Abstracts from the

Arctic Forum

2003

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Cover: Byron Hunter, Elia Charlie, and Oscar Rivers: Fourth of July at Black River fishcamp. *Photo © James H. Barker.*

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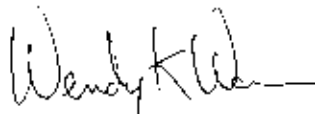
Foreword

Each year the Arctic Research Consortium of the U.S. (ARCUS) hosts the Arctic Forum in conjunction with the ARCUS annual meeting. The goal of the Arctic Forum is for arctic researchers in all disciplines to be able to interact with colleagues and agency representatives. This collection of abstracts showcases the oral presentations and poster session at the Arctic Forum held April 28 and 29, 2003, in Washington, D.C.

The ARCUS annual meeting and Arctic Forum are the culmination of our efforts each year to represent the arctic research community on behalf of ARCUS's 43 U.S. and international member institutions. ARCUS serves its member institutions by acting as a communication channel, providing information about current research activities and arctic science issues to the research community, and informing agencies and the public about arctic research. This work is done at many levels, including newsletters and other publications, electronic communications, K–12 education projects, workshops, and symposia like the Arctic Forum. The Arctic Forum provides access for individual researchers to information on research, education, and facilities outside of their fields, which has led to many successful collaborations. Since its inception in October 1994, the Arctic Forum remains one of only a few interdisciplinary arctic science meetings. The Arctic Forum abstract series begins with *Arctic Forum 1998*.

This abstract volume illustrates the diversity and interdisciplinary nature of arctic research today. The overall theme of the Arctic Forum in 2002 was Responding to Global Change: Resiliene and Vulnerability in Arctic Systems. The Forum presentations included the winners of the Seventh Annual ARCUS Award for Arctic Research Excellence in the categories of social sciences, life sciences, physical sciences, and interdisciplinary. James R. Mahoney, director of the U.S. Climate Change Science Program, gave the keynote address.

As executive director of ARCUS, I appreciate the efforts of the many researchers who share their results with the community through the Arctic Forum. We thank Igor Krupnik and Terry Chapin for chairing the Forum and the National Science Foundation for supporting this opportunity. Sue Mitchell of ARCUS edited this abstract volume; Katy Mulcrone provided expert proofreading. We invite you to join us at the Arctic Forum in spring 2004.



Wendy K. Warnick
Executive Director

ntroduction to the Session
Responding to Global Change: Resilience and Vulnerability in Arctic Systems

Igor Krupnik, Smithsonian Institution; F. Stuart Chapin (Arctic Forum Co-Chairs)

The Arctic is changing rapidly and in many complex ways, including changes in physical and biochemical environment, ecological processes in ecosystems, and cultural and economic values that shape the lives of arctic residents. Many of these processes are specifically Arctic manifestations of broader synchronous changes that are occurring globally, either as part of long-term cycles or as directional transformations in the global environment. The changes also involve restructuring of many critical interactions among components of the arctic system, including the atmosphere, oceans, lands, and their human inhabitants. These interactions produce feedbacks that can either amplify or buffer the global drivers of change; they also have specific arctic dimensions, both in terms of the components and of the speed of the processes involved.

The scholarly examination and the net result of these interactions are critically important to arctic residents and to the development of our common understanding of global change. Some of the current processes and components of the arctic system are resilient to change and thus may be predictable, whereas other are highly vulnerable to rapid shifts, so past experience provides little guidance for the future. If, as we assume, the Arctic is the world's "early warning system," we must find clues to these specific arctic responses in adaptation to stresses and in minimizing risk of abrupt and irreversible shifts that often lead to system destruction.

This is why the Arctic Forum of 2003 addresses the issues of resilience and vulnerability in the arctic system(s)—physical, biological, ocean, terrestrial, human, and cultural alike. Many in the arctic research community believe that an interdisciplinary approach to the issue of resilience/vulnerability to the ongoing rapid change represents the true cutting edge of today's polar science. Various forms of these resilience/vulnerability responses are amply documented by current scholarly research and in daily observations by arctic residents. For the Arctic Forum 2003, we have commissioned presentations from scholars in various fields related to recent research projects as well as from representatives of the management agencies, arctic Native residents, and representatives from business and government.

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Presentation Abstracts

Building Resilience in the Arctic: Cross-scale Institutions and Traditional Environmental Knowledge

Fikret Berkes, University of Manitoba

In areas experiencing rapid change, such as the Arctic, building capacity to respond and adapt to change is a fundamental concern. The concept of resilience provides a window for the study of change, emphasizing learning, self-organization, and adaptive capacity. How do societies and institutions deal with environmental change and, in turn, shape change? The objective of this paper is to explore the idea that cross-scale institutional linkages help deal with change by building resilient systems that (1) have the ability to buffer disturbance, (2) have the capability for self-organization, and (3) have capacity for learning and adaptation. The resilience approach suggests asking how we can improve the ability of social systems and environmental systems in the Arctic to improve their shock-absorbing capability, increase their ability for self-organization, and increase their capacity for learning.

Resource and environmental management institutions exist at various scales—local, regional, national, international. There are two main ways in which these institutions may be linked across scale. These cross-scale linkages may be horizontal (across geographic space) or vertical (across levels of organization). It has been hypothesized that cross-scale linkages, both horizontal and vertical, may speed up learning and communication, thereby improving the ability of a society to buffer change, speed up self-organization, and increase capacity for learning and adaptation. The use of community-based management approaches and traditional environmental knowledge provides a mechanism by which the coping and adapting strategies of the local people can be strengthened and vulnerabilities reduced.

For example, in the Canadian western Arctic, co-management institutions, evolving since the signing of the 1984 Inuvialuit Final Agreement, provide cross-scale linkages for feedback horizontally (across the region) and vertically (across levels of organization from the local hunter-trapper committees to regional agencies and beyond). These linkages have the potential to facilitate the transmission of community concerns, such as those about marine contaminants and climate change, to the regional, national, and international levels, thereby helping northern societies respond to environmental problems.

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mpact of an Extreme Melt Event on the Hydrology and Runoff of a High Arctic Glacier

Sarah Boon, University of Alberta; Martin Sharp; Peter Nienow

Between 28–30 July 2000, an extreme melt event was observed at John Evans Glacier, Ellesmere Island (79° 40' N, 74° 00' W). Hourly melt rates during this event fell in the upper 4% of the distribution of melt rates observed at the site during the period 1996–2000. Synoptic conditions during the event resulted in strong east to west flow over the northern sector of the Greenland Ice Sheet, with descending flow on the northwest side reaching Ellesmere Island. On John Evans Glacier, wind speeds during the event averaged 8.1 m s^{-1} at 1183 m a.s.l., with hourly mean wind speeds peaking at 11.6 m s^{-1}. Air temperatures reached 8°C, and rates of surface lowering measured by an ultrasonic depth gauge averaged 56 mm d^{-1}. Calculations with an energy balance model suggest that increased turbulent fluxes contributed to melt enhancement at all elevations on the glacier, while snow albedo feedback resulted in increased melting due to net radiation at higher elevations. The event was responsible for 30% of total summer melt at 1183 m a.s.l. and 15% at 850 m a.s.l. Conditions similar to those during the event occurred on only 0.1% of days in the period 1948–2000, but 61% of events occurred in the summer months and there was an apparent clustering of events in the 1950s and 1980s. Such events have the potential to impact significantly on runoff, mass balance, and drainage system development at high-arctic glaciers, and changes in their incidence could play a role in determining how high-arctic glaciers respond to climate change and variability.

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Resilience and Change in Arctic Terrestrial Ecosystems: A Key Role in the Arctic System

F. Stuart Chapin, University of Alaska Fairbanks

The Alaskan arctic and boreal ecosystems are warming as rapidly as any place on Earth, resulting in changes in a wide range of physical and biological processes. In the absence of directional changes, these linkages among interactive processes buffer high–latitude ecosystems against large changes. For this reason, high-latitude ecosystems appear quite resilient and insensitive to large change in environment and densities of key animal populations. This resilience to short-term variability renders the arctic vulnerable to directional changes in climate. It now appears that certain critical thresholds have been crossed, leading to changes in stability of permafrost, vegetation, and disturbance regimes. These changes may be difficult to reverse and have potentially important impacts on society within and outside the Arctic.

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We Are Sugpiaq: Archaeology, Environment, and Oral Traditions of the Outer Kenai Coast, Alaska (Film and Discussion)

Aron L. Crowell, Smithsonian Institution

Film, approx. 15 minutes, in English/Sugcestun. Produced by the Arctic Studies Center, Pratt Museum, and Native villages of Nanwalek, Port Graham, and Seldovia, Alaska.

Sugpiaq/Alutiiq residents of the Kenai Peninsula, southern Alaska, are working with the Smithsonian Institution's Arctic Studies Center, the Pratt Museum, and the National Park Service to record oral histories, excavate 100 to 800 year-old ancestral village sites, and document ongoing environmental change. Oral traditions about life in old settlements of the outer Kenai coast, narrated by Alutiiq elders, provide a detailed framework for archaeological interpretation. The film traverses time and space between contemporary village life, interviews with elders, and fieldwork at sites along the spectacular glaciated Pacific shore of the Kenai Peninsula. It explores community perspectives on ancestors, heritage, land, subsistence resources, and cultural identity.

Oral accounts, artifacts, and faunal data from the outer coast illuminate indigenous adaptations to a rich but unstable coastal environment, where earthquakes, volcanoes, climate change, biological regime shifts, and advancing glaciers have factored in human history. Native narratives refer directly to colder conditions during the Little Ice Age (A.D. 1250–1900) when the sites under investigation were occupied. Migrations and settlement shifts also correlate with sudden natural disasters, such as a massive tectonic event that flooded coastal villages at around 1170 A.D. Contemporary Sugpiaq/Alutiiq communities depend heavily on salmon, seals, plant foods, and other subsistence resources, an intimate and spiritually rich relationship with the environment that informs the archaeological study of human ecology. Sugpiaq/Alutiiq hunters and gatherers are keen observers of present-day environmental changes, including ocean temperature-related declines in seal and sea lion populations, and are actively involved in government co-management of subsistence resources.

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Microorganisms in Arctic Sea-ice Environments and Their Resilience and Vulnerability to Climate Variations and Change

Hajo Eicken, University of Alaska Fairbanks; Christopher Krembs; Karen Junge; Jody Deming; Rolf Gradinger

Microorganisms living within arctic sea ice are subjected (on a seasonal basis) to what may qualify as the widest range of environmental conditions in any type of marine environment. Hence, the strategies of bacterial and microalgal assemblages in dealing with the adverse conditions encountered in the sea-ice habitat may help us obtain better insight into their resilience and vulnerability to impacts of global change on the Arctic Ocean's ice cover.

Recent studies have shown that microbial communities in polar terrestrial and marine environments are quite adept at dealing with the adverse, coupled effects of low temperatures and high salinities. In our work, we have demonstrated that bacteria thriving within the pore space of arctic sea ice can remain active down to temperatures of at least –20°C. Based on optical microscopy and other methods characterizing distribution and activity of bacteria under very low in-situ temperatures, it appears as if the remarkable resilience of these bacterial assemblages is enhanced, if not controlled, by the presence of particulate surfaces. At the same time, some organisms are capable of mitigating the effects of low temperatures and high ambient brine salinities through the production of organic polymers. The latter may play a pivotal role in the mitigation of environmental stress associated with very low temperatures as well as in the interaction between organisms and their physical environment.

The other extreme in arctic sea-ice environmental conditions is controlled by summer melt processes. Tracer studies have demonstrated that a substantial fraction of the sea-ice microbial habitat is being flushed by low-salinity meltwater during the summer months and that such freshwater immersion may be increasing in duration and extent due to enhanced ice and snow melt. While posing different physiological and ecological challenges to ice microbial communities, many of which are poorly understood, enhanced meltwater fluxes may have dramatic impacts on ice microbial communities as well as the sea-ice system as a whole.

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Women's Participation in Self Government Negotiations in the Northwest Territories, Canada

Stephanie Irlbacher Fox, University of Cambridge

This paper provides general background on self government negotiating processes in Canada's Northwest Territories and focuses on women's participation. It begins by briefly contrasting western feminist and indigenous feminist perspectives. A combination of statistical information, participant observations, interviews with self government negotiators, and narrative are sources for describing women's involvement in self government negotiation processes. Drawing from perspectives of indigenous feminism, I describe how what may appear as exclusion of women in formal talks is not representative of women's involvement in the negotiation process. The conclusion offers questions for further research and consideration, suggesting factors that should be taken into account as part of that task.

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Geographic Distribution and Seasonal Patterns of Larval Shedding of the Muscle-Dwelling Nematode *Parelaphostrongylus odocoilei* in Thinhorn Sheep from Northern North America

Emily Jenkins, University of Saskatchewan; Alasdair Veitch; G. D. Appleyard; Eric P. Hoberg; Susan J. Kutz; L. Polley

In 2000, the muscleworm *Parelaphostrongylus odocoilei* (previously reported only in cervids and mountain goats) was identified in Dall sheep (*Ovis dalli dalli*) from the Mackenzie Mountains, Northwest Territories (NT), Canada. Subsequently, we determined the geographic distribution of *P. odocoilei* through examination of fecal samples from thinhorn sheep (*Ovis dalli*), bighorn sheep (*Ovis canadensis canadensis*), and mountain goats (*Oreamnus americanus*) across northwestern North America. Larvae of *P. odocoilei* were recovered from several populations of thinhorn sheep and both populations of mountain goats examined, but were not present in the single bighorn sheep population examined. We confirmed the identity of these larvae by obtaining and comparing sequences of the ITS-2 region of ribosomal DNA to those of *P. odocoilei* validated using adult parasite identification. Our results demonstrated that *P. odocoilei* is established in the Mackenzie Mts. (NT), the Selwyn Mts. (Yukon Territory - YT), the central Alaska range (Alaska), the St. Elias Mts. (YT), the northern end of the Rocky Mts. (British Columbia), and the Coastal Mts. of British Columbia. Sequence data were consistent for larvae in thinhorn sheep and mountain goats across this geographic range, suggesting that *P. odocoilei* is not differentiated into subspecies or "cryptic" species. Our work represents the first application of molecular methods for identification of unknown protostrongylid larvae in a broad-based survey of geographic and host distribution. We also described seasonal variations in prevalence and intensity of larval shedding of *P. odocoilei* and the sheep lungworm *Protostrongylus stilesi* by examining fecal samples from a population of Dall sheep in the Mackenzie Mountains bimonthly from March 2000 to March 2002.

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The prevalence of *P. odocoilei* larvae ranged from 87–100%, while the prevalence of *P. stilesi* larvae ranged from 75–100% except in August of each year, when the prevalence dropped to 18% (2000) and 32% (2001). The mean intensity of larval shedding for both *P. odocoilei* and *P. stilesi* displayed a consistent pattern in both years, peaking during late winter/early spring and reaching a trough in late summer. This combination of traditional parasitology and a novel application of molecular diagnostic techniques greatly expands knowledge of the geographic range and epidemiology of *P. odocoilei* in thinhorn sheep in arctic and subarctic North America.

Simulation Modeling and Local Communities: Lessons Learned from Assessing Resilience in a Cross-Cultural Setting

Gary Kofinas, University of Alaska Fairbanks

The NSF Sustainability of Arctic Communities Project experimented with the use of simulation models to facilitate the interactions of researchers and indigenous communities of the Canada-U.S. Arctic Borderlands. Our project developed a transparent, user-friendly model that served as a discussion tool to assess community sustainability in the face of climate change, tourism, and oil development. The interaction of community knowledge holders and research scientists illustrates how the contributions of each group addressed different scales of analysis and also highlighted underlying cultural perspectives. More recently, our project has used a simulation model to focus caribou hunters' attention on the problem of collective action in conditions of resource scarcity. This model was used with a co-management board to prompt a gaming exercise that generated community and regional policy responses for human adaptation. These experiences provide lessons for assessing resilience in a cross-cultural setting.

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"The Earth is Faster Now" or "Have We Seen These Warm Weathers Before?"—Arctic People Experiencing Rapid Climate Change

Igor Krupnik, Smithsonian Institution

Several recent studies have revealed the utmost value of traditional ecological knowledge of the Arctic people in the study of recent climate change. They also demonstrate that indigenous observation may become a powerful tool in the multifaceted analysis and monitoring of the arctic environment. Whereas attention is currently focused upon the documentation and cultural "encoding" of indigenous observation practices, indigenous knowledge—like science research—has many components and it follows several analytical steps, though in its own way.

In every northern community, continuous observation by individual subsistence users is backed by the shared processing of data. Expertise is recorded and disseminated via storytelling, youth training, and knowledge exchange with relatives and partners. Based upon this shared expertise, people analyze signals of change, pose questions, and formulate hypotheses. They express concerns about the speed and direction of change, and they advance various explanations that help rationalize phenomena they observe. Like polar scientists, Native experts have to address the same basic dichotomy, namely, whether the processes are unique or the scope of change is within the range of individual and/or community memory. Much like in the current academic debates, there are (at least) two opposing schools of indigenous interpretations: those stressing the global and linear character of change (*The Earth Is Faster Now*, Krupnik and Jolly 2002) and those stressing its recurring nature from a historically oriented perspective ("We Have Seen These Weathers Before"). Those interpretations carry different assessments of risk and they offer diverging strategies in coping with the shifts in the human environment. Modern studies in arctic communities offer a rare window to grasp the anxieties, concerns, and frustration associated with the present, as well as former episodes of rapid climate change. As people faced recurrent and often dramatic shifts in their environment, they obviously posed the same basic queries about the nature of the processes and the risks involved. Whereas resilience was the law of survival, it required continuous and painful readjustment in terms of community resources, knowledge change and loss, and human suffering. This new—and more nuanced—perspective on the cost of "arctic adaptations" should be added to the story of temperature curves, animal bone counts, carbon dates, and climate computer modeling.

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Working Together: Cooperation in the Production and Distribution of Wild Food in Alaska

James S. Magdanz, Alaska Department of Fish and Game; Charles J. Utermohle; Robert J. Wolfe

Since 1978, the Division of Subsistence of the Alaska Department of Fish and Game has been studying subsistence in Alaska, primarily from a social science perspective. In most small rural Alaska communities, Division researchers have observed, 30% of the households typically account for 70% of the community's subsistence harvest. They have found stages of household development to be a reliable predictor of the diversity and quantity of wild food harvests and have proposed a model of household development for Alaska's subsistence economies.

In 1994, division researchers conducted household surveys in Wales and Deering, two Iñupiaq Eskimo communities on the northwest coast of Alaska. Using approximately 1,000 individual reports from each community about the harvesters, processors, and distributors of wild foods, researchers traced the flow of wild foods through each community. They explored the roles of men and women, of single-person households and elder households, and especially of local family networks in the production and distribution of wild food. Viewing production and distribution from the perspective of extended family networks helped explain variation in wild food production and demonstrated the roles of different individuals and different social types of households in the production and distribution system. Networks of cooperating households provided increased economic security for their members. Communities with extensive networks for wild food production would be expected to be more resilient in times of change.

Although the study villages are both in one region of the state, division researchers believe wild food production is similarly organized throughout rural Alaska. The social network analysis methods used in Wales and Deering could be applied to any small community dependent upon wild food.

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The U.S. Climate Change Science Program and its Relevance to the Arctic

James R. Mahoney, U.S. Climate Change Science Program

Global climate change is a capstone issue for our generation, and the role of the Arctic in climate change is a focal point of the U.S. Climate Change Science Program.

Program History and Focus

In 1987, the U.S. Global Change Research Program (USGCRP) was initiated as a budgetary exercise by NOAA, NSF, and NASA and was codified by the U.S. Congress in 1990. In June 2001, President Bush announced a new climate science initiative called the Climate Change Research Initiative (CCRI), and in February 2002 he announced the U.S. Climate Change Science Program (CCSP), incorporating the USGCRP and the CCRI. The CCSP has a cabinet-level management structure with membership by 13 U.S. federal agencies and has four areas of focus:

- Science—CCSP deals with ongoing science, including long-term studies and process studies;
- Observations and data—Although a part of the science component, these are kept as a separate element to increase the attention paid to the need for observations and data for long-term analyses;
- Decision support—increasing attention given to "cross-walking" between the science and stakeholder communities;
- Communication and education—dialogue to frame problems the CCSP is addressing.

CCSP Strategic Plan

A draft strategic plan for the CCSP was published in November 2002 and scientific and stakeholder comments were solicited through an international workshop, a written comment period, and a National Research Council review. The revised strategic plan will be published in June 2003 and reviewed again by the National Research Council. The revised plan will call attention to issues such as decision support, ecosystem perspective, technology, crosscut issues, international cooperation, stakeholder communication, and resources and budget.

Changes in the Arctic, such as increasing winter temperatures, thawing permafrost, and warming of Arctic Ocean waters are important and relevant issues in the consideration of climate change. Interagency and international programs addressing the issues of arctic climate change include the Study of Environmental Arctic Change (SEARCH), Arctic-Subarctic Ocean Fluxes (ASOF), and the Arctic Climate Impact Assessment (ACIA). In addition, NOAA's FY 2003 science priorities that have direct relevance to Arctic science include sustained environmental observations (i.e., enhanced efforts at Barrow Observatory and participation in SEARCH, ASOF, and ACIA), the inclusion of arctic processes in climate models, the encouragement of international cooperation in arctic science, and arctic ocean exploration.

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Panel Discussion: How Will the Challenges Posed by Global Changes be Met by Society?

Daniel Mann, University of Alaska Fairbanks; Taqulik Hepa; Charles Johnson; Mike Kunz; Roger Simmons

Daniel Mann, University of Alaska Fairbanks, moderated a panel discussion on: How will the challenges posed by global changes be met by society? The purpose of this panel discussion was to explore the potential gap between what is happening on the land and what government agencies plan to do about it. Panelists will respond to the following questions:

1. Do you see evidence for global change in your area?
2. The U.S. Global Change Research Policy stresses three things:
   - scientific enquiry into the causes of climate change,
   - monitoring of changes, and
   - development of "decision-support resources."

   How relevant are these efforts to your local problems?
3. The U.S. government is spending large amounts of research money trying to separate "natural" from human-made causes of climate change. Is this important? Is it important to be able to assign blame for climate change?
4. Coping with climate change will cost money. Parks, refuges, and environmental regulations cost money to maintain. Will paying for climate change trigger the degradation of the conservation-estate?
5. In contrast to a place like Massachusetts, most of the land and resources of the Arctic are not owned by individuals. What challenges does public ownership pose for how we deal with climate change in the Arctic?
6. Arctic systems span national boundaries. How will international arctic issues be resolved?

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Suffering and Solace: Vulnerability and Resilience to Environmental Change in Northern Iceland c. A.D. 1700–1900

Astrid E. J. Ogilvie, University of Colorado

> *… thus when the animals are dead; the people must consequently die also, here in the north where there is no other food source apart from the animals, especially when all the northern coasts are spanned by the evil sea ice, as this year, when the ice first broke up on 23 August.* (Report from Jón Jakobsson, Espihóll, Eyjafjardarsysla, 14 October 1802).

Before the Viking settlement around A.D. 870 to 930, the island of Iceland had remained pristine and untouched by the impacts of humans and their domestic animals. Following the settlement, the fragile ecosystem was very soon severely affected by erosion and land degradation. This, in turn, was to have a continued negative impact on Icelandic society and economy. Other environmental changes that affected the population were volcanic eruptions, changes in climatic regimes, and variations in the incidence of the East Greenland ice which periodically drifts to the coasts of Iceland. This presentation will look to past, present, and possible future environments of Iceland, and their impacts on society. However, the major focus will be on the period c. A.D. 1700 to 1900. This time period encompassed a number of crisis years in Iceland. These are described in many historical documents, which give detailed accounts drawn from the local knowledge exhibited by careful Icelandic observers. The main sources used for this presentation are contemporary official reports that give information on legal, economic, and social matters, issues with regard to trade, the state of the hay harvest, fishing, and also weather and climate. An emphasis is placed on northern Iceland since this region experienced greater climatic impacts due to sea-ice incidence than did the south.

In times of unusually severe climate and weather, links can clearly be seen with a disruption of society involving the desertion of farms, the occurrence of begging and crimes related to petty theft. Loss of life amongst the domestic animal and the human population was also frequent, as well as the incidence of hunger-related diseases. Examples of crisis years during the period A.D. 1700–1900 were the 1750s, the 1780s, the early 1800s, and the 1880s. Thus, for example, unusually severe weather in the 1750s may be implicated in the loss of a large percentage of the population. In 1783–84, the Lakagígar volcanic eruption occurred in southern Iceland, but its effects were soon felt all over the country as well as in other parts of the world (Demarée and Ogilvie, 2001). It was one of the most noteworthy and largest fissure eruptions in historical times and had a catastrophic effect on Icelandic society. The eruption must be seen as the primary cause of the ensuing

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famine in which some 20% of the Icelandic population lost their lives. However, the severe weather and the presence of sea ice during the years 1782–84 also undoubtedly played a part in negatively impacting the human population. The last great subsistence famine may be said to have occurred in Iceland in the 1880s.

The "suffering" mentioned in the title of this presentation, and endured by the Icelandic people in their vulnerable state during past climate-induced and environmentally induced economic crises is surely self evident. However, there was also "solace" in the form of resilience and adaptability to difficult situations. Both these aspects will be discussed.

Reference:

Demarée, G. R., and Ogilvie, A. E. J. 2001: Bon baisers d'Islande: climatological, environmental and human dimensions impacts in Europe of the Lakagígar eruption (1783–1784) in Iceland. *History and Climate: Memories of the Future?* (Eds. P. D. Jones, A. E. J. Ogilvie, T. D. Davies and K. R. Briffa). Kluwer Academic/Plenum Publishers, New York, Boston, Dordrecht, London, Moscow, 219–246.

Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope

Gordon Orians, University of Washington

Since 1977, Alaska's North Slope has produced 14 billion barrels of crude oil from an industrial complex that today extends over an area about the size of Rhode Island. Although the industry has made great strides in developing environmentally sensitive ways of exploring and extracting hydrocarbons, there is a legacy of cumulative effects on the physical, biological, and human environment. Roads, drilling pads, pipelines, and off-road travel have altered drainage patterns and permafrost, influenced the distributions of some animals, and affected tundra vegetation, and some of the effects are likely to persist long after industrial activities cease. The large influxes of money have altered the lives of residents of the North Slope in many ways, many of them positive. Knowledge of the inevitable trade-offs of industrial activities on tundra should help guide discussions about the nature and extent of future activities.

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Alaska Native Subsistence Life Ways Rely on Healthy Ocean Ecosystems

George Owletuck

The North Pacific is one of the most productive marine ecosystems in the world. Subsistence use of marine species has sustained Alaska Natives and our cultures for millennia. However, this now may be at risk. Recently, the U.S. Department of Commerce concluded that many U.S. fisheries are over-fished, including Alaska's oceans. Dramatic declines in the Bering Sea populations of sea lions, fur seals, harbor seals, spotted seals, sea otters, crab, shrimp, salmon, and numerous species of sea birds are compelling indicators of an ecosystem in trouble. The sustained and precipitous declines of many marine species in the North Pacific are the direct result of adverse environmental circumstances coupled with commercial fisheries expansion and mismanagement, in which maximizing the quantity of fish harvested is allowed with few thoughts about the potential impact of high-volume fishing on other species or Alaska's indigenous communities.

The magnitude of the ongoing decline of fish and wildlife in the Bering Sea is a serious and immediate threat to the viability of indigenous coastal and river cultures throughout Alaska. The survival of marine species and that of Alaska's indigenous peoples rely on healthy marine ecosystems. An ecosystem-based strategy to preserve the productivity of the North Pacific ecosystem must be developed. The establishment of marine protected areas in Alaska, where coastal indigenous communities co-manage the marine protected areas using their traditional knowledge and environmental wisdom on an equal basis with science, is in order.

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We Will Change If We Can, If We Have To: What Inuit *Qaujimajatuqangit* and Western Scientific Knowledge Tell Us About Resiliency and Vulnerability of a People Living with Climate Change and Caribou

Natasha Thorpe, Golder Associates Ltd.

Inuit observations of a warming climate, and how climate change has influenced caribou, were recorded as part of the Tuktu (caribou) and Nogak (calves) Project (TNP) between 1996 and 2001. This community-driven effort sought to document and communicate Inuit knowledge, or Inuit Qaujimajatuqangit (IQ), of the Bathurst caribou and calving grounds by working with elders and hunters from four communities in the Kitikmeot region of western Nunavut, Canada. In this presentation, the goals, objectives, and methods of the TNP are introduced. Next, Inuit experiences of climate change impacts and adaptations—demonstrative of both the resiliency and vulnerability of the arctic system—are presented. People are being forced to adapt to thinner ice, rapid spring melt, permafrost thaw, new and varied flora and fauna, frequent storms, stronger winds and unpredictable and variable weather. These environmental impacts alter caribou migration, behaviour, and body condition and are changing the relationship between people and caribou. The TNP shows that while IQ is valuable and useful in its own right, it also contributes to a local, regional, and global understanding of climate change impacts and adaptations by either affirming scientific findings or contributing new observations.

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Rapid Shifts in the Arctic Climate System: Implications for Vulnerability and Resilience

John E. Walsh, University of Alaska Fairbanks

The reality of rapid climate shifts in the past has become increasingly evident from paleoclimatic data. Evidence from ice cores, for example, indicates that North Atlantic temperatures have changed by 5–10˚ C, while precipitation rates changed by 50%, in the several-decade timespan of a human generation. Such shifts have significant implications for the vulnerability and resilience of various components of the Arctic system. One can make the case that, in recent decades, abrupt changes of a smaller magnitude have occurred in high latitudes in response to shifts in the atmospheric circulation in the North Atlantic and the North Pacific. Projected greenhouse-driven changes are actually smaller in magnitude than some of these recent changes, but their persistent character makes cumulative impacts more of a concern in the context of arctic vulnerability. In this presentation, we will address projected changes in the Arctic in terms of three specific impacts relevant to sustainability and vulnerability: coastal erosion, permafrost degradation, and fire. Coastal erosion, in turn, is a potential consequence of rising sea level and changes in coastal storm activity. In each case, the timeframe of likely impacts, as well as feedbacks that may significantly alter the timeframe, will be discussed in terms of model projections.

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nteractions Between Carbon and Nitrogen Mineralization and Soil Organic Matter Chemistry in Arctic Tundra Soils

Michael Weintraub, University of California Santa Barbara; Joshua P. Schimel

We used long-term lab incubations and chemical fractionation to characterize the mineralization dynamics of organic soils from tussock, shrub, and wet meadow tundra communities to determine the relationship between soil organic matter (SOM) decomposition and chemistry and to quantify the relative proportions of carbon (C) and nitrogen (N) in tundra SOM that are biologically available for decomposition. Despite large losses of soil C, respiration rates generally did not decline, and SOM chemistry was relatively unchanged after the incubation. The decomposition dynamics we observed suggest that tundra SOM, which is largely plant detritus, fits within existing concepts of the litter decay continuum. The lack of changes in organic matter chemistry indicates that this material had already decomposed to the point where the breakdown of labile constituents was tied to lignin decomposition. Our results suggest that a large proportion of tundra SOM is potentially mineralizable, despite the fact that decomposition was dependent on lignin breakdown, and that the historical accumulation of organic matter in tundra soils is the result of field conditions unfavorable to decomposition and not the result of fundamental chemical limitations to decomposition. Our study also suggests that the anticipated increases in shrub dominance may substantially alter the dynamics of SOM decomposition in the tundra.

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Henrik Ibsen and the Environment

Trond Woxen

The Father of the Modern Drama, Henrik Ibsen, is known for deep psychological insights into his characters. However, some of his plays (and other writings) also focus on environmental issues. These issues have mostly been overlooked. In this presentation, Ibsen's concern with the environment will be explored.

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Poster Abstracts

Propagation of the "Great Salinity Anomaly" of the 1990s Around the Northern North Atlantic: Subarctic Gyre Spin-up Confirmed

Igor M. Belkin, University of Rhode Island

Time series of temperature and salinity extending through 2001 are used to describe propagation of the "Great Salinity Anomaly" of the 1990s (GSA '90s). Comparison of the distance-time relations for the GSA '70s, '80s, and '90s reveals a substantial intensification of the large-scale circulation in the northern North Atlantic, especially in the Subarctic Gyre. The advection rate of the GSA '70s, '80s, and '90s between Newfoundland and the Faroe-Shetland Channel is conservatively estimated to have been 4, 10, and 10 cm/s, respectively. The circulation intensification apparently occurred within a decade between the GSA '70s and '80s. During the next decade, the advection rate increased from 10 to 13 cm/s between Newfoundland and Iceland Basin. The GSA '90s was advected towards the Faroe-Shetland Channel by the northern (Iceland Basin's) branch of the North Atlantic Current, whereas the contribution of the southern branch via the Rockall Trough was minimal.

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Fronts of the Arctic/Subarctic Marginal Seas From Pathfinder SST Data

Igor M. Belkin, University of Rhode Island; Peter C. Cornillon; David S. Ullman

The arctic/subarctic seas feature a variety of fronts that clearly manifest in the surface layer, both in temperature and salinity. Thermal fronts were studied from the Pathfinder satellite SST fields, 1985–1996, obtained from the AVHRR 9-km twice-daily images (8,364 images in total). The SST fronts were detected from each individual image using the Cayula-Cornillon front detection and declouding algorithms. Long-term (1985–1996) frontal frequencies (normalized on cloudiness) were computed for each 9-km pixel and mapped for the Arctic Ocean marginal seas and the northern North Atlantic subarctic seas. Analysis of synoptic frontal SST maps together with frontal frequency maps allowed us to distinguish a number of new fronts and elucidate important features of some previously known fronts, especially with regard to their spatial structure and its seasonal and interannual variability.

The Arctic Ocean marginal fronts are best developed in the Chukchi and Beaufort Seas in summer when the Chukchi Sea and southern Beaufort Sea become ice-free. Most fronts are topographically controlled by shelf break (e.g. in the southern Beaufort Sea), canyons (Herald Canyon, Barrow Canyon) and shelf banks (e.g. Herald Shoal and Hanna Shoal). In both seas the thermal fronts are spatially associated with distribution of biota, including sea birds and marine mammals.

Major fronts of the Nordic Seas are topographically controlled. The East Greenland Front, West Spitsbergen Front, and Norwegian Coastal Front are shelf-slope fronts aligned with the respective shelf breaks/upper slopes; the Norwegian Atlantic Front is controlled by the Voring Plateau's western flank; the Iceland-Faroe Front extends over the Iceland-Faroe Ridge, while the Jan Mayen Front is located over the Jan Mayen Ridge and Mohn Ridge. The Iceland Sea frontal pattern is more complex than previously known and displays a "horseshoe" pattern formed by the East Icelandic and Kolbeinsey Ridge fronts. In the Labrador Sea, the West Greenland Front follows the shelf break. The Baffin Front emerges as an independent feature, originated largely in the Baffin Bay. The offshore Labrador Front is fairly stable, aligned with the shelf break. In summer, the newly identified mid-shelf Labrador Front is also observed. This double-front structure sometimes persists through October.

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Newly found fronts are described off Melville Bay (northern Baffin Bay), along Foxe Channel/southern Foxe Basin, and in the Eastern Arctic marginal seas, namely the Barents, Kara, Laptev, and East Siberian seas. Some of the eastern arctic fronts are related to a huge freshwater runoff of great Eurasian rivers.

In the Gulf of Alaska and Bering Sea, the SST fronts are best defined in spring (May) and fall (November), while being masked by surface heating in summer. In the Chukchi and Beaufort Seas the SST fronts are best seen in summer (August–September), when both seas are typically ice-free. Seasonal evolution of SST fronts is noted off the Oregon-Washington coasts and Vancouver Island, in Hecate Strait and Dixon Entrance.

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Adaptation and Sustainability in a Small Arctic Community: Results of an Agent-Based Simulation Model

Matthew Berman, University of Alaska Anchorage; Craig Nicolson; Gary Kofinas; Stephanie Martin

Climate warming could alter key Arctic ecosystem functions that support fish and wildlife resources harvested by local aboriginal communities. Another set of global forces increasingly directs local cash economies that communities use to support subsistence activities. Agent-based computational models (ABMs) may contribute to an integrated assessment of community sustainability by simulating how people interact and adapt to changing economic and environmental conditions. Relying on local knowledge to provide rules for individual and collective decision-making and parameters for unmeasured relationships, our ABM generates hypothetical social histories as adaptations to scenario-driven changes in environmental and economic conditions. The model generates projections for wage employment, cash income, subsistence harvests, and demographic change over four decades based on a set of user-defined scenarios for climate change, development, and government spending. Model outcomes for one Canadian arctic community—Old Crow, YT—assess how potential adverse economic events or a warmer climate (or both occurring at once) might affect the local economy, resource harvests, and the well-being of residents.

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nterannual Variability of UV Irradiance, Ozone, and Aerosol in the Arctic

Randolph D. Borys, Desert Research Institute; Melanie A. Wetzel; James Slusser; Catherine Cahill

Field measurements, satellite remote sensing, and radiative transfer modeling has been used to explore the variability of UV irradiance in a high latitude region near Fairbanks, Alaska. Observations include continuous measurements from a new permanent monitoring site at Poker Flat Research Range, which began operations in September 2000 and results from shorter field projects with additional sensor systems that took place in September 2000 and March–April 2001. The results indicate a relatively pristine environment with widely differing aerosol sources but relatively small aerosol impact on UV irradiance, and the controlling influences of cloud, surface albedo, and ozone column amount.

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Upstream Environment for SBI: Modeled and Observed Biophysical Conditions in the Northern Bering Sea

Jaclyn Clement, Naval Postgraduate School; Wieslaw Maslowski; Lee Cooper; Jacqueline Grebmeier; Waldemar Walczowski; Jeffrey S. Dixon

Using a high-resolution Pan-Arctic ice-ocean model, the circulation of the northern Bering Sea and transport through Bering Strait are investigated and discussed in relation to their influence on downstream conditions in the Chukchi and Beaufort seas. Model results are compared to observational data, including salinity and nutrient concentrations in the Bering Sea and transport measurements in Bering Strait. The high resolution ($^1/_{12}^\circ$ or ~9 km) and large domain of the model allow for realistic representation of flow through Anadyr, Shpanberg, and Bering straits and calculation of transport estimates.

A long-term model estimated mean transport through Bering Strait is ~0.65 Sv. The modeled seasonal pattern of transport is comparable to observational data collected from moorings in Bering Strait, with lower monthly mean transports during winter and higher transports in July and August. The monthly mean transport through Bering Strait is highly correlated with the transport through Anadyr Strait over the model 23-year integration time period (r = 0.83), while the correlation coefficient for Bering and Shpanberg Straits is somewhat lower (r = 0.64).

Observational data in the northern Bering Sea from late spring through summer and fall indicate an east-to-west increase in nitrate concentration, silicate concentration, and salinity. Model results show a similar salinity pattern across the Bering shelf, which represents the characteristics of Alaska Coastal Water to the east and Anadyr Water to the west. However, the model overestimates the salinity near the Alaska coast, which is possibly due to a lack of freshwater input from the Gulf of Alaska via the Alaska Coastal Current. In the Bering Sea, salinity can be used as a proxy for nutrient concentrations, especially in deeper parts of the water column (P. Stabeno, pers. comm.). This allows the model to be used in determining the biologically relevant characteristics of water moving north through Bering Strait and across the Chukchi shelf. Upstream conditions in the northern

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Bering Sea are important for developing hypotheses regarding the Shelf-Basin Interaction (SBI) study region in the Chukchi and Beaufort seas. The model's ability to cross political boundaries and examine high-resolution results over a large scale and long time period is critical for understanding the role of Pacific Water in shelf-basin exchanges, in the arctic general circulation, and in climate change.

Tree-Ring Reconstructions of Arctic Oscillation Indices Since A.D. 1650

Rosanne D. D'Arrigo, Lamont-Doherty Earth Observatory; Edward R. Cook; Michael E. Mann; Gordon C. Jacoby

Arctic Oscillation (AO) changes are inferred from a tree-ring reconstruction of a warm-season temperature index. The reconstruction covers A.D. 1650–1975 and is based largely on chronologies from circumpolar-Arctic and circum-North Atlantic areas. It accounts for 48% of the variance in the instrumental AO record from 1900 to 1975, verifies using independent data, and exhibits its largest variance at low frequencies. A reconstruction of an AO summer sea level pressure index shows similar trends. Trends (including lower values during "Little Ice Age" periods) also resemble those of an Arctic temperature reconstruction based on annual ring widths from trees at treeline sites in the northern boreal forests. The arctic temperature reconstruction is based on 26 chronologies back to 1655 and 20 chronologies from 1600–1654. Comparison of these reconstructions with proxies of the North Atlantic Oscillation (NAO) and other indices can help clarify relationships between the AO and NAO, at least during the boreal warm season.

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Archeology of Alaska Glaciers and Snow Fields

E. James Dixon, University of Colorado; William F. Manley

Approximately 10% of the Earth's land surface is covered by ice. Global warming is rapidly melting ice and exposing rare archeological remains. These sites are important to understanding the role of high latitude and high altitude environments in human adaptation and cultural development. GIS modeling is used to identify areas in Alaska's Wrangell St. Elias National Park exhibiting high potential for the preservation and discovery of frozen archeological remains. Areas holding the highest potential for archeological site discovery are: (1) ice-covered passes used as transportation corridors, and (2) glaciers and areas of persistent snow cover used by animals that attracted human predators.

A preliminary GIS model was field tested by aerial reconnaissance and pedestrian survey. Archaeological and/or paleontological specimens were found at 32 sites. Historic artifacts included horse hoof rinds and associated horseshoe nails on the Nabesna glacier. This unusual discovery indicated that a horse had been shod on the glacier in historic times. A can fragment and a piece of culturally cut wood were recovered on the ice near the terminus of the Chisana glacier. These discoveries were all made below the ELA's of these large glaciers at an elevation of approximately 3,400 ft. (~1,036 m). The recovered artifacts demonstrate the presence of exceptionally well-preserved archeological remains that were successfully predicted by the GIS model for glaciers historically documented as trails and passes over mountain ranges. A prehistoric antler projectile point possibly associated with a punctured large mammal scapula was recovered near a snowfield in the vicinity of Tanada Peak at approximately 5,800 ft. (~1,767 m). In addition to the archaeological specimens, numerous paleontological specimens, including well preserved rodents, were encountered during the survey. Discoveries include the remains of Dall sheep, caribou, carnivores, the frozen remains of medium-sized mammals, micotines, birds, mammalian hair, fecal material, and even a complete perfectly preserved fish.

Field survey determined that site potential values from the model were higher for the documented sites than for the study area in general, suggesting that the *a priori* model meaningfully identified areas of archeological potential. This also suggests the model is based on fundamentally sound criteria, but requires refinement. Several important observations indicate where and how it should be refined. For example, six sites fell outside predictions. Subsequent analysis of these six sites demonstrate that all were located on relatively small perennial snow patches observed during aerial reconnaissance, but not predicted by the model because cartographic, photographic,

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and satellite imagery lacked the resolution to detect these small features. These problems can be corrected by incorporating multispectral remote sensing data and high-quality landsat images for the northern Wrangells in the GIS model.

Global warming presents an unprecedented opportunity to identify ice fields and similar contexts holding the highest potential for the exposure and discovery of frozen archeological remains. Preliminary research demonstrates that these locales can be detected by GIS modeling to identifying glaciers and perennial ice patches most probably used by humans. These features can be documented through the analysis of social/cultural, biological, remote sensing, and geologic data. Glaciers and ice patches are melting at an unprecedented rate, and it is anticipated that increasingly older and significant artifacts will be exposed on thawing surfaces. This research will provide a valuable tool to focus limited resources on areas exhibiting the greatest potential for archeological and paleontological discovery and recovery.

Circulation and Variability in the Western Arctic Ocean from a High-Resolution Ice-Ocean Model

Jeffrey S. Dixon, Naval Postgraduate School; Wieslaw Maslowski; Jaclyn Clement; Waldemar Walczowski

Interactions of the Atlantic Water circulation with Pacific Water exported from the Chukchi shelves towards the Chukchi Rise and in the southern Canada Basin are not well understood. Comprehensive modeling provides tools to supplement limited observational data and to improve our knowledge of the circulation in the Western Arctic. The Naval Postgraduate School pan-arctic sea ice and ocean model, developed in part for the Shelf-Basin Interactions (SBI) program, provides valuable insights into the circulation of the region. One of the main goals of this effort is to more accurately model the circulation in the main SBI region (i.e., shelves and slopes of the Chukchi and Beaufort seas) as well as the upstream conditions for this region.

To address some of the issues related to the circulation in the Western Arctic, the time-mean and interannually variable velocity fields are analyzed. The bases of this investigation are results from the recently completed 24-year model integration for 1979–2002, forced with realistic daily-averaged atmospheric fields from the European Centre for Medium-Range Weather Forecast. Velocity output at three separate depth intervals are averaged to present the circulation in the upper ocean, at the halocline depth and in the Atlantic Layer. Decadal variability is analyzed comparing results from the early 1980s, 1990s, and 2000s. The western Arctic Ocean response to the climate regime shifts of the recent decades is estimated by calculating decadal differences of velocity fields at various depths. Property fluxes across the Bering Strait are compared with those downstream across the Chukchi Cap to better understand their variability as well as to quantify the fate of Pacific Water in the region.

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Distribution of Zooplankton in Arctic Waters: Spatial Patterns and Temporal Dynamics in Svalbard Waters

Ketil Eiane, University Courses in Svalbard (UNIS)

Around Svalbard, water masses originating from different sources (Norwegian Sea, Barents Sea, Arctic Ocean) meet. The planktonic ecosystem in this area is characterized by coexistence of both boreal and arctic species. By studying how a group of three similar and ecologically important species of zooplankton (*Calanus* spp.) varies in abundance in the area, we show that although coexistence is common, the relative importance of the different species largely reflects the regional variability in water masses. Temporal dynamics of the species complex was monitored over a season in a semiconfined fjord where water exchange has little effect on the populations. In this location an arctic species dominates the system even if its numerical response during the productive season (May–August) is similar to that of the boreal species. However, during the unproductive winter season the mortality rate of the arctic species is lower than that of the boreal species. This suggests that differentiated survival through the long unproductive season may be one of the mechanisms that regulate plankton diversity in Arctic waters.

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Nitrogen Resorption from Senescing Plant Tissue in Arctic Tundra and its Effects on Whole-Ecosystem Properties

Howard E. Epstein, University of Virginia; William M. Yeatman

Nitrogen resorption from senescing plant tissue for use in future growth is a ubiquitous process and can represent a substantial portion of the nitrogen used in net primary productivity. For vascular plants in arctic tundra ecosystems, the proportion of N retranslocated from senescing tissue has been observed to range from 10–80%, largely differing based on plant functional type and species. Values for N retranslocation efficiency are quite variable within plant species and also across studies; standard deviations of leaf N concentrations range from 0.02 to >0.50% for means on the order of 0.30 to 2.50% (dead and live leaf tissue). In low arctic tundra, dominated by dwarf shrubs and tussock graminoids, resorbed N can account for 40–50% of the N used in annual net primary productivity. Given the importance of this process in terms of plant N availability, variance in N retranslocation could lead to substantial changes in whole-ecosystem properties in arctic tundra. In addition to collecting a dataset on N resorption in low arctic tundra from Ivotuk, Alaska, we used a dynamic tundra vegetation model (ArcVeg) to assess the sensitivity of tundra systems to variability in N retranslocation. Since shrubs represent a substantial portion of the total resorbed N in the system (due to relatively high leaf biomass and high resorption), we conducted a sensitivity analysis of N resorption rates for both *Betula nana,* a dominant deciduous dwarf shrub in low arctic tundra, and *Ledum palustre,* a dominant evergreen dwarf shrub, by altering resorption rates from –15% to +15% around the mean values. We also varied N resorption rates for the deciduous shrub and evergreen shrub functional types as a whole. Variation in N resorption rates for both single, dominant species and dominant functional type led to substantial changes in simulated plant community composition and total community biomass. Increasing N resorption rates from 40% to 70% for *B. nana,* for example, increased its own biomass almost ten-fold and increased total community biomass by ~10%. Other community responses to increased N resorption in *B. nana* were a decline in the biomass of evergreen shrubs as well as other deciduous shrubs. This study suggests that uncertainties in N resorption rates by different plant species and functional types have a substantial impact on our general understanding of the nitrogen cycle and vegetation dynamics in arctic tundra.

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Vulnerability of Communities in the Canadian Arctic to Natural Hazards in Light of Climate Change: A Framework for Assessment

James D. Ford, University of Guelph; Barry Smit

The vulnerability of the Arctic to climate change is widely accepted. Climate models predict significant increases in temperature with implications for the extent, distribution, and thickness of the sea ice and permafrost, river hydrology, coastal processes, the occurrence of storms, and the habitat and populations of animal and plant species. It is also widely accepted, on the basis of natural science studies and traditional knowledge, that these alterations are happening now.

These changes in geophysical and biological systems are expected to have implications for communities in the Arctic, although there has been little research on this issue. For thousands of years, communities have coped with variations in climate and the associated ecological conditions. However, there are suggestions that climate change stresses, particularly given their speed of onset, their associated extremes, and their superimposition on other stresses, may exceed the communities' resilience or ability to adapt.

This paper outlines a framework to assess the vulnerability of Arctic communities to risks associated with climate change, focusing on geophysical hazards. Vulnerability is conceptualized as the susceptibility for harm in a system relative to a stimulus or stimuli, and is a function of exposure of the system to the stimulus and the adaptive capacity of the system to deal with the exposure. In our example, exposure relates to the communities' likelihood of experiencing the specified geophysical hazards, given the communities' location. Adaptive capacity relates to the resource use options and risk management strategies available to the communities to deal with the hazards before, during, and after their occurrences.

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Model-Based Monitoring of Pan-Arctic Tundra

Haoyu Gu, University of Michigan; Hanh Pham; Yi-Ching Chung; Roger D. DeRoo; Anthony W. England

The overall objective of the three projects described in this poster is to enable near-daily monitoring of the thickness and water content of the active layer throughout the pan-Arctic, using model-based inferences about land surface processes and assimilated satellite microwave brightness. The tasks leading to this capability are development and plot-scale calibration of a Soil-Vegetation-Atmosphere Transfer/Radiobrightness (SVAT/R) model for arctic tundra, embedding of these SVAT/R models in well-understood regional land surface hydrology models, validation of the embedded models, and extension of the approach to the pan-Arctic. These three projects describe (1) development of a forward SVAT/R model for tussock tundra and plot-scale calibration of this model through field experiments near Toolik Lake beginning during the summer of 2004; (2) development of the inverse SVAT/R model for tussock tundra that assimilates microwave brightness observations to infer active layer temperature and moisture profiles, and calibration of this model through field experiments near Toolik Lake beginning in the summer of 2004; and (3) development of the airborne radiometer needed to validate the regional embedded model.

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Glacier Macroinvertebrates: A Mystery to be Lost

Paula L. Hartzell, Clark University

Glaciers in the Pacific Northwest of North America provide up to one third of stream flow during late summer–early fall dry months, yet the chemical and biological processes of glaciers and their role in the larger environment is little understood. Since many of this region's glaciers are extremely sensitive in response to climate change, and their biota generally limited in dispersal ability, their biota offer a unique opportunity at monitoring climate change effects, study of ecological and evolutionary processes, and a dangerous loss of diversity before it has even been discovered.

The purpose of the 2002 field season was to increase understanding of our cryoecology by performing an initial baseline inventory of macroinvertebrates living in glacial snow and ice of the North Cascades, Washington. The study included an initial type collection along with pertinent biological and physical contextual data, identification and inventory of specimens, and limited analysis for preliminary statements of spatial and ecological distribution of identified taxa. Dominant taxa included ice worms (*Mesenchytraeus solifugus*) and *Collembola*. New species of *Collembola* were identified belonging to *Isotoma* (*Myopia*), *Agrenia,* and *Isotoma* (*Desoria*). A surprisingly wide variety of other macroinvertebrate taxa were observed and collected in smaller numbers.

Distribution of *Collembola* species suggests that historical connections (specifically time since isolation) are more important than size of glacier in determining species composition at this scale and are more reminiscent of aquatic communities than terrestrial. Species distribution poses interesting north-south differences, with greater diversity to the north. Morphological and particularly molecular (28S rDNA) differences between North Cascades and Alaskan ice worms appear to represent significant differences, although further sampling is needed. Best fit model predictors for macroinvertebrate density included time of day, weather, percent dirt cover (during daylight hours), and substrate (pool versus snow-stream versus avalanche ice).

Long-term monitoring, incorporation of Native knowledge, and recognition of potential management concerns is necessary in order to capitalize and/or protect these biotically diverse resources before they are (potentially) lost. Work beginning in 2003 will include measurement of microbial communities, description of new taxa, phylogenetic description and analysis, carbon transport and cycling, and a larger regional scope for sampling (Alaska, Yukon, British Columbia, Washington).

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Heterotrophic Bacteria and Phytoplankton Spatial Distribution in the Central Arctic Under Ice Surface Water Layer in April–May

Vladimir V. Ilinskiy, Moscow State Lomonosov University

The microbial communities of the deep-water zone of the Arctic Ocean are not yet well understood. For the most part this region is covered with drifting ice sheets and, therefore, hard to reach for research vessels. Russian microbiologist A. E. Kriss was the first to carry out microbiological research in some parts of the central Arctic in 1954, during a wintering expedition on the "North Pole" research station, located directly on the drifting ice. He investigated the distribution of saprotrophic bacteria, able to grow on the rich nutrient media at six microbiological stations, at latitudes of 82° to 90° N.

The aim of our research was to obtain quantitative information about the total bacteria (direct count), viable heterotrophic bacteria of the three different groups (copiotrophic, oligotrophic, and hydrocarbon-oxidizing) and phytoplankton distribution in the Russian sector of the central Arctic in April and May. Water samples for microbiological investigations were taken from under the drifting ice surface using a ZoBell water sampler and water samples for phytoplankton counts and hydrochemical analyses were done using a bottle-type bathometer. The personnel and the equipment were transferred to the research site and back to land laboratory by MI-6 helicopter.

Microbiological research was done at thirteen stations, located north-northwest of the islands of the Severnaya Zemlya Archipelago. Copiotrophic bacteria dominated among the viable heterotrophic bacteria groups, with numbers varying from 20 to 2140 CFU per liter. Oligotrophic bacteria density varied from less than 20 to 1190 CFU/l and the numbers of hydrocarbon-oxidizing bacteria coupled with hydrocarbon-tolerant bacteria varied from less than 10 to 1190 CFU/l. Strong pair correlations ($r > 0.9$) were found between all the viable bacteria groups numbers. The viable bacteria accounted for 0.0001 to 0.01% of the total microbial number, counted using epifluorescent microscopy, and ranged from 1.90×10^7 to 1.10×10^8 cells per liter. The phytoplankton number varied from single cells in April to 1.07×10^5 cells/l at the end of May. Hydrocarbon concentrations, measured by the IR-spectroscopy method, were usually small and only rarely exceed 0.05 mg/l.

Based on our data estimates, the total bacteria and phytoplankton numbers in the central Arctic are high enough and comparable to those in other Arctic Ocean regions, including those situated far south and closer to the continent. But only a very small part of the microbial population was able to grow on the nutrient media, and this part is at least one order of magnitude lower than in other Arctic Ocean areas to the south of our investigations area. This situation may reflect the specific stress-state condition of the high Arctic microbial communities under low water temperature (close to the freezing point) and under limited nutrient and energy resources.

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nternational Polar Year (IPY)

Leonard Johnson, University of Alaska Fairbanks

The year 2007 will mark the 125th anniversary of the initial International Polar Year (IPY), and it seems appropriate to launch another polar effort.

It is clear that a complex suite of significant, interrelated atmospheric, oceanic, and terrestrial changes have occurred in the polar regions in recent decades. These events are affecting every part of the polar environment and having repercussions on society. Polar contributions to and the effect of global climate change are still a matter of conjecture, and to a large extent so are the extraterrestrial contributions. As part of the global heat engine, the polar regions have a major role in the world's transfer of energy, and the ocean/atmosphere system is known to be both an indicator and a component of climate change.

Goals

In a similar thrust to both the IPY and International Geophysical Year, the goal would be to obtain synoptic measurements for studying large-scale processes at high latitudes. The hypothesis is that if scientific processes can be summed and simplified from a great number of stations over a broad geographic region, they will be easier to understand and predict. Observing systems would ideally be in place over a number of years to separate annual from seasonal variability.

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It is not clear if the profound changes in the polar regions are due in some part to anthropogenic changes or if it is part of a natural fluctuation. The environmental paleohistory of the high latitudes is required by a drilling program as outlined by JEODI (Joint European Ocean Drilling Initiative).

The terrestrial solar coupling needs definition by obtaining a coordinated set of observations to study at the largest scale the solar generated events that affect life and climate on earth.

The efforts must be characterized by a high level of international cooperation and collaboration and interdisciplinary scientific endeavors.

It should be noted that polar and space research presents exceptional opportunities to integrate educational outreach into research projects by communicating the unique results to the interested scientific community and to all peoples of the Earth.

Why 2007?

The IODP (Integrated Ocean Drilling Program) will commence in October 2003 with field operations being launched in subsequent years with the Arctic having a strong potential to be a focal point. The *Aurora Borealis* will be in the field with unprecedented multidiscipline all season data collection capacity and a scientific drilling capability. Likewise the Alaska ARRV and *Sir John Franklin* will be operational.

The SEARCH program data collection, internationalization and monitoring phase will also be under way.

Plant Community and Ecosystem Properties in Arctic Frost-Boil Systems

Alexia M. Kelley, University of Virginia; Howard E. Epstein; Donald A. Walker

Frost boils are a type of patterned ground formation common in arctic ecosystems. These landscape features, typically 0.5 to 3 m in diameter, are initially formed through differential freezing and thawing of soils (cryoturbation) and may persist on the landscape for long periods of time. The disruption associated with soil heaving causes frost boils to be distinctly different in terms of plant community structure and soil biogeochemistry from the surrounding inter-boil areas. The properties of frost-boil ecosystems are strongly influenced by regional climate gradients. In this study we are investigating the interactions among nutrient cycling, plant communities, and cryoturbation. Soil biogeochemistry and plant community traits of frost boils and inter-boil areas were examined along a latitudinal climate gradient in arctic Alaska. Preliminary data from three sites on the Arctic Slope of Alaska show that normalized difference vegetation index (NDVI) and leaf area index (LAI) of frost boils (average NDVI across sites = 0.41, average LAI across sites = 0.19) are less than those of inter-boil areas (average NDVI = 0.54, average LAI = 0.88). Both NDVI and LAI decrease with increasing latitude, however the NDVI values on frost boils decrease more rapidly than those outside of frost boils. Thaw depth is between 19 to 29 cm deeper in frost boils than inter-boil areas and is on average 23 cm deeper at the more northern sites, as compared to the more southern study sites, due to the insulating effect of vegetation on soils. Soil moisture is lower in frost boils (mean of 42.3% by volume) than inter-boil areas (mean of 70.2%), largely because of greater mineral soil content and less organic matter in frost boil surface soils. This work is part of a larger study that seeks to understand the relationships among frost boils, climate, vegetation, and nutrient cycling.

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Cloud Radiative Forcing in Arctic Polynyas: Parameterization and Modeling

Erica L. Key, University of Miami; Peter J. Minnett; Robert H. Evans; Bruce A. Albrecht; Tim N. Papakyriakou; Zafer Top

Despite their applicability to climate change scenarios, polynyas have been the subject of few modeling studies (e.g. Lynch et al., 1995; Morales-Maqueda and Willmott, 2000). Most of these previous works have focused on water mass formation within the polynya and not on the ice-ocean-cloud feedback mechanisms which evolve with and perhaps perpetuate these areas of open water. Motivation for studying these feedbacks grows inversely with the ice cover, which reached an extreme low during the 2002 positive arctic oscillation index (AOI). However, the variables which control incoming radiation and heat exchange across the ice/water interface are not yet detectable by satellite and only sparsely sampled in field projects. Combining data collected in shipboard and aircraft surveys, at coastal weather stations and ice camps, as well as remotely sensed fields, the polynya environment is defined for radiative transfer modeling.

Data from four polynyas across the North American Arctic are used to test the sensitivity of the Streamer radiative transfer model (Key and Schweiger, 1998) to variations in cloud microphysics and surface albedo. Temperature and moisture profiles from radiosondes, forecast models, and satellite data initialize the model atmosphere. Scene information from time-lapse cloud imagery, combined with satellite retrievals and an assumed microphysical structure based on aircraft surveys, fulfill model input requirements. Ozone and aerosol profiles from ozonesondes and lidar data provide additional ground truth for the validating model runs. From this detailed description of the polar atmosphere, the model identifies a 450 W/m^2 sensitivity to the rapidly changing surface albedo at low solar zenith angles. Current measurements of albedo do not have the spatio-temporal resolution to amend this error making radiative transfer models prone to overestimation of downward heat and radiative fluxes into the ice.

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The ALIAS Project: Arctic Logistics Information and Support

Josh G. Klauder, Arctic Research Consortium of the U.S.; Thom Depace Wylie Gruenig™; Kalina Grabinska-Marusek

The ALIAS website is a gateway to logistics support information for arctic research, funded by NSF and created and maintained by the Arctic Research Consortium of the United States (ARCUS).

ALIAS supports the collaborative development and efficient use of all arctic logistics resources. It contains information about circumpolar resources in a fully searchable format and allows online updates in near-real time, via input from resource managers and users.

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The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change

Igor Krupnik, Smithsonian Institution; Dyanna Jolly

ARCUS has published a collection of 10 papers describing contemporary efforts to document indigenous knowledge of environmental change in the Arctic. Compiled and edited by Igor Krupnik and Dyanna Jolly, *The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change* is available from ARCUS for $25 U.S. Copies will be available for sale at the ARCUS annual meeting.

The Earth is Faster Now reviews major individual studies on indigenous knowledge and climate change undertaken during the past few years, primarily in North America. The text is accompanied by local observations, quotations from interviews, personal observations, illustrations, and photographs. Contributors include well-known academic researchers and Native people from Canada, Finland, and the United States. The publication is designed to be useful to both researchers and communities as a tool for networking and communication.

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Alaska Paleoglacier Atlas

William F. Manley, University of Colorado; Darrell S. Kaufman

Three decades after the last Alaska-wide compilations of glacial geology (Karlstrom et al., 1964; Coulter et al., 1965), we have coordinated a broadly collaborative effort to create a digital map of reconstructed Pleistocene glaciers. Our goal is a comprehensive and consistent overview of former glacier limits across Alaska, with emphasis on Pleistocene maximum and late Wisconsin (LGM) extents. The geospatial database is targeted for a scale of 1:1,000,000—suitable for visualization and regional analyses. The atlas is now available online at http://instaar.colorado.edu/QGISL/ak_paleoglacier_atlas, and includes layers for Geographic Information Systems (GIS), as well as images and documentation.

A first draft was created by digitizing the statewide map of Coulter et al. (1965). Polygons delineating paleoglaciers were then modified to incorporate decades of glacial-geologic research (see Hamilton, 1994). This draft was updated after community review to include contributors' unpublished maps and information. In all, the first version integrates information from 26 publications and 42 source maps. We encourage further contributions to this evolving resource. Modern glaciers were added from ESRI's Digital Chart of the World.

The digital atlas depicts glaciers that once covered >1,200,000 km^2, from the continental shelf bordering the North Pacific to the northern foothills of the Brooks Range. Late Wisconsin glaciers occupied 727,800 km^2—only 48% of the state but nearly 10 times the area of modern glaciers. A companion paper (Kaufman and Manley, 2003; part of an INQUA effort for a global atlas with regional reviews) summarizes the glacial-geologic evidence and highlights recent revisions, remaining uncertainties, and implications for paleoclimate forcing.

Since they were released Aug. 15, 2002, the APG maps and GIS layers have received considerable interdisciplinary attention. After eight months, the website has seen 2,397 visits, with 111 downloads of the Late Wisconsin layers, 85 of the Pleistocene Maximum layers, and 94 downloads of the maps in an MS Word document. To our knowledge, the atlas layers have been used at other organizations for an interactive educational Climate Change CD-ROM, various websites, teaching at high school and college levels, and studies of geophysical isostatic and inverse modeling, interpretation of geomagnetic anomalies, habitat analysis for shorebird nesting, salmon DNA evidence for LGM refugia, human migration into the Americas, and LGM climate modeling, among others.

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Polar Bears Use Coastal Habitats as Sea Ice Contracts

Rosa H. Meehan, U.S. Fish and Wildlife Service; Scott L. Schliebe; Susanne B. Kalxdorff; Kelly Proffitt

Warming trends in the Arctic are detrimentally affecting polar bears. Studies of polar bear population dynamics in Hudson Bay demonstrate a significant positive relationship between the time of breakup and the physical condition of adult females (earlier breakup relates to poorer condition of the bears). Along the Alaskan Beaufort coast, surveys during the fall open water and early freeze-up period document an increased use of coastal habitats by polar bears. Polar bears were found primarily on barrier islands, with some use of the mainland observed. A greater proportion of females and young were observed than males. Bone piles remaining from whaling provide an alternate food source to seals and attract large congregations of bears. The change in use of coastal habitats is likely related to the continued contraction of seasonal ice cover. Since polar bears feed primarily on ring seals, the overall decrease in ice cover directly results in reduced feeding habitat and prey availability to the extent that changes in ice cover reduce the abundance of ring seals. Ultimately, the condition of bears entering the winter will likely diminish, affecting survival and reproduction, should these trends continue.

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Modeling Thaw Depth Over Permafrost for the Arctic Drainage Basin and the Comparison to Measurements at CALM Field Sites

Christop Oelke, University of Colorado; Tingjun Zhang; Mark Serreze; Richard Armstrong

A finite difference model for one-dimensional heat conduction with phase change is applied to investigate soil freezing and thawing processes over the Arctic drainage basin. Calculations are performed on the 25 km x 25 km resolution NSIDC EASE-Grid.

NCEP reanalyzed sigma-0.995 surface temperature with a topography correction, and SSM/I-derived weekly snow heights used as forcing parameters. The importance of using an annual cycle of snow density for different snow classes is emphasized. Soil bulk density and the percentages of silt/clay and sand/gravel are from the SoilData System of the International Geosphere Biosphere Programme. In addition, we parameterize a spatially variable peat layer and modify soil bulk density and thermal conductivity accordingly. Climatological soil moisture content is from the Permafrost/Water Balance Model (P/WBM) at the University of New Hampshire.

The model domain is divided into three layers with distinct thermal properties of frozen and thawed soil, respectively. Calculations are performed on 54 model nodes ranging from a thickness of 10 cm near the surface to 1 m at 15 m depth. Initial temperatures are chosen according to the grid cell's International Permafrost Association permafrost classification on EASE grid.

Active layer depths, simulated for the summers of 1999 and 2000, compare well to maximal thaw depths measured at about 60 Circumarctic Active Layer Monitoring Network (CALM) field sites. A remaining RMS-error between modeled and measured values is attributed mainly to scale discrepancies (100 m x 100 m vs. 25 km x 25 km) based on differences in the fields of air temperature, snow height, and soil bulk density. For the whole pan-Arctic land mass and the time period 1980 through 2001, this study shows the regionally highly variable active layer depth, frozen ground depth, lengths of freezing and thawing periods, and the day of year when the maxima are reached.

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Arctic Coastal Dynamics (ACD): Status Report

Volker Rachold, Alfred Wegener Institute for Polar and Marine Research; Jerry Brown

Coastal dynamics, directly reflecting complicated land-ocean interactions, play an important role in the balance of sediments, organic carbon, and nutrients in the arctic basin. Recent studies indicate that sediment input to the Arctic shelves resulting from erosion of ice-rich, permafrost-dominated coasts may be equal to or greater than input from river discharge. Thus, the understanding and quantification of coastal processes is critical for interpreting the geological history of the arctic shelves. The predictions of future behavior of these coasts in response to climatic and sea level changes is an important issue because most of the human activity that occurs at high latitudes concentrates on the arctic coastlines.

The overall objective of the Arctic Coastal Dynamics (ACD) program is to improve our understanding of circumarctic coastal dynamics as a function of environmental forcing, coastal geology and cryology, and morphodynamic behavior. In particular, the project aims to:

- establish the rates and magnitudes of erosion and accumulation of arctic coasts;
- develop a network of long-term monitoring sites including local community-based observational sites;
- identify and undertake focused research on critical processes;
- estimate the amount of sediments and organic carbon derived from coastal erosion;
- refine and apply an arctic coastal classification (includes ground-ice, permafrost, geology etc.) in digital form (GIS format);
- extract and use existing information on relevant environmental forcing parameters (e.g., wind speed, sea level, fetch, sea ice, etc.);
- produce a series of thematic and derived maps (e.g. coastal classification, ground-ice, sensitivity etc.);
- develop empirical models to assess the sensitivity of arctic coasts to environmental variability and human impacts.

As an initiative of the International Permafrost Association (IPA) the multidisciplinary, multinational forum ACD receives support for an annual workshop from the International Arctic Sciences Committee (IASC).

The third IASC-sponsored ACD workshop was held in Oslo, Norway, on December 2–5, 2002. Participants from Canada (3), Germany (3), Great Britain (1), the Netherlands (1), Norway (6), Russia (11), Switzerland (1), and the United States (2) attended. Of these five were young scientists supported by IASC. Two current INTAS projects provided support for six additional Russian participants. The objective of the workshop was to review the

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status of ACD according to the Science and Implementation Plan, with the main focus on the quantitative assessment of the sediment and organic carbon input to the Arctic Ocean through coastal erosion. During the first part of the workshop, 29 papers dealing with regional and/or circumarctic coastal dynamics were presented. Based on the material presented, three regional working groups and two circumarctic working groups were organized. The main task of the regional working groups was to continue previous efforts to segment and classify the coast for their sectors. The coastal segmentation and classification is the basis for the assessment of the sediment and organic carbon input through coastal erosion. Additionally, representative photographs of coastal sites for each sector were selected for inclusion in a coastal photo library. The circumarctic working groups focused on GIS development and extraction and presentation of environmental data, respectively.

Workshop accomplishments and extended abstracts of individual reports will appear in a special issue of *Reports on Polar and Marine Research*. The metadata for key sites, the photo library, and a specialized Russian bibliography are included on the IPA CAPS2 CD-ROM in preparation at the NSIDC for the eighth International Conference on Permafrost. Coordination is maintained with the U.S. Land-Shelf Interactions (LSI) science program and the IGBP Land-Ocean Interactions in the Coastal Zone (LOICZ) program. See our web site for more ACD programmatic details: www.awi-potsdam.de/www-pot/geo/acd.html.

Commander Islands as the Significant Point for Monitoring Some Dangerous Changes in Bering Ecosystem

Vladimir F. Sevostianov, Commander Islands and BC Nature Protection and Conservation Association

As you may be aware, the number of sea otters has dramatically declined during the last seven years in some parts of the Northern Pacific. At this time, we can foresee a truly catastrophical reduction in the population of sea otters near the Aleutian Islands. They seem to disappear for unknown reasons.

Almost the same situation is occurring with Steller sea lions and some other species that are at the top level of the feeding chain. For the time being, the growing concern is a very dangerous situation with the arctic fox (*Medniy* subspecies—the biggest native one in the world). It is hard to imagine that it may be completely destroyed by extensive epizootic lasting over the last 20 years. But we had the most dangerous signal in 2000, when five dead whales were found on the beaches of the Commander Islands. In 2001, a dead right whale was found on Bering Island. All these facts clearly display that something is drastically wrong with the natural functions in the whole ecosystem of the Bering Sea.

Two small islands, closing the Aleutian's chain on the east and Kamchatka on the west are the Bering and Medniy Islands. That's right, it's the Commander Islands Archipelago.

Actually, in the waters between Russia and the U.S. (Alaska and Aleutians) lies a sea so rich in wildlife and so varied in coastal and subsea habitats that it's considered one of the most biologically productive and diverse marine environments. Covering almost a million square miles of subarctic waters, the Bering Sea supports vast populations of fish and shellfish, birds from every continent and countless numbers of whales, porpoises, dolphins, walruses, sea lions, fur seals, sea otters, and seals. But only on the Commander Islands can we see the full picture of this diversity. The main reason is a unique combination of geological and hydrological factors around this small area, namely a large chain of active underwater volcanoes, which creates the most favorable conditions for phytoplankton and zooplankton to flourish, forming the base of living for other high range organisms in the ecosystem. The variety of phyto- and zooplankton is a huge contributing factor to the vast biodiversity of seaweeds near the coastline of the Commander Islands, making this one of the world's richest areas of seaweeds in terms of both species and biomass.

So, I can establish beyond doubt that for many natural, historical, economic, and other reasons the Commander Islands are an essential focal point for future field expedition work and ultimately for conservation projects in the unique ecosystem of the north Pacific.

Evidence gathered and projects originating there will be of vital importance for all countries: the U.S., Russia, Canada, Japan, and Korea among many others.

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SBI—Microzooplankton: Roles as Herbivores and as Food for Mesozooplankton

Evelyn B. Sherr, Oregon State University; Barry F. Sherr; Carin J. Ashjian; Robert Campbell

During the 2002 field year of the Shelf-Basin Interactions (SBI) project, we carried out dilution assay experiments to evaluate microzooplankton grazing rates and phytoplankton growth rates, and mesozooplankton grazing experiments to determine relative grazing of copepods on phytoplankton and on heterotrophic protists. Based on changes in chlorophyll-a content as a proxy for change in phytoplankton biomass, two out of six dilution experiments in the spring, and eight of twelve experiments in summer, showed significant rates of microzooplankton herbivory. Phytoplankton intrinsic growth rates varied from 0 to 0.4/day in spring and summer. We also independently analyzed change in phytoplankton stocks in a subset of the dilution experiments via flow cytometric enumeration of small and large phytoplankton size classes. The preliminary results indicated that for some experiments, over the three-day incubation period cell-specific fluorescence for smaller phytoplankton cells decreased, resulting in underestimation of phytoplankton growth rates based on chlorophyll. In at least one experiment in the spring, flow cytometry data showed significant grazing loss for large cells, presumably diatoms, but not for smaller cells. Preliminary flow cytometry and inverted microscopy counts made for a subset of the mesozooplankton grazing experiments showed that, in general, the mesozooplankton appeared to be consuming large phytoplankton cells and heterotrophic protists, but not small phytoplankton cells. Inspection of representative microscope slide preparations made during the two cruises has shown a diverse phytoplankton and protistan assemblage.

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Variations in White Spruce (*Picea Glauca*) Performance at and Below Treeline in Three Mountain Ranges Across the Boreal Zone in Alaska

Matthew Smith, University of Alaska Anchorage; Tumi Traustason; Bjartmar Sveinbjörnsson; Roger Ruess

Studies of white spruce growth and related characteristics were conducted above and below the forest limit, i.e., in the treeline zone and forest zones in the Brooks Range in northern Alaska, in the White Mountains in central Alaska, and in the Chugach Mountains in southcentral Alaska.

Branch extension growth was greatest in the Chugach Mountains and similar and much lower in the White Mountains and the Brooks Range. In the Chugach Mountains and to lesser extent in the White Mountains growth was lower at treeline than in the forest while the reverse was true for the Brooks Range.

Needle retention in the forest was much lower in the Chugach Mountains than in the other two mountain ranges, which were similar. Treeline needle retention was much lower than in the forest in the Chugach Mountains, somewhat lower in the White Mountains, and identical in the Brooks Range.

Needle concentrations of total nonstructural carbohydrates (TNC) did not vary between age classes or locations and thus needle TNC pool size was largely a function of needle mass which in turn was affected by needle retention. TNC pools were highest in the Chugach Mountains, where treeline trees had significantly lower pool sizes. The White Mountain trees in the forest had slightly larger TNC pools than treeline trees (not statistically significant) and in the Brooks Range, treeline trees had significantly larger TNC pools than did forest trees and were similar to the White Mountain tree TNC pool sizes.

We conclude that tree branch growth is strongly affected by the availability of stored carbohydrates in the needles, and growth is thus source limited.

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Evidence of Compensation in Weekly Production Patterns of a Dominant Arctic Sedge

Paddy Sullivan, Colorado State University; Jeffrey Welker; Jace Fahnestock

Terrestrial arctic systems support relatively few vascular plant species that differ in their effects on ecosystem processes and in their response to directional climate change. Consequently, recognizing when and how dominant species will respond is required as we build a mechanistic understanding of arctic systems in a changing climate. In this study, we experimentally warmed Alaskan tussock tundra and used minirhizotron technology, in conjunction with leaf measurements, to monitor weekly *Eriophorum vaginatum* production patterns throughout the 2001 and 2002 growing seasons.

Open-top chambers warmed daily meant soil surface temperatures differed by 0.94˚ C between mid-May and late August. However, in parallel with a general seasonal decline in photosynthetically active radiation, the magnitude of warming declined from approximately +2.0˚ C in May to +0.5˚ C in August. Warming advanced production peaks in each sequentially produced leaf cohort, accelerated rates of leaf production during the period of strongest warming, and led to significantly higher green leaf length per tiller on all sampling dates prior to July 1. However, warming did not affect above-ground primary productivity. Similarly, warming accelerated rates of root production during the period of maximum warming and led to significantly higher live standing root mass on one late season sampling campaign. These effects were manifest in weak evidence of an increase in below-ground primary productivity.

Under ambient conditions, while leaf production patterns were highly responsive to episodic deviations from generalized seasonal environmental trends, root production patterns were generally consistent with the trends. Conversely, under warmed conditions, leaf production patterns faithfully tracked general environmental trends, while root production patterns could not be predicted using detailed micro-meteorological data or general environmental trends. These results complement the observation of an inverse relationship between leaf and root production rates under ambient conditions that became a weak positive relationship under warmed conditions.

We propose, under ambient conditions, that *E. vaginatum* compensates for early season temperature constraints by responding, at the expense of root production, to favorable microclimatic episodes late in the growing season. The higher early-season leaf length observed with warming may enhance early-season carbon assimilation and permit more extensive below-ground production in a system where the soil carbon pool is approximately 90% root-derived.

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Alaska Treelines: Tree Damage and Growth Above and Below the White Spruce (*Picea Glauca*) Forest Limit in Three Alaskan Mountain Ranges

Tumi Traustason, University of Alaska Anchorage and University of Alaska Fairbanks; Matthew Smith; Bjartmar Sveinbjörnsson; Roger Ruess

In this study we evaluate physical damage of white spruce at treeline and in forest in three Alaska mountain ranges. Treeline trees in the coastal Chugach Mountains have the most extensive crown damage in addition to the highest number of stem brakes. The damage is strongly directional towards the prevailing wind direction, pointing to needle and branch tip loss from wind damage. Overall crown deformation is lower in the calmer White Maintains and the Brooks Range and is similar in treeline and forest zones. Average growth is lower in the interior where the damage was similar between forest and treeline. Treeline trees are shorter than forest trees in all three mountain ranges, but have similar height/basal ratio except in the Chugach Mountains, where treeline trees have a lower ratio. This is presumably brought about by repeated loss of the apical meristem and/or greater allocation to secondary rather than primary growth.

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Facilitating Scientific and Technical Research with the Former Soviet Union

Marianna V. Voevodskaya, Russian Academy of Sciences; David H. Lindeman; Shawn T. Wheeler

The U.S. Civilian Research and Development Foundation (CRDF) for the Independent States of the former Soviet Union is a private, nonprofit, grant-making organization created in 1995 by the U.S. government (National Science Foundation).

The CRDF promotes scientific and technical collaboration between the U.S. and the countries of the former Soviet Union (FSU). The foundation's goals are to support scientific cooperation in basic and applied research, advance the transition of former weapons scientists to civilian activities, and encourage research and development cooperation between U.S. industry and FSU science.

Three CRDF programs provide support to U.S. scientists engaged in collaborative arctic and geosciences-related research in the FSU. First, under a contract with the National Science Foundation, CRDF provides an office and personnel in Moscow to assist Office of Polar Programs (OPP) and Geosciences Directorate (GEO) grantees and collaborators with programmatic activities, including identifying and communicating with individual and institutional partners, navigating government agencies, facilitating travel and visas, and providing on-site office support to visiting U.S. travelers. Second, the CRDF Cooperative Grants Program allows U.S.-FSU collaborators in arctic sciences and geosciences to apply for two-year research and development grants averaging approximately $80,000. Third, the CRDF Grant Assistance Program (GAP) enables U.S. government agencies, universities, and other organizations to use CRDF's financial and administrative infrastructure to transfer payments, purchase and deliver equipment and supplies, and carry out other project management services to collaborators in Russia and elsewhere in the FSU.

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The Arctic Research Consortium of the United States

Wendy K. Warnick, Arctic Research Consortium of the U.S.

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. ARCUS promotes arctic research by improving communication among the arctic research community, by organizing workshops, and by publishing scientific research plans. 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.

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Coupling of Carbon and Water Cycles in a Cold, Dry Ecosystem: Integrative Physical, Chemical, and Biological Processes and Their Controls on CO_2 Exchange

Jeffrey Welker, Colorado State University; Ron Sletten; Bernard Hallet; Josh Schimel; Jace Fahnestock

We propose to quantify the coupling of the carbon and water cycles and the interacting physical, chemical, and biological (PCB) processes that control C exchange between cold, dry terrestrial ecosystems and the atmosphere. We are focusing on cold, dry ecosystems because: (1) understanding of carbon and water interrelationships and net C exchange is only rudimentary for this extreme environment, making it impossible to predict the vulnerability of this ecosystem to the expected anthropogenically exacerbated warming; (2) these tundra systems are sufficiently simple allowing the quantification of all key components and the development of a system behavior conceptual model; and (3) the vital role of unfrozen water in this cold, dry environment underlies the importance of thresholds (e.g., 0° C is a distinct threshold for water availability) and highly nonlinear interactions between PCB processes. Our discoveries will contribute to the understanding and the quantification of global carbon and water cycling, as well as to the understanding of extreme habitats on Earth and possibly on other cold, dry planetary bodies. We are committed to the educational facets and broader implications of our research, and thus we will be offering a field course of our main study that will include U.S. and international students.

We will focus on three levels of biocomplexity. First, we will quantify the seasonal changes in the coupling of C and water at the leaf and ecosystem scales using in situ isotopic ($\delta^{13}C$ and $\delta^{18}O$) approaches. Second, we will evaluate and quantify how the seasonal patterns of physical (soil temperature and soil water), chemical (soil solution and weathering) and biological (microbial and vegetation) processes interact to regulate the dynamics of net C exchange. Third, we will use a biogeochemical model (TEM) to investigate net CO_2 exchange and the complex PCB interactions under current climates and a range of likely future climate change scenarios and integrate these with arctic and global carbon budget estimates. Our program will be based on articulating the complexities of carbon and water coupling under

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current conditions, but also on the responses of the biological, chemical, and physical processes and interactions in response to field manipulations of winter and summer precipitation (both increases and decreases) and warming (+2° and +4°C). This experimental approach will be the means by which we can evaluate the interactions and nonlinearities of carbon and water coupling, net carbon exchange, and PCB processes.

We anticipate that our study will result in a new insight into the adaptations of plant and microbial life in cold, dry ecosystems and the coupled nature of carbon and water in an ecosystem that is very different from more temperate ecosystems where most of our current understanding of these processes has originated. Furthermore, we will gain a more precise understanding of the extent to which this ecosystem responds to future climate change and the consequences of these changes for arctic and global C budgets. We are confident that our proposed study will be most productive because: (1) our research team has a history of large-scale, field collaborative studies in the high and low Arctic; (2) we have assembled an interdisciplinary, international team with much experience and a common interest in extreme habitats limited by water and temperature; (3) we have specific student participation opportunities, field course and project publication plans that will ensure timely synthesis, integration, and dissemination of our project's findings to the scientific community; and (4) our project will contribute to several national and international efforts addressing carbon and water cycling, e.g., FLUXNET, BASIN (Biosphere-Atmosphere Stable Isotope Network) and the Global Network for Isotopes in Precipitation (GNIP).

Arctic Forum Program

Monday afternoon, 28 April 2003

1:00 p.m. Welcome and Introductions — Arctic Forum Co-Chairs: Igor Krupnik, F. Stuart Chapin

Responding to Global Change: Resilience and Vulnerability in the Arctic Systems
Session chair: F. Stuart Chapin

1:10 p.m. The U.S. Climate Change Science Program and its Relevance to the Arctic
James R. Mahoney
Director of the United States Climate Change Science Program
Assistant Secretary of Commerce for Oceans and Atmosphere
and Deputy NOAA Administrator

1:50 p.m. Building Resilience in the Arctic: Cross-scale Institutions and Traditional Environmental Knowledge
Fikret Berkes
Natural Resources Institute
University of Manitoba

2:20 p.m. Rapid shifts in the Arctic system: Implications for resilience of physical, natural and human components
John Walsh
International Arctic Research Center
University of Alaska/Fairbanks

2:50 p.m. BREAK

3:15 p.m. We Are Sugpiaq: Archaeology, Environment, and Oral Traditions of the Outer Kenai Coast, Alaska
Aron Crowell
Arctic Studies Center
Smithsonian Institution

3:45 p.m. "The Earth is Faster Now" or Have We Seen These Warm Weathers Before? *Arctic People Experiencing Rapid Climate Change*
Igor Krupnik
Arctic Studies Center
Smithsonian Institution

The ARCUS Award For Arctic Research Excellence

4:15 p.m. Introduction — Session Chair: Timothy Boyd, Oregon State University

4:30 p.m. Interdisciplinary Research: *Interactions Between Carbon and Nitrogen Mineralization and Soil Organic Matter Chemistry in Arctic Tundra Soils*
Michael Weintraub
Department of Ecology, Evolution, and Marine Biology
University of California Santa Barbara

4:50 p.m. Social Sciences: *Women's Participation in Self Government Negotiations in the Northwest Territories, Canada*
Stephanie Irlbacher Fox
Scott Polar Research Institute
University of Cambridge

5:10 p.m. Physical Sciences: *Impact of an Extreme Melt Event on the Hydrology and Runoff of a High Arctic Glacier*
Sarah Boon
Department of Earth and Atmospheric Sciences
University of Alberta

5:30 p.m. Life Sciences: *Geographic Distribution and Seasonal Patterns of Larval Shedding of the Muscle-Dwelling Nematode* Parelaphostrongylus odocoilei *in Thinhorn Sheep from Northern North America*
Emily Jenkins
Department of Veterinary Microbiology
University of Saskatchewan

5:50 p.m. Comments on the Award for Arctic Research Excellence — Timothy Boyd

6:00 p.m. Poster Session: Presenting Arctic Science
(Hosted Bar and Reception begin)

ARCUS Annual Reception and Banquet
Reception: 6:00 p.m.—Salon A
Banquet: 7:30 p.m.—Potomac Room

Award Ceremony
ARCUS Award for Arctic Research Excellence

Special Presentation
Trond Woxen
Henrik Ibsen and the Environment

Tuesday, 29 April 2003

8:00 a.m. Continental Breakfast

8:30 a.m. Welcome and Introductions — Arctic Forum Co-Chairs: Igor Krupnik, F. Stuart Chapin

Responding to Global Change: Resilience and Vulnerability in the Arctic Systems
Session chair: Igor Krupnik

8:35 a.m. The Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope
Gordon Orians
Department of Zoology
University of Washington

9:15 a.m. Resilience and Change in Arctic Terrestrial Ecosystems: A Key Role in the Arctic System
F. Stuart Chapin
Institute of Arctic Biology
University of Alaska Fairbanks

9:45 a.m. Suffering and Solace: Vulnerability and Resilience to Environmental Change in Northern Iceland c. AD 1700–1900
Astrid Ogilvie
Institute of Arctic and Alpine Research
University of Colorado

10: 15 a.m. BREAK

10:45 a.m. ***How will the challenges posed by global changes be met by society?***
Panel Discussion Moderator: Daniel Mann, University of Alaska Fairbanks

- Taqulik Hepa, Department Wildlife Management, Alaska North Slope Borough
- Charles Johnson, Alaska Nanuuq Commission
- Mike Kunz, Northern Field Office, Bureau of Land Management, U.S. Department of the Interior
- Roger Simmons, Consul General of Canada

12:15 p.m. LUNCH

2:00 p.m. *Sila Alangotok: Inuit Observations on Climate Change*
(This 14-minute video documents the changes being witnessed by the Inuvialuit of Sachs Harbour, Canada, who have lived on the land and have learned its patterns for generations.)

2:15 p.m. We Will Change If We Can, If We Have To: What *Inuit Qaujimajatuqangit* and Western Scientific Knowledge Tell us About Resiliency and Vulnerability of a People Living with Climate Change and Caribou
Natasha Thorpe
Tuktu and Nogak Project, Canada

2:45 p.m. Working Together: Cooperation in the Production and Distribution of Wild Food in Alaska
James Magdanz
Division of Subsistence
Alaska Department of Fish and Game

3:15 p.m. Alaska Native Subsistence Life Ways Rely on Healthy Ocean Ecosystems
George Owletuck
Anchorage, Alaska

3:45 p.m. BREAK

4:00 p.m. Microorganisms in Arctic Sea Ice Environments and Their Resilience and Vulnerability to Climate Variations and Change
Hajo Eicken
Geophysical Institute
University of Alaska Fairbanks

4:30 p.m. Simulation Modeling and Local Communities: Lessons Learned from Assessing Resilience in a Cross-Cultural Setting
Gary Kofinas
Institute of Arctic Biology
University of Alaska Fairbanks

5:00 p.m. Synthesis and Summary of Issues
Fikret Berkes, Discussant
Mark Serreze, Discussant

5:30 p.m. Adjournment

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