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Intriguing aspects of low latitude night-time F region irregularities over East and South-East Asia

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Abstract

Generally, the occurrence of F region irregularities associated with Equatorial Plasma Bubbles is considered difficult to predict due to its day-to-day variability. Recent investigation shows that the dominant period of variability of EPB can be >25 days (quasi 27 day), presumably associated with solar rotation period. VHF scintillation recorded from Pingtung, Taiwan in 2015 indicated the co-existence of planetary scale variability (4-8 days), 10-15 days variability and quasi 27 day variability. Lomb-Scargle power spectrum of S4 time series indicated that the larger period variability (quasi 27 days) is much more dominant than the other scales (which includes day-to-day variability). Interestingly, the dominant period of S4 variability corresponded exactly with the dominant period of high-latitude geomagnetic variability. Continuous operation of Equatorial Atmosphere Radar (EAR) in 2012 also indicated similar observation. Dominant period of variability of EPB in EAR observations corresponded with the high-latitude geomagnetic variability. These observations reveal that EPB are controlled predominantly by geomagnetic activity through large period variability (quasi- 27 days).

1 Introduction

Day-to-day variability of equatorial plasma bubble (EPB) continues to be extensively investigated even after decades of its discovery not only due to scientific quest but also due to its detrimental effects on the navigation/communication systems. While it is possible to forecast the solar cycle and seasonal behavior of the EPB over different longitude sectors, understanding its intra-seasonal variability remains one of the most important aspects of the ionospheric research [1, 2, 3]. Not only the day-to-day variability of EPB is a concern, but it has been found to be impacted by planetary scale forcing [4, 5]. Investigations have revealed not only the EPB to display such effects but the background conditions impacting the Rayleigh-Taylor (RT) instability also display significant planetary scale variability. Investigations have revealed that the planetary scale waves influence the F region irregularities by modulating the height of the F layer [4] and also the conductivity of the E region [4, 5, 6]. Most of the investigations have focused on 3 to 7-day planetary scale variability in the EPB and associated F region irregularities, while the background ionosphere has been found to display 10 to 16 days variability also [7].

Geomagnetic storms and its impact on the ionospheric processes have been studied in details over the last several decades. Generation and also the suppression of the irregularities in the equatorial ionosphere have already been investigated. Prompt penetration of the interplanetary electric field and the disturbance dynamo are the important phenomena associated with the geomagnetic storm that plays an important role in the characteristics of the ionospheric irregularities in the equatorial ionosphere. However, the role of the geomagnetic activity in producing a periodic variability in the ionospheric irregularities has seldom been investigated before. Geomagnetic forcing is generally regarded intermittent in characteristics, active only for a brief period (few minutes to few hours) during intense geomagnetic storms. In the present investigation, the intra-seasonal variability of the ionospheric irregularities has been investigated based on the VHF scintillations observations recorded from Pingtung in Southern Taiwan and EPB observations recorded with Equatorial Atmosphere Radar (EAR) located at Kototabang, Indonesia. Emphasis has been given to study the intra-seasonal variability of the F region irregularities.

2 Data

In this investigation, VHF scintillations recorded at Pingtung (22.60N, 120.50E, Dip lat. 12.50) in southern Taiwan during January to December of 2015 have been used to infer the presence of the ionospheric irregularities. This VHF receiver was established in August 2014 and after testing, observations are being made beginning January 2015. The VHF receiver at Pingtung receives signals from a geostationary satellite transmitting in VHF band (244 MHz) and the setup is such that the ionospheric pierce point (IPP) at 350 km altitude lies over the China Sea Area (20.690N, 116.470E, Dip lat. 11.460). VHF signal intensity is recorded at a sampling rate of 50 Hz. Scintillation S4 index is calculated with every 60 seconds of data (3000 samples).

Equatorial Atmosphere Radar located at Kototabang, Indonesia is a coherent scatter radar operating at 47 MHz. Between 18 to 06 local time it is operated routinely in the F region mode to observe F region irregularities. The present study also utilized fixed radar beam observation of the EPB during 2012. Reasonably continuous observations (in 2012) have been used to examine the existence of planetary scale variability of the EPB. In addition to the EAR data, solar F10.7 cm flux data, geomagnetic AE, ap and kp indices data is utilized in the present study.

3 Results and Discussion

3.1 VHF Scintillation observations

Figure 1 shows the S4 index recorded at Pingtung during 10 to 22 UT in 2015. The local time at the IPP in China Sea area is UT + ~7:25 hours. Thus the observation presented in the figure corresponds to the dusk to dawn period. The S4 > 0.2 are mostly observed during the equinox months, which represents the EPB season. In the summer months (~day 160 to 240) S4 > 0.2 are seen during the midnight period (after 15 UT). In Figure 1, it is interesting to see that the occurrence of the VHF scintillations is quasi-periodic in days. White arrows in the figure indicate the clusters of EPB events. It can be clearly seen that the occurrence of EPB (scintillation event) is not random, but highly structured and periodic.

The Lomb-Scargle (LS) transformation of daily averaged S4 time-series has been carried out to derive spectrum of intra-seasonal periodicities. It has been found that the dominant period of S4 variability in vernal and autumnal equinox EPB seasons are 25 days and 28.5 days, respectively. LS spectra of Ap and AE geomagnetic indices also indicate exactly similar periodicities in them. F layer height in the post-sunset hours recorded by ionosonde located at Sanya also displayed similar period of variability. Details of this investigation have recently been made available in the literature [8].

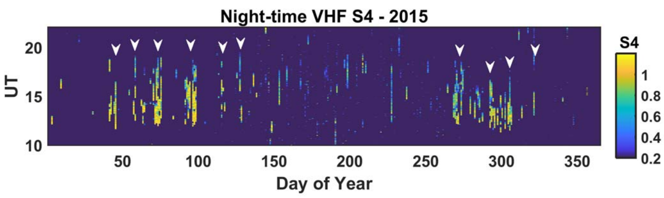

Figure 1. VHF S4 recorded at Pingtung, Taiwan in 2015 White arrows in this figure indicates the clusters of EPB event. Note that the occurrence of EPB is not random, but highly structured. Reader may refer to the published literature for more details [8]

3.2 EAR Observation of F region irregularity

Figure 2 presents SNR recorded by EAR in the autumnal equinox EPB season in 2012. Here, top, middle and bottom panels indicates SNR corresponding to backscattered echoes from 300, 400 and 500 km altitude, respectively. In the figure, grey color marks the gap in the data. Considering the complexity of the EAR system, data is quite continuous. However, one or two days of continuous data gap can be seen on few days. Despite these, it is possible to figure out intra-seasonal variabilities in the occurrence of EPB. For example, the echo SNR is generally higher on day numbers 240-247, 260-280 and 292-305 in comparison to the day numbers sandwiched between them. Thereafter, EPB activity can be seen on day number 325 which just remained an isolated occurrence. Possibly, by then the EPB season have ended. EPB generally display a higher occurrence during equinoctial months due to the alignment of the sunset terminator with the magnetic meridian.

LS spectral transformation of EAR echo SNR variability have also been carried out and compared with the periodicity of geomagnetic variability during that period. Interestingly, the dominant period of SNR variability displayed a remarkable similarity with dominant geomagnetic periodicity. A detailed manuscript describing all these results related to EAR and related observations is in preparation.

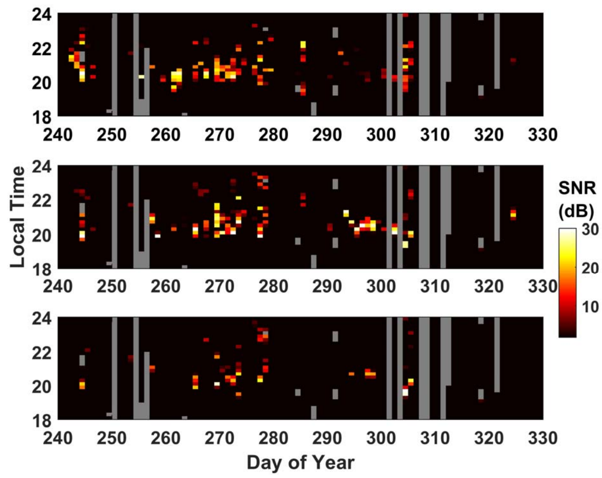

Figure 2. SNR variability in the autumnal equinox EPB season observed with EAR. Top, middle and lower panels indicate SNR of the echo received from 300, 400 and 500 km height, respectively. Intra-seasonal variability is clearly seen. Grey color indicate data gap.

4 Conclusions

Observations recorded over East Asian and South East Asian region indicate that the F region ionospheric irregularities display a range of intra-seasonal periodic variability. These include 3-7 day variability, 10-16 day variability and quasi 27 day variability. Frequency domain analysis shows that the higher period variability has a larger magnitude than the smaller period variability. Dominant period of quasi 27 day variability of ionospheric irregularities display a remarkable similarity with dominant period of geomagnetic variability. This further highlight that the possible impact of geomagnetic variability on the low latitude processes can be periodic in nature. Results also support a need for a better understanding of the periodic planetary scale and geomagnetic variability in the prediction models of the ionospheric irregularities/scintillations.

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