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Seasonal Variations of Equatorial Anomaly Crest using GPS Ionospheric Tomography

Seasonal Variations of Equatorial Anomaly Crest using GPS Ionospheric Tomography

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Abstract. The seasonal variation of the electron density profile in equatorial anomaly region is investigated using Global Positioning System (GPS) ionospheric tomography method from a dense network of Malaysian Real-Time Kinematic Network (MyRTKnet). In this study, the monthly variation of the electron density is reconstructed to study the development of the equatorial anomaly crest over the study area. It is found that the equatorial anomaly crest appears during the noon and last for a few hours before disappeared. The result also shows that the anomaly crest show strong appearance during both equinoxes, where March to May shows stronger crest compared to October to November month-to-month variations.

1. Introduction

The equatorial regions is common with the occurrence of ionospheric special features such as equatorial electrojet (EEJ), equatorial plasma bubble (EPB), equatorial spread-F (ESF) and also equatorial ionization anomaly (EIA). Particularly at this region, the ionosphere structure are dominantly controlled by the fountain effects that caused by the eastward electric field [1]. The perpendicular east-west electric field and north-south geomagnetic field lifted the upward electrodynamic (ExB) drift of plasma, where E and B represent the electric and magnetic field, respectively, to a higher altitude during the daytime. Then, it diffuses downward along the geomagnetic field lines toward the higher latitudes under influence of gravity and pressure gradients and produces the EIA.

The EIA structures shows a decreasing structure of electron density that called as trough in F-region at the geomagnetic equator and two crests structure that are formed on the either side within ±15° magnetic equator. The strength of the anomalies are varies with the geophysical conditions of the days, seasonal and solar activity [2, 3, 4]. This phenomenon occurs in daytime near the equatorial region and it is one of the main factor that contributes to the enhancement of the scintillation effects from the spread-F or the plasma bubbles irregularities [1,5]. Numbers of study has been carried out to study the structure of the EIA.

Previously, [6] has been investigated the total electron content (TEC) variability near the EIA crest and the results is compared with the IRI model. The seasonal variation of the ionospheric total electron content (TEC) in Asian equatorial anomaly region also has been investigated by [7]. Later, [8] has been study on the solar activity dependence of the electron density in the equatorial anomaly region using CHAMP data. They used the tomography imaging to detect the tilting of the ionization crest and also found the changes of the ionospheric thickness over latitude. They found that the both northern and southern anomaly crest are fully developed during midday in winter, post-noon in equinoxes and late afternoon in summer. Recently, [4] present the study on the variability of the EIA that focused on the crest-to-trough TEC ratio in East African anomaly region.

As the GPS is low cost in maintenance and capable to improve the spatial coverage compared to other instruments, the GPS has been widely used as a tools in monitoring the ionospheric structures and its behaviors [9, 10, 11]. With the dynamics structure of the ionosphere, the tomography method has been used to reconstruct the ionospheric profile from GPS measurements as its capability in imaging the ionospheric structure and also improving the local ionospheric modelling [9,10]. In this study, we reconstructed the electron density profile using GPS tomography methods to study the ionospheric variations over the equatorial anomaly region. We focused on the seasonal variation of the electron density profile and its diurnal variations to observe the effects towards the development of the equatorial anomaly crest.

2. Data and Measurements

A dense GPS network of MyRTKnet stations, which consists of 50 GPS CORS, that covered the whole Peninsular Malaysia is used in this study. It is located at the geomagnetic belt, within 1N to 7N (geomagnetic latitude: 8.825S to 2.95S) in geographical latitude and 99E to 104E in geographical longitude. Figure 1 shows the maps of the study area based on its geomagnetic location.

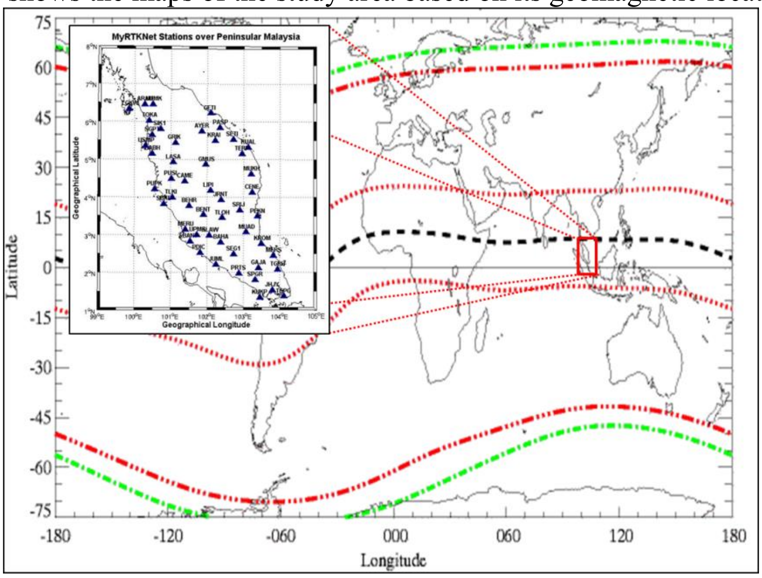

Figure 1. The geomagnetic location of Peninsular Malaysia.

To reconstruct the electron density profile of ionosphere, the slant TEC (STEC) is derived from the GPS measurements. The STEC represents the ionospheric TEC line-of-sight direction along the ray path from satellite to GPS receiver and it can be expressed mathematically as follow.

$$STEC = \frac{1}{40.3}\left(\frac{f_1 f_2}{f_1 - f_2}\right)[(P_1 - P_2) - c(DCB_r - DCB^s)] \quad (1)$$

where f_1 and f_2 are the GPS signal frequencies, P_1, P_2 represent the GPS pseudorange measurements, c is the speed of light and DCB_r, DCB^s represent the differential code bias for receiver and satellite respectively. Then, the electron density profile can be estimated using the general equation of the GPS tomography as follow.

$$Y = Ax + E \quad (2)$$

where Y represent the matrix of the observed STEC, A consists of the matrix of the length of the ray path of the satellite to receiver, x represent the matric of the electron densities that will be estimated and E is the errors during the approximation.

3. Results and Discussion

The ionospheric profile is reconstructed over the study area is reconstructed for one year data during year 2010. The month-to-month variation of the electron density profile during year 2010 is presented in Figure 2. It is noted that, even though the occurrence of the geomagnetic activities may affect the variation of the ionosphere, the results are still valid to describe the variation of the ionosphere [7].

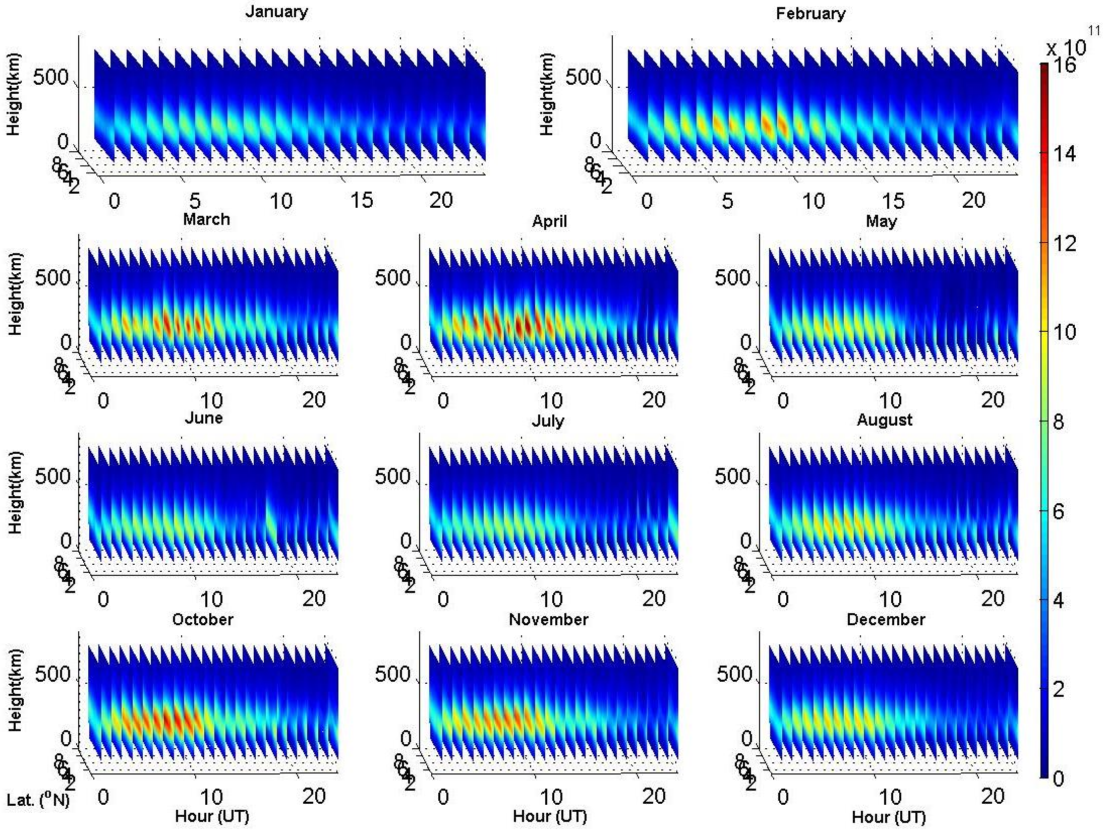

Figure 2. The month-to-month variation of the electron density profile. The horizontal axis represents the geographical latitude (x-axis) and time in universal time (UT)(y-axis) while the vertical axis represent the height of the profile in km. .

The result shows that the formation of the equatorial anomaly crest is begin at the morning local time for the whole month. It reaches maximum at post-noon, within 06 UT to 08 UT and the features decreases and disappear as the daytime passes. The same trend of formation of the equatorial anomaly crest is found by [8] that used the CHAMP electron density data, where they shows that the IRI-2001 reproduces the formation of EIA better around noon. Since the TEC is directly related with the maximum electron density of the ionosphere, [6] also explained that the increasing and decreasing of the TEC that is related with time is also depend of the production rate of ionization. During sunrise, the intensive ionization increases the electron concentration and as the temperature increase with the daytime passes, the loss rate increases and overcome the production rate and will results in gradually decreases of TEC in the evening.

Other than that, it is found that the equatorial anomaly crest is found maximum during both equinoxes, where it is higher during March to May month-to-month variations compared to October to November month-to-month variations. It is also found that the crest is minima during January monthly variations. The difference may cause by the differences of the solar activity that occurred during both equinoxes. This finding also presented by [8] that shows the difference in both equinoxes as the solar activities occurrences during March to May equinoxes are 60% stronger compared to October to November equinox.

4. Conclusion

In this study, we presented the tomography imaging of the seasonal variation of the electron density profile over the equatorial anomaly regions. A month-to-month variation is presented to observe the equatorial anomaly crest in the study area. It is found that the formation of the equatorial anomaly crest is begin at the morning and achieved maximum at the pass non local time. The feature disappears as the daytime passes. The findings also show the crest during both equinoxes is higher, where the March to May month-to-month variation is appear stronger compared to October to November variations. The difference also shown by previous study as it is triggered by the solar activity occurrences is higher during March to May month.

Acknowledgement

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References

[1] Aggarwal M. TEC variability near northern EIA crest and comparison with IRI model. Advances in Space Research. 2011 Oct 1;48(7):1221-1231.
[2] Balan N, Souza J, Baily GJ. Recent developments in understanding of equatorial ionization anomaly: A review. Journal of Atmospheric and Solar Terrestrial Physics. 2017 Jul 1.
[3] Luo W, Zhu Z, Xiong C, Chang S. The Response of Equatorial Ionization Anomaly in 120°E to the Geomagnetic Storm of 18 August 2003 at Different Altitudes From Multiple Satellite Observations. 2017 Dec 1;15(12):1588-1601.
[4] Oryema B, Jurua E, Ssebiyonga N. Variations of Crest-to-Trough TEC Ratio of the East African Equatorial Anomaly Region. International Journal of Astrophysics and Space Science. 2015 Mac 2;4(1):12-20.
[5] Abdu MA. Equatorial ionosphere thermosphere system: electrodynamics and irregularities. Advances in Space Research. 2005 Jan 1;35(5):771-787.
[6] Andreeva ES, Franke SJ, Yeh KC. Some feature of the equatorial anomaly revealed by ionospheric tomography. Geophysical Research Letters. 2000 Aug 15;27(16):2465-2468.
[7] Tsai HF, Liu JY, Tsai WH, Liu CH, Tseng CL, Wu CC. Seasonal variations of the ionospheric total electron content in Asian equatorial anomaly regions. Journal of Geophysical Research: Space Physics. 2001 Dec 1;106(A12):30363-30369.
[8] Liu HX, Stolle C, Forster M, Watanabe S. Solar activity dependence of the electron density in the equatorial anomaly regions observed by CHAMP. Journal of Geophysical Research: Space Physics. 2007 Nov 1;112(A11).
[9] Chen CH, Saito A, Lin CH, Yamamoto M, Suzuki S, Seemala GK. Medium-scale travelling ionospheric disturbances by three-dimensional ionospheric GPS tomography. Earth, Planets and Space. 2016 Dec;68(1):32.
[10] Ssessanga N, Kim YH, Kim E. Vertical structure of medium-scale travelling ionospheric disturbances. Geophysical Research Letters. 2015 Nov 16;42(21):9156-9165.
[11] Hong J, Kim YH, Chung JK, Ssessanga N, Kwak YS. Tomography Reconstruction of Ionospheric Electron Density with Empirical Orthonormal Functions Using Korea GNSS Network. Journal of Astronomy and Space Sciences. 2017;34(1):7-17.