CROSS-CORRELATION ANALYSIS FOR TWO NON-STATIONARY TIME SERIES OF SEISMIC ACTIVITY BETWEEN EASTERN ALPS AND THE UPPER SILESIAN COAL BASIN

Agnieszka BRACŁAWSKA[1] and Adam F. IDZIAK[1]

[1] *University of Silesia in Katowice, Faculty of Earth Sciences, Department of Applied Geology, ul. Będzińska 60, 41-200, Sosnowiec, Poland, abraclawska@us.edu.pl*

Introduction

The general purpose of our research is to check if there are temporal relationships between the seismic activity of the Eastern Alps region and the occurrence of strong seismic shocks in Upper Silesian Coal Basin (USCB) in Poland. Confirmation or denial of this hypothesis will be very import to explain the genesis of strong seismic events in USCB. In addition, we focus on a detailed analysis of seismic databases in terms of temporal changes in the occurrence of earthquakes, taking into account the area of the Eastern Alps and investigating the possible impact of seismicity of this region on the occurrence of strong seismic shocks in USCB.

Former research of seismicity in the Upper Silesian Coal Basin showed that it has a bimodal character (Kijko 1986). Tremors occurring in this area can be divided into low-energy events caused directly by the underground exploitation and regional ones (high-energetic), the cause of which are not yet fully explained (Pilecka & Stec 2006). The second type of seismicity is probably induced by the combination of two factors: the mining and tectonic one. The explanation of the genesis of high-energetic events is the subject of our research.

To check these hypothetical relationships, we created two time series, one for the USCB and second for the Eastern Alps.

Samples and methods

For the needs of our research we needed a seismic databases containing all information on events occurring between 1987-2017 and one type of magnitude – local magnitude (M_L) from the area of the USCB and from the Eastern Alps. Seismic events in the USCB were recorded by the Upper Silesian Regional Seismic Network conducted by the Central Mining Institute. This database includes events with $M_L \geq 2.0$ (energy $\geq 6 \cdot 10^6$ J) recorded between 1987-2012. 18 076 shocks were registered during the period considered. In turn, data on seismic events from the Eastern Alps region came from the fallowing international seismological centers: European Mediterranean Seismological Centre (EMSC), the International Seismological Center (ISC - on-line bulletins), German Research Centre for Geosciences (GFZ) and from Real Time Seismology of NE Italy (Centro di Ricerche Sismologiche). In the studied period, 7 536 shocks were recorded.

We pay special attention to the strict connections between the seismicity of the considered areas and its tectonics. Both regions are characterized by inhomogeneous distribution of earthquakes. In the USCB tremor epicentres do not occur uniformly throughout the whole basin but grouped in several regions belonging to different structural units and are separated by regions where strong shocks are not observed. In the case of the Eastern Alps, shocks are mainly concentrated in the area of the most important fault zones and geological structures.

We carried out analyzes of changes in seismic activities in the area of the Eastern Alps and its potential impact on the USCB by two statistical methods: time series analysis and cross-correlation.

The aim of the analysis of time series is detecting the nature of the phenomenon represented by observation sequences in successive units of time (in the case of our research, it was quarterly activity). In turn, cross-correlation is a function of the correlation values of two time series moved by Δt relative to each other depending on the value of Δt. The classical definition of cross-correlation assumes the stationarity of both time series and it can be questioned its application to real data, usually characterized by high degree of nonstationarity (in particular in the case of seismology). In statistics a stationary process is a stochastic process whose unconditional joint probability distribution does not change when shifted in time (Enders,

Enders (2010). When the mean value, variance and autocorrelation function change with the change of time, the random process x (t) is called nonstationary. Consequently, parameters such as mean and variance also do not change over time. Since stationarity is an assumption underlying many statistical procedures used in time series analysis, non-stationary data is often transformed to become stationary. The obtained time series of seismic activity were characterized by high nonstationarity. For this purpose we conducted the analysis according to the method proposed by Podobnik & Stanley (2008). This method is designed to investigate power-law cross-correlation between different simultaneously recorded time series in the presence of nonstationary.

Results

The analysis of time series in terms of nonstationarity allowed us to conduct a cross-correlation analysis to check the relationship between the seismic activity of the Eastern Alps and the intensity of strong seismic events in the USCB. After applying the cross-correlation analysis, it turned out that the seismic activity in the Eastern Alps does not have much impact on the occurrence of strong seismic shocks in Upper Silesian Coal Basin.

Conclusions

Our results indicate that the seismic activity in the Eastern Alps does not have much impact on the occurrence of strong seismic shocks in Upper Silesian Coal Basin. The explanation of the genesis of strong seismic events in USCB is still matter of discussion.

It should also be noted that there are other geological structures between the USCB and the Eastern Alps – the Bohemian Massif and the Sudetes. The seismic activity of Eastern Alps probably influences on these structures to a greater extent than on the USCB.

In conclusion the hypothesis about the temporal relationships between the seismic activity of the Eastern Alps region and the occurrence of strong seismic shocks in USCB should be rejected.

References

Enders W., 2010. Applied Econometric Time Series (Third ed.). New York: Wiley. pp. 53–57.

Kijko A., Drzęźla B., Mendecki A.,1986. Bimodal character of the distribution of extreme seismic events in mines. Publications of the Institute of Geophysics Polish Academy of Sciences, M-8, 191, 91–101.

Pilecka E., Stec K., 2006. Analiza związku wysokoenergetycznej sejsmiczności z anomaliami grawimetrycznymi i magnetycznymi na terenie GZW. Warsztaty 2006 z cyklu: Zagrożenia naturalne w górnictwie. Mat. Symp., 331– 337.

Podobnik B., Stanley H.E., 2008. Detrended Cross-Correlation Analysis: A New Method for Analyzing Two Nonstationary Time Series. Physical Reaserch Letters, 100, 084102. DOI: 10.1103/PhysRevLett.100.084102).