

## DIURNAL VARIATION OF THE OCCURRENCE OF PLASMA IRREGULARITIES IN THE EQUATORIAL ELECTROJET OVER BRAZILIAN SECTOR

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This paper was prepared for presentation at the 11<sup>th</sup> International Congress of The Brazilian Geophysical Society held in Salvador, Brazil, 24-28 August 2009.

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### Abstract

**Equatorial electrojet (EEJ) observations using VHF radars show backscattered echoes from two types of electron density irregularities, Type 1 and Type 2. In this paper, we present an statistics of occurrence irregularities in the ionospheric plasma at the e-region hight, observed by a 50 MHz coherent backscatter radar installed in Brazil. This radar detects small-scale irregularities (3 meters) between approximately 90 to 130 km heights in the equatorial ionosphere.**

### Introduction

The ionosphere is a region of the Earth's atmosphere situated between 60 and 2000 km of height. It is constituted, basically, for ionized gases with high temperatures, i.e., a plasma. It is basically divided in 3 regions: D, E and F (Rishbeth, 1969). Also, the F-region is divided in F1 and F2 layers, and in some times a F3 layer can appear depending upon the latitude (Batista et al., 2000, 2003). The ionospheric layers have properties that vary accordingly the hour of the day, season of the year and solar conditions.

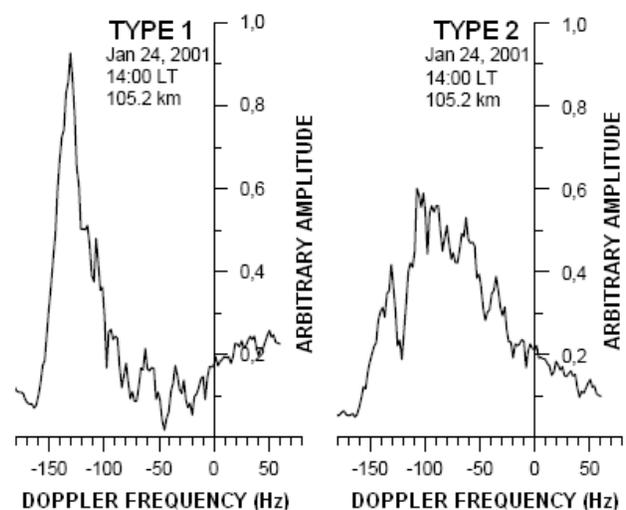
The ionosphere is generated for the ionization of atoms and neutral molecules, when the solar radiation interacts with them, causing the liberation of electrons, i.e., the neutral particles become ions. The net effect is the generation of the ionospheric plasma. Therefore, the ionosphere is mainly generated by the interaction between the atmosphere and the solar radiation. At night, when the solar radiation is absent, the ionosphere reduces its content (ionic and electron density), being almost undetectable in its lower portion.

In the Ionosphere we also observed several physical phenomena. Some of them are ordinary ones (solar quiet dynamo, equatorial electrojet, auroral electrojet, fountain

effect, Appleton anomaly, etc.), others are sporadic (spread-F, scintillations, disturbances dynamo, etc.). The solar quiet dynamo is specially important because it triggers the equatorial electrojet.

The neutral atmosphere is heated by the solar radiation, generating the expansion of the atmosphere due to pressure gradients, resulting in the generation of neutral winds (**U**). These neutral winds drag ions due to high ion-neutral collision rates at the E-region rates. During the day this neutral winds blow to the poles through the magnetic field inducing electric field **E=UxB** in high latitudes, due to interaction of the ions with high magnetic inclination field lines in this latitude. These sequence of phenomenons driving the appearance of the atmospheric dynamo, resulting in positive polarization in the dawn terminator and negative polarization in the dusk terminator (Aveiro, 2005).

The atmospheric dynamo generates the equatorial electrojet (EEJ) in the layer E. This phenomenon is defined as an intense electrical current centered on the magnetic equator which has two types of plasma irregularities, Type 1 and Type 2, as shown in FIGURE 1 (Denardini, 1999, 2004).



**FIGURA 1:** Examples of Type 1 (left) and Type 2 (right) irregularities spectra obtained by coherent radars.

Source: (Denardini, 2003, p. 53)

The spectrum related with Type 1 irregularities (left) show thin spectral width, with its center of distribution close to ion-acoustic speed (~ 360 m/s). The spectra of the Type 2 (right) have larger width and smaller Doppler velocities than the ion-acoustics speed. Type 1 irregularities are more likely observed when the radar pulses are transmitted in oblique, Type 2 irregularities appear in both oblique and vertical sounding (Bowles, 1963; Denardini 2004).

**Instrumentation and Data Selection**

For this study, it was utilized data from the westward oblique beam of the 50 MHz coherent backscatter radar, also known by the acronym RESCO. The data were collected during 120 days in the years of 2002, 2003, and 2004 (TABLE 1).

**TABLE 1:** List of the days which the data of the RESCO were selected to the analysis grouped by season, month and year of acquisition.

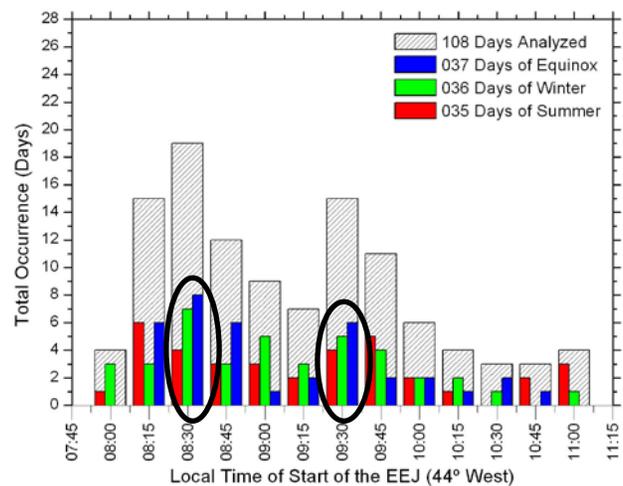
| <b>Summer</b>            |      |                                |
|--------------------------|------|--------------------------------|
| January                  | 2002 | 22,23,28,29                    |
|                          | 2003 | 20,21,22,23,24                 |
|                          | 2004 | -                              |
| February                 | 2002 | 15,16,20,21                    |
|                          | 2003 | 17,18,19,20,21,24              |
|                          | 2004 | -                              |
| November                 | 2002 | 5,6,7,8,9,10                   |
|                          | 2003 | -                              |
|                          | 2004 | 11,12,16,17,18                 |
| December                 | 2002 | 1,2,3,4,5,6,7,8                |
|                          | 2003 | -                              |
|                          | 2004 | 6,14                           |
| <b>Winter</b>            |      |                                |
| May                      | 2002 | 2,3,20,21,22,23,24,27,28,29,31 |
|                          | 2003 | 19,20,21,22,23,26,27,28,29     |
|                          | 2004 | -                              |
| June                     | 2002 | 20,21,24,25,26,27,28           |
|                          | 2003 | -                              |
|                          | 2004 | -                              |
| July                     | 2002 | 22,23,25,26,29                 |
|                          | 2003 | -                              |
|                          | 2004 | -                              |
| August                   | 2002 | 1,14,19,26,27,29               |
|                          | 2003 | -                              |
|                          | 2004 | 1,4                            |
| <b>Equinoxes</b>         |      |                                |
| March                    | 2002 | 19,20,21,22,25                 |
|                          | 2003 | 17,18, 25,26,31                |
|                          | 2004 | -                              |
| April                    | 2002 | 22,23,24,25,26                 |
|                          | 2003 | 1,2,3,14,15,16                 |
|                          | 2004 | 26,27,28,29,30                 |
| September                | 2002 | 10,11,12,13,17                 |
|                          | 2003 | -                              |
|                          | 2004 | 10,13,14,15,16                 |
| October                  | 2002 | -                              |
|                          | 2003 | -                              |
|                          | 2004 | 11,13,14,18                    |
| Total Days Analyzed: 120 |      |                                |

The RESCO has been operated since 1998 at São Luís, State of Maranhão (2.51° S, 44.27° W, mag. lat. -2.3°), and detect plasma irregularities with 3 m scale length. It is composed by 768 coaxial antenna cables, organized in 32 x 24 arrangements. The 32 antennas are arranged in groups of 4 to be feed by the 8 transmitters (Aveiro, 2009).

From the RTI maps, we obtained the start and end times of the occurrence of 3-m irregularities. Besides, we investigated the heights of the EEJ irregularities in the hours mentioned above. The results of this analysis were compiled in the form of histograms of days of occurrence by local time and days of occurrence by time. General histograms were obtained for the four cases studied and specific histograms were obtained to the summer, winter and equinoxes.

**Results and Discussions**

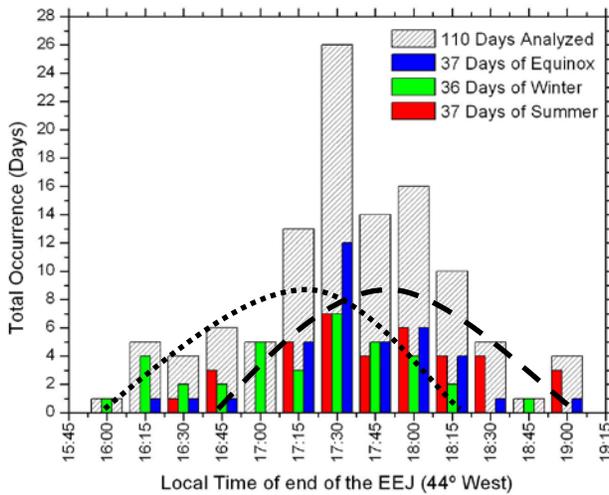
The FIGURE 2 shows the histogram of the number of the days when the EEJ started in the period between 07:45 and 11:15 (LT). The red bars show the density of the days during summer at each time interval. The green bars give the density of the days during winter. The blue bars show the density of the days during equinoxes. The hachured bars represent the summatory of the tree periods. Notice that the number of days are equally distributed along the seasons.



**FIGURE 2:** Histogram of days of occurrence versus the begin hour of the irregularities observation in the EEJ.

In general, the EEJ usually appear in the interval from 8:15 to 9:45 (LT). Also, we noted that there are 2 peaks in the appearance of the EEJ, one at 8:30 and other at 9:30 (LT). In both peaks, the seasonal occurrence show the same order: higher occurrence in equinoxes, middle occurrence in winter and lower occurrence in summer. The appearance of the EEJ after 9:00 AM (LT) should be carefully examined, in most cases the radar was turn on after this time.

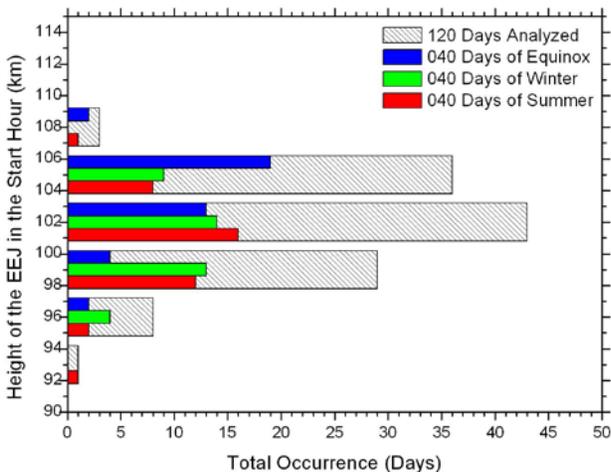
The FIGURE 3 represent the number of the days which the EEJ finished to be observed between 15:45 and 19:15 (LT). The different colored bars in this histograms represents the same seasons of the FIGURE 2, as well the hachured bar.



**FIGURE 3:** Histogram of days of occurrence versus the end hour of the irregularities observation in the EEJ.

Regarding the time of the end of the EEJ we can note that there is a decrease in the number of occurrences in the period from 17:15 (LT) to 18:15 (LT). We also observe some rare cases when the EEJ lasted after 18:30 (LT), mainly in summer. Besides some of the stations follow almost the same patterns, we noticed that there is a peak around 17:30 (LT) in equinoxes. In general, during winter day, the EEJ tends to diminish earlier than the summer days, as shown by the dashed and dotted lines. The dotted line indicates the winter days distributions, while the dashed line the summer days.

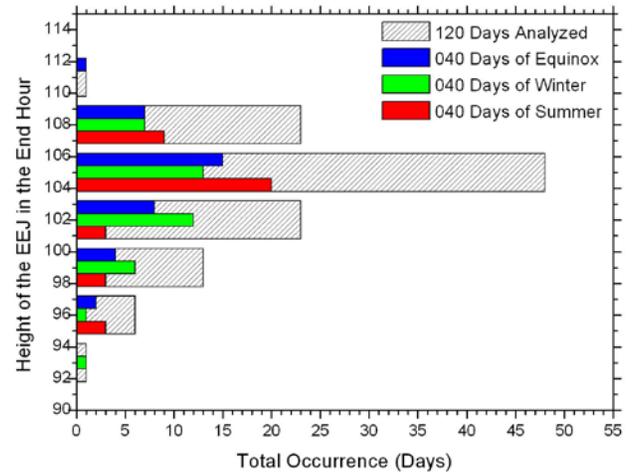
The FIGURE 4 represents histograms of the occurrence in days versus the height of the EEJ in the start hour. The red bars show the density of the days during summer at each height interval. The green bars give the density of the days during winter. The blue bars show the density of the days during equinoxes. The hachured bars represent the summatory of the three periods. Notice also that the number of days were kept equally distributed along the seasons.



**FIGURE 4:** Histograms of the occurrence of days versus the observation height of the EEJ in the start hour

In general, the heights of the start of the EEJ during the winter and during the summer peak between 99 and 102 km. During the equinox days, the heights peak between 102 and 105 km.

The FIGURE 5 represents histograms of the occurrence in days versus the height of the EEJ in the end hour. The different colored bars in this histograms represents the same seasons of the FIGURE 4, as well the hachured bar. In general, the heights of the end of the EEJ are well established. For all seasons the EEJ ended to be observed between 104 and 106 km. The hachured bars showed that it occurred in 50 days at this height, and during around 20 days in the height immediately above and below it.



**FIGURE 5:** Histograms of the occurrence of days versus the observation height of the EEJ in the end hour

**Conclusions**

This study showed a statistical occurrence of plasma irregularities on a scale of 3 m, observed by the RESCO radar in SLZ. Despite already known by the practice, this study revealed the average time and average heights of occurrence of these irregularities to the study period. It was observed that the irregularities of the EEJ are present from 8:15 until 18:00 (LT), but with some variations among the seasons. In relation to the EEJ height, there is a EEJ peak that appears in a lower height during EEJ formation and in a higher one when it is disappearing.

**Acknowledgements**

L. M. G. thanks to CNPq for her Fellowship (102033/2008-0). C. M. Denardini thanks to CNPq for the research support (305923/2008-0). H. C. Aveiro thanks to CNPq for his fellowship (131326/2007-4). H. C. Aveiro thanks to CNPq for his fellowship (131326/2004-4). P. D. S. C. Almeida for his Fellowship (132668/2008-4). L. C. A. Resende thanks to CAPES for her MSc Fellowship .

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ISSN 2175-455