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SEISMICITY ON THE TERRITORY OF BULGARIA AND THE ADJACENT LANDS RECORDED BY NOTSSI IN 2017

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Abstract. A map of epicenters of 114 earthquakes with magnitude Mw >= 2.5 that occurred during 2017 in Bulgaria and surroundings (sector outlined by latitude j = 41°- 44.5° N and longitude l = 22°- 29° E) registered by NOTSSI is presented. Expert generalized analysis is proposed. Catalog of earthquakes is applied.

Key words: Bulgaria, seismicity.

The Balkan Peninsula is one of the active regions in the Alpine-Himalayan seismic belt. High activity is observed in Western Turkey, Greece, and Vrancea region – Romania, Bulgaria, Northern Macedonia, Albania, and Serbia. The depth distribution is very characteristic. There are two highly active levels in the range of 20-40 km and 90-110 km and a less active one in 50-70 km.

Bulgaria is an earthquake prone country. Over the past centuries, Bulgaria has experienced strong earthquakes. Some of the strongest European earthquakes during the 20th century have been occurred in Bulgaria. At the beginning of the 20th century, from 1901 to 1928, five strong earthquakes with magnitude larger than or equal to 7.0 occurred on the territory of Bulgaria – 30.03.1901 Ms = 7.2 Shabla earthquake; 04.04.1904 Kresna earthquakes with Ms magnitudes 7.1 and 7.8; 14.6.1913 Ms = 7.0 G.Orjahovitsa earthquake and two earthquakes near the city of Plovdiv in 1928 - 14.04 with magnitude Ms = 6.8 and 18.04 with magnitude Ms = 7.0.

Strong seismic impact on the territory of Northern Bulgaria has the intermediate earthquakes in Vrancea – Romania region. The strongest being the one in 1944 with magnitude of 7.7 and some may remember the one in 1977 with magnitude of 7.4 caused a lot of deaths and destructions.

The present study contains generalized information and analysis of the data about the seismic events recorded by the National Operative Telemetric System for Seismological Information (NOTSSI) during 2017. Seismic data is gathered in real time by 26 Bulgarian stations and a number of stations from neighbouring countries which increases the accuracy of hypocentral locations. Between 2005 and 2010 almost all stations are modernized and equipped with broadband seismometers. A number of stations also are equipped with accelerometers of type RefTek 131A-02/3 of the company "Refraction Technology". The data from the digitizers DAS 130-01 are collected through the RTPD (Real time protocol demon) module and the data from foreign stations and from Quanterra digital systems are collected with the sl2rptd module.

Data are transferred to the National seismological center in the Geophysical Institute, BAS in real time. Then they are archived in PASSCAL format and additionally in the widely used miniSEED format. The data are processed automatically (relevant signals are recognized and the main parameters of the earthquake are evaluated) by the program Seismic Network Data Processor (SNDP) (Christoskov et al., 2012). The data are later processed manually by an on-duty seismologist and corrections are made if required. At present the body P-wave magnitude Mp is evaluated by formula:

$$M_p = \log\left(\frac{A}{T}\right)_{max} + \sigma_{BB}(\Delta) + S_j\,, \tag{1}$$

where – $\log(A/T)_{max} = V_{max}/2\pi$, A is the amplitude in μm, T is a period in s, and V_{max} is the peak ground velocity in $\mu m/s$ of P-phase recorded on the broadband seismograph vertical-component at epicenter distances less than 10°; $\sigma_{BB}(\Delta)$ is the calibration function; and s_j is the j station magnitude correction.

In the present study Mp is transformed into the more reliable and more widely used Mw magnitude, which would allow the creation of a uniform catalogue of earthquakes, needed for reliable evaluation of the seismic hazard on the territory of the country and surroundings. Mp is transformed into Mw through the formula (D. Solakov et al., 2018):

$$M_w = 0.93M_p + 0.31\,. \tag{2}$$

The high sensitivity of the seismographs allows recording and processing of a great number of local and regional earthquakes. Different magnitude's lower thresholds for reliable determination of local and regional earthquakes are established: Mw = 2.5 for the territory of Bulgaria, Mw = 3.0 for the central part of the Balkans, Mw = 5.0 for regional events. The accuracy of the epicenter location is different; except on the distance it depends also on the epicenter position the position of the epicenter with respect to the recording network. The parameters of seismic events occurring at a distance more than 100-150 km outside the territory of Bulgaria should be accepted only informatively and cannot be used for reliable seismotectonic investigation.

After comprehensive analysis of the digital records and application of the above mentioned calculation procedures it is established that 114 of all registered earthquakes are on the territory of Bulgaria and surroundings outlined by space window 41o – 44.5o N and 22o – 29o E. In the Fig. 1 are plotted the earthquake epicenters using different magnitude levels.

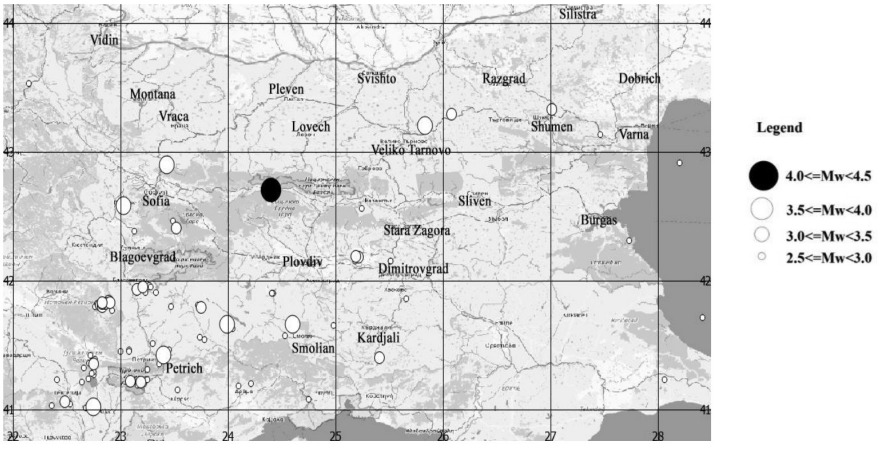


Fig. 1. The earthquake epicenters using different magnitude levels.

The number of the events in the magnitude interval Mw = 2.5 – 3.0 is 84, in Mw = 3.1 - 3.5 there are 21, in Mw = 3.6 - 4.0 there are 8 and in Mw = 4.1 - 4.5 there is 1 earthquake, as shown in Fig. 2. Fig. 3 shows that the data fit well with theoretical expectations, meaning that all incoming earthquakes have been detected by the network.

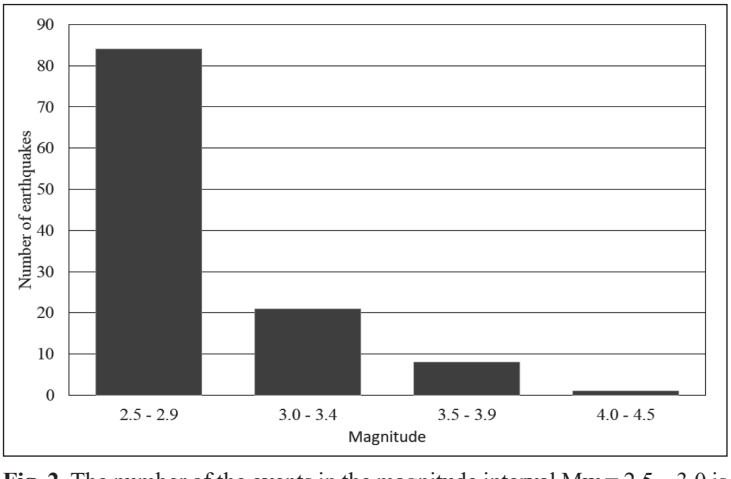


Fig. 2. The number of the events in the magnitude interval Mw = 2.5 – 3.0 is 84, in Mw = 3.1 - 3.5 there are 21, in Mw = 3.6 - 4.0 there are 8 and in Mw = 4.1 - 4.5 there is 1 earthquake.

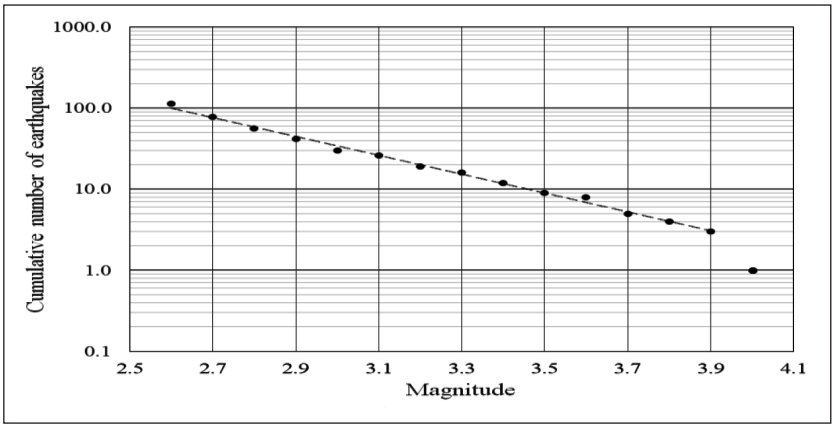


Fig. 3. The number of the events in the magnitude interval Mw = 2.5 – 3.0 is 84, in Mw = 3.1 - 3.5 there are 21, in Mw = 3.6 - 4.0 there are 8 and in Mw = 4.1 - 4.5 there is 1 earthquake.

Throughout the year 21 earthquakes in total were felt on the territory of Bulgaria from local and regional sources. The strongest event during the studied period occurred in the Plovdiv region close to Klisura with a magnitude of Mw = 4.1. Maximum intensity on

As a whole, events with Mw < 3.0 which occur outside Bulgaria are difficult to be localized by the national seismological system.

Table 1. List of earthquakes with Mw >= 2.5 in Bulgaria and surroundings during 2017

Date	Time	Latitude	Longitude	Depth	Magnitude
		[N°]	[E°]	[km]	[Mw]
03.01.2017	22:02:32	43,2	25,83	16	3.8
04.01.2017	4:34:22	42,15	25,18	15	2.9
04.01.2017	9:50:33	44,26	25,26	10	2.7
31.01.2017	1:16:15	41,27	22,75	4	2.6
03.02.2017	2:35:25	41,45	23	6	2.7
03.02.2017	9:12:09	41,54	23,78	7	2.8
04.02.2017	8:20:12	41,46	23,45	10	2.6
06.02.2017	17:05:46	41,29	22,75	13	2.6
21.02.2017	20:59:56	41,4	25,41	16	3.0
26.02.2017	19:59:46	41,28	22,73	10	2.8
27.02.2017	10:16:19	41,93	23,15	20	3.0
05.03.2017	20:17:28	41,18	24,1	11	2.6
10.03.2017	2:07:44	42,18	25,21	15	3.1
12.03.2017	0:09:19	41,95	23,16	14	2.7

Table 1.

15.03.2017	11:20:43	41,95	23,21	17	3.4
16.03.2017	3:44:16	41,01	22,77	3	2.6
16.03.2017	13:40:50	41,01	22,77	10	2.6
18.03.2017	22:01:30	41,9	24,42	20	2.7
20.03.2017	13:19:47	41,96	23,27	14	2.7
22.03.2017	16:54:45	41,86	25,66	16	2.6
22.03.2017	22:01:30	41,9	24,41	20	2.7
24.03.2017	17:26:45	42,41	23,51	13	2.7
24.03.2017	17:40:27	42,41	23,52	13	3.2
24.03.2017	18:34:46	42,41	23,52	13	2.6
02.04.2017	7:59:37	41,51	23,3	15	2.8
08.04.2017	21:10:54	41,96	23,18	14	2.6
09.04.2017	10:14:33	41,95	23,17	16	2.6
10.04.2017	15:11:12	42,46	23,49	12	2.8
15.04.2017	12:41:54	41,38	22,74	3	2.9
21.04.2017	19:35:26	41,15	23,53	4	2.6
26.04.2017	2:53:21	42,18	25,22	10	2.8
29.04.2017	0:07:45	41,35	22,75	5	3.2
03.05.2017	20:42:05	43,53	22,15	2	2.6
04.05.2017	14:31:17	41,46	23,08	12	2.6
04.05.2017	14:44:13	41,45	23,08	13	2.8
09.05.2017	22:42:34	42,38	23,13	13	2.6
11.05.2017	20:33:23	41,9	24,41	20	2.8
26.05.2017	19:58:01	41,57	24,53	20	2.6
07.06.2017	9:43:55	42,31	27,73	2	2.6
26.06.2017	22:36:07	41,91	23,23	11	2.6
28.07.2017	2:58:38	41	22,75	5	2.7
29.07.2017	3:31:39	41,02	22,75	18	3.7
31.07.2017	15:45:08	41,2	23,22	11	2.9
02.08.2017	16:30:02	41,21	22,64	2	2.6
19.08.2017	13:19:36	43,29	26,08	14	3.3
21.08.2017	14:44:26	41,8	23,47	4	2.7
27.08.2017	22:12:48	41,06	22,48	10	3.4
29.08.2017	23:13:51	41,63	24,04	20	2.6
31.08.2017	9:12:04	41,32	22,66	20	2.8
03.09.2017	20:13:31	41,04	22,53	13	2.6
04.09.2017	8:10:05	41,95	23,26	9	2.6
08.09.2017	19:17:44	41,31	23,25	13	2.6
10.09.2017	6:28:02	41,71	28,41	2	2.9
14.09.2017	1:53:18	42,58	23,03	13	3.6

Table 1.

17.09.2017	16:37:00	41,65	24,98	20	2.9
24.09.2017	20:36:07	43,13	27,46	5	2.6
26.09.2017	16:27:59	41,03	22,36	10	2.6
27.09.2017	7:38:15	41,97	23,22	14	2.7
27.09.2017	22:42:00	41,81	22,81	7	3.1
27.09.2017	22:45:07	41,81	22,78	13	2.6
30.09.2017	12:19:51	41,42	22,72	9	2.6
02.10.2017	8:48:24	41,8	22,76	4	2.7
03.10.2017	5:30:44	41,23	23,24	12	2.8
03.10.2017	9:34:05	41,23	23,25	15	2.9
04.10.2017	0:37:42	41,37	22,74	8	2.8
04.10.2017	4:23:27	41,82	22,78	8	2.7
04.10.2017	10:40:17	41,83	22,85	14	2.9
04.10.2017	10:40:17	41.83	22.85	14	3.5
04.10.2017	12:53:24	41.83	22.83	10	2.6
04.10.2017	17:59:59	41.91	23.33	20	2.8
09.10.2017	6:05:14	41,81	22,82	11	2.9
09.10.2017	6:06:28	41,8	22,83	11	2.9
09.10.2017	7:31:33	41,8	22,83	12	3.1
18.10.2017	3:51:34	41,39	22,76	10	2.6
18.10.2017	5:48:29	41,19	23,16	12	2.7
19.10.2017	8:00:47	41,82	22,86	20	3.3
19.10.2017	8:17:15	41,84	22,9	20	2.8
19.10.2017	8:19:33	41,84	22,89	20	3.1
19.10.2017	8:27:21	41,83	22,9	20	3.4
21.10.2017	8:25:19	41,36	22,71	1	2.7
03.11.2017	6:16:07	42,15	25,51	14	2.6
03.11.2017	9:34:02	41,21	23,19	15	3.1
06.11.2017	22:53:32	41,01	22,68	10	2.7
07.11.2017	17:11:57	41,81	23,72	2	2.7
07.11.2017	17:17:05	41,78	23,75	17	2.6
10.11.2017	23:51:05	41,03	22,77	1	3.1
11.11.2017	4:54:05	42,9	23,43	17	3.9
11.11.2017	6:45:48	42,15	25,51	14	2.6
12.11.2017	15:06:52	41,21	23,1	13	2.8
12.11.2017	15:39:45	41,21	23,09	11	2.9
12.11.2017	15:58:18	41,21	23,1	12	2.6
13.11.2017	6:08:51	41,22	23,09	7	3.0
16.11.2017	23:43:59	41,79	23,75	14	3.1

Table 1.

18.11.2017	16:18:18	41.36	22.73	10	2.7
19.11.2017	1:26:26	41.24	22.7	4	2.6
22.11.2017	9:47:15	42,91	28,2	5	2.7
24.11.2017	7:53:48	41,56	23,74	13	2.7
24.11.2017	12:12:59	43,33	27,01	13	3.2
24.11.2017	17:26:50	41,66	24,6	13	3.6
24.11.2017	17:31:43	41,64	24,61	13	3.0
25.11.2017	10:35:44	41,65	24,6	13	2.6
26.11.2017	19:01:31	42,7	24,4	14	4.1
27.11.2017	9:12:51	42,18	25,21	20	2.7
28.11.2017	3:40:16	41,95	23,28	20	2.7
03.12.2017	9:31:06	41,23	22,41	7	2.9
07.12.2017	23:24:34	41,35	23,36	11	2.9
07.12.2017	23:50:14	42,19	25,19	14	3.3
08.12.2017	4:05:57	41,42	23,4	15	3.9
16.12.2017	19:15:57	41,08	24,75	10	2.8
18.12.2017	17:51:11	41,66	23,99	20	3.6
21.12.2017	10:24:02	41,2	24,21	8	2.7
28.12.2017	2:33:18	41,77	22,92	19	2.6
29.12.2017	12:24:10	42,56	25,24	4	2.6
29.12.2017	23:09:19	41,82	22,83	11	3.3

As usual, the largest concentration of the epicenters in the other regions of Bulgarian territory during 2017 is marked in the southwestern part of the investigated region (presented in Fig.1 and Table 1). In 2017 no events of Mw ≥ 4.0 occurred in this region. The strongest felt earthquake for the south-western part of Bulgarian territory is with magnitude Mw = 3.5. It occurred on April 10th in Blagoevgrad region with intensity of III degree on MSK-64 scale.

A detailed analysis of seismicity in the individual seismic zones is hard to be fulfilled because of the insufficient quantity of events and the narrow magnitude range of the earthquakes. The joint statistics of all the events in Fig. 1 characterize predominantly the seismicity parameters of the southwestern part of the territory under investigation.

The depth distributions in Fig. 4 show that the majority of events occur in the range 10-20 km depth. Fig.6 does not show correlation between magnitude and depth, as the majority of the events occurred in the 8-20 km depth range. The number of events does not decrease smoothly with increase of the depth. At the same time the number of events in the interval 10-15 km is bigger. The magnitude distribution of the events in depth (Fig. 5) permits to note some differentiation of depth “floors” with the increase of magnitude - the maximums can be traced out for the depth interval from 5 to 20 km. The stronger events with magnitude of Mw >= 3.75 have depth in the range 10-20 km.

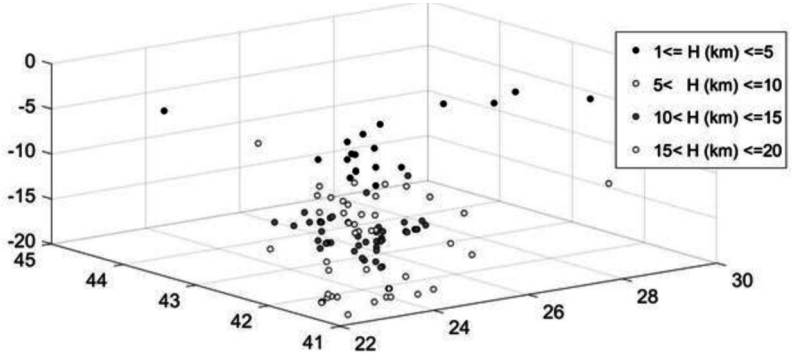


Fig. 4. The depth distributions.

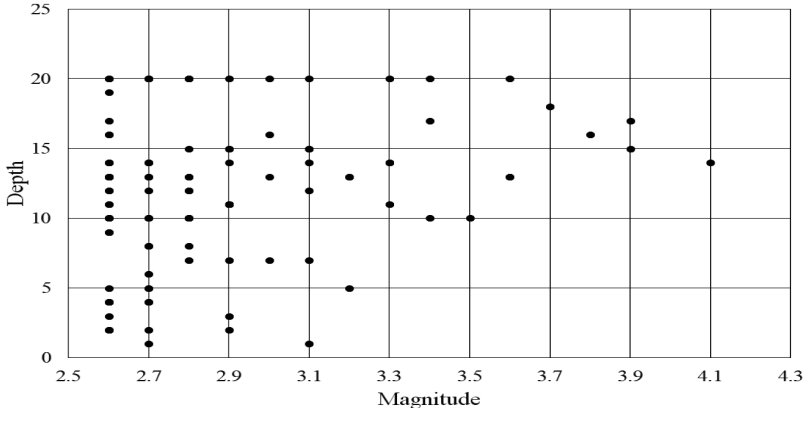


Fig. 5. The magnitude distribution of the events in depth.

Fig. 6 illustrates the distribution of seismicity in time according to the number of events per months. The highest amount of earthquakes is displayed in November, when 24 earthquakes occurred, and it is associated with seismic activity in South-Western Bulgaria – Bulgaria-Greece border and the seismic activity in the North Black sea. The lowest earthquake quantity is in June and July, with 2 and 3 events respectively. Fig. 7 shows that there is no definite distribution of the earthquakes throughout the months for they show no tendency towards an average amount.

The graphs below show the daily distribution of the number of earthquakes each month. We see that the distribution is not spread out equally and there are any more than 6 earthquakes/day.

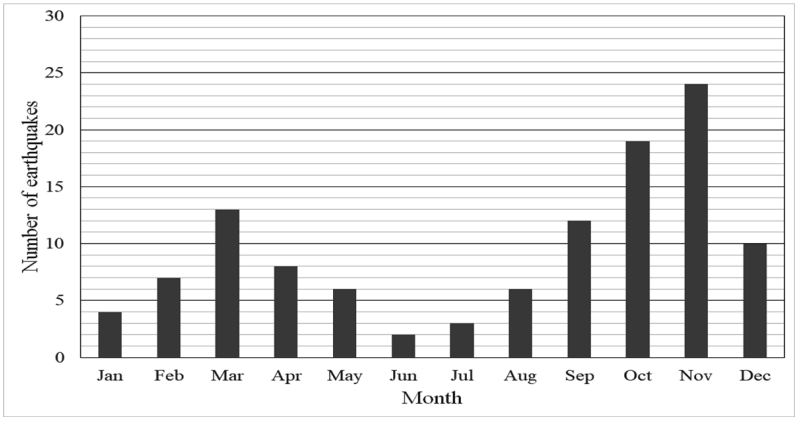
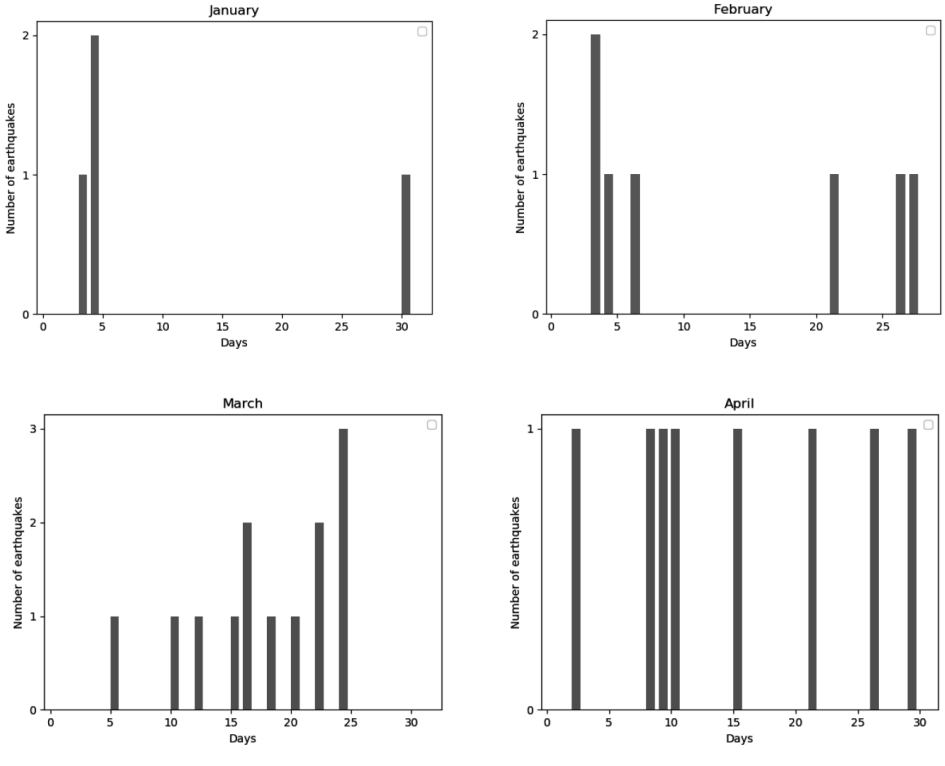


Fig. 6. The distribution of seismicity in time according to the number of events per months.



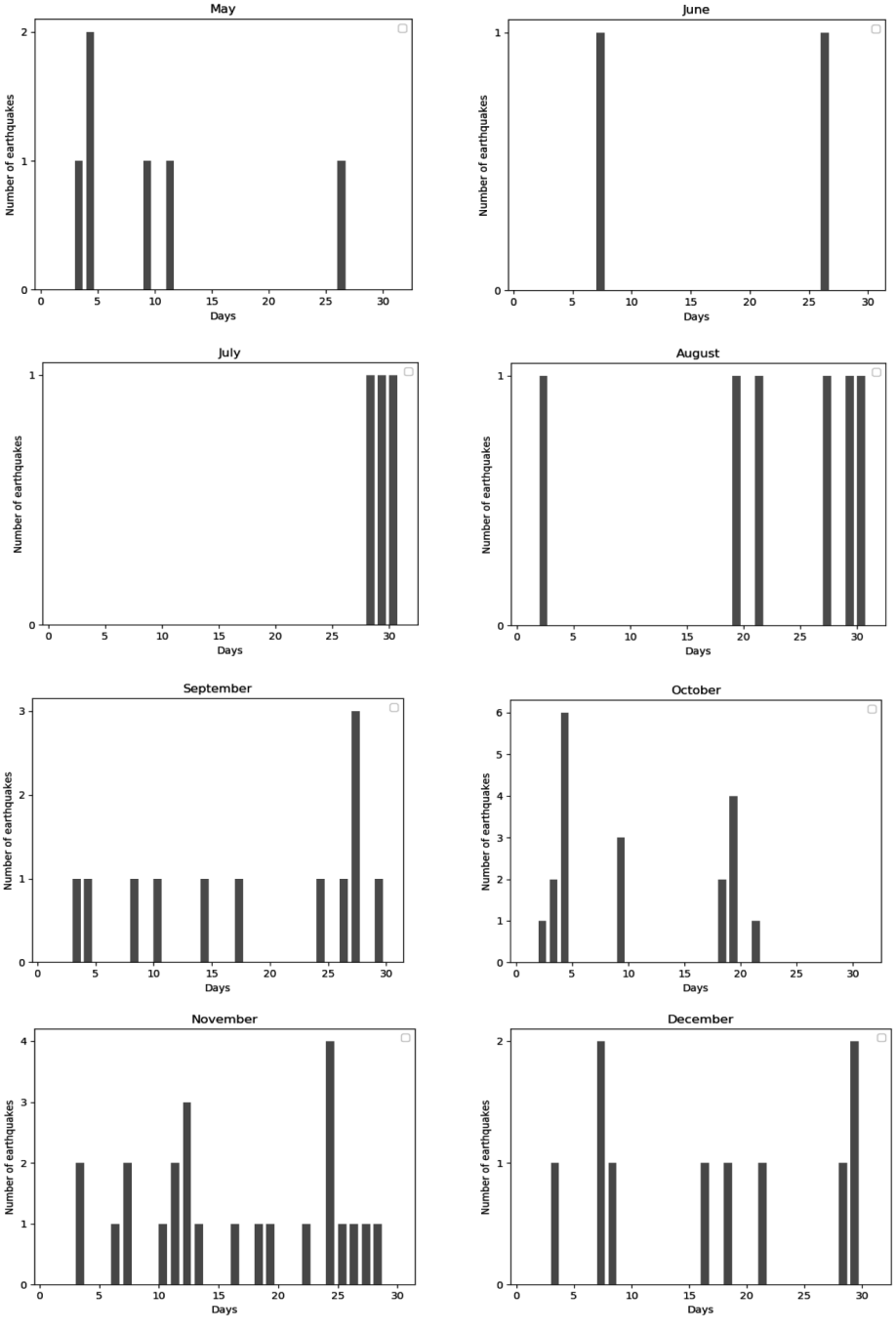

May
June
July
August
September
October
November
December
Number of earthquakes
Days

Fig. 7.

Acknowledgments: The authors express their gratitude towards the seismologists who have worked in NOTSSI for the period 01.01.2017 - 31.12.2017.

References

Christoskov L., L. Dimitrova, D. Solakov, S. Simeonova. 2012. Instrumental seismological observations in Bulgaria. Journal of BAS, 2, 19-27 (in Bulgarian)

D. Solakov, S. Simeonova, P. Raykova, I. Aleksandrova. EMPIRICAL RELATIONS CONVERTING Md AND Mp MAGNITUDES APPLIED IN BULGARIAN SEISMOLOGICAL ROUTINE PRACTICE TO MOMENT MAGNITUDE. Comptes rendus de l'Acad´emie bulgare des Sciences, 71, 8, 2018, DOI:DOI:10.7546/CRABS.2018.08.09, 1076-1085. SJR: 0.21, ISI IF: 0.27

Сеизмичност на територията на България и прилежащите земи по данни от НОТССИ през 2017 г.

В. Бучакчиев, Е.Ойнаков, Д. Драгомиров, Й. Милков

Резюме: Представена е карта с епицентрите на 114 земетресения магнитуд Mw >= 2.5 случили се през 2017 г. в България и околностите (сектор ограничен от географска ширина $\varphi = 41^{o}$ - 44.5^{o} N и географска дължина $\lambda = 22^{o} – 29^{o}$ E) регистрирани от Националната Оперативна Телеметрична Система за Сеизмологична Информация (НОТССИ). Представен е обобщен анализ. Приложен е каталог със земетресенията.

Ключови думи: България, сеизмичност

Благодарности: Авторите изразяват своите благодарности към соизмолозите, които са работили в НОТССИ през периода 01.01.2017 – 31.12.2017.