

## The Hockey Stick

In 1999, Mann, Bradley and Hughes published a reconstruction of temperatures for the past thousand years, later expanded to cover the past two thousand, based on proxy data. It was described as a hockey stick diagram because it showed temperature as fairly flat and declining until about the past century, the handle of the hockey stick, followed by a sharp rise, the blade. One controversial feature was that it did not show the medieval warm period and the subsequent little ice age reported by earlier studies. One implication of their results was that current temperatures were higher than any in the past two thousand years, including the peak of the Medieval Warm Period. Another was that the warming of the past century was substantially faster than warming in the past.

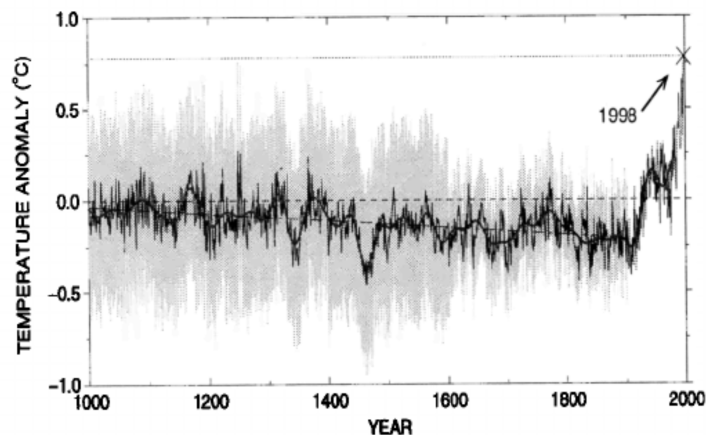


Figure 1 (From Figure 3, Mann, Bradley and Hughes 1999)

The solution to the problem of estimating temperatures for times in the past for which there are no records of measured temperature is to use proxies, things affected by temperature. Thus, for example, since the rate of growth of trees depends in part on temperature, the separations between tree rings from old trees can be used to estimate the temperature when they were formed. Other natural processes produce similar information. What the precise relationship is can be unclear, in part because a proxy may be affected by things other than temperature. Tree rings might be narrow not because temperatures were low but because water was scarce or broad due to CO<sub>2</sub> fertilization. The relationship is commonly modeled as linear but that cannot be true at all temperatures, since if it gets hot enough a tree stops growing and dies; it is risky to extrapolate the relationship beyond the temperatures where it has been observed.<sup>1</sup>

Mann's work was challenged on a number of bases, two of which were, I think, important. One was that the proxies used made heavy use of tree ring data, argued to be an unreliable measure of temperature that happened to show a steep increase in the past century for reasons unrelated to climate.<sup>2</sup> The other was that Mann and his coauthors had used a statistical approach which could be expected to give misleading results, that the long handle of the hockey stick was a statistical artifact.

<sup>1</sup> For a discussion of some of the problems, see Stephen McIntyre, "[On the Divergence Problem.](#)"?

<sup>2</sup> Stephen McIntyre, "[Ring Widths and Temperature #1.](#)" summarizes the literature as of 2006.

## The Problem

Anyone trying to reconstruct temperatures in the distant past has to decide which proxies to use and how to weight them. Mann and his coauthors did so by choosing and combining proxies in a way that gave a good fit to the period for which good instrumental data were available and using the same proxies with the same weighting to extrapolate back to the earlier period.

That sounds like a reasonable procedure but there is a problem, pointed out by McIntyre<sup>3</sup> and others. Each proxy gives a series representing in part temperature, in part random variation from other causes. Ones for which the random element happens to make a good fit to the instrumental data will be included, ones for which the random element makes a poor fit left out. With enough proxies to choose among it will be possible to select a group whose combined effect makes a close fit to the instrumental data, since with enough parameters you can fit anything. But the farther back you go before the period whose data they were fitted to, the less what you get reflects actual temperature, the more uncorrelated random noise — which explains the straight handle of the hockey stick. The reconstruction had some relation to actual temperatures, just less than its authors thought.

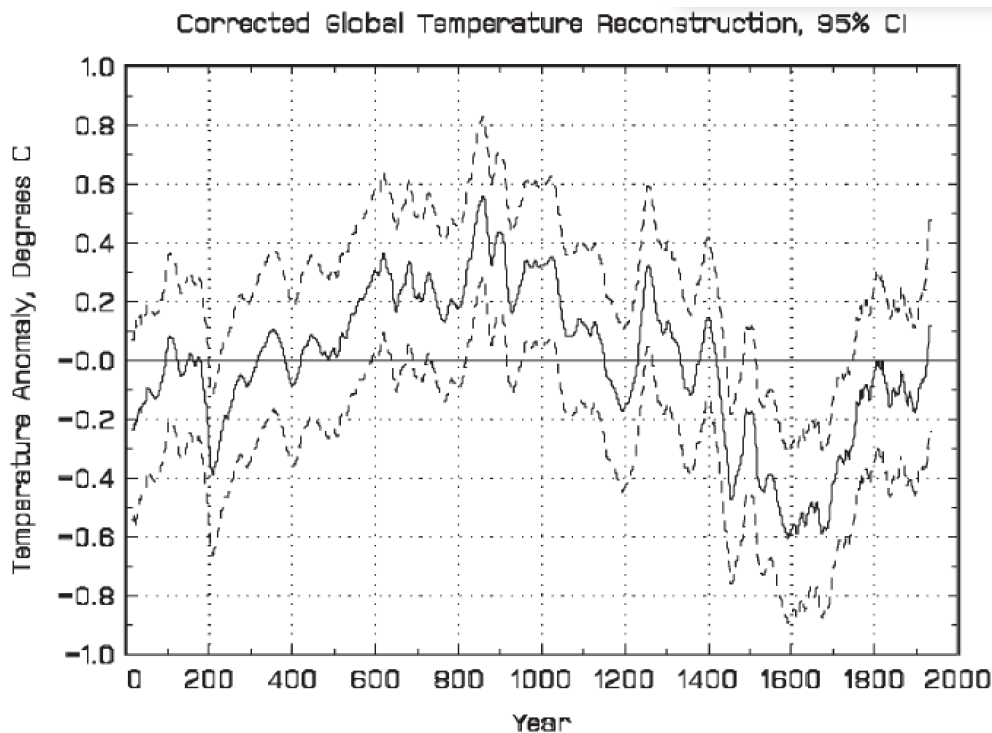


Figure 2. Corrected reconstruction with 95% confidence intervals.

Data for this graph is online at <<http://www.econ.ohio-state.edu/jhm/AGW/Loehle/>>

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<sup>3</sup> Stephen McIntyre, [Ross McKittrick](#), "[Hockey sticks, principal components, and spurious significance](#)," *Geophysical Research Letters*, Vol. 32, Issue 3, February 2005.

## A Corrected Reconstruction

In a later paper,<sup>4</sup> Loehle et. al. avoided those problems by taking existing estimates of temperature produced by other scholars from a variety of proxies, excluding any that depended significantly on tree rings, and calculating the average of their interpolated values with no attempt to fit them to the instrumental data by either selection or weighting: they excluded. Doing that produced the graph of temperature shown above. Unlike the hockey stick, it shows both the medieval warm period and the little ice age.

Due to data limitations in the available proxies, the authors only ran the graph up to 1935, estimating the temperature then at  $.41^{\circ}\text{C}$  below the peak of the medieval warm period. From 1935 to 1999 global temperature rose by another  $.60^{\circ}$ , making the 1999 temperature  $.18^{\circ}$  higher than their best estimate of the MWP maximum although lower than the upper bound of their 95% range. Global temperature at present is well above that upper bound.

Their graph shows considerably more natural variation than Mann's — it no longer looks like a hockey stick — but not enough to explain recent warming. The most rapid warming that they show for any substantial period is about  $.4^{\circ}/\text{century}$ , in contrast to about  $1.2^{\circ}/\text{century}$  for warming from 1911 to 2018.

If we accept their estimate as more reliable than Mann's, as I am inclined to do, the result remains qualitatively the same although less striking. Current temperature is the highest in the past two thousand years and warming over the past century is about three times as rapid as past warming. Temperature has, however, varied considerably more in the past than shown by Mann's hockey stick.

One of the commenters on my blog produced a summary of why the hockey stick controversy matters:

If you were to believe that MBH99 [the original hockey stick article] is essentially a correct summary of what happened to the temperature trend, this might lead you to believe two important corollaries:

(1) short-term "natural variation" has been demonstrably insignificant in magnitude and couldn't possibly have been enough by itself to explain much of the positive trend seen in the last half of the 1900s.

(2) Recent temperatures are "unprecedented" during the era for which humanity has significant written records.

If you believe #1, you're not going to look very hard for "natural" trends that might help explain the data. If you believe #2, you're not going to look very hard at past historical records from warmer times to estimate how "bad" climate change might become in the near future.

If Loehle's or Moberg's curves are more correct than MBH99 was, then current temperatures are NOT "unprecedented" - we are currently within measurement error of where things were about a thousand years ago. We're not in "uncharted waters"; there's

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<sup>4</sup> Craig Loehle, Ph.D. and J. Huston McCulloch, "Correction to: A 2000-Year Global Temperature Reconstruction Based on Non-Tree Ring Proxies," *Energy & Environment*, Vol. 19 No. 1 2008.

no reason to predict imminent horrible environmental effects never seen before that man can't adapt to because we adapted to it just fine last time. There's also less reason to predict "runaway"-type feedback effects - if they didn't show up in the past they are unlikely to do so now.

So that's why MBH matters to skeptics. An additional reason MBH matters to *alarmists* is that alarmists are trying to maintain an aura of infallibility. If they *admit* that MBH was based on bad statistics but kept around for its propaganda value, people have to wonder what *other* claims in climate science might have been similarly motivated.

The commenter's claim that we are within measurement error of where things were about a thousand years ago was true of Loehle's curve when the hockey stick was published but no longer true by the time the commenter made it. On the other hand, while current temperatures are probably the highest of the past two thousand years they are lower than they were for most of the past five hundred million years, as shown by the graph in chapter XXX [Media], which supports skepticism about horrible environmental effects never seen before.