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IONOSPHERIC PLASMA IRREGULARITIES FROM ATOMIC OXYGEN AIRGLOW EMISSIONS

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Simultaneous measurements of the atomic oxygen nightglow emissions at 777.4 nm and 630.0 nm have been used in the past few years to determine the ionospheric F-layer peak electron density and peak height, and to investigate the pattern of F-layer depleted plasma regions, or ionospheric transequatorial plasma bubbles, and their associated irregularities in the tropical ionosphere. Meridional scanning observations of these emissions at low latitudes, made with ground-based filter photometers, are presented in the form of computer generated three-dimensional perspective views, showing the spatial north-south and temporal intensity variations of these OI emissions, for both normal conditions and in the presence of magnetic field-aligned large scale plasma irregularities or bubbles. The significant features of these observations are discussed. This remote sensing airglow technique shows to be very useful to study ionospheric plasma dynamical processes and to investigate the pattern and time evolution of large scale plasma irregularities in the nighttime tropical ionosphere.

IRREGULARIDADES DE PLASMA NA IONOSFERA A PARTIR DE EMISSÕES DO OXIGÊNIO ATÔMICO – Medidas simultâneas das emissões de luminescência noturna do oxigênio atômico em 777,4 nm e 630,0 nm têm sido utilizadas nos últimos anos para determinar a densidade eletrônica e a altura do pico da camada F ionosférica em baixas latitudes, e para investigar a morfologia das regiões de depleção de plasma na camada F, ou bolhas de plasma ionosférico transequatoriais, e as irregularidades associadas na ionosfera tropical. Observações de varredura meridional destas emissões em baixas latitudes, realizadas através de fotômetros de filtro instalados na superfície, são apresentadas na forma de vistas em perspectiva tridimensionais geradas por computador, mostrando as variações da intensidade temporal e espacial norte-sul destas emissões do oxigênio atômico durante condições geofísicas normais, como também na presença de irregularidades em grande escala ou bolhas de plasma alinhadas ao longo do campo magnético. As características principais destas observações experimentais são discutidas. Esta técnica de sensoriamento remoto, utilizando luminescência, demonstra ser bastante útil para estudar processos dinâmicos no plasma ionosférico e para investigar a morfologia e evolução temporal das irregularidades de plasma em grande escala na ionosfera tropical noturna.

INTRODUCTION

The distribution of ionization around the magnetic equator, in the tropical ionospheric F-region, is strongly dependent on the ionosperic plasma dynamical transport processes. As a result of the combined effects of magnetic field-aligned plasma diffusion, electromagnetic **E** x **B** plasma drift and thermospheric neutral wind drag, two crests of enhanced plasma densities are produced on both sides of the magnetic equator, at about $\pm$ 15° magnetic latitude (e.g., Anderson, 1973a, b; Matuura, 1979). Recombination processes associated with the O^+ low-latitude ionospheric ionization generates many atomic oxygen line emissions corresponding to the tropical airglow. Two arcs of enhanced airglow intensities are produced about the magnetic dip equator, associated with this low-latitude ionospheric plasma ionization distribution which is known as the Appleton anomaly (e.g., Reed et al., 1973; Bittencourt & Tinsley, 1976).

The atomic oxygen tropical airglow emissions which are generated mainly from the radiative

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recombination mechanism (such as the 130.4 nm, 135.6 nm and 777.4 nm line emissions) are strongly dependent on the F-region peak electron density $n_m(e)$, whereas the emissions which arise from the dissociative recombination mechanism (such as the 630.0 nm line emission) are extremelly sensitive to variations in the F-region peak height h_m, with only a small dependence on $n_m(e)$. Simultaneous column intensity measurements of one of the radiative recombination emissions (e.g., 777.4 nm) with the 630.0 nm column intensity emission have shown to be very useful for remote sensing of the ionospheric F-region plasma properties and can be used to determine the important ionospheric plasma parameters $n_m(e)$ and h_m (Tinsley & Bittencourt, 1975; Sahai et al., 1981a).

This remote sensing technique can also be used to investigate and to map large scale F-region plasma irregularities, as shown by Bittencourt et al. (1983), and to study F-region dynamical processes, since h_m is a very sensitive indicator of ionospheric motions (see, e.g. Bittencourt & Sahai, 1978). Variations or perturbations in the ionospheric F-region parameters as a result of thermospheric neutral wind effects, or due to the presence of ionospheric wave phenomena, and ionospheric modifications produced by geomagnetic disturbances can also be determined through the simultaneous observations of these atomic oxygen nightglow emissions.

In this paper we present and discuss simultaneous north-south geomagnetic meridional scanning measurements of the atomic oxygen 777.4 nm and 630.0 nm emissions, as a function of local time, obtained at a low-latitude station at Cachoeira Paulista (geomagnetic latitude 12.0°S; geographic coordinates 22.7°S, 45.0°W). The results presented illustrate the importance of ground based simultaneous scanning observations of these emissions for determining the spatial structure, and local time variation, associated with F-region field-aligned plasma irregularities, or plasma bubbles, over a large geographical region of the sky.

F-REGION PLASMA IRREGULARITIES AND ATOMIC OXYGEN NIGHTGLOW EMISSIONS

Experimental and theoretical investigations of depleted plasma regions, or ionospheric transequatorial plasma bubbles, and their associated ionospheric irregularities in the tropical ionosphere have been made, in the past few years, using simultaneous observations of the OI emissions at 777.4 nm and 630.0 nm (e.g., Sahai et al., 1981b; Sahai et al., 1983). Simultaneous meridional scanning measurements of these emissions, or all-sky imaging measurements, can be used to construct maps showing the north-south and local time variations of the vertical column intensities of these emissions and of the corresponding ionospheric F-region parameters $n_m(e)$ and h_m, during magnetically quiet periods, as well as during magnetically disturbed conditions, or in the presence of large scale ionospheric plasma irregularities.

Figures 1 and 2 illustrate the observed vertical column intensity variations for the 777.4 nm and 630.0 nm atomic oxygen emissions, respectively, as a function of local time and zenith distance in the magnetic north-south meridian, for the nights of October 02/03 and 04/05, 1980, measured at Cachoeira Paulista. The results are presented in the form of computer generated three-dimensional perspective views. Large scale field-aligned airglow depletions or patches are seen in both the emissions on the night 02/03, at about 21:30 LT and 23:30 LT, which are the optical signatures of intertropical transequatorial ionospheric plasma bubbles in the

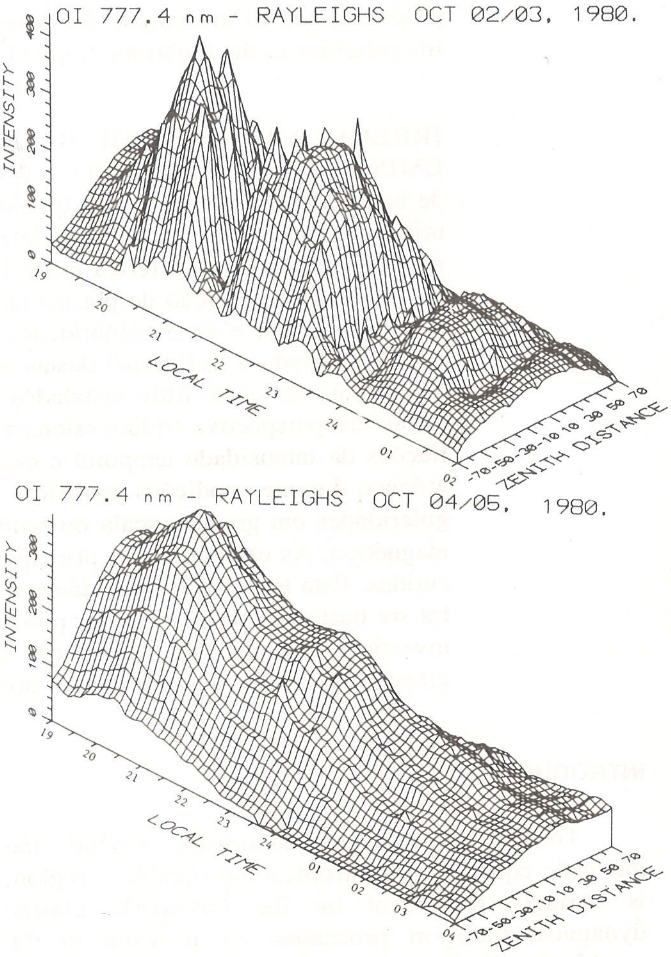
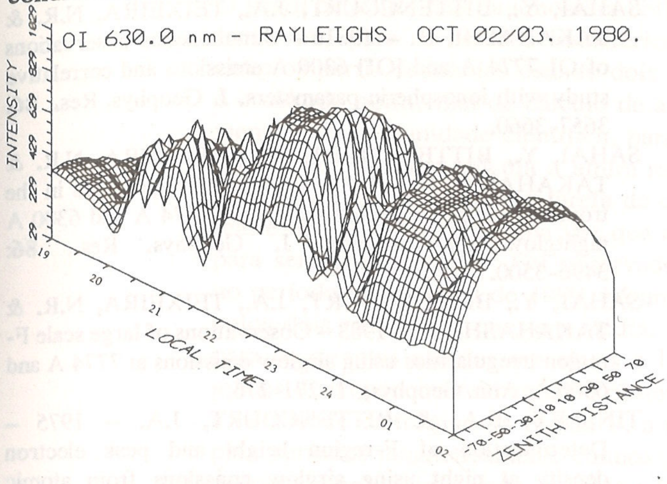


Figure 1. Observed intensities for the OI 777.4 nm emission as a function of local time and zenith distance scanned along the magnetic north-south meridian, at Cachoeira Paulista.

Figura 1. Intensidades observadas para a emissão OI 777,4 nm em função da hora local e da distância zenital com varredura ao longo do meridiano norte-sul magnético, em Cachoeira Paulista.

height range of the airglow emissions (e.g., Moore & Weber, 1981; Mendillo et al., 1985). These airglow depletions are not present on the night 04/05. The data obtained on this night (04/05) shows a typical nocturnal variation of the atomic oxygen airglow emission intensities associated with the Appleton anomaly ionization distribution for normal geophysical conditions.



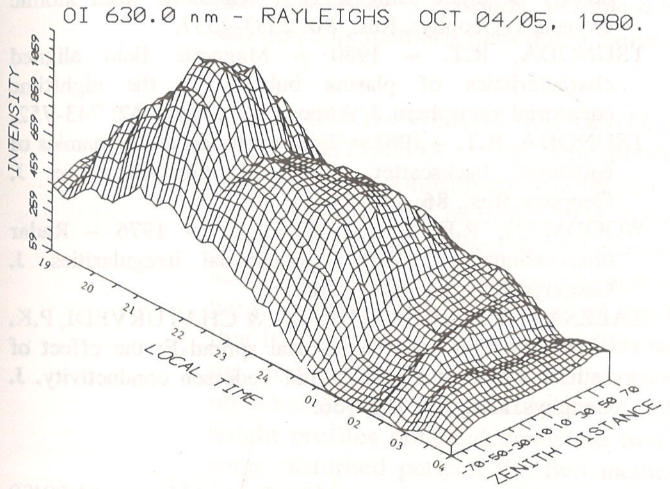


Figure 2. Observed intensities for the OI 630.0 nm emission as a function of local time and zenith distance scanned along the magnetic north-south meridian, at Cachoeira Paulista.

Figura 2. Intensidades observadas para a emissão OI 630,0 nm em função da hora local e da distância zenital com varredura ao longo do meridiano norte-sul magnético, em Cachoeira Paulista.

DISCUSSION

The characteristics of the magnetic field-aligned plasma bubbles in the nighttime tropical ionosphere have been investigated, for example, by Tsunoda (1980, 1981) using measurements of both incoherent scatter and backscatter from ionospheric plasma irregularities made with the ALTAIR radar. These measurements showed that the plasma bubbles are aligned along the magnetic field lines and also allowed the determination of the upward bubble velocity (which is of the order of 100 m/s). Determination of plasma bubble vertical rise velocities, using spaced ionosonde observations, have been presented by Abdu et al. (1983). All-sky imaging nightglow measurements have also been made by Moore & Weber (1981) and Mendillo & Baumgardner (1982), who described the development and motion of F-region nightglow depletions as associated with the magnetic field-aligned low density plasma bubbles which develop in the post-sunset ionosphere, after a rapid upward lifting of the ionospheric layer caused by an enhanced **E** x **B** plasma drift velocity.

These plasma depletions drift toward the east in the equatorial ionosphere and are often tilted or curved to the west of the magnetic meridian because of the upward motion of the bubble. The associated airglow depletions often show a westward tilt with respect to the magnetic meridian, which must be the optical manifestation of the westward tilts of plasma depletion plumes recorded by incoherent scatter radar (Woodman & La Hoz, 1976; Tsunoda, 1980, 1981) and by in situ probes (McClure et al., 1977). This curvature is most apparent away from the magnetic equator, for magnetic latitudes greater than about 12°. The combination of the angle between the depletion axis and the magnetic meridian, with the eastward drift produces an apparent north-south velocity in ground-based photometer records scanning along the magnetic meridian. This type of behavior can be seen in the airglow patches shown in Figs. 1 and 2 on the night 02/03, around 21:30 LT, where the depletion appears first in the north and gradually moves to the south.

Another interesting feature can be observed about 23:30 LT, which is possibly due to a wishbone type structure. Bifurcation of a buoyantly rising bubble has beeen investigated theoretically, using a computer simulation technique, by Zalesak et al. (1982).

CONCLUSIONS

Atomic oxygen nightglow emissions which result primarily from radiative recombination and from dissociative recombination processes are very useful for remote sensing of the ionospheric F-region peak electron density and peak height. Simultaneous measurements of these emissions provide a very useful and powerful technique to study dynamical processes in the tropical F-region and, in particular, to study the spatial and local time variations of large scale plasma irregularities or transequatorial field-aligned plasma bubbles.

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