Supplementary Material for:

A tree-ring reconstruction of East Anglian hydroclimate variability over the last millennium

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Contents:

Supporting Figures

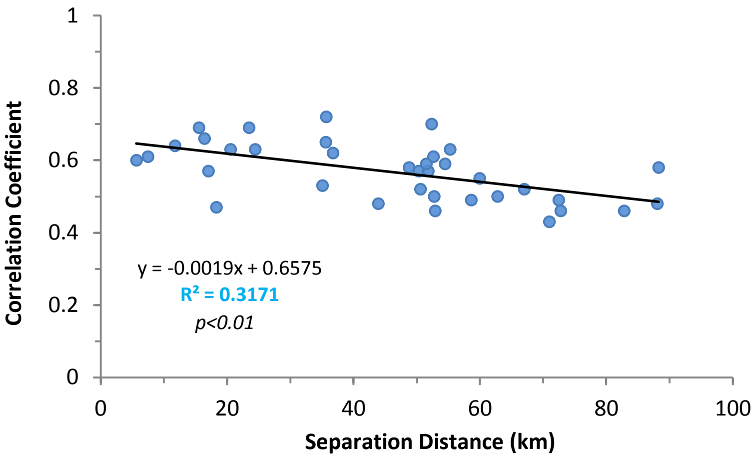

Figure SM1 Spatial coherency of oak growth variability. Plot showing the relationship between site separation distance (km) against inter-site correlation strength for the nine modern oak chronologies over the 1879-1981 common period. All chronologies detrended with a 10-year high pass smoothing spline. Site separation distance is able to explain 31.7% of inter-site correlation variability, with correlation reducing by 0.19 per 100 km increase in distance

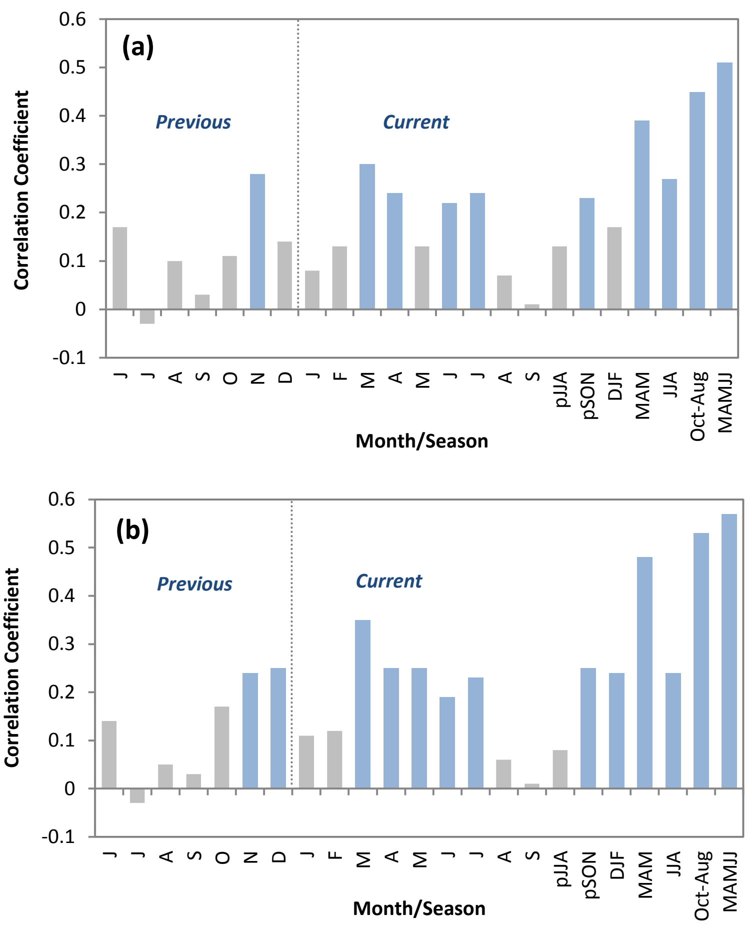

Figure SM2 Empirical demonstration of chronology climate sensitivity. Correlation coefficients for individual monthly and various seasonal measures of East Anglia precipitation variability calculated for the period 1901-2009 against **a** 10-year and **b** 100-year high-pass smoothed chronologies. Significant correlations ($p<0.05$) are shown in blue. Correlations closely match those derived using the RCS East Anglian chronology, thereby emphasising the robustness of these associations regardless of standardisation procedure

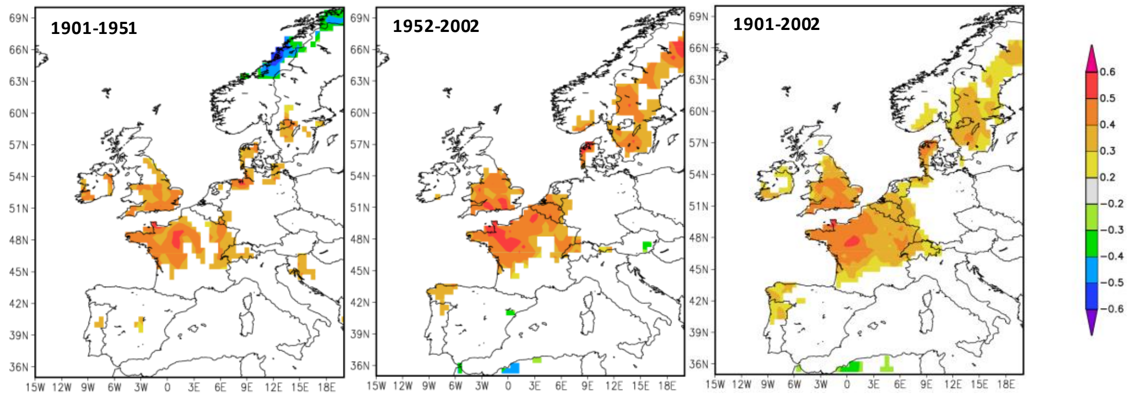

Figure SM3 Spatial field correlations of 0.5^o x 0.5^o latitude/longitude gridded European scale MAMJJ self-calibrating Palmer Drought Severity Index (scPDSI) (CRUTS2.1; Mitchell and Jones 2005; van der Schrier et al. 2006) against the RCS East Anglian oak chronology for early, late, and full length periods. All correlations significant at $p<0.1$. In common with the spatial patterns derived for precipitation, positive association is established between East Anglian oak growth and the scPDSI across England, northern France, Benelux, and southern Scandinavia

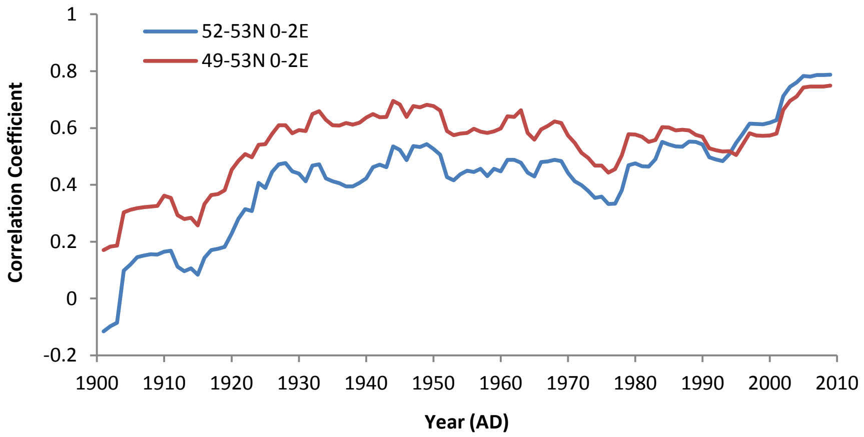

Figure SM4 31-year moving period correlations between the East Anglian chronology and two gridded precipitation datasets. Stronger correlations, particularly during the early period, are obtained when correlating against the gridded data that includes part of northern France (49-53^{o}N, 0-2^{o}E) than when using precipitation data solely for East Anglia (52-53^{o}N, 0-2^{o}E).

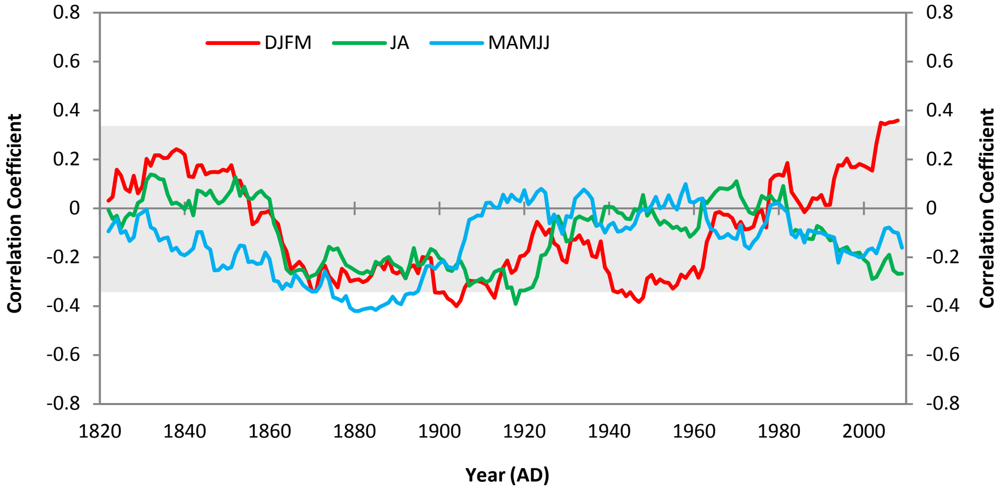

Figure SM5 Empirical demonstration of chronology NAO sensitivity. 31-year moving period correlations between the East Anglian chronology and winter (DJFM), summer (JA), and MAMJJ Gibraltar-Iceland NAO index (Jones et al. 1997) for the period 1822-2009. Grey shading represents non-significant correlation at the p<0.05 significance level. This figure reveals no statistically significant associations between East Anglian oak growth and the NAO during winter, summer, or MAMJJ periods

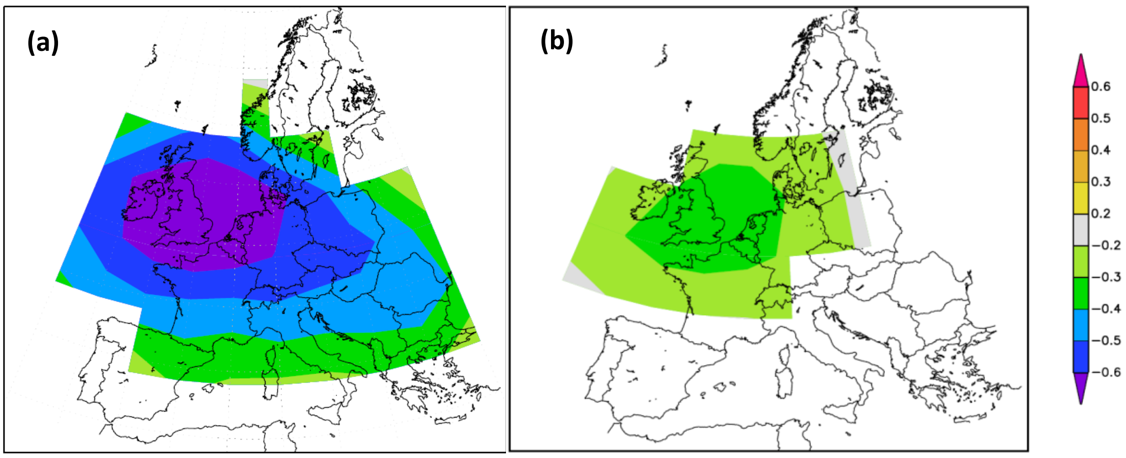

Figure SM6 Spatial sea-level pressure signals. Field correlations of gridded 5^{o} x 5^{o} latitude/longitude European scale MAMJJ mean sea-level pressure (SLP) (Trenberth and Paolino 1980) against **a** gridded (49-53^{o}N, 0-2^{o}E) instrumental precipitation and **b** the East Anglian oak precipitation reconstruction for the period 1899-2009. Negative associations are demonstrated between SLP and both instrumental and reconstructed East Anglian precipitation series. Thus, low SLP is associated with high precipitation and increased oak growth. All correlations significant at p<0.1

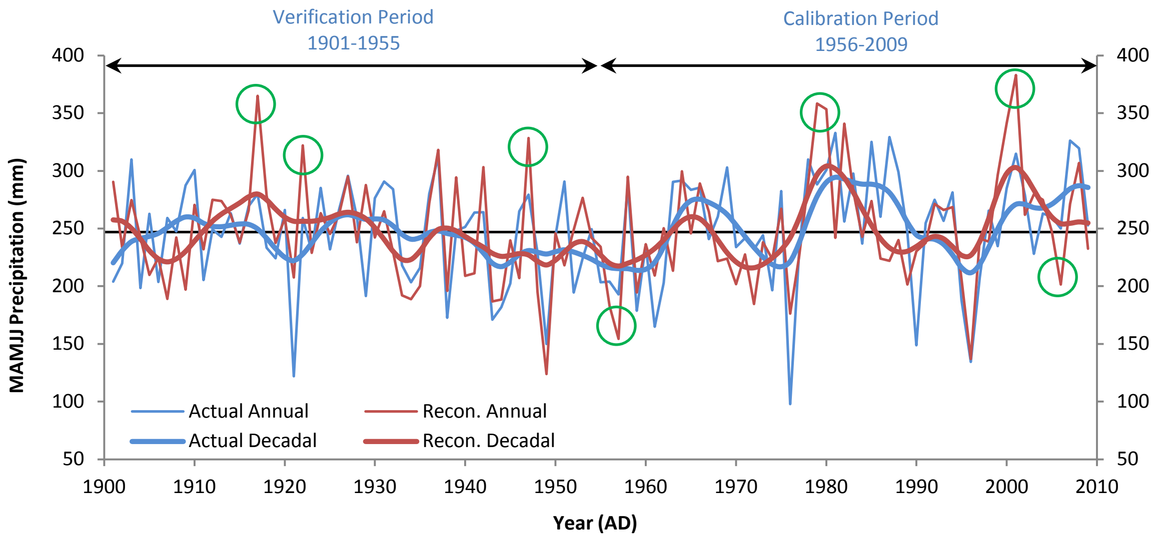

Figure SM7 Split period calibration and verification procedure for the scaled (Esper et al. 2005) reconstruction of MAMJJ precipitation over the period 1901-2009. Calibration shown for both annual and decadal smoothed timescales. Note the reduced underrepresentation of extreme years compared to the OLS regression approach, but also now the overrepresentation of precipitation in years highlighted by green circles

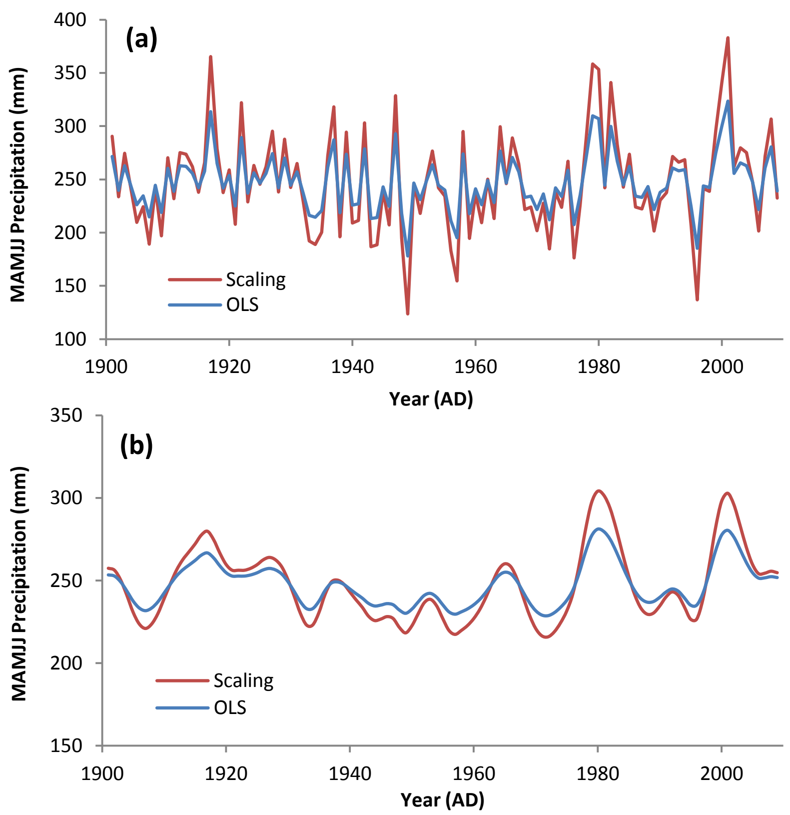

Figure SM8 Comparison of the OLS linear regression and scaling techniques at **a** annual and **b** decadal smoothed timescales for the period 1901-2009. This figure demonstrates how the regression based variance reduction associated with the OLS regression approach is partially overcome by using the scaling approach, thereby reducing the underrepresentation of extreme wet and dry years. However, this in turn increases the chances of over calibrating precipitation in the reconstruction

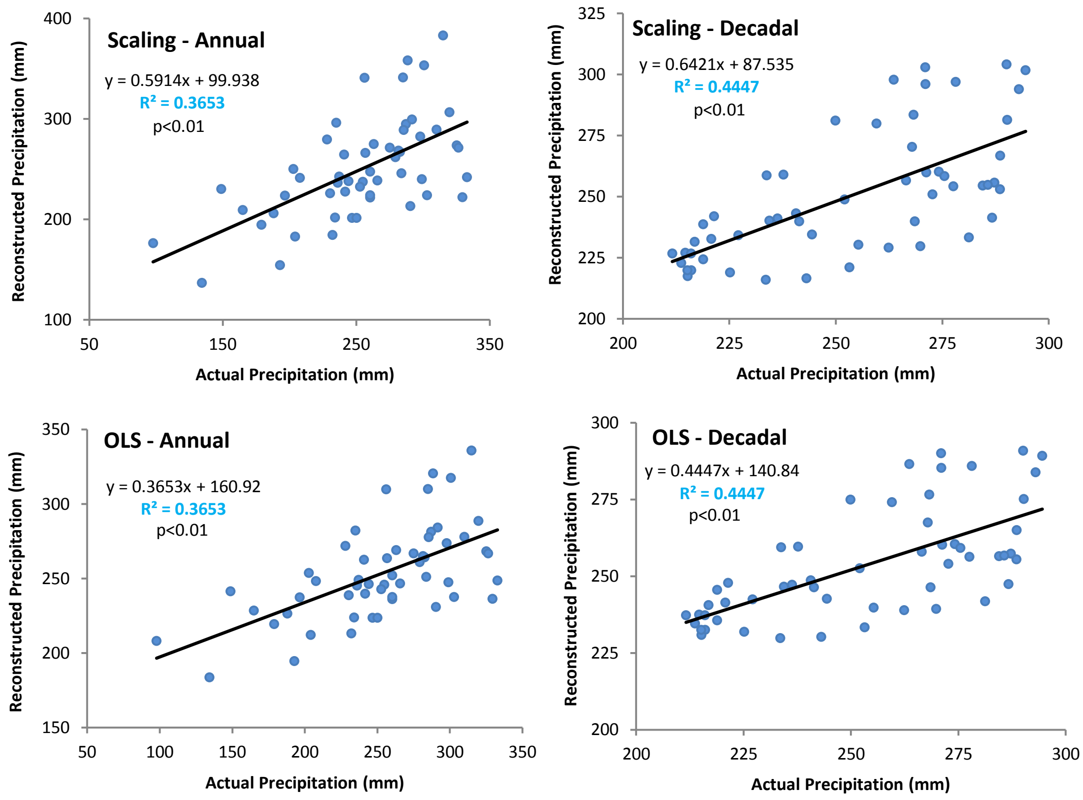

Figure SM9 Late period (1956-2009) annual and decadal smoothed calibration scatter plots for both the OLS linear regression and scaling reconstruction approaches

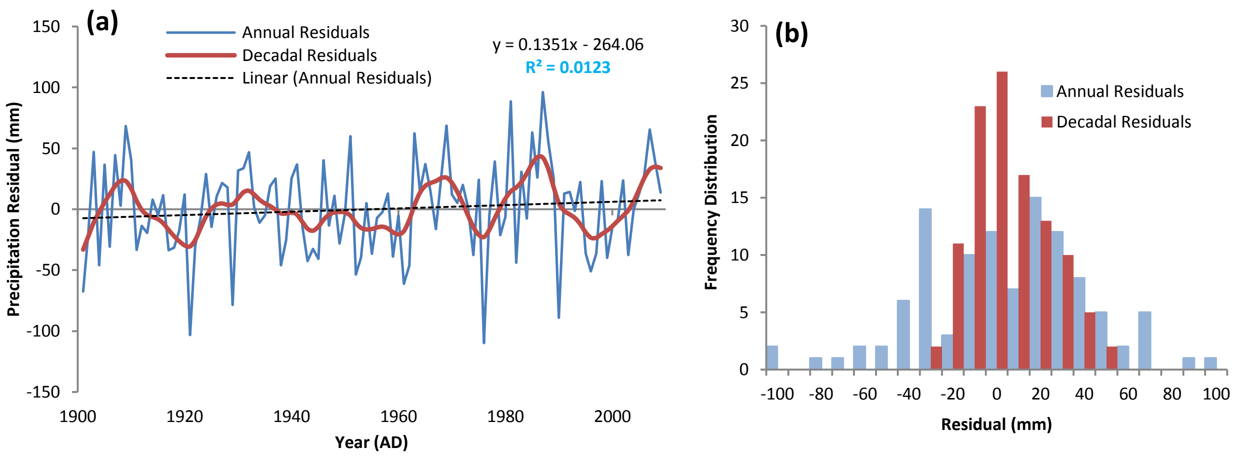

Figure SM10 OLS regression residuals. **a** Time series of annual and decadal regression residuals with linear trend line demonstrating no significant trend in the annual residuals. **b** Percentage frequency distribution plot of the annual and decadal regression residuals reveals the residual precipitation indices to be normally distributed

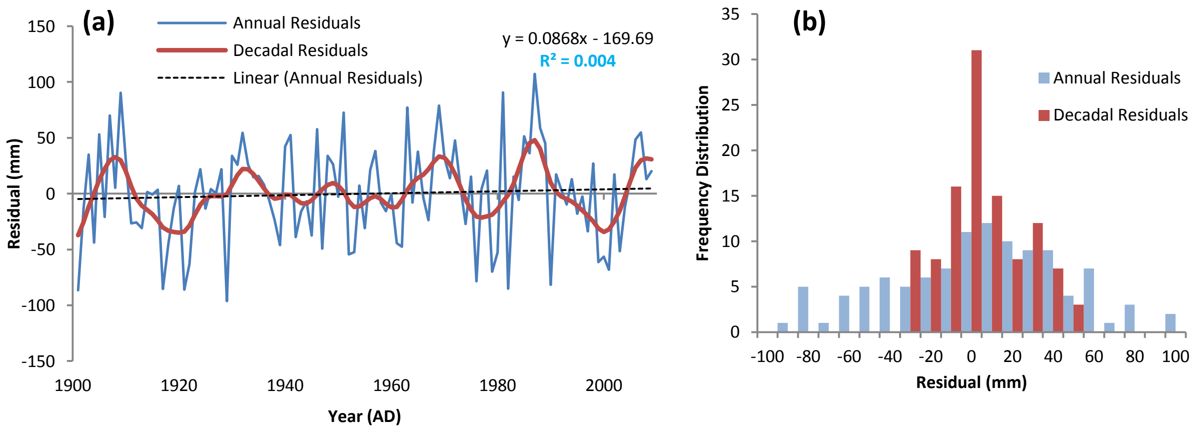

Figure SM11 Scaling residuals. **a** Time series of annual and decadal scaled residuals with linear trend line demonstrating no significant trend in the annual residuals. **b** Percentage frequency distribution plot of the annual and decadal residuals reveals the residual precipitation indices to be normally distributed. Scaled residuals show improved normal distribution and reduced trend in the annual residuals compared to the OLS regression approach (Fig. SM9)

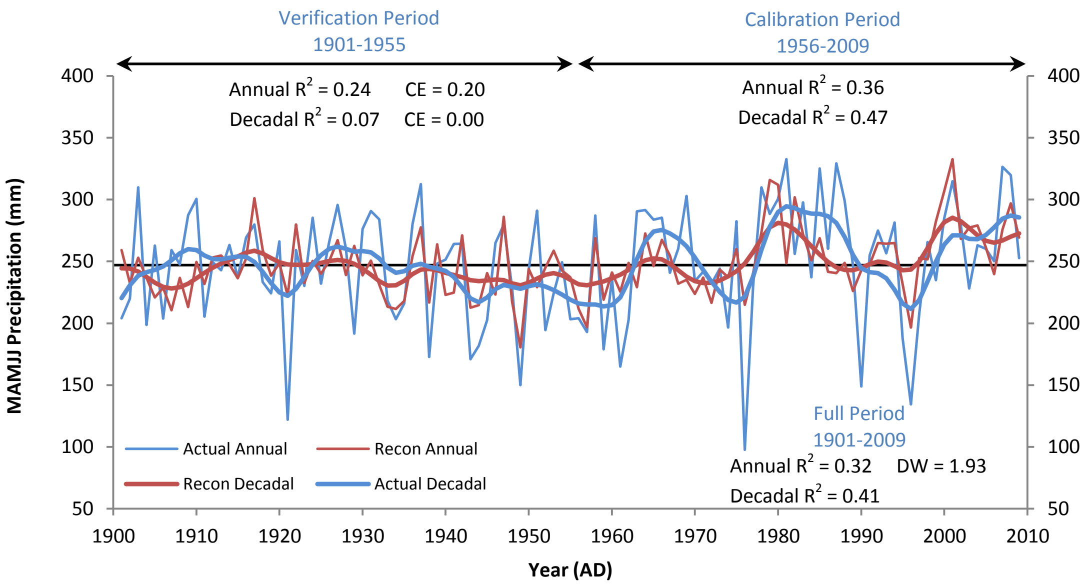

Figure SM12 Split period calibration and verification procedure for the OLS regression reconstruction of MAMJJ precipitation for the 100-year high-pass spline (100SPL) oak chronology over the period 1901-2009. Calibration is shown for both annual and decadal smoothed timescales. Verification statistics reveal a robust annual, but non-robust decadal, reconstruction of precipitation in East Anglia, emphasising that the RCS derived chronology is a better proxy for past precipitation variability

Supporting Tables

Table SM1 Generalized soil properties for the nine modern oak chronology locations from the (National Soil Resources Institute, 2010)

Site	Texture	Acidity/Basicity	Permeability	Fertility
Babingley	Sandy	Very acidic	Naturally Wet	Very Low
Blickling	Loamy	Slightly acidic	Freely draining	Low
Bradfield	Loamy/Clay	Slightly acidic	Slightly impeded	Moderate-High
Felbrigg	Loamy	Slightly acidic	Freely draining	Low
Foxley	Loamy/Clay	Slightly acidic, but base-rich	Seasonally-wet, impeded drainage	Moderate
Hethersett	Loamy/Clay	Acidic	Slightly impeded	Moderate-High
Hevingham	Loamy	Slightly acidic	Freely draining	Low
Sandringham	Sandy	Slightly acidic	Freely draining	Low
Sotterley	Loamy/Clay	Slightly acidic, but base-rich	Seasonally-wet, impeded drainage	Moderate

Table SM2 Comparison of the actual 20 driest MAMJJ years in the gridded instrumental precipitation series and the 20 driest years reconstructed from the East Anglian oak chronology. The reconstruction successfully estimates 10 of the 20 driest years in the instrumental record (highlighted in orange)

Reconstructed Year	Driest Reconstructed Precipitation (mm)	Instrumental Year	Driest Instrumental Precipitation (mm)
1949	178.0	1976	97.8
1996	185.3	1921	121.9
1957	195.2	1996	134.3
1976	207.5	1990	148.8
1956	211.2	1949	149.9
1972	212.1	1961	164.9
1943	213.4	1943	170.9
1944	214.3	1938	172.7
1934	214.5	1959	178.9
1907	214.7	1944	181.7
1933	216.3	1995	188.0
1959	217.8	1929	191.5
1948	218.0	1957	192.8
1938	218.5	1952	194.6
1909	219.1	1974	196.5
1935	220.9	1904	198.5
1989	221.6	1945	202.4
2006	221.6	1962	202.8
1970	221.8	1934	203.4
1995	224.2	1955	203.4

Table SM3 Comparison of the actual 20 wettest MAMJJ years in the gridded instrumental precipitation series and the 20 wettest years reconstructed from the East Anglian oak chronology. The reconstruction successfully estimates 8 of the 20 wettest years in the instrumental record (highlighted in blue)

Reconstructed Year	Wettest Reconstructed Precipitation (mm)	Instrumental Year	Wettest Instrumental Precipitation (mm)
2001	**323.6**	1981	332.8
1917	313.5	1987	329.4
1979	**309.7**	2007	326.4
1980	**306.9**	1985	325.1
2000	300.1	**2008**	**319.7**
1982	299.9	**2001**	**314.9**
1947	293.0	**1937**	**312.4**
1922	289.3	**1978**	**310**
1937	**287.1**	1903	309.8
2008	**280.7**	1969	302.9
1942	278.7	1910	300.7
1964	**276.7**	**1980**	**300.7**
1999	274.8	1988	299.0
1927	**274.3**	1983	297.8
1958	274.1	**1927**	**295.8**
1939	273.7	**1964**	**291.6**
1901	271.5	1951	290.9
1978	**271.0**	1931	290.8
1966	270.8	1963	290.4
1929	270.1	**1979**	**288.4**

Table SM4 Comparison of the 20 highest instrumental MAMJJ mean sea level pressure (SLP) years over East Anglia (Trenberth and Paolino 1980) and the 20 driest years reconstructed from the East Anglian oak chronology. The reconstruction successfully estimates 8 of the 20 highest pressure (i.e. driest) years (orange)

Reconstructed Year	Driest Reconstructed Precipitation (mm)	Instrumental Year	Highest Instrumental Mean SLP (mb)
1949	**178.0**	**1938**	**1020.2**
1996	**185.3**	1990	1019.8
1957	195.2	1945	1019.6
1976	**207.5**	**1943**	**1019.5**
1956	211.2	**1949**	**1019.3**
1972	212.1	1973	1019.1
1943	**213.4**	1997	1018.9
1944	**214.3**	**1976**	**1018.8**
1934	214.5	1921	1018.8
1907	214.7	1929	1018.4
1933	216.3	**1955**	**1018.2**
1959	217.8	1961	1018.1
1948	**218.0**	1982	1018.0
1938	**218.5**	**1948**	**1018.0**
1909	219.1	**1996**	**1018.0**
1935	220.9	**1944**	**1017.9**
1989	221.6	1967	1017.9
2006	221.6	1953	1017.8
1970	221.8	2003	1017.7
1995	**224.2**	1906	1017.7

Table SM5 Comparison of the 20 lowest instrumental MAMJJ mean sea level pressure (SLP) years (Trenberth and Paolino 1980) over East Anglia and the 20 wettest years reconstructed from the East Anglian oak chronology. The reconstruction successfully estimates 6 of the 20 lowest pressure (i.e. wettest) years (blue)

Reconstructed Year	Wettest Reconstructed Precipitation (mm)	Instrumental Year	Lowest Instrumental Mean SLP (mb)
2001	**323.6**	1930	1012.9
1917	313.5	1916	1012.9
1979	309.7	1931	1013.1
1980	306.9	**1937**	**1013.1**
2000	300.1	1932	1013.2
1982	299.9	1936	1013.2
1947	**293.0**	1928	1013.2
1922	**289.3**	1934	1013.4
1937	**287.1**	**2008**	**1013.4**
2008	**280.7**	1924	1013.6
1942	278.7	1909	1013.6
1964	276.7	**1947**	**1014.0**
1999	274.8	**1927**	**1014.1**
1927	**274.3**	**2001**	**1014.1**
1958	274.1	1903	1014.1
1939	273.7	1910	1014.1
1901	271.5	1912	1014.1
1978	271.0	1951	1014.2
1966	270.8	1985	1014.4
1929	270.1	**1922**	**1014.5**

Supporting Material References

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