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Aspects regarding the use of the INFREP network for identifying possible seismic precursors

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ABSTRACT

In the last decades, one of the main research directions in identifying seismic precursors involved monitoring VLF (Very Low Frequency) and LF (Low Frequency) radio waves and analysing their propagation characteristics. Essentially this method consists of monitoring different available VLF and LF transmitters from long distance reception points. The received signal has two major components: the ground wave and the sky wave, where the sky wave propagates by reflection on the lower layers of the ionosphere. It is assumed that before and during major earthquakes, unusual changes may occur in the lower layers of the ionosphere, such as the modification of the charged particles number density and the altitude of the reflection zone. Therefore, these unusual changes in the ionosphere may generate unusual variations in the received signal level.

The International Network for Frontier Research on Earthquake Precursors (INFREP) was developed starting with 2009 and consists of several dedicated VLF and LF radio receivers used for monitoring various radio transmitters located throughout Europe. The receivers' locations were chosen so that the propagation path from these VLF/LF stations would pass over high seismicity regions while others were chosen to obtain different control paths.

The monitoring receivers are capable of continuously measuring the received signal amplitude from the VLF/LF stations of interest. The recorded data is then stored and sent to an INFREP database, which is available on the Internet for scientific researchers. By processing and analysing VLF and LF data samples, collected at different reception points and at different periods of the year, one may be able to identify some distinct patterns in the envelope of the received signal level over time. Significant deviations from these patterns may have local causes such as the electromagnetic pollution at the monitoring point, regional causes like existing electrical storms over the propagation path or even global causes generated by high-intensity solar flares. As a consequence, classifying these perturbations and minimizing them (when possible) would represent an important step towards identifying significant pattern deviations caused by seismic activities.

Taken into consideration some of the issues mentioned above, this paper intends to present some aspects meant to improve the overall performance of the existing INFREP network. The signal-to-noise ratio improvement of the monitoring receiver may be achieved by relocating the antenna (or even the entire monitoring system if possible) in areas with less electromagnetic pollution within the VLF and LF bands. Other solution may involve replacing the existing electric "whip" antennas with magnetic loop antennas.

Regarding the measuring method, long-term averaging of the received signal to reduce the electromagnetic noise should be carefully applied. If the averaging time is too long, there is a risk that, during a seismic event, the details of the received signal envelope would be lost. Moreover, this may reduce the possibility of making correlations between the monitored stations and INFREP receivers in case of sudden ERP (Effective Radiated Power) variations of the VLF/LF stations. For the same reason, the time synchronization of the recorded data using (for instance) GPS technology is highly recommended.

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Other aspects related to the overall performance improvement of the INFREP network consist of monitoring other VLF/LF stations such as the Krasnodar station (south of Russia), part of the ALPHA/RSDN-20 VLF navigation system, or the 77.5 kHz DCF77 time signal transmitter (near Frankfurt am Main, Germany). Moreover, the installation of a new reception point in Romania (near Cluj-Napoca) for monitoring the Vrancea area (within the Carpathians Mountains) and the Adriatic region will provide complementary scientific data within the network.

1. The Ionosphere and the long-distance VLF/LF radio wave propagation

In general, we define the ionosphere as the region of the Earth's upper atmosphere, which is ionized by solar and cosmic radiation. During daytime, the ionization of particles is caused mainly by the Sun. During night-time, the ionization process is caused by galactic cosmic radiation. In the last decades, VLF/LF (Very Low Frequency/Low Frequency) sub-ionospheric radio sounding techniques are considered one of the possible solutions of the short-term earthquake prediction problem. In essence, these methods consist of monitoring different VLF and LF available transmitters from long distance reception points (Freund et al., 2006; Biagi et al., 2004; Hayakawa et al., 2012, 2010; Hayakawa, 2010).

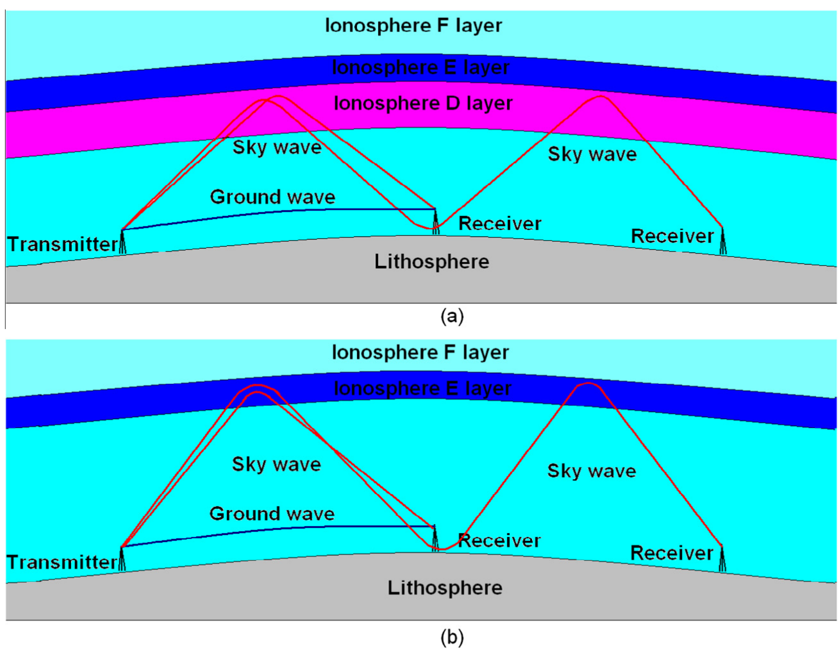

Fig. 1. VLF/LF propagation during daytime (a) and night-time (b).

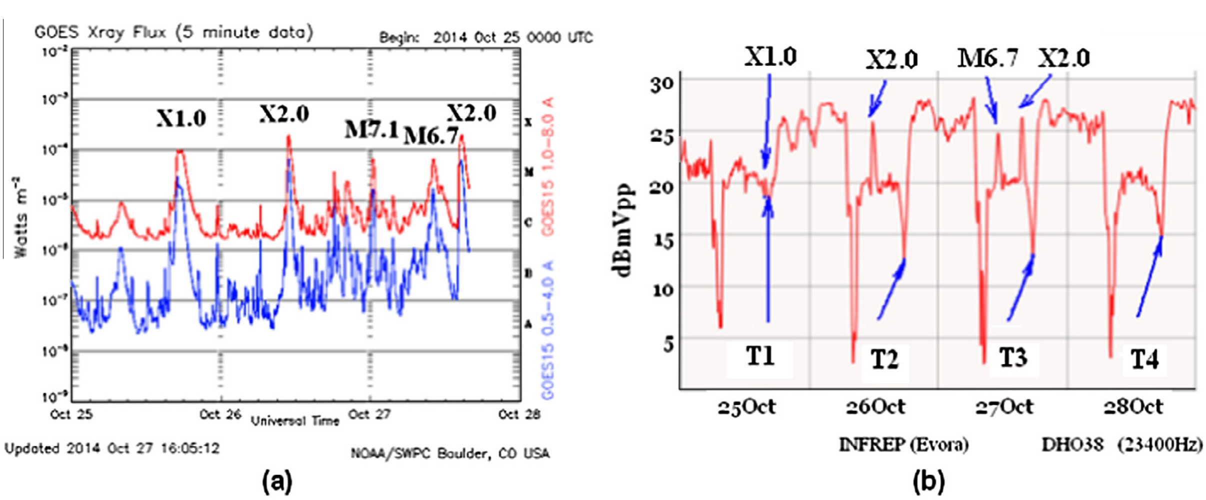

Fig. 2. Solar flare influence (a) over the amplitude of the received signal (b).