Measuring historical non-climatic and climatic effects on tree ring width in Tioga Pass, California

Andrew Budnick, Hillary Clark, Eden Full, Elizabeth Shoenfelt

Undergraduates, Class of 2013, Princeton University

Introduction

Tioga Pass is located east of Mono Lake in Mono County, California. This pass is home to many trees, including the Jeffery Pine. We are interested in determining whether these trees accurately measure climate data, what factors might influence their growth, and whether recent atmospheric CO_2 increases have affected their growth.

Methods

We first collected approximately 170 cores from the area around Tioga Pass as shown in Figure 1. Upon arrival home, these cores were dried, mounted, sanded, and scanned for processing. We then used a MATLAB program to manually measure the widths of each tree ring.

These ring widths were then standardized using the method described by Fitts (1976) to remove changes in growth rate as a variable for width. Any outlier cores that were either misshapen, impossible to measure or badly fit to a standardization curve were rejected, and the remaining cores were averaged. This gave us 328 years of tree growth history.

These indices could then be compared to other climate related data such as precipitation and temperature.

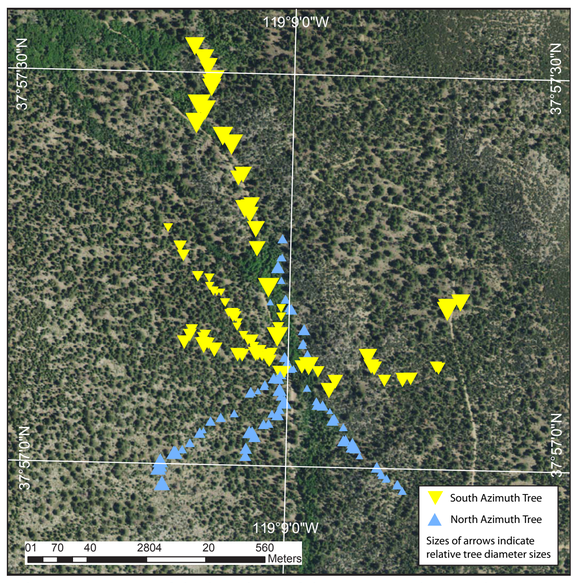

Figure 1 - A map of the locations of the trees cored. Note that we began in the center and teams progressed outward in a star shape. The blue triangles were cores taken pointing northward, and the yellow triangles were cores taken pointing southward.

Analysis - Climate factors

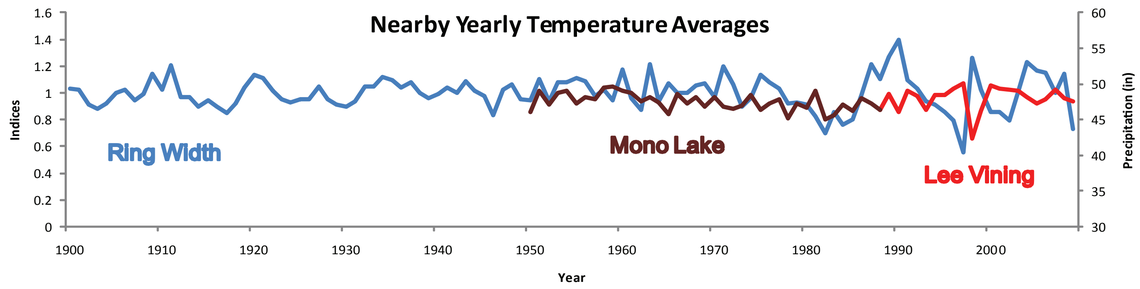

Figure 4 - Displays the comparison between annual average tree ring growth in Tioga Pass and temperature from the surrounding areas of Lee Vining and Mono Lake, California. The correlation between temperature and ring growth seems to be only somewhat applicable, as when temperatures rise so does growth. Of course, this suggests the more amount of sunlight, the more a tree will grow. The steep drop in Lee Vining temperature around 1998 correlates with a highly stunted tree ring growth, suggesting the extreme cold of that year had a negative effect. Meanwhile, the extremely large amount of tree ring growth around 1990 does not correlate to significantly higher temperatures.

Due to the very specific correlation between annual average tree ring growth and the annual rainfall in the areas surrounding Tioga Pass, it is fair for us to conclude that the amount of water trees receive per annum is the most important factor in determining their growth for that year. Although severely high and low temperatures could cause large and small amounts of growth within the trees respectively, the peaks and dips of these graphs do not look nearly as visually compatible as they do within the precipitation comparisons. The levels of Mono Lake are constantly changing (mostly declining) do to human-influenced and natural causes, and thus we cannot draw any conclusions about whether they affect tree ring growth, although most likely not.

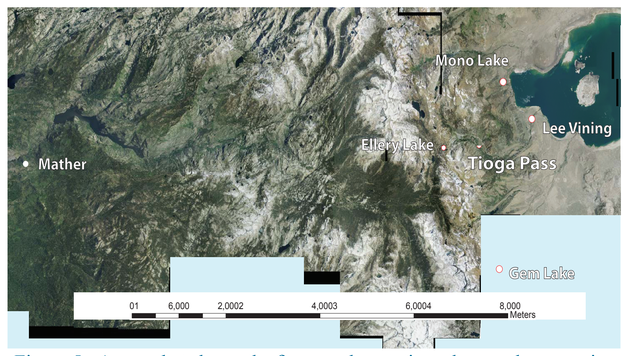

Figure 5 - A map that shows the five weather stations that we drew precipitation data from and compared to the ring data. As observed, the further away from Tioga Pass one gets, the less correlated the amount of annual rainfall is with the average width of the ring annually. This allows us to conclude that the level of precipitation immediately surrounding the area of one tree is specific to it's growth and that the growth rate of trees in different regions will differ depending on the amount of rainfall they are receiving.

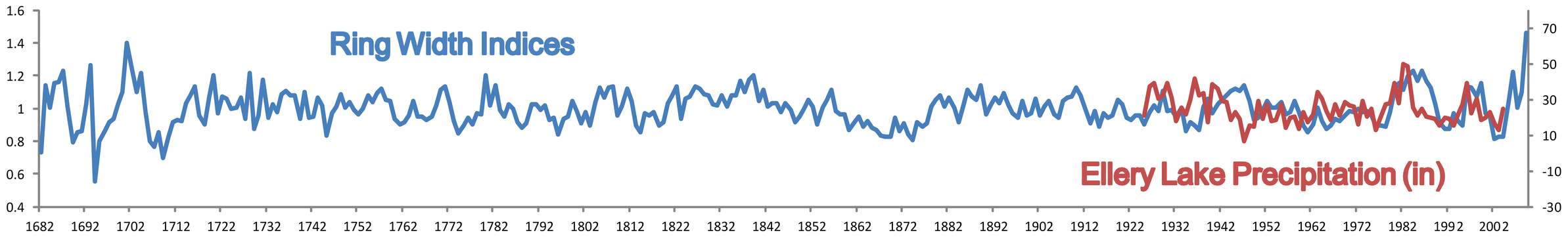

Figure 6 - The closest correlation that we found was between the ring width and the precipitation levels at the Ellery lake weather station (the red line on the right). Note that, although the lines are not necessarily matched, many of the same increases and decreases are visible, sometimes with a slight delay in the ring width. Because Ellery Lake is the closest weather station to the location in Tioga Pass where we were, it is the best match out of all of hte precipitation data that we analyzed.

Analysis - Non-climate factors

There are several non-climate factors that may skew our tree ring data, especially as we attempt to fit it only to specific elements of weather (such as precipitation levels). Experimental error and location variables are two of the most significant areas of deviation in our project.

These plots separate variables within the data to see if specific characteristics of tree location are significant variables of tree ring widths. "Significant" here is qualitative – looking at deviations from our original average (from all the data) to detect patterns that are much different from the original and/or much different from one another.

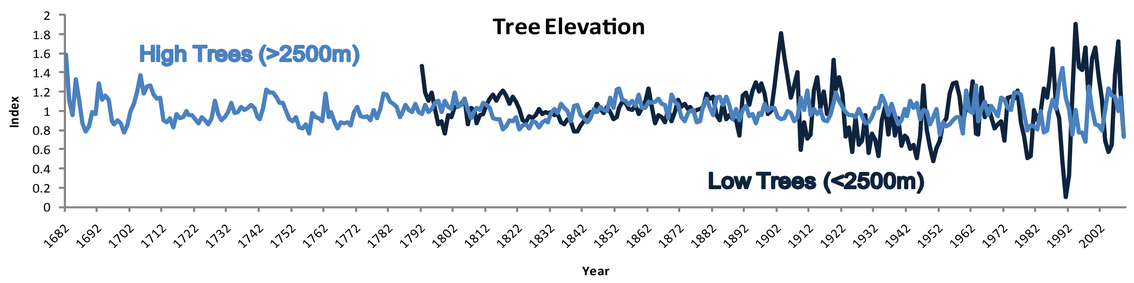

Figure 2 - This graph plots the trees at a high elevation (>2500m and in red) separate from the trees at a low elevation (<2500m and in green). The known weather data is in blue. The mean standard deviation for the high elevation data is 0.3137, and 0.2965 for the low elevation data. Unfortunately, this doesn't explain why the data is so varied towards the center of the graph. Our mean standard deviation here factors in the data from the single (oldest) core, which invariably does not show deviation from the mean, and thus skews our values. The best means of detecting noise is from the standard deviation lines in the area immediately about the areas of interest. There are higher standard deviations in the points where high and low data seems to vary the most, suggesting that the difference is simply "noise," so more rigorous statistical research would need to be conducted in order to note any statistically significant variation among variables.

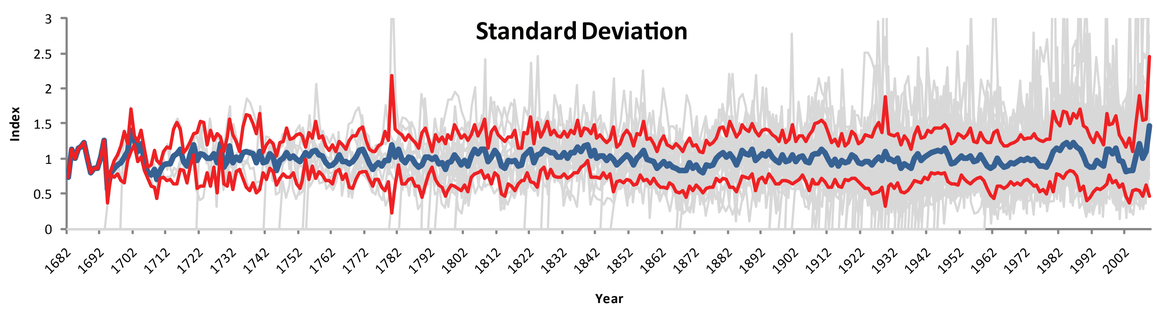

Figure 3 - The error from our control core (9 trials of M063) was an average standard deviation of 0.0734. This mean standard deviation is a valid means of analysis because all of the data sets were the same size. So additional to the calculated statistical standard deviations at each point, there is systematic error from the core-clicking process.

Acknowledgements - We would like to thank Professors Adam Maloof and Frederik Simons, along with the other professors and assistants on the trip: Kevin, Blair, Catherine, Ryan and Nicole. Thanks to WMRS for hosting us in California. Finally, thanks to the rest of FRS 145 for your research assistance and pleasant company.

Analysis - CO_2 influence

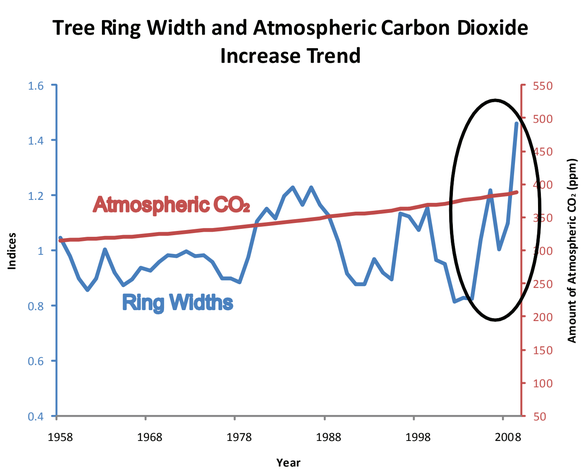

Figure 7 - Plot of the Keeling Curve (Keeling et al, 2005) on a secondary axis along with the refined ring width indices of our collected tree core data from 1958, the year that the Scripps Institute of Oceanography began collecting data, to 2009. The Keeling Curve indicates the variation in the concentration of atmospheric carbon dioxide based on monthly measurements taken at the Mauna Loa Observatory, Hawaii. The increasing trend of the curve correlates with the ring width indices data (the circled portion) within the past ten years. The ring width indices have increased significantly relative to trends in the past. This suggests a relationship between carbon dioxide levels and the growth of trees in this area.

Since 1958, the concentration of atmospheric carbon dioxide has steadily increased (Keeling et al, 2005). By examining the increasing trend in ring width indices in the most recent ten years of our collected data, a direct relationship between ring width and carbon dioxide levels is observed. Our data supports the hypothesis made by LaMarche (1984), which is that increased ring width, a sign of improved tree growth, is caused by fertilization effects of increased atmospheric carbon dioxide concentrations. Hughes (1991) states that this is a short-term process caused by significant gas injections into the atmosphere, hence the abrupt significant increase relative to the other data. Our data is also geographically consistent with the hypothesis made by Graumlich (1991), which extended LaMarche's conclusion to eastern California near the Sierra Nevada mountain ranges. However, in order to further confirm these hypotheses, continued tree core analysis into ring widths is recommended to determine whether or not the increasing trend continues.

Conclusions

We found that the tree ring widths correlated very closely to the precipitation data for nearby stations, and that the correlation dropped off the farther away you were from Tioga Pass. We did not find any significant correlation of the data between temperature or level of Mono Lake.

The amount of variation in the data did not allow us to come to a conclusion about whether different elevations had an effect on the growth of trees.

We also conclude that our data supports work done by others suggesting that an increase in CO_2 can be correlated to an increase in tree ring growth.

Works Cited:

Fritts, H. (1971) Dendroclimatology and dendroecology. Quaternary Research 1(4):419-49.
Fritts, H. (1976) Tree Rings and Climate. Academic Press: New York.
Graumlich, L. (1991) Subalpine Tree Growth, Climate, and Increasing CO2: An Assessment of Recent Growth Trends. Ecology: Vol. 72, No. 1, pp. 1-11.
Hughes, M. (1991) The tree-ring record. In: Global changes of the past. Ed.R.S.Bradley. UCAR/Office of Interdisciplinary Earth Studies: Boulder.
Keeling, C., Piper, S., Bacastow, R., Wahlen, M., Whorf, T, Heimann, M., Meijer, H. (2005) Atmospheric CO2 and 13CO2 exchange with the terrestrial biosphere and oceans from 1978 to 2000: observations and carbon cycle implications. pages 83-113, A History of Atmospheric CO2 and its effects on Plants. Springer Verlag: New York.
LaMarche, V. Jr., Graybill, D., Fritts, H. and Rose, M. (1984) Increasing atmospheric carbon dioxide: Tree-ring evidence for growth enhancement in natural vegetation. Science 225, 1019-21.
National Climatic Data Center. National Oceanic and Atmospheric Administration, 2009. < http://www.ncdc.noaa.gov/oa/ncdc.html>
Salzer, M., Hughes, M., Bunn, A., and Kipfmueller, K. (2009) Recent unprecedented tree-ring growth in bristlecone pine at the highest elevations and possible causes. Proceedings of the National Academy of Sciences 106: 20348-20353.