



Satellite study of VLF ground-based transmitter signals during seismic activity in Honshu Island

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ABSTRACT

The paper is related to the study of the VLF (very low frequency) signal transmitted from the radio-navigation station in Komsomolsk-na-Amure at frequencies 11.9 kHz and 14.8 kHz during seismic activity in Japan. First, using data collected with the electric field experiment on board the DEMETER satellite, global maps of electromagnetic signal at the frequencies of the transmitter have been obtained. Second, particular analysis of the VLF signals have been done at the time of two powerful earthquakes which took place in the region of Honshu Island on 2005/08/16 and on 2007/07/16. Comparison with averaged background data revealed disturbances in the signal intensity transmitted from the Komsomolsk-na-Amure station and received by the satellite. Discussions to understand why such changes can be associated with seismic activity are developed.

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1. Introduction

Many past researches describe anomalous behaviour in electromagnetic (EM) measurements in association with seismic and volcanic activity. Ground seismo-associated phenomena, and in particular changes of EM fields, are frequently reported as being observed close to Earths seismic areas prior to, during and after earthquakes. Observations carried out in the ionosphere–magnetosphere region include perturbations of the geomagnetic field, the DC electric field, the EM waves, the ionospheric plasma and the flux of charged particles (Pulinets and Boyarchuk, 2004; Ouzounov et al., 2006; Pulinets, 2007). But the nature of the seismo-ionospheric coupling is still unclear despite the scientific interest for more than 20 years. Different types of mechanisms are mentioned. Some authors report that disorders associated with seismicity cause the depletion of intensity in EM signals (Molchanov et al., 2006; Biagi et al., 2007; Rozhnoi et al., 2007). But also large group of scientists is very sceptical about the possible influence of seismic events on the Earths EM environment (Pham and Geller, 2002) and they claim that carried studies do not show strong confirmed results. Coordinated simultaneous and continuous ground-based and space measurements allow to explore and investigate the properties of the Earths interior, as well as to survey the EM environment. In the past, such approach has been investigated when VLF (very low frequency) radio signals radiated by powerful transmitters are received on the ground after ionospheric reflec-

tion. It is possible to probe the ionosphere at the time of an earthquake when the path transmitter – satellite is going through the active seismic area. With the terminator time method, that is related to the position of a minimum of the radio signal amplitude/phase during sunset and sunrise, anomalies from 3 days to 10 days before large ($M > 6.0$) earthquakes and continuing few days after their occurrence were revealed (Hayakawa et al., 1996; Molchanov and Hayakawa, 1998). With a different method of analysis based on the study of the night time fluctuations in the radio signals phase and/or amplitude, anomalies before M5.5 earthquakes have been reported (Gufeld et al., 1992; Rozhnoi et al., 2004; Shvets et al., 2004). More recently, the VLF radio signals radiated by powerful transmitters and received onboard the DEMETER satellite have been used to investigate ionospheric perturbations in relation to seismic activity. Some possible seismic disturbances were presented by Molchanov et al. (2006) and Rozhnoi et al. (2007). Particularly, some precursory effect at the time of the Sumatra earthquake (26 December 2004; $M = 9.0$) were pointed out. They also revealed that the range of the sensitive area is from 1000 km for M5.5 earthquakes to 5000 km for M9.0 earthquakes. In order to confirm these results for different events and different transmitters, the purpose of this paper is to study signals emitted from the VLF ground-based transmitter Komsomolsk-na-Amure in Russia and received onboard the DEMETER satellite at the time of two large earthquakes in Japan. Section 2 will present the wave experiment onboard the satellite and the method to process the transmitter data. Results concerning the two earthquakes will be presented in Section 3, whereas discussions and conclusions are given in Section 4.

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2. Method of investigation

2.1. Description of the experiment

DEMETER was launched on June 29, 2004 into low-altitude polar orbit with the purpose of studying ionospheric perturbations possibly related to seismic activity and anthropogenic activity (Parrot et al., 2006). The scientific payload of the DEMETER micro-satellite is composed of several instruments which provide a nearly continuous survey of the plasma, waves and energetic particles around the Earth at an altitude of 700 km. All data shown in this paper have been recorded during the survey mode of the electric field experiment. The electric field experiment uses four electric probes to measure the three components of the electric field in a frequency range from DC up to 3.5 MHz. In the VLF range and in the survey mode, spectra of one electric component are on-board computed up to 20 kHz and continuously recorded with a time resolution of 2 s and a frequency resolution of 19.53 Hz. Details of this experiment can be found in Berthelier et al. (2006). Due to technical reasons data are only recorded at invariant lati-

tudes less than $\sim 65^\circ$. All data files and plots are organised by half-orbit (Lagoutte et al., 2006). The up-going half-orbits (invariant latitude between 65°S and 65°N) correspond to night time (~ 22.30 LT) and the down-going half-orbits (invariant latitude between 65°N and 65°S) to day time (~ 10.30 LT).

2.2. The VLF transmitter signal

The purpose of our work is to survey possible changes in VLF EM transmitter signals during seismic activity. The emission frequencies of VLF transmitters are from 10 kHz up to several tens of kHz. The choice of one VLF transmitter is connected to its frequencies of emissions which must be related to the VLF frequency range covered by the electric field experiment. It means that only VLF transmitters with frequencies between 10 kHz and 20 kHz must be investigated. Moreover, the transmitter must not be located far from seismic regions. With the data collected by DEMETER it is possible to identify working transmitters and to achieve a global survey of areas where signal transmitted from the ground can be used for further investigation. For example in Fig. 1, the spectrogram with

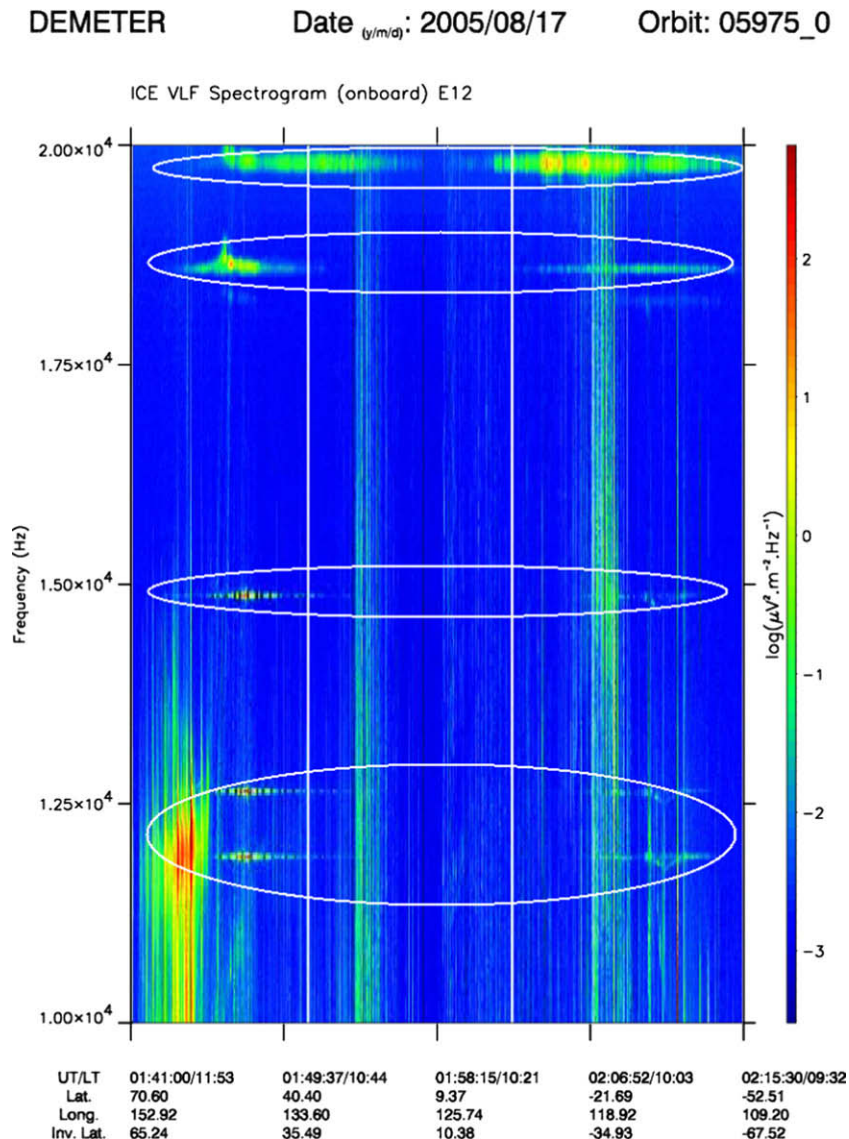


Fig. 1. Electric field spectrogram between 10 kHz and 20 kHz recorded on August 17, 2005 during a complete down-going half-orbit. Signals transmitted from VLF stations are indicated with white ellipses. Their attenuation in the equatorial zone must be noticed.

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