Radiophysical techniques of short-term earthquake precursors and their congruence. The case of L'Aquila earthquake of 06 April 2009

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Abstract

We studied six different parameters derived from three different radiophysical techniques used to monitor area over the central Italy around the time of L'Aquila M6.3 earthquake of 6 April 2009. Namely VLF monitoring, ground based ionospheric sounding and GPS vertical TEC. The parameters derived from these data are: variations of amplitude of VLF signal on different propagation passes, critical frequency *foF2* variations, cross-correlation coefficient for different pairs of ground based ionosondes, vertical GPS TEC time series, local variability index for the network of GPS receivers, and GPS TEC map. High congruence of techniques in time and space is found.

1. Introduction

Radio waves of different frequency bands interacting with atmosphere and ionosphere can carry information on variations and irregularities encountered during their pass through the media. This property of radio waves is used for remote sensing of different objects including the area of earthquake preparation [1]. If the earthquake preparation is a result of the different processes united by the common physical reason, the registered effects should demonstrate some kind of congruence in their appearance [2]. L'Aquila M6.3 earthquake of 6 April 2009 has attracted a lot of attention of the scientists all over the world, and many papers and scientific reports appeared up to now, including the studies of short-term precursors. We decided to check the behavior of precursors registered by different radiophysical techniques which permit to control the upper atmosphere and lower ionosphere (VLF monitoring [3]), the processes in the main maximum of the ionosphere by the critical frequency monitoring *foF2* [4], and GPS TEC controlling the whole slab of the ionosphere before the L'Aquila earthquake. Except simple time series analysis the correlation technique was used [5] proposed in the papers [6, 7].

2. VLF signal monitoring of the earthquake preparation area

For the VLF monitoring several radio passes were selected: first – passing over the area of earthquake preparation and second – over text area. Clear anomalies were revealed 2–8 days before the occurrence of the Abruzzo earthquake in the seismic paths, while no anomalies have been found in the control paths [3].

3. Critical frequency monitoring (*foF2*)

In [3] the cross correlation analysis technique [6] was used and drop of cross correlation coefficient was detected for the pairs of station which include the Rome ionosondes, and no drop of cross correlation coefficient was registered outside the earthquake preparation area. The first drop was registered on 30 of April, the same day when the VLF anomaly started to be registered. Then the cross-correlation anomaly disappeared and appeared again on4 of April, 2 days before the main shock. The critical frequency variation has shown the positive deviation one day before the main shock [4].

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4. GPS TEC monitoring

The local network of the GPS receivers in Italy was used for the GPS TEC monitoring. The Variability Index [7] started to be increased on 4 of April, the GPS TEC showed strong increase over L'Aquila few hours before the main shock on 5 of April, and the map demonstrated the large positive spot over the central Italy on 5 of April.

5. Congruence of registered parameters

Data analysis demonstrated the strong correlation in space and time of the registered parameters. In addition it shows the clear movement of disturbance from blow to the ionosphere. The earliest anomaly was detected by the VLF radio monitoring near 8 days before the seismic shock, next 6 days before revealed the correlation analysis of ground based vertical sounding. It should be noted that spatial correlation reveals the precursors earlier than single point critical frequency (only one day before), as well as the GPS TEC. It is natural that critical frequency at Rome ionosondes and GPS TEC foe L'Aquila receiver have shown anomaly almost simultaneously. Nevertheless, the variability index showed the star of anomalies two days earlier.

6. Conclusions

Common analysis of the parameters controlling the upper atmosphere and ionosphere demonstrated the well-defined sequence of anomalies starting at lower levels up to the top ionosphere confirming the anomaly propagation from the below.

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