Pattern Recogn. Phys., 1, 107–116, 2013
www.pattern-recogn-phys.net/1/107/2013/
doi:10.5194/prp-1-107-2013

Pattern Recognition in Physics
Open Access

Planetary beat and solar–terrestrial responses

N.-A. Mörner

Paleogeophysics & Geodynamics, Saltsjöbaden, Sweden

Correspondence to: N.-A. Mörner (morner@pog.nu)

Received: 10 September 2013 – Revised: 23 October 2013 – Accepted: 24 October 2013 – Published: 1 November 2013

Abstract. Solar activity changes with time in a cyclic pattern. The origin of those changes may be caused by planetary motion around the Sun, affecting the position of the Sun's motion with respect to the centre of mass and subjecting the Sun to changes in angular momentum and gravitational tidal forces. With modern achievements, this multi-body problem can now be addressed in a constructive way. Indeed, there are multiple criteria suggesting that the solar variability is driven by a planetary beat also affecting a number of terrestrial variables: ^{14}C and ^{10}Be production, Earth's rotation, ocean circulation, paleoclimate, geomagnetism, etc. The centennial changes between grand solar maxima and minima imply that we will soon be in a new solar minimum and, in analogy with past events, probably also in Little Ice Age climatic conditions.

1 Introduction

The geocentric model of the Universe can be regarded as the world's first and oldest model. It was presented in the middle of the 3rd century BC by Eudoxus of Cnidus and Aristotle. In the fully developed Aristotelian system, the spherical Earth is at the centre of the universe, and all other heavenly bodies (the Moon, Sun, planets and stars) are attached to 47–56 transparent concentric spheres, which rotate around the Earth (at different uniform speeds to create the rotation of bodies around the Earth). This model came to dominate science and Christian religion (where it was even elevated to a dogma) for 1800 yr until Copernicus in 1543 revealed that it was all totally wrong and the Sun must be in the centre – the heliocentric concept was re-established. In the three Keplerian laws, Kepler (1619) defined the planetary motions along very strict elliptical paths. Still in 1633, Galilei faced inquisition for his belief in the heliocentric concept. In the 1970s, it was realized (although suggested before; e.g. José, 1965) that the true centre of our planetary system is the centre of mass (CM), which even the Sun has to move around in response to the planetary beat (Landscheidt, 1976, 1979). The evolution in ruling concept over the last 2500 yr is illustrated in Fig. 1.

Although Rudolf Wolf himself proposed that the sunspot cycle was driven by the impact from Venus, the Earth, Jupiter and Saturn (Wolf, 1859) and this was further discussed by de la Rue et al. (1872), it took a century until the planetary beat theory became seriously considered (e.g. Bureau and Craine, 1970; Wood, 1975; Kuklin, 1976; Mörth and Schlamminger, 1979).

Others (e.g. Okal and Anderson, 1975) have reported the absence of any tidal effects from the planets on the Sun, the solar orbital motions being another thing, however.

2 A multi-body problem

Our solar–planetary system is a perfect example of the multi-body problem, which in principle means that the interaction of all the bodies involved – the Sun, the planets, their moons – is unsolvable with respect to gravitational interaction and individual motions.

Still, it was understood that this interaction might affect the solar activity (e.g. Mörth and Schlamminger, 1979) as well as the Sun's motion with respect to the centre of mass (e.g. José, 1965; Landscheidt, 1976).

2.1 Qualitative approaches

Personally, I tried to express these effects in different qualitative ways (Mörner, 1984a, Figs. 1 and 13; 1984b, 2013a) as illustrated in Fig. 2.

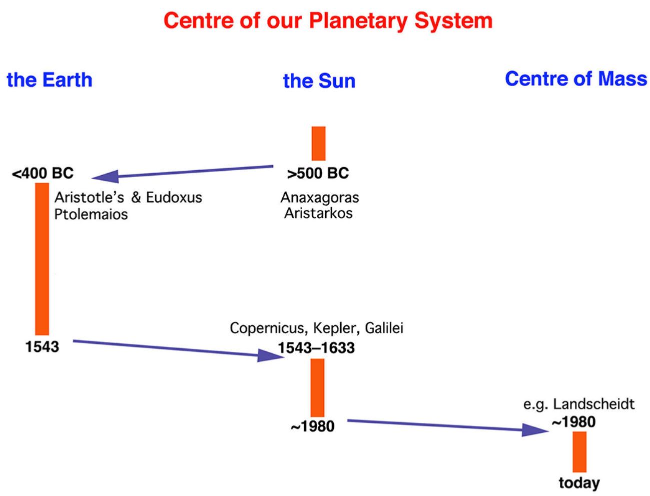

Figure 1. Changes in leading concepts of the centre of our planetary system (from Mörner, 2006).

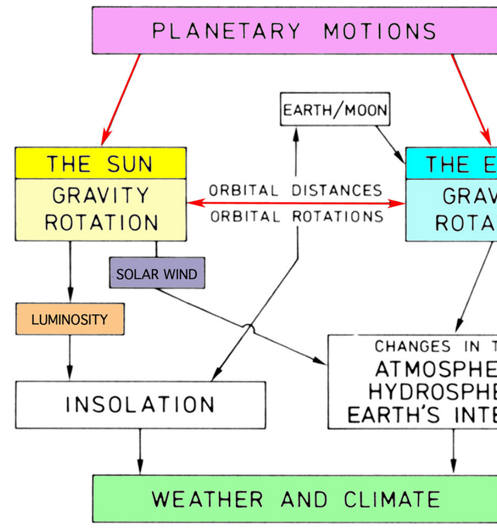

Figure 2. Planetary beat on the Sun and the Earth (rightly the Earth–Moon system) and various lines by which weather and climate may be affected (from Mörner, 1984a).

2.2 Extraterrestrial climate stress

Fairbridge (1984) formulated the situation as follows:

Extraterrestrial climate stress is applied to the planet Earth by four deterministic processes:

1. Planetary orbital motions, dominated by Jupiter and Saturn, transmit momentum by gravitational torques, causing changes in velocity and spin rate to successive planets and the Sun itself. On Earth, spin rate changes appear to trigger seismicity and volcanicity (and therefore dust veils).

2. The Sun accordingly develops its own mini-orbit around the systemic barycentre, with abrupt changes in its acceleration and turning angle that are expressed in the 11 and 22 yr solar cycle of sunspots, electromagnetic radiation of particles and particulate emission that reach the Earth and beyond as the "solar wind".

3. The Earth's geomagnetic field is modulated by the solar wind, which triggers geochemical reactions within the gases of the upper atmosphere.

4. Lunar tidal cycles, identified in many terrestrial climate series, develop standing waves in the atmosphere and help to trigger major seismic and volcanic events with contribution to the dust veil. The 18.6 yr nodal periodicity also corresponds to a nutation of the precession parameter and is commensurable in turn with the basic cycles of category 1.

2.3 Modern achievements

Obviously, we were on to something in the 1980s, but we could not yet quantify the effects. With modern achievements in statistics and computer modelling, the situation has changed considerably in theory (e.g. Wang, 1991; Diacu, 1996) as well as in practice (e.g. Scafetta, 2010, 2013a; Abreu et al., 2012).

"Is there a chronometer hidden in the Sun", Dicke asked (1978), and in opposition Wilson (2011) asked: "Do periodic peaks in the planetary tidal forces acting upon the Sun influence the sunspot cycle?". I think we are now ready to say no to Dicke and yes to Wilson, and add the following: it is an effect of the planetary beat acting upon the Sun.

3 The planetary beat

The multi-body interaction of the planetary motions on the Sun's motion is so large that the Sun's motion around the centre of mass is perturbed by up to about 1 solar radius. The planetary beat also includes the transfer of angular momentum and tidal forces (Fig. 2; further dealt with in this volume; e.g. Jelbring, 2013; Solheim, 2013; Tattersall, 2013).

The motions of the Sun around the centre of mass – in response to the planetary beat – follow cyclic pattern of 79 yr (Landscheidt, 1979) in close agreement with the main sunspot cycle over the last 2200 yr (below; Jelbring, 1995), 179 yr (José, 1965; Fairbridge and Shirley, 1987; Charvatova, 1995) not really recorded in sunspot records (Jelbring, 1995; Abreu et al., 2012) and 2160 yr (Charvatova, 1995), which may relate to the somewhat unclear Hallstatt cycle of about 2400 yr (e.g. Vasiliev and Dergachev, 2002).

The 11 yr solar cycle is well synchronized with the alignment of Venus, Earth and Jupiter (Hung, 2007; cf. Wolf, 1859; Mörth and Schlamminger, 1979; Wilson, 1987; Wilson et al., 2008; Scafetta, 2010). According to Scafetta (2010) Jupiter, Saturn, Uranus and Neptune all modulate solar dynamics (cf. Mörth and Schlamminger, 1979). According to Fairbridge (1984) and Fairbridge and Sanders (1995a), the principle cycle generated by the planets is the Saturn–Jupiter lap of 19.857 yr. Scafetta (2010) showed that the orbital periods of Jupiter and Saturn generate significant gravitational oscillation cycles of ~20 and ~60 yr. A 9.1 yr cycle refers to the Moon's orbital cycle (Scafetta, 2010). This, however, is also the cycle of solar flares according to Landscheidt (1984).

As for the longer term effects from Jupiter and Saturn, Scafetta (2012) finds "major beat periods" of about 61, 115, 130 and 983 yr. Steinhilber et al. (2007) found major power peaks in the radionuclides record of the last 9400 yr of 86, 207, 499 and 978 yr (cf. McCracken et al., 2013). Abreu et al. (2012) "estimated the planetary torque exerted on the tachocline" and found peaks at 88, 104, 150, 208 and 506 yr, which all correlated well with similar peaks in the radionuclides record of the last 9400 yr.

4 The solar variability

The variation in the solar activity is a well-established fact, and the solar–terrestrial linkage has been addressed in numerous papers (Fairbridge and Sanders, 1995b). The Schwabe–Wolf (11 yr), Hale (22 yr), Gleissberg (88 yr) and de Vries (208 yr) cycles have all become widely recognized; their driving forces are still far from solved, however.

Observations of the changes in solar activity are limited to the last 400 yr. By considering a number of different indirect observations, Schove (1955) was able to extend the record back to 649 BC. Jelbring (1995) analysed Schove's data from 300 BC up to 1990. He found the date to be "of high quality concerning sunspot cycle length and phase information … at least 2200 yr back in time". He identified seven cycles of 200, 133, 79, 50, 42, 33 and 29 yr length.

Because the intensity of the heliomagnetic field controls the galactic cosmic ray in-fall to the upper atmosphere and hence the production of the ^{10}Be and ^{14}C radionuclides, the solar activity can be reconstructed over 9400 yr or more by recording the variability of those isotopes in different terrestrial time series (e.g. Bard et al., 2000; Solanki et al., 2004; Usoskin et al., 2007; Steinhilber et al., 2007; Abreu et al., 2012; McCracken et al., 2013).

4.1 The planetary hypothesis

The idea that the planetary beat affects and controls the solar activity is old. Generally, it was held that the impact was too small to drive solar variability. The planets may perturb the solar dynamo, however, and the effects are then likely to become amplified by some internal mechanism (Abreu et al., 2012; cf. Scafetta, 2012b).

Abreu et al. (2012; cf. Steinhilber et al., 2007) were able to show that there is an "excellent spectral agreement between the planetary tidal effects acting on the tachocline and the solar magnetic activity". This is illustrated in Fig. 3. It implies a benchmark in the planetary–solar research. The planetary hypothesis took an important step towards a planetary theory.

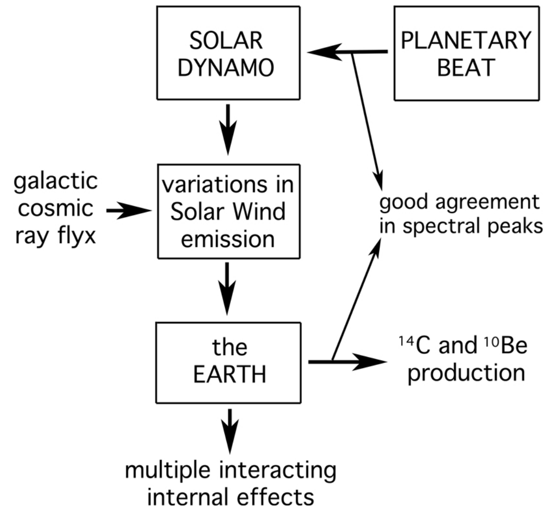

Figure 3. The planetary beat on the solar dynamo generates changes in the solar magnetic emission which controls the galactic cosmic ray flux and hence the production of ^{14}C and ^{10}Be in the Earth's upper atmosphere. The relations are evidenced by the good agreement in spectral peaks between planetary beat and production of ^{14}C and ^{10}Be (as shown by Abreu et al., 2012; these relations are further discussed and developed in Sect. 5.3).

4.2 The tachocline

The tachocline (Spiegler and Zahn, 1992; Hughes et al., 2012) seems to be the sensitive zone picking up and amplifying the planetary signals (as proposed by Abreu et al., 2012). The stratification of the outer 50 % of the Sun is illustrated in Fig. 4.

According to Scafetta (2012b), however, the Sun may operate like a nuclear fusion reactor with the capacity of amplifying the planetary tidal force signals.

5 The terrestrial responses

Planet Earth and the coupled Earth–Moon system are affected by four different solar–planetary variables, viz.

1. Transfer of heat (luminosity, irradiance) from the Sun to the Earth;

2. Solar wind interaction with the Earth's magnetosphere (Mörner, 1996a, 2012, 2013a);

3. Solar–planetary gravity interaction with the coupled Earth–Moon system;

4. Transfer of angular momentum to the coupled Earth–Moon system.

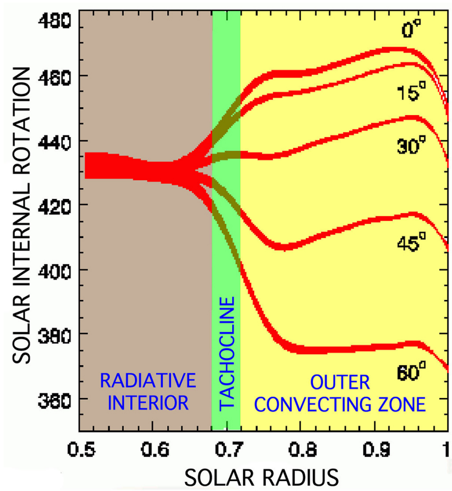

Figure 4. The tachocline at about one-third depth (~0.7) in the Sun separates the rigidly rotating inner part from the differentially rotating and convecting outer part generating variations in sunspots and solar flares, and the emission of solar wind.

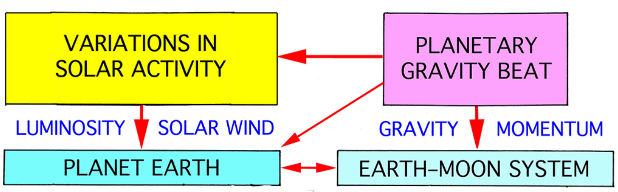

Figure 5. Planetary beat affects the Earth and the Earth–Moon system via luminosity, solar wind, gravity and momentum. Changes within the Earth–Moon system may also affect the Sun (as further discussed in Sects. 5.4 and 5.6).

This is illustrated in Fig. 5 (cf. Fig. 2). The planetary beat may hence affect the Earth both directly via its gravity pulse and indirectly via its effects on the solar dynamo. The 208 yr de Vries cycle has been identified both in the terrestrial cosmogenic radionuclides (cf. above; Abreu et al., 2012) and in the motions within the Earth–Moon system (Wilson, 2013). Consequently, this gives evidence of a twofold effect of the planetary beat; a direct gravity beat on the Earth–Moon system, and a simultaneous beat on the solar dynamo, which, via the solar wind controls of incoming cosmic rays, also controls the production of cosmogenic radionuclides (Fig. 3).

5.1 Internal effects

The cyclic planetary beat affecting the Earth (Figs. 2 and 5) gives rise to a spectrum of different processes within the Earth system. This is illustrated in Fig. 6, and has been separately addressed before (Mörner, 1984a, 1989b, 2010, 2011, 2012, 2013a).

The fact that there is a good correlation between changes in solar activity and changes in Earth's rate of rotation (LOD – length of day) can hardly be understood in other ways than that Earth's spin rate is strongly controlled by the interaction between the solar wind and the magnetosphere (Mörner, 1996a, 2010, 2012, 2013a). This is illustrated in Fig. 6 indicating that variations in solar wind (initiated by the planetary beat) affect the shielding (in-fall of cosmic rays), the geomagnetic field strength, the pressure, the gravity and the rotation.

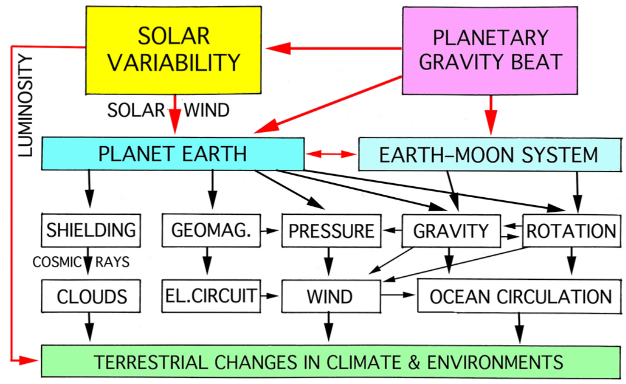

Figure 6. Planetary beat processes and the spectrum of terrestrial variables affected (from Mörner, 2012).

The causation chain – solar wind variations, interaction with the magnetosphere, changes in the Earth's rate of rotation and effects on the ocean circulation – plays a central role according to the present author (Mörner, 1996a, 2010, 2011, 2012, 2013a).

5.2 Geomagnetic field changes

The strength of the magnetospheric field surrounding planet Earth is the combined effect of the interaction of the heliomagnetic field (the solar wind) and the Earth's own internal geomagnetic field. Consequently, it has both an internal and an external component, which together control the deflection of cosmic rays and hence the production of ^{14}C and ^{10}Be in the atmosphere (as illustrated in Fig. 6 of Mörner, 1984b).

Therefore some of the peaks in ^{14}C production and in-fall of ^{10}Be may have an internal origin and hence may not represent a solar activity signal. This should be considered in the spectral analyses of cosmogenic radionuclides (Fig. 3).

The strong ^{14}C peak at 2700 BP, for example, seems to be the direct effect of an internal geomagnetic anomaly (Mörner, 2003). This may well be the case with some of the other peaks, too: for example at 1000–1100 AD when there was a trans-polar geomagnetic shift (Mörner, 1991) and a major change in rotation and ocean circulation (Mörner, 1995).

Therefore, it is interesting to note that Nilsson et al. (2011) determined a 1350 yr cyclicity in the Earth's geomagnetic dipole tilt over the last 9000 yr. This cycle peaked at 2650 BP – i.e. virtually just at the above-mentioned ^{14}C peak and geomagnetic anomaly (Mörner, 2003). Furthermore, there is a close correlation of the dipole tilt and the changes in rotation during the last 3000 yr (Nilsson et al., 2011), indicating that we are dealing with a differential rotation (Fig. 9; cf. Mörner, 1984a, 1996a) between the core and the mantle. The finding that there are two preferential dipole regions in northwestern Russia and northern Canada is consistent with the observation of flux tubes in the core and trans-polar VGP (virtual geomagnetic pole) shift indicating the displacement of the symmetry axis of two rotating bodies (Mörner, 1991).

Neither the ^{10}Be, the ^{14}C, nor the planetary beat have any peaks at around this 1350 yr cycle (McCracken et al., 2013; Tattersall, 2013) indicating that this cycle refers to an internal terrestrial cycle (as suggested by Nilsson et al., 2011). Therefore, these cyclic changes should be removed from the terrestrial cosmogenic nuclide records when trying to reconstruct solar variability from those records (e.g. Bard et al., 2000; Usoskin et al., 2007; Abreu et al., 2012; McCracken et al., 2013).

5.3 Production of cosmogenic radionuclides

The production of ^{14}C and ^{10}Be is a function of the amount of cosmic rays reaching the upper atmosphere. Variations in ^{14}C content in the atmosphere are measured in the deviation between absolute dendrochronological ages and relative radiocarbon ages, known with high accuracy for the last 9500 yr and with reasonable accuracy for the last 12 000 yr. The ^{10}Be content is distributed with precipitation, and its variations are recorded in ice cores, sediment cores, speleothems, etc.

It has often been assumed that the concentration of cosmogenic nuclides is a virtually direct function of solar variability (e.g. Bard et al., 2000; Solanki et al., 2004; Usoskin et al., 2007; Steinhilber et al., 2007; Abreu et al., 2012; McCracken et al., 2013). This is not the case, however.

The production of ^{14}C in the upper atmosphere is a function of the amount of cosmic rays being able to penetrate the magnetosphere, where the variations in shielding capacity are driven both by the solar wind (Sect. 4.1) and the Earth's own geodynamo (Sect. 5.2). This implies a double origin. Furthermore, the concentration of ^{14}C is also affected by the ocean/air ventilation and interchange of isotopes. This implies a third mode of origin. This is illustrated in Fig. 7.

The production of ^{10}Be is a function solar wind and Earth's geodynamo. Its concentration in terrestrial records is strongly controlled by precipitation. Therefore, not even ^{10}Be is a direct measure of changes in solar activity; it is only a proxy.

Therefore, the terrestrial records of ^{14}C and ^{10}Be variations must be split up into their different causation components before they can be used as true records of solar variability and analysed with respect to cyclic behaviour; if not, they only provide relative proxies.

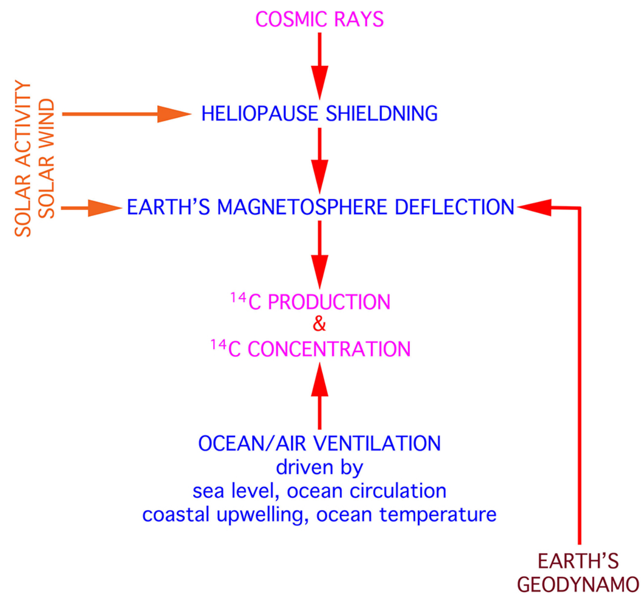

Figure 7. Illustration of the three factors controlling the ^{14}C production and concentration. Not until each factor is quantified, do we have a clear record of the solar variability.

5.4 The Earth–Moon distance

The Earth and the Moon constitute a double planet system in its motions with respect to each other and with respect to the Sun and the other planets of our solar system (i.e. a multi-body system as discussed above). The barycentre in the Earth–Moon system is located in the Earth's mantle at a depth of about 1700 km below the surface.

The Earth's rate of rotation is constantly changing. These changes must be compensated in the Earth–Moon distance (Dicke, 1966) or by interchange of angular momentum within the terrestrial system (Mörner, 1984a, 1987, 1989b, 1996a).

Dicke (1966) showed that the postglacial sea level rise after the last glaciation had to lead to a general deceleration, which had to be compensated for within the Earth–Moon system by an increased distance between the two bodies. Therefore, Mörner (1995) transferred the sea level curve of the last 30 000 yr into a curve of the changes in Earth's rate of rotation: a speed-up at the build-up of the 20 ka glaciation maximum and sea level fall to a maximum speed of an about 1800 ms higher speed at the glaciation maximum when sea level was about 120 m lower than today, and a deceleration during the sea level rise in response to the glacial melting from about 18 000 to 6000 C14 yr BP (about 22 000 to 6800 cal. yr BP). These changes had, of course, to be compensated in the Earth–Moon distance to keep the total momentum constant. When this general deceleration had finished, the Earth came into another mode dominated by regular interchanges of angular momentum between the

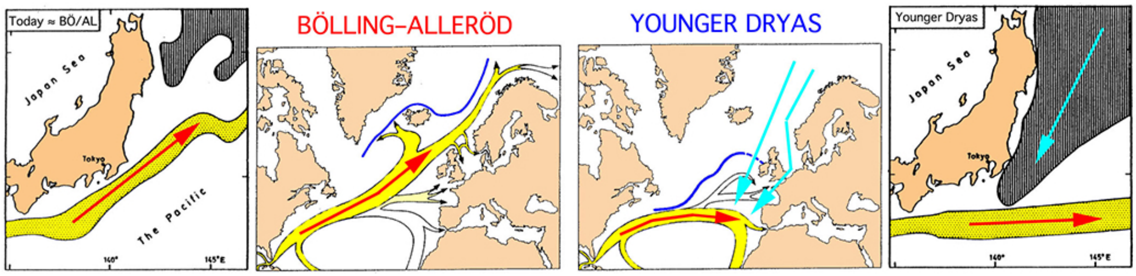

Figure 8. The strong ocean current changes in the Atlantic (middle) and in the Pacific (sides) in association with the BÖ/AL and YD high-amplitude changes in climate (based on Mörner, 1996b). These changes must be coupled with corresponding interchanges of angular momentum between the solid Earth and the hydrosphere (Mörner, 1993).

solid Earth and the hydrosphere (Mörner, 1984a, 1987, 1988, 1995, 1996a, 2013a).

The general glacial eustatic rise in sea level can be approximated by two superposed exponential curves (Mörner and Rickard, 1974). During the transitional period 13–10 C14 ka BP or 16–11.5 cal. ka BP, a sequence of extreme events occurred (Mörner, 1993): the geomagnetic pole made a sudden trans-polar shift, the onset of central uplift of Fennoscandia indicating a deformation of the gravitational potential surface; climate first underwent a sudden high-amplitude amelioration with a sudden swing of the Gulf Stream high up into the northeast Atlantic reaching into the Barents Sea, and then a high-amplitude cooling (the well-known Younger Dryas (YD) event) with extensive glacial expansion, a polar-front displacement to mid-Portugal and with large distances deflections of the Gulf Stream as well as the Kuro Siwo Current towards the Equator (Fig. 8). These changes are far too large and rapid to be understood in terms of solar variability itself. Therefore, Mörner (1993) proposed that it perhaps might be understood in terms of the strong deceleration and a delay in its compensation in the Earth–Moon system, so that it instead had to be compensated by anomalous displacements of the water masses: first to high latitudes (generating the Bölling–Alleröd warm phase – BÖ/AL) and then to low latitudes (generating the Younger Dryas cold phase). Therefore, the high-amplitude changes at around 13–10 C14 ka BP appear like the beat on a cord (Mörner, 1993).

The high-amplitude changes of the BÖ/AL warm period and the YD cold period are also recorded in the production of ^{14}C (e.g. Hughen et al., 2000; Muscheler et al., 2008). The BÖ/AL period has a low ^{14}C production due to strong shielding and high solar activity, whilst the YD period has a high ^{14}C production due to weak shielding and low solar activity (as illustrated in Fig. 7). This implies that changes in solar activity are involved in the climatic changes of the BÖ/AL and YD periods. Therefore, it seems we are facing a double origin – an internal and an external – of the high-amplitude changes within the period 16–11.5 cal. ka BP.

The question now arises of weather we can combine the internal and external factors. Indeed, Jelbring (2013) has proposed that changes in the Earth–Moon system may affect the solar activity. This opens the possibility of a cause–response relationship as follows: changes in the Earth's rotation affect the Earth–Moon system (and related parameters), which affects the solar activity.

5.5 Earth's differential rotation

The Earth consists of many different layers and sub-layers, which may move with respect to each other (Mörner, 1984a, 1987, 1988, 1996a), which, in principles, act as a multi-body system (cf. Sect. 2).

First of all it is an interchange of momentum between different layers (Fig. 9) where one speed-up has to be compensated by another slow-down in order to keep the total angular momentum constant. I have made much effort on the interchange of angular momentum between the hydrosphere (the ocean circulation) and the solid Earth, which strongly affects regional sea level (the redistribution of water masses) and climate (the redistribution of ocean-stored heat). This is well recorded in the El Niño–Southern Oscillation changes (Mörner, 1988, 1989b, 1996a, 2012), in the climatic–eustatic 60 yr cycle (cf. below; Sect. 5.7), in the atmosphere/ocean 60 yr changes (Wyatt and Curry, 2013), and the general centennial changes in ocean circulation (Mörner, 1984a, 1995, 1996a, 2010). Differential rotation between the core and the mantle has been discussed by several authors (e.g. Hide, 1970; Cortillot et al., 1978; Mörner, 1980; Braginskiy, 1982; Roberts et al., 2007; Livermore et al., 2013).

An excellent and direct example of the interchange of angular momentum between the solid Earth (LOD) and the hydrosphere comes from the 2004 Sumatra earthquake and tsunami in the Indian Ocean. In response to the tsunami wave, the solid Earth speeded up by 2.68 ms. Similarly, at the 2011 Japan earthquake the Earth speeded up by 1.8 ms.

Secondly, this internal multi-layer system, of course, sensitively picks up gravitational and rotational signals from the Sun, the planets and the Moon as illustrated in Figs. 5 and 6.

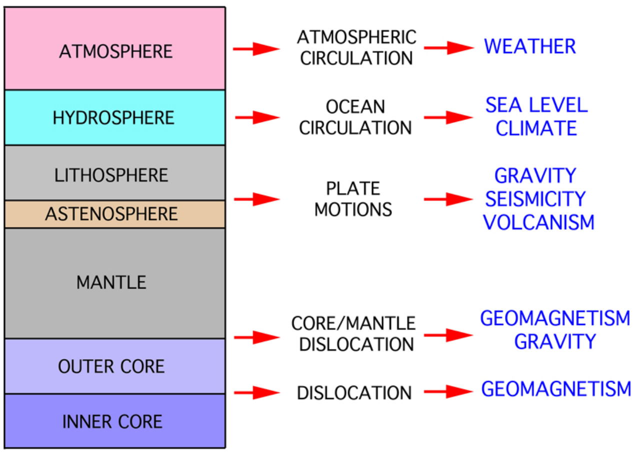

Figure 9. The Earth consists of several layers and sub-layers, which experience differential rotation with interchange of angular momentum (Mörner, 1984a, 1987, 1989b). Ocean circulation changes generate sea level changes and changes in climate (Mörner, 1989b, 1995, 2010, 2013a). Differential rotation is partly generated from internal sources (feedback interchange of angular momentum) and partly from external sources (gravitational and rotational impact from the Sun, the planets and from the Moon).

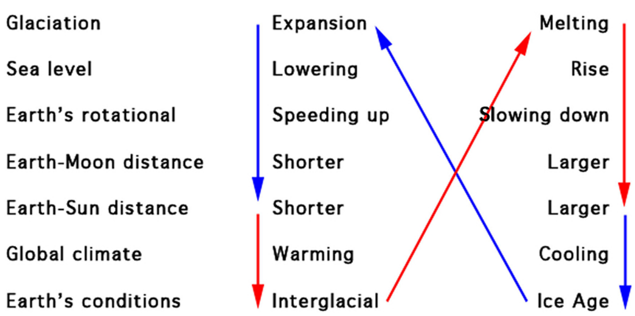

Figure 10. Hypothetical chain effects of changes in glaciation, sea level and rotation, and their effects on Earth's rotation and by that the Sun–Earth distance (Mörner, 1984b).

5.6 The Sun–Earth distance

The postglacial sea level rise and linked general rotational deceleration must be compensated as discussed above (Sect. 5.4). It should also be compensated in Earth's orbital velocity and/or the Sun–Earth distance (Mörner, 1984b, Fig. 4). According to Mörner "one may therefore hypothesize that the Earth's climate could be strongly influenced by this in some sort of feed-back mechanism" as illustrated in Fig. 10.

Even if the glacial/interglacial alterations are primarily driven by the Milankovitch variables (e.g. Roe, 2007), the Fig. 10 mechanism may imply an additional effect to account for in the Sun–Earth and planetary–Earth interactions, and hence merit at least mentioning in this volume.

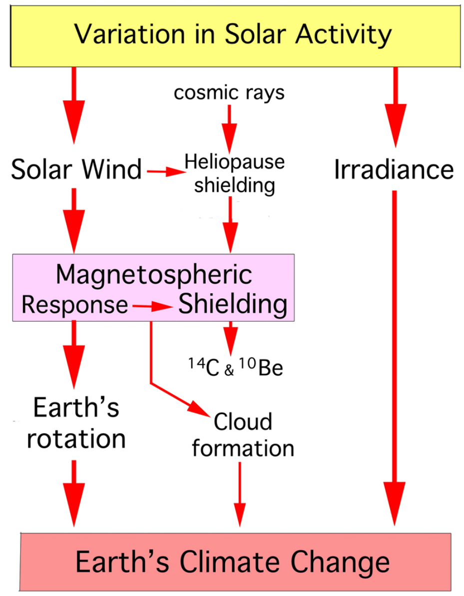

Figure 11. Three ways of affecting Earth's climate all ultimately driven by planetary beat cycles (slightly modified from Mörner, 2010, 2011).

5.7 Climatic changes

Without the constant heat energy supply from the Sun (the luminosity or irradiance), there would have been no life on planet Earth. The variations in solar activity seem to follow strict cyclic patterns. The driving forces for those cycles seem to be found in the planetary beat.

An alternative way of affecting Earth's climate is the multiple effects of the solar wind interaction with the magnetosphere, and, not least, its effects on Earth's rate of rotation and by that the ocean circulation (Mörner, 1996a, 2010, 2011, 2012, 2013a).

A third way of affecting climate is via the cloud formation as a function of cosmic ray flux (Svensmark, 1998, 2007; Svensmark et al., 2013).

These three ways of affecting Earth's climate are illustrated in Fig. 11.

According to Scafetta (2010, 2013a), the beat of Jupiter and Saturn generates a 60 yr cycle, which is also present in global temperature records (close to the 65–70 yr global temperature cycle of Schlesinger and Ramankutty, 1994). The 60 yr cycle is recorded in the atmospheric circulation (Mazzarella, 2007; Wyatt and Curry, 2013), different oceanic parameters (in ocean circulation by Mörner, 2010, 2013a; in the Gulf Stream beat by Mörner, 2010, 2013a; in Barents Sea fish catch by Klyashtorin et al., 2009; in sea level changes by Chambers et al., 2012; Mörner, 2013b; Parker, 2013 and Scafetta, 2013b), in climate (e.g. Akasofu, 2013), in rotation (e.g. Mazzarella, 2007) and in geomagnetics (Braginskiy, 1982; Roberts et al., 2007). This cycle is not present in the cosmogenic radionuclide records, however (Abreu et al., 2012, Fig. 5). Therefore, its origin may be a direct gravitational effect on the Earth–Moon system and the differential rotation of the Earth (Figs. 5–6; Mörner, 1884a, 2013a), rather than an effect of solar wind interaction with the Earth's magnetosphere. In the power spectrum of the cosmogenic changes according to Bard et al. (2000), there is a peak at 63–66 yr (Scafetta, 2012a), implying that a solar wind origin cannot be ruled out, however.

5.8 Grand minima

At the Spörer, Maunder and Dalton solar minima, the Earth experienced a rotational speed-up (decreased LOD), a deflection of the Gulf Stream to its southern course and a southward penetration of Arctic water all the way down to mid-Portugal (Mörner, 1995, 2010, 2011). This generated Little Ice Age conditions in the Arctic, northern Atlantic and northwest Europe. At around 2030–2050, we will be in a new grand minimum situation (as evidenced by a large number of authors: e.g. Mörner, 2010, 2011; Cionco and Compagnucci, 2012; Casey and Humlum, 2013; Salvador, 2013). The driving forces seem to be the planetary beat and its effects on the solar activity, and the effects of the solar wind upon the Earth (Fig. 6). During previous solar minima, the Earth experienced Little Ice Age climatic conditions. Therefore, we may once again experience such climatic conditions when the new grand minimum occurs (Mörner, 2010, 2011).

6 Conclusions

The planetary motion generates a beat on the Sun in the form of gravity (tidal force), angular momentum and motions with respect to the centre of mass. This beat generates cyclic changes in the Sun's activity. The sensitive zone in the Sun is likely to be the tachocline.

The changes in solar activity control the solar luminosity (irradiance) and solar wind emission, both factors of which affect the Earth as illustrated in Figs. 6 and 11.

The planetary beat also affects the Earth–Moon system directly via tidal forces and angular momentum.

The correlation between changes in solar activity and Earth's rate of rotation (LOD) seems primarily to be a function of the solar wind interaction with the magnetosphere.

At the next solar minimum, to occur around 2030–2050, there might be a return to Little Ice Age climatic conditions (as was the case during the Dalton, Maunder and Spörer minima).

The planetary beat hypothesis has become a theory. There is, of course, much more to learn, decode and improve, but the theory is here to stay.

Edited by: S.-A. Ouadfeul
Reviewed by: J.-E. Solheim and one anonymous referee

References

Abreu, J. A., Beer, J., Ferriz-Mas, A., McCracken, K. G., and Steinhilber, F.: Is there a planetary influence on solar activity?, Astron. Astrophys., A88, 1–9, 2012.

Akasofu, S.-I.: On the present halt of global warming, Climate, 1, 4–11, 2013.

Bard, E., Raisbeck, G., Yiou, F., and Jouzel, J.: Solar irradiance during the last 1200 years based on cosmogenic nuclides, Tellus, 52B, 985–992, 2000.

Braginskiy, S. I.: Analytical description of the secular variations of the geomagnetic field and the rate of rotation of the Earth, Geomagn. Aeronomy, 22, 88–94, 1982.

Bureau, R. A. and Craine, L. B.: Sunspots and planetary orbits, Nature, 228, 984, doi:10.1038/228984a0, 1970.

Casey, J. and Humlum, O.: Global Climate Status Report for 2013, Space and Science Research Corporation (SSRC), September 2013, 1–15, www.spaceandscience.net, 2013.

Chambers, D. P., Merrifield, M. A., and Nerem, R. S.: Is there a 60-year oscillation in global mean sea level, Geophys. Res. Lett., 39, L18607, doi:10.1029/2012GL052885, 2012.

Charvatova, I.: Solar-terrestrial and climatis variability during the last several millennia in relation to solar intertial motion, in: Climate: History, Periodicity and Predictability, edited by: Rampino, M. R., Sanders, J. E., Newman, W. S., and Königsson, L. K., van Nostrand Reinhold, 1343–1354, 1995.

Cionco, R. G. and Compagnucci, R. H.: Dynamicas characterization of the last prolonged solar minima, Adv. Space Res., 50, 1434–1444, 2012.

Copernicus, N.: De revolutionibus orbium coelestium, 1543.

Cortillot, V., Ducroix, J., and Le Mouel, J.-L.: Sur une acélérationrécente de la variation séculaire du champmagnétique terrestre, C.R. Acad. Sci. Paris, 287, 1095–1098, 1978.

de la Rue, W., Stewart, B., And Loewy, B.: Further investigations on planetary influence upon solar activity, http://tallbloke.wordpress.com/2012/11/06, 1872.

Diacu, F.: The solution of the n-body problem, Math. Intell., 18, 66–70, 1996.

Dicke, R. H.: The secular acceleration of the Earth's rotation and cosmology, in: The Earth–Moon system, edited by: Marsden, B. G. and Cameron, A. G., 98–164, Plenum Press, NY, 1966.

Dicke, R. H.: Is there a chronometer hidden in the Sun?, Nature, 276, 676–680, 1978.

Fairbridge, R. W.: Planetary periodicities and terrestrial climate stress, in: Climatic Changes on a Yearly to Millennial Basis, edited by: Mörner, N.-A. and Karlén, W., 509–520, Reidel Publ. Co. (Dordrecht/Boston/Lancaster), 1984.

Fairbridge, R. W. and Sanders, J. E.: The Sun's orbit, A.D. 750–2050: Basis for new perspectives on planetary dynamics and Earth-Moon linkage, in: Climate: History, Periodicity and Predictability, edited by: Rampino, M. R., Sanders, J. E., Newman, W. S., and Königsson, L. K., 446–471, van Nostrand Reinhold, 1995a.

Fairbridge, R. W. and Sanders, J. E.: Selected bibliography on Sun–Earth relationships and cycles having periods less than 10,000 years, in: Climate: History, Periodicity and Predictability, edited by: Rampino, M. R., Sanders, J. E., Newman, W. S., and Königsson, L. K., 475–541, van Nostrand Reinhold, 1995b.

Fairbridge, R. W. and Shirley, J. H.: Prolonged minima and the 179-yr cycle or the solar inertial motion, Sol. Phys., 110, 191–220, 1987.

Galilei, G.: Mumbling "E pur si muove" (sic movit) at facing the inquisition in 1633.

Hide, R.: Interaction between the Earth's liquid core and solid mantle, Nature, 222, 1055–1056, 1970.

Hughen, K. A., Southon, J. R., Lehman, S. J., and Overpeck, J. T.: Synchronous radiocarbon and climate shifta during the last deglacialtion, Science, 290, 1951–1954, 2000.

Hughes, D. W., Rosner, R., and Weiss, N. O.: The Solar Tachocline, Cambridge Univ. Press, 2012.

Hung, C.-C.: Apparent relations between solar activity and solar tides caused by the planets, Report NASA/TM-2007-214817, http://gltrs.grc.nasa.gov/Citations.aspx?id=330S, 2007.

Jelbring, H.: Analasis of sunspot cycle phase variations – based on D. Justin Schove's proxy data, J. Coastal. Res., S.I. 17, 363–369, 1995.

Jelbring, H.: Energy transfer in the Solar System, Pattern Recogn. Phys., in preparation, 2013.

José, P. D.: Sun's motion and sunspots, Astron. J., 70, 193–200, 1965.

Kepler, J.: Harmonice mundi, 1619.

Klyashtorin, L. B., Borisov, V., and Lyubushin, A.: Cyclic changes of climate and major commercial stocks of the Barents Sea, Mar. Biol. Res., 5, 4–17, 2009.

Kuklin, G. V.: Cyclical and secular variations in solar activity, in: Basic Mechanisms of Solar Activity, edited by: Bumba, V. and Kleczek, J., IAU Symp. 71, 147–190, Reidel Publ. Co., 1976.

Landscheidt, T.: Beziehungen zwischen der Sonnenaktivität und dem Massen-zentrum des Sonnensystem, Nachr. Olders-Ges. Bremen, 100, 2–19, 1976.

Landscheidt, T.: Swinging Sun, 79-year cycle, and climate change, J. Interdiscipl. Cycle, 12, 3–19, 1979.

Landscheidt, T.: Cycles of solar flares and weather, in: Climatic Changes on a Yearly to Millennial Basis, edited by: Mörner, N.-A. and Karlén, W., 473–481, Reidel Publ. Co. (Dordrecht/Boston/Lancaster), 1984.

Livermore, P. W., Hollerbach, R., and Jackson, A.: Elecromagnetically driven westward drift and inner-core superrotation in Earth's core, P. Natl. Acad. Sci., 110, 15914–15918, 2013.

Mazzarella, A.: The 60-year solar modulation of global air temperature: the Earth's rotation and atmospheric circulation connection, Theor. Appl. Climatol., 88, 193–199, 2007.

McCracken, K. G., Beer, J., Steinhilber, F., and Abreu, J.: A phenomenological study of the cosmic ray variations over the past 9400 years, and their implication regarding solar activity and solar dynamo, So. Phys., 286, 609–627, 2013.

Mörner, N.-A.: Eustasy and geoid changes as a function of core/mantle changes, in: Earth Rheology, Isostasy and Eustasy, edited by: Mörner, N.-A., 535–553, Wiley (Chichester/New York/Brisbane/Toronto), 1980.

Mörner, N.-A.: Planetary, solar, atmospheric, hydrospheric and endogene processes as origin of climatic changes on the Earth, in: Climatic Changes on a Yearly to Millennial Basis, edited by: Mörner, N.-A. and Karlén, W., 483–507, Reidel Publ. Co. (Dordrecht/Boston/Lancaster), 1984a.

Mörner, N.-A.: Terrestrial, solar and galactic origin of the Earth's geophysical variables, Geogr. Ann., 66A, 1–9, 1984b.

Mörner, N.-A.: Short-term paleoclimatic changes; observational data an a novel causation model, in: Climate; History, Periodicity and Predictability, edited by: Rampino, M. R., Sanders, J. E., Newman, W. S., and Königsson, L.-K., 256–269, van Nostrand Reinhold Co, 1987.

Mörner, N.-A.: Terrestrial variations within given energy, mass and momentum budgets; Paleoclimate, sea level, paleomagnetism, differential rotation and geodynamics, in: Secular Solar and Geomagnetic Variations in the Last 10,000 Years, edited by: Stephenson, F. R. and Wolfendale, A. W., 455–478, Kluwer Acad. Press, 1988.

Mörner, N.-A.: Global Change: The lithosphere: Internal processes and Earth's dynamicity in view of Quaternary observational data, Quaternary Int., 2, 55–61, 1989a.

Mörner, N.-A.: Changes in the Earth's rate of rotation on the El Niño to century basis, in: Geomagnetism and Paleomagnetism, edited by: Lowes, F. J. et al., 45–53, Kluwer Acad. Press, 1989b.

Mörner, N.-A.: Trans-polar VGP shifts and Earth's rotation, Geophysics Astrophysics Fluid Dynamics, 60, 149–155, 1991.

Mörner, N.-A.: Global change: the high-amplitude changes 13–10 ka ago – novel aspects, Global Planet. Change, 7, 243–250, 1993.

Mörner, N.-A.: Earth rotation, ocean circulation and paleoclimate, GeoJournal, 37, 419–430, 1995.

Mörner, N.-A.: Global Change and interaction of Earth rotation, ocean circulation and paleoclimate, An. Brazilian Acad. Sc., 68 (Supl. 1), 77–94, 1996a.

Mörner, N.-A.: Earth rotation, ocean circulation and paleoclimate: the North Atlantic–European example, Geol. Soc. Spec. Publ., 111, 359–370, 1996b.

Mörner, N.-A.: The 2700 BP solar-terrestrial signal, EGS-AGU-EUG meeting, Nice, 6–11 April, Abstracts ST1, 2003.

Mörner, N.-A.: 2500 years of observations, deductions, models and geoethics, Boll. Soc. Geol. It., 125, 259–264, 2006.

Mörner, N.-A.: Solar Minima, Earth's Rotation and Little Ice Ages in the Past and in the Future. The North Atlantic – European case, Global Planet. Change, 72, 282–293, 2010.

Mörner, N.-A.: Arctic environment by the middle of this century, Energy & Environment, 22, 207–218, 2011.

Mörner, N.-A.: Planetary beat, Solar Wind and terrestrial climate, in: Solar Wind: Emission, Technology and Impacts, edited by: Escaropa, C. D. and Berós Cruz, A. F., 47–66, Nova, 2012.

Mörner, N.-A.: Solar Wind, Earth's rotation and changes in terrestrial climate, Physical Review & Research International, 3, 117–136, 2013a.

Mörner, N.-A.: Sea level changes: past records and future expectations, Energy & Environment, 24, 509–536, 2013b.

Mörner, N.-A. and Rickard, D.: Quantitative analyses of eustatic changes and climate cycles, Colloque Int. CNRS, 219, 142–153, 1974.

Mörth, H. T. and Schlamminger, L.: Planetary motions, sunspots and climate, in: Solar-Terrestrial influences on Weather and Climate, edited by: McCormac, B. M. and Seliga, T. A., 193–207, Reidel Publ. Co, 1979.

Muscheler, R., Kromer, B., Björck, S., Svensson, A., Friedrich, M., Kaiser, K. F., and Southon, J.: Tree rings and ice cores reveal ^{14}C calibration uncertainties during the Younger Dryas, Nat. Geosci., 1, 263–267, 2008.

Nilsson, A., Muscheler, R., and Snowball, I.: Millennial scale cyclicity in the geodynamo inferred from dipole reconstructions, Earth Planet. Sc. Lett., 311, 299–305, 2011.
Okal, E. and Anderson, D. L.: On the planetary theory of sunspots, Nature, 253, 511–513, 1975.
Parker, A.: Natural oscillations and trends in long-term tide gauge records from the Pacific, Pattern Recogn. Phys., 1, 11–23, doi:10.5194/prp-1-11-2013, 2013.
Roberts, P. H., Yu, Z. J., and Russell, C. T.: On the 60-year signal from the core, Geophys. Astro. Fluid, 101, 11–35, 2007.
Roe, G.: In defense of Milankovitch, Geophys. Res. Lett., 33, L24703, doi:10.1029/2006GL027817, 2007.
Salvador, R. J.: A mathematical model of the sunspot cycle for the past 1000 years, Pattern Recogn. Phys., in preparation, 2013.
Scafetta, N.: Empirical evidence for a celestial origin of the climate oscillations and its implications, J. Atmos. Sol.-Terr. Phy., 72, 951–970, 2010.
Scafetta, N.: Multi-scale harmonic model for solar and climate cyclical variation throughout the Holocene based on Jupiter-Saturn tidal frequencies plus the 11-year solar dynamo cycle, J. Atmos. Sol.-Terr. Phy., 80, 296–311, 2012a.
Scafetta, N.: Does the Sun work as a nuclear fusion amplifier of planetary tidal forcing? A proposal for a physical mechanism based on the massluminosity relation, J. Atmos. Sol.-Terr. Phy., 81–82, 27–40, 2012b.
Scafetta, N.: Solar and planetary oscillation control on climate change: hind-cast, forecast and comparison with the CMIP5 GCMS, Energy & Environment, 24, 455–496, 2013a.
Scafetta, N.: Discussion on common errors in analyzing sea level accelerations, solar trends and global warming, Pattern Recogn. Phys., 1, 37–57, doi:10.5194/prp-1-37-2013, 2013b.
Schlesinger, M. E. and Ramankutty, N.: An oscillation in the global climate system of period 65–70 years, Nature, 367, 723–726, 1994.
Schove, D.: The sunspot cycle, 649 BC to AD 1986, J. Geophys. Res., 60, 127–146, 1955.
Solanki, S. K., Usoskin, I. G., Kromer, B., Schüssler, M., and Beer, J.: An unusually active Sun during recent decades compared to the previous 11,000 years, Nature, 431, 1084–1087, 2004.
Solheim, J. E.: Signals from the planets, via the Sun to the Earth, Pattern Recogn. Phys., in preparation, 2013.
Spieger, E. and Zahn, J.-P.: The solar tachocline, Astron. Astrophys., 265, 106–114, 1992.
Steinhilber, F., Abreu, J. A., Beer, J. et al.: 9,400 years of cosmic radiation and solar activity from ice cores and tree rings, P. Natl. Acad. Sci., 109, 5967–5971, 2007.
Svensmark, H.: Influence of cosmic rays on Earth's climate, Phys. Rev. Lett., 81, 5027–5030, 1998.
Svensmark, H.: Cosmoclimatology: A new theory emerges, Astron. Geophys., 48, 1.18–1.24, 2007.
Svensmark, H., Enghoff, M. B., and Pedersen, J. O. P.: Response of cloud condensation nuclei (> 50 nm) to change in ion-nucleation, Phys. Lett., A377, 2343–2347, 2013.
Tattersall, R.: Are solar variation and terrestrial climate influenced by the spatio-temporal distribution of mass in the Heliosphere?, Pattern Recogn. Phys., in preparation, 2013.
Usoskin, I. G., Solanki, S. K., and Kovaltsov, G.A .: Grand minima and maxima of solar activity: new observational constrains, Astron. Astrophys., 471, 301–307, 2007.
Vasiliev, S. S. and Dergachev, V. A.: The ~2400-year cycle in atmospheric radiocarbon concentration: bispectrum of ^{14}C data over the last 8000 years, Ann. Geophys., 20, 115–120, doi:10.5194/angeo-20-115-2002, 2002.
Wang, Q.: The global solution of the n-body problem, Celes. Mech. Dyn. Astr., 50, 73–88, 1991.
Wilson, I.: Connecting the 208 year de Vries cycle with the Earth-Moon system, http://tallbloke.wordpress.com/, 22 August, 2013.
Wilson, I. R. G.: Do periodic peaks in the planetary tidal forces acting upon the Sun influence the sunspot cycle?, General Science Journal, 1–25, 2011.
Wilson, I. R. G., Carter, B. D., and Waite, I. A.: Does a spin-orbit coupling between the Sun and the Jovian Planets govern the solar cycle?, Publ. Astronomical Society of Australia, 25, 85–93, 2008.
Wilson, R. M.: On the distribution of sunspot cycle periods, J. Geophys. Res., 92, 10101–10104, 1987.
Wolf, R.: Extract of a letter to Mr. Carrington, Mon. Not. R. Astron. Soc., 19, 85–86, 1859.
Wood, R. M.: Comparison of sunspot periods with planetary synodic period resonances, Nature, 255, 312–313, 1975.
Wyatt, M. G. and Curry, J. A.: Role of Eurasian Arctic shelf sea ice in a secularly varying hemispheric climate signal during the 2oth century, Clim. Dynam., in press, 2013.