

# Some additional results based on Swarm data, but not directly related to main topic of project

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# Pre-seismic geomagnetic and ionosphere signatures related to the Mw5.7 earthquake occurred in Vrancea zone on September 24, 2016

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## Abstract

To emphasize the relationship between the pre-seismic geomagnetic signals and Vrancea seismicity, in this work it is hypothesized that before an earthquake initiation, the high stress reached into seismogenic volume generates dehydration of the rocks and fracturing processes followed by release of electric charges along the faulting systems, which lead to resistivity changes. These changes were explored on September 2016 by the normalized function  $B_{zn}$  obtained from the geomagnetic data recorded in ULF range (0.001–0.0083 Hz). A statistical analysis was also performed to discriminate on the new  $B_{zn}^*$  time series a pre-seismic signature related to the Mw5.7 earthquake. Significant anomalous behavior of  $B_{zn}^*$  was identified on September 21, with 3 days prior to the onset of the seismic event. Similar information is provided by registrations of the magnetic and electron concentration variations in the ionosphere over the Vrancea zone, by Swarm satellites, 4 days and 1 day before the earthquake.

**Keywords** Pre-seismic geomagnetic signature · Mw5.7 earthquake · Seismic active Vrancea zone · Swarm satellite · Ionospheric effects



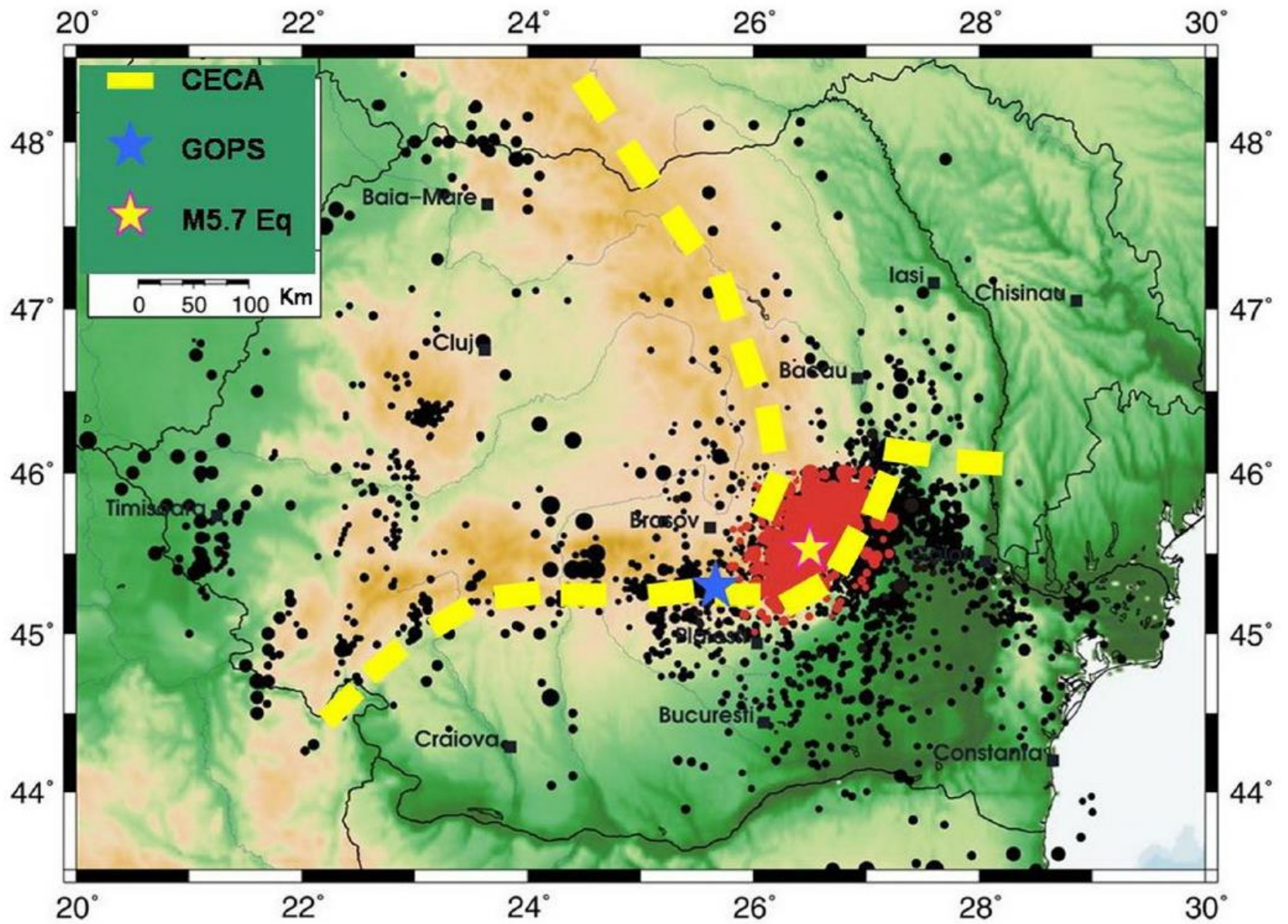
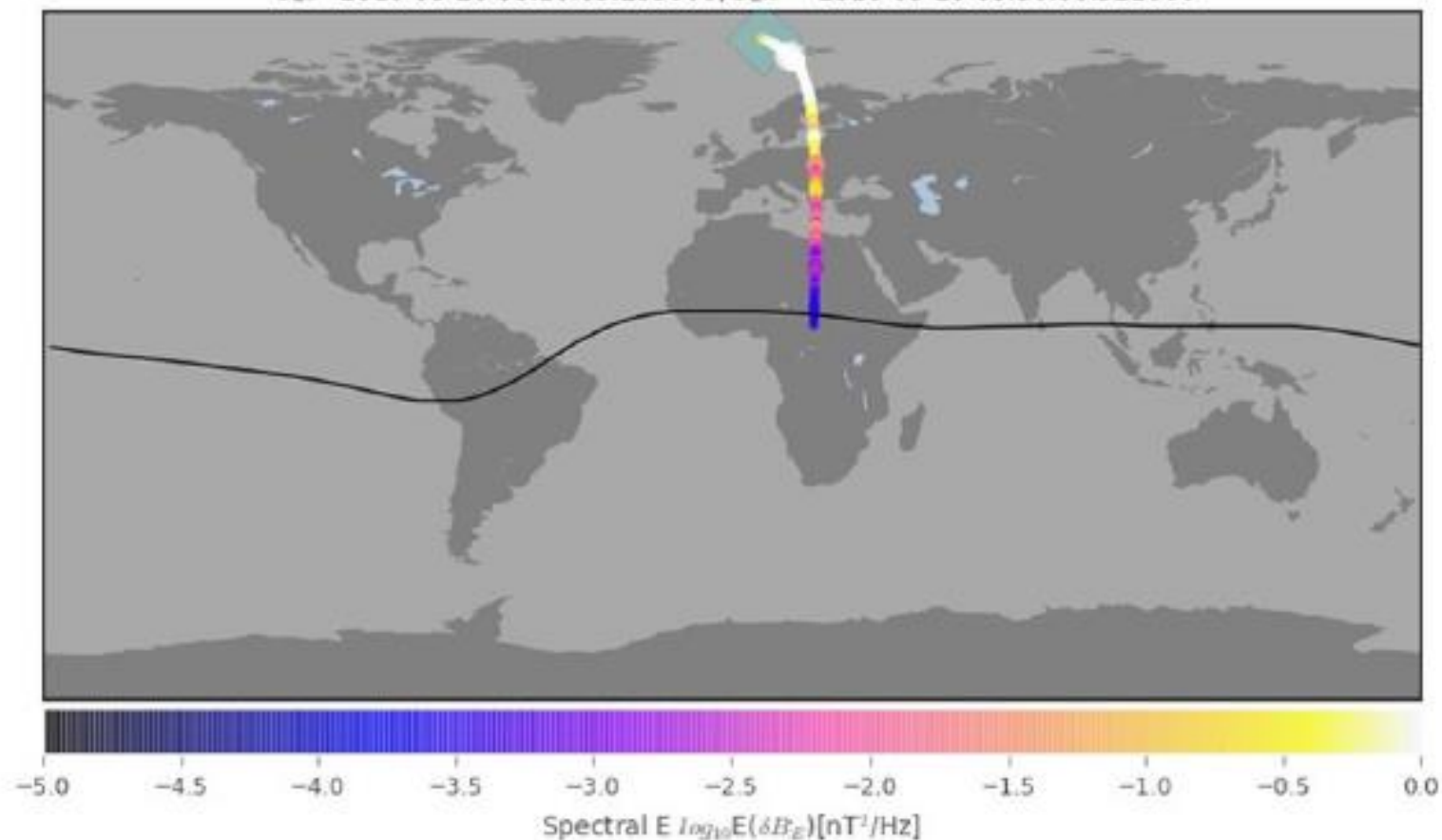


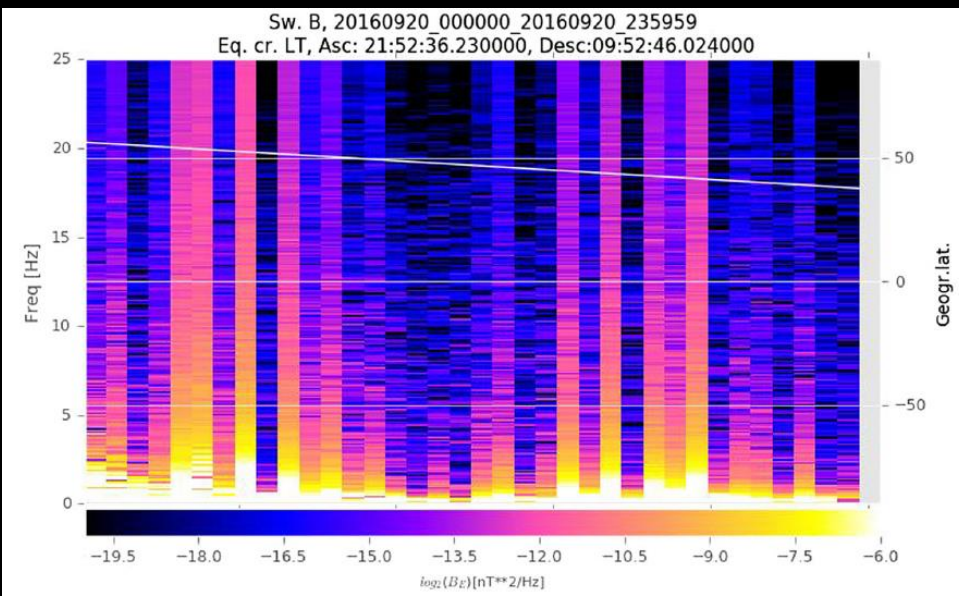
Fig. 2 Map with crustal (black dots) and intermediate (read dots) earthquakes in Vrancea zone. Carpathian Electrical Conductivity Anomaly (yellow dashed line); epicenter of M5.7 earthquake (yellow star); Geodynamic Observatory Provita de Sus (blue star)

Sw. B, 20160920\_000000\_20160920\_235959  
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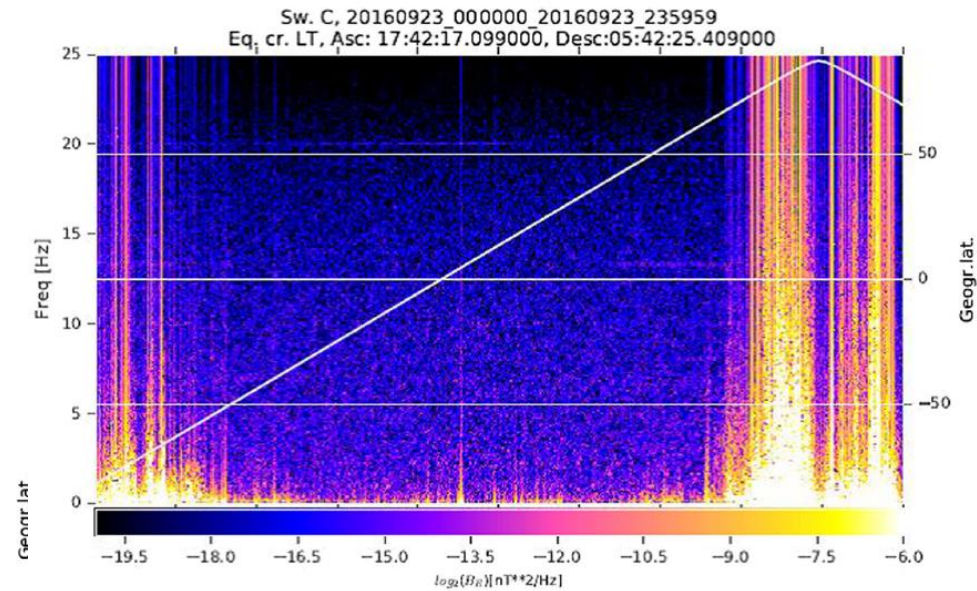
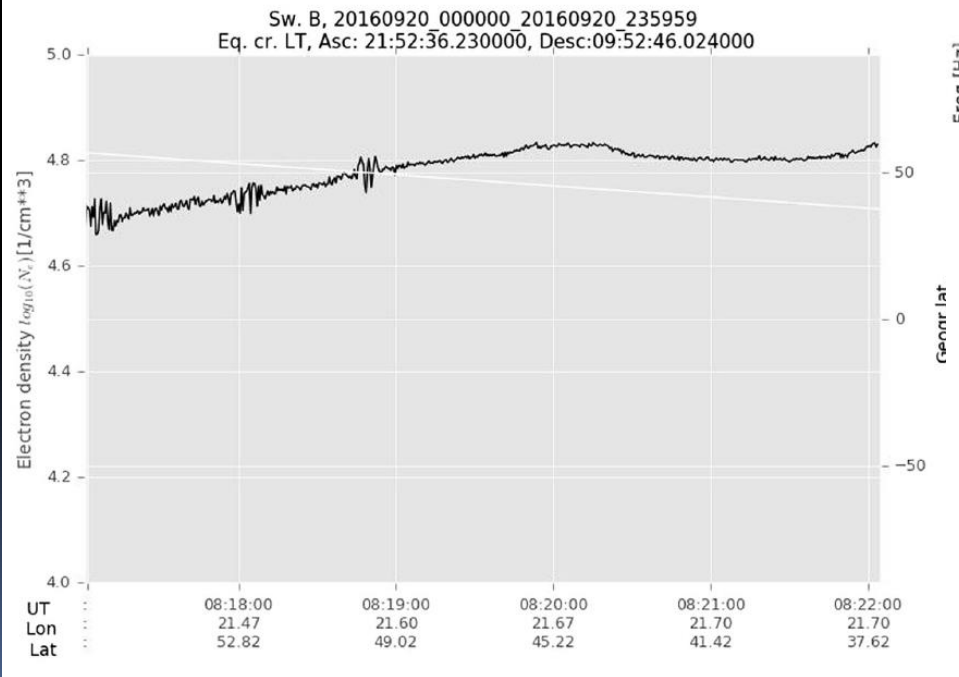


**Fig. 8** The part of Swarm B orbit related to the flight over Vrancea zone on September 20. The color of the dots on the orbit line corresponds to the intensity of the magnetic field variations





**Fig. 9** The spectra of the magnetic field variations (upper panel) and electron concentration registered by Swarm B satellite in the vicinity of the Vrancea zone on September 20



**Fig. 10** The same as in Fig. 9, but for the September 23 and taken for entire half orbit crossing area in vicinity of the Vrancea zone. White line represents the position of the satellite

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On behalf of the President of the Geonomical Sciences Section, Acad.Nicolae Panin, I have the great pleasure to inform you that the Presidency of the Romanian Academy has awarded/the „Stefan Hepites” Prize for the year 2018,/ to your scientific contribution: „Pre-seismic geomagnetic and ionospheric signature related to the Mw5.7 earthquake occurred in Vrancea zone on September 24, 2016” publishedd in 2018 in /Acta Geophysica/ (Springer). Our sincere and warm congratulations!

## **COMPARATIVE STUDY OF THE ENERGETIC ELECTRONS REGISTERED TOGETHER WITH THE BROAD BAND EMISSIONS IN DIFFERENT REGIONS OF THE IONOSPHERE**

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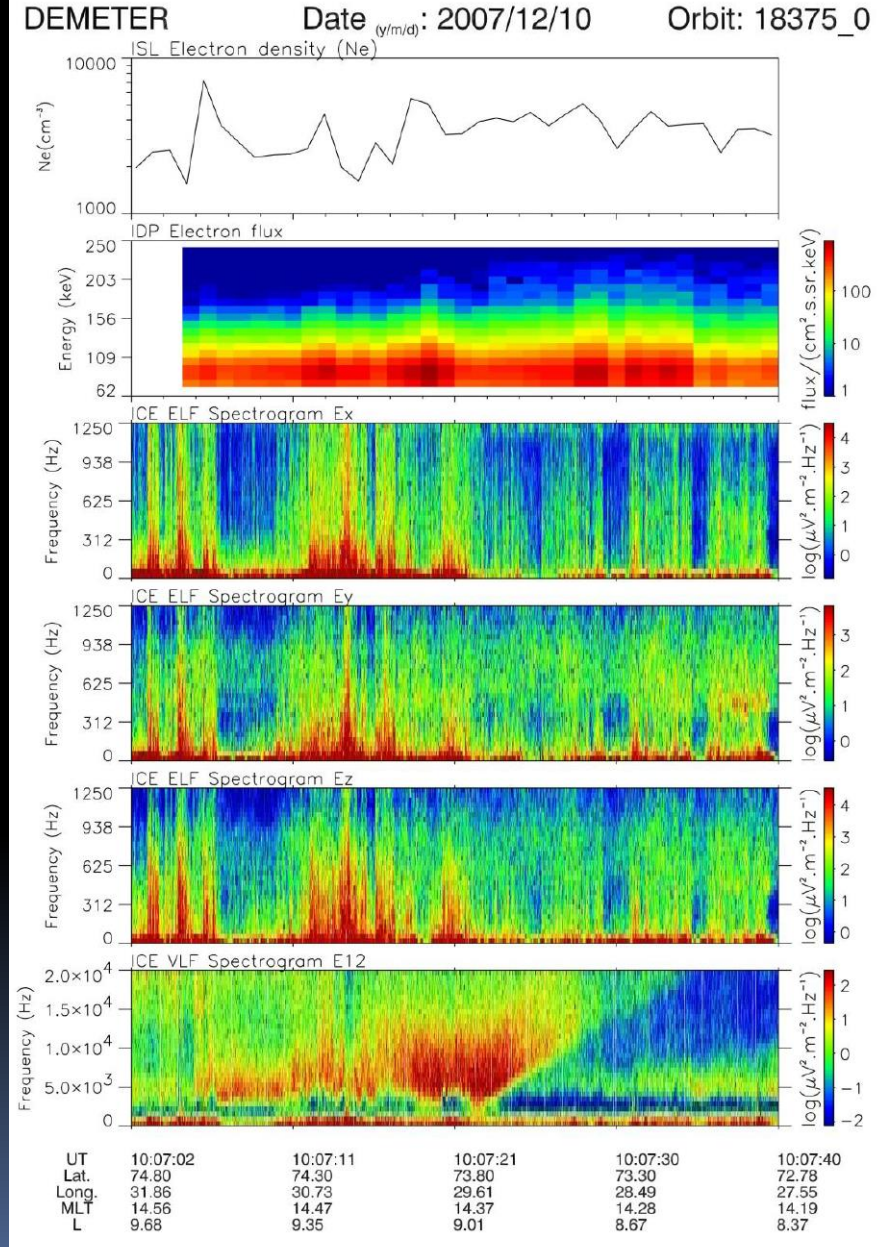
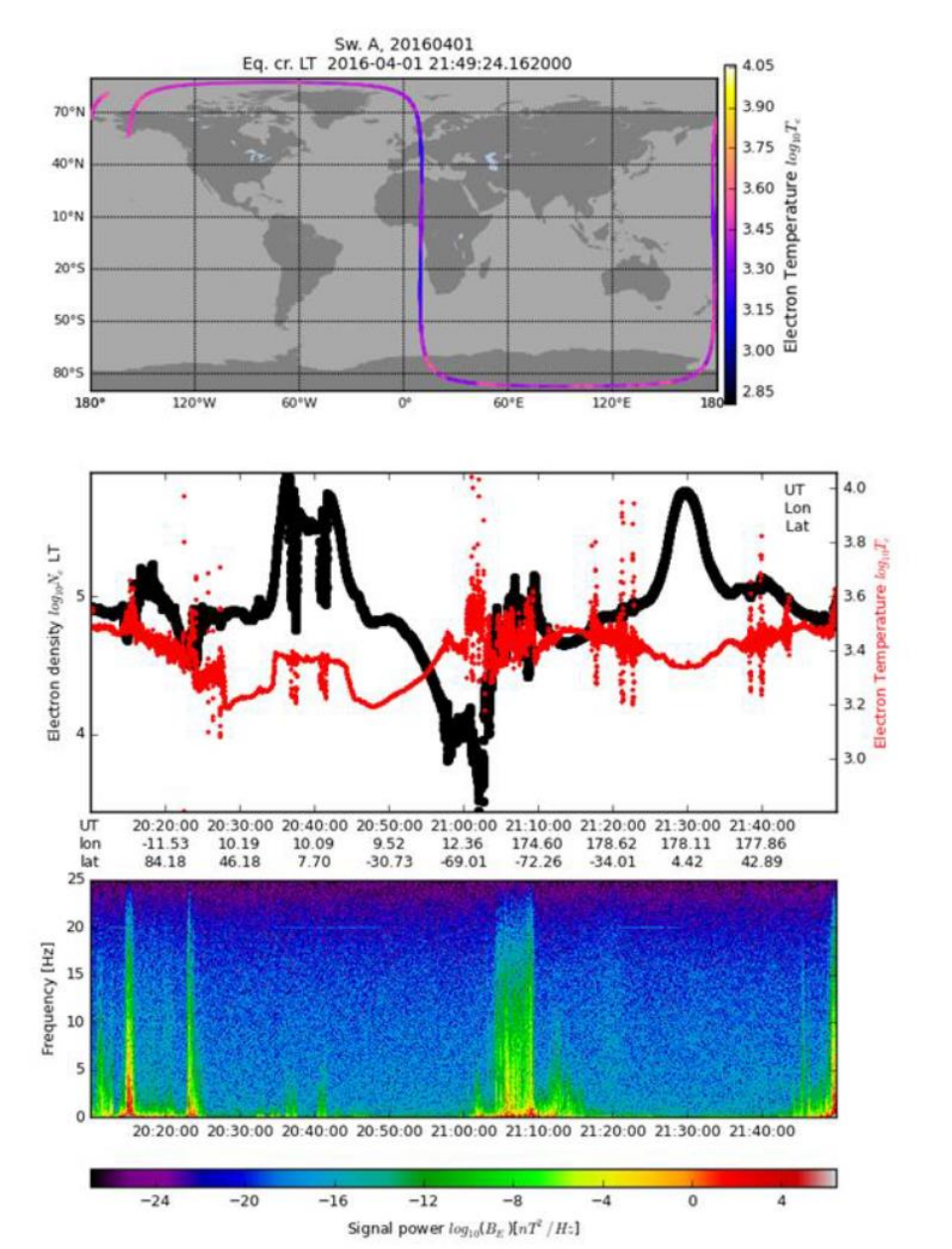
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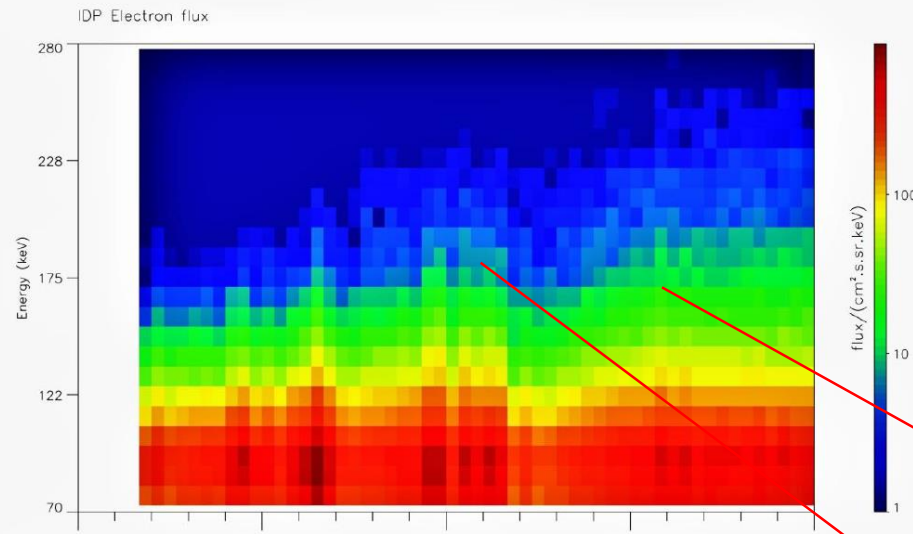
**ABSTRACT.** ELF/VLF waves have been registered in the outer polar cusps simultaneously with high energy electrons fluxes by the satellites Magion 4 (subsatellite to Interball 1), Polar and CLUSTER. Further we discuss similar observations in the different regions of the ionosphere, where DEMETER registered energetic electrons. The DEMETER satellite operating on the nearly polar orbit at the altitude 650km crossed different regions in the ionosphere. Registrations of ELF/VLF/HF waves together with the energetic electrons in the polar cusp, in the ionospheric trough and over thunderstorm areas are presented in this paper. The three satellites of ESA's Swarm mission provide additional information on the ELF waves in mentioned areas together with electron density and temperature. A brief discussion of the generation of these emissions by so-called "fan instability" (FI) and beam instability is presented.

**Key words:** atmosphere-ionosphere-magnetosphere system, thunderstorms, energetic electrons, ELF/VLF/HF waves, plasma instabilities, DEMETER, Swarm.



# IONOSPHERIC POLAR CUSP

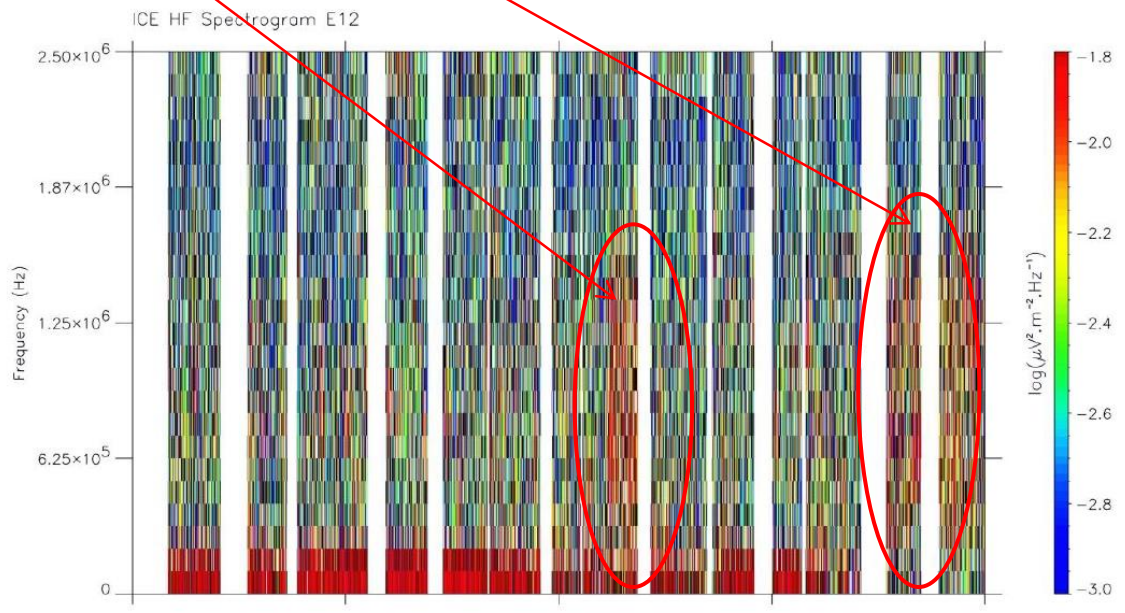




UT	10:07:00	10:07:15	10:07:30	10:07:45
Lat.	74.91	74.12	73.32	72.51
Long.	32.09	30.32	28.54	27.06
MLT	14.58	14.43	14.28	14.14
L	9.76	9.22	8.68	8.21

Spectrogram of electron energy from DEMETER in the polar cusp. Fluxes of electrons with energy up to 230keV are seen at 10:07:16, 10:07:30 and 10:07:45 until 10:08:00UT The beams of electrons can be distinguished at 10:07:13, 10:07:18, 10:07:29, 10:07:33UT around energy 80-90keV.

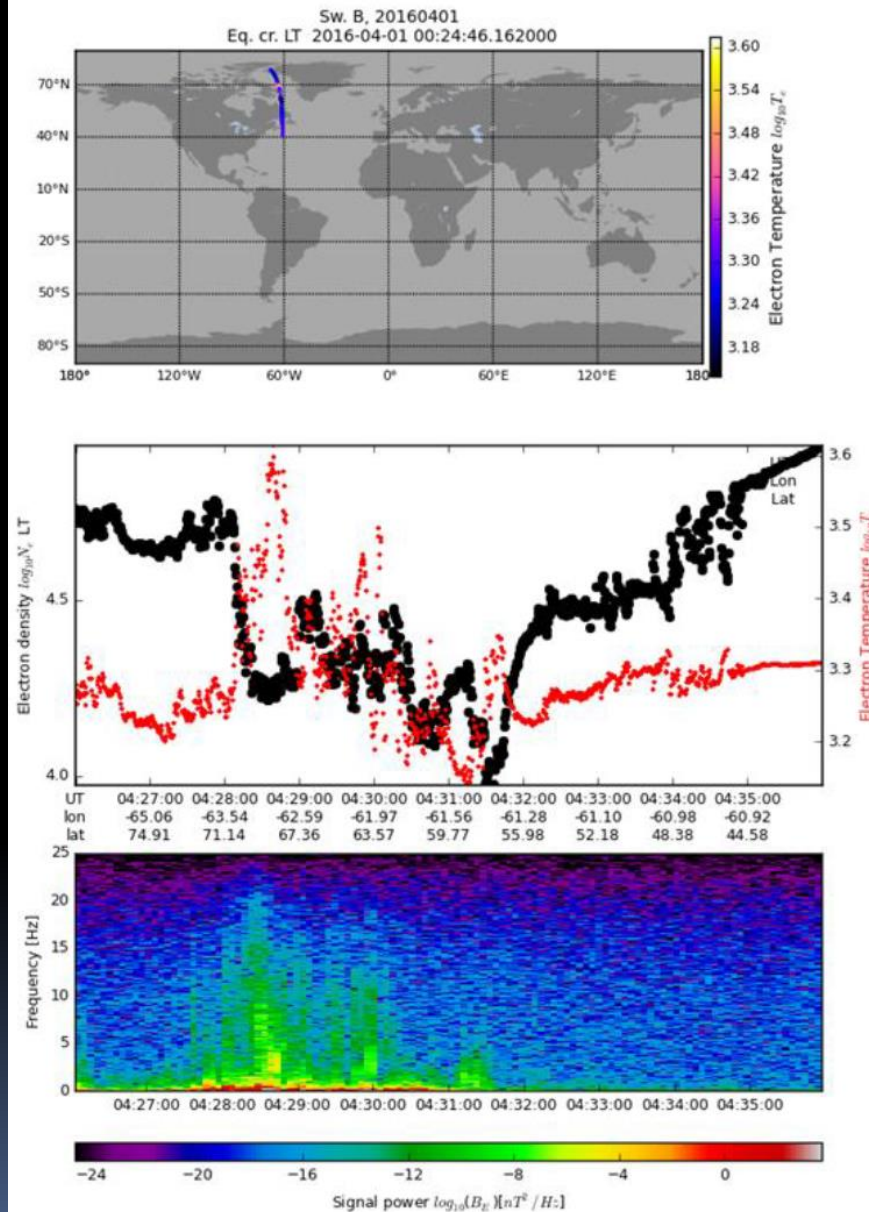
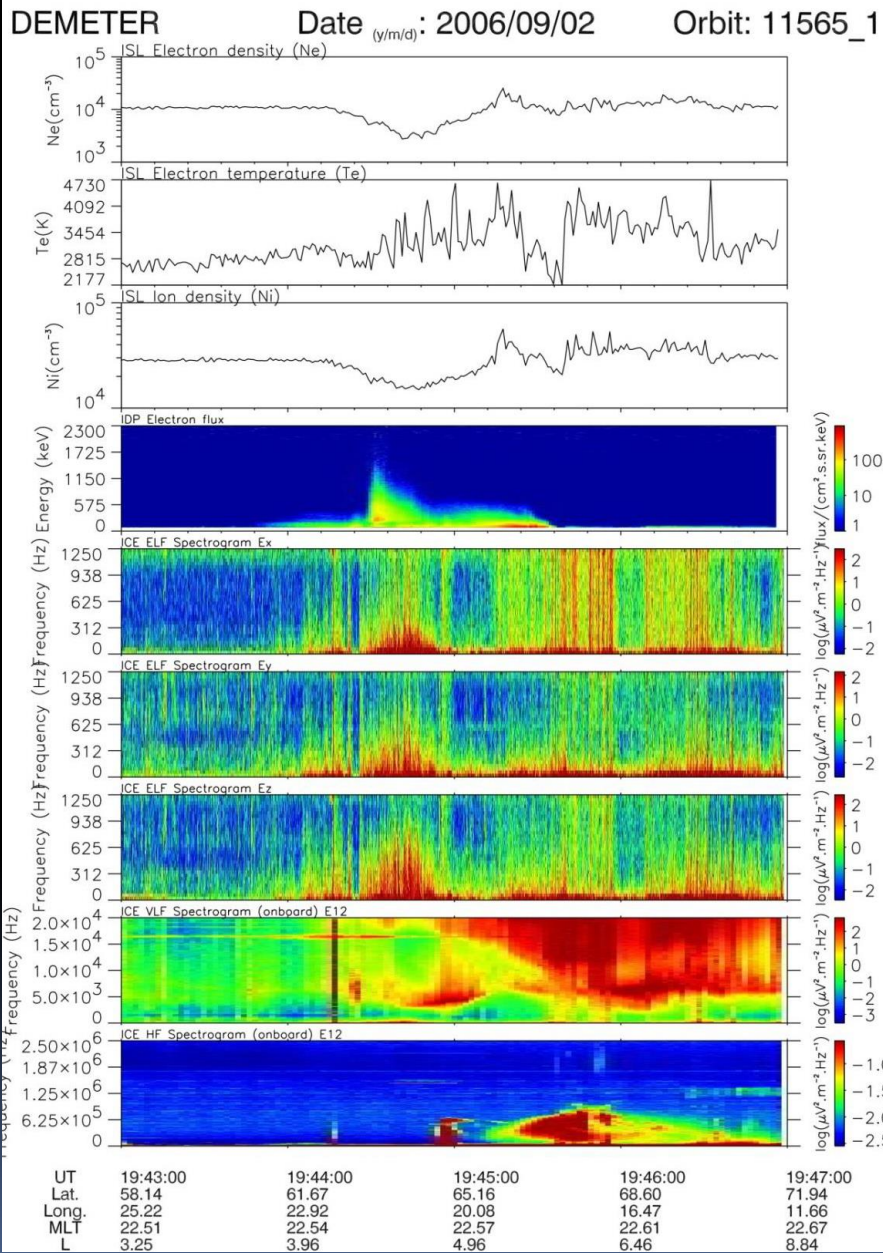
High frequency (0.55-1.8 MHz) – electric field variations observed by DEMETER in the polar cusp during an energetic electron event. A good correlation of energetic electrons presence (as shown in Figure 4) with enhancement of HF emissions is apparent at 10:07:30 and 10:07:45-10:08:00 UT. The plasma frequency at this epochs was  $f_{pe} \approx 0.8$  MHz and electron cyclotron frequency  $f_{ce} \approx 1.33$  MHz



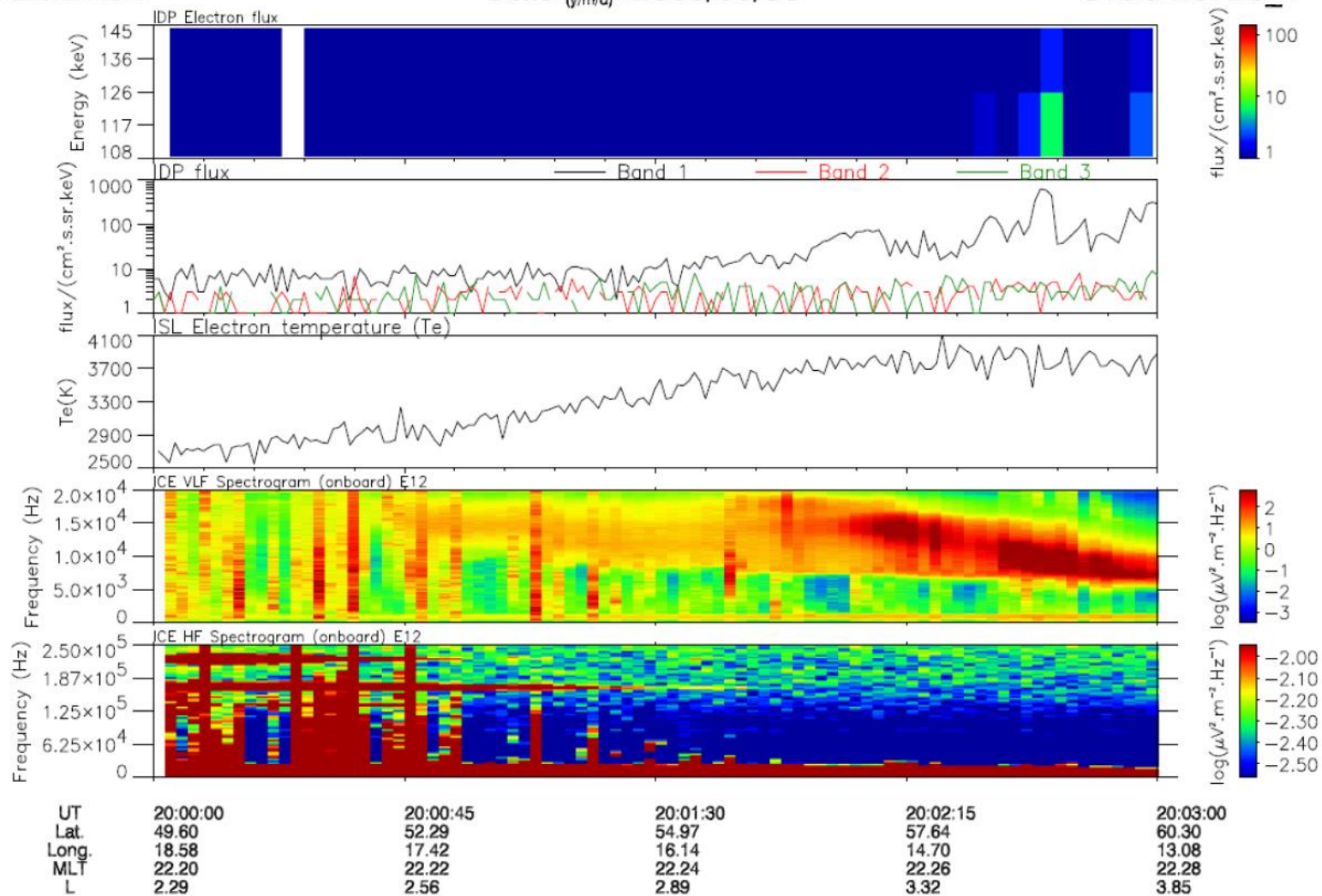
UT	10:07:00	10:07:15	10:07:30	10:07:45	10:08:00
Lat.	74.91	74.12	73.32	72.51	71.69
Long.	32.09	30.32	28.54	27.06	25.57
MLT	14.58	14.43	14.28	14.14	14.00
L	9.76	9.22	8.68	8.21	7.73



# THE IONOSPHERIC TROUGH







The parameters of ionospheric plasma at 660 km altitude observed by DEMETER together with VLF and HF over thunderstorms in Poland on June 30 2009. The panels present from the top to the bottom: energetic electrons energy spectrum, integrated flux of energetic electrons in three ranges - band 1: 971-2350 keV, band 2: 526- 971 keV and band 3: 72-526 keV, electron temperature and spectrograms of VLF and HF emission

# Conclusions

We present observations of waves (ELF/VLF/HF) together with plasma and energetic electrons in the polar cusp, ionospheric trough and over thunderstorms from the DEMETER satellite.

- The interpretation of the observations suggests multi-steps processes.
  - ELF/VLF waves resonantly interact with energetic particles (electrons) in the magnetosphere, which leads to precipitation of electrons into the ionosphere.
  - The next step is the stimulation of plasma instabilities: fan and beam instability.
  - The results from DEMETER presented in the present paper confirm that frequencies of registered waves are in the ranges related to prediction based on the theory of these instabilities.
- Swarm satellites cannot perform directed measurements of energetic particles, but results from them contain the information about strong variations of the electron temperature and density which are considered to result from the aforementioned processes.



*Merry Christmas  
and Happy New  
Year*