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Variability of horizontal component of geomagnetic element (*H*) with mean quiet-day variation

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[1] The variability of $Sq(H)$ with mean quiet-day variation at equatorial electrojet latitudes and other latitudes has been studied using the correlation between the hourly amplitudes of the H variations dH, at these stations. It was found that these hourly amplitudes of H under equatorial electrojet regions are well correlated with themselves. High significant correlation was established among them. On the other hand, low correlation was found among pairs of equatorial electrojet stations and other latitude stations not under the equatorial electrojet. It was discovered that most times, the variation in the current intensities of the worldwide part of Sq (WSq) and the equatorial electrojet (EEJ) have contrasting phases. It was concluded that the very low correlation coefficients calculated and the contrasting phases of EEJ and WSq current intensities were due to the fact that changes in EEJ current intensity are controlled mainly by E_z, while changes in WSq current are driven mainly by E_y. *INDEX TERMS:* 2409 Ionosphere: Current systems; 2736 Magnetospheric Physics: Magnetosphere/ionosphere interactions; 2712 Magnetospheric Physics: Electric fields; *KEYWORDS:* Equatorial electrojet; Geomagnetic field; Current system.

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1. Introduction

[2] Several studies of the relationship between the equatorial electrojet and other latitudes current system basically known as the Sq system have been carried out for many years by many workers, yet controversy still exist. Thus *Ogbuehi et al.* [1967] considered the EEJ as a current circuit whose strength changes independently of the WSq strength. *Mann and Schlapp* [1988] noted that the daily ranges of H at stations under the EEJ are obviously less well correlated with those of other stations, than is the case for the pairs of equatorial stations not involving an electrojet station. *Okeke and Onwumechili* [1993] found evidence that the daily variations of the EEJ and the WSq are not in phase. *Okeke et al.* [1998] showed that the variabilities of the current intensities of EEJ and WSq current layers are independent. Other works of *Greener and Schlapp* [1979], *Balsley* [1973], *Raghavarao and Anandarao* [1987], and several others support the notion that EEJ and WSq current systems are independent.

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[3] On the other hand, *Osborne* [1964] found that there was little correlation between the electrojet and the rest of the Sq current system. *Forbes* [1981] concluded that the electrojet and Sq current system must be regarded as coupled interactive systems. *Hesse* [1982] agreed that EEJ is a part of Sq current system. *Mayaud* [1967] found that the correlation between the daily ranges of $Sq(H)$ at Koror (EEJ station) and Guam or Hollandia was only slightly smaller than that for two low-latitude stations of similar relative position not subject to the influence of the electrojet. *Schlapp* [1968] also found no significant difference between correlation coefficients of pairs of nearby equatorial stations involving and not involving the electrojet.

[4] From the review, it is evident that not much work has been carried out in comparing the midlatitude and high-latitude stations with the EEJ stations. It is therefore the objective of this paper to carry out a correlation study in EEJ, low-latitude, midlatitude, and high-latitude regions in order to study the relationship between these stations and that of the EEJ. It is also important to study the contrasting phases of both EEJ and WSq current systems. This study utilizes the data from virgin EEJ regions and results from this preliminary studies would thereby be compared with the results obtained from older long existing EEJ stations, where much work have been carried out.

Table 1. Stations Used in the Analysis

Station	Abbreviation	Geographic Longitude, °C	Geographic Latitude, °C	Geomagnetic Longitude, °C	Latitude, °C
Scott Base	SBA	166.78	−77.85	−66.76	−78.84
Manhay	MAB	5.68	50.30	90.14	51.59
Kakioka	KAK	140.18	36.23	−152.23	26.94
Pohnpei	PON	158.33	7.00	229.19	0.09
Kiritimati	KTM	−157.50	2.05	273.49	3.09

2. Data and Analysis

[5] The stations used in the analysis and their coordinate are as listed in Table 1. Two stations are purely EEJ regions and are of virgin areas, these are the Pohnpei and Christmas Island (Kiritimati Island). The low-latitude station is the Kakioka, the midlatitude station is Manhay, and the high-latitude station is the Scott Base. Other stations apart from Pohnpei and Kiritimati, which are some distance from the EEJ stations, are regarded as the WSq stations. These are the low-latitude, midlatitude, and the high-latitude stations. The data utilized are those of January to December 1998.

[6] The quiet days used in the analysis are the international quiet days (IQDs) of each month of the year used. The range of $Sq(H)$ which is represented by dH were calculated for each of the IQDs and for the months, this was done after removing the noncyclic variation from the data. The two midnight averages of H were calculated for all the IQDs and dH was defined as the deviation of H from this midnight average. The calculations were carried out for all the 24 hours of the IQDs and all the months. The monthly mean values of dH were also calculated. Then the correlation coefficients (R) for all the stations were calculated at 10% significance level, employing

$$R_{dHadHb} = \frac{1}{n}\Sigma(dH_{ai}dH_{bi} - dH_a dH_b)/\sigma dH_a dH_b \qquad (1)$$

$$dH_a = \frac{1}{n}\Sigma dH_{ai} \qquad (2)$$

$$dH_b = \frac{1}{n}\Sigma dH_{bi} \qquad (3)$$

$$\sigma dH_a = \frac{1}{n}\Sigma(dH_{ai} - dH_a)^2 \qquad (4)$$

$$\sigma dH_b = \frac{1}{n}\Sigma(dH_{bi} - dH_b)^2 \qquad (5)$$

The summation runs from i to n (where n is the number of values in the batch). The dH_a and dH_b are various values of dH at two paired stations in the analysis. This was employed in calculating the coefficients of correlation between paired stations, in order to ascertain the relationship between the variations in H in EEJ latitude and other latitudes.

[7] On the contrasting phases of EEJ and WSq changes, the superposed horizontal magnetic field (SPMF) is defined as

$$h_t(\text{SPMF}) = h_t(\text{sample}) - h_t(\text{mean}Sq) \qquad (6)$$

following *Okeke et al.* [1998]. The h_t(SPMF) determines the hour-to-hour changes in the amplitude of $Sq(H)$ on a sample day relative to the monthly mean $Sq(H)$ amplitude [*Okeke et al.,* 1998]. In this analysis, h_t on a sample day is the mean of H on any other quiet day not inclusive in the IQDs of the month; for this study, 14 January was chosen as a sample day having Kp index generally $< 2-$. Then h_t (mean Sq) is the monthly mean Sq based on the five IQDs of each month. The values of SPMF were then plotted versus local time, from which the hour-to-hour changes in the amplitude $Sq(H)$ on this sample day relative to the monthly $Sq(H)$ amplitude i are determined. Fifty-six days having Kp index generally less than 4+ were used in this analysis.

3. Discussion of Results and Conclusion

[8] Table 2 depicts the values of correlation coefficients obtained when the dH values of these stations were correlated in pairs as shown in Tables 1 and 2. It is obvious that the two EEJ stations PON and KTM correlated highly with themselves, having a correlation coefficient of 0.76. On the other hand, when PON was correlated with the other latitude stations, not within the EEJ, it was noted that low and negative correlation coefficient were obtained. For example, when PON was correlated with SBA a correlation coefficient of 0.23 was obtained, while a negative correlation coefficient of −0.37 was obtained when PON was correlated with MAB. Also a low correlation coefficient of 0.29 was obtained when it was correlated with KAK.

[9] When the second EEJ station KTM was correlated with SBA, MAB, and KAK, the correlation coefficients obtained are 0.41, −0.33, and 0.16, respectively. One interesting result obtained is that SAB and MAB correlated very poorly, yielding a negative correlation coefficient of −0.98, even when both are regarded as the WSq stations. More noticeable is the correlation coefficient obtained for SBA and KAK, which is also −0.97. On the other hand, it should be noted that KAK correlated well with MAB, having a coefficient as 0.51. The contrasting and noncontrasting phases in both EEJ and WSq are illustrated in Figure 1.

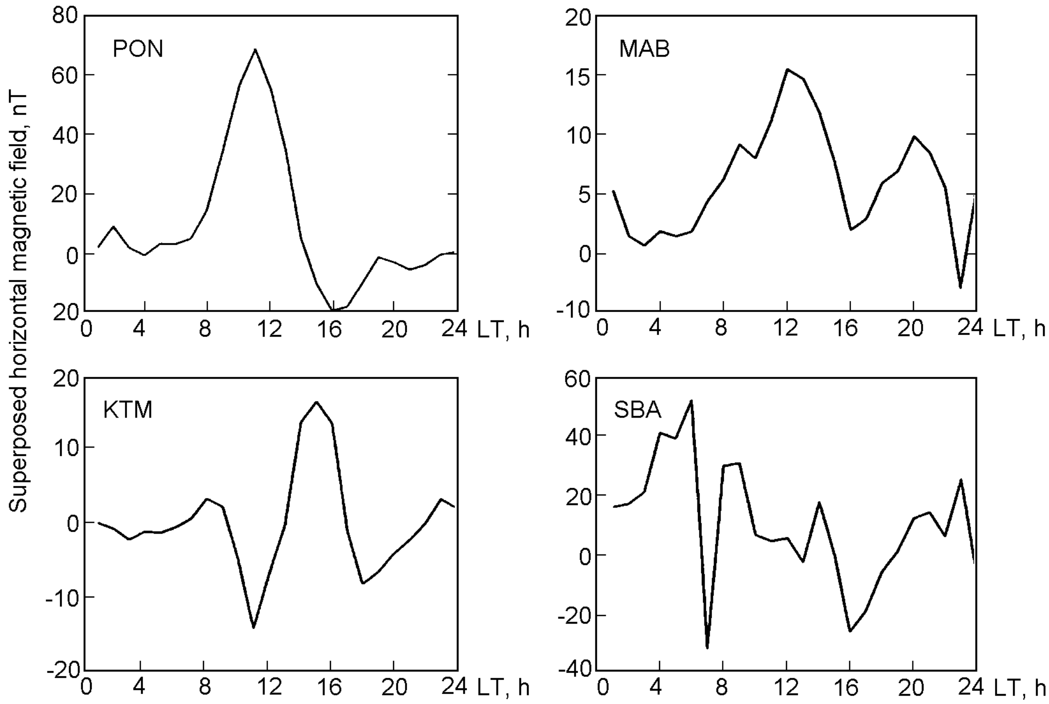

Figure 1. Diurnal variation of SPMF on 14 January 1998 at Pohnpei, Kiritimati, Manhay, and Scott Base.

[10] The correlation coefficient found are statistically significant for all the EEJ paired stations, but are found to be insignificant with other latitude stations (WSq stations). *Osborne* [1964] found little correlation between the electrojet and the rest of the Sq current system. This work is in variance with other works of *Forbes* [1981], *Hesse* [1982], *Mayaud* [1967], and *Schlapp* [1968], who found no significant difference between correlation coefficients of pairs of nearby equatorial stations involving /not involving the electrojet. On the other hand, this reconfirms the works of *Ogbuehi et al.* [1967], *Okeke and Onwumechili* [1993], and *Okeke et al.* [1998], who showed that the variabilities of the current intensities of the EEJ and WSq current layers are independent. It is also in agreement with works of *Greener and Schlaap* [1979], *Balsley* [1973], *Fejer* [1991], *Raghavarao and Anandarao* [1987] and some others. It has been shown that the scale of spatial coherence is less for station pairs separated in latitude than for those separated in longitude [*Greener and Schlapp*, 1979; [*Schlapp*, 1968]. This explains the correlation coefficients as obtained in Manhay and Scott Base, as well as that obtained in Kakioka and Scott Base and for that obtained in Manhay and Pohnpei.

[11] It has been noted that part of E_z in the EEJ regions is generated by E_y, several workers [e.g., *Raghavarao and Anandarao*, 1987; *Richmond*, 1973] have shown that local zonal winds produce also appreciable E_z. This is why the variations of WSq current intensity driven mainly by E_y, and the variability of EEJ current intensity driven by E_z, are not always correlated. This is the reason for the contrasting phase. From Figure 1, Pohnpei and Manhay are not in contrasting phase as depicted. This indicates that they are not always in contrasting phase. This could be as a result of some ionospheric irregularities and some contributions from effects on abnormal quiet days (AQDs). This could be attributed to counter electrojet on these AQDs. It is still concluded that EEJ current system and the WSq current system are independent. This results from the new virgin EEJ stations where no readings had ever been recorded, reconfirms as well as contradicts some of the results of other previous workers who carried out their work using older existing EEJ stations as it is evident from this study.

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Figure 2. Values of Correlation Coefficients

	SBA	MAB	KAK	PON	KTM
SBA	1.00	−0.98	−0.97	0.23	0.41
MAB	−0.98	1.00	0.51	−0.37	−0.33
KAK	−0.92	0.51	1.00	0.29	0.16
PON	0.23	−0.37	0.29	1.00	0.76
KTM	0.41	−0.33	0.16	0.76	1.00

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