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# Comment on "Geomagnetic Activity Associated With Earth Passage of Interplanetary Shock Disturbances and Coronal Mass Ejections" by J. T. Gosling, D. J. McComas, J. L. Phillips, and S. J. Bame

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*Gosling et al.* [1991] have presented a very nice set of statistical data on solar wind driver gases (CMEs), interplanetary shocks, solar wind velocities, magnetic field magnitudes and $B_Z$ values, and geomagnetic activity (*Kp*). The statistics are quite nice and similar to our own. We have no questions or comments concerning these.

We note that Gosling et al. have one conclusion that is substantially different than prior work, however. In the last sentence of their abstract, they state, "The initial speed of a CME close to the Sun appears to be the most crucial factor in determining if an earthward directed event will be effective in exciting a large geomagnetic disturbance." This is an unusual claim and goes quite contrary to prior perceptions of the interplanetary cause of magnetic storms, big and small. If this point is indeed correct, it will be a big revelation to magnetospheric researchers. However, in looking at their paper in detail, we feel the statistical data that they presented do not support this claim. In this comment we will try to help clarify this issue and attempt to bring the *Gosling et al.* [1991] statistics and prior results into accord.

The Gosling et al. conclusion was derived from statistics presented in their Figures 7 and 8. In Figure 7 they present the values of the north-south component of the field (in GSM coordinates) for all CME events plus the preceding 9 hours of data. The figure shows that for major, large, "other" and "no" storm cases, $B_Z$ values are more or less symmetric about zero. In Figure 8, they show statistics for the 24-hour intervals following shock passage. Again, for all storm intensity categories, the data are more or less symmetric about a zero value. From these statistics, the authors state (p. 7837): "What is perhaps surprising to those accustomed to relating geomagnetic activity to strong negative $B_Z$ is the lack of a strong asymmetry in the distribution of large negative and large positive values of $B_Z$ for events which produced geomagnetic storms, . . .".

We think the authors have missed a very important point and have possibly misread their own statistics. All previous studies of substorms [*Arnoldy,* 1971; *Tsurutani* and *Meng*, 1972; *Perrault and Akasofu*, 1978; *Clauer* et al., 1981; *Baker et al.*, 1983] and magnetic storms [*Burton et al.*, 1975; *Akasofu et al.*, 1985; *Vasyliunas*, 1987; *Gonzalez et al.*, 1989; *Feldstein*, 1992] have indicated that the primary cause of geomagnetic activity is related to a combination of solar wind velocity and southward directed magnetic fields, with the emphasis on the latter feature. *Murayama* [1982] and *Maezawa and Murayama* [1986] have reported a density-related dependence, but this is secondary in nature. In fact, *Gonzalez and Tsurutani* [1987] showed that a necessary and sufficient criterion for major ($D_{ST} \leq$ -100 nT) storms during solar maximum was that the interplanetary dawn-to-dusk electric field was $\geq$5 mV/m (this was approximately equivalent to $B_S$ $\geq$10 nT) for 3 hours or longer. Gonzalez and Tsurutani also showed that there was an equal number of similar northward directed field events during their 500 days of study, indicating that whatever process was creating strong nonzero $B_Z$ components, it was doing so in a random fashion.

The problem with the criteria used to construct Figures 7 and 8 is that the time intervals are much too large to observe the storm-time $B_Z$ dependence. Nine hours prior to the CME plus the CME duration, or 24 hours after the shock, will allow a whole host of field directions and will perhaps miss the detailed relationship between the storm and $B_S$. One concrete example of this is the field directionality within magnetic clouds. *Klein and Burlaga* [1982] have presented a model of their "idealized" magnetic cloud which has southward, then zero, then northward fields all within the same cloud. The magnetic clouds that are associated with high-speed streams are in the driver gas (CME) portion of the stream. Thus, one would expect to find a wide range of $B_Z$ values within one single driver gas. The durations of the southward field intervals of the magnetic cloud detected in the *Tsurutani et al.* [1988; 1992a, b] major and great magnetic storm events are greater than 3 hours but less than 10 hours (note the driver gas regions contain much wider $B_Z$ structures than that usually observed in the sheath or compressed field regions, the latter typically being more fluctuating in nature). Thus, the intervals chosen to construct Figures 7 and 8 will typically contain much broader regions than the southward field regions that causes the storms.

The best way to see the storm dependence on $B_Z$ is to perform cross correlation analyses between $B_Z$ and a geomagnetic activity index [*Arnoldy*, 1971; *Baker et al.*, 1983] or by making a case-by-case individual storm examination [*Burton et al.* 1975; *Gonzalez et al.*, 1989; *Pisarsky et al.*, 1989]. When one does this, one finds that every major storm is related to a southward $B_Z$ event.

The location of the southward magnetic field within a high-speed stream contains critical information that should not be ignored. The southward interplanetary magnetic fields (IMFs) causing the storms could be either in the compressed sheath magnetic fields behind the interplanetary shock or part of the driver gas [*Tsurutani et al.*, 1988]. The former is slow solar wind plasma that has been shocked and swept up by the high-speed plasma, and the latter is plasma convected outward from the coronal mass ejection source at the Sun. The latter is often related to a solar



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flare or prominence eruption [Joselyn and McIntosh, 1981; Tang et al., 1989] which occurs after the CME is released [Harrison et al., 1990].

The (relative) velocity of the high-speed stream (to the upstream slow-speed stream) is physically important toward defining the strength of the interplanetary forward shock and thus the sheath magnetic field strength. Because the interplanetary dawn-dusk electric field is given by $V_{SW} \times B_S$, the (relative) solar wind velocity should be doubly important toward the creation of a magnetic storm. Although this argument for the importance of solar wind velocity is logically compelling, a recent study of great ($D_{ST} \leq$ -249 nT) magnetic storms [*Tsurutani et al.*, 1992a] indicated that some of these very intense events are associated with only moderately high solar wind velocities (550 to 600 km/s). The two storms referred to above had driver gas magnetic fields that were quite large (30 and 35 nT) and at times were almost entirely southward in direction. The maxima in $B_S$ corresponded to the maxima in $D_{ST}$ (with appropriate short time delays). In these cases it is obvious that the magnetic field $B_S$ component was the dominant cause of the storms.

The possibility that solar wind energy transfer occurs via a viscous-type interaction has been previously discussed [*Axford*, 1964; *Eviatar and Wolf*, 1968; *Sonnerup*, 1980; *Tsurutani and Thorne*, 1982; *Gendrin*, 1983; *Tsurutani et al.*, 1989; *Thorne and Tsurutani*, 1991]. However, more recently, *Tsurutani et al.* [1992b] have presented arguments to indicate that viscous interaction during strong northward IMF directions may be 50 to 100 times less efficient for energy input into the magnetosphere than magnetic reconnection. The example they use is the August 1972 interplanetary event. This event has the highest solar wind velocity in the history of interplanetary spacecraft measurements. The corresponding geomagnetic activity during a strong northward IMF portion of the event was exceptionally low.

## SUMMARY

In summary, we believe that the Gosling et al. results are consistent with magnetic storms being caused by $B_S$ fields. We do not think that their statistics are inconsistent with the reconnection picture of energy transfer as has been widely claimed by many other studies for substorms and storms.

We are currently not aware of any major magnetic storm that has occurred without an associated large and long-duration southward magnetic field component (in GSM coordinates). If such an event exists, it would be a service to the community to present and discuss the event in the literature. We leave this as a challenge to the readers.

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