Paleoclimate of the Last 10,000 Years, Glacier Bay National Park and Preserve: Progress Understanding Climate Change In Southeast Alaska

ANNUAL REPORT 2008

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

Daniel Lawson [1, 3]
Greg Wiles [2]

[1] CRREL, 72 Lyme Road, Hanover, NH
[2] Department of Geology, The College of Wooster, Wooster, OH
[3] Departments of Geography and Earth Sciences, Dartmouth College, Hanover, NH

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A Dendroclimatic Record of Paleoclimate of the Last 10,000 Years, Glacier Bay National Park and Preserve: Progress Understanding Climate Change In Southeast Alaska

2008 Annual Report

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Daniel Lawson[1,3] and Greg Wiles[2]
[1] CRREL, 72 Lyme Road, Hanover, NH 03755
[2] Department of Geology, The College of Wooster, Wooster, OH 44691

Executive Summary

Our investigations in 2008 focused on continuing collection and analyses of tree rings from living trees and building a long ring-width series from interstadial wood. These interstadial forests were extensive and their preservation, although discontinuous and fragmented, is remarkable. In situ stumps, still rooted in growth position, and logs held within sediments remain from forests that existed at various times between glaciations over approximately the last 10,000 years.

The emerging glacial history based on tree-ring dating is improving our knowledge of the glacial history of the mid to lower bay over the past 5000 years. Detail is being added to the previously recognized 4000, 3000, 1200 and recent Little Ice Age advances in Glacier Bay. These initial results suggest a more dynamic advance and retreat history than has been evident in previous work. Our chronology is consistent with the work on relative sea level by Mann and Streveler (2008) in Icy Strait and broadly consistent with the compilation of Connor et al. (in press). The record is also beginning to show a strong correlation to North American and global records of glacial cycles and paleoclimate trends.

Tree-ring work in 2008 has resulted in five completed undergraduate theses, two to be completed in March 2009, two new undergraduate theses starting in 2009 and an ongoing PhD dissertation. These projects are focusing on ring-width tree-ring series from the subfossil wood collection and links to the glacial history. Additional collections of living tree-ring sites taken from Excursion Ridge in 2008 were sampled for latewood density and ring-width at the WSL-Tree Ring Lab in Switzerland. These data along with new processing of previously sampled yellow cedar are being incorporated in dendroclimatic modeling studies for student theses completed in 2008. We continue to present the results of this work at professional meetings and are preparing results of this and previous work in Glacier Bay for journal publication.

Introduction

Heavy snowfall in the high mountains surrounding Glacier Bay feeds one of the larger active glacier complexes along the Gulf of Alaska, a part of the largest glaciated region in the world outside of the large ice sheets (Meier 1984; Meier et al 2007). With the exception of some lowlands at the southeastern and southwestern margins, Glacier Bay was covered by ice as recently as AD 1770 during the Little Ice Age (LIA) (Motyka et al., 2003). The recent loss of the LIA ice in Glacier Bay has had a significant effect on global sea level rise (Arendt et al., 2002, Larson et al., 2006); it is estimated to have contributed as much as 1 cm of global sea level rise of the total LIA rise of approximately 20 cm. The deglaciation of the Glacier Bay watershed is one of the best documented in the world, with ice margins retreating distances as far as 100 km at some of the highest rates ever recorded. During this retreat, forests that were overridden previously by ice have been uncovered and radiocarbon dating of 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 as early as 12,500 years ago (Lawson et al, 2007).

Global climate is changing and humans have a significant role in affecting those changes. Placing these contemporary changes into a long-term context is crucial to our understanding of how the climate system works and to demonstrating the full range of natural variability of the climate system especially on annual to millennial time scales. As warming progresses, major changes in the cryosphere and biosphere are being observed especially in the higher latitudes (e.g. Hinzman et al., 2005, IPCC 2007). 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 where its unique 10,000+ year long tree-ring chronology can provide high-resolution information on the highly variable climate of the Holocene with respect to each cycle of glacial advance and retreat.

Our studies will provide a high resolution record of a length that currently is unknown anywhere else within the high latitude regions of Alaska and the North Pacific region. For the North Pacific region, most observational climate records are less than 100 years long, spanning only the interval of possible anthropogenic influence, and other tree ring records generally less than 1200 years in length. The large repository of interstadial wood within Glacier Bay will provide the only long-term thermal history that will put the current climatic trends in a 10000 year perspective. With these paleoclimate data, we can reconstruct critical parameters required to understand climate dynamics and to calibrate Global Climate Models (GCM's) for better predicting future changes in climate.

In this Annual Report, we describe the results of our most recent work extracting tree-ring records from the interstadial wood and living trees within the context of the overall research effort. The tree-ring record is providing calendar dates on wood that are of significance to glacial history, geomorphologic events and potentially archaeological significance. To extract a climate signal from the series, we are using the meteorological records from along the Gulf of Alaska. In addition the synergy between understanding climate and contemporary tree growth will be greatly aided by comparing the records from the climate monitoring efforts within Glacier Bay (Lawson et al 2006a, 2006b;

Finnegan et al 2007). The combined monitoring record and paleo-records will allow us to understand current and future short and long term changes in the climate of Glacier Bay that many other researchers in Glacier Bay can use.

Brief History of Previous Work

The continuing sampling of interstadial wood has revealed that a huge repository of information exists that may provide the first information on paleoclimate of the park over the last 10,000 or more years. Generally well-preserved wood is first exposed by erosion of glacial and glaciofluvial deposits and the initial sampling suggested that it may be possible to develop a tree-ring record for each of the time periods represented by the ancient forests. However, we also realized early on that the interstadial forest was transitory – that it remained suitable for sampling for only a brief period of time, perhaps as little as two to three years after exposure, and further that because of the environment in which the trees are exposed, mainly eroding slopes and active flood plains and debris fans the wood is removed to fjords or reburied rather quickly. Examples of these environments are shown in last year's report (Lawson et al. 2007).

The wood sampling began in earnest in 1996, with basic laboratory processing and radiocarbon dating of the samples done as sections and cores were acquired. All wood samples were slowly dried, stabilized with glue and then rough and fine sanded for an initial appraisal of their suitability for tree-ring work. Samples of the wood were radiocarbon-dated to define the range of representative ages, and later used to identify the groups of wood required for further sampling of sections necessary for the tree-ring analyses. Although sections of interstadial wood received the initial laboratory processing annually, the detailed analysis of the tree-ring record was not begun until 2002, the primary reason for the delay being that sufficient dated samples had to be gathered to prove that enough wood existed in the park to piece together a long tree-ring record.

It is important to realize that a lengthy record covering multiple glacial cycles and periods of forest growth is extremely unique and invaluable toward developing a climatic record during the Holocene. No other repository is known from a heavily glaciated terrain like that of Glacier Bay. In most instances, subsequent glacial activity removes evidence of much, if not most of the record of previous glaciations, and thus in nearly all formerly glaciated regions of the world, a long-term record of ancient forests would be impossible to document and obtain enough samples for a tree-ring analysis. Glacier Bay goes against that principle and the more sampling we have done, the clearer it has become apparent that the Park has preserved within it an unprecedented record of the glacial history and the paleoclimate of the interstadial forests. Because all wood has to be first located by searching on foot, it takes a significant amount of time to obtain samples necessary for the analysis and hence the initial delay in conducting the tree-ring analyses. In addition many samples are split, have some rot and contain sand within the cracks and wood itself, causing some samples to be incomplete or unuseable.

We have sampled interstadial wood at numerous sites across the Glacier Bay watershed. We have located wood in the West and East Arms, as well as the lower bay. Traverses in search of interstadial stumps and logs have often found wood in many valleys feeding the primary inlets and bays, sometimes in almost inaccessible higher altitude steep slopes, as well as within the intertidal zone as tectonic and isostatic uplift exposes it. Logs and stumps we sampled prior to 2006 no longer exist in the field due to erosion and transport into the sea, or re-burial within fluvial deposits. Decay of wood has also taken its toll and only fragments often remain on exposed surfaces.

Extensive sample processing and tree-ring analysis has provided the first calendar-dated tree-ring record for Glacier Bay and several groups of interstadial wood have been counted and ring-widths analyzed. These chronologies will be linked with other groups to provide a continuous record that currently spans nearly 3000 years. The results through the past 1500 years have been correlated with other calendar-dated chronologies within the Gulf of Alaska, and our work now provides the first tree-ring record 1500 years beyond it. As we continue to develop the chronologies, additional analyses, including ring density, stable isotopic composition and radiocarbon content of each ring will be undertaken to provide further high resolution information about seasonal and annual paleotemperature trends and other paleoclimatic information. Our results to date on paleoclimate are included in previous annual reports beginning in 2004.

Overall Objectives

The overall objective of our research is to develop a high-resolution record of climate for Glacier Bay and the North Pacific region over the past several thousand years using the exactly-dated tree-ring records and reconstructed glacial histories of the Park. Our paleoclimatic studies in 2008 specifically focused on sampling and developing tree-ring chronologies and analyzing these records for their climatic significance. Specific tasks included:

1) Sampling living trees and developing ring-width and latewood density series for the past several hundred years.
2) Identifying the climate signal in these series,
3) Using the tree-ring series in on-going modeling of ocean-atmosphere climate variability in the North Pacific,
4) Linking the living tree-ring record with that of interstadial wood that grew for various intervals through the past 5000 years to the existing radiocarbon-dated record of glacial cycles.

Background on Dendrochronology and Methods

In this section, we outline some basic principles of dendrochronology and standard methods employed in our research. For those readers familiar with this, please skip to the next section on our 2008 work. Tree-ring data from Glacier Bay is a record of past temperature variability and has been used to reconstruct past temperature changes from Sitka, Alaska (Erlanger 2008). Climate data now being collected at sites across Glacier Bay (Lawson et al 2006 a, b) will provide data on how climate varies regionally across the Park, and will allow us to determine whether historical records from climate stations outside Glacier Bay reflect the climate within the bay.

Tree-ring records from the interstadial trees are developed from sections cut from in situ stumps and logs in glacial sediments. We use standard geological methods to determine the nature of the deposits associated with the wood and to interpret their origins, particularly whether the death of the wood resulted from a glacial advance and thus aid in producing information on the glacial history of the bay. These methods include defining the glacial stratigraphy by sedimentological analysis of deposits (e.g. Benn and Evans 1998). Each core and section sample site is located precisely by GPS, photographed and various parameters, such as dimensions, position of each sample section relative to the roots, tree species and overall condition, are recorded.

In the lab, the core and wood sections are slowly dried and then glued and sanded for counting and measuring the rings. We must carefully scrutinize multiple wood sections to account for missing rings, as rings may be locally absent on a cross section due to various stresses in the environment. In addition, small samples (several grams) of the outermost five rings of interstadial wood sections are radiocarbon-dated.

Ring-width chronologies from the interstadial sites are crossdated with chronologies from the living sites when they overlap in age, or used as floating tree-ring series when they lie outside the range of the calendar-dated series (Figure 1). As we continue to obtain and to analyze tree ring records from new interstadial wood sections, we will link these floating series to develop a continuous tree-ring record. Thus, a current focus is to obtain the necessary sections for filling in the entire series beyond the calendar-aged wood. We are especially encouraged because the extensive set of living tree-ring records and interstadial records from other regions along the Gulf of Alaska match well with the tree –ring records from Glacier Bay. For example, a 1500 year long tree-ring record from Columbia Bay in Prince William Sound correlates well with tree-ring series from Geikie Inlet and other sites currently being investigated from Berg Bay and North Fingers that have known caches of logs in the age range of 1200 yr. BP.

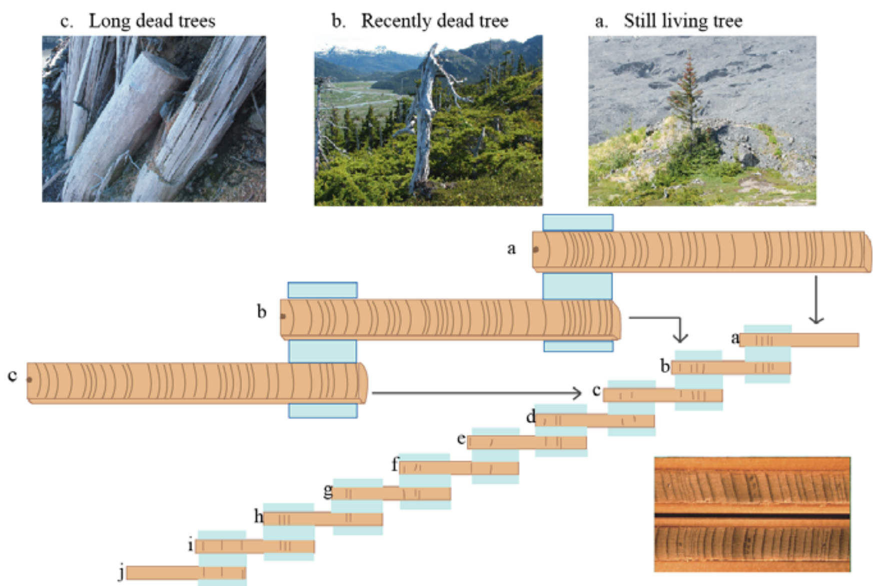

Figure 1. *Diagram showing the tree-ring crossdating technique. The age of the wood increases to the left. We are now establishing calendar-dated tree-ring records from living trees in Glacier Bay and matching them with floating ring-width series from interstadial wood, extending the calendar-dated series back several millennia.*

We have also begun building floating ring-width series dating back to 4,000 yr BP, 3000 yr BP that are serving as the basis to expand these series and link them with the calendar-dated series that spans almost the last 2000 years.

Thus as we continue to acquire and process multiple groups of wood sections, it is reasonable to expect to link at 3000 to 4,000 year series within five years and eventually the entire ten thousand year period of the Holocene may be spanned. To accomplish this we must also collect a sufficient number of wood sections of a particular age range to produce a continuous and reproducible tree–ring record. We estimate that based on measuring 2 to 3 radii from each cross section and needing approximately 20 radii for a reliable, well-replicated dendroclimatic signal that we will need approximately 7 – 10 samples cross-sections throughout the tree-ring series.

The resulting living ring-width series are correlated (calibrated; Fritts, 1976) with the instrumental data from meteorological records from nearby sites, which include Juneau, Sitka, Haines and Yakutat. We also compared the series to an existing network of tree-ring series available from the Gulf of Alaska (Wilson et al., 2007, Erlanger, 2008).

Work Accomplished During 2008

Students at The College of Wooster Tree Ring Lab are continuing work in the lower Bay in dating the glacial history. Caitlin Fetters will be completing her undergraduate thesis at The College of Wooster on 23 March 2009. Her thesis focuses on dating emergent forests along the shore of the lower bay. The tree-ring dating of these logs is beginning to reveal the advance history of the tidewater glacier during the early decades of the AD 1700s.

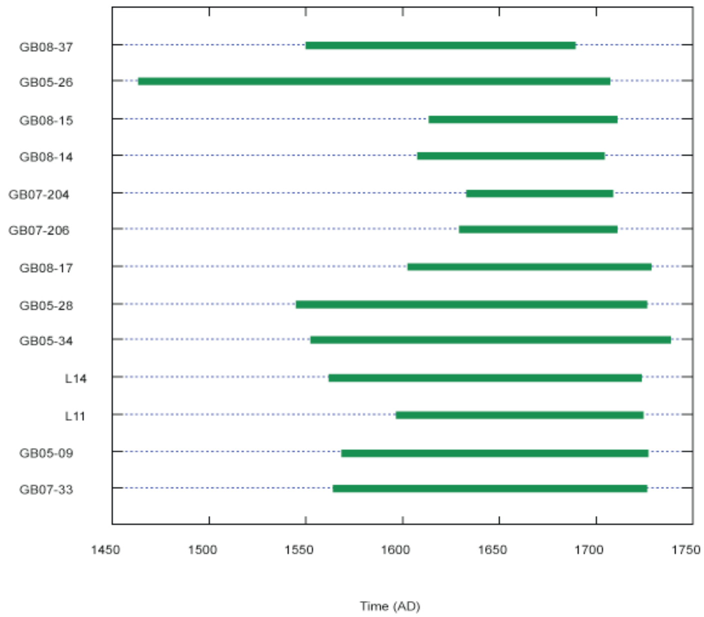

Figure 2. Calendar-dated logs from the lower bay. Most of these samples are from the intertidal areas along the east side of the lower bay. The location of these samples and the calendar dated range for each log are shown in Figure 3. Calendar-dates are derived using ring-width series samples from tree line sites at Beartrack Cove and Excursion Ridge which we developed over the past three years.

Calendar dates have been obtained for the outer rings of logs dug from the present intertidal zones along the shores on the west and east sides of the lower bay, south of Rush Point (Figure 2). Caitlin's work is being done in collaboration with Nora and Richard Dauenhauer (Dauenhauer, and Dauenhauer, 1987) who have compiled the original Tlingit legends and have studied and compiled the Tlingit stories within Glacier Bay. Close attention is also being made to the comprehensive work and interpretation of radiocarbon-based chronology summarized by Connor et al. (in press).

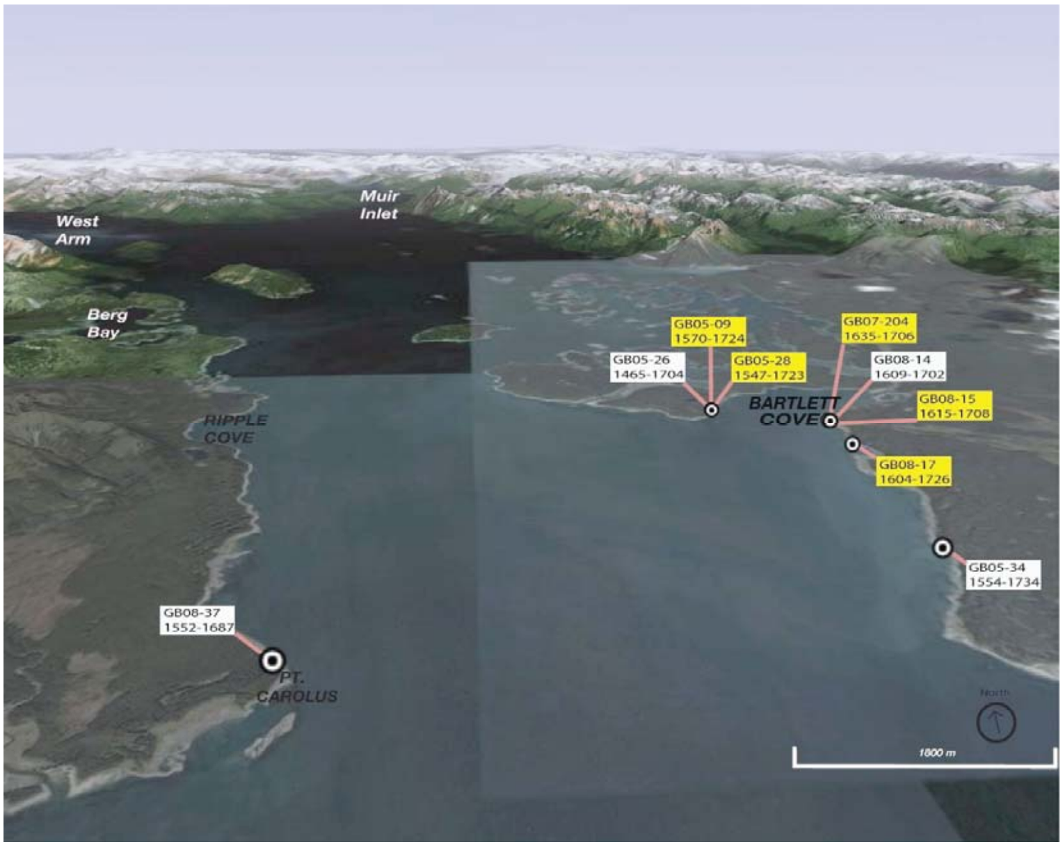

Figure 3. Locations of tree-ring dated logs from the intertidal areas along the lower bay. The yellow labels are those logs that have the outer rings, those in white have been abraded and the outer rings are not preserved.

Mike Krivicich, also a senior at The College of Wooster, will be completing his undergraduate thesis this spring. His topic is assembling tree-ring data from North Fingers Bay and Berg Bay on the west side of Glacier Bay. He has obtained radiocarbon ages on logs and in situ stumps in glacial sediments from within these bays that show two intervals of glacier expansion. One associated with the later ice advance recognized from Geikie Inlet about 1300 yr BP (Lyon, 2006) and another associated with the Little Ice Age (LIA) advance.

A calibrated radiocarbon age from North Fingers Bay north of Berg Bay suggest that trees were killed between 640-780 AD during the LIA. Four logs were internally crossdated showing that this was a general time of inundation into North Fingers Bay.

Work is underway (Krivicich, in progress) to link these data with those of previous work summarized in Lyon et al. (in review).

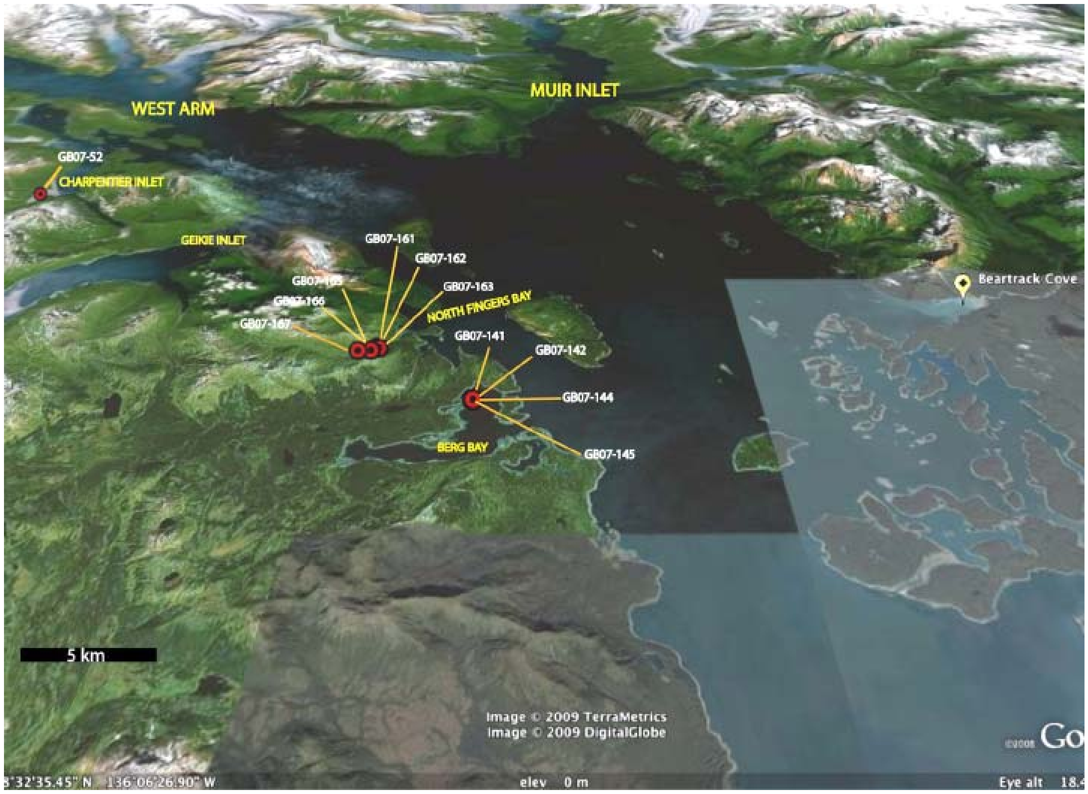

Figure 4. Locations of samples from Berg Bay and North Fingers Bay. These samples represent a variety of ages. The location of a radiocarbon age obtained from Charpentier Inlet and the location of Geikie Inlet discussed in the text are also shown.

Calibrated radiocarbon ages from Berg Bay suggest that wood was killed some time between AD 1330 and 1480 and again between AD1620-1820 AD. The latter sample is included in a floating ring-width series that includes three logs. Given the age of the Berg Bay logs, they should crossdate with existing tree-ring chronologies from the region and efforts are underway to calendar date this floating series.

These results are demonstrating that work done over the last two years can begin to be incorporated (crossdated) with the work by Lyon et al (2006, in prep) who worked on an extensive tree-ring series from Geikie Inlet. In Geikie Inlet, the logs calendar-dated between AD 490-970, with most kill dates in the late AD 880s. This age range is similar to those in North Fingers Bay according to the radiocarbon ages (AD 610-780 AD). Lyon (2006) also had another series from Geikie that C-14 dated to about 3000 BP. Further north in Charpentier Inlet, radiocarbon dating and ongoing tree-ring dating by PhD student (University of Cincinnati) Sarah Laxton shows tree killing and inferred ice expansion at about 3750 +/- 70 BP, which has a calibrated range of 4400 to 3900 yr BP and one individual log has over 320 growth rings, an important length record of ice-free conditions and for tree –ring comparisons.

Sarah Laxton has been assembling tree-ring data samples in the 4000-5000 14C yrs BP age range from the Charpentier Fan and from new locations including Francis and Drake Islands, Sebree Island, and Tlingit Point that were sampled in summer 2008. The ring-widths from the samples gathered from these latter locations will be measured and attempts will be made to cross-date them with the emerging chronologies from Charpentier.

Samples collected from Charpentier Fan in 2007 were analyzed in the University of Victoria Tree-Ring Laboratory (UVTRL). Ring-widths were measured from the Charpentier samples and attempts were made to cross-date these samples with 12 other previously measured samples from the Charpentier Fan site (Figure 5, 6). The preliminary findings from the Charpentier sample analyses were presented at the AGU meeting in December (Laxton et al, 2008). The crossdating has proven difficult; however, the results are encouraging and based on our previous experience at Geikie Inlet, with further sample analyses and thus better replicated data set, we anticipate improve correlations. Efforts are now being placed in expanding this mid-Holocene tree-ring chronology across the other mid-bay locations samples in the 4000-5000 ^{14}C yrs BP age range. Sarah will also expand the chronology at the Charpentier site using samples obtained over the period of 2004 to 2007.

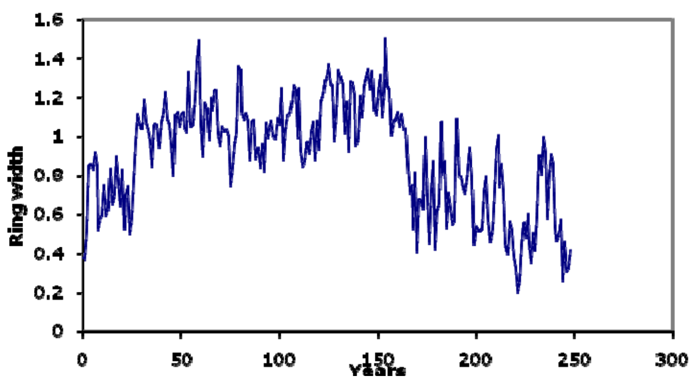

Figure 5. Floating Chronology: GB06-220, GB06-206, GB06-194

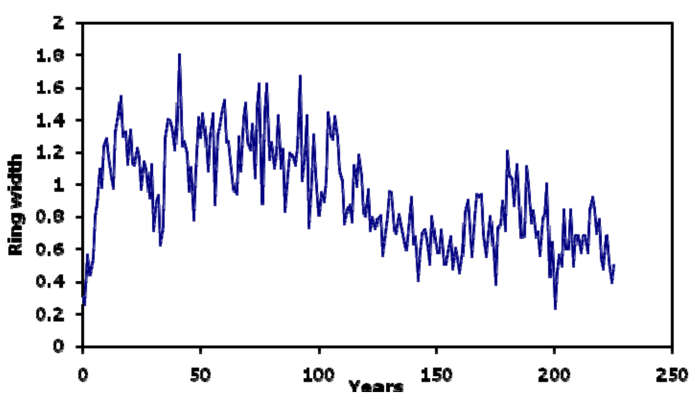

Figure 6. Floating Chronology: GB07-47, GB07-51, GB07-53

Taken together, the data processed along the lower end of Glacier Bay from Charpentier Inlet to the recent Little Ice Age terminal position a few hundred years ago at Icy Strait suggests that there are multiple advances of glacier ice in the fjord over the past 5000 years and that these in some cases are separated by forest growth – advances at 4000, 3000, 1300 yr BP and again at some time before AD 1600 AD through the early decades of the AD 1700s, the ice reaching its maximum at Icy Strait about AD 1734. These intervals match well with the times of inferred relative sea level rise and glacial loading (advance) (Figure 7, Mann and Streveler 2008). Our work will continue to attempt to complete the Little Ice Age interval and its intriguing link to the Tlingit legend. This is being developed by Fetters (in progress) and will be reported separately once completed.

Although preliminary, our results can be compared with collaborative work within the park at Brady Glacier (Capps et al., 2009) which shows that this former tidewater glacier was advancing near its recent terminal position about AD 1820. The arrival of the large Brady Glacier to its terminus almost 100 years after the maximum at Glacier Bay further shows that the large tidewater systems in Alaska are often asynchronous in their histories.

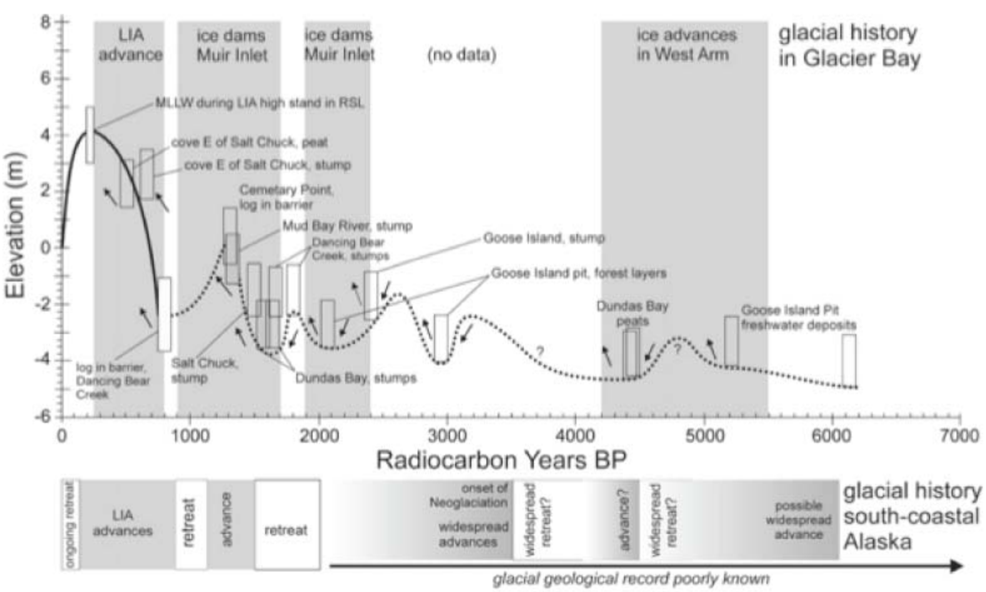

Figure 7. Relative sea level curve from Mann and Streveler (2008). The advances we have identified with radiocarbon and ongoing tree-ring work shows ice expansion at about 3000, 1300 and finally between AD 1400 and 1730. These intervals match well with the times of inferred relative sea level rise and glacial loading (advance).

In addition to the work done on the subfossil wood collection and the glacial history, we are now collaborating with research scientists at Swiss Federal Research Institute (WSL). Two chronologies have been generated by WSL and will be added to the climate modeling efforts. Both are from the cores taken on Excursion Ridge and include a ring-width (not shown) and latewood density series (Figure 8). Latewood density is a parameter measured that is often more sensitive to a different climate input. For example, ring width series in southern coastal Alaska are records of early to mid summer temperature variability and the density variability may respond to a larger climatic window including spring to late summer temperature. The value of using multiple tree-ring parameters is that together they tend to explain more of the variance in climate indices of interest, especially those that describe Pacific Decadal Variability (PDV) such as the Pacific Decadal Oscillation (PDO) and the North Pacific Index (NPI).

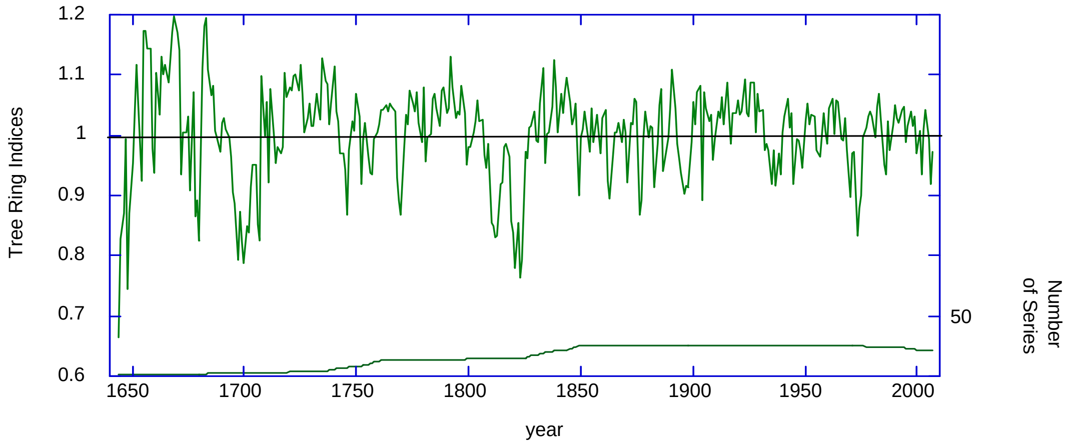

Figure 8. Latewood density tree-ring series from Excursion Ridge (Son of Excursion Ridge). These data were processed by the Swiss Institute for Forest Research. The latewood density series shows pronounced low density years during the late 1600s and early 1800s. Both of these intervals are times of increased vulcanism worldwide and in particular the western Pacific basin. This chronology is only the second latewood density series generated for coastal Alaska. Climatic analysis of the series is underway.

Significance and Products

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 the research on the paleoclimate of Glacier Bay, a climatically-sensitive region of the North Pacific. 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. The record of glacial activity in the Park is also unique; other parts of the Gulf of Alaska as well as neighboring British Columbia have few well-defined records of glacial activity beyond 3000 years ago. Yet here, our initial data suggest that at least 6 cycles of glacial advance and recession have occurred within the last 9000 years. We have made significant progress toward our continuing

primary objective 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.
Our work on the tree ring series to date has produced a significantly longer record than that available elsewhere in the Gulf of Alaska region, extending the paleo-record back more than a 1000 years so far. Once completed the 10000 year record will be the longest, high latitude calendar-dated record of past climate from North America.

The primary significance of this research is thus the development and analysis of a millennia-scale tree-ring record for Glacier Bay National Park and Preserve and defining its relationship to global and regional changes in climate and the resulting periods of glacial advance and retreat. The combined records of climate change are a unique and important contribution to understanding the past and current changes in climate of Glacier Bay and thereby providing a basis for managing and adapting the Park to future climatic change.

Based on our initial and ongoing analyses, this chronology of paleoclimate has the potential of being one of the longest tree-ring records in the world. The temperature proxy record already suggests that an interval during the First Millennium AD may have been as cold as the better studied Little Ice Age, a significantly new finding. Knowledge of the paleotemperature trends during the advance and retreat cycles of the glacial systems will allow us to examine how they relate to the decadal and millennial scale variability in climate and the factors causing those changes. Ultimately it will be a major contribution to larger-scale efforts to reconstruct climate variability for the Northern Hemisphere (D'Arrigo et al., 2005; Mann and Jones, 2003; Moberg, et al., 2005). The paleo records of climate and glacier response will be the only paleoclimatic data spanning the periods of abrupt (decadal) climatic changes of the Holocene, a scenario that recent research indicates could cause extreme societal and environmental disruptions were such events to happen today.

We will continue to present the preliminary and ultimately final results of our research at national and international meetings on climate change, past and present. We will also publish our research results within prestigious professional journals as they are obtained, and provide the Park with Annual Summaries of our research activities and results. In addition, our data will continue to be archived on the Glacier Bay network server and be contributed to the International Tree-Ring Data Bank, maintained by NOAA in Boulder.

Collaborators and synergistic activities

Over the past year, we have collaborated with other researchers working in Glacier Bay. Using our Beartrack and Excursion Ridge ring-width chronologies, Brian Luckman (University of Western Ontario), Danny Capps and John Clague (both at Simon Fraser University) were successful in tree-ring dating the killing of a forest at Brady Glacier. Rosanne D'Arrigo (Lamont-Doherty Earth Observatory, Tree Ring Lab) and Rob Wilson (University of Edinburgh) are serving as advisors on the project and will be involved with us in modeling the dendroclimatic record. The new collaboration with Dr. David Frank of WSL-Switzerland is adding a new aspect to the tree-ring work. This lab is one of the premier groups that generate and analyze latewood density series.

We also provided wood sampled from the lower bay area for dating and inclusion in the LIA glacial and Tlingit history analyses of Streveler, Connor, Howell and Montieth. Chris Fastie (Middlebury) and Roman Motyka (UAF) have generously shared their ring-width data from sites within Glacier Bay and Icy Strait which we will compare with our results. We have submitted a NSF proposal with R. D'Arrigo (Lamont) to fund the continuing field and laboratory work.

We also worked with many volunteers from the seasonal and permanent staff of the park this past summer, each traveling into the field with us to engage them in our field work, providing a better understanding of our research and its significance, and hopefully providing a background useful to their work. We are extremely grateful of course for the assistance they provided!

In addition to the undergraduate students doing their theses, several high school and college undergraduate students assisted us in the field this past summer. If funded by NSF, we hope to engage a high school science teacher next season through the PolarTrec program.

Completed and Current Theses

Lyon, E., 2007, "Progress towards the development of a multi-millennial tree-ring chronology, Glacier Bay National Park and Preserve, Alaska", unpublished thesis, Department of Geology, The College of Wooster.

Malcomb, N., 2007, "Using tree-ring time series from the Gulf of Alaska to model mass balance from the Northeast Pacific Rim", unpublished thesis, Department of Geology, The College of Wooster.

Trutko, A., 2008, "Development and climatic analysis of the Bear Track and Excursion Ridge Ring Width Series, Glacier Bay National Park and Preserve, Alaska", unpublished thesis, Department of Geology, The College of Wooster.

Erlanger, E., 2008, "Reconstructing Sitka, Alaska temperature change for the last 450 years using tree rings, unpublished thesis, Department of Geology, Union College.

Plourde, A., 2008, "Using North Pacific tree ring chronologies to reconstruct Laurentian Great Lakes levels over the past several hundred years", unpublished thesis, Department of Geology, Colorado College.

Laxton, S., in progress, "Manifestation of the ~5 ka rapid climate change event in Glacier Bay, Alaska: interpreting a dendro-glaciologic record", Department of Geology, University of Cincinnati, Ohio.

Fetters, C., in progress, Tree-Ring Dated Little Ice Age History and Tlingit Legends During the Early 18th Century in Glacier Bay, Glacier Bay National Park and Preserve, Alaska: undergraduate thesis, The College of Wooster.

Krivicich, M., in progress, Developing the Glacial History of Middle/Lower Glacier Bay, Alaska through the Tree-Ring dating of Subfossil Wood, Glacier Bay National Park and Preserve: undergraduate thesis, The College of Wooster.

Acknowledgements
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Appendix A   Current Sample Analyses (in progress)

Sample ID	Lat	Long	Site Name	C 14	Calib 5.0 (AD)	# of Rings or cal-dated range	Outer Ring Present
GB07-47			Charpentier Fan			249	
GB07-51			Charpentier Fan			153	
GB07-53			Charpentier Fan			168	
GB06-220			Charpentier Fan	4090 ± 40 BP		228	
GB06-206			Charpentier			225	
GB06-194			Charpentier Fan			230	
GB07-52	N 58º 42.121	W 136º 32.279	Charpentier Inlet	3750+/-70 BP	4400-3900 yr BP	~320	NA
GB07-161-01	N 58º 34.300	W 136º 13.605	North Fingers			239	NA
GB07-162-01	N 58.57142	W 136.2267	North Fingers			85	NA
GB07-163-01	N 58.57174	W 136.22690	North Fingers			240	NA
GB07-165-01	N 58.57021	W 136.23140	North Fingers			238	NA
GB07-166-01	N 58.57021	W 136.23140	North Fingers	1310+/-50 BP	640-780 AD	224	NA
GB07-167-01	N 58.56969	W 136.23911	North Fingers			308	NA
GB07-141-02	N 58.54261º	W 136.16595º	Berg Bay	220+/-50 BP	1620-1820 AD	166	NA
GB07-142-02	N 58.54250º	W 136.16602º	Berg Bay			194	NA
GB07-143-01			Berg Bay	480+/-40 BP	1330-1480 AD	C14 - Sample only	NA
GB07-144-02	N 58.54248º	W 136.16592º	Berg Bay			134	NA
GB07-145-02	N 58.54261º	W 136.16592º	Berg Bay			153	NA

Samples from the Lower Bay	Lat	Long	Site Name	C 14	Calib 5.0 (AD)	# of Rings or cal-dated range	Outer Ring Present
GB07-33	NA	NA				1566-1723	Y
GB05-09	N 57°27.280’	W 135°55.866’				1570-1724	Y
GB05-34	N 58°24’09.4”	W 135°54’27.2”				1555-1735	Y
GB05-28	N 58°27’17.8”	W 135°55’51.7”				1547-1724	Y
GB08-17	N 58°26.218’	W 135°54.002’				1604-1726	N
GB07-204			E. Bartlett Cove			1635-1706	Y
GB07-206			E. Bartlett Cove			1631-1708	Y
GB08-14	N 58°26.869’	W 135°53.900’				1609-1702	Y
GB08-15	N 58°26.877’	W 135°53.896’				1615-1708	Y
GB05-26	N 58°27’17.16”	W 135°55’51.7”				1465-1704	N
GB08-37	N 58°23.122’	W 136°02.445’				1552-1687	N
GB07-205			E. Bartlett Cove			1572-1714	Y
GB05-24	N 58°27’15.6”	W 135°55’53.1”				1564-1723	Y