Relationship between water level temporal changes and seismicity in the Mingechevir reservoir (Azerbaijan)

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Introduction and Background

The Mingechevir reservoir is located in the north-west of Azerbaijan on the Kur river (Figure 1) . This water reservoir is extended from north-west towards south-east through Kur river valley by 75 km. The area of the dam is 625 km^2 with the average width accounting for 6-8 km. The volume of the dam is 16 km^3. The dam filling started in 1953. This reservoir is the largest one in the Caucasus and carries a number of geo-hazards interrelated with geodynamics and technogenic factors.

Few studies were focused on the comparison between water level variation and seismicity in Mingechevir reservoir area (Islamova, 2011; Yetirmishli et. al., 2018), and found that earthquakes in this area were related with the variations of the water level, generally occurring within the interval of 1-3 months after reaching the maximum level. However, these studies did not provide a statistically robust assessment of the relationship between the fluctuations of the water level and the onset of seismicity in the area around the dam. Therefore, the aim of the present study is to investigate such relationship more in detail, by using several and independent statistical methods. In this study, we focus on the area extending from 40.60° N to 41.10° N latitudes and 46.50° E to 47.40° E longitudes (Figure 1), which includes the Mingechevir reservoir.

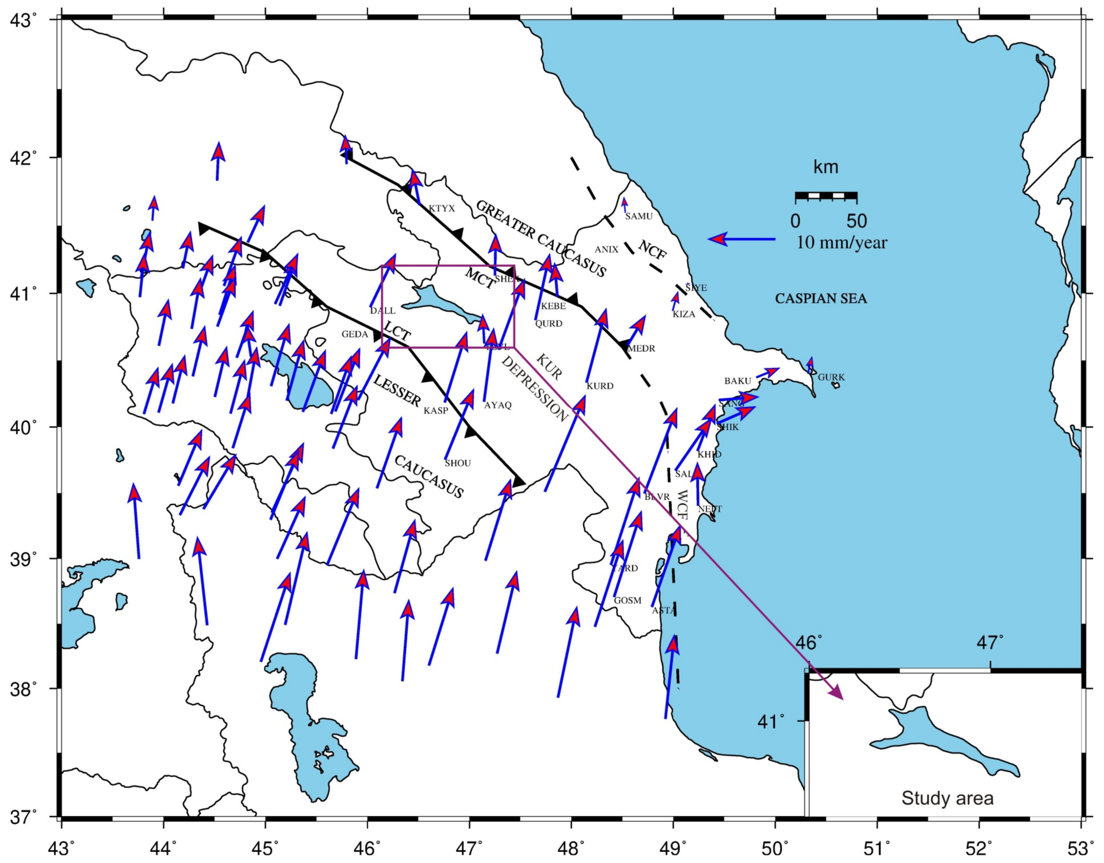

Figure 1.Azerbaijan GPS network, GPS site velocities with respect to Eurasia(Reilinger et. al., 2006b) with updated velocities in Azerbaijan for the period 1994–2013 (Kadirov et. al., 2015). Base map shows topography and simplified tectonics (Greater and Lesser Caucasus fold-mountain systems, the Kur mega-trough). Abbreviations: NCT = North Caucasus Thrust fault, MCT = Main Caucasus Thrust fault, LCT = Lesser Caucasus Thrust fault, WCF = West Caspian Fault, NCF = North Caspian fault.

Tectonic, Geodynamic and Seismic Setting

The territory of Azerbaijan represents the mountainous section of the Greater Caucasus, the Lesser Caucasus, Kur depression zone, and the South Caspian Basin (Fig.1). Mountains of the Greater and Lesser Caucasus extend between the Black and Caspian seas and creates a part of the continuous Alpine-Himalayan orogenic belt (Kadirov et al. 2012) (Fig. 1). Greater and Lesser Caucasus is the main orogens of the Azerbaijan earthquake-prone country. The Azerbaijan territory has been exposed to the continuous collision between Arabian and Eurasian plates (McKenzie, 1972; Reilinger et al. 2006; Kadirov et al. 2012; Kadirov et al. 2015). The collision closed the Greater Caucasus region, further deformed it together with the Eurasian Platform during Middle-Late Miocene, and the Kur Basin and the Greater Caucasus become zones of the maximum underthrusting.

Mingechevir water reservoir is located on the Kur depression zone.

Seismicity Data

The seismic dataset analysed in this study was built selecting the seismicity occurred from January 2010 to December 2018 around Minghechevir reservoir. The data were recorded by RCSS-ANAS seismic network and include 498 events with local magnitude between 0.5 and 4.7. Fig. 2 shows the epicentral distribution of the analysed seismic dataset. The estimation of *b*-value was performed by means of maximum likelihood method (Aki, 1965). Since the *b*-value estimate depends on M_c , it is firstly required that the completeness of the seismic catalogue is evaluated. Fig. 3 (left) shows the cumulative (CFMD) and non-cumulative frequency-magnitude distribution (NCFMD) of the Minghechevir seismicity, used to calculate M_c. By using the maximum curvature method (MAXC) (Wiemer and Wyss, 2000) M_c is estimated as the magnitude that corresponds to the highest frequency of events in the NCFMD. In our case, the value of M_c is 1.6, from which the *b* is 0.900.05. Therefore, we analysed the seismic dataset of events with magnitude 1.6; this dataset contains 269 events (Fig. 3 (right)).

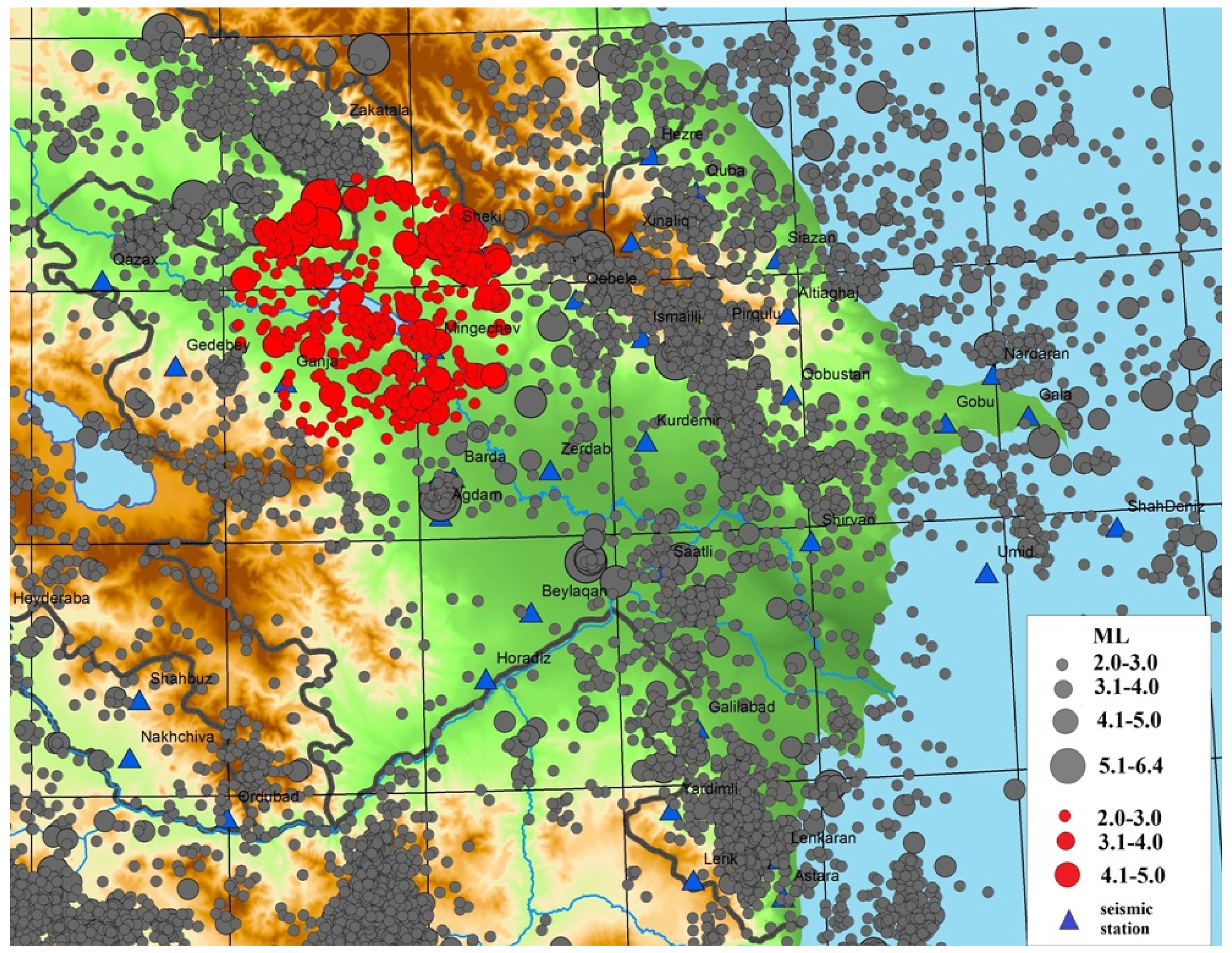

Figure 2. Spatial distribution of the seismicity of Azerbaijan from January 2010 to December 2018 (in red the events for distance from the center of the reservoir up to 60 km).

Methods and data analysis

In cases where seismicity is not so intense, like around Minghechevir dam, investigating the time series of the monthly (or even yearly) number of events could furnish important information about the seismic process. Actually, coarser time resolution (month or year) make the time series shorter, while, finer temporal resolution (hour or day) make them longer. However, in the second case, time series would present much more null values than the first; therefore, it is crucial to take into account both the time resolution and the lsize of the time series. In our case we analysed the time series of the monthly number of earthquakes occurred in Minghachevir area whose hypocenters are less than 55 km depth and less than 30 km far from the center of the reservoir, with magnitude larger or equal to 1.6 (that represents the magnitude of completeness of the catalogue).

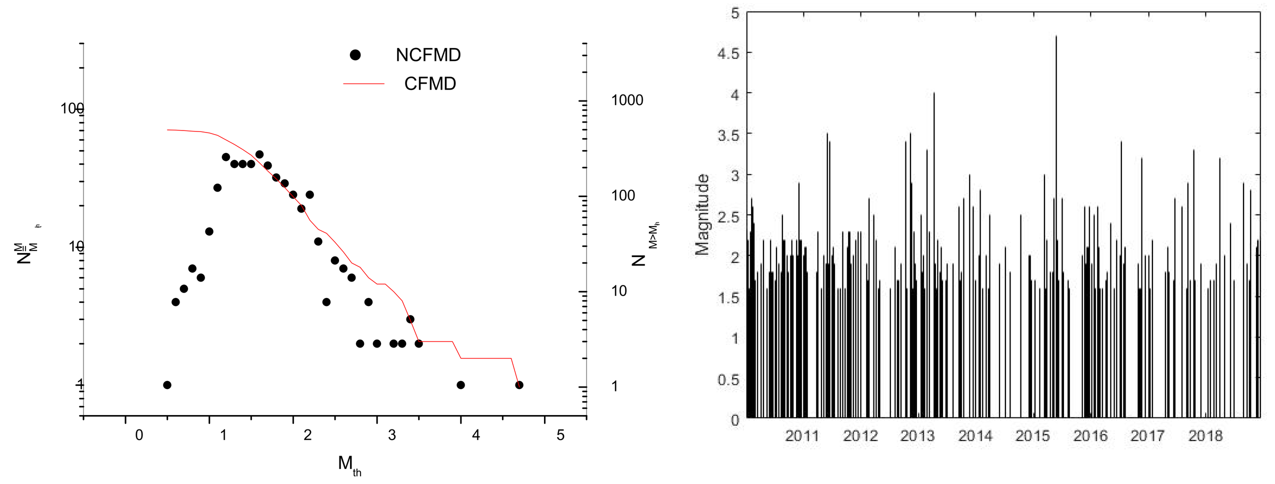

Figure 3. Spatial distribution of the seismicity of Azerbaijan from January 2010 to December 2018 (in red the events for distance from the center of the reservoir up to 60 km).

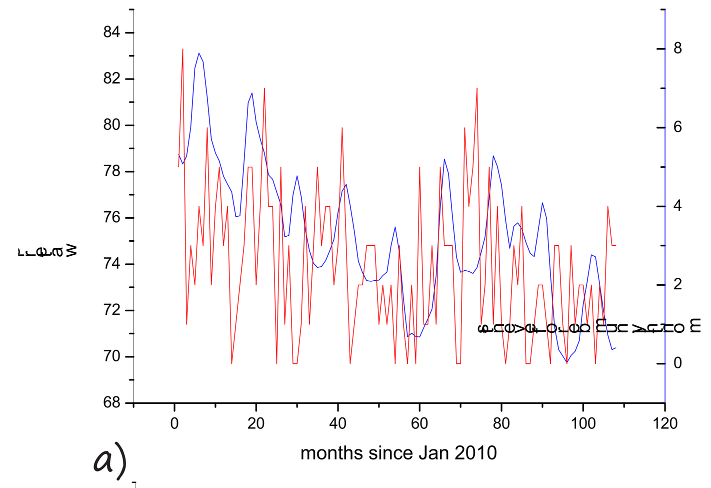

Figure 4. Time variation of the monthly means of water level (blue) and monthly number of earthquakes (red) during the investigation period (the magnitude of the events is 1.6).

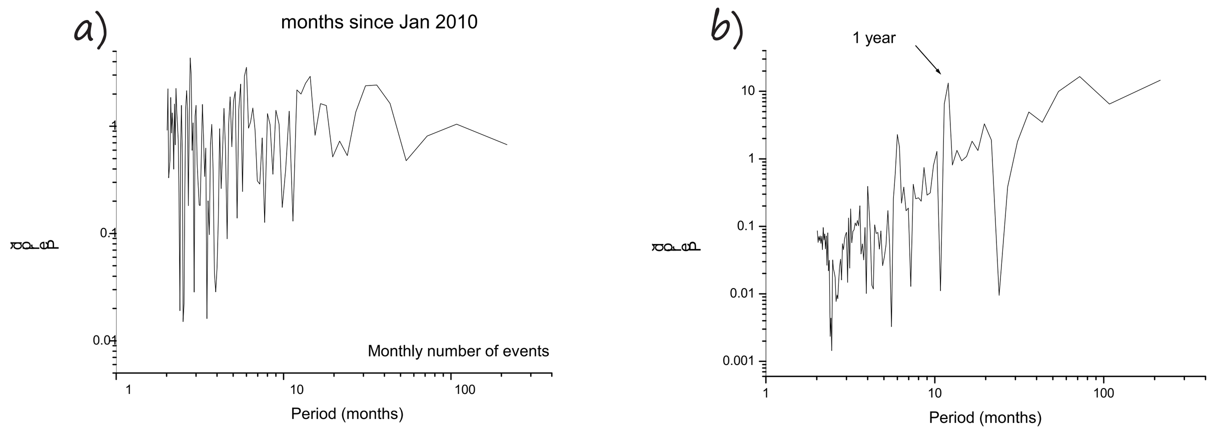

Figure 5. Correlogram-based periodogram of the monthly number of earthquakes (a) and water level (b)

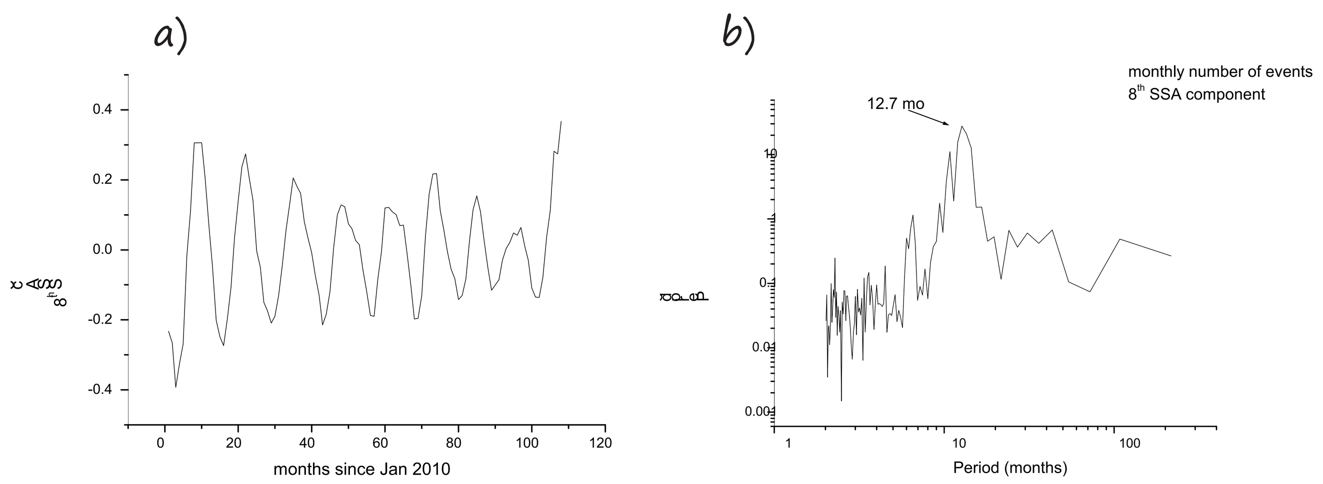

Figure 6. Time variation of the SSA 8th component (a) of the monthly number of earthquakes and its correlogram-based periodogram (b).

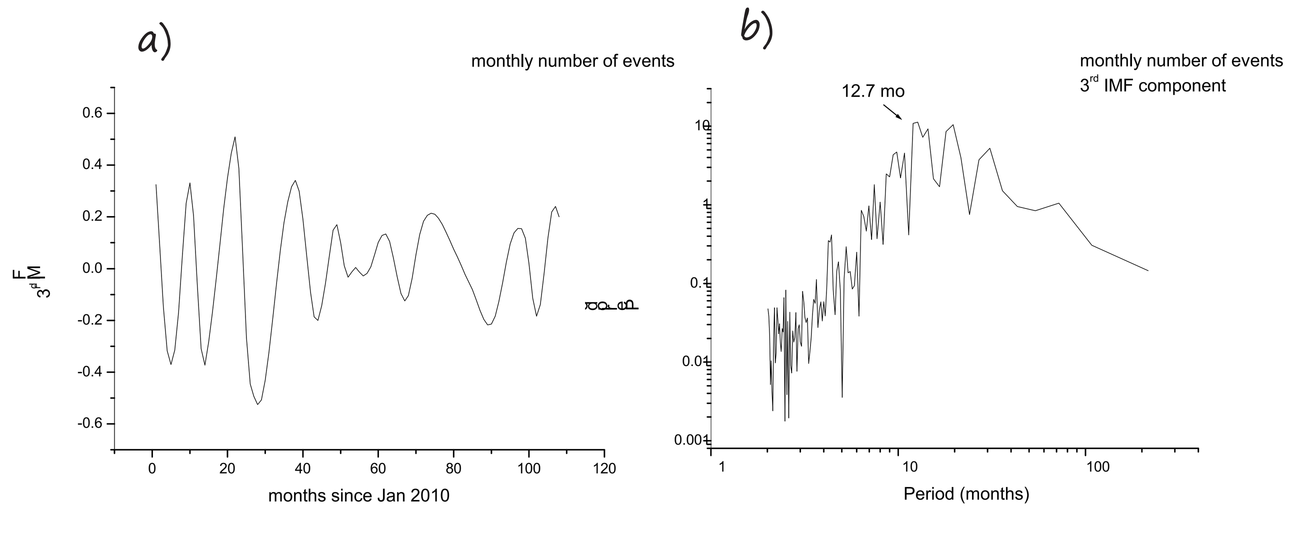

Figure 7. 3rd IMF (a) of the 3rd IMF of the EMD decomposition of the monthly number of earthquakes and its correlogram-based periodogram (b)

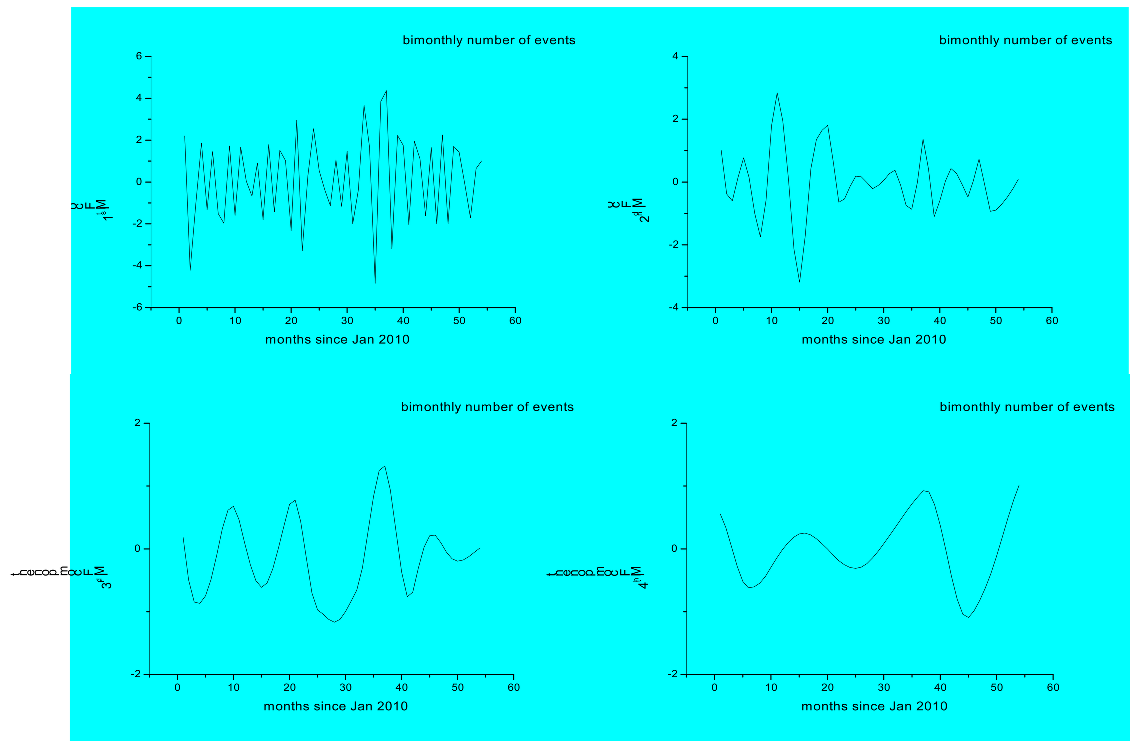

Figure 8. IMF components of the bi-monthly number of earthquakes

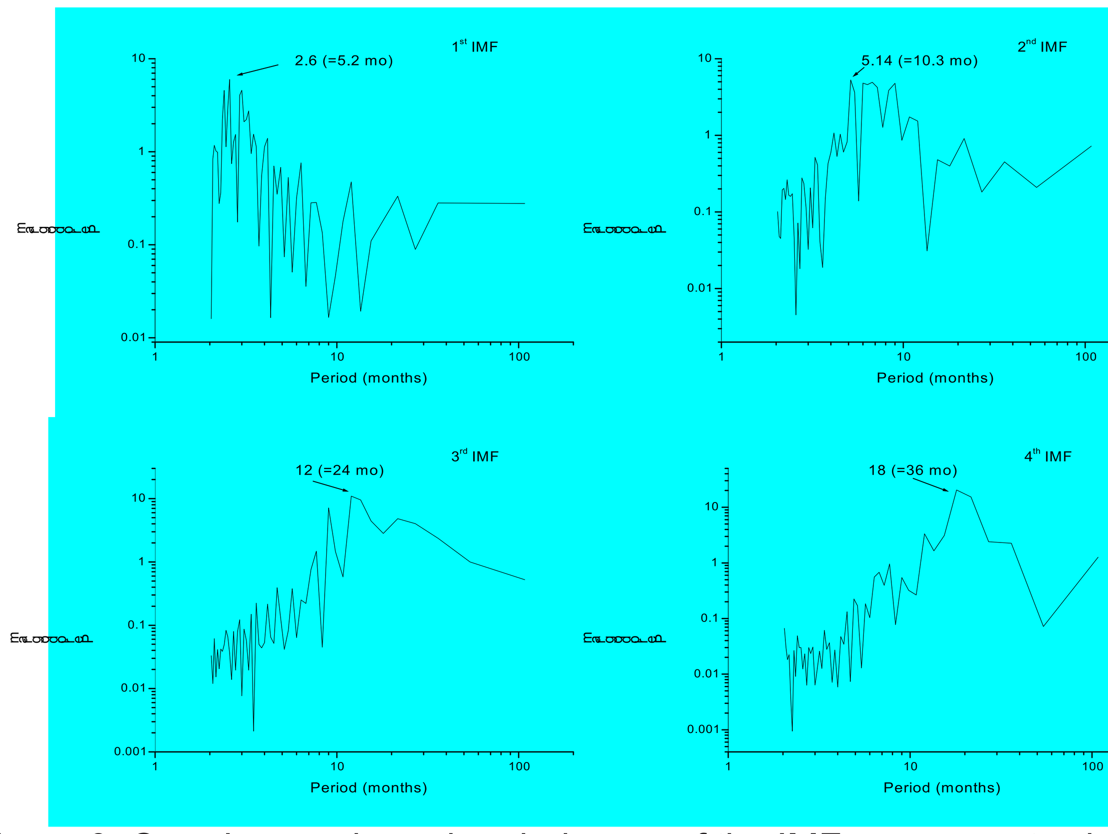

Figure 9. Correlogram-based periodogam of the IMF components shown in Fig. 8

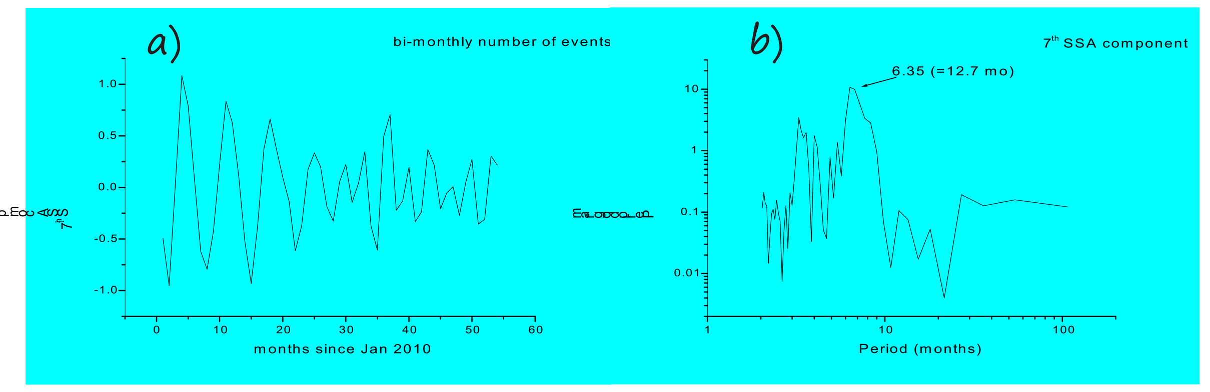

Figure 10.(a) 7th SSA component of the bi-monthly number of earthquakes, (b) correlogram-based periodogam of the SSA components shown in (a)

Conclusions

The application of the correlogram-based periodogram did not reveal any significant periodic behaviour in the monthly earthquake counts, while the annual periodicity was clearly identified in the water level. The annual climatic cycle. which is the main forcing of the water level fluctuation, dominates the dynamics of the water level that, thus, shows very clearly such periodicity. Seismicity is a much more complex phenomenon, where tectonic events and reservoir-triggered events could co-exist, and this might hide the annual periodicity, when this is searched by using the correlogram-based periodogram. The application of the decompositional techniques (SSA and EMD) allowed to decompose the time series of monthly earthquake counts in a number of independent components, whose spectral content was studied by applying the correlogram-based periodogram.

The correlogram-based periodogram identified the annual periodicity in the water level and in one reconstructed component (the 8th) of the SSA decomposition; furthermore a quasi-annual periodicity was found characterizing one intrinsic mode function (the 3rd) of the empirical mode decomposition of the monthly number of earthquakes. It should be noted that the association of the annual periodicity with the 8th eigenvalue of the SSA and the 3rd component of the EMD just suggests that the influence of the water level on generating seismicity is weaker than other sources; however such influence does exist. These results could suggest that the annual or quasi-annual periodicity of one of the components of the monthly number of earthquakes could be linked with the annual cycle of the water level, supporting in a statistical manner that the seismicity occurring in Minghechevir area could be of reservoir-triggered type, and indicates that the yearly cycle of the water level of the reservoir could be one forcing of the ongoing seismicity. The analysis of earthquakes located within different distance and depth ranges has revealed that the annual periodicity can still exist at distances larger than 30km from the center of the reservoir, but with a larger attenuation.