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Research Paper

Evaluation of Macroseismic Field of 21 September 2019, Durres Earthquake in Albania

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Abstract: The Albanian region is historically subjected to strong earthquakes (Io>VIII EMS-98), as gathered from the numerous data. Currently, the seismicity of the Durres' region in Albania is characterized by high-energy earthquakes. A moderate earthquake M_L 5.8 struck the Durres in western Albania, on September 21, 2019. The macroseismic investigation were carried out based on online web survey managed by IGEWE and EMSC, the degree of damage to structures of human origin, and the surface effect of the ground shaking. This shock was widely felt throughout Albania, in neighbouring countries, Montenegro, Italy, Kosovo, North Macedonia and Greece, and in the epicentral area, EMS intensity reached VII-VIII degree. One main aspect that has great influence on the scale of the felt throughout these countries is related to the depth of the main shocks. A statistical analysis was applied to the data collected to investigate the spatial distribution of intensity of these earthquakes. Effects reported in from towns and villages are analysed in depth. The intensity map consists of the geographical distribution of intensities averaged for each town or village. This map is compiled and later is continuously updated from others information's. Isoseismals represent the spatial distribution of macroseismic intensities, and their shapes depend on source properties, lithosphere structures, tectonic line orientations, site geology and topography. Our results identify two main areas of amplification and de-amplification of earthquake intensity. This paper gives assessment of intensity, of attenuation function for intensity of this earthquakes, intensity isoseismic map and evaluation of seismic hazard in Western Albania.

Keywords: *Earthquakes, Questionnaire, Macroseismic Intensity, Attenuation,*

Introduction

The macroseismic intensity is a useful measure used in many studies in Albania covering a wide range of seismological applications (Sulstarova et al. 1983, Muco et al 1992, Aliaj et al. 2010, Bozo et al 2017). Earthquake intensity is a qualitative descriptive measure of earthquake and is based on the degree of damage to structures of human origin, the amount of disturbance to the surface of the ground and the extent of human and animal reaction to the shaking. The "Did You Feel Earthquake?" questionnaires from IGEWE and EMSC has collected shaking and damage reports from Internet users immediately following the earthquake. These questionnaires are used for collecting macroseismic data for September 21, 2019 earthquake felt in the Albania and in neighboring countries, Montenegro, Italy, Kosovo, North Macedonia, and Greece etc. The maximum reported damage was in Durres and Tirana district. Based on these responses and field observations, intensity is defined on EMS-98 scale. The September Durresi earthquake caused damage in the unreinforced-structures and in buildings with reinforced-structures to the districts of Durres Tirana, Kruja, Laci, Lezha *etc.* (Figure 1). One main aspect that has great influence on the scale of the damage in the affected zone is related to the depth of the earthquake. People reported damaging of buildings, falling of household materials from shelves, rattling of doors, windows, furniture and other objects. The intensity attenuation can have determined from distribution of Intensity values and from the isoseismal shapes (Sulstarova, 1983; Muco, 1992; Bozo *et al*., 2018).

Materials and Methods

The most of questionnaires are collected from users located throughout Western Balkan. A large number of questionnaires came from the large area, as commonly occurs in the case of moderate magnitude events, where people immediately response after mainshock. According to the European-

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Mediterrian-Scale-98 (EMS-98) definition, people felt the earthquake occurrence in the III EMS-98-degree and can submit questionnaires. For this reason, III EMS-98 were included in the macroseismic information. The collected data became the basis for the assessment of seismic intensity in terms of the standardized EMS-98 scale (Grünthal, 1998).

Questionnaires from internet data and updating to data from Civil Emergency for September 21 earthquake came from 87 municipalities. For a more reliable estimation of earthquake intensity we excluded all municipalities with less than 3 questionnaires. We gathered 1175 macroseismic questionnaires from internet. According to reports, the Durres earthquake shook an area up to epicentral distances of 200–250 km. In total, exist an intensity of VII-VIII from an area of 120 km^2. 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 87 municipality intensity data in the EMS-98 scale derived from 1175 questionnaires. Based on Sulstarova relation between macroseismic (I_0 epicentral intensity) and instrumental parameters were found I_0 in average soil condition (eq. 3). (Aliaj et al., 2010).

$$I_0 = 1.75M_S - 4.55\log h + 3.45 \quad (h>10 \text{ km}) \qquad [1]$$

I_0 epicentral intensity, Ms surface magnitude, h depth. For this earthquake h=29, km results *Io*=6.7 in average soil conditions. First, we expressed all $\mathbf{I_i}$ isotropic intensities as a function of the epicentral distance alone. After having modeled the I_i isotropic component, we defined regional anisotropic component and local specific parameters by analysis of questionnaires. Then, we averaged the municipality intensity data within intervals of epicentral distance of 5 km of width.

Earthquake Felt Report

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. Macroseismic Intensity don't require instrument to measure it. The sensors that have been used historically in intensity scales can be broken down into three groups: a) Living things, b) Objects and nature environment., c) Buildings.

Figure 1. Photo of buildings damages in the epicentral area

The descriptions are collected in a web-based form experts and non-experts so the number of participants is large enough. The user gives an estimation of earthquake intensity by submitting the form on web page. Intensity information is analysed to generate intensity from all parameters following the EMS- 98 standard. The rate of responses from users allowed us to plot entries contributed as a function of time (Figure 2).

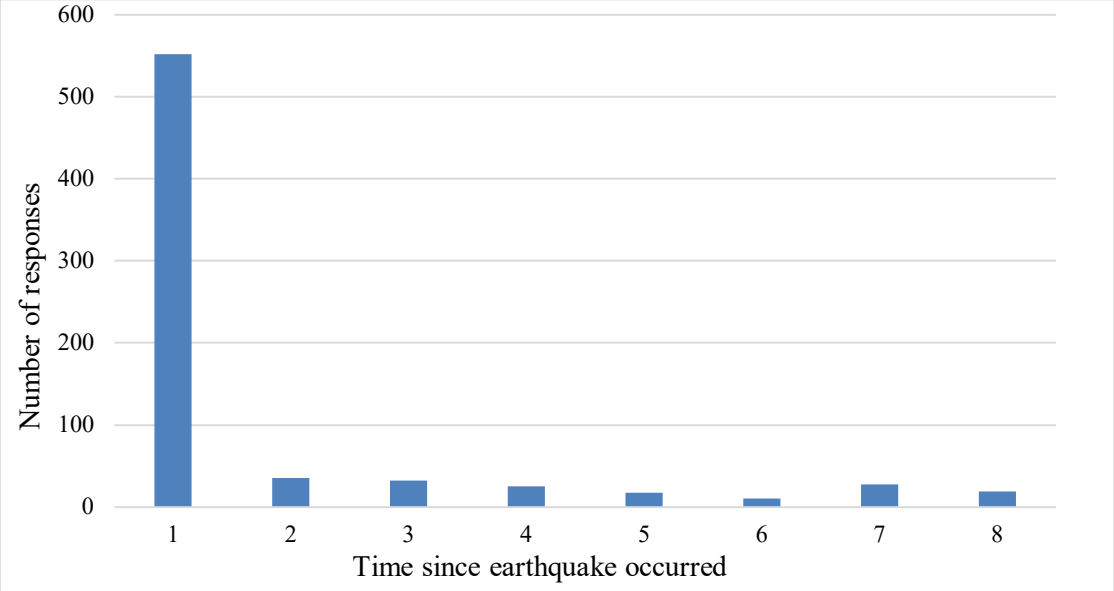

Figure 2. Plot of individual questionnaire responses versus time for the 21 September 2019, M_L= 5.8, Durres, earthquake. Over 552 entries were received in the first hour.

Questionnaire response rates have reached in eight hours for the earthquake see figure 1 Data were collected through a macroseismic questionnaire available at the website www.geo.edu.al of IGEWE and www.emsc.it of EMSC. In the first hour from the occurrence of the event we found 552 questionnaires in both IGEWE and EMSC website from users located throughout Albania and its surroundings Balkan countries. Large number of reactions in the first hour compared to following hours is connected to using smartphones immediately after panic. We have used data "sensed" by communities for estimating the earthquake intensity in Albania and its surrounding area. 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.

Results and Discussion

As results from Fig. 1, the earthquakes were felt respectively: up to 250 km distance in Southeastern of Durres, up to 200 km distance in Northeastern of Durres. In the epicentral area, EMS intensity reached VII-VIII (Figure 2) (Ormeni *et al*., 2019). The earthquake depths of the Durres' seismic events give us important information about the seismic layer where most of seismic energy was generated and the macro-seismic effect on the surface and depth of the tectonic faults caused by the earthquakes. For the felt of earthquake, we count more than 1175 compiled questionnaires averaged over 87 towns or villages. 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 (Figure 3). Where $\boldsymbol{I_m}$ represents the average intensities of municipality in the distance of 4 *km* of width.

Figure 3. Municipality macroseismic EMS-98 intensities assessed using 1175 questionnaires, compiled through the seismicity site (www.geo.edu., www.emsc-csem.org), and questionnaires compiled by EMSC and other alternative way. *The purple star represents the instrumental epicenter. The inset shows an enlargement of the epicentral area (Ormeni et al 2019). The attenuation of Intensity versus the epicentral distance was then fitted with a 2nd degree polynomial function for Durresi earthquakes respectively [Eq. 2]:*

$$\mathbf{I_i = 7.5521 - 0.035d + 5*10^{-5}d^2} \qquad M_L=5.8,\ h = 29\ km) \qquad [2]$$

This mathematical relation was calculated up to a distance of 250 km for this earthquake (Figure 4). The most affected areas were the "Keneta", "Plazh" area, the center of Durrës', and the town of Thumanë. Damages were also reported in the towns of Shkembi Kavajes, Plazhi Golemit, Vore, Manez, Bubes, Maminas, Kombinat, Laç-Kurbin, as well in Kamëz, Fushë-Krujë, Kavaj's towns and in Tirana's city. Based on the spatial distribution of damage, one ellipse is formed on a main axis pointing generally NW-SE. This direction coincides with the strike of the faulty plane of the focal mechanism solution. Shallow quakes generally tend to be more damaging than deeper quakes. Seismic waves from deep quakes have to travel farther to the surface, losing energy along the way. The strongest main shock ML6.3 generated at a depth of around 39 km may be less damaging, but is more widely felt The intensity of tremors from the Durres' earthquake diminished with the increasing distance from the earthquake's

source, therefore the intensity of tremors at the surface from this earthquake, which occurred 39 km deep, is considerably less than if the same earthquake had occurred at 10 km depth. Macroseismic field became extinguished in longer distances where the intensities were "not felt". In our data set we observed the presence of both nugget variance as consequence of random components and spatial attenuation. The final filtered macroseismic field I_R, with the original intensity data points, is depicted in Fig. 5. The intensity isoseismals lines in fig 5 separate different macroseismic degrees in the filtered IR field. The attenuation of Intensity from the epicenter of Durres earthquake show high attenuation in the east of the Durres as opposed to a low attenuation on the south and North side due to different crust properties and the directivity of strike. The filtered macroseismic field of the Durres earthquakes (Figure 5) shows respectively: higher intensities on the Southeast sides of the Durres. This main trend was highlighted for Durresi earthquake by the isoseismal separating the III from IV intensity degree and IV from V intensity degree and by the isoseismal separating the V from VI intensity degree. Analysis of that data obtained by compiling a web questionnaire defined reliable regional macroseismic field. Our results show two main areas of amplification and de-amplification of earthquake intensity.

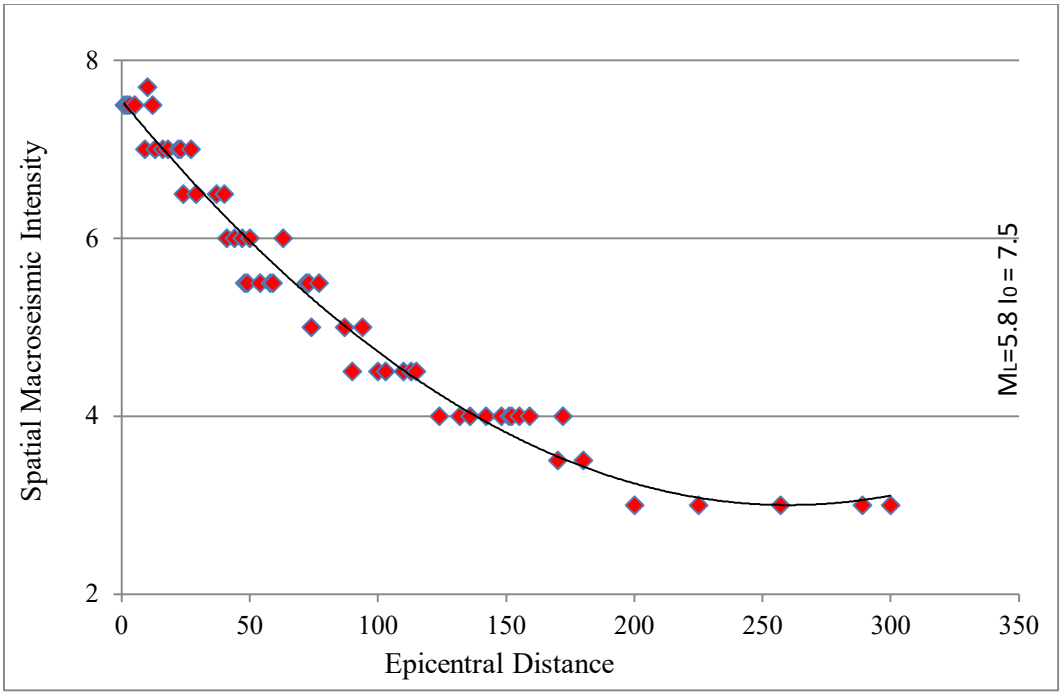

Figure 4. Macroseismic attenuation as a function of epicentral distance. *The dots are the spatial averaged intensities within intervals of epicentral distance of 4 km of width, the black line represents the polynomial fit [Eq. 2].*

The data collection via the Internet outline are numerous and remarkable. Reported intensities Web-based survey is able to investigate intensity attenuation. We analysed not only the highest intensities area but extended it to peripheral field portions. The web-based surveys give a possibility to detect attenuation or amplification anomalies from web-based surveys. Fault mechanism solution give the orientation of high seismic effect respectively macroseismic field amplification. In the studied area the isoseismal-line with NW-SE trend are more prominent in imagery being parallel to the assessed source orientation. Based on the focal plane solutions provided by the IGEWE website, the mainshock was generated by the activation of an NW-SE striking thrust fault (Ormeni et al 2019. www.igeo.edu.al).

Observations of macroseismic field are available for civil emergency and seismological analyses. The citizen-based science of the "Did you feel an earthquake?" portals provides an unmatched opportunity for interaction between the scientists of a IGEWE and the community of Albanian citizens. Macroseismic maps also greatly facilitate IGEWE communication about earthquake hazards.

Figure 5. *Municipality and the regional macroseismic field, the coloured lines represent isoseismals separating intensity degrees.*

Conclusions

Study of macroseismic field after the September 21, 2019, Durresi earthquake gives add information for earthquake source parameters. Observations of macroseismic field are available for civil emergency and seismological analyses. The strong main shock ML5.8 generated with a depth of around 29 km may be less damaging but is more widely felt. The EMSC and IGEWE "Did You Feel an earthquake?" system, relying on Internet data collection after earthquakes, has significant advantages over earlier macroseismic intensity data collection approaches. This study emphasizes needs of qualified information by community of Albanian citizens collected through web-based questionnaires applied by EMSC and by Institute of Geosciences, Energy, Water and Environment (IGEWE) This statistical analysis proceded not only to the highest intensities area, but it is also extended to all macroseismic field anomalys. This attenuation equation of Intensity will be very important when a great number of such attenuation relations will be gathered and when they could be used as inputs for the earthquake hazard assessment and/or for prompt and effective actions of civil emergencies.

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