Program ARSTAN

Chronology development with statistical analysis

USERS MANUAL for Program ARSTAN by Edward R. Cook and Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Adapted from Users Manual for Program ARSTAN, in Tree-Ring Chronologies of Western North America: California, eastern Oregon and northern Great Basin, by R. L. Holmes, R. K. Adams and H. C. Fritts, Laboratory of Tree-Ring Research, University of Arizona, 1986, pages 50 to 65.

INTRODUCTION

Program ARSTAN produces chronologies from tree-ring measurement series by detrending and indexing (standardizing) the series, then applying a robust estimation of the mean value function to remove effects of endogenous stand disturbances. Autoregressive modeling of index series often enhances the common signal. Extensive statistical analysis of a common time interval provides characterization of the data set. Three versions of the chronology are produced, intended to contain a maximum common signal and a minimum amount of noise. Principal component analysis separates different signals contained in the tree rings and further characterizes the data set. Many options are provided to enable you to tailor the processing to a wide variety of situations and purposes.

The concept and methodology of Program ARSTAN were developed by Dr. Edward R. Cook (1985) at the Tree-Ring Laboratory, Lamont-Doherty Earth Observatory of Columbia University in Palisades, New York. ARSTAN includes several concepts not previously applied to tree-ring chronology development. In 1983 Dr. Cook provided the source code for Program ARSTAN to the Laboratory of Tree-Ring Research at the University of Arizona, where Richard L. Holmes updated the program to ANSI standard FORTRAN-77 and in collaboration with Dr. Cook developed several enhancements.

RUNNING PROGRAM ARSTAN

Your disk space must be sufficient for the output file for printing, the data files to be produced, and temporary files created during execution.

At the beginning of program execution you will be asked for a job identification of up to five letters or numbers to identify printed output and other files produced by the program ("Z" is the default job identification). Either upper or lower case may be used in responding to prompts.

ARSTAN will ask for the name of the file containing the tree-ring measurements. Next you may provide a title of up to 80 characters to identify this job and the chronology and other output files.

```
$> ARSTAN

*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*

                       DENDROCHRONOLOGY PROGRAM LIBRARY

                        P R O G R A M     A R S T A N

                      Version 1.26V 09:14  Mon 01 MAY 1995

*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*
```

```
Identify job (up to 5 letters) => ABCDE

TREE RING MEASUREMENTS
  ... Name of EXISTING INPUT file => COD.RWM

First  6 lines file COD.RWM
Coddington Lake, MN  From Paul Sheppard  21 Mar 1995
     188=N    1801=I CDO03A                                              -2(26F3.0)~
 50 47 49 45 28 71 89 86 77 63 59 93113 86101121117 88111108105126106133 86113
109213156145135142 76104 94103 96 52 41 33 48 31 47 41 46 43 44 28 27 47 41 84
 61 55 58 48 87102107121153117 79 46 55 63 81 85 772172172301991491471711841 80
175209216142148125125132150116 76 95 73133119105 94113 82 93104 63105 53 60 55
....:....1....:....2....:....3....:....4....:....5....:....6....:....7....:....8

Title:
Coddington Lake, MN  21 Mar 1995
Time series span  1772  1988   217 years    31 series

CHRONOLOGY time span     1772 to 1988    217 years,  31 series,   5324 rings
COMMON INTERVAL, Optimum 1857 to 1988    132 years,  27 series,   3564 rings


TITLE FOR THIS RUN => Coddington Lake chronology

                A R S T A N
Options which may be to modified:                           Current values
 1  INFORMATION on series in file
 2  DETRENDING method    (Double detrending)                   1   128
 3  INTERACTIVE detrending of series                             N
 4  SPECIAL TREATMENT, selected series                           0
 5  STABILIZE VARIANCE, LOG TRANS, NORMALIZE                  N   0  N  N
 6  INDICES: compute by Division or Subtraction                  D
 7  PRINT PLOTS of  10-year means of series                      N
 8  LIST values of series                                        N
 9  SAVE individual series, format                               N
10  COLUMNS of ident indicating TREE or TREE MASK             1 to 5
11  TREE SUMMARIES produced                                      N
12  AUTOREGRESSIVE MODELING; method                              S
13  CHRONOLOGY COMPUTATION & FORMAT                              R  I
14  YEAR-BY-YEAR LIST of chronology                              Y
15  COMMON INTERVAL analysis                                  1857  1988  O
16  RED NOISE fraction common interval analysis                  N
17  Number of EIGENVECTORS & AMPS to save                        6

(<CR> to execute Program ARSTAN)    Option number => 2

First DETRENDING CURVE option L:
 L = 1  Negative exponential curve or linear regression
 L = 2  Neg expo, linear regr. of neg. slope or horiz. line
 L = 3  Linear regression (trend line)
 L = 4  Horizontal line through the mean (no detrending)
 L > 4  Cubic smoothing spline of 50% frequency response of L years
 L <-1  Spline of 50% frequency response of L percent of series length
 L =-1  No line fit; chronology is arithmetic mean of series
 L = 0  Statistics only:  No detrending, no chronology
First detrending L => 1

Second detrending option L:
    Options are same as for first detrending.
    For no second detrending touch <CR>
```

```
Second detrending L => 80

Percent of variance in indices from spline where indices contain
           50.00% of variance at wavelength of   80.00 years
     Wavelength__Variance     Wavelength__Variance     Wavelength__Variance
        25.35      99.0%         60.77      75.0%        113.14      20.0%
        32.05      97.5%         67.26      66.7%        138.55      10.0%
        38.35      95.0%         80.00      50.0%        167.04       5.0%
        46.16      90.0%         95.14      33.3%        199.92       2.5%
        56.55      80.0%        105.28      25.0%        252.35       1.0%

1 CDO03A    188 years
  2 CDO03B    166 years
... etc. ...
 30 CDO20A    197 years
 31 CDO20B    193 years
Multivariate autoregressive modeling selected AR model order 2
Tree mask:
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
1212121212121212121212121121212
Chronology contains  5324 rings,     0 absent rings (   0.000%)
Files created in this run of ARSTAN are ABCDEARS.OUT, ABCDEARS.CRN, etc.

                   Program ARSTAN    09:14  Mon 01 MAY 1995
                              - = [ ARSTAN ] = -
```

The menu shows current settings of values for controlling program execution. Items in the menu are: (Initial setting appear below in italics)

(1) Information on series in the file
(Informative only)
(2) Detrending methods (spline, least-squares regression line, negative exponential curve or horizontal line)
(1 & 128: Detrending is negative exponential then 128-year spline)
(3) Interactive detrending of series
(Not interactive)
(4) Special treatment for selected series
(0 series for special treatment)
(5) Stabilize variance (of detrended series, chronology or both)
(No stabilization, method 0 used)
(6) Method of computing indices (division or subtraction)
(Division)
(7) Print plots of series showing 10-year means
(Not printed)
(8) List values in series on printout
(No listing)
(9) Save detrending curves, detrended series and residuals
(Not saved)
(10) Columns in series identification which identify a tree
(Columns 1 through 5)
(11) Tree summaries produced
(Not produced)
(12) Method of autoregressive modeling (same order for all, each series with its order, constrained order
or no modeling)
(Same order for all)
(13) Method for chronology computation (robust mean or arithmetic mean)
(Robust mean)
(14) Year-by-year list of chronology indices with statistics on indices
(Year-by-year list is printed)

(15) Common interval analysis of the red-noise fraction of the data (common interval analysis of
detrended series and white-noise fraction is done automatically)
(No analysis of red-noise fraction)
(16) Number of principal components and amplitudes to save
(6 components and amplitudes saved)

Any of these values may be changed by first typing the number at the left, then responding with the modifications desired. When no more changes are to be made, touching <CR> alone begins processing of the data.

You have the choice of either typing in a mask for the chronology, or allowing the program to separate trees automatically by columns in the identification (item 10 of the menu); in the latter case just touch <CR>.

The program will compute the optimum common interval containing the maximum possible number of data (length of common interval times number of series included). You may accept this common interval by touching <CR> or override the beginning and ending dates supplied by the program.

During program execution brief messages are printed on the screen to keep you posted on the progress of the program. The full results are in the printout file and the chronology and other data are in additional files. At the end of execution a list is shown of files created.

CONTROL PARAMETERS IN THE MENU:

(1) Information on series in the data file. This is purely informative, displaying the series identification, first and last year, and the length of the series.
(2) Detrending methods

First detrending; the following options for detrending have these effects:

1: A negative exponential curve is fit, or if it fails, a linear regression line is fit.

2: A negative exponential curve is fit, or if it fails, a linear regression line of negative slope or
a horizontal line through the mean is fit.

3: A linear regression line is fit.

4: A horizontal line is fit through the mean (no detrending).

5 or greater: A smoothing spline is fit with 50% frequency cutoff of this many years.

-1: No detrending or division by the mean: measurement series are not transformed.

Negative: A smoothing spline is fit with stiffness of this percent of the series length. For example,
if detrending is -75, the 50% cutoff frequency is 75 percent of each series length.

0: Only a table of measurement series statistics is produced; there is no detrending or chronology.

Second detrending option:

Curve-fitting options are the same as described for first detrending. If you select zero,
no second detrending is done.

Prior to detrending, series may be log-transformed after adding a constant equal to one-sixth of the series mean.

The series may be normalized after detrending. If desired, the variance of all series may be set to 1.0, thus weighing all series equally in the chronology, whether actually complacent or sensitive.

The relative stiffness of the alternate smoothing spline may be specified. If the curve specified for the first detrending cannot be fit, the second detrending spline stiffness is this percent of the smoothing spline indicated for the second detrending. For example, if the first detrending is 1 (negative exponential curve), the second detrending is -100 (smoothing spline of stiffness equal to the series length), and the relative stiffness is 67, first detrending is a negative exponential curve and second is a spline of stiffness equal to the series length N x 1.0. If the negative exponential curve cannot be fit, the first detrending is a regression line and the second is a spline of stiffness equal to the series length N x 1.0 x .67

The minimum smoothing spline stiffness may be set; the spline stiffness will never be less than this value. One may not wish to fit a very flexible spline to short series in order to conserve in the series a persistence structure similar to that of the longer series.
(3) Interactive detrending permits you to see how the detrending curve fits each series and to try different methods until satisfied with the result. Statistics of the detrended series are displayed. You may cancel the interactive detrending at any time during the run and the program will proceed automatically, using the detrending options selected from the menu.

(4) It may be necessary to deal with some series differently. This option enables you to indicate certain series for special treatment. The treatments that can be specified include exceptions to the above general curve-fitting procedure, truncation of data at either or both ends or omission from processing. You are prompted for the treatment desired for the selected series. Note that the series identifications are case-sensitive.

(5) Stabilization of variance. Sometimes it is a characteristic of a site, a species, or certain trees, that the variance changes a great deal through time. In this situation you may wish to modify the series so that the variance does not fluctuate so much. Program ARSTAN allows you to request variance stabilization of each detrended index series, of the chronologies only, or both. Options for variance stabilization include those for detrending plus a square root transform or a log transform after adding a constant of one-sixth of the series mean to each value.

We recommend the use of a cubic smoothing spline if the variance will be stabilized. Here a spline is fit through the absolute departure values from the mean and the series is divided by the spline curve values. One way of picturing this is to imagine normalizing the detrended series to a mean of zero, flipping the negative departures to positive (keeping track of these), and fitting a spline to this series. The departures are divided by the respective spline values, and the indices whose departures were originally negative are given a negative sign. Finally the mean of the series is added back in to yield a series with stabilized variance.

(6) Options for computing indices:
Division (ratio): measurement divided by curve value.

Subtraction (residual): measurement minus curve value.

(7) Line printer plots may be printed showing means by decade (or by a period you specify) of measurements, detrending curves and indices for each series.

(8) Values in individual series may be listed. You may select to list ring measurement series, detrended index series, and/or residual series from autoregressive modeling.

(9) Individual series may be saved on disk files in compact or measurement format.

(10) Columns of the series identification which identify a tree. This is used by the program in the common interval analysis and to compute tree summaries if requested. The default columns are 1 to 5, which implies that the first three columns are a site code and columns four and five are the tree number. For example in a series identified as ABC08A, ABC is the site code, 08 is the tree number, and A is the radius within the tree.

(11) You may request summaries (chronologies) of each tree. Series that belong to the same tree are determined by the chronology mask or by the portion of the series identification which designates the tree. The summaries are computed by arithmetic mean and saved in the file ABCDEARS.TRE.

(12) Options for autoregressive modeling method:

S: The same order autoregressive process as selected by multivariate autoregressive modeling may be fit to each series using its own coefficients. This is the default method.

E: Each series may be modeled as an autoregressive process where the order is selected for the individual series by first-minimum Akaike Information Criterion search.

C: You may override the first-minimum Akaike Information Criterion search by specifying the order to be fit to each series.

N: You may specify that no autoregressive modeling be done. The chronology is then computed by the standard method only.

The next question is which series to use for computing the pooled autoregression model (default is to use all series). Responding "N" indicates that a subset of the series is to be used. You are then prompted to provide a mask to indicate which series are to be included in the model. Each column of the mask corresponds sequentially to the respective series. Enter a '1' if the series is to be used, or a '0' if it is to be bypassed. This option may be invoked if there is reason to believe that a subset of the series is uncontaminated by disturbance and therefore has a clean stochastic structure for modeling and for producing the 'ARSTAN' chronology.

(13) Chronology computation may be done by means of a biweight robust mean estimation (default), by arithmetic mean value function, or no chronology may be requested.

(14) The printout lists each annual index of the chronology with statistics and a line-printer plot. You may suppress printing this list.

(15) If you wish, the common interval analysis will include analysis of the red noise fraction of the series (detrended series minus residual series).

(16) You may specify the number of eigenvectors and principal component amplitudes to be calculated for the common interval, printed and saved in file

ABCDEARS.AMP. If the number entered is greater than the number of series, all possible are saved. The default is six saved.

CHRONOLOGY COMPUTATION

You may use all series for the chronology (default), or select series to be included. If all series are to be used, the series belonging to the same tree may be determined automatically by the program for common interval analysis and/or tree summaries by leaving the chronology mask blank (see item 10 in the menu above).

If not all series are to enter the chronology, or an inconsistent method is used for identifying trees, a mask is entered into columns 1 to 80. Each column corresponds to a series sequence number. For common interval analysis, series from a given tree are coded sequentially '1', '2', '3', etc. This coding is necessary for calculating the average correlation for pairs within and between trees, and for computing the signal-to-noise ratio. Zeroes embedded in the mask cause those series to be excluded from the chronology.

COMMON INTERVAL ANALYSIS

Program ARSTAN will compute the optimum common interval, containing the maximum possible number of data in a rectangular matrix (length of common interval times number of series). If this is acceptable, respond with <CR>; otherwise type "N" and provide first and last years for the desired common interval analysis.

WHAT PROGRAM ARSTAN DOES

Program ARSTAN performs the following tasks:

(1) These files are written and saved in ITRDB index (I) format or Compact (C) format:

ABCDEARS.OUT	Output for printing	
ABCDEARS.CRN	Tree-ring chronologies	(I)
ABCDEARS.SDV	Standard deviations of chronology indices	(C)
ABCDEARS.AMP	Principal component amplitudes	(C)
ABCDEARS.MSM	*Ring measurement series	(C)
ABCDEARS.CV1	*First detrending curves	(C)
ABCDEARS.IN1	*Series after single detrending	(C)
ABCDEARS.CV2	*Second detrending curves	(C)
ABCDEARS.IN2	*Series after second detrending	(C)
ABCDEARS.RSD	*Residuals from autoregressive modeling	(C)
ABCDEARS.TRE	*Summary (chronology) of each tree	(I)
ABCDEARS.PLO	*File for plotting in Program PAGEPLOT	(M)

* (File created only if requested)

(2) The menu is printed showing the run control options you have specified.

(3) Ring measurement data series are read. For each series:

(a) Detrending is performed as specified. A curve is fit to each measurement series to model biological growth trend, and the measurement values are divided by the curve values to produce a detrended series.

(b) Decade means plots are printed if requested.
(c) Variance of the series is stabilized if requested.
(d) The detrended series is saved on disk file if requested.

(4) Ring measurements and/or indices of each series are listed if requested.

(5) Statistics of each series before and after detrending are printed.

(6) Multivariate autoregressive modeling is performed. The following are computed in the autoregressive modeling:

(a) Lag-product sum matrices
(b) Pooled lag-product sums
(c) Pooled autocorrelations
(d) Yule-Walker estimates of pooled autoregression
(e) Akaike Information Criterion (AIC)
(f) Autoregression coefficients based on first-minimum AIC search (unless constrained) and selected autoregressive modeling order
(g) Impulse response function weights of the pooled autoregression process
(h) Box-Pierce two standard error limits of residual autocorrelation function based on the pooled autoregression coefficients.

(7) Univariate autoregressive modeling is performed, fitting an autoregressive process of the selected order to each series, and the following are computed for the residual series:

(a) Statistics for each series;
(b) Autoregressive coefficients for each series and the variance explained by autoregression;
(c) Normalized residuals which are outliers over three standard deviations from mean.

(8) Multivariate autoregressive modeling is performed on the residual series to determine if residual multivariate lag effects remain. The following are computed as before:

(a) Lag-product sum matrices
(b) Pooled lag-product sums
(c) Pooled autocorrelations
(d) Yule-Walker estimates of pooled autoregression
(e) Akaike Information Criterion (AIC) and selected order of autoregression.

If no significant multivariate persistence remains after the univariate fitting, the selected autoregression order is now zero.

(9) The 'STNDRD' version of the chronology is computed. Detrended (standardized) tree-ring index series are combined into a mean value function of all series or of those selected in the chronology mask. Means for each year are computed as either the biweight robust estimate or the arithmetic mean (Cook, 1985). The biweight mean is an integral part of the ARSTAN methodology and is strongly recommended to remove effects of endogenous stand disturbances and to enhance the common signal contained in the data. Statistics on the chronology are printed, including the distribution of values, autocorrelation structure and the gain or loss in efficiency of robust estimation of the mean. If you request

that no autoregressive modeling be done, this is the only version of the chronology produced.

(10) The 'RESID' (residual) version of the chronology is computed in the same manner as the STNDRD version, this time using the residual series resulting from step (7) above. Robust estimation of the mean value function produces a chronology with a strong common signal and without persistence. The same statistics are also printed for this chronology.

The portion of the residual chronology containing four or more series is modeled up to the autoregressive order selected in the first multivariate autoregressive modeling in step (6f). If the first-minimum AIC search results in a selected order greater than zero, the entire residual chronology is whitened using the auto-regressive coefficients from this modeling. Statistics on the resulting white noise residual chronology version are printed, including distribution of values and autocorrelation structure.

(11) Using the autoregressive coefficients selected in the first multivariate autoregressive modeling in step (6f), the pooled autoregression (persistence) model is reincorporated into the residual chronology to produce the 'ARSTAN' chronology. Statistics on the chronology are printed, including distribution of yearly values and autocorrelation structure.

(12) A comparison is made between the 'STNDRD' and 'ARSTAN' versions of the chronology to determine if the standard error has been reduced in the chronology by autoregressive modeling.

(13) A common interval analysis is done with all detrended series covering the time interval specified for this analysis. This interval may be the optimum computed by the program or an interval you specify. The optimum common interval is the maximum time span which is covered by the maximum number of radial index series (the largest rectangular matrix). It is the period of time for which this product of the length of the interval times the number of series completely covering this interval is the greatest. This effectively omits from the analysis those spans of years for which there is a minimum of comparative data. The resulting interval contains the greatest number of tree rings possible for analysis.

If autoregressive modeling is done, the common interval may be shortened in the early part by a number of years equal to the order of autoregressive modeling, in order to include the same series in this analysis and in the residual analysis described in (14) below.

The following are computed for the detrended series for the common interval:

(a) statistics on individual detrended series and on the 'STNDRD' chronology version;
(b) correlations between each series and the chronology;
(c) average correlation for all pairs of series: those between trees, those within trees and those between the series and the chronology;
(d) signal-to-noise ratio based on number of trees;
(e) agreement of the sample chronology variance with that of the theoretical population chronology, and of reduced samples (Wigley, Briffa and Jones, 1984);
(f) eigenvalues, eigenvectors and amplitudes for the requested number of principal components; these are written on the *.AMP file.

(14) A common interval analysis is carried out as in step (13), using the individual residual series and the 'RESID' chronology version. The residual series are the results of autoregressive modeling of the detrended series and contain approximately equal amounts of variance at all wavelengths; by analogy to light wave frequencies these are white noise series, and the analysis describes the white noise fraction of the unmodeled individual series and chronology.

(15) If red-noise fraction analysis is requested, the residual version (autoregressively modeled) of each series and the chronology used in (14) is subtracted from its detrended version used in (13) to produce series containing only the variance that was removed by autoregressive modeling. A common interval analysis is done on these series.

(16) Each version of the chronology is printed in the standard format for publication.

(17) A one-page summary is produced of key statistics of the chronologies. The summary may be photocopied for your file.

COMMENTS ON RUNNING PROGRAM ARSTAN

In Program ARSTAN, careful selection should be made among the available options. Do not rely on the initial settings as the recommended method.

Detrending is intended to remove overall trend in tree-ring measurement series, and to remove part of the variance at very low frequencies approaching the length of the series. Information on climatic variance at these very low frequencies is not contained in the time series in any case. Detrending causes the time series characteristics of the various measurement series to be more similar to each other, and prepares them for subsequent autoregressive modeling. If the detrending is successful in accomplishing the task of removing a large proportion of the non-climatic variability, autoregressive modeling may only marginally change the time series characteristics of the 'STNDRD' chronology version when producing the 'ARSTAN' version.

Fritts (1976, p. 254-290) discusses the concept and reasons for detrending tree-ring series. Further discussion is given by Holmes et al. (1986) in sections titled "Standardization and chronology development," "Effects of undiscovered absent rings" and "Evaluating standardization procedures," and in Appendix 2.

In detrending, three curve-fitting techniques are commonly used:

(1) NEGATIVE EXPONENTIAL CURVE.

A modified negative exponential curve of the form: Y = A * e (-B * t) + D

is fit to the data set. An iteration procedure is used, which continues until the improvement of the fit is very small. If the fitted curve has a negative constant (D) or a positive slope (B), the curve is rejected and a linear regression is fit to the data (Fritts et al., 1969). The coefficients of the equation are applied to the data to estimate the growth curve, and the data are divided by the estimates to obtain indices that are stationary with a mean of 1. The negative exponential curve conforms to a theoretical decrease in annual tree growth increments due to the geometry of an increasing trunk diameter but the fit is often better in the early part than in the later part of the time series.

(2) LINEAR REGRESSION LINE.

The simplest detrending method is to fit a least squares regression line through the data. It conforms to no theoretical model of tree growth, and is probably best used on series that are relatively short or that have an unusual growth pattern that the negative exponential curve cannot accommodate.

(3) CUBIC SMOOTHING SPLINE.

This method smoothly fits a succession of cubic polynomial curves to the data in one pass; it is not an iterative process. It follows the path of the data much as a draftsman's flexible ruler would do. Its elegance lies in its predictability and in the certainty of its time series behavior. The amount of variance to be removed at a particular frequency can be precisely specified; it will remove variance of lower frequencies (longer wavelengths) with a transition to little or no removal of variance of higher frequencies (shorter wavelengths). Thus its flexibility can be exactly specified and is almost infinitely adjustable. In Program ARSTAN, the flexibility specified is the 50 percent cutoff wavelength (Cook and Peters 1981).

When plotting tree-ring data and the curves fit to them we have observed that frequently the curves do not fit ideally. When the data appear to be a typical "die-away" process a negative exponential curve often fits well the earliest third or so of a series where the slope is steeply negative and the curvature is strong. Toward the middle and later parts of the series it may tend to ride along for many decades almost entirely above or below the actual values of tree growth, yielding long stretches of low or high indices. On the other hand, a very stiff cubic spline (50 percent frequency cutoff at 300 years or more) may follow the data far better than the negative exponential curve for the later two-thirds of the series, but it may be too stiff to follow the bend in the steeply downward trending early part of the series.

A two-stage process of detrending frequently solves this problem by first fitting a negative exponential curve, then fitting to the resulting indices a cubic spline of a stiffness adequate to follow the local mean of the data without removing variance in the desired range of frequencies, and again calculating the indices.

When you give a number for spline rigidity a table is printed on the screen and on output showing the distribution of variance at several wavelengths, for example:

```
Rigidity of SPLINE  <32>: 20

     Percent of variance in indices from spline where
         indices contain  50.00% of variance at wavelength of   20.00 years
     Wavelength  Variance     Wavelength  Variance     Wavelength  Variance
         6.34      99.0%         15.19      75.0%         28.29      20.0%
         8.01      97.5%         16.81      66.7%         34.64      10.0%
         9.59      95.0%         20.00      50.0%         41.76       5.0%
        11.54      90.0%         23.79      33.3%         49.98       2.5%
        14.14      80.0%         26.32      25.0%         63.09       1.0%
```

VERSIONS OF THE CHRONOLOGY

The *.CRN file created by the program contains three versions of the site chronologies with different time-series characteristics.

(1) 'STNDRD' version.

A chronology is computed of series of tree-ring data that have been detrended by curve-fitting to remove a large part of the variance due to causes other than climate. Program ARSTAN provides several choices of how this chronology is computed: single or two-stage detrending of measurement series may be done with a variety of options; indices for a series may be computed either as ratios (by division) or as residuals (by subtraction); variance may be stabilized; and the mean value function may be computed either as arithmetic means or as biweight robust estimated means to remove effects of endogenous stand disturbances and to enhance the common signal. If no autoregressive modeling is done, the STNDRD chronology is the only version produced.

(2) 'RESID' version.

The residual version is produced in the same manner as the STNDRD version, but in this case the series averaged are residuals from autoregressive modeling of the detrended measurement series. Robust estimation of the mean value function produces a chronology with a strong common signal and without persistence.

If modeling of the residual chronology reveals that it is an autoregressive process, the chronology is whitened by modeling the portion of the chronology containing four or more series, and applying the model to the entire residual chronology. This produces the 'RESID' version. If the initial residual chronology is not an autoregressive process it is not modeled. The earliest date of the RESID version may be one or more years later than the STNDRD, depending on the order of the AR model and of the rewhitening process.

(3) 'ARSTAN' version.

The pooled model of autoregression is reincorporated into the RESID version to produce the ARSTAN chronology. The pooled autoregression contains the persistence common and synchronous among a large proportion of series from the site, without including that found in only one or a very few series (Cook, 1985). It is intended to contain the strongest climatic signal possible. The earliest date of the ARSTAN chronology is usually the same year as the STNDRD, or if the RESID version required whitening, it is intermediate between the STNDRD and RESID versions.

EIGENVALUES, EIGENVECTORS AND PRINCIPAL COMPONENTS

If common interval analysis is done, the eigenvalues and the requested number of eigenvectors and principal component amplitudes for the common interval are written on the *.AMP file (default is to save four series). Eigenvalues, eigenvectors and principal component amplitudes are produced independently for the detrended series and the residual series.

FLOW CHART FOR PROGRAM ARSTAN   Output files*

Read file of ring measurement series

Perform first detrending on each series
First curve fit: _ARS.CV1*
Indices from first curve fit: _ARS.IN1*

Perform second detrending on each series (default)
Second curve fit to first indices: _ARS.CV2*
Indices from second curve fit: _ARS.IN2*

Stabilize variance of each series (optional)

Indices with variance stabilized: _ARS.IN2*

Edit some series within program (optional)
Ring measurements, edited: _ARS.MSM*

Compute pooled autoregressive model of persistence for the entire site (default)

Model each series to the selected autoregressive order
Residuals from autoregressive modeling: _ARS.RSD*

Tree-ring chronologies are produced in three versions:

Compute STANDARD chronology by robust (arithmetic) estimation of mean of detrended series
Standard chronology: _ARS.CRN (or _ARS.STD*)

Compute RESIDUAL chronology by robust (arithmetic) estimation of mean of modeled series;
rewhiten residual chronology if it has significant autocorrelation
Residual chronology: _ARS.CRN (or _ARS.RES*)

Compute ARSTAN chronology, returning modeled pooled persistence to the residual chronology
ARSTAN chronology: _ARS.CRN (or _ARS.ARS*)

Perform statistical analysis of a common time interval

Statistical analyses of tree-ring series are performed for a time interval entirely covered by many or most or occasionally all of the series. The interval may be a time span selected by the user or the optimum time span calculated by the program. The optimum span is that which includes the largest possible number of rings, calculated as the length of the span in years times the number of series covering the span.

Common interval analyses are done separately on the detrended ring-measurement series and on the autoregressively modeled series (white noise), and at the user's option, on the difference between the detrended and the modeled series (red noise).

Principal components analysis is done for each common interval analysis
Eigenvalues, eigenvectors and principal components: _ARS.AMP

A large variety of statistics is calculated and written on the output for printing. The chronologies are listed and the last page is a summary of statistics.
Output for printing: _ARS.OUT

_ARS.xxx underscore stands for the user's one- to five-letter identification.

_ARS.xxx* Starred files are produced only at the user's request.

Program CASE

Read casewise (column) data file

USERS MANUAL for Program CASE by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program CASE reads a file with one or several time series in column (casewise) format, converting them into Compact format. The program operates quite automatically and will handle a variety of spreadsheet files. (Save them as text or ASCII from a graphics program.) Current capacity is 4096 rows and 200 columns in addition to the year (first) column.

Data are read as columns which must be delimited by a tab or comma or by one or more spaces between data columns. The program presents the first eight lines of the file on the screen and asks if the first line contains identification for the series. The program scans the first column; if the numbers are sequential it asks if the first number is the date of the first line of data. Touch <CR> if this is correct, otherwise type in the date of the first line of data.

Program COFECHA

Crossdating and measurement quality control

USERS MANUAL for Program COFECHA by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Adapted from Quality Control of Crossdating and Measuring: A Users Manual for Program COFECHA, in Tree-Ring Chronologies of Western North America: California, eastern Oregon and northern Great Basin, by R. L. Holmes, R. K. Adams and H. C. Fritts, Laboratory of Tree-Ring Research, University of Arizona, 1986, pages 41 to 49.

INTRODUCTION

Program COFECHA performs data quality control on a set of tree-ring measurements, verifying crossdating among ring measurement series and indicating possible dating or measurement problems. The printout from COFECHA provides documentation demonstrating the quality of crossdating within a tree-ring site.

Program COFECHA serves as a tool for the identification and documentation of portions of a tree-ring data set that may have dating errors or important errors in measurement. It may also be used to check crossdating among chronologies from sites within a region.

For each series a note is made of segments which correlate poorly with the corresponding segments of the master dating series (the mean of all other series) or which correlate higher at a position other than the position as dated. Single values are noted which have the effect of strongly lowering or raising the correlation of the series with the mean of all other series. Divergent year-to-year changes, absent rings and statistical outliers are listed. Basic statistics for each series appear in a table.

If there are series of difficult or questionable dating you may find their probable dating by putting them in a second data file. If the dating for the site is unknown, you may determine preliminary best-fit relationships among the series by giving their file name as the second file with a blank name for the first file.

At many research centers Program COFECHA has saved a great deal of personnel time by providing reliable quality control and archival documentation of crossdating. It may be especially useful to an investigator working alone or in a small group, or in dealing with unfamiliar species.

RUNNING PROGRAM COFECHA

COFECHA will ask for the name of the file containing dated tree-ring measurement series. Next it will ask for a second file of undated or counted measurement series, which will be examined separately. If there are series of difficult or questionable dating you may find their probable dating by including them in this second data file. If the crossdating for the site is entirely unknown, preliminary best-fit relationships among the series may be determined by including them in the second file, giving a blank name (respond with <CR> alone) for the first file. If no file of undated measurements is to be examined, touch <CR> without giving a file name. You may give a title to identify this run of the program. Either upper or lower case letters may be used in responding to prompts. The program may be terminated at any prompt by typing a slash ("/") and <CR>.

A menu shows the current setting of parameters for running the program. Any of these values may be changed by first typing the number appearing at the left, then responding with the modification desired. When no more changes are to be made, touching <CR> alone begins processing of the data. Often very few or no changes need be made to the default values.

```
Menu for Program COFECHA:

Select number or first letter to modify:        Current values

1  Rigidity of SPLINE for filtering                  32
2  SEGMENT length to examine                         50 lagged  25
3  AUTOREGRESSIVE MODEL                               A
4  TRANSFORM series to logarithms                     Y
5  CRITICAL level of correlation                  0.3281
6  MASTER dating series, save                         N
7  LIST ring measurements                             N
8  Parts of output to print                     1234567
```

Brief messages on the screen are intended to keep you posted on the progress of the program. On termination of the program a summary message is shown. The results for printing are in the file ABCDECOF.OUT (assuming ABCDE is the job identification).

WHAT PROGRAM COFECHA DOES

Before crossdating and measurement problems are identified the data are transformed by the program so as to enhance those time-series characteristics which are related to crossdating, while minimizing the features unrelated to the task. The following steps are performed on each series of tree-ring measurements:

(1) A cubic smoothing spline with 50% cutoff of 32 years is fit to the series, and each value of the series is divided by the corresponding value of the spline curve, resulting in a series without trend or long waves and with a mean of 1. In short, low-frequency variance is removed from the series.

If you give a negative number for spline rigidity, there is no transformation of the series: no spline, no autoregressive modeling and no log-transform.

Experience with data sets from several regions suggests that the optimum job of discovering errors is done by using a smoothing spline with 50% frequency response of around 32 years. A more rigid spline may leave too much long-term variance in the series, and the resulting filtered series may still contain information unrelated to the dating pattern.

(2) The persistence of the smoothed series is removed by autoregressive modeling, thus removing short waves which may remain after the spline fit. This step makes the series conform more closely to the assumption of the Pearson correlation that the values are serially independent; the crossdating match stands out more sharply thereby. Robert Monserud (1986) makes an interesting analysis of this concept. Autoregressive modeling decreases the effect of varying the spline frequency response, although a very flexible spline (less than about 20 years) may add spurious high-order autocorrelation to the series. This step may be omitted at the user's option.

(3) The logarithm of each value in the series is taken after adding a constant of one-sixth of the mean. The constant is added to avoid the possibility of taking the logarithm of zero (which is negative infinity) in the case of a locally absent ring. The aim of the log transform is to weigh

proportional differences in ring measurement more nearly equally; a minor disadvantage is that after log transformation the distribution of values in the series is negatively skewed. This step may be omitted at the user's option.

Filtering with a smoothing spline, modeling and log-transformation, by removing low-frequency variance and persistence and examining only the high-frequency variance proportional to ring widths, mathematically simulates human perception on visual examination of a ring series for crossdating.

(4) The transformed measurement series is saved on a direct-access file for subsequent processing. The series is added to an accumulating series and a counter series is incremented for the time interval.

(5) After all series have been transformed, the accumulated series is divided by the counter series to give an arithmetic mean value function of all transformed dated series. The resulting master dating series is intended to embody the crossdating characteristics of the site, and may be saved for further analysis.

(6) Each transformed series is tested against the master dating series. The master series is first adjusted by removing the component contributed by the series under consideration to avoid comparing it against itself.

The series is tested segment by segment against the adjusted master series for crossdating and general measuring accuracy, by calculating correlations for each 50-year segment of the series under examination with the master series matched at the point of crossdating. For each segment the correlation is verified to be positive and significant at the 99% level. The correlation is also checked to see that it is higher when matched as dated than at any position shifted up to ten years earlier (-10) or later (+10) from the dating. Experience indicates that ten years on either side is adequate to locate most crossdating errors, and will also catch errors made by skipping or repeating a decade while measuring.

The default critical level of correlation below which segments will be flagged are:

Length of segment	Correlation at 99% confidence level
10	0.7155
15	0.5923
20	0.5155
25	0.4622
30	0.4226
35	0.3916
40	0.3665
50	0.3281
60	0.2997
70	0.2776
80	0.2597
90	0.2449
100	0.2324
120	0.2122

Successive segments are lagged 25 years, giving a 50% overlap. In order to test to the ends of the series, the first segment begins with the first year of the series and the last ends with the last year; all segments are of the same length. Intermediate segments begin on years evenly divisible by the lag. The overlap of the first two and the last two segments is therefore usually greater than the lag.

A segment length of 50 years provides sufficient degrees of freedom so that there are few segments where very high or low correlation occurs by chance, and the correlation at 99% significance is low enough that few segments are flagged unnecessarily. Yet 50 years is short enough to allow detection of dating errors of a few years in length, and thus allow the dendrochronologist to narrow the search for dating problems. The length of segments may be decreased for short series (but less than 30 years is not recommended) or lengthened to 100 years or more for long series in species with relatively weak crossdating or widely separated key crossdating years such as Sequioadendron giganteum.

If in any time interval a major proportion of the series that make up the master series are incorrectly dated, the master series itself may not contain the correct dating pattern, and most or all of the series will show low correlation for that interval. Test runs of the program show that if there are sufficient samples, more than half may be erroneously dated in a given time interval, so long as they are not systematically misdated in the same way, and the program will still correctly identify those series containing errors while not flagging the correct series. Thus the inclusion among the dated series of some with severe errors, though not to be preferred, generally does not destroy the dating pattern.

The level of correlation among correctly crossdated ring measurement series may differ with tree species, geographic area, site homogeneity, amount of stand competition, and degree of disturbance. Through time a given tree may suffer differing amounts of stress from competition with other trees for light and moisture, competition for moisture with ground cover, access to soil by the roots, and disturbances such as fire and insect attack. This could cause the tree growth pattern through time to become either more similar to or more divergent from that of other trees. For these reasons, Program COFECHA does not provide precise accept/reject criteria for making objective decisions as to whether a series has been crossdated correctly throughout, but rather is to be used as a tool to assist the researcher in verifying the dating and measurement accuracy.

Because visual characteristics of tree rings contain many clues to crossdating in addition to ring width, the program results should not be used as a substitute for visual crossdating on the wood sample. COFECHA is intended to assist data quality control by thoroughly examining all series from the first to the last value (the end of a series which extends beyond all others cannot be checked). It thus gives the dendrochronologist an independent tool to confirm the accuracy of dating and measurement. It may be used to assist in deciding to accept or reject series or portions of series for inclusion in a site chronology or for other analyses.

At the end of a run of Program COFECHA a brief summary appears; the summary is also printed on output:

```
****************************************
*C* Number of dated series       40 *C*
*O* Master series 1696 1990  295 yrs *O*
*F* Total rings in all series   7096 *F*
*E* Total dated rings checked   7068 *E*
*C* Series intercorrelation    0.643 *C*
*H* Average mean sensitivity   0.288 *H*
*A* Segments, possible problems    7 *A*
****************************************
```

PRINTED OUTPUT FROM PROGRAM COFECHA

Output from Program COFECHA appears in seven or eight parts:

Part 1: Title page, options selected, summary, absent rings by series
Part 2: Histogram of time spans
Part 3: Master series with sample depth and absent rings
Part 4: Bar plot of Master Dating Series
Part 5: Correlation of each series with Master
Part 6: Potential problems: low correlation, divergent year-to-year changes, absent rings, outliers
Part 7: Descriptive statistics
Part 8: Undated series adjustments for highest correlations (if there is a file of undated series)

The following paragraphs describe the results printed on the output.

PART 1. The cover page shows the name(s) of the data file(s), the run title, and a list of contents of the printout. The menu is printed showing the options selected and below it is a brief summary of the results and a count of absent rings by year. On the following page a histogram shows in graphic form the time span covered by each dated series. Next, the master series in normalized form (mean = 0, standard deviation = 1) is listed along with the number of individual series contributing to the value for each year. Following this is a bar plot of the master series which serves as a visual aid to verification of crossdating. The bar plot is similar to a skeleton plot, but wider rings are indicated by longer bars. The relative width of all rings is shown along with an alphabetic code; lower-case letters indicate rings narrower than the local mean, upper-case wider than the local mean. The symbol "@" indicates that the value is very close to the local mean; each letter progressing through the alphabet indicates an additional quarter standard deviation from the mean. The bar plot may assist in finding the exact year of problems in crossdating or measurement.

PART 2. Correlations of each segment of the series with the master are printed in a table. Given a segment length of 50 years, correlation values are underlined and flagged with "A" if they are less than 0.3281, representing the 99% confidence level of significance in a one-tail test of the distribution of the correlation coefficient with 48 degrees of freedom. Correlations are flagged with a "B" if a correlation at some position other than as dated gives a higher correlation with the master series. At the right margin are the number of flagged correlations and total number of segments for the series.

PART 3. Potential problems in dated series are reported here. All information pertaining to questions about a given series appears together.

[A] A line is printed for any segment which correlates higher at some position other than where it was dated, or which correlates below the 99% confidence level. This line shows the correlation of the segment at each position from -10 to +10. The value as dated (position +0) is underlined, and the highest correlation is underlined and bracketed. The position of highest correlation is also printed in the column labeled "High". For clarity, an open dashed line separates non-consecutive segments.

Crossdating may be erroneous in the segments listed. Crossdating errors are often indicated by the occurrence of a low correlation at the dated position (+0) and a much higher correlation at some position near the dated position, for example at +1, -1, +2 or -2. If the misdating continues for more than a few rings, two or more successive segments may correlate higher at the same nonzero position. A value of -2, for example, suggests that moving the dating back two years will give a higher correlation; possibly two rings (locally absent?) may not have been recorded at the later end of the flagged segments. If there are unflagged segments prior to the flagged ones, two extra rings may have been recorded (double or false?) at the early end of the segments. If the highest correlation is at position +10 or -10, the measurer may have skipped a decade or repeated it.

[B] For the entire series and for segments listed in [A] above, the effect on the correlation with the master series is listed for the rings whose presence most lowers or raises the correlation. A ring that either lowers or raises the correlation of a segment, particularly if its absolute value is greater than about .07, may indicate a measuring error or an especially wide or narrow ring that is misdated.

[C] Year-to-year differences in ring measurement are shown where they diverge by 4.0 standard deviations or more from the mean of the year-to-year differences of the other series for the same pair of years. This information may help to locate problems to the exact year.

[D] Locally absent rings (years with zero-value measurements) are listed.

[E] Rings are listed which are statistical outliers, defined for this purpose as being more than +3.0 standard deviations larger or more than -4.5 standard deviations smaller than the mean of the other series for that year. These individual rings are possible sources of dating or measurement error.

The listing of a segment or a ring in this section indicates that there may be an error in crossdating or one or more large errors in measuring. Most measurement errors will have the effect of lowering the correlations of the segments in which they occur. Listed segments may be candidates for remeasurement to check for errors in the original measurements. Dates of locally absent rings (zero values) should be independently confirmed since they are determined by judgment rather than from direct observation.

A disturbance to the growth of the tree may produce a listing. A fire or other disturbance, sudden removal of competition, severe insect infestation or other environmental changes abruptly affecting the tree in question differently from others in the stand, may cause ring growth to be anomalous for one or a few years, and thus produce low correlation in one or two segments of the series and divergent year-to-year changes. This phenomenon was noted by L. O. White (personal communication), who observed in his collection of Pinus lambertiana from the Mendocino National Forest in California that evidence of fire often occurred within segments of measurement series with somewhat low correlation in Program COFECHA; these segments were nevertheless correctly dated.

We recommend a close examination of Part 3 of the output to confirm correct crossdating and to select those portions of series in which the dating and measurement should be checked. After corrections are made, Program COFECHA should be run on the clean measurement data set to confirm and document the correct crossdating of the site collection.

PART 4. This is a table of descriptive statistics of the ring measurement series. Included are the total number of segments in each series and how many segments were found to have potential problems. The mean correlation of the series with the master series is given, along with standard time series statistics of the measurement before and after transformation, including the order of the autoregressive model (AR) applied to the series.

PART 5. Date adjustment for unknown series. If there is a second data file with undated ring measurement series, a section appears whose purpose is to find the most probable dating of the unknown series which cannot be confidently dated by skeleton plot or other commonly used techniques. Tentatively dated series may be included here. Possible crossdating matches for these series are indicated. This section is very similar in concept to M. L. Parker's (1967 and 1971) Shifting Unit Dating Program.

For the unknown series as with the dated series, correlations are calculated for 50-year segments of the counted series lagged successively 25 years, but here the segments are tested at every position from beginning to end of the master dating series. For each segment the eleven highest-correlating positions are shown (the eleven best matches), starting with the highest ("Corr #1"), along with the number of years to add to the counted series to obtain the indicated match. If the same number appears consistently in one of the "Add" columns of the #1, #2 or #3 correlation there is a high probability that the correct dating of the series may be obtained by adding this number to the count of each ring. The dating should of course be verified on the wood sample, since there are many clues to crossdating in addition to ring width. At the end of the section dealing with a series is a tabulation of the segment adjustments which appear three or more times with their mean correlation.

Further discussion is given by Holmes et al. (1986) in sections titled "Crossdating, measurement and related procedures" and "Effects of undiscovered absent rings," and in Appendix 1.

Program CRONOL

Chronology with unlimited series

USERS MANUAL for Program CRONOL by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program CRONOL produces a chronology in two versions from a set of crossdated tree-ring measurement series by detrending each series then computing a chronology (a mean series) intended to contain a maximum common signal and a minimum amount of noise. Careful selection should be made among the options depending on the characteristics of your data and what aspects of the data you will study. Do not rely on the initial settings as the recommended method.
(1) The Standard version of the chronology is derived by first detrending the measurement series, fitting to each series a curve to model biological growth trend, and dividing out the growth model. The chronology is then computed as a biweight robust mean or arithmetic mean of the detrended individual series.
(2) The Residual version of the chronology is derived by performing autoregressive modeling on the detrended ring measurement series. The biweight robust mean or arithmetic mean of the residual (white noise) series is a chronology with a strong common signal and without persistence.
Program CRONOL includes mainly concepts and methodology developed by Dr. Edward R. Cook at the Tree-Ring Laboratory, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York. Most of the details of Program CRN are explained more fully in the section on Program ARSTAN.
RUNNING PROGRAM CRONOL
CRONOL will ask for the name of the file containing the tree-ring measurements. Next provide a title of up to 60 characters to identify the printed output of the program and the chronologies produced.
The menu shows current settings of values for controlling program execution. Items in the menu are as follows; initial settings appear in parentheses:
(1) Detrending methods: choice of one- or two-step detrending by a smoothing spline, least-squares regression line, negative exponential curve or horizontal line through the mean
      (128: First detrending: 128-year spline;
           0: Second detrending: none)
(2) Stabilize variance of detrended series, chronology or both
      (No stabilization, method 0 used)
(3) Print chronologies in vertical list format in addition to standard publication form
      (Print chronology only in publication form)
Any of these values may be changed by typing the number at the left, then responding with the modifications desired. When no more changes are to be made, touching <CR> alone begins processing of the data.
During program execution brief messages are printed on the screen to keep you posted on the progress of the program. The full results are in the output file for printing and the two chronology files.
CONTROL PARAMETERS IN THE MENU
(1) Detrending methods
First detrending; the following options for detrending, described more fully in the section on Program ARSTAN, have these effects:
1:    A negative exponential curve is fit; if it fails, a linear regression line is fit.
2:    A negative exponential curve is fit; if it fails, a linear regression line of negative slope or a horizontal line through the mean is fit.
3:    A linear regression line is fit to the data series.
4:    A horizontal line is fit through the mean (no detrending).
5 or greater: A cubic smoothing spline is fit with a rigidity (50% frequency cutoff) of this many years.

-1: No detrending or transformation of the series is done
Second detrending option:
Curve-fitting options are the same as described for the first detrending. If you touch <CR> or type zero, no second detrending is done.
(2) Stabilization of variance.
You may request variance stabilization of each detrended index series, of the chronologies only, or both. For variance stabilization a cubic smoothing spline is employed of a rigidity you select.

CHRONOLOGY COMPUTATION
Program CRONOL performs the following tasks:
(1) Ring measurement data series are read, and for each series detrending is performed as specified. One curve (or two curves in succession) is fit to each measurement series to model biological growth trend and other low-frequency effects you wish to remove, and the measurement values are divided by the curve values to produce a detrended series.
(2) Variance of the series is stabilized if requested.
(3) Autoregressive modeling is done, fitting an autoregressive process to each series of the order determined by the first minimum of the Akaike Information Criterion. Statistics are printed on each series.
(4) The Standard version of the chronology is computed. Detrended tree-ring index series are combined into a biweight robust mean (default) or an arithmetic mean of the series.
(5) The Residual version of the chronology is computed in the same manner as the Standard version, this time using the residual series resulting from autoregressive modeling.
(6) The Standard and Residual versions of the chronology are saved on a disk file named __CRN.DAT, or if requested in two files: __STD.CRN and __RES.CRN, and printed on the output in the standard form for publication.

DENDROCHRONOLOGY PROGRAM LIBRARY (DPL)

USERS MANUAL by Richard L. Holmes

Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA

February 1999

TABLE OF CONTENTS

INTRODUCTION TO THE PROGRAM LIBRARY

The Dendrochronology Program Library((DPL) is a set of some thirty-two interactive computer routines which perform data processing tasks and analysis commonly carried out in dendrochronology during the process of chronology development and analysis. There are also routines for applications in ecology, climatology, hydrology and archeology. Versions of the DPL have been prepared for the VAX/VMS and Unix operating systems and for PC-compatible computers. This manual describes the routines in the DPL, and Programs ARSTAN, the state of the art for chronology computation and analysis, and RESPO, to compute response and correlation functions.

The DPL performs tasks such as crossdating quality control and measurement verification (Program COFECHA), listing of measurements for trouble-shooting and documentation (LRM), tree-ring data editing and correction (EDRM), estimating missing (not absent) ring measurements (MIS), and chronology development and analysis (Programs ARSTAN and CRONOL).

It also deals with monthly meteorological data, estimating missing values (MET), checking for homogeneity between stations (HOM), and seasonalizing climatic data (SEA). Relating tree rings and climate, it computes response and correlation functions and reconstruction coefficients (Program RESPO), reconstructs time-series (REC), and verifies the reconstructions (VFY).

Other programs do tasks such as manipulating data series, changing data formats, and preparing or reading casewise files (Programs FMT, CASE and YUX), principal components analysis (Program PCA), constructing correlation matrices (MAT), determining the effect of an impact on tree growth (IMP), and inventorying data files (SUR). The remaining routines carry out other tasks occasionally needed.

DATA FORMATS

All the programs will read data in several ASCII formats, among them the standard formats for ring measurements and indices established by the International Tree-Ring Data Bank (ITRDB), known also as the Tucson formats. If the format of your data is different from any of these, you may be able to change it with Program FMT, or you may need to reformat it in some other way. One or more lines of text may precede the data in the files as a header or title.

Most programs also provide options for the format of output data files. Program FMT may be used to change data from one format to another. Programs YUX and CASE may be used to create and to read and convert data files in column (casewise) format, directly importable into spreadsheet programs.

Following is a description of several formats for input and output files. The percentage indicates the approximate space the format requires compared to that needed by the Compact time series format.

3 or M = ITRDB standard ring measurement format (also called the Tucson measurement format). Precision of data is 0.001 ("3") or 0.01 ("M"). Format for each line is (A8,I4,10I6), where (A8) is the series identification, (I4) the first year of data in the decade, and (10I6) a decade of ring measurements, usually in units of 0.001 mm or 0.01 mm. If the first year is not a decade year (it does not end in 0), the actual first year of data is recorded, and the first spaces for measurement values contain measurements through the year ending in 9. Succeeding lines contain full decades of measurements from the year ending in 0 through the year ending in 9. Following the last actual data value is a dummy value of -9999 if the precision is 0.001 or 999 if the precision is 0.01; this indicates the end of the series. A new line with only the dummy value may be required. If this is not the last series in the file, the next line is the first decade of the following series. (230%)

I = ITRDB standard ring index or chronology format (also called the Tucson index format). Format for each line is (A6,I4,10(I4,I3)), where (A6) is the chronology identification, (I4) the first year of the decade, and (10(I4,I3)) a decade of chronology indices in units of 0.001, followed by the number of tree-ring series represented by the index. If the first decade is incomplete, the date is the beginning year of the decade ending in 0, and the first spaces are filled with dummy values of 9990 and series numbers of 0. Following the last actual data value the decade is filled to the end with dummy values as at the beginning of the first decade. There must be at least one dummy value to indicate the end of the chronology, even if this requires a new line. The first decade of the next chronology follows on the next line. (260%)

A = Accurite (ring measurement format. The DPL reads this format but does not produce new files in this format.

C = Compact time series format. This format is recommended for most time series because it is not limited by the scale of the data and it conserves precision at any scale. The first line shows the number of values and the date of the first value, followed by the series identification. To the right is the power of ten to which the data are to be multiplied, the data format and a tilde (~) in the last column (but not beyond column 80) to indicate the type of format. The format is adjusted by the program creating the file to conserve precision while making efficient use of space. (100%)

1 = Single column of values.

2 = Two columns: year then value.

V = Two columns: value then year. Each value is identified with the year in the second column, and series identification may appear to the right of the first year. (530%)

S = Spreadsheet or casewise format. The DPL can both read existing files and write new files in this format.

T = Meteorological data format, either University of Arizona style (I4,12I5) or Lamont-Doherty style with the year preceded by a space (I5,12I5). The first value is the year of data, and the (12I5) values are monthly meteorological data read as (12F5.1). (172%)

X = Format specified by the user. Specify the format for real (floating point) data and include parentheses. If it is an input file, give the number of data values. For example, the data format you would specify for the meteorological data format is (4X,12F5.1), and if there are twenty lines of data, respond 240 to the prompt for the number of values.

GENERAL COMMENTS ON USING THE PROGRAM LIBRARY

Either upper or lower case letters may be used in responding to prompts. The program may be terminated at any time you are prompted for a reply by typing a slash (/) followed by <CR> (Enter).

Certain programs and routines (COFECHA, ARSTAN, CRONOL, RESPO and several others) request a job identification code of up to five letters or numbers to identify output for printing and data files produced by the program. Responding with <CR> will cause the default identification "ZZ" to be used. New files produced by the program combine the identification code with the routine code, and add an extension according to the type of file, for example, ABCDEFCOF.OUT or ABCDEFCRN.DAT.

When opening an existing file the first few lines are shown on the screen to show you the format and so you can verify that this is the file you want to use. The program attempts to determine the data format of the file. If the determination is correct, touch <CR>, otherwise respond "N" and give the code for the correct format from the choices listed. If the file is not to be read as data (such as text), simply touch <CR>.

Output files for printing are identified by the extension *.OUT.

RUNNING PROGRAMS IN BATCH MODE

On the PC a batch file has the extension ".BAT" and require an auxiliary file for each program run. The batch file contains only the name of the program, the symbol (<) and the name of the input file. This causes the program to read input from a file rather than from the keyboard:

```
File COFECHA.BAT: COFECHA<INPUT1.DAT          PC command to run first program
                        COFECHA <INPUT2.DAT          PC command to run second
program

File INPUT1.DAT:        ABCDE              Lines usually typed on keyboard
                        FILE1.DAT
                        <Blank>
                        Title for job
                        <Blank>

File INPUT2.DAT:        FGHIJ              Lines usually typed on keyboard
                        FILE2.DAT
                        <Blank>
                        Title for job
                        <Blank>
```

PROGRAM MENU AND SAMPLE SCREEN

Routines in the DPL are accessed by selecting the desired routine from the Menu. Programs such as ARSTAN, CASE, COFECHA, CRONOL, EDRM, EVENT, FMT, OUTBREAK, PCA, RESPO, SIGLOF and YUX stand alone and do not appear on the DPL menu. At the Laboratory of Tree-Ring Research they are executed by typing DPL and the program name on the same line (see below).

The menu screen of Program DPL is shown here for illustration, displaying the routines that may be called.

```
                          DENDROCHRONOLOGY PROGRAM LIBRARY

AGE  Tree growth by age                  REC  Reconstruct time series
ARI  Aridity indices                     SEA  Seasonalize meteorologic data
ART  Generate artificial time series     SPL  Random split of file by percent
BAR  Bar plots by page or in columns     SUR  Survey data file or list idents
CLD  Climate diagrams temp & precip      TSA  Time series analysis statistics
COL  Copy selected columns of file       VFY  Verify calibration model
HOM  Homogeneity of meteorologic data    COF  =>  [Run Program COFECHA]
IMP  Impact before and after event       CRN  =>  [Run Program CRONOL]
LNP  Printer plot of time series         EDT  =>  [Run Program EDRM]
LRM  List ring measurements              FMT  =>  [Run Program FMT]
MAT  Correlation matrices                PCA  =>  [Run Program PCA]
MET  Estimate missing meteorology data   YUX  =>  [Run Program YUX]
MIS  Estimate missing ring measurement   ?    General information
ORD  Sort in order by selected column    (Day number 23433   DPL version 4.90P)

Select routine => MAT
Identify job (up to 5 letters) => ABCDE
```

The following pages describe the routines in the Dendrochronology Program Library.

Routine AGE   Tree growth by age

Computes functions of tree growth by age of the tree rather than by a dated chronology. Measured tree-ring series are assigned ring numbers corresponding to the age of the tree when the ring was formed rather than a calendar date.

For each series the first ring will not be identified by a date, but by the ring number or age of the tree when that ring was produced. The first ring outside the pith is counted as ring number one. If the pith is not present on the sample, the ring number must be estimated. Routine EDRM may be used to adjust the initial ring number of each series.

Incremental and cumulative tree diameter and basal area are computed and extrapolated to pith (year 1). Cubic smoothing splines with a rigidity specified by the user are fit to provide smoothed series as well. Relevant statistics are printed, and if desired the individual series of these parameters are saved on disk files.

Routine ARI   Aridity indices

Calculates various monthly and annual indices of aridity, also known as bioclimatic indices, using monthly temperature and precipitation data. The following indices are derived, generally using temperature in C and precipitation in mm.

Abbreviations used in the formulas:

```
Ta   = Mean annual temperature (C)
Tm   = Mean monthly temperature (C)
Pa   = Total annual precipitation (mm)
Pm   = Total monthly precipitation (mm)
TK   = Temperature in degrees Kelvin (absolute)
MaxK = Mean maximum temperature of the warmest month in K
MinK = Mean minimum temperature of the coolest month in K
TF   = Temperature in F
```

Pi = Precipitation in inches

Lang's pluviofactors.

Annual index = Pa / Ta

De Martonne's annual and monthly aridity indices, a measure of the effectiveness of precipitation or of aridity of a region.

Annual index = Pa * .1 / (Ta + 10)

Monthly index = Pm * 1.2 / (Tm + 10)

Emberger's annual coefficients, using the difference between the mean maxima of the warmest month and the mean minima of the coolest month. Temperatures are converted to Kelvin.

Annual coefficient =
Pa * 1000 / (((MaxK + MinK) / 2) * (MaxK - MinK))

Thornthwaite's annual P/E indices, precipitation effectiveness.

Index = Sum (n=1,12) of (Pmn * 1.64) / (Tmn + 12.2)

Thornthwaite's annual P-E indices of long-term effectiveness of precipitation for plant growth. Temperatures below -2C are taken as -2C. P-E indices over 40 are taken as 40.

Index =
10 * Sum (n=1,12) of 11.5 * (Pmin / TmFn - 10)x(10/9)

Thornthwaite's moisture provinces, from the P-E index (1931) revised in 1948 to use the moisture index. Both the classifications of 1931 and 1948 are calculated.

Thornthwaite's heat index, a function of low temperatures under cold conditions, increasing exponentially with increments in temperature.

Index = Sum (n=1,12) of (Tmn / 5) 1.514

Thornthwaite's annual indices of long-term effectiveness of temperature for plant growth, or thermal efficiency (T-E) index. Negative indices are taken as zero.

Index = Sum (n=1,12) of (TmFn - 32) / 4

Thornthwaite's temperature provinces, from the T-E index (1931) revised in 1948. Both the classifications of 1931 and 1948 are calculated.

Bhalme and Mooley annual drought index (BMI) for a selected span of months.

Routine ART Generate artificial time series

Generates a file of artificial time series to simulate tree-ring or other series. A random series is first created, with which all artificial series will "crossdate."

The normality of the distribution depends on the number of random values with a flat distribution (all values equally probable) that are averaged to approximate a normal distribution. Around 12 values gives a distribution close to normal. The fewer the number of values averaged the flatter is the distribution; the greater the number of values averaged, the more the distribution clusters around the midpoint.

Three types of distribution may be chosen:
0: Normalized, with mean of zero.
1: Indexed, with mean of one.
2: Negative values are changed to positive, giving a positively skewed distribution.
3: A constant is added to values in the time series to raise the smallest value to zero, thus there are no negative values.

You give the first and last year of each series, and provide an approximate first-order autocorrelation. Choose a proportion of noise to be added, which will make the series correlate less well with others as more noise is added. A cosine wave may be added to the series, specifying period, phase and magnitude of the wave.

Each series of generated data is self-documented and an unlimited number of series may be produced.

Routine BAR Bar plots by page or in columns

Makes bar plots of tree-ring or other time series in the same style as the bar plot of the master dating chronology produced in Program COF (COFECHA). In a file containing several series you may elect to plot or skip each series.

Routine BAR produces bar plots page by page as in Program COFECHA; or in continuous columns, up to ten in parallel on the page.

Each series is filtered by fitting a flexible cubic smoothing spline, then dividing the series by the spline curve values to remove trend and long waves. The resulting plots are similar to skeleton plots, except that longer bars in a bar plot indicate wide rings rather than narrow ones as in a skeleton plot.

The plot shows the date of each ring and its relative width by the length of the bar. At the end of the bar is an alphabetic code: each letter progressing through the alphabet indicates a quarter standard deviation from the local mean. Lower-case letters indicate rings narrower than the local mean, upper-case letters wider than the local mean; "@" indicates very close to the local mean. The length of bars is selected so that there is an equal number of bars of each length.

Bar plots may be used as a quick graphic presentation of a time series, to assist in crossdating as a skeleton plot is used, or to pinpoint the exact year of problems in crossdating or measurement.

Routine CLD Climate diagrams

Climate diagrams are produced from monthly temperature and/or precipitation data. You may elect to produce climate diagrams either for a span of years or for selected individual years.

These diagrams permit rapid visual assessment of the climatic character of a year compared to the long-term average, since both values are displayed together.

The first diagram shows the average monthly temperature and/or precipitation for the entire time span of data. Means for each month are shown by a "T" for temperature and "P" for precipitation.

The diagrams which follow are for individual years. On the diagram for a given year the monthly values are plotted in upper-case "T" or "P" and the average monthly values for the entire span of data in lower-case "t" or "r". The interval displayed for each year covers 16 months from January through April of the following year.

Routine COL Copy selected columns

Selected spans of columns are copied from one file into a new file. The new file may contain up to 256 columns.

Either List carriage control (for data) or FORTRAN carriage control (for printed output) may be selected for the new file. If desired, the new file may have leading blanks. Trailing blanks are trimmed from the new file.

If for example you give 9 and 72 as the first and last columns to take for the first segment, and columns 1 to 8 for the second segment, then request that the new file start in column 3, the resulting file will have columns 9 to 72 from the old file in columns 3 to 66 of the new file, and columns 1 to 8 from the old file in columns 67 to 74 in the new file.

Routine HOM Homogeneity of meteorologic data

Examines monthly temperature, precipitation or similar data from a pair of meteorological stations for homogeneity. Two analyses are performed.

(1) The Mann-Kendall statistical test for randomness is performed on the data sets. For each year the number of years following with larger ratios (Station 1 value / Station 2 value) is calculated and these are totaled and compared with the expected number. A pass/fail test is made for the 90%, 95% and 99% critical limits.

$$Tau = 4P / (Nyr * (Nyr-1)) - 1$$

where P is the sum over years of the ratios beyond a given year which are greater than the ratio for that year, and Nyr is the number of years in the series. The 90% critical limit depends on the number of years and is such that for 90% of all samples, the absolute value of Tau is less than the 90% critical limit. Thus if the given Tau does not lie in this range, there is less than a 10% chance that the ratios form a homogeneous series. The 95% and 99% critical limits are defined similarly. Note that if a given Tau would occur on 7% of all samples, the result would fail the 90% limit and pass the 95% and 99% limits. Hence the 90% limit is the most stringent.

(2) A scattergram is made to enable visual assessment of the relationship between the stations.

For temperature, since the data values are not zero-based, a scattergram is made plotting the year versus cumulative temperature differences (Station A minus Station B).

For precipitation, since the data values have a base of zero, a scattergram is made plotting cumulative precipitation of Station A versus that of Station B (double mass plot).

For both temperature and precipitation the points plotted on the scattergram run from the lower left corner to the upper right corner. If the stations are homogeneous, their relationship has remained constant through time, and the points will fall close to a straight line and there will be no change in slope.

If there is a change in slope, you may determine the year of the change (the year is printed at each point) and its direction. If, for example, precipitation at Station A is plotted along the horizontal and precipitation at Station B along the vertical axis, and the slope becomes more positive (steeper) at year T, then beginning in year T+1, either Station A began to register relatively less precipitation than before or Station B began to register more. This occurrence is often due to a change in type or location of instrumentation at the meteorological station.

To determine which station has the inhomogeneity, each station must be compared with at least two others, for example A with B, B with C, and A with C. The station with inhomogeneous data will show a break in slope at the same year in the same direction with both comparison stations.

If there is a jog in the scattergram plot without a change in slope, there is a large discrepancy between the stations in the year following the jog. This implies a probable error in the data.

Time spans may differ between the two stations, in which case the common time span will be compared. There must not be missing values in the common time span of either data set. (See routine MET for estimation of missing values in monthly meteorological data.)

Routine IMP Impact before & after event

Tree-ring measurement series or chronologies are used to compare mean growth before and after an impact or disturbance which is thought to cause a change in growth, for example, a hailstorm or fire.

The impact year is the first year the tree will exhibit the effect of impact. This would be the first narrow ring in the case of a negative impact on growth. Indicate a span of years before the impact year to establish the base rate of growth. Select a span of years after the impact to be compared as a whole and year by year with the base rate.

Printed for each series is the growth before and after the impact in terms of the base, as well as the mean growth in the time span after impact compared with the base rate before impact. For each year before and after the impact, the mean growth and index as a proportion of base growth is shown.

In lieu of this routine you may prefer to use Program EVENT to perform Superposed Epoch Analysis. In this program (see description) each year in a list of event dates is taken as a key or zero window year. Time series values for event years and for a window of years before and after the event years are superposed and averaged over the chronology time span. Random simulation determines the significance of the relationship.

Routine LNP   Printer plot of series

Line printer plots of time series are produced for printing. Series are displayed horizontally across the page, each value represented by a vertical bar identified with the last digit of the year. If a series is more than 125 values long it is continued below.

You may elect to draw a horizontal line at the mean or at any level you specify. From a file containing several series you may select the series to be plotted, and if desired choose to plot only a portion of the series. Scaling of the plots is automatic.

Routine LRM   List ring measurements

A listing of tree-ring measurement values is produced for all tree-ring series in a file for printing. For each year measurements appear in a single column, and the values in a given series may be followed horizontally.

A diagonal bar between adjacent values indicates when the year-to-year change in measurements exceeds 20 percent of the mean of the two values, "/" when the change is positive, "\" when negative; nothing appears if the adjacent values are within 20% of their mean. Absent rings are indicated by "**AB*" so they are easily seen on the page.

The printout may be used to check crossdating and locally absent rings and to locate unusual features, and also serves as an archival record of tree-ring measurements.

Routine MAT Correlation matrices

Produces one or more correlation matrices for a set of time series, using one or more time intervals you specify.

Any series not covering the specified time interval is excluded from the correlation matrix. By default every series in the file covering the span is included in the correlation matrix. An option permits you to select those series you want to include.

If you give one file name, correlations will be calculated for all possible pairs of series in the file.

If you give two file names, correlations will be calculated for each series in file 1 with every series in file 2.

If one of the data sets is very large, give it as the second file.

Tables of correlations to three decimal places are written on a file for printing along with the mean correlation and mean absolute correlation for each series. You may elect to mark with an asterisk all correlation values exceeding an absolute threshold; default (<CR>) is no marking of correlations.

Additional correlation matrices may be produced for the same data file by specifying other time intervals.

The matrices are on a file for printing. You may also elect to save the matrices as tables in a data file.

Routine MET Estimate missing meteorology data

Missing monthly meteorological data may be estimated for a small or large number of temperature, precipitation or river flow stations. Station data must be of the same type and should be from a homogeneous climatic region. Missing values must be set previously either to blank or to a value of -999 or more negative.

If for a given month no station has data, you may elect either to fill in the mean for that month at each station, or to leave the value missing.

If data are precipitation or river flow, an estimate that results in a negative value is set to zero.

The mean and standard deviation is calculated for each month at each station. The departure for each month and year is then calculated and averaged across stations to produce regional average departures for each month and year.

You may save the file of regional mean departures and/or averages, or convert a previously made file of regional departures to averages.

Monthly data values are estimated by calculating the value with a departure from the mean for the month at that station equal to the average departure of the other stations for that month and year. The standard deviation for the month at that station is multiplied by the regional average departure for the month and year, and the mean value for the month at the station is added. The output for printing documents all estimated values. New files with estimated data are produced for those stations with missing data. If a station has no missing data, no new file is produced.

In many analyses the file of mean regional departures may be used as meteorological data. If desired, routine MET may be run again, selecting the option from the menu to convert a file of regional departures to regional averages.

Routine MIS Estimate missing ring measurement

If tree-ring measurement series have single missing rings, that is, not consecutive, routine MIS will estimate the value of each missing ring k based on the measurements of the immediately preceding (k-1) and following (k+1) rings and the relationship of these three rings (k-1, k, k+1) in all other series where they are present. Missing ring measurements must be set to a negative value before running routine MIS.

Routine ORD Sort in order by selected column

Reorders lines in a file, such as a table of data, by putting them in ascending order by selected columns. The routine displays on the screen the first few lines from the file to show the column structure or format.

If for example you respond with 40 and 50 for the first and last columns, the new file will have the same lines reordered so that columns 40 to 50 appear in ascending order.

Routine REC Reconstruct time series

Regression coefficients and a set of predictor variables are used to reconstruct a time series. For a valid estimation the predictors must be the same variables as in the original calibration or regression analysis.

Two files are required. The first contains the regression coefficients for reconstruction. Each line pertains to one predictor time series. The first eight columns are either the identification of the predictor, left-justified, or its sequence number in the predictor file in free format. Following in column 9 or after is the regression coefficient for that predictor in free format. If the intercept is given, identify it as "INT", left-justified. The order of the coefficients is unimportant.

The second file contains the predictor variables. Any of the formats described above may be used for these time series.

The reconstructed time series is saved on disk file and printed in publication format along with descriptive statistics.

Routine SEA Seasonalize meteorologic data

Monthly meteorological data may be grouped into seasons of one or several months, creating a new file with seasons replacing months. Up to twelve seasons or groups of months may be chosen. They may overlap, may include only one month, and may include months in the prior and following years as well as the current year.

If the data are temperature, the season mean is recorded; if precipitation or river flow, the total is recorded.

To indicate first and last months, give the number of the month: 1 to 12 for the current year, -1 to -12 for the prior year, and 13 to 24 for the following year. For example, -7 to 3 will give a nine-month season from the prior July through the current March, averages for temperature and totals for precipitation or river flow; 5 to 5 will give a one-month "season" including the current May only.

The span of each season is automatically indicated in the new file, and routines in the Dendrochronology Program Library will read it without difficulty.

Routine SPL Random split of file by percent

Divides a casewise data file randomly into two new files in the proportion specified.

For example, if a file contains 127 data lines, and you specify the proportion as .375, the first new file will have 48 data lines (37.8%) randomly selected, the second new file the remaining 79 data lines (62.2%).

This routine may be used to select a random sample of yearly values for calibration, reconstruction or verification as an alternative to using spans of consecutive years.

Routine SUR Survey data file

This routine surveys one or more data files of time series. The first few lines of the file and the identification and time span of each series appear on the screen and the time span and common interval (if any) of the entire data set are calculated.

The series may be viewed and listed in order as they appear in the file, ordered by identification or by first year, by last year, or by length of the series.

At the end of the run you may elect to keep or delete the file for printing, which duplicates the information presented on the screen.

Routine TSA Time series analysis

Calculates descriptive statistics of time series in their entirety and in 50% overlapping segments of a length you may specify (default is segments of 50 values). If you give a negative number for length of segments, analysis will be done on the entire series only.

Statistics computed include the mean, median, mean sensitivity, variance, standard deviation, coefficient of variation, skewness, kurtosis, autocorrelation and partial autocorrelation to ten lags, and the Ljung-Box Portmanteau Q statistics. There is no limit to the number of series in a file that may be processed. In addition to the printed output you may save the statistics in a table.

Routine VFY Verify calibration

Verifies reconstructions of meteorological series or tree-ring chronologies by comparison of actual data with estimated data for one or more common time spans.

You provide first and last years for a calibration time interval and for a verification time interval. Subsequently additional time intervals may be analyzed for the same data.

Several tests are performed for significance, such as the product sum test, correlation, reduction of error, T-value, sign-products test, and negative first differences. Significant values are starred. Risk, drift, variance, covariance, and difference of means between actual and estimated data are calculated.

Switching screen colors

Type a tilde (~) at any prompt to select among several screen color schemes. If your PC computer does not have a line in the file CONFIG.SYS enabling ANSI.SYS, then select the color scheme "X".

DISCLAIMER

The following disclaimer applies to the Dendrochronology Program Library, Program ARSTAN, all programs in the Dendroecology Program Library, and any other software distributed directly, via Anonymous FTP, or by any other means.

Although every effort is made to ensure that the software functions properly, no warranty is made to this effect and neither the author, the Laboratory of Tree-Ring Research, nor the University of Arizona can accept responsibility for any problems with it, including operation on any particular computer system. The user must judge the efficacy of the software for the intended use.

The software is made available free of charge. Any payment accepted is for actual costs of diskettes, copying, printing and/or postage.

We appreciate your comments and suggestions, and will try to help with any problems you may encounter.

ACKNOWLEDGMENTS

The Dendrochronology Program Library was developed over several years at the following research centers:

(Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona, USA

(Laboratorio de Dendrocronología, Centro Regional de Investigaciones Científicas y Tecnológicas [CRICYT-Mendoza] (Regional Center for Scientific and Technological Research), Mendoza, Argentina

(Bundesforschungsanstalt für Forst- und Holzwirtschaft, Ordinariat für Holzbiologie (Institute for Wood Biology, Federal Forest and Wood Research Institute), Universität Hamburg, Germany

(Tree Ring Laboratory, Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, USA

Part of the work was done with the support of the U. S. National Science Foundation. Major contributors to the programs include Edward R. Cook of Lamont-Doherty Earth Observatory (ARSTAN), Janice M. Lough of the Australian Institute of Marine Science, Townsville (RESPO), and Richard L. Holmes of the

University of Arizona. Many users have contributed to additions and improvements to the programs by useful comments, helpful suggestions and good advice.

Your suggestions and ideas on how the programs may be improved are always welcome.

VAX, MAINFRAME, PC-COMPATIBLE AND MACINTOSH VERSIONS

The Dendrochronology Program Library and associated programs were developed in ANSI standard FORTRAN-77 programming language on a VAX/VMS mainframe operating system. It has also been compiled for other mainframe computers (Data General, Amdahl, IBM), and for PC-compatible and Macintosh computers.

Programs ARSTAN and RESPO are separate from the rest of the DPL because their memory requirements are much larger or different from the other programs. Programs COFECHA, CRONOL and EDRM are independent prrograms as well as forming part of DPL.

INSTALLATION ON A PC-COMPATIBLE COMPUTER

The programs operate with 32-bits and require a fully compatible PC of level 386, 486 or newer. With a math coprocessor they will operate much faster than without. There have been some models of computers which are not truly PC-compatible and cannot run the programs. We do not recommend running the programs when another program is also running (for example "Windows").

We recommend creating a directory such as C:\BIN for the executable files. Copy all the *.EXE files into this directory. The programs require the presence of the memory-manager program DOSXMSF.EXE in the directory; they will not run without it. In the AUTOEXEC.BAT file insert in the PATH statement the directory name C:\BIN; In this way you may run a program from any directory simply by typing the program name. For example, type DPL to run the Dendrochronology Program Library or ARSTAN to run Program ARSTAN.

Make sure that the CONFIG.SYS file contains these lines:

```
DEVICE=C:\DOS\ANSI.SYS       (If ANSI.SYS is in directory C:\DOS)
FILES=30                           (These values may be
BUFFERS=20                     somewhat larger if desired)
```

REFERENCES CITED

Cook, E.R. 1985.

A time-series analysis approach to tree-ring standardization. Ph.D. Dissertation, Department of Geosciences, University of Arizona, Tucson.

Cook, E.R., and Peters, K. 1981.

The smoothing spline: a new approach to standardizing forest interior tree-ring width series for dendroclimatic studies. Tree-Ring Bulletin 41:45-53.

Fritts, H.C. 1976.

Tree rings and climate. Academic Press, London, 567 pp.

Fritts, H.C., Mosimann, J.E., and Bottorff, C.D. 1969.

A revised computer program for standardizing tree-ring series. Tree-Ring Bulletin 29:15-20.

Holmes, R.L., Adams, R.K., and Fritts, H.C. 1986.

Tree-ring chronologies of western North America: California, eastern Oregon and northern Great Basin, with procedures used in the chronology development work, including users manuals for computer programs COFECHA and ARSTAN. Chronology Series VI. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Monserud, R.A. 1986.

Time-series analyses of tree-ring chronologies. Forest Science 32:349-372

Parker, M. L. 1971.

Dendrochronological techniques used by the Geological Survey of Canada. Geological Survey of Canada Paper 71-25, p 26, Department of Energy, Mines and Resources, Ottawa.

Parker, M. L. 1967.

Dendrochronology of Point of Pines. Masters Thesis, Department of Anthropology, University of Arizona, Tucson, p 91-100.

Thornthwaite, C.W. 1948.

An approach toward a rational classification of climate. Geographical Review 38:55-94

Thornthwaite, C.W. 1931.

The climates of North America, according to a new classification. Geographical Review 21:633-655

Wigley, T.M.L., Briffa, K.R., and Jones, P.D. 1984.

On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology. Journal of Climate and Applied Meteorology 23(2):201-213.

KEY TO TASKS

You may use this key to tasks by looking up an action you would like to carry out and consulting the description of the routines or section listed. For page numbers see the table of contents on page 1.

Task to perform	Routine or section to see
Accurite measurement format	FMT
Accurite measurement format, description	Data formats
Add a constant to data series	FMT
Bar plots in parallel columns	BAR
Bar plots, one page per series	BAR
Casewise format	FMT, CASE, YUX, Data formats
Change dating of set of series by a constant	FMT
Change format of file of data series	FMT
Chronology format	FMT
Chronology format, description	Data formats
Chronology, compute	ARSTAN, CRONOL
Climatic data diagrams	CLD
Climatic data format	FMT

Program EDRM

Edit file of ring measurements

USERS MANUAL for Program EDRM by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program EDRM enables you to edit efficiently a file of tree-ring measurements or other time series, producing a new file which incorporates the changes you have made. Each series in the file may be copied to the new file intact, it may be edited in one or several respects and then copied, or it may be omitted from the new file. The new file is written at your option in compact or measurements format. Note that if a large number of data are to be entered, or if certain types of change are to be made, it may be easier to use a text editor.

The program allows you to copy one or more lines from the beginning of the existing file as headers in the new file.

In editing a time series you may display the data; insert, change or delete values; truncate at the beginning and/or end; shift the dating forward or back; split the series into two or more; and/or change the identification.

The menu for editing is:

```
      No   1  CPP01A   Interval  1752  1920   169 years

      C: COPY as is             F: new FIRST year       U: new LAST year
      I: INSERT value           E: ELIMINATE value      R: REPLACE value
      (: Cut from BEGINNING     ): Cut from END         P: DISPLAY data
      T: Take remaining series  O: OMIT series          N: New identification
      X: Exit program           Q: Re-edit series       K: COPY and re-edit
      S: Copy all until ..      Select:

==>
```

The menu for editing presents several editing options. You may:

C: Copy the series into the new file as it is currently, edited or not.
F: Adjust the dating of the series by resetting the date of the earliest ring.
U: Adjust the dating of the series by resetting the date of the latest ring.
I: Insert a ring measurement value in the series, moving the earlier part backward in time ("<")
or the later part forward in time (">") to make space for the inserted value.
E: Eliminate a ring measurement value in the series, moving the earlier part forward in time (">")
or the later part backward in time ("<") to fill the space left by the deleted value.
R: Replace a ring measurement value, substituting another value.
(: Truncate the series by cutting off values at the beginning.
): Truncate the series by cutting off values at the end.
P: Present data on the screen, displaying 50 values with dates from any part of the series.
The date you give will appear as close as possible to the center of the screen.
T: Take all remaining series in the old file into the new file without further editing.

O: Omit this series from the new file, skipping to the next series in the old file.
N: Change the identification of the series to a new string of up to eight characters.
X: Exit the program, leaving in the new file only those series you have copied to this point.
Q: Restore the series to the original and edit it anew. Use this option if you have made an error in editing.
K: Copy and re-edit. This way you may divide a series into two or more parts by editing to keep only the first part, then copying with this option to re-edit. Edit the series again, this time keeping the second part. Change the series identification with option "N" before copying it to the new file to avoid duplication.
S: Skip ahead several series, copying them to the new file without editing, until you reach the next series you wish to edit.

Some sample replies to items on the menu, the prompt from the program, and one possible reply:

```
Reply  Prompt            Reply

  P    Around what year?: 1820

  I    Date of value BEFORE which to insert: 1813
       Value to insert: .45
       Move:  < early portion BACK;  > late portion FORWARD: <

  )    LAST year to keep: 1917

  F    Correct date of FIRST year: 1762

  N    Present identification_: CPP01A
       New identification    _: SBE09B

  C    No   1  SWE09R   Interval  1762  1928   167 years, COPIED
```

DENDROECOLOGY PROGRAM LIBRARY

PROGRAM EVENT USERS MANUAL

SUPERPOSED EPOCH ANALYSIS IN FIRE HISTORY STUDIES

by Richard L. Holmes and Thomas W. Swetnam
Laboratory of Tree-Ring Research
University of Arizona, Tucson, Arizona USA

May 1994

INTRODUCTION

In June 1993 Dr. Thomas W. Swetnam, head of the Fire History group at the Laboratory of Tree-Ring Research, University of Arizona, requested that a Fortran computer program be written to perform superposed epoch analysis on tree-ring chronologies for fire events or other phenomena. VAX-VMS Version 6.1 (1993) ANSI Fortran-77 programming language and the University's VAX mainframe computer were used to develop the program. Subsequently the program was compiled with Microsoft "PowerStation" (1994) Fortran-77 to run on PC compatible computers of type 386 and newer. Features were added to the program as researchers used it in fire history research.

PURPOSE OF PROGRAM EVENT

Program EVENT performs superposed epoch analysis using a time series and a list of event dates or key years. For each event an event window is taken, which includes values in the time series leading up to, including and following the event. Windows for each event are superimposed and averaged, and the mean pattern emerging is examined to determine if there may be predictability in the pattern of time series around the events.

A large number of simulations is performed by picking dates at random to simulate event years. A distribution of means is computed from the simulations, and confidence limits for this distribution are used to determine if there is statistical significance in the pattern surrounding the events.

PROGRAM CAPACITY

Maximum number of simulations	4096
Maximum time span of chronology	2076 BC to AD 2020
Maximum event window size	40 (years preceding + event year + years following)
Maximum number of events	800

RUNNING PROGRAM EVENT

Upon starting Program EVENT the user gives a run identification of up to five letters and numbers which will identify files created by the program. If you give no name then "Z" is used as the run identification.

The user then provides the names of two data files:

(1) Tree-ring chronology, reconstruction, or other time series. Two or more chronologies may appear consecutively. Any standard format may be used.

(2) List of event years in a single column. Two or more lists may appear consecutively provided that an alphanumeric header is placed between them.

The program presents a menu on screen, listing the options and current values.

(1) Epoch window size. The user may select the number of years prior to each event and years following each event for analysis. The number of years in the epoch window to be analyzed will be the sum of these values plus one -- the event year itself. Default is 6 years prior and 4 years following the event: 6 + 1 + 4 = 11.

(2) Since an event may occur close to the beginning or end of the chronology, one or more years of the epoch window may fall beyond the time span of data. The user may select to exclude or to include such incomplete epochs. Default is to exclude incomplete epochs.

(3) Method of picking simulated events. Three methods are available for obtaining the years for simulated events:

(Random sampling with replacement: Simulated event years are picked independently at random from the chronology; some years may be picked more than once. This is the default method.

This approach may be the most statistically sound, as sampling with replacement is prescribed in the monograph we followed in developing the algorithm for estimating confidence intervals (Mooney and Duval 1993).

(Random sampling without replacement: Simulated event years are picked at random from the chronology, but no year is picked more than once.

(Actual event spacing rearranged: By this method the time intervals between consecutive actual events are calculated, then they are shuffled at random and simulated event years are picked with these rearranged time intervals.

This method and the previous one may produce a more realistic simulation of fire interval distributions. In the case of actual event spacing rearranged, the same interval distribution in the event year data will be preserved in the simulation. However, if the event years are fairly evenly spaced, the intervals will be of similar length and there will then be little independence in the distribution of simulated events.

(4) The number of simulations may be varied; default is 1000 simulations. A "seed" number may be specified to begin the random series; this should be a large integer. Thus exact repetition of a prior program run may be carried out. Default is a value chosen by the program, a count of days since 1 January 1935.

(5) The user may specify a time span to process in order to exclude part of the chronology from processing, or in order to use the same time span for all chronologies. By default the entire time span is processed which is in common between the chronology and the event dates with their windows.

(6) If desired, each chronology may be processed in segments rather than as a whole (default is to process the entire time span). To process the chronology in segments the user specifies the starting year of the segments (which will set the beginning years); the segment length in years; and the lag between segments in years (default for the lag between consecutive segments is half the length of the segments). Thus for example if the chronology spans 1523 to 1992, and the user specifies the starting year of segments as 1501, segment length as 100, and lag as 50, then the segments analyzed will be 1523-1622, 1551-1650, 1601-1700, 1651-1750, 1701-1800, 1751-1850, 1801-1900, 1851-1950, 1893-1992. Note that the first and last segments are the same length as the others, but they abut against the ends of the chronology.

(7) Results are written to files named with the run identification (for example "Z" followed by "EVE.___". The file of results for printing is "ZEVE.OUT". As an option the results may also be saved in two additional files: (1) "ZEVE.SSH", a tab-delimited file for direct importation into a spreadsheet program such as EXCEL or QUATTRO; and (2) "ZEVE.TBL", similar to the printed output but containing the tables only.

When the selected options appearing on the menu are to the user's satisfaction, pressing <CR> (Enter) starts program execution. As each chronology is read, chronology statistics appear on the screen. If the mean is extremely large or small, values appearing in the tables may be difficult to interpret. Therefore the user is asked if the chronology values should be multiplied by a constant to change the scale or range of the data (default multiplier is 1.0, no change). The chronology mean may be used as a guide; for example if the mean is near 1000, multiplying the data by .001 will bring the mean near unity.

RUNNING THE PROGRAM IN AUTOMATIC MODE

If a file named "EVENT.INI" exists in the directory in which the program is run, EVENT reads the file to obtain file names and to initialize parameters. The menu appears on the screen with modified parameters and the user is then asked whether to accept the initialized parameters; if the reply is "N" then the user is prompted for the file names and the menu again appears. Any of the parameters set in the EVENT.INI file may be changed at this point.

How to set up an initialization file:

1. The file must have the name EVENT.INI
2. Each line starts with a five-letter code for the option to be set; the code must be in capital letters.
3. Comment lines may be included, but be sure they do not start with an actual code word. Using lower-case letters is one way to assure this.
4. A space and the new value of the parameter follow the code.
5. All initialization codes are included in this illustration, although those not to be changed from the default value may be omitted.
6. The order of appearance is unimportant.
7. If a code is repeated, the last occurrence is effective.
8. If an error occurs the option is not changed.
9. The following example gives the default settings, except for file names and run title.
10. See documentation for explanation of options.

Here is a sample EVENT.INI file. Options are listed in the order they appear on the menu:

```
Code      Value                                       Explanation
----- ------------        ----------------------------------------
JOBID AZR                 Job or run ident up to 3 letters/numbers
CHRON FHAZ10.DAT          Name of file with one or more chronologies
EVENT FHRSE.DAT           Name of file with list of event years
TITLE Arizona chronology 10 and RSE set of event years
BEFOR 6                   Number of event window years before event
AFTER 4                   Number of event window years after event
SIMUL R                   Method of selection of simulated events
INCLU N                   Include incomplete epochs in analysis
NSIMU 1000                Number of simulations
RSEED 0                   Integer seed for random number generation
YEARA 0                   First year to process
YEARZ 2020                Last year to process
START 0                   Starting year of regular segments
```

SEGMT 0	Length of segments in years
SGLAG 0	Lag in years between consecutive segments
CLIMA Y	Find climatic events and patterns also
PCLIM Y	Print list of climatic events
SAVEF Y	Save files for spreadsheet and tables

OUTPUT FROM PROGRAM EVENT

First on the printed output is information on the parameters used in running the program. Names of the data files used, menu options selected, and names of files created by the program appear in the first section.

Time series statistics are computed and printed for the chronology or segment of the chronology: mean, median, mean sensitivity, standard deviation, skewness, kurtosis, trend in variance, partial autocorrelation orders 1, 2 and 3, and Ljung-Box probability of randomness.

For each epoch window year for both actual and simulated events the two-tailed confidence limits for the assumed normal distribution are computed. (One-tailed limits are given here for information only):

Percent included	Two-tailed confidence limits Std dev +/-	(One-tailed confidence limits Std dev +/-)
95.0%	1.960	(1.645)
99.0%	2.575	(2.327)
99.9%	3.294	(3.090)

The ACTUAL EVENTS table lists the event dates used in the analysis. Events are not used if they are not within the time span of the chronology or segment, or too close to the end if incomplete epochs are excluded.

For each event year the mean, standard deviation, confidence limits and range of values are listed.

The SIMULATED EVENTS table presents the results of random simulations, each simulation containing the number of events used in the ACTUAL EVENTS analysis.

For simulated events, confidence limits are computed in two ways:

(1) Based on assumed normal distribution of means as just described.

(2) Based on percentile rank of simulated event means. Percentiles derived by ranking 1000 simulations (for example) will take values 25 and 976 (2.5% and 97.5%) for the 95% limits, and values 5 and 996 (0.5% and 99.5%) for the 99% limits. The 99.9% limits are not examined, since these would be the extreme high and low values and therefore unreliable.

For each event year the mean, standard deviation, confidence limits computed by both methods, and range of values are listed. Note that the entries in the SIMULATED EVENTS table are not precisely analogous to those in the ACTUAL EVENTS table: Values here are the means, standard deviations, etc., of the means from each simulation, not those of individual events as in the earlier table. For example, if there are 57 events and 1000 simulations, the ACTUAL EVENTS table deals with means, etc., of 57 actual events, while the SIMULATED EVENTS table deals with the 1000 means, etc., each the mean of 57 randomly picked simulated event dates.

Next are two bar graphs of years across the epoch window. The first illustrates mean actual events and confidence bands based on the simulations based on an ASSUMED NORMAL DISTRIBUTION of the time series data. For actual events the window year digit appears at the mean and the line of dashes is the +/- 1.960 standard deviation band. For simulated events two-tailed standard deviation limits at the 95.0%, 99.0% and 99.9% levels are indicated by symbols. The event window year is flagged near the number at the left if the actual mean surpasses any of these levels, and the level of confidence exceeded is indicated.

The second bar graph is similar, but confidence bands for simulated events are based on PERCENTILE RANK of the simulation means. As explained above the 99.9% confidence is not calculated.

Finally there is a table of DEPARTURES OF ACTUAL FROM SIMULATED EVENTS for the means across the event window. Departures are means of actual events minus simulated event means of the assumed normal distribution, and of means of actual events minus simulated event medians for the rank percentile distribution.

REFERENCE

Mooney, Christopher Z., and Robert D. Duval (1993)
Bootstrapping: a nonparametric approach to statistical inference.
Sage University Paper series on quantitative applications in the social sciences, no. 7-95, 73 pp.
Sage Publications, Newbury Park, California.

TREE-RING CHRONOLOGY SAMPLE FILE (Any standard format such as Compact or ITRDB Measurement, Index or Chronology formats may be used)

```
AZ 10                  <- Chronology identification
1600    1431
1601     977
1602     880           <- Year and chronology index  (If there are no decimal
1603     857                 points the values will be read as whole integers;
1604    1181                 in this example the mean will be close to 1000.)
1605     721
            ... etc. ...
1930    1076
1931    1564
1932    1691
1933    1273
```

EVENTS LIST SAMPLE FILE (Events are listed in a single column)

```
RSE                    <- Identification for set of events
1616
1619
1624
1631
            ... etc. ...
1887
1893
1900
1910
```

==>

SAMPLE SCREEN DISPLAY FOR PROGRAM EVENT (User responses are in bold type)

```
                    FIRE HISTORY - CHRONOLOGY AND EVENTS IN
                           SUPERPOSED EPOCH ANALYSIS
                               Version 1994-1.23V

Compares time series values for years before and after each fire or other
event, for a number of events over time, with random simulation of the events
to determine significance of the relationship.

Each event date is taken as the key or zero year.

Identify job (up to 3 letters): AZR

Provide the names of two files with

 (1)  Chronology or reconstruction;  and
 (2)  List of event years

CHRONOLOGY or RECONSTRUCTION
  ->  Name of EXISTING file: FHAZ10.DAT

LIST of EVENT DATES
  ->  Name of EXISTING file: FHEVRSE.DAT

TITLE FOR THIS RUN: Arizona 10 and RSE set of event years

-------------------------------------------------------------------------------
Options:                                                Current values
       1  Years prior to event                                 6
       2  Years following event                                4
            Window analyzed                                   11 years
       3  Simulation: Random sample or Actual event spacing  R
       4  Include incomplete epochs                            N
       5  Number of simulations to run                      1000  Seed    21521
       6  Time span to process                                 0  2020
       7  Process by segments, starting year                   0
            Segment length                                     0 years
            Lag between segments                               0 years
       8  Save spreadsheet and tables                          Y

Number of option to modify or <CR> to proceed: <CR>

CHRONOLOGY  1600  1913   314 years  AZ 10
   972.2102 mean
   271.0178 std dev
   289.0000   1846.0000 range
     0.2092 mean sensitivity

Multiply values in series by  <1.0>: .001
 1000 simulations; percentiles     25  976      5  996
]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
   11 years of window
 1 2 3 4 5 6 7 8 91011

New file: AZREVE.OUT for printing

-  =  [    SUPERPOSED EPOCH ANALYSIS    ]  =  -
```

PROGRAM EXTRAP

Users Manual by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
August 1995

USING PROGRAM EXTRAP

Program EXTRAP projects a growth trend established in the early part of a tree-ring record and extrapolates it forward in time to predict expected ring growth. It is generally used to determine deviation from expected growth following a known or conjectural impact on tree growth, such as a fire, insect attack, logging, or other disturbance.

Program EXTRAP asks the user the following:

(1) File name for the tree-ring measurements to be processed;

(2) Name for a new file to contain extrapolated growth curve series;

(3) Name for a new file to contain detrended growth index series;

(4) The last year of measurements to which to fit the growth curve, that is, the last year before the impact or disturbance.

Program EXTRAP reads the file of tree-ring measurements, one series at a time, processes each series to yield an extrapolated growth curve and detrended indices, and saves the curve and indices respectively in two new data files while recording information on an output file for printing.

The portion of each series of tree-ring measurements from the beginning to the year specified by the user (the base interval) is fit with a negative exponential curve (detailed below). If such a curve cannot be fit due either to a general upward trend in the data or to a convex upward shape of the data curve, a least-squares linear regression line is computed to fit the data (detailed below). If there are ten years of data or less in the base interval the series is skipped, since this is too few to establish a growth trend.

The program then uses the coefficients of the negative exponential curve or regression line to produce a curve extending for the full length of the series, that is, extrapolating the curve forward in time to include the data after the impact date.

Tree-ring measurements are divided by the corresponding growth curve values, yielding a detrended time series of indices containing the departure from expected growth.

NEGATIVE EXPONENTIAL CURVE

A modified negative exponential curve of the form:

$$Y = A * e^{(-B * t)} + D$$

is fit to the data set. An iteration procedure is used, which continues until the improvement of the fit is very small. If the fitted curve has a negative constant (D) or a positive slope (B), the curve is rejected and a linear regression is fit to the data (Fritts et al., 1969). The coefficients of the equation are applied to the data to estimate the growth curve, and the data are divided by the estimates to obtain indices that are intended to be stationary with a mean of 1. The negative exponential curve conforms to a theoretical decrease in annual tree growth increments due to the geometry of an increasing trunk diameter.

LINEAR REGRESSION LINE

The simplest detrending method is to fit a least squares regression line through the data:

$$Y = A * t + D$$

It conforms to no theoretical model of tree growth, and is probably best used on series that are relatively short or that have an unusual growth pattern that the negative exponential curve cannot accommodate.

DATA FORMAT

Program EXTRAP reads ring measurement series from a data file in standard format for ring measurements established by the International Tree-Ring Data Bank (ITRDB), known also as the Tucson format for measurements. If the format of your data is different from this, you may change it using Program DPL/FMT (Routine FMT in the Dendrochronology Program Library). Output data files are also in measurement format.

ITRDB standard ring measurement format is (A8,I4,10I6) for each line, where (A8) is the series identification, (I4) the first year of data in the decade, and (10I6) a decade of ring measurements, usually in units of .01 mm. If the first year does not end in 0, the actual first year of data is recorded, and the first spaces for measurement values contain measurements through the year ending in 9. Succeeding lines contain full decades of measurements from the year ending in 0 through the year ending in 9. Following the last actual data value is a dummy value of 999 to indicate the end of the series; this may require a new line with only the dummy value. The first decade of the next series follows on the next line.

RUNNING PROGRAM EXTRAP

Either upper or lower case may be used in responding to prompts. At any point where a response is requested you may quit the program by responding with a slash ("/").

The output file for printing is EXTRAP.OUT and contains page breaks, allowing it to be printed with the desired line spacing and paging on standard printers. Data output files have names provided by the user.

ACKNOWLEDGEMENTS

Program EXTRAP was written at the request of graduate student Linda Mutch in February 1993 by Richard L. Holmes in ANSI Standard Fortran-77. It is modeled after an earlier program also written by Holmes at the University of Hamburg in December 1986 for Prof. Dr. Dieter Eckstein and graduate student Ursula Bentrup. Versions of Program EXTRAP are available for the VAX and most other mainframe computers and for IBM-PC compatible computers.

REFERENCE CITED

Fritts, H.C., Mosimann, J.E., and Bottorff, C.D. 1969. A revised computer program for standardizing tree-ring series. Tree-Ring Bulletin 29:15-20.

Program FMT

Change format, manipulate data

USERS MANUAL for Program FMT by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program FMT converts data files from one format to another, with the option to perform one or several operations on each series.

Codes and names of formats in which data may be read from an existing file (explanation below):

C:	Compact format (default)
M:	Measurements with precision of 0.01
L or 3:	Measurements with precision of 0.001
I:	Index or chronology format
A:	Accurite ring measurements
T:	Meteorological data format
S:	Spreadsheet (casewise) format
1:	Single column of values
2:	Two columns: year, value
V:	Two columns: value, year (includes "Universal Vertical")
X:	User-supplied format

Formats in which data may be written to a new file (explanation below):

C:	Compact format (default)
M:	Measurements with precision of 0.01
L or 3:	Measurements with precision of 0.001
I:	Index or chronology format
S:	Spreadsheet converted to series by column or by row
2:	Two columns: year, value
V:	Two columns: value, year ("Universal Vertical")
T:	Meteorological data format
K:	Meteorological to separate meteorological months
W:	Individual months to meteorologic format
P:	Publication format for chronologies
X:	User-supplied format

You may choose among any of these formats for input and output files. See the section above on DATA FORMATS for detailed descriptions of available formats.

OPTIONS FOR DATA MANIPULATION

In addition to reading and writing data files the program is capable of performing several manipulations of data. When prompted for the format of a new file, K and W are special cases.

K = Data in a file in meteorological format will be separated into series of individual months. You may elect to have them placed consecutively in a single file, or each month in a separate file. If desired you may select those months to copy. (This procedure is the inverse of "W".)

W = Individual series may be combined consecutively into a single series in meteorological format. (This procedure is the inverse of "K".)

The menu gives additional options for data manipulation, listing the option and the initial setting:

```
 1  Select series to include                           Include all
 2  Time stamp title: [10MAY94-1740]                       No
 3  Truncate series start & end                      0     0  (No truncation)
 4  Minimum length of series to include                    0  (No minimum)
 5  Include only series covering                     0     0  (Include all)
 6  Adjust year dates of all series                        0  (No adjustment)
 7  Multiply data by constant                         1.0000  (No multiplier)
 8  Add constant to data                              0.0000  (No constant)
 9  Save sample depth from chronology                      No
10  Spline fit to data                                     No    0.00
      Fit cubic smoothing spline to data and save SPLINE curve
      or INDICES from division.  Specify spline rigidity.
11  Autoregressive modeling                                No
12  Normalize series                                       No
13  Set skewness and Kurtosis to zero                      No
14  Convert between Fahrenheit and Celsius                 No
15  Separate file for each series                          No
```

If desired, the data may be multiplied by a constant and/or have a constant added. If both, you specify which operation is done first.

If the data are chronology indices, you may save also the number of series for each index.

You may truncate at the beginning and/or end each series that surpasses the dates you specify. By specifying both beginning and ending years you will make a rectangular matrix of data.

To accommodate archaeological work or very long series where 8000 is sometimes added to the date, the dating may have a positive or negative constant added to it. Thus if a series is dated -400 to 1986, adjusting the year date by 8000 will yield "dates" of 7600 to 9986. Conversely, if a series is "dated" 7600 to 9986, adjusting by -8000 will give dates of -400 to 1986.

Each series may be normalized to a mean of zero and variance of one.

The first line of the original file may be copied into the new file as a title, or you may provide a new title. Responding with <CR> when prompted will omit a title from the new file.

Program JOLTS

FINDING GROWTH SURGES OR SUPPRESSIONS IN TREES

Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1998; February 1999

INTRODUCTION

In January 1995, Dr. Christopher Fastie expressed interest in examining the occurrence, coincidence and statistical characteristics of growth surges in Alaskan trees. After consultation with Dr. Thomas W. Swetnam and Richard L. Holmes, this program was written to assist Dr Fastie in his project. VAX-VMS ANSI Fortran-77 programming language was used to develop the program, and subsequently the program was compiled with Microsoft "PowerStation" (1993) Fortran-77 for PC compatible computers, and in LS Fortran for Power Macintosh.

Subsequently Dr. Fastie requested modifications to the program, including the capability to find suppressions as well as surges in growth. At this point the name of the program was changed from SURGES to JOLTS.

PURPOSE OF PROGRAM JOLTS

To find surges or suppressions in tree growth. The term "jolts" is used to mean either surges or suppresions, according to the user's choice for the program run.

Menu choices include:

1 The RUNNING MEAN method, window size:
    Number of years in running mean prior to jolt
    Number of years in running mean starting at jolt

2 The SMOOTHING SPLINE method, offset years:
    Number of years prior to jolt to look at spline value
    Number of years following jolt to look at spline value

3 Spline rigidity
    A smoothing spline may be fit to the series to avoid sudden changes that may occur in the running mean. Enter a frequency response period for the spline

4 Jolt factors for the change from pre- to post- jolt to define growth jolts
    (Must be greater than 1.0):
        Running mean jolt factor
        Spline jolt factor

5 Time span to analyze
    Time span for analysis; for entire time span respond with <CR> twice:
    First year and last year of analysis
    If zeroes, analysis by time span cancelled

6 Tree age span to analyze
    Span of tree ages (ring numbers) for analysis; for rings of all ages respond with zero twice:
    First ring number of analysis
    Last ring number of analysis
    If negative, analysis by tree age cancelled

7 Files created by the program are:

Output for printing	(Out)	File name ____.OUT
Summary statistics	(Sum)	Appended to existing file

Graphics spreadsheets (Gra) File names ____JLT.GRR and ____ JLT.GRS
Fire History (FHX2) format (Fhx) File names ____ JLT.FHR and ____ JLT.FHS

The user may choose to save on disk any or all of these files.

Reported for RUNNING MEAN and SMOOTHING SPLINE methods:
Number of series with jolts
Jolts in all trees
Jolts per tree, all trees
Jolts per tree with jolts
Informs if first year of running mean factor is always smaller (if surge) or always larger (if suppression) than the mean of rings prior to the jolt.

Summary of jolts found:
Jolt factor, Running mean method and Spline method, Mean & St Dev
Spline maximum slope in jolts, Mean & St Dev

Spreadsheet files for use in graphics programs:
File ___JLT.GRR contains data from the running mean method
File ___JLT.GRS contains data from the spline method

Information in columns of spreadsheet files:
Column 1 Year
Column 2 Count of trees
Column 3 Count of trees recording
Column 4 Mean tree radius
Column 5 Trees in first year of jolt
Column 6 Mean jolt value
Column 7 Std dev of jolt value
Column 8 Mean tree radius at first year of jolt
Column 9 Percent of trees recording
Column 10 Trees in year of maximum jolt
Column 11 Mean jolt value
Column 12 Std dev of jolt value
Column 13 Percent of trees recording
Column 14 Trees within jolt
Column 15 Mean jolt value
Column 16 Std dev of jolt value
Column 17 Percent of trees recording

DENDROECOLOGY PROGRAM LIBRARY

PROGRAM OUTBREAK USERS MANUAL

Detecting Outbreaks of Spruce Budworm and Tussock Moth
in Annual Tree-Ring Growth,
and Distinguishing Between the Insect Species

by Richard L. Holmes and Thomas W. Swetnam
Laboratory of Tree-Ring Research
University of Arizona, Tucson, Arizona USA

September 1996

INTRODUCTION

In April 1993 Dr. Thomas W. Swetnam, head of the Fire History group at the Laboratory of Tree-Ring Research at the University of Arizona, requested that a computer program be written to assist in reconstruction and analysis of a multicentury history of outbreaks of western spruce budworm (Choristoneura occidentalis Freeman) and Douglas-fir tussock moth (Orgyia pseudotsugata McDunnough) in Oregon.

Data for this study consisted of sets of annual series of tree-ring width measurements of tree species that serve as hosts to the insects and of control species that do not serve as hosts. From previous work we know that characteristic tree-ring patterns caused by these two insects, known as signatures, may be detected and quantified in tree-ring series. To carry out this task Richard L. Holmes developed Program OUTBREAK, using VAX-VMS Version 6.1 (1993) ANSI Fortran-77 programming language and the University's VAX mainframe computer. Subsequently the program was adapted for Microsoft "PowerStation" (1993) Fortran-77 to run on PC-compatible computers of level 386 or newer.

Features were added to the program as researchers used it to study insect outbreaks. The program may be used for studies similar to this in other locales and with other pests.

PURPOSE OF PROGRAM OUTBREAK

Program OUTBREAK attempts to identify occurrences of spruce budworm and tussock moth outbreaks in indexed series of annual tree-ring width measurements, and to distinguish between outbreaks by the two species. The length and severity of each outbreak is quantified and presented in tables and graphically for each tree and for the mean of all trees. A year-by-year list is printed showing departures and count of trees affected by outbreaks. Histograms show distributions of outbreak length, maximum growth reduction, mean periodic growth reduction and maximum rate of growth reduction. The corrected mean series is listed. A file is produced which may be read directly by spreadsheet and graphics programs.

Upon starting Program OUTBREAK the user gives a run identification of up to five letters and numbers which will identify files created by the program. If no name is given, then "ZZ" is the run identification.

The user provides the names of two (or one) input data files. If two files, the first is a tree-ring control (non-host) index chronology; the second is a set of experimental tree-ring index series, each usually representing individual trees. If only one file, this is a set of experimental tree-ring index series already corrected with a control chronology or not needing correction.

The control chronology, from a species unaffected by these insects, is subtracted from each experimental series to diminish the effects of climatic variation.

A title may be given to describe the run, then a menu of control options which the user may modify.

The following appears on the screen as the program runs. Text typed by the user appears in bold:

```
*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*

                        DENDROECOLOGY PROGRAM LIBRARY

                      P R O G R A M     O U T B R E A K

                   Finds Outbreaks of BUDWORM and TUSSOCK

                                Version 1.50P

*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*=*

Identify job (up to 5 letters) => ABCDE        (In this example, this is the
identification for files)

Provide the names of files with
  (1) CONTROL (NON-HOST species) chronology, and
  (2) HOST species experimental tree indices or chronologies

If you respond with <CR> to the CONTROL chronology prompt, the TREE-GROWTH
indices or chronology will be considered to be already corrected.

CONTROL CHRONOLOGY  (Non-host)
  ... Name of EXISTING INPUT file => CONTROL.DAT

First 5 lines of file CONTROL.DAT
524=N    1469=I Ctrl_A                                                 -5(13F6.0)
183503149290130316 98827 98021 57144 933791152831444531821031606051357771O8928
 80869 56846 81879 30804 76632 85818 76330 34742 54224 58162 46654 41305 18794
 17683 36561 39287   522135697 87039 75733 54927 97020 884931344291389731247 37
135237127511125041138621113989105055165375159517103892120043100609 80616 71540
....:....1....:....2....:....3....:....4....:....5....:....6....:....7....:....8
Format is Compact, correct?  <Yes>/No => <CR>

HOST TREE INDICES or CHRONOLOGIES
  ... Name of EXISTING INPUT file => SPRUCE.DAT

First 5 lines of file SPRUCE.DAT
107=N    1885=I Spruce                                                 -5(13F6.0)
151504 91983 98648105514 98116 95978110323 970631291981121981290 61 89229128924
143858119494151898141879 92890 73192 71768 52886 63070 77692 78993 69399 69894
 60102 77940 907341153161473511248 58 95520 86843 84010 87020 75125 57293 80944
101889118553 98546116311108059 937861105401223701241611390961303 48 87388 72027
....:....1....:....2....:....3....:....4....:....5....:....6....:....7....:....8
Format is Compact, correct?  <Yes>/No => <CR>

TITLE FOR THIS RUN => Spruce tree summaries and Control chronology A
```

A menu then appears on the screen, listing the options and current selected values:

```
Options:                                                     Current values

       P  Names of pests                                     BUDWORM TUSSOCK

Maximum growth reduction threshold in STD DEV
       1  BUDWORM                                               -1.28
       2  TUSSOCK                                               -1.28

Minimum number of years for outbreak
       3  BUDWORM                                                   8
       4  TUSSOCK                                                   3

Maximum years to count in outbreak
       5  TUSSOCK                                                   4
       6  Rate of increase in growth reduction to
            identify TUSSOCK outbreaks                          1.000

       7  File for plotting with PAGEPLOT                           N
       8  File of negative corrected indices                        N
       9  Fractional power for control indices > 1             1.0000
```

Number of option to modify or <CR> to proceed => 9 (In this example, you select item 9)

Fractional power to raise Control chronology indices greater than 1.0 to avoid false corrections

Power to raise indices > 1.0 (0. to 1.) => .3

The menu reappears on the screen, listing current selected values. The one that was changed was:

9 Fractional power for control indices > 1.0 .3000

Finally, touching Enter (<CR>) in response to the prompt starts execution of the program:

Number of option to modify or <CR> to proceed => <CR>

Files created by the program are:

```
      ABCDEOBR.OUT      output for printing
      ABCDEOBR.COR      tree indices corrected, Measurement format
      ABCDEOBR.MNC      mean of corrected tree indices, Measurement format
      ABCDEOBR.NOR      tree indices corrected, normalized, Compact format
      ABCDEOBR.DIF      differences, uncorrected minus corrected, Compact format
      ABCDEOBR.COL      data in tab-delimited columns for spreadsheet
                   OBR.CRN    mean chronology in publication format, appended
```

And if you choose menu item 7, "File for plotting with PAGEPLOT":
ABCDEOBR.PLU Uncorrected experimental indices & control to plot overlaid

OPERATION OF PROGRAM OUTBREAK

Correcting by means of the control chronology

The control chronology is read, then one by one the experimental tree-ring index series are read. For each series descriptive statistics for the common time span of the control chronology and experimental series are printed. If requested, these series and their differences are saved on disk file for plotting.

Each yearly index value in the experimental series is corrected by subtracting from it the corresponding control chronology index, adjusting for differences in the means and standard deviations of both series by the equation:

$$Hc(i) = Hi(i) - (Ci(i) - Cmn)\ Hsd / Csd$$

where Hc(i) is the host chronology corrected index for year (i)
Hi(i) is the host tree-growth index for year (i)
Ci(i) is the control chronology index for year (i)
Cmn is the control chronology mean in the common time span
Hsd is the host series standard deviation in the common time span
Csd is the control chronology standard deviation in the common time span

If negative values occur in the corrected experimental series, they are set to zero.

If menu item 9 was set to a value less than 1.0, each index in the control chronology exceeding 1.0 is raised to the specified fractional power before subtracting it from the experimental series, but the original mean and standard deviation are used in the equation. The purpose of this adjustment is to suppress the effect of large positive excursions in the control chronology which, when subtracted from the experimental series, will introduce apparent growth depressions that may be erroneously diagnosed as insect outbreaks.

If the user has not provided the name of a control chronology file, the experimental series are considered to be already corrected or to need no correction, and the process just described is not done.

After reading all tree-ring index series, mean series and descriptive statistics are computed for:

(1) Mean of corrected tree-ring indices
(2) Mean of normalized corrected tree-ring indices
(3) Differences, uncorrected minus corrected series

Processing the corrected series

Each corrected experimental series is scanned as described below for evidence of insect outbreaks over its entire time span, or over time spans specified by the user.

Spruce budworm outbreaks

To locate spruce budworm outbreaks, a preliminary scan flags with "b" all years in the normalized series that are negative, that is, where experimental tree growth is less than growth in the control chronology.

Since during a budworm outbreak there may occasionally be a single year where growth is normal or above (meaning growth increase rather than reduction), the outbreak is allowed to have up to one positive value between negative values within the outbreak period before the year of maximum growth reduction, and one such value after that year. If more than one is found the potential outbreak span is shortened accordingly and the new outbreak span is checked again.

The first and last years of potential budworm outbreaks are determined by locating the ends of consecutive strings of flagged years.

Each potential budworm outbreak is checked for compliance with the selected values in the menu. If it does not attain the threshold in standard deviations for maximum growth reduction or the minimum length for budworm outbreaks it is eliminated as a possible outbreak. Maximum growth reduction and percentage of growth reduction is calculated, and the maximum year-to-year increase in growth reduction is found. The year of maximum growth reduction is flagged with a capital "B".

Mean periodic growth reduction is summed over the span of each outbreak. Information on spruce budworm outbreaks for the experimental tree-ring series is recorded.

Tussock moth outbreaks

A procedure similar to that for spruce budworm is followed for tussock moth. To locate tussock moth outbreaks, a preliminary scan flags with "t" all values in the normalized series that are negative. The first and last years of potential tussock outbreaks are determined by locating the ends of consecutive strings of flagged years.

Each potential tussock moth outbreak is checked for compliance with the selected values in the menu. If it does not attain the threshold in standard deviations for maximum growth reduction or the minimum length for tussock outbreaks, or if the rate of increase in growth reduction fails to meet the threshold, it is eliminated as a possible outbreak. Only the first four years (by default) are considered to be part of the tussock outbreak, and the outbreak is eliminated if it does not have four years by the end of the series. Maximum growth reduction and the percentage of growth reduction is calculated, and the maximum year-to-year increase in growth reduction is found. The year of maximum growth reduction is flagged with a capital "T".

Mean periodic growth reduction is summed over the span of each outbreak. Information on tussock moth outbreaks for the experimental tree-ring series is recorded.

Tabulation of outbreaks by series

A listing of outbreaks is printed for each tree, indicating which insect was determined to be responsible, the time span of the outbreak, year and amount of maximum growth reduction, the mean periodic growth reduction, and the year and amount of maximum year-to-year increase in growth reduction. If an outbreak fits the criteria established for both insects, it may be attributed to both; the time span and other characteristics may however be different.

Following the listing a two-line time plot is printed, one line for budworm, one for tussock, covering one century across the page. For each year is indicated whether there was determined to be no outbreak ("."), a budworm ("b") or tussock ("t") outbreak, or a maximum growth reduction year for a budworm ("B") or tussock ("T") outbreak.

Yearly list of departures and counts

A yearly list of departures is printed for each tree, one column per year, a decade per section. Each departure value is flagged as above if it is in a budworm ("b") or tussock ("t") outbreak, or if it is a maximum growth reduction year for a budworm ("B") or tussock ("T") outbreak. At the foot of the column for each year are counts of the number of trees, the count of infested trees ("ct") and the count of trees in maximum growth reduction ("mx") in the outbreak, for budworm and tussock.

Plot of outbreaks by series and year

The next section of printed output is a condensed version of the two-line time plot described above in the section on tabulation of outbreaks by series, allowing an overview of outbreak intervals. The corrected mean series is also included in this plot with the same analysis as is done for individual trees.

Histograms

A set of histograms presents the distribution of counts of outbreaks for spruce budworm ("[" toward the left) and tussock moth ("]" toward the right) for:

(1) Length of outbreak in years
(2) Maximum growth reduction as departure in standard deviations
(3) Maximum growth reduction as corrected index
(4) Maximum growth reduction as percent
(5) Mean periodic growth reduction
(6) Maximum rate of increase of growth reduction

Corrected mean series

Finally the corrected mean series is listed, showing annual indices and number of trees.

Data file in tab-delimited columns for spreadsheet

A disk file is produced which may be read directly by spreadsheet and graphics programs. The file name is ABCDEOBR.COL. The ten tab-delimited columns in this file contain:

(1) Year
(2) Number of trees in the analysis
(3) Count of trees in a BUDWORM outbreak event
(4) Percent of trees in a BUDWORM outbreak event
(5) Count of trees in a BUDWORM year of maximum growth reduction
(6) Count of trees in a TUSSOCK outbreak event
(7) Percent of trees in a TUSSOCK outbreak event
(8) Count of trees in a TUSSOCK year of maximum growth reduction
(9) Mean corrected tree index
(10) Normalized corrected mean index

Program capacity

Maximum length of tree-ring series	4096 years
Maximum time span of tree-ring series	2076 BC to AD 2020
Maximum number of trees	2560
Maximum number of outbreaks per series	128

Program PCA

Principal components analysis

USERS MANUAL for Program PCA by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program PCA performs a principal components analysis is done on a set of time series in a file, and eigenvalues, eigenvectors and principal components are saved, along with output for printing.

After you give the data file name the overall time span and the optimum time span will be displayed. The optimum time interval is the largest possible rectangular matrix in the data set. You may select the time interval to analyze, in which case all time series covering the interval will be used. If you respond with <CR> to the prompt for start and/or end of the time interval the program will select the start and/or end of the optimum interval.

You are prompted for a 3- or 4-character mask for identification. Ideally you should choose positions which uniquely identify each series. For example, if a typical series identification is CPP06B where all series start with CPP, you may want to use a mask of "---xxx" where "-" is a space and "x" is any non-blank character. You are also prompted for a three- or four-character identification, which should be a general identification; in this example you might use CPP.

The file with extension ".EV" contains the eigenvalues and eigenvectors, the file with extension ".PC" contains the principal components, and the file with extension ".ID" contains the masked unique identifications of the series. The data file is easily plotted by the scattergram program SCATTER (see description).

Program RESPO

Response and correlation function

USERS MANUAL for Program RESPO by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program RESPO computes response functions of tree growth to climate by means of principal components, using two methods for selecting components for the regression. The correlation function is also calculated and printed along with the response function. Regression weights may be saved for subsequent plotting or for reconstruction.

If you want to print the principal component and correlation matrices, respond "N" to the question on condensed output.

With the "E" type analysis, RESPO may be used to reconstruct a tree-ring chronology or climate from proxy data and regression weights from a prior run of Program RESPO.

For the tree-ring chronology, you may select a version of the chronology (STD, RES, ARS) or by responding with <CR> to select the first chronology in the file. If the data are for the Southern Hemisphere, where months of meteorological data may have a calendar date later than that of the tree ring chronology, respond "S" to adjust the chronology dates.

In giving the first and last years of analysis, remember that if the response period selected goes back to the prior year, the first year of analysis must be at least one year later than the first year of meteorological data. The same is true for the chronology if prior years of growth are to be considered. If you respond to the prompt for time interval with <CR> the maximum possible interval will be used.

If you wish to consider for example a tree-response period from the previous July through the current September, the response period would have 15 months. You would respond by specifying month 9 (September) as the latest month of analysis for both temperature and precipitation, and specifying 15 months to use. If you respond to the prompt with <CR> months 1 through 12 will be used.

You may save the values for the correlation and response function for plotting; the file will have the name ABCDERES.PLT.

Program RESPO was written by Dr. Janice M. Lough of the Australian Institute of Marine Science, Townsville, and modified by Richard L. Holmes.

DENDROECOLOGY PROGRAM LIBRARY

Description of Program SAMDEP

Selection of series to achieve a level sample depth over time

by Richard L. Holmes
Laboratory of Tree-Ring Research
University of Arizona, Tucson, Arizona USA

April 2000

Purpose of program SAMDEP

Since time machines have not yet been invented, site collections of tree-ring samples must be obtained from available trees. As a result the time span covered by the samples is often much better represented for some spans of years than for others, resulting in uneven sample depth. Most often the sample depth decreases as one goes back in time from the present and trees drop out of the sample. Archeological collections, on the other hand, may exhibit irregular variations in sample depth through time.

In January 1999 Dr. Christopher Baisan of the Dendroecology and Fire History group at the Laboratory of Tree-Ring Research, University of Arizona, requested that a computer program be written to assist in leveling out the sample depth of tree-ring measurement site collections. The desirability of this quality is:

(1) Tree-ring chronologies computed from collections of widely varying sample depth may exhibit different time-series characteristics between the well-replicated portions and those with few samples.

(2) When developing long time series for reconstruction of a parameter such as precipitation, temperature or streamflow where data are available for the most recent period, the time span paralleled by the instrumented data should be as similar as possible to the span to be reconstructed in all characteristics other than the variability imposed by exogenous factors. In addition, short series that do not extend much beyond the instrumented data add nothing to the reconstruction, since they are absent during the time span of the reconstruction.

Program SAMDEP ("Sample Depth") produces a new file containing a subset of series which attempts to maintain an even sample depth chosen by the user.

Algorithm used to level the sample depth

The input file is a set of detrended tree-ring series from a site collection, though original measurements may also be used. Output files are (1) the series selected to obtain as level as possible sample depth throughout; and (2) a log file describing what the program did.

The user specifies the target sample depth for the collection

The user may set the relative importance to be given to inclusion in the selected set to the length of the series, its mean correlation with other series, and its mean sensitivity. The latter two are available only if there is an output file from a run of Program COFECHA for this same data set; in this case Program SAMDEP reads Part 7 of the output to find the mean correlation and mean sensitivity of each series. Note that the run of Program COFECHA must be for the same data set with the series in the same order.

The user may also tell the program to include in the selected set all series of a certain length or greater, and/or to exclude any series less than a certain length.

Program SAMDEP first calculates the sample depth for each year of the time span covered by the series. All series are selected for the new set that cover years where the sample depth is at or below the target level.

The series are given a ranking which combines the series length, mean correlation with other series, and mean sensitivity. The algorithm for including samples is based on a score combining the following weights, with low score being best:

```
           1.0  times rank for length
       +   1.5  times rank for mean correlation with other detrended series
       +   0.5  times rank for mean sensitivity
```

These weights are adjustable by the user; default values are shown here.

The program then looks at those years where sample depth is greater than the target but the selected set is less than the target. The program examines each series not yet included in order of its ranking. If it covers any part of the selected set where the target sample depth is not reached, the series is included, sample depth is recalculated for the entire span, and the procedure in this paragraph is repeated.

When the inclusion of additional series does not bring up the sample depth of any year where it is still under the target, the program creates the new file and stops.

xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>xv>

The following is screen output of a run of Program SAMDEP. Text typed by the user appears in bold italics:

```
Program SAMDEP:  Selection of series for sample depth

Input data is detrended tree summary series from a tree-ring collection site.
Optional input is the Program COFECHA file for printing (Part 7 is used);
this must be for the same series in the same order as the input data.

Output is a selection of series according to the criteria selected
by the user for TARGET SAMPLE DEPTH, and weights (relative importance)
for ranking the series by LENGTH in years, CORRELATION with
other series, and mean SENSITIVITY.

Original series
  ... Name of EXISTING INPUT file =>  FRE.RWM

___First  5 lines file FRE.RWM
FREDERICK BUTTE, OREGON  [JUOC]  COFECHA  6 MAY 85
455=N    1498=I FRE01A                                          -2(26F3.0)
 90 50 54 48 34 87 88 70 70 61 50 27 34101 64 18 40 21 27 15 19 64 24 19 53101
 64 30 52 56 33  8 61 51  9 54 64 69 86 46 93118 53 86 72 17 53 41 34 41 26 41
 39 70 48 51 23 31 50 64 47 50 68 36 45 48 86 68 77 69 66 56 43 16 35 68 56 27
....:....1....:....2....:....3....:....4....:....5....:....6....:....7....:....
Format is Compact or Precision, correct?  <Y>/N =>  Y

COFECHA output file (Optional)
  ... Name of EXISTING INPUT file =>  FRECOF.OUT

Selected series
  ... Name of NEW OUTPUT file =>  FRESEL.LOG
```

```
Opening log file FRESEL.LOG

Reading COFECHA output file
   1903 lines read from COFECHA output
Time span  1097 to  1982   886 years,  76 series,  22228 rings

Where sample depth does not exceed the target, all series will be used.
In the time span where there are more samples than required, a selection
will be made based on the weighted rank of the series by LENGTH, and
if COFECHA output is used, by CORRELATION and SENSITIVITY as well.

MENU OPTIONS                      Current values
  T  Target sample depth                20

Weights (relative importance) for ranking series by:
  L  Length in years                  1.00
  C  Correlation with other series   1.50
  S  Mean sensitivity                   .50

Option or <CR> to proceed =>  T
Provide a target sample depth  <20> =>  20

Where sample depth does not exceed the target, all series will be used.
In the time span where there are more samples than required, a selection
will be made based on the weighted rank of the series by LENGTH, and
if COFECHA output is used, by CORRELATION and SENSITIVITY as well.

MENU OPTIONS                      Current values
Relative weight to give to ranking of series
  by LENGTH in years  <1.0> =>  1.0

Where sample depth does not exceed the target, all series will be used.
In the time span where there are more samples than required, a selection
will be made based on the weighted rank of the series by LENGTH, and
if COFECHA output is used, by CORRELATION and SENSITIVITY as well.

MENU OPTIONS                      Current values
Relative weight to give to ranking of series
  by CORRELATION with other series  <1.5> =>  1.5

Where sample depth does not exceed the target, all series will be used.
In the time span where there are more samples than required, a selection
will be made based on the weighted rank of the series by LENGTH, and
if COFECHA output is used, by CORRELATION and SENSITIVITY as well.

MENU OPTIONS                      Current values
Relative weight to give to ranking of series
  by Mean SENSITIVITY  <0.5> =>  0.5

Where sample depth does not exceed the target, all series will be used.
In the time span where there are more samples than required, a selection
will be made based on the weighted rank of the series by LENGTH, and
if COFECHA output is used, by CORRELATION and SENSITIVITY as well.

MENU OPTIONS                      Current values
Option or <CR> to proceed =>  <Enter>

Length of series in years, ordered long to short, ten per line:
   629    608    582    551    505    455    450    438    415    407
   407    386    358    346    328    319    318    309    306    303
   303    300    299    298    295    286    273    272    271    271
```

```
   269    269    265    260    257    256    256    255    255    255
   252    250    250    249    249    248    248    248    245    244
   244    244    243    242    242    242    241    241    241    241
   241    240    239    236    236    229    224    221    221    217
   217    216    209    198    167    128

Include all series of what length and longer?
        <CR> = None included automatically =>  500

Exclude all series shorter than what length?
        <CR> = None excluded automatically =>  200

Selected series:
Time span  1097 to  1982   886 years,  32 series,  11703 rings
Percent of series retained  42.11
Percent of rings  retained  52.65
Theoretical minimum pct     50.32   11185 rings

The following is a .LOG file output from the same run of Program SAMDEP.

PROGRAM SAMDEP: Selection of series for length and sample depth

Original file of series:     FRE.RWM
New file of selected series: FRESEL.RWM
Log file of program run:     FRESEL.LOG
COFECHA output file:         FRECOF.OUT

Input data is detrended tree summary series from a tree-ring collection site.
Optional input is the Program COFECHA file for printing (Part 7 is used);
this must be for the same series in the same order as the input data.

Output is a selection of series according to the criteria selected
by the user for TARGET SAMPLE DEPTH, and weights (relative importance)
for ranking the series by LENGTH in years, CORRELATION with
other series, and mean SENSITIVITY.

Time span  1097 to  1982   886 years,  76 series,  22228 rings

Target sample depth is                  20

Weights (relative importance) for ranking of series by:
  L  Length in years                  1.00
  C  Correlation with other series    1.50
  S  Mean sensitivity                  .50

Sequence number and LENGTH, ranked
   4  629   3  608   2  582  57  551  59  505   1  455  37  450  20  438
  25  415  38  407  58  407  73  386  16  358  28  346  14  328  13  319
... etc. ...
  26  236  50  229   6  224  71  221  22  221  68  217  66  217  67  216
  23  209  19  198  65  167  34  128

Sequence number and CORRELATION, ranked
  57 .906  59 .896  58 .884  53 .866  60 .861  67 .859  46 .855  50 .847
  56 .845  51 .844  34 .842  52 .835  38 .833  12 .833  55 .833  37 .831
... etc. ...
  72 .695  63 .693  65 .689  73 .688  20 .672  19 .662  18 .655  70 .655
  23 .654  22 .599  21 .589  24 .541

Sequence number and SENSITIVITY, ranked
  42 .705  58 .703  52 .696  54 .688  53 .665  41 .664  59 .653  55 .652
```

```
  45 .646  60 .643  57 .632  46 .609  56 .609  49 .607  28 .603  51 .599
... etc. ...
  39 .406  68 .396  31 .387  69 .379  29 .376  74 .335  36 .333  26 .332
  73 .326  35 .326  23 .268  22 .264

Series of length  500 or more are included

Series shorter than  200 are excluded

Sequence number and SCORE, ranked (low score is better)
   57    95.   59   100.   58   143.   53   247.   60   325.   56   381.
   46   411.   54   446.   52   446.   51   450.   38   506.   37   532.
... etc. ...
   63  1476.   71  1519.   70  1528.   66  1571.   65  1610.   24  1680.
   19  1680.   26  1706.   22  1887.   23  1905.

 ORIGINAL Sample Depth
                          Annual values
 Date     0    1    2    3    4    5    6    7    8    9
 1097                                          1    1    1
 1100      1    1    1    1    1    1    1    1    1    1
... etc. ...
 1690     19   19   19   19   19   19   19   20   20   20
 1700     20   20   20   20   20   20   20   20   20   20
... etc. ...
 1960     60   60   60   60   60   60   60   59   59   59
 1970     59   59   59   59   59   59   59   59   59   59
 1980     59   59   59

Time spans at or above target sample depth of  20 series:
  Depth is OK from  1637 to  1637     1 years
  Depth is OK from  1697 to  1982   286 years

Time spans below target sample depth:
  Below depth from  1097 to  1636   540 years
  Below depth from  1638 to  1696    59 years

Sample depth OK in    287 years  32.39 %
Low sample depth in   599 years  67.61 %
Total time span is    886 years

 SELECTION Sample Depth
                          Annual values
 Date     0    1    2    3    4    5    6    7    8    9
 1097                                          1    1    1
 1100      1    1    1    1    1    1    1    1    1    1
... etc. ...
 1690     19   19   19   19   19   19   19   20   20   20
 1700     20   20   20   20   20   20   20   20   20   20
... etc. ...
 1960     20   20   20   20   20   20   20   20   20   20
 1970     20   20   20   20   20   20   20   20   20   20
 1980     20   20   20

   4 iterations

     5 series selected for length
    27 series selected for sample depth
    32 total series selected

Selection status of each series  Key:  L  Selected for length
```

```
                                                N  Selected for sample depth
                                                X  Omitted
 Seq  Ident    Start / End Years  Status
   1  FRE01A    1498  1952   455    N    INCLUDED
   2  FRE01B    1401  1982   582    L    INCLUDED
   5  FRE03A    1742  1982   241    X     omitted
... etc. ...
  12  FRE08A    1680  1982   303    N    INCLUDED
  13  FRE08B    1664  1982   319    N    INCLUDED
... etc. ...

Time spans at or above target sample depth of  20 series:
  Depth is OK from  1697 to  1982   286 years

Time spans below target sample depth:
  Below depth from  1097 to  1696   600 years

Sample depth OK in    286 years  32.28 %
Low sample depth in   600 years  67.72 %
Total time span is    886 years

New file of selected series: FRESEL.RWM
Time span  1097 to  1982   886 years,  32 series,  11703 rings
Percent of series retained  42.11
Percent of rings  retained  52.65
Theoretical minimum pct     50.32   11185 rings

Length of selected series in years, ordered long to short:
    629    608    582    551    505    455    450    438    415    407
    407    386    358    346    328    319    318    309    306    303
    303    300    299    298    295    286    271    269    269    260
    217    216

Time spans at or above target sample depth of  20 series:
  Depth is OK from  1697 to  1982   286 years

Time spans below target sample depth:
  Below depth from  1097 to  1696   600 years

Sample depth OK in    286 years  32.28 %
Low sample depth in   600 years  67.72 %
Total time span is    886 years
```

Program SCATTER

Scattergrams

USERS MANUAL for Program SCATTER by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program SCATTER produces line printer scattergram plots of pairs of data points in two series in a file. Each point is plotted in the X-axis direction as a value in the first series, in the Y-axis direction as a value in the second series.

The series to be plotted need not be consecutive in the file. Several plots may be made using the same or different pairs of data series. For example, from the *.EV or the *.PC file output by Programs ARSTAN and PCA. For example, eigenvector 1 may be plotted versus eigenvector 2, then eigenvector 1 versus eigenvector 3. Another example is to plot one chronology or time series versus another to determine years of agreement and divergence.

Symbols displayed at each point may have up to three characters. You may elect to number the points consecutively beginning with a number of your choice such as 1 or a year; to input from the keyboard a symbol for each point; or to prepare beforehand a file of these symbols listed in a single column. If you are plotting eigenvectors from a run of Program PCA, the file with extension ".ID" is produced for this purpose.

Description of computer program SIGLOF

SIGNIFICANCE OF LOW FREQUENCY VARIANCE IN TREE-RING CHRONOLOGIES

Richard L. Holmes
Laboratory of Tree-Ring Research
University of Arizona

June 1995; Febrary 1999

INTRODUCTION AND PURPOSE OF PROGRAM SIGLOF

Dr. Ramzi Touchan and Gregg Garfin of the Laboratory of Tree-Ring Research were interested in putting to use the technique for identifying low-frequency tree-ring variation as described by Paul Sheppard (1991). They asked Richard L. Holmes to write a Fortran program to apply the technique and to produce a spreadsheet file for plotting by a graphics program such as Excel. VAX-VMS Version 6.1 (1993) ANSI Fortran-77 programming language and the University's VAX mainframe computer were used to develop program SIGLOF. Subsequently the program was compiled with Microsoft "PowerStation" (1993) Fortran-77 to run on PC compatible computers.

A set of tree-ring measurement series are first detrended using a method which preserves low-frequency variance equal to and shorter than the wavelengths of interest. There are three methods for accomplishing this:

(1) A deterministic curve may be fit to the time series, such as a modified negative exponential curve or linear regression line. Each measurement value is then divided by the corresponding value of the curve, and the resulting indices are saved. Program ARSTAN or CRONOL may be used to accomplish this.

(2) A stochastic curve may be used, such as a cubic smoothing spline of frequency response sufficiently long so as not to remove variance expressed in the range of wavelengths to be studied. Each measurement value is then divided by the corresponding value of the spline curve, and the resulting indices are saved. If for example the wavelengths of interest are in the range of 50 years, a spline of frequency response of about 10% at wavelengths of 50 years will leave 90% of the variance at that wavelength in the detrended tree-ring measurement indices, and nearly all of the variance at shorter wavelengths.

(3) In some cases it is preferable to fit first a deterministic curve such as a modified negative exponential curve, followed by a rigid spline curve fit to the indices from the exponential curve. The resulting indices may have more desirable characteristics than if either curve is used alone (Holmes et al, 1986).

When detrending the measurement series, be sure to save the individual indexed series or the tree summaries, since Program SIGLOF requires them for analysis.

The user specifies a spline rigidity about equal to the shortest wavelength of interest, and also specifies a proportion of variance at this wavelength to save in the spline; default is .90 (90%). Program SIGLOF fits a cubic smoothing spline of 90% (default) frequency response at this wavelength to each indexed series, saving the spline curves which contain 90% of the variance from the indexed series at the frequency of interest. More of the variance at longer wavelengths, less at shorter wavelengths, will be contained in the resulting splines.

Program SIGLOF then produces an arithmetic mean series of the spline curves, and parallel curves illustrating the 95% and 99% confidence bands about the mean series. The confidence bands are calculated as (Sheppard, 1991):

C = Y(i) (SE(yi) * t0.05df(i)

where

C is the confidence band above and below Y(i)
Y(i) is the mean smoothed index value of the year i
SE(yi) is the standard error of the mean index for year i
t0.05df(i) is the critical value for year i of the Student's t distribution for (= 0.05 and
degrees of freedom (df) is (sample depth -1)

Program SIGLOF prepares a spreadsheet file with the name __.SSH, containing nine columns of data:

Col.	Data in column
1	Year
2	Spline chronology containing low-frequency variation
3	95% Confidence band, minus side
4	95% Confidence band, plus side
5	99% Confidence band, minus side
6	99% Confidence band, plus side
7	Line at mean of data (1.0)
8	Time intervals significant at 95%
9	Time intervals significant at 99%

This file may be imported directly into graphics or spreadsheet programs such as Excel and Quattro Pro.

REFERENCES

Holmes, Richard L., Adams, Rex K. and Fritts, Harold C. 1986.

Tree-ring chronologies of western North America: California, eastern Oregon and northern Great Basin, with procedures used in the chronology development work, including users manuals for computer programs COFECHA and ARSTAN. Chronology Series VI. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Sheppard, Paul R. 1991.

Identifying low-frequency tree-ring variation. Tree-Ring Bulletin V. 51, pp 29-38. Laboratory of Tree-Ring Research, University of Arizona, Tucson.

Program SPANFIRE

SPATIAL ANALYSIS OF FIRE EVENTS

Thomas W. Swetnam and Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona
November 1994

INTRODUCTION

In September 1993 Dr. Thomas W. Swetnam, head of the Fire History group at the Laboratory of Tree-Ring Research, University of Arizona, requested that Richard Holmes write a computer program to perform spatial analysis of fire events or other phenomena. VAX-VMS ANSI Fortran-77 programming languagewas used to develop program SPANFIRE. Subsequently it was compiled with Microsoft "PowerStation" (1993) Fortran-77 to make it available for PC compatible computers. Features were added as researchers used SPANFIRE in fire history research.

PURPOSE OF PROGRAM SPANFIRE

Program SPANFIRE ("Spatial Analysis of Fire Events") performs spatial analysis of fire events by finding the proportion of trees scarred to all trees recording, by number, by means of convex hulls and Voronoi (Thiessen) polygons, and by mean distance between trees. Data required for analysis are the X and Y coordinates (location) of the trees and the dates of recording and scarring of each tree.

DATA FILES

Two sets of data are required for spatial analysis of fire events:

(1) TREE COORDINATES (X, Y), one line for each tree, showing distances W-E and S-N from a point of origin. This is a typical small file of tree coordinates (Rows are trees; columns are W-E distance and S-N distance from the origin respectively):

```
    W - E         S - N                   Distance coordinates
....:....1....:....2    Columns
 5140.23 3527.14
 4894.58 3462.38
 4940.24 3869.25
 4032.54 4280.41
....:....1....:....2    Columns
```

(2) Table of FIRE EVENTS, one line for each fire year, containing information on which trees were living and which trees were scarred in that year. Symbols in this file are:

```
1     Fire scar in this year for this tree
0     Tree not scarred this year
*     This tree did not record for this year
```

This is a typical small file of fire events. Rows are fire years; columns are trees.

```
Year 1 2 3 4 5 6 7 8 9101112131415161718    Tree numbers
....:....1....:....2....:....3....:....4    Columns
 1307 * 0 0 0 1 1 0 0 0 0 1 0 * * 0 0 *
 1328 0 0 0 0 0 1 0 0 1 1 0 0 * * 0 0 *
 1387 0 0 1 1 0 0 1 0 1 1 1 0 * 0 0 0 *
 1407 0 0 0 1 0 0 0 0 1 1 0 0 * 0 0 0 *
 1430 0 0 0 1 0 1 1 0 0 0 1 0 0 0 0 0 0
```

```
 1460 0 0 1 0 1 1 1 0 0 0 1 0 0 0 0 0 0
 1473 0 1 0 1 0 0 1 0 1 0 1 0 0 0 0 0 0
 1499 0 0 0 1 1 1 0 0 0 1 0 0 0 0 0 0 0
 1539 0 0 0 0 1 0 1 0 0 1 0 0 0 0 0 0 0
 1571 0 1 1 1 0 0 1 0 0 1 1 0 0 0 * 1 1
 1592 0 0 0 1 1 0 1 * 0 1 1 0 0 0 * 0 0
....:....1....:....2....:....3....:....4    Columns
```

Data may be in one file, in which case tree coordinates must appear first, separated by a blank or title line from the fire events. If data are in separate files, give first the file name for tree coordinates.

PROGRAM CAPACITY

Maximum number of trees is 256; maximum time span is 2076 BC to AD 2020 (4096 years).

MENU OPTIONS

Values that may be changed by the user appear on a menu:

1 Metric conversion factor. By default the tree coordinates in the data file are given in meters. If the coordinates are not in meters they should be converted so that the results will then appear in Hectares. If coordinates are in feet, enter -1 for this item; the program will multiply all coordinates by 0.3048 to convert distances to meters. If coordinates are in another unit, enter a multiplier factor to convert to meters. Coordinates are subsequently adjusted by subtracting the minimum value.

2 Unit area (pixel size). By default the unit area or pixel is 1 by 1 meters. For each tree there is a Voronoi or Thiessen polygon, a convex polygon containing all points closest to the tree on which it is centered; this is the area represented by the tree. To compute this area a convex hull containing all the trees is divided into small square units known as "pixels". For each pixel the program determines which tree is closest and assigns the pixel area to that tree. This is a straightforward but computationally slow method known as the "discrete brute force" algorithm (Mark, 1987). A small pixel will give greater precision but will cause the program to run slowly. A large pixel will give lower precision but greater speed.

3 Voronoi polygon areas may be computed once for each tree and the same areas used throughout the analysis (default, or enter "1"). Under this method the program will run efficiently, and it may be theoretically the sounder method. Alternatively, tree polygon areas may be recomputed each time the combination of trees changes (enter "R"), that is, when a new tree enters the data set or a tree ceases to record. Since under this method each pixel must be reassigned whenever a tree enters or leaves the group, the program may run slowly.

4 Each tree may be included in the total area beginning either with the first ring present on the tree (default; enter "R") or with the first appearance of a scar (enter "S").

5 A scattergram of tree locations may be produced.

6 A spreadsheet file with percentages by fire year may be produced.

7 By default the program computes and prints summary statistics on fires over the entire time span only. Alternatively the user may specify that these statistics be computed over periods of time such as every 50 or every 100 years.

OUTPUT FROM PROGRAM SPANFIRE

The printed output first shows the run title and the names of data files read and created by the program. The number of trees and the number and time span of fire years are noted. The menu is shown with options as selected by the user. Next are the conversion factor and range of coordinates after conversion. Coordinates are then adjusted by subtracting the minimum value; thus one of the coordinates in each direction will be zero.

A table of distances among trees shows the linear distance in meters between each pair of trees.

For the convex hull around all trees, the vertices are recorded along with the tree numbers at the vertices and the azimuthal direction clockwise from north from each vertex to the next. The source code for finding the vertices and computing the area of the convex hull was written in Basic programming language by James Swetnam and revised by Anthony Caprio.

Voronoi polygon areas are computed for each tree. A table lists the time span covered by each tree along with the area of its Voronoi polygon and its adjusted coordinates in meters and in the original units. Statistics appear on the distribution of polygon areas, and a comparison is made between the area of the convex hull and the sum of the tree polygon areas.

The percentage of trees scarred is calculated for each fire year. Four methods are used and values and percent are listed:

(1) By number of trees scarred as a proportion of the number of recording trees.

(2) By area of the convex hull around the scarred trees as a proportion of the convex hull around all recording trees (the convex hull can be calculated only if three or more trees are scarred).

(3) By area of the Voronoi polygons of the scarred trees as a proportion of the area of the Voronoi polygons of all recording trees. If the user has elected in menu item 3 to recompute when the set of trees changes, an "R" indicates that areas were recomputed for this year

(4) By mean distance between pairs of scarred trees as a proportion of the mean distance between pairs of all recording trees.

In the following table summary statistics are given for the four methods above for the entire time span of record, or by period if the user has so specified.

The next table gives statistics for each fire year on the distribution of distances between pairs of scarred trees and pairs of all recording trees. At the right edge of this table the fire record for each tree and year is shown; symbols are:

F Tree recorded a scar in this year.
N Tree was recording but was not scarred.
n Tree was not yet recording: this symbol appears only if the user has responded "S" in menu item 4 to include trees in calculating the total area only with the first appearance of a scar.
. No data: tree was not recording in this year.

The final table ranks the fire years by percentage of trees scarred. Ranking is independently done by the four methods described above: by number of trees scarred as a proportion of the number of recording trees; by area of the convex hull around the scarred trees as a proportion of the convex hull around all recording trees; by area of the Voronoi polygons of the scarred trees as a proportion of the area of the Voronoi polygons of all recording trees; and by mean distance between pairs of scarred trees as a proportion of the mean distance between pairs of all recording trees.

REFERENCE

Mark, David M., 1987.
Recursive algorithm for determination of proximal (Thiessen) polygons in any metric space.
Geographical Analysis 19(3): p264-272.

Program SSA

SINGULAR SPECTRUM ANALYSIS

José A. Boninsegna and Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
August 1995

INTRODUCTION

In May 1993 Dr. José A. Boninsegna, head of the Laboratorio de Dendrocronología, CRICYT, Mendoza, Argentina, began his sabbatical year at the Laboratory of Tree-Ring Research. One of his main achievements during this year was the development of Program SSA. A version of a singular spectrum analysis program by Dr. Edward R. Cook, Lamont-Doherty Earth Observaztory, was provided to Dr. Boninsegna and was very useful in developing this program. VAX-VMS Version 6.1 (1993) ANSI Fortran-77 programming language was used to develop the program. Subsequently the program was compiled by Richard Holmes with Microsoft "PowerStation" (1993) Fortran-77 to make it available for PC compatible computers.

PURPOSE OF PROGRAM SSA

Program SSA will perform Singular Spectrum Analysis on one or more time series in a data file. The principal philosophy of the process is best described by R. Vautard and M. Ghil, Climate Dynamics Laboratory, UCLA, Los Angeles, California, USA, 1988

Menu options include:

You may specify that the matrix contain a fixed number of lags or a fraction of the length of the time series. You may set a fixed number of lags to use for all series, or give a denominator of the fraction of series length as the number of lags.

To reduce noise you may cut off the number of PCs at the point where:
- E: the eigenvalues drop below 1.0;
- P: the cumulative product of the eigenvalues drops below 1.0;
- O: select the number of PCs directly.

You may elect to save in a disk file the eigenvalues, eigenvectors & PCs.

You may elect to save in a disk file the reconstructed components (RC).
You may elect to save in a disk file the sums of selected RCs.

RECONSTRUCTED COMPONENT (RC) GROUPS:
Select groups of RCs to be summed. They may be given in any order. Finish each group with zero, and end selection and return to menu with 999

You may elect to save in a disk file the accumulated components.

Number of lags for MEM analysis (Divisor for number of lags)

You may elect to save in a disk file the ten first MEM of reconstructed components.

You may elect to use SSA for either detrending or as a band pass filter.

Minimum wavelength to save for detrending

You may compute indices by subtraction or division

Band ranges to separate (up to 20) - Give MAX and MIN for each range

You may elect to process all series in the data file.

Program SSA performs maximum entropy spectral analysis on the amplitudes. Spectral analysis of principal components gives the number, eigenvalue, percent of variance, cumulative variance, and peak of variance for each component. The peaks are analyzed and summed to the limit of the desired period. The sign of the eigenvectors is reversed if necessary to provide a direct relationship with the variables

Program SSIZ

Effect of sample size on fire frequency estimates

by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
August 1995

INTRODUCTION

In March 1994 Dr. Thomas W. Swetnam, head of the Fire History group at the Laboratory of Tree-Ring Research, University of Arizona, requested that a Fortran computer program be written to perform tests of the effect of reduced sample size on observed frequency of fire events or other phenomena. VAX-VMS ANSI Fortran-77 programming language was used to develop the program. Features were added to the program as researchers used it in fire history research. Subsequently the program was compiled with Microsoft "PowerStation" (1993) Fortran-77 to run on PC compatible computers.

PURPOSE OF PROGRAM SSIZ

Program SSIZ performs tests of the effect of reduced sample size using a list of event dates or key years.

A large number of simulations is performed by picking sets of trees at random to simulate reduced number of trees in the sample. A distribution of means emerges from the simulations, and confidence limits for this distribution are used to determine if there is statistical significance in the pattern surrounding the events.

PROGRAM CAPACITY

Maximum number of simulations	4096
Maximum time span of chronology	2076 BC to AD 2020
Maximum number of events	800

RUNNING PROGRAM SSIZ

Upon starting Program SSIZ the user gives a run identification of up to five letters and numbers which will identify files created by the program. If you give no name then "Z" is used as the run identification. The user then provides the names of a data file in either FIRE2 format developed by Henri Grissino-Mayer, or binary Fire Event format developed by Anthony Caprio, both at the Laboratory of Tree-Ring Research.

The program presents a menu on screen, listing the options and current values.

(1) The user may specify a time span to process in order to exclude part of the chronology from processing, or in order to use the same time span for all chronologies. By default the entire time span is processed which is in common between the chronology and the event dates with their windows.

(2) If desired, the data set may be processed in segments rather than as a whole (default is to process the entire time span). To process the data in time segments the user specifies the segment length and the lag between segments in years (default for the lag between consecutive segments is half the length of the segments). Thus for example if the chronology spans 1523 to 1992, and the user specifies the segment length as 100, and lag as 50, then the segments analyzed will be 1523-1622, 1550-1649, 1600-1699, 1650-1749, 1700-1799, 1750-1849, 1800-1899, 1850-1949, 1893-1992. Note that the first and last segments

are the same length as the others, but they abut against the ends of the chronology.

(3) The number of simulations may be varied; default is 1000 simulations. A "seed" number may be specified to begin the random series; this should be a large odd integer. Thus exact repetition of a prior program run may be carried out. Default is a value chosen by the program, a count of days since 1 January 1935.

(4) Method of picking simulated events. Three methods are available for obtaining the years for simulated events:

Random sampling without replacement: Reduced sets of trees are picked at random from the data set, but no tree is picked more than once. This is the default method.

Random sampling with replacement: Reduced sets of trees are picked independently at random from the data set; some trees may be picked more than once.

(5) The data file may be in either FIRE2 format developed by Henri Grissino-Mayer, or binary Fire Event format developed by Anthony Caprio, both at the Laboratory of Tree-Ring Research. The program determines automatically which of these formats is used for the data.

(6) Results are written to files named with the run identification (for example "Z" followed by "SSZ.___". The file of results for printing is "ZSSZ.OUT". As an option the results may also be saved in two additional files: (1) "ZSSZ.XL1" and "ZSSZ.XL2", tab-delimited files for direct importation into a spreadsheet program such as EXCEL.

When the selected options appearing on the menu are to the user's satisfaction, pressing <CR> (Enter) starts program execution.

OUTPUT FROM PROGRAM SSIZ

First on the printed output is information on the parameters used in running the program. Names of data files read, selected menu values, and names of files created by the program appear in the first section. In the simulations of fire events per century with reduced sample size an event year is counted if it is observed to occur in that year in one or more trees.

In the version of the program prior to 22 April 1994, an event was counted as ocurring in two or more trees if two or more trees in the reduced sample were observed to show the event for a given year. In the version since 22 April 1994, an event is counted as ocurring in two or more trees if it is observed to occur in two or more trees in the entire sample, and also to occur in at least one tree in the reduced sample.

The SIMULATED EVENTS table presents the results of random simulations, each simulation containing the number of events used in the ACTUAL EVENTS analysis. For simulated events, confidence limits are computed in two ways:

(1) Based on assumed normal distribution of means as just described.

(2) Based on percentile rank of simulated event means. Percentiles derived by ranking 1000 simulations (for example) will take values 25 and 976 (2.5% and 97.5%) for the 95% limits, and values 5 and 996 (0.5% and 99.5%) for the 99% limits. The 99.9% limits are not examined, since these would be the extreme highest and lowest values and therefore would be unreliable.

Program YUX

Make casewise (column) data file

USERS MANUAL for Program YUX by Richard L. Holmes
Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona USA
February 1999

Program YUX prepares a file that may be imported directly into most spreadsheet programs, placing one or more time series in column (casewise) format. The maximum number of columns is currently 200, maximum rows is 4096.

Series may come from one file or from several files in the same or different formats. At your option the new file is either exclusive or inclusive:

I: Inclusive, containing the full length of all series. If you choose to make the new file inclusive you are prompted for a symbol of up to eight characters for missing data (before the beginning and after the end of any series shorter than the entire time span). If you respond with <CR> then the character is null (ASCII value zero), which is recognized as missing data by many spreadsheet programs. Another is "NaN" (Not a Number).

E: Exclusive, containing only the part of each series in the time interval common to all series. A series is rejected if it does not cover all or part of the common interval. The common interval is shortened if a new series being added covers part but not all of the current common interval.

The user specifies a column delimiter; this may be any characters you type, up to 3. Frequently used delimiters are tab, comma, or one or more spaces; these are recognized by spreadsheets.

Columns may be identified automatically with the series identification at the head of the column; you may type in a short identification for each column; or columns may have no identification. If any column identification is blank, the identification line is not printed.

As series are read from the existing data file the identification and time span appear on the screen and you are prompted to say whether to include the series in the new file. You may respond "Y" for yes (default), "N" for no, "A" to take all remaining series in the file, or "Q" to quit this file:

```
CPP01A    Spans  1752  1920   169 data
Include this series?  <Yes>/No/All/Quit:
```

You may add data from additional files. Responding with <CR> will terminate adding data.

Finally you are prompted for the name of an optional file containing identification for the rows; this will be the first column in the new file. Most often you will respond with <CR>, indicating there is no such file. In this case the first column will contain consecutive year numbers.