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ABSTRACT

Simultaneous measurements of the permitted OI 7774 Å and the forbidden OI 6300 Å nightglow emissions were carried out at Cachoeira Paulista (geog. 22.7^{o}S, 45.0^{o}W), Brazil, during the period of April 1978 to March 1979. Both the emissions were observed with tilting filter type photometers. During spread-F conditions, on several nights, both the emissions showed simultaneous short-time large intensity depletions, indicating the presence of large-scale irregularities in the F-region. Data for the period September - October, 1978 are presented and discussed. The depletions observed are possibly associated with the passage of F-region holes or bubbles drifting across the sky.

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INTRODUCTION

During the recent past, ionospheric irregularities in the equatorial regions have been subject of intensive experimental and theoretical investigations. A variety of experimental techniques, including incoherent backscatter radar, in situ observations by rockets and satellites, scintillations in ionospheric radio wave propagation, ionosonde, and airglow observations, have provided valuable informations on ionospheric irregularities (see, e.g., reviews by Ossakow, 1979; and Basu and Kelly, 1979).

Atomic oxygen emissions, which are due to F-region recombination processes, can be used as a diagnostic tool to study large-scale F-region irregularities. The OI emissions at 7774 Å and 6300 Å are particularly suitable for ground-based mapping of these irregularities.

The 6300 Å emission, which is due to dissociative recombination of O_2^+ ions in the ionospheric F-region, has been used to monitor large-scale ionospheric wave disturbances and plasma depletions (see, e.g., VanZandt and Peterson, 1968; Weber et al., 1978; Sobral et al., 1980a; Sobral et al., 1980b). McClure et al. (1977) have indicated that part of the vertical ionospheric motions, responsible for the 6300 Å airglow maps of VanZandt and Peterson (1968), was due to ionospheric processes associated with the plumes and bubbles of ionospheric irregularities.

The 7774 Å emission, first observed by Weill and Joseph (1970), is due mainly to radiative recombination of O^+ ions in the ionospheric F-region, with a small contribution from ion-ion recombination (Tinsley et al., 1973), and is a very good indicator of the F2 - region electron density, in the way described by Tinsley and Bittencourt (1975). Also, simultaneous observations of the 7774 Å and 6300 Å emission provide an indirect measurement of the F2 - peak height (Tinsley and Bittencourt, 1975).

In this paper, we present and discuss observations of short-period large depletions in the F-region electron density detected by the OI 7774 Å and 6300 Å nightglow measurements during spread-F conditions from a low-latitude station at Cachoeira Paulista (geographic 22.7°S, 45.0°W; geomagnetic latitude 11.95°S), Brazil, during the period September - October, 1978. Simultaneous ionosonde observations from Cachoeira Paulista are also presented. This is the first time the 7774 Å emission has been used to study large-scale, low-latitude F-region irregularities.

INSTRUMENTATION

The 7774 emission measurements were made with a tilting-filter type photometer. The photometer characteristics are given in Table 1. The photometer response at filter positions P_2 and P_3 were used to estimate the OH (9-4) and continuum contribution at position P_1 for and OH rotational temperature of 185°K (Takahashi et al., 1974) measured at Cachoeira Paulista.

The zenith intensities of the 6300 emission were also measured with a tilting-filter type photometer with a field of view of 5° diameter. The interference filter (bandwidth ~ 11 Å) was rocked between two positions to give the on-line and background intensities. The isophot maps of the 6300 emission were obtained from an all-sky scanning filter-wheel type phtometer with a field of view of 6° diameter. The observed intensities were corrected for the van Rhijn effect.

The ionospheric data presented were obtained from an ionosonde (Magnetic AB model 10005 W) also operating at Cachoeira Paulista.

OBSERVATIONS AND DISCUSSION

During the period September - October, 1978, the nightglow observations were obtained on 8 clear nights. Figures 1 and 2 show the variations of the observed zenith intensities for the 7774 and 6300 emissions (each 5 minutes) and h'F (each 15 minutes) for September 28 - 29 and October 3 - 4, 5 - 6, 24 - 25 and 25 - 26. A common feature, observed on all of these nights, is simultaneous large intensity depletions in both the emissions during the Sp-F conditions in the pre-midnight period, except on October 5 - 6 when both Sp-F and intensity fluctuations continued till late night. It is also observed, from the h'F variations on these nights, that the F-layer lifts up rapidly before the onset of the Sp-F and intensity drop-outs, and the ionograms during this period show obligue traces indicating irregular ionospheric structure. It may be pointed out that the ionospheric data from Fortaleza (3.0^{o}S, 38.0^{o}W), Brazil, the nearest equatorial ionospheric station, also indicated rapid F-layer uplifting around 1800 - 1900 hours on these nights with presence of strong Sp-F later.

Figure 3 shows data for September 25 - 26, 26 - 27 and October 2 - 3, when neither larger intensity fluctuations nor Sp-F were observed. Also, only the normally expected uplifts of the F - layer after sunset, in the absence of spread - F, were observed. Data on October 2 - 3 clearly show that the local time maximum in the 7774 emision precedes that in the 6300 emission by aproximately one hour. VanZandt and Peterson (1968) have also observed in Hawai, a time difference of approximately one hour between the local time maximum of f_0F_2 and of the 6300 emission. As indicated by Tinsley et al. (973), this is to be expected because of the fact that the field aligned ionization is tilted at the local dip angle and the 6300 emission vertical profile maximizes at a lower height than that of the 7774 emission profile, provided the F-region is moving equatorward.

Tinsley et al. (1973) showed that the radiative recombination is the major source for the 7774 emission in the tropical region and that the column emission rate, J_{7774}, due to this process, is given by

$$J_{7774} = \int \alpha_{7774} [n(e)]^2 \, dz \qquad (1)$$

where α_{7774} is the partial rate coefficient for radiative recombination, n(e) is the electron density and z denotes the height. Therefore, neglecting small contribution from the ion-ion recombination, the observed 7774 emission is a function of the integrated $[n(e)]^2$ and the large drop-outs in the 7774 intensity variations, shown in Figures 1 and 2, are due to depletion in electron densities, possibly associated with the passage of F-region holes or bubbles.

It is interesting to note that the 6300 emission also show simultaneous drop-outs in the intensities. Using the same notation as in equation (3) of Tinsley and Bittencourt (1975), the column emission rate J_{6300}, due to dissociative recombination, is given by

$$J_{6300} = \int \frac{K A_{6300} \, \gamma_1 \, n(O_2) n(O^+) \, dz}{A(1 + d(z)/A)} \qquad (2)$$

where $n(O_2)$ is the molecular oxygen density, $n(O^+)$ is the atomic oxygen ion density, γ_1 is the reaction rate coefficient for the dissociative recombination of O_2^+, K is the quantum efficiency (that is, the fraction of ^1D excited states produced per dissociative recombination of O_2^+), A and A_{6300} denote the Einstein coefficients for transition from the ^1D state and for the transition leading to the 6300 Å emission, respectively, and d(z) is the height-dependent quenching coefficient.

The 6300 Å emission rate is greater on the bottomside of the F-layer (because of the decrease with height of $n(O_2)$ with a scale height of ~ 50 km). A lowering of the F-layer, until the bottomside comes down to about 250 km (where quenching begins to become important) greatly enhances the 6300 emission and, hence, the 6300 intensity depends mainly on the vertical motions of the F-region, and more specifically on the height of the bottomside of the F-region. Large intensity drop outs of the 6300 emission are also associated with large-scale F-region irregularities.

Since the 6300 Å emission is strongly height dependent, with only a linear dependence on n(e), the spatial structure observed in this emission, during spread-F conditions, could be due to height variations and vertical motions of the irregularities in the bottomside F-region, as well as due to the depletions in n(e), whereas the spatial structure in the 7774 Å emission reflects only the depletions in n(e). Note, however, that the amplitudes of the drop-outs in 7774 Å emission, as seen in Figures 1 an 2, are larger than those in the 6300 Å emission, since the 7774 Å intensity depends on $[n(e)]^2$.

The duration of the depletions observed are of the order of 10 minutes and are consistent with that reported by Yeh et al. (1979). Only on a few occasions (e.g. October 24-25; 22:00 hours) it was observed that the recovery of the 7774 intensity from the depletion was slower than the drop out. This is possibly due to the orientation and vertical structure of the n(e) depletion in the F-region since, according to McClure et al. (1977), the plasma bubbles typically drift upward and westward with respect to the background plasma (but perhaps eastward in a corotating frame), probably leaving behind them slanted trails of low ionization.

Figure 4 shows three isophot maps of the 6300 emission during the period 2153-2207 hours on October 24-25. It is observed, from Figure 2, that both the 6300 and 7774 emission showed large drop-out in the intensities at 22:00 hours (the 7774 emission intensity dropped from 305 Rayleighs at 21:50 hours to 53 Rayleighs at 22:00 hours) and the isophot maps of the 6300 emission (spatial structure of two emissions should be similar) in Figure 4 show the spatial structure associated with the rapid zenith fluctuations. It is evident from Figure 4 that the large drop-out in intensity, observed at 22:00 hours, is associated with an eastward movement of a region of low intensity located in the south-west at 21:53 hours.

It may also be pointed out that the 6300 emission observations during the period September 1978 - March 1980 (from September 1978, the 6300 emission data are available for time intervals of 5 minutes or less) show large intensity variations during the pre-midnight period on some nights in every month, except winter months (May, June and July, 1979) and this seasonal behaviour could be possibly due to seasonal variation of the equatorial vertical drifts (Fejer et al., 1979) where upward drift is shortest during local winter. Kaushika and Mendonça (1974) have also reported nighttime fluctuations (scintillations) in Faraday rotation angle during equinox and summer months from a nearby station at São José dos Campos (23.2^{o}S, 46^{o}W, mag. dip. - 23.7^{o}).

The rapid and large increase in h'F, which occurs just after sunset, as observed at Cachoeira Paulista and Fortaleza on nights when large drop-outs in the airglow emissions during Sp-F conditions are present, seems to indicate that the irregularities are possibly associated with the rapid lifting of the whole low-latitude field tube by an electric field (the fountain effect) resulting in a large influx of plasma coming down the field lines at the latitude of Cachoeira Paulista. The plasma irregularities or bubbles could have been generated at the observed latitudes via the Rayleigh-Taylor instability mechanism and/or generated at the bottomside equatorial F-region and transported upwards, during the period of enhanced upward drift velocities. Generally Sp-F appears after the F-region has become very high and "disconnected" in terms of electrical conductivity from the underlying E-region.

CONCLUSIONS

The large drop-outs in the 7774 emission intensities during Sp-F conditions are possibly associated with the passage of F-region holes or bubbles drifting across the sky. Simultaneous 6300 emission data also exhibit similar temporal behaviour and isophots show spatial structure during disturbed ionosphere. However, sometimes the spatial structure could be due to height variations of the F-layer as well. The 7774 emission is dependent only on F-region electron density profile and hence would be very useful in studying F-region irregularities.

It is worth noting that the 7774 emission data obtained, give an indication of the F-region electron densities during Sp-F conditions, when these data cannot be obtained by an ionosonde. Also, by scanning the sky, the spatial structure over a large geographical region can be determined and, again, this is not possible with an ionosonde.

Modifications of the 7774 emission observations are planned to permit study of spatial and smaller-scale details of the ionospheric irregularities. Complementary airglow observations with ionospheric sounding measurements are likely to be very useful in mapping ionospheric irregularities.

ACKNOWLEDGEMENTS

We acknowledge helpful discussions with B.A. Tinsley, J.P. McClure and B.R. Clemesha. This work was partially supported by the Brazilian National Fund for Science and Technology under contract FINEP-537/CT.

TABLE 1

7774 PHOTOMETER CHARACTERISTICS

1. Aperture: 65 mm dia.
2. Field of View: 3^{o} full angle.
3. Wavelength Scanning: tilting-filter technique.
4. Photometer Sensitivity: ~ 7 counts/R-sec at 7774 Å.
5. Filter Positions

Filter Positions	Half-power bandwidth ($\Delta\lambda$)	Peak wavelengths
P_1	7.5 Å	7774 Å (OI 7774; OH(9-4) $Q_1(3)$, $P_2(1)$; Continuum)
P_2	14.6 Å	7752 Å (OH(9-4) $Q_1(1)$,$Q_2(1)$, $Q_1(2)$, $Q_2(2)$; Continuum)
P_3	16.8 Å	7738 Å (OH(9-4) $R_2(2)$,$Q_2(1)$, $Q_1(1)$; Continuum)

6. Scan Time: 150 sec.

FIGURE CAPTIONS

Fig. 1 - Observed 7774 Å intensities (closed circles), 6300 Å intensities (open circles) and virtual heights (crosses) for September 28-29 and October 3-4, 1978. The vertical scale for the 6300 Å emission is twice of that indicated.

Fig. 2 - Same as in Fig. 1 but for October 5-6, 24-25, 25-26, 1978.

Fig. 3 - Same as in Fig. 1 but for September 25-26-, 26-27, and October 2-3, 1978.

Fig. 4 - Isophots of the observed 6300 Å emission on October 24-25, 1978 between 2153 - 2207 hours.

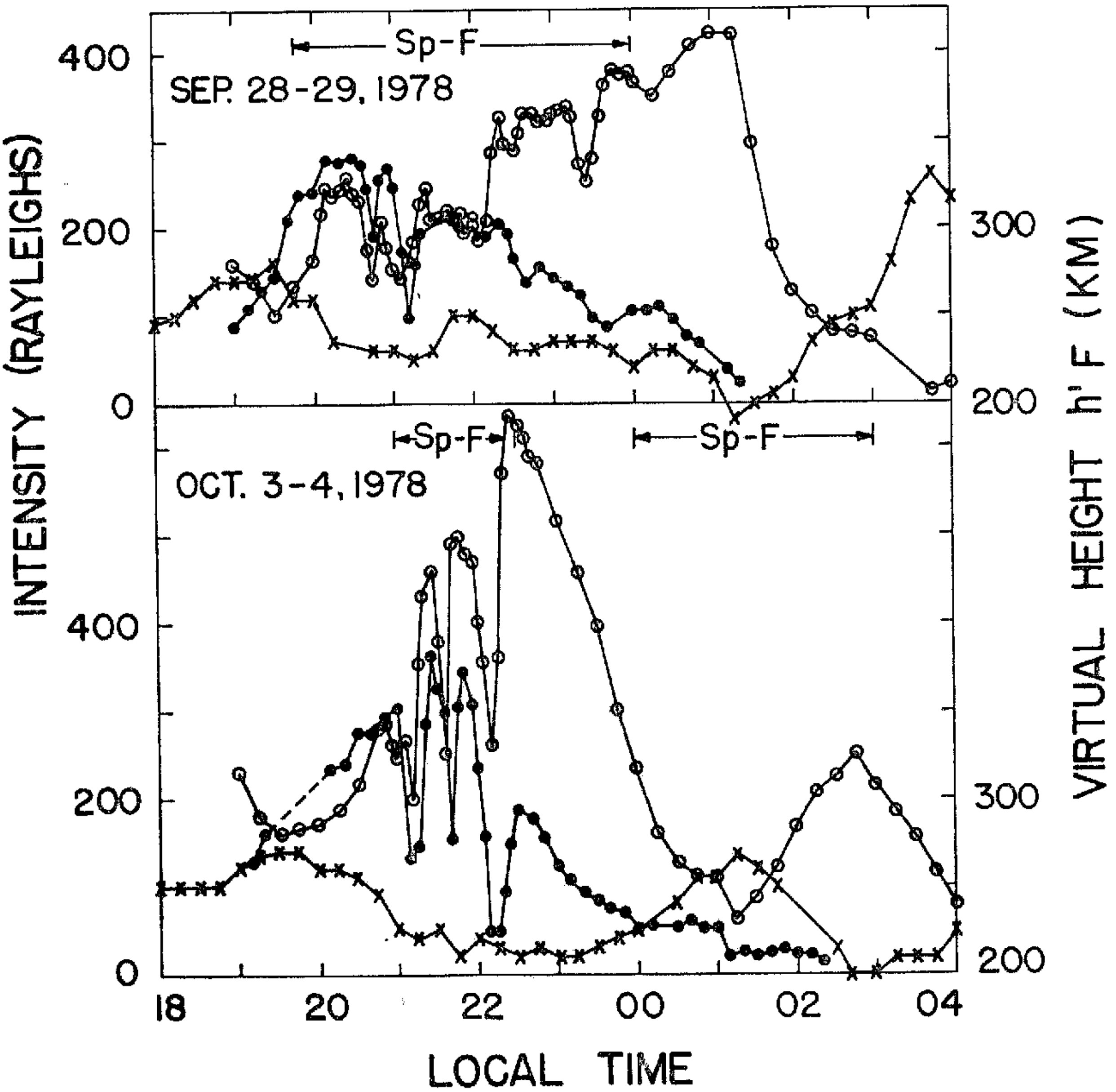
Sp-F
SEP. 28-29, 1978
Sp-F
Sp-F
OCT. 3-4, 1978
INTENSITY (RAYLEIGHS)
VIRTUAL HEIGHT h' F (KM)
400
200
0
400
200
0
300
200
300
200
18
20
22
00
02
04
LOCAL TIME

Fig. 1

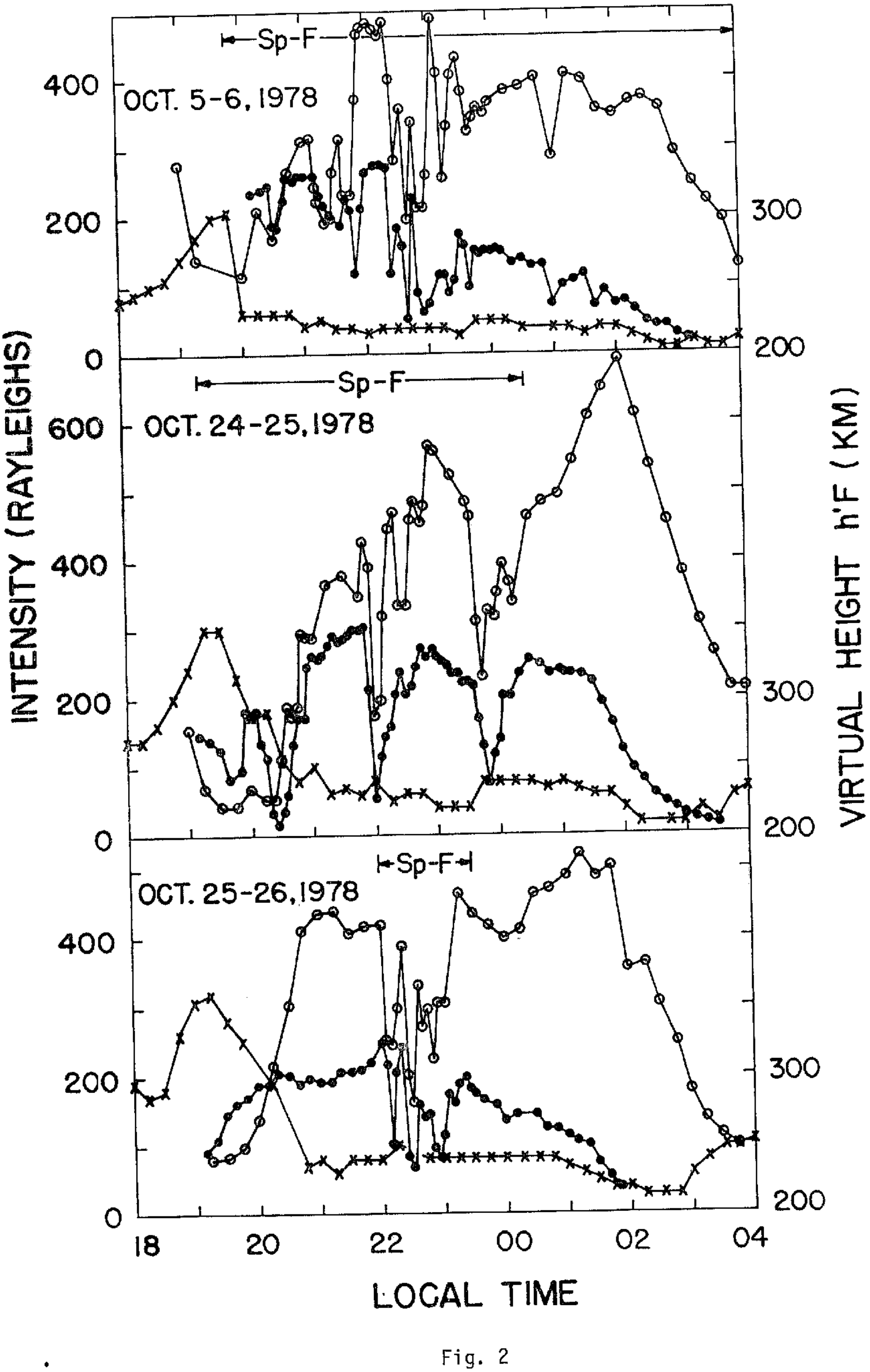
Sp-F
OCT. 5-6, 1978
Sp-F
OCT. 24-25, 1978
Sp-F
OCT. 25-26, 1978
INTENSITY (RAYLEIGHS)
VIRTUAL HEIGHT h'F (KM)
0
200
400
600
300
200
18
20
22
00
02
04
LOCAL TIME

Fig. 2

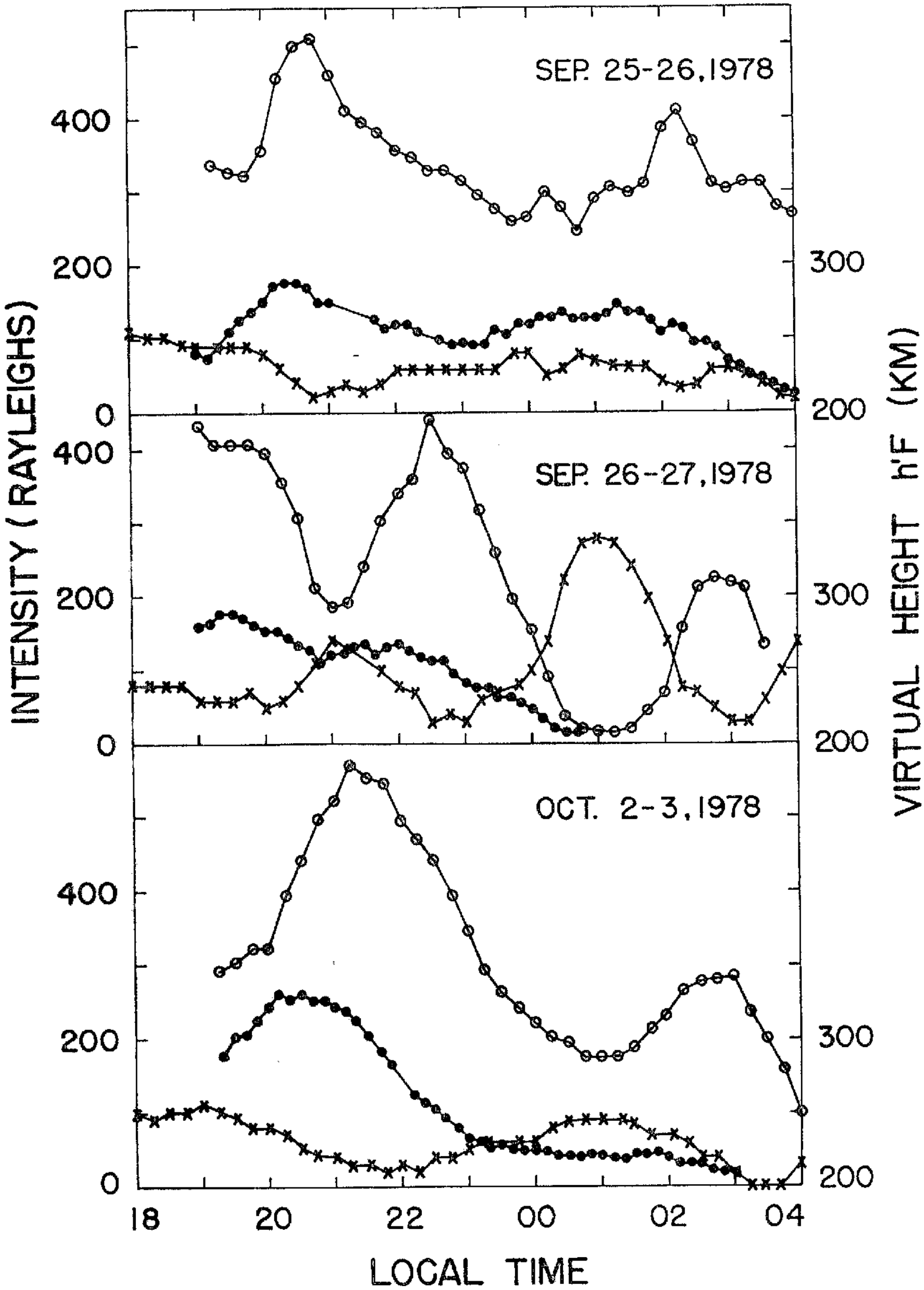
SEP. 25-26, 1978
SEP. 26-27, 1978
OCT. 2-3, 1978
INTENSITY (RAYLEIGHS)
VIRTUAL HEIGHT h'F (KM)
0
200
400
300
18
20
22
00
02
04
LOCAL TIME

Fig. 3

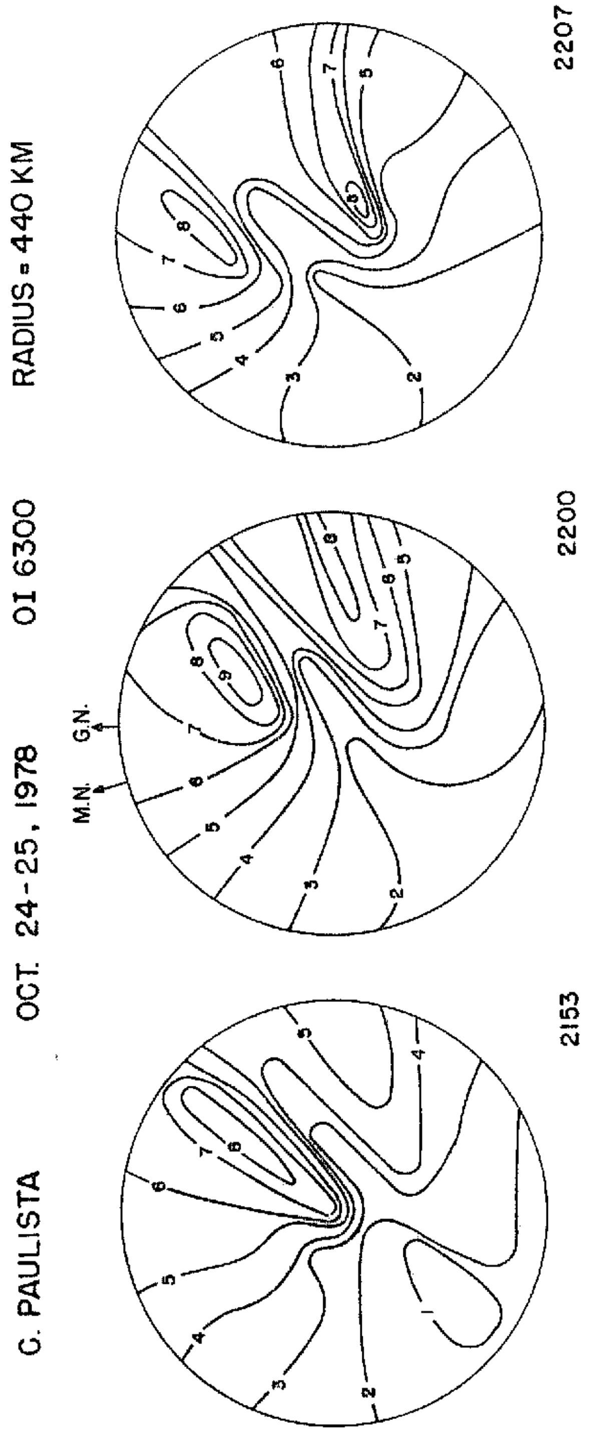
C. PAULISTA
OCT. 24-25, 1978
OI 6300
RADIUS = 440 KM
M.N.
G.N.
2153
2200
2207

Fig. 4

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87 bolha de plasma
87 região F
87 luminosidade da noite
87 medidas
88 plasma bubbles
88 F region
88 nightglow
88 measurement
91 8103

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Instrumentation

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TABLE 1. 7774 Photometer Characteristics

Filter Positions	Half-Power Bandwidth($\Delta\lambda$)	Peak Wavelengths
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P_2	14.6 Å	7752 Å (OH(9-4) $Q_1(1)$, $Q_2(1)$, $Q_1(2)$, $Q_2(2)$; continuum)
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Aperture: 65 mm diameter.
Field of view: 3° full angle.
Wavelength scanning: tilting-filter technique.
Photometer sensitivity: ~7 counts/R s at 7774 Å.
Scan time: 150 s.

indicated rapid F-layer uplifting around 1800-1900 hours LT on these nights with presence of strong Sp-F later.

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Tinsley et al. [1973] showed that the radiative recombination is the major source for the 7774 emission in the tropical region and that the column emission rate, J_{7774}, due to this process, is given by

$$J_{7774} = \int \alpha_{7774}[n(e)]^2 \, dz \qquad (1)$$

where α_{7774} is the partial rate coefficient for radiative recombination, n(e) is the electron density, and z denotes the height. Therefore, neglecting small contribution from the ion-ion recombination, the observed 7774 emission is a function of the integrated $[n(e)]^2$, and the large drop outs in the 7774 intensity variations, shown in Figures 1 and 2, are due to depletion in electron densities, possibly associated with the passage of F-region holes or bubbles.

It is interesting to note that the 6300 emission also show simultaneous drop outs in the intensities. By using the same notation as in equation (3) of Tinsley and Bittencourt [1975], the column emission rate, J_{6300}, due to dissociative recombination, is given by

$$J_{6300} = \int \frac{K A_{6300} \, \gamma_1 \, n(O_2) n(O^+) \, dz}{A(1 + d(z)/A)} \qquad (2)$$

where $n(O_2)$ is the molecular oxygen density, $n(O^+)$ is the atomic oxygen ion density, γ_1 is the reaction rate coefficient for the dissociative recombination of O_2^+, K is the quantum efficiency (that is, the fraction of ^1D excited states produced per dissociative recombination of O_2^+), A and A_{6300} denote the Einstein coefficients for transition from the ^1D state and for the transition leading to the 6300 emission, respectively, and d(z) is the height-dependent quenching coefficient.

The 6300 emission rate is greater on the bottomside of the F-layer (because of the decrease with height of $n(O_2)$ with a scale height of ~50 km). A lowering of the F-layer, until the bottomside comes down to about 250 km (where quenching begins to become important) greatly enhances the 6300 emission and, hence, the 6300 intensity depends mainly on the vertical motions of the F-region, and more specifically on the height of the bottomside of the F-region. Large intensity drop outs of the 6300 emission are also associated with large-scale F-region irregularities.

Since the 6300 emission is strongly height dependent, with only a linear dependence on n(e), the spatial structure observed in this emission, during spread-F conditions, could be due to height variations and vertical motions of the irregularities in the bottomside F-region, as well as due to the depletions in n(e), whereas the spatial structure in the 7774 emission reflects only the depletions in n(e). Note, however, that the amplitudes of the drop outs in 7774 emission, as seen in Figures 1 and 2, are larger than those in the 6300 emission, since the 7774 intensity depends on $[n(e)]^2$.

The duration of the depletions observed are of the order of 10 min and are consistent with that reported by Yeh et al. [1979]. Only on a few

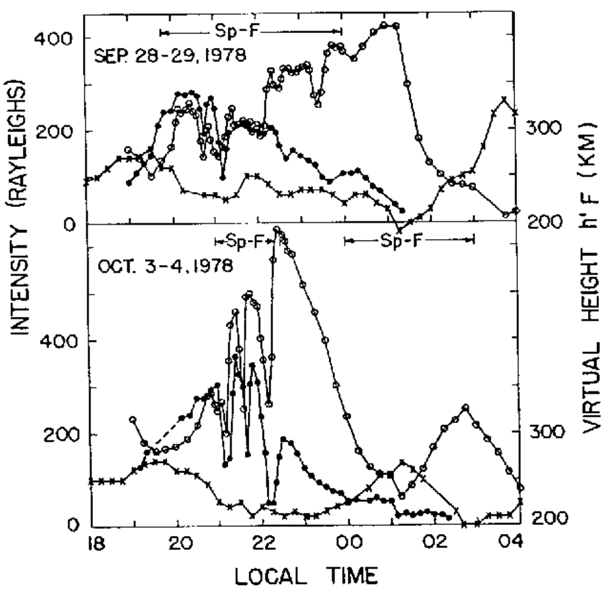

Fig. 1. Observed 7774 Å intensities (closed circles), 6300 Å intensities (open circles), and virtual heights (crosses) for September 28-29 and October 3-4, 1978. The vertical scale for the 6300 Å emission is twice of that indicated.

occasions (e.g., October 24-25; 2200 hours LT) it was observed that the recovery of the 7774 intensity from the depletion was slower than the drop out. This is possibly due to the orientation and vertical structure of the n(e) depletion in the F-region since , according to McClure et al. [1977], the plasma bubbles typically drift upward and westward with respect to the background plasma (but perhaps eastward in a corotating frame), probably leaving behind them slanted trails of low ionization.

Figure 4 shows three isophot maps of the 6300 emission during the period 2153-2207 hours LT on October 24-25. It is observed, from Figure 2, that both the 6300 and 7774 emission showed large drop out in the intensities at 2200 hours LT (the 7774 emission intensity dropped from 305 Rayleighs at 2150 hours LT to 53 Rayleighs at 2200 hours LT) and the isophot maps of the 6300 emission (spatial structure of two emissions should be similar) in Figure 4 show the spatial structure associated with the rapid zenith fluctuations. It is evident from Figure 4 that the large drop out in intensity, observed at 2200 hours LT, is associated with an eastward movement of a region of low intensity located in the south-west at 2153 hours LT.

It may also be pointed out that the 6300 emission observations during the period September 1978 to March 1980 (from September 1978, the 6300 emission data are available for time intervals of 5 min or less) show large intensity variations during the premidnight period on some nights in every month, except winter months (May, June, and July 1979) and this seasonal behavior could be possibly due to seasonal variation of the equatorial vertical drifts [Fejer et al., 1979] where upward drift is shortest during local winter. Kaushika and Mendonça [1974] have also reported nighttime fluctuations (scintillations) in Faraday rotation angle during equinox and summer months from a nearby station at São José dos Campos (23.2°S, 46°W, magnetic dip - 23.7°).

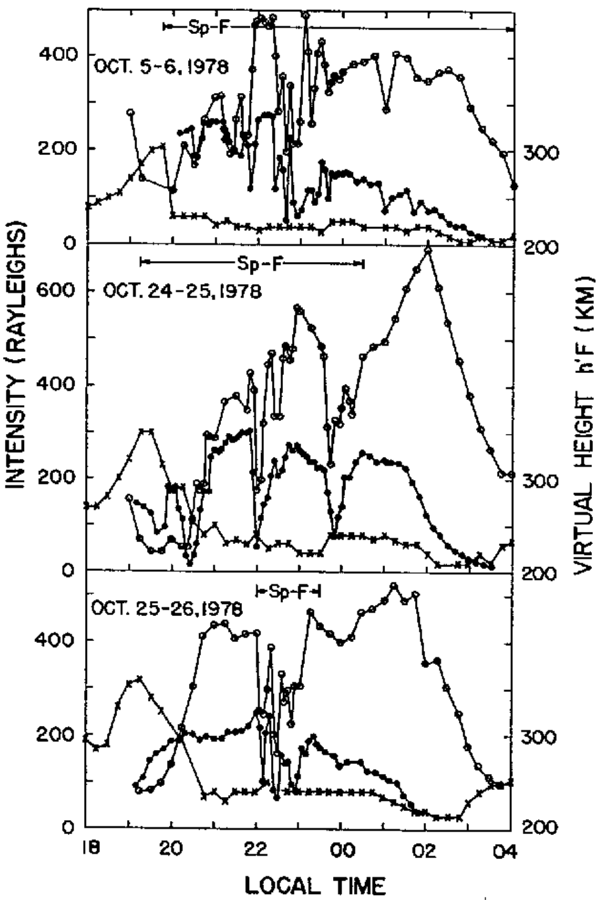

Fig. 2. Same as in Figure 1 but for October 5-6, 24-25, 25-26, 1978.

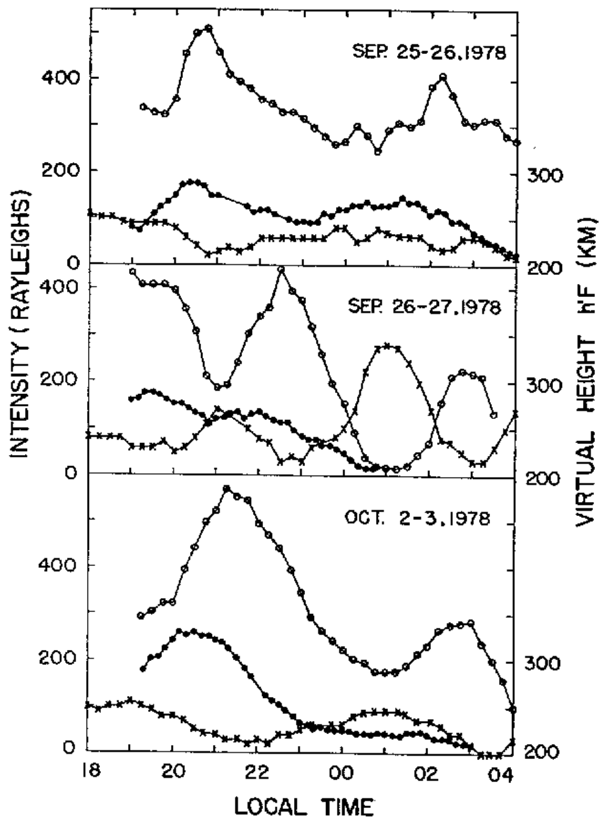

Fig. 3. Same as in Figure 1 but for September 25-26, 26-27, and October 2-3, 1978.

The rapid and large increase in h'F, which occurs just after sunset, as observed at Cachoeira Paulista and Fortaleza on nights when large drop outs in the airglow emissions during Sp-F conditions are present, seems to indicate that the irregularities are possibly associated with the rapid lifting of the whole low-latitude field tube by an electric field (the fountain effect) resulting in a large influx of plasma coming down the field lines at the latitude of Cachoeira Paulista. The plasma irregularities or bubbles could have been generated at the observed latitudes via the Rayleigh-Taylor instability mechanism and/or generated at the bottomside equatorial F-region and transported upward, during the period of enhanced upward drift velocities. Generally Sp-F appears after the F-region has become very high and 'disconnected' in terms of electrical conductivity from the underlying E-region.

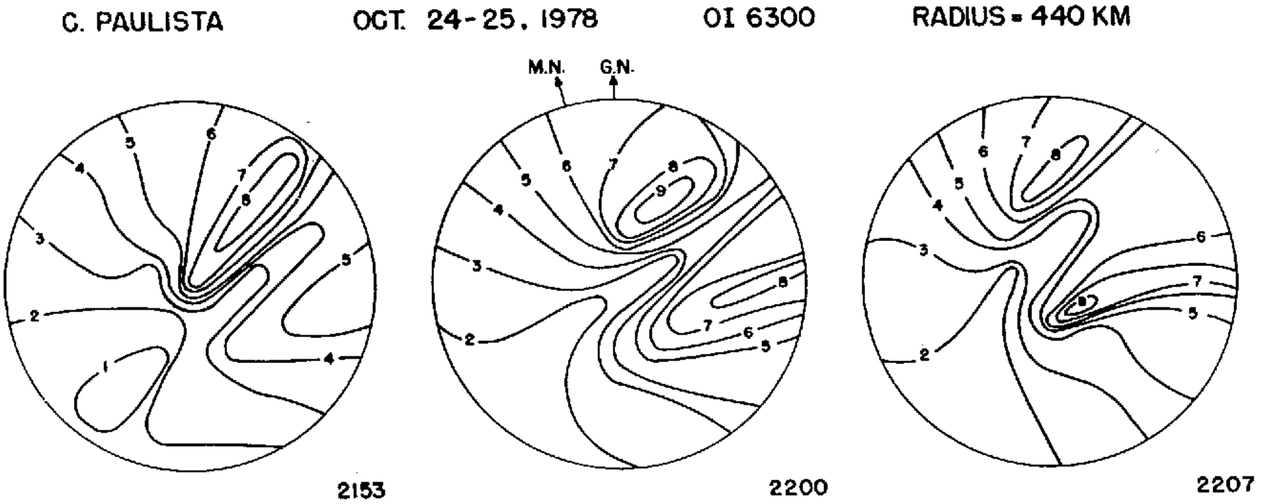

Fig. 4. Isophots of the observed 6300 Å emission on October 24-25, 1978 between 2153-2207 hours LT.

Conclusions

The large drop outs in the 7774 emission intensities during Sp-F conditions are possibly associated with the passage of F-region holes or bubbles drifting across the sky. Simultaneous 6300 emission data also exhibit similar temporal behavior and isophots show spatial structure during disturbed ionosphere. However, sometimes the spatial structure could be due to height variations of the F-layer as well. The 7774 emission is dependent only on F-region electron density profile and hence would be very useful in studying F-region irregularities.

It is worth noting that the 7774 emission data obtained give an indication of the F-region electron densities during Sp-F conditions when these data cannot be obtained by an ionosonde. Also, by scanning the sky, the spatial structure over a large geographical region can be determined, and, again, this is not possible with an ionosonde.

Modifications of the 7774 emission observations are planned to permit study of spatial and smaller-scale details of the ionospheric irregularities. Complementary airglow observations with ionospheric sounding measurements are likely to be very useful in mapping ionospheric irregularities.

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PLASMA IRREGULARITIES IN THE TROPICAL F-REGION DETECTED BY OI 7774 Å AND 6300 Å NIGHTGLOW MEASUREMENTS

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Abstract. Simultaneous measurements of the permitted OI 7774 Å and the forbidden OI 6300 Å nightglow emissions were carried out at Cachoeira Paulista (geographic 22.7°S, 45.0°W), Brazil, during the period of April 1978 to March 1979. Both the emissions were observed with tilting filter-type photometers. During spread-F conditions, on several nights, both the emissions showed simultaneous short-time large intensity depletions, indicating the presence of large-scale irregularities in the F-region. Data for the period September-October 1978 are presented and discussed. The depletions observed are possibly associated with the passage of F-region holes or bubbles drifting across the sky.

Introduction

During the recent past, ionospheric irregularities in the equatorial regions have been the subject of intensive experimental and theoretical investigations. A variety of experimental techniques, including incoherent backscatter radar, in situ observations by rockets and satellites, scintillations in ionospheric radio wave propagation, ionosonde, and airglow observations, have provided valuable informations on ionospheric irregularities [see, e.g., reviews by Ossakow, 1979; Basu and Kelly, 1979].

Atomic oxygen emissions, which are due to F-region recombination processes, can be used as a diagnostic tool to study large-scale F-region irregularities. The OI emissions at 7774 Å and 6300 Å are particularly suitable for ground-based mapping of these irregularities.

The 6300 Å emission, which is due to dissociative recombination of O_2^+ ions in the ionospheric F-region, has been used to monitor large-scale ionospheric wave disturbances and plasma depletions [see, e.g., VanZandt and Peterson, 1968; Weber et al., 1978; Sobral et al., 1980; Sobral et al., 1981]. McClure et al. [1977] have indicated that part of the vertical ionospheric motions, responsible for the 6300 Å airglow maps of VanZandt and Peterson [1968], was due to ionospheric processes associated with the plumes and bubbles of ionospheric irregularities.

The 7774 Å emission, first observed by Weill and Joseph [1970], is due mainly to radiative recombination of O^+ ions in the ionospheric F-region, with a small contribution from ion-ion recombination [Tinsley et al., 1973], and is a very good indicator of the F2 region electron density, in the way described by Tinsley and Bittencourt [1975]. Also, simultaneous observations of the 7774 Å and 6300 Å emission provide an indirect measurement of the F2 peak height [Tinsley and Bittencourt, 1975].

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In this paper we present and discuss observations of short-period large depletions in the F-region electron density detected by the OI 7774 Å and 6300 Å nightglow measurements during spread-F conditions from a low latitude station at Cachoeira Paulista (geographic 22.7°S, 45.0°W; geomagnetic latitude 11.95°S), Brazil, during the period September-October, 1978. Simultaneous ionosonde observations from Cachoeira Paulista are also presented. This is the first time the 7774 Å emission has been used to study large-scale, low-latitude F-region irregularities.

Instrumentation

The 7774 emission measurements were made with a tilting filter-type photometer. The photometer characteristics are given in Table 1. The photometer response at filter positions P_2 and P_3 were used to estimate the OH(9-4) and continuum contribution at position P_1 for an OH rotational temperature of 185°K [Takahashi et al., 1974] measured at Cachoeira Paulista.

The zenith intensities of the 6300 emission were also measured with a tilting filter-type photometer with a field of view of 5° diameter. The interference filter (bandwidth ~ 11 Å) was rocked between two positions to give the on-line and background intensities. The isophot maps of the 6300 emission were obtained from an all-sky scanning filter wheel-type photometer with a field of view of 6° diameter. The observed intensities were corrected for the van Rhijn effect.

The ionospheric data presented were obtained from an ionosonde (Magnetic AB model 10005 W) also operating at Cachoeira Paulista.

Observations and Discussion

During the period September-October 1978, the nightglow observations were obtained on eight clear nights. Figures 1 and 2 show the variations of the observed zenith intensities for the 7774 and 6300 emissions (each 5 min) and h'F (each 15 min) for September 28-29 and October 3-4, 5-6, 24-25, and 25-26. A common feature, observed on all of these nights, is simultaneous large intensity depletions in both the emissions during the Sp-F conditions in the premidnight period, except on October 5-6 when both Sp-F and intensity fluctuations continued until late night. It is also observed, from the h'F variations on these nights, that the F-layer lifts up rapidly before the onset of the Sp-F and intensity dropouts, and the ionograms during this period show oblique traces indicating irregular ionospheric structure. It may be pointed out that the ionospheric data from Fortaleza (3.0°S, 38.0°W), Brazil, the nearest equatorial ionospheric station, also

TABLE 1. 7774 Photometer Characteristics

Filter Positions	Half-Power Bandwidth(Δλ)	Peak Wavelengths
P_1	7.5 Å	7774 Å (OI 7774; OH(9-4) $Q_1(3)$, $P_2(1)$; continuum)
P_2	14.6 Å	7752 Å (OH(9-4) $Q_1(1)$, $Q_2(1)$, $Q_1(2)$, $Q_2(2)$; continuum)
P_3	16.8 Å	7738 Å (OH(9-4) $R_2(2)$, $Q_2(1)$, $Q_1(1)$; continuum)

Aperture: 65 mm diameter.
Field of view: 3° full angle.
Wavelength scanning: tilting-filter technique.
Photometer sensitivity: ~7 counts/R s at 7774 Å.
Scan time: 150 s.

indicated rapid F-layer uplifting around 1800-1900 hours LT on these nights with presence of strong Sp-F later.

Figure 3 shows data for September 25-26, 26-27, and October 2-3, when neither larger intensity fluctuations nor Sp-F were observed. Also, only the normally expected uplifts of the F-layer after sunset, in the absence of spread-F, were observed. Data on October 2-3 clearly show that the local time maximum in the 7774 emission precedes that in the 6300 emission by approximately 1 hour. VanZandt and Peterson [1968] have also observed in Hawaii, a time difference of approximately 1 hour between the local time maximum of f_0F_2 and of the 6300 emission. As was indicated by Tinsley et al. [1973], this is to be expected because of the fact that the field aligned ionization is tilted at the local dip angle and the 6300 emission vertical profile maximizes at a lower height than that of the 7774 emission profile, provided the F region is moving equatorward.

Tinsley et al. [1973] showed that the radiative recombination is the major source for the 7774 emission in the tropical region and that the column emission rate, J_{7774}, due to this process, is given by

$$J_{7774} = \int \alpha_{7774}[n(e)]^2 \, dz \quad (1)$$

where α_{7774} is the partial rate coefficient for radiative recombination, n(e) is the electron density, and z denotes the height. Therefore, neglecting small contribution from the ion-ion recombination, the observed 7774 emission is a function of the integrated $[n(e)]^2$, and the large drop outs in the 7774 intensity variations, shown in Figures 1 and 2, are due to depletion in electron densities, possibly associated with the passage of F-region holes or bubbles.

It is interesting to note that the 6300 emission also show simultaneous drop outs in the intensities. By using the same notation as in equation (3) of Tinsley and Bittencourt [1975], the column emission rate, J_{6300}, due to dissociative recombination, is given by

$$J_{6300} = \int \frac{KA_{6300}\,\gamma_1\, n(O_2) n(O^+)\, dz}{A(1 + d(z)/A)} \quad (2)$$

where $n(O_2)$ is the molecular oxygen density, $n(O^+)$ is the atomic oxygen ion density, γ_1 is the reaction rate coefficient for the dissociative recombination of O_2^+, K is the quantum efficiency (that is, the fraction of ^1D excited states produced per dissociative recombination of O_2^+), A and A_{6300} denote the Einstein coefficients for transition from the ^1D state and for the transition leading to the 6300 emission, respectively, and d(z) is the height-dependent quenching coefficient.

The 6300 emission rate is greater on the bottomside of the F-layer (because of the decrease with height of $n(O_2)$ with a scale height of ~50 km). A lowering of the F-layer, until the bottomside comes down to about 250 km (where quenching begins to become important) greatly enhances the 6300 emission and, hence, the 6300 intensity depends mainly on the vertical motions of the F-region, and more specifically on the height of the bottomside of the F-region. Large intensity drop outs of the 6300 emission are also associated with large-scale F-region irregularities.

Since the 6300 emission is strongly height dependent, with only a linear dependence on n(e), the spatial structure observed in this emission, during spread-F conditions, could be due to height variations and vertical motions of the irregularities in the bottomside F-region, as well as due to the depletions in n(e), whereas the spatial structure in the 7774 emission reflects only the depletions in n(e). Note, however, that the amplitudes of the drop outs in 7774 emission, as seen in Figures 1 and 2, are larger than those in the 6300 emission, since the 7774 intensity depends on $[n(e)]^2$.

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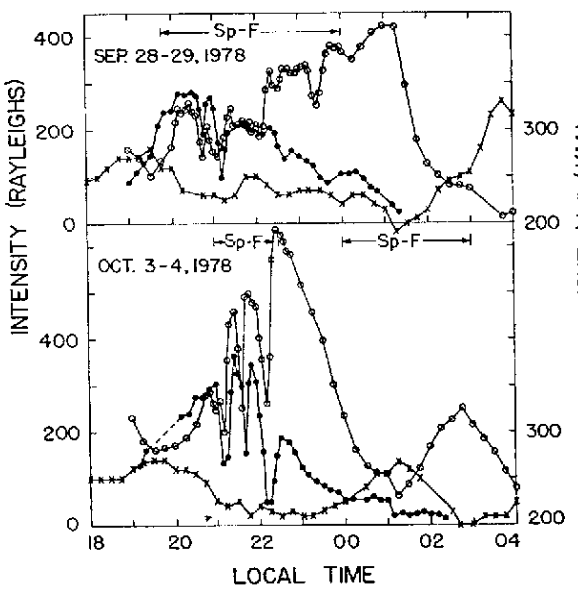

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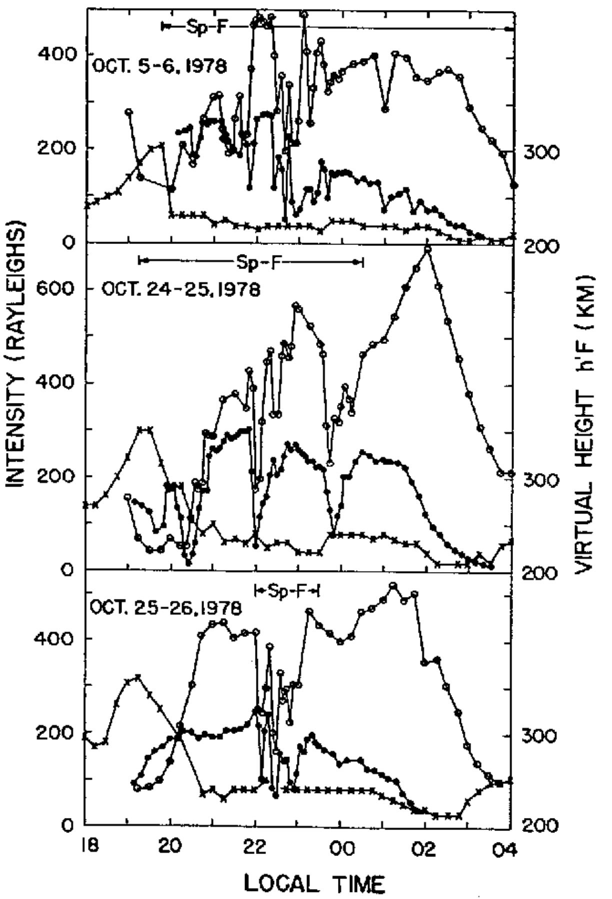

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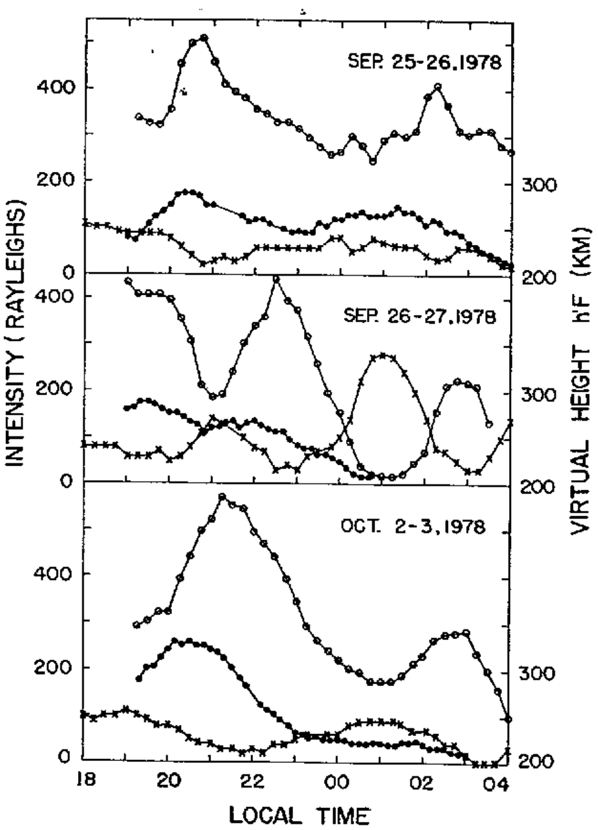

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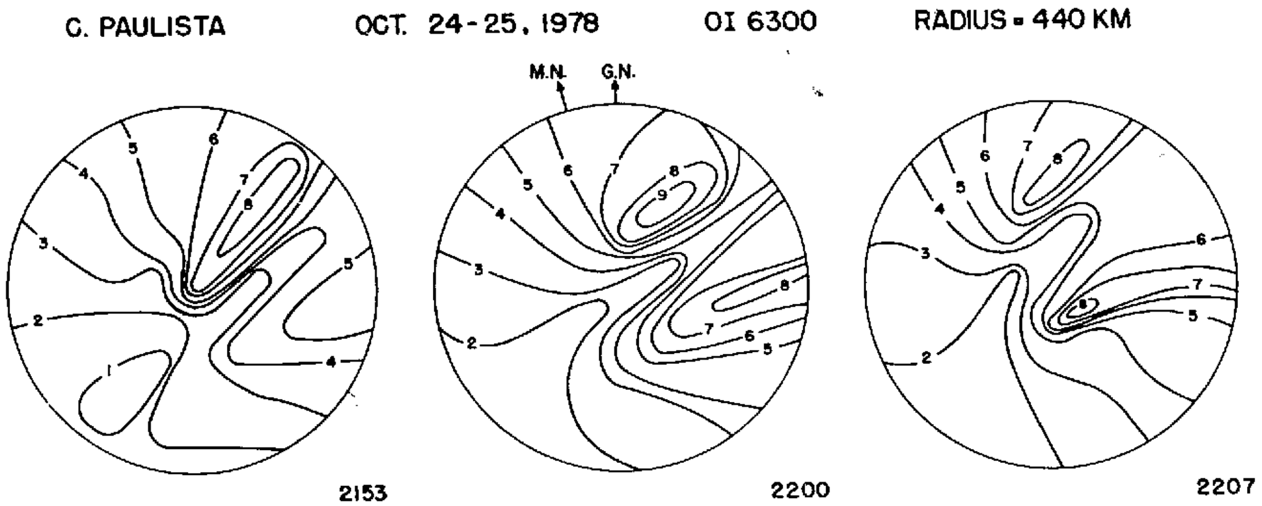

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