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14. Abstract/Notes

Ionospheric total electron content (TEC) measurements carried out by VHF electronic polarimeters over Brazilian tropical locations, namely São José dos Campos (23°S, 46°W, dip lat. 13°S) and Natal (5.8°S, 33.23°W, dip lat. 4.8°S), are analysed together with other ionospheric parameters obtained from ionosondes namely f_0F_2 and h_pF_2, operated over Fortaleza (4°S, 38°W, dip lat. 1.8°S) and Cachoeira Paulista (22.5°S, 45°W, dip lat. 13°S), to determine changes in these parameters during magnetically disturbed periods, during the years extending from 1979-1983, a period covering the recent solar activity maximum and the subsequent declining phase. An important feature of the nighttime TEC variations is the regular occurrence of a pronounced pre-midnight enhancement over low latitude location and a post-midnihgt-morning enhancement near the equator, during mainly the equinoctial months. The association of these nighttime enhancements in TEC with the equatorial ionization anomaly crest movements is not established, and is being investigated using detailed numerical modelling of the tropical F-region processes. Magnetic storm effects on the night TEC enhancements and on the other F-region parameters, namely f_0F_2 and h_pF_2, are analysed and discussed in this paper for four moderate-to-severe magnetic storm events that occurred in different seasons during the epoch of this study.

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NIGHTTIME ENHANCEMENTS IN THE TEC, AND MAGNETIC STORM RESPONSE, OF THE TROPICAL F-REGION OVER BRAZIL

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Abstract

Ionospheric total electron content (TEC) measurements carried out by VHF electronic polarimeters over Brazilian tropical locations, namely São José dos Campos (23°S, 46°W, dip lat. 13°S) and Natal (5.8°S, 33.23°W, dip lat. 4.8°S), are analysed together with other ionospheric parameters obtained from ionosondes namely f_0F_2 and h_pF_2, operated over Fortaleza (4°S, 38°W, dip lat. 1.8°S) and Cachoeira Paulista (22.5°S, 45°W, dip lat. 13°S), to determine changes in these parameters during magnetically disturbed periods, during the years extending from 1979-1983, a period covering the recent solar activity maximum and the subsequent declining phase. An important feature of the nighttime TEC variations is the regular occurrence of a pronouced pre-midnight enhancement over low latitude location and a post-midnight--morning enhancement near the equator, during mainly the equinoctial months. The association of these nighttime enhancements in TEC with the equatorial ionization anomaly crest movements is not established, and is being investigated using detailed numerical modelling of the tropical F-region processes. Magnetic storm effects on the night TEC enhancements and on the other F-region parameters, namely f_0F_2 and h_pF_2, are analysed and discussed in this paper for four moderate-to-severe magnetic storm events that occurred in different seasons during the epoch of this study.

Introduction

Many outstanding features of the tropical ionospheric processes, especially those related to its response to magnetic disturbances, as they manifest themselves in variations of the different parameters, such as the total columnar ionization content and peak F-layer densities and heights, are far from being understood, mainly due to lack of adequate and relevant data coverage from tropical locations. Analyses of such data obtained from Brazilian tropical locations are particularly important due to the geomagnetic peculiarities of these locations in Brazil, where the magnetic equator crosses the geographic equator, resulting in a global maximum of the magnetic declination angle in this region. These geomagnetic peculiarities could significantly influence the quiet, as well as the disturbance characteristics of the tropical ionosphere over Brazil in different degrees with respect to other tropical regions of the earth. In the present work we have attempted to establish some of the most salient features and peculiarities of ionospheric behaviour in Brazil during quiet, as well as disturbed intervals, using data of total electron content (TEC), peak F-region densities and heights obtained from different locations in Brazil during the last few years that cover the epoch of the recent solar activity maximum and its subsequent declining phase.

Average quiet day behaviour in these parameters was established for use as a reference to determine the disturbance variations in these parameters. Tropical ionospheric response to disturbances of magnetospheric and high latitude origin are known to be markedly different from that of the midlatitude ionosphere. Regarding the midlatitude ionospheric response which has been investigated somewhat extensively, the following salient features have been observed: 1. An enhancement lasting for a few hours in the F-layer peak electron density and TEC within a few hours after the onset of a moderate magnetic storm (known as positive phase), believed to be caused by an equatorward thermospheric wind set up in the initial phase of storm energy absorption in the high latitude ionosphere. 2. A negative phase, namely a marked decrease in the ionization within a day or two of the storm onset lasting for a few days, returning to quiet time values with recovery of the storm disturbances. This is believed to be caused by equatorward propagation of thermospheric disturbances fronts having higher $[N_2]/[O]$ ratio, in a second phase of the storm energy absorption (Rishbeth, 1974, 1975; Evans, 1973; Seaton, 1956; Jones, 1973; Davies, 1974; Prolss, 1981; Prolss and Von Zahn, 1976). However, there are significant departure from this average picture in the case of individual storms depending upon the local time of the storm onset, season, etc. (See, for example, Mendillo, 1973; Kane, 1978). Relatively little is known about the characteristics of the F-region storm over low latitude where the presence of the equatorial ionization anomaly (or fountain effect) complicates the picture. One of the important aspects of the low latitude ionosphere response seems to be the tendency for inhibition of the anomaly development either due to equatorward winds or disturbance electric fields of magnetospheric and high latitude origin (see, for example, Rajaram, 1977; Prolss and Von Zahn, 1976; Rishbeth, 1975).

Data analysis, and TEC quiet time variations

The data samples covered in the present analysis are the total electron content values obtained from measurements of Faraday rotation angle of the VHF beacon from the geostationary satellite GOES-3 over São José dos Campos (23°S, 46°W, dip lat. 13°S) and Natal (5.8°S, 33.23°W, dip lat. 4.8°S), during September 1979 and 1982, April 1981, July 1982 and January 1983. These periods are representative of equinox, summer and winter months, respectively. For Natal only the data during September 1979 were used and the data for São José dos Campos covered the rest of the periods. Thus no simultaneous TEC data over the equatorial and low latitude locations have been used for this analysis. On the other hand, simultaneous ionogram parameters, namely f_0F_2 (or N_mF, the peak F-layer density) and h_pF_2 (the height representative of the F-layer peak) for Fortaleza (4°S, 38°W, dip lat. 1.8°S) and Cachoeira Paulista (22.5°S, 45°W, dip lat. 13°S), have been used together with the TEC data over São José dos Campos for studying storm events during September 1982, April 1981, and January 1983. For the storm event in July 1982 data of TEC over São José dos Campos alone are used. Hourly equatorial DST values published by NSSD/NASA were used to separate the magnetically quiet and disturbed periods. TEC diurnal variations representing the mean of several quiet days (usually all days having DST values close to zero, or $< |20|$, for which data were available) were used as reference to determine the disturbance variations in TEC. In the case of $f_0F_2(N_mF_2)$ and h_pF_2 the deviations of disturbed values with respect to the mean quiet day values (namely Δf_0F_2 and Δh_pF_2) were also determined as a function of local time at 15 minutes time resolution.

Figure 1a presents TEC local time variations representing quiet conditions (solid line) of April 1981, plotted together with the TEC variations during 12-15 April that were magnetically disturbed as the DST values indicate. The most noticeable feature in the quiet TEC variation is a pronounced peak in TEC at around 2300LT. Such nighttime enhancements in the TEC of tropical ionosphere does not seem to have been reported for other equatorial longitudes. The TEC variations over Natal for September 1979, presented in Figure 2, also show nighttime enhancements, but they are confined to post-midnight-morning hours. It may be noted further that such TEC nighttime enhancements seem to be very weak or absent in the results for summer and winter months over São José dos Campos, presented in Figures 3a, 4 and 5a. From the present data samples it appears that the nighttime TEC enhancements observed over the Brazilian tropical locations are presented only during equinoctial months. Possible relationship between these TEC enhancements and the equatorial fountain effect could be assessed from a realistic numerical modelling of the anomaly development.

Magnetic storm effects on TEC, N_mF_2 and h_pF_2

From a careful study of Figures 1a, b, c, 3a, b, c, 4 and 5a, b, c, the following observations on magnetic storm response of the TEC, $f_0F_2(N_mF_2)$ and h_pF_2 can be noted.

1. In general, magnetic disturbances cause, more frequently, enhancements in TEC and f_0F_2 over all these stations. However, a clear tendency for negative storm effects is seem during summer months (see the Figures 5a, b, c). (See, Evans, 1973; Matuura, 1972; Jones and Rishbeth, 1971).

2. The nighttime peak in TEC, that occurs mainly during equinoctial months over low latitudes, is suppressed during moderate to severe magnetic disturbances. This suppression occurs mainly as a result of storm associated TEC enhancements occurring predominantly in the evening hours, filling the valley region of the quiet time TEC variation, (Figure 1a). The magnetic storm effect on the nighttime TEC enhancement during other seasons is not clear, since such TEC enhancements are very small in these months.
   The DST variation does not seem to produce a detectable effect on the post midnight TEC enhancements over Natal (Figure 2), although more such events will have to be analysed for drawing any conclusion on this point.

3. During night hours (from near sunset to near sunrise hours) the storm induced TEC changes seem to accompany the f_0F_2 in phase, namely the TEC enhancements and decreases are associated with f_0F_2 enhancements and decrease, respectively, over the low latitude locations (see, for example, the variations in these parameters during 21LT-07LT on 13-14 April,morning hours of 15 April, (14th night seems to be an exception), in Figure 1a and b, 18LT-04LT on 28-29 September 82 in Figure 3a and b, 18LT-06LT on 09-10 Jan 1983, morning hours of 12 January 1983 in Figure 5a and b). On the other hand, such a good association between TEC and Δf_0F_2 variations does not seem to be occurring during daytime hours. (See, for example, 13 April 1981 in Figure 1a and b, 27 September 1982 in Figure 3a and b, 10 and 11 January 1983 in Figure 5a and b).

4. Storm associated changes in h_pF_2 are not well defined except on a few occasions, when Δh_pF_2 shows opposite variations with Δf_0F_2 at both Cachoeira Paulista and Fortaleza.

5. Storm induced changes in F-layer peak density seem, in general, to be out of phase between the equatorial location Fortaleza and the low latitude location Cachoeira Paulista.

Discussion and Conclusion

The DST induced changes in the different ionospheric parameters observed over the Brazilian tropical locations do not seem to be always consistent (repeatable from one storm to another) or simple. Larger and simultaneous data samples from these different locations would certainly be helpful for identifying more consistent ionospheric storm response features of this region. The most consistent effect so far identified seems to be the tendency for frequent enhancement in TEC and f_0F_2, in agreement with results from other longitud regions presented by other workers (see, for example, Rajaram,1977). However, in contrast to the results from other low latitude stations, the Brazilian locations seem to present well defined negative phases of storm effects as seen in some of the events presented here and in a few events presented in an earlier work by Abdu et al. (1980).

One of the most outstanding features of the TEC variation over Brazil seems to be the pronounced nighttime enhancements in TEC occurring in equinoctial months, during pre-midnight hours over low latitude and during post-midnight hours over locations closer to the equator. While the low latitude TEC enhancements becomes unidentifiable during magnetic disturbances (due to the evening and pre-midnight TEC enhancements), the post-midnight TEC enhancement over the equator does not seem to be affected owing to magnetic disturbances. Another important finding from the present analysis is that the storm induced variations in TEC and f_0F_2 seem to be occurring in phase (in a majority of the cases) during night and morning hours, while during daytime hours these variations do not follow each other. Quantitative interpretations of these different findings are being pursued by detailed dynamical modelling of the tropical ionosphere and by including larger data samples in the analysis.

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Figure Captions

Figure 1. (a) TEC mean local time variation over São José dos Campos representative of quiet conditions of April 1981 (solid line). The dashed curve represents the TEC variations on 12, 13, 14 and 15 April 1981, a magnetically disturbed period marked by DST changes that reached ~ 290γ on morning of 13 April. Note that the TEC values are given in Faraday rotation angle that is linearly proportional to TEC. The upper part of this figure shows the DST variation.
(b) Plots of DST (top), and Δf_0F_2 (middle) and Δh_pF_2 (bottom) over Cachoeira Paulista during the same days as those of (a).
(c) Same parameters as in (b) plotted for Fortaleza.

Figure 2. TEC local time variations over Natal on four days during September 1979. Note the TEC enhancements during the post-midnight-morning hours an all these days. A storm main phase onset occurred around 21LT on 17 September.

Figure 3. (a) TEC (Faraday rotation angle) variations over São José dos Campos similar to those presented in Figure 1(a), for a few disturbed days (dashed line) of September 1982. Quiet time variation is shown by the solid line.
(b) Local time plots of DST (top),and Δf_0F_2 (middle) and Δh_pF_2 (bottom) over Cachoeira Paulista during the same days as those of (a).
(c) Plots similar to (b) for Fortaleza.

Figure 4. TEC (Faraday rotation angle) variation over São José dos Campos before and during a magnetic storm that occurred in July 1982. Descriptions are the same as those of Figure 1(a) and 3(a).

Figure 5. (a) TEC (Faraday rotation angle) variations before, during and following a magnetic storm in January 1983. Descriptions are the same as those of Figures 4, 1(a) and 3(a).
(b) Plots of DST (top), and Δf_0F_2 (middle) and Δh_pF_2 (bottom) over Cachoeira Paulista, during the same days as those of (a).
(c) Similar plots, as in (b), for Fortaleza.

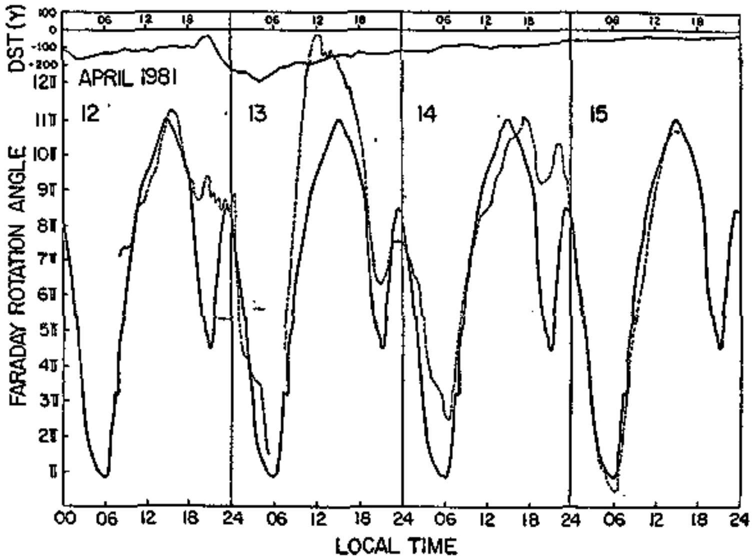
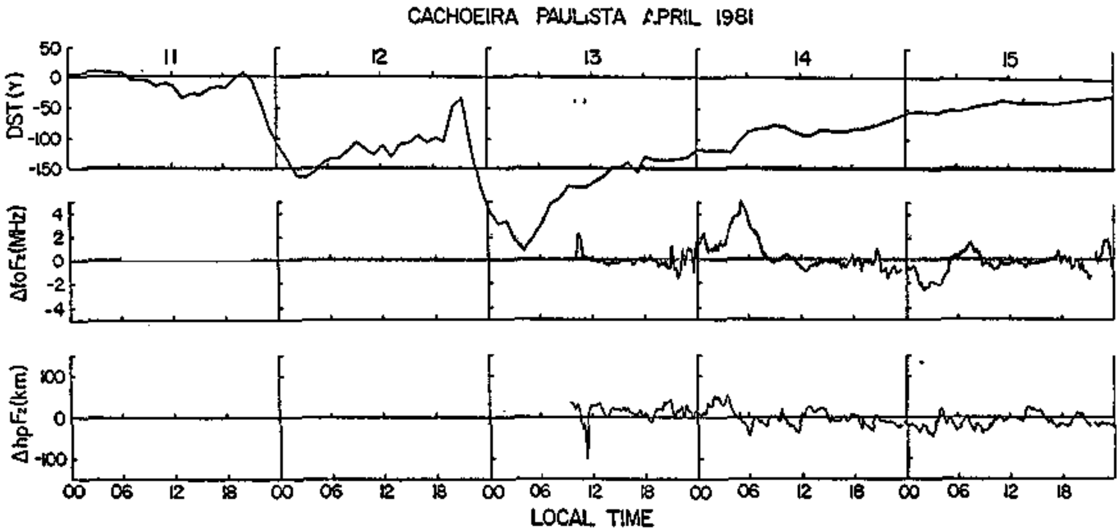


Fig. 1a



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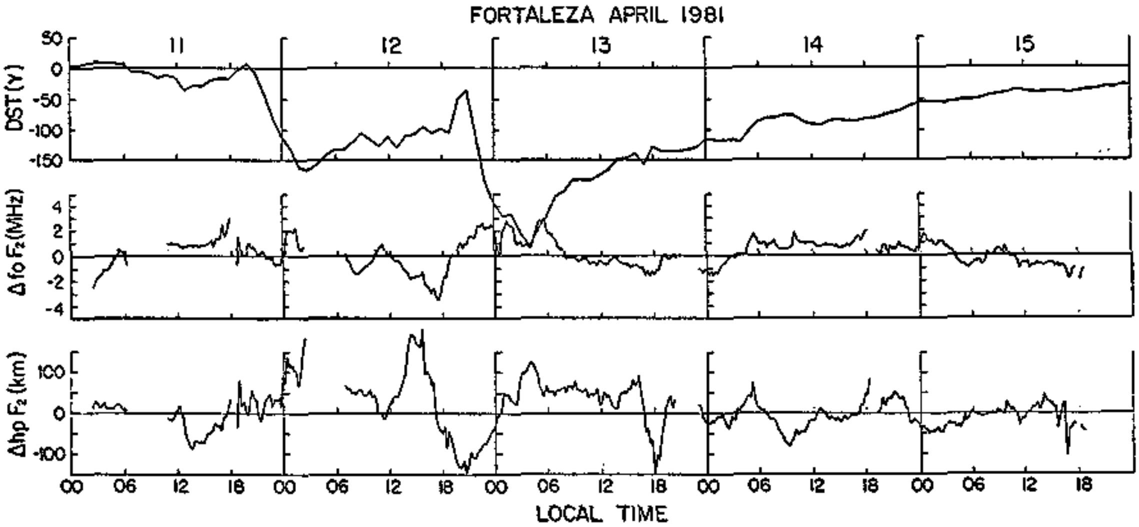

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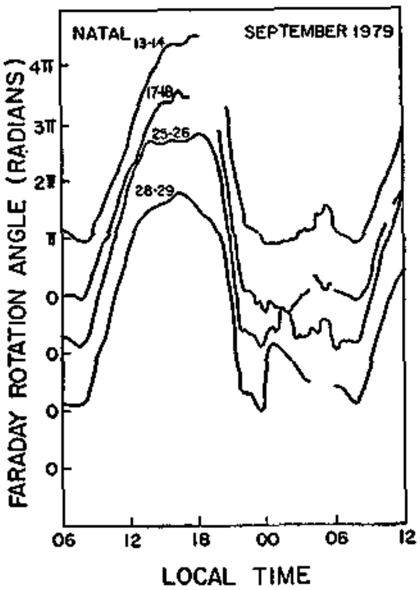

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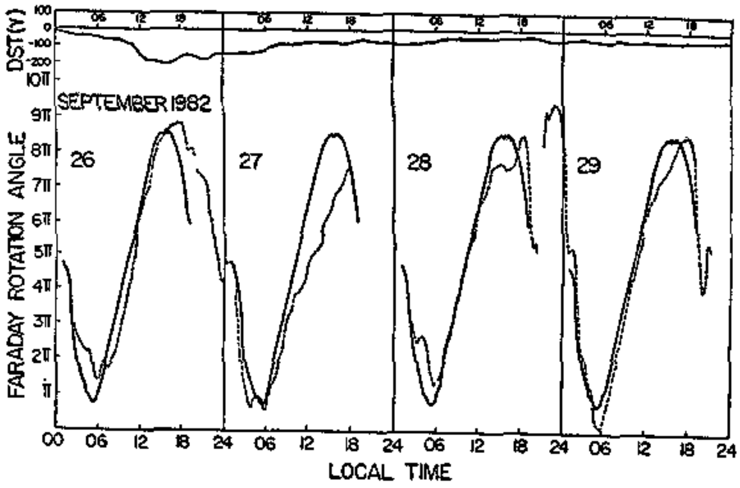

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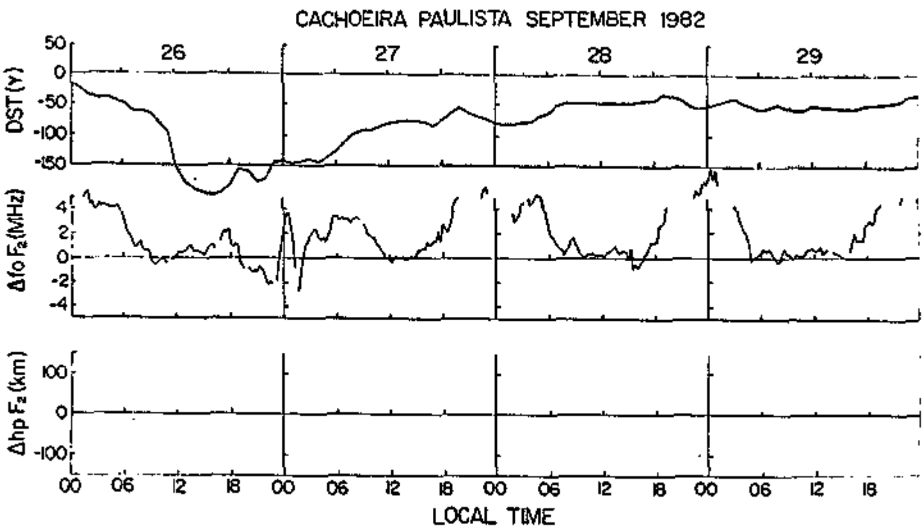

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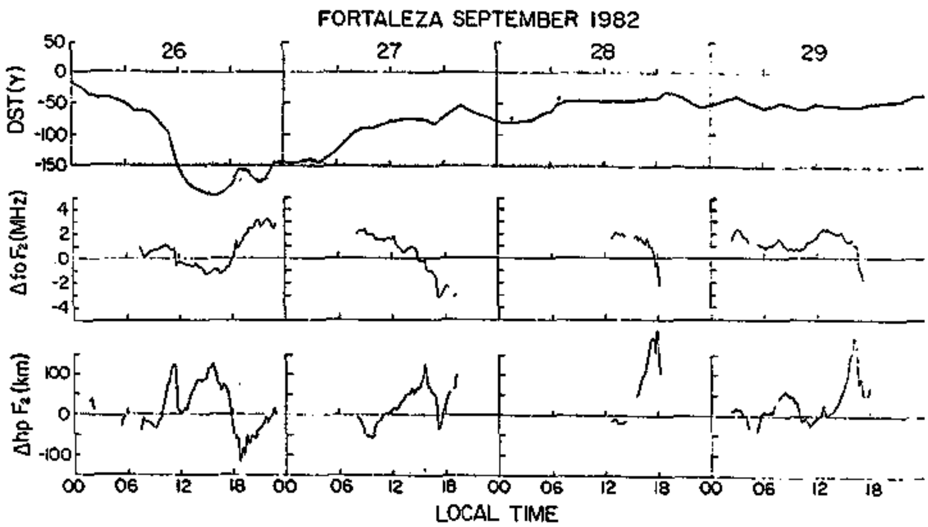

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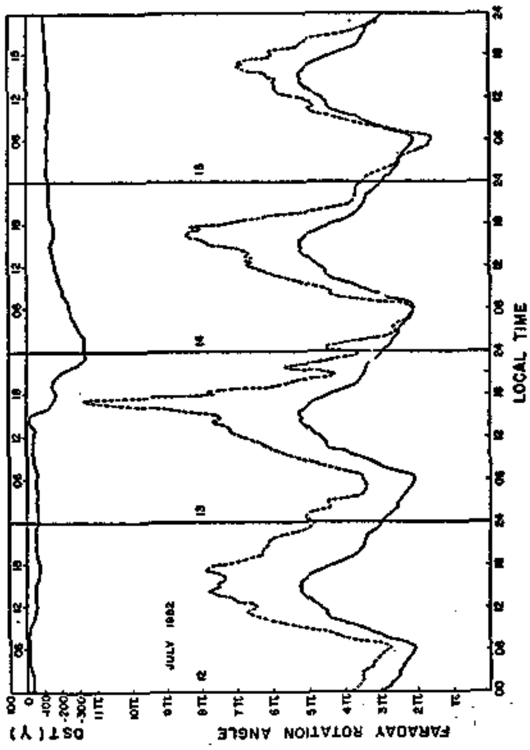

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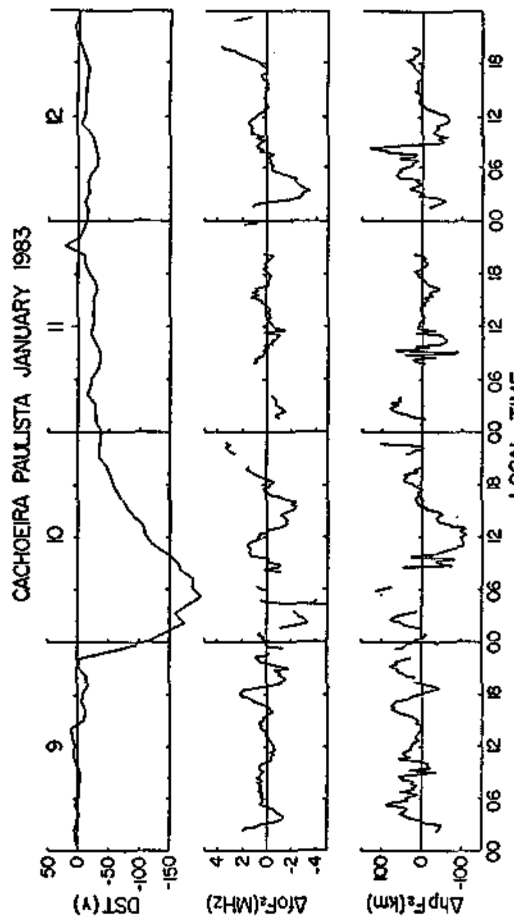

Fig. 5b

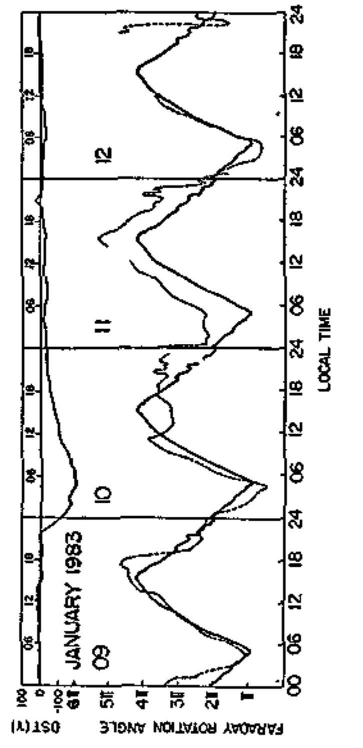

Fig. 5a

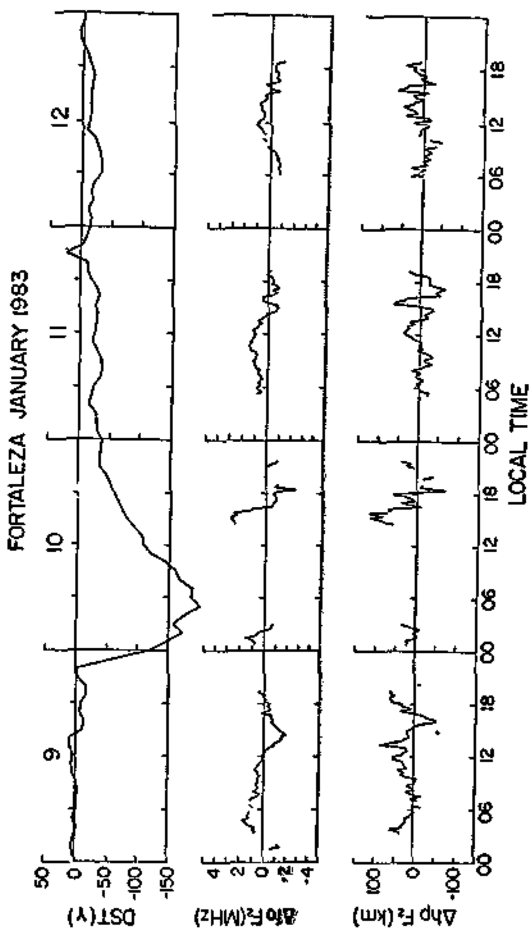

Fig. 5c