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Post-midnight equatorial irregularity distributions and vertical drift velocity variations during solstices

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Abstract

Longitudinal distributions of post-midnight equatorial ionospheric irregularity occurrences observed by ROCSAT-1 (1st satellite of the Republic of China) during moderate to high solar activity years in two solstices are studied with respect to the vertical drift velocity and density variations. The post-midnight irregularity distributions are found to be similar to the well-documented pre-midnight ones, but are different from some published distributions taken during solar minimum years. Even though the post-midnight ionosphere is sinking in general, longitudes of frequent positive vertical drift and high density seems to coincide with the longitudes of high irregularity occurrences. Large scatters found in the vertical drift velocity and density around the dip equator in different ROCSAT-1 orbits indicate the existence of large and frequent variations in the vertical drift velocity and density that seem to be able to provide sufficient perturbations for the Rayleigh-Taylor (RT) instability to cause the irregularity occurrences. The need of seeding agents such as gravity waves from atmospheric convective clouds to initiate the Rayleigh-Taylor instability may not be necessary.

Keywords: Post-midnight irregularity distributions; Post-midnight vertical drift velocity and density distributions

1. Introduction

The high vertical drift velocity in the pre-reversal enhancement (PRE) of post-sunset equatorial ionosphere will lift the ionosphere high enough to accelerate the growth rate of the Rayleigh-Taylor (RT) instability if triggered. The resultant ionospheric irregularity structure has manifested as the equatorial plasma bubble (EPB), equatorial spread-F event (ESF), or simply named as the density irregularities. The seasonal/longitudinal (s/l) distributions of these irregularity occurrences have been well documented in the literature (Basu et al., 1976; Aarons, 1982, 1993; Maruyama and Maturra, 1984; Tsunoda, 1985; Watanabe and Oya, 1986; Kil and Heelis, 1998; McClure et al., 1998; Huang et al., 2002; Burke et al., 2004; Hei et al., 2005; Su et al., 2006; Gentile et al., 2006; Stolle et al., 2006).

During the post-midnight period, the PRE effect has completely disappeared and the ionosphere is sinking in general. The growth rate of the RT instability becomes very small so that there should be no density irregularity occurrences observed. However, the experimental data indicate that the observations of such density irregularities during solar minimum years have been reported recently (Niranjan et al., 2003; Gentile et al., 2011; Dao et al., 2011; Yizengaw et al., 2013; Ajith et al., 2015). Although the longitudinal distribution of the reported post-

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midnight irregularities seems different from the well-known post-sunset ones, the occurrence condition of post-midnight irregularity structure is still closely related to the upward drift velocities (Gentile et al., 2011; Yizengaw et al., 2013). Here in this report we will examine the longitudinal distribution of post-midnight irregularity occurrences using the ROCSAT-1 (or simply ROCSAT) data taken during moderate to high solar activity years of 1999–2004 to compare with the published results taken during low solar activity period. The differences in the longitudinal distributions of post-midnight irregularity occurrences between high and low solar activity years could add to the understanding of irregularity occurrence mechanism and morphology.

Two solstice seasons are chosen for the study as irregularity occurrences have been shown to have strong occurrence patterns in the longitudinal distribution in the post-sunset period. Whether the characteristics of such high contrast in the post-sunset irregularity occurrence pattern still exist in the post-midnight period is the goal of current study. In addition, correlation study of longitudinal irregularity distribution with the vertical drift velocity and density will also be carried out to see if similar ionospheric condition exists for the irregularity occurrences in the post-sunset and post-midnight periods.

2. Post-midnight equatorial irregularity distributions during solstices

The ROCSAT observed density irregularity occurrence distributions at 600-km altitude in the post-midnight 02–06 LT sector during magnetic quiettimes ($K_p < 3$) are shown in Fig. 1. Method of identifying density irregularity structures has been given in a previous report (Su et al., 2006), and is recapitulate here. A 10-s data segment (320 points) of density in logarithmic scale is calculated for the density fluctuation value σ after the data segment is linearly detrend,

$$\sigma = \frac{\left[\frac{1}{10}\sum_{i=1}^{10}(\log n_i - \log n_{oi})^2\right]^{1/2}}{\frac{1}{10}\sum_{i=1}^{10}\log n_{oi}}, \quad (1)$$

where n_i and n_{oi} are the measured ion density and the linearly fitted value at the ith data point, respectively. We set $\sigma \geq 0.3\%$ to identity the density irregularity structure having scale length between 7.5 km and 75 km. The density irregularity structure found by this identifying method will include the initial growing plasma bubbles as well as the remnants of the decayed bubbles.

Fig. 1 shows the irregularity distribution for June solstice in the top panel, and for December solstice in the bottom panel during the post-midnight period. To emphasize the locations of irregularity occurrences with respect to the dip equator, three red dashed lines are drawn in each panel to indicate the dip equator and ±15° in dip latitude. The spatial resolution of irregularity occurrences is 1° by 1° in geographic longitude and latitude.

We first notice that the longitudinal distribution of irregularity occurrences in both solstices seem familiar as they resemble closely to the well-known post-sunset ones published in the literature (see e.g., Su et al., 2006). For June solstice, the post-sunset distribution the highest occurrence appears at African sector (longitude 0° to 60°) and the second one is around the central Pacific region (longitude 140° to 230°(−130°)). Longitudes of the highest irregularity occurrence during December solstice appears at South American coastal area and across the Atlantic Ocean to the African continent (longitude −50° to 10°). Furthermore, we also notice that many mid-latitude irregularities have appeared in the longitude sector from 100° to 150°

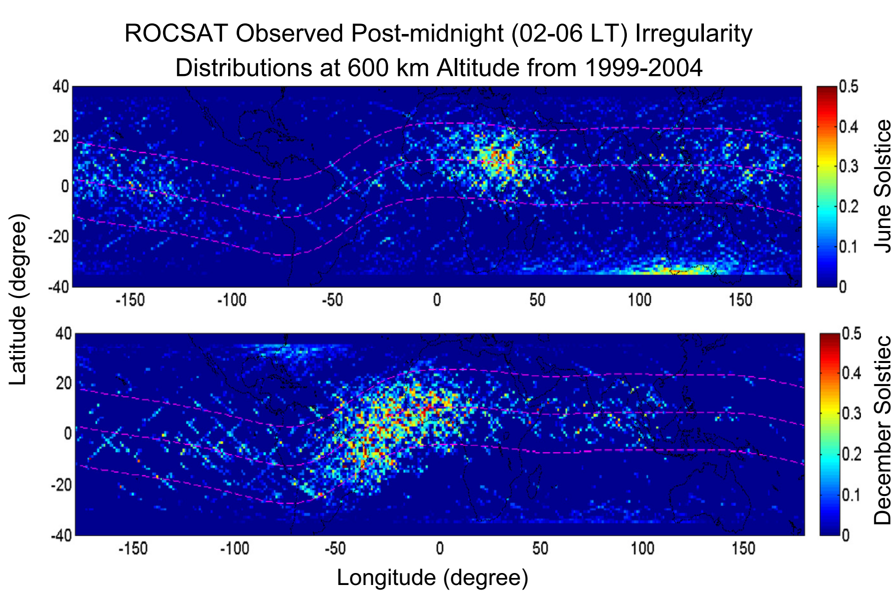

Fig. 1. Global longitudinal distributions of density irregularity occurrences during solstice observed by ROCSAT in the 02–06 LT sectors for two solstices from 1999 to 2004. The dotted lines in each panel indicate the dip equator and ±15° in dip latitude.