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   clearly reveals a dominant period of about 104 minutes that seems to
   correspond to the period of the large scale waves and no single
   dominant period is present for the smaller scale waves. Whereas all
   these waves have a poleward velocity component, the smaller scale
   waves show up this feature more markedly. The equatorial source of
   the smaller scale disturbances and other characteristics have led us
   to suggest that these disturbances are perhaps the low latitude
   manifestations of the upward propagating field aligned plasma bubbles
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WAVE DISTURBANCES IN THE LOW LATITUDE IONOSPHERE AND
EQUATORIAL IONOSPHERIC PLASMA DEPLETIONS

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ABSTRACT

An isolated nighttime ionospheric wave disturbance was observed simultaneously by a meridional scanning 6300 Å photometer, a 6300 Å zenith photometer, a 30 MHz riometer and an ionosonde over Cachoeira Paulista, a low latitude station in Brazil. From the results, we have identified at least two different scale sizes for the disturbances which could be broadly classified as: (a) a larger scale component easily identified in the riometer data and has characteristics similar to those of a large scale TID and (b) smaller scale disturbances observable in the scanning photometer data, occurring during the ascending phases of the larger scale waves. A Fourier analysis of the zenith airglow variations clearly reveals a dominant period of about 104 minutes that seems to correspond to the period of the larger scale waves and no single dominant period is present for the smaller scale waves. Whereas all these waves have a poleward velocity component, the smaller scale waves show up this feature more markedly. The equatorial source of the smaller scale disturbances and other characteristics have led us to suggest that these disturbances are perhaps the low latitude manifestations of the upward propagating field aligned plasma bubbles in the equatorial ionosphere.
INTRODUCTION

Low latitude ionosphere dynamics has assumed added importance in the light of the increasing interest by scientific groups in recent years in the studies of the dynamics and morphology of the equatorial ionospheric irregularities. Observational evidence on the latitudinal extension of the equatorial irregularity dynamics, in particular, could provide important input for verifying theories of the irregularities and related phenomena. The purpose of this work is to present and discuss an isolated event of low latitude propagating disturbance observed simultaneously by four instruments, namely, a meridional scanning 6300 Å photometer, a 6300 Å photometer looking at zenith only, a 30 MHz riometer with a vertical looking antenna and an ionosonde, all working at the same location. The large scale oscillation both on the riometer and airglow data discussed here is more sinusoidal-like and has a longer duration than anyone obtained on more than 100 (unpublished) similar experimental results from Cachoeira Paulista. The results suggest an equatorial source for the disturbances and hence seem to have implications on the possible latitudinal extension of the plasma density bubbles in the equatorial ionosphere (for recent works on the subject see Booker, 1979; Ossakow et al, 1979 and Fejer and Kelley, 1980).

OBSERVATIONS

Routine measurement of meridional profiles of 6300 Å nightglow emission is being carried out by a scanning photometer at Cachoeira Paulista (22°44' S, 45°00' W). Briefly, a mirror placed at 45° with respect to the horizontally oriented PMT axis is made to rotate back and forth around a horizontal axis such as to see the sky within zenith distances of 75° north to 75° south, in the magnetic meridional plane. A tilting filter was used such that one way scanning of the sky was carried out at the passband centered at 6300 Å and in the reverse scan a second tilt position of the filter at which the passband is centered a few Angstrom away from 6300 Å represented the sky background intensity. Each scanning irrespective of its direction required
approximately 2.3 minutes. The narrow bandwidth (3 Å) of the filter and
the usually high intensity of the red nightglow during events such as
the one presented here permit us to discard any contamination by the
OH 9-3 rotational band (Burnside et al., 1977). The angular diameter of
the photometer receiving angle was 5°. A 30 MHz riometer with a vertical
looking 5-element yagi antenna and an ionosonde were in operation in the
immediate vicinity of the airglow observation site.

RESULTS AND DISCUSSION

A simultaneous recording by three instruments of an event
that occurred on the night of 24-25 October, 1978 is presented in Figure 1.
The zenith nightglow intensity as read from the scanning data shows
correlated variations with time with the riometer absorption, especially
in the large scale features, from around 2000 LT till around 0100 LT.
Some additional features in the airglow variations, namely, (a) deepened
minima at 2015, 2200 and 2340 LT (Figure 1) and (b) superimposed smaller
scale structures, have important implications, as will be discussed
shortly, but are absent in the absorption data due to spatial averaging
by the relatively wider riometer reception angle. Owing to spread-F
activity that usually accompany wavelike disturbance in the airglow
over Cachoeira Paulista (Sobral et al, 1980) regular values of \( f_0F_2 \) for
this case also could not be deduced from the ionograms for most part of
this event. However, the contours of the virtual height of constant
electron densities, shown in Figure 1, suggest an inverse relationship
with the average trend of the airglow variation. It is the large scale
quasi-periodic fluctuations in the airglow intensity about this mean
trend that are related to the absorptions variations. Since the latter
depends upon the height integrated square of the electron density (\( \int N^2 dh \))
near the \( F_2 \) peak (Abdu and Rai 1975) the spatial and temporal structures
in the airglow or absorption profiles could, in fact, be referred to as
structures in the electron density itself. The decrease in the riometer
absorption at about 0100 LT is related to a rapid decrease in the \( f_0F_2 \),
(the absorption being proportional \( f_0F_2^4 \)), observable after the spread-F
activity had subsided at this time but not shown in the figure. On the
other hand, the rising trend in the airglow intensity that was seen
from about 2000 LT to 0200 LT is a clear height dependent event as could be verified from the ionosonde data. This may explain the fact that the correlated variation in the photometer and riometer record were present only until 0100 LT.

Meridional scanning airglow data show that during intervals immediately following the minima in the airglow intensity (such as the three intervals marked with an asterisk in Figure 1), namely, when the airglow intensity starts increasing, there appear smaller scale wavelike disturbances propagating in a direction away from the equator. An example of such travelling disturbances is shown in Figure 2 corresponding to one of these intervals, namely from 2200 to 2300 LT. The left and the right hand extremes of each profile correspond to the zenith angles of 75°S and 75°N respectively. North to south propagating disturbances are clearly seen from 2200 LT until about 2257 LT in Figure 2, whose estimated wavelength and trace speed are respectively 400 (± 40) m/s and 270 (± 30) m/s. These propagating disturbances are in fact superimposed on the larger scale quasi-periodic wave mentioned before (and which can be easily identified from the riometer record). The trace speed of this larger scale wave seems to be away from the equator as is evident in Figure 3, that presents time profiles of the airglow intensities for three fixed directions (45°N, Zenith and 45°S) in the meridional plane, read from the scanning data. On the basis of the most significant minima and their relative positions on those curves we have estimated the period and the southward speed of the large scale component as 150 (± 70) minutes and 600 (± 230 m/s), respectively.

Simultaneous 6300 Å airglow data from a zenith photometer for the interval 2000 to 0100 LT was subjected to a discrete Fourier transform analysis making use of 156 data points read at two minutes interval. The scanning photometer data set was not used for this analysis since the minimum sampling period in this case would be about 4.5 minutes). The result is shown in Figure 4 in which the square of the DFT plotted along the ordinate is proportional to the power spectrum.

A dominant period of 104 minutes correspond to that seen clearly in the riometer data (Figure 1). There are several smaller periodicities, some
of them being around 25 minutes corresponding to those seen in the scanning data (Figure 2). The mean trend of the curve seems to indicate a linear spectrum, somewhat similar to the spectrum of the much smaller scale irregularities observed from a rocket flight in Brazil (Basu and Kelley, 1977) and similar also to the composite spectrum of plasma fluctuations as given by Booker (1979) where the spectrum linearly decreases at angular spatial frequencies greater than that corresponding to the scale height of the atmosphere.

Multiple trace type of spread F was observed (during the spread F occurrences of Figure 1) which is typically caused by the higher frequency end of the TID spectrum, where the scale of the fluctuations is of the same order of magnitude as the Fresnel zone for an ionosonde (Booker, 1979).

The parameters of the larger scale disturbances mentioned above, agree well with those of the TID's generated by auroral electrojet during magnetically disturbed periods (Chimonas and Hines, 1970; Francis, 1974; Richmond, 1978). However, magnetic indices showed that very quiet conditions prevailed for at least 3 days preceding this event, a fact, which, taken together with the poleward velocity component, seems to rule out any possible auroral source for the disturbances of both the smaller and larger scale sizes.

The poleward propagation of the airglow disturbances presented here could in fact be a manifestation of the latitudinal extension of the plasma bubbles in the equatorial ionosphere. Dynamics of these plasma depleted regions have been the subject of extensive investigation by ground based radars, in situ satellite and rocket probes and theoretical modelling (see for example, Woodman and LaHoz, 1976; McClure et al., 1977; Kelley et al., 1976 and Scannapieco and Ossakow, 1976). In particular, field aligned plasma depleted regions associated with spread-F events in the equatorial ionosphere have been observed by satellite probes (McClure et al., 1977; Heron and Dorling, 1979) and by ground based photometers (Weber et al., 1978). Owing to its field aligned nature, an upward propagation of a plasma depleted region in the equatorial ionosphere could appear, near its
extremities, as a poleward propagating plasma depleted region by a ground based instrument observing at latitudes in the immediate vicinity of the magnetic equator. Thus, the poleward propagating airglow disturbances displayed in Figure 2 could in fact result from the upward propagation of a succession of field aligned plasma depleted regions over the equatorial ionosphere. The scale size of the disturbances observed by our photometer would in fact correspond, from the geometric characteristics of the geomagnetic field lines, approximately to half of these values (Heron and Dorling, 1979) for the bubble dimension in the equatorial plane.

The condition for generating plasma instabilities under collisional Rayleigh-Taylor mode as given by Ossakow et al. (1979) is that the linear growth rate $\gamma$ be positive, where

$$\gamma = \left[ \frac{1}{n_0} \frac{dn_0}{dh} \frac{g}{v_{in}} - v_R \right],$$

where $dn_0/dh$ is the unperturbed electron density gradient, $v_{in}$ is the ion to neutral collision frequency, $g$ is the gravitational acceleration and $v_R$ is the recombination frequency. Evaluation of this expression using the 6 MHz and 8 MHz frequency curves in Figure 1 shows that $\gamma$ becomes positive around 1900 LT which is about the onset of the TID detected on riometer record plus the subsequent appearance of spread-F echoes in the ionograms.

Range type spread-F was present during this night over Fortaleza (30'S dip) situated near the magnetic longitude of Cachoeira Paulista. However no clear relationship with the observed airglow could be established from this one event. However, a recent study (Sobral et al. 1980) has shown that almost the totality of the North-South propagating airglow disturbance observed over Cachoeira Paulista, during a 26 month period of study, was accompanied by range type spread F in the ionogram over the same location. This strengthens our suggestion that the N-S airglow disturbances presented here could indeed be manifestation of the upward propagating field aligned plasma depleted
region in the equatorial ionosphere. Thus, the large scale wave (seen as
a TID in the riometer data) might point out the possible role of TID's
in initiating the disturbances that eventually give rise to the plasma
bubbles detectable in the scanning photometer data.

CONCLUSIONS

Observations of an isolated ionospheric disturbance
simultaneously by a 6300 Å scanning photometer, a 6300 Å zenith looking
photometer a riometer and an ionosonde have made possible easy
identification of larger and smaller scale propagating disturbances over
Cachoeira Paulista. The larger scale disturbance (poleward speed of
600 ± 230 m/s, T = 100 minutes) has the characteristics of a large
scale TID, but does not seem to have a high latitude source. The
Fourier analysis of zenith airglow data has revealed a dominant period
of oscillation of about 104 minutes which presumably corresponds to
the period of the larger scale disturbance. The smaller scale disturbance
(poleward speed of 270 ± 30 m/s, T = 25 minutes) also has phase
velocities directed away from the equator. We have tried to interpret
these poleward moving disturbances as manifestations of the upward
propagation of field aligned plasma density depletions in the equatorial
ionosphere.

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OI 6300 Å nightglow intensity of the zenith looking photometer.
FIGURE CAPTION

Fig. 1 - Zenith profiles of the OI 6300 Å airglow intensity, riometer absorption and virtual heights of constant electron density. Notice the zenith airglow and riometer absorption minima of the larger scale wave at around 2015, 2200 and 2340 LT. The time intervals indicated by an asterisk denote the occurrence of intense multiple trace spread F, and the north-south propagating airglow disturbances (explained in the text).

Fig. 2 - Geomagnetic meridional profiles of the OI 6300 Å airglow intensity. A pronounced valley in the airglow profile appears at zenith at 2200 LT which clearly propagates southwards. It corresponds to a large electron density rarefaction.

Fig. 3 - OI 6300 Å intensity versus time plot for three photometer directions, 45°N, zenith and 45°S.

Fig. 4 - Square of the discrete Fourier transform (DFT) of about 156 airglow data points with a sampling period of two minutes. Notice the linear trend of this plot which is similar to the spectrum of plasma fluctuation given by Booker (1979).
REFERENCES


Heron, M.L. and E.B. Dorling, Equatorial ionospheric plasma density bubbles observed by ESRO-4, Planet. Space Sci., 27, 1303, 1979.


Fig. 1

CACHOEIRA PAULISTA
24-25 OCT. 1978

ABSORPTION IN DB

01 6300 Å ZENITH INTENSITY

30 MHz RIOMETER ABSORPTION

* TIME INTERVALS DURING WHICH NIGHTGLOW DISTURBANCES EXISTED
CROSS SCANNING RANGE

CONTOURS OF CONSTANT ELECTRON DENSITY FROM IONOGRAMS

8.0 MHz
60 MHz
2.8 MHz

VIRTUAL HEIGHT IN KM

LOCAL TIME
$\chi = 75^\circ$ SOUTH

ZENITH

ISO RAYLEIGHS

2200

2205

2216

2220

2225

2230

2236

2241

2246

2257

2302

2308

2313

2313

HORIZONTAL LINES ARE ZERO LEVELS OF THE OI 6300 Å SIGNAL

$\chi = 75^\circ$ NORTH

TUESDAY, READER TO THE FIRST PROFILE UNDER IT $\chi =$ ZENITH ANGLE IN THE GEOMAGNETIC MERIDIONAL PLANE

OCTOBER 24, 1978

CACHOEIRA PAULISTA

NORTH - SOUTH SCANNING DATA OF OI 6300 Å NIGHTGLOW

Fig. 2
Fig. 3

OI 6300 Å INTENSITIES
24-25 OCTOBER 1978
CACHOEIRA PAULISTA
45°N
ZENITH
45°S

LOCAL TIME