SPECTRAL DISTRIBUTION OF SMALL SCALE ELECTRON DENSITY IRREGULARITIES ASSOCIATED WITH EQUATORIAL F-REGION PLASMA BUBBLES

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Abstract: Spectral distribution of small scale electron density irregularities associated with equatorial F-region plasma bubbles is estimated from fluctuations in the amplitude of the current collected by a rocket-borne Langmuir Probe launched from the Brazilian rocket launching station in Natal. The SONDA III rocket, carrying a High Frequency Capacitance Probe (HFC) and two airglow photometers in addition to a swept voltage Langmuir Probe, was launched into an ionosphere marked by a developing plasma bubble event at 2030hrs local time on December 11, 1985. The electron density profile estimated from the LP and HFC data clearly shows the presence of two large plasma depletions or bubbles in the topside F-region centered at 370km and 430km. FFT anlysis of the LP current fluctuations in the frequency range of approximetely 50Hz to 800Hz provided information on the spectral distribution of small scale electron density irreguarities along the rocket trajectory. Small scale irregularities are observed inside the plasma bubbles in regions of downward electron density gradient indicating their possible generation by the well known cross-field instability mechanism. A brief study of the spectral features of these irregularities is reported in this paper.

INTRODUCTION

Plasma bubbles have been the subject of active investigation since their first identification from radar, rocket, satellite and optical measurements (see 1). They are known to have field line perpendicular scalelengths of tens to hundreds of kilometers which represent, in fact, the lower wave number limit of a large spectrum of irregularities, that could extend down to meter or even centimeter size irregularities. Haerendal(2) suggested the generation of plasma bubbles through the well known Rayleigh-Taylor gravitational instability process. The generation of small scale irregularities are attribuled to subsequent cascading and secondary processes. However, the roles of different instability mechanisms in the different scale size domains are not yet clearly understood.

In-situ observation of the plasma irregularities inside plasma bubbles, could indeed provide valuable information about the role of different plasma processes responsible for the generation of these irregularities.

A SONDA III rocket, carrying a swept voltage Langmuir probe (LP) and a dual frequency High Frequency Capacitance (HFC) probe along with other optical diagnostic payloads was launched into a nighttime equatorial ionosphere over Natal, Brazil, at 2030 Hrs (LT) on 11 Dec. 1985. The launch time was marked by a developing plasma bubble event, as evidenced by supporting ground based observations (1). The rocket reached an apogee altitude of 530 km, and during its ascent passed through at least two well developed large plasma bubbles above the F-peak, centered around the altitudes of 370 km and 430 km. Main results from this experiment on the spectral distribution of small scale plasma irregularities inside these large plasma bubbles are presented and discussed in this paper.

RESULTS AND DISCUSSION

Details on the experimental set up and reduction of LP and HFC data to obtain the electron density height profiles are discussed in (1). Information about the amplitude of plasma irregularities is obtained the following way. Fluctuations in the LP sensor current are separated using a high pass filter with 3db cut off frequency at about 10 Hz. Spectral Analysis of this signal is made using a 32 point FFT algorithm to obtain the relative power contained in the plasma density fluctuations in the scale length range of about 3m to more than 30m. The time interval between two consecutive spectra is 20ms corresponding to a spacial resolution of about 40m.

The upleg electron density profiles obtained from the Langmuir and the High Frequency Capacitance probes are shown in figure 1. Basic differences observed in the height profiles are discussed in detail in (1) and hence will not be discussed here.

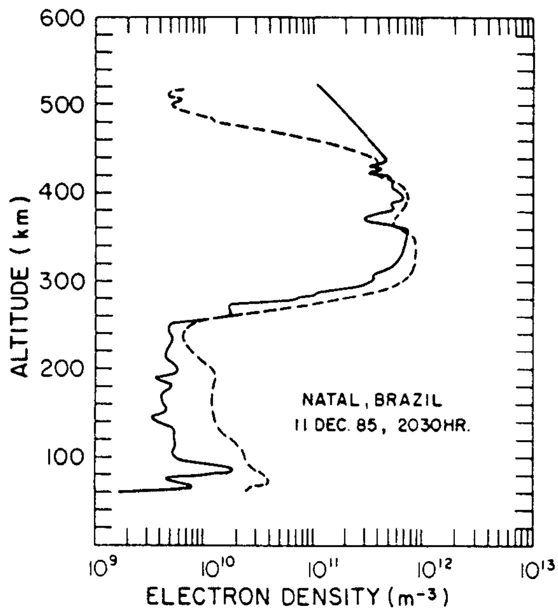

Figure 1

The upleg electron density profiles obtained by the Langmuir probe (dashed curve) and the High Frequency Capacitance probe (continuous curve) both showing the presence of at least two large plasma bubbles above the F-peak.

The presence of at least two large plasma bubbles centered around the altitudes of 370km and 430km can be seen in both the profiles. Height variation in the spectral distribution of small scale electron density irregularities in the height region of these two bubbles is shown in the sequence of selected power spectra displayed in figures 2 and 3. The height corresponding to each spectrum and the sensor potential applied are indicated in each spectrum. It should be noted here that the y-axis in the spectral plot is the square of the amplitude of the Fourier Transform and hence is a direct measure of the relative power contained in the irregularities of the particular scale size indicated along the x-axis of the spectral plots. A close look at the electron

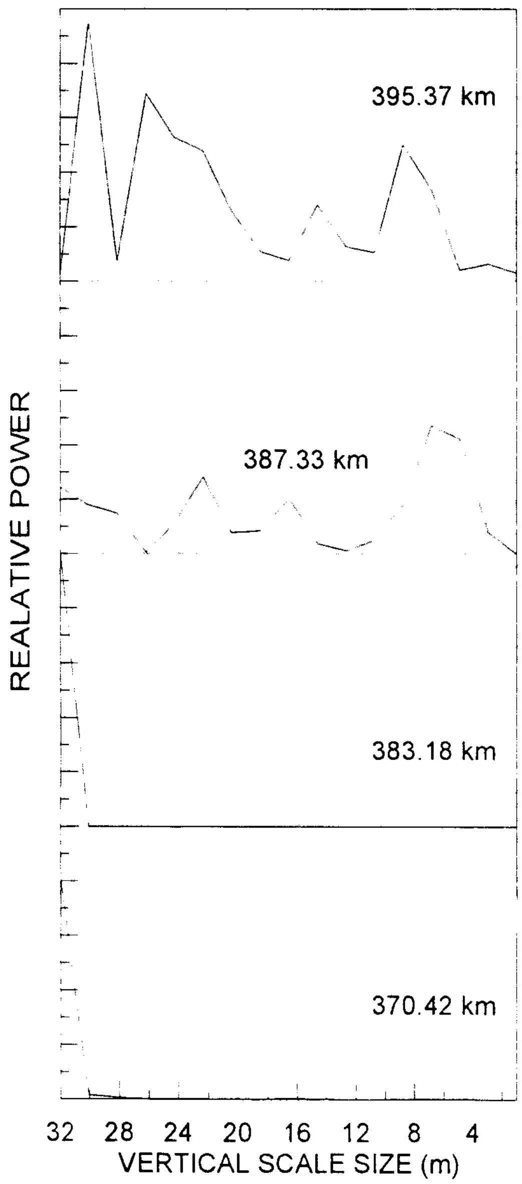

Figure 2

Power spectra of electron density fluctuations obtained by a 32 point FFT analysis of the LP data corresponding to four different height regions.

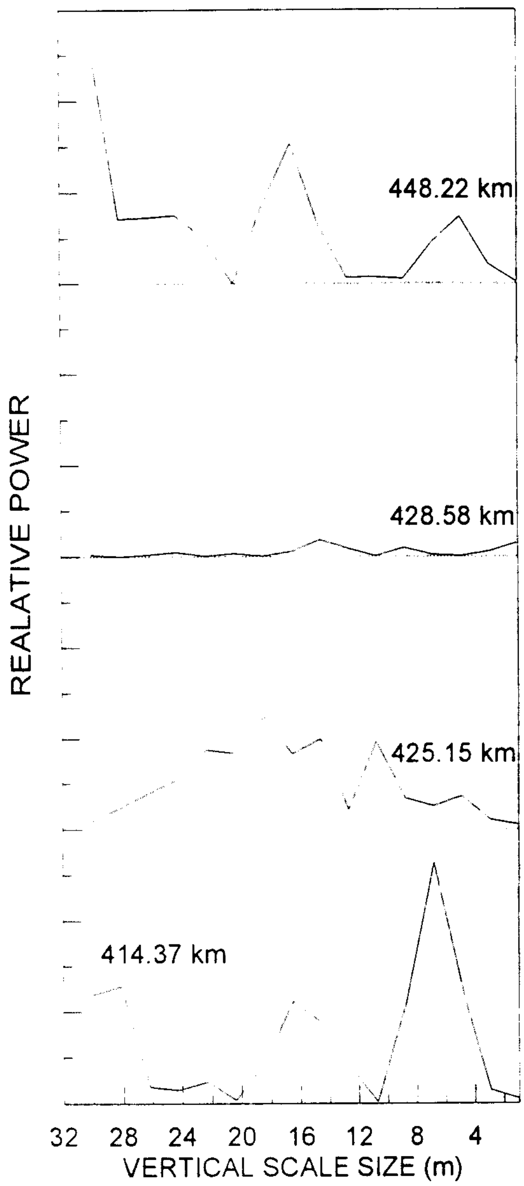

Figure 3

Power spectra of electron density fluctuations obtained by a 32 point FFT analysis of the LP data corresponding to four different height regions.

density profile given in figure 1 and the spectral plots given in figures 2 and 3 leads to the following important observations:

(1) Large scale plasma irregularities are present practically throughout the height region under consideration. The bubbles themselves are large scale irregularities and their generation is attributed to the well known mechanism of gravitational Rayleigh-Taylor instability (2).

(2) Inside as well as outside the bubbles, the small scale irregularities are confined mainly to regions of downward electron density gradients. Small scale irregularities are practically abscent in regions of upward electron density gradients.

The second observation, namely, the presence of small scale irregularities in the regions of downward electron density gradients, and their practical absence in the regions of upward gradients, is consistent with the hypothesis that these irregularities are generated by the well-known cross-field instability mechanism. This requires that the ambient electric field and the electron density gradient be in the same direction or in other words one needs downward electric field inside the plasma bubble in the region of downward electron density gradient. In fact the nighttime equatorial F-region is normally associated with downward polarisation electric field. This pefectly fits into the theory that these small scale irregularities are generated by the cross-field instability mechanism.

CONCLUSIONS

From the discussions presented here one can arrive at the following conclusions.

(1) The direction of the vertical polarisation electric field seems to be downward inside as well as outside the equatorial plasma bubbles producing small scale irregularities in regions of downward electron density gradients, suggesting their generation through the cross field instability mechanism.

(2) From the view point of the generation mechanism of small scale irregularities the presence of plasma bubbles results in the generation of regions of electron density gradients favourable for the generation of small scale irregularities. It does not apprently alter the direction of the ambient polarisation elctric field.

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