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A shared frequency set between the historical mid-latitude aurora records and the global surface temperature

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ABSTRACT

Herein we show that the historical records of mid-latitude auroras from 1700 to 1966 present oscillations with periods of about 9, 10–11, 20–21, 30 and 60 years. The same frequencies are found in proxy and instrumental global surface temperature records since 1650 and 1850, respectively, and in several planetary and solar records. We argue that the aurora records reveal a physical link between climate change and astronomical oscillations. Likely in addition to a Soli-Lunar tidal effect, there exists a planetary modulation of the heliosphere, of the cosmic ray flux reaching the Earth and/or of the electric properties of the ionosphere. The latter, in turn, has the potentiality of modulating the global cloud cover that ultimately drives the climate oscillations through albedo oscillations. In particular, a quasi-60-year large cycle is quite evident since 1650 in all climate and astronomical records herein studied, which also include a historical record of meteorite fall in China from 619 to 1943. These findings support the thesis that climate oscillations have an astronomical origin. We show that a harmonic constituent model based on the major astronomical frequencies revealed in the aurora records and deduced from the natural gravitational oscillations of the solar system is able to forecast with a reasonable accuracy the decadal and multidecadal temperature oscillations from 1950 to 2010 using the temperature data before 1950, and vice versa. The existence of a natural 60-year cyclical modulation of the global surface temperature induced by astronomical mechanisms, by alone, would imply that at least 60–70% of the warming observed since 1970 has been naturally induced. Moreover, the climate may stay approximately stable during the next decades because the 60-year cycle has entered in its cooling phase.

1. Introduction

Since ancient times people have claimed that climate and weather changes are partially related to cyclical astronomical phenomena linked to the orbits of the Sun, the Moon and the planets (Ptolemy, 2nd century; Ma'šar, 886; Kepler, 1606; Swerdlow, 1998; Iyengar, 2009). Because of this conviction the ancient astronomers developed calendars that contain several cycles (Aslaksen, 1999) as well as the well-known annual cycle. During the last 70 years, numerous scientific evidences appear to have corroborated that ancient conviction. For example, Milankovic (1941) theorized that variations in eccentricity, axial tilt and precession of the orbit of the Earth determine climate patterns such as the 100,000 year ice age cycles of the Quaternary glaciation. Milankovitch's theory fits the data very well, over the past million years, in particular if the temporal rate of change of global ice volume is considered (Roe, 2006). More recently, a number of authors (Shaviv, 2003; Shaviv and Veizer, 2003; Svensmark, 2007) have shown that the cosmic-ray flux records well correlate with the warm and ice periods of the Phanerozoic during the last 600 million years: in this case the cosmic-ray flux oscillations are believed to be due to the changing galactic environment of the solar system, as it crosses the spiral arms of the Milky Way. Over millennial and secular time scales several authors have found that changes in sunspot number and cosmogenic isotope productions well correlate with climate changes (Eddy, 1976; Sonett and Suess, 1984; Hoyt and Schatten, 1997; White et al., 1997; van Loon and Labitzke, 2000; Bond et al., 2001; Kerr, 2001; Douglass and Clader, 2002; Kirkby, 2007; Scafetta and West, 2005, 2007, 2008; Shaviv, 2008; Raspopov et al., 2008; Eichler et al., 2009; Soon, 2009; Meehl et al., 2009; Scafetta, 2009). Moreover, instrumental global surface records since 1850 appear to be characterized by a set of frequencies that can be associated to a Soli/Lunar tidal cycle (9.1-year period) and to the motion of the Sun relative to the barycenter of the solar system (about 10-10.5, 20-21, 30 and 60-62 year periods) (Scafetta, 2010a,b).

In this paper, we study the historical mid-latitude aurora records since 1700 (Křivský and Pejml, 1988; Silverman, 1992) and show that these records share the same set of frequencies that characterize the climate system as well as the natural oscillations of the solar system. This finding reveals the existence of a clearer physical mechanism, missing in our previous study (Scafetta, 2010b), which could link the astronomical cycles to climate oscillations. The major implication of this paper is that there exists an astronomical harmonic modulation of the electric properties of the Earth's atmosphere that modulates

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the clouds and, therefore, the terrestrial albedo (Svensmark, 1998, 2007; Svensmark et al., 2009; Kirkby, 2007; Tinsley, 2008).

This research would also support the development of a novel astronomically based theory of climate change that may credibly compete and likely substitute the current mainstream anthropogenic global warming theory (AGWT) advocated by the IPCC (Solomon et al., 2007). In fact, the AGWT advocates claim that astronomical forcings of the climate are almost negligible and that the climate variations are induced by some still poorly understood and modeled red-noise-like *internal chaotic dynamics* of the climate system, and by trends in greenhouse gases (GHG) (mostly CO_2 and CH_4) and aerosol records. More precisely, global surface temperature has risen (Brohan et al., 2006) by about 0.8 °C and 0.5 °C since 1900 and 1970, respectively. Solomon et al. (2007, 2009) and other researchers (Lean and Rind, 2008) have claimed that more than 90% of the observed warming since 1900 and practically 100% of the observed warming since 1970 have had an anthropogenic cause. While Lean and Rind's methodology that the climate responds linearly with the forcings can be easily questioned by simply noting that the heat capacity of the climate system is not zero (Scafetta, 2009), the IPCC claims derive from Figures 9.5 and 9.6 in the IPCC report (AR4-WG1, 2007) showing, by means of professional climate general circulation models (GCMs), that natural forcings alone (volcano and solar irradiance) would have caused a cooling since 1970: the observed post-1970 warming has been interpreted as being induced by human activity alone. However, the very large uncertainty in the aerosol forcings and in the climate sensitivity to GHG changes (Solomon et al., 2007; Knutti and Hegerl, 2008; Rockström et al., 2009; Lindzen and Choi, 2011; Spencer and Braswell, 2011), and the current very poor modeling of the water vapor feedback (Solomon et al., 2010), of the cloud system (Lauer et al., 2010), of the ocean dynamics and of the biosphere question the robustness of the current GCMs for properly interpreting and reconstructing the real climate (Idso and Singer, 2009).

On the contrary, if a significant feature of the climate system is characterized by a specific set of harmonics, it may be possible to partially reconstruct and forecast it in the same way in which ocean tides are currently predicted, that is, by means of harmonic constituent models based on astronomical cycles (Thomson, 1881; Fischer, 1912; Doodson, 1921). A harmonic constituent model is just a superposition of several harmonic terms of the type

$$F(t) = A_0 + \sum_{i=1}^{N} A_i \cos(\omega_i t + \phi_i). \quad (1)$$

The frequencies ω_i are deduced from astronomical theories. The amplitude A_i and the phase ϕ_i of each harmonic are empirically determined using regression on an adequate sample of observations, and then the model is used to forecast future scenarios. Currently, in most US costal locations tidal forecast is made with 35–40 harmonic constituents (Ehret, 2008).

In the following, we show that in general typical energy balance models and general circulation models can be in first approximation mathematically reduced to harmonic models if they process harmonic forcings. Thus, we propose that the climate oscillations too can be approximately reconstructed and forecasted by using a planetary harmonic constituent model philosophically equivalent to Eq. (1) based on astronomical cycles.

2. A possible link between mid-latitude auroras and the cloud system

In this paper, we postulate that the annual frequency occurrence of mid-latitude aurora events is a measure of the level of electrification of the global ionosphere, which is mostly regulated by incoming cosmic ray flux variations (Kirkby, 2007; Svensmark, 2007). When the Earth's magnetosphere is weaker relative to the surrounding space environment the ionosphere can be highly ionized by cosmic rays, and large auroras would more likely form at the mid-latitudes. This phenomenon would occur because when the upper atmosphere is highly ionized, it would also be electrically quite sensitive to large solar wind particle fluxes and favor the formation of extended mid-latitude auroras. In fact, higher ionization of the atmosphere would mostly occur when the magnetosphere is weaker and cosmic ray as well as solar wind particles can more easily reach the mid-latitudes. Then, the level of atmospheric ionization and of the global electric circuit of the atmosphere should regulate the cloud system (Kirkby, 2007; Svensmark, 2007; Tinsley, 2008). If the above theory is correct, the frequencies of the mid-latitude aurora records should be present in the climate records too.

Indeed, cloud-related climatic effects can largely dominate other mechanisms such as CO_2 and CH_4 GHG forcing (Kirkby, 2007; Svensmark, 2007). For example, in the past billion years the Earth experienced severe glaciations despite the fact that the CO_2 concentration could be even 10 times higher than today (4000–6000 ppmv against the actual 390 ppmv) (Hayden, 2007). In addition to major continental drifts and other geological events (Courtillot and Renne, 2003), it has also been argued that the high cosmic ray incoming flux that occurred during known major glaciations could have increased the cloudiness of the Earth causing a global cooling (Shaviv, 2003, 2008; Shaviv and Veizer, 2003; Svensmark, 2007).

The cloud system controls a large part of the terrestrial albedo and regulates the amount of total solar irradiance reaching the Earth's surface. The solar irradiance reaching the Earth's surface warms the ocean and the land. A small astronomical modulation of the terrestrial albedo through the cloud system can greatly increase the climate sensitivity to solar forcing (Shaviv, 2008; Scafetta, 2009). Evidently, if the current GCMs are missing an important forcing of the cloud system, they would poorly reconstruct and, potentially, severely misinterpret climate variations at multiple temporal scales. Indeed, a correlation between galactic cosmic ray fluxes and high-altitude, mid-altitude and low clouds has been found (Svensmark, 2007; Rohs et al., 2010; Laken et al., 2010).

3. A 60-year cycle in mid-latitude aurora and climate records

Fig. 1 shows the global surface temperature (HadCRUT3) (Brohan et al., 2006) from 1850 to 2010 (monthly sampled). Global surface temperature records (land, ocean, north hemisphere, south hemisphere) have been found to be characterized by a clear and large quasi-60-year cyclical modulation (Scafetta, 2010b). In fact, the following 30-year trends are evident in the record: 1850–1880, warming; 1880–1910, cooling; 1910–1940, warming; 1940–1970, cooling; 1970–2000, warming; and a small cooling since 2000 that may last until 2030–2040.

Fig. 2A shows the global surface temperature record detrended of its upward trend and smoothed with a 8-year moving average that highlights its 60-year cyclical modulation with a peak-to-trough amplitude of about 0.3–0.4 °C.

Fig. 2B shows the annual frequencies of mid-latitude auroras obtained from the supplement of the catalogue of mid-latitude auroras $<55°$N from 1700 to 1900. This record contains the historical aurora observations reported mostly in central Europe since 1000 AD (Křivský and Pejml, 1988). The record before 1700 is largely incomplete, and the data are not depicted in the figure. Fig. 2B also depicts the catalog of the aurora observations in the Faroes Islands from 1872 to 1966. Despite the fact that Faroes' record refers to a northern region (62N), Silverman (1992) noted that it appears to have physical properties compatible with the