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SPECTRAL FREQUENCY ENVELOPES RELATED TO VLF/ELF EMISSIONS OBSERVED BY ICE EXPERIMENT ON BOARD THE DEMETER MICRO-SATELLITE

СПЕКТРАЛЬНЫЕ ЧАСТОТНЫЕ ОГИБАЮЩИЕ, СВЯЗАННЫЕ С ОНЧ/КНЧ ИЗЛУЧЕНИЯМИ, НАБЛЮДАЕМЫЕ ВО ВРЕМЯ ЭКСПЕРИМЕНТА ICE НА БОРТУ МИКРОСПУТНИКА DEMETER

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В докладе описана возможная связь между сейсмическими событиями и ОНЧ и КНЧ излучениями на основе экспериментальных данных с микроспутника DEMETER института ‘Instrument Capteur Electrique’ (ICE). Мы применяем так называемый спектральный метод, который позволяет измерять и рассчитывать степень активности ОНЧ/КНЧ, наблюдаемых во время каждой полутраектории микро спутника. Мы определяем коэффициент индекса ОНЧ/КНЧ, который указывает активность основных наблюдаемых компонент, т.е. шипящих и хоровых излучений. Наши результаты используются для распознания, разделения и классификации

ОНЧ/КНЧ излучений по записям эксперимента DEMETER/ICE. Мы обсуждаем преимущества этого метода и возможности связи его с сейсмическими событиями.

1. Introduction

It is well know since several decades that electromagnetic effects, like the electric and magnetic perturbations, are caused by natural geophysical activity such as earthquakes and volcanic eruptions. It includes: electromagnetic emissions in a large frequency range, perturbations of ionospheric layers, anomalies on the records of VLF transmitter signals, and night airglow observations (Parrot, 1996). Such phenomena, called seismo-electromagnetic phenomena, can be considered as short term precursors because they occur between few hours and/or days before the shock. Two papers published by Gokhberg et al. (1982) and Warwick et al. (1982) advanced the investigation of the seismo-electromagnetic effects. Authors reported earthquakes events which were accidentally recorded by experiments not devoted to this study. Also they detailed observations of various parameters measured in the atmosphere or in the ionosphere in relation with seismic activity. There are many hypotheses on the generation mechanism of these seismo-electromagnetic perturbations which can be found in the following recent review papers: Hayakawa and Molchanov (2002), Pulinets and Boyarchuk (2004), and Meloni et al. (2004). Since the beginning of the 21st century three satellites were launched: COMPASS-1, (Russia, December 2001), QuakeSat, (USA, June 2003), and DEMETER, (France, June 2004). These space missions were mainly devoted to investigate the precursors emissions related to seismo-electromagnetic effects.

In this paper we report on ELF/VLF emissions observed by the ‘Instrument Capteur Electrique’ (ICE) experiment onboard the DEMETER micro-satellite. We apply the so-called ‘spectral method’ which allows to quantify and to estimate the VLF/ELF activity level observed during each half-orbit of the micro-satellite. We discuss the advantage of such a method and the means to link it to the occurrence of seismic events.

2. ICE experiment onboard DEMETER micro-satellite

The main objective of the ICE experiment is to detect and characterize the electromagnetic perturbations in the ionosphere that are associated with seismic activity. As a secondary objective, this instrument also aims at characterizing the electromagnetic effects that can be generated by tropospheric storms in the ionosphere. In addition, this experiment provides real time observations that can be of use for space weather purposes. The objective of the ICE instrument on DEMETER is thus to perform a continuous survey of the DC and AC electric fields over a wide frequency range and with a high sensitivity in order to search for possible electrostatic and/or electromagnetic waves in the ionosphere that might be induced by seismic activity. The instrument and the onboard data processing have been designed to provide an optimum set of data in the various frequency ranges, emphasizing full characterization of the 3 components of the waves at frequencies below 1 kHz and single axis waveform transmission and spectrum measurements at higher frequencies (Berthelier et al., 2006).

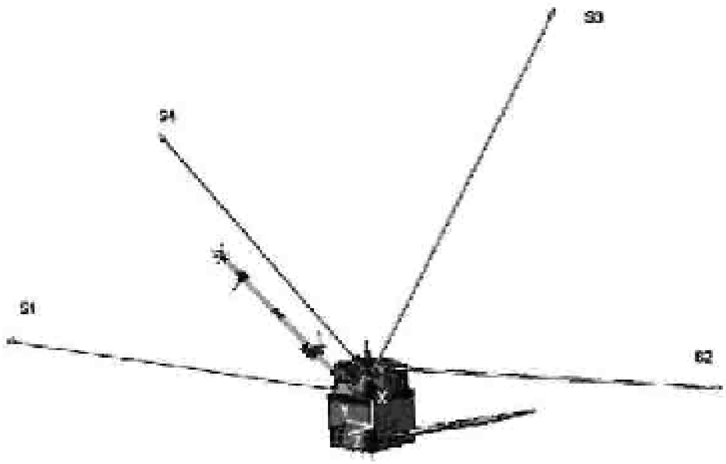

Fig.1: Position of the ICE sensors on the spacecraft

The ICE experiment consists of 4 spherical sensors with embedded pre-amplifier electronics mounted on the ends of 4 booms or antenna “arms” and associated electronics, included in the BANT module, to fulfill the onboard signal processing requirements. When measuring the potential difference between two of these sensors, ICE operates as a double probe instrument in which the component of the electric field is determined along the axis defined by the two sensors. Any pair of sensors among the four can be used for this objective which enables the 3 components of the DC and AC vector electric field to be obtained. Four frequency ranges have been defined, **DC / ULF** [0-15 Hz], **ELF** [15 Hz-1 kHz], **VLF** [15 Hz-17.4 kHz] and **HF** [10 kHz-3.175 MHz]. Depending on the frequency range and on the spacecraft and ICE modes of operation, the data that are stored in the mass memory can be the waveform of the signal obtained from either the voltage difference between two sensors or that measured by a single sensor and the spacecraft potential, and/or the power spectra of the signal obtained from the voltage difference between two sensors.

The 4 sensors, labeled S1, S2, S3 and S4 in **Figure 1**, are spherical aluminum electrodes 60 mm in diameter each mounted at the end of a 4 meter deployable boom. Due to the remote position of the sensors with respect to the spacecraft body, electromagnetic interferences generated by the spacecraft subsystems or other payload instruments are significantly reduced. Finally, the orientation of the 4 booms have also been chosen so that the 3 components of the electric fields that can be obtained from the voltage differences between individual sensors, as indicated below, are close to a three axis orthogonal configuration. The sensors are coated with a thin layer of carbon filled epoxy in order to minimize the variations of the surface potential over the surface and improve the quality of DC electric field measurements. The spherical shell of each sensor includes a small electronics board consisting of a unity gain preamplifier and a polarization current source.

3. Spectral method applied to ELF/VLF observations

We attempt in our analysis to apply the spectral method to classify the different components observed on the dynamic spectrum recorded by DEMETER/ICE experiment. Such method was used to separate Jovian decametric radio emissions recorded by ground based stations (Boudjada and Genova, 1991; Boudjada et al., 1995). Several components were classified using basically the instantaneous frequency bandwidth of the emission combined to the frequency and time resolutions of the receiver.

Figure 2 shows a dynamic spectrum of the ELF/VLF radiation recorded on 24th Nov. 2004 by the ICE experiment where the time (in hours) and the frequency (in Hz) are indicated by the horizontal and vertical axes, respectively. For our study we have used only one of the electric field components. In the nominal configuration this is the E12 component, but a tele-command order allows one of the 2 other components, E34 or E13, to be selected. The power spectrum is computed with frequency and temporal resolutions that depend on the spacecraft and ICE modes of operation. In the burst mode the power spectrum is stored with a 19.53 Hz frequency resolution and averaged over 2.048 s.

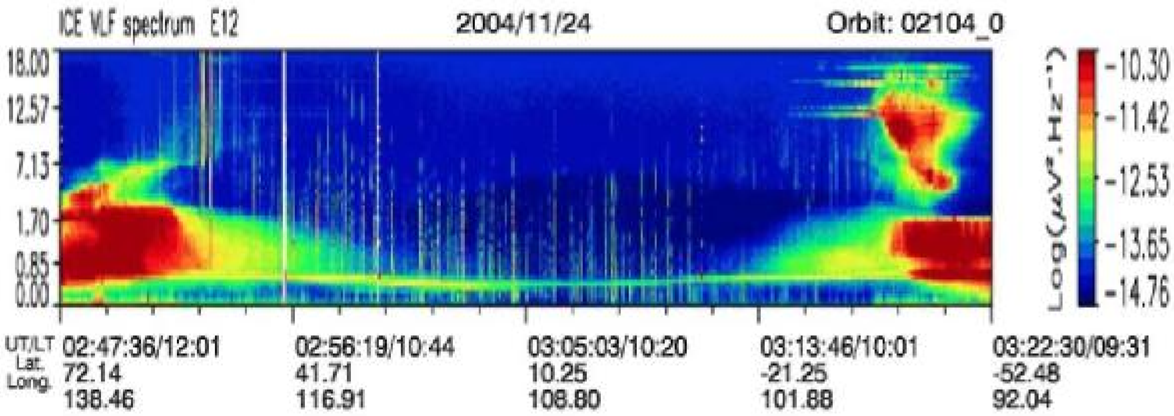

Fig.2: Dynamic spectrum recorded by the ICE experiment onboard DEMETER micro-satellite.

The intensity is indicated by color level where the strongest (red) and lowest (bleu) signal level are of about 10^{-10} and 10^{-14} μV^2 Hz^{-1}, respectively. We proceed to a classification of the ELF/VLF emissions taken into considerations their corresponding spectral shapes: (a) continuum and not structured (Type-1), (b) radiations with positive (Type-2) or negative (Type-3) frequency drift rates, and (c) bursty emissions without frequency drift rates (Type-4). Considering a given spectral shape we store the following parameters: (a) time of the beginning and the ending of the emissions, (b) minimum and maximum frequencies, and (c) intensity level (µV2.Hz-1, or mV2.Hz-1). Also the corresponding satellite positions like (a) local time (LT in hour and minutes), and (b) latitude and longitude satellite positions. We apply this method to the two earthquakes observed in 2004 in the Adriatic region. The first event has a magnitude of 5.30 and was observed on 24th Nov. 2004 (22:59 UT) at a latitude of 45.66°N and longitude of 10.64°E. The second seismic event occurred one day later at 06:21 UT, magnitude 5.20, and a latitude of 43.24°N and a longitude of 15.58°E. Afterwards we consider frequency occurrence for all observed components (Type 1, Type 2, Type 3 and Type 4) for two periods:

- 23rd , 24th , 25th Nov. 2004 which is close the Adriatic events
- 03rd , 04th , 05th Nov. 2004 which is about three weeks before the Adriatic events

The main propose is to combine the ELF/VLF frequency occurrences before and close to the Adriatic seismic events. It appears clearly from **Figure 3** that the frequency occurrence seems to be similar. It is not possible to conclude concerning a possible shift in frequency between the two periods taking into consideration the ELF/VLF selected types.

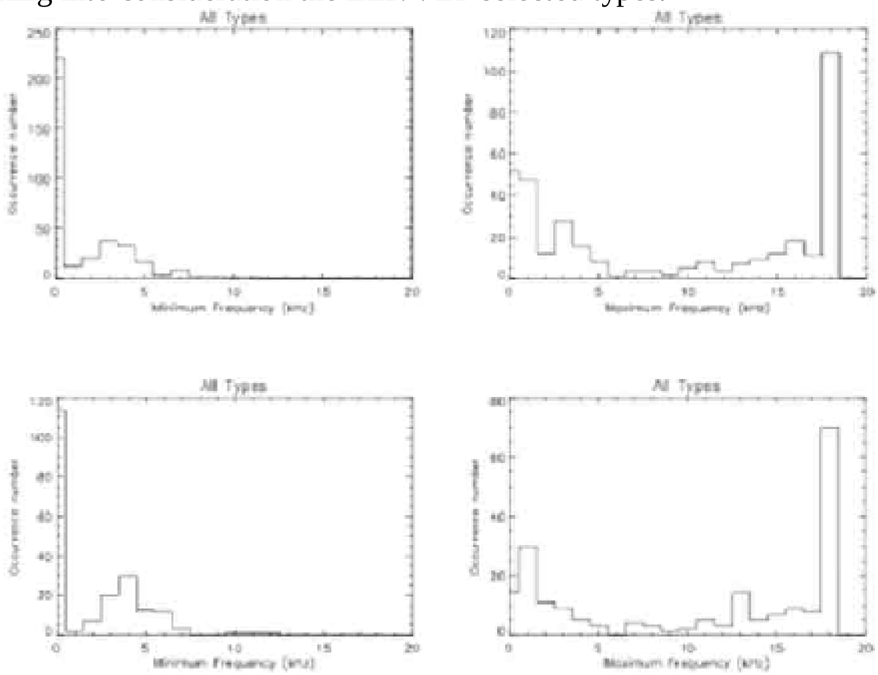

Fig.3: Frequency occurrence histograms associated to ELF/VLF components observed during two periods: (a) 23rd , 24th , 25th Nov. 2004 (two upper panels) and (b) 03rd , 04th , 05th Nov. 2004 (two lower panels)

4. Conclusion

We apply the spectral method to the ELF/VLF emissions recorded by the ICE experiment onboard the DEMETER micro-satellite. We consider different types of emissions which are classified taking into considerations the corresponding shapes on the dynamic spectrum. In the case of the two Adriatic seismic events, we analyze the frequency occurrences for two given periods. It turns out that: (a) the same features are observed before and close to the seismic events and (b) their corresponding frequency occurrences are identical.

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О ВОЗМУЩЕНИЯХ foF2 В СРЕДНЕШИРОТНОЙ ИОНОСФЕРЕ ПЕРЕД СИЛЬНЫМИ ЗЕМЛЕТРЯСЕНИЯМИ

fo*F2* DISTURBANCES IN MIDDLE LATITUDE IONOSPHERE BEFORE STRONG EARTHQUAKES

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Within the last years in a series of works the deflection of character of ionospheric *foF2* frequency from its median values during earthquake preparation has been studied in connection to the problem of earthquake prognosis. It has been found out that the modification of *foF2* does not take place before all earthquakes. Thus it was interesting to carry out statistical investigations and to pick out a part of events which have been accompanied by noticeable anomaly variations in the *F*-region.

In this work the statistical investigations of ionospheric effects before strong earthquakes are carried out by the use of data from 4 Japanese stations of vertical sounding. The statistical analysis of the variations of the averaged diurnal frequency of the maximum ionospheric electron density *foF2* is performed in connection to the occurrence of some tens of earthquakes with magnitudes $M > 6.0$, depths $h < 80$ km and distances from the vertical sounding station $R < 1000$ km. It is shown that, on the average, *foF2* decreases a few days before the earthquakes. The decrease amounts in average to about 5 % a day of the shock.

Введение

В ряде работ проводились исследования поведения характеристик ионосферы в связи с подготовкой землетрясений. Ионосферный слой *F* самый динамичный из регулярных слоев, он более всего подвержен изменениям, связанным с различными