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Investigating H and Z geomagnetic component disturbance field in the mid-latitude

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The relationship in the variations of geomagnetic horizontal component (H) and vertical component (Z) in Boulder station (40.1°N, 254.8°) has been investigated. In the analysis, series of significant changes in amplitude and period are observed in H as well as in Z during the day-time. The changes in H and Z for the average yearly diurnal variations and for the monthly variations do not exhibit consistent similar pattern for the years under study. The variations in H component of the field exhibit no significant peak around noon as should have been expected. The H component peak is observed to be positive throughout the period of study. The Z component variation was nearly mostly negative for all the years. Cause of these variations is expected to have arisen largely from different sources, either external or internal. It therefore seems that variations in H and Z component fields in mid-latitude as compared to those in equatorial electrojet regions are in contrast. The reason is attributed to the fact that cause of variation in equatorial electrojet (EEJ) regions emanate from the same source, while that in the mid-latitude emanate from different source.

Key words: Geomagnetic components, mid-latitude, disturbance field, variations, electrojet.

INTRODUCTION

Vonlland and Taubenheim (1958), made a very crucial discovery that magnetic intensity decreases with latitude. Bhargava and Yacob (1971) had shown that increasing values of geomagnetic disturbance index, Ap, are associated with increasing values of daily means of geomagnetic field. Sarabhai and Nair (1969) had earlier suggested that the daily variation of the horizontal intensity at a low latitude station, outside the effect of EEJ is due to a decrease of the ambient field on the night side rather than an increase during the day time.

It is important to note that the disturbance daily variation SD, which depends on local time, is not a constant intensity but could decrease from the first to the second day of the storm. Its variation is also very different from that of Sq, both in times of max and min and in relation to latitude. One of the most striking features of the characteristics of the D- field is the increasing predominance of the SD part of the field as compared with the Dst part, when auroral zone is being approached from the low latitudes.

It has earlier been observed that for middle and low latitudes, Sq variation is greatest during the day hours having a sharp peak shortly before noon. In contrast, SD variation is mainly diurnal with an early morning peak.

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In the past, Vestine (1947) attributed ionospheric current systems of appropriate forms and strength.

Onwumechili (1959) studied the relation between H- and Z- component variation near equatorial electrojet station. In his study, it was found that H and Z both increase and decrease together; it was concluded that these variations in both H and Z could arise from the same cause; hence they have much in common.

Work of Fambitakoye (1971) gave the first latitudinal profile of dH and dZ due to normal and counter electrojet events using nine equatorial stations in central Africa.

Rastogi (2006) found that during heavy storm, variations in H field component near the earth surface are higher at stations closer to magnetic equator. He attributed the cause of the special storm time effect to additional westward electric field imposed due to the interaction of solar wind with interplanetary magnetic field (IMF).

Okeke and Hamano (2000) found that the amplitude of dH has diurnal variation which peaks during the day at about local noon in all the three EEJ regions, which they attributed to the enhanced dynamo action at these three stations.

Messanga et al. (2014) examined the variability of H component of geomagnetic field in Central African sector provided by Yaounde Cameroon Amber. It was found that the scattering of H component of magnetic field variation is more on disturbed than that on quiet condition.

Jean-Louis et al. (2013) investigated solar events through geomagnetic activities and physical processes on the sun. Their results confirm the classification scheme that quiet activity reflects slow wind effects, while recurrent activity effects reflects high wind stream and unclear activity answers to the fluctuations between high wind stream and slow wind effects. From available literature, it is obvious that much work has been carried out on H, Z in connection with EEJ zones, while little attention has been given to H and Z in mid-latitude. Hence, it becomes pertinent that this study be carried out so as to compare the variations in H and Z geomagnetic components in mid-latitude with those in EEJ zones.

Sources of data

The geomagnetic field data for Boulder Colorado (40.1°N, 254.8°E), was obtained from World Data Center (WDC) for geomagnetism, Kyoto, Japan. The disturbed days for the disturbance field variation were selected as the five most disturbed days of each month for the nine years (1990 – 1998), employed in this study.

METHODS OF ANALYSIS

The nine years diurnal variations were computed using MatLab software. The average of the hours of the five most disturbed days of each month was equally computed, this yields the monthly disturbance field values. Tables 1, 2 and 3 depict S_d variations of H component, S_d variations for the Z components and average monthly S_d variation for H and Z components for the year 1990 to 1998. The base line is defined as:

$$H_O = (H_1 + H_2 + H_{23} + H_{24})/4 \quad (1)$$

Where H_1, H_2, H_3 and H_{24} are the four hours flanking local mid night.

The amplitude of the hourly variation is given by:

$$\Delta H_{s_d} = (H_i - H_0) \quad (2)$$

Where H_i is the ith hour of H –component value.

Then, the Z- component variation is given by:

$$\Delta Z_{s_d} = (Z_i - Z_0) \quad (3)$$

Where Z_0 and Z_i are the base line values for each month and ith hour value respectively.

The disturbed value is split into two parts: (i) the storm-time variation, (Dst) (ii) the solar daily disturbance (SD) or disturbance local – time equality Ds. The disturbance field D is given by:

D = Dst + Ds

and

<D> = Dst + SD

<D> is the average D over 24 h.

This has been taken care of and in this work is referred to as disturbance field.

DISCUSSION

The results presented in Figure 1a to i in this study demonstrate that the diurnal variation in H and Z on international disturbed days for all the nine years under study depict that generally, the features are different for each year. One striking feature of the variation is that while Sd of H maintains the positive for the diurnal variation, Sd of Z consistently remains negative, except for the year, 1997 and 1998. Though in 1993, Figure 1d, both Sd of H and Z attained three maxima at early hours, at 02hrUT, 10hr UT and 16hr UT, this is a striking and abnormal situation. For these two years, 1997 and 1998, it could been seen that both Sd of H and Z continued to be zero until about 18 to 22 h UT and approximately at 14 to 16 h UT respectively. This is another striking and abnormal feature. This could be attributed to the modification of wind and ionospheric conductivity, an observation that is at invariance with the result of Onwumechili (1959).

The average monthly Sd variations for both Sd of H and Z from 1990 to 1998 (Figure 2a to i) show that both variation in H and Z are similar in pattern, still H maintaining positive, while Z negative in most cases, indication that the cause of variation is likely to be from different sources. Except for Figure 2c and h (1992 and

Table 1. Sd variations for H component.

Time	Year								
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
0	- 08.00	- 12.00	- 42.00	- 121.00	- 03.00	- 05.00	00.00	- 05.00	- 05.00
1	08.00	12.00	42.00	121.00	03.00	05.00	00.00	05.00	05.00
2	02.00	03.00	- 115.00	02.00	00.00	01.00	01.00	03.00	02.00
3	01.00	00.00	- 119.00	03.00	- 01.00	00.00	00.00	00.00	- 01.00
4	04.00	02.00	- 118.00	03.00	02.00	02.00	- 01.00	00.00	- 04.00
5	07.00	09.00	- 176.00	02.00	04.00	03.00	02.00	- 02.00	- 07.00
6	09.00	08.00	- 163.00	04.00	03.00	03.00	05.00	00.00	- 03.00
7	10.00	04.00	- 120.00	02.00	08.00	05.00	08.00	03.00	- 01.00
8	10.00	- 01.00	- 121.00	- 36.00	07.00	09.00	09.00	04.00	00.00
9	08.00	01.00	- 119.00	124.00	08.00	09.00	12.00	05.00	05.00
10	11.00	04.00	- 119.00	06.00	12.00	13.00	11.00	07.00	08.00
11	11.00	07.00	- 116.00	08.00	14.00	13.00	12.00	08.00	10.00
12	11.00	11.00	- 113.00	10.00	14.00	14.00	13.00	10.00	10.00
13	12.00	07.00	- 162.00	13.00	15.00	14.00	14.00	12.00	10.00
14	02.00	- 08.00	- 115.00	- 35.00	04.00	04.00	07.00	04.00	158.00
15	- 11.00	- 23.00	- 163.00	114.00	- 01.00	- 05.00	- 03.00	- 04.00	- 10.00
16	- 21.00	- 35.00	- 53.00	- 12.00	- 09.00	- 11.00	- 09.00	- 11.00	- 19.00
17	- 29.00	- 45.00	- 25.00	- 13.00	- 15.00	- 14.00	- 10.00	- 14.00	- 22.00
18	- 31.00	- 42.00	- 128.00	- 12.00	- 15.00	- 12.00	- 09.00	- 14.00	- 20.00
19	- 30.00	- 37.00	- 171.00	- 51.00	- 11.00	- 10.00	- 06.00	252.00	- 19.00
20	- 24.00	- 30.00	113.00	- 45.00	- 07.00	- 07.00	- 02.00	256.00	- 12.00
21	- 14.00	- 20.00	- 37.00	00.00	- 03.00	- 04.00	00.00	- 07.00	- 07.00
22	- 07.00	- 07.00	05.00	03.00	- 02.00	- 03.00	- 01.00	- 06.00	- 04.00
23	- 03.00	- 08.00	52.00	03.00	- 01.00	- 02.00	00.00	- 03.00	- 03.00

Table 2. Sd variations for Z component.

Time	Year								
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
0	- 03.00	06.00	- 39.00	- 119.00	- 03.00	00.00	- 01.00	00.00	- 01.00
1	03.00	- 06.00	39.00	119.00	03.00	00.00	01.00	00.00	01.00
2	03.00	- 02.00	- 52.00	01.00	03.00	01.00	01.00	01.00	01.00
3	01.00	- 01.00	03.00	00.00	01.00	01.00	01.00	02.00	03.00
4	01.00	- 05.00	04.00	- 01.00	00.00	00.00	01.00	01.00	03.00
5	- 01.00	- 09.00	- 50.00	- 03.00	- 05.00	- 02.00	00.00	00.00	00.00
6	- 03.00	- 16.00	- 42.00	- 07.00	- 08.00	- 05.00	- 03.00	- 03.00	- 06.00
7	- 06.00	- 24.00	- 09.00	- 11.00	- 14.00	- 09.00	- 05.00	- 05.00	- 12.00
8	- 11.00	- 30.00	- 11.00	- 55.00	- 19.00	- 13.00	- 07.00	- 07.00	- 15.00
9	- 13.00	- 34.00	- 13.00	101.00	- 24.00	- 12.00	- 09.00	- 09.00	- 17.00
10	- 18.00	- 39.00	- 18.00	- 17.00	- 26.00	- 16.00	- 10.00	- 09.00	- 23.00
11	- 21.00	- 42.00	- 16.00	- 15.00	- 28.00	- 18.00	- 10.00	- 11.00	- 25.00
12	- 19.00	- 43.00	- 14.00	- 13.00	- 28.00	- 18.00	- 09.00	- 12.00	- 26.00
13	- 10.00	- 45.00	- 65.00	- 09.00	- 25.00	- 17.00	- 08.00	- 12.00	- 24.00
14	- 19.00	- 41.00	- 01.00	- 46.00	- 22.00	- 17.00	- 08.00	- 11.00	138.00
15	- 24.00	- 42.00	- 39.00	110.00	- 23.00	- 19.00	- 10.00	- 13.00	- 21.00
16	- 31.00	- 44.00	78.00	- 12.00	- 26.00	- 22.00	- 16.00	- 17.00	- 24.00
17	- 36.00	- 44.00	102.00	- 15.00	- 27.00	- 25.00	- 19.00	- 20.00	- 26.00
18	- 36.00	- 39.00	- 06.00	- 15.00	- 26.00	- 23.00	- 19.00	- 20.00	- 23.00
19	- 34.00	- 31.00	- 82.00	- 51.00	- 22.00	- 19.00	- 15.00	- 16.00	- 19.00

Table 2. Contd.

20	- 26.00	- 20.00	159.00	- 46.00	- 16.00	- 13.00	- 11.00	- 11.00	- 13.00
21	- 16.00	- 10.00	06.00	- 01.00	- 11.00	- 08.00	- 06.00	- 06.00	- 07.00
22	- 07.00	02.00	49.00	05.00	- 06.00	- 03.00	- 02.00	- 01.00	- 03.00
23	00.00	06.00	119.00	12.00	00.00	01.00	00.00	01.00	01.00

Table 3. Average monthly Sd variations for H and Z components for the years 1990 to 1998.

Year	Months											
	JAN	**FEB**	**MAR.**	**APR.**	**MAY**	**JUN.**	**JUL.**	**AUG.**	**SEP.**	**OCT**	**NOV**	**DEC**
1990H	06.00	14.00	09.00	- 25.00	- 09.00	- 12.00	00.00	- 09.00	- 06.00	03.00	- 03.00	- 02.00
1990Z	-02.00	- 10.00	- 29.00	- 39.00	- 25.00	- 28.00	00.00	- 09.00	- 09.00	- 11.00	- 03.00	- 02.00
1991H	00.00	09.00	- 17.00	- 10.00	- 12.00	- 41.00	- 29.00	- 10.00	- 01.00	06.00	01.00	09.00
1991Z	00.00	- 04.00	- 40.00	- 23.00	- 18.00	- 40.00	- 41.00	- 26.00	- 19.00	- 31.00	- 41.00	- 07.00
1992H	- 1004.00	- 21.00	- 05.00	16.00	- 15.00	40.00	08.00	12.00	- 91.00	76.00	- 02.00	- 77.00
1992Z	149.00	- 16.00	07.00	05.00	- 04.00	45.00	00.00	07.00	- 84.00	76.00	03.00	116.00
1993H	105.00	- 07.00	- 46.00	39.00	00.00	01.00	00.00	02.00	- 01.00	- 04.00	04.00	06.00
1993Z	105.00	- 01.00	- 36.00	38.00	05.00	01.00	- 13.00	- 22.00	- 20.00	- 10.00	- 15.00	- 15.00
1994H	01.00	11.00	07.00	00.00	00.00	06.00	05.00	06.00	- 06.00	- 04.00	- 09.00	- 02.00
1994Z	- 04.00	- 29.00	- 12.00	- 34.00	- 22.00	- 12.00	- 17.00	- 10.00	- 11.00	- 16.00	- 09.00	- 05.00
1995H	04.00	08.00	07.00	- 07.00	- 04.00	- 04.00	10.00	- 01.00	- 04.00	06.00	00.00	- 02.00
1995Z	- 06.00	- 08.00	- 13.00	- 11.00	- 19.00	- 14.00	- 12.00	- 10.00	- 14.00	- 14.00	- 07.00	- 05.00
1996H	- 01.00	01.00	09.00	04.00	00.00	- 02.00	01.00	- 01.00	07.00	07.00	03.00	00.00
1996Z	- 04.00	- 04.00	- 08.00	- 11.00	- 09.00	- 07.00	- 08.00	- 09.00	- 09.00	- 05.00	- 05.00	- 04.00
1997H	- 07.00	09.00	06.00	05.00	00.00	- 04.00	- 05.00	- 06.00	- 02.00	04.00	269.00	- 01.00
1997Z	- 06.00	- 09.00	- 07.00	- 10.00	- 15.00	- 11.00	- 06.00	- 07.00	- 08.00	- 09.00	- 02.00	- 04.00
1998H	- 01.00	15.00	05.00	80.00	- 08.00	- 01.00	- 04.00	- 16.00	- 11.00	- 07.00	- 08.00	- 05.00
1998Z	- 03.00	- 09.00	- 11.00	75.00	- 22.00	- 12.00	- 11.00	- 34.00	- 14.00	- 07.00	- 20.00	- 05.00

Tables 1, 2 and 3 depict S_d variations of H component, S_d variations for the Z components and average monthly S_d variation for H and Z components for the year 1990 to 1998.

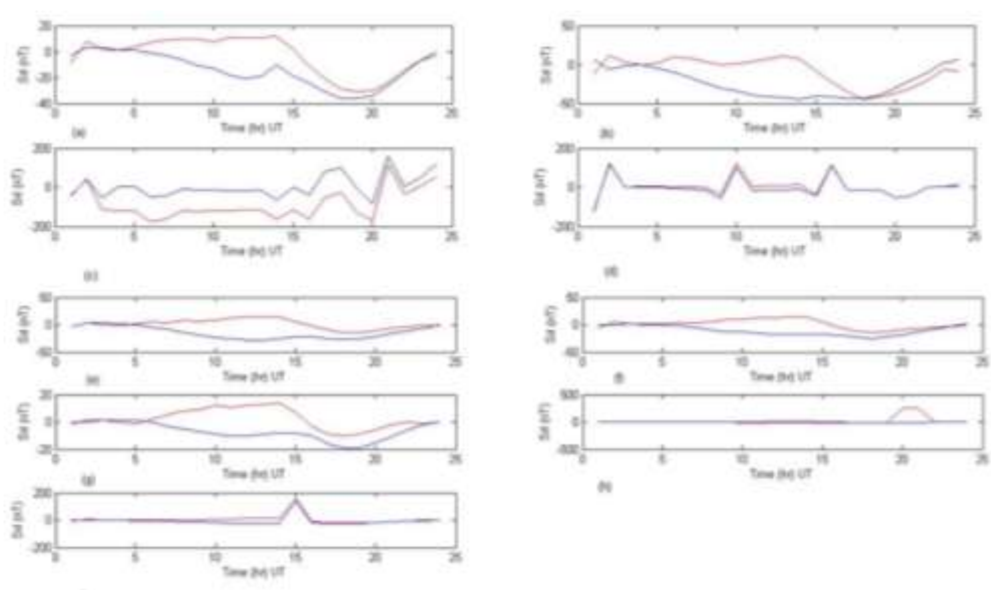

Figure 1 (a-i). Sd diurnal variations for H and Z components from 1990-1998.

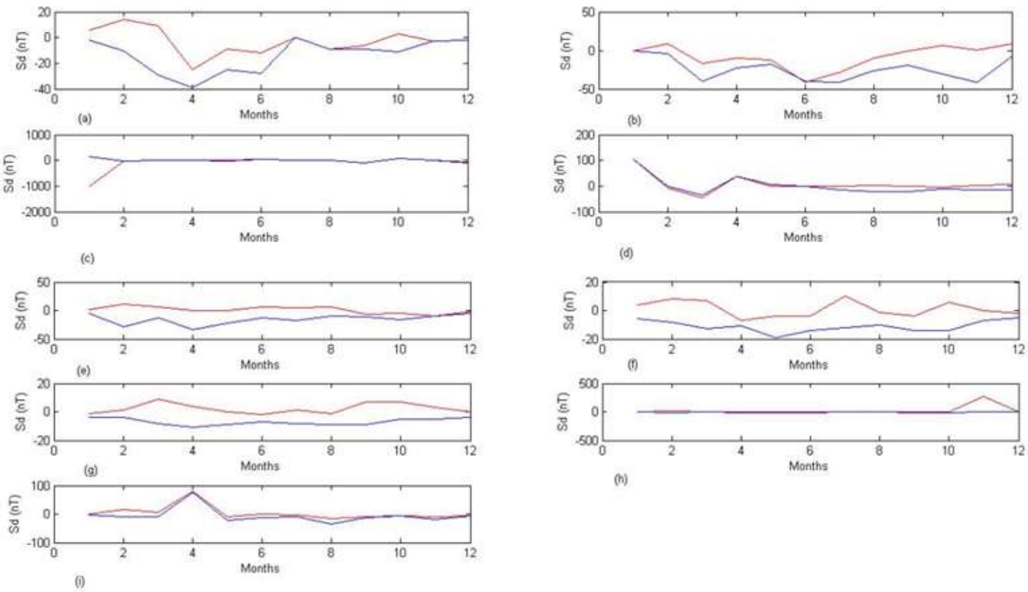

Figure 2 (a-i). Average monthly Sd variations for H and Z components from 1990-1998.

1997) depict very different pattern of variation in both, particularly in 1997 in both Figures 1h and 2h, the same horizontal line along zero is observed. This could be due to extra galactic origin. This year 1997 could be regarded as an abnormal year that requires a further research work for more robust deduction. This could lead to investigation on the relationship between cosmic rays and geomagnetic field variations that invariably will contribute to causes of climate change.

Conclusion

Results of our analysis are compared with those carried out around the dip equator. The comparison confirms that the variation of H and Z components in mid latitudes as compared with the equatorial region is in contrast. The reason being that those in the equatorial electrojet regions come from the same source while those of the mid latitudes are from different sources. It is deduced that the daily diurnal variation of SD horizontal intensity at this mid latitude could be equally attributed to decrease of the ambient field during the night rather than the increase during the day.

Conflict of Interests

The authors have not declared any conflict of interests.

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