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LATITUDINAL GRADIENT IN THE PLASMA BUBBLE ZONAL VELOCITIES AS OBSERVED BY SCANNING 630-nm AIRGLOW MEASUREMENTS

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Abstract. Equatorial ionospheric plasma bubble zonal velocities were measured using two 630-nm scanning photometers. Simultaneous scanning measurements were made in two east-west planes that were tilted 30° northward and southward of the vertical. The results of measurements carried out during 5 days covering the summer equinoctial period of 1988, presented here, show evidence of marked latitudinal gradient in the bubble zonal velocities, the velocities decreasing with increasing latitude over our low-latitude observing site, Cachoeira Paulista (-28°dip). We suggest that this velocity gradient is consistent with expectations at solar minimum, when our measurements may be associated with the region above the maximum in the eastward plasma velocity height profile.

Introduction

The nighttime equatorial ionospheric plasma motion is controlled mainly by the F region dynamo-induced electric field driven by the zonal component of the neutral wind which blows eastward from evening to early morning hours [Rishbeth, 1971; Sipler and Biondi, 1978; Wharton et al., 1984; Fejer et al., 1985]. This electric field also serves as a primary driving force in the generation of the F region irregularities that are often characterized by the presence of flux tube aligned transequatorial plasma bubbles, or plasma depletions [McClure et al, 1977; Tsunoda, 1980]. Since the bubbles drift zonally with velocities often comparable with that of the ambient plasma, they can, under proper conditions, be used as tracers of the ambient plasma motion. The bubble-induced depletions in the 630-nm airglow intensities, as recorded in the E-W profile of this emission observed by scanning photometers, have been analyzed to determine the zonal propagation characteristics of these bubbles over the Brazilian low-latitude location Cachoeira Paulista [see Sobral et al., 1985; Abdu et al., 1987].

Plasma bubble zonal velocity characteristics over Cachoeira Paulista have also been studied using the bubble-induced total electron density depletion signatures as measured by VHF electronic polarimeters operated in east-west spaced mode [Abdu et al., 1985, 1987]. These results over low latitude, when assessed in the light of the ambient plasma zonal velocities over the equator as measured by the Jicamarca radar [Fejer et al., 1985] and also with Fabry-Perot zonal neutral wind measured over near equatorial stations Kwajalein and Natal e.g., Sipler and Biondi, 1978], would seem to suggest the possible existence of a latitudinal variation in the zonal velocities, whether referred to neutral wind, ambient plasma, or plasma bubble motions. Intercomparisons of the existing data, which are diverse and nonsimultaneous, are not, however, helpful to draw any conclusion regarding such a possibility. In this context an attempt is made here, from observations using an east-west scaninng 630-nm photometer set-up, to determine the existence or otherwise of latitude-dependent east-west plasma bubble velocities.

The results to be discussed here were obtained using an experimental set-up consisting of two east-west scanning photometers whose scanning planes were tilted 30° toward north and south of the vertical. The photometer viewing angle (cones of 5° each) projections, at a reference altitude of 300 km, north and south of the vertical, are shown in Figure 1. Each photometer scan covers 75° of elevation angle centered around the vertical.

Results

The results to be presented and discussed here correspond to five nights of observations during the months of January and March 1988 (see Table 1). For these nights the data were of excellent quality in the sense that the signal-to-noise ratio of the emission was high, with clearly defined depletion valleys being present in the zonal intensity profiles. Some examples of eastward propagating valleys have been presented before by Sobral et al. [1980, 1985]. Figure 2 shows plots of the 630-nm intensity zonal profiles corresponding to the two scanning planes, namely, 30°N and 30°S, obtained on one of the nights (January 17), during the present set of observations. Well-defined eastward propagating airglow depletion valleys are clearly seen in both scanning planes. The dashed lines that follow the propagation of the valleys in this figure will be referred to, from here on, as airglow depletion "tracks". Such tracks were used to calculate the eastward velocities (V_E). V_E values calculated on January 17, using the three tracks (that are shown in Figure 2), and 20 minute data samples, namely, 2020-2040, 2040-2100, and 2100-2120 LT are presented in Figure 3, wherein the variances in the velocities are shown as vertical bars. No clear local time trend in V_E is evident. The velocities in the northern scanning plane are clearly higher than those in the southern plane, since the mean of the former velocities is higher than that of the latter velocities by a factor of up to 38 percent. In Table 1 we have presented numerical values of V in the scanning planes 30°N and 30°S of zenith for a total of 10 tracks corresponding to the

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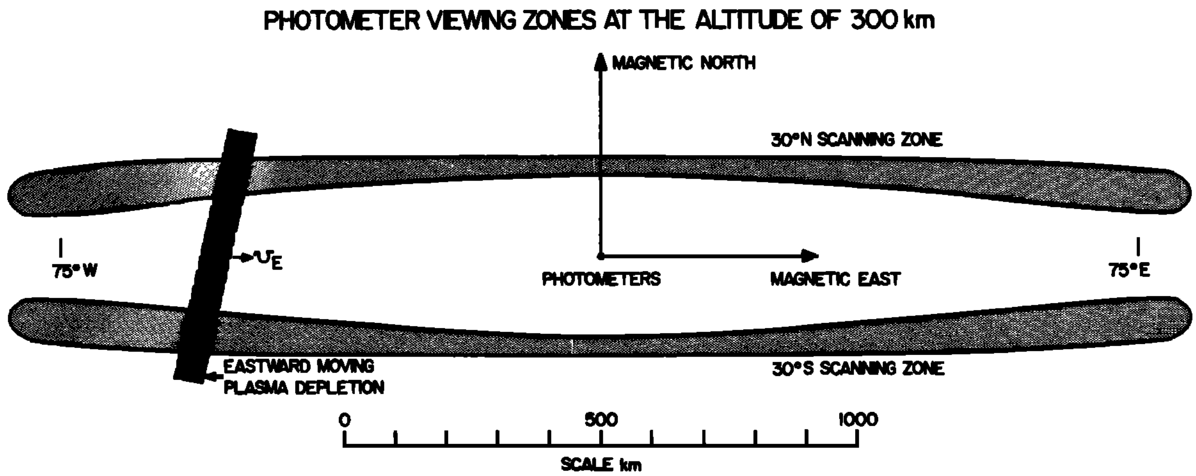

Fig. 1. East-west scan projection at 300 km height of the photometer viewing angles (cones of 5°each) at 30° north and south of vertical.

five nights of observation presently under consideration. The largest differences between the two sets of velocities occurred on the nights of January 17-18 and of March 22-23, 1988, the northern velocities being higher by a factor over 38 percent. A plot of all these velocities, in northern versus southern format, is shown in Figure 4, which clearly demonstrates a tendency for northward velocities to exceed the southward velocities. The difference between the two seems to increase for higher values of the velocities.

Discussion and Conclusions

The meridional distance, at 300 km reference altitude, of the north and south photometer sensing regions is around 340 km. The height of the airglow emission layer, nominally situated approximately one scale height below the F peak, is not expected to vary significantly within such a latitudinal distance. The systematically different plasma bubble zonal velocities obtained from the northward and southward looking photometers therefore represent essentially a latitude variation in the velocities, decreasing from north to south.

If we consider the flux tube alignment characteristics of the transequatorial plasma bubble structures [Tsunoda, 1980; Weber et al., 1978; Tinsley, 1982; Abdu et al., 1983], the negative latitude gradient feature of the V_E observed in the present measurement will correspond to a negative height gradient of the eastward velocities above the magnetic equator. This negative gradient would be present within a height range from approximately 590 km to 760 km, which represents the apex of the field lines passing, respectively, through the north and south photometer scanning zones over Cachoeira Paulista.

From simplified theoretical considerations, and using flux tube integrated electron densities and collision frequencies, Anderson and Mendillo [1983] have calculated integrated Pederson conductivity and eastward ExB plasma drift (V_E) vertical profiles over the equator. The integrated conductivity in their model (their Figure 4) increases rapidly up to a height of approximately 550 km and less rapidly above this height, the turnover height depending upon the flux tube integrated electron density peak height. The height profile of their eastward plasma velocities above the 550-km level, however, depends also upon the precise latitudinal variation in the zonal neutral wind in such a way that their model yielded a negative height gradient of V_E at heights above 550 km for a latitudinally decreasing (negative gradient) wind function; the V_E height gradient was positive when a latitude independent neutral wind was assumed. We might recall also, as mentioned earlier and by Abdu et al. [1987], that the zonal plasma bubble velocity measured over low-latitude sites would approach very closely that of the ambient plasma.

Table 1. East-West Airglow Depletion Velocities Observed With Photometer Scanning in the Northern and Southern Planes

Date, 1988	Velocity, ms	
	VE(30°N)	VE(30°S)
Jan. 17-18	180	167
	176	133
	188	136
Jan. 19-20	35	36
	22	26
March 11-12	90	72
March 13-14	124	101
	106	106
	63	58
March 22-23	151	109

Data are for 10 airglow depletion tracks (see the text) on the five nights of observations discussed in the text.

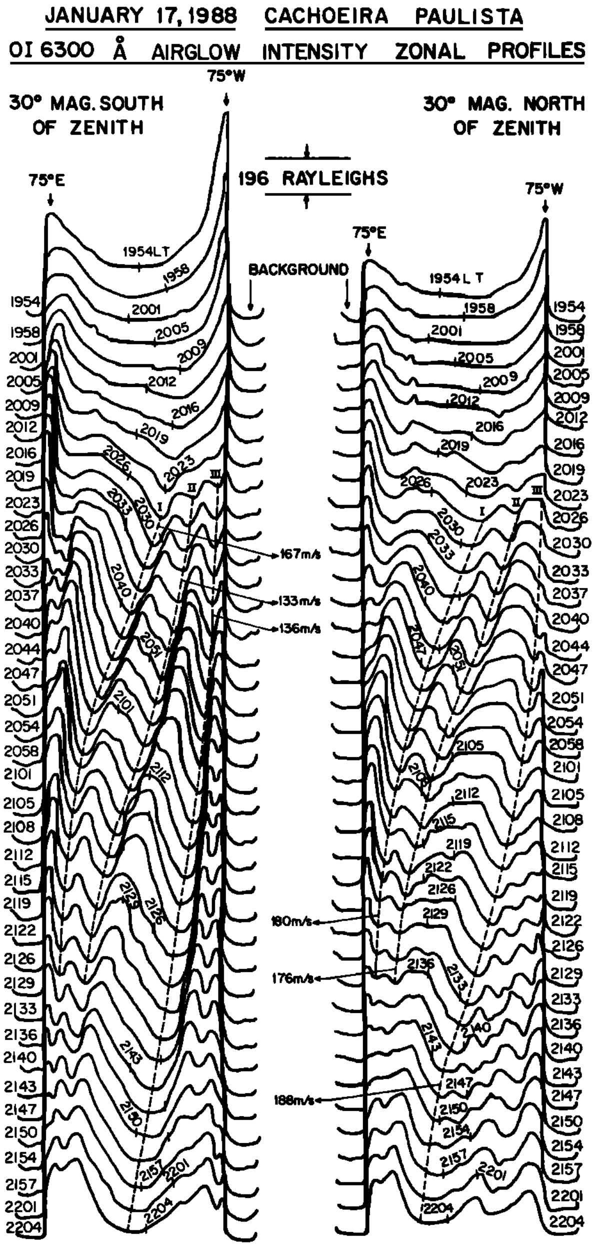

Fig. 2. The 630-nm airglow intensity zonal profiles corresponding to the two scanning planes 30°N and 30°S of vertical obtained on the night of January 17, 1988.

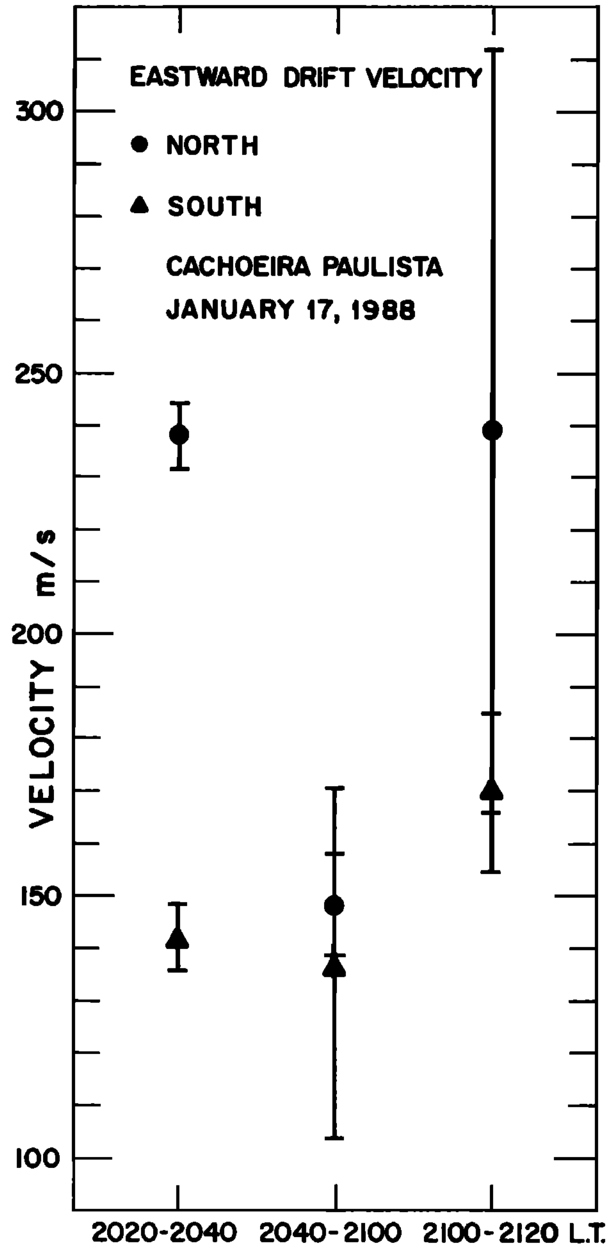

Fig. 3. Eastward velocities of the airglow depletions determined for the data in Figure 3 as explained in the text. The vertical bars represent the variance in the velocities.

On the basis of the above considerations our observations of a latitudinally decreasing plasma bubble zonal velocity could imply the existence of a latitudinally decreasing neutral zonal wind over our low-latitude site.

In a recent study, Abdu et al. [1987] compared the bubble zonal velocities obtained from simultanous measurements by spaced VHF polarimeters and a scanning 630-nm photometer over Cachoeira Paulista. They found that the eastward bubble velocity presented a positive height gradient, namely, latitude gradient, over Cachoeira Paulista which indicated a positive height gradient over the equator. These results might appear to be at variance with the present observation of a negative latitude gradient over the same location. This apparent discrepancy could be explained as follows. As shown by Anderson and Mendillo [1983], the sense of the eastward velocity height gradient over the equator would depend upon the precise nature of the latitude variation in neutral zonal wind. Thus it could be argued that the neutral wind latitude gradient was positive during the measurements reported by Abdu et al. [1987], whereas it has turned negative during the present

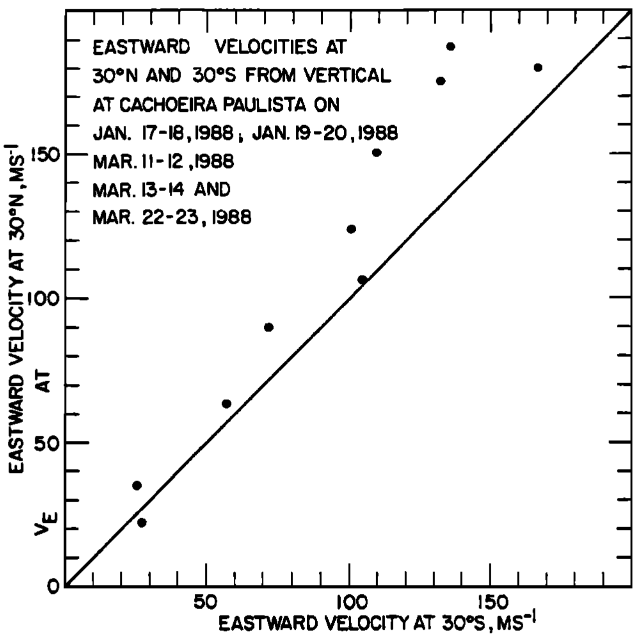

Fig. 4. Zonal velocities of the airglow depletions observed northward of the station are plotted against those observed southward, on the five nights of observation.

measurements. While such changes in the neutral wind latitude distribution could be conceivable, we do not find it entirely convincing that a reversal in the wind gradient could have taken place between the two epochs of measurements.

A more likely explanation, we believe, could be found in the nature of the F peak height variations. The measurement of Abdu et al. [1987] were taken during the 1981-1983 period, which was close to the solar activity maximum epoch, whereas the present measurements represent conditions closer to the solar activity minimum. The nighttime F peak height undergoes substantial decrease (especially over the equator) from solar maximum to minimum, since it is controlled mainly by the F region dynamo electric field and the associated evening prereversal enhancement in the F region ionization vertical drift velocities, whose positive dependence on solar activity has been demonstrated from Jicamarca radar measurements by Fejer et al. [1979]. These variations in the F peak height could, in turn, shift downward or upward the V_E and conductivity profiles such as those calculated by Anderson and Mendillo [1983]. Therefore the following scenario could be considered. The F layer field lines over Cachoeira Paulista corresponding to the photometer scanning zones in the present measurements could be mapped onto the negative gradient (or "topside") region of the V_E vertical profile over the equator (as mentioned earlier). During the previous measurement (representing a higher mean solar activity level) by Abdu et al. [1987] the higher altitude of field line integrated Nmax could shift the turnover point (or peak) of the V_E height profile to relatively higher levels. As a result, the F region field line corresponding to the polarimeter and photometer measurements over Cachoeira Paulista could be mapped onto the positive gradient region (or bottomside) of the V_E height profile.

In conclusion, the plasma bubble zonal velocities, as measured by east-west scanning 630-nm photometers, show clear evidence of a latitude gradient, which, in the present measurement, shows up as the eastward velocities increasing equatorward from our low-latitude observing site. From published models based on simplified theoretical considerations it appears that such velocity gradients could be produced by a similar latitude gradient in the zonal neutral wind and/or by a downward shift (with decreasing solar activity) of the integrated Pederson conductivity height profile in the equatorial plane.

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