3. Forests, Climate Stress, Insects, and Fire

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3.1 Introduction

Forests are one of the major renewable resources of Alaska. Alaska's forests provide habitat for wildlife (including many species important for subsistence), forest products and opportunities to expand forest products production, and the scenic backdrop for much of Alaska's tourism industry. Ecological processes in high latitude forests are a significant feedback to the world carbon cycle and a major potential source of additional greenhouse gases to the atmosphere.

There are two major types of forest in Alaska (1) the coastal temperate rainforest of southeast and southcentral Alaska and (2) the boreal forest or taiga of southcentral and interior Alaska (Figure 3.01). The boreal forest covers the larger area by far, about 46.2 million ha (114 million ac) versus 5 million ha (12.3 million ac) for the coastal forest (Labau and Van Hess 1990).

Worldwide, cool temperate rainforests are confined to narrow coastal strips in Chile, New Zealand, Australia, northwest Europe, and northwestern North America, including southeast and southcentral Alaska. They are not naturally abundant on the Earth, and a large proportion of the remaining unlogged share of this forest type is found in Alaska. Alaska contains 19% of world total of 26.6 million ha (65.7 million ac) of temperate rainforest, and 38% of the total unlogged area (11.6 million ha; Ecotrust et al. 1995).

The coastal forest of Alaska supports a significant forest products industry which is undergoing structural change. The two large pulp mills in southeast Alaska which were the major part of the industry closed operations in the last two years. However, strong markets exist for sawlogs from both southcentral and southeast Alaska. The majority of logs produced from privately owned land in the coastal region are exported, but Alaska-based sawmill operations are limited by the lack of available logs from the public lands, which cannot be exported. The new Tongass National Forest Land and Resource Management Plan will probably result in a timber harvest of less than half the level typical of the 1980s. Investment in new forms of value added forest products manufacture is likely for the new harvest level, but the long-term survival of the forest products industry depends directly on the availability of a predictable supply of suitable wood from public lands.

Two established industries depend on the coastal forest remaining in a relatively lightly disturbed or undisturbed condition. The fishing industry depends on the critical contribution the coastal forest makes to high quality salmon habitat, a important factor in one of the world's most productive fisheries. The coastal forest is also the scènic background for a vigorously expanding tourism industry, especially cruise ships and wilderness lodges. Alaska Native communities make use of the coastal forest across the spectrum of land uses, from protected wildlife habitat to industrial logging and many uses in between.

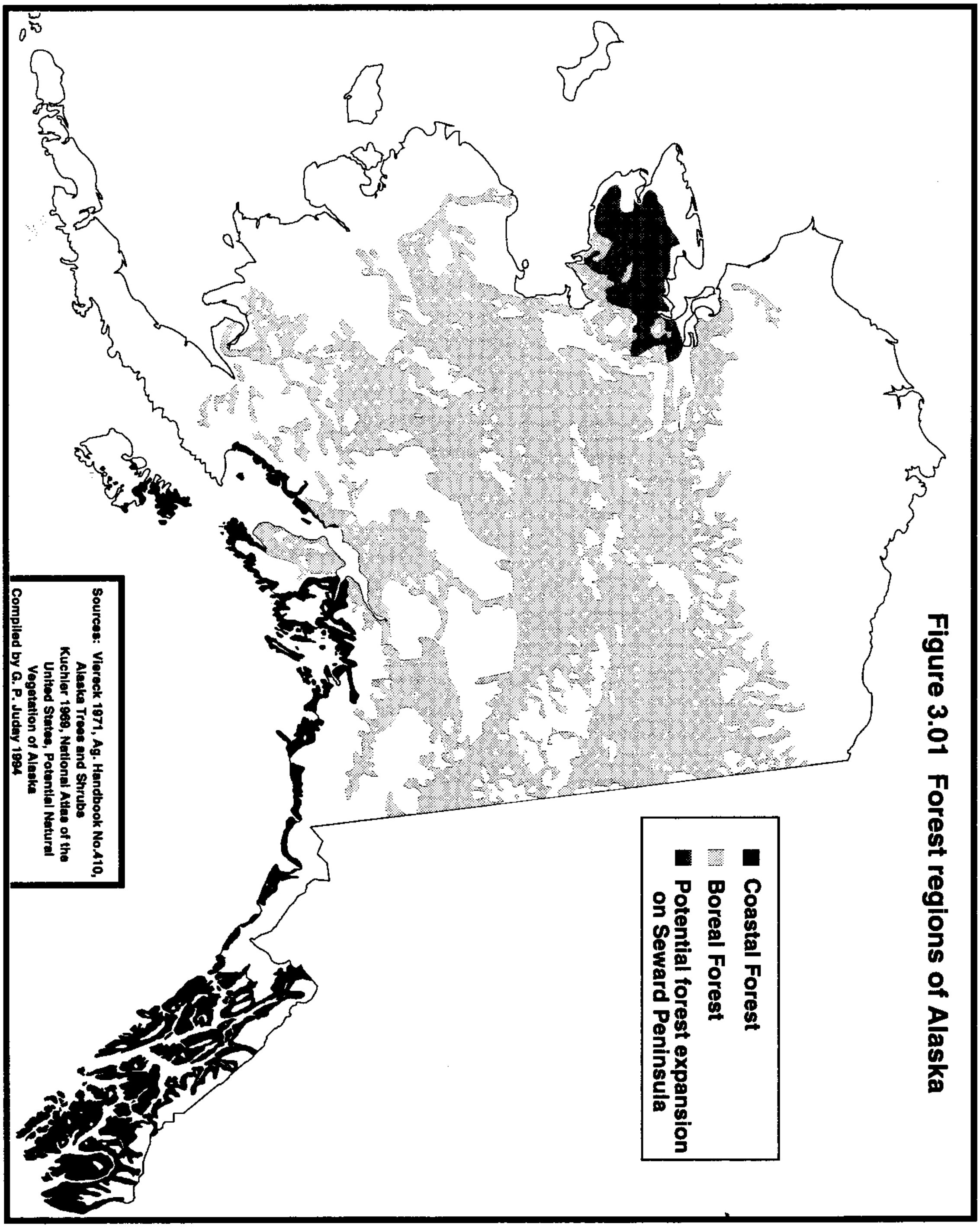


Figure 3.01 Forest regions of Alaska

The world boreal forest zone makes up about 17% of the Earth's land surface area (Bonan 1992) and increasingly is being used as a source for the world timber trade. Of all the major forest regions of the world, the boreal zone supports the lowest density of settled human populations. In much of the boreal forest native peoples still pursue traditional ways of life modified to various degrees by modern circumstances. The boreal forest is among the last of the Earth's forest regions to be widely exploited for industrial economies. Timber and mineral extraction are fairly recent land uses, but they have increased greatly in extent since the mid 20th century.

The most widespread form of active, programmed land use today in boreal Alaska is forest management, specifically fire management and wood products harvest. A small forest products industry operates in the Alaskan boreal region, concentrated on supplying local markets with rough lumber, house logs, fuelwood, and specialty products. The dominant large conifer, white spruce (*Picea glauca*), is significantly more valuable than the broadleaf trees. Export of higher value boreal white spruce increased significantly in response to a doubling or tripling of stumpage prices after major reductions of public timber harvest were implemented on public lands in the Pacific Northwest. Another small (in extent), but important and expanding land use in the Alaska boreal forest region is hard rock mining. Within one to a few decades most of the new large mines in the United States will be in Alaska, and many are either in the boreal region or serviced from it. Expansion of human settlements, both villages and urban centers, and the construction of transportation facilities are increasing in boreal Alaska, generating additional demands for forest management in specific areas.

Nearly all of the Alaska boreal forest still supports most of its native wildlife including free-ranging large predators. Alaska hosts a huge influx of migratory birds that depend on summer breeding grounds in its boreal forests. Many prime wilderness areas are attracting increasing numbers of visitors with attendant impacts. Large-scale fires are suppressed when human habitation or commercially valuable timber is threatened. A forest management response is needed for events such as extensive insect-caused tree mortality.

In Alaska, productive forest sites within the boreal zone are limited to permafrost-free locations with suitable soils, mainly along the larger rivers and on low elevation south slopes. Certain wetlands in the boreal region, especially those that experience non-acidic groundwater flow, are highly productive as well. Only about 12% of the Alaska boreal forest is sufficiently productive to meet the definition of commercial forest land (Labau and Van Hess 1990). However, the total productive Alaska boreal forest area of about 5.5 million ha (13.5 million ac) is greater than the productive forest land base of many states. With continued climate warming sufficient to thaw permafrost, the productive boreal forest area in Alaska would expand by a factor of 3 or 4 times. Currently productive sites within the Alaska boreal forest are scattered across diverse landscapes with a limited transportation system, so that access to them is a significant cost to any form of timber cutting or management.

The boreal forest is an important component of the Earth's climate system. The stored pools of carbon in boreal forest soils and trees represent a significant share of the total terrestrial carbon reservoir. The release of this carbon to the atmosphere as carbon dioxide or methane as the result of climate warming could be a major positive feedback loop in future climate warming.

Several features of climate, especially temperature, control many different forest responses (Figure 3.02). It could be said that a forest could experience several different kinds of warming. In considering the issue of current or potential global warming/global change effects on forests in Alaska it is important to be specific. Changes in any one of these characteristics of temperature variability could produce significant forest change while other features of temperature remained essentially unchanged. However, a considerable amount of ecological research on the forests of Alaska has been conducted in the last 3 decades, and some of the major pathways of climate-driven change are now understood. The forests of Alaska are a good place to study and observe climate change. The climate of the far north is naturally highly variable from year to year, as its residents know. The forests of Alaska are limited by several different features of the current climate and so they respond in different measurable ways to the climate changes as they happen. Recently a substantial amount of evidence has begun to accumulate that climate change in Alaska's forest regions has surpassed the range of background variability and is changing systematically in ways that are posing significant challenges to several Alaska forest resources.

Figure 3.02 Characteristics of temperature variability important in climate change effects on forests and other Alaska vegetation

Characteristic of temperature variability	Consequences to vegetation
Maximum daily	Various threshold values must be equaled or exceeded to trigger various plant development functions (e.g. seed production) throughout the growing season.
Minimum daily	Low levels retard plant development, even when daily means are otherwise suitable, can represent damaging or killing freezing conditions (e.g. insects in winter).
Mean monthly	Useful overall summary, especially for long-term trend analysis (e.g. tree-rings).
Growing degree days	Useful measure of cumulative heat accumulation, various thresholds associated with several different seasonal plant development functions.
Frost-free season	Represents consecutive number of days without lethal cold - in Alaska can be 0, -2, -4^{o}C or colder depending on the plant species or variety.

3.2 Past effects of climate change

Past Climate Change

Historically, coastal forests of Alaska have experienced and responded to variations in climate. These responses can provide insights into how coastal forests are likely to respond to future climate changes. During the current interglacial, regional vegetation patterns of southeast Alaska have changed several times in response to changing climate. Heusser (1952) described 5 major climatic periods and their associated vegetation for southeast Alaska over the past 8000 years. The period from 8000 to 6000 years B.P. was cool and moist; this period was characterized by dominance of shore pine (*Pinus contorta var. contorta*). From 6000 to 5000 years B.P. the climate became warmer and drier and Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) succession took place. Western hemlock predominance was achieved from 5000 to 2000 years B.P. when maximum warmth and dryness occurred. Mountain hemlock (*Tsuga mertensiana*) attained its maximum during this time. The warming and drying that occurred during this thermal maximum allowed forests to invade muskegs[1], and fires occurred (Heusser 1953) in a region that is now occupied by temperate rainforests.

From 2000 to 200 years B.P. the climate became cooler and wetter; a hemlock maximum occurred, and pine expanded its range. The later phase of this cool wet period, from about 1350 to 1840 A.D., is recognized across the northern hemisphere as the Little Ice Age. The final climatic period in southeast Alaska has been the warming and/or drying since the end of the Little Ice Age. Tree-ring reconstructions of some of the features of the climate of south coastal Alaska indicate the timing and the magnitude of warming since 1600 A.D. (Wiles et al. 1996).

Not all vegetation change that occurred in the coastal forest since the termination of the worldwide glacial period 12,000 B.P. was directly controlled by climate. Sitka spruce is still expanding its range westward in the Alaska coastal region (Veblen and Alaback 1996). Time and geographic barriers along the complex mountainous Alaska coast probably have prevented Sitka spruce from occupying all climatically suitable sites. The area of the coastal landscape covered by muskegs has declined by 40% since deglaciation because of forest expansion (Stephens et al. 1970).

In addition to the major periods of climate and vegetation change on the scale of thousands of years, decadal and century long climatic changes result in vegetation responses such as changes in vegetation abundance and limited changes in distribution (Bartlein 1988). For example, the cooler and wetter climate that occurred during the Little Ice Age allowed muskegs to expand at the expense of the surrounding forests (Heusser 1953).

Instrument-based climate records are available for a few locations in the Alaska coastal region starting in the early years of the 20th century (Juday 1984). Mean annual temperature at coastal stations shows a strong cycling trend with a period of about 19 years between peaks (Figure 3.03; Juday 1984, Royer 1993). In the mid 1970s temperatures in Alaska coastal stations increased abruptly to the highest level of the 20th century; even the low period in the temperature cycle that followed was markedly warmer than any similar period in the instrument-based record (Figures 3.04 and 3.05). Storm frequency and intensity increased at the same time as the recent rapid rise in temperature. The number of days with gale-force winds at coastal locations more than doubled in the late 1970s compared to the previous two decades (Figure 3.06).

[1]A muskeg is a relatively open wet peatland with a ground cover high in *Sphagnum* mosses and/or sedges (Stephens et al. 1970).

Figure 3.03 Smoothed mean annual temperature (MAT) at Valdez, Sitka and Juneau Downtown

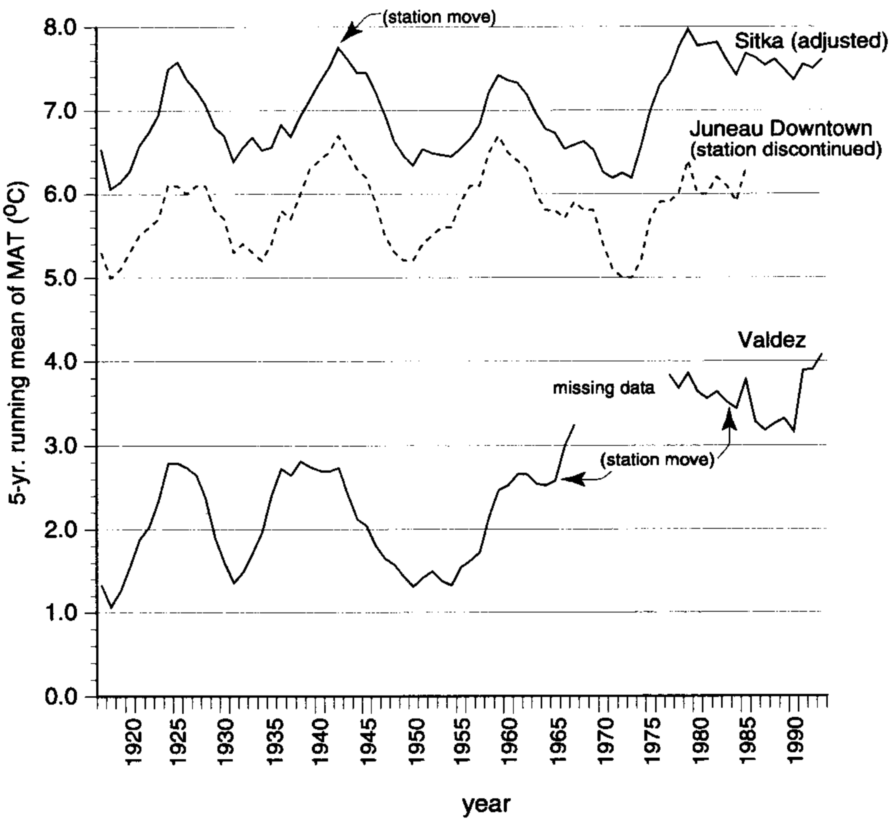


Figure 3.04 Smoothed mean annual temperature, Anchorage, 1918-1994

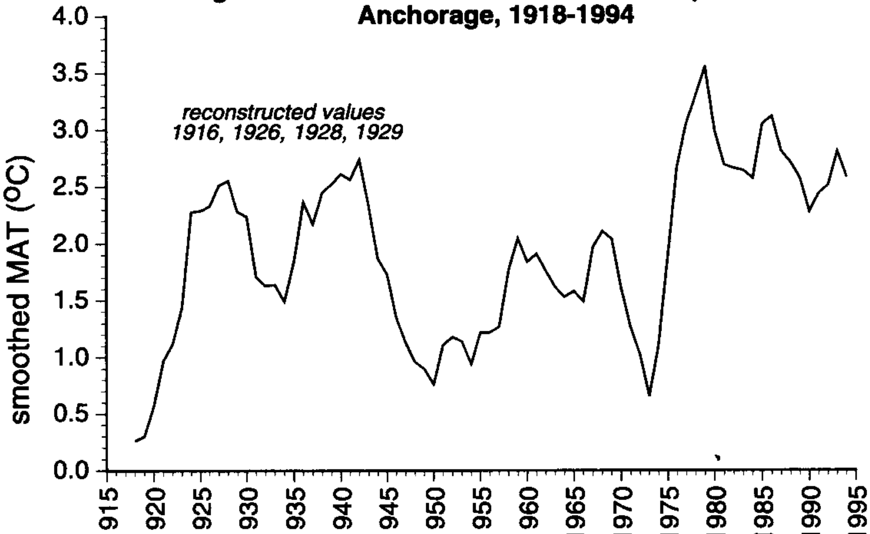


Figure 3.05 20th century mean annual temperature (MAT), unsmoothed, and 4.5° C warmer scenario at Anchorage

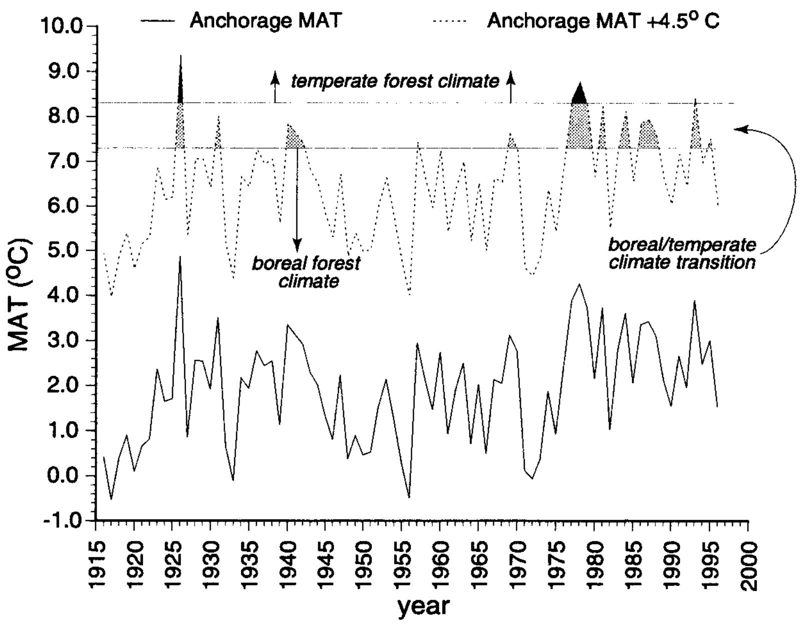
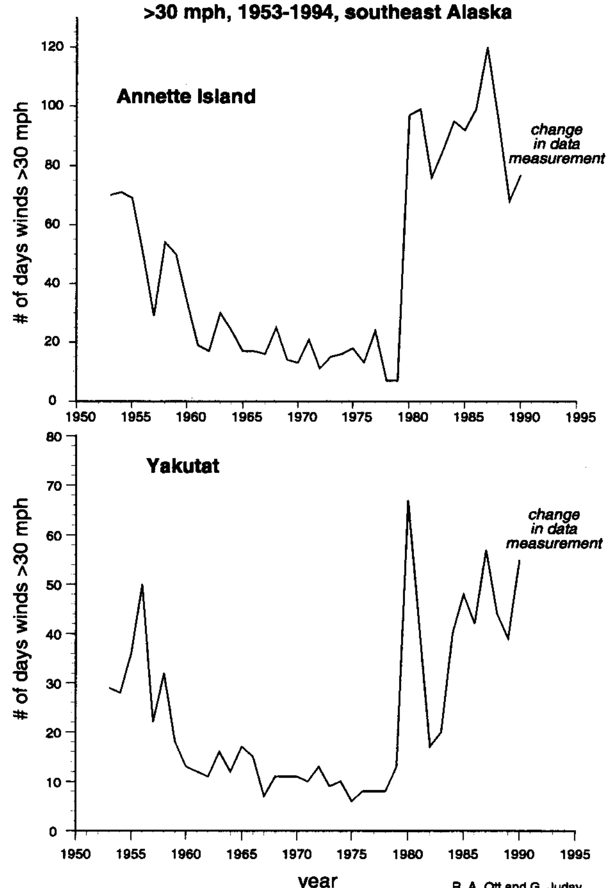


Figure 3.06 Number of days, by year, with fastest mile wind >30 mph, 1953-1994, southeast Alaska



R. A. Ott and G. Juday, also from Harris 1989. (data: National Weather Service)

The coastal forest of Alaska displays evidence of several responses to the warming of the past 20 years that are consistent with the anticipated effects of global change. In southeast Alaska, the frequency of snow avalanches at low and moderate elevations has declined since the late 1970s in response to climatic warming (more of the winter precipitation falling as rain and less as snow). The result is that mountain hemlock is currently colonizing alpine tundra in the region, and the shrub salmonberry (*Rubus spectabilis*) is invading meadows dominated by heather (*Cassiope*) or sedge (*Carex*; Veblen and Alaback 1996). A decline in the frequency of severe snow accumulation at low elevations in southeast Alaska has allowed Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) better access to critical winter forage plants. A series of winters with low snowfall is partly responsible for higher winter survival and increased overall population levels of deer. One result may be reduced tree regeneration of the Alaska yellow-cedar (*Chamaecyparis nootkatensis*), a preferred browse species of deer (Hennon 1992).

The boreal forest of western North America today is the product of many and often pronounced climatic fluctuations from its establishment, following the most recent glacial period. Throughout the last glacial period the climate of lowland central Alaska, central Yukon Territory, and far eastern Russia was too arid to permit the formation of ice sheets. These regions were never glaciated, but trees were unable to grow in the extremely cold and arid landscape. Following the end of full glacial conditions across interior Alaska about 14,000 years ago, an abrupt warming occurred, permitting the northward migration of trees in North America (Pielou 1991).

Balsam poplar (*Populus balsamifera*) was usually the first tree species to appear in interior Alaska following the late glacial warming. Balsam poplar appears to have expanded across the landscape from 10,000 to 8,000 B.P. from small populations that were already present. Other tree species migrated from newly established populations in Canada northwestward across interior Alaska as the glacial ice sheets retreated in Canada and the climate warmed. About 9,000 years ago in western Canada white spruce spread rapidly northward across 2,000 km of newly deglaciated land in only 1,000 years. This rapid movement of forest was caused by the transport of seeds on strong northward winds caused by clockwise atmospheric circulation around the remnant ice cap of northern Quebec and western Hudson Bay (Ritchie and MacDonald 1986). Spruce and most other elements of the boreal forest were generally established near their current limits in Alaska about 6,000 years ago (Ager 1983).

Studies of past climates using tree-rings have produced a reliable picture of temperature variation in interior and northern Alaska since the early 1500s. Alaska temperature trends are in general agreement with overall northern hemisphere high latitude temperature trends (D'Arrigo and Jacoby 1993, Jacoby and D'Arrigo 1989). Temperatures during the Little Ice Age were distinctly cooler than during the 20th century in interior Alaska. The tree-ring reconstructions show the full effects of the Little Ice Age in the earliest portions of the record (from at least the 1500s to 1700), a partial warming in the early 1700s, an abrupt return to cold from about 1800 to 1840, and a steady warming since 1840 interrupted only by a minor cooling from the mid 1940s to the mid 70s.

Tree-ring reconstructions of climate are based on a substantial period of overlap with modern instrument-based climate data. The climate record from the University Experiment Station beginning in 1906, combined with the Fairbanks Airport (mid-1948 onward) provide representative data for most of the 20th century in central interior Alaska (Juday 1984).