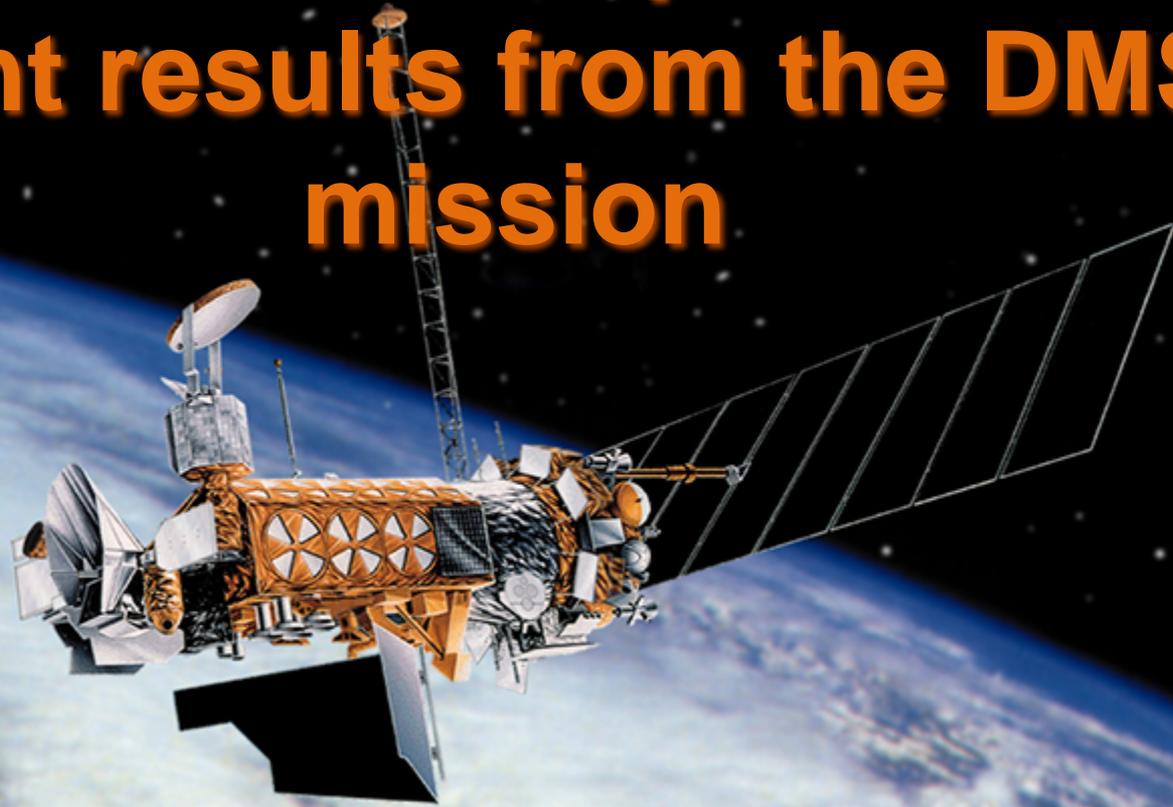


High-speed and supersonic equatorial vertical plasma drifts: recent results from the DMSP mission



<http://www.dmsplegacy.com>

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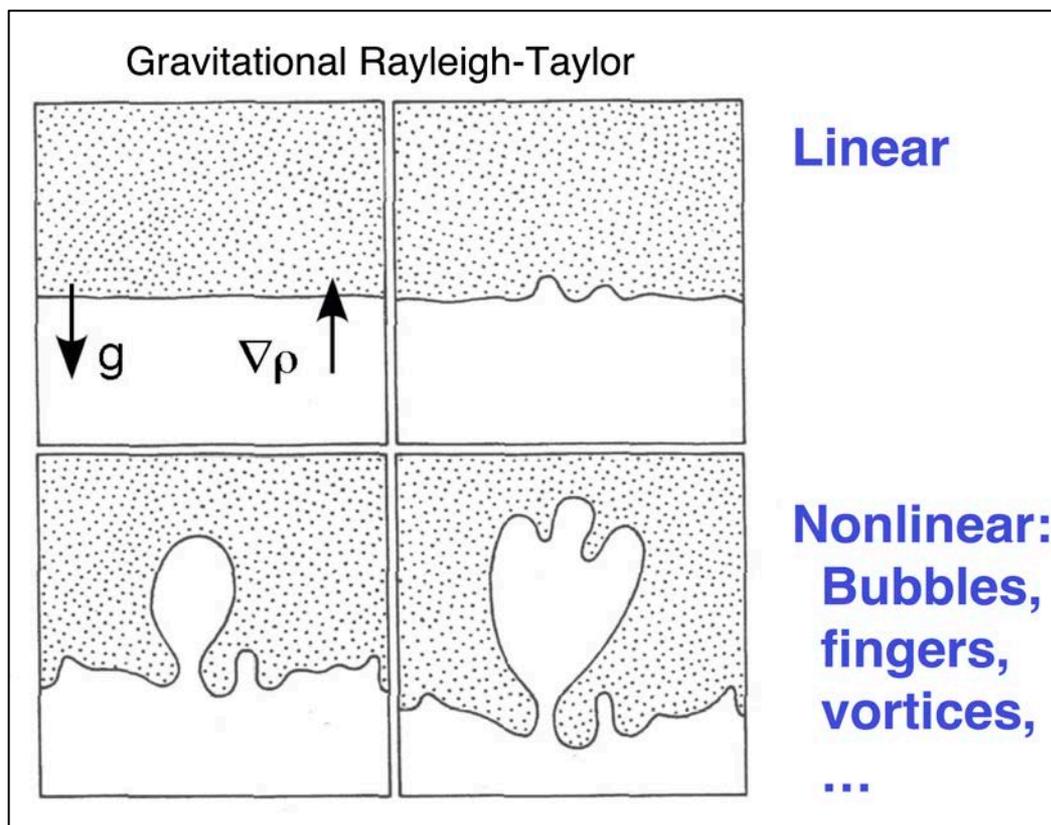
Defense Meteorological Satellite Program (DMSP)



- Since 1962
- Sun-synchronous ~polar orbit, $h \approx 840-860$ km
- Now : F15, F16, F17, F18, ~~F19~~
- Ni, Ne, Ti, Te, V, O⁺/He⁺ H⁺, etc.

Equatorial Plasma Bubbles/Drift

- Post-Sunset sector + occasionally elsewhere
- Pre-dawn – at the recovery phase of geom. storms

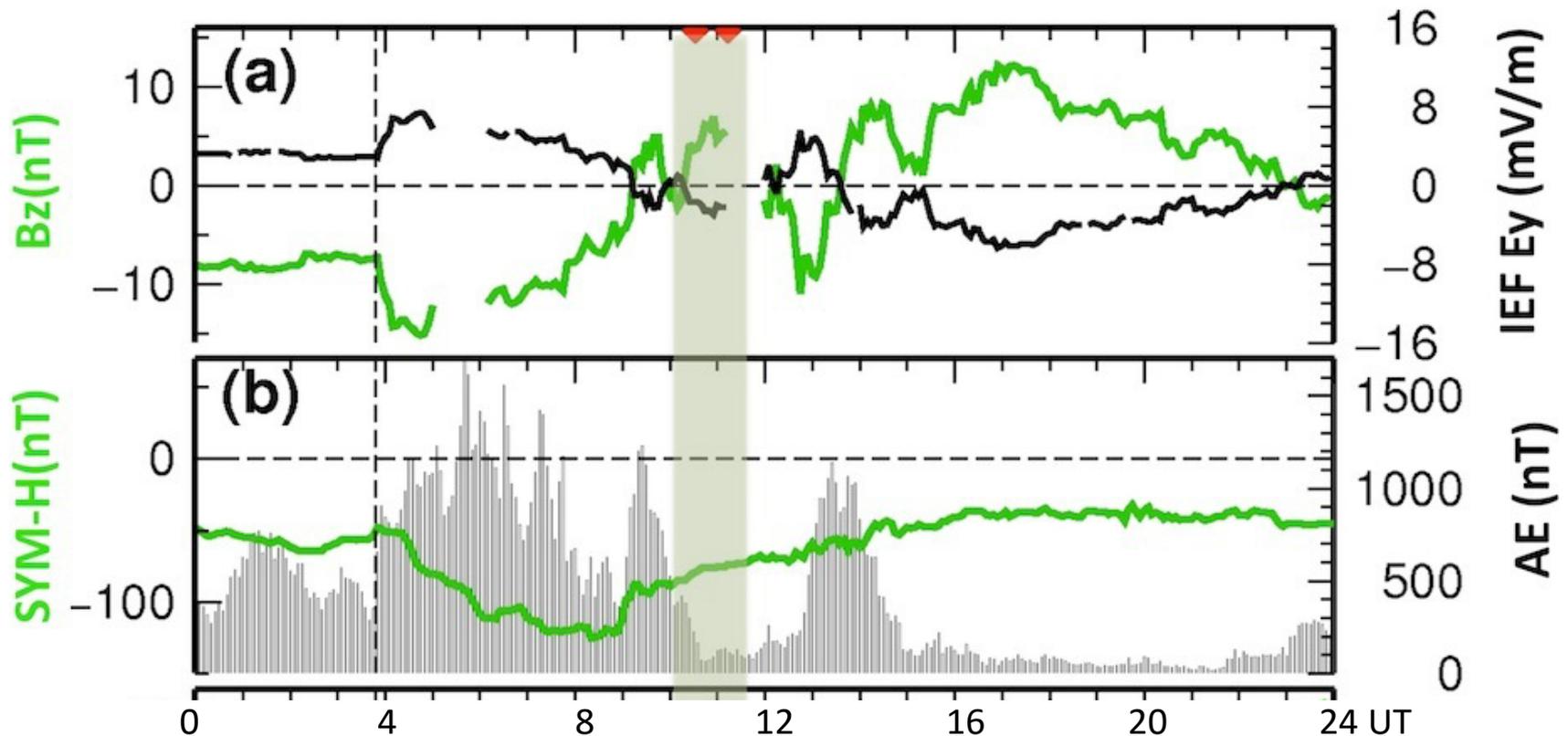


Background plasma drift : $\sim 100-150$ m/s ----- Inside bubbles: $\leq \sim 800$ m/s

Primary aim:

pre-dawn irregularities & geom. storms

19 February 2014 -> min SYM-H = -130nT

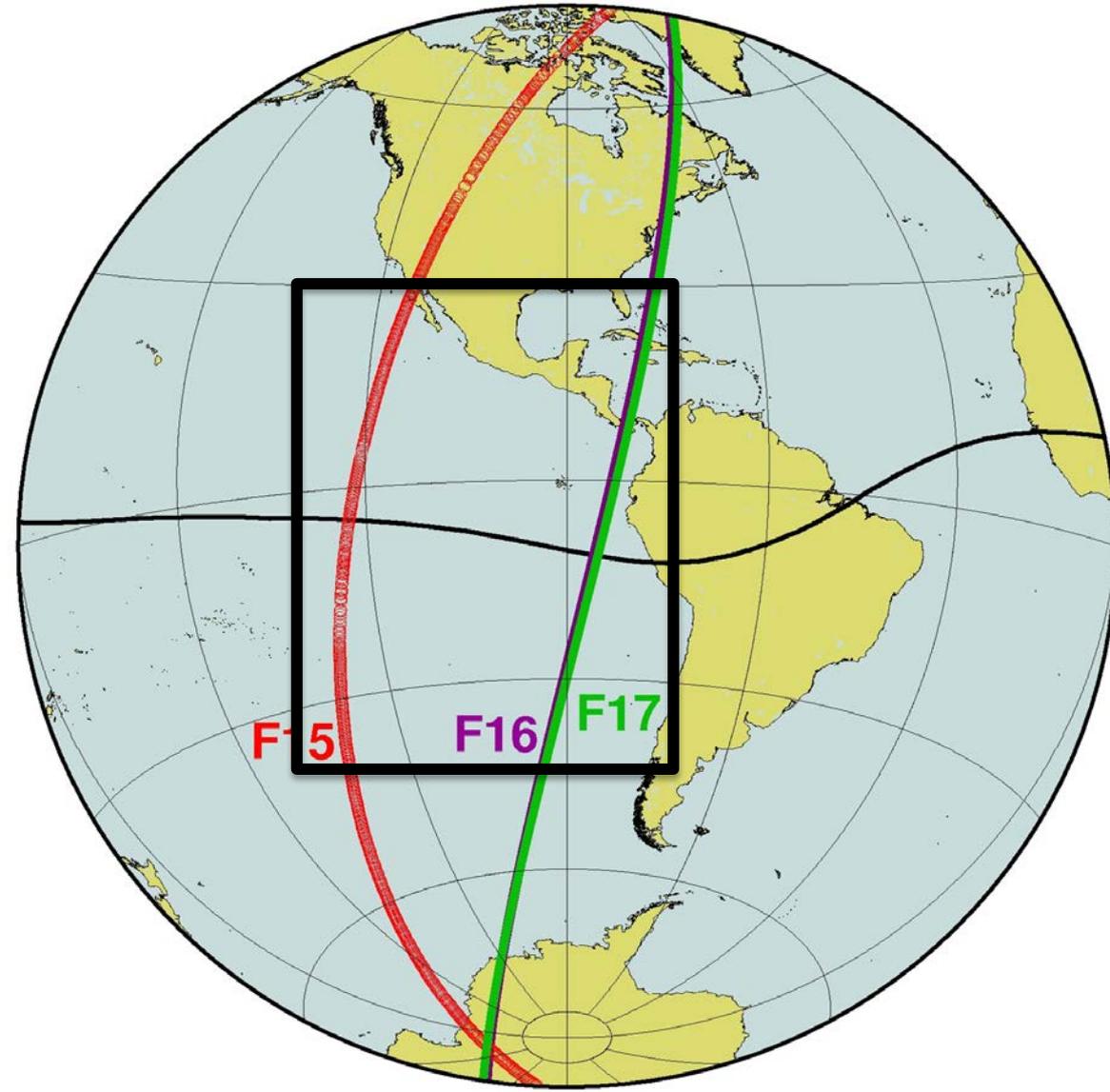


19 February 2014 : (~10.3-11.7 UT)

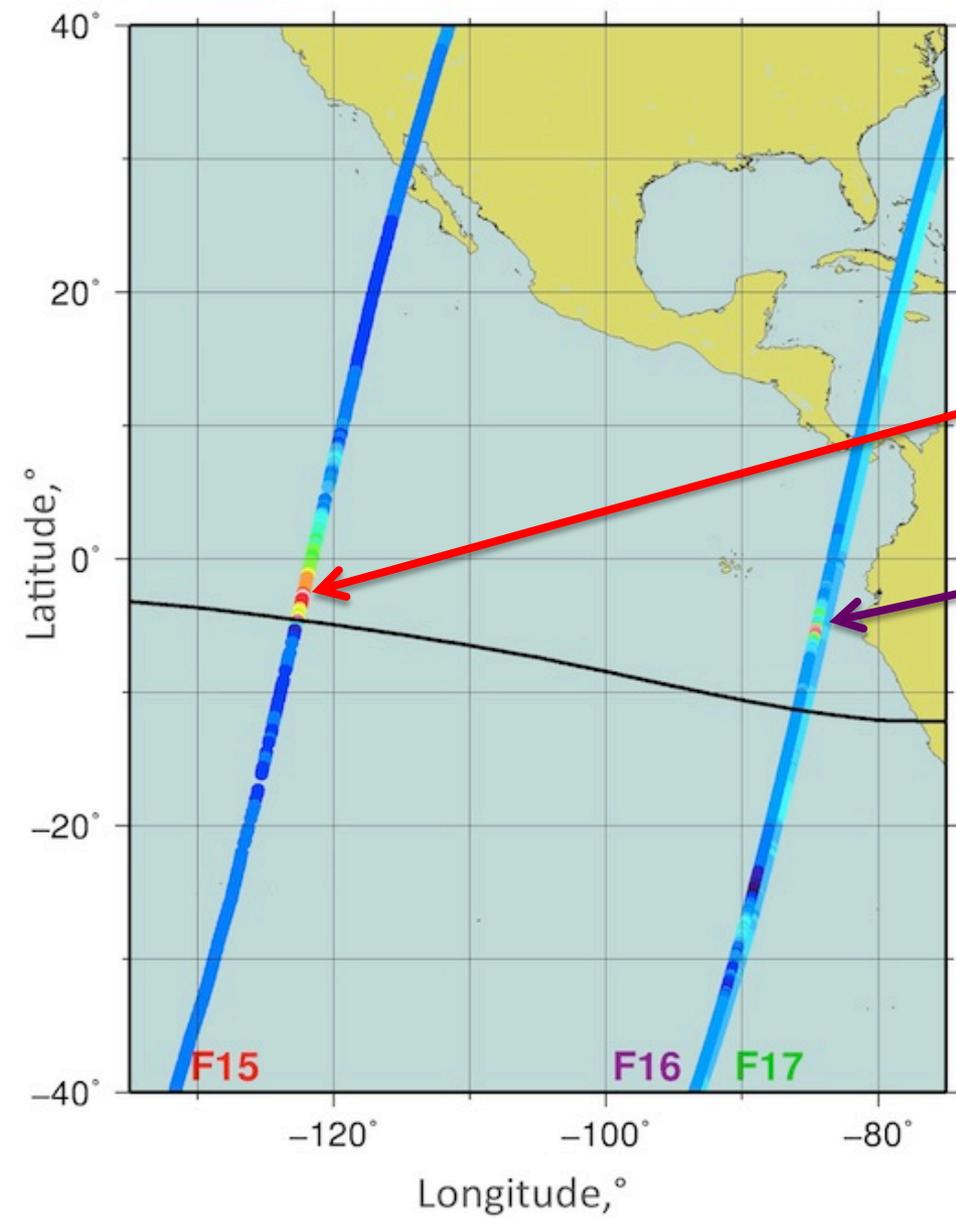
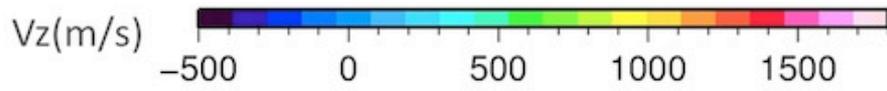
F16 – 10.55UT – 4.79LT

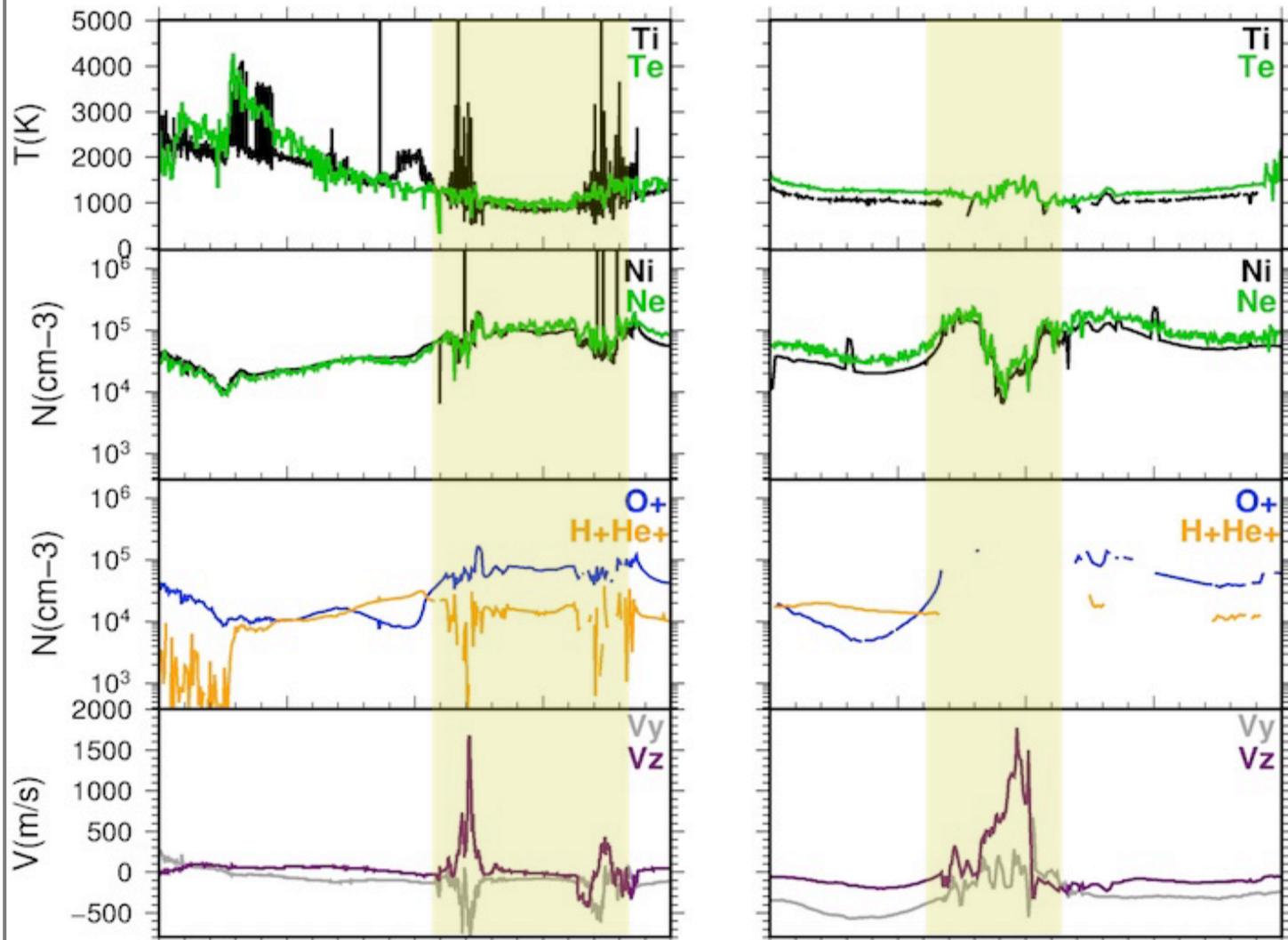
F15 – 11.17UT – 3.04LT

F17 – 11.42UT – 5.90LT



19 February 2014



(a) DMSP F16**(b) DMSP F15**

| | | | | | | | | | | |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| UT | 10.3 | 10.4 | 10.5 | 10.6 | 10.7 | 11.0 | 11.1 | 11.2 | 11.3 | 11.4 |
| LT | 5.54 | 5.22 | 4.99 | 4.77 | 4.49 | 3.52 | 3.25 | 3.03 | 2.79 | 2.47 |
| Glon | 288.68 | 282.32 | 277.39 | 272.63 | 266.98 | 247.86 | 242.22 | 237.44 | 232.48 | 226.00 |
| Glat | 45.41 | 24.54 | 3.52 | -17.52 | -38.44 | 37.95 | 16.92 | -4.22 | -25.33 | -46.24 |
| Mlat | 56.51 | 37.10 | 15.96 | -6.56 | -28.47 | 47.21 | 24.27 | 0.76 | -21.94 | -43.83 |

Sub/Super/Hyper – sonic ?

- Subsonic: $V < C_s$
- Supersonic: $V > C_s$ (Mach > 1.2)
- Hypersonic: $V \gg C_s$ (Mach > 5)

Ion Sound Velocity (O^+):

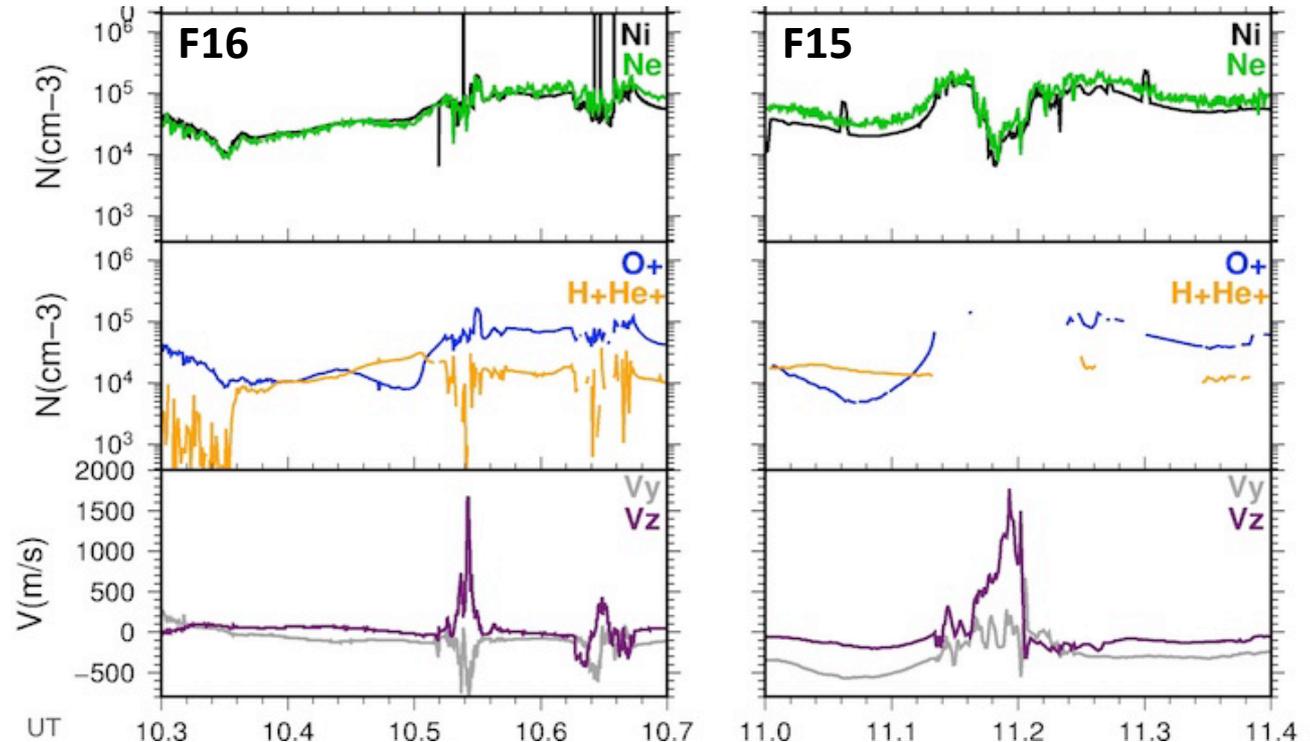
$$C_s = \sqrt{\frac{\gamma Z k T_e}{m_i}} = 9.79 * 10^5 \sqrt{\frac{\gamma Z T_e}{\mu}}$$

Can this be REAL??

| | Date | Location (C, G) | | | | Vz-max (m/s) | Te (K) | Cs (m/s) |
|----|------------|--------------------|-------|------|-----|-----------------|-----------|-------------|
| #1 | 19/02/2014 | 275.3 | 4.79 | 855 | F16 | 1638.2 | 1290 | 1053 |
| #2 | 19/02/2014 | 237.72, -2.80 | 11.19 | 3.04 | 835 | F15 | 1220 | 1022 |

DMSP data quality & reliability

- ✓ 1) high-density plasma, i.e. $N_i > 10^3$ ions/m³
- ✓ 2) predominantly O⁺ plasma environment
- ✓ 3) standard deviations < 206 m/s (by the UTD)



Aggson et al. (1992)
up to ~2 km/s

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 97, NO. A6, PAGES 8581-8590, JUNE 1, 1992

Equatorial Bubbles Updrafting at Supersonic Speeds

THOMAS L. AGGSON,¹ WILLIAM J. BURKE,² NELSON C. MAYNARD,² WILLIAM B. HANSON,³
PHILIP C. ANDERSON,¹ JAMES A. SLAVIN,¹ WALTER R. HOEGY,¹ AND JACK L. SABA⁴

We present plasma and electric field observations from two satellite encounters with equatorial plasma bubbles updrafting at velocities of ~2 km/s. These large, upward velocities are consistent with an adaptation of Chandrasekhar's model for the motion of plasma blobs supported against gravity by a magnetic field; that is, $V_z = -g$. Vector magnetic field measurements, available during one of the bubble encounters show a perturbation of ~150 nT, directed radially outward from the Earth, near the western wall of deepest plume. This magnetic variation is too large to be caused by simple shunting of the $g \times B$ current by a generator located near the background plasma pedestal. Rather, it is Alfvénic in nature, radiating from the bubble's leading edge.

Huba & Joyce (2007)
up to ~1.9 km/s

INTRODUCTION

Plasma bubbles, responsible for the bottomside irregularities in the ionosphere, are unstable to secondary instabilities. These instabilities are characterized by large density gradients and are associated with turbulence [Hudson and Ledvina, 1997]. The growth rate of the linear growth rate of the secondary instabilities is determined by the motion of the primary bubbles. The density depletions in the peak of the F layer are also found to be associated with these instabilities.

GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L07105, doi:10.1029/2006GL028519, 2007

Equatorial spread F modeling: Multiple bifurcated structures, secondary instabilities, large density 'bite-outs,' and supersonic flows

J. D. Huba¹ and G. Joyce²

Received 1 November 2006; revised 31 January 2007; accepted 7 March 2007; published 10 April 2007.

[1] The Naval Research Laboratory has recently developed a new two-dimensional code to study equatorial spread F (ESF): NRLESEF2. The code uses an 8th order spatial interpolation scheme and the partial donor cell method. This allows the model to capture very sharp gradients over ~4 grid cells and to assess the impact of numerical diffusion on the dynamics of 'bubble' evolution. Simulation results are presented that show new and complex ESF bubble dynamics: multiple bifurcations, secondary instabilities, density 'bite-outs' of over three orders of

references therein]. These numerical studies have shed light on a number of processes affecting the evolution of ESF: the role of a conducting E-layer, an inhomogeneous neutral wind, seeding conditions, molecular ions, and the interaction of multiple bubbles. Despite the progress made by these studies there are still a number of observations that have not been reported in simulation studies.

[4] In this Letter we present new results of the onset and evolution of ESF bubbles using a 2D simulation code (NRLESEF2) recently developed at the Naval Research

Hysell et al. (1994)
up to ~1.2 km/s

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 99, NO. A8, PAGES 15,065-15,085, AUGUST 1, 1994

VHF radar and rocket observations of equatorial spread F on Kwajalein

D. L. Hysell, M. C. Kelley, W. E. Swartz, and D. T. Farley
School of Electrical Engineering, Cornell University, Ithaca, New York

Abstract. VHF radar observations of equatorial spread F on Kwajalein are presented. The observations show that the spread F is characterized by a large spread in velocity and a large spread in density. The spread F is observed to be highly irregular and to exhibit a large spread in velocity and a large spread in density.

In the Summer 1990 Equatorial Spread F campaign at Kwajalein, the Cornell 50 MHz portable radar interferometer was used in conjunction with the Altair UHF incoherent scatter radar. The radar supported two soundings per hour. The soundings provided the following information: (1) the spread F is characterized by a large spread in velocity and a large spread in density. (2) the spread F is highly irregular and exhibits a large spread in velocity and a large spread in density. (3) the spread F is observed to be highly irregular and exhibits a large spread in velocity and a large spread in density.

coherent scatter radar measurements on July 30. The measurements were obtained using the Altair UHF incoherent scatter radar. The radar supported two soundings per hour. The soundings provided the following information: (1) the spread F is characterized by a large spread in velocity and a large spread in density. (2) the spread F is highly irregular and exhibits a large spread in velocity and a large spread in density. (3) the spread F is observed to be highly irregular and exhibits a large spread in velocity and a large spread in density.

BUT... only in the post-sunset sector!

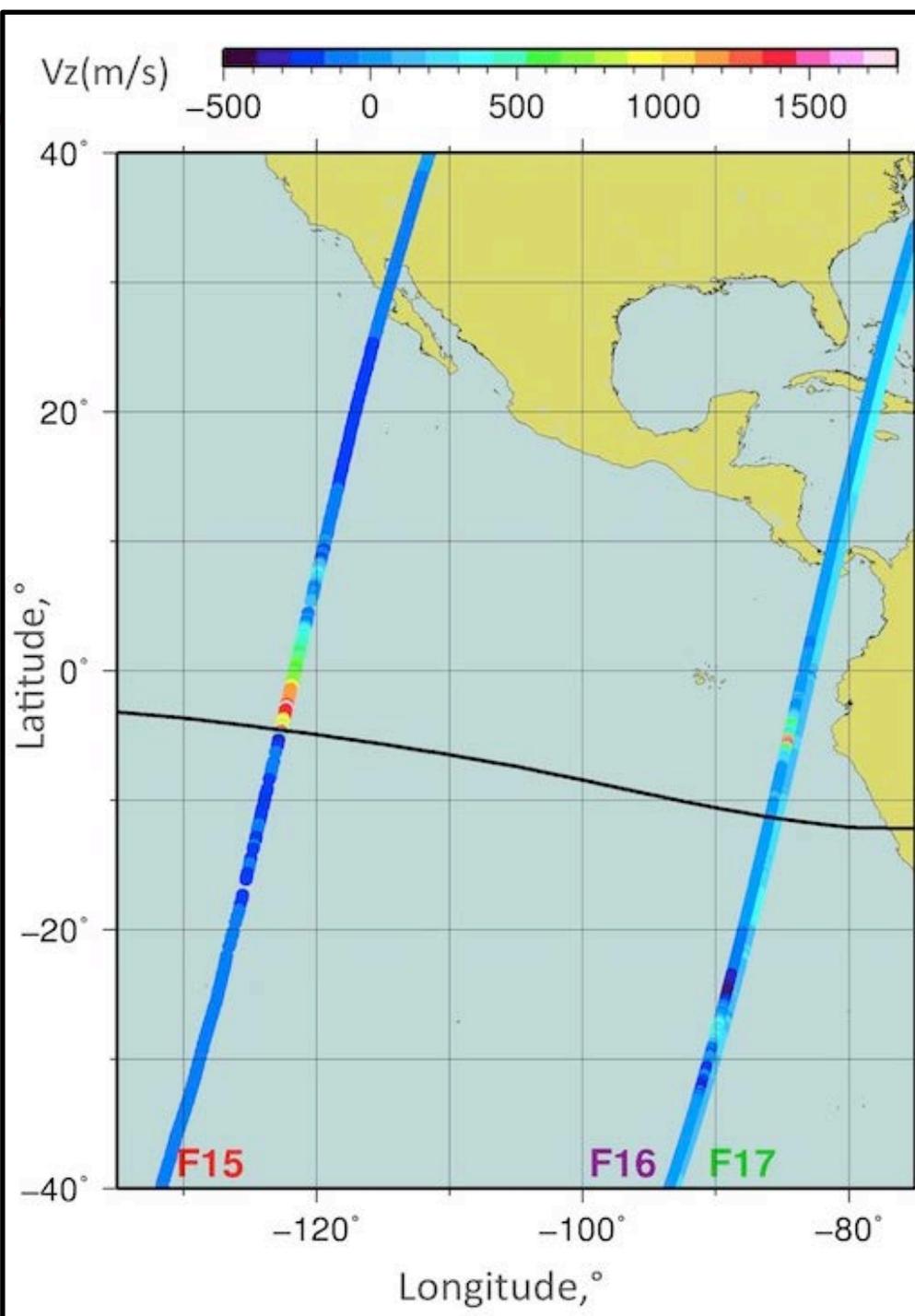
secondary instabilities, large density 'bite-outs,' and supersonic flows, *Geophys. Res. Lett.*, 34, L07105, doi:10.1029/2006GL028519.

2. Numerical Model

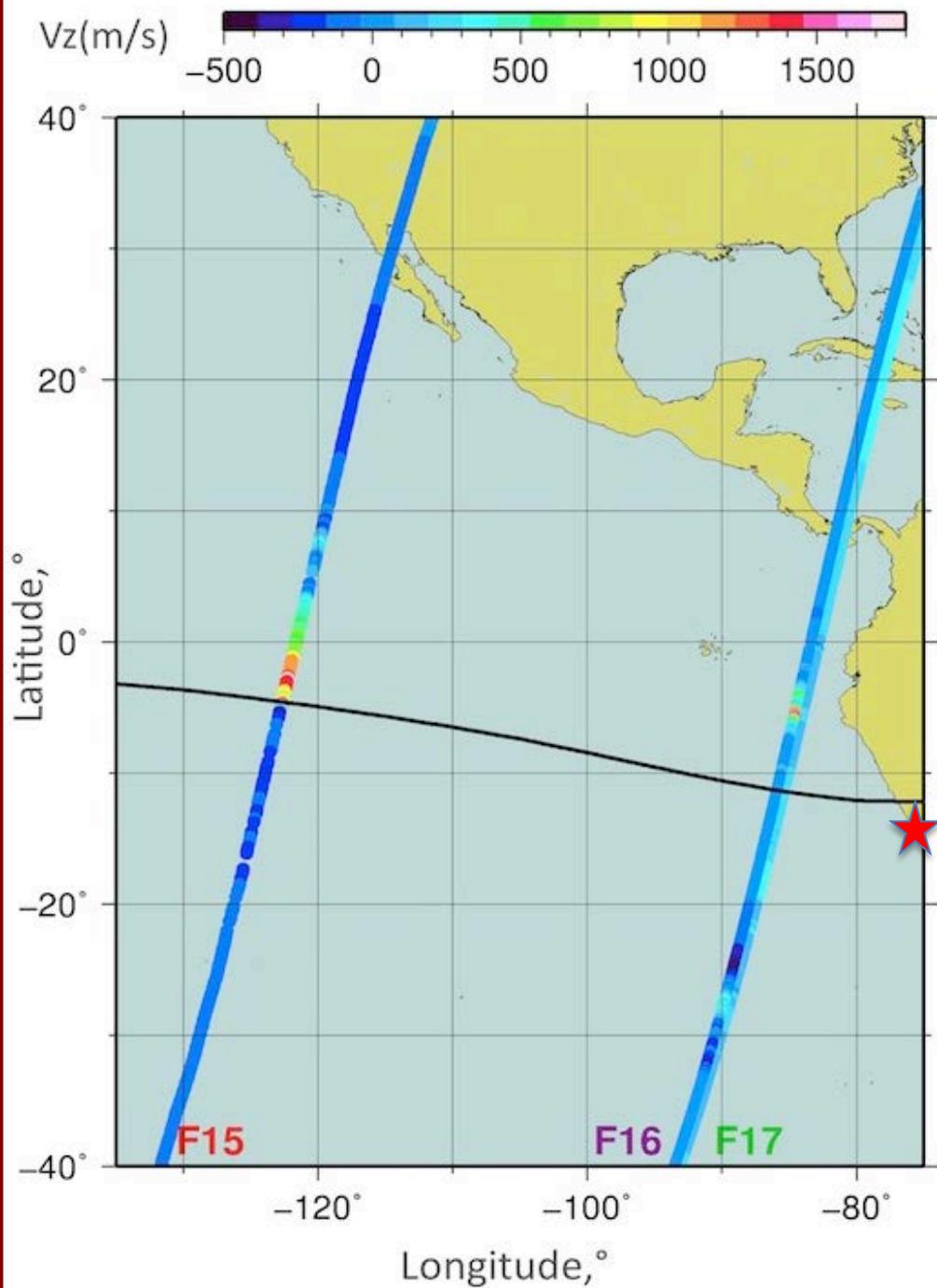
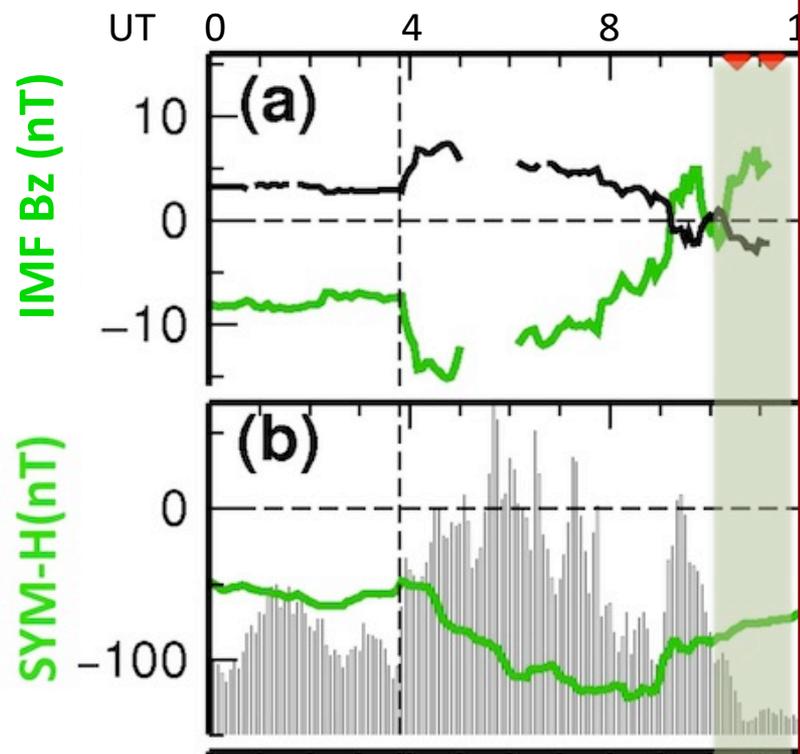
[5] The Naval Research Laboratory has recently devel-

The Mai

SOURCE?

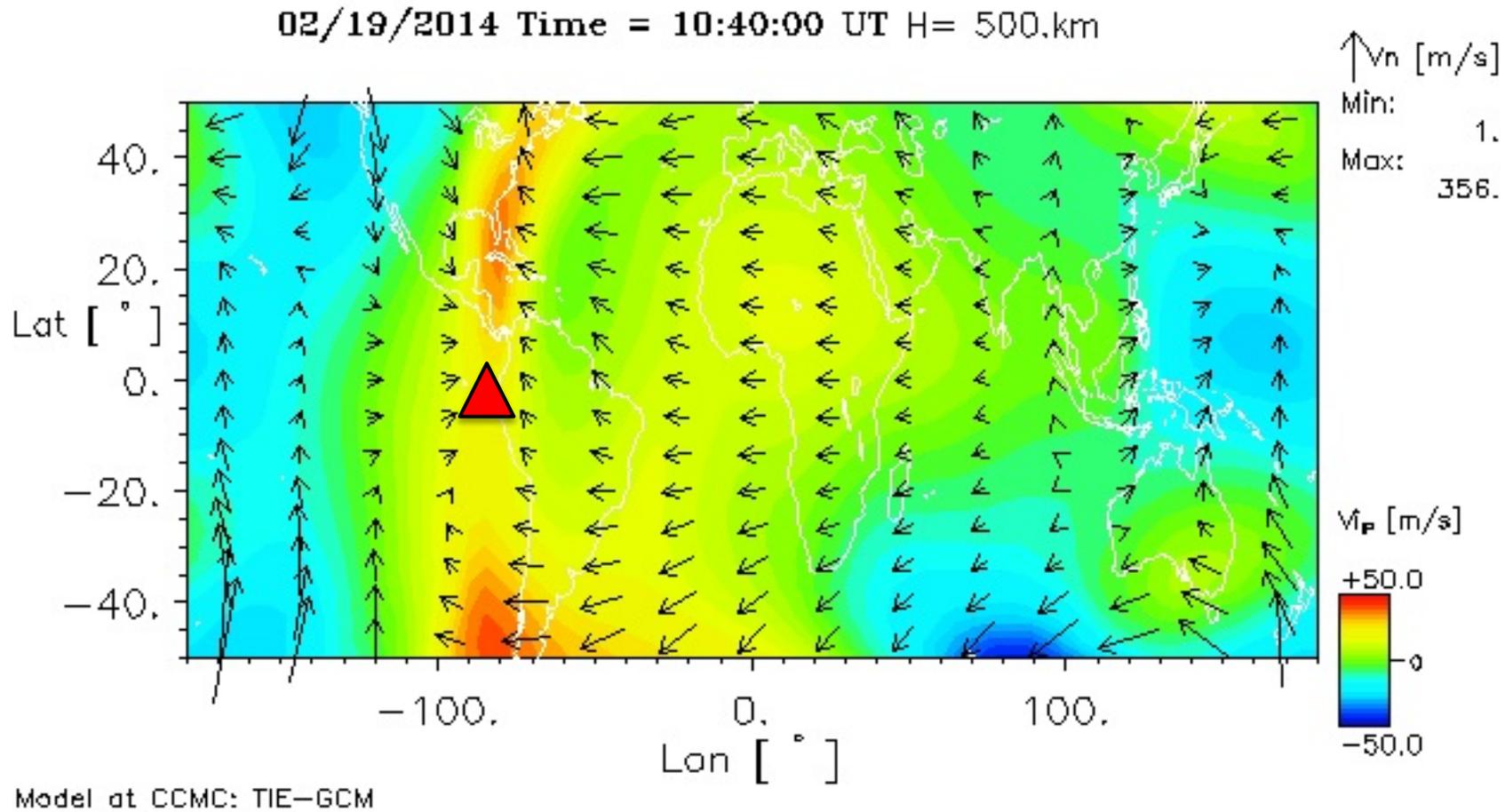


19 Febru



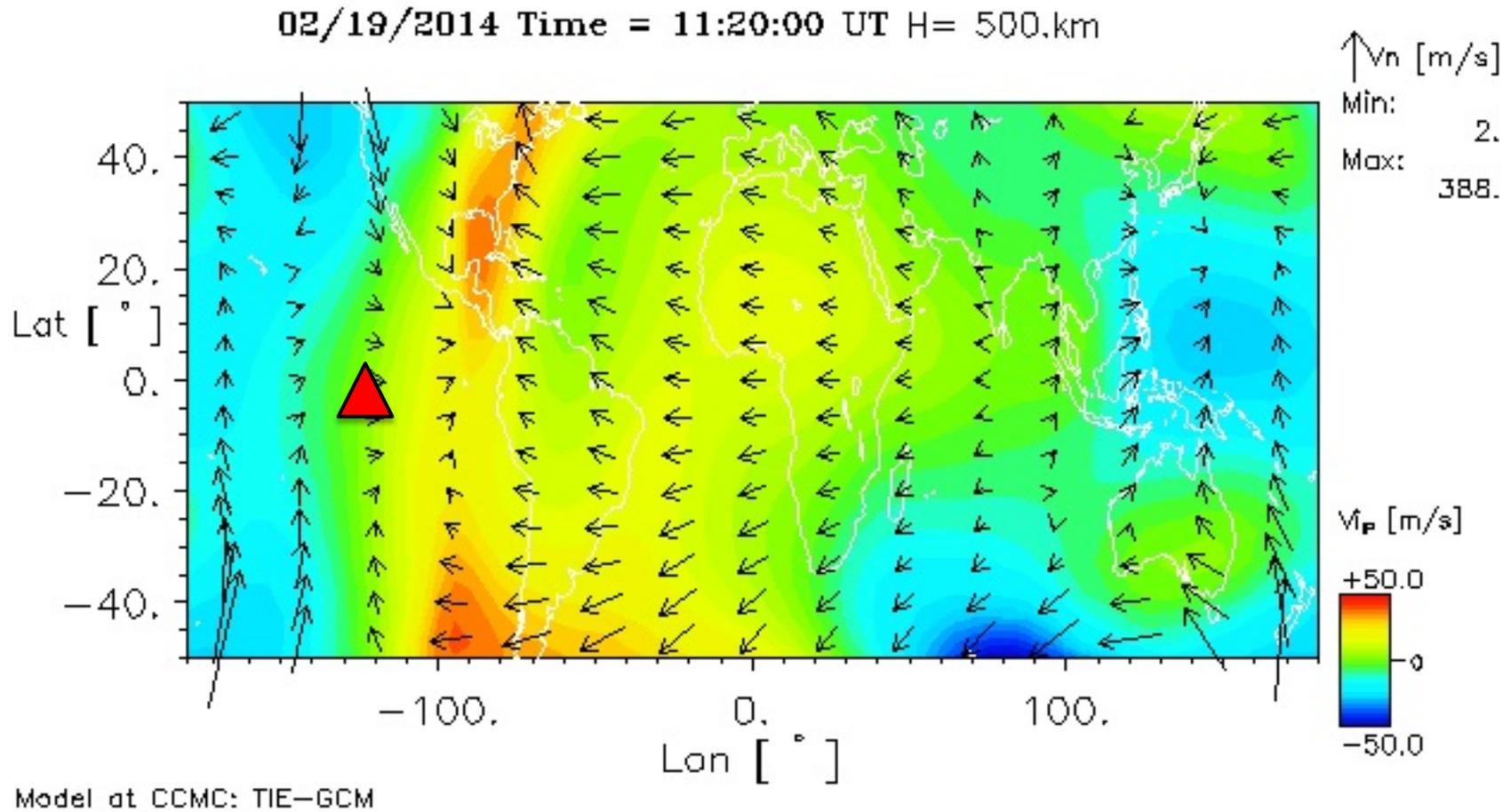
Event #1 - 19/02/2014 - 10:32 UT

TIE-GCM simulations (1)

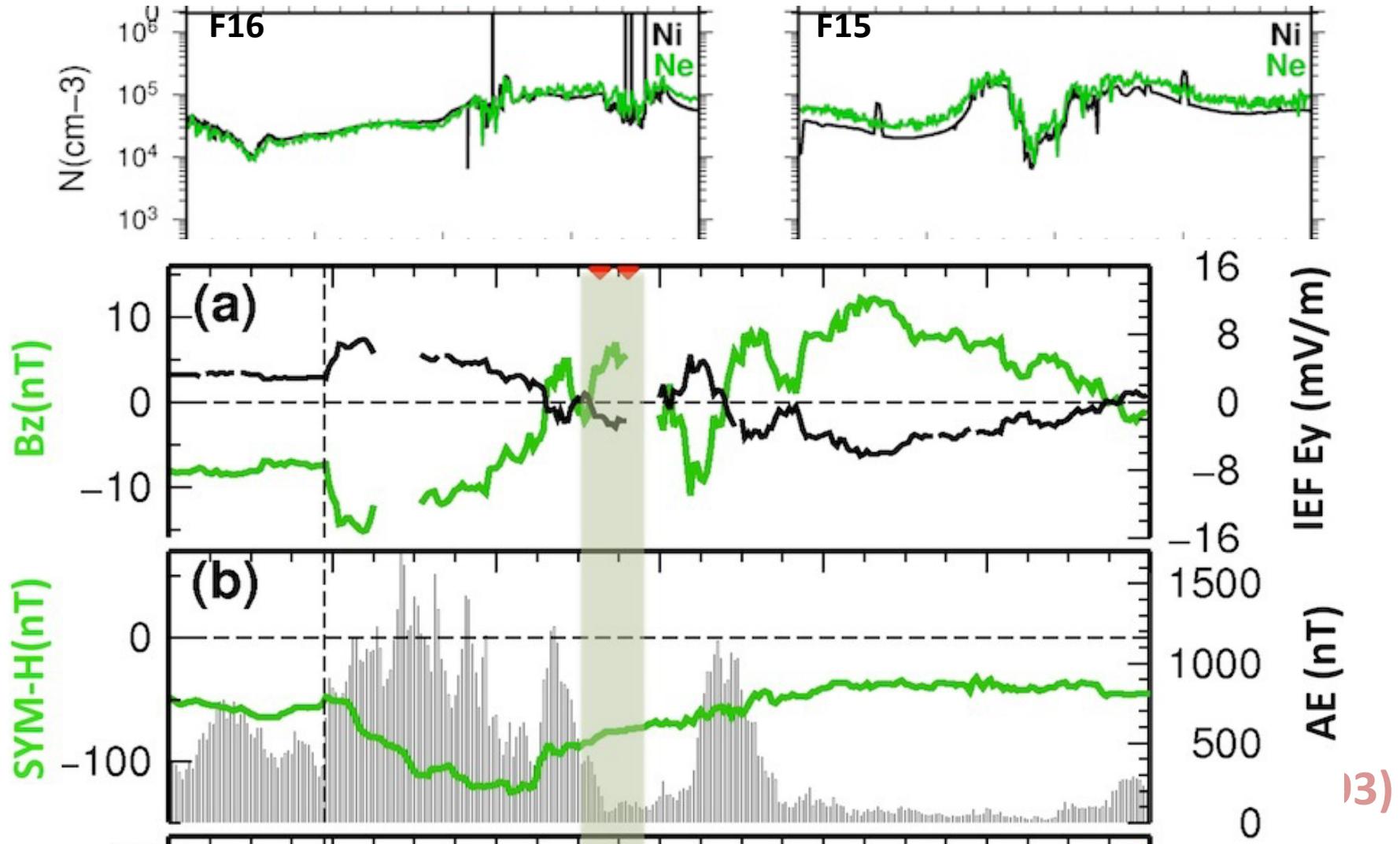


Event #2 - 19/02/2014 - 11:11 UT

TIE-GCM simulations (2)



Supersonic upward plasma drift



LSTIDs from substorms? (Bowman, 1978)

High-speed & supersonic events, 2002-2015

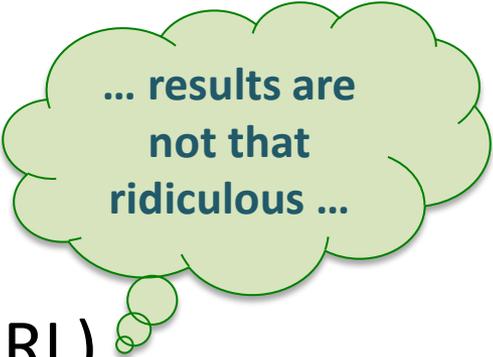
(DMSP, H = 849 ÷ 857 km)



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

} ~storm

Acknowledgement



... results are
not that
ridiculous ...

- 1) J. Huba (NRL)
- 2) M. Hairston & W. Coley & Center for Space Sciences (UTD)
- 3) R. Redmon & W. Denig (NOAA)
- 4) CCMC (<http://ccmc.gsfc.nasa.gov>) for TIE-GCM run

Thank you!





Geophysical Research Letters

RESEARCH LETTER

10.1002/2015GL066369

Key Points:

- First observations of the supersonic upward drift in the early morning sector
- Two supersonic events were detected quasi-simultaneously over the eastern Pacific
- Such events are extremely rare to occur in the early morning sector

Supporting Information:

- Supporting Information S1

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Citation:

Astafyeva, E., and I. Zakharenkova (2015), First detection of the supersonic upward plasma flow structures in the early morning sector, *Geophys. Res. Lett.*, 42, doi:10.1002/2015GL066369.

Received 1 OCT 2015

Accepted 28 OCT 2015

Accepted article online 4 NOV 2015

First detection of the supersonic upward plasma flow structures in the early morning sector

Elvira Astafyeva¹ and Irina Zakharenkova¹

¹Institut de Physique du Globe de Paris, Paris Sorbonne Cité, Paris VII - Denis Diderot University, UMR CNRS 7154, Paris, France

Abstract We present the first observations of the supersonic updrafting plasma drifts in the predawn sector. Two DMSP satellites quasi-simultaneously detected two fast-speed events: one of ~385 km spatial extension and with the maximum upward velocity of 1683 m/s appeared at ~3 LT, and the other of ~1500 km large with maximum speed of 1770 m/s occurred at ~5 LT. Both supersonic structures were observed above the eastern Pacific region, separated by ~35° of longitude in space and by 45 min in time. The events occurred at the recovery phase of the geomagnetic storm of 19 February 2014, during rapid oscillations of the interplanetary magnetic field B_z and the interplanetary electric field E_y components, which increased the eastward electric field in the equatorial nighttime ionosphere and triggered the generation of plasma irregularities. The storm time penetration electric fields seem to be the principal driver of the observed supersonic events.

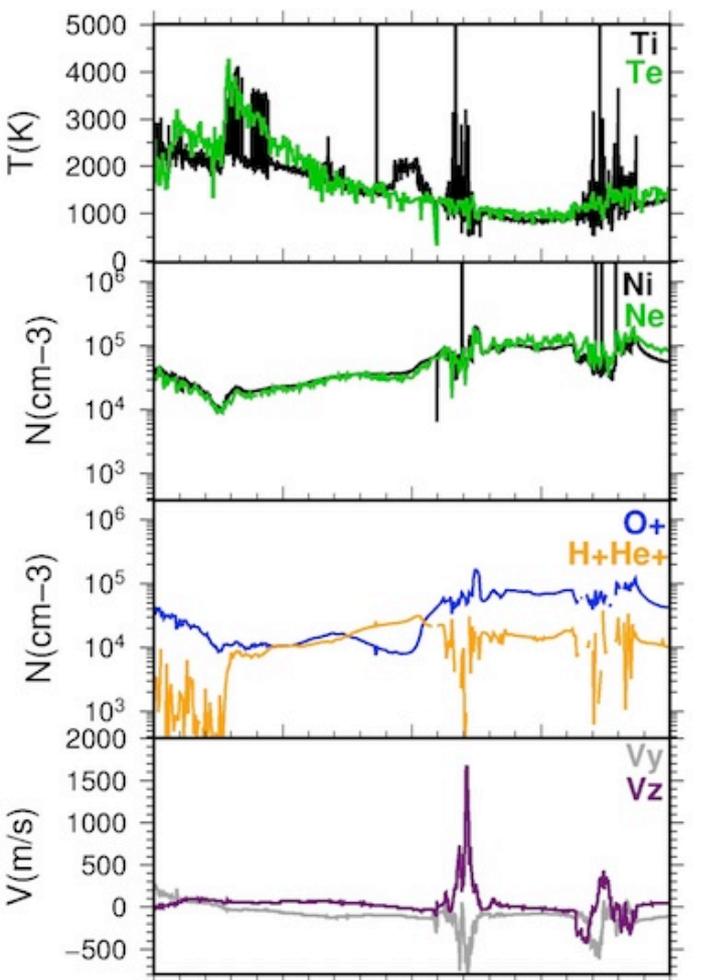
1. Introduction

Irregularities in the ionospheric plasma density, also known as ionospheric irregularities, often cause amplitude and phase scintillations of radio waves and, consequently, can seriously disrupt the radio-based communication [e.g., Basu et al., 2008; Demyanov et al., 2012; Astafyeva et al., 2014; Kelly et al., 2014]. 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 $E \times B$ instability, is the main cause of generation of large-scale density depletions at the bottom of the F layer, which can further rise as high as 1000 km [Woodman and La Hoz, 1976; Ott, 1978; Fejer et al., 1999; Burke et al., 2003].

Contrary to the postsunset ionospheric irregularities and plasma bubbles that occur quite often after sunset, the postmidnight events are rare to observe [e.g., Burke et al., 2009; Yokoyama et al., 2011; Huang et al., 2013; Yizengaw et al., 2013]. Even more rare events are occurrences of intensive ionospheric irregularities and/or plasma bubbles in the predawn sector. Those were occasionally observed at the recovery phase of magnetic storms [e.g., Yeh et al., 2001; Li et al., 2012; Zakharenkova and Astafyeva, 2015; Zakharenkova et al., 2015].

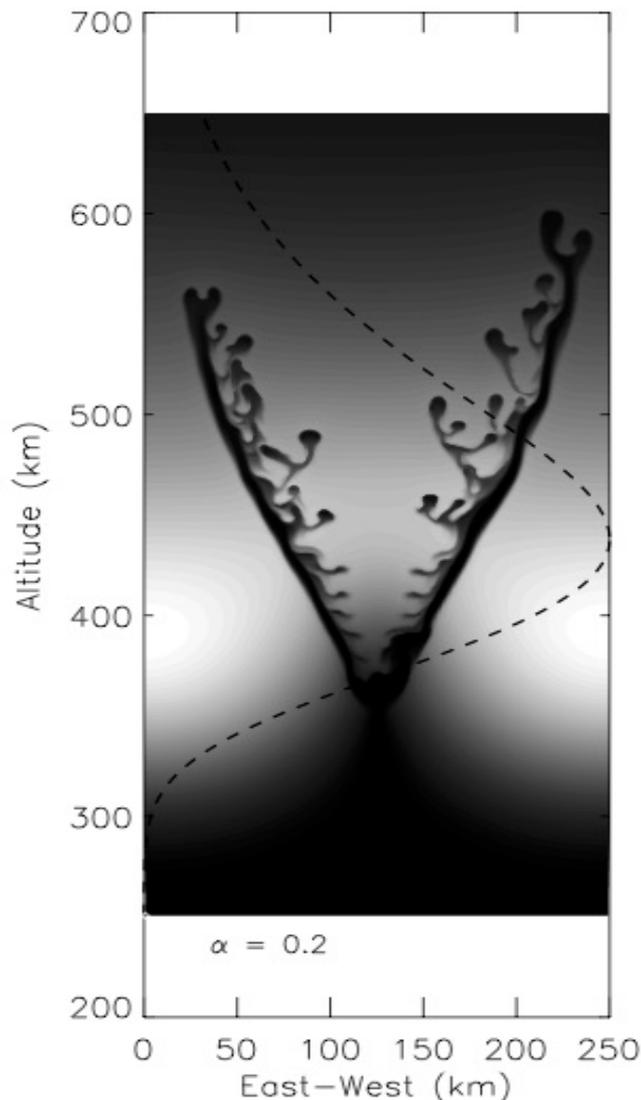
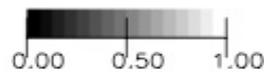
Case-study: DMSP F15, F16, F17

(a) DMSP F16

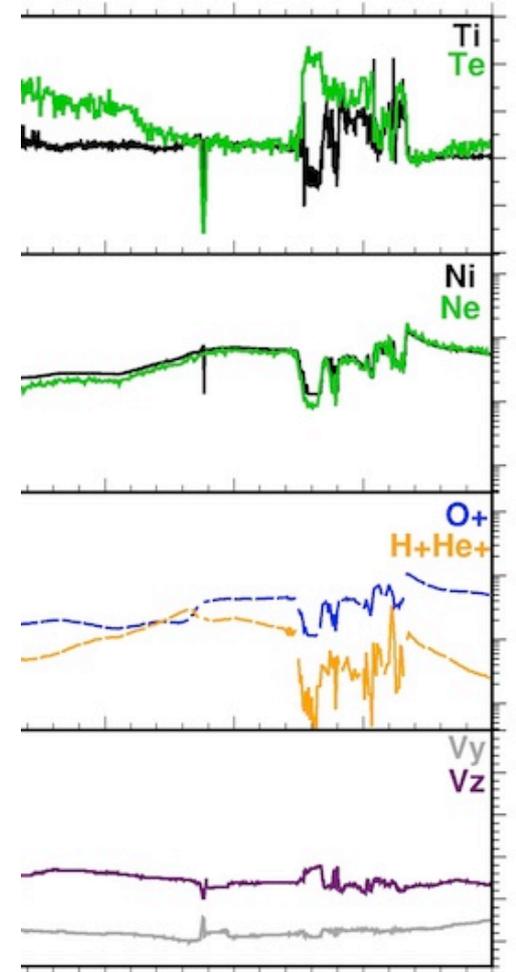


| | | | | | |
|------|--------|--------|--------|--------|--------|
| UT | 10.3 | 10.4 | 10.5 | 10.6 | 10.7 |
| LT | 5.54 | 5.22 | 4.99 | 4.77 | 4.49 |
| Glon | 288.68 | 282.32 | 277.39 | 272.63 | 266.98 |
| Glat | 45.41 | 24.54 | 3.52 | -17.52 | -38.44 |
| Mlat | 56.51 | 37.10 | 15.96 | -6.56 | -28.47 |

Density
t = 2179 s

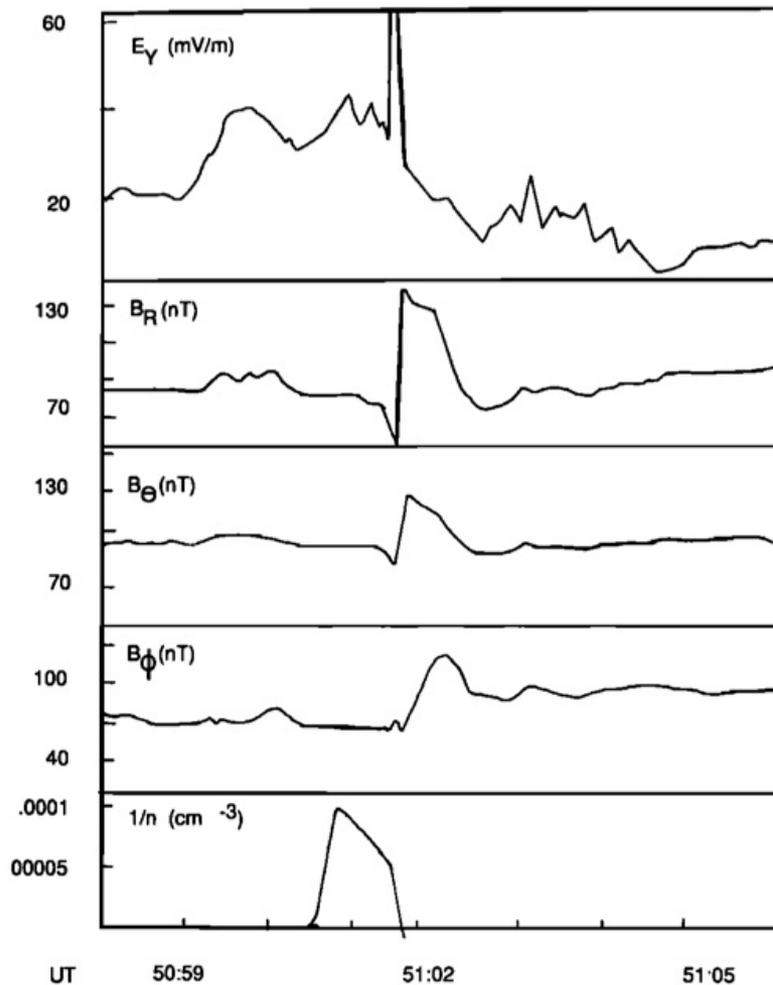


(c) DMSP F17

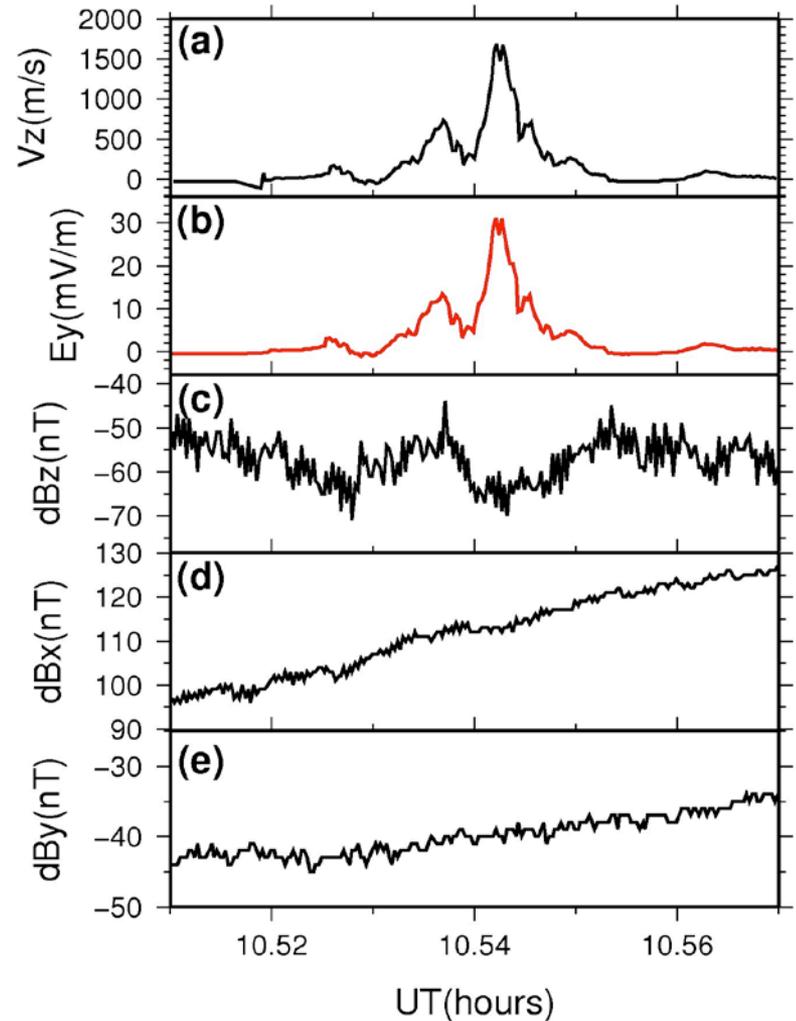


| | | | | |
|------|--------|--------|--------|--------|
| UT | 11.4 | 11.5 | 11.6 | 11.7 |
| LT | 6.12 | 5.90 | 5.66 | 5.31 |
| Glon | 280.85 | 276.02 | 270.93 | 264.17 |
| Glat | 15.64 | -5.43 | -26.45 | -47.27 |
| Mlat | 28.36 | 6.52 | -15.97 | -37.39 |

Aggson et al. (1992)



Our event (F16)



triaxial fluxgate magnetometer onboard DMSP F16 (not available for the DMSP F15).

TIE-GCM simulations

