

BRIEF ANALYSIS

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Breaking the “Hockey Stick”

by David R. Legates

The United Nations’ Intergovernmental Panel on Climate Change (IPCC) claims that human activities are responsible for nearly all earth’s recorded warming during the past two centuries. A widely circulated image used by the IPCC dramatically depicting these temperature trends resembles a hockey stick with three distinct parts: a flat “shaft” extending from A.D. 1000 to 1900, a “blade” shooting up from A.D. 1900 to 2000, and a range of uncertainty in temperature estimates that envelops the shaft like a “sheath.” [See the figure.] This image was produced by Michael Mann, Ray Bradley and Malcolm Hughes (*Nature*, 1998; *Geophysical Research Letters*, 1999). Last year, Mann and Phil Jones claimed to have extended estimates back to A.D. 200 (*Geophysical Research Letters*, 2003). However, five independent research groups have uncovered problems with the underlying reconstructions by Mann and his colleagues in their 1998 and 1999 work that have persisted through his most recent collaborative efforts, calling into question all three components of the “hockey stick.”

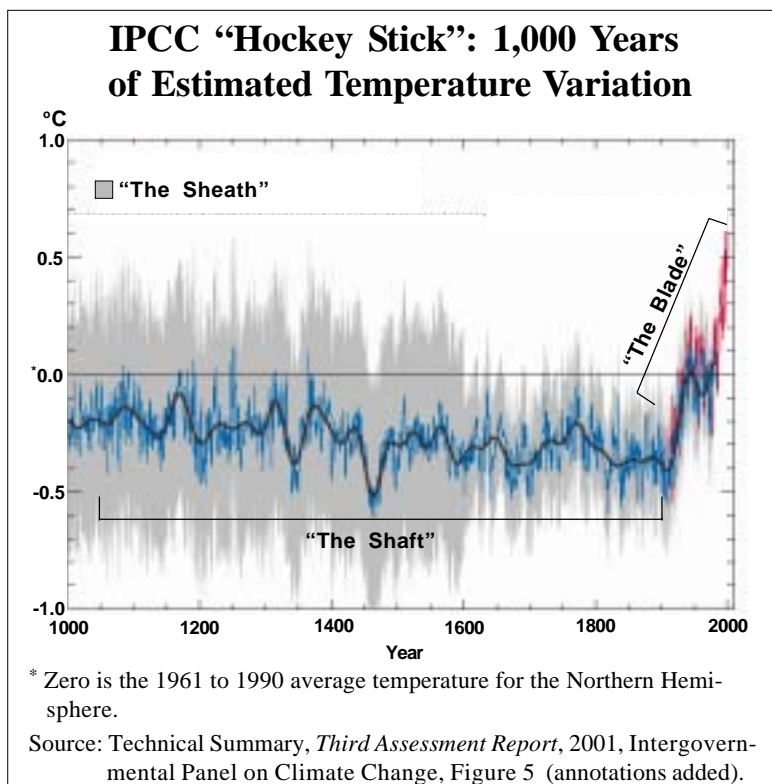
Fractures in the Shaft. Mann and Jones indicate that globally- and hemispherically-averaged air temperatures from A.D. 200 to 1900 were nearly constant. Missing from their timeline, however, are the widely recognized Medieval Warm Period (about A.D. 800 to 1400) and the Little Ice Age (A.D. 1600 to 1850). Most proxy records from around the globe show these climatic events, as Willie Soon, Sallie L. Baliunas and I concluded in a 2003 paper published in *Energy and the Environment*. For instance:

- In such widely disparate regions as Argentina, Chile, southern Peru, southern Africa and northern China, records indicate a marked warming at the beginning of the last millennium followed by extreme cold during the middle centuries.
- Historical proxies for temperature — such as tree rings, ice cores and bore holes — in New Zealand, Australia and California also confirm widespread, significant warming and cooling trends.

Stephen McIntyre and Ross McKittrick also pinpointed methodological problems (*Energy and the Environment*, 2003) that plagued the version of the “hockey stick” used by the IPCC.

McIntyre and McKittrick found errors in the collection and use of varying data from multiple sources. They contend that Mann and his colleagues in their 1998 and 1999 papers unjustifiably truncated or extrapolated trends from source data, used obsolete data, made incorrect calculations, and associated data sets with incorrect geographical locations. More recently, David Chapman, Marshall Bartlett and Robert Harris (*Geophysical Research Letters*, 2004) identified methodological problems in a 2003 *Geophysical Research Letters* study by Mann and G.

Schmidt. Specifically, Mann and Schmidt eliminated specific proxy records (data from bore holes) they thought were inaccurate. Chapman et al. showed that Mann and Schmidt had unjustifiably excluded the bore-hole data and concluded that their methods were “just bad science” and that they presented a “selective and inappropriate presentation” of results. Jan Esper, David Frank and Robert Wilson (*EOS Transactions of the American Geophysical Union*, 2004) further argued that the fatal flaw with Mann, Bradley and Hughes’ temperature reconstruction is its incorrect representation of longer-term trends. They observed



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that the statistical methods used inappropriately remove trends over long time periods. Basically, to construct their climate trend data, Mann and his colleagues used proxies with very limited data sets based on only one or two trees for the early part of the record and a methodology that removed long-term cooling trends by erroneously correlating temperature trends with the age of the tree.

This flaw in methodology was also highlighted by Henry Pollack and Jason Smerdon (*Journal of Geophysical Research*, 2004) and led to a retraction by Mann (and Scott Rutherford) in the *Journal of Geophysical Research* (June 2004). In this article they admit to underestimating the temperature variations indicated by the proxy data since 1400 by more than one-third, which explains why their previous work failed to track the Little Ice Age. While admitting this error, Mann and Rutherford fail to recognize the extent to which it undermines their historical reconstruction and its relation to present temperature trends.

Broken Blade, Bad Climate History. Recently, my colleagues and I closely examined the “blade” of Mann’s latest temperature reconstruction (*Geophysical Research Letters*, February 2004). According to the IPCC (2001) and many other published sources, the earth warmed only 0.6°C (1°F) during the 20th century. However, that contrasts sharply with the most recent reconstruction by Mann and Jones, which shows warming over the last century of 0.95°C (1.5°F) — a temperature rise more than 50 percent larger than the IPCC claims. Mann’s warming estimate has grown substantially over the last couple of years, apparently to accommodate his continuing claim that the 1990s were the warmest decade of the last two millennia, but we found that the blade of the hockey stick could not be reproduced using either the same techniques as Mann and Jones or other common statistical techniques. Since reproducibility is a hallmark of scientific inquiry and the blade does not represent the observed climate record, it is unreliable.

Tearing Holes in the Uncertainty Sheath. Mann and Jones’ uncertainty assessment — the estimate of how much warmer or cooler than their reconstruction the temperature could actually have been — is based solely on how well the proxy records match the observed data. However, their assessment fails to account for several significant forms of error, including:

- Biases in hemispheric air temperatures estimates resulting from sparse and irregularly distributed

instrumental records that under-represent the oceans, high latitude regions, mountainous areas (i.e., high altitudes), and non-populated landscapes;

- Reconstructions based on a small number of trees — including some proxy records limited to a single tree; and a spatially-limited set of proxy records — some reconstructions used less than five distinct geographic locations;
- The inability of a proxy record to represent regional air temperatures — because some proxy samples are contaminated by drought-sensitive species;
- The observed variability in both the proxy record and the instrumental record.

At the very least Mann and Jones should have noted these factors as potential sources of error in their results, meriting further research. My preliminary analysis indicates that the uncertainty is probably twice as large as Mann and Jones’ indicate, meaning that recent temperature trends do not show unprecedented warming.

The Hockey Stick is Broken. Mann wrote the part of the IPCC *Third Assessment Report* (2001) that proclaims that nearly all of the climate change seen during the last two millennia occurred during the 20th century and that it is due to human activities. The report contends that industrialization put carbon dioxide and other greenhouse gases into the atmosphere, leading to increasing global air temperatures. Furthermore, based on Mann’s work, the IPCC claimed that the 1990s were the warmest decade of the last millennium and 1998 was the warmest year. But a review of the data shows that these claims are untenable. Mann’s research is clearly the outlier.

Consider that if 1) the amount of uncertainty is doubled (an appropriate representation of the “sheath”), 2) appropriate 20th century increases in observed air temperature are applied (a correct representation of the “blade”), or 3) the period from A.D. 200 to 1900 correctly reproduces millennial-scale variability (a reliable representation of the “shaft”), then one can have no confidence in the claim that the 1990s are the warmest decade of the last two millennia. The assertions of Mann and his colleagues — and, consequently, the IPCC — are open to question if even one component of their temperature reconstruction is in error, let alone all three!

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