Yellow cedar response to climatic shifts at Cedar Lake: Juneau, Alaska

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Introduction

Yellow cedar (Curpressus nootkatensis) is an economically, environmentally, and culturally significant resource. Since the late 1800's, the species has experienced widespread mortality throughout its extensive range. Previous research suggests rapid climate change has reduced the amount of snowpack in the Gulf of Alaska leading to less insulation of the species' shallow roots.Yellow cedar appears to be very responsive to temperature and precipitation. These responses are captured using tree ring width and blue intensity, an emerging method of measuring yellow cedar growth. By examining different decadal climatic factors and how they relate to tree growth we are able to understand the mechanisms that may contribute to the increasing mortality of the species.

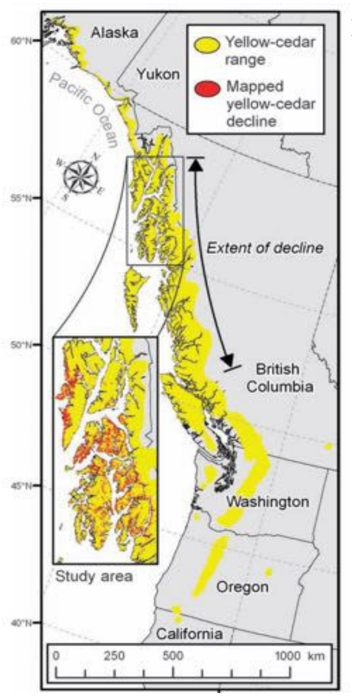


Fig. 1 (right, below) Map of the cedar sites considered in the study, including Cedar Lake

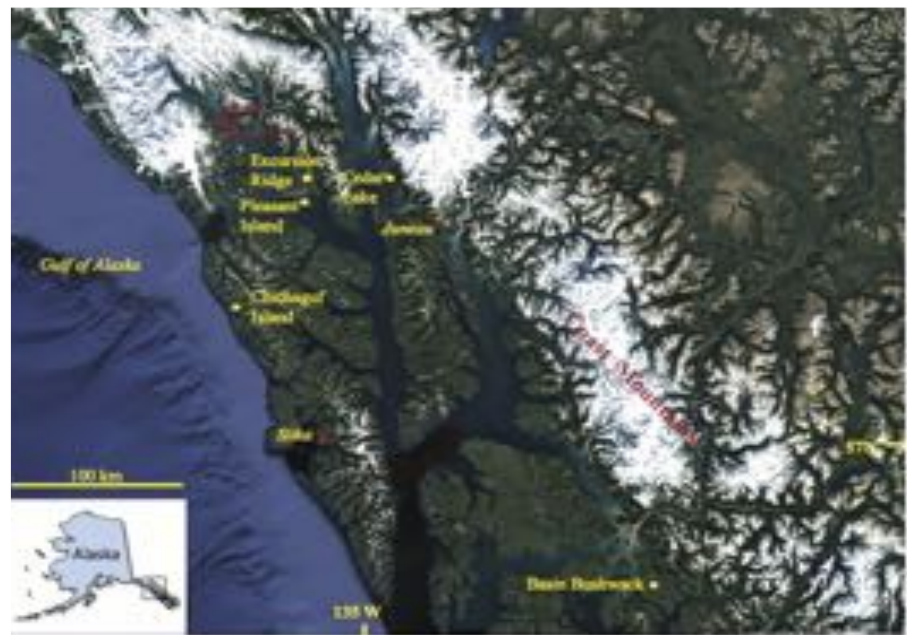
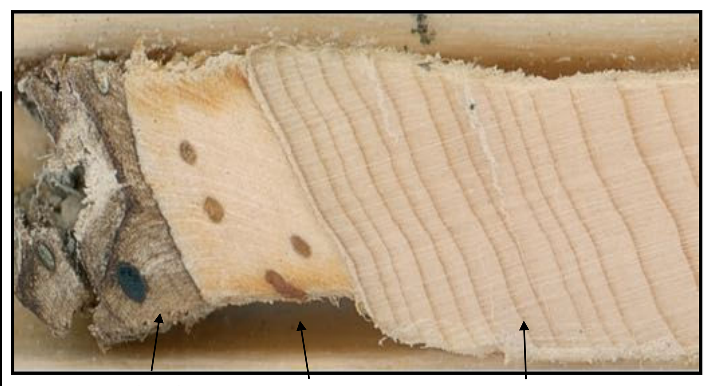


Fig. 2 (above) Extensive range of the yellow cedar trees. They extend from Alaska to the northernmost tip of California.

Stripped Tree



Outer bark

Inner bark (cambium)

Individual rings

Fig. 3 (above) Scanned image of a yellow cedar tree core. From left to right: the outer bark, the inner bark (cambium), and the individual rings. The indigenous people of the area utilize the cambium, by stripping away the outer layers of the bark, for various culturally significant purposes such as shelter, clothing, and rituals.

Methods

A 5mm increment borer was used to sample 42 trees at Cedar Lake. Once collected, the 60 cores were mounted then sanded to provide an adequate surface to count and measure the individual rings. Each series was measured using the Velmex measure system, capturing ring widths to the nearest 0.001mm. We used standard methods of dendrochronology, including programs such as Climate Explorer, COFECHA, EDRM, and ARSTAN.

Chronology development

The well-replicated master chronology was standardized using a conservative negative exponential detrending curve.

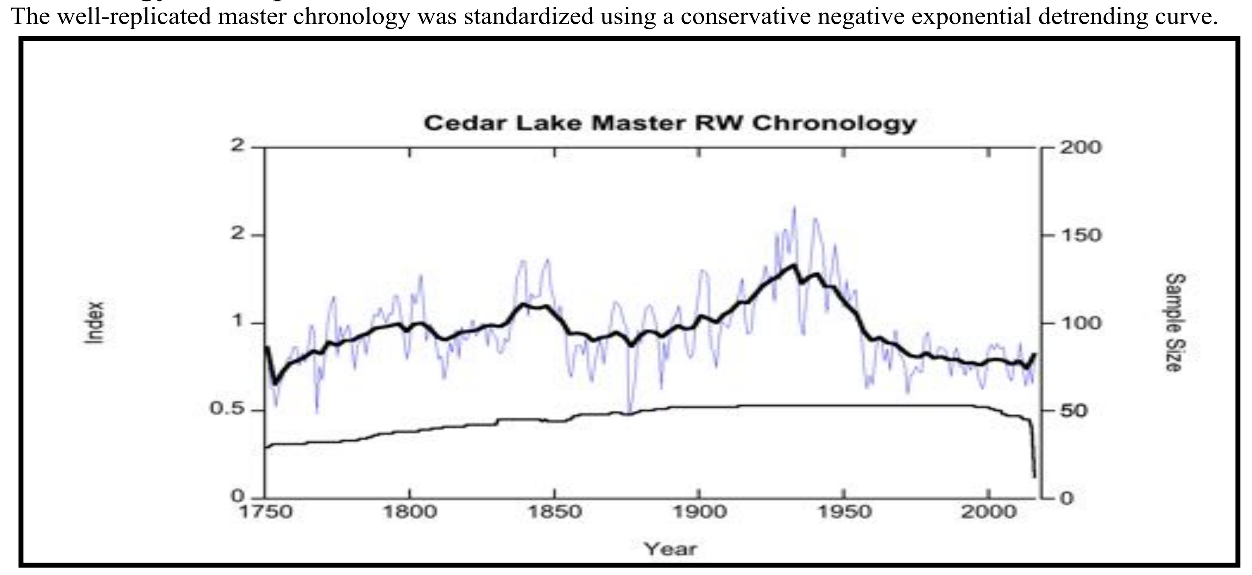
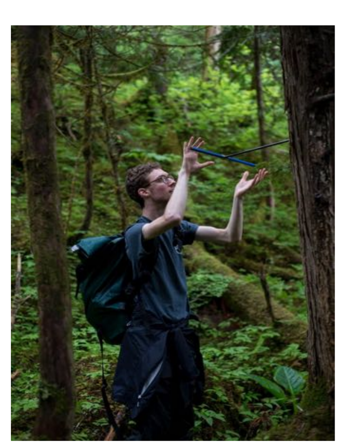


Fig. 4 Truncated master chronology composed of 60 series. The oscillations in the graph represent the average ring width measurement displayed over 250 years. There is a significant shift at the year 1950 which prompted further investigation.

Left - The Keck Alaska team after sampling at Cedar Lake. Below- coring at Cedar Lake



Results

Climate Correlations

We used monthly station data, climate indices, and regional averages to investigate the climate signals in trees rings. The data were obtained from KNMI Climate Explorer.

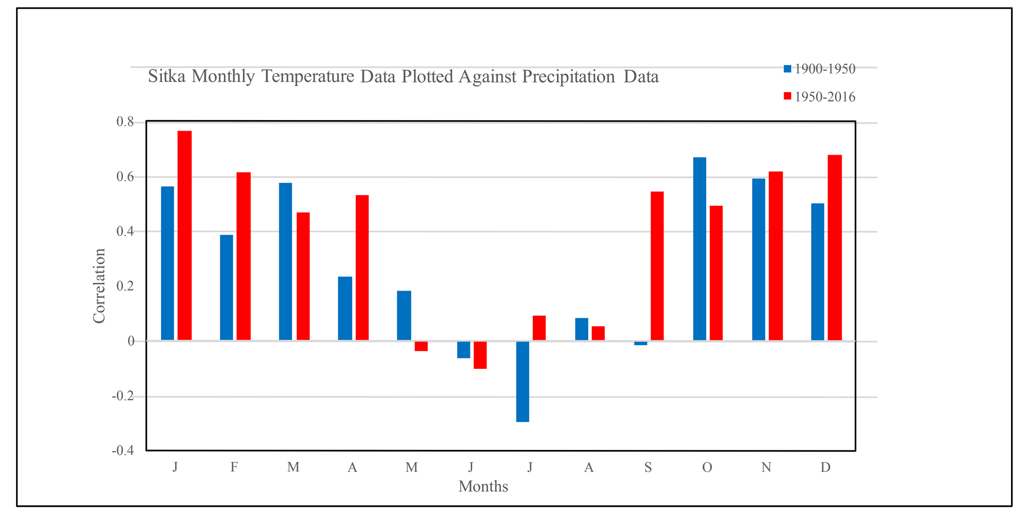


Fig.5 Correlation between temperature and precipitation in Sitka. The positive and negative correlations demonstrate the direct relationship between temperature and precipitation. After 1950 the positive correlation between temperature and precipitation is consistent, and the direct relationship is even stronger.

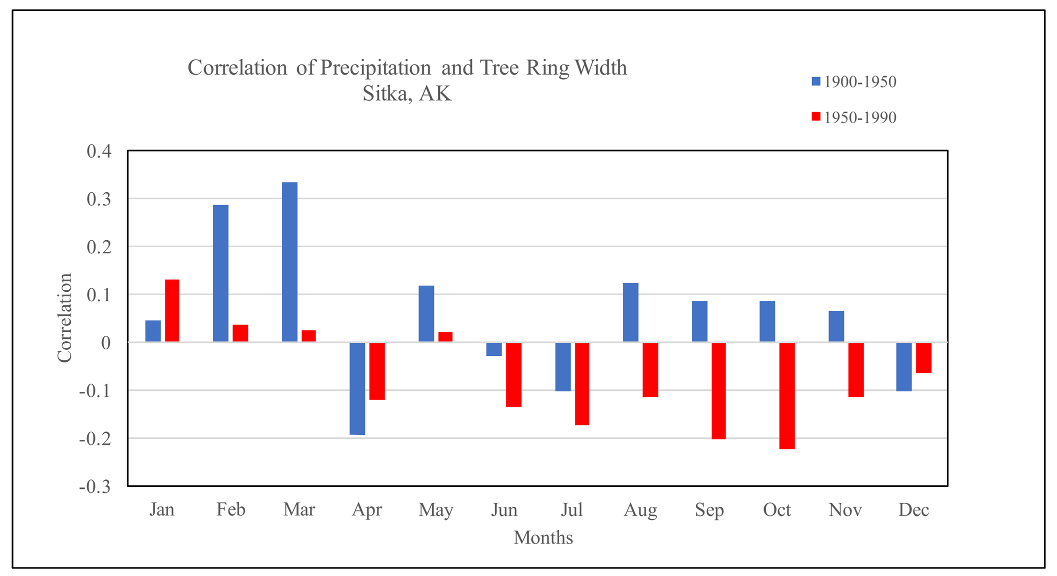


Fig. 6 Correlation between Cedar Lake ring width and monthly precipitation at Sitka, 1900-1950 and 1950-1990. Ring width responded best (positive) to precipitation before 1950 during February/March, two months of average precipitation. Ring width shows the strongest response (negative) after 1950 in September and October.

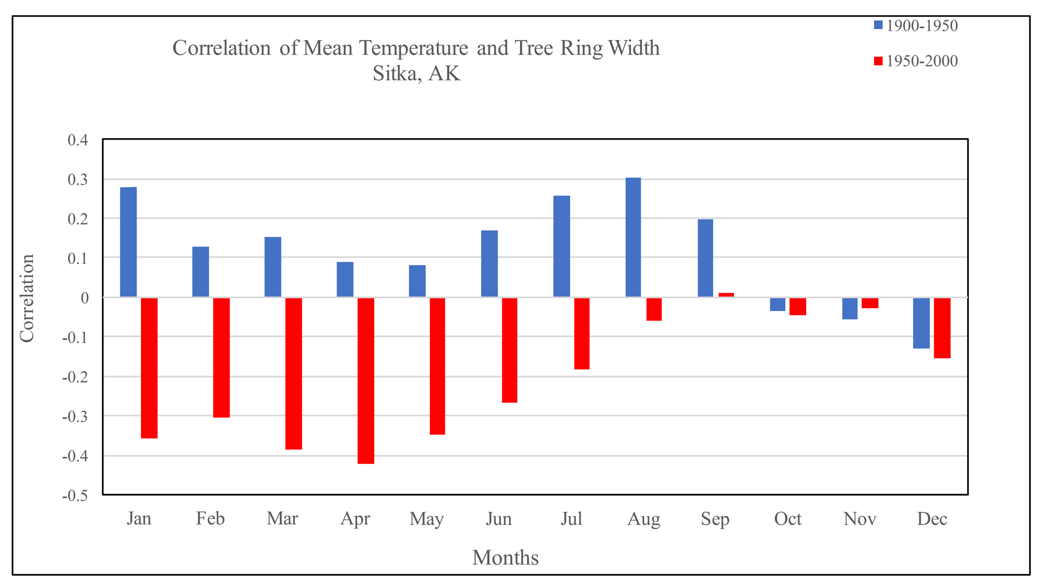


Fig. 7 Correlation between mean temperature and tree ring width. Between 1900 and 1950 there is a positive correlation between ring width and temperature, it is highest in January and August. After 1950 there is a negative correlation between mean temperature and ring width, and the spring months have the highest negative correlation. Increasing spring temperatures which produce this negative correlation help credit the melting snowpack hypothesis.

Pacific Decadal Oscillation

Pacific Decadal Oscillation (PDO) is a system of climatic variability similar to El Niño, but on a much larger time scale (~30 years). PDO is marked by widespread variations in the Pacific Basin and the North American climate.

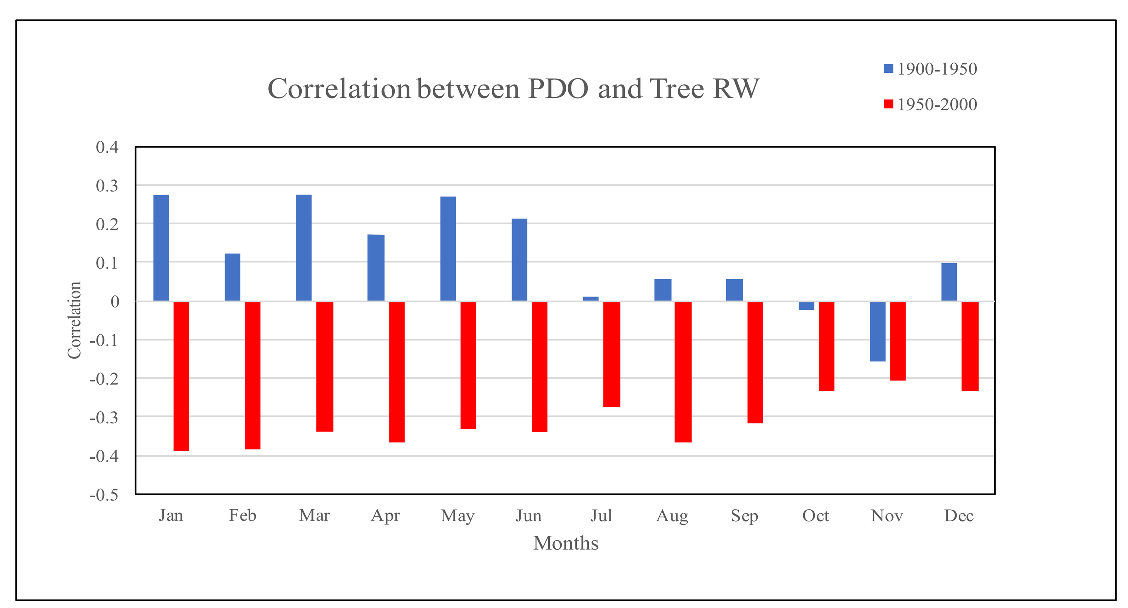


Fig. 8 Relationship between the master chronology and the PDO index. Between 1900 and 1950 there is a weak positive correlation. After the 1950 there is a strong negative correlation.

Discussion

Blue Intensity

Blue intensity (BI) is a novel approach to measure tree ring density. Earlywood density is determined by tracheid size, while latewood density is determined by cell wall dimensions. BI correlates well with different climate parameters, giving further insight into the relationship between tree growth and climate.

The Delta Blue Intensity (DBI) is a derived parameter from the BI measurements. Using a method of taking the earlywood and latewood blue intensity, and subtracting the earlywood maximum from the latewood minimum, we are able to test for different climate indicators or signals. The DBI measurements are consistent with different climate signals, when taken at a lower frequency we found that DBI correlated broadly with our other findings from tree ring width.

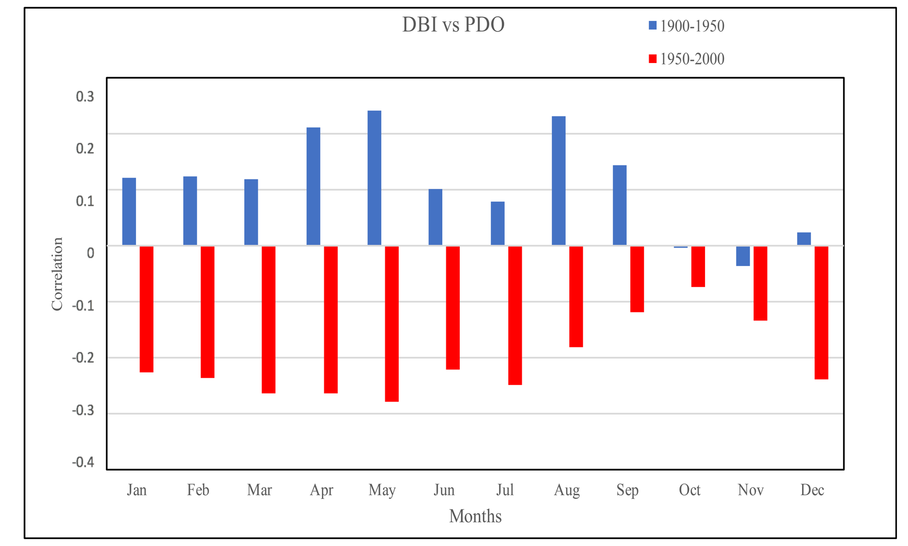


Fig. 9
Correlation between DBI and PDO. DBI has a relationship to PDO that is similar to the relationship between ring width and PDO.
The switch from positive to negative correlation after the year 1950 is a strong trend in both graphic representations.

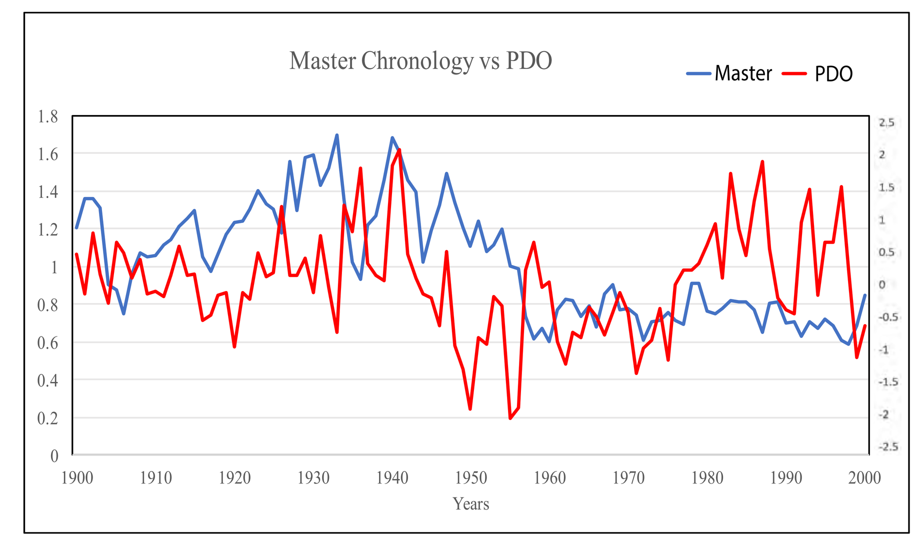


Fig. 10 Cedar Lake ring width master chronlogy plotted against the Pacific Decadal Oscillation. From 1900 to 1940, PDO is in the "positive" phase, which the trees like. Between 1940 and 1976, it is in the "negative phase," and after 1976, it is back in the "positive" phase. The relationship between ring width and PDO becomes negative after 1950.

-There is a declining step-function displayed in the master chronology at the year 1950, which is also evident in the temperature, precipitation, PDO, and DBI data.

-After 1950, precipitation has a negative correlation to ring width during the wettest months, suggesting that is has been detrimental to growth.

-This relationship may be due to an exorbitant amount of water responsible for inundating the root systems beyond favorable living conditions.

-After 1950, temperature has a strong negative correlation to ring width during the spring months. Increased temperature during this time supports the premature melting snowpack hypothesis and the inundation of the delicate root systems.

-Before 1950 the trees correlated well to the positive phase of PDO. After 1950 the trees stop responding as expected to the PDO.

-The yellow cedar are now in environments that are not as suitable for their needs as they once were. The environment is changing too rapidly for the yellow cedar to naturally adapt.

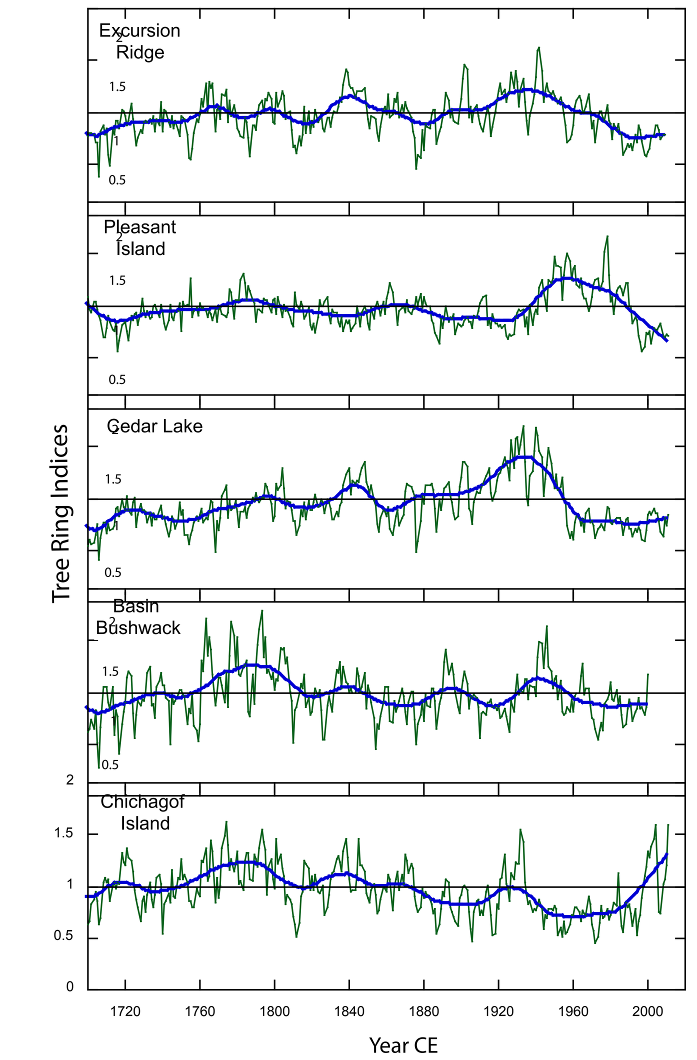


Fig. 11
Plots of the yellow cedar ring width chronologies across SE Alaska.

All have a downward trend, expect the Chichagof site. This may be because this site has already been recognized as in decline – trees have been thinned out.

When there is a release the trees start to grow better. However, the location could be the primary reason- the location (coastal and southern lying) has warmed to the point where frosts damaging roots are not an issue.

The other sites have not reached decline yet.

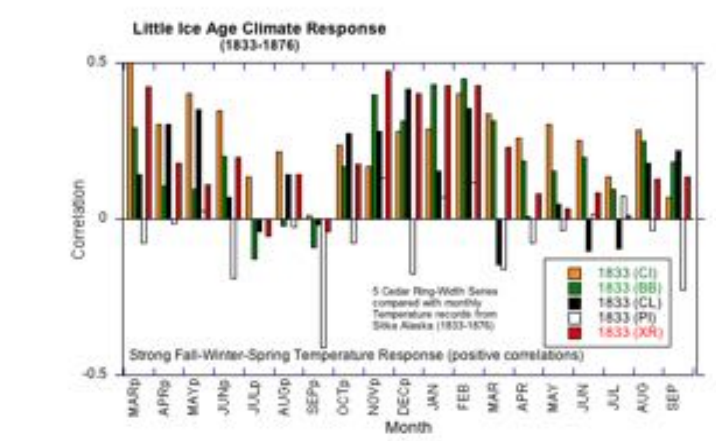


Fig. 12 Yellow cedar are more in tune to the cold snowy times of the Little Ice Age. At this time, the trees preferred warmer weather. This observation is consistent wit the work of Krapek et al, 2017, that shows trees colinizing regions alogn the Gulf of Alaska during intervals of the LIA.

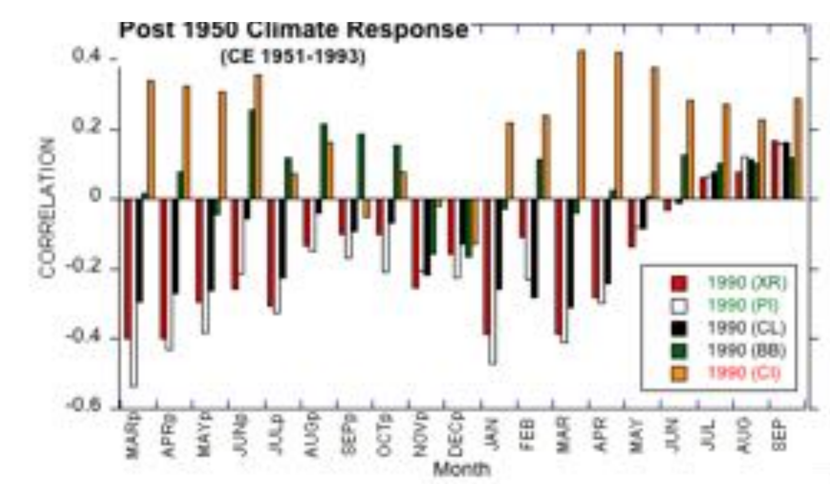
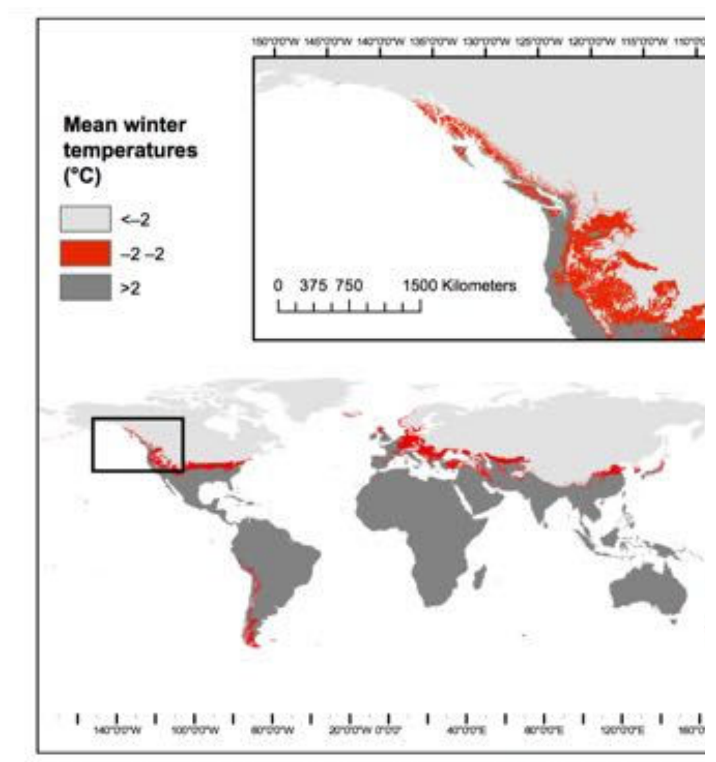


Fig. 13
Correlation between Sitka mean temperature and SE Alaska ring widths for the period 1951-1993.Most sites (except Chichagoff) are now negatively correlated with winter and spring temperatures, so warming is hurting the trees.
Chichagoff might be positively correlatedbecause it has warmed enough that damaging frosts are no longer an issue, or from competitive release.

Fig. 14 Map from Buma et al. 2016 showing locations where mean winter temperatures are about 0°C (red). As the world warms, this threshold is crossed, and trees at these sites may become vulnerable to root damage from freezing. This is already the case in southeast Alaska, where the yellow cedar's preferrred climate is rapidly changing. Winter warming above 0°C is associated with premature melting of yellow cedar's protective snowpack and the transition from snow to rain.



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