

THE SOLAR WIND B_z -EVENTS AND THEIR EFFECTS ON THE GEOMAGNETIC ACTIVITY

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Abstract. Southern vertical component of the Interplanetary Magnetic Field (IMF $B_z < 0$) is usually regarded as a predictor of the magnetospheric electromagnetic state disturbance. If IMF $B_z < -5$ nT for 3 hours consecutively, this component indicates the occurrence of a magnetic storm and its development. So far, this criteria is commonly accepted. As a result, a geomagnetic forecast turns out to be reduced to the IMF B_z variation forecast, insufficiently reliable, for the indistinct role of the solar activity in the generating IMF B_z sign and sign change during the solar wind moving from the Sun to the Earth. The geomagnetic activity caused by solar plasma ejections depends on the Earth's moving trajectory through the body of a solar plasma ejection. Meanwhile the Earth's should cross the ejection area during interval when amplitude of IMF B_z is great but positive and these conditions do not cause a magnetic storm generation. We have examined hourly average $|B_z|$ measured by satellites in near space and found B_z -events when $|B_z| > 5$ nT during 4-hour interval. A number of events when the Earth, while crossing a solar ejection, experiences positive and negative B_z -events during a year are compared. Moreover, the results of statistical analysis of the influence of B_z -events on the geomagnetic activity are presented.

Introduction

The southern vertical component of the Interplanetary Magnetic Field (IMF $B_z < 0$) is the most geoeffective parameter. [Tsurutani, *at al.*, 1989]. The most intense geomagnetic storms with peak $Dst \leq -100$ nT are primarily caused by strong negative vertical IMF component with duration greater than 3 hours. [Gonzalez, *at al.*, 1994]. Therefore the modern prediction of the geomagnetic activity bases on forecast of occurrence of IMF $B_z < 0$ in the solar wind region close to the magnetosphere. Meanwhile question about origin of increasing this geoeffective parameter amplitude is leaving open, and we don't know whether occurrence of the southern vertical IMF component is caused by the solar magnetic field or great amplitudes of negative IMF B_z occur during the solar wind moving from the Sun to the Earth in the interplanetary space [Tsurutani *et al.*, 1989]

As noted, with increasing of statistic data for coronal plasma solar mass ejection (CME) condition for occurrence of intense geomagnetic disturbances could be created both in the solar ejecta and as in the region of interaction of the mass ejection with the solar wind during in the interplanetary space.

Results of modelling of the magnetic field within magnetic cloud show a magnetic storm could be caused by magnetic cloud if :

- the solar mass ejections occur in the specific solar region from which they probability direct towards the Earth and reaching it;
- the negative vertical IMF B_z component is observed in this magnetic cloud;
- the Earth should move through the body of the cloud where magnetic filed of the negative vertical IMF B_z component is observed.

Therefore it is rather possible that duration of phases and amplitude characters of magnetic storms depend on the Earth's trajectory moving through the body of the solar mass ejection only. Depending on the Earth's trajectory mass ejection should cause magnetic storms with different intensity and duration or could not originate a magnetic storm at all. Correspondingly, it is important to examine proportion between number of positive and negative B_z -events observed by satellites.

The geomagnetic activity is estimated by Dst -index. From study of magnetic storms and variation of negative IMF B_z during these storms it has been established relationship between magnetic storm classes and observed IMF B_z with duration equal to 3 hours (See Table1).

Table 1. Classification of magnetic storms

Magnetic storm class	Dst peak, nT	IMF B_z (nT) with duration equal to 3 hours in the beginning of a storm
Weak	-30 - -50	- 5
Moderate	-50 - -100	- 10
Intense	-100 - -200	- 15
Major	-200 - -350	- 20

We have been analysed so called B_z -events (negative B_z -events - B_z^- -events and positive ones - B_z^+ -events), having $|B_z| \geq 5$ and *duration* $\tau \geq 4$ hours, using statistics of 1967- 1984 and 1996 - 2004 from OMNI data set: <http://omniweb.gsfc.nasa.gov>.

B_z -events and the solar activity during 1967 - 1984

It has been known that occurrence of B_z -events practically follows by the solar activity variation. But peak of B_z -events is wider and is extended over final phase of the solar activity increasing and the starting phase of the solar activity decreasing in the 11-year solar cycle. B_z -events occur mainly in the solar activity maximum that may be caused by non-stationary events on the Sun.

Assignment of the solar wind parameters in B_z -events during 1967 – 1987 such as module of the IMF vector (B), density (N) and velocity (V) of the solar wind, and particle temperature (T) is demonstrated in Figure 1. Each panel shows total number of B_z^+ -events and B_z^- -events during the interval under study and expressed as percentage number of B_z^+ -events and B_z^- -events within scale spacing corresponding to mentioned parameters.

As can be seen, appreciable percent of B_z -events occurrence is fixed simultaneously with increasing, in comparison with mean, values of the solar wind parameters.

B_z -events and the solar activity during 1996 - 2004

Using data of 1996 - 2004 we have examined and compared

- a) number of B_z -events;
- b) number of solar mass ejection events registered by SOHO spacecraft (SME-events);
- c) number of solar mass ejection events directed towards the Earth and reaching it, so called interplanetary CME – (ISME-events).

It has been shown annual variation of ISME-events number is similar to that of number B_z -events. Maximum discrepancy is distinguished in 2002 when number of ISME-events decreases more sharply than number of B_z -events.

Annual variation of SME-events is similar to the same variation of the solar activity. Little minimum peak in 1999 is exceptional case caused probably with error of narrow SME registration that occurred in this year. Little minimum peak of ISME-events and B_z -events is distinguished in 1999 as well.

Thus, we can say that SME-events and B_z -events are typical ones when the solar activity is high. Number of B_z -events correlates with number of events when the solar mass ejection reaches the Earth. Besides, number of B_z^+ -events is roughly equal to that of B_z^- -events.

Maximum peak of B_z -event occurrences in Equinox

As it is known, annual variation of the geomagnetic activity has maximums in *vernal* and autumnal *equinox*. It should be possible to explain that modulation of IMF B_z component, transformed to the Solar Magnetospheric system coordinates (GSM), is caused by inclination of the Earth's axis and the solar one to the ecliptic and inclination of magnetic dipole axis to the Earth rotation axis. According to this model *vernal* and autumnal GSM B_z^- -events number *should* be much larger than GSE one. (GSE is the Solar Ecliptic coordinate system).

Using data of 1998-2002 we have computed average monthly number of GSM B_z -events and GSE B_z -events. In spring and autumn GSM B_z -events are indeed rather more than GSE one, but in summer number of GSM B_z -events is roughly equal to that of GSE B_z -events.

When IMF vector components transform from GSE coordinates to GSM coordinates, negative GSM B_z amplitudes grows under sunward IMF sector structure in spring and under anti-sunward one in autumn. In other words IMF sector structure direction should increase or decrease as number of B_z^+ -events as number of B_z^- -events. We have computed average monthly differences of GSM B_z -event numbers and GSE B_z -event ones and differences average monthly GSM B_z -event numbers and GSE B_z -event ones normalized to number of average daily values of IMF components causing IMF sector structure (sunward or anti-sunward).

Maximum of B_z -event numbers in April and September don't depend on the solar activity or number of solar mass ejection events observed near the Earth. Its appearances should be explained by *Russell and McPherron* [1973] effect based on transformation of IMF vector components from GSE coordinates to GSM coordinates.

B_z -events and geomagnetic activity

Geomagnetic activity relationship with B_z -events was examined using data of 2000 which is the solar activity maximum. We have chosen 46 storms with $Kp \geq 5$ or $Dst \leq -50$ nT. For each storm we have found B_z^- -events, and for specified B_z^- -event we have calculated duration τ , average B_z amplitudes, and average of the solar wind velocity (V).

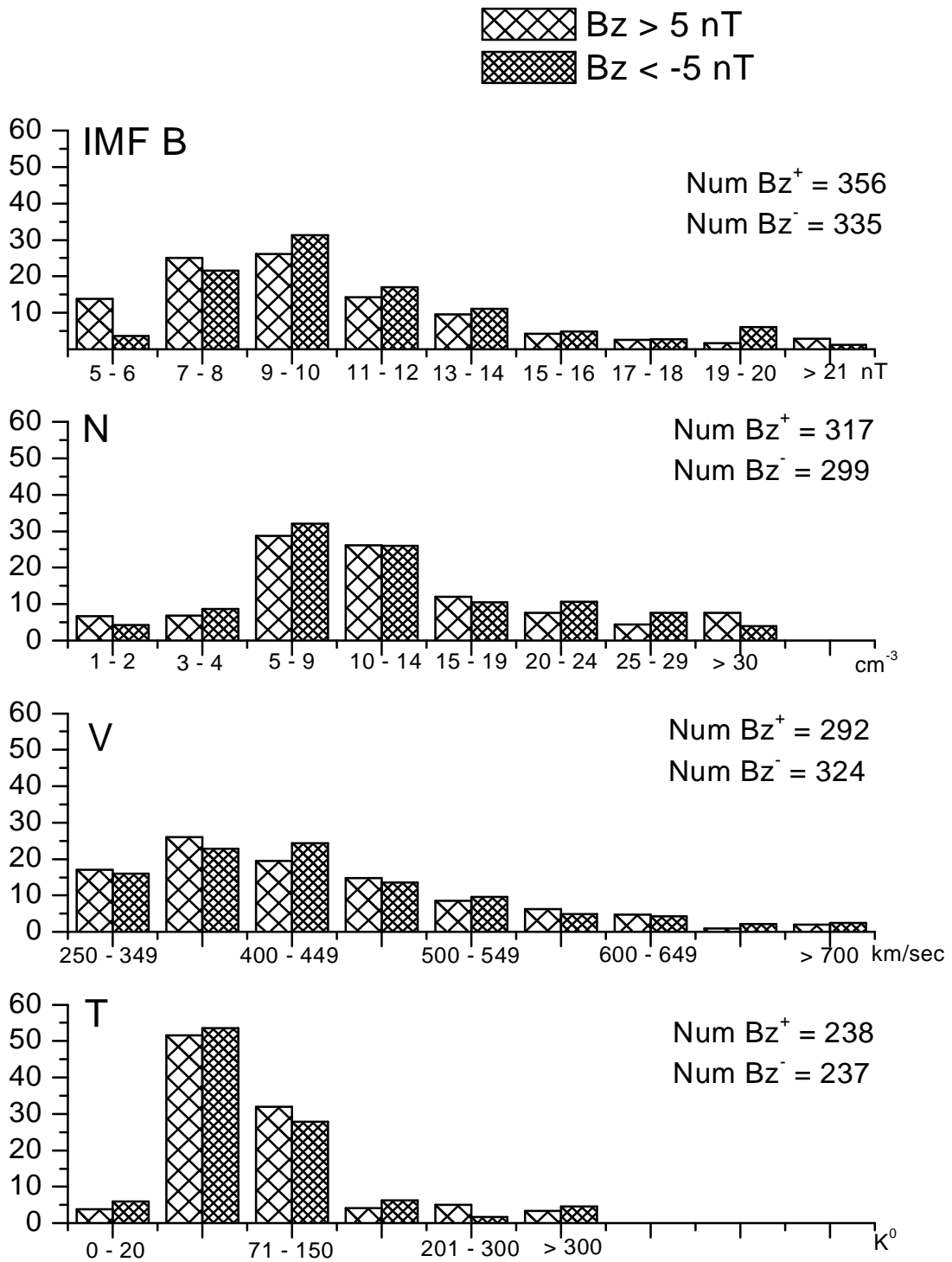


Figure 1. Assignment of the solar wind parameters in B_z -events during 1967 – 1987 (from top to bottom): module of the IMF vector (B), density (N) and velocity (V) of the solar wind, particle temperature (T). Each panel shows total number of B_z^+ -events and B_z^- -events (Num B_z^+ and Num B_z^- correspondingly) and expressed as percentage number of B_z^+ -events (sparse hatching) and B_z^- -events (dense hatching) within indicated on the bottom axis scale spacing.

It has been established that classification of magnetic storm intensity according to Kp don't ever coincide with that according to Dst . Among specified storms we have found 15 storms without Bz -events including 7 storms with $-79 \text{ nT} \leq Dst \leq -50 \text{ nT}$. The rest storms were weak ($Dst > -50 \text{ nT}$, $Ap < 20$). All intense and major storms were accompanied by intense and durational Bz -events.

Our statistical results support to known fact that not all CMEs originate a magnetic storm. At the same time they don't support opinion of some researchers that during the solar maximum CMEs don't lead to occurrences of major magnetic storms as they don't contain durational negative Bz -events. Occurrences of major magnetic storms trends to increase with increasing product of Bz , τ and V . But it should be impossible to evaluate intensity of a storm at Bz -event rather reliably.

Note that three major magnetic storms in October, 2000, were caused by the most intense Bz -events ($Bz \geq 10 \text{ nT}$) with duration of 18, 20, 25 hours correspondingly. Full halo, located near the vertical current layer under the bipolar coronal streamer belt over the solar region between coronal holes having opposite magnetic polarity, are considered to be a likely cause of major magnetic storms. However, hypothesis that these solar regions are acceptable for IMF southward removal should be subject of special study.

Conclusion

We have been analysed specified negative and positive Bz -events, having $|Bz| \geq 5$ and **duration** $\tau \geq 4$ hours, basing on using statistics of 1967- 1984 and 1996 - 2004.

During these two periods of the study maximum number of occurrence of Bz -events was increased with increasing the solar activity when there were maximums of the solar spots and flares.

During 1967 - 1984 Bz -events were accomplished by increasing IMF parameters (the solar wind velocity and density, IMF Bz component and plasma temperature) that is typical for regions of interaction between high speed solar streams and the quiet solar wind. Increasing IMF parameters are caused by dominance of short time Bz -events in the regions of interaction between high and slow solar streams.

Number of Bz -events correlates with number of solar ejecta, especially with number of events when the solar mass ejection reaches the Earth. But not all CMEs reached the Earth cause a magnetic storm.

Equinoctial maximums of Bz -events are observed under sunward IMF sector structure in spring and under anti-sunward one in autumn.

Intense Bz -events caused by CME are observed in the solar activity maximum of 2000, and it isn't agree with hypothesis according to which in the solar activity maximums there are no intense and durational Bz -events. Weak magnetic storms could develop without of occurrences of Bz -events in the solar wind. Intense and major storms are accomplished by intense and durational Bz -events. But it is impossible to evaluate intensity of a magnetic storm with estimating the intensity and duration of Bz -events.

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