A Dendroclimatic Record of Paleoclimate of the Last 10,000 Years, Glacier Bay National Park and Preserve
2005 Progress Report

Studies Conducted As Part of Research Project:
Long-term tidewater and terrestrial glacier dynamics, glacier hydrology, and Holocene and historic glacier activity and climate change in Glacier Bay National Park and Preserve

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Abstract

Global climate is changing, and humans may have a significant role in affecting those changes. Our knowledge of how the climate system works is hampered by a lack of long-term records, which are needed to demonstrate the full range of natural variability of the climate system especially on annual to century time scales. As contemporary warming progresses, major changes in the cryosphere and biosphere are being observed especially in the higher latitudes. It is with this need in mind that we are conducting research on the paleoclimate of Glacier Bay, a climatically-sensitive region of the North Pacific region. Our research involves analysis of the climatically-driven glacial fluctuations during the Holocene, and linking this record to a unique, potentially -10,000-year long tree-ring chronology of high-latitude climatic information derived from ancient wood of trees overridden by successive ice advances.

Our continuing primary objective is to collect sections of ancient trees overridden by the glaciers during the Holocene excursions across Glacier Bay before they are lost to erosion and decay. The recovery and processing of these samples is the primary resource in building a tree ring record. Presently we are engaged in showing that this effort is possible and that the ring-width data from archived wood and samples taken in 2005 have a strong regional climate signal. Preliminary efforts to crossdate the subfossil Glacier Bay tree-ring samples with other records from the Gulf of Alaska were successful and the combination of Glacier Bay tree-ring series with a regional tree-ring master chronology for the Gulf of Alaska extends the record back into the second century AD.

Introduction

Heavy snowfall in the high mountains surrounding Glacier Bay feeds one of the larger active glacier complexes in North America, a part of the fourth largest glaciated regions in the world (Meier 1984). With the exception of some lowlands at the southeastern and southwestern margins, Glacier Bay was covered by ice as recently as 250 years ago during the Little Ice Age. This recent loss of ice in Glacier Bay alone has had a significant effect on global sea level rise (Arendt et al., 2002; Larsen et al 2005). Glacial retreat since that time is one of the best documented in the world, with ice margins retreating distances as far as 90 km at some of the highest rates ever recorded. During this retreat, forests that were overridden by ice advance have been uncovered and these interstadial forests reveal that in addition to the advance during the Little Ice Age, ice apparently advanced into Glacier Bay several other times beginning about 10,000 years ago (Lawson et al, 2006).

Numerous global warming scenarios (IPCC 2001) and observations indicate that Arctic and Subarctic regions are particularly sensitive to current and predicted climatic changes, but our knowledge is hampered by relatively short-term climatic records from instrumented sources. The large repository of interstadial wood within Glacier Bay may provide detailed data on long-term changes in the climate of the North Pacific region, a region that is particularly sensitive to annual, decadal and longer periods of climatic change. Paleoclimate data from our analysis will provide critical parameters that are now lacking but required to calibrate Global Climate Models (GCMs) and better predict future changes in climate. Other studies of modern and exhumed wood from areas in the western Gulf of Alaska have found that the tree rings of these samples crossdate and correlate well with climate (Barclay et al. 1999, Wiles et al. 1999). However, these studies are limited in time, spanning only the last 1000 years or so; the former forests in Glacier Bay provide the only known Subarctic North American repository of wood that may continuously span the last 10,000 years.

As part of our research in Glacier Bay in 2005, we initiated the dendrochronological analysis of new wood sections and crossdating of samples from the period 1400 years BP, a period of time with few tree ring records in any Subarctic region. With such data, various parameters such as long-term annual and seasonal temperatures and trends in precipitation can be assessed. We also obtained cores of living trees to identify the climate signal in the ring-width data.

2005 Objectives

Our studies of the paleoclimate of Glacier Bay in 2005 specifically focused on the following:

1) Collect tree cores from living trees to examine the climate signal in the tree-ring record and compare it with the regional tree-ring network available in the Gulf of Alaska.
2) Obtain sections of interstadial wood that grew within the last 700 to 1200 years.
3) Examine selected groups of existing radiocarbon-dated cross sections and build floating ring-width series within these intervals.

Methodology

Tree-ring analysis is being conducted at laboratories at Dartmouth College, The College of Wooster and CRREL under the direction of the PIs. We collected cores of modern trees to assess the suitability of the two major tree species, Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) as sources of tree-ring records that reflect climate. Dendroclimatic studies involve the statistical comparison of tree growth (such as measured ring widths) to regional temperatures; this is most often accomplished with comparison with the instrumented climate records (Fritts 1976). In addition to the climate data available from the Historical Climate Network (HCN), data is now being collected at sites across Glacier Bay (Finnegan et al., 2006) and will provide insights into how climate varies regionally across the Park, as well as allow us to determine how representative historical records from climate stations outside Glacier Bay reflect the climate within the bay.

In addition to modern tree growth, initial work with radiocarbon-dated, subfossil exhumed wood shows that crossdating is viable for intervals over the last 2000 years. In order to know the exact year of growth on each of these older specimens, we need to connect them to the present day tree growth, which can be done with the oldest still-living trees that we have begun to sample. We know of at least three locations where trees of up to 700 years in age still live in the Park; it is these trees we planned to sample in order to begin the process of developing a long-term chronology of exact known ages using both living trees and the older cross-sections.

2005 Results

We focused our efforts on obtaining cores of living trees for subsequently calibrating modern climate signals to the tree-ring record, and obtaining select cross sections of ancient trees overridden by glaciers at different times during the Holocene. We cored living trees from five stands of old and young growth spruce and hemlock, obtaining sections from Dundas Bay and Bartlett Cove. Several of the sites that we sampled in Dundas Bay have trees that are ~600-700 years old, which will allow for some age overlap with the youngest ancient cross-sections previously sampled in lower Glacier Bay. These cores are critical to filling gaps in the paleo-record and linking our ancient wood data to that of the present, thus making the annual and seasonal reconstructions of climate from the longer chronology. Core samples of the older trees in Dundas Bay will allow us to explore the statistical relationships between tree growth and climate in the period of roughly 100 years for which we have modern climatic data. The shorter (approx. 200 year-old) chronologies sampled previously at Bartlett Cove, Geikie Inlet and a higher elevation site above Tlingit Point will provide depth in the more recent time period, along with good spatial and altitudinal coverage of the Bay.

The initial analysis of the tree cores is underway in the Tree Ring Lab at Dartmouth College. We have prepared the cores for analysis and completed dating of those from Bartlett Cove area. We are now at work on the longer record samples from Dundas Bay.

Some of these cores however, have proven unusable due primarily to gaps in the record and additional core sampling is planned for 2006. Data from these cores will go towards bridging the gap between the present day and the youngest cross sections of interstadial wood for which we have approximate (radiocarbon) dates, and ultimately allow for calendar dating of many of the cross sections we have sampled.

We also obtained 20 cross-sections from newly exposed, in situ interstadial stumps and logs, focusing our efforts on areas that we believed would fill gaps in the longer chronology. Sections were obtained from the head of Geikie Inlet where radiocarbon dating had previously shown the ancient trees were growing during the critical time period of ~1800 to 1100 years BP. We also obtained four sections from younger stumps on Lester Island, where a single previous radiocarbon date indicated an age of about 500 years BP. Both groups of sections are critical to linking modern and ancient tree ring records.

The interstadial cross sections have been processed at CRREL and we have initiated their analysis of the tree ring record at the Wooster Tree Ring Lab of the sections of ~ 1000 yrs BP interval. Selected 1000 yr BP samples from previous years were also examined to determine whether they crossdated with tree- ring records from Columbia Bay in Prince William Sound in the central Gulf of Alaska region. Although limited samples were available, these results are extremely encouraging (Figure 1). The tree-ring record of ten logs from Glacier Bay was compiled into a floating ring-width series and then dated with the master chronology from Columbia Bay. The dating, although preliminary, is strong evidence of similar climate response, and we plan to increase the sample size through this important interval to strengthen the common signal in the record. This work is significantly extending the Gulf of Alaska tree-ring record by almost 400 years (Figure 1) and is extremely encouraging for the future of dendroclimatology in the North Pacific region.

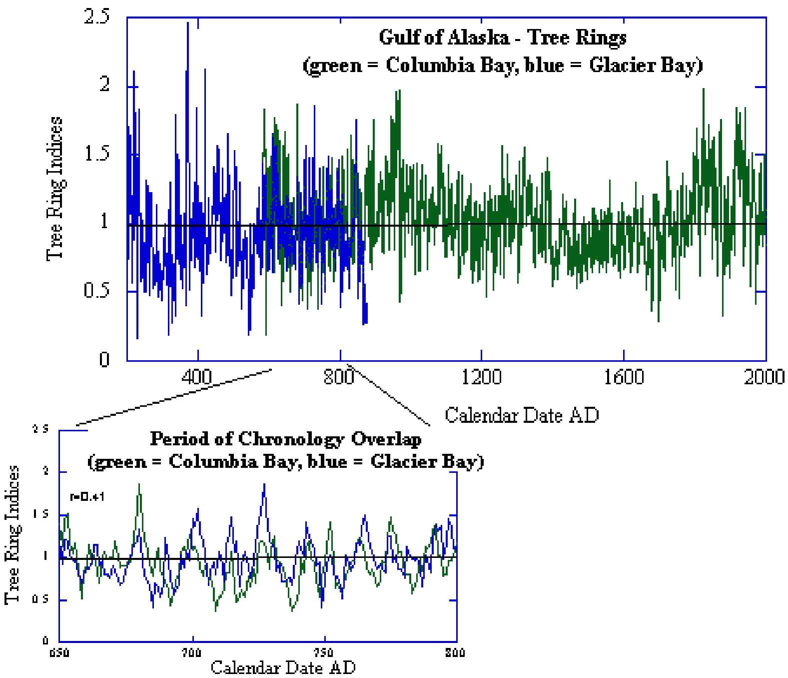

Figure 1. Tree-ring dating of the Glacier Bay samples. The green curve is a ring-width record composite from logs in Columbia Bay, Prince William Sound. The inset shows graphically the matching ring-width variations from the Glacier Bay chronology and the Prince William Sound record.

Continuing Work

Based on our initial results, we anticipate being able to show that the modern trees growing in Glacier Bay exhibit variations in tree-ring widths that relate to climatic changes, mainly temperature and precipitation, as has been done for similar species of trees in other parts of the Gulf of Alaska (Barclay et al. 1999, Wiles et al. 1999). We will continue laboratory analyses of the ancient sections of wood of the last millennia, as well as complete the analysis of the modern core records over the next several months. During field work in 2006, we will continue to obtain crucial cores and sections to complete the record of the last millennia and allow us to verify what our limited sampling has shown to date – a strong crossdating with the western Gulf of Alaska tree-ring records and thus a clear link to ancient changes in climate of Glacier Bay.

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