Evolution / suppression parameters of equatorial postsunset plasma instability

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Abstract

Vertical ion **E**×**B** drift (V_{ZP}) and the peak *hm*F2 ($hmF2_P$) of the postsunset equatorial *F*-layer, which are the most essential parameters requisite for the generation or inhibition of postsunset bottomside equatorial irregularities were deduced from ionosonde observations made in the Africa region (Ouagadougou: ~3°N dip latitude) between January 1987 and December 1990 for solar activity minimum, medium, and maxima ($F_{10.7}$= 85, 141, 214, and 190, respectively) for geomagnetic undisturbed conditions. We investigate variations of evening equatorial prereversal drift and the corresponding altitude at four levels of solar activity. Our observations show strong variations with solar variability. Correlation analysis between these parameters indicates that the correlation coefficient value between ($hmF2_P$) versus V_{ZP} decreases appreciably with increasing solar flux value. There seem to be no significant link between these parameters under high solar activity, especially, for solar intensity $F_{10.7}$>200 units. We suspect and demonstrate that meridional neutral wind in *F*-region contributes substantially to the variations of the prereversal vertical plasma drifts enhancement and the peak *hm*F2, particularly, the electrodynamics during twilight high solar flux conditions.

1. Introduction and Data Base Description

The *F* region vertical iron drift at the magnetic equator is a parameter of primary importance for all studies of equatorial ionosphere. In the early evening hours, a unique feature of the equatorial and low latitude ionosphere is the pre-reversal enhancement (PRE) in the vertical ion velocities that occurs shortly after local sunset, superimposed in the typical diurnal variation of daytime upward and nighttime downward drifts [1]. The phenomenon is mainly driven by eastward electric fields and can significantly change the height of ionosphere. The equatorial electric field and plasma drift vary with longitude at a given local time and affect the growth rate of the Raleigh-Taylor (RT) instability through the gravitational and electrodynamics drift terms and by controlling the electron gradient in the bottomside of the *F*-region after dusk.

The height of the postsunset equatorial *F*-layer is another most important parameter that controls the generation or inhibition of equatorial bottomside plasma instability. Hitherto, the postsunset height studies have been limited to the height of the base of the *F*-layer, *h*'F resulting in a dearth of data on the peak *hm*F2. Thus, both evening pre-reversal vertical drift velocity enhancement and the corresponding altitude *hmF2p* should constitute important seeding mechanism for the generation / suppression of *F* region irregularities after dusk. Already, it has become an established fact that the evening rapid rise of the *F*-layer, produced by a prereversal enhancement in the *F*-region ionization drift velocity, is closely linked in some way with the development of the equatorial spread *F* (ESF) [2, 3]. Furthermore, numerous studies regarding the effects of evening equatorial pre-reversal drifts in *F*-region instability have been presented [4-7]. Unfortunately, electrodynamics effects on the early evening ionosphere are poorly studies in the African longitude sector. However, lack of study of these onset parameters necessary to trigger equatorial plasma instability in Africa hinders the development of realistic global thermosphere/ionosphere forecast models. The understandings of ionosphere variability in regard of these key factors have practical and scientific impacts.

Based on the ground-based ionosonde measurements, the analysis of seasonal and solar cycle variability in *F*-region vertical ion drifts over Ouagadougou has been performed in our earlier study [8]. By using ionosonde observation from Ouagadougou (12.4°N, 1.5°W, dip latitude, ~3°N), this paper establishes the relationship between evening equatorial pre-reversal vertical drift velocity and the corresponding evening peak hmF2 at various level of solar activity. The variation patterns of there parameters are also examined. Details of the procedure for measuring *F* region vertical drifts and the peak altitudes using ionosonde were fully described in earlier publication [8]. Uncertainties in V_{ZP} are in the range of ~(±1-2 m/s), while that of $hmF2_P$ varies between ~(±4-13 km).

2. Results and Discussion

We present in Figure 1a (top panel) the variation of evening equatorial pre-reversal vertical drift velocity for four different values of solar flux intensity $F_{10.7}$ and in Figure 1b (bottom panel) the corresponding monthly values of evening maximum *hm*F2. The averaged monthly solar flux intensity $F_{10.7}$ values were 85, 41, 214, and 190, respectively. The pre-reversal peak in vertical drifts is smaller at all months for the lowest flux value. The moderate and high solar maxima show considerable fluctuations. Of particular important, the values of V_{ZP} during moderate solar activity year 1988 ($F_{10.7}$ =141) are either roughly comparable or even higher than V_{ZP} during the maximum solar activity year 1989 ($F_{10.7}$ =214) and 1990 ($F_{10.7}$ = 190) in equinoxes (April and October) and December solstice (November and December) months. On the average, the magnitude of the evening pre-reversal enhancement in vertical iron drift during 1987 (low), 1988 (medium), 1989 (high), and 1990 (high) is 5.5 m/s, 13.7 m/s, 17.1 m/s, and 15.5 m/s, in that order. Clearly, the values indicate solar activity dependent. A close look at Fig. 1b, one notes that the variability patterns show apparent solar activity dependent, but not as strong as in the PRE in vertical ion drift. Again, peak *hm*F2 are smaller in values at all months for the lowest flux value. In addition, the trends during 1989 (high) and 1990 (high) are not significant compared to V_{ZP} trends during the same periods. It is also notice that values of peak *hm*F2 during the moderate solar activity year 1988 are approximately similar to maximum hmF2 during 1989 and 1990 solar maxima periods. Overall average value of *hmF2p* is ~370 km, 470 km, ~535 km, and 523 km for 1987, 1988, 1989, and 1990 periods, respectively. The average value of peak hmF2 also indicates solar activity dependent.

Figure 2 presents the dependence of evening pre-reversal maximum in F2 peak height *hmF2p* on the postsunset vertical ion drifts for 1987, 1988, 1989, and 1990, respectively. Notice that the occurrence time of evening peak in vertical drift is in the range 1700-2200 LT. Fig. 2 shows four panels of plots along with the best-fit representing solar cycle minimum (left top), moderate (right top), maximum (bottom left), and maximum (bottom right) conditions. The best fit parameters are put together as Table 1. It is interesting to see that the slope connecting *hmF2p* and V_{ZP} decrease appreciably with increasing phase of solar cycle. The correlation coefficient values, in the linear regression analysis is very good for low and moderate solar activity year of 1987 and 1988, very poor during high solar activity period of 1989, but fair during high solar flux year of 1990. Also, the regression coefficient values decrease drastically with increase in the epoch of solar cycle. Furthermore, the data suggest that the parameter required to initiate / suppress postsunset bottomside irregularities exhibit strong anti-correlation with solar effect. Thus, we suspect that even when meaningful onset values ($\mathbf{E}\times\mathbf{B}$ in vertical iron drift or peak *hm*F2) needed to ignite postsunset plasma instability are met, plasma irregularities can still be inhibited during high solar activity periods. This result is in agreement with the report of [9] that used space-based (ROCSAT-1) observations to show anti-correlation between the solar activity effect and topside density irregularity occurrence rate at longitude of bad alignment in a solstice season. It is observed that the magnitudes of the PRE in vertical ion drift are generally smaller, even the yearly averaged value is less than 20 m/s for each level of solar activity. However, [10] noted that a mild evening enhancement in the upward plasma drift could lead to a significant suppression of ionospheric plasma instability.

Table 1: Regression parameters for Fig. 2

Year	F10.7 (in flux units)	Slope	Regression Coefficients
1987	85	8.84	0.86
1988	141	5.69	0.83
1989	214	0.47	0.21
1990	190	2.59	0.50

It must be noted that Ouagadougou station is not located exactly at the magnetic equator, thus meridional neutral wind could play a vital role during high solar epoch. Therefore, an idea of how transequatorial wind intensity could affect the variation of evening prereversal enhancement and peak *hm*F2 can be obtained from the data presented in Figure 3, which shows the difference in the *hm*F2 values over two magnetic conjugate point stations obtained from Ibadan (3^{o}S dip latitude) and Ouagadougou (3^{o}N dip latitude) during similar solar and geophysical conditions. The *hm*F2 values over the northern conjugate station is subtracted from that of the southern conjugate station ($hmF2_{IBA}$-$hmF2_{OUA}$). The resulting ΔhmF2 represents direct measure of the transequatorial wind [11]. A positive (negative value of ΔhmF2) represents northward and (southward) transequatorial wind. The data for the tree different seasons are plotted in Figure 3. We observe that northward transequatorial wind is considerably large in December solstice, especially during the evening hours over Ouagadougou, moderate in equinoxes, and significantly weaker in June solstice. Thus, the large transequatorial winds (northward) in equinoxes and December solstice could be responsible for anti-solar correlation between the $hmF2_P$ and V_{ZP} while at the same time quenching the instability growth in an otherwise unstable flux tube, thus maintains a stable ionosphere with perhaps no equatorial spread *F* instability during equinoxes and solstice high solar flux conditions.

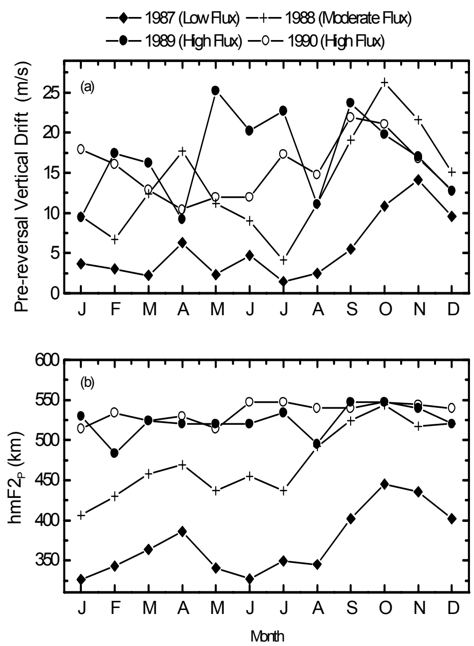

Figure 1. Variation of (a) pre-reversal vertical ion drift and (b) the corresponding maximum *hm*F2 for four levels of solar activity.

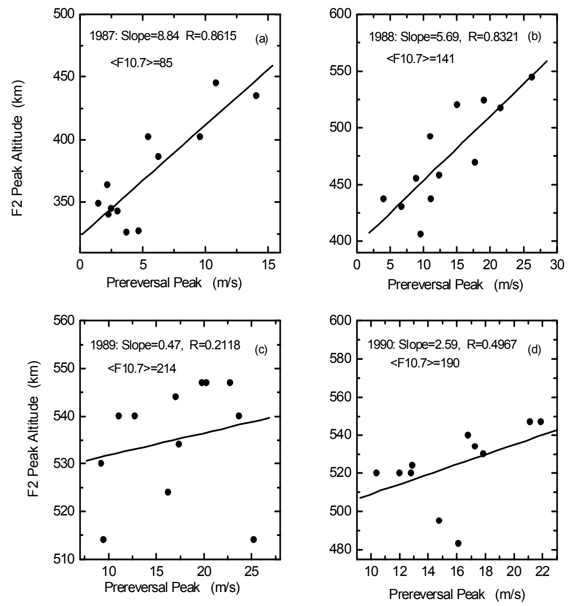

Figure 2. Dependence of ionospheric peak F2 maximum height ($hmF2_P$) on the evening prereversal enhancement in vertical ion drift.

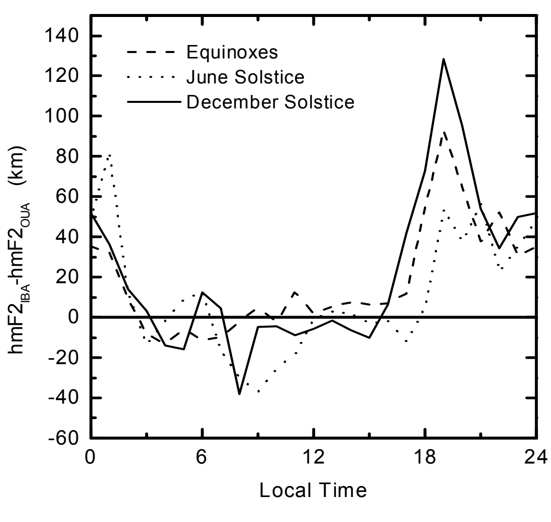

Figure 3. Meridinal neutral wind over Ouagadougou *F*-region ionosphere.

3. Summary

There exists significant variation, particularly in the evening enhancement in the *F*-region vertical drift velocity and the evening maximum *hm*F2 measured over Ouagadougou for the four different values of solar decimetric flux. The *F*-region parameters (V_{ZP} and peak *hm*F2) required to trigger the ESF instability exhibit strong anti-correlation with solar activity effect. We noted that these parameters are extremely poorly correlated during periods of high solar activity ($F_{10.7}$>200 units). In this way, the prereversal vertical drift peak and the corresponding altitude are confined to a narrow range and, as a result, the ionosphere irregularity generation and evolution may be weakened or inhibited. Two effects are found to contribute to the variation of these evening *F*-region parameters, especially the electrodynamics; solar variability and the meridional neutral wind in the *F*-region.

Acknowledgments

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