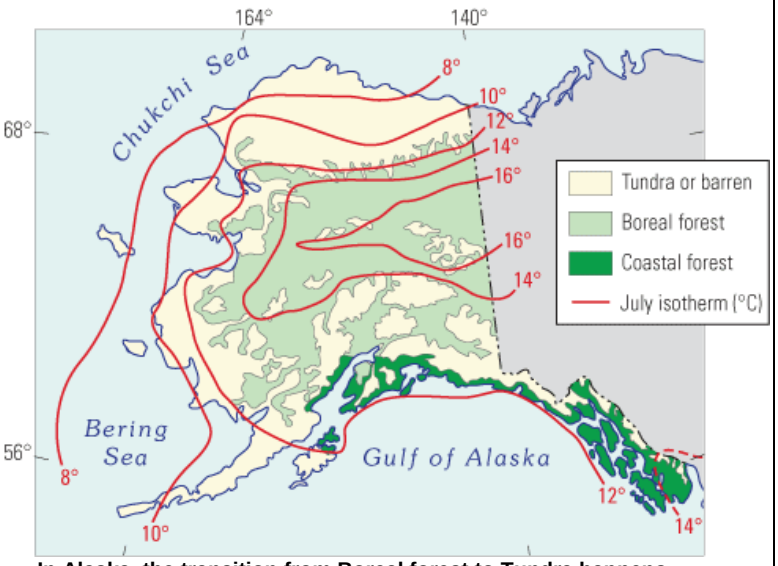
Earth Gauge
A National Environmental Education Foundation Program

# Climate Change and Ecosystems of the Far North

***The Earth's recent warming trend has been most pronounced at the high latitudes. Read below for examples of how ecosystems between 50 and 80 degrees North (a distance extending from Winnipeg, Manitoba to the northern tip of Greenland) have responded to recent climate change.***

## *THE FAR NORTH: A TALE OF TWO ECOREGIONS*

Two main ecoregions, or life zones, characterize the far north. The Boreal Forest ecoregion runs from about 50 degrees (southern Ontario) to 70 degrees (the northern tip of Scandinavia) North. Frequent glacial movement here means the bedrock is often exposed, which creates shallow rock basins where peat bogs are common. Needleleaf trees, such as black and white spruce in Alaska, and deciduous larch trees in Siberia, are the most common type of species found in the Boreal Forest, although broadleaf tress like aspen, birch, and willows live there as well.




**In Alaska, the transition from Boreal forest to Tundra happens around the 12 degree Celsius (54 degrees Fahrenheit) isotherm. Image courtesy of USGS.**

Moving farther north, trees become scarcer and plants such as grasses, sedges, mosses and low-lying shrubs, as well as lichens, become more common. Together, these plants form the Tundra ecoregion, which extends from south of the Arctic Circle (66 degrees North, or the northernmost tip of Iceland) to the Arctic Ocean. Most of the Tundra soils, which are poorly developed and composed primarily of gravel, are frozen permanently with only the top few inches (the active layer) thawing out during the summer months. About three percent (5900) of the world's plant species live in the Tundra and have evolved to survive in this extreme environment. Only about one-third of these species are vascular plants, or plants with complex structures for transporting water and nutrients, such as grasses and trees.

## *RECENT CLIMATE CHANGE IN THE FAR NORTH*

With the exception of the Antarctic Peninsula, the far north is warming faster than anywhere else on the planet:

- The Arctic summer is now the warmest it has been in at least 400 years. Between 1961 and 2004, average summertime temperatures in the Alaskan Arctic and western Canada rose by 2.5 degrees Fahrenheit, while winter temperatures rose by 3.6 degrees Fahrenheit.
- In Alaska, the snow-free season is growing by as much as 9.1 days per decade.
- Since the 1970's, the average date of soil thaw in the Northern Hemisphere's Tundra regions has been advancing by three days per decade.
- The Arctic growing season, or the period between the last frost in spring or summer and the first frost in the fall, has grown by 12 days since the 1970's.
- Over the last century, the average extent of Northern Hemisphere snow-cover decreased by about two million square miles. Yet, the overall amount of precipitation increased. This has resulted in areas of the far north experiencing greater snow depth. In the Swedish Arctic, for example, average snow depth has been growing by ten percent per decade since the 1930's.

***TREE AND SHRUB EXPANSION***

The area where the boreal forest and tundra ecoregions merge (which is known as the boreal/tundra ecotone), has experienced changes over the 20th century related to the contemporary warming trend. Warmer temperatures have been conducive to tree and shrub expansion there for several reasons. First, the annual thaw of the permafrost now penetrates deeper into the soil, allowing plants that require larger root systems to survive. Second, warmer temperatures and increases in winter snow depth (snow serves as an insulator against the deep winter freeze), stimulate microbial activity in the soil, which results in more nitrogen cycling and more available nutrients for plants. Third, disturbed soil is more conducive to plant colonization, and the melting of the permafrost is a disturbance in itself. As a result, an expansion of trees and shrubs into the Tundra has been observed:

- Over the past 50 years, 4,500 square miles of Alaskan Arctic Tundra (or about 2.3 percent of the total), became covered with trees and/or shrubs.
- In the Alaskan Arctic between the Brooks Range (which sits at about the 50 degree Fahrenheit July isotherm – see image on the previous page for reference) and the Arctic coast, comparisons of photographs taken in recent years with photographs taken from the same locations in the late 1940's show an expansion of shrub cover. In some places, the shrub cover extent doubled.
- Total shrub/tree cover is currently expanding into the world's Arctic Tundra at a rate of 8,600 square miles, or 0.4 percent, a year.

***FEEDBACK CYCLES BETWEEN INCREASES IN SHRUB/TREE COVER AND WARMING***

Shrub and tree expansion as a result of a warmer climate appears to promote further warming and further expansion of shrub/tree cover through the following mechanisms:

- Shrubs and trees are generally darker than the grasses, sedges, and lichens they replace. Darker objects absorb more energy from the sun, which results in a warmer local climate, more permafrost melting, and more tree/shrub expansion.
- Snow blown by the wind tends to accumulate around shrubs and trees. This increases the snow depth around these plants, which further insulates the soil, promoting more microbial activity and more nutrient availability. This enables shrubs to reproduce more easily.

***FIRE AND CHANGES IN NORTH AMERICA'S BOREAL FORESTS***

***Alaska:*** In Alaska's Boreal Forests, minimum spring temperatures have risen by eight degrees Fahrenheit over the last 80 years, and the growing season has lengthened by 20 days. Warmer temperatures and a longer growing season mean increased summer and fall drought stress. Despite this increased drought stress, there does not appear to be a multidecadal trend of increasing fire frequency or annual area burned. There has, however, been a tripling of the frequency of large fires (defined as fires that affect more than one percent of a defined forest region). Also, between 1948 and 1998, 68 percent of the area affected by fire burned during El Niño years. Drought also affects the frequency of insect outbreaks, which appear to be on the rise in Alaska. A longer growing season now allows Alaska's spruce beetles to complete their life cycles in just one year, whereas a few decades ago it would take two.

**A riparian zone in south central Alaska's boreal forests. Photograph Courtesy of USGS**

***Canada:*** In Canada's Boreal Forests (which produce about 11 percent of the world's roundwood timber supply), where the species composition is somewhat different than Alaska's, fire frequency has doubled since the 1920's. Drought stress is a factor in 78 percent of the fires that occur there. As in Alaska, drought stress also promotes insect outbreaks. Canada's Boreal Forests have experienced a steady increase in the frequency of insect outbreaks over the 20th century. Insect induced stand mortality affected about five million acres annually during the 1940's, but has been affecting an average of 7.5 million acres annually in recent decades. Warmer winter temperatures mean that fewer insects die during the winter months.

***Sources***


*Brown, RD. "Northern Hemisphere Snow Cover Variability and Change, 1915-97." Journal of Climate 13 (2000): 2339-2355.*

*Callaghan, TV et al. "Effects of Changes in Climate on Landscape and Regional Processes, and Feedbacks to the Climate System." Ambio 33 (2004): 459-468.*

*Callaghan, TV et al. "Biodiversity, Distributions and Adaptations of Arctic Species in the Context of Environmental Change." Ambio 33 (2004): 404-417.*

*Chapin, FS III et al. "Role of Land-Surface Changes in Arctic Summer Warming." Science 310 (2005): 657-660.*

*Chapin, FS III et al. "Global Change and the Boreal Forest: Thresholds, Shifting States or Gradual Change?" Ambio 33 (2004) 361-365.*

*Danby, RK and Hik, DS. "Variability, contingency, and rapid change in recent subarctic alpine tree line dynamics." Journal of Ecology 95 (2007): 352-363.*

*Deŕy, SH and Brown, RD. "Recent Northern Hemisphere snow cover extent trends and implications for the snow-albedo feedback." Geophysical Research Letters 34, L22504, doi:10.1029/2007GL031474.*

*Hartman, B and Wendler, G. "The Significance of the 1976 Pacific Climate Shift in the Climatology of Alaska." Journal of Climate 18 (2005): 4824-4839.*

*Hinzman, L et al. "Evidence and Implications of Recent Climate Change in Northern Alaska and Other Arctic Regions." Climatic Change 72 (2005): 251–298.*

*Keyser, AR et al. "Simulating the effects of climate change on the carbon balance of North American high-latitude forests." Global Change Biology 6 (2000): 185-195.*

*McGuire, AD et al. "Land cover disturbance and feedbacks to the climate system in Canada and Alaska." Chapter 9 (pages 139 - 161) in Imzd Change Science: Ohsel-virzg, Moniloritig, and Ulzder*stnditzg Trojectol-ies of Challge OH the Earth's SU+KZE. ditcd by Gutman, C., Janetos, A.C., Justice, C.0, Moran, E.F., Mustard, J.F., Rindf~lssR, .R., Skole, D., Turner 11, B.L., and Cochrane, M.A. Dordrecht, Ncthcrlands, Kluwer Adademic Publishers.*

*Podur, J et al. "Statistical quality control analysis of forest fire activity in Canada." Canadian Journal of Forest Research 32 (2002): 195-205.*

*Sturm, M et al. "Snow-Interactions in Arctic Tundra: A Hypothesis with Climate Implications." Journal of Climate 14 (2001): 336-344.*

*Sturm, M et al. "Increasing shrub abundance in the Arctic." Nature 411 (2001): 546-547.*

*Sturm, M et al. "Winter Biological Processes Could Help Convert Arctic Tundra to Shrubland." Bioscience 55 (2005): 17-26.*

*Sturm, M and Douglas, T. "Changing snow and shrub conditions affect albedo with global implications." Journal of Geophysical Research 110 (2005): G01004, 1-13.*

*Tape, K et al. "The evidence for shrub expansion in Northern Alaska and the Pan-Arctic." Global Change Biology 12 (2006): 686-702.*

*Xiao, J and Zhuang, Q. "Drought effects on large*