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

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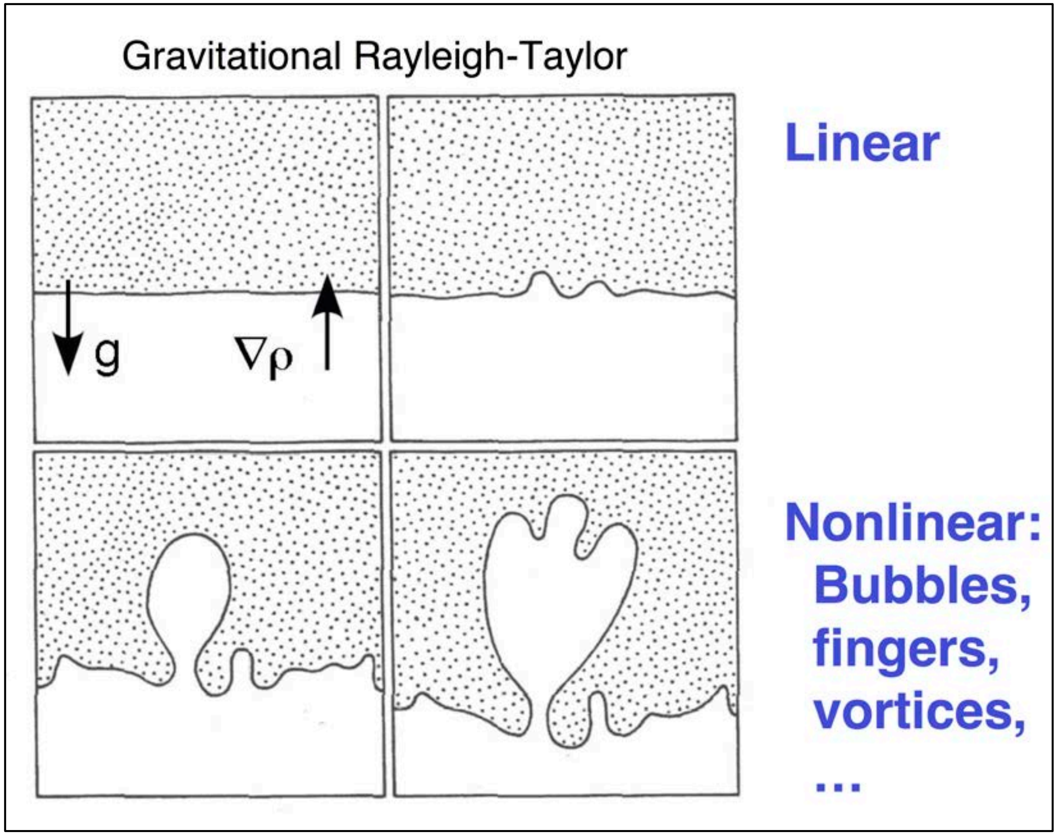
Beacon Satellite Symposium 2016

Defense Meteorological Satellite Program (DMSP)

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

Equatorial Plasma Bubbles/Drift

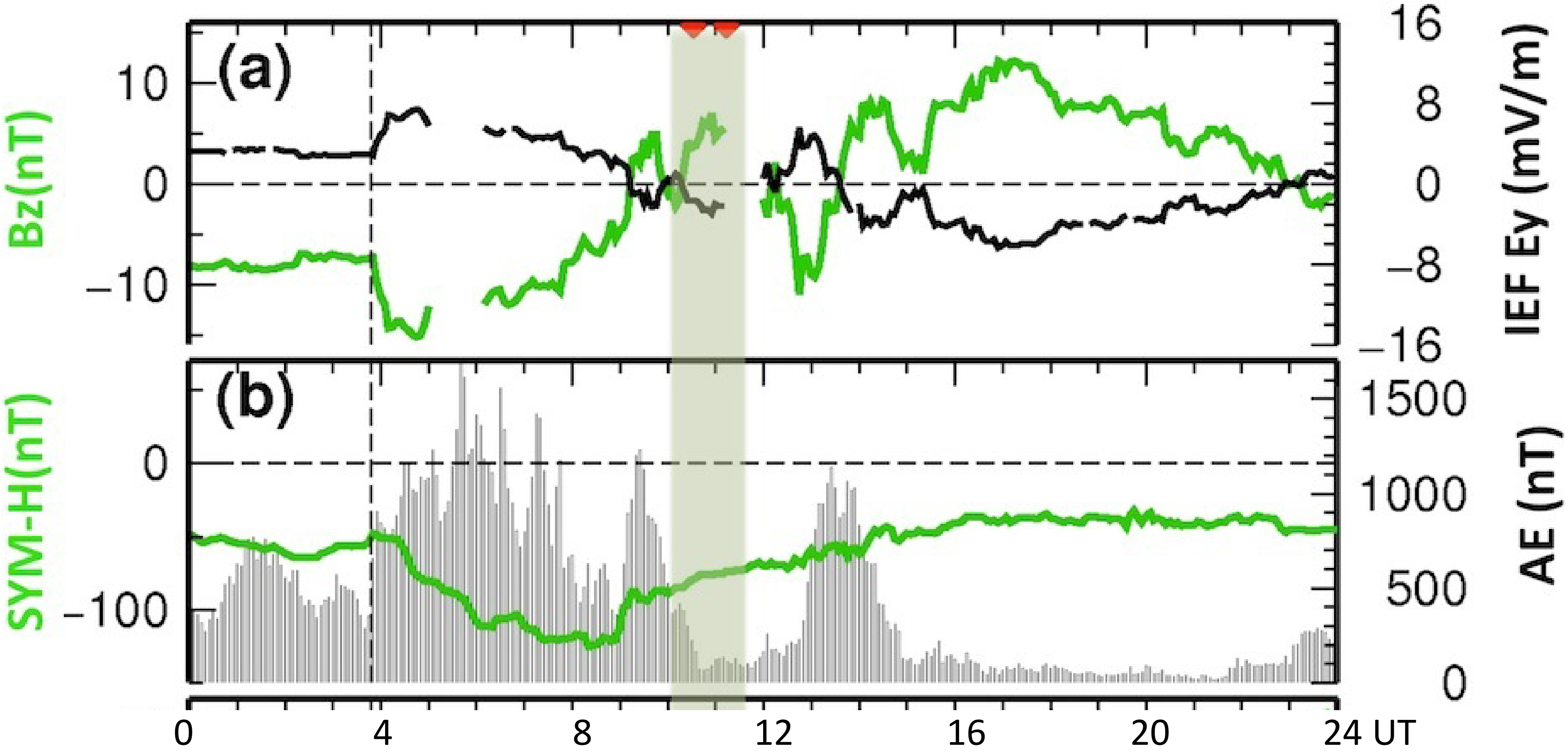
- Post-Sunset sector + occasionally elsewhere
- Pre-dawn – at the recovery phase of geom. storms



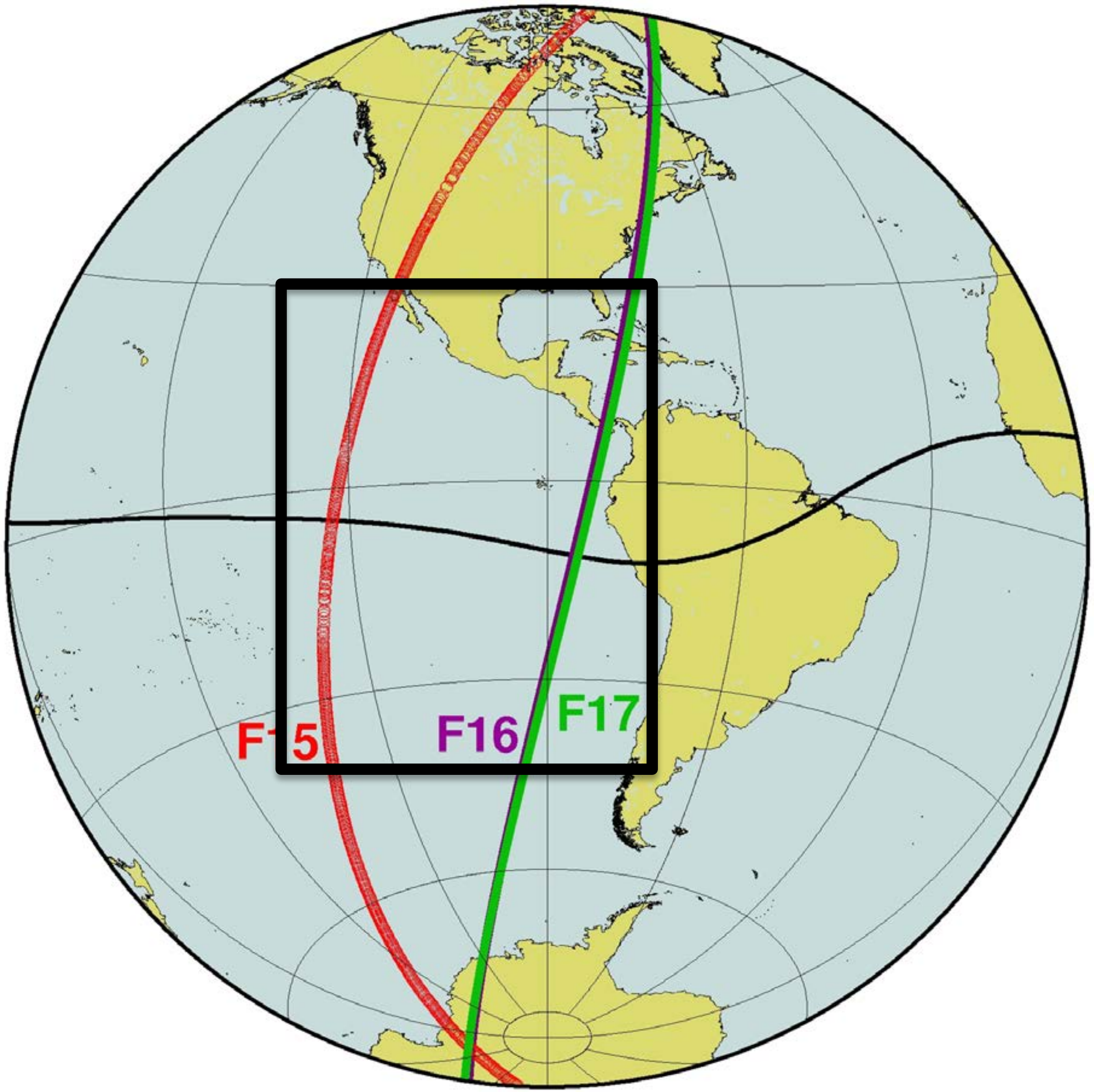
Background plasma drift : ~100-150 m/s ------ Inside bubbles: ≤~800 m/s

Primary aim: pre-dawn irregularities & geom. storms

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



19 February 2014 : (~10.3-11.7 UT)

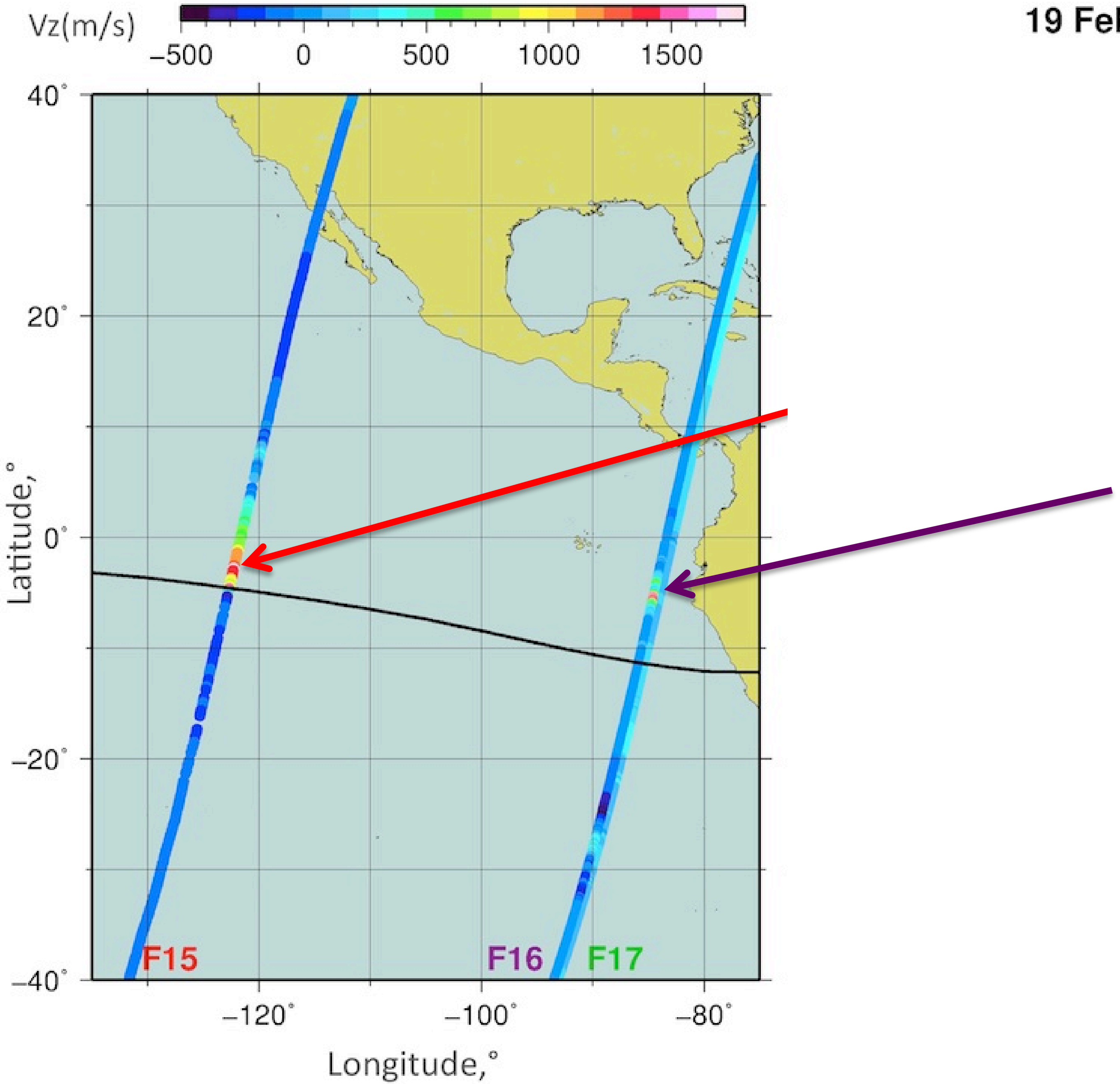


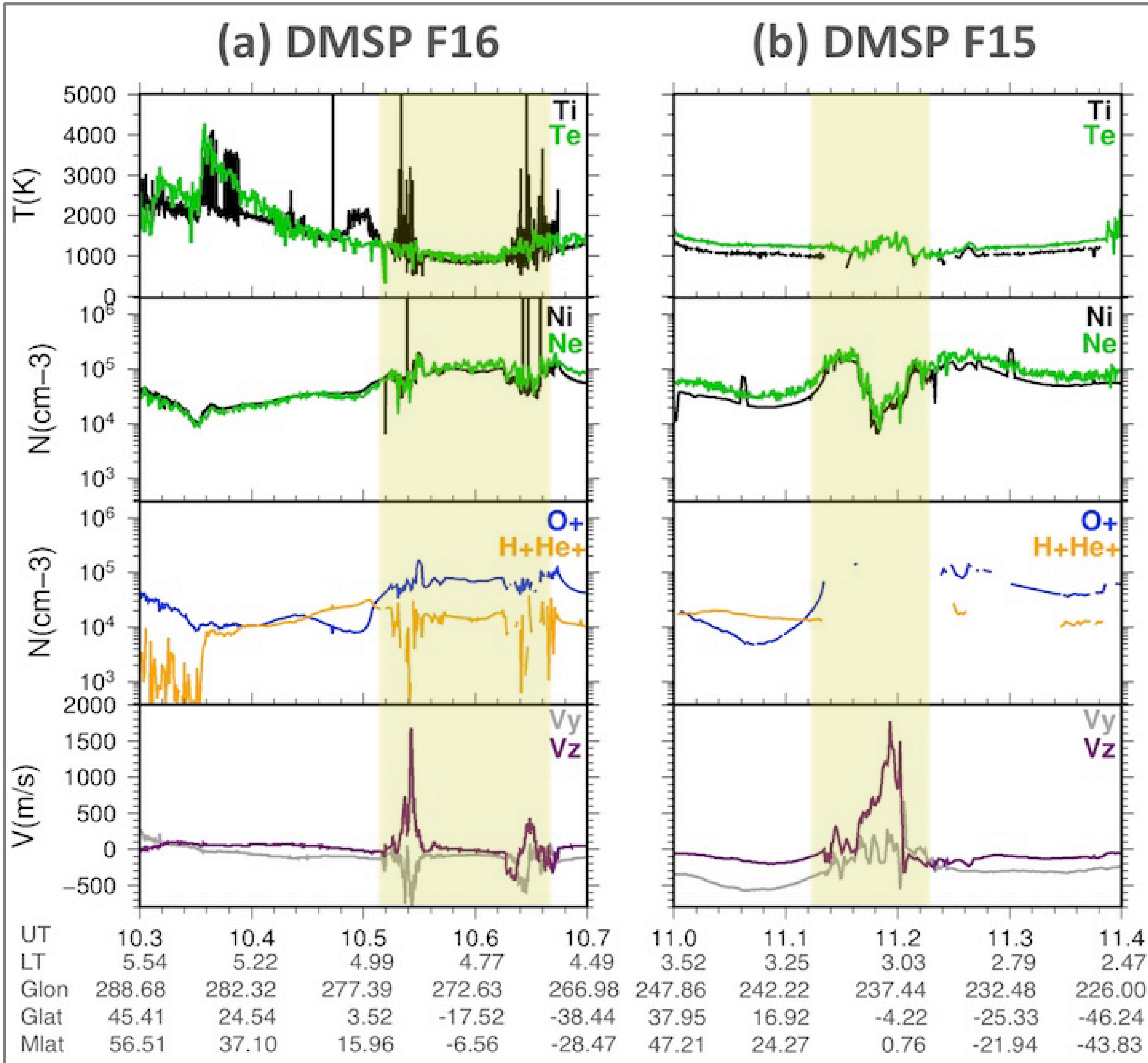
F16 – 10.55UT – 4.79LT

F15 – 11.17UT – 3.04LT

F17 – 11.42UT – 5.90LT

19 February 2014





Astafyeva and Zakharenkova (GRL, 2015)

Sub/Super/Hyper – sonic ?

- Subsonic: V<Cs
- Supersonic: V>Cs (Mach>1.2)
- Hypersonic: V>>Cs (Mach>5)

Ion Sound Velocity (O^+):

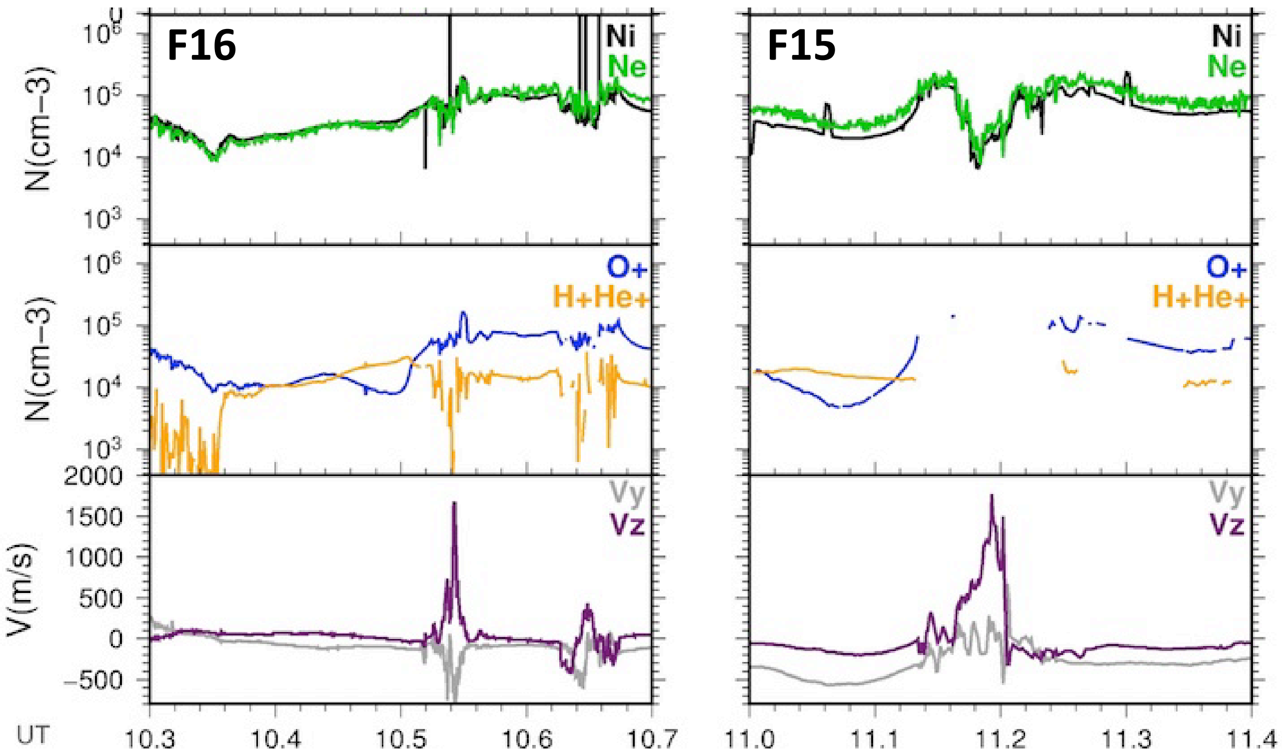
$$C_s = \sqrt{\frac{\gamma Z k T_e}{m_i}} = 9.79 * 10^5 \sqrt{\frac{\gamma Z T_e}{\mu}}$$

Can this be REAL??

	Date	Location (G[illegible] G[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Vz-max (m/s)	Te (K)	Cs (m/s)
#1	19/02/2014	275.3[illegible]	[illegible]	4.79	855	F16	1638.2	1290	1053
#2	19/02/2014	237.72, -2.80	11.19	3.04	835	F15	1770.6	1220	1022

DMSP data quality & reliability

- ☑ 1) high-density plasma, i.e. $N_i > 10^3$ ions/m^3
- ☑ 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. SABA[4]

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

Huba & Joyce (2007)

up to ~1.9 km/s

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. Huba[1] and G. Joyce[2]

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

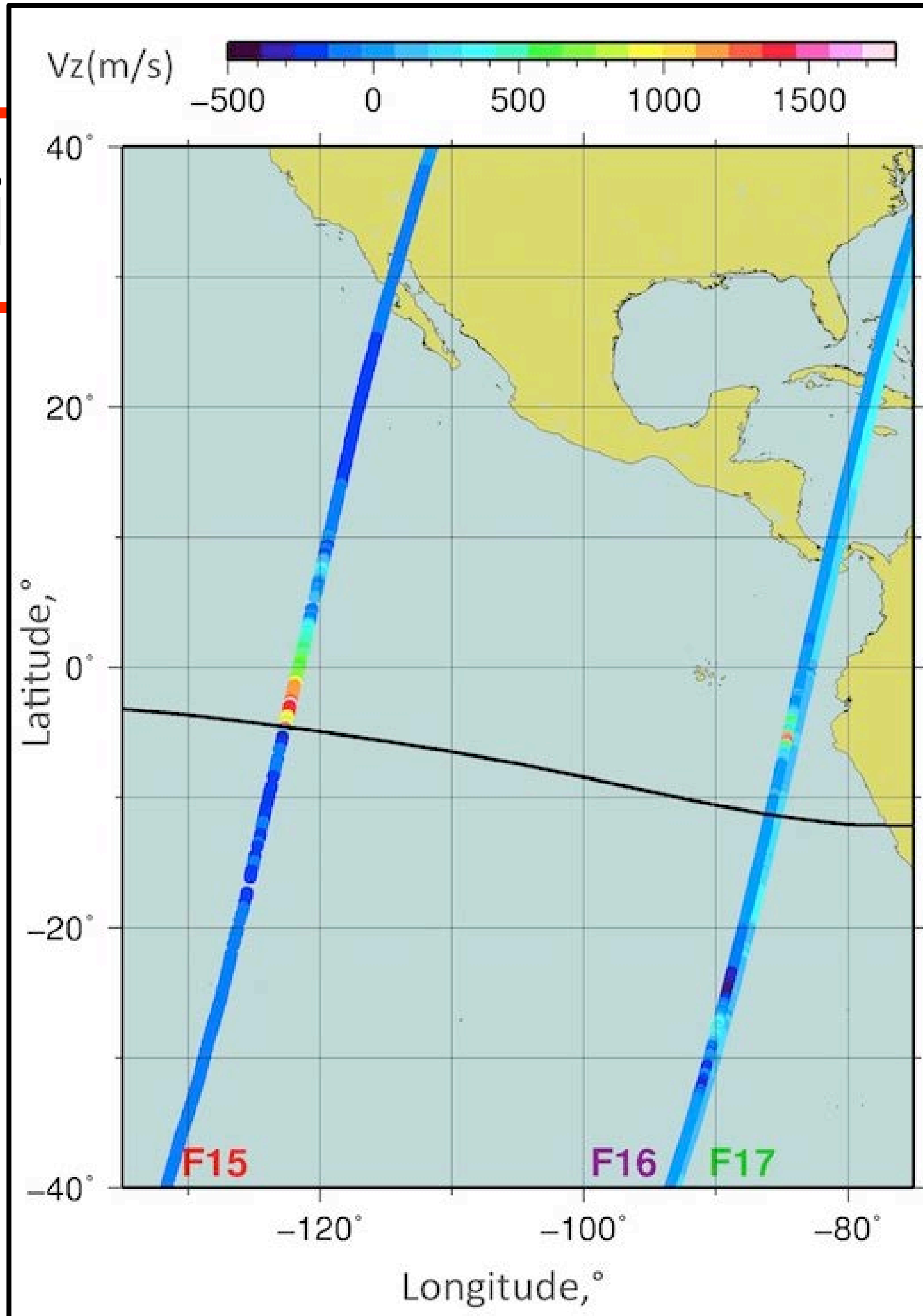
[1] The Naval Research Laboratory has recently developed a new two-dimensional code to study equatorial spread *F* (ESF): NRLESF2. The code uses an 8th order spatial interpolation scheme and the partial donor cell method. This allows the model to capture very sharp gradients over ∼ 4 grid cells and to 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

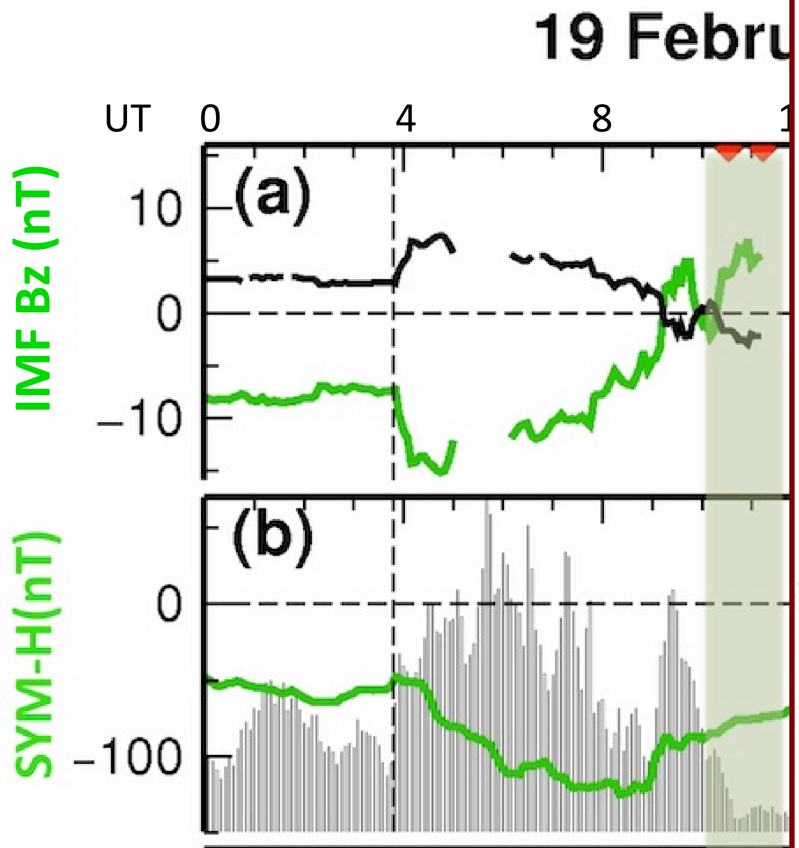
references therein]. These numerical studies have shed light on a number of processes affecting the evolution of ESF: the role of a conducting *E*-layer, an inhomogeneous neutral wind, seeding conditions, molecular ions, and the interaction of multiple bubbles. Despite the progress made by these studies 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

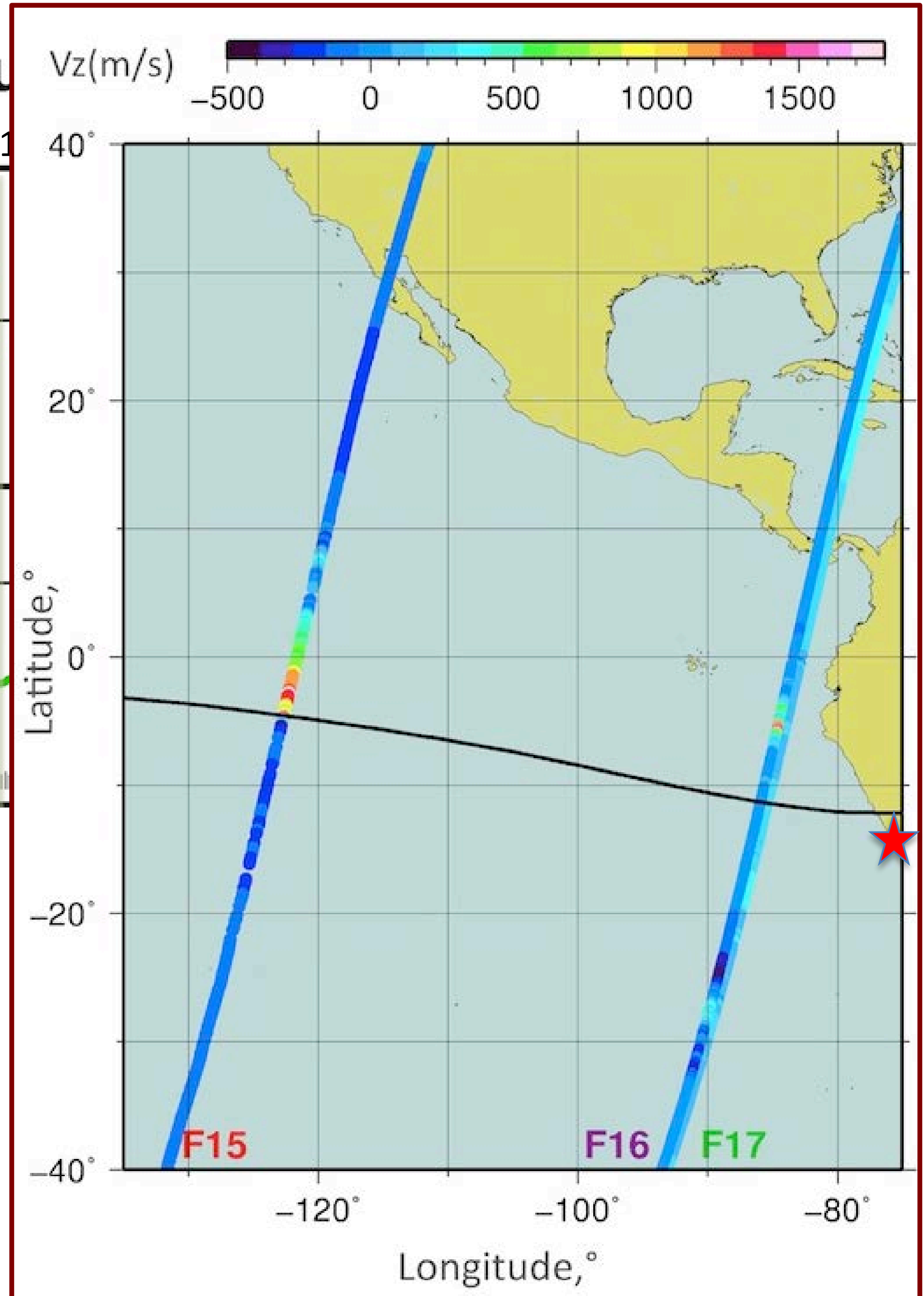
BUT… only in the post-sunset sector!

The Mai URCE?


Vz(m/s)
−500
0
500
1000
1500
40°
20°
0°
−20°
−40°
Latitude,°
−120°
−100°
−80°
Longitude,°
F15
F16
F17



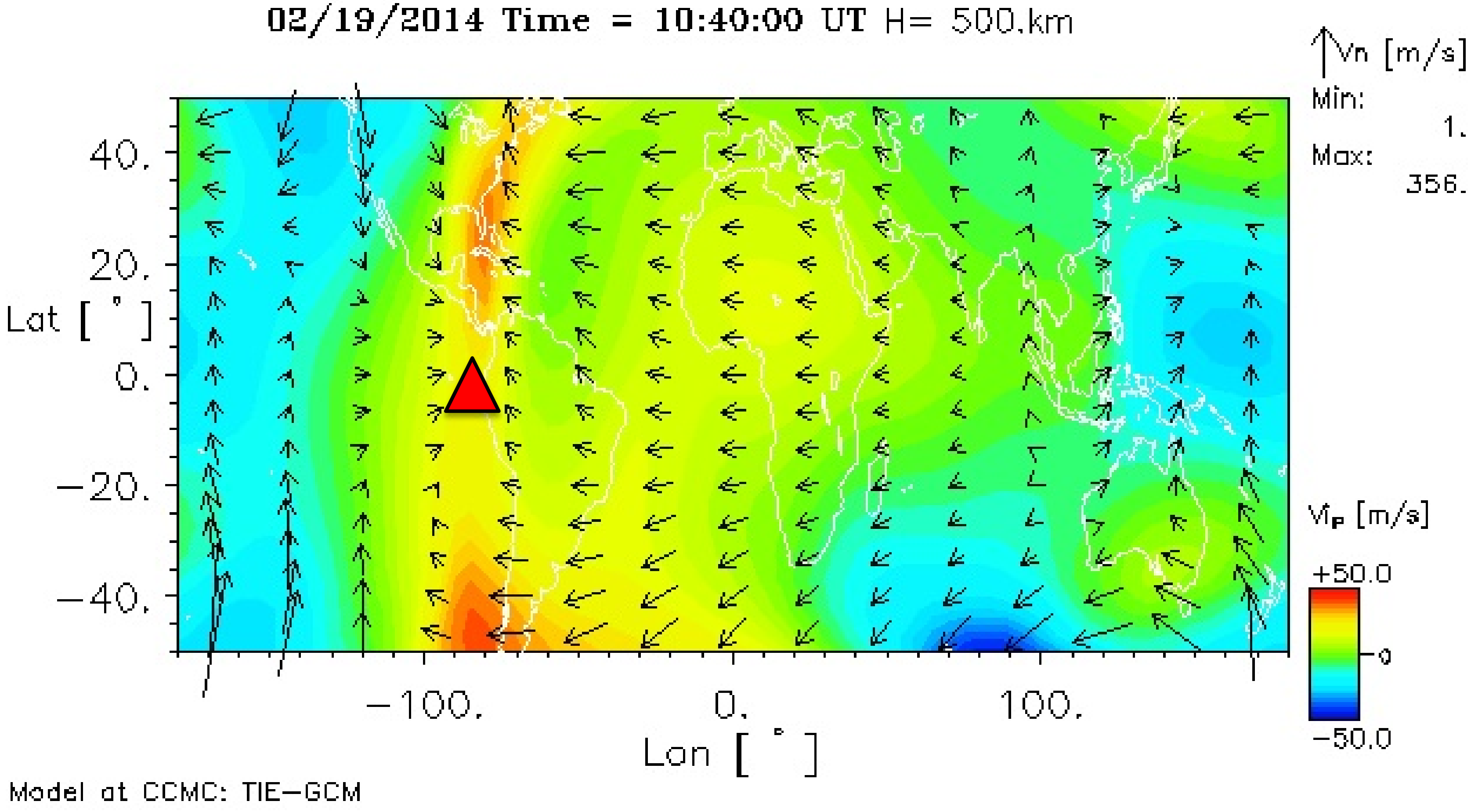
19 Febru
UT 0 4 8
(a)
IMF Bz (nT)
10
0
−10
(b)
SYM-H(nT)
0
−100



Vz(m/s)
−500 0 500 1000 1500
40°
20°
0°
−20°
−40°
Latitude,°
−120°
−100°
−80°
Longitude,°
F15
F16
F17

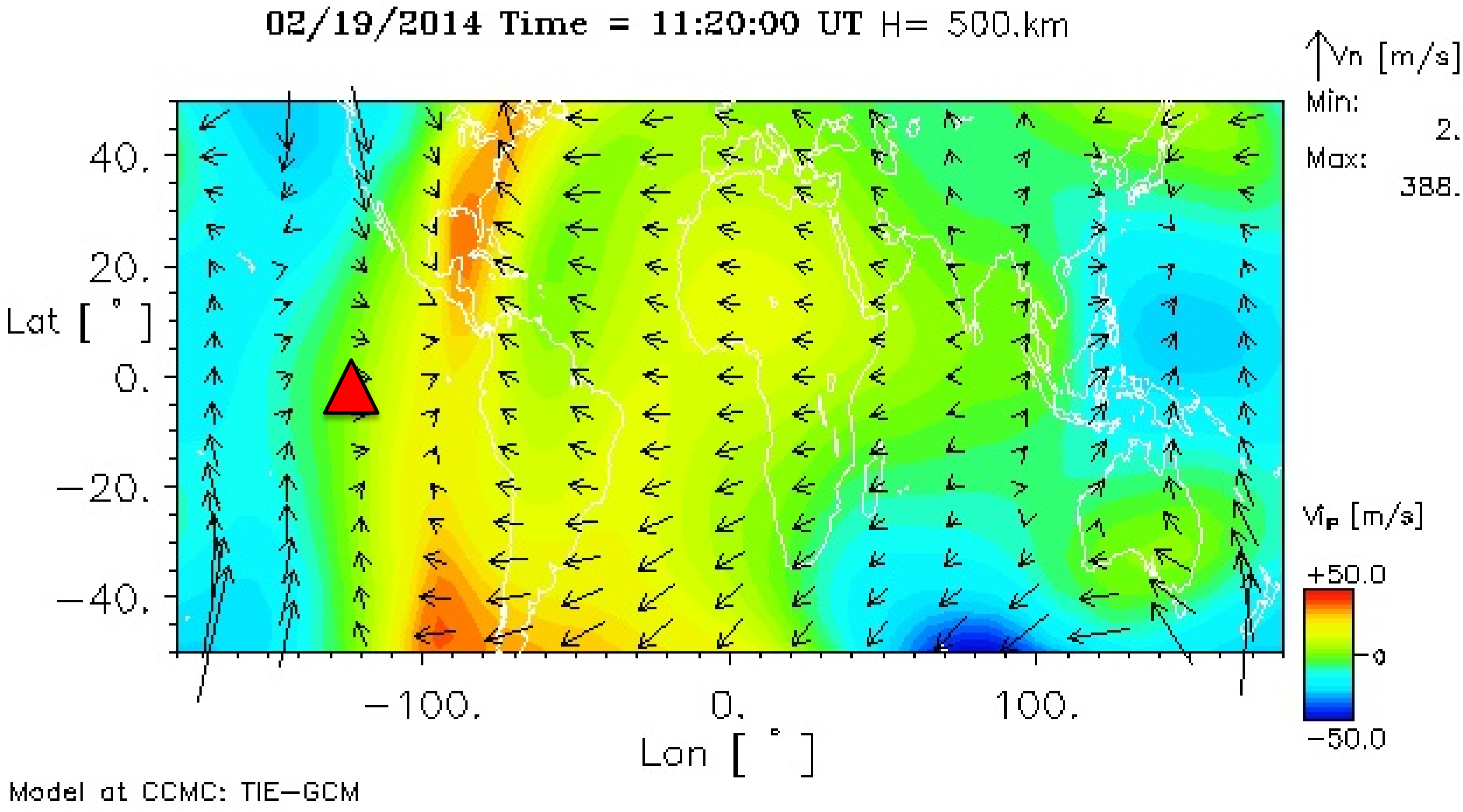
TIE-GCM simulations (1)

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

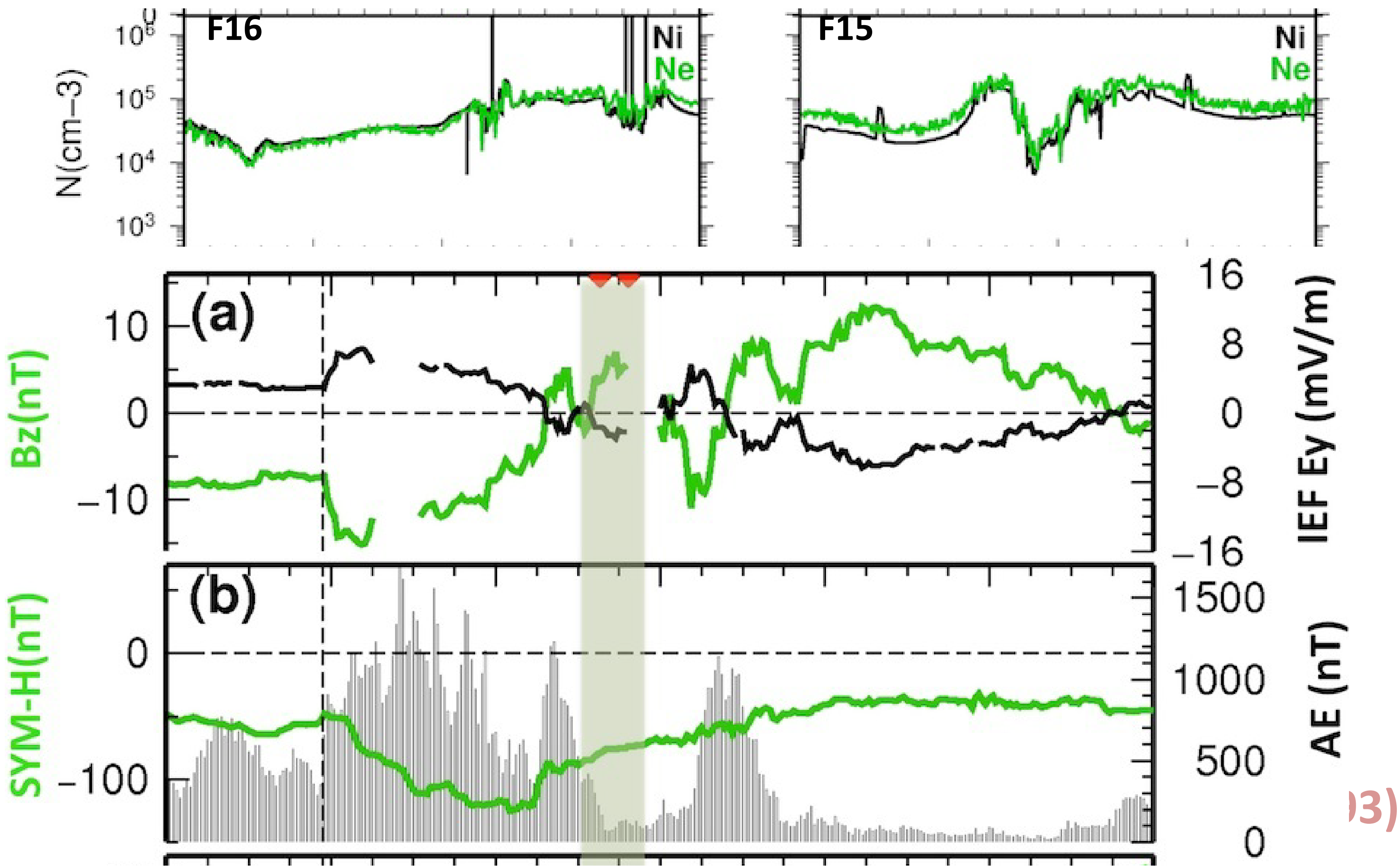


TIE-GCM simulations (2)

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



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!

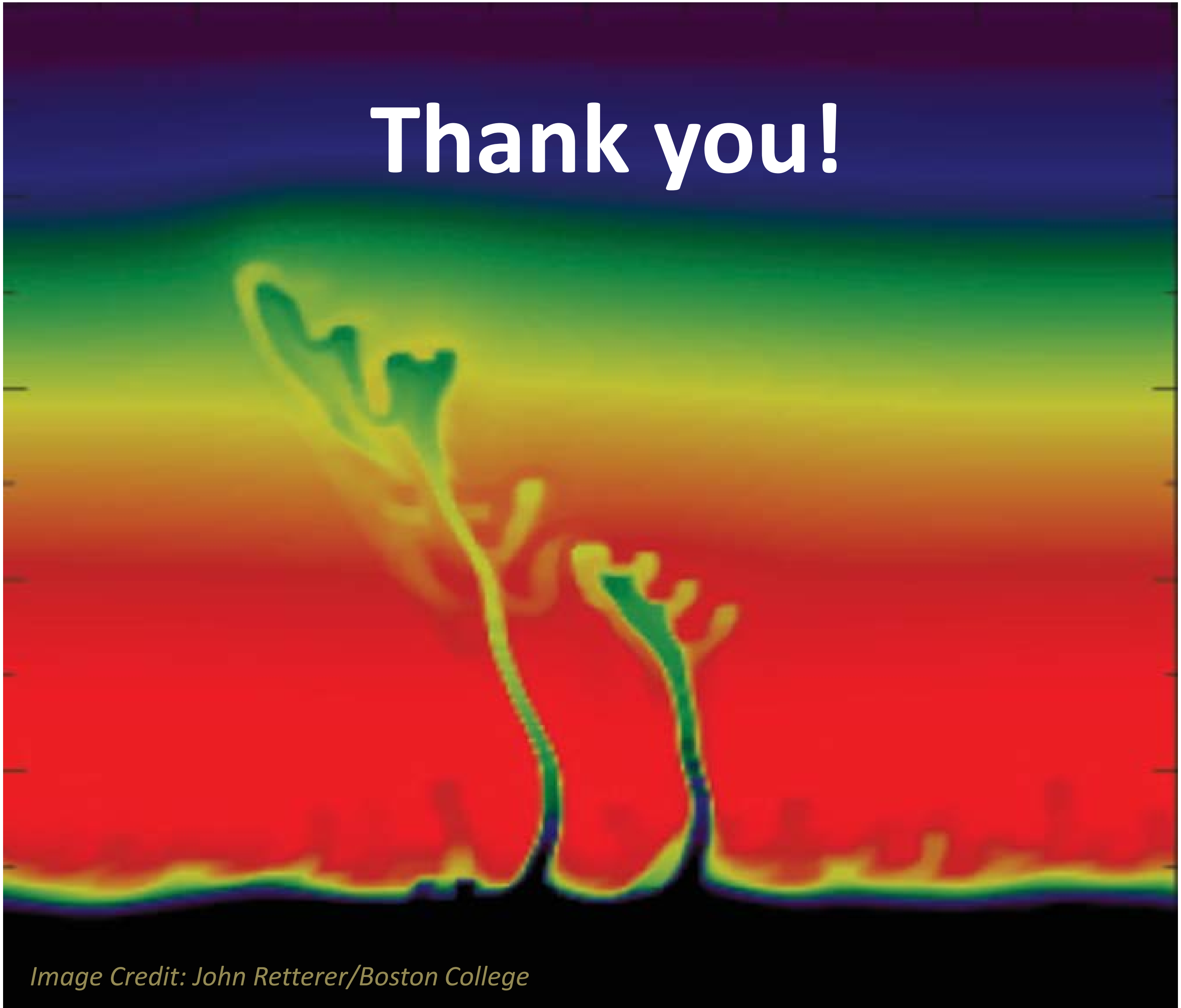


Image Credit: John Retterer/Boston College

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

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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

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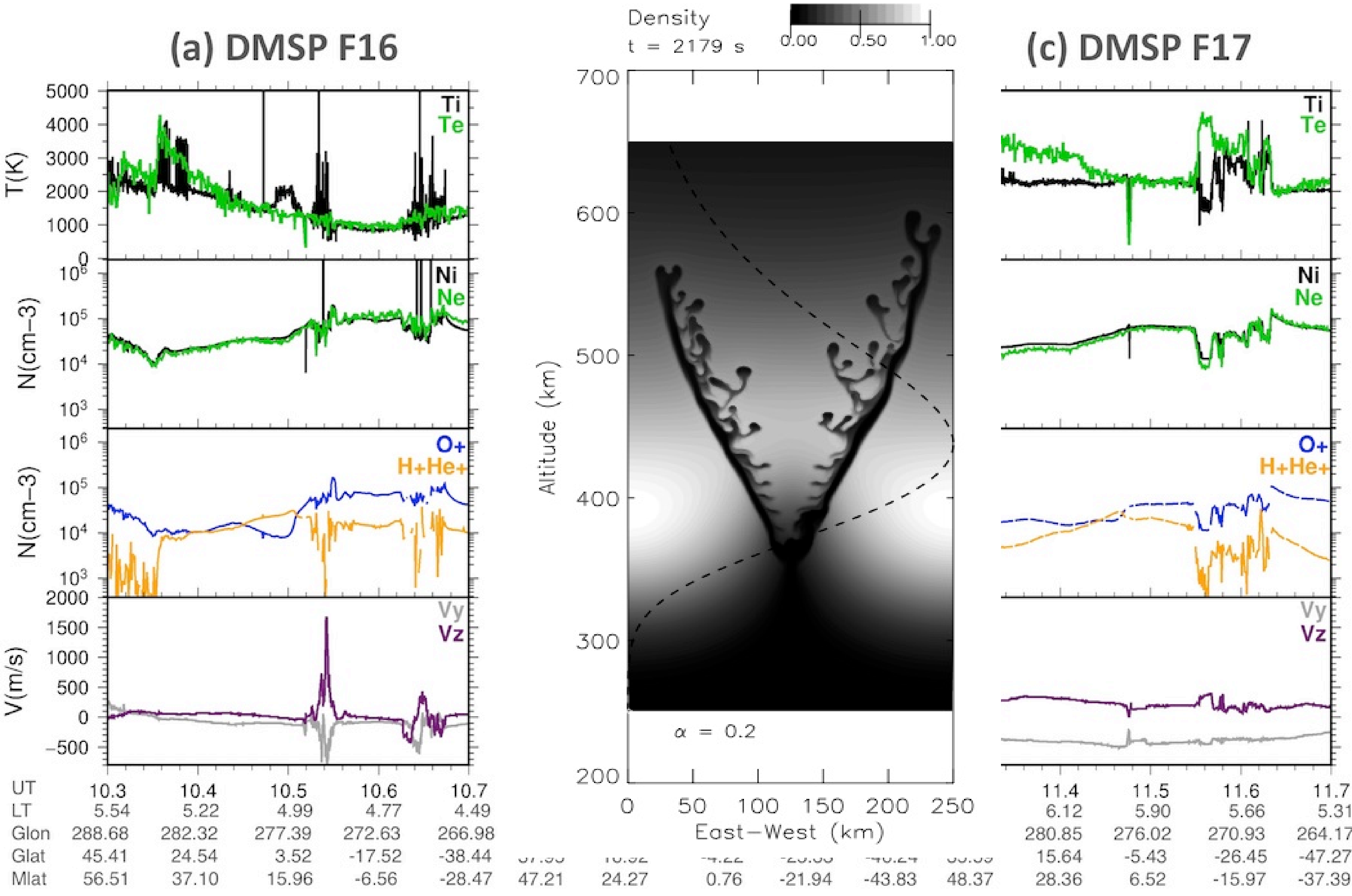
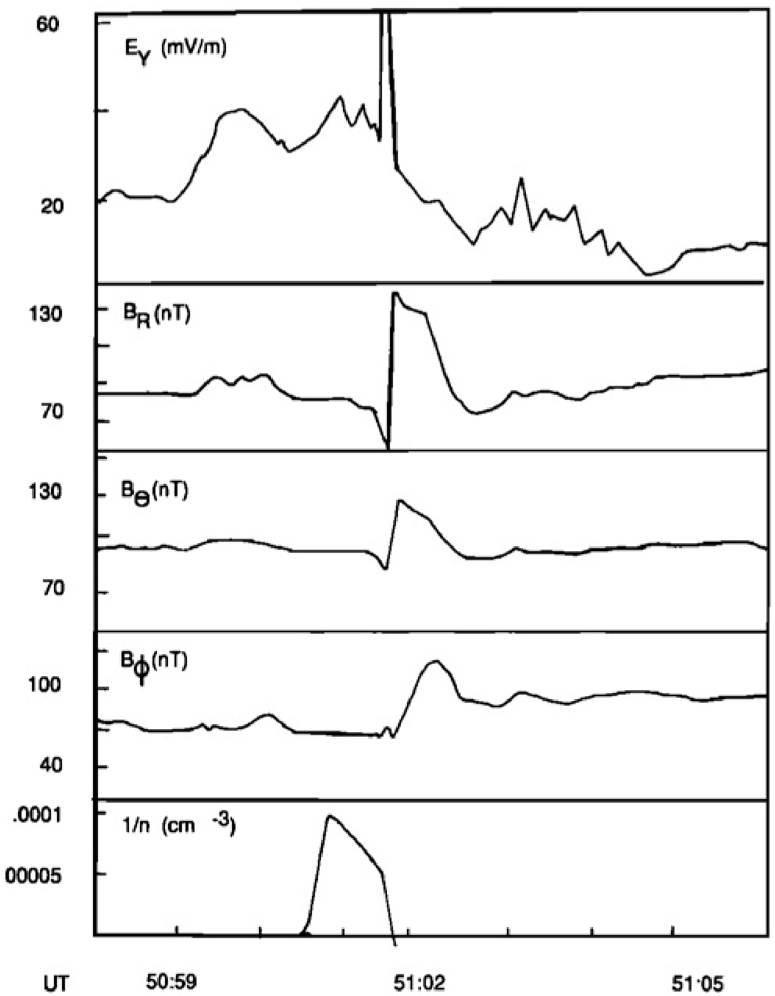
DMSP – « fast equatorial post-sunset bubbles » (Hanson et al., JGR, 1997)

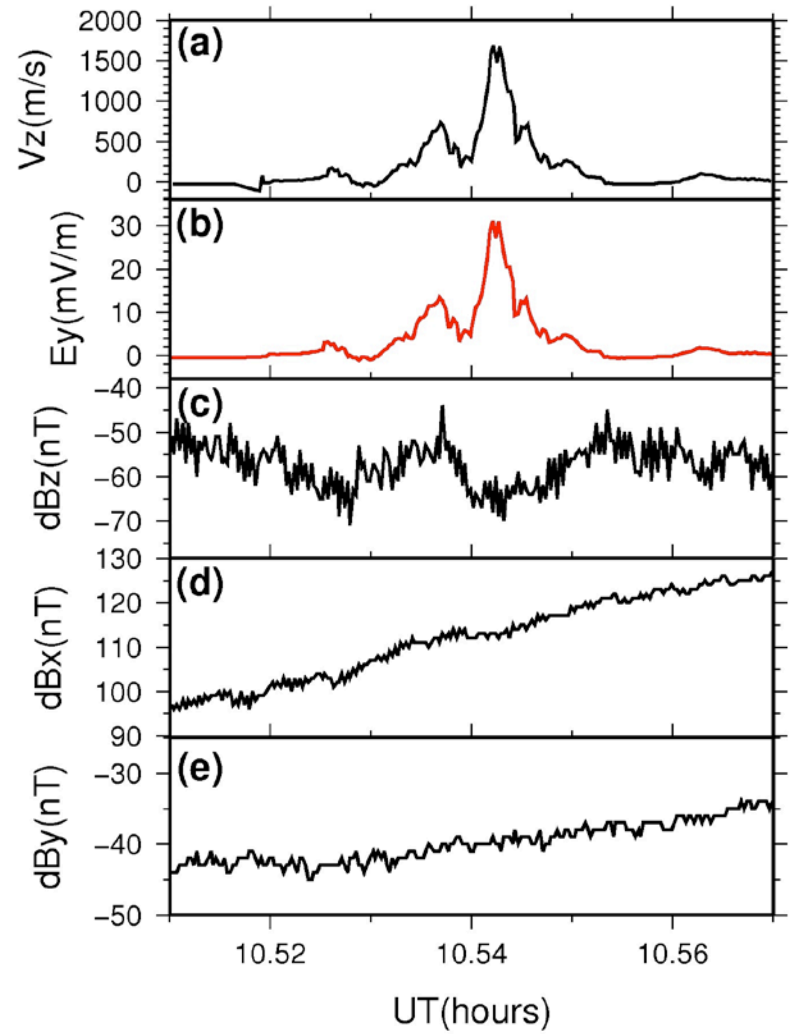
Case-study: DMSP F15, F16, F17



Aggson et al. (1992)



Our event (F16)



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

TIE-GCM simulations