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Millennial Temperature Reconstruction Intercomparison and Evaluation: Supplementary material

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1 Introduction

This document describes supplementary data files accompanying "Millennial Temperature Reconstruction Intercomparison and Evaluation" by Juckes, Allen, Briffa, Esper, Hegerl, Moberg, Osborn, Weber and Zorita (hereafter 'the Manuscript'). Also included are some figures and background discussion.

The software (in the 'python' language) used to generate the reconstructions presented in the manuscript will be made available on `http://mitrie.badc.rl.ac.uk` when the manuscript is published.

2 Supplementary data files

cpd-2006-0049-sp2.zip contains:

```
1: mitrie_proxies_v01.nc
2: mitrie_instrumental_v01.nc
3: mitrie_cited_reconstructions_v01.nc
4: mitrie_new_reconstructions_v01.nc
5: mitrie_new_reconstructions_1400_v01.nc
6: mitrie_new_proxy_pcs_1000_v01.nc
7: mitrie_new_proxy_pcs_1400_v01.nc
8: mitrie_proxies_v01.csv
9: mitrie_cited_reconstructions_v01.csv
10: mitrie_new_reconstructions_v01.csv
```

The first contains the proxy data used for this study. The second contains the instrumental data. The third has the previously published reconstructions used in figure 1. The fourth and fifth contain all the new reconstructions referred to in this study, with start years AD1000 and AD1400 respectively (those starting in AD1400 are not referred to in the manuscript, but are

discussed in this document below). The sixth and seventh contain principal components of collections of proxies.

Files ending in `.nc` are in NetCDF format, which can be read by software which is freely available from `http://www.unidata.ucar.edu/software/netcdf/`.

Files ending in `.csv` are in 'comma separated variable' format, which can be read by most spreadsheet programmes. The file contents are derived directly from the corresponding NetCDF files.

The naming of the new reconstructions in files `mitrie_new_reconstructions_v01.nc` and `mitrie_new_reconstructions_1400_v01.nc` is of the form:

`mr_<proxy_collection>_<start>_<technique>_nht_01.`
`<proxy_option>.<calibration_option>[_<suffix>]`,

where the suffix is optional.

`<proxy_collection>` is a nmonic for the collection of proxies used, one of: 'jbb', 'mbh', 'ecs', 'msh', 'hca', 'union', 'mbh98', 'mbhx', 'mbh98x', 'u85' and 'um⟨nn⟩', for ⟨nn⟩ $= 01, 02, ...18$. The first 6 are as described in the Manuscript, 'mbh98' is the collection of proxies used by Mann et al., (1998) which extend back to AD1400. 'mbhx' and 'mbh98x' are variations of 'mbh' and 'mbh98' respectively in which the proxy principal components have been recalculated. 'u85' uses only those proxies from the 'union' collection which extend to 1985. 'um⟨nn⟩', for ⟨nn⟩$= 01, 02, ...18$ are subsets of the 'union' collection obtained by omitting proxy number "nn" (more details below). Each reconstruction in the data file has an attribute '`proxy_collection`' which lists the proxies used.

`<start>` denotes the start year, AD1000 or AD1400.

`<technique>` can be "cvm" or "invr", corresponding to "CVM" and "INVR" described in the Manuscript.

`nht` denotes the Northern Hemisphere mean temperature used to calibrate all these reconstructions.

`<proxy_option>` is set to '02' or '12' for calibration proxy principal components evaluated without or with padding of proxy series respectively. In the latter case, padding is with persistence for up to 10 years at the end of the proxy series.

<calibration_option> is set to '001' or '002' for calibration periods starting in AD1856 and AD1902 respectively.

The optional suffix is used to describe variants of the MBH proxy collection:
_ff: including filled french data.
_pc: using the unadjusted first proxy PC.
_mbh: using the standardisation of mbh: centred and standardised on detrended-variance of last 79 years.
_mbhx: centred and standardised on variance of last 79 years
_mbhl: centred and standardised on detrended-variance of last 125 years
_cen: centred on the whole period.
_std: centred and normalised on the whole period.

The results of the principal component decomposition in files mitrie_new_proxy_pcs_1000_v01.nc and mitrie_new_proxy_pcs_1400_v01.nc are stored in variables:
mppc<pc_number>_<sub_collection>_pc_<start>_<tag>.nc where:
<pc_number> is '01', '02', or '03': the index of the PC.
<sub_collection> is one of itrdb_namer, stahle_swm, for the ITRDB, North American and Stahle, South West Mexico, sub-collections of Mann et al. (1998) respectively;
<start> is the start year, 1000 or 1400;
<tag> is one of mbh, mbhx, mbhl, cen, std.

The 25 series used, for the itrdb_namer sub-collection with start year AD1000, are: AR052, AZ510, CA528, CA529, CA534, CA530, CA533, CO522, CO524, GA002, GA003, LA001, NC008, NM560, NM572, NV510, NV512, NV513, NV514, NV515, NV516, NV517, UT508, UT509, VA021.

For the AD1400 start year this increases to 56 series: AR049, AR050, AR052, AR053, AZ510, AZ550, CA065, CA073, CA084, CA087, CA528, CA529, CA530, CA531, CA532, CA533, CA534, CA555, CO511, CO522, CO523, CO524, CO525, CO535, CO545, CO547, GA002, GA003, GA004, LA001, NC008, NM559, NM560, NM572, NV049, NV053, NV056, NV060, NV061, NV510, NV511, NV512, NV513, NV514, NV515, NV516, NV517, OR009,

OR012, OR015, SD017, UT508, UT509, VA021, WY023, WY023X.

If extrapolation of series which end between AD1970 and AD1980 is allowed (the 'padded' version of the proxy collection) a further 14 series can be included: AZ082, AZ086, CA535, CO067, CO076, CO509, CO509X, MT006, NM025, NM026, NV037, UT023, WY005B, WY006.

The 'um⟨nn⟩' reconstructions are made using the following proxies, omitting number ⟨nn⟩ in the list:

```
 1: GRIP: borehole temperature (degC) (Greenland), [85],
 2: Chesapeake Bay: Mg/Ca (degC) (USA), [85],
 3: Shihua Cave: layer thickness (degC) (China), [85],
 4: China: composite (degC), [85],
 5: Arabian Sea: Globigerina bull,
 6: Indian Garden (USA),
 7: Methuselah Walk (USA),
 8: Yamal (Russia), [85],
 9: Boreal (USA), [85],
10: Taymir (Russia), [85],
11: Tornetraesk (Sweden), [85],
12: Upper Wright (USA), [85],
13: Northern Fennoscandia,
14: Northern Urals (Russia), [85],
15: Crete (Greenland),
16: Morocco,
17: Quelcaya 2 [do18] (Peru),
18: Quelcaya 2 [accum] (Peru)
```

The 10 proxies marked with `[85]` are used in the 'u85' reconstruction.

3 Omission of data by McIntyre and McKitrick (2003) [MM2003]

MM2003 claimed that when errors in the MBH1998 analysis were corrected proxy data suggested 15th century temperatures above those recorded in the 20th century. A response by Mann et al. suggests that the different result is due to omission of data which is not explicitly referred to in the MM2003 paper. Subsequent publications by McIntyre and McKitrick do not address the suggestion that data was omitted, but they do acknowledge this in an unpublished manuscript submitted to Nature
(`www.uoguelph.ca/~mckitri/research/fallupdate04/MM.resub.pdf`). The following paragraphs clarify this point.

MM2003 say that their regression coefficient uses all available proxies, but prior to this step they have, following MBH1998, combined proxies from heavily sampled region into principal components. However, unlike MBH1998 they only perform one principal component calculation for each region, for the time period when all proxies in that region are available. MBH1998 also carry out calculations for earlier times using the appropriate subsets of data back to those times.

In MM2003, the key section is 2(i). This subsection does not have a heading, but is intended to justify the assertion at the beginning of section 2: "(i) incorrect calculation of all 28 tree ring principal components". The subsection discusses a number of issues concerning the subjective choice of the 5 regions in which the principal components are calculated. Table 7 gives some information about the principal components calculated. Note the statement that the "WDCP [World Data Center for Paleoclimatology] Available Period" for North America is given as AD1619 to 1971. There is, of course, a vast amount of North American data prior to AD1619: this date is the earliest date at which all North American sites used by MBH1998 are available.

The supplementary information for MM2003 (http://www.climate2003.com/SI.MM03.htm) offers "The corrected dataset incorporating updated versions of series as annotated above and freshly calculated principal component series as used in MM03 is here." The file obtained from the link contains 112 series corresponding to the list provided in the appendix of MM2003. The

PCs of the North American tree-ring data have no data prior to AD1691, as implied by careful reading of MM2003.

4 Anomalous reconstruction of McIntyre and McKitrick (2005) [MM2005]

The McIntyre and McKitrick papers are concerned mainly with the MBH1998 reconstruction from AD1400 and the methods used to generate it. Although the research described in the manuscript deals with reconstructions from AD1000 to 1980, we will here look briefly at the AD1400-1980 period in order to evaluate the McIntyre and McKitrick criticisms.

As discussed in the manuscript, MM2005 produce a reconstruction which is substantially warmer than that of MBH1998 in the 15th century, though also substantially cooler than their earlier analysis in MM2003. The difference between MM2003 and MM2005 is primarily due to the inclusion in the latter of data which was omitted in the former, as described above. Wahl and Ammann (2006) ascribe the difference between MM2005 and MBH1998 to another apparent error by McIntyre and McKitrick: the omission of the normalisation of proxies prior to the calculation of proxy principal components.

As the Wahl and Ammann work is, at the time of writing, unpublished, we have included here independent verification of their conclusion: these results also show that the lack of sensitivity to reasonable variations in principal component analysis found by Wahl and Ammann is also found with the slightly different reconstruction technique used here.

Figures S1, S2 shows the first proxy principal component of the North American network, calculated under various different conventions. Figure S2 differs from fig. S1 in allowing the use of padding, as used by MBH1998, so that proxy series which end slightly short of AD1980 can still be used. Whether or not padding is used, the greatest impact is obtained when the normalisation is omitted (brown curves). It is also true, as argued by MM2005, that the standardisation used by Mann et al. (1998, 1999) does produce a clearer transition from a near level pre-industrial curve to a steadily rising curve in the last 150 years.

We now look at the impact of these changes on the reconstruction. The Gaspé data, which was extrapolated from it start date, AD1403, to AD1400 by MBH1998, has been omitted here.

We find marginal impact when the calibration period is AD1856 to 1980 (Fig. S3). With a shorter calibration period, AD1902 to 1980 (Fig. S4, as used by MBH1998, MBH1999, MM2003, MM2005), we find a result similar to that of MM2005: using proxy PCs from un-normalised collections does produce an anomalous 15th century.

Figure S5 shows the modified principal components used in the reconstructions show in Fig. 3 of the manuscript.

5 Sensitivity to the end of the analysis period

This manuscript, as in many earlier studies, has used proxies up to AD1980. It is clearly desirable to make the overlap between the proxies and the observational data as large as possible in order to reduce uncertainty in the statistical regression. The advantages which would be gained by extending the study period to, say, AD2005, have to be offset against the major disadvantage that many of the proxies do not extend to that date. The choice of AD1980 as a cut-off admits a large number of proxies and also captures a substantial fraction of the variability in the instrumental temperature record.

Briffa et al. (1998), D'Arrigo et al. (2006) curtail their study period for a different reason: these two papers are heavily dependent on high latitude tree-ring data which has been found to have an inhomogeneous response to temperature over the last century: stronger in the early part of the century.

The proxy data used in this study do not allow a detailed investigation of this issue. Moving the cut-off date forward 5 years reduces the number of proxies from 18 to 10 (denoted the 'u85' proxy collection), but does not change the character of the reconstruction significantly.

Figure S6 shows that the resulting reconstructions is not greatly different from the 'union' reconstruction. Moreover, most of the difference arises from the different choice of proxies, as shown by the curve 'u85b' which uses the same calibration period as the 'union' curve with the 'u85' proxy collection. The difference between 'u85' and 'u85b', which results from extending the calibration period by 5 years, is minimal.

This is perhaps to be expected as the proxies which suffer from the problems highlighted by

Briffa et al (1998)., D'Arrigo et al. (2006) make up a relatively small part of the 'Union' proxy collection.

Figure S7 shows the unsmooothed series for the calibration period, showing how the 'u85' composite captures the up-turn in temperatures at the start of the 1980s.

6 Sensitivity to omission of proxies

Figure S7 shows 18 reconstructions, each made by omitting one member of the 'union' collection. It is clear that no single proxy has a dominant influence.

The largest identifiable influences are that inclusion of proxy series one (The GRIP borehole temperatures) generates a warmer estimate in the 10th century by about 0.1K (i.e the reconstruction omitting this proxy is cooler than all those including it, in the 21 year mean, in this period) and inclusion proxy series 5 (Arabian sea) cools the reconstruction by about 0.1K in the 13th and 14th century.

7 Web sites

The ITRDB data can be obtained from: `www.ncdc.noaa.gov/paleo`.

The data used by Mann et al. (1998) is available here:
`http://www.nature.com/nature/journal/v430/n6995/suppinfo/nature02478.html`

More information about proxy data sources and the scientific basis for expecting a temperature signal can be found at: `http://mitrie.badc.rl.ac.uk/short_reviews`.

Information about the primary funders of this work is given at: `http://www.rivm.nl/en/`.

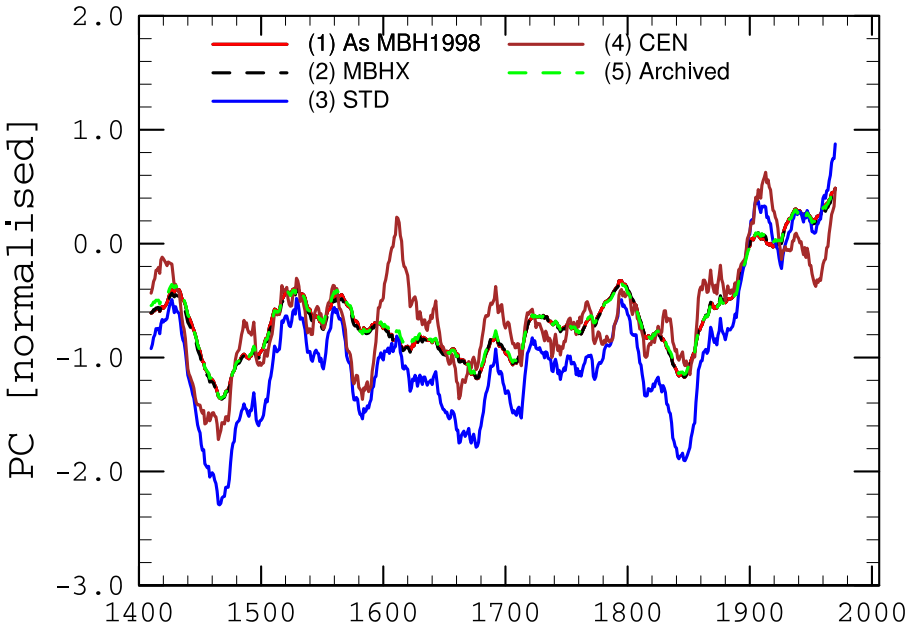

Fig. 1. Proxy principal components: the first principal component of the North American ITRDB network of Mann et al., 1998. (1) Using the normalisation as in Mann et al. 1998, (2) as (1), but using full variance for normalisation rather than detrended variance, (3) normalised and centred on the whole series, (4) centred only (5) as archived by MBH1998. 21-year running means.

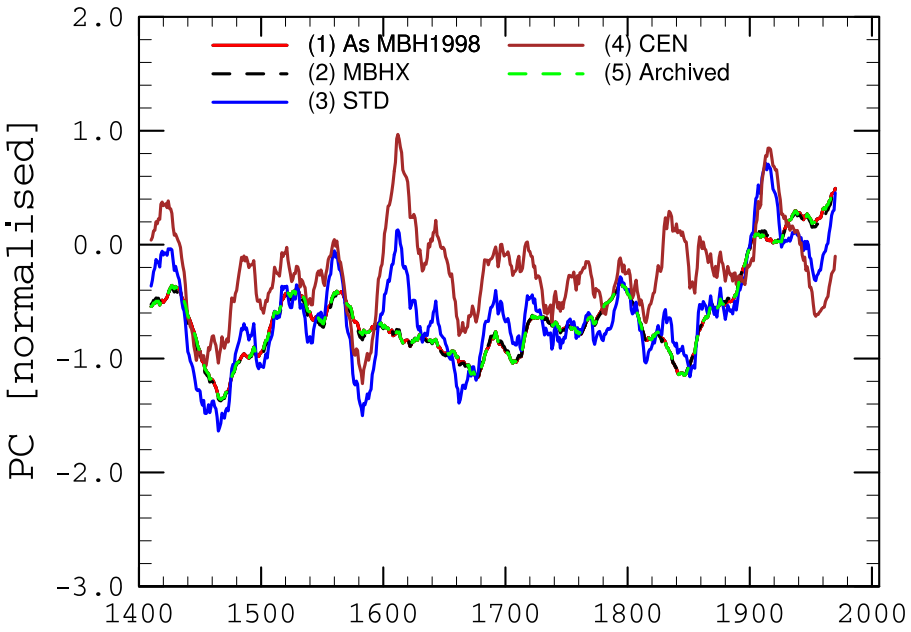

Fig. 2. As Fig. S1, except allowing padding of up to 10 years data, so that the proxy network is 70 instead of 56 trees (see section 2 of this document for lists of proxies).

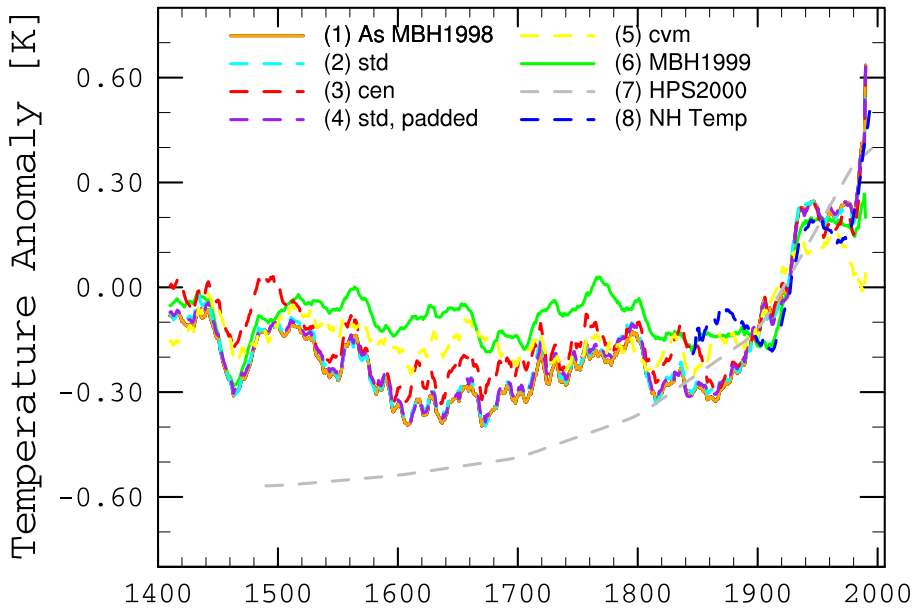

Fig. 3. (1-5) Various reconstructions, AD1400 to AD1980, using variants of the Mann et al, 1998 data. Calibrated on AD1856 to 1980 Northern Hemisphere temperature. (6-7) are reconstructions by MBH1999 and HPS 2000 respectively, (8) is the Northern Hemisphere instrumental temperature. (1-4) use the INVR technique, (1) using the same proxies as MBH1998, (2) using proxy PCs recalculated with standardisation on the whole series, (3) using proxy PCs which have been centred but not normalised, (4) as (2), but with padding of proxy series. (5) is as (2), but using the CVM technique instead of INVR. 21-year running means.

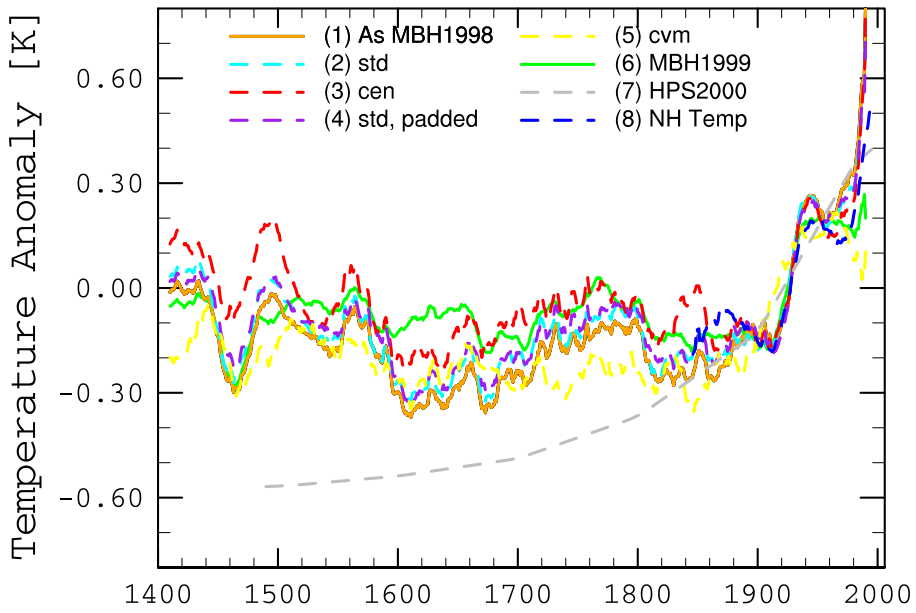

Fig. 4. As Fig. S3, except calibrated on AD1902 to 1980.

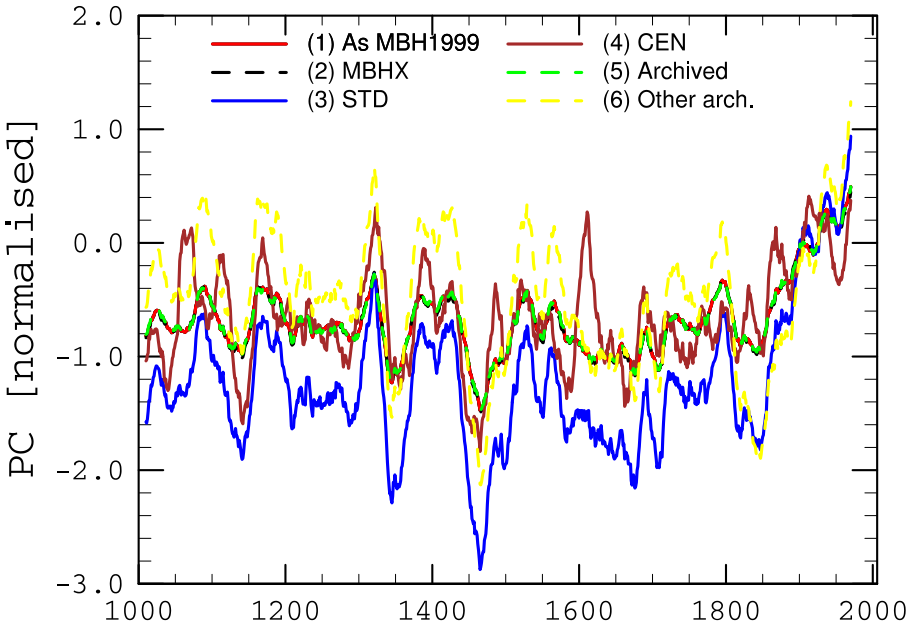

Fig. 5. First principal component of the ITRDB North America network, as used by MBH1999. (1) calculated using the method of MBH1999, (2) as (1), except normalising with the full variance of the calibration period rather than the detrended variance, (3) centering and normalising on the whole series, (4) centering only, no normalisation, (5) as archived by MBH1999, (6) adjusted version (see MBH1999). 21-year running means.

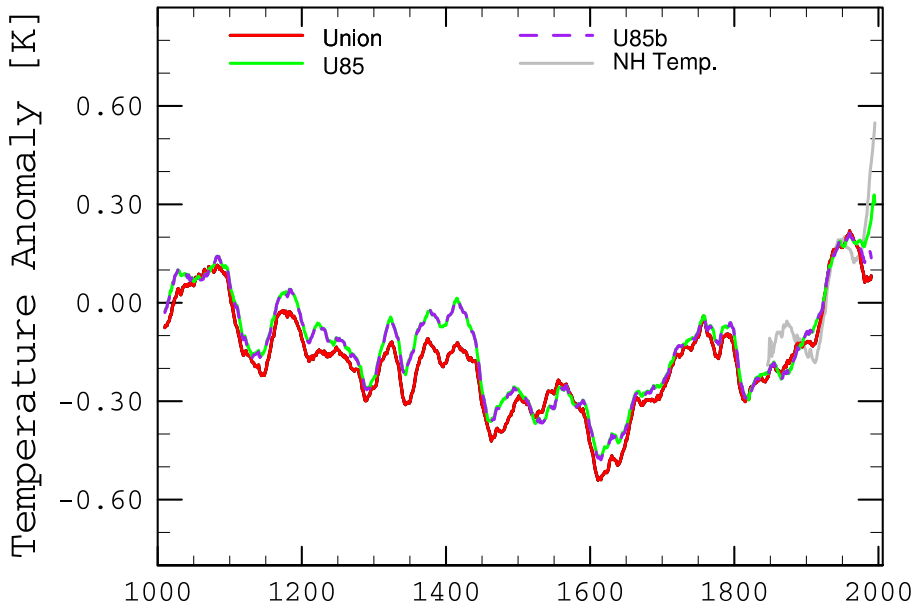

Fig. 6. The ‘u85’ reconstruction, using 10 proxies which extend to 1985, compared against the ‘union’ reconstruction. Also shown is the Northern Hemisphere temperature record. The ‘u85b’ reconstruction uses the same data as ‘u85’, but is only calibrated on the period 1856 to 1980.

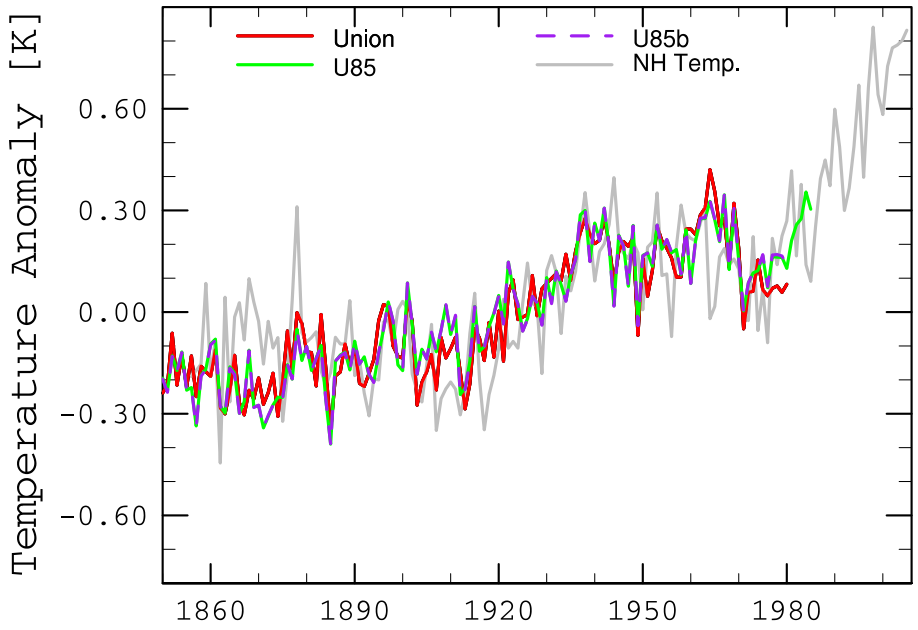

Fig. 7. As S6, but only showing the period after 1850 and unsmoothed.

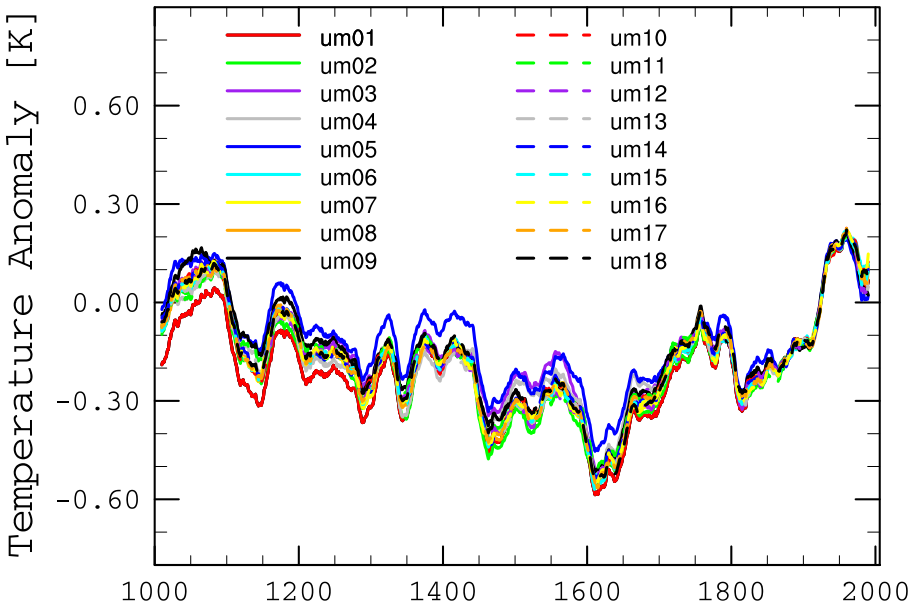

Fig. 8. Various reconstructions. With mean of 1900 to 1960 removed. 21-year running means.