CENTENNIAL CYCLES OF THE SOLAR ACTIVITY AND EARTH ROTATION

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ABSTRACT. The centennial variations of the Universal Time UT1 and Length of Day LOD are investigated by means of long historical observational series of UT1 and LOD variations, which cover time span more than 3 centuries long. The correlation between the centennial cycles of the Earth rotation, climate and Total Solar Irradiance TSI is determined using the time series of North America temperature ($2.2Ka$) and precipitation ($8Ka$), Mean Sea Level MSL variations at Stockholm tide gauge station since 1774 and reconstructed TSI variations since 843. The model of the solar influences on the centennial and decadal cycles of the Earth rotation is based on a main centennial cycle and harmonics, ending by oscillation with period around $9a$. The value of the dominating period of the main centennial cycle of this model is determined among $171.44a$, $178.7a$ (Jose cycle), $210a$ and $230a$ (de Vries cycle) by looking for the minimum residuals of UT1, LOD, TSI and MSL approximation.

1. INTRODUCTION

The irregular and long-term variations of the Earth rotation are mainly caused by the displacements of matter in different parts of the planet which excitation mechanism is the influence of the Sun and solar activity cycles. The solar cycles can drive great number of geodynamical processes connected with the convections of the Earth fluids on the surface and inside the Earth. Many of climate and weather parameters are affected directly by the variations of the solar activity.

The time series of universal time UT1 and climatic variations give good opportunity to study the long-term oscillations of UT1, corresponding to the sunspots, magnetic and equatorial solar asymmetry cycles of the solar activity with periods of about 11, 22 and 45 years (Chapanov et al., 2008a, b, c; 2009c).

It has been shown that the delayed 11.2-year oscillations of UT1 are highly-correlated with the sunspot cycles (Wolf's numbers Wn for the period 1753.5-1950.5 with correlation coefficients 0.64 and linear regression $\mathrm{UT1} - \mathrm{TT} = 0.66Wn + 29.67$ [ms] (Chapanov et al., 2008c). Similar results are obtained in (Chapanov 2006; Chapanov and Gambis, 2008a) by means of the solution C04 of the IERS for the EOP. The time series of UT1 variations reveal strong correlation between the 11-year and 22-year cycles of the Earth rotation and the Mean Sea Level (MSL) (Chapanov and Gambis, 2009a, 2009b). A model of the Earth rotation excitation, based on the global water redistribution, is suggested in (Chapanov and Gambis, 2009b).

The existing long climatic and astronomical time series with centennial and millennial time spans are useful to study interconnection between the centennial cycles of the solar activity and Earth rotation.

2. TIME SERIES AND SPECTRA OF EARTH ROTATION AND CLIMATIC DATA

The available data of Earth rotation, solar activity and climatic parameters consist of time series with duration from centuries to several millennia:

- LOD and UT1–TT for the period 1623-2005 (Fig.1, a, b);
- Smoothed Wolf's numbers for the period 1700-2010 (Fig.1, c);
- Total solar Irradiance TSI for the period 1610-2010 (Lean et al., 1995, Lean 2000) and for the period 843-1961 (Bard et al., 2000, Fig.1, d);

- 2.2Ka time series of North America temperature (Salzer and Kipfmueller, 2005, Fig.2, a);
- 8Ka time series of North America precipitation for the period (Hughes and Graumlich, 2000, Fig.2, b);
- Mean sea level at Stockholm for the period 1774-2002 (Ekman, 2003, Fig.2, c, d)

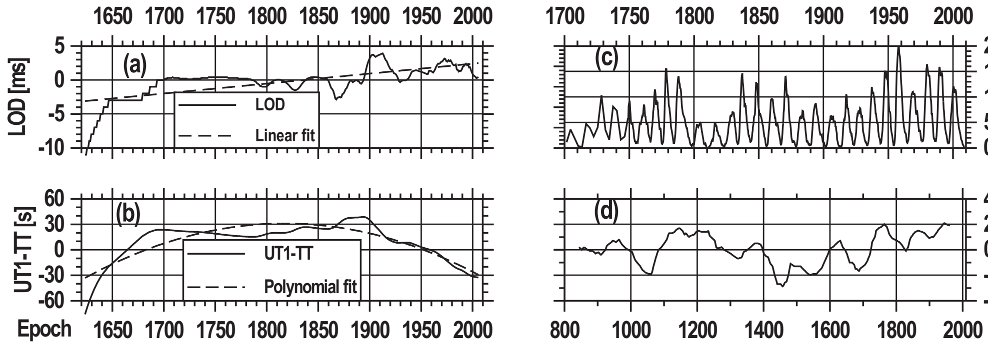

Figure 1: Time series of Lenght of Day LOD (a), the difference between the Universal Time UT1 and Terrestrial Time TT (b), Wolf's numbers (c) and Total Solar Irradiance TSI, according Bard et al. solution (2000) - (d).

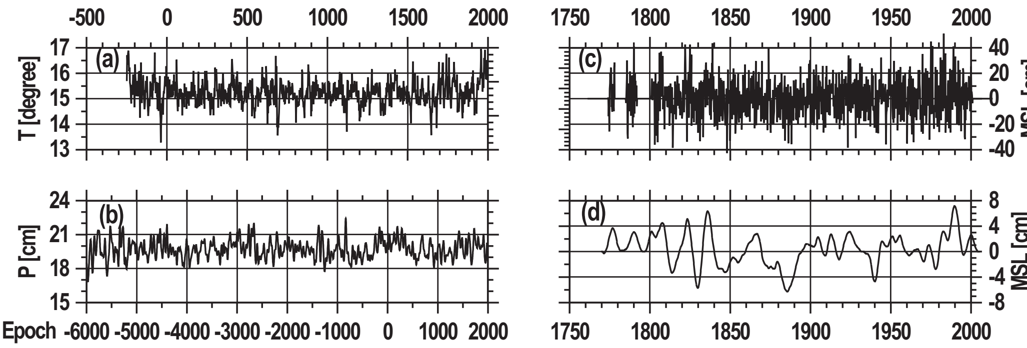

Figure 2: Time series of North America temperature (a) and precipitation (b), detrended Mean Sea Level (MSL) at Stockholm (c) and 5-year averaged MSL (d).

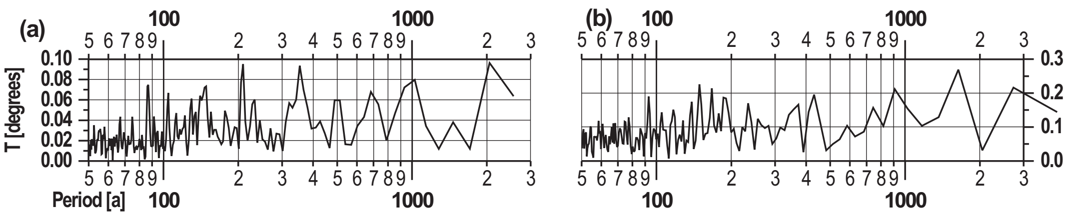

Figure 3: Amplitude spectra of North America temperature (a) and precipitation (b).

Jose (1965) points out a repeating solar system configuration of the 4 outer planets with period of 178.7 years. He suggests this configuration modulates the solar cycles. Sharp (2010) suggests other value - 171.44 years, which is the synodic period of Uranus and Neptune. The amplitude spectra of North America temperature and precipitation show a millennial long-periodical oscillation with period between 2000 and 3000 years (Fig,3, a, b). This long-periodical oscillation is known as Hallstatt cycles with period, estimated between 2300 and 2400 years in scientific papers. The North America temperature spectrum contains significant oscillations with periods 210 and 230 years, which appear as the 10-th and 11-th harmonics of 2300-year Hallstatt cycle. So, the candidates of the main centennial cycles of climatic variations, driven by the solar activity are four oscillations with periods of 171.44, 178.7, 210 and 230 years.

3. MODELS OF CENTENNIAL OSCILLATIONS

The model of the centennial cycles of the Earth rotation and solar activity is

$$F = f_0 + f_1(t - t_0) + \sum_{j=1}^{N_k} a_j \sin j \frac{2\pi}{P_k}(t - t_0) + b_j \cos j \frac{2\pi}{P_k}(t - t_0), \tag{1}$$

where t_0 is the mean epoch of observations F, N_k - the harmonics number of the frequencies $\omega_k = 2\pi/P_k$, which correspond to different centennial periods P_k. We will examine four centennial models with main periods P_k =171.44, 178.7, 210 and 230 years. The number of the harmonics N_k should be greater or equal to $P_k/11 + 1$, which includes all solar frequencies with periods from 11 years to P_k years.

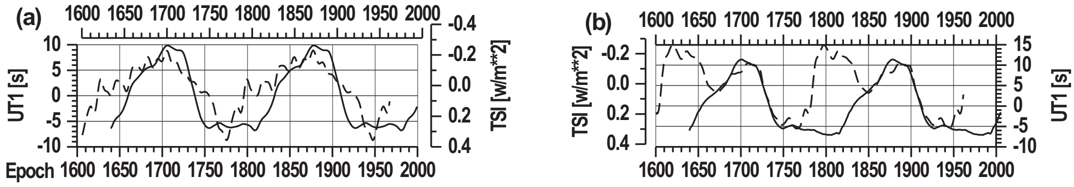

Figure 4: Comparison between UT1 and TSI centennial cycles, determined by 171.44-year model (a) and 178.7-year model (b).

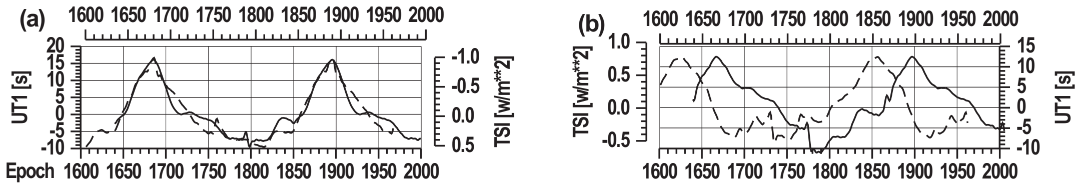

Figure 5: Comparison between UT1 and TSI centennial cycles, determined by 210-year model (a) and 230-year model (b).

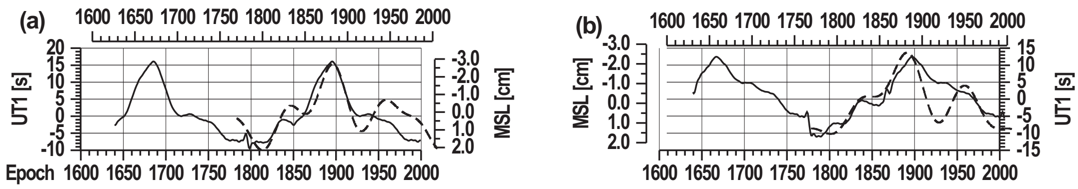

Figure 6: Comparison between UT1 and MSL centennial cycles, determined by 210-year model (a) and 230-year model (b).

The centennial cycles of UT1 variations are compared with corresponding TSI cycles from the solution of Bard et al. (2000), which provide more smooth curve than other solar indices. The 172-year model yields poor agreement between the UT1 and TSI variations (Fig.4, a). Partial correlation between the UT1 and negative TSI variations exists in the case of 178.7-year model (Fig.4, b), which points out that this oscillation and its harmonics are presented in the centennial solar-terrestrial influences, but it is not the dominating period. The same conclusion is valid for 230-year model (Fig.5, b), where the TSI and UT1 cycles are significantly shifted. The 210-year model yields almost exact match between the UT1 and negative TSI cycles (Fig.5, a), so the dominating period of the centennial solar-terrestrial influences is with value of about 210 years. A relatively good agreement between the UT1 and negative MSL centennial cycles exists (Fig.6), so the probable source of Earth rotation centennial variations is cooling effects of the solar grand minima and corresponding increasing of the polar ice thickness.

4. CONCLUSIONS

The best agreement between the centennial cycles of the TSI and UT1 is achieved by 210a model.

The dependence between the TSI and UT1 centennial variations is negative, so the Earth rotation acceleration is connected with the decrease of the MSL, due to cooling effects of solar grand minima and corresponding increasing of the polar ice thickness.

Partial correlation exists between the 180- and 230-year cycles of the time series of solar and climatic indices, UT1 and LOD. The solar grand minima are irregular in time and the time intervals between them are not multiple by the examined periods, so the appropriative model of the centennial cycles of the Earth rotation should combine 180a, 210a, 230a oscillations and their harmonics.

Acknowledgement. The paper was supported by the contract DO02-275 with the Bulgarian NSF and the Grant Agency of the Academy of Sciences of the Czech Republic under the project IAA300130702.

5. REFERENCES

Bard, E., G. Raisbeck, F. Yiou, and J. Jouzel, 2000, "Solar irradiance during the last 1200 years based on cosmogenic nuclides", TELLUS B, vol. 52 (3), pp. 985-992.

Chapanov, Ya., 2006, "On the long-periodical oscillations of the Earth rotation", Proc. Journées 2005 "Systèmes de référence spatio-temporels"', Warsaw, 2006, 129-130.

Chapanov Ya., Gambis D., 2008a, "Correlation between the solar activity cycles and the Earth rotation", Proc. Journées 2007 "Systèmes de référence spatio-temporels", Paris. 2008, 206-207.

Chapanov Ya., Vondrák J., Ron C., 2008b, "22-year Oscillations of UT1, Core Angular Momentum and Geomagnetic Field", Proc. Journées 2008 "Systèmes de référence spatio-temporels", Dresden, 22-24 September 2008, 182-185.

Chapanov Ya., Vondrák J., Ron C., 2008c, "Decadal Oscillations of The Earth Rotation", AIP. Conf. Proc. Vol. 1043 "Exploring the Solar system and the Universe", Bucharest, 14-20 April, 2008. 2008, 197-200.

Chapanov Ya., Gambis D. 2009a, "Change of the Earth moment of inertia during the observed UT1 response to the 11-year solar cycles", Proc. Journées 2008 "Systèmes de référence spatio-temporels", Dresden, 2009, P.131-132.

Chapanov Ya., Gambis D., 2009b, "Solar-terrestrial energy transfer during sunspot cycles and mechanism of Earth rotation excitation", Proc. IAU Symposium 264, 2009.

Chapanov Ya., Vondrák J., Ron C., 2009c, "Common 22-year cycles of Earth rotation and solar activity", Proc. IAU Symposium 264, 2009.

Chapanov Ya., Gambis D., 2010a, "A model of global water redistribution during solar cycles, derived by astronomical data", Conf. BALWOIS-2010, Ohrid, 2010.

Chapanov Ya., Gambis D., 2010b, "Long-periodical variations of Earth rotation, determined from reconstructed millennial-scale glacial sea level", Conf. BALWOIS-2010, Ohrid, 2010.

Ekman, M, 2003, "The world's longest sea level series and a winter oscillation index for northern Europe 1774 - 2000", Small Publications in Historical Geophysics, 12, 31 pp.

Hughes, M. K. and L. J. Graumlich, 2000, "Multi-Millennial Nevada Precipitation Reconstruction". International Tree-Ring Data Bank. IGBP PAGES/World Data Center-A for Paleoclimatology Data Contribution Series #2000-049. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

Jose, P., 1965, "Sun's motion and sunspots", Astronomical Journal, 70, pp. 193 - 200.

Lean, J., Beer, J., & Bradley, R., 1995, "Reconstruction of Solar Irradiance Since 1610: Implications for Climate Change", Geophys. Res. Let., 22, No. 23, pp. 3195-3198

Lean, J., 2000, "Evolution of the Sun's Spectral Irradiance Since the Maunder Minimum", Geophys. Res. Let, 27, No. 16, pp. 2425-2428

Salzer, M.W. and K.F. Kipfmueller, 2005, "Reconstructed Temperature and Precipitation on a Millennial Timescale from Tree-Rings in the Southern Colorado Plateau", U.S.A. Climatic Change, 70, No 3, pp. 465 - 487

Sharp, G., 2010, "Are Uranus & Neptune responsible for Solar Grand Minima and Solar Cycle Modulation?", arXiv:1005.5303v3 [physics.geo-ph], 15pp.