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Day-time enhancement of Geomagnetic Disturbance at the magnetic equator in India

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ABSTRACT. Geomagnetic disturbance daily variation $SD(H)$ and storm-time hourly depressions in H occurring at the magnetic observatories, Trivandrum and Annamalainagar, stations close to the magnetic equator are compared with those occurring at Alibag (mag. lat. 13°N) to show that the disturbances are of about the same magnitude during the night-time at the three observatories, while during the day-time disturbance magnitudes near the magnetic equator are enhanced in varying degrees depending on the type of disturbance. It is inferred that geomagnetic disturbances arise at least partly from E-layer electric currents and that such currents are augmented at the magnetic equator during the day. The fact that the disturbances are not enhanced at the magnetic equator during the night must be due to the insignificant ionization in the E-layer and the absence of inhibition of vertical Hall currents at night.

1. Introduction

With the finding of abnormally high diurnal ranges in $Sq(H)$ at the magnetic equator, the question whether geomagnetic disturbance is also enhanced there arises as a logical sequence. Chapman (1951) has examined this question and has adduced evidence to show that SD as well as D_{st} near the magnetic equator are normal, that is, comparable with that shown in regions well away from the magnetic equator. Since then it has been shown that SC's, SI's, other short-period fluctuations and even the initial phase of geomagnetic storms are augmented during the day-time near the magnetic equator (Sugiura 1953, Forbush and Vestine 1955, Srinivasamurthy 1960, Maeda and Yamamoto 1960, Onwumechilli 1960, Onwumechilli and Ogbuehi 1962). Forbush (1960) has reported that SD too, sometimes but not always, exhibits enhanced effects in the same way as does Sq always.

Yacob and Pisharoty (1963) have given a condensed account of geomagnetic quiet-day and disturbed-day field variations in the region of the magnetic equator in India. Indications have been made of day and night dissimilarity in the magnitudes of all geomagnetic disturbances in H, including the disturbance daily variation, $SD(H)$, short period fluctuations in H and storm-time hourly mean total disturbance maguitudes. Detailed elaboration of the diurnal variation in the enhancements of the short-period fluctuations in H has since been given by Yacob and Khanna (1964). In this contribution magnitudes of geomagnetic disturbance in H registered at Trivandrum (mag. lat. 0°19′S, geog. long. 76°57′E) and at Annamalainagar (mag. lat. 2°42′N, geog. long. 79°41′E), stations close to the magnetic equator, are compared with those occurring at Alibag (mag. lat. 12°55′N, geog. long. 72°52′E), a station well away from the magnetic equator, to bring out the day and night dissimilarity in their effects near the magnetic equator. The types of geomagnetic disturbance examined are (1) disturbance daily variation, $SD(H)$, (2) magnitudes in H of storm-time hourly mean total disturbance of individual geomagnetic storms. The location of the three observatories within a narrow belt of longitudes of width less than 30 minutes of time, apart from the fact that Alibag is quite distant from the magnetic equator, is well suited for a comparative study of disturbance magnitudes at these observatories with a view to bring out their day and night dissimilarity and enhancements in the magnetic equatorial region. The comparative study is confined to the IGY period.

2. Geomagnetic Daily Disturbance Variation $SD(H)$

For the period of the IGY the hourly values of H for all the ID and the IQ days were averaged separately hour-wise and the mean hourly values for ID days were subtracted from the corresponding mean hourly values for IQ days, after applying the non-cyclic corrections, to give the hourly depressions in H due to disturbance. If the mean hourly values for the IQ and ID days for the hour t were H_t^q and H_t^d and the mean non-cyclic changes (reckoned at 0^h GMT) were N^q and N^d respectively then the mean hourly values corrected for the non-cyclic changes were

$$H_t^q + \frac{(12-t)}{24} N^q \text{ and } H_t^d + \frac{(12-t)}{24} N^d .$$

The hourly depression at hour t is then given by

$$\left[H_t^q + \frac{(12-t)}{24} N^q \right] - \left[H_t^d + \frac{(12-t)}{24} N^d \right].$$

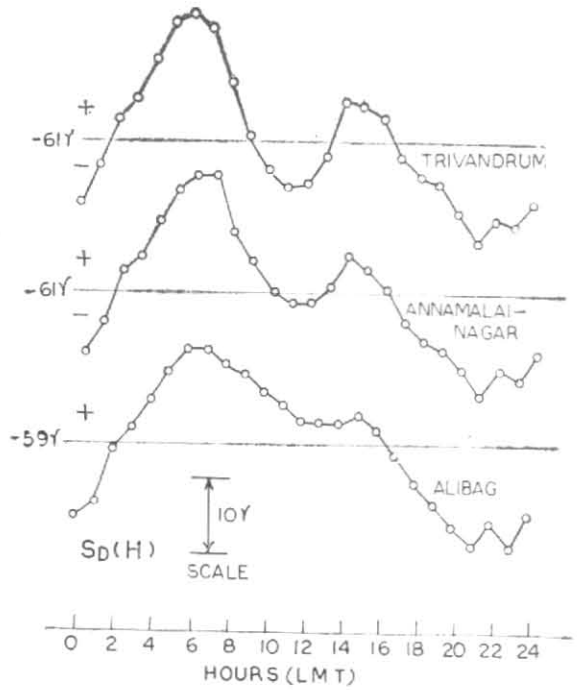

Fig. 1. Mean disturbance daily variation $SD(H)$ for the period October 1957 to December 1958, obtained from 67 IQ days, and 57 ID days

The mean of the hourly depressions for the 21 hours GMT gave the mean daily disturbance in H and the departures of the hourly depressions from this mean constituted the mean disturbance daily variation, $SD(H)$. $SD(H)$ was derived for each of the three observatories under consideration from 67 IQ and 57 ID days common to all the three observatories during the IGY. All the five IQ and ID days of each month could not be used on account of loss of record at one station or other. But each month had at least a few days of both IQ and ID. The actual period of comparison is confined to October 1957 to December 1958, since Trivandrum and Annamalainagar started functioning only from October 1957.

The $SD(H)$ variations obtained for Trivandrum, Annamalainagar and Alibag are shown in Fig. 1. The $SD(H)$ variations for all the observatories are similar in trend except for the day hours. At all the observatories $SD(H)$ is minimum (least depression in H) at about 6^h LMT and is maximum (maximum depression in H) at about 21^h LMT. The night-time magnitudes are almost the same at the three observatories. But the day-time magnitudes indicate that $SD(H)$ is enhanced for stations near the magnetic equator. The ranges in $SD(H)$ for the day hours (from 6^h to 18^h LT through noon) at Trivandrum, Annamalainagar and Alibag are 23γ, 17γ and 10γ respectively while the ranges for the night hours (from 18^h to 6^h LT through midnight) are 30γ, 29γ and 27γ respectively. It is thus seen that while the night-time ranges are about the same at all the three observatories, the day-time ranges in $SD(H)$ are significantly different with the greatest range for the observatory nearest to the magnetic equator, *viz.*, Trivandrum. The peak day-time depression in $SD(H)$ occurs at about the time of maximum $Sq(H)$. The ratio of the day-time $SD(H)$ range at Trivandrum to that at Alibag is 2·3 and the ratio for Annamalainagar and Alibag is 1·7. These ratios of the day time $SD(H)$ ranges are comparable with the ratios of the mean $Sq(H)$ ranges for the IGY at these stations, which are 2·1 and 1·6 respectively. It thus appears that $SD(H)$ near the magnetic equator is augmented during the day time in the same way as $Sq(H)$ is.

The results of harmonic analysis of $SD(H)$ for the three observatories are given in Table 1. The amplitudes are in terms of depressions in H and the phase angles are reckoned from local midnight.

It may be seen that while the predominant component of $SD(H)$ is the first harmonic of the variation for Alibag, both the first and second harmonics tend to have equal predominance at Annamalainagar and Trivandrum. The amplitudes of the first harmonics at the three stations are comparable with a tendency to decrease slightly towards the magnetic equator. The local time of maximum depression for the first harmonic is about the same for all the stations and is 20^h. The amplitude of the second harmonic, on the other hand, shows large increase towards the magnetic equator, with the amplitude for Trivandrum more than double that for Alibag. The time of first maximum depression of the second harmonic is almost the same at all the observatories and is 11^h, which is about the time when $Sq(H)$ attains its maximum. The difference seen in the amplitudes of the second harmonic is evidently a consequence of daytime enhancement of $SD(H)$ near the magnetic equator.

3. Magnitudes of storm-time hourly Mean Disturbance for individual Geomagnetic Storms

Storm-time depressions in H for individual sudden-commencement geomagnetic storms in respect of each observatory was derived by subtracting from the mean storm-time hourly values the corresponding mean quiet-day values (mean for the IQ days) of the month in which the particular storm occurred. The storm-time hourly differences so obtained were the magnitudes of disturbance, being the total of $D_{st}+DS+Di$.

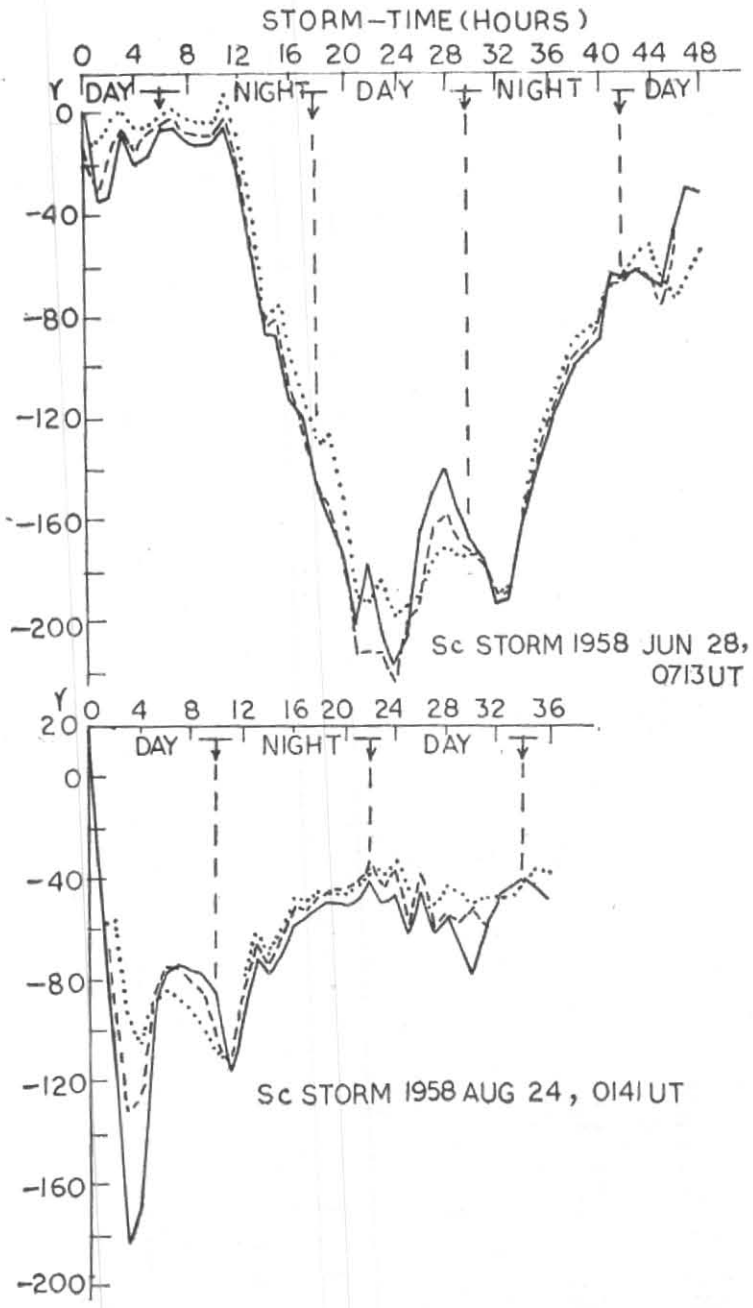

Fig. 2 (a). Storm-time hourly values of H freed from the quiet-day hourly values, for different sudden commencement storms, at Trivandrum, Annamalainagar and Alibag

(Thick continuous line — Trivandrum; Dashed line — Annamalainagar; Dotted line — Alibag)

These hourly disturbance effects for the three observatories are plotted in Figs. 2a, 2b and 2c for some selected storms.

Again a day and night dissimilarity in the magnitudes of geomagnetic disturbance near the magnetic equator is seen. During the night hours the mean hourly depressions in storm-time H are about the same for Trivandrum, Annamalainagar and Alibag. Differences are in evidence only for the day hours. During the day-hours the plotted curves in Figs. 2a, 2b and 2c tend to separate out with the curve for Trivandrum showing greater decrease if H is falling and greater rise if H is rising. This feature is a clear evidence that even

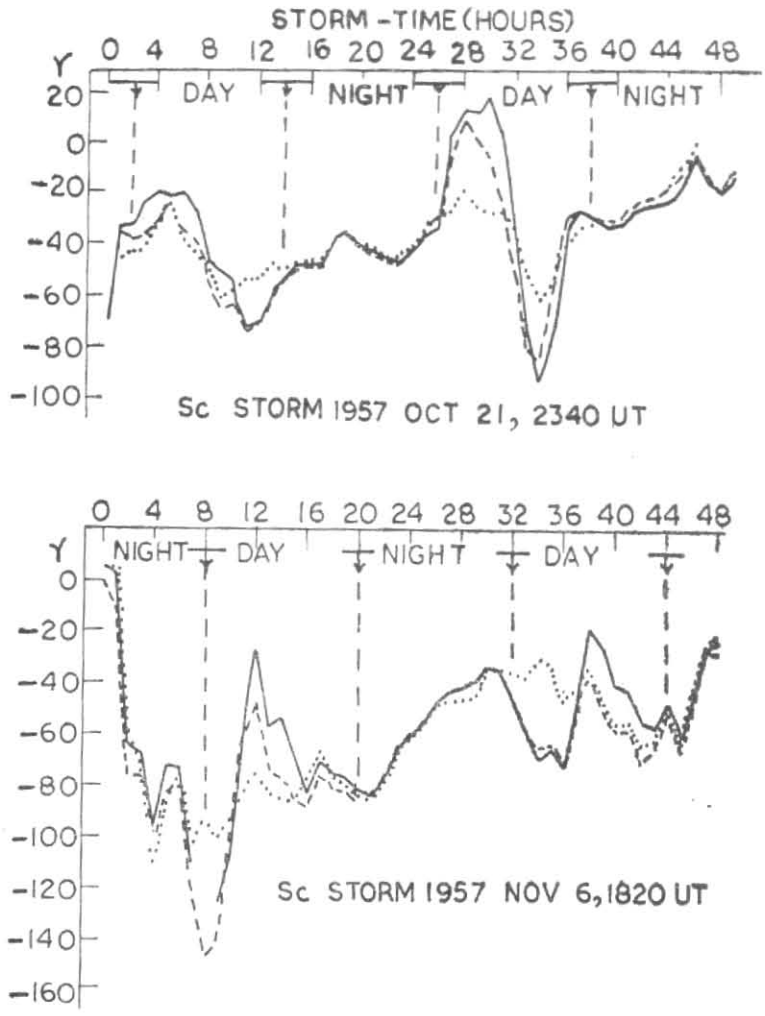

Fig. 2(b). Storm-time hourly values of H freed from the quiet-day hourly values, for different sudden commencement storms, at Trivandrum, Annamalainagar and Alibag

(Thick continuous line — Trivandrum; Dashed line — Annamalainagar; Dotted line — Alibag)

the storm-time mean hourly total disturbance $D_{st}+DS+Di$ is enhanced during the day-time at and near the magnetic equator. But the differences during the day-time from observatory to observatory are small and certainly not comparable with magnitudes of storm depressions in H.

4. Discussion

The foregoing results together with those already reported for short period fluctuations in H (Yacob and Khanna 1964) indicate that magnitudes of geomagnetic disturbance near the magnetic equator are enhanced during the day-time in varying degrees, depending upon the type of disturbance. During the night time the disturbance magnitudes are comparable with those occurring in regions away from the magnetic equator. The day-time enhancements are greatest for the short-period fluctuations in H and are least for the storm-time hourly depressions in H. Since differences in magnitudes of geomagnetic disturbance (during the day-time) are noticed at stations of such lateral separation as between Alibag on one hand and Trivandrum and Annamalainagar on the other, it is to be expected that the source responsible for these differences must be at heights less than the lateral separation of the stations. They must be due, at least partly, to ionospheric electric currents.

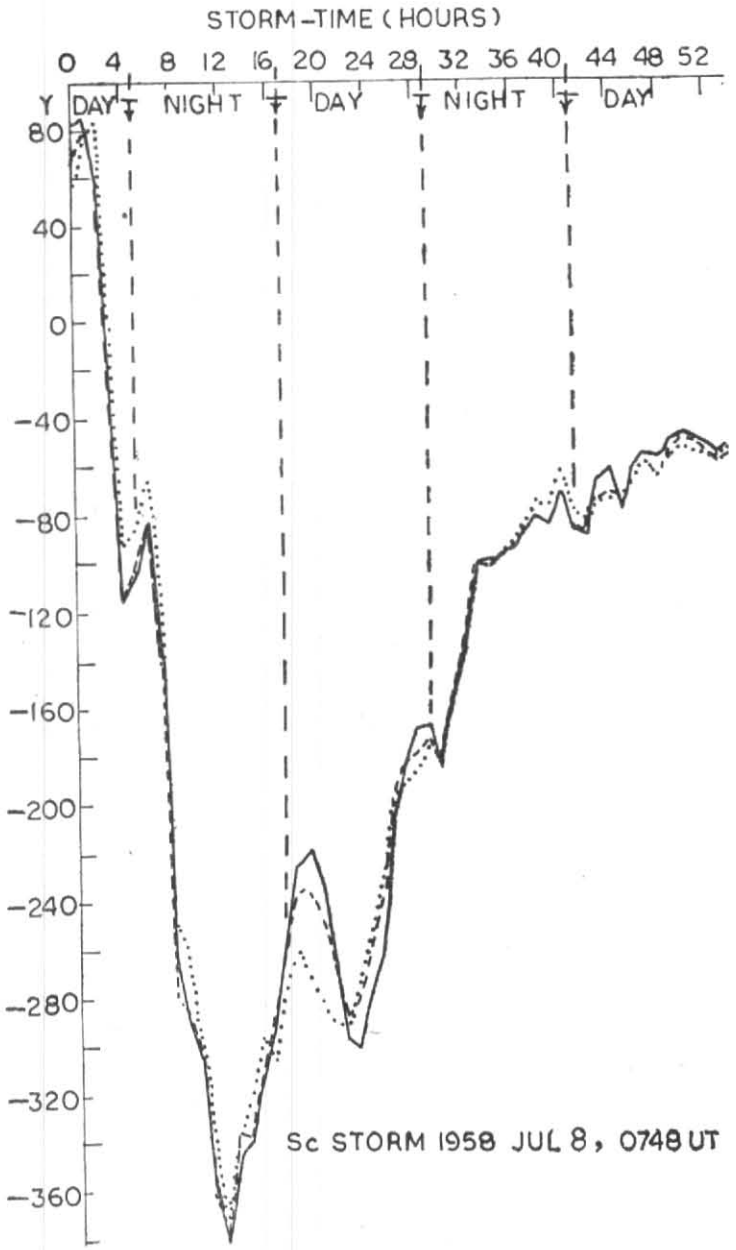

Fig. 2(c). Storm-time hourly values of H freed from the quiet-day hourly values, for a sudden commencement storm, at Trivandrum, Annamalainagar and Alibag

(Thick continuous line — Trivandrum; Dashed line — Annamalainagar, Dotted line — Alibag)

The mechanism, by which the ionospheric electric currents (presumably in the E-layer) responsible for geomagnetic disturbances are enhanced during the day-time near the magnetic equator, must be the same as that postulated for the Sq current enhancements, namely, the increased effective ionospheric conductivity at and near the magnetic equator, arising from the inhibition of vertical Hall currents in the E-layer of the ionosphere. The fact that geomagnetic disturbances are not enhanced at the magnetic equator during the night-time shows that during the night no inhibition of Hall currents occur presumably because of the absence of sharp layer formation and fall in conductivity of the relevant ionospheric region. Vestine (1963), however, postulates an

TABLE 1

Station		24-hour component	12-hour component	8-hour component	6-hour component
Alibag	Amplitude (γ)	10·7	4·0	0·8	0·4
	Phase (°)	139·2	120·3	308·9	72·6
	Time of (first) maximum depression	20h 43m	10h 59m	2h 08m	0h 17m
Annantalainagar	Amplitude (γ)	9·7	6·0	2·1	1·0
	Phase (°)	149·6	123·5	330·3	160·1
	Time of (first) maximum depression	20h 02m	10h 53m	2h 40m	4h 50m
Trivandrum	Amplitude (γ)	8·2	8·1	2·9	1·0
	Phase (°)	150·8	126·7	331·9	166·2
	Time of (first) maximum depression	19h 21m	10h 47m	2h 38m	4h 44m

additional ring current at a small equatorial distance from the surface of the earth in order to account for the differences in $SD(H)$ magnitudes noticed by him for the geomagnetic equatorial region and for regions of higher latitudes. If this could be the explanation the night and day dissimilarity, as seen in the present contribution should not occur, unless an appropriate eccentricity is also envisaged for the postulated auxiliary ring current. The day-time enhancements of geomagnetic disturbance near the magnetic equator do appear to be electric-current effects in the ionosphere.

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