Abstract. Research of fractal dimension of the series of the physical parameters having uniform time discretization allows us to reveal structural features of investigated current parameters. It is very important under conditions of variations of the parameters caused by the certain physical reasons. In case of studying of a solar wind in the near-Earth space environment we investigate the structure of velocity and plasma density of solar wind. Phenomena of solar activity on a solar disk help us to recognize the source of solar wind. The area of generation of the solar wind, coming to the Earth, is located in the central part of a disk of the Sun. Displays of solar activity share on two big categories: 1 – the long-term solar activity existing during one or several Carrington rotations of the Sun, 2 – the sporadic displays having short-term powerful course. Typical displays of solar events of a category 1 are solar spots, variations of background magnetic fields on the Sun, coronal holes in solar atmosphere. Sporadic displays are expressed most brightly in solar flares, filament eruptions, coronal mass ejections. Heliophysical data help us to proof the identification of a source of a solar wind.

Fractal dimension calculations have been spent by a technique of a sliding window. At the heart of calculations the method of Higuchi lies. Structural features of various streams are classified on magnitude and type of variations of fractal dimension. High speed streams of solar wind from coronal holes have the fractal dimension ~ 1,7-2,0. Heliosphere plasma layer transition has fractal dimension fall up to 1,5 or deeper (in the case of high speed stream after transition of heliosphere plasma layer).

Sporadic phenomena manifest the growth branch of new solar cycle N24. Fractal dimension in the case of sporadic phenomena varies; the interpretation of “portrait” of sporadic phenomenon is based on fractal analysis and heliophysical data. The fractal estimations of time series of solar wind parameters (Wind data) allow us to evaluate the altered structure of flows, connected with the origins on photosphere, in solar corona and with the propagation on 1 AU from the Sun to the Earth. Geomagnetic disturbance is in use as additional information about solar wind action on the Earth magnetosphere.

INTRODUCTION

Solar recurrence within last centuries was defined on a variation of number of solar spots. However in all displays of solar activity the repeatability of many processes on the Sun has own display. Phases of a branch of growth, a maximum, a branch of descending and a minimum of 11-year-old solar cycle have the features forming a basis of forecasting of solar activity in the future. The current period of the end of 23-th solar cycle in a secular minimum differs from minima of 20-th century the expressed fall of spot generation on the Sun and low level of geomagnetic activity. The deep minimum gives the chance to research of long-term variations of parameters of a solar wind. Last solar minimum is especially interesting to research of long-term phenomena of solar activity. Coronal holes reach own maximal development in the phase of minimum. In near-equatorial belt of the Sun the heliosphere plasma layer (HPL) gets the most flat configuration. The flare activity falls; coronal mass ejections are absent previously in minimum too.

It is necessary to notice that historical view on the solar activity, only as about level of sunspot generation on solar disk, today cannot be satisfactory. Now the concept of solar activity becomes much wider, than representation about sunspots on the solar disk and W numbers, as the characteristic of spot generation.

The retrospective analysis of solar cyclic repetition and disorder of the published forecasts specify in insufficiency of earlier accepted estimations. Deviation from empirical Gnevyshev-O’l rule speaks us about change of the tendency in processes of sunspot appearance, look Fig. 1. However, Wolf’s numbers represent a solar activity in general features, therefore it is necessary to research of variations of global solar physical characteristics. Energy transformations on the Sun provide a variety of solar activity, which never stops, finding other forms in time of realization. Data of synoptic charts of the Sun (http://wso.stanford.edu/), coronal holes (http://sohodata.nascom.nasa.gov/cgi-bin/data_query/) and high-speed streams of solar wind...
dynamics of large-scale solar magnetic fields and heliospheric plasma layer variations characterize heliophysical processes in the last solar minimum.

Fig.1 Wolf numbers and geomagnetic aa indices from 1863 up to 2010. The most regular transformation we look in the middle of XX century. Four last 11-year cycles had irregular maximum W values. Up to 70-th years the Sun had on e tendency of cycle genesis, after 80-th – another tendency, which differing from Gnevyshev-O’l rule.

NEAR-EARTH COSMIC DATA IN TREATING

A lot of information is represented by data in near-Earth cosmic space. In our work plasma and interplanetary magnetic field of solar wind were treated with help of fractal methods. The fractal estimations of time series of solar wind parameters (Wind data) allow us to evaluate the altered structure of flows, connected with the change of the origins on photosphere, in solar corona and with the propagation on 1 AU from the Sun to the Earth.

GEOMAGNETIC ACTIVITY REFLECTS SOLAR ACTION

Geomagnetic disturbance (http://isgi.cetp.ipsl.fr) is in use as additional information about solar action on the Earth. The giant magnetosphere cavity is the complex and sensitive object, which reflecting in own parameters a variation of plasma and interplanetary magnetic field in solar wind. We may use substorms and magnetic storms indices as the level of energy transformation to the Earth’s atmosphere layers. We use AE, aa, ap and Dst indices in our study. Even at first sight it is visible that annual values of geomagnetic activity and Wolf’s numbers correlate poorly, Fig.1. But concrete displays of AE index (http://wdc.kugi.kyoto-u.ac.jp/ae_provisional/index.html) can be useful in a phase of the end of a minimum, when the weak sporadic streams of coronal mass ejections (CME) (http://cdaw.gsfc.nasa.gov/CME_list) are growing gradually in the time. It allows the identification of the current displays of influence of a solar wind on magnetosphere. According mentioned above, we investigate by fractal methods [1] SW plasma flows and will reveal a features in SW: 1 – “activity impulses” by Gnevishev-O’l and long-lived HPL transitions in connection with sector structure of interplanetary magnetic field; 2 – sporadic phenomena, as filaments
eruptions, CME in flares (http://sohodata.nascom.nasa.gov/cgi-bin/data_query/). A division of recurrent and sporadic events is rather interesting in the beginning of a growth phase of new 24-th cycle.

FRACmAL METHODS AND FRACmAL DIMENSION

Fractal calculation was performed by method of (Higuchi, 1988). From the finite set of time series with regular time discretion is created new time series, where the element of series is defined as

\[ X_k^m, X(m), X(m + k), X(m + 2k), \ldots, X \left( m + \left\lfloor \frac{N - m}{k} \right\rfloor \cdot k \right), \quad (m = 1, 2, \ldots, k), \]  

(1)

The expression (1) in big square brackets denotes the Gauss” notation and both k and m are integers; m and k indicate the initial time and the interval time, respectively. The length of the curve, \( X_k^m \) is defined as follows:

\[ L_m(k) = \left( \sum_{i=1}^{N-m/k} | X(m + ik) - X(m + (i-1)k) | \right) \cdot \frac{N-1}{k} \cdot k^{-1} \]  

(2)

The term \( N - 1/[N - m/k] \cdot k \) in (2) represents the normalization factor for curve length of subset time series. The curve length is determined for the time interval. \( \langle L(k) \rangle \) as the average value over k sets of L.

If the impression is \( \langle L(k) \rangle \propto k^{-D} \), the curve is the fractal with fractal dimension \( D \).

REZULTS AND DISCUSSION

Fractal dimension calculations have been made for Carrington rotations № 2092-2099 in 2010, when the first sporadic phenomena began to amplify, Fig. 2, (1-7). Fractal dimension variations of plasma density and solar wind speed were calculated by the described technique [2]. Fractal dimension results allow us to reveal the structure change in solar wind flows and to treat them on the basis of events of solar activity registered on the Sun in central part of visible solar disk. The time delay between events of solar activity and arrival of a solar wind to the Earth is defined on speed of a solar wind. It is quite comprehensible to individual sporadic events. Sector structure of interplanetary magnetic field in SW and solar magnetogram (SOHO MDI) are supplementing each other. Sector structure (negative sector – red, positive sector – blue) is designated on Figures 2, as additional characteristics of the situation in solar wind.

Let's notice that in CR 2091 the slowest solar wind is observed for all period of 23-th minimum of solar activity. This rotation is similar to CR 2089. However the neutral line of the chart of solar surface field in CR 2089 lies near to solar equator, but in CR 2091 neutral line leaves to higher heliolatitudes. It speaks about increase of solar activity. Therefore we proceed to the study of the next Carrington rotations.

CR 2092 – Fig.2 (1). Fractal dimension calculation of January 2010 is seen on Fig 2, (1). Geomagnetic activity is very quiet even in AE-indices. The first HPL transition had place in January 5 (+/–). The slow dense wind remained up to 11.01.2010. Growth of SW speed is seen in January 11-16. Density \( N \) was low. Possibly, FD variations on 10-12.01.2010 are provided by co-rotating interaction regions (CIR). It is the most probable reason. The second bay of SW speed was seen on January 20. FD variation is connected with high-speed flow and HPL transition (−/+). It is the description of the very quiet CR 2092.

CR 2093 – Fig.2 (2). The beginning (+)-(–), the middle (–/+), and the end (+/–) of February are designated by transitions of SS. In the beginning of month we see high-speed stream (HSS), then we look CME as plasma layers (February 6-11, 2010). In the day of February 15 the SS variation (–/+), indices AE grow up to 1000 nT. After the day 19.02.2010 geomagnetic activity is absent. We see co-rotating interaction region of CME in the day 25.02.2010 and reveal the next typical HPL transition (+/–) on 28.02.2010.

CR 2094 – Fig. 2 (3). Quiet SW (Vx ~ 400 km/s with N~1–10) shows two-sector structure with transition (−/+), and the end (+/-) of February are designated by transitions of SS. In the beginning of month we see high-speed stream (HSS), then we look CME as plasma layers (February 6-11, 2010). In the day of February 15 the SS variation (−/+), indices AE grow up to 1000 nT. After the day 19.02.2010 geomagnetic activity is absent. We see co-rotating interaction region of CME in the day 25.02.2010 and reveal the next typical HPL transition (+/–) on 28.02.2010.
The SW plasma density has growing on March 24-25, 2010 – it may be the arrival of coronal mass ejection, which was registered SOHO on March 20 as a partial halo.

**CR 2095** – Fig. 2 (4). Beginning of April is disturbed magnetically, AE~1000 nT. In negative sector there is a powerful "impulse of activity", following by geomagnetic storm: storm sudden commencement (SSC) 05/8.26 UT, AE~2000 nT. It is the result of flare (B3.7, AR 11060). The flare generated high speed stream, co-rotation interaction region and filament eruption. Typical sector strcuture transition (−/+)) is seen April 12, 2010. SS has a variation in (−) sector on April 19-21, 2010.

It is the first Carrington rotation with powerful sporadic phenomenon.

**CR 2096** – Fig.2 (5)."Impulse of activity" (Vx>700 km/s) had place 02.05.2010, AE>1000 nT. May 2010 is more interesting and disturbed month, but SW data has big gap in calculations, look Fig.2 (5).

**CR 2097** – Fig.2 (6). Beginning of CR 2097 May 20-27, 2010 is not disturbed. Time interval May 28 – June, 4 has a big disturbance in AE indices. Sporadic phenomena are presented in CR 2097.

**CR 2098** – Fig.2 (6,7). Geomagnetic active period begins in June 16, AE>1000 nT. FD has variation in (−) sector, after transition HPL (+/−) (June 25, 2010) we look in FD the real high speed stream on June 27-30, AE>1000 nT. The high-speed stream is not uniform (the abrupt velocity growth begins on Jun 29, 2010). Active high speed stream is prolonged up to July 3, 2010. SS transitions we see on June 07, 2010 and July 10-11, 2010. July 8, 2010 and July 10, 2010 AE indices were very low.
CONCLUSION

Solar wind flow structure is the valuable characteristics in solar cycle. The growth phase beginning of 24-th solar cycle is connected with the transformations of fractal dimension values of solar wind. It confirms the increase of the sporadic phenomena in the beginning of new 24 cycle of solar activity.

BIBLIOGRAPHY