22-YEAR OSCILLATIONS OF UT1, CORE ANGULAR MOMENTUM AND GEOMAGNETIC FIELD

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ABSTRACT.The possible interconnection between the 22-year cycles of the Earth rotation from one side and solar activity, geomagnetic field, Core Angular Momentum (CAM), global water redistribution, from the other one is investigated by means of annual UT1 data for the period 1623–2005, smoothed Wolf's numbers, AA and DST geomagnetic Indexes, Mean Sea Level (MSL) changes at Stockholm, and several solutions for CAM from the Special Bureau for the Core (SBC). The amplitude of 22-year UT1 oscillations is about 0.6s. Significant correlation exists between the 22-year cycles of UT1 and geomagnetic Index AA, most of the CAM solutions and MSL change at Stockholm. The analysis shows very small influence of the geomagnetic field on the observed 22-year UT1 cycles, whose excitation are 22-year climatic variations mainly and MSL oscillations with amplitude of about 9mm.

1. INTRODUCTION

The Earth rotation data for the period 1623.5-2005.5 are available from the IERS EOP Data Center. The annual time series of UT1-TT (Universal Time UT1 and Terrestrial Time TT) and LOD (Length of Day) are combination between the solution of Stephenson and Morrison (1984), based on lunar eclipses and star occultations before 1955 and modern determinations afterwards. These time series give good opportunity to study the long-term oscillations of UT1 and their connection with some natural phenomena as solar activity, climatic and weather variations, atmospheric and ocean circulations and conditions etc. A model of Earth rotation periodical variations, based on Fourier approximation of UT1 data, is created in (Chapanov et al., 2008). The model separates UT1 oscillations into different frequency bands, corresponding to the intrinsic cycles of the solar activity and liquid earth core. This model is used here to study interconnection between the 22-year cycles of the solar activity, geomagnetic field, core angular momentum and mean sea level.

2. UT1-TT DATA AND MODEL OF EARTH ROTATION

The UT1 data consist of visible long term oscillations and a parabolic part (Fig.1, a). According to

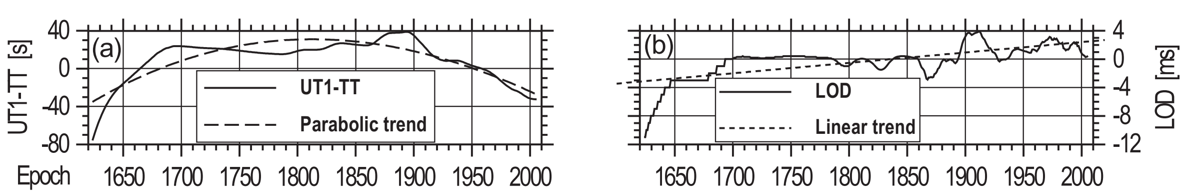

Figure 1: LOD and UT1-TT time series based on Morrison and Stevenson solution for the Earth rotation.

the LOD behavior (Fig.1, b), the data contain significant short-periodic noise for the period 1623-1700 due to step-wise variations, almost no change in the period 1700-1790 and significant decadal oscillations after 1800. The periodical part of the UT1-TT variations are determined after excluding the polynomial part of power 2 from the data (Fig.2, a). The model of the Earth rotation for the period 1623.5-2005.5 is created by means of a Fourier approximation of the UT1-TT variations with use of 100 harmonics, which includes oscillations with periods longer than 3.8a and estimated accuracy of amplitudes about 11ms. The coefficients of the model are estimated by means of the Least Squares Method. Part of the peaks of UT1 amplitude spectrum (Fig.2, b) are connected with the cycles of some natural phenomena: 6.5-year gravity cycles (1); 11-year sunspot variations (2); 12-year core cycles (3); 18.6-year tides due to motion of lunar node (4); 22-year solar magnetic cycles (5); 45-year solar equatorial asymmetry (6), and many other signals coming from the liquid core of the Earth.

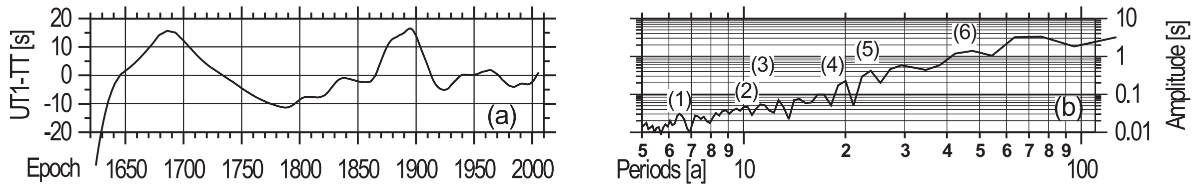

Figure 2: Periodical part of UT1-TT variations, determined by excluding of the parabolic term.

3. 22-YEAR CYCLES OF THE SOLAR ACTIVITY AND UT1

Three time series of 22-year cycles of UT1, determined by the coefficients of Fourier approximations of UT1 data since 1623, 1800 and 1868 are used here. The first time series contains three oscillations with periods from the band 21-24a (Fig.3, a) and will be used to compare common 22-year cycles between the Earth rotation and solar activity. The second time series contains three oscillations with periods from the band 20-25a, and will be used to compare common 22-year cycles between the Earth rotation, CAM and mean sea level (Fig.3, b). The last time series contains two oscillations with periods 20 and 23a and will be used to compare common oscillations of UT1 and AA geomagnetic Index (Fig.3, c).

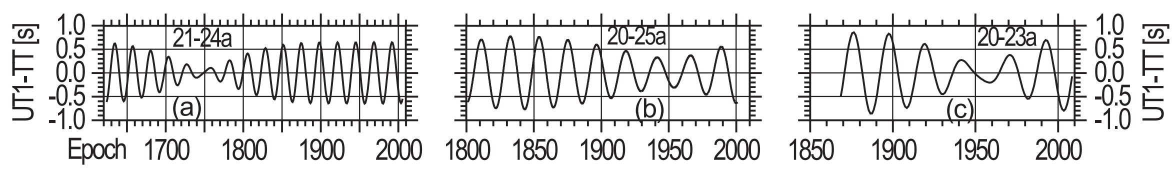

Figure 3: UT1-TT variations with periods from the band 21-24a since 1623 (a); with periods from the band 20-25a since 1800 (b); and with periods from the band 20-23a since 1868 (c).

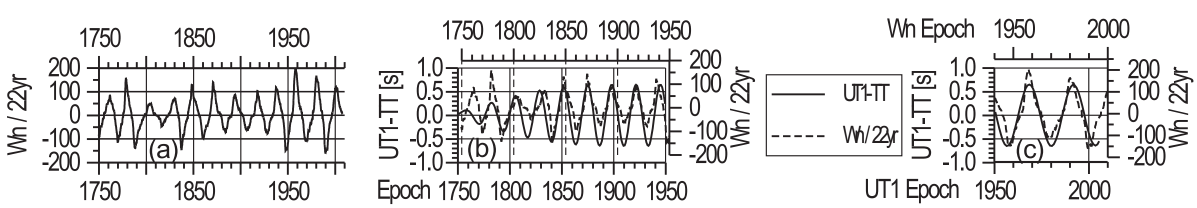

Figure 4: Extended time series of 22-year solar activity cycles, determined by sign alternation of Wolf's numbers cycles(a). Comparison between the 22-year cycles of UT1–TT and extended Wolf's numbers for the periods 1750–1950, (b) and 1950–2008, (c).

The amplitude of 22-year UT1 oscillations decreases during the Maunder minimum of the solar activity (1645-1715) and next 3 decades, when the UT1 oscillations synchronize their phase with the new solar magnetic cycles. The UT1 amplitude increases linearly during next five 22-year cycles (1750-1860) to the value of 600ms (Fig.3, a). The comparison between the 22-year cycles of the UT1 and solar activity is made by means of extended time series of solar magnetic cycles, determined by sign alternation of Wolf's numbers cycles (Fig.4, a). The correlation coefficients between these two time series are +0.71 for the period 1750–1950 with time delay of about 3 years (Fig.4, b), and +0.86 for the period 1950–2005, with significant fictitious phase delay (fig.4, c), due to variations of the periods of solar activity cycles.

4. GEOMAGNETIC INDEXES AND CORE ANGULAR MOMENTUM

The hourly geomagnetic Index AA for the period 1868–2008 (Fig.5, a) and daily equatorial DST Index for the period 1963–2005 (Fig.5, b) are used here, as well as some solutions for the Core angular momentum in LOD units for the period 1843–1990 (Fig.6, a), available at the server of the Special Bureau for the Core (`http://sbc.oma.be/`) of the IERS Global Geophysical Fluids Centre (GGFC).

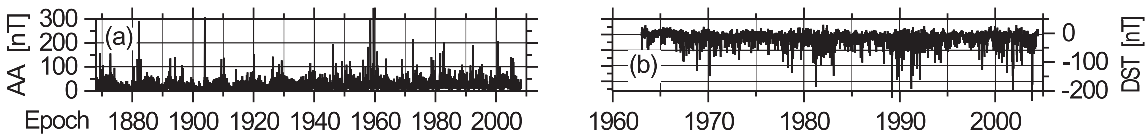

Figure 5: Geomagnetic Indexes AA – (a) and DST – (b).

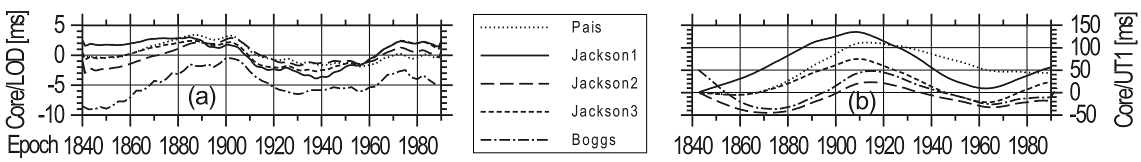

Figure 6: Core Angular Momentum in LOD units – (a) and in UT1 units – (b).

The 22-year oscillations of AA Index are determined by two oscillations with periods 20a and 23a from the Fourier approximation of the data and they are highly correlated with the 22-year cycles of UT1 with coefficient +0.92 and time advance 5a (Fig.7, a), while the long-term behavior of DST Index, determined by Vondrák's filtration reveal only partial correlation with the UT1 variations (Fig.7, b). The

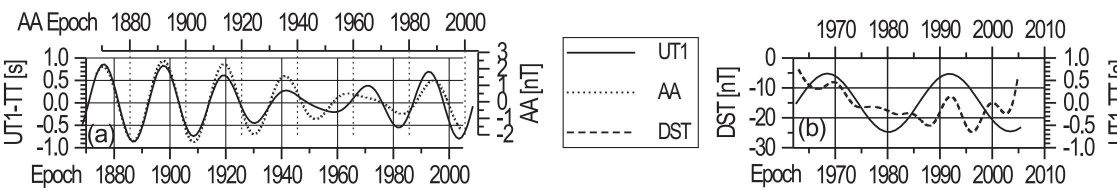

Figure 7: Comparison between 22-year cycles of UT1-TT and geomagnetic Indexes AA (a) and DST (b).

CAM in UT1 units (Fig.6, b) are determined by an integration of the following solutions for the CAM: Hide et al. (2000), Pais and Hulot (2000) and 3 solutions of Jackson (1997). The 22-year oscillations of the CAM, determined by oscillations with periods from the band 21-25a, are negatively correlated with the corresponding UT1 oscillations, but their very low amplitude of about 1-2ms is not enough to explain the amplitude of about 600ms of the observed 22-year UT1 oscillations (Fig.8, a).

5. 22-YEAR CYCLES OF THE MEAN SEA LEVEL AND UT1

The probable source of excitation of the 22-year variations of Earth rotation are 22-year climatic variations due to the solar activity and oscillations of the mean sea level connected with them. The changes of MSL, due to total solar irradiance variations and additional evaporation, followed by global water redistribution and ice thickness variations over the polar caps, are the necessary conditions to provide appropriate oscillations of the axial Earth moment of inertia with 22-year period. The UT1 and MSL oscillations should have opposite phases during the above process.

All cycles of UT1 and MSL oscillations at Stockholm with periods from the band 20-25a are highly correlated with coefficient –0.82 and delay of about 4a (Fig.8,b). The 9mm amplitude of 22-year MSL oscillations at Stockholm may explain 15% of the observed UT1 oscillations, which points out to possible resonance between the MSL change due to the solar activity (which affects Earth's inertial moment) and core oscillations.

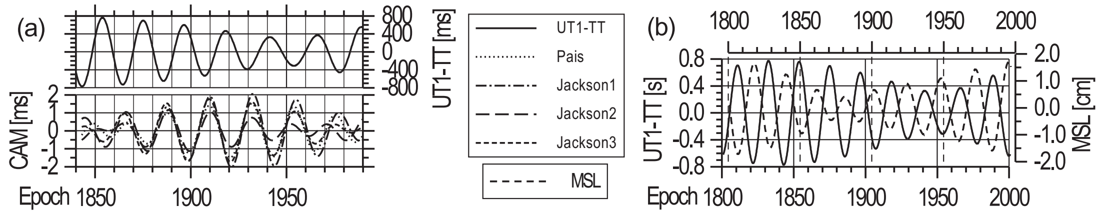

Figure 8: Comparison between 22-year cycles of the Core Angular Momentum (CAM) and UT1-TT (a); and between 22-year cycles of the Mean Sea Level at Stockholm and UT1-TT (b) .

6. CONCLUSIONS

The time series of the universal time UT1 variations for the interval 1623.5-2005.5 give good opportunity to study the long-term oscillations of UT1, corresponding to the magnetic cycles of the solar activity with period about 22a. The amplitude of 22-year UT1 oscillations decreases during the Maunder minimum (1645-1715) and next 3 decades, when the UT1 oscillations synchronize their phase with the new solar magnetic cycles. The UT1 amplitude increases linearly during next five 22-year cycles (1750-1860) to the value of 600ms.

The extended time series of 22-year cycles of the Wolf's number, determined by sign alternation, is highly correlated with the 22-year variations of UT1-TT after 1750 with a phase shift during the last 2 cycles.

The 22-year UT1 variations are in good agreement with the corresponding cycles of the AA geomagnetic Index with correlation coefficient +0.92 and time delay of about 5 year. The 22-year oscillations of CAM, determined from some solutions of SBC, are negatively correlated with the corresponding UT1 oscillations, but their very low amplitude of about 1-2ms is not enough to explain the amplitude of about 600ms of the observed 22-year UT1 oscillations.

The probable source of excitation of the 22-year variations of Earth rotation are 22-year climatic variations due to the solar activity and oscillations of the mean sea level connected with them. The changes of MSL, due to total solar irradiance variations and additional evaporation, followed by global water redistribution and ice thickness variations over the polar caps, are the necessary conditions to provide appropriate oscillations of the axial Earth moment of inertia with 22-year period. The observed amplitude of 22-year MSL oscillations at Stockholm may explain 15% of the observed UT1 oscillations, which points out to possible resonance between the MSL change due to the solar activity (which affects Earth's inertial moment) and core oscillations.

It is necessary to separate the direct influence of the solar activity on the 22-year UT1 oscillations from the core signals. Two basic approaches are available: by estimating UT1 response to the 22-year component of the Wolf's numbers variations, or by determining the Earth's inertial moment change, due to MSL oscillations and global water redistribution over the continents and polar caps.

7. REFERENCES

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