Solar Activity and VLBI-Length of Day

Hidalgo Ramírez, R.F.; Niccoli, B.; Raulin, J.-P.
Center for Radio Astronomy and Astrophysics Mackenzie, EE, UPM
Sao Paulo, Brazil

ABSTRACT

The non-uniform rotation of the Earth is caused by various agents such as fluid motions in the core, mass redistribution, ocean and atmosphere motions (Figure 1). This non-uniform rotation results in fluctuations in the Earth Orientation Parameters (EOP), and we are interested in the Length of Day (LOD). LOD is determined by *d*(UT1 - UTC) and is related with variations in the angular moment of the system Earth-Atmosphere. On other hand, solar activity directly affects the Earth's neutral atmosphere at all altitudes. We analyze the relationship between the solar activity indexes with EOP by comparing the fluctuations in the LOD with the solar parameters. Also, we investigate the periodicities and variations in the LOD time history whose cause is not well identified so far.

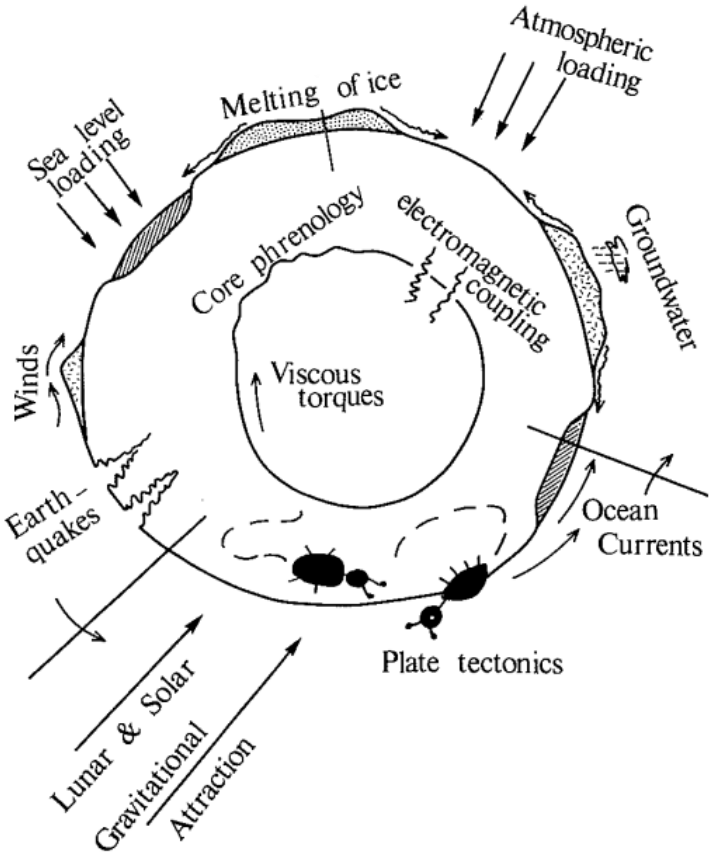

Figure 1. Different phenomena perturbing the Earth's rotation. Lambeck, K. (1980)

ANGULAR MOMENTUM AND LOD

The total angular moment of the system Earth-Atmosphere can be written as:

$$L_{Total} = L_{Earth} + L_{Atm} \quad (1)$$

Considering short time scales (a few years), torques exerted by the moon and the sun can be neglected, leading to:

$$\Delta L_{Earth} + \Delta L_{Atm} = 0 \quad (2)$$

Equation 2 shows the relationship between the Earth and atmosphere angular momentum (AAM). Also:

$$L_{Earth} = \omega I_{Earth} = \frac{2\pi}{LOD} I_{Earth} \quad (3)$$

Derivative of Equation 3 shows that small variation in LOD are due to variations in the Earth angular momentum.

$$\Delta L_{Earth} = -\Delta LOD \frac{2\pi}{LOD^2} I_{Earth} \quad (4)$$

Equations 2 and 4 relate the LOD and AAM. Also, Figure 2 shows that variations in LOD and AAM have an excellent short term agreement (Volland, 1996, Gipson and Ma, 1999; Gipson, 2016)

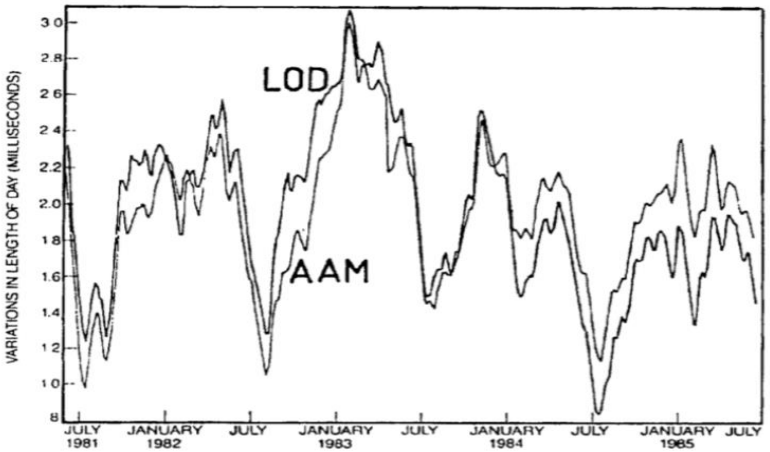

Figure 2. Comparison between LOD and AAM (Carter and Robertson, 1986)

Shen and Peng (2016) decomposed the LOD signal using the ensemble empirical mode decomposition. Frequency of LOD signals are summarized in the following table.

Frequency (cpy)	Period	Amplitude (ms)	Causes
39.99	9.13 d	0.12	Solid Earth tide (Seize and Schuh, 1988)
26.74	13.7 d	–	Lunar tides (Wahr, 1988)
13.18	27.7 d	–	Lunar tides (Wahr, 1988)
2.0	182 d	0.3	Solar tides and ocean currents (Rosen, 1993; Hopfner, 1996)
1.0	365 d	0.3	Solar tides and ocean currents (Rosen, 1993; Hopfner, 1996)
0.41	2.42 yr	–	Quasi-biennial oscillation in the stratosphere (Chao, 1989)
0.17	6 yr	0.12	Exchange of angular momentum between the mantle and inner core (Mound and Buffet, 2003)

INTRODUCTION

SOLAR ACTIVITY AND CLIMATE

The Sun, magnetosphere, ionosphere and Earth's atmosphere are the components of a coupled physical system. Thus, variations in the solar activity modulate this system in a complex manner (Gorney, 1990).

The variation of solar irradiance is marginally significant (1 - 3 Wm-2) (Pap and Fröhlich, 1999; Solanki and Fligge, 1999). However, at UV and EUV, the variability of the spectral irradiance is hundreds times over time scales from minimum to maximum of solar activity. Also, the Earth's atmosphere receives outflows of solar and galactic energetic particles modulated by the solar wind (Reid, 2000).

Labitzke and van Loon (1989) showed a strong association between the 11-year solar cycle and tropospheric pressures and oceans temperatures in the northern hemisphere.

Abarca del Rio et al. (2003) found that variability in the AAM and LOD agrees with solar activity and the 11-year cycle in the stratospheric quasi-biennial oscillation agrees with solar activity, but out of phase.

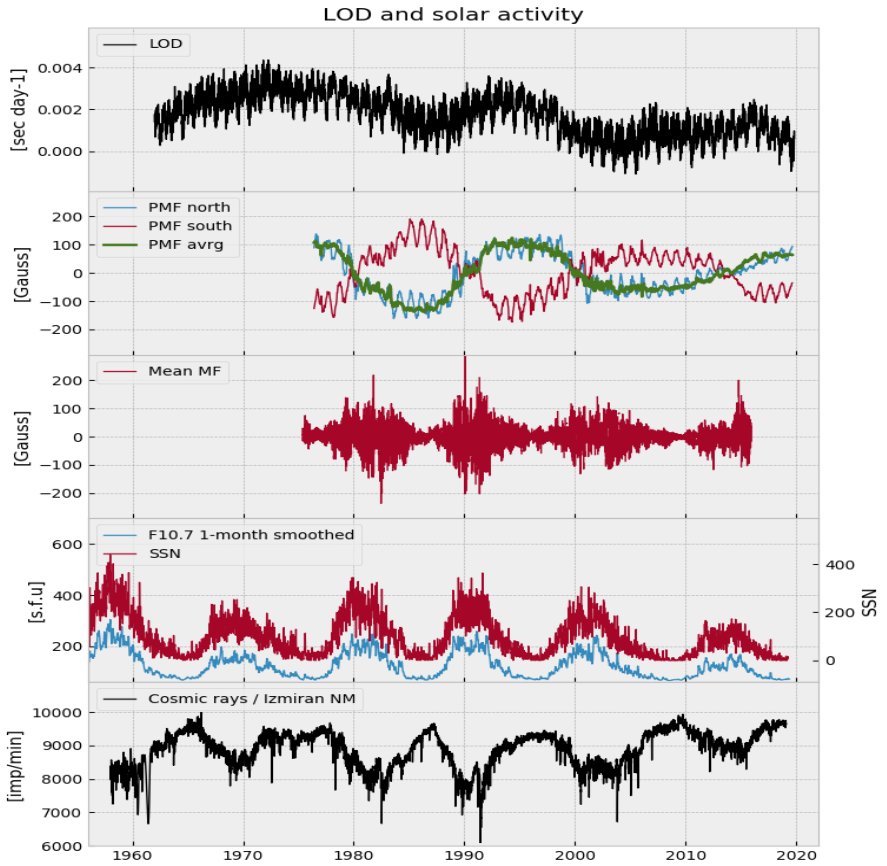

Figure 3. Comparison of LOD with solar parameters. Top to Bottom: LOD, Polar solar magnetic field, Solar mean magnetic field, F 10.7 cm index and Sunspot Solar Number, and Secondary cosmic rays

METHODS AND PRELIMINARY RESULTS

DATA

LOD and solar paramentes data was taken from IERS, WSO/Stanford, SISLO and Izmiran neutron monitor and Figure 3 shows the comparison of these parameters..

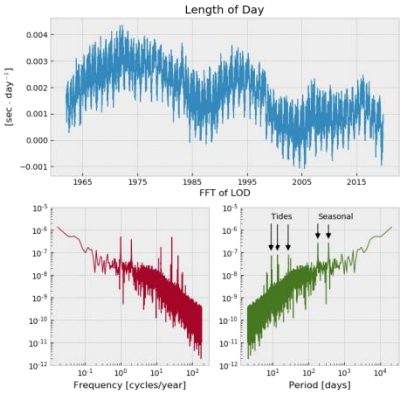

Figure 4. (Top) Time series of LOD, (Bottom left) Frequency in cycles per year of the LOD series and (Bottom right) Period in days of the LOD series.

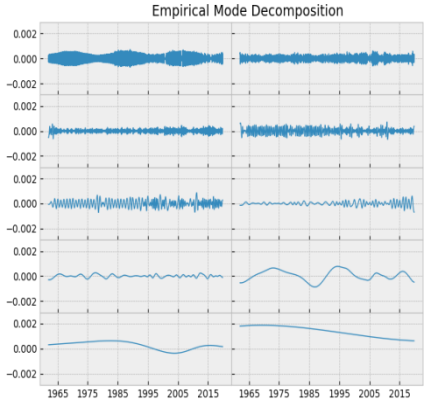

Figure 5. Ten modes of the LOD series using the EMD technique. Modes 1 to 10, from right to left and top to bottom

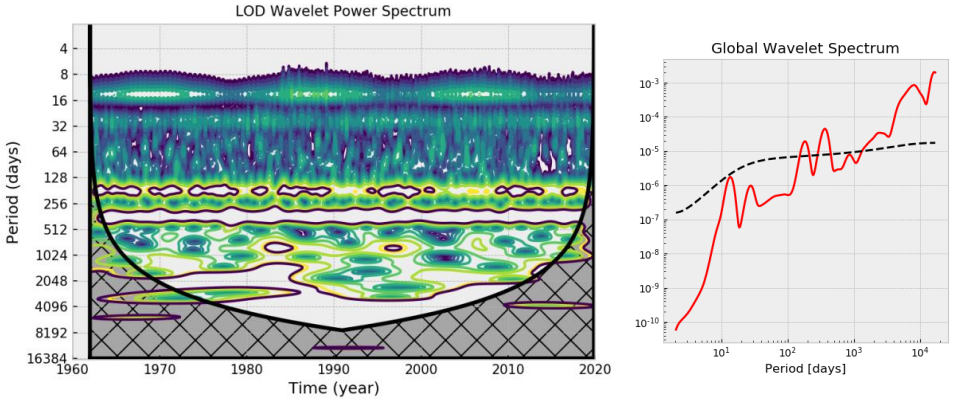

Figure 6. (a) LOD wavelet power spectrum and (b) LOD global wavelet spectrum. We use the code developed by Torrence and Compo (1998).

To analyze the LOD fluctuations and their relationship with solar parameters, we identified the periods in the signals using techniques such as Fast Fourier Transform (FFT) (Figure 4), Empirical Mode Decomposition (EMD) (Figure 5) and wavelets (Figure 6). We verified periods found by Sheng and Pen (2016) summarized in the Table 1 and identified periods comparable to solar activity, such as 11-year solar cycle. We found particularly interesting the possible correlation between LOD and the polar magnetic field (PMF) of the Sun. Figure 7 shows a comparison between LOD, PMF and some modes extracted using the EMD (Figure 5) in an arbitrary scale. We have to emphasize that this research is still in progress.

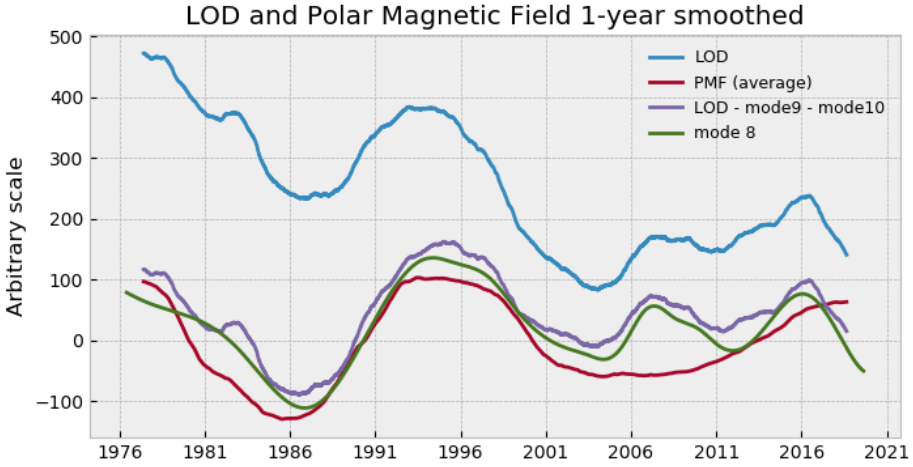

Figure 7. Comparison between LOD, LOD - LOD(mode9) - LOD (mode10), LOD(mode8) and Polar Magnetic Field (average)