INFLUENCE OF SPACE WEATHER EFFECTS ON THE UPPER ATMOSPHERE ACCORDING TO THE DRAG OF ARTIFICIAL EARTH SATELLITES

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ABSTRACT. The applying of the method of time-frequency analysis allows to reveal the detailed structure of the manifestations of the influence of the space weather's state on the upper atmosphere of the Earth. The sensitive indicator of such changes are low-orbit satellites. The drag dynamics of five low–orbit satellites was viewed as indicators manifestations of the influence of space weather on the Earth upper atmosphere. The study period includes phases of decay and a long minimum of 23-rd solar cycle, phases of growth and maximum of 24-th solar cycle. In drag dynamics of all the analyzed satellites strongly marked regular drag effects with long periods (2-4 years) and short-period effects with periods less than one year. The satellites with orbital inclinations close to the equator shows periods with trend from 25 days to 1,3 months.

1. Introduction

Evolution of the orbit and satellite's drag variations depend on: gravitational perturbations (the gravitation of the Sun, moon and other planets); oblateness of the Earth; the Earth's magnetic field; light pressure; charged and neutral particles (the effect is small and therefore neglected); aerodynamic disturbances (Earth's atmosphere). The atmosphere density variations cause a change in the height of the satellite [1, 2]. The density of the atmosphere is constantly changing and not only depends on the latitude and height above the Earth's surface, but also on the solar activities and space weather conditions. In this work, satellites are used as indicators of the impact of space weather and manifestations of solar activity on the upper atmosphere of the Earth.

2. Observational data

For analysis were taken five satellites with NORAD numbers: 25860, 27700, 12054, 25064, 23757. These satellites have the following elements of the orbits: Polar: №5860: $i=98^0$; $e=0.0002$; $a=655$ km; №27700: $i=97^0$; $e=0.005$; $a=486$ km. Midlatitude: №12054: $i=65^0$; $e=0.007$; $a=522$ km. Equatorial: №25064: $i=34.9^0$; $e=0.0007$; $a=507$ km; №23757: $i=22.9^0$; $e=0.0009$; $a=499$ km. All satellites were observed during 9 years (2005-2013). Satellite 27700 were observed during the 8 years (2005-2012). Study's satellites moved in unmanaged mode and the satellite 27700 by the end of the observation period was burned in the atmosphere. Observations of these satellites fall to decay phase of solar cycle 23 and the beginning of solar cycle 24, and the minimum phase between them.

3. Spectral analysis

Spectral analysis – is one of the signal processing methods, which allows to describe the frequency content of the measured signal. The basis for this analysis is the Fourier transform. It binds the values of the time series with their representation in the frequency domain. Disadvantage of this method is that if the amplitude of any harmonic changed in a certain period of time, this method will not be able to show at what time it happened. One option to eliminate these disadvantages, it was proposed to use the method not to the entire process, but to the process within a certain time window, which gradually shifts [3]. To recalculate the coefficients of the resulting series use the algorithm of fast Fourier transform (FFT). In this work, to build the spectrograms were used algorithm "Winograd". This algorithm has a significant advantage over the other, when the multiplication operation is more difficult than addition [4].

4. Results

For preprocessing data used STATISTICA 8. The data on changes in the atmospheric drag coefficient of satellites (Bstar) were analyzed. Due to the fact that the data series are presented on an uneven timeline, we used the interpolation B-spline. Figure 1 shows an example graph of the change of the drag coefficient of satellite 25064 in the investigated time interval.

From the resulting graphs can be seen that in the phase of minimum solar activity there are quasi-periodic oscillations with an interval of 27 to 30 days. In addition to these observations are marked sudden (abnormal) periods of braking with a period of about three months. As observation of satellites cover different periods of solar activity state, their observations were divided into two periods: 2005-2009 and 2010-2013. Using Fourier analysis, we constructed periodogram for these intervals. An example of periodogram shown in Figure 2.

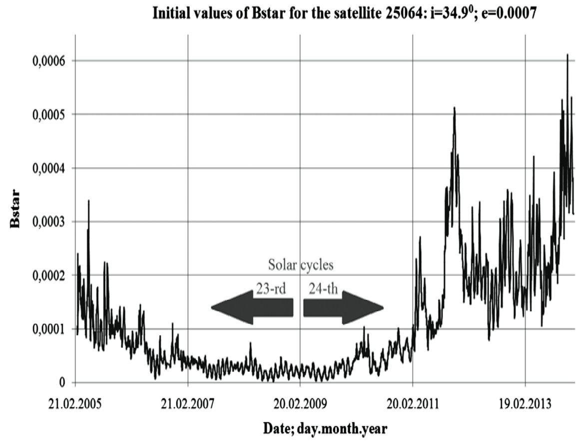

Figure 1: Initial values for equatorial satellite 25064

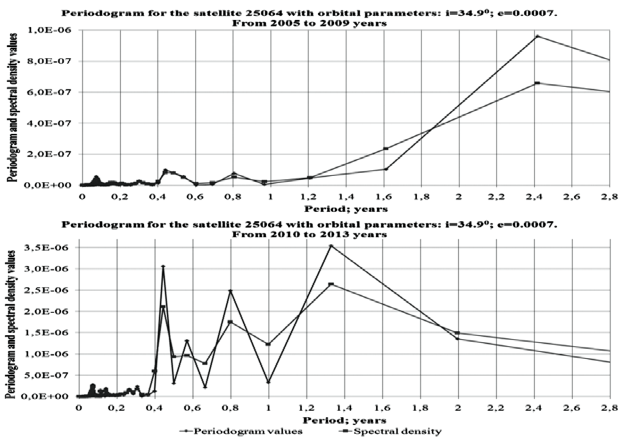

Figure 2: Periodogramm for two time periods for the Equatorial satellite 25064

Table 1.

Number of satellite	25860		27700		12054		25064		23757	
Period of periodogramm	Date 2005-2009	Date 2010-2013	Date 2005-2009	Date 2010-2013	Date 2005-2009	Date 2010-2013	Date 2005-2009	Date 2010-2013	Date 2005-2009	Date 2010-2013
Periods; Year - *, Months - **, Days - ***.	2,4*	5,3**	2,4*	1,2*	2,4*	2*	2,4*	1,3*	2,4*	5,3**
	5,27**	9,6**	1,2*	5,8**	9,6**	5,32**	5,27**	5,3**	9,7**	~1,3*
	9,7**	2*	5,3**	~27***	5,27**	6,8**	9,7**	9,6**	5,3**	9,57**
	2,5**	6,8**	26***	22***	6,44**	9,6**	~27***	6,8**	25,6***	6,8**
	14,6***	3,2**	3,2**	1,7**	2,4**	4,35**	29,4***	~27***	3,6**	3,6**
	~1**	3,7**	2,1**		3,62**	3,68**	3,6**	3,68**	26,7***	~27***
	20,7***	26,5***	~27***			2,4**		1,7**	2,2**	1,7**
	1,8**		~30***					3,2**	~9***	
	3,4**		4,1**							
			~9***							

In the resulting periodogram presented periods ranging from 9 days and ending 1.3-2.4 years. Some periods are shown in Table 1. In periodogram, built in the period of 2005-2009, for all satellites is present the maximal period of variations is equal to 2.4 years. While for periodogram, built in the time period 2010-2013, the periods with the maximum amplitude is different. For example, for equatorial orbit – 1,3 years. To identify the time of existence of periodic components used program PSELab [5]. The result of its application to the equatorial satellite 25064 shown in Figure 3.

The periods trend from 25-28 days to 1.3 months were detected. Table 2 shows some detected periods of variations for all of the studied objects. The semi-annual period is present for all satellites throughout the time range of observation, while periods more than one year are present not for all satellites.

The following steps assume comparison of the received data with the manifestations of solar activity and magnetic storms. This have the practical importance for determine the complex influence of various manifestations of space weather on the state of Earth's upper atmosphere, creating the basis for its forecasting.

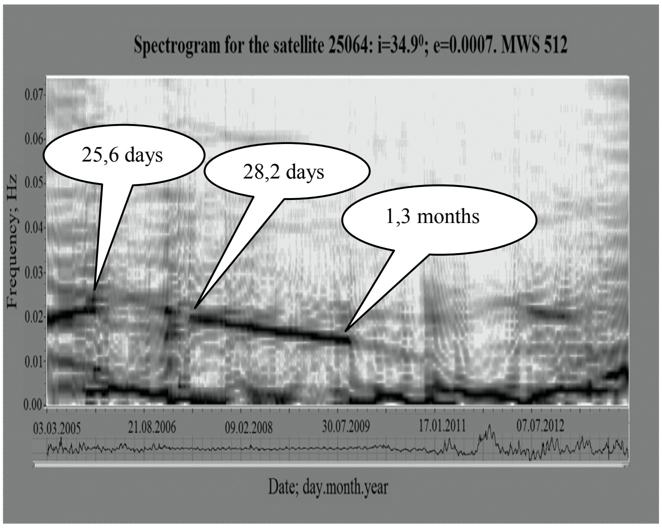

Figure 3: Spectrogram for the equatorial satellite 25064

Table 2.

Number of satellite	25860		27700		12054		25064		23757	
MWS	512	2048	512	2048	512	2048	512	2048	512	2048
Periods; Year - *, Months - **, Days - ***.	3,4*	2,5*	2,6*	2,9*	2,4*	2,4*	3,4*	3,6*	3,3*	3,7*
	7,4**	1,4*	7,1**	1,7*	7,4**	1,4*	7,2**	2,1*	7,7**	1,9*
	1,8**	5,9**	4,4**	6,8**	5,2**	8,5**	5,4**	11,7**	4,5**	1,05*
	25,9***	1,5**	1**	1,1**	3,3**	5,8**	1,3**	5,8**	1**	6,1**
	14,5***	27,1***	16,3***	1**	2,2**	3,7**	28,2***	1,5**	27,4***	1,6**
		14,5***	10,7***	16,3***	25,6***	2,9**	26,4***	29,9***	24,4***	27,4***
			8***	10,9***		1,4**				
						27,4***				

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