EVIDENCE OF LENGTH OF DAY (LOD) BIDECADAL VARIABILITY CONCURRENT WITH THE SOLAR MAGNETIC CYCLES

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Abstract: Number of factors ranging from global atmospheric and oceans circulation to the plate tectonic movements affects the length of day (LOD) on different time scales. Existence of a coincidental or causal correlation between the solar magnetic oscillations and the secular LOD changes is demonstrated.

Introduction

Change in the rate of the Earth's rotation is better known as the change in the length of day (LOD). Short term changes are mainly attributed to the atmospheric circulation, while the changes in the LOD on the multi decadal scale are considered to be mainly due to movements within the Earth's liquid core. Glaciation and deglaciation cycles cause LOD acceleration or deceleration on the multi-millennial scale.

Previous studies have demonstrated that flows of liquid in the Earth's outer core (where its magnetic field is generated) oscillate with periodicities up to several decades, with corresponding variations in the LOD. Additionally there is a partial correlation between the LOD's variations and fluctuations in the long term average of the global surface temperature.

LOD as inferred from geomagnetic data

The LOD's fluctuations on decadal time scale could be indirectly assessed by considering evidence of the angular momentum exchange (AME) between the liquid core and the surrounding mantle. In order to comply with the law of the conservation of the angular momentum, any change in the total angular momentum of the liquid outer core is translated to fluctuations in the angular momentum of the solid mantle.

The conducting inner core is strongly coupled by Lorentz forces to the circulating liquid of the outer core. However, the volume of the solid inner core is much smaller than the liquid core, thus the main effect is in the AM exchange with the mantle, directly observable as change in the LOD, or often simply referred to as the LOD.

Geomagnetic data related to the Earth's outer Core Angular Momentum (CAM) are specified as:

"The magnetic field and its rate of change at the core-mantle interface was computed at 2.5 year intervals from field model gufm1 Bloxham & Jackson (1992) Sampling time interval : 1 year. Time span from 1840 to 1990. Data unit: Excess length of day in milliseconds, over standard day of 86400 seconds. The CAM is then transformed into an equivalent change in the length of the day as seen on the solid Earth by conservation of angular momentum. Three different data series are given: rough, intermediate and smooth." :Data of Core Angular Momentum Changes: (Bloxham & Jackson, 1997)

Data Analysis

For this analysis it is considered that most realistic results can be obtained from the un-corrected rough data (Bloxham & Jackson,1992). Extracting higher frequencies (shorter periods) can be achieved by using any of the known high pass filters. However, for the convenience and benefit of the easy reproducibility, the 21 year (cantered) average is subtracted from the 'raw' geomagnetic data. The obtained difference represents higher frequencies. Since the geomagnetic data is only available for the 1840-1990 period, the resulting difference is truncated by 10 years at each end.

Repeating above analysis using the data from astronomical observations (from IERS.org) obtained result is somewhat different but it does follow similar pattern. Spectral composition for both sets of the LOD data (geomagnetic and astronomical) is shown in Fig.1.

For the LOD as inferred from the geomagnetic data principal component of 21.5 years equalling (within the margin of error) twice the period of 10.8 years the sunspot cycles' periodicity (post 1850), i.e. equal to the solar magnetic (Hale) cycle period

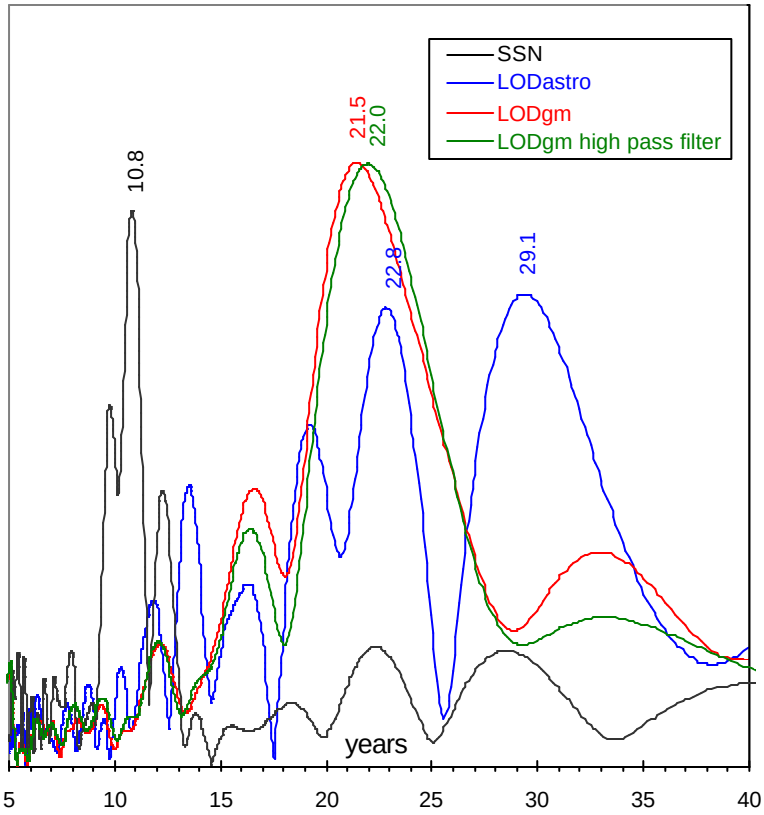

Fig. 1 LOD spectral periodogram
a) SIDC Sunspot monthly non-smoothed number (black)
b) LODastro – from astronomical observations data (blue)
c) LODgm – from geomagnetic data (red)
d) LODgm – from geomagnetic data, Butterworth high pass filter (green)

For the LOD based on the astronomic observations, the 22.8 years spectral component could be considered close enough to the Hale cycle period. Origin of a very strong 29 year component is not known, but likely to be associated with the Asian monsoons (see Miyahara et al 2010)

LOD and solar magnetic field

Sunspots are associated with rise and fall of the solar toroidal magnetic field, and normally appear in pairs.

Direction of the magnetic field vector **B** in the northern hemisphere coincides with the direction of solar rotation (positive orientation, B>0) during even-numbered cycles, it is opposite for the southern hemisphere. Relationship between direction of rotation and the magnetic field vector orientation is reversed during odd-numbered cycles (for the northern hemisphere B<0).

Analysis shows that the LOD variability follows change in the solar magnetic field orientation. The Earth's rotation acceleration is concurrent with decay of the even and continues during rise of the odd cycles. The rotation deceleration is concurrent with decay of the odd and continues during rise of the even cycles ; in other words change in the rate of the Earth's rotation follows the hemispheric sunspots' magnetic (Hale) cycle as shown in the Fig.2

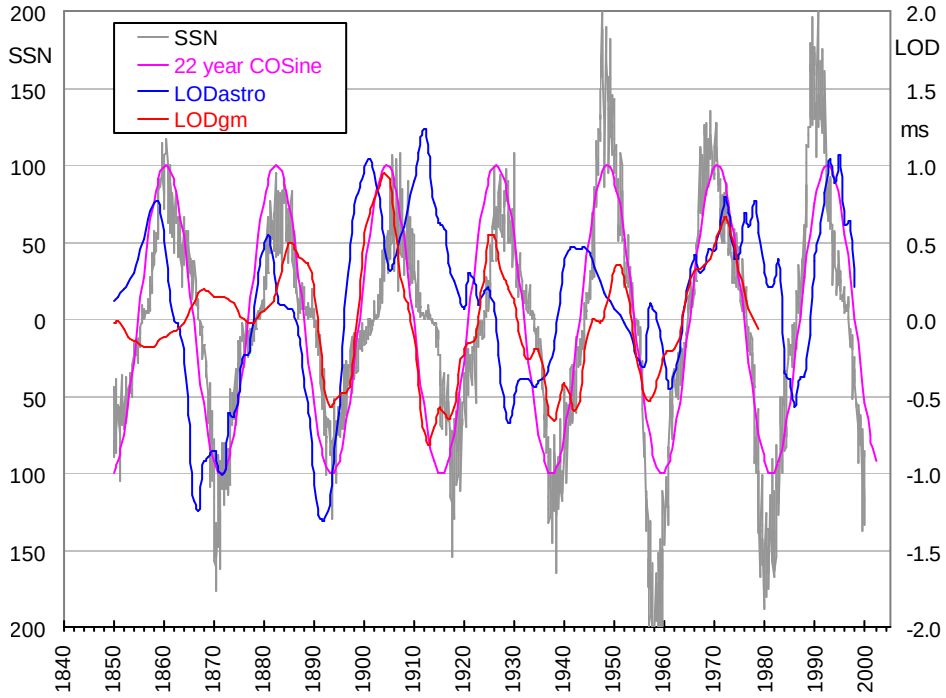

Fig. 2 LOD – waveforms of the higher frequencies:
a) SSN SIDC Sunspot monthly non-smoothed number (black, left hand scale). Even and odd cycles' numbers are positive scalars, but here for purpose of clarity are plotted on the y-axis in the opposite directions.
b) LODastro – from astronomic observations (blue, right hand scale)
c) LODgm – from geomagnetic data (red, right hand scale)
d) 22 year Cosine (magenta) as a 'simulated' Hale cycle (1866=0).
for LODgm – 22 year Cosine R^2 = 0.66 for 1880 – 1980 period.

Note that LOD as derived from astronomic observations shows a major deviation for the 1915-1925 period, coincidental with the sudden major change in the Earth's magnetic field, often referred to as the 'geomagnetic jerk'. (British geological survey)

Alternatively, the time line of the solar magnetic field evolution is often represented by spatiotemporal butterfly diagram as shown in Fig.3.

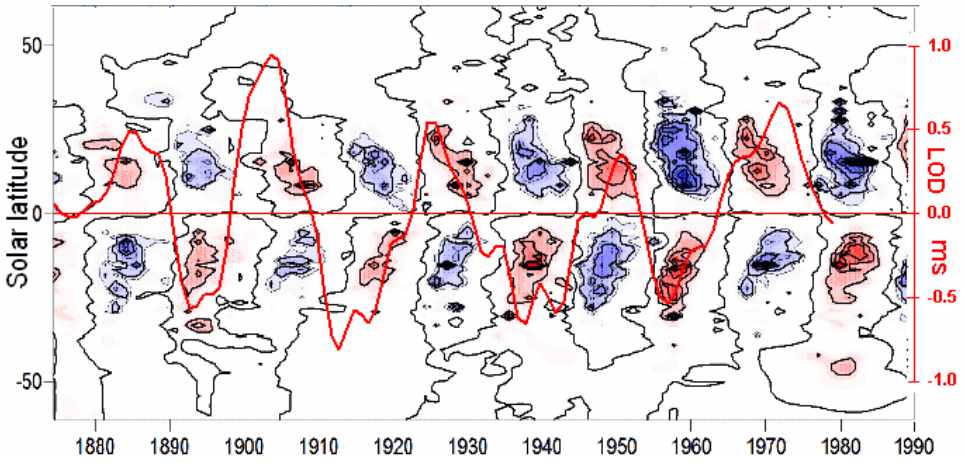

Fig. 3 Solar magnetic field evolution:
a) positive orientated magnetic field (B>0, red) negative orientated magnetic field (B<0, blue), helio-latitude (left hand scale),
b) geomagnetic LOD (red, right hand scale)

Discussion

The apparent LOD variability (21.5 – 22.8 years) at the same rate or close to the solar magnetic (Hale) cycle, as inferred from the geomagnetic or the astronomical observations, is unlikely to be a coincidence. Alternatives for a viable mechanism could be:
1. it is caused by solar activity
a) directly or b) indirectly.
2. solar cycles and the LOD oscillations have a common origin.

Direct solar effect, case 1a)
After considering known physical properties of the solar periodic oscillations (TSI cyclical variability and intensity of the heliospheric magnetic field at the Earth's orbit), initial calculations could not conclusively demonstrate the existence of the viable forcing due to insufficient energy available.

Similarly for case 2, the known facts related to the generation of the solar cycles and the changes in the Earth's rotation, do not revel existence of a clear common external driving mechanism.

Indirect solar effect, case 1b).
At the current state of knowledge, the most realistic alternative is the indirect solar effect, a possible mechanism could be postulated as:

Solar activity – ocean & atmospheric temperatures – oceanic and atmospheric circulation – angular momentum exchange – Earth's rate of rotation (LOD).

Conclusion

Both astronomical and geomagnetic data conclusively show presence of approximately 22 year periodicity within the rate of the Earth's rotation – LOD, as measured by the standard length of the day, concurrent with the solar (Hale) magnetic cycle. However, at this stage of the research, it is not possible to attribute cause directly to the solar activity, while possibility of viable indirect mechanism can not be excluded.

Acknowledgements

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Data:

Earth Core Angular Momentum Changes: http://www.astro.oma.be/SBC/data1.html
Sunspot Number: http://sidc.oma.be/silso/DATA/monthssn.dat
Astronomic observations LOD http://www.iers.org/IERS/EN/Science/EarthRotation/LODsince1623.html
Sunspot butterfly: http://www.climatedata.info/Forcing/Forcing/sunspots_files/BIG02a-sunspot_butterfly_diagram.gif.gif

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