Microseismic monitoring and source discrimination at Izvorul Muntelui dam, northeast Romania

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Motivation and Overview

Izvorul Muntelui is one of the largest dams in Romania, built between 1950 and 1960. It is located in the Eastern Carpathians, northeast Romania, in a complex tectonic environment (Fig.1) close to the Trans European Suture Zone and several crustal faults.

Although the water reservoirs often generate seismic events as a result of stress variation due to the weight of the water, weakness of fractures or increase of pore pressure in crustal rocks, before 2011, Romanian (ROMPLUS) earthquake catalogue *(Oncescu et al. 1999)* highlights only a small number of low-magnitude events.

The NE Carpathians show low seismic activity, with sparse seismic events influenced by the marginal fractures of the Moldavian Platform (Figs. 1 and 2).

With the recent development of the Romanian Seismic Network *(Popa et al. 2015)*, the magnitude detection threshold was significantly lowered, leading to an increasing number of events in the catalogue.

In this study we use novel detection technique to investigate the possible earthquake triggering effects by correlating the water level fluctuations with the seismic activity within a distance range of 0.4 deg. relative to the dam.

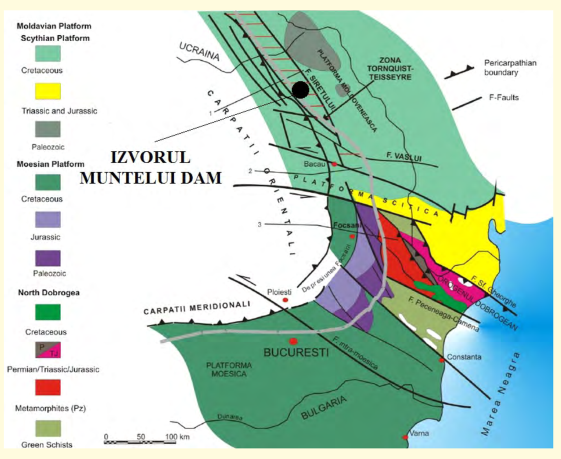

Fig.1 Romanian geological map (*modified after Badescu 2005*). Black circle corresponds to the dam location.

Fig. 3 Google Earth screenshot of the dam area.

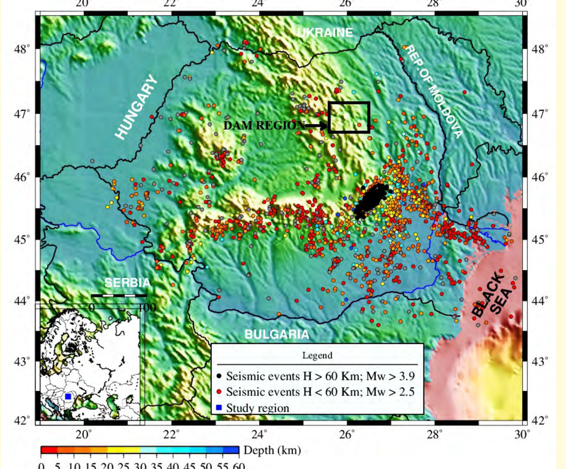

Fig. 2 Seismic activity in Romania (2007-2017). Black rectangle marks the location of study area.

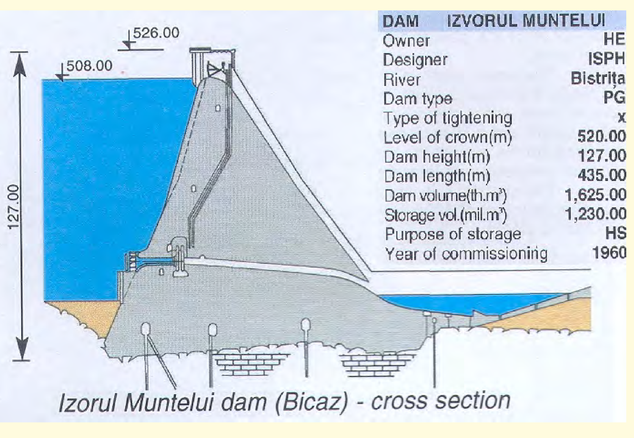

Fig. 4 Cross-section and technical details of the Izvorul Muntelui dam *(Cojocar, 2008)*.

Izvorul Muntelui is the largest inland water reservoir of Romania (Fig. 3) with an area of 33 km^2 and a length of 35 km *(Dascalu et al. 2009)*. Its a concrete gravity dam (Fig. 4) built on gorges made of Tarcau sandstones, clay schists and conglomerates.

Network performances and applied techniques

To have a better view of the seismicity patterns in the region we applied a multi-channel waveform template correlation detector (Fig. 5) to the seismic data recorded between 2012 and 2018 by a small-aperture seismic array Bucovina (BURAR), located about 100 km northwest from the dam (Fig. 6), and a 3C-, broadband station Bicaz (BIZ) located in its immediate vicinity.

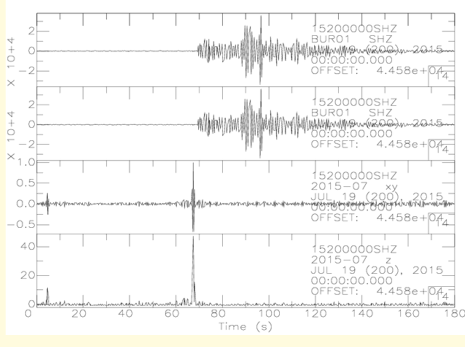

Fig. 5 Example of event detection using cross-correlation algorithm at BURAR seismic array.

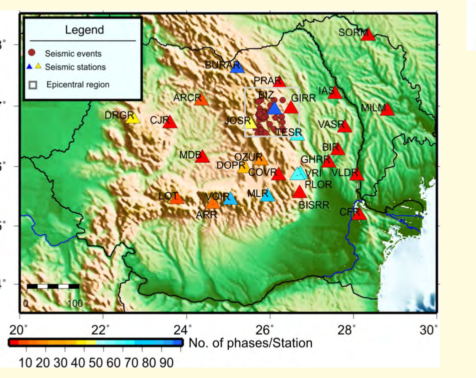

Fig. 6 Stations distribution coloured as the function of data contribution to seismic bulletins.

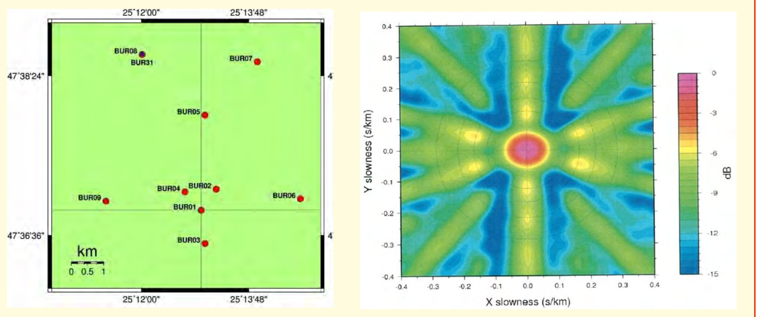

Fig. 7 BURAR sensors distribution (left) and array response (right).

BURAR is a small aperture (~5km) array installed in 2002 in cooperation with the Air Force Technical Application Center (AFTAC) of the U.S.A. It consists of 9 vertical short period sensors and a 3C-broadband sensor, installed in boreholes (Fig. 7).

Since most events occurr during the day time, we took into accounting for possible influence of anthropic events. To distinguish between tectonic and anthropic events, we have built discrimination technique based on spectral ratios (Sr) and signal complexity (C) measures, using ground truth (GT) events (from RomSeis 2014 reflection experiment) and supposed earthquakes occurred near array (Fig. 8).

$$C = \int_{t1}^{t2} S^2(t)dt \,/\, \int_{t0}^{t1} S^2(t)dt \qquad Sr = \int_{h1}^{h2} a(f)df \,/\, \int_{l1}^{l2} a(f)df$$

Arai &Yosida (2004) — *Gitterman and Shapira (1993)*

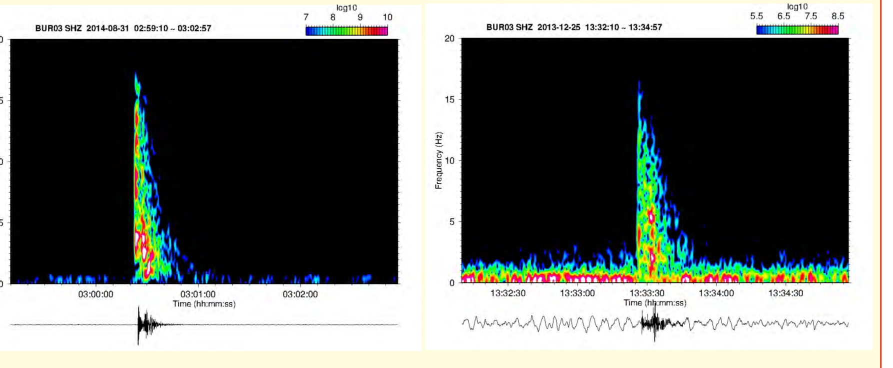

Fig. 8 Spectrograms plots for vertical component of BUR03 station associated to a GT event (left) and an supposed Eq. (right).

Cross-correlation detections and source parameters estimation

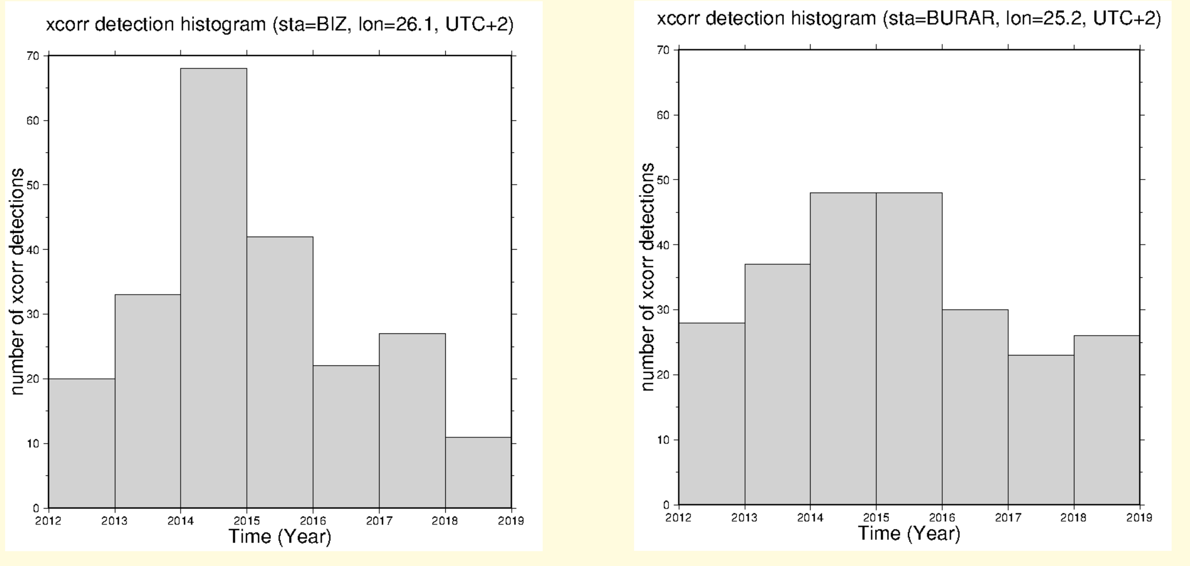

Fig. 9 Number of detections in time for BIZ (left) and BURAR (right) stations.

The CC detection algorithm shows almost three times more detections than the earthquake catalogue. Although, the total number of detections for the two stations is similar (240 for BIZ and 223 for BURAR), the temporal distribution has different shapes. This is related to data quality, their availability as well as events size (due to effect of waveform attenuation). The detected events are mainly generated during working hours and during weekdays, indicating a possibility of strong contamination by anthropic events.

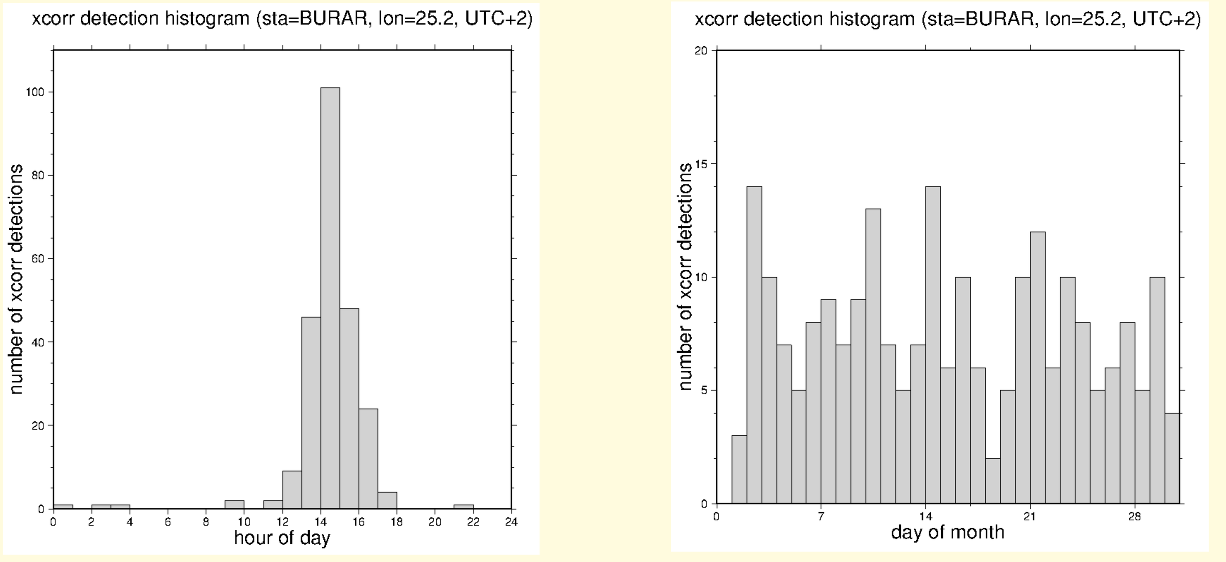

Fig. 10 Number of detections for BURAR array as the function of: hour of the day (left) and the day of the month (right).

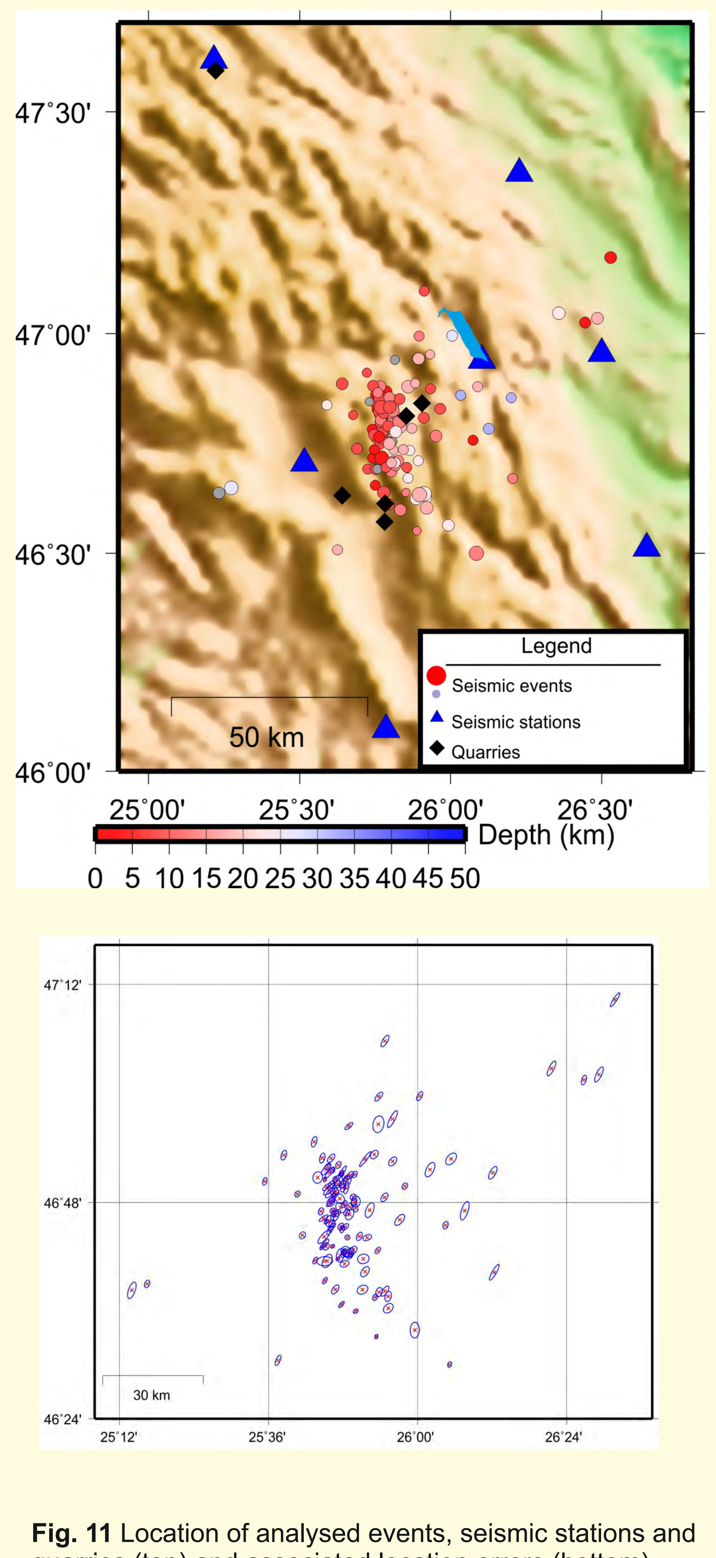

Fig. 11 Location of analysed events, seismic stations and quarries (top) and associated location errors (bottom).

From a total of 240 events detected, using records from nearby stations, we were able to locate using LOCSAT algorithm *(Nagy, 1996)* with enough accuracy (GAP < 200 and at least 8 travel times arrivals) 126 events (Fig. 11-top).

Within the location (95% confidence) uncertainties (Fig. 11-bottom) most of the events are placed near the quarries located SW of the dam. The depth distribution reveals three groups of hypocenters disposed within their errors limits as are shown in Fig 12.

The seismic activity evidenced by the CC detection algorithm reveals a narrow range of magnitudes (between 1.2 and 2.1).

The occurrence time and the magnitude range of these events provide valuable clues about their nature.

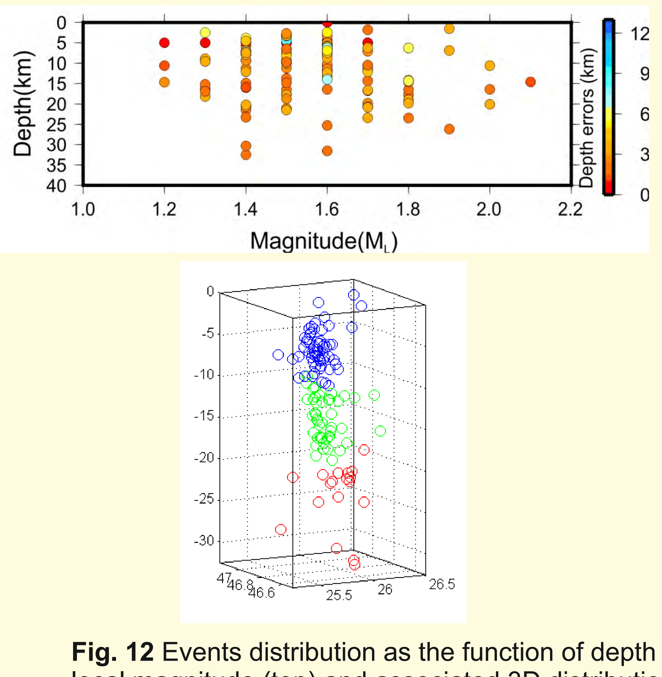

Fig. 12 Events distribution as the function of depth and local magnitude (top) and associated 3D distribution (bottom).

Discrimination analysis

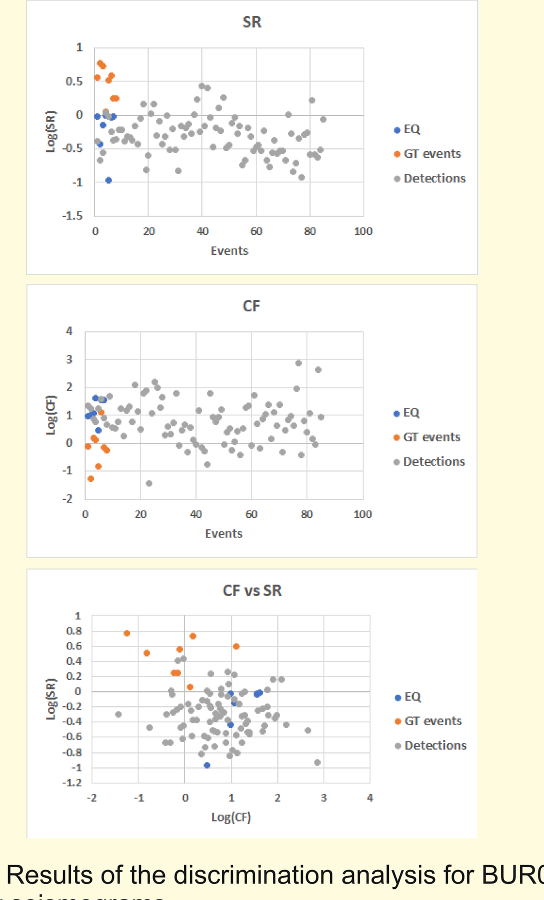

Fig. 13 Results of the discrimination analysis for BUR03 velocity seismograms.

The initial populations of GT events and supposed Eqs. were separated with over 90% accuracy. The discrimination approach indicates that many of the detected events have tectonic origin (Fig. 13). This seems to be in contradiction with the events occurrence time and magnitude range. The spectrogram of an example newly detected event (Fig. 14) shows similar frequency characteristics as the supposed Eq. in Fig. 8.

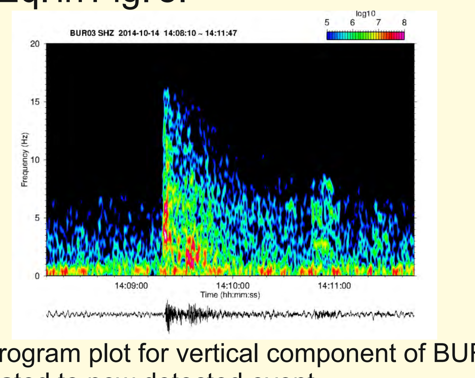

Fig. 14 Spectrogram plot for vertical component of BUR03 station associated to new detected event.

Events waveform similarity and correlation with water level variation

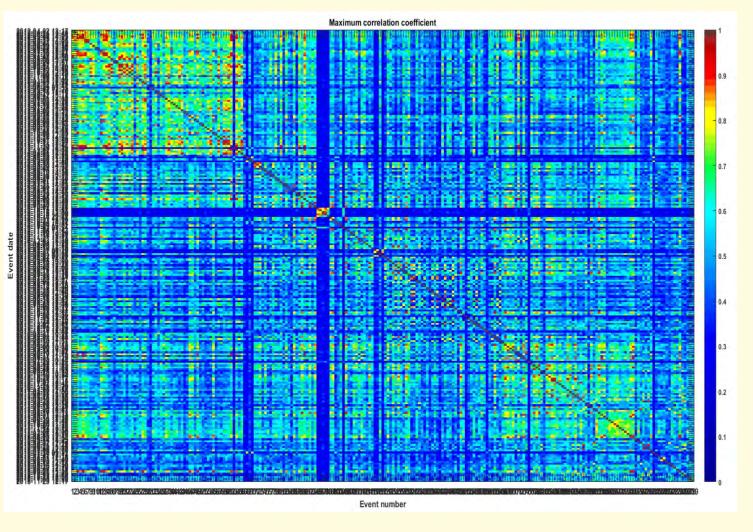

Fig. 15 Correlation matrix for BUR03 recordings filtered using a Butterworth band pass filter between 1 and 10 Hz.

The correlation matrix (Fig. 15) shows the occurrence of several event clusters with CC > 0.79. These clusters are generated in well-defined, isolated, time periods (Fig. 16), which may indicate that their sources are shifted in time.

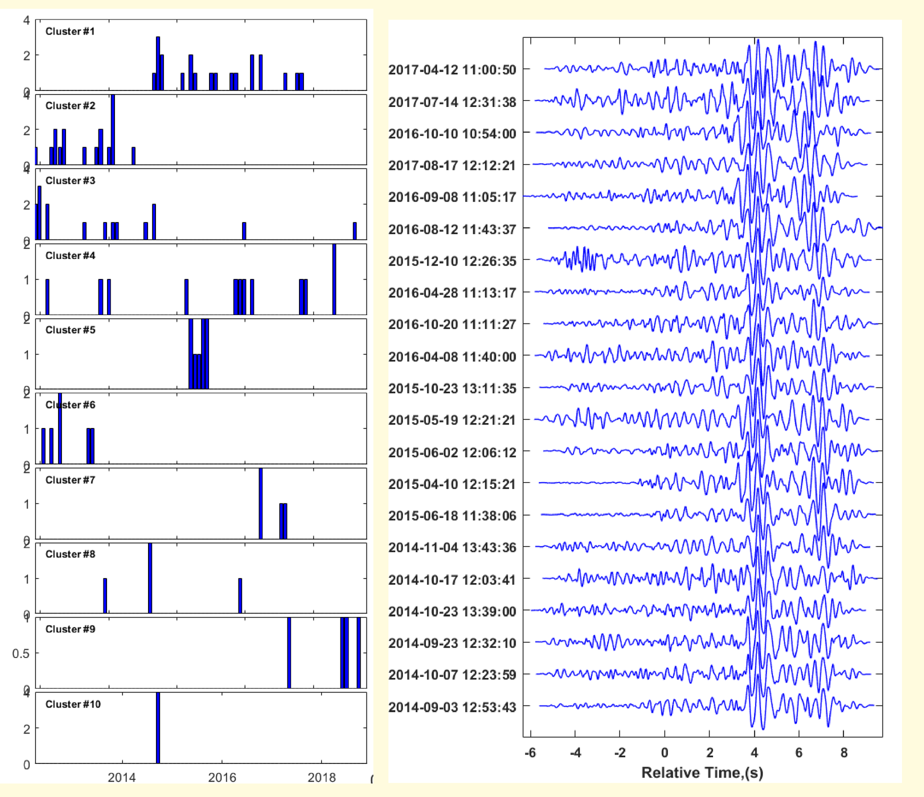

Fig. 16 Clusters of seismic events in time (left) and the waveforms (associated to the 1st cluster) recorded by BUR03 station , filtered using a Butterworth band pass filter between 1 and 10Hz.

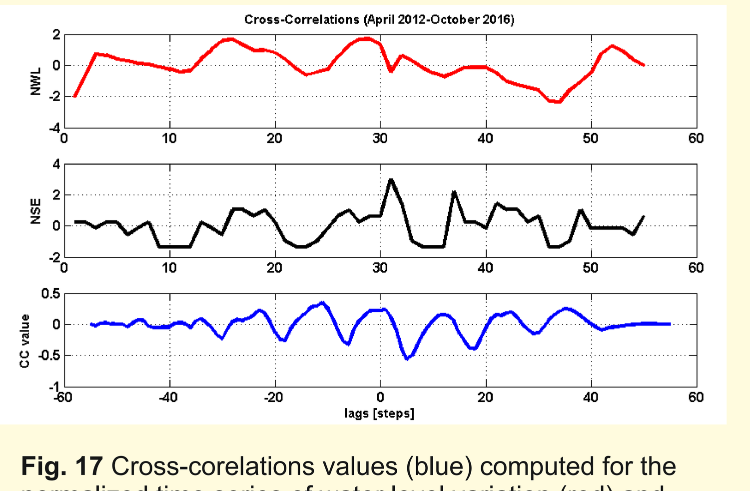

Fig. 17 Cross-corelations values (blue) computed for the normalized time series of water level variation (red) and seismic activity (black).

The water level variations (Fig. 17) between April 2012 and October 2016 are not significant and do not have noticeable influences on local seismicity. Therefore, the effect of water level variation is rather low.

Acknowledgements

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CONCLUSIONS

Seismicity generated within the radius of 0.4 deg. around Izvorul Muntelui dam, in the Eastern Carpathians, was analysed in order to determine the earthquake triggering mechanism.

Cross-correlation detection algorithm identified almost three times more events as compared with the number of events in ROMPLUS catalogue.

Shallow events of low magnitudes (~1.6) are characteristic for the study region. The local seismicity is considerably influenced by anthropic events, produced by quarries around the dam.

We suggest that the near-future seismic potential in the dam area is of low level. This conclusion is supported by the absence of evident correlation between the seismicity and water level variations.

More high quality data from stations around dam will improve the seismicity monitoring and results accuracy.

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