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Magnetospheric Contribution to Low Latitude *Sq* Variation

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Non-regular features noticed in the quiet-time diurnal variation of H component on 11 December, 1990 ($A_p = 2$) and 12 December, 1990 ($A_p = 7$) in comparison with the average quiet day variations at a chain of equatorial, low and mid-latitude locations in the Indian longitude zone are studied. Stations away from the equatorial electrojet influence exhibited a minimum in the H field around 1600 LT followed by a secondary peak at 2100 LT. The globally observed anomalously enhanced variation in the "H" component at low and mid latitude is attributed to the effect of field aligned current driven by the magnetospheric plasma convection even during relatively quiet intervals. Causative mechanism to offset this peculiar feature, at equatorial locations is also discussed.

1. Introduction

Daily variation in the magnetic field at the earth's surface during geomagnetic quiet periods, *Sq*, is known to be associated with the dynamo currents driven by winds and tidal motions in the *E*-region of the ionosphere. Active and complicated changes in the day-to day horizontal magnetic field have been explained in relation to changes in the winds at the ionospheric heights (Hasegawa, 1960). Contributions to the daily variations from the solar wind associated components under quiet magnetic conditions have been dealt in by Mead (1964), Sarabhai and Nair (1969), Olson (1970) and Bhargava and Yacob (1971). Fukushima and Kamide (1973a) proposed the role of field aligned currents associated with the magnetospheric plasma convection, in modifying the *Sq* field. The extent to which the high and low latitude ionosphere are interlinked electromagnetically during periods of quiet magnetic conditions is a point of debate. The unique configuration of the ionosphere over the equatorial region can contribute significantly in judging the nature of the effect. In this communication, the effects of electric field influence on the geomagnetic field variations at locations ranging from the equator to 60° dip latitude in the Indo-Russian longitude are discussed.

2. Analysis and Results

Tables 1(a) and 1(b) list the geographic and geomagnetic coordinates of the observatories used in the study. Figure 1 depicts the average quiet-time diurnal variation of H and D components for the month of December 1990. Parameters ΔH and ΔD indicate the departures of the horizontal and declination components of the magnetic field at a particular local hour from their fields at midnight. Referring to the curves of ΔH, *Sq* (H) started building up from 0600 LT, corresponding to the enhancement in the conductivity in the E layer by sunrise and ΔH reached its maximum at about 1200 LT. After that H continued to decrease reaching the minimum around 1800 LT. The pronounced noon-time enhancement in ΔH over the equatorial locations, Trivandrum (TRD), Kodaikanal (KOD) and Annamalainagar (ANN) is the effect of the intense eastward electrojet current flowing during the daytime hours. Systematic decrease in the noon enhancement with increasing latitude is seen upto the latitude of Sabhawala (SAB). Noon-time phase reversal of ΔH at Alma-Ata (AAA) is suggestive of the pattern of variation common at location north of the *Sq* focus latitude due to the westward directed component of the *Sq* current.

Examination of the individual quiet ($A_p \leq 7$ days) days in the same month (December 1990) revealed

Table 1(a).

Stations	Code	Geographic Latitude N	Geographic Longitude E	Geomagnetic Latitude	Geomagnetic Longitude	Dip latitude Deg. N
Trivandrum	TRD	8°29′	76°57′	0°.88S	148°.24	0.2
Kodaikanal	KOD	10°14′	77°28′	0°.60N	148°.93	2.3
Annamalainagar	ANN	11°22′	79°41′	1°.77N	151°.20	3.4
Hyderabad	HYB	17°25′	78°33′	7°.86N	150°.69	11.2
Alibag	ABG	18°38′	72°52′	9°.64N	145°.39	13.2
Ujjain	UJJ	23°11′	75°47′	13°.50N	147°.00	18.1
Shillong	SHL	25°55′	91°53′	14°.99N	163°.95	20.0
Jaipur	JAI	26°55′	75°48′	17°.30N	147°.40	23.0
Sabhawala	SAB	30°22′	77°48′	20°.78N	151°.34	27.0
Gulmarg	GUL	34°05′	74°24′	24°.50N	147°.20	30.8
Alma-ata	AAA	43°15′	76°55′	33°.69N	152°.21	43.4
Novosibirsk	NVK	54°31′	83°09′	45°.04N	159°.18	58.6

Table 1(b).

Stations	Code	Geographic Latitude N	Geographic Longitude E	Geomagnetic Latitude	Geomagnetic Longitude	Dip latitude Deg. N
Kanoya	KNY	31°24′	130°54′	21°.25N	200°.07	25.9
Kakioka	KAK	36°12′	140°12′	26°.74N	208°.01	30.3
Memambetsu	MMB	43°54′	144°12′	34°.76N	210°.46	38.1
Baclieu	BCL	09°17′	105°43′	01°.57S	176°.87	01.1
Hanoi	HAN	21°00′	105°50′	10°.14N	177°.10	15.2
Chapa	CPA	22°20′	103°50′	11°.50N	175°.22	16.8

certain peculiar characteristics. In Figs. 2 and 3 are shown the diurnal variations of ΔH and ΔD for the two days, 11 December 1990 ($A_p = 2$) and 12 December 1990 ($A_p = 7$) respectively. Three hourly K_p values representing the level of the geomagnetic activity are also marked on the time axis in their respective local time intervals to mark the geomagnetic condition of the day. Referring to the curves of ΔH on 11 December 1990, increase in the H component.from 0600 LT is seen with the onset of sunrise and building up sufficiently enhanced field by noon at low latitudes. Thereafter, a gradual reduction in the field is noticeable with the evening minimum occurring at 1800 LT, this unexpectedly, is followed by an enhancement in the horizontal component at late evening hours. The secondary northward field is seen to maximise around 2100 LT at locations ranging from the low latitude station, Hyderabad (HYB) (dip lat. 11.2°N) upto the high latitude station, Novosibirsk (NVK) (dip lat. 58.6°N). ΔD curves on the same day (11 December 1990) show the expected pattern of an eastward directed field (positive variation) in the pre-noon hours and a westward directed field (negative variation) in the afternoon, the increase in both the eastward and westward directed field strengths becoming larger with increase in latitude.

Figure 3 represents the diurnal variations of ΔH and ΔD for 12 December 1990 ($A_p = 7$), the day with an abnormal evening anomaly in the H component. Very low K_p values at most of the intervals suggest the quiet nature of the day, except the interval 2100–2400 LT. Considering the variation in ΔH, prominent northward field at low and mid latitude stations during the prenoon hours and rapid reduction in the field is evident making the evening minimum at about 1600 LT at all non equatorial locations.

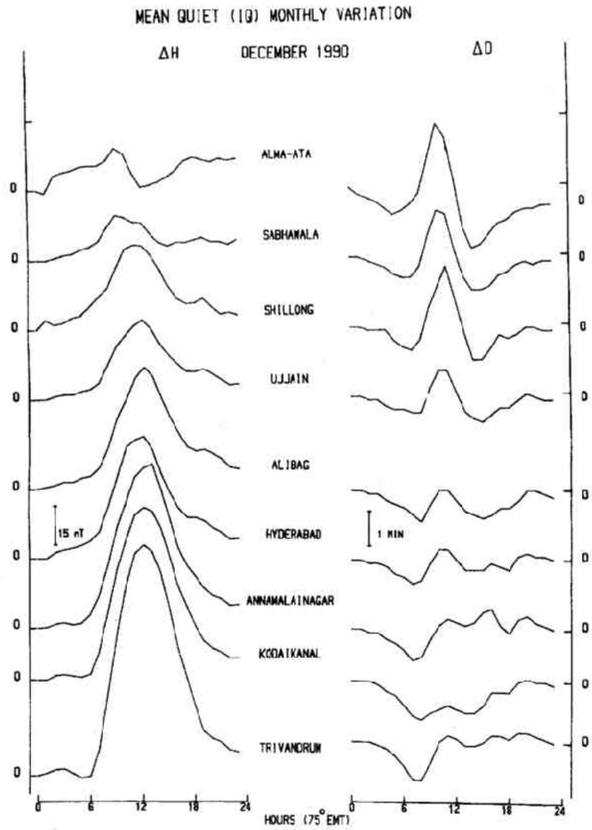

Fig. 1. Average quiet day variations of ΔH and ΔD for December Solstice in the Indian longitude.

It is worth mentioning the observation that in contrast to the sharp gradient seen in the noon-time H component of the field away from the dip latitude of $\simeq 11°$, equatorial stations (TRD, KOD and ANN) experienced a gradual reduction in the horizontal component indicating the persistance of a pronounced eastward current till late evening. Following the depression in the evening hours, low and mid latitude locations show significant and systematic enhancement in the H component with the maximum occurring at 2100 LT, whereas the prominence of this feature is not observed at the equatorial stations. It is obvious from the pattern of variations at TRD, KOD and ANN that the causative mechanism influencing the equatorial latitudes differ significantly from that of the higher latitudes even during night hours when the cowling conductivity effects are supposed to be absent.

Latitudinal characteristics of the rate of change of the horizontal component from 1600 LT to 2000 LT period for the two days considered (11 and 12 December 1990) are presented in Fig. 4. On the X-axis are marked the latitude locations and the ordinate shows the range of ΔH (ΔH at 2000 LT minus ΔH at 1600 LT) for the two days. Negative deviations observed at TRD, KOD and ANN are pronounced features seen on both the days, whereas, the low and mid-latitude deviations have perceptably large positive ranges. Systematic increase in the rate of change in the horizontal component is evident with latitude, maximising around mid latitude regions. Significantly enhanced range is seen at latitudes above 12° on 12 December 1990, depicting the anomalous behaviour of the day very clearly.

In order to elucidate the longitudinal characteristics of the anomalous pattern observed, in Fig. 5 are plotted the diurnal variations of ΔH, for 12 December and 11 December 1990 at the three latitude locations Kanoya (Dip lat. = 25.9°), Kakioka (Dip lat = 30.3°) and Memambetsu (Dip lat = 38.1°). Geographic and

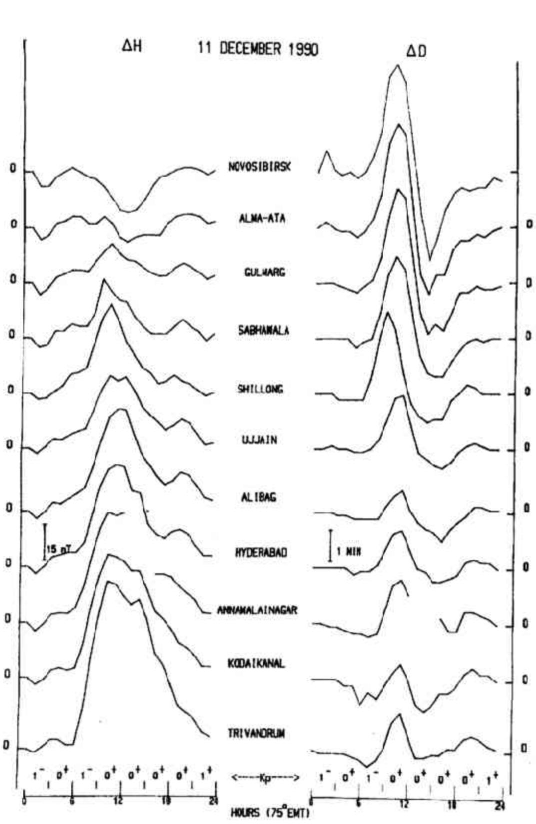

Fig. 2.

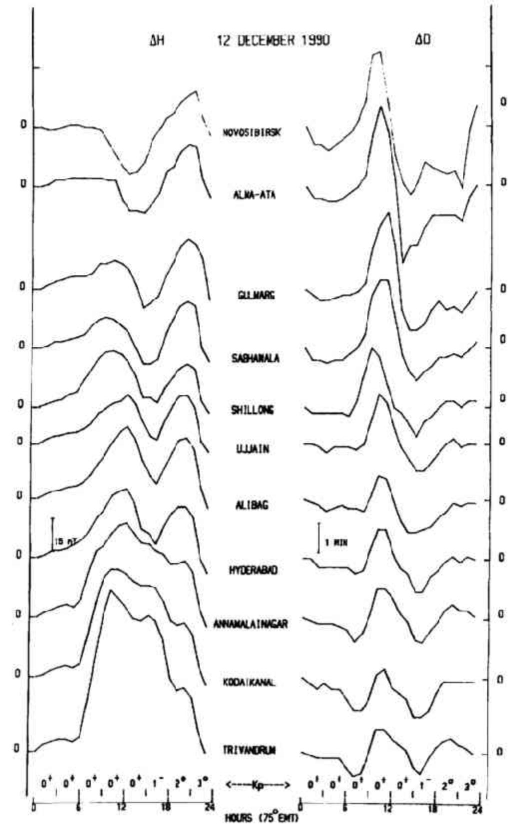

Fig. 3.

Fig. 2. Diurnal variations of ΔH and ΔD at 11 locations in the Indo-Russian longitude chain for 11 December 1990.

Fig. 3. Diurnal curves of ΔH and ΔD at 11 locations in the Indo-Russian longitude belt for 12 December, 1990. Evening anomaly in ΔH is prominent.

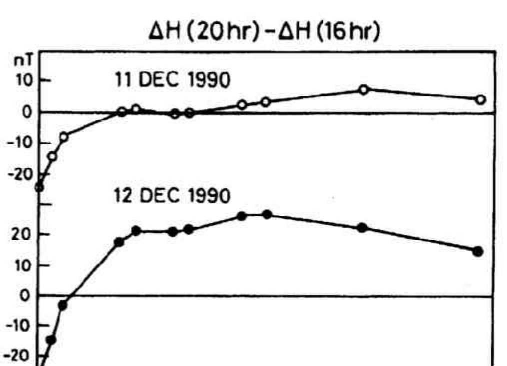

Fig. 4. Latitudinal profiles of the time derivative, ΔH (2000 LT) minus ΔH (1600 LT), of ΔH for the two days 11 December and 12 December, 1990. Negative deviations in ΔH at the equatorial stations visible from both curves.

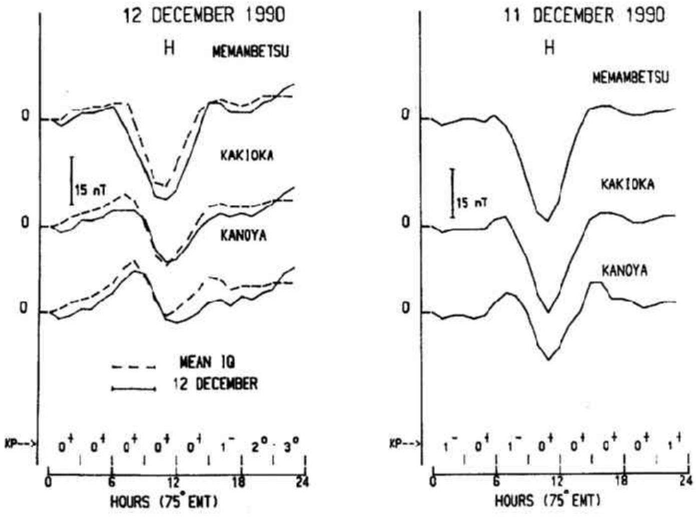

Fig. 5. Diurnal variations of ΔH on 11 December 1990 and 12 December 1990, at three midlatitude locations in the Japanese longitude. Superposed dashed curves indicate the average monthly IQ pattern for the respective stations.

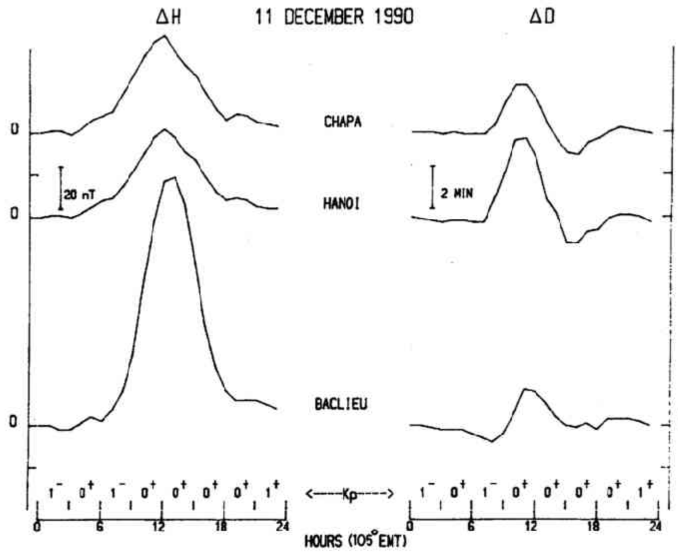

Fig. 6. Diurnal variations of ΔH and ΔD at the three Vietnam stations, Baclieu (equatorial), Hanoi and Chapa (low-latitude), for 11 December, 1990.

geomagnetic co-ordinates of the stations are given in Table 1(b). Mean monthly variation curves of ΔH for the month of December 1990 are also given for comparison. Pronounced southward field in the noon hour is an indication of the diurnal behaviour of ΔH at locations north of the focal latitude. ΔH curves of 12 December at all the three stations match very well with the mean IQ pattern.

In Figs. 6 and 7 are shown the variations of ΔH and D for the two days at three locations Baclieu (Dip lat. 1.1°N), Hanoi (Dip lat. = 15.2°N) and Chapa (Dip lat. = 16.8°N) in Vietnam longitude. Equatorial station Baclieu has the enhanced noon-time field in the horizontal component, depicting the daytime feature of the equatorial electrojet influence. The low latitudes Hanoi and Chapa show reduced daytime

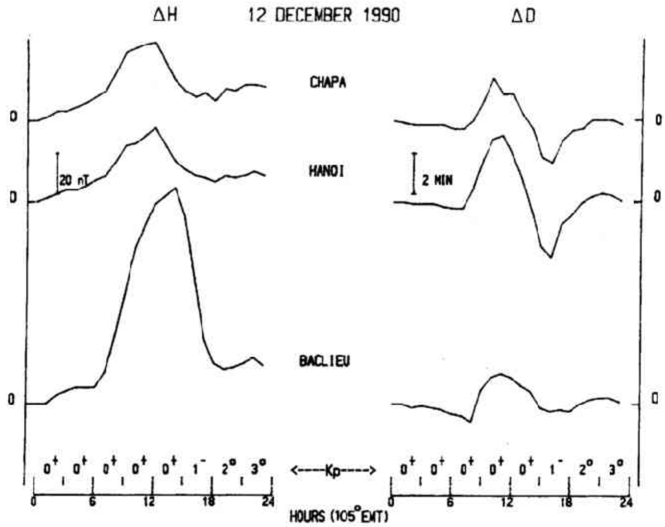

Fig. 7. Diurnal variations of ΔH and ΔD at the three Vietnam stations, Baclieu (equatorial), Hanoi and Chapa (low latitudes), for 12 December, 1990.

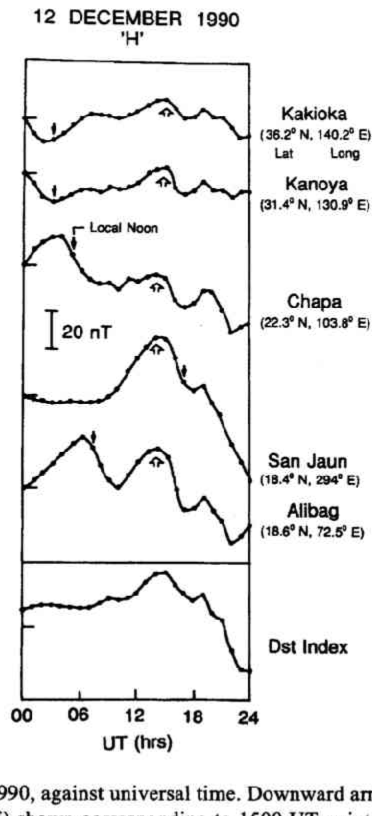

Fig. 8. Variation of H on 12 December 1990, against universal time. Downward arrows (↓) marked on the curves indicate the local noon and the upward arrows (⇑) shown corresponding to 1500 UT point on each curve signify the intensity of the anomaly at various longitudes.

variation. Local time variations at these low latitude locations do not exhibit any pronounced anomaly pattern as was observed in the Indo-Russian chain. In a view to ascertain the anomalous evening pattern on 12th Dec. through the influence of the magnetospheric contribution, representation of the universal time variation for 12th December at various longitude regions are shown in Fig. 8. Geographic latitude and longitude of the stations are also indicated with the curve. Pronounced northward field at 1500 UT is a common feature at all the longitudes, the varying magnitude of the effect is apparent. The peaked value of curve of the variation in D_{st} index observed at 15–16 UT ($K_p = 2$) matches with the enhanced variation in ΔH observed at the low and mid latitude locations at all the longitudes. The D_{st} index shown in the lowermost block of the curve suggests the global characteristic of the enhanced contribution to the northward field from the low and middle latitudes around 1500 UT.

3. Discussions

Existence of large scale electric fields contribute significantly in the acceleration and injection of charged particles in the magnetosphere (Axford, 1969; Fukushima and Kamide, 1973b). According to Fukushima and Kamide (1973a), for geomagnetic bays or longitudinal asymmetry of ΔH during magnetic storms, the contribution from the field-aligned current is greater than that of partial ring current. Butcher and Brown (1981) examined the variation of Sq (H) on abnormal quiet days characterised by certain distinct pattern of the times of the minimum in H at stations poleward of the Sq focus and southward of the focus. The present result viz., the observed intensification of the horizontal field during pre-midnight hours at low and mid latitudes on the day 12 December (Fig. 3) even prior to the onset of any disturbance when K_p value is still as low as 2^0 cannot be considered as the abnormal quiet day in the definition of Butcher and Brown (1981, and references therein). This feature signifies the contribution to the Sq field from the field aligned current. A quantitative study of the Sq (H) variations at low latitude stations by Rastogi and Iyer (1976) showed that during high sunspot years Sq (H) at equatorial and low latitude stations continued to decrease smoothly after sunset until about midnight. Takeda and Araki (1985) examined the geomagnetic field in the nighttime without the effect of ring current. They observed that SdI $\{SdI = H(\text{GUAM}) - [H(\text{KAKIOKA}) - Sq(\text{KAKIOKA})] \sec\theta_1 \cos\theta_2$ where θ_1 and θ_2 are the geomagnetic latitudes of Kakioka (26.5°N) and Guam (14.4°N)$\}$ at low latitude station Guam (Dip lat. 6.3°N) showed a depression during night and inferred the existence of prominent nighttime ionospheric currents at the sunspot maximum.

Gonzales *et al.* (1979) and Fejer (1986) provided evidence of the close coupling of the high latitude and equatorial ionosphere, especially during disturbed conditions due to the penetration to the dip equator of the auroral current system or magnetospheric convection. Araki *et al.* (1985) observed that the preliminary impulse of geomagnetic sudden commencement (SC) is seen at low latitudes without the equatorial enhancement of its amplitude at night especially during high sunspot years. One salient feature emerged from the present analysis (Fig. 3) is the absence of the prominent peak in ΔH at equatorial latitudes during the pre-midnight hours as seen from the low and mid latitude curves. This finding is in confirmation with the observations of Fejer *et al.* (1983), who has attributed the masking of the disturbance effect by transient electric field perturbations. Alternately, the high latitude low latitude interaction phenomena can be explained in terms of the modification of the low or equatorial latitude storm time circulation by localised heat sources as suggested by Sastri (1988). Sastri's (1988) study using the ground based magnetic data and other geophysical and ionospheric parameters revealed the absence of any detectable signatures of disturbance dynamo electric fields near the dip equator on certain occasions when negative ionospheric storms did prevail at mid latitudes in a longitude zone. He has ascribed this off-set mechanism as the modification of the low latitude storm time circulation by winds associated with localised heat sources. The absence of expected anomalous enhancement of the field at the equatorial stations on relatively quiet intervals may thus be attributable either to the masking effect of the transient electric field perturbations or to the effects of localised heat sources in the equatorial thermosphere. Simultaneous consideration of the magnetic and ionospheric data over a number of such cases of diurnal variations would provide a quantitative estimate of the high latitude-low latitude interaction phenomenon.

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