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16. Summary/Notes

Recent data on the OI 6300Å nightglow obtained at Cachoeira Paulista (geog. 22°42'S, 45°01'W), Brazil, are analysed. The photometer scanned the meridional zenith angle range of 75° north to 75° south. Some nights presented remarkable wavelike structures on the OI 6300Å meridional profiles. Such wavelike structures occurred essentially during the premidnight periods. These disturbances propagate from north to south at an average speed of about 262 m/s ± 50 m/s, assuming the emitting layer to be at an altitude of 250 km. These airglow disturbances seem to be part of a single periodic wave which originates at lower latitudes. An attempt is made to associate the north traveling atomic oxygen red line enhancements with gravity waves. A discussion is made on the general aspects of the dynamics of the ionosphere near Cachoeira Paulista during nighttime.

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INTENSE WAVELIKE OI 6300Å NIGHTGLOW DISTURBANCES AT 22°42' SOUTH, BRAZILIAN ZONE, AS DETECTED BY SCANNING PHOTOMETRIC MEASUREMENTS.

by

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ABSTRACT

Recent data on the OI 6300Å nightglow obtained at Cachoeira Paulista (geog. 22°42'S, 45°01'W), Brazil, are analysed. The photometer scanned the meridional zenith angle range of 75° north to 75° south. Some nights presented remarkable wavelike structures on the OI 6300Å meridional profiles. Such wavelike structures occurred essentially during the premidnight periods. These disturbances propagate from north to south at an average speed of about 262 m/s ±50 m/s, assuming the emitting layer to be at an altitude of 250 km. These airglow disturbances seem to be part of a single periodic wave which originates at lower latitudes. An attempt is made to associate the north-to-south traveling atomic oxygen red line enhancements with gravity waves. A discussion is made on the general aspects of the dynamics of the ionosphere near Cachoeira Paulista during nighttime.

1. INTRODUCTION

In an effort to study the dynamics of the ionosphere near Cachoeira Paulista (geographic coordinates $22^{o}42'S$, $45^{o}01'W$; geomagnetic coordinates $11^{o}57'S$, $22^{o}32'W$), Brazil, nighttime scanning measurements of the atomic oxygen red line and ionosonde measurements were made at that site. Studies of the ionospheric dynamics by using the atomic oxygen red line have already been reported (Barbier, 1957; Barbier and Glaume, 1962; Peterson et al. 1966; Kulkarni and Rao, 1971).

The set of scanning measurements of the atomic oxygen nightglow, here presented, is restricted to the magnetic meridional plane and covers the zenith distances ranging from 75^{o} north to 75^{o} south. We count, in this work, on a total of about 91.5 hours of observations, which were run in 13 nights in the following way: (i) two nights in November 1977; (ii) four nights in February 1978; and, finally, (iii) seven nights in March 1978. The experiments (i), (ii) and (iii) yielded, respectively, 16.5 hours, 24 hours and 51 hours of useful data.

Cachoeira Paulista is located in the heart of the (following GledhillIs (1976) notation) Brazilian geomagnetic anomaly. At this site, relatively few measurements of ionospheric dynamical effects have been made. That was the main motivation of our work. The ionospheric measurements performed up to present at this location mostly concern aeronomic effects of the precipitating electrons proceeding from the inner Van Allen radiation belts (Ginzburg et al., 1962; Gledhill and Torr, 1966; Martin et al., 1973).

The set of data here introduced is the first set of extensive, conclusive, and small time grid scanning measurements (one $75^{o}N$ - $75^{o}S$ scanning was made approximately each 4.5 minutes) of the atomic oxygen and nightglow near Cachoeira Paulista. Therefore we are able to study, for the first time, the oxygen red line disturbances propagating along the meridional plane through this location.

The intertropical red arc is expected to appear first at the geomagnetic latitudes of $12^{o}N$ and $12^{o}S$. Therefore, Cachoeira Paulista (geomagnetic latitude $11^{o}57'S$) is supposed to be right under the spot where the intertropical red arc will first appear during nighttime. In the discussion section of this work we conclude that such an apparition has not been easily distinguished in our experimental data.

The most surprising result of the scanning measurements of the oxygen red line, here presented, is a wavelike motion, from north to south, of the red line north-south profiles. It appears essentially in the premidnight period. Its average speed has been measured to be 262 m/s ± 50 m/s and seems to be superimposed on the movement of the intertropical red arc, which travels in the opposite direction (i.e. south to north). This and other important features of the nighttime dynamics near Cachoeira Paulista are considered in more detail in the discussion section.

Local ionograms have supplemented the atomic oxygen red line data. Spread F occurrences, h_{max} f_0F_2 data are helpful supplements. A very strong spread F event seems associated with a particularly strong north to south traveling red line enhancement (November 9, 1977).

2. EXPERIMENTAL SET-UP

A tilting filter of 3Å bandwidth has been used to measure the atomic oxygen red nightglow. The sky scanning was made by a mirrow placed looking up at an angle of 45^o with the horizontal plane, so as to reflect the dim sky light into the horizontally displayed photo multiplier tube. The atomic red line measurements were made continuously during a one way sweep of scan. In the north to south scanning motion, the filter was set at a fixed inclination in order to read the sky background (which is here defined as a narrow continuun band placed a few Angstrons away from the wave length of 6300Å). During the south-to-north scanning motion, the filter was set to another inclination so as to read the atomic oxygen line itself (with a bandpass of 3Å), plus background. The net red line intensity is, then, the difference between these two records. The scanning period (i.e. the time required for the mirror to go back and forth) is around 4.5 minutes.

Figure 1 illustrates the scanning range at a reference altitude of 250 km. At this altitude, the geomagnetic latitude range scanned is 13.3^o and its corresponding path length (taking into account the earth's curvature) is 1537 km. At the reference altitude of 300 km these figures change to 15.42^0 and 1795 km.

Figures 1, 3, 4 and 5 show typical recordings of the red line. The data shown in them have not been corrected for the Van Rhijn effects. Such a correction seems to be unnecessary, for the type of discussion involved in this work. The signal amplitudes are dimensionless.

The oxygen red line was often so much stronger than the background, such that the background profiles look flat as compared with the red line profiles.

A local ionosonde produced ionograms each 15 minutes.

The scanning speed was uniform with zenith angle. Therefore, plots like those of Figures 6 and 7 require a careful linearization. According to the chart speed used, a space of 1 mm in the chart paper represents, in the direction of the chart speed and centered on the red line signal, a horizontal distance of about 11.9 km at an altitude of 250 km. Similarly, a distance of 1 mm at the extreme of the scanning, represents a horizontal distance of 256 km at the same reference altitudes. Therefore, we avoided using data too close to the scanning extremes.

3. DISCUSSION

One general feature of the behavior of the atomic oxygen red nightglow, here presented, is a very high intensity in the beginning of the night (in the period of about 18:00 hr to 19:30 hr). At the same time, the extreme north of the sky presents a low intensity red line. Later on, still in the premidnight period, the nightglow intensity tends to increase considerably to the north, which is generally accompanied by a decrease of intensity at the extreme south. In other words, the large south to north red line intensity ratio decreases considerably from the beginning of the night until midnight. Such a general feature seems to be primarily caused by the south to north moving tropical red arc. Let us now call by "transition period" the time interval during which the south to north red line intensity ratio goes from high to low. During the transition period, quite often, we observe very strong enhancements of the red line moving from north to south, not previously cited in the literature. Details about these moving nightglow enhancements will be given soon.

As well understood now, the intertropical red arc displays a long ridge of enhanced OI 6300Å emission broadly extending in the east-west direction. Previous scanning measurements of the atomic oxygen red line at Mt. Abu (Kulkarni and Rao, 1971), clearly show the ridges of the intertropical red arc. Despite the suitable latitudinal position of Cachoeira Paulista ($11^{o}57$'S geomag) to detect the intertropical red arc, we have not detected its slow traveling peak. Perhaps such moving peak of the intertropical red arc had so small a longitudinal variation as not to show a peak over Cachoeira Paulista. As opposed, Kulkarni and Rao's atomic oxygen red line data present abrupt longitudinal variation of the intertropical red arc around its peak. Figure 1 illustrates how the south to north intensity ratio decreases with time. Figure 2 shows the zenith variation of the atomic oxygen red line plus some ionosonde data. The intertropical red arc can hardly be seen there. Under such a lack of a crest in the intertropical red arc it becomes hard to evaluate its south to north speed. Such speeds are of the order of 1.5^{0} latitude per hour, at a reference altitude of 300 km (which corresponds to the speeds of 47 m/s and 39 m/s at the reference altitudes of 300 km and 250 km respectively).

Further, our data do not clearly show that the intertropical red arc appears first in the neighbourhood of zenith, at Cachoeira Paulista. The formation of the intertropical red arc is supposed to happen at geomagnetic latitudes of 12^{0}N and 12^{0}S (Barlier and Glaume, 1960). Figure 1 shows a typical strong red line at the extreme south, in the early evening. It is seen that the oxygen red line increases further to south, beyond the zenith distance of 75^{0}S. Therefore, if the formation of the intertropical red arc implies a peak of OI 6300Å emission, such formation must occur to the south of the zenith distance of 75^{0}S (which corresponds to geomagnetic latitudes of 18.6^{0}S or 19.7^{0}S, if the reference altitudes are either 250 km or 300 km, respectively).

Figures 1, 3, 4 and 5 clearly show the previously cited north-to-south traveling atomic oxygen red line enhancements. These enhancements, occuring in February and March, 1978 were detected in the transition period, as said in the beginning of the section. Figures 6 and 7 show the propagation of the crests of the red line. Notice the relatively low dispersion of the data points of Figures 6 and 7. The straight lines of these figures are least square fitted to the data points, for better accuracy in estimating the traveling speeds. The straight lines of Figures 6 and 7 provide an average north to south speed of the atomic oxygen red line crests of 262 m/s ± 50 m/s. Both space and time variations of these propagating disturbances suggest a gravity wave origin. The passage of these emission enhancements over Cachoeira Paulista coincides with spread F occurrences (Figures 1 and 9). Some times the spread F occurrence during this period is very severe. The spread F ceases then after the passage of the disturbance. Röttger (1973) has interpreted spread F occurrences as influenced by gravity waves.

On the other hand, we found no evidence that such north to south moving enhancements are related to TI 's originated in the north auroral region. An inspection of the geomagnetic indexes shows that such red line disturbances exist without any previous significant variations of the geomagnetic index, during many days preceding the red line disturbances. Therefore, the odds are in favor of gravity waves as the causing mechanism of the north-to-south traveling red line disturbances. However, an important question still remains: where does the gravity wave energy come from?

Sobral et al (1978) have reported strong south-to-north traveling atomic oxygen red line enhancements, going at an average speed of 300 m/s at reference altitude of 300 km, at Arecibo (geographic coordinates 18.4^{0}N, 66.8^{0}W), which is roughly symmetric to Cachoeira Paulista (geographic coordinates of 22.7^{0}S and 45^{0}W) in relation to the equatorial plane. It has been concluded that the south-to-north traveling enhancement at Arecibo is primarily triggered by the global pressure system. A pressure bulge is built up near the equator whose effect is to show down or even to reverse the local nighttime equatorward wind system. However, there is a time difference of a couple of hours between such an event at Arecibo and the north-to-south traveling red line enhancements at Cachoeira Paulista. For example, in the night of January 15, 1972 the large red line enhancement at Arecibo was first detected at a zenith angle of 63^{0}S at about 0120. On our February 1978 record we see the emission enhancement starting around 2200h at the northernmost sector of the scanning. If the generating mechanism is the same for both disturbances of Arecibo and Cachoeira Paulista, one might ponder about their differences in time. The months of these observations, January and February are summer time in the southern hemisphere. Therefore, the northern nighttime transpolar winds might prevail at the equator against the equatorwards southern hemisphere wind system coming from the south pole, thus resulting a pressure bulge located south of the geographic equator. If such is the case, it is obvious that the ionospheric effects of the pushing of the pressure bulge will first appear at Cachoeira Paulista.

Despite the north-to-south traveling red line enhancement observed at Cachoeira Paulista consistently occur during the transition period,any direct association with the intertropical red arc, which is traveling in the opposite direction, is not obvious.

The general behaviour of the red line profiles, here presented, is quite consistent after about 0100 hr. During this later period of the night, the north-south profiles of the atomic red line intensity present practically no wave like structures, as they severelly did present during the premidnight period. However very large, but erratic, red line enhancements were observed roughly simultaneously along the meridional plane.

4. CONCLUSIONS

The set of meridional scanning atomic oxygen red line data here introduced, plus complementary ionosonde data, allow us to assert the following about ionospheric dynamics near Cachoeira Paulista:

1. the north-south atomic oxygen red line profiles present a variety of wavelike structures during the premidnight period. After about 0100 hr, such wavelike motions disappear and the enhancements appear simultaneously spread all over the meridional plane.
2. There is a downnight north-to-south propagation of red line enhancements at an average speed of 262 m/s ± 50 m/s during the south-to-north motion of the intertropical red arc not previously detected.
3. The odds are in favor of gravity waves as the causing mechanism of

the north-to-south traveling red line enhancements. However, in this case, the energy source for this gravity wave is unknown.

4. The formation of the intertropical red arc is not obviously seen at specifically the zenith. In this case, the formation should take place south of $18.6^{o}S$ or $19.7^{o}S$ considering the reference altitudes of 250 km and 300 km respectively.

REFERENCES

Barbier, D. "Interprétation de la luminescence nocturne de la raye rouge de l'oxygene", C.R. Acad.Sci., Paris 244, 2077-2080, 1957.

Barbier, D. et Glaume, J., "Les radiations de l'oxygène 6300 et 5577Å de la luminescence du ciel nocturne dans une station de basse latitude", Ann.Geophys., 16, 319-339, 1960.

Barbier, D. and Glaume, J., "La couche ionospherique nocturne F dans la zone intertropicale et ses relations avec l'emission de la raye 6300Å du ciel nocturne", Planet. Space Sci., vol. 9, 133-148, 1962.

Ginzburg, V.L.; L.V. Kurnosova and V.I. Logachev; A.A. Razonerov; I.A. Sirotkin and M.I. Fradkin, "Investigation of charged particle intensity during the flights of the second and thi d space ships", Planet. Space Sci., 9, 845-854, 1962.

Gledhill, J.A. and D.G. Torr, "Ionospheric effects of precipitated electrons in the south radiation anomaly", Space Res., 6, 222-229, 1966.

Gledhill, J.A. "Aeronomic effects of the South Atlantic Anomaly", Rev.Geophys. and Space Phys., vol. 14, no. 2, May, 173-187, 1976.

Kulkarni, P.V. and V.R. Rao. "6300Å night airglow emission our the magnetic equator". Ann.Geophys., t. 28, fasc. 2, 1972, 475-481.

Martin, I.M., D.B. Rai, J.M. da Costa, R.A.R. Palmeira and N.B. Trivedi. "Enhanced electron precipitation in the Brazilian magnetic anomaly in association with sudden commencement", Nature, 240, 84-86, 1973.

Peterson, V.L., T.E. VanZendt and R.B. Norton, "F region nightglow emissions of atomic oxygen", J.Geophys.Res., 71, 2255-2265, 1966.

Sobral, J.H.A., H.C. Carlson, D.T. Farley and W.E. Swartz. "Nighttime dynamics of the F region near Arecibo as mapped by airglow features". J.Geophys.Res. paper 7A1170. 1978 (in publication).

DESCRIPTION OF THE FIGURES

Figure 1 - Position of the geomagnetic meridional scanning. The scanning range shown refers to an altitude of 250 km, and the zenith distance of 150^{o} centered at zenith.

Figures 2, 4, 5 and 6 - Geomagnetic meridional profiles of the OI 6300Å nightglow. The emission intensity is shown dimensionless. The dashed lines lie along the north to south traveling OI 6300Å enhancements. The left and right hand sides of each profile are south and north, respectively.

Figures 3 and 9 - Profiles of the zenith OI 6300Å nightglow and the F2 region peak (h'F). Notice the presence of spread F during more intense airglow variations. During these days pronounced north to south traveling red line enhancements were seen.

Figures 7 and 8 - Straight lines least square fitted to the peak of the north to south traveling OI 6300Å enhancements. Such peaks are represented by points. The emitting layer is supposed to be at an altitude of 250 km.

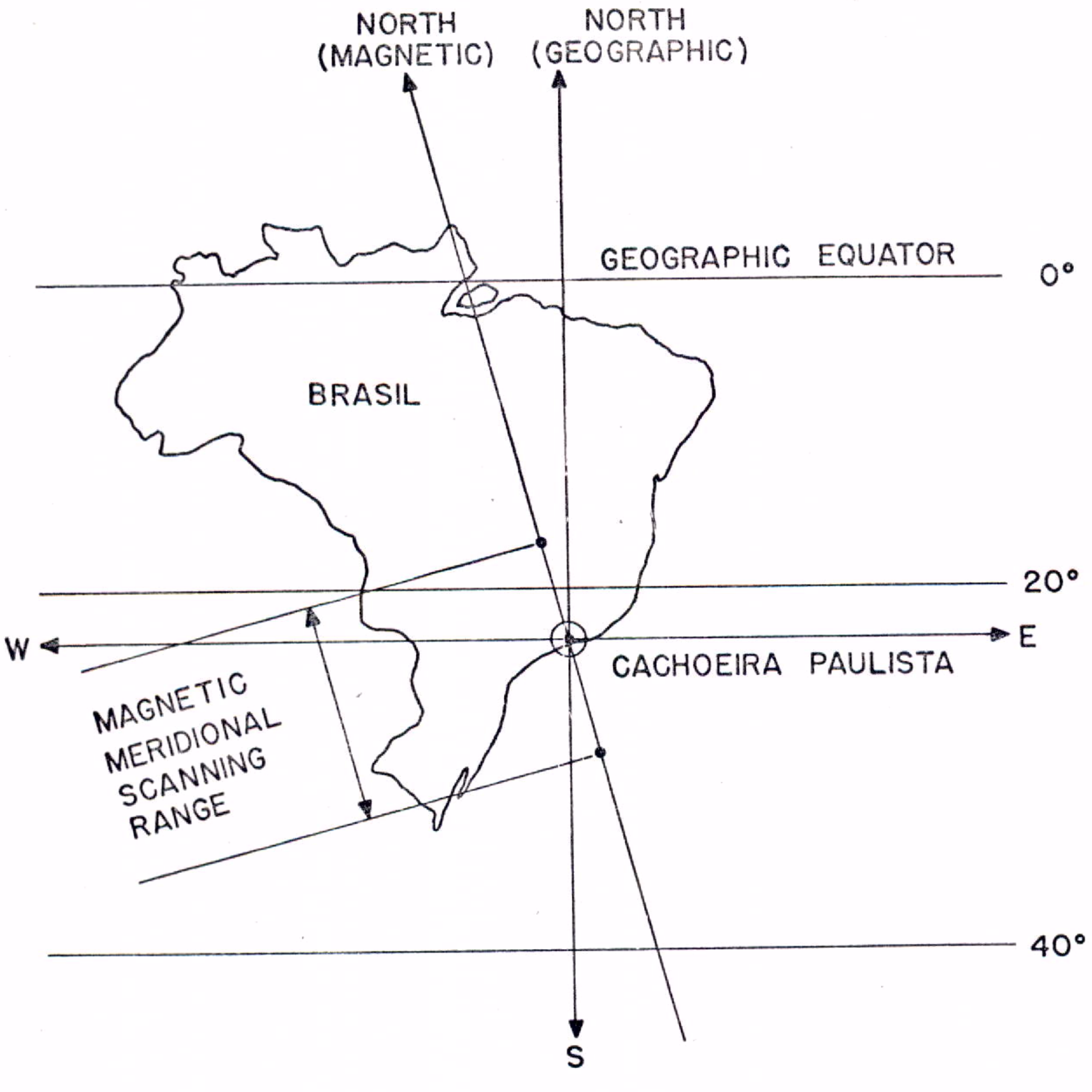
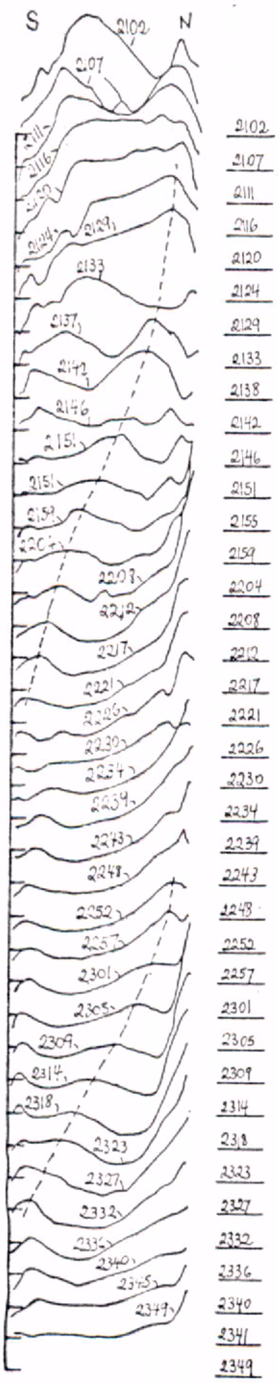
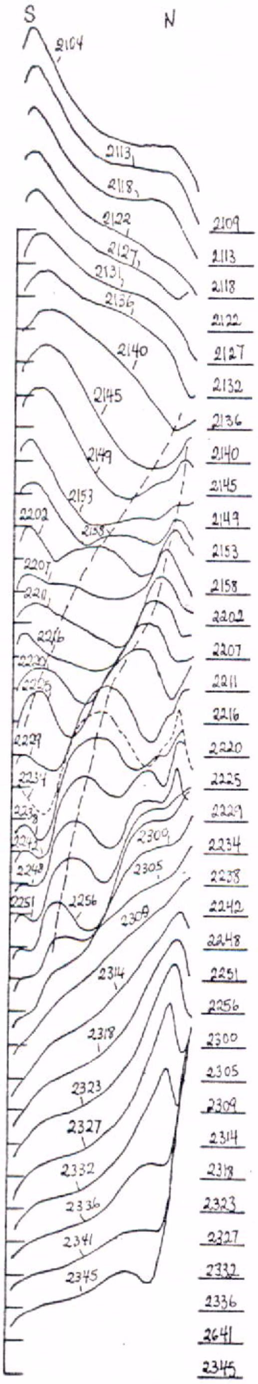

NORTH
(MAGNETIC)
NORTH
(GEOGRAPHIC)
GEOGRAPHIC EQUATOR
0°
BRASIL
20°
W
E
CACHOEIRA PAULISTA
MAGNETIC
MERIDIONAL
SCANNING
RANGE
40°
S

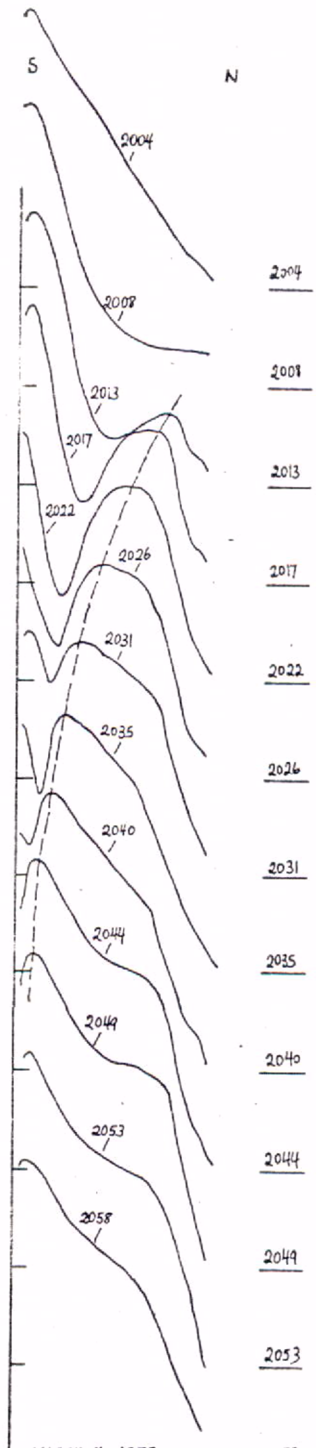
FIGURE 1



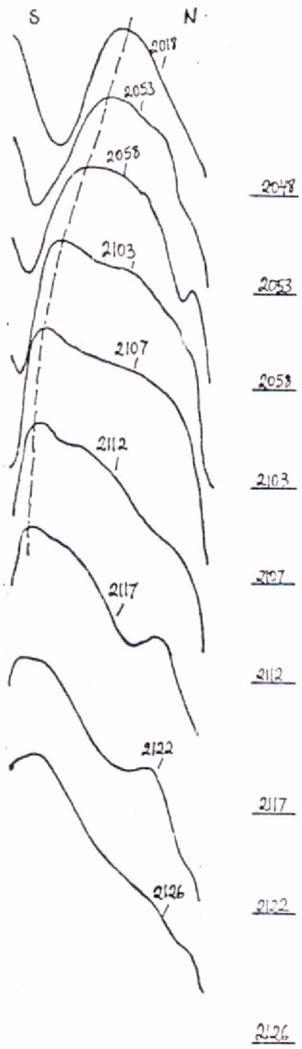
NOVEMBER 9, 1977
FIGURE 6



FEBRUARY 3, 1978
FIGURE 2



MARCH 11, 1978
FIGURE 4



MARCH 13, 1978
FIGURE 5

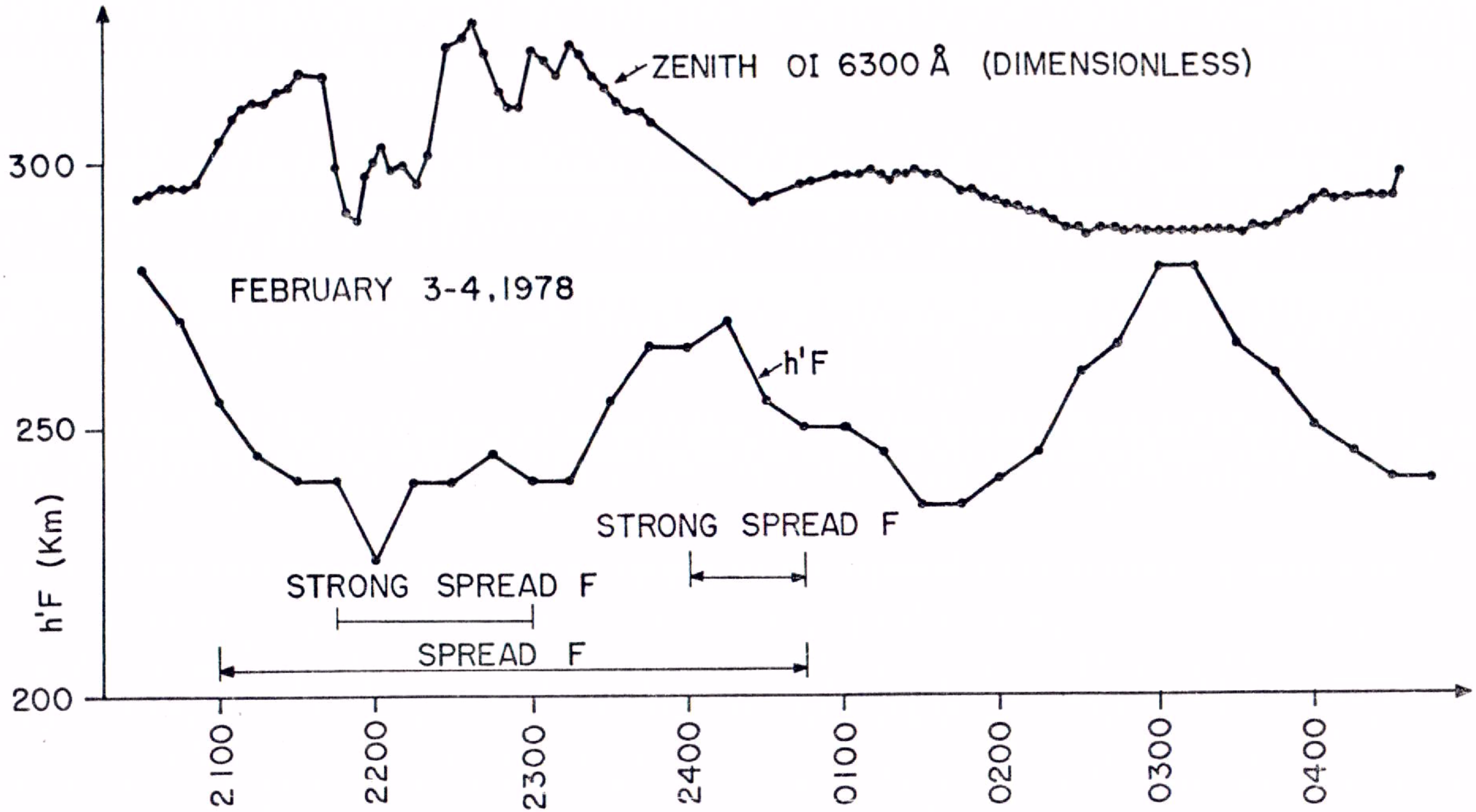
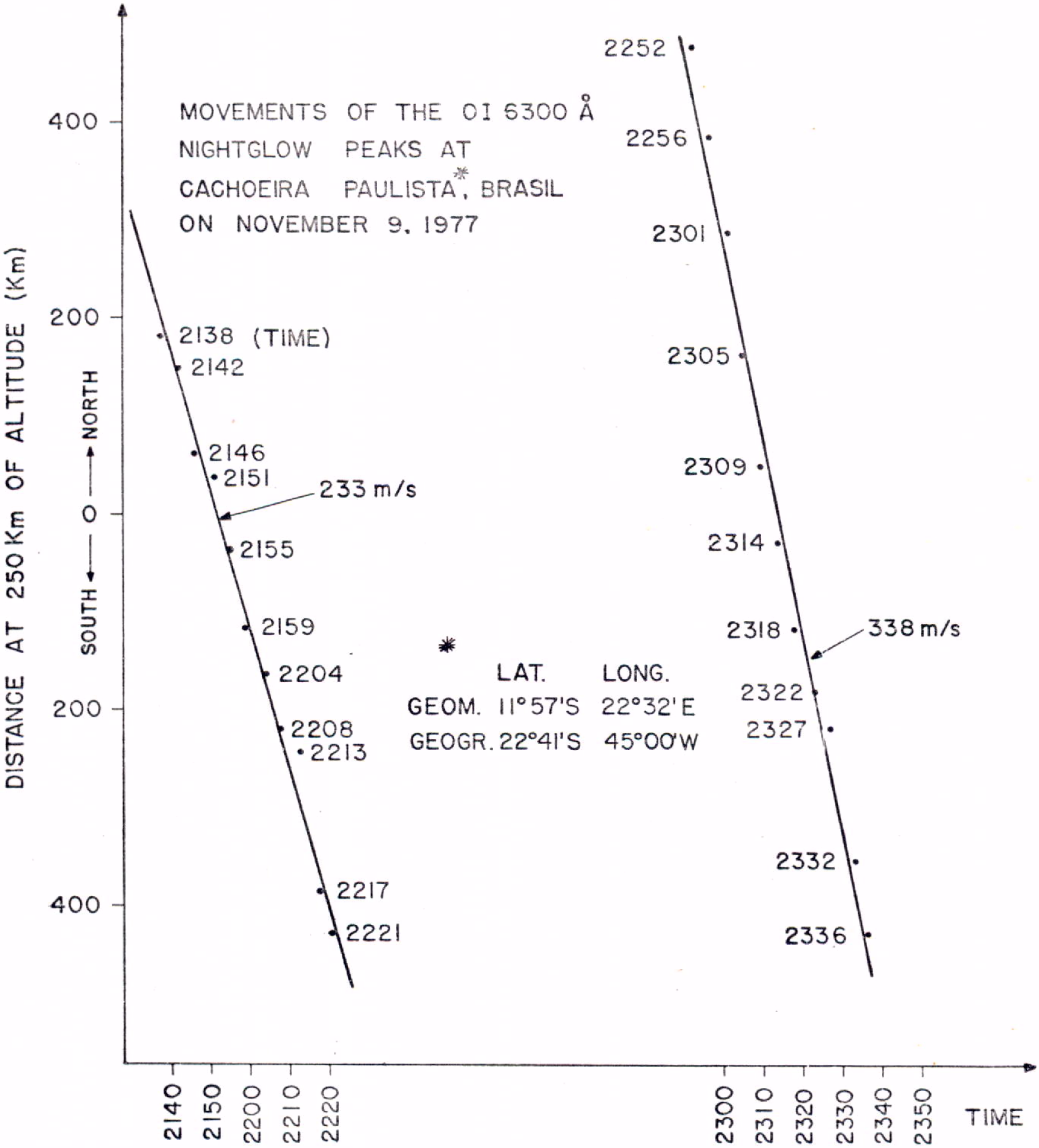

ZENITH OI 6300 Å (DIMENSIONLESS)
FEBRUARY 3-4, 1978
h'F
STRONG SPREAD F
STRONG SPREAD F
SPREAD F
300
250
200
h'F (Km)
2100
2200
2300
2400
0100
0200
0300
0400

FIGURE 3



MOVEMENTS OF THE OI 6300 Å
NIGHTGLOW PEAKS AT
CACHOEIRA PAULISTA*, BRASIL
ON NOVEMBER 9, 1977
DISTANCE AT 250 Km OF ALTITUDE (Km)
SOUTH ← 0 → 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
2140
2150
2200
2210
2220
2300
2310
2320
2330
2340
2350
TIME

FIGURE 7

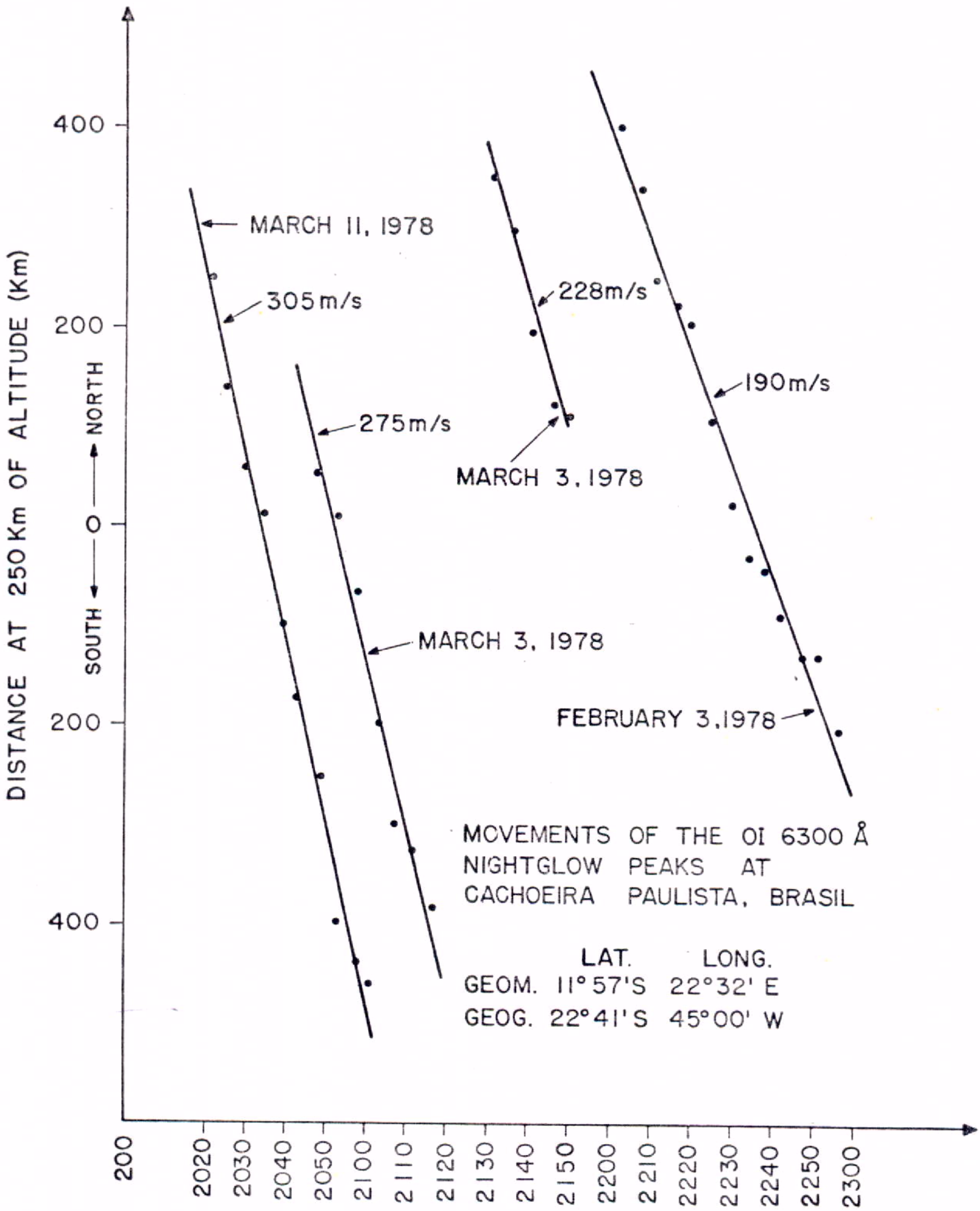

DISTANCE AT 250 Km OF ALTITUDE (Km)
SOUTH
NORTH
400
200
0
200
400
200
2020
2030
2040
2050
2100
2110
2120
2130
2140
2150
2200
2210
2220
2230
2240
2250
2300
MARCH 11, 1978
305 m/s
275 m/s
MARCH 3, 1978
228m/s
MARCH 3, 1978
190m/s
FEBRUARY 3,1978
MOVEMENTS OF THE OI 6300 Å
NIGHTGLOW PEAKS AT
CACHOEIRA PAULISTA, BRASIL
LAT. LONG.
GEOM. 11°57'S 22°32' E
GEOG. 22°41'S 45°00' W

FIGURE 8

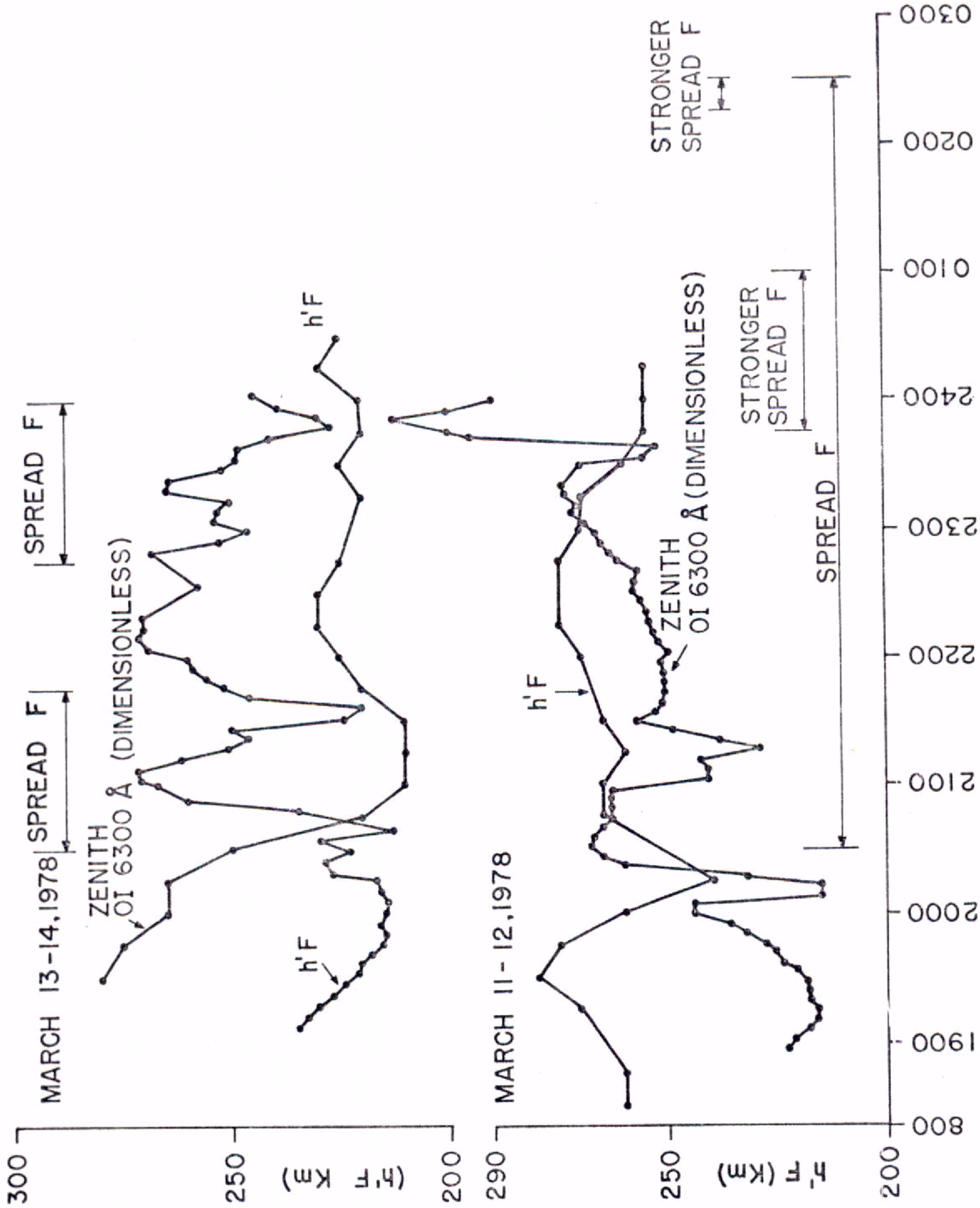

MARCH 13-14, 1978
ZENITH
OI 6300 Å (DIMENSIONLESS)
SPREAD F
SPREAD F
h'F
h'F
300
250
200
(h'F Km)
MARCH 11-12, 1978
ZENITH
OI 6300 Å (DIMENSIONLESS)
h'F
SPREAD F
STRONGER
SPREAD F
STRONGER
SPREAD F
290
250
200
h'F (Km)
1800
1900
2000
2100
2200
2300
2400
0100
0200
0300

FIGURE 9