Evidence of a Significant Solar Imprint in Annual Globally Averaged Temperature Trends - Part 1

26 03 2008 http://wattsupwiththat.wordpress.com/2008/03/26/evidence-of-a-significant-solar-imprint-in-annual-globally-averaged-temperature-trends-part-1/

NOTE: This essay represents a collaboration over a period of a week via email between myself and Basil Copeland. Basil did the statistical heavy lifting and the majority of writing, while I provided suggestions, reviews, some ideas, editing, and of course this forum. Basil deserves all our thanks for his labor. This is part one of a two part series. -Anthony

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Evidence of a Significant Solar Imprint in Annual Globally Averaged Temperature Trends By Basil Copeland and Anthony Watts

> *It is very unlikely that the 20th-century warming can be explained by natural causes. The late 20th century has been unusually warm.*

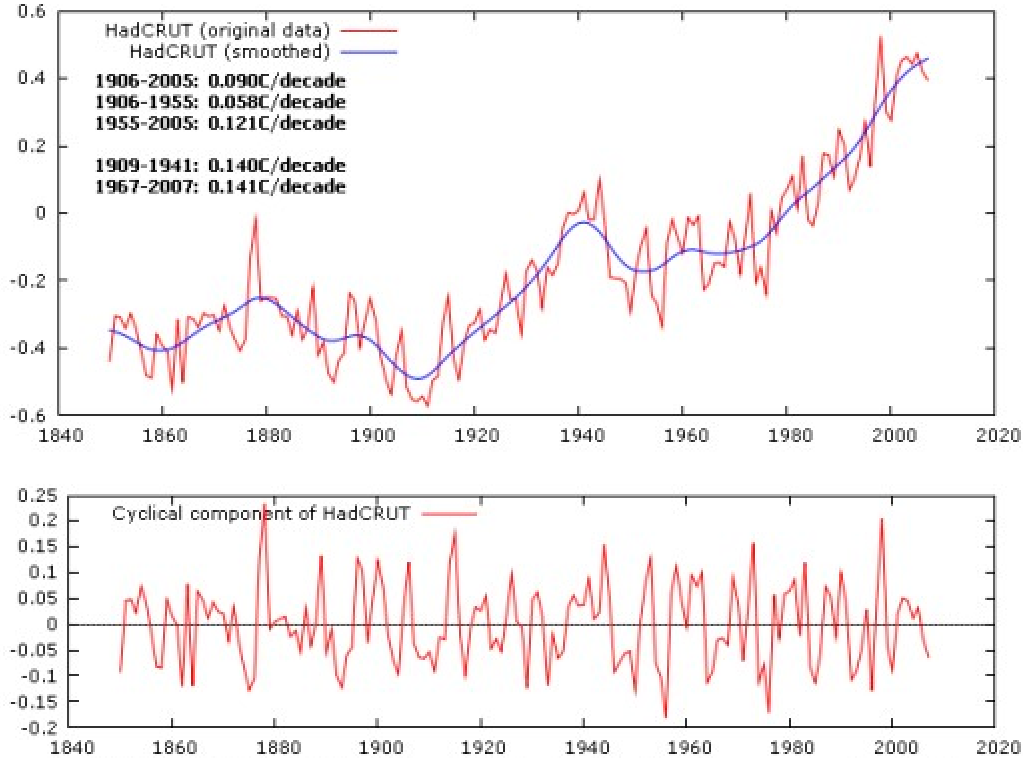
So begins the IPCC AR4 WG1 response to Frequently Asked Question 9.2 (Can the Warming of the 20th Century be Explained by Natural Variability?). Chapter 3 of the WG1 report begins:

> *Global mean surface temperatures have risen by 0.74°C ± 0.18°C when estimated by a linear trend over the last 100 years (1906-2005). The rate of warming over the last 50 years is almost double that over the last 100 years (0.13°C ± 0.03°C vs. 0.07°C ± 0.02°C per decade).*

Was the warming of the late 20th century really that unusual? In recent posts Anthony has noted the substantial anecdotal evidence for a period of unusual warming in the earlier half of the 20th century. The representation by the IPCC of global trends over the past 100 years seems almost designed to hide the fact that during the early decades of the 20th century, well before the recent acceleration in anthropogenic CO2 emissions beginning in the middle of the 20th century, global temperature increased at rates comparable to the rate of increase at the end of the 20th century.

I recently began looking at the longer term globally averaged temperature series to see what they show with respect to how late 20th century warming compared to warming earlier in the 20th century. In what follows, I'm presenting just part of the current research I'm currently undertaking. At times, I may overlook details or a context, or skip some things, for the sake of brevity. For example, I'm looking at two long-term series of globally averaged annual temperature trends, HadCRUTv3 and GHCN-ERSSTv2. Most of what I present here will be based on HadCRUTv3, though the principal findings will hold true for GHCN-ERSSTv2.

I began by smoothing the data with a Hodrick-Prescott (HP) filter with lambda=100. (More on the value of lambda later.) The results are presented in Figure 1.



HadCRUTv3, 1850-2007, with Hodrick-Prescott filtering (lambda=100). Shown are decadal rates of growth from the smoothed series for selected time periods. There is no significant difference in the rate of growth at the end of the 20th century, and the rate of growth from 1909 to 1941.

Figure 1 - click for a larger image

The figure shows the actual data time series, a cyclical pattern in the data that is removed by the HP filter, and a smoothed long term low frequency trend that results from filtering out the short term higher frequency cyclical component. Hodrick-Prescott is designed to distinguish short term cyclical activity from longer term processes.

For those with an electrical engineering background, you could think of it much like a bandpass filter which also has uses in meteorology:

> *Outside of electronics and signal processing, one example of the use of band-pass filters is in the atmospheric sciences. It is common to band-pass filter recent meteorological data with a period range of, for example, 3 to 10 days, so that only cyclones remain as fluctuations in the data fields.*

(Note: For those that wish to try out the HP filter, a freeware Excel plugin exists for it which you can download here)

When applied to globally averaged temperature, it works to extract the longer term trend from variations in temperature that are of short term duration. It is somewhat like a filter that filters out "noise," but in this case the short term cyclical variations in the data are not noise, but are themselves oscillations of a shorter term that may have a basis in physical processes.

For example, in Figure 1, in the cyclical component shown at the bottom of the figure, we can clearly see evidence of the 1998 Super El Niño. While not the current focus, I believe that analysis of the cyclical component may show significant correlations with known shorter term oscillations in globally averaged temperature, and that this may be a fruitful area for further research on the usefulness of Hodrick-Prescott filtering for the study of global or regional variations in temperature.

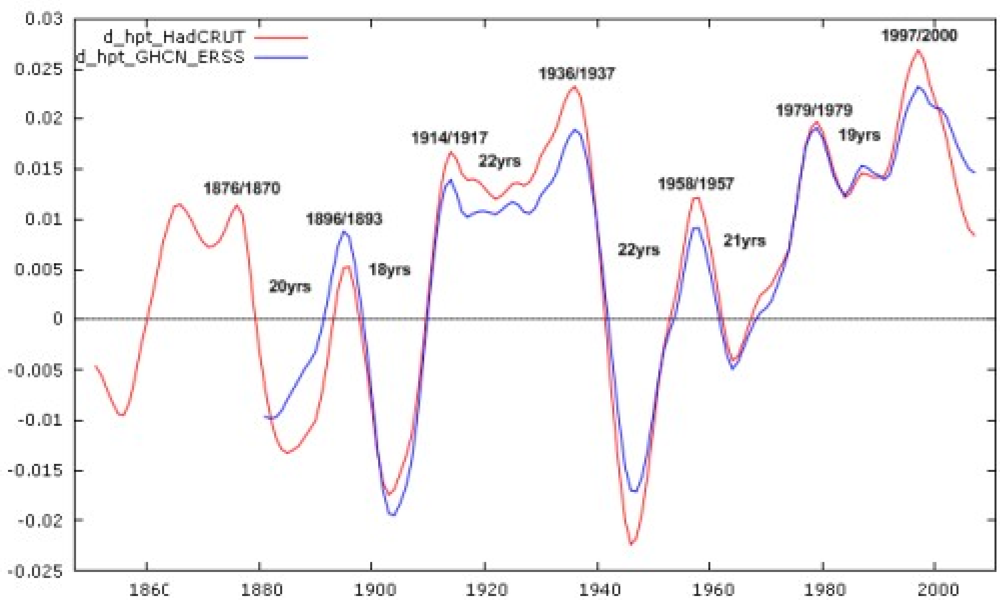
My original interest was in comparing rates of change between the smoothed series during the 1920's and 1930's with the rates of change during the 1980's and 1990's. Without getting into details (ask questions in comments if you have them), using HadCRUTv3 the rate of change during the early part of the 20th century was almost identical to the rate of change at the end of the century. Could there be some sense in which the warming at the end of the 20th century was a repeat of the pattern seen in the earlier part of the century? Since the rate of increase in greenhouse gas emissions was much lower in the earlier part of the century, what could possibly explain why temperatures increased for so long during that period at a rate comparable to that experienced during the recent warming?

As I examined the data in more detail, I was surprised by what I found. When working with a smoothed but non-linear "trend" like that shown in Figure 1, we compute the first differences of the series to calculate the average rate of change over any given period of time. A priori, there was no reason to anticipate a particular pattern in time (or "secular pattern") to the differenced series. But I found one, and it was immediately obvious that I was looking at a secular pattern that had peaks closely matching the 22 year Hale solar cycle. The resulting pattern in the first differences is presented in Figure 2, with annotations showing how the peaks in the pattern correspond to peaks in the 22 year Hale cycle.

Besides the obvious correspondence in the peaks of the first differences in the smoothed series to peaks of the 22 year Hale solar cycle, there is a kind of "sinus rhythm" in the pattern that appears to correspond, roughly, to three Hale cycles, or 66 years. Beginning in 1876/1870, the rate of change begins a long decline from a peak of about +0.011 (since these are annual rates of change, a decadal equivalent would be 10 times this, or +0.11C/decade) into negative territory where it bottoms out about -0.013, before reversing and climbing back to the next peak in 1896/1893. A similar sinusoidal pattern, descending down into negative annual rates of change before climbing back to the next peak, is evident from 1896/1893 to 1914/1917. Then the pattern breaks, and in the third Hale cycle of the triplet, the trough between the 1914/1917 peak and the 1936/1937 peak is very shallow, with annual rates of change never falling below +0.012, let alone into the negative territory seen after the previous two peaks. This same basic pattern is repeated for the next three cycles: two sinusoidal cycles that descend into negative territory, followed by a third cycle with a shallow trough and rates of change that never descend below +0.012. The shallow troughs of the cycles from 1914/1917 to 1936/1937, and 1979/1979 to 1997/2000, correspond to the rapid warming of the 1920's and 1930's, and then again to the rapid warming of the 1980's and 1990's.

While not as well known as the 22 year Hale cycle, or the 11 year Schwabe cycle, there is support in the climate science literature for something on the order of a 66 year climate cycle. Schlesinger and Ramankutty (1994) found evidence of a 65-70 year climate cycle in a number of temperature records, which they attributed to a 50-88 year cycle in the NAO. Interestingly, they sought to infer from this that these oscillations were obscuring the effect of AGW. But that probably misconstrues the significance of the mid 20th century cooling phase. In any case, the evidence for a climate cycle on the order of 65-70 years extends well into the past. Kerr (2000) links the AMO to paleoclimate proxies indicating a periodicity on the order of 70 years. What I think they may be missing is that this longer term cycle shows evidence of being modulated by bidecadal rhythms. When the AMO is filtered using HP filtering, it shows major peaks in 1926 and 1997, a period of 71 years. But there are smaller peaks at 1951 and 1979, indicating that shorter periods of 25, 28, and 18 years, or roughly bidecadal oscillations. There is a growing body of literature pointing to bidecadal periodicity in climate records that point to a solar origin. See, for instance, Rasporov, et al, (2004). A 65-70 year climate cycle may simply be a terrestrial driven harmonic of bidecadal rhythms that are solar in origin.

In terms of the underlying rates of change, the warming of the late 20th century appears to be no more “unusual” than the warming during the 1920’s and 1930’s. Both appear to have their origin in a solar cycle phenomenon in which the sinusoidal pattern in the underlying smoothed trend is modulated so that annual rates of change remain strongly positive for the duration of the third cycle, with the source of this third cycle modulation perhaps related to long term trends in oceanic oscillations. It is purely speculative, of course, but if this 66 year pattern (3 Hale cycles) repeats itself, we should see a long descent into negative territory where the underlying smoothed trend has a negative rate of change, i.e. a period of cooling like that experienced in the late 1800’s and then again midway through the 20th century.



Annual HadCRUTv3 and GHCN-ERSSTv2 globally averaged temperature trends are smoothed with Hodrick-Prescott filtering (lambda=100). Plotted are the first differences of the smoothed series, representing annual rates of change in temperature in the smoothed series. Peaks occur roughly in sync with the 22 year Hale solar cycle for reversal in the Sun's magnetic field. The first number above each peak is the year of the peak in the rate of change in temperature from the smoothed series; the second number is the solar cycle peak. Unusual warming in the 1920's and 1930's, and again in the 1980's and 1990's, is indicated by the shallow troughs that follow the 1914 and 1979 peaks.

Figure 2 - click for a larger image

Figure 2 uses a default value of lambda (the parameter that determines how much smoothing results from Hodrick-Prescott filtering) that is 100 times the square of the data frequency, which for annual data would be 100. This is conventional, and is consistent with the lambda used for quarterly data in the seminal research on this technique by Hodrick and Prescott. I’m aware, though, of arguments for using a much lower lambda, which would result in much less smoothing.

In Part 2, we will look at the effect of filtering with a lower value of lambda. The results are interesting, and surprising.