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CORRELATION BETWEEN AURORAL ACTIVITY AND RATE OF DEVELOPMENT OF A STORM IN ITS MAIN PHASE

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We investigated the relationship between the rate of storm development in its main phase (|ΔDst|/ΔT) and the average value (ΣAE/ΔT) of AE index for the main phase where |ΔDst| is the Dst-index variation, ΣAE is the total value of AE index for the main phase of magnetic storm, ΔT is the main phase duration. We considered storms initiated by corotating interaction region (CIR) and interplanetary coronal mass ejection (ICME) (magnetic cloud and ejecta). For CIR events, the value of ΣAE/ΔT is shown to correlate with the rate of storm development in its main phase in contrast to the storms initiated by the ICME. As found, there is a weak correlation between ΣAE/ΔT and the minimum value of Dst index for CIR and ICME events.

Keywords Magnetic storm · *AE* index · *Dst* index · Solar wind · Electric field

INTRODUCTION

It is known that during periods of long-term south B_z component of the interplanetary magnetic field (IMF) in Earth's magnetosphere along with substorm disturbances there occur magnetic storms. Effectiveness of the south IMF B_z component in generating magnetospheric disturbances is associated with the effect of the solar wind (SW) electric field $E_{sw}=V_xB_z$ on the magnetosphere [Burton et al., 1975; Gonzalez et al., 1994; Kane, 2005]. Intensity of substorm and storm disturbances is estimated from geomagnetic activity indices *AE* and *Dst*. The high-latitude *AE* and low-latitude *Dst* indices representing largely the intensity of ring current and currents of the auroral zone correlate with each other because they have common drivers (E_{sw}). Special attention is paid to the studies of magnetospheric disturbances during the main storm phase with the most pronounced effects of SW interaction with Earth's magnetosphere. Results of statistical and morphological investigations reveal that the intensity of magnetospheric-ionospheric disturbances (magnetic storms and substorms) depends greatly on SW type [Plotnikov, Barkova, 2007; Yermolaev et al., 2010]. At present, the following SW types are distinguished: interplanetary coronal mass ejections (ISME), including magnetic clouds (MS) and ejecta, corotating interaction regions (CIR), and sheath regions. The analysis of the relationship between SW parameters for SW streams of different types and the geomagnetic activity indices *AE* and *Dst* [Plotnikov, Barkova, 2007; Yermolaev et al, 2010.; Guo et al, 2011.; Yermolaev et al, 2012.; Liemohn, Katus, 2012; Nikolaeva et al, 2013.; . Cramer et al, 2013] indicates that during magnetic storms the minimum value ($|Dst_{min}|$) increases with increasing electric field E_{sw} for streams of all types. For ICME events (MC + ejecta), $|Dst_{min}|$ attains the saturation at large values of

E_{sw} [Nikolaeva et al., 2015]. Unlike D_{st}, *AE* during the main storm phase is independent of E_{sw} for streams of almost all types, except MS. There is a nonlinear dependence of *AE* on E_{sw} in MS events.

It should be noted that the *Dst* variation defines intensity not only of the ring current, but also of the current on the magnetopause, the current system of the magnetotail, and high-latitude magnetospheric-ionospheric currents [Feldstein et al., 2005]. Using the high-latitude *AE* index, we can take into account the contribution of magnetospheric-ionospheric current systems to the *Dst* variation.

However, due to different time scales of substorm and storm disturbances, *AE* gives only a rough idea of the role the magnetospheric-ionospheric current systems play in the development of a magnetic storm. In addition, during magnetic storms not only the intensity of auroral currents, but also their shift to lower latitudes determines the value of *AE*.

The purpose of this work is to examine the relationship between the dynamics of *Dst* and *AE* variations during the main storm phase for different SW types.

EXPERIMENTAL DATA

For the analysis, magnetic storms have been selected from the catalog of large-scale phenomena of the solar wind for 1976–2000 [Yermolaev et al., 2009]. More detailed information is given on the website [ftp://ftp.iki.rssi.ru/omni/]. For the 1976–2000 period, 72 magnetic storms initiated by CIR and ICME (MC + ejecta) events have been chosen. Magnetic storms caused by a sheath region are not considered in this paper. Hourly *AE* and *Dst* values have been taken from the website [http://wdc.kugi.kyoto.u.ac.jp / the index.html]. The minimum negative |*Dst*| during the magnetic storms was more than 50 nT. Moderate and strong magnetic storms after a magnetically quiet period were analyzed. For each of the event, the rate of magnetic storm development during the main storm phase $|\Delta Dst|/\Delta T$ was calculated. Duration of the main storm phase ΔT was defined as the time interval Dst_0 from the instant of a sharp decrease in *Dst* to its minimum value Dst_{min}, and $|\Delta Dst| = |Dst_{min} - Dst_0|$. To account for the displacement of the auroral oval during a magnetic storm and substorm as well as the duration of substorm disturbances (1–3 hr), the average value of *AE* for the main phase $\Sigma AE/\Delta T$ was computed, where ΣAE is the total value of *AE* during the main phase.

RESULTS AND DISCUSSION

Figure 1 shows the relationship between the average value of *AE* ($\Sigma AE/\Delta T$) and the rate of magnetic storm development for the storms initiated by CIR (left) and ICME (right) events. Squares mark individual magnetic storms; straight lines are linear approximations. The table lists equations of linear regressions between $\Sigma AE/\Delta T$ and the rate of magnetic storm development for two SW types. For comparison, the table gives correlation coefficients and probabilities of relationship of $\Sigma AE/\Delta T$ with the rate of magnetic storm development as well as with $|Dst_{min}|/\Delta T$ and $|Dst_{min}|$.

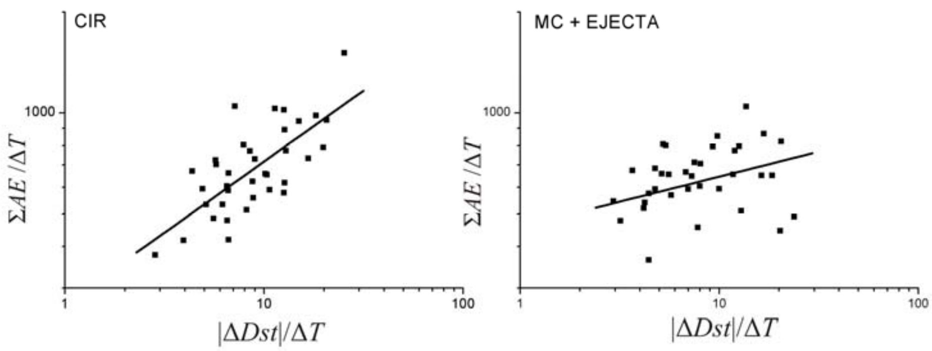

Figure 1. Relationship between $\Sigma\ AE/\Delta T$ and the rate of magnetic storm development $|\Delta Dst|/\Delta T$ for storms initiated by CIR and ICME (MC + ejecta) events

It can be seen that $\Sigma\ AE/\Delta T$ monotonically increases for different SW types with increasing rate of magnetic storm development. However, the analysis shows (Table) that the relationship between $\Sigma\ AE/\Delta T$ and $|\Delta Dst|/\Delta T$ is more strongly pronounced and statistically significant for the storms initiated by CIR events (r = 0.71; P = 99%) than for those driven by ICME (r = 0.33; P = 97%). Thus, the average *AE* index is clearly correlated with the rate of magnetic storm development for CIR-events, whereas for ICME events this correlation is weak. If instead of the rate of magnetic storm development $|\Delta Dst|/\Delta T$ we consider a new parameter $|Dst_{min}|/\Delta T$, which includes $|Dst_{min}|$ and ΔT, then there is a slight increase in the correlation coefficient between $\Sigma\ AE/\Delta T$ and $|Dst_{min}|/\Delta T$ in contrast to the correlation coefficient between $\Sigma\ AE/\Delta T$ and $|\Delta Dst|/\Delta T$ (Table).

The number of storms, correlation coefficients r, probabilities P, and approximations for the relationship of $\Sigma\ AE/\Delta T$ with the rate of storm development, with the parameters $|Dst_{min}|/\Delta T$, and $|Dst_{min}|$ for CIR and ICME initiated storms

SW type	N	$\|\Delta Dst\|/\Delta T$			$\|Dst_{min}\|/\Delta T$		$\|Dst_{min}\|$	
		r	P	approximation	r	P	r	P
CIR	36	0.71	0.99	$\ln y=0.42\ln x+2.43$	0.76	0.99	0.32	0.95
ICME	36	0.33	0.97	$\ln y=0.14\ln x+2.66$	0.35	0.97	0.26	0.88

To evaluate the possible relationship between $\Sigma\ AE/\Delta T$ and Dst, a relationship was built between $\Sigma\ AE/\Delta T$ and $|Dst_{min}|$ (Figure 2). The analysis shows extremely weak correlation between them (r <0.5) for different SW types (Table).

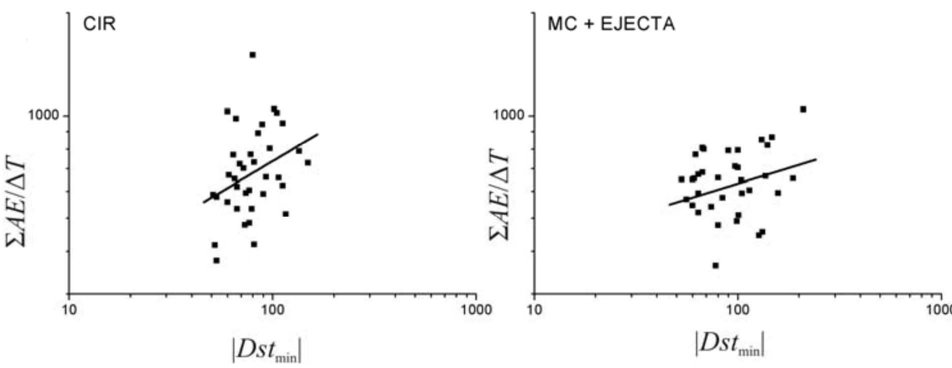

Figure 2. Relationship between $\Sigma\ AE/\Delta T$ and $|Dst_{min}|$ for storms initiated by CIR and ICME (MC + ejecta) events

It is known that the time variation of *Dst* ($d|Dst|/dt$) during the main storm phase is conditioned by the SW electric field [Kane, 2010; Yermolaev et al, 2010.; Nikolaeva et al, 2014.; Yermolaev et al., 2016]. If we suppose that the *Dst* variations are related to $|\Delta Dst|/\Delta T$, then $|\Delta Dst|/\Delta T$ is determined by the mean value of E_{sw} [Yermolaev et al, 2016]. Thus, the results obtained indicate that for CIR events $\Sigma AE/\Delta T$ may correlate with the average value of E_{sw} during the main storm phase.

CONCLUSION

In this paper, the relationship has been studied between $\Sigma AE/\Delta T$ and the rate of magnetic storm development for magnetic storms initiated by ICME (36) and CIR (36) events. The following results have been obtained.

1. During CIR events, $\Sigma AE/\Delta T$ correlates with the rate of magnetic storm development as opposed to ICME events.
2. The value of $\Sigma AE/\Delta T$ correlates weakly with $|Dst_{min}|$ for CIR- and ICME-generated magnetic storms.

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