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LONGITUDINAL EXTENT OF COUNTER ELECTROJET EVENTS

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The global extent in longitude of the occurrence of the counter electrojet events has been studied using the hourly values of the horizontal component of the earth's magnetic field observed at three equatorial stations, namely Huancayo (Geog. Long. - 75°W, Dip - 14°N), Addis Ababa (Geog. Long. - 39°E, Dip - 0°S) and Trivandrum (Geog. Long. - 77°E, Dip - 0.5°S) during sunspot minimum years. It is observed that during November, December and January months, counter electrojet events are observed in all three places at the same local time. This large longitude extent is explained in terms of local wind modulating the global tidal components, while the limited longitude extent during certain events is explained in terms of the modulation due to quiet time magnetopause current system, as well as disturbance dynamo effects.

A EXTENSÃO LONGITUDINAL DE EVENTOS DE ELETROJATO REVERSO *Estudou-se a extensão global em longitude da ocorrência de eventos de Eletrojato reverso usando valores horários do componente horizontal do campo geomagnético observado em três estações equatoriais, Huncayo (-75° W, Dip -1,4° N), Adis Abeba (-39° E, -0° S) e Trivandrum (-77° E, -0,5° S) durante períodos anuais de mínimo em manchas solares. Nota-se que durante novembro, dezembro e janeiro, nos três locais acima, observam-se eventos de Eletrojato reverso na mesma hora local. Essa faixa grande em longitude é explicada em termos dos ventos locais modulando as componentes globais das marés, ao passo que a extensão longitudinal menor observada em alguns eventos é explicada em termos da modulação devida ao sistema de corrente da magnetopausa de período calmo, como também efeitos do dínamo perturbado.*

INTRODUCTION

The Equatorial Electrojet (EEJ) is an intense band of electric current, which flows along the magnetic dip equator in the E region (90-120 km) of the ionosphere. The equatorial enhancement of the ionospheric current is explained as being due to the large vertical polarization field maintained within only a few degrees on either side of the dip equator, due to large anisotropy of the ionospheric conductivity in combination with the horizontal magnetic field of the earth. The vertical polarization field in turn drives the electrojet by the ExB drifts (westwards) of electrons constituting an eastward current, which varies with local time, primarily as the electron densities in the E region vary with the zenith angle of the ionizing UV and EUV radiations from the sun. One of the most intriguing aspects of the equatorial electrojet is the reversal of this eastward flow of current to westward current in the early morning (0500-0700 LT) and afternoon (1400-1600 LT) hours, as indicated by the horizontal component of the earth's magnetic field (H) decreasing below the nighttime level. The reversal of the normal eastward current to westward current is named as the equatorial counter electrojet (CEJ) by Gouin (1962) and Gouin and Mayaud (1967). In the last four decades, large number of studies (Rastogi, 1974, 1989; Mayaud, 1969, 1977; Reddy, 1977, 1981, 1989; Forbes, 1981 and references therein - all excellent review articles dealing with the magnetic aspects of the equatorial electrojet) on the equatorial magnetic field variations during CEJ events have shown that (i) the phenomenon is generally confined to equatorial electrojet latitudes and its occurrence is highly unpredictable and (ii) the longitude extent of the event is very small such that out of two stations separated in longitude by 30-60° (local time by about 2 to 3 hours), CEJ is observed only at one of the stations.

The confinement of the CEJ phenomenon to equatorial electrojet latitudes can be explained only in terms of the current reversals caused by abnormal local wind fields (Reddy and Devasia, 1981; Ananda Rao and Raghava Rao, 1987). Somayajulu et al (1993 - this issue), utilizing the observations of the measured mean winds and the amplitudes and phases of the tidal components at an equatorial station, Trivandrum, using the meteor wind radar have shown the presence of westward winds of sufficient magnitude in near coincidence with a sequence of CEJ events in June and January. The controversy regarding the longitudinal extent of the CEJ events, in our opinion, has merely occurred because of the series of days considered by different authors (Rastogi, 1973, 1974; Kane, 1976 and references therein) include some moderately disturbed days, thus bringing in the disturbance dynamo effects (Blanc and Richmond, 1980) to dominate in certain longitude sectors. However, Onwumechili and Akasofu (1972) and Marriott et al. (1979) (using the same sequence of days of January 12-15, 1964 at different longitudes) have come to the conclusion that the longitude extent of the CEJ event is commonly spread over 5 - 8 hours and sometimes occurs within a much wider band during January months (Mayaud, 1977). In this paper, from a detailed study of (only 22 CEJ events are presented), 60 CEJ events, it is shown that the CEJ events have limited longitude extent on certain days because of the disturbance dynamo effects, as well as the modulating effect of magnetopause current system in certain longitudes.

DATA ANALYSIS

In this study, published hourly values of the variation of the horizontal component 'H' of the earth's magnetic field, for the year 1962-1965 and 1975-1977, at three stations namely Trivandrum (Geog. Lat. - 8.2°N, Geog. Long. 77°E, Dip - 0.5°S), Huancayo (Geog. Lat. - 12.1°S, Geog. Long. 75°W, Dip - 1.3°N) and Addis Ababa (Geog. Lat. - 8.5°N, Geog. Long. - 39°E, Dip - 0°) are used for the detailed study of the longitudinal extent. The study has been restricted to magnetically quiet days, which satisfy the criterion set forth by Mayaud (1969). The criterion is that $A_p \leq 6$ for 48 hours centered on the UT noon of the selected day. We have considered only those periods in which the CEJ has occurred at least on three consecutive days. The nighttime baseline values for the CEJ days were obtained by taking the average of the magnetic field values during 0000-0400 hours LT for each station, after applying the necessary D_{st} correction. Thus, the variations of the horizontal component of the earth's magnetic field (ΔH) shown in all the figures are above and below this baseline value. The study includes afternoon CEJ events only. It is to be mentioned that the shape, duration and exact local time of occurrence of these CEJ events at all three stations may not coincide exactly as many of the procedures adopted in the reduction of the hourly magnetic field values at the laboratories may not be common. Further, it is to be emphasized that the present study does not aim at a quantitative understanding of the shape, size and duration of the CEJ events.

RESULTS

Fig. 1 shows the local time variations of the horizontal component (ΔH) of the earth's magnetic field above the average nighttime level at Trivandrum (TRV), Addis Ababa (AAE) and Huancayo (HUN), during three consecutive CEJ events, observed from January 13-15, 1964 which have been studied by Rastogi (1974) and Onwumechili and Akasofu (1972). Marriott et al. (1979) have made a detailed theoretical simulation of this event to explain the day-to-day variability of the CEJ intensity. The numbers shown in the ΔH variations of Fig. 1 are the electrojet strength in nanotesla, above the nighttime level, indicating the largest daily H variation and the maximum intensity of the CEJ event, defined as the magnetic field strength reached below the nighttime level. The most interesting point to be noted is that the CEJ event is discernible at all the three stations with varying intensities. The CEJ event is very strong at Huancayo with a maximum value of -86nT on January 13, 1964 and a maximum value of -40nT on January 14, 1964. The CEJ event is weak at Trivandrum and only an indentation is seen on January 15, 1964, whereas at Addis Ababa the intensity of the CEJ events varies from -16nT to -28nT. Within the error limits, the local times at which the electrojet strength maximum occurs coincide at all the three stations. Fig. 2 shows the universal time (UT) variations of ΔH at the three stations during January 13-15, 1964. Note that the universal times of the maximum in electrojet strength and the minimum in ΔH during the CEJ event at the electrojet stations are separated by times, approximately equivalent to the difference of their longitudes. The CEJ events therefore occur at local times that are not very different for each electrojet station (Fig. 1). This is consistent with a pattern fixed with respect to sun or moon, so that each station sees it in its appropriate local time as the earth rotates.

Fig. 3 depicts another series of CEJ events observed on consecutive days during January 26-29, 1963. Some of the interesting points to be noted are:

(a) The equatorial electrojet strength is almost the same (about 60-70nT) at all the three stations on January 26, 1963. In contrast, on January 28, 1963, the electrojet strength at Huancayo is approximately two times the electrojet strength at Trivandrum. This cannot be easily explained as it is well-known that the strength of the electrojet current depends on many variables such as the global east-west electric field, intensity of the geomagnetic fields, neutral winds, the electron density, collision frequencies of charged particles and hence conductivities, etc.

(b) The CEJ strength on January 26, 1963 is larger at Addis Ababa (-66nT) compared to Huancayo (-11nT) and Trivandrum (-22nT), whereas it is of comparable magnitude on January 29, 1964 at Addis Ababa (-40nT) and Huancayo (-30nT) and is very weak at Trivandrum (-10nT).

Hutton and Oyinloye (1970) have studied the ΔH behavior at Zaria (Dip - 3°N) and Ibadan (Dip - 6°S) for the CEJ event of January 28, 1963 and found that the CEJ strength at Zaria was -90nT whereas at Ibadan it was -52nT. Therefore, it is clear that CEJ events are observed over a wide longitude extent, at least during January months consistent with the conclusion of Marriott et al. (1979).

Fig. 4 displays the observed ΔH variations on six consecutive quiet days from January 29 - February 3, 1965, showing the narrow longitudinal extent of CEJ events (the series of quiet days actually starts

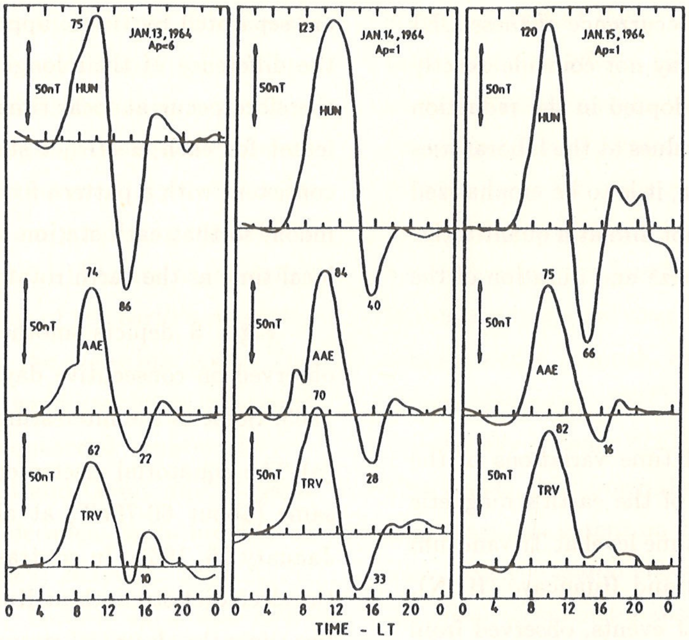

Figure 1. Local time variations of the horizontal component of the earth's magnetic field (ΔH) at Trivandrum (TRV), Addis Ababa (AAE) and Huancayo (HUN) during January 13 - 15, 1964. The numbers at the ΔH maximum and minimum gives electrojet strength and intensity of the CEJ event in nanotesla.

Variações em hora local da componente horizontal do campo magnético terrestre (ΔH) em Trivandrum (TRV), Addis Abeba (AAE), e Huancayo (HUN) durante Janeiro 13-15, 1964. Os números correspondentes a ΔH máximo e mínimo indicam a intensidade do evento em nanotesla.

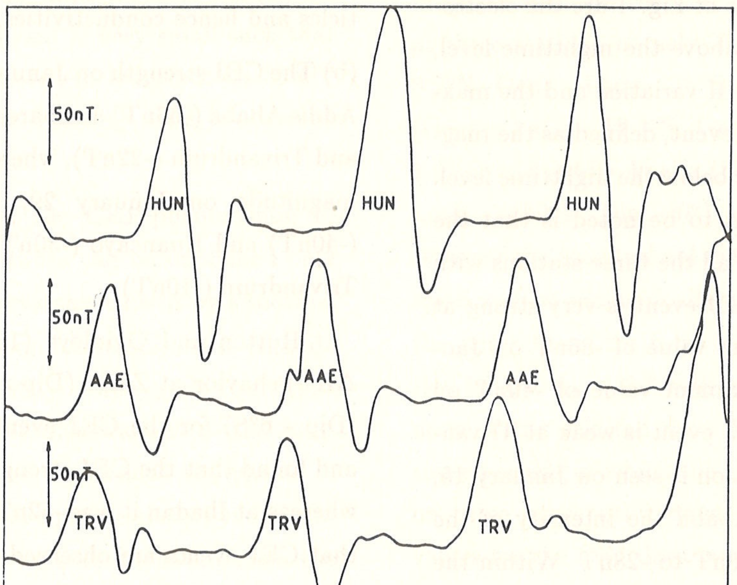

Figure 2. Universal time variation of the horizontal component of the earth's magnetic field (H) during January 13-15, 1964. One can consider these as magnetograms shown in a sequence.

Variação com hora Universal da componente horizontal do campo magnético terrestre (H) durante janeiro 13-15, 1964. Estes podem ser considerados magnetogramas mostrados em sequência.

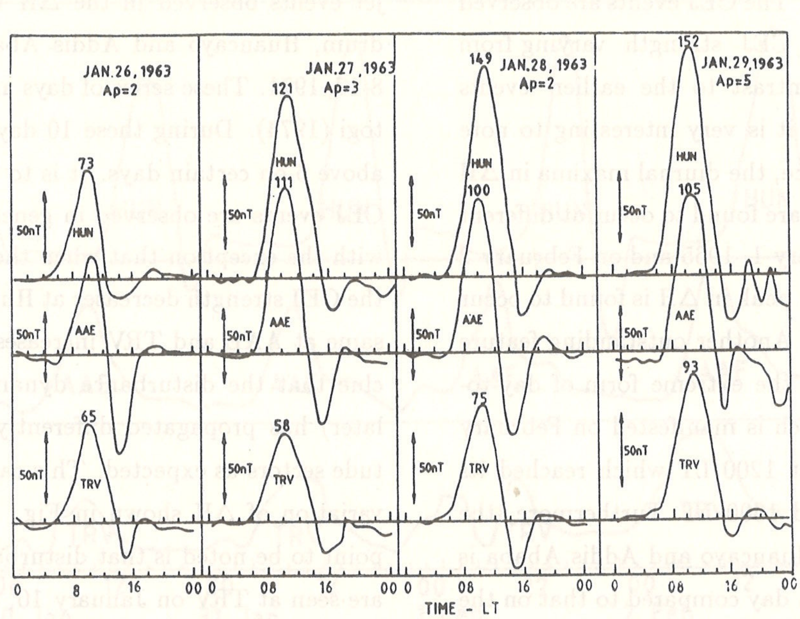

Figure 3. Same as Fig. 1 for January 26-29 1963.

O mesmo que a Fig. 1, para janeiro 26-29, 1963.

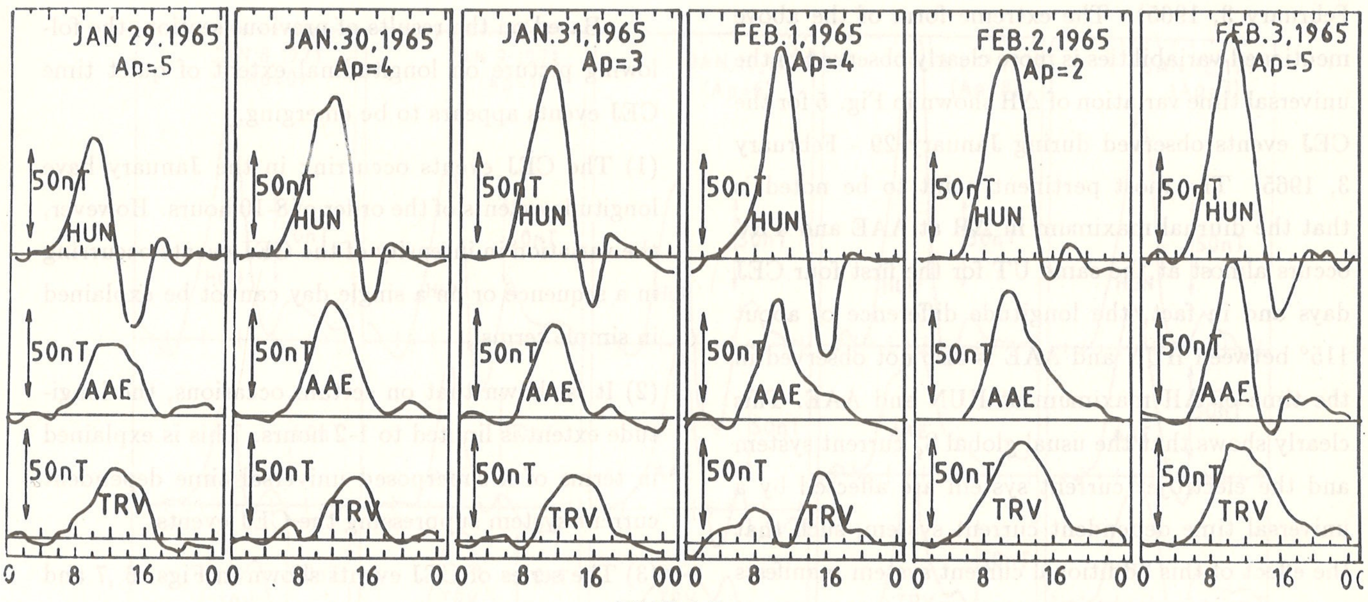

Figure 4. Same as Fig. 1 for January 29 - February 3, 1965.

O mesmo que a Fig. 1, para janeiro 29 - fevereiro 3, 1965.

from January 26, 1965). The CEJ events are observed only at Huancayo with CEJ strength varying from -20nT to -50nT. In contrast to the earlier events (Fig. 1 and Fig. 3), it is very interesting to note that during this sequence, the diurnal maxima in ΔH at all the three stations are found to occur at different local times until February 1, 1965 and on February 2 and 3, 1965, the diurnal peak in ΔH is found to occur at the same local time. Another outstanding feature to be noted at TRV is the extreme form of day-to-day variability ΔH which is manifested on February 1, 1965 as a reversal at 1200 LT which reached its maximum value around 1600 LT. Furthermore, the electrojet strength at Huancayo and Addis Ababa is almost twice on the last day compared to that on the first day whereas at TRV, it is almost steady (about 40nT) on the first four days increasing to about 60nT on the last day. When the CEJ event is observed at Huancayo, a small depression is clearly seen at AAE on four days (January 29, January 31, February 1 and February 3, 1965). The extreme form of the above mentioned variabilities is more clearly observed in the universal time variation of ΔH shown in Fig. 5 for the CEJ events observed during January 29 - February 3, 1965. The most pertinent point to be noted is that the diurnal maximum in ΔH at AAE and TRV occurs almost at the same UT for the first four CEJ days and in fact, the longitude difference of about 115° between HUN and AAE is also not observed in the time of ΔH maximum at HUN and AAE. This clearly shows that the usual global S_q current system and the electrojet current system are affected by a universal time dependent current system, such that the effect of this additional current system manifests in the ΔH variation at AAE (39°E) and TRV (77°E) in the daytime sector, whereas these effects are not observed because HUN (75°W) is in the nighttime sector.

DISTURBANCE DYNAMO EFFECTS

Figs. 6 and 7 show a series of counter electrojet events observed in the ΔH variation at Trivandrum, Huancayo and Addis Ababa during January 8-17, 1971. These series of days are discussed by Rastogi (1974). During these 10 days the A_p values are above 6 on certain days. It is to be pointed out that CEJ events are observed in general at all longitudes with the exception that when the A_p value is 7 or 8, the CEJ strength decreases at Huancayo, whereas the same at AAE and TRV increases. This gives us the clue that the disturbance dynamo effect (discussed later) has propagated differently to different longitude sectors as expected. This can be seen in the UT variation of ΔH shown in Fig. 8. The interesting point to be noted is that disturbance dynamo effects are seen at TRV on January 10, at AAE on January 11 and at Huancayo is manifested as a decrease in the electrojet strength on January 12, 1971 as if it is a propagating disturbance.

DISCUSSIONS AND CONCLUSIONS

Based on the results of previous section, the following picture on longitudinal extent of quiet time CEJ events appears to be emerging.

(1) The CEJ events occurring in the January have longitude extents of the order of 8-10 hours. However, the variation in intensity of the CEJ events occurring in a sequence or on a single day cannot be explained in simple terms.

(2) It is shown that on certain occasions, the longitude extent is limited to 1-2 hours. This is explained in terms of a superposed universal time dependent current system suppressing the CEJ events.

(3) The series of CEJ events shown in Figs. 6 ,7 and 8 brings out the disturbance dynamo effects upon the background quiet day pattern in such a way that the disturbance electric fields and currents act to reduce or reverse the normal quiet day pattern.

The normal quiet day S_q current system and the equatorial electrojet in daytime are mainly caused by

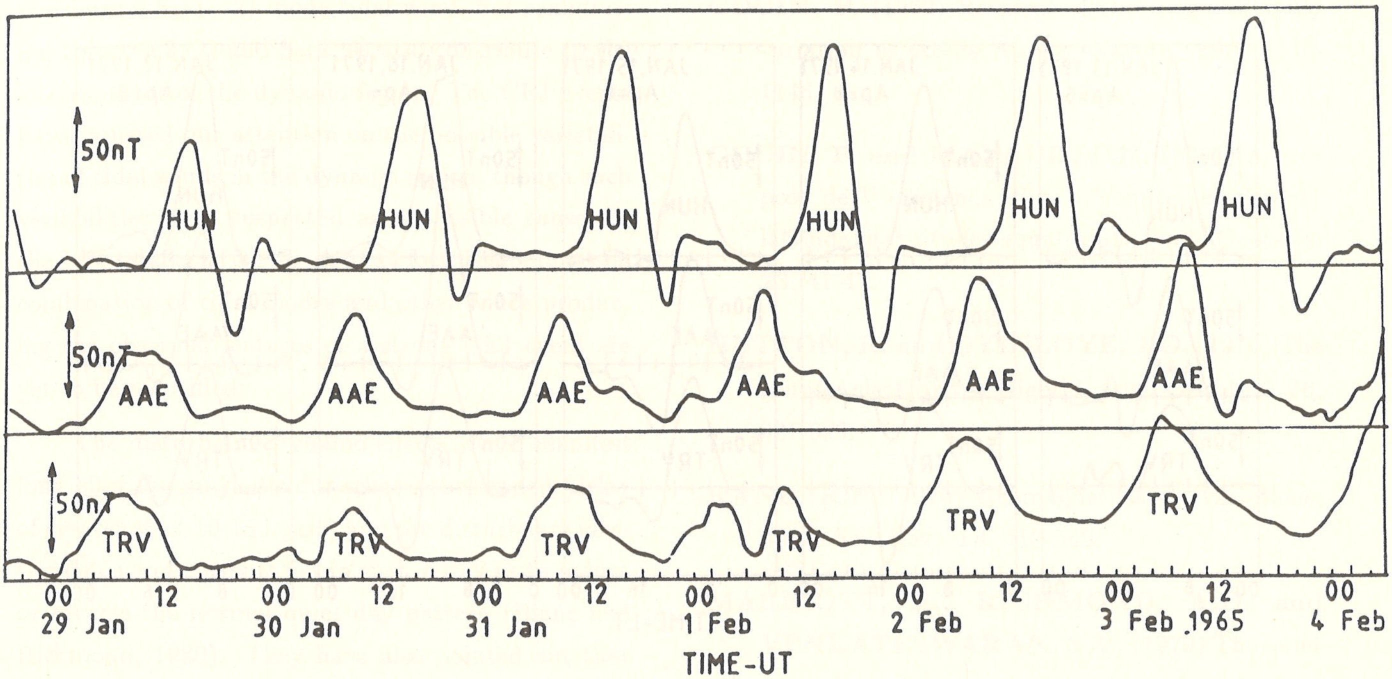

Figure 5. Sames as Fig. 2 for January 29 - February 3, 1965.

O mesmo que a Fig. 2, para janeiro 29 - fevereiro 3, 1965.

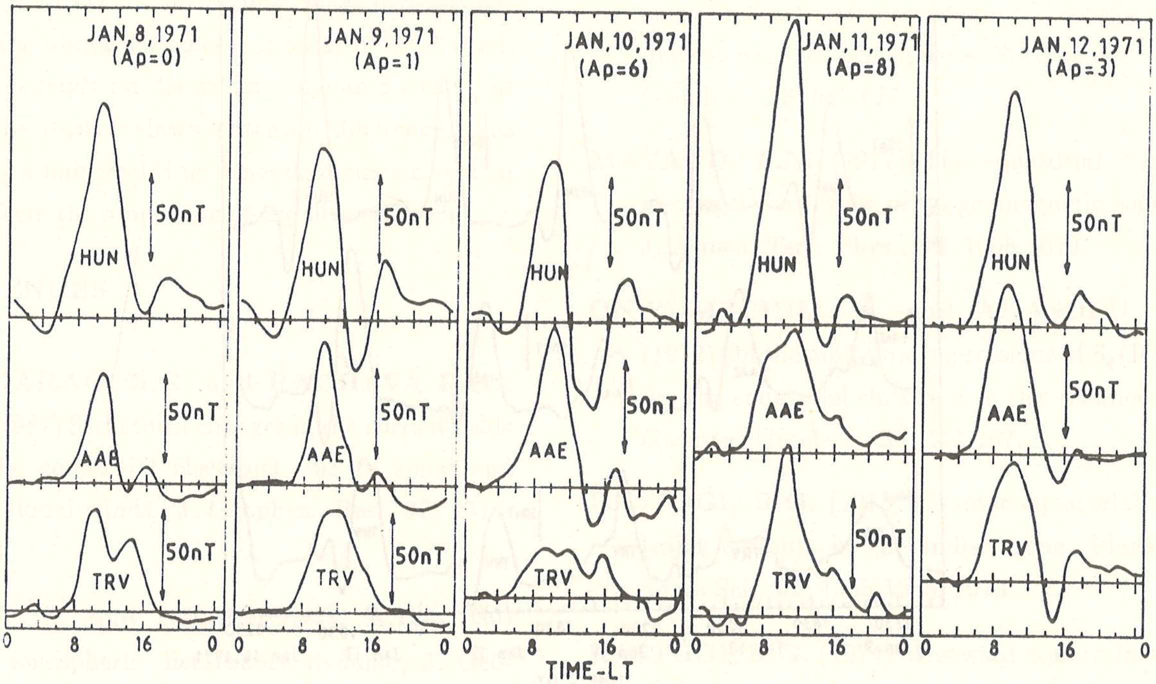

Figure 6. Same as Fig. 1 for January 08-12, 1971.

O mesmo que a Fig. 1, para janeiro 8-12, 1971.

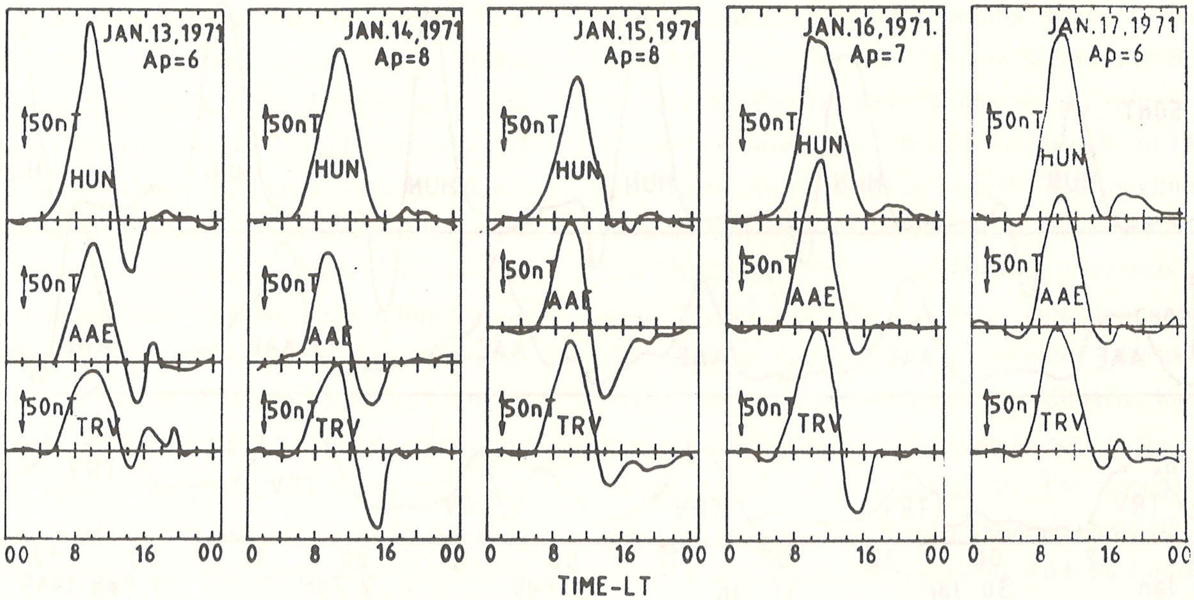

Figure 7. Same as Fig. 1 for January 13-17, 1971.

O mesmo que a Fig. 1, para janeiro 13-17, 1971.

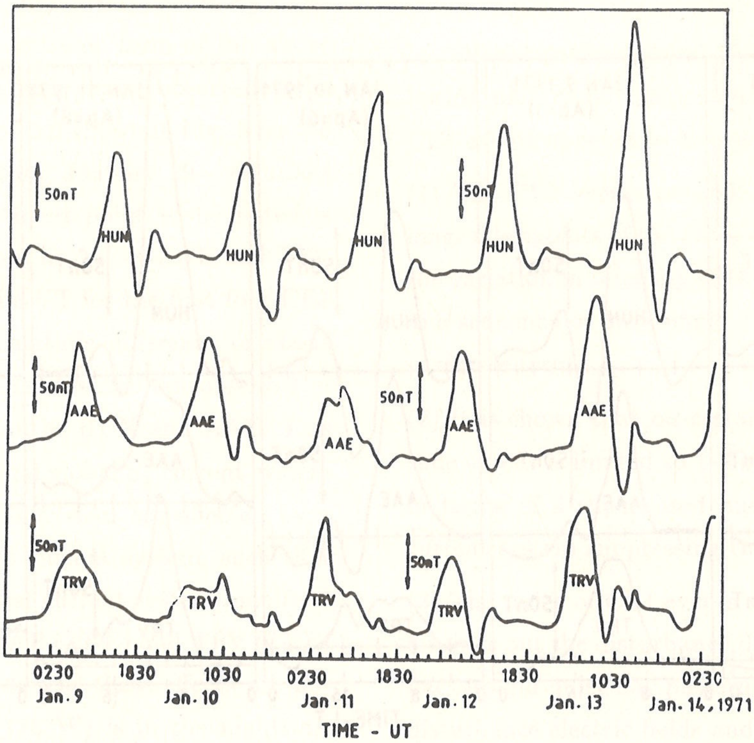

Figure 8. Same as Fig. 2 for January 09-14, 1971.

O mesmo que a Fig. 2, para janeiro 9-14, 1971.

the diurnal $S_1(1, -2)$ mode tidal wind, but semidiurnal tides $S_2(2, 2)$ and $S_2(2, 4)$ also contribute to the electric fields of the dynamo region. The CEJ events have focussed our attention on the possible variabilities of tidal winds in the dynamo region, though such variabilities were suspected as a possible cause for the large shifts in the S_q current foci. The abnormal combination of tidal modes and other winds producing the observed features of a strong CEJ event are yet to be identified.

The disturbance dynamo effects which manifest long after the magnetic disturbance has ended (delay of greater than 10-15 hours) and the disturbance electric fields and currents act in such a way as to reduce or reverse the normal quiet day pattern (Blanc and Richmond, 1980). They have also pointed out that the electrodynamic state of the lower latitudes and the equatorial electrojet is dominated by the effects of dusk-to-dawn potential difference and anti S_q current flow. Therefore, we conclude that the longitudinal extent of CEJ events during quiet days depends not only on the abnormal combination(s) of tidal wind, but also depends on disturbance dynamo effects, as well as the dusk-to-dawn potential difference, thus producing a universal time dependent current system which affects the amplitude of the diurnal mode.

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