CORRELATION BETWEEN THE SOLAR ACTIVITY CYCLES AND THE EARTH ROTATION

Ya. CHAPANOV[1], D. GAMBIS[2]
[1] Central Laboratory for Geodesy of Bulgarian Academy of Sciences
Acad. G. Bonchev Str., Bl.1, 1113 Sofia, Bulgaria
e-mail: astro@bas.bg
[2] IERS EOP PC, Observatoire de Paris 61,
Avenue de l'Observatoire, 75014 Paris, France
e-mail: daniel.gambis@obspm.fr

ABSTRACT. The correlation between the solar activity cycles and the Earth rotation is investigated by means of UT1 series from the solution C04 of the IERS. The different oscillations of the Earth rotation are separated by an approximation of the difference UT1-TAI for the period 1962-2006, which includes power polynomials of degree up to 3, main oscillations with periods 22a, 18.6a, 12a, 6.75a, 1a and their harmonics. The UT1-TAI oscillations at solar activity frequencies are approximated with step-variable periods as follow: 11.1a for UT1 data before 1977.5; 10.3a for data between 1977.5 and 1987.8; 9.7a for data between 1987.8 and 1997.5; and 10.0a for data after 1997.5. The step-variable periods yield better approximation of the Earth rotation response to different solar activity cycles. The estimated UT1-TAI oscillations at solar activity frequencies are highly-correlated with the smoothed values of the Wolf's numbers with mean delay of about 1.5a.

1. MODELS OF EARTH ROTATION RESPONSE TO SOLAR ACTIVITY CYCLES

The most popular combination of all UT1-TAI observations comes from the solution C04 of the IERS, which is determined daily since the epoch 1962.0. This solution gives a good opportunity to study long-term variations of the Earth rotation and their relationships with some natural phenomena. A model of the Earth rotation variations is

$$\Delta UT1 = \sum_{m=0}^{3} p_m (t-t_0)^m + \sum_{k=1}^{6} \sum_{i=1}^{n_k} a_{ik}\mathbf{sin} i\omega_k (t-t_0) + b_{ik}\mathbf{cos} i\omega_k (t-t_0) + \sum_{j=1}^{44} B_j \mathbf{sin}\xi_j + C_j \mathbf{cos}\xi_j \quad (1)$$

where ΔUT1 is the difference UT1-TAI, the mean epoch t_0 is 1984.0, p_m are polynomial coefficients, n_k - the harmonics number of the frequencies $\omega_k = 2\pi/P_k$, which correspond to six periods P_k, and the coefficients B_j and C_j represent 44 zonal tidal terms ξ_j. The model of universal time response to the solar activity cycles includes oscillations with the following periods and their harmonics (Table1).

Table 1: Periods and harmonics numbers of the oscillations, included in the model of UT1 response to the solar activity.

Oscillations	Periods P_k	Harmonics number n_k
Solar activity (magnetic cycles)	22.06a	1
Lunar node	18.61295a	8
Empirical oscillation	11.94a	5
Solar activity (spot cycles)	10.47a	4
Gravity oscillations	6.75a	10
Seasonal oscillations	1a	10
Zonal tides	5.64d to 177.84d	44 waves

The model (1) approximates the UT1-TAI variations for the period 1962.0-2006.0 with accuracy about 1.5ms and maximal residuals between 4ms and 6ms, when the maximal number of used harmonics is 40. Here the model of universal time variations is truncated, so the quasi-biennial UT1 oscillations stay in the residual part of the approximation.

The Earth rotation response to solar activity cycles is determined by the UT1 residuals plus the oscillations with fixed period 10.47a (first case) and with step-variable periods 11.1a, 10.3a, 9.7a, 10.0a (second case, Table2). The correlation coefficients between the UT1 response to solar activity and the monthly mean Wolf's numbers W_n are +0.86 and +0.90 (Fig.1).

Table 2: Step-variable periods of UT1 response to the solar activity.

Time interval	Period P_k	Time interval	Period P_k
1962.0 – 1977.5	11.1a	1977.5 – 1987.8	10.3a
1987.8 – 1997.5	9.7a	1997.5 – 2006.0	10.0a

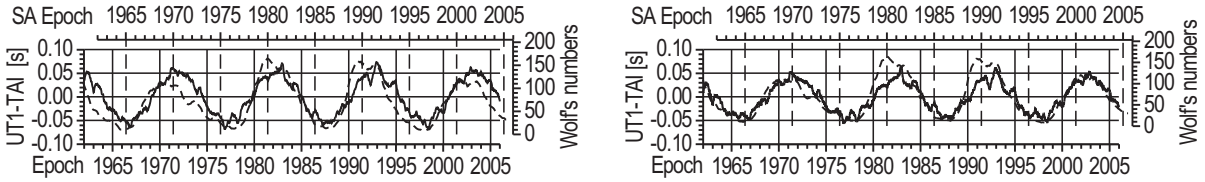

Figure 1: Comparison between the Earth rotation responses to the solar activity cycles and monthly mean Wolf's numbers. The time delay is 1.5a. The correlation coefficient is +0.86 in case of fixed period 10.47a (left) and +0.90 in case of step-variable periods (right).

2. REGRESSION MODELS OF SOLAR ACTIVITY INFLUENCE ON EARTH ROTATION VARIATIONS

Linear regression models of Earth rotation response to solar activity cycles are determined.

$$\begin{aligned} \Delta UT1_f &= 0.71W_n - 48.67, \\ \Delta UT1_v &= 0.59W_n - 42.06, \end{aligned} \tag{2}$$

where $\Delta UT1_f$ and $\Delta UT1_v$ are in [ms], the index f means the case of fixed period of 10.47a and the index v - the case of step-variable periods (Fig.2). The case of step-variable periods provides better linear fitting.

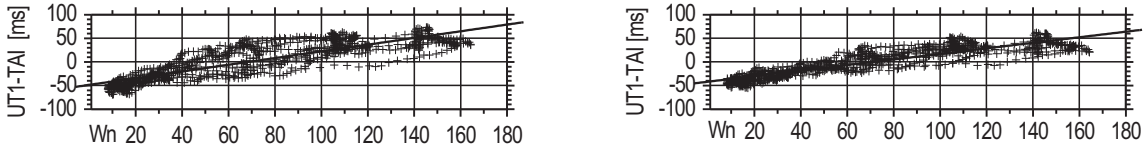

Figure 2: Linear regressions between the Earth rotation responses to the solar activity cycles and monthly mean Wolf's numbers W_n. The regression coefficients are 0.71ms per unit W_n in case of fixed period of 10.47a (left) and 0.59ms per unit W_n in case of step-variable periods (right).

3. CONCLUSIONS

The decadal variations of the Earth rotation are strongly affected by 11-year cycles of the solar activity. The Earth rotation response to the solar activity cycles is delayed by 1.5a. The correlation coefficient between 11-year UT1 variations and monthly mean Wolf's number is 0.86, when mean period of solar cycles 10.47a is used. The UT1 response to solar cycles, determined by step-variable periods, provides a better fit to the monthly mean Wolf's number, which increases the correlation coefficient to 0.90 and allows significant improvement of the linear regression model.