Arctic Forum 2004

Abstracts

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Cover Photos:
Top: Arctic sea ice seen from USCGC *Healy* in Summer 2003.
Photo by James Rodgers.

Middle: Heike Merkel from the Geophysical Institute in Fairbanks, Alaska and Kazu Tateyama from the Kitami Institute of Technology in Japan lowering a CDT profiler (conductivity- depth- temperature) through the ice into the underlying water column during the Spring 2004 SBI project cruise in the Arctic Ocean on the USCGC *Healy*.
Photo by Steve Roberts, UCAR/JOSS.

Bottom: Polar bear seen from USCGC *Healy* in Summer 2003.
Photo by James Rodgers.

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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 May 13–14, 2004, 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' 46 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 theme for 2004 Arctic Forum was "Recent Decrease of the Arctic Sea Ice: Its Causes, Consequences, and Historical Perspective." Warren Matumeak, Native elder and Mark Serreze, University of Colorado gave the keynote addresses.

As executive director of ARCUS, I appreciate the efforts of the many researchers who shared their results with the community through the Arctic Forum. We thank Wieslaw Maslowski and Mark C. Serreze for chairing the Forum and the National Science Foundation for supporting this opportunity. Birte Horn-Hanssen of ARCUS was the managing editor for this abstract volume and designed the layout. Tina Buxbaum and Sarah Behr of ARCUS also edited this publication. We invite you to join us at the Arctic Forum in spring 2005.

Wendy K. Warnick
Executive Director

Introduction to the Session
Recent Decrease of the Arctic Sea Ice: Its Causes, Consequences, and Historical Perspective

Wieslaw Maslowski, Naval Postgraduate School; Mark C. Serreze, University of Colorado (Arctic Forum Co-Chairs)

The Arctic region is highly variable with major large-scale regime shifts taking place at time scales ranging from several years to decades. The perennial sea ice at the surface buffers some of this variability but it is also highly sensitive to relatively small imbalances in external atmospheric and oceanic forcing. As evidenced from in-situ data sources, satellite remote sensing, and submarine sonar records, the last decade has experienced strong warming and decreases in sea ice extent and thickness. A record minimum in ice extent for September 2002 (referenced to the period 1979 –2002) was nearly matched in September 2003 and 2004. The sea ice changes appear to have been attended by increased southward export of freshwater into the regions of deep-water formation in the sub-polar North Atlantic.

Some of these changes have been successfully modeled. However, an in-depth understanding of how changes in the sea ice regime are coupled to changes in other arctic system components and global climate is still missing. Regardless of the causes, there are potentially important societal impacts. The Northeast Sea Route is becoming open for shipping on a seasonal basis. Marine ecosystems of the arctic marginal seas have been observed to respond to the warming and retreat of the sea ice cover. These ecological adaptations impact feeding habits and migratory routes of arctic marine mammals and native/local communities that depend on them for food.

The Arctic Forum of 2004 focused on the recent changes in the arctic sea ice cover. The forum reviewed current knowledge of its causes and consequences in the context of past, present, and projected future climate states. Leading experts in the arctic research community discussed aspects of the atmosphere, physical oceanography, marine ecosystems, coastal transformation, and societal impacts as well as past and present perspectives of arctic native communities and of management and government agencies.

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Presentation Abstracts

Changing Marine Access in the Arctic

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

There is substantial observational evidence that the arctic sea ice cover is undergoing profound changes including larger areas of open water during the summer, a diminished presence of multiyear sea ice, and a thinning of the ice cover in the central Arctic Ocean. Any combination of these changes can have significant implications for arctic marine transportation and offshore development. There is also ample operational experience that icebreakers can operate effectively in the central Arctic Ocean: from 1977–2003, 44 ships have made transits to the North Pole and five voyages have been conducted across the Arctic Ocean. Russian icebreakers have maintained year-round navigation to Dudinka on the Yenisey River since 1978. Icebreaking cargo carriers have also been successfully operated in the waters of the Canadian Archipelago during the last decades of the 20th century.

As part of the Arctic Climate Impact Assessment (ACIA), projected changes of arctic sea ice coverage throughout the 21st century have been evaluated in the context of potential enhancements for marine access. The evaluation is based on sea ice simulations by five different Global Climate Models (GCMs), each forced by increasing greenhouse gas concentrations. Projected ice conditions for 2020, 2050, and 2080 indicate extensive open water areas around the perimeter of the Arctic Ocean. Greenhouse gas warming reduces arctic sea ice coverage in all the model simulations, especially during the summer. A case study for Russia's Northern Sea Route illustrates how the GCM simulations can be used to project a plausible lengthening of the navigation season along the Russian Arctic. Despite the coarse resolution of the sea ice simulations used in the ACIA, the information gained from this assessment represents a first-order, strategic attempt at planning for future arctic marine transportation.

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Déjà Vu: Paleoenvironmental Look at Sea Ice Extent During Earlier Warm Periods

Julie Brigham-Grette, University of Massachusetts; Zachary Lundeen

The Arctic is currently experiencing environmental change at rates unprecedented in historical times. Yet estimates of past rates of change, especially sea ice extent and other proxies, can provide us with the necessary long-term perspective on recent changes and help us to appreciate their magnitude. Past change during interglacials should give us an idea of how rapid climate change may operate in the future.

Interglacial periods, like today, flood the Bering Strait, and reinvigorate the exchange of water masses between the North Pacific, Arctic Ocean, and North Atlantic. Since first submergence about 5–5.5 million years ago, this marine gateway has repeatedly experienced the penetration of warmer water masses from as far south as northern Japan to as far north as the Beaufort Sea. Permanent sea ice likely became established about 2.6 My BP. During the last interglacial (MIS 5e, ~125 ka BP), the winter sea ice limit was as much as 800 km further north than now, and summer sea ice was likely thin and may have been periodically absent (Brigham-Grette and Hopkins, 1995; Jakobsson et al., 2003). Tree line across much of Alaska and nearby Chukotka was hundreds of kilometers further north, notably eliminating tundra across Chukotka to the Arctic Ocean (Lozhkin and Anderson, 1995). Scenarios of a warmer arctic in Stage 5e are consistent with the partial elimination of the Greenland Ice Sheet (Cuffey and Marshall, 2000).

A number of proxies including the distribution of fossil whale bones and drift wood in the western Canadian Arctic indicate that summer sea ice was much less than present during the early Holocene when Northern Hemisphere insolation was higher than today. Sediment cores from the Chukchi Sea dating back to about 15 ka BP suggest that a major increase in shelf productivity at 8500 years BP may reflect a major shift in sea ice extent to near “normal” or modern conditions. Alternatively, a return to high productivity at this time may simply reflect establishment of the northward flow of nutrient rich waters from the deep Bering Sea. Studies of sediment cores (*Healy* cruise 2002) from the Bering and Chukchi seas are ongoing to establish high-resolution records of past sea ice extent since the last glacial maximum, about 20 ka BP.

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Impact of Climate Change on Alaska Native Communities

Patricia L. Cochran, Alaska Native Science Commission

The circumpolar Arctic—the northern regions of the United States (Alaska), Russia, Sweden, Norway, Iceland, Finland, Greenland (Denmark), and Canada—is unique, fragile, and vulnerable. In recent years, this region has been characterized as an early warning indicator of global environmental health, relating particularly to climate change and the long-range transport of certain persistent organic pollutants (POPs) and heavy metals such as mercury. The Arctic Council has recently completed a four-year assessment of climate change in the Arctic—the Arctic Climate Impact Assessment. Some key findings include UV-B impacts; sea level rise; sea ice reductions; Northwest and Northeast Passage openings; permafrost disappearance; climate regime shifts; movement of tree line; significant reductions in the number and distribution of seals, walrus, and polar bears; impacts on caribou population and health; and the introduction of new diseases and parasites. These findings have a significant impact on the region's inhabitants, particularly its indigenous peoples.

The purpose of this session is to present the concerns of climate change from an indigenous perspective and begin a dialogue to structure a collaborative effort among indigenous peoples of the Arctic to proactively address the issues of climate change. It is vital to strengthen the voice of the region's inhabitants in key policy debates—since collectively, arctic indigenous peoples are disproportionately burdened by these developments yet underrepresented at national and international forums where decisions are made.

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Carbon and Nitrogen Cycling and the Changing Arctic

Louis A. Codispoti, University of Maryland

The Arctic Ocean and its adjacent and marginal seas represent a region where signals of global warming can be amplified. Carbon and nitrogen cycling ultimately depend on primary production, and observed and projected changes, such as decreased ice cover, can impact the Arctic Ocean primary production regime. The suite of direct determinations of marine primary production in the Arctic is small and biased towards post-bloom conditions because the navigation season lags early phytoplankton blooms. Additional difficulties arise from the heterogeneity of this system. Light and nutrient regimes differ considerably from region to region, and there tends to be a vertically distributed sequence of blooms that starts with the ice, progresses into the surface layer, and then migrates into the shallow nutriclines that typify this region.

Interestingly, several studies suggest that estimates based on seasonal changes in dissolved oxygen, carbon dioxide, and nutrients considerably exceed estimates based on direct determinations of carbon and nitrogen uptake by phytoplankton. This situation arises because chemical signals can accumulate and integrate the effects of new production over seasonal time scales and can thus "catch" blooms missed by direct determinations.

Under a warming scenario, the availability of light to phytoplankton in the Arctic Ocean will tend to increase due to decreased ice cover and earlier melt of the ice snow cover, but unless there are changes in stratification, new production in the upper ~25m is not likely to increase. This is because Arctic Ocean waters are strongly stratified.

This stratification and the decadal residence time of the Arctic Ocean surface water causes a net fixed nitrogen loss due to sinking biogenic material and produces a surface layer in which new production is limited by nitrate and not by light. Modest increases in primary production in the open Arctic Ocean are possible, however, because of increased insolation of the nutricline. Plausible changes in stratification might also alter the vertical nitrate flux with implications for primary production. With warming, coastal waters may experience increased turbidity arising from increases in runoff, resuspension of shallow sediments, and coastal erosion. This would decrease light penetration thereby countering the influence of decreased ice cover.

Primary production in the Arctic is a complex, poorly-understood system. In the face of changes that we cannot yet accurately predict, it would be wise to manage living resources with an excess of caution!

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Observations of a Decreasing Arctic Sea Ice Cover from Satellites

Josefino C. Comiso, NASA Goddard Space Flight Center

The extent and area of the sea ice cover in the entire Northern Hemisphere has been observed to be decreasing at 2% and 3% per decade, respectively, using satellite passive microwave data from 1979 to 2003. The changes are negative in all regions including the peripheral seas, except at the Bering Sea where the extent of the ice has been increasing at 8% per decade. The most remarkable change, however, is in the perennial ice area, which has been declining at a relatively rapid rate of -9 ± 2% per decade during approximately the same period.

The average area of 4.8 x 106 km^2 for perennial ice cover in the last five years is significantly less than the 5.8 x 106 km^2 average of the first five years of data in the series with the least extensive perennial ice cover occurring in 2002. The perennial ice cover consists mainly of the thick multiyear ice floes and a sustained decline could have profound effects on the arctic climate system. The correlation of the decrease in the perennial ice cover with surface ice temperature is relatively strong with the correlation coefficient being 0.8. A lengthening of the melt season by an average of about two days per decade over sea ice covered regions is also observed suggesting that the decline in area and volume of the perennial ice cover is, in part, caused by the warming. Results of regression analysis on a season-by-season basis show that the trend is most positive in spring and autumn, only moderate in summer because of the upper limit in the ice temperature, and negligible in the winter. These results are consistent with the seasonal trends in the sea ice cover.

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The Arctic in Global Climate Models and Projections of Future Change

Gregory Flato, Meteorological Service of Canada

Positive climate feedbacks at high latitudes amplify the warming projected for the Arctic as greenhouse gas concentrations increase. These same positive feedbacks, involving snow and ice, also amplify errors and uncertainties in climate models. The ability of contemporary climate models to reproduce arctic climate and its variability will be reviewed drawing heavily on results from the Canadian Centre for Climate Modelling and Analysis (CCCMA). Comparisons with observations indicate aspects of the simulated climate that are well represented and aspects that remain problematic. Projected future changes in arctic climate from several global models will be presented and compared to provide an illustration of uncertainty in future climate and to indicate areas in which model improvements might be valuable.

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Human Dimensions Research: Rationale and Implementation

Bruce Forbes, University of Lapland

Global environmental change presents great challenges to circumpolar countries. It comprises elements of both indirect climate-driven and more direct anthropogenic or human-induced change. Threats to the sustainability of arctic social and ecological systems include rapid changes in:

- climate: snow cover, vegetation, permafrost, fire, insect outbreaks, etc
- land-use: such as mineral and petroleum extraction, cutting of timberline forests (e.g. North America, Eurasian Arctic), and large herbivore management (e.g. Fennoscandia, Russia, Alaska and Canada)
- socio-economic/legal systems: employment in changing industries, health/demographic shifts, land-tenure/property rights

An inability or unwillingness to mitigate many of the above changes obliges us to examine the adaptive resilience that often characterizes human-environment relations in the Arctic. Relative to climate change, land-use and other socio-economic drivers are sometimes under appreciated as critical components of global change. In truth, however, one cannot study e.g. treeline dynamics or shrub abundance in many parts of Fennoscandia or Russia and arguably North America without accounting for human activity and herbivores. Management of any living resource in a time of rapid change is, therefore, about people as much as it is about individual species, populations, or plant or animal communities, if not more so.

Participatory approaches to research and management are relatively new in Europe and Russia compared to North America, where co-management has been around for decades. Local people can have detailed ecological knowledge and need to have a meaningful role in regional resource management as well as in policy-relevant research programs. Sustainable development under global change requires building adaptive capacity to enhance ecological as well as socio-economic resilience. Human dimensions research has an important role to play in addressing all of these issues.

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The Role of Hydrology in Arctic Climate Change

Larry D. Hinzman, University of Alaska Fairbanks

The broadest impacts to the terrestrial arctic regions will result through consequent effects of changing permafrost structure and extent. As the climate differentially warms in summer and winter, the permafrost will become warmer, the active layer (the layer of soil above the permafrost that annually experiences freeze and thaw) will become thicker, the lower boundary of permafrost will become shallower, and permafrost extent will decrease in area. These simple structural changes will affect every aspect of the surface water and energy balances.

As the active layer thickens, there is greater storage capacity for soil moisture, and greater lags and decays are introduced into the hydrologic response times to precipitation. When the frozen ground is very close to the surface, the stream and river discharge peaks are higher, and the base flow is lower. As the active layer becomes thicker, the moisture storage capacity becomes greater, and the lag time of runoff increases. As permafrost becomes thinner, there can be more connections between surface and subsurface water. As permafrost extent decreases, there is more infiltration to groundwater. This has significant impacts on large and small scales. The timing of stream runoff will change, reducing the percentage of continental runoff released during the summer and increasing the proportion of winter runoff. This is already becoming evident in Siberian rivers. As permafrost becomes thinner and is reduced in spatial extent, the proportions of groundwater in stream runoff will increase as the proportion of surface runoff decreases, increasing river alkalinity and electrical conductivity. This could impact mixing of fresh and saline waters, formation of the halocline, and seawater chemistry. As the air temperatures become higher and the active layer becomes thicker, we have reason to believe the surface soils will become drier. As the surface soils dry, the feedbacks to local and regional climate will change dramatically, with particular emphasis upon sensible and latent heat flux. This may impact recycling of precipitation, capabilities to predict weather, and may indeed increase variability of many processes and variables, including convective storms.

Accelerated degradation of glaciers throughout the world is well documented. Regional rivers have demonstrated responses to glacier melt through gradual but consistent increases in runoff in watersheds with significant glacial coverage, while similar rivers with no significant glacier coverage are demonstrating reduced runoff trends as evaporative losses increase. Increased runoff from degrading glaciers cannot continue indefinitely, and regional planning must consider markedly different hydrological conditions in the future.

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Security and International Relations

Robert Huebert, University of Calgary

Since the end of the cold war, little attention has been given to the issue of security in the Arctic. A combination of factors including a low population, limited political influence, and the high cost of operating in a remote location has meant that security concerns have been minimal in the past 15 years. This is about to change.

As the Arctic warms, accessing once remote locations will become easier which will make the strategic location of the Arctic important again. With decreasing sea ice, the viability of the Northwest Passage and Northern Sea Route will increase. As shipping in the two waterways increase, the control and regulation of the waterways will come into question. Also, the vast resources once locked away due to prohibitive cost of accessing and processing them in the north will become more readily accessible as the climate warms.

There are two facets of security in the north. First, there is environmental security which deals with the impact of climate change and trans-boundary pollutants. Second, there are traditional security issues caused by conflicting continental shelf claims and disputes over the status of shipping lanes. There has been great cooperation between northern nations in areas of environmental security with the creation of the Arctic Council and other organizations. Steps have been taken to ensure northern aboriginal peoples are involved in the decision making process. But as the Arctic opens up, traditional security and national interests are already beginning to have a detrimental impact on international cooperative efforts.

The Arctic is a vast region that is only just beginning to be noticed again. Traditional and environmental security concerns in the near future will determine the level of international cooperation and conflict into the future.

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Panel Discussion: Partnerships and Collaborations in Arctic Research

David Klein, University of Alaska Fairbanks; Julie Brigham-Grette; Patricia Cochran; Gregory Flato; Bruce Forbes; and Ian Stirling

David Klein, University of Alaska Fairbanks, moderated a panel discussion on: *Partnership and Collaborations in Arctic Research*. The purpose of this panel discussion was to explore community adaptation to climate change along with community and researcher collaboration and outreach efforts. Panelist responded to the following questions:

1. What are the issues and research questions? Panelists discussed community outreach, research participation, and ways to improve information transfer and thus aid adaptation to the changing environment. The seven regional research plans being developed in Alaska were discussed as an example of steps being taken to integrate communities into research planning.

2. What are the consequences for arctic communities? Panelists discussed what adaptations to climate driven change are working for arctic communities and the role value systems and culture play in this adaptation. The whaling culture was used as an example of an adapting culture.

3. Can we address the questions through partnerships and collaborations? Panelists discussed the need to improve information flow between scientists and the general public. How do you get the general public to connect climate change to weather and understand the ramifications? We need to continue gathering data, however data needs to be presented to the public in a manner they can understand.

4. Who are the partners? Panelists discussed how collaborative efforts between researchers, media, lawmakers, educators, students, and communities play a pivotal role in dissemination of knowledge and information and how this partnership can be improved. Panelists reiterated that involvement of educators and children is the key to community involvement, understanding, and survival in this changing world.

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The Rate and Causes of Arctic Sea Ice Melt: Modeling Perspective

Wieslaw Maslowski, Naval Postgraduate School

The Arctic Ocean has been warming during the 1990s and 2000s, and the warming appears to have accelerated during the last several years as observed by satellites and in situ measurements and as simulated by models. The main manifestation of this trend has been a decrease of the ice cover, which through positive ice-albedo feedback may lead to further reductions and subsequent increases of freshwater export into the active convection regions in the North Atlantic. Such changes have major consequences to the global ocean thermohaline circulation as well as to long term global ocean heat and salt transports and climate.

To investigate the variability of sea ice cover and freshwater fluxes into the North Atlantic, we use a high-resolution coupled ice-ocean model of the Pan-Arctic region forced with realistic atmospheric data for 1979–2002. Model results suggest that the decrease of sea ice cover might be, in part, a result of thermodynamic interactions at the ice-ocean interface and, in particular, the upward heat fluxes, which are affected by the increased advection of warm Atlantic and summer Pacific waters into the central Arctic Ocean, during the 1990s. More importantly, the rate of decrease of sea ice thickness and volume appears to be larger than that of ice extent/concentration as modeled and observed from satellite data. The decrease of the total sea ice volume and the subsequent increase of freshwater content determined by the air-sea-ice interactions in the Arctic Ocean translate into the increased total freshwater export into the North Atlantic. This warming trend, if continued, will not only significantly affect global climate but will also change the strategic/economic importance of the Arctic Ocean through its use for commercial shipping routes and increased exploration of natural resources.

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Local Observations of Recent Change

Warren Matumeak, Native Elder

As an Iñupiaq elder from the town of Barrow, Alaska, and originally the Land Management Administrator for the North Slope Borough, I went on to become planning director and, finally, Wildlife Department Director. Having lived the Iñupiaq subsistence life, which includes reindeer herding and whaling, I have intimate first hand experience with nature and the changes occurring in the Arctic.

I see climate changes occurring near my home in Barrow every day. The changes can be seen in the decrease of multiyear sea ice, in the breakup of the river which occurs earlier and earlier each year, and in the loss of clams and shellfish due to increased seagull predation. These changes, I and other indigenous people see, can be perceived as both positive and negative. The Iñupiaq welcome the warmer temperatures but do not appreciate the lack of multiyear pack ice and the increased difficulty of whaling that these warm temperatures bring. The subsistence way of life has had to adapt to the environment. The world is changing and I and other indigenous people are baring witness.

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Weekly to Interannual Variations in the Sea Ice Draft Distribution at the North Pole Environmental Observatory

Richard E. Moritz, University of Washington

A two-year time series of sea ice draft D(t) was estimated from measurements made by Upward Looking Sonars (ULS) from 10 April 2001 to 21 April 2003. The moorings were located at the North Pole Environmental Observatory (NPEO: 89.56 N, 66.65 E in year 1; 89.45 N, 53.63 E in year 2). Sample statistics and Probability Density Distributions (PDFs) of D(t) have been estimated by grouping the data in non-overlapping, two-week intervals with probability weighting proportional to the ice speed recorded simultaneously by an Acoustic Doppler Current Profiler (ADCP).

In the first year, the sample mean draft varied from 3.7 meters in early April to 2.3 meters in late August, with an overall annual mean of 3.0 meters. The sample mean draft estimated for 15 September 2001 was 2.3 meters, a value near the middle of the seasonally adjusted estimates derived from submarine sonar profiles near the North Pole in the 1990s (Rothrock et al.,1999). The modal draft in year 1 lags behind the sample mean, with extrema of 2.3 meters in late June 2001 and 1.6 meters in early January 2002.

The open water fraction (OWF), estimated by counting ice drafts smaller than .05 meters, exceeded 1% from mid-June to early October and for a brief period in late December. The maximum OWF of 13% occurred in July 2001. The mean ice draft was larger throughout most of the second year, especially in summer. The sample mean ice draft for 15 September 2002 was 3.2 meters, i.e. 90 cm greater than in the preceding year, and just outside the envelope of the Rothrock values for the 1990s.

Analysis of the ice draft time series, monthly mean maps of multiyear ice concentration estimated from SSM/I data, and monthly mean anomaly maps of sea level pressure suggests that ice advection played a major role in these interannual differences.

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The Role of Coastal Processes in the Arctic System

Volker Rachold, Alfred Wegener Institute

The coastal zone is the interface through which land-ocean exchanges in the Arctic are mediated and it is a focal area for human activity that occurs at high latitudes. Arctic coasts are highly variable, and their dynamics are a function of environmental forces and coastal geology, geocryology, and morphodynamic behavior. Global and regional climate changes will significantly affect physical processes, biodiversity, and socio-economic development in the arctic coastal areas.

Changes in the arctic coastal zone are likely to invoke feedbacks on the Arctic and the global system. The arctic coastal region is the transition zone between onshore and offshore permafrost, which, if degraded, will likely result in the release of permafrost-bonded greenhouse gases (GHG) from the coastal zone. In addition, the ground-ice-rich, permafrost-dominated coastlines are rapidly eroded and the resulting coastal sediment, organic carbon, and nutrient fluxes play an important role in the material budget of the Arctic Ocean.

Along with the potential for climate warming, arctic coastal marine environments are facing increasing levels of human impacts. With these impacts, there is a growing imperative for a formal scientific assessment of biotic structure, composition, and function for the circumarctic coastal zone. These multi-scale metrics are the components of biodiversity, as the term is used in the scientific literature.

In this sense, the quantification of arctic coastal permafrost and biodiversity is not only highly desirable for the arctic region and its largely coastal inhabitants, but there is a growing awareness that such measures can provide vital information for early warning and improved understanding of related global impacts. This presentation presents an overview of activities and results of current projects addressing these issues on a circumarctic scale.

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Variations in the Age of Arctic Sea Ice and Summer Sea Ice Extent

Ignatius G. Rigor, University of Washington; John M. Wallace

Three of the past six summers have exhibited record low sea ice extent on the Arctic Ocean. Using sea ice drift data from the International Arctic Buoy Programme and sea ice concentration data from satellite microwave data (NASA Bootstrap Algorithm) we show that these minima may have been dynamically induced by changes in the surface winds. We show that high-index Arctic Oscillation (AO) conditions decrease the areal extent of old, thick ice from 80% of the Arctic to 30% and recirculate younger, thinner ice anomalies back to the Alaskan coast more quickly, decreasing the time that new ice has to ridge and thicken before returning for another melt season.

During the 2002 and 2003 summers, this anomalously younger, thinner ice was advected into Alaskan coastal waters where extensive melting was observed, even though temperatures were locally colder than normal. We hypothesize that the recent minima in arctic sea ice extent may be interpreted as a delayed response to the 1989–95 high-index AO event. The age of sea ice explains more that 50% of the variance in summer sea ice extent.

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Background on Sea Ice and Arctic Climate

Mark C. Serreze, University of Colorado

Satellite observations indicate that since 1979 arctic sea ice extent has declined at a rate of approximately 3% per decade. This is primarily due to large ice losses in late summer and early autumn. There is also evidence, albeit less clear, that the ice cover is thinning. Most climate models point to continued ice losses through the 21st century as the climate warms. Are we seeing one of the early signs of greenhouse warming? We know that there have been changes in the atmospheric circulation characterized by primarily positive modes of the North Atlantic Oscillation (NAO)/Arctic Oscillation (AO). The rise in the NAO/AO accounts for part of the recent arctic warming that has been observed, as well as altered patterns of sea ice circulation. Both are consistent with the sea ice losses. This may just be part of a natural climate cycle. But the recent warming, while especially large in the Arctic, is a global phenomenon. Influences of the NAO/AO appear to be superimposed on this more general warming trend. And although the jury is still out, there is evidence that a more positive NAO/AO may actually be part of an emerging greenhouse signal.

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Polar Bears, Seals, and Climate in Hudson Bay and the High Arctic

Ian Stirling, Canadian Wildlife Service

From 1981 through 2003, the condition of adult male polar bears and females accompanied by dependent young has declined significantly in western Hudson Bay. This decline is reflected in aspects of reproduction and survival. The average date of breakup of the annual ice on western Hudson Bay is now about 2.5 weeks earlier than it was in the early 1970s. There is a significant positive relationship between the time of breakup and the condition of adult males and females (i.e., the earlier the breakup, the poorer the condition of the bears). The trend toward earlier breakup is correlated with steadily warming air temperatures over the study area in spring (0.3–0.4°C from April through June per decade) for the last 50 years.

We suggest that the proximate cause of the decline in physical and reproductive parameters of polar bears in western Hudson Bay over the last 22 years has been the trend toward earlier breakup. This has shortened the most important feeding period for polar bears before their annual period of fasting during the open water season in Hudson Bay. The ultimate factor responsible for the earlier breakup in western Hudson Bay appears to be a long-term warming trend in atmospheric temperatures. Changes in ringed seal and harbour seal populations appear to be underway and are likely to be affecting polar bears but these relationships are not yet well understood.

In the high Arctic, some areas dominated by multiyear ice and low productivity may, in the short term at least, become more biologically productive habitat for polar bears and seals. However, if long-term projections of the disappearance of ice in the polar basin are correct, this improvement in habitat will be temporary. The relationships between polar bears and their prey species will be described to provide an understanding of their dynamic importance. Projections of potential future problems for polar bears and seals in the future will be speculated upon.

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Changes in Arctic Sea Ice: What are the Consequences for Whales?

Robert Suydam, Alaska North Slope Borough; Sue Moore

Climate warming has caused profound changes in the arctic ecosystem, most visibly in the extent and thickness of the sea ice. Ice-dependent species of marine mammals, such as polar bears, walruses, and ringed and bearded seals, may be especially vulnerable to reductions in sea ice extent and thickness. Resting, molting, foraging, and denning/pupping habitats are rapidly disappearing. It is reasonable to predict that populations of these ice-dependent species will undergo reductions in number and that individual health and body condition will be compromised.

Predicting the impacts of sea ice reduction to ice-associated whales, such as bowhead, beluga, and gray whales, is more complex. It is likely that whales will be impacted most by responses in trophic cascades that are linked to changes in sea ice. Forecasting how environmental change will alter, and potentially tip, trophic relationships in the Arctic is difficult. For example, a reduction in sea ice extent may result in shifts in distribution and abundance of ice-associated prey such as arctic cod, which might reduce beluga productivity. Alternatively, high transport conditions between subarctic and arctic waters may enhance foraging opportunities for bowhead and gray whales. A variety of such forecast scenarios can be envisioned.

Distinct seasonal habitats have been identified for bowhead, beluga, and gray whales in the Chukchi and Beaufort Seas. These habitat relationships were found to vary with sea ice cover and transport (in-flow) of water at the Bering Strait. For example, bowhead whales showed strong affinity for Beaufort shelf waters in open water or light-ice conditions, switching to Beaufort slope habitat in heavy-ice conditions. Belugas were associated with the Beaufort slope and Chukchi Sea canyons in both ice conditions, but sighting rates for these whales were significantly higher during heavy-ice years. Additionally, satellite tracking of belugas showed they consistently used deep, ice-covered waters of the Arctic Ocean, possibly to exploit abundant prey. Gray whales hung tenaciously to shallow shoal areas in the northeastern Chukchi Sea in high-transport conditions but not in low.

Reduction in sea ice could have both positive and/or negative effects to arctic whales. Decreasing ice cover could increase productivity, although other coupled environmental changes, such as freshwater inflow, could have negative effects. Predation could increase because killer whales have easier access to arctic waters. Additionally, reduced ice cover could facilitate offshore human activities including in-

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creased commercial shipping, tourism, fishing, and oil and gas/mineral exploration and development, which could have negative effects on whales.

Our ability to understand and predict responses of whales to changing environmental conditions in the Arctic will require an integrated ecosystem-based research approach, across a suite of disciplines, supported by international partnerships. Future monitoring of high arctic cetaceans by satellite telemetry, in combination with remote sensing and on-site observations, will contribute to the identification of important feeding habitats as well as information on the plasticity of movement and use patterns of whales under changing ice regimes.

Shrub Increase in Northern Alaska Documented Using Repeat Aerial Photography

Kenneth Tape, University of Alaska Fairbanks; Matthew Sturm; Charles H. Racine

Evidence from arctic Alaska suggests that the terrestrial landscape is changing in response to documented warming and elevated carbon dioxide concentrations in the atmosphere. In this study, 202 old (1946–51) oblique aerial photographs from arctic Alaska were repeated from helicopter, and comparison of old and new photographs revealed an increase in shrub cover over the last half-century. A quantitative method for comparing photographs yielded an increase in alder shrub cover from 14–20%, and similar increases were observed for willow shrubs. This shrub expansion was observed in many landscape positions, including river floodplains where the increase in vegetation has resulted in narrower, more stable floodplains. The pervasiveness of the change documented in the photographs can only be explained by a perturbation operating on a similarly large scale. In the absence of large-scale disturbances like fire, the increase in shrubs documented here is likely an indirect product of elevated temperatures or carbon dioxide concentrations.

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Poster Abstracts

The International Polar Year 2007–2008: Efforts of the U.S. National Committee

Mary R. Albert, Cold Regions Research and Engineering Lab

Change is ubiquitous in Earth's history, and evidence is clear that the Earth is changing rapidly now. The harbingers of change can be seen vividly in the polar regions. The arctic ice cover is melting, ice shelves in Antarctica are crumbling, glaciers in temperate regions are disappearing, ecosystems are changing, and permafrost thawing is causing collapse of roads, buildings, and pipelines. Are we witnesses to an extreme in natural variability, the threshold of an abrupt change, or something subtler? How will changes first seen in the polar regions affect us all?

Plans by many nations are underway toward International Polar Year (IPY) 2007–2008. Previous IPYs (1882–83 and 1932–33) and the International Geophysical Year (1957–58, which began as an IPY) produced unprecedented exploration and discoveries in many fields of research and fundamentally changed how science was conducted in the polar regions. IPY 2007–2008 will kick off with an intense, internationally coordinated campaign of activities that initiate a new era in polar science. IPY 2007–2008 will address research in both polar regions that involve strong linkages to the rest of the globe. It will be multi- and interdisciplinary in scope and truly international in participation. It will educate and excite the public and help produce the next generation of engineers, scientists, and leaders.

IPY 2007–2008 will benefit society by exploring new frontiers and increasing our understanding of the key roles of the polar regions in globally-linked systems. Recent technological developments give us a new ability to investigate previously unexplored areas, using new tools and new ways of looking to understand once unanswerable questions. Autonomous vehicles, genomics, and remote sensing instruments and networks are just a few of the technologies providing new tools for investigating previously inaccessible realms. The polar regions continue to loom large in facilitating our understanding of the processes by which solar activity may seriously disturb the Earth's space environment, affecting the performance of modern technologies deployed in space and on Earth. We believe that research is needed now so that future generations may mitigate vulnerabilities and adapt to potential change.

Various international organizations and individual nations are actively planning for the International Polar Year. The International Council for Science (ICSU) formed an international planning group to catalyze IPY development across national boundaries, and now ICSU and the World Meteorological Organization jointly sponsor the IPY. Other endorsements to date include the Scientific Committee on Antarctic Research, the International Arctic Science

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Committee, and the Arctic Council. Interested countries have begun to form national committees and develop a consensus for science themes that will form the backbone of the activities. In the U.S., the Polar Research Board of the National Academies formed the U.S. National Committee to facilitate IPY planning.

The U.S. National Committee for the International Polar Year actively welcomes input from the science community. Many discussions, both web-based and at professional meetings, have occurred since our formation last summer and our report on the vision for U.S. participation in IPY will be available in mid-May. Please visit our web site (www.us-ipy.org) to read about our current and planned activities and to learn how you can contribute.

The U.S. National Committee for the International Polar Year 2007–2008 includes: Mary Albert (chair), Robert Bindschadler, Cecilia Bitz, Jerry Bowen, David Bromwich, Richard Glenn, Jacqueline Grebmeier, John Kelley, Igor Krupnik, Louis Lanzerotti, Peter Schlosser, Philip Smith, George Somero, Christina Takacs-Vesbach, Gunter Weller, and Douglas Wiens. The PRB chair, Robin Bell, and staff, Chris Elfring, Sheldon Drobot, and Kristen Averyt, are also active participants.

A 20-year Simulation of Arctic Sea Ice 1979–1998 Using Assimilated Sea Ice Motion

Todd Arbetter, University of Colorado

A multi-category dynamic-thermodynamic sea ice distribution model is used to simulate sea ice for the Arctic Ocean for two decades. This model keeps track of three ice types (first-year level, multiyear level, ridged) with 12 thickness categories each. In some runs, observed sea ice motions are blended into the model using optimal interpolation.

In the 1990s, there is a noticeable decrease in the amount of multiyear level (undeformed) ice present in the Arctic Basin, without an equal increase in ridged ice. Thus, a shift in the nature of the ice from perennial (multiyear) to seasonal (first-year) can be inferred from the model results.

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Thermal Fronts of the Bering Sea

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

The Bering Sea features a variety of fronts that manifest in the surface layer, both in temperature and salinity. As part of a global survey of ocean fronts (e.g. Belkin and Cornillon, 2003), 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 image using the Cayula-Cornillon edge detection and declouding algorithms. Long-term (1985–1996) frontal frequencies (normalized on cloudiness) were computed for each 9-km pixel. Analysis of synoptic frontal SST maps, together with frontal frequency maps, revealed a number of new fronts and elucidated important features of some previously known fronts, especially with regard to their spatial structure and its seasonal and interannual variability.

The Bering Sea frontal pattern changes dramatically as the season progresses. The frontal pattern in May features a well-defined ridge of elevated frontal frequencies extended from Bristol Bay westward to Cape Navarin. The ridge is not isobathic, so the corresponding front is located over shallow depths (~50 m) in Bristol Bay but continues over the outer shelf (100–200 m depth) in the northwestern part of the sea. Hence, the front location does not correspond to any of the major known fronts (inner, middle, or outer) since these fronts are believed to be isobathic (e.g. Coachman, 1986). The front configuration is, however, remarkably similar to the sea ice cover's edge in May; the edge is located about 1° of latitude to the north of the front. The front thus appears to be related to the marginal ice zone processes and represents an imprint left in the ocean by the sea ice cover.

In November, the frontal pattern is different. Instead of one major front, several fronts extend essentially in the same SE–NW direction over the shelf break, outer shelf, and inner shelf. Some inner shelf fronts are observed well inshore of the 50 m isobath, so they are not necessarily related to the tidal mixed front believed to be associated with the 50 m isobath (e.g. Coachman, 1986). Two distinct fronts in the northwest correspond to the northward Anadyr Current and southward Kamchatka Current, branches of the Bering Slope Current.

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Human Dimensions of the Northwest Passage in Global Context: Past, Present, and Future

Ellen Bielawski, University of Alberta

The opening of the Northwest Passage due to arctic sea ice decrease is an environmental change that Inuit, Inuvialuit, and Iñupiat have not seen since their prehistoric ancestors settled the area between the Bering Strait from northern Alaska to Greenland approximately 1000 years ago. European search for the Northwest Passage initiated contact between Europe and Aboriginal North America and Greenland.

Work with Inuit on Cornwallis, Baffin, and Somerset Islands since 1975 provides the contemporary context for the human impact of sea ice melt. Research on the prehistoric record and community participation are complemented by comparison between two voyages through the Arctic Islands (1975 and 1988) and the present annual ice cover, rate of melt, and implications for residents.

Inuit prehistory, history (including resettlement from Hudson Bay to the high Arctic in the 1950s) and current environmental adaptation intersect with international interests in the Northwest Passage, especially the conflict between Canada's claim of sovereignty to the Arctic Islands and surrounding waters and the United States' claim that these are international waters.

The next decade will require significant environmental, cultural, policy, economic, and strategic decisions for Nunavut, Northwest Territories and Alaska; Canada, the U.S. and Greenland, and all of their Aboriginal people. This research synthesizes the issues and places the unfolding story in global context.

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Dynamics of Seabird Populations of the Western Aleutian Islands Over Four Millennia to the Present

Douglas Causey, Harvard University; Arkady B. Savinetsky; G. Vernon Byrd; Debra G. Corbett; Christine Lefevre; Jeffrey C. Williams

Quantitative temporal and spatial analysis of early Aleut archeological sites reveals that there are strong dynamic and static patterns in the reconstructed biotic environment. Spatial patterns are quite dynamic through time, but significant biogeographic breaks seem to be localized around oceanographic passes. The Near Islands in the far western Aleutian Islands have the most distinct fauna over all temporal and spatial scales and show the greatest patterns of change. The analysis reveals a close association of past and present distributions to the prevailing oceanography. An example of particularly intriguing patterns is the inferred coupling through time of increased urchin abundance, decreased otter abundance, decreased size of halibut and nearshore cottids, and mixed patterns of presence and abundance of on-shore, near-shore, and pelagic feeding seabirds. Recent ten-fold population declines, however, of several widespread species like Red-faced and Pelagic Cormorants (Phalacrocorax urile, P. pelagicus) over the past three decades suggest either substantial changes in nearshore oceanography or dramatic decoupling with local conditions. These patterns are anomalous by comparison to the patterns of the preceding three millennia.

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The Voyage of the *S.S. Manhattan*: Oil, the Northwest Passage, and Industrial Development in the Arctic

Ross A. Coen, University of Alaska Fairbanks

The voyage of the *S.S. Manhattan*, an icebreaking tanker that traversed the Northwest Passage in 1969, proved commercial use of the Canadian Arctic as a marine transportation route was feasible, though logistically difficult and prohibitively expensive. However, as global climate change presently reduces both thickness and coverage of circumpolar sea ice, an increase in trans-arctic shipping and offshore oil exploration is possible. The *Manhattan's* experimental, data-gathering voyage was predicated on the belief that scientific research and technological innovation could overcome any challenge posed by the arctic environment. This effort, therefore, occurred largely to the exclusion of meaningful consideration of how such industrial expansion would impact the north itself. The voyage of the *Manhattan* provides a historical baseline of sorts indicating that future industrial development in the Canadian Arctic will similarly depend on the application of science and technology on a massive scale; yet such scientific endeavors must be placed in an appropriate humanistic context where social, economic, political, and environmental impact are considered.

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Using Multimedia Technology to Document and Communicate Inuit Knowledge of Environmental Change: An Interactive Poster

Shari Fox Gearheard, Harvard University

This poster is one that the viewer can "drive." It presents the multimedia, interactive CD-ROM, *When the Weather is Uggianaqtuq: Inuit Observations of Environmental Change.*

In this CD-ROM, Inuit from two communities in Nunavut (Baker Lake and Clyde River) share their observations and perspectives on recent environmental changes. The integration of video clips of interviews, maps drawn by Inuit, photos, music, and text helps to illustrate Inuit observations of changes and the impacts on their livelihoods.

When the Weather is Uggianaqtuq is a pilot project using multimedia technology to improve research reporting to communities and designing more creative educational research products. The Inuit involved in this project have approved it as an educational tool for their own communities as well as for students, researchers, decision-makers, and others in Nunavut and beyond who are interested in issues around arctic environmental change.

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Clues to Sea Ice Change from Satellite-Derived Atmospheric Parameters

Jennifer Francis, Rutgers University; Eli Hunter; Jaclyn Secora

Changes in sea ice extent observed during recent decades are caused primarily by a combination of dynamic (wind stress) and thermodynamic (surface-atmosphere energy transfer) forcings that likely vary spatially and temporally to their relative importance. Using atmospheric parameters derived from satellite sounding instruments, we are attempting to identify which factors (such as changes in 10-meter winds, surface longwave fluxes, advective heating) were most closely related to sea ice change in several regions of the sea ice periphery. Observed temporal patterns in the duration of the melt season also appear to correspond to satellite-derived changes in heating. This poster will present preliminary findings in this investigation.

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Barrow, Alaska: A Pivotal Location for the Study of the Role of Ice-Radiation Feedback Processes in Arctic Change

Thomas C. Grenfell, University of Washington; Donald K. Perovich; Hajo Eicken; Bonnie Light

The arctic sea ice cover has demonstrated a measurable decrease in thickness and extent accompanied by an increase in the duration of the melt season over the last two decades culminating in record or near-record fluctuations in 1998 and again in 2002 followed by a further strong melt season in 2003. Seasonal changes and short-term variability in the state of the ice cover and their effect on the interaction of solar radiation with the ice and underlying ocean are of particular importance in this context. Positive feedback processes, associated with decreases in albedo and increasing transmissivity occurring during the summer melt, act to accelerate these changes. The rates of spring warming and summer melt, as well as the length of the melt season, are strongly influenced by the albedo, which in turn decreases as the melt season progresses. At the same time, increased ice transmissivity provides more energy to the upper oceanic mixed layer, further increasing the potential for bottom and lateral melting of the ice. This ice-albedo-transmission feedback plays a central role in modulating the heat and mass balance of the arctic sea ice cover. Along the coastal contact zone, the feedback processes are even more complex due to interactions with the adjacent land surfaces. Indeed, this zone appears to be a focal point where these feedback processes are amplified.

To understand and model the processes involved, it is necessary to determine how shortwave radiation is distributed within the ice-ocean system and how this distribution affects heat and mass balance. This system is complex due to the spatial and temporal inhomogeneity of the spring/summer ice cover. Surface conditions vary from deep snow to bare ice to melt ponds to open leads, and with ice thickness ranging from zero (open water) to ridges tens of meters thick, all within an area that is often less than one square km. Each of these categories has a different set of physical and optical properties. Treatment of the surface as a locally homogeneous medium with effec-

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tive bulk optical properties represents a serious oversimplification that significantly limits the predictive power of regional to large-scale climate and dynamics models. An approach to dealing with this problem is to carry out surface-based observations of the processes involved to determine the detailed spatial and temporal variability associated with the various surface types and develop appropriate models to apply this information on larger scales. Barrow, Alaska is critically situated for studies of the processes described above. We will present results from a three-year observational sequence of heat, mass, and total and spectral radiation balance of the sea ice cover plus adjacent tundra and lakes that illustrates the strong interannual variability. This information allows us to make an accurate determination of partitioning of solar heating in this zone and provides the basis for radiation feedback modeling of sea ice in general. We describe in detail the response to extreme melting conditions in 2002, which will be important for generalizing to conditions attendant to increases in the length of the melt season. We propose that this type of study be continued during IPY 2007–08 and that Barrow is an area of critical importance with regard to both a scientific understanding and human dimensions in the Arctic. It offers a key scientific location in combination with superior logistics support and extensive opportunities for K–12 outreach and support of higher education.

Real Impacts of Climate Change in Alaska

Larry D. Hinzman, University of Alaska Fairbanks

In Alaska, we no longer discuss climate change using words such as “possible” or “potential.” It has arrived. It is real. There is ample evidence of impacts from a changing climate in Alaska, primarily due to the predominance of snow, ice, and permafrost. The presence or absence of frozen ground or water will dominate the local ecology, hydrology, physical characteristics, and surface energy balance. As the soil or ice progresses through thawing, threshold changes occur that may initiate a cascade of events resulting in substantial changes to the regional character. If one examines any individual scientific discipline, evidence of climate change in arctic regions offers only pieces of the puzzle. Here we present a broad array of evidence to provide a convincing case of change in the arctic climate and a system-wide response of terrestrial processes.

The thermal regime of the Arctic holds unique characteristics and consequently will display marked changes in response to climate warming. In many cases, threshold changes will occur in physical systems proceeding from permanently frozen to periodically thawed. Dramatic changes also accompany biological systems adapting to an evolving environment. It is expected that the effects and consequences of a warming climate will become even more evident within the next 10 to 50 years.

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Lakes of the Bolshezemelskaya Tundra, Russia: Four Decades of Change

Robert M. Holmes, Marine Biological Laboratory; Alexander V. Zhulidov; Tatyana Y. Gurtovaya; Ludmila V. Boeva; James W. McClelland; Bruce J. Peterson; Peter Raymond

Russia contains a far larger share of the Arctic than any other nation. During the Soviet period, tremendous efforts were directed toward studying many aspects of the Arctic, including its ecology, limnology, and hydrology. Yet many of the resulting data sets were never published and access to the data was often restricted.

Several recent cooperative efforts have had success compiling, analyzing, and publishing long-term environmental data from the former Soviet Union and the Russian Federation. However, a vast quantity of potentially valuable data remains "undiscovered," at least in the western literature. Given the sensitivity of the Arctic to global change and the important feedbacks from the Arctic to global climate, efforts to "rescue" existing long-term data sets from the vast Russian Arctic should be a priority.

Here we present data on the limnology of lakes in the Bolshezemelskaya Tundra in the northeast European Russian Arctic. The lakes are at a latitude similar to that of Toolik Lake, Alaska and the surrounding landscape is similar to Toolik in many ways. The lakes were periodically surveyed beginning in the early 1950s. The studies involved scientists from several Soviet laboratories including the Hydrochemical Institute in Rostov-on-Don, the Komi Branch of the Soviet Academy of Sciences, and the Limnology Institute of the Russian Academy of Science.

The data suggest widespread and dramatic changes in physical, chemical, and biological properties of these tundra lakes. While there can always be legitimate questions about data quality in long-term data sets such as this, the consistency and magnitude of apparent trends strongly suggests that substantial changes have occurred. Although data available from Toolik Lake span a shorter time period, some

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of the changes that have been observed in the Bolshezemelskaya Tundra lakes are remarkably similar to those observed at Toolik Lake. For example, increases in alkalinity and temperature have been observed in both places and rates of change are of a similar magnitude. In addition to temperature and alkalinity changes, the lakes of the Bolshezemelskaya Tundra also show large changes in biological variables such as primary and bacterial production and even in basic morphological characteristics (lake size and depth).

All of these trends are broadly consistent with global warming. Other mechanisms, such as increased atmospheric N-deposition, might contribute to the observed changes in lake productivity. Further study of these systems, and continued compilation and analysis of existing long-term Russian data sets, should help us move toward the goal of understanding the responses and feedbacks of arctic ecosystems to global change.

Microbiological Parameters in the Coastal Waters of Golomanniy Island (Georgiy Sedov Archipelago, Severnaya Zemlya) from January to October

Vladimir V. Ilinskiy, Moscow State Lomonosov University

The Central Arctic islands microbial communities' seasonal changes and dynamics are not well understood. Severnaya Zemlya islands coastal areas have no strong anthropogenic pressure because these islands have no permanent inhabitants, but only small polar stations without strong effects on the surrounding marine and terrestrial environments. The most important aspects here may be in main terrestrial influence on the coastal marine microbial communities.

The aim of our research was to obtain quantitative information about the seasonal changes and dynamics of the most important microbiological parameters—total bacteria (direct count with acridine orange) and viable heterotrophic bacteria of the three different groups (copiotrophic, oligotrophic, and hydrocarbon-oxidizing) coupled with phytoplankton number. Water samples for microbiological investigations were taken monthly using ZoBell water sampler and for the phytoplankton count, using a bottle-type water sampler.

Water temperature during all observation periods remained very low and varied from -1.8°C in January to -1.2°C in August. Salinity in August was 29.98‰ and 30.53‰ in April. Total bacteria number was analyzed from June to September and varied from 1.09 x 108 cells/l at the 1 m depth in June to 7.21 x 108 cells/l in September. Copiotrophic bacteria dominated among the viable bacteria groups with maximal numbers up to 5.66 x 104 CFU/l in August. Oligotrophic bacteria number was maximal in August as well and did not exceed 3.3 x 104 CFU/l. Viable bacteria count was maximal in summer at the surface micro layer area and total bacteria number was maximal at 1 m depth. Hydrocarbon-oxidizing bacteria were present only in some samples with maximal number from 200 to near 1000 cells/l.

Only single phytoplankton cells were observed in water samples from January to April. June was the only month in which phytoplankton cell numbers were high enough—up to 0.33 x 106 cells/l. Maximal phytoplankton number was observed in August—up to 3.67 x 106 cells/l at the surface micro layer area. In September, phytoplankton maximum was observed to be lower, at 1 m depth—up to 2.58 x 106 cell/l.

High bacteria and phytoplankton numbers were observed in the near shore ice samples, at the lower ice surface, directly contacting with seawater. Even in April, when phytoplankton numbers in water samples were very low, in the ice samples it was high—up to 0.41 x 106 cells/l. Phytoplankton abundance was especially high in the ice samples taken in June, when the lower ice surface was brown and phytoplankton number exceeded 29 x 106 cells/l in comparison with only 0.33 x 106 cells/l

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in surrounding water. Bacteria number in the ice samples in April was near the same as in water, but in June copiotrophic bacteria number in the ice samples was at least one order higher than in water and the total bacteria number in the ice samples was two times the water number.

As compared with Central Arctic offshore waters, microbial communities inhabiting coastal waters of the small arctic islands have near the same features with copiotrophic bacteria domination and relatively small proportion of hydrocarbon-oxidizing bacteria. Arctic islands near shore ice may be a very important base for the microbial and phytoplankton communities' maintenance during the hydrological winter period.

Spatial Analysis of Coastal Erosion over Five Decades near Barrow, Alaska

William F. Manley, University of Colorado

There has been increasing interest in recent years in processes affecting arctic coastlines, including shoreline erosion and the release of both inorganic and organic sediment to the nearshore marine environment. Beyond scientific interest, the prospect of continued —and possibly accelerated—coastal erosion is a major concern for many arctic communities. Documenting and understanding spatial variability in erosion rates is increasingly attainable as high-resolution imagery becomes available and as GIS and remote-sensing tools are more widely accepted. This study presents such an analysis for a broad area near Barrow, Alaska.

Shoreline erosion and accretion were quantified by comparison of co-registered datasets and imagery. Orthorectified Radar Imagery (ORRI) was acquired by Intermap Technologies in July 2002 at 1.25 m horizontal resolution. Twenty frames of black and white aerial photos from August 1955 were scanned and georectified to the ORRI using an image-to-image polynomial transformation in ArcGIS, with resulting resolution of about 1.4 m and an RMS error of 2.6 m. The 2002 and 1955 shorelines were digitized with points spaced every 20 m along the 250 km of mainland coastline. For barrier islands and the Barrow Spit, the 1955 coastline was digitized from DRG files depicting the USGS 15-minute topographic maps. Using a variety of vector ArcInfo commands, horizontal displacement of the mainland shoreline was converted to erosion and accretion rates for the intervening 47 years. (Note that time-averaged rates will underrepresent episodically high rates during storm events). Overall error considering georectification, digitizing, and transient waterline shifts due to microtidal fluctuation and wave-set up is approximately 3.1 m for the mainland coast, equating with 0.07 m/yr. For barrier features, where the DRG's are less accurate, error is about 28 m (0.6 m/yr).

Nearly all of the mainland coast (91%) has experienced erosion. Highly variable across the study area, rates average -0.91 m/yr, with an average horizontal shoreline displacement of -42.5 m. (Rates and displacements are negative for erosion). Relatively low rates of about -0.3 m/yr occur along the Chukchi coast where bluffs up to 15 m high back sand- and gravel-dominated beaches. Rates are higher along the low coastal plain facing Elson Lagoon, exceeding -5 m/yr near Scott, Ross, and Christie Points, before decreasing again in the sheltered waters of inner Admiralty Bay. Rates also decrease within small bays and inlets on a local scale. Lateral accretion from 1955 to 2002 is uncommon, limited to short stretches of widening beach along the Chukchi coast, and isolated progradation or shifting of small nearshore spits and bars. Immediately adjacent to Barrow, the shoreline has eroded -0.2 to -0.8 m/yr in agreement with a higher-resolu-

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tion, related study, whereas the beach near the NARL/UIC complex has prograded on average +0.3 m/yr. The narrow offshore barrier islands have migrated considerably with an average horizontal shift of 205 m. Although erosion over five decades has been locally variable, a few patterns emerge. High bluffs and coarse beach sediment protect the Chukchi shoreline, whereas very low coastal bluffs exposing ice-rich, peaty soils are susceptible along the Beaufort mainland coast. Beyond bluff height and shoreface lithologies, fetch plays an important role with the inner portions of bays and inlets protected at a variety of scales. It appears also that erosion is more pronounced where ice-wedge polygons are strongly developed within mature thaw-lake basins. Near Barrow, human activities in the nearshore zone may have played a role, and erosion is a concern—even though it occurs there more slowly than the region as a whole. The importance of extreme weather events and the possibility of accelerated change due to warming and decreasing summer sea ice will be examined as other imagery improves the temporal resolution for analysis.

Weekly to Interannual Variations in the Sea Ice Draft Distribution at the North Pole Environmental Observatory

Richard E. Moritz, University of Washington

A two-year time series of sea ice draft D(t) was estimated from measurements made by Upward Looking Sonars (ULS) from 10 April 2001 to 21 April 2003. The moorings were located at the North Pole Environmental Observatory (NPEO: 89.56 N, 66.65 E in year 1; 89.45 N, 53.63 E in year 2). Sample statistics and probability Density Distributions (PDFs) of D(t) have been estimated by grouping the data in nonoverlapping, two-week intervals with probability weighting proportional to the ice speed recorded simultaneously by an Acoustic Doppler Current Profiler (ADCP).

In the first year, the sample mean draft varied from 3.7 meters in early April to 2.3 meters in late August, with an overall annual mean of 3.0 meters. The sample mean draft estimated for 15 September 2001 was 2.3 meters, a value near the middle of the seasonally adjusted estimates derived from submarine sonar profiles near the North Pole in the 1990s (Rothrock et al.,1999). The modal draft in year 1 lags behind the sample mean, with extrema of 2.3 meters in late June 2001 and 1.6 meters in early January 2002.

The open water fraction (OWF), estimated by counting ice drafts smaller than .05 meters, exceeded 1% from mid-June to early October and for a brief period in late December. The maximum OWF of 13% occurred in July 2001. The mean ice draft was larger throughout most of the second year, especially in summer. The sample mean ice draft for 15 September 2002 was 3.2 meters, i.e. 90 cm greater than in the preceding year, and just outside the envelope of the Rothrock values for the 1990s.

Analysis of the ice draft time series, monthly mean maps of multiyear ice concentration estimated from SSM/I data, and monthly mean anomaly maps of sea level pressure suggests that ice advection played a major role in these interannual differences.

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Unexpected Adventures During Studies of Alaska's Northern Chukchi Sea: Characterizing Sea Ice Beyond Iñupiat Whalers' Horizons

David W. Norton, Arctic Rim Research

Analyses, in collaboration with Iñupiat whalers, of coastal sea ice within 200 km of Barrow did not produce the quantitative results that the National Science Foundation may have expected. Instead, some of the most time-consuming analyses of nearshore sea ice during this project fell outside the work invested in by NSF, yet turned out to be fundamental or qualitative in nature.

This poster presentation unapologetically explores several research experiences that were unnerving:

- getting seriously sidetracked during research
- almost, failing to see an obvious phenomenon
- dealing with qualitative findings
- announcing findings that others take for granted
- worrying about the future of "inductive" science

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VECO Polar Resources

National Science Foundation Office of Polar Programs

VECO Polar Resources (VPR) is the National Science Foundation's (NSF) arctic logistics contractor. VPR annually supports over 100 grants and 500 scientists in Alaska, Iceland, Norway, Russia, Sweden, and the Arctic Ocean.

- Air, Ground and Sea Transportation: VPR coordinates aircraft support ranging from military "heavy-lift" airplanes to commercial helicopters and small bush planes. They also provide trucks, snow machines, all-terrain vehicles, and boats. In addition to moving personnel, VPR can transport cargo to and from virtually any field location.
- Field Camps: VPR can provide facilities as small as a mobile tent camp or as large as a fully staffed, semi-permanent field camp.
- Remote Medical Services: VPR provides researchers with medical kits and offers a 24-hour medical hotline staffed by physicians. This service is available for both emergency and non-emergency field consultations.
- Safety Training: VPR arranges safety courses throughout the year in various U.S. locations. Courses include training in wilderness medicine, field skills, aircraft safety, and oil field protocol.
- Proposal Assistance: VPR can work with researchers to develop a logistics plan and field support cost estimate to include with proposals to the NSF.
- Remote Communications: VPR can provide radio and/or satellite systems to meet all of your voice and data communications needs.

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Arctic Science Discoveries

National Science Foundation Office of Polar Programs

The past five decades of intense research have increased our understanding of the Arctic, but much remains to be learned. The Arctic Sciences Section of the National Science Foundation funds basic research on the Arctic through the Arctic Natural Sciences, Arctic Social Sciences, and Arctic System Science programs, with field research support from the Research Support and Logistics program. Some recent research results are presented both as answers to important questions and leads to future research directions:

- Studying Arctic Change: The Study of Environmental Arctic Change (SEARCH) is an interagency, interdisciplinary, multiscale program to study changes occurring in the Arctic and their potential impacts.
- Ringed Seal Migration: Working with Alaska Native hunters, researchers attached a satellite tracking device to follow a ringed seal as it migrated northward with the melting ice of the Chukchi Sea in spring.
- Photochemistry in Greenland Snow: Light-mediated chemical reactions (photochemistry) occur at the air-snow interface and significantly impact the chemical composition of air trapped in ice and of the air overlying the snow.
- Small Streams on the Move: Small streams contribute more to removing nutrients such as nitrogen from water than do their larger counterparts. Based on data collected initially from streams in NSF's Arctic Tundra Long-Term Ecological Research site in Alaska, the findings were confirmed by data from 12 sites across the country.
- Living Conditions in the Arctic: This international effort involves a partnership of researchers and indigenous organizations across the Arctic to advance our understanding of changing living conditions among Inuit and Saami peoples and the indigenous peoples of Chukotka.
- On the Gakkel Ridge: The Gakkel Ridge is the slowest spreading center in the world, giving scientists the opportunity to explore Earth's inner layers as the mantle spreads at about 1 cm per year onto the ocean floor near the North Pole.
- Understanding the Arctic Ocean: The Western Arctic Shelf Basin Interactions (SBI) project is investigating the impact of global change on physical, biological, and geochemical processes over the Chukchi and Beaufort Sea shelf basin in the western Arctic Ocean. The closely affiliated Chukchi Borderlands project studies the region where relatively cold, fresh, and nutrient-rich water from the Pacific Ocean meets warmer, saltier, and deeper water from the Atlantic Ocean over a bottom tortuously rife with slopes, ridges, and deep-sea plateaus.

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Discovery, Understanding, Teaching, Learning

National Science Foundation Office of Polar Programs

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

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

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

Ideas: Earth's polar regions offer compelling opportunities to convey the broader impacts of research. The Foundation's Polar Advisory Committee—external scientists and educators—has made a list of ideas to help investigators explain in their proposals how their research would achieve broader impacts: http://www.nsf.gov/od/opp/opp_advisory/oaccrit2.htm.

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

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Air-Ice Chemical Interactions: the Revolution in Atmospheric Chemistry

Paul Shepson, Purdue University; Eric Wolff

Until recently, the snow and ice covered regions of the world received little interest from the atmospheric chemistry community. However, a number of field programmes, principally in the Arctic and Antarctic, have revealed many unexpected and interesting phenomena and opened up the possibility that the chemistry of the ice may control aspects of boundary layer chemistry over large regions of the world, rather than the other way round. In addition, for some species the exchanges between snow and the atmosphere, as well as post-depositional ice processes, have a decisive impact on the signal that is retrieved from ice cores: our best hope of reconstructing atmospheric chemistry from the pre-instrumental period. It is now recognized that changes in one compartment of the Earth System can strongly affect the state of other compartments. As the Earth and its climate change, particularly in response to phenomena such as greenhouse gas increases and stratospheric ozone depletion, it becomes increasingly important to understand the interactions between different parts of the system. The physical processes that involve ice are now being studied by the World Climate Research Program project CliC (Climate and Cryosphere). Until recently, it was generally assumed that the main biogeochemical role of ice was that it restricted exchanges between the more active ocean and land surfaces and the atmosphere. However, studies in recent years have revealed evidence that important chemical exchanges also occur between ice and the atmosphere, and it makes sense to study these processes and their consequences generically. AICI aims to do this, forming a bridge between scientists working on ice-covered surfaces in both polar regions and in the mid-latitudes, atmospheric scientists interested in processes occurring on ice particles, laboratory scientists studying the properties of ice, and modellers who need to parameterize processes that involve ice.

This project has been jointly endorsed by IGAC (International Global Atmospheric Chemistry) and SOLAS (Surface Ocean Lower Atmosphere Study)—both of which are IGBP Core Projects—but it is also relevant to ILEAPS (Integrated Land Ecosystem-Atmosphere Process Study) and to PAGES (Past Global Changes), as well as to WCRP-CliC. This poster describes the goals of Air-Ice Chemical Interactions and current and future activities in the Arctic at Summit, Greenland, Ny Ålesund, Barrow, and Alert, and parallel investigations at Halley Bay, Neumayer, and Dumont D'Urville and South Pole, Antarctica.

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Ilimmarfik—The New Center for Social Sciences and Humanities Research in Greenland

Marianne A. Stenbaek, McGill University

Human and social sciences have a direct relevance and impact on the inhabitants in the Arctic. Social sciences and humanities research in the Arctic has changed significantly in the last 15 years as the social, economic, and political conditions have undergone major changes. The local inhabitants have taken on a direct participatory role in research and large multi-country and multi-disciplinary projects are now the norm. The paradigms of research have, therefore, changed to embrace collaboration, internationality, interdisciplinary research.

The Greenland Home Rule government is meeting these needs by having approved plans and the financial means for a new social sciences and humanities research and education facility in Nuuk, Greenland.

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Facilitating Collaborative Scientific and Technical Research in the Arctic Sciences and Geosciences

Marianna Voevodskaya, National Science Foundation; David H. Lindeman; Shawn Wheeler

The U.S. Civilian Research and Development Foundation (CRDF) is a private, nonprofit, grant-making organization created in 1995 by the U.S. government (National Science Foundation). The CRDF promotes international, scientific, and technical collaboration, primarily between the United States and Eurasia, through grants, technical resources, and training. The Foundation's goals are to support exceptional research projects that offer scientists and engineers alternatives to emigration and strengthen the scientific and technological infrastructure of their home countries; advance the transition of foreign weapons scientists to civilian work by funding collaborative non-weapons research and development projects; help move applied research to the marketplace and bring economic benefits both to the U.S. and the countries with which the CRDF works; and strengthen research and education in universities abroad.

Three CRDF programs provide support to U.S. and Russian scientists engaged in collaborative arctic and geosciences-related research. 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 US-Russian collaborators in arctic sciences and geosciences to apply for two-year R&D grants averaging approximately $65,000. Third, the CRDF Grant Assistance Program (GAP) enables U.S. government agencies, universities, and other organizations to utilize CRDF's financial and administrative infrastructure to transfer payments, purchase and deliver equipment and supplies, and carry out other project management services to collaborators in Russia and elsewhere in the former Soviet Union.

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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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Is the Decreasing Arctic Sea Ice Cover Caused by Increasing Greenhouse Gases?

John W. Weatherly, Cold Regions Research and Engineering Lab

Recent papers on the thinning and shrinking sea ice cover of the Arctic Ocean have suggested that these changes can be explained by both natural climate oscillations and large-scale trends. The changes in patterns of ice motion are consistent with the dynamic response of sea ice to changing pressure patterns indicated by the Arctic Oscillation, which seem to transport thicker sea ice out of the Arctic Ocean. Anomalously warm air temperatures and ocean temperatures also appear to have contributed to less sea ice growth, resulting in thinner ice. Both warmer air and ocean temperatures are consistent with the warmer phase of the Arctic Oscillation.

Global climate model simulations also show that anthropogenic global warming trends since the 1980s have contributed to the present-day thinning and shrinking sea ice cover. The climate models show that greenhouse gases up to present day reduce the ice extent by 1 million square kilometers, similar to the reduction seen in satellite data. This decrease is not seen when models include only natural forcing, including solar radiation and volcanoes. There is, however, large natural variability in the ice records that makes verifying this trend difficult for several decades.

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International Partners in Ice Core Science (IPICS)

Jim White, University of Colorado; Eric Wolff

In order for the scientific community to have confidence in predictions of future climate, they need to understand the causes of past climate changes. Ice cores provide records at high resolution, with particularly good proxies for climate and atmospheric parameters. Ice cores have already revolutionized our view of the Earth System, providing, for example, the first evidence that abrupt climate changes have occurred, and showing that greenhouse gases and climate have been tightly linked over the last 400,000 years. Among the polar sciences, ice core studies have made a huge contribution to societally relevant and global-scale issues, such as understanding climate change and tracking the extent of global pollution. They have also been highly collaborative, with almost all the major breakthroughs carried out by consortia of nations.

Much more has still to be done, with the aim of meeting the challenge of understanding how the Earth's combined biogeochemical/climate system works, and how it will respond to the change in composition of the atmosphere currently taking place. A broad international group of ice core scientists recently met to plan a 10–15 year strategy for ice core science. This includes the goals of obtaining the longest possible climate records from both Greenland and Antarctica through deep ice core drilling, combined with collection of an array of coastal cores in both polar regions to assess the variability of climate and atmospheric circulation during crucial periods.

We propose here an ambitious project that will involve the efforts of all polar scientists, including the glaciologists, biologists and geochemists working on ice cores, airborne and surface geophysicists, and subglacial geologists. It will involve, first, several years of reconnaissance and mapping of areas of the poles that have typically received less attention than the interiors of the main ice sheets, then, at least a decade of coring and analysis of the Antarctic and pan-Arctic ice caps, coastal domes, and near shore ice.

Both the deep coring and coastal array elements of the IPICS strategy demand international collaboration and coordination. None of them can be attempted by any single nation. They involve both polar regions, and they require a kick-start that can be provided by an International Polar Year. Although the strategy will take at least ten years to complete, we propose during IPY to:

- commence the geophysical and glaciological surveys required to identify the location of the longest coherent climate record in Antarctic ice,
- commence the drilling to obtain the longest coherent climate record in Greenland ice,

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- commence the survey and drilling of a bipolar network of shallow and intermediate cores around the coastal regions of the polar ice sheets and caps.

The international group of scientists who propose this project see it as a bold step in our study of polar ice and a launching pad for a new generation of polar scientists. We would intend to include a significant outreach and educational programme within our work—ice core science is one of the most attractive and easily understood areas of scientific endeavor.

IPICS Committee: Richard Alley (Pennsylvania State University, USA); Laurent Augustin (LGGE, France); Nobuhiko Azuma (Nagaoka University of Technology, Japan); Erik Blake (Icefield Instruments, Canada); Edward Brook (Washington State University, USA); Hubertus Fischer (Alfred Wegener Institute, Germany); David Fisher (Geological Survey of Canada); Joan Fitzpatrick (USGS, Denver, Colorado, USA); Massimo Frezzotti (ENEA, Italy); Yoshiyuki Fujii (NIPR, Tokyo, Japan); Michael Gerasimoff (ICDS, University of Wisconsin, USA); Jean Jouzel (LSCE and IPSL, France); Valter Maggi (University of Milan-Bicocca, Italy); Paul Mayewski (University of Maine, USA), Joseph McConnell (Desert Research Institute, Reno, Nevada, USA); Heinz Miller (Alfred Wegener Institute, Germany); Vin Morgan (Australian Antarctic Division); Robert Mulvaney (British Antarctic Survey, UK); Dominque Raynaud (LGGE, France); Jakob Schwander (University of Bern, Switzerland); Margit Schwikowski (Paul Scherrer Institute, Switzerland); Jeff Severinghaus (Scripps Institute of Oceanography, UCSD, USA); Thomas Stocker (University of Bern, Switzerland); Pavel Talalay (St Petersburg Mining Institute, Russia); Kendrick Taylor (Desert Research Institute, Reno, Nevada, USA); Mark Twickler (University of New Hampshire, USA); Stefan Vogel (Byrd Polar Research Center, Ohio State University, USA); James White (University of Colorado, Boulder, USA); Frank Wilhelms (Alfred Wegener Institute, Germany); Eric Wolff (British Antarctic Survey, UK).

Arctic Forum Program

Thursday, 13 May 2004

8:00 a.m. Continental Breakfast and Registration

8:30 a.m. Welcome and Introductions — Arctic Forum Co-Chairs: Wieslaw Maslowski, Mark C. Serreze

8:40 a.m. Background on Sea Ice and Arctic Climate — Mark C. Serreze
Cooperative Institute for Research in Environmental Sciences
University of Colorado

9:10 a.m. Local Observations of Recent Change — Warren Matumeak
Barrow, Alaska

9:40 a.m. Observations of Decreasing Sea Ice Cover from Satellites
Josefino Comiso
Goddard Space Flight Center
National Aeronautics and Space Administration

10:05 a.m. Weekly to Interannual Variations in the Sea Ice Draft Distribution at the North Pole Environmental Observatory — Richard Moritz
Applied Physics Laboratory
University of Washington

10:30 a.m. BREAK

10:50 a.m. Variations in the Age of Arctic Sea Ice and Summer Ice Extent
Ignatius Rigor
Applied Physics Laboratory
University of Washington

11:15 a.m. The Rate and Causes of Arctic Sea Ice Melt: Modeling Perspective
Wieslaw Maslowski
Department of Oceanography
Naval Postgraduate School

11:40 a.m. The Arctic in Global Climate Models and Projections of Future Change
Gregory Flato
Canadian Centre for Climate Modelling and Analysis
Meteorological Service of Canada

12:05 p.m. LUNCH

1.35 p.m. The Role of Hydrology in Arctic Climate Change — Larry Hinzman
Water and Environmental Research Center
University of Alaska Fairbanks

2:00 p.m. The Role of Coastal Processes in the Arctic System — Volker Rachold
Alfred Wegener Institute of Polar and Marine Research

2:25 p.m. Déjà Vu: A Paleoenvironmental Look at Sea Ice Extent During Earlier Warm Periods — Julie Brigham-Grette
Department of Geosciences
University of Massachusetts

2:50 p.m. Carbon and Nitrogen Cycling and the Changing Arctic — Louis Codispoti
Center for Environmental Science
University of Maryland

3:35 p.m. Changes in the Arctic Sea Ice: What are the Consequences for Whales?
Robert Suydam
Department of Wildlife Management
Alaska North Slope Borough

4:00 p.m. Polar Bears, Seals, and Climate in Hudson Bay and the High Arctic
Ian Stirling
Canadian Wildlife Service
Environment Canada

4:25 p.m. Changing Marine Access in the Arctic Ocean — Lawson Brigham
U.S. Arctic Research Commission

4:50 p.m. Security and International Relations — Robert Hubert
Department of Political Science
University of Calgary

ARCUS Annual Reception and Banquet
Reception: 5:15 p.m.—State Room
Banquet: 6:45 p.m.—Terrace East & West Rooms

Special Presentation
Charles Wohlforth
The Whale and the Super Computer: On the Northern Front of Climate Change

Friday, 14 May 2004

8:00 a.m. Continental Breakfast and Registration

8:30 a.m. Welcome and Introductions Arctic Forum Co-Chairs: Wieslaw Maslowski
Mark C.Serreze

8:35 a.m. Impact of Climate Change on Alaska Native Communities
Patricia L. Cochran
Alaska Native Science Commission

9:00 a.m. Human Dimensions Research: Rational and Implementation Bruce Forbes
Arctic Centre
University of Lapland

9:25 a.m. Student Award Paper: Shrub Increase in Northern Alaska Documented Using Repeat Aerial Photography Kenneth Tape
Geophysical Institute
University of Alaska Fairbanks

9: 50 a.m. BREAK

10:45 a.m. ***Panel: Partnerships and Collaboration in Arctic Research***
Panel Discussion Moderator: David Klein, University of Alaska Fairbanks

- Julie Brigham-Grette, Department of Geosciences, University of Massachusetts
- Patricia Cochran, Alaska Native Science Commission
- Gregory Flato, Canadian Centre for Climate Modelling and Analysis
- Bruce Forbes, Arctic Centre, University of Lapland
- Ian Stirling, Canadian Wildlife Service, Environment Canada

11:20 a.m. Final Thoughts Arctic Forum Co-Chairs: Wieslaw Maslowski
Mark C. Serreze

11:35 a.m. Adjournment

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Special Presentation

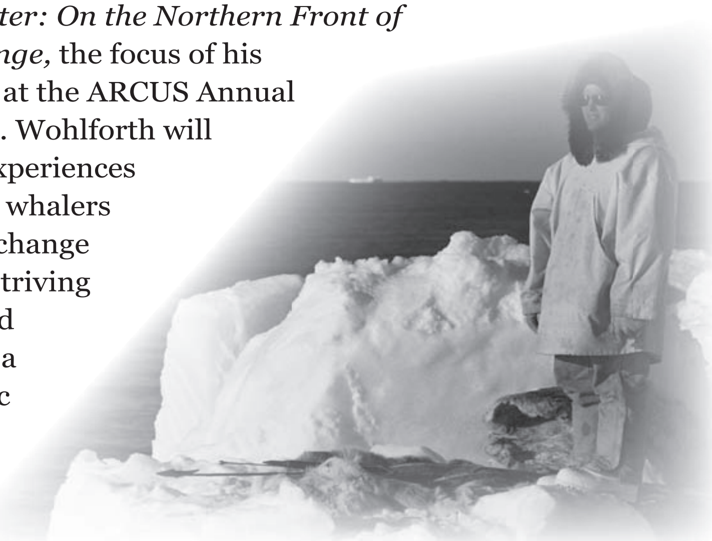
Charles Wohlforth

The Whale and the Supercomputer:
On the Northern Front of Climate Change

Thursday, 13 May 2004

Books will be available for purchase and signing.

Charles Wohlforth is a lifelong Alaskan whose passion for writing and devotion to the state of Alaska has seen him published in magazines such as National Wildlife and Outside. He is the author of several books, including *The Whale and the Supercomputer: On the Northern Front of Climate Change,* the focus of his presentation at the ARCUS Annual Meeting. Mr. Wohlforth will discuss his experiences with Iñupiaq whalers and climate-change researchers striving to understand and adapt to a shifting arctic landscape.



Special Presentation and Book Signing

ARCUS 16th Annual Meeting and Arctic Forum • Washington Terrace Hotel

Signing during Reception at 5:15 p.m. in the Stateroom. Presentation during Banquet, which begins at 6:45 p.m. in Terrace Rooms East & West. Members of the public are welcome to attend both events. Banquet tickets are $40 and may be purchased at the meeting, however, reservations must be made beforehand.