Global-scale temperature patterns and climate forcings over the past six centuries: A comment.

Stephen McIntyre[1], Ross McKitrick[2]

[1]*Toronto Ontario Canada;* [2]*Department of Economics, University of Guelph, Guelph Ontario Canada N1G2W1.*

In a recent paper[1] (herein MM03), we developed an updated version of the climate proxy data set used by Mann et. al.[2] (MBH98) to compute a Northern Hemisphere (NH) temperature index. The most significant changes were the replacement of obsolete versions of proxy data used in MBH98 with current versions from the World Data Center for Paleoclimatology (WDCP) and the use of conventional principal component analysis (PCA) to reduce networks of tree ring chronologies to regional aggregates using the maximum period in which all sites were available. Applying the methodology of MBH98 to the new data yielded an NH temperature index in which the values in the 15th century exceeded those in the late 20th century, thereby contradicting the conclusions in MBH98 of a unique 20th century climate warming.

In their response,[3] Mann et. al. highlighted the influence of three (of 22) proxy series in their data that extend back to 1400. The three proxies are: a ring width series from the site at Twisted Tree Heartrot Hill (TTHH) in northern Canada; the first principal component (PC1) of earlywood and latewood ring widths from a roster of 10 sites in southwestern United States and Mexico ("SWM") studied by Stahle et al.[4] and the PC1 of ring widths and some densities from 70+ North American sites ("NOAMER") partly overlapping the SWM network. Mann et. al. confirm that the early 15th century portion of their NH temperature index would, like ours, exceed the late 20th century without these series. Hence the robustness of the MBH98 conclusions hinges on the quality and availability of these series in the 15th century. We show herein that these series are problematic.

The version of the TTHH series used in MBH98 included a 16th century site chronology based on a single tree; however, this version was not archived at WDCP. The archived site chronology only commences in 1529, when 3 trees become available, and this is the version we use. However, even the TTHH series as used by MBH98 does not begin until 1459 so it is irrelevant to the pre-1450 interval in any case. We note that this site is drawn from a network of Jacoby and d'Arrigo[5], who do not apply their network prior to 1600.

The SWM network is based on Stahle et al. (1998), now stated by MBH to have been erroneously attributed in MBH98 to Stahle and Cleaveland 1993. For each site in the SWM network, MBH98 use two series: earlywood and latewood widths, although Stahle et al. do not use latewood widths. In MM03 we did not extend the SWM PC1 back to the period AD1400-1450 because many sites were unavailable, preventing the use of a conventional principal components algorithm. Of the sites listed in the MBH98 Supplementary Information (SI), only 2 are available before 1450. In the FTP data[6] actually used in MBH98, there are 3 sites (6 series) extending back prior to 1450. Two of these sites (4 series) have identical values for the first 120 years for earlywood widths and the first 125 years for latewood widths, each differing thereafter, suggesting that the data are either spliced versions of different sites or different editions of the same site. Either way at least one of the two sites is clearly ineligible pre-1450, leaving only two potentially eligible sites. In other regions, MBH98 does not extend a PC1 back through an interval with only 2 sites; consistent application of this criterion would exclude the availability of the SWM PC1 in the pre-1450 period. Moreover, one of the two remaining sites is Spruce Canyon CO, which is used in the NOAMER roster and should therefore be dropped from the SWM group. The data for the remaining SWM site, Cerro Barajas, as used in MBH98, includes physically impossible negative values in the early portion of the series, which are not present in the version archived at WDCP. The unavailability of the SWM PC1 in the AD1400-1450 period is clearly established. We note that Stahle et al. themselves do not apply their network prior to 1706.

Regarding the NOAMER PC1, MBH98 stated that the network of site series were represented through conventional principal components analysis (PCA), and that the proxies thus generated were then scaled to the 1902-1980 mean and standard deviation before calibration to the 1902-1980 temperature PCs. Inspection of their Fortran software[7] shows that, in fact, the tree ring site chronologies were first scaled to the 1902-1980 mean and standard deviation, then the PCs were computed using singular value decomposition (SVD) on the transformed data rather than the covariance or correlation matrix. WDCP tree ring chronologies are already scaled to a mean index value of 1000 so no transformation is needed to carry out conventional PCA. For stationary series in which the 1902-1980 mean is the same as the 1400-1980 mean, the MBH98 method approximately zero-centers the series. But for those series where the 1902-1980 mean shifts (up or down) away from the 1400-1980 mean, the variance of the shifted series will be inflated. Since PCA overweights high-variance series, the result is that the PCs calculated in MBH98 are dominated by series that rise (or fall) in the 20th century. The over-weighting is increased further by using SVD on the transformed data rather than the covariance matrix.

For example, Sheep Mountain CA (ca534) exhibits the distinct "hockey stick" shape of the final MBH98 NH temperature index, while another NOAMER site Mayberry Slough AR (ar052) has a growth peak in the early 19th century (Figure 1). The MBH98 algorithm assigns 390 times the weight to Sheep Mountain compared to Mayberry Slough in the first PC.[8] Ironically, the Sheep Mountain CA series drops sharply in the 1980s (not shown), after the calibration period.

FIGURE 1. Two NOAMER site chronologies used in MBH98. Though both series are full-length, the first series is given 390 times the weight of the second series. The transformation of data prior to calculation in the MBH98 software causes series whose mean shifts at the end of the series to be over-weighted.

As another illustration of the pernicious effect of the MBH98 algorithm, we generated 70 series of stationary red noise and compared the PC1 from the MBH98 approach and that of a standard software package. To generate the data we took the 70 NOAMER sites available back to 1400 and fitted a lag 1 autoregression model to each. The coefficients ($\beta^1,...,\beta^{70}$) were all of magnitude less than 1. Then we generated 70 random vectors $a_t^1,...,a_t^{70}$ of length 1081, using the AR1 series $a_t^i = \beta^i a_{t-1}^i + e_t^i$, i=1,…,70. Each series was initialized at zero and the e_t^i vectors were

N(0,1). The first 500 values were then dropped from each series, yielding 70 vectors of stationary red noise, each of length 581. The (conventional) first principal component from these 70 series, after smoothing with a 25-year moving average, exhibits the expected stationary sawtooth pattern (Figure 2, top). The MBH98 method, in which the 70 series were first shifted to the mean over rows 503-581 and scaled to the standard deviation of the same interval, yields the distorted PC shown in Figure 2, bottom panel. The reason for the hockey stick-shape is that some of the underlying vectors randomly trail up or down at the end of their length, and these are selected for high weighting by the MBH98 method. Ten simulations were carried out and a hockey stick shape was observed in every simulation.

FIGURE 2. First principal component from 70 stationary red noise series, smoothed with Lowess (f=0.1). Top: Standard method (princomp command in the programming package R). Bottom: MBH98 algorithm, which pre-scales the data to the late-sample mean and standard deviation.

Figure 3 contrasts the NOAMER PC1 for the AD1400 network using the MBH98 method (top panel), the simple mean of the proxies (middle panel) and a conventional principal components algorithm[9] (bottom panel). The standard PC1 obviously tracks the mean quite closely, as would be expected, and both differ materially from the MBH98 “PC1”. Since the NOAMER “PC1” is so influential on the result of MBH98 (and is also cited as key to MBH99[10]) the distortion induced by the unnecessary transformation of data is material to the robustness of their conclusions.

FIGURE 3. Top panel: first principal component of the post-1400 NOAMER tree ring network, computed by MBH98 using late-sample prescaling. Middle panel: simple mean of proxies. Bottom panel: first PC as computed by standard software without late-sample prescaling.

Consequently, we find the three series highlighted by Mann et. al. to be problematic. To assess the overall materiality of these points we have reproduced the MBH98 methodology as closely as we could[11]. Figure 4 shows the original MBH98 NH temperature index (top panel) and our replication using MBH98 data, including the flawed PC series (second panel). The overall replication is reasonably good, with correlation between the two of 0.89. Remaining differences may be due to slight differences in the sequences of rosters used for PC calculation and proxy calibration (which cannot be unambiguously reconstructed from available information) or perhaps to slight scaling differences due to the unavailability of the particular edition of the instrumental temperature data used in MBH98. Figure 4 (third panel) shows the result using the same procedures as the middle panel with the following changes to the data: (1) a conventional principal components algorithm is used to generate the PC series used as proxies; (2) the SWM PC1 is not applied prior to 1450 (but two NOAMER PCs are applied in the AD1400-1450 period); (3) data versions archived at WDCP are used throughout, including for TTHH; (4) other data adjustments[12] as discussed in reference 1. The only adjustments material to the 15th century portion of the index (other than 1-2 above) are (1) the use of the current WDCP version of the Sheenjek River AK series, which can be applied in the AD1400-1450 reconstruction step; (2) the deletion of 4 unannotated fills by MBH98 in the Gaspe tree-ring series for 1400-1403.[13]

Figure 4. Top panel is NH temperature index from MBH98. Middle panel is authors' replication of the same using publicly disclosed data and methods (correlation=0.89). Bottom panel is authors' replication after correcting the problems discussed in the text. Methodology between middle and bottom panels is identical. Note particularly the change in relative height of the 15th century portion of the graph.

Any remaining methodological differences between MBH98 and us are immaterial to our main result, since our replication series shows the same uniquely high 20th century values of the MBH98 NH temperature index, but the same calculation on corrected data (using a conventional PC algorithm) does not. We do not use these results to assert that the early 15th century was "warm", as we do not endorse MBH98 methodology for other reasons not discussed here. Thus, any inconsistency of this graph with other paleoclimate studies is irrelevant. We do assert, based on the above considerations, that claims that late 20th century values of the MBH northern hemisphere temperature index are the highest in the past 600 years or in the last millennium cannot be sustained.

Supplementary Information accompanies the paper on *Nature*'s website (http://www.nature.com).

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Correspondence and requests for materials should be addressed to S.M. (e-mail: stephen.mcintyre@utoronto.ca).

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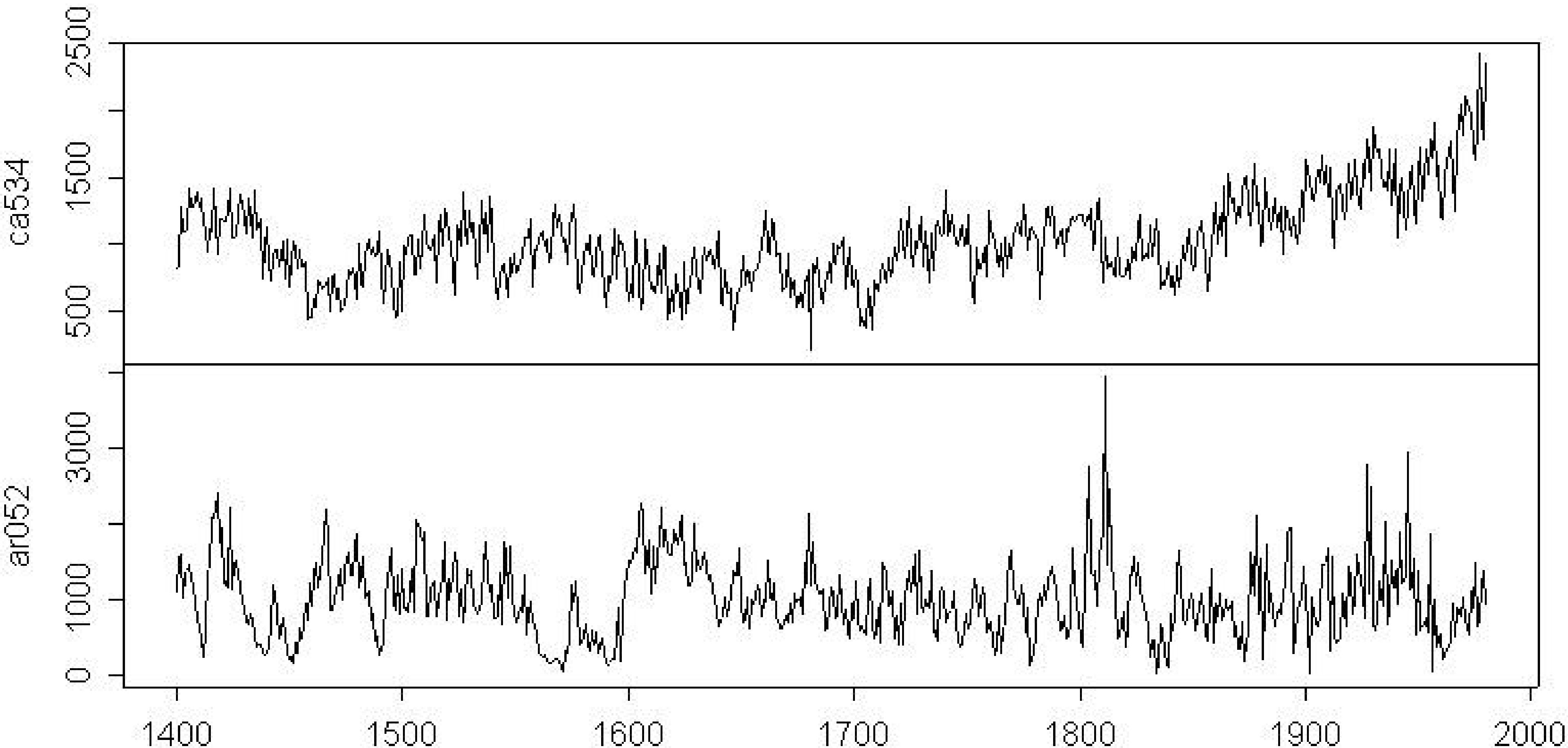
[6] ftp://holocene.evsc.virginia.edu/pub/MBH98/ ("FTP").
[7] FTP/TREE/ITRDB/NOAMER/pca-noamer
[8] The MBH98 weights are located at FTP/TREE/ITRDB/NOAMER/BACKTO_1400/eof01.out, with the sited identifications at FTP/TREE/ITRDB/NOAMER/BACKTO_1400/ noamer-itrdb-ad1400.txt.
[9] This uses the command "princomp" in the statistical programming package R.
[10] Mann, M.E., Bradley, R.S. and Hughes, M.K., (1999). *Geophysical Research Letters*, 26, 759-762.
[11] We have requested copies of the computer programs used in MBH98 in order to fully reconcile our results to MBH98, but MBH have refused to disclose these programs.
[12] See ref. 1 for details. This includes use of annual rather than seasonal CEngT, CEurT data; use of full CEurT and chin004 series; correct geographical placement of precipitation records; replacement of known obsolete records with updated series; and, where fills are necessary, using average of remaining series.
[13] The Gaspe series is the only example in MBH98 where missing early years were extrapolated; the objective in this single case was presumably to make this proxy available in the 1400-1450 interval. However, the same series is also included in the NOAMER PC roster (as series cana036), which is not filled in MBH98, and, in this case, the series is not applied before 1450. The underlying Gaspe site series in the first half of the 15th century is based on only one tree, and the originating authors (Jacoby and d'Arrigo, ref. 5) do not use the series prior to 1600. The availability of the Sheenjek River series maintains the number of Northern treeline sites unchanged, without the need for the use of the questionable early portion of the Gaspe series.



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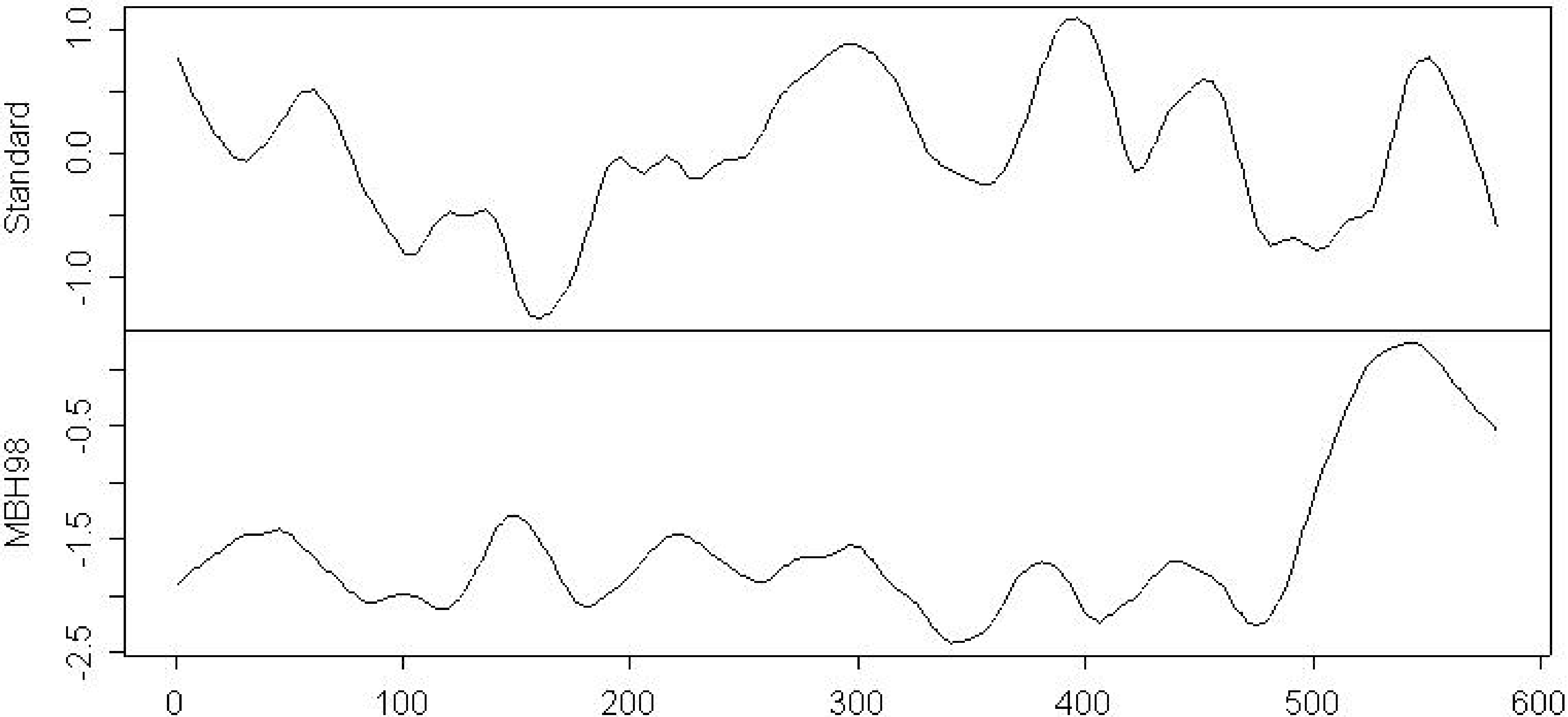

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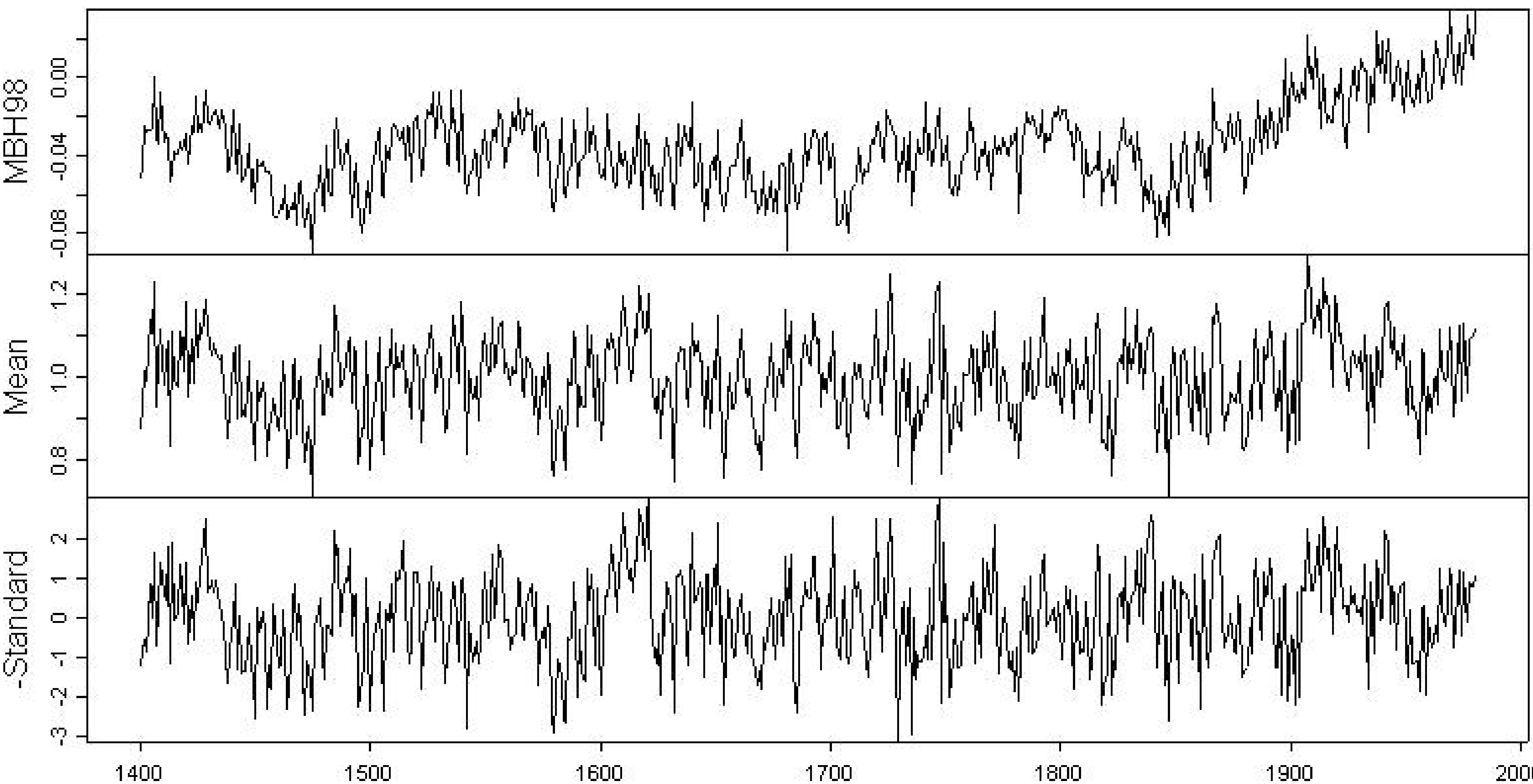

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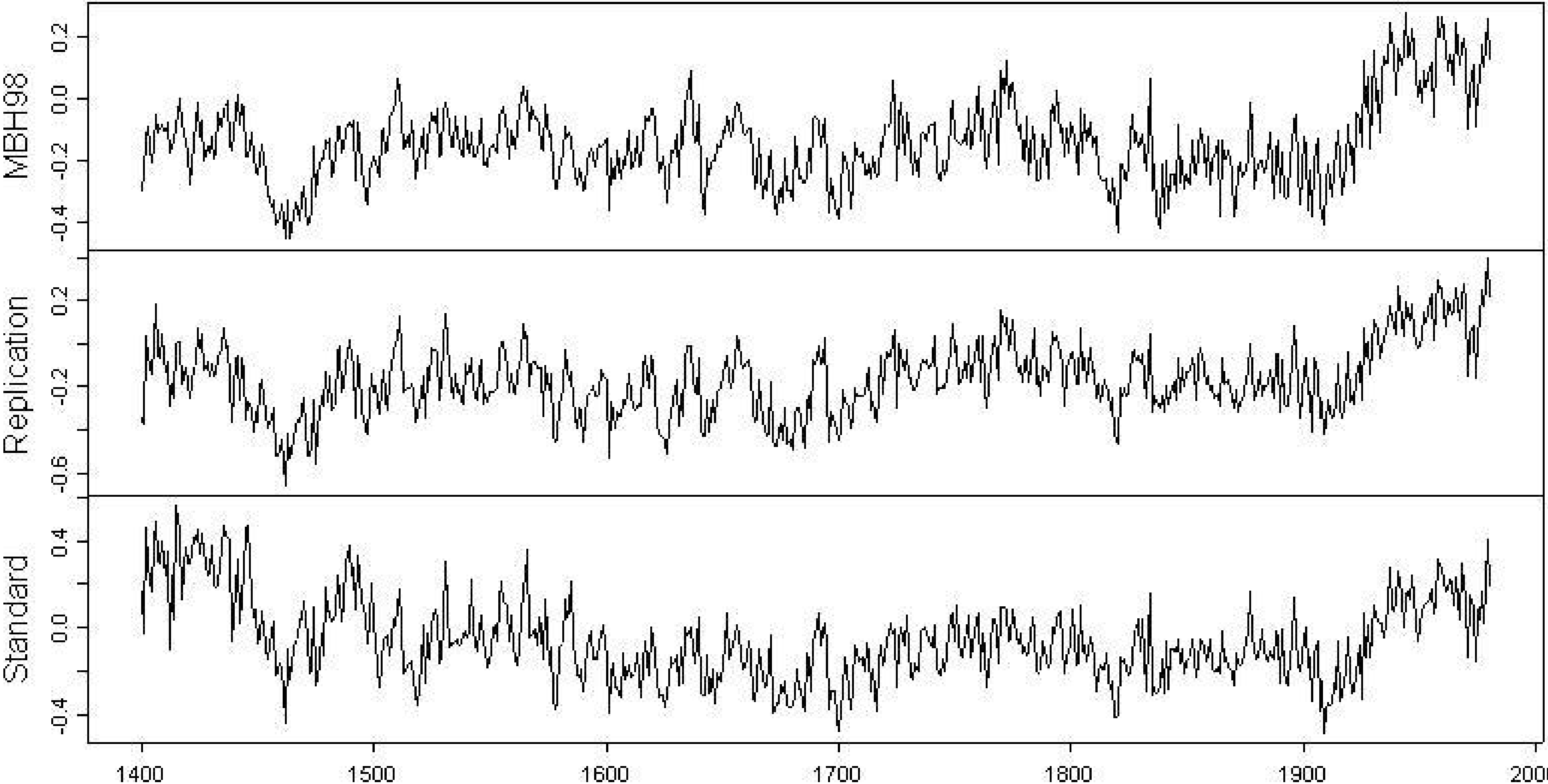
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