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High resolution coherence analysis between planetary and climate oscillations

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Abstract

This study investigates the existence of a multi-frequency spectral coherence between planetary and global surface temperature oscillations by using advanced techniques of coherence analysis and statistical significance tests. The performance of the standard Matlab mscohere algorithms is compared versus high resolution coherence analysis methodologies such as the canonical correlation analysis. The Matlab mscohere function highlights large coherence peaks at 20 and 60-year periods although, due to the shortness of the global surface temperature record (1850–2014), the statistical significance of the result depends on the specific window function adopted for pre-processing the data. In fact, window functions disrupt the low frequency component of the spectrum. On the contrary, using the canonical correlation analysis at least five coherent frequencies at the 95% significance level are found at the following periods: 6.6, 7.4, 14, 20 and 60 years. Thus, high resolution coherence analysis confirms that the climate system can be partially modulated by astronomical forces of gravitational, electromagnetic and solar origin. A possible chain of the physical causes explaining this coherence is briefly discussed.

Keywords: Planetary oscillations; Solar oscillations; Climate oscillations; Coupling between planetary, solar and climate oscillations; Advanced method of spectral coherence analysis

1. Introduction

The planets and the sun generate the gravitational and electromagnetic fields present in our solar system. Because the orbital movements of the planets is periodic and highly synchronized (Scafetta, 2014a), a component of these forces varies harmonically. As a result, oscillations in the sun and, directly or indirectly, in the atmosphere–ocean system could emerge yielding specific climatic oscillations (cf.: Mörner, 2013; Mörner et al., 2013). A collective synchronization of coupled oscillators, where weak periodic forces can synchronize an entire system to specific internal or external forcing frequencies, may be involved in this complex process (cf. Strogatz, 2009).

Indeed, a planetary theory of solar and climate oscillations has been proposed since antiquity by a large number of authors such as Ptolemy et al. (1940), Ma'Sar (886) and Kepler (1979). All ancient civilizations advocated it based on their observations of the sky and understanding of geophysical and sociological phenomena (cf. Temple, 1998).

For example, the existence of a complex solar and lunar influence on the tidal system has been well-accepted since antiquity and today it is established science. The tidal phenomenon is studied in details at multiple time scales (cf. Wang et al., 2012). When in the 19th century the 11-year solar cycle was discovered, Wolf (1859) commented that the variations of the spot-frequencies could depend on the influences of Venus, Earth, Jupiter and Saturn.

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Milankovitch (1930)'s orbital oscillations are today well-known to induce periodic climatic glaciations (cf. Roe, 2006). Numerous evidences for a solar influence on the climate at multiple scales are also well-known (e.g. Hoyt and Schatten, 1997). More recently, several authors have advocated a planetary theory of solar and climate oscillations on shorter scales (e.g. Abreu et al., 2012; Charvátová, 2009; Cionco and Soon, 2015; Hung, 2007; Jakubcová and Pick, 1986; Jose, 1965; McCracken et al., 2013, 2014; Mörner et al., 2013; Mörner, 2015; Puetz et al., 2014; Salvador, 2013; Solheim, 2013; Tan and Cheng, 2013; Tattersall, 2013; Wilson, 2013), which includes some of my studies (e.g. Scafetta, 2010; Scafetta, 2012a,b; Scafetta, 2014a; Scafetta and Willson, 2013a,b; Scafetta et al., 2013).

Several of the latter studies have pointed out that solar dynamics appears to be the result of interfering harmonic modes coherent to planetary harmonics. The proposed planetary-based solar harmonic models have reconstructed and hindcast several features of solar variability during the last 1000 years and during the entire Holocene. For example, these models have been able to approximately reconstruct the 11-year solar cycle variation using a combination of the orbits of Venus, Earth, Jupiter and Saturn (Hung, 2007; Salvador, 2013; Scafetta, 2012a,b; Wilson, 2013). By doing so, these models have hindcast the occurrence of grand solar minima such as the Maunder, Dalton and others, a quasi millennial solar oscillation, and have forecast a new grand solar minimum by 2030 (cf. Mörner, 2015). Also alternative studies (e.g. Shepherd et al., 2014) have argued that solar activity could be made of interfering harmonic modes that should yield a grand-minimum around 2030.

A coupling between planetary oscillations and climate change must necessarily involve a complex and long chain of physical mechanisms that are being investigated in the scientific literature. First, gravitational and electromagnetic planetary forces need to partially modulate solar activity: some authors have proposed how this can happen (e.g. Abreu et al., 2012; Scafetta, 2012b; Wolff and Patrone, 2010). The variation of solar activity would then modulate both total solar irradiance and, probably more importantly, the intensity and the dynamics of the solar wind and of the cosmic ray flux. The latter influence the ionization level of the atmosphere (e.g. Svensmark, 1998; Kirby, 2007) and the Earth's electric circuit and, consequently, modulate cloud formation and regulate the Earth's albedo (Tinsley, 2008; Svensmark et al., 2009; Svensmark et al., 2012). Finally, an astronomically induced albedo variation could easily induce climatic variations. In fact, if the Earth's albedo oscillates by just a few percent driven by astronomical forcings, the resulting oscillations should be sufficient to induce the observed climatic oscillations because these are of the order of a fraction of Celsius degree. The hypothesis that, together with the more traditionally accepted solar irradiance forcing (cf. Hoyt and Schatten, 1997), there might be a particle-based astronomical forcing of the atmospheric chemistry partially modulated by oscillations coherent to the planetary ones, is confirmed by the fact that planetary oscillations have been observed also in aurora's records since 1600 (Scafetta and Willson, 2013a).

However, evaluating the statistical significance of the empirical result is complicated. While basic astronomy determines accurately the major gravitational oscillations of the solar system due to the planetary revolution around the sun, the analysis of the climate is more problematic. Any coupling between astronomical and climate records could be masked by non-linearities, errors of measure and by a climatic variability driven by alternative internal and anthropogenic mechanisms, which are typically non-harmonic. To reduce the uncertainty, long and accurate global climatic records should be analyzed so that the non-harmonic climatic components could be filtered out and the hypothesized harmonic astronomical component could emerge more clearly. Yet, accurate global climatic records are short (about 165-year long) and, therefore, spectral coherence evaluations can be ambiguous (cf. Scafetta, 2014a).

Scafetta (2014a, Fig. 5) used the JPL's HORIZONS Ephemeris system to calculate the wobbling and the speed of the Sun from 12 December 8002 BC to 24 April 9001 AD to demonstrate that the major gravitational oscillations of the solar system are approximate harmonics of a 178.4-year base period: that is the period of the planetary harmonics is about $P_n \approx 178.4/n$ year with $n = 1, 2, 3 \ldots$ (cf. Jakubcová and Pick, 1986). For example, two major oscillations of the solar system already noted since antiquity (Ma'Sar, 886; Kepler, 1606) are the quasi 20-year conjunction period of Jupiter and Saturn and their quasi 60-year trigon, which are the 9th and 3rd harmonic of the 178.4-year base period, respectively, while the orbital periods of the four Jovian planets (Jupiter, 11.86 year; Saturn, 29.46 year; Uranus, 84.01 year; and Neptune, 164.8 year) are roughly the 15th, 6th, 2nd and 1st harmonics of the 178.4-year base period. Thus, the climate could be expected to be modulated by a large number of close astronomically-induced frequencies, as already well-know to occur for the tidal system (cf. Wang et al., 2012).

A major statistical problem usually encountered in natural science is that spectral analysis is able to solve close frequencies and their beats only if the analyzed record has a minimum length of the same order of magnitude of the base period of the harmonic generating sequence. Therefore, because a relevant set of astronomical frequencies is made of harmonics of a 178.4-year base period, a minimum spectral resolution of about $1/178.4\ \text{year}^{-1}$ is required for a significant analysis. Unfortunately, the 165-year long climatic record is of the same order of magnitude of the 178.4-year base period. Thus, to determine unambiguously the statistical confidence of the spectral results could require the adoption of advanced techniques of analysis because such an outcome could be algorithm dependent.