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SPONTANEOUS AND INITIATED SUBSTORMS WITH A SHARP ONSET OF THE EXPANSION PHASE

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The purposel of the paper is to show difference in the development of spontaneous and initiated substorms depending on previous history of geomagnetic disturbances and conditions in the interplanetary medium.

In the capacity of substorm characteristics, AE-index values at the end of the growth phase (AE_p) and at a maximum of the expansion phase (AE_m) have been accepted. Introduced in [1] gradations of the geomagnetic disturbance level before a substorm: high, moderate and low has been used. The latter reflects prehistory of magnetospheric disturbances several hours before an expansion phase onset of the substorm analyzed and it is determined by the time interval Δt between T_0 and the preceding maximum $AE(t) \geq 250$ nT during which the AE-index is less than 100 nT. If $\Delta t < 30$ min, the level of preceding disturbance is supposed to be high, for $0{,}5 \leq \Delta t \leq 1{,}5$ h it is assumed to be moderate, for $\Delta t > 2$ h it is assumed to be low. By the data of [2] and 1-minute values of auroral indices for 1978-1990, 438 events of substorm disturbances with a sharp onset of the expansion phase have been selected. The IMF data and interplanetary medium parameters have been taken from the King catalogue at CD-ROM. By the IMF B_z orientation and change ability of the IMF |B|, the substorms have been divided into four classes as following: 1- $B_z<0$ and $U<0{,}8$ nT/min; 2- $B_z>0$ and $U<0{,}8$ nT/min; 3- at the end of the growth phase the B_z orientation changes from the southern to northern one; 4- before the onset of expansion phase, sharp changes of B_y are observed and $U>0{,}8$ nT/min, where $U = [(dB_x/dt)^2 + (dB_y/dt)^2 + (dB_z/dt)^2]^{1/2}$ is the rate of the IMF changing during 10 min before expansion phase onset. The events of classes 1 and 2 have been related to spontaneous substorms and the events of classes 3 and 4 - to initiated ones. In each class the events have been divided into three groups according to auroral disturbance level before a substorm: group A - the disturbance is high, B - moderate, C - low. For each class the dispersion analysis has been performed to estimate the influence of the disturbance level on variations of AE_p and AE_m parameters as well as the influence of the velocity V and dynamic pressure p of the solar wind plasma on the magnetospheric activity. The correlation analysis has been also performed. The results of the dispersion analysis are shown in Table 1, those of the correlation analysis - in Table 2.

Table 1. The average parameters of the substorms and solar wind

Groups	Spontaneous substorms											
	$B_z<0$						$B_z>0$					
	Parameter											
	n_i	AE_p, nT	AE_m, nT	α	V, km/s	p, nPa	n_i	AE_p, nT	AE_m, nT	α	V, km/s	p, Npa
A	57	293	746	2.55	458	3.3	40	236	540	2.29	538	4.6
B	38	165	576	3.49	438	2.8	31	133	404	3.04	472	2.8
C	34	134	531	3.96	415	2.4	36	110	373	3.39	452	2.5
Total	129	213	639	3.	441	3.0	107	164	445	2.71	490	3.4
σ		96	192	0.93	99	2.02		77	142	0.49	105	2.47
η^2		0.363	0.206		0.174	-		0.357	0.219		0.117	0.139
	Initiated substorms											
	By change of B_z sign from - to +						By fast change of B_y - component					
	Parameter											
	n_i	AE_p, nT	AE_m, nT	α	V, km/s	p, nPa	n_i	AE_p, nT	AE_m, nT	α	V, km/s	P, nPa
A	43	294	747	2.55	520	3.1	63	372	962	2.59	503	5.5
B	31	183	491	2.68	474	2.9	24	160	531	3.32	470	4.2
C	24	167	520	3.11	445	2.9	17	146	467	3.20	382	2.6
All	98	227	603	2.66	487	3.0	104	286	781	2.73	475	4.8
σ		118	216	1.68	93	1.8		112	265	1.24	112	4.9
η^2		0.185	0.257		0.086	-		0.398	0.418		0.135	-

Table 1 also presents the dimensionless values $\alpha = AE_m/AE_p$ which give a rough estimation for the ratio of maximum current densities in DP_1 and DP_2 systems, correlation ratios η^2 being a measure of influence of the factor considered, the mean square deviations σ and the number n_i for each group of the events. The correlation coefficients between AE_p, AE_m, V and p (Table 2) which exceed critical values at confidence probability 0,95 are underlined.

Table 2. The correlation coefficients between AE_p, AE_m, V, p

Groups	Spontaneous substorms									
	$B_z < 0$					$B_z > 0$				
	Parameter									
	AE_p			AE_m		AE_p			AE_m	
	AE_m	V	p	V	p	AE_m	V	p	V	p
A	0.74	0.22	-0.02	0.35	0.01	0.78	0.08	0.67	0.20	0.62
B	0.60	0.21	-0.02	0.32	0.08	0.43	0.14	0.13	0.28	0.06
C	0.56	0.27	0.23	0.46	0.01	0.41	0.04	0.30	0.24	0.41
All	0.75	0.27	0.11	0.42	0.12	0.73	0.26	0.61	0.35	0.55
	Initiated substorms									
	By change of B_z sign					By fast change of B_y				
	Parameter									
	AE_p			AE_m		AE_p			AE_m	
	AE_m	V	p	V	p	AE_m	V	p	V	p
A	0.76	0.25	0.31	0.34	0.47	0.67	0.09	0.05	0.13	0.20
B	0.87	0.09	0.03	0.13	0.15	0.62	0.25	-0.22	0.07	-0.14
C	0.80	0.22	0.01	0.35	0.28	0.81	0.15	-0.08	0.17	0.02
All	0.88	0.38	0.32	0.38	0.31	0.64	0.03	0.05	0.13	0.20

From the results presented in Tables 1 and 2 it is seen:

1. For all the classes of substorms high geomagnetic activity level before substorms was observed when the Earth passed through the high-speed streams of the solar wind. The dependence of the level of preceding solar wind disturbance on the dynamic pressure was statistically significant only for the substorms from the second class, which developed under the northern orientation of the IMF B_z.

2. For B_z>0 correlation between the dynamic solar wind pressure and AE_m and AE_p parameters has been found. For B_z<0 such correlation is not found.

Results 1 and 2 demonstrate that the influence of the dynamic solar wind pressure on the current system intensity in the auroral zone under the southern orientation of the IMF B_z is, most likely, overshadowed by more significant effects of the magnetospheric convection and that the influence manifestes at B_z>0 when the convection velocity decreases.

3. For spontaneous substorms (classes 1 and 2) the energy accumulated in the magnetosphere before a substorm during the period of preceding disturbances influences to a considerable extent on the intensification of the DP2 current system and to the least extent – on the DP1. The values of η^2 for AE_p in the case of spontaneous substorms are ~1,5 times greater than those for AE_m. For the initiated substorms (classes 3 and 4) η^2 for AE_p and AE_m are approximately the same.

4. For spontaneous substorms the ratio $\alpha= AE_m/AE_p$ decreases with the growth of magnetic disturbance level. For initiated substorms the variations of α are slight when the level of disturbance before substorm changes. It suggests that for initiated substorms the relationship between the maximum currents in the DP2 and DP1 systems is approximately linear, while for spontaneous substorms it is, most likely, non-linear. In this case the «saturation effect» of DP1 system current is displayed: the current in the substorm current werge with increasing of the current in the DP2 system, on the average, to the least extent.

5. For spontaneous substorms the correlation coefficient between AE_m and AE_p increases with increasing of the disturbance level before the substorm onset. For initiated substorms such dependence is absent.

Results 3-5 show that according to statistical characteristics spontaneous substorms developed at the southern (class 1) and northern (class 2) orientation of IMF B_z are more similar to each other than to initiated substorms (classes 3 and 4). It evidences against the Lyon hypothesis [3] according to which practically all substorms are initiated by a rapid change of IMF.

References

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