EMSEV 2012
Gotemba Kogen Resort, Gotemba, Japan
October 1–4, 2012
Abstract 3-04

The ionospheric ELF turbulence in the equatorial region originated from the seismic activity and geomagnetic disturbances– results of DEMETER satellite

M.Kościesza[1)], J. Blecki[1)], J. Słomiński[1)], M. Parrot[2)], S. Savin[3)], R. Wronowski[1)]

1) *Space Research Centre PAS, Warsaw, POLAND,*

2) *LPC2E/CNRS, Orleans, FRANCE*

3) *IKI/RAN, Moscow, RUSSIA*

Abstract

We report the observation of ELF plasma turbulence registered by DEMETER satellite in equatorial region of the ionosphere. The intensification of the variations of the electric field have been seen during geomagnetic disturbances. Other are associated with the seismic activity. We apply to study this turbulent processes wavelet, bispectral analysis and statistical description of the electric field fluctuations. These registrations are correlated with the plasma parameters measured onboard DEMETER satellite and with geomagnetic indices.

1. Introduction

Turbulence is one of the most universal event in the nature. It appears in the Earth's atmosphere, in the oceanic flows and in many technical problems as well as in studies of the plasma environment of the Earth and other planets. It plays crucial role in the dynamics of the astrophysical processes among other in the processes taking place on the Sun. A wide range of plasma instabilities exist in various regions of the terrestrial ionosphere, leading to the development of plasma turbulence. But there are many examples where an instability results in a fairly regular motion; then it is not turbulence. The turbulence appears when some physical parameter exceeds a certain level. The onset of turbulence may be gradual or it may occur with explosive suddenness; it may occur with relative spatial homogeneity or in local and periodic bursts. These different characteristics reveal different non-linear causative factors underlying the appearance of turbulence. One suspects, and this is confirmed in many cases, that the origins of turbulence lie in latent instabilities that are called into play at appropriate levels of excitation. Since there are numerous types of instabilities, both microscopic and macroscopic, it is to be anticipated that there will be different types of' turbulence.

2. Experiment description

DEMETER is a low-altitude satellite (710km) launched in June 2004 onto a polar and circular orbit which measures electromagnetic waves. In December 2005, the altitude of the satellite was decreased to 660km. The ELF (Extremely Low Frequency) range for the electric field is from DC up to 1250 Hz. There are two modes: a survey mode where spectra of one electric and one magnetic component are onboard computed and a burst mode where, in addition to the onboard computed spectra, waveforms of one electric and one magnetic field component are recorded. The choice of the component is done by telecommand. The burst mode allows performing a spectral analysis with higher time and frequency resolution. Details of the wave experiment can be found in [1,2,3] During the burst mode, the waveforms of the six components of the electromagnetic field are also recorded up to 1.25kHz.

3. Results

The traditional Fourier analysis is not relevant to study turbulence. More useful is wavelet analysis. The main advantage of using the wavelet transform is that it preserves the information about local features (e.g. singularities) of the signal and allows reconstruction of the signal over a given range of scales. This property is of particular importance in studying turbulence, which often shows coherent structures apparently related to nonlinear processes. Further we use the complex Morlet wavelet which is represented by the function of time t and central frequency ω_0. When we discuss the development of the plasma turbulence and cascade of the energy in the spectrum, the first step in this cascade is the 3- wave interaction. The resonance conditions for these processes are: $\omega_1+\omega_2 = \omega_3$, $\mathbf{k_1}+\mathbf{k_2} = \mathbf{k_3}$, where ω_1, ω_2 and ω_3 are the wave frequencies and $\mathbf{k_1}$, $\mathbf{k_2}$ and $\mathbf{k_3}$ are the wave vectors of the interacting waves. Verification of these conditions is possible using the so called bispectral analysis. It allows finding the nonlinearly interacting wave modes by computing the bispectrum of the signal which gives the information about phase coherence of these waves. The computer procedures for applications of the methods of wavelet and bispectral analysis have been developed in the package SWAN [4]. These methods of analysis have been applied earlier to study the nonlinear processes in the magnetospheric cusp [5]. Statistical methods of the turbulence description use the probability distribution function (PDF) and its parameters, skewness and kurtosis, as well as, structural function determining the intermittency of the turbulent processes.

The main results which will be given in our presentation are maps of the distribution of the ELF plasma turbulence obtained during different conditions of the geomagnetic activity. The some characteristics of the turbulence as a slope of the spectra, developing of the cascade and such parameters of PDF as kurtosis and scenes for the different regions of ionosphere will be presented.

Figure 1 shows the results of the DEMETER measurements (panel left) of the spectral density of the electric field disturbances, electron density and temperature and ion density and temperature in the vicinity of the equator together with geomagnetic indices (panel right).

Figure 2 presents the measurements of the electron density, spectral density of the electric field variations (left upper panel), wavelet spectrogram ((upper right panel), bispectrum (lower left panel) and slope of the single spectra of the electric field variations (lower right panel) taken by DEMETER satellite before Haiti earthquake.

References

[1.] Parrot, M., et al, The magnetic field experiment IMSC and its data processing onboard DEMETER: Scientific objectives, description and first results, Planetary and Space Science, 54, pp. 441-455, 2006.

[2.] [Berthelier, J.J., et al., ICE-the electric field experiment on DEMETER, Planetary and Space Science, 54, pp.456-471, 2006.

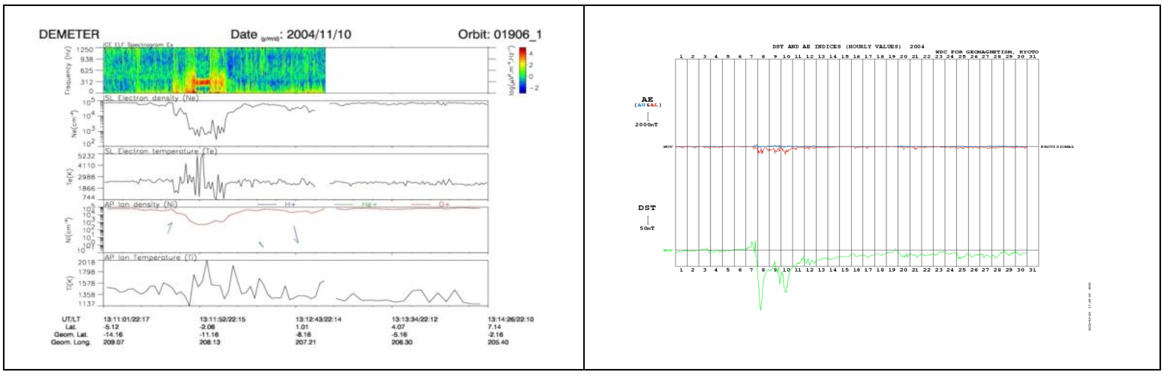
[3.] Cussac, T., et al, The Demeter microsatellite and ground segment, Planetary and Space Science, 54, pp. 413-427, 2006.

[4.] Lagoutte, D., et al , SWAN Software for Waveform Analysis, Analysis Tools version 2.3, LPCE/NI/003.D — Part 1, Part 2 Part 3, 1999.

[5.] Błęcki, J., et al, Nonlinear Interactions of the Low Frequency Plasma Waves in the Middle-altitude Polar Cusp as Observed by Prognoz-8, Interball-1 and Cluster Satellites, Acta Geophysica, 55, pp. 459-468, 2007.

Acknowledgements

This work was supported by the Centre National d'Etudes Spatiales (CNES) and the grant UMO-2011/01/N/ST10/07293. The authors thank J.J. Berthelier the PI of the electric field experiment for the use of the data.



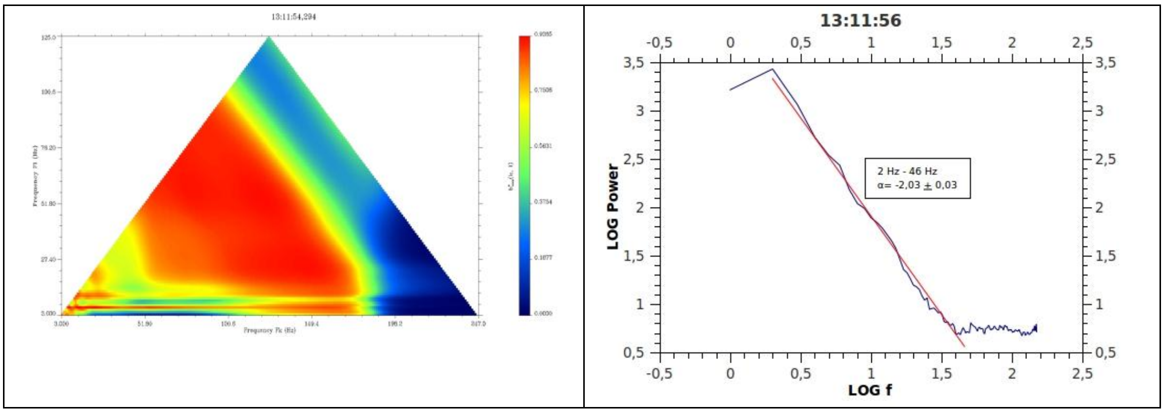


Fig. 1: The DEMETER measurements (upper left panel) of the spectral density of the electric field disturbances, electron density and temperature and ion density and temperature in the vicinity of the equator together with geomagnetic indices (upper right panel). Bispectrum of the electric field variation (lower left panel) and single spectrum with slope 2.03 characteristic for MHD turbulence (lower right panel).

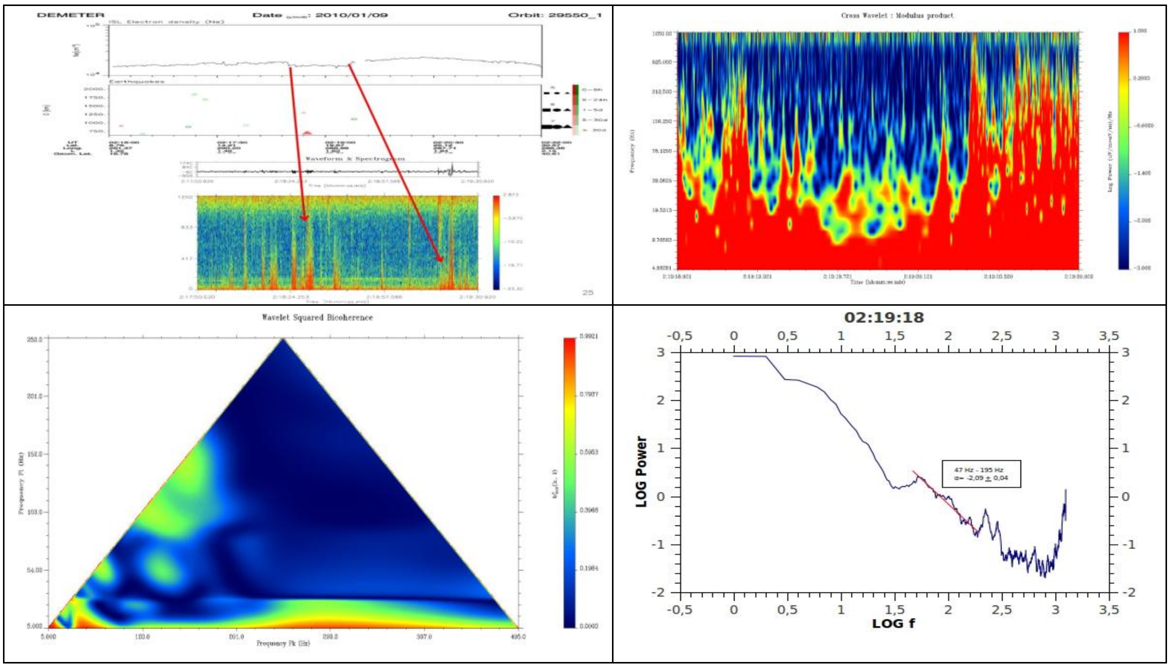


Fig.2: The measurements of the electron density, spectral density of the electric field variations (left upper panel), wavelet spectrogram ((upper right panel), bispectrum (lower left panel) and slope of the single spectra of the electric field variations (lower right panel) taken by DEMETER satellite before Haiti earthquake.