Key evidence for the accumulative model of high solar influence on global temperature

David R.B. Stockwell*

August 23, 2011

Abstract

Here we present three key pieces of empirical evidence for a solar origin of recent and paleoclimate global temperature change, caused by amplification of forcings over time by the accumulation of heat in the ocean. Firstly, variations in global temperature at all time scales are more correlated with the accumulated solar anomaly than with direct solar radiation. Secondly, accumulated solar anomaly and sunspot count fits the global temperature from 1900, including the rapid increase in temperature since 1950, and the flat temperature since the turn of the century. The third, crucial piece of evidence is a 90° shift in the phase of the response of temperature to the 11 year solar cycle. These results, together with previous physical justifications, show that the accumulation of solar anomaly is a viable explanation for climate change without recourse to changes in heat-trapping greenhouse gasses.

1 Introduction

Views on the contribution of the Sun to climate change throughout the Earth's history remain unsettled. Some studies, using a variety of correlative methods, have found strong correlations of temperature with solar variability over a range of time scales [Douglass and Clader, 2002, Shaviv, 2008, Scafetta and West, 2007, Scafetta, 2009, 2010]. Others studies find these correlations unconvincing, as known feedbacks do not provide sufficient amplification of the relatively small changes in solar brightness [Duffy et al., 2009, Lockwood and Fröhlich, 2008].

Here we show three crucial tests of the conjecture that changes in solar irradiance above or below the mean solar irradiance are accumulated over time, amplifying the small, direct forcings as described in detail previously [Stockwell, 2011a,b], to produce the observed variations in global temperature. The accumulation model extends previous work on the mechanism of multi-decadal ocean oscillations [Stockwell and Cox, 2009a,b]. The model is consistent with energy balance models of the climate system with very long decay times Spencer and Braswell [2008], Stockwell and Cox [2009a] and has similar dynamics to such systems as the change in the level of surge tanks, RC electrical circuits and electronic integration amplifiers Stubberud et al. [1994].

*davids99us@gmail.com

As an example of the accumulative model, consider that without temperature-dependent losses, an increase of $0.1W/m^2$ for one year would accumulate $3.1x10^6$ Joules of heat ($31x10^6$ sec in a Yr) to the ocean, heating the ocean mixed zone to 50m by 0.018K (4.2 J/gK). Note that while this would give an apparent climate sensitivity of 0.18K/Watt, the apparent sensitivity would increase to 1.8K/Watt after 10 years. The main difference between the model and the conventional view is that climate sensitivity is a rate of the form K/Watts/Yr, and not K/Watt. For heat to accumulate over long periods, the heat loss from the ocean must not be strongly temperature dependent. Thus, the accumulative model is consistent with the conventional assessment of high (or positive) water-vapor feedbacks (e.g. [Dessler, 2010]). Clearly, over longer periods the model could produce glacial/interglacial variations in global temperature.

The parameters of the model are calculated by regressing the integral of the solar anomaly against the temperature, where the anomaly is calculated as the raw value minus the mean value of irradiance (or sunspot count) over a sufficiently long period of time.

2 Key Evidence

In an accumulation system the output is proportional to the integral of the input, not to the input itself. Therefore, an accumulation system can be recognized by a higher correlation with the cumulative sum of the input anomaly than with the non-accumulated direct input. The scatter-plots in Fig. 1 show the correlations of direct (red) and accumulated (black) solar irradiance over a range of datasets (Table 1): solar irradiance by Lean [Lean, 2001] against satellite-measured atmospheric (TTS - troposphere/stratosphere 10km peak response, TLT lower troposphere 2km peak response [Mears and Wentz, 2009]), surface data (HadCRUTv3GL [Jones et al., 1999]), and ocean heat content (OHC [Levitus et al., 2009]); the sun-spot record [Solanki et al., 2004] against a millennial temperature proxy (Moberg [Moberg et al., 2005]); and orbital variations in the Southern hemisphere [Berger and Loutre, 1991] against the 8000 kYr year EPICA ice-core data [Jouzel et al., 2007]. With the exception of the upper atmosphere, TTS, discussed below, the correlation of cumulative solar irradiance with global temperature exceeds the direct relationship. Thus, the accumulation mechanism dominates the direct relationship at all time scales. All previous studies that have used a direct relationship (e.g. [Hegerl, 2003]) or short decay times (e.g. [Lockwood, 2009]) have, therefore, underestimated the contribution of solar variation to global temperature.

Fig. 2 shows two models of recent global temperature changes using cumulative solar irradiance and sun-spot counts. For clarity, the effects of stratospheric aerosols (from volcanic eruptions noted on the graph) on global temperature are omitted. The correlation of the cumulative models including stratospheric aerosols exceeds the direct correlation (R2=0.65 vs. 0.03 for sunspots and 0.51 vs. 0.23 for irradiance respectively). The higher correlation of sun-spot data over the solar irradiance may be due to greater accuracy and less uncertainty of the mean value. The fit of the model deteriorates in the early 20th century where the data is more uncertain.

Note that in Fig. 2, the peaks of the cumulative model lag the peaks of solar irradiance, and match the peaks of global temperature. This suggests a third, crucial test of the accumulation theory. If the periodic forcing were a sine wave, then the integrated response will continue rising until the forcing crosses from positive to negative, thus shifting the peak exactly 90°. This is shown by the following, basic relationships:

$\int sin(t)dt = -cos(t) = sin(t + \frac{\pi}{2})$

Fig. 3 shows the phase shift using the cross-correlation (the function *ccf* in the statistical language R [R Development Core Team, 2008]) of solar insolation with global temperature series. By examination of the figure, the observed phase shift matches the expected shift of 2.75 years, one quarter of the average 11 year solar cycle, on all series except the global land temperature. This indicates the ocean is the accumulator of solar anomaly, and the land-based series is subject to other, or confounding factors.

The conventional theory of climate change attributes shifts (or lags) to the interaction of the 'thermal inertia' of bodies with specific feedbacks such as water vapor, greenhouse gasses, albedo, etc. As free parameters, the duration of the lag is also free in the conventional theory – contingent on the specific situation. The exact value of the lag is predicted by the accumulation theory, however, and observed in real data with an extremely small probability of coincidence.

3 Discussion

In the view of the accumulative theory, Earth's climate system is not chaotic. These results show that robust relationships emerge when the accumulative structure of the system is properly considered. The difficulty arises because small, but persistent solar anomalies can produce trending behaviour almost indistinguishable from a random walk, and are prone to spurious correlation. Analytical difficulties arise in two main way. Firstly, errors accumulate along with the accumulation of solar anomaly, leading to sensitivity to the equilibrium value. Secondly, the accumulated heat is not correlated with the direct forcing over time, even though completely determined by it, so leading to the presumption of low solar influence. This is an example of the pitfalls of analysing a dynamic system without the benefit of a correct dynamic model.

If the system is so sensitive to solar forcing, why then is the putative large forcing from greenhouse gas accumulation (GHGs) since 1950 not strongly evident? While the accumulation theory is not yet sufficiently advanced to answer this question conclusively, the theory predicts GHGs forcing anomaly will be greatest in the non-accumulative upper atmosphere [Stockwell, 2011a,b], (see TTS in Fig. 1), and so subject due to greater losses than solar anomaly incident on the accumulative ocean mixed layer. General circulation models (GCMs) show very low responses to solar anomaly [Stott et al., 2003] and large responses to GHGs. However, correction of the known deficiencies and errors in the ocean mixing parameters [Wigley, 2005, Douglass et al., 2006] that exaggerate net anthropogenic forcing [Hansen et al., 2011] should ultimately lead to a reconciliation.

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4 Tables

	R2 Direct	R2 Integ
TTS	0.01	0.00
TLT	0.00	0.23
HadCRU	0.01	0.56
OHC	0.00	0.69
Moberg	0.01	0.30
EPICA	0.00	0.03

Table 1: Direct correlation of temperature indices with solar insolation (R2 Direct) and with the cumulative sum of the insolation anomaly (R2 Integ) over data-sets from the annual to million year time scales.

5 Figures

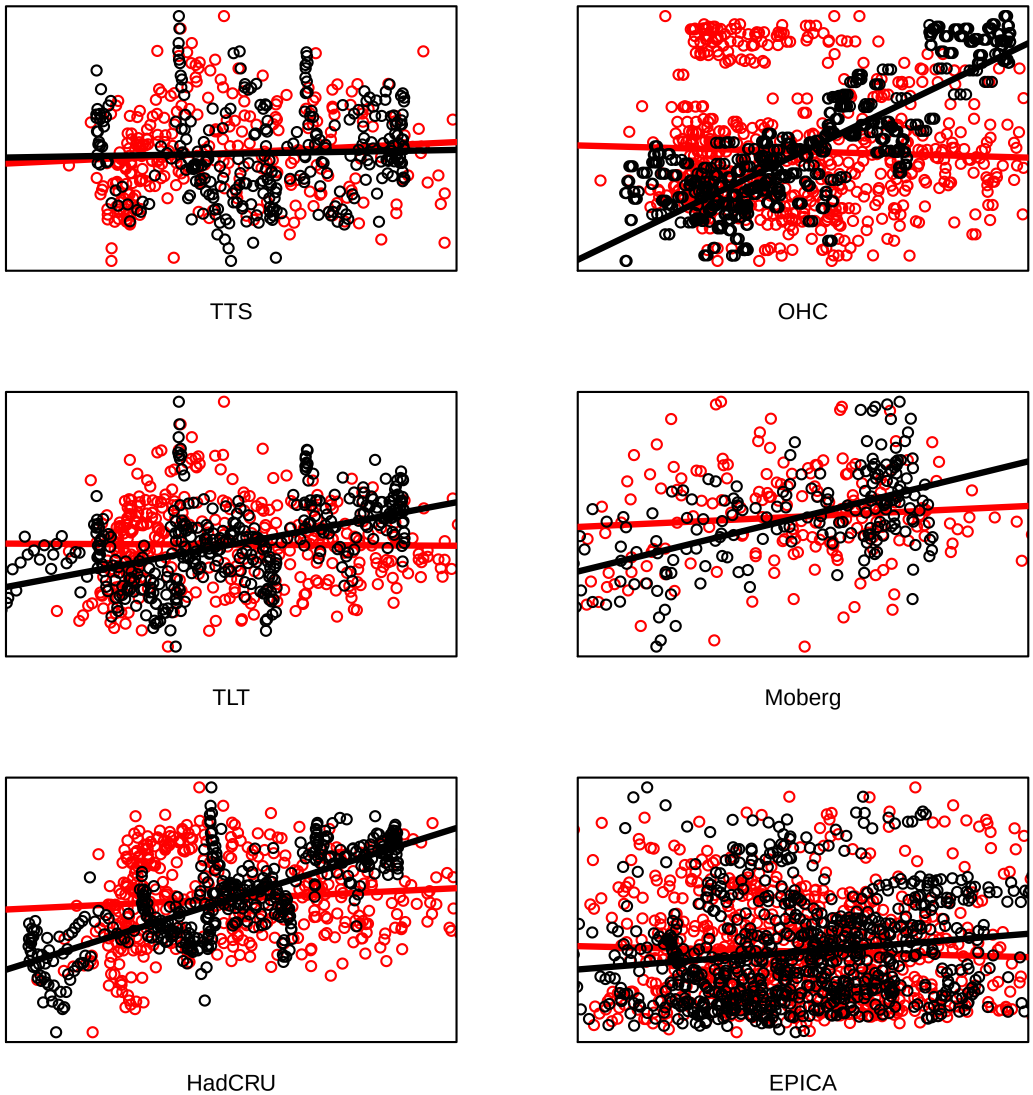

Figure 1: Correlation of global temperature with the cumulative sum of solar insolation (black) exceeds direct solar radiation (black) over the decadal (TTS, TLT), hundred (HadCRU, OHC), thousand (Moberg), and million (EPICA) year time scales.

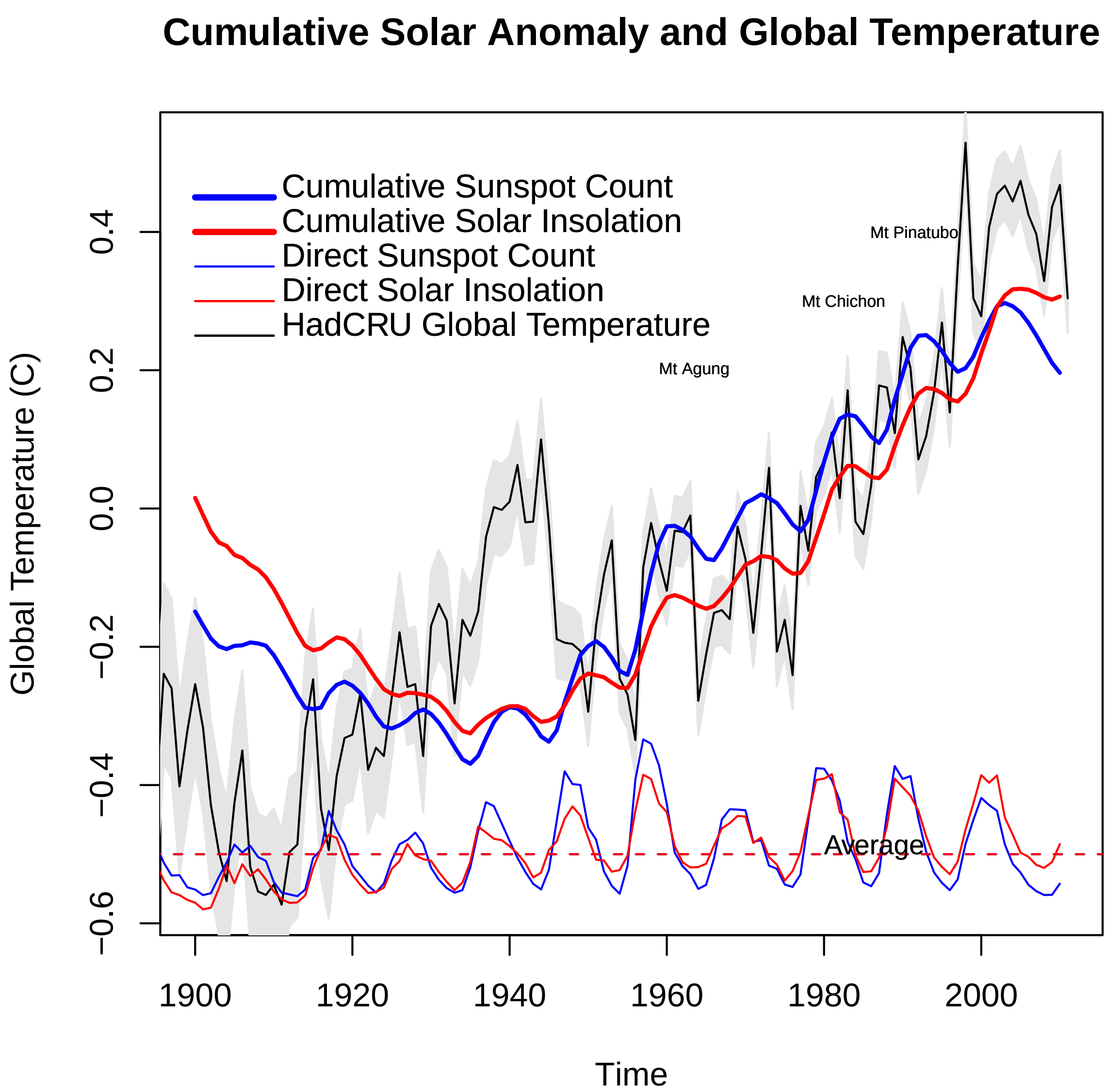

Figure 2: Regression of HadCRUTv3GL with cumulative solar intensity (blue) and (red) stratosphere aerosol (volcanic) anomalies. The direct solar irradiance and sunspot count data is plotted below.

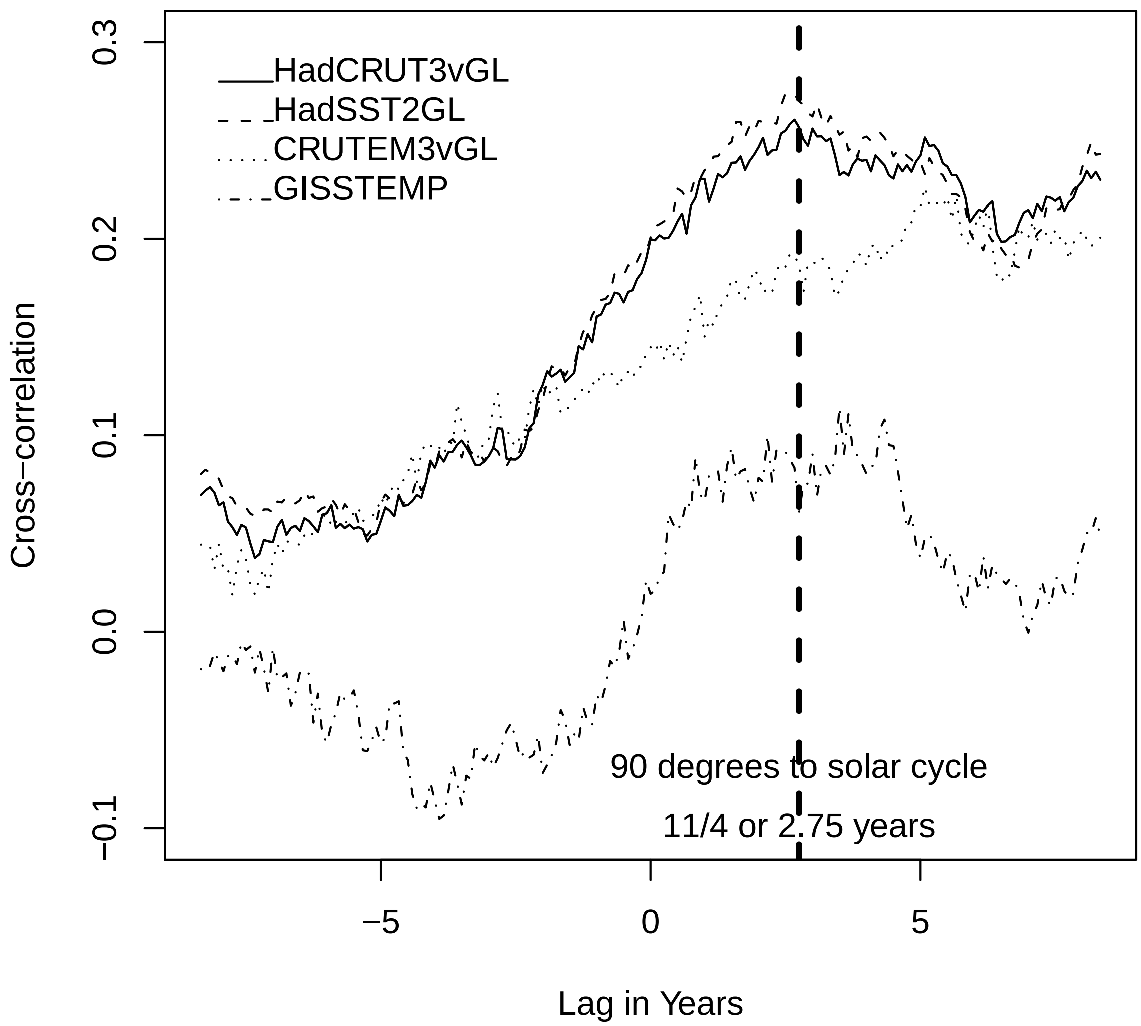

Figure 3: Cross-correlation of detrended global temperature datasets with solar insolation shows a 90° phase shift, as predicted by the accumulation theory.