INTRA-RING GROWTH PARAMETERS IN DENDROCHRONOLOGY

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1. INTRODUCTION

This work forms part on an ongoing project to examine the modelling of tree ring growth and the changing sensitivity of that growth to climate. The independence of the common signals from intra-ring parameters in terms of crossdating ability and the changing relationships of these signals with climate on inter-annual to inter-decadel timescales is examined.

The potential for gaining added dendrochronological "value" by using sub-ring parameters rather than simple total ring-width data is explored in example northern boreal locations, Rorstaddalen and Borareloa in western Norway. Two sites of Pinus sylvestris L. were chosen where there is a long meteorological record and an expectation of a strong positive response to summer temperature.

2. SITES

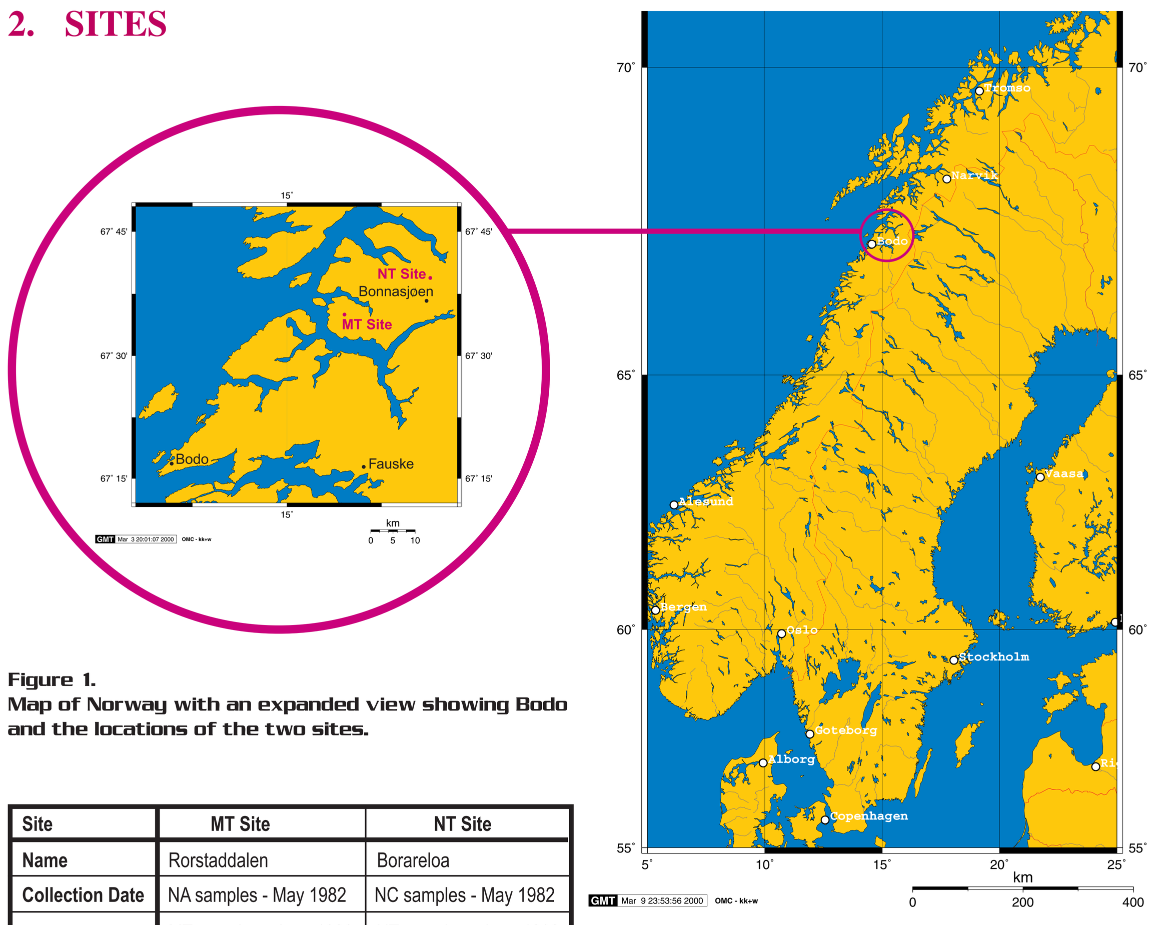

Figure 1.
Map of Norway with an expanded view showing Bodo and the locations of the two sites.

Site	MT Site	NT Site
Name	Rorstaddalen	Borareloa
Collection Date	NA samples - May 1982	NC samples - May 1982
	MT samples - June 1998	NT samples - June 1998
Latitude	67° 36' North	67° 37' North
Longitude	15° 20' East	15° 44' East
Altitude	30 - 100 m (NA)	120 - 200 m
	80 - 150 m (MT)	
Tree species	Pinus silvestris L.	Pinus silvestris L.
Samples 1982	43 cores from 22 trees	43 cores from 16 trees
Samples 1998	47 cores from 22 trees	56 cores from 28 trees

Table 1.
Site statistics.

The meteorological station is at Bodo, Norway at 67° 17' North, 14° 22' East. The meteorological data consists of mean monthly temperature and precipitation data from 1869 to 1997 and includes a few interpolated values in the 1870s. The proximity of Bodo to the sea means that these data have been moderated by the maritime climate.

The MT site at Rorstaddalen is closer to the sea and 100m lower in elevation than the NT site at Borareloa, which is shielded from the sea by topography and has a more continental climate. The MT site treeline is formed by lack of soil, above the trees there is solid rock. At the NT site there are areas of soil above the tree line. The oldest trees were found at the MT site, where the samples had an even spread of germination dates from 1400 onwards, producing a relatively flat mean age curve (Figure 2.). The NT samples showed two major germination phases around 1650 and 1780, which produced a steeper, mean age curve (Figure 2.).

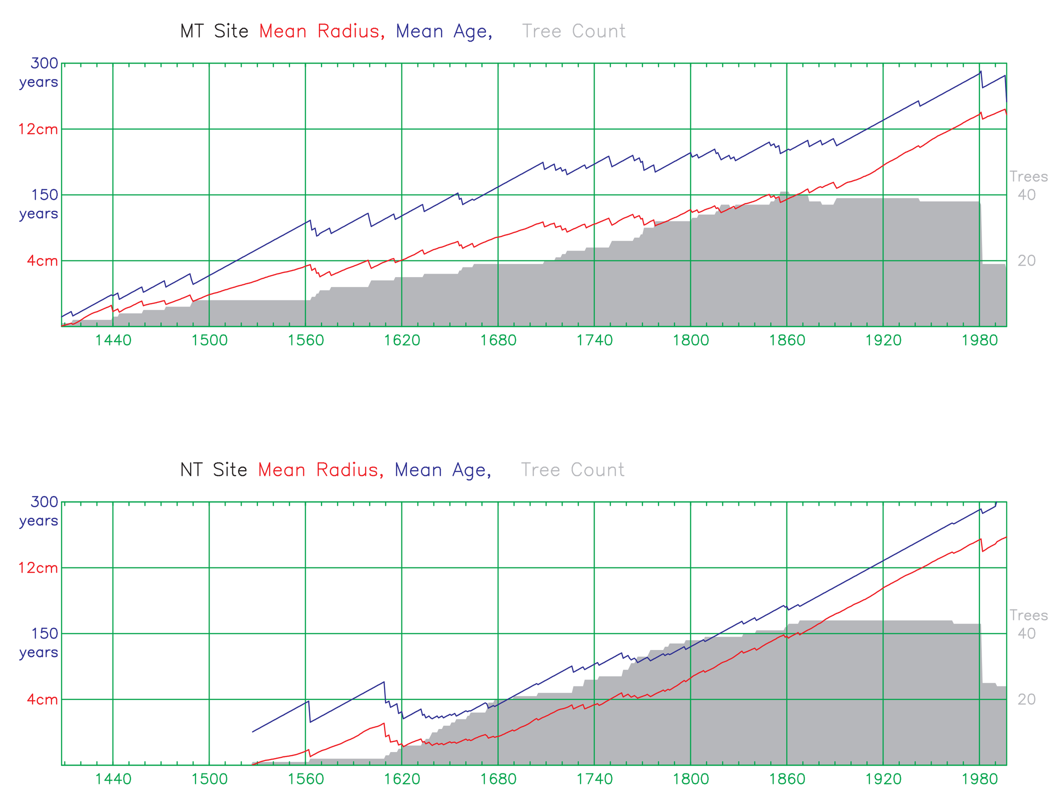

Figure 2.
Shows for each site the mean radius, mean age and the number of samples through time.

3. MEASUREMENTS

Measurements were made for each year of both earlywood and latewood radial increments on two or more cores from 40+ trees of varying ages from each site. The earlywood - latewood boundary was generally a single row of cells whilst the earlywood - latewood boundary spread across several rows of cells and was established by visual observation and judgement, using colour contrast to estimate the position halfway between the last earlywood cells and first latewood cells.

A few older MT trees had several rings missing from both cores in the period 1820-1915 yet were complete from 1915 to 1997. Missing rings are rare but why mainly at the milder site and from what source is this extra lease of life after 1915?

For cross dating and chronology building "Raw Measurement" data for each series were developed as follows:
Ring-width (RW) = sum of earlywood and latewood measurements
Earlywood (EW) as measured
Latewood (LW) as measured
Latewood Ratio (LE) = (latewood / earlywood) * 1000 , limited to a maximum of 2000

4. CROSS DATING

Crossdating was achieved by visual comparison of cores and by using correlation calculations from COFECHA. For the ring-width, earlywood and latewood series indices were developed for each core by taking a log transform of the residuals from an AR model of the residuals from a 30-year low pass spline. Latewood ratio series indices were created from a simple log transform of the data because the data has almost no low frequency variance and little autocorrelation.

The latewood ratio was chosen firstly because it highlights the differences between the measured values of latewood and early wood whereas latewood percentage uses the compound value of ring-width and secondly the simple difference would require scaling because earlywood is wider than latewood. The log transform reduces the positive skew of the latewood data.

The strength of the common signals in the four sets of measurement files is shown as the running Rbar plots for both sites in Figure 3a & 3b and as tree to site correlations in Table 2. All four sets of data at each site have sufficient common signal to crossdate the trees independently.

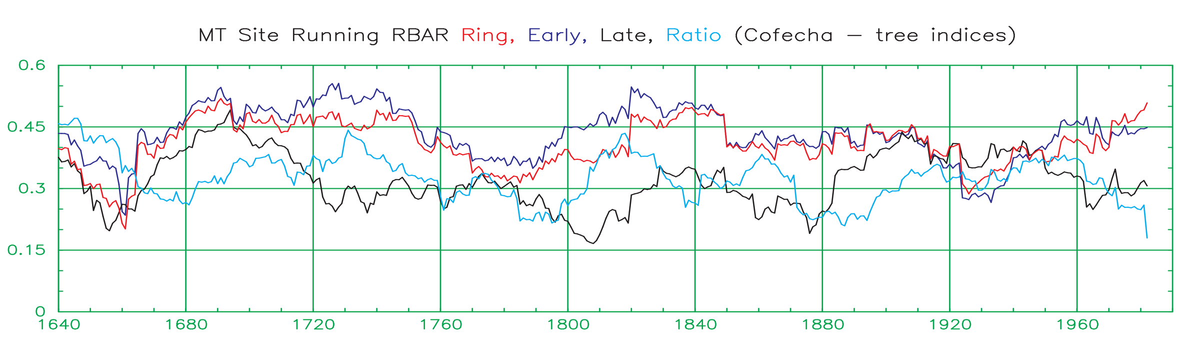

Figure 3a.
Showing for each site the mean between tree running 30-year correlations for each year plotted at the centre year.

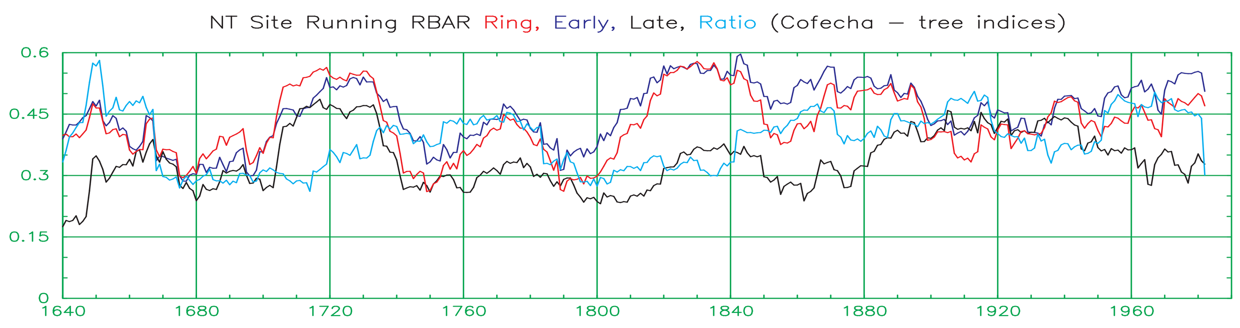

Figure 3b.
Showing for each site the mean between tree running 30-year correlations for each year plotted at the centre year.

	MT Site		NT Site	
	Correlation	SDEV	Correlation	SDEV
Ring-width	0.61	0.14	0.65	0.13
Earlywood	0.63	0.14	0.67	0.13
Latewood	0.55	0.15	0.59	0.13
Latewood Ratio	0.55	0.17	0.59	0.14

Table 2.
The mean and standard deviations of the correlations of 50-year segments overlapped by 25 years for each tree against its site index, calculated by program COFECHA.

If only one of these parameters were used for cross dating then earlywood or ring-width wood be chosen. The inter parameter correlations show in Figures 4 & 5 give a measure of the independence of the variance in these parameters and show that the signals of ring-width and latewood ratio have less than 10% common variance opening up the possibility of using these as two sets of nearly independent parameters for cross dating.

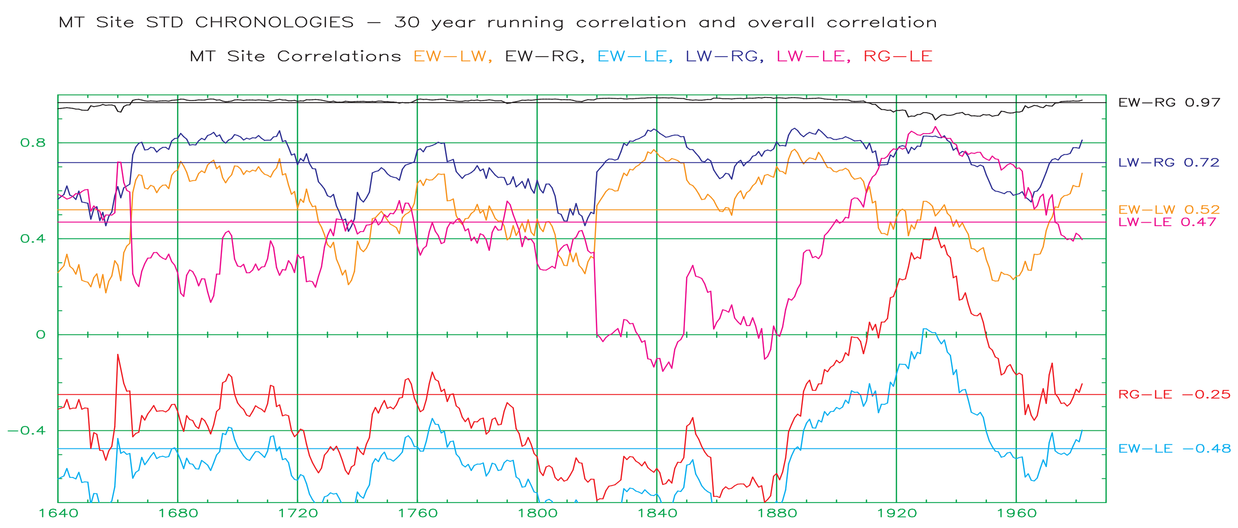

Figure 4.
Shows the 30-year, running correlation and full period correlation between the indices of the inter-ring parameters for the MT site.

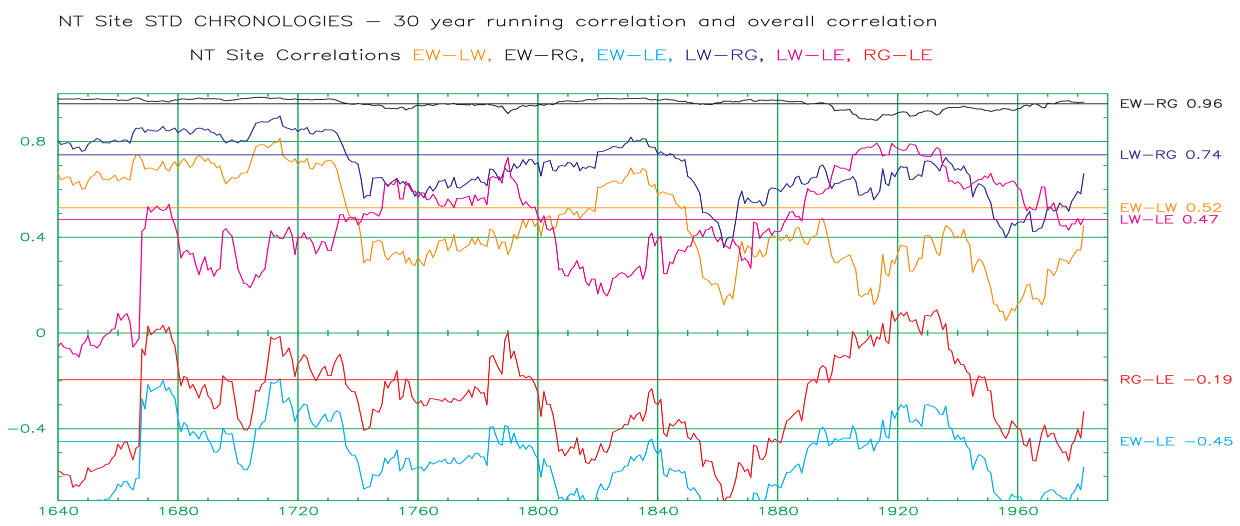

Figure 5.
Shows the 30-year, running correlation and full period correlation between the indices of the inter-ring parameters for the NT site.

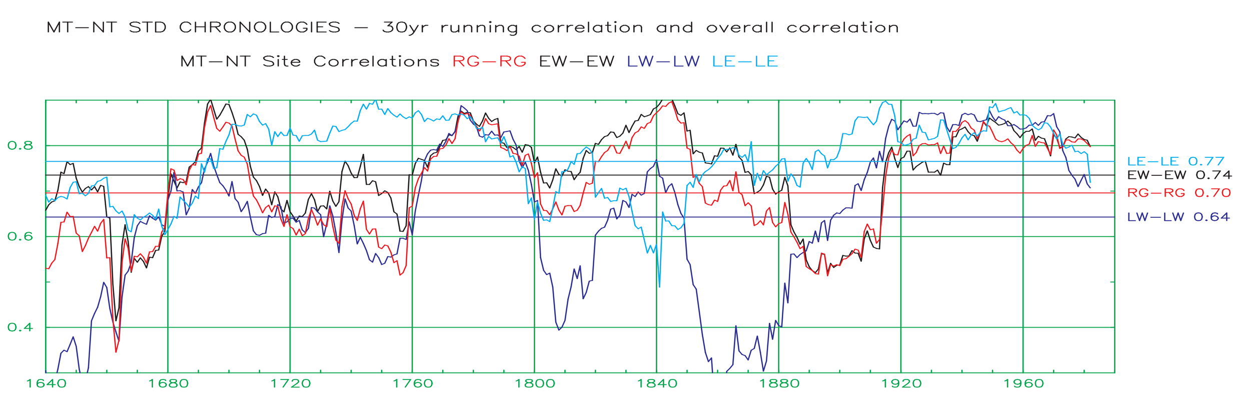

Figure 6.
Shows for each of the intra-ring parameters the 30 year running correlations and full period correlations between the two sites.

To be of value the intra-ring parameters need to be persistent over distance and the correlations shown in Figure 6 demonstrate that for these two sites the intra-ring parameters are highly correlated over the 20 kms separating the sites.

This demonstrates that the latewood ratio, because of its independence from ring_width, has the potential to enhance our ability to crossdate material. Ongoing work will look at the persistence of these intra-ring signals over distance and within different tree species and evaluate the potential for improving crossdating of both short samples and of chronologies across large distances.

5. RESPONSE TO METEOROLOGICAL DATA

The requirement here was to look at inter annual and inter decadel timescales so all chronologies were developed by taking the robust mean of the residuals from a high pass 30-year spline thus creating "STD" high frequency chronologies using program ARSTAN.

The growth response to the meteorological data is examined by calculating correlations between normalised monthly or seasonal data and the individual chronologies representing the intra-ring parameters at each of the two sites. Seasonal data were produced as the arithmetic mean of normalised monthly values. Three separate correlation periods were used, the "full period" of 1869 to 1997, the "early period" of 1869 to 1933, and the "late period" of 1932 to 1997 and these were plotted as colour coded bars in the figures.

Correlations with monthly temperature and precipitation from the previous April to current September and with a series of summer temperature seasons of two and three months are plotted and months are labelled with three character month names where previous years data.are postfixed with "-1".

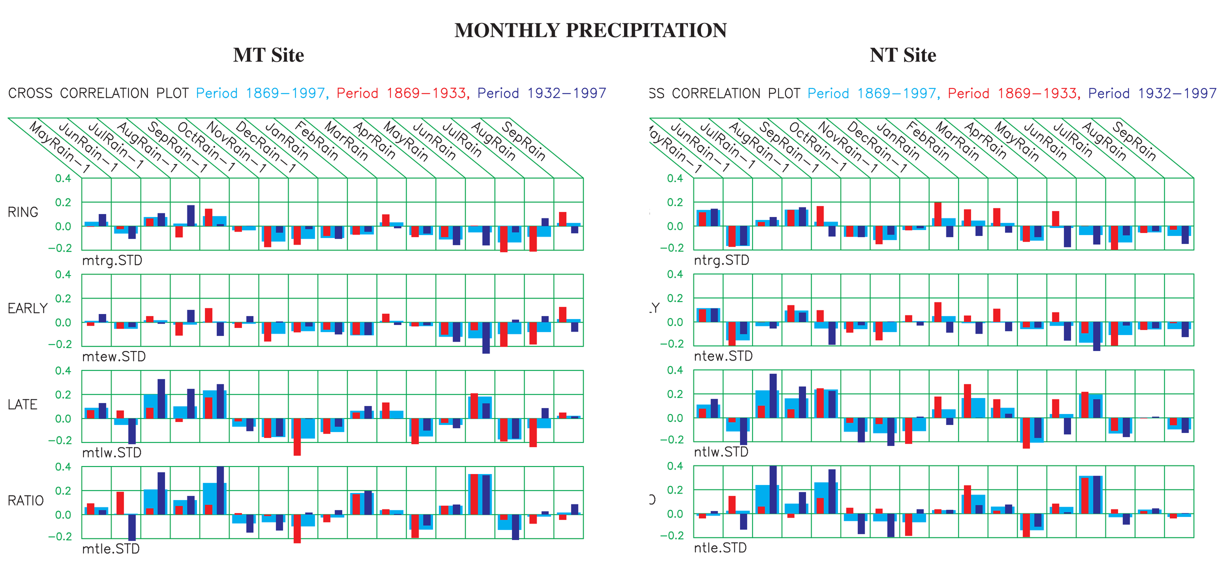

Figure 7.
Correlations of the chronologies at each site with monthly precipitation data from the previous year's April to current September.

Referring to Figure 7, the response to precipitation over the full period at both sites by ring-width and earlywood was not significant. Latewood and latewood ratio show a positive response to the previous summer months precipitation in July, August and September which is stronger in the recent period. Latewood ratio shows a strong positive response to current June precipitation, which is similar in both the early and late periods and appears to be the difference of mild positive and negative responses by latewood and earlywood respectively.

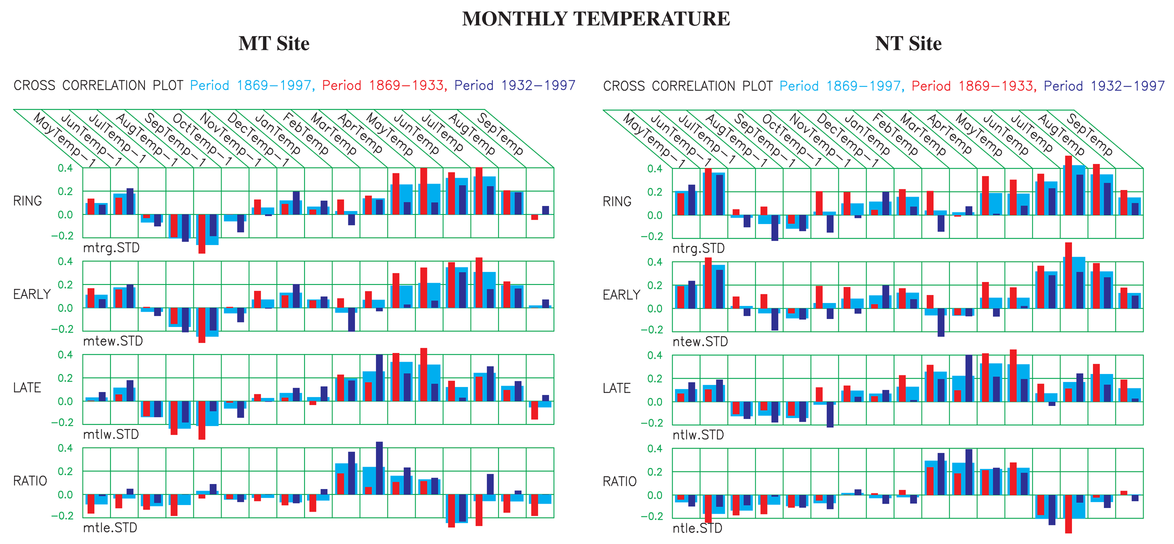

Figure 8.
Correlations of the chronologies at each site with monthly temperature data from the previous year's April to the current September.

The main differences between the responses to temperature at the two sites are that firstly the MT site earlywood responds to earlier summer months, June and July as compared to July and August, than the NT site earlywood, and that secondly the MT site has a mild negative response to previous August and September while the NT site has a mild positive response to previous May and June.

The main differences between the response to temperature of latewood and earlywood are that latewood has its highest positive correlation in April and May whereas early wood responds to later summer months. Intuitively one would expect earlywood to be more responsive to spring and early summer and latewood to respond to late summer, yet the opposite takes place at these two sites and the difference between latewood and earlywood is greater in the recent period.

The ring-width response to temperature appears to be the mean of latewood and earlywood responses, allowing for their respective proportions in the ring-width, while latewood ratio response to temperature looks like the difference of the of latewood and earlywood responses to temperature.

The response during April-August at both sites is markedly higher during the early period than the later period for all except the latewood ratio. The latewood response to March temperature was negligible in the early period but significant in the later period.

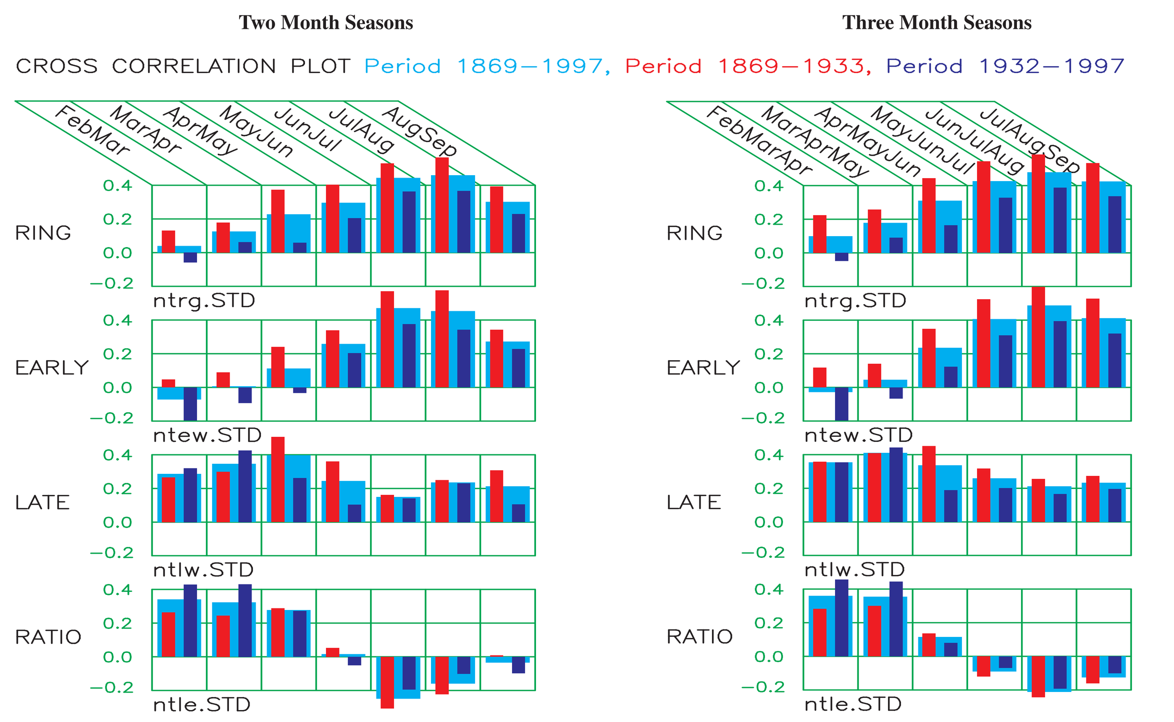

Figure 9.
Correlations of the NT Site chronologies against two and three month seasons of temperature data.

The responses to seasonal temperature were similar at both sites. Figure 9 shows clearly that earlywood responds to summer months whilst latewood responds to spring months. This figure also highlights the difference between the ring-width - temperature relationships and the latewood ratio - temperature relationships and the different "climatic" sources of their signals and thus one cause behind their relative independance.

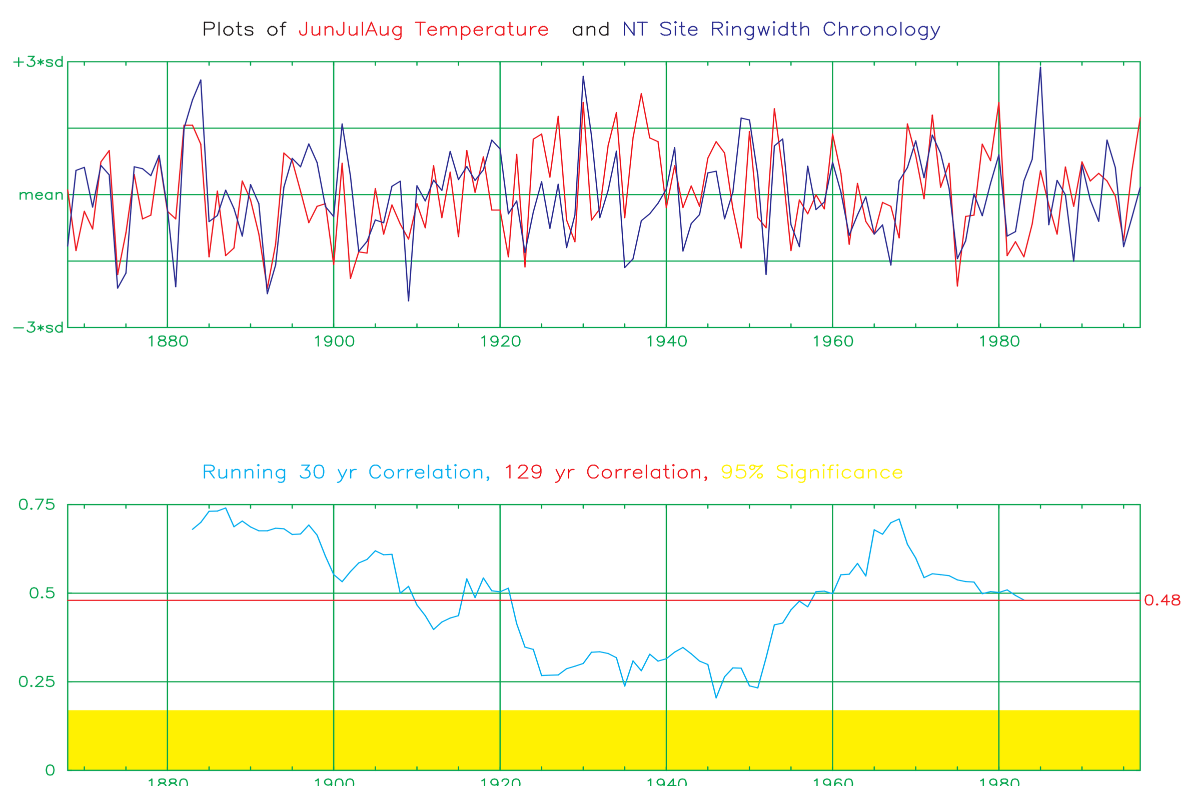

Figure 10.
Plots of the June to July season signal against the NT site ring-width chronology.

The strength of the relationship shown by the running correlations in Figure 10 appears to be reduced by individual events with a reasonable fit in most years. The low temperature and low growth of 1935 match but low growth persisted in the trees for two years while temperature was high in 1936-8 and again but less marked in 1922-4. In 1983-4 the temperatures are low yet growth is very high.

6 DISCUSSION AND CONCLUSIONS

Latewood ratio is a form of latewood percentage and as such has been discussed widely in the literature. Reports concerning the date at which earlywood formation ceases and latewood formation initiates show relatively large year to year variation and relative consistency, for a specific year, for trees within a site. Latitudinal and altidudinal variations exist, suggesting climate control. Initial tests suggest that the latewood ratio is consistent over wider ranges than those represented by the two sites used here. The latewood ratio might be thought of as "latewood standardised using the early wood curve".

The potential to improve cross dating by the use of intra-ring parameters is demonstrated. There are many short tree samples which might be brought into use if our confidence in the statistical levels of correlation can be improved. Many chronologies and species need to be investigated to ascertain what improvements, if any, can be made to the levels of statistical confidence using intra-ring parameters.

A reduction in the response of tree-ring growth to summer temperatures from the early period to the later period of meteorological data has been reported for several northern boreal sites (Briffa 1990,Luckman 1997, Kalela-Brundin 1998). The use of intra-ring parameters at these two sites enhances the detail with which these these changes can be viewed and intra-ring parameters have the potential to improve our ability to reconstruct past climate parameters.

The high frequency nature of the latewood ratio, and similar derivatives, reduces its potential in direct retrodiction of climate parameters but it may be useful in predicting tree growth. Long runs from climate models can produce meteorological data for a site, which could be used to "grow" model trees and by comparison of model trees with real trees could assist in the validation of the climate models.

This project will go on to explore the intra-ring parameters over larger areas and within different tree species.

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