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Dynamics of zonal components of cosmic ray distribution during geomagnetic storm periods

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We are presenting the results of the study of zonal harmonics of cosmic ray distribution during geomagnetic storm periods. In order to determine the zonal harmonics, the spherical analysis of neutron monitor worldwide network data has been used - the method of the global survey. 56 huge geomagnetic storms that had happened during 1997-2005 were reviewed. It was determined that an abrupt increase ($> 0.7\%$) of the amplitude of zonal component of isotropic part of cosmic ray distribution appears before a geomagnetic storm. The predictor appears with a probability of about 0.75 and the preceding time of the beginning of magnetic storm is 10 hours. Thus, the global survey method can be used for effective short-term forecasting of the beginning of geomagnetic disturbances.

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1. Introduction

The method of the global survey [1] that has been developed in the Institute of Cosmic Rays allows to determine the first 9 components of angular cosmic ray distribution for each hour of observation according to the data of neutron monitor worldwide network. The creation of the NMDB database enables usage of this method in the real time mode [2]. In the work [3] we have studied the behavior of a radial X_{11} and an azimuthal Y_{11} component of galactic cosmic ray (CR) diurnal anisotropy A_{11} before the beginning of 25 geomagnetic storms with amplitudes $\leq -50nT$. It was determined that during the period from a few hours to 2 days before the beginning of most of geomagnetic storms, the considerable specific changes in the behavior of this vectors not observed during the solar wind quiet periods are taking place. However, the usage of these changes as predictors of geomagnetic disturbances has a serious flaw. They can also appear when the interplanetary environment disturbances, which do not cause geomagnetic storms, are approaching to the Earth. In this work, the behavior of the north-south component of isotropic part C_{00} and the diurnal variation of CR intensity C_{10} during the magnetic storms with $Dst \leq -100nT$ are being studied based on the method of the global survey and the results of work [4]. The interest to this study is caused by the fact that during geomagnetic storms a B_z-component of interplanetary magnetic field increases, which can define a behavior of this CR distribution zonal components [5].

2. Experimental data

The average monthly values of zonal components C_{00} and C_{10} during geomagnetic field quiet periods are close to zero, but for each hour, depending on the level of geomagnetic activity, they fluctuate in different ranges. The fig.1 shows the data of Dst-variations and of zonal components C_{00} and C_{10} during relatively quiet periods of geomagnetic activity at the minimum (August 1996) and maximum (June 2001) of solar activity. As seen from the (fig.1), for the solar activity minimum the amplitude fluctuates (fig.1a) in the range $\pm 0.4\%$. In the maximum of solar activity (fig.1b) the relative increases of Dst-variations are being observed, and the fluctuations of the amplitude of zonal components can reach the values $\pm 0.7\%$. The above-mentioned examples of variation of zonal components C_{00} and C_{10} are typical for the geomagnetic field quiet periods. Therefore, the values given above can be taken as a criterion of absence of huge geomagnetic disturbances.

During the periods of geomagnetic storms, the deviations of C_{00} and C_{10} from the given values can be significantly greater and be observed before the beginning of geomagnetic storm main phase. The fig.2 shows the Dst-variations and the values of $C00$ and C_{10} during the geomagnetic storms, which were observed at the minimum (November,1997) and maximum (November, 2001) of solar activity. At the minimum of solar activity (fig.2a), November 7th and November 23rd,1997, the magnetic storms with the amplitudes -110 and 108 nT respectively were observed. The value of C_{00} reaches the value $> 4\%$ in the first case and $> 1\%$ in the second case. Thus the appearance of values $C_{00} \geq 0.7\%$ was before the beginning of the given magnetic storms by 12 and 16 hours respectively. In the component C_{10} the increase $\geq 0.7\%$ was not observed. At the maximum of solar activity the amplitudes of magnetic storms become significantly greater. In the data presented from November 6th and November 24th, 2001 (fig.2b) they reach the values of -292 and -221 nT respectively. For these disturbances the time of the appearance of the amplitude $C_{00} \geq 0.7\%$ is

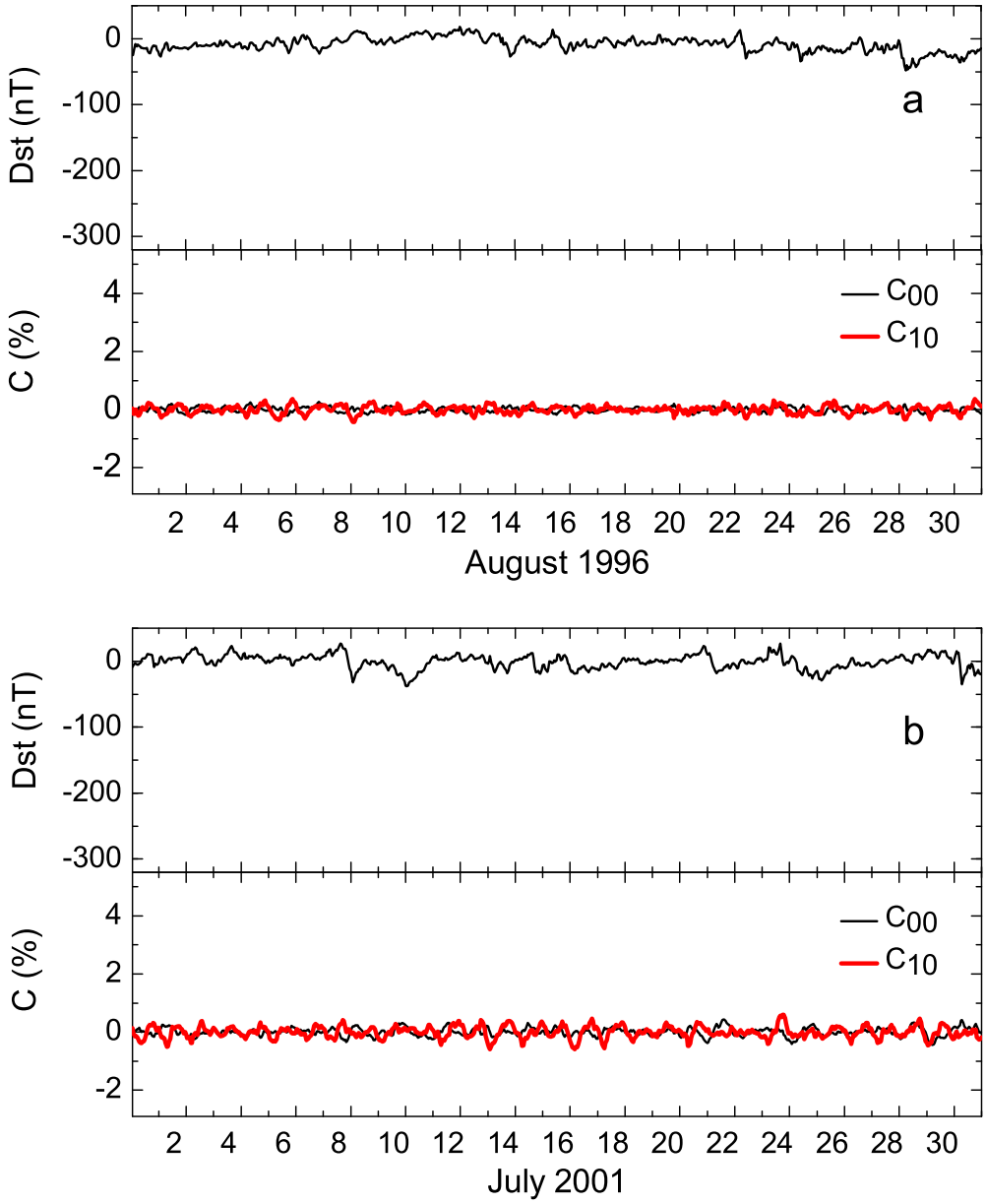

Figure 1: The geomagnetic field Dst-variations and the behavior of zonal components C_{00} and C_{00} during the quiet geomagnetic activity periods for minimum (a) and maximum (b) of solar activity.

before the beginning of geomagnetic storms by 27 and 9 hours respectively. The effects of the increase of the component $C_{10} \geq 0.7\%$ in those cases were not observed as well.

In total we have considered 56 geomagnetic storms [4]. In the table 1 the start dates and amplitudes of minimal decrease of Dst, advance $(-\triangle t^h)$ or delay $(+\triangle t^h)$ times of the zonal harmonic magnitude increases $C_{00} \geq 0.7\%$ and $C_{10} \geq 0.7\%$ relatively to the beginning of the magnetic storm are shown.

As seen from the table, the preceding predictor with the value of $C_{00} \geq 0.7\%$ before the geo-

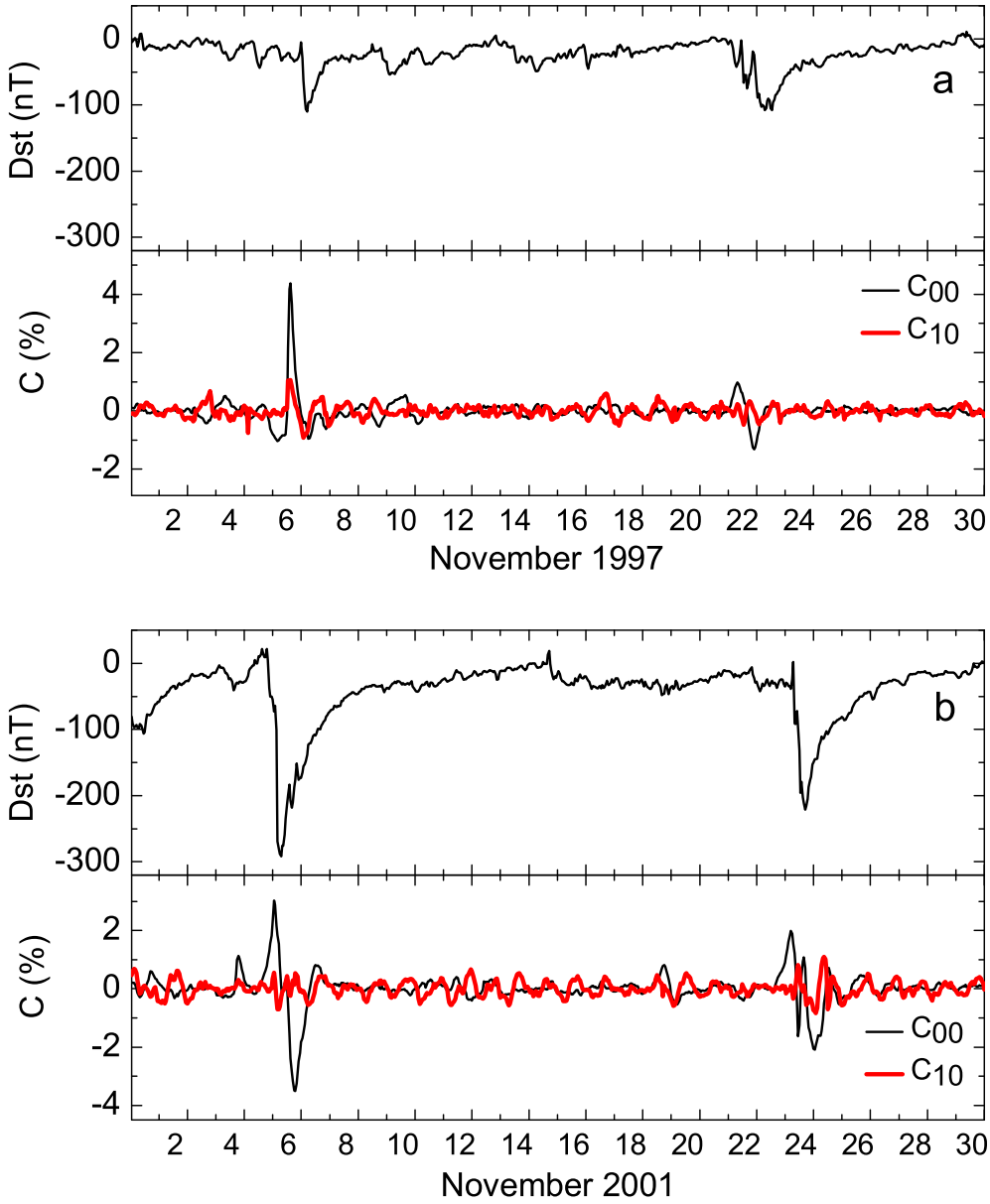

Figure 2: The geomagnetic field Dst-variations and the behavior of zonal components C_{00} and C_{00} during the disturbed geomagnetic activity periods for minimum (a) and maximum (b) of solar activity.

magnetic storm are observed occurs in 42 events, with the average advance time of approximately 10 hours. As well, during the periods from several hours to 1.5 days, mainly the increase of the value of the positive part of CR isotropic component C_{00} was being observed. The increase of the zonal component of diurnal variation C_{10} occurs only in 22 events and it is often after the appearance of predictor C_{00} and the beginning of geomagnetic storm. The absence of zonal component modulation effects during the geomagnetic storms have been observed in 8 events. The analysis of correlation of the value and advance time of appearance of the geomagnetic storm predictors with the given in [4] coordinates with the class of their solar sources has also been carried out. As

Table 1: The dates and amplitudes of studied magnetic storms. The periods of advancing $(-\triangle t^h)$ or delaying $(+\triangle t^h)$ of predictor appearance $C_{00} \geq 0.7\%$ and $C_{10} \geq 0.7\%$ relatively to the beginning of selected storms are pointed out.

No	*SSC*, *begin.*(UT)	*Dst* (nT)	$(\triangle t^h)$ (C_{00})	$(\triangle t^h)$ (C_{10})	*No*	*SSC*, *begin.*(UT)	*Dst* (nT)	$(\triangle t^h)$ (C_{00})	$(\triangle t^h)$ (C_{10})
1	1997.05.15 08:00	-115	0	-	29	2001.11.05 21:00	-292	-27	-
2	1997.11.07 01:00	-110	-12	0	30	2001.11.24 08:00	-221	-9	-8
3	1997.11.22 22:00	-108	-16	-	31	2002.03.23 18:00	-100	-	-
4	1998.05.04 04:00	-205	-4	-	32	2002.04.17 14:00	-127	-9	-
5	1998.08.26 24:00	-155	-26	-	33	2002.04.19 13:00	-149	-13	-
6	1998.09.25 03:00	-207	-21	-2	34	2002.05.11 15:00	-110	-30	-
7	1998.11.07 13:00	-149	+3	+14	35	2002.05.23 12:00	-109	-7	-
8	1998.11.08 23:00	-142	-23	-10	36	2002.08.20 20:00	-106	-	-
9	1999.02.18 05:00	-124	-1	-5	37	2002.09.07 15:00	-181	-1	-
10	1999.09.22 22:00	-173	-	-	38	2003.05.29 22:00	-144	-14	-
11	2000.02.12 10:00	-133	-13	-	39	2003.10.29 08:00	-353	-19	-19
12	2000.04.06 19:00	-288	+2	+2	40	2003.10.30 17:00	-383	-2	-
13	2000.05.24 04:00	-147	-	-	41	2003.11.20 05:00	-422	-5	+12
14	2000.07.15 17:00	-301	-31	-30	42	2004.01.22 12:00	-149	-21	-
15	2000.08.12 03:00	-235	-17	-17	43	2004.04.03 17:00	-112	-	-
16	2000.09.17 22:00	-201	-41	-41	44	2004.07.22 22:00	-101	-10	+7
17	2000.10.13 17:00	-107	-	-	45	2004.07.24 13:00	-148	-12	-
18	2000.10.28 24:00	-127	-18	-16	46	2004.07.26 24:00	-197	-12	+3
19	2000.11.26 20:00	-119	-12	-	47	2004.11.07 22:00	-373	-15	-
20	2001.03.31 05:00	-387	-10	-	48	2004.11.09 13:00	-289	-5	+8
21	2001.04.11 17:00	-271	-11	-	49	2005.01.18 01:00	-121	-2	-11
22	2001.04.18 03:00	-114	0	-	50	2005.01.21 21:00	-105	-12	-1
23	2001.08.17 18:00	-105	-12	-	51	2005.05.15 07:00	-263	-17	-1
24	2001.09.25 23:00	-102	-14	-	52	2005.05.20 06:00	-103	-	-
25	2001.10.01 01:00	-148	-	-26	53	2005.05.29 24:00	-138	-19	-
26	2001.10.03 08:00	-166	+5	+5	54	2005.06.12 19:00	-105	-12	-
27	2001.10.21 19:00	-187	-10	0	55	2005.08.24 10:00	-216	-12	-
28	2001.10.28 05:00	-157	-	-	56	2005.09.11 04:00	-147	-13	-

a result, there was no dependence of parameters C_{00} and C_{10} from the flare coordinates has been detected. It can be noted that the good efficiency of predictor appearance comes from X-class flares ($\sim 80\%$) and the weak dependence comes from C-class ($\sim 50\%$).

3. Conclusion

1. The modulation effects in the behavior of the isotropic part of zonal components and the diurnal variation of CR intensity have been studied based on the method of global survey during 56

geomagnetic storms. 2. The method of finding of the predictor before the beginning of geomagnetic disturbances with the Dst amplitude $\leq 100nT$ has been proposed. The probability and the average advance time of appearance of the predictor are 0.75 and 10 hours respectively. 3. The usage of this method in the real time mode will allow to increase the efficiency of the magnetic storm short-term forecasting.

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