Notes from an International

Workshop on the Foreign Policy Implications of Arctic Warming

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This document should not be considered a detailed report of the workshop but is a compilation of notes gathered by several individuals. It is useful to stimulate discussion on the topics addressed at the workshop and to stimulate the memory of the participants in the workshop.

Organization of the notes:
For the most part the notes have been organized in order of the major discussion topics presented in the workshop. However, subjects often came up in discussions other than those of the major topics. In these cases those statements and comments have been integrated with the most logical major discussion topic. Therefore, statements cannot be attributed to any particular discussant.

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Workshop on the Foreign Policy Implications of Arctic Warming

By John Kelmelis[1], Emily Becket[2], and Sandra Kirtland[3]

Introduction

The United States Government, through the Department of State, U.S. Geological Survey, National Oceanic and Atmospheric Administration, and other agencies, has initiated a series of analyses on earth science findings with foreign policy implications. Among the issues identified as important to that series by an interagency team at a workshop held in June 2004 is the warming trend observed in the Arctic.

The Arctic Climate Impact Assessment (ACIA) was published in November 2004, while this workshop was being planned. The organizers of the workshop took advantage of the ACIA as one of the sources of information for discussion, but not the only source. Subject matter experts from a variety of organizations and institutions within and outside government and from several countries participated in the workshop.

The ACIA reported that the Arctic region is warming and will continue to do so in the foreseeable future. If the Arctic region is warming, there are likely to be a number of foreign policy issues that must be addressed by the United States and other nations. These issues include the availability and potential for exploitation of energy, fisheries, and other resources; access to new sea routes; new submissions under Law of the Sea; national security; and others. At this workshop participants discussed the scientific issues relating to the environmental changes taking place in the Arctic region, the economic and societal sectors that may be affected by changes in conditions in the Arctic region, and the interests and concerns of the Arctic nations. The workshop on the foreign policy implications of Arctic warming was held to share information and ideas among interested parties. This exchange of information is intended to stimulate discussion among foreign policy experts and provide creative ideas for foreign policy planning.

This workshop was conducted under the Chatham House Rule as amended in 2002. It states, "when a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant may be revealed."[4] The purpose of the rule is to encourage open and frank discussion without fear of reprisal or recrimination. There was no policy formation at the workshop; rather, participants worked to gather information and ideas for use by policy makers. The goal is to have open dialog among international participants in order to better understand a variety of viewpoints.

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[1] U.S. Geological Survey and U.S. Department of State.
[2] University of Maryland.
[3] Georgetown University.
[4] "The Chatham House Rule originated at Chatham House with the aim of providing anonymity to speakers and to encourage openness and the sharing of information. It is now used throughout the world as an aid to free discussion. Meetings do not have to take place at Chatham House to be held under the rule." http://www.chathamhouse.org.uk/index.php?id=14

In this workshop we concentrated on issues relating to the effect of a changing environment in the Arctic and not with the causes of climate change. Regardless of the cause, we must prepare for and respond to the effect.

Scientific Underpinnings

1. The Arctic Climate Impact Assessment

The ACIA "is a project of the Arctic Council and the International Arctic Sciences Committee to evaluate and synthesize the knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences" in the arctic. Fifteen nations began working on the ACIA in the late 1990s; the project was formally initiated in 2000. More than 300 authors contributed to the document, and more than 200 independent scientists reviewed the report in an effort to ensure the content of the report reflects the best knowledge and consensus in the scientific community.

An overview document, which is drawn exclusively from the 1,200-page Science Document, is scheduled for release during 2005. The 18 chapters of the Science Document cover the past, the present, and impacts to the future. The overview, a document of highlights designed for broad distribution, presents scientific results and impacts with implications for national and foreign policy interests.

The ACIA team has been charged with putting scientific information into a form useful for a non-scientific audience. The Assessment will provide the basis for deliberation for policy makers in many countries. An essential aspect of the ACIA is that it attempts to present a balanced and realistic outlook as it addresses the variety of different aspects that may affect diverse interests. The report has generated controversy, in part because it addresses the politically sensitive subject of climate change. The document may be downloaded from www.ACIA.uaf.edu.

2. The Science and Implications

The Arctic, which is evenly split between land and ocean, is shaped by glaciers, rich in natural resources, and home to many indigenous peoples. Most freshwater comes to the region in a 2- to 3-week snowfall period. This region exhibits a very wide temperature range, for example eastern Arctic Russia experienced 42°C during summer 2004 and often experiences -60°C in winter. Scientific evidence demonstrates that the Arctic is facing substantial changes in many areas, including surface temperature changes, high contaminant concentrations (PCBs and mercury), and possible stratospheric ozone depletion.

The many glacial cycles over the last several millions of years represent a chronology of climate change. Ice cores, which contain ice, particles, and bubbles of trapped gasses dating from recent times to in excess of 100,000 years in Greenland and in excess of 740,000 years in the Antarctic, can be analyzed for temperature and atmospheric conditions. Snow is converted after 2 to 3 years into ice containing tiny bubbles filled with a sample of the atmosphere that existed at the time of freezing. These bubbles are effectively "time capsules" that can be analyzed for contents of the atmosphere in the distant past. Analyzing the gas contents can provide information on when the gas was trapped and what the temperature and other environmental factors were at that time. From this, the atmospheric CO_2 concentrations, the concentrations of other gasses, and temperature variations can be plotted. The analysis of these ice cores has allowed us to understand of climate changes on timeframes of hundreds of thousands of years. In addition to ice-core evidence, tree rings (the study of which is known as dedrochronology), lake sediments, and ocean sediment cores are used. Tree rings provide information from different regions in the recent past, and ocean sediment cores can extend the record back to millions of years.

The climate in the Arctic is changing now, and, according to ACIA, change will accelerate with attendant physical, ecological, sociological, and economic effects. Some estimates are that these changes may take place in only a decade or a generation.

The Arctic is a bellwether for global climate change. CO_2 has a long persistence in the atmosphere (decades to centuries with 15% to 30% remaining for thousands of years)[5]; therefore, if peak emissions are reduced, it will take many years before atmospheric CO_2 concentrations decline and the climate system responds. Thus, climate effects will exhibit a long latency period. In addition, the ocean conducts and convects heat and has a high heat capacity. Because of this, it acts as a buffer for temperature change and can extend periods of change from decades to centuries to possibly a 1,000-year timescale. There is considerable uncertainty in the projections, although physical evidence indicates that important changes are taking place.

Trends in Observations—Evidence of Climate Change

- **Warming trends.** On the basis of average temperature data from the entire Arctic, a warming trend has been observed in the winter temperature record from 1880 to the present. These data are from the National Oceanic and Atmospheric Administration (NOAA) and have been corrected for the urban heat island effect. For the period 1960-1990, satellite and in-situ monitoring provide evidence that the planet has been warming on the average. Although some areas have cooled, the general trend is warming. Nothing in the last 125 years compares to the warming since ~1980. The high complexity and variability in the climate system results in a nonlinear trend in response to climate forcing at various scales. For example, although there has been a strong global warming trend for the past 30 years and 1998 was the warmest year on record with 2002 and 2003 being the second and third, respectively, 2004 was only the 24th warmest year on record. Some studies have suggested that a 30-year meteorological cycle influences Arctic temperatures. There has also been some question whether the Arctic warming observed in the 1950s was greater than today's. Analysis has shown that currently the Arctic is slightly warmer than it was during that period, and ocean data show the temperature has warmed beyond that range. However, there are inconsistencies with remotely sensed temperatures of the land surface and troposphere. For instance, the tropical land surface and middle and upper troposphere are generally warming, while the lower troposphere appears to be cooling. [Recent analysis has removed that inconsistency.][6]
- **Oceans.** During 2004, the northern oceans were the warmest on record. The oceans, because of their high heat capacity, control the magnitude and timing of climate change. Some observed data have suggested that the waters of the northern oceans are becoming less saline, possibly due to melt water from glaciers and increased fresh water entering the oceans from rivers.
- **Precipitation/drought.** Some computer models suggest that Arctic precipitation will increase, perhaps as much as 5% to 15%. However, some locations are expected to experience increased

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[5] Tamara S. Ledley, Eric T. Sundquist, Stephen E. Schwartz, Dorothy K. Hall, Jack D. Fellows, and Timothy L. Killeen, 1999, Climate change and greenhouse gasses, *EOS*, v. 80, no. 39, p. 453.

[6] Newly derived correction for satellite diurnal drift, when applied to microwave measurements of lower troposphere temperatures in the tropics indicate lower troposphere warming is in line with surface and middle and upper troposphere warming derived from satellites. Mears, C.A., and W.J. Frank, 2005, The effect of satellite derived lower tropospheric temperature, *Science*, Vol. 309, Issue 5740, 1548-1551.

aridity as well. Physical analysis of these trends suggests a likelihood that some droughts will be more severe than those experienced in the recent past.

- **Alaska.** When averaging the whole state, Alaska has experienced increased annual temperatures. However, there is considerable seasonal variation. Arctic Alaska warming in winter and spring have been +0.8° and +0.7°C per decade, respectively, since 1960. Summer temperatures have increased +0.3°C per decade, while autumn temperatures have decreased slightly at -0.2°C per decade over the same time period.
- **Timescales.** Arctic warming has been very rapid. There have been up to 10°C variations across the region over the last 20 to 30 years. The Intergovernmental Panel on Climate Change (IPCC) estimates an increase of 0.3° to 0.6°C for the planet over the past century and approximately 2.0°C over the next century. Portions of the Arctic are expected to experience a temperature change of as much as 8 to 10 times that number. An example of warming that has already taken place is the surface temperature in Yakutsk, where the average winter temperature was -52°C until 1985, when it started to diverge from its historic trend and has now reached -38°C. This increase is expected on human timescales. While prehistoric changes for most of the planet are believed to have occurred on geologic timescales, there is evidence of abrupt climate change in the past.
- **Greenland ice sheet melt.** The science community has only begun to understand the melt-rate increase. Studies have shown that along the edges of the ice sheet a high degree of coastal melting is taking place along with melting of permafrost. There is some increase in snow accumulation in high altitudes where relative cooling is taking place. However, recent observations indicate that high altitude melting may be taking place and running off in streams beneath the ice cap surface. Observations are showing considerable water runoff, not merely melt ponds on the ice cap. Usually, the glacial ponds provide insulation for the ice beneath them. Exposed ice disappears more rapidly than ice beneath cold water. It is now recognized that water is draining through the porous ice and lubricating the base of glaciers, resulting in more glacial runoff and more rapid flow of glaciers to the sea. There is considerable regional variability in Greenland's temperature change and change in quantity of ice and snow. [Observations indicate that Greenland's ice sheet diminished more in 2005 than in previous years.][7]
- **Sea-ice.** There has been an observed reduction in sea ice extent of about 8%. U.S. Navy submarine transects have measured a reduction in ice thickness by as much as 40% during the past 20 years.
- **Sea-level rise.** The IPCC predicts a 20-90 cm sea-level rise during the 21st century. Current estimates are that complete melting will take 500 to 700 years and raise sea level by 700 cm. [The melting of mountain glaciers and ice caps is expected to provide about one half the sea level rise. However, a recent study suggests that only half the sea level rise previously predicted from melting of mountain glaciers and ice caps will take place. Additional study is warranted.][8]

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[7] Perkins, S., 2005, Glacial Change, Greenland's ice loss doubled in 2005, *Science News*, v. 168, p. 387.
[8] Raper, S.C.B., R.J. Braithwaite, 2006, Low sea level rise projections from mountain glaciers and icecaps under global warming, *Nature*, v. 439, p. 311-313.

Models, Scenarios, and Analogs

Two of the approaches that can be used to provide reasonable ideas of what future environmental conditions would be are models and analogs. Both use scenarios for future human behavior.

- **Models.** Models give a reasonable projection of how the planet will change, not a prediction. They are the major tools in use to project future conditions. General circulation models (GCMs) and climate models generally require supercomputing capabilities. They usually model physical processes, are bounded by parameters that are put in by scientists, tested against observed historic conditions, and run to provide a projection of possible future conditions.

  ACIA has used the output from five models on which to base its assessment. All five of the models have been determined to be the best for ice and show more rapid warming in the Arctic than in the rest of the world, aside from the intrinsic high variability in the climate system. Two key messages can be taken from the model results: arctic warming is more rapid than the average warming throughout the world, and the system is highly variable. The models reflect the variability. The general trend within the high variability in model results is the important factor, as the models do not predict the type or timing of individual events. The models show high variability in warming and cooling in different regions of the Arctic due to the large amount of ice in Greenland, which tends to cool that whole region, and the geographic distribution of the land masses, which restricts the outflow of sea ice near eastern Canada and Greenland. With a scenario showing that CO_2 concentrations in the atmosphere will double by 2080, up to a 10°C average Arctic temperature increase in some regions is shown in the model results.

- **Scenarios.** These are used to describe societal conditions and resulting greenhouse gas emissions. Scenarios include population growth, economic growth, different environmental policies, financial equity, gender equity, and technologies. Scenarios A2 and B2 (see ACIA for details of these scenarios) are favored, but several scenarios show a range of results. For analysis purposes, the moderate scenario, B2, was chosen. The B2[9] scenario represents the most stringent policy likely to be applied. These policies only indirectly account for CO_2 emissions from burning fossil fuels. Many other inputs are involved.

  The effectiveness of the models may be estimated by running the models with known concentrations of historic and current CO_2, sulfate aerosols, other atmospheric constituents, and other variables such as solar influence. Models run with these parameters generally replicate the last 100 years' conditions with minor variations. Results for the early part of the 20th century are similar for all the models. Divergence occurs later: some of this is due to scenarios and some due to assumptions within the model of how physical processes work or interact. The results from models run to simulate the last 100 years with all inputs set to known levels, except without the greenhouse effect from CO_2, show temperatures consistent with observations for 60 years, and then the results diverge from the results of models run with the greenhouse effect. This demonstrates model sensitivity to the abundance of CO_2 in the atmosphere.

- **Analogs.** These can be used to project future climate conditions without requiring supercomputing resources. Analogs can be used in several ways, such as (1) identifying

[9] The IPCC SRES (Special Report in Emission Scenarios) B2 scenario is one of several scenarios used to parameterize runs of coupled global climate models. B2 is conservative in that it predicts a global population growth to 10.4 billion people by 2100 and a rapidly growing economy with emphasis on environmental protection. This results in lower concentrations of CO_2 and other greenhouse gasses in the atmosphere over time than with other scenarios.

historic climate conditions similar to what is expected in the future and identifying the environmental conditions that resulted from that climate, transferring the resultant environment into the modern world to understand its implications; (2) identifying historic or prehistoric trends, determining their outcome, and logically transferring that information to analogous modern trends to estimate possible future outcomes; and (3) identifying historic or prehistoric environmental conditions, determining their cause or effect, and transferring that to the modern world to estimate logical outcomes of current conditions and processes.

Effects of Climate Change to Date

- **Coastal communities.** Coastal communities are more sensitive to storms of spring and fall than in the past because sea ice has retreated and no longer protects them from wind and wave action. Communities dependent on historic Arctic conditions for subsistence are facing major problems as the traditional resources are less available due to a changing environment. Environmental conditions are changing rapidly as animal species and vegetation are moving northward and native species are becoming endangered in the new environment.
- **Access to the Arctic, transport.** Sea passageways are opening rapidly, including leads and channels as well as sea routes during some years. The northern sea route, which is north of Russia, is opening prior to the Northwest Passage and is creating an attractive route for transport. In the future, Arctic transport could be viable for as much as 3 to 6 months a year instead of just a few days a year. This presents a much shorter shipping route from Europe or North America to East Asia than using the Panama or Suez Canals. Based on the running of five climate models, the extent of ice in September will be ~50% of its current extent by mid to late century; however, there is a high level of disparity in the models. It is unknown what will happen at the choke points in western Canada. Some passageways opening up in northern Canada and Alaska are relatively shallow. This will control the size of vessels that can use the Northwest Passage. Increased access will raise security, economic, and social issues.
- **Atlantic thermohaline circulation.** Ocean circulation is caused by tidal forces, wind, and density differences. Ocean water density is a function of heat (thermo) and salt (haline) concentrations in the water. In the Arctic, surface ocean water evaporates and leaves water with greater concentration of salt behind. When cooled to near 0°C this saltier water is among the most dense of ocean water. Therefore, it sinks and produces the thermohaline-driven ocean currents. Some scientists hypothesize that freshening of the northern Atlantic Ocean can reduce North Atlantic deep water formation, which could slow or stop the thermohaline overturning in the Atlantic Ocean and which would also affect the currents in the Indian and Pacific Oceans as well. The equator-to-pole distribution of energy would be severely disrupted, leading to potentially severe impacts that would be felt globally. Sediment core data show this "conveyor belt" has shut down on short timescales in past. If the thermohaline circulation, of which the Gulf Stream is a part, shuts down, it will significantly affect the weather of eastern North America and northern Europe. Changes to the thermohaline circulation could have profound effect elsewhere as well. If a shutdown were to occur over 100 years, we would see a cooling Europe and a warming rest of the world. There is disagreement among the models concerning what will happen to the thermohaline circulation as a result of climate change, though most would not predict a shut down within their run timeframe. [A study published after the workshop found there has been a slowing of the Atlantic meridional overturning circulation.

Additional study is needed to determine if this is a trend and to determine what will be the effects.][10]

- **Animal species.** Projections for polar bear populations show extinction. Less ice means less area to forage for seals. Recent observers have noted thinner polar bears and fewer cubs than in the past. Some studies say disappearing ice is a major factor in the polar bears' decline. In addition a changing climate, the contamination load in streams and rivers is very high in this region. The extent of the contribution of the contamination load to the decrease in fauna is unclear.
- **Disease diffusion.** It was suggested that altered wild fowl flyways and climate change in the Arctic could accelerate diffusion rates of viruses such as West Nile. This is unconfirmed.
- **Ecosystems.** Ecosystems changes are rate limited and asynchronous. Some components of the ecosystem can adapt rapidly to change while others adapt more slowly and yet others do not adapt at all. Some will be primary adaptors, which will set some of the conditions to which others must adapt. We have a poor understanding of the relationship among many of the ecosystem components. Thus, there are uncertainties in the projections of ecosystem change, not so much with whether it will take place but more with the details of exactly what some of those changes will be.

Requirements for the Future

- **Better Datasets.** This was one of the highest scientific priorities brought into focus by the workshop participants. Although they frequently make the point, it appears that the members of the scientific community have not made clear to policymakers the importance of better and longer term data sets, particularly for the ocean. Disrupting data collection reduces opportunities for scientists to provide more reliable information to policy makers.

  Some workshop participants believe remote sensing satellite observations in the far north should be increased. The Operational Control Center and the National Ice Data Control Center are currently buying satellite imagery from Canada. The satellites are old, insufficient, and cannot cover both poles. [The Polar Regions are monitored more frequently than other parts of the world due to the orbital geometry of polar orbiting satellites. However, not all variables in the far north are adequately monitored due to the types of sensors on the systems (see breakout session reports). New satellites with radar imaging and altimetry are needed in the far north, as existing systems are either operating beyond their design life or do not have sufficiently fine resolution.] Funding to acquire data has been decreasing at a time when the need for better data is increasing. Commercial systems are good but generally very narrowly focused and do not provide the type of data needed for most Arctic applications.

  Even though the in-situ observational networks are relatively inexpensive, current observation systems are outdated and underfunded. Improved models are not useful without the relevant

[10] A comparison of oceanographic measurements at a 25°N. transatlantic section suggests there has been a 30% slowing in Atlantic meridional overturning circulation between 1957 and 2004. There is also a reduction in southward transport of lower North Atlantic deep water. The heat transport by oceanic currents substantially contribute to moderating the climates of maritime and coastal Europe. Bryden, H.L., H.R. Longworth, S. A. Cunningham, 2005, Slowing of the Atlantic meridional overturning circulation at 25°N., *Nature*, v. 438, p. 655-657.
A New Scientist article points out the changes are so big there should be some reaction of the climate of Europe. One possibility is that the warming trend in Europe during the 1990s, thought to be caused by global warming, seems to have halted. Pierce, F., 2005, Falling ocean current raises fears of mini ice age, *New Scientist.com news service*, http://www.newscientist.com/article.ns?id=dn8398

long-term datasets necessary to parameterize or validate them. In addition, long-term calibration of data is required.

- **Understanding climate behavior at finer scales.** The impacts of climate change will be felt on a local scale. Efforts to understand and predict how climate change will affect people are hampered by an insufficient ability to model regional effects. Using downscaling techniques can help. A number of efforts are underway to perform dynamic downscaling, that is, using nested dynamic models to refine GCM results into a higher resolution model for a small area. This is computer-intensive, and there is not yet a supercomputer with enough capacity to do this globally. Some current efforts have focused on statistical downscaling. This is less computationally intensive but requires at least 30 years of data, which can be used to determine the statistical relation between the large scale meteorological effects forecast by the computer model projections and the local effects. Norway has successfully performed a statistical downscaling, aided by data from their comprehensive system of meteorological stations. This reinforces the need for longer, better observational datasets. The Norwegian downscaling has helped to show that Arctic effects are real. Finer spatial scales can produce a much more accurate representation of environmental changes, which will help identify the extremes, particularly on regional levels.

  For instance, the danger posed by rapid climate change (that is, a change to the climate taking place in only a few years) could be catastrophic on a local scale. Agriculture could be destroyed and the economic base of communities could be threatened because they do not have time to respond. This type of rapid climate change may not show up well in the geologic record, such as sediment cores, because of its short duration. However, rapid climate change has been observed in ice cores.

- **Better melt models.** Using the B2 scenario, scientists project a 3° to 6°C increase by 2080 for Greenland. The IPCC projects that at 3°C or more, Greenland may melt over a timeframe "in excess of" 1000 years, but the uncertainty is very high. Melting of the Greenland ice sheet would raise sea level approximately 7 meters (approximately 23 feet).

- **Scenario accuracy.** Some discussion arose over the accuracy of the IPCC scenarios, which were developed about a decade ago [these were actually prepared in 1998 and 1999], built to support IPCC 2001, and which are being kept largely intact for IPCC 2007. It was suggested that the IPCC develop scenarios based on the knowledge that has been gained in the last decade. The great majority of the scientific community believes that the degree of warming in the future will depend on energy use, which depends on the size of the population and the size of the economy. It was remarked that the B2 scenario has performed within the error of the scenarios in population and energy over the past 10-to-15-year period and has provided a middle estimation. [The methodological error does not affect CO_2 emission estimates to a significant degree. See CICERO report cited in footnote 14]

- **Cause and effect.** The foreign policy impacts of Arctic warming must be evaluated. Mitigation is at best a long-term effort. As the international community comes to grips with climate change it will take both mitigation and adaptation actions. However, the effect in the Arctic is going to continue for many years regardless of what is done right now. This is due to the long residence time of CO_2 and other greenhouse gasses in the atmosphere and the long time it will take for the ocean to equilibrate with the warming. Regardless, reduction in the introduction of greenhouse gasses will have an effect in the long run.

Science, Policy, People and Transportation

Scientific evidence suggests that Arctic warming is a current phenomenon that is likely to accelerate. It incorporates a vast number of significant changes and dramatic consequences on many sectors at many scales. This gives rise to questions of understanding, adaptation, and mitigation. A variety of perspectives were presented at the workshop.

1. Science Needs

The International Polar Year (IPY), sponsored by the International Council of Scientific Unions and the World Meteorological Organization, is being undertaken because large-scale environmental change and its effects, on both physical and human dimensions, must be understood. It is an interdisciplinary and internationally coordinated campaign of research and observations designed to deepen our understanding of polar processes and their global linkages. The different languages and cultures in the Arctic can make cooperation difficult. However, cooperative scientific and diplomatic activities are important to improving strategies to adapt to change and to affect those changes where appropriate. One of the most critical scientific issues is the need to acquire additional data for long-term studies and to validate and improve the models.

A global approach must be taken because no one nation can afford to conduct the needed observations and research alone. Global partnerships must be extended or developed for observation and scientific analysis. The Arctic is one place where U.S. interagency cooperation is codified in law (15 U.S.C. Ch. 67, Arctic Research and Policy). NSF, the Departments of Defense, Energy, the Interior, Commerce (especially NOAA), State, Transportation, Health and Human Services, Homeland Security, NASA, the Environmental Protection Agency, the Office of Science and Technology Policy, and others such as the Smithsonian Institution all must work together.

The Observation Network

- **Study of Environmental Arctic Change (SEARCH).** Currently, U.S. Arctic research activities are focusing on SEARCH, a study of environmental change in the Arctic, the program being developed to understand the complex suite of changes that have occurred in the Arctic in the last decade. SEARCH is a broad interagency, multidisciplinary effort that incorporates a long-term observation program, a modeling program, studies of feedback processes, and assessment to determine impacts to culture and human populations. Primarily, SEARCH will establish networks of observations. Other projects include CEON (Circumarctic Environmental Observing Network) and ASOF (Arctic/Sub-Arctic Ocean Flux Array). These studies, which include modeling, synthesis, and work on the freshwater cycle, are important to our understanding of the thermohaline circulation and other processes. Measurements must be taken at all chokepoints to better understand the dynamics of freezing, thawing, changes in current, and the opening and closing of navigable passageways. Likewise, measurements must be made of freshwater input areas. These observations are essential to document and quantify changes in the environment and to validate models. For example, the timescales upon which open water cycles vary must be understood. A difficulty is that we must make decadal observations, but NSF grants tend to be 3 to 5 years.
- **International observation stations.** The U.S. maintains observing stations in Alaska and in Arctic waters. A need for more stations in Russia and elsewhere in the Arctic is evident. Some existing international stations have been operating since the 1930s and are in dire need of repair and upgrading. Some have failed and some have been burned. The future of Arctic research is

an international matter and will increasingly require international agreements to ensure data compatibility and exchange.

- **International collaborations.** Global observations, in the form of a sustained, integrated earth observation system, are critical. The U.S. strongly supports the activities of the Global Earth Observing System of Systems (GEOSS). The United States have been working since 2002 with numerous countries to establish GEOSS. In February 2005, 53 nations came together in Brussels to sign a document to cooperate on GEOSS. An example is a global tsunami monitoring system, integrated across countries, that includes not only monitoring but also an information dissemination system. The railroad system in Europe is a good analogy: it consists of many national components working together as part of a system. The United States sees this as critically important for the Arctic. If GEOSS is established, it will provide us with the scientific underpinnings to make important policy decisions.
- **Reporting stations.** Stations must exist both under the ice and over the ice. Observatories typically have 1 to 6 years residence times in Arctic waters. They ultimately flow out into the North Atlantic. Twenty observatories could cover the Arctic area, but they must be replaced as they become inoperable, obsolete, or flow out of the area of interest.
- **Security.** We must have accurate locations for observation stations at all times, so that nuclear submarines do not collide with them.

Models

- **Regional model.** ACIA found that it is difficult to quantify potential marine access and navigation using current global climate models. High quality Arctic regional climate models are needed.

Education and Outreach

- **Outcome from the 1957 International Geophysical Year (IGY).** Some of the best results of the IGY were educational. The upcoming International Polar Year can benefit education, including support to undergraduates in research programs, engage diverse communities, and further develop longstanding relationships.
- **Community relations.** A research cruise in the Beaufort Sea was a humbling experience, where the scientists and ship's crew did not talk to Eskimo whalers before setting out and nearly ran through their whaling grounds. Congressional leaders reprimanded the scientific team. The scientific community has used the incident as a lesson to improve communications and community relations. This has proved to be very important because the indigenous people know much about their environment and information they provide has considerable value.
- **Areas of potential improvement.** While international relations work well among scientists in most areas, relations with Russia could be improved, particularly in areas such as research clearance and obtaining data and information. Some scientists reported that when working in Russia their computers are confiscated and that there have been problems with crime. Some scientists suggested the Department of State could be more helpful. Russia makes up half the Arctic rim, and any study of the Arctic must include Russia; therefore, better scientific relations should be established with Russia and a better environment for scientific research should be fostered with the Russians.

Security

- **Department of Defense (DOD).** The Navy has reduced high-latitude research. DOD policy for this Arctic should be reexamined in light of changing environmental conditions. With the current capabilities and procurement trajectories the U.S. military may have limited capabilities in the Arctic.
- **Reviewing existing security related studies.** The result of analyses such as *Naval Operations in an Ice-Free Arctic*[11] and others should be reassessed and needs should be prioritized to identify the most important actions that must be undertaken. This information should be used to help develop budget priorities.
- **More open water means more traffic.** Security must be considered in light of the changing natural and cultural (including economic) environment in the Arctic.
- **Search and rescue.** Increased fishing, improved access and resulting resource exploitation, and increased scientific efforts result in greater exposure of people and equipment to dangerous conditions. Additional search and rescue assets will be necessary.
- **Homeland Security.** Increased traffic and improved access potentially makes the Arctic another route for terrorist activities.

2. Policies and Agreements

The Arctic is a region with eight sovereign nations plus indigenous peoples. There are a variety of institutions that have been created over the years to manage the conflicting interests of these parties. Each party has its own specific environmental issues, including warming, the transport of chemicals, wildlife, etc. There is no single international treaty that covers all areas; for instance,he polar bear treaty is between five nations and probably covers the most geographic extent, but it is very specific, and all portions are related to the polar bear.

Selected Existing Policies *(Not all nations participate in all agreements)*

- **Polar Bear Treaty.** Established to preserve the polar bear and its habitat in Alaska and Chukotka and regulate the harvest of polar bear for subsistence by native people.
- **London Dumping Convention.** Regulates international dumping and incineration of wastes.
- **Stockholm Convention.** Regulating persistent organic pollutants (POP).
- **Long Range Transportation of Air Pollution (LRTAP).** Treaty between the Northern Hemisphere nations to regulate long-range transport of trace constituents (Long-Range Transport of Air Pollution) including POP.
- **Framework Convention of Climate Change and The Kyoto Protocol.** These agreements address global warming. The U.S. is party only to the Framework Convention.
- **The Law of the Sea.** The most important existing treaty to operational activities and claims in the Arctic, particularly under conditions of increased Arctic navigability, is the Law of the Sea (LOS). It is often referred to as the Constitution of the Oceans. Under the treaty, coastal

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[11] William, Bradley, and Brown, Inc., 2001, *Naval Operations in an Ice-Free Arctic Symposium, Final Report*, Office of Naval Research, Naval Ice Center, Oceanographer of the Navy, and the Arctic Research Commission, http://www.natice.noaa.gov/icefree/FinalArcticReport.pdf.

countries are provided with a 12-mile territorial sea and a 200-mile Exclusive Economic Zone, with the possibility of a 200-mile continental shelf extension beyond economic zone including use of continental shelf under ocean. Nations have 10 years after becoming signatories to the LOS treaty to make submissions describing their extensions beyond the economic zone (unless they signed before the Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf were adopted in 1999, then they have 10 years from the time the guidelines were adopted). Russia was the first country to submit a claim under Law of the Sea for the Arctic region. Under this treaty, the results of the Arctic commission are purely advisory. The U.S. is the only one of the eight Arctic nations not party to the Law of the Sea. However, President Bush supports ratification, so the status of the U.S. may change. This treaty has the support of the environmental community, the petroleum industry, and the current administration. The question was raised, what should be created to supplement the Law of the Sea? The possibility of an ice-free Arctic also raises the concern that there is insufficient clarity with regard to archipelagos in the Law of the Sea. Two agencies, the USGS and NOAA, which provide scientific information needed for the U.S. to evaluate claims under the Law of the Sea, do not receive funding directly to support this activity and are experiencing budget constraints, particularly geological research.

Soft-Law and Cooperative Agreements

"Soft laws, in international relations, are international agreements not concluded as treaties and therefore not covered by the Vienna Convention on the Law of Treaties."[12] Examples of soft laws are the Barents Sea agreement in Europe, and the Arctic Council. Soft law arrangements are generally more flexible than treaties and can form the basis for future relations among nations or groups of nations. However, soft law does not have the legal standing of treaties or conventions.

- **Barents Sea Agreement.** The agreement between the governments of Iceland, Norway, and the Russia Federation concerning certain aspects in the area of fisheries is designed to ensure the long term sustainability and utilization of fish stocks in the Barents Sea. It gives the nations a possible opportunity to manage fish stocks outside a regional fisheries organization.
- **The Arctic Council.** Dating from 1986, The Arctic Council is the most important forum for work in the Arctic. It is an intergovernmental forum established to address many of the issues faced by the Arctic nations. Designed to encourage cooperation among the national governments of Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, the Russian Federation, Sweden and the United States. The indigenous populations have the status of Permanent Participants of the Arctic Council and are represented by the Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Conference, Russian Association of Indigenous Peoples of the North and the Saami Council. The Arctic Council meets every 2 years, supports studies of regional and topical interest, and provides a forum for exchange of ideas, raising issues of importance to the Arctic region and the participant nations.

Other Issues

- **Territory.** An accurate description of the physical geography of the Arctic is critical for Law of the Sea and other agreements. This includes coastline, topography, bathymetry, and geologic

[12] Hillgenberg, Hartmut, 1999, A fresh look at soft law, *European Journal of International Law*, v. 10, no. 3, p. 499-515.

mapping. Current mapping of all of these is insufficient to meet emerging needs under Law of the Sea and other existing and potential agreements. The Arctic seafloor covers a large poorly mapped area.

- **Suggestions for new agreements.** Some participants suggested it would be useful to increase nongovernment organizational participation in international agreements.
- **U.S./Russia agreements.** Fisheries and maritime boundaries will increasingly become issues as Arctic warming causes a changing Arctic environment.
- **U.S. views of global and Arctic climate issues.** Some participants felt that the conflicting views in the USA on global climate, Arctic warming, and other related issues could put the USA in a poor negotiating position in the future.

3. Population

Arctic Societies and Cultures: Future Scenarios and Current States

- **The Arctic Human Development Report (AHDR).** Though the AHDR is not part of ACIA, it was produced in parallel and was also sponsored by Arctic countries. This document is the first comprehensive assessment of human well being for the entire Arctic region. As such, it addresses Arctic human development and Arctic society and culture. The AHDR is an assessment of the current situation and does not contain predictions. However, this information may allow us to make some informed guesses.
- **Indigenous people and science.** Indigenous people can help verify model results through observations and help improve scientists' understanding of the environment by working with scientists and scholars to critically understand native lore.
- **Rapid change is sweeping the Arctic.** Native peoples are particularly aware, saying, "The earth is faster now."
- **Dichotomy of indigenous vs. non-indigenous.** Some discussion about Arctic society and culture takes an indigenous vs. non-indigenous approach. There are subtleties within this dichotomy, including recent and early immigrants. "Old settlers" have been in place for some time, and are often very closely linked to Arctic resources in terms of inhabiting the same space and often in relying on the environment for part of their livelihood.
- **Arctic populations.** There are approximately 4 million residents of the Arctic, half of whom live in Russia. The next highest population is in the U.S., followed by Norway, Finland, and Canada. ACIA divides the Arctic into four subregions: this is a useful geographical distinction in that it illuminates subregional changes, but from a social and political standpoint, we must consider that half of the Arctic is Russian. The Russian Arctic has experienced rapid population decline since the dissolution of the USSR (mostly in the non-indigenous population—the indigenous population has mostly remained flat), while most of the Arctic hasn't seen much change. The Russian Arctic population was largely maintained at its previous level by policies of the Soviet Union before it collapsed in 1989.
- **Urbanization.** There are a few large cities in the Arctic, the largest being Murmansk in Northern Russia. Typically, other population centers developed around resource extraction areas (principally oil and fishing areas). In general, there is an urbanization trend throughout the Arctic, particularly in Alaska and Iceland. Anchorage, Alaska, has developed dramatically;

it contains large populations of indigenous peoples. Many indigenous people are moving to urban areas. This reduces the population of indigenous speakers in the many communities from which they came. Once the population falls below a certain point it will be difficult to maintain the indigenous languages. Populations moving to urban areas may not concentrate insufficient numbers to maintain the language there from generation to generation.

- **Language retention.** Inuit populations show a language retention rate of 83%, but this number does not reflect huge regional differences. In western Canada and Alaska the language retention is very low. Many languages won't survive much longer; several have only a few hundred speakers remaining. It is estimated that only 10 Arctic languages will remain by the end of the 21st century. The Russian language has the highest proportion of speakers in the Arctic.
- **Importance of languages.** One aspect of language retention that is particularly salient to this discussion is that if environmental conditions are completely different, it is difficult to convey old knowledge. Language is often based on environmental conditions, and environmental knowledge may be lost.
- **Unknowns.** The effect of cumulative changes on social conditions and well-being: Arctic communities are resilient and adaptive, but now, with continued rapid social and environmental change, it is questionable whether they will be able to adapt to new environmental realities without outside intervention or without being eliminated. Scientists were surprised that there were too few data on non-indigenous residents for important analysis because ethnographical fieldwork has focused on the indigenous population. More data are needed on the non-indigenous population.
- **The future of Arctic populations.** The Arctic will grow economically and demographically. If local communities have a feeling of empowerment, they are more likely to do something about the changes to their environment. If the Arctic warms, there are likely to be more oil extractive industries, and indigenous peoples may be very eager to become involved in them. The population will likely be open to other opportunities as well. However, indications are that much of the population will still want to continue its subsistence activities.

  In general, throughout the north, indigenous groups have higher fertility rates compared to other populations in the same country, but, everywhere, particularly in Russia, there are higher death rates as well. Higher fertility will put increased pressure on the educational system and employment opportunities for the youth will be an increasing concern.

  Climate change in the Arctic is a cause for cultural change. It is likely that changing climate will affect the continuation of some cultural activities such as traditional hunting and fishing and the attendant crafts and social structure. Only recently has the threat to language diversity attracted attention.

  The population in the Russian Arctic is declining and is likely to continue unless there is a new policy to populate the Arctic or economic opportunities expand and people are lured there to improve their economic condition.

4. Transportation

Transportation and access will have the most profound effect on the Arctic. This includes access to resources as well as transport of those resources and other commodities into, out of, and through Arctic waters. All of this activity will also have significant security implications.

Perhaps the largest international issue related to transportation is the potential opening of an Arctic sea route from the Atlantic to the Pacific via the Arctic. This route would be significantly shorter than current routes through the Suez and Panama canals and would be able to accommodate larger ships. The distance from northern Europe to Japan can be reduced by up to 45% by taking the Northern Sea Route (see figure 1).

Ice Transformations of Importance to Transportation

- Extent: ~3% decrease per decade
- Multiyear Ice/Perennial Pack Ice: ~7% decrease per decade
- Thickness: 14 to 32% reductions reported (a 40% reduction has been reported by U.S. Navy transit).
- General increase in the length of the ice melt season

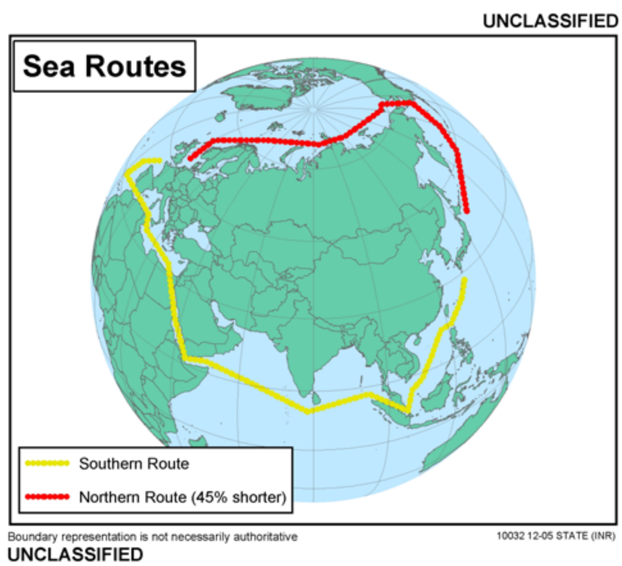

Figure 1. The Northern Sea Route (NSR) over Russia is likely to open before the Northwest Passage. The distance from Northern Europe to Japan is 45 percent shorter by the NSR than by going through the Suez Canal. Redrawn by U.S. Department of State from the International Northern Sea Route Programme http://www.fni.no/insrop/defaultINSROP.html.

Arctic Access

- **A warming Arctic is likely to mean greater marine access to the Arctic regions.** Greater access, not merely greater transport possibilities. 75% ice cover is considered quite open, 50% is "like a superhighway", and 25% is essentially open. The region of the west Arctic will be the last area in which ice will disappear. There is likely to be an increase of a few more days of access available per year but it is unclear how long that trend will continue. It is not yet known to what extent there will be open water in the summer. There is considerable variability from year to year.
- **Current access.** There has been long-standing access by nuclear submarines to the Arctic. Surface ships have had access in summer. According to one workshop participant, the Arctic had the 24th lowest ice extent in the summer of 2004. [Although that is not a record it is part of a downward trend that includes 2005. "With the exception of May 2005, every month since December 2004 has seen the lowest monthly average since the satellite record began. Although sea ice records prior to late 1978 are comparatively sparse, they imply that the recent decline exceeds previous sea ice lows. Current levels of Arctic sea ice are likely the lowest they have

been for the past few centuries."[13]] Between 1977 and 2004: 52 transits to North Pole, (42 Russian, 4 Sweden, 2 Germany, 2 USA, 1 Canada, 1 Norway), 5 trans-Arctic voyages through the Northwest Passage, none through the Northern Sea Route. Most have been scientific efforts. There has been year-round navigation in the area of Norway since 1979.

- **Significant Arctic marine access during summer 2004**
  - 8 icebreakers to the North Pole
    - (5 tourism, 3 science)
  - International Arctic Ocean Drilling Program
    - (3 icebreakers Central Arctic Ocean)
  - Canadian Arctic Voyages (107)
    - Canadian Vessels 62
    - Foreign Vessels 32
    - Canadian Government Vessels 8
    - Northwest Passage Transits: Canadian Coast Guard 2
    - Northwest Passage Transits: Foreign Cruise Ship 1
    - Northwest Passage Transits: Foreign Yachts 2
  - Northern Sea Route Voyages (estimated)
    - 52 Vessels, 165 Voyages
    - 1.75 million tons of cargo
    - No NSR transits
  - Large Cruise Ships, Greenland 27
  - Icebreaking Research Vessel Operations 6
- **Icebreaker fleet.** There are approximately 60 true icebreaker ships; most are old and are in deteriorating.
- **Will transport be unescorted by ice breakers in the future?** The types of ships built for use in the Arctic will depend on the economic viability of Arctic transport, the access to Arctic resources and ability to export them, alternative uses of the ships during the times that Arctic access or transport is infeasible, agreements between nations, security and safety, and apportionment of risk (economic, safety, etc.) among governments and private industry.

Science Issues Related to Navigation

- **Sea ice extent and inter-annual variability.** Insufficient data are available to use as a basis for forecasting the extent of sea ice. The decrease in the extent of sea ice is visible from observations, but the 50-year record is insufficient to accurately identify decadal and greater time-scale oscillations. While some of the models show no summer ice in the future, most merely show a negative trend. However, there will always be winter ice in the Arctic. For

[13] NASA, 2005, Arctic Sea Ice Continues to Decline, Arctic Temperatures Continue to Rise in 2005, http://www.nasa.gov/centers/goddard/news/topstory/2005/arcticice_decline.html. (Accessed January 18, 2006)

much of the region, there will be a few meters of ice to plow through. All of the ice in the Arctic is dynamic, and less ice cover means more ice moving around.

- **Model resolution.** The global climate models are difficult to apply and have limited value in regional and local decisionmaking. Many of the features of interest are below the resolution of the models. For example, models do not convey the complexity of the Canadian archipelago, where inter-annual variability is extraordinary. All trends in sea-ice extent are negative, but there is considerable variability. These issues are not addressed directly in ACIA. The model outputs show decreasing summer ice.
- **Mapping and charting needs.** Plots of submarine tracks do not coincide with bathymetric knowledge. In at least one case the track intersects with a mapped seamount. Improved bathymetric data are needed throughout the Arctic for submarine navigation and for surface ships as well. The navigation charts are generally poor and out of date. In addition, accurate navigation charts are unavailable for regions becoming newly opened to navigation. Coastline data are inaccurate in many instances and must be mapped or remapped.

Security Issues Related to Navigation

- **Department of Homeland Security and Coast Guard.** Responsible for security issues, the coastline and maritime laws; increased transportation will mean potentially increased access to the United States and its assets by terrorists and illegal aliens.
- **Regulatory issues/unfit ships traversing the Arctic.** 27 large cruise ships were voyaging in the area of Greenland during 2004, none of which is ice-strengthened nor is any designed for operation in the polar region. Iceberg monitoring will become an increasingly important issue if more ships are entering the Arctic.
- **Search and Rescue.** Search and rescue activities, already difficult in the Arctic, will become an increasing problem. No clearly defined responsibilities have been established. The Navy becomes the responsible party by default. Will Navy assets be sufficient to address the need should Arctic navigation increase substantially?
- **Panama and Suez Canals.** Increased Arctic access creates competition for the Panama and Suez Canals; some ships are already too big for the Panama Canal. Ships that are big enough to be ice worthy may be too big for the Panama and Suez Canals. The Panamanians are planning to enlarging the locks again and have held discussions with Arctic experts regarding the potential of future shipping in the Arctic and how that might affect shipping elsewhere.

Sectors

1. Petroleum Private Industry Concerns

The oil and natural gas industry articulate support for responsible action to address climate change; efforts to reduce uncertainties; near-term, cost-effective, and voluntary actions such as efficiency increases; and long-term technological development.

Involvement of the Oil and Natural Gas Industry in the Climate Change Arena

- **The American Petroleum Institute (API) climate challenge.** 100% of members develop greenhouse gas management plans. They estimate and report their own emissions.

- **Expand the use of natural gas.** Natural gas is clean burning. Capturing natural gas makes sense, particularly because methane is a gas with a significantly greater greenhouse effect than CO_2 and releasing it into the atmosphere would have significant environmental effects. Also, efficient capture and distribution of natural gas provides another source of revenue for the petroleum industry.
- **Technological approaches.** A technological approach to reducing greenhouse gas emissions is CO_2 capture, a bridging technology, focused on enhanced oil recovery. The petroleum industry already has significant technological experience in this area. Other areas of research include advanced automotive technologies.
- **Partnerships.** The oil and natural gas industry is pursuing partnerships with government agencies and research partnerships with academic institutions to help reduce global greenhouse gas emissions.
- **Global reporting guidelines.** Industry emissions reports should be globally consistent; it is difficult to estimate and compare the emissions from one facility, let alone many, using different protocols. API is promoting SANGEATM , an emissions estimating system developed by Chevron, for use throughout the petroleum industry. API promotes it as an automatic data management system that allows an operator in a refinery to estimate greenhouse gas emissions. [Note: mention of any product does not constitute endorsement by the Federal government.]

Climate Change and the Arctic

- **Factors affecting the Arctic environment.** Chemical contamination, over-fishing, land use changes, population growth, and governance changes are issues affecting the Arctic environment.
- **Human and natural factors.** Translating human activities to climatic impact is difficult. Each step requires a different modeling effort. Even the definition of a climatic impact is not clear.
- **The oil and natural gas industry in the Arctic.** It is difficult to speculate on the impact of a changing Arctic on the oil and natural gas industry because of the uncertainties in the time frame. It can be up to 100 years before there is sufficient access to some petroleum resources. In 10 years we are likely to see a fully functioning system transporting oil and natural gas from some northern regions; however, we can only predict a regional transport, not trans-Arctic shipping. For instance, movement of gas from Siberia can be estimated, but only regionally.
- **Reliability.** Projecting access to and conditions of local areas is critical because there is a long lead-time needed for petroleum development and it is costly. Economic risk must be minimized if development is to take place.
- **Intergovernmental Panel on Climate Change (IPCC).** The IPCC does not assign numerical probabilities to its results. Natural variability, natural drivers, feedback, and point estimates in the models are not included by IPCC. As well, IPCC contains some very unlikely input, such as the overstated GDP growth in some developing countries, and population estimates that are well beyond UN estimates. (For example, if the IPCC projection were followed, by 2100 the U.S. would be poorer than North Korea.) API believes the IPCC is a political group. [The IPCC is a scientific group with oversight by governments.] CICERO published the results of a simple model analysis that accounted for methodological errors in some IPCC model input scenarios. It showed that estimated CO_2 emissions in 2100 are reduced by 38% to 50%

(depending on which scenario is used) from the IPCC estimates. [Note that CICERO subsequently reported on October 18, 2005, that methodological errors in the estimates used by the IPCC do not result in inflated emissions estimates. Therefore those reductions do not exist.][14] However, future CO_2 concentrations and temperature are less influenced by the choice of GDP measure.

- **Uncertainty in emissions growth.** More rapid growth in China than originally expected may lead to China surpassing the U.S. as the greatest emitter of greenhouse gases. The relationship between CO_2 and temperature is non-linear. Improved understanding of the impacts and risks of increased CO_2 concentrations will help in decision making. However, recent research has reported a 70% probability that an atmospheric concentration of 500 ppm CO_2 will result in a 2°C warming—this kind of research is very pertinent to the discussion.

2. Energy (Oil and Gas)

- **Currently producing Arctic areas.** Russia's Timan-Pechora and north west Siberia areas; Alaska's North Slope and Beaufort Sea.
- **Current or past exploration and possible future production.** Alaska's North Slope and continental shelf; north east Russia; Russia and Norway's Barents Sea; Norwegian Sea; offshore Greenland; offshore Faroe Islands; the Canadian High Arctic and Canadian Beaufort Sea. See figure 2.

Oil and Gas Activities

Existing facilities will be affected, and new development will have to take into account climate change effects such as thawing tundra and coastal erosion, as well as increased access to offshore resources. A warming Arctic will affect all of the following stages of oil and gas production:

- **Exploration.** Offshore marine surveys, exploration wells, field work, and seismic surveys.
- **Development.** Existing infrastructure due to changing structural properties of geology (thawing permafrost, coastal erosion, increased icebergs, etc.); new infrastructure; developing new platforms and rigs.
- **Production.** Wells, including some injection wells, infrastructure including everything from housing to roads to airstrips, waste disposal, storage, and ways to get the gas out (ships, ports, pipelines, and rail).
- **Decommissioning.** Removing everything or at least stopping production, which requires more effort now than it did in the past.

Engineering can overcome the problems associated with oil and gas activities. Engineering solutions will improve as engineers gain additional experience.

[14] Holtsmark, Bjart, 2005, Methodological errors do not result in inflated emissions estimates, *Cicerone 4-2005*, Center for International Climate and Environmental Research (CICERO), Oslo, Norway, http://www.cicero.uio.no/fulltext.asp?id=3783&lang=en.

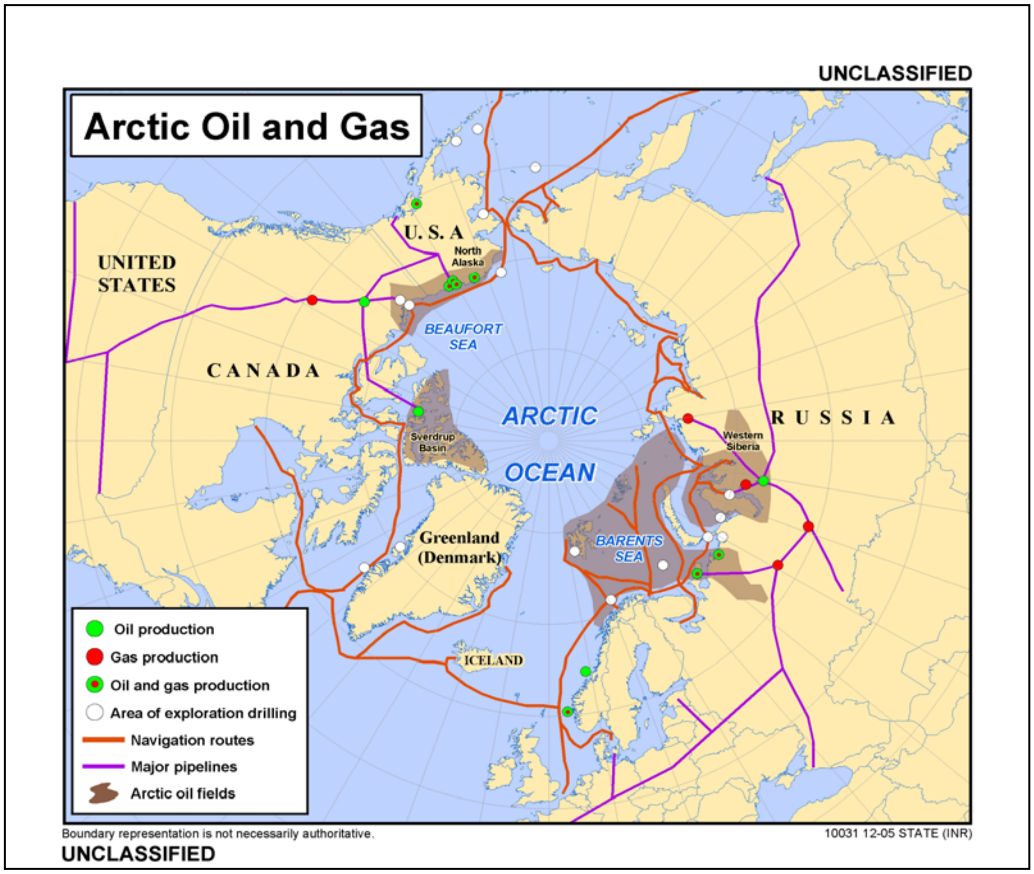

Figure 2. Oil and gas fields of the far north. Redrawn by the U.S. Department of State from the Arctic Monitoring and Assessment Program and other sources.

Challenges to Arctic Oil and Gas Production

- **Operating in the Arctic.** Originally, the Arctic was opened up by technological development. It is cold, dark in the winter, and remote, all of which contribute to dangerous operating conditions. Environmental/political sensitivity, cultural and social effects, and the complicated system of permitting for the Arctic add to the extremely high costs, even before considering the complications posed by global warming.
- **Two Types of U.S. Arctic Oil and Gas.** Offshore, which is managed by Minerals Management Service (MMS), and onshore, which is managed by the Bureau of Land Management. Of the 58 offshore exploration wells, only one is currently producing. Offshore Alaska has 600 million acres of land potentially available for lease for oil/gas exploration. Onshore there is a 23½-million acre national petroleum reserve in Alaska in which 16 wells have been drilled in recent years, and oil production from some wells is expected soon. The state of Alaska has 3.6 million acres currently under lease for oil and gas, and 3,500 active wells on the North Slope are producing a total of 1,000,000 barrels per day.
- **Meeting the challenges of a warming climate.** All management must be based on high quality science. MMS carries out independent research in the Arctic, hiring researchers from

around the world. The adaptive management technique, an approach that allows for the use of new technology and inputs from research and monitoring and feeds changes back into the management system, is particularly important.

Programs, Studies and Plans

- **Arctic Council Guidelines.** Environmental Assessment Guidelines (1997); Guidelines for Arctic Offshore Oil and Gas Activities (2002); Arctic Marine Strategic Plan (2004); Assessment of Potential Effects of Arctic Oil and Gas Activities (due 2006).
- **Guidelines for Arctic Offshore Oil and Gas Activities.** Guidelines were developed for Russia, used by Greenland. Arctic Council has been helping deal with issues of oil and gas in the environment by issuing guidelines for Arctic offshore oil and gas activities.
- **Arctic Marine Strategic Plan.** It is an overall strategy for the Arctic marine environment. The plan looks at the whole rather than small parts. It parallels the Ocean Commission's report but takes a larger view to integrate a management system so that all activities are complementary. Russia was not at the table for these discussions.
- **Arctic Monitoring and Assessment Program (AMAP).** Addresses oil and gas activities in the Arctic—where have they occurred, are occurring, or may occur 10 years in future. It is doubtful we can estimate beyond 10 years. Other issues being addressed in AMAP: social and economic consequences; sources, inputs, concentrations, and fates of petroleum hydrocarbons; effects of pollutants; effects on organisms and on populations, habitats, and ecosystems.

3. Fisheries and Mammals

Most Arctic fishing takes place in the shallow seas around the Arctic: along the Greenland coast on both sides, and in the Barents and Bering Seas. Late summer ice cover prohibits fisheries in other areas of Arctic.

Regional Arctic Fisheries

- **Greenland.** The waters offshore Greenland are classified as low productivity due to a short growing season, limited extent, and limited light penetration due to ice cover. However, the primary production is efficiently converted to higher trophic forms of fish, marine mammals, and sea birds. This results in a fish population that has supported a robust fishing industry. Important fish are shrimp, Greenland halibut, snow crabs, cod, scallops, and other fish products.
- **Barents Sea.** The Barents Sea is north of Norway and west of Russia and has an ecosystem based on diatoms, krill, capelin, and cod. Capelin are the foundation for all larger creatures. In 1986 the capelin population collapsed to a tiny fraction of the total biomass, and the fishery was closed in the 1990s. The low capelin population starved the cod; when the capelin rebounded, cod rebounded.
- **Bering Sea.** The Bering Sea is a high productivity zone locally due to upwelling taking place near the edge of the shelf. The copepods feed on diatoms; the pollack feed on the copepods. The fishery oscillates between finfish and crab; the salmon fishery is also very important. Farmed salmon is big competition for the Alaskan wild salmon fishery. The salmon dollar value has deflated some, and the tonnage of the catch is variable. Trawl fisheries for pollack and others show slight variability. Pollack is a fairly newly fished species; in the Bering Sea

catch, pollack is dominant in both tonnage and dollar value, although some smaller catches are more valuable by weight.

Effects of Climate Change and the Ecosystem-Based Approach

- **The difficulties of the ecosystem-based approach.** In Alaska the collapse in the sea-lion population has led to the closing of some fisheries—the inference made by some policy makers was that this collapse was due to the crash in sea-lion food species; however, this assertion is uncertain because the ecosystem is not well understood. This lack of understanding illustrates how difficult it is to manage from an ecosystem approach. Additional scientific information is needed to support this approach.
- **Effects on mammals.** Climate change and walrus population: if the ice recedes too far from the clam beds on which the walrus feed, mother walrus will have to abandon cubs or feed cubs less often. This population is sensitive to changes in climate: the ice edge moves faster than the population can adapt. The walrus is used by the native human population and is subject to international agreements. As the environment that supports the walrus changes it will affect indigenous people and will be cause to reexamine existing international agreements. Effects are being seen in whale populations as well. This changing environment is cause to reexamine any existing agreements on Arctic mammals. Marine mammals, for instance, are abundant in the region and their protection will require international oversight as access increases.
- **Ice changes.** Observations indicate there is an increasing amount of first-year ice in the ice cap, which means that there has been a major reduction in multi-year ice. As ice cover changes it will permit photosynthesis and fisheries in new places.
- **Changes in fish populations.** New species are entering the area. Salmon are now reported spawning in the Colville River on the North Slope. There had never been a previous sighting of salmon there within the memory of the indigenous people.
- **Shallow waters.** The potential productivity of the Arctic marginal seas is unknown but they can be expected to be about as productive as the current Bering and Barents Seas (Class II, moderately high, 150 to 300 g $C/m^2/yr$) or perhaps higher.
- **Chemical contamination.** Chemical contamination (especially PCBs and mercury) is a very sensitive issue. The whole Arctic region is deficient in information on contamination. A recently published AMAP report on contaminants in the Arctic provides details on contamination. Scientists must have very strong evidence for contaminants in fish before they publish results because there will likely be objections to those claims. Less than 10% of samples in marine mammal tissue bank have been analyzed for contaminants.

Regulatory and International Issues

- **Agreements.** The following are some unresolved issues that will affect fisheries. The U.S.-Canadian boundary in the Beaufort Sea area is not resolved (6,100 square nautical miles are in question); the Russian Duma has not yet ratified the U.S./Russia maritime boundary agreement. The United Nations Convention on the Law of the Sea (UNCLOS) claims may affect fisheries outside the EEZ by protecting the bottom against trawlers and/or fixed fishing gear.
- **Safety.** Navigation, up-to-date charts, search and rescue plans are lacking. There are no Coast Guard differential GPS beacons north of Cold Bay.

- **International resource exploitation.** It is likely that non-Arctic nations will exploit international waters (particularly Asian countries: China, Japan, Korea); resource exploitation may conflict with other uses. Interference with subsistence activities will face vigorous opposition.
- **Telecommunications.** High latitude (above 75°N) radio propagation is often erratic, and geosynchronous satellites are not effective for high Arctic communications. However, polar orbiter coverage is frequent and dense. The polar orbiter constellation may provide an opportunity for improved telecommunications.
- **Resource exploitation.** Especially offshore, oil and gas drilling and recovery may conflict with other uses.

4. Environment, Forestry and Agriculture

The Arctic and boreal regions are the most ecologically intact areas in the world. They are major contributors to the global carbon (greenhouse gas) balance. They store as much carbon as is in the atmospheric reservoir. These areas have a large tourism value, are major contributors to the carbon balance of the planet, and are potential agricultural expansion areas. These areas are inhabited by native peoples who are developing a sense of grievance for the problems they are experiencing maintaining traditional lifestyles. The boreal forest regions are potentially capable of supporting enhanced agricultural production under climate warming, but that may compromise their capability to sequester carbon.

Environmental Aspects of the Arctic and Boreal Regions

- **Boreal forest regions.** The boreal region on both continents is affected by advection of heat by ocean processes. It is inaccurate to use latitude alone to delimit the boreal region. Boreal regions are, for the most part, ecologically intact; other comparably intact regions are deserts, but deserts have significantly less primary productivity. The darker color and surface roughness of these trees aid absorption of incoming solar radiation, which may add a couple degrees to planetary temperature that smooth snow cover would not.
- **Significant energy and mineral deposits in the area.** Energy and mineral resources must be competitive with other regions on basis of cost, etc. in order for extraction to be feasible.
- **Carbon storage.** Boreal forests store about half of the world's terrestrial carbon. Fossil fuel emissions and land clearing in the tropics reduce the carbon storage capacity there and are contributing to a buildup of carbon in the atmosphere. Ocean and terrestrial plant uptake of carbon is 2.3 gigatons (Gt) each. Humans are emitting 7.9 Gt, and so the net release of carbon is 3.3 Gt. The terrestrial function is of great importance in absorbing excess carbon; 15-30% of emissions are taken up annually and stored there. We must keep the forests healthy so they do not lose their carbon storage capacity. The boreal forests of Eurasia and the temperate forests of North America are gaining uptake carbon, but the boreal forests of North America are losing carbon uptake. Evidence shows that at a sufficiently high global temperature trees would not be able to grow; the plants growing in their place would not be nearly as efficient as carbon sinks. [Ordinary plants produce a significant amount of methane. This release of methane is not accounted for in current climate models. This may affect our understanding of coupled earth systems and the dynamics of forests in storing carbon. Although there are suggestions on how

this will affect the Kyoto Protocol, this is unclear and requires improved understanding of the processes involved.][15 16]

Effects of Climate Change

- **Water balance.** Increases in precipitation do not keep up with increases in surface temperatures. The net movement of evapotranspiration vs. precipitation renders commercial forest scraggly and unusable. The parkland-prairie zone will expand through the middle of Canada due to warming. Water deficits are likely to appear in most boreal regions. Exceptions include eastern Canada, Iceland, and western Scandinavia. As warming progresses, water stress will negatively affect crop yield unless irrigation is practiced. Water limitations will become more of an impediment to crop yields than temperature.
- **Agriculture and Growing Season.** Several stations, including Fairbanks, Alaska, have seen a 50% increase in the growing season, to 120 days. Today there is commercial agriculture on several thousand farms in northern Canada and Alaska. There is considerable subsistence farming as part of subsistence life style. The cooler areas are hospitable to potatoes and forage. In warmer areas grains and oilseed crops are grown. Dairy cattle and sheep are on the decline and diversified livestock are on the increase (bison and other native animals). Rising temperatures may make (almost certain) crop production viable farther north. Crops that are currently only suitable in the warmest parts of the Arctic will be grown northward to and beyond the Arctic Circle as the climate warms. Average yield of farms is likely to increase at lower levels of warming as higher yielding crops can be grown and there are lower possibilities of limiting temperatures.

  In the warmest areas increased heat may cause a slight decrease in crop yield. In addition, warmer temperatures speed up crop development and decrease the time available for organic matter to accumulate.
- **Forests and Reforestation.** In general, change produces both negative impacts and positive opportunities. Societal impacts are relatively low in a resource, even a relative large resource, if the goal is to allow the resource to change with environmental conditions. Societal impacts are large if people have made investments based on expectations of the availability or condition of the resource.

  If the climate changes according to what the IPCC scenarios and current trends indicate,

  - The commercially productive boreal forest is not a sustainable resource in the boreal plains of Canada, east Siberian taiga, and interior Alaska.
  - Climates that would permit forest growth would occur in places that currently are too cold for survival or reproduction of trees.
  - Actual tree line advance is likely to take place from decades to centuries after the change in climate because seed disbursal and seedling establishment are also limited by factors other than climate.

  Iceland's boreal forest has been reduced to 1% of their land, and they have begun an effort to afforest 4%, retiring agricultural land to establish forests. Severe winters have reduced tree

[15] Keppler, F., J.T.G. Hamilton, M. Bras, T. Rockmann, 2006, Methane emissions from terrestrial plants under aerobic conditions, *Nature*, v. 439, p. 187-191.
[16] Lowe, D., 2006, A green source of surprise, *Nature*, v. 439, p. 148-149.

survival and short summers reduced tree growth. 21st century scenarios are favorable for forest development; it is projected that Iceland will become a net carbon sink.

- **Effects on the Canadian forests.** Canadian wood is high quality and low cost. The U.S. and Canada have some trade disputes over wood production. Large areas of the Canadian forest are committed to be commercially forested. While warming may increase the growth rate, it will also make forests more susceptible to insects and disease, for instance, bark beetles, which had their largest single outbreak in 2004. Insect growth is faster under warming conditions and they have more of an impact. The Eastern Canadian temperature is rising, which is favorable for tree growth.

  The normal storm track is moving northward, which causes an intensification of warm dry air masses in western North America. Canada experienced a high number of wildfires, particularly during the 1990s and 1980s. Record temperatures have been recorded in western North America during recent years. In 2004, 184 million hectares, approximately 8% of Yukon forests, burned.

National Views

Note: these views were stated by various participants in the workshop and do not necessarily represent the official views or the nations' governments, or workshop recorders, compilers, or other specific individuals at the workshop.

National policies are quite different when dealing with northern regions.

The Arctic vs. the Antarctic

The Arctic, Bering Sea, and the high North Atlantic are wild and remote. Most people distinguish the Arctic from the Antarctic by their fauna—bear or elk in the Arctic and penguins in the Antarctic. Physically, the Antarctic is a continent surrounded by ocean, while the Arctic is ocean surrounded by continents. The Antarctic is treated as a preserve, and primarily scientific expeditions get to the South Pole, although some adventure expeditions have undertaken the effort. On the other hand, the Arctic is accessed by all border nations. Border nations are impacted by changes in the Arctic and must adapt.

The International Polar Year, 2007-2008

The International Polar Year is a great opportunity to raise awareness about polar social, ecosystem, and climate issues. It is dedicated to earth science and will engage a new generation of earth scientists, social scientists, and policymakers. This will leave a long-standing legacy: an observation system that will illuminate changes taking place at both poles. We need to think beyond our national borders to a new level of cooperative science.

1. Canada

Some people believe Canada must progress from data collection to appropriate analysis, then to address issues related to the "Northern Dimensions"—it is time for substance and time to declare a victory over process.

Canada's Forest Resources

- As Saudi Arabia is for oil, Canada is for wood.

- Trade disputes over wood stocks are one of the greatest issues in U.S./Canada bilateral relations. Canadian production is efficient, high quality, and inexpensive and a grave challenge to lumber producers in northern tier United States.
- Ownership, goals, and administrative responsibility are changing in the northernmost Canadian forest.
- Large areas of primary forest in Canada are committed to eventual harvest. They look undisturbed now but will be cut to honor agreements.
- Warming is increasing growth in some Canadian forest types while stresses from drought, fire, and insect disturbance are big challenges to the forest production system.

Canada's Approach to the Arctic

- **Canada's Northern Dimension.** The Northern Dimension of Canada's Foreign Policy is a recent policy document that puts the North on the agenda. It remains to be seen the extent to which it will inform future policy. The policy statement was recently reassessed. The current policy has four points:
  - to enhance the security and prosperity of Canadians, especially northerners and Aboriginal peoples;
  - to assert and ensure the preservation of Canada's sovereignty in the North;
  - to establish the circumpolar region as a vibrant geopolitical entity integrated into a rules-based international system; and
  - to promote the human security of northerners and the sustainable development of the Arctic.

  There are also four priority areas for action:
  - Strengthening and promoting a central place in circumpolar relations and policy coordination for the Arctic Council.
  - Helping to establish a University of the Arctic and enhance the circumpolar policy research network.
  - Developing and expanding opportunities to work with Russia bilaterally and multilaterally.
  - Promoting the study and practical application of means to develop sustainable economic opportunities and trade.
- **Five factors affecting the future.** Federalism, demographics, policy drift, infrastructure, and leadership.
- **Human dimension.** Canada's approach over the last 15 years has been to put a human face on the Arctic. This has been achieved, and it seems as though Canada should be moving on but is not. Canada has a relatively small population in the Arctic, but the human dimension in the north is a big element in Canada's policy. The goal is to turn over more resource control to indigenous peoples, but the tools are not yet in place to complete this task.
- **Data and infrastructure.** The lack of data in this region is a real problem. There are not enough observation buoys. The thermohaline circulation is under-observed. There is no dedicated Arctic research institution in Canada. Thus far, money has been directed toward

organizational processes, but now we must move to building the infrastructure. For example, there are no Canadian deepwater ports in the Arctic.

Canadian Arctic Foreign Policy

- **What does the Arctic mean in Canadian foreign policy?** Canadians' current view of the Arctic, as in "this is Arctic, this isn't," leads to the Arctic being treated as a boutique issue, which can get disaggregated from the rest of Canadian foreign policy and from global issues such as climate change. Canada and the other Arctic nations must ask what the Arctic means to China, to Africa, etc. They must ask what the Arctic means to the global community in terms of economics and security. What does the Arctic mean in terms of security in a post-September 11, 2001, world?

2. Denmark / Greenland

Greenland has extensive autonomy from Denmark, as Greenland controls all its own domestic policy and most of its international policy. Greenland has had homerule for 25 years. Dialogs such as this workshop are essential so that we may all know each others' concerns.

The Greenland Economy, Culture, and Climate Change

- **Fish.** The Greenland economy is primarily fish dependent, like other Arctic countries. More than 95% of the economy depends on exports of fish products. Climate change has critical importance; for example, the shrimp population is very sensitive to temperature changes. In the 1980s, when the cod fishery collapsed, the Greenland economy switched to shrimp.
- **Climate change.** Greenland is feeling the effects of climate change today. The country is oriented geographically north to south. As a practical matter it is impossible to grow crops in the north. If the fishermen are no longer able to support themselves on fish, they have very few other options. The sea did not freeze over the 2004-05 winter season, forcing desperate seal hunters to kill their sled dogs. At present the government must provide support for people in the north. If climate change means people can't support themselves (hunters, fishers), it will mean the acceleration of the loss of Greenland's culture. On the positive side, an unfrozen sea will mean increased shipping abilities, cheaper shipping, and more accessible mineral exploitation.
- **The need for more research.** Research is needed to determine what will happen to the ecosystem of Greenland, what it will mean for animals, and what the threats are to human health (contaminants, cancer, diet changes, and cardiovascular disease). Cooperative research with other Arctic nations will help to determine some of the unknowns.
- **Boundary issues.** Greenland and Canada disagree on ownership of some lands, and each has taken actions aimed at bolstering its claim.

3. Finland

Finland and the ACIA

- **Finland is preparing its own national approach to climate change.** ACIA was produced when Finland was at the final stages of preparing the Finnish report on climate change. Finland is taking the ACIA very seriously and incorporated it into Finland's national approach to climate change. Finland's report on adapting to climate change covers 12 sectors, lists plusses and minuses of climate change, then suggests adaptations on different timescales. This report is like a study book and will be provided to sectors. That report will be available in English in September. Finland is a part of the EU, and the EU is very active in the climate change arena.

- **Long-term issues in the ACIA.** The public is asking what the government's approach is to the bigger issues. Long-term issues include effects of climate change on the Gulf Stream, the thermohaline circulation, and Antarctica, as well as national economic and environmental issues.

Finland and Climate Change

- **Finland has great variations in climate.** The climate in Finland has been warming, but it is still within the bounds of natural variability. There is a debate in Finland over what is human induced and what is natural variability. Finland is discussing the issue of cause and effect, and the issue of what should be done.
- **Greenhouse gas concentrations are getting higher.** There is steady physical evidence of this. In the national adaptation strategy Finland is saying it should have two responses: adaptation and mitigation. Mitigation is needed to guide us to the safe side. Uncertainty can play in both directions; we must watch and respond in a responsible way.
- **Finland has been moving ahead with research and monitoring.** Finland has a CO_2 observation station in Lapland. It studies cloud formation to enhance the understanding of the role of clouds for climate modeling.
- **Finland as part of the EU.** The EU is of the view that we should address the risks; if warming is approaching 2°C the EU and the rest of the world are at risk for severe impacts. Finland and the EU should guide their efforts globally—there is genuine interest within the EU to discuss views of risks globally and regionally with other parties. The Arctic assessment is one of the necessary regional assessments. However, a 2°C increase in Finland would be welcomed by some sectors.
- **Timescales.** There has been discussion about the slowness of the systems, both natural and human (economic, financial, etc.). We must act early to overcome the inertia in the systems, because there may be costly impacts from delay.
- **Action.** Finland is planning to take action wherever warranted.

4. Iceland

Iceland is the only Arctic state with all its territory within the Arctic. Iceland does not have an "Arctic foreign policy;" it has a foreign policy.

Iceland used to be one of the poorest countries, and had terrible famines, but now it has a booming economy and the population enjoys a high standard of living. It achieved this change by making use of its abundant natural resources and the expanding pool of technologies available to facilitate the exploitation of these resources. As reported at the workshop, the Icelandic attitude is, "in the changing Arctic environment we must dwell on opportunities as well as risks."

Iceland and Climate Change

- **Climate change will affect the economic underpinnings of Iceland.** Climate change for Iceland is not only an ecological issue but a significant economic one as well. The ocean is important in energy, fisheries, and marine transport, and any implications Arctic climate change has on these three sectors will affect Iceland's economy. Ocean resources are so important that fishing and fish products account for more than 62% of Icelandic exports. Evidence points in the direction of global warming, but scientists are still missing too many variables to project the impact of a warming climate on different areas.
- **Forests.** There is a national goal to afforest 1% of the country per decade until 4% is forested. That will convert some agricultural land to forests. This area will become production forests, protection forests, and amenity forests. Non fossil-fuel energy production and conversion of agricultural land to forests give Iceland a very favorable carbon dioxide balance. While current cold winters are unfavorable to tree survival and cold summers stunt tree growth, increased temperatures under global warming would be more favorable to tree growth and to more productive agriculture.
- **Open shipping routes.** Iceland can serve as a gate between the Atlantic and the Arctic. This could work effectively for transshipment and for refueling stopovers.

Iceland and Future Efforts

- **Ecological research.** Iceland believes countries and communities must both expand and intensify ecological research. Governments must cooperate by pooling resources to work for a better integration system. Icelanders have always been closely linked with marine transport and access to resources. The Icelandic government has invested resources in the area of increased shipping.
- **Arctic foreign policy.** It is a mistake to reduce Arctic foreign policy considerations to the implications of Arctic warming alone; the Arctic could transform into a zone of cooperation if states have room to maneuver. The Arctic will remain a region of great importance for security, and as more assets become accessible, there will be growing prominence of this region.
- **There is no circumpolar forum for Arctic transport.** This means that transportation may be inefficient and difficult for the ocean transportation industry due to differing regulations from nation to nation.
- **A permanent secretariat.** In order for the Arctic Council to effectively deal with changes in the Arctic a permanent secretariat would be needed. The Arctic Council, given its constraints, works quite well; we should think twice before throwing institutional solutions at Arctic problems. There is homework to be done in raising awareness of the Arctic within our own governments. We need to bring more government agencies onboard, we should continue mainstreaming Arctic issues within relevant international organizations where our governments are active, and we need to put the Arctic in its proper foreign policy perspective.
- **There is opportunity here as well as risk.** People in Iceland have long contended with difficult conditions, and now the challenge is to overcome these changing conditions. Icelanders can use the progress they have achieved in the 1970s as an example: to overcome difficult conditions by drawing on human resourcefulness and technology and trying to raise the level of economic and sustainable wellbeing.

5. Norway

We must remember we are the first generation to influence climate and the last generation to escape its consequences.

In Norway the entire population is "indigenous" to the Arctic, while only 400,000 people in Norway technically live in the Arctic.

Climate change is only one of many issues in the overall understanding of the Arctic—globalization and transport are just as important. The discussion of climate change in the Arctic has focused on all the problems—it is not obvious to someone in Norway that it will be bad if it gets warmer!

Norway and Natural Resources

- **Petroleum.** In the Arctic are large untapped petroleum reserves. These resources will be developed; changes in pack ice will be significant as a driver to stimulate development. The Barents Sea has the largest offshore gas field in the world. A shift in sea ice of only a few kilometers has enormous impacts on the development of this area. Changes in pack ice will have economic impacts of billions to hundreds of billions of dollars. However, sea channels are not sufficiently open today to affect immediate petroleum exploration and ship construction. In general ships are not built for the future, ships are built for the current situation. Therefore, ships will not be built for an open Arctic—they will be built to get through the pack ice.
- **Fisheries.** It is extremely difficult to predict what sort of fisheries will exist in future. There isn't enough knowledge to do this anywhere—policy decisions for the future cannot be based on current information. There may not be more productive fisheries in the future; the Arctic sea is low on nutrients. The Arctic Ocean does not produce today, because it is covered with ice, and it may not produce in the future because of its low nutrient content.

Norway and the Future

- **The thermohaline circulation.** Currently, Norway is 5-10% warmer than it would be without the influence of the Gulf Stream. Clearly, any kind of variation in the thermohaline circulation would cause large problems. This is an area of high uncertainty, but it is not possible to have certainty on any issue. Decisions must be made taking uncertainty into account.
- **Data.** Long-term data sets are critical. Models come and go, but good data persist.
- **The International Polar Year.** The IPY has the potential to leave us with an improved legacy of Arctic cooperation. The IPY can be used as a vehicle for international policy in the Arctic and globally, just as the International Geophysical Year of 1957 resulted in significant cooperative policy advances.

6. Russia

The major political and social upheavals of the 1990s affect decisions relating to the Arctic region. The largest Arctic land area and population are in Russia. The northern sea route is likely to open in Russian waters before the Northwest Passage over Greenland, Canada, and the United States. This makes sea transportation an important opportunity and issue for Russia. Meanwhile, the population of the Russian Arctic is decreasing as the policy to populate that area has been relaxed.

Natural Resources

- Russia has a vast forest area (763 million hectares), which contains approximately 25% of the global wood volume and 57% of the global conifer volume. The mean diameter of trees in Siberia is 10 inches (24 cm), relatively small for timber. There have been exceptionally large fires in recent years.
- Vast oil and natural gas resources are currently being exploited, though not to the extent possible. Pipelines have a reputation for leaks and poor construction and maintenance. Frequent spills are an environmental hazard.
- Poor water quality has been noted in Russian Arctic rivers.

Technological Resources

- Russia currently has the most icebreakers and is building Arctic worthy vessels.

Foreign Policy Issues

- Russia has acceded to the Kyoto Protocol. This will provide Russia an opportunity to benefit financially from exchange of carbon credits and has made a commitment to management of carbon stocks because of the amount involved.[17]
- Russia is making submissions under the Law of the Sea for extensive offshore regions.[18]
- Further study in this area would be valuable.

7. Sweden

Multiple influences affect populations, not just climate. Sweden is taking Arctic warming seriously. It has observed northward migration of forests. There are benefits and hazards associated with Arctic warming.

Sweden and Arctic Change

- **The ACIA.** Multiple interacting influences make Arctic warming extremely complicated, with broad implications. The ACIA report has been widely recognized, and the EU council of ministers has expressed concerns about its finding.
- **Feedback mechanisms.** Changing albedo and the release of CO_2 and methane affect global climate change significantly. We need more research and better models to understand feedbacks and other mechanisms, more cooperation from Arctic countries, and to seek to understand the measure of conflicts.
- **Increased Arctic access.** Less ice cover will lead to increased opportunities for Arctic marine navigation and oil and gas development. As well, forests and forestry are expanding north, may

[17] An area the size of Germany and France combined has begun melting in the Russian Arctic. This has the potential to release a large pulse of methane into the atmosphere. The quantity of methane is not yet calculated but it is possible that this could offset a part of their carbon reserves. New Scientist, August 11, 2005, http://www.newscientist.com/article.ns?id=mg18725124.500

[18] In September 2005 the Russian transport vessel Akademik Fyodorov traveled to the North Pole without an icebreaker escort. This is the first time in recorded history any ship has been able to do so. This was possible due to the drastic thinning of the Arctic ice that has taken place in recent years. The ship carried scientists who measured the edge of the continental shelf, information needed for submissions under the Law of the Sea.

have conflict of interest with native peoples who are already being affected in other ways by climate change.

- **International interest.** Other countries (Japan, South Korea, etc.) may be interested in Arctic uses and should be involved in international policies.
- **Action on mitigation.** Scientific uncertainty over the rate and magnitude of climate change should not delay action on mitigation. The key to addressing this is continued and invigorated action; we must share responsibility and build international framework. Industrialized countries must take the lead in this as described in Kyoto, by reducing greenhouse gas emissions. Kyoto ends in 2012, so action after that date needs to be planned for.
- **Sweden is working on a report like Finland's.**
- **Foreign policy.** There may be a need for new types of legal instruments to address the changes we are facing in the Arctic and globally.

8. United States of America

There is an undercurrent of urgency with the changes that are sweeping the Arctic. Yet in the U.S., it is often difficult to see the Arctic as other than a "boutique issue," because such a small part of the United States population lives there. Even with Alaska, it is not a major driver of foreign policy. Although the United States is very active in the Arctic the question of appropriate level of effort is open because of the increasing potential economic, environmental, and security issues arising from environmental change.

The United States has been active in the Arctic Council and continues to support its efforts but believes the Arctic Council is not the place to solve all Arctic related policy issues. Some require hard policy negotiations in a formal diplomatic setting.

Environmental Conditions

- Observable coastal erosion is taking place in Alaska because the decrease in sea ice no longer protects some of the coasts from wave action and storms during part of the year. This is affecting existing oil wells. These can be protected by engineering means.
- The number and extent of lakes has decreased in some areas. Disappearance of snow cover has trended earlier by 15 to 30 days between 1950 and 2000 at Barrow, Alaska. There have been measurable retreats in Arctic glaciers.
- Borehole temperature logs indicate that near-surface permafrost of the Alaskan Arctic coastal plain and foothills has warmed approximately 3°C since the late 1980s. Discontinuous permafrost is warming (0.05° to 0.2°C per year) and thawing. Extensive areas of subsidence are occurring due to thawing of ice-rich permafrost. Days per year when offroad travel is permitted have decreased from 1970 to 2002 (available records) due to changes in permafrost.

Technology and Infrastructure

- Engineering and technology can overcome changes in terrestrial environmental conditions for transportation and resource exploitation; however, the technological fixes may be expensive.
- If ocean transportation activities increase in the Arctic, the United States must rely on other countries for icebreaker capacity, as the U.S. icebreaker fleet is insufficient to support all U.S. polar interests at present.

- A request for the Alaska Area Research Vessel (AARV) was included in the FY 2006 Federal budget proposal. The AARV is needed as part of the fleet renewal process. Still, many workshop participants believed that Arctic science and technology did not receive sufficient consideration in the annual Federal budget process in view of the significant changes taking place there and the magnitude of their potential implications.

Arctic Policy

- Continue to use the Arctic Council for the exchange of information and ideas. However, it is not a policymaking body.
- The U.S. is committed to partnering and to assessing the affects of Arctic change on the ecosystem, societies, etc.
- Three main goals:
    - Support the International Polar Year.
    - Focus on SEARCH to understand significant atmospheric, oceanic, and environmental changes in the Arctic having direct and indirect repercussions on human society.
    - Strengthen observations through the international effort of the Global Earth Observing System of Systems.
- There exist many opportunities for the U.S. Government and various sectors of U.S. society to participate in the benefits of changes in the Arctic and to help reduce the negative effects.

9. Nations Outside the Arctic

- Important questions to consider are: What does Arctic-warming mean to nations outside the Arctic region? How would changes caused by Arctic warming affect economics, foreign relations, trade and transportation, and energy dependence on other nations?
- Some nations outside the Arctic are viewing Arctic warming as an opportunity to reach resources previously not accessible.
- In order to gain support for an Arctic foreign policy by nations outside the Arctic, there must be a clear link to their self-interest. For instance, without such a link it may be difficult to pique the interest of a nation like China for 20,000 hunters living off the land in the Arctic when China itself has to care for more than one billion people. Both commercial interests such as shipping and the global concerns such as the Arctic being the "canary in the mineshaft" for global warming are needed to pique the interest of China and other nations. A following comment suggested putting Arctic issues in a global context and selling Arctic issues globally. It is unnecessary to sell Arctic issues to China, as they have a vigorous Arctic program, and they're interested in the teleconnections between the Arctic and drought in Inner Mongolia. Arctic nations must recognize the interests beyond their borders.
- Extractive industries will be the major players in a more accessible Arctic. These are transnational corporations that are motivated by profit for their investors. They influence the activities of national governments.
- Security issues must be considered because of the inevitable exploitation of natural resources when access increases. Fish wars, arguments over who owns natural resources, and who can

transit through what straights are all possible. It is not likely all Arctic nations will be willing to demilitarize the Arctic, as was done in the Antarctic.

10. Defining and Studying the Arctic

- **Defining the Arctic.** Defining the boundary of the Arctic from a scientific perspective is difficult: one can define it by the annual seasonal cycle, the Arctic Circle, the flora or fauna such as the extent of tree type or boreal forest, extent of ice and permafrost, cultures that inhabit northern regions, national policies, or any of a number of other definitions. Unlike the Mediterranean, the Arctic has ill-defined boundaries. Some workshop participants believe that in dealing with Arctic issues we should avoid specific boundary definitions that make the Arctic sound so unique that it is marginalized. The Arctic Ocean is the most land-dominated of all the oceans. Water comes from the south, frequently from outside the Arctic, because rivers are northward flowing. This encourages a broad view, as the Arctic waters are fed by areas not considered Arctic.

  The Arctic concerns are far broader than merely the marine issues of the Arctic Ocean. A flexible forum could be established, comprised of the different agencies and organizations with interests in the region, whether or not they are part of the region. It is important to discuss the affects of the region, not only on itself but also on the rest of the world. Also, nations could work together on a regional basis to conduct regional assessments like the ACIA of different parts of the world. Thus, a better understanding of the regions and the whole world could be gained.

Breakout sessions

US government workshop participants broke into brainstorming sessions to identify issues in three themes: science, foreign policy, and security. The results were not considered recommendations but rather ideas to help identify options to improve our understanding of and our adaptation to the changing Arctic environment.

1. Science

Discussion

The key requirement is to measure the rate of changes in the environment and the interaction among the causes and effects. How regional changes are related to global change are not understood in most cases, and it is difficult to clearly prove a regional change is an indicator of global change. The scaling of changes (global, regional, local) also depends on the biophysical variable (temperature, precipitation, wind field, ecosystem component, etc.), or socioeconomic variable of interest. It is of great importance to have the ability to project global environmental changes onto a local scale as well because many adaptation decisions will be made at that scale.

A holistic approach is needed. Fragmented approaches have led to incompatibility of data and analyses, missed opportunities to share resources to reduce costs, and duplication of effort. The current trend toward holistic research and assessments should be continued. A technologic roadmap based on the science needs must be developed with multiple users in mind.

Better methods for funding scientific activities should be developed. Short-term projects (3 to 5 years) are insufficient to address long-term problems. There should be a mix of projects and programs with reliable funding at short, intermediate, and long time scales.

Overall, polar research is infrastructure intensive and limited.

Monitoring

- In many cases there is a lack of continuity in long-term records. For instance, NASA's long-term records are sporadic. Satellite measurements started in the 1960s, but gaps exist because programs are of limited duration and the measurement systems change. There is also a need for ground-based measurements to check the validity of the satellite data. It is also important to determine how the satellite records can be related to ground data collected before the satellite era.
- Long-term monitoring is a key element in assessing climate change. The WMO (World Meteorological Organization) monitoring protocol is valuable, but it has often not been adhered to. Some past records have problems. For example, snowfall in the Arctic is difficult to measure because of blowing and drifting. The ability of compare different climate records over various time periods and various locations is difficult as well.
- It is important to improve our long-term understanding of change by merging early data with the more recent data. Extended data sets should include realistic margins of error. Merging and extending data sets into the 1800s would provide valuable insights into change. A methodology must be developed to interpret very old records for the Arctic. Low density of data, sporadic nature of the records, and the unique collection methods must be addressed when merging and calibrating data sets.
- Monitoring and modeling efforts should rely on direct measurements wherever possible.
- Land cover change is important for policymaking, planning, and scientific modeling and analysis. There is a need for a consistent approach in obtaining land cover data and crosswalk data acquired for specialized applications. The 1-km resolution is too coarse for many applications.
- Synthetic aperture radar (SAR) is important for monitoring ice. The U.S. does not have a satellite that collects SAR data. The Canadian SAR satellite, Radarsat, is operating beyond its design lifetime.
- Boreal Forest records:
  - Methods to monitor and model forests in temperate zones may not translate well to the Arctic.
  - There should be more standardization of methods to monitor and analyze boreal forests and their processes so the diverse changes could be more easily compared and understood.
  - Measurements appear to diverge—for example, tree records may not always correlate with other historical records. This is a concern for recovering previous historical records.
- Permafrost monitoring is critical due to its affect on Arctic terrestrial species, importance in new and retrofitting engineering (oil wells, pipelines, roads, etc.), carbon sequestration and release issues, affects on the hydrologic cycle, and biogeochemical dynamics. This includes developing and adapting new methodologies and technologies (potentially radar), gaining better and more extensive measurements.
- Ocean monitoring:
  - More Arctic buoys are needed and a better geographic distribution should be implemented.

- Monitoring of the gateways to the Arctic must be improved.
- Monitoring of the thermohaline circulation must be improved.

- Satellite systems:
  - European Space Agency data are available but are of a coarser resolution. As navigation increases, near-real-time day and night remote sensing monitoring of ice will be crucial. This must include the ability to see through clouds.
  - Even some polar orbiting satellites do not observe very high latitudes. However, due to the orbital characteristics of most polar orbiting satellites, the Arctic is heavily monitored. Still, not all variables needed for Arctic research or operations are monitored and some are not monitored at the appropriate resolution. Polar needs should be evaluated and incorporated into the design of new systems.
  - 10- to 25-m resolution as well as 250-m resolution is important as are large swaths (500 km).
  - Continuity of data collection is important.
- A readily available catalog of monitoring techniques should be developed so data may be interpreted correctly.

Modeling

The IPCC emissions scenarios should be updated as new information is available. The IPCC developed a very large-range suite of scenarios and that would most likely capture the quantity of emissions that will be realized in the future. Each of the scenarios developed led to some degree of warming. The models have improved over time but some must still be "tuned" to ensure their fidelity with actual conditions. It is important that they have the ability to simulate past climates. Models must be recognized for what they are, that is, models. They are not a substitute for actual observation.

- Global parametric modeling is useful but a deeper understanding of and further research on the underlying physical processes is important.
- Better approaches to modeling regional conditions should be developed.

Research and Analysis

New knowledge will be needed to make adaptation more effective:

- Research and results must be understood in the context of geologic time scale. Analysis and assessments must use this as a backdrop, as it is relevant in providing context.
- Urgent effects/processes to study and understand are
  - Albedo (ice, snow, tundra, forests, etc.). How does this affect design of land cover schemes?
  - Carbon sink. Improved understanding of carbon sinks is required, particularly in light of permafrost changes and migrating forests. Timing, quantity, and other attributes should be better understood.
  - Methane emission. This may be a problem as permafrost melts.

- The effects of thresholds and non-linear systems are important. For instance, survival and reproduction of various species must be understood under conditions of complex change. Our ability to plan for changes such as the interactions of biotic species with each other and the environment must be enhanced. Tipping points can have cascading effects in this changing complex environment.
- The thermohaline circulation must be better understood—if some hypotheses are correct, changes in this circulation pattern could profoundly change weather and climate in a relatively short time.
- Solar cycle and Earth magnetic field changes must be better understood for their implications to a changing environment and their implications to adapting to the changing environment.
- Social science theory and understanding must be part of studies of the impacts of changes in the environment to anticipate changes in society and to help optimize adaptation options.

Data Management

- There is need for a consistent approach in constructing data sets.
- Data must not be lost as they have been in the past.
- Data must be accessible, such as land data at EDC and snow and ice data hosted by NOAA and NASA. Long term archival and distribution capabilities must be designed as part of the system design and funded for the long term.
- Methods must be developed to ensure that data are intercomparable. This can include standards, transformations, or other viable techniques.

Cooperation

Large-scale disturbances can have dramatic transborder effects. Some include spread of disease and invasive species, wild land fire burning and changes in carbon cycle, aerosol dispersion, and changes in cultural phenomenon such as industrial and agricultural bases. Improving our understanding of these and boundary transcending issues requires international cooperation in scientific research.

- International, interagency and interdisciplinary cooperation is needed:
    - Measurements and science priorities must be consistent.
    - Techniques must be consistent.
    - Data collection, calibration, and validation standards should be defined.
    - Ground truth data should be mandatory with projects.
    - Provisions must be established for archiving and data sharing.
    - Methods and data must intercomparable.
    - Systems will be most cost effective and scientifically effective if they are interoperable.
    - Scientific activities should use a “ground to sky” approach.
    - The GEOSS umbrella could be considered for this but GEOSS will not be effective if there is no incentive to participate.

- Need international commitment for measuring sea ice, temperature, weather, land and biota.

Communication

Better methods of informing the public about environmental issues must be developed.

2. Foreign Policy

All nations should identify opportunities and necessity for traditional diplomacy and new methods. Both will be important as the Arctic warms and environmental changes cascade through the system.

The major immediate activities will be adaptation to the changes that are taking place and the development of resources.

New analysis and creative techniques must be developed to understand how we can adapt to issues across regions, countries, and cultures.

Possible grievances:

- Could nations' populations drive national policy to negatively affect their relations with other nations because of real or perceived responsibility for warming, loss of traditional lifestyles, or other internal concerns?
- What if there are negative economic consequences such as fisheries collapse or major new pollution sources?

Resource development issues:

- Environmental safe and sound development—will new agreements be needed? Bi- or multilateral?
- How will the international community handle pollution from developing resources, increased transportation, and industrial expansion?
- Would the Arctic become the poster child for oil spills?

China and India's need for resources and industrialization will increase greenhouse gasses and their demand for petroleum. The Arctic is a logical source.

Positive issues include innovative arrangements such as:

- Leasing across borders.
- International partnerships in leasing.
- The U.S. and Canada have no unique innovative arrangements and have a disputed boundary in the Arctic. Other nations have disputed boundaries as well. Will greater access to those regions raise the specter of conflict?

Who will take, and how will they take, search and rescue responsibilities? Is this a new opportunity for international cooperation to help build bridges rather than walls?

Will the US ratify the Law of the Sea? Must settle question of who owns the continental shelf

Joint collaboration may be developed in many areas including scientific work, operational observation, environmental responsibility, etc.

Basic scientific research and applied research must be done collaboratively

- There are many opportunities to collaborate—little opportunity or capability of going it alone.

- A U.S./Russia Science and Technology Agreement would be a valuable asset for all the nations of the Arctic. [After nearly 3 years in the making the U.S. and Russia exchanged diplomatic notes to extend by ten years the bilateral Science and Technology Cooperation Agreement on January 13, 2006. The exchange took place during a short ceremony at the Russian Embassy. This extension promotes the continuation of the long-term cooperation begun during the Nixon Administration. The current agreement expires in 2015.]
- Assessments of submissions under the Law of the Sea require scientific information.
- Conducting scientific work to assess submissions under the Law of the Sea in waters north of Russia raises the potential for conflict; for instance, do we need permission of Russia to conduct the work? Some scientists believe Russia acts as though we do. Russia is more capable of working in that environment than the United States.

Organizations specific to the Arctic, such as: International Arctic Science Committee, Arctic Ocean Sciences Board, International Union for Circumpolar Health, and International Arctic Social Science Association should be enlisted to help understand the changing conditions and help develop options to aid nations in dealing with the changes taking place in the Arctic.

The Arctic is a potential source of methane from hydrates, both in terrestrial and marine environments. A consortium of nations and industries interested in hydrates has begun to grow, as have independent activities. With new access becoming available and the potential for methane release into the atmosphere due to melting permafrost, international research efforts should be encouraged on a “pay to play” basis.

Policy on global warming affects our other policies

- U.S. appears to take conflicting positions on matters of global warming and Arctic polices.
- Tony Blair, Prime Minister of England, said that the U.S. should think about working with other countries on global warming if it wants other countries to work with it on terrorism.

ACIA

- The cause and effect issue inhibits rational discussion about Arctic warming.
- It is clear that something is happening in the Arctic and that it is major.

3. National Security Issues

There are several topical areas of political friction:

- Resources (fisheries, oil, gas, coal, minerals).
- Shipping (routes, rules, protection).
- Borders (Exclusive Economic Zone, binational).
- Homeland security.
- Non-Arctic nations’ interests in resource exploitation.

There are a number of geographic areas of potential conflict:

- Sino-Siberia.
- North Korea—Sea of Okhotsk.
- China (drought).

- North Slope Security—Department of Homeland Security.
- Non-Arctic nation exploitation of resources.
- China's industrialization, expansion.

In relation to climate, the Arctic is like a canary in the mineshaft. What if the canary does not die and just gets sick?

Should a national intelligence assessment be conducted on Arctic warming? In order to conduct one it must be requested by a high authority. One of the methods is to conduct another workshop with expanded participation. If one is requested, the purpose must be stated carefully, such as assessing maritime security in an ice-diminished Arctic or identifying the national policy issues in an altering Arctic environment.

There are a number of logistical concerns (areas requiring action):

- U.S. icebreakers are not sufficient to maintain an operational presence in the Arctic.
- Communication in the Arctic is difficult because of environmental conditions and currently established technical capabilities.
- Navigation and navigation aids are not sufficient for commercial traffic.
- Ship design should be evaluated to determine the most economical and effective method of meeting expanding Arctic needs.
- The international fleet is not sufficient for full-scale Arctic commerce. Ships take a long time to design and build and are very expensive. Still, a clear evaluation of need must be made. U.S. Navy does not have the capacity to operate effectively in an expanded Arctic role.
- There is a very limited land and sea force trained in Arctic operations.