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16. Summary/Notes

This work presents and discusses certain features of the ionosphere dynamics over Cachoeira Paulista (22° 41'S, 45° W), Brazil, based on recent photometric observations of OI 6300 Å emission and ionosonde data, both taken at that site. The photometer scanned the geomagnetic meridional plane in a zenith angle range of 75°S to 75°N. Remarkable wavelike structures in the airglow intensity were observed in the premidnight period, which propagate from north to south (poleward) at an average speed of about 240 ± 70 m/s, assuming the emitting layer to be at an altitude of 250 km. These disturbances had wavelength of a few hundred kilometers and were associated with spread F echoes in the ionograms. A discussion is made on the possible source of the poleward propagating airglow disturbances. It is argued that these are possible manifestations of the vertical propagation of plasma bubbles over the magnetic equator.

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AIRGLOW STUDIES ON THE IONOSPHERE DYNAMICS OVER LOW LATITUDE IN BRAZIL

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ABSTRACT

This work presents and discusses certain features of the ionosphere dynamics over Cachoeira Paulista (22^{o} 41'S, 45^{o} W), Brazil, based on recent photometric observations of OI 6300 Å emission and ionosonde data, both taken at that site. The photometer scanned the geomagnetic meridional plane in a zenith angle range of 75^{o}S to 75^{o}N. Remarkable wavelike structures in the airglow intensity were observed in the premidnight period, which propagate from north to south (poleward) at an average speed of about 240 ± 70 m/s, assuming the emitting layer to be at an altitude of 250 km. These disturbances had wavelength of a few hundred kilometers and were associated with spread F echoes in the ionograms. A discussion is made on the possible source of the poleward propagating airglow disturbances. It is argued that these are possible manifestations of the vertical propagation of plasma bubbles over the magnetic equator.

1. INTRODUCTION

In an effort to study the dynamics of the ionosphere over Cachoeira Paulista (geographic coordinates 22°41'S, 45°00'W; geomagnetic coordinates 11°57'S, 22°32'W), Brazil, nighttime scanning measurements of the atomic oxygen 6300 Å emission (or red line emission) and ionosonde measurements were made at that site. Studies of the ionosphere dynamics, by using experimental data of the red line have already been made (Barbier, 1957; Barbier and Glaume, 1962; Peterson et al., 1966; Kulkarni and Rao, 1972; Bittencourt et al. 1976, Skinner et al., 1977; and many other works).. One of the principal motivations of the present paper is the fact that relatively little work has so far been done to understand the dynamics of the ionosphere over low latitudes. Cachoeira Paulista (Figure 1), being ideally situated for such studies, is also located very near the center of the south Atlantic (also known as Brazilian) geomagnetic anomaly, where very few observations pertinent to the dynamics of the ionosphere has so far been carried out (Abdu and Rai, 1975). The ionospheric studies carried out so far, in this region, concern mostly aeronomic effects of high energy charged particle precipitation, stemming from the inner radiation belt (Batista and Abdu, 1977; Abdu et al., 1979; see also Gledhill, 1976).

The airglow data, presented here, is the first set of scanning measurements carried out at Cachoeira Paulista. The measurements were restricted to the geomagnetic meridional plane and cover the zenith distances ranging from 75° north to 75° south. The analysis is based on a total of about 40 hours of photometric and ionosonde observations, which were taken on 5 nights and distributed as follows: one night in November, 1977; one night in February, 1978; two nights in March, 1978 and one night in June, 1978.

2. THE EXPERIMENTAL SET-UP AND DATA REDUCTION

An interference filter of 3 Å bandwidth has been used to measure the atomic oxygen red line emission. The sky scanning was made by a mirror, placed at an angle of 45° with the longitudinal axis of the photomultiplier tube, so as to reflect the dim light from the sky into the horizontally disposed photomultiplier tube. In the north to south scanning motion, the filter was set at a fixed inclination in order to read the background radiation from the sky. During the south to north motion of the mirror, the filter was set to a second position so as to read the 6300 Å emission intensity itself. The time for the mirror to go back and forth is approximately 4.5 minutes. Fig. 1 illustrates the scanning range at a reference altitude of 250 km, at which altitude, the geomagnetic latitude scanning range is approximately 13.3^{0} and the corresponding horizontal distance covered is 1537 km. At a reference altitude of 300 km, these figures are 15.4^{0} and 1795 km, respectively. Fig. 2 shows typical reproductions of recordings of the red line intensity versus latitude, where the successive curves, whose time length is about 2.25 minutes, represent integrated intensities not corrected for the Van Rhijn effect. During the passage of strong travelling disturbances, to be discussed in the next section, the intensity of the red line was usually so strong, that the background emission was negligible.

The error bar, in determining the speed of a moving disturbance from a given set of crests of red line emission, is set by the reading resolution of the chart records and is estimated to be of the order of ± 7%.

An ionosonde operated at the same location and took ionograms at 15 minutes intervals.

3. RESULTS AND DISCUSSION

A remarkable feature of the atomic oxygen nightglow often observed over Cachoeira Paulista is a very high intensity, at the south, during the early part of the evening, with a simultaneous low intensity at north. Later on, still during the premidnight period, the intensity tends to increase considerably at north and to decrease at south, as seen, for example in the data presented in Figure 2-a. In other words, the large south to north intensity ratio decreases considerably until about midnight. This general feature seems to be consistent with the south to north motion of the intertropical red arc. As presently understood, the intertropical red arc displays itself as a strip of enhanced OI 6300 Å emission extending in the east-west direction and is supposed to have a single crest that, at premidnight hours, generally moves from low latitudes towards the equator. Kulkarni and Rao's (1972) measurements of the red line at low latitudes, by means of an all-sky scanning photometer, clearly showed the crest of the intertropical red arc in the northern hemisphere. In southern hemisphere, the intertropical red arc is expected to have similar features, even though, we have not been able to detect it clearly in our scanning data. Perhaps the crest has a smooth latitudinal variation over our observing location as not to be easily detected within the spatial scanning range. The intertropical red arc is expected to appear first at the geomagnetic latitude of about 12^{o} (Barbier and Glaume, 1962) from where it would travel equatorwards. In our data, if the south to north intensity ratio decrease is an indication of the overhead passage of the anomaly crest, the same must have been present further south of our scanning limit at 75^{o}S zenith angle, which represents the geomagnetic latitude of about 18.6^{o}S at an altitude of 250 km.

During the course of the premidnight decrease in the south to north intensity ratio, when it occurs, as in Fig. 2a, or even when it does not occur, as in Fig. 2b, quite often we observe very strong red line enhancements travelling from north to south, namely, in the direction opposite to that expected for the intertropical red arc at this site. Some typical examples of these are shown in Fig. 2. These north to south travelling structures cannot be mistaken for the intertropical red arc for the following reasons: the speeds of the intertropical red arc, reported for other sites, are significantly less than the speed of the north to south propagating disturbances, deduced from our observations. For example, Skinner et al. (1977) determined the speed of the intertropical red arc to be of the order of 100 to 130 m/s (or $3\text{-}4^{o}$ latitude per hour), assuming the emitting layer at 300 km, which is approximately a factor of two less than the speed of the disturbances estimated by us, as will be discussed below. Moreover, the intertropical red arc is supposed to pass overhead, generally once per night, whereas the enhanced ridges of the airglow disturbances discussed here have been observed to pass overhead typically two to three times during the premidnight period.

Figs. 3 and 4 show least square fitted straight lines for a few cases of the propagating disturbances, which give an average speed of 238 m/s, with a standard deviation of 73 m/s. For an illustration of the wavelength of the travelling airglow disturbance, we have presented, in Fig. 5, data selected during two nights, that clearly show the progression of peaks and valleys. The wavelengths lie in the range of 350 - 550 km.

An interesting feature of these travelling disturbances is that they invariably occur during nights of significant spread F activity and, in some cases, strong spread F has been observed nearly simultaneously with intense moving airglow patches. Some examples of these cases are presented in Figs. 6 and 7, showing plots of zenith photometer intensity together with the simultaneous h'F values. In this connection, it may be pointed out that association between spread F activity and ionospheric disturbances of TID type has been reported earlier over low latitude by Röttger (1973). As can be seen in Figs. 6 and 7, the relationship between h'F and the zenith photometer intensity is not uniformly defined on these nights, with the generally assumed inverse relationship between them not being present through major parts of these mights. In fact, there are intervals when clear positive dependences are present. A positive dependence between the two parameters is normally observed only for a couple of minutes after h'F has reached its minimum as pointed out by Sobral (1973). The relatively large duration of the positive trends, seen in these figures, thus suggest that they are produced by changes in the columnar electron density in the emitting layer, perhaps caused by constructive interference of superposed modes of gravity waves in the lower F region. Other possibilities are also discussed later. In any event, the positive dependence between the airglow intensity and h'F suggests interesting possibilities towards an understanding of the observed poleward movement of the disturbances itself. Some of these posibilities are discussed below.

From the geomagnetic indices, we have verified that there were no magnetic disturbances immediately preceding the events discussed here and, hence, these airglow disturbances are unlikely to be related to TIDs of high latitude origin. Possibility of these being produced by TID's of low latitude origin, however, can not be ruled out. Röttger (1977) analysed large number of TID's observed by radio technique over Huancayo and found strong correlation between the occurrence frequency of the TID's and rainfall indices in an area in the Amazon forest, situated geomagnetically north of Huancayo, thereby suggesting possible generation of TID's by vertical motion of cumulus clouds in the tropical rainforest regions. The geomagnetic meridional plane at Cachoeira Paulista also passes through a region of the highest rain precipitation rates and vertical cumulus convection in Brazil (see Fig. 1). However, from examination of the satellite infrared maps we haven't found any correlation between these airglow disturbances and meteorogical activity on a day to day basis. The mean horizontal trace speed of the disturbances along the geomagnetic meridional plane, as measured by Röttger (1977), was 210 m/s which compares reasonably well with our result of 238 m/s, also in the geomagnetic meridional plane. But the wavelengths and periods along the geomagnetic field in our case are 350 - 500 km and 20 - 60 minutes, respectively, which differ significantly from Röttger's results which are around 180 km and 5-30 minutes respectively.

It appears more likely that the airglow disturbances presented here, are manifestations of the plasma bubbles or plasma depleted flux tubes, in the equatorial ionosphere. Recent results from radar, rocket and satellite investigations and theoretical modelling of the bubble phenomenon have provided important information towards an understanding of these plasma depleted regions in the equatorial ionosphere (Woodman and La Hoz 1976, Kelley et al, 1976, McClure et al. 1977, Tsunoda 1979, Ossakow, 1979). From the works cited above and other recent ones it now appears that the bubble phenomenon is the underlying process in the "plumes " observed by backscatter radar and many cases of the spread F echoes observed on ionograms. The bubbles have east-weast scales sizes of tens to a few hundreds of kilometers and vertical velocities, with an east-west component also present, of the order of of 150-250 m/s (for example, McClure et al. 1977). Due to the field aligned nature of the ionization at F region heights, a given plasma depleted region near (or immediately above), the F_2 peak over the dip equator can be mapped on to heights immediately below (or near) the F_2 peak over low latitude ionosphere in the immediate vicinity of the magnetic equator. Thus, an upward movement of a plasma bubble over equator could be detected as a poleward movement of a plasma depleted region over our observing station. According to Booker (1979), the plume phenomenon might have its origin from a band in the TID spectrum, that is usually present in the equatorial ionosphere, especially in the evening hours. It occurs when the phase trace speeds of these TID's become approximately equal to the drift velocity of the ambient plasma and when the resulting spacial ressonance gives rise to amplification of the Rayleigh-Taylor instability (Booker 1979, Klostermeyer 1978). Owing to such possible TID origin of the "plume" phenomenon, one could expect quasi periodicities in the occurrence of the upward propagating equatorial plasma bubbles. The quasi periodicities, we have observed in the poleward propagating airglow disturbances, is thus explicable as a consequence of the upward movement of the plasma bubbles over the magnetic equator. Our present data is not sufficient for us to comment about the east-west velocity of the bubble (we are starting shortly east-west scanning observations). The speeds and the scale sizes of the airglow disturbances, discussed before, are well within the values of the bubble parameters observed by satellites (McClure et al., 1977).

For further possible confirmation of the suggested bubble origin of the observed airglow disturbances we examined the behaviour of the spread F echoes during corresponding nights in the ionograms of the magnetic equatorial station, Fortaleza (geogr. 3^{o} 52'S, 38^{o} 25'W) situated within a few degrees from the magnetic meridional plane of the airglow observation. On all the nights of airglow disturbances presented here, range type spread F was present in the premidnight period over Fortaleza. In particular, the range spread was most intense on 29 June 1978, concurrent with the airglow disturbances on this night, which was also the most intense of the events studied in the present paper. It should be pointed out, however, that though the result of this preliminary comparison is encouraging indeed, it is by no means a conclusive confirmation of a possible association between spread F over Fortaleza and the airglow disturbances at Cachoeira Paulista, since range type spread F occurred very frequently during the general epoch of the present airglow observation. It would require a much larger data sample than is available at present to undertake a suitable examination of a possible relationship between the airglow disturbance over Cachoeira Paulista and spread F occurrence over Fortaleza. For the present, it suffices to say that the moving airglow disturbances observed over Cachoeira Paulista is consistent with, more than with any other explanation, the vertical movements of the plasma bubbles over equatorial ionosphere.

4. CONCLUSIONS

The OI 6300 Å meridional scanning photometer data and simultaneous ionosonde data presented and discussed here allow the following conclusions about the dynamics of the ionosphere over Cachoeira Paulista:

1. There is a definite north to south propagation of red line crest at an average speed of approximately 240 ± 70 m/s with wave patterns having quasi wavelengths of a few hundred (350-550) kilometers at a reference altitude of 250 km. They seem to occur on many occasions concurrently with the intertropical red arc.

2. The formation of the intertropical red arc is not clearly defined at zenith over our station, as expected from observations at other longitude zones. On some days, such formations seem to have taken place south of the geomagnetic latitude of 18.6°S.

3. The meridional profile of the red line presented a variety of wavelike structures indicating poleward propagation during the premidnight period whereas the postmidnight enhancement of the red line, whenever they occur, do so simultaneously along the geomagnetic meridional plane indicating no propagating disturbances.

4. A comparison of the OI 6300 Å and h'F data shows positive dependence between them during intervals of intense wave activity, suggesting thereby that it is the fluctuations of the columnal electron density in the emitting layer that is responsible for the airglow variations.

5. From discussions of the plasma bubble phenomena in the equatorial ionosphere, it appears that the poleward propagating airglow disturbances observed over Cachoeira Paulista could be manisfestation of vertical propagation of plasma bubbles over the magnetic equator.

ACKNOWLEDGEMENTS

We are grateful to our colleagues H. Takahashi, who built the photometer, Y. Sahai for his help in running part of the experiments presented here and to J.A. Bittencourt and B.A. Tinsley for useful comments on this work. This research was supported by the Instituto de Pesquisas Espaciais (INPE-CNPq).

FIGURE CAPTIONS

Figure 1 - Geometry of the geomagnetic meridional scanning range of the photometer measurements, reported in this work with reference to an altitude of 250 km. The scanning range at this altitude is approximately 1540 km and is limited by the zenith angle range $\pm 75^{0}$. The lines on the map represent loci of equal rain precipitation during an year. The rainfall data is from the Atlas Climatológico do Brasil, edited by the Brazilian Ministery of Agriculture, 1969.

Figure 2 - Sequences of meridional profiles of the OI 6300 Å intensity displaying the north to south travelling disturbance discussed in the text. Each horizontal line represents the zero level of intensity the corresponding intensity profile.

Figure 3 - Least square fitted straight lines adjusted to the crests of the red line.

Figure 4 - The same as represented in Figure 3, for different days.

Figure 5 - Least square fitted straight lines to both crests and valleys of the OI 6300 Å intensity. Wavelengths are indicated.

Figure 6 - Plots of the red nightglow and h'F versus time. Notice the time of occurrence of the spread-F, approximately the same as for the occurrence of the propagating disturbances of Figure 2-a. (+ indicate positive dependence between h'F and red line intensity).

Figure 7 - The same as represented in Figure 6, for different days.

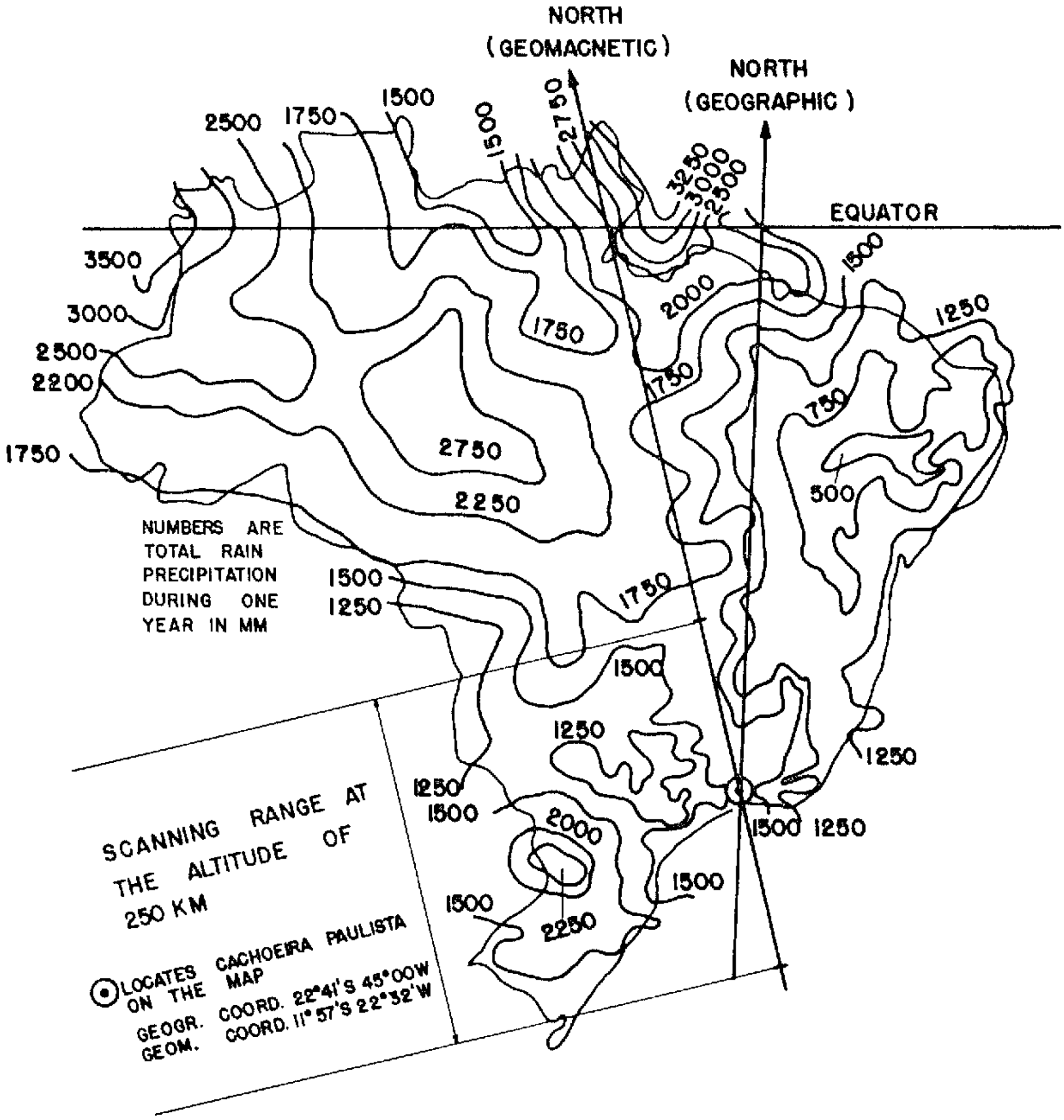

NORTH
(GEOMAGNETIC)
NORTH
(GEOGRAPHIC)
EQUATOR
NUMBERS ARE
TOTAL RAIN
PRECIPITATION
DURING ONE
YEAR IN MM
SCANNING RANGE AT
THE ALTITUDE OF
250 KM
LOCATES CACHOEIRA PAULISTA
ON THE MAP
GEOGR. COORD. 22°41'S 45°00W
GEOM. COORD. 11°57'S 22°32'W

Fig. 1

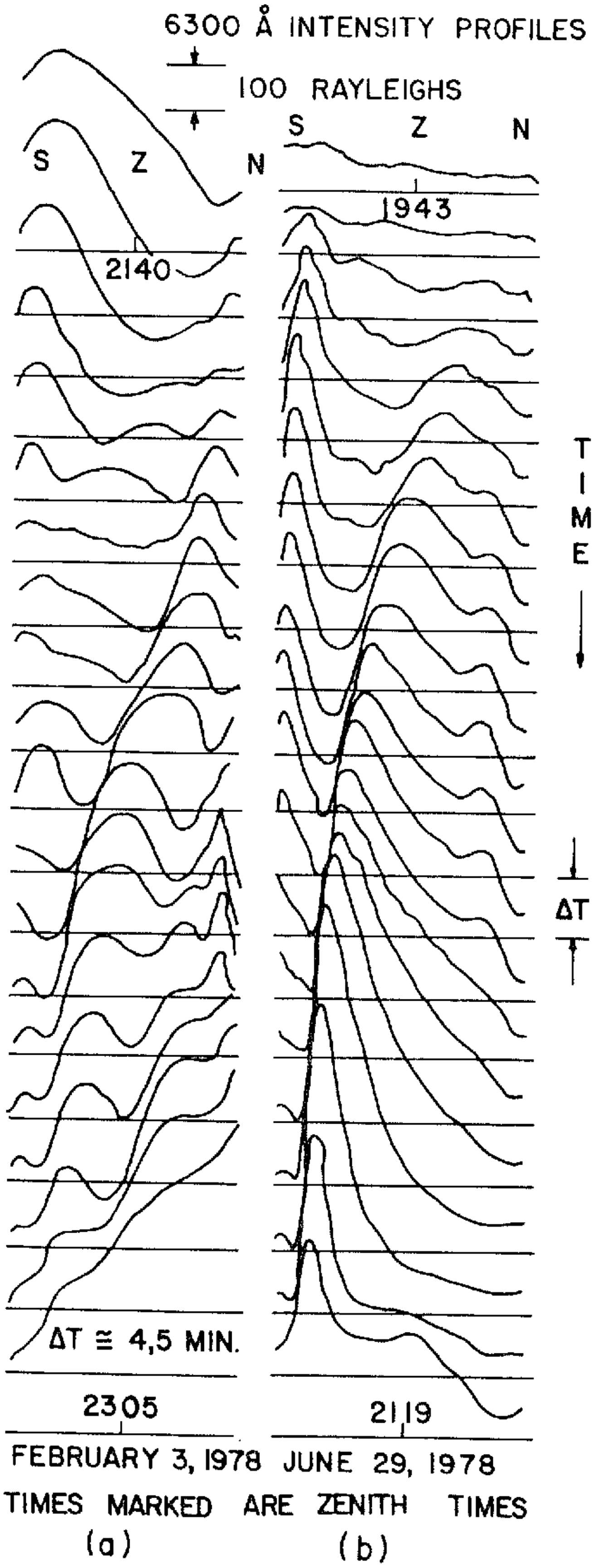

6300 Å INTENSITY PROFILES
100 RAYLEIGHS
S
Z
N
2140
S
Z
N
1943
T
I
M
E
ΔT
ΔT ≅ 4,5 MIN.
2305
2119
FEBRUARY 3, 1978
JUNE 29, 1978
TIMES MARKED ARE ZENITH TIMES
(a)
(b)

Fig. 2

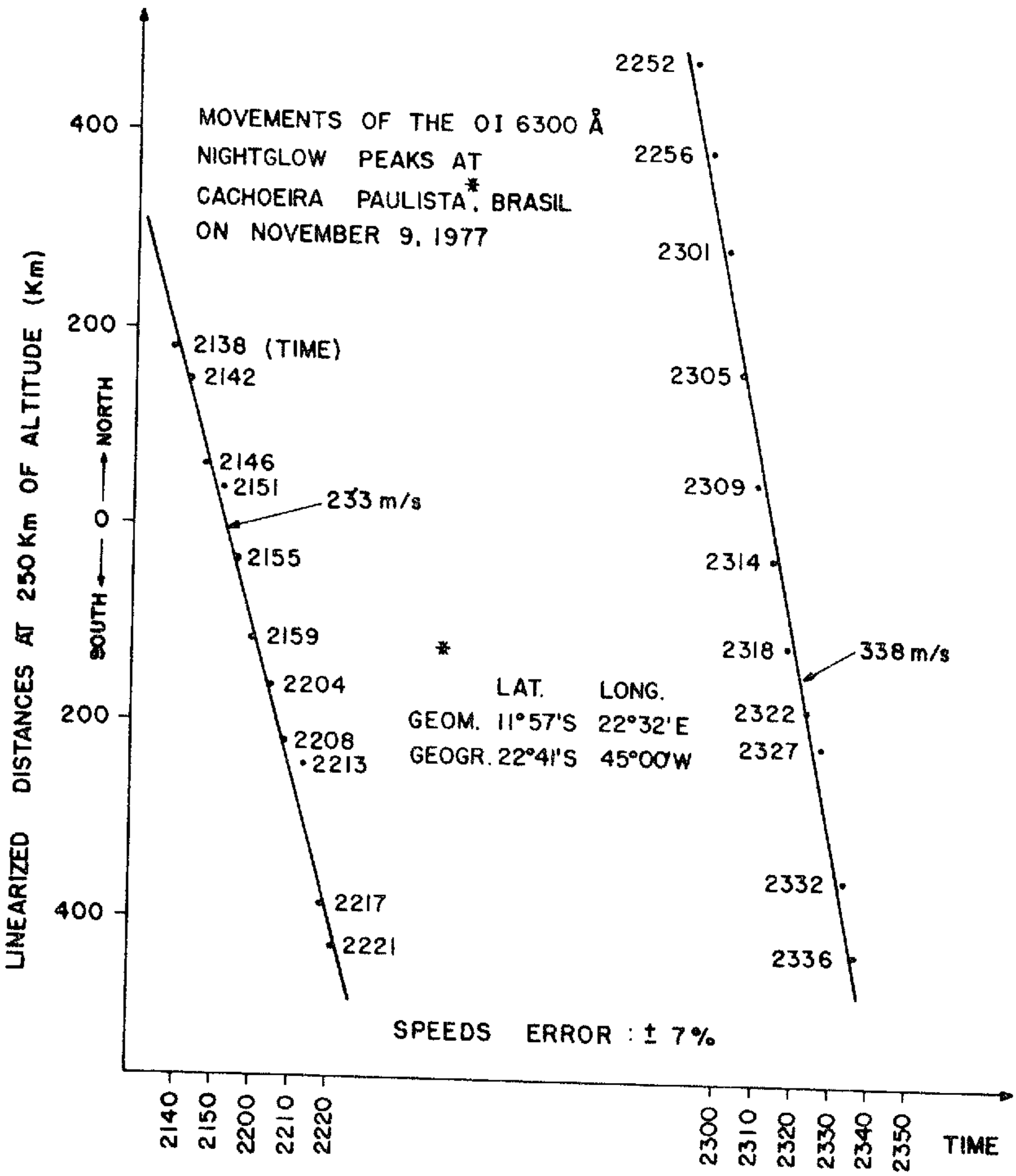

MOVEMENTS OF THE OI 6300 Å
NIGHTGLOW PEAKS AT
CACHOEIRA PAULISTA*, BRASIL
ON NOVEMBER 9, 1977
LINEARIZED DISTANCES AT 250 Km OF ALTITUDE (Km)
SOUTH ← O → NORTH
400
200
0
200
400
2138 (TIME)
2142
2146
2151
233 m/s
2155
2159
2204
2208
2213
2217
2221
2252
2256
2301
2305
2309
2314
2318
338 m/s
2322
2327
2332
2336
*
LAT. LONG.
GEOM. 11°57'S 22°32'E
GEOGR. 22°41'S 45°00'W
SPEEDS ERROR : ± 7%
2140
2150
2200
2210
2220
2300
2310
2320
2330
2340
2350
TIME

Fig. 3

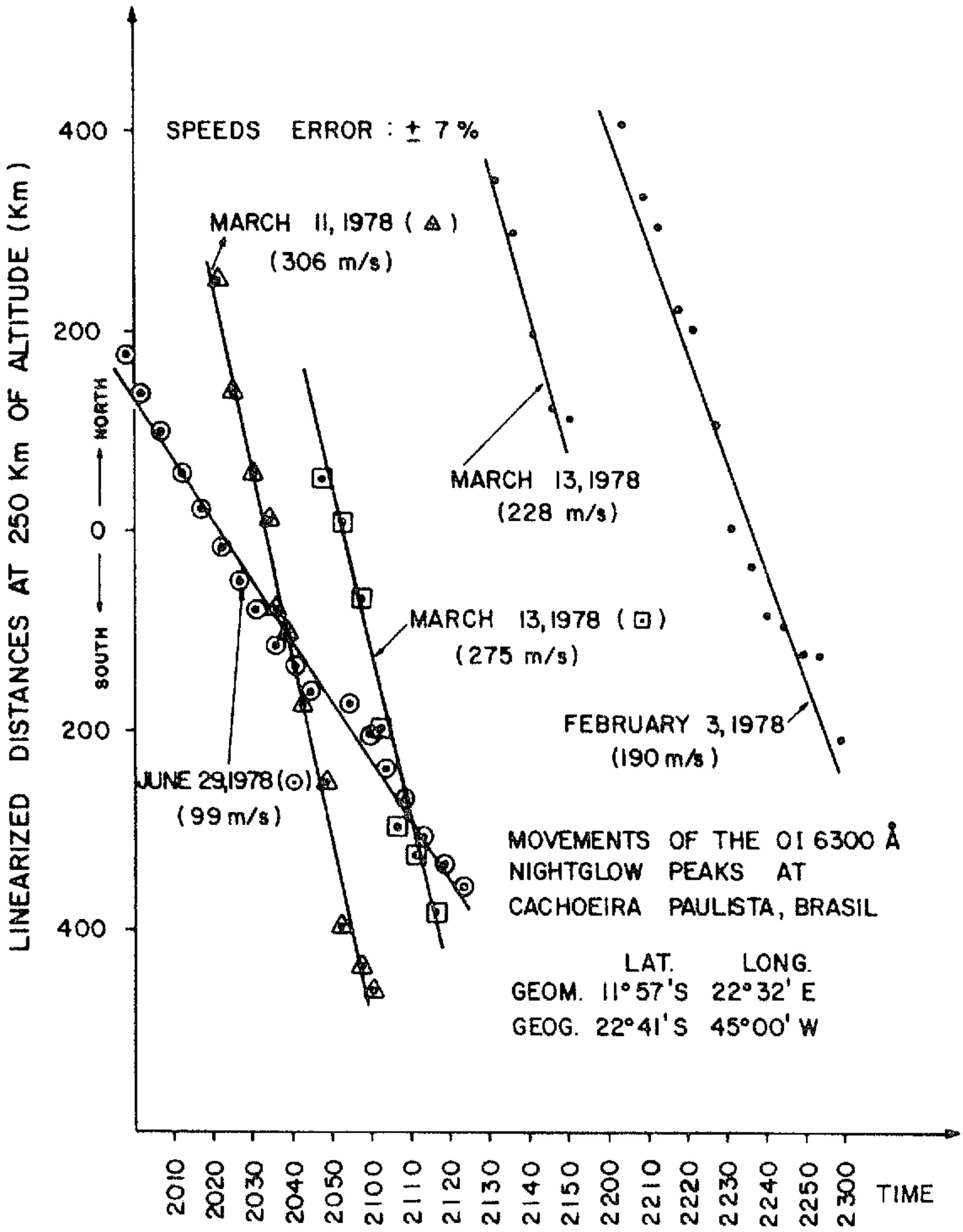

SPEEDS ERROR : ± 7 %
MARCH 11, 1978 (△)
(306 m/s)
MARCH 13, 1978
(228 m/s)
MARCH 13, 1978 (⊡)
(275 m/s)
FEBRUARY 3, 1978
(190 m/s)
JUNE 29,1978 (⊙)
(99 m/s)
MOVEMENTS OF THE OI 6300 Å
NIGHTGLOW PEAKS AT
CACHOEIRA PAULISTA, BRASIL
LAT. LONG.
GEOM. 11°57'S 22°32' E
GEOG. 22°41'S 45°00' W
LINEARIZED DISTANCES AT 250 Km OF ALTITUDE (Km)
NORTH
SOUTH
400
200
0
200
400
2010
2020
2030
2040
2050
2100
2110
2120
2130
2140
2150
2200
2210
2220
2230
2240
2250
2300
TIME

Fig. 4

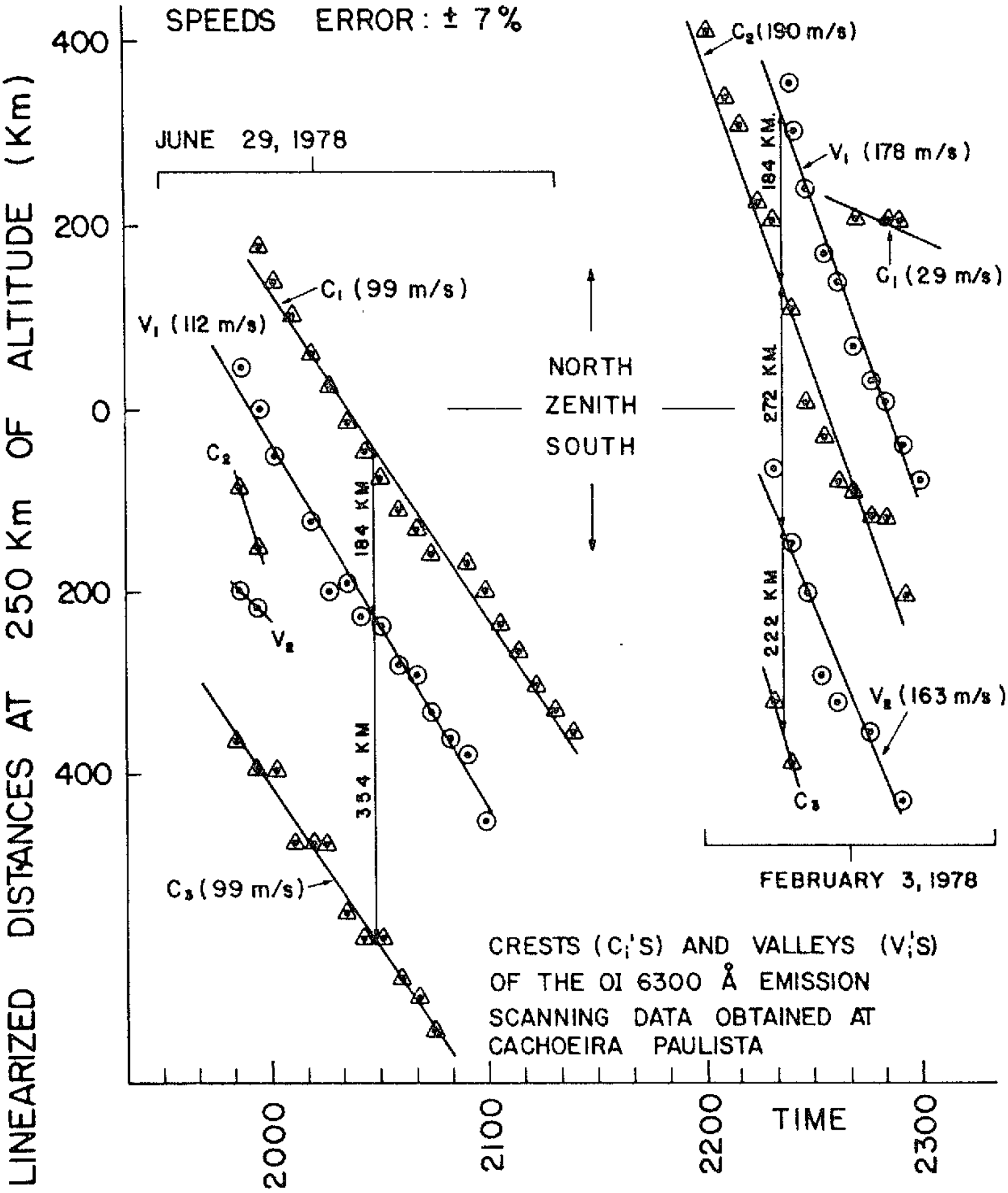

SPEEDS ERROR : ± 7%
JUNE 29, 1978
FEBRUARY 3, 1978
C₂(190 m/s)
V₁ (178 m/s)
C₁ (29 m/s)
V₂ (163 m/s)
C₃
C₁ (99 m/s)
V₁ (112 m/s)
C₂
V₂
C₃ (99 m/s)
184 KM
354 KM
184 KM.
272 KM
222 KM
NORTH
ZENITH
SOUTH
CRESTS (Cᵢ'S) AND VALLEYS (Vᵢ'S)
OF THE OI 6300 Å EMISSION
SCANNING DATA OBTAINED AT
CACHOEIRA PAULISTA
LINEARIZED DISTANCES AT 250 Km OF ALTITUDE (Km)
400
200
0
200
400
TIME
2000
2100
2200
2300

Fig. 5

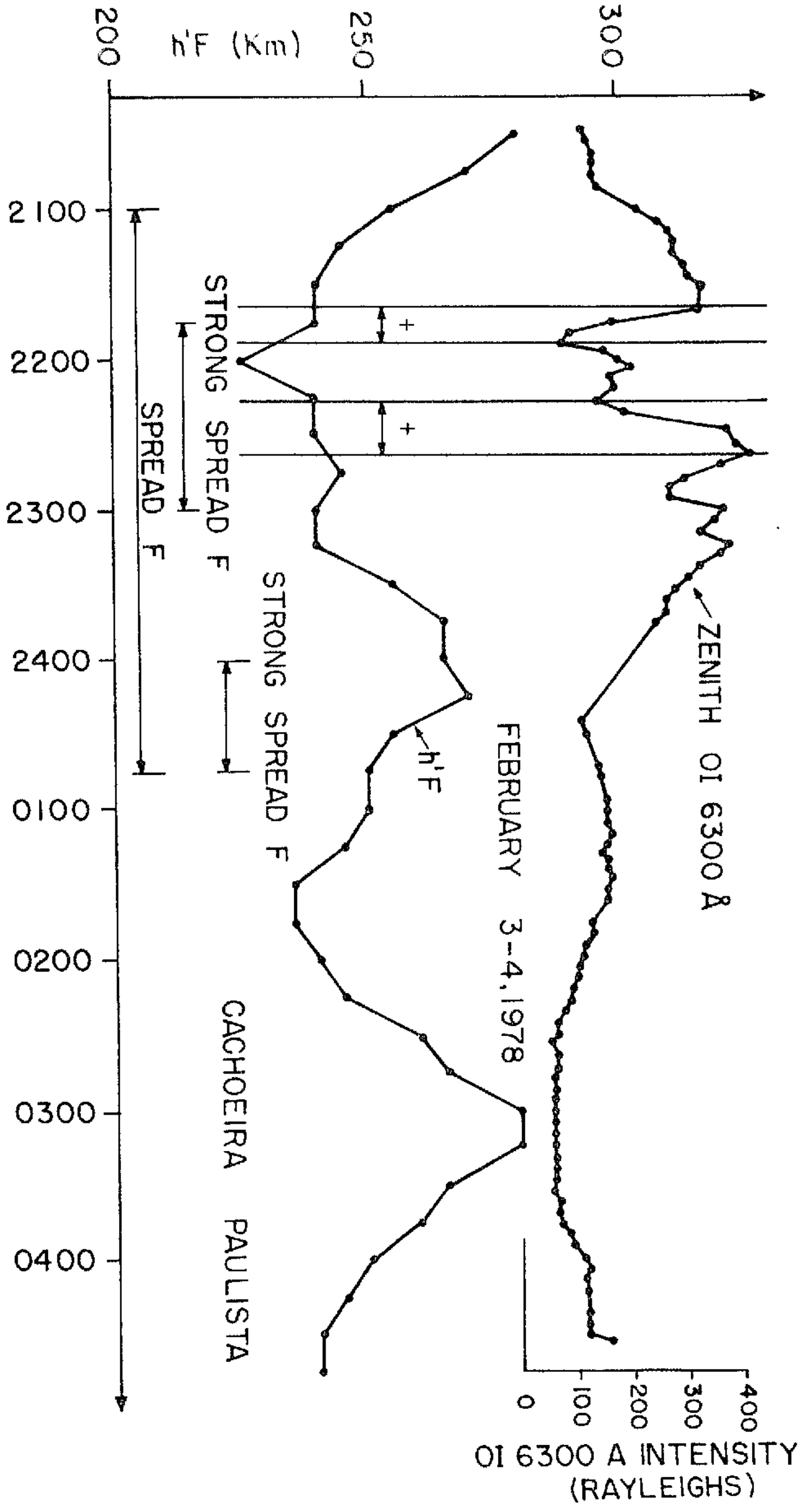
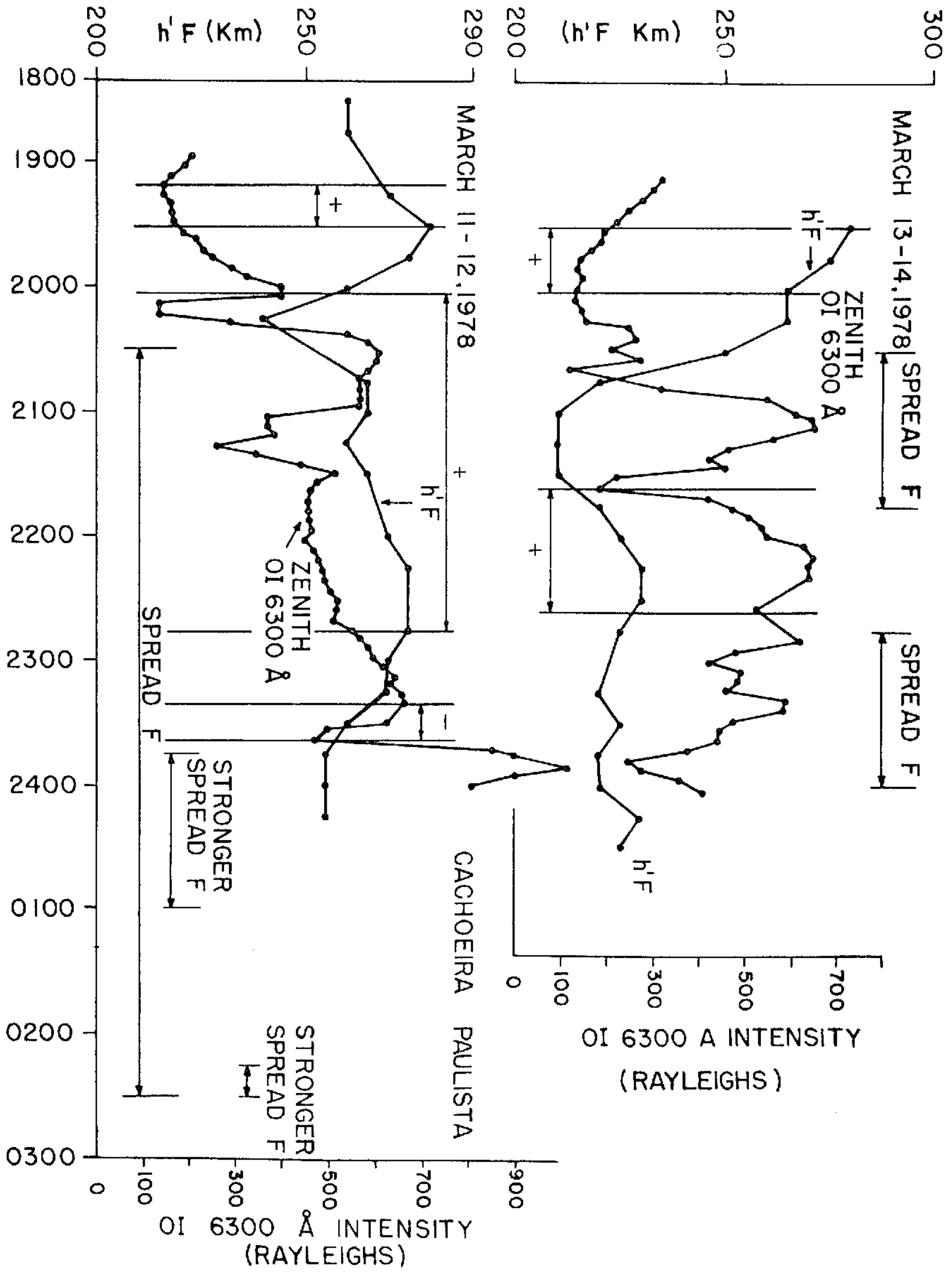

h'F (Km)
200
250
300
2100
2200
2300
2400
0100
0200
0300
0400
SPREAD F
STRONG SPREAD F
STRONG SPREAD F
+
+
h'F
ZENITH OI 6300 Å
FEBRUARY 3-4.1978
CACHOEIRA PAULISTA
0
100
200
300
400
OI 6300 A INTENSITY
(RAYLEIGHS)

Fig. 6



MARCH 13-14,1978
(h'F Km)
200
250
300
h'F
ZENITH
OI 6300 Å
SPREAD F
+
0
100
300
500
700
OI 6300 A INTENSITY
(RAYLEIGHS)
MARCH 11-12,1978
h'F (Km)
200
250
290
1800
1900
2000
2100
2200
2300
2400
0100
0200
0300
SPREAD F
STRONGER SPREAD F
CACHOEIRA PAULISTA
900
OI 6300 Å INTENSITY
(RAYLEIGHS)

Fig. 7

REFERENCES

Abdu, M.A., Batista, I.S. and Sobral, J.H.A. (1979). Particle ionization in the D and E regions over Brazilian geomagnetic anomaly during geomagnetic storms. J. Geophys. Res. 84, 4328.

Abdu, M.A. and Rai, D.B. (1975). Gravity waves in low latitude F-region. Planet. Space Sci. 23, 487.

Barbier, D. (1957). Interprētation de la luminescence nocturne de la raye rouge de l'oxygēne. C.R. Acad. Sci. Paris 244, 2077.

Barbier, D. and Glaume, G. (1962). La couche ionosphērique nocturne F dans la zone intertropicale et ses rēlations avec l'emission de la raye 6300 Å du ciel nocturne. Planet. Space Sci. 9, 133.

Batista, I.S. and Abdu, M.A. (1977). Magnetic storm associated delayed sporadic E enhancements in the Brazilian Geomagnetic anomaly. J. Geophys. Res. 82, 4777.

Bittencourt J.A., Tinsley B.A. Hicks, G.T. and Reed E.I. (1976). Tropical F region winds from OI 1356-Å and [OI] 6300 Å 2. Analysis of Ogo 4 Data. J. Geophys. Res. 81, 3786.

Booker, H.G. (1979). The role of acoustic gravity waves in the generation of spread-F and ionospheric scintillation. J. Atmos. Terr. Phys. 41, 501.

Gledhill, J.A. (1976). Aeronomic effects of the south Atlantic anomaly. Rev. Geophys. Space Phys. 14, 173.

Kelley, M.C., Haerendel G., Kappler, H., Valenzuela, A., Balsley, B.B., Carter, D.A., Ecklund, W.L., Carlson, C.W., Hausler, B. and Torbert, R. (1976). Evidence for a Rayleigh -Taylor type instability and upwelling of depleted density regions during equatorial-F. Geophys. Res. Lett. 3, 448.

Klostermeyer, J. (1978). Nonlinear investigation of the spatial ressonance effect in the nighttime equatorial F region. J. Geophys. Res. 83, 3753.

Kulkarni, P.V. and Rao, V.R. (1972). 6300 Å night airglow emission over the magnetic equator. Ann. Gēophys. 28, 473.

McClure, J.P., Hanson, W.B. and Hoffman, J.H. (1977). Plasma bubbles and irregularities in the equatorial ionosphere. J. Geophys. Res. 82, 2650.

Ossakow, S.L. (1979). Ionospheric irregularities, Rev. Geophys. Space Phys., 17, (4), 521.

Peterson, V.L., Vanzandt, T.E. and Norton, R.B. (1966). F-region nightglow emissions of atomic oxygen. J. Geophys. Res. 71, 2255, 1966.

Röttger, J. (1973). Some properties of large-scale equatorial spread-F irregularities interpreted by influences of atmospheric gravity waves. Zeitschrift für Geophys. 39, 799.

Röttger, J. (1977). Travelling disturbances in the equatorial ionosphere and their association with penetrative cumulus convection. J. Atmos. Terr. Phys. 39, 987.

Röttger, J. (1978). Drifting patches of equatorial spread-F irregularities - experimental support for the spatial ressonance ressonance mechanism in the ionosphere. J. Atmos. Terr. Phys. 40, 1103.

Skinner, N.J., Carman, E.H. and Heeran M.P. (1977). Movements of airglow structures within the intertropical red arc observed from southern Kenya. J. Atmos. Terr. Phys. 39, 1395.

Sobral, J.H.A. (1973). Airglow and incoherent scatter studies of the dynamics of the nighttime ionosphere at Arecibo. Ph.D. dissertation. Cornell University, Ithaca, New York.

Tsunoda, R. (1979). On the spatial relationship of 1-meter equatorial spread F irregularities and plasma bubbles. Presented at the XXII COSPAR Symposium, Bangalore.

Woodman, R.F. and La Hoz, C. (1976). Radar observations of F region equatorial irregularities. J. Geophys. Res. 81, 5447.