Supplementary online material

Description of the climate simulations

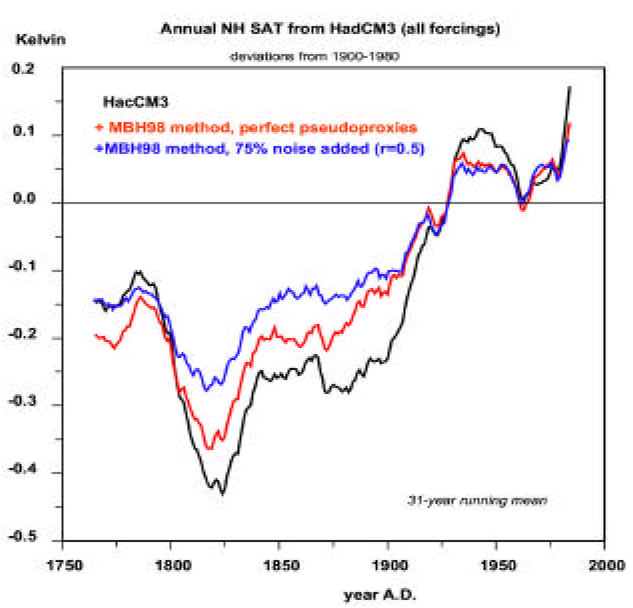
The atmospheric component of the climate model ECHO-G is ECHAM4 with a horizontal resolution of 3.75 x 3.75 degrees (T30) and 19 vertical levels *(S1)*. The ocean component is HOPE-G with a horizontal resolution of 2.8 x 2.8 degrees, grid refinement near the equator, and 20 vertical levels *(S2)*. Annual global mean concentrations of CO_2 and CH_4, were derived from air bubbles trapped in polar ice cores *(S3, S4)*. Variability of the solar irradiance and volcanic activity are aggregated into an annually changing effective solar constants with no spatial variations and no dependence on the solar spectrum. This effective solar constant was derived from net radiative forcing estimated from concentrations of ^{10}Be and historical observations of sun spots (the ^{10}Be /Lean splice in *S5*). The variations of solar irradiance have been scaled to the variance of the Lean et al. *(S6)* data in the 20th century. The evolution of the derived solar irradiance is in very good agreement with a recent reconstruction of the sun-spot number in the last millennium, also based on the ^{10}Be record *(S7)*. Volcanic radiative forcing was taken from *(S5)* derived from acidity measurements in ice cores.

N_2O concentrations were kept constant until industrial times, and then changes as in the IPCC scenarios from ECHAM4 and OPYC. Changes in ozone concentrations, vegetation or tropospheric aerosols have not been incorporated in this simulation. Earth´s orbital parameters are set constant to present values.

To complement our analysis with the ECHO-G model, we carried out our analysis using a simulation with the HadCM3 atmosphere-ocean GCM *(S8, S9)*. This simulation was forced with both natural and anthropogenic forcings for the period 1750 to 2000, and compliments a separate natural forcings run from 1500-2000. The natural forcings were volcanic (for four equal-area bands)*(S10)*, orbital *(S11)* and solar *(S5)* . The anthropogenic forcings were well-mixed greenhouse gases (as in *S12*), aerosols (adapted from *S12* from 1830-1860, and after this date as in *S12*), tropospheric and stratospheric ozone changes (following *S12* and *S13*), and land surface changes. The land surface changes were prescribed from 1750-2000 using data of *S14* and *S15*. These changes were used to modify the land-surface data set of *S16*.

Gridbox data from this simulation were used in exactly the same way as for the ECHO-G data as predictors in the method of MBH98 with varying degrees of noise added. Figure 1 below shows that, as for the results using the ECHO-G model, low-frequency variability is underestimated in the pseudoproxy reconstructions. This demonstrates that the loss of variance is not climate model-specific.

Figure S1. The NH annual temperature simulated by the model HadCM3 compared to the results of applying the MBH98 method to reconstruct the NH annual temperature from 105 model grid-points mimicking the multi-proxy network used by MBH98. Increasing amounts of noise have been added to the grid-point temperatures to mimic the loss of described variance in the local relationship between proxy data and local temperature. The corresponding local correlation is also indicated.



<u>Implementation of the Mann et al. (1998) method</u>.

Our implementation of the MBH method essentially follows their description in their original paper (*S17*). The statistical model was calibrated in the period 1900-1980. Monthly near-surface-temperature anomalies were standardized and subjected to an Empirical Orthogonal Function Analysis, in which each grid point was weighted by $(\cos \phi)^{1/2}$, where ϕ is the latitude (Mann et al. 1998 erroneously use a $\cos \phi$ weighting). The resulting EOF spatial patterns were subsequently re-scaled by the local calibration standard deviation. The resulting principal component time series were subsequently annually averaged. The annual mean near-surface air-temperatures from the gridboxes in the pseudo-proxy network were then used in the same regression set-up as in (*S17*) to reconstruct the amplitude of the principal components in the whole 1000 year simulation. The number of EOFs retained in the regression equation was previously determined, as in (*S17*), by maximizing the explained calibration temperature variance. In the reconstructions shown in this accompanying paper, the number of pseudo-proxies was kept constant in time, so that the number of retained EOFS (between 9-10 leading EOFs) used in the reconstruction is also constant in time but slighlty depended on the level of noise added. It was checked that this number of retained EOFs also explained a similar amount of temperature variance in the period 1870-1900 (independent of calibration), and that this number or a number very close to it also optimized the reconstruction at low frequencies in the whole simulation period. For the reconstructions with a small number of pseudoproxies also shown in this online text the number of retained EOFs was 2.

The near-surface temperature field was derived from the EOF spatial patterns and the reconstructed amplitudes of the principal components. From the reconstructed temperature field the Northern Hemisphere mean was calculated.

The pseudo-proxy network was co-located to the temperature-sensitive proxies of the network of MBH98 and MBH99. The instrumental pseudo-proxies used in some calculations were represent by simulated grid-point temperature without degrading. These long instrumental records, in total 11 located in Western and Central Europe, are indicated in the supplementary information in MBH98 (*S17*) and correspond to 8 pseudoproxies in the ECHO-G grid.

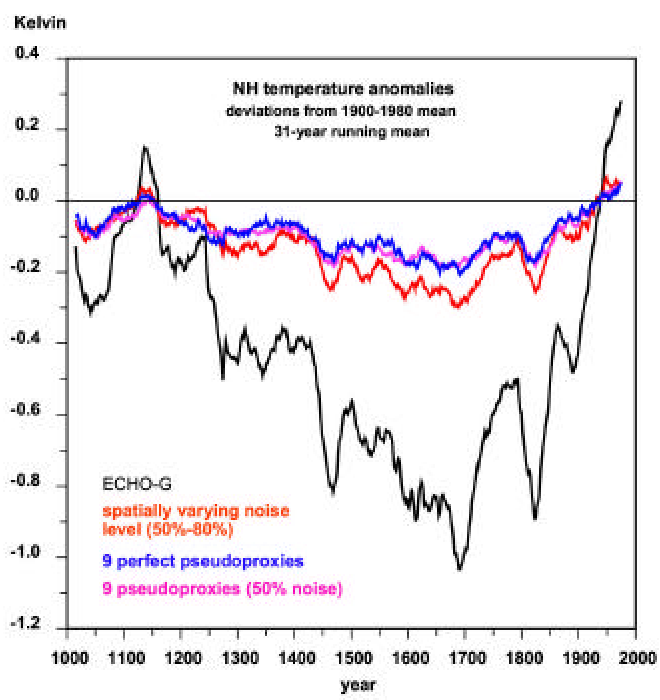
The MBH98 method is an inverse regression method. The optimized temperature fields target the whole available proxy network at a given time, so that the inclusion of a few instrumental data sets in the network should have little influence on the estimated fields, unless the instrumental records are explicitly overweighted. The advantage is that the method is robust against very noisy local records. This contrats with direct regression methods, where the estimated temperature fields are the predictands of a regression equation. In this case a few instrumental records, highly correlated to the temperature fields, may overwhelm the influence of proxy records with lower correlations in the calibration period. The disadvantage here is that the method strongly relies on the stability through time of the covariance of these best predictors with the temperature field.

Analysis with a smaller number of pseudoproxies and with spatially varying noise level

Normally, although not always, the number of proxies available back in time diminishes. For instance, in the MBH99 work the number of proxy indicators used prior to 1400 A.D. is 12 (*S18*). We have conducted further analysis to check if such a reduced numer of proxies exerts a large influence on the reconstruction process. We have thereby selected the co-located grid-points from the ECHO-G grid (wich reduced the number to 9) and applied the reconstruction method as in the previous cases (Figure S2). With this small number of pseudoproxies only the 2 leading EOFs can be resolved in the calibration period. The reconstruction exercise shows that the underestimation of the low-frequency variability of the NH temperature is severe, even for perfect pseudoproxies. Degraded pseudoproxies (50% of noise variance added)) yield a quite similar results, and in both cases the RE statistics in the calibration period was low (0.1). This indicates that the method approaches the level of almost no skill in these cases.

A further application of the method was performed with a spatially varying level of local noise, to test if this could influence in reality the reconstruction. We chose a randomly varying level of noise, between 50% and 80% of the total local variance, and distributed over the complete set of pseudoproxies, obtaining a curve which is close to the average between the two reconstructions with uniform noise level of 50% and 80, respectively (Figure S2).

Figure S2. The NH annual temperature simulated by the model ECHO-G compared to the results of applying the MBH98 method to reconstruct the NH annual temperature: using 9 model grid-points mimicking the network used by MBH99 prior to 1400 A.D (*S18*) with perfect and degraded pseudoproxies. Also, NH temperature reconstruction using the full pseudoproxy network with a spatially and randomly varying noise level (between 50% and 80% of total local variance being noise) .



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