# Electric Field and Electron Density Irregularities Associated with Plasma Bubbles

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In-situ measurements of the height variation of the ionospheric electric field and electron density variations were made with a rocket-borne double probe and two different types of electron density probes. A Brazilian made SONDA III rocket launched on 18-th December, 1995 at 2117 hrs (LT) from the equatorial rocket launching station, Alcantara reached an apogee altitude of 557km and covered a horizontal range of 589km. Several ground equipments were operated during the launch campaign with the specific objective of knowing the ionospheric conditions at the time of launch and thereby to launch the rocket into an F-region prone to the presence of large plasma bubbles. The rocket in fact passed through several medium scale plasma bubbles and the electric field double probe and the electron density probes detected the presence of a wide spectrum of electric field and electron density irregularities. In the base of the F-region the electric field double probe measurements clearly indicated the presence of large amplitude fluctuations, closely associated with large amplitude electron density irregularities But in the height region close to the rocket apogee though the electron density profile showed the presence of large scale spatial structures, the electric field measurements did not show fluctuations of similar amplitude. Being a nighttime launch one would expect the electron density irregularities, if generated by the well-known cross-field instability mechanism, in height regions where the electron density gradient is downward, i.e. in the same direction as the ambient Hall electric field. An FFT algorithm was then used to estimate the spectral distribution of the electric field and electron density fluctuations, thus estimating the height variation of the spectral variation. The results of this analysis are presented here.

## INTRODUCTION

Electron density irregularities present in the ionosphere manifest themselves in different forms at different heights and times. Sporadic-E, spread-F, radio star scintillations and VHF radar echoes are a few of such phenomena, familiar to ionospheric physicists. Basic knowledge of the plasma irregularities, responsible for these phenomena, has progressed considerably, both in theory and observations, since the discovery of the strong VHF radar echoes from the equatorial ionosphere (Bowles et al 1960, 1963). Balsley (1969), from their spectral characteristics as observed by the VHF radar, classified the plasma irregularities into two groups, namely Type I and Type II. While the Type I irregularities are now identified to be consistent with the two-stream instability mechanism (Farley, 1963; Sato, 1972), the Type II irregularities are known to be produced by the nonlinear cross-field instability mechanism (Rogister and d'Angelo, 1970, 1972; Balsley and Farley, 1973). Direct observations by Prakash et al (1970, 1971a,b) using rocket-borne Langmuir probes flown from India, confirm the existence of the Type II irregularities in the equatorial E-region. Type II irregularities are characterized by scale sizes extending from a few meters upto tens of kilometers. The short wavelength irregularities apparently seem to be generated from larger scale sizes nonlinear coupling or cascading processes (Rogister, 1972; Rogister and d'Angelo, 1970, 1972; Sato 1971, 1973; Sudan et al 1973). Neutral turbulence also seems to be another probable mechanism responsible for the generation of plasma irregularities (Prakash et al, 1970). The spectral characteristics of the different types of irregularities have been studied in detail (Prakash et al, 1970; Ott and Farley, 1974).

In-situ measurements of the height variation of the ionospheric electric field and electron density variations were made with a rocket-borne double probe and two different types of electron density probes. A Brazilian made SONDA III rocket launched on 18-th December, 1995 at 2117 hrs (LT) from the equatorial rocket launching station, Alcantara reached an apogee altitude of 557km and covered a horizontal range of 589km. Several ground equipments were operated during the launch campaign with the specific objective of knowing the ionospheric conditions at the time of launch and thereby to launch the rocket into an F-region prone to the presence of large plasma bubbles.

## EXPERIMENT AND FLIGHT DETAILS

The rocket payload designated IONEX-II had the principal objective of measuring the electric field, the electron density, the electron kinetic temperature and the spectral distribution of plasma irregularities associated with what are known as ionospheric plasma bubbles. The payload consisted of the following experiments.

1. Electric Field Double Probe (EFP)
2. Langmuir Probe (LP)
3. High Frequency Capacitance probe (HFC)

The main objective of the EFP was to measure the dc electric field and the fluctuating component of it associated with the ionospheric plasma irregularities. Two spherical electric field sensors were mounted at the extremities of two booms that were deployed after the rocket nosecone was ejected at an altitude of about 65km. Though, in the fully deployed state the separation between the sensors was expected to be more than 3m, the booms did not open fully due to the unexpectedly low spin rate attained by the rocket and the separation between the sensors obtained was only about 1.3m. This made the already difficult task of obtaining the dc component of the electric field much more difficult. However the dc and ac components of the horizontal electric field were made in the altitude region of about 95 to 557km, the apogee altitude reached by the rocket, and are being analyzed.

The basic principle of operation and the details of the electronic subsystem of the LP and HFC experiments are given in Muralikrishna and Abdu (1991). The Langmuir Probe was used to measure the electron density and the electron kinetic temperature. The spherical LP sensor of diameter about 60mm was mounted at the extremity of a short boom of about 50cm in length that remained inside the rocket nosecone. This boom was deployed along with the EFP booms soon after the ejection of the rocket nosecone. A swept voltage varying from -1V to +2.5V in about 2.5sec. was applied to the LP sensor in order to measure both the electron density and the electron kinetic temperature.

The main objective of the HFC probe was to measure the electron density height profile. The HFC sensor was identical to the LP sensor and was mounted also at extremity of a short 50cm boom kept folded inside the rocket nosecone till the ejection of the nosecone like the LP sensor boom. The sensor formed part of the tank circuit of an electronic oscillator and any change in the sensor capacitance caused by changes in the ambient electron density, is measured through a counting circuit and this information is telemetered to the ground.

## RESULTS AND DISCUSSION

Electron density profile estimated from the HFC data, during the ascent and descent of the rocket are shown in Figures 1 and 2. It should be noted here that the rocket was launched at a time when the network of ground experiments indicated possible development of plasma bubble events, and as can be seen from the Figures 1 and 2, the rocket indeed passed through a series of plasma bubbles of varying amplitudes during the ascent and descent of the rocket. Also shown in these figures are the amplitudes of the electron density fluctuations as observed by the LP experiment and of the electric field (horizontal) fluctuations as observed by the E-Field double probe.

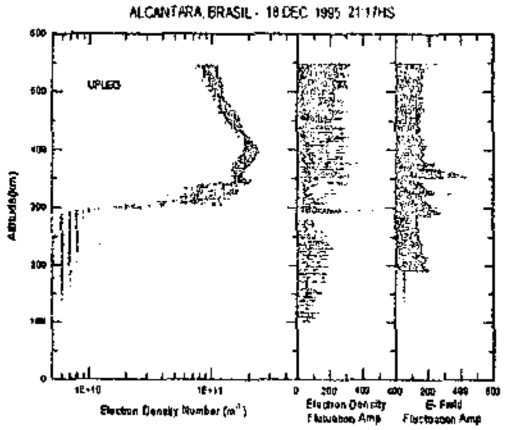

Figure 1.: Electron density height profile estimated from the HFC experiment for the upleg of the rocket. Also shown in the figure are the fluctuations (relative scale) in electron density and the electric field measured by the E-Field double probe.

It should be noted here that the E-Filed double probe measurements are modulated by the rocket spin and precession and there exists large base level noise in the fluctuation amplitude indicated. This base level noise can be removed by passing the E-field fluctuation data through appropriate band pass filters. However the existence of fluctuations with amplitudes higher than the base level noise can be clearly seen in the figures 1 and 2, and these are to be associated with the electron density structures shown in these figures.

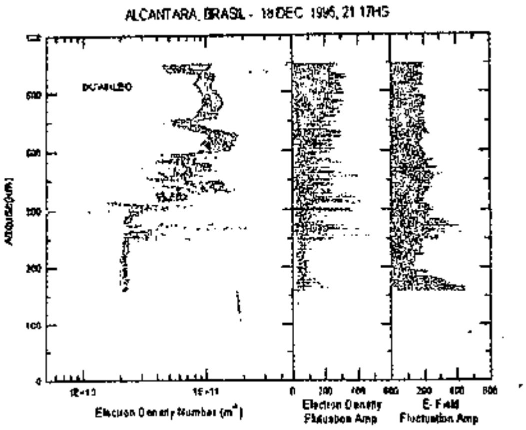

Figure 2.: Electron density height profile estimated from the LP current variation for the downleg of the rocket. Also shown in the figure are the fluctuations (relative scale) electron density and the electric field measured by the E-Field double probe.

The bubble structures seen in the upleg profile shown in Figure 1. are rather weak and confined mainly to the bottom side of the F-layer, while Those seen in the downleg profile are comparatively higher in amplitude and are seen both on the bottom side and the topside of the F-layer.. The electron density profiles obtained with the LP experiment also were very much similar to the HFC profiles. However the LP experiment can measure the ac fluctuations in the electron density up to a frequency of about 625Hz that represents an irregularity wavelength of about 3,2m in a height region where the rocket velocity is about 2km per second. Thus close to the region of apogee where the vertical component of the rocket velocity is very small the lowest irregularity scale size that can be measured with the LP goes down to practically zero. The HFC data does not permit the measurement of fast fluctuations in the electron density. Since the time duration needed to obtain one measurement with the HFC experiment is about 120ms, the distance between data points in a height region where the rocket velocity is about 2km/sec. is roughly 240m, or in other words the minimum scale size of irregularities that can be measured with HFC in this height region is about 480m. In addition to this there exist .other basic differences in the height profiles of electron density provided by the LP and HFC experiments, that are discussed in detail by Muralikrishna and Abdu (1991) and will not be presented or discussed here.

Observations such as the presence of a weak E-layer and a valley above it, are features that have been observed earlier from both rocket-borne and ground based experiments (see Prakash et al., 1970); and are considered to be characteristic features of the nighttime lower ionosphere. However, they are neither completely understood on theoretical basis, nor the existing models explain their presence. Prakash et al., (1970) discuss the possibility of wind shear mechanism to be responsible for the generation of some of the large scale structures observed in the E-region. The descent profile shown in figure 3 indicates the presence of an additional electron density peak in the height region of about 260km. This is a rather unusual phenomenon and further detailed analysis of the data has to be carried out before anything plausible can be told about this additional peak.

Observation of bubble structures in the nighttime ionosphere is rather a familiar feature. The generation of large scale plasma irregularities by the mechanism of cross-field instability is now reasonably well understood (Reid, 1968; Tsuda et al., 1969). A necessary condition for the mechanism to operate is that there should exist an electron density gradient in the direction of the ambient electric field. In the nighttime ionosphere the Hall polarization electric field is generally downwards and so the height regions favorable for the operation of the C-F instability mechanism are those where the ambient electron density gradients are downwards. Presence of large bubble structures in the bottom side F-region where the E-field is supposed to be downwards and the electron density gradient is upwards cannot be attributed to the operation of the cross-field instability mechanism. However, small scale plasma irregularities can be generated in the region of downward electron density gradients associated with the large scale bubbles.. In spite of the large horizontal separation between the region traversed by the rocket during the upleg and downleg, that ranges from about 320km at an altitude of 400km to about 550km at an altitude of 100km. similarities in the bubble features that can be seen from the figures 2 and 3, indicate the large east-west horizontal extent of these plasma bubbles, namely several hundreds of kilometers.

## CONCLUSIONS

Electron density height profiles estimated from the current collected by a spherical LP sensor and an HFC experiment show the presence of several plasma bubbles of varying spatial dimensions at different height regions especially in the rocket downleg profile. The generation of large scale plasma structures in the bottom side of the F-region cannot be explained by the cross-field instability mechanism that needs the vertical electric field and the electron density gradient to be in the same direction. Observation of an additional plasma density layer in the height region of about 260km lacks any direct explanation, and further detailed analysis of the data has to be carried out. Bubble regions are associated with both electron density and electric field fluctuations. Spectral analysis of the ac data is being under taken, and is expected to give valuable information about the plasma instability mechanisms operating, among which the cross-field instability mechanism seems to be a definite one confirming the earlier observations.

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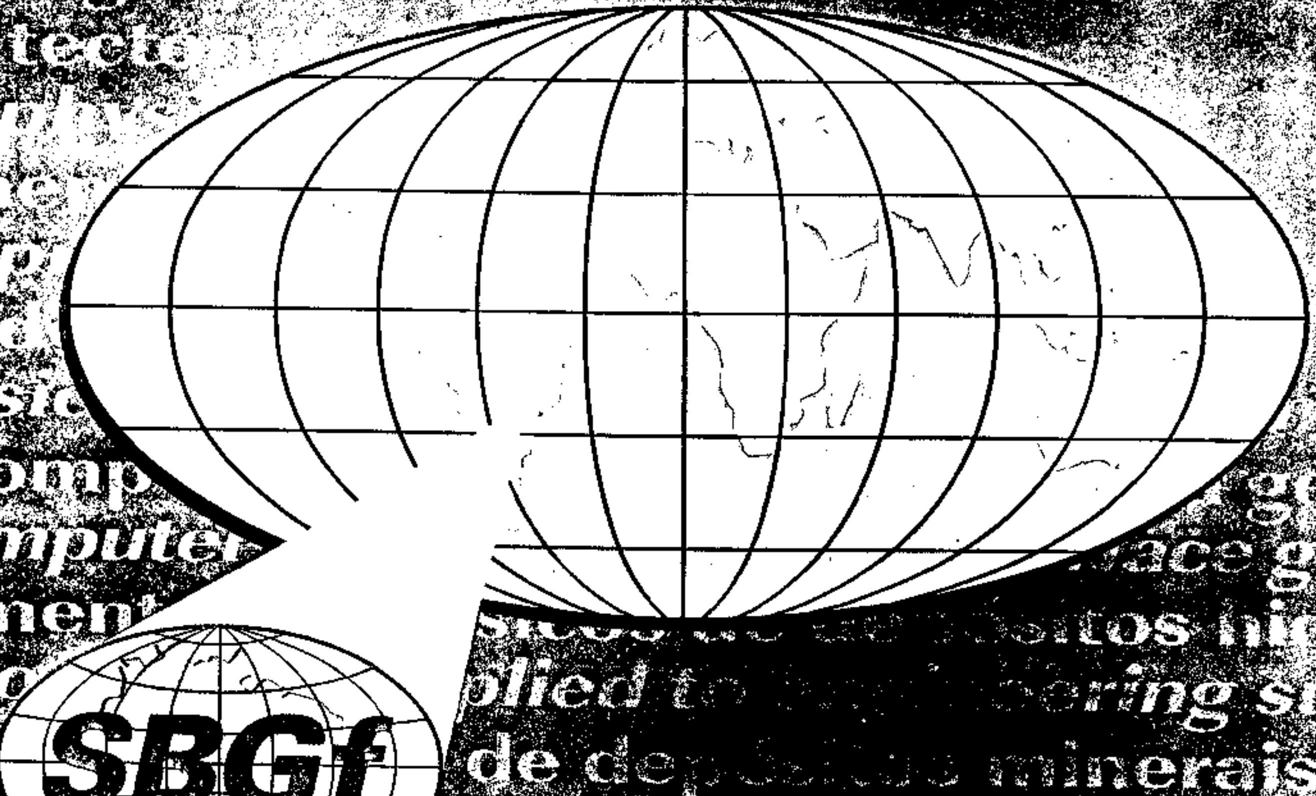

## RESUMOS EXPANDIDOS

## *EXPANDED ABSTRACTS*

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