U.S. Fish and Wildlife Service / U.S. Geological Survey
Climate Change Forum for Alaska
Technical Session, February 21
Abstracts

Vegetation Change in Alaska in Response to Climate Change: Examples from the Fossil Record

Thomas A. Ager
U.S. Geological Survey, Denver, Colorado

The broad scale history of past vegetation in Alaska over the past 20 million years has been reconstructed from pollen, spores and leaf fossils preserved in dated sedimentary deposits from south-central and interior Alaska. The fossil record provides many examples of how past climate changes have significantly altered terrestrial ecosystems in this region. A dramatic example of climate-related vegetation change in Alaska can be found in fossil-bearing deposits of middle Miocene age (ca. 17 – 15 million years ago). The greatest global warming event of the late Cenozoic (the past 23 million years) occurred during the middle Miocene. The climate of interior and south-central Alaska became cool temperate and northern hardwood forests dominated the lowland landscapes, while a rich assemblage of conifers dominated uplands. Many tree types that now grow in the northeastern United States, China, Korea, and Japan were common in Alaska during the mid-Miocene. These tree types include hickory, walnut, chestnut, wing-nut, elm, holly, basswood, ash, sweetgum, ironwood, oak, and many others. Mid-Miocene conifers included hemlock, pine, spruce, true fir, Douglas fir, redwood, and dawn redwood. Mean annual temperatures of interior Alaska during the middle Miocene were probably 16-18 degrees C warmer than today, and the mean annual precipitation was probably about three times greater than modern precipitation. The northward spread of temperate plants into high latitudes would take thousands of years, however, so any major, rapid warming that might occur in the future would not result in a return to hardwood forests in Alaska in the short term. Topographic changes that have occurred in Alaska since the middle Miocene would likely prevent the establishment of similar temperate forests in interior and northern Alaska. The rise of the Alaska Range about 6 million years ago has created a highly continental climate in interior Alaska that would be too arid for most temperate trees. Lowlands in southern Alaska would be more likely areas to support temperate plant species in the future, under a scenario of major global warming, and if seed sources were available.

Other dramatic vegetation changes driven by climate changes can be seen in the plant fossil records of the past 2.6 million years. During that time, global climates have shifted many times between cold, dry glacial intervals (ice ages) and warmer, moister climates of interglacials, such as our present Holocene interglacial. In Alaska, major glaciations vastly reduced, or possibly eliminated, boreal forests from interior Alaska, while glaciers covered 30-50% of Alaskan landscapes (vs. 4% today). During glacial times, boreal forests were replaced by tundra or steppe-tundra vegetation composed of sedges, grasses, wormwood, willows, and numerous herbaceous plants. At least eight interglacials have been documented from Alaska and Yukon during the past 2.2 million years, and the fossil evidence suggests that the composition of the forests was very similar from one interglacial to the next (spruce, birch, poplar, aspen, willow, alder). During the last interglacial about 120,000 years ago, climate was somewhat warmer than during the present interglacial, and in response, boreal forests spread onto the north slope and into western Alaska where tundra vegetation now grows.

Water resources of Alaska: Historical and future climate-related changes

Tim Brabets, Glenn Hodgkins, and Michelle Ann Walvoord
U.S. Geological Survey, Water Resources Discipline

Water-resources data (>50 years) are sparse for Alaska. In the last 50 years, changes in many data series appear to be dominated by the influence of the Pacific decadal oscillation (PDO). The PDO is a pattern of Pacific climate variability that has been shown to have regional climate signatures similar to those associated with the El Niño/Southern Oscillation (ENSO). PDO regimes typically persist for 2-3 decades while ENSO events last from 6 to 18 months. The PDO warm phase (positive polarity) is associated with anomalously cool Central-North-Pacific sea-surface temperatures (SSTs) and warm SSTs along the Pacific Northwest coast. The cold phase (negative polarity) occurs when the SSTs are reversed. Although some debate continues regarding recent changes in the polarity of the PDO, it is widely acknowledged that the climate system over the North Pacific was observed to shift its basic state abruptly during the winter of 1976-1977, resulting in a shift from a cold- to a warm-PDO. Previous PDO switches may have occurred in 1947 and 1925.

As a result of the PDO shift in 1976, annual air temperatures after 1976 were higher than earlier temperatures for different regions of Alaska by 1.6 ^{o}F to 2.7 ^{o}F and winter air temperatures were higher by 2.0 ^{o}F to 5.6 ^{o}F. Annual and winter precipitation increased for all regions except the Arctic. Snowmelt in northern Alaska has advanced about 8 days and streamflows from snowmelt-dominated basins are occurring earlier in southern Alaska, generally by 5 to 20 days. Since 1976, winter streamflows have increased in southeast Alaska. Gulkana and Wolverine Glaciers show significant loss in mass since 1976 based on 40 years of monitoring. Streams with glacial inputs have in turn shown a strong tendency for high-flow years to occur after 1976.

Many watersheds in the Yukon River Basin are undergoing permafrost thawing and thermokarst formation that results in quantitative shifts in surface-water/ground-water interaction at the basin scale. Ground water flow in the Yukon River Basin has increased since 1976 and currently comprises almost one-quarter of the water in the Yukon River as it discharges into the Bering Sea. The increased air temperatures since 1976 have caused increases in ground water contributions predominantly through permafrost melting that enhances infiltration and supports deeper flowpaths.

What will the future bring to Alaskan water resources? Several studies have used general circulation models (GCMs) to predict future temperature and precipitation in Alaska. In general, the GCMs predict warmer and wetter conditions. However, GCM predictions for Alaska are biased toward warmer and wetter conditions when compared to historical data. A 3.6 ºF increase in global temperatures projected by 2026-2060 could mean an 8 ºF increase in Alaska winter temperatures and 5 ºF increase in summer temperatures. Warmer and wetter conditions in Alaska would result in earlier snowmelt runoff, higher winter flows, and loss of glacial mass and permafrost.

Climate Change, Sea-Level Rise, and Coastal Erosion on the Alaskan Arctic Coast

Donald L. Forbes[1] and **Virginia Burkett**[2]
[1]*Geological Survey of Canada, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, NS, B2Y 4A2, Canada*
[2]*US Geological Survey, 700 Cajundome Blvd, Lafayette, LA 70506, USA*

The western Arctic coast of North America is among the most climate-sensitive and rapidly eroding coasts in the world. The stability of high-latitude coasts is affected by a range of factors, including climate and weather, sea-level rise and vertical motion, lithological composition, permafrost and ground ice, and the duration and distribution of sea ice. Low relief, regional subsidence, rising sea level, ice-rich but otherwise unlithified sediments, and diminishing sea ice combine to make this coast particularly sensitive to climate change and extreme storm events.

Sea ice may limit open-water fetch and exposure, but also plays a role in landward sediment transport, while posing a direct hazard to lives and infrastructure when it moves onshore. These hazards have been documented along the Yukon and Alaskan Beaufort coast, where ice push has been credited with nearshore scour and landward sediment transport. Late persistence of ice into the open-water season along the Beaufort Sea coast limits wave energy, but large storms late in the season (or in 'light ice' years) can have very large impacts, as in October 1963, September 1970, or August 2000. Extensive open-water fetch in the Chukchi Sea, combined with the highest storm power in the Arctic Basin, produce damaging storm surge and wave impacts along that coast.

Ice-bonded sediments in coastal deposits are particularly prone to combined thermal and mechanical erosion, which will be enhanced under climate change with rising relative sea levels, rising air and ground temperatures, and diminished sea ice duration and extent. High summer air temperatures combined with active wave erosion force a range of distinctive erosion processes, including active-layer detachment, solifluction, ice-wedge meltout, thermal niche undercutting, block toppling or sliding, and retrogressive-thaw flow failure. Melting of excess and massive ground-ice leads to loss of volume, accelerating shoreline retreat. Erosion rates increase dramatically during major storm surges, when high water levels enable more energetic waves to attack sediments and infrastructure higher up the backshore slope. These processes interact to produce rates of coastal erosion among the highest in the world when adjusted for the length of the open-water season.

Coastal stakeholders in northern Alaska and northwestern Canada (including residents and resource managers) face particular challenges in a warming climate, including rising relative sea levels, potentially more frequent storm-surge flooding, and more rapid shoreline retreat. Severe erosion and infrastructure damage in communities such as Barrow and Shishmaref attest to the vulnerability of low-lying communities and habitat along this coast. Cultural and archeological sites are being lost to the sea and landfills with toxic waste are exposed to erosion at many sites along the coast. The potential for more mobile ice has as-yet undetermined implications for the probability of ice ride-up and pile-up hazards. Changes in ice thickness and duration pose challenges for winter ice road access and hinder traditional hunting activities on sea ice. In some places (e.g.

Shishmaref, AK; Tuktoyaktuk, NWT; Hall Beach, NU), coastal erosion hazards have already led to serious consideration of relocation as an adaptation response.

The recent Arctic Climate Impacts Assessment (2005) and the forthcoming Fourth Assessment Report of the Intergovernmental Panel on Climate Change (2007) provide new guidance on projected changes in climate and sea levels over coming decades. Although evidence for accelerated erosion is sparse and conflicting, some recent work in both Alaska and Yukon has identified increased erosion rates over the past 20-30 years. In any case, projections of warmer temperatures, increased seasonal thaw depths, higher sea levels, and reduced sea ice point to a growing challenge in managing erosion losses, flood hazards, and related risks in the coastal zone of northern Alaska.

Current and Projected Climate-Induced Changes to Alaskan Permafrost

Gary Clow
U.S. Geological Survey, Earth Surface Dynamics Program

The bulk of Alaska is currently underlain by permafrost with deep (> 200 m) continuous permafrost existing on the North Slope, thinner discontinuous permafrost in central Alaska, and a zone of sporadic permafrost along the southern margin. Due to its cold impervious nature, permafrost has an enormous influence on hydrological and biological systems in this region. In addition, large amounts of organic carbon are currently stored within permafrost, some of which may be released in the form of greenhouse gases (carbon dioxide and methane) if permafrost is disturbed. Because of its sensitivity to climate, the distribution and thermal state of permafrost are important indicators of climate change in the Alaska. Recent changes include accelerated thermokarst development, particularly in areas of ice-rich discontinuous permafrost. This has led to the conversion of some upland forests into wetlands. Rates of coastal erosion have also increased. Erosion rates up to 100 m per year have recently been observed in northern Alaska. Although some of this is attributable to a reduction of protective sea ice during the critical fall season, it may also be linked to a reduction in the resistance of permafrost to erosion. Permafrost temperatures have generally warmed throughout Alaska during the last few decades with an amplification occurring in the arctic sector. Data acquired by the Global Terrestrial Network for Permafrost (GTN-P) show a 3°C warming of shallow permafrost in the western half of Alaska's arctic coastal plain since 1989.

Climate projections by an ensemble of global coupled Atmosphere-Ocean General Circulation Models (AOGCMs) done in conjunction with the first Arctic Climate Impact Assessment (ACIA, 2005) suggest significant environmental changes will occur in the Arctic during the next 80 years. According to these models, climate change will be Arctic-wide with a pronounced enhancement over the Arctic Ocean and adjacent land areas. Model projections based on the SRES B2 emissions scenario suggest air temperatures will warm about 9°C during the winter (6°C mean-annual) over the Arctic Ocean Basin by 2090. Air temperatures in northern Alaska are projected to increase roughly 7°C during the winter (4°C mean-annual) by 2090 while those in central and southern Alaska are expected to increase somewhat less. The ACIA projected air temperature increases, combined with changes in the thickness and duration of the winter snowpack, are expected to lead to much warmer ground temperatures, accelerated thermokarst development, a large reduction in the extent of permafrost, and a substantially deeper active layer where permafrost remains. A more recent analysis by Lawrence and Slater (2005) using NCAR's CCSM3 model with an explicit treatment for frozen soil processes shows a near total loss of shallow permafrost in Alaska by 2090 (based on the SRES A2 emissions scenario), with most of the loss occurring by 2040-2050. Such a loss would have profound effects on physical, hydrological, and biological systems in Alaska. Although there are large uncertainties associated with this study, it does serve to indicate very large environmental changes may occur in Alaska by mid-century. The ACIA projections and the more recent Lawrence and Slater study both suggest degradation of ice-rich permafrost is likely to pose a risk to infrastructure in Alaska during this century. Warming ground temperatures coupled with changes in surface drainage and soil moisture are likely to produce significant vegetation changes. Thermokarst development and coastal erosion rates are expected to continue to accelerate. Slope failures in mountainous terrain and along riverbanks are likely to be more common as permafrost thaws. The resulting increased sediment load may decrease water clarity. Containment structures for sewage and other contaminants that rely on permafrost are likely to lose their integrity. Unless redesigned, the breaching of these structures will result in reduced water quality. Lakes currently situated in discontinuous permafrost are expected to become smaller and less numerous while those in continuous permafrost may become somewhat larger and more numerous. Given the magnitude of the projected impacts and the large associated uncertainties, a successful management plan for Alaska must be both adaptive and capable of responding to rapid environmental changes.

Arctic Climate Impact Assessment – Scientific Report (2005): Arctic Council, Cambridge Univ. Press, 1046 pp.

Lawrence, D.M. and A.G. Slater (2005): A projection of severe near-surface permafrost degradation during the 21st century, Geophys. Res. Letters, 32, L24401, doi:10.1029/2005GL025080.