APPENDIX 3 – CHRONOLOGY DEVELOPMENT

Steps in Tree-ring Chronology Development

1. Measured tree-ring widths for the 25 tree-ring sites were organized in 25 ascii "ring-width list" files (rwl files). Each site had ring-width series from multiple trees

2. Ring-width series not screened for minimum allowable segment length

3. Outlier ring-width values, if any, identified and converted to missing values (NaN) as follows
   - **a.** All ring-width series for a site were arranged as a time series matrix
   - **b.** Means and standard deviations of ring widths were computed columnwise in sliding 51-yr window, and any ring width more than 3 standard deviations from its sliding column mean was flagged as a column outlier
   - **c.** Series were converted to Z-scores using column means and standard deviations computed over all rows
   - **d.** Row means and standard deviations computed separately for each row (year) of the Z-score series and any Z-score more than 3 standard deviations from its row mean was flagged as a row outlier
   - **e.** Any ring width that was BOTH a column outlier and row outlier was converted to a missing value (The Z-score scaling before identifying row outliers reduces chance that a ring width is a row outlier simply because it comes from a fast-growing tree)

4. Ring widths were converted to standard core indices (MATLAB© function `dtrendrw`) as follows:
   - **a.** A cubic smoothing spline with a frequency response of 0.95 at a wavelength twice the series length was fit to each ring-width series. The spline was fit using the full available length of the ring-width series.
   - b. Ring widths were divided by the fitted spline in the same year to get a tree-ring index (ratio method). The result for each ring-width series is a "core index" time series
   - c. If the fitted trend line, g, dropped below 0 mm, the following steps were taken to guard against an 'exploding' core index (division by zero or a negative number)
      - i. The longest consecutive string of years with g≥ 0 was identified
      - ii. That was the only part of the core index retained (all other years of date were truncated)

5. Trends in variance of individual core-index time series were removed as follows:
   - a. Index was converted to absolute departures from its long-term mean
   - b. A cubic smoothing spline (Cook and Peters 1981) was fit to the time series of absolute departures (same spline parameter as used to detrend the ring width series)
   - c. Absolute departures were multiplied by the ratio of long-term mean absolute departure to value of spline in each year; this yields the "adjusted" absolute departures
   - d. The original sign of the adjusted absolute departures was restored, and to these the long-term mean (step a) was added; the result is an adjusted core index
   - e. The core indices was shifted to have long-term mean of exactly 1.0; the result is a "standard" core index

6. Residual core indices were computed from the standard core indices as follows, using MATLAB© function `arwhite3`
    a. The maximum order of autoregressive (AR) modeling was set at 3
    b. Any internal missing ring-width value was replaced with 1.0
    c. An AR model was fit to the core index time series, using the adjusted AIC criterion to select best model (Hurvich C. M. and Tsai C. 1989)
    d. The AR residuals from this model are is the residual core index
    e. Any year that had an internal missing value in its standard core index series had that value restored to NaN
    f. The residual core index was shifted to have a mean of exactly 1.0

7. Standard and residual core indices were converted to a site chronology (MATLAB© function `sitechron1`) as follows:
    a. Core indices were averaged over cores to form site chronology. Following recommendation of Osborne et al. (1997), core indices were scaled to equal variance before averaging. (This is especially important if chronology is to be variance-stabilized to account for time-varying sample size.) Each core index was scaled so that its standard deviation was equal to the median standard deviation of all core indices before scaling. If any of the resulting core indices had a negative value, all core indices were scaled again as follows:
        i. the lowest core index, xcrit, in any series was identified (this must be negative)
        ii. departures from the mean for each series were scaled by the factor f, = 1.0/(1.0-xcrit+eps), where eps is the computer machine precision, a very small number, eg, 2.2204e-016 . Note that because xcrit is negative, f<1.0, and the effect of scaling is to shrink the departures from the mean. Also, because all core-index series are scaled by the same factor, the series after scaling are still equal-variance

8. The Expressed Population Signal (EPS) and Subsample Signal Strength (SSS) of the site chronology was computed as in Briffa and Jones (1990), equations 3.44 and 3.51. Computation is based on the number of trees in the chronology and on the mean between-tree correlation. When multiple cores per tree, the effective chronology signal(eqn 3.43, Briffa and Jones 1990) was used instead of the mean between-tree correlation. Both a time-invariant and pseudo-time-dependent EPS and SSS were computed (MATLAB© functions `rbaref` and `wigley1`. The time-invariant EPS and SSS utilize the full correlation matrix of core indices, where the entries in the correlation matrix are for any overlap of two series by at least 50 years. The pseudo time-dependent EPS and SSS use the same correlation matrix,but average over only those rows for series with data in the year. It is possible that some years might be represented by series that have not sufficient overlap with other series. If so, the lowest row-mean of the correlation matrix is used as the mean between-tree correlation for those years.

9. The site chronology was variance-stabilized to compensate for time-varying sample size as follows:
    a. Stabilizaton was based on the mean between-tree correlation of core indices, or on the effective chronology signal (see above) if more than one core per tree. The method for variance stabilization is described by Osborne et al. (1997). The time varying 'effective sample size' was computed using eqn 4, p. 90, and the time-dependent scaling of departures followed eqn 6, p. 92
    b. The standard and residual versions of the site chronology were variance-stabilized separately

Literature Cited

Briffa, K., and Jones, P.D., 1990, Basic chronology statistics and assessment, *in* Cook, E.R., and Kairiukstis, L.A., eds., Methods of Dendrochronology, Applications in the Environmental Sciences: Kluwer Academic Publishers, p. 136-152.

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