RESEARCH REPORT

COMPUTER-ASSISTED QUALITY CONTROL IN TREE-RING DATING AND MEASUREMENT

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INTRODUCTION

Data quality control is especially important for tree-ring measurement series from non-arid regions. Since climatic factors are less often severely limiting to tree growth in these regions, ring series are less sensitive, and the climatic signal contained therein is weaker than in arid sites (Fritts 1976). In such areas it is very important to preserve as much as possible of the climatic information through accurate crossdating and measurement, with a minimum of "noise" introduced through errors. In determining the dating of tree-ring site collections from areas of somewhat difficult crossdating, an objective and efficient tool for locating errors or for confirming the crossdating would be very useful. Fritts describes some of the difficulties encountered in crossdating and emphasizes the importance of accurate dating for inferring climate from tree-rings, particularly since precise time definition is one of the advantageous qualities of dendrochronological data in comparison with most other paleoclimatic data.

In addition, tree-ring series are occasionally found which though apparently of usable quality, fail to yield a conclusive crossdating match using the technique of skeleton plotting (Stokes and Smiley 1968), or by the widely used method of cross-matching from memory. In such a series an injury or suppression of growth may prevent the dendrochronologist from following the dating inward from the date of collection.

A new computer program for objectively checking tree-ring measurement series and aiding in the crossdating process is presented here.

COMPUTER DATING CHECKS IN THE LITERATURE

A computer routine described by Fritts (1963) may be used to determine the best match of standardized series which are difficult to date by skeleton plot techniques. This routine determines the correlation between an established chronology and an unknown series at all possible positions of overlap, the highest correlation representing the probable dating. In the example given by Fritts, the only correlation value significant at the 99% level is the one where the match is at the correct dating. With this method a reliable chronology is required for comparison, extending in both directions at least as far as the series being tested. This may be unknown prior to attempted dating. If the series being tested contains locally absent rings, double rings, or other errors, the peak correlation will be blurred, that is, spread among two or more adjacent locations and diminished accordingly. In addition, if after standardization, short-term trends in the master and test series are asynchronous, high and low correlations will be found which are unrelated to the crossdating. This method therefore does not permit confirmation of the crossdating of a group of series om a site, nor does it pinpoint a source of probable error within a series.

M. L. Parker (1967; 1971) developed a computer technique called the "Shifting Unit Dating Program" to assist in dating short archeological ring sequences from which rings may be absent or which may contain undetected double rings. This computer program calculates the correlation of a portion of the unknown ring series with a master dating chronology at all possible positions, and the three best matches are printed on the output. Successive portions of length and lag designated by the user are tested until the entire series has been matched against the master. An archaeological tree-ring specimen is considered tentatively dated if a large proportion of the units are highly correlated with the master series at sequential matches. Assisted by this technique, Parker was able to date many of the most difficult archaeological specimens studied for his master's thesis (Parker 1967). Later he established crossdating between two hemlock sites some 1000 km apart in eastern Canada (Parker 1971).

Parker's method is of assistance in dating a small number of unknown specimens against an error-free master chronology, and is an objective technique for verifying independently derived chronologies. Limitations of the method are its inefficiency for processing large number of specimens, such as an entire site collection, and its failure to deal with a site collection as a whole.

Baillie and Pilcher (1973) and Baillie (1982: 80-85) describe another computer method for crossdating two tree-ring series, by calculating the correlation coefficient, percentage agreement, and Student's "t" value for every point of overlap of the two series. With this method, as the authors state, the two series must be free from errors, locally absent rings, or double rings. This makes the application of the program impractical for workers in many areas of the world. Baillie (1982: 85) gives a concise explanation of the value of a computer check of the dendrochronologist's dating. He points out that since human judgement is based on a highly evolved ability for pattern recognition, final determination of dating should be the responsibility of the dendrochronologist, not of statistical parameters. The value of a mathematical confirmation lies in its independence.

Wendland (1975) describes a computer program which compares two ring measurement series by calculating the correlation between corresponding short portions of both series as it proceeds along the series, and producing a line printer plot of the correlation values at every position. Approximate locations of locally absent or multiple rings are indicated by near zero or negative correlations near the problem ring numbers. The user must determine which series contains the anomaly. The program deals with only two series at a time, and the results may be difficult to interpret.

Cropper (1979) reports a computer program for producing skeleton plots for tree-ring dating. This method is highly efficient for producing plots very similar to those made by an experienced dendrochronologist. It does not solve the problem of series difficult to date by skeleton plot, nor does it provide documentary confirmation of correct crossdating.

Aniol and Schmidt (1982) briefly describe the concept of "gleichlaufigkeitswerte" (proportion of agreement) wherein "pointer" years are used to check crossdating between chronologies. Pointer years are those whose growth is different in the same direction from that of the previous year in a highly significant proportion of samples within a site. The method is applied to time series as a whole, to check agreement between chronologies, rather than to check individual sample series or portions of series.

A NEW APPROACH

Program COFECHA, a new computer routine written in Fortran-77, was developed to overcome the problems in the methods described above, namely: (1) that a known error-free series or chronology must be available for the site; (2) that in some methods the series being tested must have no locally absent or double rings; (3) that only one series is tested at a time; and (4) that the series is often treated as a whole rather than being examined within for trouble spots. The main purpose of Program COFECHA is the identification of data that should be reexamined for possible error. This is accomplished in several steps. First, each series of measurements is filtered with a short cubic spline (Cook and Peters 1981) to remove low-frequency variance. Second, a log transform is performed on the series to enhance the effect of variability among small rings. Third, a master dating series is derived by taking the mean of all filtered and transformed series.

Individual filtered and transformed series are then tested against the master dating series. The master series is adjusted each time by temporarily removing the component contributed by the series under consideration. Correlations are then computed between short segments of the series and coresponding segments of the adjusted master series. For each segment, the program checks that the correlation is positive and highly significant, and also that it is higher when matched as dated than when shifted forward or back from that point. Single measurements are noted that are statistical outliers after filtering and transformation.

Program COFECHA does not provide precise accept/reject criteria for making objective decisions as to whether a series has been crossdated correctly throughout. It should not be used as a substitute for visual crossdating on the wood sample. Rather it is intended to enhance data quality control by conducting a thorough examination of all series from the first to the last value (excepting the end of that series which extends beyond all others), giving the dendrochronologist an independent tool to confirm the accuracy of dating and measurement. It may be used in conjunction with other criteria to accept or reject series or portions of series for inclusion in a site chronology.

Program COFECHA has been used regularly for data quality control in developing chronologies for California west of the crest of the Sierra Nevada and Cascade Ranges, an area of mesic forests with considerable disturbance by man. It has proven economical and very easy to run, has saved a great deal of personnel time, and provides a more reliable quality control check than was previously feasible. A version of Program COFECHA has been implemented in the Dendrochronology Laboratory of the Instituto Argentino de Nivologia y Glaciologia (IANIGLA) in Mendoza, Argentina. It has been found to be valuable in working with tropical hardwood genera from northwestern Argentina such as *Cedrela,* and *Nothofagus* (Southern Hemisphere beech) from subantarctic forests in Patagonia. Tests on tree-ring data from arid sites in the southwestern United States have yielded excellent results. The concept will likely be useful in other locales such as upper treeline sites, high latitudes, and moist forests. It may be especially helpful to an investigator working alone or in a small group, or with unfamiliar species.

DESCRIPTION OF OUTPUT

The printed output of Program COFECHA appears in six parts.

Part 1 (Figure 1). The dated and measured ring series are filtered by fitting a 20-year cubic spline, and dividing the series values by the corresponding spline curve values. This process leaves high-frequency variance in the series, while removing trend and other low-frequency variance. Unless the user specifies otherwise, a log-transform will be performed on the filtered series, in order to weigh proportional differences in ring measurement more equally. A small constant is added before transformation to avoid the possibility of taking the logarithm of zero in case of a locally absent ring. Filtering and transformation simulates the dendrochronologist's perception on visual examination of a ring series for crossdating. In tests of different spline lengths on collections from California, the best job of discovering errors without also pointing out a considerable number of places where no problem exists, was done by using a spline length of 20 years. A longer (stiffer) spline leaves too much long-term variance in the series, and the resulting filtered series is not sensitive enough to the dating, while a shorter (more flexible) spline is too sensitive, and is likely to cause selection of many correctly dated segments of a series for reexamination. A master dating series is computed as the mean of all the series, derived in the same way a conventional chronology is calculated from index series of individual radii (Graybill 1982). In Part 1 the master series in standardized form is printed in a table, along with the number of individual series that are averaged to obtain the value for each year. The series of coefficients of variation (100 times the standard deviation divided by the mean) is printed in a second table, and the years with the highest and lowest ten percent of these coefficients of variation are flagged. When only one series enters the master series (N = 1), the coefficient of variation cannot be calculated.

Each series is temporarily removed from the master dating series to avoid comparing the series partly against itself. The series is then 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, and also at each position from 10 years earlier (−10) to 10 years later (+10) than dated. Ten years on either side should be adequate to locate crossdating errors, and should also catch errors made by slipping a decade while measuring. Spanning more years would unnecessarily inflate required computing time. Successive segments tested are lagged 25 years, giving a 50% overlap. In order to test to the very ends of the series, the first segment begins with the first year of the series and the last ends with the last year. Intermediate segments begin on years evenly divisible by the lag, 25. The overlap of the first two and last two segments is therefore usually greater than 25 years.

A segment length of 50 years provides sufficient degrees of freedom so that there are few segments with high or low correlation occurring by chance, and the correlation at 99% significance is not so high that a great many segments fail. 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 problems.

If in any time interval a major proportion of the series that make up the master series are incorrectly dated, the master series itself will not contain the correct dating, and since the series then differ from each other, most of all or the series will show low correlation for the time interval. Test runs of the program show that if one series in three is erroneous in a given time interval, the program will correctly identify the series containing the error while not flagging the remainder. The inclusion of some erroneous series in the mean series therefore does not destroy the correct dating pattern.

In Part 2 (Figure 2) correlations of each segment of the series, matched with the master, are printed in a table. Correlation values less than 0.3281, representing the

99% confidence level for significance in a single-tail test of the distribution of the correlation coefficient with 48 degrees of freedom (N = 50), are underlined and flagged. At the right margin the number of flagged correlations and the total number of segments for the series appear.

In Part 3 (Figure 3) a line is printed for any segment which correlates higher at some position other than where it was crossdated, 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 value between positions −10 and +10 is underlined and bracketed. The highest correlating position is also printed in the column labeled "HIGH." For clarity, a horizontal line separates series. Nothing is printed in Part 3 if the segment does not "fail" according to the criteria described above. If no such segments are found in the entire data file, only a message line is printed at the end of Part 2.

Part 4 is a resumé and table of descriptive statistics of the ring measurement series processed. It presents the total number of segments in each series, how many segments were found to have a low correlation with the master dating series (flagged "A"), and how many matched better at other than the dated position (flagged "B"). The mean correlation of the segments is given, along with standard time series statistics of the measurements before and after filtering with the spline.

Part 5 lists for each series any years whose measurement value after filtering and transforming is a statistical outlier, defined for this purpose as being over 3.0 standard deviations (default value) from the master dating series value for that year. These individual rings should be checked for dating or measurement error.

Part 6 will appear only if there are ring measurement series in the optional second data file. The purpose of this part of the program is to find the most probable dating of unknown series which appear to be of good quality, yet cannot be confidently dated by skeleton plot or other commonly used techniques. Series included in this file may be those of uncertain dating or those simply counted and measured. This part is nearly identical in concept to Parker's (1967 and 1971) Shifting Unit Dating Program, described above.

Part 6 points out the most probable crossdating for these series. As with the series in the main data file, correlations are calculated for 50-year segments of the counted series lagged successively 25 years, but now at every position from beginning to end of the master series. For each segment the correlation values are printed, beginning with the highest correlation ("CORR # 1"), until the values fall below the 99% confidence level. Up to 11 correlation values (the 11 best matches) are printed 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 series may be dated correctly by adding this number to the count of each ring. The dating should of course be verified on the wood sample by the dendrochronologist.

INTERPRETATION OF RESULTS

The best use of Program COFECHA for data quality control is to examine Parts 2 through 5 of the output to confirm correct crossdating and subsequently to select those portions of series in which the dating and measurement should be rechecked. Once remeasurement of portions of a series has been done, another computer program may be used to assess the precision of the measurements using the method described by

Fritts (1976: 250-52). After corrections are made to the original measurements, Program COFECHA should be run on the corrected measurements to provide documentation confirming the crossdating of the site collection.

If a segment of a series is listed in Part 3 of the program output, one of three things may be indicated:

(1) The crossdating may be erroneous. Crossdating errors are usually indicated in Part 3 by the occurrence of a low correlation at the dated position (zero) and a much higher correlation at some position nearby the dated position, say at +1 or −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 (Figure 3). A value of +2, for example, suggests that two rings may not have been recorded (locally absent?) near the beginning of the segment, and/or two extra rings (double?) recorded near the end. Picking out possible crossdating errors is probably what Program COFECHA accomplishes best. Dating errors should be corrected and Program COFECHA rerun to confirm the correction and to document crossdating quality of the site collection.

(2) There may be a single or a few large errors in measuring. Most measurement errors will have the effect of lowering the correlations of the segments in which they occur. Segments correlating lower than the 99% confidence level are flagged in Part 2 and listed in Part 3. These segments are good candidates for remeasurement to check for errors in the original measurements. If the highest correlation shown in Part 3 is at position +10 or −10, the person doing the measuring may have "slipped" a decade fore or aft, although this type of error is far less likely to occur with the use of automated methods of data capture (Robinson and Evans 1980). A check of Part 5 will reveal statistical outliers, which may also be measurement errors.

(3) There may have been a disturbance to the growth of the tree. A fire, sudden removal of competition, severe insect infestation, or other trauma abruptly affecting the tree in question differently from others in the stand, may cause ring growth to be anomalous along this radius for one or a few years, and thus produce low correlation in one or two segments. This phenomenon was noted by L. O. White (personal communication), who observed in his site collection of *Pinus lambertiana* from the Mendocino National Forest, California, that evidence of fire often occurred within segments of somewhat low correlation as listed in Program COFECHA, segments which were nevertheless correctly dated.

CONCLUSION

Program COFECHA provides an efficient method of tree-ring data quality control by thoroughly checking the crossdating of tree-ring site collections as a whole, and locating possible errors in dating or large measurement errors. It also serves as documentation of the crossdating quality of dendrochronological data sets.

ACKNOWLEDGEMENTS

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COFECHA, PART 1: MASTER DATING SERIES, STANDARDIZED THU 8 SEP 1983

TITLE OF RUN: SAMPLE DATA SET FOR ILLUSTRATING PROGRAM COFECHA

MEAN OF ALL FILTERED SERIES 1680 TO 1960 (301 YEARS, 10 SERIES) (IN PARENTHESES, SERIES AVERAGED)

YEAR	0	1	2	3	4	5	6	7	8	9
1680	-.97 (5)	1.18 (6)	.59 (6)	-.12 (6)	.53 (6)	-.29 (6)	-.70 (6)	.02 (6)	-.18 (6)	-.32 (6)
1690	-.44 (6)	.63 (6)	.44 (6)	-.05 (6)	.01 (6)	-.31 (6)	-.56 (6)	1.58 (6)	1.23 (7)	-.29 (7)
1700	.27 (7)	-.22 (7)	.18 (7)	-2.07 (7)	-1.49 (7)	2.17 (7)	1.37 (7)	-.72 (7)	-1.87 (7)	-.58 (7)
1710	.69 (8)	-.48 (8)	.62 (8)	.68 (8)	-.27 (8)	-1.36 (8)	-.48 (8)	1.04 (8)	.54 (8)	.36 (8)
1720	.09 (8)	.15 (8)	-.40 (8)	-.32 (8)	1.90 (8)	-1.83 (8)	.61 (8)	.48 (8)	-.25 (8)	-1.85 (8)
1730	-.65 (8)	.75 (8)	1.85 (8)	.30 (8)	-.34 (8)	-1.36 (8)	-.02 (8)	.41 (8)	.04 (8)	.66 (8)
1740	-.18 (8)	-.66 (8)	.19 (8)	-.31 (9)	-.02 (9)	1.83 (9)	.03 (9)	.02 (9)	-.11 (9)	-.04 (9)
1750	.56 (9)	-.41 (9)	-.64 (9)	-1.93 (9)	-.92 (9)	1.57 (9)	.75 (9)	-.78 (9)	.80 (9)	1.16 (9)
1760	.10 (9)	.89 (9)	-.01 (9)	.43 (9)	-1.42 (9)	-1.71 (9)	-1.07 (9)	.27 (9)	2.08 (9)	-.03 (9)
1770	.63 (9)	-.89 (9)	.80 (9)	-.06 (9)	-.79 (9)	.52 (9)	.84 (9)	-1.73 (9)	-1.01 (9)	.66 (9)
1780	1.81 (9)	.99 (9)	-.18 (9)	-1.13 (9)	-.06 (9)	.25 (9)	.09 (9)	-.76 (9)	.22 (9)	-.05 (9)
1790	.39 (9)	-.99 (9)	1.65 (9)	.19 (9)	.53 (9)	-1.33 (10)	-2.14 (10)	.67 (10)	.69 (10)	1.64 (10)
1800	-.24 (10)	-1.80 (10)	.81 (10)	1.02 (10)	-.30 (10)	.81 (10)	.20 (10)	-1.53 (10)	-1.20 (10)	.93 (10)
1810	-.44 (10)	1.78 (10)	.55 (10)	-1.12 (10)	-.23 (10)	-.01 (10)	.49 (10)	.54 (10)	1.10 (10)	.29 (10)
1820	.15 (10)	-.29 (10)	-1.41 (10)	-1.68 (10)	-.87 (10)	.59 (10)	1.88 (10)	.05 (10)	1.04 (10)	.46 (10)
1830	-1.09 (10)	-1.45 (10)	1.56 (10)	-.02 (10)	-.03 (10)	-2.53 (10)	-.38 (10)	.11 (10)	1.52 (10)	.78 (10)
1840	1.15 (10)	-.17 (10)	-1.35 (10)	-.27 (10)	-.19 (10)	2.12 (10)	-.84 (10)	-.94 (10)	-.26 (10)	.27 (10)
1850	-.67 (10)	.06 (10)	1.18 (10)	.67 (10)	.74 (10)	.24 (10)	-.78 (10)	.70 (10)	-1.19 (10)	-1.75 (10)
1860	.96 (10)	.94 (10)	-.84 (10)	.59 (10)	.05 (10)	-1.91 (10)	.31 (10)	-.64 (10)	1.99 (10)	1.08 (10)
1870	.89 (10)	-.62 (10)	-1.24 (10)	-.10 (10)	-1.11 (10)	.85 (10)	-.46 (10)	1.20 (10)	.20 (10)	.48 (10)
1880	-.33 (10)	-.79 (10)	.65 (10)	-1.02 (10)	.30 (10)	1.88 (10)	-2.20 (10)	.34 (10)	1.26 (10)	.15 (10)
1890	-.24 (10)	-.11 (10)	.27 (10)	-1.42 (10)	-.18 (10)	-.53 (10)	-.66 (10)	1.37 (10)	.63 (10)	-.12 (10)
1900	1.26 (10)	-.23 (10)	.48 (10)	.41 (10)	-1.47 (10)	.68 (10)	-.13 (10)	.27 (10)	-1.45 (10)	.38 (10)
1910	-.85 (10)	-.25 (10)	-.18 (10)	1.95 (10)	1.61 (10)	-.95 (10)	.72 (10)	-.43 (10)	-1.47 (10)	.10 (10)
1920	-1.43 (10)	.71 (10)	-.49 (10)	1.14 (10)	.17 (10)	.32 (10)	2.23 (10)	-1.52 (10)	-.08 (10)	-2.50 (10)
1930	.42 (10)	2.49 (10)	-1.49 (10)	-1.84 (10)	-.07 (10)	-.56 (10)	.73 (10)	.65 (10)	.39 (10)	.37 (10)
1940	-.63 (10)	-.46 (10)	.02 (10)	1.68 (10)	-2.23 (10)	-.92 (10)	-.13 (10)	1.26 (10)	.14 (10)	1.43 (10)
1950	-1.26 (10)	.81 (10)	-1.85 (10)	-.25 (10)	-.08 (10)	-1.98 (10)	-1.02 (10)	1.99 (10)	2.38 (10)	-.23 (10)
1960	-1.13 (10)	-.96 (10)	-.09 (10)	-1.47 (10)	.63 (10)	-.53 (10)	.46 (10)	-.36 (10)	1.27 (10)	1.38 (10)
1970	-.23 (10)	-1.60 (10)	-.61 (10)	.92 (10)	-.92 (10)	.15 (10)	-.10 (10)	.84 (10)	.55 (10)	-.28 (9)
1980	.10 (9)	----	----	----	----	----	----	----	----	----

TITLE OF DATA: DEMONSTRATION SERIES: EXPO4A - 1762 ABSENT; EXPO6A - 1933 & 1935 ABSENT

Figure 1. Part 1: Master dating series presented in standardized form (mean = 0.0, standard deviation = 1.0).

<-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><-><->

LABORATORY OF TREE-RING RESEARCH - UNIVERSITY OF ARIZONA — THU 8 SEP 1983

TIME 16:05:23

COFECHA, PART 2: CORRELATIONS WITH MASTER SERIES OF ALL SEGMENTS AS DATED AND MEASURED — DAY OF YEAR 251

RLH 23/AG/83

SERIES FILTERED WITH 20-YEAR CUBIC SPLINE; CORRELATIONS OF 50-YEAR SEGMENTS, SUCCESSIVELY LAGGED 25 YEARS

FLAGS: __A = CORRELATION UNDER .3281 BUT HIGHEST AS DATED; __B = CORRELATION HIGHER AT OTHER THAN DATED POSITION

SEQ	SERIES	INTERVAL	1675 1724	1700 1749	1725 1774	1750 1799	1775 1824	1800 1849	1825 1874	1850 1899	1875 1924	1900 1949	1925 1974	1950 1999	1975 2024	2000 2049	2025 2074	2050 2099	2075 2124	2100 2149	2125 2174	2150 2199	FLAGS/ TOTAL
1	EXP01A	1680-1980	.60	.64	.78	.80	.72	.72	.60	.42	.43	.50	.55	.52	*								12
2	EXP02A	1795-1980	*	*	*	*	.54	.57	.58	.60	.65	.63	.60	.54	*								8
3	EXP03A	1680-1980	.58	.50	.55	.45	.51	.78	.75	.65	.59	.67	.66	.65	*								12
4	EXP04A	1681-1980	-.28B	-.23B	.05B	.43	.57	.67	.51	.46	.52	.42	.45	.37	*								3/ 12
5	EXP05A	1680-1980	.55	.67	.49	.66	.69	.61	.58	.45	.61	.47	.42	.47	*								12
6	EXP06A	1743-1978	*	*	.60	.60	.62	.39	.43	.58	.64	.54	.09B	.02B	*								2/ 10
7	EXP07A	1680-1980	.69	.56	.50	.56	.55	.65	.76	.72	.46	.51	.64	.58	*								12
8	EXP08A	1680-1980	.56	.57	.60	.49	.51	.60	.66	.74	.66	.80	.83	.81	*								12
9	EXP09A	1698-1980	.48	.47	.57	.59	.60	.56	.43	.34	.38	.49	.48	.48	*								12
10	EXP10A	1710-1980	*	.69	.72	.75	.78	.77	.74	.61	.63	.78	.77	.74	*								11

Figure 2. Part 2: Correlation with the master dating series of all segments of series as dated and measured.

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LABORATORY OF TREE-RING RESEARCH - UNIVERSITY OF ARIZONA — THU 6 SEP 1983

TIME 16:05:23

COFECHA, PART 3: SEGMENTS CORRELATING LOW, OR HIGHER AT OTHER THAN DATED POSITION — DAY OF YEAR 251

RLH 23/AG/83

CORRELATIONS WITH MASTER DATING SERIES, OF 50-YEAR SEGMENTS OF SERIES FILTERED WITH 20-YEAR SPLINE

AT EVERY POINT FROM TEN YEARS EARLIER (-10) TO TEN YEARS LATER (+10) THAN DATED

SERIES	SEGMENT	HIGH	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10
EXP04A	1681-1730	-1	*	*	*	*	*	*	*	*	*	<.37>	-.28	-.28	.13	.37	.18	-.10	-.17	-.20	-.04	.17	.02
EXP04A	1700-1749	-1	-.17	.24	-.13	-.04	.17	.24	-.10	-.34	-.11	<.53>	-.23	-.24	.04	.30	.23	-.23	-.20	-.01	-.01	.12	.05
EXP04A	1725-1774	-1	-.24	-.02	-.21	.04	-.06	-.05	-.11	-.12	.08	<.57>	.05	-.13	-.10	-.11	.20	-.03	-.35	-.07	.09	.07	.02
EXP06A	1925-1974	2	.00	.23	-.07	.09	-.10	-.03	-.14	-.12	.12	-.10	.09	-.12	<.48>	.00	-.21	-.17	.08	*	*	*	*
EXP06A	1929-1978	2	-.01	.20	-.03	.10	-.02	-.07	-.15	-.13	.11	-.08	.02	-.10	<.50>	*	*	*	*	*	*	*	*

5 SEGMENTS LISTED

Figure 3. Part 3: Segments of low correlation with the master dating series, or which match better at other than dated position.