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Electric fields and currents in the equatorial E-region over American and Indian zones - A comparison

P. Muralikrishna
Instituto Nacional de Pesquisas Espaciais - INPE/SCT, São José dos Campos - SP, Brazil.

RESUMEN

Se comparan los campos eléctricos de la región-E, estimados a partir de la observación de la velocidad de fase de irregularidades de plasma hecha mediante un radar VHF, y la intensidad de corriente, estimada a partir de medidas de superficie del nivel del campo geomagnético, sobre dos estaciones ecuatoriales, una en Jicamarca, Perú, y otra en Thumba, India. Las corrientes encima de las regiones ecuatoriales son producidas por campos eléctricos proyectados de latitudes no ecuatoriales, donde se generan por el efecto dínamo. Por esta razón, el ángulo de declinación geomagnética local juega un papel importante en la determinación de la variación diurna de los campos eléctricos en la región-E ecuatorial, los cuales, a su vez, influyen en la distribución de las corrientes locales. Puesto que la declinación geomagnética en Jicamarca es mucho mayor que la de Thumba, el presente estudio comparativo muestra claramente el rol del ángulo de declinación geomagnética en la determinación de la distribución vertical de las corrientes diurnas en la región-E ecuatorial.

PALABRAS CLAVE: región-E, región-F, radar VHF, irregularidades de plasma, acción de dínamo, mapeo de campo eléctrico, declinación geomagnética.

ABSTRACT

E-region electric fields estimated from VHF radar observation of the phase velocity of plasma irregularities and the strength of overhead currents estimated from ground level geomagnetic field measurements at two equatorial stations, Jicamarca, Peru and Thumba, India, are compared. The overhead currents in the equatorial regions are driven by electric fields mapped from nonequatorial latitudes, where they are generated by the dynamo action. The geomagnetic declination angle at a given place thus plays an important role in determining the daytime variation of electric fields in the equatorial E-region, which in turn influences the vertical distribution of the overhead currents. The geomagnetic declination angle at Jicamarca being much larger than at Thumba, the present comparative study clearly brings out the role of geomagnetic declination angle in determining the vertical distribution of daytime currents in the equatorial E-region.

KEY WORDS: E-region, F-region, VHF radar, plasma irregularities, dynamo action, electric field mapping, geomagnetic declination.

INTRODUCTION

The role of solar and geomagnetic declination angles in controlling the mapping of electric fields generated by dynamo action in the non-equatorial latitudes, onto the E- and F-regions over the equatorial latitude, was discussed in detail by Muralikrishna and Abdu (1988). From a comparative study of the daytime variation in the average east-west drift velocity of electrons in the E-region over Jicamarca (0.9°N dip lat.; 12°S geograph. lat.), and the variation in the horizontal component of the geomagnetic field at nearby station Huancayo, on magnetically quiet days, they concluded that differences in sunrise times between the equatorial latitudes and the magnetically conjugate non-equatorial latitudes caused by the large magnetic declination angle at Jicamarca and the solar declination angle changing with season of the year, influence to a great extent the development of electric fields in the equatorial E- and F-regions. In addition to a strong forenoon-afternoon asymmetry in the strength of the distributed currents above the electrojet region, they reported significant seasonal changes in the intensity of these currents mainly due to the changing solar declination angle acting in conjunction with the large magnetic declination angle.

As an extension of these studies and also as a strong supporting evidence for the hypothesis presented by Muralikrishna and Abdu (1988) similar results for the Indian sector are reported and compared with the results for the American sector. Daytime variation in the E-region east-west electric field estimated from Doppler spectra of VHF backscatter radar signals at Thumba, India (56'S dip lat.; 9°N geograph. lat.), reported by Reddy *et al.* (1987) and the variations in the horizontal component of the geomagnetic field at nearby station Trivandrum, reported by Vikramkumar *et al.* (1987) for five magnetically quiet days - two days in March 1979 and three days in October 1983 - are used here to examine the forenoon-afternoon asymmetry in the ratio of $\Delta H_T/E_Y$, and its average behaviour in the equinoctial months of March and October. The Indian sector is of very low geomagnetic declination angle, unlike the American sector where the geomagnetic declination angle is large due to the large deviation between the geographic and geomagnetic equators. Thus a comparative study between these two stations can conclusively establish the control of geomagnetic declination angle in the mapping of non-equatorial dynamo electric fields on to the equatorial E- and F-regions and thus controlling the intensity of distributed currents over the electrojet region.

RESULTS

Mean daytime variation in the horizontal east-west electric field in the electrojet region over Thumba, India (estimated from Reddy *et al.*, 1987) and in the horizontal component of the geomagnetic field at the nearby station Trivandrum (estimated from Vikramkumar *et al.*, 1987) were normalized to their respective noontime peak values (Figures 1 and 2). Figure 1 represents the mean behaviour of the parameters in the month of March, 1979 and Figure 2, that in the month of October, 1983. Also shown are the daytime variations in the ratio $\Delta H_T/E_y$ and in the factor R $= \Delta H_T/E_y/\cos\psi - 1$, where ψ is the mean solar zenith angle (see Muralikrishna and Abdu, 1988 for more details). For the purpose of comparison daytime variations in the ratio $\Delta H/V_E$ and the factor R for Jicamarca are presented in Figure 3 (reproduced from Muralikrishna and Abdu, 1988). As the geographic latitude of Thumba is 9°N and that of Jicamarca 12°S, the months of both March and October, from the point of view of solar declination angle, correspond to equinoctial months also at Jicamarca. Hence the curves presented in Figure 3 correspond to the equinoctial months.

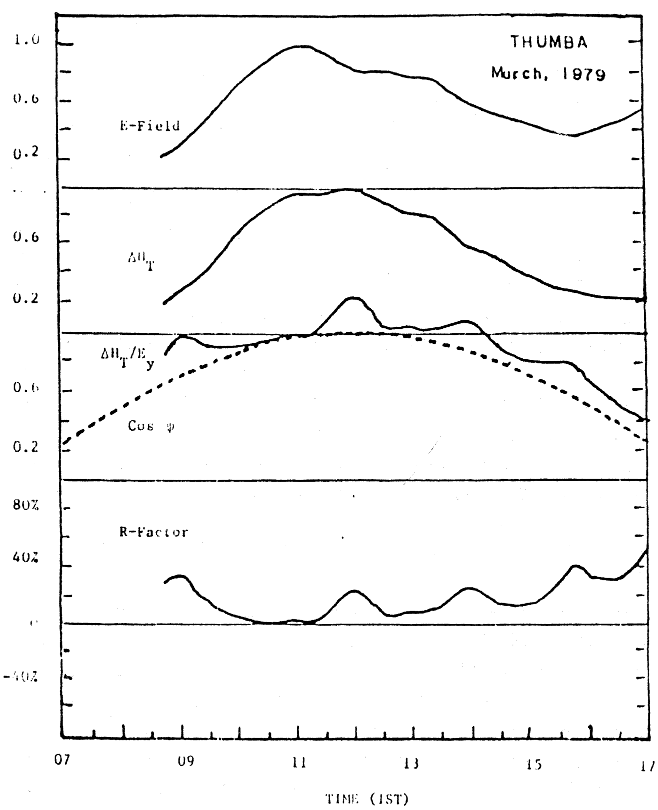

Fig. 1. Mean daytime variation in the horizontal east-west electric field in the E-region over Thumba, India compared with the mean variation in the horizontal component of the geomagnetic field at Trivandrum, India for the month of March, 1979. Also shown in the figure are the mean variations in $\Delta H_T/E_y$ and R.

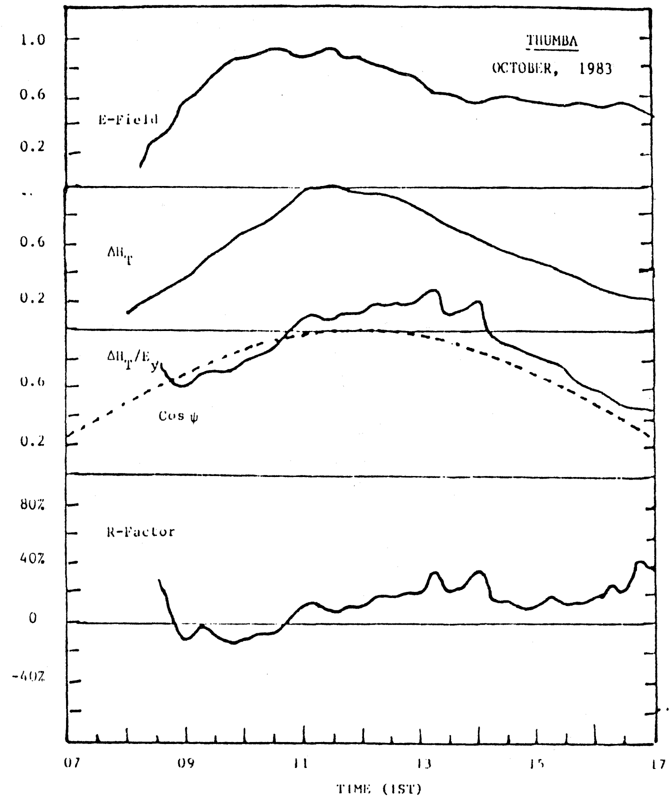

Fig. 2. Mean daytime variation in the horizontal east-west electric field in the E-region over Thumba, India compared with the mean variation in the horizontal component of the geomagnetic field at Trivandrum, India for the month of October, 1983. Also shown in the figure are the mean variations in $\Delta H_T/E_y$ and R.

DISCUSSION

A comparison of Figures 1 and 2 with Figure 3 shows that:

(i) The curve representing the time variation of the ratio $\Delta H_T/E_y$ for Thumba for the months of both March and October rather closely follows the cosψ curve except at a few points. The corresponding curve for Jicamarca shown in Figure 3, however, shows the presence of a clear forenoon-afternoon asymmetry.

(ii) Time variations in the ratio R, which represent the relative intensity of distributed currents flowing in the region above the electrojet, are significantly different at Thumba and Jicamarca.

These notable differences between the American and Indian sectors clearly have to do with the geometry of magnetic field lines at both places. Figures 4 and 5 show the geometries of field lines passing through Thumba and Jicamarca. The large magnetic declination in the American sector is evident in Figure 5.

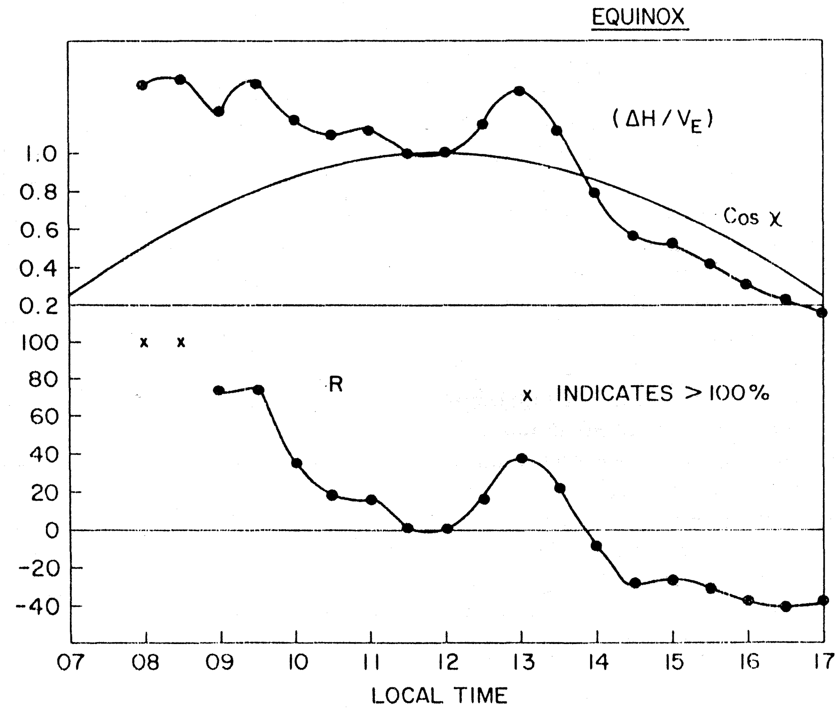

Fig. 3. Mean daytime variations in the ratio $\Delta H/V_E$ and the factor R for Jicamarca, Peru during the equinoctial months.

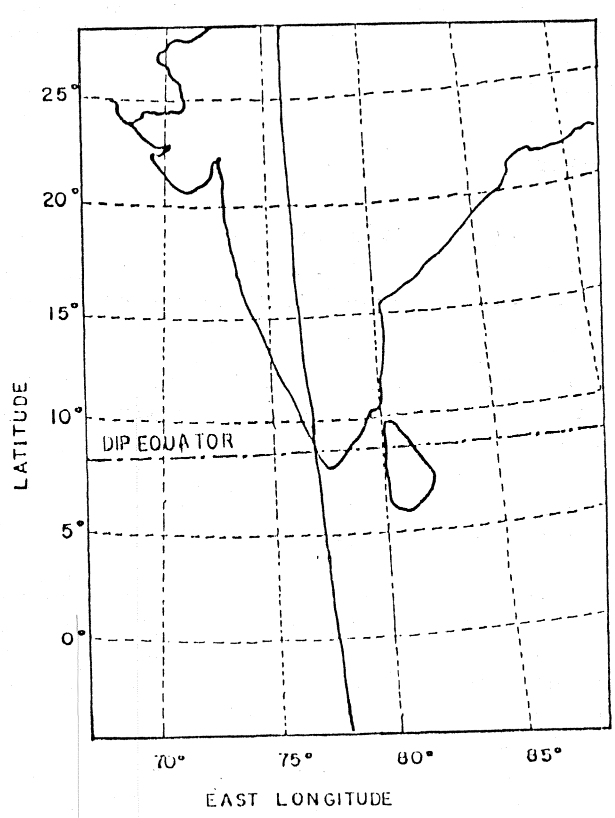

Fig. 4. Geometry of a geomagnetic field line passing through Thumba, India.

The hypothesis given in Muralikrishna and Abdu (1988) for explaining the asymmetric nature of the daytime variation in $\Delta H/V_E$ is based on the large declination angle in the American sector which causes considerable time differences in the sunrise times at the geomagnetically conjugate points and in the equatorial E- and F-regions. These time differences result in one region becoming more conducting than the other, thus affecting the mapping of the dynamo electric fields from the non-equatorial latitudes to equatorial latitudes. According to this hypothesis one does not expect a large forenoon-afternoon asymmetry in the daily variation of $\Delta H_T/E_y$ at Thumba due to the low declination angle in the Indian sector. As can be seen, present observations conclusively support this hypothesis.

CONCLUSIONS

In support of the hypothesis reported by Muralikrishna and Abdu (1988) regarding the solar and magnetic declination control on the electrojet and distributed currents in the ionosphere, the present results obtained for the Indian sector, where the geomagnetic field lines are almost north-south, clearly show that the distributed currents flowing over the electrojet region over Thumba during daytime, are very much less than those flowing over the electrojet region over Jicamarca. This seems to be a conclusive evidence for the magnetic declination control on the mapping of dynamo electric fields generated at non-equatorial latitudes onto equatorial latitudes and thereby on the intensity of the distributed currents above the electrojet.

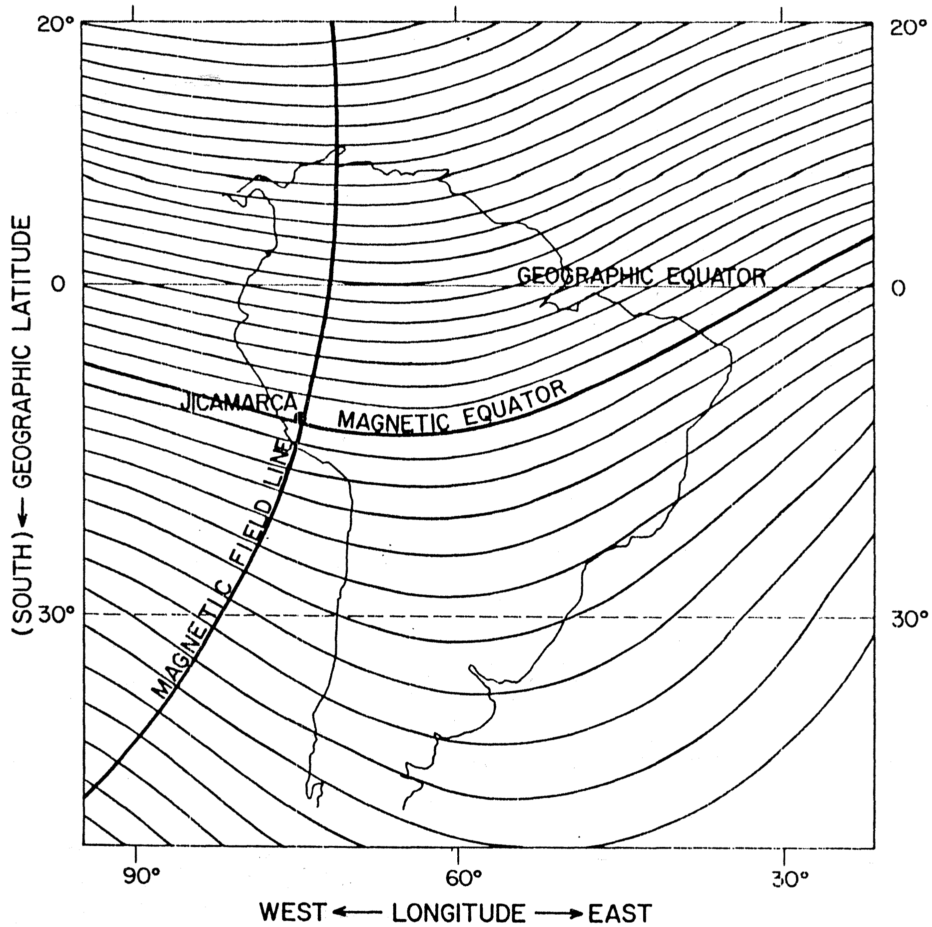

Fig. 5. Geometry of a geomagnetic field line passing through Jicamarca, Peru.

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P. Muralikrishna
Instituto Nacional de Pesquisas Espaciais - INPE/SCT
C. P. 515, 12201 - São José dos Campos - SP, Brazil.