ON CORRELATION BETWEEN VARIATIONS IN EARTH ROTATION AND FREQUENCY OF EARTHQUAKES

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1. INTRODUCTION

The behavior of the Universal time UT describes the axis rotation of the Earth and provides the data for investigating the constitution of the Earth and an interaction between its main components such as the core, the shell, an atmosphere and oceans. It is in fact the longest experimental sets of observations used for the study of geophysical processes. On the other hand regularly earthquakes are very considerable and important geophysical processes and information about them are collecting for centuries. Attempts for searching correlations between Earth rotation irregularities and the frequency of earthquakes were carried out starting from the work of Brown (1926). The present paper is devoted to this problem.

2. IRREGULARITIES IN EARTH ROTATION 1700 - 1955

The correction $\Delta T = TD - UT$ connects the observational Universal time UT and the theoretically uniform time-argument in the motion theories TD. Before the atomic time-scale was established these corrections were the only way for comparison observations with theories. In the early papers (Aleshkina E.Yu., 1994) the system of time-correction $\Delta T = TD - UT$ characterized irregularities in Earth rotation for the time span 1700-1955 was obtained from analysis of the transits of Mercury and Venus and lunar observations. Table 1 presents this system ΔT.

Year	ΔT (s)	**Year**	ΔT (s)	**Year**	ΔT (s)	**Year**	ΔT (s)	**Year**	ΔT (s)	**Year**	ΔT (s)
1700	55.8	1745	29.1	1790	23.2	1835	16.6	1880	2.5	1925	27.5
1705	49.1	1750	28.4	1795	22.6	1840	15.5	1885	2.3	1930	27.4
1710	44.0	1755	27.6	1800	22.2	1845	15.7	1890	2.4	1935	26.8
1715	38.1	1760	26.9	1805	22.0	1850	17.4	1895	1.9	1940	27.1
1720	34.9	1765	26.4	1810	21.6	1855	17.4	1900	4.3	1945	29.0
1725	32.9	1770	25.8	1815	21.3	1860	17.7	1905	10.6	1950	30.8
1730	31.9	1775	24.9	1820	21.6	1865	14.1	1910	17.1	1955	32.0
1735	30.8	1780	24.3	1825	20.4	1870	10.2	1915	22.1	1960	33.9
1740	29.9	1785	23.8	1830	19.7	1875	4.1	1920	25.4		

Table 1: The system of time-corrections $\Delta T = TD - UT$

The first derivative of ΔT gives the changes in the length of day (LOD) during the 250-years time-span. To uncover the possible periodic components in irregularities of Earth rotation we have performed frequency analysis (Aleshkina et al., 2010) of changes in LOD for this period. Three different techniques were employed: the CLEAN method (Vityazev V.V., 2001a), Lomb-Scargle method (Scargle J.D., 1982), and technique involving wavelets (Vityazev V.V., 2001b). All these methods have different mathematical grounds. CLEAN involves Fourier transform. Lomb-Scargle method is based on least-squares adjustment. The last technique exploits the special form of three-dimensional wavelet function. Hence one may consider these three methods as complementing each other. Results obtained by all methods described above both for changes in LOD and frequency of earthquakes is presented in Table 2 (see Section 4).

3. DATABASE OF POWERFUL EARTHQUAKES 1500 - 1955

On the basis of cross-identification of several databases and sources catalogue CPE2010 of powerful earthquakes of 1490-1960 with magnitudes exceeding 7.5 was carried out.

1. http://www.intute.ac.uk/hazards/Earthquakes-database.html
2. http://earthquake.usgs.gov/earthquakes/eqarchives/epic/
3. http://www.ngdc.noaa.gov/nndc/struts/
4. http://www.magicbaikal.ru/info/earthquake.htm

The fullest database about the earthquakes in direct access is the base NOAA of National Geophysical Data Center [3]. The database [1] repeats above mentioned in many respects. Unfortunately, they are not full, there are numerous recurrences of the same events and different estimations of earthquake's magnitudes in them. In such cases we used the maximal value of magnitude in sources. The following information is included in a database: calendar date, magnitude under the Richter scale (from 7.5 up to 9.9), region of an epicentre. The catalogue CPE2010 includes 689 powerful earthquakes and is available on www.ad-astra.len.su/bd/cpe2010.html.

4. CORRELATION BETWEEN ASTRONOMICAL AND GEOPHYSICAL DATA

Attempts for searching correlations between LOD changes and the frequency of earthquakes were carried out starting from the work of Brown (1926) where he tried to analyze such correlation on the basis of statistic of earthquakes in England. According to analysis of connection between earthquakes in China region and fluctuations in Earth rotation it is shown in (Du P., 1993) that the number of earthquakes with M ¿ 8 increases with increase in the rate of Earth rotation. Variations in Earth rotation can be one of the major factors for modulation of global seismic activity (Liao, Jin, Zheng, 1993). However the main difficulty is that earthquakes in general have local character. So that for the purpose of the present paper the most powerful earthquakes have a significant interest. The comparison of the frequency of such earthquakes and secular and long-periodic changes in LOD for 250 years was carried out. We carried out the same frequency analysis as it described in Section 2. Results are presented in Table 2.

As it can be seen from Table 2 LOD is likely to contain the several periods about 48, 70 and 100 years. Number of earthquakes contains the same periods about 45 and 75 - 80 years. There are other possible periods of 200 and 300 years. All these values are detected by all techniques used, which suggests that they are rather reliable. The periods of 45 - 48 years and 70 - 80 years are in good agreement and presented in both phenomena. In LOD changes there is an additional period of 100 years that is in agreement with so called Newcomb's empirical terms that are likely to be caused by changes in Earth moments of inertia. The value of 0.77 for coefficient of correlation between 250-years behavior of LOD and global earthquakes was obtained.

Series	**CLEAN**	Lomb-Scargle	**Wavelets**
LOD	P1 = 48 P2 = 68 P3 = 102	P1 = 57 P2 = 97	P1 = 48 P2 = 72 P3 = 99
Frequency of earthquakes	P1 = 44 P2 = 80 P3 = 203 P4 = 305 P5 = 610	P1 = 251 P2 = 603	P1 = 46 P2 = 75 P3 = 200 P4 = 298

Table 2: Frequency analysis for changes in LOD and frequency of earthquakes. Periods are given in years.

5. CONCLUSIONS

The following conclusions can be drawn from this analysis of the data about long-period variability of the Earth's rate of rotation and global earthquakes in the period 1500 - 1960. There are fluctuations in LOD in the period of 250 years with periods of 48, 70 and 100 years. Changes in number of powerful earthquakes in the period of 450 years have periods of 45, 75 - 80, 200 and 300 years. It is likely that periods of 45 - 48 and 70 - 80 years for earthquakes frequency and changes in LOD are connected each other. Coefficient of correlation between 250-years behavior of LOD and global earthquakes is significant and equal 0.77. Period of 100 years in LOD changes is in agreement with so called Newcomb's empirical terms that are likely to be caused by changes in Earth moments of inertia.

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REVISITING A POSSIBLE RELATIONSHIP BETWEEN SOLAR ACTIVITY AND EARTH ROTATION VARIABILITY

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ABSTRACT. A variety of studies have searched to establish a possible relationship between the solar activity and earth variations (Danjon, 1958-1962; Challinor, 1971; Currie, 1980, Gambis, 1990). We are revisiting previous studies (Bourget et al, 1992, Abarca del Rio et al, 2003, Marris et al, 2004) concerning the possible relationship between solar activity variability and length of day (LOD) variations at decadal time scales. Assuming that changes in AAM for the entire atmosphere are accompanied by equal, but opposite, changes in the angular momentum of the earth it is possible to infer changes in LOD from global AAM time series, through the relation : delta (LOD) $(ms) = 1.68\,10^{-29}$ delta(AAM) $(kg\,m^2/s)$ (Rosen and Salstein, 1983), where delta(LOD) is given in milliseconds. Given the close relationship at seasonal to interannual time's scales between LOD and the Atmospheric Angular Momentum (AAM) (see Abarca del Rio et al., 2003) it is possible to infer from century long atmospheric simulations what may have been the variability in the associated LOD variability throughout the last century. In the absence of a homogeneous century long LOD time series, we take advantage of the recent atmospheric reanalyzes extending since 1871 (Compo, Whitaker and Sardeshmukh, 2006). The atmospheric data (winds) of these reanalyzes allow computing AAM up to the top of the atmosphere; though here only troposphere data (up to 100 hPa) was taken into account.

1. RESULTS AND DISCUSSION

Both the low frequency term of AAM (LF AAM), as the annual and semiannual amplitude modulation (AN-A AAM and SA-A AAM) present power at interannual, decadal and interdecadal time scales. Some analyses are described. We show on the following figures the decadal band pass filtered times series of each of the signals. The decadal cycle of Semi Annual amplitude is inverted (-SA-A). The comparison between the decadal oscillation in Solar Activity (SUN) and these in the LF AAM and AN-A terms (Fig A and Fig B) show that both series appears to phase shift through times. Clearly in phase opposition to the solar activity forcing at the turn of 19th to 20th century in phase from 1955-1985 and out of phase since then (at the turn of the 20th to 21th century) when the decadal signal in AAM lengthens (see Abarca del Rio et al., 2003). Interestingly the comparison with the inverted decadal modulation of the semiannual cycle (Fig C), show that both signals appears to be somehow in phase or varies accordingly from roughly 1920 to 1990, extending herein precedent findings (Bourget et al, 1992)

2. CONCLUSION

The analysis performed here shows that both the low frequency signals in AAM as the annual and semiannual amplitude modulation present interannual to secular time scales. We concentrate our study particularly in the so-called Schwabe cycle (9-13 yr periods) in solar activity where the different terms in AAM, low frequency, the modulation of the annual and semiannual cycle do also presents a cycle at these times scales. The comparison with the decadal cycle in the SUN shows that only the decadal cycle in the semiannual cycle modulation presents an homogeneous phase shift with the SUN for almost 70 years (1920-1990), therefore extending precedent findings (see Bourget et al, 1992). We will finally conclude as on our precedent paper (Abarca del Rio et al., 2003) in this field: "The present results indicate the need for better understanding of atmospheric dynamics at decadal time scales. It seems that the coming years will be fruitful in this regard, given the advent of extended and improved atmospheric and solar data".

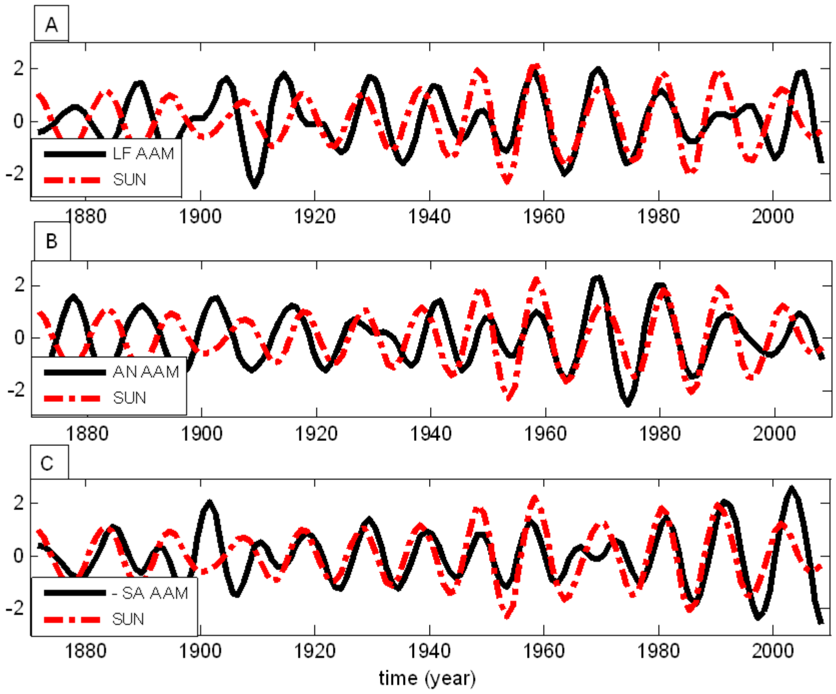

Figure 1: Decadal band pass filtered times series, from up to bottom of: Solar Activity (SUN; as represented by the Sunspots number), the Low Frequency AAM (LF AAM) Annual and Semiannual amplitude modulation (AN AAM and SA AAM respectively. The decadal cycle of Semi Annual amplitude is inverted (-SA-A).

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