Lessons from Continuity and Change in the Fourth International Polar Year

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Amy Lauren Lovecraft, Editor

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PRESENTATION ABSTRACTS
(Arranged Alphabetically by Poster Author)
Energy Balance Coupling In Near Surface Snow Metamorphism

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Snow is a granular material which in the natural environment is consistently subjected to conditions conducive for phase change. Snow temperature and temperature gradient are primary parameters driving snow metamorphism. Dependent on circumstances, microstructure will develop a generally rounded or a faceted granular configuration. It is the ice grain and pore space microstructure that determine virtually all of the thermal, mechanical and optical properties of the snowpack. This presentation is focused on near surface metamorphism, which is profoundly influenced by changes in atmospheric conditions. The snowpack near surface properties define the dynamic interface with the atmosphere, therefore, the structure that develops is very sensitive to subtle environmental changes. Snow properties such as conductivity and solar albedo, which strongly influence the overall energy balance, are substantially altered with the morphology, motivating the research interest. In addition to atmospheric feedback from the snow, these properties have significant hydrologic implications. Mechanical strength is influenced, which can affect slope stability when surface layers are subsequently buried. Topography and terrain features such as vegetation and rock outcroppings are also important influences.

Small scale changes at the snow surface, resulting from environmental drivers, alter snow albedo, which may in turn feed back to the environment. These highly coupled processes are the focus of the current research. Our group has been working on development of software to calculate the energy balance at the snow surface in complex topography. The model utilizes digital elevation maps (DEM) to numerically fabricate terrain, taking into account properties of snow, vegetation and rock outcrops. Meteorological data coupled with geographic location allows for a means to calculate the energy input to small planar surface sections that together form a mosaic describing the terrain. Both infrared (long-wave) and solar (short-wave) radiation including shadowing, multiple refection and emissive contributions are accounted for. A surface thermal map, also accounting for the conduction from the underlying snow, provides an upper boundary condition that contributes to snow metamorphism. The model has been run on 30 m resolution USGS maps and is currently implemented on 1 m scale LIDAR generated topography across several mountain landscapes.

Complementing these field studies, laboratory investigation is underway utilizing a state of the art low temperature climate simulation laboratory, designed with snow metamorphism in mind. In addition to room temperature, the fully programmable chamber features a metal-halide solar simulation luminary, a cold plate (evaporator) covering the ceiling to simulate the sky long-wave emission and controlled room humidity. Physical alteration of the snow surface morphology and grain microstructure are monitored for specified environmental conditions. Features such as near surface radiation recrystallization, diurnal recrystallization, surface hoar, melt freeze, micro-penitents and the influence of contaminants are considered. As the metamorphic process proceeds, snow surface reflectivity in the visible through near infrared wavelengths is examined using a laboratory scale hyperspectral imaging system.
Forecasting Resilience in Human-Hydrological Systems for Arctic Societies

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Arctic communities are increasingly faced with social-ecological changes that act at variable speeds and spatial scales. Such changes are beginning to affect vital resources, particularly water supplies. Currently, there are few computational tools that integrate multiple social and environmental processes in order to aid communities’ adaptation to change. We propose a modeling and simulation approach that can integrate such processes at different spatiotemporal scales in order to address issues affecting community water supplies – Forecasting Environmental Resilience of Arctic Landscapes (FERAL). Demonstrating the proposed approach, an agent-based modeling tool is developed and applied to a community on Seward Peninsula. Results show patterns of water use and perceptions of water availability, enabling forecasting trends for this resource to be made based on current understanding. More broadly, we demonstrate the need for constructing tools that address issues at the community level for better understanding human and hydrological interactions and policy decisions affecting water supplies.

Findings from the AMAP 2008 Oil and Gas Assessment

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The Arctic Monitoring and Assessment Program (AMAP), under the Arctic Council, has recently completed a major assessment, Oil and Gas Activities in the Arctic: Effects and Potential Effects (www.amap.no), which draws on more than a thousand studies to investigate many aspects of oil and gas activities and their effects on the environment and people. Teams of scientists, with expertise in the many different fields required to undertake a comprehensive assessment of all the effects of oil and gas activities in the Arctic, have worked on each chapter. Their work has been subjected to national and international peer review. In this presentation, we will review the key findings of the assessment and then focus on the results of the chapter on “Social and Economic Effects.”

In the regions where they occur, oil and gas activities are major contributors to regional and national economies. As such, they are also drivers of social and economic change. Industrial activity creates employment opportunities and can also stimulate local businesses. Public revenues from taxes and royalties can be used to pay for improved public services, including schools and health care. At the same time, the magnitude and pace of development can mean more money to handle and the absence of one or more adults from the household during work periods. The arrival of large numbers of new workers can cause social and cultural disruption in small, remote communities. Impacts to the environment can be disruptive, too, if they affect traditional practices. An essential part of reducing negative impacts and capturing benefits is effective governance, which entails clear decision-making, public involvement, and an effective regulatory regime.

The lifecycle of oil and gas operations typically means that a great deal of activity occurs in early stages, particularly during construction. Employment opportunities come quickly but for many positions may not last long. There is relatively little time to train local residents, so that many workers are brought in from elsewhere, either to live or to commute for rotational jobs. In the production stage, jobs are more stable but there are fewer of them. The potential for disruption is thus higher at the beginning, precisely when local communities are learning to adapt to industry presence. Furthermore, the need for adaptive activities
such as training often occurs prior to the flow of revenues that might finance them. Where oil facilities expand over time to satellite fields, opportunities may last longer and allow local residents to adapt better.

Public revenues, on the other hand, tend to be more evenly distributed throughout the life cycle. For regions that can plan accordingly, oil and gas activities can form the basis for major improvements in public services and standards of living. Norway’s oil and gas policy, for example, is to develop its reserves to provide lasting benefit to the nation as a whole. The creation of public and private trust funds, put in practice in several regions and countries, is one means of capturing revenues for long-term use.

The involvement of arctic peoples in oil and gas activities is one way of harnessing the potential for benefit while also providing ways to anticipate and thereby reduce negative impacts. In Alaska and Canada, indigenous-owned businesses have become involved, particularly through oilfield services and related enterprises. The desire to develop petroleum reserves has also led to the settlement of indigenous land claims in Alaska and Canada. The public regulatory process also allows indigenous and other concerns to be heard during the decision-making process. In Russia by contrast, resources have been extracted without regard for land claims and with modest opportunity for local involvement.

Despite considerable progress in local involvement in some parts of the Arctic, oil and gas activities remain capable of creating dislocation and challenges from the rapid changes to people and communities from development. Handling the rapid and often temporary transition to a highly technical working environment was a challenge for many individuals in the Mackenzie Delta following the renewal of exploration activities there in 2000. Such family and money-management challenges typically occur at transition times, when activity levels go up or down sharply, and not just during boom periods.

Residents of regions with oil and gas potential have typically shown interest in developing those resources, along with caution about impacts and concern for equitable sharing in economic benefits. With the benefit of experience elsewhere, Greenland is planning carefully to develop service sector capacity and to develop resources at a pace that allows local involvement to remain high. Canada’s Mackenzie Delta region benefited from Alaska’s North Slope experience to the west.

Voices of the Caribou People – The Film

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Voices of the Caribou People is a film project by the communities, for the communities and the outside world. It is an initiative of CARMA (Circum-Arctic Rangifer Monitoring & Assessment Network) as part of their IPY research to monitor and assess the impacts of global change such as climate change, industrial development and associated cultural and economic implication on the Human-Caribou System. CARMA’s indigenous participants chose to use film as a tool to highlight their changing world and to incorporate the local perspectives in the broader social-ecological context. The aim of this project is to collect Voices from the communities that have long subsisted on caribou in the form of short videos and provide an opportunity to share those with other indigenous communities, give insight to CARMA researchers on local people’s needs of northern science, and communicate the important issues concerning human-caribou systems to the greater world.

Six communities across North America participated in the project this summer and the community members, which included elders and youth, leaders and hunters, men and women; talked about their observations about the changes affecting them and the challenges that they are face with about their sustainable future. A total of 97 people were videographed who talked about issues ranging from impacts
of oil & gas exploration, mining activities, non-local hunting, high energy costs to impacts of climate related variabilities. Important characteristic of this project is the commitment to tell their stories in their own voices. The participants found the videography to be very useful for several reasons. The elders felt it to be the communities’ legacy and repository of traditional ways, in the changing times. The leaders reckon visual images as a powerful medium to reach out to policy makers and greater public. These often isolated communities looked at this as a useful way of connecting with other indigenous communities and gateway for social and political exchanges among them. This 11 min film is a short snippet of the collective voice from these communities regarding their strong dependence of caribou and the challenges they are facing to meet their needs in wake of larger global changes.

**Cultural Preservation Program for Alaska**

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Recently the Long Term Ecological Research Program (LTER) and the Institute of Arctic Biology (IAB) held a workshop in Venetie with the purpose of assessing the community needs related to climate change. During this workshop people of the community stated the need to educate their own people because children are losing identity and they want bring it back. Given the desire to preserve the cultures identity I designed a Cultural Preservation Program.

Considering that culture is transmitted to new generations within the family and the community, I designed a method for knowledge preservation which actively involves the family and community.

Tape recorders will be left in schools or with tribal councils of different villages with the intention that pupils of primary and high schools take them home and record the knowledge of elders. The children will be given instructions on how to use the tape recorders and collect information. This will provide each child the opportunity to ask their own grandparent or other elders about their way of life in the past. In addition, stories about the past, children will interview their grandmother to document recipes she used to prepare meals in the past and then their mother to obtain the recipes she cooks with currently. The children will then e-mail their interviews to the Cultural Preservation Program website where the interviews will be archived.

This new method will trigger the process of transmitting knowledge from one generation to the next. In the first stage of the project, community members will be interviewed in the privacy of their own family using an inexpensive device, while enjoying family life at the same time. This provides children the opportunity to discover and rescue their own culture. In addition, they can share their experience with their families, friends, the community, and even with other communities.

Information from the interviews and interaction with school teachers, the program will develop environmental education programs. Videos about trapping, hunting, fishing, and hand crafting skills will be put in the web site with the help and advice of elders.

We will make comparisons between the nutrition value of past and current recipes. For better nutrition and successful interventions, we will need to incorporate strategies to improve diet choices, related to both traditional and Western foods. On the website there will be different videos showing the mothers healthy ways to cook foods obtained from subsistence activities. We hope that this will help reduce the levels of obesity and diabetes found in rural communities.
At the same time, we will help to implement outdoor for the younger generations. With the participation of elders, children can be taught skills needed for successful harvest of ecosystem products and also gain valuable experience. The first objective is to start with 2 Athabascan villages to calibrate the method and after that, we’ll apply it in all Alaska.

Frozen Soil Impacts on Stormwater Infiltration Treatment BMP Designs

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Infiltration treatment BMPs are used to mitigate the impacts of impervious developments by using soil as a filter to remove pollutants from runoff during infiltration. However, in cold regions, frozen soils negatively impact the performance of infiltration facilities by reducing the available pore spaces for infiltrating water, thus causing significant increase in runoff volumes. To understand the impacts of frozen soils on hydraulic conductivity rates and to determine how designers can better use infiltration treatment BMPs effectively in cold climates, laboratory experiments were carried out on two types of soils (loam and sandy loam) collected from two infiltration treatment BMPs sites located in Spokane and Richland, Washington. Hydraulic conductivity measurements for unfrozen and frozen soil columns were performed using a developed air permeameter flow test. The time allowed for soil-water redistribution prior to freezing was purposely varied among the soil columns (t = 2, 4, 8, and 24 hr) to investigate its significance on the reduction of hydraulic conductivity of frozen soils. The results showed that depending on the time allowed for soil-water redistribution prior to freezing, hydraulic conductivity decreased by 0 to 2 orders of magnitude along the depth of the frozen loamy soil columns, while it decreased by 1 to 3 orders of magnitude for frozen sandy loam soil columns. For both soils, the minimum reduction in soil hydraulic conductivity was observed when the soil columns were drained for a 24-hour prior to the onset of freezing. However, while a 24-hour of draining period was found to be sufficient for hydraulic conductivity of loamy soil to return back to its same order of magnitude before freezing (10-3 cm/s), it was found that this draining period is insufficient for frozen sandy loam soils to behave the same as unfrozen soil in respect to hydraulic conductivity. Using the results of this work, two regression equations have been proposed to guide the selection of an appropriate correction factor for hydraulic conductivity of loamy and sandy loam soils to incorporate in the design of highway BMPs in cold regions.

Abstract: Indigenous Knowledge, Climate Change and Education

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Climate change is already profoundly affecting the lives and cultures of people who depend on traditional ways of acquiring sustenance from the land. The observations of Alaska Native people today not only mirror scientists’ predictions, but provide firsthand evidence that the effects are being felt now. As scientists and Native people continue to document the effects of climate change throughout Alaska, educators have taken steps to develop curriculum resources that will help students better understand the forces that are impacting their future. Examples of these educational responses include the following programs, which will be described briefly:

- Science Observation Networks engage students in research on climate change
  - GLOBE (Global Learning and Observations to Benefit the Environment)
  - OLCG (Observing Locally, Connecting Globally)
  - MapTEACH (Mapping Technology Experiences with Alaska’s Cultural Heritage)
- Alaska Climate Modeling Program
A Changing Sense of Place: Climate and Native Well Being

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A 'sense of place' can be defined as a sense of belonging, attachment, and an individual or collective ownership of a particular location, especially a community. For Indigenous peoples, this concept of community is comprised not only of human beings, but extends to the landscape and its non-human inhabitants, and the spiritual relationship between all community members. Indigenous people actively draw on the power of their place physically and spiritually (Deloria and Wildcat 2001), forming a tie to traditional lands which can transcend generations living in an urban setting far removed from those lands. “It is this … place-based existence … that fundamentally distinguishes Indigenous peoples from other peoples of the world (Alfred and Corntassel 2005).”

But what happens to Indigenous peoples when changes in global climate drastically alter the very land itself? Global climate is naturally variable, and Indigenous peoples have successfully weathered those changes through a number of adaptation strategies (Houser et al. 2001). However, the current warming trend is happening at an alarming and unprecedented rate, with the Arctic region changing even faster than the global average (ACIA 2004). Noticeable and substantial shifts in weather patterns, ice formation, flora, and fauna are being observed, often within a single generation (Krupnik and Jolly 2002). In Alaska, severe impacts related to climate change are already being experienced, including thawing in discontinuous permafrost, increased ground subsidence, erosion, landslides, and disruption and damage to forests, buildings, and infrastructure. According to a 2003 report by the U.S. Government Accounting Office (GAO 2003), 184 Native villages in Alaska (~80%) are subject increasing erosion, flooding, or both due at least in part to climate change.

Climate change already poses drastic threats to the subsistence livelihoods of Alaska Natives, as many populations of marine mammals, fish, and seabirds have been reduced or displaced due to retreat and thinning of sea ice and other changes. But perhaps more devastating to Indigenous peoples than the immediate physical impacts are the social and cultural impacts that these changes trigger. Both the climate and the landscape provide an important sense of place for Native peoples, who are integral to the natural environment. As vegetation and wildlife species and patterns shift, Indigenous peoples experience of their environment is likely to change from the relationships that have been sustained through many generations (Houser et al. 2001), leading to substantial distress for both individuals and the community (Fox 2002).

This article explores a general framework that may help Indigenous peoples maintain their identity, their sense of individual and communal self, throughout these changing times. These principles include maintaining confidence in the ability to adapt, remaining grounded in cultural traditions and traditional knowledge, promoting healing within the community, and developing agile and adaptive leaders. While there is no avoiding the painful throes of adaptation to climate change, proactive measures such as these can help Alaska Natives and other Indigenous peoples weather the coming storm.


Opening the Arctic Seas: Envisioning Disasters and Framing Solutions

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Joseph Cunningham, University of New Hampshire
Amy Merten, National Oceanic and Atmospheric Administration
Nancy Kinner, University of New Hampshire

Cross Cutting Session: University - Community - Industry: Partnerships to Inform Policy Development

The Coastal Response Research Center (CRRC), a partnership between the National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration (ORR) and the University of New Hampshire (UNH), develops new approaches to spill response and restoration through research and synthesis of information. The Center, in cooperation with the U.S. Coast Guard Office of Spill Planning and Preparedness and the U.S. Arctic Research Commission, hosted a workshop entitled Opening the Arctic Seas: Envisioning Disasters and Framing Solutions in March 2008. The identified current international incident response capabilities assessed of future needs and identified research gaps and action items to improve the ability of Arctic nations and indigenous communities to prepare for and respond to marine incidents.

The decline of sea ice has resulted in increased activities such as: vessel traffic, oil and gas exploration, mineral speculation and exploration, northern-moving fisheries, and tourism in sub-Arctic and Arctic waters. In 2005, the Arctic Climate Impact Assessment reported that reduced sea ice will most likely lengthen the shipping season, shorten routes, and allow for more economical offshore oil development.
(Weller, 2005; Symon et al., 2005). In July 2008, the U.S. Geological Service (2008) estimated that the Arctic contains 90 billion barrels of oil and more than 17,000 trillion cubic feet of natural gas.

Participants represented a broad spectrum of constituencies and expertise: governmental agencies, industry, non-governmental organizations and indigenous people from the Arctic nations. Discussion centered on scenarios that involved: cruise ships, drill ships, and fishing vessels, as well as various environmental threats including oil and explosives. Through a scenario based analysis, attendees generated a list of recommended policies, strategies, and research needs aimed at mitigating risks. Research priorities were identified that address gaps in preparedness and response. The report serves as a resource for funding entities and a tool to inform the Arctic nations and Arctic Council about how best to address the current state of unpreparedness.

Common recommendations capable of significantly improving response and recovery included centered on: ports and waterways management; vessels and crew safety; response agreements and plans; and, strategies to improve prevention, preparedness, response, foster community involvement and, ensure availability of funds for response. Overall research needs included: update of weather data and navigational charts for the Arctic, study the behavior of oil in cold water and technologies for Arctic spill response; and, improvement of baseline information for Arctic resources that could be affected by potential incidents.

The main theme that resonated throughout all of the recommendations was fostering international cooperation between the Arctic nations. Such cooperation will be critical to: improving joint contingency plans and multinational agreements that guide international response efforts; and, developing and instituting mandatory safety regulations for Arctic operations. Another major theme was implementation of comprehensive prevention and preparedness measures such as conducting extensive risk assessments for the Arctic seas, shipping routes, and ports; and, increasing stockpiles of emergency response equipment and supplies throughout the Arctic. By properly managing risk using policies and strategies supported by sound scientific research will create opportunities for development and tourism in the Arctic with minimal environmental damage and loss of life.


The Human Rights of Climate-Induced Relocation

Robin Bronen, University of Alaska Fairbanks, Resilience and Adaptation Program

Climigration – forced migration due to climate change - will present one of the most severe challenges to resilience capacity for the communities forced to migrate as well as for local and national governments. The Intergovernmental Panel on Climate Change predicts that 150 million will be displaced by climate change by 2050. Erosion, flooding and sea level rise will be the primary causes.

Climigration involves the forced migration of communities because those communities are no longer sustainable for ecological reasons. Climigration is different from migration caused by catastrophic random environmental events because it involves an on-going change in a community’s habitat that impacts infrastructure as well as the livelihoods of the people residing in the community. Failure to recognize these ecological signals will critically impede a community’s ability to build resilience.
capacity. To determine which communities are most likely to be displaced, a complex assessment of a community’s ecosystem vulnerability to climate change, as well as the vulnerability of its socio-economic and political structures must be considered.

Alaskan indigenous peoples are at the forefront of this humanitarian crisis. Erosion is presently forcing communities to relocate. Currently, no organized planning or response mechanisms exist at the local, national or international scale for governments struggling to meet the enormous new needs of these communities. In Alaska, government agencies are struggling to respond to the relocation needs of Alaskan indigenous communities because their mission of disaster relief and erosion control is inconsistent with the tasks required to relocate these communities.

There is also no lead agency designated with creating a relocation strategy and coordinating the various agencies working on community infrastructure and related socio-economic needs. Tribes are also hampered because they may not have the capacity to administer government funds and have limited administrative staff to work with multiple government agencies on relocation activities.

To ensure the resilience capacity of these vulnerable communities, it is imperative that the international community create Guiding Principles on Climigration, based in human rights doctrine, to address this humanitarian crisis and guide national and local governments in their institutional response. Refugee law and the Guiding Principles on Internal Displacement provide a theoretical basis for creating these principles. However, neither addresses the complex crises of populations facing climigration.

Scholars often use the term “environmental refugee” to describe environmentally-displaced people. Refugee doctrine, however, does not provide an appropriate response. Refugee doctrine is based on the principle that a person needs legal protection because they are outside of their country of origin due to persecution by a government actor or an actor the government can not control. The majority of climigrants will migrate within their country of origin and no one government is responsible for a community’s migration. Most significantly, persecution is not a contributing factor in forced migration due to climate change. For these reasons the international refugee resettlement framework is not an appropriate solution to resolve the humanitarian crisis created by climigration.

The Guiding Principles of Climigration will create a common language to guide the international, national and local humanitarian response so that nation-states and local communities can implement an adaptation strategy that will ensure the resilience of the communities forced to migrate. The Principles will affirm the socio-economic and cultural human rights that must adhere to the relocation process. Forced migration creates significant stress on the well-being of those forced to leave their communities. These adverse consequences can be minimized only if the affected community is a key leader in the relocation process and culturally and linguistically appropriate mechanisms for participation are fundamental components of the relocation.

The Principles must also ensure that families and tribes remain together, that socio-cultural institutions remain intact and customary communal rights to resources are protected. The human rights principles regarding access to safe and sanitary housing, potable water, education and other basic amenities must also be affirmed. In order to create appropriate community infrastructure, a detailed socioeconomic survey must be completed of all affected households prior to the relocation. The Principles must also create a framework for creating sustainable development opportunities. In this way, the relocation process will enhance the resilience capacity of communities by addressing socio-economic issues.

Climigration is forcing communities to permanently relocate. Guiding Principles, based in human rights doctrine, need to be created to ensure the resilience capacity of these communities. These Guiding
Principles will then provide operational guidance to an institutional framework of response. The experience of Alaskan indigenous communities can guide the creation of these principles.

**Firn Densification Rates in the Percolation Zone of Western Greenland**

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We conducted ground based georadar surveys at thirteen locations along a 70 km long transect of the EGIG line in the percolation zone of the western part of the Greenland Ice Sheet. The purpose of these surveys is both to gain an understanding of the hydrologic pathways of surface generated meltwater as well as to measure densification of the upper 80 m of the percolation zone, and how densification rates change with elevation. To determine the density of a layer we assume a lack of liquid water and use the CRIM equation to solve for overall density from electromagnetic (EM) velocity. In this study we used three methods to solve for the EM velocity 1) Common Mid-Point (CMP) reflection analysis solving for velocity with a ray-based model inversion technique, 2) multi-offset, single line acquisition solving for velocity with a reflection tomography inversion technique, and 3) impedance analysis of single offset data to determine radar velocity variation with depth along a single trace. We show that near surface density varies laterally over tens of meters and that density curves calculated from CMPs are representative of measured core densities. The CMP density curves are smoothed over depth and represent volumes that are orders of magnitude larger than traditional core density curves; therefore they may be better measures of densification rates for regions of the Ice Sheet. We also found that firn density increases at significantly higher rates at lower elevation sites and that the rates at lower sites deviate substantially from standard firn densification curves.

**The Arctic/Subarctic Connection: Change in The Three Oceans Surrounding Northern North America**

Eddy Carmack, Ph.D., University of Alaska Fairbanks, Fisheries and Oceans Canada & Chapman Chair

The Arctic Ocean is, in fact, a great estuary, inextricably linked to its neighboring subarctic Atlantic (salty) and Pacific (fresh) oceans, and to the overlying wind-field that envelopes all three domains. Efforts to understand "changes" in the Arctic Oceans (e.g. warming, ice retreat, frontal and domain shifts, ecosystems responses and acidification) must take this system-wide view into account. In response to this challenge the Canadian-funded IPY program called Canada’s Three Oceans (C3O) was carried out in 2007/08 aboard two science-capable icebreakers - together encircling Canada - to establish a physical and biogeochemical baseline along a oceanographic transit extending from Vancouver Island in the subarctic Pacific to Newfoundland in the subarctic Atlantic. Preliminary results are presented along with selected examples of the types of changes currently ongoing at a frighteningly rapid pace, and of how neither the physics nor the ecology of advection can be ignored.
Connecting Fisheries to Places: The Community Quota Entity Program in the Gulf of Alaska

Courtney Carothers, Ph.D., Assistant Professor of Fisheries, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks

Fisheries enclosure has spread rapidly in North Pacific waters. The right to fish has been commodified for most large commercial fisheries in the region. As a result, very few fisheries remain accessible without significant capital investments for the purchase or leasing of fishing rights. Policies that limit and commodify fishing rights have disproportionately affected certain communities and certain groups of participants. For a complex set of reasons, indigenous fishing communities in Alaska tend to be disadvantaged by the switch to privatized fishing rights. This paper explores one recent program that attempts to redress this trend by providing a mechanism to redistribute the wealth in two privatized-access fisheries. The Community Quota Entity (CQE) program recently implemented in the Gulf of Alaska was designed specifically to enable a set of communities identified as having lost significant fishing rights to collectively recapture those rights. Drawing on ethnographic research in three CQE communities, this paper explores the political history of the program’s development, the factors that enabled certain communities to successfully organize CQEs, and the challenges that have prevented all but one CQE from actually purchasing fishing rights. As market-based quota programs continue to win favor in regulation, linking fishing rights to place may be a necessary step to provide for the sustained participation of indigenous fishing communities in the Gulf of Alaska. While the CQE program provides a mechanism for this, it has not successfully redistributed fishing rights.

Water And Climate Data Rescue On The Seward Peninsula: Accessing The Past, Planning For The Future

Jessica Cherry, Ph.D., University of Alaska Fairbanks
Jenny March, University of Alaska Fairbanks

The enhanced data collection efforts associated with the International Polar Year (IPY) 2007-2009 have also motivated scholars to look back at the observations collected during previous IPYs as well as other historical data. Considerable amounts of historical data relating to climate and water in the Arctic remain undigitized, uncataloged, or otherwise difficult to access. However, the perspective offered by such early records is invaluable to our understanding of long-term environmental change. This presentation describes efforts to identify, obtain, digitize, catalog, and build databases of climate and water related data for the Seward Peninsula, AK. This is a particularly sensitive region impacted by changes in sea ice, permafrost distributions, and other components of the climate system. Datasets include daily quantitative and qualitative weather observations from before 1948 and the National Ocean Service color and infrared aerial photography from the 1970s. Such data is highly relevant for planning and adapting to future climate changes.
Southeast Alaska Hydropower: Reconsidering Climate Variability And Change In The Development Process

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Amy Tidwell, Ph.D., University of Alaska Fairbanks
Nancy Fresco, University of Alaska Fairbanks
Susan Walker, NOAA-NMFS

The goal of this project is to assess whether recent precipitation and reservoir inflow anomalies in Southeast Alaska are within the normal range of variability over the observational record, or whether they are evidence of a potential regime shift associated with climate change. Total and seasonal water availability (rain and snow pack) appears to be changing with climate throughout southeast Alaska where hydropower supplies the majority of electricity. NOAA-Fisheries, Alaska Region and three climate and hydropower experts at the University of Alaska-Fairbanks are working with the municipal hydropower utilities managers to 1. Apply their understanding of large-scale climate variability to Southeast Alaska precipitation, temperature, evapotranspiration, snow pack, and reservoir inflow 2. Study long-term climate projections and watershed responses (mean and variability) downscaled to the catchments feeding the reservoirs 3. Consider how natural variability on seasonal-to-decadal scales and longer-term climate change affects water resource management. Progress to date is shown here.

Straddling The Line: Cooperative And Non-Cooperative Strategies For Management Of Bering Sea Pollock

Keith Criddle, Ph.D., University of Alaska Fairbanks

The eastern Bering Sea fishery for walleye pollock (Theragra chalcogramma) yields gross exvessel revenues about $⅓ billion and a first wholesale value over $1 billion; it is the premier US fishery. While there is general agreement that this fishery is managed under principles that will ensure sustainability, the eastern Bering Sea pollock stock is not wholly contained within the US EEZ and there are concerns about the role of historic and potential future catches from regions such as the Bogoslof Basin, the Donut Hole, and the Navarin Basin. The management of straddling stocks can be highly contentious and challenging, particularly when the stock is migratory or when the spatial distribution of abundance is variable. The absolute abundance of pollock and the spatial distribution of pollock abundance have varied considerably over the past three decades, with warmer conditions being associated with a shift of the center of abundance to the north and west, where a portion of the stock is subject to harvest by vessels licensed to operate in the Russian Federation EEZ. We use stochastic simulations to identify optimal cooperative and non-cooperative harvest management strategies from the perspective of US and Russian pollock fisheries under climate-induced changes in abundance and the distribution of abundance. Like it or not, this stock is a shared stock. Game theory suggests that cooperative solutions offer many advantages; identifying cooperative solutions provide important leverage in negotiations. In the absence of cooperation it is even more important to identify strategic noncooperative solutions.
**Hillslope Stability Affected by Permafrost Degradation in NW Alaska: Implications for Sediment Dynamics, Fish Habitat and the Sustainability of River Villages.**

**Benjamin T. Crosby**, Ph.D., Idaho State University, Department of Geosciences  
Neil Olson, Idaho State University

The sensitivity of arctic terrestrial ecosystems to climate change depends directly on the behavior and stability of arctic rivers and their drainage networks. These rivers determine the efficiency and process by which water, sediment, organisms, nutrients and chemical compounds translate from the uplands to the sea. Though large scale hydrologic, biologic and cryospheric systems have been extensively studied regarding their sensitivity to climate change (Manabe, 1980; Hinzman, 1992; ARCUS, 1998; Vorosmarty, 2001; Kane, 2003), most studies do not consider the impact of landscape instability, a fundamental boundary condition in those systems. In this study we explore how permafrost degradation in both coastal and upland environments results in hillslope instability.

Our first study site, the Baldwin Peninsula, extends 108 km northwest into Kotzebue Sound but narrows to a neck less than 700 meters wide at its midpoint. Currently, water discharge and fish runs from Selawik and Kobuk Rivers are routed around the northern tip of the peninsula. The eventual breach of the narrow neck will result in drastic changes in fish passage, the growth of the Noatak River delta and local economies dependent on subsistence and commercial fishing. GIS analysis of historical aerial photos, paired with field measurements of bluff retreat reveal three interesting findings: (1) erosion rates are similar on both the west (ocean-facing) and east (estuarine) sides of the peninsula, (2) bluff erosion is initiated by thermal slumping of bluff material but sustained by coastal undercutting and (3) coastal erosion has remained relatively steady (0.5 m/year on each side) over the 50 years of record.

Our second study site examines a large retrogressive thaw slump initiated along the banks of the Selawik River in the Spring of 2004. This failure delivers massive quantities of fine grained glacial till into the river. This slump has grown significantly since its initiation and by the summer of 2007 had liberated over 650,000 cubic meters of ice rich sediment. This sediment is delivered both to the river and to a growing debris fan that has partially dammed the Selawik River, flooding upstream reaches. Downstream of the slump, important spawning grounds for whitefish and sheefish are inundated with silt, compromising their viability and the health of the aquatic ecosystem many tens of kilometers downstream.

As warming in the arctic continues, the increasing frequency of landscape instability in both coastal and river environments will demand adaptation from both the human and biologic systems unique to this region. We find that though the environments and triggers are unique for coastal and inland features, their forms are surprisingly similar. Further study will provide an opportunity to find common physical conditions that lead to these events as well as offer insight into how long these features persist within the arctic landscape. Understanding these features will help local communities anticipate changes in the navigability of their rivers and coastal regions as well as anticipate future variability in fish stock essential to subsistence practices.

**Implementation of A Storm Surge Model For Western Alaska**

**Austin Cross**, University of Alaska Fairbanks, International Arctic Research Center

Storm surge is a major hazard for Alaskan settlements that needs to be better understood for forecasting. Storm surge is the rise in seawater from cyclones piling up water higher than average. When this high water reaches shore it can cause severe flooding, endangering life and property. This is particularly
problematic for many western Alaska coastal communities located at or near sea level, having been built on barrier islands and river deltas. Water levels any higher than normal can result in inundation of many areas.

Although much of the focus of research is on surge associated with hurricanes, winter low pressure systems can cause significant surge related flooding as well. Hydrodynamic models can forecast water levels resulting from surge based on available geographic and atmospheric data. Experimenting with the different atmospheric forcings, parameters and patterns can be identified for weather forecasters and emergency management personnel to recognize potentially destructive situations. Using real world data it is possible to model past scenarios and compare the results with water level measurements from gauges in Nome and Red Dog Mine on the western Alaska coast. If the results verify, the model can then be used to obtain water level values at innumerable other places where gauges may not exist to find past, present and future levels.

I am currently in the process of implementing one such model, ADCIRC, which requires intricate configuration to ensure accuracy. Results of the study are forthcoming.

**Large Scale Modeling of Arctic Sea Ice Algal Distributions**

**Clara Deal**, Ph.D., University of Alaska Fairbanks  
Scott Elliott, Los Alamos National Laboratory  
Meibing Jin, University of Alaska Fairbanks  
Elizabeth Hunke, Los Alamos National Laboratory  
Mathew Maltrud, Los Alamos National Laboratory

In the framework of the Los Alamos National Laboratory sea ice model, or CICE, a module describing the lower trophic level part of the ice ecosystem has been developed. This model includes an ocean mixed layer that supplies nutrients to the ice. A short description of the model is given and model results are discussed. The model simulates the seasonal variability in ice algal biomass and is forced by shortwave radiation, temperature, winds, climatological nutrients, and surface heat and salt flux. Application of the model to the entire arctic allows investigation of regional variability of sea ice algal primary production. The model results help interpolate between sparse measurements of the organic matter produced within sea ice, which sustains the ice-associated arctic food web. It is expected that the model will be run under diminishing sea ice conditions to investigate the impact of rapid change on the arctic sea ice ecosystem.

**Storm Track Climatology in the North Pacific: Relevance to Coastal States**

**Michel dos Santos Mesquita**, University of Alaska Fairbanks

Storm tracks drive dangerous coastal states. Surface winds associated with storm tracks may drive ocean waves that can impact the Arctic coastline. One example is the state of Alaska. Cities such as Kivalina and Shishmaref may have to relocate soon due to coastal erosion increase. Therefore, understanding the characteristics and variability of extra-tropical storm tracks that impact the Alaska region is of importance to emergency planning and hazard mitigation efforts. The North Pacific and Bering Sea regions represent loci of cyclogenesis and storm track activity.

In this research climatological properties of extra-tropical storms in the North Pacific/Bering Sea will be presented based upon aggregate statistics of individual storm tracks calculated by means of a feature-tracking algorithm run using NCEP/NCAR reanalysis data from 1948(49) to 2002, provided by NOAA-
CIRES. Storm identification is based on the 850-hPa relative vorticity field (Vr) instead of the more often used Mean Sea Level Pressure because Vr is a prognostic field, is a good indicator of synoptic-scale dynamics, and is directly related to the wind speed. Emphasis extends beyond winter to provide detailed consideration of all seasons. Results will be shown with respect to the frequency and intensity of the storms.

Major climatic indices that impact the North Pacific region were also correlated with the storm frequency and intensity. Results will also be shown with respect to the El Niño Southern Oscillation, the Trans Niño Oscillation and the North Pacific index. These indices are important in understanding underlying storm dynamics.

**Geophysical and Iñupiat Perspectives and Observations of Shorefast Sea Ice**

Matthew Druckenmiller, University of Alaska Fairbanks, Geophysical Institute
Hajo Eicken, Ph.D., University of Alaska Fairbanks, Geophysical Institute

This paper will examine ongoing efforts to observe the evolution of the shorefast sea-ice off Barrow, Alaska from multiple perspectives. While geophysical monitoring has been carried out systematically since the late 1990's, local indigenous knowledge has observed local and regional ice conditions for countless centuries as the Iñupiat people have pursued the traditional hunt of the bowhead whale and other marine mammals from the ice. In 2006/07 and 2007/08 a collaborative effort to share knowledge and coincident observations between these two fundamentally different ways of knowing has taken place. Local ice experts and experienced whalers kept observation journals and participated in interviews regarding the impact of ice conditions on hunting, travel, and assessments of ice stability and safety. Geophysical observations included a coastal radar to track near shore ice movement and stabilization, a coastal webcam for assistance in identifying key events in the shorefast ice's annual evolution, a mass balance site for monitoring level ice growth, sea level changes and snow accumulation, and SAR satellite imagery for identifying and tracking the extent of the shorefast ice edge. Ground-based electromagnetic induction sounding was used from a sled to measure the ice thickness distribution along the ice trails built by the community to access their whaling camps at the ice edge. These parallel observations are compared in the context of assessing ice stability throughout winter and spring. Differences in epistemology and in scales of observation are considered as this work attempts to identify areas where these seemingly disparate types of observations and knowledge may interface to improve the range of information accessible to those concerned with personal and community safety on the ice.

**Because Science Matters: Engaging Students In Chemistry By Using Traditional Knowledge**

Lawrence Duffy, Interim Dean Graduate School, University of Alaska Fairbanks

In our undergraduate chemistry courses, we need to engage students by including the concerns of our students as well as the place-based context they learn in. Including traditional knowledge when it intersects with a chemical principle or a challenging real world issue adds concreteness to the scientific process. Traditional and indigenous knowledge fits well with courses using the SENCER pedagogy.

Science Education for New Civic Engagement and Responsibilities is a national dissemination project for courses in science, technology, engineering and mathematics. SENCER courses connect science and civic engagement by teaching through complex, capacious, current, and unresolved public issues to the underlying scientific principles. The more that our students are exposed to culturally responsive chemistry courses that encompass biocomplexity, the more effective they will be as agents of long-term stewardship
in the circumpolar north through periods of rapid change and ecological challenge. It is therefore critical that issues such as sustainability, environmental health, food security and precaution be integrated into science teaching. In studying public issues of the north, students and faculty can use examples from Traditional Knowledge to illustrate the use of chemical principles. As part of the IPY UARCTIC effort, examples from climate change, nutrition, nuclear science and chemical ecology were developed to illustrate this integration.

These place-based examples of traditional knowledge were used in three courses: 1. Chemistry and Complex Systems; 2. Introduction to Radioactivity in the North; and 3. Demystifying Biotechnology. Exposure to traditional knowledge broadens the average students’ world view and strengthens their understanding of the scientific process (funded by NSF Division of Undergraduate Education).

**The Potential Contribution Of Arctic Observing Networks And Local Knowledge In Reducing Environmental Risks And Impacts In Arctic Offshore Oil And Gas Exploration**

**Hajo Eicken**, Ph.D., University of Alaska Fairbanks, Geophysical Institute & International Arctic Research Center,
Sharman Haley, Ph.D., University of Alaska Anchorage, Institute for Social and Economic Research
Richard Glenn, Ph.D., Barrow Arctic Science Consortium & Arctic Slope Regional Corporation
Amy Lovecraft, Ph.D., University of Alaska Fairbanks, Department of Political Science,
Nathan Coutsoubos, University of Alaska Fairbanks

During the Fourth International Polar Year (IPY), substantial planning and implementation efforts have gone into building up a series of Arctic Observing Networks to help track, understand, and respond to Arctic environmental change. Many of these observing programs are focusing on climate and ecosystem change. However, the substantial socio-economic and geopolitical transformations underway in the Arctic create an urgent need for information that can help planners and decision makers and Arctic communities in general respond and adapt to rapid change. Arctic coastal and offshore oil and gas exploration is one such area where scientific observation program activities and information needs overlap. Moreover, many of the environmental challenges of coastal and offshore oil and gas exploration could potentially benefit and receive significant guidance from an exchange with local and indigenous knowledge holders.

We report on activities that are part of the University of Alaska’s North by 2020 Forum on Local and Global Perspectives on the North (www.alaska.edu/ipy/north2020/main.xml) aimed at improving communication and exchange between academia and the key stakeholder groups. Specifically, we discuss the role of the University as an honest broker of information emerging out of academic and community-based observation networks relevant for decision makers. While somewhat removed from the traditional responsibilities of the university for teaching and research, such a role is commensurate with the challenges posed by increasing intertwining of environmental, socio-economic and (geo)political problems extending over a range of scales. At the same time, the role of honest broker also presents an opportunity for research and student training that bridges the traditional gaps between fundamental, applied and local knowledge.

Working with a broad group of experts that represent the major stakeholder groups in Arctic coastal and offshore oil and gas exploration (local communities, federal, state and local-level regulators, disaster response agencies, industry, environmental organizations, and academia) we held a workshop to explore the question of “How technological advances, local knowledge, science and adaptive management can help minimize environmental risks and impacts of offshore oil and gas, particularly in the exploration phase?” The workshop took place in mid-November 2009 in Barrow, Alaska and drew roughly 90 participants with a broad range of backgrounds but some level of expertise in the problems discussed.
The meeting was successful in accomplishing its goals and generated a number of key conclusions and follow-on activities that we will discuss in more depth in our presentation. The meeting participants and related activities of the North by 2020 Oil & Gas theme provide important guidance on what is required to more effectively exchange knowledge and information at the interface of indigenous (Iñupiaq) and western environmental science, how to improve communication to help identify common values and avoid misunderstandings, and how academia can best be involved in an appropriate role.

Alaska Native Voices and Economic Development

Faith Gemmill, Executive Director, Resisting Environmental Destruction on Indigenous Lands

This abstract supports the idea for an Alaska Native Panel: Voices of Impacted Community Members.

We believe that the voice of impacted community members in relation to further development of the Arctic would benefit this year’s symposium which focuses on the lessons learned from polar research as well as the lessons learned elsewhere that can inform studies of the Arctic. Often, the people that will be impacted most are ignored in the debate, and it is time for this to be rectified.

At this time, there are many areas in Alaska under threat by proposed economic development projects within the lands and oceans that sustain the subsistence livelihood of Alaska Natives, and Alaska Native peoples are in duress in face of these impending projects.

Subsistence in Alaska is of critical importance to Alaska Natives; subsistence is about our entire way of life. We, the Indigenous peoples of Alaska rely upon our lands to provide for our necessary physical, cultural, spiritual and social needs. Subsistence encompasses all facets of our lives. When we defend our subsistence rights we are defending our inherent sovereign rights.

Therefore, Alaska Natives strongly reject the notion that our ancestral homelands can be put forth as national sacrifice areas through attempts to access the remaining lands and seas that Alaska Natives rely on for subsistence needs for mining, oil and gas and other unsustainable fossil fuel development. These economic development plans are part of unjust US energy and economic development policies put upon us and our homelands and the waters that nourish our lives are at threat due to these policies.

Alaska Natives are challenging the oil industry and demanding our rights to a safe and healthy environment conducive to subsistence. Alaska Natives aim to address the human and ecological health impacts brought on by unsustainable development practices of the fossil fuel industry, and the ensuing effect of catastrophic climate change. Alaska Natives support the self determination right of Tribes in Alaska, as well as a just transition from fossil fuel development to sustainable economies, and sustainable development.

The Outer Continental Shelf (offshore) of Alaska almost in its entirety including 83 million acres offshore within Cook Inlet, Bristol Bay, Chukchi and Beaufort Seas is at threat under the five-year OCS plan of the US government. Shell Oil and ConocoPhillips are poised to begin OCS offshore oil and gas development. This issue touches at the heart of the subsistence debate, because Alaska Native coastal villages’ subsistence way of life is so interconnected with the oceans and is now endangered.

The Arctic National Wildlife Refuge is the last 5% of Alaska’s northern coast that is protected, 95% is already open to oil and gas development, yet ExxonMobil, ConocoPhillips, ChevronTexaco and BP are seeking access to this area which imperils the Gwich’in and Inupiat subsistence way of life.
Teshekpuk Lake of the National Petroleum Reserve of Alaska, a place of significance to the subsistence needs of the Inupiat is at threat. The National Petroleum Reserve has already been encroached upon to create Alpine oil field which surrounds the community of Nuiqsut and now has severe and serious human and ecological health impacts.

In the Yukon Flats Wildlife Refuge, the US Fish and Wildlife Service is actually considering a land exchange with Doyon Native Corporation to facilitate oil and gas development within this wildlife refuge set aside for subsistence purposes and which is the prime use area for Gwich’in and Koyukon Athabascans.

Violations of the integrity of Alaska Native ancestral lands are now felt globally through catastrophic effects of climate imbalance and warming of the North. Alaska Natives are hit first and hit hardest by global warming in the Arctic. The current climate imbalance impacts every facet of Alaska Native traditional subsistence way of life which is so interconnected to the land.

Our lands no longer are able to withstand the massive exploitation that is the result of unsustainable energy policy of the US government and State of Alaska. Alaska Natives support sustainable energy solutions to address the current energy crisis of the US. We believe that it is time to transition toward sustainable and renewable energy development.

We can no longer abide the destruction and legacy of fossil fuel and other forms of exploitation and development in Alaska yet when these issues are discussed in forums, the voice of impacted community members becomes lost as scientists, biologists, petroleum experts, corporation representatives and Alaska state representatives dominate the discussion, meanwhile the people of this land are the ones with the most at stake.

**Climate Change, Food Systems, and Community Needs in Alaska**

Craig Gerlach, Ph.D., University of Alaska Fairbanks
Philip Loring, University of Alaska Fairbanks
David Atkinson, Ph.D., University of Alaska Fairbanks

In this paper we use the Alaskan food system as a framework for understanding community vulnerabilities and barriers to response to climate change and other related challenges faced by Alaska’s communities, both rural and urban. Across the state communities are engaged in dramatic ecological, economic, cultural, and demographic restructuring; in a global context climate change and economic turmoil, the costs and uncertainties of living in Alaska are on the rise and trends like rural-to-urban migration is undermining community stability, health, and futures at both ends of the rural-urban axis. Though ecological variability has always been an aspect of life in Alaska, households and communities that rely heavily on Alaska’s wild, ‘country food’ resources are especially vulnerable to the new and unprecedented environmental variability and changes that are now occurring: changes in terrain and land cover, unpredictable and extreme weather, and shifts in seasonality, to name a few. With people now mostly geographically-fixed to their communities by infrastructure and sources of wage income, and restricted in their ability to traverse the landscape by the patchwork of regulatory structures, resource management regimes, and private, state and federal land ownership, the flexibility that once supported many thriving Alaskan lifestyles is significantly constrained. The necessary alternative is to find short-term livelihood security in increased wage-earning (when jobs are available) and with imported, store-bought foods. This is a transition that is already gentrified in many places throughout the state, though it brings its share of additional vulnerabilities and consequences that many find unacceptable but unavoidable.
What tools and support to people and their communities need if they are to more healthfully respond to the contemporary challenges of climate change? We report from two seasons of needs assessment done across the state with a transect of Alaskan communities, both coastal and up-river, north and south, rural and urban. We find that ecological change, policy and regulation, and the household experience each proceed at a different set of spatial and temporal scales, and for the fisher or hunter or farmer, and this leaves interstices between what is experienced, what is needed, and what can be done. Across the board, community members highlight their need for assistance bridging these gaps so that they can better and more effectively respond. More high-quality and locally-scaled information, better institutional flexibility, and a general climate of support and facilitation for local responses are invariably described as essential where they are already in place, and greatly in need where they do not.

In order to assure a food secure-future for these communities, they require both a resource governance regime that affords them the freedom to innovate and adapt, and access to quality climate and weather information so that they might predict water and landscape conditions and make the best decisions about where and when to hunt and fish in times of uncertainty. Communication between scientists and rural communities is improving with mutual awareness through collaboration, although more work is still needed from both sides before it will be possible to correlate and integrate spatial, temporal and observational scales. Subsistence harvests are daily and seasonal, whereas climate models are often based on decades and/or millennia, and do not always provide the high quality weather information needed on a seasonal basis. There is a need to synthesize and communicate climate change information to both institutions and local communities. For planning purposes, forecasters must move toward integrating fine-grained local and regional climate and seasonal weather information with community-based knowledge through hunter experimentation and testing in the field. New paradigms for effective linkages between institutional and local responses to change also must be explored, so that communities are empowered to make local decisions regarding resource management based on the highest-quality local and scientific knowledge and observations.

**Strengthening Institutions For Stakeholder Involvement In Management of Offshore Oil And Gas**

**Sharman Haley**, Ph.D., University of Alaska Anchorage, Institute of Social and Economic Research
Chandra Meek, University of Alaska Fairbanks
Jim Powers, University of Alaska Southeast
Branka Valcic, University of Alaska Fairbanks

Iñupiat hunters use the Beaufort and Chuckchi Seas intensively for marine mammal harvesting. This customary and traditional use is of critical importance culturally, socially and spiritually as well as nutritionally and economically. Oil and gas activities in particular, and marine traffic in general, pose some level of risk to the health and distribution of marine mammals, hunter access, and the marine ecosystem generally. Unlike the policy arenas of wildlife management and onshore federal lands management, Iñupiat interests in the offshore marine environment are not formally represented in governance institutions designed to facilitate and regulate mineral extraction. Therefore, their role in decision-making is not commensurate with their stake in the outcomes. This paper discusses why this is inefficient and reviews a range of institutional options for incremental change to better incorporate stakeholder interests in the management regime.

We start with an overview of the current stakeholder interests and institutional arrangements. This includes a review of past and present conservation measures to protect key subsistence areas, including the deferrals of leasing tracts surrounding several, but not all, community whaling areas on the North Slope. It also includes discussion of conflict avoidance agreements negotiated by industry with the Alaska Eskimo Whaling Commission. The next section provides the theoretical framework. It includes
development and application of the theory of externalities in this context, as well as a legal analysis of court cases defining historically why Inupiat have no recognized aboriginal claims in the sea, discussing the principle of federal preemption and the corresponding federal obligation to consider Inupiat interests in decision-making.

The legal basis for exercising regulatory authority on the Alaskan Outer Continental Shelf (OCS) is established in federal law. Questions have been raised during the most recent review of Shell Offshore, Inc. proposed plan for oil and gas exploration in the Beaufort Sea on federal obligations to consider Inupiat interests in decision-making on the OCS. In this section we review federal law, the Alaska Statehood Act, the Alaska Constitution, international law, Canadian territorial/federal laws as well as relevant case law to examine avenues for Inupiat voice in the process of oil and gas development on the OCS. While many of the traditional avenues for stakeholder participation have been explored, including appeals of EPA permits and litigation through the U.S. Court of Appeals, 9th Circuit, other potential avenues may exist.

This paper will also examine whether a case can be made for the extension of terrestrial jurisdiction to offshore areas due to the existence of adjacent sea ice. With the increased interest in development of oil and gas reserves in the northern regions, other Arctic countries are struggling with similar issues. Despite the fact that many Arctic country’s legal structures differ from the United States, they may have best management practices in use in that could be considered for adoption in the U.S.

Possible mechanisms for strengthening institutional representation of Inupiat in offshore governance include: Marine Protected areas or cultural heritage protected areas; Co-management institutions; expanding Coastal Zone management in the offshore; and expanding Title 19 planning and zoning powers of the North Slope Borough.

**Arctic Transport Today and Tomorrow: Implications of a Changing Marine Environment at the Top of the World**

**Nancy Hemsath, Institute of the North**

Early in the 21st century, the Arctic is undergoing extraordinary changes. Long known as a storehouse of untapped natural resources, high commodity prices and a growing worldwide demand in recent years have the Arctic poised as a significant contributor to the global economy. Increasing regional and coastal marine transport to support the exploration and extraction of oil, gas and hard minerals, coupled with the increasing presence of the global marine tourism industry, have created a complex set of users in the maritime Arctic. The potential impacts are unknown, but will be significant for Arctic indigenous people and the marine environment already undergoing significant changes. Simultaneous with the globalization of the Arctic, marine access in the Arctic Ocean has been changing in unprecedented ways driven by global climate change. Arctic sea ice is undergoing a historic transformation which has significant implications for longer seasons of navigation and new access to previously difficult to reach coastal regions. The international scientific community has already taken advantage of these changes through pioneering voyages in the central Arctic Ocean. The same sea ice retreat also has important influences on the regional, Arctic marine ecosystems and future fisheries. Taken together, these changes present increased pressure on the existing legal and regulatory structures already challenged to meet the needs for enhanced marine safety and environmental protection. Such challenges will require unprecedented levels of cooperation among the eight Arctic states and broad engagement with many non-Arctic stakeholders and actors within the global maritime industry. In November 2004, the Arctic Council Ministers asked the Protection of Arctic Marine Environment working group to conduct a comprehensive Arctic marine shipping assessment under the guidance of Canada, Finland and the United States. AMSA data gathering
and planning began in summer 2005. The foci of the assessment are marine safety and marine environmental protection. AMSA was designed to be circumpolar in breadth, but also considers regional and local perspectives where impacts, particularly on Arctic communities, are considered to be greatest. However, the overall scope focuses on ships, their infrastructure needs and impacts in the Arctic Ocean. More than 180 experts participated. Twelve major workshops covered: scenarios of future Arctic navigation; indigenous marine use; Arctic marine incidents; environmental impacts; Arctic marine infrastructure; and the future of Russia’s Northern Sea Route. Town hall meetings were conducted in northern communities in Canada, Norway and the United States. The AMSA 2009 Report, is designed to educate and inform the Arctic Council, the Arctic community, the global maritime industry and the world at large about the current state of Arctic marine use and future challenges. This report will be a negotiated text, agreed upon by the eight states of the Arctic Council: Canada, Denmark, Finland, Iceland, Norway, Sweden, the Russian Federation, and the United States and will be presented to the April 2009 Arctic Council Ministerial meeting in Tromso, Norway. The report is a condensed version of a larger detailed study compiled and drafted by the AMSA Team titled the Arctic Marine Shipping Assessment Research Document.

Moved by the State and Left Behind: Local Reactions to Forced Relocation in a Coastal Zone of the Russian North

Tobias Holzlehner, University of Alaska, Department of Anthropology

State induced resettlement policies intertwine political macro processes, local communities, and various forms of belonging in the uprooted landscape of relocation. This paper reflects on a case study of forced relocation, which occurred in several villages around Chukotka’s East Cape, in Northeastern Russia. From the 1930s to the 1960s the inhabitants of mainly native coastal villages have been subjected to a relocation policy by the Soviet state that left dozens of settlements and hunting bases deserted. For ostensible military and/or economic reasons, flourishing native communities were closed and the inhabitants were forcibly relocated to larger villages. These forced relocations were part of a process of state making during the Cold War, at a time when the Soviet Union consolidated its northeastern border with the United States. Coastal villagers, especially of Eskimo origin, were seen as potential “imperialist spies” due to their proximity and kinship relationships with Alaskan Yupik Eskimos across the Bering Strait. The politically forced resettlements in this coastal border zone can be seen as centripetal forces that pull unbound elements towards the center of the state, politically as well as economically. The collapse of the Soviet Union destroyed these bonds and left the uprooted people behind.

This paper explores local reactions to translocal forces through time (i.e., Sovietization of the High North, the Cold War, and collapse of the Soviet Union). Focusing on individual strategies of place making amidst a relocated population, the paper addresses the central role of memory and nostalgia in relation to border landscapes and state policies. Space and place making as significant elements of landscape inhabitation have been thoroughly acknowledged. But what becomes of a place when it has been abandoned? What of the attachment to and the sense of place when one is forcibly removed from the dwelling?

As a social history of ghost towns, this paper tracks the life histories of its former inhabitants through the landscape of forced relocation at the high point of the Sovietization of the Russian North. At the same time, contemporary strategies of past inhabitants to make sense and use of the abandoned village sites are considered. The ruins of former settlements are not only places of the past, but also play a role in present-day lives as some individuals have moved back into formerly abandoned village sites or have reestablished hunting bases in the vicinity of old settlements. Thus the paper explores notions of
abandonment and nostalgia in relation to space and examines stories and strategies of how coastal people in Chukotka come to terms with the ruins of a volatile past.

**Optimized Decision-Making Software allows to evaluate and forecast impacts of Sustainable Development and Oil & Gas Activities: Protected Areas beyond the MARXAN algorithm**

Falk Huettmann, Ph.D., University of Alaska Fairbanks, Institute of Arctic Biology

The Arctic represents a precious region of the globe affected by climate change, human disturbance and natural variation. It is considered one of the last remaining wilderness areas, but major development plans, e.g. oil & gas and transportation, are currently being proposed or already underway stressing resources and environments. A public discussion on the protection and development of the Arctic has not really happened, and would be difficult to implement globally if traditional avenues are followed. It is obvious that the planned 10% protection regime and the current impact legislation and its related culture basically fails and needs re-thinking. Here we present a MARXAN software optimization modeling analysis taking into account 50 circumpolar GIS layers and model predictions for marine and terrestrial ecosystems. This methods represent best available science, Strategic Conservation Planning, and is widely applied for Marine Protected Areas (MPAs) elsewhere to resolve conflicts. Our models help to assess the previous performance of sustainable development. Further, it allows to find the best available solution for impacts brought by oil and gas development, or related transportation and climate change, using base-scenarios. GIS-based solutions presented are a first step and require to be further fine-tuned and approved by various governments, stakeholders and legislation. The pre-cautionary principles outlined by IUCN, as well as best professional practices, truly applies to the Arctic and its Ecological Services. But based on the track record in the Arctic and world-wide, it becomes obvious that developing the Arctic involves loss of genetic diversity, habitats, and sustainability, and that it is currently detrimental to existing legislation even. We are proposing to make data-based Strategic Conservation Planning a legal policy requirement for Arctic development schemes, and that it could become another legacy the International Polar Year (IPY) could provide for the global village.

**An Arctic Water Resource Vulnerability Index for Community-Based Assessments**

Andrew Kliskey, Ph.D., University of Alaska Anchorage
Lilian Alessa, University of Alaska Anchorage
Richard Lammers, University of New Hampshire
Chris Arp, United States Geological Survey
Dan White, Ph.D., University of Alaska Fairbanks
Larry Hinzman, Ph.D., University of Alaska Fairbanks

People in the northern latitudes face increasing uncertainty in their daily lives as they contend with rapid environmental changes at multiple scales. Despite the importance of water resources at local scales indicators have been developed that operate from regional to global scales and for mid-latitude to equatorial environments. Until 2008, no appropriate index existed for assessing the vulnerability of Arctic communities to changing water resources. The Arctic Water Resource Vulnerability Index (AWRVI) was developed in response to this key need so that stakeholders could easily assess their relative vulnerability to changes in their water resources. AWRVI is based on a social-ecological systems perspective that includes physical and socio-economic indicators of change and is demonstrated in three case study communities / watersheds in Alaska. For the first time, AWRVI allows an improvement in the diagnostic capability of examining the suite of constituent physical and social scores as a composite in which individual indicators yield valuable guidance for developing adaptive strategies for resilience.
The Impacts of Oil and Gas on Arctic Peoples Using a Multiple Securities Perspective (GAPS)

Alana Kronstal, University of Victoria, Studies in Policy and Practice

In current political discourse, matters of security in the northern regions are most often raised in relation to concerns about arctic sovereignty. In contrast, the GAPS International Polar Year project draws on the concept of human security to provide a theoretical lens from which to consider the potential impacts of oil and gas activity on Arctic peoples. Indeed GAPS researchers from Canada, Norway and Russia have explored how multiple processes interact to support human security in the Arctic, or to render people insecure, as they face increasing change. This presentation highlights research completed to date as part of GAPS that include a study on invasive plant species along pipeline routes, an examination of the role of resource extraction on First Nations governance, an in-depth look at the state of homelessness and housing security in a northern territory, and a study exploring mental health and addiction issues in the Northwest Territories of Canada.

This presentation outlines the goals of the GAPS initiative and the various sub-projects which underlie it. It expands the way in which the concept of human security is used and suggests it can function as a tool to link research between natural and social scientists. It closes with comments on the collaborative measures taken to ensure community and local perspectives are prioritized and reflected in this multi-disciplinary, multi-country research initiative.

Successful Aging Through The Eyes Of Alaska Natives. The Health and Wellbeing Of Alaska Native Elders

Jordan Lewis, University of Alaska Fairbanks

Much of the literature addressing successful aging focuses on non-minority populations, establishing a broad definition of what it means to age successfully based on mainstream concepts and definitions of aging. Consequently, this mainstream definition of successful aging precludes localized and indigenous perspectives and runs the risk of assessing them inappropriately as aging less successfully than their non-minority counterparts. Through in-depth interviews with Alaska Native elders in Bristol Bay, this study investigates the cultural beliefs about aging from an Indigenous perspective. Utilizing qualitative research with an inductive research analytic strategy (Grounded Theory), ideas, concepts, and themes emerged from the data. A purposive sample of seventeen Alaska Native elders in the Bristol Bay region (four villages) representing Aleut, Athabascan and Yup'ik Eskimo groups were interviewed. The Explanatory Model (EM) interview consisted of 15 questions and enabled the researcher to establish a conceptual understanding of successful aging among the different Alaska Native cultural groups in Bristol Bay. Focus groups will be conducted in three separate villages to share the interview results in order to triangulate the data from this study. The hypothesis of this research study is that those elders who are able to continue living a subsistence lifestyle, engage in cultural activities, have a family support system, and pass down their traditional knowledge will age successfully in their communities.

Insight into how successful aging is defined by Indigenous people will inform the factors that determine whether or not villages are able to meet the needs of their elders and enable them to live their remaining years as they wish. This research explores the concept of successful aging from an Alaska Native perspective and the idea that the presence of elders contributes to the health of the community.
The Role of Alaska Native Elders In The Cultural Resilience Of Rural Communities

Jordan Lewis, University of Alaska Fairbanks

Alaska Native elders play a vital role in the resilience of Alaska Native communities and in order to ensure they are able to continue preserving the culture and language, it will be important to have social institutions in place that are flexible and adaptable to change. Cultures and communities will continue to evolve over time and in order to ensure their survival, it will be important that Alaska Native elders and systems are able to adapt to change and bridge the traditional and modern institutions. This research addresses the role of Alaska Native elders in adding value to communities and about our collective responsibilities to support community and cultural resilience.

Ways to Help and Ways to Hinder: Climate, Weather and Policy in Alaska

Philip Loring, University of Alaska Fairbanks

Climate change poses unique challenges to livelihoods in Alaska, for residents of rural and urban places alike. If these challenges are to be met, they require that people be afforded the flexibility to experiment and innovate in response, and have the best possible information at hand when doing so. However it is questionable whether current paradigms for land tenure and natural resource management policy and for information sharing and social learning are even compatible with the needs that they are now expected to serve. Indeed many have provided examples of how existing policy structures and learning practices tend to complicate, rather than empower, local decision making abilities.

How might we better understand the fundamentals of this apparent disconnect between environmental change, policy, and action, such that we might design new structures of learning and governance that can facilitate addressing these highly complex problems? This poster synthesizes the findings of two seasons of needs assessment done across the state, with a transect of Alaskan communities coastal and up-river, rural and urban, comparing experiences with environmental change, resource management, and land tenure. We find that the household experience, resource management policy and regulation regimes, and ecological change all proceed at their own set of spatial and temporal scales, and for the fisher or hunter or farmer this leaves interstices between what is experienced, what is needed, and what can be done. The poster compares the circumstances of two seemingly different livelihoods: the small-scale commercial fisher in Dutch Harbor, and the subsistence hunter in Fort Yukon. Both share similar goals of making a living, make decisions at similar spatial and temporal scales, and have to navigate problems of environmental variability and resource competition within a complex context of resource management policy. Each, however, has a very different experience that is driven at least in part by differences in the policy and information regimes of which they are a part. High quality and locally-scaled information, better institutional flexibility, and a general climate of support and facilitation by state and federal agencies for local responses to environmental challenges are invariably described as essential where they are already in place, and greatly in need where they do not.

The details of these cases should be of interest to anyone involved in the development of new paradigms for effective linkages between institutional and local responses to change. When local expertise is legitimized by a policy regime that affords flexibility and decision-making, and empowered by the highest-quality science and needs-driven, locally-scaled forecasting products, a variety of outcomes including household success and individual health and safety, and the responsible management of local resources become necessarily linked. What this means is that while scalar incongruities between the state, environmental change, and the household experience may be irreconcilable, the very need to bridge these
gaps may provide an exciting, new and more powerful mandate for designing the policy and information institutions of the future.

**Additional Reference Data Via High Resolution Imagery and Autocorrelation Issues**

**Sylvio Mannel, Ph.D., Idaho State University**

Reference data and accuracy assessments via error matrices build the foundation for measuring success of classifications. Erroneous or insufficient reference data can lead to skewed accuracy results which are often falsely attributed to the classification method. For a forest study we supplemented our 207 ground-measured field sites with 4000 additional photo-interpreted reference sites. We first used aerial photography to identify the extent of homogenous regions around field data sites and then picked additional reference points within these areas (Mannel et al. 2006). This resulted in clusters of additional data points around actual field locations. Random cross-validation of auto correlated data may introduce a bias on overall accuracy of classified land cover classes, which in our case was between 5-10%. We suggest separating reference data by clusters and furthermore utilizing several clustered reference sets (versus only one) to calculate accuracies.

**Permafrost And Active Layer Modeling Across Alaska And Northern Eurasia Using AVHRR Long-Term Records**

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**Vladimir Romanovsky, University of Alaska Fairbanks**
**Josefino Comiso, NASA Goddard Space Flight Center**

High latitude environments such as those over northern Eurasia and North America are particularly vulnerable to climate change which is expected to be pronounced in these areas. Climate warming is likely to cause a permafrost thawing with subsequent effects on surface albedo, soil organic matter degradation, hydrology and greenhouse gas emissions. Thawing and freezing of soils is affected by many factors, with air temperature, vegetation, snow accumulation, and soil moisture being among the most significant.

Recently, there have been a number of experiments to simulate soil temperature and permafrost dynamics on regional and global scales. In these simulations that employ some stand-alone equilibrium or transient permafrost models, the upper boundary conditions are usually the air temperature from observations or climate forcing from available Global or Regional Climate Models. In this research we used the GIPL-1.1 model, which is a spatially distributed model of permafrost based on an approximate analytical solution of soil freezing and thawing, which includes an estimation of thermal offset due to the difference in frozen and thawed soil thermal properties. The GIPL-1.1 model also accounts effectively for the effects of snow cover, vegetation, soil moisture, and soil thermal properties. Two decades of satellite clear sky thermal infrared data from 1981 to 2005 was used as upper boundary conditions in order to simulate the distribution and temperatures of permafrost and active layer thickness in the entire Arctic and sub-Arctic permafrost domain. Under cloud-free conditions, infrared data provide skin depth (surface) temperatures and are shown to be generally consistent with surface air temperatures. The key source of historical surface temperature data is the Advanced Very High Resolution Radiometer (AVHRR) onboard National Oceanic and Atmospheric Administration satellites (Comiso, 2000, 2001, 2003). The monthly satellite-derived snow water equivalent (SWE) climatologies from 1978 through 2003 also was used to perform simulation. Global SWE data are gridded to the Northern and Southern 25 km Equal-Area Scalable Earth Grids (EASE-Grids). Global snow water equivalent is derived from Scanning Multichannel Microwave
Radiometer (SMMR) and selected Special Sensor Microwave/Imagers (SSM/I) (Armstrong & Brodzik, 2001).

The results of permafrost modeling using GIPL-1.1 model show a very good agreement between simulated permafrost temperatures and spatial distribution of permafrost, observed data, and the distribution of permafrost derived from the International Permafrost Association (IPA) permafrost map.

Spatial Variations in Arctic Snow From Local to Kilometer Scales

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Ken Tape, University of Alaska Fairbanks
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Over 1 billion people worldwide live in locations were stream flow is dominated by snow melt. Forecasting water supply in these regions during the spring can be difficult, as the total amount of water that the snowpack contains, the snow water equivalent (SWE), can have large spatial variations in short distances. This makes extrapolation from point measurements difficult, and causes large uncertainties in predicted stream flow. Historical records of SWE at an index site are typically correlated with downstream river discharge, however in a changing climate these relationships are likely to change.

Measuring SWE from space using active radar is a promising alternative, however signal interpretation remains challenging. Evaluating and improving SWE retrieval algorithms from both passive and active remote sensors was the major goal of the NASA Cold Lands Processes Experiment (CLPX) in 2002-03 in Colorado. During December 2007 and February 2008, the second CLPX took place on the North Slope of the Brooks Range, in Arctic Alaska, as part of the International Polar Year. This large multi-institution project built on what was learned during the first CLPX, and was a focused experiment to test active microwave retrieval algorithms from an airborne platform. In support of this project, we performed high resolution measurements of the snowpack on the ground, using a wide range of state-of-the-art techniques. Radar frequencies which penetrate the snow but not the ground are optimal for measuring snow. This requirement causes the wavelengths of the signals to be on the same order as the grain size of the individual snow crystals. The scattering from the snowpack is very sensitive to crystal size and shape, and is not well understood. Unfortunately, standard techniques for measuring snow grain size involve a subjective description of a snow sample scraped from the side of a snow pit. Agreement between observers is difficult, and quantitative application of the qualitative measurement is challenging. We used several different new high resolution instruments, all of which are sensitive to snow microstructure, to make quantitative measurements at high horizontal and vertical resolution, coincident with the airborne measurements.

We chose 3 locations within the larger study area for intensive measurements from the millimeter to 10 meter scale. At each of these sites, we made measurements with 3 different ground based microwave radar systems. These systems were first used to simulate airborne radar signals in well-characterized conditions, by measuring in the far-field at an incidence angle of 35 degrees. Next, these 3 radars were used at 0 degrees incidence to measure SWE, snow depth and stratigraphy at high horizontal and vertical resolution (less than 1cm). Following the radar measurements, a 10 meter trench was excavated, and a series of in-situ measurements were performed. A SnowMicroPenetrometer (SMP), which is sensitive to snow structure, was used to measure penetration hardness at the grain scale, with a vertical resolution of 0.004mm. SMP profiles were made every 20 cm along the length of the trench. An in-situ electrical probe, the snowfork, was used to collect profiles of electrical properties, every 50 cm. Near Infra-red (NIR) photography was used to document snow stratigraphy, and was attached to a custom-made track
which enabled rapid continuous pictures over the 10 m trench. Standard manual measurements of stratigraphy were made every 20 cm, and density and temperature were also measured.

Ground-based radar measurements were also made with the 3 different systems throughout the region around each 10 meter trench, out to the kilometer scale. The majority of variability observed in this type of snowpack occurs because of the interaction of wind and the underlying vegetation. The 10 meter trenches captured much of the local variability in snowpack properties. Information gained from these very detailed measurements in the trenches is used in conjunction with the longer ground-based radar traverses to infer variations in properties up to the kilometer scale. These measurements at the local to the kilometer scale will help put the standard ground-truth point-scale measurements in the context of the much larger remote sensing footprints.

Wind Energy Stakeholders & Interaction in Alaska

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Harnessing renewable resources for local energy use has the potential to create both local and statewide benefits in Alaska by growing local economies, mitigating effects of global warming, utilizing local resources and reducing high fuel costs and other community vulnerabilities. This potential comes at a time when communities across Alaska face complex challenges to the sustainability of their social-ecological systems, many of which result from volatile energy costs, inefficient energy use and unstable energy supply.

Local communities, the state of Alaska and the public and private sector are working to address and mitigate many of these problems. Communities are developing local energy plans and seeking funding to assess and develop renewable energy systems. The state of Alaska is developing a state energy plan and recently created the Renewable Energy Grant Fund, which provides financial assistance for feasibility studies, energy resource monitoring and work related to renewable energy construction. Public and private sectors are working to develop appropriate and reliable renewable energy technologies that will have direct applications in rural communities.

Recent years have yielded significant advancements in developing appropriate renewable technologies and creating policies and funding opportunities to assist renewable energy development in Alaska. These factors are essential; however, they do not capture the social, political and institutional variables that are inherent in any renewable energy planning, decision-making or development. Consequently, it is unclear how certain social, political and institutional factors either facilitate or create barriers to a community and utility’s capacity to plan for, develop and operate renewable energy projects in Alaska. These factors are the primary focus of my master’s research.

A portion of my research takes an in-depth look at the political environment and the actors involved in wind energy development and decision-making in Alaska so that I may better understand the context and complexity of these factors. This focus aims to analyze how certain actor’s involvement and interaction ultimately leads to action, as well as how these actions help determine policies and decision-making at the local and state level.

Actors involved in my research include the public, interest groups and individuals at the local, state and federal level. Specific actors I am looking at include, but are not limited to, the Alaska Energy Authority, Denali Commission, State of Alaska Renewable Energy Task Force, electric utilities, permitting agencies, Tribal and City governments, planning groups and citizens. Most of these actors are involved in funding,
permitting, technical assistance or planning activities for wind energy development and are major factors in deciding whether a wind projects are developed.

This portion of my research primarily examines the following questions:

- How is the interaction between actors structured?
- Who are the “visible” and “hidden” actors?
- What are the limitations and advantages of decision-making interactions?
- How often and in what ways do agencies interact with a community/utility seeking to develop wind energy systems?
- When does an agency begin working with a community, who initiates communication and why?

If accepted, my presentation at the Lessons from Continuity and Change in the Fourth International Polar Year Symposium will primarily cover stakeholder involvement and interaction in the planning and decision-making process for wind development in Alaska. I will provide an historic overview of wind energy development in Alaska that details past projects, policies and actors involved in the decision-making process. My presentation will also detail current projects, policies and stakeholders and discuss changes that have occurred. Through examining the stakeholders and their interaction, I hope to provide insight into the complexity of the decision-making and planning process for wind energy development in Alaska.

**Enhancing the Fit of Marine Policy in Alaska Through the Use of Local Networks**

**Chandra Meek**, University of Alaska Fairbanks

An emerging stream of environmental policy analysis focuses on the extent to which institutions for regulating human-environmental interactions fit the problems they are designed to solve. Much of this work has focused on how well policies fit the biophysical characteristics of the resource in question. In this paper, I examine how well institutions for marine mammal management in Alaska fit the local social context in which policy implementation takes place. I argue that federal rules implemented through local self-organized networks can more effective than rules implemented by federal agencies using ad-hoc networks. Through interview data and social network analysis, I examine the structure of networks formed to manage subsistence harvests of bowhead whales and polar bears in two villages in Alaska. Federal policy networks created through law are compared to self-organized networks of subsistence whalers and polar bear hunters. Federal and local networks for whaling mirror each other and serve to channel effective collective action through local venues. Federal and local networks for polar bear hunters, on the other hand, are fragmented among multiple levels of social organization and do not provide a central venue for collective action. I find that the use of local networks increases participation in resource management, thereby laying the foundation for coordinated governance capitalizing on local knowledge.

**Applying Responsible Engineering Practices to Arctic Marine Infrastructure**

**Andrew Metzger**, Ph.D., University of Alaska Fairbanks

Abstract Due to fossil fuel demand, safe extraction of oil and gas resources in Alaska’s Arctic is a concern for oil and gas producers; communities local to proposed exploration and production; environmental interests; as well as the Alaska and United States governments. Supplying fossil fuel
demands while preserving the environment, and ways of life that depend on it, is not a trivial endeavor. Building the infrastructure for this task will require diligent and responsible engineering practices. The purpose of this presentation is to demonstrate current engineering practices and give an overview of engineering design philosophy as well as how these may be applied to the arctic environ. This discussion is also intended to explain engineering design methodology to a general audience. To further illustrate these concepts, the initial discussion will segue into a discussion on the design-demands of coastal and offshore infrastructure in Polar Regions. Specifically, identifying load demands placed on structures in an arctic marine environment. Existing information shall be presented and apparent gaps in the knowledge base for this topic shall be identified. The author will attempt to make the case that responsible engineering practices are prevalent and, with a reasonable understanding of environmental stressors encountered in the arctic, may be applied to development of infrastructure necessary for acquisition of resources within that region. An anticipated ancillary to this presentation is identifying potential loci of collaboration between engineering academe and the geophysical research community.

Futures of Arctic Marine Transport 2030 – An Explorative Scenario Approach

Marc Mueller-Stoffels, University of Alaska Fairbanks
Hajo Eicken, Ph.D., University of Alaska Fairbanks

Scenarios are valuable tools for decision makers. The prediction of the future development of most real systems is inherently complex and usually inaccurate. Scenarios allow us to develop and bring into focus several images of future developments. These images can help decision makers to plan for a range of futures. Scenarios can also be a useful tool in identifying early indicators as to what the actual future development will be.

Scenario processes have been successfully employed in state, regional, local, and corporate planning and hazard or disaster response. Public scenario processes, as the one employed in this study, can be used to induce conversation between different stakeholder groups and to stimulate thinking ‘outside the box’.

In this work we investigated possible futures for the Arctic Ocean and its coastal regions relative to marine transportation for the year 2030. Key factors for the developments in the Arctic were identified based on the data accumulated in an expert workshop of the Arctic Council’s Arctic Marine Shipping Assessment (AMSA). While this contribution is not part of the formal AMSA process, we explore to what an extent consistency analysis can help refine and evaluate some of the AMSA scenarios. Each key factor was assigned several possible future projections, i.e., directions this key factor could possibly develop. The accumulated data were then made available on the web for comment by a broad range of experts and laymen. After revision of the data, the Consistency and Robustness Analysis (see corresponding poster) was used to assess possible futures for the Arctic. Based on the outcome of these calculations five scenarios were developed encompassing the most divergent future developments. We will outline these five scenarios and early indicators as to which of these scenarios is likely to mirror the actual development best. Further, we will discuss several Wild Card events we identified during the process that decision makers should be aware of and have contingency plans for.
Incorporation of Surface and Subsurface Storage In Stream Temperature Predictions

Bethany Neilson, Ph.D., Utah State University

Quantification of surface (e.g., dead zones) and subsurface (e.g., hyporheic storage) mass exchange in rivers has typically been approximated using a one zone solute modeling approach that provides a lumped characterization of these zones (transient storage). While this lumped approximation may be adequate to understand mass transport, some heat transfer mechanisms within the subsurface and surface zones are very different and must be represented separately. A Two-Zone Temperature and Solute model has been developed that accounts for heat and mass exchange associated with each of these zones while simultaneously accounting for other important heat transfer processes such as surface fluxes and bed conduction. Results from a case study will be presented that show surface and subsurface storage zones providing a buffering mechanism for instream temperatures and emphasize the need for inclusion of these processes in temperature models. The results stress how these processes can alter daily temperature extremes which affect the ecological health of the stream.

An Arctic Emergency Liaison Office is Needed for a New Frontier ("ARCTIC 911")

George Newton, Qinetiq - North America, Planning Systems, Inc

As climate change creates a more accessible Arctic, this frontier area will experience increasing human activity. The waters are essentially unknown, uncharted and potentially dangerous to the inexperienced mariner. The land, known best by the Arctic-area natives who have lived there for centuries, is remote, nearly devoid of communications resources and other infrastructure. Weather is a constant threat to safety. The recent Ilulissat Declaration of 28 May 2008 conveys significant concern for the occurrence of accidents in the Arctic and the need to protect the Arctic ecosystem.

The Arctic is also unique because its geographical nature brings the Arctic littoral nations close together. On the other hand, knowledge of the Arctic – what works?, what does not?, what is dangerous? and who knows the answer? – is spread through 8 countries. Because distances are compressed (the distance from Barrow to Murmansk is roughly the same as the distance from Miami to Boston, for example), an expert in one country who knows how best to combat an oil spill in loosely compacted sea ice can be quickly made available to another country where the casualty occurred………if that person’s expertise and contact information is known.

As development and use of the Arctic area grows, there inevitably will be accidents, ship casualties, oil spills, personnel injuries, and lost individuals. An accident in the Arctic will, in most instances, have international implications, driven either by its location or where individuals and resources needed to counter the event.

In order to generate the best response to such an incident an Arctic Emergency Liaison Office should be developed. It would be staffed 24/7, not with Arctic experts, but with individuals possessing the knowledge and resources to know who the Arctic experts are, where the necessary resources are, and how to obtain them. The Office would be the equivalent of a 911 dispatcher (thus "Arctic 911"). It would be located where comprehensive communications capability can be maintained, and as far north.

There is precedent for this type of activity in the International Submarine Emergency Rescue Liaison Office (ISMERLO), created to generate response to any submarine casualty worldwide after the loss of the Russian submarine “Kursk”. The ISMERLO Office in Norfolk, VA, does not know all the answers
needed in a submarine emergency, but they do know who has them, where the right equipment is, and how contact can be made.

Because of the fragile nature of the Arctic and the sensitivity of all to its development and use, the world needs an single office, staffed with trained individuals from each Arctic state, to initiate the right response to FIRST accident in the Arctic, not the second one. If the response to an accident is similar to that which occurred following the “Exxon Valdez” disaster, future use of the Arctic and its development will cease for a generation.

**Oil, Microstructure and Brine Flux: Entrainment and Migration of Contaminants in Sea Ice**

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The pore structure of sea ice provides space for the entrainment of oil and water-soluble contaminants. Both are slowly released to the ice surface and into the ocean during spring warming; the release, its timing and rate affect remediation strategies and the potential biological impact of oil spills in sea-ice covered waters.

From an ongoing effort to quantify migration and release rates, we demonstrate the parameters and processes involved in fluid transport through sea ice. Preliminary results from both laboratory experiments and computational fluid dynamics simulations suggest that oil is both encapsulated at the base of growing sea ice and entrained into the surrounding sea ice pore volume. The continuous brine flux into the ocean during both sea ice growth and melt has the potential to carry along with it water-soluble compounds from the entrained oil. The biological impact of this release depends on the toxicity of those contaminants and its timing with respect to under-ice algal bloom. Release of oil to the ice surface appears to be governed by both comparatively fast transport through brine channels and comparatively slow mobilization and percolation in the fine-scale pore network. Ultimately, the release rates may guide effective remediation efforts.

**Impact of Ship Emissions on Deposition Into Southwest Alaska Ecosystems**

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In the Gulf of Alaska, every summer season is accompanied by a massive surge of shipping traffic from tourism, trade, commerce, etc. With emissions comparable to road and aviation transportation, these oceangoing vessels are only required to meet modest regulations for emission standards, thus allowing substantial amounts of pollutants to be released into the atmosphere within relatively pristine regions of southwest Alaska. In this photochemically active environment, pollutants are transformed and transported over great distances until their final removal from the atmosphere usually by way of wet or dry deposition. Increased concentrations of secondary constituents such as ozone can be hazardous to the health of humans and vegetation while acidic deposited material can damage vegetation and affect nearby water bodies by increasing the acidity levels harming fish and other organisms. Thus, ship emissions can have adverse effects on remote, coastal regions and marine ecosystems in Alaska that are within the vicinity of shipping lanes. In order to investigate the impact of ship emissions, the fully coupled meteorology and chemistry model, WRFChem, is used to examine physical and chemical processes such
as transport, transformation, and deposition. The dependence of deposition into ecosystems on meteorological conditions and emission pattern is elucidated. Model simulations for a typical summer tourist season will be presented without and with the inclusion of ship emissions for comparison in order to identify the impact on ecosystems in southwest Alaska.

Values Of Nushagak Bay: Past, Present, And Future

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Nushagak Bay is a large relatively pristine estuary covering about 80 Kms2 in southwestern Alaska and hosts one of the world’s last great sustainable salmon fisheries. The cultural history of the region is among North America’s oldest yet the landscapes are still unspoiled and naturally productive. The estuary’s healthy quality is a consequence of two major factors, historically low population densities (0.06/km2) and a culture interlinked with the biota. Environmental stewardship has especially been important in Yupik culture and is believed necessary for continued coexistence in the region. However, over the last 50 years globalization and climate change have been rapidly altering the region’s socio-economic and ecological systems. Further, the introduction of multi-billion dollar industries (oil and gas exploration, mining, and mass nature/game outfitting) have been main drivers of regional change and pose serious environmental challenges both presently and in the future. To maintain the estuary’s health, many residents see value in merging traditional knowledge with Western scientific practice. This requires maintaining access to subsistence resources (e.g. salmon, moose, caribou, and berries) while exploring the best use (or non-use) of non-renewable resources. Therefore, it is important for managers and stakeholders to adapt to the shifting patterns in the climate, habitats, and economy.

Elders claim that some of the important traditional knowledge and social links to subsistence are being lost and replaced by nonrenewable resource use exploited by modern technology. Therefore, to maintain good stewardship, traditional knowledge must be taught along with modern science methods. The global changes imposed by outside influences require cultural adaptation; however, most rural villages do not have the modern technical expertise to measure current trends needed for decision making nor the economic capital to integrate adaptation into existing social capital. Because of this, many important management decisions are made by state and federal agencies using regulations and data collected outside the region. Local education in resource valuation is critical to develop full cost accounting and cooperative management efforts that equally consider natural, human, social, and manufactured capital concerns.

Nushagak Bay is in need of such a comprehensive valuation and ecosystem management plan. To help measure ecosystem health, the Bristol Bay Environmental Science Lab has begun the process of documenting species to ecosystem level diversity and establishing baseline statistics. Physical data being collected include water temperature, pH, DO, salinity, turbidity, substrate type and tidal current flow while ecological data include species diversity and habitat quality. To promote place bases educational, data collection is often assisted by local university students involved in directed research projects studying specific taxa or physical features on the estuary. Nushagak Bay has a Shannon Diversity (H’) value of 1.54, ranking it below similar subarctic estuaries such as Ungava Bay, near Labrador and Lower Herring Bay in Prince William Sound where the Shannon Diversity values are H’=2.11 and H’=2.5, respectively. This lower diversity is most likely due to the low salinity and high turbidity of Nushagak Bay. Continued sampling will provide more insight into the benthic community structure and water quality. Future topics of study include food web analysis to better understand trophic energy dynamics.
Arctic Challenges Faced By The United States Coast Guard

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Recent fluctuations of minimum sea ice extent in the Arctic region have resulted in the United States Coast Guard (USCG) re-examining the extent and range of current/future operations north of the Arctic Circle. The potential closure of federal waters within the United States Exclusive Economic Zone (EEZ) in the Arctic to fishing by the Department of Commerce, the listing of the polar bear as threatened under the Endangered Species Act, the decision by the 9th Circuit Court of Appeals to halt the drilling proposed by the Shell Offshore, Inc., prospects for the ratification of the United Nations Law of the Sea treaty by the 111th Congress, and the recent appearance of cruise ships off the coast of Barrow, AK, are just a few of the issues which will be explored in this paper for effects on USCG operations in Alaska. These obstacles include logistical difficulties (e.g., the lack of a deep draft port in the U.S. coastline adjacent to the Beaufort and Chukchi Seas), legal impediments (e.g., the lack of a resolved maritime boundaries with both Russia and Canada) and preparations for potential response missions (e.g., coordination of oil spill response efforts), to name just a few. A brief historical explanation of the past role of the USCG in the Beaufort and Chukchi Seas will be followed by a theoretical exploration of possible new operational obligations this agency will be expected to assume in the near/immmediate future.

Controls on the Distribution of Arctic Vegetation – A GIS Analysis

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The Arctic is changing rapidly, showing the effects of the polar amplification of global climate change (ACIA, 2004). The effects of recent climate change on northern oceans and arctic sea ice are obvious (Comiso et al., 2008); the effects on vegetation are more subtle and harder to measure. The satellite record of the Normalized Difference Vegetation Index (NDVI) shows increases in the Arctic (Jia et al., 2007), but measuring these increases on the ground has proved difficult. There are both spatial-scale and time-scale issues when trying to sample heterogeneous vegetation in a way that represents satellite pixels. An alternative is to study the present arctic vegetation, using the range of existing conditions to help understand what will happen as conditions change, essentially a space-for-time substitution. Analysis of existing arctic vegetation can shed light on the factors controlling its distribution, allowing better understanding and prediction of the effects of climate change.

This study compared circumpolar data sets, to investigate which factors are most important in controlling arctic vegetation distribution. GIS spatial analysis was used to compare different parts of the Arctic. The base map for the study was the Circumpolar Arctic Vegetation Map (CAVM Team, 2003), a 1:7.5 million vector map with 14 km minimum mapping unit diameter. This map includes data layers for NDVI (1-km AVHRR maximum NDVI grid), elevation, lake cover, and substrate pH (http://www.arcticatlas.org/atlas/cavm). Additional data layers analyzed include land surface temperature (Raynolds et al., 2008), permafrost characteristics (Raynolds and Walker, 2008), landscape age (Raynolds and Walker, 2009 (in press)), peatland distribution (MacDonald et al., 2006), and growing season length (Smith et al., 2004).

Arctic vegetation distribution is largely controlled by climate, particularly summer temperatures. Plant community composition is limited to species that are able to tolerate the coldest summer temperatures at any given location (Bliss and Petersen, 1992). Plant energy budgets are limited by summer temperatures, which restrict the amount of plant vegetative growth and reproductive effort possible in any year.
A General Linear Model analysis of NDVI showed that 74% of the spatial variation in arctic NDVI can be explained by variation in summer temperatures (Summer Warmth Index, SWI= sum of monthly averages > 0°C) (Raynolds et al., 2008).

The types of changes that can be expected vary spatially with vegetation type. For example, areas with tussock-sedge, dwarf-shrub, moss vegetation occur mostly on older landscapes, in the warmest bioclimate subzones. Climate change in this vegetation type is likely to cause a build-up of organic material (live and dead) over time. This has the counterintuitive effect of insulating the soil from summer warming, resulting in a thinning of the active layer, restriction of drainage, and acidification of soils (Shur and Jorgenson, 2007). Plant community composition is likely to change, resulting in an increase in cover of deciduous shrubs and graminoids, and decrease in cover of nonvascular plants (Walker et al., 2006).

Many other factors influence arctic vegetation, including the chemistry of the substrate material, time since glaciation, and precipitation. Whereas temperatures decrease relatively uniformly with latitude, these other factors have irregular distributions, creating a mosaic of controlling conditions across the Arctic. In places that were recently glaciated, such as the center of the Laurentide Ice Sheet in Canada, the young age of the landscape is the dominant factor controlling vegetation, due to the limited time for soil and plant community development. In other places, such as parts of Victoria Island in Canada, extremes of soil chemistry control the vegetation. These areas will not respond to climate change as strongly as areas where the vegetation is primarily temperature-limited.

Adjustment of Students Migrating from Rural Communities to Attend University

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Migration is associated with greater health risks due to challenges migrants face in their new environment, such as isolation from family and community, changes in social norms, increased stress, and competing needs that take priority over health promotion (Decosas & Adrien, 1997; Paschane & Fisher, 2000). Rural-to-urban migration in Alaska is increasing, with most migrating for educational and employment opportunities (Martin, Killorin, & Colt, 2008). Migration from rural to urban environments often occurs when rural youth in Alaska go to college.

The purpose of this preliminary study was to examine the experiences of young men migrating from rural communities in Alaska to attend an urban university. The transition to an urban university places rural students in a new environment and a new culture, where they face unique stressors and opportunities. This exploratory study examined the young men's adjustment to the college transition, social support, and changes in norms, relationships, alcohol use, and sexual behavior.

A total of 6 semi-structured interviews and 1 focus group were conducted with young men in their first year at UAA or UAF who had migrated from rural communities to attend university. Interviews and the focus group explored the issues and challenges young men migrating from rural areas to attend college face in the transition from one culture to another, and examined contextual risk and protective factors affecting sexual risks, alcohol use, and emotional adjustment. These factors were considered with respect to both the current college environment as well as connections to the rural communities the youth migrated from.

Many participants reported experiencing culture shock in adapting to the social and environmental changes associated with the transition to an urban university. However, this transitional period was also a time for personal growth resulting in an increase in self-efficacy and self esteem. Many participants relied on support from peers and family members, including support from the rural communities they came from or support in their new urban environments. Results suggested some consistency in alcohol use and sexual behavior through the transition. Pregnancy prevention was cited as the main reason for condom use among sexually active participants, and little discussion of STDs were reported between sexual partners. The students’ health behaviors and adjustment were also affected by the social environment, peer norms, and social support, both from their home communities and in their new college environment.

Implications of the results for future research informing strategies designed to facilitate adjustment to challenges of migration will be discussed. This research can point to individual, community and cultural strengths that can be utilized to facilitate resilience in response to rapid change. Migration is a time of both risk and opportunity, and may be a critical period that can be conducive for interventions to reduce the significant health disparities in rural Alaskan communities.
Community Adaptation as an Integrator of Social-Ecological Context

Martin D. Robards, Ph.D, U.S. Marine Mammal Commission
Joshua A. Greenberg

Human communities around the world exist in dynamic and reciprocal relationships with their particular environments, and are in turn linked to those environments and people that spatially and temporally bound them. The characteristics of human-environment systems are complex; they respond to disturbances in a non-linear manner, are self organizing, and evolve through time. As such, responses to interventions or disturbances are not mechanistic; rather they are process-oriented and organic, with feedbacks at multiple temporal and spatial scales leading to emergent properties that are often difficult to predict. We use the case of Alaskan wild salmon to demonstrate the relationships between system characteristics, adaptation processes, and outcomes at local and global scales. Alaska salmon fisheries are in crisis due to declining economic revenues, driven by the proliferation of reliable and increasingly high-quality products from fish farms around the world. Conventional responses to reduced revenues by the wild capture industry have been to increase economic efficiency through implementing a range of entry entitlement and quota allocation schemes. However, Robards and Greenberg demonstrate that while these mechanisms may provide resilience to economic efficiency at a broad scale, they have not benefited local community fishing interests, and have precipitated declines in local ownership of the Alaska fishery. For Alaska salmon fishing communities to be viable, economic efficiency remains a relevant consideration, but in a directionally changing environment (biological, social or economic), communities unable to procure livelihoods from their local resources (through access or value) are likely to seek alternative economic opportunities. The adopted strategies in Bristol Bay, such as oil and gas development or mining, are logical adaptations for communities seeking to transform in a changing world, but may not be conducive to resilience of a ‘fishing community’ or the sustainability of their wild fish resources. Furthermore, the loss of local relationships with specific resources such as salmon now hinders opportunities for managers to benefit from local constituencies in accomplishing their desired outcomes.

Modeling Evaporative Losses from Tundra Lakes Using Remote Weather Stations

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Michael Lily, GW Scientific
Amy Tidwell, Ph.D., University of Alaska Fairbanks
Horacio Toniolo, University of Alaska Fairbanks

Access to freshwater resources is crucial to ecological, municipal, and industrial stakeholders on Alaska’s North Slope. In many instances, those freshwater resources consist of tundra lakes that recharge primarily during the spring melt. In order to ensure that sufficient water is available for all stakeholders, water managers must limit the amount of water withdrawn from tundra lakes based upon estimated water balance calculations and predicted needs. The estimated needs are often driven by the volume of under-ice water required to maintain healthy lacustrine ecosystems over the course of the winter. In the case of tundra lakes recharged in the spring, however, it is not clear how much water is lost over the summer season due to evaporative losses, and consequently how much water is available at freeze-up to sustain the overwintering habitat. This problem is exacerbated in remote regions where hydrologic observations are not commonly reported. In this presentation, we utilize existing models to predict evaporative losses from example tundra lakes based upon observed remote weather station data. Results from this analysis will be relevant to North Slope water managers, as summer evaporative losses may be a critical component of the annual water balance.
Importance and Interaction of The Energy Balance Components Governing Radiation-recrystallization of Snow

Andrew Slaughter, Montana State University
Edward Adams, Montana State University

Seasonally, snow covers nearly one-third of the Earth’s land surface, which has obvious impacts on a variety of scientific endeavors including climatology, hydrology, and glaciology. The morphologic state of the snow microstructure is of paramount importance to the local energy balance. Of particular relevance is the surface snow since it is directly interacting with the atmosphere, and is subject to rapid and continuous change. The altered structure may serve as a positive or negative feedback since parameters such as albedo and thermal conductivity are influenced.

Depending on atmospheric conditions and the current snow state, a wide variety of near surface microstructures may develop. The present study focuses on what is termed radiation-recrystallization. This process is governed by the energy exchange at the snow surface as controlled by incoming and reflected solar radiation, absorbed and emitted infrared radiation, and the exchange of heat at the surface due to turbulent and conductive flux. While general conditions governing the process have been described, little quantitative analysis indicating the relative interactive sensitivity has been accomplished.

A one-dimensional heat-transfer model that incorporates each of these components and reasonably replicates the thermal environment of the snow is utilized for a numerical examination of the governing parameters using variance-based sensitivity analysis. Specifically the SOBOL and FAST methods are employed. Both of these methods are capable of quantifying the relative importance of each of the input parameters to the conditions associated with radiation-recrystallization as well as the importance of the interactions between each parameter. The results of this analysis indicate that factors such as the amount and balance of solar and infrared radiation, albedo, and thermal conductivity, among others, are crucial factors governing the growth of radiation-recrystallized crystals. Comparing these numerical results to precise laboratory experiments capable of mimicking climatic conditions and detailed observations in the natural environment indicate similar sensitivity to variations and relative magnitude of these parameters.

The aforementioned research, particularly results derived from the laboratory, provides information regarding metamorphism at a single point with defined environmental conditions. Thermal modeling software, RadTherm/RT (Thermo Analytics), has been developed for complex topography in collaboration with Montana State University. This allows extrapolation to mountainous terrain by utilizing the software to define boundary conditions for individual elements. Thus, using the knowledge gained from the laboratory and analytical techniques, it is possible to reasonably predict the potential of radiation-recrystallization occurring over larger regions. The results from a case study in southwest Montana demonstrate the potential to predict the occurrence of radiation-recrystallization, and the model could eventually predict such parameters as albedo that are influential to a multitude of endeavors in the natural sciences.

Alaska’s Freshwater Management Regime: Decentralized Capacity-Building and Adaptation for Future Changes

Jedediah R. Smith, University of Alaska Fairbanks

Watershed partnership activity indicates a growing capacity to identify and address challenges related to changes in freshwater systems at a local and regional scale. However, watershed partnership role in institutional management decisions is unclear.
Alaska is experiencing rapid environmental change as the direct result of global warming, and its interaction with land, water, and natural resource development. The potential cost for assessing changes across the vast landscape of the state is high. Some of these impacts, such as erosion affecting rural communities, are more salient and documented. Other changes, such as permafrost affecting surface waters, are less predictable. Further, since statehood 50 years ago, Alaska has undergone rapid community and economic development that has brought an inequitable distribution of infrastructure, and consequently regulatory ability to address changes. In other words, Alaska is not experiencing blanket change, but rather changes that vary on a bioregional scale. The cumulative impacts on individuals and communities demonstrate a need for a cohesive management regime that is responsive to changes at the watershed level.

The watershed basin as a scale for management may be a more appropriate fit for allocation and regulatory decisions that carry impacts outside of administrative boundaries. Partnerships that include diverse stakeholders from within the basin theoretically increase compliance with pollution regulations. Watershed partnerships can potentially form a cohesive policy community, reduce conflict, and address local concerns efficiently. Regulatory agencies that recognize watershed partnerships as legitimate nodes of entry into the public process may be able to reduce transaction costs and conflict of regulatory, allocation and development decisions at an administrative level.

Alaska’s 10 watershed partnerships grew out of the proliferation of similar partnership activity in Lower 48 states during the mid 1990s. Alaska’s partnerships address specific needs within their geographic and economic regions. For example, the Yukon River Intertribal Watershed Council has built a robust water quality monitoring program that utilizes tribal funding resources, traditional ecological knowledge networks, and a close relationship with the US Geological Survey to bridge the use of science and Traditional Ecological Knowledge within the basin and enhance knowledge and observation of changes. Similarly, the Anchorage Waterways Council has a volunteer network of water quality monitors and an extensive outreach and community education focus that has been instrumental in increasing non-point source pollution compliance. The Tanana Valley Watershed Association is currently in the process of developing a riparian management plan for the Fairbanks-North Star Borough that would establish a set of mutually agreed upon rules intended to protect property owners from flood and erosion damage and enhance fish habitat in waterways that have been affected by urban development.

Such partnerships are noticeably absent from the northern and northwestern portions of the state where populations are lower. However, partnership presence in regions of higher populations or where development poses significant risk to freshwater resources suggests these entities may also be appropriate vehicles for influencing management decisions across administrative boundaries.

A review of more than 300 newspaper articles since statehood has uncovered focusing events that have contributed to current water policies. Semi-structured interviews with current state and federal agency regulators, watershed partnership executives and facilitators have also helped identify regional concerns, as well as access issues related to policy process.

Elinor Ostrom’s Institutional Analysis and Development framework is used to analyze institutional arrangements, Alaska’s Clean Water Act regulatory permitting process, which transcends many of the state’s social and ecological water issues. The focusing events identified in newspapers, such as floods, village water delivery system vulnerabilities, and placer mine permitting and water quality issues provide a map to connect Alaska’s policy development over time. Watershed partnership activity demonstrates the growing capacity for a new comprehensive and cohesive water management regime for Alaska.
Education Outreach plays a major and vital role and contributes to the uniqueness of the Fourth International Polar Year (IPY) that is occurring at a time of significant environmental change in both the Arctic and Antarctic regions. The communication of and engagement in the IPY science research process and results for pre-college, undergraduate and graduate students and the general public is very important. The IPY Joint Committee (International Council for Science and the World Meteorological Organization), scientists, educators and media specialists recognized this. The significance of and interest in education outreach is evident from the more than fifty multi-nation project proposals out of 228 endorsed project proposals for this 4th IPY. International, national and state education outreach activities are being conducted.

The IPY International Programme Office (IPO) (www.ipy.org) and its Working Groups on Education Outreach and Communication consisting of international scientists, educators and media personnel, have spearheaded many worldwide efforts on primary, secondary and tertiary education, communication and community engagement. Among these activities are the International Polar Days that are celebrated quarterly where a specific aspect of polar research is highlighted; multi-lingual flyers and related hands-on activities for primary and secondary students are provided; and, web, audio and video connections to the polar regions and scientists as well as press releases are made available to the public including those from non-polar regions. Polar research highlighted in the International Polar Days include sea ice, ice sheets, the changing Earth—past and present, land and life, and people. The IPY IPO and its Education, Outreach and Communication Working Groups in collaboration with the Association for Polar Early Career Scientists (APECS) is also developing a Polar Resource Book that will serve as a guide for teachers and scientists in bringing polar science into the classrooms and making it more accessible to people including those outside academia, and beyond the 4th IPY.

Another international effort is through the University of the Arctic (UArctic) IPY Higher Education Outreach Office hosted and supported by the University of Alaska Fairbanks for the coordination of UArctic’s IPY education outreach projects being conducted in its member institutions. The UArctic is a collaborative network of over ninety universities, colleges, indigenous organizations, and other institutions dedicated to higher education and research in the North (www.uarctic.org). In the United States, IPY activities supported by the United States government are featured in the US IPY website http://www.ipy.gov/ as well as in state IPY websites such as http://www.alaska.edu/ipy/ in Alaska. IPY Education Outreach projects range from conference/symposium/short courses, semester–long courses for undergraduate and graduate students and K-12 teachers, summer schools during Arctic expeditions, to a graduate training program as well as programs for engaging students in IPY and IPY research, and various public events from seminars, science cafes, to concerts to increase IPY awareness and involvement of communities.
Arctic Council Oil and Gas Assessment: Findings and Recommendations

Dennis Thurston, Ph.D., Minerals Management Service

The Arctic Council Assessment, “Oil and Gas Activities in the Arctic--Effects and Potential Effects,” covers oil and gas activities; social and economic effects; sources, inputs and concentrations of petroleum hydrocarbons and other contaminants related to oil and gas activities; effects on the environment and human health; and status and vulnerability of ecosystems.

Key Findings and recommendations of the assessment.

Activities: The Arctic has substantial hydrocarbon resources and resource potential and a long history of activities. Although, levels of activities have fluctuated and are dependent on many factors, oil and gas activities including transportation are likely to continue in existing production centers and expand into new areas.

Socioeconomic Effects: Oil and Gas activities are major drivers of change in the Arctic. The economic value of activities plays a significant role in national, regional and local-level effects and indigenous Arctic people are becoming more involved and affected as development expands. Effects are mitigated by the planning, regulatory and allocation functions of governments and vary by scale and “life-cycle” stage of the activity. Updating and development of a legislative foundation, enactment and enforcement regulatory systems, and the use of international standards and best practices are important to the reduction of negative environmental and socioeconomic effects.

Sources, Inputs and Concentrations: Contamination from oil and gas activities in the Arctic is relatively small compared to inputs from natural seepages, which make up the majority of total input of oil hydrocarbons to the Arctic environment. Low background concentrations of oil hydrocarbons and PAH are found in the Arctic marine environment but information on land and in freshwater systems is more limited. Several sources of emissions and discharges of petroleum hydrocarbons and related contaminants in the Arctic exist and result in local pollution in some areas especially close to industrial and urban communities. Available information indicates low levels in areas distant from human activities. Oil and gas activities are currently a minor source of oil hydrocarbons and PAH on a regional scale but have the largest potential for large-scale accidental or long-term releases of contamination to land and sea.

Effects and Potential Effects: Oil and gas activities have had environmental effects locally but long-term changes to arctic wildlife populations have not been documented. Physical impacts, disturbances and habitat fragmentation are the main issues for terrestrial environments. The physical “footprint” of the activity although growing smaller may have cumulative effects when combined with past oil and gas activities, other human activities, and effects of climate change. Oil spills on land have a limited spatial extent but may have long-lasting impact.

Oil spills have the greatest potential to impact aquatic, coastal and marine environments. Small spills are relatively frequent while large spills are rare events but even small spills can affect many animals if they occur at times and places where the animals have congregated in large numbers. Seabirds and fur-bearing marine mammals are vulnerable to oiling while whales have low vulnerability. An oil spill in ice-covered waters could have large ecological impact including effects on sea birds, small cod-fishes that spawn under the ice, marine mammals and whales.

Health: Human health in the Arctic can potentially be affected by oil and gas activities but there is limited information to assess if effects have occurred to date. There are insufficient human exposure and epidemiological data available for the Arctic region to conclude whether non-occupational population
groups are currently affected. Psychological damage appears to be a consistent impact of oil spill situations. Oil and gas activity in the Arctic can have a positive impact on health.

Technology, Practices and Governance: Technology and use of best practices have lowered the environmental impacts, but risks remain.

Governance, regulatory systems, and international standards are important aspects of the performance of industry and are contributing to reduction of negative effects. The legal regimes of Arctic countries are relatively stable, modern and designed to protect human health, rights of indigenous residents and the environment, but in some cases regulatory systems are outdated, incomplete, or enforcement is inadequate.

Recommendations of the assessment include continued efforts to
• prevent oil spills and pollution;
• use Best Practices and clear and flexible regulations; and
• clean up and remediate polluted sites.
• monitor contaminated and polluted areas, animal populations; and human health

The assessment lacked information on
• point sources of pollution and concentration gradients;
• habitat fragmentation;
• socio-economic conditions and human health; and
• standards and regulations.

Gaps in the assessment included information on research or studies
• to improve technology including oil spill clean-up;
• of comparative socio-economic effects;
• on human health effects;
• into contaminated sites and natural seeps;
• behaviour and fate of oil in sea ice;
• exposure and toxicology;
• animal populations and ecosystems;
• sensitive areas; and
• the coordination of research.

A Decision Support System for Water Resources, Environmental, And Infrastructure Planning For the North Slope of Alaska

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Kelly Brumbelow, Texas A&M University
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Alaska’s North Slope hosts a phenomenal wealth of natural, cultural, and economic resources. It represents a complex system, not only in terms of the biophysical system and its global importance but also from the standpoint of its social dynamic. A major challenge at the forefront of domestic energy development on the North Slope is the need for best management practices that will ensure benefits for all stakeholders. To do so requires stakeholder cooperation that enables cost-effective development strategies that fit within a broader context of long term cultural, economic, and environmental sustainability.
Ice roads and ice pads provide a cost-effective means of oil and gas exploration with minimal impact to the sensitive underlying tundra. Consequently, these ice structures have become integral to oil and gas exploration activities on the North Slope. Their widespread use represents a challenge to water resource managers, however, due to the large volume of water required to construct and maintain them. Crucial questions on water balance and ecosystem impact must be considered in the state regulatory process that permits construction of these ice structures.

As mineral extraction activities come online, more permanent infrastructure is built that carries longer term impacts on ecosystems and human subsistence activities. Regulation of these infrastructure types is conducted at multiple levels of government and is influenced by a large number of stakeholders.

The North Slope Decision Support System (DSS) is currently under development as a technology in support of oil and gas exploration and development that explicitly considers optimal water use, direct and cumulative environmental impacts, and multiple objectives and values among stakeholders. Major modules of the DSS include information systems, natural system models, planning and management functions, and regulation workflow. Development of the DSS is a collaborative effort of academic and industry personnel with significant stakeholder involvement from multiple agencies of local, state, and federal government, private energy companies, and non-governmental organizations.

1982-2003 Trends in a Remotely Sensed Vegetation Index in Arctic and Subarctic Alaska

David Verbyla, Ph.D., University of Alaska

Alaska is a global “hotspot” of change in a remotely sensed vegetation index. The Normalized Vegetation Difference Index (NDVI) is available globally as 2-week maximum data from 1982-2003 from a series of NOAA satellite sensors. The NDVI data have been processed to correct for major volcanic eruptions in 1982 and 1991, sensor degradation, orbital drift, and other technical problems. By selecting the maximum NDVI value from dozens of observations for each two-week period, cloud contamination and other problems are minimized. The maximum NDVI is correlated to the fraction of photosynthetically active radiation absorbed by plants, and thus to photosynthetic activity.

Since 1982, annual maximum NDVI has significantly increased in arctic Alaska, in contrast to significant declines in subarctic Alaska. In arctic Alaska, NDVI has increased most strongly in central and eastern regions, consistent with a steepened climatic gradient in continentality over the past 20 years. There was no significant trend in annual Maximum NDVI in warmer tundra regions of western and southwestern Alaska. In colder arctic tundra areas, there was a strong correlation between annual maximum NDVI and the previous year’s summer warmth index. This interannual response and the longer-term increase in NDVI in arctic Alaska may be related to broadleaf shrub growth and expansion.

There was a significant decline in annual maximum NDVI in subarctic Alaska, just south of the Brooks Range. This is likely due to increased drought stress and insect infestations in the boreal region of a warmer and drier continental climate. The spatial pattern of subarctic NDVI trends corresponded to an east-to-west maritime to continental climate gradient, with the strongest declines occurring in eastern subarctic Alaska. There was no significant relationship between annual maximum NDVI and temperature or precipitation in subarctic Alaska. This may be due to high spatial variability of precipitation and insect infestations. There was no significant relationship between spring NDVI and maximum annual NDVI in either arctic or subarctic Alaska. Thus whether spring greenup was early or late did not control maximum NDVI for the growing season.
The University Of Alaska Fairbanks Unmanned Aircraft Program's Arctic Research

Gregory Walker, University of Alaska Fairbanks
Donald Hampton, University of Alaska Fairbanks
Kathe Rich, University of Alaska Fairbanks

Staff at the University of Alaska Fairbanks Geophysical Institute are evaluating Unmanned Aircraft Systems and conducting experiments focused on overcoming limitations keeping this new technology from becoming feasible to meet various needs within Alaska.

This work is addressing specific technical areas where the potential impact on understanding the Arctic can best exploit the technology. The University team is developing new payloads and conducting operational experiments focusing on the study of marine mammals, sea-ice roughness, vertical profiling of the atmosphere over the Arctic Ocean, aerosol sampling, sea ice forecast satellite validation, and satellite based sea surface temperature calibration. Operations are pending that originate from land as well as both ice hardened research ships, such as the NOAA ship Oscar Dyson as well as US Coast Guard ice breakers.

The technology involved in these modern unmanned systems has matured rapidly within the military. This university effort is focused on exploiting this new technology to aid in solving existing civil, commercial, or scientific needs. The technology has the potential to make significant enhancements within the arctic scientific community.

Squaw Creek: Monitoring a Subarctic Alaskan Stream

Sarah Wingert, University of Alaska Fairbanks Bristol Bay Campus
Todd Radenbaugh, University of Alaska Fairbanks Bristol Bay Campus

Squaw Creek, in Dillingham Alaska, is the site of a community-based water quality monitoring project, which aims to highlight changes occurring in aquatic ecosystems due to climate change and watershed development, foster community partnerships on all levels, and use place-appropriate education to enhance local science curriculum. Squaw Creek is also a restored salmon stream monitored by University of Alaska Fairbanks Bristol Bay Campus' Environmental Science Lab, U.S. Fish and Wildlife Service and Alaska Department of Fish and Game for water quality and aquatic life. It has been the focus of water quality and stream ecology classes at the middle school, high school and college level.

Squaw Creek watershed contains a combination of residential and industrial developments, though a major portion remains pristine wet tundra and birch/willow/alder forest. Beginning in 2007, weekly water quality measurements were taken between June and September at four sites along the creek. Parameters measured include water temperature, pH, dissolved oxygen, conductivity and turbidity; one sample per season was analyzed for metal content. Results demonstrate that average values at all sites are within EPA water quality standards.

In addition to water quality monitoring, Squaw Creek is the site of a salmon restoration project. Each summer, a fish passage weir with an underwater video camera is installed at the most downstream site to monitor fish passage into the creek from Nushagak Bay. The weir camera has detected and recorded silver and pink salmon escapement and indicates that the number of salmon returning has increased. The weir has also documented the passage of starry flounder (Platichthys stellatus), stickleback (Gasterosteus sp.), rainbow smelt (Osmerus mordax), river otter (Lontra canadensis), and beaver (Castor canadensis). To investigate fine-scale species composition within the creek minnow traps were baited and set weekly
during summer months. Traps yielded Coho fry, Alaskan blackfish (Dallia pectoralis), slimy sculpin (Cottus cognatus), Burbot (Lota lota), giant sea lice (Saduria entomon), and caddis fly larvae (Trichoptera sp.).

As the Squaw Creek Water Quality Monitoring Project continues to develop we will test for nutrients and metals. Next summer we will use aquatic macro-invertebrate indices as an additional tool to observe ecosystem health. The goal of the Squaw Creek Water Quality Monitoring Project is to develop Squaw Creek into a community resource for research, education and recreation.

**Downscaled Present and Future Climate Information Over Alaska For Stakeholders**

**Jing Zhang**, Ph.D., Arctic Region Supercomputing Center  
Uma Bhatt, Geophysical Institute  
Jeremy Krieger, Arctic Region Supercomputing Center  
David Atkinson, Ph.D., International Arctic Research Center

Alaska and surrounding coastal areas are prominent geographical features that are largely covered by sea ice on a seasonal basis over the ocean and exhibit sharply varied topography on land. The complex geographical features significantly complicate Alaska regional climate systems. Thus the representation of complex topography in high resolution models is needed for accurately modeling Alaska regional climate. A study has been established to use the high resolution regional model, such as MM5 or WRF, to conduct dynamical downscaling of global climate simulations for the Alaska region. The CCSM3 20th century climate simulation (1979-1999) was first downscaled and the downscaled present-day climate was verified against the observations and has correctable biases. The bias-reduced downscalings compare favorably to the observations. The downscaled future A1B scenario of the CCSM3 21st century simulation for 2010-19, 2050-59 and 2090-99 over Alaska will be presented.
POSTER ABSTRACTS

(Arranged Alphabetically by Poster Author)
**Documenting Local Knowledge About Change: Voices Of The Caribou People Project**

Archana Bali, University of Alaska Fairbanks, Institute of Arctic Biology
Gary Kofinas, University of Alaska Fairbanks

In order to understand the implications on local social-ecological systems of various global changes that are taking place in the North today, it is mandatory to incorporate the knowledge and observations of the local communities to inform scientific research. But such integration of local knowledge with science presents a suite of epistemological and political problems. To address this issue, we initiated a video based project with the help of Indigenous Peoples who traditionally have been a very important component of the arctic social-ecological systems.

Voices of the Caribou People project aims to portray the caribou people – northern communities who have a close relationship with caribou; and their changing world, as they view it. This summer we worked with 6 North American communities to create video-sketches on them that document local observations of changes taking place on their homelands, caribou and livelihoods and how these changes are impacting their traditional culture. Communities from Alaska to Quebec participated in the project and 97 people were interviewed who included elders, hunters, community leaders, women and youth. The participants talked about changes about caribou itself as well as caribou hunting and uses, and voiced their concerns regarding their future.

Participants expressed satisfaction in not being treated as subjects of research but rather as having their voices presented without modification or a third-party critique. The collective voices of caribou people illustrate that communities share many similarities and some differences in the challenges they face. These challenges include the ubiquitous problem of increased energy costs, greater extractive development activities in homelands, and social problems of engaging youth in traditional pursuits. The Voices of Caribou People project is still in progress. It is funded by CircumArctic Rangifer Monitoring and Assessment Network (CARMA) and is part of their IPY research on human-rangifer systems and seeks to present indigenous perspectives in scientific research. It also provides an opportunity for caribou people to share their coping strategies with other indigenous communities, give insight to researchers on local people’s needs of northern science, and communicate the important issues concerning human-caribou systems to the greater world.

**Interior Alaska Rivers and Their Connection to Climate**

Peter Bieniek, University of Alaska Fairbanks
Uma Bhatt, University of Alaska Fairbanks

In order to investigate climate predictability it is essential to understand the link between Interior Alaska river parameters (monthly/seasonal average river discharge and ice breakup date) and the large-scale winter climate. Multiple rivers in Interior Alaska (Yukon River, Tanana River, and Chena River) are investigated. The relationship between discharge and observed ice breakup date for each river and the large-scale winter climate are investigated using correlation and composite analysis. The mechanisms that control river flow and breakup data depend on local and regional temperature and precipitation, therefore the analysis is carried out at hemispheric, regional, and local scale for each river parameter. The river parameters are significantly correlated with North Pacific sea surface temperatures (SST) and mean sea level pressure. These results show that during warm (cold) winters, SST is below (above) normal in the central (eastern) midlatitude Pacific, which is consistent with the El Niño (La Niña) pattern. These correlations appear relatively strong and indicate a link between the large-scale winter climate and weather conditions in Interior Alaska, which then impacts the rivers.
Data Collection and Modeling for Determining Stream Bed Conduction Parameters

Jonathan Bingham, Utah State University

Current climate models and projections predict changes in air temperature, precipitation and evaporation. These changes could exacerbate already stressed water systems with regard to water temperature. Water temperature has been cited as a water quality concern due to its effects on aquatic ecosystems. Stream temperature models have been produced in order to forecast changes in anthropogenic impacts or climatic changes. If the dominant processes are not accurately represented within these models, our ability to predict the effects of these changes can be limited. Typically, in-stream temperature models take into account climatic drivers such as ambient air temperature, wind and solar radiation. Nevertheless, stream bed fluxes also impact in-stream temperatures and yet are often ignored or are quantified without site specific information. Bed conduction is one of these thermal fluxes that has been shown to have a variable influence on stream temperature depending on conditions. In this research, several new data collection techniques have been developed to estimate sediment thermal properties from in-situ measurements by isolating sediment heat transfer due to bed conduction from that of hyporheic exchange. Hobo temperature sensors were inserted to different depths in the sediment and a 12 inch diameter steel cylinder was then placed around these sensors. Different methods of capping the cylinders were applied to determine the most appropriate technique for excluding these sensors from hyporheic flow. In order to estimate the sediment thermal properties, the resulting sediment temperature time series were used to estimate bed conduction parameters. In this inverse modeling effort, thermal diffusivity was altered until model output temperatures mimicked those observed in the sediment. The resulting thermal properties from each capping technique will be compared to thermal properties estimated by laboratory testing. Finally, the impacts of different sediment thermal property values on predicting instream temperatures for various situations will be quantified.

Incorporation of Thermal Imagery in Parameter Estimation and Model Calibration

Quinten Bingham, Utah State University
Bethany Neilson, Utah State University

Heightened demands for water throughout the United States, primarily due to climatic and demographic change, have directly influenced the instream temperature regime of rivers. Elevated instream temperatures often prove detrimental to local aquatic biota and often times endangered fish species. An improved dynamic temperature model (Two-Zone Temperature and Solute Model) has been developed to assist in more representative quantification of energy and mass exchange processes taking place within a river. Due to representation of more processes within the model (e.g., dead zone and hyporheic exchange), the number of parameters requiring estimation increases. Numerous research projects have been conducted to determine which data are best suited to populate, calibrate, and corroborate the model to increase certainty in predictions. In this study thermal infrared (TIR) and 3-band imagery of the river was collected, in addition to many other data types. A combination of both types of imagery provides the ability to measure, versus estimate, physical parameters such as average channel widths and dead zone surface areas. Additionally, the use of the TIR for model corroboration has provided the ability to test spatial representation of the longitudinal temperature regime. With these detailed data, it is anticipated that the increased accuracy of instream temperature predictions will provide for improved water management decisions. These data and the results of model corroboration will be presented.
Approaching Ideas on Northern Watershed Change

Rena Bryan, University of Alaska Fairbanks, International Arctic Research Center, Larry Hinzman, Ph.D., University of Alaska Fairbanks

This poster presents a technical approach that is being developed to evaluate change in size and distribution of northern lakes and wetlands spatially and temporally under a climate warming scenario. Our approach uses modeled present and future temperatures at the top of the permafrost (TTOP) in 1 km spatial resolution over the Yukon River Watershed, Alaska and Yukon Territory. A map of groundwater discharge and recharge areas that is derived from relative elevation, precipitation, and satellite image classification of wetlands will overlay TTOP. We discuss combining the information from the permafrost and groundwater hydrology to gain information on the dynamics of shrinking and growing lakes and wetlands. The landscape shifts expected for the future restrain estimates of carbon dioxide and methane flux to the atmosphere and shape considerations of these local and regional measurements in the global budget. We present parameterization of soils, landcover, and groundwater discharge/recharge and the role of these parameters in the models. Further work is needed to quantify watershed-scale surface water storage change.

Temperature and extent change of permafrost on the Seward Peninsula

Robert Busey, University of Alaska Fairbanks, International Arctic Research Center, Larry Hinzman, Ph.D., University of Alaska Fairbanks, International Arctic Research Center

Current observations show the Seward Peninsula sitting on the margin of the continuous / discontinuous permafrost transition in western Alaska. This region of sub-arctic Alaska could be viewed as a proxy for a warmer Arctic, due to the broad expanses of tussock tundra, invading shrubs, and fragile permafrost. With annual average air and permafrost temperatures just below freezing, the area is susceptible to dramatic change in response to a warming climate. To investigate the potential rate and mechanisms of change in frozen ground distribution, we model past, present, and future ground temperatures using observed meteorological forcing and the equilibrium numerical soil temperature model TTOP.

Past surface air temperatures are estimated using the long-term observational record from Nome for the period 1908-1918. Air temperature and precipitation are then distributed spatially using the physically-based MicroMet model. Current meteorological forcing data are collected from our own network of stations, as well as those managed by the National Weather Service, USDA/NRCS Snotel program, and the Bureau of Land Management. Finally, we will analyze output from several Intergovernmental Panel on Climate Change (IPCC) General Circulation Models (GCMs), which were found to most accurately represent 20th century conditions. The future scenario is presented using the SRES A1B IPCC criteria covering the years 2092-2100. The A1B emissions scenario is a middle-of-the-road GCM estimate. For all three time periods, the TTOP model estimates soil temperatures at 100 meter resolution and hence, permafrost distributions based on the meteorological inputs. Soil thermal and mechanical properties are estimated using soil data collected during the Arctic Transitions in the Land-Atmosphere System (ATLAS) project, work by Hofle et al in 1998, a large-scale survey done by the Natural Resources Conservation Service in 1990, and our own field work on the northern Seward Peninsula in 2007. The results show minimal change over the course of the 20th century, but project more significant change by the end of the 21st century, particularly on the continuous / discontinuous margin.
Implementation Of A Storm Surge Model For Western Alaska

Austin Cross, University of Alaska Fairbanks, International Arctic Research Center

Storm surge is a major hazard for Alaskan settlements that needs to be better understood for forecasting. Storm surge is the rise in seawater from cyclones piling up water higher than average. When this high water reaches shore it can cause severe flooding, endangering life and property. This is particularly problematic for many western Alaska coastal communities located at or near sea level, having been built on barrier islands and river deltas. Water levels any higher than normal can result in inundation of many areas.

Although much of the focus of research is on surge associated with hurricanes, winter low pressure systems can cause significant surge related flooding as well. Hydrodynamic models can forecast water levels resulting from surge based on available geographic and atmospheric data. Experimenting with the different atmospheric forcings, parameters and patterns can be identified for weather forecasters and emergency management personnel to recognize potentially destructive situations. Using real world data it is possible to model past scenarios and compare the results with water level measurements from gauges in Nome and Red Dog Mine on the western Alaska coast. If the results verify, the model can then be used to obtain water level values at innumerable other places where gauges may not exist to find past, present and future levels.

I am currently in the process of implementing one such model, ADCIRC, which requires intricate configuration to ensure accuracy. Results of the study are forthcoming.

Geophysical and Iñupiaq Perspectives and Observations of Shorefast Sea Ice

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This paper will examine ongoing efforts to observe the evolution of the shorefast sea-ice off Barrow, Alaska from multiple perspectives. While geophysical monitoring has been carried out systematically since the late 1990's, local indigenous knowledge has observed local and regional ice conditions for countless centuries as the Iñupiat people have pursued the traditional hunt of the bowhead whale and other marine mammals from the ice. In 2006/07 and 2007/08 a collaborative effort to share knowledge and coincident observations between these two fundamentally different ways of knowing has taken place. Local ice experts and experienced whalers kept observation journals and participated in interviews regarding the impact of ice conditions on hunting, travel, and assessments of ice stability and safety. Geophysical observations included a coastal radar to track near shore ice movement and stabilization, a coastal webcam for assistance in identifying key events in the shorefast ice's annual evolution, a mass balance site for monitoring level ice growth, sea level changes and snow accumulation, and SAR satellite imagery for identifying and tracking the extent of the shorefast ice edge. Ground-based electromagnetic induction sounding was used from a sled to measure the ice thickness distribution along the ice trails built by the community to access their whaling camps at the ice edge. These parallel observations are compared in the context of assessing ice stability throughout winter and spring. Differences in epistemology and in scales of observation are considered as this work attempts to identify areas where these seemingly disparate types of observations and knowledge may interface to improve the range of information accessible to those concerned with personal and community safety on the ice.
Learning Networks to Promote Climate Change Resilience – Lessons from Micronesia

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Climate change is rapidly changing the relationship between marine resource users and the ecosystems they depend upon to meet their economic, socio-cultural and spiritual needs. While the impacts of climate change are affecting communities at higher latitudes faster than equatorial communities, all coastal communities have begun to recognize the need for more rapid adaptation to their changing world.

Unfortunately, for communities in most developing countries, and for the many isolated rural communities across Alaska, there is limited access to knowledge about climate change trends and adaptation strategies. Those barriers limit the potential resilience of communities. Ignorance and inaction significantly diminishes the potential for those communities to make effective development choices and limits their ability to participate equitably in adaptation responses. By delaying community engagement in climate change adaptation, the costs of response will inevitably rise.

Similar challenges have been addressed for the past six years by communities and governments concerned with conservation and development issues in the small Pacific islands states in Micronesia. Micronesia comprises some seven countries spread over 3 million square miles of the central and western Pacific ocean and contains some 2150 islands covering just 717 square miles of land. Micronesia countries have both a rich and diverse mix of cultures and governance systems.

In response to the need to build a greater level of conservation knowledge and capacity in Micronesia in the most cost-effective and culturally appropriate manner, The Nature Conservancy has worked since 2003 with community and government leaders to establish the Micronesian Leaders in Island Conservation Learning (MIC) network. The Nature Conservancy’ Micronesia program believes that the only way to obtain lasting conservation results is to work closely with the local communities and help build the skills of conservation leaders and their organizations.

The learning network was established with a mixture of government and non-government leaders who were supported to meet twice per year to collaboratively share knowledge and build capacity. Between each retreat, cross visits between site level managers were facilitated and continued technical support was provided by The Nature Conservancy (TNC) until such time as the MIC network was able to manage those functions independently.

MIC has had a demonstrably beneficial impact on conservation in Micronesia. In its first five years, the MIC network worked with more than 25 leaders and 20 government and non-government organizations in Micronesia to help them strengthen the effectiveness of their organizations and expand the impact of their conservation work. These groups work on management or monitoring of some 34 important biodiversity sites.

Achievements of the MIC network include:

- start-up and/or staffing of four new conservation organizations in Micronesia;
- Helped advance conservation at four priority areas in the Federated States of Micronesia (FSM) using learning exchanges;
- Facilitated rapid agreement on FSM’s National Implementation and Support Partnership (NISP) by 12 government agencies and NGOs to achieve the Convention on Biological Diversity’s 2010 targets;
• Provided expert assistance and training to strengthen collaboration for Palau’s nationwide Protected Area Network (PAN);
• More extensive and focused engagement with the US Coral Reef Task Force; and
• Promoting the *Micronesia Challenge*, a call to action issued by President Tommy Remengesau challenging the other nations and territories of the Micronesia region to effectively conserve 20% of their land and 30% of their marine area by 2020.

A 2006 review of the MIC noted the significant impact that it had achieved at both the individual (member) level and at the institutional level – greatly enhancing the strength and resilience of those communities directly engaged. However, as with any nascent strategy, particularly one in which progress is achieved indirectly through partners, there are always areas for improvement – self reflection and formal evaluations of MIC activities are key elements of MIC network success and adaptation (see [http://mic-network.blogspot.com/](http://mic-network.blogspot.com/)).

In the ultimate analysis, the MIC network provides inspiration for all organizations involved – its systematic and careful design and implementation have yielded a wide range of new insights into conservation partnership. By working collaboratively, MIC members have begun to achieve more than the sum of the parts of their work in an area of the world where collaboration is a challenging, but critical precondition for conservation success.

This type of learning network model offers much promise in Alaska where similar levels of challenge exist in relation to knowledge sharing about climate change. A series of Alaskan climate change adaptation learning networks built on the same systematic approach used in the MIC example may enable communities to be more self reliant and able to develop and apply locally effective resilience strategies.

**Rainbow Trout Sensitivity to Contaminated Sediments During Early Development**

**John Foltz**, Washington State University
Jeffrey L. Ullman, Washington State University

The state of salmon in the Pacific Northwest is of concern with 13 of the 17 evolutionary significant units listed as threatened or endangered under the Endangered Species Act. Anthropogenic impacts to the aquatic ecosystem are numerable and include the addition of toxic chemicals. Many of these pollutants are hydrophobic in nature and partition out of the water column and into underlying sediments. The embryonic life stage for salmonids has a close physical association with benthic substrates and represents a critical life period that could potentially be affected by contaminated sediments.

Previous studies have examined the impact of contaminated sediments at the end of embryonic development, but not throughout the early life stages. Studies also have not determined whether impacts result from toxic compounds associated with the sediment or aqueous fractions. The goal of this study was to investigate contaminated sediment effects on early salmonid life stages using rainbow trout (*Oncorhynchus mykiss*) as a model species. Specific objectives consisted of: 1) Determine the uptake rate during specific intervals of embryonic development and post hatch to swim up, thus examining if there are critical periods within the fertilization to swim up stage, 2) Determine a bio-concentration factor for rainbow trout embryos, and 3) Examine if the uptake of a toxic hydrophobic compound was directly from the sediment or from the sediment to the water before uptake by the embryo.

Within static aquaria with aeration, newly fertilized (less than one minute) rainbow trout embryos were placed into one of three treatments: 1) Direct contact with an uncontaminated artificial substrate, 2) Direct contact with a contaminated artificial substrate, or 3) Suspended in the water column above a contaminated artificial substrate (i.e., no sediment contact). Embryos were incubated at 14°C in 24-h darkness for time periods of 1hr., 2hr., 12hr., 24hr., 7 days, to the eyed stage, at the hatch stage and at the
swim up stage. At the end of each time period, the embryos were collected, euthanized and analyzed for contaminant uptake. Chemical uptake rates were calculated for each embryonic period and statistically compared.

This study helps to demonstrate potential impacts imparted by contaminated sediments on salmonids. Furthermore, this study elucidates critical windows during early life stage development that may be sensitive to pollutant exposure.

**Wave States in the Chukchi Sea**

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David Atkinson, Ph.D., University of Alaska Fairbanks

Our study examines waves in the southeast Chukchi Sea during fall storms of 2007. The Arctic is inundated with storms during the fall season, which affect coastal erosion. Shishmaref, Alaska has recently been in the headline news regarding coastal erosion. To study these storms observational, a bottom-mounted Aanderaa RDCP600 was deployed on the Chukchi Sea shelf approximately 89 kilometers north of Shishmaref, Alaska to measure wave height and direction, along with other wave parameters. At a depth of 33 meters the instrument, which was set for acoustic based wave measurement, was able to capture wave direction during stormy periods. The acoustic based waves are sampled at a 2 Hz rate for 15 minutes every 2 hours. This sampling rate is designed to target longer wave periods. This paper presents the RDCP wave data.

**ELOKA: Data Management Support for Community-Based Arctic Observing Networks**

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Shari Gearheard, National Snow and Ice Data Center  
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Mark Parsons, National Snow and Ice Data Center

Over the last decade, Arctic residents and indigenous peoples have been increasingly involved in research concerning their communities and their environment. Arctic communities have made significant contributions to understanding recent environmental change, and community-based research, including traditional knowledge research and community-based monitoring, will be an important part of IPY activities and any Arctic Observing Network (AON).

One of the greatest challenges of local and traditional knowledge (LTK) research and community-based monitoring to date has been effective and appropriate means of recording, storing, and managing data and information. It has been a challenge to find effective means of protecting sensitive information while also making community-based data and information available to Arctic residents and researchers, as well as other interested groups such as teachers, students, and decision makers. Without a network and data management to support LTK and community-based research, a number of problems have arisen such as: misplacement or loss of extremely precious data (e.g., information from Elders who have passed away); lack of awareness of previous studies and repetition of research in the same communities resulting in research fatigue and waste of resources; and a reluctance or inability to initiate or maintain community-based research or monitoring because no data management system is available. There is an urgent need for effective and appropriate means of recording, preserving, and sharing data and information being collected in Arctic communities. ELOKA seeks to fill this gap.
In 2006, ELOKA responded to the NSF IPY Announcement of Opportunity to 'develop and deploy a pan-Arctic observing system that will measure the full range of continuing environmental changes underway.' ELOKA was successful in obtaining funding and is working toward providing the needed support to local and traditional knowledge research, and community-based observations and monitoring, which are key components to any Arctic Observing Network (AON). ELOKA will provide a data management and networking service for community-based research that keeps control of data in the hands of community data providers, while still allowing for broad searches and sharing of information.

We understand that the development of a circumpolar network and data management service for Arctic LTK and community-based observations will take time, collaboration, and input from many sources. Our hope for IPY is to get ELOKA off the ground and build a strong foundation for its development. To reach this goal, ELOKA has been launched through partnerships with several community-based projects that represent different regions, cultures, and data management needs. We are developing data management systems and testing their utility with our partners. We expect to be able to offer data services to more projects in the near future as we refine our system and learn more about the needs of different community-based projects around the Arctic.

Proteomics of A Microbial Community From A Trichloroethylene Contaminated Aquifer

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The elucidation of the molecular processes carried out by microbial communities in their natural environments and in environments that have been perturbed by human activity is essential to unraveling biogeochemical cycles and to the development of bioremediation strategies. The inability to replicate environmental conditions in the lab has necessitated the development of culture-free techniques for studying microbial ecosystems. The emerging field of community proteomics has allowed researchers to gain insight into the molecular processes occurring within a microbial community through analysis of its protein complement. This approach introduces less bias than traditional methods because no prior site knowledge is necessary since probes targeting genes and/or transcripts for amplification are not needed. In addition, abundant proteins are directly sequenced from environmental samples so results are relevant to the primary metabolic processes occurring within the microbial community.

Community proteomics is being used in our lab as part of a multipronged approach to study the biological processes contributing to the degradation of trichloroethylene (TCE) in the Snake River Plain’s fractured basalt aquifer at the US Department of Energy’s Test Area North (TAN) site on lands of the Idaho National Laboratory near Idaho Falls, Idaho USA. TCE is a recalcitrant anthropogenic contaminant of many aquifers and it is a suspected carcinogen. The chemical properties of TCE and other chlorinated solvents lead to the formation of non-aqueous phase liquid (NAPL) plumes that are resistant to conventional cleanup methods such as “pump and treat.” An alternative remediation strategy involving monitored natural attenuation (MNA) has been proposed at TAN based upon the hypothesis that indigenous microbial communities involved in aerobic methanotrophy can co-metabolically degrade TCE due to the proven non-specific activity of methane monooxygenase (MMO) enzymes. In order for MNA to be used in place of traditional remediation techniques, there must be historical evidence showing a decrease in TCE concentration over time as well as extensive characterization of the site in order to determine the fate of TCE due to abiotic and biotic processes.

Proteomic analyses were carried out on protein extracts derived from two types of samples: concentrated groundwater containing planktonic and/or dislodged microbial cells, and biofilm samples taken from
basalt substrates that had been incubated in flow-through in situ reactors placed within the TAN aquifer. We developed methods for overcoming challenges for characterization of each sample type, including reducing sample complexity by a novel time-course lysis method, protein recovery from low biomass samples, and reduction of interfering species released from the environmental sample matrices. Total protein extracts were derivatized and digested with trypsin. The peptides produced were sequenced using UPLC-MS/MS and the peptide sequence information was used to identify proteins by comparison to sequence data in appropriate databases. Results of analyses of planktonic samples revealed that MMO proteins are found in all wells examined to date at the TAN site. In addition, methyl-CoM reductase, an enzyme involved in methanogenesis as well as being implicated in anaerobic methane oxidation, was identified in one TAN site well. This study thus used proteomics to prove that enzymes capable of degrading TCE are being actively expressed in the TAN aquifer, as well as many other proteins involved in the metabolism of the community as a whole.

**Laboratory Experiments of Entrapment and Movement of Oil in Sea Ice**

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Chris Petrich, University of Alaska Fairbanks  
Hajo Eicken, Ph.D., University of Alaska Fairbanks

Entrapment, fixation and transport of oil in sea ice are important processes for the understanding of preservation and migration of oil and water-soluble oil components in ice-covered waters. We present preliminary results from laboratory experiments aimed to examine the entrapment and upward migration of oil through both growing and melting sea ice.

Ice was grown from artificial seawater in two different types of vessels (a 190 liter PVC barrel of height 95 cm and diameter 51 cm, and a 26 liter rubbermaid container with approximate dimensions 42x28x26 cm³) in a cold room at a temperature of -20 ºC. During growth, oil lenses (either North Slope Crude or Synthetic Oil) introduced beneath the ice were encapsulated by growing ice. Oil migrated 1.5–3 cm into the pore space of the overlying ice. Comparison of ice porosity and oil concentration for experiments of various boundary conditions suggest that 1/3 to 2/3 of the pore space above the oil lens can be occupied by oil.

In melt studies, for which cold room temperature was increased to around –1 ºC, we examined the mode and rate at which oil is transported through the ice to the surface. Oil transport near the surface was confined to discrete brine channels with oil volume flux of the order of $10^6$ kg m⁻² s⁻¹. As the vertical percolation of oil ceased, ~20% of the total ice volume remained contaminated with (1–4 wt%) of oil.

**Arctic Sea Ice Monitoring and Research Through Indigenous Observations**

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Hajo Eicken, Ph.D., University of Alaska Fairbanks, Geophysical Institute  
Matthew Druckenmiller, University of Alaska Fairbanks, Geophysical Institute  
Marie Kapsch, University of Alaska Fairbanks, Geophysical Institute

Indigenous communities along the Arctic coast have used sea ice for hunting and travel for centuries. This has resulted in an unmatched familiarity with the ice environment and an accumulation of a vast body of traditional knowledge on sea ice processes and changes. Increasingly, science is turning to traditional knowledge for its long-term record of local environmental conditions that has been passed down through generations.
Here, local sea ice experts who are also experienced hunters and community leaders provide daily written observations on sea ice, weather, and ice-associated community activities, such as hunting and travel. These observations help to identify key dates in the annual evolution of the local ice cover such as the first appearance of slush ice or the beginning of break-up. The data received from local observers complement geophysical methods of monitoring and studying Alaska's coastal and landfast sea ice. Local observers focus on the morphology of the local landfast ice; deformation events and the distribution of key features such as grounded ridges or multiyear ice floes are critical in the assessment of the stability of the ice. As the ice is intricately linked to the subsistence activities of the community, the stability of the ice is constantly evaluated during periods of heavy use. Methods to help assess stability and avoid rescue situations are of primary interest to many of these communities.

Significant challenges exist in how such information is used in conjunction with research-derived data. It is crucial to understand not only what is being observed but also why and how these observations are being made; context is important, especially as longer-term records of local observations are maintained.

We have developed a database that currently houses observations from 2006 to present, primarily for Barrow, Wales and Gambell, Alaska, with efforts under way to enlist additional observers and villages. Both the written ice observations and transcripts from interviews, performed with other experienced members of the communities, are entered into the database where they are archived in a searchable format. These diverse datasets are currently being analyzed as they relate to key events in the annual evolution of the seasonal ice cover, as well as the stability of landfast ice, breakout events, and hazards associated with spring melt. Additional work is underway to compare larger-scale satellite data of ice cover to local observations on the “ground” in an attempt to test how remote sensing and real-time data might be used to assess risk. This could prove to be a useful tool for hunters who currently use satellite images to plan their trips to the ice.

**Assessing Nearshore Biodiversity: The NAGIS Project**

**Ann Knowlton**, University of Alaska Fairbanks  
**Katrin Iken**, University of Alaska Fairbanks  
**Brenda Konar**, University of Alaska Fairbanks

The Natural Geography in Shore Areas (NaGISA) project is an ambassador program for the Census of Marine Life (CoML). NaGISA’s primary goal is to quantify nearshore biodiversity on a global scale with emphasis on macroalgal covered rocky habitats and seagrass beds. The focus and implementation of NaGISA is unique in that the target habitats are structurally complex and found worldwide, and that local communities and students are involved in data collection.

Eight regional centers across the globe coordinate sampling efforts covering 1000’s of miles of coastline. NaGISA utilizes a standardized protocol to facilitate comparisons of biodiversity on large geographical scales. Biodiversity data collected by NaGISA researchers can be used for temporal and spatial comparisons, as well as provide baseline information for coastal monitoring efforts. Data collected are incorporated into an international marine database, the Ocean Biogeographic Information System (OBIS), and available to researchers worldwide.

With rapidly changing environmental conditions, particularly in polar areas, assessment of current biodiversity components is vital to understanding and evaluating future changes. NaGISA’s sampling of both Arctic and Antarctic nearshore communities will help scientists, resource managers, and local stakeholders make informed management and policy decisions.
An Empirical Attempt of Watershed Mapping in Micro-Scale Resolution

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Polygonal tundra show extensive micro-scale (< 1m) variations in vegetation, thermal and hydrological regime. The tundra landscape is sparsely monitored with a single point measurement often assumed to represent local (1 km) or regional (10 km) scale conditions. Modeling efforts have mainly focused on simulations resolving regional scales partly due to limited availability of high resolution field information such as digital elevation and vegetation maps. In an attempt to enhance watershed mapping of soil and hydrological regimes, our objective was to quantify the extrapolation of measurements from a spatially intensive monitored area to the entire watershed.

We have developed land cover classification and digital elevation maps (DEM) with micro-scale resolution of the Barrow Environmental Observatory in northern Alaska. One of our intensively monitored polygons shows differences in ground surface temperatures exceeding 10°C in winter and 20°C in summer across the 20×20 m area. Hourly near-surface soil moisture differed up to 30% with a minimum of 65% and a maximum of 95% saturation. Topographical differences of up to 0.7 m across the polygon form the major hydraulic gradients also on the local scale.

By combining our field measurements with a high resolution land cover classification (0.7 m spatial resolution) derived from Quickbird satellite imagery, we aim to examine the correlations of vegetation to the 29 sites of measured soil temperature, soil moisture and observed soil horizons across the polygon. A preliminary correlation analysis shows a strong link between spatial distributions in vegetation (2.5 m spatial resolution) and topography (1 m spatial resolution). The micro-scale land cover classification, which covers several square kilometers, could potentially extrapolate seasonal changes in soil thermal and hydrological regime across the entire watershed through the established empirical correlations. We can validate the empirical model by using a subset of existing measurements, each representing a particular vegetation type. Gaining an understanding of the micro-scale temporal and spatial variations of the soil and thermal regime are key factors to successfully project future regional changes in the Arctic and their global implications.

Ways to Help and Ways to Hinder: Climate, Weather and Policy in Alaska

Philip Loring, University of Alaska Fairbanks

Climate change poses unique challenges to livelihoods in Alaska, for residents of rural and urban places alike. If these challenges are to be met, they require that people be afforded the flexibility to experiment and innovate in response, and have the best possible information at hand when doing so. However it is questionable whether current paradigms for land tenure and natural resource management policy and for information sharing and social learning are even compatible with the needs that they are now expected to serve. Indeed many have provided examples of how existing policy structures and learning practices tend to complicate, rather than empower, local decision making abilities.
How might we better understand the fundamentals of this apparent disconnect between environmental change, policy, and action, such that we might design new structures of learning and governance that can facilitate addressing these highly complex problems? This poster synthesizes the findings of two seasons of needs assessment done across the state, with a transect of Alaskan communities coastal and up-river, rural and urban, comparing experiences with environmental change, resource management, and land tenure. We find that the household experience, resource management policy and regulation regimes, and ecological change all proceed at their own set of spatial and temporal scales, and for the fisher or hunter or farmer this leaves interstices between what is experienced, what is needed, and what can be done. The poster compares the circumstances of two seemingly different livelihoods: the small-scale commercial fisher in Dutch Harbor, and the subsistence hunter in Fort Yukon. Both share similar goals of making a living, make decisions at similar spatial and temporal scales, and have to navigate problems of environmental variability and resource competition within a complex context of resource management policy. Each, however, has a very different experience that is driven at least in part by differences in the policy and information regimes of which they are a part. High quality and locally-scaled information, better institutional flexibility, and a general climate of support and facilitation by state and federal agencies for local responses to environmental challenges are invariably described as essential where they are already in place, and greatly in need where they do not.

The details of these cases should be of interest to anyone involved in the development of new paradigms for effective linkages between institutional and local responses to change. When local expertise is legitimized by a policy regime that affords flexibility and decision-making, and empowered by the highest-quality science and needs-driven, locally-scaled forecasting products, a variety of outcomes including household success and individual health and safety, and the responsible management of local resources become necessarily linked. What this means is that while scalar incongruities between the state, environmental change, and the household experience may be irreconcilable, the very need to bridge these gaps may provide an exciting, new and more powerful mandate for designing the policy and information institutions of the future.

**Polybrominated Diphenyl Ether (PBDE) Sorption Behavior: Relation to Sediment Flux and Sediment Remediation**

*Reuven Miropolsky, Washington State University*
*Jeffrey L. Ullman, Ph.D., Washington State University*

The primary techniques used for contaminated sediment remediation – dredging, capping, and monitored natural recovery – have limitations such as cost, effectiveness and/or a slow rate of recovery. Therefore the need exists for improved in-situ remediation techniques. One such alternative method involves active capping materials that either enhance contaminant isolation or react with chemicals to enhance degradation. This approach helps stabilize contaminated sediments, lessens pollutant bioavailability, and can allow for application of decreased cap thickness.

Polybrominated diphenyl ethers (PBDEs) are a family of flame retardant chemicals that are of increasing concern in the environment. PBDEs are a significant concern in the Pacific Northwest, evidenced by reports indicating elevated concentrations in Puget Sound and the Columbia River System, as well as the State of Washington being the first state to regulate PBDEs. Furthermore, PBDEs have been found in Arctic marine food webs and have been shown to biomagnify from seals to polar bears.

This study examines sorption behavior of PBDEs to sediments and selected capping material. Little information exists on either PBDE sorption to sediments or PBDE behavior in relation to active caps.
Laboratory batch studies were used to determine partition coefficients for different PBDE congeners. Data were fit to sorption isotherms to elucidate binding behavior to sediments displaying varying physicochemical characteristics and active capping material. This information is needed to better understand the potential for PBDE flux from sediments to aquatic food webs and to examine the potential use of active caps as a remediation technique for these contaminants.

**Explorative Scenarios Using Consistency and Robustness Analysis and Wild Cards**

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Scenarios are valuable tools for decision makers. They allow us to develop and bring into focus several images of future developments where predictions are not feasible. These images can help decision makers to plan for a range of futures. Scenarios can also be a useful tool in identifying early indicators as to what the actual future development will be. Scenario processes have been successfully employed in state, regional, local, corporate and catastrophe planning. Public scenario processes can be used to induce conversation between different stakeholder groups and to stimulate thinking ‘outside the box’.

Scenarios can be classified to be normative or explorative. Normative scenarios can be understood as stories of the future written by an author well informed on the specific topic under consideration. The drawback of narrative scenarios is that it is possible that seemingly unlikely, but very consistent, futures are often overlooked. Explorative scenario methods attempt to remedy this problem by implementing a process that ‘blinds’ the investigator for parts of the process to the bigger picture. The aim is to allow for easily dismissed, but interesting possible futures to survive the process of narrowing down the space of possible futures to about five.

One such explorative scenario method is scenario construction by consistency analysis (Gausemeier et al., 1996). In this analysis key factors driving the development of the field under consideration are identified. Each key factor is assigned several future projections, i.e., ways in which it could develop in the future. Each future projection is assigned a plausibility value. In general, any combination of future projections of the different key factors represents a possible future. However, some of these possible futures contain future projections that are inconsistent with each other. To rule out such inconsistencies each future projection of a key factor has to be compared with all future projections of the other key factors and their pair-wise consistency determined. From the resulting matrix consistent future projection bundles (raw scenarios) can be calculated. However, this process results in no information with respect to plausibility of the raw scenarios.

We have extended the consistency analysis into a robustness analysis. We denote raw scenarios as ‘robust’ if they not only have a high consistency, but a high robustness, that is a compounded variable of consistency and plausibility. Further, our analysis allows the incorporation of Wild Cards (Steinmüller and Steinmüller, 2004), i.e. disruptive events with high impact on the field under investigation.

For the example of the ‘Futures for the Arctic 2030’ process (see oral presentation) we will explain the Robustness Analysis and further useful data analysis tools for scenario processes. Further, we will describe our experience with a web-based ‘Open-Scenario’ approach, which invites all stakeholders to comment in the process. By this we hope to make a broader audience aware of the usefulness of explorative scenario processes.
Detection of Fracture Induced Anisotropy in Temperate Glaciers Using Georadar

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Global climate change is rapidly altering the size and flow of glaciers, among other properties. Glacier motion is dependant on water input to the base of the glacier. By improving our understanding of water transport and storage within glaciers, we will be able to better quantify glacier motion and the effects of climate change. Over six field seasons our group has been studying the hydrologic properties of the Bench Glacier, in the Chugach Mountains, AK.

Borehole videos show planar fractures in the lower two-thirds to three-quarters of the glacier. These voids are not cylindrical as they would be if formed by flowing water but are fractures likely caused by the stress field throughout the glacier. Besides video, these boreholes were used for slug tests to determine connectivity of the fractures with other fractures as well as the bed. Radar images show the presences of a reflection free zone near the surface of the glacier, confirming the lack of voids near the surface. Still little is know about the distribution, orientation and overall water contained in the voids.

We executed three georadar surveys designed to help determine these voids properties. The first survey, June 2006, is a large 3D multi-offset survey, collected in three azimuths. This provides a three dimensional image of the glacier interior. Additionally the different azimuths should yield insight into the nature of these voids. Transverse waves through a medium containing preferentially oriented inclusions travel at different speeds depending on their polarization relative to the inclusions. Two additional surveys, conducted in August 2007 and 2008 also tested the azimuthal orientation of the fractures. We collected three polarizations; co-polarized end-fire (transverse electric, TE), co-polarized broadside (transverse magnetic, TM) and cross-polarized. Each polarization was collected in five directions ranging from 0 to 90 degrees relative to the axis of the glacier.

Preliminary results indicate an azimuthally dependent radar velocity with about 5% anisotropy. By applying the Alford rotation to georadar data we hope to extract more details of the void orientation. This will yield new insight into the formation and distribution and content of englacial voids.

Arctic and Global Climate Responses to Ecosystem-Induced Summer Albedo Changes

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Several Arctic and boreal research studies have shown the strong role of high latitude terrestrial ecosystems in the modulation of the climate by exchange of energy, momentum and moisture between land surface and atmosphere. The changes in climate also have consequences on ecosystems and ecosystem carbon fluxes due to the ecosystem’s sensitivity to temperature and precipitation changes. A difference in temperature of ±1K can be decisive for the survival or death of plants. Therefore, it is essential to better understand the feedback between climate and ecosystem changes.

To assess the influence of ecosystem-induced summer albedo changes occurring north of 50N on climate the Community Climate System Model version 3 (CCSM3) simulations are performed without and in conjunction with the summer-albedo change data from simulations performed with the Terrestrial
Ecosystem Model (TEM version 7) for 2003 to 2053. These simulations are denoted REF and ALB hereafter.

The results show that TEM-simulated albedo changes do not have a consistent trend over a given year. However, the albedo changes averaged over the Pan-Arctic slightly increase as summer progresses. Comparison between REF and ALB reveals that shortwave radiation (SW) significantly decreases up to 10 Wm⁻² over western and southern Siberia and increases up to 8 Wm⁻² over eastern Siberia and eastern Canada whereas in late winter and spring, SW significantly increases up to 8 Wm⁻² over Europe in response to summer albedo changes over Pan-Arctic. Surface and soil temperature also significantly decreases up to 4 K over Pan-Arctic for all seasons. Precipitation significantly decreases up to 15 mm/month over Europe in summer and spring. There are also significant global consequences of Pan-Arctic summer albedo changes except for precipitation. This result clearly suggests that summer albedo change over Pan-Arctic can result in alterations to SW, surface and soil temperature elsewhere in the globe through non-linear feedbacks within the atmosphere’s general circulation.

**The Impact of Fuel Prices on Subsistence in Northwest Alaska**

**Julie Raymond-Yakoubian**, University of Alaska-Fairbanks and Kawerak, Inc.

This poster offers data on the impact of rising fuel prices on subsistence practices in the Bering Strait region of Alaska. Data was obtained during the summer of 2008 over the course of approximately 30 interviews in communities throughout the region. The high price of gasoline in Bering Strait area villages has led to changes in the day to day practices associated with obtaining subsistence foods. These changes have had consequent impacts in other areas of rural residents’ lives such as sharing and exchange networks, diet and stress levels. Resident’s thoughts and views on the situation, as well as an analysis of the circumstances, are presented.

**Estimating Uncertainty in Approaches Used to Quantify Surface Water-Groundwater Exchange**

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Bethany Neilson, Ph.D., Utah State University

Surface water-groundwater exchanges play an important role in understanding solute transport and transformations. Two approaches to quantifying surface water-groundwater exchanges were applied to a mountain stream highly influenced by groundwater. The approaches included differential gauging using discharge measurements and instantaneous tracer experiments. Differential gauging incorporated the development of stage-discharge relationships at the reach boundaries and was used to quantify a change in stream discharge at a reach scale. Instantaneous tracer experiments were additionally performed to quantify stream discharge at a sub-reach scale. Sodium chloride was used as a tracer for these experiments and responses were measured in-situ with specific conductance. Site specific correlations between specific conductance and chloride concentration were constructed to complete stream discharge calculations. Statistical techniques were performed to estimate the uncertainty in correlations and the resulting stream discharge calculations from each tracer injection. Similar techniques were also performed to estimate the uncertainty in the stage-discharge relationships. The calculated discharges and estimated uncertainty in the differential gauging and instantaneous tracer experiment approaches will be presented and compared.
The Mathematics of Estimation: Interdisciplinary Pedagogy And Education For Sustainable Development

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Interdisciplinarity has become relevant for emergent sciences of the 21st century. Yet mathematics in nearly every country in the world is still rooted in rudimentary computational processes and problems that emphasize "simplistic thinking". Curricular documents in Asia-Pacific, Europe and the United States, make a call for connecting mathematics (internally) and externally to relevant problems and the promotion of mathematical literacy.

The goals for educating current and future generations should have more emphasis on connections, coherence, civic consciousness and cross-curricular competencies necessary for solving problems confronting humanity. By civic consciousness, I mean shared global problems e.g., fair trade, environmental indexes, ethical issues, information reporting (ability to fact check, source check, detect biases). Most (math) education programs typically do not prepare prospective teachers to incorporate interdisciplinary activities that cohere with reading, science, mathematics and societal issues.

Several research projects were designed and implemented to connect the standard curriculum to socially relevant problems, i.e., combine uses of mathematics and critical thinking skills. In these projects scenarios were created that involved making Fermi estimates, reasoning in ratios, and problem solving. The purpose of this approach was to create a paradigm shift and humanize the purpose and relevance of mathematics in global economies and societies of today.

Several scenarios were used in the context of the culture and communities that surround the students. Examples include comparing amounts of waste produced in the community versus different countries to make linkages between consumerism and the environment; debt calculations between (ex-colonial) countries abundant in natural resources, or the debtor, and those that do not have the same magnitude of resources, the collector, to study equitable distribution of global resources; and to compare data on GNP per capita income and resource consumption to highlight the reasons for discrepancies and their consequences in OECD and non-OECD countries.

There are numerous possibilities and implications for the use of such scenarios also in professional development programs. For instance, the implementation of interdisciplinary activities around Earth week involve science, math, field trips to local water treatment and recycling plants, as well as local landfills. This can be followed by the presentation of findings to the community by pre-service students, teachers and school children.

The future of our planet is intricately connected to the concepts and skills that future generations derive from their school education. We need to foster critical thinking and to develop an awareness for the value of making reasoned choices that seek to will good for humanity. The implications of these projects are discussed.
Collection of Ocean Current and Wave Height Data From A CODAR In The Southeastern Chukchi Sea, Alaska

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Coastal Ocean Dynamic Applications Radar (CODAR) is a powerful research and operations tool for the Arctic Coast. CODAR works by transmitting a radio signal in the High Frequency (HF) band in between 5-25 MHz. The signal is scattered off of ocean waves and reflected in all directions, however ocean waves of exactly half the transmit wavelength of the HF signal will reflect the signal back to the transmit source if they are traveling in a direction either towards or away from the radar. The reflected electromagnetic waves add coherently and produce a strong signal at a precise wavelength, a phenomenon called Bragg scattering. It has been demonstrated that first-order Bragg peaks of the returned signal are used to derive ocean surface currents and second-order sea echo spectra can be used to derive information about the directional wave spectra. In September through December 2008, hourly averages of ocean currents and wave heights were collected by a single CODAR instrument installed at the DeLong Mountain Terminal near Kotzebue, AK. Currents in excess of 60 cm/s and wave heights near 3 meters were observed during several storm events. In addition, a period of sea ice formation during light winds and coastal polyna formation was observed in early November. Two CODAR instruments are capable of producing 2-dimensional maps of ocean surface currents with high resolution (2 km) over a large area (1,600 square km). The data collected from this experiment demonstrates the successful application of CODAR technology to the Arctic environment of the Southeastern Chukchi Sea.

Assessing the Role of Soil Characteristics on E. Coli Attachment

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Food-borne diseases remain a persistent challenge to public health, causing approximately 76 million illnesses and 5,000 deaths every year in the United States. The number of incidents has more than doubled since 1987. Livestock and poultry are a significant source of pathogens, often entering surface waters via runoff from fields containing manure. Human exposure can then occur either by direct consumption of water or by consumption of crops or vegetables contaminated by irrigation water.

Bacterial attachment to soil particles plays an important role in the fate and transport of pathogenic bacteria. The objective of this study was to assess the role of physicochemical soil characteristics on attachment of a non-pathogenic E. coli strain. E. coli are commonly used as indicators of fecal contamination and can be used to simulate the fate and transport of the pathogenic E. coli O157:H7 strain. Batch equilibrium experiments using six soils showed E. coli attachment is significantly governed by total organic carbon content, clay percentage and soil pH. Attachment can be successfully modeled by Freundlich and Langmuir isotherms. These findings have implications on development of best management practices (BMPs) to protect surface waters from contamination.
PRESENTATIONS – FULL PAPERS

(Arranged Alphabetically by Author)
This paper summarizes the “Social and Economic Effects” chapter of Assessment 2007: Oil and Gas Activities in the Arctic – Effects and Potential Effects (AMAP 2009). The chapter uses a set of case studies to examine the social and economic effects of oil and gas activities in the Arctic, including governance, sustainable development implications, and possible impact on the ways of life of indigenous and non-indigenous residents of the Arctic. The analysis considers effects at the national, regional, and local levels. It also examines the pattern of effects across time, as the mix of activities and their effects may be quite different from one stage to another across the lifecycle of an oil or gas project. Despite differences from one region to the next in geographic context, political and economic institutions, culture and history, and stage of oil and gas development, some common themes emerge, which are the focus for this summary paper.

**Governance and response**

In keeping with the advanced administrative capacity of Arctic countries, governance of oil and gas activities is taken seriously. Such responses include establishing appropriate environmental management regimes, promoting economic development, and seeking equitable distributions of the costs and benefits of oil and gas activities. Governance responses can also occur at the local level. In Russia, the degree of local involvement in governance has typically been lower. In Norway, and in Greenland’s approach to planning so far, governance regarding oil and gas has been concentrated at the national level, emphasizing the retention of earnings by government to be used for the common good. The national emphasis is not surprising, given that oil and gas reserves in Norway and Greenland are offshore, thus reducing local roles and impacts in comparison with on-shore activities in North America and Russia.

In the on-shore cases, local governance efforts have focused on securing economic opportunity and benefit, while also protecting the environment and cultural practices. In Alaska and Canada there has been emphasis on training workers, though the success of such programs has been mixed. Kuukpik Corporation in Alaska and the Inuvialuit Development Corporation in the Northwest Territories have been able to use oil and gas activity as a catalyst for further business development. In Russia, Yerv has managed to secure some payments to local residents for land use. Oil and gas workers have created a market for local products such as reindeer meat, which supports a traditional activity that has also been harmed by the environmental impacts of oil and gas activity. Culturally, revenues from oil and gas have been used to support cultural programs and to improve local involvement in social and environmental planning and management. For example, the North Slope Borough in Alaska has established several wildlife management programs, aimed at sustaining traditional hunting, and funded largely through revenues from oil and gas activity in the region.

In addition to formal regulatory response, a variety of other responses have arisen as well, mitigating impacts at the individual and community level. The development of markets among oil and gas workers in Russia is one response by reindeer herders. In Nuiqsut, hunters have adapted their activities to avoid oil facilities. And the winter that there was lots of construction work on Alpine, the community allocated jobs equitably, ensuring that every household had at least one wage earner and someone at home to care for children and elders.

**Effects on social and economic systems**

Oil and gas activity can greatly increase regional and national GDP. On a regional and national level, this increase makes possible overall economic growth, increased investment, and the creation of public trust funds for future benefit, as has been done in Norway and Alaska. During the peak times of activity in the
lifecycle of oil and gas activities, the demand for labor can create labor shortages, and the demand for goods and services can drive prices up. In the production phase, labor demands are lower but revenue is at its peak. In Norway, for example, petroleum activities accounted for only 3% of national employment in 2003, but 18.8% of GDP, 24.8% of government revenues, and 46% of export earnings.

Oil and gas activity can serve as a powerful engine for economic growth, through increased income from oil and gas employment, through the growth of businesses supporting oil and gas activities, and from the stimulation of overall economic activity. This is especially true during the peak of employment and activity in the construction phase, but the effects can persist throughout the life of a project, particularly in combination with greater regional revenues at the macroeconomic level, which may contribute to a larger overall economy.

Oil and gas activities, and particularly the associated economic growth, lead to increased regional populations from in-migration and reduced out-migration. Longer life expectancy in recent decades, from better public health and health care, may also be due in part to the economic growth provided by oil and gas activities. As noted earlier, the Yamalo-Nenets Autonomous Okrug is the only region of the Russian Arctic to have increased in population between 1989 and 2002. In Alaska, the statewide population has increased dramatically since the development of North Slope oil fields, in part due to growth of the overall economy and state government revenues. In addition to overall population size, oil and gas activities can shift demographic patterns. Areas with strong development tend to have a relatively large proportion of young males, and thus relatively smaller proportions of women, children, and the elderly. Demands for social services can thus be shifted accordingly, including an increased need for police activity.

Development and associated rapid changes in economic conditions (either upwards or downwards) can lead to social disruption such as substance abuse, domestic violence, and so on. When people move or are moved away from their homelands and their cultural setting, mental health can suffer. On the other hand, the availability of financial resources can lead to improved availability of health services such as doctors, hospitals, and so on. Determining the overall net gain or loss in health requires more detailed studies than are currently available.

Responses to oil and gas activities often include education and training programs, both directed to careers in the petroleum industry and towards higher education in general. In Inuvik and Nuiqsut, for example, there are scholarship programs funded by industry and others for local students who wish to pursue a university education. There are also technical training courses for industry jobs, an emphasis that has been considered in Greenland and will be pursued if oil and gas prospects are developed. In Russia, fewer training opportunities have been provided, consistent with the approach of recruiting large numbers of workers from outside the Arctic regions.

As discussed above, greater resources for the institutions of environmental and economic governance increases their ability to play substantial roles in regulation, adaptation, management, and so on. Furthermore, as demonstrated by the Norwegian experience, regulatory regimes (regarding environment as well as economics) in particular are more likely to be effective if established in advance of the activity, rather than as a response after activity has begun. In the Inuvik region, oil and gas revenues and associated business development have acted in concert with land claims agreements to increase local capacity for governance. Similar changes have been seen in Alaska’s North Slope Borough. In Russia, the lack of revenues to local institutions in the Soviet era prevented the development of effective local governance. Recent shifts indicate a growing role of local institutions, though how far that will continue remains to be seen.
In North America, local communities identify cultural protection as a priority in their planning for oil and gas development. Throughout the Arctic, modernization has tended to disrupt traditional social and cultural practices in many ways. Oil and gas activities can exacerbate this trend, by environmental degradation as seen in Russia, or by increasing the pace of societal change, as seen in Alaska and Canada. At the same time, oil and gas revenues to local institutions can be used to provide cultural programs, protect local practices, and strengthen a sense of cultural identity. The North Slope Borough, for example, has used oil revenues to support an extensive and costly program to protect bowhead whaling from international regulatory attempts to end this practice. The Inuvialuit have expanded wildlife management programs. Yerv and Yamal Potomka! in Russia are beginning to promote ways to use oil and gas activities to sustain local cultures and practices.

Oil and gas activities can have considerable negative impacts on the environment, primarily on a local scale. For local residents, these impacts can alter traditional hunting, fishing, herding, and gathering practices through environmental degradation or by the creation of physical barriers such as pipelines that can affect animals or people. Larger scale impacts may stem from accidents during transport (e.g., oil spills) or widespread pollution. By creating local markets for traditional products, such as reindeer meat, oil and gas activities can also help sustain contact with nature, as seen in Russia. In the North Slope Borough, income stemming directly or indirectly from oil and gas activities has been associated with high production of traditional foods.

Social health can be considered as the smooth functioning of society, whether at the community level, regionally, or nationally. Oil and gas activities can increase divisiveness, particularly if benefits and costs are not shared equitably, but can also stimulate social cooperation and provide revenues to support social programs. Economic stimulus, particularly during booms and busts, can lead to increased drug and alcohol use and consequent social problems such as domestic violence, divorce, and crime, particularly during transition periods. In the Yamalo-Nenets area, cooperative relationships are being established between reindeer herders and oil and gas workers and industry representatives, which may create a better overall social milieu. In the Nenets area, by contrast, controversies over who is to benefit from cooperative programs with organizations such as Yerv may tear the region’s social fabric as some gain and others lose.

The various types of effects cannot be considered in isolation from one another. Similar stimuli can lead to different outcomes depending on the particular situation and how the various effects interact. For example, economic opportunity can spur population growth, stressing cultural integrity by the influx of newcomers, creating social problems and consequent social and individual health impacts. Or, similar opportunity can be harnessed to improve local resources, which can be used for more effective governance, which in turn may improve cultural programs, leading to better social health. What the beneficial outcomes have in common is a concerted effort to plan for oil and gas effects. In the Mackenzie Delta-Beaufort Sea region, development slowed for many reasons in the 1980s and 1990s, which allowed for the creation of local capacity. In Norway, setting clear national goals and developing a comprehensive regulatory regime for the activity helped plan specific regulations, in advance of oil and gas activities, that have resulted in substantial national benefit. In Russia, Soviet-era planning took little account of local interests. In recent years, improved local planning has helped ameliorate the situation to some extent.

Knowledge gaps and further studies
The lack of common statistical measures hindered our ability to compare experiences and effects in the various case study areas. Beyond basic demographic information, many important indicators were either unavailable or incompatible across regions.
To fill these gaps and provide a more solid foundation for further research and comparison, social and economic statistics related to oil and gas activities should be collected on a circumpolar basis. These statistics should include, indicators regarding:

- Employment
- Wage Income from Oil and Gas Activities
- Industry Expenditures
- Royalty and Tax Revenues
- Gross Domestic Product (GDP) Contribution
- Social Infrastructure
- Occupational Health and Safety

**Conclusions**

In the Arctic regions where it has occurred, oil and gas development accounts for a substantial proportion of GDP. In Norway, the economy is reasonably diverse. Elsewhere in the Arctic, there are few other industries or economic drivers outside the public sector. Oil and gas activities therefore exert or have the potential to exert a major influence on Arctic social and economic systems. Population trends support this interpretation, with large increases in areas that where oil and gas activities spur substantial economic activity. Oil and gas activities may overwhelm social and economic systems, or those systems may be able to harness oil and gas activities to achieve other goals. Effective governance is thus a key variable with regard to successfully responding to the challenges and opportunities presented by oil and gas activities. Functional regulatory regimes for the environment as well as the economy, ideally set up in advance of the activities in question, are essential components of such governance.

A number of trends and patterns are apparent from the case studies. Life cycle stages present specific trajectories of employment, revenue, activity, and so on. The most dramatic of these, such as large-scale construction but also accidents such as oil spills, are also relatively brief. Capitalizing on these windows of opportunity requires careful timing. Training a workforce for jobs that are transient in nature will produce at best a brief benefit, and at worst a workforce for which there is no employment to be found. By contrast, overall revenues are greatest during production, which requires relatively few workers. Thus, direct employment and revenue may not match well. Harnessing revenue to create economic stimulus and thus overall gains in employment and services may offer a longer-term benefit than aiming for jobs in industry. Here, too, planning is necessary to determine appropriate goals and the means to achieve them. In turn, this requires effective institutions, capable of learning from experience, and with the power to act effectively.

Costs and benefits are not evenly distributed across stakeholders, nor from local to regional and national levels, nor throughout the lifetime of a development. The distribution of power is one factor in shaping the degree to which such unevenness creates tensions and negative impacts, or can be reduced for broad benefit. When local organizations and institutions lack power, local interests may be neglected, so that costs are borne disproportionately by local residents while benefits accrue primarily at the regional and national level. When local organizations have control through regulatory authority or land and resource ownership, more benefits are likely to be retained locally and local ability to respond and adapt are likely to be enhanced. Norway, however, provides a counterexample, with the benefits of oil and gas being distributed throughout society by national policy and regulation.

Looking to the future, the question is how oil and gas activities can contribute to the overall sustainable development of Arctic regions. Oil and gas development has brought tremendous wealth and associated improvements in public health, education, and other services to a generation of Arctic residents in some
regions, and promises similar benefits in others. While these activities and revenues may persist for many decades, they still extract finite resources and thus will eventually end. In other regions, oil and gas development has degraded the environment and disrupted local social and cultural systems leaving a legacy of negative impacts that reduce the potential for sustainability or the assets that contribute to it. The lesson is that institutions matter. Oil and gas activities can be harnessed to stimulate broader economic growth, to support the retention of cultural practices, and to increase financial, human and social capital that provide lasting benefits. An essential determinant is the ability to plan, act on those plans, and adapt based on subsequent experience.

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VOICES OF THE CARIBOU PEOPLE

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Voices of the Caribou People is a film project undertaken with caribou user communities of North America, for the communities and the outside world. It is an initiative of CARMA (Circum-Arctic Rangifer Monitoring & Assessment Network) as part of its IPY research to monitor and assess the impacts of global change such as climate change, industrial development and associated cultural and economic implications on the Human-Caribou System. CARMA’s indigenous participants chose to use film as a tool to highlight their changing world and to incorporate their local perspectives in the broader social-ecological context.

From May to August 2008, we worked with six indigenous communities from Alaska to Quebec (Figure 1). We documented local knowledge about social-ecological systems and people’s observations of changes that are taking place on village homelands and livelihoods, and how these changes are affecting caribou people’s traditional culture. Approximately 20-24 members were interviewed in each community, including elders, hunters, leaders, women and youth. For non-english speaking participants, translators were provided. A total of 105 hours of video-data was collected. We are now working with individual communities to create their video-sketches that capture the major challenges and concerns; and to share these videos among the northern communities and with the outside world.

The participants recorded their observations about how caribou migration, body condition and population has fluctuated, over the time, in response to climate related variability and anthropogenic disturbance such as roads and mines. The hunters spoke about caribou availability, accessibility and current conditions. Community elders spoke about changes in lifestyle, caribou usage and climatic conditions. The leaders talked about the major challenges that their communities are faced with and what do they need from scientists and researchers in terms of information and support, to adapt to the changes. The youth spoke about importance of caribou in their life and their future aspirations.

The collective voices of caribou people illustrate that communities share many similarities and some differences in the challenges they face. The issues common to all communities include higher energy costs, greater extractive developmental activities in homelands, and social problems of engaging youth in traditional pursuits. In addition to these problems, non-local hunting, low-flying aircrafts, and loss of language were also described. Although in every community people spoke about their observations of a warming trend and increased variability in weather conditions, climate change as an issue was not described as a big threat. The limited concern about climate change may be because the communities are also dealing with industrial developmental proposals that require their immediate attention. Often they are required to make decisions with very little information regarding the impacts of industrial development on their land. In this respect, climate change is comparatively a diffused issue that may have resulted in their passive approach towards it.

The Voices of Caribou People project is still in progress. It seeks to incorporate indigenous perspectives in scientific research. It also provides an opportunity for caribou people to share their coping strategies with other indigenous communities, It will also offer insight to researchers on local people’s needs of northern science, and communicates the important issues concerning human-caribou systems to the greater world. The participants found video to be a very useful tool for several reasons Andin many cases expressed satisfaction in not being treated as subjects of research but rather as having their voices presented without modification or a third-party critique. The elders felt it to be the communities’ legacy and repository of traditional ways in the changing times. The leaders consider visual images as a powerful medium to reach out to policy makers and greater public. These often isolated communities looked at the
video-project as a useful way of connecting with other indigenous communities and gateway for social and political exchanges among them.

This 11-minute film is a short snippet of the collective voice from these communities regarding their strong dependence on caribou and the challenges they are facing to meet their needs in wake of larger global changes.
CULTURAL PRESERVATION PROGRAM FOR ALASKA

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Introduction

Recently the Long Term Ecological Research Program (LTER) and the Institute of Arctic Biology (IAB) held a workshop in Venetie with the purpose of assessing the community needs related to climate change.

During this workshop people of the community stated the need to educate their own people because children are losing identity and they want bring it back. Given the desire to preserve the culture identity and the need to overcome the bad nutrition condition of many indigenous communities (Bersamin et. al., 2006, 2008; Henry-Stones 2008) I designed a Cultural Preservation Program using digital media and the Internet with the following objectives: 1- To rescue local history and tales. 2- To develop environmental education programs. 3- To improve the feeding behavior to prevent obesity and diabetes.

I found a number of publications and web sites with similar objectives in Alaska and the world: research into indigenous communities’ history and knowledge base preservation, interaction with the internet, disease control and increasing survival possibilities, just started in Australia (Australian Research Council, 2008).


However, in these programs usually anthropologists or other scientists interviewed elders, in a few cases community members were trained to do the same job (ANKN-, 2003; Alaska Rural Systemic Initiative –ARSI- and ANKN, 1997). Considering that culture is transmitted to new generations within the family and the community, I designed a method for knowledge preservation within this framework.

Activities

The main goal is to scan all the families of each village, not only a sample. To achieve that, tape recorders will be left in schools or with tribal councils of different villages with the intention that pupils of primary and high schools take them home and record the knowledge of elders. The children will be given instructions on how to use the tape recorders and collect information.
This will provide each child the opportunity to ask their own grandparent or other elders about old stories of their way of life in the past. In addition to stories about the past, children will interview their grandmother to document recipes she used to prepare meals in the past and then their mother to obtain the recipes she cooks with currently. The children will then e-mail their interviews to the Cultural Preservation Program website where the interviews will be archived.

This method of cultural preservation will trigger the process of transmitting knowledge from one generation to the next from the first stage of the project: community members will be interviewed in the privacy of their own family using an inexpensive device, while enjoying family life at the same time. This provides children the opportunity to discover and rescue their own culture. In addition, while they play with the website, they can share their experience with their relatives, friends, the community, and even with other communities depending on privacy issues.

Each family and each community will decide to participate or not in the project, if they do, they will be provided with a password. That action will keep in the hands of each family the decision of sharing their knowledge with others or preserve it for themselves while they enjoy the pride to listen to their own voices in the Internet.

To guarantee the successful incorporation of Indigenous Knowledge as well as the protection of this information, Indigenous People must control the collection and use of this information for resource management (Higgings, 2000). Article 8 (j) of the Convention on Biological Diversity states that arising from the utilization of such knowledge, innovations and practices, provisions shall be made for the equitable sharing of benefits with the holders of this knowledge (Secretariat of the Convention on Biological Diversity, 2003).

Information from the interviews and interaction with school teachers, the program will develop environmental education programs. Videos about trapping, hunting, fishing, and hand crafting skills will be put in the web site with the help and advice of elders.

We will make comparisons between the nutrition value of past and current recipes. For better nutrition and successful interventions, we will need to incorporate strategies to improve diet choices, related to both traditional and Western foods. On the website there will be different videos showing the mothers healthy ways to cook foods obtained from subsistence activities. We hope that this will help reduce the levels of obesity and diabetes found in rural communities.

At the same time, we will help to implement a work-out program and outdoor activities for the younger generations. With the participation of elders, children can be taught skills needed for successful harvest of ecosystem products and also gain valuable experience. The experience of ARSI and ANKN (1997) in Old Minto Camp is an example that will be taken in account for the implementation of these activities.

Before the implementation of this project it will be necessary to better understand the relationship the school children have with their surrounding environment (i.e. plants & animals). In the schools of the villages we will determine the perception children have of local species by
having them write his/her age and grade level and then draw on a piece of paper all the wild species known to them, plants and animals. They will also write the use of each species (e.g. food, trade, medicine, nuisance, ritual use, construction material, etc).

This activity, called “Animals and Plants of the Bush” will allow us to have a written register of the species used. The environmental perception will be measured according to the frequency of each species in the drawings, giving us a quantitative indicator. Figure 1 show an example developed in Argentina, where that method to study wildlife use and the environmental perception of school children was developed and implemented by Barbarán (2001)

Figure nº 1: The mammals species of Acambuco Provincial Reserve (Salta, Argentina) are identified with numbers from 1 to 35, according to the quantity of species drawn by the school children of that study area. The perception of each species is ordered according to its frequency in the drawings.

A diagnostic about the environmental perception of the community is necessary in that each village will write its own book about their use of wild species. At home the student will ask the usefulness of different species of wild plants and animals or any other elements of the ecosystem deemed as useful.

They will draw each species on a sheet of paper writing its name and use. If a plant is drawn, the pupil will then collect a piece of it and make a herbarium so that the species is physically documented and available for teaching activities. Each drawing and archived plant will be collected by the teacher and will be made into a book that can be added to as necessary.

That method was developed by teacher Claudio Basso in 2005, to register the use of wildlife with medicinal use and applied in the primary school of Alumbre, a remote village of Calchaqui Valley placed in the S.W. of Salta Province, Argentina. We will measure the perception of the community calculating the frequency of each species drawn and archived.
With the information obtained, we will publish scientific articles, books, CDs and videos with our findings, as well as environmental and nutrition education and identify new research and community needs.

**Assessment of the Project**

In order to assess the success of the project, perception measurement activities will be repeated in the schools between two or three years after the implementation of this initiative. The nutritional component of the program will be assessed measuring Body Mass Index of school children, before and after the project. According to assessment results we will make proper corrections and start again.

**Going Ahead**

The dialogue with indigenous organizations and tribal councils as well as the capitalization of previous experiences through collaboration, cooperation and coordination with other institutions, research projects and scientists working in cultural preservation, rural education and nutritional health in the study area is key for the success of this project and will be the first task to be done.

We have the intention to start with two Athabascan villages working a year to calibrate the method and after that, we’ll apply it in all Alaska.

**Acknowledgements**

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Climate Change and Indigenous Peoples

The Arctic region as a whole has been at the forefront in documenting the impact of climate change on the people and communities that occupy the northern latitudes. In 2005 the Arctic Council, an international NGO with representation from across the Arctic region, published the Arctic Climate Impact Assessment which detailed the changes that are taking place and the impact those changes are having on the physical, socio-economic and political structures of the region (Arctic Council, 2005). Among the areas in which changes are being observed are abnormalities and fluctuations in the availability of subsistence foods brought about by changes in seasonal weather patterns accompanied by the transport and accumulation of contaminants from local and distant sources. Such changes are of particular consequence to the indigenous populations whose life and livelihood depends on a reciprocal relationship with the surrounding environment. As Angayuqaq Oscar Kawagley, a Yupiaq Elder has put it:

Alaska Natives have always expected fluctuations from year-to-year in weather, hunting conditions, ice patterns and animal populations, but since the 1970’s they have noticed many indicators of major climate change (Kawagley, 2006).

Climate change is already profoundly affecting the lives and cultures of people who depend on traditional ways of acquiring sustenance from the land. The observations of Alaska Native people today not only mirror scientists’ predictions, but provide firsthand evidence that the effects are being felt now. The important role of indigenous people as collaborators in monitoring the effects of climate change is evident in the following comments by Mark Nuttall, editor of a special issue of Indigenous Affairs focusing on “climate change and indigenous peoples:”

Indigenous peoples must be assured that they will play a key role in the regional and global dialogues that will determine the kind of responses to climate change and the social and economic changes that will take place in their homelands. Recognition of human, cultural, and linguistic rights of indigenous peoples is a prerequisite for their effective participation in policy discussion and contribution to international decision-making that will influence new forms of economies, patterns of global consumption, governance and livelihoods necessary to meet the challenge of climate change (Nuttall, 2008).

Educational Responses to Climate Change in Alaska

As scientists and Native people continue to document the effects of climate change throughout Alaska, educators have taken steps to develop curriculum resources that will help students better understand the forces that are impacting their future. Examples of these educational responses include the following programs, which will be described briefly:

- Science Observation Networks engage students in research on climate change
  - GLOBE (Global Learning and Observations to Benefit the Environment)
  - OLCG (Observing Locally, Connecting Globally)
  - MapTEACH (Mapping Technology Experiences with Alaska’s Cultural Heritage)
- Native Science Fairs displaying Indigenous Knowledge (Center for Ocean Science Educ.)
- Alaska Natives and the Geosciences (ANKN and WGBH Teachers Domain Resources)

The most extensive example of getting students involved in climate-related research is the GLOBE program. GLOBE is a worldwide hands-on, primary and secondary school-based science and education program that promotes and supports students, teachers and scientists to
collaborate on inquiry-based investigations of the environment and the earth system. Students gather local weather data and enter it into a global database through which they can track changing weather patterns from a local to global scale. There are 110 countries around the world participating in the program.

A similar program to GLOBE that is specific to Alaska is OLCG (Observing Locally – Connecting Globally), which combines Alaska Native observations of climate change with the observations of Western scientists to gain a better understanding of interactions across local to global systems. Detailed information about the program can be found on the UAF web site at http://www.uaf.edu/olcg/

Figure 5. Caribou migration paths mapped by Arctic Village students

Another education program that engages students directly with their environment is MapTEACH (Mapping Technology Experiences with Alaska’s Cultural Heritage). The program provides a culturally responsive geo-science outreach curriculum for middle- and high-school students and teachers in rural Alaska. MapTEACH emphasizes hands-on experience with spatial technology including GPS (Global Positioning System), GIS (Geographic Information System), and remote sensing imagery, used in conjunction with traditional cultural activities (see Figure 5). Participating students and teachers work directly with scientists and are presented with a chance to practice real scientific inquiry at a novice level, using real data in a real-world setting (http://www.mapteach.org/).

A recent addition to the curriculum resources provided for schools is the Arctic Climate Modeling Program developed through the UAF Geophysical Institute. ACMP is a multifaceted program that blends Native Ways of Knowing with contemporary climate modeling tools to engage students in in-depth comparative research on climate change. Schools are equipped with a fully functional weather station that students use to transmit real-time data into a web-based Science Observation Network monitored by scientists at the University of Alaska Fairbanks (www.arcticclimatemodeling.org/).
Students are taught both from the scientific perspective used by university researchers and from the traditional Native cultural perspective used for centuries by Alaska Native Elders. The local and instrumental data gathered by the students is then incorporated into the climate modeling tools to gain greater insights into the climate changes that are underway.

In a variation on a similar theme, the UAF Alaska Native Knowledge Network has partnered with the WGBH Educational Foundation and the International Arctic Research Center to incorporate lessons on Indigenous knowledge and climate change in the WGBH Teacher’s Domain curriculum resources web site, which are used by teachers around the world (http://www.teachersdomain.org/).

A new program that is currently under development is a permafrost monitoring K-12 outreach program whereby UAF researchers are installing monitoring equipment in boreholes adjacent to schools throughout Alaska, which students then use to report data on the status of changing permafrost conditions in their community (http://www.uaf.edu/permafrost/).
Finally, we have been actively engaging students from throughout Alaska in the development of science fair projects that illustrate the complementary relationship between traditional cultural knowledge and Western science. The science projects are judged by science experts for their scientific merit and by local Elders for their cultural merit. These projects have served to increase student interest in science while at the same time enhancing their appreciation of their own cultural knowledge.

In summary, the following quote from George Noongwook, an Elder from Savoonga on St. Lawrence Island captures the stance of Alaska Native people in their efforts to come to terms with the effects of climate change on their lives:

"We cannot change nature, our past, and other people for that matter, but we can control our thoughts and actions and participate in global efforts to cope with these global climate changes. That I think is the most empowering thing we can do as individuals."
For further information on the impact of climate change on indigenous peoples and the observations that are outlined above, the following recent publications are recommended:

ANSC. (2005). Impact of Climate Change on Alaska Native Communities. Anchorage, AK: Alaska Native Science Commission


A CHANGING SENSE OF PLACE: CLIMATE AND ALASKA NATIVE WELLBEING

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The United Nations identifies Indigenous peoples by a variety of factors which includes, but is not limited to, having a special relationship with their traditional lands; a relationship which “has a fundamental importance for their collective physical and cultural survival as peoples (Chakrabarti 2007).” But what happens to Indigenous peoples when changes in global climate drastically alter the very land itself? The current warming trend is happening at an alarming and unprecedented rate, with the Arctic region changing even faster than the global average (ACIA 2004), with noticeable and substantial shifts being observed within a single generation (Krupnik and Jolly 2002). What happens to your sense of place as the plant and animal people that your parents and grandparents introduced you to travel on, and new neighbors move in to take their place? What effects might that have on your sense of place, your sense of wellbeing, your sense of self?

A 'sense of place' can be defined as a sense of belonging, attachment, and an individual or collective ownership of a particular location, especially a community (Tapley 2003). For Indigenous peoples, this concept of community is comprised not only of human beings, but extends to the landscape and its non-human inhabitants (Ferguson 2005). There is an inherent spiritual relationship between Indigenous people and the land (Tofa 2006). Sense of place for indigenous peoples is an “intertwining of the boundaries of land, tribe, and self (Jones and Hunter 2003).” It is because of this close relationship to the land that global climate change has the potential for devastating effects to Alaska Native wellbeing.

The Arctic is now experiencing some of the most rapid and severe climate change on earth (ACIA 2004). According to Edward Parson, Lynne Carter, and others that were part of the 2001 study on Climate Change Impacts on the United States, changes seen in the past century include:

- Alaska’s climate has warmed about 2.2° Celsius (4° Fahrenheit) since the 1950s, 3.9° Celsius (7° Fahrenheit) in the interior in winter.
- Most of the state has grown wetter, with a 30% average precipitation increase between 1968 and 1990.
- The growing season has lengthened by about 14 days.
- Dramatic reductions in sea ice and permafrost have accompanied the recent warming.
- Alaska’s warming is part of a larger Arctic trend corroborated by many independent measurements of sea ice, glaciers, permafrost, vegetation, and snow cover.

In Alaska, severe impacts related to climate change are already being experienced. The warming trend described above has been accompanied by several decades of thawing in discontinuous permafrost, causing increased ground subsidence, erosion, landslides, and disruption and damage to forests, buildings, and infrastructure. Sea ice off the Alaskan coast is retreating (14% since 1978) and thinning (40% since the 1960s), with widespread effects on marine ecosystems, coastal climate, human settlements, and subsistence activities (Parson et al. 2001). According to a 2003 report by the U.S. Government Accounting Office (GAO 2003), 184 Native villages in Alaska are subject increasing erosion, flooding, or both due at least in part to climate change.

The heavy reliance on Arctic communities for subsistence resources adds another physical vulnerability to climate change. A changing climate puts such resources at risk and will affect both sustenance and
cultural dependence on those resources (Houser et al. 2001). Present climate change already poses drastic threats to subsistence livelihoods of Alaska Natives, as many populations of marine mammals, fish, and seabirds have been reduced or displaced due to retreat and thinning of sea ice and other changes. In the longer term, projected ecosystem shifts are likely to further displace or alter the resources available for subsistence, requiring communities to change their practices or move (Parson et al. 2001).

Perhaps more devastating than the immediate physical impacts on Indigenous peoples are the social and cultural impacts that these changes trigger. The cultural context of Native peoples is being disrupted (Houser et al. 2001), and that disruption in the lives of Arctic peoples is likely to continue for the foreseeable future. According to the Intergovernmental Panel on Climate Change (IPCC 2007), even if greenhouse gas emissions ceased today global average surface air temperatures would continue to warm up and additional 1º Celsius. All of the models show similar temperature increases for the next several decades, leading the IPCC to conclude that “adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions (IPCC 2007).”

Both the climate and the landscape provide an important sense of place for Native peoples, and the shifting species and patterns of climate, vegetation, and wildlife will necessarily alter the relationships that have been sustained through many generations (Houser et al. 2001). Native peoples will lose their natural sense-makers (Kawagley 2008), leading to substantial distress for both individuals and the community (Fox 2002):

“For example, consider how extremely skilled Elders and hunters can no longer predict the weather as they have in the past. No longer able to be confident in their predictions, some Elders and hunters are genuinely distressed, not only because they can no longer advise travel parties with assurance, but because their personal relationship with the weather itself has changed.”

When changes of this magnitude are taking place, it is easy to fall into despair. Dr. Angayuqaq Kawagley (2008) speaks of this type of loss: “I think that it will be kind of horrific, psychologically…. It would be just like losing a family member. There would be a lot of grief attached to it, because they have known it for so long, then all of a sudden it is gone.” This grief may be a difficult one to recover from, and there is the potential for it to be the proverbial straw that broke the camel’s back. For, as Justine Rose Webb of Murdoch University wrote regarding the colonization of the Pilbara region of Australia, “When the very essence of your life is taken away, like a line of dominos, the momentum pushing you down can be the easiest way to fall (Webb 2003).”

So, in light of the bleak outlook painted above, how do Indigenous peoples maintain their identity, their sense of individual and communal self, throughout these changing times? Unfortunately there is no single, easy answer to that question, but there are some ideas put forth that may assist a community in preparing for the changes that are occurring. Like all things in nature there are no broad lines or sharp demarcations between these ideas, rather they need to be woven together, and to cycle back to one another as the seasons of the year.

**Have Confidence in Yourself**

First, Alaska Natives need to have faith in their innate adaptability. Their adaptability, and the past experiences and lessons that have been learned about coping with climate fluctuations, have sustained Native cultures through many generations. The environmental patterns and social structures that sustained Native peoples in North America for many millennia began shifting rapidly approximately 500 years ago. The colonizing cultures brought new plants, animals, and ways of working with the earth (Houser et al. 2001). They also brought new diseases which eradicated whole villages (Napoleon 1996), missionary schools that tried to educate and convert Alaska Natives out of their Indigenousness
(Kawagley 2006), and government policies of both genocide and assimilation (Deloria 1988). As Nancy Maynard stated in the Final Report: Native Peoples – Native Homelands Climate Change Workshop in 1998: “The fact that North American Indigenous societies have survived into the 21st century, with cultures, traditions, languages, and portions of their Native Homelands relatively intact, speaks of a respectful and enduring reliance upon traditional ecological knowledge, spiritual strength, and cultural adaptations… (Maynard 1998).”

**Be Grounded in Your Culture**

In order to maintain that adaptability, Alaska Natives must be well grounded in their culture and traditional knowledge (Kawagley 2008). In his paper *Oral Traditions in the First Steps Toward Decolonization*, Leo Killsback states that “Indian people need to look to their oral traditions to understand, find guidance, and seek solutions to the problems they face (Killsback 2006).” This is true even for, and perhaps especially for, climate change. The oral histories of Alaska Native peoples not only tell what past climate was like, they also frequently contain lessons on what the community did to adjust and survive. Thus, the retelling of these stories by Elders can help teach the younger generation how to adapt to adversity (Houser et al. 2001).

However, we must not fall into the trap of looking only backward, and viewing traditional knowledge as a static body of knowledge. Traditional knowledge is that information that people in a given community, based on experience and adaptation to a local culture and environment, have developed, and continue to develop, over time (Tano 2006). In many Yupiaq communities, the traditional knowledge as it is currently being passed down is primarily the *substance* (knowledge and skills handed down over generations) rather than the *process* (forming knowledge through practical engagement with the environment) of relating to the environment (Kawagley 2008). Both traditions are required in order to construct a body of knowledge that will help best deal with the changing environment (Fox 2002).

**Promote Healing**

Alaska Native peoples are still dealing with extensive the extensive and deep-seated grief caused by what the Yupiaq call *Yuut Tuqurpallratni*, the Great Death which resulted from the influenza pandemic of the early 1900s (Napoleon 1996). This pandemic destroyed families and even entire villages throughout Alaska. The widespread shock and grief has affected multiple generations with what has been described as a form of cultural post-traumatic stress disorder (Becker 2008). Dr. Kawagley (2008) feels that this disruption may be even worse for the Yupiaq because they have not recovered as a people from the trauma of *Yuut Tuqurpallratni*:

> “Most of us are not healed. We haven’t repaired ourselves, because we haven’t brought closure to our griefs, especially griefs of my ancestors, my grandparents, of the terrific loss of life. And here it is, there is going to be more grief as a result of the climate change. Because the cold made everything about me, and once that is gone, boy that is going to wreak havoc among my own mind, my own self.”

In his book *Yuuyaraq: The Way of the Human Being*, Harold Napoleon (1996) promotes the use of the traditional talking circle as a way of dealing with the grief that is lingering from *Yuut Tuqurpallratni*. Dr. Kawagley believes that something similar should be established within communities for dealing with the losses associated with climate change:

> “There is going to be a few, I would think, that will feel a loneliness, a depression, because of [the loss of the seal]. And so we may have to maybe set up a place where they can meet and talk about these changes and losses of the seal and all that means, as an example. I can somehow
foresee some grief meetings to address those and help people to get over that and find a replacement, find a replacement for whatever they find all of a sudden gone (Kawagley 2008).”

Emotional and spiritual healing, whether through talking circles or other traditional healing methods, will be critical to provide the individual and community with leaders who are able to guide us through the changes ahead.

Be Agile and Adaptive Leaders

Alaska Native peoples are living in an era that is both complex and uncertain, and need to develop and nurture leaders who can meet the physical, economic, and sociocultural challenges resulting from climate change. These leaders are needed in all walks of life, “to help unravel complex problems, to introduce a degree of certainty, and to facilitate the kind of decision-making required to not only survive, but to thrive (Tano 2006). According to Merv Tano of the International Institute for Indigenous Resource Management, these need to be Agile Leaders. He describes Agile Leaders as those who:

- Realize that we exist in an era of permanent change
- Are creative thinkers with a deep sense of purpose
- Have a broad repertoire of behaviors and experience
- Adaptive and resilient to changing situations

Agile leaders need to be well versed in Western science and management, but thoroughly grounded in their Native language, culture, and traditions (Kawagley 2008). They must recognize the value in both Native ways of knowing and Western science, see the complementary uses of the two, and use both methods appropriately as the basis to implement true adaptive management (Tano 2006). Agile Leaders must work from a strong foundation in their culture, and accept only those values and beliefs from the outside world that they deem to be good and necessary, and things that will strengthen their culture’s values, beliefs, and traditions (Kawagley 2008). These Agile Leaders must build bridges between the Western and Indigenous worldviews, but build those bridges on Indigenous terms and from an Indigenous place of power. Only then can Alaska Native peoples safely weather the coming storm.

Conclusion

Global climate is changing. Even if the emission of all greenhouse gases were to stop today, the cycle has started and there is no choice but to see it through. The world is adrift on a sea of change, and those changes will be painful. The land and those neighbors that share the land will change. These changes will affect Native peoples to the core of their being. There will be times when they feel lost, betrayed, and perhaps resentful at those who have caused the changes that they must now deal with.

But Alaska Native peoples have faced changes in the environment, as well as social and cultural upheaval, before and survived. They can have confidence in their ability to adapt as Indigenous peoples because they have done so since the world was young. They have been able to do so because they passed down their stories, recognized the value in those lessons, helped and healed each other through the changes, and had agile leaders who could adapt to the chaos of changing situations.
References


The Coastal Response Research Center, a joint partnership between the University of New Hampshire and the National Oceanic and Atmospheric Administration, in cooperation with the U.S. Coast Guard and the U.S. Arctic Research Commission, hosted a workshop in March 2008 to identify key strategies, action items, and research needs for preparedness and response to potential Arctic marine incidents. The workshop report provides a qualitative analysis of risk factors for five potential marine incidents likely to happen as shipping, tourism, and exploration and development of natural resources increase with the retreating of the Arctic’s multi-year ice. Participants included indigenous peoples; NGOs; oil, shipping and tourism industries; response organizations; and governmental entities. Incidents discussed involved shipping, oil spills, search and rescue, environmental damage, and disruption of indigenous communities. Research priorities were identified by workshop participants to address gaps in preparedness and response for these types of incidents. The report serves as a tool for enhancing Arctic preparedness and response capabilities.

The following scenarios were based on existing and predicted activities with similarities to previous incidents in likely locations where resources for response are lacking:

- A cruise ship runs aground while exiting a fjord on the west coast of Greenland in mid-September. Progressive flooding destabilizes the vessel and 1400 passengers must abandon ship.
- A bulk ore carrier becomes trapped in the ice while attempting a late season crossing of the Arctic en route to the Bering Sea.
- Numerous vessels are in the vicinity of an exploratory drilling operation 20 miles offshore in a disputed area along the U.S. – Canada border in 50 meters of water where an ice management vessel collides with a drill ship.
- An oil tanker collides with a fishing vessel during near-zero visibility conditions in a region of the Barents Sea disputed by Russia and Norway. The tanker releases 25,000 barrels of crude oil.
- A tug towing a barge laden with mining explosives and other containerized cargo grounds during ice conditions on St. Lawrence Island, a critical habitat for threatened and endangered species.

The report includes detailed recommendations to improve the response to these hypothetical incidents. Several recommendations were common to all incidents, and would significantly enhance the efficacy of response and recovery.

- Ports and Waterways Management:
  - Designate potential ports of refuge in the Arctic and develop guidelines for their use.
  - Control and track vessel movements.
- Vessels and Crew Safety:
  - Institute mandatory safety regulations for Arctic operations.
- Response Agreements and Plans:
  - Strengthen multinational plans and agreements or create one Arctic agreement for all types of responses.
- Strategies to Improve Prevention and Preparedness:
Conduct comprehensive environmental risk assessments and impact assessments for the Arctic.

Increase emergency response assets, equipment, and supplies in the Arctic, placing emphasis on regions of active development.

Improve knowledge for Arctic incident response through training and engagement of the local community, responders, and the shipping industry.

Strategies to Improve Response:
- Consider alternative countermeasures for oil spill cleanup.
- Expand communications capabilities throughout the Arctic.
- Improve logistical support capabilities for responders.

Strategies to Foster Community Involvement:
- Involve indigenous people and local communities in planning, response, recovery, and restoration decisions and operations.
- Conduct outreach to the local community and keep stakeholders well informed.

Strategies to Ensure Availability of Funds For Response:
- Establish an international Arctic response fund.
- Increase penalties and insurance requirements for ships operating in the Arctic.

Research Needs:
- Update weather data and navigational charts for the Arctic.
- Study the behavior of oil in cold water and technologies for spill response.
- Improve baseline information for Arctic resources that could be affected by potential incidents.

The main theme that resonated throughout the recommendations is the importance of fostering international cooperation between Arctic nations. Such cooperation will prove critical to enhancing joint contingency plans and multi-national agreements aimed at guiding international response efforts and developing and instituting mandatory safety regulations for Arctic operations. The second major theme was implementation of comprehensive prevention and preparedness measures. Such measures range from conducting extensive risk assessments for the Arctic seas, shipping routes, and ports to increasing stockpiles of emergency response equipment and supplies throughout the Arctic. By managing risk using appropriate policies and strategies supported by sound scientific research, opportunities for development and tourism in the Arctic can continue with reduced risk for environmental damage and loss of life.

The workshop report is available at [http://www.crcc.unh.edu/arctic_response_issues/](http://www.crcc.unh.edu/arctic_response_issues/).
HUMAN RIGHTS OF CLIMATE-INDUCED RELOCATION IN ALASKA

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ABSTRACT: Forced migration due to climate change will present one of the most severe challenges to the resilience of communities forced to migrate as well as to local and national governments. The Intergovernmental Panel on Climate Change (IPCC) has identified the regions of the world most vulnerable to climate change and predicts that 150 million people will be displaced by 2050. Alaska is projected to experience increased climatic change more rapidly. Temperature increases since 1974 confirm this projection. Several communities in Alaska are faced with permanent relocation due to climate change. Erosion, flooding, and sea level rise are the primary causes of displacement. This paper describes the experience of Alaskan indigenous communities and outlines a legal and institutional framework, based in human rights doctrine, to respond to climate-induced human migration.

Key words: Climate Migration Indigenous Alaska Governance

DEFINING CLIMATE-INDUCED MIGRATION
In Alaska, climate change is evident. Temperatures have increased 2 to 3.5 degrees Celsius since 1974, arctic sea ice is decreasing in extent and thickness, wildfires are increasing in size and extent and permafrost is thawing. (IPCC, 2007:339); (Borenstein, 2008). These ecological phenomena are creating a humanitarian crisis for the indigenous communities that have inhabited the arctic and boreal forest for millennia.

Four Alaskan indigenous communities must relocate immediately and dozens of others are at risk. There is currently no organized institutional system in place, and government agencies are struggling to meet the enormous new needs of these communities.

In order to create an appropriate humanitarian response, the first step is to define the displacement category of climate-induced migration and profile the population groups that must move. After creating a definition, a legal and institutional framework can be constructed to relocate communities.

The disparate drivers of climate-induced migration can be segregated into three distinct categories: random extreme weather events, such as hurricanes and tornadoes, the depletion of ecosystem services, such as drought and salt water intrusion, and on-going ecological changes caused by the combination of random extreme weather events and depletion of ecosystem services that severely impact public infrastructure, such as health clinics and schools, as well as the livelihoods and lives of the people residing in the community.

These climate change drivers cause three patterns of migration: the migration of individuals and households where climate change is one of several factors causing migration, mass migration where entire communities are forced to temporarily evacuate and mass migration where entire communities are forced to permanently relocate. Each migration pattern requires a unique institutional adaptation strategy to ensure that the humanitarian response is appropriate and that people’s human rights are protected.

“Climigration” is the word that best describes forced permanent migration of communities due to climate change. Climigration results from on-going climate-induced ecological changes in a community’s environment that severely impact infrastructure, such as health clinics and schools, as well as the livelihoods and well-being of the people residing in the community. Climigration occurs when a community is no longer sustainable for ecological reasons. Climigration differs from migration caused by catastrophic random environmental events, such as hurricanes, where disaster relief and the temporary relocation of individuals and communities is the humanitarian response.
Failure to recognize the signals of permanent socio-ecological changes will critically impede a community’s capacity to adapt and can lead to social and economic collapse. Government agencies will also be hampered if they are unable to identify the early ecological warning signals requiring a community to relocate. Funding will be one of the key factors which will facilitate the relocation process. The sooner a community and governmental agencies recognize that relocation must occur, the sooner funding can be diverted from disaster relief to the relocation effort. Determining which communities are most likely to encounter displacement will require a complex assessment of a community’s ecosystem vulnerability to climate change, as well as the vulnerability of its social, economic and political structures.

Early indicators of socio-ecological vulnerability demonstrating that relocation is required may include: 1) repetitive loss of community infrastructure; 2) imminent danger to the community from the on-going ecological changes and random extreme weather events; 3) no ability for community expansion; 4) number of evacuation incidents; 5) number of people evacuated; 6) predicted rates of environmental change (e.g., sea level rise) from IPCC; 7) repeated failure of hazard mitigation measures; 8) viability of access to transportation, potable water, communication systems, power and waste disposal; and 10) decline in socio-economic indicators, including food security, loss of livelihood, and public health.

ALASKA

In Alaska, climigration is happening. Shishmaref, Kivalina, Shaktoolik and Newtok are faced with the most critical situation because of their geographic location on the west coast of Alaska. These coastal communities must relocate because climate-induced disappearance of sea ice and sea-level rise create stronger storm surges that are eroding the land on which they are situated, thereby precluding a sustainable future of each community in its present location. Newtok is a Yupik Eskimo village located on the Ninglick River beside the Bering Sea. (ASCG, 2004). Shishmaref and Kivalina are Inupiat Eskimo villages and located further north on the Chukchi Sea. (Weyiouanna, 2007); (Swan, 2007a). Shaktoolik is a Malemiut Eskimo village located on Norton Sound. These villages have active subsistence lifestyles and have existed on the coast of Alaska for thousands of years. (US Corps of Engineers, 2006). Environmental studies conducted by the US Corps of Engineers and engineering firms hired by Newtok, Kivalina and Shishmaref indicate that a catastrophic climatic event could submerge all communities within the next 15 years. (US Corps of Engineers, 2006; Tetra Tech 2004; Tryck, Nyman Hayes 2006; DOWL 2004; ASCG 2004). There is no higher or more distant ground to which these villages can move to avoid the encroaching erosion. Their only alternative is migration. Despite the consensus that these communities must relocate, no government funding has been specifically allocated to begin this process.

Each community is involved in an ad hoc process with state and federal government agencies that are struggling to provide protection to the communities while they figure out a relocation process. Climate change is challenging the disaster relief framework of response. Government agencies have responded to increased coastal erosion through their traditional methods of erosion control and flooding prevention. However, due to the severity of the erosion, these adaptation strategies have proved ineffective to protect the communities from a rapidly deteriorating environmental habitat. In Kivalina, the Army Corps of Engineers built a new seawall to protect the community in 2006. The day after the dedication ceremony, a storm ruined a critical component of the seawall leaving the community vulnerable and exposed (deMarban, 2006). In 2007, the community was forced to evacuate when a fall storm that threatened the lives of community members (Bragg, 2007). Temporary evacuation of the villages, rebuilding public infrastructure and erosion control structures, and returning the population to original locations is no longer protecting the communities. Permanent relocation is the only durable solution. Newtok is the most advanced in its relocation efforts. The community has identified a relocation site and has acquired the land through an act of Congress. A state agency planner has also been dedicated to coordinating the efforts of approximately 25 different government agencies to facilitate relocation.
However, these agencies have no mandate or dedicated funding for relocation assistance (Cox, 2007). Complex regulations that guide the work of each agency also present tremendous roadblocks to moving forward with the relocation effort. The regulations of several agencies require that an existing community with a minimum population be at the site before infrastructure is built. The agencies responsible for erosion control and flood prevention have no regulatory guidance to relocate the communities.

In addition, there is no lead agency designated to create a relocation strategy and coordinate the various agencies working on housing, transportation, community infrastructure, education, health and related socio-economic needs (Cox, 2007). The indigenous tribes are also hampered because of limited administrative and technical staff to work with multiple state and federal agencies on relocation activities. The Governor of Alaska created a Sub-Cabinet on Climate Change in 2007. A sub-committee of the Sub-Cabinet, the Immediate Action Work Group, has been meeting since November 2007 to develop an action plan to provide protection to endangered communities. Their work, however, has been challenging because relocation is the only durable solution, and no government agency has the authority or experience to relocate communities.

GUIDING PRINCIPLES OF CLIMIGATION
The humanitarian crisis in Alaska clearly demonstrates the need to create clear guidelines so that governments can protect and assist the communities forced to migrate due to climate change. Alaska is the logical place to develop climigration principles that can serve as a model for other regions because of the rapid pace of climate change, the inevitability of permanent displacement in many cases, and the large number of communities where this issue must be addressed in the coming years.

Guiding Principles on Climigration, based in human rights doctrine, need to be developed. Refugee law, the Universal Declaration of Human Rights, the Guiding Principles on Internal Displacement and the recently adopted Universal Declaration on the Rights of Indigenous Peoples provide a theoretical basis for creating these principles. However, none of these legal documents address the complex and unique social, economic and political crises of populations facing climigration.

Guiding Principles of Climigration will ensure that the social, economic and cultural human rights of individuals and the communities forced to migrate are protected during displacement as well as during resettlement. (United Nations: 1976). Forced migration creates significant stress and adverse impacts on the health and well-being of those forced to leave their communities. (World Bank: 2004). These adverse consequences can be minimized only if the affected community is a key leader in the relocation process and culturally and linguistically appropriate mechanisms for participation and consultation are fundamental components of the relocation process.

The Guiding Principles will also affirm that families and tribes remain together during the relocation process. For indigenous communities, tribal relationships are essential to cultural identity. United Nations (2007). The relocation process must ensure that socio-cultural institutions remain intact. (World Bank: 2004). The Guiding Principles must also ensure that subsistence rights and the customary communal rights to resources are protected and that the relocation process is framed with an intent to improve income strategies. (United Nations: 2007).

The Guiding Principles will also affirm the human rights principles regarding access to safe and sanitary housing, potable water, education and other basic amenities. (United Nations: 1976). The living standards of the affected communities must not be diminished in the relocation process and must implement sustainable development opportunities as part of the relocation process. (World Bank: 2004). In this way, the relocation process will enhance the resilience of communities by addressing socio-economic issues that are currently contributing to the vulnerability of communities.
Creating an international institutional framework of response to migration caused by climate change is the next essential step that needs to be taken by the international community. Debates about the number of people forced to migrate delays the creation of institutional response mechanisms and ensures that a global humanitarian crisis will occur. The institutional response requires the identification of continua of conditions that cause communities to migrate for environmental reasons.

The first continuum will identify the environmental causes of flight. Climigration will be at one end of the continuum when no other environmental issue is causing the community to relocate. At the other end of the environmental displacement continuum, factors such as overuse of resources will be included. This continuum will define the variety of environmental factors that can force communities to migrate. Accurately defining the cause of the environmental displacement is critical in order to ensure that the institutional response is appropriate.

The second continuum will define the institutional response and will incorporate factors, such as the temporal nature of the displacement and the site of the relocation. The institutional framework created will mirror the environmental displacement continuum to ensure that the humanitarian response is appropriate. For example, the agencies that have traditionally provided “disaster relief” and erosion control will continue to engage in these activities until it is determined that relocation must occur to protect the life and well-being of the community. At this point, the community, along with tribal, state and federal governments, will shift their focus to create a relocation process.

Climate change is forcing communities to permanently relocate. There is no ability to return home. For these reasons, guiding principles and an institutional framework, based in human rights doctrine, need to be created to address the specific circumstance of climigration and ensure the resilience of communities forced to migrate. The experience of Alaskan indigenous communities is guiding the creation of these principles and the institutional response.

References:
U.S. Army Corps of Engineers, Alaska District.
The right to fish has been limited and commodified for most commercial fisheries in the North Pacific. As a result, very few fisheries remain accessible without significant capital investments for the purchase or leasing of fishing rights. Policies that commodify fishing rights have disproportionately affected certain communities and certain groups of participants (Lowe and Carothers 2008). For a complex set of reasons, small, remote fishing communities in Alaska tend to be disadvantaged by the switch to privatized fishing rights (Langdon 1980; Reedy-Maschner 2008; Carothers 2008). This paper explores one program that attempts to redress this trend by providing a mechanism to enable the collective redistribution the wealth in two privatized-access fisheries. While, to date, only one community has successfully purchased community quota, this program has generated collective community organization that may provide an important building block for future community-based fishing rights programs.

The Community Quota Entity (CQE) program implemented in the Gulf of Alaska in 2004 was designed specifically to enable a set of communities identified as having lost fishing rights to collectively recapture those rights (NOAA Fisheries Service 2003; Langdon 2008). The program provides an opportunity for 42 communities to purchase halibut (*Hippoglossus stenolepsis*) and sablefish (*Anoplopoma fimbria*) quota. Before acquiring community quota, however, communities are required to undertake a lengthy application process for the formation of a new non-profit, or Community Quota Entity (CQE). The implementation of this program provided an experiment-like opportunity to test some predictions about what facilitates successful collective action.

As of January 2008, 19 communities had formed CQEs. Community size and degree of quota share lost were found to be significant predictors of CQE formation. The populations of eligible CQE communities ranges from 21 to 1,397 people (N= 42; mean = 311). Approximately 75% of communities that are larger than the mean size have organized CQEs, compared to just 37% of communities that are smaller than the mean. A Pearson’s correlation coefficient shows a significant bivariate relationship between population size and CQE formation (r = 0.33; p<0.05).

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1 Significance is reported for a 2-tailed hypothesis as group size was not predicted to have a clear directional effect on CQE organization.
The magnitude of halibut and/or sablefish quota share loss was another important predictor of CQE formation.\textsuperscript{2} Every community that formed a collective entity has exhibited a net loss of quota share, ranging from 17% to 100% loss (with the exception of Kasaan which had no allocation of quota share in 1995, nor has any current holdings). The mean percentage of loss among this group of communities is 61%. The set of communities that have not formed CQEs exhibit an average loss of quota share at a lesser magnitude (17%). All else being equal, the more quota share a community lost since the initial issuance of halibut quota in 1995, the more likely they were to organize a CQE. A Pearson’s coefficient shows that this relationship is statistically significant ($r = 0.37; p<0.013$).

During 2005 and 2006, I conducted field research in three Alutiiq communities in the Kodiak Archipelago, in part to understand how the communities would organize to participate in the CQE program. Each community approached the task of CQE organization in distinct ways. Larsen Bay’s CQE was formed almost entirely by the tribal council president with little involvement from the community. In Ouzinkie, a group of community fishermen, separate from established community governance entities (e.g., city government, tribal government, and the village Native corporation), formed their own CQE with community support. Old Harbor’s CQE was formed under the leadership of the Old Harbor Native Corporation. Old Harbor, with the financial support of the village corporation, is the only community that has purchased community quota through its CQE.

The rationale for the CQE program was initially stated to promote a “redistribution of opportunity based on equity considerations” (NPFMC 2004: 177). Because of the high price of quota shares, to date, the CQE program has not been an effective mechanism for communities to regain lost fishing rights. The program has generated collective organization within communities. The results of the study suggest that larger communities and those that have experienced significant loss of fishing rights are more likely to organize to be able to take advantage of this program. As market-based quota programs continue to win favor in regulation, indigenous fishermen and other groups that have been negatively affected by these programs can benefit from increasing their collective involvement in a growing political space to debate the equity of distributive effects of market-based resource allocation.

References Cited


\textsuperscript{2} Data files from NOAA Fisheries Service is publically available at: http://www.fakr.noaa.gov/ram/ifqreports.htm.

\textsuperscript{3} As the CQE program was meant to provide a mechanism to bring back lost quota share, I predicted a directional relationship between magnitude of quota share loss and CQE formation, and thus report significance for a one-tailed test.


Straddling the Line: Cooperative and Non-Cooperative Strategies for Management of Bering Sea Pollock

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Abstract—The Eastern Bering Sea fishery for walleye pollock (*Theragra chalcogramma*) yields gross exvessel revenues about $\frac{1}{3}$ billion and a first wholesale value over $1$ billion; it is the premier US fishery. While there is general agreement that this fishery is managed under principles that will ensure sustainability, the eastern Bering Sea pollock stock is not wholly contained within the US EEZ and there are concerns about the role of historic and potential future catches from regions such as the Bogoslof Basin, the Donut Hole, and the Navarin Basin. The management of straddling stocks can be highly contentious and challenging, particularly when the stock is migratory or when the spatial distribution of abundance is variable. The absolute abundance of pollock and the spatial distribution of pollock abundance have varied considerably over the past three decades, with warmer conditions being associated with a shift of the center of abundance to the north and west, where a portion of the stock is subject to harvest by vessels licensed to operate in the Russian Federation EEZ. We use stochastic simulations to identify optimal cooperative and non-cooperative harvest management strategies from the perspective of US and Russian pollock fisheries under climate-induced changes in abundance and the distribution of abundance. Like it or not, this stock is a shared stock. Game theory suggests that cooperative solutions offer many advantages; identifying cooperative solutions provide important leverage in negotiations. In the absence of cooperation it is even more important to identify strategic noncooperative solutions.

Introduction

The fisheries of the North Pacific are among the most productive in the world, accounting for over 30% of world total landings of fish, mollusks and crustaceans. While fisheries within the US EEZ are governed by the MSFCMA which includes provisions intended to ensure sustainability and while fish stocks in US waters in the Bering Sea, Aleutian Islands, and Gulf of Alaska regions are considered to be healthy, stock abundance and allowable catches have fluctuated substantially for many exploited species. These fluctuations reflect latent processes that govern intra- and inter-species dynamics, the conduct of fisheries, and the influence of varying abiotic factors. Statistically significant intertemporal correlations have been observed between environmental factors and recruitment, growth, mortality, and the abundance of fish populations. (See *inter alia*, Bell and Puter 1958; Cushing 1982; Mysak et al. 1982; Sinclair et al. 1985; Corten 1986; Hallowed et al. 1987; Haldorson et al. 1988; Khen 1989; Quinn and Collie 1990; Glantz 1992; Gargett et al. 2001, Clark and Hare 2002.) Climate models (e.g., Manabe et al. 1991) suggest that the pronounced warming can be anticipated in northern high latitude regions; this warming can be expected to lead to changes in sea-surface temperature, changes in the strength of ocean currents and upwellings, and changes in the extent of sea-ice cover; changes that can be expected to impact the productivity of fish stocks. While some stocks may be adversely affected, others may benefit from the changes. Criddle et al (1998) and Criddle and Herrmann (2008) derive estimates of the economic consequences of environmentally induced variations in total allowable catches. In addition to affecting the total allowable catch, environmental variation can be expected to change the geographic distribution of catches and
may affect product attributes; these changes can also be expected to affect the relative competitiveness of various sectors in the commercial fishery and the magnitude of benefits that accrue to communities that are tied to those sectors. In addition, changes in input prices, regulatory systems, and technology can be expected to influence the magnitude and distribution of benefits between sectors within the fishery and among communities that support those sectors. This paper explores the instability created by shifts in the geographic distribution of an exploited fish population and the consequent exposure of that population to potentially discordant management regimes. Although there has been an extensive history of joint research activities by Russian Federation and US fisheries scientists, there continues to be considerable uncertainty regarding the structure of pollock stocks in the eastern Bering Sea, Western Bering Sea, Aleutian Islands, Bogoslof basin, Donut Hole, and Navarin basin regions and considerable uncertainty regarding how that stock structure shifts through time both within years and between years. However, even without resolving the dynamic structure of these stocks, it is possible to examine the implications of alternative management strategies in face of the ambiguity about historic and current stock structure and the role of climate-forced changes in that stock structure. While the US EEZ pollock fisheries have operated under conservative harvest exploitation rates and tight enforcement of catch limits, Russian Federation EEZ pollock fisheries have been prosecuted at higher official exploitation rates and it is widely believed that actual harvests substantially exceed official catch limits and thus the actual exploitation rate has exceeded the official management target. The governance and industrial organization of pollock fisheries in the US EEZ differs markedly from the governance and industrial organization of Russian Federation EEZ pollock fisheries. Since 1999, the US fisheries have operated under a rights-based governance structure that has allowed firms to form cooperatives to contractually sub-allocate shares of the total allowable catch (TAC) to individual vessels. In contrast, the governance of Russian Federation EEZ fisheries has remained in flux with ever-changing rules about the duration of catch quotas, whether the quotas can be held by foreign nationals or figurehead corporations, and the extent of processing required prior to export. While the US EEZ pollock fishery has become highly capitalized, very profitable, and geared to value-added production, conditions in the Russian Far East have not been conducive to investment needed to modernize fishing or processing capital. Thus Russian portions of the Bering Sea and Sera of Okhotsk have largely become a source of minimally processed exports for China-based reprocessors. The lack of investment in modern processing technology means that the same volume of fish harvested in Russian Federation EEZ waters yields a lesser quantity of lower-quality products than it would yield if harvested in the US EEZ. These effects are exacerbated to the extent that the portion of the eastern Bering Sea pollock stock that distributes into the Russian EEZ consists of disproportionate numbers of younger fish. An additional source of uncertainty regarding the geographic distribution of Bering Sea pollock stocks arises from ambiguity about the demarcation between the US EEZ and Russian Federation EEZ; the demarcation has not been formally ratified by the Russian Federation parliament.

**Model**

Management of transboundary fish stocks has been characterized as a two-party game (e.g., Levhari and Mirman, 1980; McKelvey, 1997; Kaitala & Pohjola, 1988; Dockner et al., 1989; Kaitala, 1993; Laukkanen, 2003; Jorgensen and Yeung, 1996; Lee et al., 2000; McKelvey et al., 2003). The solution to mathematical games can be approached from analytic or numerical
perspectives. While analytical solutions yield generalizable rules, they are not well-suited for simulation of complex systems. Numerical solutions can be derived for complex simulations, but yield case-specific results. We overcome concerns about the specificity of numerical solutions by simulating over a wide-range of specifications of stock structure, target and probable exploitation rates, product recovery rate, production costs, and stock distribution.

Solutions to two-party games depend on conjectures about the extent to which each party engages in strategic behavior. Quasi-competitive behavior represents an extreme under which each party endeavors to set a harvest management strategy that ignores the strategies that might be adopted by the other party. In the case of the Bering Sea pollock fishery, a quasi-competitive solution is characteristic of the current approach to fishery management: we do our thing, the Russians do their thing, and we both pretend that we are harvesting stocks that do not migrate or diffuse across the convention line. Collusive strategies represent the polar opposite case where the parties collude to optimize their joint product. In the context of Bering Sea pollock, this would amount to the US and Russian Federation agreeing to a joint management strategy that maximized the total net benefits of harvests without concern about the distribution of benefits between nations. Cournot-Nash equilibria, Stackleberg equilibria, and Stackleberg disequilibria represent conjectures under which both parties recognize that their individual benefits are conditional on each other’s choices, but stop short of collusion. In the case of Bering Sea pollock, these solutions represent recognition that there are externalities associated with harvest management strategies independently adopted by the US and the Russian Federation and that the optimal choice of a management strategy for the US EEZ pollock fishery will depend on the management strategy that the Russian Federation adopts, and vice versa. Moreover, the choice of optimal strategy will vary as a function of: variations in stock abundance and the distribution of the stock; the relative value of product, product recovery rates, and differences in the magnitude of harvesting and processing costs; the enforceability of catch limits at fishery and individual participant levels; the character of governance regimes; etc.

While the structure of two-party games is conceptually simple, their solutions can be surprising. For example, based on a bioeconomic simulation, Lee et al. (2000) concluded that it was optimal for the US to follow a conservative harvest strategy for Atlantic swordfish even though US catches are a small share of the total catch. The benefits of US adherence to a conservative harvest strategy were manifested in population growth, and while foreign nations were found to capture the lion’s share of the benefits of US conservatism, the gains to US fishermen were nevertheless sufficient to warrant unilateral adoption of a conservative harvest strategy.

Following Criddle and Hermann (2008), stock dynamics can be represented by

$$X_t = \beta_1 X_{t-1} + \beta_2 X^2_{t-1} + \beta_3 X_{t-1} - h_{ijt-1} + \varepsilon_t$$

Where $X_t$ is exploitable biomass in area $i$ in time $t$, $r_t$ is the number of recruits in area $i$ in time $t$, $h_{ijt-1}$ is the catch in direct or incidental sector $j$ in area $i$ in time $t$, and $\varepsilon_t$ includes contemporaneously and serially correlated sample, observation, and specification error processes. Rather than impose a particular functional form and dynamic structure on the linkage between recruitment and environmental variables, recruitment is modeled using a Ricker function

$$\ln \{r_t\} = \ln \{X_{t-1}\} + r_0 + r_1 X_{t-1} + \eta_t$$

and environmental variables ($Y_t$) are included as covariates in a multivariate time series error-correction model. The advantage of this approach is that it is not necessary to assume a prior
specification of the functional form or lag-length of the association between recruitment and the environmental covariates. In addition, this approach also allows for possible direct associations between environmental covariates and the carrying capacity, growth rate or natural mortality of pollock. Moreover, this approach does not imply that there is a direct causal relationship between the environmental covariates and stock abundance or recruitment, but is instead consistent with the use of the environmental covariates as proxies for latent processes that influence the dynamics of recruitment and stock abundance.

While the residuals to equations (1) and (2) may be characterized by complex contemporaneous and serial correlations, they can be regarded as draws from stationary stochastic processes. Because even nonlinear stationary time series have linear state space representations (Aoki 1987), the dynamic factors that are important in the residuals of equations (1) and (2) can be modeled using innovation form equations (3) and (4):

\[
\begin{align*}
\omega_t &= \begin{pmatrix} \eta_t & \epsilon_t & Y_t \end{pmatrix} = Cz_t + \epsilon_t \\
z_{t+1} &= Az_t + Be_t
\end{align*}
\]

Equations (3) and (4) form a system of matrix equations that can be solved for a vector of latent state variables, \( z_t \), that represent dynamic factors present in the covariates and structural model residuals. The state variables are unobservable but can be determined after the model parameters have been estimated and are constructed to be minimum sufficient statistics for the past realizations of \( \omega_t \). The number of states can be less than, equal to, or greater than the number of series modeled depending on the degree to which the series are correlated and on the complexity of the underlying dynamics. Equation (3) projects the residuals of equations (1) and (2) and the environmental covariates onto the latent state variables. Equation (4) describes the dynamics of the state variables and is written as a first-order difference equation because equations (3) and (4) can be augmented to first-order by defining states equal to the lag of other states. The matrices \( A \) and \( B \) represent the intertemporal dynamic linkages between state variables. Because the states extract all of the information in the past, only serially uncorrelated innovations (\( \epsilon_t \)) orthogonal to the states remain. The solution to equations (3) and (4) is developed in Aoki (1987) and Aoki and Havenner (1991).

Following Criddle (1993), the bioeconomic model can be represented as a stochastic dynamic optimization of net benefits subject to equations (1), (2), (3), and (4). The solution to this dynamic optimization provides a framework for structuring stochastic simulations of changes in net benefits in response to changes in environmental variables, changes in the abundance and distribution of pollock, changes in input and product markets, and changes in management regimes.

In this study, equations (1) and (2) represent vectors of pollock abundance and recruitment among eastern Bering Sea, western Bering Sea, and Navarin pollock stocks. While the model does not include the level of detail incorporated in stock assessment models used for management of the US fishery, it reflects historic patterns of variation in each region and provides a basis for dynamic simulations for a range of shifts in the geographic distribution of the pollock stocks, varying rates of mixing among the stocks, differential rates of exploitation in the US EEZ and Russian Federation EEZ fisheries, differing costs of production, product recovery rates, product forms, and governance structures that affect the profitability and responsibility of fishing operations, etc. The sequential (migratory) character of exposure of pollock to harvesting in different regions at different life stages is modeled following Criddle.
(1996) and Criddle and Streletski (2000) with simulations run for conditions that reflect varying levels of cooperation or noncooperation between the US and Russian Federation.

For a quasi-competitive equilibrium, net revenue is:

\[ NR_{US} = P_{US}(Q_{US}) - TC_{US} \quad \text{and} \quad NR_{RF} = P_{RF}(Q_{RF}) - TC_{RF} \]

The corresponding first-order conditions for an optimal quasi-competitive equilibrium solution are:

\[ \frac{\partial TC_{US}}{\partial (Q_{US})} = P_{US} \quad \text{and} \quad \frac{\partial TC_{RF}}{\partial (Q_{RF})} = P_{RF} \]

For a collusive equilibrium, net revenue is:

\[ NR = P_{US}(Q_{US}) + P_{RF}(Q_{RF}) - TC_{US} - TC_{RF} \]

and the first-order conditions for a collusive equilibrium solution are:

\[ \frac{\partial (TR_{US} + TR_{RF})}{\partial Q_{US}} = \frac{\partial TC_{US}}{\partial Q_{US}} \quad \text{and} \quad \frac{\partial (TR_{US} + TR_{RF})}{\partial Q_{RF}} = \frac{\partial TC_{RF}}{\partial Q_{RF}} \]

For a Cournot-Nash equilibrium, net revenue is the same as for the quasi-competitive equilibrium, however, the first-order conditions for a Cournot-Nash equilibrium solution differ from the first-order conditions for an optimal quasi-competitive equilibrium solution:

\[ \frac{\partial (TR_{US})}{\partial Q_{US}} = \frac{\partial TC_{US}}{\partial Q_{US}} \quad \text{and} \quad \frac{\partial (TR_{RF})}{\partial Q_{RF}} = \frac{\partial TC_{RF}}{\partial Q_{RF}} \]

where the US treats \( Q_{RF} \) as fixed and the Russian Federation treats \( Q_{US} \) as fixed.

For a Stackelberg equilibrium with the US as leader, net revenue and the first-order conditions are the same as for the Cournot-Nash equilibrium, however, the US treats \( Q_{RF} \) as a function of \( Q_{US} \). Similarly, for a Stackelberg equilibrium with the Russian Federation as leader, net revenue and the first-order conditions are the same as for the Cournot-Nash equilibrium, however, the Russian Federation treats \( Q_{US} \) as a function of \( Q_{RF} \).

These simulations identify conditions under which cooperation or noncooperation is optimal from the perspective of the pollock fishery as a whole and from the perspective of the US and the Russian Federation.

References


LARGE SCALE MODELING OF ARCTIC SEA ICE ALGAL DISTRIBUTIONS

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1. Introduction

A rich and diverse microbial community inhabits arctic sea ice (Horner et al. 1985). Micro-algae residing in the ice not only nourish sea ice biota, but also comprise an important food source to water column and benthic ecosystems. In the permanently ice-covered Arctic Ocean, greater than 50% of the primary production is attributed to ice algae (Gosselin et al. 1997), and for the surrounding seas, the percentage is between 4 and 26% (Legendre et al. 1992). Early in the year, algae attached to the underside of sea ice may be the only food available to grazers below. Upon ice melting, ice algae are injected into the water column, thus potentially “jump starting” the phytoplankton bloom, extending the growing season and shaping the structure of the food web.

The extent and thickness of sea ice have diminished considerably over recent decades, with the most dramatic losses occurring in the last couple of years (Lindsay et al. 2009). Reduction in sea ice cover is likely to reduce the amount of algae growing within sea ice (Legendre et al. 1992) due to loss of habitat and changes in ice physical properties. Sparse field observations limit our understanding of the impacts of sea ice loss on sea ice algae and furthermore do not provide an adequate baseline on which to assess changes. Addition of an ice ecosystem to a global sea ice model, such as CICE (Hunke and Lipscomb 2008, Hunke and Holland 2007), supports the study of large scale spatial and temporal sea ice algal distributions and estimates of ice primary production for the past, present, and future.

CICE is a dynamic sea ice model used as a primary component of the Community Climate System Model (CCSM; J. Climate special issue 2006). It is coordinated and maintained at Los Alamos National Laboratory. For this study, the ice algal community developed in CICE is the ice ecosystem model of Jin et al. (2006a). This model has been tested in the fluctuating ice zone of the Bering Sea (Jin et al. 2007), land-fast ice in the Chukchi Sea (Jin et al. 2006a), and multi-year pack ice in the Canadian Basin (Lee et al. 2009). Implemented within the CICE framework, this model run globally allows extrapolation out to seasonal and basin-wide scales.

To date, results have been published from only one large scale model of sea ice algae, and it was specific to the Antarctic. This model of Arrigo et al. (1998) was not formulated to simulate sea ice algal growth in the bottom layer of sea ice, where generally over 90% of the ice algal biomass is concentrated in arctic sea ice. The ice bottom offers a substrate on which ice algae can grow, where nutrients are available and light is sufficient for growth.

The motivation behind the present work lies in the influential role of ice algae as producers of organic matter and as strong producers of the climate active trace gas dimethylsulfide. Both processes are important linkages in arctic biosphere-climate feedbacks which have not yet been
effectively considered in global climate models. This modeling study is a step in that direction by generating the first dynamic simulation results of ice algal biomass on a pan-arctic scale.

2. Material and methods

For the purpose of this study, arctic waters are defined as encompassing the southern extent of the seasonal sea ice zone. The central arctic is between 83°N and 90°N.

2.1. Description of the coupled sea ice-ecosystem model

The numerical ice ecosystem model of Jin et al. (2006), which simulates the ice algal community in the bottom three centimeters of sea ice, was coupled to the Los Alamos sea ice model, CICE. CICE treats atmospheric effects at the ice surface (snow accumulation, wind stress and radiation penetration) plus transport of the pack along the ocean surface and seasonal growth and melting. The model includes the elastic-viscous-plastic representation for sea ice dynamics (Hunke and Dukowicz 2002). In the present effort, CICE has been configured in a stand-alone mode driven from above and below by atmosphere and ocean model data for 1981. The slab ocean maintained underneath CICE is given, for purposes of demonstration of the biogeochemistry, a depth of 20 m. Key processes integral to the functioning of the ice algae have been retained from Jin et al. (2006), such as 1) nutrient input into the skeletal layer, 2) re-release into the water column, and 3) light and nutrient limitation terms. The model’s one-degree grid resolution is not capable of resolving small-scale features, but processes such as lead and ridge formation are present.

2.2. Model run

The model was run using meteorological and ocean model forcing as in Holland (2007), beginning in the year 1981. This period is prior to or around the time of the onset of the recent trend in sea ice decline. Passage through autumn-winter reseeding and organism scavenging processes remains numerically challenging and full parameterizations are not yet available. Model results from the first or “baseline” year were compared with available field observations to evaluate the ability of the model to simulate ice algal biomass accumulation in the bottom layer of sea ice on regional and seasonal scales. For the model run, nutrient concentrations were set to the World Ocean Atlas 2005 (WOA05) monthly climatology http://www.nodc.noaa.gov/OC5/WOA05/pr_woa05.html

3. Results and Discussion

Ice algal biomass expressed as Chlorophyll a (Chl a) concentration was simulated using a version of CICE that includes a module describing the sea ice algal community. For large scale comparisons, we use summarized ranges of observations, means and maxima, and patterns (e.g., regional differences, seasonal variability, or trend). For the purpose of model-field data comparisons, literature values for Chl a concentration (mg Chl a m⁻²) measured in sea ice are assumed to be uniform in the bottom layer of the ice core (0-10 cm), allowing direct comparison to results from the model which assumes a 3-cm-thick bottom layer.
Because CICE does not account for sediments in the ice which can shield out a large fraction of sunlight, model results from regions of high sediment load, such as the Siberian shelf seas, should be viewed as maximum values. The computations may also be biased high at times due to a lack of a parameterization for zooplankton grazing and upper ice biology (i.e. absorption of photosynthetically active radiation, or PAR). Comparisons need to be made with such model limitations in mind. At the same time, the scarcity of field observations severely limits the number and type of evaluations that can be made. However, use of an ecosystem model that has been validated for different sea ice types increases confidence in the model results.

3.1. Regional differences

Polar maps of simulated weekly and monthly mean Chl \( a \) reveal spatial patterns of ice algal biomass accumulation consistent with observations. Shown here are mean weekly model results from May (Figure 1), generally considered a peak month for the spring-summer ice algal bloom. Units in the graphic are base ten logarithm of Chl \( a \) concentration. Values in the northern Bering and Chukchi seas exceed 100 mg Chl \( a \) m\(^{-2}\) over large areas. However, most of the model results for the central Arctic are below 10 mg Chl \( a \) m\(^{-2}\). Field observations summarized by Gradinger et al. (2006 and references therein) reach above 70 mg Chl \( a \) m\(^{-2}\) in the first-year ice of North American waters and are only about 1 mg Chl \( a \) m\(^{-2}\) in the multi-year ice of the Transpolar Drift system and the Beaufort Gyre. In the model results, the vicinity of the Beaufort Gyre stands out as a region of low ice algal biomass accumulation.

A recent compilation of sea ice algal biomass accumulation for the Arctic shows the data are extremely variable (Arrigo 2003). Peak arctic Chl \( a \) abundances in sea ice range from 5 to 300 mg Chl \( a \) m\(^{-2}\), with a spring-summer average for all the studies of 87.5 mg Chl \( a \) m\(^{-2}\). Arrigo (2003) notes that even in a given sea ice habitat, Chl \( a \) accumulation can vary markedly depending on the environmental conditions that prevail during the growth phase. Nevertheless, generalizations can be made for different regions. Gosselin et al. (1997) reported a maximum of 15 mg Chl \( a \) m\(^{-2}\) for pack ice from a transect across the central Arctic. The maximum value for the central Arctic from the model is close to 10 mg Chl \( a \) m\(^{-2}\). Gradinger et al. (1999) measured values ranging from 0.1-0.14 mg Chl \( a \) m\(^{-2}\) in the bottom 2-4 cm of central arctic pack ice, and between 26-300 mg Chl \( a \) m\(^{-2}\) in the bottom 3-6 cm layer in Canadian and Alaskan coastal pack ice. Again the early model versions seem to be in rough agreement. The order of magnitude difference between drifting pack ice and coastal first-year pack ice has been attributed to the

![Figure 1. Polar map of base ten logarithm mean ice bottom layer Chl \( a \) concentration (mg Chl \( a \) m\(^{-2}\)) for mid-May (week 20). The white line is the 15% ice edge contour and the black lines are ice thickness contours of 1, 2, 3 and 4 m, working inward from the ice edge.](image-url)
relative size of the nutrient supply (Sakshaug 2004). It is relatively well established that light availability and nutrient supplies place the strongest controls on sea ice biology. Future, computational sensitivity studies will show if this is the case in the model as well.

3.2. Temporal variability

The time series plot of simulated weekly mean arctic ice bottom Chl \(a\) concentration (Figure 2) shows a broad spring-summer shoulder with values in the tens of mg Chl \(a\) m\(^{-2}\). From about the first week of March (week 10) until August (week 31), the simulated mean ice bottom layer Chl \(a\) concentration is above 10 mg Chl \(a\) m\(^{-2}\). The maximum mean of nearly 100 mg Chl \(a\) m\(^{-2}\) appears during the 20\(^{th}\) week (mid-May). Observations indicate that growth of sea ice algae mainly occurs in the spring and summer (Gradinger 2008), although there is a potential for growth in autumn. The unexpectedly high second (autumn-winter) shoulder in the time series, which has a peak value about one order of magnitude less than in spring-summer, may in part be explained by continued algal growth in the perennial ice, which in turn relates to losses accruing during the melt period. These have proven difficult to parameterize in the model. Rapid algal growth in the newly formed ice may also be a factor, but observations are so sparse that it is not clear that high values can be excluded.

4. Conclusion

The coupled ice ecosystem-CICE model developed in this study cannot be considered to be complete, let alone completely correct, because it does not take into account a number of potentially significant processes, such as zooplankton grazing, absorption of PAR by upper ice biology, and sediment incorporation into sea ice. The scheme used for transferring nutrients across the ice-water interface will need to be modified for year-round model application in upcoming versions of stand-alone CICE. Model estimates of the absolute magnitude of ice algal biomass are generally higher than field observations. These problems will likely be solved when the model is run as a fully coupled ocean general circulation framework. We plan to couple the sea ice biogeochemistry model with the Parallel Ocean Program, or POP, which is also a component of the CCSM. For now, even the current early generation model results may offer advantages relative to interpolation or extrapolation from sparse field observations. Care has been taken to implement the descriptions in well-tested models of arctic ice physics and biological processes (Jin et al. 2006ab, 2007; Lee et al. 2009). At least some crucial aspects, such as nutrient and light limitation processes are thus represented with fidelity.

The fact that the present model does show regional differences and a seasonal trend in agreement with field observations encourages further development of this modeling approach. We plan in
the near term to obtain estimates of sea ice primary production across the Arctic and to examine the impact of diminishing sea ice on ice algae and primary production. With this present model framework in place, we will be ready to aptly utilize the numerous field observations of sea ice biology that are becoming available as a result of the IPY.

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References


### Storm Tracks in the North Pacific – Relevance to Coastal States

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Storm tracks drive dangerous coastal states. Surface winds associated with storm tracks may drive ocean waves that can impact the Arctic coastline. One example is the state of Alaska [Mason et al., 1996]. Cities such as Kivalina and Shishmaref may have to relocate soon due to coastal erosion increase. Therefore, understanding the characteristics and variability of extra-tropical storm tracks that impact the Alaska region is of importance to emergency planning and hazard mitigation efforts.

The Arctic is highly vulnerable to observed and projected changes in climate, according to the Arctic Climate Impact Assessment (ACIA) report and many other Arctic climate projections [Manabe and Stouffer, 1994; Serreze et al., 2000; Johannessen et al., 2004]. One of the predicted effects of climate change is an increase in severe storm activity (frequency and intensity) in the North Pacific, Bering Sea and Arctic Ocean [Dickson et al., 2000; Graham and Diaz, 2001].

In the Alaska region strong storms are an annual occurrence in the Bering Sea and Gulf of Alaska, with peak activity coming in the fall/winter season [Fathauer, 1978; Salmon, 1992]. Relatively few of these storms form locally; instead they consist of “old” systems that have moved into the region from the North Pacific and which undergo a process of re-energization – a result of locally favorable patterns in atmospheric dynamics that often occur. Some storms continue north through the Bering Strait. These storms represent a serious hazard to users of these marine regions, subsistence and commercial alike, as well as to the many coastal communities. The greatest threats from these storms are waves and water-level surges, a “storm-surge”.

The impact that a storm surge may have on the coastal communities of Alaska can be devastating. For example, Nome suffered the effects of storm surge on October 19, 2004, when a powerful autumn storm moved up from the Aleutian Islands. The storm surge height reached 10.45 feet with overall damage of approximately 20 million US$. Erosion is another problem faced by Alaska’s coastal communities which, being caused by wave action, is also related to both the intensity and frequency of storms. The case of relocating whole communities is frequently discussed in Alaska. This has severe cultural and economical implications. Other examples include hazards to Alaska’s million-dollar fisheries economy. The primary season for the Bering Sea crab fishery is fall and winter, which presents real dangers for fishing boats. Improving our understanding of the climatology and the dynamics of storms in the Bering Sea is important to better comprehend, prepare for and mitigate coastal erosion and marine hazards.

Research on storms has focused on tracking individual storms to identify typical trajectories, intensities, and possible changes through time. Storm tracking dates back to the mid-nineteenth century when scientists started to classify and plot individual storms, using synoptic weather maps [Mohn, 1870; Loomis, 1874; Bergeron, 1950]. An important event in meteorology was the first formalized description of the life-cycle of a mid-latitude cyclone in 1919 at the Bergen School, Norway, which made the effective tracking of storms possible. In this early work, storms were tracked by relating their position...
with time and using statistical methods [Petterssen, 1950; Klein, 1957]. The onset of powerful computer modeling allowed a more global, synoptic approach based on statistical methods through the so-called 'synoptic objective analysis' [Murray and Simmonds, 1991; Serreze et al., 1993; Sinclair, 1994; Hoskins and Hodges, 2002; Zhang et al., 2004]. This type of analysis made it possible to employ algorithms that identify local minima/maxima of storm diagnostic parameters, such as sea level pressure, within blocks of grid points. This is how most traditional tracking algorithms work nowadays.

In this research climatological properties of extra-tropical storms in the North Pacific/Bering Sea will be presented based upon aggregate statistics of individual storm tracks calculated by means of a feature-tracking developed by Hodges [1994, 1995, 1996, 1999]. The 850-hPa relative vorticity field ("VR850" hereafter) is used instead of the more often used mean sea level pressure. Emphasis extends beyond winter to provide detailed consideration of all seasons. Results will be shown with respect to the frequency and intensity of the storms. Major climatic indices that impact the North Pacific region were also correlated with the storm frequency and intensity. Results will be shown with respect to the El Niño Southern Oscillation (ENSO), the Trans Niño Oscillation (TNI) and the North Pacific index (NP).

**Methodology**

Storm systems were identified and tracked using the algorithm developed by Hodges [1994, 1995, 1996, 1999]. The algorithm identifies a storm center to be a relative vorticity maximum which exceeds a certain user-defined threshold. In order to solve the correspondence between the feature points in consecutive time steps, a specialized cost function is applied [Hodges, 1995].

Relative vorticity at 850-hPa, from the NCEP/NCAR reanalysis (NOAA-CIRES) from 1948(49)-2002, is used as the analysis variable. This level has been chosen to avoid the noisy relative vorticity signal in the boundary layer. VR850 is less influenced by the large-scale background flow and it does not depend on any extrapolation techniques. This variable is also directly related to the wind speed [Sorteberg and Walsh, 2008] and it is thus relevant for the North Pacific region.

El Niño Southern Oscillation and Trans Niño indices were provided by the Climate and Global Dynamics Division (CGD/UCAR). The North Pacific index was provided by the Physical Sciences Division (NOAA).

Two tracking output variables were retained for this analysis:

i. Track density (TDENS) – Number of storm tracks through a region per season. Units: storms (10^6 km^2 season)^{-1};

ii. Intensity (INT) – Depth of the vortex. Units: vortex depth in 10^{-5} s^{-1} of the storm per 10^6 km^2 estimation region;

**Results**

The overall track density pattern is dominated by a strong North Pacific track. Track densities are highest in winter – about 30-38 storms (10^6 km^2 season)^{-1} – and lowest in summer – about 20-30 storms (10^6 km^2 season)^{-1}. During winter, the maximum number of storms covers most of the North Pacific and the Gulf of Alaska. Spring and fall track densities have similar characteristics. Both have a similar core within the Pacific maximum, stretching over the North Pacific towards the Gulf of Alaska with a density of exceeding 30 storms (10^6 km^2 season)^{-1}. Winter storms are more intense and summer intensities are weakest [Mesquita et al., 2008]. Spring and autumn track intensity patterns and magnitudes are almost identical. The small winter intensity maximum is situated southeast of Kamchatka Peninsula. The summer intensity maxima pattern is also shifted northwards and rotated slightly towards the Aleutian Islands.
The ENSO index showed good relationship with the storm track variable in the winter, summer and autumn. Most of the correlation was positive and along the mean storm track corridor in the NP. As for the intensity, the relationship with ENSO was very sporadic over most of the NP for all seasons. Summer seems to have a larger influence, especially over the storm track corridor area. The correlation with the track density and the TNI index was not very robust. A few areas over the NP showed negative correlation during winter and summer. And negative correlation over AK for all seasons. As for the intensity, the statistically significant correlations were few. They were mostly negative over the NP (winter) and AK (spring, summer and autumn).

The NP index showed very strong relationship with the track density variable. Negative correlations were observed over most of the NP for all seasons. And very strong positive correlations were found over the Bering Sea area. The intensity shows also good relationship with the NP index. This was especially during winter: negative correlation over the Gulf of Alaska and positive over western AK. During autumn, most of the correlation was positive over the Bering Sea/Strait areas.

Discussion and Conclusion

Winter emerged as the most active season for most of the storm parameters analyzed here. Overall, the track density is higher in winter. Simmonds and Keay [2002] found high winter mean cyclone over the Sea of Okhotsk and the Gulf of Alaska and this is in accordance with our results, except that we find higher counts during autumn (season not used in their study). Storm tracks are located farther south in winter compared to summer [White, 1982; Nakamura, 1992; Simmonds and Keay, 2002; Mesquita et al., 2008]. The north-south gradient of temperature is higher in the winter, which allows for more baroclinic instability in winter. In addition to that, the Kuroshio Extent [Qiu, 2000], also known as the North Pacific current, would provide energy to help feed new storm systems in winter.

Summer storms are the least intense, with winter, spring and autumn intensities being larger but similar to one another. Simmonds and Keay [2002] also found that, in general, the mean intensity is significantly reduced in summer with the most intense summer systems found over and southwest of the Aleutian region, also in accordance with our results [Mesquita et al., 2008].

The NP index has shown to be the most influential over the North Pacific compared to ENSO and the TNI. The TNI did not show many robust correlations, whereas the ENSO index showed some relationship, especially with the track density variable. Other studies have shown that the ENSO impact on storms in the North Pacific seem to be somewhat delayed [Mason et al., 1996]. This may be the reason why we just see some correlation with the ENSO there. The NP index has been shown to be a delayed manifestation of ENSO in the North Pacific [Trenberth and Hurrell, 1994]. This could also explain the fact that the storm tracks in the North Pacific are so well correlated with this index.

References

Introduction
In our undergraduate chemistry courses, we need to engage students by including both the real world concerns of our students as well as the place based context they learn in. Including traditional knowledge when it intersects with a chemical principle or challenging real world-issue adds concreteness to the scientific process. Traditional and indigenous knowledge fits well with courses using SENCER pedagogy.

Science for New Civic Engagement and Responsibilities is a national dissemination and faculty development project for courses in science, technology, engineering, and mathematics. SENCER courses connect science and civic engagement by teaching through complex, capacious, current, and unresolved public issues to the underlying scientific principles. The more that our students are exposed to culturally responsive chemistry courses that encompass biocomplexity, the more effective they will be as agents of long term stewardship in the circumpolar north through periods of rapid change and ecological challenge. It is therefore critical that issues such as sustainability, environmental health, food security, and precaution be integrated into science teaching. In studying public issues of the north, students and faculty can use examples from Traditional Knowledge to illustrate the use of chemical principles. As part of the IPY UArctic effort, examples from climate change, nutrition, nuclear science, chemical ecology, and biotechnology were integrated with traditional knowledge into three courses: 1. Chemistry and Complex Systems; 2. Introduction to Radioactivity in the North; and 3. Demystifying Biotechnology. Exposure to traditional knowledge broadens the average students’ world view and strengthens not only their understanding of the scientific process but engages them in community issues.

The SENCER national curriculum reform project is now almost a decade old. For the Arctic, the original arguments for the project are as compelling as they were in 2000 when the National Center for Science and Civic Engagement was started: it is important that science instructors must make the connections between science, people, and society more transparent. Equally important, through these connections, is the goal to invite students to engage in the complex social issues that face us today locally, regionally, and globally. If anything, polar researchers would argue that issues such as climate change, energy production, sustainable use of resources, and waste reduction are even more relevant today. As a 2008 report states,

“The commitment that many campuses have made to increased environmental sustainability and stewardship continues to be more than just rhetoric. A majority of schools currently have written declarations promoting environmental sustainability or stewardship or plan to develop them. And a majority also have written declarations that state that educating students about sustainability or stewardship is part of the school’s academic mission.”

As part of IPY the terminology “adapt and adopt” has been used informally.

The course “Environmental Radioactivity, Stewardship, and People of the North” at the UAF came into existence for IPY by adapting/adopting one of the SENCER Model Courses. Currently, over 20 such model courses exist, and each provides potential adapters with a syllabus, learning goals, and assessment tools. The SENCER Model course, “Environmental Chemistry and Ethnicity” (subtitle of “Uranium and
American Indians”), which was first co-taught in 2002 at the University of Wisconsin-Madison by one of the authors of this paper (CM) and Omie Baldwin. The UM-M course uses stories of the Navajo uranium miners, the radium dial-painters in the 1920s, and the nuclear testing in Alaska in the 1950s to illustrate these same relationships between people and the environment.

**Results**
The new course at the UAF, “Introduction to Radioactivity in the North,” similarly teaches the complex relationships between people and radioactivity in the context of the Arctic. Students learn how nuclear chemistry and biomedical science are relevant to the lives of people in the North, including Alaska Natives and rural circumpolar people. Complex societal issues are central both to the storyline of the course and to the intellectual tasks required of the students taking this approach. Using readings such as *Firecracker Boys*, students

- become familiar with and be able to discuss the methods and ethical frameworks used by scientists and engineers;
- learn about historical events in the north and consider the role of this history and Alaska Native culture in environmental and nuclear issues;
- know what questions to ask and how to predict potential hazards when you are given a scenario involving a particular radioactive substance or an issue such as the proposed “nuclear battery” in Galena, Alaska.

While enrollment has been low, the feedback from the students has been deeply encouraging.

“…[this] is the best course I have taken at this university for many reasons – the ability to successfully integrate science and the issues surrounding it being just one of many.”

These lines, excerpted from a longer piece by a student in her final reflection piece for the course, would warm the heart of any instructor. Even the dissatisfaction expressed by this student took a positive spin: “Most of my complaints would revolve around not learning enough – every issue seemed interesting enough to have an entire class about.”

At UAF in Chemistry in Context (Chemistry of Complex Systems), Native Science methods have been included in the scientific method discussion, traditional knowledge of ice and water in resources discussion, caribou gut in the protein section and origins/identity in the genetic engineering section. In the UAF Biotechnology course, traditional knowledge of food and disease is included in the genetically modified plant and animal discussions. The SENCER approach to arctic science will leave a legacy of new engaging courses at UAF and UArdctic.

We are grateful to the students who invested their time and efforts in this course, teaching both us and each other. This project, funded through a CCLI Adaptation and Implementation Award, DUE-0632397.
The economic, social and cultural rights of Indigenous peoples remain inseparable and interdependent of our lands, territories and resources. Indigenous subsistence lifestyles, cultures, and traditional social systems form an intricate web and way of life that maintains the identity, social and physical health, and survival of indigenous peoples around the world. When we destroy one strand of the web of life, we compromise the entire web.

As sources of fossil fuel are becoming less readily available, transnational corporations are more anxious in their quest to find and exploit new sources of energy. Many times Indigenous homelands are put in detriment in this quest for new sources of fossil fuel. Indigenous communities are disproportionately impacted by fossil fuel exploration and extraction activities, and by the resulting effects of pollution, global warming, and climate change.

Places that are currently imperiled by proposed unsustainable economic development initiatives include the Arctic National Wildlife Refuge, Teshekpuk Lake wetlands of the National Petroleum Reserve of Alaska, the Yukon Flats Wildlife Refuge, the Outer Continental Shelf (offshore) of Alaska including 83 million acres offshore within Cook Inlet, Bristol Bay, Chukchi and Beaufort Seas. Other initiatives within the State of Alaska include unsustainable mineral extraction and coal fired power plant proposals that are within Indigenous subsistence areas.

Alaska fossil fuel development has caused toxic waste, roads, pipelines, poor air and water quality and harmed subsistence and other resources. As the subsistence resources are undermined the right of the people to live a subsistence land based way of life is undermined. Subsistence in Alaska is of critical importance to Alaska Natives; subsistence is about our entire way of life. Indigenous peoples of Alaska rely upon our lands to provide for our necessary physical, cultural, spiritual and social needs. Subsistence encompasses all facets of our lives. When we defend our subsistence rights we are defending our inherent sovereign rights.

Alaska Natives reject the notion that our ancestral homelands can be put forth as national sacrifice areas through attempts to access the remaining lands and seas that Alaska Natives rely on for subsistence needs for mining, oil and gas and other unsustainable fossil fuel development.

The burning of fossil fuels is the major human cause of emissions that are resulting in global warming. Global warming is leading to shifts in the world environment that are resulting in a significant increase in devastating and alarming weather patterns. Effects of global warming alone include altered weather patterns, more severe storms, erosion of coastal areas, and migratory disruptions of key wildlife resources. These impacts lead to loss of subsistence resources and rights, relocation of communities, and to negative social statistics related to human and ecological health. The use and reliance on fossil fuels must be curbed. We can initiate renewable energy sources that are ecologically sound and sustainable with minimal impact on Indigenous peoples rights, homelands, and livelihood.

Alaska Natives are demanding our rights to a safe and healthy environment conducive to subsistence. Alaska Natives aim to address the human and ecological health impacts brought on by unsustainable development practices of the fossil fuel industry, and the ensuing effect of catastrophic climate change.
Alaska would benefit from the vision of a just transition from fossil fuel development to clean, renewable energy for sustainable economies, and sustainable development.

Panelists:

Faith Gemmill-Gwich’in from Arctic Village, AK is the Executive Director of Resisting Environmental Destruction on Indigenous Lands will provide facilitation of this panel

Vernor Wilson- Yupik from Dillingham, AK is the Program Associate of the Kamchatka/Bering Sea Ecoregion of World Wildlife Fund. The North Aleutian Basin is valuable to the local communities for its abundant subsistence resources that sustain traditional cultures and ways of life. Bristol Bay fisheries are the base of the economy and livelihood for residents of the region.

Ted Frankson Sr.-Inupiat of Point Hope, AK is the Director of the Wildlife Department of the Native Village of Point Hope. Proposed oil development of the Chukchi Sea will threaten critical spring migration routes for bowhead and beluga whales, important feeding areas for many species of whales, and Pacific walruses, staging and molting areas for migratory birds, polar bear and walrus habitats. These species provide Inupiat people with necessary subsistence needs.

Rosemary Ahtuanguruak (TBA)-Inupiat of Nuiqsut, AK is a council member of Inupiat Communities of Arctic Slope. The region of Teshekpuk Lake is important to a number of bird species. The offshore area contains the feeding area for bowhead whales during their fall migration and the late summer use area for beluga whales. Onshore, it provides the most consistently used wintering area for the Teshekpuk Lake Caribou Herd, and is part of the outer range of the Western Arctic Caribou Herd.

Faye Gallant is the Tribal Campus Climate Challenge Organizer with Indigenous Environmental Network and REDOIL will provide an overview of the Tribal Campus Climate Challenge.
The weight of evidence has finally converged on the point where there is both scientific and public consensus about the fact that climate and weather patterns are rapidly and gradually changing, in the Arctic and elsewhere (Main et al. 2008; IPCC 2007; ACIA 2005). Although geographers, anthropologists, historians, novelists and poets have long recognized and appreciated the relationship between population size, community and economic organization, ecosystem structure and function, a similar consensus is now emerging in the Sustainability and Resilience literature, about the ‘goodness of fit’ between human communities and the ecosystems that they depend on. If the human system expands beyond what the ecosystem is capable of supporting, then the stability of any ecosystem and the services it provides for the support of human and biological communities are likely to be irreparably stressed, with local, regional and global systems at all scales impacted, regardless of social organization, technological sophistication, governance regime or economic philosophy. The inevitable result of ecological overshoot is collapse in the worst case, reorganization in the best, whether driven by climate and weather or some other biophysical, cultural or social force. Whether from the perspective of an urban or rural community, or from that of a scientist, planner or policy maker, the contemporary challenge is how to cope with the cumulative effects of change, how to ensure that healthy and sustainable systems have the resources needed to thrive now and in the future, and how to create positive social and ecological conditions that will foster sustainable futures.

Historic, documentary and ethnographic records are rich with excellent case studies illustrating how the drivers of change are linked to the human responses to them, with climatic over the long run, weather in the short run, or some combination of social, ecological and climatic processes interacting at multiple temporal and spatial scales to condition what contributes to the successes and failures of human response at any scale, in any society. We have to be aware of these lessons if we are to learn from them, and metaphors such as the adaptive cycle may provide one way to visualize stability and change, but there are more substantive studies, more substantive frameworks and methods available to help us understand the same (e.g., Spicer 1962, 1971). Even Arnold Toynbee remarked that “civilization is a movement not a condition,” and the rise of uniformity in any form will mark its decline. True for social and ecological systems, true for food production systems, and true for academic and intellectual movements as well.

Where change is rapid, unprecedented or unanticipated, the potential for people to rely upon natural resources such as wild fish and game, to rely on local food productions strategies such as gardening or small-scale farming, to have a secure, abundant and safe water supply, even to their ability to conduct economic activity necessary to support a way of life, may be compromised (Nuttall et al. 2004; Wernham 2007; Barnett and Adger 2007). Where change is gradual, the assumption is that it may be understood and planned for, although the effectiveness of policy strategies linked to this assumption are still to be shown through practice. The sectors or components of the problem are fundamentally the same in either scenario of gradual or punctuated change, although the synergistic relationships among components of a system, and social and ecological outcomes may well be different. All communities have the potential to either plan intelligently for a safe and secure future, or to simply default to the time tested but timed-out strategy of impact mitigation, whatever the forcing function, and regardless of temporal scale. Community and individual health and security, in some cases even survival, are the stakes.

There are multiple ways to define and measure community food security, water quality and health. Here we scope community security to include, at least, access to and control over land and resources, access to healthy and nutritious food, unrestricted access to and control over secure energy futures, access to and control over a secure supply of safe water, high quality education, and unrestricted access to high quality and affordable health care, with each situated as they must be in a culturally appropriate context for
individual and community health and well-being. The need for us to understand change in the biophysical system, as well as to understand what are effective and ineffective social and cultural responses to climatic, social and ecological drivers and associated human agents of change, is brought into even sharper focus when we look at the whole system, when we link the rural to the urban, and both to larger frameworks of economics, policy, politics, governance, and to institutional and regulatory bodies.

This presentation is linked to and is a précis for a second presentation in this IPY conference, one entitled “Ways to Help or Hinder: Matching Climate and Policy in Alaska by Philip Loring and collaborators. We use the Alaskan food system as one framework for understanding community strengths and vulnerabilities, with some of the problems and prospects for effective response to these and other related challenges briefly outlined. What tools and support do people and communities need if they are to respond to the contemporary challenges of climate change and food systems in more effective ways, whether in the present or projected for the future? How can scientists improve the communication stream to the rural communities, how can rural residents improve the communication stream to the scientific community, and how can all of us learn to communicate more effectively with politicians and policy makers?

Rural and urban communities across Alaska, whether on the coast, near the coast, or in the interior, are all engaged in a sometimes dramatic ecological, economic, cultural, and demographic restructuring (Martin et al. 2008; Meadow et al. in press; Huskey et al. 2004). In a global context of climate change and socioeconomic turmoil, the costs and uncertainties of living in Alaska are on the rise, with downward trends reflecting the limitations of rural and urban infrastructure, employment opportunity, the increased cost of food, fuel and transportation, with these just some of the factors that in combination are making life challenging for all. Rural-to-urban migration, migration within and out of state, is undermining community stability, health, and community futures at both ends of the rural-urban axis (Goldsmith 2008; Fried and Robinson 2006; Larsen et al. 2007; Knapp 2005). Households and communities that rely heavily on Alaska’s wild food resources, whether for ‘subsistence’ or ‘commercial’ purposes, are especially vulnerable in a number of common dimensions to the new and unprecedented environmental variability and changes that are now occurring: changes in terrain and land cover, unpredictable and extreme weather, and shifts in seasonality, to name a few (Loring and Gerlach in press; Ford in press).

With people now mostly geographically-fixed to their communities by infrastructure and sources of wage income, and restricted in their ability to traverse the landscape by the patchwork of regulatory structures, resource management regimes, and private, state and federal land ownership, the flexibility that once supported many thriving Alaskan lifestyles is significantly constrained (Hall et al. 1985; Caulfield 2002; Loring 2007). The necessary alternatives involve transitioning to short-term wage-earning activities in other sectors (e.g., mining, firefighting), that is if and when jobs are available, and to finding some degree of food security with increased reliance on imported, store-bought foods. This is a nutrition transition that is “gentrified” in many places throughout the state (Reed 1995; Wernham 2007; Egeland et al. 1998; Bersamin et al. 2007), but regardless of nutritional quality and problems with food access across racial and income groups, the urban or rural commercial store does introduce a measure of food security for some, with food available on the shelf most or all of the time, and assuming that there is the means for purchase.

The nutritional and ecological transition brings more than a share of additional vulnerabilities and consequences for individual, community and cultural health. Whether available in sufficient quantities or not, food of low nutritional quality has an especially severe and differential impact on low-income groups, although this is clearly not restricted to low-income groups. While many find this situation unacceptable for social and economic justice reasons, others argue that such vulnerabilities are unavoidable and simply reflect the dictates of an industrial food production system that is either responsible for the protection from, or for the proliferation of a global food crisis; those who champion the western industrial agricultural paradigm tend to find justification in western political will, and the seductive but one-sided symmetry of a neoclassical growth economy (see Collier 2008 for an example of this kind of thinking).
Weather represents one of the dominant controlling factors in the life of inhabitants of arctic regions (Nelson 1986; Krupnik and Jolly 2002). For instance, the weather controls sea ice, which in turn governs the life cycle of many animals and plants that form the basis for survival (Hovelsrud et al. 2008). Sea ice also serves to buffer and/or armor the coast against the impact of storms, limiting the degree and extent of damage (Atkinson 2005). Weather may limit overland travel (e.g. low visibility) and the general ability to conduct economic activity by confining residents to their communities during critical subsistence periods. Severe weather and episodic extreme weather events, strong winds and freezing rain, for example, can also strongly affect the distribution and abundance of both marine and terrestrial animals, and with impacts on the efficiency and efficacy of community infrastructure for food processing and storage, including in this context fish drying racks, ice cells and other meat storage facilities, smoke houses and root cellars as well (See Binford 1978; Nelson 1986 for background on caribou and terrestrial mammal hunting systems; and Nelson 1969 for information on northern marine mammal hunting systems). Long-term shifts in major patterns of atmospheric and ocean circulation can affect the distribution and movement of fish stocks on which a community depends, with this just one example of a weather/subsistence food correlation, and a direct and cumulative weather-related impact on subsistence resources and marine productivity.

When temperatures are too warm during the fall and spring drying seasons, and assuming that there has been success in the hunt, then meat storage requires the use of commercial freezers, freezers require electricity, and typically for most rural Alaskan communities, electricity requires expensive diesel imported from urban distributors. The impacts and effects are direct and indirect, cumulative and catastrophic, with an example of the latter being a wind-driven surge in water level that washes away a dock or inundates a community. The weather can also kill—many hunters and fishers have lost their lives at sea when the weather turns unexpectedly and unpredictably, with the ability or inability to read weather signs reflecting the fact that contemporary ecological changes are occurring in new and unexpected ways that are not necessarily coded in local knowledge, or reflects instead, the intergenerational loss of knowledge. Extremes can affect heavy infrastructure as well, such as the bulk loading facility at Teck Cominco’s Red Dog Mine in Alaska, or for that matter housing and other village infrastructure along the west coast of Alaska from Barrow to Dutch Harbor. This latter concern will only grow as increasing emphasis is placed on activities such as resource extraction, the expansion of oil, gas and mineral interests across the state, especially when the context for development is one of climate change and a precarious economic state. Besides daily and seasonal weather extremes, climatic extreme events accumulate and with serious impact across annual and decadal scales.

Despite the rigors of weather in this region, ecological variability has always been an aspect of life in Alaska, but over a long period of time residents have learned how to adjust to these challenges through flexibility and careful observation of their surroundings, including weather and natural history. General patterns of weather are understood well enough that residents have some capacity to predict trends or shifts in conditions, to know when a period of good travel/hunting weather is at hand, and when plants and animals in their surroundings come in and out of harvesting season. This capacity is essential for survival, yet it has largely developed over a long period characterized by relatively stable weather patterns, quite unlike the new, stochastic trends being predicted for the North. Many Alaskans now find that new, non-linear and/or directional changes to weather, water levels, landscape cover, and seasonality, are making the environmental cues that they have learned (or been taught) to predict the weather and behaviour of animals, are now much less effective, noting that the “world i s not the way it used to be” (McNeeley and Huntington 2007; Krupnik and Jolly 2002).

In order to assure a food secure-future for these communities, there is a need for access to quality climate and weather information so as to sharpen predictions about water and landscape conditions, and to make the best and most well informed decisions possible about where and when to hunt and fish in times of uncertainty, where and when to hunt and fish successfully and safely. Today, however, there are at least two essential problems in linking climate and storm information to observed community impacts: a) that
the precise nature and full range of possible community responses to weather is not fully and clearly expressed, and or that the meaning is simply assumed by physical scientists, and b) climate models do not possess the spatial detail to address local climate change requirements at a seasonal scale and with respect to weather. There are of course downscaling models and methods, algorithms and transfer functions that are scientifically useful and quite sophisticated, but the derived information is not always easy to convey to the public, especially with respect to projections, predictions, forecasts. These problems limit the applicability and predictability of currently employed weather forecast tools to go the extra step in terms of community-relevant detail. Finally, many villagers from communities up and down the Yukon River have expressed their frustrations with climate change research in general, saying that it has been overemphasized to the exclusion of other socioeconomic, educational, food and energy issues.

Communication between scientists and rural communities is improving though, with mutual awareness through collaboration, although more work is still needed from both sides before it will be possible to correlate and integrate observations and forecasts across spatial and temporal scales. Subsistence harvests are daily and seasonal, while climate models are often based on decades and/or millennia, and thus do not always provide the high quality weather information needed on a daily or seasonal basis, information that a subsistence hunter, a subsistence or commercial fisherman, a subsistence gardener or farmer needs or would like to have. There is still a need to synthesize and communicate climate change information to both institutions and local communities, but it is also important for us to work more critically with the synergistic interactions of climate and weather change, socioeconomics, and subsistence in ways that are relevant to communities and regions. For planning purposes, forecasters must move toward integrating fine-grained local and regional climate and seasonal weather information with community-based knowledge gained through hunter experimentation and testing in the field. New paradigms for effective linkages between institutional and local responses to change are explored in this talk, with the intent of empowering communities to make local decisions regarding resource management based on the highest-quality local and scientific knowledge and observations.

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STRENGTHENING INSTITUTIONS: LOCAL INVOLVEMENT IN OFFSHORE OIL AND GAS MANAGEMENT

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The dramatic run-up in oil prices between 2001 and 2008 fueled keen interest in oil and gas exploration worldwide. In Alaska, observers were startled by record breaking bids totaling more than $2.6 billion for leases offered by the U.S. Minerals Management Service (MMS) in a remote area of the Chukchi Sea. Shell Offshore Inc. (Shell), which paid $2.1 billion for Chukchi leases, was eager to begin exploration activities both in the Chukchi and in the Beaufort where it is also a major lease holder. While federal agencies approved Shell’s 2008 plan for exploration in the Beaufort Sea (and state agencies concurred), no drilling occurred because of a legal challenge asserting that the environmental review process did not adequately consider potential for harm to migrating whales and traditional Inupiat hunting. While the 9th Circuit Court of Appeals initially agreed with the plaintiffs, the case is not over (Alaska Wilderness League v. Kempthorne, November, 2008).

This is just the latest chapter in a 30 year saga of conflict over oil and gas development offshore Alaska. The conflict of interest between surface users—Inupiat subsistence hunters—and subsurface owners—the state and federal governments who own the oil and gas rights, plus the oil industry that wants to develop the resource—is structural. Can good institutional design help mitigate the conflict? In this paper we use theories of institutional analysis, participatory democracy and conflict resolution to critique the current institutional regime and assess policy options for strengthening institutions for management of offshore oil and gas.

Current Management Regimes and Opportunities for Local Participation

Regulation of offshore oil and gas activities in Alaska involves a complex management framework of state and federal agencies. The State of Alaska has primary responsibility for state waters three nautical miles from the shoreline while the federal government has authority for activities in the Outer Continental Shelf (OCS). The major federal laws related to offshore oil and gas activities include the OCS Lands Act, the National Environmental Policy Act (NEPA), the Coastal Zone Management Act (CZMA), the Marine Mammals Protection Act, the Clean Water Act (CWA) and the Clean Air Act (CAA). Alaska statutes give state agencies authority to regulate certain activities in state waters. Through the CZMA, the State of Alaska reviews activities for consistency with state standards and regulations, including coastal district enforceable policies.

Both state and federal review processes provide opportunities for local participation throughout the lease sale, exploration and development phases. For federal sales, local participation is sought four times during preparation of a five-year leasing program and subsequent sales: during the scoping process, the comment periods on the draft Environmental Impact Statement (EIS),
the final EIS, and the proposed notice of sale. Under Section 19 of the OCS Lands Act, MMS is required to accept the state’s recommendations for a lease sale or development project if the recommendations provide a reasonable balance between the national interest and well-being of local citizens; no deference is required for the comments of local governments. For state lease sales, public involvement is concentrated at the beginning of a 10-year planning period when the state’s Best Interest Finding is being prepared for leasing over large areas.

Opportunities for public review of OCS exploration projects under the OCS Lands Act are more limited due to the requirement that the agency make its decision within 30 days an exploration plan is deemed complete. MMS approval is contingent upon the state’s consistency determination which must be issued within 90 days under the ACMP. On the state side, exploration projects do not usually require either a NEPA review or a best interest finding. An ACMP review is usually required, but the scope of review may be limited to activities directly related to required permits.

Offshore development projects undergo a more thorough review than exploration projects because they involve longer time periods and the potential for greater effects. Yet there can be issues related to the timing of agency reviews. For example, because the applicant determines when the ACMP and state permit reviews begin, there may not be adequate information for the public if the review is initiated before federal agencies issue their records of decision on the project.

Another avenue for participation occurs in the ACMP consistency review process for both state and federal lease sales and exploration and development projects. According to state law, ACMP reviews must be completed within 90 days. This timeline may not be sufficient for complex OCS exploration projects when questions arise about the adequacy of information. The scope of an ACMP review may be limited to only certain activities or certain effects to coastal uses or resources. For example, OCS seismic survey activities are not subject to review even though they are known to affect the migration patterns of bowhead whales. In addition, state legislation passed in 2003 directs ADNR to reduce the number of consistency reviews by adding as many activities as possible to lists of activities that do not require individual review. Limitations to coastal district enforceable policies and statewide ACMP standards implemented in 2004 have resulted in the inability of coastal districts to comment on certain effects to coastal resources and uses during ACMP reviews. For example, under state law, subsistence concerns cannot be considered during a review unless DNR approves designation of an area for a specific type of subsistence use. Since federal waters cannot be designated, effects on subsistence are limited in OCS reviews to impacts on designated areas in state waters.

While there are many opportunities for local involvement in offshore decision making, these opportunities are not always effective due to cultural factors, local capacity and competing interests. The oral traditions of Inupiaq people result in more emphasis on public testimony rather than written comments, and they do not always understand it is necessary to repeat their testimony for each agency that initiates a public review. There is a limited capacity in villages affected by oil and gas activities to understand and participate effectively in agency processes. In addition, the competing interests of tribes, local government and Native corporations sometimes results in a less than unified position among the North Slope residents.
Theories of inclusion

Theories of participatory and deliberative democracy explain how social capital and trust are built and buy-in is achieved among diverse groups of stakeholders, and why bottom-up and inclusive approaches are more effective and resilient than top-down approaches. The trust and “buy-in” that are the foundation of institutional sustainability can be best achieved when decision-making processes account for the individual calculations of interest of stakeholders and where shared values are developed within flexible arrangements for making and implementing policies (Ager, et al, 2005; Lipschutz 1996; Janicke 1996). To understand how participatory practices might enhance the efficiency of outcomes for a diverse set of stakeholders, therefore, we need to examine both the cross-scale linkages needed to aggregate the preferences of local, national and international actors, as well as ways to satisfy at least some of the material interests of actors at all those three levels.

Formal democratic processes and the rule of law will not be enough. Janicke (1996) notes that even in developed, politically liberal countries like the United States and Canada, effective environmental policy often requires new democratic forms that are more inclusive and participatory than established national electoral, legislative, judicial and administrative processes. Institutional forms for effective participation: (1) provide regular and reliable opportunities for substantive input into decisions about processes as well as outcomes; (2) allow serious consideration of the preferences of all stakeholders; (3) provide mechanisms for reaching compromises and resolving conflict; and (4) include the capacity to recognize and correct error. Processes for making, implementing and modifying policy decisions should all reflect stakeholder preferences. Institutions must be able to identify additional stakeholders, and give stakeholders the capacity to self-identify by keeping affected groups and the general public informed, and by actively preparing stakeholders of different backgrounds, cultures and educational levels for constructive interaction (Agrawal and Gibson 1999; Chambers 1995; 1993; Rosenberg 2007). Institution-building, following these precepts, will be more an act of discovery than an act of creation.

The economic theory of externalities also shows that when stakeholders lack well defined rights and roles in resource allocation decisions that affect them, the resulting allocations may be inefficient for the society as a whole.

Risks to Local Users

Inupiat hunters use the Beaufort and Chukchi Seas intensively for marine mammal harvesting. This customary and traditional use is of critical importance culturally, socially and spiritually as well as nutritionally and economically. The observation-based local environmental knowledge developed through these traditional activities is also valuable for science and for safety and emergency response.

Oil and gas activities in particular, and marine traffic in general, pose some level of risk to the health and distribution of marine mammals, hunter access, and the marine ecosystem. The question of what level of risk is acceptable, as well as the proper level of avoidance, mitigation or compensation for unique social and cultural risks, lies at the heart of the conflict. In its most
recent EIS, the Minerals Management Service estimated the risk of a large oil spill in the Beaufort Sea as a result of productive fields over the next 20 years at 26% percent (DEIS 2008: Appendix A.1-23). The agency also estimated that development of leases in the Chukchi Sea would result in 0.51 oil spills over the 25 year production life of the field (ibid). The cumulative impact of a major oil spill on animals and people is estimated to be major (DEIS 2008: 4-552). As required by Executive Order 12898, MMS does analyze subsistence use as a unique risk class subject to review for environmental justice issues. For instance, they estimate that the lack of a mechanism for conflict avoidance between producers and subsistence hunters would result in, “major impacts to the subsistence resources and hunts for bowhead and beluga whales, walrus, bearded seals, and polar bears” (DEIS 2008 4-549).

Institutional Options

It is an artifact of Western concepts of land ownership that aboriginal claims based on use and occupancy have been recognized on land but not the sea. The legal question is still evolving, however: in People of Village of Gambell v. Hodel, 869 F.2d 1273 (9th Cir 1989) (Gambell III), the 9th Circuit Court of Appeals held that the federal government’s paramount interested in the Outer Continental Shelf (OCS) did not extinguish the aboriginal rights of the villages, nor did the Alaska Native Claims Settlement Act (ANCSA) which was limited to the geographical boundaries of the state of Alaska and its territorial waters. The villages’ rights in the OCS are not of sovereignty, but rights of occupancy and use that are subordinate to and consistent with national interests. The court went on to discuss at length the aboriginal rights doctrine expressed by the US Supreme Court in Johnson 21 U.S. at 589-90, concluding “‘Humanity demands and a wise policy requires’ that the aboriginal subsistence rights of the Villages not be ignored.” (869 F.2d 1273:16)

The principal mechanisms currently used by federal and state agencies to protect local and Inupiat interests in the marine environment include deferrals of leasing surrounding community whaling areas on the North Slope, mitigation measures and stipulations written into lease agreements, conflict avoidance agreements, and alternative measures required through consistency reviews under the Coastal Zone Management Act.

The Alaska Eskimo Whaling Commission (AEWC) and industry have directly negotiated a series of Conflict Avoidance Agreements (CAA) governing oil and gas activities. The heart of the agreement is to schedule oil activities so that they do not interfere with whaling. The agreements are not required by federal law or state statute, but are encouraged by MMS through lease stipulations. The agreements serve to document that industry permit holders are in compliance with the Marine Mammal Protection Act’s provision protecting subsistence hunting from any “unmitigable” adverse impact (Section 101 (D)(5)(A)(i)(I)). The MMS is now considering a proposal to remove the lease stipulations and substitute advisory language that the lessee must show how they will comply with the requirements of the Endangered Species Act and Marine Mammal Protection Act through an Adaptive Management and Mitigation Plan (AMMP).

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4 This risk assessment is proposed for a particular level of development, which MMS points out, may be higher than what actually transpires.
Both ADNR and MMS have chosen to defer leasing in whaling areas near Barrow and Kaktovik. Notably, neither ADNR nor MMS have deferred leasing near Cross Island, the whaling grounds for Nuiqsut, located offshore from Prudhoe Bay. In his 2004 decision to reduce the scope of the Eastern Deferral, the commissioner of ADNR wrote:

The 10-year best interest finding for the Beaufort Sea Areawide determined that leasing the entire lease area, including the deferred tracts, is in the state’s best interest. However, ADNR decided at the time that due to the low expected interest in the tracts in the frontier areas weighed against the concerns over impacts to subsistence hunting activities, ADNR should defer leasing on those tracts nearest Barrow and from Kaktovik east to the Canadian border. … Based on a reassessment of the potential interest in the deferred tracts, ADNR has determined that it will … lift the eastern two-thirds of the eastern deferral area—specifically tracts 1 through 26. These tracts are adjacent to MMS’s Eastern Whaling Deferral, which was recently removed from deferral status and offered for lease by MMS in 2003. This area is far enough from the hunting grounds used by the residents of Kaktovik to reduce concerns associated with industry impacts on subsistence whale hunting. Concerns have also been expressed over impacts to whale feeding patterns in this area. Recent research indicates, however, that while this area is used by the whales for feeding, it is no more important than any other area along their migration route. For these reasons, it is appropriate and timely to partially lift the deferral, and offer for sale tracts 1 through 26.

This record of decision shows that: (1) ADNR and MMS seek to coordinate their leasing policies, (2) subsistence interests are weighed against industry interest in the tracts, and (3) previous deferrals may be revoked at any time. The decision goes on to note that the North Slope Borough (NSB), Alaska Eskimo Whaling Commission (AEWC), Inupiat Community of the Arctic Slope (ICAS) and ADNR’s own Office of Habitat Management & Permitting were all on record opposing this finding, asserting that the deferral areas should remain intact and that existing mitigation measures are not sufficient to protect subsistence gathering activities and bowhead whale harvesting.

One way to secure Inupiat interests in critical subsistence use areas might be to designate a marine protected area (MPA). At present, a near-shore region of the Chukchi Sea is included in the Alaska Maritime National Refuge. MPA goals range from conservation of biodiversity and habitat, preservation or restoration of ecosystems and their services, preservation of cultural heritage and education to research and fisheries management. A successful designation of an MPA integrates multiple dimensions, including ecological, social, economic, cultural, and institutional, of the system in which it will be introduced.

More comprehensive approaches in other U.S. and foreign jurisdictions include integrated oceans management, marine spatial planning or ocean governance (Rutherford et al. 2005; Crowder et. al 2006; Young et al. 2007). The task of managing multiple, sometimes competing uses in the ocean is more complex than the existing tools available to address the problems (Crowder et al. 2006). Similar to the CZMA, ocean governance would not replace existing institutions (e.g. for oil and gas development, fisheries, marine mammal conservation, shipping, etc.), but would overlay a process of determining where compatible uses could occur, and then designing monitoring programs to manage for or against particular ecosystem thresholds (Crowder et al. 2006), such as a particular noise level or a level of disturbance to subsistence activities.
Another way to protect Inupiat interests might be to expand or strengthen co-management regimes. Co-management functions through long term arrangements between stakeholders and governmental agencies to pursue joint goals. These are formalized into an agreement, memorandum of understanding, a contract for services, or sometimes written into law. What distinguishes co-management of marine mammals in Alaska from other types of collaborative processes is the recognition of the unique trust relationship the federal government has with recognized tribes, who have a unique sovereign status in federal law. When seeking to understand new rules or mitigate a federally approved development project, tribes can request formal consultations through their government-to-government relationship with federal agencies, as described by Presidential Executive Order 13175.

The strongest example of co-management in Alaska is the Alaska Eskimo Whaling Commission (AEWC), a governing body made up of whaling captains from all of the whaling communities in Alaska. The AEWC signs multi-year agreements with the National Marine Fisheries Service to engage in specific management functions such as harvest assessment, research, decision-making, allocation of authorized catch limits among the legally recognized whaling communities, and sanctioning whalers who break rules relating to the bowhead whale harvest. Other co-management bodies in Arctic Alaska, such as the Alaska Beluga Whale Committee, the Nanuuq Commission, the Ice Seals Committee, and the Eskimo Walrus Commission, typically do not have these powers. The strength of co-management boards lies not only in legal authorities but also in common ways the agencies and boards relate to each other (de facto rules) (Pomeroy and Berkes 1997; Kruse et al. 1998; Kofinas 2005; Meek, 2009). A strong co-management agreement relies on high levels of mutual trust or specific rules requiring consensus decision-making.

A final means for strengthening the local role in decision-making is to restore and strengthen local powers under the Alaska coastal management Act (ACMA). Potential development in the OCS provided one of the most important reasons the Alaska State Legislature passed the Alaska Coastal Management Act in 1977. Amendments to the federal Coastal Zone Management Act (CZMA) in 1976 gave states a more powerful role in influencing federal decisions because activities permitted in the OCS must be consistent with the state’s environmental standards, including enforceable policies of a state’s coastal management program. The enforceable policies of the ACMP include the statewide standards in regulation (11 AAC 112) and the enforceable policies contained in each coastal district’s approved coastal management plan.

The original emphasis of the ACMP provided local coastal districts with a powerful role in project review and approval. However, the scope of authority of the coastal districts to address offshore issues decreased significantly in 2003 as a result of a major amendment to the Act and a subsequent revision of the ACMP regulations. There were three major changes to the program. First, the amendments eliminated the ability for local coastal districts to establish meaningful enforceable policies that address certain impacts of development to coastal resources and uses. As a result, no district policies have been approved that deal specifically with oil and gas activities or offshore development. In addition, the ADNR revised the ACMP statewide standards to limit their application to certain issues and limited areas of the coastal zone.

Second, the legislation removed activities permitted by the Alaska Department of Environmental Conservation (ADEC) from the coordinated ACMP consistency review process. This means the ACMP no longer provides an avenue for public involvement in air or water quality issues related
to OCS oil and gas activities. For example, coastal districts such as the North Slope Borough can no longer address impacts of a potential oil spill to subsistence resources and uses through the ACMP.

Third, the program concentrated coastal decision making power into a single agency, the Department of Natural Resources. Before 2003, the program had been housed in the Office of the Governor which provided an important role in resolving disputes because it was perceived as a neutral party that did not issue permits. In addition to moving the program to the ADNR, the legislation also eliminated the Coastal Policy Council, a body made up of coastal districts and state agency representatives. This body had oversight for the program including approval of coastal district plans, approval of program changes and responsibility for the consistency review process.

One of the cornerstones of the ACMP is the state regulatory provision (11 AAC 110.250) that gives review participants such as agencies or local coastal districts “due deference” for their comments during a consistency review. Due deference means that appropriate deference will be given to commentors in the context of (a) their expertise or area of responsibility and (b) all the evidence available to support any factual assertion of the commentor. This provision has withstood regulatory revisions and continues in force today. This cornerstone can potentially shift a decision to the commentor who receives the deference. In reality, agencies have usually held the upper hand given their expertise and information gathering abilities. There have been cases however, where local districts have had enough background and evidence to shift a decision given the due deference they received. For example, during the review of the McCovey Exploration project in the late 1990s, the State of Alaska gave deference to the NSB because Inupiaq people had centuries of experience dealing with ice hazards and the state did not have in-house expertise. Another example of local expertise involves the NSB’s traditional knowledge about marine mammals and through scientific studies conducted by its Wildlife Department. Traditional knowledge has gained acceptance for use as evidence in coastal management reviews (Kuitsarak Corp. v. Swope, 1994). Changes to the ACMP regulations in 2004, however, has placed additional burdens on local coastal districts regarding substantiation of local knowledge. At the heart of coastal management is the concept that those who are closest to the impact, who are often the true experts, should have a say over it. Due deference carries out that belief.

Conclusion

There is no magic bullet to resolve the long standing conflicts over the terms of development for offshore oil and gas in Arctic Alaska. But strengthening institutions for local involvement in decision making may help. The North Slope Borough is not necessarily opposed to offshore oil development: property taxes on oil and gas facilities comprise nearly 80 percent of NSB revenues and production onshore is declining Borough Mayor Edward Itta seeks “a cooperative approach to establish the world’s most effective array of safeguards, based on the best scientific data, technology, and operational standards. If it is too expensive to meet high standards, then [we are] not ready to drill offshore.” (North by 2020, 2008) Until Inupiat believe that their core values are adequately protected, litigation will continue; there is no room for good faith negotiation until the bottom line is secure. Empowering local people to become more involved in oil and gas decision-making will ensure the people most likely to be impacted have a meaningful seat at the table.
References


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THE ROLE OF ELDERS IN THE SUSTAINABILITY OF NATIVE COMMUNITIES

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The concept of resilience has not been widely applied in the aging literature, even though most elders demonstrate resilience in their later years. For example, many elders face stressful events, health problems, loss of loved ones, financial insecurities, and isolation, and they tend to remain resilient and continue to live their lives to the fullest. In this context resilience can be defined as “the ability to bounce back or to overcome adversity” (McCubbin, 2001, 2). Alaska Native peoples and communities have overcome adversity such as the in-migration of non-Natives and missionaries seeking to educate Natives and assimilate them into western society. Today, partly in response to land-claims legislation that recognized Native rights, Alaska Natives have shown greater determination to revive their cultural traditions and languages while adapting to changes, seeking to establish a balance between traditional and modern institutions.

Resilience is defined in this paper as the “ability of a community to establish, maintain, or regain an ‘expected’ or ‘satisfactory’ level of community capacity in the face of adversity and positive challenge” (Bowen, 1998, 14). This definition of resilience is particularly relevant to this paper in that it focuses on the positive aspects of resilience, indicating growth of the system, or individual. This definition relates to the Alaska Native elders’ capacity to face positive challenges and grow from adversity and adapt to change. Cultural resilience is defined as, “a culture’s capacity to maintain and develop cultural identity and critical cultural knowledge and practices” (Neill, J., 2006). A resilient culture also copes with other challenges such as natural disasters and encounters with other cultures (Neill, J., 2006).

Elders are also an important source of Indigenous knowledge in addressing resilience, which can be integrated with western science to enable Native communities to hunt and fish to meet their needs for food and to maintain traditional ties to the land and sea. As Native elders are required to relocate to urban centers for health care reasons, to be near family, or they pass on, it is increasingly challenging to maintain traditional culture and language to ensure Alaska Native cultures are not assimilated or lost over time. Providing health care that enables Alaska Native elders to age successfully in their communities could enhance community sustainability by strengthening connections with traditional culture and language.

Rural communities in Alaska are experiencing changes that have direct, and indirect, impacts on the role of elders in their communities. Alaska Native elders have continually demonstrated resilience and adaptation, but as more of our youth out-migrate, elders are left to adapt to these changes alone. One of the more noticeable changes occurring is the introduction of technology. As more activities and jobs are replaced by technology, many Alaska Native elders feel less relevant. As the youth leave their communities and the need for Alaska Native elders diminishes, it will be important to ensure the elders feel important and needed by their community.

One of the challenges today is convincing the younger generations to learn from their elders and understand the traditional ways of knowing. It will be important for the elders to share and document their knowledge with others before they pass on and the knowledge is completely lost. Another important point is that many Indigenous scholars are trying to gain recognition for the existing Indigenous knowledges that are said to complement Western science in many ways, but are based on their own schools of thought. Ideally, it would be beneficial to have Alaska Native elders involved in the creation of knowledge and assisting with the documentation of traditional knowledge. One of the challenges with incorporating traditional knowledge is that the elders are reluctant to share but in convincing researchers and community members to invite the elders to their classrooms, their homes, and community gatherings to learn from them. The role elders play in cultural and community resilience is the continued sharing of their knowledge and living their traditional lifestyle so that others may follow in their footsteps and understand the complex, yet interconnected, social-ecological systems.
The Alaska Native elders are teachers of traditional knowledge and they need to be given the opportunity to demonstrate how to integrate traditional knowledge with modern technology. We need to support our elders and their communities to ensure they are able to share their knowledge and experiences that have shaped Alaska to be what it is today.
WAYS TO HELP OR HINDER: MATCHING CLIMATE AND POLICY IN ALASKA

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This paper compares experiences of weather and environmental change as reported by commercial fishers Unalaska, AK, fishing out of the Bering Sea and Aleutian Islands (BSAI) ground fish and crab fisheries, with those of the hunters and fishers of the Yukon and Tanana River Flats region (the Yukon Circle) of Interior Alaska. For the purposes of needs assessment, people in each location were asked to describe the challenges they face to making a successful harvest, environmental or otherwise. Climate change in particular was not prompted, but not surprisingly climate and weather issues came up early and often in conversations with people from both regions; the most commonly cited issues were observed changes in the distribution and abundance of fish and game, and safety issues related to the unpredictability of weather/land cover/sea conditions. Across the board, people described issues of personal safety and the challenging decisions they must make, and described myriad ways that scientists and policymakers could help by providing more quality, timely information such as weather forecasts and other useful scientific information. Interestingly, remarks regarding policy varied significantly; issues such as the effectiveness of quotas and bag limits, or the timing of hunting seasons, though commonly raised as problematic in the Yukon Circle, were discussed favorably by those on the coast.

We apply a diagnostic framework provided by Loring et al (2008) to better understand the similarities and differences in regional experiences with climate, weather, and policy, with the intent of identifying lessons that might be used to guide management approaches in the future. This is a framework for understanding decision-making and path dependence, and is specifically designed to capture how external forces, whether ecological, political, social, socioeconomic or cultural, converge to make sustainable interactions with ecosystems more or less possible (ibid). It is anchored around the concept of resource viability: whether or not a resource is practically usable to a particular user or user-group, beyond basic access and availability; viability can be constrained or enhanced by a set of physical and ecological circumstances, such as weather, distribution, and abundance of wildlife, and land cover for example, but is also determined and regulated by social, cultural, and economic policies and constraints, as well as anything else that might limit or enable the user’s ability to access and use those resources, for instance adequate material supplies or ecological knowledge.

What we find is that there are inherent difficulties for matching policy implementations to the ‘on-the-ground’ challenges of environmental change (Figure 1). Environmental changes like those we associate with climate change happen at broad spatial and temporal scales, affecting entire landscapes, watersheds, and ice sheets at multi-decadal (successional), annual, and seasonal time-frames. The hunter and fisher, however, experience the ‘down-scale’ impacts of these changes, affecting particular places within their familiar, ‘working’ landscape or seascape, at weekly and even daily time-frames. Traditional approaches to policy-making, which these people rely upon to help them adapt to these new ecological constraints, operate at yet a third set of spatial and temporal scales, characterized by management-units and park boundaries, state, national, and international jurisdictions, and by the timelines of legislative sessions, election
cycles, and fiscal years (Huntington 1992; Caulfield 1992; Biermann and Dingwerth 2004). Too, these policy structures tend to deal reactively with environmental change and surprise, operating from the perspective of outcomes mitigation (Chapin III et al. 2006; Ebi et al. 2006; Brock and Carpenter 2007), with a decision-making process that can take months, if not years, to complete.

Figure 1. Three sets of very different spatial and temporal scales characterize environmental change, the household experience, and policy-making.

To put this another way, while science observes and understands a trend like sea-ice loss at a very broad set of geographic, ecological and temporal scales, the people of coastal communities experience the impacts of these changes, as changes in day-to-day weather, river- and sea-ice thickness, intense storms, or high wave action. These can create new constraints on the harvest of wild food resources, and people regularly have to make last-minute, ad-hoc decisions about where or whether to fish or hunt accordingly. The distinction here is not merely between climate and weather, however, because many of the ongoing climatic and environmental trends being experienced, whether changing precipitation patterns, shifts in seasonality or in fish and wildlife abundance, can also create cumulative stresses that can be as, if not more limiting to community livelihoods and well-being than any one particular storm event (Hamilton et al. 2000; National Research Council 2002). The question, is whether policy structures enable people to make appropriate decisions in response to these day-to-day events, fostering adaptation and thus mitigating any cumulative effects of change, or if policy limits people in their adaptive response, even unintentionally.
In the case of Interior Alaska, climate warming is already having a notable, yet unpredictable effect, on land cover and fish and wildlife distributions (Hinzman et al. 2005; Hander et al. 2008; Crosby 2008; Fleener and Thomas 2003; NRC 2004). River ice dynamics are changing; the timing of fall freeze-up and spring break-up are becoming increasingly variable from year to year, as are water temperatures, though both show a general trend of warming and a longer ice-free period (Mills et al. 2008; Juday 2007; Hunt et al. 2008). The timing of these events is linked in many ways to the distribution and movement of fish and game, and the unpredictability of river ice conditions can pose real hazards regarding safety when traveling by snowmobile or dog team on the frozen surface. Too, there is only a small window of time in the annual lifecycle of moose, when harvest for food is appropriate; if found too early in the year the bull will be too thin, or too late he may already be in the rut, and in either case not ideal for consumption. In the past, residents of the Yukon Circle (primarily Alaska Natives) had more flexibility to adjust to this kind of ecological variability, by altering their harvest strategies and their seasonal and annual patterns of movement across the landscape. But the current wildlife management paradigm situates most authority over when, where, and how much to hunt with management structures that are too slow or too removed from local circumstances to adjust to the challenges of environmental change (Huntington 1992). The ability of the hunter or fisher to respond to environmental changes is limited, by narrow hunting and fishing seasons, quotas and bag limits, and periodic unexpected area closures, which tend to confound rather than enable their ability to make anything more than the most superficial changes to their hunting and fishing strategies (Loring et al. 2008; Loring and Gerlach in press). Many describe facing the difficult decision: 1) hunt in season, risking travel across a potentially unsafe landscape or waterway, when moose may not be available or appropriate for consumption 2) break the law by hunting out of season, when travel is safer and moose more readily available; or 3) do not hunt at all, and rely more on store-bought foods that are imperfect nutritional and cultural substitutes.

A tradeoff between personal safety and harvest success has also long-characterized the so-called “deadliest catch” fishing lifestyle in commercial fishing communities like Dutch Harbor. For years the shellfish and groundfish fisheries of the BSAI region were managed under what are called derby-, or Olympic-style fishery management regimes, with established time slots for open fishing (typically 24-48 hours at a time), during which participants would have to race to catch as many pounds as they could (McCay 1995; Woodby et al. 2005). This model frequently forced fishers to engage in unsafe fishing practices, however, as fishing openings were necessarily set in advance of accurate weather forecasting, and fisherman felt compelled economically to participate in the fishing window virtually regardless of conditions. Given that climate change is expected to impact patterns of severe storm and wave activity throughout the BSAI (Atkinson 2005), the question of increased risk is an obvious one. However, unlike the hunters of the Yukon Circle, who see the risk associated with their lifestyle increasing, coastal fishers reported the opposite; they now enjoy much flexibility in deciding when and where to fish, flexibility that makes their profession significantly safer and much less vulnerable to these potential impacts of climate change on storm and sea conditions.

This flexibility is made possible by the Limited Access Privilege (LAP) approach to fisheries management that is now common to the governance structures of a number of Alaska’s commercial fish and shellfish populations, taking such forms as Individually-Transferable
Quotas (ITQs), Individual Vessel Quotas (IFQs), and Community Development Quotas (CDQs) (Holland and Ginter 2001). In 1995 LAP-type systems were implemented for both Alaskan Halibut and North Pacific sablefish, and then in 2005 for the Bering Sea/Aleutian Island crab populations (NOAA 2008). Though each system comes with their own set of caveats that must be evaluated, the most commonly reported benefit of LAPs by the fishers themselves is that they eliminate the ‘race’ effect caused by derby-style management, with fixed quotas that can be filled at any time during an extended fishing period, 8 and a half months for sablefish, 9 months for Halibut, for instance (NOAA 2008). In this way, authority and decision making is appropriately scaled; broad decisions regarding Total Allowable Catch (TAC) remain with governing bodies that have the resources to facilitate a decision making process that incorporates all appropriate information and relevant stakeholders; hour-to-hour day-to-day, even month-to-month decisions, however, are left with the capable judgments of the fishers themselves.

The ‘inherent difficulties’ that we describe earlier for matching environmental change, the household experience, and policy, are called ‘scale asymmetries’ by some (e.g., Ommer 2007). Yet, as we show in the case of Dutch Harbor, they are quite possible to accommodate with a policy paradigm that situates appropriate authority at appropriate geographic, temporal and organizational scales. This means creating regulatory structures that afford flexibility and adaptability to the resource-users themselves, entrusting them with the authority to make ad-hoc resource decisions within day-to-day and week-to-week timeframes in response to the so-called “fast” variables of environmental change, while reserving the weight of broader institutional mandates for “slower” matters, securing the integrity of the resource-base at large, for example, via the enforcement of international treaties, and for providing quality institutional support to resource users, particularly timely information about weather, and fish and animal populations and distributions, in order facilitate their decision making process.

This should not be taken as an wholesale endorsement of the LAP approach to fisheries management, by either the authors or those interviewed; LAPs represent a privatization of an otherwise open-access resource, a change that carries a number of widely-acknowledged and debated caveats, for social equity, justice, and environmental stewardship to name but three (see e.g., Anderson 1995; McCay 1995). These must be scrutinized prior to any implementation. Rather, the intent is to highlight the outcomes possible when authority and expertise to make resource management decisions is situated socially at scales that match the speed of the ecology.

The current management paradigm of the Interior and the old paradigm of the BSAI acknowledged little-to-no ability for stewardship with the users themselves; narrow seasonal openings treat hunters and fishers as nothing more than mindless bursts of water from a faucet, controllable only by keeping the state’s governing hand on the knob. But people have repeatedly proved that they do have the capacity, intelligence, expertise, and ethic to make a great many of these down-scale harvest decisions themselves. Where policies are designed to expand individual capacity and community authority to adapt and innovate, citizens will thus be able to assume responsibility, empowered to act in their own best interests as a more cohesive group. Only where policy-makers embrace people’s strength and knowledge in this regard, will new policy solutions foster the kind of dramatic adaptation that is required to meet short-term needs as well as to influence new climate change trajectories in the long term.

REFERENCES


Additional reference data via high resolution imagery and autocorrelation issues

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Abstract

Reference data and accuracy assessments via error matrices build the foundation for measuring success of classifications. Erroneous or insufficient reference data can lead to skewed accuracy results which are often falsely attributed to the classification method. For a forest study we supplemented our 207 ground-measured field sites with 4000 additional photo-interpreted reference sites. We first used aerial photography to identify the extent of homogenous regions around field data sites and then picked additional reference points within these areas (Mannel et al. 2006). This resulted in clusters of additional data points around actual field locations. Random cross-validation of autocorrelated data may introduce a bias on overall accuracy of classified land cover classes, which in our case was between 5-10%. We suggest separating reference data by clusters and furthermore utilizing several clustered reference sets (versus only one) to calculate accuracies.

Increase of reference data via Digital Orthoquads

Reference data is commonly used to train and subsequently test classifications. A large number of reference data points, covering the spectral range of the desired land cover classes, is crucial for a robust, solid and repeatable classification (Congalton 1991). Yet, erroneous or insufficient reference data can easily skew classification attempts.

In a project using Decision Tree classification of forested areas in the Black Hills, SD, USA we encountered the need for a large number of reference data. After finishing our ground surveys we sampled additional reference points around ground sampled plots from homogenous areas identified on Digital Orthophotoquads (DOQ). The DOQs were black and white with a ground resolution of 1-meter (figure 1). We first randomly sampled 207 ground plots stratified by tree species and density and collected information on species, canopy cover, density, and basal area on the ground. We overlaid the ground data with DOQs to identify the extent of homogenous regions adjacent to and resembling the field data locality. Identifying borders around different land cover types is a typical technique performed by most photo-interpreters (Woodcock et al. 1994). We then picked additional reference points in these areas. DOQ-based reference data can only be sampled close to actually measured plots, because plant species are hard to identify just from photographs alone (Hacker et al. 1990). This procedure assumes that similar-appearing areas close to a measured vegetation plot will contain approximately the same mix and density of species as the known site. We sampled more than 4000 additional points clustered around field sampled plots this way (figure 1).
Figure 1. Clusters of reference points based on field-measured plots and aerial photographs (1-meter resolution) depend on homogeneity and extent of the land cover. The bottom shows the matching Landsat TM scene (30-meter resolution).

The number of additional points sampled from the aerial photography depends on extent and homogeneity of the land cover type. Aspen in figure 1, for example, is situated in a small and heterogeneous area. Additional points could not be identified around the small Aspen stand.

How to take autocorrelation into account

Accuracy assessments are often performed using the holdout method where reference data is manually divided into one training and test dataset (Congalton and Green 1999). A problem with the holdout method is that training and test data may not be representative of the entire population. In other words different training/test data sets may give different accuracies. One commonly used technique is crossvalidation, where the data is randomly separated into different training/test datasets and an average accuracy being produced. However, if training and test data are spatially close the accuracy assessment might be biased due to spatial autocorrelation (Kettig and Landgrebe, 1976). To avoid autocorrelation we modified the holdout and crossvalidation method by designating a cluster with autocorrelated points adjacent to each other to be either entirely training or test data (figure 1).

Random splitting of autocorrelated data may lead to overestimated accuracies. Friedl et al.’s (2000) accuracy for a nearest neighbor classification of AVHRR data, for example, dropped from 91.5% to just 37.9% after taking autocorrelation into account. We expected inflated accuracies when applying random cross-validation to our autocorrelated reference data.

We applied a traditional 10fold random crossvalidation where points where not separated into clusters. In comparison we then applied a 4fold holdout method, where an entire cluster was either test or training data. The 4fold holdout method used 4 different training/test trials. The test data for each trial were chosen by randomly selecting 1/3 of the reference clusters. The remaining 2/3 clusters became training data. We felt it necessary to select at least 1/3 of the clusters as test data in order to capture enough data.
variability. Just like in a traditional holdout method, each individual test trial was evaluated with an error matrix. We then averaged the accuracy of all four trials (4-fold holdout method).

**Results**

Random cross-validation which does not account for autocorrelation yielded 5-10% higher accuracies than manual 4-fold cross validation (table 3). This is consistent (although less drastic) with previous research by Friedl et al. (2000) who found up to 54% inflated accuracies when not adjusting for autocorrelation in AVHRR data.

<table>
<thead>
<tr>
<th>Land cover</th>
<th>Random cross-validation</th>
<th>4-fold holdout method</th>
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<tbody>
<tr>
<td>Meadow</td>
<td>94</td>
<td>87</td>
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<tr>
<td>Bare</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Open pine</td>
<td>78</td>
<td>73</td>
</tr>
<tr>
<td>Dense pine</td>
<td>85</td>
<td>77</td>
</tr>
<tr>
<td>Spruce</td>
<td>89</td>
<td>80</td>
</tr>
<tr>
<td>Aspen</td>
<td>88</td>
<td>84</td>
</tr>
<tr>
<td>Water</td>
<td>100</td>
<td>95</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>84</td>
</tr>
</tbody>
</table>

*Random cross-validation of autocorrelated data leads to overestimated accuracy.*

*4-fold holdout method averages accuracies of the four trials.*

**Discussion**

The extensive amount of reference data, collected from high resolution aerial photography around actual ground sampled plots, laid the foundation for successful land cover discrimination of lower-resolution remotely sensed data. We found this method useful in natural forests ecosystems to separate species dominance and mixture. It is also applicable to forest plantations where trees form blocks or for many other land cover categories depending on the date of DOQ acquisition and rate of land cover change. However, with autocorrelation present in the reference data, random cross-validation inflates accuracy, in our case by up to 10%. We still suggest using several training/test datasets (typical for cross validation), however, training and test data should be separated in clusters, i.e. via the here presented 4fold holdout method.

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SPATIAL VARIATIONS IN ARCTIC SNOW FROM LOCAL TO KILOMETER SCALES

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Over 1 billion people worldwide live in locations where stream flow is dominated by snowmelt. Forecasting water supply in these regions during the spring can be difficult, as the amount of water that the snowpack contains (snow water equivalent - SWE), varies largely over short distances. This makes spatial extrapolation from point measurements difficult, and causes large uncertainties in predicted stream flow. Historical records of SWE at an index site are typically correlated with downstream river discharge. In a changing climate, however, these relationships are likely to change. Using active radar to measure SWE from space is a promising alternative, but signal interpretation remains challenging. Evaluating and improving SWE retrieval algorithms from both passive and active remote sensors was the major goal of the NASA Cold Land Processes eXperiment (CLPX) in 2002-03 in Colorado. During December 2007 and February 2008, the second CLPX took place on the North Slope of the Brooks Range, in Arctic Alaska, as part of the International Polar Year. This large multi-institution project was a focused experiment to test active microwave retrieval algorithms from an airborne platform. In support of this project, we performed high-resolution measurements of the snowpack from the ground using a wide range of techniques.

Radar frequencies, which penetrate the snow, but not the ground, are optimal for measuring snow, however this requirement causes the wavelengths of the signals to be of a similar order of magnitude as the grain size of the individual snow crystals. The scattering from the snowpack is therefore very sensitive to crystal size and shape, and is not well understood. Unfortunately, standard techniques for measuring snow grain size involve a subjective description of a snow sample scraped from the side of a snow pit. Observations can be subjective, and quantitative application of the qualitative measurements is challenging. To overcome this problem, we used several different new high-resolution instruments, all of which are sensitive to snow microstructure, to make quantitative measurements at high horizontal and vertical resolution, coincident with the airborne measurements.

We chose 3 locations within the larger study area for intensive measurements from the millimeter to 10-meter scale. At each of these sites, we made measurements with 3 different ground based microwave radar systems. These systems were first used to simulate airborne radar signals in well-characterized conditions, by measuring backscatter in the far-field at an incidence angle of 35 degrees. Next, these 3 radars were used at 0 degrees incidence to measure SWE, snow depth and stratigraphy at high horizontal and vertical resolution (less than 1cm). Following the radar measurements, a 10-meter trench was excavated, and a series of in-situ measurements were performed. A SnowMicroPenetrometer (SMP), which is sensitive to snow microstructure, was used to measure penetration hardness at the grain scale, with a vertical resolution of 0.004mm. SMP profiles were made every 20 cm along the length of the trench. An
in-situ electrical probe, the Finnish Snowfork, was used to collect profiles of electrical properties, every 5 cm vertically and every 50 cm horizontally. Near Infra-red (NIR) photography was used to document snow stratigraphy, and was attached to a custom-made track, which enabled rapid continuous pictures over the 10 m trench. Standard manual measurements of stratigraphy were made every 20 cm, and density and temperature were also measured.

Figure 1: Snowpack stratigraphy and density in three parallel 10-m trenches, separated by 25 cm, near Imnaviat Creek, North Slope of Brooks Range, Alaska. Density range is indicated in kg/m³ on the colorbar on the right. Underlying surface roughness is primarily caused by vegetation, and combined with wind causes large variability in snow depth and stratigraphy. Variability in layer thickness decreases with distance from the vegetation, due to a decrease in roughness of the surface on which each storm-related snowfall is deposited.

Ground-based radar measurements were also made with the 3 different systems throughout the region around each 10-meter trench, out to the kilometer scale. The majority of variability observed in this type of snowpack occurs because of the interaction of wind and the underlying vegetation. The 10-meter trenches captured much of the local variability in snowpack properties, and give a view of the Arctic snowcover at a resolution that captures the variability caused by the vegetation. Information gained from these very detailed measurements in the trenches is used in conjunction with the longer ground-based radar traverses to infer variations in snowpack properties up to the kilometer scale. Backscatter measurements from the far-field radar profiles indicate that surface roughness of the layers provides a large contribution to the overall radar backscatter, and may be more important than the effect of grain size. These measurements at the local to the kilometer scale will help put the standard ground-truth point-scale measurements in the context of the much larger remote sensing footprints.
Introduction

Scenarios are valuable tools for decision makers. The prediction of the future development of most real systems is inherently complex and usually inaccurate. Scenarios allow us to develop and bring into focus several images of plausible future developments. These images can help decision-makers plan for a range of futures. Furthermore, scenarios can be a useful tool in identifying indicators that can be tracked and provide early indications of the future development and trajectory of a system.

Scenario processes have been successfully employed in state, regional, local, and corporate planning and hazard or disaster response. Public scenario processes, as the one employed in this study, can be used to induce conversation between different stakeholder groups and to stimulate thinking ‘outside the box’.

In this work we investigated possible futures for the Arctic Ocean and its coastal regions with respect to marine transportation for the timeframe 2030 to 2050. Key factors for the developments in the Arctic were identified based on the data accumulated in an expert workshop of the Arctic Council’s Arctic Marine Shipping Assessment (AMSA) led by futurists of the Global Business Network (GBN). While this contribution is not part of the formal AMSA process, we explore to what an extent robustness analysis (Mueller-Stoffels, Gauger and Steinmüller, 2009) can help refine, evaluate and further validate some of the AMSA scenarios (Brigham, 2007). We present four scenarios based on this analysis.

Robustness Analysis

The AMSA Workshop notes supplied us with a list of important factors and forces for the development of the field under investigation as seen by the workshop participants. The items in this list where assigned two scores: (i) uncertainty and (ii) importance, with values ranging from 0 to 15. The sum of uncertainty and importance was used as a sorting criterion and the top 19 items on the list where selected as key factors (KF).

Key Factors (KF) are the basis for the Robustness Analysis. They are the factors considered to be most likely to influence the development of the field under investigation. Each of these KF is assigned two or more Future Projections (FP). FP are the possible ways a KF could develop. Table 1 gives the list of KF and their respective FP. Definitions for the KF and FP were developed, where possible based on peer-reviewed literature. Note however, that this was not possible for all of the FP, since some are well outside the realm of current research and evidence. Nonetheless, such FP are valid, as they are meant to stimulate ‘outside the box’ thinking. The data were then published online for public comment and further refinement.

A set of FP, one from each KF, is called a raw scenario. The task at hand is to find robust, plausible and consistent raw scenarios. All the above measures (robustness, plausibility, consistency) are relative, that is they are only useful to compare raw scenarios based on the same KF and FP set to each other, but have no absolute meaning.
Table 1: List of Key Factors, respective Future Projections and Wild Cards.

<table>
<thead>
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<th>Key Factors</th>
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<td>Legal framework</td>
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<td>Tense Relationships</td>
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<td>Wild Card</td>
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Further, we introduced two Wild Cards (see Table 1, Steinmüller and Steinmüller, 2004) and tested the stability of selected raw scenarios under occurrence of these Wild Cards.

The sheer number of possible combinations of FP requires that the selection process for raw scenarios be software aided. Further, a combinatorial problem, which is very computationally intensive, required us to use a genetic algorithm to retrieve desirable raw scenarios. Due to the amount of data accumulated by defining KF and FP and generating the consistency matrix and raw scenario bundles it is not possible to give in-depth information here. Please visit our comprehensive web site at http://seaice.scenlab.com.

From the software’s output a variety of raw scenarios was selected for further production of the final scenarios. The criteria employed for selection of raw scenarios were: (i) no more than two partial inconsistencies, (ii) ideally a combination of high robustness, consistency and plausibility values, (iii) diversity of the set of selected raw scenarios.

**Conclusion**

Our findings using an explorative scenario technique are comparable to those of Brigham (2007) based on the same AMSA workshop. This further validates these scenarios within the given set of factors and forces.

It is important to understand that scenarios are the next-best option in situations where a forecast is not feasible. However, as any scenario process heavily relies on, at best, ambiguous and, at worst, heavily biased human input they have to be used as auxiliary planning tools. In a planning process one would not only pick a favorite scenario and plan for it, but one should have plans flexible enough to adapt to developments in line with the other scenarios as well. Nevertheless, a further aspect of scenarios is that they can be used as a tool for shaping the future. That is, stakeholders can identify key factors that they can influence in their favor.

In this respect, our study supports the notion that the development of the earth’s climate, as well as the legal climate in the Arctic are the most important key factors for the marine shipping industry and other stakeholders. However, our scenarios lead us to expect that economic development in the region will take place regardless of the legal climate.

The Robustness Analysis is one of many scenario building methods. One shortcoming of it is that there is no inherent possibility of ‘if-then’ implementation. That is, the type of situation where the occurrence of a certain FP of KF A forces a specific FP of KF B. This problem can be alleviated by using a cross impact analysis (e.g., Godet, 1975).

**References**


Introduction

In the Gulf of Alaska, every summer season is accompanied by a massive surge of shipping traffic from tourism, trade, commerce, etc. With emissions comparable to road and aviation transportation (Eyring et al. 2005), these oceangoing vessels are only required to meet modest regulations for emission standards, thus allowing substantial amounts of pollutants to be released into the atmosphere within the relatively pristine regions of southwest Alaska. In this photochemically active environment, pollutants are transformed and transported over great distances until their final removal from the atmosphere usually by wet or dry deposition. Increased concentrations of secondary constituents such as ozone can be hazardous to the health of humans and vegetation while acidic deposited material can damage vegetation and affect nearby water bodies by increasing the acidity levels harming fish and other organisms. Thus, ship emissions can have adverse effects on remote, coastal regions and marine ecosystems in Alaska that are within the vicinity of shipping lanes.

Methods

To investigate the impact of ship emissions, the fully coupled meteorology and chemistry model, WRFChem (Grell et al. 2005), is used to examine physical and chemical processes such as transport, transformation, and deposition. The model uses a 7km grid increment encompassing a domain of approximately 1000km by 900km centered over Kodiak Island and includes four national parks and preserves - Kenai Fjords, Lake Clark, Katmai, and Aniakchak. Five day simulations are performed from May 20th – August 20th, 2006 without and with the inclusion of ship emissions for comparison in order to identify the impact on ecosystems in southwest Alaska during a typical summer tourist season.

Results

Figure 1 shows the contribution of ship emissions to accumulated deposition for several primary species including NOx, SO2, PM2.5, and PM10 for the 2006 tourist season. As shown in the figure, the major shipping routes throughout the Gulf of Alaska are clearly visible including routes around the Cook Inlet and throughout Prince William Sound as well as a route extending southwest along the Aleutians. The majority of the particulate matter emitted from ship stacks is categorized as PM2.5 rather than PM10 (Cooper and Gustafsson 2004) which explains the less dramatic contribution of ship emissions to PM10 deposition. PM10 aerosols are also strongly affected by gravitational settling due to their large size and are thus less likely to be transported distantly from their emission source.

Prince William Sound is evidently the most heavily traversed region in the Gulf of Alaska as it serves as a popular tourist destination for cruise ships and a beacon for oil tankers crossing through to the port of Valdez. Figure 1 shows over 90% of the total deposited NOx is attributed to ship emissions as well as 80-90% of SO2, 30-40% of PM2.5, and about 10% of PM10, respectively. The port of Valdez experiences enhanced PM2.5 and PM10 deposition from ship emissions due to incomplete combustion processes when ships are berthing. When the ship engines are running less efficiently, higher amounts of particulate matter are released into the atmosphere (Cooper and Gustafsson 2004). The location and unique topography of Prince William Sound tend to affect the regional meteorological conditions which also enhance pollutant concentrations and consequently deposition. As low pressure systems move in from the southwest, the mountains of the Alaska Panhandle obstruct their eastward propagation. Consequently, lows stagnate in and around the Prince William Sound and eventually dissipate. The Chugach Mountains to the north act as a barrier for winds within the sound as well as limiting precipitation to the windward side of the mountains. Low wind speeds and varying wind direction allow for greater pollutant concentrations to accumulate due to less dispersion from the wind. The precipitation on the windward side of the Chugach Mountains also increases the deposition rate within Prince William Sound.

The Kenai Peninsula is another region strongly affected by ship emissions. The port cities of Seward and Homer are commercially popular, and the route between these ports governs the emission situation along the eastern coast of Kenai. On the other hand, shipping traffic en route to Anchorage traverses the Cook Inlet which governs the western coast of the peninsula. Bombarded by ship emissions
around the entire coastline, even remote regions of Kenai Peninsula are at risk for contamination including
the Kenai Fjords National Park. According to Figure 1, ship emissions contribute up to 90% of NOx
deposition on the coasts of the Kenai Peninsula with over 30% contribution over the interior. Likewise, up
to 80% of SO2 deposition on the coastline and over 20% of the interior SO2 deposition is attributable to
ships. Tustumena and Skilak Lake are two water bodies within the interior of Kenai that could be affected
by acidification from SO2 deposition induced by ship pollution. PM2.5 emissions from ships account for
around 30% of the accumulated deposition on the coastline while contributing about 5-10% of the interior
PM2.5 deposition. Unlike the primary constituents mentioned above, PM10 deposition on the Kenai
Peninsula is not drastically affected by ships with the exception of areas around Seward where 10-15% of
the deposition is due to ship emissions. The Gulf of Alaska is commonly dominated by low pressure
systems which are known to bring strong onshore winds to the eastern coast of the Kenai Peninsula.
Precipitation is enhanced on the windward side of the Kenai Mountains thereby increasing deposition rates
to the eastern peninsula. Unfortunately, the Kenai Fjords National Park occupies the eastern area, putting
even the supposedly protected ecosystems at risk for extreme damage.

Lake Clark and Katmai National Parks and Preserves lie on the western coast of the Cook Inlet and
are thus affected by the influx of shipping traffic toward Anchorage. Results from Figure 1 show that 10-
40% of NOx and 10-30% of SO2 deposition on the west coast of Cook Inlet is due to the nearby shipping
route. There are no ports on the west coast of Cook Inlet, and thus particulate matter is less of a concern
for this region. Similar to the locations previously discussed, precipitation is enhanced on the windward
side of the Aleutian Mountain range which extends southwest to form the Aleutian Islands. Also due to the
unique location and topography of this region, an interesting wind pattern seems to commonly develop in
the area. Between the Kenai Peninsula and Kodiak Island, winds tend to converge and channel between
the two land masses. In most cases, winds are easterly from a low pressure system which creates very
strong onshore winds directly toward Iliamna between Lake Clark and Katmai National Parks. This wind
pattern is perhaps the cause of the slight jutting feature in the accumulated deposition due to ships (Figure
1) which consequently spreads the impact of ship emissions further inland.

Conclusions
Ship emissions have been shown to have a dramatic impact on many coastal landscapes in the Gulf
of Alaska with respect to the deposition of several pollutant species including NOx, SO2, PM2.5, and PM10.
Input of these constituents into remote ecosystems can have many adverse effects such as acidification of
lakes and streams and altering soil composition. Major port cities including Valdez, Anchorage, Whittier,
and Seward as well as areas directly on the coasts near shipping lanes like Prince William Sound are
greatly threatened by pollutant deposition, but inland regions such as the interior of the Kenai Peninsula are
not immune from the damaging effects. Topography and meteorological conditions unique to certain
regions are also of importance when assessing the risk of ship emission impacts; for example, areas on the
windward side of mountain ranges experience enhanced precipitation and thus increased deposition rates.
Ship emissions are responsible for a substantial amount of pollution affecting the Gulf of Alaska, but still
only fall under modest regulations. By understanding the behavior and ramifications of ship emissions,
policy measures can better resolve current issues and develop strategies for a global solution in the future.

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Figure 1: The contribution of ship emissions (in percentages) to the total accumulated deposition in the 2006 summer tourist season for a) NO$_x$, b) SO$_2$, c) PM$_{2.5}$, and d) PM$_{10}$.
VALUES OF NUSHAGAK BAY: PAST, PRESENT AND FUTURE

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Nushagak Bay is a large relatively pristine estuary covering about 80 km² in southwest Alaska. This estuary system hosts one of the world’s last great sustainable sockeye salmon fisheries, with an estimated 10 million sockeye salmon returning each season, for example the 2008 return was 10,158,000 sockeye or 2% less than average (ADF&G 2008). The harvest of salmon is important to the region commercially but by many measures it is more important culturally.

The cultural history of the Nushagak region is among North America’s oldest, yet the land, rivers and estuaries are still unspoiled and naturally productive. For Nushagak Bay, the estuary’s healthy quality is a consequence of two major factors; historically low population densities (0.06/km²) and a culture interlinked with the biota. Environmental stewardship has been important in Yupik culture and is believed necessary for continued coexistence within the region. However, over the last 50 years globalization, insatiable consumerism, and climate change have been rapidly altering the socio-economic and ecological systems within the region. With the introduction of multi-billion dollar industries (industrial fishing, oil and gas exploration, mining, and mass nature/game outfitting) regional change and environmental challenges are coming to the region. To maintain the health of Nushagak Bay, many residents see value in merging traditional knowledge with western scientific practice. This requires maintaining access to subsistence resources (e.g. salmon, moose, caribou, and berries) while exploring the best use (or non-use) of non-renewable resources. Therefore, it is important for managers and stakeholders to adapt to the shifting patterns in the climate, habitats, and economy.

Figure 1. Types of capital needed to sustain healthy communities.

The global changes imposed by outside influences require cultural adaptation; however, most rural villages do not have the modern technical expertise to measure current trends needed for decision making, nor the economic capital to integrate adaptation into existing social capital. Because of this, many important management decisions are made by state and federal agencies using regulations and data collected outside Bristol Bay region. Local education in resource valuation is critical to develop full cost accounting and cooperative management efforts that equally consider natural, human, social, and manufactured capital concerns (figure 1). Communities surrounding Nushagak Bay are in need of such a comprehensive valuation and ecosystem adaptation plan.
Nushagak elders claim that important traditional knowledge and social links to subsistence are being lost and replaced by non-renewable resource use exploited by modern technology (Radenbaugh and Fox 2007). One way to promote good stewardship and promote healthy ecosystems in rural Alaska is to teach traditional knowledge alongside modern scientific methods (Kawagley 1995, Barnhardt 2005).

To help measure ecosystem health, the Bristol Bay Environmental Science Lab (BBESL) at the UAF Bristol Bay Campus has started a place-based research and education program to document species-to-ecosystem level diversity with special emphasis on non-commercial species. This program uses both scientific methods and traditional knowledge to acquire knowledge and establish baseline data (including water quality statistics). Physical data collected includes water temperature, pH, dissolved oxygen, salinity, turbidity, substrate type and tidal current velocity. To promote place-based education and local science literacy, data collection is assisted by local environmental studies students involved in directed research projects studying specific taxa or physical features within the estuary.

Our studies suggest that Nushagak Bay can be sub-divided into habitat zones based on fauna, sediment, salinity and average current velocity (Figure 2). Due to the strong river influence the head of the bay is dominated by a riverine community. The majority of the bay typifies estuarine communities and it is not until the Etolin Point -- Cape Constantine boundary that true marine communities are encountered. Four large rivers flow into Nushagak Bay: the Igushik, the Snake, the Wood-Tikchik and the Nushagak. For this reason the bay has low average salinity and a very high sediment load. The highest recorded sea surface salinity measurement was 10 ppt. The upper estuary (Figure 2) always has cloudy, murky water clarity, with average turbidity measured at 200 NTU, while the river and Lower estuary zones are often less turbid.

Figure 2. Trawling locations, 2007-08 and location of major estuary zones based on sediments and fauna.
The benthic species diversity in Nushagak Bay has a Shannon Diversity (H') value of 1.54, ranking it below similar subarctic estuaries such as Ungava Bay, near Labrador and Lower Herring Bay in Prince William Sound where the Shannon Diversity values are H'=2.11 and H'=2.5, respectively (Stewart et al. 1985, Jewett et al. 2001). The lower diversity is most likely due to the low salinity and high turbidity of Nushagak Bay. The bulk of our trawling has been within the upper and middle reaches of the bay, well within the riverine and estuarine habitat zones. Commonly found species include Rainbow smelt, Starry Flounder, Bay shrimp, and two types of amphipod. Less commonly we encounter Lamprey eels, Pacific salmon smolt, eelpouts and sticklebacks. Continued sampling of bottom habitat type, water profiles and organism calorie content will provide more insight into benthic community structure and water quality. Also, by extending the boundaries of our sampling area to include the mouth of Nushagak Bay and into Bristol Bay we can categorize the Nushagak Bay estuary from the rivers to the marine basin. Future topics of study include food web analysis using stable isotopes to better understand trophic energy dynamics.

**Literature Cited**


Migration is associated with greater health risks due to challenges migrants face in their new environment, such as isolation from family and community, changes in social norms, increased stress, and competing needs that take priority over health promotion (Decosas & Adrien, 1997; Paschane & Fisher, 2000). However, it is also a time of opportunity for promoting healthy behaviors that can persist through later life changes. The psychological impact of migration results from the cultural shift that takes place when moving to a substantially different world than the one that was left behind (Orvik, 1985).

Alaska provides a unique and important environment in which to examine the impact of rural-to-urban migration on health and adjustment. Close to half of the Alaska population lives in rural communities that are geographically dispersed, often inaccessible by road, and distant from urban areas. Remote communities in Alaska face disparities in access to health and mental health care (Mohatt, Hazel, & Mohatt, 2001). The Alaskan population is highly mobile, with one-quarter of the population of Anchorage and half of the population of Fairbanks being recent arrivals (Goldsmith, Angvik, Howe, Hill, Leask, 2004). Indigenous communities in Alaska have a history of migration, and migrate for employment, subsistence activities, and access to health and human services (Paschance & Fisher, 2000). Rural-to-urban migration in Alaska is increasing, with most migrating for educational and employment opportunities (Martin, Killorin, & Colt, 2008). Although women are more likely than men to migrate from rural communities, men are more likely to return to their communities. The trend for migration to urban areas is likely to continue and accelerate with climate-induced and economic challenges of living in rural Alaska.

A greater understanding of the impact of rural-to-urban migration is needed, particularly an understanding of the experiences of rural Alaska youth. Migration from rural to urban environments often occurs when rural youth in Alaska go to college. Many people who migrate from rural communities in Alaska seeking educational opportunities move to improve their lives (Martin, Killorin, & Colt, 2008). Thus migration may be a critical period for intervention, and may provide an opportunity to establish healthy behaviors in a new environment that can persist through later transitions. These healthy behaviors can also contribute to the health of rural communities when students return home to their communities, reducing health disparities in rural Alaska. Understanding what factors influence health and adjustment for students migrating from rural communities is critical for planning and developing interventions to facilitate resilience and reduce risks during this critical transition.

The purpose of this preliminary study was to examine the experiences of young men migrating from rural communities in Alaska to attend an urban university. The transition to an urban university places rural students in a new environment and a new culture, where they face unique stressors and opportunities. For many rural students, the transition to college may be the first sustained leap they take into a vastly different culture and environment, which can magnify the impact of more commonly experiences changes that students face upon entering college, including changes in their social networks and norms, reduced social constraints, and increased academic challenges. Thus, the first year of college or university may be a particularly vulnerable time for rural students.

METHOD

This exploratory study examined young rural men's adjustment to the college transition, social support, and changes in norms, relationships, alcohol use, and sexual behavior. A total of six semi-structured interviews were conducted towards the end of the academic year with young men who
had migrated from rural communities to attend university. A focus group was also conducted, although only two participants took part in this group. Inclusion criteria were: male, full-time students, first year at UAA or UAF, no previous attendance at college or university, between the ages of 18 and 21 at enrollment, rural. The University of Alaska definition of “rural” was based on where students attended high school. If students graduated from a high school outside the urban areas of Anchorage, Fairbanks, Juneau, the Kenai Peninsula, the Matsu-Borough, Sitka, or Ketchikan, they were considered “rural”. This definition identified urban centers according to population size and whether or not the community was located on the road system. Potential participants were identified through the UAF Planning, Analysis and Institutional Research Office (PAIR), and contacted by e-mail with information about the study. Individuals indicating an interest in the study met with male interviewers who described the purpose of the study, obtained informed consent, and conducted the interviews and focus group.

Protocols for participant interviews were semi-structured to facilitate exploration of unanticipated issues and pursuit of rich examples while maintaining a core set of questions. Interviews and the focus group explored the issues and challenges young men migrating from rural areas to attend college faced in the transition from one culture to another, and examined contextual risk and protective factors affecting social and emotional adjustment, sexual behavior, and alcohol use. These factors were considered with respect to both the current college environment as well as connections to the rural communities the youth migrated from.

With consent of participants, interviews and focus groups were audiotaped and transcribed for analysis. Atlas-TI, a software program for coding qualitative data, was used to conduct qualitative analyses on the interview and focus group transcripts. Analyses examined key themes emerging from the young migrants’ stories of transition and specific issues associated with their experiences of migration.

RESULTS

Many participants reported challenges in adapting to the changes associated with the transition to an urban university. Social and environmental changes the students experienced during their transition included social isolation, sensory overload, and homesickness. Many missed their friends and family and the activities they had enjoyed back home. Some reported that, although there were a lot of people around, they did not have close friends like they had back home. Some felt like an outsider or felt that others did not understand their experiences. However, others enjoyed social opportunities in their new university environment and formed new friendships.

Students also reported environmental challenges such as greater air pollution, increased population, and adjustment to geographical differences. Many reported challenges associated with the university transition, including modified schedules, heavier academic workloads, increased academic difficulty, financial challenges, and challenges navigating university procedures and technologies.

Many participants discussed the importance of support from peers and family members in helping them cope, including support from the rural communities they came from and support in their new urban environments. For example, many students maintained closed connections to friends and family, and had their friends and family visit them from home. New friendships formed at the university were also important for helping students adjust to the challenges of university life, and helped them feel they were not alone. Students also appreciated university support that facilitated their adjustment, including university activities and social functions, support from residence life staff and instructors, and university resources.

Although some students were initially apprehensive about the transition to a new university, many felt they adjusted better than they expected to the new challenges. The transitional period was a time for personal growth for many students, resulting in an increase in self-efficacy and self esteem. Students discovered the strength of being able to handle new challenges, greater freedom and independence, new coping and
self-regulation skills, skills in reaching out for resources and support, new relationships, use of technology, and greater learning. These experiences of personal growth seemed to facilitate resilience for students dealing with the cultural shift associated with migration.

Results indicated some consistency in alcohol use, with those who used alcohol in their home community also using alcohol in their new environment, and those who chose not to use alcohol in their home community also abstaining in their new environment. Those who engaged in substance use did so during celebrations, parties, and social events. Availability also influenced substance use, with some reporting using drugs in their new urban environment that had been unavailable in their home community. Students’ substance use was also affected by with their social and residential environment, such as norms regarding alcohol use, and living with others who used substances. Participants identified social pressure regarding the use of alcohol and substances in both rural and urban environments. However, some students who had made a decision not to use alcohol resisted alcohol use despite social pressures.

Results also suggested some consistency in sexual behavior through the transition. Attitudes about sex and condoms influenced sexual practices in both rural and urban environments. Participants who had not had sex reported lack of interest or a suitable partner, the focus on academics, or concerns about pregnancy or STD’s as reasons for continued sexual abstinence. Some reported sexual pressure from peers but identified strategies to avoid sexual situations. Pregnancy prevention was cited as the main reason for condom use among sexually active participants, and little discussion of STDs was reported between sexual partners.

DISCUSSION

This study provided insights on risk and protective factors affecting social and emotional adjustment, alcohol and drug use, and sexual behaviors for young men migrating from rural areas to urban environments during the transition from high school to university. The transition to an urban university posed many challenges, but also provided opportunities for personal growth. The students’ health behaviors and adjustment was affected by the social environment, peer norms, and social support, both from their home communities and in their new college environment. The students’ values, attitudes, and coping skills also served as protective factors facilitating healthy behaviors and resilience in adapting to the challenges of migration.

Additional research is needed to further explore factors affecting health and adjustment for rural-to-urban migrants. Such research should examine migrants’ experiences over time, combine quantitative and qualitative methodologies, and include larger and more representative samples of rural students. Although Alaska Natives account for approximately 44% of first-year rural students at UAA and UAF, and European-American students account for 42%, all of the participants who volunteered for the current project were European-Americans. Face-to-face communication rather than e-mailed invitations for participation may be particularly important to reach Native students and allow building trust and rapport. The current study was also limited by reliance on self-reported behavior. Future studies can supplement qualitative interviews with computerized surveys that reduce social desirability bias in reports of socially-sensitive behaviors such as unprotected sex and substance use (Turner et al., 1998).

Further research on the experiences of rural students can inform strategies to facilitate resilience among youth migrating from rural communities in Alaska for educational opportunities, reduce vulnerability to health risks for the youth and the rural communities they return to, and contribute to health and well-being in rural communities that are facing rapid change, including cultural changes affected by migration. This research can examine the impact of changes in the social and cultural context during the transition to an urban university, identify potential critical periods for risk reduction and health promotion interventions, point to contextual factors that must be addressed in interventions, and identify the individual, community, and cultural strengths that can be harnessed to facilitate health and adjustment among youth migrating from rural to urban environments.

ACKNOWLEDGMENTS
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Watershed partnership activity indicates a growing capacity to identify and address challenges related to changes in freshwater systems at local and regional scales (Kenney, 1997; Lubell, 2002; Wooley, 1999). However, measuring watershed partnership effectiveness in institutional management decisions is not clearly defined (Griffin, 1999). The watershed basin as a scale for management may be a more appropriate fit for allocation and regulatory decisions that carry impacts outside of administrative boundaries such as in Alaska. However, aggregating stakeholders into a cohesive body at this scale is challenging because of conflicting interests and administrative jurisdictions.

Partnerships that include diverse stakeholders from within the basin theoretically increase compliance with pollution regulations (Lubell, 2002). As Alaska transitions to a water discharge permitting system in which the state has primacy, cooperation may prove an important step in maintaining compliance. Qualitative measures of watershed council participation in the Lower 48 states have yielded, at best, limited understanding of success, one based on subjective criteria, basin-specific ecological characteristics and diverse political culture (Griffin, 1999). But watershed partnerships across Alaska have engaged in a variety of activities and with resource agencies, indicating a growing capacity to play an institutionalized role in freshwater governance.

Alaska is experiencing rapid environmental change, the direct result of global warming and its interaction with land, water, and natural resource development. The potential cost on public infrastructure to the state could top $32 billion by 2030 (Larsen, 2007). Some of these impacts, such as erosion affecting rural communities, are more salient and documented. Other changes, such as the extent of melting permafrost on surface water access, are less predictable. A review of more than 300 newspaper articles from the last 50 years has uncovered focusing events that have contributed to current water policies, suggesting decisions made without complete knowledge. Since statehood, Alaska has undergone rapid community and economic development that has brought an inequitable distribution of infrastructure, and consequently a fragmented regulatory ability to address changes. Some events, such as the failure of municipal sewer systems in rural Alaska, indicate a lack of long-term sustainable planning for public health infrastructure that could lead to potentially more harmful downstream effects. Other events, such as flooding, have revealed a lack of planning, leading to development in flood prone areas. The long term consequences of this could increase over time if the frequency of flooding events increases.

Most of Alaska’s partnerships are involved in some type of water quality monitoring project that provides data to resource agencies, yet funding sources are inconsistent. The Yukon River Intertribal Watershed Council has built a robust water quality-monitoring program that utilizes tribal funding resources, traditional ecological knowledge networks, and a close relationship with the US Geological Survey to bridge the use of science and Traditional Ecological Knowledge within the basin and enhance knowledge and observation of changes. Similarly, the Anchorage Waterways Council has a volunteer network of water quality monitors and an extensive outreach and community education focus that has been instrumental in increasing non-point source pollution compliance in the city of Anchorage. The Tanana Valley Watershed Association is currently in the process of developing a riparian management plan for the Fairbanks-North Star Borough that would establish a set of mutually agreed upon rules intended to protect property owners from flood and erosion damage and enhance fish habitat in waterways that have been affected by urban development.
Results from interviews with watershed partnership directors indicate a willingness to build consensus within regions and contribute cooperatively with resource agencies in providing data and collaborating in decision-making. Two partnerships reported collaborative practices with existing administrative governments. Two partnerships reported specific concerns over resource development projects within the region that threatened polarize the partnership and disrupt the ability to make consensus-based decisions.

“We are able to bring people together to talk about issues. We try to be nonpolitical. We try to be balanced. We’re successful in bringing the city, agency, and diverse stakeholders together. Everyone here, regardless of politics, loves salmon and loves fish.”

“I’d rather… gather information ahead of development pressure. When it comes time for ideas to be discussed, it will be based on way more than limited information. There is so little data when discussed, they become emotional discussions. Finding out about function of an ecosystem serves to generate light instead of heat.”

“We have established a lot better rapport and trust. People don’t automatically assume what you are going to say. They have a lot harder time tuning us out.”

Watershed partnerships are noticeably absent from the northern and northwestern portions of the state where populations are lower. Partnership presence in regions of higher populations or where development poses significant risk to freshwater resources indicates an incentive to collect data for agency management decisions that carry downstream impacts across administrative boundaries.

Important factors for continued participation of watershed partnerships include the identification of unified goals among partners within the basin, and access to stable funding sources for the ongoing cost of projects such as water quality monitoring. Together, these criteria will strengthen incentives to participate at the watershed scale. If councils can maintain objective goals, contribute defensible data to resource agencies, and continue to educate and engage stakeholders they can be important participants in resource management decisions.

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ARCTIC COUNCIL OIL AND GAS ASSESSMENT: FINDINGS AND RECOMMENDATIONS

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The Arctic Council Assessment, “Oil and Gas Activities in the Arctic--Effects and Potential Effects,” was written with the help of about 200 scientists and national experts and covers oil and gas activities; social and economic effects; sources, inputs and concentrations of petroleum hydrocarbons and other contaminants related to oil and gas activities; effects on the environment and human health; and status and vulnerability of ecosystems.

Key Findings of the Assessment.

Activities Past, Present and Near Future

The Arctic has substantial hydrocarbon resources with a long history of exploration and development activities dating back to the early 20th century in Russia, the United States and Canada that continues today. The Arctic also promises large resource potential as recently reported by the U.S. Geological Survey’s Arctic assessment which estimated a mean undiscovered technically recoverable resource of 90 billion barrels of oil and 1670 trillion cubic feet of natural gas with over 80% located offshore.

Although levels of activities have fluctuated and are dependent on many factors, oil and gas activities including transportation are likely to continue in or adjacent to existing production centers and slowly expand into new areas.

Areas thought to have high resource potential, whether previously explored or unexplored, are being considered for more focused exploration activities and throughout the Arctic areas are being made available for exploration licensing and leasing. If a decision to develop results, it will lead to increased capital investment and expanded infrastructure.

Socioeconomic Effects

The assessment looked at 8 case studies--Yamal-Nenets, and Nenets in Russia; Nuiqsut in Alaska; Norman Wells, Mackenzie Delta, and Bent Horn in Canada; Greenland; and Norway as well as two mini-case studies in Barrow Alaska and Ikhil, Canada.

The assessment found that oil and gas activities are major drivers of change in the Arctic. The economic value of activities plays a significant role in national, regional and local-level effects.

Oil and gas revenues have brought wealth and associated improvements in public health, education, and other services to a generation of Arctic residents in some regions. However, in other regions, development has had adverse effects on the environment and disrupted local social and cultural systems, leaving a legacy of negative effects that reduce the potential for sustainability. Oil and gas revenues can also support the retention of cultural practices.

Indigenous people in the Arctic are becoming more involved and affected as development expands. Effects can be mitigated by the planning, regulatory systems and allocation functions of governments and vary by scale and “life-cycle” stage of the activity.

Many Arctic regions are at early stages in the oil and gas “life cycle” and are experiencing the initial effects of large-scale development projects. Social and economic effects tend to increase and be more local at the exploration and construction stage, then to stabilize and be more regional in the production stage. Updating and development of a legislative foundation, enactment and enforcement regulatory systems, and the use of international standards and best practices are important to the reduction of negative environmental and socioeconomic effects.
Sources, Inputs and Concentrations. The assessment presents a Hydrocarbon Budget that although preliminary, shows contamination from oil and gas activities in the Arctic is relatively small compared to inputs from natural seepages and run off from coal deposits, which make up the majority of total input of oil hydrocarbons and PAH to the Arctic environment.

Without regard for source, the levels of oil hydrocarbons in the marine area are generally low in the Arctic, and fall within ranges normally considered to be background. For all sea areas, levels in sediments are for the most part well studied. Less information is available on levels in seawater and marine biota.

Information on land and in freshwater systems is more limited. For most Arctic countries the measurement of petroleum hydrocarbons and PAH in biota has not been a high priority in most monitoring programmes because the concentrations are usually low in biota and input to the environment is assumed to be low.

Several sources of emissions and discharges of petroleum hydrocarbons and related contaminants in the Arctic exist and result in local pollution in some areas especially close to industrial and urban communities. Available information indicates low levels in areas distant from human activities. Oil and gas activities are currently a minor source of oil hydrocarbons and PAH on a regional scale but have the largest potential for large-scale accidental or long-term releases of contamination to land and sea.

With some exception, the data sets available for this assessment have generally not been detailed enough to establish the areal extent of local pollution nor to provide quantitative relationships between sources and concentrations in the environment.

Effects and Potential Effects. Oil and gas activities have had environmental effects locally but long-term changes to arctic wildlife populations have not been documented.

Physical impacts, disturbances and habitat fragmentation are the main issues for terrestrial environments. The physical “footprint” of the activity although growing smaller may have cumulative effects when combined with past oil and gas activities, other human activities, and effects of climate change. Oil spills on land have a limited spatial extent but may have long-lasting impact.

Oil spills have the greatest potential to impact aquatic, coastal and marine environments. Small spills are relatively frequent while large spills are rare events but even small spills can affect many animals if they occur at times and places where the animals have congregated in large numbers. Seabirds and fur-bearing marine mammals are vulnerable to oiling while whales have low vulnerability. An oil spill in ice-covered waters could have large ecological impact including effects on sea birds, small cod-fishes that spawn under the ice, marine mammals and whales. Physical effects from seabed disturbance and noise are local. Noise associated with oil and gas activities can cause physical and behavioral effects in marine mammals and fish.

Health. Human health in the Arctic can potentially be affected by oil and gas activities but there is limited information to assess if effects have occurred to date. There are insufficient human exposure and epidemiological data available for the Arctic region to conclude whether non-occupational population groups are currently affected. Psychological damage appears to be a consistent impact of oil spill situations. Oil and gas activity in the Arctic can have a positive impact on health. Fish exposed to oils may be tainted by undesirable tastes and odours that persist for variable periods limiting their value as a food source.

Technology, Practices and Governance. Experience with the effectiveness and the impacts of past activities and growing concern by industry, governments, and all stakeholders including local residents, has led to the development of new technologies and practices for Arctic oil and gas activities. Arctic specific technology and use of best practices have mitigated or lowered the environmental impacts of activities. Challenges remain for technology and best practices as new areas are accessed further north and as the regions climate changes. These technologies and practices must continue to evolve and adapt to changing
and new conditions. The aging of older facilities and transportation systems requires diligent monitoring and maintenance programs and a plan for decommissioning, even though the cost of these are high in the Arctic.

Governance, regulatory systems, and international standards are important aspects of the performance of industry and contribute to the reduction of negative effects. The legal regimes of Arctic countries are relatively stable, modern and designed to protect human health, rights of indigenous residents and the environment. However, in some cases regulatory systems are outdated, incomplete, or enforcement is inadequate. International cooperation and coordination is needed in common fields of concern such as trans-boundary pollution, joint oil spill and emergency response, safety and environmental technical research, and joint fisheries, migratory bird and mammal studies.

Increasingly industry is conforming to a number of internationally accepted standards in order for them to fully participate in the worldwide petroleum market. These standards include common reporting requirements for reserves, petroleum quantity and quality measurement, safety procedures and environmental protection.

Recommendations of the assessment include continued efforts toward:

**Prevention of Oil Spills and Pollution** The Assessment recommends the prevention of oil spills and pollution by considering:
- The conduct of risk assessments in association with all means of transport of oil and gas;
- The use of best practices and technology in transport and storage of oil.
- Seasonal restrictions on oil and gas activities;
- The need for the establishment of protected areas closed to oil and gas activities;
- Strengthened capabilities and improved coordination of oil spill prevention, preparedness, and response, including rapid availability of adequate oil spill response equipment and well-trained personnel.
- Reducing or ending the flaring of associated natural gas (except in emergencies and for safety reasons);
- Using material and chemicals that are environmentally manageable and techniques that conserve, recycle and reuse waste.

**The Use of Best Practices and Clear and Flexible Regulations** The Assessment recommends in particular:
- Clear and flexible regulations should continue to be used that are goal-oriented and supported by appropriate guidance to reduce the risk of accidents and the extent of environmental effects, and to improve safety.
- Establishment of mechanisms to share experiences, and coordinate and cooperate concerning their methods of risk and impact assessments and management of the oil and gas industry.
- Adaptive management approach to ensure that new information can be incorporated into the management and decision-making processes and changes in conditions can be accommodated or mitigated.
- Appropriate consultations and collaboration with communities that may be affected to develop strategies for avoiding negative impacts while harnessing economic and other opportunities.
- Closed-loop drilling systems where drilling wastes are re-injected or cleaned and safely deposited.
- “Roadless” development techniques to reduce the physical impacts of roads; conduct of activities on frozen land in winter months to avoid physical impacts on the ground and vegetation.
- Reducing or eliminating discharges to the terrestrial and aquatic environment and ending the use of sumps and pits for the disposal of spent muds and cuttings from onshore drilling and production operations.
- Building, modernization, and maintenance of transportation systems, including pipelines, and other infrastructure according to the highest industry and international standards.
• Consideration of seasonal restrictions on activities to avoid disturbance to wildlife in sensitive periods and areas.

The Clean Up and Remediation of Polluted Sites  The assessment recommends:
• Action should be taken to clean up and remediate sites that are badly polluted, including old or abandoned sites, in order to significantly reduce or prevent threats to the health of human populations and wildlife living in the vicinity or downstream aquatic or marine areas.

Monitoring  Both effects and compliance monitoring programs should be strengthened in areas of activities. The assessment recommends:
• Monitoring of contaminated and polluted areas.
• Monitoring of Human health.
• Monitoring of wildlife including animal populations; to regulate activities for reducing disturbance and impacts, including using marine mammal observers aboard seismic, icebreaking, and other ships.
• Emphasis should be given to compliance monitoring of infrastructure and practices to ensure that standards and regulations are effectively and consistently followed.

The Assessment Lacked Complete Information  Many topics and databases were lacking in the assessment, either from the absence of data or information, from unusable format for analysis, or from difficult access. This includes information on:
• Point sources of pollution and concentration gradients;
• Habitat fragmentation;
• Socio-economic conditions and human health; and
• Standards and regulations.

Gaps in the assessment  Gaps resulted from lack of data or programs to support the analysis and included information on some research or studies:
• to improve technology including oil spill clean-up;
• of comparative socio-economic effects;
• on human health effects;
• into contaminated sites and natural seeps;
• behaviour and fate of oil in sea ice;
• exposure and toxicology;
• animal populations and ecosystems;
• sensitive areas; and
• the coordination of research.
Alaska is a global “hotspot” of change in a remotely sensed vegetation index. The Normalized Vegetation Difference Index (NDVI) is available globally as 2-week maximum data from 1982-2003 from a series of NOAA satellite sensors. The NDVI data have been processed to correct for major volcanic eruptions in 1982 and 1991, sensor degradation, orbital drift, and other technical problems. By selecting the maximum NDVI value from dozens of observations for each two-week period, cloud contamination and other problems are minimized. The maximum NDVI is correlated to the fraction of photosynthetically active radiation absorbed by plants, and thus to photosynthetic activity.

Since 1982, annual maximum NDVI has significantly increased in arctic Alaska, in contrast to significant declines in subarctic Alaska. In arctic Alaska, NDVI has increased most strongly in central and eastern regions, consistent with a steepened climatic gradient in continentality over the past 20 years. There was no significant trend in annual Maximum NDVI in warmer tundra regions of western and southwestern Alaska. In colder arctic tundra areas, there was a strong correlation between annual maximum NDVI and the previous year’s summer warmth index. The strongest trend in increasing NDVI occurred within the central and eastern Arctic coastal plain, a region substantially cooler than the Arctic foothills. This interannual response and the longer-term increase in NDVI in arctic Alaska may be related to broadleaf shrub growth and expansion, consistent with greenhouse experiments and observations based on historic field photographs.

There was a significant decline in annual maximum NDVI in subarctic or boreal Alaska, just south of the Brooks Range. This is likely due to increased drought stress and insect infestations in the boreal region of a warmer and drier continental climate, consistent with results from tree ring studies, and statewide forest insect surveys. Exclusion of 1973-2003 wildfire burn areas did not significantly change this declining trend, because the area burned within any study regions was small relative to the study region area.

The spatial pattern of subarctic boreal NDVI trends corresponded to an east-to-west maritime to continental climate gradient, with the strongest declines occurring in eastern subarctic Alaska. There was no significant relationship between annual maximum NDVI and temperature or precipitation from climate stations in subarctic Alaska. This may be due to high spatial variability of precipitation and insect infestations. There was no significant relationship between spring NDVI and maximum annual NDVI in either arctic or subarctic Alaska. Thus whether spring greenup was early or late did not control maximum NDVI for the growing season.
Abstract

Alaska and its surrounding coastal areas are prominent geographical features that are largely covered by sea ice on a seasonal basis over the ocean and exhibit sharply varied topography on land. The complex geographical features significantly complicate Alaska regional climate systems. Thus, the representation of complex topography in high resolution models is needed for accurately modeling Alaska regional climate. A study has been established to use a high resolution regional model to conduct dynamical downscaling of global climate simulations for the Alaska region. The CCSM3 20th century climate simulation (1979–1999) was first downscaled and the downscaled present-day climate was then verified against observations and was found to have correctable biases. The bias-reduced downscalings compare favorably to the observations. The downscaled future climate over the Alaska region under A1B scenario of the CCSM3 21st century projections for 2010–19, 2050–59, and 2090–99 shows that strong warming occurs in winter, wind speed increases over the north but decreases over the south, and the annual mean precipitation increases significantly over the Alaska Range.

1. Introduction

While General Circulation Models (GCMs) allow for global scale climate simulation and projection under a range of scenarios, the coarse spatial and temporal resolution of GCM modeling make it hard to assess the local and regional impacts of climate change. This is particularly true for regions with complex orography (Leung et al. 2003). Alaska and its surrounding areas are prominent geographical features with seasonal ice over the ocean and sharply varied terrain on land. Thus, GCM outputs must be downscaled to high spatial and temporal resolution for the Alaska region to produce high resolution climate scenarios for use in impacts research.

Generally, there are three downscaling approaches: regional climate modeling (e.g., Lynch et al. 1998), time-slice simulations with a higher resolution model driven by a GCM (e.g., Bengtsson et al. 1996), and statistical downscaling (e.g., Wilby et al. 2000). Regional models are computationally prohibitive to integrate for periods on the order of a century, and the sparseness of meteorological data over Alaska, along with its complex geographical features, makes statistical downscaling problematic. Thus, the time-slice approach, which has worked successfully in a study of Alaskan glaciers’ response to climate change (Zhang et al. 2007a&b), was used in this study.

We employed the National Center for Atmospheric Research (NCAR) Community Climate System Model Version 3 (CCSM3) (Collins et al. 2006) to provide global scale information and a sophisticated Arctic regional modeling system, Arctic MM5 (Zhang and Zhang 2004), based on the Fifth-Generation PSU/NCAR Mesoscale Model (MM5) (Grell et al. 1994) with the addition of coupled thermodynamic sea ice (Zhang and Zhang 2001) and mixed layer ocean models (Kantha and Clayson 1994), for the high-resolution regional climate downscaling. The data and downscaling methodology are described in Section 2. Section 3 compares the MM5 downscalings with station observations. The downscaled future climate features over Alaska are summarized in Section 4.

2. Data and Methodology

The CCSM3 20th century simulations over the period 1979–1999, along with 21st century projections over three future decades (2010–19, 2050–59 and 2090–2099), have been selected for use in this downscaling study. The downscaling domain employed by the Arctic MM5 has a grid spacing of 30 km, covering
Alaska along with parts of northwestern Canada and northeastern Russia. The model physical schemes used include: Reisner mixed-phase microphysics (Reisner 1998); Grell cumulus (Grell 1993); Rapid Radiative Transfer Model (RRTM) longwave radiation (Mlawer et al. 1997); MRF (Medium Range Forecast) planetary boundary layer (Hong and Pan 1996); and the NOAH land surface model (Chen and Dudhia 2001), with which the thermodynamic sea ice model and mixed layer ocean model referenced above are coupled.

In performing long-term simulations with the Arctic MM5, the use of a nudging technique is essential to ensure that the model does not deviate significantly from reality. In this downscaling study, we applied nudging to the region above the model-defined boundary layer, which is beneficial in maintaining an accurate synoptic environment over the course of a long-term simulation, while still allowing the high-resolution model to develop the boundary layer according to its own physics.

Three future time-slice projections (2010–19, 2050–59, and 2090–99) were used to provide changes for the 21st century based on the middle-of-the-road A1B scenario, which represents balanced fossil and non-fossil fuel use.

3. Validation of MM5 downscalings with observations

The MM5 downscalings of CCSM3 20th century simulations were compared with station observations to estimate biases in the downscaled simulations. This comparison provides a measure with which to estimate errors due to model biases in the MM5 downscalings of future CCSM3 projections. Not only do the model biases need to be analyzed, but there is also a need to further demonstrate that the biases are time independent. To this end, the differences between the MM5 downscalings and station observations over the first (1979–89) and second (1989–99) 10-year periods were analyzed in order to estimate the model biases over different periods; corrections to the biases were then applied to the downscaled results for comparisons.

The downscaled variables at the 30 km model resolution were interpolated to the locations of weather stations with the Cressman interpolation technique, taking the land type and elevation information into account. Since the stations are exclusively located on land, water and land-ice grid points were excluded from the interpolation. The elevation limits were set to exclude grid points with elevations higher or lower than the station elevation by more than 100 meters from the interpolation, as interpolated values show much greater sensitivity to elevation than to horizontal distance.

The comparisons between interpolated MM5 downscalings and station observations show that systematic biases exist in the downscaled CCSM3 climate. There are cold biases in summer and warm biases in winter, especially for inland stations. MM5 tends to produce excessive precipitation throughout the year. There are also significant positive biases in the downscaled wind speeds during winter months. The model biases have a seasonal cycle, and following the method of Zhang et al. (2007a), mean monthly biases were calculated by computing the differences between the monthly averages of station observations and MM5 downscalings. The MM5 downscalings (temperature, wind speed, and precipitation) were then corrected as follows:

\[
T_{(d,m,y)}^c = T_{(d,m,y)}^u + dT_{(m)}
\]
\[
W_{(d,m,y)}^c = W_{(d,m,y)}^u + dW_{(m)}
\]
\[
P_{(d,m,y)}^c = P_{(d,m,y)}^u + \frac{P_{(d,m,y)}^u}{P_{(m,y)}^u} \times dP_{(m)}
\]

where subscripts \(d\), \(m\), and \(y\) refer to the \(d^{th}\) day of the \(m^{th}\) month in the \(y^{th}\) year; superscripts \(c\) and \(u\) represent corrected and uncorrected variables, respectively; \(T_{(d,m,y)}^x\) is daily mean temperature; \(W_{(d,m,y)}^x\) is daily mean surface wind speed; \(P_{(d,m,y)}^x\) is daily precipitation; \(P_{(m,y)}^u\) is monthly precipitation; and \(dT_{(m)}\),
$dW_{(m)}$, and $dP_{(m)}$ are averaged monthly biases of temperature, wind speed, and precipitation for the $m^{th}$ month, respectively.

Following Zhang et al. (2007a), the mean monthly precipitation correction $dP_{(m)}$ was distributed over the daily precipitation $P_{(d,m,y)}$ with the weighting function $P_{(d,m,y)} / \bar{P}_{(m,y)}$, the ratio of daily to monthly precipitation, to ensure that a larger precipitation correction is applied on days with large precipitation amounts than on those with little rain.

The corrected 10-year (1989–99) averaged daily temperature for Fairbanks and wind speed for Nome, with biases calculated from two periods (the previous (1979–89) and current (1989–99) ten years), were compared with observations as shown in Figure 1. Both corrected model time series show reasonable agreement with the observations. The biases in the original MM5 downscalings are thus correctable and can be assumed to be time independent.

4. Downscaled future climate (A1B scenario) over Alaska

The MM5-downscaled future climate forced by three time-slice projections of the CCSM3 21st A1B scenario (2010–19, 2050–59, and 2090–99) were corrected with biases calculated from the entire 20th century simulation (1979–99). That is, the biases and bias corrections identified and applied for the past simulations were assumed to be time independent and applied to the future downscalings. Figure 2 depicts the evolution of bias-reduced MM5 downscalings (monthly temperature and wind speed) at Nome, AK during the four downscaling periods (1979–99, 2010–19, 2050–59, and 2090–99). The surface temperature at Nome under the future A1B scenario exhibits strong warming (as large as 10K) during the winter months, while much weaker warming (~1K) is seen during the summer months. The surface wind speed, however, demonstrates an opposite trend, with wind speed decreasing in the 21st century. A temperature increase occurs with the same pattern (stronger during winter and weaker during summer) at nearly all stations, while the change in wind speed varies among different stations. At Barrow, for example, there is not seen to be any significant change in the surface wind speed (not shown).
Comparisons of the average wind field between the three future decades (2010–19, 2050–59, and 2090–99) and 1979–99 indicate that wind speed increases over the north, but decreases over the south, particularly over southwestern Alaska and British Columbia during the 2050s and 2090s. In addition, the wind field changes seen in winter (DJF) are greater than those in summer (JJA) (Figure 3).

Annual mean precipitation increases over most areas in all three decades of the 21st century, particularly the mountainous regions. Greater precipitation increases (Figure 4) are associated with regions of warmer modeled temperatures (not shown). In the 2090s, the largest precipitation increase over the Alaska Range is ~1 m/year. For the same period, the increase is ~0.5 m/year over the Brooks Range.
Figure 4 Annual mean precipitation changes in the 2010s (left), 2050s (middle), and 2090s (right); positive signifies an increase in precipitation.

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In order to understand the implications on local social-ecological systems of various global changes that are taking place in the North today, it is mandatory to incorporate the knowledge and observations of the local communities to inform scientific research. But such integration of local knowledge with science presents a suite of epistemological and political problems. To address this issue, we initiated a video based project with the help of Indigenous Peoples who traditionally have been a very important component of the arctic social-ecological systems.

Voices of the Caribou People project aims to portray the caribou people – northern communities who have a close relationship with caribou; and their changing world, as they view it. This summer we worked with 6 North American communities to create video-sketches on them that document local observations of changes taking place on their homelands, caribou and livelihoods and how these changes are impacting their traditional culture. Communities from Alaska to Quebec participated in the project and 97 people were interviewed who included elders, hunters, community leaders, women and youth. The participants talked about changes about caribou itself as well as caribou hunting and uses, and voiced their concerns regarding their future. They recorded their observations about how caribou migration, body condition and population has fluctuated, over the time, in response to climate related variability and anthropogenic disturbance such as roads and mines. The hunters spoke about caribou availability, accessibility and current conditions. Community elders spoke about changes in lifestyle, caribou usage and climatic conditions. The leaders talked about the major challenges that their communities are faced with and what do they need from scientists and researchers in terms of information and support, to adapt to the changes. The youth spoke about importance of caribou in their life and their future aspirations. Participants expressed satisfaction in not being treated as subjects of research but rather as having their voices presented without modification or a third-party critique.

The collective voices of caribou people illustrate that communities share many similarities and some differences in the challenges they face. These challenges include the ubiquitous problem of increased energy costs, greater extractive development activities in homelands, and social problems of engaging youth in traditional pursuits. In addition to these problems, non-local hunting, low-flying aircrafts, and loss of language were described. The participants found video to be a very useful tool for several reasons. The elders felt it to be the communities’ legacy and repository of traditional ways in the changing times. The leaders consider visual images as a powerful medium to reach out to policy makers and greater public. The Voices of Caribou People project is still in progress. It is funded by CircumArctic Rangifer Monitoring and Assessment Network (CARMA) and is part of their IPY research on human-rangifer systems and seeks to present indigenous perspectives in scientific research. It also provides an opportunity for caribou people to share their coping strategies with other indigenous communities, give insight to researchers on local people’s needs of northern science, and communicate the important issues concerning human-caribou systems to the greater world.
Current climate models and projections predict future changes in air temperature, precipitation and evaporation. These changes could exacerbate already stressed water systems with regard to water temperature. Water temperature has been cited as a water quality concern due to its effects on aquatic ecosystems. Mathematically based stream temperature models have been produced in order to forecast instream temperature changes due to anthropogenic impacts or climatic changes. If the dominant processes are not accurately represented within these models, the ability to accurately predict the effects of these changes can be limited. Typically, instream temperature models account for surface fluxes based on climatic drivers such as ambient air temperature, wind and solar radiation. However, stream bed fluxes such as hyporheic exchange and bed conduction can also have an impact. Even though the effects of these bed fluxes can be significant, they are often ignored or are quantified without site specific information. Recently, many researchers have sought to quantify stream bed fluxes through site specific monitoring of bed sediment temperatures. Unfortunately, these monitoring efforts capture the confounded effects of hyporheic exchange coupled with bed conduction, which requires assumptions regarding the thermal properties of the sediments in order to quantify the portion of the response due to bed conduction.

In this research, several new data collection techniques have been developed to estimate sediment thermal properties from in-situ temperature measurements by isolating heat transfer due to bed conduction from that of hyporheic exchange. Similar to other studies, three Hobo™ temperature sensors were inserted to different depths in the sediment. One additional probe was placed in the stream just above the sediment to establish a boundary condition. To separate out the hyporheic and bed conduction fluxes, different methods of excluding the sensors in the streambed from advective flows were applied. These methods included the insertion of a 30 cm diameter steel cylinder, 30 cm deep around the buried probes with: no lid or cap at the sediment surface (i.e., open); a cap constructed of low permeability geotechnical fabric that was stretched over the top of the cylinder (i.e., semi-porous); and an aluminum cap attached to the cylinder top (i.e., non-porous).

The resulting temperature time series were then used in calibration of a sediment heat transfer model that treated the bed as a semi-infinite slab. The thermal diffusivity values for each location were adjusted to minimize the residual sum of squares between the model output and the observed streambed temperatures. In the way of a standard for comparison, sediment samples from a site (consisting of a 30 cm diameter sediment sample taken to a depth of 23 cm) were sent to a thermal properties lab for analysis. The resulting thermal diffusivities from the inverse modeling varied widely ($10^3$) depending on the isolation method used. In comparing modeling results to those from the lab, the aluminum capping method best approximated pure bed conduction.
Heightened demands for water throughout the United States, primarily due to climatic and demographic change, have directly influenced the instream temperature regimes of rivers. Elevated instream temperatures often prove detrimental to local aquatic biota and often times endangered fish species. To predict how these changes affect instream temperatures, a dynamic temperature model (Two-Zone Temperature and Solute Model) has been developed to assist in more representative quantification of energy and mass exchange processes taking place within a river. Since this model represents more instream processes (e.g., effects of dead zones and hyporheic exchange), the number of parameters requiring estimation increases. Numerous research efforts have been conducted to determine the data that are best suited to populate, calibrate, and corroborate this model to increase certainty in predictions. To further these efforts, thermal infrared (TIR) and 3-band imagery of the river was collected along with many other data types. A combination of both types of imagery provides for measurement, versus the estimation of parameters such as average channel widths and dead zone surface areas.

Measurement of these two parameters was achieved by delineating dead zones from the main channel in the TIR imagery by creating a temperature pixel classification break based on spatial temperature differences. Determination of the temperature threshold for delineation was facilitated by instream dead zone temperature data collected simultaneously with TIR imagery. These instream data were collected in representative dead zones by in-situ temperature data loggers. The average and standard deviations of the dead zone temperatures were calculated and provide temperature bounds as the delineation threshold. This method provided dead zone areas ranging from 30-40% for all river segments. From this analysis, dead zone and main channel areas can be calculated for each segment. Other delineation methods are currently being tested.

To determine more representative width estimates, the river was segmented into 31m reaches (which corresponds to the reach length in the modeling effort), and the average width was calculated for each segment. These improved parameter estimations are anticipated to improve model calibration and corroboration. Additionally, future efforts will use the TIR data for model corroboration and provide the ability to test spatial representation of the longitudinal temperature regime. With these detailed data and more representative parameter estimates, it is anticipated that the increased accuracy of instream temperature predictions will provide for improved water management decisions.
APPROACHING IDEAS ON NORTHERN WATERSHED CHANGE

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The Spatial and Temporal Lake and Wetland Distribution Model will evaluate potential standing water changes over the next century in the Yukon River Watershed in 1 km spatial resolution using the Max Planck GCM ECHAM5-A1B climate warming scenario. Permafrost extent and hydraulic gradients interact in a complex, but predictable manner to enable prediction of the future standing water landscape. Predicted landscape shifts should constrain estimates of carbon dioxide and methane flux to the atmosphere and shape considerations of these local and regional measurements in the global budget.

Our modeling methods combine three models to produce potential lake and wetland surface area changes. The MicroMet model is a quasi-physically based model developed in 2006 by Liston & Elder to spatially interpolate point meteorological data using known temperature-elevation, wind-topography, humidity-cloudiness, and radiation-cloud-topography relationships to improve the meteorological realism of the Barnes technique of distributing irregularly spaced data to a regular grid. We call on 1997-2007 data from 104 Integrated Surface Data meteorological stations and 97 grid points in the ECHAM5-A1B 2090-2100 projection. Currently, we are using a constant linear lapse rate to reproduce temperature-elevation relationships. In the future, we plan to include more spatially relevant air temperature lapse rates calculated using adjacent station data and weather balloon data. The Temperature at the Top of the Permafrost (TTOP) model is a numerical model for estimating the thermal state of permafrost. This model is attributed to Smith & Riseborough, 1996. TTOP relates more readily available near surface temperatures to temperatures at the depth of seasonal variation using user-defined landcover n-factors (to relate air temperature to soil surface temperature) and soil thermal conductivities (to simulate the propagation of heat through the active layer). TTOP would yield warm top of the permafrost temperatures with high soil thermal conductivity, land cover with high n-factor, and a high number of thawing degree-days/year. Here we present parameterization of soils and landcover and the role of these parameters in TTOP. We made point thermal conductivity measurements and vegetation community observations along the Elliot, Dalton, Richardson, Alaska, Klondike, and Taylor Highways. We are developing a physically based potentiometric surface algorithm that we are naming HydraulicGradients. The HydraulicGradients model assimilates information on the spatial array of groundwater recharge and discharge in the watershed by considering relative elevation and precipitation in neighboring high elevations. We are validating this module with existing fen and bog landcover classification and with comparison of local isotopic signatures of surface water to groundwater and precipitation.

Our goal is to provide insight into surface water changes in the next century as affected by the permafrost changes in the next century, assuming non-changing hydraulic gradients in the watershed. The changing physiography of the Arctic and the resulting interactions with the atmosphere have been growing research concerns for the last decade and were particularly intensive in the 2007-2008 International Polar Year.
Our study examines waves in the southeast Chukchi Sea during fall storms of 2007. The Arctic is inundated with storms during the fall season, which affect coastal erosion. Shishmaref, Alaska has recently been in the headline news regarding coastal erosion. To study these storms observational, a bottom-mounted Aanderaa RDCP600 was deployed on the Chukchi Sea shelf approximately 89 kilometers north of Shishmaref, Alaska to measure wave height and direction, along with other wave parameters. The wave gage was deployed a latitude of 67°03.499’ and longitude of 166°20.717’. At a depth of 33 meters the instrument, which was set for acoustic based wave measurement, was able to capture wave direction. The acoustic based waves are sampled at a 2 Hz rate for 15 minutes every 2 hours. This sampling rate is designed to target longer wave periods. The instrument recorded from 15 July 2007 through 21 December 2007. The instrument showed that the largest percentage of waves originated from the northwesterly direction, i.e. the open Chukchi Sea area. The current speed is strongest in the northeasterly direction, i.e. from Kivalina, Alaska. The current speed was below 103 cm/s for 90% of the measurements of the horizontal current speed. For 50% of the measurements, the current speed was below 58 cm/s.
Polyagonal tundra show extensive micro-scale (< 1m) variations in thermal and hydrological regimes. The tundra landscape is sparsely monitored with a single point measurement often assumed to represent local (1 km) or regional (10-100 km) scale conditions. Modeling efforts have mainly focused on simulations resolving regional scales partly due to limited availability of high-resolution field information such as digital elevation and vegetation maps. In an attempt to enhance watershed mapping our objective was to a) quantify micro-scale spatial and temporal variations in the thermal and hydrological regimes and b) evaluate thermal and hydrologic relationships to land cover (vegetation type). Following the land cover classification, the micro-scale measurements could potentially be extrapolated across the watershed. Here we present the measured micro-scale variations across a 20×20 m polygon in 29 positions. Each measurement site has a soil temperature profile (Hobo, U23-004) extending to the bottom of the active layer and a volumetric water content sensor (CSI, CS616) placed at 10 cm depth.

From October 2007 through September 2008, ground surface (defined as the interface between live and dead organic material) temperatures fluctuated between -28 and 20°C. The largest temperature range (48°C) was observed among sites located at the polygon rims due to thinner snow cover and drier soils compared to the troughs (35°C range). Hourly near-surface soil moisture in summer differed up to 30% (65% to 95%) saturation. The mean effect of the snow insulation (air temperature – ground surface temperature) was measured to be 3.4 to 6.3°C with larger values located in the troughs. Spatial differences in ground surface temperatures were slightly larger in summer (<15°C) than winter (<12°C), indicating a larger spatial variation in the available energy at the surface and/or in the surface energy balance partitioning during the summer. In 2008, the start of thaw (defined by a rapid increase in temperature following the release of latent heat) at the ground surface differed up to six days across the polygon. The ground of the higher polygon rims was the first to appear during melt along with snowmelt-inundated troughs, which highlights the role of advective heat and the differing importance of snowdrifts on snowmelt pattern. Mean annual ground surface temperature was -7.3±0.9°C, which was similar to mean annual temperature at the top of the permafrost (-7.4±0.6°C). Minimum temperature at the top of the permafrost varied between -20.3 and -16.8°C. Spatial differences in hourly temperatures at the top of the permafrost were up to 5.9°C with a peak during a cold spell in mid-January and another one just prior to the snowmelt. The active layer in 2007 and 2008 measured 15 to 46 cm (29 cm) and 21 to 48 cm (36 cm), respectively, with shallower thaw in the troughs. Summer 2007 was unusually warm and experienced extreme low precipitation compared to the more typical conditions found in summer 2008 suggesting that the thermal regime of troughs to be more sensitive than the rims to intra-annual variations.

We found quite large micro-scale variations in both the thermal and hydrological regimes across patterned ground at the Arctic Coastal Plain. In this environment of ice- and organic rich soils, gaining an understanding of the micro-scale temporal and spatial variations of the soil and thermal regime are key factors to successfully projecting future regional changes in the Arctic and their global implications.
Scenarios are valuable tools for decision makers. They allow us to develop and bring into focus several images of future developments where predictions are not feasible. These images can help decision makers to plan for a range of futures. Scenarios can also be a useful tool in identifying early indicators as to what the actual future development will be. Scenario processes have been successfully employed in state, regional, local, corporate and catastrophe planning. Public scenario processes can be used to induce conversation between different stakeholder groups and to stimulate thinking ‘outside the box’.

Scenarios can be classified to be normative or explorative. Normative scenarios can be understood as stories of the future written by an author well informed on the specific topic under consideration. The drawback of narrative scenarios is that it is possible that seemingly unlikely, but very consistent, futures are often overlooked. Explorative scenario methods attempt to remedy this problem by implementing a process that ‘blinds’ the investigator for parts of the process to the bigger picture. The aim is to allow for easily dismissed, but interesting possible futures to survive the process of narrowing down the space of possible futures to about five.

One such explorative scenario method is scenario construction by consistency analysis (Gausemeier et al., 1996). In this analysis key factors driving the development of the field under consideration are identified. Each key factor is assigned several future projections, i.e., ways in which it could develop in the future. Each future projection is assigned a plausibility value. In general, any combination of future projections of the different key factors represents a possible future. However, some of these possible futures contain future projections that are inconsistent with each other. To rule out such inconsistencies each future projection of a key factor has to be compared with all future projections of the other key factors and their pair-wise consistency determined. From the resulting matrix consistent future projection bundles (raw scenarios) can be calculated. However, this process results in no information with respect to plausibility of the raw scenarios.

We have extended the consistency analysis into a robustness analysis. We denote raw scenarios as ‘robust’ if they not only have a high consistency, but a high robustness, that is a compounded variable of consistency and plausibility. Further, our analysis allows the incorporation of Wild Cards (Steinmüller and Steinmüller, 2004), i.e. disruptive events with high impact on the field under investigation. For the example of the ‘Futures for the Arctic 2030’ process (see oral presentation) we will explain the Robustness Analysis and further useful data analysis tools for scenario processes. Further, we will describe our experience with a web-based ‘Open-Scenario’ approach, which invites all stakeholders to comment in the process. By this we hope to make a broader audience aware of the usefulness of explorative scenario processes.

For more extensive information and references please visit http://seaice.scenlab.com.
ARCTIC AND GLOBAL CLIMATE RESPONSES TO ECOSYSTEM-INDUCED SUMMER ALBEDO CHANGES

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Several boreal research studies have shown the strong role of high latitude terrestrial ecosystems in the modulation of the climate. Concurrently, the ecosystem and ecosystem carbon fluxes appear to be vulnerable to climate changes. Therefore, it is essential to better understand the feedback between climate and ecosystem changes. Many General Circulation Models (GCMs) simulations have suggested that changes in surface albedo have significant regional consequences by influencing the energy budget terms, temperature, precipitation, evaporation and snow cover and global consequences through teleconnection. To assess the influence of ecosystem-induced summer albedo changes occurring north of 50°N on regional and global climate, simulations are performed with the Community Climate System Model version 3 (CCSM3) for 2003 to 2053 without and in conjunction with the summer-albedo change data obtained from simulations performed with the Terrestrial Ecosystem Model (TEM version 7). These simulations are denoted REF and ALB hereafter. The spatial distribution of TEM-simulated summer albedo shows mostly a decrease over the Pan-Arctic.

With decreasing summer albedo one would expect an increase in soil and surface temperatures. However, on average, soil temperature significantly decreases up to 2K over western Siberia, Alaska, Europe and southern Siberia, the Middle East, eastern and western Africa and western South America in summer. In fall, winter and spring, soil temperature significantly decreases up to 2K over Alaska, Europe, central and western Siberia, the Middle East and the African desert. The increasing cloudiness over North Atlantic Ocean and western Siberia in ALB simulation in summer is responsible for significant decrease in soil temperature over Pan-Arctic as less solar radiation reaches the surface. In summer, albedo changes occurring over the Pan-Arctic cause significant surface cooling (up to 1.5K) in Alaska and western and southern Siberia. Surface temperature also decreases up to 0.5K over central Asia, the Middle East, China, the eastern and western part of Africa and South America. The cooling occurring over Pan-Arctic may be caused due to increasing cloudiness over North Atlantic Ocean and western Siberia whereas the cooling occurring outside the range of where albedo changed likely reflects the change in surface wind speed in response to albedo change. Consequently, the advection of cold air from western and southern Siberia is enhanced. Intensification of the tropical easterly jet in ALB is responsible for advection of cold air from southern Siberia to eastern and western part of Africa and South America in summer. Surface temperature also decreases in winter and spring due to increase in snow cover. In conjunction with the changes of Pan-Arctic summer albedo, precipitation significantly decreases (up to 20mm/mon) also occur in summer and spring over Europe.

Overall, changes in soil temperature followed the same pattern as surface temperature and significantly decrease over Alaska and Siberia in response to summer albedo change. These alterations in summer albedo also teleconnect to middle and lower latitudes by modulating the soil and surface temperature in those regions through nonlinear feedbacks within the atmosphere’s general circulation. Herein changes in cloudiness play an important role.
The impact of fuel prices on subsistence in Northwest Alaska

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The continuation of a subsistence lifestyle in rural Alaska is a priority for a majority of residents. Subsistence foods and practices are critical to cultural sustainability in a changing world. Many Alaska Natives specifically point to the connection between particular foods and their sense of identity. “Eskimo foods” are shared with relish while stories of growing up on the land and about food preparation are told. Children and young adults learn about subsistence methods, community history, culture, family values and respect for the environment through the practice of subsistence.

The increasing cost of fuel in rural communities, particularly recently, is having an unprecedented impact on the practice of subsistence and the sustainability of communities. Many individuals and families are having to make difficult and painful choices when it comes to food and heating fuel or gas for snow machines, boats and four-wheelers. Many people feel that they are in a “heat or eat” situation.

There are many recent examples of the difficult situation of many Northwest Alaska residents. Whaling crews from St. Lawrence Island recently successfully landed two whales. One of the whales was landed only a mile offshore from the island, while the other was landed tens of miles offshore. In the case of the second whale, only 6 boats were available to haul it ashore, which took several hours. Typically there are many more boats involved, but this time fuel was so expensive that hunters pooled their money and were able to purchase only enough fuel for 6 boats. This put the whalers in a very dangerous situation as bad weather was approaching while they were towing in the whale. With more boats this would have been accomplished much more quickly and much less dangerously. This is just one example of the difficult situation that many subsistence practitioners are being put in due to the high cost of fuel.

The high cost of fuel has led to additional changes in subsistence practices which may lead to long-term cultural changes as well. For example, if families spend less time at fishcamps, children have far less experience practicing subsistence fishing, fish processing, and even less fish to eat. These costs may also be having an impact on species selection and harvest locations.

The current situation also provides the possibility of evaluating theories of adaptation given the importance of fuel and fuel prices in the material and social fabric of rural subsistence lifestyles. Because fuel is so important for the procurement of subsistence foods, but is also substantial item in personal finances, dramatic increases in fuel prices raise the specter of cascading socio-cultural impacts, the likes of which may only have parallels in contact situations.

Data for this poster has been collected through both semi-formal interviews and informal discussions with Bering Strait and Norton Sound residents, as well as participant observation of subsistence activities.
ESTIMATING UNCERTAINTY IN APPROACHES USED TO QUANTIFY SURFACE WATER-GROUNDWATER EXCHANGE

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Surface water-groundwater exchanges play an important role in understanding solute transport and transformations. Two approaches to quantifying surface water-groundwater exchanges were applied to a mountain stream highly influenced by groundwater during a period where the average stream discharge was approximately 0.350 cms. The approaches included differential gauging using discharge measurements and dilution gauging using instantaneous tracer experiments. Differential gauging incorporated the development of stage-discharge relationships at the reach boundaries of two separate reaches, an upper and lower reach of 515 and 560 meters, respectively, and was used to quantify a net change in stream discharge at a reach scale. Dilution gauging was additionally performed to quantify stream discharge at a sub-reach scale ranging from 55 to 100 meters. The stream discharges estimated at the sub-reach boundaries were used to quantify net changes in discharge at the sub-reach scale. Tracer mass recoveries were also quantified to provide additional information on groundwater recharge.

Each of the two approaches implemented has uncertainty associated with the estimations of stream discharge. Uncertainty identified in the differential gauging approach includes instrumental error, error in the standard velocity-area technique, and error in the stage-discharge relationships themselves. For the dilution gauging approach, sodium chloride was used as a tracer and responses were measured in-situ with specific conductance as a surrogate to chloride. To relate responses to chloride, correlations between chloride concentration and specific conductance were constructed. Additionally, site specific stream background chloride concentrations were measured and subtracted from responses in order to complete stream discharge calculations. Uncertainty in the dilution gauging approach includes: 1) error in chloride to specific conductance correlations, 2) in-situ instrumental error, and 3) error in background chloride measurements due to analytical techniques. Statistical techniques were used to quantify the errors that contribute to the uncertainty in the stream discharge and mass recovery calculations from each tracer injection. Similar techniques were also performed for the differential gauging approach.

The net gains and losses to stream discharge at the sub-reach scale were approximated to range from 5 to 22% of the total discharge without incorporating uncertainty. Estimation of the uncertainty in these calculations was used to determine the reliability in these approaches to capture small net gains and losses. Preliminary results indicate that the stream discharge estimations using the dilution gauging approach are significantly more reliable than using the differential gauging approach. Additionally, the dilution gauging approach has the advantage of approximating gains and losses occurring simultaneously within a sub-reach through the use of discharge and tracer mass recovery calculations. Although differential gauging is not preferable for estimating small changes in stream discharge at the sub-reach scale, it was still found to be useful for providing reliable estimations of the net change to stream discharge at the reach scale.
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