Characterization of VHF radar observations associated with equatorial Spread F by narrow-band optical measurements

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Abstract. The VHF radars have been extensively used to investigate the structures and dynamics of equatorial Spread F (ESF) irregularities. However, unambiguous identification of the nature of the structures in terms of plasma depletion or enhancement requires another technique, as the return echo measured by VHF radar is proportional to the square of the electron density fluctuations. In order to address this issue, co-ordinated radar backscatter and thermospheric airglow intensity measurements were carried out during March 2003 from the MST radar site at Gadanki. Temporal variations of 630.0-nm and 777.4-nm emission intensities reveal small-scale (“micro”) and large-scale (“macro”) variations during the period of observation. The micro variations are absent on non-ESF nights while the macro variations are present on both ESF and non-ESF nights. In addition to the well-known anti-correlation between the base height of the F-region and the nocturnal variation of thermospheric airglow intensities, the variation of the base height of the F-layer, on occasion, is found to manifest as a bottomside wave-like structure, as seen by VHF radar on an ESF night. The micro variations in the airglow intensities are associated with large-scale irregular plasma structures and found to be in correspondence with the “plume” structures obtained by VHF radar. In addition to the commonly observed depletions with upward movement, the observation unequivocally reveals the presence of plasma enhancements which move downwards. The observation of enhancement in 777.4-nm airglow intensity, which is characterized as plasma enhancement, provides an experimental verification of the earlier prediction based on numerical modeling studies.

Key words. Airglow and aurora; equatorial ionosphere; ionospheric irregularities

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1 Introduction

The structures and dynamics of equatorial Spread F (ESF) irregularities have been investigated with VHF backscatter radar which is one of the powerful tools to simultaneously observe the bottomside and topside ionospheric irregularities. Many observations from various longitudinal sectors (Tsunoda, 1980; Patra et al., 1995) have been reported ever since the first backscatter radar observation was reported by Woodman and La Hoz (1976). In order to understand different aspects of ESF, a number of co-ordinated measurements have been carried out by different workers (Suszsezewicz et al., 1980; Kelley et al., 1986; Raghavarao et al., 1987; Sridharan et al., 1997). Plasma irregularities associated with equatorial Spread F manifest themselves in a variety of forms on VHF radar maps ranging from rising plumes and multiple plumes to ESF structures confined to the bottomside of the ionosphere. A few meter scale size irregularities are generally responsible for the back scatter echoes recorded by the VHF radar. The causative mechanism for the ESF irregularities in the scale sizes of 1–10 m is not yet comprehensively understood (Huba and Ossakow, 1979). However, co-ordinated measurements (Suszsezewicz et al., 1980; Kelley et al., 1986) have revealed that the plume structures as observed by the VHF radar are the manifestations of large-scale plasma bubbles generated by the action of collisional Rayleigh-Taylor (CRT) instability (Haerendel, 1974) and associated nonlinear processes (Ossakow, 1981; Sekar et al., 1994). The multiple plume structures are generated by CRT instability seeded by spatially varying electric fields associated with gravity waves (Huang and Kelley, 1996). The confinement of ESF structures to the bottomside of the ionosphere was shown (Sekar and Kelley, 1998) to be due to the combined action of vertical shear in zonal plasma drift and westward electric field associated with a particular temporal pattern of the zonal electric field. Thus, the VHF radar echoes have been used to interpret the physical processes...