UDC 55 CODEN – GEOME 2 ISSN 0352 – 1206

GEOLOGICA MACEDONICA

Geologica Macedonica	Год.	**24**	Број	1	стр.	1–74	Штип	2010
Geologica Macedonica	Vol.		No		pp.		Štip	

Geologica Macedonica *Geologica Macedonica*	Год. Vol.	**24**	Број No	1	стр. pp.	1–74	Штип Štip	2010

GEOLOGICA MACEDONICA

Published by: – Издава:

The "Goce Delčev" University, Faculty of Natural and Technical Sciences, Štip, Republic of Macedonia

Универзитет „Гоце Делчев“, Факултет за природни и технички науки, Штип, Република Македонија

Language editor	Лектура
Marijana Kroteva	**Маријана Кротева**
(English)	(англиски)
Georgi Georgievski, Ph. D.	**д-р Георги Георгиевски**
(Macedonian)	(македонски)
Technical editor	Технички уредник
Blagoja Bogatinoski	**Благоја Богатиноски**
Proof-reader	Коректор
Alena Georgievska	**Алена Георгиевска**
Address	Адреса
GEOLOGICA MACEDONICA	**GEOLOGICA MACEDONICA**
EDITORIAL BOARD	**РЕДАКЦИЈА**
Faculty of Natural and Technical Sciences	**Факултет за природни и технички науки**
P. O. Box 96	**пошт. фах 96**
MK-2000 Štip, Republic of Macedonia	**МК-2000 Штип, Република Македонија**
Tel. ++ 389 032 550 575	**Тел. 032 550 575**

E-mail: todor.serafimovski@ugd.edu.mk

400 copies	Тираж: 400
Published yearly	Излегува еднаш годишно
Printed by:	Печати:
2ri Avgust – Štip	2ри Август – Штип
Price: 500 den	Цена: 500 ден.
The edition was published in December 2010	Бројот е отпечатен во декември 2010

Photo on the cover:	На корицата:
Argillitic alteration, Kadiica, Republic of Macedonia	Аргилитска алтерација, Кадиица, Република Мекедонија

Geologica Macedonica	Год.	24	Број	1	стр.	1–74	Штип	2010
Geologica Macedonica	Vol.		No		pp.		Štip	

СОДРЖИНА

Geologica Macedonica	Год.	24	Број	1	стр.	1–74	Штип	2010
Geologica Macedonica	Vol.		No		pp.		Štip	

TABLE OF CONTENTS

Geologica Macedonica, Vol. 24, No 1, pp. 1–12 (2010)
GEOME 2 ISSN 0352 – 1206
Manuscript received: March 20, 2010 UDC: 550.380
Accepted: September 27, 2010

Original scientific paper

THE STRUCTURE OF THE BIG MAGNETIC STORMS

Spomenko J. Mihajlović[1], Rudi Čop[2], Paolo Palangio[3]

[1]*Geomagnetic Institute, Geomagnetic Observatory Grocka, Belgrade, Serbia, 11306 Grocka,*
[2]*Higher Education Center Sezana, Laboratory for Geomagnetism and Aeronomy, Slovenia,*
[3]*INGV, Osservatorio Geofisico, Castello Cinquecentesco, 67100 L'Aquila, Italia*
mihas@sezampro.rs //rudi@artal.si // palangio@ingv.it

A b s t r a c t: The records of geomagnetic activity during Solar Cycles 22 and 23 (which occurred from 1986 to 2006) indicate several extremely intensive A-class geomagnetic storms. These were storms classified in the category of the Big Magnetic Storms. In a year of maximum solar activity during Solar Cycle 23, or more precisely, during a phase designated as a post-maximum phase in solar activity (PPM – Phase Post maximum), near the autumn equinox, on 29, October 2003, an extremely strong and intensive magnetic storm was recorded. In the first half of November 2004 (7, November 2004) an intensive magnetic storm was recorded (the Class Big Magnetic Storm). The level of geomagnetic field variations which were recorded for the selected Big Magnetic Storms, was ΔD_{st} > 350 nT. For the Big Magnetic Storms the indicated three-hour interval indices geomagnetic activity was K_p = 9. This study presents the spectral composition of the D_i – variations which were recorded during magnetic storms in October 2003 and November 2004.

Key words: magnetic storms; geomagnetic activity; variations in the geomagnetic field; spectrum of variations

INTRODUCTION

During the solar cycles (about 11.5 years) observatories recorded several events of geomagnetic disturbances. These may be the SSC-type geomagnetic storms (SSC – ***s****udden* ***s****torm* ***c****ommencement*) or a g-type geomagnetic storms (g – ***g****radual beginning*). The variations described can be used as the basis for a survey of the compound structure of the external geomagnetic field.

In Observatory yearbooks are contented the average solar daily variation for different months of the year, and even separately for quiet, disturbed and all days. Based on the geomagnetic activity index K_p, and solar activity indices R_i, the five quiet and disturbed days are selected very soon after the end of each month by the ISGI – International Service of Geomagnetic Indices in Paris (France). During Solar Cycles 22 and 23, which took place from 1982 to 2005, on the basis of the geomagnetic data recorded at several mid-latitude European observatories diurnal geomagnetic activity variations geomagnetic disturbances and class intensive geomagnetic storms were analyzed.

The amplitudes of the regular daily variation will reach a maximum value during the summer solstices and a minimum value during the winter solstice. This property is proof that the regular daily variations have a seasonal character and that they depend on solar activity changes. At the mid-latitude geomagnetic observatories the measured variation amplitudes during the summer were about 60 nT and during winter 20 nT (nano Teslas, nT).

The sunlight daily variation is directly connected to the upper atmosphere electrical conductivity and to the motions of the atmospheric gas through the geomagnetic field lines of force. These motions and their complex interactions with the field, create an electrical current system in the ionosphere detectable on the Earth's surface as a slow modulation of the three components of the geomagnetic field that can be observed clearly.

At the Geomagnetic Observatory Grocka GMO (GCK) (Serbia), the geomagnetic storms which occurred during the period 1958–1990 were classified (Mihajlović J. S.; 1996a). Classification as well as statistics and spectral analysis were made for a group (family) of 150 geomagnetic storms. Geomagnetic storms with sudden commencement (SSC-type) and geomagnetic storms with gradual commencement (g-type), were chosen from the 150 classified geomagnetic storms and analysed (Mihajlović J. S.; 1996b). In addition, the intensive magnetic storms which occurred during the period 1986–2005 were also classified; these storms were recorded at Mid-latitude European Geomagnetic Observatories (Cander Lj. R., Mihajlović J. S.; 2005).

Table 1 presents the coordinates of the geomagnetic observatories which made the geomagnetic storm classification, and Table 2 presents the parameters of the Big Magnetic Storms which occurred during the period 1982–2005.

Table 1

Mid-latitude European geomagnetic observatories

Observatory	Code	Geographical latitude
Panagjurishte	PAG	40.6°N
Ebro	EBR	40.8°N
L'Aquila	AQU	42.4°N
Grocka	GCK	44.6°N
Tihany	TIH	46.3°N
Chambon-la-Foret	CLF	50.1°N
Belsk	BEL	50.2°N
Niemegk	NGK	54.1°N
Wingst	WNG	54.5°N
Brorfelde	BFE	55.6°N

At several European GMO's the total of 37 ssc-type magnetic storms were analyzed. The parameters used for magnetic storm classification are: magnetic storm level and magnetic storm duration. The maximum change in the geomagnetic field, which was recorded over the disturbance interval, defines the magnetic storm level. For the magnetic storms analyzed there was registered a maximum intensity change in the geomagnetic field's horizontal component as follows: ΔH_{max} = ΔH_{level} > 200 nT. The magnetic storms lasted about seventy-two hours or $\Delta t_{st} \geq 72$ hr's (Δt_{st} – the storm time intervals). Table 2 contains a group of eight Big Magnetic Storms which were taken from the total number of the selected magnetic storms.

The Class of Big Magnetic Storms (Table 2) were compared with the magnetic storm categories designated during observation at the Japanese observatories of Kakioka (KAK), Memambetsu (MEM) and Kanoya (KNY) (Tsunomura S.; 1999a) and also with the monthly reports on the rapid variations which were recorded at the worldwide network of magnetic observatories and published by ISGI (International Service of Geomagnetic Indices, Publications, Office Monthly Bulletin – Preliminary Report on Rapid Variations)).

On the basis of the geomagnetic data recorded at several mid-latitude European geomagnetic observatories during Solar Cycles 22 and 23, which took place from 1986 to 2005, the daily geomagnetic-activity variations, geomagnetic disturbances, and the intensive magnetic storm classes were analyzed.

Table 2

The List of Big Magnetic Storms which were recorded during Solar Cycles 22 and 23 which occurred from 1986 to 2006 (Indices g.m.a. K = 9)

Magnetic storm	Duration (start)	Duration (end)	Level amplitude (nT)
1982, July 11th	13 Jul 1982 16:17 UT	15 Jul 1982| 22:00 UT	420
1986, February 6th	06 Feb 1986 13:15 UT	10 Feb 1986 23:45 UT	445
1989, March 13th	13 Mar 1989 01:28 UT	15 Mar 1989 21:50 UT	574
1990, April 9th	09 Apr 1990 08:44 UT	15 Apr 1990 06:00 UT	584
1991, October 17th	17 Oct 1991 13:33 UT	21 Oct 1991 19:20 UT	392
2000, July 14th	14 July 2000 06:46 UT	17 July 2000 13 54 UT	478
2003, October 29th	29 Oct 2003 06:12 UT	01 Nov 2003 21:00 UT	700
2004, November 7th	07 Nov 2004 02:57 UT	11 Nov 2004 14:00 UT	500

GEOMAGNETIC DISTURBANCE

Geomagnetic activity may be analyzed during a month on the basis of mid-time values and in this way regular and periodic variations may be selected as components of the geomagnetic structure. During certain days of the month recorded data for geomagnetic activity may show disordered, irregular and non-periodic variations in the geomagnetic field. They emerge at irregular time intervals and have different periods; the amplitudes/intensity of these variations may have several tens to several hundreds of nT.

The group of authors in period 1960–1972 have been defined another kind of division of the *D* field, based on physical considerations (Akasofu S.-J., Chapman S.; and M. Sugiura). These are associated with theoretical ideas as to the electric current systems by which the *D* field is produced. They are denoted by *DCF*, *DR* and *DP*: *D* for disturbance; *CF* for corpuscular flux; *R* for ring current and *P* for polar.

The *DCF* field is produced by electric currents flowing near the surface of the hollow carved by geomagnetic field in the solar stream or cloud that generates magnetic storms. The current flows as long as the corpuscular flux continues. The main effect of the *DCF* field at the earth's surface is to increase H component in low and middle latitudes, more on the dayside than on the night side of the Earth.

The *DR* field is produced by enhanced west ward electric current round the Earth during the storm. This current is associated with the motions of energetic particles in the outer geomagnetic field. The main effect of the *DR* field at the earth's surface during storms is to reduce H component in low and middle latitudes. The *DCF* and *DR* currents flow at distances of a few earth radii far above the main terrestrial ionosphere.

The *DP* field is produced by currents flowing in the ionosphere. They are driven by elelctromotive forces in the auroral zones. This *DP* field has a different time scale from that of magnetic storm.

They may be a fourth addition to the preexisting fields during the storm. The solar gas may carry with it a magnetic field transported away from the Sun. This field may be denoted by *DSM* (Disturbing Solar Magnetism).

The disturbing field *D* during a magnetic storm may be divided into the following four main parts:

$$D = DCF + DP + DR + DSM.$$

In the disturbed category of geomagnetic activity come disturbed daily variations and non-periodic disturbed variations, as well as short-term periodic changes in the geomagnetic field, which are observed as pulsations. All the aforementioned geomagnetic field variations which have all the aforementioned characteristics, or some of them, constitute a geomagnetic disturbance.

Sugiura and Akasofu, Chapman, (1961, 1972) and other researchers selected some morphological characteristics common to all geomagnetic disturbances by analyzing and investigating a great number of magnetic storms and other magnetic disturbances. Each geomagnetic disturbance is composed of: the regular part of the geomagnetic field's disturbance (*DS*); non-periodic variations (D_{st}), and the irregular part of the geomagnetic field's disturbance (D_i).

Selecting the days when geomagnetic disturbances were recorded as the days for analysis and applying the method of geomagnetic field variation processing, it is possible to regard the morphology of the variations, which are integral parts of the geomagnetic disturbances, in a different light. The geomagnetic field variations which may be expressed as the mid-time variation values for the days during the disturbance are defined as the regular part of geomagnetic disturbance or the DS-variation of the geomagnetic field. The subtraction of the geomagnetic field variations, which were recorded during the geomagnetic storm, from the defined *DS*-variation will present the non-periodic and irregular part of the geomagnetic disturbance.

One of the most important attributes of magnetic storms is that these geomagnetic disturbances have three phases: the initial phase, the main phase and the recovery phase (Figure 1, Figure 2). The appearance of an SSC impulse in the recorded data signifies the beginning of a magnetic storm (SSC impulse – ***S****udden* ***S****torm* ***C****ommencement*). It is followed by a sudden change ("jump") in the intensity of the geomagnetic field's horizontal component (ΔH) which is recorded over a short interval, which can last 3–5 minutes (Figure 1, Figure 2). These are very important parameters which describe the morphology of the SSC impulse and announce the sudden commencement of SSC-type magnetic storm.

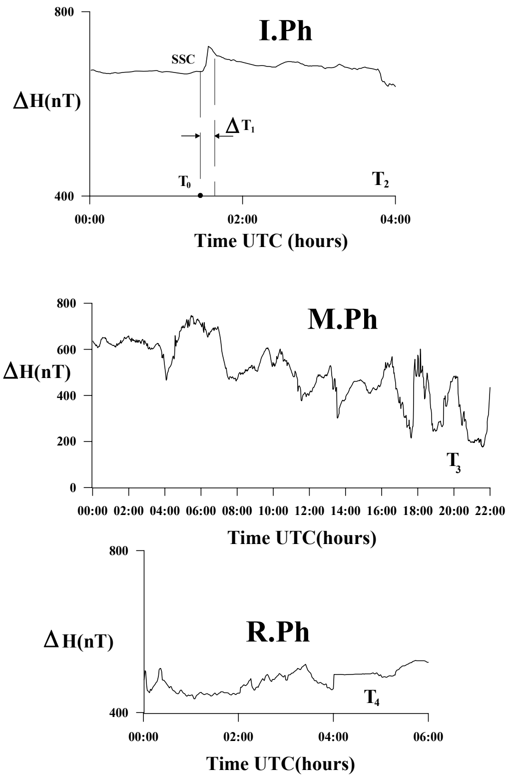


Fig. 1. The morphology of a geomagnetic storm shown in three phases
a) the initial phase (I.Ph); b) the main phase (M.Ph);
c) the recovery phase (R.Ph)

Changes in the Earth's Magnetic Field, without a predetermined period and different amplitudes, are determined as geomagnetic disturbances. The most typical geomagnetic disturbances are magnetic storms. They are represented by intensive variations in the geomagnetic field. These variations have a complex morphology.

The line of increase in the geomagnetic field's horizontal component values determines the initial phase of a magnetic storm. The initial phase can last for 30 minutes to a few hours (Figure 1, Figure 2). The main phase of a magnetic storm starts with the moment of decrease in the intensity of the geomagnetic field's horizontal component. The decrease in the field's intensity can last for a few hours to a few days. During the main phase of a magnetic storm, geomagnetic field variations with different amplitudes and periods can be recorded. It can be assumed that the recovery phase of a magnetic storm starts when the horizontal component values start their return to the level before registration of the storm (Figures 1, Figure 2).

The described geomagnetic field changes which occur during magnetic storm are a macrostructural model of the magnetic storm. This model highlights the cumulative, principal characteristics associated with the magnetic storm phenomenon.

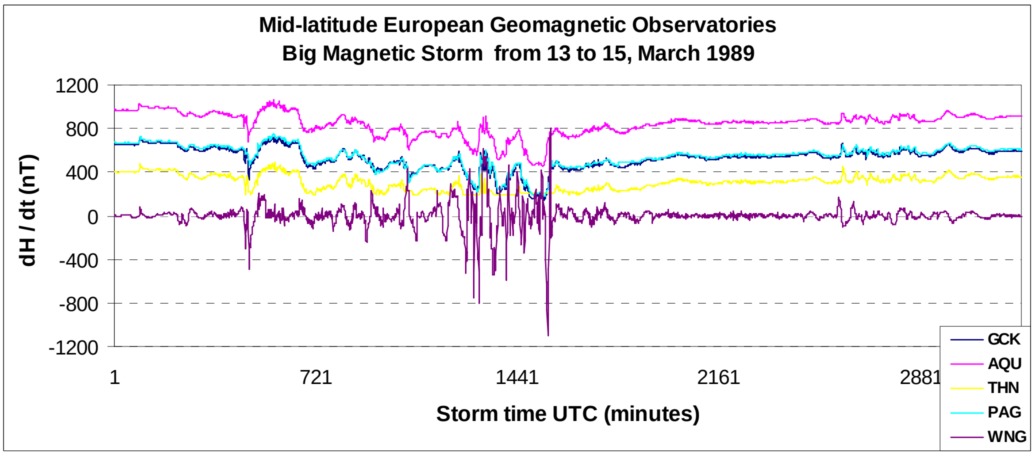


Fig. 2. The variations recorded in the horizontal component of the geomagnetic field during the Big Magnetic Storm on 13, March 1989, at Mid-latitude European Geomagnetic Observatories

The described methodology for geomagnetic field variation analysis during a geomagnetic disturbance was used for the intensive geomagnetic storms recorded on February 6, 1986 and on March 13, 1989 (Villante U. et al. 1990; Chander R. Lj., Mihajlović J. S., 1998). The data from these two geomagnetic storms which were recorded at mid-latitude geomagnetic observatories were used for the analysis (Table 1, Table 2, Figure 1, Figure 2).

The recorded variations mean hours values for the geomagnetic field's horizontal components (*H* or *X* component) may be determined for the geomagnetic storms' time intervals, on the basis of the study of a great number of geomagnetic storms during various seasons. When the described analytic procedure is applied to geomagnetic disturbances, the result is a regular variation of the geomagnetic field according to certain rules, which is essential for all recorded changes in the geomagnetic storm and this is called the non-periodic variation (D_{st}). The geomagnetic field's non-periodic variation (D_{st}) is linked to the time (t_{st}) when the geomagnetic storm starts. Referring to its basic interpretation this variation is defined as the storm time variation (D_{st}), or variation over the interval which starts with the magnetic storm's commencement and finishes when the geomagnetic storm ends (Akasofu S-J. and Chapman S. 1961, 1972; Bartels J.; 1963).

The deviation in the geomagnetic field's variation – presented in minutes and measured during the geomagnetic storm interval – from the determined D_{st}-variation, illustrates the irregular part of the geomagnetic field's disturbance. This deviation is the result of subtraction: the disturbed daily variation (S_D) & non-periodic variation (D_{st}) minus the geomagnetic field's variation which was recorded during the geomagnetic storm. Such a geomagnetic field variation is called an irregular variation (D_i). This type of geomagnetic field variation is composed of a complex signal which characterizes a "chaotic, irregular" feature of the geomagnetic disturbance. The structure of the geomagnetic field's irregular variation (D_i) contains the individual characteristic of each geomagnetic storm (Mihajlović J. S., 2000; Cander Lj. R., Mihajlović, 2005).

If we can say for the D_{st} variation that it is a picture of the magnetic storm (the morphology of the magnetic storm), then the D_i variation is the rhythm of each magnetic storm (the power of the magnetic storm).

This study presents the methodology for analysing the geomagnetic field variation, using the recorded data at several mid-latitude geomagnetic observatories, during the two Big Magnetic Storms on 29, October 2003 and on 07, November 2004 (Table 1, Table 2).

Big Magnetic Storm on 29. October 2003

In 2003 during the last ten days of October, intensive and very turbulent changes in the solar radiation spectrum were recorded in both solar activity and the sun's magnetic field. The recorded phenomena: solar storms, explosive and hyperactive solar flares with strong coronal mass ejection (CME) caused large magnetic storms in the geomagnetic field, which were classified in the clas or category of the Big Magnetic Storms.

The beginning of the intensive magnetic storm in October (29, October 2003) was signified by an SSC (A) impulse. The amplitude of the SSC (A) impulse which was recorded at the Geomagnetic Observatory Grocka (GCK; φ = 43.4°), was $\Delta X = -54$ nT, $\Delta Y = -40$ nT, $\Delta Z = -10$ nT. Figure 3 shows the October Big Magnetic Storm which was recorded at the mid-latitude European GMO's.

In the interval from the start (the time when the sudden storm commencement impulse was recorded) through the approximately 120 or 150 minutes of minute values changes in the geomagnetic field's H-component intensity at the listed geomagnetic observatories reached $\Delta H > -700$ nT (Figure 3). Therefore, it is necessary to mention, as this storm's particular feature or individual characteristic, that extremely high values in the geomagnetic field's intensity were recorded constantly during the initial phase. The extremely high sunspot group activity continued over the next few days, and disturbed geomagnetic activity and the geomagnetic storm lasted till November 2nd 2003.

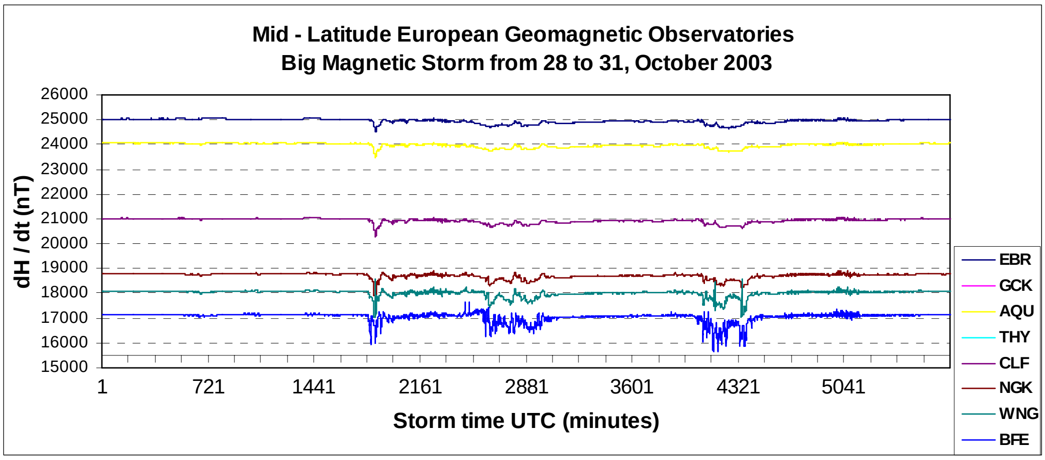


Fig. 3. The October's Big Magnetic Storm which was recorded at the mid-latitude European Geomagnetic Observatories

The specific characteristic of the October Big Magnetic Storm was its non-periodic variation (D_{st}). Figure 4 shows the D_{st}-variation of the October Big Magnetic Storm which was recorded at the mid-latitude European geomagnetic Observatories (last diagram) and the D_{st}-variation data recorded at the Geomagnetic Observatories: GCK, AQU and WNG which are shown separately (first diagram). The maximum changes in the geomagnetic field's horizontal components (*H* or *X* component) are represented by the mean hours values witch during the October's Big Magnetic Storm were greater than four hundred nano Teslas $\Delta H > - 400$ nT (Fig. 4.).

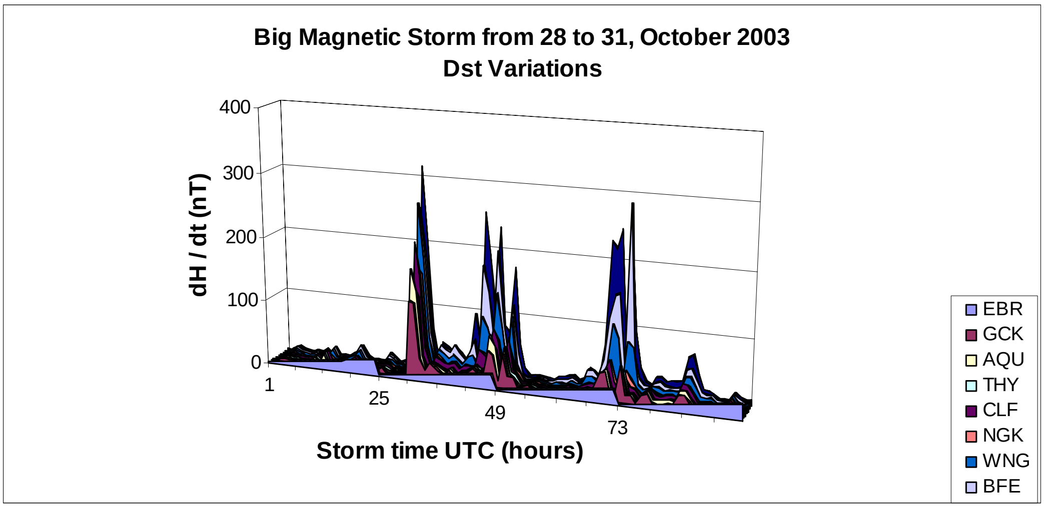


Fig. 4. The D_{st} variation structure which was recorded during the October's Big Magnetic Storm

The results of the analysis and surveys of the March Big Magnetic Storm (13, March 1989) showed that the recorded data of the D_{st}-variation have a tendency to reduce the geomagnetic field's horizontal component intensity (a depression in the horizontal component intensity). This may be taken as a standard or regular morphology and structure of the non-periodic variation (D_{st}) (Cander R. LJ., and Mihajlović J. S.; 1998).

In the D_{st}-variation structure, during the main phase of the October's Big Magnetic Storm, three cycles of intensity reduction in the geomagnetic field's horizontal component were recorded. The cycles of intensity reduction in the geomagnetic field's H-component lasted about ten hours. On diagrams on Figure 5 is shown the amplitude spectrum of the non-periodic variation (D_{st}) signal recorded at the GMO (GCK).

The Fourier transformation of the non-periodic variation (D_{st}) signal, which was recorded during October Magnetic Storm, showed that the changes in the geomagnetic field's H-component intensity came about in cycles with a frequency from $\Delta\omega = 0.05$ to $\Delta\omega = 0.38$ cycles per hour, that is their periods were $\Delta T = 150 - 180$, $\Delta T = 200 - 240$, $\Delta T = 500$, $\Delta T = 600$ and $\Delta T = 1000 - 1200$ minutes (Figure 5.). In the amplitude spectrum of the non-periodic variation (D_{st}) signal the dominant changes were the changes in the geomagnetic field's H-component intensity, which were from $\Delta H = 2$ nT/minute to $\Delta H = 6$ nT/minute, and they were recorded at the Geomagnetic Observatory Grocka (GCK), (Figure 5.).

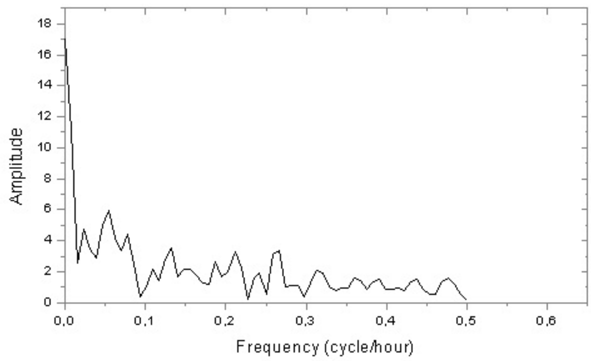
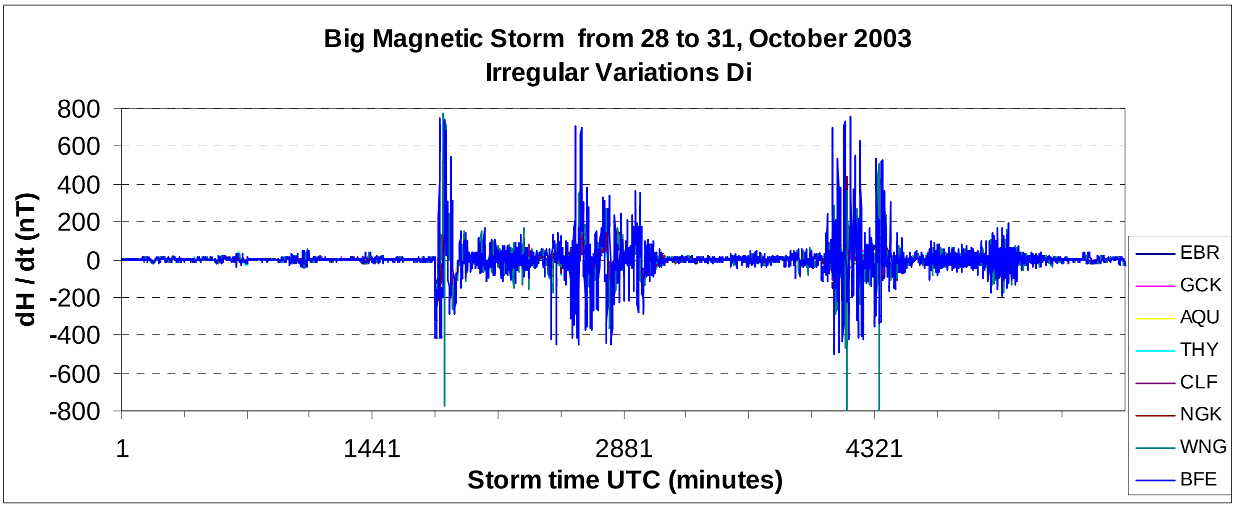


Fig. 5. The amplitude spectrum of the non-periodic variation (D_{st}) signal which was recorded during the October Big Magnetic Storm at the Geomagnetic Observatory Grocka (GCK)

In anlysis October's Big Magnetic Storm, the geomagnetic field's irregular variation (D_i) was extracted (Cander R. LJ., and Mihajlović J. S.; 2005). By taking a Fourier transformation of the irregular-variation signal (D_i), which was recorded during the October Magnetic Storm, the characteristics of the amplitude spectrum and the frequency spectrum of the geomagnetic storm's recorded variations were obtained. Diagrams on Figure 6 show the morphology and amplitude spectrum of an irregular variation (D_i) during the October's Big Magnetic Storm which was recorded at several European GMO's.

In this amplitude spectrum of the D_i variations which have frequencies from $\Delta\omega$ = 0.025 to $\Delta\omega$ = 0.5 cycles/minute were recorded (Fig. 6). It is a complex spectrum of electromagnetic pulsations with periods from two to fifteen minutes, and with an maximum amplitude of several hundred nT.

The specific characteristics of the irregular variation (D_i), which were recorded during the October's Big Magnetic Storm, are a very complex amplitude spectrum and frequency spectrum. During intervals which lasted from 100 to 150 minutes, a complex geomagnetic field variation spectrum was recorded; the complex spectrum of the P_c1 – P_c5 classes of geomagnetic pulsations (or changes in the Earth's magnetic and electromagnetic fields with periods from ΔT = 1 sec to ΔT = 20 minutes was also recorded. The solar flare group activity, the proton fluxes and the coronal mass ejections (CMEs) caused induction of the geomagnetic activity's irregular variation (D_i) with a complex spectrum.



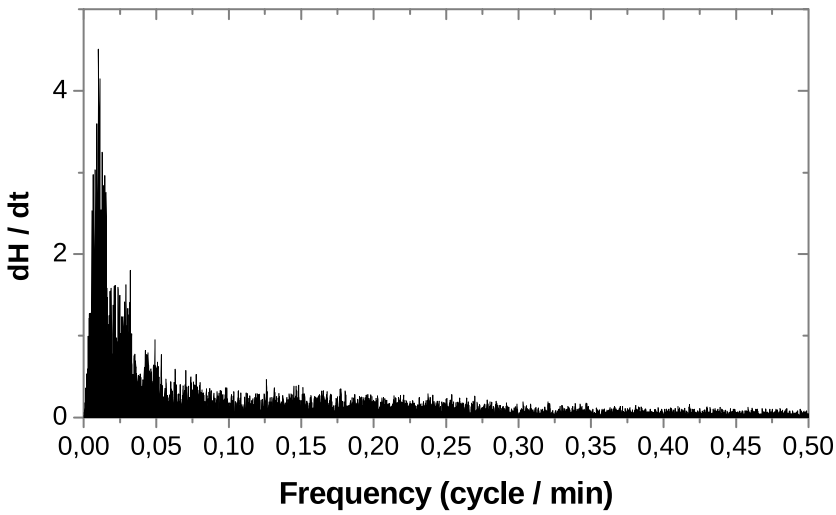


Fig. 6. The D_i irregular variation of geomagnetic field which was registered during the October Big Magnetic Storm a) the D_i irregular variation signal (upper diagram); (b) the D_i irregular variation amplitude spectrum which was recorded at the Geomagnetic Observatory Grocka (GCK) (bottom diagram)

Big Magnetic Storm on 07, November 2004

At 2:57 UT on 07, November 2004, an SSC (A) impulse was registered. It marked the start of the geomagnetic disturbance. The amplitude of the SSC (A) impulse which was recorded at the Geomagnetic Observatory Grocka (GCK) was ΔX = +4.1 nT; ΔY = –2.3 nT; ΔZ = –0.5 nT. After the first SSC impulse, geomagnetic activity conditions were moderately disturbed. This situation lasted about eight hours. A second SSC (A) impulse was recorded at 10:52 UT with an amplitude of ΔX = +14.0 nT, ΔY = +4.0 nT, ΔZ = –2.3 nT. The second SSC (A) impulse signified the development of the magnetic storm.

During the initial interval, which lasted 80 minutes, an increase in the geomagnetic field's *X*-component intensity was recorded; this increase signified the start of the November's Big Magnetic Storm's initial phase. The increase in the geomagnetic field's X-component was about ΔX = 30 nT. On Figure 7 are shown the registrations of the November's Big Magnetic Storm which were recorded at mid-latitude European Geomagnetic Observatories.

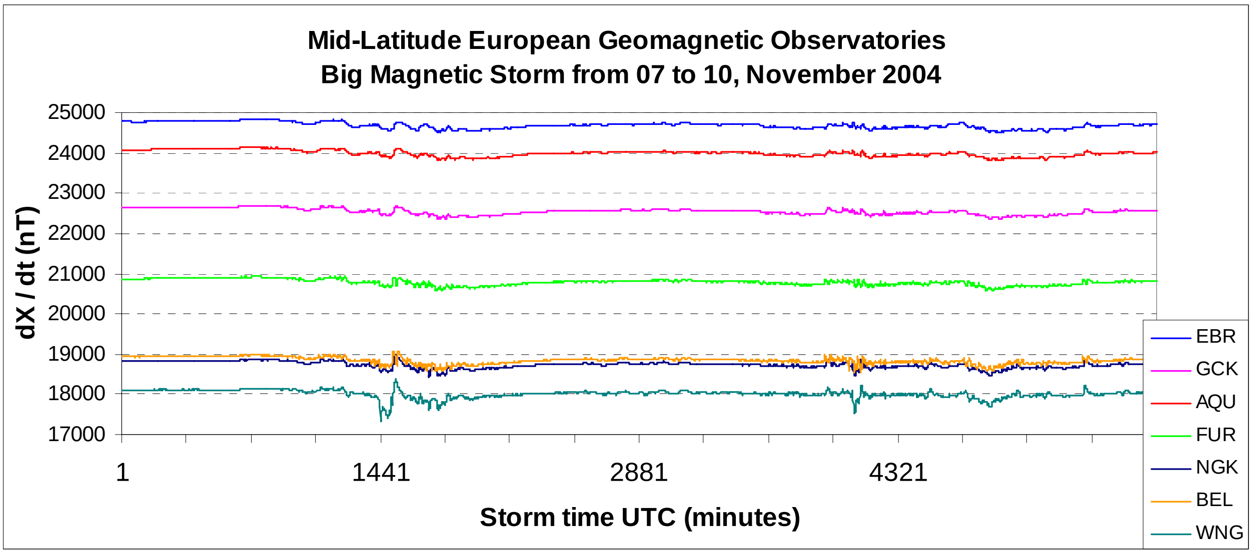


Fig. 7. The November's Big Magnetic Storm which was recorded at the mid-latitude European Geomagnetic Observatories

The recorded geomagnetic data during the November's Big Magnetic Storm show that the main phase development started after the geomagnetic field's X-component increased. The specific characteristic of the November Storm's main phase is the X-component reduction, which occurred in time interval which lasted approximately ten hours (Fig. 7.).

In the D_{st}-variations structure, during the main phase of the November's Big Magnetic Storm, a reduction in the geomagnetic field's X-component intensity was recorded over two cycles (depression). Figure 8 shows the non-periodic variation (D_{st}) signal recorded at the Geomagnetic Observatories of Grocka (GCK), L'Aquila (AQU) and Niemegk (NGK).

By taking the Fourier transformation of the non-periodic variation (D_{st}), which was recorded during the November Magnetic Storm, the periods of the changes in the geomagnetic field's X-component intensity were obtained (Fig. 8.)

The irregular variation (D_i) of the geomagnetic field which was registered during the November magnetic storm is illustrated in Figure 9. In the morphology of the irregular variation (D_i), two signals with extremely high values of the geomagnetic field's horizontal component $\Delta X > \pm 300$ nT can be observed.

Figure 9 illustrates the amplitude spectrum of the irregular variation (D_i) in the geomagnetic field. In this amplitude spectrum, the D_i variations with frequencies from $\Delta\omega$ = 0.025 to $\Delta\omega$ = 0.35 cycles/minute and periods from ΔT = 40 minutes to ΔT = 3 minutes were recorded. This is basically a complex pulsation spectrum; during the interval when the November Big Magnetic Storm was recorded these pulses had amplitudes greater than ±200 nT.

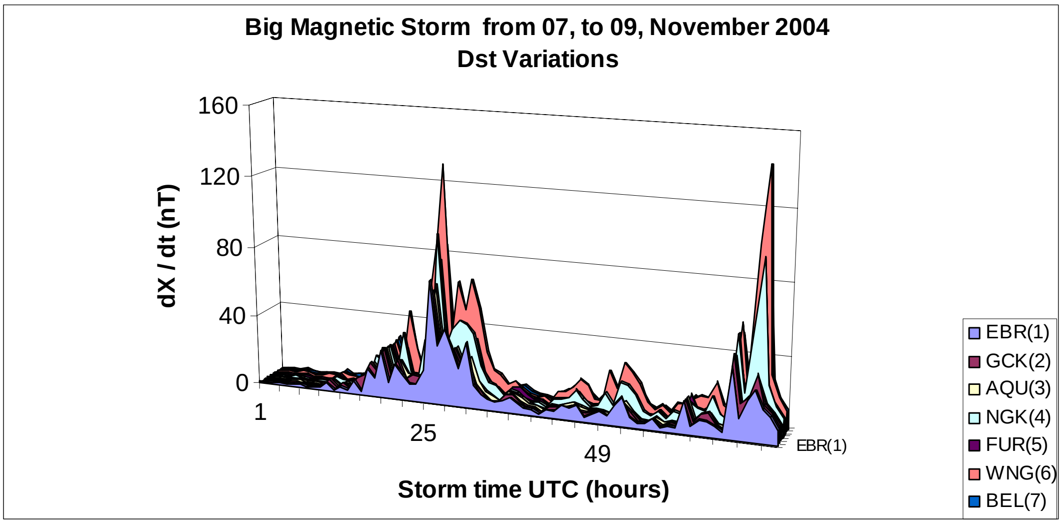
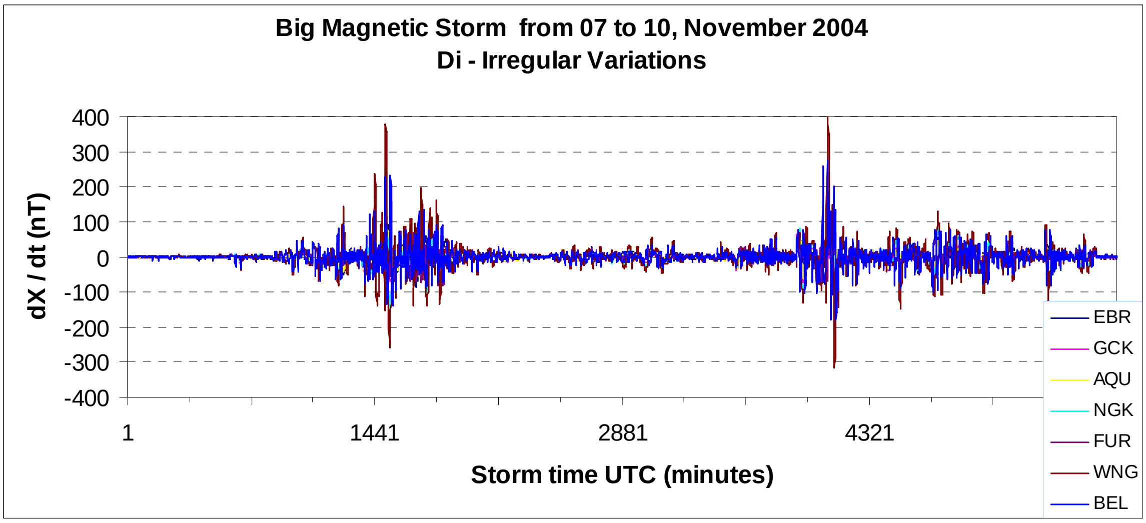


Fig. 8. The D_{st}-variation structure which was recorded during the November Big Magnetic Storm



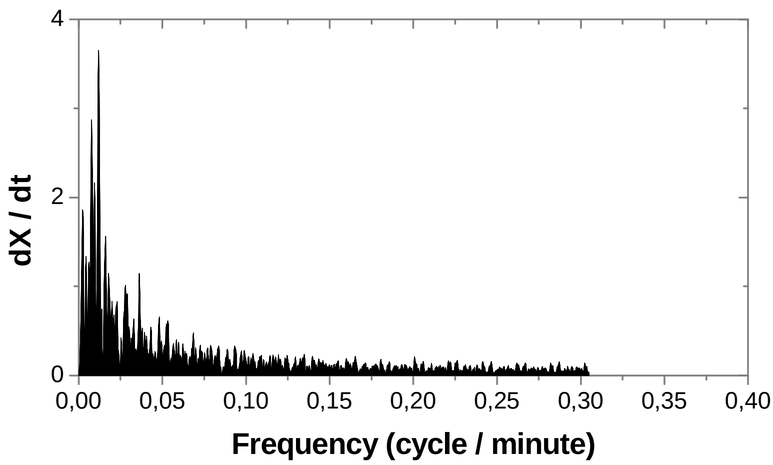


Fig. 9. The Di irregular variation of geomagnetic field which was registered during the November Big Magnetic Storm (a) the D_i irregular variation signal (upper diagram); b) the D_i irregular variation amplitude spectrum which was recorded at the Geomagnetic Observatory Grocka (GCK) (bottom diagram)

CONCLUSIONS

The structure of the geomagnetic activity disturbance is illustrated with graphs of three Big Magnetic Storms (in March 1989, in October 2003 and in November 2004) which were recorded at Mid-latitude European Geomagnetic Observatories. During the months in which these three storms were recorded the types of daily variations in the geomagnetic field were analyzed. These variations were designated as the daily variations for magnetically quiet days (S_q) and the daily variations for magnetically disturbed days (S_d).

By defining the type of daily variation in the geomagnetic field, which was recorded during the duration of the extreme geomagnetic storms (Δt_{st} – the storm time interval), the individual characteristics of these Big Magnetic Storms were determined. The types of variations in the geomagnetic field which were analyzed are: non-periodic variation (D_{st}) and irregular variation (D_i).

Referring to the literature, many groups of authors have carried out research in which they defined the D_{st}-variation as the long-term periodic changes in the geomagnetic field during the storm time interval. These changes represent the trend ("depression") in the intensity of the geomagnetic field's horizontal component during the main phase of a geomagnetic storm (Sugiura M., Chapman S., Bartels J., Akasofu S. -J., 1960–1972; Tsurutani B. T., Gonzales W. D., 1994–2004; Yago K. and Kamide Y., 2003; Cander Lj. R. and Mihajlović J. S., 1996–2005).

The non-periodic variation of the geomagnetic field (D_{st}), which was recorded during the Extreme Geomagnetic Storm in March 1989, had a distinctive line of reduction in the intensity of the geomagnetic field in one cycle. The structure of the D_{st}-variation which was recorded during the main phase of the March Big Magnetic Storm is, on the whole, equivalent to the definition of the standard (regular) macro-structural model of the non-periodic variation type.

The structure of the D_{st}-variation which was recorded during the main phase of the October Big Magnetic Storm has three cycles of reduction in intensity in the geomagnetic field's horizontal component, and the structure of the D_{st}-variation which was recorded during the main phase of the November Big Magnetic Storm has two cycles of reduction (depression) in the intensity of the geomagnetic field's horizontal component. The cycles of the intensity changes in the geomagnetic field's *H*-component lasted about ten hours.

The spectral analysis of the irregular variation signal (D_i) which was recorded during the October Big Magnetic Storm, showed that the geomagnetic field's variations were predominantly within the frequency band from $\Delta\omega = 0.025$ to $\Delta\omega = 0.5$ cycles per minute, or with periods approximately from $\Delta T = 2$ to 15 minutes with the distribution of the changes in the geomagnetic field's *H*-component intensity approximately $\Delta H > \pm 500$ nT. The spectral components of the irregular variation signal (D_i), which was recorded during the November Big Magnetic Storm, showed that the geomagnetic field's variations were predominantly within the frequency band from $\Delta\omega = 0.025$ to 0.35 cycles per minute, or with periods approximately from $\Delta T = 3$ to 40 minutes with the distribution of the changes in the geomagnetic field's *H*-component intensity approximately $\Delta H > \pm 300$ nT.

In these two extreme magnetic storms during the initial time interval of approximately 100 to 150 minutes the following data were recorded: the complex spectrum of the geomagnetic field's variations, and the complex spectrum of the P_c1–P_c5 class of geomagnetic pulsation – these were changes in geomagnetic activity and changes in the Earth's electromagnetic field with periods lasting from 10 seconds to 20 minutes.

The complex spectrum of the irregular variations (D_i) of the geomagnetic field which were recorded during the October and November Big Magnetic Storms indicates extremely strong processes in energy exchange in the solar magnetic field, and extremely high incidences of solar flares, proton fluxes and CMEs which induced very major changes in interplanetary conditions – and consequently in solar-geophysical conditions and geomagnetic activity conditions.

Acknowledgments: Results of researching of geomagnetic field variations and geomagnetic disturbances (geomagnetic storms), which are registered on European observatories of middle geomagnetic latitude, are shown on workmanship assemblies and workshops, in international MEM Project, which last from 2004 to 2008. In this work is shown the part of results of those researching...

I want to express acknowledgement lider partners of MEM Project: Regione Abruzzo, Osservatorio Geofisico L'Aquila, Instituto Nazionale Geofisica e Vulcanologia (INGV), Roma, Italia, which enabled to me to realize role in the MEM Project :"Geomagnetic field spatial modeling on regional scale".

REFERENCES

Akasofu S.-I. and Chapman S., 1972: *Solar – Terrestrial Physics, Chapter V–VIII*; Oxford University.

Akasofu S. -I. and Chapman S., 1961: A Study of magnetic Storms and Auroras; *Scientific Report No. 7.; Geophysical Institute of the University of Alaska*; March 1961.

Bartels J., 1963: Discussion of Time-Variations of Geomagnetic Activity, Indices Kp and Ap, 1932–1961, *Extrait des Annales de Geophisyque;* Tome 19, No. 1. Janvier-Mars.

Cander R. Lj. and Mihajlovic J. S., 1998: Forecasting ionospheric structure during the great geomagnetic storms; *J. Geophys. Res*., **103**, A1, 391–398, January 1.

Cander Ljiljana R. and Spomenko J. Mihajlovic, 2005: Ionospheric spatial and temporal variations during the 29–31 October 2003 storm; *Journal of Atmospheric and Solar-Terrestrial Physics,* **67**, 1118–1128; Elsevier Ltd.

Mihajlović Spomenko J., 1996a: "Morfologija varijacija geomagnetskog polja registrovanih na geomagnetskoj opservatoriji Grocka u periodu 1958-1990. godine" – Monografija, Izdanja Geomagnetskog instituta Grocka, pp. 1-63; Beograd, 1996.

Mihajlović Spomenko J., 1996b: "Morfologija geomagnetskih bura registrovanih na opservatorijama Jugoistočne Evrope", *Doktorska disertacija*, pp. 1-107, Beograd, 1996.

Mihajlović J. S; Rašić M., 2000: Solarno-geofizički procesi i geomagnetski poremećaji, *10. Kongres fizičara Jugoslavije; Zbornik radova*, Knjiga II; pp. 913–920.; Jugoslovensko Društvo Fizičara; Beograd.

Sugiura M. and Chapman S. 1960: The average morfology of geomagnetic storms with sudden commencement, *Abb. Akadem. Wissensch. Gottingen*; Math-Physik; KI.; Sond 4. Gottingen.

Sugiura M., 1961: A Study of the Morfology of Magnetic Storms, *Final Report, Geophysical Institute of the University of Alaska*; October 1961.

Tang F., Tsurutani B.T. et al. 1994: Solar Sources of Interplanetary Southward B_Z Events Responsible for Major Magnetic Storms (1978–1979), *JGR;* **94**, A4, 3535–3541, April 1.

Tsunomura S. et al. 1999a: A study of geomagnetic storm on the basis of magnetic observations in the Japanese chain observatories, *Memories of the Kakioka magnetic observatory*, vol. **27**, pp. 1–105, Japan.

Tsurutani B. T. et al. 1998: Magnetic Storms, *Geophysical Monograph*, Series 98, American Geophysical Union (AGU); Washington, DC, USA.

Tsurutani B. T. and Suess S. T. (editors), 1998: *From the Sun: Auroras, Magnetic Storms, Solar Flares, Cosmic Rays*; Copyright 1998 by the American Geophysical Union; Washington, DC, USA.

Tsurutani B. T., Gonzales W. D., et al. 2004a: Properties of slow magnetic clouds; *JASTP,* **66**, 2, January, pp 147–151, Published in Association with U.R.S.I., Elsevier Ltd.

Tsurutani B. T., Gonzales W. D., et al. 2004b: Prediction of peak – D_{st} from halo CME/magnetic cloud-speed observations, *JASTP,* **66**, 2, January, pp 161–165, Published in Association with U.R.S.I.; Elsevier Ltd.

Villante V.; Villante U.; et al. 1990: The strong geomagnetic storms of March 13, 1989, Analysis at a low latitude station, *Annales Geophysical*, 8, 337–342.

Yago K.; Kamide Y., 2003: Use of lognormal distributions in D_{st} variations for space weather forecast, *Space Weather*, **1**, 1, 1004, Winter, AGU.

The Data Sources

Solar Influences Data Analysis*, Sunspot bulletin*, 2004, No. 11, Monthly Summary of Solar and Geomagnetic Activity.

Solar Influences Data Analysis, *Sunspot Bulletin,* 2003, No. 10, Monthly Summary of Solar and Geomagnetic Activity.

ISGI Publications, *Office Monthly Bulletin*, No. 3–10, October, 2003; No. 4–11, November, 2004.

www.sidc.be, April 2007.

Р е з и м е

СТРУКТУРА НА ГОЛЕМИТЕ МАГНЕТНИ БУРИ

Споменко Ј. Михајловиќ[1], **Руди Чоп**[2], **Паоло Паланџио**[3]

[1]*Геомагнетен Институт 11306 Гроцка, Геомагнетна Опсерваторија Гроцка, Белград, Србија,*
[2]*Центар за високо образование Сежана, Лабораторија за геомагнетизам и аерономија, Словенија,*
[3]*INGV, Osservatorio Geofisico, Castello Cinquecentesco, 67100 L'Aquila, Italia,*
mihas@sezampro.rs //rudi@artal.si // (palangio@ingv.it)

Клучни зборови: geomagnetina aktivnost; geomagnetina bura, varijacii na geomagnetnoto pole; spektar na varijacii

Евиденцијата на геомагнетна активност за време на соларните циклуси 22 и 23 (кој се случија 1986–2006) укажуваат на неколку исклучително интензивни А-класа геомагнетни бури. Овие бури се класифицираат во категоријата на големи магнетни бури. Во година на максимална сончева активност во текот на Сончевиот циклус 23, или поточно, за време на фазата назначена како пост-максимална фаза во сончевата активност (PPM – Phase Post maximum – фаза на пост-максимум), во близина на есенската рамнодневица, на 29, октомври 2003 година, евидентирана е исклучително силна и интензивна магнетна бура. Во првата половина на ноември 2004 година (07. ноември, 2004), евидентирана е интензивна магнетна бура (Класа Голема Магнетна бура). Нивото на варијации на геомагнетното поле кои се снимени за избраните Големи Магнетни бури, беше ΔD_{st} > 350 nT. За големите магнетни бури наведениот тричасовен интервал покажува геомагнетна активност беше K_p = 9.

Оваа студија претставува спектрален состав на D_i-варијации што беа снимени за време на магнетни бури во октомври 2003 и ноември 2004 година.