Occurrence of Ionospheric Equatorial Ionization Anomaly at 840 km Height Observed by the DMSP Satellites at Solar Maximum Dusk

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Abstract Although it is accepted that the electron density double peaks of the Equatorial Ionization Anomaly (EIA) generally merge into a single-peak with increasing altitude and thus the signature of EIA becomes inconspicuous in the higher topside ionosphere, it is still unclear that to what altitudes the double-peak structure can extend. In this study, we used measurements of the DMSP F12-F15 satellites at solar maximum years 2000–2002 by checking latitudinal profiles of the ion density orbit by orbit. The EIA can still be observed at DMSP heights, and the EOR can reach 30% at specific longitudes at dusk side in equinox seasons. The EOR behaves wave-like longitude structure that depends on seasons. Moreover, the irregularity occurrence rate shows similar longitudinal and seasonal variations with EOR, and the local time evolutions of them show that the former peaks earlier than the latter. The observations of equatorial vertical $E \times B$ plasma drifts indicated that the prereversal enhancement (PRE) of eastward electric field plays a significant role in the formation of the equatorial ionization anomaly at an altitude of 840 km just after sunset, but the occurrence of the equatorial ionization anomaly at this altitude dose not precisely represent the characteristics of the prereversal enhancement of eastward electric field.

1. Introduction

One of the most significant features of the low-latitude ionosphere is the so-called Equatorial Ionization Anomaly (EIA), which is characterized by an electron density trough at dip equator and two crests at about $\pm 15^\circ$ magnetic latitude, i.e., EIA double-peak structure (Appleton, 1946; Croom et al., 1959; Duncan, 1960; Rishbeth, 2000; Stening, 1992). It is generally accepted that the EIA is induced by the “fountain effect,” which means that equatorial plasma moves upward under the effect of the upward vertical $E \times B$ drift and diffuses to both sides of the dip equator along the geomagnetic field lines due to the gravitational and pressure gradient forces (Balan et al., 1997, 2017; Hanson & Moffett, 1966; Rishbeth, 2000; Stening, 1992). The strength of the fountain effect is mainly controlled by the equatorial daytime eastward electric field. Equatorial vertical $E \times B$ plasma drift is generally downward at night and upward in daytime (Fejer, 1981; Fejer et al., 1991, 2008; Wang et al., 2008; Woodman, 1970). In particular, equatorial upward plasma drift at sunset has a prereversal enhancement (PRE) that significantly increases with increasing solar activity. The EIA could be amplified for both amplitude and latitude extension of the crests during PRE periods (e.g., Lin et al., 2009; Tulasi Ram et al., 2009; Walker et al., 1994; Yeh et al., 2001; Zhang et al., 2009a).

Generally, the double-peak structure of the EIA only can extend from the F2-peak region to the lower topside ionosphere; the double peaks merge gradually with increasing altitude to form a single-peak structure (Hanson & Moffett, 1966; King et al., 1967). The altitudinal extension of EIA double-peak structure depends on the strength of the fountain effect. In general, EIA becomes inconspicuous in the higher topside ionosphere; however, it could be significantly enhanced and extend to higher altitudes under extreme conditions such as superfountain. Strong eastward electric fields during some storms could result in superfountain effect, which leads to the double-peak structure extends up to higher altitudes (Balan et al., 2009; Lin et al., 2009; Lu et al., 2013; Mannucci et al., 2005). In addition, some researches indicated that even during
quiet times, enhanced F region dynamo process can lead to obvious EIA structure in the topside ionosphere, although the corresponding triggering mechanism is still not understood (Yizengaw et al., 2009). It is notable that the double-peak structure also can be modulated by other dynamic processes such as trans-equator plasma transport induced by neutral winds. Moreover, low-latitude ionospheric electric field can also significantly affect the ionospheric irregularities, such as the equatorial plasma bubbles (EPBs), which refers to irregular plasma density depletions observed by satellites and radar backscatter in the topside ionosphere (Woodman & Lahoz, 1976). EPBs are generated on the bottomside of the nighttime equatorial F region and rises to higher altitude as a result of nonlinear evolution of the generalized Rayleigh-Taylor (RT) and $E \times B$ instabilities (Gentile et al., 2011; Li et al., 2008). These ionospheric irregularities can significantly affect radio wave transmission.

Previous studies mainly focused on the EIA in the F2-peak region and the lower topside ionosphere (Basu et al., 2009; Dang et al., 2016; Huang et al., 2018; Liu et al., 2001; Luan et al., 2015; Tulasi Ram et al., 2009; Rishbeth et al., 2000; Sagawa et al., 2005; Sunda & Vyas, 2013; Tsai et al., 2001; Tulasi Walker et al., 1994; Wu et al., 2004; Xiong et al., 2013; Yue et al., 2015; Zhang et al., 2009; Zhao et al., 2009). The EIA structure in the higher topside ionosphere has seldom been investigated in detail. The topside ionosphere is mainly controlled by ionospheric dynamic processes. It can be speculated that the diurnal evolution of the fountain effect can affect the latitudinal structure of the low-latitude topside ionosphere at some altitudes. Recently, Chen et al. (2016) investigated the climatology variations of the topside plasma density. They indicated that pronounced double-peak structure can significantly extend up to the topside ionosphere at 600 km at solar maximum sunset hours, while no evident EIA appears in the seasonally averaged distribution of the plasma density at ~840 km with longitudes and latitudes. Although the climatology of latitudinal structure of the averaged plasma density showed that EIA double-peak structure is not a prevalent phenomenon at 840 km, it does not mean that EIA double-peak structure cannot occur at that altitude. Some cases with EIA double-peak structure could be erased in seasonally averaged latitudinal profiles of the plasma density. It is essential and valuable for ionospheric space weather to reveal the EIA occurrence in the higher topside ionosphere. In the present study, we statistically investigate the EIA and irregularity occurrence (in view of both are related to equatorial electric field) in the dusk sector at solar maximum through checking latitudinal profiles of plasma density measured by the DMSP satellites orbit by orbit. The results provide us more detailed knowledge on the variations of the EIA and its relationship with irregularities and electric field in the topside ionosphere than previous understanding.

2. Data and Method

The DMSP satellites are three-axis stabilized spacecrafts that fly in circular, Sun-synchronous polar orbits (inclination 98.7°) at an altitude of about 840 km. The orbital period of DMSP satellites is ~100 min. DMSP satellite carries a suite of sensors called the Special Sensor Ions, Electrons, and Scintillation (SSIES) to measure the plasma density (Rich, 1994). In this study, the observations of the DMSP satellites of F13 to F15 during 2000–2002 were used. DMSP-F12 spacecraft was retired in August 2002 and the effective observations in 2002 are rare, thus we only use F12 observations during 2000–2001. The $E \times B$ plasma drift data measured by the ROCSAT-1 were used to analyze the influences of the fountain effect on EIA occurrence rate. The ROCSAT-1 was launched into a 600 km circular orbit with an inclination of 35° on January 27, 1999; the orbital period is 96 min (e.g., Fejer et al., 2008; Zhang et al., 2015). The ionospheric plasma and electrodynamics instrument on board the ROCSAT-1 continuously measured ion drift velocity from March 1999 to June 2004. We used the plasma drifts when the ion density is larger than $10^4$ cm$^{-3}$ and the oxygen ion fraction is larger than 85% to guarantee the data accuracy (Yeh et al., 1999; Zhang et al., 2017). We excluded the observations with F10.7 value less than 120 sfu (solar flux units, 1 sfu = $10^{-22}$ W/m$^2$/Hz) and we only use observations with Ap index less than 22 nT during the 3 days before the observations to remove geomagnetic disturbance effects.

Plasma density irregularities often occur in the low-latitude topside ionosphere (Kil et al., 2009; Li et al., 2008). Although different criteria for identifying plasma density irregularities have been used in different studies (e.g., Huang et al., 2018; Kil & Heelis, 1998; McClure et al., 1998; Su et al., 2006), the reported statistical results of these studies are similar. Our criterion for identifying irregularities is summarized briefly as follows: (1) calculate the second order difference of logarithm of ion density (Ni) to dip angle
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(D2Y) in range of −60° to 60° dip angle; (2) mark the irregular scatters defined as the points whose D2Y is beyond the threshold (0.05/m³ degree²); (3) the profiles with irregular scatters taking up extending over 20° dip angle were considered as irregularity profiles. Figure 1 shows an example of irregularity profile and the distribution of D2Y. An empirical value of (0.05/m³ degree²) of D2Y was used as the threshold to identify the irregularity. After irregularity identification, the EIA double-peak structures were identified according to the following criteria: (1) the locations of two EIA crests are in the range of −40° to 40° dip angle (∼22.8° dip latitude); (2) the location of EIA trough is in the range of −10° to 10° dip angle (∼5.0° dip latitude); (3) the significance level of each crest (Cr=(NiC−NiT)/NiT, where NiC and NiT are ion densities at the crest and trough respectively, is larger than 5%. The profiles meeting with the above three criteria were marked as EIA double-peak profiles or EIA profiles for short. Figure 2 shows a typical EIA profile. Blue circles represent the measurements and red solid scatters correspond to smoothed plasma density. The smooth filter function is local regression using a weighted linear least squares and a second degree polynomial model. The smooth span, a percentage of the total number of data points, is set to 10%. For each EIA profile, we record the plasma densities and the dip angles of the two EIA crests and the trough as NiSC, NiNC, NiT, DipSC, DipNC, DipT, respectively. Based on processes above, the latitudinal profiles of plasma density are classified into three categories, namely, the EIA profiles, the irregularity profiles and regular profiles (excluding EIA and irregularity profiles). To simplify the following description, we refer to EIA occurrence rate as EOR, irregularity occurrence rate as IOR, calculated by the number of corresponding category divided by the number of total profiles.

3. Results and Discussion

There are four DMSP satellites (F12, F13, F14, F15) operated in orbits during the solar maximum years 2000–2002 except for DMSP-F12, which was retired in August 2002. Each DMSP satellite nearly passes through low-latitude region at two fixed local times separated by 12 h because of the Sun-synchronous polar orbits. In this paper, we mainly focus on EIA variation at evening sectors. Figure 3 displays the EOR in the dusk topside ionosphere observed by DMSP F12-F15 satellites. The EOR was averaged using a longitude bin of 30° with a 15° sliding step and a day number of year (DOY) bin of 60 days with a 20 days sliding step. The first column of Figure 3 gives the number of total sample profiles (including the EIA profiles, irregularity profiles and regular profiles) and the second column is the number of EIA profiles. The results from top to bottom are observed by DMSP-F13, F12, F14, and F15 satellites, respectively, and the corresponding local times have been marked.
The main characteristics of EOR are as follows: the EOR is large during Equinoxes and the December solstice, and the maximum can be up to 30% at specific longitudes. However, the EIA double-peak structure rarely occurs during the June solstice. The EOR shows significant longitudinal variations. The largest EOR reaches ~30% around 60°W and 0°E in the Equinoxes. The EOR shows clearly local time evolution in the dusk sectors. The large EOR was observed by the DMSP-F12 and F14 at ~19:30 to 20:30 LT, while the EOR observed by the F13 (~18:00 LT) and F15 (~21:30 LT) are relatively small, with the maximum value of less

Figure 2. A typical profile with an EIA double-peak structure measured by the DMSP-F15 at 21:31 LT on November 9, 2000. The key parameters of the EIA are marked. EIA, Equatorial Ionization Anomaly.

Figure 3. Longitudinal and seasonal distributions of the numbers of sample profiles (left), EIA profiles (middle), and EOR (right) at solar maximum at different local time sectors observed by DMSP-F13, DMSP-F12, DMSP-F14, and DMSP-F15, respectively, from top to bottom. The mean local times when DMSP satellites passed dip equator are labeled. EIA, Equatorial Ionization Anomaly; EOR, EIA occurrence rate.
than 15%. It is should be noted that the EOR shows a wave-4 pattern in Figure 3. It is well known that the formation of the wave-4 longitudinal variations of the equatorial vertical plasma velocity and of the resultant EIA on the dayside is driven by tidal forcing (e.g., Kil et al., 2011). The PRE can play a significant role for the formation of the EIA after sunset, meanwhile, the contribution of the equatorial vertical plasma drift before the PRE also cannot be ignored.

The global distributions of the location for EIA crests and troughs are displayed in Figure 4. The EIA profiles observed by the DMSP-F12, F13, F14 and F15 satellites have been grouped into three seasons, June Solstice (May-August), Equinoxes (March-April, September-October), and December solstice (November-February). The averaged local time at dip equator has been marked in every panel. The red, blue and black solid points are for south crests, troughs, and north crests, respectively. The results show that there is distinct longitudinal variation in the EIA crest and trough locations. As shown in Figure 4, the EIA mainly occurs in Equinoxes and December solstice seasons. The EIA troughs mainly appear at dip equator around 40°W, while they shift to the southern side of dip equator around 110°E. Similarly, the crests are basically symmetrically located around ±10° dip latitude around 40°W, while both northern and southern crests move southward more or less around 110°E, especially at ∼20:30 LT in December solstice. Our results are basically consistent with previous studies, which indicated that EIA trough location has distinct longitudinal variation (e.g., Huang et al., 1986; Liu et al., 2001).

It is generally accepted that the formation of EIA double-peak structure is as a result of the fountain effect driven by upward $E \times B$ plasma drift. In order to understand the controlling factors for the EIA in the topside ionosphere, we analyzed equatorial ionospheric vertical plasma drift measured by the ROCSAT-1 to illustrate its impact on the topside EIA. Figure 5 is an example for ROCSAT-1 plasma drift observations with 1.5 h delayed DMSP-F14 plasma density observations. Figure 5 shows (a) successive DMSP-F14 observed plasma density profiles and (b) corresponding $E \times B$ plasma drift measured by the ROCSAT-1. The
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oxygen ion fractions are nearly 100% and ion densities are larger than $10^5$ cm$^{-3}$ during the ROCSAT-1 measurements, thus plasma drift measurements are reliable. Figure 5c gives the relative position of DMSP-F14 (thick curve) and ROCSAT-1 (thin curve). It can be clearly seen in Figure 5 that strong prereversal enhancement occurred at $\sim$ 19:00 LT when the ROCSAT-1 passed dip equator from 19:00 to 23:00 UT, correspondingly, there are prominent EIA structures measured by DMSP-F14 from $\sim$20:30 to 23:30 UT. Moreover, the vertical plasma drift velocities corresponding to the single-peak plasma density profiles (the black and green lines) are significantly smaller than those corresponding to the EIA profiles. Therefore, the strong PRE can explain the formation of EIA in the topside ionosphere in this case. In addition, we analyzed all profiles that ROCSAT-1 and DMSP satellites have simultaneous observations. ROCSAT-1 vertical plasma drift observations within $\pm$2.5° around the dip equator and $\pm$5° of the longitude of DMSP satellites orbit have been used. Stolle et al. (2008) indicated that a preferred response time of the CTR (the ratio of EIA crests to trough) to variations of vertical plasma drift is 1–2 h. We tried different response times; the results show that the median of $E \times B$ plasma drift distribution appears the maximum difference between EIA profiles and regular profiles when the response time is $\sim$ 1.5 h. Thus, we extracted ROCSAT-1 observations when it passed through the dip equator 1.5 h before the DMSP satellites. The corresponding vertical plasma drift distribution are summarized in Figure 6, which gives the median, upper quartile, lower quartile of vertical plasma drift for EIA, irregularity, and regular profiles. Since lower EOR and beyond the PRE periods for F13 and F15, we only use F12 and F14 observations of $\sim$ 19:30 and 20:30 LT in Figure 6. It can be seen that the median values of upward plasma drifts are larger in EIA and irregularity profiles than in regular profiles. Although we cannot obtain $E \times B$ plasma drift from ROCSAT-1 for each DMSP-observed profile, the ROCSAT-1 measurements can still give us averaged longitudinal, seasonal and local time distribution of vertical plasma drift at solar maximum, which may be helpful for understanding electrodynamics process of topside EIA formation. Figure 7a depicts the longitude and local time map of the upward $E \times B$ plasma drift measured by the ROCSAT-1 at afternoon and evening hours during solar maximum years 2000–2002. The corresponding EOR during PRE periods are also displayed for comparison in Figure 7b. The white (red) bars are numbers of total profiles (EIA profiles) and the red lines are EOR. The longitudinal bin is 30°, with a 15° sliding step. It can be seen that the EIA mainly occurs at Equinoxes and December Solstice. The EIA

Figure 5. (a) Latitudinal profiles of the DMSP-F14 observed plasma density. The start and end time of DMSP-F14 satellite pass is given at the top left, and the local time when satellite pass the dip equator is also identified at the top right. (b) The local time variations of the vertical plasma drifts observed by the ROCSAT-1 on 1 March 2000. The universal time interval of each segment is shown at the top left. The gray shaded areas are approximate local times when the DMSP satellites pass the dip equator and 1.5 h before. (c) The geographic locations of each DMSP-F14 (thick curve) and ROCSAT-1 (thin curve) pass. The horizontal solid gray curve depicts the location of the dip equator.
rarely occurs at June Solstice. The seasonal feature of PRE is similar to that of EOR. The EOR at $\sim19:30$ LT is greater than that at 20:30 LT. The longitudinal variation of EOR seems to be consistent with that of pre-reversal enhancement of equatorial vertical plasma drift, especially in Equinoxes. For example, the $E \times B$ plasma drift has three peaks around 90°W, 10°E, and 110°E in the Equinoxes, which is approximately in accordance with the longitude variation of EOR. However, the EOR shows somewhat different longitudinal distribution from the $E \times B$ plasma drift in December Solstice, especially at 20:30 LT sector. The largest EOR is at $\sim110°$E longitude but the $E \times B$ plasma drift in that longitude sector is not largest. The similarity between morphologies of EIA and PRE tends to indicate that the PRE of equatorial upward plasma drift plays a significant role in the formation of the EIA at 840 km after sunset. However, we should also keep in mind that the morphology of the EIA after sunset depends on the accumulated effects of the equatorial vertical plasma drift. The contribution of the vertical drift before the PRE also cannot be ignored to some extent, as mentioned hereinbefore.

In addition to the topside EIA, another phenomenon related to the PRE is irregularity. Previous studies have shown that the irregularity increases with increasing PRE $E \times B$ drift (Kil et al., 2009; Li et al., 2008). Since the vertical $E \times B$ plasma drift is one of the most important factors for both EIA and irregularity in the
It is necessary to further compare topside EIA and irregularity occurrence features. We statistically analyzed the IOR in the same periods using DMSP observations. Figure 8 depicts the seasonal/longitudinal variations of IOR. It can be seen that IOR is greater in the Equinoxes and December Solstice than in the June Solstice, which is similar to the seasonal variations of EOR. The IOR shows local time evolution. Nearly no irregularities occurred at 18:30 LT (DMSP-F13 observations) while it occurred frequently after 19:30 LT (DMSP-F12, F14, and F15 observations). The maximum IOR is more than 40%. It should be noted that the DMSP-F12, F14, and F15 recorded similar longitudinal and seasonal variations patterns of IOR. The observations during equinoxes show the occurrence of IOR peak near 10°E. There are two peaks of IOR around 40°W and 70°E in the December Solstice, while the peaks shift to 10°E and 180°E in the June Solstice. The longitudinal variations of the December and June solstice IOR are nearly anticorrelated. The statistical results of IOR was basically consistent with previous studies (Gentile et al., 2011; Li et al., 2008), indicating that our results are reliable. The EOR and IOR are similar in longitudinal and seasonal dependence. However, local time evolutions of EOR and IOR are somewhat discrepant. It seems that the occurrence rate maximum of irregularity appears later than that of EIA.

The comparison of the longitude variations of EIA, irregularity, and prereversal $E \times B$ drift is further presented in Figure 9 in order to more clearly understand their relationship. Figure 9 depicts longitudinal variations of the PRE $E \times B$ drift, EOR, IOR, the ratio of the EOR to IOR, and the combined occurrence rate (COR) of EIA together with irregularity for three seasons. The ratio of EOR to IOR greater than 10 was set to 10 for viewing convenience in the figure. The averaged PRE $E \times B$ drift velocity are obtained within the period from 18:00 LT to 18:30 LT in Figure 9. The vertical bar represents the standard deviation of PRE velocity in each bin. The PRE velocity is strongest in equinoxes, followed by that in December solstice, and weakest in June solstice, which is consistent with the EOR and IOR. The PRE velocity shows wave-like longitude variation. It can be seen that longitude distribution patterns of EIA, irregularity, and PRE $E \times B$ drift are similar. The longitude patterns of EOR peaks basically agree with those of PRE $E \times B$ drift. However, longitude patterns of the strengths of these peaks are not consistent well between EOR and PRE $E \times B$ drift, the longitude pattern changes with local time for EOR. The maximum difference between EOR and $E \times B$ drift longitude patterns occurs around 110°E during December solstice; for example, EOR is larger but $E \times B$ drift is smaller in 110°E sector than in 60°W sector at ~20:30 LT. We compared the characteristics of EIA profiles in these two longitude sectors. Figure 10 shows the CTR distribution, the shape of profiles and the local time evolution between these two longitude sectors. The EIA profiles within ±15° longitude

**Figure 8.** Same as Figure 3 but for irregularity occurrence rate.
centered in 60°W and 110°E were used to calculate the CTR in Figure 10a. It can be seen that the median CTR is obviously smaller in 110°E sector than in 60°W sector in Figure 10a. Moreover, the EIA profiles in 60°W sector present more obvious EIA double-peak feature than in 110°E sector in Figure 10b. This feature can be clearly seen from an example in Figure 10c, which depicts local time evolution of EIA profile in two longitude sectors in November 17, 2001. The latitudinal profile changes from the earlier single-peak to the later double-peak structure. It should be learned that EIA feature is more obvious in 60°W sector than that in 110°E sector although larger EOR was observed around 110°E than 60°W. By contrast, longitudinal variations of IOR are more consistent with those of PRE; both the longitudes and strengths of the peaks of IOR and PRE velocity present very similar longitude patterns.

Both the topside EIA and irregularity can be as a result of strong PRE. However, when irregularities occur, the occurrence of the EIA becomes very difficult to be determined from the plasma density profiles comparing with the situation when irregularities are absent. As shown in Figure 9, EOR tends to decrease after IOR increases and maintains at higher levels. Irregularities are generated on the bottomside of the nighttime equatorial F region and rises to higher altitude as a result of nonlinear evolution of the generalized Rayleigh-Taylor (RT) and $E \times B$ instabilities to form large plasma density depletions (i.e., EPB) in the equatorial LI ET AL.

Figure 9. Longitudinal variations of the prereversal $E \times B$ drift, EOR, IOR, the ratio of the EOR to IOR, and the combined occurrence rate of EIA together with IRR from the top to bottom, respectively. The left, middle, and right are for equinoxes, June solstice, and December solstice, respectively. EOR, EIA occurrence rate; EIA, Equatorial Ionization Anomaly; IRR, irregularity.
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4. Summary

The EOR in the topside ionosphere under geomagnetically quiet condition was statistically investigated orbit by orbit using DMSP measurements at dusk side during solar maximum years 2000–2002. The result indicated that EIA can still occur at ~840 km in the evening sector; the maximum EOR could be up to 30% at specific longitude regions. The EOR is seasonally dependent. The EOR is large in equinox and the December solstice, while it is very small in the June solstice. The EOR shows a wave-like longitudinal pattern with varies with seasons. The plasma irregularity occurs more frequently than the EIA structure at DMSP height in the dusk sector at solar maximum, and the maximum occurrence rate can reach ~50%. Local time evolutions of EOR and IOR are somewhat different. The EOR has a maximum during 19:30–20:00 LT, while the peak IOR appears at later local times. The observations of vertical $E \times B$ plasma drifts implied that the seasonal and longitudinal variations of topside EIA and irregularity were mainly controlled by the PRE of eastward electric field at solar maximum, but the longitude pattern of EOR peak strength is not always well

Figure 10. (a) The distributions of the CTR in ~110°E and ~60°W longitude sectors in December solstice. The central red lines indicate the medians; the left and right edges of the boxes indicate the 25th and 75th percentiles, respectively. (b) The EIA profiles recorded by the DMSP-F14 in December solstice; the left for ~110°E longitude sector and the right for ~60°W longitude sector. (c) The local time evolutions of Ni latitudinal profiles observed on December 16–17, 2001; the left for ~110°E longitude sector and the right for ~60°W longitude sector. Different colors represent observations at different local times labeled in the figure. EIA, Equatorial Ionization Anomaly.
consistent with that of PRE. In other words, the occurrence of the equatorial ionization anomaly at this altitude does not precisely represent the characteristics of the prereversal enhancement of eastward electric field. By contrast, longitudinal variations of irregularity are more consistent with those of PRE. A possible reason for these is that sometimes irregularities affect the identification of EIA profile in observations, although both of them can be as a result of stronger PRE. As a result, longitude variations of the combined occurrence rate of EIA together with irregularity show better consistency with those of PRE drift velocity. The results provided us more detailed knowledge on the EIA in the topside ionosphere and its relationship with irregularity and equatorial ionospheric electric field.

Data Availability Statement

The DMSP satellites data are available from this website http://cedar.openmadrigal.org/list/. The ROC-SAT-1 data were provided by National Central University of Taiwan, which can be downloaded from http://sdbweb.ss.ncu.edu.tw/ipei_download.html.

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