Zonal plasma bubble drift velocities dependence on geomagnetic activity at low latitude in Brazil

Pedrina M. Terra Santos (*), INPE, Brazil; J. H. A. Sobral, INPE, Brazil; M. A. Abdu, INPE, Brazil; J. R. Souza, INPE, Brazil; H. Takahashi, INPE, Brazil; Brum, C. G. M., INPE, Brazil

Copyright 2003, SBGf - Sociedade Brasileira de Geofísica

This paper was prepared for presentation at the 8th International Congress of The Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 14-18 September 2003.

Contents of this paper were reviewed by The Technical Committee of The 8th International Congress of The Brazilian Geophysical Society and does not necessarily represents any position of the SBGf, its officers or members. Electronic reproduction, or storage of any part of this paper for commercial purposes without the written consent of The Brazilian Geophysical Society is prohibited.

Abstract

A study of the zonal plasma bubble drift velocities is carried out using experimental airglow data registered at Cachoeira Paulista (22.5^0 S, 45^0 W, dip 30^0 S) during the period from October to March, between 1980-1994. This study is based upon 111 nights of zonal scanning photometer measurements of OI 630 nm airglow. The zonal velocity magnitudes of the ionospheric bubbles are investigated taking into account the geomagnetic effects. A detailed analysis of these plasma bubble velocities, as a function of geomagnetic activity, shows that the velocity variations expressed $V_{final} - V_{inicial}$ are less during quiet nights than during disturbed nights. In addition it is noted that the mean velocities present the highest (lowest) values during quiet (disturbed) nights of solar maximum (minimum).

Introduction

The low-latitude large-scale ionospheric plasma depletions, or plasma bubbles, have been extensively monitored over the South American region for more than two decades, through several techniques, such as optical techniques (Weber et al., 1978; Sobral et al., 1980a, b, 1985, 1997, 1999; Aarons et al., 1980; Sobral and Abdu, 1990, 1991; Taylor et al., 1997; Sahai et al., 2000). The plasma bubbles drift zonally eastward with velocities of about 100ms^{-1} (Sobral and Abdu, 1990, 1991). These motions, usually called drifts **E x B** or zonal drift, occur due to a combination between the action of vertical electric ionospheric and the geomagnetic fields.

The study of the zonal drift of the plasma bubbles is very important to understand the low latitude ionospheric dynamics, since these bubbles are a consequence of the action of the total ionospheric dynamo system on these regions (Heelis et al., 1974; Richmond et al., 1976; Fejer et al., 1985). Another application for this study is to providing input data to the model and theorical simulation developments of the ionospheric dynamics (Anderson e Mendillo, 1983; Nakamura et al., 1984).

In this work a detailed study of the zonal plasma bubble drift velocities dependence on geomagnetic activity is carried. These velocities were registered at Cachoeira Paulista (22.5° S, 45° W, dip 30° S) region using a photometric observational database of the airglow 6300 nm, which was registered over that region during the period from October-March between 1980 and 1984.

Analysis method of the zonal plasma bubble drift velocities

To the analysis of the zonal plasma bubbles drift velocities dependence on geomagnetic activity it was fixed the solar activity parameter. Five nights with the lowest and the highest relative ΣKp values were selected to each month of the minimum and maximum solar activity period (Tables 1 and 2). The ΣKp values are related to the first night bubble occurrence. The solar minimum and maximum activity period division was made with annual means of the sunspot number (NMS). It was determined that the maximum solar activity period corresponds to NMS > 94.3 (1980 – 1982 and 1988 – 1992) and the minimum to NMS < 67 (1983 – 1987 and 1993 – 1994).

Table 01 – Relation of the 05 nights with the lowest (quiet) and the highest (disturbed) relative ΣKp values to each month of the minimum activity period.

Solar minimum activity period (1983-1987/1993-1998)					
Disturbed nights			Quiet Nights		
Month	Date	ΣKp	Month	Date	ΣKp
October	13-14/10/84	23+	October	30-31/10/84	12+
November	19-20/11/87	21-	November	17-18/11/87	12+
December	15-16/12/87	15o	December	14-15/12/93	8-
January	26-27/1/93	28o	January	4-5/1/87	5+
February	6-7/2/83	36o	February	16-17/2/85	13+
March	17-18/3/94	35+	March	22-23/3/85	8o
October	15-16/10/85	36o	October	31/10-1/11/86	13+
November	20-21/11/87	19+	November	18-19/11/87	11-
December	11-12/12/93	14+	December		
January	3-4/1/86	17o	January	5-6/1/87	5+
February	9-10/2/94	36o	February	6-7/2/86	16o
March	25-26/3/84	35o	March	30-31/3/87	8+
October	29-30/10/86	23o	October	28-29/10/86	14+
November	1-2/11/86	18o	November	28-29/11/84	11+
December			December		
January	8-9/1/83	17-	January	13-14/1/86	6+
February	16-17/2/83	33-	February	28/2-1/3/87	21+
March	13-14/3/86	28o	March	24-25/3/87	9o
October	30-31/10/86	23o	October	14-15/10/85	16o
November			November	2-3/11/86	12o
December			December		
January	4-5/1/86	10o	January	7-8/1/83	8o
February	15-16/2/83	30+	February	23-24/2/87	23o
March	11-12/3/83	26+	March	20-21/3/85	10-
October	26-27/10/87	19o	October	27-28/10/84	16+
November			November		
December			December		
January			January	7-8/1/87	9o
February	16-17/2/94	29+	February	22-23/2/87	25-
March	15-16/3/83	24°	March	25-26/3/87	11-

Table 02 - Relation of the 05 nights with the lowest (quiet) and the highest (disturbed) relative ΣKp values to each month of the maximum activity period.

Solar maximum activity period (1980-1982/1988-1992)					
Disturbed nights			Quiet Nights		
Month	Date	ΣKp	Month	Date	ΣKp
October	14-15/10/82	32-	October	1-2/10/80	5-
November	4-5/11/89	31-	November	14-15/11/90	2+
December	30-31/12/81	31+	December	6-7/12/80	7-
January	14-15/1/88	35-	January	27-28/1/90	7o
February	18-19/2/82	34+	February	13-14/2/80	4+
March	30-31/3/90	40+	March	12-13/3/80	2+
October	30-31/10/89	29-	October	24-25/10/92	5+
November	2-3/11/89	26°	November	25-26/11/89	3+
December	3-4/12/88	25+	December	5-6/12/88	7+
January	24-25/1/90	34-	January	23-24/1/80	10-
February	23-24/2/88	32-	February	10-11/2/80	7°
March	28-29/3/90	30°	March	22-23/3/88	6°
October	17-18/10/82	28+	October	31/10-1/11/81	9+
November	12-13/11/88	26-	November	13-14/11/90	6o
December	31/12-1/1/82	25°	December	18-19/12/90	10-
January	31/1-1/2/90	26-	January	13-14/1/88	13+
February	20-21/2/82	31-	February	11-12/2/80	8+
March	2-3/3/81	29-	March	9-10/3/81	8-
October	26-27/10/89	28o	October	2-3/10/80	10-
November	6-7/11/91	25+	November	15-16/11/90	6o
December	4-5/12/91	24-	December	8-9/12/88	10o
January	28-29/1/81	24+	January	28-29/1/90	13+
February	27-28/2/81	28+	February	17-18/2/80	12o
March	10-11/3/89	27-	March	20-21/3/80	9+
October	24-25/10/89	25+	October	15-16/10/88	11+
November	18-19/11/90	24-	November	29-30/11/92	11-
December	3-4/12/91	22-	December	7-8/12/80	12+
January	29-30/1/81	24-	January	17-18/1/88	14o
February	2-3/2/81	28+	February	16-17/2/82	13+
March	24-25/3/90	26+	March	13-14/3/88	10-

Results and discussions

The mean zonal drift velocities of the plasma bubbles calculated to the nights related in the Tables 1 and 2 were plotted according to the local time, to the minimum and maximum solar activity periods. Thus the accelerations and the mean initial and final velocities for each period (Table 3) were obtained. Trough Table 03, it is observed that the highest and lowest mean zonal drift velocities were found at February/maximum/quiet and October/minimum/disturbed, respectively. It is also noted that the velocity variations (V_{final}-$V_{inicial}$) are less during quiet nights than during disturbed nights.

Table 03 – Accelerations and mean initial and final velocities calculated to the nights related in the Tables 1 and 2.

Period	Quiet/ Disturbed	Acceleration ($ms^{-1}h^{-1}$)	V_i (ms^{-1})	V_f (ms^{-1})
January/maximum	Disturbed	23,6	41,78	159,76
January/maximum	Quiet	-12,4	143,21	68,79
January/minimum	Disturbed	4,21	55,9	68,54
January/minimum	Quiet	-14,55	113,62	26,3
February/maximum	Disturbed	-14,78	150,4	61,7
February/maximum	Quiet	12,03	147,04	**195,16**
February/minimum	Disturbed	-31,32	190,19	33,58
February/minimum	Quiet	-12,46	117,99	55,66
March/maximum	Disturbed	3,42	116,22	129,91
March/maximum	Quiet	4,63	122,24	145,371
March/minimum	Disturbed	-14,7	111,48	23,28
March/minimum	Quiet	4,71	60,79	98,5
October/maximum	Disturbed	-10,79	138,38	84,43
October/maximum	Quiet	-7,16	188,02	145,05
October/minimum	Disturbed	-17,05	147,15	**10,73**
October/minimum	Quiet	-10,18	103,49	62,78
November/maximum	Disturbed	-0,54	87,51	84,24
November/maximum	Quiet	-19,03	184,81	70,62
November/minimum	Disturbed	-5,83	101,67	66,69
November/minimum	Quiet	-12,21	145,37	59,93
December/maximum	Disturbed	-13,81	131,39	76,13
December/maximum	Quiet	-9,64	134,7	76,83
December/minimum	Disturbed	-33,08	157,3	24.98
December/minimum	Quiet	-4,52	125,64	121,117

Figure 01 presents the dispersion diagrams at the local time to the studied nights, independently of the month, to the solar maximum and minimum activities. It is observed that the zonal velocities to the quiet and disturbed nights tend to decrease according to the local time. In Table 04 the accelerations and mean value tendencies of the zonal velocities at 20LT and 02LT plotted in the Figure1 are presented. It is noted that the mean velocities present the highest (lowest) values during quiet (disturbed) nights of solar maximum (minimum).

Table 4 – Accelerations and mean value tendencies of the zonal velocities at 20LT and 02LT plotted in the Figure1.

Period	Quiet/Disturbed	V_{20LT}(ms^{-1})	V_{02LT}(ms^{-1})	Acceleration ($ms^{-1}hr^{-1}$)
Maximum Solar	Disturbed	116,32	94,64	-3,61
Maximum Solar	Quiet	161,91	110,96	-8,49
Minimum Solar	Disturbed	149,24	47,24	-17,00
Minimum solar	Quiet	108,16	74,91	-5,54

In addition the zonal drifts general tendency regarding to the geomagnetic activity was studied. It was plotted a dispersion diagram of the velocity points registered between 18LT and 22LT during 111 nights of plasma bubbles occurrence at Cachoeira Paulista according to their respective ΣKp values. The results are presented in Figure 2. It is noted that the zonal plasma drift velocities are inversely proportional to ΣKp values. This result agrees with Sobral et al., 1985.

Conclusions

A study of the zonal plasma drift velocities detected at Cachoeira Paulista during the period from October to March, between 1980-1994 was made. These zonal velocity magnitudes were investigated regarding to the geomagnetic activity.
The principal conclusions of this study are:

∴ The velocity variations expressed as $V_{final} – V_{inicial}$ are less during quiet nights than during disturbed nights (Table 03);

∴ The mean velocities present the highest (lowest) values during quiet (disturbed) nights of solar maximum (minimum).

∴ Generally, the zonal zonal plasma drift velocities behavior is inversely proportional to ΣKp values. To ΣKp=5 and ΣKp=40 were obtained 132,83 ms^{-1} and 106,38 ms^{-1} as mean velocities, respectively (see Figure 03).

References

Aarons, J.; Mullen, J. P.; Koster, J. P.; da Silva, F.; Medeiros, R. T.; Bushby, A.; Pantoja, J.; Lanat, J. Paulson, M. R. *Seasonal and geomagnetic control of equatorial scintillations in two longitudinal sectors.* Journal of Atmospheric and Terrestrial Physicis, 42(9/10), 861-866,1980.

Anderson, D. N.; Mendillo, M. *Ionospheric conditions affecting the evolution of equatorial plasma* *depletions*. Geophysical Research Letters, v. 10, n. 7, p. 541, 1983.

Fejer, B. G.; Kudeki, E.; Farley, D. T. *Equatorial F region zonal plasma drifts*. Journal of Geophysical Research, v. 90, p. 249, 1985.

Heelis, R. A.; Kendall, P. C.; Moffett R. J.; Windle D. W.; Rishbeth, H. *Electrical coupling of the E- and F-regions and its effect on F-region drifts and winds*. Planetary and Space Science, v. 22, p. 743-756, 1974.

Richmond, A. D.; Matsushita, S.; Tarpley, J. D. *On the production mechanism of electric currents and fields in the ionosphere*. Journal of Geophysical Research, v.81, n.4, p.546-555, Fevereiro, 1976.

Sahai, Y.; Fagundes, P. R.; Bittencourt, J. A.; *Transequatorial F-regions ionospheric plasma bubbles: solar cycle effects*. Journal of Atmospheric and Solar-Terrestrial Physics, 62(15), 1377-1383, 2000.

Sobral, J.H.A.; Abdu, M.A.; Batista, I.S. *Airglow studies on the ionosphere dynamics over low latitude in Brazil*. Ann. Géophys., v.2, p. 199-204, 1980a.

Sobral, J.H.A.; Abdu, M.A.; Zamlutti, C.J.;Batista, I.S. *Association between plasma irregularities and airglow brazilian low latitudes*. Geophysical Research Letters, 11(7), 980-982, 1980b.

Sobral, J.H.A.; Abdu, M.A.; Sahai, Y. *Equatorial plasma bubble eastward velocity characteristics from scanning airglow photometer measurements over Cachoeira Paulista*. Journal of Atmospheric and Terrestrial Physics, 47(8-10), 895-900, 1985.

Sobral, J.H.A.; Abdu, M.A.; *Latitudinal gradient in the plasma bubble zonal velocities as observed by scanning 630 nm airglow measurements*. Journal of Geophysical Research, 95(A6), 8253-8257, 1990.

Sobral, J.H.A.; Abdu, M.A.; *Solar activity effects on equatorial plasma bubble zonal velocity and its latitude gradient as measured by airglow scanning photometers.* Journal of Atmospheric and Terrestrial Physics, 53(8), 729-742, 1991.

Sobral, J.H.A.; Abdu, M.A.; González, W. D.; Tsurutani, B. T.; Batista, I. S. *Effects of intense storms and substorms on the equatorial ionosphere/thermosphere system in the American Sector from ground based and satellite data*. Journal of Atmospheric and Terrestrial Physics, 59(13), 1611-1623, 1997.

Sobral, J.H.A.; Abdu, M.A.; Takahashi, H.; Sawant, H. S.; Zamlutti, C. J.; Borba, G. L..; *Solar and geomagnetic activity effects on nocturnal zonal velocities of ionospheric plasma depletions*. Advance in Space Research, 24, 11, 1507-1509,1999.

Taylor, M. J.; Eccles, J. V.; Labelle, J.; Sobral, J. H. A.; *High-resolution OI (630nm) image measurements of F Region depletion drifts during the Guará campaign*. Geophyscial Research Letters, 24(13), 1699-1702, 1997.

Weber, E. J.; Buchau, J.; Eather, R. H.; Mende, S. B.; *North-south aligned equatorial airglow depletion*. Journal of Geophysical Research, 83(A2), 712-716, 1978.

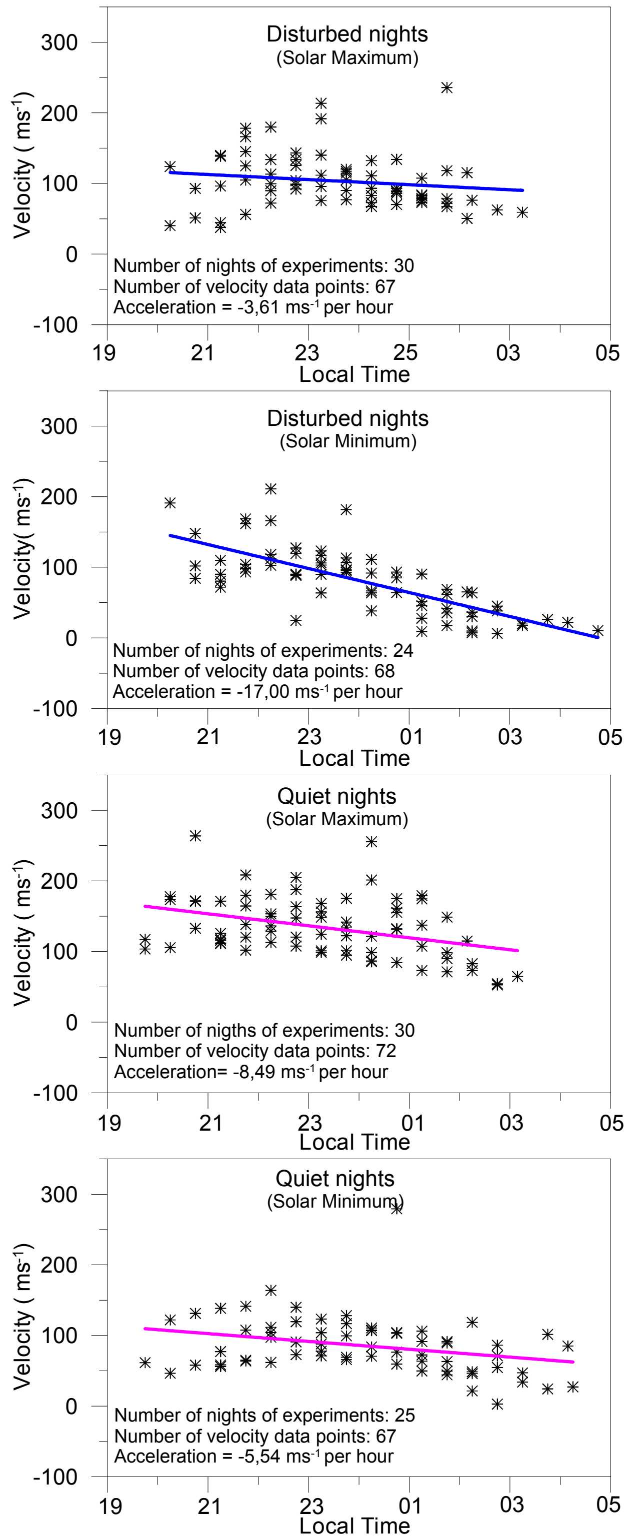

Figure 1 – Dispersion diagrams of the nights with the lowest and the highest ΣKp values registered from October to March between 1980-1994 according to local time.

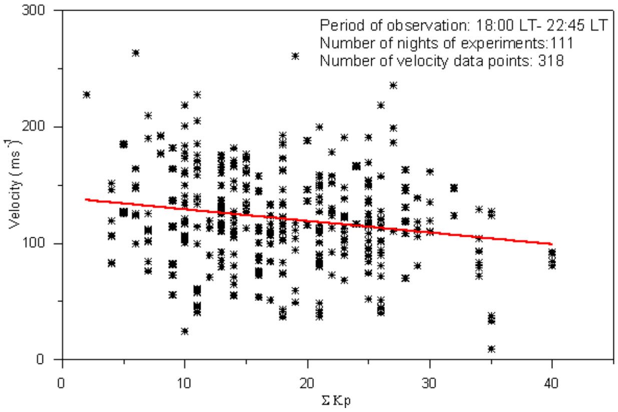

Figure 02 – Dispersion diagram of zonal drift velocities registered during 111 nights according to ΣKp values.