

Hockey Stick, 1998-2005, R.I.P.

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The “hockey stick” representation of the temperature behavior of the past 1,000 years is broken, dead. Although already reeling from earlier analyses aimed at its midsection, the knockout punch was just delivered by *Nature* magazine. Thus the end of this palooka: that the climate of the past millennium was marked by about 900 years of nothing and then 100 years of dramatic temperature rise caused by people. The saga of the “hockey stick” will be remembered as a remarkable lesson in how fanaticism can temporarily blind a large part of the scientific community and allow unproven results to become “mainstream” thought overnight.

The “Hockey Stick” is dead. This once-feared icon of global warming purported to show annual average temperature of the Northern Hemisphere for the past 1,000 years. It was derived from the climatic information that is stored in a variety of climate-sensitive or climate “proxy” data records—things such as tree rings, coral banding records, and sediment cores. It’s called the “hockey stick” because its long handle corresponds to 900 years (from 1000 to 1900) of little temperature variation, and its blade represents 100 years (1900 to 1999) of rapid temperature rise (Figure 1). The “hockey stick” made its debut in the journal *Geophysical Research Letters* in 1999 in a paper by Michael Mann, Raymond Bradley, and Malcolm Hughes that built upon a 1998 paper by the same authors in the journal *Nature* which detailed the methodology for creating a proxy temperature reconstruction.

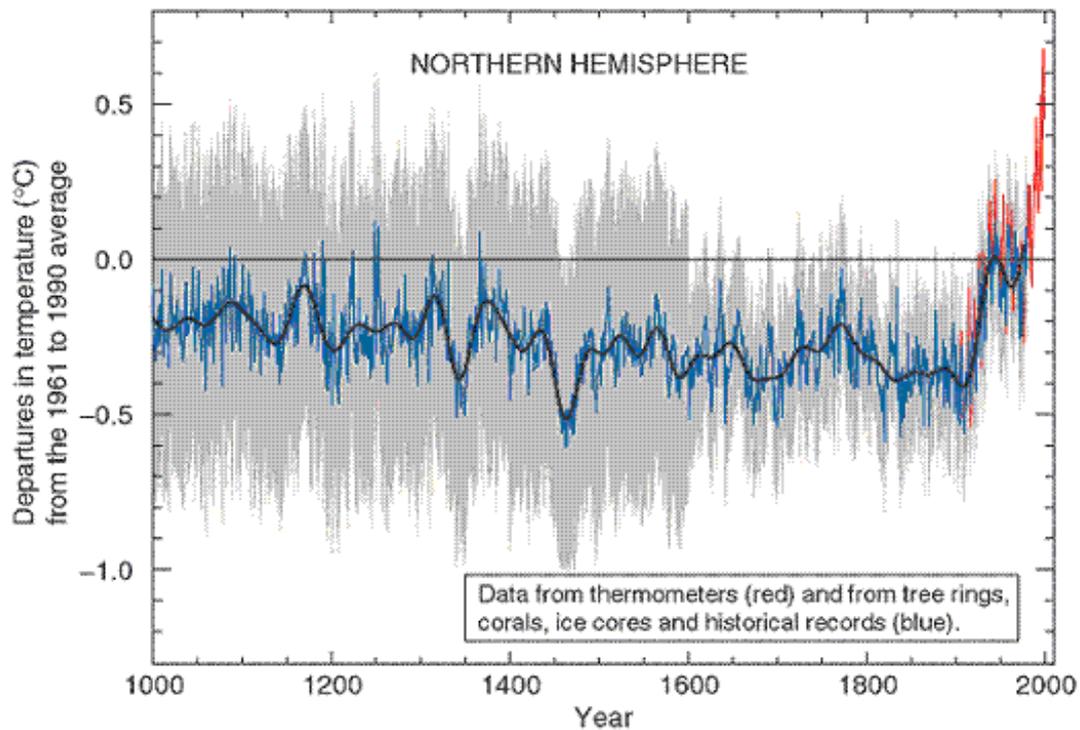


Figure 1. Mann et al.’s “hockey stick”—the multi-proxy temperature reconstruction of the Northern Hemisphere for the past 1,000 years (blue line with gray shading depicting confidence bands). The red line is the temperature data from actual observations. (Source: Intergovernmental Panel on Climate Change 2001).

So compelling was 1,000-yr long “hockey stick” graphic, that it quickly became the poster child for anthropogenic global warming. As such, it was prominently displayed as the first figure of the oft-read Summary for Policymakers of 2001 *Third Assessment Report* of the Intergovernmental Panel on Climate Change. The “hockey stick” graphic gives the appearance that left to its own devices, nature displays very little in the way of temperature variation, but that during the past century, humans have come along and thrown everything out of kilter. It is thus the perfect representation of the greenhouse alarmists’ message—humans have caused the weather to be like never before (and this is bad).

However, the shape of the “hockey stick” looked strangely out of place against the existing knowledge of the climate of the past millennium. Where was the Little Ice Age (LIA)—a well-documented cold period lasting from about the 16th to the 19th century? And where was the Medieval Warm Period (MWP)—a relatively warmer period extending from about 11th to the 13th century? By containing little indication that these climate episodes existed, the “hockey stick” presents a completely new picture of the climate of the past 1,000 years. Natural variability is reduced to little more than annual-to-decadal scale fluctuations superimposed on longer-scale constancy. This is not the same story that is told in countless weather and climate textbooks used in classrooms around the world.

It’s not that a single discovery can’t change the existing scientific paradigm—in fact sudden changes are more characteristic of how science progresses than are slowly evolving ideas—it is just that rarely are new paradigms so immediately embraced and exalted as was the “hockey stick.” Instead, new paradigms are typically met with skepticism and disdain as the mainstream is slow to let go of the conventional wisdom. In the case of the “hockey

stick” this process was turned on its head—the “hockey stick” immediately was held up as the symbol of “mainstream” thought and anyone who did not wholly accept it was labeled as a skeptic. Additionally, the members of the mainstream often united in organized efforts to severely rebuke each any every critique of the “hockey stick,” oftentimes resorting to personal attacks against the critical party.

Nevertheless, despite attempts to quell dissent, the pursuit of scientific understanding is relentless, and ideas that are unable to stand up under the weight of careful scientific scrutiny eventually collapse. Such has been the fate of the “hockey stick.”

The first sign that something amiss with the “hockey stick” was published in 2003 by Harvard scientists Willie Soon and Sallie Baliunas. Soon and Baliunas performed a survey of the existing scientific literature concerning the climate of the past 1,000 years and compiled evidence for and against the existence of the MWP and the LIA. They found that overwhelmingly, within the scores of scientific articles that they reviewed, there was strong evidence to support the existence of these well-known climatic episodes that were largely absent from the “hockey stick” reconstruction. Apparently, the handle of the “hockey stick”—that part of it which represents natural variation—is too flat.

Then came the painstaking effort by Steven McIntyre and Ross McKittrick to simply attempt to reproduce the “hockey stick” using the data and procedures described by Mann and colleagues in their 1998 *Nature* publication. In their professions McIntyre (a mineral consultant) and McKittrick (an economist) had encountered numerous hockey-stick-shaped graphs that were typically used to try to sell an idea based upon some measure of performance. Their experience was that these types of graphs inevitably broke down under careful scrutiny. Familiar with accounting procedures, they decided, out of personal interest, to “audit” the “hockey stick” and see if they could recreate it starting from scratch.

The resulting trials and tribulations of McIntyre and McKittrick make for a truly eye-opening look at the supposed “openness” of the scientific process. For years they toiled tirelessly in their task, working through countless roadblocks erected by the “hockey stick’s” original creators, and documenting an embarrassing number of errors in the original procedure including inaccurate data descriptions, insufficient methodological details, data compilation errors, data handling mistakes, and questionable statistical techniques. While no individual mistake was likely sufficient enough in and of itself to throw into question the “hockey stick,” taken together, the list of errors indicate a certain lack of rigor and attention to detail by the “hockey stick’s” creators. Their efforts are detailed in two scientific articles (McIntyre and McKittrick, 2003; 2005), in an upcoming book chapter, and in McIntyre’s personal [web page](#). Additionally, the *Wall Street Journal* chronicled much of this activity in a front page article on February 14, 2005.

The third dissenting voice was that of Jan Esper and colleagues in 2004. Esper is an expert in climate reconstructions based upon tree-ring records (the primary type of proxy data relied upon by Mann et al. in creating the “hockey stick”). It turns out that one must be careful when using tree rings to reconstruct long-term climate variability because as the tree itself ages, the widths of the annual rings that it produces changes—even absent any climatic variations. This growth trend needs to be taken into account when trying to interpret any climate data contained in the tree-ring records. In most cases, the tree-ring

records are first detrended to remove this growth trend, and then the remaining variation in the rings is used to derive a climate signal. The problem with this technique is that by detrending the tree-ring record, long-term climate trends are lost as well. Esper et al. point out that this could be one likely reason why the handle of the “hockey stick” is so flat—it lacks the centennial-scale variations that were lost in the standardization of its primary data source. Using an alternative technique that attempted to preserve as much of the information about long-term climate variations as possible from historical tree-ring records, Esper and colleagues derived their own annual Northern Hemisphere temperature reconstruction. The result (Figure 2) is a 1,000-yr temperature history in which the LIA and the MWP are much more pronounced than the “hockey stick” reconstruction—more evidence that the “hockey stick” underestimates the true level of natural climate variation.

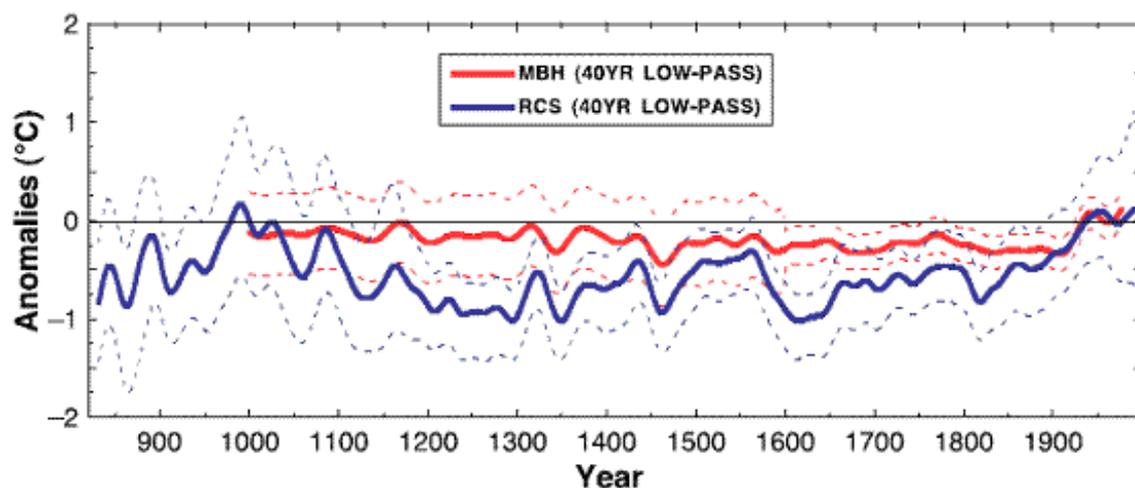


Figure 2. A comparison of 1,000-year temperature reconstructions. The red line is the temperature history of the Northern Hemisphere as developed by Mann and colleagues, a.k.a. “the Hockey Stick.” The blue line represents the Northern Hemispheric temperature history as constructed by Esper’s research team (source: Esper et al., 2002).

The chorus of dissent grew louder with the publication of a paper by Hans von Storch and colleagues in *Science* in late-2004. Von Storch was interested in how well the temperature reconstruction methodology used in producing the “hockey stick” actually worked. In order to investigate this, he used a climate model, run with historic changes in solar output and volcanic eruptions to produce a temperature record for the past 1,000 years. For von Storch’s purposes, it was not necessary to produce an accurate temperature record, just one that was reasonably representative of what may have happened. Next, he employed a methodology similar to Mann et al.’s, using “proxy” data derived from the climate model temperature record to see how well the Mann et al. methodology could reconstruct the actual data from which it was drawn. What von Storch’s research team found was that the techniques used to construct the “hockey stick” vastly underestimated the true level of variability in the known (modeled) temperature record (Figure 3). It is thus reasonable to conclude that the same techniques, when applied in the real world, would similarly underestimate the true level of natural variability and thus underplay the importance of the LIA and MWP. Again, the von Storch finding adds further evidence that the handle of the “hockey stick” is too flat.

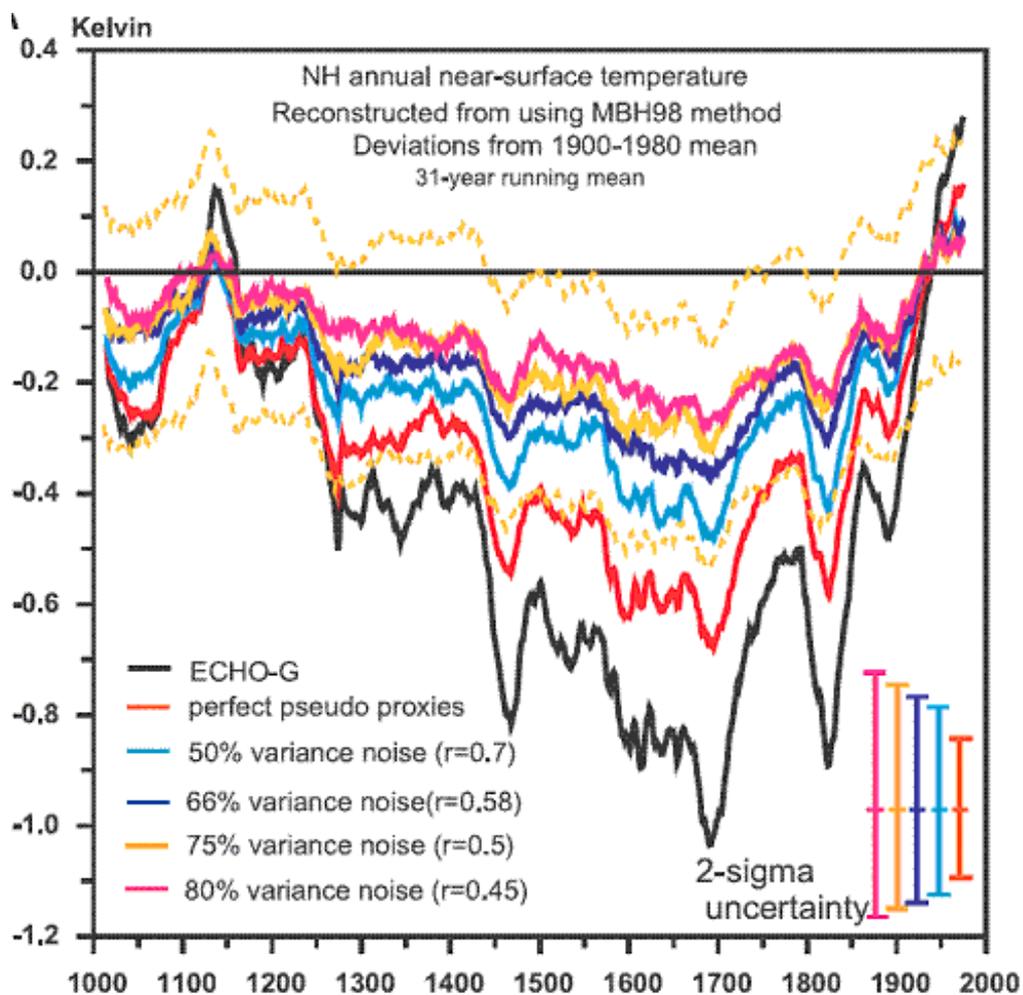


Figure 3. Modeled temperature history for the past 1,000 years (black line) and attempts to reconstruct that history using a Mann-like multi-proxy technique when different amounts of noise are included (colored lines). The more noise, the lower the variance. (Source: von Storch et al., 2004).

And now, with the publication of a paper in *Nature* magazine in early 2005 by Anders Moberg and colleagues, it's all over for the hockey stick. Recognizing that different kinds of proxy temperature records may be more appropriately related to climatic variations at different time scales, Moberg applied a statistical technique called 'wavelet analysis' that allows each proxy to explain temperature variations on a timescale that it was most sensitive to. For example, as discussed above, tree-rings have difficulty in capturing long-term variations but are quite useful for investigating annual-to-decadal scale variability. Other proxies, such as lake and ocean sediments, contain climate information, but are harder to date precisely on annual or even decadal time scales. These low temporal resolution proxies are nonetheless useful for capturing long-term, multi-century climate variations. By combining high-resolution with low-resolution proxy information, Moberg et al. produced a 1,000-yr (actually a 2,000-yr) long temperature reconstruction for the Northern Hemisphere. Moberg's reconstruction (Figure 4) contains strong MWP and LIA signals. The natural variation of temperatures in the Moberg reconstruction is two to three times that of the Mann et al. "hockey stick." Again, the handle of the "hockey stick" was found to be too flat.

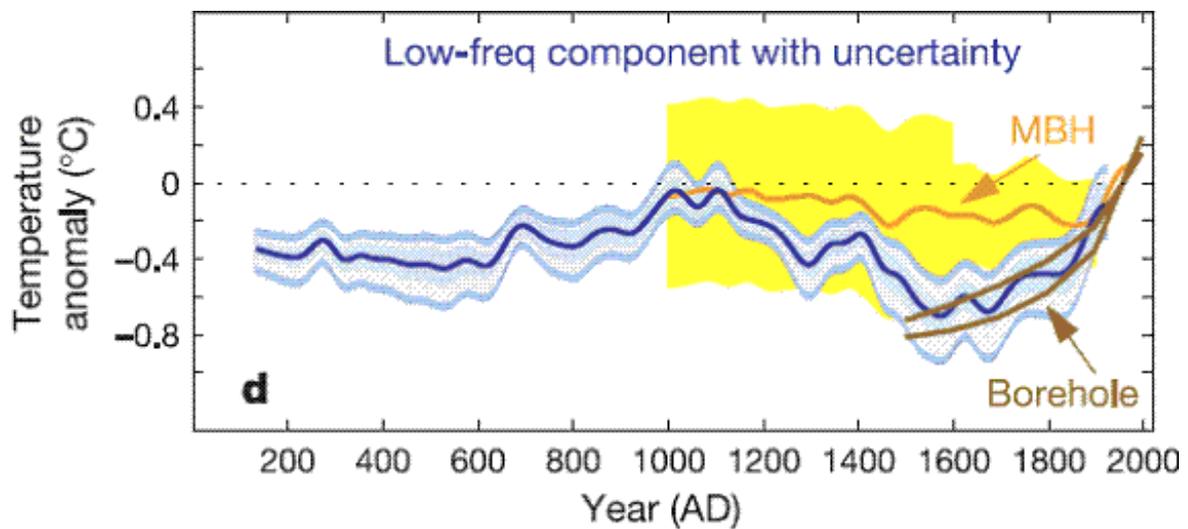


Figure 4. The low-frequency component of climate as determined by Moberg et al. (blue curve with shaded uncertainty bands) compared with the Mann et al. record (orange curve and shaded uncertainty band). (Source: Moberg et al., 2005).

Had the original reconstruction by Mann and colleagues looked like the latest reconstruction by Moberg et al., no one would have paid it much attention, because it would have fit nicely with the expectations given all of the prior research on the climate history of the past millennium. It would have been nothing remarkable.

But, the “hockey stick” was remarkable. And as such, it will be remembered as a remarkable lesson in how fanaticism can temporarily blind a large part of the scientific community and allow unproven results to become mainstream thought overnight. The embarrassment that it caused to many scientists working in the field of climatology will not be soon forgotten. Hopefully, new findings to come, as remarkable and enticing as they may first appear, will be greeted with a bit more caution and thorough investigation before they are widely accepted as representing the scientific consensus.

In this way, the lead graphic in the upcoming IPCC’s Fourth Assessment Report, due out in late 2007, may even survive to be included somewhere in the *Fifth Assessment Report* which will no doubt follow five or so years hence. The “hockey stick” won’t be so lucky.

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