" forum, as well as podcasts and interactive "Live from IPY!" calls. Teachers and researchers also conduct outreach through school, public, and professional talks and presentations and by connecting with formal media sources including television, newspaper, magazine, and radio.

The diverse outreach components of the PolarTREC program ensure that the science and excitement of the polar regions reaches

a broad audience, far beyond the classrooms of the PolarTREC teachers. Featured in this poster is a small portion of the media attention received by PolarTREC teachers and teams between December 2006 and May 2008. It highlights their incredible outreach efforts and their success in communicating their experiences to audiences locally and around the world.

Additional outreach examples—from articles to presentations—are available in the "Newsroom and Learning Resources" archives at the PolarTREC website: www.polartrec.com.

To join the discovery, make global connections, and be part of the International Polar Year or for more information, see the PolarTREC abstract or visit the PolarTREC website at: www.polartrec.com, or contact ARCUS at: info@polartrec.com or 907-474-1600.

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Monitoring Change in the Arctic: Use of the National Institute of Standards and Technology's Marine Environmental Specimen Bank

Stacy S. Vander Pol, Hollings Marine Laboratory; Paul R. Becker; Rusty D. Day; Jocelyn R. Flanary; Jennifer M. Keller; John R. Kucklick; Amanda J. Moors; David Point; and Rebecca S. Pugh

The National Institute of Standards and Technology (NIST) maintains the cryogenic Marine Environmental Specimen Bank (ESB) in Charleston, South Carolina. This bank contains approximately 1,700 Alaskan marine mammal tissue samples, collected from 17 species since 1987, and approximately 1,200 Alaskan seabird egg clutches, collected from five species, since 1999.

Recent projects examining contaminant concentrations in these tissues illustrate the benefits of specimen banking for monitor-

ing environmental changes. For instance, the concentration of emerging contaminants such as brominated flame retardants (BFRs) increased in beluga whale blubber samples collected from the Chukchi Sea between 1990 and 2000. Likewise, butyl tin compounds also increased in the liver of these animals and in ringed seals during the same time span. Ringed seals collected from Barrow, Alaska, had higher concentrations of organic contaminants in their blubber than those from Nome, Alaska, but the ratios suggested fresh sources

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of hexachlorocyclohexane (HCH) and DDT entering the northern Bering Sea. In addition, samples of blood and liver from northern fur seals and beluga whales are currently being analyzed for perfluorinated compounds. Analyses of the seabird egg samples for BFRs, PCBs, organochlorine pesticides, butyl tins, and both mercury isotopic signatures and concentrations have shown differences between species at the same location, concentration differences between the Gulf of Alaska and Bering and Chukchi Seas, and temporal changes. As the environment changes and new techniques or compounds of concern emerge, the samples banked in the Marine ESB will continue to provide a valuable resource for monitoring these changes.

Cumulative Impact Analysis on the Yamal Peninsula, Russia: A Blueprint for a Comparative Study in Northern Alaska?

Donald (Skip) A. Walker, University of Alaska Fairbanks; Bruce C. Forbes; Florian Stammler; Timo Kumpula; Anatoli Gubarkov; Elina Karlejaarvi; Uma Bhatt; Gary Kofinas; Martha Reynolds; Vladimir Romanovsky; Patrick Kuss; Marina Leibman; Natalia Moskalenko; Artem Khomutov; George Matyshak; Howard E. Epstein; Qin Yu; Jiong Jia; Joey Comiso; and Jed Kaplan

Oil and gas activities over the past 30+ years have had profound effects on the social-ecological systems of the Yamal region of Russia and northern Alaska. Both regions are also undergoing rapid climate warming, with important ramifications for tundra vegetation and permafrost soils.

Russian and Finnish scientists are studying the terrain, permafrost, and socio-ecological impacts of development on the Yamal Peninsula and are collaborating with U.S. scientists, who are primarily examining the climate-related impacts to the vegetation and how these are related to the changing sea ice concentrations and are employing state-of-the-

art vegetation change models to predict the combined effects of land-cover changes due to altered climate and industrial development.

Here, we summarize some of the recorded effects in the Yamal region of industrial development and the role of terrain sensitivity, reindeer herding, and climate change. Our aim is the co-production of knowledge relevant to assessing the overall cumulative effects—both positive and negative—from past resource exploration and from climate change. We point the way to a comparative study of cumulative effects in North America that would draw on the different lessons learned in both regions, with a goal of collaborating intensively with the

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local people to develop tools to better predict the cumulative effects of resource development and climate change in these and other regions of the Arctic.

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North American Arctic Transect: The Need for Baseline Observations Along an Extended Arctic Observation Network in Advance of Rapid Melting of the Perennial Ice Cover

Donald (Skip) A. Walker, University of Alaska Fairbanks

The broad vision for the network of terrestrial observatories includes both intensive ongoing observations at established flagship observatories and observations at a more widely dispersed network of sites that includes important areas of the Arctic that are not represented by the current network. It is also important to consider how the terrestrial network is coordinated with the ocean and sea ice observing networks.

The North American Arctic Transect was established as part of the Biocomplexity of Patterned Ground project (<http://naat.geobotany.org/index.html>). These sites will be highlighted in an upcoming special section of the *Journal of Geophysical Research–Biogeosciences* that will include 12 articles devoted to biocomplexity of arctic terrestrial environments.

Of special importance are the sites at Mould Bay and Isachsen, which are in the coldest part of the Canadian Archipelago. These sites are cold because they are in the region of perennial sea ice where summer air temperatures are held close to 0°C all summer. These areas are likely to undergo major

changes in climate if the perennial sea ice vanishes.

This poster advocates the establishment of baseline observations at these sites before the sea ice is eliminated and the warming climate eliminates or greatly reduces these two subzones. It would be highly desirable for the U.S. and Canada to develop the logistic capability for a team of researchers to work at these sites for at least two years to establish the critical terrestrial baseline. Considerations for forming this team include:

- Most importantly, these sites are in a rare and endangered bioclimate subzone that is likely to vanish if the perennial sea ice is eliminated.
- Subzone A is an entirely unique bioclimate subzone that is recognized by Russian geobotanists as a completely separate bioclimate zone (not just a subzone). Among its unique vegetation properties are extremely small vascular flora (about 60 species for the entire circumpolar subzone) but a very rich cryptogamic flora; a complete lack of woody plant species and sedges; a

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dominance of rushes, grasses and a few small hardy forbs; and a lack of peat in wetlands. Similar faunal uniqueness has been studied most extensively in Russia by Chernov.

- There is a long-term climate record at both sites dating back to the 1940s.
- There is a good, long runway at Mould Bay and an adequate runway at Isachsen.
- There are good camp facilities at Mould Bay and poor, but adequate, accommodations at Isachsen.
- A good foundation of observations for future studies was established during the Biocomplexity of Patterned Ground studies: www.geobotany.uaf.edu/library/reports/#bc_reports.
- The sites could also serve for sea ice, oceanographic, and snow studies and could be linked to a truly integrated examination of ocean-land observations in what will likely be an area of extremely dynamic changes as the perennial ice melts.

Dipole Anomaly Drove the 2007 Arctic Sea Ice Minimum

Jia Wang, National Oceanic and Atmospheric Administration; and Jinlun Zhang

The record low arctic sea ice in the summer of 2007 is found to be triggered by the Arctic Dipole Anomaly pattern. This local, second-leading mode in the Arctic produced a strong meridional wind anomaly that drove more sea ice out of the Arctic Ocean during the summer of 2007 from the western to the eastern Arctic into the northern Atlantic.

We identify the Dipole Anomaly (DA) pattern in the arctic atmosphere, and its relationship with winter sea ice motion, based on the International Arctic Buoy Programme dataset (1979–2004) and datasets from the National Centers for Environmental Prediction and the National Center for Atmospheric Research for the period of 1948–2007. The DA is the second-leading mode of empirical orthogonal function of monthly mean sea level pressure

north of 70°N during the winter season (October–March) and accounts for 13% of the variance. One of its two anomaly centers is over the Canadian Archipelago and the other is situated over northern Eurasia and the Siberian marginal seas. Due to the DA's strong meridionality, it becomes an important dynamic mechanism to drive both anomalous sea ice out of the Arctic Basin and cold air outbreaks into the Barents Sea, the Nordic Seas, and northern Europe.

The Pan-Arctic Ice-Ocean Modeling and Assimilation System was used to examine the response of sea ice motion to the 2007 DA forcing. The spatial patterns and temporal variations of sea ice are identified to be closely related to the DA. A new feedback loop in the western Arctic is proposed.

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The Arctic Research Consortium of the U.S.

Wendy K. Warnick, Arctic Research Consortium of the U.S.; and Helen V. Wiggins

The Arctic Research Consortium of the U.S. (ARCUS) is a nonprofit membership organization composed of universities and institutions that have a substantial commitment to research in the Arctic. ARCUS was formed in 1988 to serve as a forum for planning, facilitating, coordinating, and implementing interdisciplinary studies of the Arctic; to act as a synthesizer and disseminator of scientific information on arctic research; and to educate scientists and the general public about the needs and opportunities for research in the Arctic. ARCUS, in collaboration with the broader science community, relevant agencies and organizations, and other stakeholders, coordinates science planning and educational activities across disciplinary and organizational boundaries.

Examples of current ARCUS science planning activities include serving as the project office for the multi-agency Study of Environmen-

tal Arctic Change (SEARCH) program, providing support to the related Bering Ecosystem Study (BEST), and serving as the Science Management Office for the National Science Foundation Arctic System Science (ARCSS) Program. ARCUS' central educational activity is PolarTREC (Teachers and Researchers Exploring and Collaborating), an International Polar Year program whereby K–12 educators and researchers work together in hands-on field experiences in the Arctic and Antarctic to advance polar science education. Additional science planning, educational, information, and outreach activities include, among many others, the *Witness the Arctic* newsletter, the Arctic Visiting Speakers' Series, the ArcticInfo listserv, the Internet Media Archive, and the annual Arctic Forum conference.

More information about these and other ARCUS activities can be found on the ARCUS website at: www.arcus.org.

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Arctic Synthesis Collaboratory: A Virtual Organization for Transformative Research and Education on a Changing Arctic

Wendy K. Warnick, Arctic Research Consortium of the U.S.; Helen V. Wiggins; Larry Hinzman; Marika Holland; Maribeth S. Murray; Charles Vörösmarty; and Alysa J. K. Loring

Scientific Rationale

The rapid rate of arctic change and our incomplete understanding of the arctic system present the arctic community with a grand scientific challenge and three related issues. First, a wealth of observations now exists as disconnected data holdings, which must be coordinated and synthesized to fully detect and assess arctic change. Second, despite great strides in the development of arctic system simulations, we still have incomplete capabilities for modeling and predicting the behavior of the system as a whole. Third, policy-makers, stakeholders, and the public are increasingly making demands of the science community for forecasts and guidance in mitigation and adaptation strategies.

About the Arctic Synthesis Collaboratory

The Arctic Synthesis Collaboratory concept, developed through a series of NSF-funded workshops and town hall meetings, is envisioned as a cyber-enabled, technical, organizational, and social-synthesis framework to foster:

- interactions among interdisciplinary experts and stakeholders;
- integrated data analysis and modeling activities;
- training and development of the arctic science community; and
- delivery of outreach, education, and policy-relevant resources.

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Collaboratory Components

The Arctic Synthesis Collaboratory is organized around four integrated functions that will be established virtually as a distributed set of activities, but also with the advantage of existing facilities that could sponsor some of the identified activities.

- *Community Network "Meeting Grounds"*

The Collaboratory will link distributed individuals, organizations, and activities to enable collaboration and foster new research initiatives. Specific activities could include: an expert directory, social networking services, and virtual and face-to-face meetings.

- *Data Integration, Synthesis, and Modeling Activities*

The Collaboratory will utilize appropriate tools to enable the combination of data and models. Specific activities could include: a web-enabled model library, user forums, a data search and discovery system, and an online library.

- *Support Scientist Professional Development*

Experts at all career levels must keep pace with the newest developments in data integration and modeling, interdisciplinary science, and cyber-enabled collaboration. Specific project activities could include: web seminars, short courses, and a mentor program.

- *Education, Outreach, and Policy Resources*

An Arctic Virtual Outreach Center will provide critical education, outreach, and policy elements of the Collaboratory. Specific activities could include: public E-seminars, a virtual pressroom, K–12 classroom resources, and an E-newsletter.

For more information, contact Helen Wiggins, Arctic Research Consortium of the U.S. (ARCUS) at: helen@arcus.org, or go to the website of the community workshop New Perspectives through Data Discovery and Modeling at: www.arcus.org/ARCSS/2007_data/index.html.

SEARCH: Study of Environmental Arctic Change—A System-Scale, Cross-Disciplinary, Long-Term Arctic Research Program

Helen V. Wiggins, Arctic Research Consortium of the U.S.; Peter Schlosser; Alysa J. K. Loring; Wendy K. Warnick; and the SEARCH Science Steering Committee

The Study of Environmental Arctic Change (SEARCH) is a multi-agency effort to observe, understand, and guide responses to changes in the arctic system. Interrelated environmental changes in the Arctic are affecting ecosystems and living resources and are impacting local and global communities and economic activities.

Under the SEARCH program, guided by the Science Steering Committee (SSC), the Interagency Program Management Committee (IPMC), and the Observing, Understanding, and Responding to Change panels, scientists with a variety of expertise—atmosphere, ocean and sea-ice, hydrology and cryosphere, terrestrial ecosystems, human dimensions, and paleoclimatology—work together to achieve goals of the program. Over 150 projects and activities contribute to SEARCH implementation.

The Observing Change component is underway through National Science Foundation's (NSF) Arctic Observing Network, National Oceanic and Atmospheric Administration (NOAA)-sponsored atmospheric and sea ice observa-

tions, and other relevant national and international efforts, including the EU-sponsored Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES) Program. The Understanding Change component of SEARCH consists of modeling and analysis efforts, with strong linkages to relevant programs such as NSF's Arctic System Science Program. The Responding to Change element is driven by stakeholder research and applications addressing social and economic concerns. As a national program under the International Study of Arctic Change, SEARCH is also working to expand international connections in an effort to better understand the global arctic system.

SEARCH is sponsored by eight U.S. agencies, including: NSF, NOAA, the National Aeronautics and Space Administration, the Department of Defense, the Department of Energy, the Department of the Interior, the Smithsonian Institution, and the U.S. Department of Agriculture. The U.S. Arctic Research Commission participates as an IPMC observer.

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For further information, please visit the SEARCH website: www.arcus.org/search, or contact Helen Wiggins, SEARCH Project Office, ARCUS (helen@arcus.org) or Peter Schlosser, SEARCH SSC Chair (schlosser@ideo.columbia.edu).

U.S. Civilian Research and Development Foundation: Facilitating Collaborative Arctic Research

Julie Wilson, U.S. Civilian Research and Development Foundation; and Erik A. Edlund

The U.S. Civilian Research and Development Foundation (CRDF) is a private, nonprofit, grant-making organization established in 1995 by the U.S. government through the National Science Foundation (NSF). CRDF promotes international scientific and technical collaboration, primarily between the U.S. and Eurasia, through grants, technical resources, and training.

CRDF provides support to U.S. and Russian scientists engaged in collaborative arctic-related research through several channels.

- *On-site Assistance*

Under a contract with the NSF, CRDF has an established office and personnel available in Moscow to assist the Office of Polar Programs and Geosciences Directorate grantees. The NSF grantees receive help identifying and communicating with individual and institutional partners, navigating government agencies, facilitating travel and visas, and providing on-site support to visiting U.S. travelers.

- *Services*

CRDF's Grant Assistance Program services enable U.S. government agencies, universities, private companies, and other organizations to utilize CRDF's financial and administrative infrastructure to transfer payments, purchase and deliver equipment and supplies, and carry out other project management services for collaborators in Russia and throughout Eurasia.

- *Grant Funding*

This fall, CRDF's Cooperative Grants Program will be announcing grant competitions to support international collaborative climate change research. U.S.–Russian and U.S.–Ukrainian teams investigating the effects of climate change in the Arctic will be eligible to apply. Grant funds will support two-year research projects and can be used for travel, equipment, materials and supplies, foreign salaries, and U.S. graduate student stipends.

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Evaluating Arctic Tundra System Responses to Climate Change and Grazing Disturbances: A Modeling Approach

Qin Yu, University of Virginia (Student Scholarship Winner); and Howard E. Epstein

Arctic terrestrial ecosystems are assumed to be one of the most sensitive systems, enduring low temperatures, short growing seasons and freeze-thaw dynamics. The comparatively slow rates of productivity and decomposition may make it particularly difficult for these systems to recover from disturbances. One major disturbance in arctic terrestrial systems is grazing by caribou and reindeer; different grazing intensities and climate regimes may result in different productivities and plant species compositions. This study is to evaluate how tundra ecosystems with different grazing patterns will respond to warming and how the combinations of climate change and grazing may affect system response. It is unclear whether climate warming or grazing is the dominant factor that controls this system.

We applied a nutrient-based transient vegetation dynamics model (ArcVeg) to simulate how typical arctic tundra ecosystems respond to different degrees of grazing. Two different herbivore-grazing regimes in tundra systems were considered and compared in this study: managed reindeer herds and wild caribou herds. Reindeer, as a major food source for nomadic herders, such as the Nenets of the Yamal Peninsula in northwestern Siberia, tend

to graze tundra more intensely than wild caribou herds, such as those in Alaska, Canada, and North America. Grazing intensity was represented by the combination of annual probability of grazing and percentage of biomass removed by grazing. We used three parameter combinations: (0.1, 25%) indicating the system would be grazed every ten years, and 25% of plant biomass was removed by grazing, (0.5, 50%) 50% of plant biomass removed every two years, and (1, 75%), 75% removed by grazing each year. The first scenario is more similar to caribou grazing, whereas the latter two are indicative of managed reindeer herds.

We also manipulated climate in model warming scenarios. A key assumption of the model is that with higher temperatures, decomposition rates increase, thus increasing the availability of soil nitrogen for facilitating plant growth. The warming scenario for our simulation was assumed to be a 2°C temperature increase linearly ramped over a 50-year period.

Grazing and temperature have opposite effects on system productivity, with higher grazing intensity resulting in lower productivity and warmer temperatures leading to greater productivity. Under similar grazing regimes,

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the modeled biomass increased as a result of warming by approximately 130% in Subzones A and B (polar desert and high arctic), while only about 50% in Subzones C, D, and E (mid- and low-Arctic). Under the same climate regime, biomass for Subzones C, D, and E decreased about 30% more than Subzones A and B due to increasing grazing intensities, indicating that Subzones C, D, and E may be less resistant to grazing disturbances.

In general, heavy grazing decreases plant functional types richness and total biomass while warming in general increases total biomass. Compared to systems without warming under the same grazing regime, systems enduring warming may be more resilient to grazing due to higher biomass. Heavy grazing removes most lichen and deciduous shrubs, altering nutrient cycling of that system, since lichens can have associated nitrogen-fixers. Reducing nitrogen input to tundra ecosystems may cause such nitrogen-limited systems to be more easily affected by other disturbances.

Breaking the Ice: From Land Claims to Tribal Sovereignty in the Arctic

Barry S. Zellen, Naval Postgraduate School

This poster presents the findings presented in my book, *Breaking the Ice: From Land Claims to Tribal Sovereignty* (Lexington Books, March 2008), which presents a comparative history of arctic land claims and examines the evolution of the land claims model as the resolution of native land claims migrated from Alaska to the western Northwest Territories (NWT), based on research I conducted during my decade-long residency in the north.

The main thesis is that land claims started out as a tool of assimilation, designed with the notion of quickly bringing Alaska Natives into the modern economy with the corporate model being its dominant characteristic. The original model proved inadequate to meet the full needs and aspirations of northern natives (who sought to preserve their traditions as much if not more than to modernize their economies), with a tribal sovereignty movement emerging to challenge the emerging corporate culture and placing aboriginal title to traditional lands at risk of forfeiture if the land claim was not modified.

When land claims crossed into Canada and came to the NWT, the model was changed dramatically—so that land claims would, in

addition to creating new corporations, also help to promote aboriginal culture and traditions, preserve the land and the wildlife, and help empower not just new corporate interests but traditional cultural interests as well. Alaska Natives have likewise sought to modify their original land claim, defusing the “1991 time bomb,” which would have seen native land title come under risk. Additional efforts have been made to protect subsistence hunting in the years that have followed.

With these efforts by natives to transform the land claims model—and make it reflect not just the future as defined by modern governments but also their age-old traditions—land claims now help to balance both visions of the Arctic’s future. While not perfect, land claims have proven to be resilient and adaptive—providing northern natives with an important stepping stone toward self-government, protecting much of their traditional land base, while at the same providing them with tools and managerial experience to make self-government more viable and successful.

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On Thin Ice: Climate Change, Globalization, and the Age of the Arctic

Barry S. Zellen, Naval Postgraduate School

This paper considers the convergence of two broad global trends in the arctic region—continued economic globalization that integrates the world economies and the accelerating pace of climate change that has led to longer ice-free summer shipping seasons in the Arctic—and raises the possibility of a fully ice-free Arctic by the end of this century, impacting the peoples of the north dramatically. With the Arctic in transition, this paper examines the geo-strategic issues relating to arctic security during the post-colonial period:

- The rise of new native governments and co-management systems to govern the Arctic;
- The end of the Cold War division of the Arctic and the continuing economic modernization of the arctic region; and
- The current race for arctic resources and resulting diplomatic tensions as state interests collide in the north.

With the ice melting and the possibility of a fully navigable polar sea now becoming increasingly likely by century's end, what will be the economic and strategic implications of an arctic thaw? Is there risk of military conflict and protracted diplomatic tensions arising from increased resource competition? Do emerging native structures of government have the resources and influence to limit the impacts of state-level actors and multinational corporations as access to the Arctic increases? This paper will speculate on the future of the Arctic, extrapolating from history onto a new climatic reality to imagine future fault-lines of conflict and pathways to reconciliation for the peoples of the north.

Opening Reception

ARCUS Reception at the Embassy of Finland: Welcoming Notes

Pekka Lintu, Ambassador, Finnish Embassy

We are very pleased to have the Arctic Research Consortium of the U.S. (ARCUS) here today at the Embassy of Finland. We compliment the work of ARCUS, which aims to provide leadership in advancing knowledge and understanding of the Arctic. And, if I am right, it is also the 20th anniversary year of ARCUS—let me also offer my congratulations.

Today, the Arctic is prominently on the global agenda, not only due to the discussion on climate change but also very importantly due to the huge opportunities opening up—new sea routes, new access to rich natural resources, etc.

Finland, although not a coastal arctic state, is very interested in all these developments. The coastal Arctic is our neighborhood. We

strongly advocate a comprehensive approach, including security policy, climate change, environmental protection, economic interests, as well as the region's indigenous peoples.

As a member, my country is very committed in the work done in the Arctic Council, as well as in the Barents-Euro Arctic Council. We actively participate in the research within the Arctic Council and Polar Year.

Finland shares the interest in the region's sustainable economic and social development. We also have interest and expertise in off-shore technology, arctic construction and infrastructure, arctic wind power, navigation technology, and tourism.

Once again, welcome to the embassy!

Congressional Briefing

Socioeconomic Tipping Points: Policy Implications of Arctic Climate Change

Moderator: Joshua Schimel, University of California Santa Barbara

Panelists: Martin Miles, Environmental Systems Analysis Research Center; Maribeth S. Murray, University of Alaska Fairbanks; and Craig Fleener, Gwich'in Council International

Recent media, policy, and public attention have focused on the potential impacts of climate change in the Arctic and around the globe. The increasing pace and scale of observed environmental changes may represent “tipping points”—new, unknown, and potentially irreversible vanguards of arctic and global change. These tipping points represent challenges—and opportunities—that will require attention and response from policy and decision makers. This briefing, moderated by Joshua Schimel from the Department of Ecology, Evolution, and Marine Biology at the University of California Santa Barbara, was designed to assist Congress in understanding the state of scientific research—the intent to provide a basis for navigating research findings and media headlines, in order to inform decision-making and policy.

This briefing brought together experts with various perspectives on the issue of environmental tipping points: Martin Miles, Environmental Systems Analysis Research Center, spoke to changes in the arctic climate and sea

ice; Maribeth Murray, Department of Anthropology at the University of Alaska Fairbanks, on human dimensions of climate change; and Craig Fleener, Gwich'in Council International, on opportunities and costs of climate change to local communities.

Changes in Arctic Climate and Sea Ice

Previous years' warm temperatures have created thinner perennial ice, which is more vulnerable to minor changes—and is partially responsible for the dramatic changes that have been observed. Each season, warm waters from the Atlantic and the Pacific flow into the Arctic; in conjunction with anomalous weather conditions, bringing warmer temperatures and winds, sea ice has begun to melt at a faster rate. As more ocean water is exposed from beneath the ice, less heat is reflected, thus allowing the waters to absorb more warmth. This increased water temperature enhances sea ice melting, which exposes still more water, and exacerbates warming. These changes in sea ice cover filter down and affect

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not only marine but terrestrial and socioeconomic ecosystems as well. Changes in sea ice cover lead to changes in terrestrial vegetation, permafrost thaw, coastal erosion, loss of glacial material, climate change, and changes in animal behavior. These changes then affect infrastructure, resource stability and use, food security, and transportation. The dramatic loss of sea ice experienced in 2007 is a strong indication that changes are happening more quickly than models have predicted. These unexpected, dramatic changes will require policy makers to act more quickly and respond to issues that may not have previously existed.

Human Dimensions of Climate Change

The major sea ice loss of 2007 had immediate and cumulative impacts on both the arctic peoples who subsist off the land, as well as people in urban centers. For subsistence use, travel on the ice was extremely unsafe; this meant that hunters had to postpone their hunts, waiting many weeks for the winds to shift and move unstable ice. The thinner sea ice, too, created a more dangerous hunt—there was insufficient ice on which to haul-out and butcher the meat and to provide cooling. By the time the winds had shifted, moving unstable ice, the marine mammals had moved farther north; consequently, hunters had to travel farther to support their families. The increased travel distance created several complications, the first being an increased

need for fuel to travel the longer distances; it also meant that the meat could not be processed and stored in a timely manner. Further, warmer than normal air temperatures created an environment for increased insects, which quickly infested the meat and, in many cases, it spoiled by the time they returned home.

These immediate impacts continue to trickle down and are felt cumulatively by people in larger areas—a less successful subsistence hunt means that people have to rely more heavily on purchased foods, which, in addition to being expensive, brings diminished health returns. The need for increased income, both to purchase foods and to spend on larger amounts of fuel, leads to an increased out-migration to urban areas where there are more cash-employment opportunities. This out-migration then affects not only the rural communities, but places a burden on urban centers that are not prepared to deal with a heavy increase in population. On the national and international scale, increased warming in the Arctic may present a unique opportunity to expand fishing areas and develop new transportation routes. However, the ships in existence today are not built to withstand the harsh conditions of the Arctic. This can inevitably lead to increased wreckage, which then creates an enormous strain on the Coast Guard, endangering not only lives, but also delicate ecosystems. The changes in the Arctic are

drastic, and are happening rapidly. To make informed decisions, it is important to understand how these changes trickle down to create stress on the national socioeconomic system.

Opportunities and Costs to Local Communities

Arctic peoples have always adapted to change. But the changes they now face are so unusual and are happening so quickly that people are beginning to experience fear—fear of being unable to provide enough for their families to survive. Age-old techniques of reading the land and adapting to minor changes no longer work, and policy measures that the government has put into place do not mesh with reality in remote villages. If the law says that you are allowed to hunt during a specified two-week period, but the caribou do not come until after that time period has passed, there is a problem. Too often, government representatives to remote areas have no concept of what life there is like—they are too far removed from the situation to understand it and are thus unable to make good decisions that work for both the people and the land. Government officials and policy and decision makers must come together with the people and talk to them, to learn about life and the changes facing them. In order to survive, the people are going to need the government to help them develop new coping skills. The land provides

everything the people need to survive. The decision making table must, therefore, be filled with not only government representatives, but, importantly, the people who are experiencing the changes first-hand. The major challenge is to create better information-sharing structures so that changes can be met productively.

Discussion

With the increased interest in the Arctic, scientists need to communicate effectively with the public, policy makers, and the media. This briefing provided an opportunity to learn about the various problems and consequences facing the Arctic. It was followed by a question and answer period in which congressional staffers, the public, and the media were given the opportunity to ask scientists direct questions. Special thanks was offered to Senator Stevens' office for providing the briefing room.

CONGRESSIONAL SCIENCE BRIEFING

“Socioeconomic Tipping Points: Policy Implications of Arctic Climate Change”

Tuesday, 13 May 2008

12:30–2:00 pm

U.S. Senate Committee on Commerce, Science & Transportation Hearing Room
253 Russell Senate Office Building, Washington, D.C.

~All Members of Congress and Congressional Staffers Welcome ~

Recent media, policy, and public attention have focused on the potential impacts of climate change in the Arctic and around the globe. The increasing pace and scale of observed environmental changes may represent “tipping points”—new, unknown, and potentially irreversible vanguards of arctic and global change. As we enter into the final stages of the International Polar Year 2007–2008 (IPY), the scientific and policy communities are presented with an unprecedented opportunity to build on the wealth of data collected in the IPY to produce transformative advances in our understanding of climate change and to formulate appropriate policy and scientific responses—thus ensuring a successful national IPY legacy that addresses critical stakeholder issues.

This briefing will assist Congress in understanding the current state of scientific research on climate change and tipping points, with the intent to provide a basis for navigating research findings and media headlines to inform decision-making and policy. Leading scientists will discuss climate change implications such as infrastructure damage, food security, transportation, coastal erosion, national security, and the economic benefits of mitigating change.

Presenters

Moderator: **Joshua Schimel**

Department of Ecology, Evolution & Marine Biology, University of California Santa Barbara

Panel Members:

Martin Miles

Environmental Systems Analysis Research Center

~Changes in arctic climate and sea ice~

Maribeth Murray

Department of Anthropology, University of Alaska Fairbanks

~Human dimensions of climate change~

Craig Fleener

Gwich'in Council International

~Opportunities and costs to local communities~



The Arctic Research Consortium of the United States (ARCUS) is a nonprofit membership organization composed of universities and institutions that have a substantial commitment to research in the Arctic. For more information, contact ARCUS at: Phone: 907.474.1600, E-mail: info@arcus.org, or on the web at: www.arcus.org.

**Student Scholarship
Winners'
Position Statement**

Student Position Statement

Student Scholarship Winners: Ruth Adler; Nicholas L. Balascio; Elena P. Bondareva; Laura S. Brosius; Xuehua (Sherry) Cui; Waliul Hasanat; Timo Kumpula; Jordan Lewis; Elizabeth A. Nelson; Ethan H. Roth; and Qin Yu

Winners of the 2008 Arctic Forum student scholarships were requested to submit a short summary of their views on the final panel discussion question (see page 24): *What are the three highest priority actions—scientific, educational, management, or political—we should take to improve our ability to respond to these observed and predicted changes?*

Students raised several issues, which fall into the following themes: education, traditional ecological knowledge, and communication; policy, management, and international collaboration; and environmental impacts, science, and research. The following is a compilation of their ideas, comments, and concerns.

Education, Traditional Ecological Knowledge, and Communication

With the recent public concern about climate change and global warming, the public has begun to place heavy demands on the science community for solutions. Because the public ultimately influences policy makers, it is vital that they be able to make informed decisions and think critically about the science presented. Therefore, the first priority action should be centered on education, traditional ecological knowledge, and communication.

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Since change is occurring in the Arctic more rapidly than anywhere else on Earth, it is important that other regions are aware of the Arctic's role as "a canary in the coal mine." The message the science community must send is that although change may not be occurring at the same rate everywhere on Earth, it is a reality and an issue that requires immediate action. To do this, the science community must tap into the traditional, local knowledge held by village elders. Reindeer herders, hunters, fishers, whalers, and other locals have detailed information about changes in their environment that can supplement scientific knowledge. Without this information, the science community cannot hope to paint a whole picture to the public at large. Without this whole picture, information is incomplete and good decisions cannot be made. It is therefore crucial to foster the transfer of traditional ecological knowledge to the science community and to promote communication between the science community and the public at large.

The science community must find a way of effectively communicating their science outside of academia. Communication and education can be encouraged by recruiting, engaging, and enlisting people who are concerned about arctic climate change and directing their enthusiasm and energy towards the education of outside organizations and individuals. Youth initiatives, in particular, are an invaluable way to generate new faces as well as new ideas for

old causes. The science community must focus on educating not only their students and colleagues but the general public as well.

Policy, Management, and International Collaboration

It is becoming increasingly apparent that strategic planning and action must be taken to better understand and respond to global climate change. Many problems have been identified, but few solutions have been developed. These solutions must be made at the global level. Therefore, in addition to local and national policy and management, international collaborations must be developed. Extreme climate changes in the Arctic and Antarctica demand a higher level of strategic planning and collaboration than ever before.

It is imperative that management structure be achieved at the community, university, and government levels and that the science community consider its influence of these various levels of policy and management. Often, current policies and management techniques are developed far from the local site, with little consideration as to how they actually affect the local communities they involve. The science community has an obligation to the people who live and subsist off the lands they study; it is not enough to report on

evidence of a changing landscape. There are socioeconomic implications as well. The science community is obligated to help provide arctic peoples with the resources, knowledge, and evidence necessary to defend their land while maintaining healthy ecosystems necessary for subsistence. The community must work to support policy and management techniques that foster healthy ecosystems—from the microbes we study to the people who live on the land. Proper management can also be used to help bridge international, disciplinary, and political divides. Scientific investigation of arctic change, its implications, and solutions must become a cooperative effort between those nations that are directly affected by arctic change. This necessitates expansion of international collaborations and the establishment of a joint funding body that will oversee solely collaborative projects. Researchers from institutions outside the Arctic should also be encouraged to participate in such collaborative investigations, thus lending a different perspective and also acting as liaisons of arctic science to other states and nations.

Environmental Impacts, Interdisciplinary Science, and Research

We as a society need to consider the political and socioeconomic implications of resource extraction in an ice-free Arctic Ocean. Offshore drilling will have a substantial impact on the North Slope communities and

the marine mammals they subsist from. It is up to the science community to continue its research and interdisciplinary science to provide evidence of and solutions to climate change. Research needs to focus on environmental and social impacts of climate change. Key environmental issues include:

- Potential environmental disaster from petroleum exploration in the Barents, Kara, and Beaufort Seas.
- Potential environmental disasters from petroleum exploration on land in Russia and Alaska.
- Indigenous peoples' (Inuit, Saami, Nenets) rights. Who owns the land? How will compensation be made? What will happen after the resources are used?

Researchers from all areas of the circumpolar regions should aim to establish stronger networks and collaborations to eliminate overlap and expedite progress.

To really move forward in understanding and mitigating climate change, we must understand the system as a whole. For this reason, interdisciplinary science is crucial, and the science community must work to foster interdisciplinary research and modeling. It is unreasonable to separate human activities from the natural system; human activities are interwoven with the natural world, so good modeling strategies that include both natural

science and anthropological regimes must be incorporated into the process. This will enhance understanding from different aspects and will drive international and interdisciplinary cooperation.

While the idea of exploration is always an enthralling one, in the 21st century scientists can no longer be doing science just for the sake of doing it. We have to ask ourselves: what is the social context in which our work fits? Who does it stand to benefit? We should be forming as many collaborations as possible, not only with scientists but also real people. The scientific frontier requires us to be interdisciplinary and approach problems differently than in the past.

Conclusion

Taken together, these priorities will continue to strengthen the progress in counteracting climate change and helping those most affected by it. These actions will begin to help those in need of assistance now and in the future, as environmental regions around the world, respond differently. The science community is tasked with some serious work. To achieve goals and mitigate problems caused by climate change, we must think seriously about the priorities we set. These must include: education, traditional ecological knowledge and communication; policy, management, and international collaboration; and, importantly, environmental impacts and continued scientific research, especially of an interdisciplinary fashion. The Arctic is at the forefront of climate change and will continue to serve as the example of what can, and will, happen to the environment as a result of environmental change.

Appendices

Arctic Forum Agenda

Tipping Points—The Arctic and Global Change

The interconnectedness of the Arctic is demonstrated when a single change sends ripple effects throughout the arctic marine, terrestrial, atmospheric, socioeconomic, and global systems. These changes may be "tipping points" that represent new, unknown, and potentially irreversible vanguards of arctic and global change. 2008 Arctic Forum sessions explored tipping points from environmental and socio-economic viewpoints, potential consequences and opportunities, and scientific, policy and management, and educational response strategies.

Wednesday, 14 May 2008

National Association of Home Builders

1:30 p.m. Welcome and Introductions *Arctic Forum Co-Chairs*
Craig Fleener, Gwich'in Council International
Martin Miles, Environmental Systems Analysis Research Center

1:40 p.m. Arctic Climate Change: Where Reality Exceeds Expectations *Mark C. Serreze*
Cooperative Institute for Research in Environmental Sciences

ENVIRONMENTAL TIPPING POINTS: How is climate change affecting the arctic environment? Do these changes represent tipping points to a new state of the arctic system? What are the possible future scenarios and connections to the globe?

2:10 pm Arctic Sea Ice Now and in the Future *Julienne Stroeve*
National Snow and Ice Data Center

2:35 p.m. Marine Mammals and Diminishing Ice: Slow Science on a Faster Earth
Brendan P. Kelly
University of Alaska and the National Science Foundation

3:00 p.m. Climate Change and Marine Mammal Conservation Policy *Tim Ragen*
Marine Mammal Commission

- 3:25 p.m. Break
- 3:50 p.m. Arctic Ocean Acidification: A Contemporary and Future View of Changes to the Marine Carbon Dioxide System
Richard Bellerby
Bjerknes Centre for Climate Research
- 4:15 p.m. Changes in Terrestrial Ecosystems in Response to a Decade of Warming
Mads Forchhammer
University of Aarhus
- 4:40 p.m. Panel Discussion: Environmental Tipping Points
- Panel Focus Questions:
1. How do we know a tipping point when it is happening? Are the current changes a tipping point?
 2. How will the future Arctic be different?
 3. Why do we care? How will this influence the lives of people living outside the Arctic?
 4. What do we do about it? What new science and policy responses do we need to deal with the changes, and why?
- Moderator:*
Joshua Schimel, University of California, Santa Barbara
- Panelists:*
Caspar Amman, National Center for Atmospheric Research
Martin Sommerkorn, WWF International Arctic Programme
Craig Fleener, Gwich'in Council International
Maribeth S. Murray, International Study of Arctic Change
- 5:50 p.m. Summary Remarks
Arctic Forum Co-Chairs
Craig Fleener, Gwich'in Council International
Martin Miles, Environmental Systems Analysis Research Center
- 6:00 p.m. Poster Session and Evening Reception: Poster presentations on a wide range of arctic research, education, and outreach activities, with hosted bar and appetizers. Opening Poster Session remarks by Vera Alexander, President, ARCUS Board of Directors. Entertainment by "Atlantic Echo," Traditional Finnish Vocal Quartet.

Thursday, 15 May 2008

National Association of Home Builders

8:00 a.m. Continental Breakfast

9:00 a.m. Welcome and Introductions

*Arctic Forum Co-Chairs
Craig Fleener, Gwich'in Council International
Martin Miles, Environmental Systems Analysis Research Center*

SOCIOECONOMIC TIPPING POINTS: How is climate change affecting economic and social activity?

8:40 a.m. Well Adapted But Still Extinct: Norse Greenland in New Perspective

*Tom McGovern
Hunter College*

9:05 a.m. Arctic Health and a Changing Physical Environment: New Perspectives on Increased UVB, Ozone Depletion, and Increased Warming

*Ed De Fabo
George Washington University*

9:30 a.m. Coming to Terms with the Future of Northern Food Systems

*S. Craig Gerlach
University of Alaska Fairbanks*

9:55 a.m. Local Opportunities and Challenges from Arctic Climate Change: A Saami Perspective

*Rune Fjellheim
Arctic Council Indigenous People's Secretariat*

10:20 a.m. Break

10:45 a.m. Future Marine Transportation in the Russian Maritime Arctic

*Lawson Brigham
U.S. Arctic Research Commission*

11:10 a.m. Sovereignty and Security in the New Arctic: The Coming Blizzard

*Robert Huebert
University of Calgary*

11:35 a.m. Lunch

Trip to AAAS Arctic Art Exhibition

The AAAS exhibit displays art by school children living in remote Siberian villages, including photographs and information on climate change in the Arctic. Traditional Siberian beaded vests were also on display. The works were part of the Woods Hole Research Center's Student Partners Project.

Young Investigator Career Development Lunch

An informal lunch meeting, focused on career development issues for young investigators, was scheduled from 11:35 a.m.–1:30 p.m.

RESPONSE AND ADAPTATION: What are the appropriate scientific, policy, outreach, and educational responses to potential tipping points?

1:30 p.m. New Approaches to Linking Scientific Synthesis, Policy and Education

*Charles Vörösmarty
University of New Hampshire*

1:55 p.m. Development of Cyberinfrastructure During Rapid and Interconnected Change

*Dan Lubin
National Science Foundation*

2:20 p.m. Climate Change, Tipping Points, and the Media *Erika Englehaupt*

Environmental Science and Technology

2:45 p.m. U.S. Arctic Research Program Response to a Changing Arctic: Current and Future Goals

*Mead Treadwell
U.S. Arctic Research Commission*

3:10 p.m. Break

3:35 p.m. Panel Discussion: Priority Actions and Response Strategies
What are the three highest priority actions—scientific, educational, managerial, or political—we should take to improve our ability to respond to these observed and predicted changes?

Moderator:

Peter Schlosser, Lamont-Doherty Earth Observatory

Panelists:

Vera Alexander, University of Alaska Fairbanks

Max Holmes, Woods Hole Research Center

Robert Huebert, University of Calgary

Anya Suslova, Sakha Republic (Yakutia) State University

Simon Stephenson, National Science Foundation

5:00 p.m. Summary Remarks

Arctic Forum Co-Chairs

Craig Fleener, Gwich'in Council International

Martin Miles, Environmental Systems Analysis Research Center

5:15 p.m. Arctic Forum Adjourns

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ARCUS 20th Annual Meeting & Arctic Forum 2008

TIPPING POINTS

the arctic and global change

13–15 MAY 2008 • WASHINGTON, D.C.

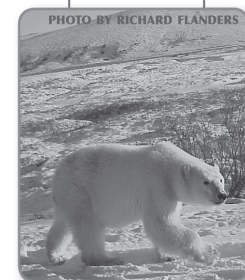
NATIONAL ASSOCIATION OF HOME BUILDERS CONFERENCE CENTER

HOSTED by the Arctic Research Consortium of the U.S. (ARCUS), *Arctic Forum 2008* will include information on how changes in the Arctic send ripple effects throughout the marine, terrestrial, atmospheric, socioeconomic, and global systems. Presentations and discussions will address how these changes may be *tipping points* by focusing on the following questions:

- Do changes in the Arctic represent tipping points with global consequences?
- How is climate change affecting economic and social activity?
- What actions should we take to improve our ability to respond to observed and predicted changes?

Please join us for an opening reception at the Finnish Embassy on Tuesday, 13 May and for a poster session and evening reception at the National Association of Home Builders Conference Center on Wednesday, 14 May. For more information and to view the agenda, go to www.arcus.org.

*Have we reached major tipping points
in the arctic system?*



A SPECIAL INVITATION

The AAAS Art of Science and
Technology Program

The Art of Science and Technology Program of the American Association for the Advancement of Science was established in 1985 to present science-related art of all kinds. Its goal is to display work that reflects the centuries-old interaction of art and science that can be seen both in contemporary art and in historical materials.

Exhibitions span the range of scientific inquiry. The public is invited to view the rotating exhibitions presented on the first and second floors of the William T. Golden Center for Science and Engineering.

Paintings by Children of the
Sakha Republic of Siberia

In the AAAS Gallery
10 March – 6 June 2008



ADVANCING SCIENCE, SERVING SOCIETY
1200 New York Avenue, NW
Washington, DC 20005 USA
Metro: Metro Center



ADVANCING SCIENCE, SERVING SOCIETY
AAAS

The AAAS Gallery 10 March – 6 June 2008

In the Sakha Republic, Siberia, students living in the small communities along the banks of the Lena River have become key partners in a scientific research initiative exploring the impacts of climate change on the Arctic. Now known as the Student Partners Project, the program was begun in 2002, when a 13-year-old girl named Anya, the daughter of a boat captain, just happened to be along for a research expedition along the Lena that included Max Holmes, an earth system scientist with the Woods Hole Research Center. Dr. Holmes noticed her interest in the scientific sampling work, and communicating through a little English, a little Russian, and a lot of hand signals, she quickly mastered the basic sampling protocols.

Anya's participation quickly grew to include fellow students and teachers at her school in the community of Zhigansk, and in other communities throughout the Arctic. This initiative, funded by the National Science Foundation, is not only advancing scientific understanding of a part of the world already experiencing climate change, but is also creating the next generation of scientists and scientifically-literate citizens.

The artwork, done by fifth through tenth graders from Zhigansk and Kostotem, depicts the children's environment and their perceptions of the environmental changes going on around them. Given to Dr. Holmes as a gift, the collection, which demonstrates a remarkable skill level and an awareness of their world, gives us a glimpse of a remote world many of us know very little about.

The exhibition is co-sponsored by AAAS and the Woods Hole Research Center.

OPPOSITE AND COVER DETAIL:
Holiday of the Reindeer
Watercolor on Paper
Senya Koryakin
Zhigansk Middle School
Zhigansk, Sakha Republic, Siberia



The American Association for the Advancement of Science
and the Woods Hole Research Center

cordially invite you to attend a lecture and art exhibit

*The Student Partners Project: Engaging Students and
the Public in the Science of Climate Change*

Dr. Robert Max Holmes, Associate Scientist
Woods Hole Research Center

14 May 2008

Lecture at 6:00 pm

Reception and Exhibit Viewing

Beginning at 7:00 pm

First Floor, AAAS Headquarters
1200 New York Avenue, NW
Washington, DC

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