DISAPPEARING SOLAR FILAMENTS AND GEOMAGNETIC ACTIVITY

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Abstract. As a sequel to our recent identification of the high-speed stream as the candidate structure in the solar wind at 1 AU, that is primarily responsible for the geomagnetic disturbances occasionally noticed after 'disparition brusques' (DBs) of solar filaments (Sastri *et al.*, 1985), we report here that the streams, inferred to be recurrent in our earlier study, were consistently preceded by a stream interface, as expected of corotating streams. This observation substantiates the role of corotating streams of coronal hole origin in the apparent link between DBs and geomagnetic activity, and strengthens the view that DBs are not a unique source of geomagnetic activity.

In a very recent paper (Sastri *et al.*, 1985), we have examined the possible origin of the association between the 'disparition brusques' (DBs) of quiescent solar filaments and geomagnetic activity that is recently reported from case studies (Joselyn and Bryson, 1980; Joselyn and McIntosh, 1981) and statistical analyses (McNamara and Wright, 1982; Wright and McNamara, 1983). Our work dealth with the composite data base of interplanetary plasma and magnetic field parameters (King, 1977, 1979, 1983), relevant to 30 clearcut instances when the DB of a filament (estimated size > 15 sq. deg.) was followed by a geomagnetic disturbance ($\mathrm{Ap} \geq 30$) within 8 days (out of 104 DB events ascertained to have occurred over the period January 1967 through March 1978 with size > 15 sq. deg.). The study revealed that the geomagnetic disturbances noticed after DBs were almost invariably associated (in 28 out of the 30 events) with the passage of high-speed streams at the Earth, and a majority of the streams (19 out of the 28) were found to exhibit the $\sim$ 27-day recurrence pattern, and so also the geomagnetic storms related to them. This finding is quite in accordance with the established fact that the transit of streams at the Earth leads, in general, to geomagnetic storms, and that the streams are a vital link between solar and geomagnetic activity (see Burlaga and Lepping, 1977; Legrand and Simon, 1981; Akasofu, 1981, and references therein). A similar role of streams was also evident in the case of the geomagnetic storms inferred as associated with only DBs by Joselyn and McIntosh (1981) (see Table II of Sastri *et al.*, 1985). Besides, the delay in the onset of the geomagnetic disturbances w.r.t. DBs was found to depend not on the characteristics of the filament (e.g., size), but on the date of transit of the stream at the Earth, and there was an absence of a systematic spatial relationship between the potential sources of the streams (coronal holes and flares) and DB sites. These results based on near-Earth space craft measurements also received support from the interplanetary scintillation (IPS) observations. For example,

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the geomagnetic storm of 27–29 August, 1978, which was attributed to filament activity (Joselyn and Bryson, 1980; Joselyn and McIntosh, 1981) has been assessed as due to a high-speed stream that originated from a low-latitude coronal hole (Tappin *et al.*, 1983; Watanabe and Marubashi, 1985). Watanabe and Murabashi (1985) suggested, however, a contribution of two additional IP disturbances to the storm besides the stream. Serious doubts are thus now cast on the claims that DBs represent a source of geomagnetic activity, and can be used for forecasting storms. The objective of this communication is to document the outcome of a further study made to confirm the apparent recurrent nature of streams in the data sample of our earlier study, and point out the role of corotating streams in the relationship between DBs and geomagnetic activity.

It is widely known that basically two types of high-speed streams are encountered near the Earth namely, quasi-stationary corotating streams and transient streams (some, but not all, of which are associated with shocks). The corotating streams which originate in coronal holes (see Hundhausen, 1979, and references therein) and with we are particularly concerned here, are characterised by the presence of a thin stream interface at the front, and high temperatures and low densities in the stream, with the temperature and density varying directly and inversely, respectively, with the flow speed (e.g., Hundhausen, 1972; Burlaga *et al.*, 1984a). The stream interface is a boundary that demarcates a region of cool dense material from one of anomalously hot rarefied material (as from a coronal hole) in the solar wind, and as such the density (N) decreases and the temperature (T) and flow speed (V) increase across it (see Burlaga, 1974; Gosling *et al.*, 1978). The magnetic field strength (B) attains high values at the interface and the flow direction also changes. The presence of the interface, unambigious recognition of which is possible at 1 AU, is considered to be a necessary and sufficient condition for a corotating stream of coronal hole origin, as the interface is always evident in front of such streams and never ahead of transient flows from flares or prominences (Burlaga and King, 1979; Burlaga *et al.*, 1984a, b). We relied on this unique feature of corotating streams in the present attempt to confirm the recurrent nature of streams evidenced in our earlier study. The effort is felt necessary and worthwhile in view of the controversial nature of the topic under discussion, and also the fact that coronal hole data were not available for some of the streams in our data sample.

We have carefully scrutinised the hourly data (King, 1977, 1979, 1983) of the solar wind proton number density (N), proton temperature (T), bulk flow speed (V), and magnetic field strength (B), pertinent to the 14 streams (simultaneous data of the parameters were not available or too scanty for 5 out of a total of 19 streams; see Table IA of Sastri *et al.* (1985) for details of DBs, geomagnetic disturbances that apparently followed them and the streams actually responsible for the disturbances) that were noticed to exhibit the ~ 27-day recurrence pattern and an association with low-latitude coronal holes (where data were available) in our earlier study. It is found that each one of the streams had a distinct interface ahead of it as anticipated. In fact, 3 out of the 14 interfaces were identified earlier by Burlaga (1974) and Gosling *et al.* (1978) (the ones on 28 September, 1967; 12 December, 1972, and 25 January, 1974).

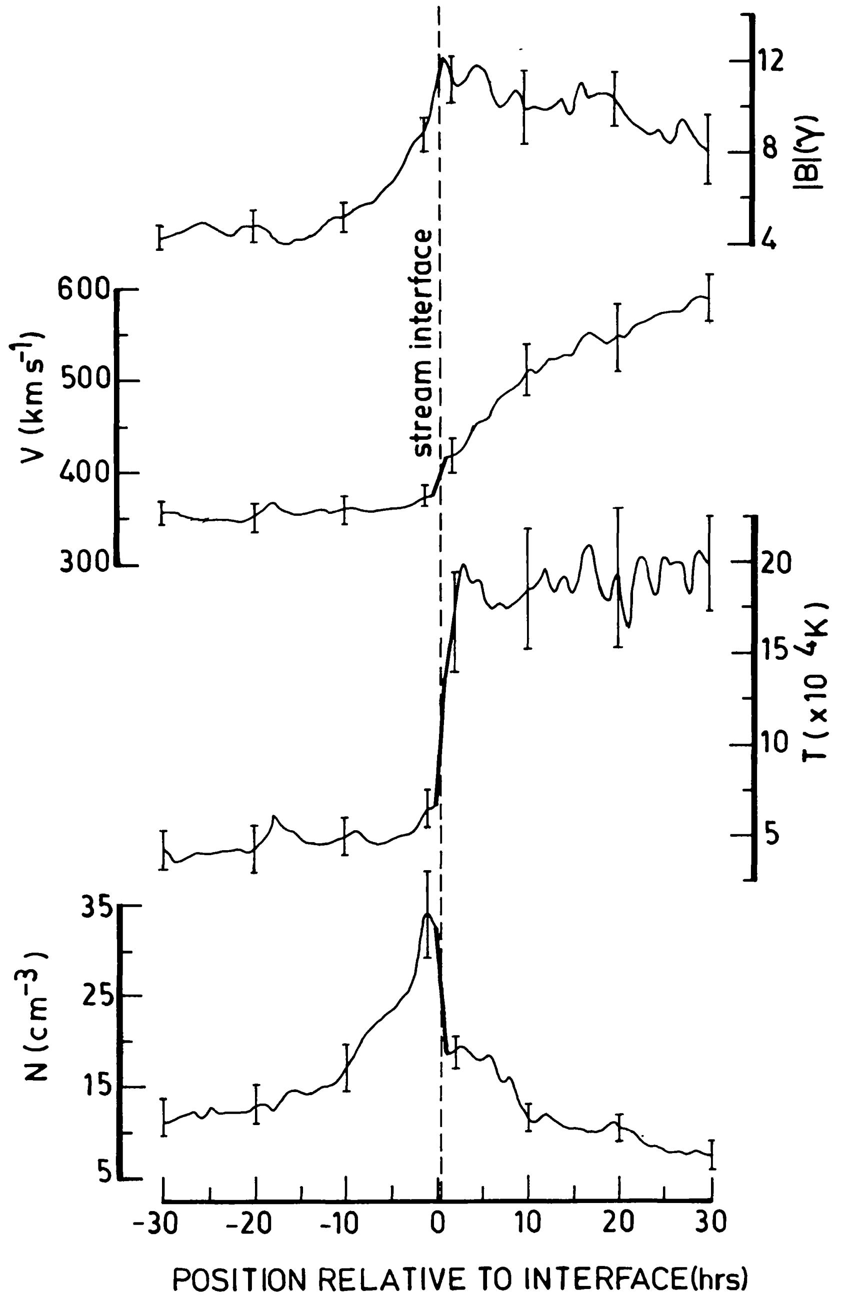

Fig. 1. Average temporal profiles of the proton density (N), proton temperature (T), bulk speed (V), and magnetic field strength (B) of the solar wind at 1 AU around 14 interfaces in front of recurrent streams that resulted in geomagnetic disturbances (apparently after DBs of solar filaments with delays < 8 days). The profiles are derived from a superposed epoch analysis of the hourly averages of the parameters with the time at which the changes (characteristic of interfaces) in N, T, and V, were seen as the zero hour.

To illustrate the genuiness of our identifications, the average profiles of N, T, V, and B were computed around the interfaces, using the superposed epoch analysis technique. The result presented in Figure 1 clearly demonstrates the characteristic signatures of interface in N, T, V, and B mentioned earlier (see also Figures 1–3 of Gosling *et al.*, 1978). We have also examined the streams relevant to the 12 geomagnetic storms ascertained by Joselyn and McIntosh (1981) as due only to DBs (see Table II of Sastri *et al.*, 1985). We are left with a set of 6 storms after eliminating the ones common to our data sample and those with incomplete or no data, and out of these 4 were associated with apparently recurring streams and 2 with non-recurrent streams. The resurring streams which were noticed on 30 January, 1976; 25 November, 1978; 24 April, 1979, and 22 May, 1979 (see Lindblad and Lundstedt, 1983; Richardson and Zwickl, 1984), all had interfaces in front of them except the last one. The interface ahead of the stream of 24 April, 1979 occurred at rather high values of flow speed because of a shock that preceded it (see Burlaga, 1974, for a discussion of chance coincidences between interfaces and shocks).

The present study thus shows that a substantial number of streams responsible for the geomagnetic storms that apparently followed DBs (specific events so far reported) were indeed corotating streams of coronal hole origin. This reaffirmed result and the others of our earlier study mentioned previously clearly indicate that the apparent link between DBs and geomagnetic activity originates primarily from fortuitous temporal associations between the times of DBs and the transits at the Earth of solar wind streams. The plausibility of this physical situation becomes all the more clear when one considers the facts that, on a long-term basis, a stream is encountered at the Earth every ~ 7 days (Intriligator, 1977), and that the Earth is circumflown predominantly by streams of coronal hole origin at any phase of the solar activity cycle (Bobrov, 1983). Let us now examine the physical mechanisms proposed earlier for the cause and effect relationship between DBs and geomagnetic activity. Joselyn and McIntosh (1981) and Wright and McNamara (1983) opined that the geomagnetic storms that accompany DBs may be due to the interception at the Earth of interplanetary disturbances caused by DBs related coronal mass ejections (CMEs). Although CME's are known to exhibit a high-degree of association with DBs/EPLs with or without flares (Munro *et al.*, 1979), and are not observed to return to rhe Sun (Gosling *et al.*, 1974), positive identification of the 1 AU signature of CMEs (associated particularly with low-energy events like DBs) is yet to be achieved. Several candidate signatures nevertheless have been proposed in recent times, and out of these the ones relevant to DBs (in our opinion) are the noncompressive density enhancements, NCDEs (Gosling *et al.*, 1977) and magnetic clouds associated with stream interfaces and cold magnetic enhancements (Klein and Burlaga, 1982). Although NCDEs especially those associated with polarity reversals of the interplanetary magnetic field, IMF are now considered as 1 AU signatures of coronal streamers (Borrini *et al.*, 1981), some could be slow moving coronal transients (J. T. Gosling, personal communication). NCDEs cannot, however, be expected to be primary sources of geomagnetic storms ($\mathrm{Ap} \geq 30$). This is because they occur typically in regions of low flow speed (~ 365 km s^{-1}) and moderate magnetic field strength (~ 6 gamma), whereas combinations of high values of flow speed and magnetic field and a southward IMF are needed to result in appreciable geomagnetic activity (e.g., Svalgaard, 1977; Akasofu, 1981; Baker *et al.*, 1983). On the other hand, magnetic clouds associated with interfaces and cold magnetic enhancements are potential sources of geomagnetic activity, because they are essentially regions of high magnetic field strength and in which the field direction changes appreciably by means of rotation of one component of it parallel to a plane, although the flow speed is not high. There is only one magnetic cloud associated with the corotating streams considered here. This was the one that preceded the interface of the stream of 25 January, 1974 (see Table 1b of Klein and Burlaga, 1982). The cloud which commenced on 24 January 1974 at 00 : 00 UT and continued for 30 hours was, however, not the main cause of the storm of 25–28 January, 1974, because the main phase of the storm (as seen in D_{st} index) started only after the passage of the cloud (*Solar-Geophysical Data*, NOAA, U.S.A.). It nevertheless caused moderate levels of global geomagnetic activity ($kp \leq 5$) and auroral substorm activity ($AE \leq 513$ gamma) at times of high magnetic field strength and southward IMF as can be expected (see King, 1977; *UAG-59*, *WDC-A for STP*, NOAA, U.S.A. and *Solar-Geophysical Data*), Since interface-associated clouds have been suggested to be soronal transients swept up by corotating streams (Klein and Burlaga, 1982), we have examined whether the cloud of 24–25 January could be the coronal transient of the DB (20–21 January) that occurred at an appropriate earlier time (3–6 days) to it and also the storm. Calculations following the method of Wilson and Hildner (1984) showed that the filament desintegration ought to have occurred sometime during the period 03 : 43 UT on 18 January, 1974 and 04 : 35 UT on 19 January (the so-called 'event window') had the cloud been associated with this DB. But the filament was still seen in tact on 20 January at 22 : 06 UT (see Table 1A of Sastri *et al.*, 1985). The cloud could be the one associated with the filament (S04, E22, estimated size ~ 17 sq. deg.) that desintegrated sometime after 23 : 55 UT on 17 January.

To conclude, the observations detailed above enable us to emphasize that corotating streams of coronal hole origin are one of the basic sources of geomagnetic storms that sometimes accompany (by change temporal coincidences) DBs. Continued efforts to identify the 1 AU signatures of DBs related CMEs are needed to help asses the geomagnetic effects of DBs in a rigorous way, in view of the current satisfactory understanding of the response of geomagnetic activity to solar wind variability (e.g., Akasofu, 1981; Baker *et al.*, 1983).

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