J. Int. Environmental Application & Science, Vol. 12(3): 224-229 (2017)

Fast Information Exchange and Evaluation of Macroseismic Field of Moderate 2017 Albania Earthquakes

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Received April 05, 2017; Accepted August 12, 2017

Abstract: The macroseismic questionnaire is addressed to a single non-specialist person; reported effects are statistically analysed to extrapolate EMS-98 intensity referred to that observer. A macroseismic investigation of the January 27, 2017, M_s=4.6 (Richter) Kucova earthquake, in southern Albania, and of the April 08, 2017, M_s=5.0 (Richter) Kurbnesh earthquake, in northern Albania, were carried out through an online web survey. Data were collected through an internet macroseismic questionnaire available at the website managed by IGEWE. The procedures are still in development and require refinement. A statistical analysis was applied to the data collected in order to investigate the spatial distribution of intensity of these earthquakes. Map of macroseismic intensity for these earthquakes are compiled and later are continuously updated from others information. The aim of the questionnaire is to evaluate seismic effects as felt by the compiler. Effects reported in questionnaires coming from towns are analysed in deep. This paper give a fast way for assessment of intensity, of attention function for intensity of this earthquakes, intensity isoseismal map and will be a proposal and first step for the basis of an automatic system for assigning EMS-98 intensity values to questionnaire data gathered from website managed by IGEWE.

***Keywords**: Earthquakes, Macroseismic Intensity, Questionnaire, effects, attenuation*

Introduction

The last year, the Department of Seismology, Institute of Geoscience, Energy, Water and Environment (IGEWE, 2016) "Did You Feel Earthquake?" questionnaires has automatically collected shaking and damage reports from Internet users immediately following earthquakes. These questionnaires has become vital for fast collecting macroseismic data for January 27, 2017 earthquake and of the April 08, 2017 earthquakes felt in the Albania and surrounding area; it is also one of the most popular, interactive websites within the Institute of Geosciences, Energy, Water and Environment (IGEWE). These questionnaires from IGEWE websites as a first step for large database are integrated to fast collecting questionnaires from EMSC websites. The aim of this paper is to give insight into the concept of a community-based map creation process in the context of earthquake intensity estimation. The Kucova January 27, 2017 earthquake, characterized by the relevant magnitude of M_s=4.6, was felt over a large area of Central Albania, the Kurbneshi April 08, 2017 earthquake, characterized by the relevant magnitude of M_s=5.0, was felt over a larger area of Central and northern Albania. Since 2016 in its current aspect and formulation, the Department of Seismology in the Institute of Geosciences, Energy, Water and Environment (IGEWE) manages to collect of macroseismic information from the population (http://www.geo.edu.al). This is used to assess the intensity of earthquakes as well as to elaborate the results in real time in the form of data, for each seismic event felt by the population. Although given by non-expert compilers, the over 150 questionnaires filled in were statistically elaborated and based on the relation of seismic intensity attenuation (Aliaj *et al.*, 2010) were estimated the macroseismic intensity field of the Kucova and Kurbneshi earthquakes.

Materials and Methods

In the first 3 hours from the occurrence of the events we have collected most questionnaires from users located throughout Albania. A relatively large number of responses came from the epicentral area, as commonly occurs in the case of low and moderate magnitude events, considering people

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immediately fill in the questionnaire. According to the European-Mediterrian-Scale-98 (EMS-98) definition, people recognizing the earthquake occurrence in the II EMS-98 degree area are generally so few (about 5%) that they are unlikely to submit questionnaires in the first place. For this reason, I and II EMS-98 were not included in the macroseismic information.

A renewed method of macroseismic survey, based on voluntary collaboration through Internet, is running at Department of Seismology, Institute of Geoscience, Energy, Water and Environment (IGEWE) since October 2016. Questionnaires from internet data and updating to data from Civil Emergency for January earthquakes came from 21 municipalities and for Aprile earthquakes came from 25 municipalities. For a more reliable estimation of earthquake intensity we excluded all municipalities with less than 3 questionnaires. For each municipality, a specific score distribution, within the spectrum of macroseismic degrees, was given to each answer, relative to the observed effects. The intensity, expressed as a rational number, was then assessed computing the modal value or the average of the local maxima of the distribution (Tosi *et al*., 2015). The final dataset was composed of 46 municipality intensity data in the EMS-98 scale derived from 154 questionnaires. Based on Sulstarova relation between macroseismic (I_0 epicentral intensity) and instrumental parameters were found I_0 as average (Eq. 3; Aliaj *et al*., 2010).

$$I_0 = 1.97M_s - 3.06\log h - 0.61 \quad (h<10 \text{ km}) \qquad \text{(Eq. 1)}$$

$$I_0 = 1.75M_S - 4.55\log h + 3.45 \quad (h>10 \text{ km}) \qquad \text{(Eq. 2)}$$

I_0 epicentral intensity, Ms Surface magnitude, h depth. Respevtively: for Kucova earthquake, h=5km results *Io*=6.3 and for Kurbneshi earthquake h=15, km results *Io*=6.8. Moreover, the field was distinguished by three main spatial components based on the range of their spatial influence: I_0 epicentral intensity, Ms Surface magnitude and R_i epicentral distance in km. For seismic intensity attenuation the following relation is used as average:

$$I_i = 7.604 + 1.426M_s - 2.351\ln(R_1 + 27) \qquad \text{(Eq. 3)}$$

I_i is macroseismic intensity in isotropic , R_i epicentral distance in km, M_s surface magnitude (Aliaj et al, 2010). First, we expressed all $\boldsymbol{I_i}$ isotropic intensities as a function of the epicentral distance alone (eq. 3). After having modelled the I_i isotropic component, we proceeded to regional anisotropic component and local random variations parameter. This component reflects the influence of all local random components definite by analysis of questionnaires. Then, we averaged the municipality intensity data within intervals of epicentral distance of 5 km of width.

Earthquake Report Form

The estimation of earthquake intensity applied here is operationalized using the standardized EMS-98 scale (Grünthal, 1998). The macroseismic intensity represents a classification of the magnitude of ground motion based on observed phenomena in a defined area, e.g. a town [De Rubeis et al., 1992]. Effects of ground motion on people, objects in houses as well as damages to buildings form the basis for the appraisal. EMS-98 intensity denotes how strongly an earthquake affects a specific place. The European macroseismic scale has 12 divisions, as follows: I not felt, II scarcely felt, III weak, IV largely observed, V strong, VI slightly damaging, VII damaging, VIII heavily damaging, IX destructive, X very destructive, XI devastating, XII completely devastating. Instead of querying the users directly for their intensity estimation, these values are deduced from recognized natural phenomena in a standardized way. As an example, by paraphrasing the different intensity classes with textual descriptions (e.g. “hanging objects swing heavily, small objects maybe shifted. Doors and windows swing open and close”), it is possible for users to integrate their local event-specific knowledge into the overall system without knowing the actual semantics of an intensity class. The descriptions are collected in a web-based form to the corresponding class. Following this approach, non-experts are able to take part in a survey, such that the number of participants is large enough to gain significant results from the data. The form used here contains among questions concerning the mentioned textual descriptions also variables for spatially referencing the event. The user is given the opportunity to either enter a postal code, an address, or a set of geographical coordinates.

Communication Procedure

Basically, the process chain performs the following activities.

1. The user gives an estimation of earthquake intensity by filling out and submitting the form on a web page.
2. Intensity information is analysed to generate intensity from all parameters following the EMS- 98 standard.
3. The whole report (coordinates and estimated intensity) is saved in the database for archiving and further processing from other updating.
4. All information gathered generates average intensities for each area.
5. Average intensity estimations are described on the map together with symbol information.

The impressive rate of responses and feedback from users prompted us to routinely plot entries contributed as a function of time (Fig. 1). Questionnaire response rates have reached 7 per hour for Kurbneshi earthquake and 18 per hour for Kucova earthquake see figure 1, requiring substantial web resource allocation and capacity. These plots are provided online for each event, and they show logical patterns of immediate post-earthquake surges followed by decays. Continuous plots of the entry rates allow operators to track system performance and gauge future bandwidth requirements. The data quality and quantity depend primarily on population density and prevalence of Internet access, but not necessarily on earthquake awareness or the overall hazard of the region.

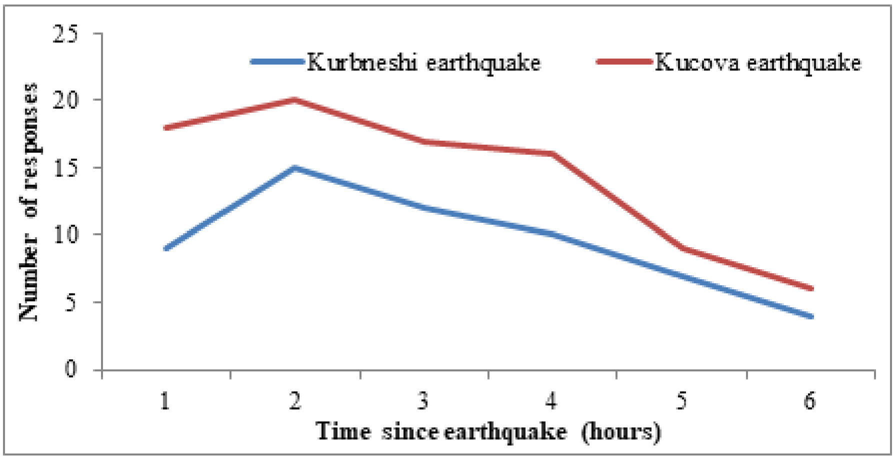

Figure 1. Plot of individual questionnaire responses versustime for the January 2017, M_s= 4.6, Kucova, earthquake (red line). *Over 7 entries were received in the first hour. The earthquake occurred at 18:07 local time. April 08, 2017, M_s=5.1, Kurbnesh earthquake (blue line). Over 17 entries were received in the first hour*

Results and Discussion

As results from Figure 1, the earthquakes were felt respectively: up to 80 km distance in Northwetern of Kucova, up to 70 km distance in Southwestern of Kucova and up to 120 km distance in Southwestern of Kurbneshi and up to 110 km distance in northeastern of Kurbneshi. The estimation of earthquake intensity applied here is operationalized using the standardized EMS-98 scale (Grünthal, 1998). The macroseismic intensity represents a classification of the magnitude of ground motion based on observed phenomena in a defined area, e.g. a town (De Rubeis et al., 2016). Therefore, regional macroseismic anomalies could be linked to the efficiency of wave propagation inside the crust-upper mantle system (Sharra et al., 1998).. The average intensities $\boldsymbol{I_m}$ were plotted as orange dots (Fig. 2). Where $\boldsymbol{I_m}$ represents the average intensities of municipality in the distance of 4 *km* of width. The attenuation of Intensity versus the epicentral distance was then fitted with a 2*nd* degree polynomial function for Kucova and Kurbneshi earthquakes respestively (eq. 4, 5):

$I_i = 6.1915 – 0.065d + 0.0003d^2$ (M_s=4.6, h < 10 km) (Eq. 4)

$I_i = 6.7038 - 0.0612d + 0.0003d^2$ (M_s=5.0, h >10 km) (Eq. 5)

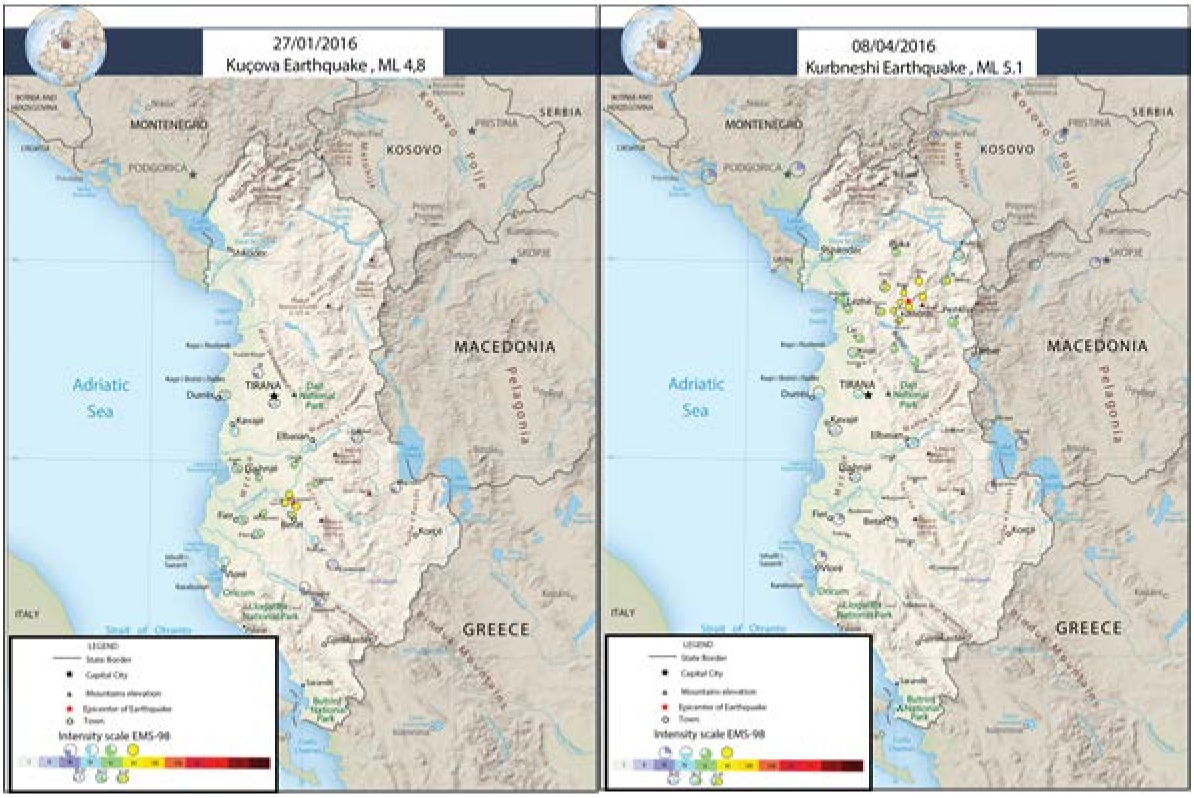

Figure 2. Municipality macroseismic EMS-98 intensities assessed using 50 questionnaires, compiled through the seismicityv site (http://www.geo.edu.) and questionnaires compiled by other alternative way. The purple star represents the instrumental epicenter. The inset shows an enlargement of the epicentral area.

The fit was calculated up to a distance of 80 km for Kucova earthquake and up to a distance of 120 km for Kurbneshi earthquake (Fig. 3). At longer distances, the intensities were "not felt" so that the macroseismic field became flat. In our data set we observed the presence of both nugget variance as consecuence of random components and spatial attenuation. The final filtered macroseismic field I_R , with the original intensity data points, is depicted in Fig. 4. In this figure we have also drawn the intensity isoseismals, which are the lines separating different macroseismic degrees in the filtered I_R field. The attenuation of Intensity from the epicenter of Kucova earthquake show high attenuation in the east of the Kucova as opposed to a low attenuation on the other side due to different crust properties (Ormeni, 2013). The attenuation of Intensity from the epicenter of Kurbnesh earthquake show high attenuation in the southeast and northwest of the Kurbneshi as opposed to a low attenuation on the other side due to different crust properties and the directivity of strike (Ormeni, 2014). The filtered macroseismic field of the Kucova and Kurbneshi earthquakes (Figure 5) shows respectively: higher intensities on the west sides of the Kucova epicenter and higher intensities on the southwest and northeast sides of the Kurbneshi epicenter.

This main trend was highlighted for Kucova earthquake by the isoseismal separating the IV from V intensity degree and by the isoseismal separating the V from VI intensity degree. This main trend was highlighted for Kurbneshi earthquake by the isoseismal separating the IV from V intensity degree and by the isoseismal separating the IV from III intensity degree. Our results, thus, show that data obtained through crowdsourcing by simply compiling a web questionnaire was able to define a reliable regional macroseismic field and to identify two main areas of amplification and de-amplification of earthquake intensity. An advantage of our macroseismic intensity data collection lies on the possibility to analyze all available information with statistical procedures in fast time. Due to fast data collecting, we were able to significantly distinguish aftershocks separately. Despite the limitations of data collection via the Internet outline, the advantages are both numerous and remarkable: We moreover supply, with the calculated intensity, the number of compiled questionnaires on which it is based:

normally this information is not reported on traditional survey. Reported intensities are compared with those derived from traditional macroseismic survey, showing the reliability of web-based method. Our method has proved to give quickly good results at a very low cost in terms of funding and time. This analysis is not limited to the highest intensities area, but it is easily extended to more peripheral field portions. Web-based survey is able to investigate intensity attenuation. The web-based method carries the increase of available data in respect to direct survey, given by the analysis of a greater number of events of low magnitude.

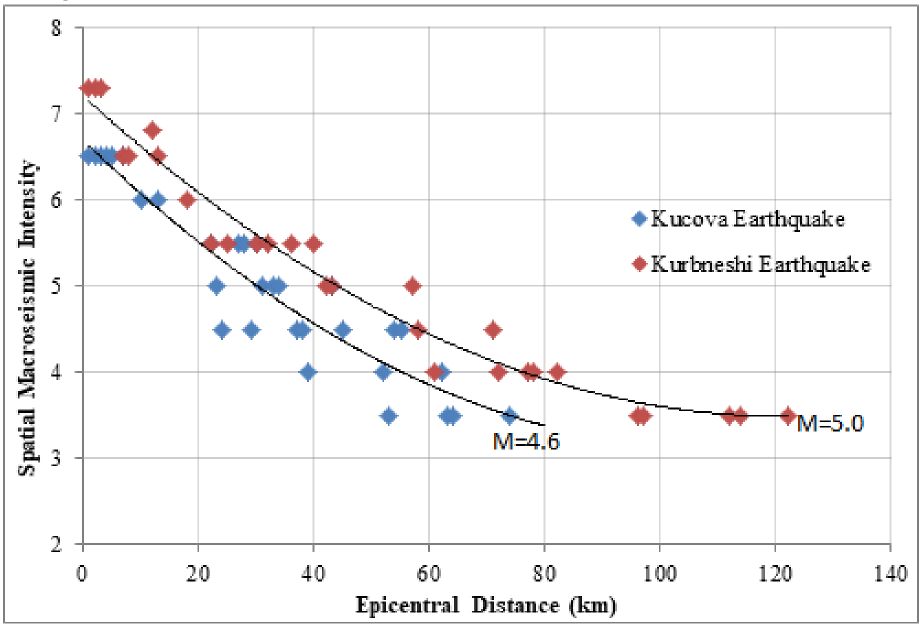

Figure 3. Macroseismic attenuation as a function of epicentral distance (blue dots Kucova earthquake and red dots Kurbneshi earthquake). *The dots are the spatial averaged intensities within intervals of epicentral distance of 4 km of width, the black line represents the polynomial fit (Eq. 4, 5).*

The attenuation or amplification anomalies receive, from web-based surveys, an enhanced possibility to be detected. Moreover when spatial density is adequate, it is possible to evidence anomalies at a more detailed scale. Although medium-high magnitude events are not still yet experienced, we can expect that, for high magnitude events, with destructive effects, we can suffer a lack of data from the highest intensity epicentral area. Macroseismic observations are available for social-science and seismological analyses. The citizen-based science of the “Did you feel it?” portal provides an unmatched opportunity for interaction between the scientists of a government agency and the community that they serve. Portaly “Did you feel it?” provides a two-way flow of post-earthquake information providing the Institute of Geosciences, Energy, Water and Environment (IGEWE) with quality macroseismic data, as well as an avenue of information for concerned citizens, and a form of reassurance for those who experienced frightening ground shaking. Macroseismic maps also greatly facilitate IGEWE communication about earthquake hazards.

Conclusions

Macroseismic investigation with data collected through web-based questionnaires is today routinely applied by Institute of Geosciences, Energy, Water and Environment (IGEWE). The IGEWE “Did You Feel It?” system, relying on Internet data collection after earthquakes, has significant advantages over earlier macroseismic intensity data collection approaches, yet there are some notable limitations arising from its web dependence. Awareness of these limitations reduces potential detrimental impacts, and we are continuing to improve the system as new tools and approaches become apparent. An advantage of our procedure is the possibility to statistically analyse data in fast time and in future in almost real time. Web-based survey is able to investigate intensity attenuation. From a technical point of view, the whole system is relatively straightforward to establish and use and therefore gives a good foundation for integrating community data into the scientific research.

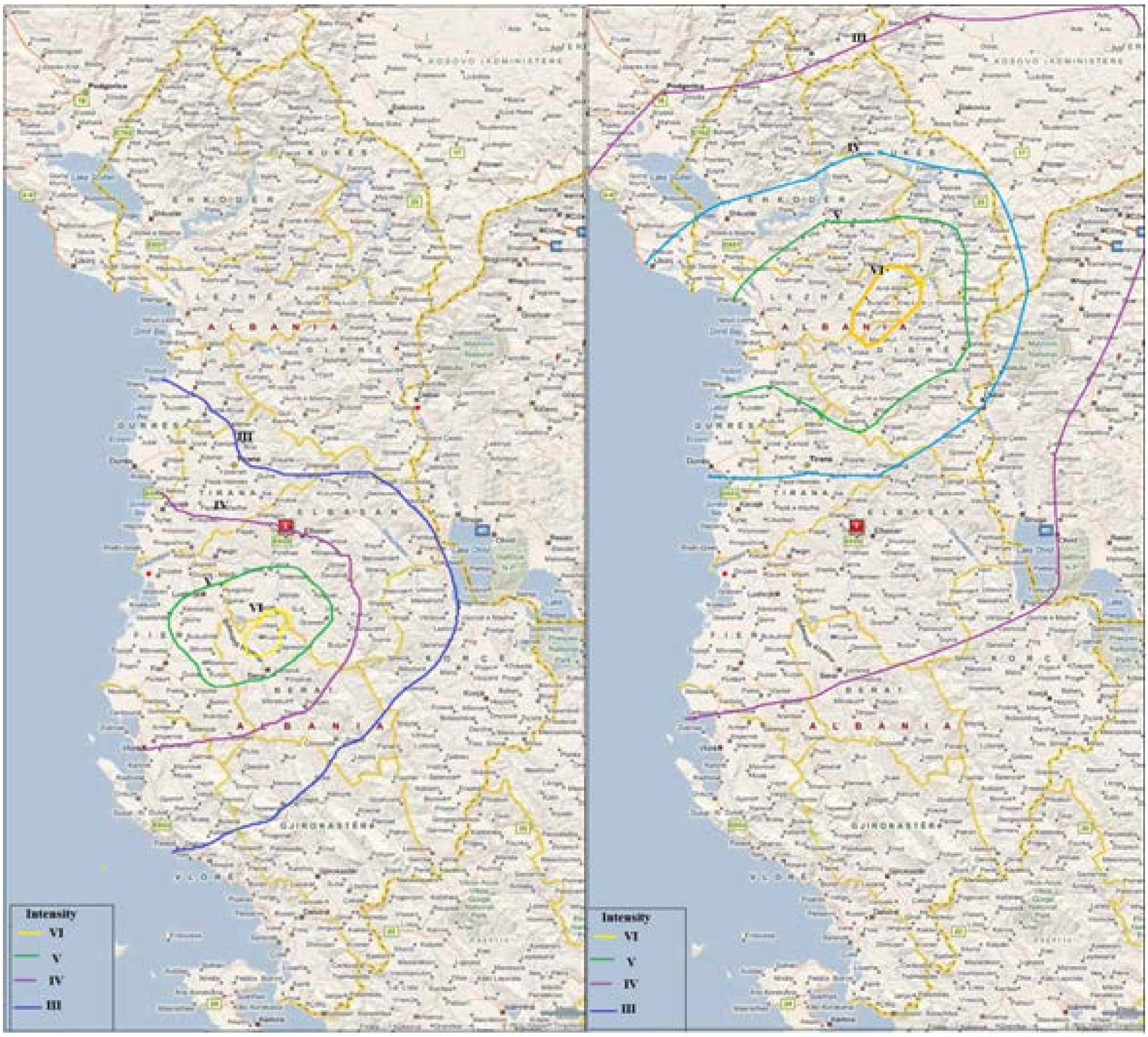

Figure 4. Municipality and the regional macroseismic field, the coloured lines represent isoseismals separating intensity degrees.

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