

# ***Auditing Temperature Reconstructions of the Past 1000 Years***

Stephen McIntyre

World Federation of Scientists

Erice, Sicily

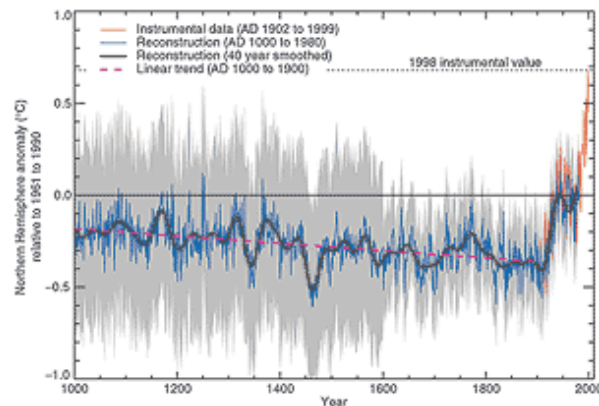
Aug. 20, 2008

## **Abstract:**

Temperature reconstructions of the past 1000 years, especially the one from Mann et al (1998, 1999) have been a prominent image in the climate change debate, giving rise to, among other things, that 1998 was the “warmest year of the millennium”, a prominent claim in IPCC Third Assessment Report (2001). Similar claims are made in the IPCC Fourth Assessment Report (2007), which stated that it is “likely” that the last 50 years were the “warmest in the past 1300 years”. I discuss efforts to verify these claims, showing that the evidence in the IPCC studies is contradicted by updated versions of key series and is insufficient to support this claim.

## ***1000-Year Temperature Reconstructions***

The 1000-year temperature reconstruction of Mann et al (1999), commonly called the “Hockey Stick”, appears no fewer than 6 times in IPCC (2001) and was featured in the backdrop of the Press Conference releasing the 2001 IPCC Report. Contrary to some later claims, this was not an incidental illustration of the 2001 Report, it could almost be said to be their logo.



**Figure 1. From IPCC (2001) Figure 2.21 showing the “Hockey Stick” graph of Mann et al (1999).**

It gave rise to public statements by governments such as the following one by the Canadian Minister of the Environment:

The 20th century was the warmest in the Northern Hemisphere in the past 1000 years. The 1990s was the warmest decade on record and 1998 was the warmest year - in Canada and internationally. (David Anderson, April 5, 2002)

The graphic continues in use, most recently in the (July 2008) draft report of the U.S. Climate Change Science Program (2008), but most prominently in *Inconvenient Truth* (Gore 2006), where Gore commented:

the vaunted Medieval Warm Period (the third little red blip from the left below) was tiny in comparison to the enormous increases in temperature in the last half-century - the red peaks at the far right of the graph. These global-warming skeptics - a group diminishing almost as rapidly as the mountain glaciers - launched a fierce attack against another measurement of the 1000 year correlation between CO<sub>2</sub> and temperature known as the “hockey stick”, a graphic image representing the research of climate scientist Michael Mann and his colleagues.



**Figure 2. Left - Al Gore presents Hockey Stick in *Inconvenient Truth*.**

The IPCC (2007) report continued to advocate a Hockey Stick, though their language was slightly more restrained:

[It is] likely that this 50-year period was the warmest Northern Hemisphere period in the last 1.3 kyr.

Its illustration supporting this claim was a “spaghetti graph”, consisting of the Mann et al (1998-99) reconstruction, 9 other reconstructions extending back to the Medieval Warm Period, plus several shorter reconstructions. Despite the seeming inconsistency of the various reconstructions, IPCC concluded that they supported an assessment that the modern warm period was “likely” warmer than the Medieval Warm Period.

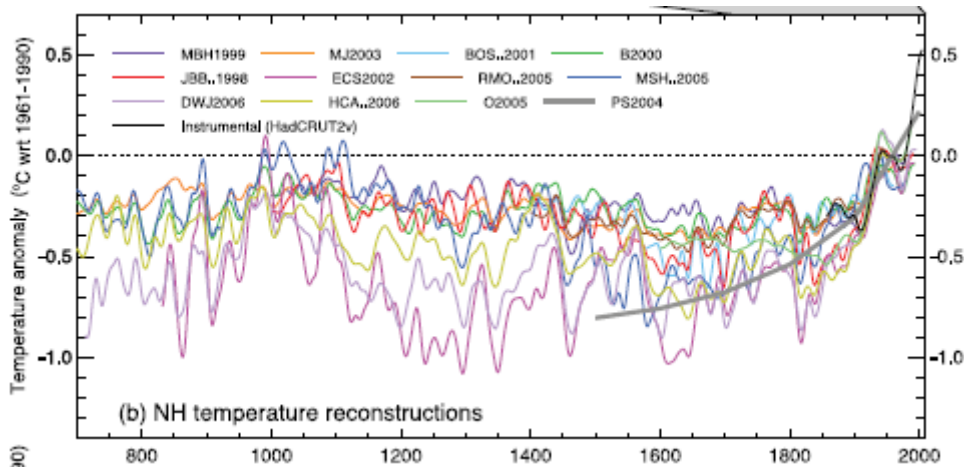


Figure 3. IPCC (2007) Figure 6.10b. Spaghetti graph of 1000-year reconstructions.

In the first part of this paper, I will review our critical analysis of the Mann et al (1999) reconstruction used in IPCC (2001), and, in the second part, I will discuss critical issues common to the other reconstructions in the IPCC (2007) report.

Critical analysis of the Mann reconstruction has been described in McIntyre and McKittrick (2003, 2005a,b,c,d) and at [www.climateaudit.org](http://www.climateaudit.org). This analysis has attracted considerable public interest, being considered at greater or lesser length by two panels reporting to U.S. congressional committees (NRC 2006; Wegman et al 2006) and IPCC (2007), with the latter having a very different opinion to the others, and was considered at hearings of a congressional subcommittee. The principal response to our criticism is an article by two of Mann's coauthors (Wahl and Ammann 2007), Supplementary Information to which became available only in July 2008.

### ***Mann et al (1998, 1999)***

Our examination of the Mann reconstruction included both an attempt to numerically replicate the reported reconstruction from source data and a consideration of the statistical methodology and robustness of the reconstruction.

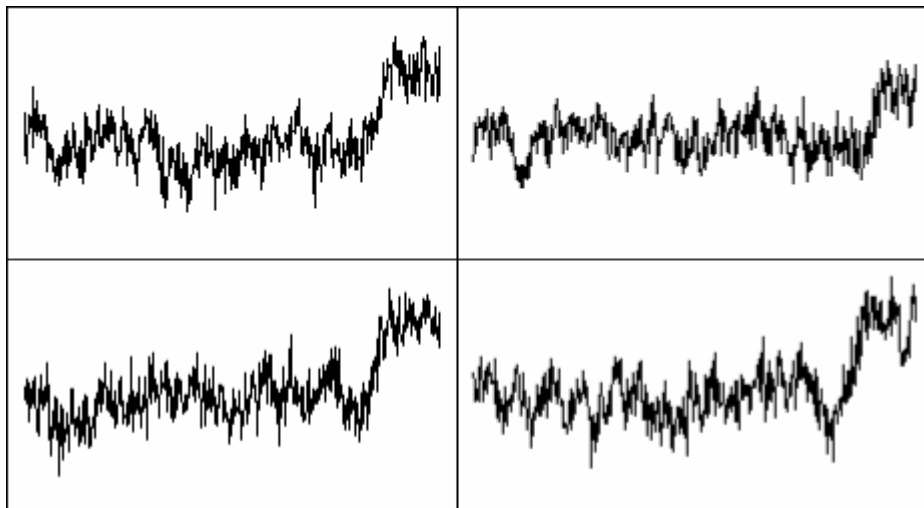
The reconstruction was described in two papers – Mann et al (1998) contained a Northern Hemisphere temperature reconstruction to 1400 AD, extended to 1000AD in Mann et al (1999).

Mann et al (1998) reported use of 11 steps, referred to as “experiments”, each of which uses different proxy networks. However the results for of the individual “experiments” were not available; all that was available was a splice of all 11 steps, preventing even elementary statistical analysis of, say, the first step without running the gauntlet of replicating the entire project from scratch. The authors refused to provide the results of the individual steps. Both Nature and the U.S. National Science Foundation have supported this refusal and these results remain unavailable to this day, though approximations are possible.

In response to our original inquiry for input proxy data, Mann said that he had

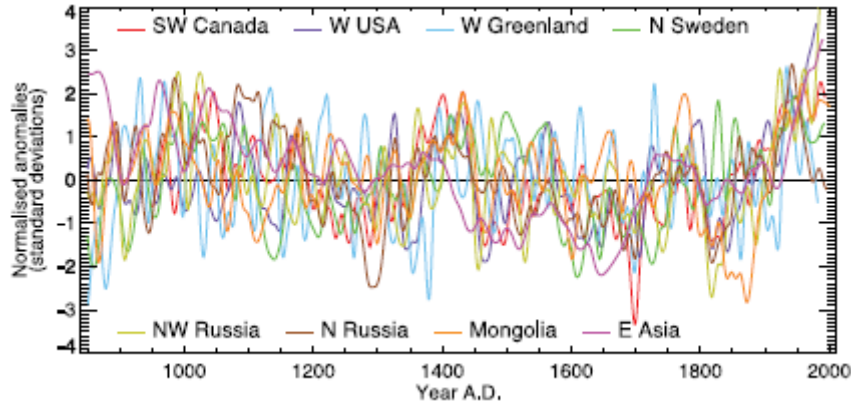
“forgotten” the location, but would ask an associate to locate it for me. The associate said that the information did not exist at one site, but volunteered to collect it for me; a few weeks later, I was directed to a URL at Mann’s website. Later, noticing problems with this data set, we sought confirmation from Mann that this was the data actually used in Mann et al (1998) and were told that no one else had any problems with it. After publication of McIntyre and McKittrick (2003), Mann then said that we had used the “wrong” data, the first data set was deleted without any trace and another data set materialized. This new version contained many discrepancies with the original Supplementary Information; we filed a Materials Complaint to Nature. This resulted in a third version, which was archived accompanying a corrigendum (Mann et al. 2004).

In addition, the methodological descriptions were both incomplete and inaccurate for some important details. The methods used to calculate confidence intervals and to determine the number of retained principal components remain unknown to this day. After considerable puzzlement, we were able to determine that Mann had made an unreported modification to a standard principal components calculation, in which he centered the data over a short segment rather than over the entire data set, as required in an analysis of variance. We found that this modification resulted in a severely biased estimation procedure, such that Hockey Stick shapes were even produced from random red noise. In effect, it mined data sets for hockey stick shaped series. Both U.S. panels, (National Research Council 2006; Wegman et al 2006) considered this matter and agreed with these findings.



**Figure 4. Three simulated PC1s using Mann’s algorithm on red noise plus the MBH reconstruction.**

Ironically, after the error in Mann’s PC methodology had been identified, and even, after the error had been confirmed by the NRC and Wegman reports, reconstruction use of the MBH PC1 as a Western U.S. proxy actually increased, with Mann’s PC1 being used in Osborn and Briffa (2006), Hegerl et al (2007), Juckes et al (2007). Indeed, it even occurs as one of only 8 proxies singled in IPCC (2007) Box 6.4 Figure 1 as illustrating the “heterogeneous nature of climate during the ‘Medieval Warm Period’”. IPCC rejected a review comment, objecting to its use.



**Figure 5. IPCC 2007 Box 6.4 Figure 1. Spaghetti graph showing 8 proxies supposedly showing the “heterogeneity” of the Medieval Warm Period.**

We were unable to verify claims of “statistical skill”. IPCC (2001) stated that the Mann et al (1998-99) reconstruction had “statistical skill”. Mann et al (1998) reported the consideration of verification RE and verification  $r^2$  tests to assess statistical skill and Mann et al (1998) Figure 3 illustrated verification  $r^2$  results for their AD1820 step. However, we found that the verification  $r^2$  score for the AD1400 step was only 0.02, obviously not significant, a finding reported in McIntyre and McKittrick (2005). Although a May 2005 media advisory from the University Corporation for Atmospheric Research (UCAR), written by Mann co-authors Ammann and Wahl, stated that our claims were “unfounded”, Wahl and Ammann (2007) Table 1S confirmed our findings, reporting a verification  $r^2$  score of 0.018 for the AD1400 step.

We were unable to confirm 99<sup>th</sup> percentile benchmarks used in Mann et al (1998) for the RE statistic, a statistic common in the reconstruction community but with no known statistical distribution and essentially unknown in the wider statistics community. From Monte Carlo tests on red noise, Mann et al (1998) reported a 99<sup>th</sup> percentile of 0.0, from which they asserted that the reconstruction was “99% significant”, a form of expression not employed in modern statistics. However, their benchmark failed to replicate all relevant conditions of the Mann et al reconstruction process. We carried out new simulations that more fully modeled the Mann et al process, resulting in a 99<sup>th</sup> percentile of 0.54, rather than 0.0 (McIntyre and McKittrick 2005a, 2005c). This showed that a seemingly high RE value could arise without a significant relationship. Notwithstanding these results, Wahl and Ammann (2007) employed a benchmark of 0.0, citing Ammann and Wahl (2007) as authority. However, the Supplementary Information to Ammann and Wahl (2007) became available only in July 2008 and showed a 99<sup>th</sup> percentile of 0.52 for their AD1400 network, rather than the 0.0 used in their analysis ([www.climateaudit.org](http://www.climateaudit.org)).

We were unable to verify the Mann et al (1998, 2000) that their reconstruction was “robust” to the presence/absence of all dendroclimatic indicators, a claim illustrated in Mann et al (2000) using the AD1730 step. We showed that this claim is incorrect as to the earlier periods (McIntyre and McKittrick 2003, 2005b) as the AD1400 step reconstruction is materially affected by the presence/absence of bristlecones, a point implicitly conceded by the figure in Mann et al (2003) and by language in Wahl and

Ammann (2007), though there has been no explicit concession on this point.

The validity of our criticisms was acknowledged by both U.S. panels.

Wegman et al (2006) stated:

While the work of Michael Mann and colleagues presents what appears to be compelling evidence of global temperature change, the criticisms of McIntyre and McKittrick ... are indeed valid. ..

I am baffled by the claim that the incorrect method doesn't matter because the answer is correct anyway. **Method Wrong + Answer Correct = Bad Science.**

The language in the NAS panel was more nuanced. Although they recognized the validity of our specific criticisms of Mann et al, they also thought that a similar result was "plausible" on other grounds (but did not carry out any due diligence of their own on other studies.) In testimony to a subcommittee of the House Energy and Commerce Committee, NAS panel chairman North was asked whether he disagreed with Wegman and replied:

**DR. NORTH.** No, we don't. We don't disagree with their criticism. In fact, pretty much the same thing is said in our report.

**DR. BLOOMFIELD.** Our committee reviewed the methodology used by Dr. Mann and his coworkers ... We had much the same misgivings about his work that was documented at much greater length by Dr. Wegman.

However, IPCC (2007) reported that Wahl and Ammann (2007) had shown that the impact of the errors "very small" as follows:

McIntyre and McKittrick (2005a,b) raised further concerns about the details of the Mann et al. (1998) method, principally relating to the independent verification of the reconstruction against 19th-century instrumental temperature data and to the extraction of the dominant modes of variability present in a network of western North American tree ring chronologies, using Principal Components Analysis. The latter may have some theoretical foundation, but Wahl and Amman (2006)[sic] also show that the impact on the amplitude of the final reconstruction is very small

This comment is obviously unresponsive to the failure of the original claims of "statistical skill", "robustness" to the presence/absence of dendroclimatic indicators or to the validity of strip bark bristlecones as a temperature proxy.

This assertion arises out of an argument in Wahl and Ammann (2007), amplifying ideas previously presented by Mann at realclimate in December 2004 (Mann 2004), which argued that the Hockey Stick-type reconstruction could be salvaged through by increasing the number of retained principal components in the North American AD1400 tree ring network from 2 to 5. By doing so, the controversial bristlecone pine data set (which was no longer in the PC1 once the erroneous principal component method was corrected) is included in the PC4, but, once included in the regression procedures of the

next step, imprints the reconstruction. This tactic had already been discussed in McIntyre and McKittrick (2005b), where it had been pointed out that this was merely a method of “getting” the bristlecones into the reconstruction and did not deal with issues of the failed verification statistics, non-robustness and problems arising from potential flaws in bristlecones as a proxy.

Wegman (2006b) stated that this methodology had “no statistical integrity”.

Wahl and Ammann [argue] that if one adds enough principal components back into the proxy, one obtains the hockey stick shape again. This is precisely the point of contention ... A cardinal rule of statistical inference is that the method of analysis must be decided before looking at the data. The rules and strategy of analysis cannot be changed in order to obtain the desired result. **Such a strategy carries no statistical integrity and cannot be used as a basis for drawing sound inferential conclusions.**

IPCC (2007) did not refute or even discuss Wegman. There were numerous review comments objecting to IPCC’s failure to even acknowledge that the claims of Wahl and Ammann (2007) were in dispute. Some misgivings on this are evident in the IPCC Review Editor reports. In the entire corpus of IPCC Working Group 1 Review Editor reports ([www.climateaudit.org](http://www.climateaudit.org)), this is the **only** item on which disagreement was noted. Review Editor Mitchell stated:

There will inevitably remain some disagreement on how they have dealt with the reconstructions of the past 1000 years and there is further work to be done here in the future...

IPCC policies state that Review Editors are obliged to “ensure that where significant differences of opinion on scientific issues remain, such differences are described in an annex to the Report,” but Review Editor Mitchell did not do so. Both IPCC and the U.K. Meteorological Office rejected requests for Review Editor Mitchell’s comments, though IPCC policies say that all expert comments are to be maintained in an open archive for 5 years. In response to Freedom of Information, the U.K. Meteorological Office first stated that Review Editor Mitchell had already destroyed all relevant records and then that these records were his “personal” property.

Underlying many of these issues is the validity of the bristlecone pine ring width “chronologies” of Graybill and Idso (1993), the weighting of which is affected by the principal components methodologies. Graybill and Idso (1993), the original publication, stated that these series were not temperature proxies and attributed their 20<sup>th</sup> century growth pulse to CO<sub>2</sub> fertilization. The NAS Panel (2006) stated that “strip bark” chronologies (a category which includes the Graybill bristlecone chronologies) should be “avoided” in temperature reconstructions, noting potential fertilization problems (though our own field investigations on Almagre bristlecones, referred to below, indicate that the salient problem with strip bark may well originate with simple mechanical deformation following a strip bark event.)

Wahl and Ammann (2007) conceded that, without the bristlecones, the MBH reconstruction lacked statistical significance in the early steps (failing both verification r

and RE tests); however, they argued that, because inclusion of bristlecones in the AD1400 step increased the value of the RE statistic, these proxies provided “necessary” statistical skill and should therefore be included in reconstructions, an argument that seems contrived at best and for which no statistical authority was cited, nor to my knowledge, can be found.

As discussed later, new sampling of key bristlecone sites has failed to replicate a key Graybill chronologies into question and further called into question whether bristlecone ring widths are a temperature response, making some of these issues moot.

### ***The IPCC 2007 Spaghetti Graph***

IPCC 2007 reconstructions remain dominated by tree ring chronologies. These are affected by two major problems, additional to the issues of the Mann reconstructions: 1) the failure of tree ring proxies to increase together with temperatures in the second half of the 20<sup>th</sup> century (the “Divergence Problem”), raising questions about whether they would be able to do so in earlier periods; 2) inconsistency between different tree ring versions for critical sites, reversing medieval and modern relationships for sites used in the majority of the reconstructions.

#### **1) Divergence Problem**

Briffa et al (1998), reporting on a large-scale study (387 sites) throughout the Northern Hemisphere, noted that, for the most part, ring widths have not increased in the late 20<sup>th</sup> century (the “Divergence Problem”). The Briffa et al (2001) reconstruction declines in the late 20<sup>th</sup> century. This reconstruction was used in the 2001 IPCC spaghetti graph, but the post-1960 portion of the reconstruction, which retreats back to 19<sup>th</sup> century levels, was deleted from the spaghetti graph without notice to the reader, increasing the visual coherence of the graphic.

Briffa et al (2002) presented a far-fetched rationalization for ignoring the problem in reconstructions, a rationalization for which no further evidence has been subsequently provided:

In the absence of a substantiated explanation for the decline, we make the assumption that it is likely to be a response to some kind of recent anthropogenic forcing. On the basis of this assumption, the pre-twentieth century part of the reconstructions can be considered to be free from similar events and thus accurately represent past temperature variability.

After I objected to the repetition of this deletion, IPCC refused to rescind the deletion, but did agree to at least report the deletion, which they did as follows:

Briffa et al. (2001) specifically excluded the post-1960 data in their calibration against instrumental records, to avoid biasing the estimation of the earlier reconstructions (hence they are not shown in Figure 6.10).

In their discussion of why this question was lingering on, IPCC (2007) reported that their ability to resolve this question was hampered by the lack of recent data at important sites:



At this time there is no consensus on the [divergence] issue and the possibility of investigating them further is restricted by the **lack of recent tree ring data at most of the sites** from which tree ring data discussed in this chapter were acquired.

Many people may feel that it should be possible to readily update tree ring chronologies in the U.S. Michael Mann (2004b) provided the following explanation of this failure, an explanation which is not completely convincing:

paleoclimatologists are attempting to update many important proxy records to the present, this is a costly, and labor-intensive activity, often requiring expensive field campaigns that involve traveling with heavy equipment to difficult-to-reach locations (such as high-elevation or remote polar sites). For historical reasons, many of the important records were obtained in the 1970s and 1980s and have yet to be updated.

## 2) Proxy Inconsistency

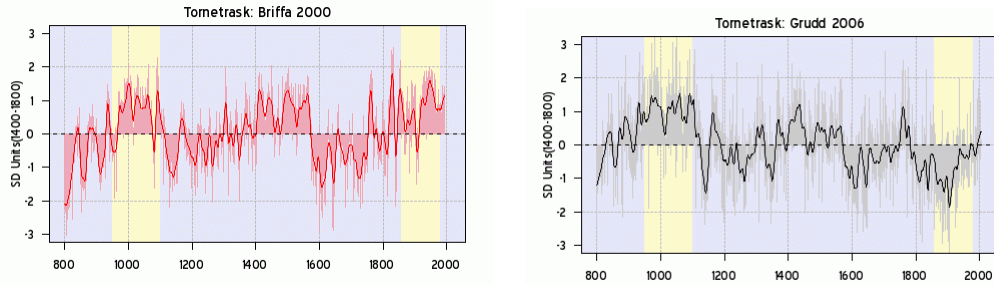
The second major issue affecting the IPCC 2007 is the inconsistencies between older and more recent versions of the Tornetrask, Urals and bristlecone ring width series. Contrary to IPCC claims, updated versions are available for three key sites: Tornetrask, Urals and Sheep Mt bristlecones. In each case, there is a substantial change in the differential between the 11<sup>th</sup> century and the 20<sup>th</sup> century, with the update in each case in favor of the medieval period.

This problem arising from only three sites affects 9 of 10 reconstructions, because, despite frequent claims that the reconstructions are “independent”, these three series are used in all or nearly the reconstructions. Briffa’s Tornetrask series are used in every reconstruction, as well as the IPCC proxy spaghetti graph in Box 6.4 Figure 1 (see “N Sweden”); his Urals series (Box 6.4 Figure 2 “NW Russia”) or its predecessor is used in all but one reconstruction while bristlecones/foxtails, either as Mann’s PC1 or directly, are used in all but 3 reconstructions.

Exacerbating the problem, in the 11<sup>th</sup> century, all the IPCC reconstructions rely on a very small number of proxies – between 3 and 18. In all but two cases, **all** or all but one of the medieval proxies are drawn from the 8 stereotyped proxies illustrated in IPCC 2007 Box 6.4 Figure 2. This non-independence was noted by Wegman et al (2006), who observed that it was hardly surprising that they would yield similar results.

### a) *Tornetrask*

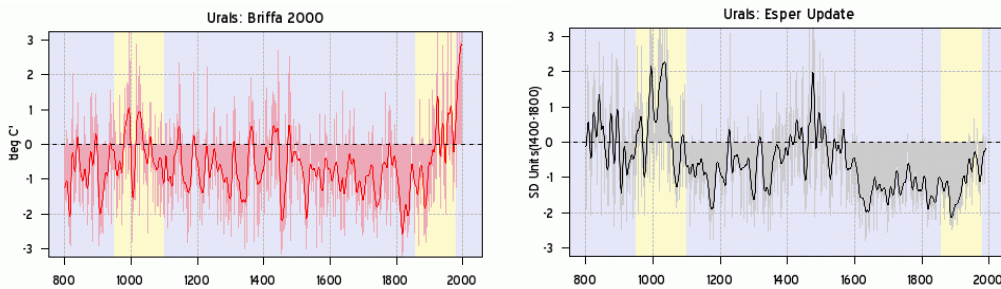
Although IPCC (2007) stated that there is a lack of recent data at key sites, Tornetrask was updated by Grudd (2006; 2008). The figure below compares the version used by IPCC (Briffa 2000) to Grudd’s version. In the newer Grudd version, the medieval warm period is noticeably warmer than the 20<sup>th</sup> century, while they are comparable in the Briffa version. IPCC did not reconcile the differences.



**Figure 6. Tornetrask reconstructions. Left – Briffa 2000. Right – Grudd 2006, 2008.**

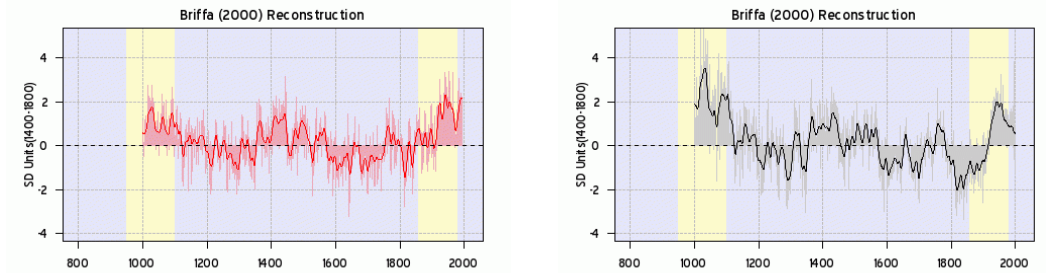
b) *Polar Urals*

A second key IPCC site, Polar Urals, also published by Briffa, was updated in 1998, though, in this case, the update was primarily subfossil material from the medieval period. Briffa et al. (1995) had previously reported a very cold 11<sup>th</sup> century, stating that 1032 was the coldest year of the millennium. This series was used in all reconstructions before 2000. However, this result was based on only 3-4 short cores in the 11th century – much fewer than usual quality control standards in the field. New measurements of medieval material were available by 1998 and were incorporated in the Urals version used in Esper et al (2002) (and only in this one reconstruction), shown in the right panel of the figure below; in this version the 11<sup>th</sup> century is shown as warmer than the 20<sup>th</sup> century. Instead of using the updated version of the Polar Urals site of Briffa et al (1995), which had been used, inter alia, by Mann et al (1998, 1999), Briffa (2000) reported results from a site about 200 km away (Yamal), where Briffa’s calculations resulted in a series with a dramatic growth increase in the 20<sup>th</sup> century.



**Figure 7. Urals tree ring chronologies. Left – Yamal from Briffa (2000). Right – updated Polar Urals version used in Esper et al (2002)/**

Merely using newer versions of these two series reverses the medieval-modern relationships in the Briffa (2000) reconstruction, as shown below. (Similar results are obtained with other reconstructions using updated versions from the key sites discussed here).



**Figure 8. Briffa (2000) Reconstruction (before fitting to temperature). Left – version from Briffa (2000); right – varying the Tornetrask and Urals versions to newer versions.**

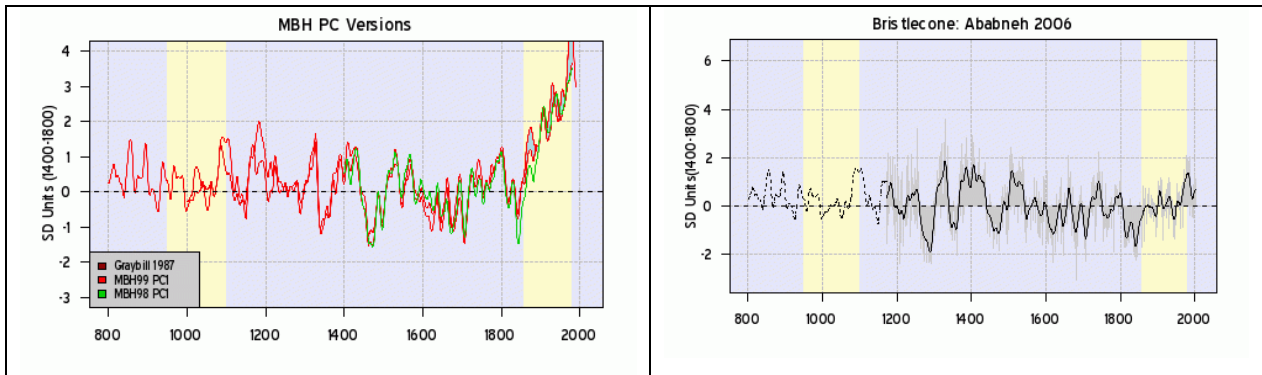
There are other lines of evidence supporting the idea of relative medieval warmth at this site. Shiyatov (1995) had reported that conditions for tree growth at the Polar Urals site in the Medieval Warm Period were the most favorable in record by a number of indices: treeline, stand density, longevity, size of trees and increment in diameter and height. In 2004, Naurzbaev et al (2004) stated that the MWP was 1.5 to 3 deg C warmer than at present.

“trees that lived at the upper (elevational) tree limit during the Medieval Warm Epoch (900 to 1200) show **annual and summer temperature warmer by 1.5 and 2.3 deg C, respectively**, approximately one standard deviation of modern temperature. Note that these trees grew 150-200 m higher (1-1.2 deg C cooler) ... implying that this may be an underestimate of the actual temperature difference.

A review comment requested IPCC to cite this article, but IPCC refused.

c) *Sheep Mt, California Bristlecones*

The most important single site in the Mann et al reconstruction was the Sheep Mt, California bristlecone site collected by Donald Graybill in the 1980s. Again, contrary to the IPCC claims, this site was updated between 2002 and 2006 by Linah Ababneh of the University of Arizona, a student of MBH coauthor Hughes (Ababneh (2006, 2007)). She carried out a much larger sampling program than Graybill's, but did not replicate the distinctive Hockey Stick shape of the Graybill results, obtaining a distinctly non-HS shaped chronology. Neither IPCC 2007 nor Wahl and Ammann 2007 reconciled or even discussed these discrepancies.



**Figure 9. Bristlecone chronologies. Left- Sheep Mountain, California; MBH98 PC1 and MB99 PC1; right – Sheep Mt, California (Ababneh 2006, 2007).**

As in the Polar Urals, there are many subfossil trees above treeline in California. Lamarche (1973) reported a substantial decline in treeline since the Holocene Optimum and since the Medieval period. Recently Millar et al (2006) analyzed subfossil medieval trees above present treeline dating the precise death of the forest to a nearby volcanic eruption in 1351 and concluded that the Medieval Warm Period in California was 3.2 deg C warmer than present in California.

Using contemporary distributions of the species, **we modeled paleoclimate during [the MWP] to be significantly warmer (+3.2 deg C annual minimum temperature) and slightly drier (-24 mm annual precipitation) than present.**

Once again, IPCC was asked to cite this article, but refused, while using the problematic Mann et al PC1 as a representation of temperature history in the western U.S. during the medieval period.

*d) Almagre, Colorado Bristlecones*

Another Graybill bristlecone site is located at Mount Almagre, Colorado near Colorado Springs. In summer 2007, in a program lasting 3 days in total, Pete and Leslie Holzmann, my wife, my sister and I updated the chronology. We obtained 64 cores, even identifying some of the precise trees that Graybill had sampled (no small accomplishment since there was no map or location information beyond longitude, latitude and site name). The cores were measured and analyzed at the University of Guelph and all the measurements were online in Oct 2007 as soon as I received them and within a few months of taking the sample. Almagre is (for now) the highest millennium-length tree ring chronology in the world.

According to the hypothesis of a linear relationship between world temperature and bristlecone ring widths, Almagre ring widths should be growing at a record rate right now. However, in the 30 years since 1980, they have declined and currently are more or less at their long-term average. Although IPCC weakly argued that “‘divergence’ was restricted to “some northern, high-latitude regions”, this showed divergence at a mid-latitude site.

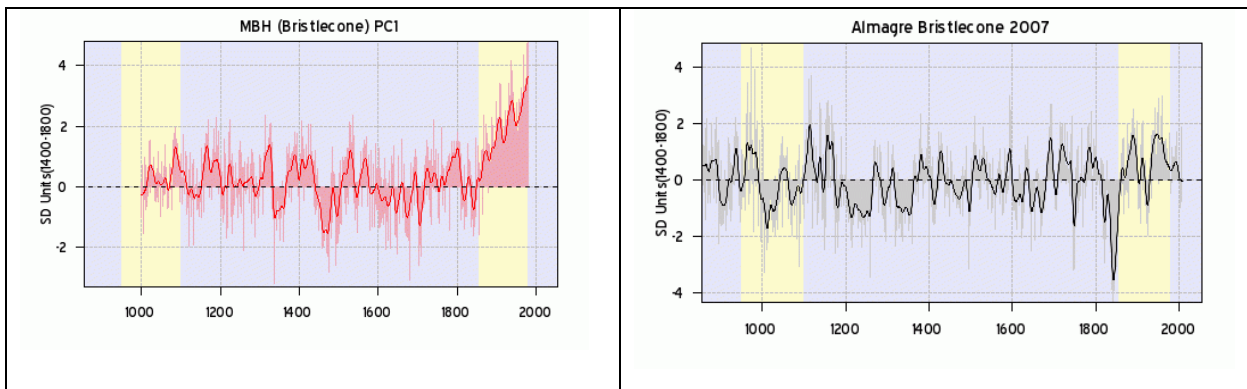


Figure 10. Almagre Chronologies: black – Lamarche (co071); Graybill (co524); blue-incorporating 2007 samples.

## Conclusions

Although the statistical problems of the Mann et al (1998, 1999) reconstruction are by no means conceded within the reconstruction community, they have nonetheless been identified for some time. Two blue ribbon U.S. panels have acknowledged these criticisms, but IPCC 2007 did not.

Updated versions of Tornetrask, Urals and Sheep Mountain have opposite medieval-modern differentials to the IPCC versions. Because virtually all of the IPCC reconstructions rely on these three sites and because the framework of MWP proxies in IPCC reconstructions is so limited, changes in only 3 site versions turn out to have a knock-on impact on 9 of 10 reconstructions, an issue which also affects the Mann et al 1999 reconstruction additional to all the other problems. IPCC failed to provide any accounting or reconciliation of the discrepant versions.

Adding to the problems of the IPCC 2007 reconstructions is the “Divergence Problem” – ring widths going down in the last half of the 20<sup>th</sup> century, while temperatures go up.

In the absence of any such explanation and reconciliation, IPCC could not state within its probability definitions that:

[It is] likely that this 50-year period was the warmest Northern Hemisphere period in the last 1.3 kyr.

Verification of paleoclimate studies has been made far more onerous than necessary, by the failure of authors to archive data and to properly document methodological procedures. Econometrics journals have dealt with similar problems by requiring authors to archive data (as used with accurate data citations to the precise version) and source code as a condition of reviewing. This procedure is recommended for paleoclimate journals as well. In addition, the U.S. National Science Foundation (NSF) has essentially abandoned its duties to ensure that paleoclimate authors comply with existing U.S. data archiving policies and many problems could be averted merely by NSF carrying out its duties.

## REFERENCES

- Ababneh, L., 2006. Analysis of Radial Growth Patterns of Strip-Bark and Whole-Bark Bristlecone Pine Trees in the White Mountains of California: Implications on Paleoclimatology and Archaeology of the Great Basin. *University of Arizona Ph.D. Thesis*.
- Ababneh, L., 2007. Bristlecone pine (BCP) paleoclimatic model for archaeological patterns in the White Mountain of California. *Quaternary International*.
- Briffa, K.R., 2000. Annual climate variability in the Holocene: interpreting the message of ancient trees. *Quaternary Science Reviews*, 19(1-5), 87-105.
- Briffa, K.R. et al., 1992. Fennoscandian summers from ad 500: temperature changes on short and long timescales. *Climate Dynamics*, 7(3), 111-119.
- Briffa, K.R. et al., 1995. Unusual twentieth-century summer warmth in a 1, 000-year temperature record from Siberia. *Nature*, 376(6536), 156-159.
- Briffa, K.R. et al., 2001. Low-frequency temperature variations from a northern tree ring density network. *Journal of Geophysical Research*, 106(D3), 2929-2941.
- Briffa, K.R. et al., 2002. Tree-ring width and density data around the Northern Hemisphere: Part 1, local and regional climate signals. *The Holocene*, 12(6), 737.
- Briffa, K.R. et al., 1998. Reduced sensitivity of recent tree-growth to temperature at high northern latitudes. *Nature*, 391(6668), 678-682.
- Climate Change Science Program (U.S.), 2008. *Global Climate Change Impacts in the United States (Public Review Draft)*, Available at: <http://www.climatechange.gov/Library/sap/usp/public-review-draft/>.
- Cook, E.R., Esper, J. & D'Arrigo, R.D., 2004. Extra-tropical Northern Hemisphere land temperature variability over the past 1000 years. *Quaternary Science Reviews*, 23(20-22), 2063-2074.
- D'Arrigo, R., Wilson, R. & Jacoby, G., 2006. On the long-term context for late twentieth century warming. *J. Geophys. Res.*, 111.
- D'Arrigo, R. et al., 2008. On the 'Divergence Problem' in Northern Forests: A review of the tree-ring evidence and possible causes. *Global and Planetary Change*, 60(3-4), 289-305.
- Esper, J., Cook, E.R. & Schweingruber, F.H., 2002. Low-Frequency Signals in Long Tree-Ring Chronologies for Reconstructing Past Temperature Variability.

- Science*, 295(5563), 2250-2253.
- Gore, A., 2006. *An Inconvenient Truth. The Planetary Emergency of Global Warming and What We Can Do About It*, Rodale Press, Emmaus, Pennsylvania (United States).
- Graybill, D.A. & Idso, S.B., 1993. Detecting the aerial fertilization effect of atmospheric CO<sub>2</sub> enrichment in tree-ring chronologies. *Global Biogeochemical Cycles*, 7(1), 81-95.
- Grudd, H., 2006. *Tree Rings as Sensitive Proxies of Past Climate Change*, Stockholm: Stockholm University, Faculty of Science, Department of Physical Geography and Quaternary Geology.
- Grudd, H., 2008. Torneträsk tree-ring width and density AD 500–2004: a test of climatic sensitivity and a new 1500-year reconstruction of north Fennoscandian summers. *Climate Dynamics*, (DOI 10.1007/s00382-007-0358-2).
- Hegerl, G.C. et al., 2007. Detection of Human Influence on a New, Validated 1500-Year Temperature Reconstruction. *Journal of Climate*, 20(4), 650-666.
- International Panel on Climate Change, 2001. *Climate Change 2001: The Scientific Basis*.
- International Panel on Climate Change, 2007. *Climate Change 2007: The Physical Basis. Review Comments and Responses*,
- Juckles, M.N. et al., 2007. Millennial temperature reconstruction intercomparison and evaluation, *Clim. Climate of the Past*, 3, 591-609.
- LaMarche, V.C., 1973. Holocene climatic variations inferred from treeline fluctuations in the White Mountains, California. *Quaternary Research*, 3(4), 632-660.
- Mann, M.E., Bradley, R.S. & Hughes, M.K., 2004. Corrigendum: Global-scale temperature patterns and climate forcing over the past six centuries. *Nature*, 430, 105.
- Mann, M.E., Bradley, R.S. & Hughes, M.K., 1998. Global-scale temperature patterns and climate forcing over the past six centuries. *Nature*, 392, 779-787.
- Mann, M.E., Bradley, R.S. & Hughes, M.K., 2003. NOTE ON PAPER BY MCINTYRE AND MCKITRICK IN "ENERGY AND ENVIRONMENT". Available at: <http://holocene.meteo.psu.edu/Mann/EandEPaperProblem.pdf>.
- Mann, M., 2004a. False Claims by McIntyre and McKitrick regarding the Mann et al. (1998) reconstruction. . *realclimate.org*. Available at:

- <http://www.realclimate.org/index.php?p=8>.
- Mann, M., 2004b. Myth vs. Fact Regarding the "Hockey Stick". *realclimate.org*. Available at: <http://www.realclimate.org/index.php?p=11>.
- Millar, C.I. et al., 2006. Late Holocene forest dynamics, volcanism, and climate change at Whitewing Mountain and San Joaquin Ridge, Mono County, Sierra Nevada, CA, USA. *Quaternary Research*, 66(2), 273-287.
- National Research Council, 2006. *Surface Temperature Reconstructions for the Last 2,000 Years*, Available at: <http://books.nap.edu/openbook.php?isbn=0309102251>.
- Naurzbaev, M.M., Hughes, M.K. & Vaganov, E.A., 2004. Tree-ring growth curves as sources of climatic information. *Quaternary Research*, 62(2), 126-133.
- Osborn, T.J. & Briffa, K.R., 2006. *The Spatial Extent of 20th-Century Warmth in the Context of the Past 1200 Years*, American Association for the Advancement of Science.
- Preisendorfer, R., 1988. *Principal Component Analysis in Meteorology and Oceanography*, Elsevier, Amsterdam.
- Shiyatov, S.G., 1995. Reconstruction of climate and the upper timberline dynamics since AD 745 by tree-ring data in the Polar Ural Mountains. *International Conference on Past, Present and Future Climate. Helsinki: Publication of the Academy of Finland*, 144-147.
- Wahl, E.R. & Ammann, C.M., 2007. Robustness of the Mann, Bradley, Hughes reconstruction of Northern Hemisphere surface temperatures: Examination of criticisms based on the nature and processing of proxy climate evidence. *Climatic Change*, 85(1), 33-69.
- Wegman, E.J., Scott, D.W. & Said, Y.H., 2006. Ad Hoc Committee Report on the« Hockey Stick» Global Climate Reconstruction. *A Report to Chairman Barton, House Committee on Energy and Commerce and to Chairman Whitfield, House Subcommittee on Oversight and Investigations: Paleoclimate Reconstruction*.
- Wegman, E., 2006. Response of Dr. Edward Wegman to Questions Posed by the Honorable Bart Stupak . Available at: <http://www.uoguelph.ca/~rmckitri/research/StupakResponse.pdf>.