

AN OBJECTIVE METHOD TO IDENTIFY MISSING OR FALSE RINGS

WAYNE M. WENDLAND

Center for Climatic Research
The University of Wisconsin

INTRODUCTION

A continuing problem of dendrochronology is the identification of false or missing rings in tree cores. Occasionally, trees produce two apparent rings during one calendar year, or, in some instances, one year's growth is missing. Missing or multiple rings may also be the result of errant counting. Although these anomalies have been known to exist since the early days of dendrochronology, their identification is essentially still a subjective, qualitative technique. Experienced workers verify false and missing rings by comparison with adjacent cores. Schulman (1939) suggested using the so-called Douglass Criterion to identify false rings, *i.e.*, rings with non-distinct limits are suspect of being annual multiples. The hypothesis was then to be tested by crossdating "signature" years from contemporaneous cores. Signature years are those marked with very narrow rings in most all cores from a given region reflecting a prominent anomaly. However, conclusions are subjective and the product of experience.

Numerical methods have been developed for tree-ring research, and clearly show that some subjective practices can be computerized so that preliminary work can be speeded with credible, standardized results. Numerical methods can efficiently screen large amounts of data and "point up" suspect areas. Fritts and his group at the Laboratory of Tree-Ring Research (Fritts 1963; Fritts and others 1969) have developed several numerical methods which extract, among other things, the growth curve for individual trees, and complete analysis of variance. These methods are routinely used by many researchers to quantify analysis techniques and to standardize analysis patterns.

Recently Baillie and Pilcher (1973) presented a program to be used to crossdate two cores or chronologies. However, the input data to the program must be chronological, *i.e.*, no missing or false rings. The following program was written to provide an objective routine whereby tree cores could be scanned for mutual agreement. The method is straightforward and simple. After mounting and surfacing, the cores are immediately measured and the increments are punched on cards. The two cores for the test are often from the same tree, or can be of near-by trees from the same stand. Subsequent to the test for missing or false rings, it is a simple matter to insert missing data, or omit a multiple ring if necessary, by a data handling program and repunch the chronology for further analysis.

METHOD

The following program (Figure 1) calculates running correlation coefficients coupled over a specified number of years (usually between 10 and 20), for the series of data beginning with the most recent period. If the cores are of a similar area and species, correlation coefficients should be positive and of relatively large magnitude for episodes when the increments from each core are in phase. Similarly, they should be expected to be of less significance for those times when the cores are out of phase. Though missing or

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      DIMENSION TR1(350),TR2(350),SM(350),COR(350)
C   BOTH CORES MUST CONTAIN THE SAME NUMBER OF ANNUAL PINGS
      DO 70 L=1,350
        TR1(L)=0
        TR2(L)=0
        SM(L)=0
      70  COR(L)=0
C   READ CORES
      IYR=1
      LYR=20
      3  READ 1,(TR1(L),L=IYR,LYR)
      1  FORMAT(20X,20F3.0)
        IF (TR1(IYR).EQ.0) GO TO 5
        IYR=LYR+1
        LYR=LYR+20
        GO TO 3
      5  IYR=1
        LYR=20
      7  READ 1,(TR2(L),L=IYR,LYR)
        IF (TR2(IYR).EQ.0) GO TO 30
        IYR=LYR+1
        LYR=LYR+20
        GO TO 7
C   READ CONTROL DATA
      30  READ 8,MYRS,MCAL,ID1,ID2
      8  FORMAT(2I6,2A6)
        IF (MYRS.EQ.0) STOP
C   MYRS=NUMBER OF YRS IN EACH CALCULATION.  MCAL=NUMBER OF ITERATIONS
      PRINT 40,ID1,ID2,MYRS
      40  FORMAT(13H1CORES USED ,A6,3X,A6,22H.  NUM OF YRS OVERLAP,I7)
C   INITIATE AND STEP OVERLAP AND CALCULATE CORRELATION
      MIT=1
      MAX=MYRS
      DO 20 NN=1,MCAL
        SXY=0
        SXS=0
        SYS=0
        S1=0
        S2=0
        DO 10 L=MIT,MAX
          S1=S1+TR1(L)
          SXY=SXY+(TR1(L)*TR2(L))
          SXS=SXS+(TR1(L)**2)
          SYS=SYS+(TR2(L)**2)
        10  S2=S2+TR2(L)
          A=MYRS
          XM=S1/A
          YM=S2/A
          ASUM=0
          BSUM=0
          COV=0
          DO 100 L=MIT,MAX
            ASUM=ASUM+((TR1(L)-XM)**2)
            COV=COV+((TR1(L)-XM)*(TR2(L)-YM))
            BSUM=BSUM+((TR2(L)-YM)**2)
          100  SM(NN)=COV/A
              COR(NN)=SM(NN)/SQRT((ASUM/A)*(BSUM/A))
              MIT=MIT+1
        20  MAX=MAX+1
C   OUTPUT OF DATA
      90  NP=1
        M=MCAL/10
        K1=1
        K2=10
        DO 111 L=1,M
          PRINT 112,NP,(COR(I),I=K1,K2)

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Figure 1. FORTRAN program to calculate correlation coefficients from two cores.

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112 FORMAT(I5,10F10.3)
    K1=K1+10
    K2=K2+10
111 NP=NP+10
    CALL PLOT
    GO TO 30
    SUBROUTINE PLOT
    DIMENSION I$TARS(5) /* * * * * * */
    DIMENSION LINE(21)
    PRINT 1,(I,I=-10,9,1)
    1 FORMAT('1NO.',2X,20('.',I3,2X),'. 10'/)
    DO 2 I=1,MCAL
    DO 3 J=1,21
    LINE(J)='.'
    3 CONTINUE
    TFMP=COR(I)+1.0
    TEMP=TFMP*120./2.
    ICN=TEMP+1.5
    ICN=MIN(121,ICN)
    ICN=MAX(1,ICN)
    NWDS=ICN/6
    NRES=MOD(ICN,6)
    IF(NWDS.EQ.0) GO TO 4
    DO 5 J=1,NWDS
    LINE(J)='I*****'
    5 CONTINUE
    4 CONTINUE
    IF(NRES.NE.0) LINE(NWDS+1)=I$TARS(NRES)
    PRINT 6, I,LINE
    6 FORMAT(1X,I3,2X,21A6)
    2 CONTINUE
    RETURN
    END

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Figure 1. Continued

false rings are not the only cause of reduced correlation, this method provides an objective method to screen cores. The method is particularly helpful when processing large numbers of cores, as it points up those cores which must be further checked.

PROGRAM

The program is written in FORTRAN IV language and requires one control card specifying the number of increments to be included in each correlation coefficient calculation (MYRS), and the number of running correlation coefficients desired (MCAL). The output is in the form of a series of correlation coefficients, each one for the specified interval of increments, beginning with the most recent interval. For example, if MYRS is specified as 20 years, the first correlation coefficient is calculated from the most recent 20 increments from each of the two cores, the second coefficient is from the second through the 21st increment, etc. Following the table of correlation coefficients, the sub-routine PLOT produces a graph of the coefficients (see Figure 2) on the printer.

DISCUSSION

We have used the technique in our laboratory, and find that correlation calculations of 10 or 20 increments (MYRS) provide the clearest indication of false or missing rings. Episodes shorter than about 10 years often show irregular sequences of correlation coefficients due to natural variation inherent between cores of the same tree or area, and those longer than about 20 years are severely filtered, thereby reducing information.

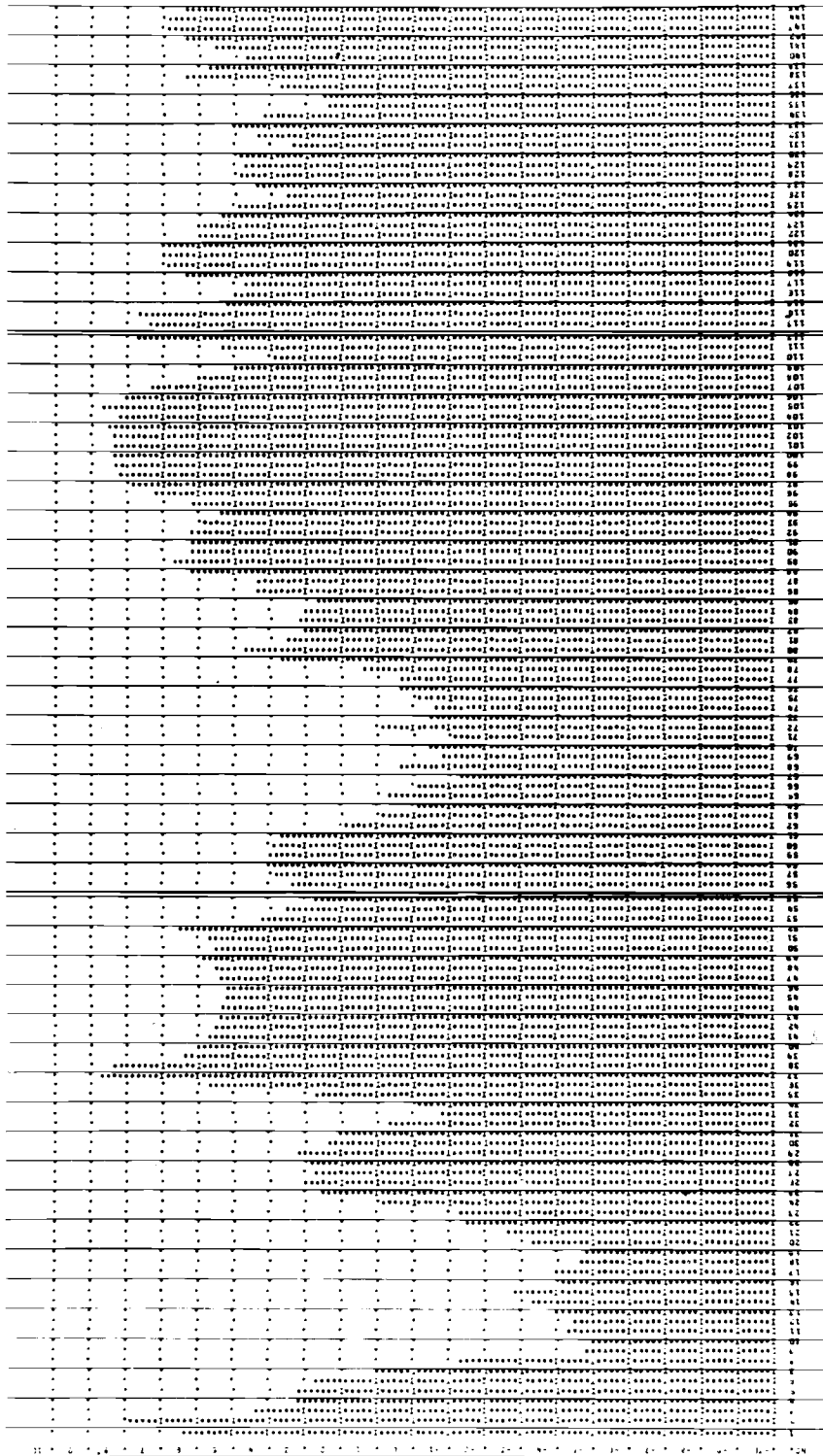


Figure 2. Output of program showing series of correlation coefficients of two cores for 15-year intervals from 1970 (#1) to 1826 (#145). Increment for 1954 is a multiple ring of 1955 growth.

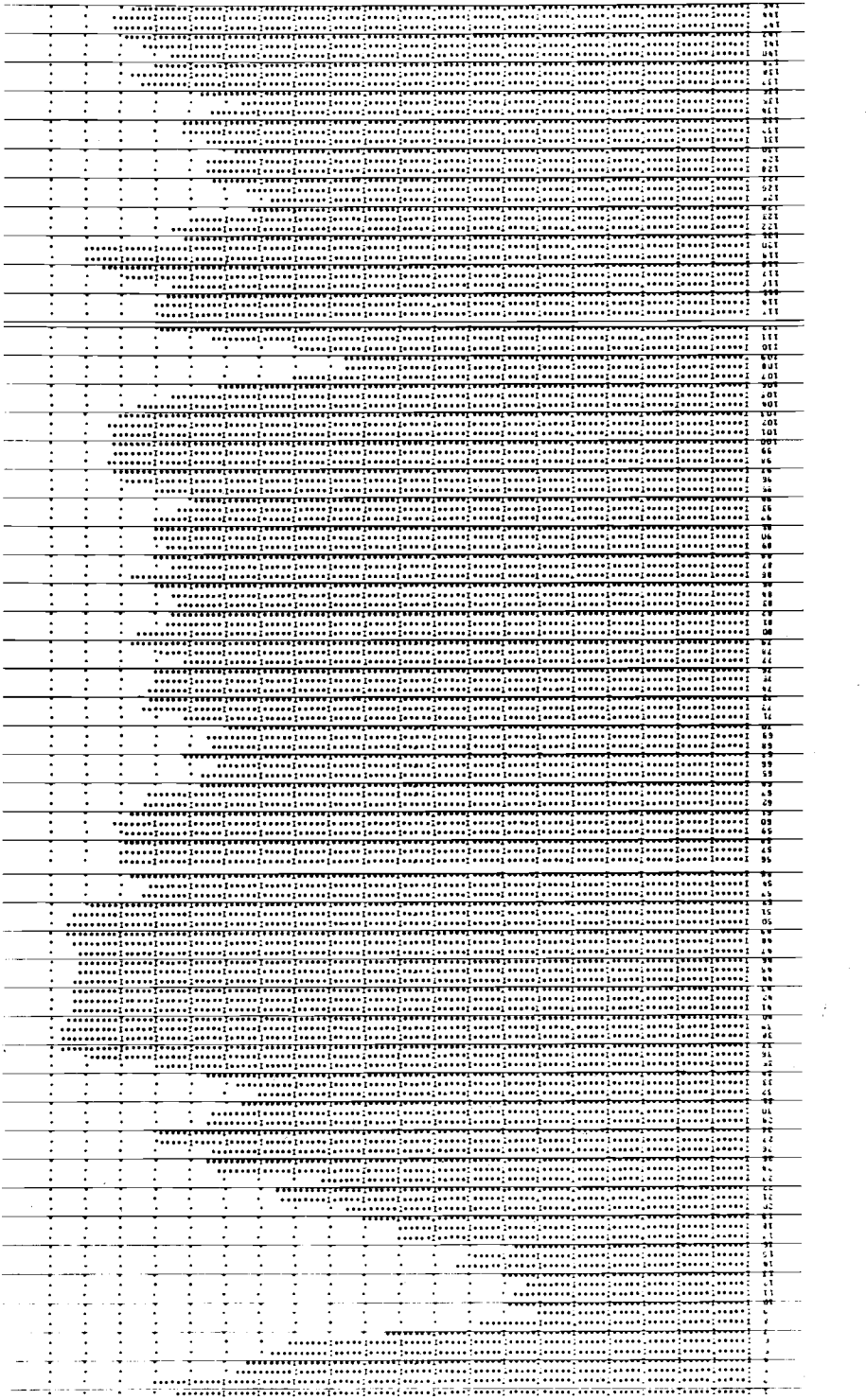


Figure 3. Same as Figure 2 except increment for 1955 and all previous years correctly given.

Moreover, correlation coefficients become increasingly sensitive to low frequency oscillations, such as a growth curve, with larger values of MYRS if the outer rings of each core are not of the same year. Perfect chronologies from two cores of sensitive tree should produce a series of correlation coefficients with relatively large positive values. A series of coefficients calculated from two series of random numbers (unrelated variables) is of an oscillating nature, with a mean value of about zero. Less sensitive (more complacent) trees yield cores which lie between these limits.

Figure 2 shows the analysis of two cores (#060400 and 060404) from one red pine (*P. resinosa*) from northern Wisconsin. The numbers of the X-coordinate represent the last year of 15-year interval correlation coefficients. Number 1 refers to 1970, 2 to 1969, etc. The correlation coefficients show little continuity with time. Strong negative correlation is shown centered at about 15 years (1956) and at about 70 years (1901), with additional smaller scale fluctuations. The negative correlation about the mid-1950s prompted further investigation in that area of the cores. A multiple ring was discovered (verified by visually crossdating signature years from one core to the other) in core #060400 for 1954. The correlation coefficients were subsequently recalculated with the corrected increments for 1955 and 1954, which of course, also placed all previous increments one year later in the chronology. The results are shown in Figure 3. The correlation coefficients are virtually everywhere greater than in the first calculation, and certainly more consistent with time. Interestingly, the negative correlations centered at about 10 years (1960) remain, suggesting a continued mismatch, not caused by a missing or false ring, but differential radial growth perhaps due to some event in or about the tree, e.g., fire, clearing about the tree, or damage. This example clearly shows that the method can screen cores for mutual correspondence and indicate times when the cores are mismatched. However, some cores may poorly correlate with each other for reasons other than false or missing rings, thereby requiring a personal verification. The benefit of this technique is its ability to screen many cores and direct personal verification to suspect areas.

It is apparent that the pattern of continuity of correlation coefficients is more important than absolute magnitudes for identification of missing or false rings. It is equally apparent that subsequent personal verification of suspect areas is necessary.

CONCLUSIONS

This procedure screens tree cores and presents the correlations for specified time intervals throughout the length of the cores. Times associated with weak or negative correlation should be personally checked to ascertain the cause of the poor correlation. False or missing rings are only two of the possibilities. Objective procedures, as the above, standardize analysis and judgement techniques and speed identification of suspect chronologies.

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REFERENCES

- Baillie, M.G.L. and J.R. Pilcher
1973 A simple crossdating program for tree-ring research. *Tree-Ring Bulletin* 33:7-14.
- Fritts, H.C.
1963 Computer programs for tree-ring research. *Tree-Ring Bulletin* 25(3-4)2-7.
- Fritts, H.C., J.E. Mosimann, and C.P. Bortorff
1969 A revised computer program for standardizing tree-ring series. *Tree-Ring Bulletin* 29(1-2)
15-20.
- Schulman, E.
1939 Classification of false annual rings in west Texas pines. *Tree-Ring Bulletin* 6(2)11-13.