Climate Change in the Alaskan Arctic and Subarctic : A vast Panorama of Comprehensive Environmental Change

Testimony to U.S. House of Representatives, Committee on Science and Technology

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Mr. Chairman and members of the Committee. I would like to thank you for the invitation to present some information to the Committee concerning recent climatic changes, their current effects, and the likely future situation in the Arctic and Subarctic. I have been assisted in preparing my presentation by senior colleagues at the University of Alaska in subjects related to climate change of interest to the Committee.

I have had the opportunity to work with these colleagues in teams involved in integrated climate change assessment, and they have provided publications and data for this presentation. I have attempted to restrict my characterization of their findings to these sources, but if further clarification is required I will convey the issues back to them for a definitive response.

I also recently had the opportunity to accompany Mayor Stanley Tocktoo in recent meetings and testimony before Congress, and he generously shared information from the presentation he used which was assembled by the community of Shishmaref, Alaska.

The focus of my presentation is the American portion of the Arctic - in Alaska. For a comprehensive review of the whole region, especially the background setting and processes of this unique part of the world, I refer the Committee to the Arctic Climate Impact Assessment:

www.acia.uaf.edu

This written statement is meant to accompany the Powerpoint presentation I have provided the Committee, which has maps, graphics, citations, and other specific details.

1. **Permafrost.**

One of the unique features of the Arctic and Subarctic regions is the extensive presence of cold soils and permafrost. Permafrost is soil and ground material that remains frozen for more than a year. Permafrost forms when mean annual temperatures are below freezing, generally in the range of 0 to –2 degrees C. Differences in soil texture, water content, and site characteristics can allow permafrost to form at annual temperatures equal to freezing, or require annual temperatures well below freezing. Permafrost everywhere disappears at a great enough depth where heat from the geothermal gradient overcomes cold surface temperatures. Permafrost (the frozen material itself) occurs at a range of temperatures from near 0 degrees C to ten or more degrees below. As a result, the coldest regions make up a continuous permafrost zone across the landscape. Slightly warmer cold regions are within the discontinuous permafrost zone, where occurrence of the frozen state is influenced by local factors. Areas with only isolated or sporadic masses of permafrost make up a third zone.

Permafrost can be ice-rich, in which case thawing melts the frozen water content and causes ground subsidence, or it can be dry, leading to little potential for surface change between the frozen or thawed condition. Temperature trends in permafrost are increasing clearly, and across nearly all the Arctic and Subarctic. Permafrost temperatures are in exceptionally close agreement with predictive models of mean annual air temperature, snow depth and duration, and soil composition. Reliable permafrost temperature measurements generally date back only to about 1970, although the predictive models can be run backward in time with good confidence. Observations of permafrost thawing at its southernmost limits in the US, Canada, and central Asia are widespread.

Surface-disturbing activities, such as road and building construction, and natural events such as wildfire, can tip the thermal equilibrium toward thawing in warmer permafrost regions, and have for some time. But these processes are producing more widespread effects in recent warmer conditions. All the permafrost in central Alaska has been trending upward in temperature, and now nearly all of it is only –0.5 to –2.0 degrees C. Annual air temperatures above freezing are now occurring across large portions of the permafrost regions, and are certain to thaw the permafrost if sustained. The only questions are exactly where (the sequence of microsites) and how fast. Calculations indicate that a substantial fraction of existing permafrost has started or will start the thaw process (which may take decades or centuries to complete to the greatest depths) in the next several decades.

Linear infrastructure (roads, pipelines, railroads, etc.) are at most risk from thawing permafrost, because such developmets must proceed from point A to point B at some location, making avoidance of permafrost unworkable. Developments and structures can be engineered to minimize thaw or even keep ground material frozen. But such engineering features are substantial costs and are not easily retrofitted.

Permafrost and other cold soils hold an amount of carbon that, if it were entirely combusted, would double atmospheric CO2 content. Warming and/or thawing of the cold or permafrost soils is beginning to move this carbon into the atmosphere in a variety of ways.

Some of the largest wildland fires or burning seasons on record have occurred in the Arctic and Subarctic in direct response to increasing temperatures and drying.

2. **Boreal Forest.**

About half of the world forest area has been converted to other land uses on a long-term or essentially permanent basis. The boreal forest is the most stable by far of all the world's forest regions in terms of forest conversion or destruction. Until recently the boreal forest has also been the most ecologically intact of the world's forest regions. These characteristics, and the substantial annual surplus of growth (which removes carbon from the atmosphere) compared to decomposition (which releases carbon to the atmosphere) made the boreal forest one of the key land areas of the world in naturally reducing the buildup of greenhouse gasses.

Now, a variety of high temperature-related stresses have become pervasive in much of the boreal forest, especially in Alaska, seriously affecting its ability to continue to store carbon at the same levels as the past.

Measurement of tree-ring growth versus temperatures over the last century or so have shown that many trees on many site types consistently grow less in the warmer years and grow more in the cooler years. This negative response to warming has only been appreciated for the last decade or so, and it has been shown to be a consequence of high temperature-cause d lack of water that induces plant shut-down.

Because the temperature increases during the last few decades in central Alaska have been among the greatest on the planet, the tree growth reduction effect has been considerable. Temperatures that consistently predict the growth of trees in boreal Alaska are approaching lethal limits. During the record warm summer of 2004 and 2005, some tree death from drought appears to have occurred in populations of Alaska birch.

High temperatures also trigger outbreaks of forest-damaging or forest-killing insects. Outbreaks of known or suspected high temperature-related insects have occurred simultaneously across boreal Alaska and now much of western Canada.

Finally, wildland fires have increased to record levels and burned 1/4th to 1/3rd of all forest land in the northeast (hottest and driest summers) quarter of Alaska.

3. **Arctic Sea Ice.**

Arctic Ocean sea ice is a complex and dynamic phenomenon. A variety of physical processes occur as sea water nears freezing temperatures, changes from the liquid to the solid state, and coalesces into larger scale structures.

Of key biological importance is the expansion of water to maximum density at 4 degrees C, which then causes sinking in the water column to the bottomwater at that temperature. The sinking action forces or displaces older, nutrient-rich bottomwater upward, allowing a bloom of marine productivity during the time of year that sunlight is available. Ice crystal and structures themselves serve as secure attachment point for specially adapted algae, with is another unique source of marine production in these cold waters compared to the rest of the world ocean.

The Arctic is the world’s most land-dominated ocean. Several northward-flowing rivers transfer relatively large amounts of heat, freshwater, and nutrients into the ocean. The result of all the processes promoting productivity is a highly productive marine ecosystem in the northern, ice-edged seas, in distinct contrast to the level of annual production in nearby land ecosystems. It is no co-incidence at all that the cultures and current activities of the native people of the Arctic are highly oriented to hunting the abundant marine mammals, birds, fish, and other resources of the productive continental shelves and shores of their homeland.

During the strong global warming (probably due to orbital influences on the amount of solar energy reaching the far north) that decisively ended the last ice age starting about 12,000 years ago, a period of seasonally ice-free Arctic Ocean occurred probably about 8,000 years ago. A gradual cooling bgan between then ad 6,000 years ago, and continued with irregular warm periods, until the last century.

Comprehensive satellite-based records of the mount of sea ice start in the late 1970s. But the orientation of the Arctic residents and harvested resources toward the sea, visiting fleets, and records from explorers and the early scientific era give a good picture of the extent and location of sea ice for the last century and a half, with trends and low precision before, and very high precision for the most recent 30 years.

Changes in sea ice that are unique in the last several centuries have appeared suddenly and extremely strongly in the last 5 years, culminating in an extreme record of ice disappearance in September 2007. Influx of warmer Atlantic and Pacific Ocean bottom water, expulsion of multi-year ice, ice thinning, coating of the ice with small, dark soot particles, and cycles of atmospheric currents all played a role in the recent disappearance of Arctic sea ice. But the feedback influence of converting sunlight-reflective ice with sunlight absorbing open water on over huge areas of the Arctic Basin, represent one of the strongest feedbacks to global temperature increases in recent times of the planet. This change is not likely to be reversed soon.

A I am sure the committee is aware, a whole new set of strategic international relations has appeared as a result of the Arctic Ocean now becoming navigable to ordinary marine vessels. The residents of the Arctic now have a more difficult time gaining access to harvestable food resources on stable or predictable ice platforms. The lack of nearshore ice may be reducing local marine productivity by putting the ice edge over deep water. Finally, the existence of large areas of open water allows more frequent and stronger storms to batter the shore which is devoid of ice protection. The resulting extreme acceleration of shoreline erosion is displacing people of the region.

I thank the Committee for focusing on these historic, rapidly unfolding, and powerful events, and I offer to assist members in obtaining additional information.

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