Geomagnetic Disturbances Around the Solar Minimum of Cycle 22 and Their Solar Sources

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Abstract

The solar sources of geomagnetic disturbances around the solar minimum of cycle 22 were investigated using *in situ* solar wind observations and solar observations from space. About half of the geomagnetic disturbances were associated with coronal mass ejections (CMEs). Approximately 20% of the geomagnetic disturbances were associated with both CMEs and high-speed solar wind streams. It was found that geomagnetic disturbances associated with CMEs tend to have large magnitudes and those associated with high-speed solar wind streams tend to have long durations.

Key words: Geomagnetic disturbances — Sun: activity — Sun: corona

1. Introduction

Joselyn (1986) identified the solar sources of 238 geomagnetic storms (geomagnetic Ap index ≥ 30) between June 1976 and December 1984 using ground-based observations. About 20% of all storms were associated with eruptive flares, about 17% were traced to coronal holes, about 13% were related with filament disappearance, and about 8% were unexplained. Approximately 40% of all storms were associated with more than two solar sources. McAllister et al. (1996) found the formation of a large arcade in soft X-ray solar images of *Yohkoh* without any Hα signature or enhancement of the total X-ray flux measured by GOES. The *Ulysses* spacecraft observed an interplanetary coronal mass ejection (ICME) associated with this event. Webb et al. (1998) also noted that a CME on 6 January 1997 observed by the coronagraph on the SOHO spacecraft lacked obvious surface signatures of eruptive solar activity. This CME was associated with the geomagnetic disturbance on 10-11 January. CMEs and high-speed solar wind from coronal holes are thought to be two major solar sources of geomagnetic disturbances. Eruptive flares and filament disappearances are considered to be low-coronal counterparts of CMEs. Corotating interaction regions (CIRs) between slow and high-speed solar wind streams determine the magnitude of the disturbances while the duration of the high-speed solar wind streams determines the duration of the geomagnetic disturbances (Watari, 1997). Interactions between CMEs and recurrent high-speed solar wind streams were reported by Crooker and McAllister (1997) and Watari and Watanabe (1998). It it important to determine solar sources of geomagnetic storms accurately in the Sun-Earth connection problem. In this paper we investigated the solar sources of the geomagnetic disturbances between January 1995 and December 1997 using *in situ* solar wind observations by the WIND spacecraft and soft X-ray solar observations by *Yohkoh* and examined the magnitudes and the durations of the disturbances.

2. Observations and Discussion

Figure 1 shows contour maps of the geomagnetic Dst index (left panel) and the solar wind speed (right panel) measured by the WIND spacecraft between January 1995 and December 1997. The vertical axis of the figure is labeled with both the Bartels rotation number and the starting date of each rotation. The numbers on the horizontal axis indicate the first through the 27th day of each rotation. Recurrent high-speed solar wind streams were observed during the period shown in Figure 1. Their effects on the geomagnetic disturbances, however, were weaker in 1996 and 1997 than in 1995. The geomagnetic activity was very quiet at the solar minimum (in June 1996).

Figure 2 summarizes the solar sources of the geomagnetic disturbances (Dst $\leq$ -50 nT) between January 1995 and December 1997. They were investigated using the *in situ* measurement of the solar wind by the WIND spacecraft according to the method of Taylor et al. (1994). The solar sources were examined using the soft X-ray solar observations by *Yohkoh* and CMEs observed by SOHO (Brueckner et al., 1998). About half of the disturbances were associated with CMEs and about a fifth of the disturbances were associated with both CMEs and high-speed streams. The solar sources of seven disturbances were still uncertain. Soft X-ray arcades were frequently observed associated with the disturbances.

Figure 3 shows a scatter plot of the durations and the maximum values of |Dst index| of the geomagnetic disturbances (Dst $\leq$ -50 nT) associated with CMEs (+), high-speed streams ($\times$), and both ($\diamond$). The average duration and the maximum value of |Dst index| are 31 hours and -83 nT for the disturbances associated with CMEs, 65 hours and -66 nT for those associated with high-speed streams, and 62 hours and -96 nT for those associated with both. The disturbances associated with high-speed streams tend to have longer durations than those associated with CMEs. On the other hand, the disturbances associated with CMEs tend to have larger values of maximum |Dst index| than those associated with high-speed streams. Several disturbances associated with both had large values of maximum |Dst index| and long durations. Strong compression between the CME and the high-speed stream was observed when the high-speed stream overtook with the CME (e.g., the geomagnetic disturbances on 18 October 1995 and on 10 January 1997).

3. Concluding Remarks

About half of the geomagnetic disturbances were associated with CMEs around the solar minimum. About 20% were associated with both CMEs and high-speed streams. Geomagnetic disturbances associated with CMEs tend to have large magnitude while those associated with high-speed streams tend to have long durations. Several disturbances associated with both high-speed streams and CMEs had a long duration and large amplitude.

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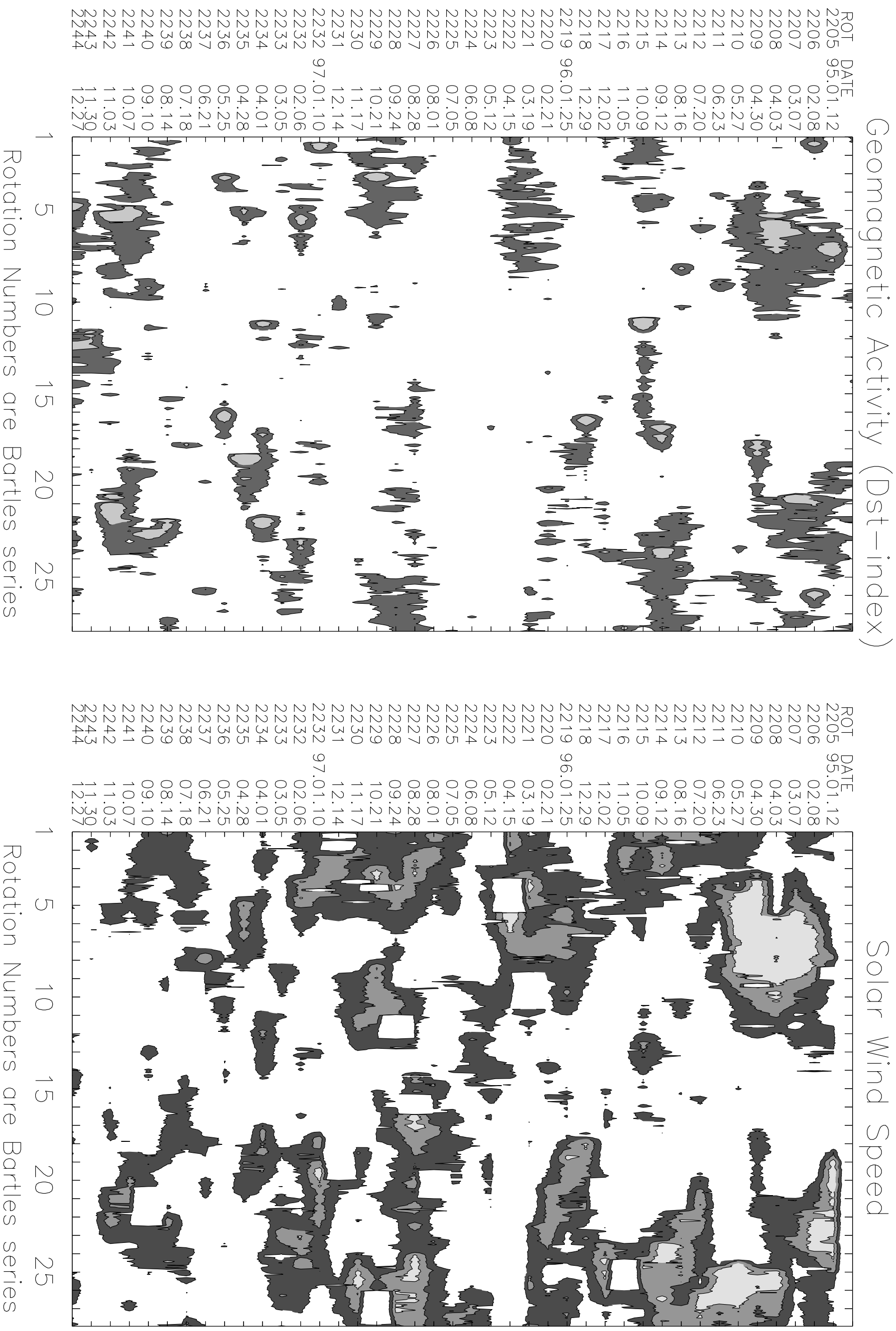

Fig. 1. Contour maps of the geomagneitc Dst index (left panel: contour levels are −25 and −50 nT) and the solar wind speed (right panel: contour levels are 400, 500, and 600 km/s) measured by the WIND spacecraft between January 1995 and December 1997.

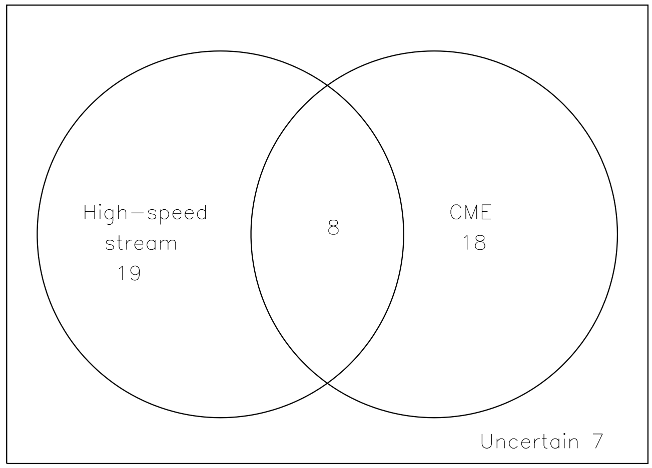

Fig. 2. The solar sources of the geomagnetic disturbances between January 1995 and December 1997.

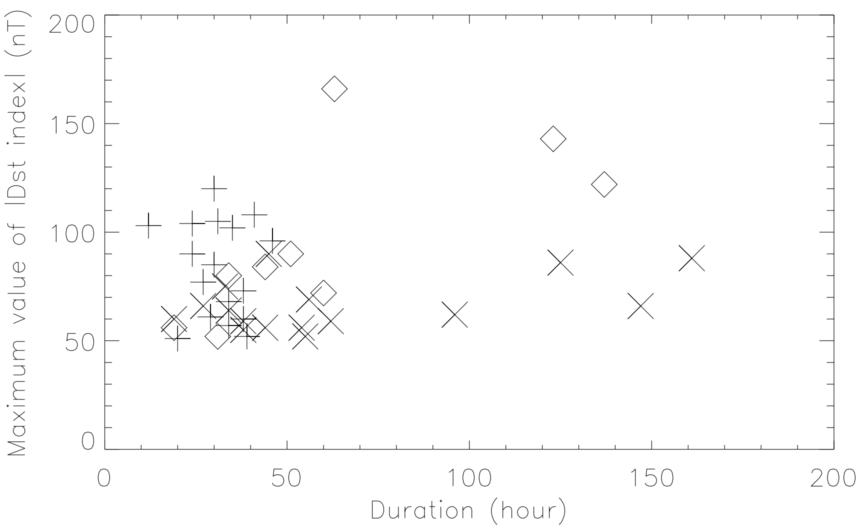

Fig. 3. A scatter plot of durations and maximum values of |Dst index| of the geomagnetic disturbances associated with CMEs(+), high−speed streams (x), and both (◇).