

On Past Temperatures and Anomalous late-20th Century Warmth

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Evidence from paleoclimatic sources and modeling studies support AGU's official position statement on "Climate Change and Greenhouse Gases," holding that there is a high probability that man-made gases, primarily from the burning of fossil fuels, are contributing to a gradual rise in global mean temperature. More specifically, a number of reconstructions of large-scale temperature changes over the past millennium support the conclusion that late-20th century warmth was unprecedented over at least the past millennium. Modeling and statistical studies indicate that such anomalous warmth cannot be explained by natural factors but, instead, require a significant anthropogenic forcing of climate that emerged during the 19th and 20th centuries.

Two (nearly identical) recent papers [Soon and Baliunas, 2003 and Soon *et al*, 2003--henceforth both referred to as 'SB03'] challenge this view, and have been used to support the claim that recent hemispheric-scale warmth is *not* unprecedented in the context of the past millennium (see e.g. "20th Century Climate Not So Hot", press-release, Harvard-Smithsonian Center for Astrophysics, March 31, 2003: <http://cfa-www.harvard.edu/press/pr0310.html>). Such claims are inconsistent with the preponderance of scientific evidence. We therefore review these claims within the context of the AGU position statement, especially since such claims have found their way into the media and have been read into the U.S. Senate record.

Instrumental data for use in computing global mean surface temperatures are only available for about the past 150 years [Jones *et al*, 1999]. Estimates of surface temperature changes further back in time must make use of historical documents and natural archives or "proxy" indicators, such as tree rings, corals, ice cores and lake sediments, to reconstruct the patterns of past climate change. Due to the paucity of data in the Southern Hemisphere, recent studies have emphasized the reconstruction of Northern Hemisphere (NH), rather than global mean temperatures over roughly the past 1000 years. A large number of such reconstructions [Bradley and Jones, 1993; Overpeck *et al*, 1997; Mann *et al*, 1999; Jones *et al*, 1998; Crowley and Lowery, 2000] now support the conclusion that the hemispheric-mean warmth of the late 20th century (i.e., the past few decades) is likely unprecedented in the last 1000 years [Jones *et al*, 2001; Folland *et al*, 2001]. Preliminary evidence [Briffa and Osborn, 1999] suggests that such a conclusion may well hold for at least the past two millennia (Figure 1). Climate model simulations employing estimates of natural and anthropogenic radiative forcing changes [Crowley, 2000; Gerber *et al*, 2002; Bertrand *et al*, 2002; Bauer *et al*, 2003] agree well, for the most part, with the proxy-based reconstructions (Figure 1). The simulations, furthermore, show that it is not possible to explain the anomalous late 20th century warmth without the contribution from anthropogenic forcing factors [e.g., Crowley, 2000] and that the role of anthropogenic forcing can clearly be detected in the proxy-based temperature reconstructions [Hegerl *et al*, 2003]. Here, we raise the following key points regarding recent assertions (SB03) challenging these findings:

(1) In drawing inferences regarding past regional temperature changes from proxy records, it is essential to assess proxy data for actual sensitivity to past *temperature* variability. Seminal work in the reconstruction of past climate [Lamb, 1965] examined a number of different variables, including hydrological indicators, for insights into past climate change, but only in a particular region (Europe) where the synoptic-scale relationship between temperature and hydrological variability was fairly well established and understood. The existence of possible underlying dynamical relationships between temperature and hydrological variability should not be confused with the patently *invalid* assumption that hydrological influences can literally be *equated* with

temperature influences in assessing past climate (e.g. during Medieval times). Such a criterion is implicit, for example, in the SB03 approach which defines a global 'warm anomaly' as a period during which various regions appear to indicate climate anomalies that can be classified as being *either* 'warm', 'wet', *or* 'dry' relative to '20th century' conditions. Such a criterion, *ad absurdum*, could be used to define *any* period of climate as 'warm' or 'cold' and thus makes no meaningful contribution to discussions of past climate change.

(2) It is essential to distinguish [e.g. by compositing or otherwise assimilating different proxy information in a consistent manner-- e.g. *Bradley and Jones*, 1993; *Hughes and Diaz*, 1994; *Jones et al*, 1998; *Mann et al*, 1998;1999; *Briffa et al*, 2001] between regional temperature anomalies and anomalies in hemispheric mean temperature which must represent an average of temperature estimates over a sufficiently large number of distinct regions [see e.g. *Folland et al*, 2001; *Trenberth and Otto-Bliesner*, 2003]. It is well known that weather patterns have a wave-like character to them. This character ensures that certain regions tend to warm (due, for example, to a southerly flow in the Northern Hemisphere winter mid-latitudes) when other regions cool (due to the corresponding northerly flow that must occur elsewhere). The details of these waves (their position and amplitude) are influenced, on climatic timescales, by processes such as the El Niño/Southern Oscillation phenomenon. This past winter is a case in point. January 2003 was about 2°C below normal (1961-90 base) on the east coast of the U.S., but about 4°C above normal in much of the west. Here Utah, Nevada and parts of California and Alaska had their warmest January on record (the change in location of the Iditarod dog sled race was a consequence of the warmth in Alaska!). The mean temperature anomaly over the contiguous U.S. was 1.1°C above normal, much less warm than the western U.S., and of the opposite sign to temperature anomalies in the eastern U.S.. Global or hemispheric temperature variations over longer timescales, in a similar manner, represent a small residual of much larger, often canceling regional variations [e.g., *Williams and Wigley*, 1983; *Crowley and Lowery*, 2000].

In a similar vein, it is important that to define a warm period, warm anomalies in different regions should be synchronous and not merely required to occur during any 50 year period within a very broad interval in time, such as AD 800-1300, as in SB03. Figure 2 demonstrates the considerable spatial variability in temperature variations of the past millennium, and the false impression one might gain regarding hemispheric-scale temperature changes from the apparent temperature changes in any particular region. The specific notions of the 'Little Ice Age' and 'Medieval Warm Period' arose, understandably, from the Eurocentric origins of historical climatology [e.g. *Lamb*, 1965]. While relative hemispheric warmth during the 10th, 11th and 12th centuries, and cool conditions during the 15th to the early 20th century are evident from reconstructions of hemispheric-mean temperature (Figure 1), the specific periods of coldness and warmth apparent differ from region to region (Figure 2) from those for the Northern Hemisphere as a whole. Rather than indicating inconsistency, the difference between such regional and hemispheric-scale anomalies follows naturally from the physics governing atmospheric variability.

(3) It is essential, in forming a climate reconstruction, to define carefully a base period for modern conditions against which past conditions may be quantitatively compared. It is, furthermore, important to identify and, where possible, quantify uncertainties and demonstrate, using independent data, the reliability of any reconstructions [*Mann et al*, 1999; *Jones et al*, 2001]. The conclusions of the most recent IPCC report [*Folland et al*, 2001] that late-20th century mean warmth likely exceeds that of any time during the past millennium for the Northern Hemisphere, is based on a careful comparison of temperatures during the most recent decades with reconstructions of past temperatures, taking into account the uncertainties in those reconstructions. As it is only the past few decades during which Northern Hemisphere temperatures have exceeded the bounds of natural variability, any analysis (SB03) that considers

simply '20th century' mean conditions, or interprets past temperatures using the evidence from proxy indicators not capable of resolving decadal-timescale trends, can provide only very limited insight into whether or not recent warming is anomalous in a long-term and large-scale context.

Healthy debate with regard to the details of past climate change exists within the peer-reviewed scientific climate literature [Bradley *et al*, 2001; Briffa and Osborn, 2000;2002; Huang *et al*, 2000; Folland *et al*, 2001; Esper *et al*, 2002; Mann *et al*, 2003], and it remains a challenge to reduce uncertainties and properly synthesize global means. Nevertheless, the conclusion that late-20th century hemispheric-scale warmth is anomalous in a long-term (at *least* millennial) context, and that anthropogenic factors likely play an important role in explaining the anomalous recent warmth is a robust consensus view.

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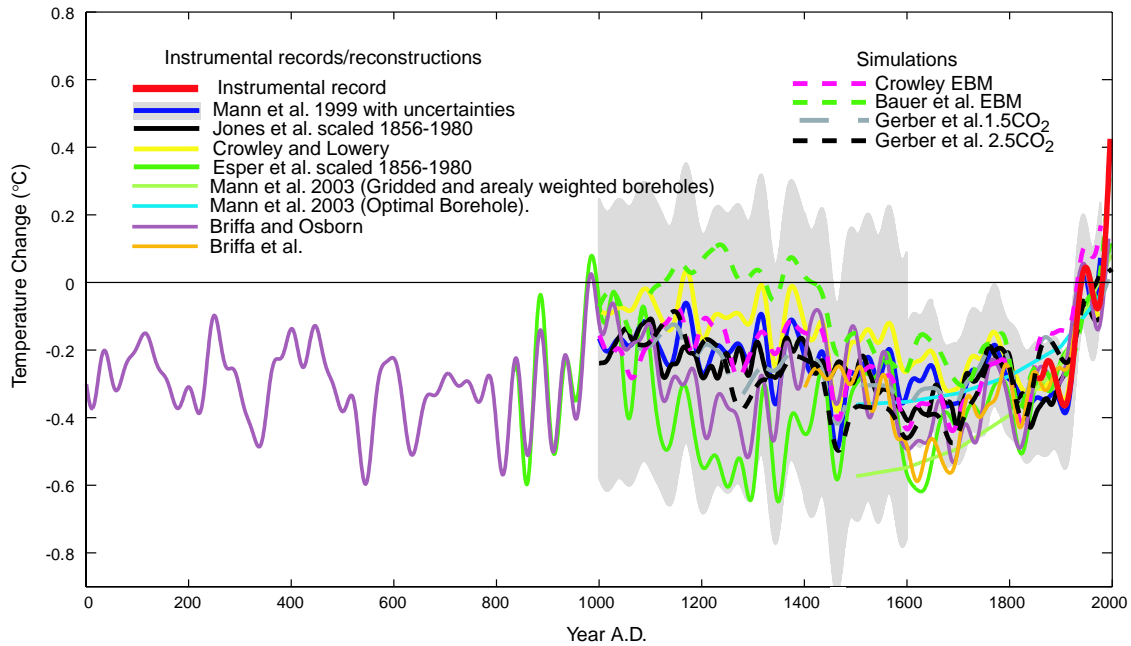


Figure 1. Comparison of proxy-based NH temperature reconstructions [Jones *et al.*, 1998; Mann *et al.*, 1999; Crowley and Lowery, 2000] with model simulations of NH mean temperature changes over the past millennium based on estimated radiative forcing histories [Crowley, 2000; Gerber *et al.*, 2002--results shown for both a $1.5^{\circ}\text{C}/2^{\circ}\text{CO}_2$ and $2.5^{\circ}\text{C}/2^{\circ}\text{CO}_2$ sensitivity; Bauer *et al.*, 2003]. Also shown are two independent reconstructions of warm-season extratropical continental NH temperatures [Briffa *et al.*, 2001; Esper *et al.*, 2002] and a more tentative extension back through the past two thousand years based on very long Eurasian tree-ring width chronologies [Briffa and Osborn, 1999]. All reconstructions have been scaled to the annual, full Northern Hemisphere mean, over an overlapping period (1856-1980), using the NH instrumental record [Jones *et al.*, 1999] for comparison, and have been smoothed on time scales of >40 years to highlight the long-term variations. The smoothed instrumental record (1856-2000) is also shown. The gray shading indicates estimated two-standard error uncertainties in the Mann *et al.* [1999] reconstruction. Also shown are reconstructions of ground surface temperatures (GST) based on appropriately areally-averaged [Briffa and Osborn, 2002; Mann *et al.*, 2003] continental borehole data [Huang *et al.*, 2000], and hemispheric surface air temperature trends, determined by optimal regression [Mann *et al.*, 2003] from the GST estimates. All series are shown with respect to the 1961-90 base period.

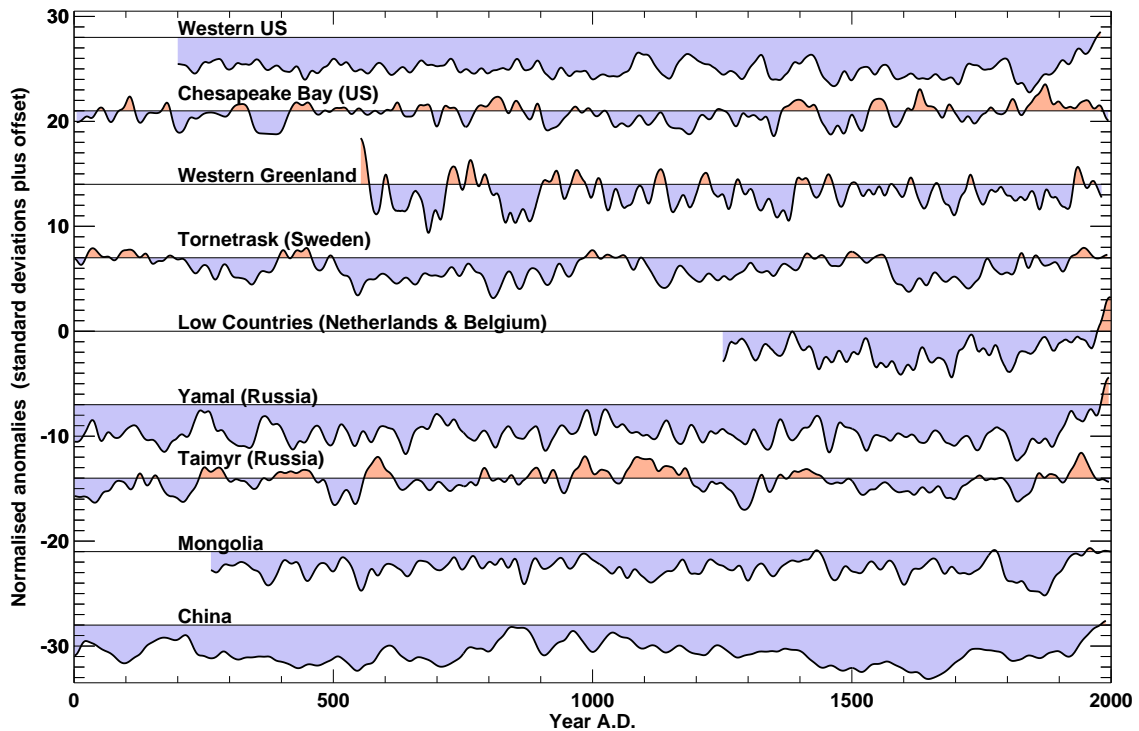


Figure 2. Temporal histories of nine temperature-sensitive proxy records, chosen to illustrate a variety of proxy types, NH locations and spatial and seasonal representation. All series have been smoothed with a 40-year low-pass filter, then normalised so that the filtered series have unit standard deviation over 1251–1980 (when all series have data) and the *unfiltered* series (to avoid edge effects of the filter) have zero mean over 1961–1990 (to facilitate comparison with Figure 1). Series have been offset by steps of 7 standard deviations for display purposes. Blue (red) shading indicates filtered values below (above) the 1961–1990 means (the latter are shown by thin horizontal lines). Original sources for each series are: “Western US” [Mann *et al*, 1999]; “Chesapeake Bay” [Cronin *et al*, 2003]; “W. Greenland” [Fisher *et al*, 1996]; “Tornetrask” [Grudd *et al*, 2002]; “Low Countries” [van Engelen *et al*, 2001]; “Yamal” [Hantemirov and Shiyatov, 2002]; “Taimyr” [Naurzbaev *et al*, 2002]; “Mongolia” [D’Arrigo *et al*, 2001]; “China” [Yang *et al*, 2002].