Comment on "Hockey sticks, principal components and spurious significance" by S.McIntyre and R.McKitrick

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Central to their GRL *McIntyre and McKitrick* [2005], is the M&M claim that Mann, Bradley and Hughes, MBH, invalidated their paleo-climate proxy reconstructed temperature anomalies reported in *Mann et al,* [1998] through the use of an unusual method of data standardization. Before assembling their data into global hemispheric results MBH98 employed a singular value decomposition, SVD, to group together localized site results from multiple proxy tree ring records. The first step in their procedures was to 'standardize" individual proxy records by dividing the data by its first-order detrended standard deviation for the period 1902-1980. This was followed by 'centering' the baseline for each record by subtracting its mean for 1902-1980, short (segment) centering.

Proxy records extend over time-spans varying from a century to many centuries. Calibration (training) proceeded in terms of the observed instrumental temperature record

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from 1902-1980. Short-segment centering ensures that, irrespective of duration, all records are directly comparable. M&M claim that the only acceptable procedure (their so-called conventional procedure) is centering against the 1400-1980 mean (full centering). They assert that correct results are only obtainable by use of full centering. The data MM05 GRL analyzed is a subset spanning the full time period, 1400-1980. All that is required, to refute their claim that full-centering is requisite, is to show that the same results are obtained irrespective of centering method.

We now outline the basis for our calculations. Fuller details appear in many statistical text-books cf for instance Jolliffe *Jolliffe* [2002]. A data array X of r independent proxies with p variables is represented in terms of r orthogonal p-dimensional 'vectors', V normalized to unit length, called the principle components, or PCs. The PCs are ranked in terms of their share of the overall summed variance. Sign and size information are provided through an amplitude matrix A (often referred to as the matrix of PC 'scores') with

$$X_{ij} = \sum_{l=l}^{r} A_{il} V_{lj}$$

The X_{ij} are the normalized and standardized data for the i proxy and the jth element. Complexity can be reduced by approximating the data via

$${}_{m}X_{ij} = \sum_{l=l}^{m} A_{il} V_{lj}$$

where the prefixed subscript m flags the number of PCs that are being used. The history derived in this approximation is ${}_{m}Y_{j}$, where the ${}_{m}Y_{j}$ are the column means of ${}_{m}X_{ij}$. If $m = r$, the prefix r is dropped and the corresponding Y_j are the column means of X_{ij}. To

distinguish full- centered derived quantities from short-centered quantities we accent all quantities derived using full centering.

M&M derive their conclusions using the "NOAMER" tree proxy data *McIntyre and McKitrick* [2005]. This consisted of 15 bristle-cone pine-type proxies and 55 proxies containing other species. These two groups have substantially different growth patterns and their proxy derived 'temperature' histories, as discussed by Graybill and Idso *Graybill and Idso* [1993] markedly differ. To adequately represent such data must, almost certainly, require, at least, the use of two PC terms. However all results and figures in the MM05 GRL derive solely from (m=1) PC1 analyses. To obtain convergent results, we show that at least two terms must be retained in the PC expansion. When sufficient terms are retained results become independent of centering convention.

The plots shown in Figure 1 A-D all use common scales and units. Where differences are small, residual differences are displayed to facilitate comparison. For reference, **A** plots short-centered results derived from the proxy temperature signals $_{\mathbf{2}}\mathbf{Y_j}$ versus year j.

B plots ($_{\mathbf{2}}\mathbf{Y_j} - _{\mathbf{1}}\mathbf{Y_j}$) versus year. This is the difference between m-2 results and results approximated solely by PC1, m=1. The differences are $\sim 30\%$ and thus, as expected, the m=1 approximation is very poor.

C plots ($\mathbf{Y_j} - _{\mathbf{2}}\mathbf{Y_j}$) versus year. The $\mathbf{Y_j}$ is based on the full PC vector set and therefore is an 'exact' result. The plotted differences between the 'exact' and m=2 results are a few percent Therefore the data are already well represented in terms of the first two leading PC vectors, m=2.

D plots $({}_{\mathbf{2}}\mathbf{Y_j} - {}_{\mathbf{2}}\hat{\mathbf{Y}}_{\mathbf{j}})$ versus year. Having established that m=2 provides a more than adequate approximation, the quantity plotted is the difference between results obtained from short and long centering. Other than a constant offset, the differences are, at most, a few percent, Due to the different centering conventions a constant offset is to be expected. However a constant offset leaves unaffected all physically relevant quantities such as temperature anomalies and changes. Differences at a few percent level in no way invalidate the MBH98 results, quite the contrary.

Section 2 of the M&M GRL analyze results from simulations based on trend-less red-noise and conclude that the MBH analysis produced hockey sticks "some of which bore a quite remarkable similarity to the actual MBH98 temperature reconstruction". The units used by M&M to compare between MBH results and simulated noise results were arbitrary and unrelated. To check the significance of this M&M claim we followed similar procedures and simulated an ensemble of seventy-member data sets based on lag-coefficient 0.5 AR1 noise and analyzed them via short centered $({}_{\mathbf{1}}\mathbf{Y})$. ($m = 1$ was used to bring our results into correspondence with M&M's). Analysis of the noise simulations finds hockey-sticks heights randomly distributed up or down and thus with an ensemble mean height of zero, The standard deviation of the heights about the zero mean is $\sim \pm 0.025$. Our figure **1 A** contains a 'typical' simulated hockey stick in units identical to those of the real MBH signal. At first sight the hockey-stick appears to be a 'zero-baseline'. Only when multiplied by ~ 50 does it become comparable to the MBH98 data.

We conclude first that had M&M used comparable units in their GRL Figure 1 comparisons, they could never have claimed a "remarkable similarity". Secondly, from our

figure D, we conclude the MM05 GRL claim that short-centering invalidated the MBH98 results is false.

References

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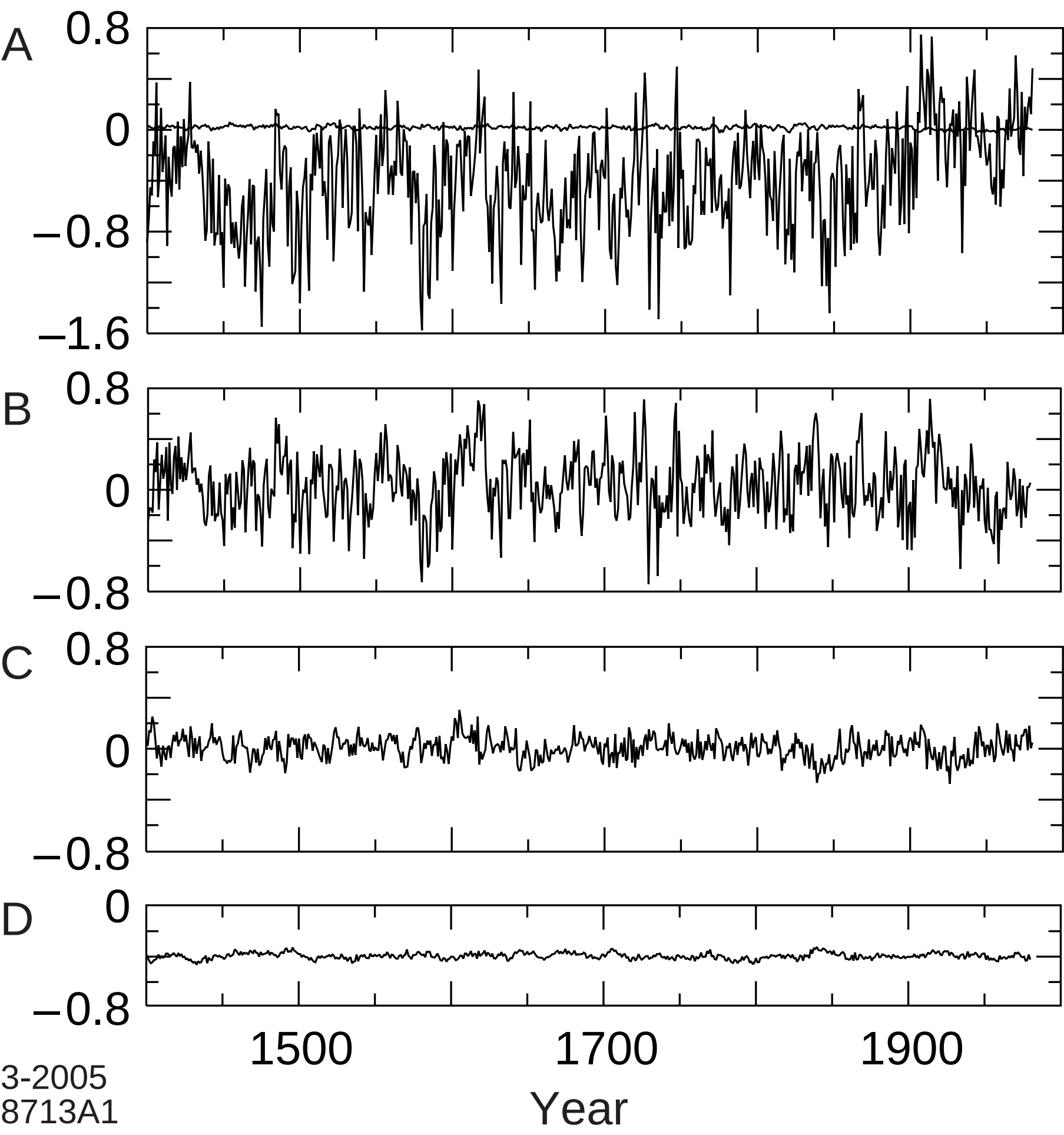
Figure 1. All units in **A-D** are with respect to data first normalized by division by the detrended standard deviation for 1902-1980 and then centered. The data span the years from 1400-1981. The notation is defined in the text. **A**. Combined history from short centered data, using the first two leading PCs, $({}_2Y)$ versus year. What appears to be a base-line at zero, is, in fact, a $({}_{\mathbf{1}}\mathbf{Y})$ versus year plot of a typical 'hockey stick' generated from a normalized and short-centered red-noise Monte Carlo simulation. **B.** Residual differences, $({}_{\mathbf{2}}\mathbf{Y} - {}_{\mathbf{1}}\mathbf{Y})$ between a short-centered $m = 2$ and $m = 1$ histories. **C.** Residual differences, $(\mathbf{Y} - {}_{\mathbf{2}}\mathbf{Y})$, between 'exact' and $m = 2$ short-centered data, plotted versus year. **D.** Residual differences, $({}_{\mathbf{2}}\mathbf{Y} - {}_{\mathbf{2}}\hat{\mathbf{Y}})$, between short and full centered data versus year.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