Indian Journal of Radio & Space Physics
Vol. 39, August 2010, pp. 203-207

Preliminary reverse impulse in SC (Y) at off - equatorial stations in India

R G Rastogi[1,$, *] & K Ahmed[2]
[1]Physical Research Laboratory, Ahmedabad 380 009, India
[2]Indian Institute of Geomagnetism, Navi Mumbai 410 218, India
[$]E-mail: profrgrastogi@yahoo.com

Received 7 January 2010; revised 4 June 2010; accepted 17 June 2010

The storm sudden commencement (SSC) at 2345 hrs UT on 24 September 1998, occurring at around local sunrise for Indian stations had produced uniquely two–step impulses on the H magnetogram at all stations. The amplitude ΔH had increased progressively from Trivandrum to Gulmarg, unlike the characteristic of the day time equatorial enhancement of SC (H). The solar wind parameters too showed abnormal variations during the period of SC.

The magnetogram trace for declination (or eastward field Y) recorded a preliminary reverse impulse (PRI) close to the latitude of Sq focus at stations Gulmarg, Ujjain, Nagpur and Shillong. The PRI was absent in SC (Y) at equatorial stations Trivandrum and Pondicherry. This observations show a new complex relationship between the ionospheric dynamo and magnetospheric dawn / dusk electric field with the equatorial geomagnetic field around sunrise.

Keywords: Preliminary reverse impulse (PRI), Sudden storm commencement (SSC), Geomagnetic eastward component

PACS Nos: 94.20.Vv; 94.30.*vf*; 96.60.Vg

1 Introduction

Geomagnetic ground survey in Peru by Giesecke during September - November 1949 showed that the daily range of horizontal geomagnetic field, H, slowly increased from 7°S latitude to a peak at 13°S (close to the magnetic equator) with a ratio of about 2. Chapman[1] suggested this phenomenon due to a narrow eastward flowing current in the ionospheric E-region during the day time and named it equatorial electrojet. Baker & Martyn[2] suggested that orthogonal electric and magnetic fields in the ionospheric E-region over the magnetic equator generates there a Hall polarization field causing and abnormal increase of the eastward Cowling conductivity. Thus, the ionosphere within ±3° over the magnetic equator is very sensitive to the changes of horizontal electric field, whatever may be its origin.

Sudden storm commencement (SSC) in H is very important phenomenon relating to the interaction of the plasma cloud ejected from the Sun with the earth's magnetosphere and consequent effects on the ionospheric electric field and current at low and high latitudes. Newton[3] in his pioneering study of SCs at Greenwich for the years 1879-1944 observed occasional preliminary reverse impulse (PRI) in SC (H) before the main positive impulse, now denoted as SC*. Chakravarty[4] did not find any SC* in the magnetograms of Alibag for the period 1905-1944. Srinivasamurty[5] found 13 cases of SC*, out of total 229 SCs, at Kodaikanal during the period 1949 – 1957. Matsushita[6] on examining the microfilm copies of the magnetograms during the IGY period found SC* to occur in H at equatorial electrojet station during mid day hours and at high latitude stations during late evening hours. Examining the original magnetograms at Kodaikanal for the period 1949-1968, Rastogi[7] found about 50% of SCs around mid day hours were of SC* type. Both the occurrence as well as the amplitude of PRI was shown to decrease from Trivandrum to Alibag[8]. Recently, Han & Liu[9] had described the complex feature of SC (H) during the dawn time at equatorial electrojet station Jicamarca.

This paper presents some unique features of SCs in H, Y and Z components at Indian observatories at 2345 hrs UT on 25-September 1998. The list of stations and the relevant co-ordinates are given in Table 1.

2 Observations

On 24 September 1998, an interplanetary shock arrived at 10 R_E at 23:44:19 hrs UT causing the occurrence of SC in H at ground observatories[10]. Figure 1 shows the variation of parameters of solar wind velocity, solar wind density, solar wind magnetic field and the consequent solar wind pressure

Table 1 —List of stations and their co-ordinates

Station	Code	Geog Lat °N	Geog Long °E	Geom Lat °N	Dip Angle °
Trivandrum	TRD	8.5	77.0	-0.3	1.1
Ettaiyapuram	ETT	9.2	78.0	0.3	3.0
Kodikanal	KOD	10.2	77.5	1.4	4.8
Pondicherry	PON	11.9	79.9	2.9	9.5
Visakhapatnam	VSK	17.6	83.3	7.8	22.3
Alibag	ABG	18.6	72.9	10.2	26.4
Nagpur	NAG	21.2	79.1	12.1	29.3
Ujjain	UJJ	23.2	75.8	14.4	34.4
Shillong	SHL	25.6	91.9	15.7	37.2
Gulmarg	GUL	34.1	74.6	24.8	51.9

on the magnetosphere and the interplanetary electric filed, E = -V*Bz corrected for the distance of 1 AU. The variations of the auroral index AE, symmetric H index and Kodaikanal H magnetograms are also reproduced in the figure to indicate the effect of solar plasma at high, middle and equatorial latitude of the earth. This data have been derived from CDAWeb site of Adnet systems of NASA GSFC.

Kodaikanal magnetograms experienced the first impulse at 2345 hrs UT and the second one at 2352 hrs UT. The SYM/H, which is derived as the average deviation at mid latitudes had single rather slow impulse at 2345 hrs UT. The AE index also showed a single impulse at 2345 hrs UT. The IMF-Bz showed rather mild positive impulses at 2345 and 2352 hrs UT. The solar velocity and density data had a gap during 2345-2348 hrs UT, but a significant impulse was recorded at 2350 hrs UT. Both these parameters fluctuated violently for about 15 minutes. The interplanetary electric field did not show any significant impulse close to the time of SC.

The H, Y and Z magnetograms at all Indian observatories situated from the magnetic equator (Trivandrum) to the latitude of the focus of Sq current system (Gulmarg) are reproduced in Fig. 2 (a-c). Referring to the Fig. 2(b) for H magnetograms, the signature of SC had developed in two steps at every station. The Z magnetograms at low latitude showed double steps but at higher latitudes, the second step was comparatively small. The abnormally large SC (Z) at equatorial station has to be explained as a result of induction at sub-surface conducting regions[11].

In Fig. 2(a), the impulse SC(Y) at Trivandrum, close to the magnetic equator was small and positive. SC(Y) at other stations was negative. It is important

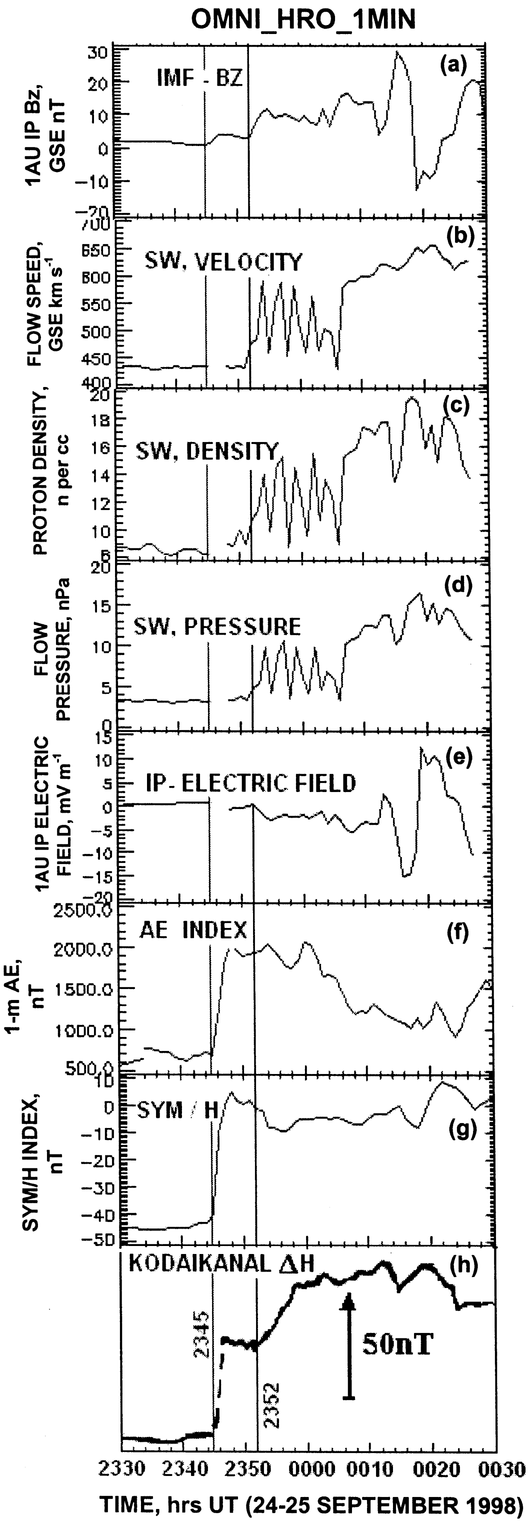

Fig. 1 — Variations of: (a) Interplanetary magnetic field components; (b) Solar wind velocity; (c) Solar wind density; (d) Solar wind pressure; (e) Interplanetary electric field; (f) Auroral index AE; (g) Ring current index SYM/H; and (h) H magnetogram at Kodaikanal around time of SC at 2345 hrs UT on 24 September 1998

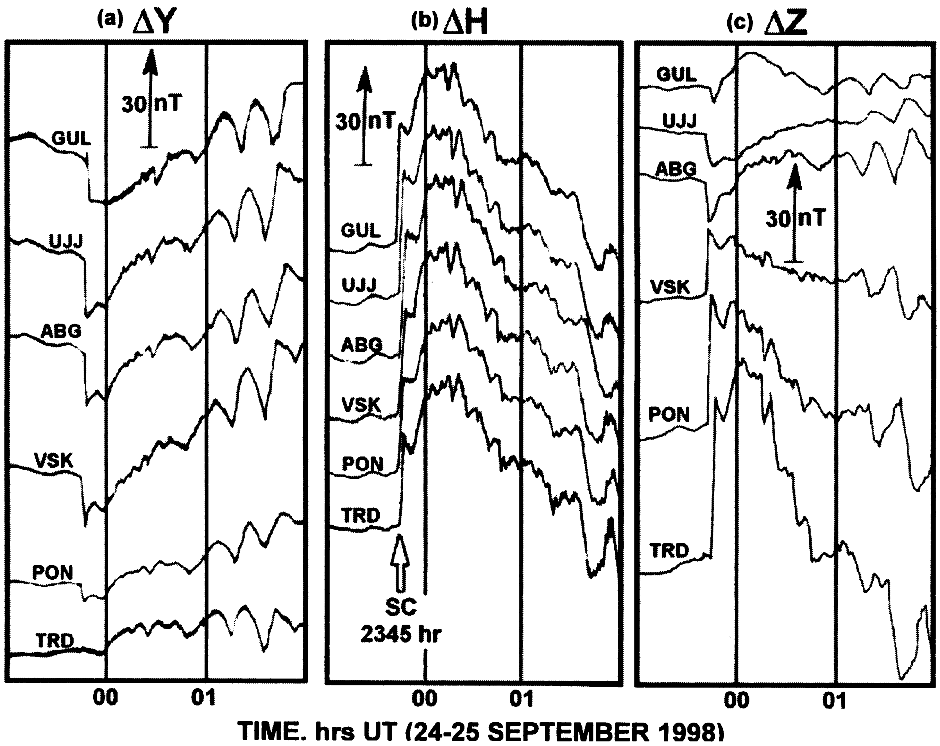

Fig. 2 — Reproduction of H, Y and Z magnetograms at Indian Observatory extending from the equatorial station, Trivandrum to the station close to the focus of Sq current system, Gulmarg

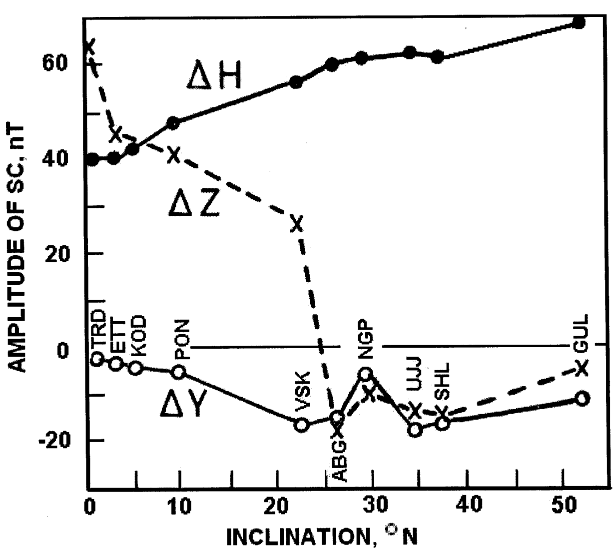

Fig. 3 — Latitudinal variations of the amplitude of SC in H, Y and Z components at Indian stations

to note that this PRI was observed at all non-equatorial stations and most prominently at Gulmarg.

The latitudinal variations of SC in H, Y and Z components at all Indian stations are shown in Fig. 3. The amplitude of SC (H) clearly showed an increase with increasing latitude. The amplitude was 40 nT near the dip equator and 68 nT near the latitude of Sq focus. The SC (Z) showed large positive impulse at low latitudes from Trivandrum to Visakhapatnam and negative at higher latitude. The amplitudes of SC (Y) increase slowly with increasing latitude.

To understand the condition of the ionosphere at the time of SC, the vertical incidence ionograms at Thumba (≡ Travindrum) are reproduced in Fig. 4. The critical frequency of the F2 layer (FoF2) is steadily decreased from 0430 to 0500 hrs LT. At 0515 hrs LT, the sunrise at the F-layer heights generated fresh ionization producing a new layer sometimes called F3 layer. The ionogram at 0530 hrs LT showed a rapid increase of foF2. Thus, it is clear that the SC (at 0445 hrs LT) occurred when both the F- and E-layers did not show any new ionization. Thus, the night time ionizations in the E-layer would not sustain any current generated by SC. Therefore, any effect of the magnetospheric electric field would not be detectable. The ΔH due to SC should be only due to the magnetospheric pressure. There is still a problem that there was rather small impulse in IMF-Bz at 2345 hrs LT, while at 2352 hrs UT, there were large impulses in IMF-Bz, solar wind density and velocity.

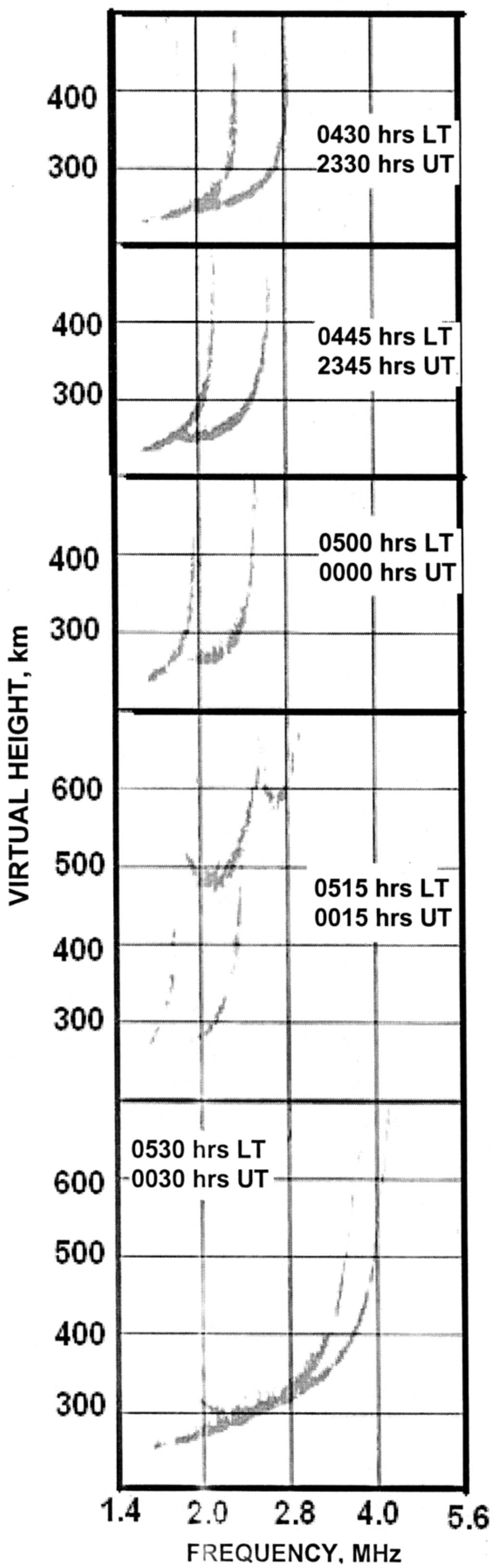

Fig. 4 — Series of ionograms at Thumba around the time of SC at 2345 hrs UT on 24 September 1998

3 Discussion

Chapman & Ferraro[12] were the first to suggest that the geomagnetic storms are initiated by impact on the earth of ionized plasma bubble ejected from the Sun following a solar flare. Gold[13] postulated the existence of an interplanetary shock at the leading edge of the plasma cloud as an explanation of the sharp rise of H in SCs. Rastogi[14] showed that SC* at the equatorial stations were observed only when the event was associated with the increase of both the direction (latitude θ) as well as the magnitude of the interplanetary magnetic field.

The equatorial enhancement of SC (H) indicated the effect of atmospheric dynamo electric field as well as a magnetospheric dusk/dawn electric field. Though both these electric fields reverse direction at dawn and at dusk time, but not necessary at the same time on each day. Rastogi[15] postulated the existence of two current systems flowing simultaneously within the equatorial electrojet region but at two different heights, electrojet current at 100 km and the Sq current at 106 km. This further complicates the phenomenon of sudden impulses. During the dusk and dawn periods, the ionospheric currents at low latitudes are zonal but at middle latitudes the current, if any, would be meridional. Thus, the phenomena of the sudden commencement or sudden impulse at low latitudes are no more a simple effect of the compression of magnetosphere, but involve complex relationship between solar wind parameters with the earth's magnetosphere and ionosphere. A close network of geomagnetic observatories in India would be useful for studying the complex phenomenon of geomagnetic storms.

Acknowledgements

One of the authors expresses thanks to Physical Research Laboratory, Ahmedabad for the facility provided to him as a visiting professor. Thanks are also due to Indian Space Research Organization, Banglore for a research grant and to Indian National Science Academy, New Delhi for granting him a Honorary Scientist position. The work at Indian Institute of Geomagnetism, Navi Mumbai is supported by the Department of Science and Technology, Government of India, New Delhi. Thanks are also due to Space Physics Laboratory, Trivandrum for the Thumba ionograms.

References

1 Chapman S, The equatorial electrojet as detected from the abnormal electric current distribution above Huancayo, Peru and elsewhere, *Arch Meteorol Geophys Bioclimatol A, Meteorol Geophys (Austria)*, 4 (1951) pp 368-390.

2 Baker W J G & Martyn D F, Electric current in the ionosphere the conductivity 1, *Philos Trans R Soc Lond A, Math Phys Sci (UK)*, 246 (1953) pp 281-294.

3 Newton H W, Sudden commencement in the Greenwich records (1879-1944) and related sunspot data, *Mon Not R Astron Soc Geophys Suppl* (*UK*), 5 (6) (1948) pp 159-185.

4 Chakravarty S K, Sudden commencements in geomagnetic field variation, *Nature (UK),* 167 (1951) 31.

5 Srinivasamurthy B, Sudden commencements and impulses in Kodikanal magnetograms, there hourly frequency, *Indian J Meteorol Geophys*, 10 (1959) pp 209-212.

6 Matsushita S, On geomagnetic sudden commencements, sudden impulses and a storm duration, *J Geophys Res (USA)*, 67 (1962) pp 3753-3777.

7 Rastogi R G, On the occurrence of SSC (-+) at Kodaikanal, *Planet Space Sci (UK)*, 19 (1971) pp 371-374.

8 Rastogi R G & Sastri N S, On the occurrence of SSC (-+) at geomagnetic observatories in India, *J Geomagn Geoelectr (Japan),* 26 (1974) pp 529-537.

9 Han De-Sheng & Li Qi, Geomagnetic sudden commencement at dawn–time dip equator, *Earth, Planet Space (Japan)*, 60 (2008) pp 607-612.

10 Russell C T, Wang Y L, Raeder J, Tokar R H, Smith C W, Ogilvie K W, Lazarus A J, Lepping R P, Szabo A, Kawano H, Mukai T, Savin H, Yermolev Y L, Zhou X-Y & Tsurutani B T, The interplanetary shock of September 24, 1998: Arrival at Earth, *J Geophys Res (USA)*, 105 (A11) (2000) pp 25143 – 25154.

11 Rastogi R G, Elctromagnetic induction by the equatorial elctrojet, *Geophys J Int (UK)*, 158 (2004) pp 16-31.

12 Chapman S & Ferraro V C A, A new theory of magnetic storms Part 1: initial phase, *Terr Magn Atmos Electr (USA),* 36 (1931) pp 77-97.

13 Gold T, *Gas dynamic of cosmic clouds*, edited by H C Van de Hulst and J M Burgers (North Holland Publishing Co, Amsterdam), 1955, 103.

14 Rastogi R G, Theory of preliminary negative impulse in storms sudden commencement in H at equatorial stations, *Proc Indian Acad Sci,* 87A (3) (1978) pp 57-60.

15 Rastogi R G, On the simultaneous existence of eastward and westward flowing equatorial electrojet current, *Proc Indian Acad Sci*, A81 (1925) pp 80-92.