On Certain Aspects of Daily Variation of Geomagnetic Field at Low Latitudes

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The daily variations of horizontal component of geomagnetic field, H , at low latitudes show significant asymmetry during active solar years. After reaching a maximum value at or slightly before noon the H field decreases to the nighttime base level rather slowly even after sunset. The effect is present during any of the seasons and at different longitude sectors. The maintenance of current after sunset is observed even in ΔH Trivandrum minus Alibag. The continuation of positive ΔH (TRD – ABG) after sunset is more prominent during disturbed than on quiet days. The midday peak of ΔH at equatorial station occurs later during local winter than during local summer months at different longitudes. The equatorial electrojet current is suggested to be due to combined effects of multitude of sources of electric fields having different daily, seasonal and solar cycle variations.

1. Introduction

The daily variation of horizontal geomagnetic field (H) at stations close to the magnetic equator has assumed increasingly greater importance in recent times. The unique condition of orthogonality of electric field, magnetic field and the plasma density gradient in the E region over the magnetic equator makes this region very sensitive to the changes of the electric fields. The normal eastward electric field during the daytime causes a strong eastward current called equatorial electrojet. Besides, the atmospheric dynamo, other sources of electric fields at equatorial regions are due to action of solar wind with the interplanetary magnetic field reversals near the magnetopause (RASTOGI and PATEL, 1975), due to the penetration of high latitude electric fields to low latitudes (AKASOFU and CHAPMAN, 1963), due to regular magnetopause current (MEAD, 1964), due to symmetrical quiet time ring current (SCHIED, 1969), due to partial ring current (KAVANAGH *et al.*, 1968) and other magnetospheric processes. SARABHAI and NAIR (1971) have discussed various sources of magnetic field variations at low latitudes. OLSON (1989) has described the contributions of various magnetospheric currents to the Sq variations in different components of the geomagnetic fields observed at ground level. The isolation of regular and systematic deformations in the daily variations of the equatorial electrojet would help understanding of the relative importance of the various sources affecting the equatorial ionosphere.

RASTOGI and IYER (1976) found that the solar daily variation of H at an equatorial station shows significant differences during low and high sunspot years. During low sunspot years, H returns to the nighttime base level well before the sunset but during the high sunspot years the values of H continue to decrease monotonously since noon upto hours beyond the sunset.

The present article describes the daily variation of H at equatorial and tropical latitude stations during different levels of solar activity specially about the asymmetries in the daily variations and the continuation of ionospheric currents during the night time hours.

2. Presentation of Data

RASTOGI and IYER (1976) had compared the yearly mean daily variations of H at low latitudes during the years 1959 to 1964 to show the abnormal features of the Sq variations. The post-sunset continuation of ΔH above the mid-night level was observed at both Trivandrum as well as Alibag. In Fig. 1 are shown Sq (H) variations at Huancayo and Trivandrum averaged for D months (November, December, January and February); E months (March, April, September and October) and J months (May, June, July and August) of the years of low (1964) and high (1958) solar activity. The post-sunset asymmetry in ΔH at Huancayo and Trivandrum was present during any of the seasons of the year of high sunspots, 1958.

Another interesting feature noticeable is that the largest amplitude of solar daily range of H at Huancayo and Trivandrum occurs in equinoctial months. The daily range of H at Huancayo was larger during D months than during the J months. The peak value of ΔH occurred earlier during D months (local summer) than during the J months (local winter). At Trivandrum, ΔH

Fig. 1. Seasonal average solar daily variations of H at Huancayo and Trivandrum during low (1964) and high (1958) solar activity years.

was larger during J months (local summer) than during the D months (local winter), and there are definite indication that the time of maximum ΔH was again earlier during local summer than during the local winter months.

To elucidate the seasonal variation in the time of daily maximum of ΔH , in Fig. 2 are shown the daily variations of H at Huancayo and Trivandrum for hours around midday for each month of the low sunspot year 1964. Referring to the daily variation curves for H at Huancayo, it is very clear that the peak value of H occur earliest (at 1010 LT) in January, the peak occurs later during succeeding months until in the month of June the peak occurred at 1215 LT. During later months, the time of peak value of H occurred earlier in local time. Thus in the American sector, Huancayo, the peak value of ΔH occurred earliest during local summer and later during the winter months, the time shift being about two hours.

Fig. 2. Solar daily variations of H field at Huancayo and Trivandrum during individual months of 1964 showing the seasonal variation in the time of midday peak of ΔH .

Fig. 3. Yearly mean solar daily variations of the H field on International Quiet days at the equatorial station, Trivandrum, at tropical latitude station, Alibag and at Trivandrum minus Alibag for each of the years 1958 to 1965.

Referring to the curves for Trivandrum, it is seen that the peak of ΔH occurred earliest during May (1005 LT) and later in December (1155 LT). The month to month change was not so regular as in the case of Huancayo. However, it is easy to conclude that the strength of the electrojet is weaker during local winter than during summer months and the peak occurs about two hours earlier in winter than in summer months.

In Fig. 3 are shown the yearly mean solar quiet day variations for 1958 of H at Trivandrum, at Alibag and ΔH Trivandrum minus Alibag for each of the years from 1958 to 1965. The annual mean sunspot numbers are also indicated in the diagram to show the level of solar activity during these years.

During the low sunspot years 1965 ($R = 15$), 1964 ($R = 10$) and 1963 ($R = 28$), the levels of ΔH at Trivandrum as well as at Alibag were practically zero throughout the night time hours, 1800 LT to 0600 LT. The values of ΔH (TRD – ABG) remained steadily close to zero throughout the night hours. Actually it attained the zero level sometimes before sunset and remained zero definitely upto 0600 LT. ΔH (TRD – ABG) increased steadily afterwards reached the peak value between 1000–1100 LT and attained negative value during some hours in the afternoon, characterising the occurrence of counter-electrojet events during the afternoon hours of low sunspot years (PATIL *et al.*, 1990a, b).

With increasing solar activity, the ΔH value continues above the midnight level upto increasing hours of the night after sunset. During 1958 the ΔH (TRD – ABG) attains near midnight level only around midnight itself and ΔH (TRD – ABG) continues to decrease upto presunrise hours. The negative value of ΔH are seen during the presunrise hours of high sunspot years both in the variation of ΔH (TRD) and more clearly in the variation of ΔH (TRD – ABG). This feature is consistent with the results of PATIL *et al.* (1990a, b).

In Fig. 4 are shown the yearly mean solar activity variations of ΔH (TRD – ABG) for each of the years from 1969 to 1985. The level of solar activity during each of the years are also indicated on the curves by the annual mean sunspot numbers. During the low sunspot years 1973 ($R = 39$) and 1974 ($R = 34$), the ΔH (TRD – ABG) values were close to zero throughout the night as well as during couple of hours before sunspot, the eastward electrojet current was confined only between 0700 and 1600 LT. During the minimum sunspot years 1975 ($R = 16$), 1976 ($R = 13$), 1977 ($R = 28$) and 1985 ($R = 18$) the value of ΔH (TRD – ABG) showed negative values between 1600–1700 LT due to counter electrojet events. During high sunspot years, the asymmetry of daily variation of ΔH (TRD – ABG) was very clear with higher values in the afternoon than during the forenoon hours and ΔH (TRD – ABG) was positive for one or two hours after sunset and showed negative values during presunrise hours.

It is to be noted that the level of ΔH (TRD – ABG) was practically constant from 2300 LT to 0300 LT during any period of solar activity. Thus, any of these time period can be taken as the period of no electrojet current and the value of base-level for computing ΔH during any hour of the day.

Next, we investigate any possible effect of geomagnetic disturbances on the abnormalities in the daily variations of H at Trivandrum and Alibag. In Fig. 5 are shown the solar daily variations of ΔH (TRD – ABG) averaged over International Quiet and Disturbed days during different solar epochs, low sunspot years 1962–1964 ($R = 25$), medium sunspot years 1968–1970 ($R = 106$) and very active solar epoch 1958–1960 ($R = 152$). It is seen that during low sunspot years 1962–64, ΔH (TRD – ABG) had reached the night time base level both on IQ or ID days before sunset. However it is important to note that the afternoon counter-electrojet effect was absent on ID days. During the years 1968–70, the evening values of ΔH (TRD –

ABG) were higher on disturbed than on quiet days. The continuation of positive ΔH (TRD – ABG) after sunset is much more evident on disturbed days of maximum sunspot years 1958–60.

Another interesting point to be noted is that the midday values of ΔH (TRD – ABG) are consistently smaller on quiet than on disturbed days during any of the solar epoch. It has been shown by direct comparison of magnetic field data and the VHF back scatter doppler shift data that the doppler shift is much better related to ΔH (TRD – ABG) than to ΔH (TRD) on quiet or on geomagnetic storm days (RASTOGI and PATIL, 1986). The ionospheric drifts at the equatorial station Thumba are correlated with ΔH (TRD – ABG) or ΔH (KOD – ABG) rather than with ΔH (TRD) or ΔH (KOD) alone (RASTOGI, 1975). The q type of sporadic E at equatorial stations is also related closely to the difference of ΔH over the equator minus ΔH at the station outside the electrojet belt (CHANDRA and RASTOGI, 1974). Thus, it had been

Fig. 4. Yearly mean solar daily variations of ΔH (TRD – ABG) for each of the years 1965 to 1985.

Fig. 5. Solar daily variations of equatorial electrojet current designated by ΔH at Trivandrum minus ΔH at Alibag during years of varying solar activity.

concluded that the ΔH (TRD – ABG) very truly depicts the strength of equatorial electrojet current strength. Considering this, the present data confirm that the equatorial electrojet current strength is weaker on disturbed than on quiet days of any of the years with low or high solar activity.

3. Conclusions

Classically the equatorial electrojet current had been considered just the enhancement of the global Sq currents due to the enhanced electrical conductivities over the magnetic equator. SARABHAI and NAIR (1971) had indicated the effects due to various magnetospheric currents on the ground measurements of H field at the ground level at equatorial latitudes. Using simultaneous, ionospheric drift, magnetometer and ionosonde data at equatorial stations in India, RASTOGI (1975) had shown the equatorial electrojet current is composed of one flowing eastward during the day light hours at 107 km altitude related to global Sq current and another current at 100 km altitude which may be flowing either eastward or westward. One of the source of ionospheric current over the equator other than related to Sq current was identified by RASTOGI and PATEL (1975) to be related to the sudden reversal of the interplanetary magnetic field. Complex vertical structures in the horizontal electric field over the equatorial

station Thumba have been identified by (REDDY, 1989) using VHF backscatter. The increase of ΔH at the sudden commencement of geomagnetic storms is explained as the result of the compression of magnetosphere by the pressure of enhanced solar wind following solar eruptions. An increase of electric field in the E region over the magnetic equator at the time of the SSC increase of ΔH has been inferred from the ionospheric data of HF soundings (RASTOGI, 1976) and VHF scatter soundings (REDDY *et al.*, 1981) signatures of electron clouds in the solar wind has been detected at equatorial latitudes in sympathy with high latitude phenomena (SOMAYAJULU *et al.*, 1985). Thus it has been clear that besides the classical atmospheric dynamo electric fields, the equatorial region is subjected to temporary imposition of electric fields due to numerous events near earth's environment. These modification of equatorial electric fields have direct repercussions on the plasma density, plasma irregularities and the dynamics of the equatorial ionosphere. A detailed understanding of these modifications of equatorial electric fields should yield to a better understanding of the interaction between equatorial geomagnetism and ionosphere. Simultaneous operations of vertical ionosonde, VHF back scatter radar, the HF doppler radar and the magnetometers at the same location near the magnetic equator would greatly assist understanding the complex phenomena of equatorial ionosphere.

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