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Spectra of Electron Density and Electric Field Irregularities in the Nightime Ionosphere over Brazil

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Abstract

Some new results obtained from in-situ measurements of the height variation of the ionospheric electron density and electric field made with rocket-borne probes during a campaign conducted from Alcantara (2.31^{o}S; 35.2^{o}W) in Brazil are presented here. The rocket campaign 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.. During this campaign a Brazilian made SONDA III rocket was launched on 18-th December, 1995 at 2117 hrs (LT) from the equatorial rocket launching station, Alcantara in Brazil.. The rocket reached an apogee altitude of 557km and covered a horizontal range of 589km. The payload consisted of an Electric Field Double Probe (EFP), a Langmuir Probe (LP) and a High Frequency Capacitance probe (HFC) In-situ measurements of the height variation of the ionospheric electron density and the horizontal electric field variations were made with the probes. 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 electron density probes detected the presence of a wide spectrum of electron density irregularities.Some new features observed in the k-spectra of the electron density and electric field variations are presented and discussed here.

INTRODUCTION

The main scientific objective of the campaign conducted from Alcantara (2.31^{o}S; 35.2^{o}W) in Brazil was to measure the characteristic features of the electric field and electron density fluctuations and to study the spectral distribution of plasma irregularities associated with what are known as ionospheric plasma bubbles.. Plasma bubbles, flux tubes of depleted plasma density, observed frequently in the equatorial nighttime ionosphere have been the subject of active investigation in the last couple of decades(see Abdu et al, 1991 and references therein). These bubbles are characterised by scale lengths of thousands of kilometers along the geomagnetic field lines and tens to hundreds of kilometers perpendicular to the field lines. Their generation through the Rayleigh-Taylor (R-T) gravitational instability process and subsequent cascading, by secondary processes, into a heirarchy of irregularities was suggested by Haerendal (1974).

An electric field double probe (EFP) was used 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. Two electron density probes were also launched along with the EFP. One of them, namely the high frequency capacitance probe (HFC) measured the absolute value of the slow varying component of the electron density while the other one, namely a Langmuir Probe (LP) measured the relative variation of the electron density including the small scale fluctuations in it. One could also measure the kinetic temperature of the electrons by operating the LP in a slow sweep mode. 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 spherical sensors of LP and HFC had diameters of about 60mm and were mounted at the extremities of two short booms of about 50cm in length that remained folded inside the rocket nosecone. These booms were deployed along with the EFP booms soon after the ejection of the rocket nosecone.. A sweep 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.

RESULTS AND DISCUSSION

During the IONEX-II campaign noted here that the rocket was launched at a time when the network of ground experiments indicated possible development of plasma bubble events. The rocket trajectory is given in figure 1. Given also in figure 1 is the estimated velocity of the rocket during the upleg and downleg. The trajectory and the rocket velocity data are used to associate the observed temporal fluctuations in the electron density and the electric field (approximately horizontal) to obtain corresponding spatial fluctuations.

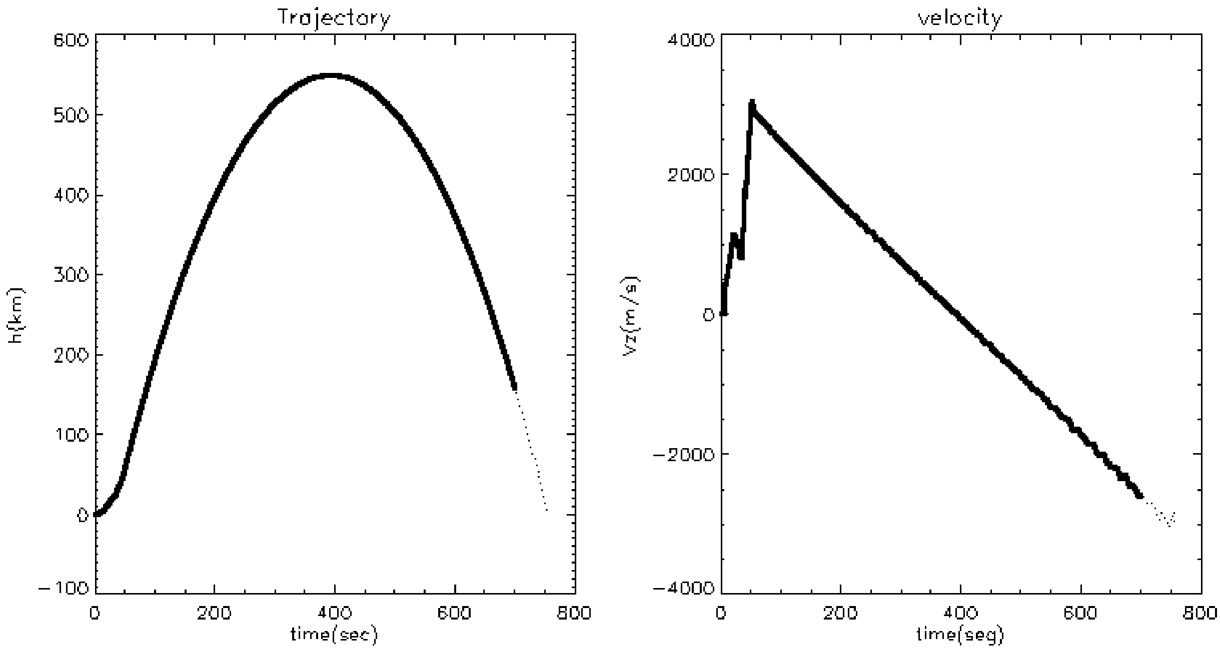

Figure 1 - Rocket height and vertical velocity versus time after launch.

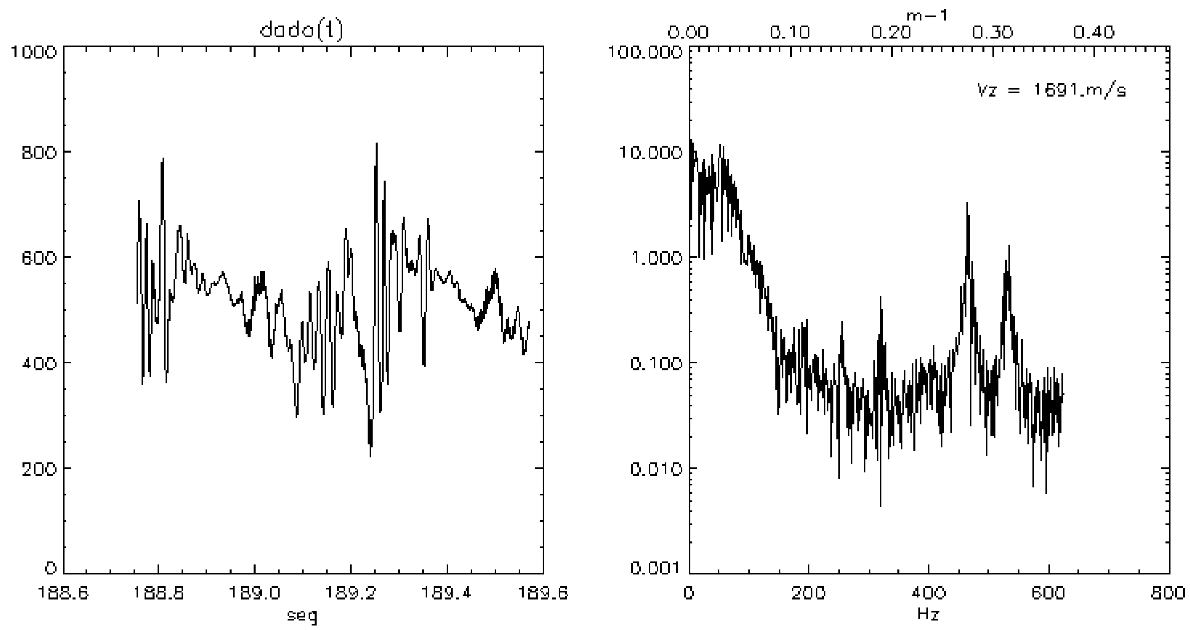

Figure 2 - A segment of electric field fluctuation data observed between 188.6 and 189.6 seconds after launch (left) and the frequency spectrum of the same (right). The mean rocket velocity here is 1691m/s

The rocket indeed passed through a series of plasma bubbles of varying amplitudes during the ascent and descent of the rocket. Rather weak bubble structures were seen in the upleg profile and were confined mainly to the bottom side of the F-layer, while those seen in the downleg profile were comparatively higher in amplitude and were seen both on the bottom side and the topside of the F-layer.. The electron density profiles obtained with the LP and HFC profiles were very much similar. However the LP and EFP experiments could 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. 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.

The spectra electric field fluctuations estimated from the EFP for the whole flight is shown in figure 3. One can see from this figure that there are two dominant frequencies observed in the F-region altitudes as indicated by the long dark traces seen in the upper part of the figure 3.

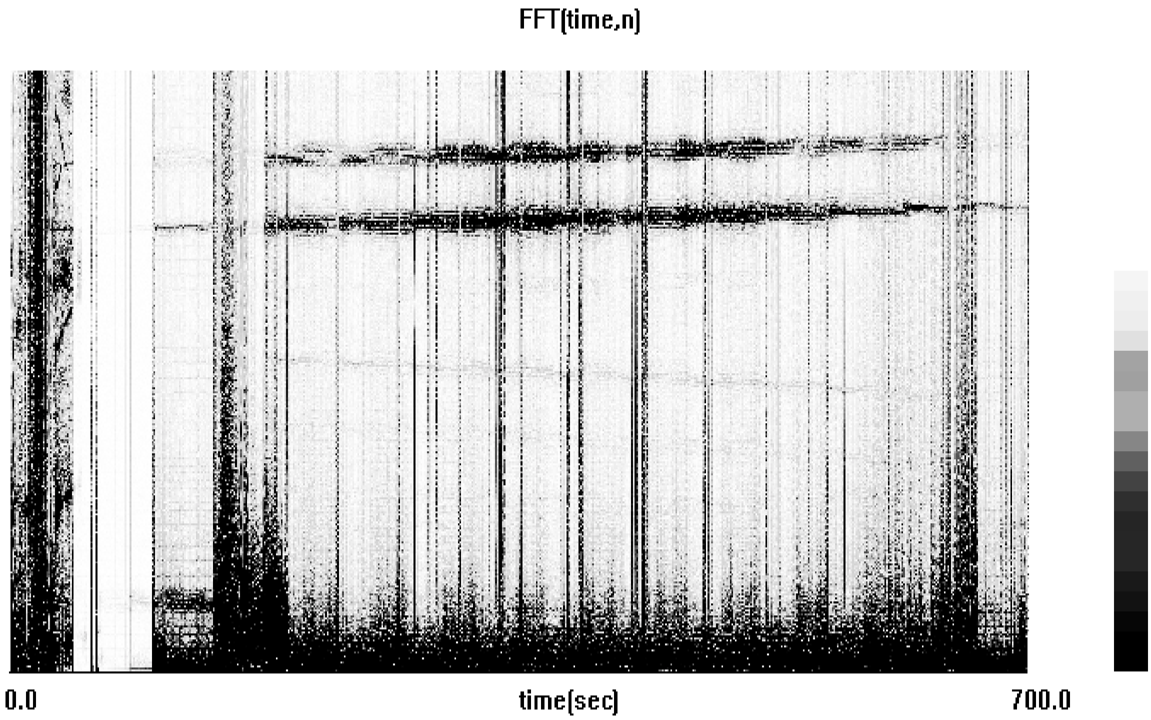

Figure 3 - Gray scale spectra of electric field fluctuations as a function of the time after launch. The vertical axis indicates the spectral frequency and the gray level the spectral amplitude.

It should be noted here that the spectral features of the electron density fluctuations are also very much similar to those of the electric field fluctuations shown in the figures 2 and 3.it. This indicates that there exists a close correlation between the fluctuations in the electron density and the horizontal electric field. Also the appearace of sharp spectral lines as indicated by the narrow and almost continuous traces in the spectra shown in figure 3 indicates that the k-spectra of irregularities is not a flat one as is expected from the existing theories on the production of plasma irregularities. The development phase of the plasma bubbles seem to be associated with sharp spectral lines. As the bubble develops these sharp lines may disappear by transfering their energy to smaller scale size irregularities.

CONCLUSIONS

The study reported here leads us to the following conclusions:

1. Equatorial plasma bubbles are associated with electron density and electric field irregularities, especially in the upper F-region altitudes
2. Spectral features of the electron density and electric field irregularities indicate the presence of sharp lines, contrary to what is expected from the existing theories on the formation of plasma irregularities by cascading processes

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