PLASMA BUBBLES AND EQUATORIAL SPREAD F IRREGULARITY STUDIES OVER BRAZIL

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ABSTRACT

For more than 20 years ionospheric studies have been conducted in Brazil, in order to understand the plasma bubble and spread F irregularity phenomena and their influence on radio-wave propagation. Most of the studies were carried out using ground-based equipments (ionosondes, polarimeters, scintillation measurements and photometers), operating in Cachoeira Paulista (22.5°S, 45°W), São José dos Campos (23°S, 46°W) and Fortaleza (4°S, 38°W). In situ measurements carried out using payloads on board of sounding rockets launched from Natal (5.9°S, 35.3°W) have also contributed to the study of the plasma bubble phenomena over Brazil. The equatorial spread F phenomena are often associated with plasma depleted magnetic flux tubes, namely, plasma bubbles. The plasma bubbles are generated over the equatorial F region through the Rayleigh-Taylor gravitational instability process. The enhanced post-sunset **ExB** drift is of prime importance on the generation of plasma bubbles and equatorial spread F irregularities. The magnetic declination angle over Brazil is very high (it attains a global maximum over Brazilian longitude sector). The observational studies and theoretical simulations conducted in Brazil have shown that the very high magnetic declination angle greatly affects the seasonal distribution of spread F occurrence. In this paper, all these observational aspects as well as the simulations conducted to explain them, are reviewed.

INTRODUCTION

The plasma bubble phenomena are regions of depleted plasma that occurs in the low and equatorial latitude nighttime ionospheric F-region. They are generated by plasma instability processes that set in under the ambient ionospheric conditions governed by sunset electrodynamics, the most obvious manifestation of which is the rapid vertical uplift of the F-layer. The primary instability is believed to be driven by the Rayleigh-Taylor (R-T) gravitational fluid instability process. The steeping density gradients that results from the primary instability mechanism then become unstable to secondary instability processes leading to the generation of smaller scale sizes in a hierarchy of irregularities. Basically, the thermospheric zonal wind that blows eastward across the sunset terminator is responsible for the F layer dynamo electric field. In the presence of a longitudinal gradient in the F-layer Pedersen conductivity, this results in the generation of eastward electric field which contributes to the vertical uplift of the layer and to the instability growth rate factor (γ).

GROUND BASED EQUIPMENTS

Plasma bubble manifest themselves in ionograms as diffuse echoes known as spread F. The ionosondes operating in Fortaleza (FZ) and Cachoeira Paulista (CP) have given a great contribution to the understanding of the plasma bubble morphology and spread F characteristics over the Brazilian region [1-13]. The analysis of simultaneous data from FZ and CP permitted the study of the plasma bubble vertical rise velocities [7], their seasonal and solar cycle dependences [5, 10] and the important aspect of the magnetic declination control of equatorial spread F and F region dynamo [2, 8, 9, 11, 13]. The spread F associated irregularities, once developed after sunset (1830-1930 LT) go through a statistical maximum during the premidnight hours (~22 LT) with a decay phase that could continue till sunrise (~6

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LT). The onset local times at locations away from the magnetic equator get later with increasing latitude due to the fact that the depleted flux tubes rising upward over the equator are responsible for extending the ESF belt to latitudes away from the equator in such a way that the width of the belt is defined by the flux tube extremities (feet)intersections with the low latitude F regions. This is also a reason for the statistical duration of the spread F over low latitude to be somewhat shorter than over the equator. Similar statistics should apply for VHF/UHF scintillations as well [14-17]. The use of spaced VHF receptor have allowed to infer the plasma bubble zonal velocities over low latitudes in Brazil [16,17].

Since 1981 scanning photometer data have been used to study ionospheric plasma bubbles. Their manifestation in the airglow measurements are depletions in 630 nm airglow profiles over CP [18-26]. They have been used as tracers of the zonal plasma drift velocities [18,24] and the results are comparable to the obtained by VHF polarimeters [24].

IN SITU MEASUREMENTS

In situ measurements of electron density height profile of the equatorial nighttime ionosphere, under a developing spread F event was carried out using a high frequency capacitance probe on board of a sounding rocket launch from Natal, Brazil [27]. During the upleg of the flight the experiment detected a series of plasma bubbles in varying degree of their growth phase. The launch criteria, based on ionosonde and scintillation data (no radar was available to the campaign), supported the view that the range type spread F, observed in the ionogram over low latitude, are indeed produced by flux tube aligned depletion that developed upward over the equator under the gravitational R-T instability mechanism. Another rocket experiment was conducted from Natal, this time to, inject chemical components in the bottomside equatorial F2 region, to create a hole in ionization [28]. The hole induced depletions were observed in total electron content (TEC) monitoring stations and in ionosondes located 300 km magnetically east of the chemical release point.

The satellite experiments give a worldwide coverage of plasma bubble and spread F irregularities occurrence. The results from the DE2 and AE satellite [29-31] gave information about zonal and vertical plasma drifts (electric fields) in the low latitude F region and its seasonal variation. The BSS (bottommside sinusoidal irregularities) have been identified in satellite measurements [32-34] and is believed to be correlated with the frequency type spread F seen in low latitude ionograms. The Japanese satellites have given a great contribution to the global studies of spread F and plasma bubble occurrence and characteristics [35-38].

MODELS

In order to explain the seasonal and longitudinal variation on spread F occurrence over Brazilian region, when compared with Jicamarca, Peru, a numerical model was developed [13]. That model took in account the effect of the magnetic declination over the F region dynamo development, that was essential to explain most of the peculiar features observed over the Brazilian region [13, 39, 40]. Although this model self-consistently solves the E and F region electrodynamics, their electron density profile (input) is a very simple Chapman layer and needs improvement.

CONCLUSIONS

The studies conducted so far have brought out a fairly good description of the morphology of the irregularities. Good progress has been achieved in our understanding of the seasonal/ longitudinal effects. There are strong indications that the day-to-day changes in the thermospheric wind (both magnitude and direction) could be the major key to explain the

ESF variability. Therefore, systematic and regular measurements should be carried out at key locations in the equatorial regions.

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