Supplementary Material

Pros and cons with changing the protocol when producing the Blue Intensity data

In the main article we argue that contrary to the Campbell et al. (2011) protocol, BI images should be inverted and that the optically derived parameter should be called Blue Absorption Intensity rather than Blue Reflectance Intensity. This would facilitate the comparison between Maximum Latewood Density (MXD) and Maximum Latewood Blue Absorption Intensity (MXBI).

Advantages:
1. Since radiographic images are inverted to be positively correlated with wood density, it can also be argued that optical BI images should be inverted to be positively correlated with the "lignin-content". This would simplify the nomenclature because MXBI, rather than the traditionally used minimum blue intensity, is a more intuitive counterpart to MXD. Moreover, minimum blue intensity is usually inverted to be positively correlated with summer temperatures in the end.

2. This would enable the usage of the same tree-ring standardization in ARSTAN and other software for both MXD and MXBI.

3. It would relieve problems in Windendro when trying to find the earlywood-latewood boundary, which is usually encountered when working with non-inverted images.

Disadvantages:
1. A change in nomenclature could confuse the situation even more if authors continued to use both the old and the newly proposed denotations.

2. Analyses in Coo-recorder (Cybis.se) have to be inverted at the post processing stage. However, this is not a major issue because all data-series only needs to be subtracted from 255, the maximum BI value. This is usually performed anyway (see point 1, Advantages).

To conclude, we think that the advantages are greater than the disadvantages. Given that the published amount of Blue Intensity papers is still small, it is better to change this now before it is used more extensively.

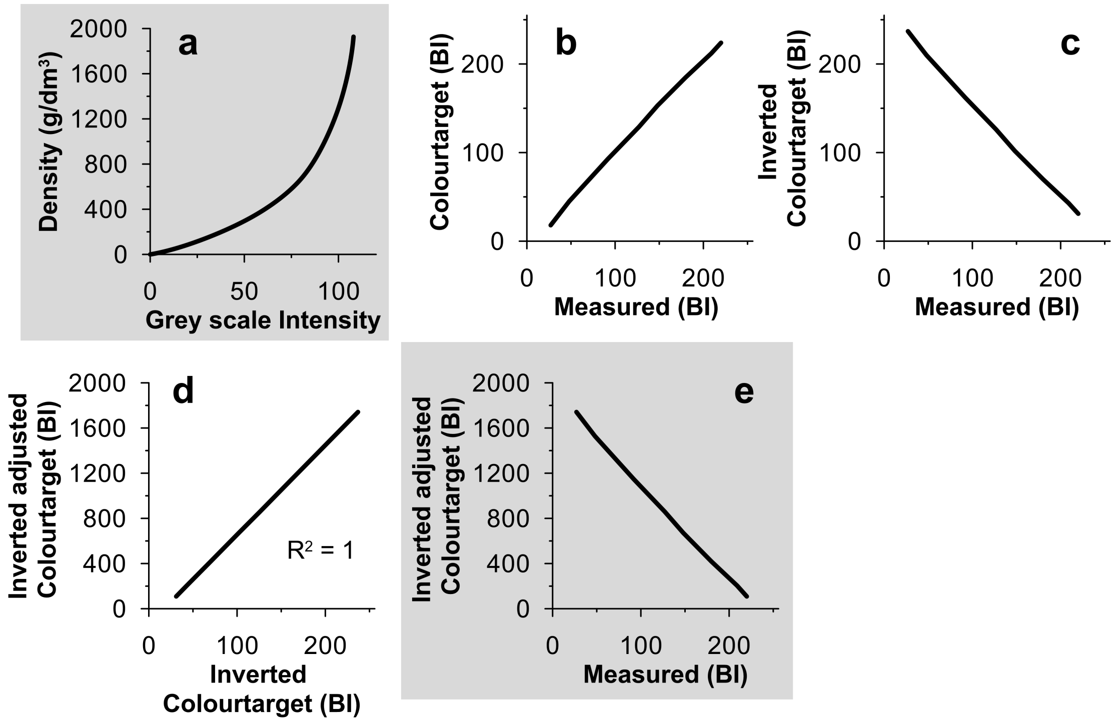

Figure S1. a) The relationship between radiodensitometric wood density and radiographic grey values. b) The relationship between colour target IT8/7 and measured Blue Reflectance Intensity in WinDendro. c) Inverted colour target. d) The inverted colour target is linearly adjusted to produce values in the natural range of wood density. e) The relationship between the measured Blue Absorption Intensity and the adjusted colour target (ACT) Blue Intensity used in this study. All Blue Intensity values in this study are presented with this adjustment. Grey boxes indicate a) the radiographic to wood density and e) the blue reflectance intensity to blue absorption intensity relationships that were used in this study.

Climate analysis with different standardization options

There is generally no difference in correlation between the different standardization options and temperature (Fig. S2). Notable are the higher correlations for April-May and September of the Latewood RCS chronologies and the April-June correlations of the EWBI RCS chronology. These deviations are a result of the fact that both the RCS chronologies and temperature data contain more low-frequency variability. In EWBI it is likely that the negatively biased trend is obscuring the high-frequency relationship with temperature. In the latewood chronologies, it is likely that temperatures in April, May and September have similar overall trends to the latewood chronologies, explaining the increase in the correlation. On the other hand, it is the interannual variability that drives the high correlations with June, July and August together with similar overall trends. Overall, the latewood RCS chronologies do not show much lower correlations with temperature than the chronologies that were pre-whitened. This suggests that the trends in the RCS chronologies are also quite similar to the target data. No apparent correlation between precipitation and tree-ring data can be gleaned from the climate-correlations (Fig. S3). The correlation between the latewood chronologies and July precipitation is significant, but as precipitation and temperature in July is significantly anti-correlated we draw no conclusions at this stage.

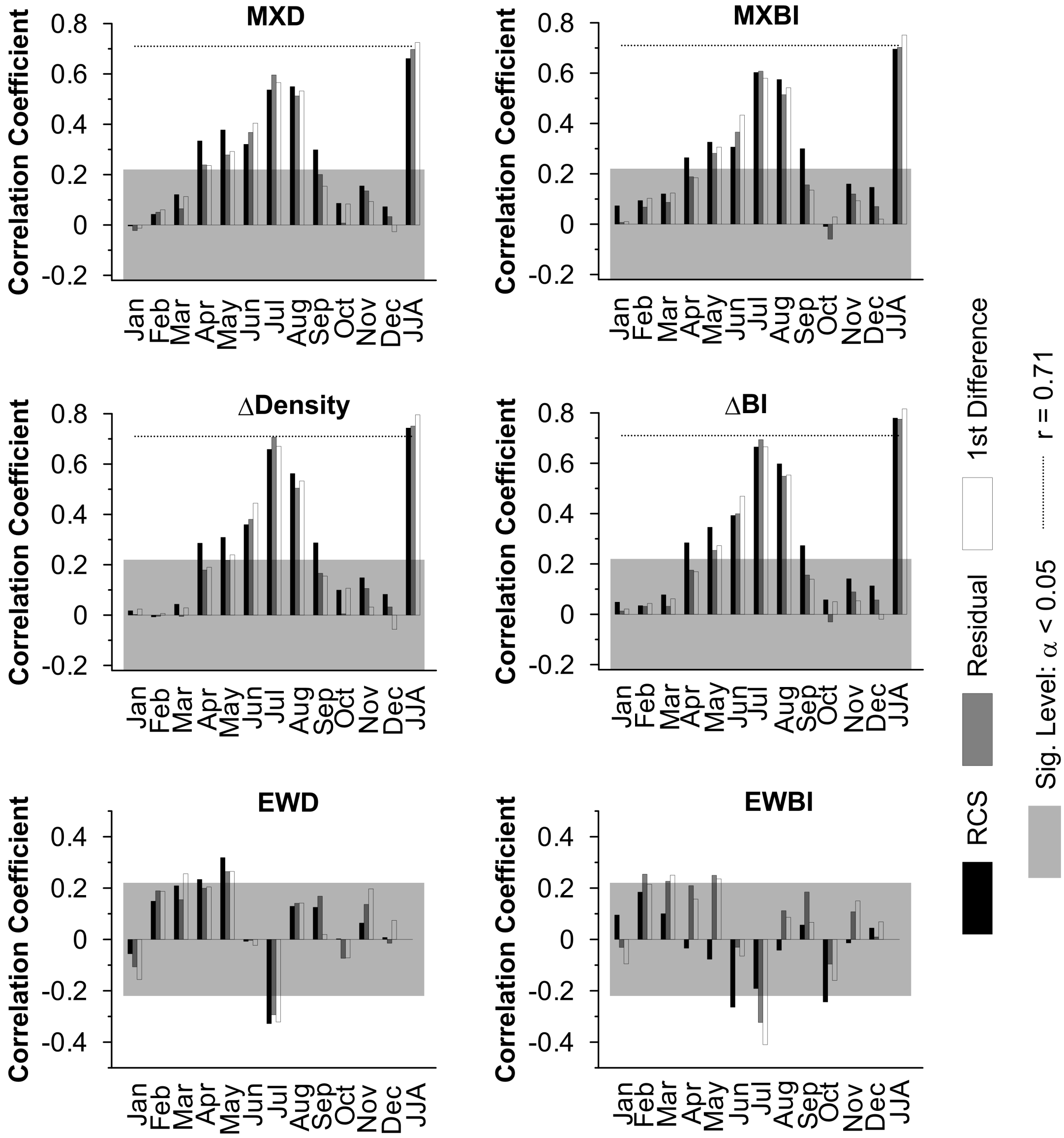

Figure S2. Correlations between the Arjeplog tree-ring data and monthly temperatures. Three different variants of the tree-ring data are shown: Regional Curve Standardised data (RCS; Briffa et al. 1992, black bars), residual chronology from RCS (grey bars) with standardisation performed in ARSTAN (Cook and Krusic, 2005), and first differenced data (white bars). The tree-ring parameters produced for this study (MXD, ΔDensity, EWD and MXBI, ΔBI, EWBI) are correlated against the 2.5° grid point land temperature CRU TS 3.1 dataset (Harris et al., 2013) closest to the site (Lat. 65-67.5°, 17.5-20°). The period of analysis was 1902-2009, where there is an overlap between the tree-ring chronologies and observational data. The significance levels are based on two-tailed significance testing ($p < 0.05$) for the Pearson Product-Moment Correlation Coefficient and adjusted for autocorrelation in the RCS chronologies (Dawdy and Matalas, 1964). The levels for the pre-whitened data are slightly lower (not shown).

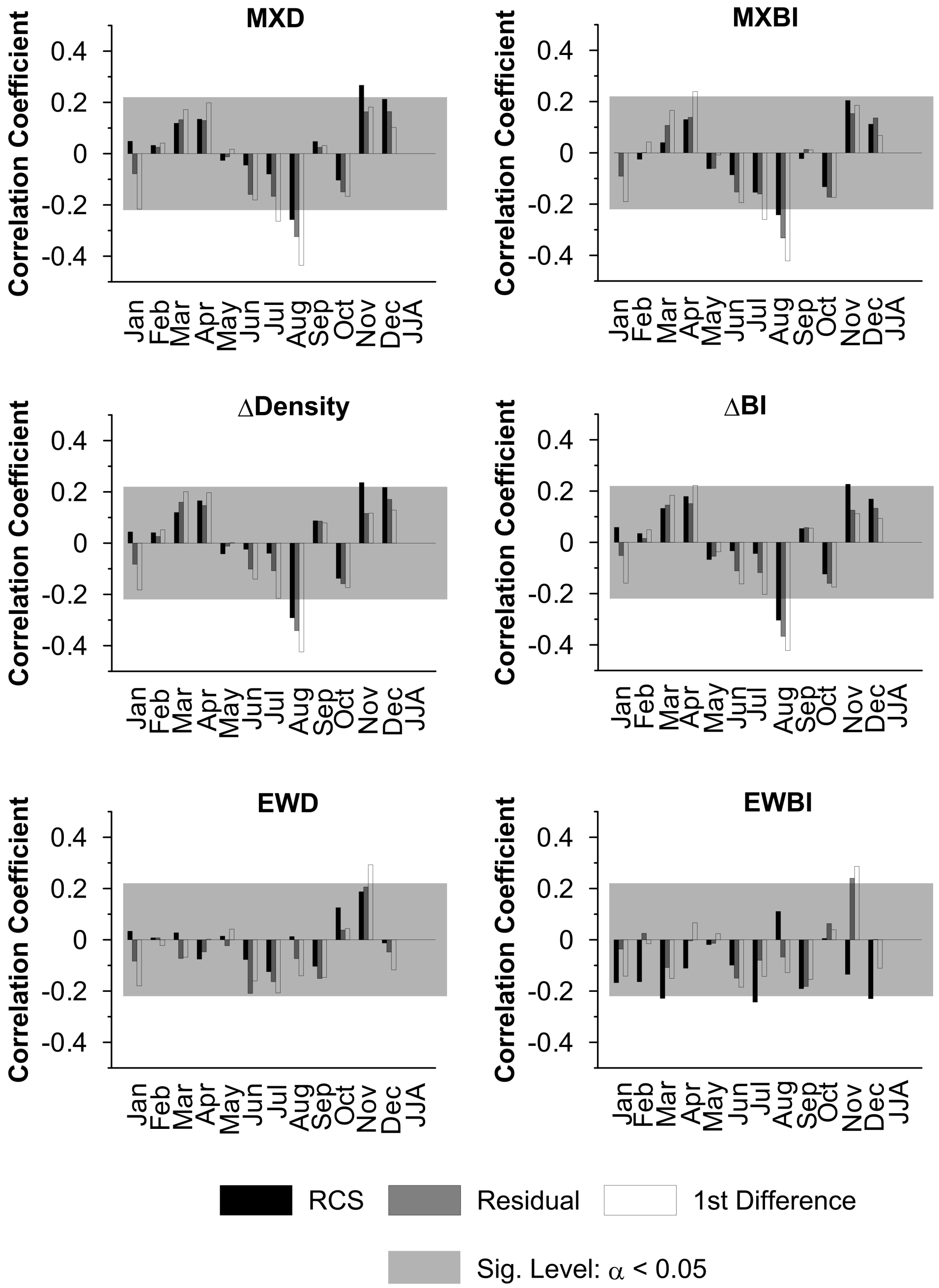

Figure S3. As Figure S2 but with the land precipitation CRU TS 3.10.01.

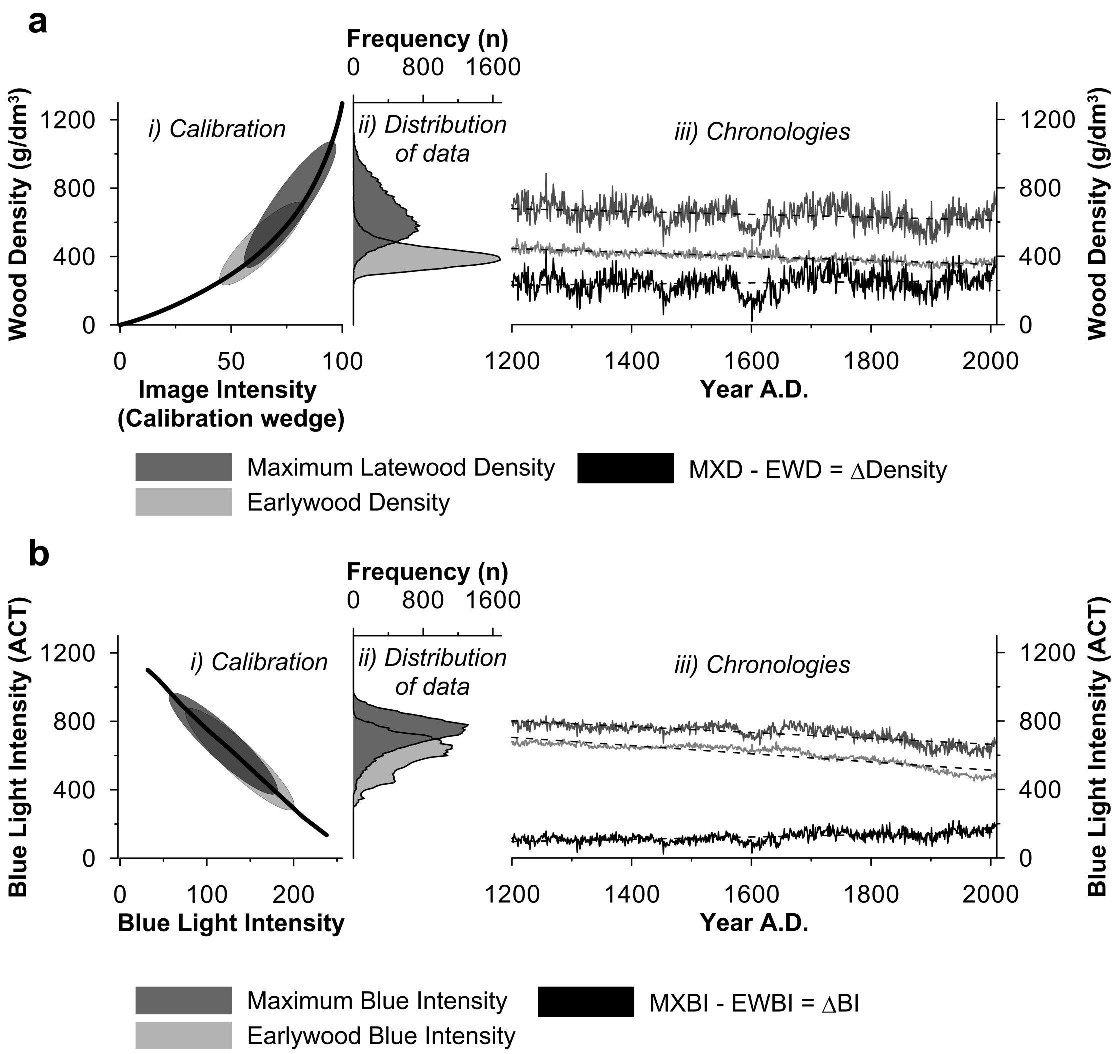

Figure S4. Chronology data for the parameters: MXD, ΔDensity, EWD and MXBI, ΔBI, EWBI, not standardised. a) Panel i) black line displays the relationship between radiographic measurements and wood density based on the cellulose acetate calibration wedge (the 'standard'), where the common interval of distribution of MXD (dark grey areas) and EWD (light grey) values are indicated schematically. b) Panel i) adjusted colour target IT8/7 (ACT) Blue Intensities, where the common interval of distribution of MXBI (dark grey areas) and EWBI (light grey) values are indicated schematically. In a) and b) panels ii) histograms, of the data points after calibration into density or ACT Blue Intensities is indicated. In a) and b) panels iii) the mean chronologies for earlywood, maximum latewood and also the Δ parameter. Note the difference in variance between density and BI.

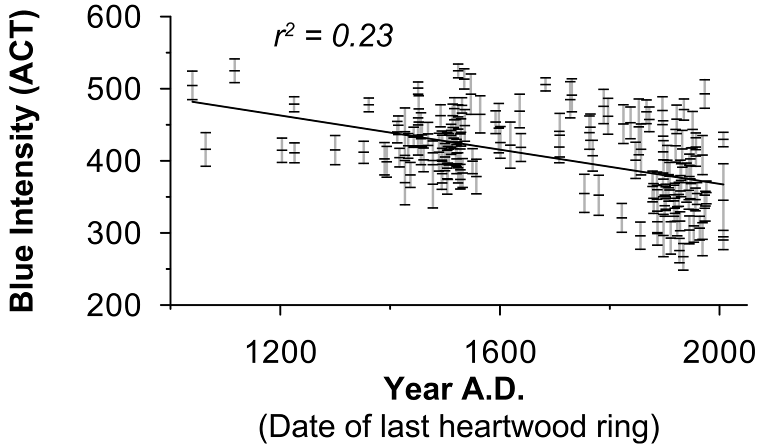

Figure S5. For each sample, the MXBI and EWBI measurements are combined and treated as one sample. Means and standard deviations of these combined measurements are calculated and regressed against the date of the last heartwood ring. Note the differences in means of more modern tree-samples compared to the dead-wood samples.

Indications of a non-linear relationship between wood-density and Blue Intensity

We examine the relationship between wood density and Blue Intensity and suggest that the model describing it should have an exponential rather than a linear fit (see Fig. S6). The sample arps3121 is representative for the whole sample population given that its relationship with the density is almost identical to the mean relationship with the density for the whole sample-population. In the sample analysis, both radiographic greyscale and BI are inverted (according to the proposed new nomenclature). It should be kept in mind that the analyzed tracks of arps3121 are different but from the same core. In Figure S6, the BI values are not adjusted to the density range and encompasses the original range: 0-255. The x-ray absorption and the blue light absorption record similar features of the wood. In this particular case, the BI explains 92% of the variance in wood density with a non-linear model. However, this needs to be investigated further before this can to be clearly established.

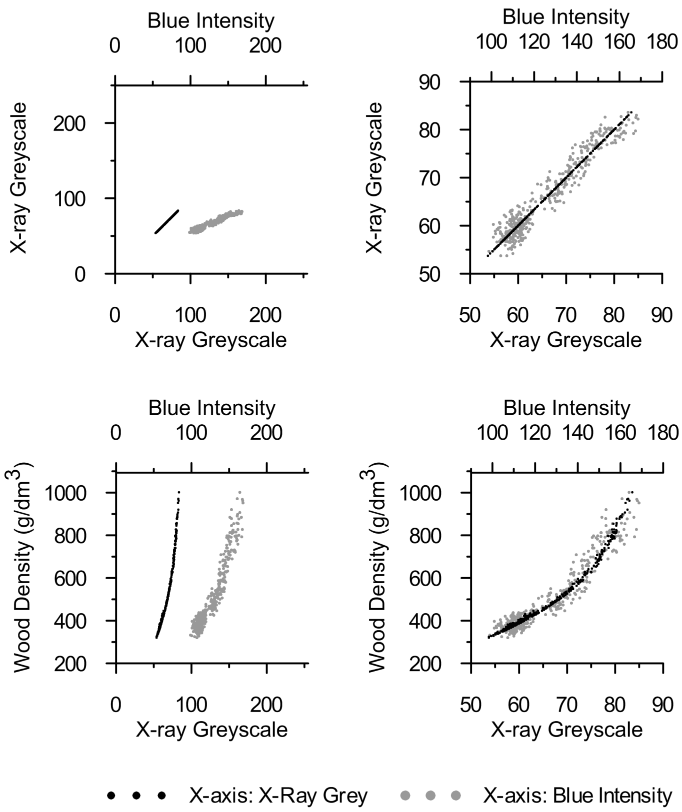

Figure S6. Top panel shows the relationship between sample arps3121 radiographic measurement in grey scale vs. itself (black dots) and vs. blue intensity (grey dots). The top right graph is the same as the left, but the scale is expanded so that the scatter occupies the entire view for both BI and radiographic measurements. Lower panel shows the relationship between radiographic and the BI measurements vs. radiodensitometric measurements respectively. The right graph shows the relationships with an expanded scale.

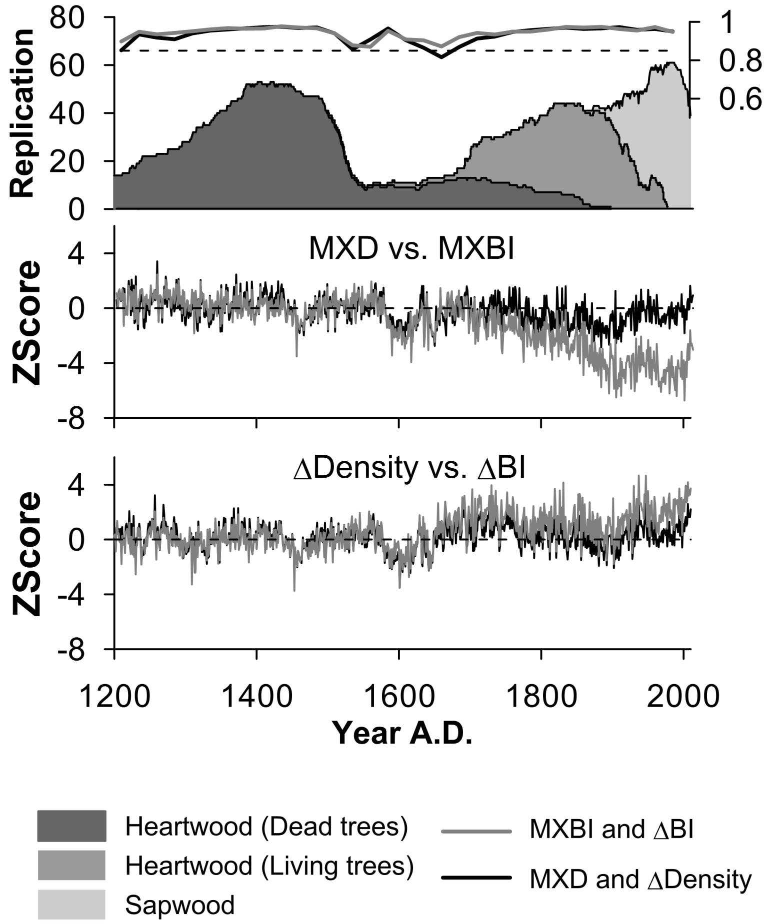

Figure S7. Top panel shows EPS and sample depth where representations of deadwood heartwood, living-tree wood heartwood and sapwood are indicated as different shades of grey. The two lower panels are raw chronologies for MXD and MXBI, and ΔDensity compared to ΔBI.

References

Briffa, K. R., Jones, P. D., Bartholin, T. S., Eckstein, D., Schweingruber, F. H., Karlén, W., Zetterberg, P., and Eronen, M.: Fennoscandian summers from AD 500: temperature changes on short and long time scales, Clim. Dynam., 7, 111–119, 1992.

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Dawdy, D.R., and Matalas, N.C., 1964, Statistical and probability analysis of hydrologic data, part III: Analysis of variance, covariance and time series, *in* Ven Te Chow, ed., Handbook of applied hydrology, a compendium of water-resources technology: New York, McGraw-Hill Book Company, p. 8.68-8.90.

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