A statistical study of plasma bubble zonal drift velocity variations with geomagnetic activity and events of corotating and transient solar wind streams

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Abstract

A study of the plasma bubble zonal drift velocities is carried out using experimental airglow data registered at Cachoeira Paulista (22.5° S, 45° W, dip 30° S) during the period from October to March, between 1980-1994. This study is based upon 109 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. The geomagnetic activity condition in this study is based on the 3-hour geomagnetic index Kp. A detailed analysis of these plasma bubble velocities, as a function of geomagnetic activity, shows that the velocity variations expressed by $V_{final} - V_{initial}$ are smaller 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). Also it is observed that the tendency of the plasma bubbles is to appear earlier during corotating stream events than transient or no stream periods.

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, Sobral and Abdu, 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 plasma bubble zonal drift is very important to understand the low latitude ionospheric dynamics, since these bubbles are consequences of the action of the entire 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 modeling and theoretical simulation developments of the ionospheric dynamics (Anderson e Mendillo, 1983; Nakamura et al., 1984).

Methodology

In this work a detailed study of the plasma bubble zonal drift velocities dependence on geomagnetic activity is carried. This study is based upon 109 nights of zonal scanning photometer measurements obtained during the period from October-March between 1980 and 1984. These velocities were registered at Cachoeira Paulista (22.5° S, 45° W, dip 30° S) region using a photometric observational database of the airglow 630 nm.

To the first analysis presented here, the set of data (109 nights) were grouped into two groups according to the solar activity. It was selected five nights with the lowest and the highest relative ΣKp values to each month of the minimum and maximum solar activity periods (Table 1). The ΣKp values are related to the first night bubble occurrence. It was determined that the maximum solar activity period corresponds to Sunspot Number > 94.3 (1980 – 1982 and 1988 – 1992) and the minimum to Sunspot Number < 67 (1983 – 1987 and 1993 – 1994).

To the second analysis the set of the data were grouped into four groups:

a) data registered at disturbed days during the solar maximum activity (30 nights of experiments);

b) data registered at quiet days during the solar maximum activity (30 nights of experiments);

c) data registered at disturbed days during the solar minimum activity (24 nights of experiments), and

d) data registered at quiet days during the solar minimum activity (25 nights of experiments).

After, the points of mean velocities registered at 109 nights of experiments during the maximum and minimum solar activities were plotted as a function of ΣKp. To finalize this work, these mean velocities were plotted as a function of local time and of Kp, during corotating, transient and no stream periods. The so-called corotating stream period is characterized by a long-lasting high-speed solar wind stream emitted by coronal holes that exhibited an apparent tendency to recur at intervals of ~27 days. The so-called transient stream period is characterized by the other kinds of streams (the flare-generated streams, for example).

TABLE 1 – Relation of the 5 nights with the lowest (quiet) and the highest (disturbed) relative ΣKp values to each month of the minimum and maximum activity periods.

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-

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

The mean zonal drift velocities of the plasma bubbles calculated for the nights related in Table 1 were plotted according to local time, for minimum and maximum solar activity periods. Thus the accelerations and the mean initial and final velocities for each period were obtained, and are shown in Table 2. 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}-$V_{initial}$) are smaller during quiet nights than during disturbed nights.

TABLE 2 – Accelerations and mean initial and final velocities calculated for the nights related in the Table 1.

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 1 presents the dispersion diagrams at the local time for the studied nights, independently of the month, for solar maximum and minimum activities. It is observed that the zonal velocities for the quiet and disturbed nights tend to decrease according to the local time. In Table 3 the acceleration and mean value tendencies of the zonal velocities at 20LT and 02LT plotted in the Figure 1 are presented. It is noted that the mean velocities present the highest (lowest) values during quiet (disturbed) nights of solar maximum (minimum).

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.

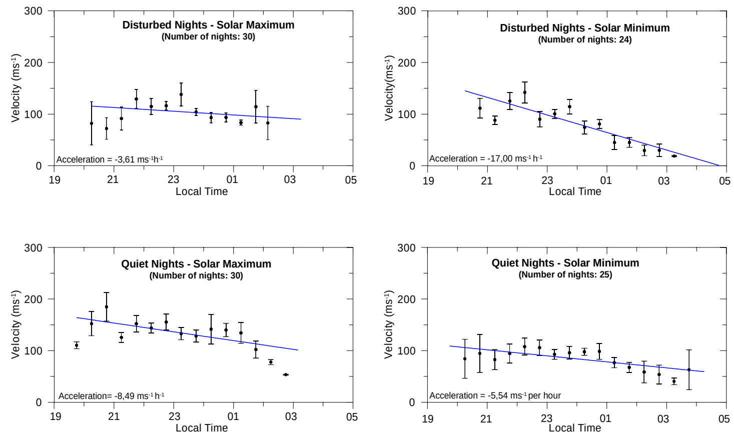
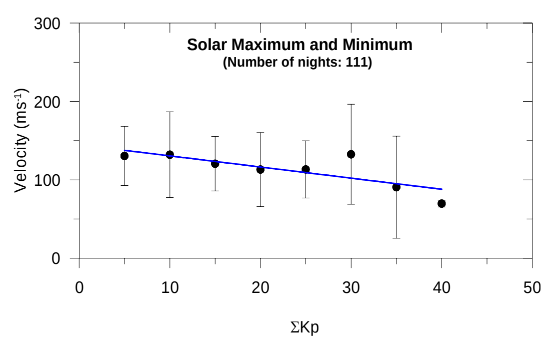


TABLE 3 – Acceleration and mean value tendencies of the zonal velocities at 20LT and 2LT plotted in the Figure1.

Period	Quiet/Disturbed	V_{20LT}(ms^{-1})	V_{02LT}(ms^{-1})	Acceleration ($ms^{-1}h^{-1}$)
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

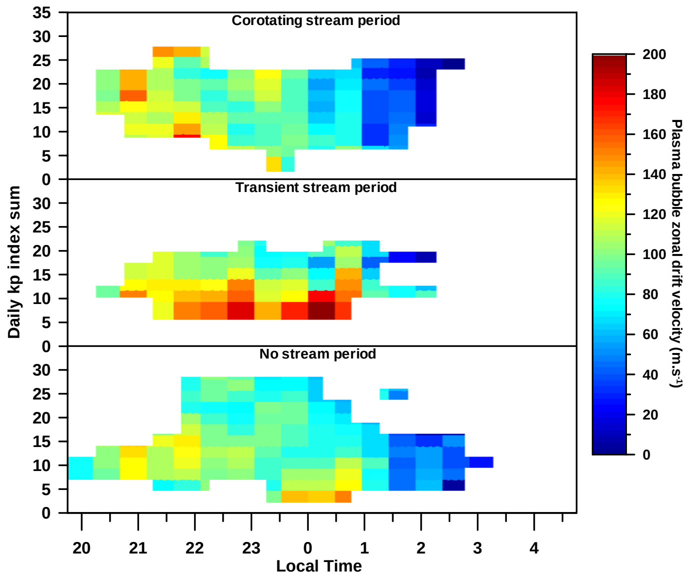
In addition to the zonal drifts, general tendency regarding to the geomagnetic activity was studied. It was plotted a dispersion diagram of the velocity points registered between 18LT and 22LT during 109 nights of plasma bubbles occurrence at Cachoeira Paulista according to their respective ΣKp values. 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

FIGURE 2 – Dispersion diagram of zonal drift velocities registered during 109 nights according to ΣKp values.Figure 3 shows a statistical study about the zonal



drift velocity variations of the plasma bubbles according to the local time and the daily ΣKp index during corotating, transient and no stream periods. It is noted that the tendency of the plasma bubbles is to appear earlier during corotating stream than transient or no stream event periods.

FIGURE 3 – Zonal drift velocities registered during 109 nights according to local time and ΣKp daily values.



Conclusions

A study of the zonal plasma drift velocities detected at Cachoeira Paulista during the period from October to March, between 1980-1994 was developed. These zonal velocity magnitudes were investigated regarding to the geomagnetic activity.The principal conclusions of this study are: The velocity variations expressed as $V_{final} - V_{initial}$ are smaller during quiet nights than during disturbed nights (Table 2);

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

∴ Generally, the zonal plasma drift velocities behavior is inversely proportional to ΣKp values. For ΣKp=5 and ΣKp=40 were obtained 137.7 ms^{-1} and 88 ms^{-1} as mean velocities, respectively (Figure 2). Also it is noted that the tendency of the plasma bubbles is to appear earlier during corotating stream than during transient or no stream event periods.

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