Journal of Atmospheric and Solar-Terrestrial Physics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Simultaneous optical measurements of equatorial plasma bubble (EPB) from Kolhapur (16.8°N, 74.2°E) and Gadanki (13.5°N, 79.2°E)

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ARTICLE INFO

Article history:
Received 23 January 2014
Received in revised form
21 April 2014
Accepted 2 May 2014

Keywords:
Ionosphere
Spread-F
EPB
Plasma drift

ABSTRACT

In this paper, we study the Equatorial Plasma Bubble (EPB) features using All sky imager (ASI) observations of O(^{1}D) 630.0 nm night airglow emission from Kolhapur (16.8°N, 74.2°E, 10.6°N dip lat.) and Gadanki (13.5°N, 79.2°E, 6.5°N dip lat.) during March 2012. The optical data was supported by the ionosonde measurements from Tirunelveli (8.7°N, 77.8°E, 0.5°N dip lat.) which revealed the occurrence of equatorial spread-F. The EPBs were monitored at both locations as nearly north–south aligned intensity depleted regions. We computed east–west plasma drift velocity over Kolhapur and Gadanki for the nights having coordinated measurements. Also, the observed plasma bubble drift velocities are compared with the zonal neutral wind velocities obtained from the HWM-07 model and the empirical drift model of England and Immel (2012). We observed that, generally, the mean zonal drift velocities of the plasma bubbles tend to decrease with local time (after midnight). Our results reveal the drift velocity noted in Kolhapur data varies from 124 m/s to 181.8 m/s, while from the Gadanki data show the drift velocity to range from 116.3 m/s to 160.3 m/s.

1. Introduction

The equatorial spread-F (ESF) is a major nighttime phenomena occurring at low- and equatorial ionosphere. The optical signatures of the ESF are often named as equatorial plasma bubble (EPB or the equatorial plasma depletion (EPD). The irregularities associated with them are responsible for severe interference and sudden disruption in trans-ionospheric radio propagation in Giga Hertz frequency range, and thus affects the navigation and communication systems. Weber et al. (1978) were first to observe the magnetically North–South aligned structures of low-intensity regions in the OI 630.0 nm airglow images during the period of spread-F observations. It is now well appreciated that these low-intensity regions are the optical signatures of depletions in the electron densities, which are mapped in the all-sky images of OI 630.0, 557.7 nm and 777.4 nm emissions (e.g., Pimenta et al., 2003).

According to the present knowledge, EPBs are initiated at the bottom side of the F-region through the generalized Rayleigh–Taylor (RT) instability (Herrero et al., 1993; Prakash, 1999; Kelley, 1989). The RT instability gets the required seed perturbations by the means of gravity waves, vertical winds and electric fields (Sahai et al., 1994; Sinha and Raizada, 2000; Weber et al., 1980; Biondi et al., 1988; Taori et al., 2011, 2012; Dashora et al., 2012). Thus, it is the RT instability which is responsible for the formation of narrow channels of deep plasma bites out in the nighttime equatorial ionosphere, noted in the optical data as EPBs (e.g., Kelley et al., 1981). While the premises of RT instability satisfy most of the observed features, investigations should be continued for a better understanding of the day-to-day variability of the EPB phenomenon.

Observations of plasma drifts in the equatorial region have been widely studied using satellite and ground-based techniques. Several researchers have conducted observations of 630.0 nm, 777.4 nm, and 557.7 nm airglow emissions using all-sky imager (ASI) to study the EPBs (Sales et al., 1996; Weber et al., 1996; Fagundes et al., 1997; Garcia et al., 1997; Kelly et al., 2000; Sahai et al., 2000; Sinha et al., 2003; Shiokawa et al., 2004; Mendillo et al., 1997, 2005, Mukherjee et al., 1998, 2008; Taori et al., 2013, Taori and Sindhya, 2014). These studies invariably report that the EPBs extend from equatorial regions to the low latitudes. The scale size of the irregularities varies from few tens of centimeters to few hundreds of kilometers, which are sensitive to a wide range of diagnostic techniques (Abdu, 1993). With regard to the simultaneous multi-location studies, Martinis et al. (2003) used observations from two locations in South America to study the changes in drift velocity of plasma depletions as a function of both latitude and local time (LT). They used a coupled model to show that a

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http://dx.doi.org/10.1016/j.jastp.2014.05.008
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combination of Pedersen conductivities and the zonal neutral winds were needed to explain the observed drift velocities during the early evening hours, whereas after ~22–23 LT the latitudinal dependence could be explained by the F-region winds alone which was substantiated by a recent investigation (e.g., Sobral et al., 2011).

In the present study, we use simultaneous all sky imager observations from Kolhapur and Gadanki stations during clear, moonless nights, and obtain the signatures of the plasma bubbles by studying the images at OI 630.0 nm emission. The observed drift velocity of EPBs and the noted differences are discussed together with a comparison with model values.

2. Instrumentation

2.1. All sky imager at Kolhapur

The all-sky imager operating at Kolhapur (16.5°N, 74.2°E, 10.6°N dip lat.) was procured from Keo-Scientific Limited, Canada. The imager is in regular operation from Kolhapur whenever the moonless clear nights are available. All Sky Imager (ASI) is being used to observe the atmospheric airglow features to study the ionospheric irregularities. The front-end optics collects the incoming radiation in 180° field of view with a (f/4 Mamiya RB67) fisheye lens that has a focal length of 24 mm and F-ratio of 4. The collected light beam is collimated by a telecentric plano convex lens combination to pass through a narrow-band filter with nearly perpendicular to incidence angles. The six filters are constructed up in the filter wheel to allow the transmission of OI 630.0 nm, OI 557.7 nm, 840.0 nm, 846.0 nm, and OH Meinel bands at 720.0–910.0 nm and the background at 857.0 nm. The integration times used in the present setup are 120 s, 120 s, 06 s, 06 s, 90 s and 10 s, respectively. The filtered collimated beam passes through a Canon camera lens (50 mm, f/0.95) mounted on to the CCD camera to make an image onto the CCD detector's plane. The detector in the CCD camera is a thermoelectrically cooled CCD (PIXIS 1024) to a temperature of −80° to reduce the thermal noise. The CCD chip has 1024×1024 pixel^2 of 24 μm. The filter wheel and camera

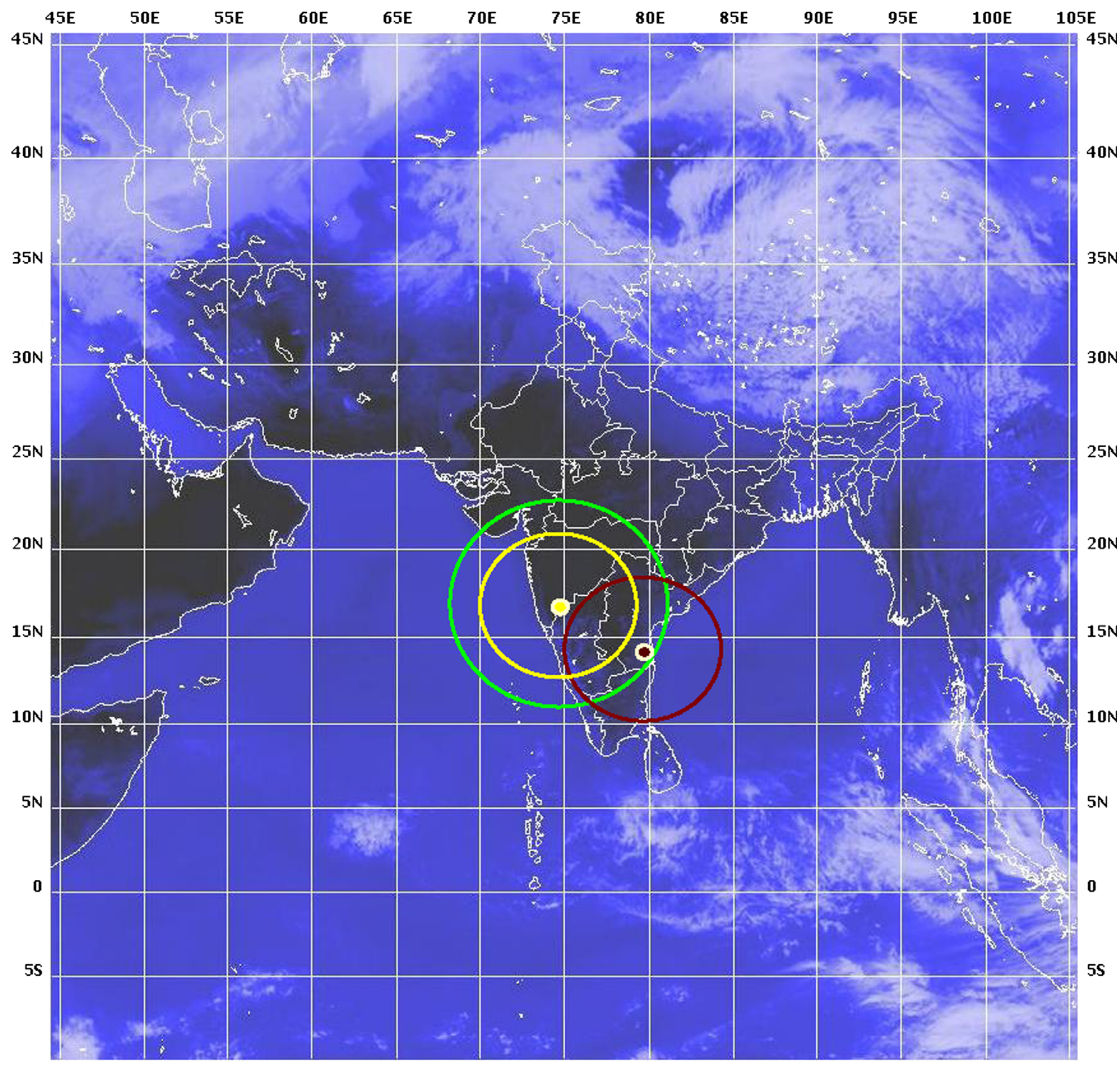

Fig. 1. High resolution infra-red image obtained from Kalpana satellite data on 17–18 March 2012. The location of airglow observation, Gadanki and Kolhapur are shown as filled red and yellow circle. The open red and yellow circles show the area covered by the imager field of view used in the present study at 250 km altitudes over Gadanki and Kolhapur stations, respectively. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)