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Mr. Chairman and Members of the Committee: As Director of the National Climatic Data Center, which is part of the National Environmental Satellite, Data, and Information Service (NESDIS) within the National Oceanic and Atmospheric Administration (NOAA), and as Program Manager for one of five different NOAA Climate Goal Programs (Climate Observations and Analysis), I am pleased to have the opportunity to testify before you today. The National Climatic Data Center houses the World Data Center for Paleoclimatology which includes the data sets that have been used to reconstruct temperatures of the past millennium.

I was one of two Coordinating Lead Authors for Chapter 3 of the Intergovernmental Panel on Climate Change (IPCC) 2001 Assessment which contained a number of statements related to temperature change over the past 1000 years. Chapter 3's remit was to assess the data for changes and variations in climate. Coordinating Lead Authors act as Chairs during the Lead Author chapter meetings. Each chapter has multiple Lead Authors, and Chapter 3 of the 2001 IPCC Assessment had ten Lead Authors. The Coordinating Lead Authors are ultimately responsible for ensuring that the final chapter is delivered to the IPCC Bureau on schedule. Each Chapter is agreed to by all Lead Authors and discussed and reviewed with other Chapter Lead Authors. The IPCC has a very comprehensive review process. Review Editors are assigned to each chapter to oversee the review process.

My testimony reviews how the Lead Authors of the 2001 IPCC Assessment developed the various findings contained in that Assessment. Since 2001, there has been considerable additional work related to this topic. I will relate this new work to the findings in 2001 and the June 2006 National Research Council Report on this same topic. I also note that IPCC has an updated policy-makers summary for the Fourth Assessment scheduled for release in 2007.

The primary intent of the IPCC periodic assessments is to provide government policy-makers with the latest and most comprehensive scientific information possible about

human influences on our global climate in a language that has meaning and relevance to governmental policy-makers. The IPCC assessments have, however, provided much more. From purely a scientific perspective, participation in the IPCC process is extremely beneficial, as it provides the means for the world's scientists to discuss leading-edge issues with rigorous worldwide scientific review. The IPCC process ensures that the scientists who participate gain from the process a fuller appreciation of where important pay-offs in new research and observing systems are most likely to emerge. This has important impacts on our nation's climate change programs including the Climate Change Science Program.

The IPCC 2001 Assessment

In 2001 the IPCC had several key findings related to changes of temperature during the past 1000 years. This included the time prior to the advent of measuring temperatures with modern instruments such as thermometers, or from more sophisticated methods such as remotely sensed spectral radiances from satellites. Temperatures derived prior to using modern instruments are referred to as the pre-instrumental temperature record. Data from the pre-instrumental period back to 1000 A.D., and up through instrumental period make up what has come to be called the "hockey stick" temperature time series. The 2001 IPCC Assessment included the following findings regarding climate change over the past millennium:

- *New analyses indicate that the magnitude of the warming over the 20th century is likely to have been the largest of any century in the last 1,000 years.*

- *The 1990s are likely to have been the warmest decade of the millennium in the Northern Hemisphere and 1998 is likely to have been the warmest year. Because less data are available, less is known about annual averages prior to 1,000 years before the present and for conditions prevailing in most of the Southern Hemisphere prior to 1861.*

- *Evidence does not support the existence of globally synchronous periods of cooling or warming associated with the 'Little Ice Age' and 'Medieval Warm Period'. However a reconstructed Northern Hemisphere temperature does show a cooling during the 15th to 19th centuries and a relative warm period during the 11th to the 14th centuries, although the latter period is still cooler than the late 20th century.*

- *Analyses of borehole temperatures[1] indicate a non-linear increase in global average ground surface temperatures over land of 1.0 ± 0.3ºC over the last 500*

[1] The heat received from the atmosphere at the earth's surface is conducted into the underlying soil and rock. It takes considerable time for this heat to work its way down to deeper layers earth. This transfer of heat occurs constantly over time, and with current methods the signal is strong enough to estimate temperatures about 400 years before the present. Time series of such temperatures are referred to as borehole temperatures and these measurements are used to relate profiles of temperatures with depth to the history of temperature changes at the ground surface.

years, with most of the increase occurring since the late 19th century. There may be additional uncertainties due to the assumption used in this technique, and decreasing resolution back in time limits confidence in the exact timing of the warming."

These four findings were developed after careful consideration of the published literature on this topic. At that time several new analyses of Northern Hemisphere temperatures had become available. The work of Dr. Michael Mann and his colleagues (Mann et al., 1998) enabled the IPCC to consider, for the first time, the rate and strength of the 20th Century warming in comparison to temperatures over the past 1000 years. It is unlikely however, that this work alone could have led the IPCC to the findings listed above. Two other different reconstructions (Jones et al., 1998; Briffa, 2000) of Northern Hemisphere temperatures were also considered that were based on a smaller set of proxies[2]. Unlike Mann's time series data that reflected annual temperatures, these other reconstructed temperatures best reflected summer temperatures and were limited to Northern Hemisphere land areas. One reconstruction used various types of proxies and the other used tree ring density (as opposed to tree ring width). Additionally, other proxies without annual resolution such as borehole ground temperatures and glacial length were considered in the IPCC (2001) findings. A limiting factor in all these analyses is the sparseness of proxy data, especially as one goes further back in time.

Similar to the recent U.S. Climate Change Science Program Synthesis and Assessment Product 1.1, the IPCC lead authors considered uncertainties related to two types of construction errors. Such errors can be thought of as having two fundamentally different sources: parametric and structural. Parametric uncertainty, which results from limited data to estimate the coefficients of various equations in a statistical model, is much less important than structural uncertainty. The human decisions that underlie the development of the reconstructed temperatures may be thought of as forming a structure for depicting real and artificial behavior in the temperature data. Assumptions that guide the decisions made by the experts in selecting specific analysis techniques may not be correct, or important factors may have been ignored. These possibilities lead to structural uncertainty. Structural uncertainty can only be estimated by comparing the differences of equally plausible reconstruction analysis techniques. The IPCC 2001 lead authors were able to estimate the structural uncertainty associated with the IPCC findings because of the availability of several reconstructed temperature time series.

It is important to note that the language used by IPCC in the 2001 Assessment included an expert assessment of the certainty (or uncertainty) of the various findings. The IPCC used the following descriptive terms to represent uncertainty: "virtually certain" indicated a greater than 99% probability of being true (odds better than 99 to 1), "very likely" reflected a certainty of between 90% and 99% (odds better than 9 to 1), and the term

[2] A proxy climate indicator is a local record that is interpreted, using physical and biophysical principles, to represent some combination of climate-related variations back in time. Climate-related data derived in this way are referred to as proxy data. Examples of proxies are: tree ring records, characteristics of corals, and various data derived from ice cores.

"likely" reflected a certainty of being true between 66% and 90% (odds better than 2 to1) of the time. Similar expert assessments of certainty (or uncertainty) have proven to be quite reliable in related areas of the science, such as weather forecasting.

The total measure of uncertainty for the findings in the IPCC Assessment incorporates both the parametric and structural uncertainty of the reconstructed temperatures. In developing the 2001 Assessment, the IPCC Coordinating Lead Authors and Lead Authors debated whether to use the terminology "likely" versus "very likely" in describing the rate of 20th Century warming, the warmth of the 1990s, and that of 1998 as record highs in comparison with the annual temperature record of the preceding 1000 years. The final decision was to use the term "likely."

This reasoning was based on the newness of the reconstructed temperature results and the limited number of analyses that were available. These factors reduced our confidence in the reconstructed time series reflecting the "hockey stick" curvature late in the record, and led to the selection of the use of the term "likely." The term "likely" reflects a much lower threshold of scientific rigor than is normally associated with more confident findings (as mentioned above, the term "very likely" is linked to odds better than 9 to 1). "Likely" was thus selected as the modifier for the various findings related to the rate of temperature change in the 20th Century and the warmth of the 1990s and 1998 in comparison with the previous 1,000 years for the Northern Hemisphere.

Since IPCC 2001

It is common practice in science to challenge new results and test them under different conditions. Replication of results is a key component of science. The results of these tests are critical to scientific advancement. Indeed, the work of Dr. Michael Mann and his colleagues has brought an opportunity to test and refine the various techniques of developing reconstructed temperatures. Several research teams have challenged the technique used by Mann and colleagues to develop reconstructed temperatures. This includes criticisms of the weight given to specific proxies, the statistical method used and its propensity for underestimating multi-decadal temperature variability, and the short period of overlap with the instrumental record available to calibrate proxy data. These challenges are not without validity, but now each of them has been assessed in a variety of new analyses.

Over the past several years there have been many new analyses using many of the same proxy data Mann and colleagues used, as well as new proxies including longer time periods or slightly expanded geographic coverage (Esper et al., 2002; Briffa and Osborn, 2002; Mann and Jones, 2003; Briffa et al, 2004; Moberg et al., 2005; Rutherford et al., 2005; Esper et al., 2005; D'Arrigo et al., 2006; Hegerl et al., in press). Of all these analyses only one shows temperature during Medieval times higher than those of the early 20th Century, and none of the analyses show temperatures higher than the last few decades of the 20th Century and into the 21st Century. The various analyses used different statistical methods, proxies, and temperature calibration approaches.

In addition, there have been new analyses of glacial length, borehole surface temperatures, corals, and isotopic records of low latitude ice cores (Oelermans, 2005; Cole, 2003; Pollack and Smerdon, 2004; Hoffman et al., 2003; Vuille and Werner, 2005; Vuille et al., 2005). These analyses indicate that the later half of the 20th Century is certainly warmer than any time during the past several hundred years (based on the length of the borehole and glacial length proxies) and the past 1200 years (based on isotopic ice core records).

In June the National Research Council (NRC) reassessed the so-called "hockey stick" reconstructed time series. The NRC Report not only assessed the observational data, but considered how well the data stands up to our ability to simulate the temperature record of the past 1000 years. The NRC found that for the most part, given the various limitations of our knowledge about the history of important causes of climate variations and change (such as changes in solar variability and volcanic eruptions), the climate model simulations are consistent with the inferred large-scale tree-ring and multi-proxy-base reconstructions of the Northern Hemisphere temperature.

The NRC Report indicates it is plausible that the last few decades of the 20th Century were warmer than any other time during the past 1000 years. The NRC has less confidence in quantifying the relative warmth of a specific decade or year because of the difficulty in calculating and estimating uncertainties at this high temporal resolution, e.g., by specific year or decade. It should be noted, however, that the NRC Report did not use language similar to IPCC. In the IPCC Assessment (2001) significant findings are highlighted when the odds are as low as 2 to 1 in favor of being correct, while a more stringent level of scientific certainty is usually imposed on new results (e.g., better than 20 to 1) within the scientific community. The NRC Report went on to state that the Little Ice Age from 1500 to 1850 "is supported by a wide variety of evidence." Further, it notes that evidence for Medieval Warm Period "can be found in a diverse but more limited set of records." Jones et al. (1998) and Osborn and Brifiia (2006) provide local paleoclimatic proxies back to 1000 A.D., or earlier, showing that the Medieval Warm Period was not a hemispheric-wide phenomena, unlike the warmth of the past few decades. In contrast to IPCC 2001, the recent NRC Report did not highlight the rate of temperature increase during the 20th Century compared to the previous ten centuries.

Reducing Uncertainties

To improve our estimates of reconstructed temperature more paleoclimatic proxy records await our extraction. This includes ice cores, corals, sediments at the bottom of the sea, and tree rings among other types of proxy records. As stated in the IPCC 2001 Assessment, more proxies from the Southern Hemisphere would be of great value, as we are unable to estimate Southern Hemisphere temperatures prior to a few hundred years ago. The recent NRC Report also emphasizes the value of increased geographic coverage for longer-term proxies (earlier than ~1600 A.D.). In addition, the power of any single type of proxy is greatly increased when combined with other proxy records to develop multi-proxy data sets, or to estimate the uncertainty of the reconstructed temperature time series.

Setting out to extract and calibrate proxy paleoclimate data is a necessary, but not a sufficient condition to narrow our uncertainties related to quantifying and attributing past climate variations and change. The data from the proxies must be made publicly available for analysis. At the present time, there is no formal process whereby federally-funded scientists must submit their data to a long-term data archive facility for use by others. The submission of data to institutions like NOAA's National Climatic Data Center's World Paleoclimatic Data Center requires significant investment of time by the principal investigators who collected the data to provide the useful information about the proxy data to the receiving Data Center. In addition, if such data are submitted, a significant investment by the Data Center would need to be made to ensure the data are useable to others in perpetuity and safeguarded for future generations. Some initial discussions to help formalize such transactions are beginning to emerge.

This concludes my testimony. Thank you for allowing me the opportunity to help inform the Committee on this topic.

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