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Solar system oscillations and models of natural processes

Boris L. Berry *
505-35 Woodridge Crescent, Ottawa, Ont., Canada K2B 7T5
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Abstract

Tidal and momentum interactions of the bodies of the solar system create stable oscillations of the momenta of inertia of the Sun and planets. The laws of momentum conservation are the reasons for synchronous oscillations, which are observed in geodynamic, solar and climatic processes. The stable harmonics of the processes have to be detected from representative sets of helio-geophysical data. The regular parts of natural processes can be modelled by the sum of the stable harmonics.

Keywords: The solar system; Stable oscillations; Harmonic models; Solar activity; Terrestrial processes

1. Introduction

Stable oscillations exist in geophysical, solar, biological, economical and other processes. The problems of cyclicity are investigated in all space–time scales available to science—from the micro-world to the Universe, from minimal parts of a second to tens of billions of years. If anything unites our world, pride of place must be given to the stable cyclical processes. Millennial tectonic, solar and climatic periods left in their wake the layers with volcanic dust, permafrost and other traces of regular changes of terrestrial processes. Intra- and extra-secular oscillations in natural conditions exert a direct influence on our life; therefore, the importance of research of steady periodic oscillations is obvious (Berry, 1998).

There are theoretical and empirical proofs that momentum interactions of the Sun and large outer planets periodically accelerate the barycenter of the solar system (SS), the Sun and planets (Freeman and Hasling, http://www.wxresearch.org/papers/orbit2004.htm) and create synchronous oscillations in the processes of celestial bodies. As well the solar–lunar tidal forces periodically deform the geoid, change the momentum of the inertia of the Earth and the length of the days (LOD). The latter is the main accurately measurable global geodynamic parameter (http://hpiers.obspm.fr/eop-pc/), which correlates significantly with tectonic and climatic stable oscillations (Berry, 1992). Many problems related to these interactions of the external forces and internal processes could not be solved until now. Thus, the helio-geophysical oscillations have remained theoretically unpredictable and have had to be computed from various sets of observed and reconstructed data.

* Tel.: +1 613 828 5764.
E-mail address: bberri@sympatico.ca.

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2. The regular set of SS oscillations

The long evolution of the SS oscillations related with the interactions of the celestial bodies has led to resonance and commensurabilities in the periods of planet and satellite revolutions. The accuracy of resonance (10^{-3}) approximately equals to a ratio of the mass of the planets to the mass of the Sun (Molchanov, 1966). The periods of the discrete resonance SS can be approximately described by a geometrical progression, which is similar to the geometrical progression for accounting the notes of discrete musical instruments (Bragg, 1968). The latter empirical progression classifies and approximately expresses all main musical frequencies (periods) and their harmonics.

Most of the music we hear is based on a system called 12-tone equal temperament. There are musicians (http://www-math.cudenver.edu/~jstarret/microtone.html) who divide the octave into 19 or 31 equal parts. Taking in account the revolving periods of the planets (9 periods) and the 14 periods of the satellites of heliotidal planets (the Earth and Jupiter) it was empirically found that the intrinsic periods of the SS (T_K) can be expressed better if an octave is divided into 16 equal parts (Berry, 1998):

$$T_K = T_0 \times 2^{K/n} = 0.075 \times 2^{K/16} \quad (1)$$

where T_0 is the sidereal period of the moon revolution in years and K is the sequence of integer numbers. According to the Fisher criteria the discovered regularity of Eq. (1) exists with probability 96%.

This progression (1) contains the planet Jupiter's revolving period (11.86 years) as $T_{117} = 11.89$ years. Using the Jupiter's period, which creates the strongest tidal and momentum oscillations in the SS, as T_0, will result in only a 0.25% difference in T_K. Thus, the lunar resonance period (the revolving period equals the rotational one) is quite representative for the whole SS. As the musical notes the terms of the progression (1) are very convenient for the classifications, descriptions and distinguishes of natural periods of the SS. Eq. (1) will be helpful for investigators of tectonic, solar, climatic, biological and other processes.

3. Models of natural processes

Physical–empirical models for this article were created as approximations of the representative series of the proxy and instrumental records of the natural processes by the sum of stable harmonics. The stable harmonics of solar and terrestrial processes were detected from their series by least squares fit. Random components of the processes or annual uncertainties of the models were expressed as the standard deviations (S.D.) of the natural processes from their models.

3.1. The model of global seismicity (MGS)

The main reason for the activation of earthquakes is solar–lunar tidal waves (http://hpiers.obspm.fr/eop-pc/). The LOD and climate are global parameters (Sidorenkov, 2002). To compare them with tectonic activity we created the series of the GS index S_G and its MGS, index S_{GM} (Berry, 1991). To detect the S_G the Earth's surface was divided into four sectors at the meridians: (1) 0–90°, (2) 90–180°, (3) 180–300° and (4) 300–360°. The annual numbers of earthquakes are calculated separately for the southern and northern parts of the sectors. The Earth's surface was divided into eight regions (R). For each year the index S_G was evaluated:

$$S_G = R_E + \frac{(E - R_E)}{R} \quad (2)$$

where R_E is the number of regions where there was one earthquake or more of them with magnitudes $M > 7.5$, $R = 8$ and E is the number of the earthquakes of $M > 7.5$ for a year. The equation was weighted for the first earthquake in a region weightless for all others. The GS series characterizes the global component of the process (Fig. 1).

The MGS index was detected from the S_G series (1897–1985) by least squares fit (Berry, 1992):

$$S_{GM} = \sum A_j \times \cos\left(2\pi \times \frac{Y}{T_j} - \varphi_j\right) \pm \text{S.D.} = 0.518 \times \cos\left(\frac{2\pi \times (Y - 1897)}{13} - 3.5505\right)$$
$$+0.242 \times \cos\left(\frac{2\pi \times (Y - 1897)}{17} - 2.674\right) + 0.402 \times \cos\left(\frac{2\pi \times (Y - 1897)}{22} - 3.269\right)$$

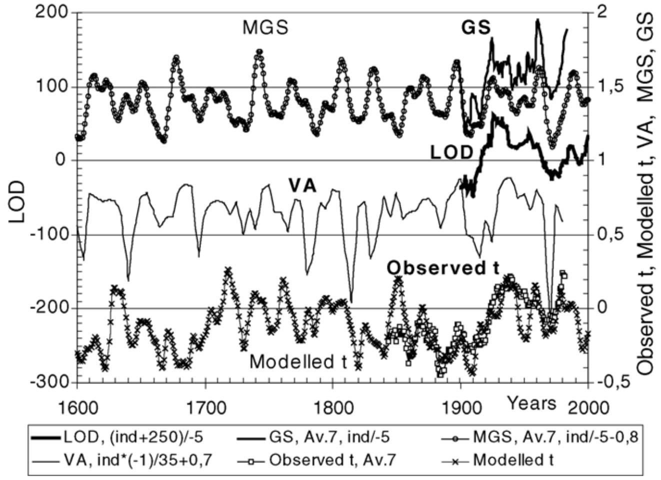

Fig. 1. Tectonic (LOD, GS, MGS, VA, ind) and climatic (observed, t °C, and modelled temperatures, t_{M1} °C) processes for 1600–2000. All tectonic series have reverse form. Av.7 is the 7-year average values.

$$+0.760 \times \cos\left(\frac{2\pi \times (Y-1897)}{31} - 3.127\right) + 0.325 \times \cos\left(\frac{2\pi \times (Y-1897)}{63} - 1.230\right) \pm 0.384 \quad (3)$$

where Y are Gregorian years and A_j, T_j and φ_j are amplitudes, periods in years and phases in radians.

The levels of significance (LS) are smaller than 0.001 for correlation coefficients between all series for the 20th century including the LOD and observed hemisphere temperature anomalies t °C (Vinnikov et al., 1987). From 1600 to 2000, the LS are also smaller than 0.001 for the correlation coefficients between the MGS and Volcanic Aerosols (VA) (Zielinski et al., 1994) and between the VA and modelled temperature t_{M1} °C (Fig. 1).

3.2. The model of sunspot numbers (MSSN)

The MSSN was detected from the indexes I_{SSN} of Hale cycles (http://www.kms.dk/fags/ps11sidc.htm):

$$I_{MSSN} = 2 + 86.932 \times \cos\left(\frac{2\pi \times (Y-1473.8)}{22.046}\right) + 31.0473 \times \cos\left(\frac{2\pi \times (Y-1473.8)}{17.92}\right) \pm 34.6 \quad (4)$$

The periods of oscillations 22.0 years ($T_{131} = 21.8$) and 17.9 years ($T_{126} = 17.6$) create the pulsation with $T_{166} = 99.3$ years (1). The correlation coefficient between the MSSN and SSN is $r = 0.86$ with LS $\ll 0.001$ for 1700–2001. The 11-year cold temperature anomalies coincide with the even Wolf cycles (the negative parts of the Hale cycles) and sometimes with the cycles of tectonic activity (Fig. 2).

3.3. The model of northern hemisphere temperature anomalies (t_{M1} °C)

The model t_{M1} °C was detected from the detrended tree-ring series (1656–1967) (Berry, 1992):

$$t_{M1} = -0.1 + 0.101 \times \cos\left(\frac{2\pi \times (Y-1660)}{230} - 2.787\right) + 0.06129 \times \cos\left(\frac{2\pi \times (Y-1660)}{105} - 4.623\right)$$
$$+ 0.09768 \times \cos\left(\frac{2\pi \times (Y-1660)}{73} + 1.346\right) + 0.04236 \times \cos\left(\frac{2\pi \times (Y-1660)}{55} - 4.206\right)$$
$$+0.0712 \times \cos\left(\frac{2\pi \times (Y-1660)}{44} - 1.57\right) + 0.04959 \times \cos\left(\frac{2\pi \times (Y-1660)}{27} - 0.143\right)$$
$$+0.1015 \times \cos\left(\frac{2\pi \times (Y-1660)}{22} - 4.344\right) + 0.0529 \times \cos\left(\frac{2\pi \times (Y-1660)}{18} - 3.278\right)$$

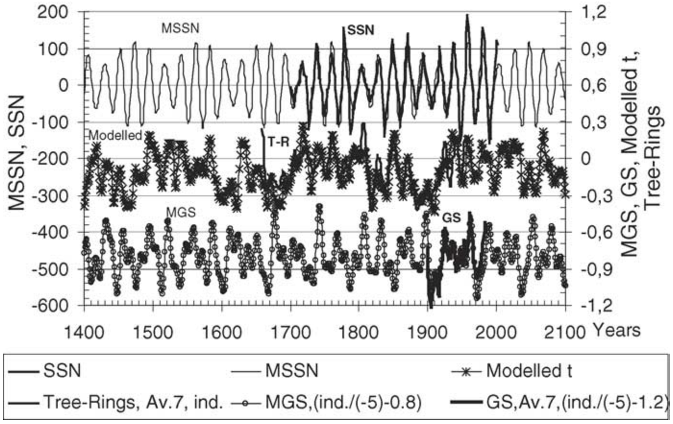

Fig. 2. Tectonic (MGS, GS, ind.), climatic (modelled temperatures, t_{M1} °C, tree-ring (T-R), ind.) and solar (MSSN, SSN, ind.) processes for 1400–2100. Av.7 is the 7-year average values.

$$+0.04172 \times \cos\left(\frac{2\pi \times (Y-1660)}{15} + 0.18\right) + 0.03811 \times \cos\left(\frac{2\pi \times (Y-1660)}{11} - 0.216\right)$$
$$+0.02545 \times \cos\left(\frac{2\pi \times (Y-1660)}{9} - 2.345\right) + 0.02226 \times \cos\left(\frac{2\pi \times (Y-1660)}{7} - 2.619\right) \pm 0.204 \quad (5)$$

The zero line corresponds to the 1951–1975 mean of the t °C. The model includes 12 SS harmonics T_j (T_K, years) (1): 230 ($T_{185} = 226$), 105 ($T_{167} = 104$), 73 ($T_{159} = 73.3$), 55 ($T_{152} = 54.2$), 44 ($T_{147} = 43.6$), 27 ($T_{136} = 27.1$), 22 ($T_{131} = 21.8$), 18 ($T_{126} = 17.6$), 15 ($T_{122} = 14.8$), 11 ($T_{115} = 10.9$), 9 ($T_{110} = 8.78$), 7 ($T_{105} = 7.07$).

The correlation coefficient between the t_{M1} (5) and tree-ring series is $r = 0.755$ for 1659–1964 (Fig. 2), with $r = 0.685$ between t_{M1} °C and t °C for 1844–1982 (Fig. 1), 0.37 between t_{M1} °C and SSN for 1700–2001 and 0.602 between t_{M1} °C and GS for 1899–1983 (Fig. 2). The LS is small (<0.001) for all the coefficients.

In Fig. 2 we see highly significant correlations between t_{M1} °C and MSSN for the reconstructed and observed interval 1400–2000: $r = 0.344$, LS $\ll 0.001$, and for the prediction interval 2001–2100: $r = 0.446$, LS < 0.001. There are also confidence correlations (LS < 0.001) between t_{M1} °C and MGS: $r = -0.138$ for 1400–2100 and -0.286 for 1900–2100.

The many temperature anomalies could be explained by the simultaneous influences of the variations of the SSN and GS. The frequency spectrum of the tectonic processes has common and different harmonics with the solar activity spectrum. That is why the anomalies of the VA sometimes coincide with anomalies of the SSN and sometimes they have opposite directions (Fig. 2). In the former case they increase amplitudes of temperature variations and we see resonance climatic oscillations in 1620–1665, 1715–1735, 1790–1825, 1840–1900 and 1925–1980, in the latter case (1600–1620, 1665–1715, 1735–1790, 1825–1840 and 1900–1925) they decrease temperature variations and the correlations between solar activity and climate. The air temperatures depend on many other processes (Sidorenkov, 2002). So the t_{M1} °C is more complicated than the sum of the MSSN and MGS (Fig. 2).

4. The correlations between hemisphere temperatures (t_{M1} °C) and regional seismicity

Zonal (quasi-horizontal) and meridional (quasi-vertical) stresses of the lithosphere generate strong earthquakes inside and outside the latitudinal belt ±40° with the periods about 40.0 years (Mogi, 1985). In fact, this cycle connects with the double 18.6-year lunar declination period 37.2 years ($T_{143} = 36.7$ (1)). The time borders of the tectonic activity in the belt coincide well with maximum (28.5°) declinations (1894–1913, 1931–1950, 1968–1987 and 2006–2024) and can be predicted.

There are compressions in the lithosphere along NW–SE and along SW–NE axes in the transition zone with latitudes 40–50°, for example, in the Vrancea tectonic area (46°) of the Carpathians (Enescu and Enescu, 1999, http://www.rcep.dpri.kyoto-u.ac.jp/%7Ebenescu/SelectedAbs.html#Work2). The hemisphere temperatures decrease if

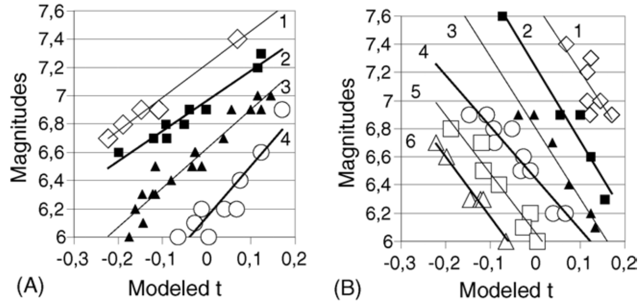

Fig. 3. Correlations between magnitudes (M) of the Vrancea earthquakes and amplitudes of the modelled temperatures t_{M1} °C for: (A) warming-up (zonal stresses) and (B) cooling-off (meridional stresses) tendencies.

the meridional circulations happen more often and the LOD become longer. When the LOD is shorter zonal and rare meridional circulations increase the temperatures (Sidorenkov, 2002). Thus, we can compare the modelled temperatures t_{M1} °C (taking in account Mogi's period ∼38 years) and magnitudes (M) of earthquakes in a representative region.

For the counting experiment we selected the 46 Vrancea's earthquakes with $M \geq 6.0$, which happened in 1400–2000 (Kutas et al., 2001). The M and calculated from 38-year running mean zero line amplitudes of the modelled temperatures t_{M1} °C compared for the same years (Fig. 3). We received two different types of the trend lines between the M and temperature amplitudes associated with the quasi-horizontal (Fig. 3A) and quasi-vertical (Fig. 3B) components of the destructed stresses.

The levels of significance among the series are reasonably small, LS < 0.01 for A1, <0.05 for B1 and <0.001 for the rest correlation lines. Highly significant correlations between these two series of independently calculated data tell us not only about the common reasons for the tectonic and atmospheric processes but also about the high quality of the reconstructed seismic and modelled climatic data.

5. Reconstructions, verifications and predictions

The modelled t_{M1} °C (5) compared with the 7-year running-mean series (Mann et al., 1998): $r = 0.416$ for 1403–1977, and with the 20-year running-mean series of the reconstructed hemisphere temperatures (Cook et al., 2004): $r = 0.280$ for 1000–1992. The LS < 0.001 for these correlation coefficients. The curves capture many of the same decadal scale events. The latter reconstruction contains periods: 515 years ($T_{204} = 515.3$ (1)) and 1029 years ($T_{220} = 1030.5$ (1)). If we add these periods to our model (5) we will have a new model:

$$t_{M2} = -0.3895 + 0.2 \times \cos\left(\frac{2\pi \times (Y - 949)}{1029}\right) + 0.2 \times \cos\left(\frac{2\pi \times (Y - 987)}{515}\right) + t_{M1} \tag{6}$$

$R = 0.654$ (LS $\ll 0.001$) between modelled (6) and reconstructed (Cook et al., 2004) temperatures (Fig. 4).

The current warm phase (1920–2035) is a coincidence of the maxima of the periods: 230, 515 and 1029 years. These stable periods and their harmonics were also discovered in the 9600-year series of solar activity variations (Stuiver and Braziunas, 1995). The long periods have repeated many times in history of solar activity since 8000 B.C. Thus,

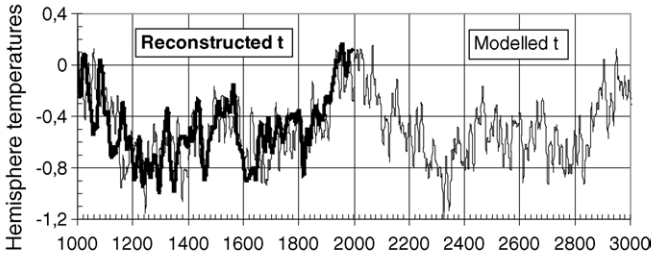

Fig. 4. Reconstructed (Cook et al., 2004) and modelled t_{M2} °C (6) hemisphere temperatures for 1000–3000.

the model (6) can be extrapolated in the future at least for 1000 years. Our small climatic optimum will be cancelled around 2115 (−0.4 °C) and we will have the absolute temperature minimum around 2330 (Fig. 4).

Temperature minimums usually come together with increases in the GS and VA (Figs. 1 and 2). In the warm phase we should expect the strong regional earthquakes in 2006–2024 inside the latitudinal belt ±40° and the activation of the GS ($M > 7.5$) in 2005–2010 (Berry, 1992). The latter activation already began: $M = 7.5$, 2004/11/11 (New Moon 11/12); $M = 8.1$, 2004/12/23; $M = 9.0$, 2004/12/26 (Full Moon 12/26); $M = 8.7$, 2005/03/28 (Full Moon 03/25). The significant GS and VA will be around 2037–2038, 2061–2062, 2074, 2088 and 2100 in the next 115-year cold phase (Fig. 2).

6. Conclusion

Because of the stable oscillations of the SS included in solar and terrestrial processes it is possible to create models of their behaviours and extrapolate regular parts of these processes. The GS (1897–1985) and MGS (1600–2000) series were verified (Fig. 1) by the significant correlations with the LOD series (1900–2000) and the VA series (1600–1980). The strong earthquakes and volcanic eruptions depend not only on periodic tectonic forces, but also on the solidity of the rocks. So, the impulsive processes can happen slightly earlier or later or do not happen at all during the time intervals of maximum stresses. These differences in the dates of local tectonic events do not play a significant role when we investigate 7-year average global data.

The modelled temperature t_{M1} °C series was verified by the correlations with independent temperature reconstructions (Mann et al., 1998; Cook et al., 2004; Fig. 4) and by the correlations with the Vrancea earthquakes (Fig. 3). The MSSN correlates strongly with the Hale cycles of solar activity (1700–2001), with measured (1844–1982) and modelled (1400–2100) hemisphere temperatures (Fig. 2). Thus, these complicated helio-geophysical processes can be modelled by the sum of harmonic series and extrapolated in the time scale 10–1000 years.

The geophysical models automatically include the main oscillations connected with: (A) the primary external periodic actions of the SS related with the momentum and tidal interactions of the planetary system and solar–lunar tidal forces, which have an influence on the Earth, its core and strata, (B) the secondary external periodic actions of solar activity, which have an influence on the magnetosphere, atmosphere, biosphere and the surfaces of the Earth, (C) the primary internal periodic processes in the terrestrial solid and fluid strata and (D) the secondary terrestrial interactions and feedbacks, which change the amplitudes of the primary processes.

Therefore, regular oscillations of solar and terrestrial processes depend on the dynamic and geometrical characteristics of the solar system. Terrestrial processes depend also on the solar activity, the solar–lunar tidal forces, on the movements of the terrestrial inner core, processes in all fluid and solid strata and feedback. The absence of precise knowledge or the physical–chemical models, which quantitatively explain all these solar and terrestrial processes, does not hamper the frequency analysis of the series, their approximation and the creation of the harmonic models of the processes.

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