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Observed continentality in radial growth–climate relationships in a twelve site network in western Labrador, Canada

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ABSTRACT

Despite their suitability for dendroclimatological research, the boreal regions of central and western Labrador remain under-researched. In an attempt to evaluate the growth trends and climatic response of this region's trees, master chronologies have been developed for its four dominant conifer species. Balsam fir (*Abies balsamea* (L.) Mill.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) Britton, Sterns, Poggenb.) and eastern larch (*Larix laricina* (DuRoi) K. Koch) were sampled systematically within a 3×4 grid of twelve sites at the intersection of 62°W, 64°W and 66°W longitude, and latitudes 52°N, 53°N, 54°N and 55°N. The two most dominant species at each site were sampled, yielding a total of twenty-four master chronologies, all of which reflected a highly significant common signal at each site. The chronologies were subjected to a response function analysis to determine the nature of the growth–climate relationships in the region. Summer temperature proved to be the predominant limiting factor with regard to radial growth at most sites. The onset of the optimum temperature regime, however, varies across the network of sites, revealing evidence of a gradient of continentality in the data. Growth–temperature correlations indicated a significant relationship with July temperature at most eastern sites, while western sites tended to correlate with May, June and August temperatures. Central sites tended to correlate with June–July temperatures. We interpret these results as demonstrating the bioclimatic gradient of change between coastally proximal, maritime-influenced sites and inland, continentally influenced locales. This transition occurs approximately 330 km inland from the open Labrador Sea.

Introduction

Tree rings can serve as reliable proxies for observation of climatic variability (Hughes, 2002), especially where there are limited past climatic information and abundant trees present. A region where dendrochronological analyses should be prominent is Labrador, where both of these conditions are met yet tree-ring studies are few. Schweingruber et al. (1993) included a few tree-ring sites in Labrador in their continent-wide comparison of ring width and maximum latewood density chronologies. D'Arrigo et al. (1996) have used maximum latewood density chronologies from parts of Labrador to reconstruct land and sea surface temperatures for the northwest Atlantic. Tree rings sampled from northern Labrador have also been used to monitor climate variability (D'Arrigo et al., 2003) and the effects of climate change upon latitudinal and altitudinal tree line dynamics in the region (Payette, 2007). Tree-ring data in the form of trampling scars have also been used to monitor caribou populations in northeastern Quebec and Labrador (Morneau and Payette, 2000; Boudreau et al., 2003).

To date, however, no systematic analysis has been undertaken to examine the radial growth trends for forests across Labrador. There has also been no significant exploration of the relationship between ring width and climatic variability across the entire region, in either a north–south or east–west direction. It was the purpose of this study to address such a gap in the research by creating master chronologies of the dominant conifer species in central and western Labrador. Moreover, by creating a coordinate-based, systematic sampling network, we seek to lay a foundation for a grid that may be expanded upon in adjacent regions. Such an expanding grid may serve as a powerful tool in spatially analyzing growth dynamics in the broader eastern boreal forest.

A secondary objective of this study was to evaluate the particular spatial trends of the radial growth–climate relationship in Labrador. Labrador is subject to the converging effects of both maritime and continental climatic influences (Rollings, 1997; Roberts et al., 2006) and as such, experiences complex and dynamic bioclimatic interactions (Fig. 1). As climate proxies, tree rings provide us with lengthy records of this growth–climate relationship and, when sampled across a gridded network of sites, may form the

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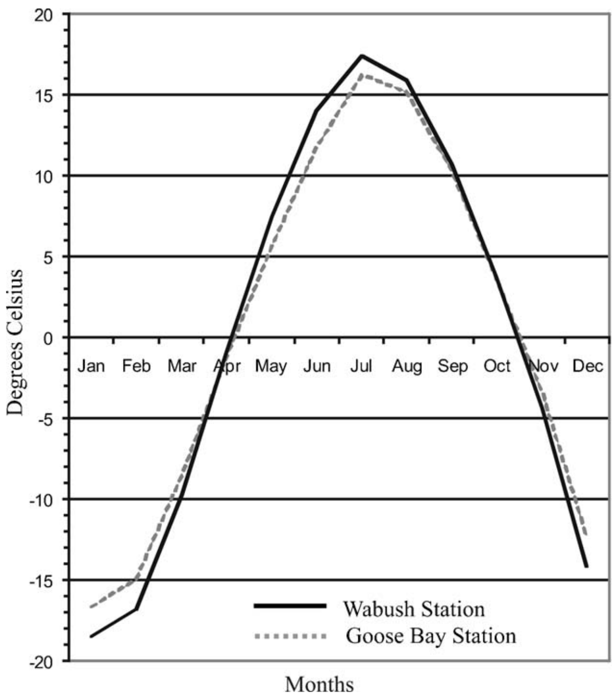

Fig. 1. An example of continentality vs maritime effects illustrated in the historical temperature data from Wabush station, NL (# 8504175) and Goose Bay Station, NL (# 8501900). The inland site (Wabush) is on average colder in the winter and warmer in the summer than the more maritime site illustrated by the data from Goose Bay, even though both sites are at similar latitudes. The data were averaged over the length of the available temperature record and adjusted for elevation.

basis for in-depth spatial analysis across both latitudinal and longitudinal transects. Continentality has been observed by Linderholm et al. (2003), whose tree-ring study of Scots pine in Fennoscandia revealed a gradual transition in the growth–climate relationship across a west to east transect. Similar descriptions of observed continentality in tree-ring networks are seen in the works of Kirchhefer (1999) and Littell et al. (2008), and we seek here to evaluate whether this process can be identified through dendroclimatological analysis in Labrador as well.

Study sites and species

Much of the research into the relationship between climate and tree growth has targeted sites at the limits of conifer growth tolerance (Fritts, 1976; Gedalof and Smith, 2001; Lloyd and Fastie, 2002; Larocque and Smith, 2005), including studies conducted in parts of Labrador (D'Arrigo et al., 1996, 2003). The goal of choosing sites where trees are the most environmentally stressed is to capture a strong growth–climate relationship in the data (Hughes, 2002). The drawback of this approach, however, is the reduced ability of the researcher to demonstrate the spatial variability of this relationship in a systematic way. The rationale of the gridded sampling design presented here is to address such a disadvantage.

A gridded sampling design will allow for a dendrochronological analysis across a broad region such that gradients of change may be more easily observed. Specifically, we have sought to optimize our ability to capture differences in radial growth and growth–climate relationships along latitudinal and longitudinal gradients – an ability that is minimized in studies where individual sites are selected either randomly or at locations targeted for climatic sensitivity.

With this in mind, trees were sampled at twelve remote sites in central and western Labrador along a latitudinal and longitudinal network consisting of three north-to-south transects. Each transect comprised four sites located at a uniform distance from one another. Study sites were located at the intersection of coordinates formed at 62°W, 64°W and 66°W longitude and at 52°N, 53°N, 54°N and 55°N latitude (Fig. 2). Sampling was conducted as close as possible to these pre-determined grid intersection points, but was subject to some logistical considerations associated with accessing remote locations. When the exact node could not be sampled, a forest setting within five minutes of latitude from each pre-determined node was selected.

The theoretical grid is almost entirely contained within the boundaries of Labrador, though a few of the northern (Lac Indian, Claude Lake) and southern sites (Angie Lake and Petit Lac aux Sauterelles) are found near the Labrador border in Quebec (Fig. 2). From north to south, the grid measures approximately 333 km, while from east to west, the grid measures approximately 256 km and 274 km, respectively, along the north and south boundaries.

Ecoregions that fall within the network of sites include low subarctic forest, mid subarctic forest, high boreal forest and high subarctic tundra (Roberts et al., 2006). The region is dominated by black spruce (*Picea mariana* (Mill.) Britton, Sterns, Poggenb.), with co-dominant species including balsam fir (*Abies balsamea* (L.) Mill.), eastern larch (*Larix laricina* (DuRoi) K. Koch) and white spruce (*Picea glauca* (Moench) Voss) at more northern and eastern sites (Roberts et al., 2006).

Methods

Radial-growth data

Mature trees of dominant or co-dominant size in each forest were selected away from adjacent water bodies or other site inhomogeneities, to minimize aberrant ring patterns within trees. Increment cores were collected from each of the two most dominant conifer species at each site. To form a chronology, a total of 40 cores were collected from 20 trees (two cores from each tree), for each species, at each site. The collection resulted in a total of 480 trees forming 24 chronologies. To check for homogeneity of signal within the ring patterns of each tree, radial-growth measurements were first visually, and then statistically, crossdated using COFECHA (Holmes, 1983). Measurements were standardized using the program ARSTAN (Cook, 1985; version ARSTAN_41d, 03/18/07) to eliminate the biological growth trend during a conservative single detrending procedure, whereby each measurement series was fit with a negative exponential curve, with a default if $k < 0$ to a linear regression of any slope. "Standard" master chronologies were created from the averages of each detrended core at each site. These standard master chronologies were subsequently used to analyze and compare the different chronologies across space and time.

Climate data

Adjusted Historical Canadian Climate Data (AHCCD) were obtained from Environment Canada for the purpose of establishing radial growth–climate relationships for central and western Labrador. Data from the four nearest climate stations – Goose Bay, NL [Station # 8501900], Churchill Falls, NL [Station #s 8501130, 8501131, 8501132], Wabush, NL [Station # 8504175] and Schefferville, QC [Station # 7117825] – were utilized. Monthly temperature and precipitation data were inputs to the response function analysis program DENDROCLIM2002 (Biondi and Waikul, 2004), used to assess the strength of the growth–climate relationships at each of the twelve sites. For this analysis, sample sites were paired with data from the nearest climate station. Radial growth chronologies were analyzed with mean and maximum monthly temperature data and total precipitation data from April of the