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DEMETER observations of manmade waves that propagate in the ionosphere

Observations par Demeter d'ondes d'origine humaine se propageant dans l'ionosphère

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ABSTRACT

This paper is a review of manmade waves observed by the ionospheric satellite DEMETER. It concerns waves emitted by the ground-based VLF and ELF transmitters, by broadcasting stations, by the power line harmonic radiation, by industrial noise, and by active experiments. Examples are shown including, for the first time, the record of a wave coming from an ELF transmitter. These waves propagate upwards in the magnetosphere and they can be observed in the magnetically conjugated region of emission. Depending on their frequencies, they perturb the ionosphere and the particles in the radiation belts, and additional emissions are triggered.

RÉSUMÉ

Cet article constitue une revue des ondes d'origine humaine observées par le satellite ionosphérique Demeter. Cela concerne les ondes émises par les émetteurs TBF et EBF, par les stations de radio, par le rayonnement des lignes électriques et par les expériences actives. Des exemples sont présentés dont, pour la première fois, l'enregistrement d'une onde émise par un émetteur EBF. Ces ondes se propagent vers la magnétosphère, et elles peuvent être observées au point conjugué magnétique de leur région d'émission. Selon leurs fréquences, elles perturbent l'ionosphère et les particules dans les ceintures de radiation, et de nouvelles émissions sont déclenchées.

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1. Introduction

DEMETER was an ionospheric micro-satellite in operation between June 2004 and December 2010. Its orbit was circular (660 km), polar, and nearly sun-synchronous (10.30 LT and 22.30 LT). Its payload measured electromagnetic waves in different frequency ranges from ULF to MF, and also plasma parameters (for example the electron and ion density). The description of the experiments can be found in [1]. The VLF electric and magnetic spectrograms were always onboard calculated with a low time (2 s) and frequency (19 Hz) resolution all around the Earth, except in the auroral zone (invariant latitude $>65°$). The MF electric field spectrogram (up to 3 MHz) is also continuously recorded. From time to time, the magnetic and electric field experiments are switched in burst mode where waveforms are registered up to 20 kHz in order to have a better frequency and better time resolutions.

Normally the field strength of the electromagnetic waves decreases with distance from the source, but in the ionosphere or the magnetosphere it could be enhanced due to interaction with energetic particles. The aim of this paper is to show examples of manmade waves emitted from the ground and recorded in the ionosphere by DEMETER at various frequencies.

Waves emitted by VLF transmitters are presented in section 2, by ELF transmitters in section 3, and by electricity networks in section 4. Section 5 displays examples of ELF waves generated at high latitudes by powerful HF emissions for scientific purpose. Conclusions are given in section 6.

2. VLF transmitters

Ground-based VLF transmitters are used for communications by the army in different countries. They are powerful in order that the signal can be received at very large distances. Normally, the emitted wave propagates in the waveguide formed by the Earth surface and the bottom of the ionosphere, but this wave can escape in the ionosphere. Their effects have been studied for a long time because the wave propagates in the magnetosphere mainly along the magnetic field lines

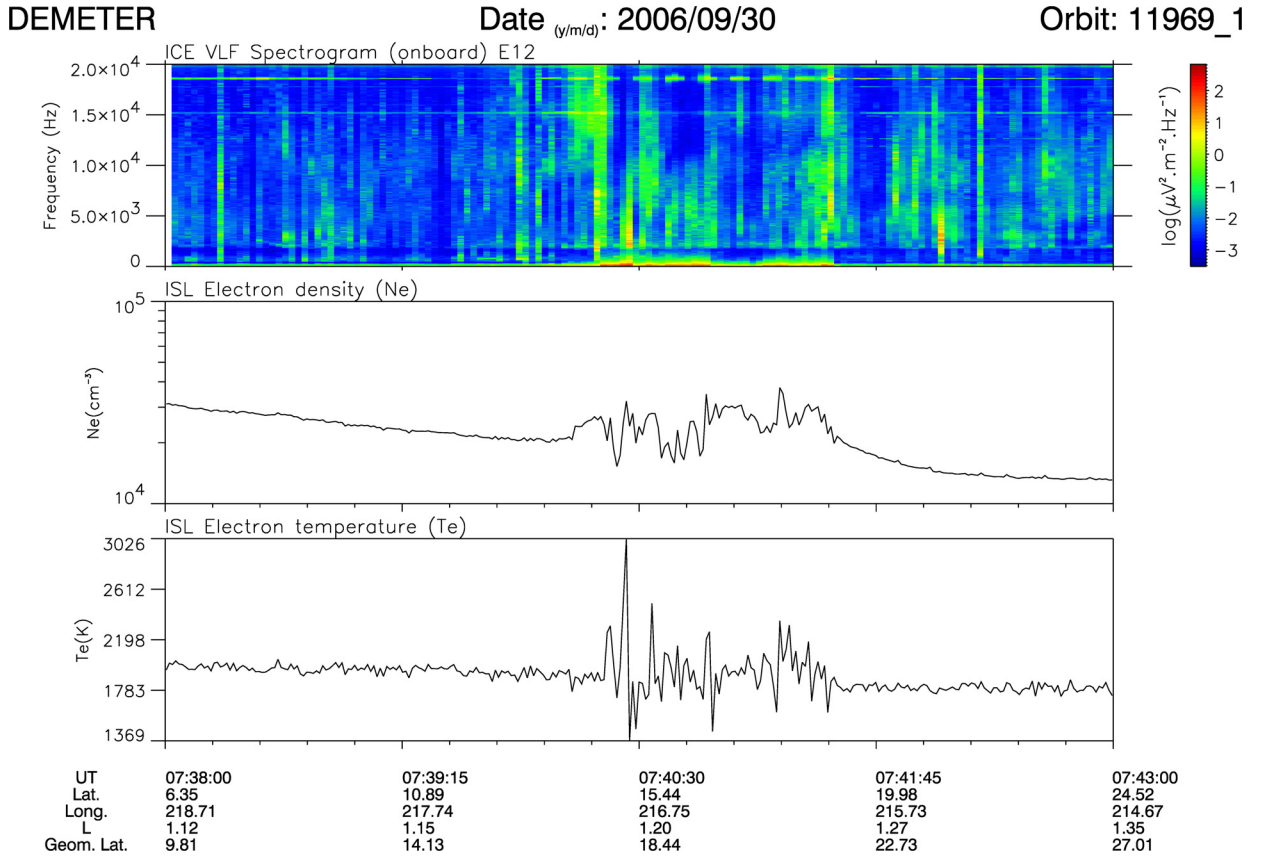

Fig. 1. The top panel represents the spectrogram of an electric field component recorded on 30 September 2006 between 07:38 and 07:43 UT. The frequency range is up to 20 kHz. The intensity is color coded according to the color scale on the right. The middle (bottom) panel displays the electron density (temperature). Below, the geographic latitude and longitude are indicated, together with the L-value and the geomagnetic latitude.

Fig. 1. Le panneau du haut présente le spectrogramme d'une composante du champ électrique enregistré le 30 septembre 2006 entre 07:38 et 07:43 TU. La gamme de fréquence est jusqu'à 20 kHz. L'intensité est codée en couleur suivant l'échelle de couleur à droite. Le panneau du milieu (bas) représente la densité (température) électronique. Les valeurs de la latitude et de la longitude géographique sont données en bas, ainsi que les valeurs de L et de la latitude géomagnétique.