COMMENTS ON INTERPRETATION OF CLIMATIC INFORMATION FROM TREE RINGS, EASTERN NORTH AMERICA

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ABSTRACT

A general discussion regarding problems inherent to developing climatically sensitive tree-ring chronologies from eastern North America is presented. Tree-ring collections from eastern forests are typically not as climatically sensitive as western collections. Collections have been made from a diversity of sites, but it seems that collections from wet sites or sites of extremely shallow soils may have limited potential. The detrimental effect of crown crowding on sensitivity suggests preference be given to shade-tolerant species and to trees with less crowded crowns exposed in the canopy. Nonclimatic trends in tree-ring data are classified as growth trends and competition trends. Standardization of ring widths removes much of the growth trends, and merging individual tree chronologies into a mean collection chronology eliminates much of the competition trends of individual trees. Separation of ring width into earlywood and latewood widths, where possible, may be quite beneficial for non-pored and diffuse-porous species. However, this procedure seems to be of little value for ring-porous species.

Es werden die Probleme beim Aufbau klimasensitiver Jahrringchronologien im Osten Nordamerikas diskutiert. Die Jahrringfolgen aus östlichen Wäldern sind weniger klimageprägt als die aus westlichen Wäldern. Es wurde Jahrringmaterial von einer Vielfalt von Standorten gesammelt. Anscheinend enthalten Jahrringfolgen von feuchten oder extrem flachgründigen Standorten nur begrenzte Klimainformationen. Die nachteilige Wirkung von zusammengedrängten Kronen auf die Sensitivität legt nahe, schattentolerante Baumarten und Bäume mit weniger gedrängten Kronen aus dem Kronendach vorzuziehen. Die nichtklimatischen Trends in den Jahrringfolgen werden als wachstums- bzw. als konkurrenzbedingt eingestuft. Eine Standardisierung der Jahrringbreiten entfernt einen hohen Anteil des Wachstumstrends, und das Mitteln von Baumjahrringfolgen zu einer Chronologie eliminiert einen hohen Anteil des Konkurrenztrends der einzelnen Bäume. Die Trennung der Jahrringbreite in Frühholz- und Spätholzbreite kann sich — falls überhaupt möglich — günstig bei Nadelbäumen und zerstreutporigen Laubbäumen auswirken. Jedoch scheint dieses Verfahren für ringporige Laubbäume nur von geringer Bedeutung zu sein.

Une discussion générale concernant les problémes inhérents au développement d'une chronologie sensible au climat est présentée ici. Les séries provenant des forêts orientales ne sont typiquement pas aussi sensibles au climat que les séries occidentales. Des récoltes ont été faites dans une diversité de sites, mais il semble que les échantillons obtenus dans des sites humides ou àsol très superifciel ont un potentiel limité. L'effet nuisible de l'enchevêtrement des couronnes sur la sensibilité des cernes, suggère que la préférence soit donnée à des espèces tolérantes à l'ombre et aux arbres moins serrés situés sous le couvert. Les tendances non climatiques dans les données dendrochronologiques sont considérées comme des tendances de croissance et de concurrence. La standardisation des cernes enlève la plus grande partie de la tendance de croissance et fonde les chronologies individuelles des arbres. Quand elle est possible, la distinction de l'épaisseur du bois initial et du bois terminal des cernes peut être très bénéfique pour les espèces non poreuses ou à bois poreux diffus. A l'inverse ce procédé présente peu de valeur dans les bois poreux.

INTRODUCTION

Early attempts in North America to relate tree-ring widths to climatic factors were more successful in semiarid parts of southwestern United States than in humid regions. Therefore, it is not surprising that the principal North American developments in dendrochronology and its specialized subdivision, dendroclimatology, occurred in the southwest (reviewed in Fritts 1976). Recently, some success has been realized in application of dendroclimatic techniques to eastern tree-ring data (Cleaveland 1975; Cook 1976; Cook and Jacoby 1977; Phipps and others 1979; Duvick 1979; Conkey 1979; Puckett 1979). But it is still generally agreed that ring-width data from temperate regions are not expected to be as climatically sensitive, that is, as closely correlated with climate, as data from semiarid regions. The number of tree-ring collections existing for a given area is usually in direct response to past interest. Thus, there are relatively few sensitive tree-ring series of reasonable length from eastern deciduous forests, and, for the most part, they have only recently been collected.

The basic unit for dendroclimatic reconstruction has been the mean chronology, obtained by averaging data from several individual trees from a single species at a single collection site. Cook (1982) has pointed out the value of establishing a series of chronologies, each dating back to at least 1700 and together representing a network of sites throughout eastern North America. In making this recommendation, Cook has indicated several species that have proven or may prove to be valuable sources of data. However, there simply have not been enough collections made to know which species will yield the most information, or, for that matter, even to know which types of sites will yield collections with the greatest climatic sensitivity.

Dendroclimatological studies underway in eastern United States have generally utilized multivariate techniques and methods as described by Fritts (1976). Ring-width data from several collections (mean chronologies), are calibrated with available climatic data, and then calibration results are used with tree-ring data to estimate, or reconstruct, climatic conditions backward in time. Methods of developing mean chronologies from data collections, criteria for assessing climatic sensitivities, and techniques of calibration and reconstruction in eastern North America are based on methodologies developed for western North America primarily from southwestern material. Intuitively, it seems probable that there is more dendroclimatic information in our eastern tree-ring data than we are currently extracting. It might be well, then, to continually question and examine currently employed techniques in building tree-ring chronologies from regions other than the Southwest.

SITE SELECTION

As a general rule, the more limiting an environmental factor is to growth, the more directly variations in that factor may be correlated with variations in growth. This has been the basis for selecting sites for precipitation sensitivity at the forest-desert border in semiarid southwestern regions (Fritts 1976). As has been known for some time, trees from dry ridges have a greater chance of containing climatically sensitive tree rings than trees on moist, protected slopes (Stokes and Smiley 1968; Fritts 1976). A different way of stating the same thing is that site selection may be enhanced by picking sites of soil water recharge, such as ridge crests and convex slopes. Based on statistics from our collections (Table 1) and those by others (DeWitt and Ames 1978), collecting in areas of convex slopes has been demonstrated to yield climatically sensitive collections in the temperate-subhumid part of the continent, but species selection must also be taken into account. Coupled with site selection is consideration of tree age. Extent of forest disturbance since settlement is great enough in eastern North America that forest stand ages in excess of 150 years are not common. Fortunately, areas in which environmental factors are quite limiting to growth may also be undesirable for lumbering, agriculture, or commercial development. For example, bluffs overlooking

Table 1. Characteristics of collections from different sites.

	Quercus prinus	Quercus rubra	Fagus grandifolia	Pinus taeda
Soil moisture	dry	dry	moist	wet
Canopy crowding	moderate	open	dense	moderate
Shade tolerance	moderate	moderate	tolerant	intolerant
Percent variance:				
within trees	40	32	44	34
chronology	26	43	40	47

rivers may either contain trees of poor form or be inaccessible to normal lumbering operations. In either case, the trees may be both climatically sensitive and of considerable age. This apparent wealth of potential data is considerably tempered by the fact that trees of poor form are often not sound and therefore may not yield sample cores with more than a few dozen rings.

In addition to collection sites on convex slopes of soil water recharge, a certain amount of success has been realized using sites of soil water discharge, including concave slopes, swamps and wetlands. A direct correlation has been shown between precipitation and growth of selected trees in swamps (Phipps and others 1979). The general relationships among chronology statistics for the range of conditions from wetland to very dry sites are illustrated in Figure 1. Relative to mesic sites, both wetland and dry sites tend to produce chronologies with increased ring-to-ring variability, though increases in variability do not seem to be as great for wetland sites.

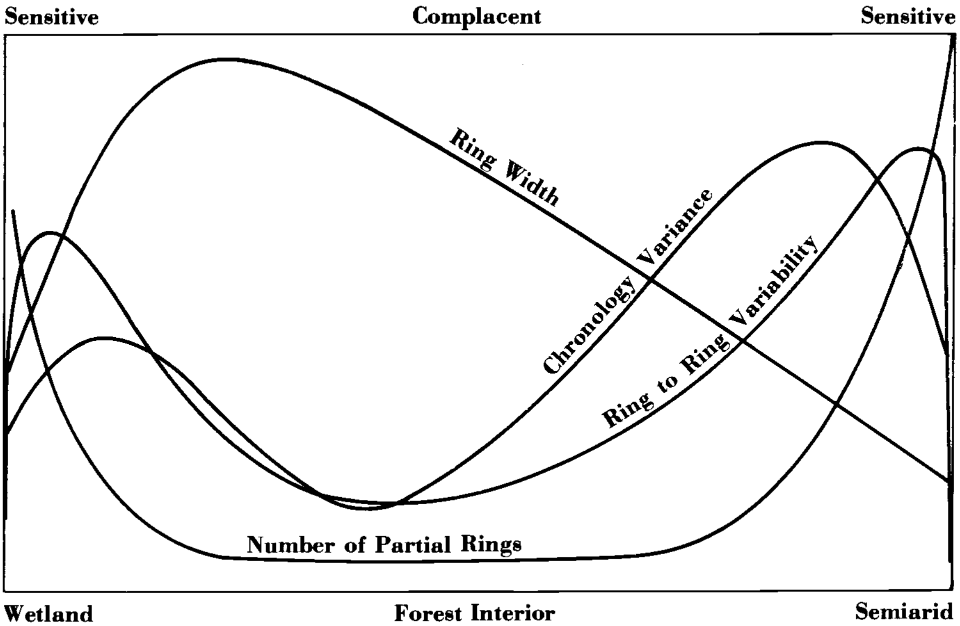

Figure 1. Tree-ring characteristics relative to water availability from wetland to semiarid sites. Modified from Fritts (1976, Fig. 6, 18).

Progressing toward more extreme conditions, either wet or dry, a point is eventually reached at which environmental conditions are limiting enough to produce physiological shock. The expected consequence of physiological shock is that amount of growth and variability of growth will be reduced for one to several years. If physiological shock occurs repeatedly, the resulting annual increments are quite small and show little ring-to-ring variability (illustrated at extreme ends of graph, Figure 1).

Collection sites may be broadly classified as hydric, mesic, and xeric (Figure 1). It may be argued that wet-site (hydric) trees, physiologically attuned to wet conditions, are relatively more sensitive to (limited by) dry conditions than dry-site (xeric) trees. Unfortunately, greater sensitivity may also mean increased chances of physiological shock. During a drought the root systems may be left high and dry. During extremely wet conditions (to and including inundation), respiratory gas exchange and, hence, growth is curtailed. Either of these extremes may be sufficient to induce physiological shock. On the other hand, though more deeply rooted, dry-site trees may experience shock subsequent to drought, it is unlikely that soil conditions are ever wet enough to induce physiological shock. One cannot, for example, imagine a ridgetop tree being inundated. Thus, wet-site trees may be subject to a relatively great frequency of physiological shock as a result of both extremely wet and extremely dry conditions. By contrast, dry-site trees may experience physiological shock less frequently as a result of extremely dry conditions and almost never as a result of extremely wet conditions. Thus, with greater probability of physiological shock, chronologies of wet-site trees would not seem to have as good a change of great ring-to-ring variability as dry-site chronologies (illustrated in Figure 1 as lower variability).

Very wet sites, such as swamps, cause the formation of shallow or restricted root systems. Shallow root systems, in turn, limit water uptake capacity and, hence, growth. Conditions other than wetlands that result in restricted root systems may be expected to produce growth responses similar to wetland trees. For example, Hill (1980), studying *Quercus stellata* Wangenh and *Carya glabra* (Mill.) Sweet growing with extremely restricted root systems in very shallow soil over bedrock, found the ring-width series to be typified by periods of great ring-width variability alternating with periods of little variability. The chronologies could thus be described as being alternately near and just past the inflection point (Figure 1) of ring-to-ring variability for xeric sites. Thus, it would seem the important consideration in sample site selection is the degree to which environmental factors of a site limit growth, not whether the site is normally hydric or xeric.

Another tree-ring collection source that must not be overlooked in the East is old buildings (Stahle 1978). Unfortunately, early builders did not have the foresight to use only "climatically sensitive" trees in their construction work. Trees were often carefully selected from secondary forests in order to obtain the straightest, tallest stems for use as long structural beams. As a consequence, trees selected may show pronounced vigor, because regrowth in secondary forests may have been only minimally limited by environmental factors. On the other hand, we have encountered construction timbers from secondary forests that contained good enough ring-to-ring variability to be readily datable. In these cases, steep, rocky slopes apparently had been used as timber sources. Because the slopes were unsuitable for cultivation, forests would have been allowed to remain, and, fortuitously, environmental conditions were harsh enough to produce tree rings with good variability.

SPECIES AND TREE SELECTION

The relatively luxuriant growth of eastern deciduous forests is a mixed blessing. On the one hand, there are available a vast array of species and habitats from which to sample. On the other hand, most areas are closed-canopy forests in which the growth of any one tree may be as much or more reflective of its immediate environment than it is of regional climate. Thus, when collecting from closed-canopy sites, it is generally accepted that overstory trees are expected to be more climatically sensitive than understory trees. Evidence suggests that the more shade tolerant a species, the less it is influenced by its immediate surrounding neighbors. Of the two factors, shade tolerance and crown exposure in the canopy, the latter may be more important than previously realized. Oaks (*Quercus*) as a group are relatively shade intolerant or at least not particularly shade tolerant. Though forest regions as described by Braun (1950) are certainly distinct, our deciduous forests are essentially oak forests. With an abundance of oak species (at least two of them, *Quercus alba* L. and *Q. prinus* L., are noted for longevity), it is inevitable that oaks will be extensively collected. Because of shade intolerance, growth of oaks is expected to be moderately to strongly reflective of conditions local to each tree, depending on the degree of crown crowding.

Assuming that growth responses common among samples are in response to environmental factors common to the total sample collection, then percent variance in common among samples (from analysis of variance) may be used as a rough indication of the climatic information in various collections. This may be used to compare collections from species of different degrees of shade tolerance from sites with different degrees of crowding in the canopy (Table 1). The *Quercus prinus* L. site is a dry ridgetop and the forest has a canopy that is neither exceptionally open nor very closed. The *Quercus rubra* L. site is also dry upland, but has a very shallow soil, and the forest canopy is more open than the *Q. prinus* site. The *Fagus* site is a concave slope and quite mesic. The *Pinus* site is in the interior of a wet organic muck swamp. Of the two collections from dry sites, the one from the stand with a more open canopy (*Q. rubra*) had a considerably higher proportion of variance in common among samples (43 versus 26 percent). By contrast, even though canopy densities are great and water is not expected to be appreciably limiting, variance in common among the very shade tolerant *Fagus* samples was essentially as great as for the *Q. rubra* and the *Pinus* collections. The *Pinus* are shade intolerant but, as early successional stage species, were never part of the understory, and the canopy in this specific case is not particularly crowded. Though these are but isolated examples, they tend to support the general conclusions that the more open the canopy of the site the better, and, given a choice between species, the more shade tolerant the species the better.

When sampling in relatively closed stands (that is, stands in which crowns of adjacent trees may be in close contact with one another) on relatively flat topography, we feel it is more important to emphasize relative crown radius than compass direction. Thus, we sample opposing radii beneath the least crowded (greatest) crown diameter, regardless of compass direction. If only one radius is relatively uncrowded, the tree is preferably not sampled, nor are trees sampled in which the crowns are crowded on all sides.

Trees growing on slopes normally lean downslope. In temperate-subhumid forests, degree of tree trunk lean seems to be directly related to the degree of slope and inversely related to the shade tolerance of the species. Even where the lean is not great enough to cause reaction wood formation, there is a measurable difference between ring widths of the upslope and downslope radii (Phipps 1974). Sampling only radii perpendicular to slope direction, again regardless of compass direction, can help minimize ring-width differences between sampled radii. Selection of trees on slopes should, thus, emphasize those trees in which crown diameters perpendicular to slope direction are uncrowded. On the other hand, there seems to have been no study which has examined the relative climatic sensitivity of ring width from various radii of slope trees. Could it be, for example, that the downslope radius (usually not sampled) is the climatically most sensitive radius? Generally, the downslope side of the crown is less crowded than the sides perpendicular to slope direction.

STANDARDIZATION AND THE MEAN CHRONOLOGY

Each tree is a discrete biological entity controlled by its own genetic pattern which, in turn, affects its physiological growth responses to an array of environmental factors. This strongly suggests that, as with other biological sampling strategies, multiple sampling and data merging (averaging) are desirable in dendroclimatological studies. However, it is quite important to remove non-climatic trends in the data before merging (Fritts 1976). Non-climatic trends seem to be of two types, which are strongly interrelated. Though perhaps simplistic, it may be possible to think in terms of one type of trend as being related to crown size and trunk (or main stem) diameter. This type trend is the one often referred to as the growth trend. Crowns of trees in typically dense deciduous forests increase in size until the crown is within the forest canopy, but then reach a fairly stable size in dynamic equilibrium with spacing of surrounding crowns. From this time forward, there seems to be a tendency for annual increments of cross-sectional area at any given height to remain nearly constant, though ring width necessarily decreases. Of course, anything that causes a change in crown size will result in a shift in the crown-size trend. As examples, removal of surrounding trees may result in a rather abrupt shift (such as release after death of an adjacent tree), while closing of the canopy after disturbance can result in a more gradual shift. Thus, the normal growth trend of wide-to-narrow rings with time may be superimposed with numerous, smaller shifts or changes in trend. Indeed, in our closed-canopy deciduous forests, the basic growth trend may be completely masked by changes and shifts in trend.

The second type of non-climatic trend may be considered as more strictly physiological. Any of several factors may, during the life of a tree, increase or decrease its physiological sensitivity to climatic factors, resulting in what may be termed competition trends. The degree of overtopping, shading, and crowding of the crown and root system may change abruptly or gradually over many years. These changes may be associated with, but frequently are independent of, crown size and tree age (that is, crown-size trends). Death of old branches of a tree, as well as death of adjacent neighbors could, through changes in crown and root crowding alone, result in competition trends on any given sampled radius. Whether or not these trends are great enough to be bothersome, they must be continually changing throughout the lifetimes of trees in closed-canopy forests. It follows that the greater the growth differences between opposite sides of a tree, the greater the competition trends. Analysis of variance results show that ring-width differences between samples of a given tree of our typical deciduous forest chronologies are strikingly greater (averaging 45.9 ± 16.7 percent from 21 collections) than that component of chronologies from western sites (25.6 ± 9.4 percent from 38 collections, as calculated from data of Stokes and others (1973). A change in physiological sensitivity in all radii can also often be seen in situations in which environmental conditions are very limiting to growth and ring-to-ring variation is great. For such trees, an extreme year, such as resulting from a severe drought, may cause enough of a physiological shock that regardless of climatic variation during the next few years, very little ring-to-ring variability may be noted.

Distinguishing two types of trends in tree-ring data, growth trends and competition trends, does not of itself indicate the relative importance of each or how to distinguish the two. Both growth trends and competition trends may be dealt with in part by selective sampling. Selecting sites that do not have complex histories of frequent disturbance can often be helpful in narrowing a list of sites for reconnaissance sampling. Growth trends are more or less independent of year-to-year width variations and are expressed as the average or general trend of several consecutive rings. Excursions in growth trend, such as trends from narrow to wide rings in opposition to the basic trend of gradually decreasing width with age, are most easily detected during cursory field inspection. Competition trends, though typically more subtle, are also frequently detectable in cursory field examinations. Competition trends are expressed as changes in ring-to-ring width variability. An extreme example might be change from a segment of great ring-to-ring variability to a segment of little variability.

In the closed-canopy deciduous forests of eastern North America difficulty can be expected in obtaining collections without considerable non-climatic trends in the data. If the growth trends are simple (that is, not compounded by shifts or changes) and the record lengths are extensive, then a considerable part of the trend may be dealt with by simply deleting the inner rings. These rings not only account for most of the curve in the growth trend but generally display low physiological sensitivity. Unfortunately, most deciduous forest material contain compound trends and are of short enough record length that the luxury of discarding 50-100 of the innermost rings of each sample cannot be afforded.

The most universally applied programs for standardizing tree rings, INDXA and INDEX, use curve-fitting options to remove trends from the data (Fritts and others 1969; Graybill 1979). The programs calculate indices (standardized ring-width indices) as the ratios of ring width to corresponding values from the fitted curve. Of the several curve options available, the negative exponential curve is probably the one most commonly used for material from western and southwestern North American sites. This is the curve that describes the simple growth trend. Perhaps the most commonly used INDXA (or INDEX) option available for use with typical eastern tree-ring material has been the polynomial curve-fitting option. One unresolved problem with any type of curve fitting is how closely to fit the curve. A curve that is not fitted closely enough leaves a considerable non-climatic trend in the data. The more closely the curve is fitted, the greater the risk of losing some climatic information. Additional work is needed to develop methods for dealing with complex trends. Toward this end E. R. Cook at Lamont-Doherty has added a cubic spline option to his revision of INDXA (Peters and Cook 1981). The cubic spline is intended to accommodate sudden shifts in trend.

At best, standardization by curve fitting may remove most of the growth trends, but removes little of the competition trends. This, for closed-canopy eastern forest chronologies, is certainly a matter for concern. After all, the strength of a calibration between tree rings and climate is a function of how sensitive growth is to change in climatic variables. If sensitivity is continuously changing, and it certainly seems that at least in individual samples it can, the relationship (calibration) between growth and climate, again on an individual sample basis, may often be expected to change or drift with time. Sensitivity on a year-by-year basis is the very feature of a tree ring-record that we wish to preserve. What is not wanted are changes or shifts in sensitivity.

If it is assumed that, on a year-by-year basis, ring-width variability is an expression of physiological sensitivity, then mean annual sensitivity (difference in width between two years, relative to the mean of the two) provides a useful means of identifying trends or shifts in sensitivity. Hill (1980) recently examined a situation where periods of years of great sensitivity alternated with periods of small rings with little sensitivity. The samples examined did not all have insensitive periods during the same years. Hill reasoned that sensitivity in the mean chronology was reduced when sensitive segments from some samples were averaged with insensitive segments from other samples. No amount of data manipulation would cause an insensitive segment to magically become sensitive. However, by deleting from individual samples those segments of low sensitivity, she was able to put together a revised mean chronology with substantially greater mean sensitivity values. Though this was an extreme case, it seems likely that the more typical of our deciduous forest chronologies could also be improved by removing insensitive segments from individual samples. Determination of just how important competition trends are in eastern chronologies must await further investigation. Intuitively, though, it seems that recognizing and dealing with these trends may be an important means of enhancing climatic signals in temperate-subhumid forest chronologies.

EARLYWOOD AND LATEWOOD

In keeping with continuing efforts to extract as much environmental information as possible from tree rings, several attempts have been made to separate ring width into earlywood and latewood widths. The rationale behind this is that because earlywood is formed earlier in the season than latewood, they are each rsponding to environmental conditions for somewhat different time periods. Thus, separation is expected to yield a little more information than the use of total ring width alone.

The gradual transition from earlywood to latewood in many species does not result in a sharp demarcation from which simple width measurements can be taken. A distinct intra-annual boundary between earlywood and latewood generally does not exist in diffuse-porous woods, such as *Fagus, Acer, Betula, Nyssa,* and *Liriodendron.* In non-pored eastern species the boundary is generally not distinguishable in many species, such as *Tsuga, Taxodium,* and *Chamaecyparis,* but may be distinguished in some species in some instances. We have been able to separately measure earlywood and latewood of *Pinus taeda* L. from the Great Dismal Swamp (Phipps and others 1979), but have seen samples of that species from other locations in which separation would not have been possible.

Analysis of the Great Dismal Swamp *Pinus taeda* data with temperature and precipitation records indicated that earlywood growth responded to previous late summer, fall, and current spring conditions, and latewood was more reflective of conditions in late spring and early summer of the current year (Phipps and others 1979). Precipitation, temperature, and prior growth explained 72 percent of the variation in total ring width, and 87 and 82 percent of the variation in earlywood and latewood widths, respectively, during 1917-50. There seems little doubt that, where it is possible to separate ring width of non-pored species into earlywood and latewood widths, more growth variance may be explained.

Earlywood is sharply distinguishable in most ring-porous species, such as *Quercus* and *Carya*. Earlywood in ring-porous species refers to the layer containing large tracheae and, as such, has no counterpart in the non-pored or diffuse-porous species. For this reason, it is suggested that the trachea-bearing part of ring-porous species could more properly be referred to as the pore zone. There is evidence to suggest that cambial derivatives that enlarge and differentiate into trachear (vessels) are cut off from the cambium, not during the current spring, but at the end of the previous growing season (Phipps 1967). Thus it may be speculated that the number of trachea is a function of conditions of the latter part of the previous season, and trachea size is a function of conditions of the current spring.

There is generally a gradual decrease in pore-zone width from center rings to outer rings of older trees and remarkably little ring-to-ring width variation (Phipps 1967). For segments of only a few decades or shorter, pore-zone width may generally be regarded as nearly constant. Mean sensitivity is a measure of absolute ring-width variability relative to the size of the rings. Calculating mean sensitivity from a reasonably sensitive *Quercus stellata* collection provided the following information from 38 samples, representing a maximum of 174 rings per sample:

	Mean Widths	Mean Sensitivity	Width times Mean Sensitivity
pore zone	0.40 mm	0.091	0.036 mm
latewood	0.56 mm	0.302	0.169 mm
entire ring	0.96 mm	0.179	0.172 mm

Mean sensitivity of the latewood is obviously greater than that of either the pore zone or total ring width. An approximation of absolute ring-to-ring width variation may be obtained by simply multiplying mean width by mean sensitivity. This indicates, in the example, that most of the variation in total ring width is due to variation in latewood width alone. If pore-zone width is regarded as a constant, then latewood mean sensitivity may be approximated from variation in total ring width by dividing by latewood width. In the example, $0.172/0.56 = 0.307$, which is a fair estimation of the calculated mean sensitivity for latewood, 0.302.

Latewood mean sensitivity of ring-porous species may be somewhat analogous to total ring width mean sensitivity of diffuse-porous and non-pored species. Because pore-zone width of at least the *Quercus* species displays such small ring-to-ring variation, it may be of little utility in most climatic studies. In numerous trials we have been able to extract little environmental information from pore-zone width data of *Quercus* and can see no significant difference between using data of ring-porous total ring width or ring-porous latewood width. If there is any difference, it may be that what little information is contained in pore-zone width is lost if only latewood data are used. Thus, at least with respect to width data of *Quercus,* little is to be gained by the extra measurement efforts of separating ring-porous widths into pore zone and latewood widths. However, as illustrated, total ring width mean sensitivities of ring-porous collections are not comparable with mean sensitivities of non-pored species unless the ring-porous mean sensitivities have been adjusted for pore zone width.

THE MEAN CHRONOLOGY

Fritts and others (1979) have used data from mean chronologies of Western North

America to estimate the past climatic conditions for all of North America. It would seem that a whole new generation of estimates would be possible as chronologies from eastern North America become available. The limiting factor may be that an eastern network may represent no more than about half as many years as the western network. Cook (1982) points out that, owing to the relatively few years of available streamflow records and the fact that most forest chronologies may not exceed the length of weather records in the East, streamflow may be a more utilitarian factor to estimate from deciduous forest tree-ring data than either temperature or precipitation. To this might be added that eastern North America chronologies may be useful in estimating other climate-related parameters such as air pollution. J. R. McClenahen (Ohio Agricultural Research and Development Center, Wooster, Ohio) is investigating the sensitivity of tree rings to air pollution in Ohio. Studying primarily *Quercus alba* L. and *Pinus strobus* L., McClenahen has tried to sample sites in which climate would be only minimally limiting to growth. Chronologies from sites apparently subjected to relatively greater pollutant exposure are being compared with those from similar sites in areas of minimal exposure. He has concluded that climate effects cannot be ignored or eliminated by sampling strategy alone. Results of a preliminary investigation by Puckett (1982) suggest that as a result of acid rainfall, environmental conditions may now be more limiting to tree growth. Puckett, who has obtained some convincing results, nevertheless points out that, as yet, apparent changes in growth response to acid rainfall are small in areal extent. Further, within affected areas, some species seem to show little response change. Note that Puckett's preliminary work was based on collections made by Cook (1976), in which collection sites were selected to be those on which climatic factors would be most limiting to growth. McClenahen is collecting from sites on which climatic factors are least limiting to growth. I am unaware of any study thus far that specifically examines growth responses to pollutants as a function of the degree to which climate limits growth.

The use of mean chronologies as estimators of climatic parameters assumes that variance in common between samples composing the chronology represents responses to environmental factors in common to all samples. Further, it is assumed that merging data of the samples into a mean chronology weights the mean chronology in favor of that variance in common among samples. In light of the foregoing discussion of compound and complex physiological sensitivities and trends, it is not surprising to find, however, that chronologies of some individual trees from a collection correlate more closely with climatic factors than the mean chronology of the collection. Unfortunately, we do not yet know the frequency or magnitude with which tree-ring series of individual eastern forest trees display excursions in sensitivity. If periods of physiological sensitivity variation of an individual tree are random with respect to time, then merging several tree chronologies into a single mean chronology should have the effect of smoothing the trends or changes of the individual samples. Thus, while standardizing ring widths of individual samples is intended to remove the growth trends, merging the sample indices into a mean chronology should remove competition trends. Just as additional work is needed to improve standardization techniques as applied to eastern tree-ring series, learning how to identify and handle competition trends might enhance the climatic signal that may be extracted.

General sensitivity to environmental variables may not be as great in eastern deciduous forest collections as in collections from semiarid sites, and the practical limit for network collection length may be 250-300 years as opposed to 500-600 years for networks of western collections. It would seem that the greatest potential for dendroclimatological studies with deciduous forest tree-ring data may be finer rsolutions of local climatic conditions, estimating hydrologic variables, such as streamflow, and examination of climate-related variables, such as air pollution and acid rainfall.

SUMMARY

Based on methods developed primarily in western North America, tree-ring collections from the eastern forests are generally not as climatically sensitive (correlated with climate) as collections from semiarid sites. The eastern forest has not yet been extensively sampled. As more sample collections are made, increased selection alone may result in improvement in the resolution of extractable environmental information (climatic signal).

Collections with respectable climatic signals have been obtained in eastern North America from a diversity of sites — from dry ridges to low coastal swamps. Sites resulting in restricted root systems may have a high probability of producing great ring-to-ring variability, but there is a risk that series from such sites may contain segments of little variability. Thus, collections from wet sites or extremely shallow soils may be of potential value, but must be approached with caution.

In mixed-age stands shade-tolerant species seem to be more potentially valuable sources of regional environmental variables than shade-intolerant species. Shade-intolerant, early successional stage species in even-aged stands, such as some *Pinus* species, also seem valuable, particularly for years after crown diameters have more or less stabilized.

Trends in tree-ring width data may be classified as growth trends and competition trends. Growth trends are those usually associated with age. Changes in relative positions of surrounding tree crowns during the lifetime of a tree are the most significant cause of changes in crown size and thus growth trends. Factors that affect physiological changes result in competition trends. Standardization of individual samples removes growth trends, and merging of sample data into a mean chronology seems to minimize competition trends.

Separation of ring width of non-pored and diffuse-porous species into earlywood and latewood width seems to hold considerable potential for extracting more precise environmental information. However, width data of the pore zone (earlywood) of ring-porous species seems to be of limited utility. Because most width variation of ring-porous species is in the latewood, mean sensitivity of total ring width should be adjusted for pore-zone width before being compared with mean sensitivity of diffuse-porous and non-pored species collections.

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