EPSC Abstracts
Vol. 7 EPSC2012-871 2012
European Planetary Science Congress 2012

Global picture of the ionospheric ELF turbulence – results of DEMETER mission

J. Blecki (1), J. Słomiński (1), M.Kościesza (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
(jblecki@cbk.waw,pl / Fax: +4822 8403131)

Abstract

We report the global picture of the observation of ELF plasma turbulence registered by DEMETER satellite in different regions of the ionosphere. The intensification of the variations of the electric field are seen in the trough region, in auroral region and sometimes, when DEMETER was operating there, in polar cusp. Some stochastic bursts of this turbulence have been seen around the world and were associated with the thunderstorms. Other are associated with the seismic activity and with fluxes of the energetic electrons registered in the polar cusp at the ionospheric altitude and south Atlantic anomaly. 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.

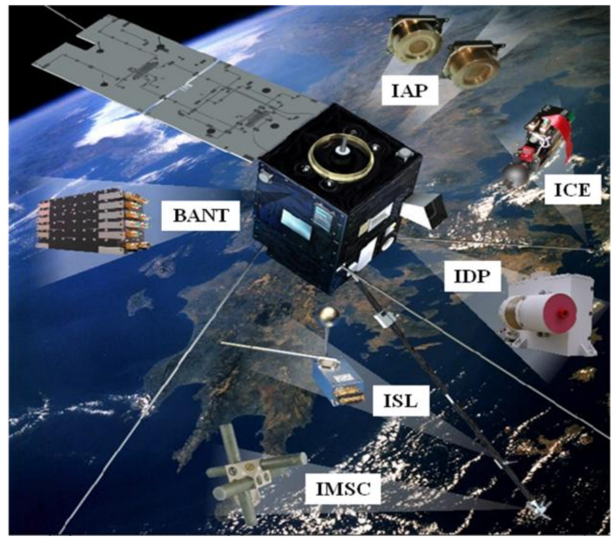

Figure 1: The schematic view of the DEMETER satellite and its instrumentation.

3. Methods of analysis

Wavelet Analysis. The traditional Fourier analysis is not relevant to study turbulence. The Fourier transform spreads information about the localized features over all scales making it impossible to study the evolution of different scale structures simultaneously. The important property of the wavelet transform is that the square of the wavelet coefficients can be interpreted as local energy and their statistics is easy to visualize and understand. The usefulness of wavelet analysis in studying the turbulence has been underlined by Farge [4] in the context of coherent structures. 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. Applications of the wavelet analysis to study turbulence in the space plasma were discussed by [5]. Further we use the complex Morlet wavelet which is represented by the function of time t and central frequency ω_0.

Bispectral analysis When we discuss the development of the plasma turbulence and cascade of the energy in the spectrum, the first step in this cascade and the fundamental process which is involved 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. This method for the studies of the plasma processes was first proposed by Kim and Powers [6]. 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. A quantitative measure of the phase coherency may be obtained using the bicoherence spectrum The computer procedures for applications of the methods of wavelet and bispectral analysis have been developed in the package SWAN [7]. These methods of analysis have been applied by authors of this paper earlier to study the nonlinear processes in the magnetospheric cusp [9]. 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.

4. Results

The main results which will be given in our presentation are maps of the global 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. Below are two examples of the overall pictures of the ELF turbulence in the polar cusp and ionospheric trough are given.

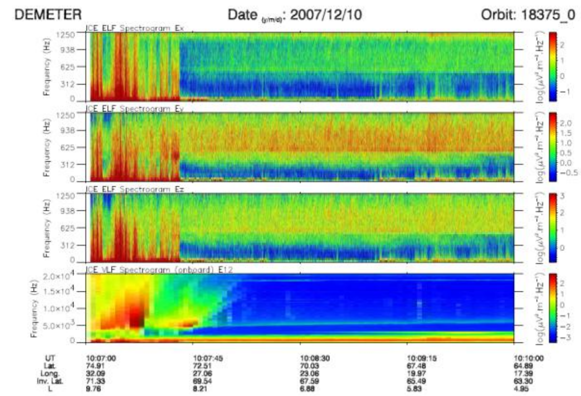

Fig.2 Example of the plasma turbulence spectra registered by DEMETER in the polar cusp.

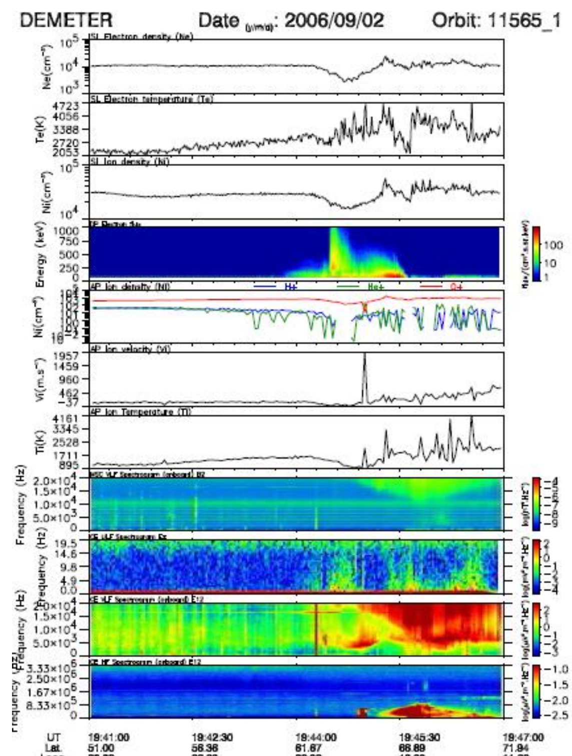

Fig.3 Plasma parameters and ELF plasma turbulence registered by DEMETER In the ionospheric trough.

6. Summary and Conclusions

The measurements of the DEMETER satellite performed during six years of its operation in the different regions of the ionosphere shown that ionosphere is the excellent laboratory to study of the nonlinear plasma processes. More examples and more detail discussion will be given in our presentation.

Acknowledgements

This work was supported by the Centre National d'Etudes Spatiales (CNES) and the grant UMO-2011/01/N/ST10?07293. It is based on observations with the electric field experiment ICE and the magnetic field experiment IMSC embarked on DEMETER. The authors thank J.J. Berthelier the PI of the electric field experiment for the use of the data.

References

[1] Parrot, M., et al, 2006: 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.

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

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

[4] Farge, M. , 1992, Wavelet transforms and their applications to turbulence, *Annales Review Fluid Mechanics*, **24**, pp. 395-457.

[5] Wernik, A.W., 2002, High-latitude ionospheric plasma turbulence: advanced analysis methods and results, *Acta Geophysica. Polonica*, **50**, pp.119-134.

[6] Kim Y.C. and E. J. Powers, 1978, Digital bispectral analysis of self-excited fluctuation spectra. *Physics of Fluids*, **21,** pp. 1452–1453.

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

[8] Błęcki, J., et al2007, 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.