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High-speed and supersonic equatorial vertical plasma drifts: recent results from the DMSP mission

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ABSTRACT

It is known that irregularities of the ionospheric plasma density can cause amplitude and phase scintillations of radio waves, leading to serious disruption of the radio-based communication. Very intensive ionospheric irregularities often occur at equatorial latitudes after sunset (often referred to as equatorial spread-F, ESF). Without solar ionization, the ions recombine and form a lower density layer, which, in turn, is unstable to plasma interchanges. The Rayleigh-Taylor (R-T) instability, along with ExB instability, is the main cause of generation of large-scale density depletions at the bottom of the F-layer [7]. Besides the post-sunset events, ionospheric irregularities and plasma bubbles can also rarely occur in the post-midnight and pre-dawn sectors, during geomagnetically quiet conditions as well as at the recovery phases of geomagnetic storms.

The ionospheric irregularities and plasma bubble structures were reported to drift in the zonal direction, eastward in the post-sunset sector and night, westward in the early morning, and the reversal of the zonal drift velocity occurs around 04LT [3, 6]. In the vertical plane, the vertical plasma drift velocities usually vary within ±100-150 m/s. Inside plasma bubbles the plasma drift velocity can reach as high as ±800m/s, but usually varies around ±300-400 m/s [6]. Upward speeds exceeding 800 m/s (hereafter referred to as high-speed drifts) were detected by Hanson et al. 1997 [5] by using the Defense Meteorological Satellite Program (DMSP) F9 and F10 data. The authors [5] noted that such high-speed events can be detected as often as in 40% of observations just after the sunset. However, the detected high-speed events were not supersonic, as their speed did not exceed the ion sound speed. The first detection of the supersonic upward drift seems to be done by Aggson et al. 1992 [1]. They used plasma and electric field observations from San Marco D and Dynamics Explorer 2 (DE 2) satellites, and observed occurrence of two events of plasma bubbles updrafting at ~1.7-1.9 km/s. Both events were observed at equatorial latitudes and at the post-sunset-pre-midnight sectors, one at ~20.5LT, and the other at ~23.2LT, at an altitude of 400-500 km.

More recently, Astafyeva and Zakharenkova [2] presented the first observations of the supersonic updrafting plasma irregularities in the predawn sector. By using data from two DMSP satellites they showed quasi-simultaneous occurrence of 2 supersonic upward drift events: the one of ~385 km spatial extension and with the maximum upward velocity of 1683 m/s appeared at ~3LT, the other, of ~1500 km large, with maximum speed of 1980 m/s, occurred at ~5LT. The events occurred at the recovery phase of the geomagnetic storm of 19 February 2014, shortly after the IMF Bz turned northward, that increased the eastward electric field in the equatorial nighttime ionosphere and triggered the generation of plasma irregularities. These prompt penetration electric fields were, most likely, the principal driver of the observed supersonic events.

Table 1. Main characteristics of the observed high-speed and supersonic events

	Date	Location (GLon; GLat)	UT	LT	H (km)	DMSP	Vz-max (m/s)
#1	19/02/2014	275.39; -5.42	10.54	4.79	855	F16	1638.2
#2	19/02/2014	237.72; -2.80	11.19	3.04	835	F15	1770.6
#3	07/02/2013	342.4; 12.15	21.17	20.0	853	F18	988
#4	08/01/2014	304.9; -8.97	23.72	20.05	857	F18	1051
#5	15/09/2014	255.7; -5.83	2.77	19.82	855	F18	1222
#6	13/11/2014	311.5; 2.61	22.9	19.68	849	F18	1307

In this work, we first show in detail the recent first-time detection of the supersonic upward plasma drifts in the early-morning sector published in [2]. We further use data from the DMSP ssatellites to study the occurrence of such high-speed and supersonic events. For this purpose, we analyze the data from F15, F16, F17 and F18 DMSP satellites during years 2002-2014, and we first select events with vertical plasma speed exceeding 800 m/s. At the second step, we check the DMSP data quality according to several main parameters: we first check that all the measurements were performed in high-density plasma, i.e. the total ion density exceeded 10^3 ions/m^3. Second, from the composition measurements we check the relative concentration of the O+ and the light ions (H+ and He+) during the event detection. It is known that the retarding potential analyzer (RPA) and the ion drift meter (IDM) instruments are designed to provide the best results in predominantely O+ plasma environment. When the percentage of light ions in the plasma increases above 15%, the IDM is compromised and the quality of the data degrades [5].

The results of our search during years 2002-2014 are presented in Table 1. The event #1 and #2 are the supersonic events detected in the early morning sector by Astafyeva and Zakharenkova [2]. The events #3 - #6 are newly detected events. One can see from Table 1 that those all occur in the evening local time sector. Events #3 and #4 are subsonic, while #5 and #6 are rather supersonic, as the vertical speed Vz exceeded the sound ion speed (~1020÷1050 m/s).

Figure 1 shows variations of the main plasma parameters as derived from the instruments onboard F18 DMSP

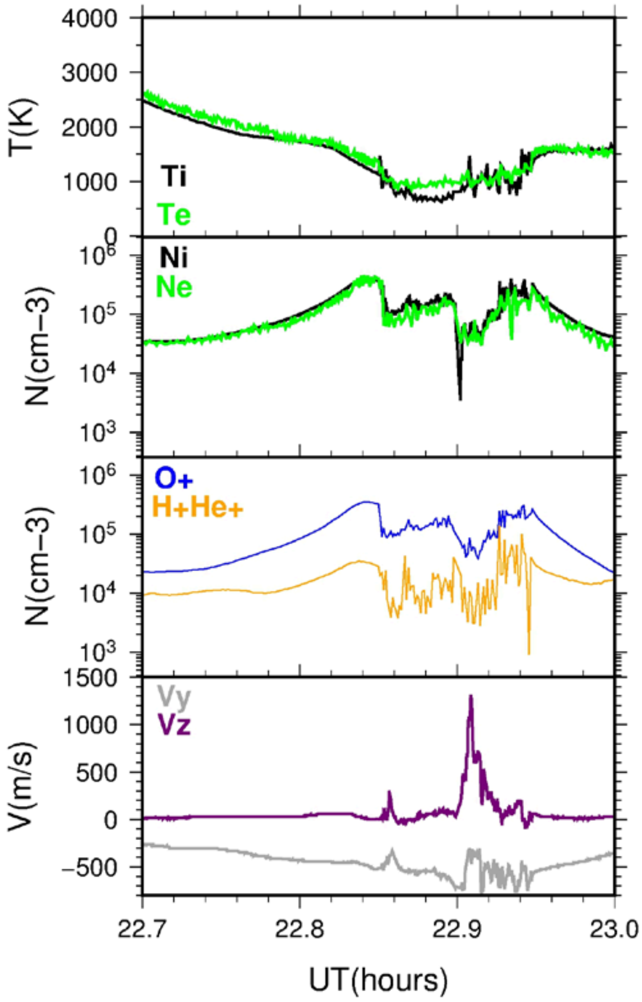

Figure 1. DMSP F18 detection of a supersonic upward drift event on 13 November 2014.

spacecraft from 22.7 to 23.0UT on 13 November 2014: ion temperature Ti, electron temperature Te, ion density Ni, electron density Ne, density of the O+ ions (blue curve) and of the light ions (He+ and H+, orange curve), vertical (violet) and horizontal (gray) plasma speed. One can see sharp rapid decrease in the ion density (Ni) from ~22.85 UT, which indicates observations of a plasma bubble. Inside the bubble, the vertical drift velocity (Vz) increases up to 1307 m/s (Figure 1). This event is detected at 22.91UT, which corresponds to 19.68 LT. Contrary to the 19 February 2014 case [2], this supersonic event occurred under quiet geomagnetic conditions, and during small-amplitude fluctuations of the IMF Bz within ±3 nT.

Key words: DMSP, ionospheric irregularities, vertical plasma drift, ion sound speed, supersonic speed

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