Ann. Geophysicae 17, 438–441 (1999) © EGS – Springer-Verlag 1999

Annales Geophysicae

Letter to the Editor

Geomagnetic storm effects at low latitudes

R. G. Rastogi

School of Physics, University of New South Wales, Sydney 2052, Australia
and Department of Physics, Gujarat University, Ahmedabad 380 009, India

Received: 30 April 1998 / Accepted: 3 September 1998

Abstract. The geomagnetic horizontal (H) field from the chain of nine observatories in India are used to study the storm-time and disturbance daily variations. The peak decrease in storm-time variation in H showed significant enhancements at the equatorial electrojet stations over and above the normally expected decrease due to the ring current effects corrected for geomagnetic latitudes. The disturbance daily variation of H at equatorial stations showed a large decrease around midday hours over and above the usual dawn-maximum and dusk-minimum seen at any mid-latitude stations around the world. These slow and persistent additional decreases of H of disturbance daily variation at equatorial latitudes could be the effect of a westward electric field due to the Disturbance Ionospheric dynamo coupled with abnormally large electrical conductivities in the E region over the equator.

Key words. Ionosphere (electric fields and currents) · Magnetospheric physics (electric fields; storms and substorms).

1 Introduction

Moos (1910) from his monumental study of magnetic data collected at Bombay, India from 1846 to 1905, identified two distinct components of magnetic disturbance in the horizontal component of the geomagnetic horizontal field (H). After removing the normal daily variation and averaging over a number of events, the magnetic storm was found to start with a sudden increase lasting a couple of hours, followed by a rapid decrease continuing for few hours and later the recovery to normal conditions in a day or two. This feature of the storm occurring at same universal time at different observatories round the world is known as storm-time variation, Dst(H). The second component depending on the local solar time was identified as additional solar daily variation imposed on normal daily variation during disturbed days. Moos had found a maximum around dawn and a minimum around dusk period. This is now known as disturbance daily variation, SD(H), and is computed by subtracting the mean solar daily variation on five international days of the month (SqH) from the corresponding mean variation on five international disturbed days of the month (SdH).

Vestine *et al.* (1947) described the results of a comprehensive study of the solar daily variations of the three components of the geomagnetic field at a large number of observatories on quiet as well as disturbed days. The disturbance daily variation of H, SD(H) was found to be a single sine wave with a dawn-maximum and a dusk-minimum at any of the stations in low and middle latitudes. Chapman (1951) concluded that the magnetic disturbance at equatorial stations does not present any abnormal features characteristic of the equatorial electrojet. Sugiura and Chapman (1960) similarly concluded, after their extensive studies of Dst and SD variations of D, H and Z components at a number of observatories, that the effect of magnetic storms at equatorial stations are similar to those at other low and middle latitude stations. Recently Rastogi (1998a) has shown that disturbance daily variation of equatorial electrojet current has a distinct minimum near noon, the amplitude of which increases near the magnetic equator.

Since 1975, a unique network of geomagnetic observatories is in operation in India confined within a narrow longitude zone, but extending in latitude from the centre of the electrojet to the focus of Sq current system. The list of these observatories with their coordinates (for the year 1976) are given in Table 1.

The present paper examines the storm-time and disturbance daily variations of H at the unique set of stations in India to check any possible abnormal effects at equatorial electrojet stations.

Table 1 List of geomagnetic observatories in India

Observatory	Code	Geog. Lat. °N	Geog. Long. °E	Dip. Lat. °N
Trivandrum	TRD	8.5	77.0	−0.3
Kodaikanal	KOD	10.5	77.5	1.6
Annamalainagar	ANN	11.4	79.5	2.8
Hyderabad	HYB	17.4	78.6	10.7
Alibag	ABG	18.6	72.9	12.8
Ujjain	UJJ	23.2	75.8	18.1
Jaipur	JAI	26.9	75.8	22.4
Sabhawala	SAB	30.4	77.8	28.9
Gulmarg	GUL	34.1	74.6	31.4

2 Disturbance daily variation of the electrojet

In Fig. 1 are shown the disturbance daily variations of H, SD(H) = Sd(H)−Sq(H) at all Indian observatories averaged over all months of the year 1980. The diurnal inequalities were properly removed from the Sq and Sd variations. The SD variations at stations outside the electrojet belt show primarily a single sine wave with a dawn-maximum and a dusk-minimum, in conformity with the results of Vestine (1947) and of Yacob and Sastri (1966). At equatorial electrojet stations TRD, KOD and ANN a significant depression of H is observed around midday hours. The magnitude of the midday depression in H is progressively reduced with increasing distance from the equatorial station Trivandrum.

This suggests that a regular westward electric field is imposed on the equatorial latitudes during the midday hours of the geomagnetically disturbed days. The amplitude of midday decreases of SD(H) showed an enhancement over the magnetic equator in a fashion similar to the daily range of Sq(H) at equatorial latitudes. Rastogi (1998b) has compared SD(H) variations at equatorial electrojet stations in Indian and American longitudes. The SD(H) at Kodaikanal showed a prominent midday decrease during the years 1954–1960 but at Huancayo SD(H) did not show any evidence of midday decrease beyond the dawn-maximum and dusk-minimum.

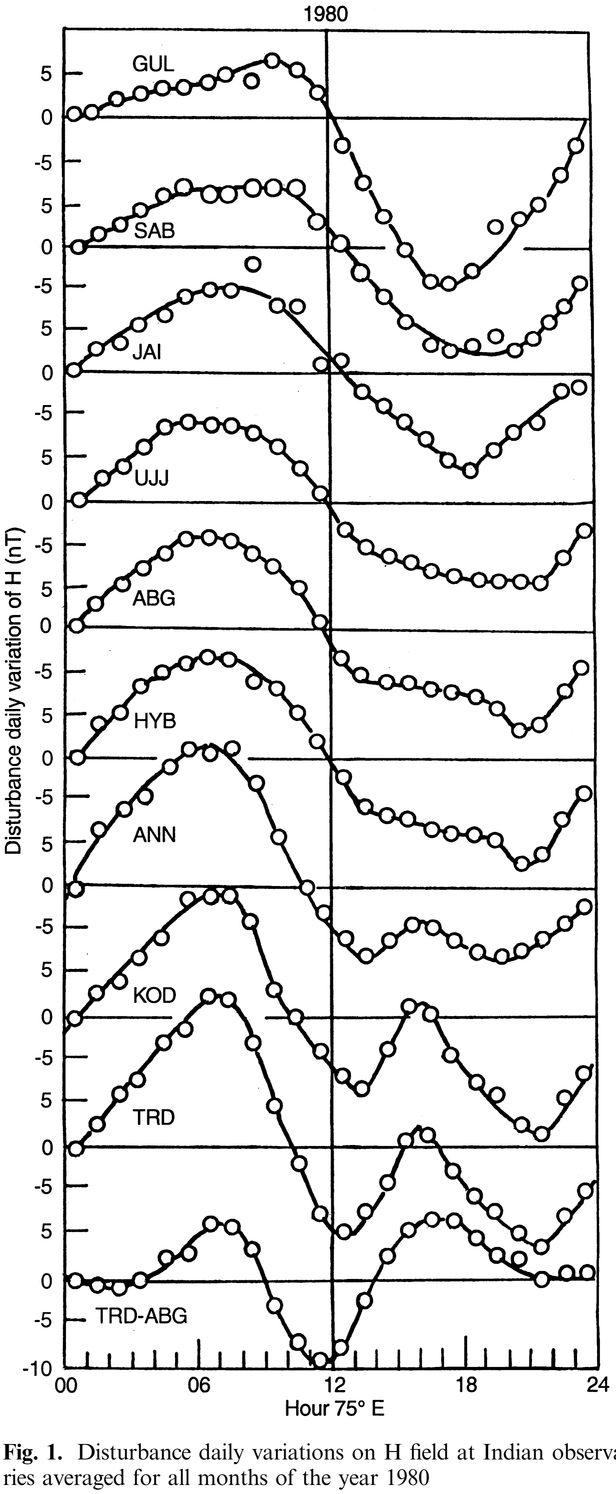

Fig. 1. Disturbance daily variations on H field at Indian observatories averaged for all months of the year 1980

3 Storm-time variation of the electrojet

In Fig. 2(a) are shown the storm-time variations of H at all of the nine Indian observatories for the magnetic storm which started at 2335 hours 75°EMT on 11 September 1986. The variations of DST-H index and of the top frequency reflected from the equatorial E region instabilities, Es-q, over Kodaikanal are also shown in the diagram. In Fig. 2(b) are shown the latitudinal variations of the observed Dst-H at the peak of the storm compared with the axial symmetric part of the Dst-H corrected for the dipole latitude, λm. The Dst-H index shows sudden increase of H at midnight of 11–12 Sept. 1986 associated with SSC. The main phase started at 0630 hours on 12 Sept. 1986 reaching the peak activity at 1130 hours (Dst-H = −170 nT) followed by a slow recovery on 13 Sept. 1986. The storm changes in H at all of the stations were very similar to the changes of Dst-H index. At Jaipur the maximum decrease of H was −170 nT almost the same as of the Dst index. The magnitude of the maximum of H was −173 nT at UJJ, −181 nT at ABG, −195 nT at HYB, −202 nT at ANN, −202 nT at KOD and −214 nT at TRD. Thus Dst observed at any of the stations was larger than the global average index and specially at the stations within

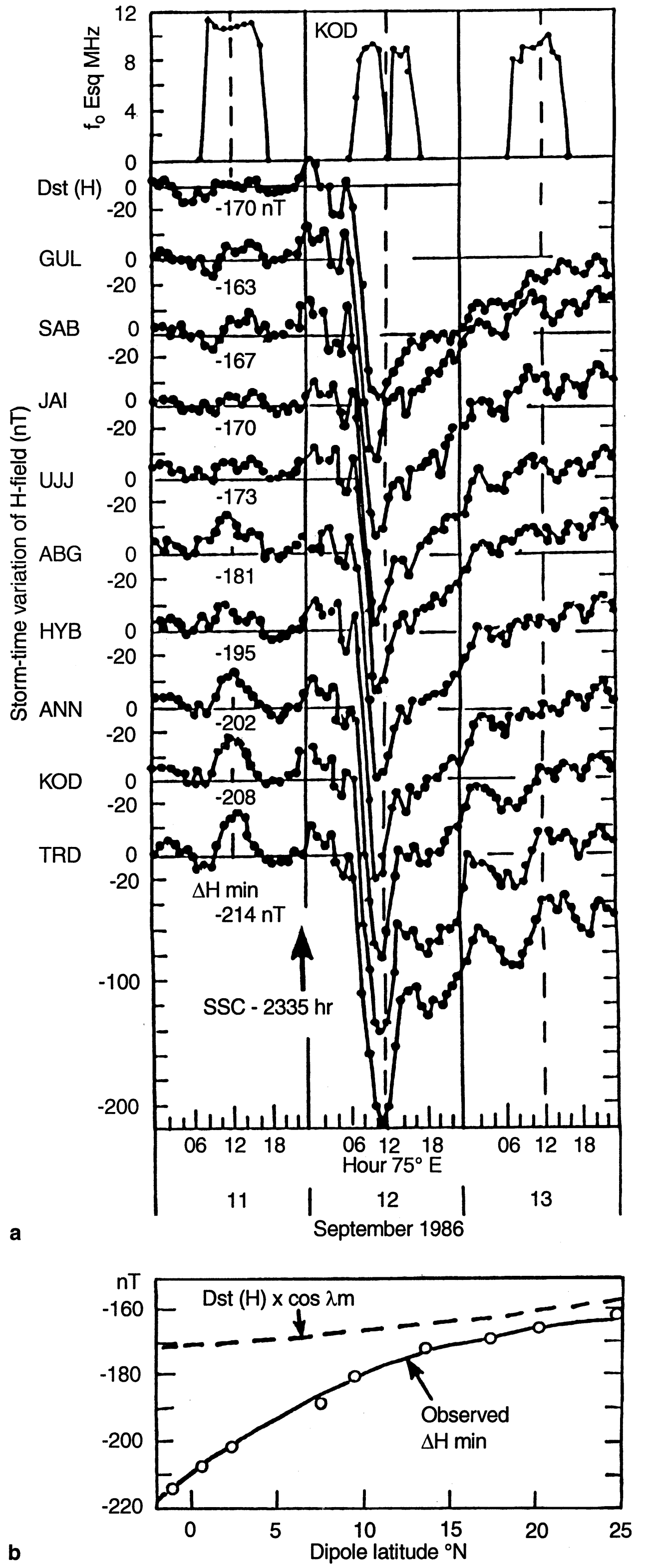

Fig. 2. a Storm time variations of H field at Indian observatories during the storm starting at 2335 hours 75°EMT on 11 Sep. 1986. **b** Latitudinal variations of the observed minimum of H at different stations during the peak disturbance activity compared with the latitudinal variation of Dst(H) index × cosine geomagnetic latitude.

the electrojet belt. Around noon on 12 Sept. 1986 the value of H(TRD) −H(ABG) was −33 nT suggesting a counter electrojet event, which is confirmed by the absence of Es-q reflections at the same time. The Eq was absent at Kodaikanal at each of the 15-min observations from 1115 to 1230 hours 75°EMT (K. Karunakaran, private communication). The regular hourly ionograms at Thumba showed Esq at all hours from 0730 hours to 1530 hours 75°E on 11 September 1986; on 12 September 1986 Esq was present from 0730 to 1130 hours, was absent at 1230 hours and present again from 1330 hours to 1530 hours 75°E (B. V. Krishna Murthy, personal communication). This shows that a strong westward electric field was imposed over the equatorial ionosphere which overbalanced the normal eastward Sq field during the peak of the storm. Referring to Fig. 2(b), the axially symmetric part of Dst increased from a value of −168 nT at 25° latitude to −170 nT at 0° latitude. The observed Dst-H increased slowly with decreasing latitude and later increased very fast at latitudes close to the equator indicating the characteristics of the equatorial electrojet. It is to be noted that no large substorms were indicated during the storm. Similar increases of Dst-H at equatorial latitudes were not seen during the storms with the main phase occurring during the local night time hours.

4 Discussion

Rastogi (1977) has shown the evidence of such a change of large electric field imposed on the dayside of the electrojet during a geomagnetic storm. The present analyses indicate a rather slow and persistent electric field imposed on the equatorial ionosphere during the main phase of the storm. Blanc and Richmond (1980) have suggested, based on their numerical analyses, that the global distribution of ionospheric currents and electric fields can be altered by the perturbations in the solar wind magnetosphere dynamo and the ionospheric wind dynamo. These modifications in the neutral atmospheric circulation during geomagnetic disturbances can decrease or even reverse the quiet time electric field pattern in the vicinity of the dip equator. Fejer *et al.*, (1983) showed evidence that the F region vertical drift at Jicamarca are sometimes perturbed 16–24 h after the onset of geomagnetic storms. Fejer and Scherliess (1955) using the radar measurements of F region vertical plasma drifts at Jicarmarca and AE indices, have shown that the high latitude electric field from the dynamo action of storm time winds produce largest perturbations a few hours after the onset of magnetic activity. Short period fluctuations in H at equatorial stations are known to occur during storms (Gonzales *et al.*, 1983; Chandra and Rastogi 1997). These effects are often related to the directional changes in the Bz component of the interplanetary magnetic field (Rastogi and Kroehl 1978). Mazaudier and Venkateswaran (1990) have described variations of the E and F region meridional winds derived from the quadristatic radar at St Santin on 23 March 1979 with a time delay of several hours after the substorm event of 22 March, when the state of magnetosphere was fairly quiet. They explained the effect as due to the thermospheric and ionospheric winds caused by disturbance dynamo electric field.

The additional storm time decrease of H at electrojet stations are in perfect time coincidence with the changes of ring current strength (= Dst H index) and hence cannot be attributed to any neutral wind modifications which are associated with a long time lag. Most probably this phenomenon is due to imposition of a westward electric field at the equatorial latitudes simultaneously with the arrival and trapping of charged particles of solar wind origin.

Unfortunately there is no equatorial chain of magnetic observatories east or west of India where such phenomenon can be studied for longitudinal inequality if any.

Acknowledgements. The author is thankful to the University of New South Wales for the facilities of the present study and to Prof. R. Stenning and Prof. D. E. Winch for useful discussions. Thanks are due to Indian National Science Academy, Gujarat University and Physical Research Laboratory for supporting the research activities of the author.

Topical Editor D. Alcaydé thanks M. A. Abdu for his help in evaluating this paper.

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