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REDUCTION OF LOWER IONOSPHERE PLASMA FLUCTUATION – NEW EARTHQUAKE PRECURSOR?

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Abstract. We present analysis of the lower ionosphere plasma short-term disturbances during period around the Kraljevo earthquake that occurred in Serbia on 3 November, 2010. Study is based on analysis of the short-term phase noise of the very low frequency (VLF) radio signal emitted by ICV transmitter located in Italy and received in Serbia. In this study we applied the procedure already described in recent research related to the signal amplitude in period around the considered event which point out the amplitude noise reduction as potential new ionospheric precursor of earthquakes. In this work, we process phase of ICV signal and results indicating phase noise reduction similar like those in the case of the amplitude shows that both signal characteristics, the amplitude and phase, can be used in future research of ionospheric plasma variations as possible precursors of earthquakes.

1. INTRODUCTION

As numerous studies performed during this and previous centuries show, variations in the ionospheric plasma can be considered as earthquake (EQ) precursors (Pulinets and Boyarchuk 2004). Observations of these variations are based on different satellite and ground-based techniques and their applications primarily depend on the considered altitude domain.

In this study we focused on the lower ionosphere and its remote sensing by the very low frequency (VLF) radio waves. This technique provides continuous information related to the waveguide within signal propagate and can be used for the lower ionosphere changes in different time scales. In addition, there are several networks of the VLF receivers which, in combination with numerous VLF transmitters located worldwide, allows monitoring large part of the lower ionosphere and detections of local disturbances like those possible connected with processes relevant for earthquakes. One of these networks, the International Network for Frontier Research on Earthquake Precursors (INFREP, Biagi et al. 2011), is located in the Europe. The data collected with its receivers located in seven European countries showed a typical variation in signal amplitudes several days before earthquake events (see for example Biagi et al. 2011). In addition, the recent research of the short-term amplitude noise shows that its reduction is recoded less than one hour before the Kraljevo EQ occurred in Serbia on 3 November, 2010.

In order to examine if these short-term ionospheric variations can be described also as changes in time evolution of another signal parameter, phase, in this work we analyze the phase noise of the VLF signal emitted by ICV transmitter located in Italy and received in Serbia (Grubor et al. 2005).

2. OBSERVATIONS AND SIGNAL PROCESSING

We analyze data obtained by remote sensing of the lower ionosphere during night-time when Kraljevo EQ occurred with 20.27 kHz signal emitted by ICV transmitter from Isola di Tavolara, Italy (40.92 N, 9.73 E) and received by the Absolute Phase and Amplitude Logger (AbsPAL) receiver located at the Institute of Physics Belgrade in Belgrade, Serbia (44.8 N, 20.4 E). The distance between the propagation path of this signal and the EQ epicentre is 126 km that is usually large for detection of long-term ionosphere variations before not so strong EQs like the considered one. However, better data sampling of 0.1 s provided in our observations allows us to analyze short-term signal changes which, as it is show in Nina et al. (2020), are recorded (in analysis of the signal amplitude) for several EQ events occurred more than 100 km from signal propagation path. Here we analyze the signal phase on the same way like in the previous research of the amplitude.

Changes of the phase noise is visualized in this analysis as variations in time evolution of phase deviation dP defined as difference between recorded, P, and

basic phase P_{base} (mean value of P within defined time bean around time t): $dP(t) = P(t) - P_{base}(t)$.

3. RESULTS AND DISCUSSIONS

Time evolution of phase deviation dP is shown in Fig. 1 where, in order to remove non-natural changes, we exclude values larger and smaller than 60^o and -60^o, respectively. As one can see, significant noise reduction is recorded less than one hour before the EQ event whose time occurrence is indicated with vertical dashed line.

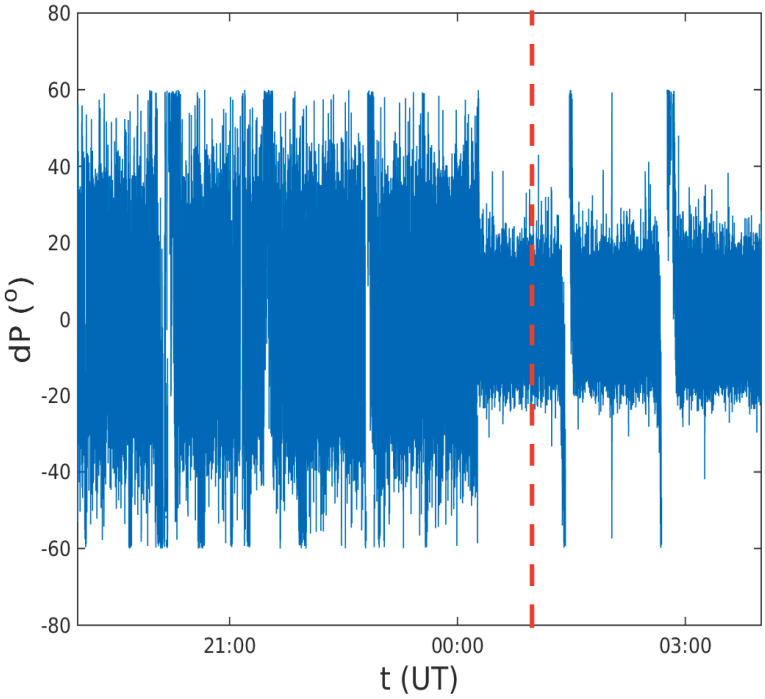

Figure 1: Time evolutions of phase deviation dP of the ICV signal in night-time of the Kraljevo earthquake. Vertical dashed line indicates the time of occurrence of the considered EQ.

In comparison with the amplitude noise, which has been analyzed in Nina et al. 2020, we can conclude that the noticed changes are very similar and that both analyses point out that reduction in lower ionosphere short-term fluctuations can be considered as new possible EQ precursor.

4. SUMMARY

In this paper, we analyzed time evolution of short-term fluctuations of the lower ionosphere plasma processing of data for the phase of the ICV signal recorded in Belgrade around time of Kraljevo EQ occurrence. As in the case of amplitude analysis, the obtained results show that significant reduction of phase noise started less than one hour before the EQ event.

Keeping in mind that this analysis presents a case study, confirmation that the recorded ionospheric changes can be a new type of ionosphere precursors of earthquakes requires statistical analyses. Here, we should point out that recent study shows reductions of amplitude noise are recorded before several other EQ events occurred during 3, 4 and 9 November, 2010 near the propagation path of the considered signal even in some cases of very weak EQ events. Although variations are visible for all of 4 EQs of magnitude greater than 4, studies with larger sample should be made before we can confirm the analyzed relationship and find its possible characteristics.

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References

Biagi, P. F., Maggipinto, T., Righetti, F., Loiacono, D., Schiavulli, L., Ligonzo, T., Ermini, A., Moldovan, I. A., Moldovan, A. S., Buyuksarac, A., Silva, H. G., Bezzeghoud, M., Contadakis, M. E.: 2011, *Nat. Hazards Earth Syst. Sci.*, **11** , 333.

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Pulinets, S., Boyarchuk, K.: 2004, *Ionospheric precursor of earthquakes*. Heidelberg: Springer.