SUN AND SOLAR SYSTEM

DAILY AND SHORT-PERIOD CHANGES DYNAMICS OF THE EARTH'S MAGNETIC FIELD IN THE 24-TH CYCLE OF SOLAR ACTIVITY ACCORDING TO MAGNETIC OBSERVATORY "ODESSA"

L.I.Guglya [1], M.I.Orlyuk [2], M.I.Ryabov [1], A.L.Suharev [1], I.M.Orliuk [2]

[1] Radioastronomical Institute of National Academy of Sciences of Ukraine
[2] Geophysics institute of S.I.Subbotin NAS of Ukraine

ABSTRACT. The Registration of Bx, By, Bz – vector components of the Earth`s magnetic field, with a time resolution in 1 second is carried out on magnetic observatory "Odessa". . Results of calculated module of a full vector of magnetic field variations for 2008-2010 are analyzed. "The quasi-daily period" of solar dynamics is determined by wavelet analysis. The daily period and the spectra of shorter duration periods are substracted by digital filtering method. In consequence of the recieved data magnetic storm time specifications are shown.

Introduction

"Odessa" Magnetic Observatory was founded by Imperial Novorossiysk University in the Botanical Garden at the beginning of the twentieth century. Odessa State University moved the observatory to Stepanovka village near Odessa in 1936. The station was transferred to the Institute of Geophysics NASU in the postwar period. The registration of Bx, By, Bz – components of the Earth's magnetic field with a time resolution of 1 second was started at the beginning of the 2008. [1]The radio telescope "URAN- 4 " RI NASU is working near Odessa since 1987. It is one of the VLBI elements of the "URAN" decametric range. Monitoring on RT "URAN- 4" "translucence" of the ionosphere by powerful cosmic radio source program is running since 1987 [2]. Combined analysis of radio-astronomical observations and magnetic field changes allow us to find out basic laws of displaying the condition of space weather[3-4].

Observational data

Spatiotemporal structure of Earth's magnetic field $\boldsymbol{B}$ is the sum of fields from different sources [8]:

$$\boldsymbol{B = Bn + Ba + Bв}$$

where $\boldsymbol{Bn}$ – normal (main) field of the Earth, which is generated by processes in the liquid kernel and mantle boundary and defines a global spatial and temporal structure of the field of the planet; $\boldsymbol{Ba}$ – anomalous magnetic field (the lithosphere) caused fief mainly magnetization of rocks; $\boldsymbol{Bв}$ – the external field due to the influence of solar and cosmic radiation, magnetic fields of the Sun and near-Earth space. External field that makes the short-period variations in the mid-latitudes, can be represented as:

$$\boldsymbol{Bв = DR+DT+DCF+DP+ Sq}$$

where $\boldsymbol{DR}$ – a variation of the magnetospheric ring current (includes partial ring current); $\boldsymbol{DT}$ – variation of currents in the magnetotail; $\boldsymbol{DCF}$ – a variation of the currents at the magnetopause; $\boldsymbol{DP}$ – variation of ionospheric currents in the auroral zone and reverse currents spreading in the Middle latitude; $\boldsymbol{Sq}$ – quiet solar-diurnal variation.

Long-period changes (over a year) of the geomagnetic field caused by internal sources. In this paper we study the short-period variations of these changes (characterizing the dynamics of the external field) for 2008-2010 years by the analysis module full magnetic field vector with a one-minute resolution. For computing module used in its Bx, By, Bz – components measured with 1s interval and accuracy of 0.1 nTl magnetic observatory "Odessa" (Geophysics institute of S.I.Subbotin NAS of Ukraine).

Figure 1 shows the initial series data characterizing the vector magnetic field of the Earth in July 2008. To smooth short-term fluctuations and highlight the main trends were calculated moving average value and applied a trigonometric polynomial (Figure 1).

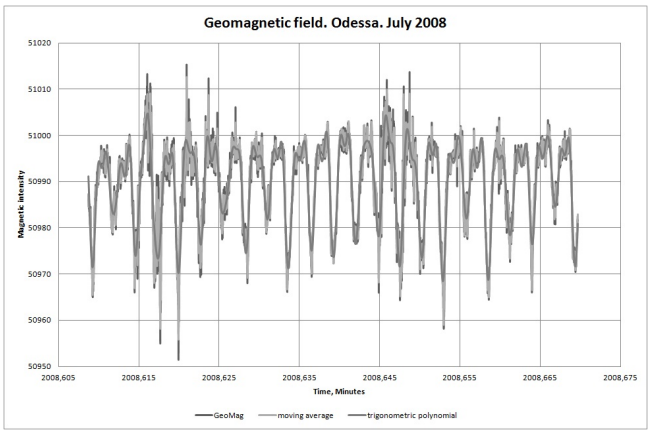

Figure 1: Variations of the Earth's geomagnetic field (Odessa, July 2008).

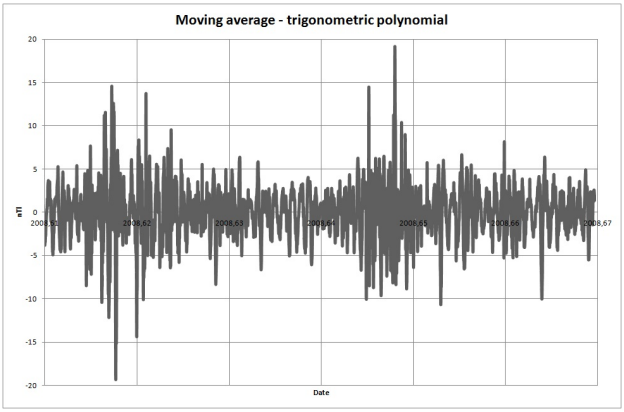

Figure 2: Variations of geomagnetic field (O-C) in July 2008. (Odessa magnetic station)

To calculate the amplitude of the oscillations of short processes was carried out the procedure for calculating the values of O-C (moving average of the values of the trigonometric polynomial subtracted). Results of computations O-C shown in Figure 2.

Solar activity in 2008 (July-December)

In July 2008 solar activity was significantly lower – just one small group of spots was detected at the end of the second decade. Maximum relative number of spots observed in June 19 W = 9. On June 28 there were no spot detected on the Sun. Flare activity was very low during the whole month, no active important phenomena was noticed. Geomagnetic situation was determined by the passage of the Earth's high-speed solar wind streams from coronal holes this month. July 12 a small magnetic storm was detected.

Sunspot activity of the Sun in August 2008 has shortly decreased. Maximum relative number of spots observed on August 22 with a value of W = 8 and visible solar disk was without spots for 29 days. Flare activity was very low during the whole month. At the same time ground-based observatories have detected geomagnetic disturbances such as two low magnetic storms on the 9 and 18 of August. Totally it was three days detected in August when geomagnetic conditions were disturbed.

Solar activity was much lower till September 22, 2008 only one small group of spots at the end of the second decade was detected. Flare activity was at a very low level the whole month. Significant active phenomena were not observed. Coronagraph on SOHO registered 18 coronal emission substances in August. This month the passage of three coronal holes on the visible sun's disk were detected, two in August and a new one. At the 4th and 14th of September two low recurrent magnetic storms were executed. Disturbed geomagnetic situation was registered within 3 days.

In October sunspot activity of the Sun in comparison with September little increased. Maximum relative number of spots observed on October 16 with a value of W =14, visible solar disk was without spots for 20 days. Medium magnetic storm was detected on the 14th of October. Totally 6 days with disturbed geomagnetic state were noticed in October. A high level of high-energy electrons flow on geostationary orbit was registered for 16 days. Low solar flares have executed on the 3 and 4th of November. Maximum relative number of spots observed on the 12th of November with a value of W =13, and for 16 days there were no spots on the sun. Coronagraph space observatory SOHO has registered 18 small coronal mass blowouts in August. A high level of high-energy electrons flow was recorded in geostationary orbit during 17 days.

Maximum relative number of spots observed on the 10th and 12th of December with a value of W = 9, and visible solar disk was without spots for 28 days. Flare activity was very low during the whole month. It was three coronal holes passage registered across the visible sun's disk which did not cause any significant disturbances in the near-Earth space. Totally 6 days with disturbed geomagnetic situation were noticed in December. A high level of high-energy electrons flow was recorded on the geostationary orbit for 4 days.

For the July – December period outbreaks of sudden onset were not reported otherwise there were 11 outbreaks with a gradual onset, which are listed in Table 1.

Table 1.

Date from	Date to	Dur.,hh	Intens.	Amp.D	Amp.H	Amp.Z
2008/07/11 23:00	2008/07/12 22:00	24	1	65	97	4
2008/07/22 11:00	2008/07/24 01:00	39	1	70	86	6
2008/08/09 00:00	2008/08/10 10:00	35	1	99	117	5
2008/08/18 10:00	2008/08/19 06:00	21	1	99	118	5
2008/09/03 23:00	2008/09/05 00:00	26	1	162	101	8
2008/09/14 19:00	2008/09/15 22:00	27	1	116	74	5
2008/10/02 09:00	2008/10/03 02:00	18	1	86	91	5
2008/10/03 09:00	2008/10/04 12:00	28	1	60	91	5
2008/10/11 08:00	2008/10/12 22:00	39	2	284	161	10
2008/11/07 20:00	2008/11/09 01:00	30	1	91	86	6
2008/12/05 10:00	2008/12/07 01:00	40	1	178	81	4

Wavelet analysis of the Earth's magnetic field

To obtain data on the spectral and spatial characteristics of the Earth's magnetic field index for 2008 (June – December) wavelet analysis was used. Wavelet analysis provides information about the existence of main periods and time of their existence. The method of application of the wavelet analysis is presented in [5].

As a result of this analysis a wavelet time-frequency spectrum of the density distribution of energy was built (Fig. 3).

On this spectrum Solar the most intense circadian period is clearly displayed. Wavelet analysis allows calculating of duration and the intensity of detected periods.

Variations circadian periods are shown in Figure 4. Figure 5 shows the fluctuation of leading period that reached 31.9 hours during 2008. On the 13th, 28th of June and the 12th of August this period is demonstrated most actively.

To identify short-period processes (less than day) time-frequency wavelet spectrum for data filtered trend component was calculated. The calculation results are displayed in Figure 6.

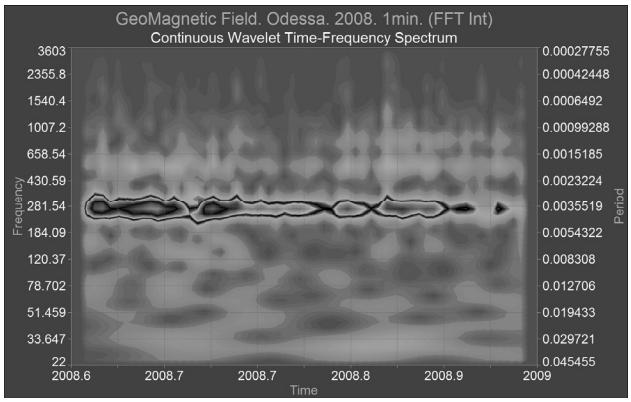

Figure 3: Wavelet time-frequency spectrum of density spreading for geomagnetic activity energy (2008)

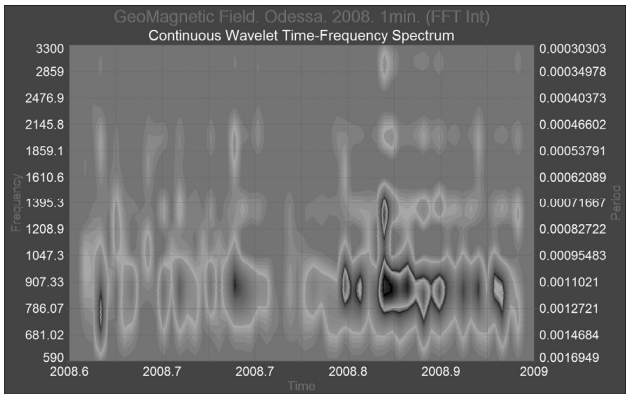

Figure 6: Time-frequency wavelet spectrum of density spreading for geomagnetic activity energy (2008). A day period is subtracted.

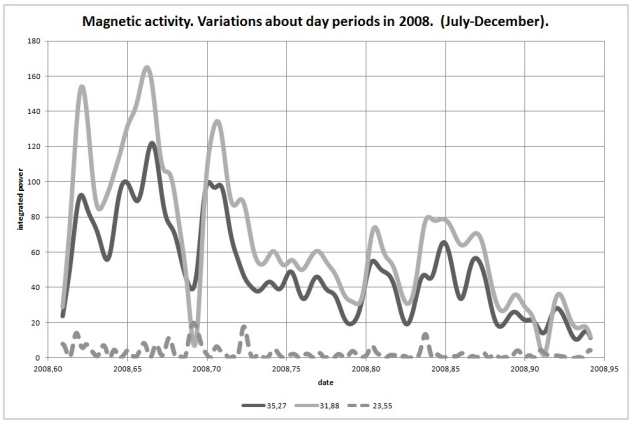

Figure 4: Circadian period variations in 2008 (July-December).

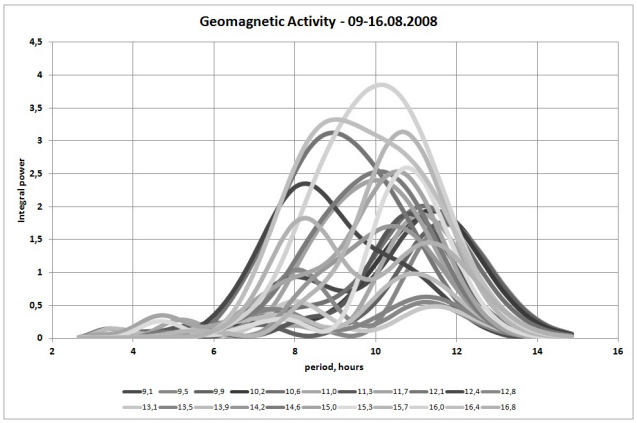

Figure 7: Duration and intensity of Earth's magnetic field periods

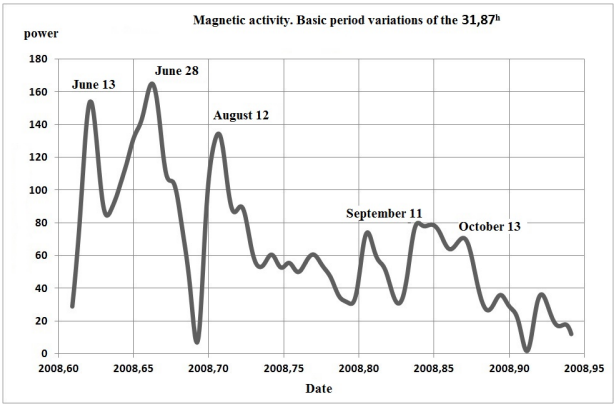

Figure 5: The leading period variations (31.9 hours) in 2008 (July-December).

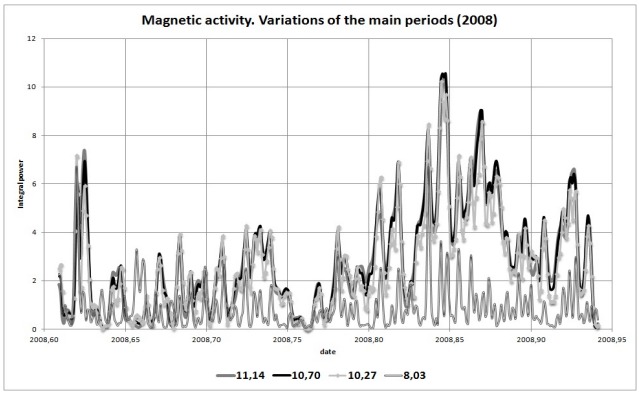

Figure 8: The most intense periods of 2008

Characteristics of less than day periods during 2008 were calculated. Appeared on 9-16 July 2008 periods are shown as an example (Figure 7). The leading periods that characterize the whole 2008 year were discovered as a result of this analysis (Table 2).

Table 2: Leading periods that characterize the July-December (2008)

date	Period (Hours)	intensity	Period (Hours)	intensity	Period (Hours)	intensity
09-16.07.2008	9,1	9,13	11,61	7,03	4,3	1,77
17-23.07.2008	11,14	2,56	7,1	1,91	4,3	0,56
24-31.07.2008	7,1	4,04	8,01	3,29	10,3	2,48
01-08.08.2008	10,3	3,92	8,01	1,09	5,5	1,28
09-16.08.2008	10,3	3,84	9,1	3,2	4,9	0,33
17-24.08.2008	10,3	4,28	8,01	1,98	4,9	1,7
25-31.08.2008	10,3	4,06	10,69	3,79	6,03	0,83
01-08.09.2008	10,69	1,89	11,14	1,65	8,01	0,84
09-16.09.2008	10,3	4,22	10,69	3,48	8,01	0,92
17-23.09.2008	10,3	6,26	10,69	5,31	6,54	2,33
24-30.09.2008	10,69	7,39	11,14	5,84	8,01	1,82
01-08.10.2008	10,69	10,55	7,1	6,39	3,25	2,59
09-16.10.2008	10,69	9,03	11,14	8,97	6,03	0,79
17-23.10.2008	10,69	6,66	11,14	4,09	4,3	0,73
24-31.10.2008	10,69	4,62	11,14	4,29	4,9	1,37
01-08.11.2008	11,61	6,61	11,14	5,82	6,81	1,73

A general picture of the most intense periods of year 2008 is got: 8 hour, 10.67 hour and 11.14 hour (Figure 8). These periods most actively identified themselves on the 14th of July 4th and 12th of October, 24th September and the 3rd of November.

The *daily periodicity Evolution* in 2009, 2010.

For receiving data about the progress in daily periodicity in 2009 – 2010 years wavelet analysis was used. The index of the Earth`s magnetic field was used as the test material.

Wavelet time-frequency spectrum of energy density distribution for 2009 and 2010 was built as a result of this analysis (Figure 9, 10).

Solar circadian period, which is the most an intense and continuous is greatly allocated on spectrums.

Based on calculations of wavelet analysis numerical values of these periods were allocated (Figure 11, 12).

On figures 11 and 12 it is visible that the leading period in 2009 and in 2010 is equal 23,9 and 24,4 hours, respectively.

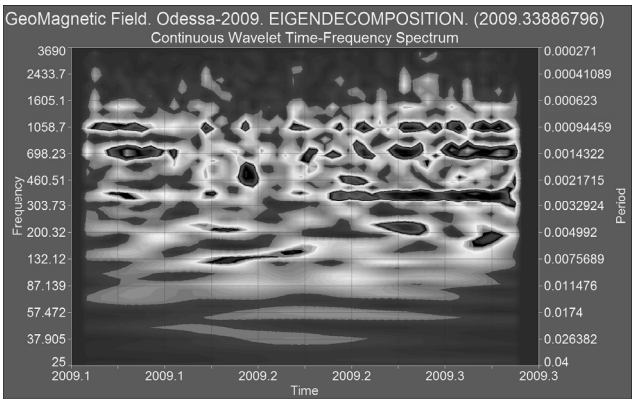

Figure 9: Wavelet time-frequency spectrum of density spreading of geomagnetic activity energy (2009)

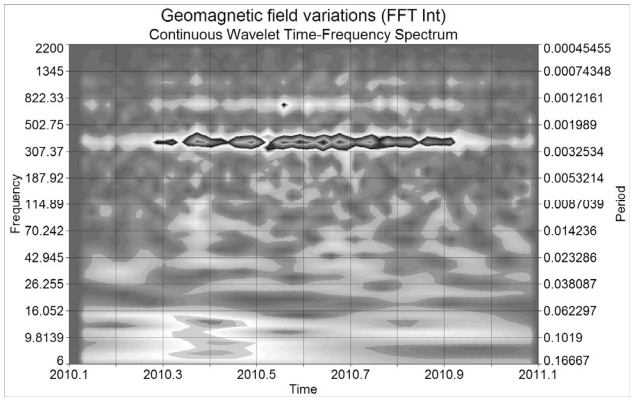

Figure 10: Wavelet time-frequency spectrum of the density spreading of geomagnetic activity energy (2010)

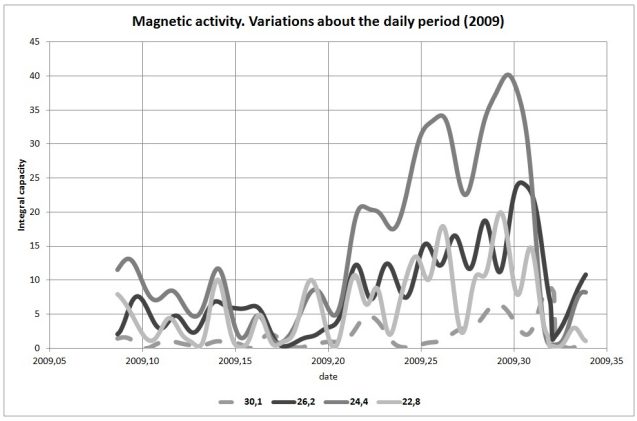

Figure 11: *Circadian variations period in 2009* (January-March)

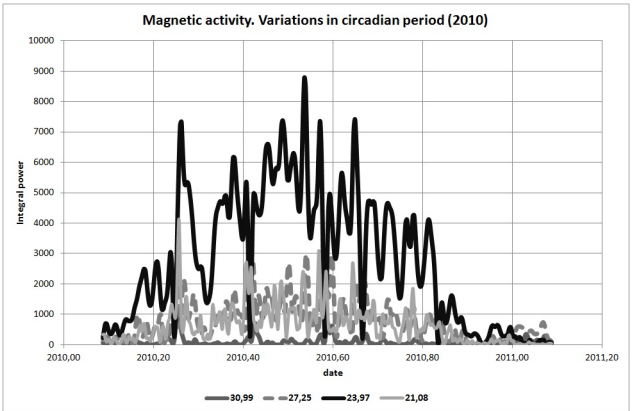

Figure 12: Circadian variations period in 2010.

Conclusion

- The dynamics of short time variations full vector magnetic field module in 2008-2010 years of the magnetic observatory Odessa data was investigated by wavelet analysis.
- Leading periods that characterize the state of geomagnetic activity were identified as a result of researches. The intensity and duration of their existence is calculated.
- The most intensive solar circadian period stands out clearly for researched period. It turned out that during the minimum solar activity leading period is – 31.9 hours (2008). During the increase of solar activity leading period is near by 24 hours (2009, 2010)
- Leading periods of less than one day duration, the calculation results of wavelet analysis are: 11.14, 10.67, 8:00 hours. These periods most actively are shown on the July 14, October 4, 12 and November 3 (2008). The magnetic storms with gradual start, caused *by* streams of energetic solar pieces from the solar coronal holes were observed on these days. During magnetic storms the circadian period was disturbed and shorter periods were increased.

References

1. Orliuk M.I., Romenets A.A., Sumaruk T.P., Sumaruk Yu.P.: 2012, *Odessa Astron. Publ.*, **25/2**, 102.
2. Guglya L.I., Ryabov M.I., Panishko S.K.: 2011, in *11-th Gamow's astronomical conference-school*, 159.
3. Druzhinin I.P., Sazonov B.I., Jagodinsky V.N. *Space-earth Forecasts*, Moscow, 1974.
4. Ivanov-Holodni G.S., Nikolsky G.M. *The Sun and ionosphere,* Moskow: Nauka, 1969.
5. Smolentsev N.K. *Introduction in the wavelet theory*, Moscow-Izhevsk, 2005, 401 p.