Equatorial Electrojet Movements at Huancayo and Eusébio (Fortaleza) on Selected Quiet Days

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(Received March 28, 1984; Revised September 17, 1984)

The $H$ and $Z$ variations for the Five International Quiet Days, each in October 1978 and February 1979, were compared for Huancayo (12°S, 75°W, dip +1.9°) and Eusébio near Fortaleza (4°S, 39°W, dip −3.5°). The $H$ ranges at both the locations fluctuated widely but not parallel to each other, indicating violent, rapid space-time variations of the equatorial electrojet characteristics. The $Z$ patterns were generally dissimilar at the two locations and indicated large scale latitudinal meanderings of the electrojet center from day to day as also during the same day.

1. Introduction

The large magnitude of the daily variation range of the $H$ component ($H_{\text{max}} - H_{\text{min}}$) of the geomagnetic field at the dip equator is attributed to an overhead "electrojet" current in the ionospheric $E$ region. The current is envisaged to be in the form of a wide, nonuniform sheet, with maximum current density at its center. For the $H$ component observed at ground, the range is maximum below the latitudinal center, which is expected to coincide with the dip equator. In contrast, the $Z$ (vertical) component is expected to show no daily variation for locations at the dip equator but increasing amplitudes on either side, but the sense reversed from north to south. As such, an examination of both the $H$ and $Z$ components should, in principle, yield information about the strength and location of the overhead electrojet. However, complications arise because of induction effects. The overhead ionospheric current induces currents in the interior of the earth and what is observed at the surface of the earth is a combined effect of the source field and the induced field.

The induction effects can be quite complicated. In general, the effect of induction is to enhance the $H$ range and decrease the $Z$ range. Detailed calculations and theoretical estimates have been presented by PRICE (1967). The nature of the terrain is very important. For example, MASON (1963) showed that in the Hawaiian island region, considerable differences were found between the $Z$ records for stations only 20 km apart, with phase differences as large as 30° for the 24-h harmonic. The differences observed in the $H$ and $D$ records were
much smaller. In coastal areas too, the amplitude of the $Z$ variations reveals considerable dependence on the distance from the coast (Schumacher, 1964; Rikitake, 1964). The induced effects are more pronounced for short periods than for long period variations. However, the effects are considerable even for the 24-h variation and can be as large as 30% (ratio of $H$ internal to $H$ external). In the case of the $Z$ variation, the effect would depend considerably upon the local geological structure.

It is obvious, therefore, that a ratio of the $Z$ range to the $H$ range may not give correct information about the location of the center of the overhead electrojet current sheet. However, there is one redeeming factor. The conductivity structure of the earth, even in highly anomalous regions, does not change rapidly, certainly not from day to day. Hence, if some changes are observed on two consecutive days or even within a few days interval, it is almost certain that these changes are not of geological origin, and these could be safely attributed to changes in strength and/or position of the external source field. In an earlier communication (Kane and Trivedi, 1980), we had shown that the simultaneous study of the $H$ and $Z$ variations indicated possible latitudinal movements of the overhead electrojet current sheet. In a recent communication (Kane and Trivedi, 1982), we had the opportunity to present a comparison of the average electrojet characteristics observed at Huancayo, Peru (12°S, 75°W, dip +1.9°) and at Eusébio (Fortaleza) Brazil (4°S, 39°W, dip -3.5°). In this communication, we present a similar comparison for two groups of Five International Quiet Days viz. Oct. 6, 7, 14, 15, 16, 1978 and Feb. 10, 13, 14, 17, 20, 1979.

2. Results

Figure 1 shows a plot of $H$ and $Z$ components (upper and lower half) at Huancayo (crosses and dashes) and Eusébio (full lines). The plot is of 20 min values, for Oct. 6, 1978, the First Int. Quiet Day in October 1978. The ordinate scales are common for both Huancayo and Eusébio and the zero level is matched for the near midnight hours (2200–2400 LT). The profile of the electrojet strength, as seen from the $H$ plots, is similar at Huancayo (HU) and Eusébio (EU) except that the $H$ range is much larger (~230 nT) at Huancayo as compared to Eusébio (~140 nT). The ratio EU($H$)/HU($H$) is only about 60%. Since the dip latitude of Eusébio is 3.5° in contrast to 1.9° for Huancayo, Eusébio is farther away from the dip equator and hence is expected to show a range only about 90% of that at Huancayo as shown by Kane and Trivedi (1982) for the Peruvian region during IGY. The observed ratio of 60% shows that the inherent strength of the equatorial electrojet was lesser at Eusébio as compared to Huancayo, by about 30%. In the earlier paper (Kane and Trivedi, 1982) also, a similar effect was pointed out.

The abscissa scale in Fig. 1 shows Local Time. Since the longitudes of the two locations are different (75°W and 39°W), the plotted data are not simultaneous but differ by about 35° (2.3 hours) in UT. The hours of maxima at the two
Equatorial Electrojet Movements at Huancayo and Eusébio

The interesting part is the lower half showing the $Z$ variations. Since the two locations are on opposite sides (Huancayo to the north, Eusébio to the south) of the dip equator, the $Z$ variations are expected to show opposite types of daily variations i.e. when Huancayo shows a maximum of $Z$, Eusébio is expected to show a minimum (and vice versa). Hence, for ease of comparison, we have inverted the plot of Huancayo $Z$, so that, under ideal conditions, the two plots should look alike in form. What one actually observes is a very significant difference between the two plots. Thus, whereas Eusébio ($Z$) shows a maximum at about 1100 LT, same as for Eusébio ($H$), the Huancayo ($Z$) shows a very broad maximum extending from 1100 LT to 1500 LT. There is no easy explanation for such a behaviour based on any imaginable induction effect and one is led to assume a latitudinal excursion of the electrojet away from Huancayo during 1100–1500 LT. However, let us assume for arguments sake that the $Z$
patterns seen in Fig. 1 are the natural patterns at Huancayo and Eusébio and the differences may be due to Huancayo being in the Andes anomaly and Eusébio being a coastal location, and, let us examine data on other days.

Figure 2 shows similar plots for the next day i.e. Oct. 7, 1978 which happened to be the Second International Quiet Day in Oct. 1978. The electrojet strengths on this day were ~160 nT at Eusébio and ~220 nT at Huancayo, giving a ratio of ~70%, in contrast to ~60% the previous day. Thus, within a day, Eusébio electrojet strength has increased by about 15%. However, on this Second Int. Quiet Day, the $Z$ patterns at the two locations are almost alike in phase and, at both locations, the $Z$ maxima occurred about 2 hours later (1400 LT) as compared to the $H$ maxima (1200 LT). Thus, soon after noon, the electrojet moved away from both the locations.

Similar plots (not shown here) were made for the 3rd, 4th and 5th International Quiet Days viz. Oct. 14, 15, 16, 1978. It was noticed that, on the Five International Quiet Days in Oct. 1978, the $H$ and $Z$ variations at Huancayo and Eusébio exhibited large dissimilarities, both in the strength of the electrojet as also in the position of the electrojet center vis a vis the two locations. In

Fig. 2. Plots of $H$ and $Z$ for Oct. 7, 1978 (Second Int. Quiet Day in Oct. 1978).
general, the electrojet center was to the south of Huancayo and to the north of Eusébio; but on Oct. 14, 1978. Eusébio (Z) indicated the possibility of the electrojet center hovering over Eusébio.

We now examine the data for the Five International Quiet Days in Feb. 1979, a summer month for this region. Figure 3 shows a plot for Feb. 10, 1979, the First Int. Quiet Day in Feb. 1979. Surprisingly, the \(H\) ranges at Huancayo and Eusébio are almost equal, indicating considerable relative strengthening of the electrojet at Eusébio. The Z patterns at the two locations are dissimilar. Huancayo (Z) has two peaks at \(\sim 1000\) LT and \(1600\) LT while Eusébio (Z) has only one prominent peak at \(1300\) LT.

Figure 4 shows the plot for Feb. 14, 1979. The Huancayo (\(H\)) range was very large on this day (\(\sim 270\) nT). Hence, Eusébio (\(H\)), which was also large (\(\sim 180\) nT), had only a ratio of \(\sim 65\%\). The Z variations on this day were very odd. Huancayo (Z) showed a very broad maximum from \(1100\) LT to \(1500\) LT. During this time, Eusébio (Z) was very small. On the other hand, the early part of the day (\(0500-1000\) LT) shows a very large negative variation of Eusébio (Z). This looks very odd and needs further scrutiny. We suspect some data errors.

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**Fig. 3.** Plots of \(H\) and \(Z\) for Feb. 10, 1979 (First Int. Quiet Day in Feb. 1979).
Figure 4 shows the plots for Feb. 17, 1979, the Fourth Int. Quiet Day. On this day, Eusébio (H) exceeds Huancayo (H). Also, whereas Eusébio (Z) has a pattern similar to Eusébio (H), the pattern of Huancayo (Z) is very odd. Up to about midday, Huancayo (Z) is almost zero, indicating the possibility that the electrojet center was overhead of Huancayo. Later, the electrojet moved away, giving positive values to Huancayo (Z) which reached a maximum at about 1600 LT.

Similar plots were made for Feb. 13 and 20, 1979 but are not shown here.

3. Summary and Conclusions

A comparison of the H and Z plots at the equatorial locations, Huancayo (12°S, 75°W, dip +1.9°) and Eusébio (4°S, 39°W, dip −3.5°) in the South-American continent, for the Five International Quiet Days, each in Oct. 1978 and Feb. 1979, indicated the following:

(1) The H ranges at Huancayo and Eusébio showed very large variations
from one quiet day to another but not always parallel. Hence, the ratio \( \text{EU}(H)/\text{HU}(H) \) varied widely from 50% to 110%. Considering the fact that the two locations are separated by only about 2 1/2 hours in LT, this indicates very rapid, violent space-time variations of the equatorial electrojet characteristics.

(2) The profiles of the \( H \) component plots were generally similar at Huancayo and Eusébio (narrow or broad). However, the hour of maxima was sometimes earlier, sometimes the same and sometimes later at Eusébio as compared to that at Huancayo.

(3) The \( Z \) patterns at Huancayo and Eusébio were generally dissimilar. Sometimes, Eusébio (\( Z \)) showed a maxima at about 1100 LT, same as Eusébio (\( H \)). But Huancayo (\( Z \)) showed a delayed maximum, at about 1400 LT.

(4) The magnitudes of the \( Z \) ranges varied widely from day to day at both the locations. Large scale latitudinal meanderings of the electrojet center were indicated, sometimes reaching even overhead of the two locations, but not simultaneously.

Ground anomalies in the Andes where Huancayo is situated are well-known.
Similarly, coastal effects at Eusébio, Fortaleza, are expected. These will certainly distort the pattern of $Z$ variations vis-à-vis the $H$ variations at both these locations. The presence of induction effects for the equatorial electrojet seems to be presently a controversial topic. For example positive results (about 25% induction) have been reported (amongst others) by ONI and ALABI (1972) for the Nigerian region, by FORBUSH and CASAVERDE (1961) for the Peruvian region, by YACOB and BHARGAVA (1973) for the Indian region and by CARLO et al. (1982) for the Ethiopian region. In contrast, MAYAUD (1974) reports an insignificant induced component in the Chad region. However, such distortions would be essentially permanent features. If, therefore, the patterns are seen to vary radically from one day to another, large scale variations in the strength and location of the overhead current system would be a reasonable conclusion. It is likely that the latitudinal excursions of the equatorial electrojet so indicated, both from one day to another as also during the same day, may be related to the encroachment of the northern and southern Sq current systems into each other, as pointed out by PRICE and STONE (1964) and HUTTON (1967a, b) from $D$ variations studies. This needs further scrutiny. A close net-work of observatories in this equatorial region should prove very valuable indeed.

Thanks are due to WDC-A for Solar Terrestrial Physics (Geomagnetism) Boulder, Colorado for the Huancayo data and to the Univ. of California at Los Angeles (UCLA) for collaboration in establishing the IMS Magnetic station at Eusébio and furnishing the data. This work was partially supported by FNDCT, Brazil under contract FINEP-537/CT.

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