

Equatorial enhancement of geomagnetic field in the Indian Region

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ABSTRACT. Equatorial enhancement of the geomagnetic field in the Indian region for different phenomena is examined. The enhancement in H is found to be nearly of the same magnitude as for the S_q ranges in H , indicating that the immediate source of the phenomena that get enhanced is located in the same region of the ionosphere as the S_q currents.

1. Introduction

Enhancement of the quiet-day magnetic variation, S_q and the Sudden Commencement (SC) amplitude during the daylight hours in the horizontal component, H , of the geomagnetic field in the equatorial region is well established (Sugiura 1953; Vestine 1953; Forbush and Vestine 1955; Matsushita 1960; and Maeda and Yamamoto 1960). In the Indian region, Sivaramakrishnan (1956) and Srinivasamurthy (1960) observed daytime enhancement of SC amplitude in H at Kodaikanal, an equatorial observatory, compared to that at Alibag. Jacob and Khanna (1964) found equatorial enhancement in the magnitude of short period (≈ 10 min) fluctuations in H during the daylight hours. The magnitude of the enhancement was found to be larger in the American region as compared to the Indian region by Rastogi *et al.* (1964).

Equatorial enhancement of some features of the geomagnetic field in the Indian region is examined here, using the data during the period 1958–1967 from the four Indian observatories, Alibag, Annamalainagar, Kodaikanal and Trivandrum with magnetic dip angles $24^\circ.5$, $5^\circ.4$, $3^\circ.6$ and $-0^\circ.8$ respectively.

2. Sudden-commencement amplitudes in H and Z

Sudden commencement (SC) amplitudes for 106 events in H and 90 in Z are considered. For each event, the ratios of the amplitudes at the three-equatorial observatories to the corresponding amplitudes at Alibag are computed and the diurnal distribution of these ratios in bihourly intervals centred at even hours of 75° Eastern Meridian Time (5 hours ahead of GMT) is formed. Mean ratios for each of the intervals are calculated and presented in Fig. 1 for H and Fig. 2 for Z .

The curves of Fig. 1 resemble similar curve for Huancayo by Sugiura (1953). For Huancayo, the

enhancement around noon is 5 to 6 times, whereas in the Indian equatorial region it is about 2 to 3 times. This difference was considered to be associated with the difference in the strength of the electrojet currents in the two regions (Rastogi *et al.* 1964). Kodaikanal and Trivandrum, which are closer to the dip equator, show greater enhancement than Annamalainagar only for a few hours around noon as noted by Bhargava (1967). The mean SC amplitudes in H at Annamalainagar continue to be larger than those at Alibag even around midnight, whereas they are diminished at the other two observatories, also observed by Gupta (1967) and Trivedi and Rastogi (1968).

SC amplitudes in Z are generally negative and smallest in size at Alibag and are positive at the three equatorial observatories. Trivandrum records higher amplitudes between 06 and 16 hr, with maximum around 10 hr of about $2\frac{1}{2}$ times the night value, simulating the quiet-day diurnal variation curve for Z . For the ratios in Z (Fig. 2) the main maximum is around 18 hr with another maximum around 10 hr, which is the more prominent one in the case of Trivandrum.

Ratios of the mean SC amplitudes in Z to those in H over the bi-hourly intervals are presented in Fig. 3. The graphs for the three equatorial observatories are almost similar, except for the peak around 10 hr for Trivandrum. They appear to be the result of a semidiurnal wave superposed on a diurnal wave. At Alibag, the ratio, which is negative in sign, attains a maximum around noon when it is the minimum for the equatorial observatories.

3. D_{st} in H and Z

D_{st} values in H and Z for 76 sudden commencement storms are computed. The ratios of the bi-hourly mean values at the equatorial observatories to those at Alibag are calculated. The ratios

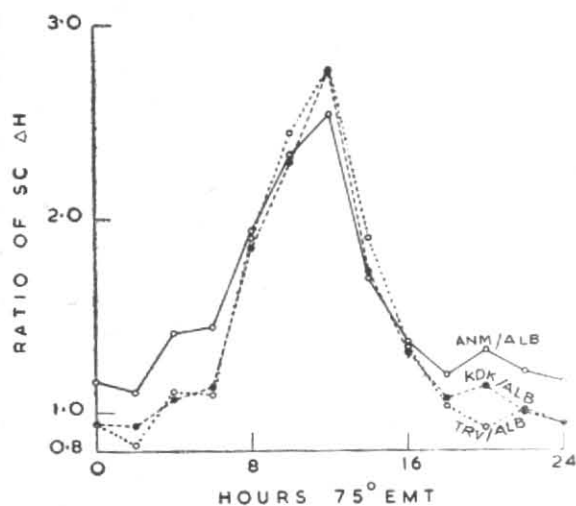


Fig. 1

No. of SC's considered : 106

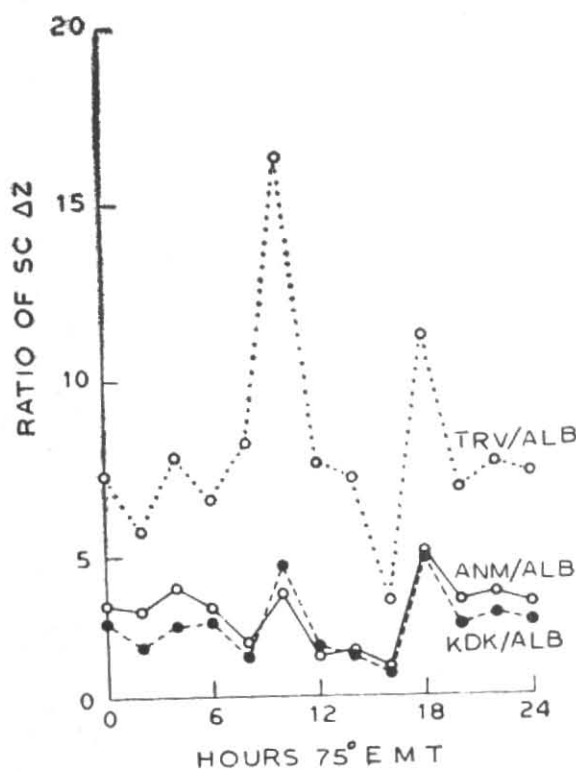
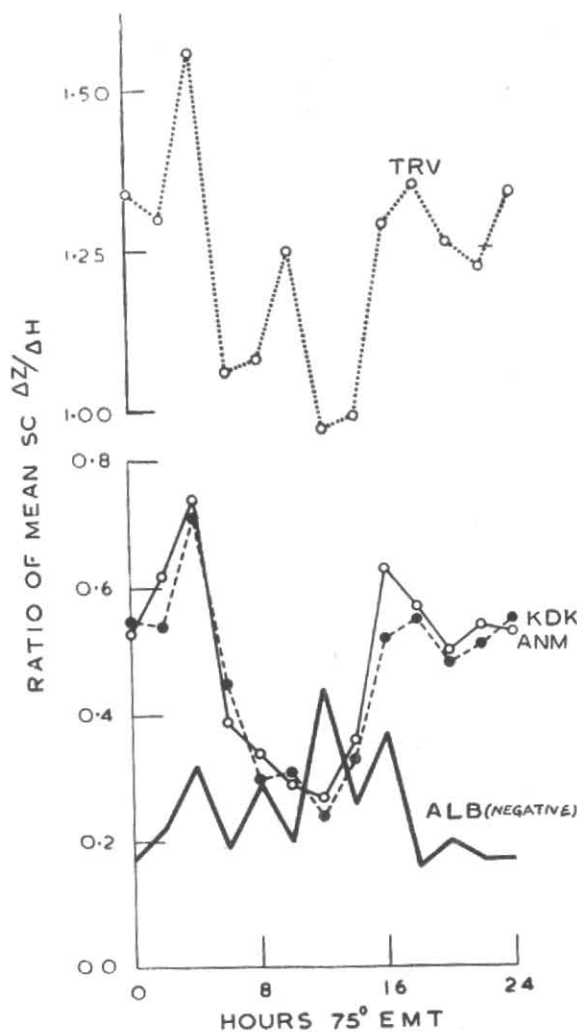


Fig. 2

No. of SC's considered : 90

Bi-hourly mean ratios of SC sizes in H (Fig. 1) and Z (Fig. 2) at the equatorial observatories to those at Alibag during 1958-1967

Fig. 3. Ratios of Bi-hourly mean SC sizes in Z to those in H at each of the observatories during 1958-1966

ALB—Alibag ANM—Annamalainagar
KDK—Kodaikanal TRV—Trivandrum

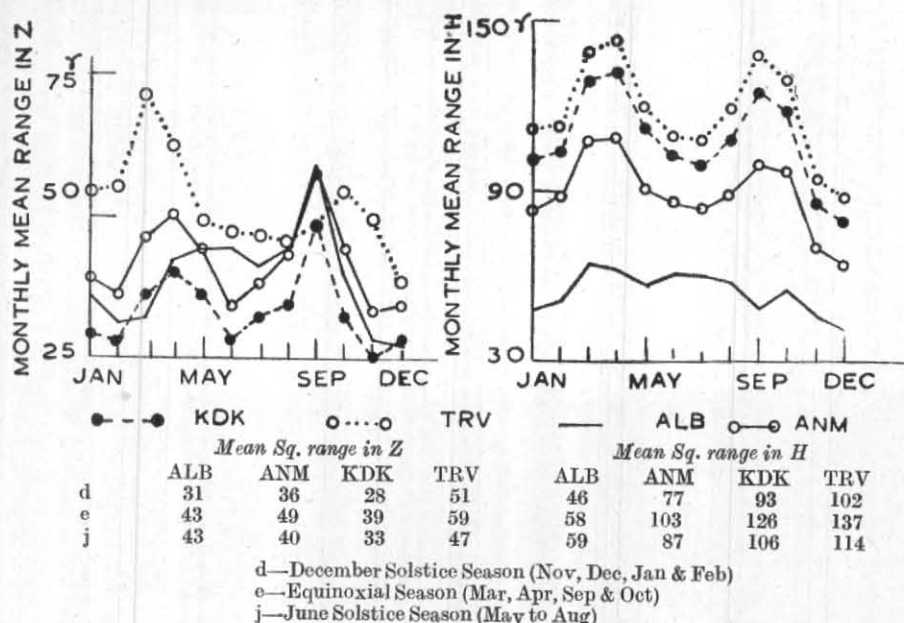


Fig. 4. Mean monthly ranges in H and Z during 1958-1966 for the International Quiet Days

for H gradually attain a maximum of about 1.3 around 10 hr, but fluctuate erratically thereafter. The ratios for Z are higher between 07 hr and 13 hr and again around 20 hr. As for the ratios of the mean D_{st} values in Z to those in H , the highest are for Trivandrum and the lowest for Alibag, being about 0.8 and 0.1 respectively. Ratios for Kodai-kanal and Annamalainagar are about 0.3.

3. Single impulses and bays

About 30 single impulses in H , generally of duration of about 10 min, during disturbed periods and about 40 days in H are examined in Alibag, Annamalainagar and Trivandrum magnetograms. The amplitudes of the impulses at the equatorial observatories, show considerable enhancement compared to those at Alibag, attaining a maximum of about 3 to 4 times around 10 hr, comparable in magnitude to similar ratios obtained by Yacob and Khanna (1964).

The bays considered show no equatorial enhancement; in fact, the bay amplitudes for Trivandrum are in all cases smaller than the corresponding amplitudes for Alibag, which was also observed by Gupta (1967). Bays appear with greater frequency around midnight.

5. Large period (1-2 hr) pulsations and solar flare effects

Ten large period pulsations and a few solar flare effects recorded at the three observatories, Alibag, Annamalainagar and Trivandrum are considered. Large period pulsations show equatorial enhancement of amplitude of about 3 to 4 times around

noon in comparison to Alibag, whereas solar flare effects (s.f.e.) showed lesser enhancement of about 2 to 3 times.

6. Quiet-day ranges in H and Z

The daily range is considered here as the difference between the instantaneous maximum and minimum attained during the international quiet Greenwich day. Mean monthly ratios over the period 1958-66 are calculated for the three equatorial observatories and are presented in Fig. 5 for H and in Fig. 6 for Z . Ratios of mean monthly ranges in Z to the corresponding ranges in H for each of the four observatories are obtained and are presented in Fig. 7. Mean monthly ranges for the period 1958-66, in H and Z are presented in Fig. 4.

Quiet-day ranges in H (Fig. 4) show maxima in the equinoxial months uniformly at all the three equatorial observatories. Ranges from May to August are low with maximum in July. But at Alibag the ranges from June to August are also high indicating a summer maximum as observed by Chapman and Raja Rao (1965); but the range for September is low. Consequently the equatorial enhancement of the range in comparison to Alibag range for September is the highest (Fig. 5). The March-April maxima are higher than September-October maxima for the equatorial observatories. The range in winter months is the lowest at all the four observatories. It is generally accepted that equatorial electrojet currents are much stronger at equinoxes than in other seasons (Hutton 1967).

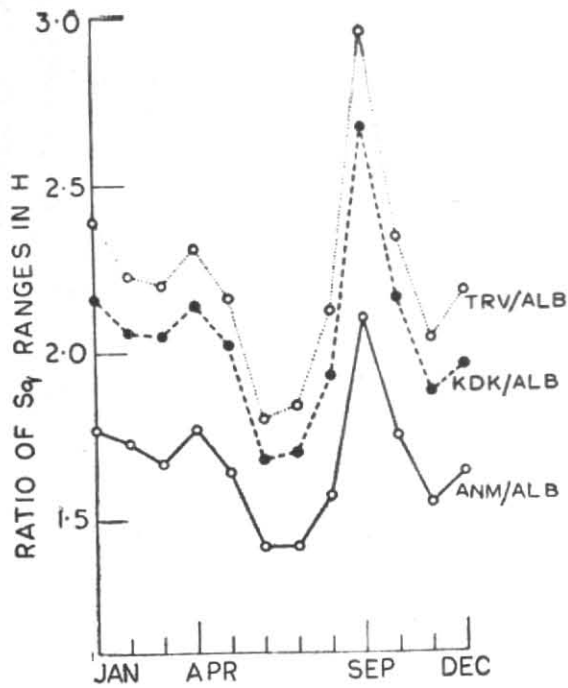


Fig. 5

ALB—Alibag ANM—Annamalainagar
 KDK—Kodaikana] TRV—Trivandrum

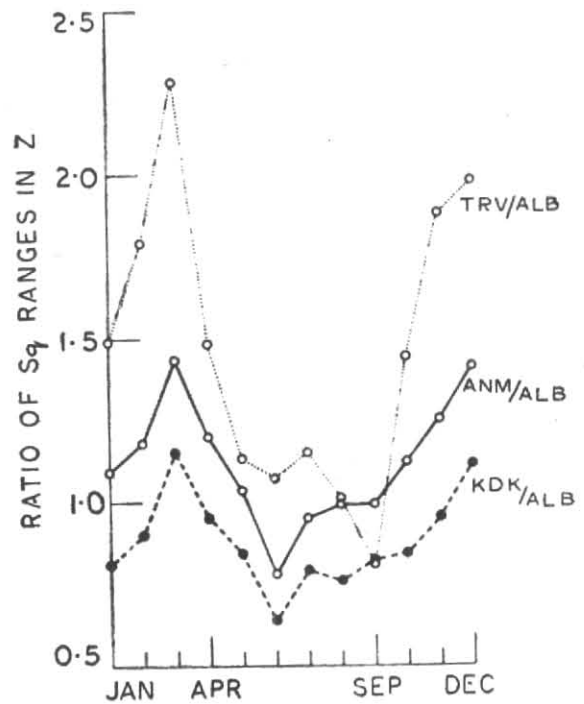


Fig. 6

Ratios of mean monthly ranges in *H* (Fig. 5) and *Z* (Fig. 6) at the equatorial observatories to those at Alibag for the International Quiet Days during 1958-1966

TABLE 1

Mean maximum enhancement in H at the equatorial observatories in comparison to Alibag

Phenomenon	ANM/ALB	KDK/ALB	TRV/ALB
S_q ranges	2.1	2.7	2.9
SC amplitudes	2.5	2.8	2.8
Solar flare effects	2.8	—	2.9
Single impulses	3.2	—	4.0
Large period pulsations	3.4	—	4.3

ALB—Alibag, ANM—Annamalainagar
KDK—Kodaikanal TRV—Trivandrum

Quiet-day ranges in Z also show equinoxial maxima at the equatorial observatories (Fig. 4). It is noteworthy from Fig. 7 that ratio of Z range to H range is lowest at Trivandrum and highest at the other three observatories for September.

SC amplitudes in H in July are larger in magnitude at all the observatories, as has been noted earlier in case of Alibag (Sastri and Jayakar 1969). The enhancement in the seasons is almost equal at Trivandrum and Kodaikanal and a little higher at Annamalainagar. Slightly higher enhancement is seen in the equinoxial season. SC amplitudes in Z are also the largest in July; otherwise there is very little seasonal variation.

Practically no equatorial enhancement is observed in D_{st} in H in the seasons. D_{st} values in Z show higher enhancement in summer months at all the three observatories, the highest in any season being at Trivandrum.

The daily means of H for the period 1958-1960 are arranged in groups of 27 consecutive days and the 27-day variation is calculated about the mean for the period for each of the four observatories. There does not appear to be any equatorial enhancement.

Mean quiet-day (Greenwich day) non-cyclic variation in H for the period 1958-1961 for which each month is computed for each of the four observatories. The values do not show any equatorial enhancement.

Mean maximum enhancements in H in comparison to Alibag are given for different phenomena in Table 1.

The maximum enhancements of the quiet-day ranges in H are comparable to similar value for Kodaikanal of about 2.5 obtained by Sivarama-

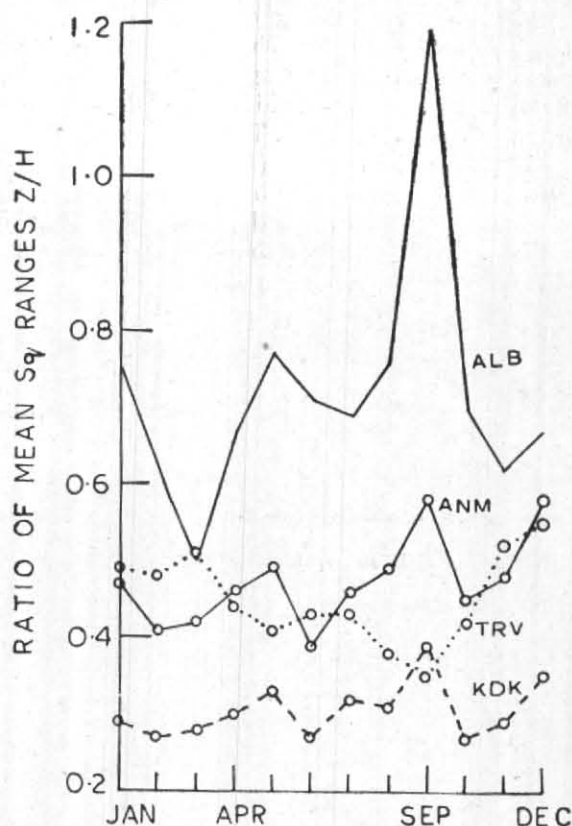


Fig. 7. Ratios of mean monthly ranges in Z to those in H at each of the observatories during 1958-1966

krishnan (1956). The values for solar flare effects and SC amplitudes in H are comparable in magnitude to the values for quiet-day ranges in H (Table 1), which indicates that the immediate source of enhancement of these phenomena is likely to be situated in the same regions of the ionosphere as the S_q current system. Volland and Taubenheim (1958) earlier suggested that s.f.e. currents might flow in D and E layers of the ionosphere in equal proportion. Raja Rao and Rao (1963) argued that s.f.e. current system was an enhancement of the normal S_q current system. But Rastogi *et al.* (1965) concluded that the current system for solar flare crochets and SCs appeared to be qualitatively similar but located at different altitudes, the one for crochets being lower. The SC is believed to result from a compression of the magnetosphere by an enhanced solar wind, propagating to the earth as a hydromagnetic wave, which is damped down below 1000 km altitude, exerting pressure on the lower regions. Thus the ionosphere is compressed in the equatorial region and eastward electric currents flow, probably at about 100 km altitude (Matsushita 1962).

Single impulses during disturbed periods and large period pulsations show higher maximum enhancements than S_q ranges. However, this difference may not be considered significant as the events considered are few. The large period pulsations have been considered (Parker 1967) as oscillations in the magnetic field brought about by variations in the mean level of the solar wind. Sudden impulses are considered to result by the same process as SCs (Matsushita 1962).

The D_{st} field, resulting from the westward ring currents at a distance of a few earth radii from the ground, is expected to show no enhancement. The ratios for D_{st} in H show practically no enhancement.

7. Acknowledgement

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REFERENCES

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| Bhargava, B. N. | 1967 | <i>Indian J. Met. Geophys.</i> , 18 , p. 267. |
| Chapman, S. and Raja Rao, K. S. | 1965 | <i>J. atmos. terr. Phys.</i> , 27 , p. 559. |
| Forbush, S. E. and Vestine, E. H. | 1955 | <i>J. geophys. Res.</i> , 60 , p. 299. |
| Gupta, B. R. D. | 1967 | <i>Indian J. Met. Geophys.</i> , 18 , p. 531. |
| Hutton, R. | 1967 | <i>J. atmos. terr. Phys.</i> , 29 , p. 1411. |
| Maeda, H. and Yamamoto, M. | 1960 | <i>J. geophys. Res.</i> , 65 , p. 2538. |
| Matsushita, S. | 1960 | <i>Ibid.</i> , 65 , p. 1423. |
| | 1962 | <i>Ibid.</i> , 67 , p. 3753. |
| Parker, E. N. | 1967 | <i>Physics of the Geomagnetic Phenomena</i> , Vol. II, Academic Press, New York & London. |
| Raja Rao, K. S. and Panduranga Rao, M. | 1963 | <i>J. atmos. Sci.</i> , 20 , p. 498. |
| Rastogi, R. G., Trivedi, N. B. and Kaushika, N. D. | 1964 | <i>J. atmos. terr. Phys.</i> , 26 , p. 131. |
| Rastogi, R. G., Kaushika, N. D. and Trivedi, N. B. | 1965 | <i>Ibid.</i> , 27 , p. 663. |
| Sastri, N. S. and Jayakar, R. W. | 1969 | <i>Indian J. Met. Geophys.</i> , 20 , p. 129. |
| Sivaramakrishnan, M. V. | 1956 | <i>Ibid.</i> , 7 , p. 137. |
| Srinivasamurthy, B. | 1960 | <i>Ibid.</i> , 11 , p. 64. |
| Sugiura, M. | 1953 | <i>J. geophys. Res.</i> , 58 , p. 558. |
| Trivedi, N. B. and Rastogi, R. G. | 1968 | <i>Ann. Geophys.</i> , 24 , p. 1037. |
| Vestine, E. H. | 1953 | <i>J. geophys. Res.</i> , 58 , p. 560. |
| Volland, H. and Taubenheim, J. | 1958 | <i>J. atmos. terr. Phys.</i> , 12 , p. 258. |
| Yacob, A. and Khanna, K. B. | 1964 | <i>Indian J. Met. Geophys.</i> , 15 , p. 83. |