Magnitude Determination with Records from Sofia University's Virtual Seismic Network

Maria Filipova, Reneta Raykova

Department of Meteorology and Geophysics, Faculty of Physics, Sofia University "St. Kliment Ohridski",

Abstract. The Virtual Seismic Network of Sofia University (VSNSU) was established in 2015 as a scientific research project, funded by Sofia University "St. Kliment Ohridski". VSNSU consists of sixteen seismic stations from different national and international networks in southeastern Europe with open access to real-time data. The stations belong to six national networks - one Bulgarian, one Romanian, one Serbian, two Greek, one Turkish, as well as two international- MedNet and Geofon. Sixteen earthquakes have been investigated, located in the Balkan Peninsula region, in order to obtain estimates for different types of magnitudes (M_l, M_b, M_S, M_d) by measuring the amplitudes of the respective wave phases and their periods, as well as the earthquake's duration for each seismic record. The estimations are compared with data from the International Seismic Centre (ISC) and the respective differences are analyzed.

Keywords: earthquakes, seismograms, magnitude, Balkan Peninsula

1. INTRODUCTION

The Virtual Seismic Network of Sofia University "St. Kl. Ohridski" (VSNSU) was established in 2015 in the frame of a scientific research project, funded by Sofia University. VSNSU consists of sixteen seismic stations (Fig. 1) from different national and international networks in southeastern Europe with open access to nearly real-time data (EMSC, 2016). The stations belong to six national and two international networks (Raykova et al., 2016).

All seismic records were obtained from IRIS (IRIS, 2016) and EIDA (EIDA, 2016) data centers. As additional information about the studied earthquakes we used the webpages EMSC (EMSC, 2016) and ISC (ISC, 2016). We encountered several problems with the information, reported by individual networks such as: differences in the epicentral coordinates, depth, origin times and magnitudes.

Magnitude is one of the most important characteristics of earthquakes and serves to give an evaluation of the energy release during the material crash. Nowadays there are a number of magnitude types and all of them characterize different features of an earthquake. The same magnitude type for an event measured from the records of different stations is possible to have different values, because of the radiation pattern of different waves, differences in the Earth's structure, the quality of the records, etc.

The stations from VSNSU cover the Balkan Peninsula region. The reported magnitudes in this area, given by different national seismic networks, generally have different values. In this study we present measurements of four types of magnitudes (M_l, M_b, M_S, M_d) using the seismic records from VSNSU in order to obtain unique estimations for each magnitude of the earthquakes in the region.

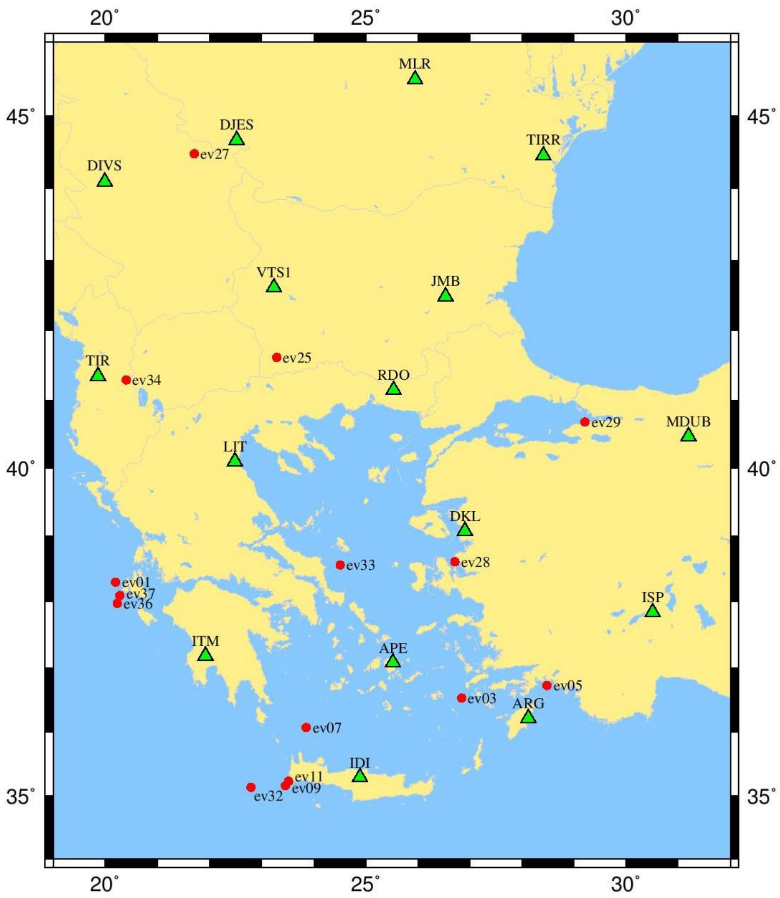

Fig. 1 VSNSU seismic stations and locations of the analyzed events.

TABLE 1. Parameters of the analyzed events taken from EMSC (EMSC, 2016).

Event	Date	Time	Lat.(ºN)	Lon.(ºE)	Depth	Magnitude
Ev01	2016-01-04	07:21:34	38.30	20.20	50	M_l 4.3
Ev03	2016-01-05	23:11:49	36.53	26.84	148	M_B 4.4
Ev05	2016-01-23	04:00:44	36.72	29.48	27	M_l 4
Ev07	2016-02-24	14:41:40	36.07	23.86	44	M_l 4.2
Ev09	2016-03-06	23:18:14	35.16	23.46	20	M_B 4.2
Ev11	2016-03-12	12:40:39	35.23	23.52	10	M_W 4.6
Ev25	2016-05-22	08:58:31	41.62	23.29	1	M_l 4.5
Ev27	2016-06-09	02:05:40	44.48	21.71	5	M_l 4.3
Ev28	2016-06-05	20:26:19	38.61	26.71	10	M_l 4.4
Ev29	2016-06-05	05:40:11	40.68	29.21	6	M_l 4.4
Ev32	2016-07-30	17:26:19	35.13	22.80	10	M_W 5.1
Ev33	2016-08-26	13:37:32	38.56	24.51	10	M_l 5.4
Ev34	2016-08-31	22:20:52	41.29	20.40	2	M_B 4.3
Ev36	2016-09-14	02:20:04	37.98	20.23	5	M_B 4.7
Ev37	2016-09-19	03:59:45	38.10	20.28	12	M_B 4.7

2. SEISMIC RECORDS ANALYSIS AND MAGNITUDE ESTIMATION

In this study we used magnitude relations proposed by several authors, calibrated for different regions, to calculate different magnitudes. Sixteen earthquakes in the Balkan Peninsula region (latitudes between 35°N-45°N and longitudes between 20°E-30°E) with magnitude equal to or greater than 4.0 were selected (EMSC, 2016). The locations of the analyzed earthquakes are shown in Fig. 1 and their parameters – in Table 1.

We used the same procedure, previously applied in 'Raykova et al. (2016)'. One-hour records were analyzed, applying the instrument response and different filters according to the measured magnitude. The measurements of the seismogram parameters (A, T, τ) were done by a script, developed to visualize and obtain relevant parameters for the selected time interval of the specific seismogram. We used the GMT (Wessel et. al., 1972) package to visualize the seismograms.

We applied several widely used magnitude relations to estimate the M_l, M_b, M_S and M_d magnitudes from the VSNSU records.

2.1 Local Magnitude M_l

For this type of magnitude we used the original definition of Richter. M_l was obtained by measuring the maximum amplitude A_H in [nm] (as the average of two horizontal components), as well as determining the hypocentral distance R in [km]. We measured the time difference t_{SP} between the first P- and S- wave arrivals in [s]. The seismic records were transformed in order to simulate a Wood-Anderson seismometer response, using the software package SAC.

To calculate M_l we used the equation (IASPEI, 2013):

$$M_l = \log(A) + 1.11\log(R) + 0.00189R - 2.09 \quad (1)$$

where R is calculated as $R = \sqrt{D^2 + h^2}$ (D is the epicentral distance [km], h is the hypocentral depth [km]) using the location given by EMSC. This equation was applied for epicentral distances shorter than 600 km.

2.2 Body Wave Magnitude M_b

For the calculation of the body wave magnitude we used the equation, proposed by Navarro and Brockman (1970):

$$M_b = \log(V) + 2.3\log(D) - 2.0 \quad (2)$$

where V is the maximum vertical amplitude of the P-wave train of the record in [nm/s].

We used another equation to take into account the depth of the earthquakes, which can be significant:

$$M_b{}^R = \log(V) + 2.3\log(R) - 2.0 \quad (3)$$

The difference between the two equations is that in (3) we used the hypocentral distance instead of the epicentral distance D. That is important, because in several cases the epicentral distance to the nearest recording station is comparable to the earthquake's depth. Both equations were applied for epicentral distances shorter than 1500 km and depths lower than 60 km.

2.3 Surface Wave Magnitude M_S

The surface wave magnitude was obtained by measuring the maximum vertical amplitude A_V in [nm] and its period T in [s]. Here we used WWSSN-LP instrument simulation records, filtered between 10 and 30 s, in order to obtain periods close to 20 s.

The used equation was recommended by IASPEI (2013):

$$M_S = \log(A/T) + 1.66\log(\Delta) + 0.3 \quad (4)$$

where Δ is the epicentral distance in degrees, Δ>2° (1°=111 km) and h<60 km. For all analyzed events Δ<1500 km, thus the period of the surface wave with the maximum amplitude is around 10 s.

We also applied definition of IASPEI (2013) for surface wave magnitude, obtained for broad-band velocity records:

$$M_{S\_BB} = \log(V/2\pi) + 1.66\log(\Delta) + 0.3 \quad (5)$$

where V is the amplitude (in [nm/s]) of the maximum train of the surface waves for periods between 3 and 60 s. This equation can be applied for earthquakes with epicentral distances $\Delta > 2°$.

2.4 Duration Magnitude M_d

For obtaining of the duration magnitude, we used the equation (Lee et. al., 1972):

$$M_d = 2\log(\tau) + 0.0035D - 0.87 \quad (6)$$

where τ is the duration (in seconds) of the earthquake's record. It is obtained through determination of the noise level in 50 s time interval immediately preceding the recorded earthquake. The beginning of the earthquake is defined as the time when the average amplitude in a one-second time interval is at least twice the noise level. The end of the earthquake is defined as the time when the average amplitude in a ten-second time interval is equal or less than the noise level.

To take into account the depth of the earthquakes, as in the case of Body wave magnitude determination, we used the equation:

$$M_d^{\,R} = 2\log(\tau) + 0.0035D - 0.87 \quad (7)$$

Duration magnitudes were estimated for distances shorter than 500 km.

TABLE 2. Average values of each magnitude. In brackets are number of stations.

Event	avM$_d$	avM$_d^R$	avM$_l$	avM$_S$	avM$_{S_BB}$	avM$_b$	avM$_b^R$
Ev01	-	-	4,3 (2)	3,7 (7)	3,8 (7)	4,3 (1)	4,4 (1)
Ev03	4,2 (3)	4,4 (3)	4,3 (3)	-	-	4,5 (1)	4,6 (1)
Ev05	3,7 (2)	3,7 (2)	3,8 (2)	3,4 (1)	3,5 (1)	-	-
Ev07	4,1 (2)	4,1 (2)	4,1 (4)	-	-	4,0 (3)	4,0 (3)
Ev09	4,5 (3)	4,5 (3)	4,2 (4)	3,1 (4)	3,2 (4)	3,7 (3)	3,8 (3)
Ev11	-	-	-	4,2 (3)	4,3 (3)	4,5 (2)	4,5 (2)
Ev25	5,5(3)	5,5 (3)	5,0 (6)	3,7 (8)	3,7 (8)	4,5 (5)	4,5 (5)
Ev27	5,5 (5)	5,5 (5)	4,8 (5)	3,3 (6)	3,3 (6)	4,4 (4)	4,4 (4)
Ev28	4,6 (4)	4,6 (4)	4,8 (3)	3,5 (6)	3,4 (6)	4,1 (7)	4,1 (7)
Ev29	5,0 (2)	5,0 (2)	5,0 (2)	3,3 (4)	3,4 (4)	4,1 (2)	4,1 (2)
Ev32	5,6 (4)	5,6 (4)	5,3 (5)	4,3 (9)	4,3 (9)	5,1 (9)	5,1 (9)
Ev33	4,6 (3)	4,6 (3)	3,4 (5)	3,0 (5)	3,1 (5)	3,8 (4)	3,8 (4)
Ev34	5,0 (2)	5,0 (2)	4,1 (4)	3,4 (6)	3,6 (6)	4,0 (6)	4,0 (6)
Ev36	5,3 (2)	5,3 (2)	4,3 (5)	3,1 (3)	3,1 (3)	4,0 (3)	4,0 (3)
Ev37	5,4 (2)	5,4 (2)	4,6 (4)	3,4 (6)	3,4 (6)	4,3 (6)	4,3 (6)

3. SUMMARY AND CONCLUSIONS

In this study we present results of estimations of the local magnitudes, body wave magnitudes, surface wave magnitudes, and duration magnitudes from VSNSU seismic record measurements. The average magnitudes estimated for VSNSU are presented in Table 2. The number in brackets represents the number of stations, used in the average magnitude determination. VSMSU network magnitudes M_d and M_d^R usually have the same values, differing not more than 0.2. Average M_b is also usually the same as M_b^R with variations equal to or less than 0.1.

Magnitudes M_S and M_{S_BB} typically have a difference equal to or smaller than 0.2.

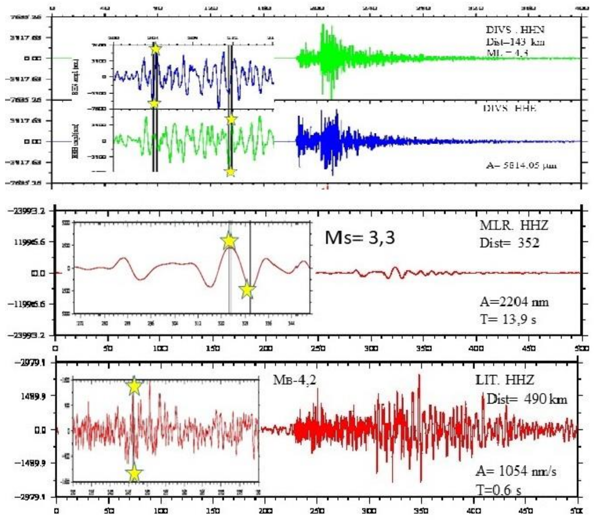

Fig. 2 Measured parameters and estimated magnitudes for several stations registering ev27. The start time of the records is 22:05:40.

One of the problems in our magnitude estimations is that we used magnitude relations proposed by several authors and calibrated for different regions. We also met several problems with the information, reported by the individual networks such as: differences in the epicentral coordinates, depth, origin times and magnitudes. Other problems may occur due to the specifics of the sources. On occasion, the displacement along the fracture could be continuous. In that case, M_l has a greater value, because of the short time interval of the earthquake and the big amplitude.

The purpose of the study is to gather a sufficient number of measurements for the Balkan Peninsula region. Future development of the subject includes determination of magnitude relations, specific to the region of Balkan Peninsula.

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