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Mark McMenamin (Mount Holyoke College) and Jack Beuthin (U of Pittsburgh, Johnstown)
Students: Evan Anderson, Anna Lavarreda, Ken O'Donnell, Walter Persons, Jessica Williams

Development and Analysis of Millennial-Scale Tree Ring Records from Glacier Bay National Park and Preserve, Alaska (Glacier Bay)
Greg Wiles (The College of Wooster)
Students: Erica Erlanger, Alex Trutko, Adam Plourde

The Biogeochemistry and Environmental History of Bioluminescent Bays, Vieques, Puerto Rico
Tim Ku (Wesleyan University) Suzanne O'Connell (Wesleyan University), Anna Martini (Amherst College)
Students: Erin Algeo, Jennifer Bourdeau, Justin Clark, Margaret Selzer, Ulyanna Sorokopoud, Sarah Tracy

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Keck Geology Consortium: Projects 2007-2008
Short Contributions – Alaska

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DENDROCLIMATOLOGY AND DIVERGENCE: A CASE STUDY FROM GLACIER BAY NATIONAL PARK AND PRESERVE, ALASKA

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INTRODUCTION

Dendroclimatology is the study of tree growth in order to reconstruct past climates. Temperature variations are extrapolated from trees selected for dendroclimatological studies, and can be used to create local temperature records for the length of time the trees lived (Schweingruber, 1996).
This dendroclimatic study focuses upon two sites in Glacier Bay National Park and Preserve, Alaska: Beartrack and Excursion Ridge (Fig. 1, Greg Wiles Abstract). Glacier Bay National Park and Preserve is classified as a temperate coniferous forest, which experiences mild temperature variations and copious amounts of annual precipitation (200-800 cm) (Ricketts et al., 1999; Wilson et al., 1986). Both sample sites are located between 810 and 920 meters above sea level, at tree line. Both sample sites comprise solely mountain hemlock (*Tsuga mertensiana*), a mid-size conifer that is found along the North Pacific coast of North America.

DIVERGENCE

Dendroclimatic proxy-records are often extracted from trees that are limited in growth by temperature (Fritts, 1976), and therefore past temperatures can be reconstructed. Trees with growth trends that closely mirror temperature record variations are called “sensitive” (Fritts, 1976). To construct dendroclimatic records that are viable, sampled trees must be sensitive. Trees with low sensitivity do not record temperature well.

Dendroclimatic studies in the northern interior of Alaska (Jacoby and D’Arrigo, 1995; Wilmking et al., 2004), the European Alps (Büntgen et al., 2006, 2007), as well as the arctic and sub-arctic of Eurasia (Jacoby et al., 2000), have recorded a loss in recent tree sensitivity. This loss of tree sensitivity is noted as divergence (D’Arrigo et al., 2007). Varying hypotheses have been postulated, but no consensus on the causation has been reached yet. Moisture stress (Jacoby et al., 1995), global dimming (Liepert, 2002), increased cloud cover (Büntgen et al., 2006), as well as standardization discrepancies (Büntgen et al., 2006), might all be reasons for divergence.

Divergent tree growth may have implications for the construction of dendroclimatic records, as well as upon carbon cycle models. Without accounting for divergence in climatic reconstructions, they may be inaccurate (Büntgen et al., 2006). Divergent effects need to be removed from chronologies if valid reconstructions are to be constructed (Büntgen et al., 2006; D’Arrigo et al., 2007). Ignoring divergence may lead to unreliable Carbon Cycle models too. The northern boreal forests, where many cases of divergence have been reported, are large carbon sinks. Divergent growth leads to lower levels of carbon sequestration than estimated (Briffa et al., 1998). A carbon cycle that does not take into account divergence may very well overestimate the amount of carbon that is absorbed by these forests, and therefore underestimate the amount of carbon dioxide that remains in the atmosphere (D’Arrigo et al., 2007).

METHODS

Mountain hemlocks were sampled at Beartrack in the summer of 2006 and at Excursion Ridge during the summer of 2007. Cores were exracted and sent to the Wooster laboratory for analysis. Cores were prepared and sanded to a fine polish. Each core’s rings were counted, and the ring width was measured from pith to bark on a Velmex sliding stage with a precision of 0.001 mm, and recorded by using Measure J2X software.

Samples from each site were combined into site chronologies. Inter-series correlations were established using the International Tree-Ring Database software COFECHA (Grissino-Mayer, 2001). COFECHA was used to assess the correlation of different cores within each series, and to recognize incorrectly measured cores.

After the Beartrack and Excursion Ridge master chronologies were compiled the Excursion Ridge chronology was divided in to two additional sub-chronologies. Recent growth trends were the basis for creating two sub-chronologies: trees that have a recent upwards trend in growth (non-divergent); or trees with a recent downwards trend in growth (divergent). Both chronologies were then studied to explore the impact of divergence on dendroclimatic reconstructions.

Both master chronologies, as well as the two Excursion Ridge sub-chronologies, were compared to Juneau mean monthly temperature records (collected from 1899-2003), as well as a Gulf of Alaska proxy-extended temperature record developed by Wilson et al. (2006). Meteorological data (from Kodiak, Seward, Cordova, Sitka, and Juneau climate stations), spanning from 1855 to 1986, was incorporated with 22 Gulf of Alaska chronologies to create a comprehensive climatic reconstruction (Wilson et al., 2006). The Beartrack master chronology was also compared to the non-divergent Beartrack sub-chronology.

RESULTS

The Beartrack chronology consists of 28 cores from 21 trees. The chronology spans 438 years, from 1569 to 2006. The inter-correlation of the Beartrack chronology is statistically significant (0.52), and the mean sensitivity is 0.24 (Table 1). The Excursion Ridge master chronology encompasses 38 cores from 29 trees, and spans 490 years, from 1517 to 2006. The series has a highly significant inter-correlation of 0.68. Mean sensitivity of the Excursion Ridge master chronology is 0.27 (Table 1). The non-divergent Excursion Ridge chronology consists of 17 cores from 14 trees, and spans 490 years, from 1517 to 2006. The series has a statistically significant inter-correlation of 0.66, as well as a significant mean sensitivity of 0.29 (Table 1). The divergent Excursion Ridge chronology comprises 11 cores from 11 trees, and spans 422 years, from 1585 to 2006. The series has a statistically significant inter-correlation of 0.63, and a significant mean sensitivity of 0.25 (Table 1).

Chronology	# of Cores	# of Trees	Time-Span	Inter-Correlation	Mean Sensitivity
Bear Track	28	21	1569 -2006 (438 years)	0.52	0.24
Excursion Ridge Master	38	29	1517-2006 (490 years)	0.68	0.27
Excursion Ridge: Non-Divergent	17	14	1517-2006 (490 years)	0.66	0.29
Excursion Ridge: Divergent	11	11	1585-2006 (422 years)	0.63	0.25

Table 1. Major statistics of the Beartrack and Excursion Ridge master chronologies, as well as those of the two Excursion Ridge sub-chronologies.

The Beartrack master chronology had a statistically significant correlation of 0.55 with the proxy-extended Gulf of Alaska temperature record. Ring width of the Beartrack chronology was most highly correlated with previous May, June, and November temperatures (R-values of 0.20, 0.25, and 0.20 respectively), and with summer temperatures of the previous year (June, July, and August of the previous year; R= 0.21).

The Excursion Ridge master chronology had most significant correlations with temperatures of the previous March (R= 0.32), April (R= 0.32), May (R= 0.35), June (R= 0.43), July (R= 0.20), August (R= 0.27), and the current February (R= 0.21) and March (R= 0.20). The Excursion Ridge master chronology is most highly correlated (R= 0.44) with seasonal temperatures of the previous summer (June, July, and August of the previous year).

The non-divergent Excursion Ridge chronology has a most significant correlation with monthly temperatures of the previous March (R= 0.31), April

(R= 0.31), May (R= 0.32), June (R= 0.40), July (R= 0.23), August (R= 0.30), and current April (R= 0.20) and May (R= 0.23). Temperatures of the previous summer (June, July, and August of the previous year) have the highest correlation with growth (R= 0.42), when comparing seasonal temperatures and growth. Comparisons of the proxy-extended Gulf of Alaska temperature record with the non-divergent Excursion Ridge chronology resulted in a statistically significant correlation of 0.58.

The divergent Excursion Ridge chronology shows significant correlations only with monthly temperatures of the previous March (R= 0.21), May (R= 0.21), and June (R= 0.29). When comparing seasonal temperature averages with growth, the temperatures of the previous summer (June, July, and August of the previous year) are most highly correlated with growth (R= 0.32). A comparison of the divergent Excursion Ridge chronology with the non-divergent Excursion Ridge chronology illustrates clear divergence within the Excursion Ridge chronology (Fig. 1

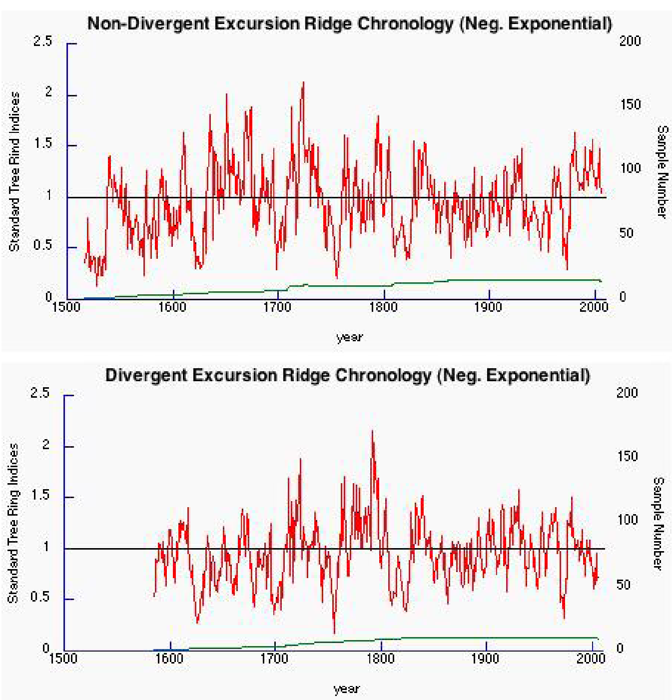

Figure 1. Graphs of the two Excursion Ridge sub-chronologies (non-divergent graph top, divergent graph bottom). Divergence is clearly noted in the divergent chronology, indicated by relatively lessened growth in recent years, as compared to the robust non-divergent chronology.

A comparison of the Beartrack master chronology and the non-divergent Excursion Ridge chronology resulted in a statistically significant correlation (R-value of 0.67).

DISCUSSION AND CONCLUSIONS

The Beartrack master chronology is better correlated to the proxy-extended temperature record than the Juneau temperature record. Though conclusive causes for this are not known, the proxy-extended temperature record is likely more representative of the Beartrack master chronology. This may be due to the fact that the Juneau meteorological station is not located at the same altitude as the Beartrack site.

The Excursion Ridge chronology must be divided into sub-chronologies, as it encompasses samples from trees with divergent and non-divergent growth signals. Removing trees that indicate divergent growth creates a chronology that more closely mirrors actual climate. The divergent Excursion Ridge chronology displays low correlations with temperature records, as the divergent trees have lost sensitivity, and as a result this chronology is not useful in producing valid climate reconstructions. Of all the chronologies, the non-divergent Excursion Ridge chronology has the best correlations with the proxy extended temperature record, as well as the Juneau temperature record (Fig. 2). The non-divergent Excursion Ridge chronology would therefore be most accurate in describing climatic variations over time in the sample site region.

Divergence is found in samples at Excursion Ridge, yet not at Beartrack, and therefore a global theory for divergence does not seem to be likely for Excursion Ridge. Due to the sample sites being located on slopes oriented in different directions, snowpack could influence divergence at Excursion Ridge, while not influencing Beartrack (Peterson et al., 2002).

Divergence has implications upon carbon cycle models, and dendroclimatic reconstructions. Without taking divergence into account carbon cycle

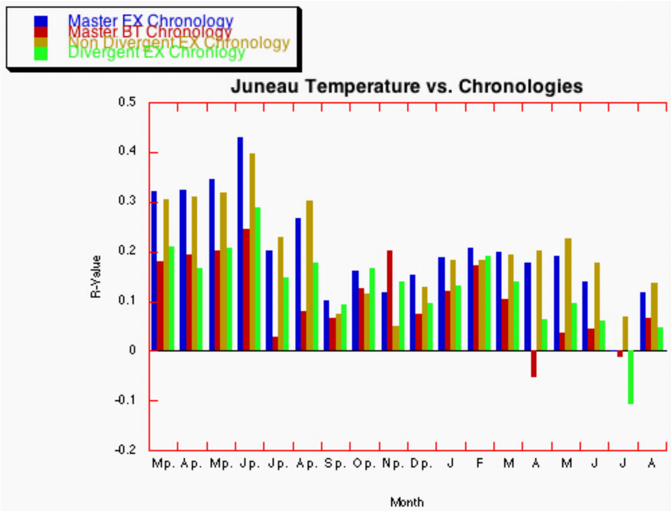

Figure 2. Histogram indicating the correlation between tree growth and monthly temperatures gathered from the Juneau, AK meteorological station. Beartrack master chronology = red, Excursion Ridge master chronology = blue, non-divergent Excursion Ridge chronology = brown, divergent Excursion Ridge chronology = green.

models may be overestimating carbon sequestration, as well as underestimating levels of CO_2 in the atmosphere (D'Arrigo et al., 2007). Divergent tree samples can skew dendroclimatic reconstructions, and thus caution must be exercised when utilizing samples from areas where divergence has been recognized. Divergent samples must be removed from chronologies in order to create valid climate reconstructions.

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