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# Fluctuations in the IMF and related changes in the low latitude horizontal component of geomagnetic field*

V K Meena Varma & S R Prabhakaran Nayar
Department of Physics, University of Kerala, Kariavattom, Trivandrum 695 581
and
V V Somayajulu
Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum 695 022

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The behaviour of the fluctuations in the horizontal component of geomagnetic field (*H*) during two magnetic storms has been studied by selecting stations in different latitudes around the globe. The fluctuating component in the dawn-dusk electric field and $D_{st}$ are also compared with the *H* component fluctuation during these events. A strong fluctuating component with a period of about 3-4 h is discernible in the interplanetary magnetic field and the geomagnetic field variations.

## 1 Introduction

Magnetospheric substorms are, generally, thought to be the most important dynamical processes resulting from the solar wind-magnetosphere interaction. In the last two decades the well organised observations have provided frameworks in which the physics of the substorm processes are explained. In the 3-phase model of the magnetospheric substorm[1], a southward turning of interplanetary magnetic field (IMF) initiates a growth phase during which solar wind drives a sequence of events and initiates the expansion phase. During the expansion phase, a large increase in energy dissipation as measured by particle precipitation and joule heating is found to occur. The expansive phase is terminated by a sudden intensification of activity at high latitudes as well as by the beginning of a recovery phase during which the various growth and expansion phase phenomena die away. The various changes that occur during the growth phase are interpreted as manifestations of a 'driven' process[2,3], whereas the sudden release of energy during the expansion phase is referred to as 'loading-unloading' process. Magnetic field variations (in *H*, *D* and *Z*) observed on the ground during magnetospheric substorms have been used to study the response of the magnetospheric-ionospheric system to the solar wind-magnetosphere interactions, as the substorms occur during periods of southward IMF (Refs 4 and 5). Recent studies show that the periodic fluctuations of the interplanetary medium play an important role in solar wind-magnetosphere coupling[6]. From the various studies made during substorms, it is now well recognized that the substorms last for about 3-4 h. Therefore, in this paper, we have studied the response of IMF, ring current index ($D_{st}$) and the horizontal component of the earth's magnetic field (*H*) recorded at low, middle and high latitude stations in the day and night sectors for the two substorms identified under Co-ordinated Data Analysis Workshop (CDAW-6) during the magnetic storm of 22 Mar. 1979 (Ref. 7). For comparison, the data obtained during the magnetic storm of 29 Aug. 1979 are also included. It is found that during a substorm, the interplanetary electric field ($E_y$), $D_{st}$ and the *H* component show a fluctuating component of 3-4 h which gives us a clue about the directly driven as well as loading-unloading processes.

## 2 Data selection and analysis

In this paper, published hourly average values[8,9] of *H* for the stations given in Table 1 are used. Hourly average values of solar wind parameters are taken from interplanetary data book[10]. The solar wind parameters taken for the study are : solar wind velocity ($V_{sw}$), the north-south component of IMF ($B_z$), and hence, the interplanetary electric field given by $E_y = -(V_{sw} \times B_z)$ in units of mV/m ($V_{sw}$ is expressed in m/s and $B_z$ in nT). The published $D_{st}$

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Table 1—List of stations for which the hourly averaged values are used

| Station | Abbreviation | Geomagn. lat. | Geogr. long. |
|---|---|---|---|
| Trivandrum | TRV | 1.0°S | 76.95°E |
| Kodaikanal | KOD | 0.6°N | 76.01°E |
| Annamalai Nagar | ANR | 1.4°N | 79.68°E |
| Alibag | ALB | 9.0°N | 72.50°E |
| Sabhawala | SBL | 20.8°N | 77.80°E |
| Tashkent | TAS | 32.0°N | 69.62°E |
| Irkutsk | IRK | 41.0°N | 104.27°E |
| Novosibirsk | NOV | 45.0°N | 82.90°E |
| Sverdlovjsk | SVER | 48.0°N | 61.07°E |
| Huancayo | HUN | 1.0°N | 75.33°W |
| Sanjuan | SAN | 29.6°N | 66.15°W |
| Fredericksburg | FRD | 49.6°N | 77.37°W |
| College | COL | 65.0°N | 149.00°W |

values[11] are also used to study the fluctuating component.

The fluctuating component with a periodicity below 5 h is obtained by taking the running mean of all the above parameters using a 5 h smoothing window. The residuals thus obtained after subtracting the running mean from the actual data will contain all periodicities below 5 h.

## 3 Results

### 3.1 Magnetic storm of 22 Mar. 1979

The magnetic storm started with a sudden commencement at 0826 hrs UT and had a minimum value of $D_{st}$ of about $-74$ nT observed during the main phase of the magnetic storm. Under the CDAW-6 study, two substorms were identified at 1054 and 1426 hrs UT during this storm[7]. Figure 1(a) shows (i) the fluctuating component with period less than 5 h in the $H$ component of geomagnetic field ($\Delta H$) recorded at stations distributed over a wide range of latitude and longitude (Table 1) in the daytime sector and (ii) fluctuation in the interplanetary electric field ($E_y$). Figure 1(a) also shows the fluctuations in $H$ component in nighttime sector and $D_{st}$ ($\Delta D_{st}$). It is interesting to note that $E_y$ and $D_{st}$ show a fluctuating component of about 3-4 h periodicity corresponding to 1054 and 1426 hrs UT substorms. Both the substorms have shown enhanced interval of [illegible]ion corresponding to the growth phase at about 1000 and 1310 hrs UT for the southward turning of the IMF, and a northward turning of IMF corresponding to the expansion phase was observed at 1054 and 1350 hrs UT. However, the $E_y$ in Fig. 1(a) shows a fluctuating component of period 3-4 h right from 0830 to 0900 hrs UT and is repeated during the second substorm period also. Similar fluctuating component is also observed in the $H$ component at all the stations [Fig. 1(a)]. However, it is seen that the fluctuating component at high latitude stations in the daytime sector is not clearly discernible compared to low latitude stations and the peak amplitude also occurs with a delay of about 1 h. Another interesting result is the increase in the amplitude of the $H$ component at the nighttime sector stations as shown in Fig. 1(a). This can be due to the fact that the nighttime stations are in the midnight-early morning sector when the westward electrojet is expected to be active. The presence of a fluctuating component of 3-4 h periodicity in $E_y$, $D_{st}$ as well as in the $H$ component of magnetic field during the two substorms shows that it has its origin in the solar wind-magnetosphere interaction region and is communicated to all regions of the magnetosphere to be recorded on the ground.

### 3.2 Magnetic storm of 29 Aug. 1979

A sudden commencement of storm (SSC) occurred on 29 Aug. 1979 at 0457 hrs UT with peak $D_{st}$ $-150$ nT. Figure 1(b) shows the fluctuating component in $H$ at daytime stations (Table 1) and $E_y$. It also shows the fluctuation in $H$ at nighttime stations (SAN, FRD, COL) and $D_{st}$. The fluctuations show 3-4 h oscillations soon after the SSC, but not as clear as in the case of 22 March storm. Moving from low latitude to high latitude stations it is noticed that there is a time lag for the oscillation. The amplitude of the oscillation is increased at stations in the nighttime sector. The dawn-dusk electric field also shows oscillations of 3-4 h periodicity. The interesting fact is that the fluctuations are more clear in $E_y$ as compared to that in $H$ component. The $D_{st}$ also shows the oscillation. A time delay of about 1 h between $E_y$ and $H$ is observed as in the case of the magnetic storm of 22 March.

## 4 Discussion

The relationship between the fluctuations in the interplanetary electric field, $D_{st}$ and $H$ component of the magnetic field observed at ground has been studied for the storm of 22 Mar. 1979 and 29 Aug. 1979 to understand the transfer of energy from solar wind to inner magnetosphere. The simultaneous occurrence of fluctuating component (of 3-4 h periodicity) in $E_y$, $D_{st}$ and $H$ suggests that it is possible for the electric field generated by the solar wind magnetosphere dynamo in the high latitude ionosphere to penetrate deep into equatorial region as seen on the surface magnetic field variation at

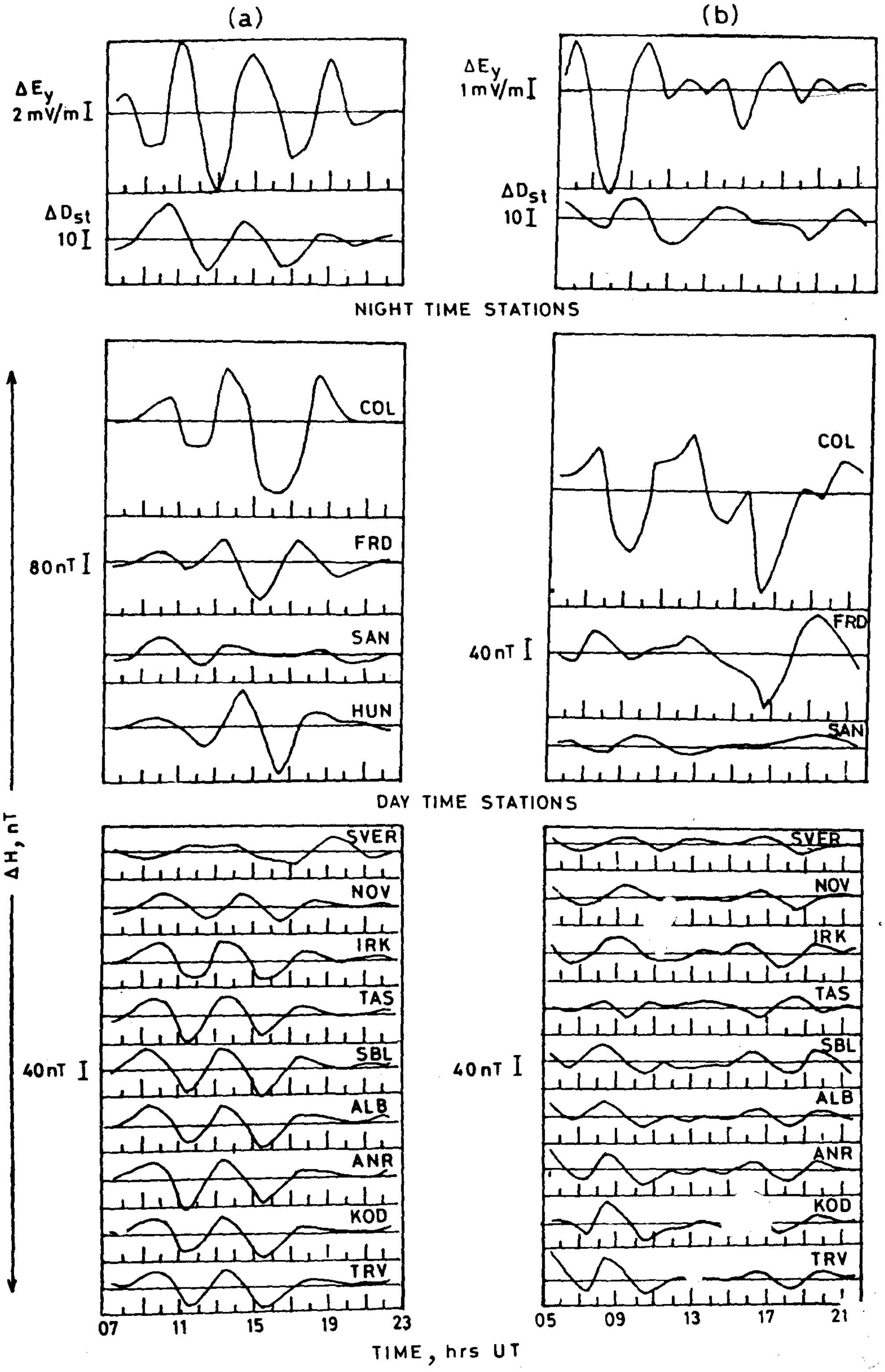


Fig. 1—(a) Fluctuations in the horizontal component of geomagnetic field in the daytime stations, nighttime stations (HUN, SAN, FRD, COL), interplanetary dawn-dusk electric field and $D_{st}$ during the magnetic storm of 22 Mar. 1979, and (b) Fluctuations in the horizontal component of geomagnetic field in the daytime stations, nighttime stations (SAN, FRD, COL), interplanetary dawn-dusk electric field and $D_{st}$ during the magnetic storm of 29 Aug. 1979

Trivandrum and Kodaikanal in the day sector and Huancayo in the night sector. There are two source mechanisms which can account for the temporal and spatial behaviour of the electric field at middle and low latitudes during geomagnetically disturbed periods[12]. The first mechanism is the solar wind-magnetosphere dynamo, in which dynamic interactions between solar wind and magnetosphere cause a flow of electric currents connecting the magnetosphere and the high latitude ionosphere[13]. Part of these currents, associated with their electric fields, penetrate directly into lower latitude through the conducting ionosphere. The second mechanism is called the disturbance dynamo, in which thermospheric winds produced by auroral heating can alter the global circulation and consequently generate electric fields and currents in middle and low latitudes by means of ionospheric dynamo action. The time scales involved in the second mechanism are of 6-10 h duration and, as such, are not conducive to the simultaneous fluctuations observed in the present study. Further, simulation studies have shown that the polarization charges accumulated in the inner magnetosphere, namely, the Alfven layer, as a result of plasma convection due to dawn-dusk electric field, tend to shield the middle and low latitude ionosphere from the direct penetration of the convection electric field. The absence of fluctuating component, during the 29 Aug. 1979 event, in the *H* component shows that the low latitude ionosphere is partly shielded from the high latitude electric fields. However, the presence of fluctuating component during 22 Mar. 1979 event shows that, most probably, the inner edge of the plasma sheet which generally causes the electric field shielding does not apparently have time to react to these changes. Therefore, future studies should aim at a more extensive latitudinal variation of *H* fields to arrive at definitive conclusions on the use of surface magnetic field variation as a tool for substorm studies.

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