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Observations of the F3-layer at equatorial region during 2005

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Abstract

The existence of the F3-layer has been observed at Brazilian equatorial stations. This paper reports on a 1-year observations at Parit Raja, Malaysia (Lat. 1°52′N, Long. 103°48′E). The greatest number of appearances of the F3-layer is around local noon while the least is after local dawn. Its occurrence is more pronounced during winter and the equinoxes. The mean height of reflection for the layer is about 600 km reaching a maximum of about 900 km during the winter of 2004/2005. It is seen that the critical frequency of the F2-layer decreases with the appearance of the F3-layer.

Keywords: Equatorial ionosphere; F3-layer; Critical frequency; Virtual heights; Digisonde; Ionogram

1. Introduction

The ionosphere is the part of the upper atmosphere where sufficient ionisation exists that can affect the propagation of radio waves. The ionosphere is responsible for refracting, reflecting, and absorbing the electromagnetic waves. The structure of ionosphere and the peak electron densities vary considerably with time (sunspot cycle, seasonally and diurnally), geographical location (polar cap, auroral zones, equatorial regions), and with certain solar disturbances (Davies, 1990). The peak electron density usually occurs in the F-region, which can be subdivided into the F1-layer and F2-layer. Above this is the topside where an additional layer has been observed in the low-latitude region at Fortaleza, Brazil (Jenkins et al., 1997a).

The existence of this layer was initially predicted using the Sheffield University plasmasphere ionosphere model (Bailey and Balan, 1996). Later, the layer was observed at Fortaleza (Jenkins et al., 1997b). Balan and Bailey (1995) addressed this layer as the G-layer and related it to the equatorial plasma fountain. The G-layer is formed during the pre-noon hours at the equator between latitudes $\pm 10^{\circ}$ and is observed to have greater maximum plasma concentration than that in the F-layer for a brief period just before noon. This layer is observed to occur more frequently during the solstices and less frequently during the equinoxes. Its occurrence

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is more frequent during the low solar activity periods. It is also observed that the occurrence of this layer is more probable at low latitudes around the magnetic equator, rather than at the equator itself (Batista et al., 2003). This layer is renamed the F3-layer since studies have shown that the layer arises from the dynamics of the F-layer at low latitudes (Jenkins et al., 1997a, b).

In 1995, at Fortaleza, the F3-layer occurred for 49% of the day and the highest occurrence was in summer for 75% of the days. The layer lasted for about 15 min to 6 h, mainly between 0800–1500 UT. The virtual height of reflection for this layer was between 375 and 750 km and its critical frequency is about 0.2–2.3 MHz higher than in the F2 layer (Balan et al., 1999). Batista et al. (2002) later used 25 years of data (for January and August only) to investigate the relationship between the F3-layer occurrences with the magnetic dip angle and solar activity. Depuev and Pulinets (2001) used the Intercosmos-19 satellite ionograms to investigate the spatial properties for the F3-layer. Using the Intercosmos-19 database, Pulinets et al. (2002) developed a parametric model, in which the model parameters were obtained for different geophysical conditions. This model is based on the Epstein function approximation.

Malaysia, located in the equatorial region, is an alternative area for the observation and investigation of the existence of the F3-layer. Although ionospheric research has been carried out worldwide since the early 1900s, in Malaysia, the focus on equatorial ionosphere only began in the 1990s (Hassan et al., 2002; Ho et al., 2002; Zain et al., 2002).

The first ionosonde station operating in Malaysia is located at the Wireless and Radio Science Centre (WARAS) at Kolej Universiti Teknologi Tun Hussein Onn (KUiTTHO), Parit Raja, Batu Pahat, Johor (Lat. 1°52′N, Long. 103°48′E). It was officially established in October 2004. Zain and Jaafar (2005) reported the existence of the F3-layer in equatorial region during the period of winter 2004. The ionograms over Parit Raja were obtained from the daily observations and hourly data collected for a period of 24 h a day continuously from 1 December, 2004 to 28 February 2005. This is in agreement with the occurrence of the F3-layer observed by Balan and Bailey (1995) and Balan et al. (1999) over Fortaleza, Brazil, during the December solstices.

The results reported by Zain and Jaafar (2005) show that during the winter of 2004, the Malaysian ionosphere has the greatest occurrence of the F3-layer within the periods of 0300–0500 UT (around local noon) while it has the least occurrence within the period of 2300–0200 UT (early morning after sunrise), during which time, the ion density is maximum at noon and minimum just after sunrise. The Malaysian Local Time (LT) is 8 h ahead of Universal Time (UT). In this paper, the observed occurrences of the F3-layer is reported for the period from January until December 2005.

2. Method of analysis

The data collected from 1 January 2005 to 31 December 2005 were analyzed for the statistical occurrences of the F3-layer over Malaysia. The ionograms were recorded at 15 min intervals. The authors were particularly interested in the time of occurrences of the F3-layer, its critical frequency and the virtual height of reflection.

The digisonde uses a 4-receiver interferometer and has been operational since the end of 2004. Fig. 1 shows an example of the ionogram taken on 2 January and 1 February 2005. It is evident from the figures that there exists an F3-layer over Parit Raja at a reflection height of 600–700 km.

3. Results and discussions

The results are based on the observations of the F3-layer for the months of January, February, April, October, November and December 2005. The monthly statistical occurrences of this layer are shown in Fig. 2. As expected, the existence of the F3-layer in January is high (about 35%) due to the winter season. Its occurrence then decreased to about 10% in February. Meanwhile, in October, the F3-layer is observed for about 15% of the month and increased rapidly to more than 50% in November. The highest occurrence is in December with nearly 80% of the time. This is in close agreement with other researchers that the F3-layer is mostly observed in winter compared to other seasons. The least existence is observed in April.

Fig. 3 shows that there are 35 occurrences of the F3-layer in January mainly between 1900 UT until 0100 UT. There is no observation of the F3-layer at 0700 UT because of system power failure due to lightnings. The highest occurrence is around 1900 and 2000 UT (i.e. around midnight) with a maximum of 4 occurrences for the whole month. The lowest occurrence is at 0100 UT with only 1