Testimony of

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before

The U. S. Senate Committee on Environment and Public Works
The United States Senate
Room 406 Dirksen Senate Office Building
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BIOGRAPHY

My name is Michael Mann. I am a professor in the Department of Environmental Sciences at the University of Virginia. My research involves the use of climate models, the analysis of empirical climate data, and statistical methods for comparing observations and model predictions.. One area of active current research of mine involves the analysis of climate "proxy" records (that is, natural archives of information which record past climate conditions by their biological, physical, or chemical nature). These data are used to reconstruct patterns of climate variability prior to the period of the past century or so during which widespread instrumental climate records are available. A primary focus of this research is deducing the long-term behavior of the climate system and the roles of various potential agents of climate change, both natural and human.

I was a Lead Author of the "Observed Climate Variability and Change" chapter of the *Intergovernmental Panel on Climate Change* (IPCC) Third Scientific Assessment Report and a scientific contributor for several other chapters of the report. I am the current organizing committee chair for the National Academy of Sciences *'Frontiers of Science'* and have served as a committee member or advisor for other National Academy of Sciences panels related to climate change. I have served as editor for the *'Journal of*

Climate' of the American Meteorological Society. I'm a member of the advisory panel for the National Oceanographic and Atmospheric Administrations' *Climate Change Data and Detection Program*, and a member of numerous other international and U.S. scientific working groups, panels and steering committees. I have co-authored more than 60 peer-reviewed articles and book chapters on diverse topics within the fields of climatology and paleoclimatology. Honors I have received include selection in 2002 as one of the 50 leading visionaries in Science and Technology by *Scientific American* magazine, the outstanding scientific publication award for 2000 from the National Oceanographic and Atmospheric Administration, and citation by the Institute for Scientific Information (ISI) for notable recognition of my peer-reviewed research by fellow scientists.

In my testimony here today, I will explain:
1) ***How mainstream climate researchers have come to the conclusion that late 20th century warmth is unprecedented in a very long-term context, and that this warmth is likely related to the activity of human beings.***
2) Why ***a pair of recent articles challenging these conclusions by astronomer Willie Soon and his co-authors are fundamentally unsound.***

CLIMATE HISTORY AND ITS IMPLICATIONS

Evidence from paleoclimatic sources overwhelmingly supports the conclusion that late-20th century hemispheric-scale warmth was unprecedented over at least the past millennium and probably the past two millennia or longer. Modeling and statistical studies indicate that such anomalous warmth cannot be explained by natural factors but, instead, requires significant anthropogenic (that is, 'human') influences during the 20th century. **Such a conclusion is the indisputable consensus of the community of scientists actively involved in the research of climate variability and its causes**. This conclusions is embraced by the position statement on "Climate Change and Greenhouse Gases" of the American Geophysical Union (AGU) which states that there is a compelling basis for concern over future climate changes, including increases in global-mean surface temperatures, due to increased concentrations of greenhouse gases,

primarily from fossil-fuel burning. This is also the conclusions of the 2001 report of the Intergovernmental Panel on Climate Change (IPCC), affirmed by a National Academy of Sciences report solicited by the Bush administration in 2001 which stated, *"The IPCC's conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations accurately reflects the current thinking of the scientific community on this issue.*

THE MAINSTREAM SCIENTIFIC VIEWPOINT

Human beings have influenced modern climate through changes in greenhouse gas concentrations, the production of industrial aerosols, and altered patterns of land-use. By studying both the record of ancient climate variability and the factors that may have influenced it, we can establish how and why the climate system varied naturally, prior to any large-scale anthropogenic impacts. Large changes in climate certainly occurred in the distant past. If we look 60 million years back in time, Dinosaurs were roaming the polar regions of the earth, and the globe was almost certainly warmer than today. Carbon dioxide levels were probably about double their current level, and had slowly attained such high levels due to changes in the arrangements of the continents ('plate tectonics') which influence the outgassing of carbon dioxide from the solid earth and thus, atmospheric greenhouse gas concentrations. These changes occur on timescales of tens of millions of years. 10,000 years ago, large ice sheets existed over North America due to natural changes that occur in the earth's orbit on timescales of tens of thousands of years. Trying to study distant past climates for insights into modern natural climate variability is hampered by the fact that the basic external constraints on the system (the continental arrangement, the geometry of the earth's astronomical orbit, the presence of continental ice sheets--what we call the 'boundary conditions') were significantly different from today. Focusing on the evolution of climate in *the centuries* leading up to the 20th century provides a perspective on the natural variability of the climate prior to the period during which large-scale human influence is likely to have occurred, yet modern enough that the basic boundary conditions on the climate system were otherwise the same. This

provides us, in essence, a 'control' for diagnosing whether or not recent climate changes are indeed unusual.

Instrumental data for use in computing global mean surface temperatures are only available for about the past 150 years. Estimates of surface temperature changes prior to the 20th century 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 rather than global mean temperatures. A number of independent reconstructions of the average temperature of the Northern Hemisphere support the conclusion that the hemispheric warmth of the late 20th century (i.e., the past few decades) is likely unprecedented over at least the past millennium. Preliminary evidence suggests that such a conclusion may well hold for at least the past two millennia, though more work, requiring the development of a more complete set of reliable proxy records spanning the past few millennia, are necessary to further decrease the uncertainties. Climate model simulations employing estimates of natural and anthropogenic radiative forcing changes agree well with the proxy-based reconstructions (Figure 1). The simulations, moreover, show that it is not possible to explain the anomalous late 20th century warmth without the contribution from anthropogenic influences. Such consensus findings are expressed in the recently published article co-authored by myself and 12 other leading climate scientists from the United States and Britain that appeared recently in the journal '*Eos*', the official transactions of the American Geophysical Union, the largest professional society in the field.

FLAWS IN A RECENT STUDY DISPUTING THE SCIENTIFIC CONCENSUS

Two deeply flawed (and nearly identical) recent papers by astronomers Soon and Baliunas (one of them with some additional co-authors--both henceforth referred to as 'SB') have been used to challenge the scientific consensus. I outline the 3 most basic problems with their papers here:

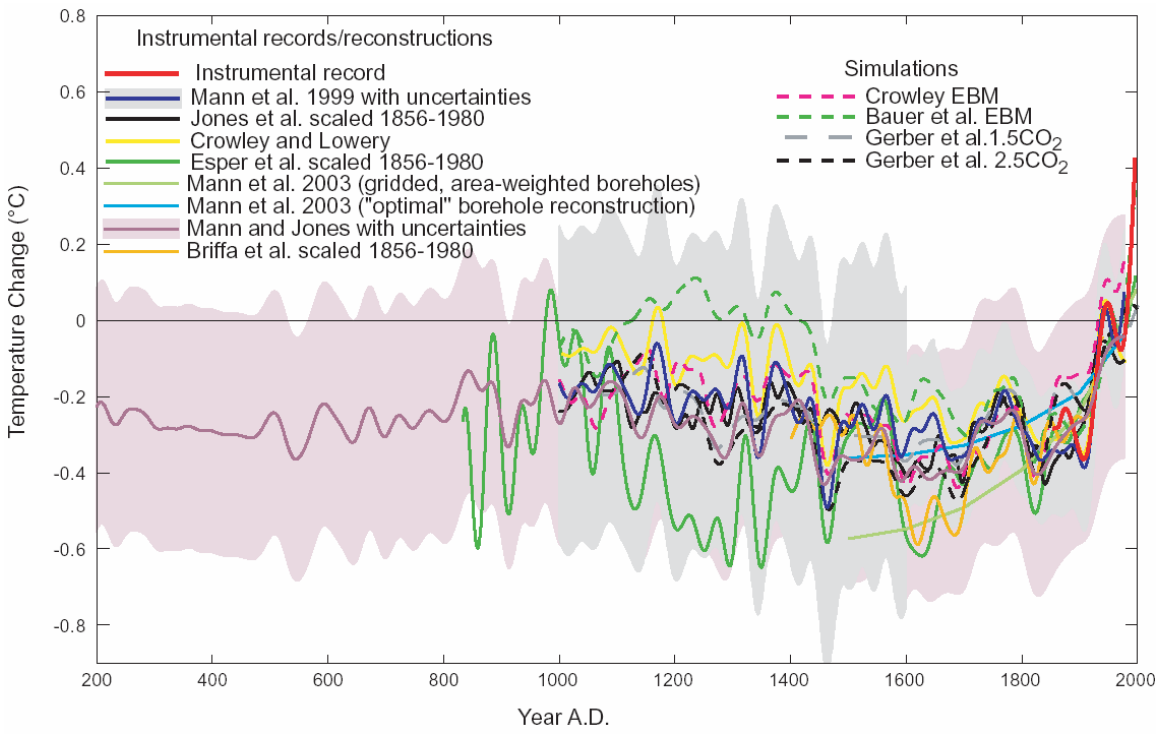

Figure 1. Estimates of changes in the average temperature of the northern hemisphere over the past one to two millennia based on reconstructions from empirical ('proxy') data, and from models driven with estimated changes in natural and anthropogenic factors. Also shown is the modern (1856-2002) instrumental record. Values shown are relative temperatures (in ^{o}C) from the 1961-1990 average (from: Mann, M.E., Ammann, C.M., Bradley, R.S., Briffa, K.R., Crowley, T.J., Hughes, M.K., Jones, P.D., Oppenheimer, M., Osborn, T.J., Overpeck, J. T., Rutherford, S., Trenberth, K.E., Wigley, T.M.L., On Past Temperatures and Anomalous Late 20th Century Warmth, *Eos*, 84, 256-258, 2003.)

1) In drawing conclusions regarding past regional temperature changes from proxy records, it is essential to assess to make sure that the proxy data are indicators of *temperature* and not precipitation or drought. SB make this fundamental error when they cite evidence of either 'warm', 'wet', *or* 'dry' regional conditions as being in support of an exceptional 'Medieval Warm Period' or 'MWP'. Their criterion, *ad absurdum*, could be used to define *any* period of climate as 'warm' or 'cold'. *Experienced* paleoclimate researchers know that they must first establish the existence of a temperature signal in a proxy record before using it to evaluate past temperature changes (Figure A1).

2) It is essential to distinguish between regional temperature changes and truly hemispheric or global changes. **SB do not make this essential distinction**. The wave-like character of weather (i.e., the day-to-day wiggles of the Jet Stream) ensures that certain regions tend to warm when other regions cool. This past winter is a case in point. January was about 2°C *below* normal on the east coast of the U.S., but about 4°C *above* normal over much of the west. Utah, Nevada and parts of California and Alaska had the warmest January on record (the change in location of the Iditarod dog sled race was a casualty of the Alaskan winter warmth!). The average temperature over the entire U.S. was about 1˚C above normal, much less warm than for the western U.S., and of the opposite sign of the eastern U.S.

In a similar manner, *average global or hemispheric* temperature variations on longer timescales tend to be much smaller in magnitude than those for particular regions, due to the tendency for a cancellation of warm and cold conditions in different regions. While relative warmth during the 10th-12th centuries, and cool conditions during the 15th-early 20th centuries are evident from reconstructions and model simulations of the average temperature of the Northern Hemisphere (Figure 1), the specific periods of cold and warmth naturally differ from region to region (Figure A2). The notion of an unusually cold 17th century 'Little Ice Age', for example, arose in a European historical context. What makes the late 20th century unique is the simultaneous warmth indicated by nearly all long-term records (Figure A2), leading to the anomalous warmth evident during this period in Northern Hemisphere average temperatures (Figure 1).

3) It is essential, in forming a climate reconstruction, to carefully define a base period for modern conditions against which past conditions may be quantitatively compared. The concensus conclusion 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 such as SB that compares past temperatures

only to early or mid 20th century conditions, or interprets past temperatures using proxy information not capable of resolving decadal trends cannot address the issue of whether or not late 20th century warmth is anomalous in a long-term context..

CONCLUSIONS

The concentration of greenhouse gases in the atmosphere is higher than at any time in *at least* the last 400,000 years, and, it increasingly now appears, probably many millions of years. This increase is undeniably due to the activity of human beings through fossil fuel burning. **Late 20th century warming is unprecedented in modern climate history at hemispheric scales.** This is almost certainly a result of the dramatic increase in greenhouse gas concentrations due human activity. The latest model-based projections indicate a global mean temperature increase of 0.6 to 2.2°C (~1 to 4°F) relative to 1990 levels by the mid 20th century. While these estimates are uncertain, even the lower value would take us well beyond any previous levels of warmth seen over at least the past couple millennia. The magnitude of warmth, but perhaps more importantly, *the unprecedented rate of this warming*, is cause for concern.

Appendix 1.

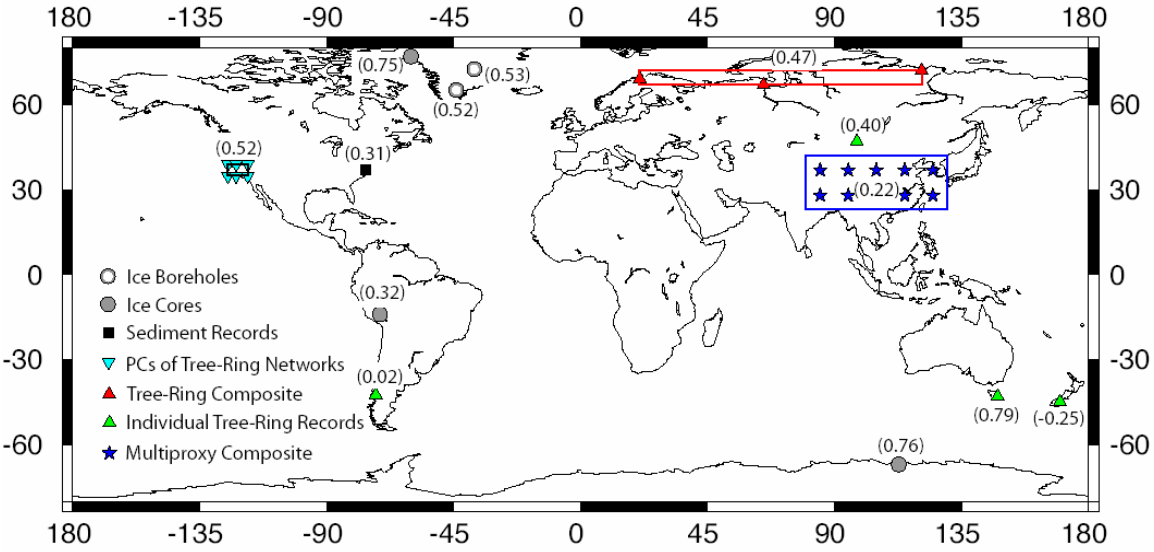

Figure A1. Locations of temperature proxy records used to reconstruct past hemispheric temperature trends (from: M.E. Mann, and P.D. Jones, 2003: *Geophysical Research Letters*, v.26, p.759-762).

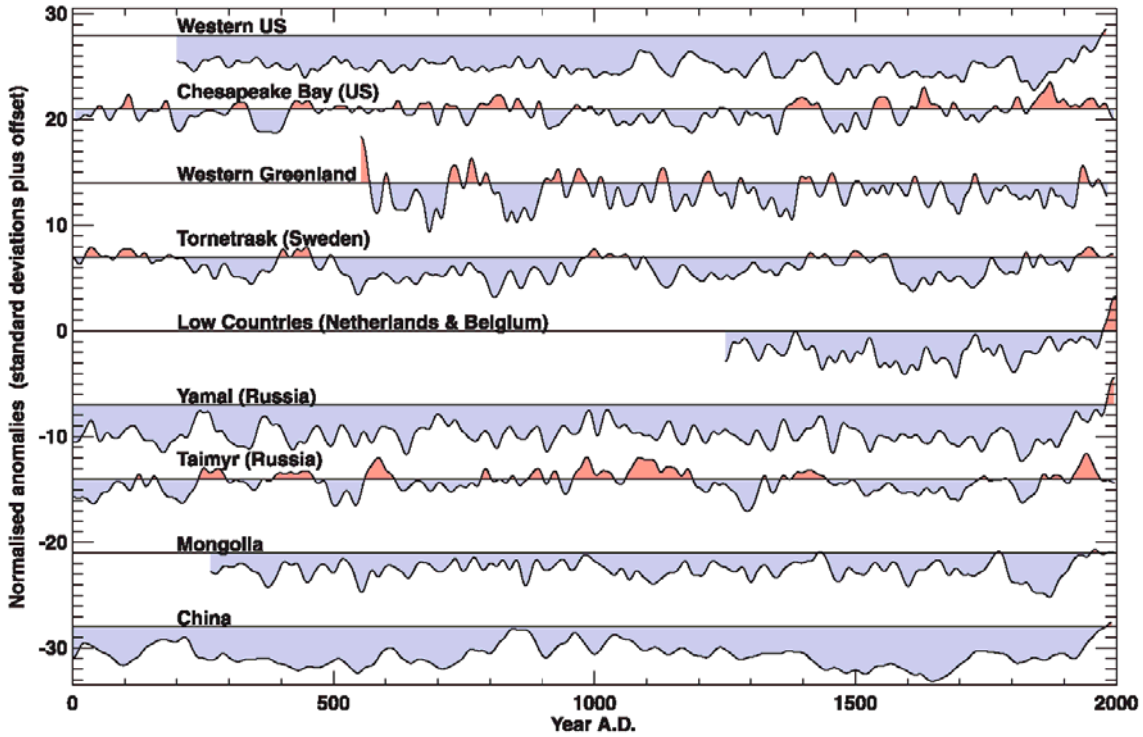

Figure A2. Temporal histories of nine temperature-sensitive proxy records across the Northern Hemisphere, smoothed to highlight changes on 40 year and longer timescales. Blue (red) shading indicates values below (above) the 1961–1990 means (from: Mann, M.E., Ammann, C.M., Bradley, R.S., Briffa, K.R., Crowley, T.J., Hughes, M.K., Jones, P.D., Oppenheimer, M., Osborn, T.J., Overpeck, J. T., Rutherford, S., Trenberth, K.E., Wigley, T.M.L., On Past Temperatures and Anomalous Late 20th Century Warmth, *Eos*, 84, 256-258, 2003.)