Earth Planets Space, **52**, 237–243, 2000

Daily variations of geomagnetic HD and Z-field at equatorial latitudes

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(Received September 22, 1999; Revised February 23, 2000; Accepted March 1, 2000)

With the establishment of the new geomagnetic field observations in the Ocean Hemisphere Network Project (OHP) in Japan, minutes values of geomagnetic components, H D and Z have been recorded. The hourly mean values were used to study the variations in these three components at these new equatorial electrojet regions. The results of the analysis carried out revealed that the amplitude of dH has diurnal variation which peaks during the day at about local noon in all the three equatorial electrojet regions. This diurnal variation in H with Sq (H) enhancement in all the three regions are attributed to the enhanced dynamo action at these regions. Diurnal variation as observed in D indicates that the equatorial electrojet current system has both east-west and north-south components. The pronounced magnitude of Z variation as observed in Kiritimati is attributed mainly to sea induction. Also some abnormal features were observed on 23rd of January at Huancayo, in the components. Seasonal variations with more pronounced equinoctial maximum were observed in H than in Z. D component showed no consistent seasonal variation in all the regions. The equinoctial maximum is due to enhanced equatorial electron density at equinox. More research work, if carried out in these new regions will be useful in making more new contributions to the field of the dynamics of the equatorial electrojet region.

1. Introduction

It has been a long established fact that variations in ground magnetic records are caused by the dynamo action in the upper atmosphere. These daily variations in the geomagnetic fields at the earths surface during geomagnetically quiet conditions are known to be associated with the dynamo currents which are driven by winds and thermal tidal motions in the E-region of the ionosphere (Chapman, 1919). At the magnetic dip equator the midday eastward polarizaton field generated by global scale dynamo action gives rise to a downward Hall current. A strong vertical polarization field is set up which opposes the downward flow of current due to the presence of non-conducting boundaries. This field in turn gives rise to the intense Hall current which Chapman (1951) named the equatorial electrojet (EEJ). The phenomenon has been given various attention and has attracted several research workers both in the past and recent times.

Earlier works of Bartels and Johnston (1940), Egedal (1947), found that the diurnal ranges of H at the stations near the equator peaks around the dip equator with assumptions that the amplitudes of the daily variations in D and Z were unaffected. Forbush and Casaverde (1961) studied the features of EEJ in DH and Z across the dip equator, and assumed that EEJ produced none or very negligible D field. However, recent work of Rastogi (1996), Onwumechili (1997) and Okeke *et al.* (1998) have shown that D field of EEJ does exist.

Patil *et al.* (1983), described the mean daily variations of different components of the geomagnetic field, declination (D), horizontal component field (H) and vertical field (Z), using the Indian observatories combined with those in the U.S.S.R. Patil *et al.* (1990) studied the average latitudinal profile of dH and dZ in the Indian and American zone. Fambitakoye (1971), gave the first latitudinal profiles of dH and dZ due to normal and counter electrojet events using nine equatorial stations in central Africa. Rastogi (1974), Fambitakoye and Mayaud (1976a,b) described profile of dH and dZ on individual days. Studies have been carried out on the seasonal variation of dH in other EEJ regions which reveals equinoctial maximum and solstitial minimum in these regions, these include the works of Chapman and Rajarao (1965), Tarpley (1973) and Doumouya *et al.* (1998).

It should be noted that, although much work has been done on the variations of geomagnetic components, study on the declination component D at equatorial stations has not been given adequate attention. Thus the main aim of this study is to include the variation patterns of the declination D at the EEJ regions under study. Moreover, two of the EEJ regions used are regions where no geomagnetic data has been recorded so far. In the Island of Kiritimati (Christmas Island), the last geomagnetic reading was taken in the year 1957, while in the Island of Pohnpei no geomagnetic recordings have ever been registered at all. Hence, it is imperative to consider the present study as a preliminary analysis in these new regions.

2. Data and Analysis

With the new designed OHP magnetometer system suitable for on-land long-term observations in remote places in the pacific areas the published minutes values of the H D and Z components of the magnetic field of the three regions of EEJ, Huancayo, Kiritimati and Pohnpei were recorded. According to Shimizu and Utada (1999), the system config-

Table 1.

Stations	Abbreviations	Geographic longitude(°)	Geographic latitude(°)	Geomagnetic longitude(°)	Geomagnetic latitude(°)
Huancayo	HUA	−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	0.99

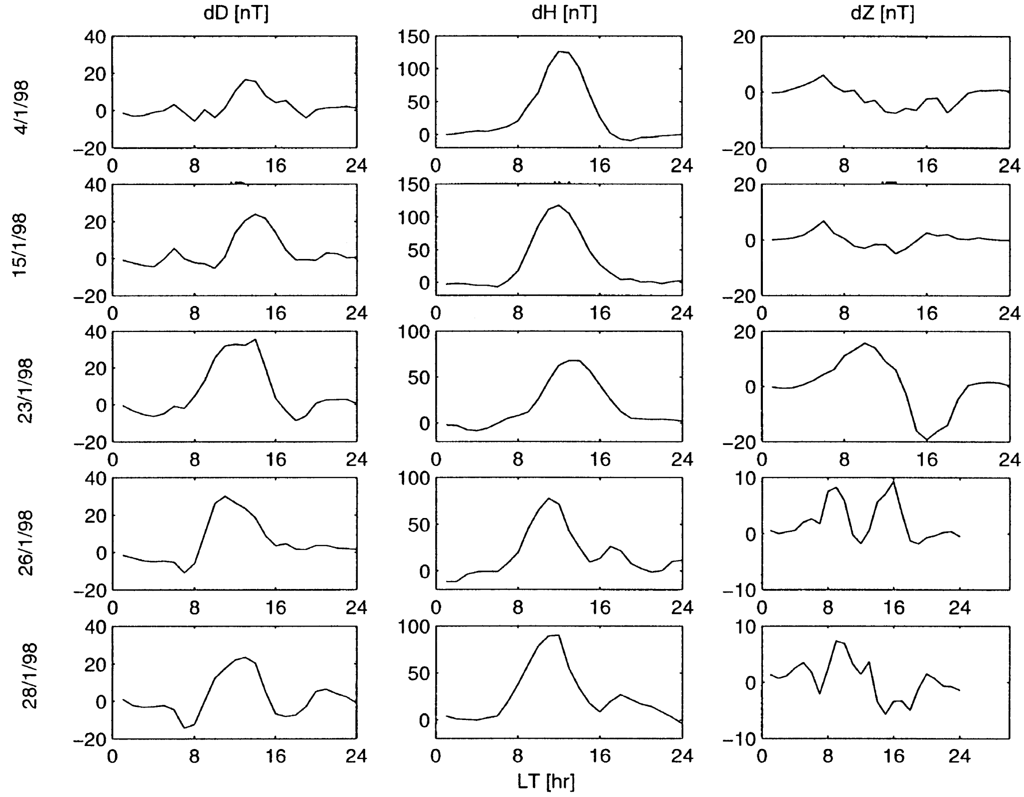

Fig. 1a. Daily variations of dD, dH and dZ at Huancayo, on 5 quiet days of January 1998.

uration of the OHP magnetometer measures long-term variation of the three components of geomagnetic field together with the intensity as well as short-period fluctuations, such as the geomagnetic micropulsations. The EEJ regions used, their abbreviations and their coordinates are indicated in Table 1.

The days selected and used in this analysis are the International Quiet days (IQDs). These days are the set of five quietest days of each month of the year, based on the magnetic activity index Kp. The mean hourly values were computed from the minute interval recorded data of H D and Z. The average of the hourly values for the preceeding and succeeding local midnights of each of the five quiet days were calculated. These values were subtracted from the hourly values at a fixed hour on each of these IQDs. The results are the values of dH, dD and dZ for each of the geomagnetic component values respectively. Thus dH, dD and dZ give the measure of the hourly amplitude of the variation of H D and Z.

The seasonal variations in the three components were also studied. The seasons were classified according to Llyod's seasons. The mean amplitude for the five IQD's were calculated for each month and used in studying the seasonal variation.

The day to day variability in the three components were also studied. The month of August was chosen to illustrate this, because it has the highest number of consecutive IQD's. This was only possible for months of the year with consecutive IQD's. This was done by calculating the variability of these hourly amplitude for a fixed hour from one IQD to the next succeeding IQD, this was done for all the IQD's for all hour of the day. The plots of this day to day variability versus local time for all the components give the nature of variability from one IQD to the next consecutive IQD. The results obtained from this analysis were compared with some results obtained by previous workers who had used older EEJ regions in their study.

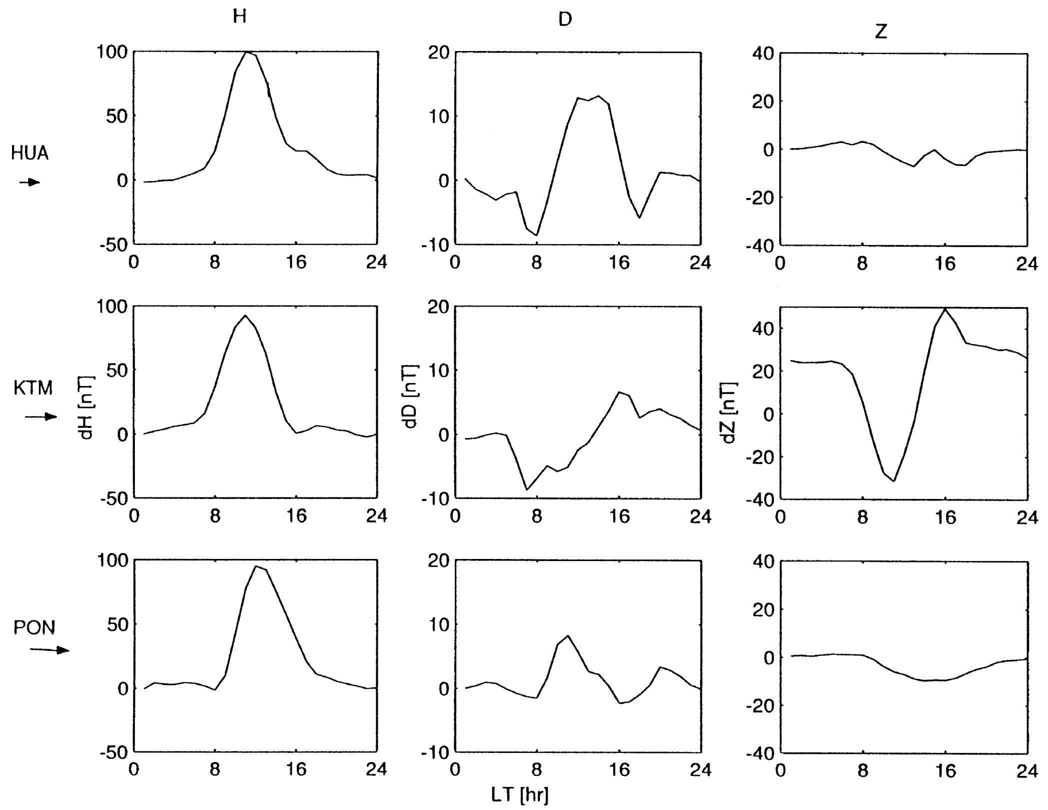

Fig. 1. Diurnal variation of the monthly means of dH, dD, dZ at HUA, KTM, PON in February 1998.

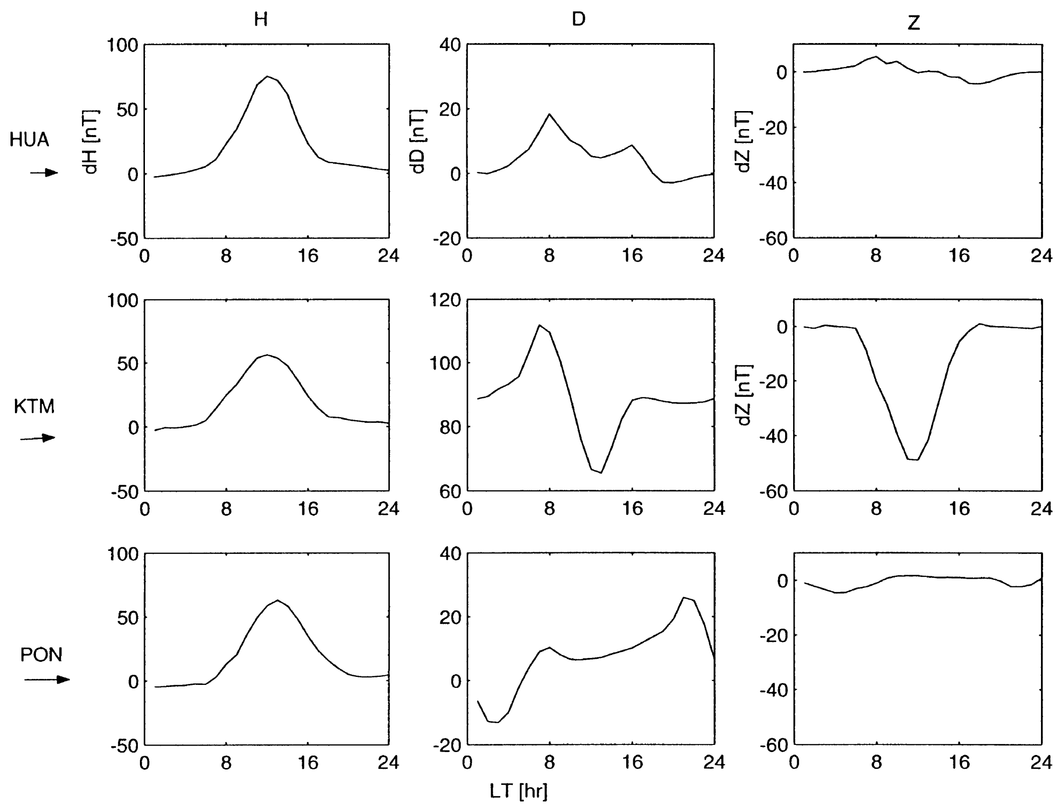

Fig. 2. Diurnal variation of the monthly means of dH, dD, dZ at HUA, KTM, PON in June 1998.

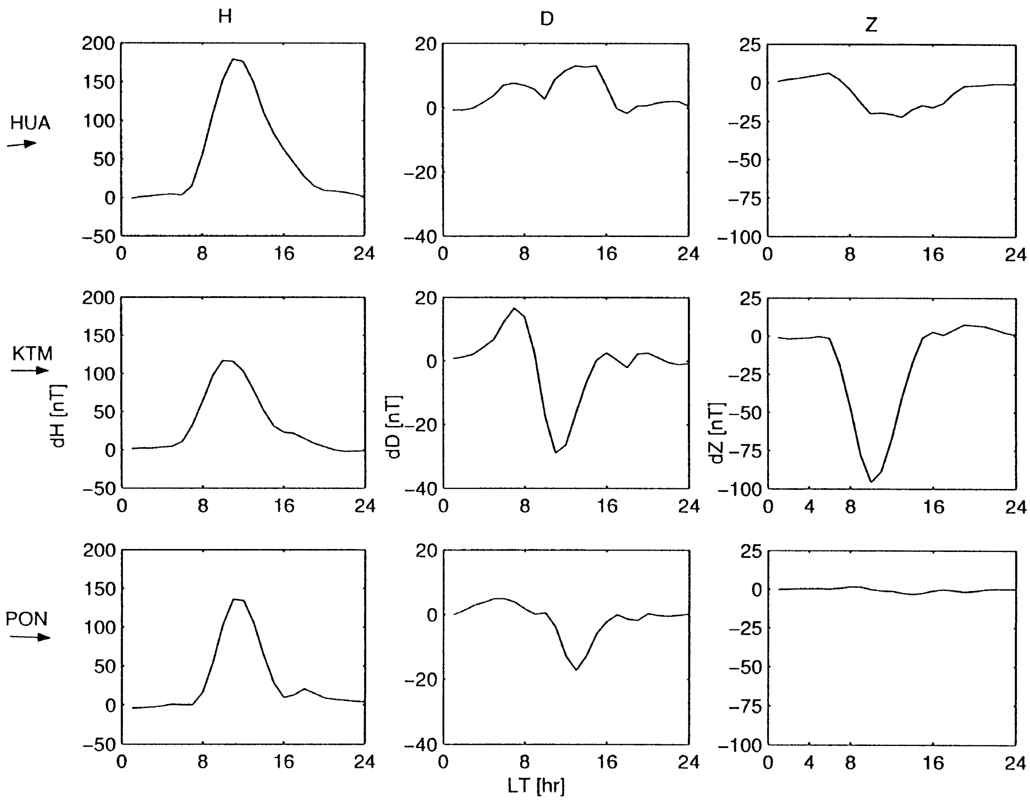

Fig. 3. Diurnal variation of the monthly means of dH, dD, dZ at HUA, KTM, PON in October 1998.

3. Results and Discussion

Figure 1a shows the geomagnetic daily diurnal variation got from the hourly mean values of H D and Z components at Huancayo on each of the five IQDs for the month of January 1998. It is clearly evident from the figure that D has deviated from the normal known variation of having morning trough and afternoon crest. On 23rd January the Z component of the geomagnetic field showed maximum values around local noon hours, this is an abnormal feature and not a common phenomenon. Alex *et al.* (1992) found similar abnormal 'Z' variation in phase with the H variation, and suggested that it could be the cancellation of EEJ. This view by these authors is however yet to be confirmed in future when more data becomes available. It is evident from the same figure that on this day, the enhancement of Sq (H) was reduced at the EEJ regions. It could be seen from the figure that the reduction in Sq (H) on this day as compared with other days of this month is approximately in the ratio of 1 : 2. This reduction could have been suggested to be due to local irregularities in Sq current system. But it has long been established that the EEJ is enhanced by localised ionospheric currents flowing at the dip equator with higher current intensities during the daytime. Here the reverse is the case, therefore we tend to suggest that this must be due to current which flows in opposite direction that inhibits the equatorial enhancement of dH over this region. The result is in conformity with that of Alex *et al.* (1992) wherein they discussed the abnormalities associated with certain characteristics of westward counter electrojet (CEJ) current which completely inhibits the equatorial enhancement of dH over the dip equator.

The diurnal variations in all the three components are illustrated in Figs. 1, 2 and 3. Figure 1 shows the geomagnetic diurnal variations in February in all the regions used. The diurnal variation in H maintains regular pattern and consistent variation in all these regions. H increases from nighttime level and maximizes around local noon. This diurnal variation so observed is in consistency with results of some other workers who used other EEJ zones. It is seen that the D and Z monthly varaitions at Huancayo exhibit a pattern different from the expected pattern. D has its noon maximum while Z has not shown a variation opposite to that of H. On the other hand the variation at KTM and PON are fairly cosistent. The variation in D so observed are in variance with early work of Bartels and Johnston (1940), Forbush and Casaverde (1961) but are in agreement with the work of Rastogi (1996), who found experimental evidence of the D field of the EEJ at Annamalainagar and reported that it is smaller at stations above and below the latitude of Annamalainagar. Onwumechili (1997) has produced the current vortex of the EEJ, and showed that the north-south component of the EEJ current is maximum at latitudes of its focus at about 3° dip latitude. Okeke *et al.* (1998), from the results of their work carried out with Indian stations, found out that the variability of D component at Annamalainagar has a considerable part due to the EEJ fields as in the case of H and Z at this station, which suggested the existence of EEJ D field.

Figures 2 and 3 show the variations in the three components in the months of June and October respectively. Except at PON in June where some abnormal features were observed

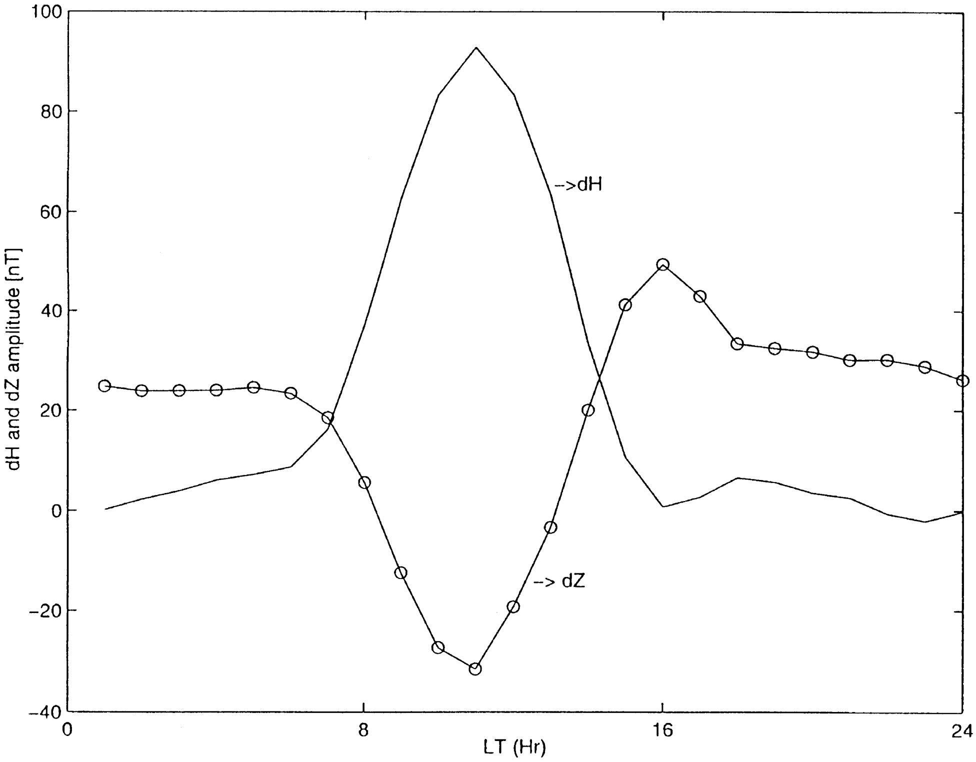

Fig. 4. The northward H and southward Z component of magnetic field of the EEJ at Kiritimati in February 1998.

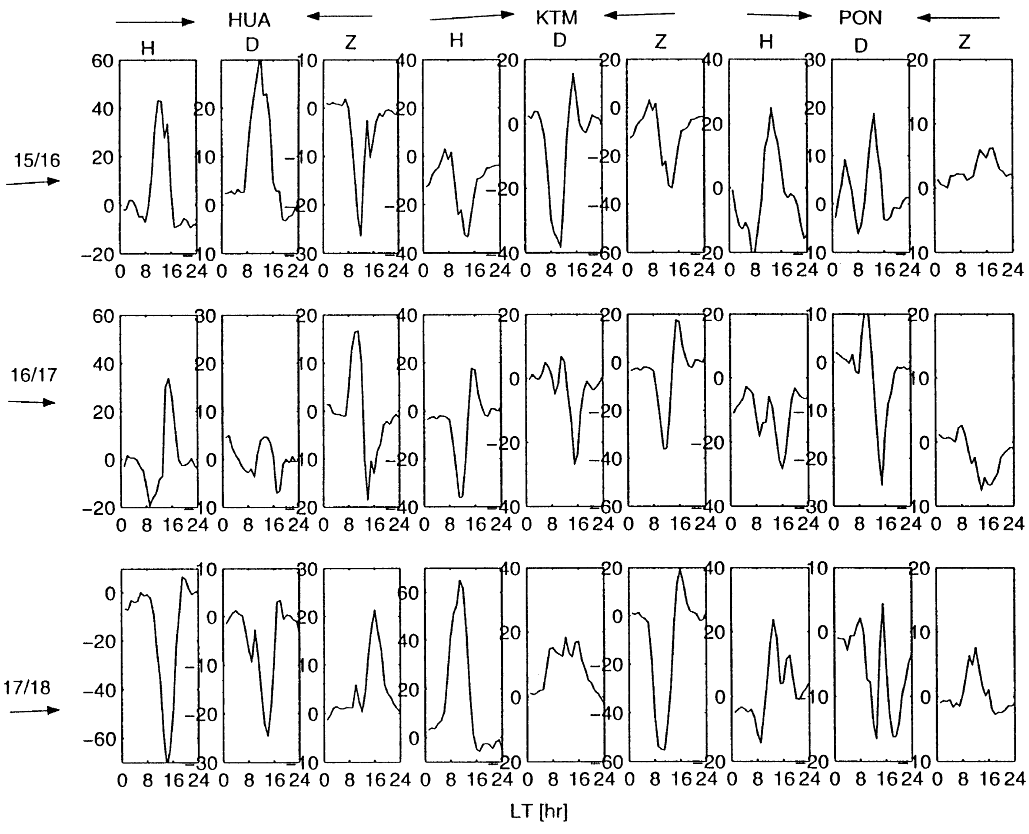

Fig. 5. Day to day variability [D-D] of H, D, Z on four consecutive IQDs in the EEJ regions in August 1998.

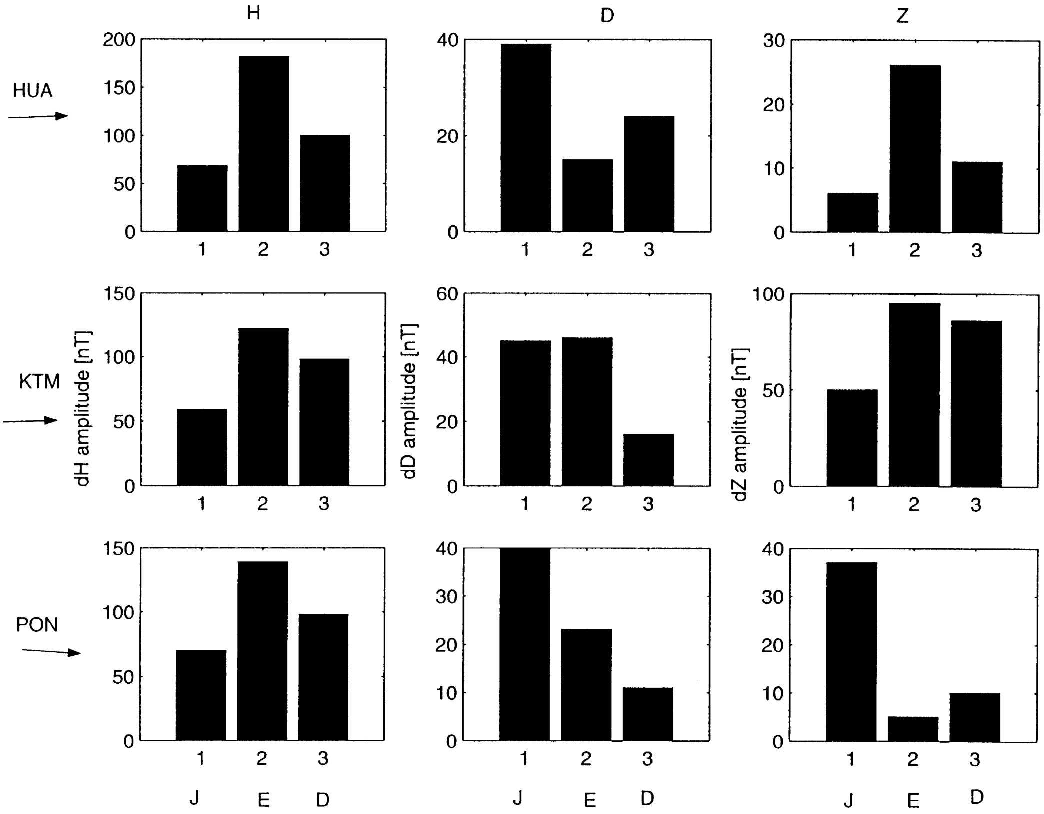

Fig. 6. Seasonal variation in H D Z components at the three EEJ regions [using Lloyds seasons].

in D and Z components other variations were noted to be almost normal. One remarkable feature to note is that D continued to vary from the expected normal variation at Huancayo throughout the months. The northward H and downward Z component of the magnetic field of EEJ at Kiritimati in February is illustrated in Fig. 4. The reversed variation of Z with respect to H component in the EEJ zone is illustrated in Fig. 4. For all the seasons, it was observed that there was a pronounced magnitude of Z component variation at KRT when compared with other two stations. This pronounced magnitude of Z component variation is largely seen in Fig. 4 in KRT. This is due to sea induction on Z component from the H component, the Kiritimati Island being on the northern side, the effect on Z is due to contribution from the H component. On the other hand the Pohnpei is on the eastern side,the induction effect on Z component here is due to D component, which is not expected to be as large as that due to H component at Kiritimati. Thus, the pronounced magnitude of Z component in the Kiritimati Island, mainly due to Island effect from sea induction.

It is generally observed from these figures that there is significant D variation. In Fig. 3 the D variation is positive during the morning hours at KTM and PON in October, in February at PON and in June at KTM, but negative in their afternoon. At HUA and PON in February and October, D showed positive in the afternoon and slight Sq (H) enhancement. This is an unsual variation, it is also observed that in October, H showed a very strong EEJ current effect in all these three regions. This strong EEJ current must have contributed to the D variation so observed.

The day to day variability of Sq (H), Sq (D) and Sq (Z) are as shown in Fig. 5, for the three EEJ regions, four consecutive IQD's in August were chosen. The variability occurence was a dawn to dusk phenomena, although more noticeable in the day time, and turns very mild during the night in all the elements and all the stations. It could be seen that the variability between two paired consecutive days are quite different from any other two paired subsequent consecutive quiet days. For example, on the 15/16, 16/17 and 17/18, it is clearly seen that the variations are remarkably different from one another. Observing from this figure, on the 15/16 day at Huancayo, the day to day variability in H was seen to have amplitude up to 40 nT, while on the 16/17 at the same station, the amplitude was about 30 nT, while on the 17/18 it goes to about -75 nT. Also in other two station there is significant diference in amplitude as well as in phase. The variability in both amplitude and phase is seen to change irratically. It is obivious from the recorded daily plots that the diference in dH between two consecutive quiet days could some times be very large and some times small and rarely could not be any diference. So, dH, dD and dZ show remarkable day to day variability.

The seasonal variations are analysed as shown in Fig. 6. It is evident from this figure that seasonal variation occurred in all the three EEJ regions with equinoctial maximum and solstitial minimum. It is observed from this figure that the equinoctial maximum occurred at Huancayo with dH amplitude of about 180 nT, it is interesting to note that at Kiritimati and Pohnpei the equinoctial maximum has each 130 and 140 nT respectively. More interesting is the equinoctial maximum of Z components at Huancayo, Kiritimati and Pohnpei, these recorded maximum as approximately 25, 98, and 5 nT respectively. The Z component at KTM has the highest equinoctial maximum. This reconfirms the results of Chapman and Rajarao (1965), Tarpley (1973), Doumouya *et al.* (1998) and some various other results obtained from other older EEJ regions. The seasonal variation in Z is similar to that observed in H in almost all the stations. The seasonal variation in D is seemingly not systematic and as such we intend to infer that there is no seasonal variation in D component.

4. Conclusions

The consistent similar pattern of variations in the H components of all the three EEJ regions, which peaks during the day time at local noon is in consistency with the dynamo action of the ionosphere which modifies the geomagnetic field. The enhancement of H at this EEJ regions are due to intense Hall due to this dynamo action. The abnormal features noticed on the 23rd of January at Huancayo in H and Z component may rightly be due to an opposing stronger current to that of EEJ current. It is concluded that diurnal variations occurred in these regions in D component. The diurnal variation in D was a dawn to dusk affair. This variation in D indicates that the EEJ current system has also a north-south component and not only an east-west component as earlier assumed by previous workers. Maeda *et al.* (1982) found D variation was only a dusk affair while our result found D to be dawn to dusk affair.

The day to day variability so observed is suggested to arise from the modification of the wind and ionospheric conductivity. The seasonal variation observed in dH amplitude with equinoctial maximum must be due to enhanced equatorial electron density at equinox. It is suggested that more future research work should be carried out in these new regions and various aspects of geomagnetic research be included.

Acknowledgments. We are grateful to Japanese Society For Promotion of Science (JSPS), and to the Grant-in-Aid for JSPS fellows for making this research possible to be carried out through their grant. The editor thanks S. Alex and O. Saka for their assistance in evaluating this paper.

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