32nd URSI GASS, Montreal, 19-26 August 2017

What Controls the Evolution of the Rayleigh-Taylor Instability into Plasma Bubbles?

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Extended Abstract

Plasma bubbles in the nighttime equatorial ionosphere result from nonlinear evolution of the Rayleigh-Taylor instability. Whether the Rayleigh-Taylor instability excited in the bottomside F region can evolve into topside plasma bubbles depends on multiple factors. It is generally believed that the most important two factors are the vertical plasma drift in the postsunset sector and the seeding effect of atmospheric gravity waves or large-scale wave structures in plasma density. However, it is not well understood whether the generation of plasma bubbles requires a minimum vertical plasma drift, how the postsunset vertical plasma drift and the seeding process affect the generation of large-amplitude and small-amplitude ESF irregularities, and whether large-amplitude and small-amplitude ESF irregularities have the same occurrence patterns.

In this study, we use ion density data measured by the Communications/Navigation Outage Forecasting System (C/NOFS) satellite to derive the longitude-month distribution of ESF occurrence probability and ion drift velocity data to derive the longitude-month distribution of the postsunset vertical ion drift. Figures 1a, 1b and 1c show the vertical ion drift at the peak of the prereversal enhancement (PRE), the occurrence probability of small-scale ESF irregularities, and the occurrence probability of large-scale ESF irregularities, respectively.

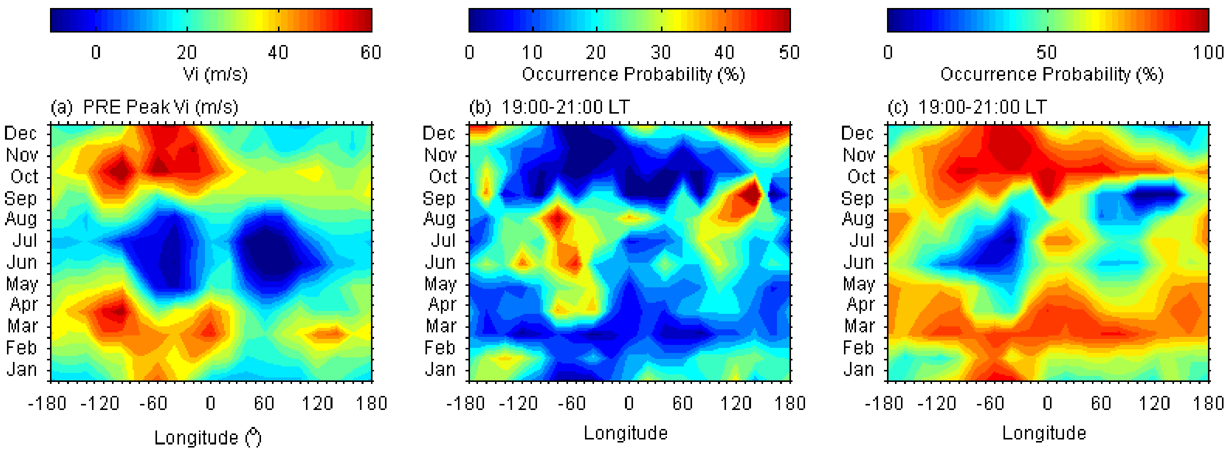

Figure 1. The longitude-month distributions of (a) the vertical ion drift at the PRE peak, (b) the occurrence probability of small-amplitude ESF irregularities with $\Delta N = 1\text{-}2\times10^{10}$ m^{-3}, and (c) the occurrence probability of large amplitude ESF irregularities with $\Delta N > 2\times10^{10}$ m^{-3} during moderate solar activity in 2011-2014.

A surprising phenomenon revealed in our study is the anti-correlation in the longitude-month distribution of the occurrence probability between small-amplitude and large-amplitude ESF irregularities, as shown in Figure 1. The occurrence probability of large-amplitude ESF irregularities is well correlated with the vertical ion drift at the PRE peak. The implication is that the postsunset vertical ion drift controls the generation of large-amplitude ESF irregularities. When ESF irregularities caused by the upward ion drift are generated, they grow into large-amplitude perturbations. Large-amplitude plasma density perturbations are associated with plasma bubbles. The upward plasma drift moves the F layer to higher altitudes and creates the condition for rapid growth of the Rayleigh-Taylor instability. The Rayleigh-Taylor instability evolves into plasma bubbles, resulting in the occurrence of large-amplitude plasma density perturbations.

In contrast, the occurrence probability of small-amplitude ESF irregularities shows a clear anti-correlation with that of large-amplitude ESF irregularities, is very low in these typical "spread-F seasons", and becomes higher around ±60° in June solstice. The anti-correlation between small-amplitude ESF irregularities and the PRE suggests that the generation of small-amplitude ESF irregularities may be related to seeding processes but are not caused by the PRE.