Dendrochronologia 29 (2011) 55–63

Contents lists available at ScienceDirect

Dendrochronologia

journal homepage: www.elsevier.de/dendro

A dendroclimatic reconstruction of June–July mean temperature in the northern Canadian Rocky Mountains

Aquila Flower*, Dan J. Smith

University of Victoria Tree-Ring Laboratory, Department of Geography, University of Victoria, PO BOX 3060 STN CSC, Victoria, BC V8W 3R4, Canada

ARTICLE INFO

Keywords:
Dendroclimatology
Climate Reconstruction
British Columbia
Canadian Rocky Mountains
White Spruce

ABSTRACT

A white spruce ring-width chronology was used to reconstruct June–July mean temperatures in the northern Canadian Rocky Mountains back to 1772 A.D. Samples were collected in an old growth subalpine forest in the remote Kwadacha Wilderness Provincial Park. Two chronologies were created, one using standard dendroclimatological methods and one through the use of principal components analysis. The ring-width chronologies both showed a strong positive relationship with minimum, maximum, and mean temperatures during the current growing season. The principal component based chronology was deemed superior for use as a proxy record due to its greater ability to explain the variance in the instrumental temperature record and stronger performance during reconstruction verification. Comparison of this reconstruction with other dendroclimatological reconstructions from western Canada revealed a coherent pattern of low-frequency variability, whereas comparisons at annual times-scales showed considerable temporal and spatial variability in the level of agreement between reconstructions. The northern Canadian Rocky Mountains reconstruction showed no evidence of the reduction in sensitivity to climatic variability that has been found in many other northern spruce chronologies during the late 20th century.

Introduction

Dendroclimatological research methods utilize the information contained in tree-rings to produce annually resolved proxy records of climatic variability (Fritts, 1976). These dendroclimatic reconstructions are used extensively as important sources of evidence in global climate research and policy papers (Hughes, 2002). By extending the limited instrumental climate record, they offer insight into long-term natural climate variability and provide annually resolved proxy historical records to which modern climate conditions can be compared.

Climate records have been reconstructed from tree-rings at numerous sites in western Canada, including the British Columbia Coast Mountains (Larocque and Smith, 2005), the southern interior of British Columbia (Wilson and Luckman, 2003), the southern Canadian Rocky Mountains (Wig and Smith, 1994; St. George and Luckman, 2001; Luckman and Wilson, 2005), and the Northwest Territories and the Yukon Territory (Jacoby and Cook, 1981; Szeicz and MacDonald, 1994; Youngblut and Luckman, 2008). Greater spatial coverage of dendroclimatic reconstructions is desirable because significant regional variations exist in the overall patterns of climate fluctuations (St. George and Luckman, 2001). Within the cordillera of western Canada, one notable spatial gap in the regional coverage of dendroclimatic reconstructions exists in the mountains of northeastern British Columbia, where only limited dendroclimatological research has been completed (Schweingruber, 1988; Briffa et al., 1994).

This paper presents the findings of a tree-ring investigation at a remote site in the northern Canadian Rocky Mountains, where dendroclimatological techniques were used to develop a proxy record of summer (June–July) mean surface air temperatures. This is the first annually resolved temperature reconstruction completed in northern interior British Columbia.

Methods

Site and sampling

A ring-width chronology was developed using increment cores extracted from white spruce (*Picea glauca* [Moench] Voss) trees growing in the remote Kwadacha Wilderness Provincial Park (Fig. 1). The Kwadacha Wilderness Provincial Park's rugged, mountainous topography is part of the Muskwa Range and reflects a history of extensive glacial activity (Bednarski and Smith, 2007).

* Corresponding author. Present address: Department of Geography, 1251 University of Oregon, Eugene, OR 97403-1251, USA. Tel.: +1 541 346 2698; fax: +1 541 346 2067.
E-mail address: aquila@uoregon.edu (A. Flower).

1125-7865/$ – see front matter
doi:10.1016/j.dendro.2010.10.001

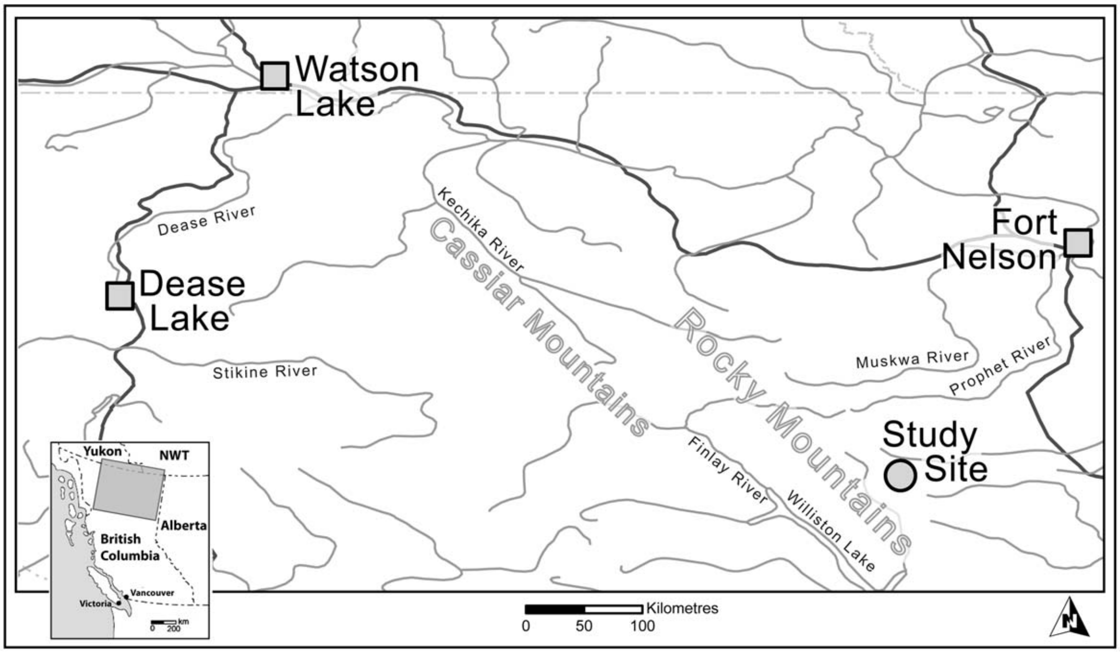

Fig. 1. Location of study site and climate stations.

The park is one of the few sites where glaciers can be found in the Canadian Rocky Mountains north of the Peace River (Ommanney, 2002) and is the source of the glacial meltwater draining into the headwaters of the Muskwa and Kechika rivers.

Samples were collected from trees found growing in a subalpine forest located between 1150 and 1400 m asl on south-east and east-facing slopes adjacent to Haworth Lake (57.8° lat N; 125.1° long W; Fig. 1). The dominant tree species at the sampling site were mature white spruce and subalpine fir (*Abies lasiocarpa* [Hooker] Nuttall) trees, with younger cohorts dominated by subalpine fir. The understory was sparsely populated with forbs and dwarf shrubs growing out of a deep layer of step moss (*Hylocomium splendens*). Nearby swampy areas were populated by black spruce (*Picea mariana* (Mill.) B.S.P) and dense thickets of *Salix* species.

Mature, dominant trees with no obvious signs of crown damage or rot were selected for sampling. Two increment cores were taken near breast height to pith with 18 inch borers from each tree at positions ≥90° apart.

Data preparation

The cores were prepared for measurement following standard dendrochronological methods (Stokes and Smiley, 1968; Fritts, 1976; Pilcher, 1990). After being air dried and glued to boards with slotted mounts, the cores were sanded with progressively finer grades of sandpaper to enhance the visibility of the annual tree-ring boundaries. Ring-widths were measured to the nearest 0.01 mm using a WinDENDRO 2006 digital image measurement and analysis system (Regent Instruments Inc., 2006).

Visual cross-dating of the ring-width series was checked using the International Tree-Ring Data Bank software program COFECHA (Holmes, 1983). Ring-width series that exhibited low correlations with the other series due to the presence of very narrow rings with faint boundaries, which hampered the accurate measurement of some of the annual rings, were removed from further analysis. Only cores older than 160 years, and with no obvious signs of damage, were included in further analyses.

Standardization and chronology construction

The ring-width series were standardized using the program ARSTAN (Cook and Krusic, 2005). A double-detrending method was used to enhance the climate signal contained in the ring-width series by reducing the noise caused by biological growth trends and endogenous disturbance events (Cook, 1985). The initial detrending was completed by fitting a growth curve to each individual ring-width series. These growth curves consisted of either a modified negative exponential curve, a linear regression line with a negative slope, or a horizontal line passing through the mean. A secondary detrending was accomplished by fitting a smoothing spline with a 67% frequency-response cutoff to each series. These splines preserve 50% of the variance in the ring-width series at a frequency equal to two-thirds of the length of each series, and therefore offer a good compromise between the risk of removing an excessive amount of low-frequency climatic variability and the danger of retaining too much low-frequency noise caused by disturbance events (Cook, 1985). Individual ring-width series were divided by the values of the fitted curves for each year to calculate the index value of each ring. Auto Regressive Moving Average (ARMA) modeling was employed to remove autocorrelation in the ring-width series (Cook, 1985). Individual ARMA models of the order determined using Akaike's Information Criterion were fit to each ring-width series in ARSTAN. Only the prewhitened residual ring-width series were used in further analysis.

The individual ring-width series were combined using a biweight robust mean function to create a master ring-width chronology (hereafter referred to as the RW chronology). The Expressed Population Signal (EPS) statistic was used to determine the change in chronology quality that occurs as sample size varies through time (Wigley et al., 1984; Briffa and Jones, 1990). EPS values were calculated for the master chronology using a 20-year moving window. The RW chronology was truncated at the decade in which the running EPS fell below the standard value of 0.85 proposed by Wigley et al. (1984).

A second master chronology was created using an unrotated principal components analysis (PCA) of the individual trees (here-