DATA AND ANALYSIS OF THE EVENTS RECORDED BY NOTSSI IN 2011

E.Botev, V.Protopopova, I.Popova, B.Babachkova, S.Velichkova, I.Tzoncheva, S.Dimitrova, V.Boychev, D.Lazarov, P.Raykova

Geophysical Institute, BAS, Akad. G. Bonchev street, bl.3, Sofia, Bulgaria, e-mail: ebotev@geophys.bas.bg

Abstract. A map of epicentres of 1836 earthquakes that occurred during 2011 in the Balkan Peninsula (sector outlined by latitude $\varphi = 37^0 - 47^0$N and longitude $\lambda = 19^0 - 30^0$E) is presented. Expert generalized analysis of the seismicity over the territory of Bulgaria and its very adjacent lands (with more then 1200 localized events) is proposed. Catalog of earthquakes with magnitude M>2.5 is applied.

Key words: Balkan Peninsula, Bulgaria, seismicity

The present scientific communication contains generalized information on the results of collection, processing and analysis of the data about the seismic events recorded by the National Operative Telemetric System for Seismological Information (NOTSSI) in 2011. The expanded information about the realized seismicity is suggested as a natural generalization and supplementation of the monthly compilations of the preliminary seismological bulletin of NOTSSI. The analysis and evaluation of the space, time and energy distribution of the seismicity, periodically been made, open up possibilities for searching for time correlations with the parameters of different geophysical fields aiming to find out eventual precursor anomalies.

The recording and space localization of the seismic events in NOTSSI during 2011 is realized by means of the new digital network (Solakov et al., 2005). The routine processing and acquisition of the initial data is organized in a real time duty regime. The operations are fulfilled by the authors of this communication. In such a way the main goal of NOTSSI, namely the seismicity monitoring in order to help the authorities' and social reaction in case of earthquakes felt on the territory of the country, is realized. The computing procedure for determining the parameters of the seismic events is an adaptation of the widespread product HYPO'71 (Solakov , 1993). The energy parameters of the events are presented mainly by the magnitude M calculated according to the record's duration by the formula (Christoskov and Samardjieva, 1983)

$$M = 1.92 + 2.72\log\tau - 0.026\Delta$$

The focal mechanism parameters are obtained by means of a program FOCMEC (Snoke,2009). The high sensitivity of the seismographs allows recording and processing of a great number of long distance earthquakes. As a result of the achieved experience in the authors interpretation work, different magnitude's lower threshold for successful determination of local, regional and long distance earthquakes is established: M=1.5 for the territory of Bulgaria, M=3.0 for the central part of the Balkans, M=5.0 for long distance events. The precision of the epicenter's determination is different; except on the distance it depends also on the specific position of the epicenter in relation 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 responsible seismotectonic investigation.

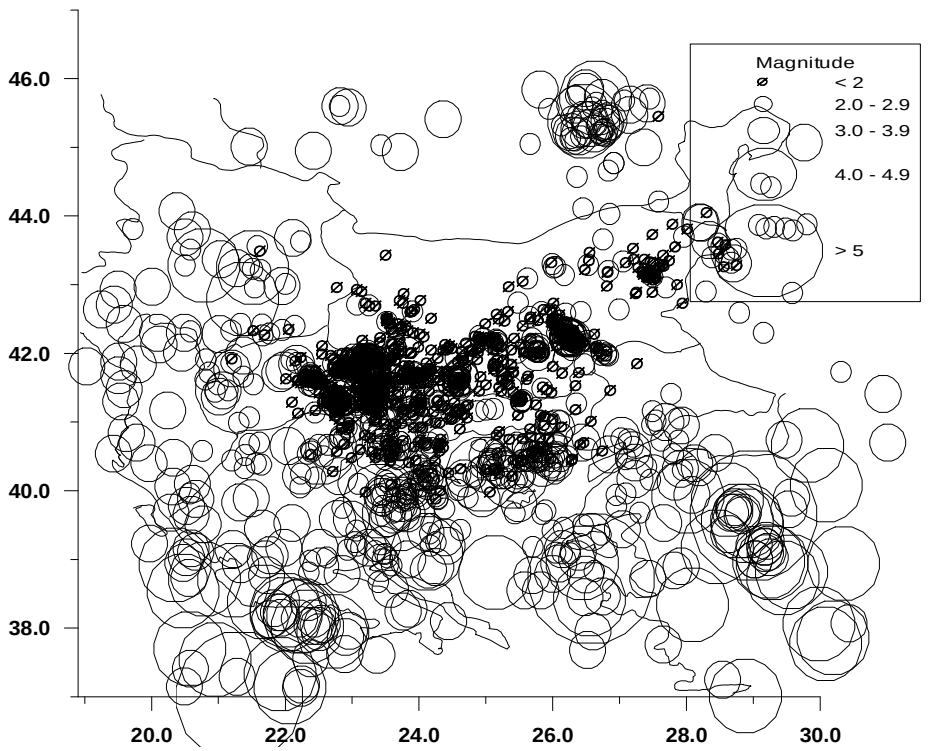

Fig.1. Map of epicenters in Central Balkans during 2011.

For the period of observations presented in this communication, the primary data about 2000 local, regional, distant earthquakes and industrial explosions on the territory of Bulgaria are recorded, classified and processed (as a work bulletin) in NOTSSI. After comprehensive analysis of the records and application of the above mentioned calculation procedures it is established that 1836 of all registered earthquakes are in the Balkan Peninsula region outlined by geographic latitude 37^0 - 47^0 N and longitude 19^0 - 30^0 E. The

epicenters of the earthquakes differentiated by magnitude levels are plotted on Fig.1. The number of the events in the magnitude interval M=0.5-1.9 is 993, in M=2-2.9 - 549, in M=3-3.9 - 238, in M=4-4.9 – 46 earthquakes. During this not so active period there are 3 events with magnitude M>5. The maximum magnitude value is M=5.8.

As a whole, the seismic situation in the study part of the Balkans during 2011 is characterized by comparatively high activity - 1829 events against 2401 in 2010, 2744 in 2009, 1775 in 2008, and around 1100- 1400 for most of the previous years. The maximum realized earthquake is with magnitude M=5.8 while this value for the previous years is lower then five, as a rule. It can be noted that the observed tendency of high increase of the activity compared with the former years is partly due to the high level of earthquake activation in Marmara sea, Central Greece, Serbia, Romania, and also due to increase of number of microearthquekes in the territory of Bulgaria.

The strongest event outside Bulgaria during the study period occurred in the region situated to the south of Marmara sea (Turkey) (M=5.8 and intensity I=III-IV of MSC scale in Kurdzhali region). Other shakable effect because of outside attack during the study period occurred around of Lesvos island – eastern edge of central part of Aegean sea (magnitude M=5.5 and intensity I=II-III in Kardzhali).

As a whole, events with M<3.0 which occur outside Bulgaria are difficult to be localized by the national seismological system; consequently, not all of them have been marked on the scheme in Fig.1.

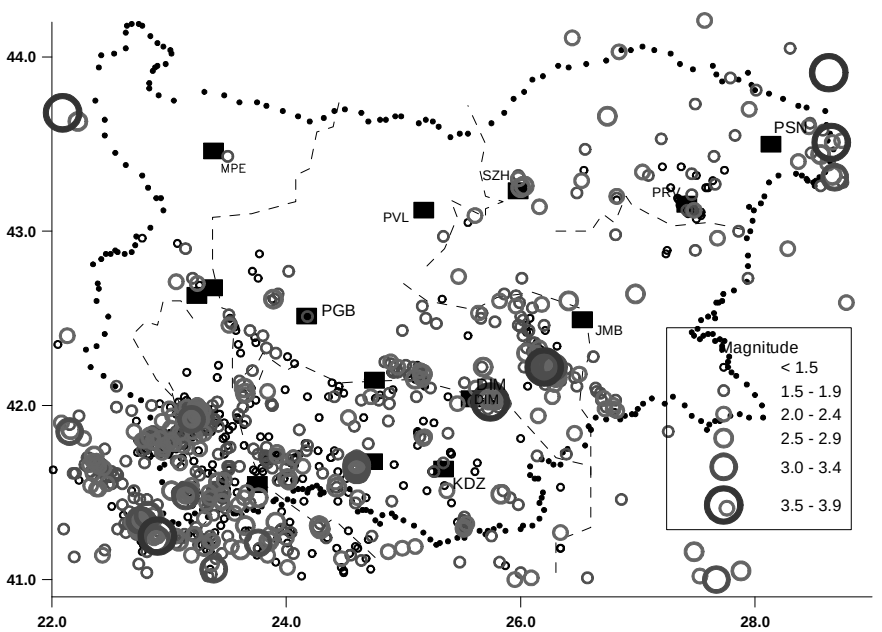

Fig.2. Map of epicentres in Bulgaria and adjacent lands during 2011

Fig.2 illustrates the seismicity just in the territory of Bulgaria and nearby lands ($\varphi = 41^0 - 44.5^0$N, $\lambda = 22^0 - 29^0$E). The earthquakes are differentiated by magnitude intervals. The seismic stations are also noted in the same figure by rectangular. The parameters of

relatively stronger earthquakes are presented in Table 1.

Table 1. List of earthquakes with M ≥ 2.5 in Bulgaria and adjacent lands during 2011

Date			Time	Coordinates		H,km	M
2011	1	3	20:43	41.19	23.3	3	2.6
2011	1	5	17:14	42.07	23.65	8	2.6
2011	1	6	17:16	41.35	22.72	15	2.5
2011	1	8	11:20	42.22	26.28	8	3.1
2011	1	14	03:31	42.25	26.23	6	2.5
2011	1	14	15:49	42.18	25.16	4	2.8
2011	1	20	19:05	41.71	22.36	7	2.5
2011	1	24	12:14	42.15	25.1	2	2.8
2011	1	28	16:30	42.3	26.05	5	2.5
2011	2	2	20:00	41.51	23.02	8	2.5
2011	2	7	22:25	41.56	23.42	10	2.5
2011	2	7	18:00	41.49	23.14	3	2.8
2011	2	7	16:22	41.51	23.17	2	2.9
2011	2	7	10:39	41.48	23.14	2	3.2
2011	2	27	34:32	42.61	23.89	10	2.5
2011	2	28	18:28	42.18	25.16	3	2.9
2011	3	13	18:02	41.36	22.87	1	2.6
2011	3	15	18:00	42.24	26.2	7	3.2
2011	3	18	06:27	41.06	23.38	1	3.1
2011	3	27	10:27	41.22	23.85	12	2.6
2011	3	28	17:21	42.21	26.3	5	2.6
2011	3	28	18:04	42.24	26.2	7	3.2
2011	3	29	09:46	42.03	25.78	2	2.5
2011	3	29	17:03	42.17	26.29	7	2.5
2011	3	29	02:55	41.86	22.16	4	2.8
2011	3	29	02:56	41.85	22.15	2	3.1
2011	3	29	07:29	42.02	25.74	10	3.7
2011	3	30	11:22	42.18	26.28	6	2.8
2011	3	31	05:25	41.22	23.08	2	2.7
2011	4	1	19:44	42.21	26.23	6	2.8
2011	4	2	00:07	43.26	26.03	3	2.5
2011	4	14	03:40	41.58	24.01	15	2.5
2011	4	18	14:18	41.25	22.9	2	3.5
2011	4	22	21:33	43.32	28.66	26	2.9
2011	4	22	21:27	43.31	28.68	25	3.1
2011	5	1	08:36	41.16	27.48	15	2.8
2011	5	4	18:40	43.63	22.22	8	2.7
2011	5	5	01:07	41.21	23.76	2	3.4
2011	5	7	19:14	43.25	26	2	2.6
2011	5	22	22:39	41.05	27.88	5	2.5
2011	6	6	12:01	42.22	26.24	8	2.6
2011	6	6	22:52	42.22	26.24	5	3.2
2011	6	24	17:32	42.24	26.23	3	2.6

2011	6	24	17:47	42.19	26.27	5	2.7
2011	6	24	17:44	42.22	26.2	4	3.6
2011	7	6	13:32	42.64	26.98	10	2.5
2011	7	22	12:57	41.33	23.91	10	2.6
2011	7	22	19:16	41.91	23.2	5	2.6
2011	7	23	07:32	41.92	23.19	1	3
2011	7	26	03:71	43.66	26.74	5	2.5
2011	7	31	17:37	41.49	25.83	5	2.8
2011	8	5	02:16	42.22	26.2	9	3.4
2011	8	5	02:17	42.25	26.22	2	3.4
2011	8	7	20:26	42.1	23.64	4	2.7
2011	8	11	02:57	41.31	22.78	5	2.6
2011	8	20	20:50	41.37	22.82	2	3.3
2011	8	23	08:30	41.3	22.83	2	2.5
2011	8	24	19:59	43.91	28.63	5	3.8
2011	9	2	11:17	41.17	23.61	2	2.7
2011	9	5	13:23	43.68	22.09	10	3.6
2011	9	11	18:52	42.03	25.73	11	2.7
2011	9	15	10:25	41.91	23.17	2	2.7
2011	9	20	11:28	42.22	25.68	15	2.6
2011	10	3	11:53	41.53	24.43	11	2.5
2011	10	5	07:23	42.19	26.23	3	2.5
2011	10	6	15:08	41.34	22.76	2	3.1
2011	10	6	15:55	41.34	22.75	1	3.4
2011	10	7	12:33	41.32	22.77	0	2.8
2011	10	8	16:06	42.25	26.16	2	2.5
2011	10	11	19:49	43.51	28.53	18	3.8
2011	10	15	41:08	42.16	26.3	6	2.5
2011	10	20	10:28	43.44	28.56	14	2.5
2011	10	21	13:18	41.61	24.6	7	2.5
2011	10	21	05:12	41	27.67	2	3.1
2011	10	21	12:26	41.66	24.6	7	3.2
2011	10	23	18:13	41.82	22.84	11	2.5
2011	10	23	13:09	41.66	24.6	11	2.6
2011	10	30	04:48	41.64	24.63	9	2.7
2011	10	30	05:54	41.65	24.61	7	3
2011	10	30	04:47	41.63	24.6	5	3.2
2011	11	10	22:20	41.31	23.65	4	2.8
2011	11	11	18:48	41.29	22.73	7	2.5
2011	11	17	15:10	41.29	24.29	5	2.5
2011	11	19	18:58	41.31	24.28	4	2.6
2011	11	29	12:20	41.47	23.76	13	2.8
2011	12	17	06:13	42.6	26.41	11	2.5
2011	12	18	21:56	41.35	22.75	2	2.7
2011	12	26	08:10	42.26	26.21	2	2.8

On the territory of Bulgaria a very much high degree of activity of weak earthquakes is observed during 2011 - 1205 events against 1607 in 2010, 2017 in 2009,

1079 in 2008, and 600-800 for most of the previous years. The earthquakes of a magnitude higher than 3.0 are in normal amount - 25 events compared with an averaged number of about 20-30 for most of the all previous years (exception is 2009 with 147 events because of the aftershocks of Valandovo M=5.2 earthquake.). The maximum realized magnitude M=3.8 in the region of Shabla is almost normal too, in comparison with the maximum magnitude in the course of previous years. As usually, the largest concentration of epicenters is marked in the southwestern part of the territory presented in Fig.2. The Kroupnik seismic source is known with the strongest crustal earthquakes in Europe (M=7.8, 7.1) for the last 160 years. In 2011 about 80 events of M<3.0 and only 2 of M≥3.0 occurred in this region. The strongest felt earthquake for the south-western part of Bulgarian territory is with magnitude M=3.2, it is felt on 07 February in Petrich region (southern slopes of Belasitza mountain) by intensity of III EMS.

The Bulgarian seismic sources in 2011 are relatively not so active than during the previous years. They produced not more than 25 earthquakes affecting different localities in this country by intensity of up to IV degrees EMS. The maximum number of felt earthquakes is occurred around the Monastery uplift. About ten cases of magnitudes less than 3.0 aroused shocks of intensity three or a bit more and about 6 with M>3 are felt in Monastery Highland territories with intensities up to V – VI degree of MSC. The maximum event with M=3.6 caused V- VI of MSK on 24 June. A strong event M=3.7 in the neighbor region of Simeonovgrad caused effects of V degree of MSC. In the rest part of the 2011 felt events caused excitation of lesser intensity. The strongest event with magnitude Ms=3.8 occur in north-eastern Bulgaria on 11 October and caused macroseismic impact with intensity of V degree EMS scale in village of Shabla on the Black sea coast. One relatively big seismic activity is associated with the Smolyan fault structure in the Rhodopean Region region where three shocks during the time of ten days shook the city of Chepelare with intensity of III EMS since 21 October to 30 October.

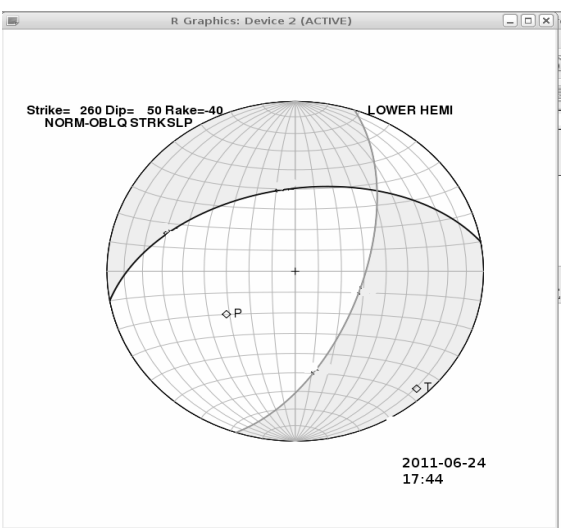

Fig.3. Focal plane solution of the strongest Monastery uplift earthquake (24.06.2011)

For the determination of the earthquake mechanism is used program FOCMEC. Input are polarities of the P wave. In the double - couple focal mechanism are included 12 first motion polarities data from seismological stations in Bulgaria and surrounding area taken from NOTSSI and ISC database (ftp://www.orfeus-eu.org/pub/data/continuous/2011/) - Fig.3. The solution is displayed on lower hemisphere. The polarities from ISC are not check as waveform. The polarities from seismological stations KAVA and PGB are poor and the solution is not with very good quality. The fault plane solutions of the some other events are with very bad quality because of a low number of polarities.

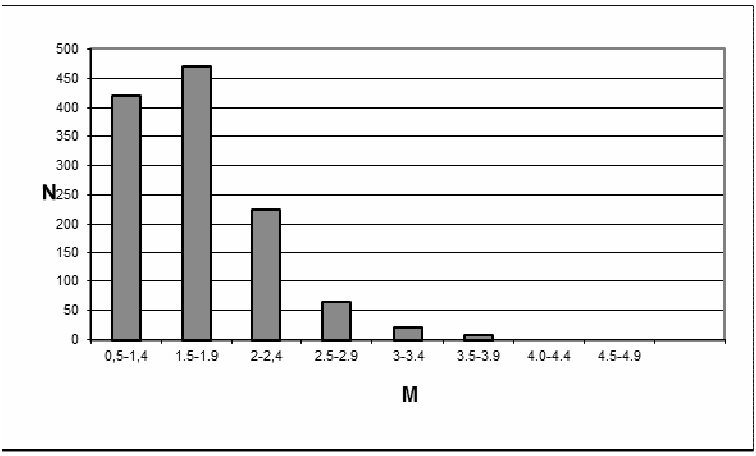

Fig.4. Magnitude - frequency distribution of the earthquakes

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.2 characterize predominantly the seismicity parameters of the southwestern part of the territory under investigation.

The magnitude-frequency distribution for the entire data set is presented in Fig.4. The number of localized events increases with the magnitude decreasing: for M=3.5-3.9 is 6 events, for M=3.0-3.4 is 19 events, for M=2.5-2.9 - 64, for M=2.0-2.4 - 225 and so on. The abrupt diminishing of the number of earthquakes in the first two intervals (M<1.5) in Fig.4 determines also the registration power of the seismic stations network.

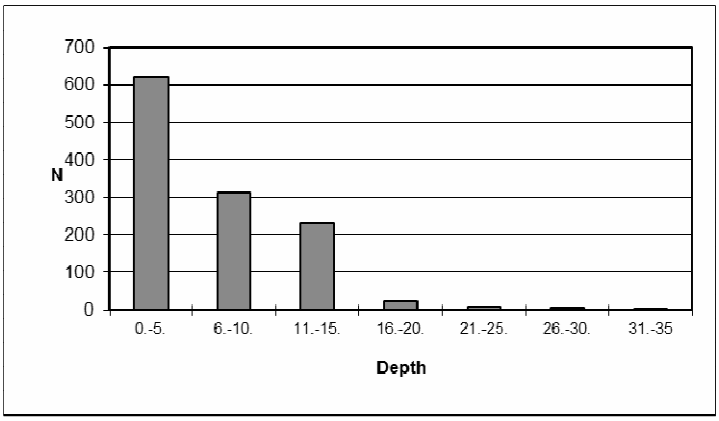

Fig.5. Depth - frequency distribution of the earthquakes

Taking the latter into account, it can be supposed that the magnitude sample for levels with M > 1.5 is comparatively closer to the reality for the bigger part of the Bulgarian territory.

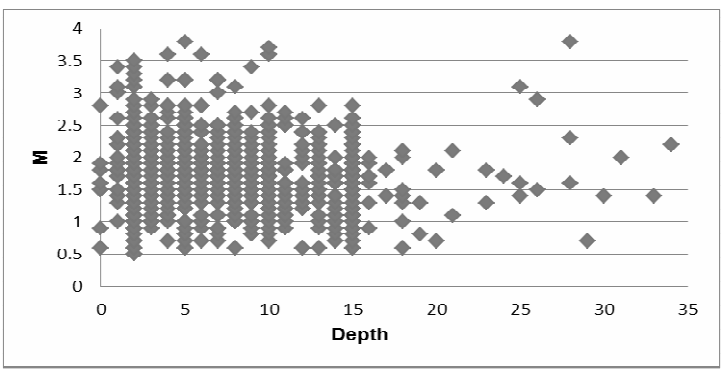

Fig.6. Magnitude - depth dependence

The picture of the depth distribution in Fig.5 shows that the majority of events occur down to 20 km depth. The number of events decreases smoothly with increase of the depth. It is possible the established predominating depth (from 0 to 5 km) to be also due to the presence of unidentified industrial explosions. In the same time the number of events in the interval 15-20 km is bigger. The magnitude distribution of the events in depth (Fig.6) do not permits to note some differentiation of depth "floors" with the increase of magnitude - the maximums can be traced out for all of the depth interval from 2 to 20 km. It is remarkable that the strongest events are not deep situated.

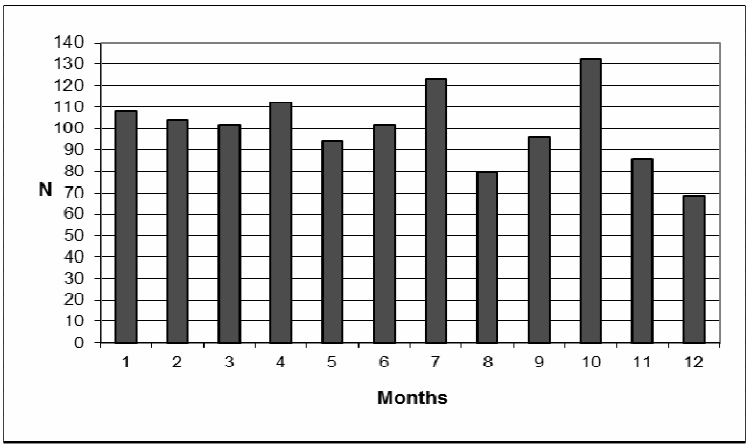

Fig.7. Time distribution of the earthquakes.

Fig.7 illustrates the distribution of seismicity in time according to the number of events per months. The biggest earthquake's amount is displayed in October, when more then 130 earthquakes occurred, approximately the similar situation in July is observed – 123 events. The lowest earthquake quantity is in August, 80 events. The energy release suggests that in October, when 132 events occurred, is the month with maximum of energy release.

Additionally, about 1100 distant earthquakes have been recorded in the period under study, as well as more than 700 industrial explosions, processed and classified in the preliminary monthly bulletins. In order to identify the artificial seismic sources the methodical approach described by Deneva et al. (1988) and some information about the quarry sites in Bulgaria have been used.

Acknowledgements: The authors owe their gratitude to the engineering staff for the perfect software and hardware ensuring of NOTSSI.

References

Christoskov L. and E. Grigorova, 1968. Energetic and space characteristics of the destructive earthquakes in Bulgaria since 1900. *Izv.BAS, vol XII* .

Christoskov L. and E. Samardjieva, 1983. Investigation on the duration of the seismic signals like a energetic characteristic of the earthquakes. *BGJ, vol.IX, N1*.

Christoskov L. et al., 1987. Real time and background data processing in the Bulgarian seismological network. *Proc. Xx gen. Assembly 1986, Kiel.* , Zurich.

Deneva D. et al., 1988. On the discrimination between industrial explosions and weak earthquakes using records of local seismics networks. *Proc. of conference in Liblice, 1988*, Praha.

Snoke J.A, 2009. FOCMEC: FOCal MECanism Determinations. VirginiaTech, Blacksburg, VA, USA, 2009, Manual.

Solakov, D., 1993. An algorithm for hypocenter determination of near earthquakes. Bulg. Geophys. J. 19 (1), 56-69

Solakov, D. et all., 2005. National Seismological Network – state and development. Proceedings of Scientific-practical conference on management in extraordinary situations and people protection, BAS, Sofia, 2005, 265-272.
ftp://www.orfeus-eu.org/pub/data/continuous/2006/

Данни и анализ на сеизмичните събития регистрирани от НОТССИ през 2011

Е.Ботев, В.Протопопова, И.Попова, Бл.Бабачкова, С.Величкова, И.Цончева, С.Димитрова, Вл.Бойчев, Д.Лазаров, Пл.Райкова

Резюме. Предлаганото научно съобщение съдържа обобщена информация за резултатите от събирането, обработката и анализа на първичните данни за сеизмичните събития, регистрирани от Националната Оперативна Телеметрична Система за Сеизмологична Информация (НОТССИ) през 2011 г. Представена е карта на епицентрите на общо 1836 земетресения в частта от Балканския полуостров, ограничена от географска ширина 37^0 - 47^0 N и дължина 19^0 - 30^0 E. По-подробно се анализира сеизмичността за територията на България и прилежащите й земи (1205 сеизмични събития в район с координати $\lambda = 22^0$ - 29^0E и $\varphi = 41^0$ - 44.5^0N). Предлага се и каталог на земетресенията с магнитуд M>2,5. Сеизмогенните прояви се обсъждат по зони, сравнени със съседни периоди време.