

DEMETER Observations of Highly Structured Plasma Density and Associated Electric Field and Magnetic Field Irregularities at Middle and Low Latitudes

R. Pfaff, C. Liebrecht
NASA/Goddard Space Flight Center

J.-J. Berthelier, M. Malingre
CETP, Saint Maur, France

M. Parrot
LPCE, Orleans, France

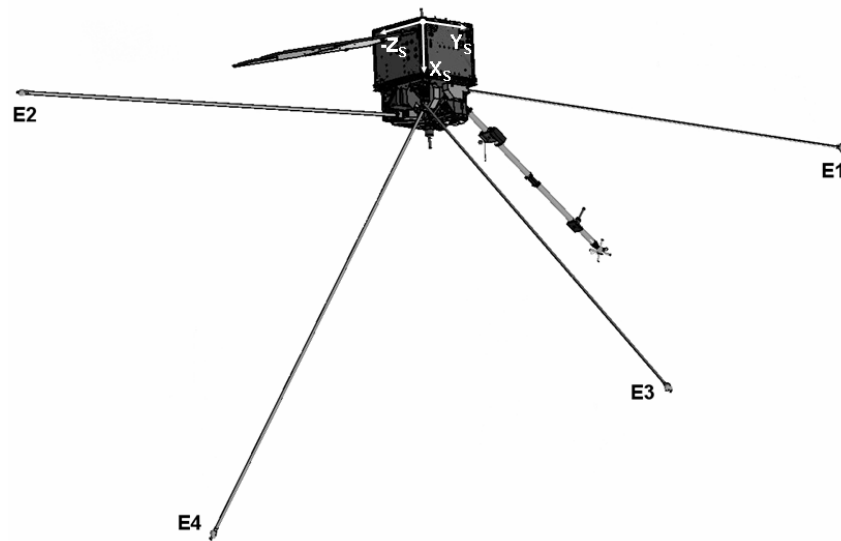
J.-P. Lebreton
ESA, Noordwijk, Netherlands

URSI
Chicago, Illinois,

12 August 2008

DEMETER, the first CNES micro-satellite

Orbit: $\sim$ circular at ~ 710 km, 98° inclination
quasi helio-synchronous, local time $\sim 10:30$ and $22:30$ at low latitudes
Orientation: X nadir, S/C velocity along -Z



Each boom arm is 4 m long.

DEMETER SCIENTIFIC PAYLOAD

5 Scientific Instrument Packages

ICE, Electric Field instrument (double probes)

IAP, Thermal Ion Analyzer (RPA and ion drift meter)

IMSC, Magnetic antenna (tri-axial search coil)

ISL, Langmuir Probe (swept)

IDP, Energetic Particle Detector (70 keV to 2.5 MeV electrons)

Fields Data in Survey Mode

Electric Field: 3 ULF waveform (DC - 15 Hz), 1 VLF (15 Hz - 20 kHz), 1 HF (10 kHz - 3.175 MHz)

Magnetic Field: 1 VLF (15 Hz – 20 kHz)

Fields Data in Burst Mode

Electric Field: 3 ULF waveform (DC - 15 Hz), 3 ELF waveform (15 Hz - 1 kHz), 1 VLF (15 Hz - 20 kHz)

Magnetic Field: 3 ELF waveform (15 Hz – 1 kHz), 1 VLF (15 Hz – 20 kHz)

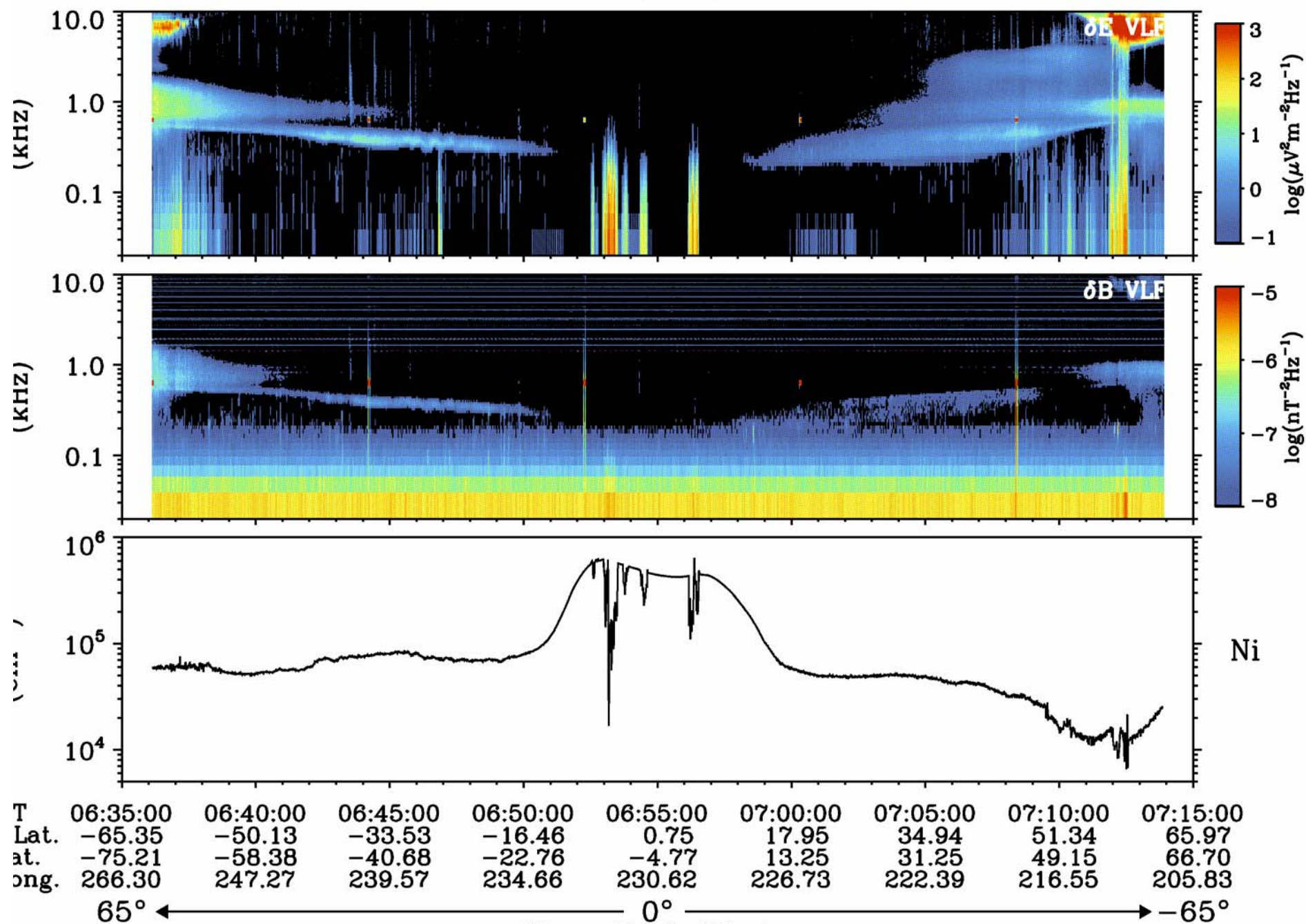
Plasma density, temperature, ion drifts:

Ne, Te: 1 sec resolution

Ni, Ti, Vi: 2.3 sec (survey), 0.360 sec (burst)

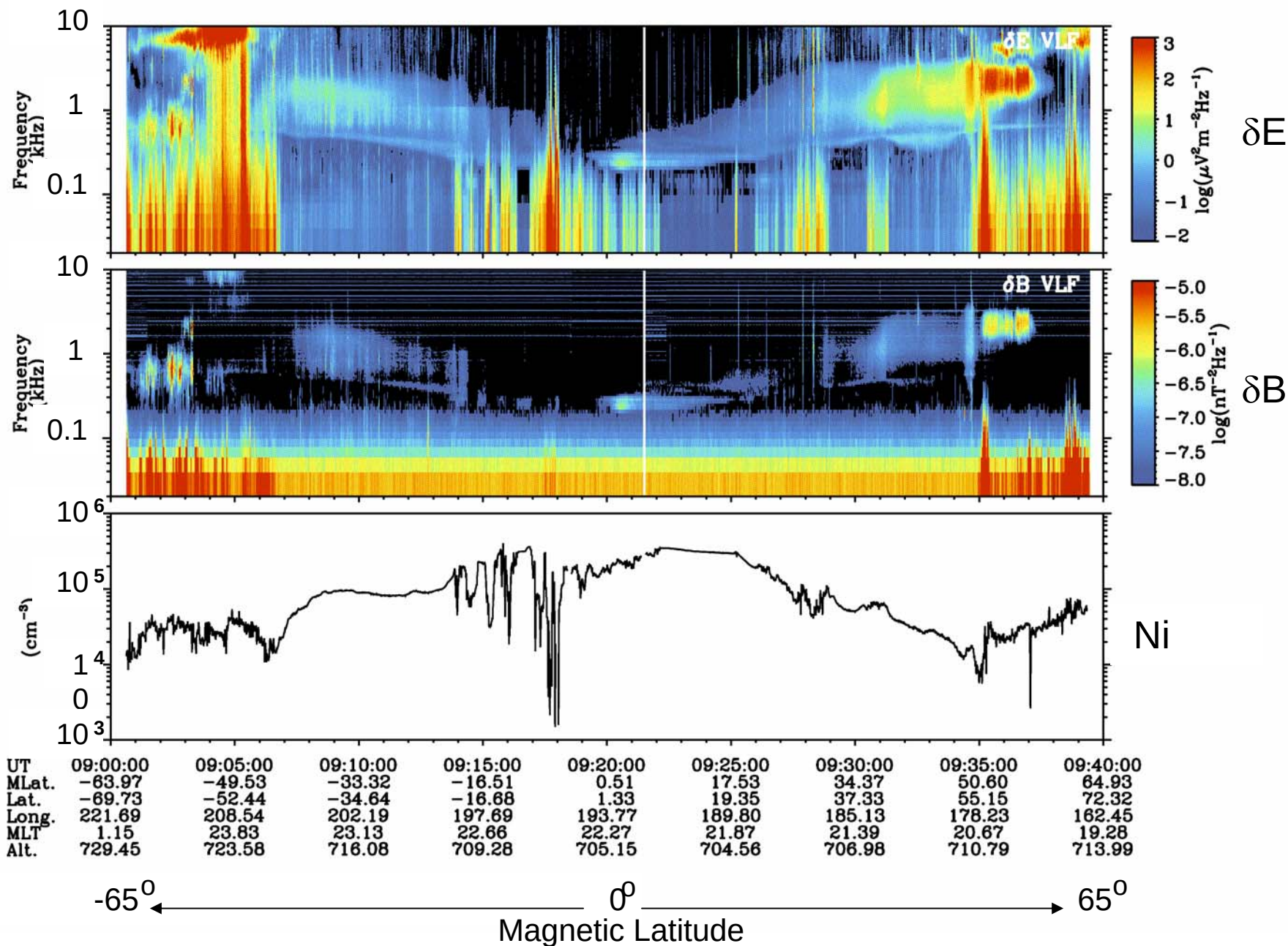
DEMETER – 18 March 2005 – Orbit: 3764_1

706 km, 22.2 LT



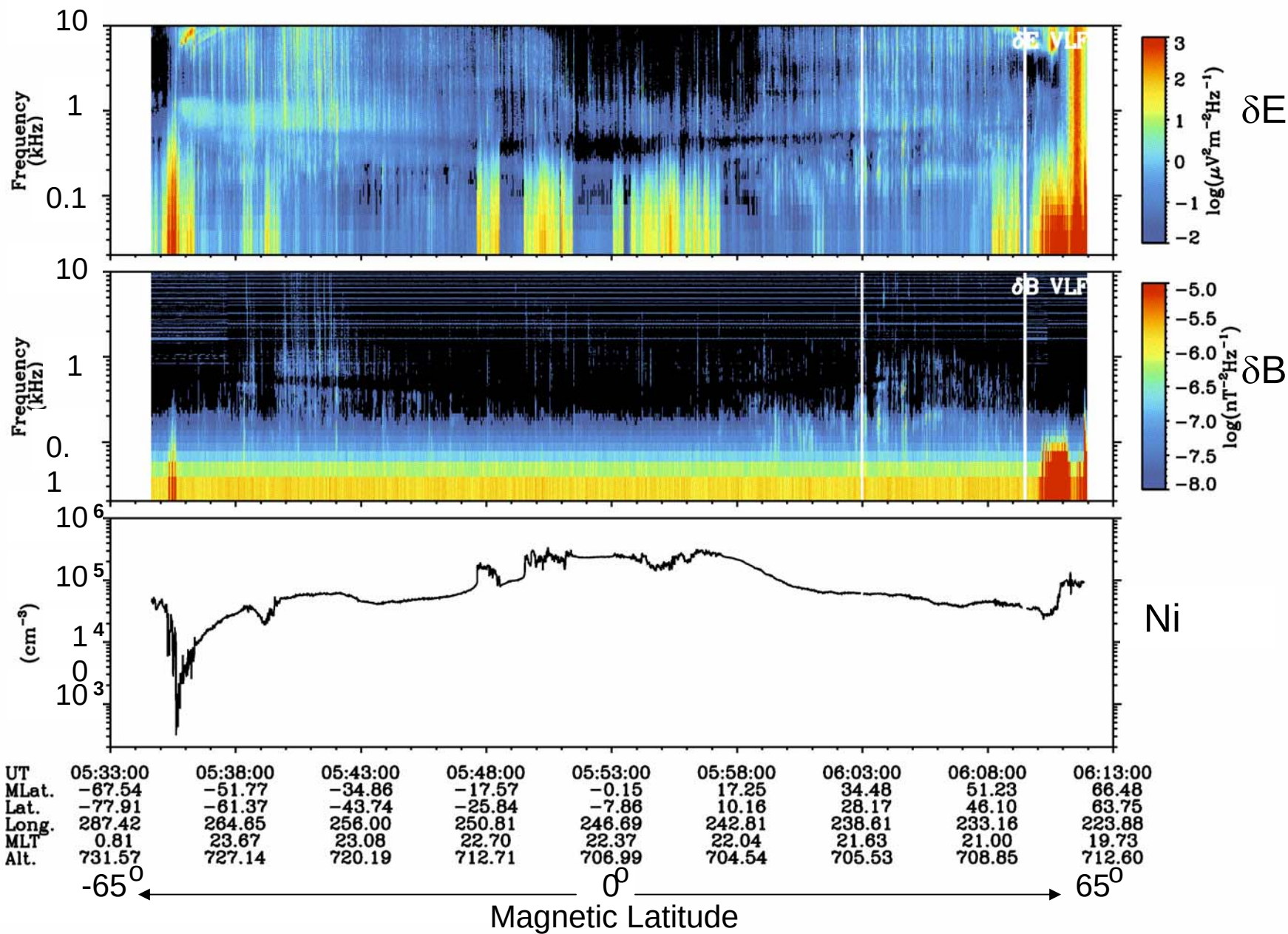
DEMETER -- 11 September 2005 -- Orbit 6343_1

705 km , 22.3 LT



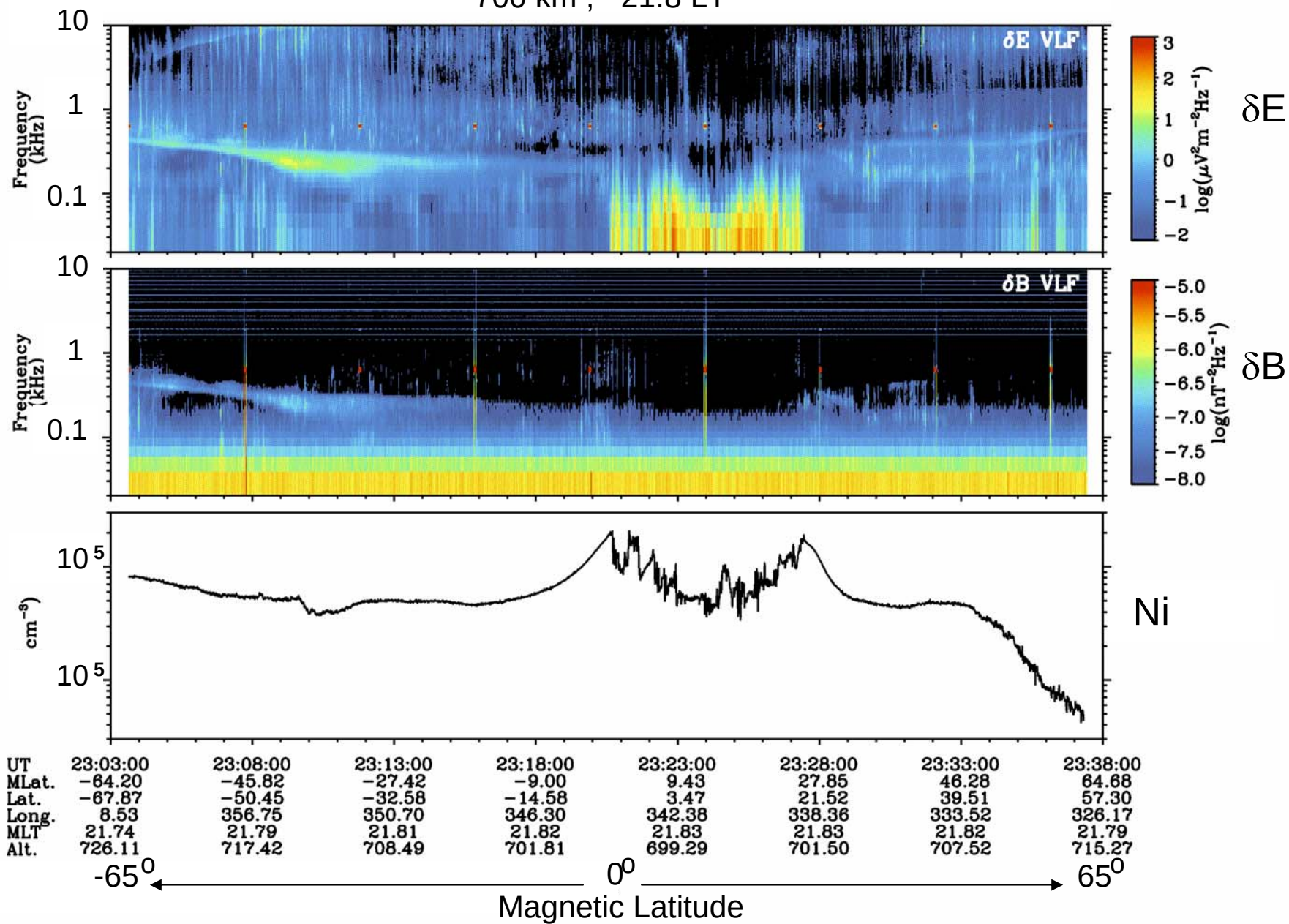
DEMETER -- 15 May 2005 -- Orbit 4608_1

707 km , 22.4 LT

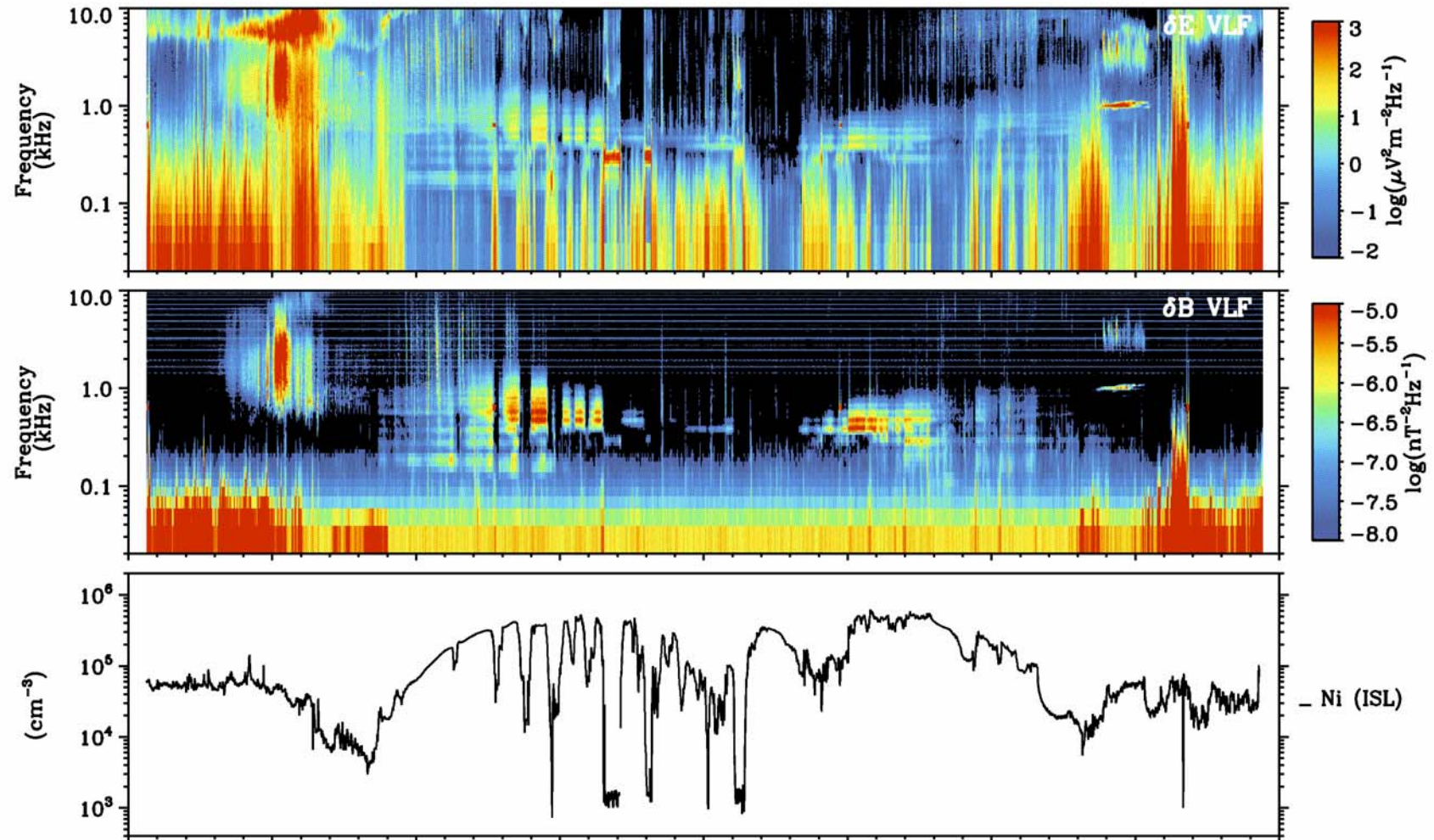


DEMETER -- 26 January 2005 -- Orbit 3032_1

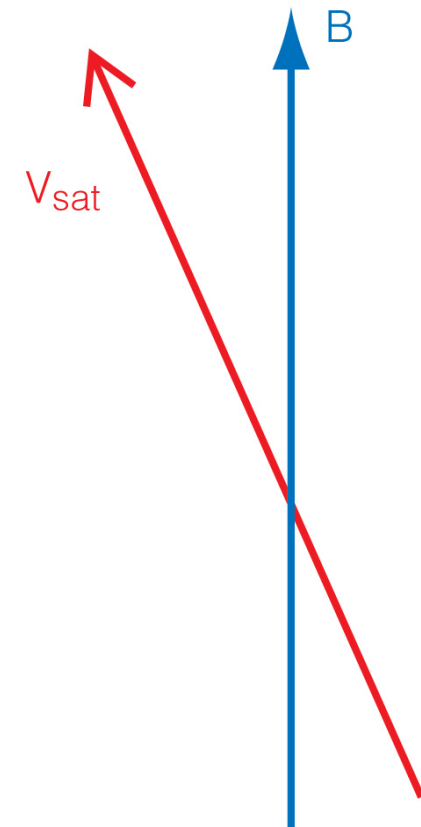
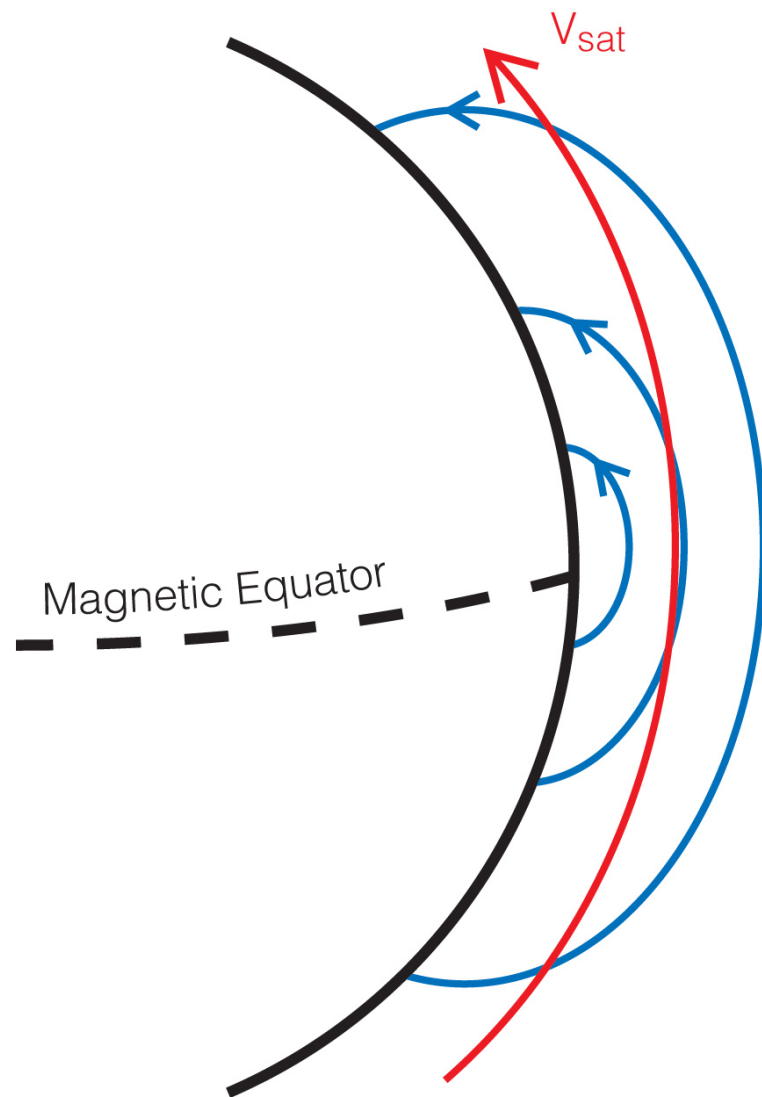
700 km , 21.8 LT



DEMETER, 10 November 2004, Orbit: 1904_1



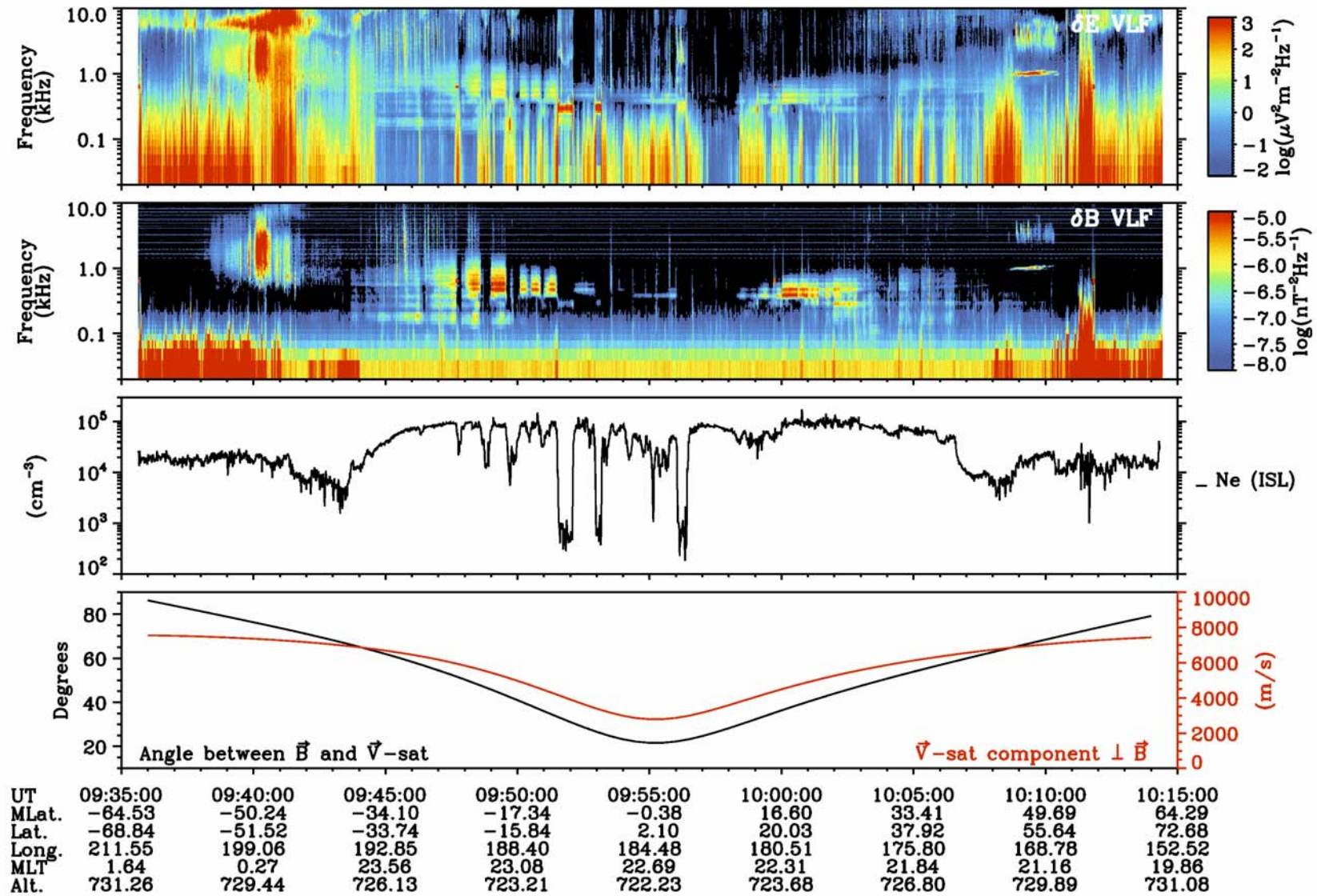
UT	09:35:00	09:40:00	09:45:00	09:50:00	09:55:00	10:00:00	10:05:00	10:10:00	10:15:00
MLat.	-64.53	-50.24	-34.10	-17.34	-0.38	16.60	33.41	49.69	64.30
Lat.	-68.84	-51.52	-33.74	-15.84	2.10	20.03	37.92	55.64	72.68
Long.	211.55	199.06	192.85	188.40	184.48	180.51	175.80	168.78	152.53
MLT	1.64	0.27	23.56	23.08	22.69	22.31	21.84	21.16	19.86
Alt.	731.26	729.44	726.13	723.21	722.23	723.68	726.80	729.89	731.08



$$\omega_{\text{obs}} = \mathbf{k} \cdot \mathbf{V}_{\text{sat}} + kV_{\phi}$$

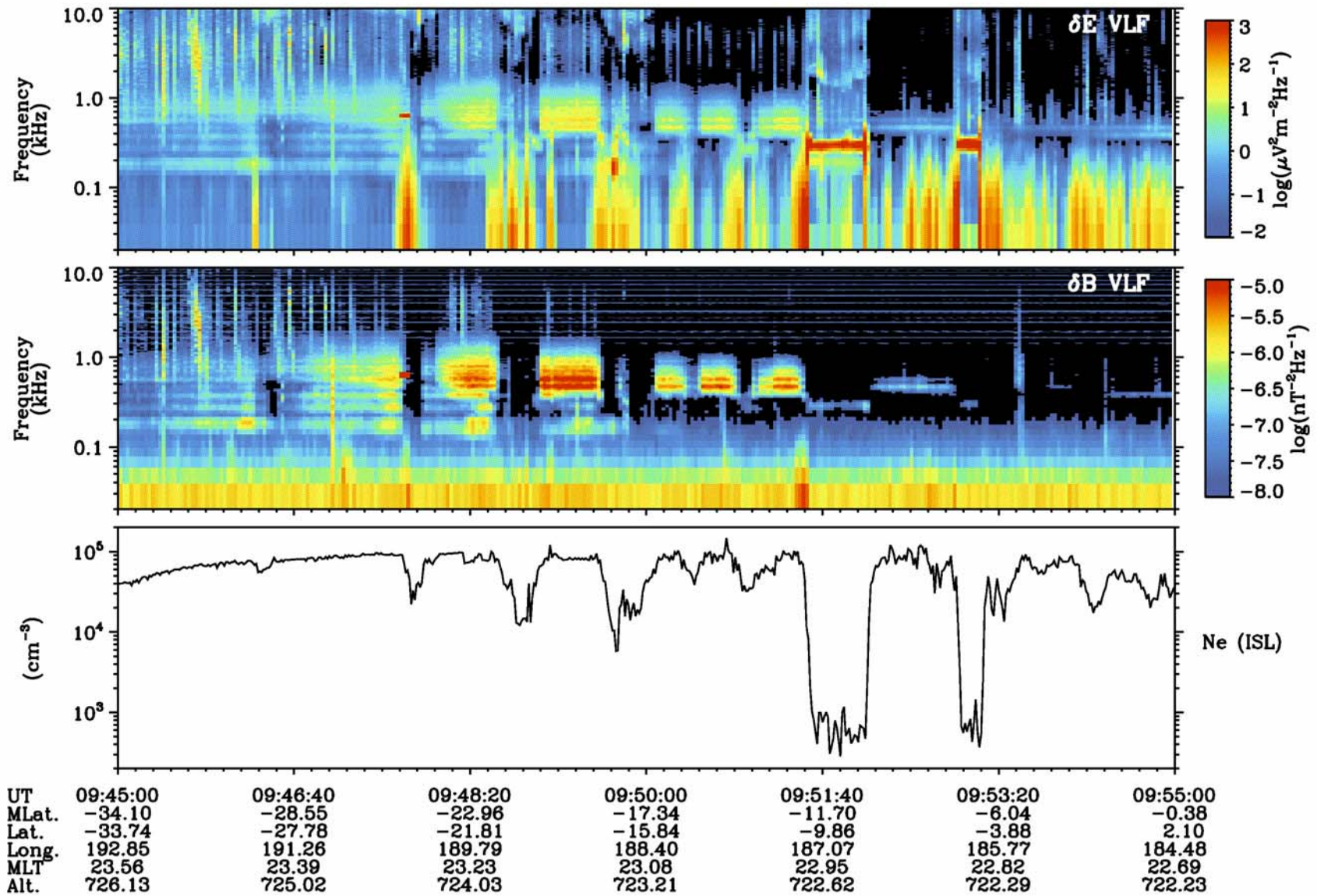
For electrostatic waves, $\mathbf{k}$ is parallel to $\delta\mathbf{E}$ which is perpendicular to $\mathbf{B}$.

DEMETER, 10 November 2004, Orbit: 1904_1

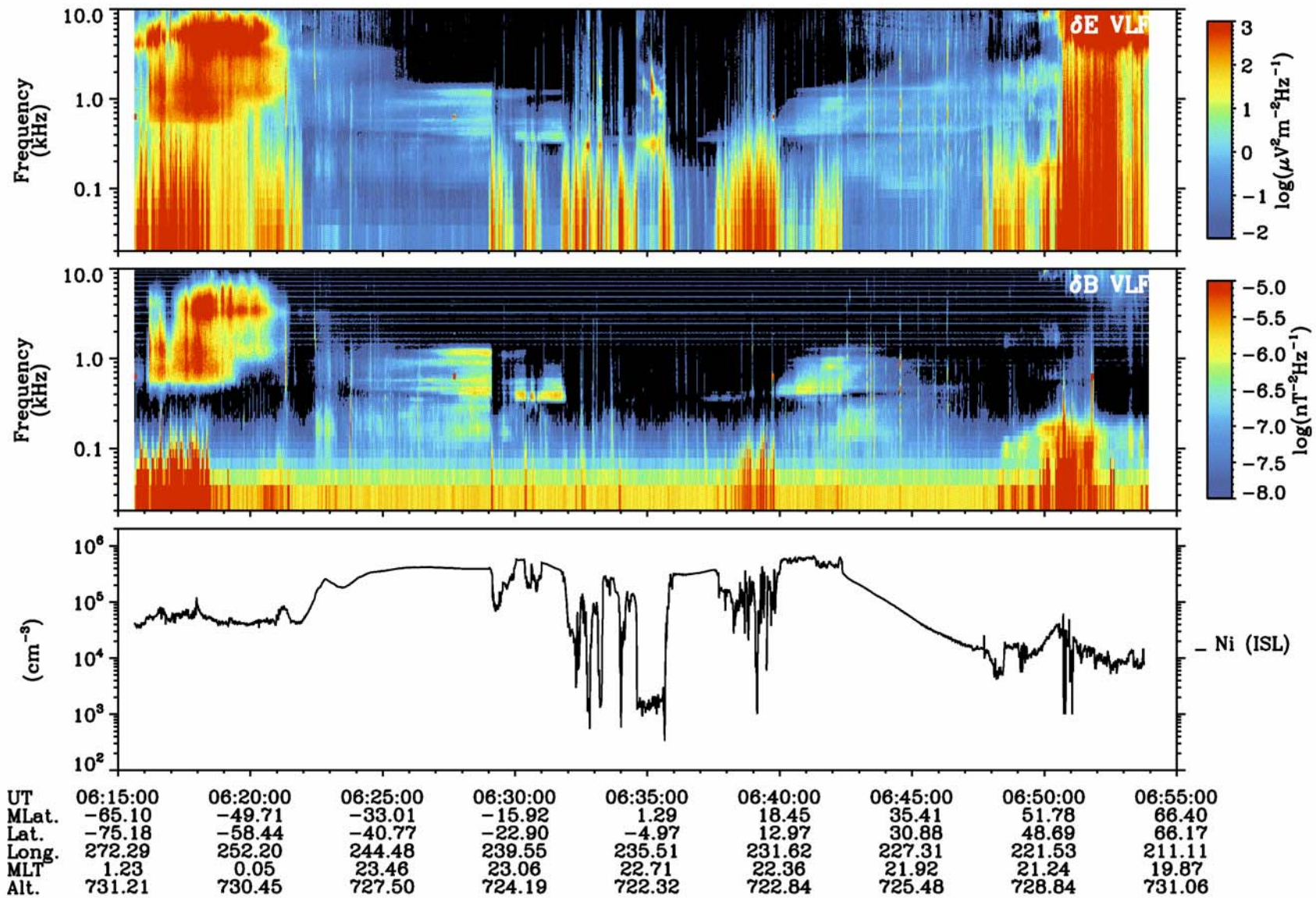


Mid- and low-latitude irregularities extend to scales of 10 m and shorter.

DEMETER, 10 November 2004, Orbit: 1904_1

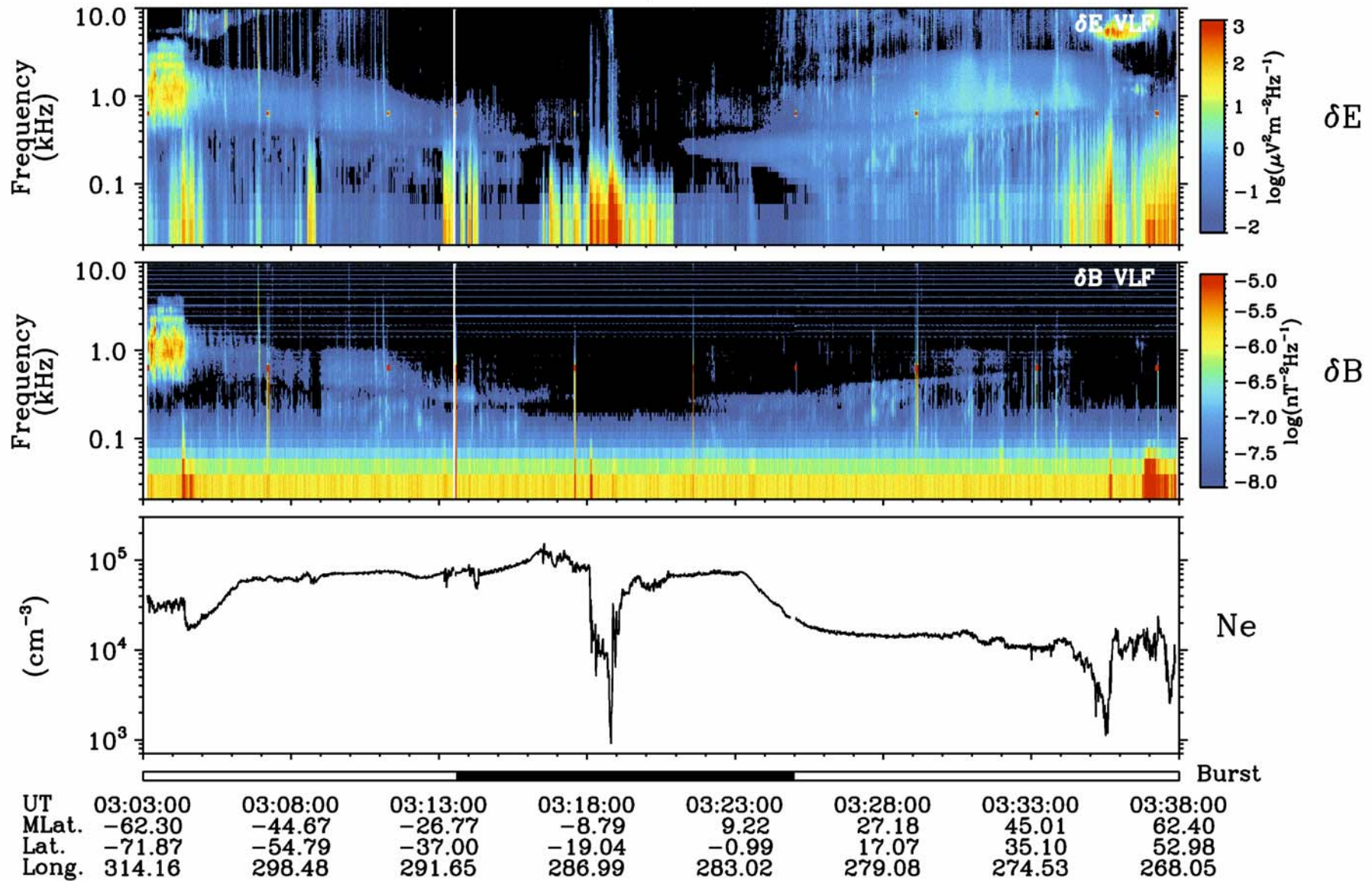


DEMETER, 10 November 2004, Orbit: 1902_1

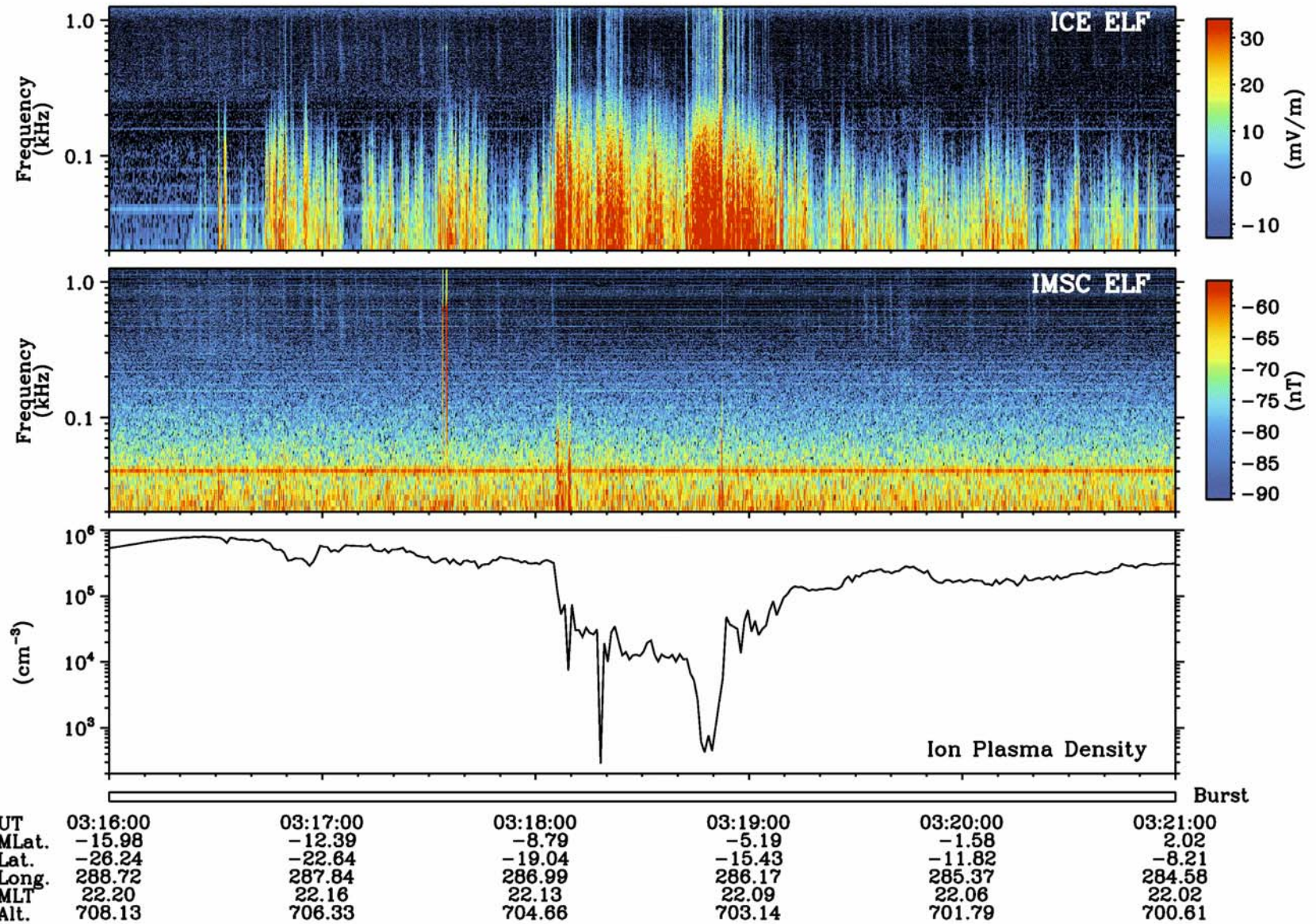


Electric and magnetic spectra are similar; Magnetic signatures usually detected on depletion walls. Filamentary spatial currents are possible explanation.

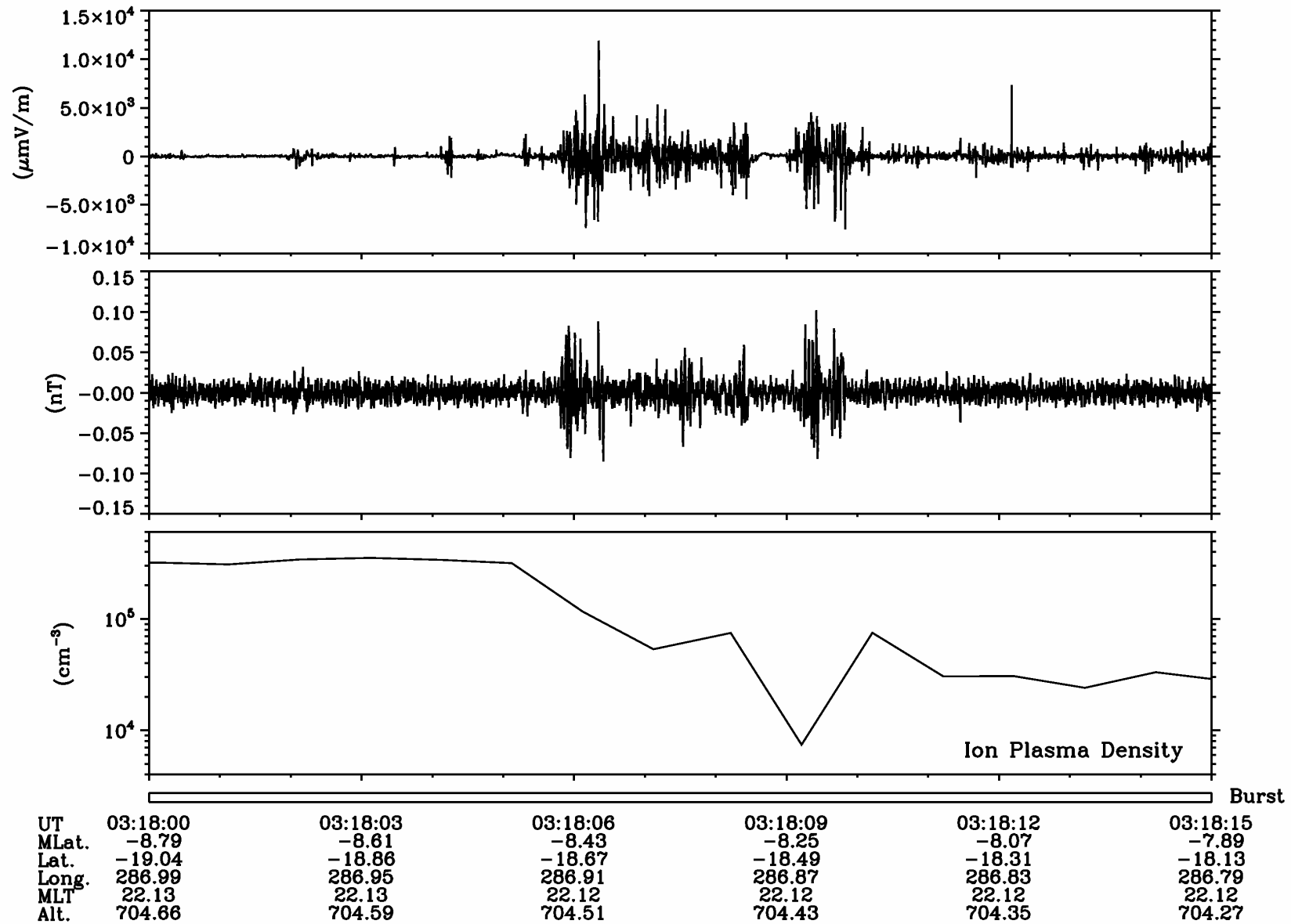
DEMETER – 17 January 2005 – Orbit: 2889_1
701 km, 22.0 LT



DEMETER, 17 January 2005, Orbit: 2889_1

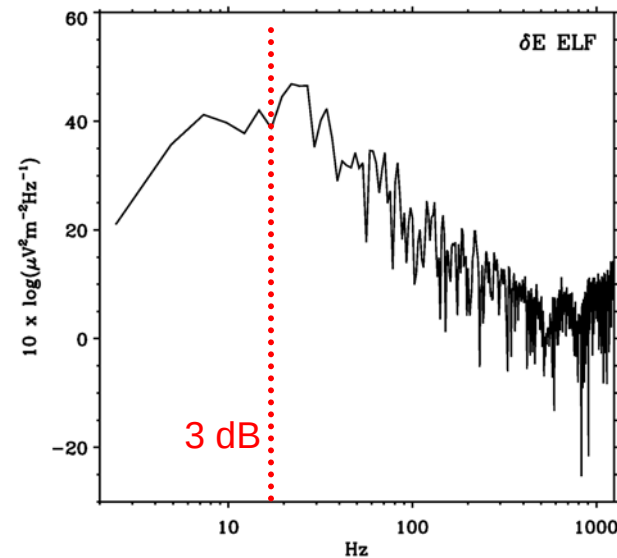


DEMETER, 17 January 2005, Orbit: 2889_1

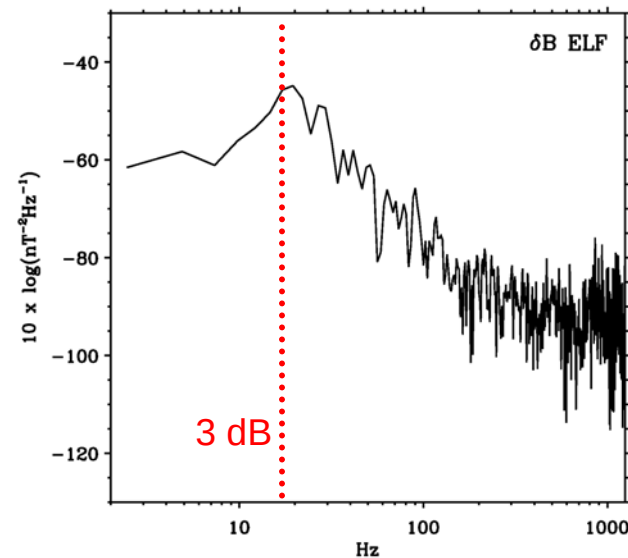


DEMETER, 17 January 2005 03:18:07.56, Orbit: 2889_1

Electric



Magnetic

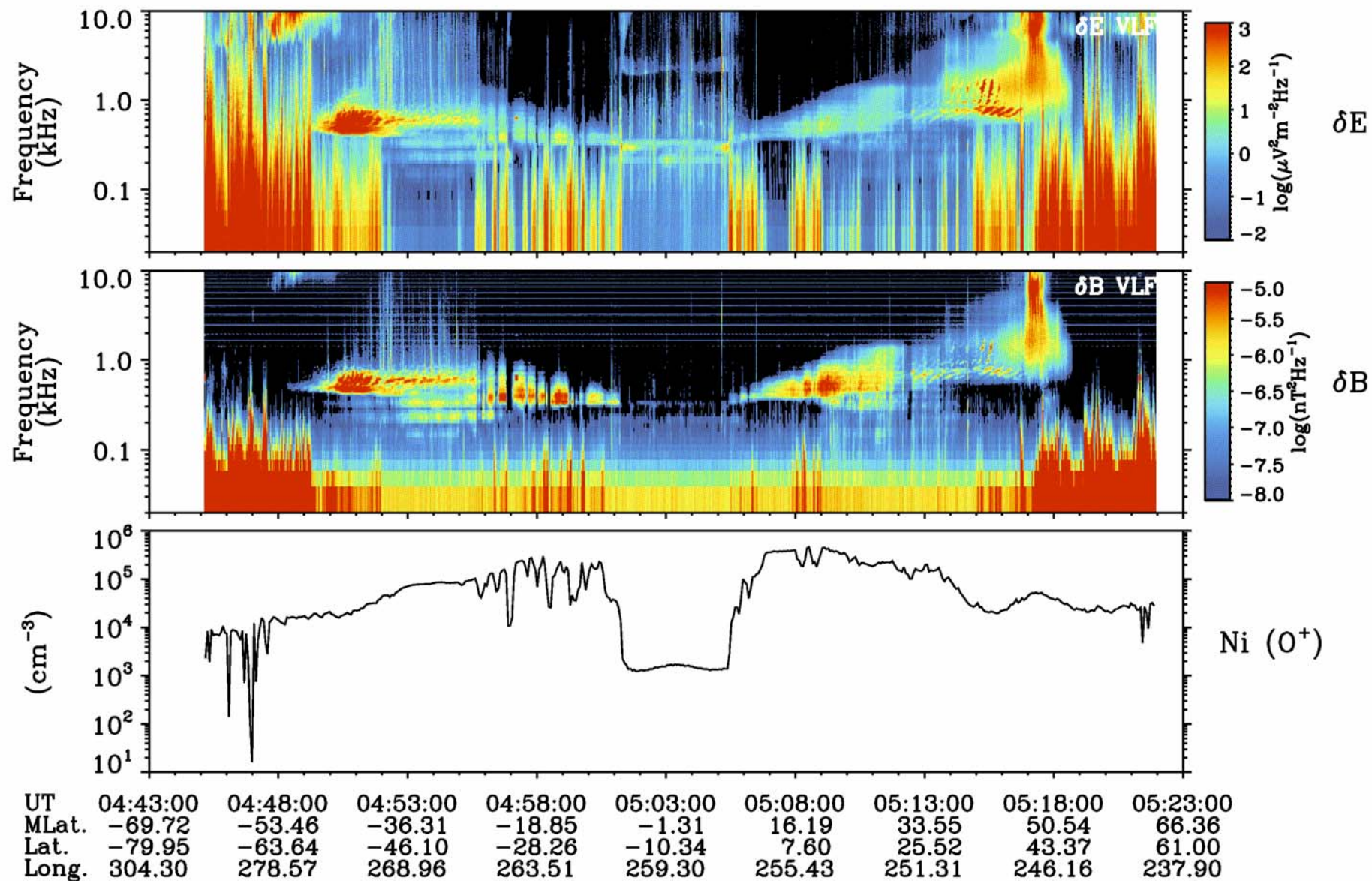


- Electric and magnetic spectra are similar.

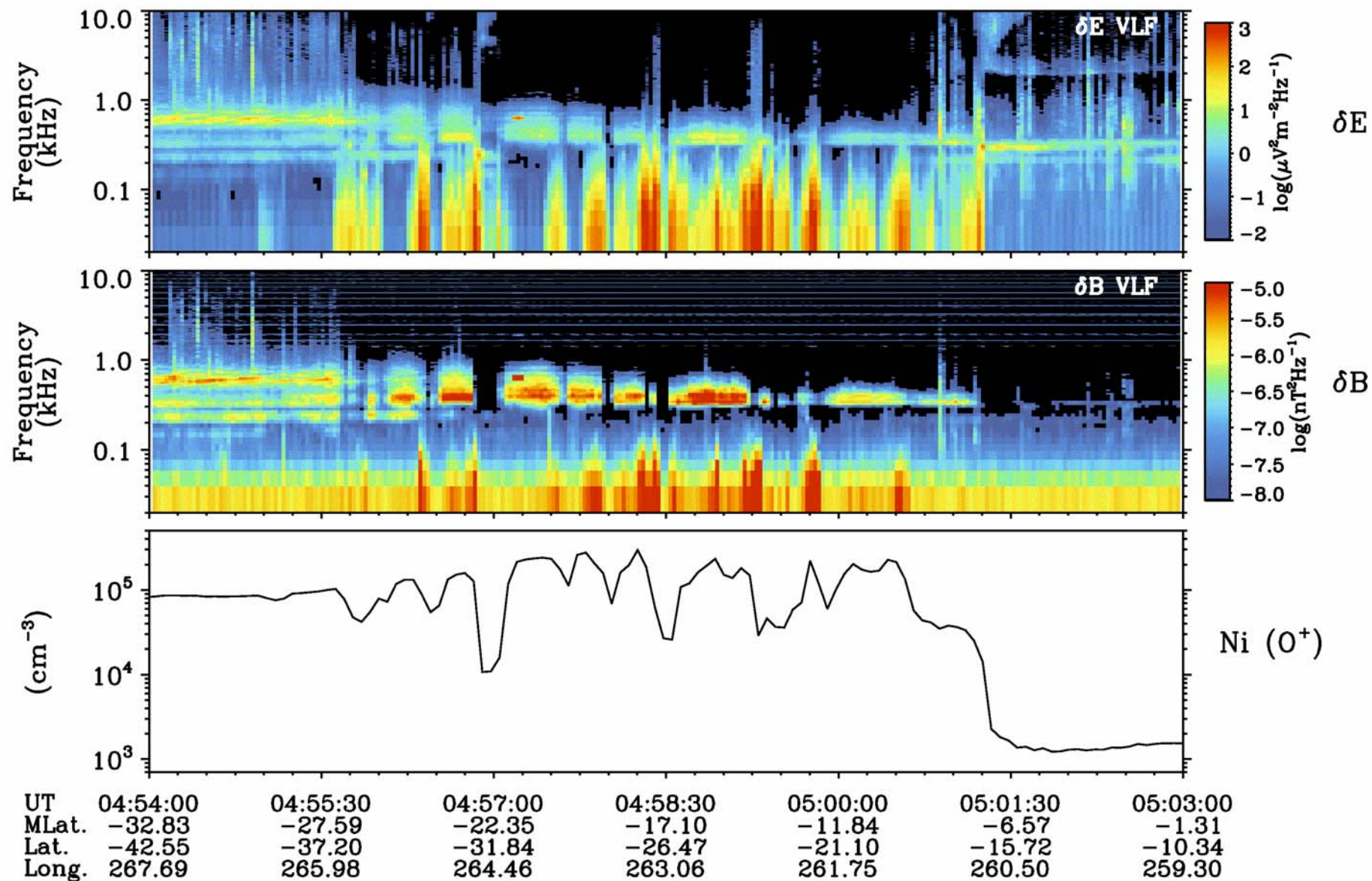
- Smallest measureable magnetic scale ~ 10 m.

- Filamentary currents on walls of depletions most plausible explanation.

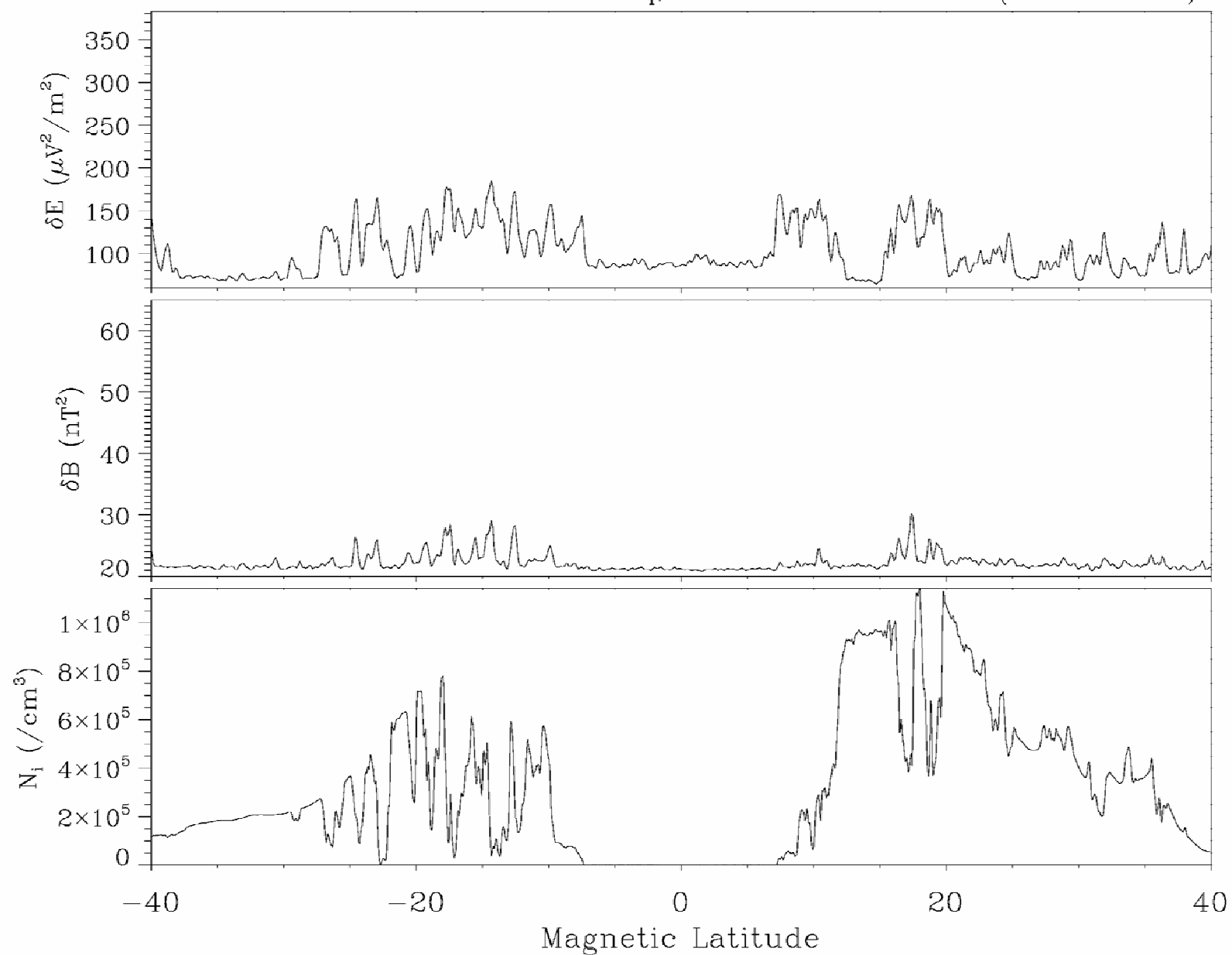
DEMETER – 08 November 2004 – Orbit: 1872_1
722 km, 22.7 LT



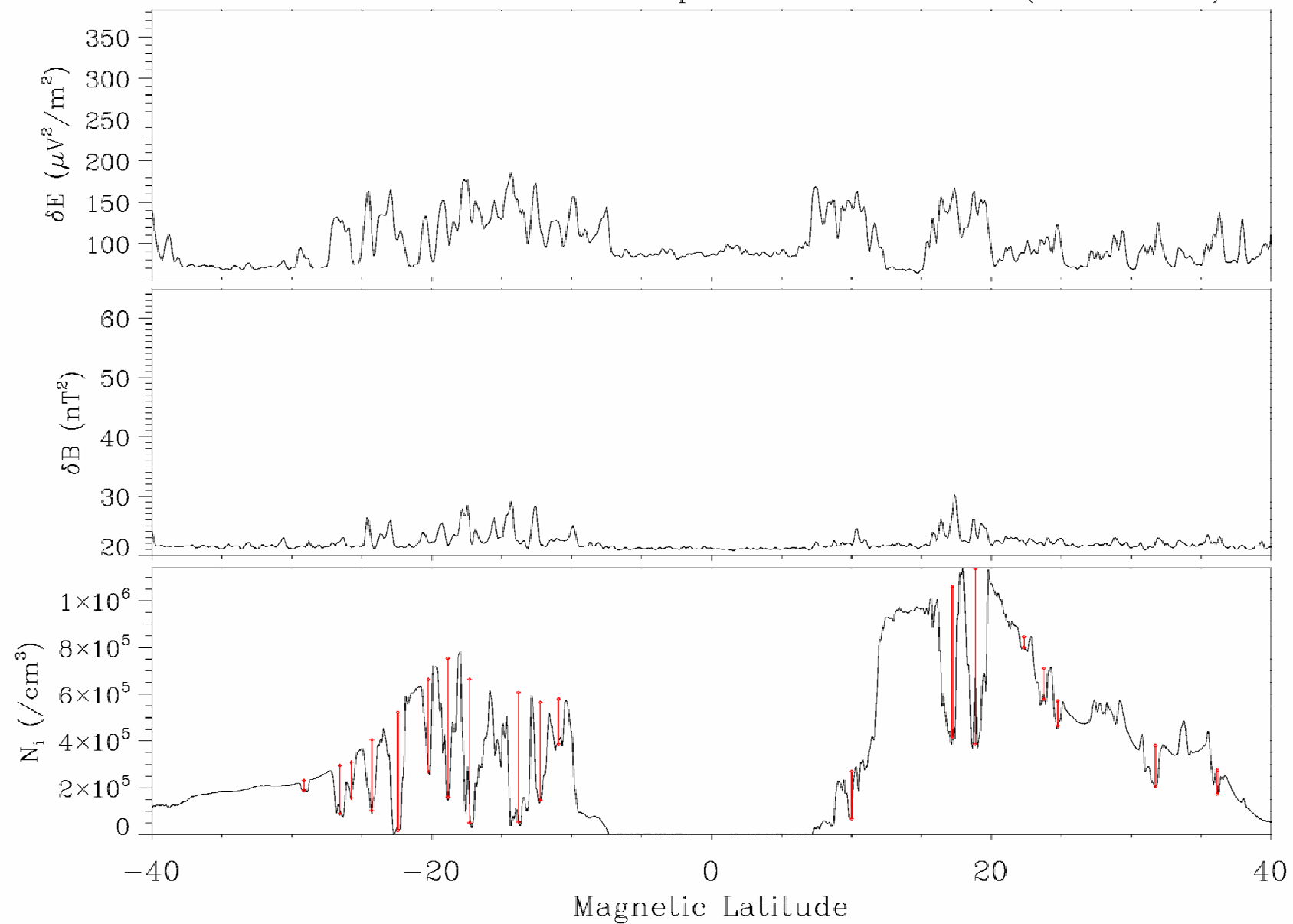
DEMETER – 08 November 2004 – Orbit: 1872_1
722 km, 22.7 LT



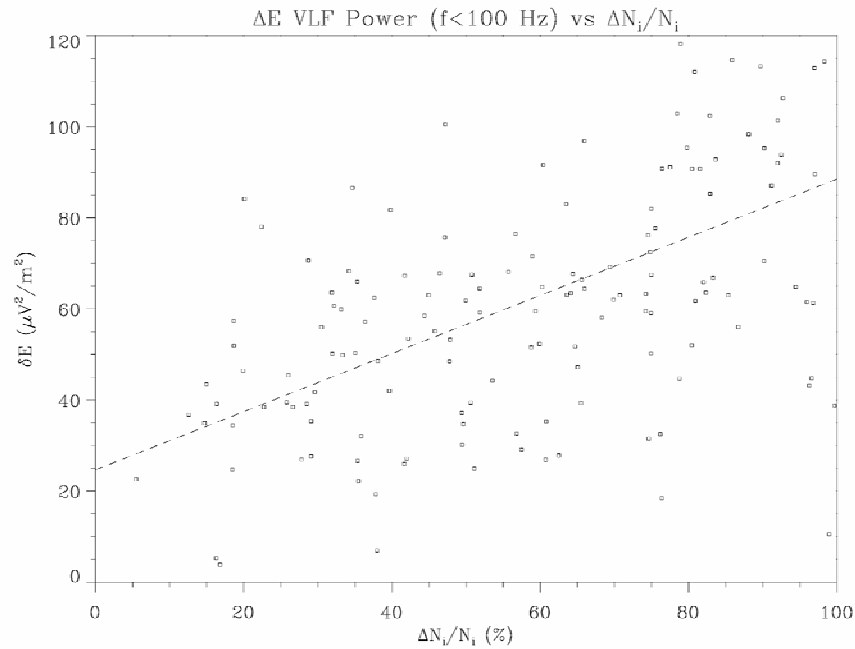
Demeter Orbit 1872_1: N_i , and δE and δB ($f < 100$ Hz)



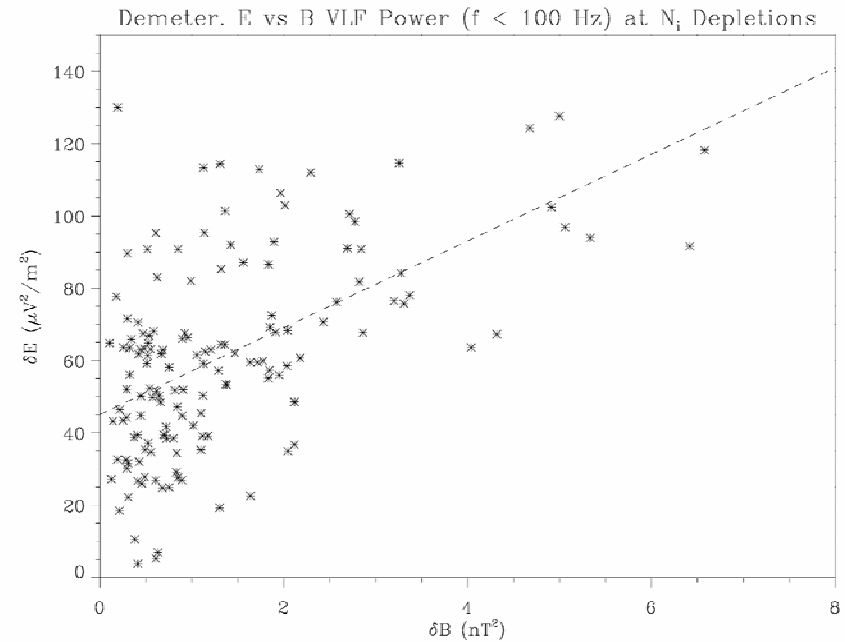
Demeter Orbit 1872_1: N_i , and δE and δB ($f < 100$ Hz)



Delta E, Delta B, Delta N/Ni for irregularity “bunches” for 8 orbits



IMP 9/18/97 11:21



IMP 5/25/97 11:02

Alfven wave velocity ~ 700 km/s $V_A = B_G / (4\pi\rho)^{1/2}$ for $N = 5 \times 10^4$ and O^+

Delta E/Delta B $\sim 50,000$ km/sec

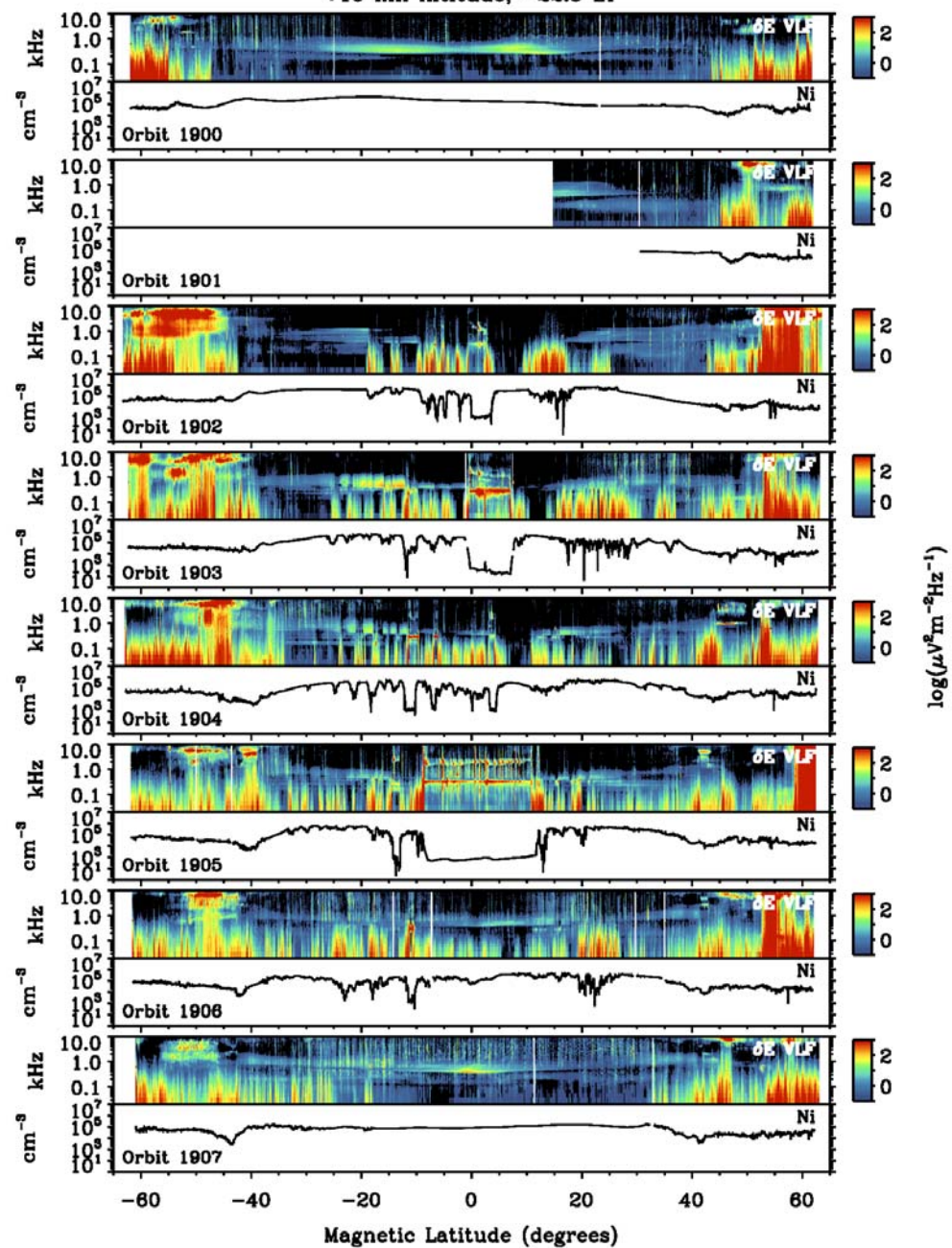
Static irregularities where Delta B/Delta E $\sim \Sigma_p$ is more realistic.

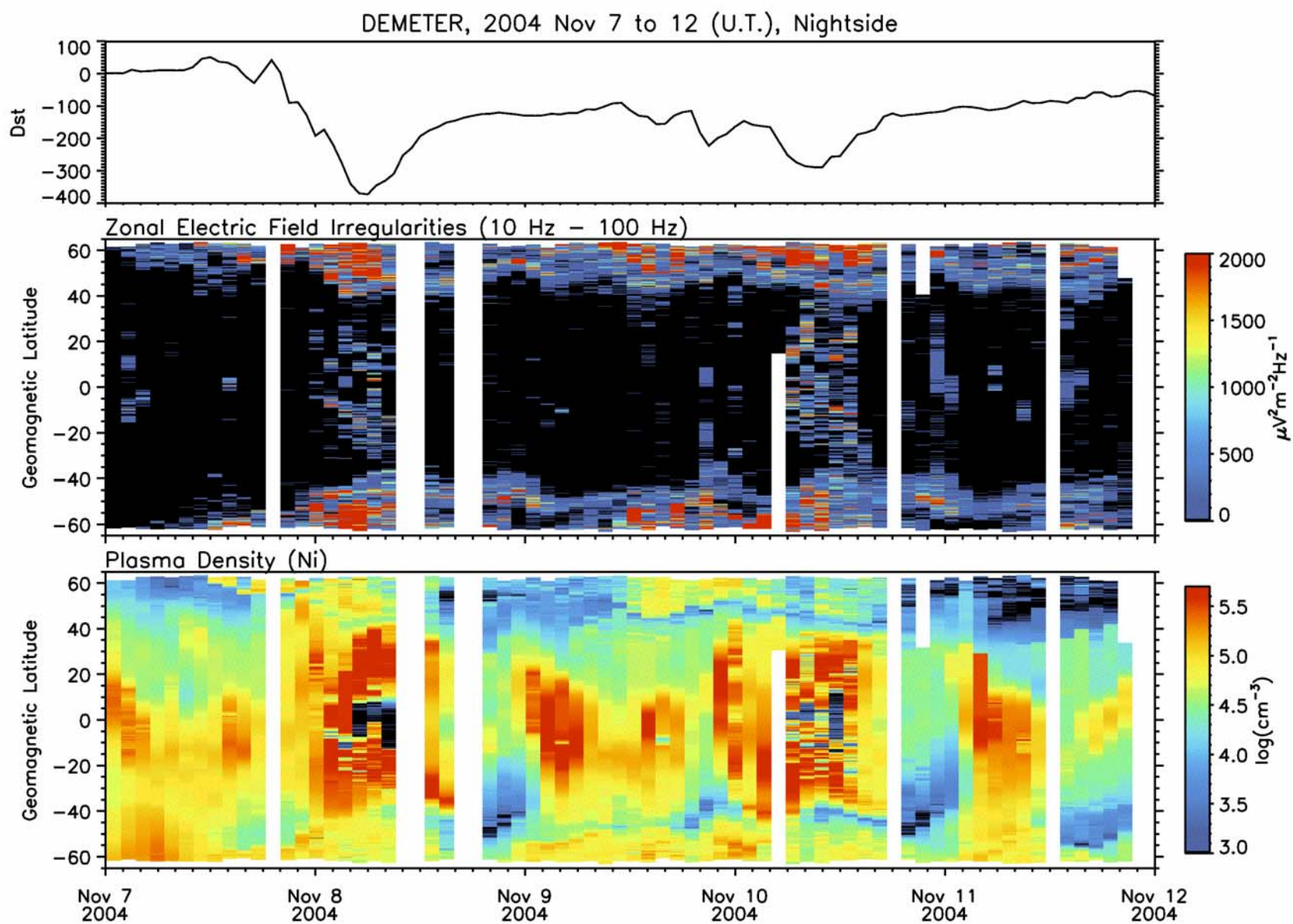
Summary (Part I) -- DEMETER Irregularities at Mid-Latitudes

- DEMETER data reveal a topside ionosphere (~ 710 km) at mid and low latitudes that is often highly variable and structured at night (22h LT).
- Irregularities associated with plasma “depletions” typically extend to scales shorter than 10 m irrespective of latitude; implies local generation.
- In general, deepest depletions correspond to largest electric field wave irregularity amplitudes, as is generally true for equatorial spread-F.
- Mid-Latitude irregularities show similar characteristics of equatorial spread-F irregularities, implying similar generation mechanisms may be at work, at least on the shorter scale (< 100 m) waves.
- Broadband AC magnetic fields are sometimes detected on walls of depletions, with similar spectral properties as electric field irregularities. Likely due to filamentary currents.
- Irregularities typically scatter ambient ELF hiss, when present.

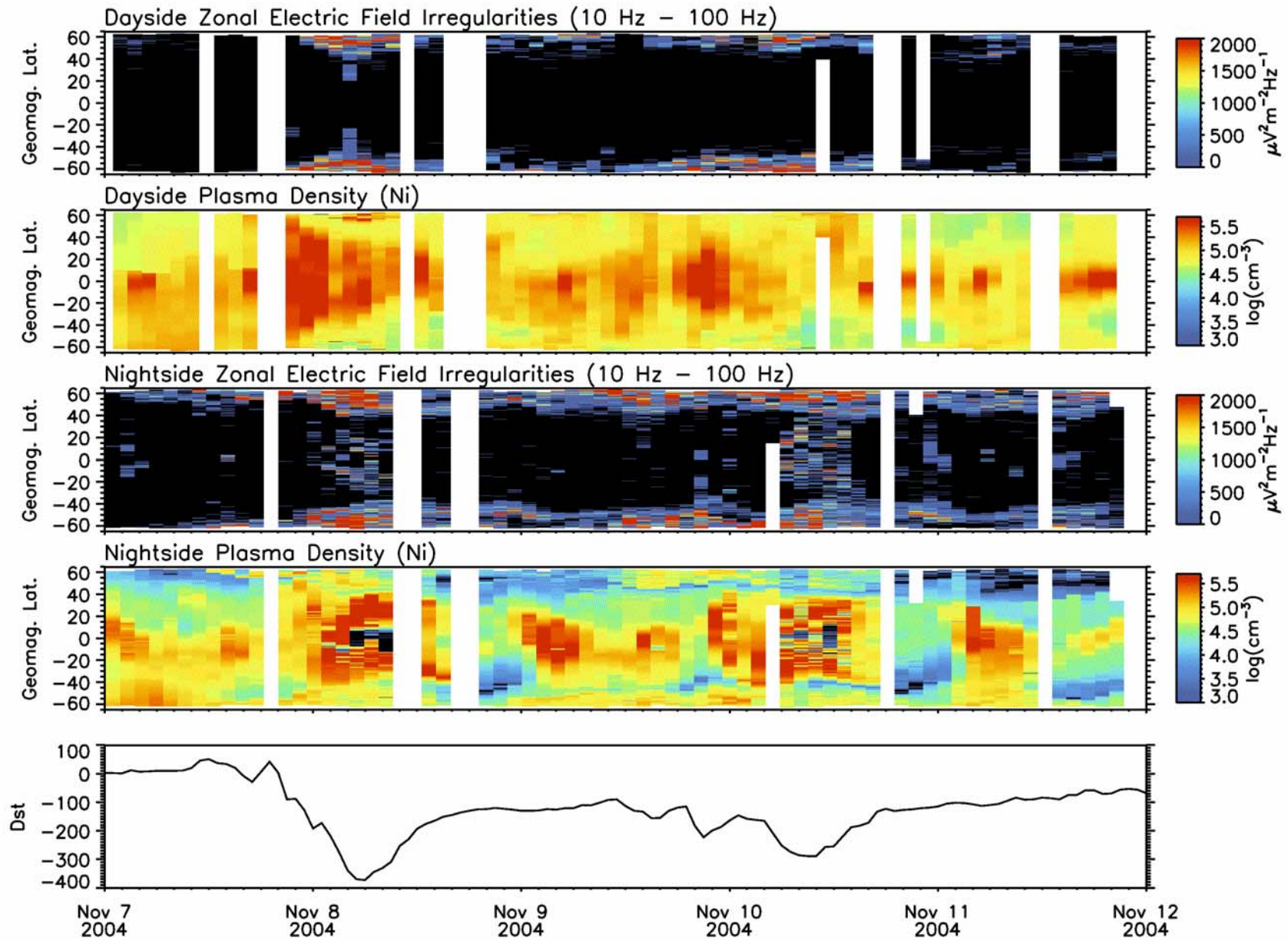
DEMETER -- 10 November 2004

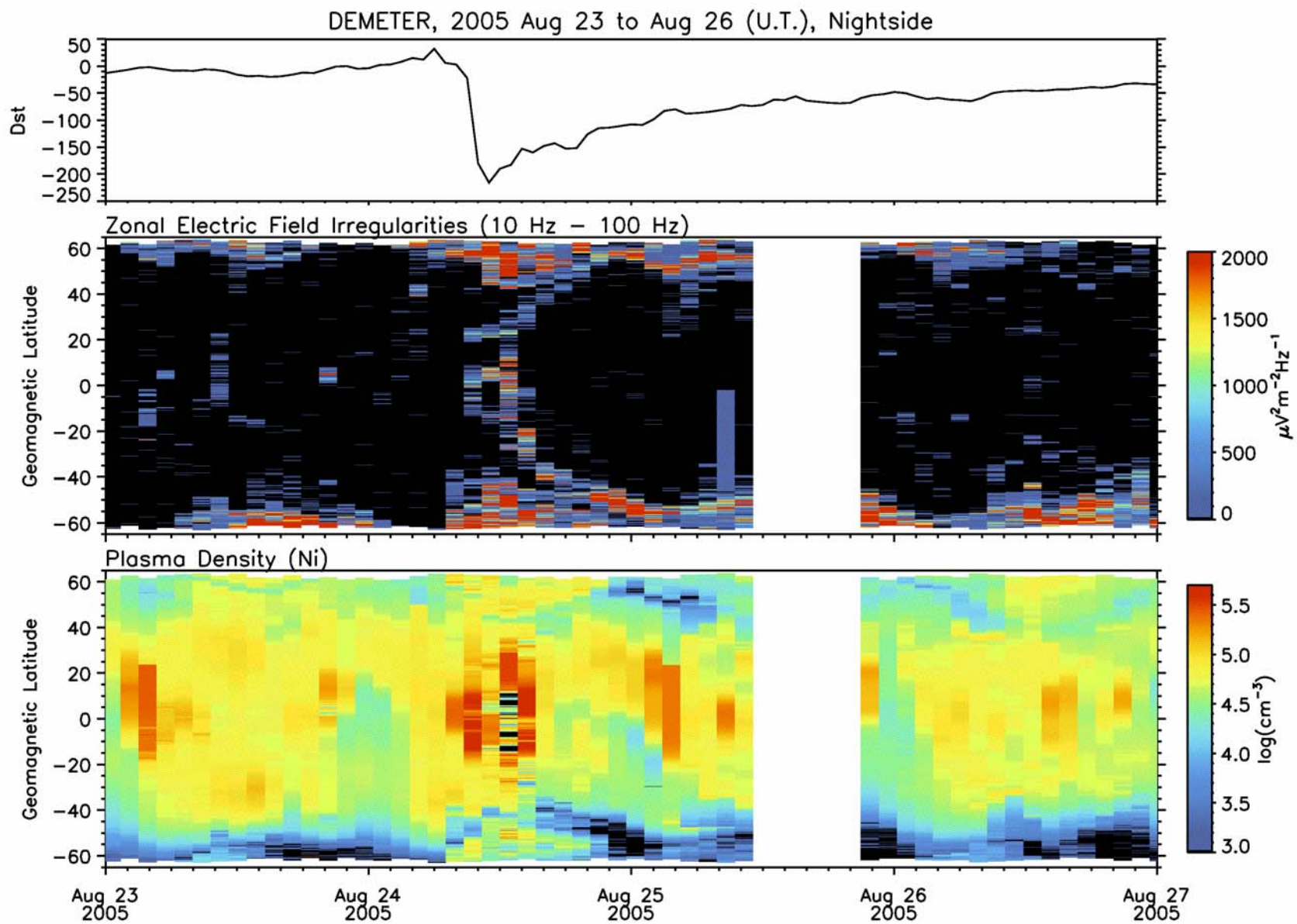
710 km Altitude, ~22.5 LT

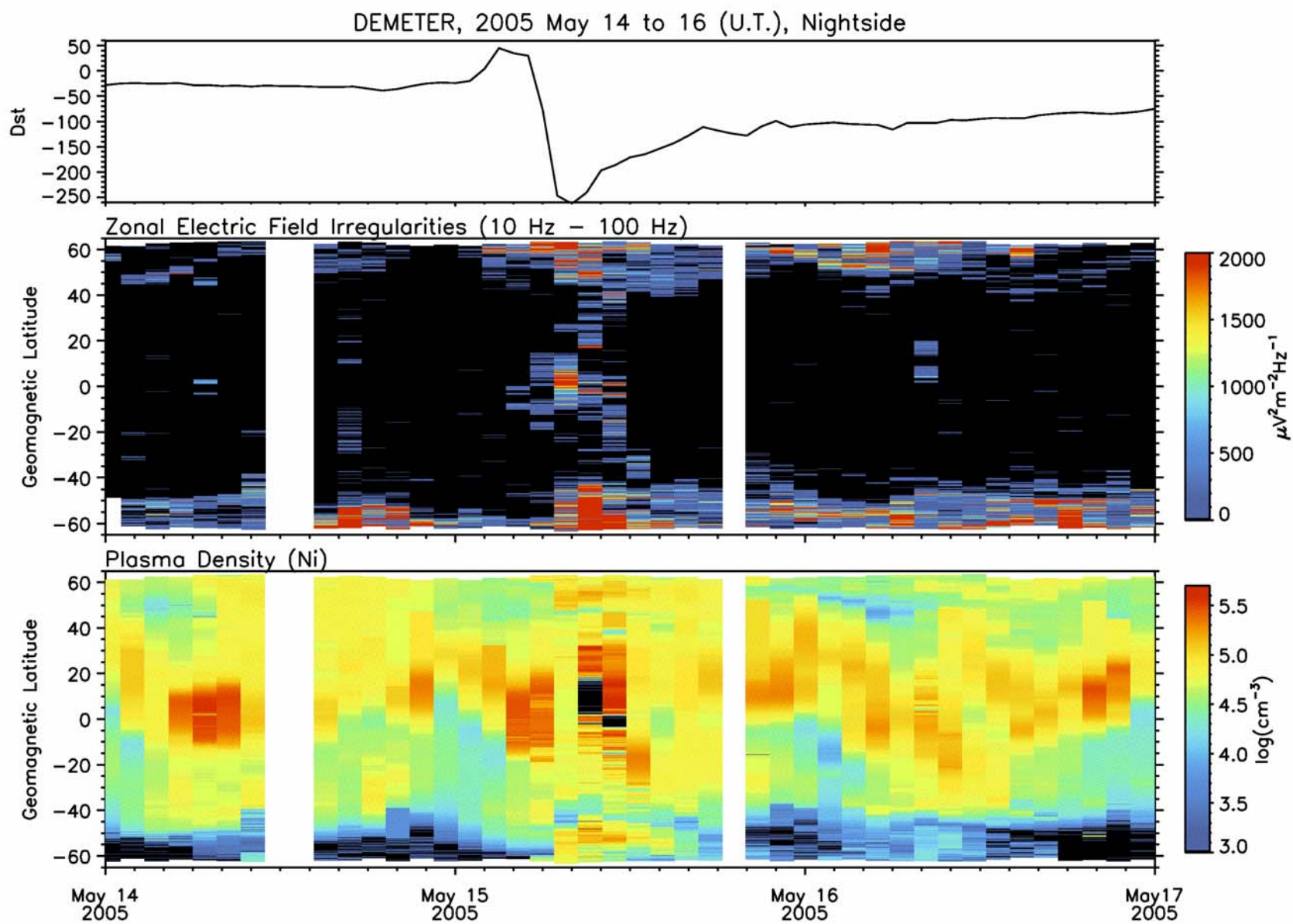




DEMETER, 2004 Nov 7 to 12 (U.T.)







Summary (Part II) -- Density Structures Associated with Storms

- Irregularities and large density depletions appear at all latitudes (mid, low) at 710 km after sunset *during major sub-storms*.
- Plasma structures and electric field irregularities typically appear for a very limited time (~ 6 hr) *precisely during largest negative excursions of Dst*.
- Rapid excursions of the F-region ledge above 710-840 km during the main storm phase suggests that a storm-driven, eastward E-field appears responsible for this rise.
- There is a tendency for initial irregularities within the storm to appear first at magnetic equator and then are observed at higher latitudes
- Unstable flux tubes that originate at the magnetic equator and rise in altitude may explain the transition of irregularities to higher latitudes as the storm progresses.
- Since the density is itself enhanced during the storm, the extension to very high altitudes (several 1000 km) of the unstable flux tube apex is not unreasonable.