WAITING FOR GLOBAL COOLING

by

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Summary

There is very little justification for asserting that global warming has gone away over the past ten years, not least because the linear trend in globally-averaged annual mean temperatures (the standard yardstick) over the period 1998-2007 remains upward. While 1998 was the world's warmest year in the surface-based instrumental record up to that point in time, 2005 was equally warm and in some data sets surpassed 1998. A substantial contribution to the record warmth of 1998 came from the very strong El Niño of 1997/98 and, when the annual data are adjusted for this short-term effect (to take out El Niño's warming influence), the warming trend is even more obvious.

Because of the year-to-year variations in globally-averaged annual mean temperatures, about ten years are required for an underlying trend to emerge from the "noise" of those year-to-year fluctuations. Hence, the fact that 2006 and 2007 were cooler than 2005, is nowhere near enough data to clearly establish a cooling trend.

> *Global warming stopped in 1998. Global temperatures have remained static since then, in spite of increasing concentrations of greenhouse gasses in the atmosphere. Global temperatures have cooled since 1998. Because 2006 and 2007 were cooler than 2005, a global cooling trend has established itself.*

All these statements, and variations on them, have been confidently asserted in the international and Australian media in the past year or so, but the data do not support them.

Data

We use here three of the most prominent globally-averaged annual mean temperature anomaly[1] data sets, one British and two American. Northern and southern hemisphere data sets are also available from these three sources. Australian (national) annual temperature data have been obtained from the Bureau of Meteorology.

Data Set	Source	Base Period	Location (nh/NH = northern hemisphere, sh/SH = southern hemisphere, gl/GLB = global)
HadCRUT3	Climatic Research Unit (CRU) University of East Anglia United Kingdom in conjunction with The Hadley Centre UK Meteorological Office United Kingdom	1961-1990	http://www.cru.uea.ac.uk/cru/data/temperature/hadcrut3nh.txt http://www.cru.uea.ac.uk/cru/data/temperature/hadcrut3sh.txt http://www.cru.uea.ac.uk/cru/data/temperature/hadcrut3gl.txt
NASA GISS	Goddard Institute for Space Studies National Aeronautics and Space Administration United States of America	1951-1980	http://data.giss.nasa.gov/gistemp/tabledata/NH.Ts.txt http://data.giss.nasa.gov/gistemp/tabledata/SH.Ts.txt http://data.giss.nasa.gov/gistemp/tabledata/GLB.Ts.txt
NOAA NCDC	National Climatic Data Center National Oceanic and Atmospheric Administration U.S. Department of Commerce United States of America	1901-2000	ftp://ftp.ncdc.noaa.gov/pub/data/anomalies/annual.land_and_ocean.90S.90N.df_1901-2000mean.dat

Table1: Data Sources for time series of annual mean temperatures.

Year-to-year variations

Annual temperature data such as the time series listed in Table 1 show year-to-year variations that arise independently of whether or not there is a longer-term warming or cooling trend. These year-to-year variations come about from a range of factors, including persistent aerosol veils in the high atmosphere from volcanoes (*e.g.*, Mt Pinatubo in 1991 caused a temporary cooling for a few years), the El Niño-Southern Oscillation (discussed below) and different accumulated effects of day-to-day and week-to-week fluctuations in the weather.

The easiest way to remove year-to-year variations in order to reveal any underlying trends is to replace each annual temperature with the simple average of a number of annual values centred on that year. For global temperature data, an average calculated over the year itself and five years either side will remove most of the year-to-year variations. This procedure produces a time series of "unweighted" 11-year average temperatures (see the solid lines in Figure 1).

[1] *Anomaly* in this context means departure from a fixed long-term average. Trends in the temperature anomalies are the same as trends in the original temperatures.

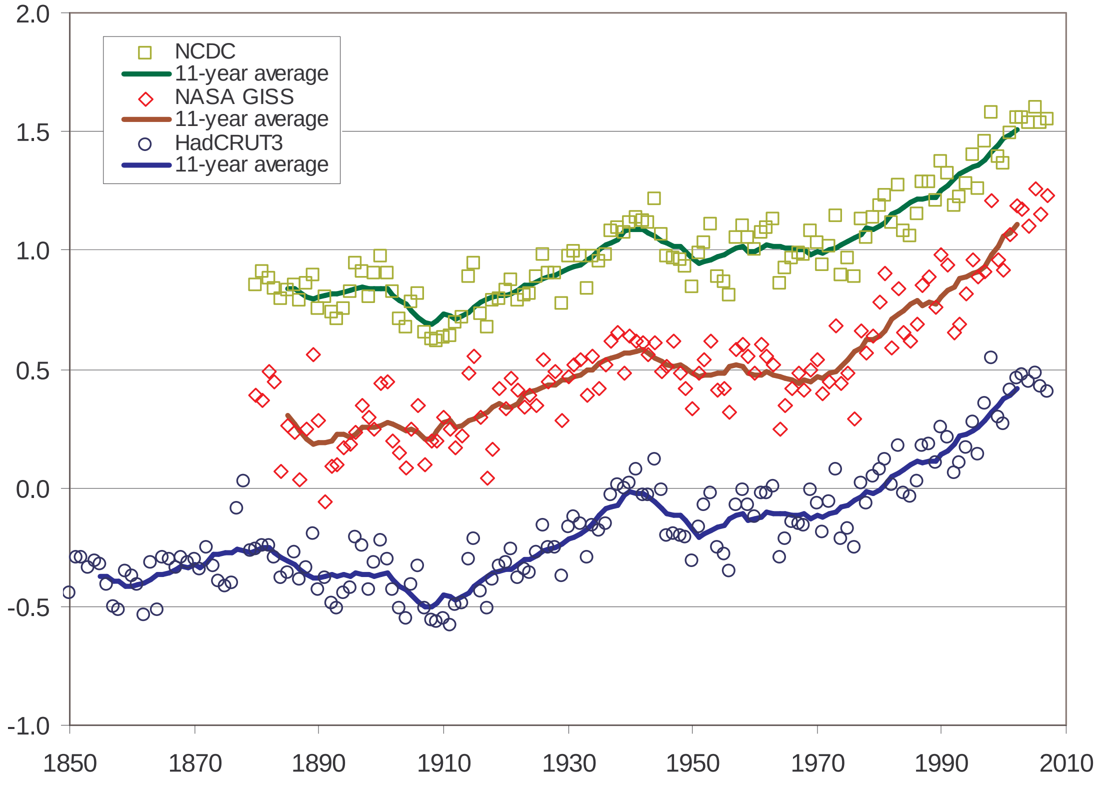

Figure 1: Three time series of globally-averaged annual mean temperature anomalies in degrees Celsius, together with their 11-year unweighted moving averages.
• The blue (circles) data (1850-2007) from the Hadley Centre (British) are calculated with respect to the 1961-1990 base period.
• The red (diamonds) data (1880-2007) from NASA GISS are calculated with respect to the 1951-1980 base period.
• The green (squares) data (1880-2007) from NOAA NCDC are calculated with respect to the 1901-2000 base period.
The latter two sets of data have been offset in the vertical direction by increments of 0.5°C for visual clarity. An averaging period of about 10 years or more is necessary in these time series to remove most of the year-to-year variation in the annual data.

The two American data sets (red and green in Figure 1) have 2005 as their warmest year. While 2006 and 2007 were cooler than 2005 in all three data sets, two such cooler years is much too short a time to conclude that the clear warming trend over the second half of the 20th Century has stopped or reversed. Figure 1 shows many sets of three consecutive years with a short-lived cooling trend that is reversed soon afterwards.

The British data set has 1998 as its warmest year (blue in Figure 1). Is the ten years from 1998 to 2007 long enough to establish a cooling trend? We have noted that ten years is about the minimum averaging time to remove the year-to-year variations in these global temperature data sets, so ten years might be just enough to reveal any downturn in the underlying trend. However, there hasn’t actually been a cooling over the decade 1998-2007 (see Figure 2). In all three data sets, the linear trend over 1998-2007 is upward (i.e., one of warming), even if the warming is weaker in the British data set than in the American data sets.

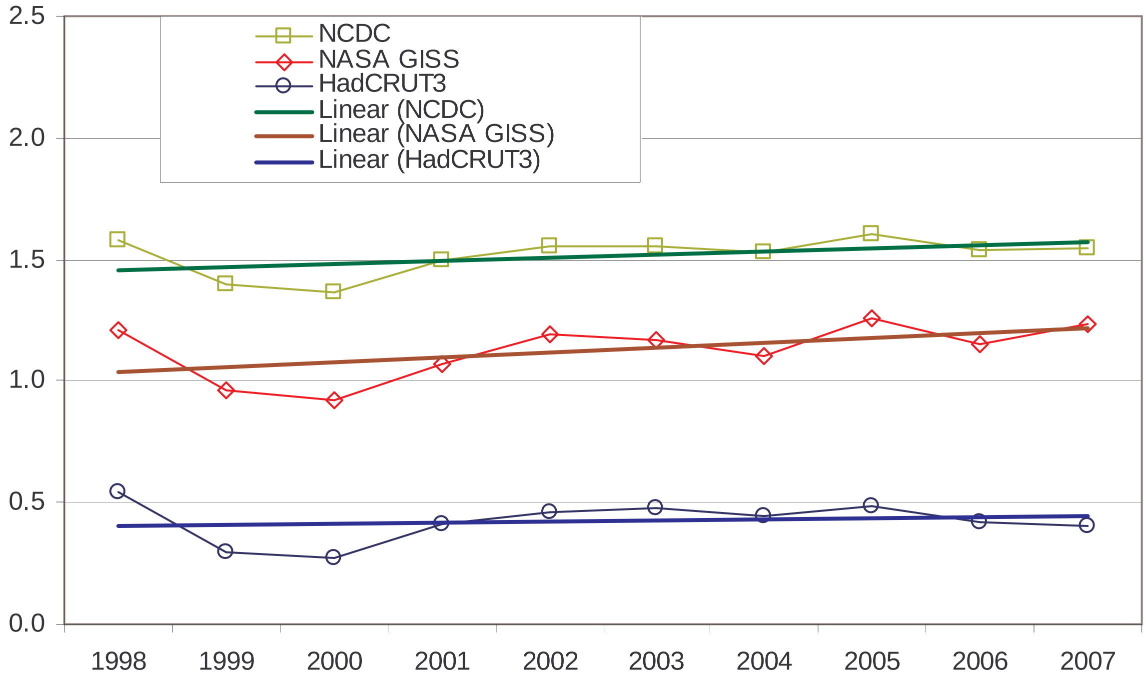

Figure 2: Linear trends (solid lines) in the three global annual mean temperature anomaly time series over the decade 1998-2007. As in Figure 1, the two American time series have been progressively offset in the vertical direction by 0.5°C for visual clarity. Even though 1998 was the warmest year of the last decade in the British data (blue curves), the fact that the next two years 1999 and 2000 were the two coolest years of the decade (in fact in all three data sets) means that an overall warming trend is still present.

These results do not support the idea that global temperatures have remained static since 1998, let alone the idea that a cooling trend has started. They are consistent with the proposition of a continued warming of the earth's lower atmosphere, driven by the greenhouse effect.

Global Temperatures and the El Niño-Southern Oscillation

It is well-known that the El Niño-Southern Oscillation (ENSO) climate phenomenon of the tropical Pacific Ocean has a marked effect on global temperatures. There is a tendency for warm years to follow El Niño events (characterised in Figure 3 by a winter/spring SOI[2] less than −10) and cool years to follow La Niña events (characterised in Figure 3 by a winter/spring SOI greater than +10). El Niño and La Niña events typically begin in the (southern hemisphere) autumn/winter of one year and typically conclude in the autumn/winter of the following year.

[2] The Southern Oscillation Index (SOI) is an important measure of the extent to which the Pacific Ocean basin is experiencing El Niño, La Niña or near neutral conditions. It is calculated from the difference in atmospheric pressures at Darwin and Tahiti.

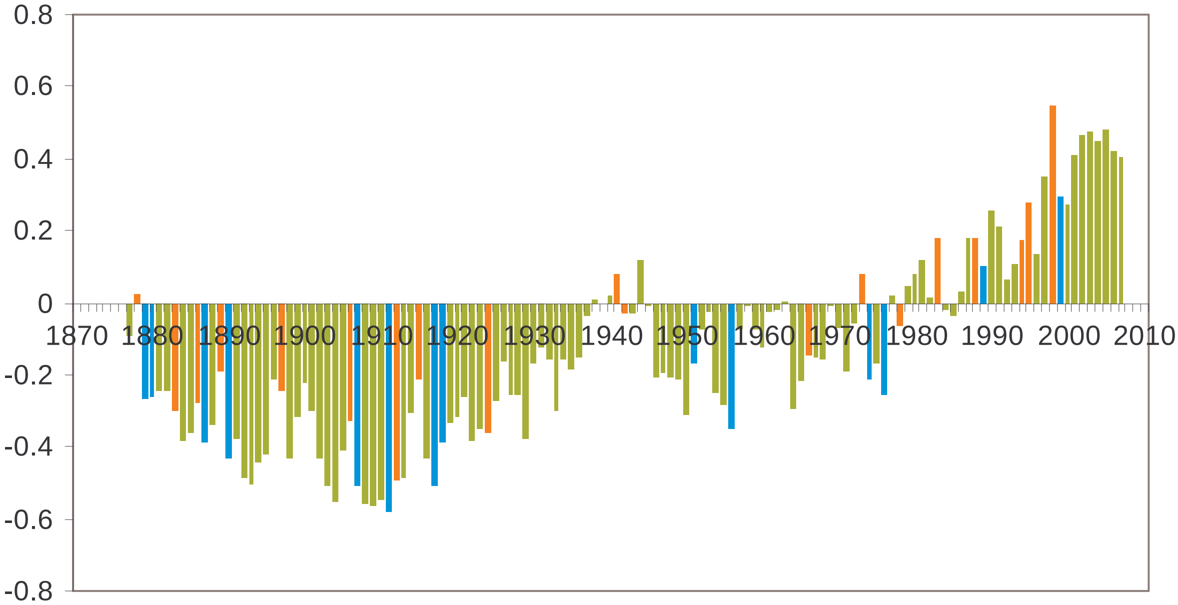

Figure 3: The Hadley Centre (British) time series of globally-averaged annual mean temperature anomalies in degrees Celsius for the period 1877-2007. The anomalies are calculated with respect to the 1961-1990 base period. Orange bars (e.g., 1978, 1983, 1988, 1994, 1995, 1998) denote years when the winter/spring (Jun-Nov) SOI of the *previous year* was less than −10. Blue bars (e.g., 1974, 1976, 1989, 1999) denote years when the winter/spring (Jun-Nov) SOI of the *previous year* was greater than +10. Relative to the upward trend, there is a tendency for warm years to follow El Niño events and cool years to follow La Niña years. The monthly SOI data used in the calculation are available from 1876 to the present (see http://www.bom.gov.au/climate/current/soihtm1.shtml).

Some of the effects of the El Niño-Southern Oscillation can be removed by determining the extent to which positive or negative values of the SOI are associated with warmer or cooler global temperatures or vice versa. In statistical jargon, the procedure used to do this is called calculating a "linear regression" of global temperature against the Southern Oscillation Index (SOI). A search has been made to find the best relationship that predicts which way temperature will rise or fall for a given rise or fall in the SOI and then using that relationship to remove the effects of ENSO from the temperature series. The results of this procedure are shown in Figure 4 for all three global temperature anomaly data sets.

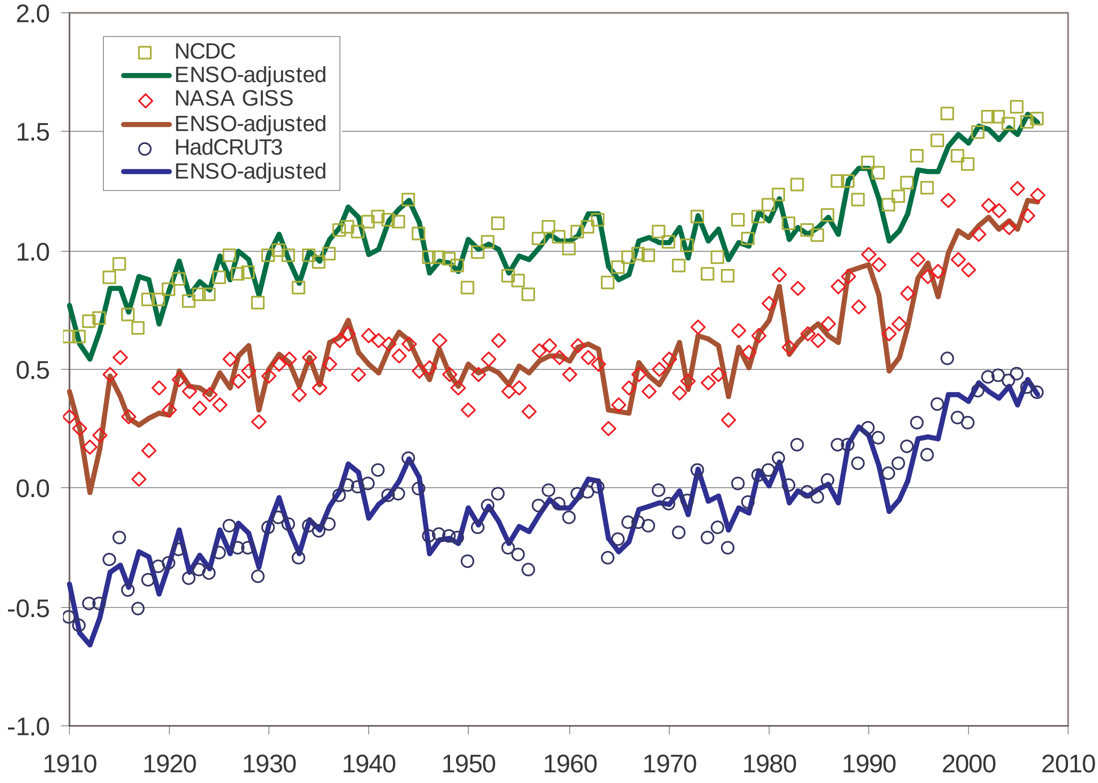

Figure 4: Three time series of globally-averaged annual mean temperature anomalies (symbols) in degrees Celsius, together with their ENSO-adjusted versions (lines), for the period 1910-2007. The adjustment process effectively removes the ENSO influence.
• The blue (circles) data from the Hadley Centre (British) are calculated with respect to the 1961-1990 base period, and ENSO-adjusted using the Feb-Jun (5-month) SOI average from the same year ($r = -0.373$) over the plotted period.
• The red (diamonds) data from NASA GISS are calculated with respect to the 1951-1980 base period, and ENSO-adjusted using the Feb-May (4-month) SOI average from the same year ($r = -0.386$).
• The green (squares) data from NOAA NCDC are calculated with respect to the 1901-2000 base period, and ENSO-adjusted using the Feb-Jun (5-month) SOI average from the same year ($r = -0.377$).
The latter two sets of data have been offset in the vertical direction by increments of 0.5°C for visual clarity. None of these series has been smoothed.

In all three data sets, the strong warming of 1998 can be seen to have arisen in large part from the very strong El Niño of 1997/98 and, when ENSO-adjusted, 1998 looks much less remarkable than it does in the original data. In other words, the reason that 1998 was so exceptionally warm is that a very strong El Niño interacted with the global warming trend to give an exceptional year.

The two American data sets show continued warming over the past 20 years in their ENSO-adjusted warming. The British data set has a rather slower rate of warming over the past 20 years when ENSO-adjusted[3], but its highest ENSO-adjusted value is nevertheless 2006 and the trend in the ENSO-adjusted data over the past 10 years (1998-2007) remains upward.

[3] It has been suggested that the weaker warming in the British data set is the consequence of it capturing less of the strong Arctic warming seen in recent years than the American data sets (*e.g.*, http://www.realclimate.org/index.php/archives/2007/08/1934-and-all-that/).

All three data sets show a strong drop in temperatures around 1991-1992, due in part to the eruption of the volcano Mt Pinatubo. The results of the ENSO-adjustment suggest that protracted El Niño activity in the period 1991-1994 may have moderated to a considerable extent the cooling that would have otherwise occurred.

Australian temperatures

The analyses described above for globally-averaged annual mean temperature anomalies are now applied to Australian-averaged annual temperature anomalies. These data, obtained from the Bureau of Meteorology, are available from 1910 onwards. The Australian-averaged annual temperature data are rather noisier than the corresponding globally-averaged temperature data because of the smaller spatial scale. This higher level of "noise" means that more aggressive smoothing approaches are required to remove most of the year-to-year variation. From Figure 6, we see that averaging over periods of at least 15 years seems to be required to remove most of the year-to-year variation, four years longer than was required for the global data.

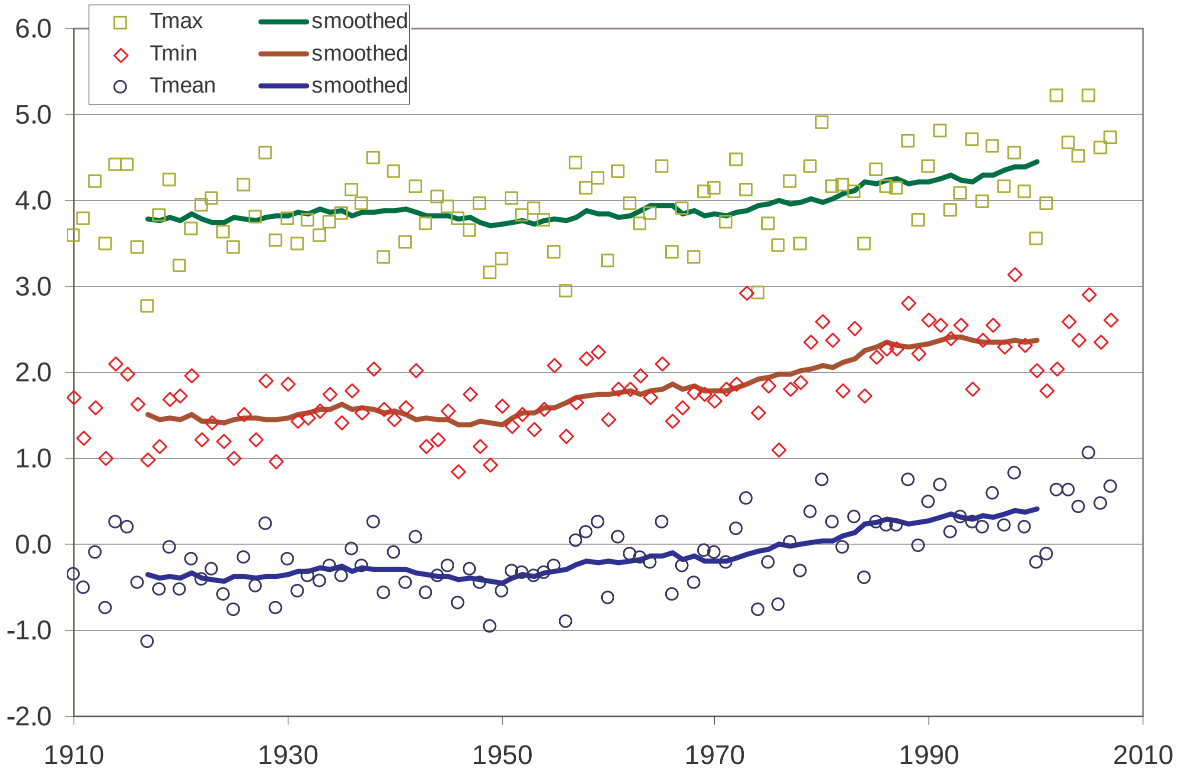

Figure 6: Australian-averaged annual maximum (green, squares), minimum (red, diamonds) and mean (blue, circles) temperature anomalies in degrees Celsius for the period 1910-2007, together with 15-year moving averages (lines). The anomalies are calculated with respect to the 1961-1990 base period. Averaging over 15 years or more is required to remove most of the year-to-year variation in the Australian annual temperature data. The maximum and minimum temperature data have been offset in the vertical direction by increments of 2.0°C for visual clarity.

The national annual mean temperature data (blue circles in Figure 6) show two distinct trend regimes. The 1910-1950 period is characterised by a very slight cooling trend, whereas the 1950-present period is characterised by a strong warming trend. The marked cessation of warming from 1940 to 1970 in the global data (Figure 1) is much less evident in the national data.

Correlations with the SOI confirm that there is a tendency for Australia to experience warmer conditions in the year after an El Niño event and cooler conditions in the year after a La Niña event. 2005 is Australia's warmest year for nationally-averaged annual mean temperature, and it remains the warmest year after the ENSO-adjustment (Figure 7).

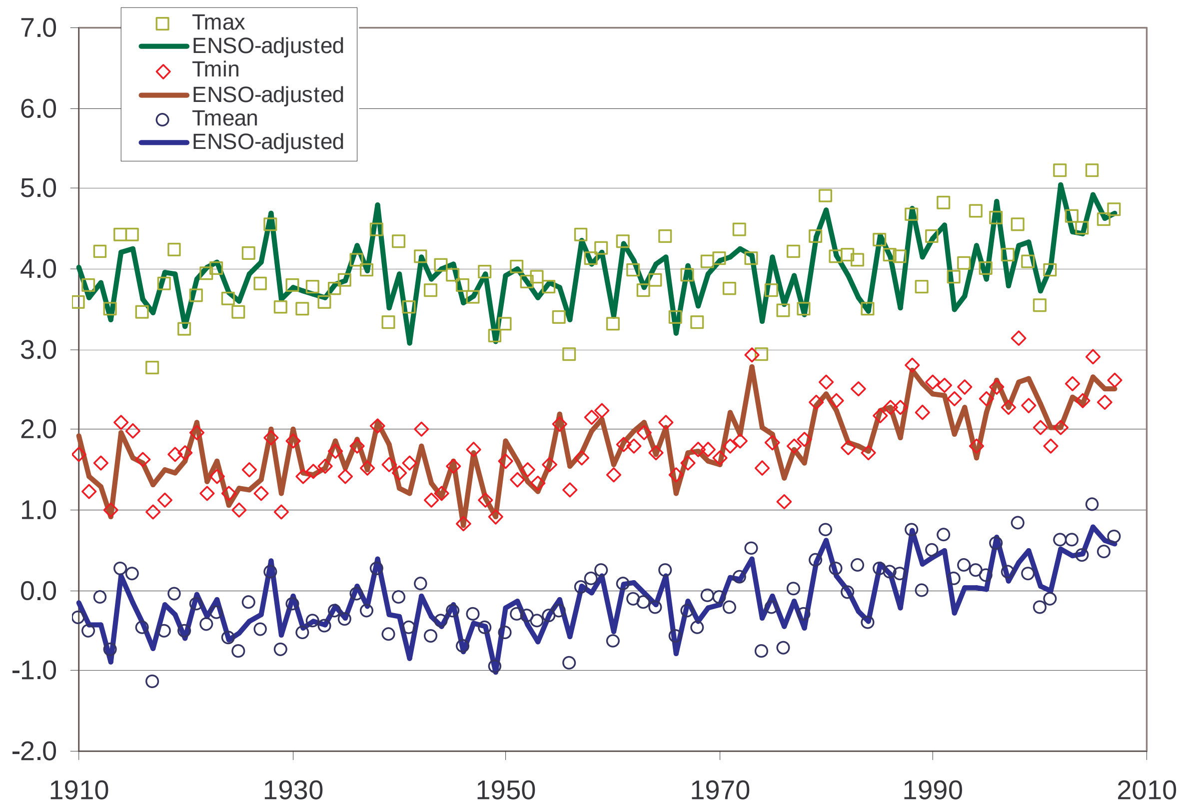

Figure 7: Australian-averaged annual maximum (green, squares), minimum (red, diamonds) and mean (blue, circles) temperature anomalies in degrees Celsius for the period 1910-2007, together with their ENSO-adjusted time series (lines). The maximum temperature data are ENSO-adjusted using the Feb-Jul (6-month) SOI average from the same year ($r = -0.506$), the minimum temperature data using the Nov-Apr (6-month) SOI average from the end of the previous year ($r = -0.425$), and the mean temperature data using the Dec-May (6-month) SOI average from the end of the previous year ($r = -0.467$). The anomalies are calculated with respect to the 1961-1990 base period, while the ENSO-adjustment is performed over the period 1910-2007. The maximum and minimum temperature data have been offset in the vertical direction by increments of 2.0°C for visual clarity.

There are no indications in these data of a cessation in the national warming trend of the past half-century.

The Future for Global Temperatures

The Intergovernmental Panel on Climate Change (IPCC, http://www.ipcc.ch) provides a range of projections for the evolution of global temperatures over the course of the 21st century based on possible future emissions of greenhouse gases. The expected warming out to 2100 is from 1.8°C (range 1.1°C to 2.9°C) as the best estimate for the low emissions (B1) scenario, to 4.0°C (range 2.4°C to 6.4°C) as the best estimate for the high emissions (A1F1) scenario. For the next two decades, a warming of about 0.2°C per decade is projected. (IPCC 4AR WG1 SPM)

In recent months, global temperatures have been suppressed by a moderately strong La Niña in the Pacific Ocean, which now appears to be weakening after its peak earlier this year. In the longer term, it would not be at all surprising, in the lead up to the next strong El Niño and its aftermath, to see global temperatures approach and then exceed the records set in the past ten years.

Acknowledgements

This article is based on a paper by one of us (Robert Fawcett), *Has the world cooled since 1998?*, published in the *Bulletin of the Australian Meteorological and Oceanographic Society* in December 2007. Relevant references (*e.g.*, on Mt Pinatubo and global temperatures, and on the removal of the ENSO signal from global temperatures) are given therein. The full December 2007 issue of BAMOS is available at http://www.amos.org.au/documents/item/82 (PDF).