# ASSOCIATION BETWEEN IONOSPHERIC PLASMA BUBBLES AND SPREAD-F

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## Abstract

A statistical study of the association between the frequency of occurrence of the ionospheric bubbles and the range spread-F (large-scale ionospheric irregularities) is presented here. This study was based on radio frequency observations (Digisonde data) and optical observations of the airglow OI630nm by an all-sky digital imager system located at the low-latitude region – Cachoeira Paulista (22.5°S, 45°W) – and at the equatorial region – São João do Cariri (7.4°S; 36.5°W). A total of 158 nights during maximum solar cycle were analyzed being 63 nights at Cachoeira Paulista and 95 nights at São João do Cariri. The frequency of occurrence of ionospheric bubbles at Cachoeira Paulista was compared with frequency of occurrence of the range spread-F over the same site. At São João do Cariri, the frequency of occurrence of the ionospheric bubbles was compared with the frequency of occurrence of the range spread-F over São Luis (2°S; 44°W) and Fortaleza (3.5°S; 38.2°W) because unfortunately there is not a Digisonde operating at São João do Cariri. This statistical study with the local time showed that the ionospheric irregularities occur with high frequency between October and March. Also, it was observed that the occurrence of ionospheric bubbles is closely related to the occurrence of the range spread-F. The observations showed that the frequency of occurrence of ionospheric bubbles in Cachoeira Paulista is greater than the frequency of occurrence of the range spread-F. Apparently, this fact occurs because of the discrepancies between the areas of covering of each instrument utilized.

## Introduction

The ionospheric irregularities are irregular distributions of electron density that occur in the ionospheric plasma. These ionospheric irregularities have been studied for decades through optical techniques as imager systems and radiofrequency soundings as Digisaondes. These instruments are efficient in the diagnostic of ionospheric irregularities.

The nighttime equatorial F region is often characterized by the presence of the large-scale plasma irregularities (hundred to thousand kilometers). The generation process of the range spread-F and ionospheric bubbles develop only in the postsunset hours and manifest as spread F in ionograms and as dark signatures in the digital images.

Thus, this statistical study presents a comparative analysis between the frequency of occurrence of ionospheric bubbles and the range spread-F with the local time in order to find out to what extent the presence of ionospheric bubbles imply the observation of range spread-F and vice-versa.

## Method

In this study, the range spread-F observations are compared with bubble observations in the OI630nm images. The period of time analyzed for Cachoeira Paulista was between January 1999 and December 1999 and for São João do Cariri, between April 2001 and March 2002. A total of 158 nights were analyzed. The intervals for the OI630nm images and ionograms are ~7 minutes and ~15 minutes, respectively. The frequencies of occurrence of the bubbles and spread-F were computed ~15 minutes time bins. The 158 nights were grouped seasonally as follows:

| Cachoeira Paulista | | |
|---|---|---|
| Summer 1999 | 11 nights | January: 4 nights<br>February: 3 nights<br>March: 4 nights |
| Autumn 1999 | 18 nights | April : 4 nights<br>May: 9 nights<br>June: 4 nights |
| Winter 1999 | 23 nights | July: 6 nights<br>August: 10 nights<br>September: 7 nights |
| Spring 1999 | 11 nights | October: 5 nights<br>November: 3 nights<br>December: 3 nights |
| TOTAL | 63 nights | |

| São João do Cariri | | |
|---|---|---|
| Autumn 2001 | 29 nights | April : 9 nights<br>May: 13 nights<br>June: 7 nights |
| Winter 2001 | 22 nights | July: 8 nights<br>August: 5 nights<br>September: 9 nights |
| Spring 2001 | 22 nights | October: 9 nights<br>December: 13 nights |
| Summer 2002 | 22 nights | January: 7 nights<br>February: 5 nights<br>March: 10 nights |
| TOTAL 95 nights | | |

**Results**

In the figures, the top panel is the representative curve of the number of nights with simultaneous observations by imager system and Digisonde. The increase and decrease in the representative curve in the early and late night were due to the meteorological conditions (clouds). The bottom panel shows the frequency of occurrence both in the ionospheric bubbles and in the range spread-F simultaneously.

In Figure 1, the frequencies of occurrence of occurrence of ionospheric bubbles are larger than the frequencies of occurrence of the range spread-F until 0LT. Later, between 0LT and 3:30LT, both frequencies of occurrence alternate in magnitude. After 3:30LT, frequencies of occurrence of the range spread-F disappear while the ionospheric bubbles still exist. Both frequencies of occurrence alternate in magnitude between 0LT and 3:30LT because the airglow OI630nm intensity decreases around 0LT interfering in the direct visualization of ionospheric bubbles by digital images. Then, the results suggest that the ionospheric bubbles exist when the range spread-F is detected even if the signature is not strong enough to be detected in the digital image. The results also show that both frequencies of occurrence began at 20LT with a maximum peak around 23LT and gradually decrease with local time. Between 3:30LT and 4:45LT, ionospheric bubbles were observed but no range spread-F. Figure 2 was elaborated for the summer months when there was the maximum number of nights simultaneously observed. Figure 3 was elaborated for the winter months when the phenomenon rarely occurs and, in this study, only one night was simultaneously observed. Figure 4 shows the results for the spring months with frequencies of occurrence concentrated before 0LT. For the autumn months, there were no ionospheric bubbles or range spread-F occurrence.

Figures 5-8 are analogous to Figure 1-4 but show the statistical results between April 2001 and March 2002 at São João do Cariri. Figure 5 shows that frequencies of occurrence of ionospheric bubbles were clearly smaller than the frequencies of occurrence of the range Spread-F at Fortaleza and São Luís during nocturnal hours. In this Figure 5, both frequencies of occurrence of ionospheric bubbles and the range spread-F grow rapidly in the early hours and remain constant until ~2LT and then decrease until 0% at 4:45LT. Figure 6 shows the frequencies of occurrence for the autumn months lower than in the other stations with seasonal statistics sufficiently consistent with the result of the statistical study by Sobral et al. (2002). This lower frequency of occurrence is associated with no ionospheric bubbles and the range spread-F occurrence at Cachoeira Paulista. Figure 7 shows frequencies of occurrence of ionospheric bubbles for the winter months which were greater than at Cachoeira Paulista because in these months, the ionospheric bubbles are not sufficiently elongated in the field line to be observed at Cachoeira Paulista (Abdu et al., 1983). Figure 8 presents the results for the spring months where the frequency of occurrence of ionospheric bubbles is maximum (~80%) between 20LT and 23LT. Finally, Figure 9 shows the frequencies of occurrence for the summer months that presented highest magnitudes in this statistical study because the equatorial region is the region of origin of the phenomenon.

**Conclusions**

In general, this statistical study showed that:

(1) All figures showed that the frequencies of occurrence of ionospheric bubbles and range spread-F presented the same magnitudes between ~20LT and ~4LT for the observed period.

(2) All figures presented similar curves with local time in both ionospheric bubbles and the range spread-F events, namely, increased in the early hours, maximum peak at ~21LT, remained constant until ~2LT and decreased until 4LT confirming the strong statistical association between both events.

(3) As to seasonality it was verified that both events occur mainly in the Spring (October, November and December) and Summer (January, February and March) months presenting maximum peaks in 100%.

(4) At Cachoeira Paulista (low latitude region), both events present the same dynamics pointing out that the range spread-F is highly seasonal and is always observed in the presence of ionospheric bubbles.

(5) At São Luís and Fortaleza (equatorial region), the range spread-F occurs practically during all the year but not necessarily related to the presence of ionospheric bubbles.

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**References**

Abdu, M. A., Medeiros, R. T., Sobral, J. H. A., Bittencourt, J. A., 1983, Spread F Plasma Bubble Vertical Rise Velocities Determined from Spaced Ionosonde Observations. Journal of Geophysical Research, v. 88, p. 9197-9204.

Kelley, M. C., 1989, The Earth's ionosphere – Plasma Physics and Electrodynamics. San Diego: Califórnia, Academic Press, 487p.

Sobral, J. H. A., Abdu, M. A., Takahashi, H., Taylor, M. J., de Paula, E. R., Zamlutti, C. J., de Aquino, M. G., Borba, G. L., 2002, Ionospheric plasma bubble climatology over Brazil based on 22 years (1977-1998) of 630nm airglow observations. Journal of Atmospheric and Solar-Terrestrial Physics, v. 64, p. 1517-1524.

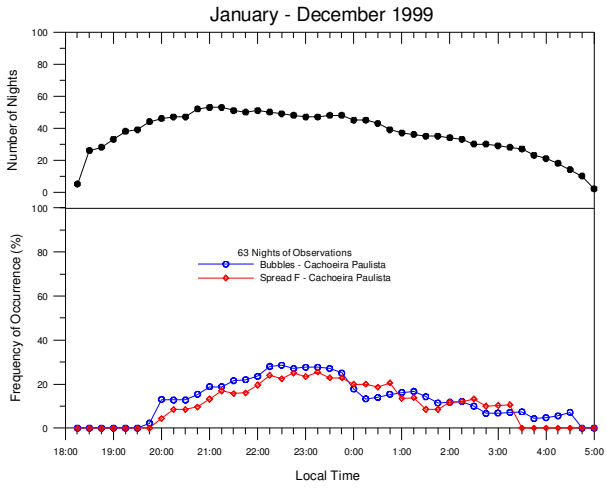


Fig.1 – Annual statistics of the ionospheric bubbles frequency of occurrence versus the range spread-F frequency of occurrence for Cachoeira Paulista.

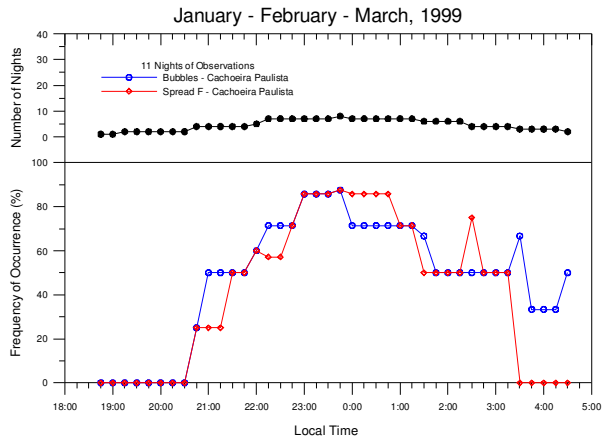


Fig. 2 – Statistics of the the ionospheric bubbles frequency of occurrence versus range spread-F frequency of occurrence for Cachoeira Paulista for the months of January, February and March (Summer).

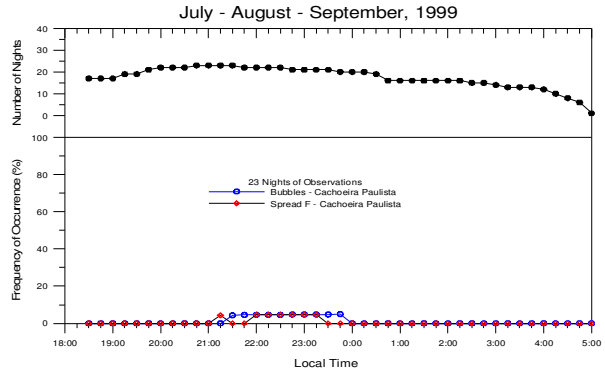


Fig. 3 – The same as Figure 2 but for the months of July, August and September (winter).

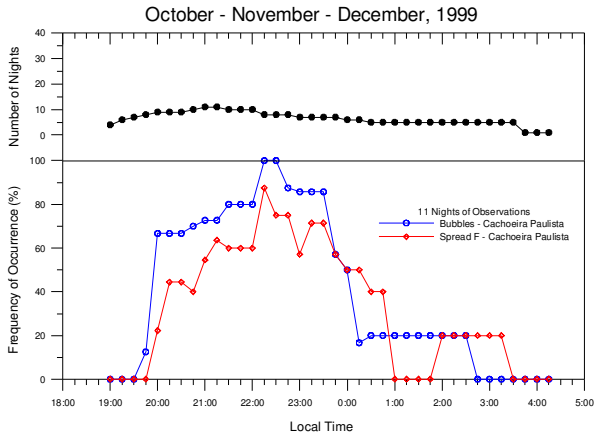


Fig.4 – The same as Figure 2 but for the months of October, November and December (Spring).

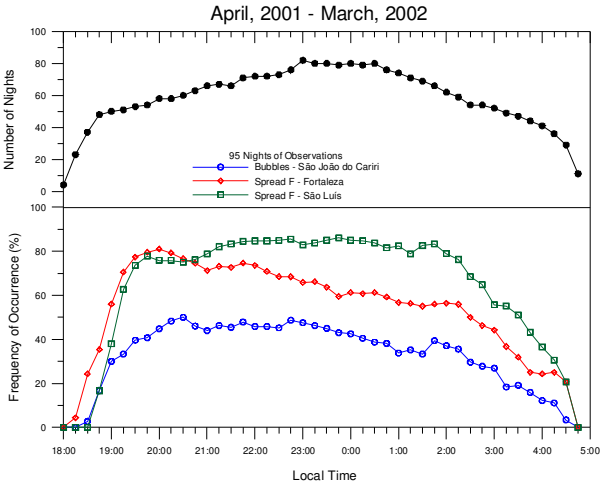


Fig. 5 – Annual statistics of the ionospheric bubbles frequency of occurrence versus the range spread-F frequency of occurrence for São João do Cariri.

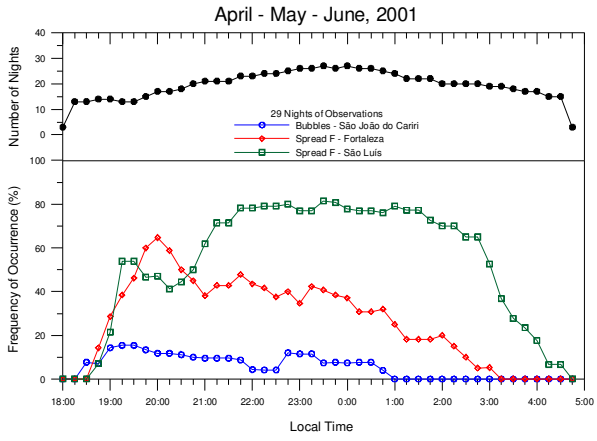


Fig. 6 – Statistics of the ionospheric bubbles frequency of occurrence versus range spread-F frequency of occurrence for Cachoeira Paulista for the months of April, May and June (Autumn).

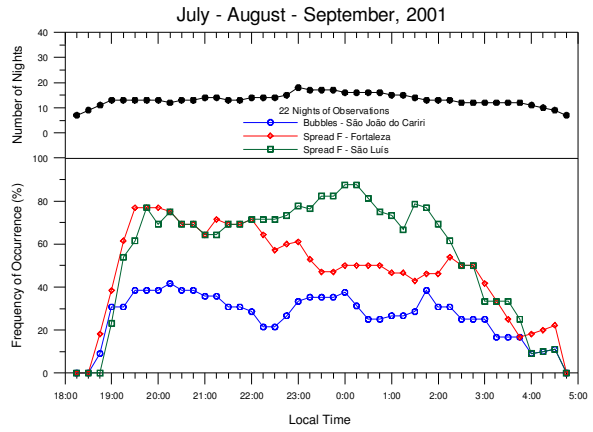


Fig. 7 – The same as Figure 6 but for the months of July, August and September (Winter).

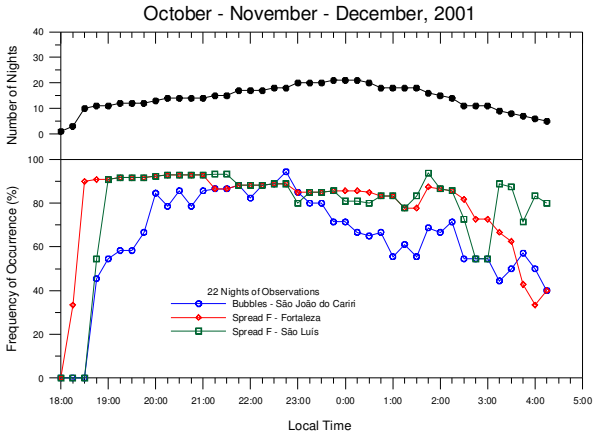


Fig.8 – The same as Figure 6 but for the months of October, November and December (spring).

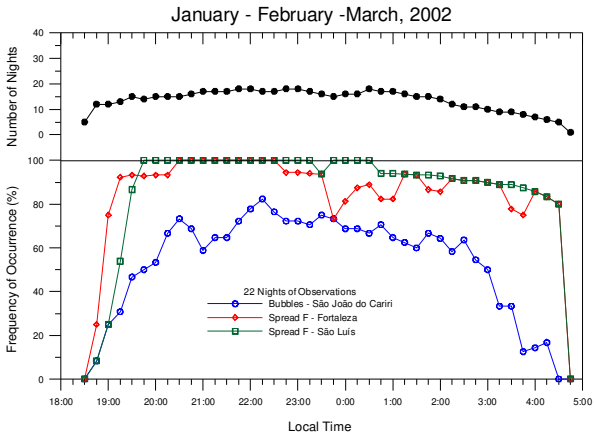


Fig. 8 – The same as Figure 6 but for the months of January, February and March (summer).