International Proceedings of Chemical, Biological and Environmental Engineering, Vol. 91 (2016)
DOI: 10.7763/IPCBEE. 2016. V91. 14

The Variation of Scaling Features of Earthquakes Temporal and Spatial Distribution in Caucasus Area

Aleksandre Sborshchikovi [+], Tamaz Chelidze, Natalia Zhukova, Ekaterine Mepharidze, Teimuraz Matcharashvili

IvaneJavakhishvili Tbilisi State University, M. Nodia Institute of Geophysics, Tbilisi State University, Tbilisi, Georgia

Abstract. In the present work the variation of scaling features of earthquakes temporal and spatial distribution in Caucasus from 1960 to 2014 was investigated. Using original and declustered Caucasus catalogues, we have obtained data sets of waiting times and inter-earthquakes distances. We took Detrended Fluctuation Analysis (DFA) method for the assessment of long-range time-correlations of used data sets. Dynamical features of seismicity in Caucasus by assessing scaling characteristics of earthquakes time and space distribution for shorter time periods and calculated DFA slopes for different sliding windows oforiginal and declustered catalogues was used. We have carried outcalculations for 5 years long sliding windowsof 500 data length for different order of polynomial fitting. Surrogate waiting times data obtained by shuffling of original series were processed also by DFA method. The dependence of scaling properties of waiting times series and distances between consecutive earthquakes catalogue of Caucasus in different released energy range also was studied.

Keywords: seismology, catalogue, scaling, dynamics.

1. Introduction

During the last decade the interest to the investigation of scaling properties of seismic process has increased. Different researches have been carried out to study the dynamical features of earthquakes spatial and temporal distributions and [1]-[6]. According to results of these researches seismic process in general cannot be regarded as a random process in all its domains [6], [7]. Moreover, it was even shown that earthquakes' distribution in the temporal and spatial domains reveals features of close to low-dimensional, nonlinear structure.

Considering that Caucasus is seismically active zone and that in the last decades it was struck by strong earthquakes, such as Spitak 07.12.1988 (M6.9), Racha 21.04.1991 (M6.9), Racha 07.09.2009 (M6.1) such researches are very important.

2. Methods and Used Material

The analysis of our research is basedon data sets of waiting times, inter-earthquake distances and magnitudes obtained from the Caucasus earthquake catalogue (1960-2014) of M. Nodia Institute of Geophysics, Tbilisi State University and Institute of Earth Sciences of Ilia State University (Fig. 1).

We have taken the original Caucasus catalogue with the number of earthquakes 6684($M \geq 3.0$). Simultaneously,number of events in declustered, according to Reasenberg's algorithm (1985), catalogue was4757 at $M \geq 3.0$ magnitude threshold.

[+] Corresponding author. Tel.: + 995 32 233-59-13; fax: + 995 32 233-28-67
E-mail address: a.sborshchikov@gmail.com

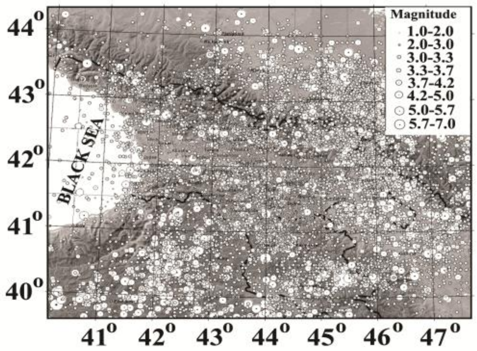

Fig. 1. Map of Caucasus.

One of our aims in this research was calculatingthe time intervals (in minutes) elapsed between successive events at *t(i+1)* and *t(i)*, named interevent time intervals, $\Delta t = t(i+1) - t(i)$.This was done for investigating features of earthquakes' time distribution . Similarly were calculated inter-earthquake distances in km.

Long-range time-correlations in the investigated interevent time, distances and magnitudes data sets were assessed by the method of Detrended Fluctuation Analysis (DFA). This method of analysis provides a quantitative parameter (DFA scaling exponent) and gives information about the correlation properties of analyzed data sets. In order to test presence of dynamical structure in used data sets we compared results obtained on original data sets with the results of data series obtained after shuffling procedure. According to DFA method given time series of N samples was integrated, then the integrated time series $Y(i)$ was divided into boxes of length n, and in each box the polynomial local trend $Y_n(i)$ of the order p (p= 1,2,3...) was calculated and removed. . Further details of used data analysis methods are described in [1].

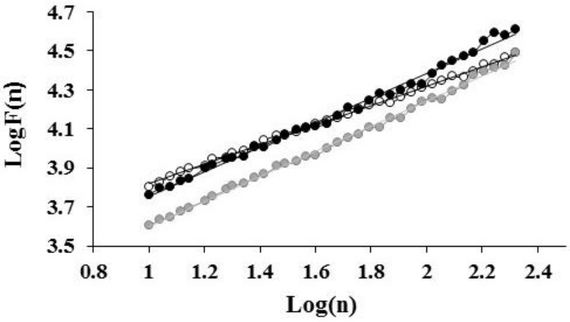

Fig. 2. DFA fluctuation curves of ITI sequences obtained from declustered, 1960-2014, Caucasian catalogue at M3.0 threshold (black – original data, white –shuffled and grey- phase randomize data). Order of the polynomial fitting is p=2. n indicates the time scale (given here as the sequential number of data in analyzed series). Linear fittings are shown by thin straight lines.

As an example of DFA calculation in Fig. 2, we show results for original waiting times and its shuffled and randomized surrogates. We see clear differences in calculated scaling exponents values which was 0.6 for original sequence and 0.49 for the same sequence after shuffling.DFA can be accomplished for different order of the polynomial fitting in order to eliminate trends of certain origin. As we mentioned in previous section, these calculations were accomplished for sliding windows of different length.

2.1. Results and discussions

The first step of our research was the analysis of waiting times, inter-earthquake distances and magnitudes sequences obtained from the original and declustered Caucasus catalogues. This was important part of research in order to understand how declustering procedure may affect long-range correlation features of earthquakes spatial, temporal and energy features. The results of analysis for waiting times sequence is presented in Fig. 3. Here for demonstration purposes results for p=2 polynomial fitting is presented, for p=3 and p=4 the situation is practically the same.

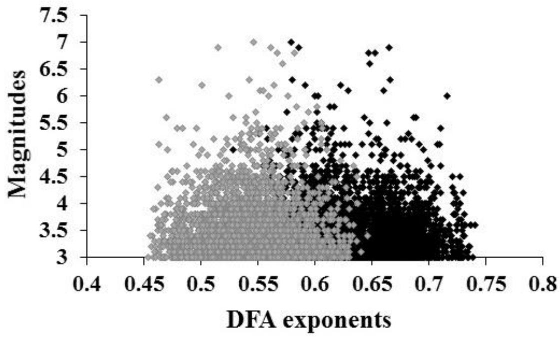

Fig. 3. DFA scaling exponents variation of waiting times obtained from original (grey), and declustered (black) catalogues. Order of the polynomial fitting p=2.

As we see, earthquakes' temporal distribution remains mostly long range correlated despite the fact that about 2000 events (aftershocks) were removed from the original catalogue by declustering procedure. In case of other considered data sets situation was similar, i.e. aftershocks depletion by declustering procedure did not change the general dynamical features of analyzed process. Thus, in following we focused on data sets from declustered Caucasus catalogue

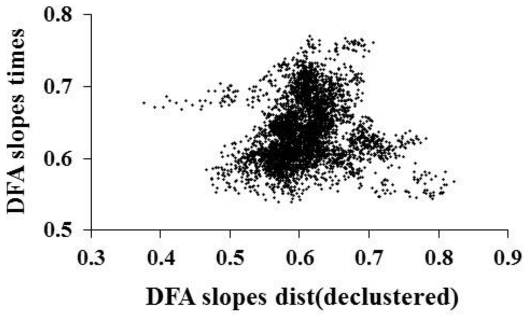

Fig. 4. DFA slopes of interevent times vs DFA slopes of interevent distances sequences. Calculations for declustered catalogue for consecutive 500 data windows by 1 data step. Order of the polynomial fitting p=3.

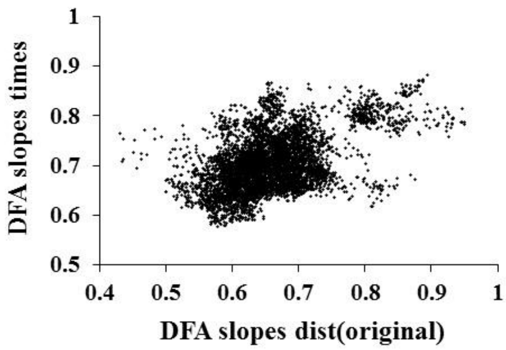

Fig. 5. DFA slopes of interevent times vs DFA slopes exponents of interevent distances sequences. Calculations for original catalogue for consecutive 500 data windows by 1 data step. Order of the polynomial fitting p=3.

Next in order to have understanding about relations between earthquakes time and space distribution in Fig. 4 and Fig. 5 we present these DFA slopes of interevent times vs DFA slopes exponents of interevent distances sequences. Calculation were made for declustered and original catalogues. We see that in most of cases earthquakes space and time distribution reveals features of persistent long-term correlated process.

This is in good accordance with our earlier findings [8]. Analysis carried out on datasets from declustered catalogues was important because often more regular, close to low-dimensional part of seismic process is often explained as a result of spatio-temporal correlations (clustering) of strong earthquakes with their aftershocks and foreshocks. We see here that after declustering there remain essential part of correlated in space and time events.

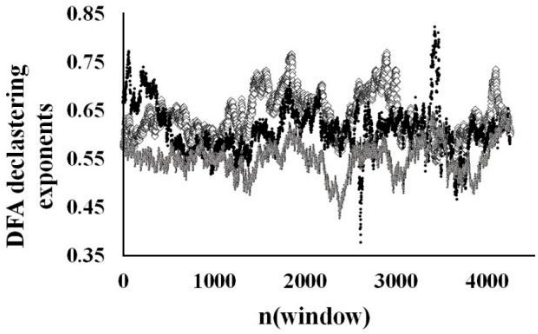

Fig. 6. DFA scaling exponents variation for waiting times (black), distances(hollow), grey(magnitudes) data sets calculated for consecutive 500 data windows shifted by 1 data step. The order of the polynomial fitting *p*=2.

General view of scaling exponents calculated for waiting times, inter-earthquake distances and magnitudes sequences accomplished for consecutive 500 data windows is presented in Fig. 6.

It is interesting that scaling exponents values vary in a wide range from window to window, what means that long-range correlation features of seismic process undergo essential changes for different periods of observation.

2.2. Conclusion

As we can see from the results of our analyses, scaling exponents of waiting times and inter-earthquakes distances in the Caucasian seismic catalog, which were calculated for consecutive sliding windows, shows substantial variation through time of observation. So, we can say, that seismic process in the time and space domains generally reveals long-range correlations though in the time periods of strong earthquake occurrence anti-persistent and random-like behavior may take place.

3. Acknowledgements

I am glad to thank Shota Rustaveli National Foundation for the grant DO/74/5-104/14 which had made possible to take part in the ICESD-2016 Conference and introduce the results of our research.

4. References

[1] T. Chelidze, T. Matcharashvili, Z. Javakhishvili, N. Zhukova, N. Jorjiashvili, I. Shengelia, E. Mepharidze, Z. Chelidze, A. Sborshchikovi. Temporal and Spatial Variations of Scaling behavior of Seismic Process in Caucasus. Bulletin of the Georgian National Academy of Sciences, 2015, vol. 9, no. 2, 59-63

[2] L.Telesca, V.Cuomo, V.Lapenna, M. Macchiato.Fluctuativion dynamics in geoelectrical data: an investigation by using multifractal detrended fluctuation analysis.*Tectonophysics* 2001,**330**:93–102.

[3] L.Telesca, V.Cuomo, V.Lapenna, M. Macchiato.Detrended fluctuation analysis of the spatial variability of the temporal distribution of Southern California seismicity.*Chaos Solitons Fractals*2004, **21**:335–342.

[4] A. Corral.*Long Term Clustering*. Scalling and Universality in the Temporal Occurrence of Earthquakes, 2004.

[5] M. D.Martinez, X.Lana, A. M. Posadas,L.Pujades. Statistical distribution of elapsed times and distances of seismic events: the case of the Southern Spain seismic catalogue. *Nonlinear Processes in Geophysics*2005, **12**: 235–244.

[6] T.Chelidze, T.Matcharashvili. Complexity of seismic process; measuring and applications. *Tectonophysics*2007, **431**: 49-60

[7] T.Matcharashvili, T.Chelidze, Z. Javakhishvilli,Nonlinear analysis of magnitude and intervent time interval sequences for earthquakes of Caucasian region, *Nonlin. Process. Geophys.*2000, **7**: 9–19.

[8] Y.Liu, P.Gopikrishnan, P.Cizeau, M.Meyer, C.-K. Peng, H. E. Stanley.Statistical properties of the volatility of price fluctuations.*Phys. Rev.*1999, E **60**: 1390.