Prospects for Predicting Energy Flow Released by Local Earthquakes

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Abstract

Regression method has been applied to design multidimensional nonlinear statistical model of seismic energy flow release by local earthquakes using the data of integrated geophysical monitoring in the Transcarpathian seismogenic zone, Ukraine, as input. It has been shown that to obtain adequate model it is necessary to utilize temporal series of geophysical parameters that are not less than 730 days long. Since variations of seismic energy flow lag behind variations of input geophysical parameters, model is capable to predict time of anomalous growth of local seismicity for 2 to 3 months in advance. Retrospective testing confirmed that ability.

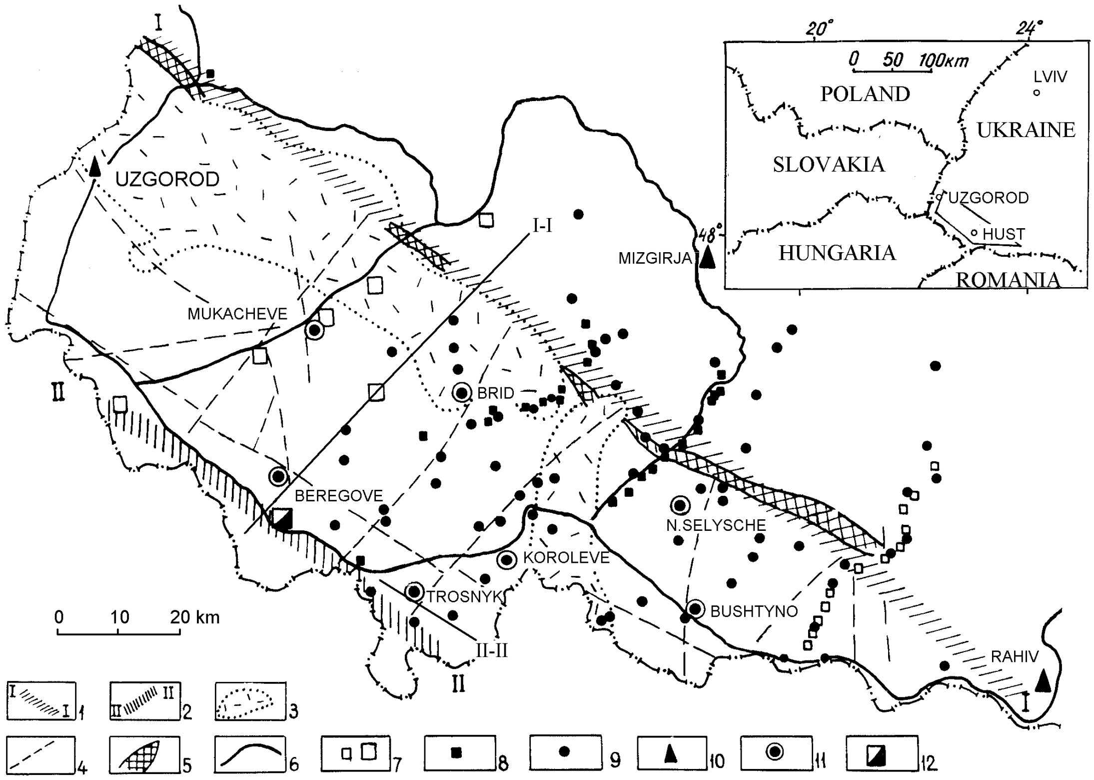
Introduction

The Transcarpathians is one of the most active seismogenic zones in Ukraine. Modern seismic activity is determined by the formation processes of the Carpathians and mountain troughs and confirmed by a great number and concentration of earthquake epicenters. Intensity of local earthquakes reaches 7° on MSK - scale (Tyachiv, 1781, 1870, Sighet, 1784, 1823; Rokoshyno, 1797**;** Dovhe, 1872; Svalyava, 1908; Teresva, 1926; Dragovo, 1937). The earthquakes with such intensity repeat every 160 years. The local earthquakes with an intensity of 8° on MSK-scale and maximal energy of K_{max} are possible here [1]. Taking into account considerable seismic activity in the Transcarpathians, as well as high density of population, concentration of industrial enterprises and international oil and gas pipes the Transcarpathian complex prognostic polygon with a net of continuous regime geophysical stations (RGS) has been initiated since 80-ies. The RGS net is mainly aimed at maintaining complex geophysical monitoring of seismotectonic process in the territory of Transcarpathian region in order to elucidate seismic danger level and control its dynamics.

Carpathian Branch of Institute of Geophysics NASU has put into operation 5 permanent RGS and 2 temporary RGS (Fig.1). The up-to-date digital equipment to register earthquakes and microseisms, deformations (in adits of RGS “Beregove” and “Koroleve”), the Earth’s crust temperature (“Trosnyk”), acoustic and electromagnetic emission (“Trosnyk”, “Beregove”), modulus of geomagnetic field (Nyzhnye Selyshche”, “Trosnyk”, “Beregove”, “Brid”), meteoparameters (“Trosnyk”, “Nyzhnye Selyshche”, “Mukacheve”) are set in special premises of permanent (“Trosnyk”, “Koroleve”, “Beregove”, “Mukacheve”, “Nyzhnye Selyshche”) and temporary (“Brid”, “Bushtyno”) RGS[2].

Long numerical series of values for a broad set of geophysical field parameters have been obtained. The methods for data processing and their analysis have been developed. A statistical model of seismic energy flow released by Transcarpathian earthquakes is constructed. Moreover, this model is shown to be used to predict monthly values of energy and a number of local earthquakes for the period of 2-3 months ahead. Preliminary application results demonstrate great prospects for complex geophysical monitoring of seismotectonic processes on the Transcarpathian complex prognostic polygon held to elucidate the seismic danger level and control its dynamics [3].

It is of necessity to determine minimal necessary length of temporal series of values of geophysical field characteristics that provides both for reliable modelling of seismic energy flow (monthly total value of energy and a number of local earthquakes) and prediction of its change for the nearest several months, as well as to determine an optimal set of geophysical field characteristics that would help to solve the problems set. The above is necessary for efficient application of complex geophysical monitoring to elucidate the seismic danger level and predict its dynamics.



1 - the Transcarpathian deep fault; 2 - the Prepannonian deep fault; 3 - Gutin volcanogenic formation; 4 - the axis of the Carpathian conductivity anomaly; 5 - Pienine zone; 6 - repeated levelling polygons; 7 - secular universal mark; 8 - fundamental levelling mark; 9 - secular variation points; 10 - seismic station;11 - regime geophysical stations; 12 - gallery;

Figure 1: The observation network on the Transcarpathian complex prognostic polygon

It is also of interest to estimate an optimal time prediction span and compare the results of modelling and prediction that are obtained by a statistical method with the corresponding results obtained due to other methods, e.g. that of neuron networks.

Both the coefficients of multiple and mutual correlation and the Fisher's criterion are studied to evaluate efficiency of statistical modelling and prediction. It is determined that their application is similarly efficient. But taking into account that mutual correlation coefficient may be used for small sampling it is expedient to be applied for retrospective investigations of prediction efficiency.

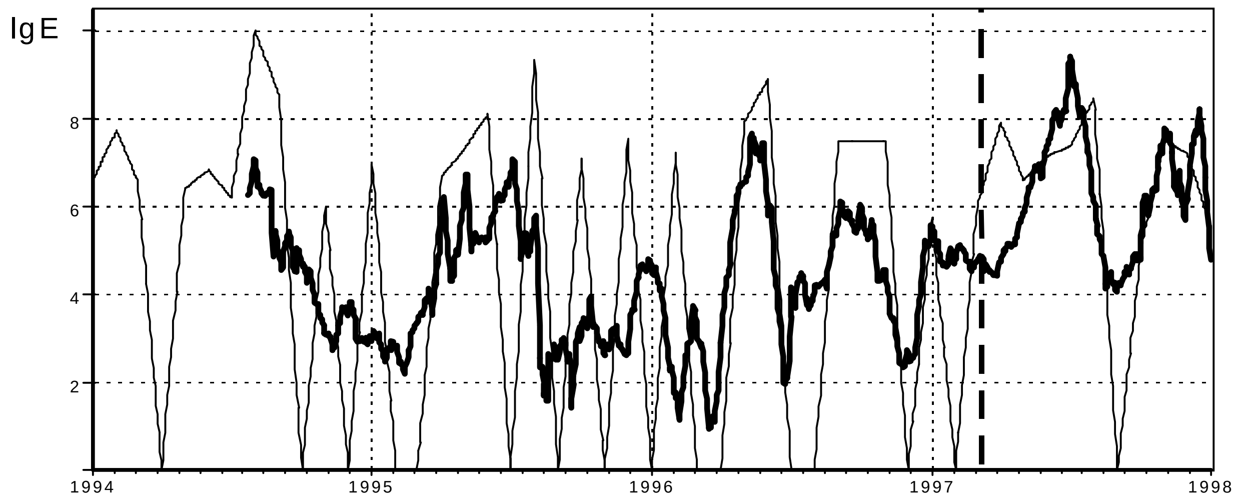
Estimation of Necessary Length of Temporal Series (Modeling Bases)

The investigations were held using temporal series of values of temperature and the Earth's crust deformation, air temperature and atmospheric pressure for the period of 1992-1998. The statistical models for variations of energy and a number of local earthquakes were constructed for the bases of 1992-1994, 1992-1995, 1992-1996, 1992-1997. Analysis of the results obtained shows that for the bases that are less than 730 days, modelling reliability is not stable. As the base increases reliability and accuracy of modelling also increases. Further increase of the base of modelling by 120 days results in increase of mutual correlation coefficient approximately by 0.01. Thus the continuous registration data of a set of geophysical field characteristics for the three-year period are necessary to model and predict seismic energy flow released by local earthquakes.

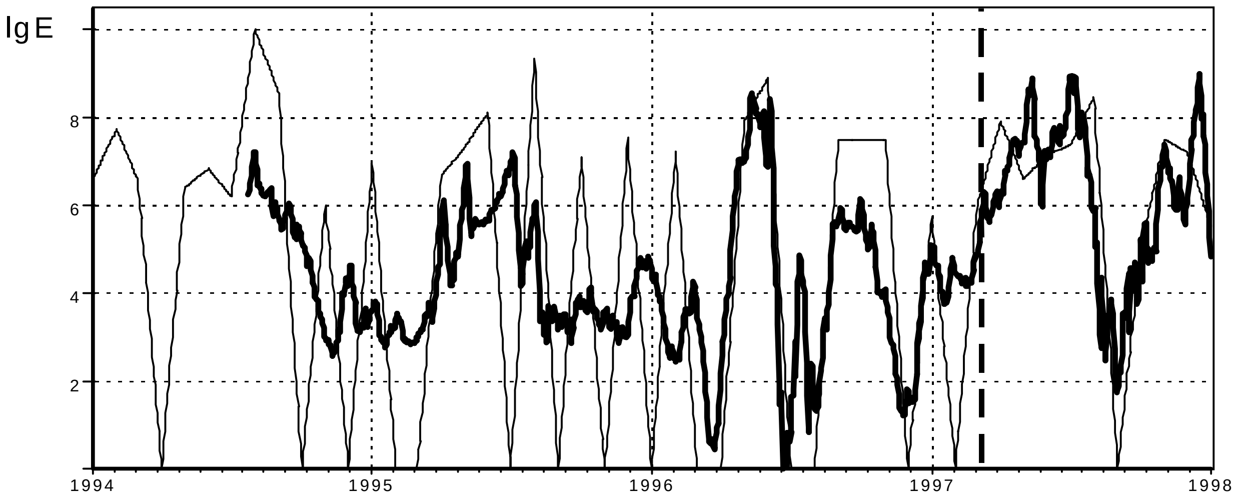
Choice of a Complex of Geophysical Field Characteristics

A necessary set of geophysical field characteristics to model and predict temporal variations of energy and a number of local earthquakes was determined using temporal series of 960 days long.

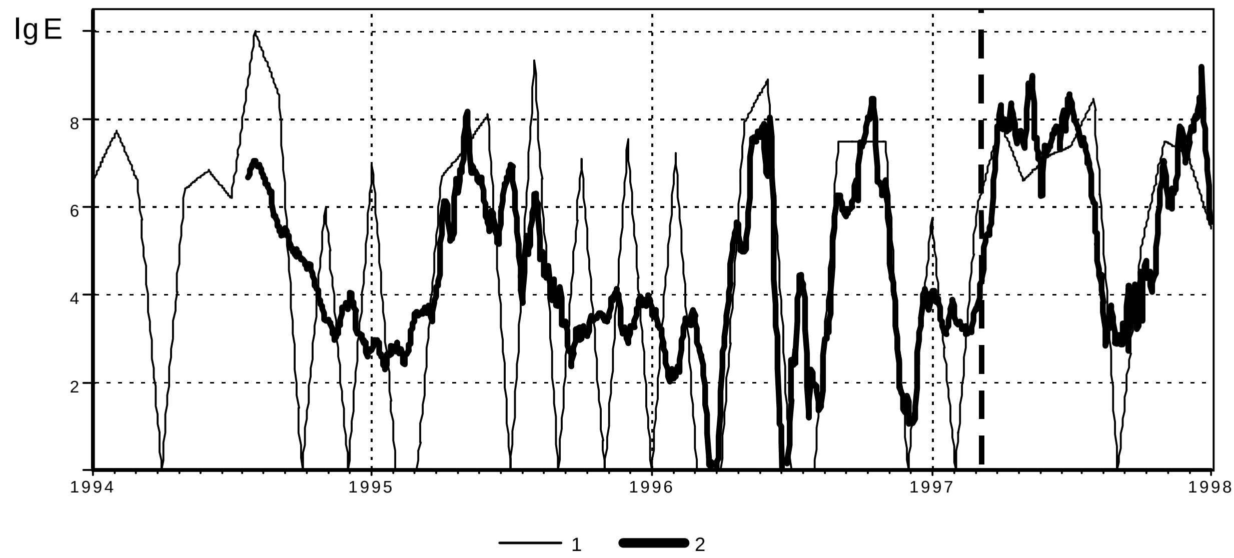
a



b



c



1 - observed values;   *2 - estimated values*

Figure 2: Modeling results on both base (1994-1996) and test (1997) time intervals for seismic energy released by Transcarpathian earthquakes using three (a), four (b) and five (c) geophysical field characteristics.

At first temporal series of values of microseism amplitude (Ma), air temperature (T) and atmospheric pressure (P) were used to construct a statistical model (Fig. 2a). Then a temporal series of horizontal deformation values (D) and finally those of geotemperature (Gt) were included (Fig.2b and 2c).
Fisher's criterion values (F, F_T), coefficients of multiple (R) and mutual (r) correlation for three models studies and mutual correlation coefficient for values of energy and a number of earthquakes (both observed and predicted) are presented in Table 1.

Table 1: Reliability estimation of statistical modeling and prediction of energy flow (lg E) and number (N) of local earthquakes

Geop. fields	Series Type	*lg E*							*N*						
		R	*F*	F_T	F/F_T	*r*	δr	$r/\delta r$	*R*	*F*	F_T	F/F_T	*r*	δr	$r/\delta r$
Ma P T	Base	0.519	45.52	2.02	22	0.520	0.024	22	0.508	44.11	2.02	22	0.509	0.024	21
	Test	0.544	32.25	2.04	16	0.570	0.039	15	0.640	29.45	3.24	9	0.648	0.034	19
D Ma P T	Base	0.592	47.09	1.84	25	0.593	0.021	28	0.588	55.63	2.02	28	0.593	0.021	28
	Test	0.742	53.24	1.80	28	0.758	0.025	31	0.552	53.83	2.04	26	0.637	0.034	18
Gt D Ma P T	Base	0.664	40.87	1.65	25	0.666	0.018	37	0.699	53.56	1.76	30	0.710	0.016	44
	Test	0.754	36.26	1.68	21	0.774	0.023	33	0.443	31.12	1.78	17	0.618	0.036	17

As it is seen in Fig.2 extending a set of input characteristics of geophysical fields considerably influences quality of energy and a number of local earthquakes modelling. The above is especially obvious in models within the time intervals of March-June 1965, August-November 1996 and March-August 1997. Significant influence of a set of input characteristics of geophysical fields on modelling accuracy is also corroborated by data analysis of quantitative estimation of modelling (Table 1).
Thus as a minimal set of geophysical field characteristics increases from 3 to 5, mutual correlation coefficient for a variation model of energy and earthquakes (1994-1996) increases from 0.520 ± 0.024 to 0.666 ± 0.018. For the time interval predicted (March-August 1997) this increase is from 0.570 ± 0.039 to 0.774 ± 0.023.
In case of modelling of a number of earthquakes we have the following results. Mutual correlation coefficient for a base time interval increases from 0.509 ± 0.024 to 0.710 ± 0.016; for the test time interval it increases from 0.648 ± 0.034 to 0.618 ± 0.036.
It is quite possible that more accurate and reliable results and an optimal set of characteristics are due to extending of geophysical fields.
It would be of great use to apply the methods based on another mathematical basis to model and predict seismic energy flow, e.g. the theory of neuron networks or fuzzy sets, and to compare the results obtained with the data of mathematical statistics.

Acknowledgments

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