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Interactive comment on "Multi-millennial-scale solar activity and its influences on continental tropical climate: empirical evidence of recurrent cosmic and terrestrial patterns" *by* J. Sánchez-Sesma

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Planetary gravitational forcing (PGF) of solar activity (SA) has been considered by many solar researchers (see references in the main part). However, numerical simulations of this forcing have been analyzed by only a few of them. For instance, Abreu et al. (2012) analyzed the PGF of solar tides.

In this comment, we compare the lateral (perpendicular to movement) forces evaluated by lateral accelerations of the solar movement around the solar system (SS) barycenter

(BC) with TSI reconstructed and extrapolated (based on the detected recurrences) records. Our work is motivated by the findings from Fairbridge and Shirley (1987) who predicted the initiation of a Maunder-type prolonged minimum on the basis of a study of solar motion with respect to the SS-BC in the years from 760 to 2100 AD. Their study detected "patterns" in solar orbits associated with different levels of SA.

In order to analyze variability in both solar dynamics and solar activity, we studied data coming from: a) lateral forces (F) of the sun due to planetary gravitational forces and movements, reconstructed and forecasted by JPL/NASA from 3000 BC to 3000 AD, and b) solar activity expressed in the total solar irradiance (TSI) average from three reconstructed records over the last millennia and extrapolated for the next millennia (all shown in Figures 3a). These records are displayed in Figure C2.1.

Lateral (perpendicular to movement) forces were evaluated based on X, Y and Z coordinates and derivatives provided by the HORIZONS (H) system from the Jet Propulsion Laboratory/NASA (JPL/NASA) for the past 5000 and future 1000 years, every 90 days, where the XY plane is the ecliptic plane centered on the BC. As an approximation, solar movement was considered only in the XY plane, and normal acceleration in this plane was evaluated to be perpendicular to the tangential direction of solar movement. These on-line solar system data and ephemeris computation services provide accurate ephemerides for solar system objects.

The simulated lateral inertial forces (F) are considered to provide gravitational influences on solar activity. In order to enhance their low-frequency oscillations, we applied the double integral function to the analyzed F record.

An integration was applied twice to the Solar signal, S(t), as follows:

See Figure C2.10 (1a) See Figure C2.10 (1b)

where, S(t) is the solar signal, expressed as force (F(t)) or total irradiance (T(t)), is its time integral, t is time, t0 is initial time (1000 AD year), N is the successive application number, and and are the long-term averages of S(t) and , respectively.

We apply equations 1a and 1b to these two records in order to enhance low-frequency variations. Results are displayed in Figure C2.2. The double integral of forces F, , is almost explained (99.9 % of variance) by a sine function of a 9400 yr oscillation, which is also displayed in Fig. C2.2a. The double integrated solar activity also shows a periodicity of ~9500 yrs. The scales of these enhanced solar signals are inverted because the sign is changed due to the double integration enhancement. A comparison of both curves is displayed in Figure C2.3a. Figure C2.3b also displays both integrated curves, however the curve is leaded 6700 yrs.

In order to verify this 6700 yr lag of the TSI response to the F oscillation of a 9500 yr period, we look for two other similar pairs of periods and lags (P/L). In order to obtain an additional pair of P/L, we analyze the lateral force F and solar activity TSI over the 1000-3000 AD period. We applied a double integration (Eq. 1) and a polynomial detrending process to F. The and its trend is shown in Figure C2.4. The detrended is compared with the TSI record, and oscillations of ~950 yrs are detected, together with a lag of ~350 yrs of TSI with respect to the supposed forcing F. These two variables are displayed in Figure C2.5

Another pair of P/L values is evaluated with the Hale SSN cycle of ~22 years that shows an alternating magnetic sign for each 22 yrs. It is compared with the Fourier series (with only 2 harmonics) of the force, F, signal based on the period from 1700 to 2000 AD. The comparison, depicted in Figure C2.5, indicates a lag of less than 1 year.

The three sets of L/P pairs are 1/22, 350/950 and 6700/9500 yrs, respectively. These three pairs, which correspond to different phases, are modeled together with a non-linear function that tends toward a lower limit of 0° for lower periods, and an upper asymptotic limit of 360° (2*Pi radians). The adjusted model for phase variations in terms of period, which is a logarithmic function, is depicted in Figure C2.6.

It is important to emphasize that the results in Figure C2.5 have not only detected an

L/P pair but also confirm the next forecasted Grand Minima (2020-2220 AD) as an unexplained modulation process associated with ~350-yr-lagged-influences of solar lateral forces.

Additionally, we developed two interesting comparisons that show similarity between F and TSI, and self-similarity in TSI. One comparison is for the TSI reconstructed and extrapolated for 2000 yrs. (over the period from 1000 to 3000 AD) and part of the F record (H/JPL) for only 70 years (over the period from 1964 to 2008 AD). This comparison is displayed in Figure C2.7, and shows the clear similarities between these two periods of T and F.

Another comparison is for our enhanced ~9500yr-solar-cycle evaluated previously, with a Fourier series model of the solar SSN cycle with a period of 10.5yrs, based on monthly SSN data from the World Data Center SILSO, Royal Observatory of Belgium, Brussels, over the period from 1964 to 2008. This comparison is displayed in Figure C2.8, and shows the clear self-similarities between these two solar cycles. Both cycles show a shorter increasing period (~25%) than the decreasing period (~45%), and a maximum plateau (~20%), and an almost nonexistent minimum plateau.

Based both on: a) the SS movement reconstruction and simulation, H services, developed by the Solar System Dynamics Group of the JPL/NASA, and b) monthly SSN data from the World Data Center SILSO for the last decades, we have provided more elements to support the idea that long-term solar activity is modulated by recurrent planetary effects. Our analysis have put foreward the following:

1). SS dynamics generate lateral forces (enhanced by) with multi-millennia scale (~9500 yr) oscillations similar to those shown by solar activity (enhanced by); 2) There is a suggested lagged response of around 67 centuries, of solar activity ( ) to the gravitational forcing (lateral force). The maximum forces F precede the maximum solar activity TSI, meaning that increases (decreases) of force F produce lagged increases (decreases) of TSI; 3) The lagged response appears to increase with forcing periods with a non-linear logarithmic function that implies scale influences and possible connections with meridional circulations in different deep layers of the Sun; 4) The similarity of the ∼9500yr TSI with the average SSN 10.5yr cycle, with scales differing at almost three orders of magnitude, suggest a self-similar process with a mechanism possibly linked to gravitational planetary recurrent forces in different scales. 5) The similarity of a 70 yr period of TSI with a smoothed F simulated record for the period from 1000 to 3000 AD, suggests a multi-fractal relation between TSI and its possible forcing F.

REFERENCES

HORIZONS System. Documentation of JPL Horizons (Version 3.75) Apr 04, 2013. ftp://ssd.jpl.nasa.gov/pub/ssd/Horizons_doc.pdf. [Data retrieved at: www.ssd.jpl.nasa.gov/?horizons]

Abreu, J. A., Beer, J., Ferriz-Mas, A., McCracken, K. G., Steinhilber, F., 2012. Is there a planetary influence on solar activity? Astronomy& Astrophysics, 548, A88 (2012) DOI: 10.1051/0004-6361/201219997

SILSO, World Data Center - Sunspot Number and Long-term Solar Observations, Royal Observatory of Belgium, on-line Sunspot Number catalogue: [Data retrieved at: http://www.sidc.be/silso/datafiles].

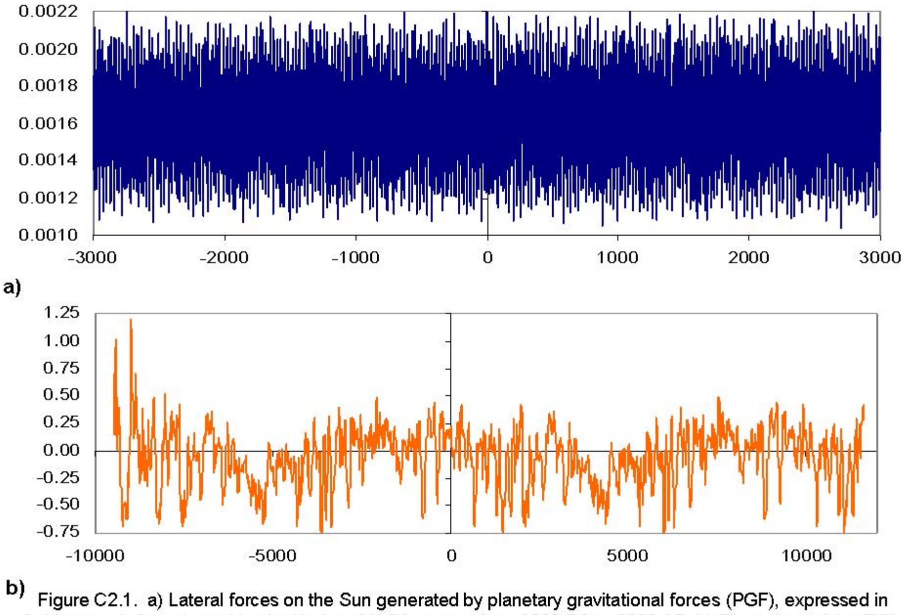

Figure C2.1. a) Lateral forces on the Sun generated by planetary gravitational forces (PGF), expressed in [arbitrary units], evaluated by the Horizon/NASA system from 3000 BC to 3000 AD. b) The solar activity (TSI) expressed in [W/m2], average values of the three reconstructed records over the last millennia and extrapolated for the next millennia (10000 BC to 10000 AD) based on ~9500 yr recurrence (records shown in Figure 3a).

Fig. 1. Figure C2.1

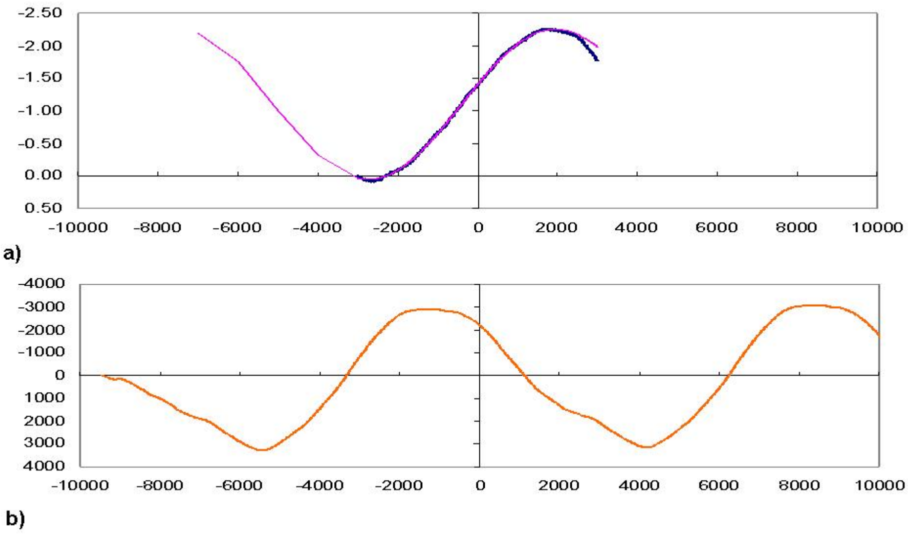

Figure C2.2. a) Double integral of the solar lateral inertial forces $\sigma F_2(t)$ due to the solar movement resulting from the planetary gravitational forces $\sigma T_2(t)$ shown in Figure C2.1.1a, and b) Double integral of the solar reconstructed and extrapolated record shown in Figure C2.1.1b. Vertical scale of values were inverted both in $\sigma F_2(t)$ and $\sigma T_2(t)$ because the double integral procedure changes the sign of the enhanced result. Please note that the last minimum of lateral inertial force F will be expected around 2500 BC and the next minimum of TSI, around 4200 AD.

Fig. 2. Figure C2.2

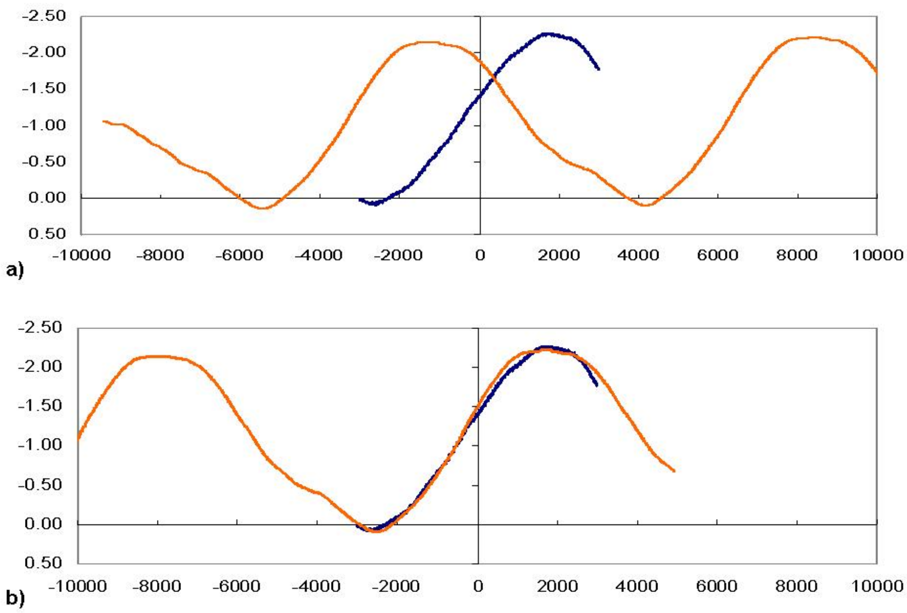

Figure C2.3. A comparison of the double integral of the solar lateral inertial forces $\sigma F_2(t)$ and the solar reconstructed and extrapolated record $\sigma T_2(t)$. To enhance a possible cause-effect relationship $|\sigma F_2(t)$, $\sigma T_2(t)$ the $\sigma T_2(t)$ record is shown a) without and b) with a lead of 6700yrs.

Fig. 3. Figure C2.3

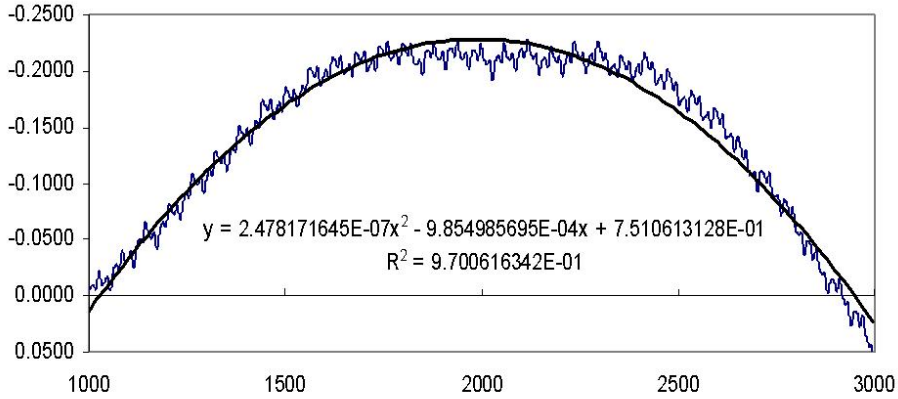

Figure C2.4. The double integral of the solar lateral inertial forces $\sigma F_2(t)$ for the period from 1000 to 3000 AD. A polynomial trend is also depicted.

Fig. 4. Figure C2.4

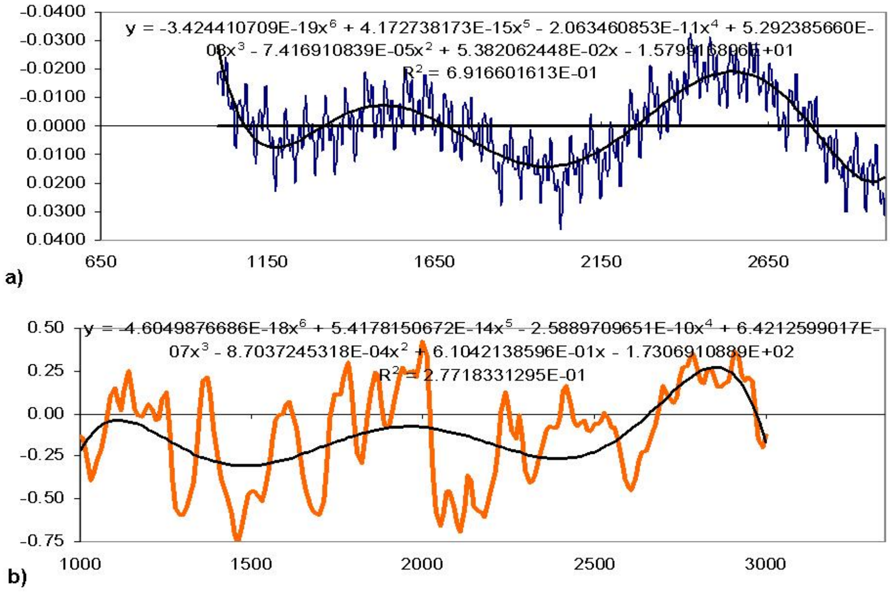

Figure C2.5. A comparison of the double integral of the solar lateral inertial forces $\sigma F_2(t)$ and the solar reconstructed and extrapolated record TSI. To enhance trends, polynomials are adjusted to both records, showing oscillations of ~950 and a lag of ~350 yrs.

Fig. 5. Figure C2.5

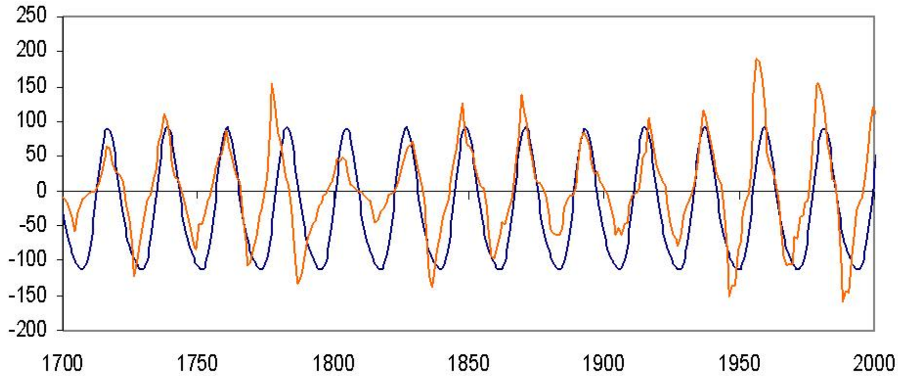

Figure C2.6. A comparison of the Hale solar cycle of SSN and the Fourier Series (with only 2 harmonics) model of the F signal. A lead of 0.5 yrs is applied to the SSN to improve the match with the F recurrent model.

Fig. 6. Figure C2.6

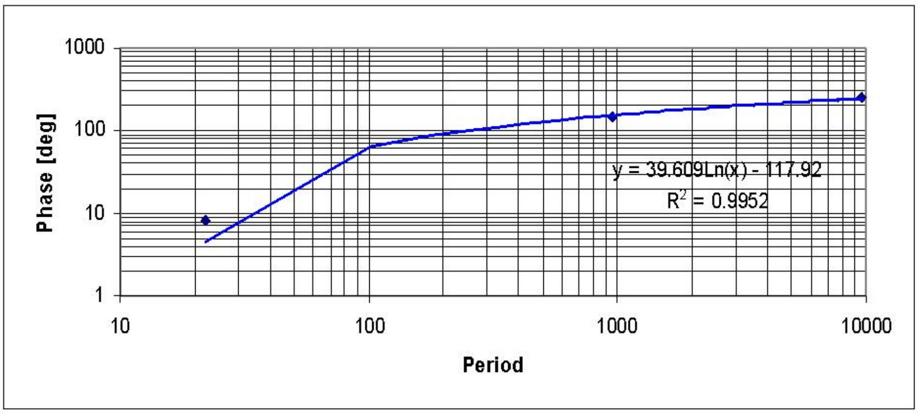

Figure C2.7. A model of phase between F (forcing) and TSI (suggested response) signals for different periods. The adjusted logarithmic model, which explains 99.5 % of the variance, shows two trends, one to zero for short periods and other, an asymptotic one, for long periods.

Fig. 7. Figure C2.7

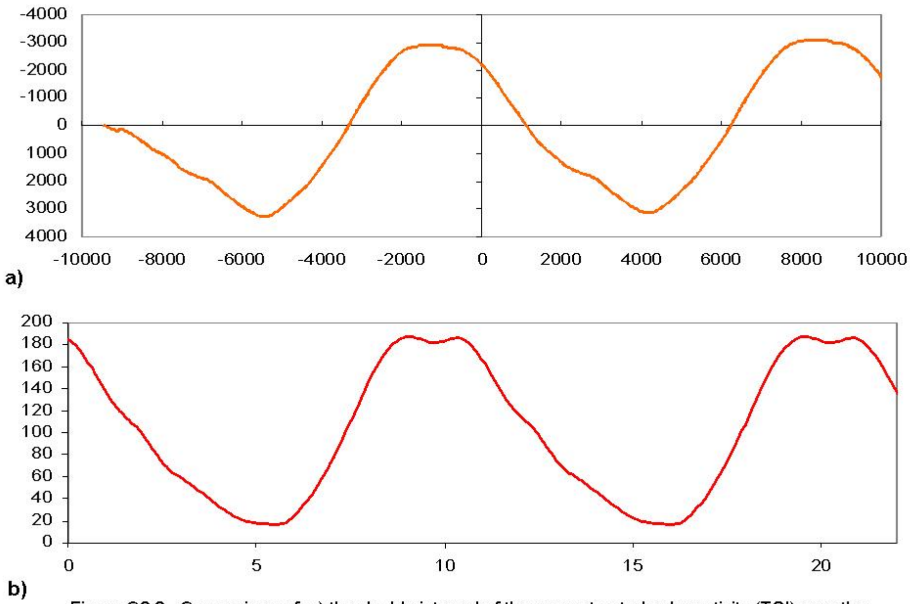

Figure C2.8. Comparison of: a) the double integral of the reconstructed solar activity (TSI) over the period from 10,000 BC to 10,000 AD, and b) the mean solar cycle obtained with a FS model based on SSN monthly data from the World Data Center SILSO, Royal Observatory of Belgium, Brussels, over the period from 1964 to 2008, with time in years without reference.

Fig. 8. Figure C2.8

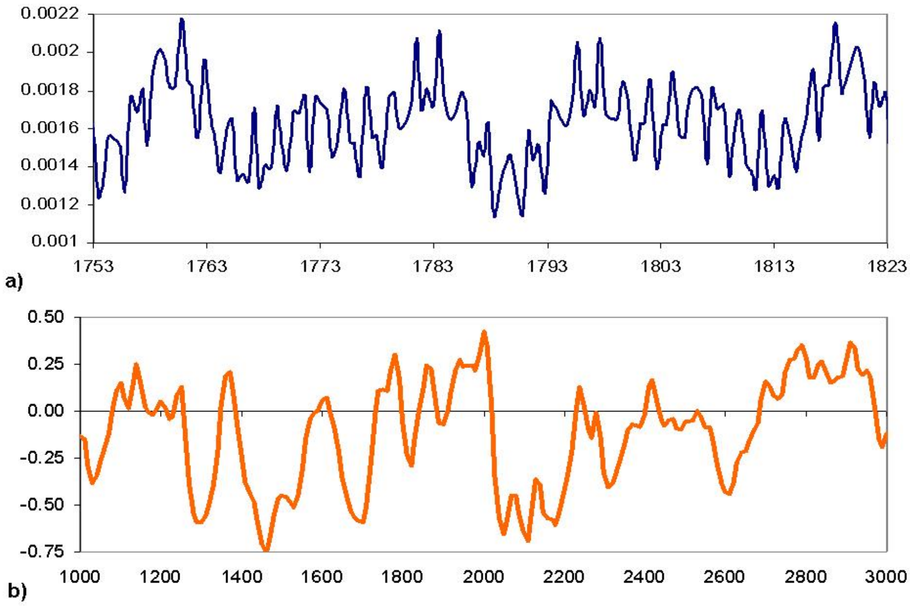

Figure C2.9. A comparison of the solar lateral forces F for the period from 1753 to 1823 AD, with the solar reconstructed and extrapolated record TSI for the period from 1000 to 3000 AD.

Fig. 9. Figure C2.9

$$\sigma S_1(t) = \int_{t_0}^{t} (S\ (t) - \mu_{S1})dt \qquad \text{(1a)}$$

$$\sigma S_2(t) = \int_{t_0}^{t} (\sigma S_1(t) - \mu_{S2})dt \qquad \text{(1b)}$$

Figure C2.10. Equations 1a and 1b

Fig. 10. Figure C2.10(Equations)