Global Temperature

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This note responds to recent inquiries about 2005 global temperature, the inquiries stimulated by a 13 October Washington Post article. The Post article used data from one of the Goddard Institute for Space Studies (GISS) temperature indices (updated monthly on the GISS web site http://data.giss.nasa.gov/gistemp) to suggest that 2005 was likely to be the warmest year in the history of instrumental data. None of us, the GISS scientists involved in constructing global temperature data sets, were consulted for input to the Post article or data verification.

Our most recent statement about the 2005 global temperature was in an April 2005 explanatory discussion accompanying publication of "Earth's Energy Imbalance: Confirmation and Implications" [*Hansen et al.*, 2005]. Specifically, Hansen stated "…because of the present strong planetary energy imbalance…we can say with confidence that 2005 will have a warmth comparable to that of 1998, and the remarkable 1998 global temperature record will soon be broken, if not this year then within the next several years."(1) A similar statement was made in the February 2005 on the GISS web summary of global temperature for 2004 (http://data.giss.nasa.gov/gistemp/2004/).

The Post article properly emphasizes that record global temperature in 2005 would have scientific implications. The existing record in the period of instrumental temperature measurements occurred when the 1997-98 "El Nino of the century" occurred on the back of a strong two-decade warming trend; in addition, the global temperature impact of the El Nino, which typically lags the El Nino by a few months, coincided almost precisely with calendar year 1998. As a result, the 1998 temperature jumped about two standard deviations(2) above the prior record. Thus, if the 1998 global temperature level is reached without help from a large El Nino, such a result would be a measure of how intense the underlying global warming trend has become.

The Post article might be criticized on several grounds. First, the reported temperature anomalies were apparently taken from one of two temperature indices on the GISS web site, but the other index would have been more appropriate for the purpose of global records. Second, a 9-month anomaly for 2005 was compared with a 12-month anomaly for 1998; empirical data from the warming in the past few decades shows that anomalies are usually smaller in the second half of the calendar year (i.e., global warming is larger in Northern Hemisphere winter and spring) so it would have been fairer to compare the 9-month 2005 anomaly to the 9-month 1998 anomaly. Third, some people object to "jumping the gun", i.e., making comparisons well before the end of the year. Our opinion is that the Post article was a useful contribution, drawing attention to what is shaping up to be a very warm year, but technical clarifications are needed.

Global Temperature Indices

We provide two global temperature indices. The first index, hereafter "met station index", is based solely on surface air temperature measured at a height of 2 meters at a few thousand meteorological stations located on continents and islands around the world. The second index, hereafter "land-ocean index", combines the met station data with sea surface temperatures (SSTs), using satellite data for recent years and earlier ship measurements. Each of the two data sources (met stations and SST measurements) has significant flaws and uncertainties. The two data sets also have different physical significance.

Meteorological station index. Our met-station index (the land-based index) was defined in 1979 using a tape of WMO (World Meteorological Organization) data made available annually by Roy Jenne of NCAR (National Center for Atmospheric Research). The result, estimated global temperature change through 1978 was first published by *Hansen et al.* (1981)[3], documented in detail by *Hansen and Lebedeff* (1987), and refined by *Hansen et al.* (1999, 2001). This met-station result for "global"[3] temperature change, updated through 2004, is shown on the left side of Figure 1.

Land-ocean index. Near-global analyses of ship-based SST (sea surface temperature) measurements began to be readily available in the late 1980s and early 1990s. We have used such SST analyses to form a "land-ocean temperature index" consisting of the surface air temperatures over land and SSTs for ocean regions. Our current land-ocean temperature index uses the analysis of *Rayner et al.* (2003), because it goes back to 1880, combined with the satellite analysis of *Reynolds and Smith* (1994) for recent years, because it is updated monthly.

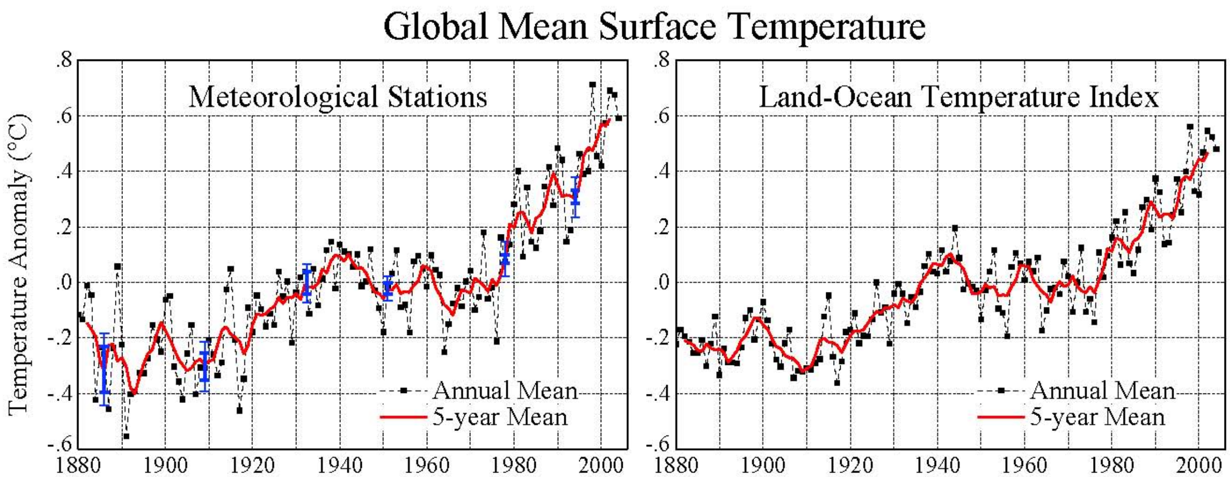

Figure 1. Global temperature indices based on (left side) only surface air temperature measurements at meteorological stations (*Hansen et al.*, 2001), and (right side) the combination of the meteorological station surface air measurements with SST data of *Rayner et al.* (2003) and *Reynolds and Smith* (1994). Temperatures are anomalies relative to the 1951-1980 base period mean. "Error bars" (95% confidence limits) at several points on the curves (large bar for annual mean temperature, small bar for 5-year mean) account only for incomplete spatial coverage of the measurement network (*Hansen and Lebedeff*, 1987), not several other potential sources of error.

Global warming curves. The met-station and land-ocean global temperature indices are compared in Figure 1. Overall, the curves for met-station and land-ocean indices have much in common, confirming the contention of *Hansen et al.* (1981) that the met stations yield a meaningful global result despite their sparseness at low latitudes and in the Southern Hemisphere. The ability of limited met stations to approximate the result including ship data is dependent on the method of combining the stations, which assumes a 1200 radius of influence for each station, combines stations within broad latitude belts, and weights each belt by area.

Note that the century time-scale temperature change is slightly larger for the met-station index than for the land-ocean index. This is an expected result for a forced climate change, as climate models show that the temperature change tends to be larger over the continents. The long-term met-station global warming falls between the land-ocean global warming and the "land" temperature changes obtained by the East Anglia (Phil Jones and colleagues) and NCDC (National Climate Data Center) groups, as shown by *Vose et al.* (2005). This result is also expected, because our use of a 1200 km radius of influence for each station gives large weight to island and coastal stations in an attempt to capture as much of the marine influence as possible.

There are many flaws in the input data for the temperature change analyses, especially in the early years, and the effect of these flaws cannot be fully removed.[4] Despite these problems, however, the reality of global warming in the past century is no longer at issue, and the approximate magnitude of the warming is confirmed by numerous proxy data, including temperature profiles in thousands of boreholes around the world, the rate of world-wide melting of glaciers, earlier spring thaws on rivers and lakes, for example.

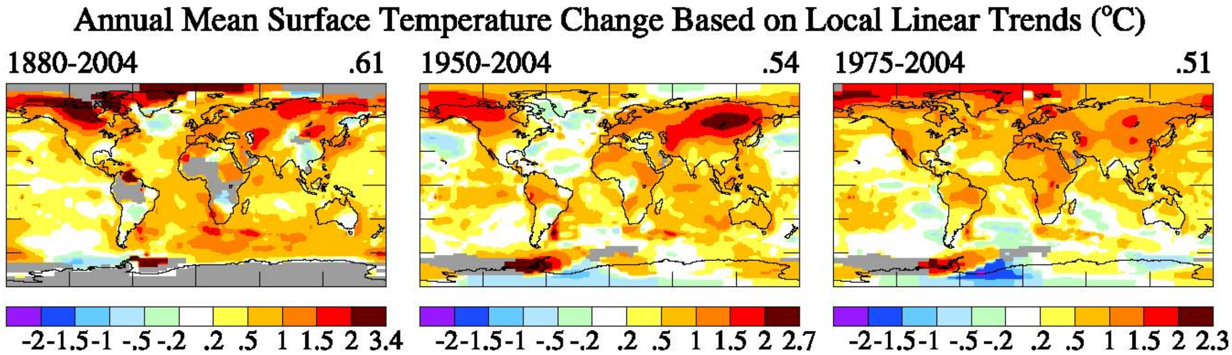

Figure 2. Change of surface temperature index for three periods based on local linear trends using surface air temperature over land and SST over ocean.

Global maps of surface temperature change. Figure 2 shows surface temperature change for three periods: 1880-2004, 1950-2004, and 1975-2004. It is notable that most of the global warming of the past century occurred in the past few decades, while greenhouse gases were increasing rapidly. This effect is somewhat exaggerated by the nature of linear trends. Thus it is best to use Figure 1 for assessing the change of the magnitude of global warming as a function of time.

The map of global temperature change over the past century (left map in Figure 2) makes it clear that the global warming is not an urban effect. Large areas of warming occur over the ocean, and the largest warmings are in regions remote from population centers. Warming is less over the ocean than over land in recent decades, an expected consequence of recent rapid growth of greenhouse gases and the ocean's large thermal inertia, which leaves much of the warming still "in the pipeline".

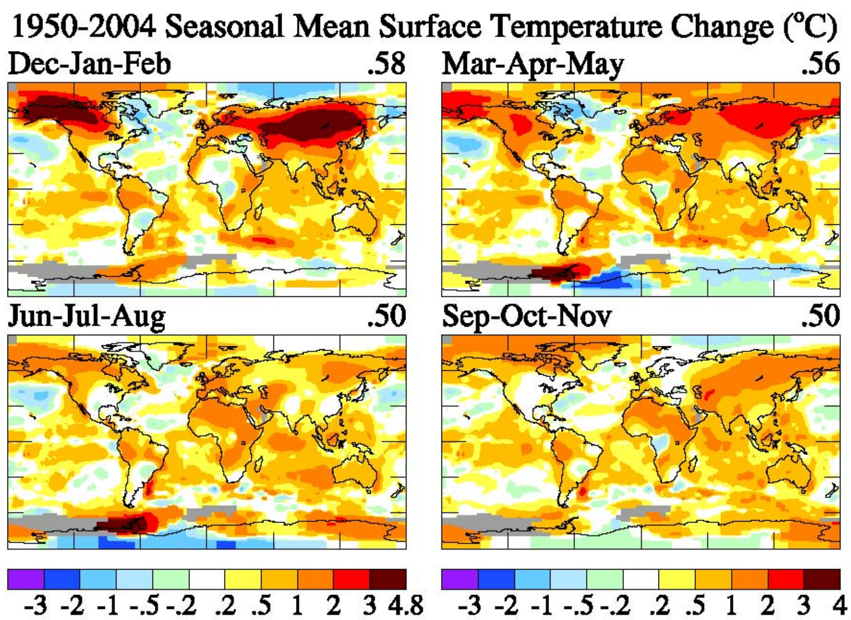

Figure 3. Change of surface temperature index for the four seasons for 1950-2004 based on local linear trends using surface air temperature over land and SST over ocean.

Seasonal temperature change. Figure 3 shows the surface temperature change for the four seasons for the period 1950-2004. Warming is larger in Northern Hemisphere winter (Dec-Jan-Feb) and spring (Mar-Apr-May) than in the other two seasons (the number on the upper right of the maps is the global mean of 54-year temperature change). The magnitude of seasonal temperature change fluctuates from year to year, but in recent years the temperature anomalies in Dec-Jan-Feb and Mar-Apr-May have averaged about 0.1°C larger than in the other seasons.

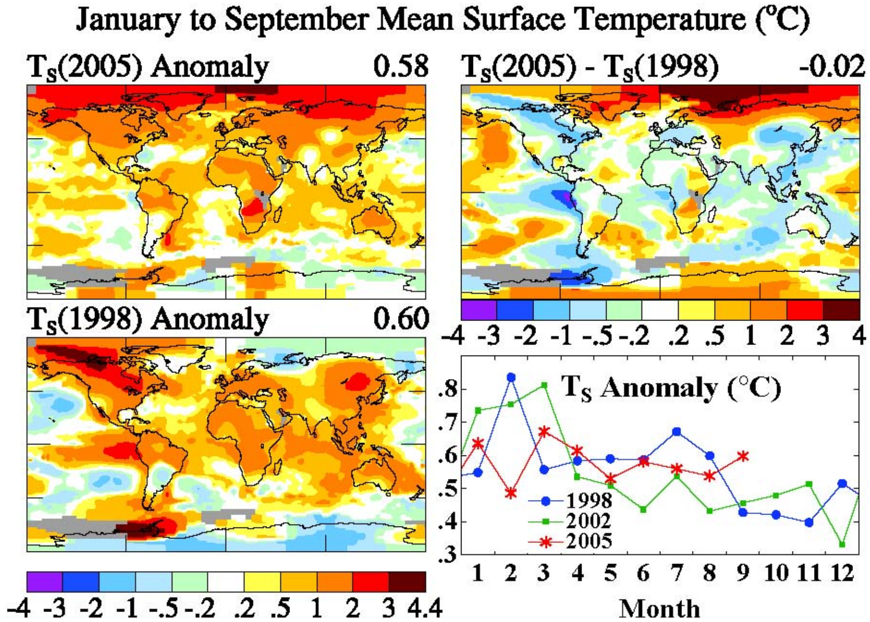

Figure 4. January to September surface temperature anomalies in 2005 and 1998, relative to the 1951-1980 base period mean, and their difference. The graph on the lower right shows the monthly anomalies for 1998, 2002 and 2005.

Comparison of warmest years. Figure 4 compares the temperature anomalies of 1998 and 2005. For the first nine months of the year, 2005 is 0.02°C cooler than 1998 in our land-ocean temperature index, and is tied with 2002 as the second warmest year in the period of instrumental data. The graph in the lower right shows that 1998 and 2002 were relatively cool in the last three months of the year, by more than the typical variation of the global temperature anomaly (Figure 3). Therefore, there is a better than 50% chance that 2005 will move up in the rankings by the end of the year.

Considering also the continuing effect of the current planetary energy imbalance, we conclude that there is no reason to change the statements that we made in February and April (see above). It is now clear that 2005 surely will have been an abnormally warm year, comparable to the warmest year on record (1998), despite not being pushed, as in 1998, by a large El Nino. It is noteworthy that September 2005 was the warmest September in the 125 years of data.

Of course, it will be interesting to see how 2005 ranks compared to 1998 at the end of the year. However, for scientific purposes, the important result (already clear) will be that the trend of global temperatures toward global warming is now so steep that in just seven years the global warming trend has taken temperatures to approximately the level of the abnormally warm year of 1998. The steep global warming trend that began in the late 1970s (Figure 1) is continuing.

Note that results of different global temperature analyses, such as those by GISS, NCDC, and the University of East Anglia, typically differ by several hundredths of a degree because of many differences in their analysis schemes. Thus the ranking of years with similar global temperatures often differs among these three groups. These small differences do not alter significantly the scientific conclusions about the general trend of global warming.

Note: The preliminary October global temperature anomaly is 0.61C, the second warmest October in the period of record, making the 10-month 2005 anomaly slightly larger than the 10-month 1998 anomaly (by less than a tenth of a degree) in our analysis.

Footnotes

(1)"Earth's Energy Out of Balance: The Smoking Gun for Global Warming" (http://www.columbia.edu/~jeh1)

(2)The standard deviation is a measure of the typical year-to-year fluctuation of temperature due to the fact that weather and climate are chaotic. There is about a 5% chance of a positive temperature fluctuation of two standard deviations occurring by chance.

(3)The delay in publication of the original analysis through 1978 was due in part to our insistence on describing it as a global index relevant to comparison with global mean climate model results, despite the fact that there were only scattered observations in the Southern Hemisphere. The capability of met stations to yield a meaningful global result is shown by comparison of the two parts of Figure 1.

(4)Local urban effects on temperature are a significant problem. We reduce urban effects by finding nearby rural stations and adjusting the long-term trend of urban stations based on the long-term trends of near neighbors. But this is an imperfect procedure, and sometimes there are no nearby rural neighbors, or the data is flawed for other recording reasons that are impossible to correct. Our global maps of temperature change sometimes reveal odd features suggesting an error. Our policy is to retain these suspicious data, if they have survived objective screening via near neighbor comparison, because to do otherwise would introduce human subjectivity. Resulting data "warts" provide a reminder of imperfect data.

(5)The Earth's energy imbalance is almost 1 W/m^2, with the planet absorbing that much more solar energy than it is radiating back to space as heat. The imbalance is due mainly to human-made greenhouse gases.

(6)It is argued elsewhere (Hansen, 2005) that global temperature is now passing through the warmest level achieved during the current warm interglacial period, to the warmest level that has occurred on Earth in the past 100,000 years.

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