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The EMSC is undertaking a major challenge this year as it was selected to organize the 32nd General Assembly of the European Seismological Commission. The conference will take place in Montpellier, France, from September 6 to September 10, 2010. It will also feature a Training Course dedicated to Young Seismologists (eligibility conditions and application procedure to come soon).
Organizing such an event is a major occasion for the EMSC to state its role and place in the Euro-Med zone. We will strive to provide all participants with an attractive programme and an enjoyable stay.

The scientific programme will focus on the Euro-Med zone. Our sessions will cover the seismic event from its very source, that is to say from tectonics to its effects on our societies (as described by the sociology of risks). We will also take a look at the newest perspectives offered by information technologies, grid and high performance computing, data assimilation, data mining etc. The programme will also feature: the social impact of seismology (involvement of citizens as key witnesses to seismic events), society acceptance of risk (e.g. acceptance of geothermic projects), sociology of risk, communication in low-risk zones etc.). The social programme is still in preparation, but we can tell you it will feature food and wine, geological trips, excursions in the beautiful French countryside... and of course tours of Montpellier, an exquisite city bathed in sunlight.

REGISTRATION WILL OPEN EARLY 2010

We hope to welcome you in Montpellier in September 2010!

If you are reading the electronic version of our Newsletter, you can click on the ESC2010 banner to access the conference website directly.
If not, please visit us at http://www.esc2010.eu

Also visit the European Seismological Commission website:
http://www.esc-web.org/

The ESC2010 LOC: *Dr. Remy Bossu, EMSC General Secretary, head of the LOC, Marie-Line Nottin, EMSC Communication Officer, Pr. Michel Cara, Institut de Physique du Globe de Strasbourg, Dr. Serge Lallemand, Géosciences Montpellier, Univ. de Montpellier, Marie-Odile Pietrusiak, Observatoire de Recherche Mediterranéen en Environnement, Communication Officer. The ESC2010 is organized with the support of Geosciences Montpellier.*

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AFTER SHOCK PROBABILITY ASSESSMENT FOR THE EARTHQUAKE OF SEPTEMBER 6, 2009, ALBANIA, BASED ON THE GUTENBERG-RICHTER AND MODIFIED OMORI FORMULAE

by Serkan Öztürk[1], Rrapo Ormeni[2]

Abstract

In this study, we made a statistical analysis for the aftershock occurrence of the September 6, 2009 earthquake, 21:39 GMT, with a magnitude M_L(5.4) that occurred on the Gjorica village, about 19km south of the city of Peshkopia, Albania. The catalog is homogenous for local magnitude, M_L, and contains about 13 day's time period. The catalog contains 117 aftershocks with a magnitude M_L larger than or equal to 2.0. A model for aftershock occurrence probability based on the combination of Gutenberg-Richter and modified Omori formulae is used in order to predict how many large aftershocks should follow small main shocks and in order to evaluate the aftershock probability that a randomly chosen earthquake is greater than or equal to a certain magnitude of aftershock. For this purpose, we made an application using aftershock sequences of the September 6, 2009 earthquake.

Introduction

The Northeastern part of Albania was struck on September 6, 2009 by an earthquake (M_L=5.4) causing many damages in Dibra district. The Dibra district has been hit by other earthquakes in the last century, resulting in human victims and enormous material loss. The minimization of the human victims, property damage, and social and economical disruption due to earthquakes, essentially depends on reliable estimates of seismic hazard. It is therefore, of a great importance to evaluate the seismic hazard properly. For this purpose, an evaluation of the aftershock probability has been analyzed in this study.

The aftershock probability evaluation method is an effective way to analyze the aftershock activity of the main shock-aftershock pattern and it must be used as a part of earthquake evaluations. The occurrence of aftershocks has been investigated statistically and physically by many seismologists and some principal results are obtained (e.g., *Guo and Ogata, 1997; Öztürk and Bayrak, 2007; Öztürk and Bayrak, 2009)*. An aftershock probability assessment as it is used on the earthquake of September 6, 2009 refers to statistically expressing and evaluating the frequency that an aftershock of a certain magnitude will occur. The modified Omori formula *(Utsu, 1961)* forecasts the number of aftershocks that will occur, but in order to perform a probability evaluation of aftershocks, it is necessary to combine this formula with the Gutenberg-Richter *(Gutenberg-Richter, 1944)* formula. In this study, a model that clarifies the number of events forecasted and the probability of one or more aftershocks by statistically processing the main shock-aftershock pattern has been defined based on the combination of modified Omori and Gutenberg-Richter formulae.

Data used

The data for doing this study were retrieved from Albanian seismological stations, Montenegro seismological stations, also from INGV, MEDNET, and AUTH networks. Complete and homogenous catalogue of aftershock sequences is provided for the main earthquake with M_L=5.4, on September 6, 2009. The number of aftershocks localized was 117 and magnitude values were $M_L \geq 2$.

Method and Analyses of Probability Evaluation

Quantitatively, the larger the magnitude of aftershock, the more their number declines exponentially. The expected number of events $N(T_1,T_2)$ larger than M magnitude of the earthquakes during the time from *Tl to T2* is calculated by:

$$N(T_1,T_2)=\int_{T_1}^{T_2}\lambda(M,s)ds = K\,exp\{-\beta(M-M_{th})\}A(T_1,T_2) \quad (1)$$

Here, *K* is a parameter from modified Omori (MO) law; *b* is a parameter of Gutenberg-Richter (GR) formula and M_{th} is magnitude of the smallest earthquake *(Ogata, 1983)*. A(*T1,T2*) is given as:

$$A(T_1,T_2)=\begin{bmatrix}\dfrac{(T_2+c)^{1-p}-(T_1+c)^{1-p}}{1-p} & (p\neq 1)\\ \ln(T_2+c)-\ln(T_1+c) & (p=1)\end{bmatrix} \quad (2)$$

where *c* and *p* are constants from MO formula. The probability *Q* of one or more aftershocks of *M* magnitude or greater occurring since the main shock, from the time T_1 to T_2 is found by Equations 3 and 4 *(e.g., Reasenberg and Jones, 1989)*:

$$Q = 1 - \exp\left\{-\int_{T_1}^{T_2} \Lambda(M,s)ds\right\} = 1 - \exp\{-N(T_1,T_2)\} \quad (3)$$

$$Q = \begin{cases} 1 - \exp\left[\dfrac{-Ke^{-\beta(M-M_{th})}}{1-p}\left\{\dfrac{1}{(T_2+c)^{p-1}} - \dfrac{1}{(T_1+c)^{p-1}}\right\}\right] & (p \neq 1) \\ 1 - \exp\left[-Ke^{-\beta(M-M_{th})}\{\ln(T_2+c) - \ln(T_1+c)\}\right] & (p = 1) \end{cases} \quad (4)$$

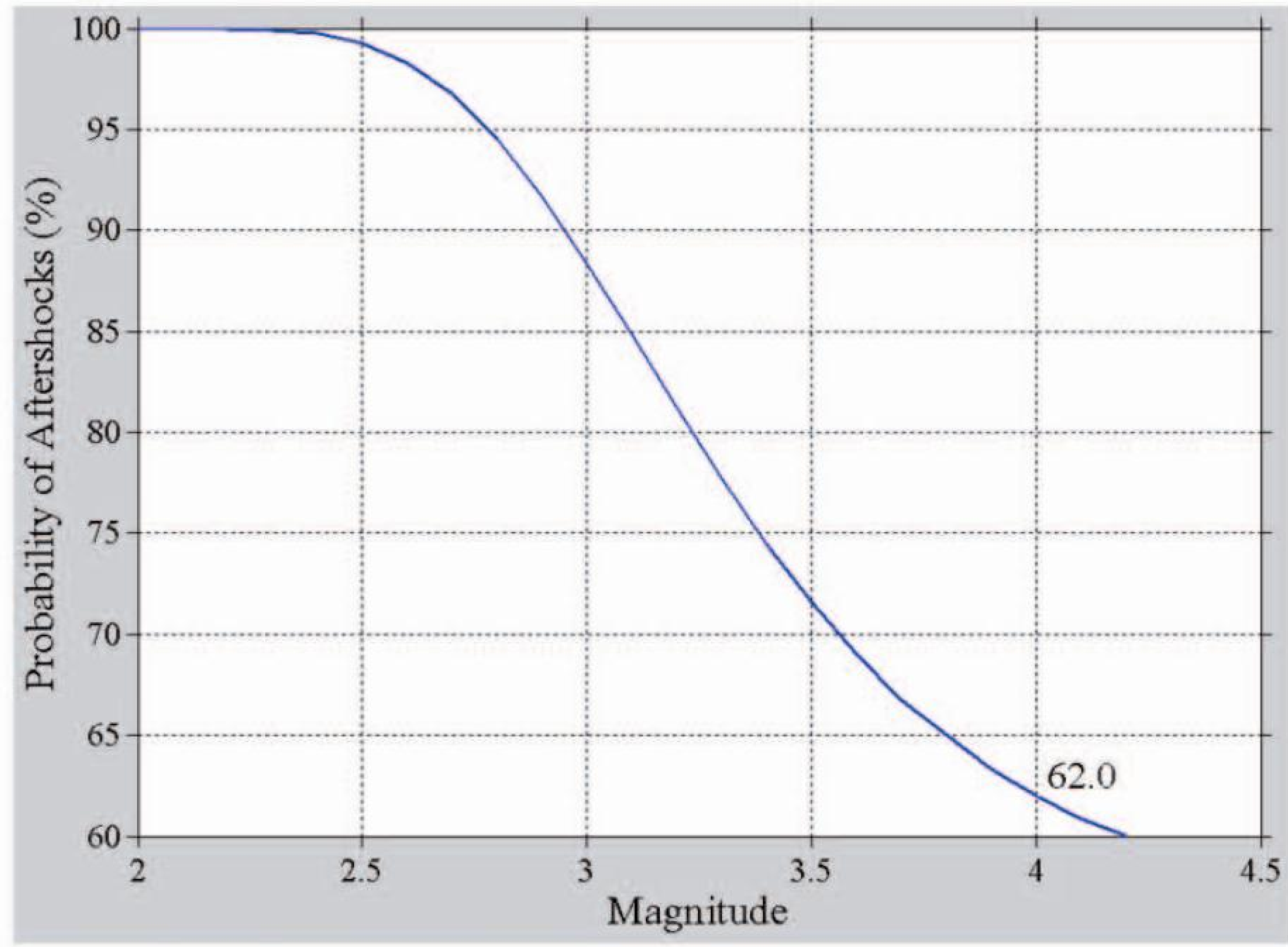

Figure 1 - Aftershock occurrence probability for one or more aftershocks

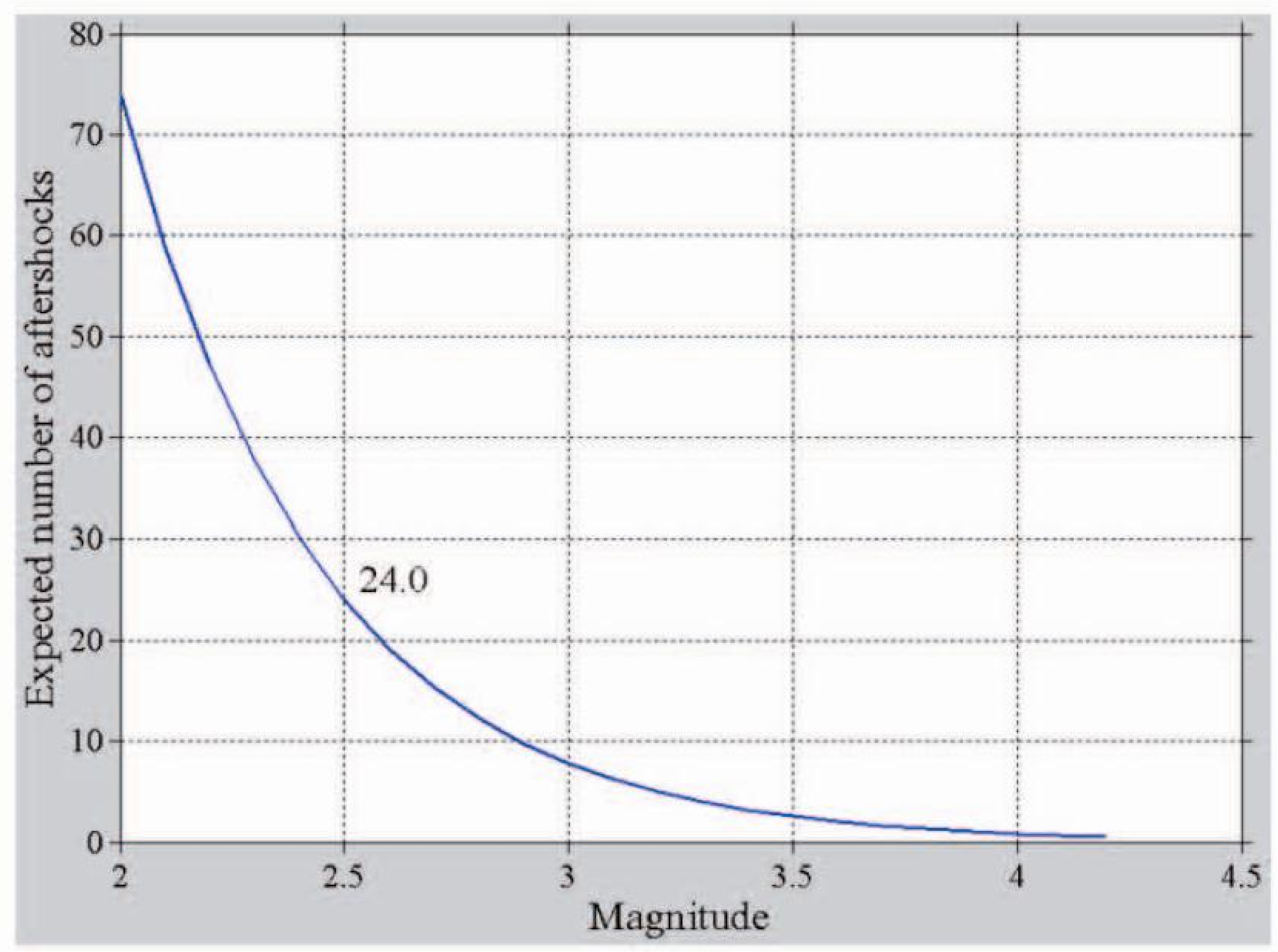

Figure 2 - The number of events forecasted for one or more aftershocks

In these equations, *K* is approximately proportional to the total number of aftershocks; *p* represents the extent of time damping; c compensates for complex aspects immediately after the main shock. *ß* represents the relationship of *b* and ß=*bln10 =2.30b* in the GR formula. *b*-value is related to both the number of small aftershocks and the large aftershocks ratio. Its large value indicates a relatively small number of large earthquakes. M_{th} is the magnitude of the smallest earthquake processed using the MO or the GR formulae. It is premised that all aftershocks larger than M_{th} are observed without omissions. T_1 to T_2, which represent the beginning and the end of the period during the aftershock probability, is evaluated; both represent elapsed time following the main shock. It must be kept in mind that Equation 4 does not represent the probability of an aftershock that matches conditions occurring exactly once; it represents the probability of it occurring more than one time.

The actual application of the probability evaluation methods based on the statistical models involves the problem of determining whether or not it is possible to find the parameters *(K, c, p, b)* for aftershock activity immediately following a main shock.

If the average parameters for the aftershock activity are known, there is a possibility that they can be used effectively as preliminary data until the actual data is available.
For this reason, specific parameters for the aftershock statistical model combining the GR and the MO formulae are compared, and their application range is studied.
Figure 1 shows the number of aftershocks forecasted and Figure 2 shows the aftershock occurrence probability versus the magnitude of aftershocks.

All calculations are considered for the starting and ending time intervals of the aftershock sequence. For the aftershock sequence, the magnitude of randomly chosen events is taken as M_L=4.0 and the aftershock probability in this magnitude level is shown on each plot. The expected number of aftershocks with magnitude M_L=2.5 is also given on graphs.
The probability of the largest aftershock occurrence for magnitude level of 4.0 is calculated as 62.0 % for Dibra earthquake of 6 September, 2009. The maximum expected numbers of aftershocks for magnitude level of 2.5 was computed 24.

General information for the earthquake occurrence of September 6, 2009 is given in Table 1. Also the maximum *(Ma_{max})* and minimum *(Ma_{min})* magnitudes of aftershock sequence are given. Also, the number of aftershocks *(N)*, completeness magnitude *(M_c)*, starting

Year	Month	Day	Origin Date	Longitude	Latitude	Depth (km)	(M_L)	Ma_{max}	Ma_{min}
2009	08	06	21:49:41	41.49	20.45	7.6	5.4	4.2	2.0

Table 1. Some properties of the earthquake occurred in Gjorica, Diber, Albania

Earthquake	N	T_1 (day)	T_2 (day)	M_c	b-value	K-value	c-value	p-value
September 6, 2009	117	0.008	13	2.8	0.98±0.09	12.59±1.99	0.019±0.031	0.83±0.11

Table 2. Aftershock parameters and statistics used in the probability evaluations

(T_1) and ending (T_2) times for the sequence, b, K, p, and c-values for the aftershock sequence are given in Table 2.

Conclusions

In this study, an example of a statistical application of the aftershock probability evaluation method is carried out for the September 6, 2009 earthquake.

It is an important fact that aftershock probability is one evaluation method and it must be used as a part of earthquake evaluations.
The number of events forecasted and the probability of aftershock activity is evaluated for one or more aftershocks by combining the Gutenberg-Richter and the modified Omori formulae.
As an example, we used M_L=2.5 for the expected number of aftershocks and M_L=4.0 for the probability of the largest aftershock occurrence.
Probability for magnitude level of 4.0 is calculated as 62.0 % and the expected numbers of aftershocks for magnitude level of 2.5 was computed 24.

Thus, such kind of evaluations can make a contribution to the success of disaster protection measures in Dibra region.

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