SOLAR AND PLANETARY OSCILLATION CONTROL ON CLIMATE CHANGE:

Hind-cast, Forecast and a Comparison with the CMIP5 GCMs

by Nicola Scafetta

(invited review)

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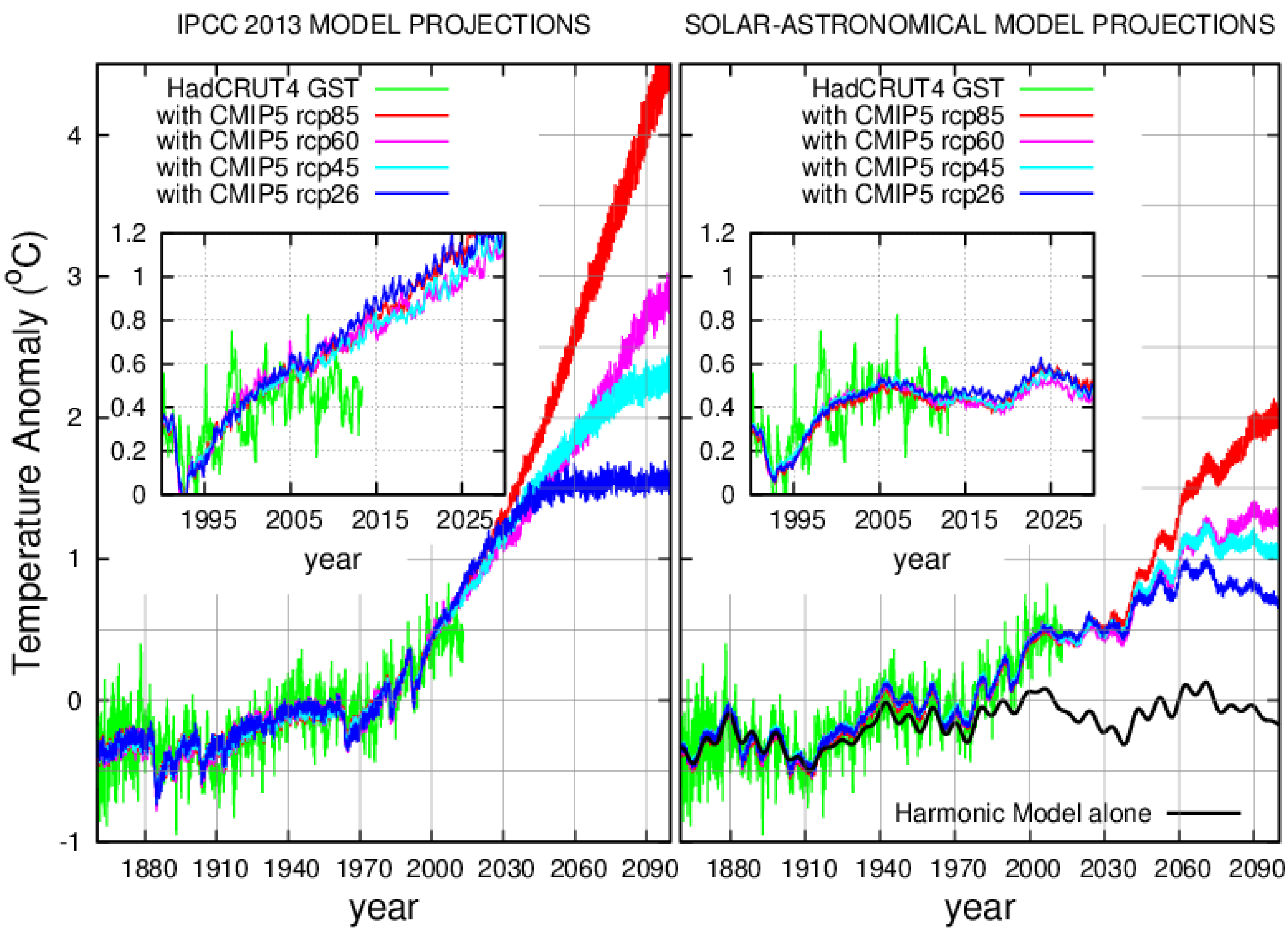

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SOLAR AND PLANETARY OSCILLATION CONTROL ON CLIMATE CHANGE: HIND-CAST, FORECAST AND A COMPARISON WITH THE CMIP5 GCMS

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ABSTRACT

Global surface temperature records (e.g. HadCRUT4) since 1850 are characterized by climatic oscillations synchronous with specific solar, planetary and lunar harmonics superimposed on a background warming modulation. The latter is related to a long millennial solar oscillation and to changes in the chemical composition of the atmosphere (e.g. aerosol and greenhouse gases). However, current general circulation climate models, e.g. the CMIP5 GCMs, to be used in the AR5 IPCC Report in 2013, fail to reconstruct the observed climatic oscillations. As an alternate, an empirical model is proposed that uses: (1) a specific set of decadal, multidecadal, secular and millennial astronomic harmonics to simulate the observed climatic oscillations; (2) a 0.45 attenuation of the GCM ensemble mean simulations to model the anthropogenic and volcano forcing effects. The proposed empirical model outperforms the GCMs by better hind-casting the observed 1850-2012 climatic patterns. It is found that: (1) about 50-60% of the warming observed since 1850 and since 1970 was induced by natural oscillations likely resulting from harmonic astronomical forcings that are not yet included in the GCMs; (2) a 2000-2040 approximately steady projected temperature; (3) a 2000-2100 projected warming ranging between 0.3 ^oC and 1.6 ^oC, which is significantly lower than the IPCC GCM ensemble mean projected warming of 1.1 ^oC to 4.1 ^oC; (4) an equilibrium climate sensitivity to CO_2 doubling centered in 1.35 ^oC and varying between 0.9 ^oC and 2.0 ^oC.

1. INTRODUCTION

Since 1850 the global surface temperature (GST) increased by 0.8-0.85 ^oC, and since the 1970s by 0.5-0.55 ^oC. Figure 1 depicts the HadCRUT4 (1850-2012) GST record[1] [1]. The observed secular warming occurred during a period of increasing atmospheric concentrations of greenhouse gases (GHG), especially CO_2 and CH_4, likely due to human emissions [2]. Current general circulation models (GCMs) interpret that anthropogenic climatic forcings caused more than 90% of the global

[1] http://www.metoffice.gov.uk/hadobs/hadcrut4/

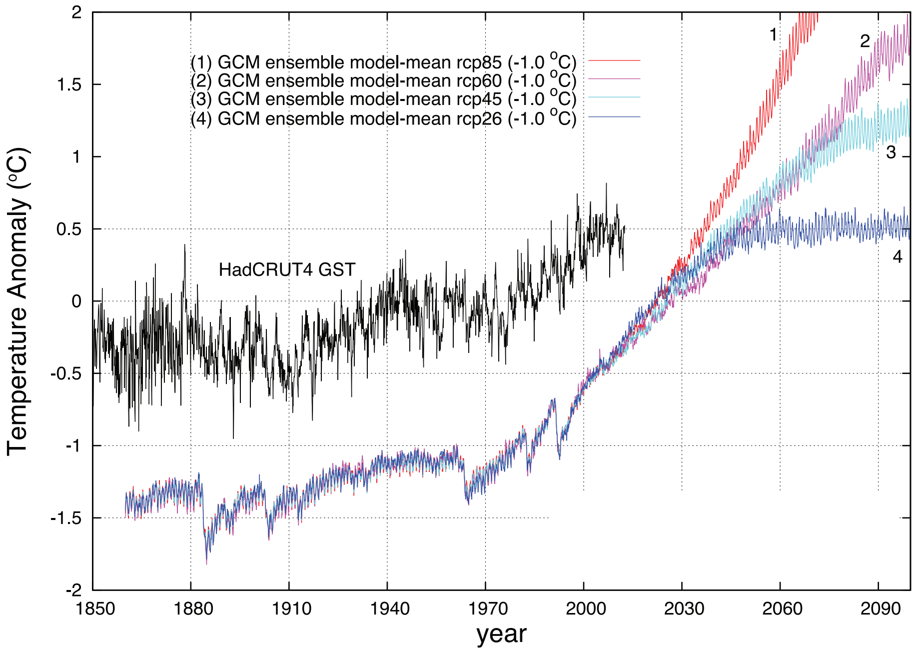


Figure 1: HadCRUT4 (1850-2012) GST (black) [1]. Four Coupled Model Inter-comparison Project 5 (CMIP5) GCM ensemble mean simulations based on known historical forcings (1860-2006) and four alternate 21st century emission projections (records are shifted by 1 ^oC for visualization).

warming since 1900 and virtually 100% of the global warming since 1970. This hypothesis is known as the *Anthropogenic Global Warming Theory* (AGWT). Based on GCM projections, various anthropogenic emission scenarios for the 21st century predict average warming between 1 ^oC and 4 ^oC (see Fig. 1) [3]. The *Intergovernmental Panel on Climate Change* (IPCC), sponsored by the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO), advocates the AGWT.

The IPCC AR4 [2] justified its interpretation and predictions by the results of GCM climate simulations as akin to those shown in figures 9.5a and 9.5b of its AR4 report[2]. These figures compare the GCM effects of all known natural and anthropogenic forcings with those of natural (solar and volcano) forcings only. It was claimed that : (1) natural forcings alone could only have induced a negligible warming since 1900 and a slight cooling since 1970 (fig. 9.5b); (2) only the addition of anthropogenic forcings could recover the observed warming (fig. 9.5a).

However, since 1997-1998 no detectable warming has been observed while the GCMs predicted an average steady warming of about 2 $^oC/century$ (Fig. 1). This obvious divergence between data and GCM simulations during the last 15 years

[2] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-9-5.html

was, however, ruled out with 95% confidence by the same AGWT advocates [4]. Thus, the current GCMs appear to be misleading in so far they overestimate anthropogenic forcings while underestimating and/or ignoring some important natural climatic mechanisms.

Indeed, large and unresolved theoretical GCM uncertainties in climate forcing and climate sensitivity to radiative forcing exist and were already known [2]; but, 13 years ago many scientists were convinced of the reliability of the available climate models owing to their compatibility with the *hockey-stick* shaped paleoclimatic temperature reconstructions proposed by Mann et al. from 1998 to 2004 [5, 6, 7]. However, as it will be demonstrated in section 3, the AGWT interpretation collapses versus novel paleoclimatic temperature reconstructions proposed since 2005 because these recent reconstructions reveal a three-to-four time larger preindustrial climatic variability.

As an alternate, a novel theory proposed by Scafetta [8, 9, 10, 11, 12] is summarized. The author found that: (1) the climate system is mostly characterized by a specific set of oscillations; (2) these oscillations appear to be synchronous with major astronomical oscillations (solar system, solar activity and long solar/lunar tidal cycles); (3) these oscillations are not reproduced by the present-day GCMs, thus indicating that these models miss important forcings of the climate system and related feedbacks. Therefore, an empirical model is proposed that is based on detected decadal, multidecadal, multisecular and millennial natural cycles plus a correction of the GCM ensemble mean simulations to obtain an anthropogenic plus volcano climatic signature. By contrast to the GCMs, the proposed empirical model successfully hind-casts and reconstructs the GST patterns at multiple time scales since 1850 and approximately hind-casts general climatic patterns for centuries and millennia. More reliable and less alarming projections for the 21st century are obtained.

2. UNRESOLVED PHYSICAL UNCERTAINTY OF CURRENT GCMS

The reliability of the current GCMs is limited by the following five major sources of uncertainty:

1. *Climate data are characterized by various errors that can bias composites*. For example, GST records (HadCRUT3, HadCRUT4, GISSTEM and NCDC) present similar patterns with a net 1850-2012 warming of about 0.8-0.85 ^{o}C [1]. However, McKitrick and Michaels [13] and McKitrick and Nierenberg [14] found that up to half of the observed 1979-2002 warming trend (~0.2 ^{o}C) could be due to residual urban heat island (UHI) effects, although the temperature data had already been processed to remove the (modeled) UHI contribution. Also a *divergence problem* of proxy temperature models and instrumental records from the 1950s onward has been observed and questions the reliability either of the proxy models or of the instrumental GST records [15, 16].
2. *There may be physical processes and mechanisms that are still unknown and, therefore, are not included in the current GCMs*. Failures in properly modeling specific data patterns can highlight this type of problems. If so, the limitation of the analytical GCM approach may be partially circumvented by adopting empirical modeling that may work well if the specific dynamics of

the conjectured unknown mechanisms are somehow identified, although the physical details of the mechanisms themselves may remain unknown. Empirical modelling is how ocean tides have been forecast since antiquity [17, 18, 19, 20, 21].

3. *The failure of GCMs may be due to not predictable chaos, internal variability and missing forcings of the climate system.* For example, since 2000 no warming has been observed while the IPCC GCMs predicted on average a steady warming of about 2 $^oC/century$ [10]. Meehl et al. [22] speculated that such GST *hiatus* periods could be caused by *unforced internal climatic variability* such as occasionally deep ocean heat uptakes. However, their adopted CCSM4 GCM did not predicted the steady temperature observed from 2000 to 2012, and produces only *hiatus* periods in 2040-2050 and 2070-2080. Essentially, because of internal dynamical chaos, it is claimed that GCMs can only *statistically,* that is in the ensemble of their simulations, vaguely reproduce the observational data pattern means. Alternatively, other authors postulated that the same post 2000 GCM-GST discrepancy was the effect of small volcanic eruptions or Chinese aerosols [23]. This interpretation was proposed despite the fact that no increase in aerosol concentration has been observed since 1998 [24]. So, the issue is quite open and confused.
4. *Radiative climate forcings used in the GCMs are characterized by very large uncertainties.* The IPCC AR4 [2] (AR4 WG1 2.9.1 "Uncertainties in Radiative Forcing"[3]) classifies the level of scientific understanding of 11 out of 16 forcing agent categories as either *low* or *very low*. For example, figure SPM2[4] of the IPCC AR4 [2] estimates a 1750-2005 net anthropogenic radiative forcing between 0.6 and 2.4 W/m^2 and the total solar irradiance forcing between 0.06 and 0.30 W/m^2. Given this large forcing uncertainty, GCM modelers could arbitrarily adjust internal parameters and forcing functions, such as the very uncertain aerosol forcing, to improve the fit of their models to the data. Indeed, an inverse correlation was found between the GCM modeled climate sensitivity and total anthropogenic forcing [25, 26].
5. *The current equilibrium climate sensitivity to radiative forcing is extremely uncertain.* The IPCC AR4 [2] suggests that a doubling of atmospheric CO_2 concentrations would induce a most likely warming in the range of 2-4.5 ^oC averaging to about 3 ^oC, which is about the average value simulated by the GCMs. The total range spans between 1-9 ^oC (see Box 10.2-fig. 1 in IPCC AR4 [2])[5]. In fact, while the greenhouse properties of CO_2 can be experimentally determined (without water vapor and cloud feedbacks, doubling of CO_2 has a forcing of about 3.7 W/m^2 causing about 1 ^oC warming [27]), the strength of the adopted climatic feedbacks can not be tested experimentally, and is indirectly estimated in various ways. Some empirical studies suggest that the real climate sensitivity may be as low as 0.5-1.3 ^oC [28, 29].

[3] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-9-1.html
[4] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/figure-spm-2.html
[5] http://www.ipcc.ch/publications_and_data/ar4/wg1/en/box-10-2-figure-1.html

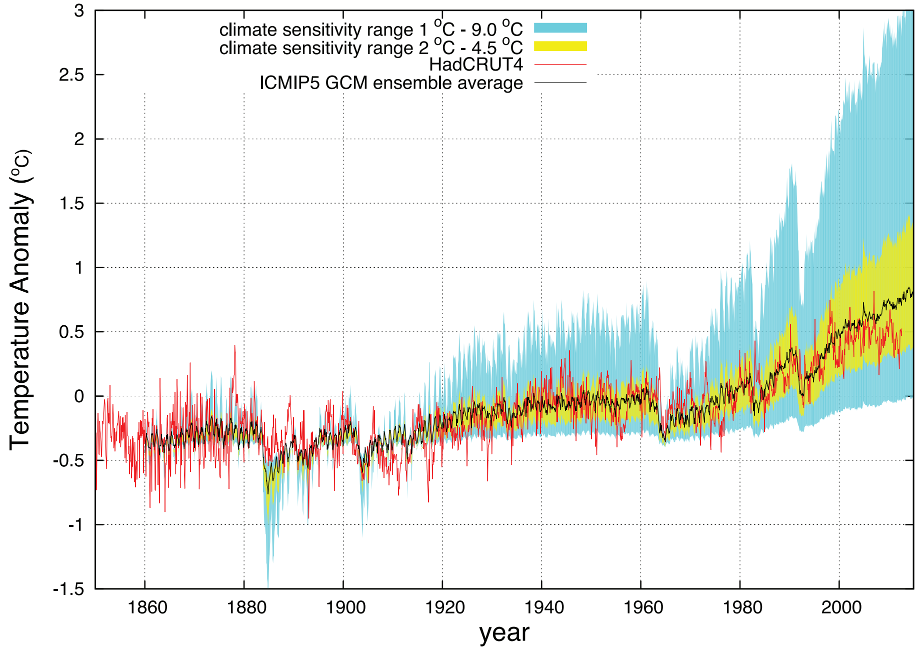


Figure 2: HadCRUT4 GST record (red) vs. the CMIP5 (rcp60) ensemble mean simulation (black). Uncertainty ranges refer to equilibrium climate sensitivity to CO_2 doubling spanning 2-4.5 ^oC (yellow), and 1-9 ^oC (cyan).

The GCM physical uncertainties appear to be *monstrous* [30]. It is legitimate to question whether current GCMs implement all relevant physical mechanisms and whether their simulations and projections can be trusted. For example, assuming an equilibrium climate sensitivity range of 2-4.5 ^oC, the net climatic forcing adopted by the GCMs would predict a 1850-2012 net warming of about 0.57-1.3 ^oC, while with a climate sensitivity of 1-9 ^oC, it would be in the range of 0.28-2.6 ^oC. As shown in Figure 2, estimated uncertainties diverge in model predictions after 100 years progressively significantly larger than from the data patterns that the models attempt to reconstruct. Thus, the performance and physical reliability of these GCMs cannot be verified within a viable accuracy while it is always possible to adjust some model parameters or some forcing functions to obtain results that, at a first sight, appear to reconstruct the temperature warming.

Contrary to what Knutti and Sedlacek [3] claimed, an ensemble agreement between different GCMs is not a guarantee of their physical reliability implying *a greater confidence in their projections* since all models may simply reach the same erroneous conclusion by mistaking or missing the same physical mechanisms. The scientific method requires that comparisons must be made with observations and not only between models. Let us see what the data tell us.

3. AGWT AGREES ONLY WITH OUTDATED HOCKEY-STICK PALEOCLIMATIC TEMPERATURE RECONSTRUCTIONS

Why did scientists supporting the IPCC accept the results of GCMs and the AGWT despite the well-known large uncertainties discussed above? This needs clarification.

In 1998-1999 Mann et al. [5, 6] published preliminary paleoclimatic GST reconstructions for the last 1000 years suggesting that from the Medieval Warm Period (MWP) (900-1400) to the Little Ice Age (LIA) (1400-1800) there was a cooling of ~ 0.2 ^oC opposed to a drastic temperature increase of ~ 1 ^oC since 1900. The shape of his GST resembles a *hockey stick*. Despite the fact that historically documented climate changes (e.g. the Viking settlements in Greenland between 900 AD and 1400 AD, and many other well-documented world-wide events [31]) contradict this hockey-stick graph that contradicts even the IPCC First Assessment Report (FAR, fig. 7.1, 1990)[6] [32], Mann's GST was considered trustworthy.

Several groups [7, 33, 34] used energy balance models to interpret the hockey-stick temperature graphs and concluded that the climate is poorly sensitive to solar changes and that the post-1900 warming is almost entirely caused by anthropogenic forcing. In 2000 Crowley [7] stated: *The very good agreement between models and data in the pre-anthropogenic interval also enhances confidence in the overall ability of climate models to simulate temperature variability on the largest scales.* Since underlying climate models were able to hind-cast the hockey-stick proxy temperature reconstructions covering the last 1000 years, in 2001 the IPCC AR-3 [35][7] could promote AGWT.

However, since 2005 a number of studies confirmed the doubts of Soon and Baliunas [36] about a diffused MWP and demonstrated: (1) Mann's algorithm contained a mathematical error that nearly always produces hockey-stick shapes even from random data [37]; (2) a global pre-industrial temperature variability of about 0.4-1.0 ^oC between the MWP and the LIA [16, 38, 39, 40, 41, 42]; (3) the existence of a millennial climatic oscillation observed throughout the Holocene that correlates with the millennial solar oscillation [11, 43, 44, 45, 46, 47] and agrees better with historical inferences [31]. Indeed, since 2001 it was clear that the climate of the last 1000 years could have been influenced by a large millennial climatic oscillation induced by solar activity [43, 44]. Nevertheless, numerous climate scientists claimed that the MWP affected only the North Atlantic.

For example, Figure 3B shows for Central England the HadCET instrumental temperature record since ~1700 AD [48] and a proxy temperature reconstruction by Lamb [49] since ~900 AD. The shape clearly contradicts Mann's hockey-stick GST: the impression is that the warming trending observed since 1700 has been mostly due to a quasi-millennial natural oscillation driven by solar activity shown in Figure 3A [50]. In fact, Lamb's curve suggests that in England the MWP was as warm as, or even warmer than current temperatures. However, findings such as Lamb-like reconstructions were dismissed [35]. For example, Jones et al. [51] claimed that Lamb's *graph was not representative of global conditions* and that *the techniques employed by Lamb were*

[6] http://www.ipcc.ch/ipccreports/far/wg_I/ipcc_far_wg_I_chapter_07.pdf
[7] http://www.grida.no/climate/ipcc_tar/vol4/english/pdf/wg1ts.pdf

not very robust. Nevertheless, today such a claim needs to be questioned because recent publications support the overall pattern of lamb's temperature reconstruction [16, 40, 41, 42]. It is worth to mention the *Medieval Warm Period Project* [8] that collects numerous peer reviewed works documenting that the MWP was a global phenomenon.

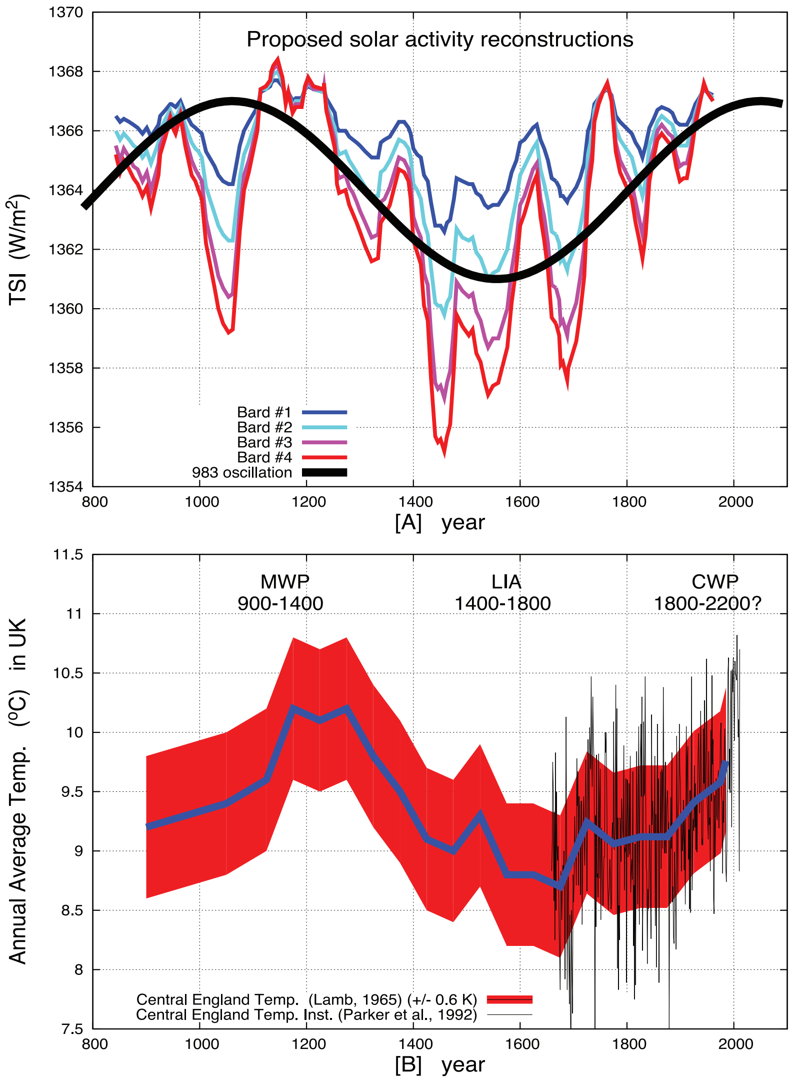


Figure 3: [A] Proposed solar activity reconstructions based on the solar proxy records of ^{10}Be and ^{14}C cosmogenic isotope production [50]. [B] Central England: HadCET temperature record (black) [48] superimposed on a proxy temperature reconstruction (red) [49].

[8] http://www.co2science.org/data/mwp/mwpp.php

Figure 4 demonstrates that climate models fitting the *hockey-stick* temperature record, do not fit present-day proxy temperature reconstructions. In the upper panel the original climate model of Crowley [7] is superimposed on the proxy temperature model of Moberg et al. [38] (1000-1850) merged with the HadCRUT4 GST (1850-2000). Their fit is poor because Crowley's model fitted the Mann et al. [5] hockey-stick graph showing just a ~0.2 ^oC cooling from MWP to LIA, while Moberg GST model shows a three/four times larger cooling, ~0.7 ^oC, during the same period. The lower panel gives an empirical model constructed by rescaling via linear regression Crowley's climate model components (solar, volcano and GHG+Aerosol) for direct comparison with Moberg GST record.

Moberg GST record implies a three times larger solar climatic impact than the original Crowley model estimate. Its volcano effect had to be reduced by about 30% while the anthropogenic forcing effect (GHG plus Aerosol forcing) by about 55%. This implies that about 50-60% of the warming observed since 1900 could have been due to a solar activity increase that has occurred since after the 17th century Maunder solar minimum. This result confirms Scafetta and West [52] and Scafetta [53], and strongly contradicts the IPCC AR3 and AR4 [2, 35], Benestad and Schmidt [54] and Lean and Rind [55] who claimed that more than 90-93% of the 20th century warming was caused by anthropogenic GHG emissions.

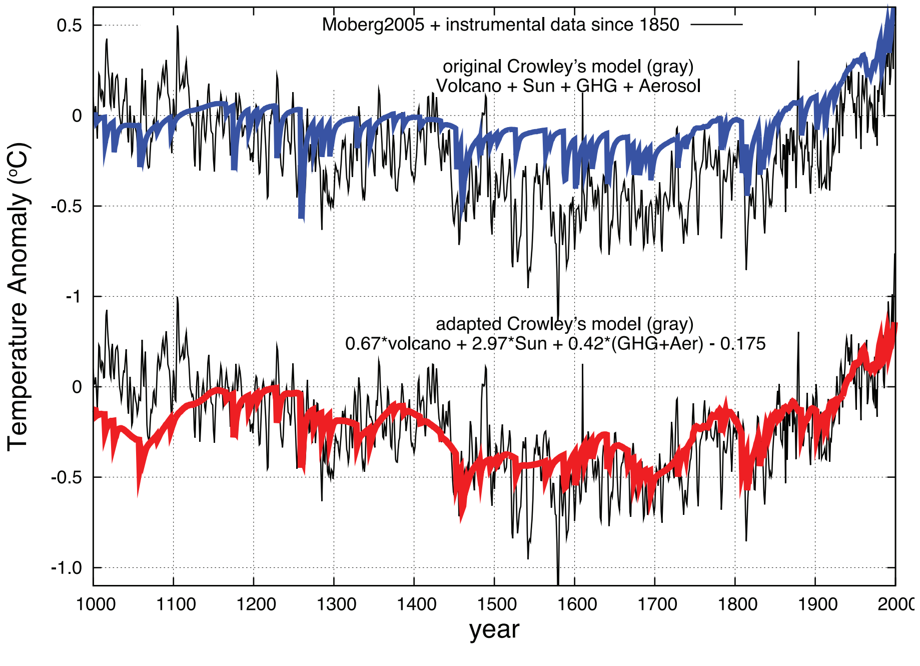


Figure 4: Moberg et al. [38] temperature reconstruction (black) merged with the HadCRUT4 GST after 1850. Upper panel: in blue original energy balance model of Crowley [7]; bottom panel: in red empirical model integrating volcano, solar and GHG+Aerosol temperature signature components produced by the Crowley model rescaled to fit the Moberg temperature record.

Thus, the energy balance model of Crowley [7] is unable to reproduce the empiri–cally determined solar signature evident in modern paleoclimatic GST reconstructions, and considerably overestimates the anthropogenic component. Today, the problem is even more significant because the most recent GCMs (the CMIP5) use a solar forcing based on the total solar irradiance (TSI) reconstruction of Lean [56], which shows a 50% smaller secular and millennial solar variability than the solar model used by Crowley, which used the model by Bard et al. [50] rescaled on an earlier TSI model by Lean et al. [57]. Therefore, or current GCMs use severely wrong TSI forcing (see Section 9), or they miss other solar related forcing mechanisms (e.g. chemical-based UV irradiance-related forcing of the stratospheric temperatures and a solar wind/cosmic ray forcing of the cloud systems [46]), or both.

Had in 2000 the current paleoclimatic temperature reconstructions been available, Crowley and other scientists of the time would have probably had a significantly lower confidence *in the overall ability of climate models to simulate temperature variability,* and would not have thought that the science was sufficiently *settled*. Very likely, those scientists would have concluded that important climate-change mechanisms were still unknown, and needed to be researched before they could be implemented to make reliable climate models.

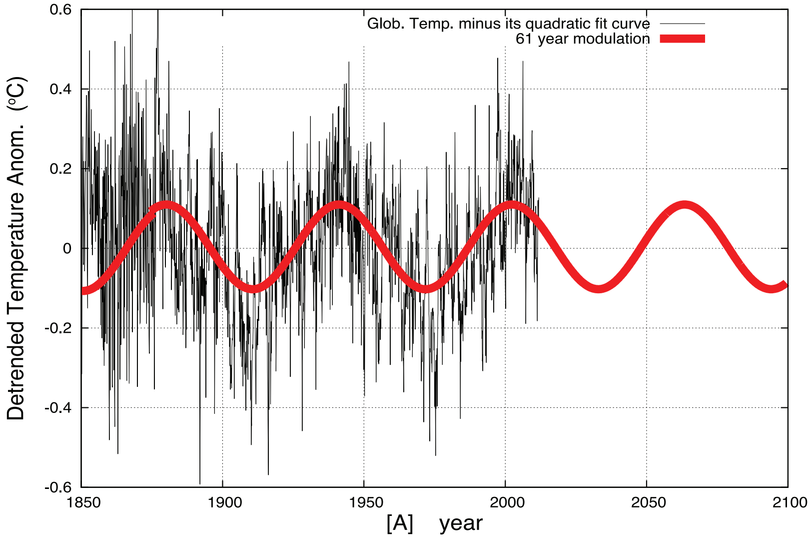
Today, the AGWT *consensus* appears to be an *accident of history* promoted since 2001 by the discredited hockey-stick GST records and by the IPCC in a quite questionable way [58, 59] and by numerous scientific organizations, such as those that in 2005 signed the Joint Science Academies statement (2005),[9] that hastily advocated AGWT despite the scientific complexity of the climate system and the large known uncertainties demanded prudence. During the last decade there has been also a politically motivated *consensus seeking process* [60], which is inconclusive in questions of science,[10] that has likely interfered with the acquisition and interpretation of evidences by discriminating opinions critical of the AGWT at major science journals [61]. This had also the effect to generate a serious *tension* between the AGWT advocates [62] and the critical voices. However, because numerous evidences contradict the hockey-stick GST graph used since 2001 by the IPCC to promote the AGWT and the GST stopped to rise 15 years ago contrary to all GCM predictions [10] (Fig. 1), today a careful investigation on the climate change attribution problem is necessary and legitimate.

4. DECADAL AND MULTIDECADAL CLIMATIC OSCILLATIONS ARE SYNCHRONOUS TO MAJOR ASTRONOMICAL CYCLES

Geophysical systems are characterized by oscillations at multiple time scales from a few hours to hundred thousands and millions of years [65]. Quasi decadal, bidecadal, 60 year , 80-90 year , 115 year , 1000 year and other oscillations are found in global and regional temperature records, in the Atlantic Multidecadal Oscillation (AMO), North Atlantic Oscillation (NAO) and Pacific Decadal Oscillation (PDO), in global sea level rise indexes, monsoon records, and similar oscillations are found also in solar proxy records and in historical aurora records

[9] http://nationalacademies.org/onpi/06072005.pdf

[10] It is worth reminding the famous quote attributed to Galileo Galilei: "In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual."



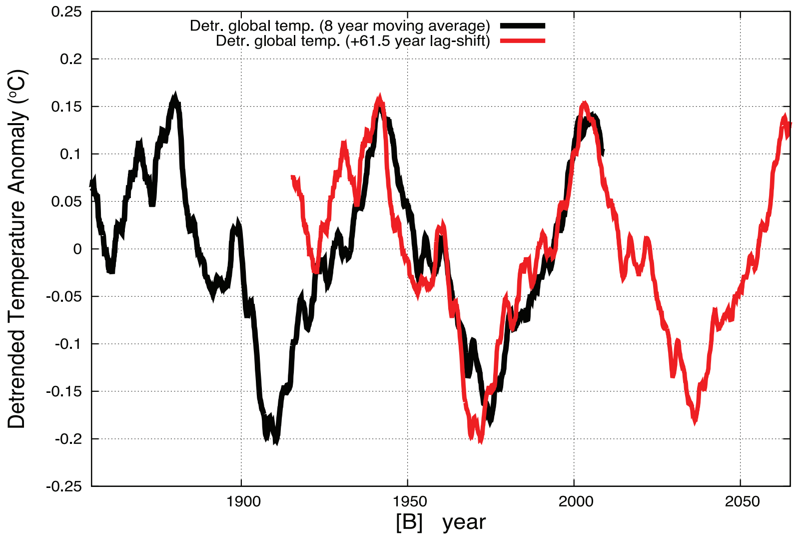


Figure 5: [A] HadCRUT4 GST record after detrending of its upward quadratic trend showing a quasi 61-year modulation. [B] 8-year moving average of the detrended GST plotted against itself with a 61.5-year shift (red). The quadratic fitting trend applied is $f(t) = 0.0000297 * (t - 1850)^2 - 0.384$. For details see Scafetta [8].

covering centuries and millennia [e.g.: 8, 9, 11, 43, 45, 47, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86].

Figures 1 and 5 show that the temperature oscillates with a quasi 61-year cycle superimposed to a general warming trend. We observe the following 30-year periods of warming 1850-1880, 1910-1940, 1970-2000; and the following periods of

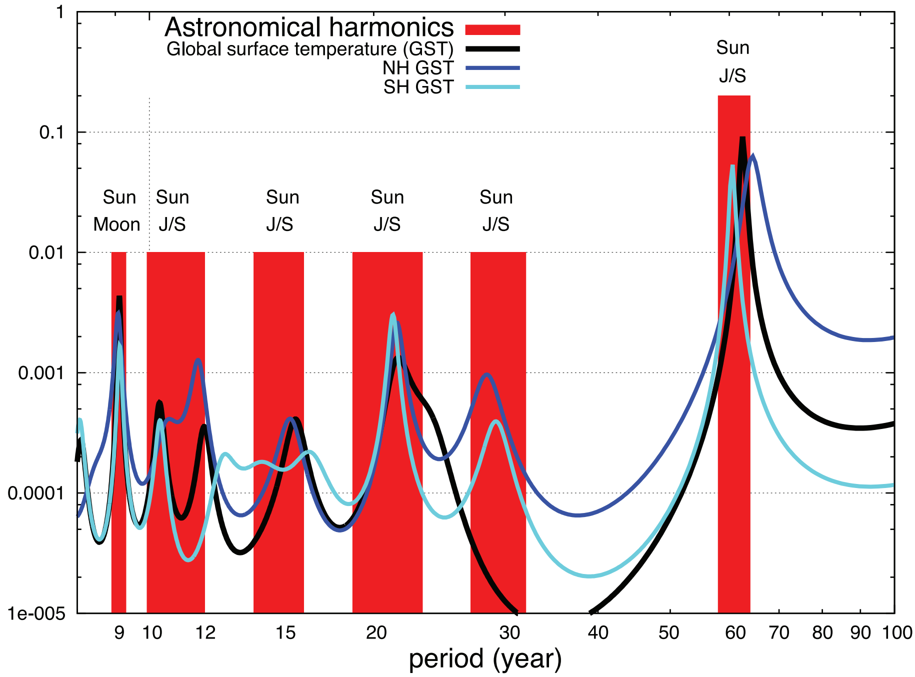


Figure 6: Maximum entropy method (MEM) power spectrum evaluations [93] of HadCRUT4 GST for the Northern Hemisphere GST and Southern Hemisphere GST. The red bars represent the major expected astronomical oscillations due to soli-lunar tidal cycles (9.1 year), and to solar cycles and gravitational oscillations of the heliosphere due to Jupiter and Saturn (after Scafetta [8]).

cooling 1880-1910, 1940-1970, 2000-2030(?). By detrending the long-term warming trend,[11] the quasi 61-year oscillation can be highlighted, as shown in Figure 5 [8], where an almost perfect match between the 1880-1940 and 1940-2000 GST periods emerges.

Figure 6 gives power spectrum evaluations for the novel HadCRUT4 GST, and for the GST of the Northern (NH) and Southern hemispheres (SH) [1]. There are two major multidecadal oscillations with approximate periods of 19-23 years and 59-63 years, plus two decadal oscillations at about 8.9-9.3 years and 10-12 years. Figure 6 also demonstrates that both hemispheres are characterized by a synchronized climate because they present a similar set of spectral peaks [see also: 8, 10]. Scafetta [8, 9, 10, 11, 12] noted that the GST oscillations appear to be synchronized with astronomical oscillations, which are highlighted as red boxes in Figure 6.

[11] This is done with a quadratic function, which captures the observed warming acceleration and is as orthogonal as possible to the multidecadal oscillations observed in the data.

The 9.1 year oscillation probably relates to a major soli-lunar gravitational tidal cycle [8, 10, 66]. In fact, the lunar nodes complete a revolution in 18.6 years, and the Saros soli-lunar eclipse cycle completes a revolution in 18 years and 11 days. These two cycles induce 9.3 year and 9.015 year tidal oscillations corresponding respectively to Sun-Earth-Moon and Sun-Moon-Earth tidal configurations. Moreover, the lunar apsidal precession completes one rotation in 8.85 years causing a corresponding lunar tidal cycle. Thus, there are three interfering major tidal cycles clustered between 8.85 year and 9.3 year periods, which generate a major oscillation with an average period of about 9.06 years. Scafetta [10, supplement pp. 35-36] showed that in 1997-1998 and 2006-2007 eclipses occurred close to the March and September equinoxes, that is when the soli-lunar spring tidal bulge peaks on the equator, having the strongest torquing effect on the ocean. Filtering methodologies showed the ~9.1 year GST cycle to peak in 1997-1998 and 2006-2007 as expected [10]. The Moon also causes an 18.6 year nutation cycle of the Earth's axis, which may contribute to an 18.6 year climate oscillation [70]. This 18.6 year oscillation presumably interferes with the two bi-decadal cycles of solar/planetary origin (discussed below), thus contributing to modulate a bidecadal cycle with an average period varying between 18 and 23 years. Other long soli-lunar tidal oscillations may exist. The solar system is also characterized by a set of natural harmonics associated with solar cycles (e.g. the ~11-year Schwabe sunspot cycle and the ~22-year Hale magnetic cycle [73]) and planetary harmonics: see Section 7.

Indeed, decadal and multidecadal oscillations are clearly reflected by the speed of the wobbling Sun (SWS) relative to the barycenter of the solar system [8, 9]. Figure 7A shows a clear quasi 20-year oscillation and a slight increase of the solar speed every 60 years. This occurred around 1880, 1940 and 2000, when GST maxima occurred (Fig. 5). In addition, Jupiter and Saturn also produce specific tidal cycles on the Sun at 9.93 years (spring tide), 11.86 years (Jupiter orbital tide), 14.97 years (minor beat cycle between Jupiter-Saturn spring tide and Saturn orbital tide), 29.46 year (Saturn orbital tide), 60.9 years (major beat cycle between Jupiter-Saturn spring tide and Jupiter orbital tide). Figure 7B shows that tidal beat maxima occurred around 1880, 1940 and 2000 during GST maxima [12]. As better explained in Section 7, the Schwabe 11-year sunspot cycles vary between about 9 and 13 years and are essentially constrained by the oscillations generated by Jupiter-Saturn spring tide and Jupiter orbital tide [11, 12].

The decadal and multidecadal astronomical periods are given as red-boxes in Figure 6 and correspond to the power spectral peaks observed in the GST records, as already demonstrated by Scafetta [8]. Figure 8A shows for the GST and SWS (Fig. 7A) a Fourier filtering within the period band of 14-28 year demonstrating a good phase matching of both curves. Figure 8B shows a Fourier filtering of GST within the period band of 8-12 years, which is reconstructed with two optimal harmonics with a 9.1 year and 10.2 year period, respectively. A 10.2 year period was used because it emerges as the main decadal peak in Figure 6 and falls within the range referring to the 9.93-year Jupiter-Saturn spring tide and the average 11-year solar cycle, and probably represents part of the 11-year solar cycle effect on climate (see also [8, 9, 10]).

GST also presents a smaller spectral peak at about 12 year, which may be related to the Jupiter orbit: for simplicity this additional harmonic as well as the 15-16 year and 30 year harmonics are here ignored. The 9.1 harmonic peaked in 1997.8, as confirmed by the soli-lunar tidal interpretation paradigm, and the other decadal cycle peaked in 2001.5 during the end of the maximum of solar cycle 23 [94]. Note that both a frequency and phase matching, as shown in Figures 5-8, is very important for identifying these oscillations as astronomically induced.

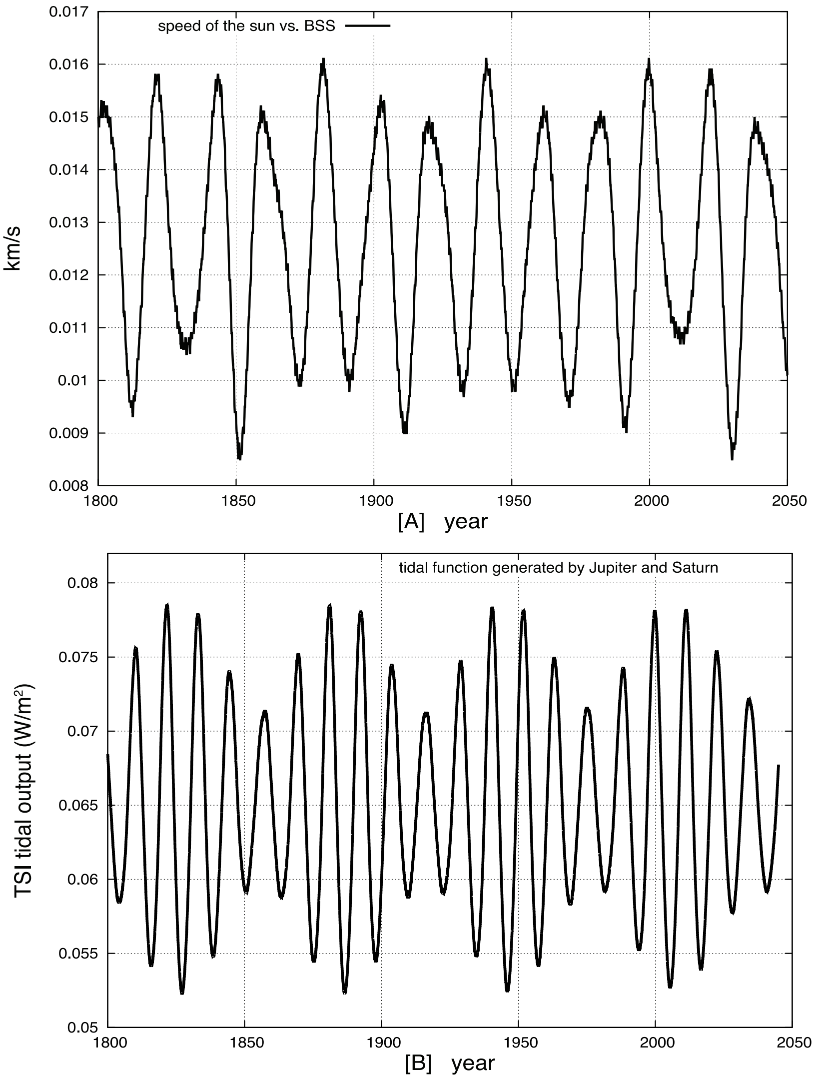


Figure 7: [A] Wobbling speed of the Sun [8]. [B] Estimate of total solar irradiance induced by Jupiter and Saturn tides. Note the 10-12 year, 20 year and 60-61 year oscillations (for details see Scafetta [11, 12]).

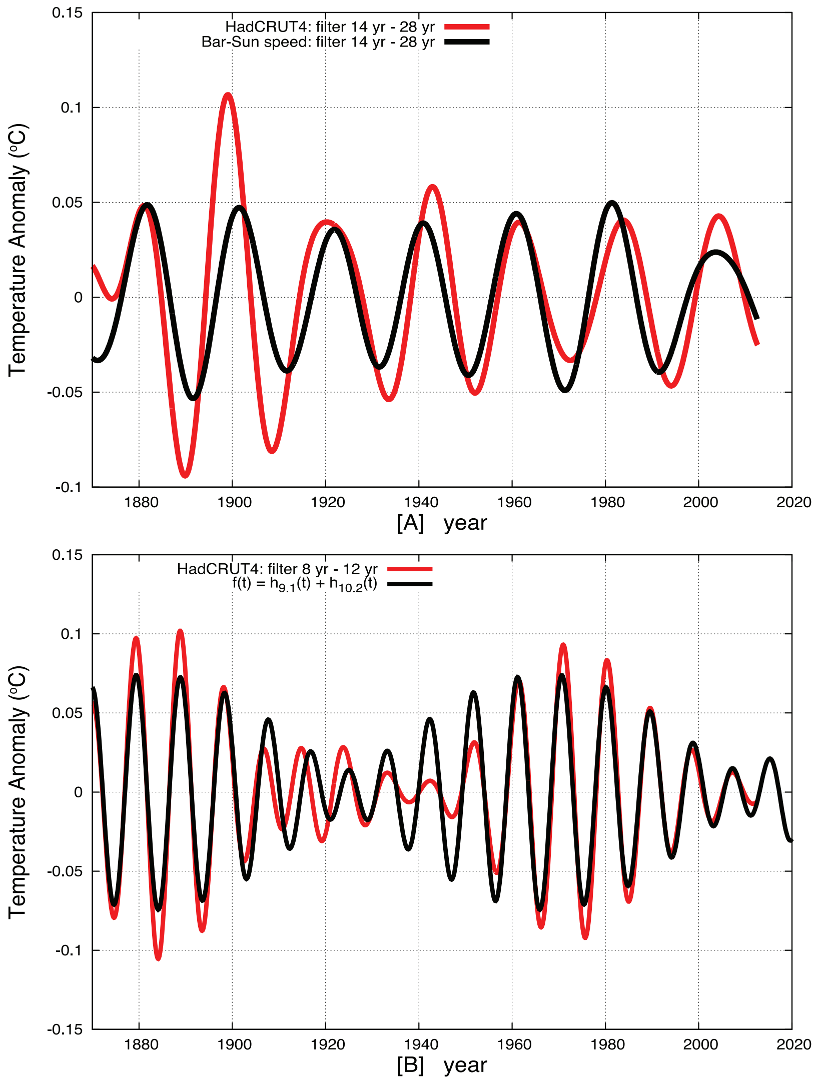


Figure 8: [A] Fourier filtering within 14-28 year of the HadCRUT4 GST and SWS given in Figure 7A. [B] Fourier filtering of GST within the period band between 8 years and 12 years compared with the regression model from 1870 to 2012, $f(t) = h_{9.1}(t) + h_{10.2}(t)$.

By adopting the following four major constituent climatic oscillation, regression against GST permits to obtain average optimal empirical harmonics:

$$h_{9.1}(t) = 0.044 \cdot \cos(2\pi(t - 1997.8)/9.1) \quad (1)$$

$$h_{10.2}(t) = 0.030 \cdot \cos(2\pi(t - 2001.5)/10.2) \quad (2)$$

$$h_{21}(t) = 0.051 \cdot \cos(2\pi(t - 2004.7)/21) \quad (3)$$

$$h_{61}(t) = 0.107 \cdot \cos(2\pi(t - 2003.14)/61) \quad (4)$$

There are at least 6 major 8.85-12 year astronomic harmonics and at least 3 major 18-23 year astronomic harmonics. Moreover, the climate system oscillates chaotically around the signal produced by such complex harmonic forcing function. This issue is here not further addressed because we use a simplified model.

5. CMIP3 AND CMIP5 GCMS DO NOT RECONSTRUCT THE OBSERVED GST DECADAL AND MULTIDECADAL OSCILLATIONS

Scafetta [10] analyzed all CMIP3 GCMs used by the IPCC AR4 [2] and their individual runs, and concluded that these models do not reproduce the decadal and multidecadal oscillations found in the GST records. Here the 83 individual runs of 18 CMIP5[12] GCMs that will be used in the IPCC AR5 in 2013 are briefly subjected to an equivalent test.

Table 1: Comparison of 30-year period trends in ^{o}C/century between the HadCRUT4 GST and the CMIP5 GCM ensemble mean simulation as given in Figure 1.

period	GST-trend	GCM-trend
1860-1880	+1.11±0.24	+0.54±0.06
1880-1910	-0.57±0.09	+0.23±0.07
1910-1940	+1.34±0.08	+0.90±0.03
1940-1970	-0.27±0.09	-0.47±0.04
1970-2000	+1.68±0.08	+1.66±0.05
2000-2012	+0.40±0.25	+1.96±0.07

Figure 1 clearly shows that the CMIP5 GCM ensemble mean simulations do not reconstruct the quasi 60-year GST oscillation observed since 1850. Table 1 summarizes 30-year trends and highlights that the GCM ensemble mean simulations fit the GST only between 1970 to 2000, which is just 18% of the 162-year available period. Thus, the CMIP5 GCM ensemble means can neither hind-cast nor forecast climate change with a reasonable accuracy.

To test whether the CMIP5 GCMs reproduce GST oscillations, geometrical averages were calculated for four periodograms on the base of the HadCRUT3, HadCRUT4, GISS and NCDC GST records. Then, a periodogram was calculated for each of the 83 individual CMIP5 GCM runs. Finally, the correlation coefficient

[12] KNMI Climate Explorer: http://climexp.knmi.nl

r between the two curves was estimated for 7 year up to 100 year periods. Only data for the common 1880-2006 interval were used and each record was linearly detrended before calculating its periodogram. Results are summarized in Figure 9 and Table 2.

Figure 9A gives the GST periodogram (red) and the GCM ensemble mean periodogram (blue). Figure 9B gives the correlation coefficient between the GST periodogram and the periodogram for 83 GCM runs (blue dots). For the GCM ensemble mean (numbered as -0-) we find $r = 0.77$, while for the other 83 GCM runs r varies between 0.03 and 0.92. The average is $\langle r \rangle = 0.55 \pm 0.22$, and suggests that the GCMs perform poorly in reconstructing the GST spectral characteristics.

The periodogram correlation coefficient for the astronomically-based empirical model (see section 7) and the GST is $r = 0.98$ of a possible maximum of $r = 1$. The likelihood to find an individual GCM simulation that performs equally or better than the empirical model is less than 1%. This finding is important as it demonstrates that the internal variability of CMIP5 GCMs is unable to reproduce the observed GST frequencies, suggesting that these models miss certain harmonic forcings.

Figure 10 summarizes the performance of one of the CMIP5 GCMs, namely the CanESM2 GCM, and the typical problems inherent to all CMIP5

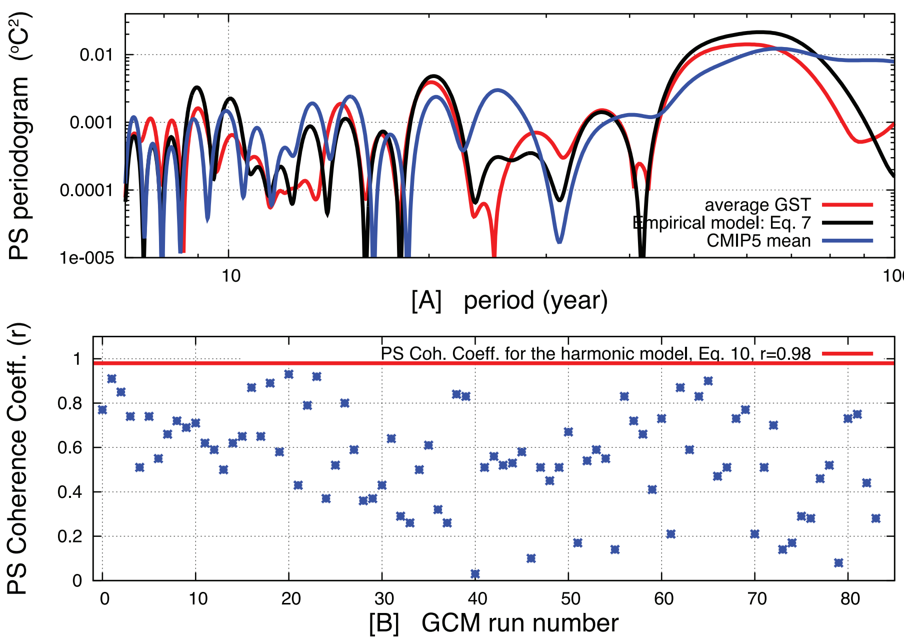


Figure 9: [A] Power spectrum periodograms of the GST (red), of the CMIP5 ensemble mean (blue) and of the astronomical model Eq. 7 (black). [B] Power spectrum coherence coefficient between GST and the CMIP5 GCM runs (blue dots) as listed in Table 2.

GCMs: (1) GCMs fail to reproduce the 2000-2012 steady GST trend; (2) the amplitude of the volcanic cooling spikes is too large in the GCMs compared to their GST signature; (3) the GCMs show for 1880-1960 steady warming whilst the GST shows a clear 60-year modulation consisting of a 1880-1910 cooling plus a 1910-1940 warming; (4) after 1950 the GCMs require a strong aerosol cooling effect to partially compensate for strong GHG warming up to 2000; since 2000 aerosol cooling no longer compensates for strong GHG warming to the end that the simulations strongly diverge from observations.

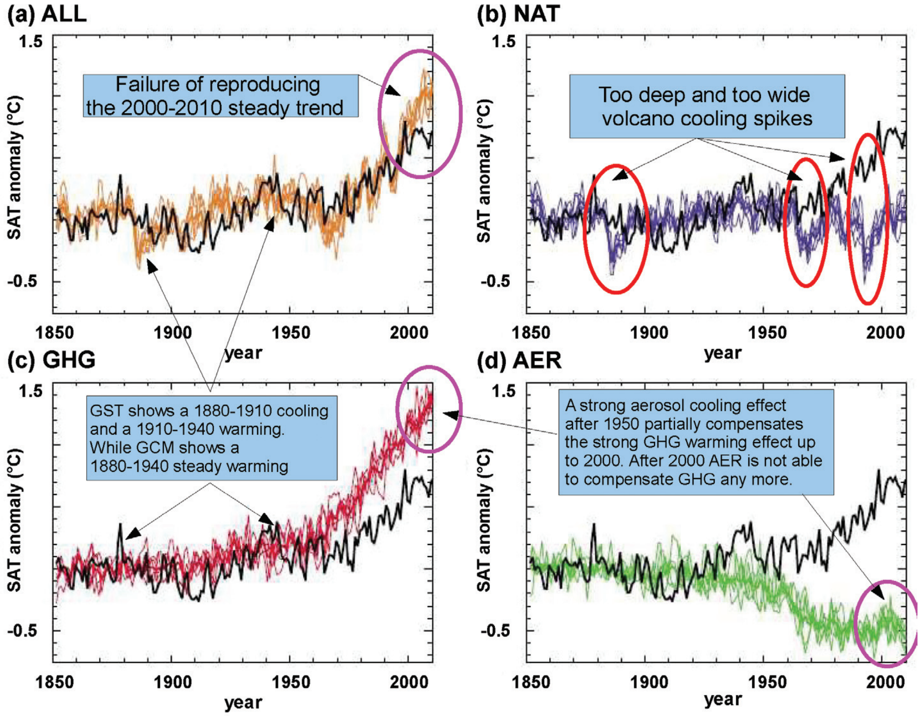


Figure 10: A reproduction of figure 1 of Gillett et al. [95]. Comments in the diagrams highlight common problems inherent to all CMIP5 GCMs. The computer simulations were run with: (a) anthropogenic and natural forcings (ALL), (b) natural forcings only (NAT), (c) greenhouse gases only (GHG), and (d) aerosols only (AER).

Table 2: Correlation coefficients r between the periodogram of GST and 83 individual runs for 18 GCMs. See also Figure 10B.

#-n model	r	#-n model	r	#-n model	r
0 model mean	0.77				
1-0 bcc-csm 1-1	0.91	29-5	0.37	57	0.72
2-1	0.85	30-6	0.43	58-0 HadGEM2-ES	0.66
3-2	0.74	31-7	0.64	59-1	0.41
4-0 CanESM2	0.51	32-8	0.29	60-2	0.73
5-1	0.74	33-9	0.26	61-3	0.21
6-2	0.55	34-0 EC-Earth23	0.50	62-0 INMCM4	0.87
7-3	0.66	35-1	0.61	63-0 IPSL-CM5A-LR	0.59
8-4	0.72	36-2	0.32	64-1	0.83
9-0 CCSM4	0.69	37-3	0.26	65-2	0.90
10-1	0.71	38-4	0.84	66-3	0.47
11-2	0.62	39-5	0.83	67-4	0.51
12-3	0.59	40-6	0.03	68-0 MIROC5	0.73
13-4	0.50	41-0 GISS-H2-H	0.51	69-0 MIROC-ESM	0.77
14-5	0.62	42-1	0.56	70-1	0.21
15-0 CNRM-CM5	0.65	43-2	0.52	71-2	0.51
16-1	0.87	44-3	0.53	72-0 MIROC-ESM-CHEM	0.70
17-2	0.65	45-4	0.58	73-0 MPI-ESM-LR	0.14
18-3	0.89	46-0 GISS-E2-R	0.10	74-1	0.17
19-4	0.58	47-1	0.51	75-2	0.29
20-5	0.93	48-2	0.45	76-0 MRI-CGCM3	0.28
21-6	0.43	49-3	0.51	77-1	0.46
22-7	0.79	50-4	0.67	78-2	0.52
23-8	0.92	51-5	0.17	79-3	0.08
24-0 CSIRO-Mk3-6-0	0.37	52-6	0.54	80-4	0.73
25-1	0.52	53-7	0.59	81-0 NorESM1-M	0.75
26-2	0.80	54-8	0.55	82-1	0.44
27-3	0.59	55-9	0.14	83-2	0.28
28-4	0.36	56-0 HadGEM2-CC	0.83	average	0.55 ±0

6. THE ANCIENT UNDERSTANDING OF CLIMATE CHANGE

For millennia the traditional understanding was that the climate system is largely regulated by numerous natural oscillations of astronomical origin working at multiple time scales [17, 19, 63, 64]. For example, soli-lunar calendars were widely used in antiquity because ancient civilizations considered soli-lunar cycles important for farming activities: in North America this tradition has been continued since 1792 by the Old Farmer's Almanac[13]. Moreover, quasi 20-year and 60-year astronomical oscillations were well known too. Ancient civilizations believed that somehow the

[13] http://www.almanac.com/

economy was related to these astronomical oscillations through the climate [17, 63, 19, 87, 88]. Indeed, cycles with periods of 7-11 years (Juglar), 15-25 years (Kuznets) and 45-60 years (Kondratiev) have been found among the business cycles.[14] A 60-year cycle was included in Chinese and Indian traditional calendars probably because these cycles were and are also reflected in the monsoon cycles [64, 67]. In Hindu tradition the 60-year calendar cycle was referred to as the Brihaspati (= Jupiter) cycle. In 886 AD Ma'sǎr [63] attempted a comprehensive interpretation of history based mostly on Jupiter-Saturn oscillations. Kepler [89], who strongly promoted astronomical climatology, designed in 1606 his famous diagram representing these two multidecadal cycles (Fig. 11, right).

As Kepler's diagram shows, quasi 20 year and 60 year oscillations could be readily deduced from the orbital period of Jupiter (11.86 year) and Saturn (29.46

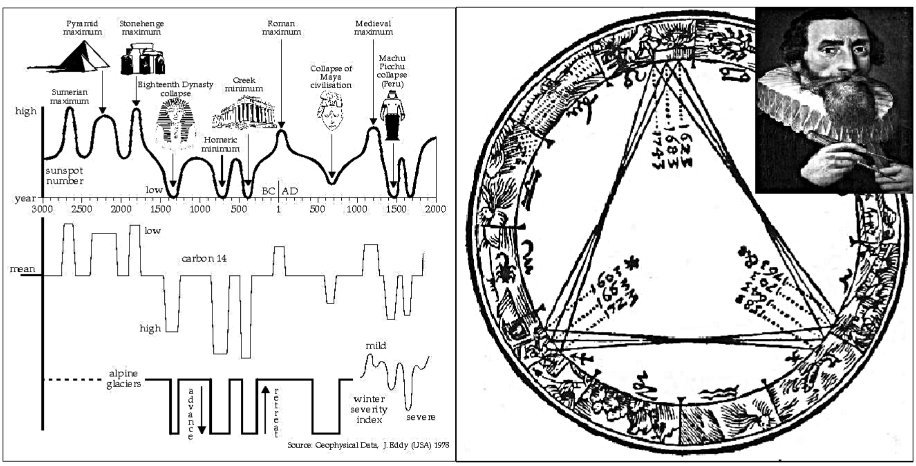


Figure 11: (Left) Schematic representation of the rise and fall of several civilizations since Neolithic times that well correlates with the ^{14}C radio-nucleotide records used for estimating solar activity (adapted from Eddy's figures in Refs. [90, 91]). Correlated solar-climate multisecular and millennial patterns are recently confirmed [43, 44, 47]. (Right) Kepler's Trigon diagram of the great Jupiter and Saturn conjunctions between 1583 to 1763 [89], highlighting 20 year and 60 year astronomical cycles, and a slow millennial rotation.

[14] http://en.wikipedia.org/wiki/Business_cycle

year). The Jupiter-Saturn conjunction period is ~ 19.85 year, at ~242.57^o of angle. Every ~60 years a conjunction Trigon completes with a ~7.7^o rotation (Fig. 7). The full astronomical configuration repeats every ~900-960 years using the sidereal orbital periods of the planets, as Ma'sǎr [63] observed following Ptolemy, or every ~800 years using the tropical orbital periods, as Kepler [89] observed. In both cases, the slow rotation of the Trigon convinced ancient civilizations of a quasi-millennia astronomical cycle that could be approximately correlated with a quasi-millennia cycle commonly observed in historical chronologies, as revealed by the rise and fall of civilizations. These events were likely driven by climatic variations (Fig. 11, left) [90, 91].

Indeed, in 1345 AD a Jupiter-Saturn conjunction occurred in the zodiac sign of Aquarius and was linked to the outbreak of the Black Death epidemic [88, pp. 158-172][15]. In 1606 Kepler [89] used a related argument to predict that European civilization would have flourished again during the following four/five centuries, and Newton excluded the possibility of another civilization collapse before 2060 AD[16]. Today, it is known that this quasi-millennial civilization cycle is also reflected in the ^{14}C and ^{10}Be cosmo-nucleotide records, which are modulated by solar activity [43, 44, 47] (Fig. 11) suggesting a planet-sun-climate link.

However, since the 18th century a planetary influence on the climate, as well as the ancient astrological planetary models were dismissed as superstitions because according Newton's gravitational law the planets are too far from the Earth to have any observable effect. Is there a solution to this curious mystery? Below a modern astronomical interpretation of the climate oscillations is given based on some of the author's studies [8, 9, 11, 12, 86].

7. PLANETARY CONTROL ON SOLAR AND CLIMATE CHANGE OSCILLATIONS THROUGHOUT THE HOLOCENE

In the 19th century an important discovery was made: the Sun oscillates with an apparent 11-year periodicity. In 1859 Wolf [96] postulated that *the variations of the sunspot-frequency depends on the influences of Venus, Earth, Jupiter and Saturn*. The theory of a planetary influence on solar activity was popular in the 19th and earlier 20th century [97, 98]. Although most solar physicists no longer favor this concept claiming that, e.g., planetary forces are too weak to influence solar activity (for a summary of objections see Ref. [11, 12]), Scafetta [11, 12] developed it further using physics and data not yet available in the 19th century, found strong supporting empirical evidence for it and proposed a physical explanation.

Indeed, a number of recent studies since the 1970s noted correlations between the wobbling of the Sun around the center of mass of the solar system and climatic patterns [99, 100, 101, 102, 103]. However, as the Sun is in free fall with respect to the gravitational forces of the planets, its wobbling should not effect its activity. Scafetta [8, 9, 11, 12, 86] investigated this conundrum taking the following four aspects into consideration:

[15]Traditional medieval astrology claimed that when the Trigon of the great conjunctions of Jupiter and Saturn occurred in the zodiac air sign of Aquarius *kingdoms have been emptied and the earth depopulated because of great cold, heavy frosts and thick clouds corrupting the air* [88, pp. 172].
[16]http://en.wikipedia.org/wiki/Isaac_Newton's_occult_studies

1. Using Taylor's theorem Scafetta [8] explained that even if the solar wobbling functions are not the direct physical cause of the observed effects, they can still be used as proxies because they would present frequencies and geometric patterns in common with the relevant physical functions even if the latter may remain unknown.
2. The gravitational and electro-magnetic properties of the heliosphere may be modulated by the reciprocal position and speed of the Jovian planets and of the Sun. Moreover, as solar wobbling is real relative to the Milky Way Galaxy, its velocity may modulate the incoming cosmic ray flux. Oscillating electro-magnetic properties of the heliosphere, of the solar wind and of the incoming cosmic ray flux probably cause climatic oscillations by means of a cloud cover modulation [46, 104] and other electro-magnetic mechanisms.
3. The Jovian planets may periodically perturb the orbit of the Earth, causing specific climatic oscillations as it happens with the multi-millenial Milankovic cycles [105] (eccentricity, 100,000-year cycle; axial tilt, 41,000-year cycle; precession, 23,000-year cycle), which are responsible for intermittent great glaciations. However, decadal-to-millennial scale orbital perturbations appear to be too small (~ 1000 kilometers) to explain the decadal-to-millennial scale climatic oscillations by variations in the Earth-Sun distance because the Earth orbits the Sun and not the barycenter. Nevertheless, this hypothesis needs to be further investigated.
4. As discussed in Scafetta [11, 12], a possible physical mechanism are planetary gravitational tidal forces. Power spectra of the sunspot record demonstrated that the 11-year Schwabe sunspot cycle is made up by three interfering cycles, which can be interpreted as due to: (1) the 9.93-year spring tidal cycle between Jupiter and Saturn; (2) the 11.86-year Jupiter orbital tidal cycle; (3) a central oscillation of about 10.87 year that is almost, but not precisely, the average between the two tidal cycles and may emerge from the solar dynamo cycle as a collective synchronization harmonic. Scafetta [12] also noted that there are gravitational recurrence patterns of about 11.07-11.08 years due to the Mercury-Venus system and the Venus-Earth-Jupiter system, which correspond to the average solar cycle length. Thus, numerous planetary tidal oscillations resonate around the 11-year Schwabe solar cycle, as postulated by Wolf [96]. See Figure 12.

Taking these considerations into account, a simple solar model was developed by Scafetta [11] involving just three harmonics, namely the two Jupiter/Saturn tidal cycles and a hypothetical solar dynamo cycle with a 10.87-year period. This model reproduces a varying 11-year cycle that correlates approximately with the Schwabe sunspot cycle, and produces beats at about 61 years, 115 years, 130 years and 983 years, which are synchronous with major solar and climatic multidecadal, secular and millennial oscillations observed throughout the Holocene. The model recovers: (1) the quasi millennial oscillation observed in both solar and climate proxy records [43, 44]; (2) the prolonged periods of low solar activity during the last millennium know as the Oort, Wolf, Spörer, Maunder and Dalton minima; (3) the seventeen 115 year oscillations found in detailed temperature reconstructions of the Northern Hemisphere covering the last 2000 years [16, 81] that correlate with periods of grand solar minima (see bottom of Figure 13A); (4) the quasi 61-year

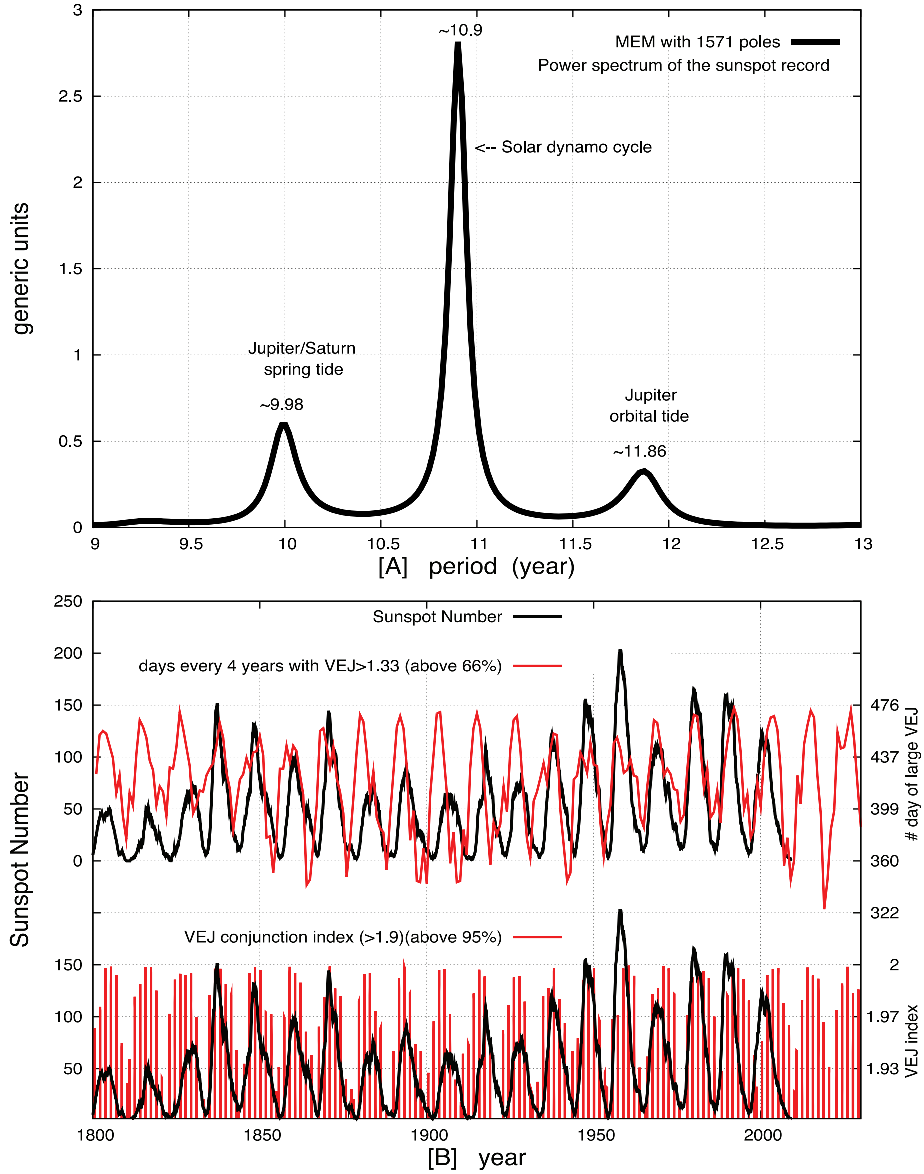


Figure 12: [A] Maximum entropy method (MEM) power spectrum of the sunspot record from 1749 to 2010 highlighting three peaks within the Schwabe frequency band (period 9-13 years) including the two major tides of Jupiter and Saturn. [B] Comparison between the sunspot record (black) and a particular tidal pattern configuration (red) made using Venus, Earth and Jupiter (VEJ) that reproduces on average the solar cycle length of 11.08 year . For details see Scafetta [11, 12].

GST modulation that has been clearly observed in GST records since 1850.

Figure 13 [11] shows that a modulated quasi 61-year beat oscillation apparently dominates solar dynamics between 1850 and 2150 AD. Other solar harmonics such

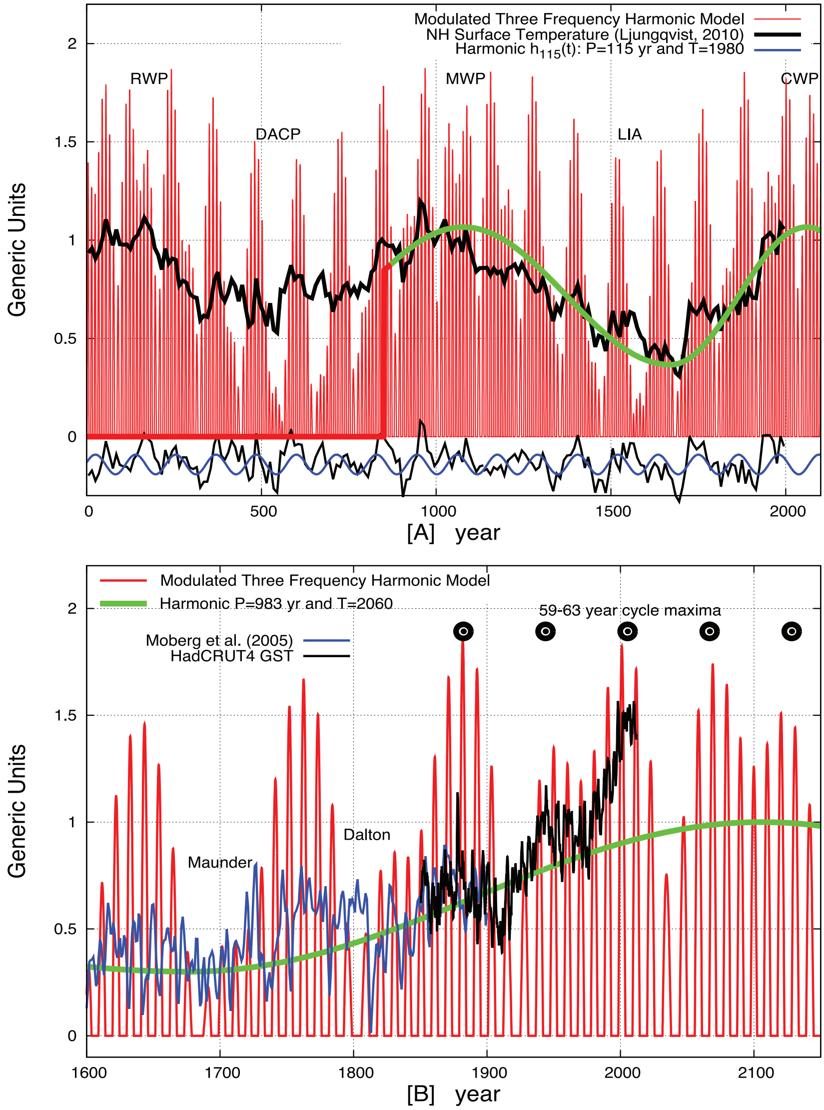


Figure 13: [A] Three frequency solar/planetary harmonic model (red) vs. the Norther Hemisphere temperature reconstruction by Ljungqvist [16] (black). RWP: Roman Warm period. DACP: Dark Ages Cold Period. MWP: Medieval Warm Period. LIA: Little Ice Age. CWP: Current Warm Period. [B] Same solar model (red) vs. HadCRUT4 GST (annual smooth: black) combined in 1850-1900 with the proxy temperature model of Moberg et al. [38] (blue). Green curve: millennial modulation (Eq. 6). After Scafetta [11].

as the ~87-year Gleissberg and the ~207-year de Vries solar cycles and other solar cycles can be readily discerned in the planetary harmonics [12, 86, 102]. In fact, the 1/7 resonance of Jupiter and Uranus is about 85 years and other harmonics occur at 84-89 year periodicities [103, 86]; the beat resonance between the quasi 60-year and the 85-year cycles is about 205 years. Solar variation is likely the result of an internal complex collective synchronization dynamics [106] emerging from numerous gravitational and electro-magnetic harmonic forcings.

Scafetta [11] estimated that the 115-year cycle should peak in 1980 and the 983-year cycle in 2060. By using the paleoclimate temperature records given in Figures 3 and 11A [16, 38], and by looking at the cooling between the Medieval Warm Period (MWP) ending around 1000 AD and the Little Ice Age (LIA) around 1670 AD, it can be deduced that the amplitude of the 115-year cycle is about $0.1 \pm 0.05\ ^{o}C$ and that the millennial cycle amplitude is about $0.7 \pm 0.3\ ^{o}C$. The millennial climatic cycle appears to have reached also a minimum around 1680: see also Humlum et al. [74]. Therefore, the two cycles can be approximately represented as:

$$h_{115}(t) = 0.05 \cdot \cos(2\pi(t - 1980)/115) \quad (5)$$

$$h_{983}(t) = 0.35 \cdot \cos(2\pi(t - 2060)/760) \quad (6)$$

Eq. 6 uses the period of 760 years for simulating the skewness of the millennial climatic cycle and should be valid from 1680 to 2060.

8. SUN AS AMPLIFIER OF PLANETARY ORBITAL OSCILLATIONS

Scafetta [12] proposed the following physical mechanism to explain how planetary forces may modulate solar activity. Planetary tides on the Sun are extremely small, and therefore scientists were discouraged from believing that these regulate solar activity. However, systems that generate energy can work as amplifiers and, evidently, the Sun is a powerful generator of energy. Since its nuclear fusion activity is regulated by gravity, the Sun may work as a huge amplifier of the small planetary gravitational tidal perturbations exerted on it.

Solar luminosity is related to solar gravity via the well-known Mass-Luminosity relation: if the mass of the Sun increases, its internal gravity increases and makes more work on its interior masses. Consequently, solar luminosity increases as: $L/L_S \approx (M/M_S)^4$ [107]. For example, if the mass of all planets were added to the Sun, the total solar irradiance would increase by about 8 W/m^2. Using an argument based on the Mass-Luminosity relation, Scafetta [12] estimated that nuclear fusion could greatly amplify the weak gravitational tidal energetic signal dissipated inside the Sun by up to a 4 million factor. If this is so, planetary tides are able to trigger solar luminosity oscillations with a magnitude compatible with the observed TSI oscillations [94], and, consequently, may be able to modulate the solar dynamo cycle. Alternative planetary mechanisms influencing the Sun may exist; see also Wolff and Patrone [108] and Abreu et al. [102].

9. TOTAL SOLAR IRRADIANCE (TSI) UNCERTAINTY PROBLEM

The three-frequency solar model (Fig. 13) predicts, akin to the GST, that solar activity increased from 1970 to 2000, reached a maximum around 2000, and will decrease until the 2030s. However, the CMIP5 GCMs adopt a solar forcing deduced from Lean's solar proxy models [56, 114] that show a flat TSI trend since 1955 with a slight decrease since 1980. Also the CMIP3 GCMs used by the IPCC AR4 [2] adopted Lean's TSI models in an effort to show that during the last 40 years a more or less stable Sun could not be responsible for the observed warming after the1970s (see also Lockwood and Fröhlich [109]). This is a highly controversial issue that needs to be clarified.

It is claimed that Lean's proxy models are supported by actual TSI observations provided by the PMOD satellite TSI composite [110, 111]. However, PMOD used *modified* TSI satellite records. For some unexplained reason, the scientific community appears to ignore that not only have the experimental teams responsible for the TSI satellite data never validated these PMOD modifications of their records, but explicitly stated that PMOD's procedures are highly speculative and

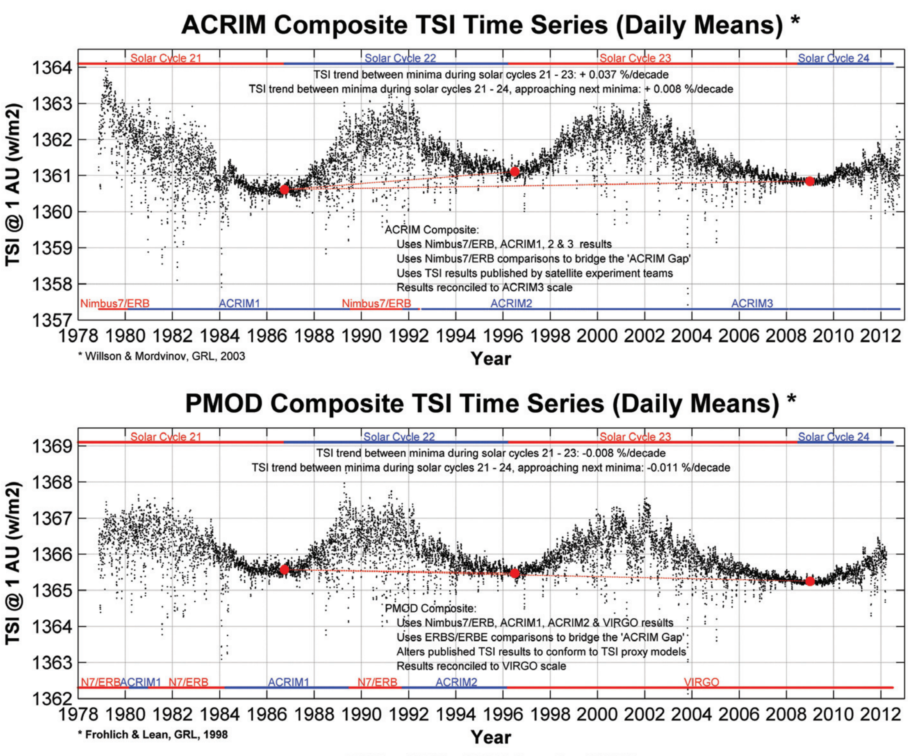


Figure 14: (Top) ACRIM total solar irradiance satellite composite [113].
(Bottom) PMOD total solar irradiance composite [111].

physically incompatible with the experimental recording equipments [94, 112] (see the Appendix). By contrast, the ACRIM TSI satellite composite [113] is based on TSI satellite data as published, and shows that TSI increased between 1980 and 2000 and decreased thereafter. Figure 14 compares the ACRIM and PMOD TSI composites. With simple empirical thermal models Scafetta and West [52] and Scafetta [53, 112] assessed the implication of adopting the ACRIM and PMOD TSI composites and showed that with the ACRIM record most of the climate change observed since the Maunder Minimum, including the 1970-2000 warming, can be attributed to variations in solar activity.

The controversy between the ACRIM and PMOD composites centers mainly on the TSI trend during the so-called *ACRIM-gap* of 1989-1992. PMOD claims that during this period the Nimbus7/ERB TSI record, which is necessary to bridge the ACRIM1 and ACRIM2 TSI records, must be shifted and inclined downward to produce by 1992 a total downward shift of about 0.8-0.9 W/m^2 [111, 112]. This modification of the Nimbus7/ERB TSI record results in a decreasing TSI trend during 1989 to 1992 and causes in the PMOD TSI composite the 1996 TSI minimum to be almost at the same level as the 1986 TSI minimum [112]. On the contrary, the ACRIM way of combining the TSI records without modifying them implies that the 1996 minimum was about 0.5 W/m^2 higher than the 1986 TSI minimum: this difference would be about 0.8-0.9 W/m^2 by adopting the same composite PMOD merging methodology [112]. Thus, without PMOD's modification, TSI clearly increased during 1980-2000, similar as the GST [52, 53].

Most arguments supporting the PMOD TSI composite are based on highly controversial proxy models such as Lean's models and a few others [e.g.: 56, 110, 116, 118], which agree with the flat PMOD TSI pattern partially employing circular reasoning. However, a correct scientific argument must focus on the ACRIM-gap data to which the most important PMOD modifications are applied. Once this is done Scafetta and Willson [94] showed that the model of Krivova et al. [116] is not compatible with the PMOD modification of Nimbus7/ERB record. Krivova et al. [117] did not query this, but remarked that other proxy models, claimed to be more accurate on short time scales, confirm the PMOD TSI composite. However, a direct comparison of the smoothed ACRIM and PMOD TSI composites and of the magnetogram-based SATIRE TSI model during the ACRIM-gap, as given by Ball et al. [118, fig. 8], shows that, similar to ACRIM, from 1990 to 1992.5 also SATIRE trends upward from 1990 to 1992.5 (slope = 0.1 ± 0.03 $W\ m^{-2}\ /year$) approximately as in the original Nimbus7/ERB measurements. Also the Climax Neutron Monitor cosmic ray intensity count, which inversely correlates with solar magnetic activity, decreases between 1989 and 1992 [112]. In general, the average cosmic ray flux steadily decreased between 1965 and 1996 [46]. Therefore, preference should be given to the ACRIM TSI composite that is probably closer to reality than the PMOD TSI composite.

In addition, while the three-frequency solar model presents a maximum in the 1940s that clearly correlates with a temperature maximum (Fig. 13), Lean's solar proxy models [56, 110] peak in 1960 similar to the sunspot number record. However, the solar maximum of the 1940s is supported by the TSI reconstruction of Hoyt and Schatten [73] and by the solar cycle length model [119, 115]. Indeed, since 1900 the TSI reconstruction of Hoyt and Schatten [73], updated by Scafetta with the ACRIM record, clearly correlates with the 60-year modulation of the GST records during the 20th century. Soon [120, 121, 122] used the updated Hoyt and Schatten [73] TSI model to demonstrate its good correlation with the GSTs of the Arctic and China, with the Japanese sunshine duration record and with the Equator-to-Pole (Arctic) temperature gradient function. Figure 15A compares these two alternate TSI models [73, 114] and highlights the severity of their difference particularly in terms of TSI multidecadal variation. Figure 15B compares the Central England Temperature (CET) record [48] and the TSI model by Hoyt and Schatten [123] plus the ACRIM TSI record; an overall good correlation is observed since 1700, which suggests that the major observed climatic oscillations are solar induced and that the Sun explains about 50-60% of the warming observed since 1900.

The good multisecular correlation between CET and the chosen secular TSI reconstruction, which includes the quasi 60-year climatic oscillation observed since 1900, contradicts a claim of Zhou and Tung [124] and Tung and Zhou [125]. These authors have inappropriately criticized Scafetta and West [126, 127] claiming that solar activity has contributed less than 10% of the warming for the first half of the 20th century. In their opinion the observed warming was mostly induced by the Atlantic Multidecadal Oscillation (AMO) during its 1910-1940 warm phase. However, the AMO is not an independent forcing of the climate system but it is a subsystem of the global temperature network and of the climate system itself. The result depicted in Figure 15B clearly suggests that the observed climatic oscillations, including those of its subsystems such as AMO, are driven by solar activity [8, 9, 80, 115, 120, 122, 123].

The TSI model proposed by Hoyt and Schatten [73, 123] uses various indexes such as sunspot cycle amplitude, sunspot cycle length, solar equatorial rotation rate, fraction of penumbral spots, and the decay rate of the approximate 11-year sunspot cycle. On the contrary, Lean's models are based mostly on regression of sunspot blocking and faculae brightening indexes. The latter indexes may not well capture the dynamics of the quiet-sun background radiation that may be responsible for a multidecadal TSI trending, as observed in the ACRIM composite. Similarly, Shapiro et al. [128] and Judge et al. [129] recently argued that multi-decadal TSI variations are significantly larger than suggested by Lean's models because the quiet-sun magnetic field may vary significantly on multidecadal time scales following the modulation potential of the galactic cosmic rays.

In conclusion, it is possible that current GCMs are using an erroneous solar input function owing to their adoption of the Lean's TSI models [2, 56, 114], which may be flawed and, therefore, may severely obscure the true solar effect on climate.

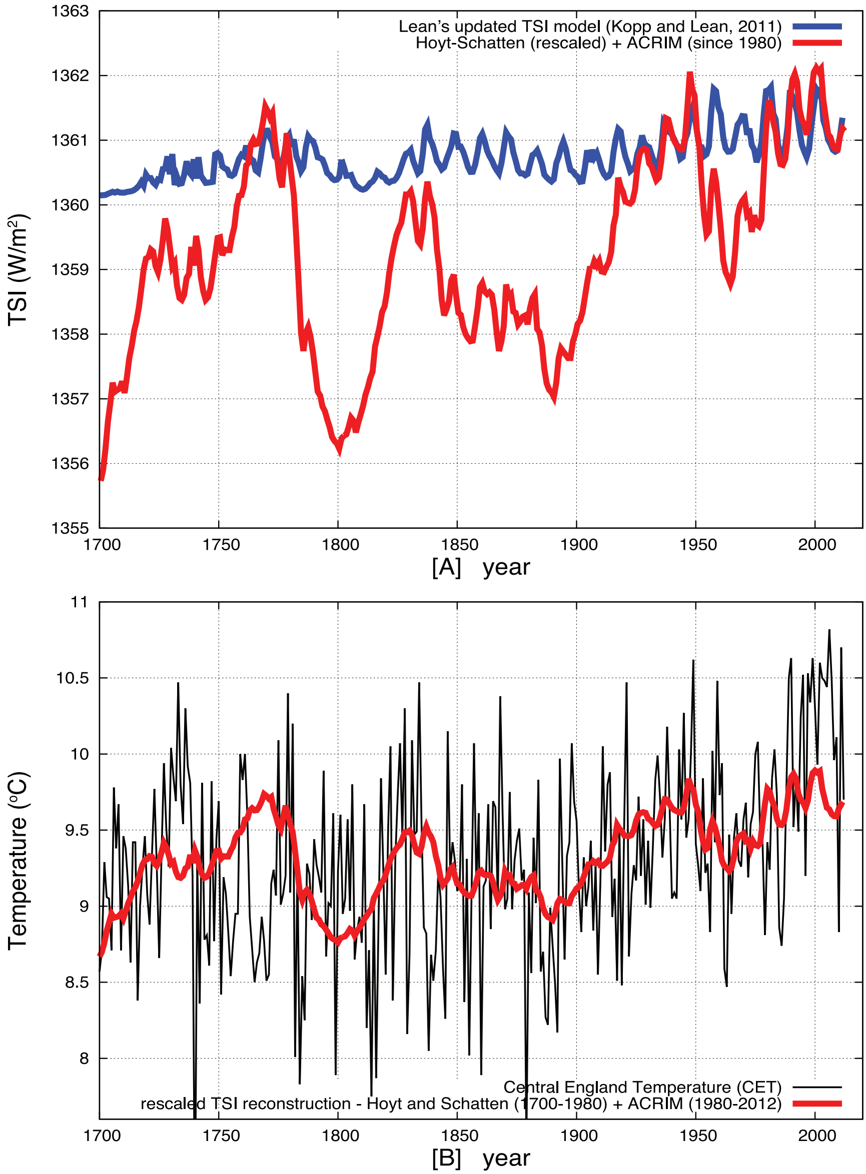


Figure 15: [A] Total solar irradiance (TSI) reconstruction by Hoyt and Schatten [73, 123] updated with the ACRIM record [113] (since 1980) (red) vs. the updated Lean's model [56, 114] (blue) used as solar forcing function in the CMIP5 GCMs adopted in the IPCC AR5 in 2013. [B] Comparison between the Central England Temperature (black) Parker et al. [48] and the TSI model by Hoyt and Schatten [123] plus the ACRIM TSI record.

10. EMPIRICAL ASTRONOMICAL MODEL

The six climatic harmonics synchronous with astronomic cycles at decadal to the millennial time scales are approximated by Eqs. 1-6. These harmonics describe phenomenologically the natural climatic oscillations observed since 1850 and, as demonstrated above and in Ref. [10], are not reproduced by the GCMs. These functions permit empirical modeling of natural variability at decadal to millennial time scales. However, GST also depends on the chemical composition of the atmosphere that can be modified by anthropogenic emissions and volcano activity.

As discussed in the introduction, the IPCC AR4 [2] concluded that 100% of the ~0.5-0.55 C^{o} warming observed since 1970 can only be explained by anthropogenic forcing. However, its adopted GCMs fail to reproduce the natural harmonics such as the 60-year oscillation (Fig. 5). Scafetta [10] argued that the failure of the GCMs to properly reproduce the 60-year oscillation, which contributed about 0.3 ^{o}C of warming between 1970 and 2000, caused the GCMs to overestimate the climatic effect of anthropogenic forcing by about 50-60%. Zhou and Tung [124] reached a similar conclusion by using the Atlantic Multidecadal Oscillation that shows a clear 60-year oscillation [131, fig. 9B] without realizing that climatic oscillations such as AMO may be astronomical/solar induced. Even assuming that the anthropogenic forcing functions used in the GCMs are correct, the above arguments imply that the GCMs significantly overestimated the climate sensitivity to radiative forcing because their output ought to be reduced to about a factor of 0.45. Such a reduction is in keeping with modern paleoclimatic reconstructions (Fig. 4) and the calculations in section 3. The proposed correction provides a first approximation estimate of the climatic effect of the anthropogenic plus volcano forcings, given that according the CMIP5 GCMs, the solar contribution to the secular GST trend is nearly insignificant (at best a few percent).

GST can be phenomenologically modeled with the following equation:

$$f(t) = h_{9.1}(t) + h_{10.2}(t) + h_{21}(t) + h_{61}(t) + h_{115}(t) + h_{983}(t) + M_{A,V}(t), \qquad (7)$$

where the natural harmonic component of the climate system is reconstructed by the six harmonics that are presumably induced by synchronized astronomical harmonic forcings. The function $M_{A,V}(t) = 0.45 \cdot m_{GCM}(t)$ is the output of the GCM ensemble averages, $m_{GCM}(t)$, given in Figure 1, reduced to a 0.45 factor. In first approximation $M_{A,V}(t)$ would simulate the anthropogenic and the short-scale strong volcano effects on climate under the assumption that the true equilibrium climate sensitivity to radiative forcing is 55% smaller than the one currently simulated by the GCMs.

The empirical climate model of Eq. 7 may require additional harmonics to include the effects of other minor oscillations and some additional nonlinear effect. In particular, Figure 13 indicates that the 61-year solar oscillation appears to be strong in 1850-2150, but too faint before 1850, while the 115-year oscillation appears to be stronger before 1850, giving rise to the cold Maunder and Dalton periods. For simplicity, these corrections are ignored.

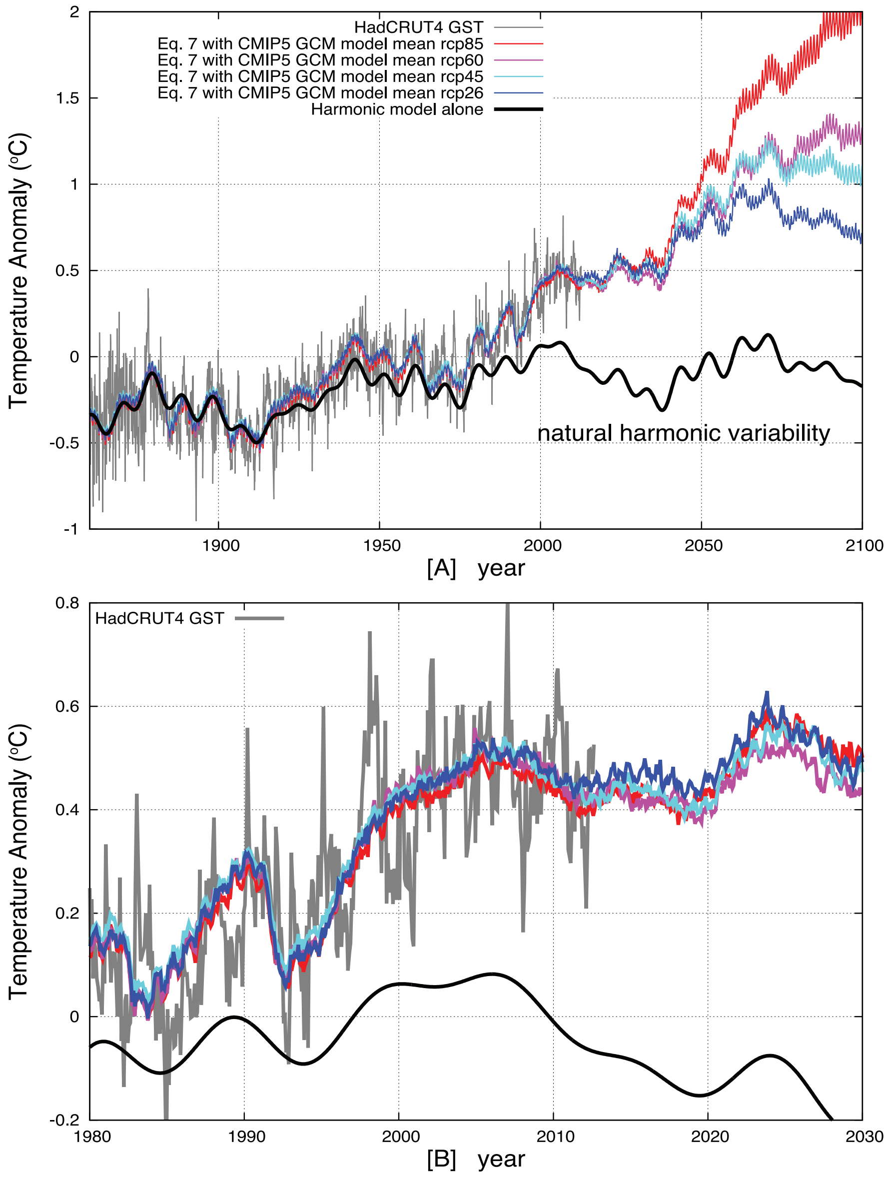


Figure 16: [A] HadCRUT4 GST (gray) superimposed on the empirical climate model given by Eq. 7 where the anthropogenic/volcano component $M_{A,V}(t)$ is derived from the four alternate CMIP5 GCM ensemble average simulations of Fig. 1. The smooth black curve corresponds to the six-frequency harmonic component alone, representing the modeled natural variability. [B] Zoom of [A] for 1980 to 2030.

Figure 16 gives the HadCRUT4 GST (gray) and the empirical climate model of Eq. 7 derived from the four alternate CMIP5 GCM ensemble average simulations and their 21st century projections as shown in Figure 1. The black curve corresponds to the harmonic model alone, which represents the natural harmonic variability. The multicolored curves show $f(t)$ that adequately reproduces both the GST upward trend since 1850 and all decadal and multidecadal oscillations observed in the temperature record.

It is important to stress that: (1) the used harmonics are also found in good synchrony with astronomical cycles; (2) the weight of the anthropogenic component, that is the factor 0.45 used to reduce the outputs of the GCM ensemble means, was determined using the period 1970-2000 [10]; (3) the amplitude of the quasi millennial cycle was deduced using the cooling from the MWP to the LIA in 1700 AD. Interesting, the correct reconstruction of the warming trending since 1850 is actually a hind-cast. Scafetta [9, 10] also showed that the harmonic model can be calibrated during the period 1850-1950 to hind-cast the climatic oscillations observed from 1950 to 2010, and vice versa. This demonstrates the hind-cast capability of the proposed harmonic model and points towards the reliability of its forecasting capability.

The proposed empirical model hind-casts the GST standstill observed since 2000, which the GCMs failed to predict, and forecasts a more or less steady climate oscillating with decadal and bidacadal oscillations up to 2030-2040 in response to the cooling phase of the 61 year solar/astronomical cycle that compensates for the projected anthropogenic warming component. Furthermore, the empirical model predicts a possible warming of 0.3-1.6 ^oC by 2100 relative to 2000 that is significantly lower than the 1.1-4.1 ^oC warming of the GCM ensemble mean projections given in Figure 1 [3].

11. CONCLUSION

It may be surprising to many to learn that planetary oscillations probably exert a significant control on the Earth's climate system, as presented in this paper. However, this is the way climate change has been interpreted and predicted for millennia by ancient civilizations that built sophisticated astronomic observatories to this purpose.

Ptolemy [17] stated that the motions of the *aether* (that is the oscillations of the heliosphere driven by the Sun, the Moon and the planets) alter the uppermost part of the Earth's atmosphere (which was believed to be made of *fire*), which then alters the lower atmosphere *acting on earth and water, on plants and animals* and, consequently, humans are also influenced by the *stars*. Kepler [19, 89] observed that the climate had to *respond to the dictates of heavenly harmonies*, and said that *nature is affected by an aspect just as a farmer is moved by music to dance* [132]. Planetary harmonics were extensively used to interpret human history [63] and forecast monsoon rainfall cycles [64]. Today, many dismiss this ancient science as *astrology,* perhaps without realizing that also calendars and ocean tidal models originated as astrological models, while today these models are scientifically very well founded. Indeed, ancient astrology was a mixing of factual facts describing astronomical-geophysical phenomena and superstitions and, by understanding this, Kepler warned to not *throw out the baby with the bathwater* [19, 133].

The GST clearly oscillates and increased since 1850. However, the GCMs used by the IPCC, such as the CMIP3 in 2007 and the CMIP5 in 2013, are unable to reconstruct the observed GST decadal and multidecadal oscillations. The traditional justification for this failure has been attributed to an internal variability of the climate system that appears impossible to properly model due to uncertainties in the initial conditions and to the chaotic dynamics of the climate system itself.

The author [8, 9, 10, 11, 12] noted that the GST records are characterized by specific frequency peaks corresponding to astronomical harmonics linked to soli-lunar tidal cycles, solar cycles and heliosphere oscillations in response to movements of the planets, particularly of Jupiter and Saturn. Moreover, he proposed a physical model that may explain how planetary tidal harmonics can modulate solar activity, and reconstructed the major known Holocene solar variations [11, 12] from the decadal to the millennial scales. Figures 6, 9 and 13 show that the observed GST and astronomic oscillations are well synchronized. Indeed, a planetary hypothesis of solar variation is reviving [134].

Empiric harmonic models based on these oscillations are able to reconstruct all observed major decadal and multidecadal climate variations with a far greater accuracy than any IPCC AGWT GCMs. A simple harmonic model based on a minimum of four astronomic oscillations with periods of about 9.1, 10-12, 19-22 and 59-63 years can readily reconstruct and hind-cast all so-called GST *hiatus* periods observed since 1850. This contradicts Meehl et al. [22] that the observed GST oscillations are due to an *unpredictable* internal variability of the climate system.

The full GST record can be reconstructed by using two additional secular (~115 years) and millennial (~983 years) astronomical harmonics plus a climate component regulated by the chemical properties of the atmosphere (e.g. GHG and aerosols). The GCM ensemble means can be used to estimate the effect of this component provided that their output is reduced to a 0.45 factor. Thus, while the current GCMs produce an average climate sensitivity to CO_2 doubling to be around 3 ^oC, the real average value of the climate sensitivity may be approximately 1.35 ^oC and may very likely vary from 0.9 to 2.0 ^oC. The climate sensitivity may be lower, though, provided part of the GST warming of non-climatic origin, such as uncorrected urban heat island (UHI) effects [13, 14] or if the preindustrial GST millennial variability is found larger than what used in Eq. 7 [41]. This estimate of low equilibrium climate sensitivity to radiative forcing is compatible with the results of other studies [28, 29].

The empirical model given in Figure 16 implies that about 50-60% of the about 0.8-0.85 ^oC warming observed since 1850 is due to a combination of natural oscillations, including a quasi-millennial cycle that was in its warming phase since 1700 AD. Since 1850 major quasi 20-year and 61-year cycles describe the GST multidecadal scales, and two decadal cycles of about 9.1 years and 10-11 years capture the decadal GST scale. Other minor oscillations of about 12, 15 and 30 year period, also linked to astronomical oscillations (see Fig. 6) appear to be present but are ignored here. The proposed six-frequency empirical climate model, Eq. 7, outperforms all CMIP3 and CMIP5 GCM runs, and predicts under the same

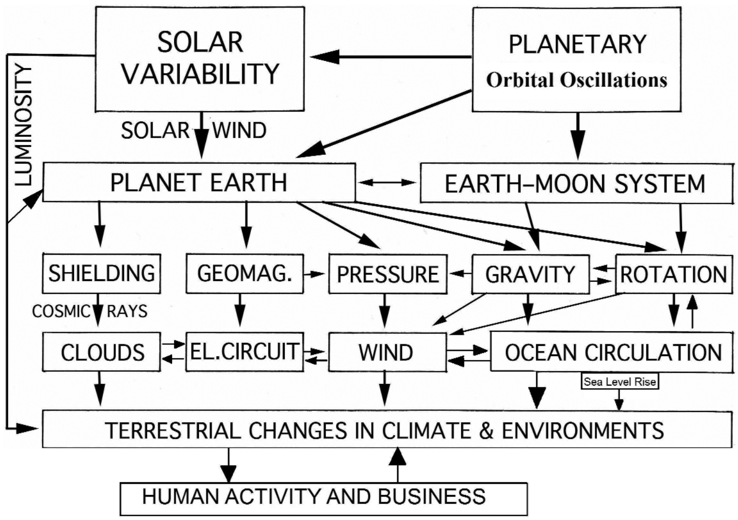


Figure 17: Network of the possible physical interaction between planetary harmonics, solar variability and climate and environments changes on Planet Earth (with permission adapted after Mörner [135]).

emission scenarios a significantly lower warming for the 21st century ranging from 0.3 ^oC to 1.6 ^oC , which is an upper limit.

The results of this analysis indicate that the GCMs do not yet include important physical mechanisms associated with natural oscillations of the climate system. Therefore, interpretations and predictions of climate change based on the current GCMs, including the CMIP5 GCMs to be used in the IPCC AR5, is questionable. Mechanisms missing in the GCMs are probably linked to natural solar/astronomical oscillations of the solar system that are a subject of further research. However, these oscillations can be already empirically modeled and, in first approximation, used for forecasting at least the harmonic component of the climate system.

Figure 17 presents a qualitative diagram summarizing the network of the possible physical interaction between planetary harmonics, solar variability, soli-lunar tidal forcings, climate and environmental changes on our Earth. Taking into account a planetary oscillation control of solar activity and lunar harmonics controlling direct or indirect natural climatic forcings, may make solar and climate change more predictable.

12. ACKNOWLEDGMENTS

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Appendix: Willson and Hoyt's statements regarding the TSI satellite records

In 2008 the author inquired with Dr. Willson, who heads the ACRIM satellite TSI measurements, and Dr. Hoyt (the inventor of GSN Group Sunspot Number indicator) who was in charge of the Nimbus7/ERB satellite measurements, about their opinion regarding the theoretical modifications applied to their published TSI records by Dr. Fröhlich of the PMOD/WRC team. These modifications are crucial for obtaining a TSI satellite composite record that does not show an increasing trend between 1980 and 2000 [110, 111], as shown in Figure 14. For detailed information visit ACRIM website[17].

In the statements reproduced in Figure 18, Willson and Hoyt agree that Fröhlich's modifications are, in their opinion, not justified because they are

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September 16, 2008

Dear. Dr. Scafetta:

Regarding Frohlich's PMOD TSI composite:

1. Frohlich made unauthorized and incorrect adjustments to the SMM/ACRIM1 and UARS/ACRIM2 TSI results. In the case of ACRIM1 he arbitrarily miss-applied the degradation correction published by the ACRIM1 Science team for the SMM 'spin mode' (1981 – 1984) to the 1980 results. He did this without any detailed knowledge of the ACRIM1 instrument or on-orbit performance, original analysis or consultation with the ACRIM1 team. His intent was clearly to revise the solar cycle 21 TSI to agree with Judith Lean's TSI proxy model.
2. Frohlich chose the ERBS/ERBE database to 'bridge' the ACRIM gap when it was clearly inferior to the Nimbus7/ERB gap data. His justification was based on hypothetical 'upward steps' in the Nimbus7/ERB results ('glitches' in Frohlich's words) that no other researchers, including both the original PI (Hickey) and the final science team (Hoyt and Kyle) believe exist. As with ACRIM1 above, Frohlich had no detailed knowledge of the Nimbus7/ERB instrument and made no original analysis or computations. The only obvious purpose appears to be to obtain a TSI composite that agreed with the predictions of Lean's TSI proxy model.
3. The TSI proxy models, such as Lean's, are not competitive in accuracy or precision with even the worst satellite TSI observations. To 'adjust' satellite data to agree with such models is incompatible with the scientific method.
4. The PMOD TSI composite panders to those who promote anthropogenic causes as the principal component of global warming, despite mounting evidence to the contrary. They cite its lack of significant TSI trending as evidence of relatively insignificant solar climate forcing during the past 30 years.

Sincerely,

Dr. Richard C. Willson

September 16, 2008

Dear Dr. Scafetta:

Concerning the supposed increase in Nimbus7 sensitivity at the end of September 1989 and other matters as proposed by Frohlich's PMOD TSI composite:

1. There is no known physical change in the electrically calibrated Nimbus7 radiometer or its electronics that could have caused it to become more sensitive. At least neither Lee Kyle nor I could never imagine how such a thing could happen and no one else has ever come up with a physical theory for the instrument that could cause it to become more sensitive.

2. The Nimbus7 radiometer was calibrated electrically every 12 days. The calibrations before and after the September shutdown gave no indication of any change in the sensitivity of the radiometer. Thus, when Bob Lee of the ERBS team originally claimed there was a change in Nimbus7 sensitivity, we examined the issue and concluded there was no internal evidence in the Nimbus7 records to warrant the correction that he was proposing. Since the result was a null one, no publication was thought necessary.

3. Thus, Frohlich's PMOD TSI composite is not consistent with the internal data or physics of the Nimbus7 cavity radiometer.

4. The correction of the Nimbus7 TSI values for 1979-1980 proposed by Frohlich is also puzzling. The raw data was run through the same algorithm for these early years and the subsequent years and there is no justification for Frohlich's adjustment in my opinion.

Sincerely,

Douglas Hoyt

Figure 18: Willson and Hoyt's statements regarding the modifications implemented by Frohlich [110, 111] to the ACRIM and Nimbus 7 published records.

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[17] http://acrim.com/TSI%20Monitoring.htm

inconsistent with the physical properties of the experimental instruments used for TSI satellite measurements. Of course, these statements do not automatically imply that Fröhlich's modifications are necessarily erroneous. However, it is clear that Willson and Hoyt, who are the principal investigators of the experimental teams in charge of the TSI satellite records modified by Fröhlich, are convinced that the modification of their TSI records are not justified and that the PMOD TSI satellite composite does not correspond to the actual TSI satellite measurements and does not properly describe the actual dynamic behavior of TSI from 1978 onward.

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