OPTICAL STUDIES OF THE IONOSPHERIC BUBBLES OVER THE BRAZILIAN REGION BY NOCTURNAL IMAGES OF THE OI 630 nm EMISSION

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Abstract

The past studies were based on OI 630 nm scanning photometer data and the present one is based on digital OI 630 nm airglow images obtained by an all-sky imager system whose data were gathered between October 1998 and August 2000, at Cachoeira Paulista - CP (22.5ºS, 45ºW) and between September 2000 and March 2002, at São João do Cariri - CA (7.4ºS, 36.5ºW), south hemisphere. This study is an extension of previous statistical studies (Sobral et al., 1990,1991,1999) of the latitude variations of the ionospheric plasma depletions zonal drift velocities, over the Brazilian low latitude station CP and equatorial latitude station CA. The present results show that, in general, the magnitudes of velocities clearly tended to decrease with local time and such decrease associated to decreasing intensity of the vertical component of the ambient electric field which, in turn can be accounted by the recombination.

Introduction

Aeronomic studies through rockets, satellites, incoherent back scatter radar, UHF/VHF scintillation systems, GPS systems, and optical instrumentation have been used to study the spread-F/ionopheric plasma depletions, or plasma bubbles, in the equatorial region (Woodman and LaHoz, 1976; Weber and Buchau 1978, 1980; Mendillo and Baumgardner, 1982; Anderson and Mendillo, 1983; Sahai et al., 1981, 1988; Sobral et al. 1980a,b, 1981, 1985, 1990, 1997; Abdu et al. 1985, 1987, 1991; Jahn et al., 1997; Kelley, 1985). The OI 630 nm airglow technique offers a convenient way of monitoring the large-scale ionospheric plasma bubbles (Weber an Buchau 1978, 1980; Sobral 1980a,b). Those studies are of particular interest for practical applications in South America because of the drastic interference of the ionospheric plasma bubbles in telecommunications over that region, that is, causing strong telecommunication signal degradation and blackouts.

The OI 630 nm airglow observations discussed here were obtained by two all-sky imager systems (1) at CP which viewed the sky through a circular area with diameters in the NS and EW directions of 8.4ºS to 36.6ºS and 30.9ºW to 59.1ºW, respectively (reference altitude: 250 km); (2) at CA which viewed the sky through a circular area with diameters in the NS and EW directions of 6.7ºN to 21.5ºS and 22.4ºW to 50.6ºW, respectively (reference altitude: 250 km).

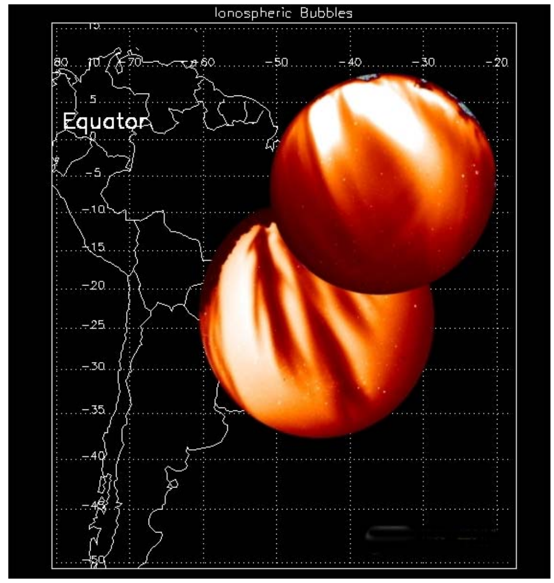

Fig.1 - Circular area of OI 630 nm airglow observations.

Observations

The set of OI 630 nm digital images of this work was originally geometrically nonlinear, that is, a given view angle (solid angle) corresponded to different areas of the ~40 km thick airglow emitting layer at 250 km of altitude, depending on the zenith position of the view angle. In order to facilitate the present analysis, the original digital images were linearized, according to the method described by Garcia et al. (1997). The resulting linearized images correspond to square shaped areas, centered at CP and at CA, of 1100 km x 1100 km (reference altitude: 250 km) covering the latitude (longitude) ranges of about 17.6ºS to 27.5ºS (40.1ºW to 49.9ºW) at CP and of about 2.5ºS to 12.3ºS (31.6ºW to 41.5ºW) at CA. Figure 3 and Figure 4 were constructed from those linearized images.

During the period of study, from October 1998 and August 2000 at CP and from September 2000 and March 2002 at CA, 311 nights of OI 630 nm airglow experiments were carried out, of which 135 nights detected the ionospheric bubbles (see Figure 2).

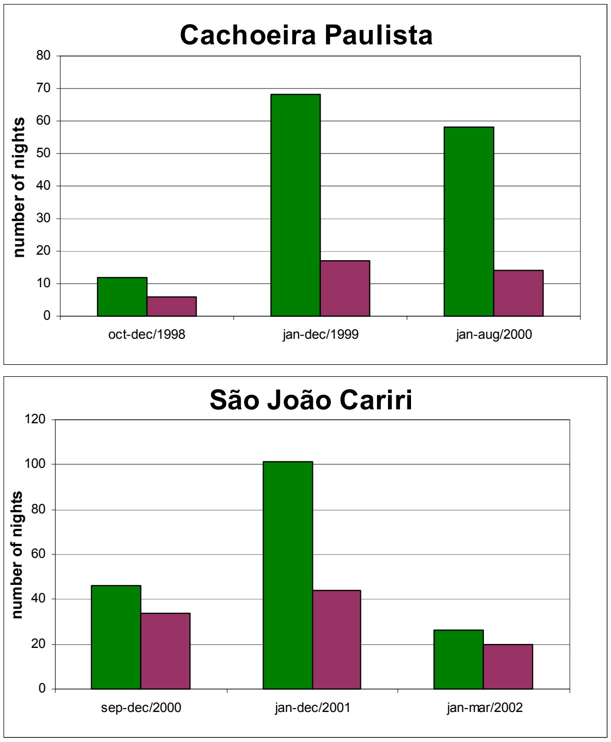

Fig. 2 – Observed period at Cachoeira Paulista - CP (22.5ºS, 45ºW) and São João do Cariri - CA (7.39^{o}S, 36.5^{o}W).

Results and Discussion

The zonal drift of the ionospheric plasma is caused by *F*-region vertical electric fields, which, in turn, are generated by the action of zonal neutral winds. It should be reminded that the plasma reaction to such a wind action is not a local effect, but an integrated flux-tube effect. So that the net zonal plasma drift velocity at a given geographic location is not a consequence of a local mechanism but a result of the interaction of the zonal winds with the plasma along the flux tube. The net flux-tube plasma eastward velocity (V_z) is given by (see Anderson and Mendillo, 1983)

$$V_z = \int \sigma_p U B ds / B \int \sigma_p dS \qquad (1)$$

where σ_p is the Pedersen conductivity, U is the zonal component of the neutral wind, B is the magnitude of the geomagnetic filed and ds is the differential linear element along the flux-tube. In the presence of the ionospheric plasma bubbles the drift velocity V_z becomes a function of the disturbed electron densities and polarization electric fields introduced by the complex bubbles' electron density spatial structures.

The experimental ionospheric plasma bubble zonal drift velocities reported here are inferred from the *F*-region OI 630 nm nocturnal airglow in the following way. Such airglow emission stems from the dissociative recombination reaction $O_2^+ + e \rightarrow O + O + h\nu$ from which one or two of the resulting oxygen atoms may be able to emit a 630nm photon through the de-excitation process $O(^3P) \rightarrow O(^1D) + h\nu(630nm)$. The intensity of the OI 630 nm emission is proportional to the product of the concentrations of the molecular oxygen and electrons (see Sobral et al., 1992, 1993). In this way, the drastic depletions of the electron concentration occurring inside the plasma bubble cause equivalent drastic reductions of the OI 630 nm emission. The zonal drift velocities here reported were derived from the zonal velocities of the OI 630 nm intensity minima, as inferred from the digital optical images.

Figure 3 and Figure 4 show the ionospheric plasma bubble zonal drift velocities versus 11 geographical latitudes around CP and CA (TABLE 1) for the set of nights of the occurrence of ionospheric bubbles events.

TABLE 1 – Geographic Latitude Ranges (^{o}S)

Cachoeira Paulista - CP	**São João do Cariri – CA**
-17.65	-2.50
-18.63	-3.48
-19.61	-4.46
-20.59	-5.44
-21.58	-6.43
-22.56	-7.41
-23.54	-8.39
-24.52	-9.37
-25.51	-10.36
-26.49	-11.34
-27.47	-12.32

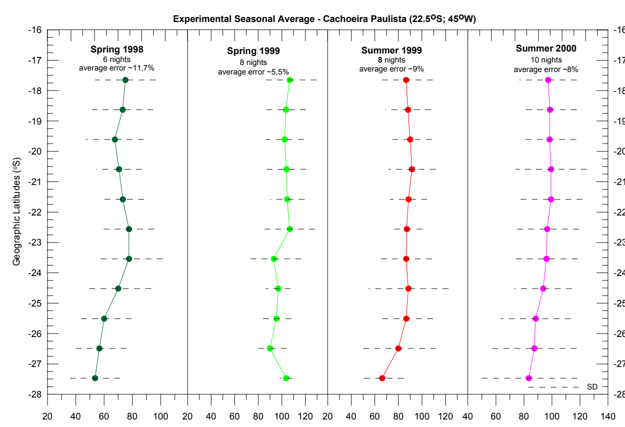

Fig. 3 - Latitudinal distribution ionospheric plasma bubble zonal drift velocities over Cachoeira Paulista during Spring and Summer from October 1998 to March 2000.

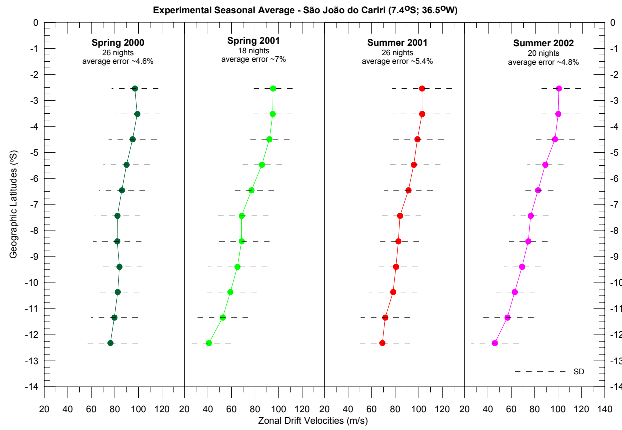

Fig. 4 - Latitudinal distribution ionospheric plasma bubble zonal drift velocities over São João do Cariri during Spring and Summer from September 2000 to March 2002.

Figure 5 and Figure 6 show the ionospheric plasma bubble zonal drift velocities versus Local Time around CP and CA for the set of nights of the occurrence of ionospheric bubbles events.

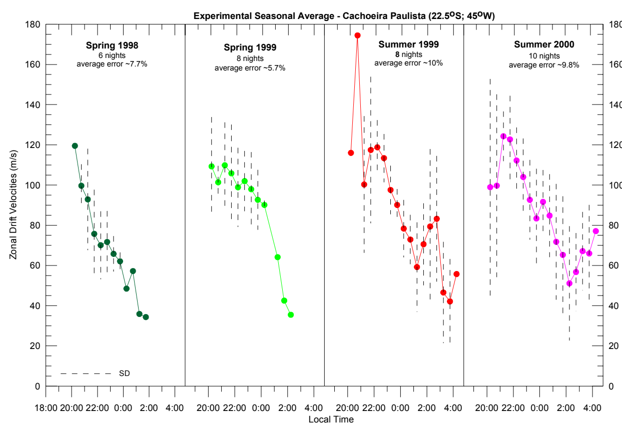

Fig. 5 - Ionospheric plasma bubble zonal drift velocities over Cachoeira Paulista during Spring and Summer from October 1998 to March 2000.

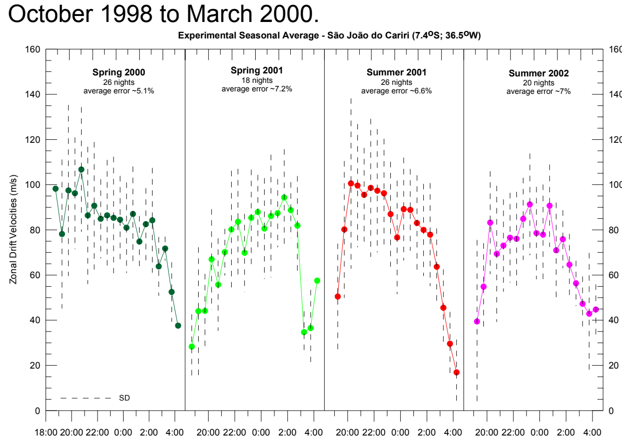

Fig. 6 - Ionospheric plasma bubble zonal drift velocities over São João do Cariri during Spring and Summer from September 2000 to March 2002.

Conclusions

In the present study, about 135 nights were considered focusing the variations of the ionospheric bubbles zonal drift velocities with geographical latitudes and local time.

The general conclusions of this study were the following ones:

1) The digital OI 630 nm images were seen to be useful in the study of the zonal drift velocities of the ionospheric bubbles, in particular because of the improved space and time resolutions.

In general, the velocities magnitudes clearly tended to decrease with local time and the increase of the geographic latitude in Spring and Summer, as consequence of the decrease in the component of the ambient electric field, since the zonal drifts are cold plasma **ExB** drifts where **E** and **B** are the ambient (*F*-region*)* electric field and geomagnetic field intensities respectively. The electric field strength decrease results from the nocturnal *F*-region recombination process.

2) All zonal drifts obtained for all the 135 nights considered were eastwards.

3) All the present ionospheric plasma bubble zonal drift velocities are consistent with those obtained through scanning photometers that operated at Cachoeira Paulista in the last maximum solar cycle (Sobral et al., 1991).

4) Ionospheric plasma bubbles were detected the until the maximum extra-tropical geographical latitude of ~28^o S, that was the largest latitude position analyzed in this study.

Acknowledgements

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