A STUDY OF SQ(H) VARIATIONS OVER EQUATORIAL ELECTROJET REGIONS.

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Abstract

The newly established geomagnetic field observations in Japan, have enabled us to analyse the 1998 data of Huancayo, Kiritimati (Christmas Island) and Pohnpei where the geomagnetic Sq(H) variations of equatorial electrojet have been studied. The diurnal variation of the monthly means of Sq(H) on the five international quiet days showed mostly expected diurnal variation of equatorial electrojet regions as well as some abnormal variations. Seasonal variation with equinoctial maxima and solstial minima was also observed from the analysis. The presence of equinoctial maxima is likely to be due to enhanced equatorial electron density and the electric field at equinox. The day to day variability may be attributed to electric field, a dawn to dusk phenomenon.

Keywords: *Equatorial electrojet, seasonal variation, amplitude, abnormal variation and solar quiet day variation.*

Introduction

The study of the daily variation of horizontal geomagnetic field (H) has assumed greater importance in recent times. It has been shown that equatorial electrojet (EEJ) is as a result of large Hall polarization and hence large Cowling conductivity at the dip equator where the earth's field is horizontal (Stewart, 1882). Schield (1969) suggested that sources of electric fields at EEJ region might be due to symmetrical quiet - time ring current. The work of Rastogi and Patel (1975) revealed that, besides the atmospheric dynamo, other sources of electric fields at equatorial regions are due to action of solar wind with the interplanetary magnetic field (IMF) reversal near the magnetopause. Rastogi and Iyer (1976) had found that the solar daily variation of H at an equatorial station, shows a significant difference during low-and high-sunspot years. During sunspot minimum, it returns to the nighttime base level well before sunset, but during sunspot maximum the value of H continues to decrease monotonically from noon until beyond sunset. Rastogi and Patil (1992) suggested that the EEJ current may be due to combined effects of multitude of sources of electric fields having different daily, seasonal and solar cycle variations.

Chapman and Rajarao (1965) found seasonal variation of H and Z fields in EEJ region with equinoctial maximum and solistial minimum. Rastogi (1962), showed that there is a significant longitudinal inequality in the strength of the EEJ current. Numerous work on Sq variabilities and EEJ variabilities have been carried out by many authors. Patil et al. (1983) found abnormally large variation in H at Trivandrum followed by that at Kodaikanal and Annamalainagar, all of Indian region of EEJ. Okeke et al. (1998), from their study of day to - day variability of geomagnetic hourly amplitude at low latitude, found that the day to - day variability occurs at all hours of the day, and has a seasonal variation with a weak maximum at the June solstice. Also the work of Doumouya et al. (1998) revealed that the amplitude dH changes continuously from dawn to dusk with a maximum at local noon, and dH was found to be maximum in equinoxes and minimum in solstices. Onwumechili (1967) found that the annual average of the five international quiet days (IQDs) of each month of the year 1958, had positive asymmetry at each of nine stations in EEJ zone worldwide.

This present study becomes very necessary since out of these three EEJ regions, Pohnpei is a virgin region where no geomagnetic data has been obtained or analysed. On the other hand, the last measurement done on Kiritimati Island was in the year 1957. This preliminary analysis carried out in particular at Kiritimati and Pohnpei is very imperative, so as to study the variations in these regions and compare with already existing ones where enormous research has been carried out.

Data

The data are from three EEJ regions, Huancayo (HUA), Kiritimati (KTM) or Christmas Island and Pohnpei (PON). The published one minute values of H recorded at the geomagnetic observatory were subjected to changes into mean hourly values using a simple program. Table 1 shows the

Table 1: Coordinates of the stations whose 1998 data were analysed

Station		Geographic Longitude $(^o)$	Geographic Latitude $(^o)$	Geomagnetic Longitude $(^o)$	Geomagnetic Latitude $(^o)$
Huancayo		-75.20	-12.06	356.12	1.40
Kiritimati	KTM	-157.50	2.05	273.49	3.09
Pohnpei	PON	158.33	7.00	229.19	0.09

The five (IQDs) were used in the analysis, which by definition are the sets of five quietest day per month, based on the disturbance index (Kp). The midnight hourly value *Ho* of H magnetic component is defined as the mean of the hourly values for the local time hours, t=1 and t=24. The Sq amplitude dH for any hour t is the difference between the hourly value H_t and the midnight value H_0. Hence,

$$H_o = ½(H_1 + H_{24}) \quad (1)$$

$$dH = H_t \; H_0 = h_t \quad (2)$$

The variability of these hourly amplitudes for the hour t from the day k to the next consecutive IQD (k+1), is the day variability (D-D), defined as;

$$D\text{-}D = h_{t(k+1)} \; h_{tk} \quad (3)$$

The diurnal variation of the variability from day k to day (k+1) is defined by the sequence of 24 values of this variability for t=1 to 24. Equation (2) gives the diurnal variation of Sq(H) on each IQD, the mean Sq(H) for all the five IQDs of each month say h_{mt} is given by;

$$h_{mt} = \frac{1}{n}\sum_{i=1}^{n} h_{ti} \quad (4)$$

where n is number of IQDs. Then the monthly mean Sq(H) values say; h_{mm}, is given by:

$$h_{mm} = \frac{1}{24}\sum_{t=1}^{24} h_{mt} \quad (5)$$

The values calculated from above equations were employed in the analysis carried out in this work. For the types of diurnal variations of Sq (H) in these EEJ regions, using a measure of asymmetry defined by Onwumechili (1967), as;

$$A_s = (H_{17} \; H_{05})/R \quad (6)$$

where H_{05} and H_{17} are the hourly mean values of H for 0500-0600 and 1700-1800 hour LT respectively, and R is the daily range of H. This enabled us to use the IQDs H values and found the three types of asymmetries and their percentage of occurrence in all the three stations thus calculated. Only available successive consecutive IQDs of the months were used in the analysis of day to day variability in this study.

Results and discussion

The diurnal variation of Sq(H) in the EEJ regions in all the months of the year 1998 at (a) Huancayo, (b) Kiritimati and (c) Pohnpei are shown in Fig. 1.

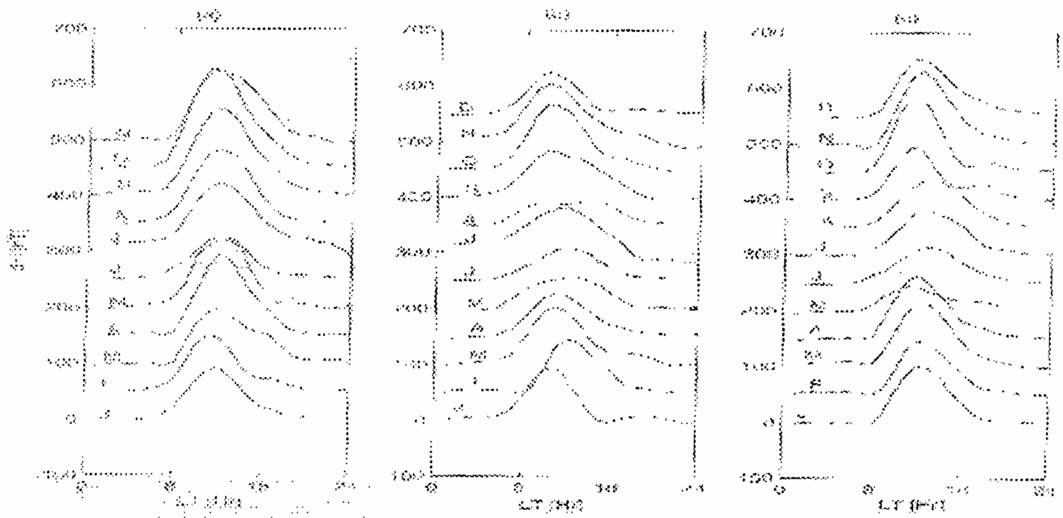

Fig. 1: Diurnal variation of the monthly means of dH on the 5 IQDs at [a] Huancayo [b] Kiritimati and [c] Pohnpei, 1998

It is observed that the enhancement of Sq(H) at these stations occur around local noon time. The variations in the three stations show a rise from the sun rise to the peak during the day time, mostly around the local noon, and then a decrease towards the sun set period. This variation in dH amplitude is quite similar to the equatorial latitude amplitude variation which has been studied by several workers. The three types of diurnal variation of Sq(H) as found by Onwumechili (1959,1967, 1997) across the EEJ axis was also observed from this analysis. From the figure, the first type of variation which rises steadily from midnight to an early maximum at about 10h LT and then decreases to a minimum at about sunset could be seen in months of March at Huancayo, also seen at Kiritimati in the month of September, while in Pohnpei, it is seen in the months of September and October. The second type of variation which usually is symmetrical and has slight minima around sunrise and sunset, and a maximum at about 11h LT are observed at Huancayo in months of February and November.

At Kiritimati, it was observed in the months of January, while at Pohnpei it was not seen in any of the months. The third type which has minimum around sunrise, a maximum at about 12h LT and then decreases slowly to midnight, was seen in the remaining months of the year. This is true for Kiritimati, except for the month of August, which showed some abnormal variation. Also in Pohnpei this third type could be observed in the remaining part of the months except for the month of May, which also showed some abnormal variation. This is an interesting result, because even when the monthly means were used, the effects of some abnormal quiet days still persisted, and could not be averaged out.

From the analysis carried out on asymmetries, it was noted that 11.4 per cent of the first type, 8.6 per cent of the second type and 80 per cent of the third type was observed in the three regions throughout the year. The observed diurnal variations of Sq(H) around noon is due to equatorial electrojet which flows mainly eastward and along the magnetic equator. This is also due to enhanced dynamo action at these regions. This is true because at the region between 70 to 140 km, where we are considering, the collision frequency of ions are greater than the gyro frequency of the electrons. Thus, ions move with neutral air but electrons are controlled by magnetic field. Hence, at the equator, where the electric field during the day is primarily in the eastward direction and the magnetic field is in the northward direction, the electrons within this height drift upwards relative to ions and produce the Hall polarization field which in turn produces additional Hall conductivity in the east direction. This then constitutes a large Hall polarization and hence large Cowling conductivity at the dip equator where the earth's field is horizontal.

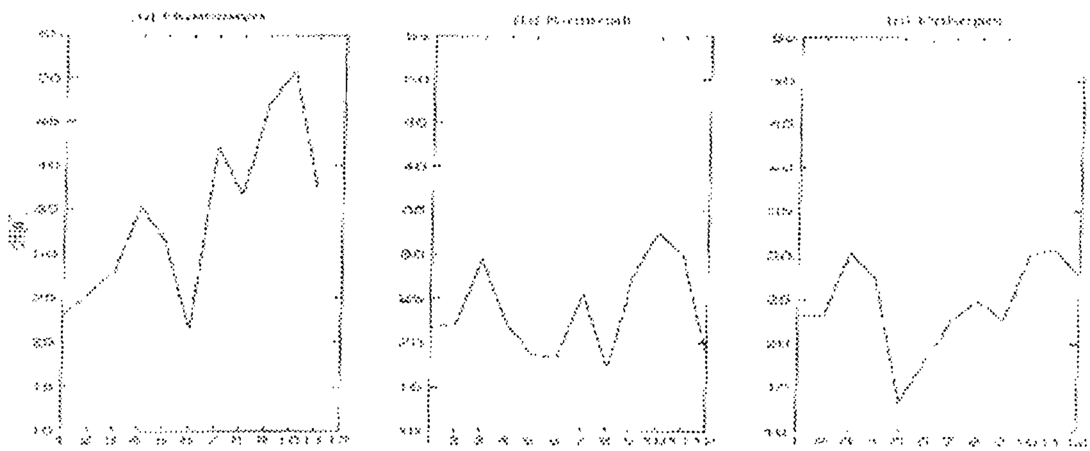

Fig. 2: Seasonal variation of dH at the EEJ stations [1-12 along x-axis represent months of the year, 1998]

Figure 2 displays the seasonal variations in the three EEJ regions. The calculated mean monthly values of dH amplitudes, enabled us to study the seasonal variations in these EEJ regions. There is a well clear seasonal variations in the three regions. The minimum occurring around the months of May, June, and August in all the three EEJ regions. There was a sudden sharp rise in October in all the three regions. The summary of this seasonal variation is demonstrated using LIyod's seasons; December solstice (D), (January, February, November and December), Equinox (E) (March, April, September and October) and June Solstice (J), (May, June, July and August). There is equinoctial maximum in all the three stations, and is clearly seen to be higher at Huancayo being almost the same at both Kiritimati and Pohnpei. There is minimal solstice with June solstice as the least, occurring in May, June, July and August. This result reconfirms the results of Chapman and Rajarao (1965), Tarpley (1973), Rastogi and Iyer (1976) and quite a few other results on seasonal variation of EEJ stations.

For each consecutive IQD of the months of March, June and August, we have computed the values of day to day variabilities (D-D) in order to investigate the D-D.

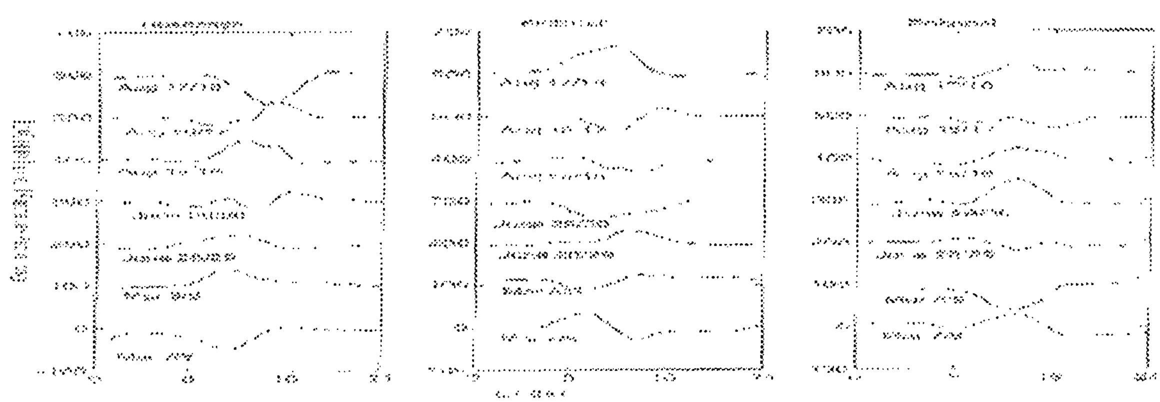

Fig. 3: Diurnal variation of D-D of H consecutive IQDs of three months in 1998, in EEJ regions

Figure 3 displays the nature of diurnal variations of D-D. It could be seen that the diurnal variations of D-D varies in both magnitude as well as in phase. The difference between two consecutive days are some times very strong and sometimes weak. It is evident from the figure that in each month and at the various three regions the D-D are not similar in variations, each with different phase and amplitude changes. The phase variation is seemingly random in all the months displayed and in all the regions. The diurnal variation of Sq(H) of D-D displays very important features, the obvious depression of Sq(H) on the 17/18 August is likely due to the observed AQD on the 18th of August. The same obvious depression occurred at Pohnpei in March on 8/9, the feature could not be explained as no reading was recorded on the 8th of March at Pohnpei.

The D-D is a dawn to dusk phenomenon, although very prominent in the day time. Since this current varies in magnitude or amplitude as well as phase (direction) consequently the resulting magnetic field also changes in intensity as well as direction. Increase in the current intensity increases the amplitudes of H even if the direction of the current is unchanged. Conversely, if the intensity of the current is unchanged, a change of its direction such that its east-west component decreases can lead to a decrease in the magnitude of H hence it could mean that changes in the magnitude of H can be responses to the changes in the amplitude or phase of the total magnetic field. It is therefore suggested that the random nature of the D-D arise from winds which generate the deriving electric fields through the dynamo process. This is because the random variability of H comes from random changes of the intensity or direction of currents or from both, originating from changes in conductivity or electric field, but because the conductivity is not likely to change randomly, therefore it must be from the wind.

The abnormal variation noted in the month of August at Kiritimati is attributed to the abnormal quiet days (AQDs) observed in this month on the 9th, 15th and 18th as could be seen in figure 4. Also at Pohnpei, the abnormal variation, which deviated from the normal Sq(H) variation in the month of May, was also due to the effects of AQD on the 28th of this month (see figure 4). The latter was an AQD clearly obvious to be due to counter electrojet (CEJ) effect. It is seen that Sq(H) was depressed below its nighttime level on an IQD, this is an indication that the current above the region in question has reversed direction. This was only observed at Pohnpei, and not in the other two regions. This is suggested to be as a result of longitudinal difference. Mayaud (1977) noted that CEJ is commonly spread with 35° longitude difference.

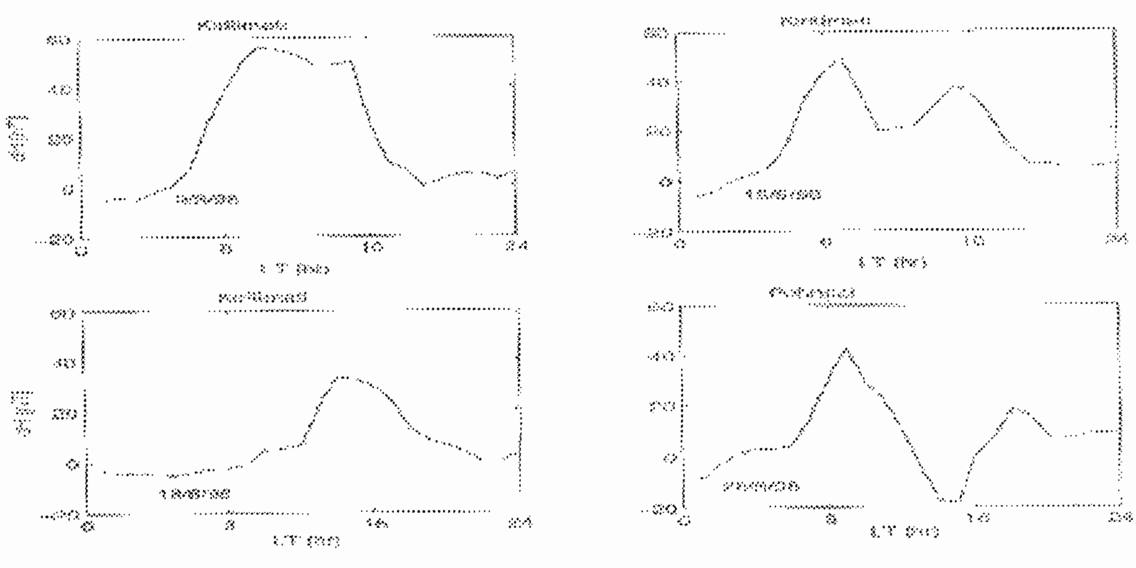

Fig. 4: Some IQDs of the months whose features affect the monthly dH plots

Conclusions

The diurnal variation of Sq(H) in the three EEJ regions observed from our analysis could be due to known dynamo action in the ionosphere, and additional Hall conductivity which is produced by large Hall polarization field. The normal three types of variations were observed, with the third type occurring with greater percentage of 80. In addition the abnormal Sq(H) variation so observed at Kiritimati and Pohnpei in months of August and May respectively was explained as an effects due to AQDs and CEJ effects respectively.

The seasonal variation with equinoctial maximum is attributed to the enhanced equatorial electron density which in turn increases the electrical conductivity when the sun is overhead at equinox as well as corresponding changes in the electric field. This result is in consistency with results of Chapman and Rajarao (1965), Doumoya et al. (1998) and several other results obtained earlier by previous workers who used older EEJ regions.

The D-D is a dawn to dusk phenomenon, as have been noted by Doumouya et al. (1998) and Okeke et al. (1998). It is suggested that ionospheric conductivity controls the magnitude of the D-D while the electric field and wind controls the phase. It is being suggested that more research work be carried out in these new regions of EEJ, as more results will be very useful in current geomagnetic research in various aspects of variations.

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