Super-fountain effect linked with 17 March 2015 geomagnetic storm manifesting distinct F_3 layer

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ABSTRACT

The existence of an additional stratification in the daytime equatorial ionospheric F region (the F_3 layer) was known since 1940s. However, its characteristics and the underlying physical mechanism have been uncovered only recently. In this paper, we present and discuss on the F_3 layer characteristics observed by six ionosondes distributed over equatorial and low latitudes (-20° to +25° dip latitudes) in the Brazilian longitude sector during the strongest geomagnetic storm (DstMin = -223 nT) of solar cycle 24, the St. Patrick's Day storm of 17 March 2015. Two eastward prompt penetration electric field (PPEF) events, as seen in equatorial electrojet (EEJ), occurred during the main phase of the storm on 17 March 2015, a strong one (~100 nT) at around ~1200 UT and a weak one (~50 nT) at around ~1725 UT. Local time variations in the F_3 layer occurrence, and ionospheric base height (h'F), peak height (hmF) and peak electron density (Nmax) are investigated. Notably, the F_3 layer occurred at all six locations, more distinctly during the stronger PPEF event. The large latitudinal extend in the occurrence of the F_3 layer in opposite hemispheres (-20° to +25° dip latitudes) covering the equatorial ionization anomaly crests is interpreted in terms of the combined effect of the super plasma fountain generated by the eastward PPEF and storm-time equatorward neutral wind.

Key Words: Storm time F3 Layer, Prompt Penetration Electric Field (PPEF), Super-Fountain Effect.

1. Introduction

Geomagnetic storms affecting the equatorial ionosphere have been a subject of intense investigation in the recent years. While many studies have dealt with the Total Electron Content (TEC) and F-layer critical frequency (foF2) variations, changes in the height distribution of electron density in response to the geomagnetic storm have been less addressed. During the St. Patrick's Day storm of 17 March, 2015, which is the strongest storm in the 24th solar cycle, the Brazilian sector was on the dayside, facilitating investigation of the storm time characteristics of several daytime equatorial phenomena including the F_3 layer [1, 2]. Here, we focus on studying the effect of this intense geomagnetic storm in modifying the ionospheric vertical structure and especially the latitudinal and hemispheric differences in the formation of storm-time F_3 layer. We carry out this study using simultaneous observations from six ionosondes distributed over a large latitudinal range of ~45^o covering equatorial ionization anomaly (EIA) crests in the northern and southern hemispheres along the Brazilian longitudes. We especially discuss the role of super plasma fountain, generated by the eastward PPEF and storm-time neutral wind, on the formation and evolution of the storm-time F_3 layer in different hemispheres.

2. Database

The observations from six digital ionosondes at different locations along the Brazilian longitudes from the UML DID base are used in this study. The locations of the digisondes cover a latitudinal span from ~20oS to 25°N dip latitudes and covers the EIA crest locations in the north and south. The storm-time zonal electric field variations as indicated by the equatorial electrojet (EEJ) are obtained using the H component magnetograms from an equatorial station Belem and an off-equatorial station Eusebio. The storm time indices and interplanetary parameters are obtained from the WDC at Kyoto (http://wdc.kugi.kyoto-u.ac.jp/dstdir/index.html) and the Space Physics Data Facility (SPDF) at http://omniweb.gsfc.nasa.gov/ow_min.html.

3. Results

The most intense storm of the 24th solar cycle occurred on 17 March 2015, has a long lasting MP when the Brazilian longitude lies in the morning-afternoon sector. The dayside equatorial zonal electric field over Brazil was dominated by two PPEF phases, a strong PPEF-1 phase at ~1200 UT with the southward turning of IMF Bz and IEFy enhancement followed by another weak PPEF-2 phase at ~1725 UT with the onset of a sub-storm [3]. A detailed analysis has been made to understand the latitudinal and hemispheric differences in the formation and evolution of storm time F_3 layer during these two PPEF phases.

The F_3 layer occurred over a large latitudinal extent during both PPEF phases from ~20°S to ~25°N dip latitudes covering the EIA crests in both hemispheres except at highest latitude station RAME during the weak PPEF-2 phase. Figure 1 shows typical ionograms displaying distinct F_3 layer observed over the six locations during the strong PPEF-1 phase. The layer started occurring earlier at equatorial latitudes and later at higher latitudes and it lasted longer at off equatorial locations at around ±10° dip latitudes than at lower and higher latitudes. During the PPEF phases (or F_3 layer), the ionospheric peak height (hmF) enhanced at all latitudes and the ionospheric base height (h'F) remained almost unchanged. All characteristics of the F_3 layer (occurrence, duration, height, density, latitude extend) also show significant north-south asymmetry during both PPEF phases (figures are not shown). The observed storm time modifications in the F-layer vertical structure and F_3 layer occurrence include the combined effects of the (1) eastward PPEF, (2) mechanical effects of storm-time asymmetric equatorward neutral wind (ENW), (3) disturbance dynamo electric field (DDEF), and (4) natural variation of the ionosphere in the absence of PPEF and wind.

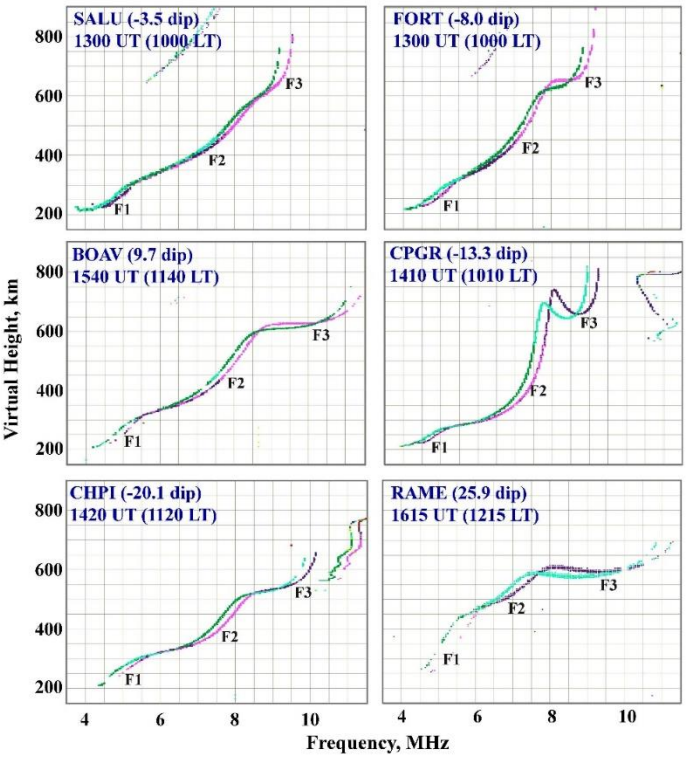

Figure 3: A set of ionograms showing the presence of F_3 layer at six different latitudes.

4. Conclusions:

- The F_3 layer occurred during both PPEF phases over a large latitudinal extent from ~20°S to ~25°N dip latitudes covering the EIA crests in both hemispheres.
- The F_3 layer started occurring earlier at the equator and later at higher latitudes in both hemispheres.
- The F-region peak height was rapidly uplifted (or raised) and the peak density reduced during F_3 layer occurrence. The F-region base height, however, did not experience any significant change.
- The F_3 layer evolved in such a way that it ascended to the topside ionosphere at lower latitudes (<10° dip latitude) while at higher latitudes the F_3 layer descended with time and merged with the F2 layer.
- The F_3 layer was more distinct, stronger, lasted longer in the northern hemisphere than in the southern hemisphere.

5. References:

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