

Seismic activity on the territory of Slovakia in 2018

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Abstract: The National Network of Seismic Stations of Slovakia (NNSS) consists of eight short period and five broadband permanent seismic stations and a data centre located at the Earth Science Institute of the Slovak Academy of Sciences (ESI SAS). The NNSS recorded and detected 11704 seismic events from all epicentral distances in 2018. Totally 86 earthquakes originated in the territory of Slovakia in 2018. This paper provides basic information on the configuration of the NNSS, routine data processing, seismic activity on the territory of Slovakia in 2018 as well as macroseismic observations collected in 2018.

Key words: Slovakia, National Network of Seismic Stations, seismicity, macroseismic observations

1. Introduction

The seismic activity on the territory of Slovakia and adjacent areas has been reported on the daily basis by the so called Seismo Reports published on the web sites of the Department of Seismology, ESI SAS <http://www.seismology.sk/SeismoReports/reports.html> and in annual reports as a part of the project Partial monitoring system – Geological factors (*Liščák et al., 2019*, in preparation) which is solved with a contract between ESI SAS and State Geological Institute of Dionýz Štúr. The aim of this paper is to provide a quick overview of earthquakes which originated on the territory of Slovakia or were macroseismically felt on the territory of Slovakia in 2018.

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2. Seismic stations operating in 2018

The seismic monitoring of the Slovak territory is provided by the NNSS operated by the ESI SAS (*ESI SAS, 2004*), *Local Seismic Network in Eastern Slovakia* operated by the Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava and local network of seismic stations around NPPs Jaslovské Bohunice and Mochovce operated by Progseis Ltd. company. The networks of seismic stations cooperate and the exchange of data is on the regular basis. The positions of the seismic stations on the territory of Slovakia are shown in Fig. 1.

In 2018 the NNSS consisted of thirteen permanent seismic stations, from which eight are short period and five are broadband. Broadband stations are: Červenica (CRVS), Kolonické sedlo (KOLS), Modra (MODS), Vyhne (VYHS) and Železná studnička (ZST). Short period stations are: Hurbanovo (HRB), Izabela (IZAB), Iža (SRO1), Kečovo (KECS), Liptovská Anna (LANS), Moča (SRO2), Stebnícka Huta (STHS) and Šrobárová (SRO). The HRB is the oldest NNSS seismic station that has been in operation since 1909 (*Pajdušák, 1997*). In 2018 the CRVS station was closed due to the changes in the property rights of the location site. A possibility to install a new station in the Šariš region has been investigated. The NNSS permanent

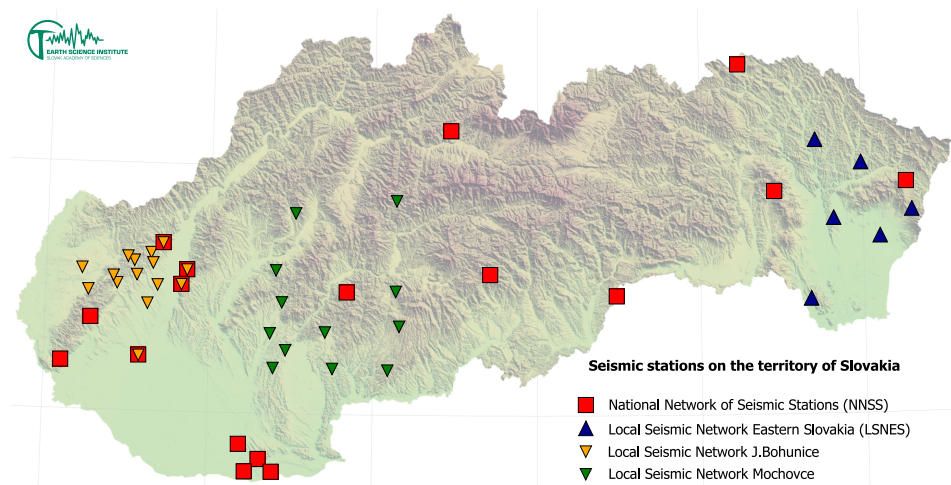


Fig. 1. Seismic stations operational on the territory of Slovakia in 2018.

seismic stations and their instrumentation are summarized in Table 1. More details can be found on the web page http://www.seismology.sk/National_Network.

Table 1. Equipment of seismic stations of the NNSS operating in 2018.

Station	ISC code	Lat. [°N]	Long. [°E]	Alt. [m]	Sensor	DAS	Sampl. freq.	Data format
Bratislava Žel. Studnička	ZST	48.196	17.102	250	3×SKD	Wave24	100/sec	mSEED
Červenica	CRVS	48.902	21.461	476	STS-2	Wave24	100/sec	mSEED
Vyhne	VYHS	48.493	18.836	450	STS-2	Wave24	100/sec	mSEED
Modra-Piesok	MODS	48.373	17.277	520	STS-2	Wave32	100/sec	mSEED
Hurbanovo	HRB	47.873	18.192	115	2× Mainka	Analog	–	smoked paper
Izabela	IZAB	48.569	19.713	450	3×SM3	Wave24	100/sec	mSEED
Iža	SRO1	47.7622	18.2328	111	LE3D	PCM	20/sec	mSEED
Kečovo	KECS	48.483	20.486	345	LE3D	Wave24	100/sec	mSEED
Kolonické sedlo	KOLS	48.933	22.273	460	Guralp- 6T-30s	Wave32	100/sec	mSEED
Liptovská Anna	LANS	49.151	19.468	710	LE3D	SEMS	100/sec	mSEED
Moča	SRO2	47.763	18.394	109	Guralp- 40T-1s	Wave24	100/sec	mSEED
Stebnícka Huta	STHS	49.417	21.244	534	LE3D	Wave24	100/sec	mSEED
Šrobárová	SRO	47.813	18.313	150	3× SKM-3	Wave24	100/sec	mSEED

Four additional short period seismic stations has been operated on the jointly bases of ESI SAS and the other institutions. The seismic stations Banka (BAN), Podolie (POD) and Jalšové (JAL) located in the Little Carpathians have been operated in cooperation with Progseis Ltd. company and the Institute of Rock Structure and Mechanics of the Czech Academy of Sciences (IRSM CAS) (*Fojtíková et al., 2015*). The seismic station Pusté Úľany (PULA) has been operated in cooperation with the IRSM CAS. These stations have been installed as temporary seismic stations.

3. Data processing

Digital data from all NNSS stations (except the analog seismic station HRB) are transferred in real-time to the data centre at the ESI SAS either by the

internet or satellite telemetry. Software package SeisComp3 (*Weber et al., 2007*) and SeedLink server are used for data acquisition and exchange.

Beside observations from the NNSS stations the data centre at ESI SAS also use the data from the above mentioned local networks of seismic stations in Slovakia and observations from networks of neighbouring countries: Austrian Seismic Network (*ZAMG – Zentralanstalt für Meteorologie und Geodynamik, 1987*), Czech Regional Seismic Network (*Institute of Geophysics, Academy of Sciences of the Czech Republic, 1973*), Hungarian National Seismological Network (*Kövesligethy Radó Seismological Observatory, 1992*), Local seismological network for monitoring NPP Dukovany (*Institute of Physics of the Earth Masaryk University, 2014*), GEOFON Seismic Network (*GEOFON Data Center, 1993*), *Polish Seismological Network*. These stations form a so-called Regional Virtual Network of ESI SAS that consists of approximately 55 seismic stations.

Routine analysis of the digital recordings at the ESI SAS has been performed by the Unix package Seismic handler (*Stammner, 1993*). Interactive locations of seismic events within Seismic Handler are performed by external program LocSat. The collected digital observations are manually processed on the daily basis. The epicentre locations are based on the IASPI91 travel-time curves. Local magnitudes have been determined from the maximum vertical trace amplitudes of Sg waves, using the pre-defined Seismic Handler formula for local events. Continuous raw seismic data from the NNSS are stored in a local archive and seismic data interpretations (together with information on equipment of stations) are stored in a web accessible database.

4. Seismic activity in 2018

The NNSS analyzed 11704 local, regional and teleseismic events in 2018. More than 45800 seismic phases were determined. Seismic events identified as quarry blasts were excluded from further processing and were not included in the event statistics. All events recorded by the NNSS and analyses at the data centre at ESI SAS have been reported in the so called Seismo Reports and published on the above mentioned web sites of the Department of Seismology, ESI SAS.

Altogether 86 seismic events located by the NNSS originated in the territory of Slovakia in 2018 (Fig. 2). Known quarry blasts are not included in

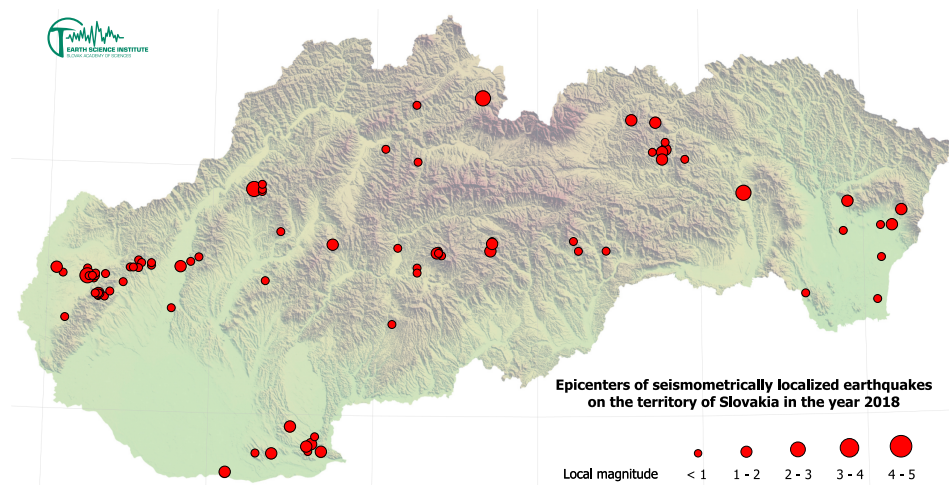


Fig. 2. Map of epicentres of local earthquakes originated on the territory of Slovakia in 2018. Diameters of the circles are proportional to local magnitudes.

this number. 31 earthquakes reached local magnitude 1.0 or more and are listed in Table 2. The strongest earthquake occurred on August 17 at 1:25 UTC in Strážovské Mts. with local magnitude M_L 2.9.

The seismicity of the Slovak territory is dominated by the Little Carpathians and Komárno seismic source zones (Hók *et al.*, 2016). The strongest earthquake in the Little Carpathians source zone was detected on the May 7 at 21:23 UTC with local magnitude M_L 1.3. The strongest earthquake in the Komárno source zone was detected on the January 17 at 5:49 UTC with local magnitude M_L 2.0. Although the low level of seismic activity from the last decades remained unchanged in 2018, these two source zones remain of the primary interest for the monitoring of seismic activity within the territory of Slovakia.

5. Macroseismic observations

Five earthquakes were macroseismically felt on the territory of Slovakia in 2018 (Table 3), four of them with the epicentre on the territory of Slovakia and one with the epicentre in Poland (Fig. 3). All of these five earthquakes were also seismometrically observed and processed. Intensities were esti-

Table 2. List of earthquakes originated on the territory of Slovakia in 2018 with $M_L \geq 1.0$.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2018-01-01	04:33:48.46	48.67	19.71	0	1.6	felt	Vepor Mts.
2018-01-02	07:28:58.28	48.70	19.72	0	1.1		Vepor Mts.
2018-01-12	15:24:13.62	49.19	20.73	0	1.4		Levoča Mts.
2018-01-17	05:49:52.23	47.84	18.39	0	2.0		Šamorín – Komárno – Štúrovo
2018-01-31	11:16:09.62	49.08	20.79	0	1.8		Levoča Mts.
2018-02-25	13:16:32.77	48.37	17.11	2.6	1.0		Little Carpathians
2018-03-13	20:05:11.06	48.69	18.74	0	1.8		Vtáčnik Mts.
2018-03-14	08:48:28.14	47.95	18.50	0	1.1		Danubian Hills
2018-04-05	02:51:39.39	47.76	18.11	2.9	1.7	felt	Šamorín – Komárno – Štúrovo
2018-04-10	23:30:20.01	49.20	20.58	0	1.1		Levoča Mts.
2018-04-22	17:10:18.02	48.82	22.24	4.4	1.4		Vihorlat Mts.
2018-04-26	13:04:46.31	48.59	17.81	0	1.2		Považský Inovec Mts.
2018-05-07	21:23:58.66	48.47	17.31	0.6	1.3		Little Carpathians
2018-05-16	08:13:00.88	48.86	21.91	3.0	1.2		Vihorlat Mts.
2018-06-11	09:11:40.00	49.07	20.77	0	1.4		Levoča Mts.
2018-07-20	13:44:18.40	49.04	20.77	0	1.2		Levoča Mts.
2018-08-17	01:25:12.86	48.91	18.25	0.3	2.9	4	Strážov Mts.
2018-08-24	14:41:04.75	48.90	21.27	0	2.1		Slanské Hills
2018-09-11	17:32:02.68	48.46	22.08	0	1.0		East Slovak Lowland
2018-10-02	21:56:53.28	47.88	18.63	2.2	1.7		Šamorín – Komárno – Štúrovo
2018-10-02	23:22:08.63	47.85	18.69	0	1.2		Ipeľ Hills
2018-10-14	15:37:33.84	48.67	19.39	0	1.0		Poľana

Table 2. Continued from the previous page.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2018-10-17	04:32:13.12	48.66	19.38	0	1.3		Poľana
2018-11-06	14:05:14.03	48.57	17.05	0	1.1		Záhorie region
2018-11-12	09:07:04.00	48.76	22.18	5.1	1.1		Vihorlat Mts.
2018-11-14	23:16:12.71	49.29	19.66	0.8	2.1		High Tatras
2018-11-19	22:09:51.82	47.85	18.61	0	1.0		Šamorín – Komárno – Štúrovo
2018-11-27	22:29:37.37	47.87	18.60	0	1.2		Šamorín – Komárno – Štúrovo
2018-12-16	15:05:37.30	48.54	17.24	5.4	2.3	3	Záhorie region
2018-12-17	04:57:35.95	48.54	17.25	3.6	1.0		Záhorie region
2018-12-31	04:51:18.14	48.60	17.63	2.9	1.0		Little Carpathians

Table 3. List of macroseismically observed earthquakes on the territory of Slovakia in 2018.

Date [YYYY-MM-DD]	Origin Time (UTC) [HH:MM:SS]	Lat. [°N]	Lon. [°E]	Depth [km]	M_L [NNSS]	I_0 [°EMS]	Region
2018-01-01	04:33:48.5	48.68	19.71	0	1.6	–	Vepor Mts.
2018-04-05	02:51:39.4	47.76	18.12	3	1.7	–	Komárno
2018-07-15	21:19:50.3	49.34	20.93	7	2.6	–	Krynica
2018-08-17	01:25:12.9	48.91	18.25	1	2.9	4	Strážov Mts.
2018-12-16	15:05:37.3	48.54	17.24	5	2.3	3	Záhorie

mated by the European Macroseismic Scale 1998 (EMS-98) introduced by *Grünthal (1998)*.

The earthquake on January 1 at 4:33 UTC with epicentre near Brezno and local magnitude 1.6 was macroseismically felt on 1 location (Table 4). Because of lack of macroseismic data it was not possible to determine the epicentral intensity.

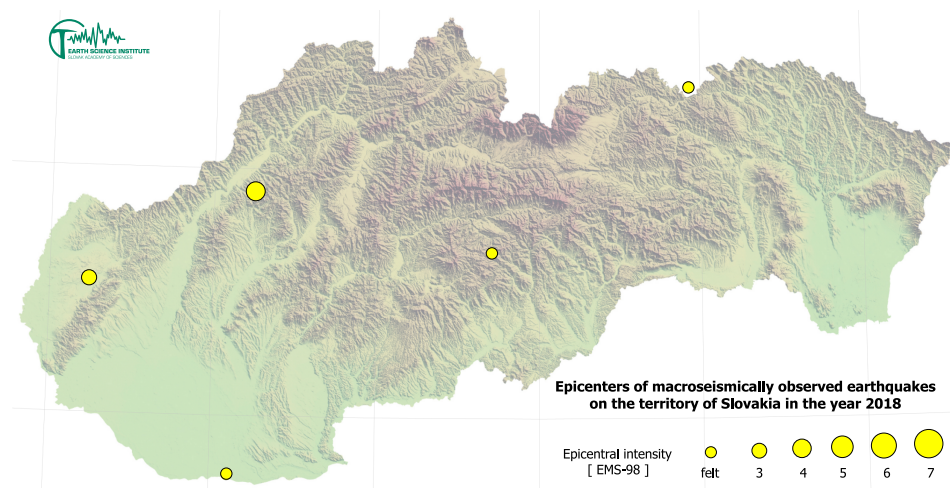


Fig. 3. Map of epicentres of macroseismically observed earthquakes on the territory of Slovakia in 2018. Diameters of the circles are proportional to epicentral intensity.

The earthquake on April 5 at 2:51 UTC with epicentre near Komárno and local magnitude 1.6 was macroseismically felt on 2 locations (Table 5). Because of lack of macroseismic data it was not possible to determine the epicentral intensity.

The earthquake on July 15 at 21:19 UTC with epicentre near Krynica, Poland and local magnitude 2.6 was macroseismically felt on 16 locations within the territory of Slovakia (Table 4). 47 macroseismic questionnaires were filled. People reported weak trembling or shaking and acoustic effects – rumbling. The maximum intensity on the territory of Slovakia was determined at 3–4° EMS-98.

The earthquake on August 17 at 1:25 UTC with epicentre near Trenčianske Teplice and local magnitude 2.9 was macroseismically felt on 26 locations (Table 7). 178 macroseismic questionnaires were filled. The event was described as a light trembling. Some people reported acoustic effects – rumbling and fizzling. The epicentral intensity was determined at 4° EMS-98.

The earthquake on December 16 at 15:05 UTC with epicentre in Záhorie region and local magnitude 2.3 was macroseismically felt on 4 locations (Table 8). 5 macroseismic questionnaires were filled. The event was described as a light trembling. The epicentral intensity was determined at 3° EMS-98.

Table 4. Macroseismic observations for January 1, 2018 earthquake, 4:33 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Čierny Balog	48.744	19.645	1	felt

Table 5. Macroseismic observations for April 5, 2018 earthquake, 2:51 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Komárno	47.766	18.118	1	felt
Nová Stráž	47.764	18.044	1	felt

Table 6. Macroseismic observations for July 15, 2018 earthquake, 21:19 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Malcov	49.305	21.065	8	3–4
Andrejovka	49.288	20.901	1	3–4
Hniezdne	49.304	20.632	1	3–4
Bardejov	49.297	21.272	7	3
Kružlov	49.311	21.136	4	3
Čirč	49.282	20.924	1	3
Sveržov	49.337	21.165	1	3
Hrabské	49.320	21.070	6	felt
Kurov	49.342	21.136	5	felt
Lenartov	49.310	21.017	4	felt
Gerlachov	49.098	20.210	3	felt
Snakov	49.326	21.046	2	felt
Frickovce	49.186	21.245	1	felt
Gabolto	49.367	21.145	1	felt
Lipany	49.156	20.964	1	felt
Lukov	49.293	21.083	1	felt

6. Conclusion and discussion

The NNSS is operated by the ESI SAS, Bratislava. Data from all stations (except station HRB) are transferred in real-time to the data centre at Bratislava. Data processing and routine analysis are performed digitally by in-

Table 7. Macroseismic observations for August 17, 2018 earthquake, 1:25 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Horná Súča	48.980	17.950	1	4
Motešice	48.824	18.183	1	4
Dubnica nad Váhom	48.958	18.183	63	3
Trenčianske Teplice	48.908	18.180	26	3
Omšenie	48.902	18.226	6	3
Trenčianska Teplá	48.937	18.121	6	3
Trenčín	48.890	18.043	5	3
Nemšová	48.970	18.115	3	3
Košecké Podhradie	48.969	18.311	2	3
Báb	48.307	17.872	1	3
Bojnice	48.779	18.583	1	3
Bolešov	49.000	18.170	1	3
Dobrá	48.923	18.106	1	3
Kopec	48.949	18.342	1	3
Nové Mesto nad Váhom	48.758	17.829	1	3
Poriadie	48.773	17.607	1	3
Pruské	49.031	18.201	1	3
Púchov	49.124	18.326	1	3
Nová Dubnica	48.938	18.161	38	felt
Horná Poruba	48.952	18.293	6	felt
Ilava	48.982	18.243	6	felt
Dolná Poruba	48.905	18.285	2	felt
Opatová	48.914	18.096	1	felt
Prejta	48.974	18.217	1	felt
Vyškovce nad Ipľom	48.072	18.864	1	felt
Žilina	49.219	18.751	1	felt

Table 8. Macroseismic observations for December 16, 2018 earthquake, 15:05 UTC.

Locality	Lat. [°N]	Lon. [°E]	No. of questionnaires	<i>I</i> [°EMS-98]
Prievaly	48.558	17.350	2	3
Bílikove Humence	48.586	17.238	1	3
Buková	48.544	17.411	1	3
Lakšárska Nová Ves	48.569	17.159	1	3

teractive seismological software Seismic Handler. Digital data are accessible both on-line and off-line in standard data format. So called Seismo Reports of seismic events recorded by NNSS are published on the web page of the ESI SAS <http://www.seismology.sk/SeismoReports/reports.html>.

The lack of system approach to financing of the NNSS persisted also in 2018. The contribution from the budget of the Slovak Academy of Sciences is assigned for a day-to-day operation of the NNSS with insufficient additional funds for network improvement. In 2018 one new broadband sensor was purchased (the new sensor replaced the functionless one on VYHS station).

Epicentres and local magnitudes were determined for 86 earthquakes originated on the territory of Slovakia in 2018. Weak seismic activity was recorded from several seismic source zones: Little Carpathians, Komárno, Záhorie, Strážov Mts. and Vepor Mts.

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