FILTERING THE EFFECTS OF COMPETITION FROM RING-WIDTH SERIES

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ABSTRACT

Spline functions were examined and compared with conventional polynomials for use in filtering nonclimatic variance from tree-ring width series. Both types of curve were fitted to ring-width series exhibiting particularly marked effects of competition and release from competition with neighboring trees during the last 100 years. Available climatic data from that interval were used to statistically evaluate the capabilities of each type of function for removing nonclimatic effects and preserving the climatic signal. The results suggest that both types of function can be used successfully for those purposes, though in the presence of extremely rapid changes in growth rate due to a sudden release from competition it may be necessary to divide the ring-width series into two segments and fit a separate curve to each segment. Tightly-fit polynomials seem to be about as effective as splines, but are less desirable from a computational point of view as, for example, when the magnitude of the (negative) exponents of the coefficients exceeds computer capacity. Further, a spline function can be prescribed from its frequency-response characteristics, so it is possible to specify in advance the extent to which it will filter out any potential climatic cycles.

Zur Beseitigung von nicht-klimatischer Varianz in Jahrringfolgen wurden Spline-Funktionen verwendet und mit herkömmlichen Polynom-Funktionen verglichen. Beide Kurventypen wurden an Jahrringfolgen angepaßt, die während der letzten 100 Jahre besonders ausgeprägte Anzeichen von Konkurrenz mit Nachbarbäumen und nachfolgenden Freistellungen aufwiesen. Mit den für die gleiche Periode verfügbaren Klimadaten wurden statistische Berechnungen durchgeführt, um die Tauglichkeit der verschiedenen Funktionstypen zur Ausfilterung nicht-klimatisch bedingter Wachstumserscheinungen und zur Bewahrung des Klimasignals abzuschätzen. Die Befunde deuten an, daß beide Funktionstypen erfolgreich für die genannten Zwecke eingesetzt werden können. Jedoch kann es bei extrem schnellen Zuwachsänderungen aufgrund plötzlicher Freistellung notwendig sein, die Jahrringfolge in zwei Abschnitte zu unterteilen und die Kurvenanpassung für jeden Abschnitt getrennt durchzuführen. Dicht angepaßte Polynome scheinen etwa gleich wirksam zu sein wie Spline-Funktionen. Sie sind aber, was die Berechnung angeht, weniger gut geeignet, z.B. wenn für die Größe der negativen Exponenten der Koeffizienten die Stellenzahl des Computers nicht ausreicht. Zudem können die Filter-Eigenschaften einer Spline-Funktion vorgegeben werden. Daher ist es möglich, das Ausmaß der Ausfilterung von möglichen Klimazyklen von vornherein anzugeben.

Des fonctions splines ont été examinées et comparées avec des fonctions polynomiales conventionnelles pour filtrer la variance non climatique dans des séries de cernes. Les deux types de courbe ont été lissés sur des séries de cernes montrant des effets de compétitions durant les derniers cent ans. Des données climatiques accessibles pour cet intervalle ont été utilisées pour évaluer statistiquement les capacités de chaque type de fonction, pour ôter effets non climatiques et préserver les climatiques. Les résultats suggèrent que les deux types de fonction peuvent être utilisés avec succès, quoique en présence de changements extrêmement rapides dans la valeur de la croissance dus à un relâchement brusque de la concurrence, il est nécessaire de séparer la série totale en deux segments et de lisser une courbe différente pour chaque segment. Les polynomiales fortement lissées semblent aussi effectives que les splines, mais sont moins désirables du point de vue calculs, par exemple lorsque la magnitude des exposants des coefficients excède les capacités des computers. De plus, une fonction spline peut être recommandée pour les caractéristiques de ses "frequency-response" de telle manière qu'il est possible de spécifier à l'avance le point jusqu'où il pourra filtrer les cycles potentiellement climatiques.

INTRODUCTION

In most forests in the eastern United States, trees grow in stands where there is competition for sunlight, water, and nutrients. Changes in competitive status among trees due to growth or death of neighboring trees, human disturbances, canopy breakthrough, etc., result in long-term (or low-frequency) changes in the growth rate of an individual tree. Competition factors can cause several long-term changes in ring width over the lifetime of a 300-year-old tree. Because that portion of the ring-width variance is not related to climate, it should be filtered from the ring-width series before the series is calibrated with climatic variations. The low-frequency variance is removed, or filtered, from the tree-ring series by first describing that portion of the variance, using some type of mathematical curve, and then dividing the value of each year's ring width by the corresponding value of the curve. Division, rather than subtraction, is used because the variance of the ring widths increases as their mean value increases, and division has been found effective for removing this nonclimatic influence (Fritts 1971, 1976). Straight lines, exponential decay functions, and conventional orthogonal polynomials have been used to represent the low-frequency variance to be filtered out of ring-width series. Of these functions, only the polynomials can approximate the oscillations in ring-width series that are caused by changes in the competitive status of a tree over long time periods. The polynomial curve-fitting option of the ring-width standardization program INDXA and the more recent version, INDEX, developed at the University of Arizona, uses a reduction-of-variance (RV) test to select a polynomial fit for a ring-width series. It attempts to fit orthogonal polynomials of successively higher order, and accepts a given order polynomial when the next two higher orders do not reduce the variance of the residuals by a prescribed percentage, the default value being 5% (Graybill 1979). Problems are frequently encountered when using these polynomials because one polynomial equation must approximate the low-frequency variations of the entire series. As a result, in some cases, the curves are poorly fit to some segments of the ring-width series.

An alternative approach is to use cubic spline functions in place of conventional orthogonal polynomials for describing the low-frequency variance to be filtered. The cubic spline is a close mathematical analogue to the flexible ruler used to standardize tree-ring series by hand (e.g., Stokes and Smiley 1968: 38), so the spline often resembles a curve "fit by eye." The terms *local* and *global* are useful towards understanding the difference between the behavior of the smoothing spline and the conventional orthogonal polynomial. The points of flexure of the spline occur at natural locations along the data sequence as dictated by the *local* behavior of the data. The conventional orthogonal polynomial estimates the shape of the unwanted low-frequency component by a least-squares polynomial regression equation that is *global,* i.e., it utilizes all of the data simultaneously. Another feature of the smoothing spline is its continuous range of flexibility from a straight line of any slope to a complete interpolatory fit to each datum. In the extreme case of inflexibility, a straight line with a slope of zero and a y-intercept of unity is fit and all the variance, at all frequencies including the very long-term trends, remains. At the other extreme, if the spline is so flexible as to pass through each datum, then all variance is filtered out and all that remains is a straight line with a slope of zero and a y-intercept of unity. There is a continuous range of possibilities between these extreme cases. A spline is selected for use as a filter based on its *frequency response function* which is related to the percentage of variance, at each frequency, that will remain with the filtered series. The frequency below which 50% or more of the variance is filtered out is called the 50% Variance Reduction Frequency, or 50% VRF.

For example, a 50% VRF of one cycle per 30 years is associated with a more flexible spline than is a 50% VRF of one cycle per 100 years. The more flexible spline would effectively filter out, say, a 55-year cycle (because it is flexible enough to describe that cycle) while the more rigid spline would allow such a cycle to remain with the filtered series. By specifying the 50% VRF, one is actually specifying the frequency-response function and the corresponding flexibility of the spline, thereby determining the filtering characteristics of the spline.

The continuous range of flexibilities coupled with the property of local behavior leads to the finding that the spline is, in effect, a symmetric, low-pass digital filter with a continuous range of frequency-response functions (Cook and Peters 1981). The advantages of the smoothing spline over normal digital filtering techniques are that (1) no filter weights need to be explicitly computed, (2) no end-points are lost as a result of filtering, and (3) the filtering characteristics are easily varied through a change in only one parameter defined as p by Cook and Peters (1981) who present a more detailed description of the properties of smoothing splines and their application to dendroclimatology.

Selection of the appropriate spline flexibility for dendroclimatic studies can be facilitated by providing systematically documented results of investigations using a wide range of flexibilities. This would provide a base of reference to aid dendroclimatic investigations in eastern North America and much of Europe. In this paper we document the results of using each of several splines, representing a wide range of flexibilities (50% VRFs), for filtering low-frequency variance from ring-width sequences of white oaks (*Quercus alba*) which were especially selected to represent varying degrees of competitive effects. We also used conventional orthogonal polynomials, instead of splines, to filter out nonclimatic variance, and compared the results with those obtained using splines with various 50% VRFs.

PROCEDURES AND ANALYSES

To assess the relative merits of the above-mentioned ways of filtering ring-width series for climatic studies, we ran several experiments each using a particular spline (described by its 50% VRF) or a conventional orthogonal polynomial to filter low-frequency variance from some ring-width series. Tree-ring chronologies derived using each filter were used to estimate annual precipitation amounts. We then compared the accuracy of the various precipitation estimates, to ascertain which filter(s) had preserved the precipitation "signal" with the greatest fidelity in the filtered tree-ring chronology. White oaks in central Iowa were used because their growth is strongly correlated with annual precipitation amounts from August of the year preceding ring formation through July of the concurrent growing season (Duvick and Blasing 1981).

Linear regression was used to calculate a series of precipitation estimates from each set of filtered ring-width data. As in Duvick and Blasing (1981), the first-order autocorrelations in the calibration period were too small (always less than + 0.16) to justify inclusion of lagged ring-width variables as predictors of annual precipitation. Therefore, the precipitation for each 12-month period was estimated using only the ring width formed at the end of that period, and no other predictors (e.g., lagged ring-width variables) were included. The regression coefficients were calculated using data from a recent period (e.g., 1920-1977), called the calibration period. The equation was then used to estimate annual precipitation during a previous period (e.g., 1874-1919) for which precipitation data are available to compare with the estimates. Data from the earlier period are called independent data because they were not used to calculate the regression coefficients. Comparing the independent data to their estimates (verification) measures the stability and reliability of the regression equation outside the calibration period. The regressions using various curve types were compared using two statistics: the correlation squared (R^2) for the calibration period, and the reduction of error (RE) for the independent period (Lorenz 1956; Fritts et al. 1979; Blasing et al. 1981). The RE can range from minus infinity to plus one, and any positive value is indicative of a successful reconstruction (Fritts et al. 1979). The RE is sensitive to differences in the means of the estimated and actual independent data, while the correlation coefficient is not. Differences in mean of estimated and actual independent data can be considerable if poorly fit curves fail to remove low-frequency changes in ring width caused by release effects or other disturbances.

Sudden increases in growth rate of a tree due to release from competition, as when a neighboring tree dies, sometimes produce a doubling or tripling of the average ring-width increment in less than ten years, and sometimes in only one or two years (Figure 1). These effects usually cannot be adequately removed with a continuous curve (either a spline or a conventional polynomial). One suggested method for dealing with this problem is to split the ring-width series into two segments, with the split occurring between the two successive rings having the greatest difference in width during the release period, and fitting a separate curve to each segment. We tried this approach on ring-width series from each of six cores which exhibited a strong release somewhere between 1882 and 1922. Splines with a 50% VRF of one cycle per 50 years were used in each case. Ring-width data filtered with split splines were compared with the same data filtered with single continuous splines (i.e., no splitting). We also tried omitting

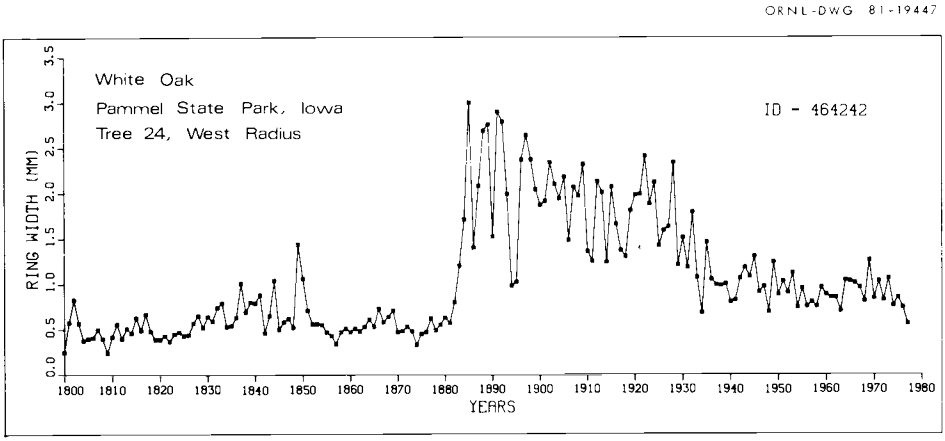

Figure 1. Ring-width series from a white oak *(Quercus alba)* in central Iowa, showing strong effects of release from competition beginning in 1882.

Table 1. Calibration and verification statistics for Iowa annual precipitation reconstructions when continuous and split splines were used to filter nonclimatic variance from each of six white oak cores which showed strong effects of release from competition in the verification period. R-SQ is the square of the correlation coefficient between precipitation and the filtered ring-width data for the calibration period (1931-76), and RE is the reduction of error.

			RE for years surrounding release		
				Split spline	
Core no.	R-SQ	Verification period	Continuous spline	No rings omitted	Some rings omitted
464242	0.36	1875-1894	−1.41	−0.07	+0.27
645581	0.47	1886-1905	−0.40	+0.01	−0.04
648052	0.33	1892-1911	+0.17	+0.42	+0.42
648252	0.38	1892-1911	+0.30	+0.45	+0.50
788042	0.30	1892-1911	+0.11	+0.58	+0.58
788062	0.27	1911-1930	−1.01	−0.04	+0.001

		RE for years during release	
Core no.	No. of years	Continuous spline	Split spline with no rings omitted
464242	3	−1.43	− 1.94
645581	1	+0.98	− 3.18
648052	4	+0.46	− 0.77
648252	4	−0.72	− 4.08
788042	2	−1.94	−25.73
788062	4	−2.44	+ 0.21

the one to four rings during the release (for which the growth rate was rapidly increasing) prior to fitting a split curve.

The filtered ring-width data for each core were calibrated using linear regression with annual precipitation values for 1931-1976. These regression equations were then used to estimate annual precipitation for the 20 years centered on the release. The RE was computed separately for the one to four years of rapid growth rate increase at the time of release, and for the remaining 16-19 years in the 20-year interval centered on the release. Table 1 summarizes the results of these tests. For the 16-19 years surrounding the release, the split splines have higher REs than do the continuous splines. The REs for the one to four years during release are usually negative for both the continuous and split curves, and the REs for the years surrounding the release tend to be higher when the rings during release are omitted prior to curve fitting. Thus, the most accurate reconstructions are most likely to be produced when the curve is split and the few rings during release are omitted.

The split curves used in the following sections of this paper thus make use of omissions, except in cases where the release took place in only one year and the spline could be split without omitting any rings. Of 221 strong releases which we have examined, 22% could be split without omitting any rings, and only 10% required omission of more than eight rings. Omissions leave gaps in the ring-width series, but at any given site the release dates generally vary and some cores will have no need for omissions, so these gaps will usually be adequately covered by samples from other trees.

To ascertain the optimum degree of flexibility of splines for retention of climatic information, to compare the splines to orthogonal polynomials, and to further compare split and continuous curves, sets of 20 cores (two cores per tree from ten trees) containing release effects or canopy effects which occurred between 1870 and 1905 were selected from each of two sites, Ledges and Pammel State Parks, located in central Iowa. A tree-ring chronology was calculated for each type of filter applied to the ring-width data at each site. (A tree-ring chronology is calculated by applying a specified type of filter to the ring-width series of each core, and averaging the filtered data over all cores for each year.) About seven of the 20 cores at each site showed very strong release effects, about seven contained more moderate release effects, and about seven contained small release effects or more gradual low-frequency variations in ring width. Splines with 50% VRF values of one cycle per 21, 28, 37, 50, 66, 88, and 117 years, corresponding to the log p values of Cook and Peters (1981) from log p = − 2.0 to − 5.0 in decrements of 0.5, were fit to each set of cores to form a tree-ring chronology for each 50% VRF value. A tree-ring chronology was also derived from a polynomial fit using the conventional 5% RV test. That is, successively higher-order polynomials are fit until the addition of two more orders would reduce the remaining ring-width variance by less than 5%. In our experience, the use of this test frequently produced curves which were not flexible enough to remove some low-frequency variations apparently not caused by climate. We therefore also tested polynomials fit using a 0.5% RV test which usually, but not always, allowed higher-order (more flexible) polynomials to be fit.

Each set of 20 cores was filtered using each curve type: (1) using no split curves, (2) splitting the strong releases only (seven cores at each site) with continuous curves fit to the other series, and (3) splitting the moderate releases as well as the extreme ones (13 cores at Ledges and 15 cores at Pammel). In most cases when series were split, some rings (usually five or less) were omitted. Each chronology was calibrated with Iowa annual (August-July) precipitation for 1920-1977, and verified using data for 1874-1919. Figure 2 is a plot of the correlation squared (R^2) for the calibration period and the reduction of error (RE) for the independent period, for the various curve types. The plotted statistic, for a specified curve type, is the average value for the two sites.

Sets of 15 cores with no apparent release effect were also selected from the Ledges and Pammel sites, and splines with 50% VRFs of one cycle per 20, 40, 50, 60, 70, 80, 100, and 120 years were fit to each of these sets. The calibration and verification periods were the same as given in the preceding paragraph. Figure 3 shows the R^2 and RE statistics for the no-release series.

Because all the release effects occurred in or just before the independent verification period, 1874-1919, the effect of changing curve flexibility and splitting is much more pronounced in the verification (RE) than in the calibration (R^2) statistics for the cores with disturbance effects. The calibration (R^2) values for the cores with disturbance effects were virtually identical whether the ring-width series were split or not, so they are plotted as one series in Figure 2.

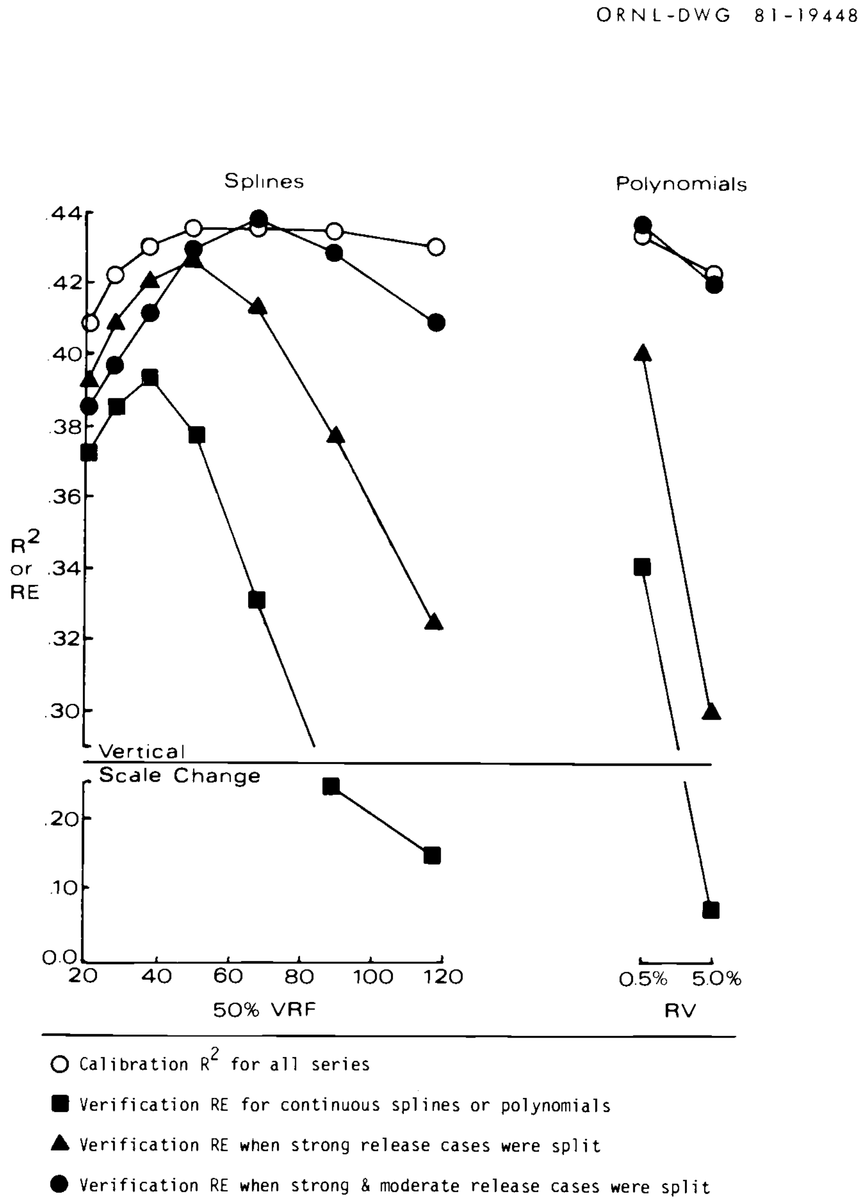

Figure 2. Comparative climatic reconstruction statistics for different curves used to filter nonclimatic variance from ring-width series. Iowa annual precipitation values were reconstructed from several white oaks exhibiting varying degrees of competition effects at each of two sites in central Iowa, and the resulting statistics were averaged for the two sites and plotted for each curve type. The 50% VRF shows the length of the cycle at which 50% of the variance is removed. The RV is the highest percentage of the residual variance that can be removed by increasing the polynomial order by two degrees. For each curve type, flexibility decreases toward the left.

When no splines were split, the more flexible splines (50% VRF = one cycle per 50 or less years) removed more of the nonclimatic variance caused by the release and thus produced higher REs than did the less flexible curves (splines with 50% VRF of one cycle per 50 or more years and conventional orthogonal polynomials). Splitting the extreme release cases removed much of the release effect before the curves were fit, resulting in higher REs for both splines and conventional polynomials, especially for the least flexible curves (the 5.0% RV conventional orthogonal polynomials and the splines with a 50% VRF value of one cycle per 50 or more years). Splitting both moderate and extreme release cases removed release effects from an increased number of cores prior to curve fitting. This resulted in further increases in RE for the less flexible curves (Figure 2).

When no splines were split, the optimum 50% VRF value was one cycle per 37 years. When the extreme release effects were split, the optimum value increased to 50 years; and when both moderate and extreme release cases were split, the optimum value further increased to 66 years. This means that when obvious release effects were

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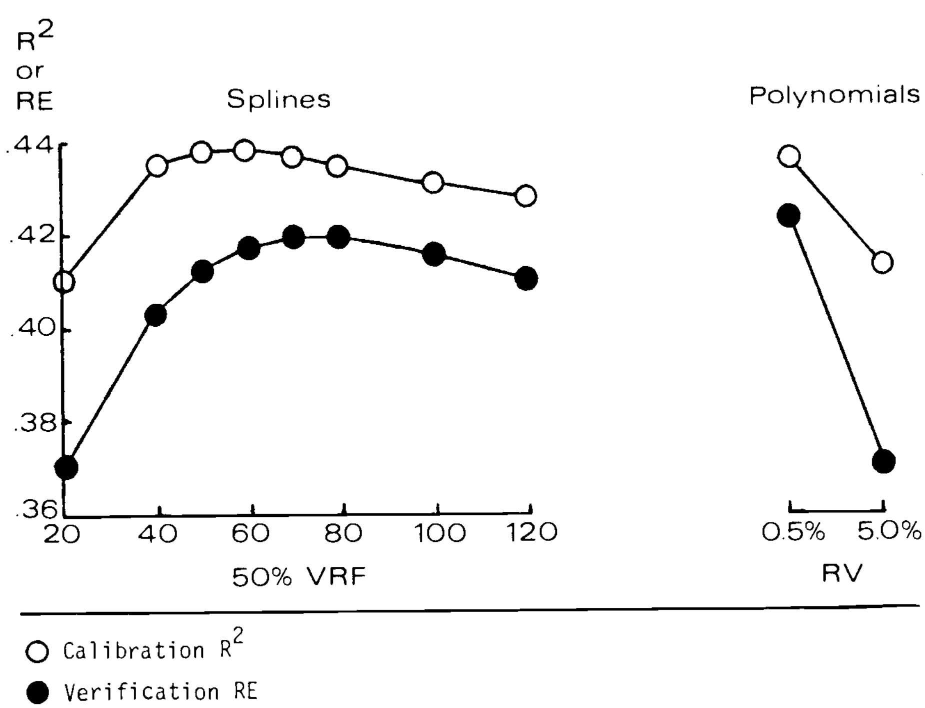

Figure 3. Comparative climatic reconstruction statistics for different curves used to filter nonclimatic variance from ring-width series which were selected for absence of apparent competition effects. Other details are the same as in Figure 2.

not removed by splitting, they had to be removed by filtering out the variance in the 37-to-66-year range of wavelengths. Unfortunately, this removed much *climatic* information from the ring-width series. Splitting the series removes release effects while allowing the selection of a filter which retains variance in the 37-to-66-year wavelengths, thereby retaining appreciably more climatic information.

The cores with no release effects have smaller variations in RE with changing curve flexibility since these series contain relatively little low-frequency variation, and the optimum splines as judged by R^2 and RE (Figure 3) have a 50% VRF of about one cycle per 60 or 70 years.

The values of R^2 and RE for the most extensively split series (Figure 2) and for the series with no apparent release effects (Figure 3) remain steady or decline for splines with 50% VRF values of one cycle per 70 or more years, and are lower for polynomials with the 5.0% RV test. These declines in R^2 and RE indicate that tree-ring chronologies derived using the less flexible curves are retaining more nonclimatic low-frequency variance than are those derived using the more flexible curves (splines with 50% VRF of one cycle per 70 or less years and orthogonal polynomials with the 0.5% RV test), and that even for undisturbed trees there appears to be little or no climatic information gained by including any more variance at the lower frequencies. In all these cases, the R^2 and RE both decline as the splines increase in flexibility from 50% VRF values of about one cycle per 30 years to one cycle per 21 years. This indicates that the most flexible splines, having 50% VRF values of about one cycle per 30 or less years, always removed more climatic variance than nonclimatic variance in those higher frequencies.

In general, first-order autocorrelations of the filtered ring-width series were highest when the least flexible splines were used. The highest first-order autocorrelation in the calibration period (+0.153) was obtained when a spline filter with a 50% VRF of one cycle per 117 years was applied to cores from the Ledges site.

Use of orthogonal polynomials usually resulted in RE values below those using the best spline fit (Figures 2 and 3). Only when splitting was used extensively or when there were no release effects did the orthogonal polynomials produce an R^2 or RE close to that using the best spline, and in those cases the orthogonal polynomials had the 0.5% rather than the 5.0% RV test. Comparing the conventional polynomials with the 5.0% RV test (the default option in the conventional program, INDEX) with splines having a 50% VRF of one cycle per 66 years (the "default option" implicitly suggested by Cook and Peters 1981), it is seen in Figures 2 and 3 that the splines are clearly and appreciably superior (in terms of R^2 and RE) in every case.

Duvick and Blasing (1981) reconstructed annual average precipitation for Iowa from the average of three chronologies in the central part of the state. They had well over 40 cores from each site, even after they had thrown out "all but those for which the conventional polynomials could be used to filter out the low-frequency nonclimatic variance to our satisfaction" (Duvick and Blasing 1981). They compared R^2 and RE terms obtained using conventional polynomial and spline filters and found the results, for each term, differed by less than 1%. This finding is not surprising and, in fact, it provides a good example of circular reasoning in view of the way the cores were selected. With more cores per site, and using data from all three sites for one reconstruction, it is also not surprising that the overall verification statistics were somewhat better than those obtained in the present study.

While it appears possible, using the 0.5% RV test, for orthogonal polynomials to produce a chronology as reliable as that using splines, we note that the orthogonal polynomial option can sometimes produce a poorly fit (inflexible, low-degree) polynomial even with a low (0.5%) RV test. In these particular tests, when most of the series were split such poor fits were infrequent enough to allow a relatively high RE. However, it is possible for two very similar ring-width series to be fit with vastly different polynomials, even when the same RV test is used in both cases. For example, using orthogonal polynomials with the 0.5% RV test, one core from a tree at Pammel was fit with a 16th degree (very flexible) polynomial while the other core from the same tree, whose ring-width series had a very similar shape, was fit with a 2nd degree (very inflexible) polynomial. Splines fit to these two cores were consistent with the similar shapes of the two series and fit well to the low-frequency fluctuations in both series. Use of a low (0.5%) RV test for orthogonal polynomials occasionally produces a polynomial of extremely high degree, resulting in fatal program errors, as when the magnitude of the (negative) exponents of the coefficients exceeds the capacity of the computer. On the Oak Ridge National Laboratory IBM 3033, using double precision, polynomials above about the 21st or 22nd degree led to errors, either in the form of poor fits or fatal program errors.

DISCUSSION AND CONCLUSIONS

If the ring-width series for a core contains an extreme release effect, the series should be split at the release, with a separate curve fit to each segment. It seems best to omit years of rapid increase in growth rate during the release because such changes in growth rate obscure climatic information in those few rings. Our best results were obtained when series from cores exhibiting moderate *or* extreme release effects were split.

Chronologies developed using splines produce reconstructions as good as, and often better than, conventional orthogonal polynomials. Unlike conventional orthogonal polynomials, splines can be easily derived for specified frequency-response functions, and can be depended upon to be of essentially the same shape when fit to similar ring-width series, whereas slight differences in the numerical values of ring widths, from one core to the next, can drastically alter the shape of a fitted curve composed of conventional orthogonal polynomials. If the conventional polynomial option is used, however, the 0.5% RV test seems better than the standard 5.0% RV test, but care must be taken that excessively high-degree polynomials are not causing errors.

The optimum 50% VRF for splines was found to be between one cycle per 30 years and one cycle per 70 years, with the lower frequencies (the longer wavelengths) being more appropriate if release effects can be neglected or if these effects have been largely removed by liberal use of splitting before the curves are fit. Splines with 50% VRF of one cycle per 30 or less years (more flexible curves) always appeared to remove some climatic variance. For less flexible curves, no detectable climatic information was ever gained by increasing the wavelength of the 50% VRF value beyond one cycle per 70 years, and for disturbed sites such a low degree of flexibilty allowed too much nonclimatic variance to be included in the filtered ring-width data. A 50% VRF of about one cycle per 60 years resulted in good fits in most cases if releases were split or were small enough to neglect. These results apply to white oak in Iowa, and are also representative of our analyses of several hundred white oak cores from several sites in Iowa, Illinois, Missouri, and Tennessee. These results also agree closely with those of Cook and Peters (1981) who worked with several species, including conifers, in the northeastern United States and report that splines with a log p of −4.0, corresponding to a 50% VRF value of one cycle per 66 years, resulted in visually good fits for cores with disturbance effects.

Briffa et al. (1983) report impressive verification statistics (R^2 and RE) for reconstructing English climate from oaks *(Quercus robur and Q. petraca)* based on ring-width series which had been subjected to a Gaussian filter with a 50% VRF of one cycle per 30 years. None of their ring-width series were split. In this case we would have selected (from Figure 2) a 50% VRF of one cycle per 37 years, which is reasonably consistent with the choice of Briffa et al.

The consistency of the optimum 50% VRF from widely separated regions and different forest types suggests that some physicially based explanation(s) should exist. Two likely candidates are forest stand dynamics and a lack of lower-frequency (e.g., one cycle per 70 or more years) climatic fluctuations that influence tree growth. Low-frequency variations in tree-growth caused by changes in competitive status, for example, may effectively obscure climatically related fluctuations of similar frequencies. If this is the sole cause, then the optimum 50% VRF range of one cycle per 30 years to one cycle per 70 years represents the cutoff frequency band beyond which competitive interactions and stand disturbances overwhelm lower-frequency climatic variance. Thus, the amount of recoverable climatic information from closed-canopy trees could be limited to the higher frequencies. If the cause is a lack of low-frequency climatic variance alone, then the optimum 50% VRF range represents a frequency band in the variance spectrum where little overlap exists between the variance accounted for by stand dynamics and that due to climate. The latter appears to be the case with the Iowa oaks because the RE was never improved by going to 50% VRF values of one cycle per more than 70 years, even for well-behaved cores. Additionally, the Iowa precipitation data used here is serially uncorrelated (Duvick and Blasing 1981). However, we must stress that this will not be the case everywhere, and stand dynamics may limit the recoverable climate information if longer-term variations in climate or shorter-term variations in stand dynamics affect tree growth.

Development of procedures for simultaneously considering effects of climate and stand competition is a prerequisite for dendroclimatology to progress significantly in eastern North America and most of Europe. This paper evaluates both some criteria and approaches by which that progress can hopefully be promoted.

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