Assessment of the efficiency of seismological equipment in extreme weather conditions in Bulgaria - first stage of Livingston Island seismicity study

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Key words: seismicity on Livingston Island, seismological equipment, heavy weather conditions, ambient seismic noise and receiver function

Abstract

Study of seismicity on Livingston Island and surrounding area is carrying out in the frame of the project DFNI I02/11/2014 "Creating an information base for study of seismicity and Earth's structure on Livingston Island and surroundings through complex research in the Bulgarian Antarctic Base area". Seismological equipment was installed on Vitosha Mountain and was working during February 2015 to test the performance of the equipment in extreme weather conditions. The seismological equipment included Broad Band seismometer CMG40T and Reftek 130 digitizer. The performance of the equipment was compared to the equipment working in stable environment in the Vitosha station. The assessment of the efficiency of the seismometer CMG40T and digitizer Reftek130 proved that the equipment is suitable to explore the seismicity of Livingston Island and surroundings. Different methods, as power spectral density noise distribution, receiver function technique, surface wave inversion, etc, will be implemented to study the natural phenomena in Antarctic region.

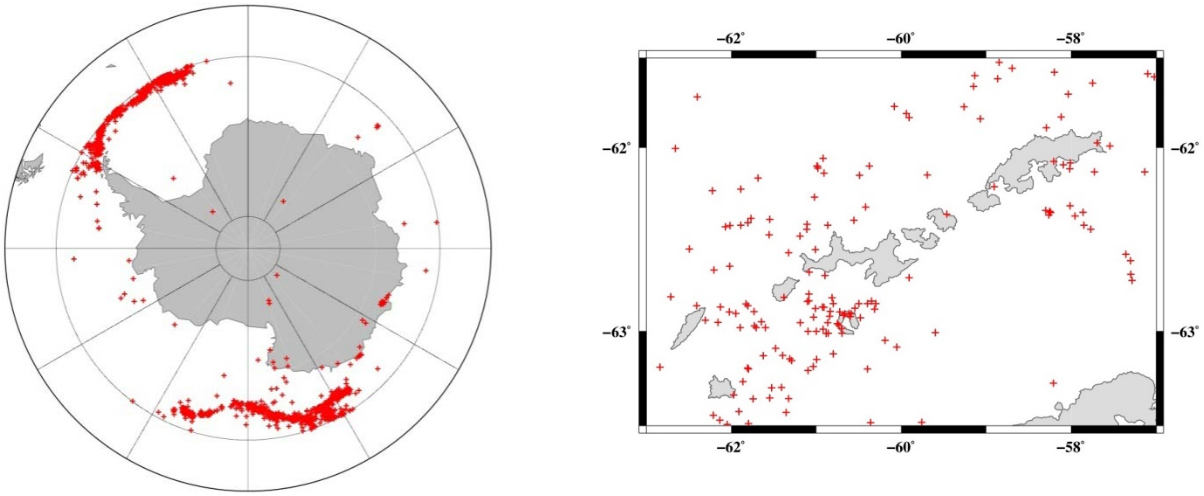
Резюме

Изследването на сеизмичността на остров Ливингстън и околните земи се провежда като част от проекта ДФНИ И02/11/2014 „Създаване на информационна база за изучаване на сеизмичността и структурата на Земята в района на остров Ливингстън и околните земи, чрез провеждане на комплексни изследвания в района на Българската антарктическа база". Избраната сеизмична апаратура беше инсталирана на Витоша през м. февруари 2015 и беше проведен тест за работоспособността на оборудването при тежки климатични условия. Апаратурата се състои от широколентов сеизмометър CMG40T и цифроващо устройство Reftek 130. Работата на апаратурата беше сравнена с тази на апаратурата, инсталирана в станция Витоша и работеща при постоянни условия. Резултатите от теста показват, че апаратурата е подходяща за изследване на сеизмичността на о. Ливингстъни околните земи. При провеждане на изследванията ще бъдат използвани методи като: разпределение на мощността на шума като функция на честотата на сигнала, функцията на приемника, инверсия по повърхностни вълни и др.

Seismicity of Antarctica

Seismicity, observed in Antarctica, is very weak in comparison to other continental regions. The continent is confined by two seismically active zones - Scotia Sea in north direction from Antarctic Peninsula and East Australian Antarctic Ridge. The locations of earthquakes with magnitude greater than 4.0 are shown in Fig. 1a. The mapped data are for the period from 1916 to 2011 and are taken from revised bulletin of ISC (2015).

Livingston Island is prone to three type seismicity – volcanic, tectonic and iced related seismicity. Livingston Island is close to the Scotia Sea seismic zone. The earthquakes in the north of the Peninsula and Livingston Island are associated with subduction in the Bransfield Strait (Robertson et al., 2002). The seismicity on the continent is separated in three settings – Trance Antarctic Mountain Events identified as tectonic; isolated events in the interior of the continent related to tectonics; and ice related coastal events (Reading, 2007). Seismicity in the region of Livingston Island is shown in Fig. 1b, where all events from ISC in the period 1916-2011 are plotted.



(a) (b)

Fig.1. Seismicity in Antarctic continent and in the region of island Livingston.

Antarctica is a perfect laboratory for exploring natural phenomena – the subduction zone; volcanic, tectonic and ice related seismicity. The research is carried out in a human noise free environment. In the last decades a large number of seismic stations are installed by scientific institutions from different countries. As a result the number of registered earthquakes increases. However the minimal magnitude Mb of the events is still around value of 3.0. Table 1 gives the annual distribution of the earthquakes in the period 1991-2011 with minimal and maximal values of Mb of the events during the relevant year.

Seismicity from the Pacific-Indian ridge, on the opposite direction of Antarctic continent in respect to Livingston Island will be suitable to study the average velocity structure of the Antarctic zone by surface wave inversion as in Raykova and Nikolova (2003).

Table 1.

Year	No events	min Mb	max Mb
1991	20	4.1	5.8
1992	19	4.2	6.2
1993	25	4.0	6.2
1994	15	4.4	5.3
1995	35	4.0	5.9
1996	66	3.2	6.2
1997	122	3.2	5.7
1998	320	3.0	7.0
1999	137	3.2	5.1
2000	77	3.4	6.4
2001	78	3.4	5.5

2002	60	3.4	6.0
2003	219	3.4	6.4
2004	88	3.5	6.2
2005	64	3.2	6.0
2006	107	3.4	7.3
2007	128	3.5	6.0
2008	112	3.3	6.4
2009	149	3.3	6.2
2010	252	3.3	6.0
2011	137	3.2	5.8

Bulgarian experience

Bulgarian Antarctic Base was funded in 1987/88 when an expedition to Antarctica was organized on the occasion of 100th anniversary of the Sofia University “St. Kliment Ohridski”. The expedition was supported by the State Committee of Researches and Technologies, the British Antarctic Service and the Soviet Antarctic and Arctic Scientific Research Institute.

Scientific researches in different fields have been conducted every Antarctic summer since 1993. Registration of seismic events was done during the astral summer 2000-2001 (Rangelov, 2002) using 4.5 Hz short-period geophone and digital autonomous device, working in triggered mode.

Complex seismological research is planned to be carried out in the frame of the project DFNI I02/11 “Creating an information base for exploration of seismicity and Earth structure of Livingston island and surroundings by complex research in the Bulgarian Arctic Base area” during the next two expeditions to Bulgarian Antarctic Base (Antarctic summers 2015-2016 and 2016-2017).

Broadband seismological equipment is expected to be installed on Livingston Island in the vicinity of the Bulgarian Antarctic Base. The equipment consists of Broad Band (BB) seismometer Guralp CMG40T with flat frequency response from 30s to 50Hz and digitizer Reftek DAS130. The digitizer works in continues mode of registration and has 2 flash memory cards with 2 GB capacity guaranteeing long term autonomous operation mode.

The first stage of the project consists in exploration of the equipment performance in heavy weather conditions (strong wind and low temperature during the winter), close to the conditions on Livingston Island. The apparatuses were installed on Vitosha Mountain in the back yard of Vitosha Geophysics Observatory. The seismometer was installed over the existing pavement and was covered by thermo isolation (Fig. 2). The digitizer was mounted close to the seismometer in a small shack. The equipment was working in February of 2015.

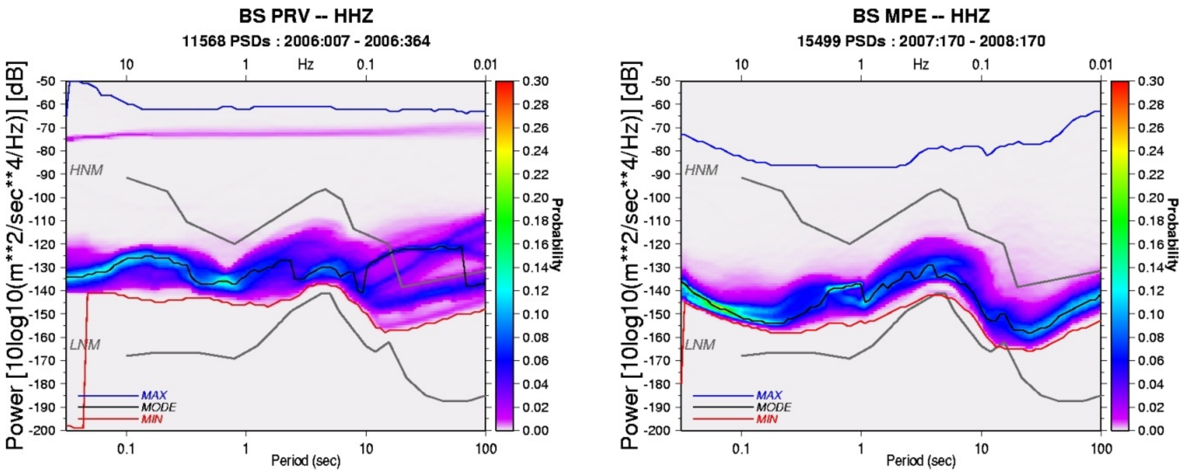
Fig.2. Seismometer CMG40T and termo isolation

As a part of Bulgarian Seismological Network two very broadband (VBB) seismometers are also in exploitation at Vitosha station. Both seismometers are situated on pillars in a 50 m long tunnel, with very stable environment. This is an opportunity to compare the performance of the seismological equipment working outside of the building to the performance of the apparatuses working in the conditions without temperature fluctuations and air flow.

Exploring ambient seismic noise

The main sources of the ambient seismic noise are the human activity close to or at the Earth surface on the one hand and on the other hand - natural phenomena like strong wind, sea and ocean storms, hurricanes etc. The power distribution of the noise (PSD) in worldwide scale as a function of period is presented by two models – New Low Noise Mode (NLNM) and New High Noise Model (NHNM) (Peterson, 1993- gray curves in Fig. 3a,b). The most dominant features, so called microseisms, are revealed in the ranges between 5-8 s (double frequency peak) and 10-18s (single frequency peak). The amplitude of the peaks depends on the location of the recording seismic station. As the seismic station is situated closer to the shore as the power of the double and single frequency peaks is the higher (Dimitrova & Nikolova, 2011).

The distribution of the man-made noise is in the period range below 1s. Each station has own noise distribution model that depends on the specific noise sources (Dimitrova, 2009). The Figs. 3a and 3b present the annual distribution of the ambient noise at two Bulgarian seismic stations PRV and MPE. The station Provadia (PRV) is situated 50 km far from Black Sea and the station Malo Peshtene (MPE) is 400km away from the Black Sea. The noise level in Fig.3a is 20 dB higher than the level in Fig.3b. The source of the noise registered by Provadya station (Fig.3a) is heavy road traffic several kilometers away while the noise in Malo Peshtene (Fig.3b) station is produced by working machineries on the several ten kilometers distance.

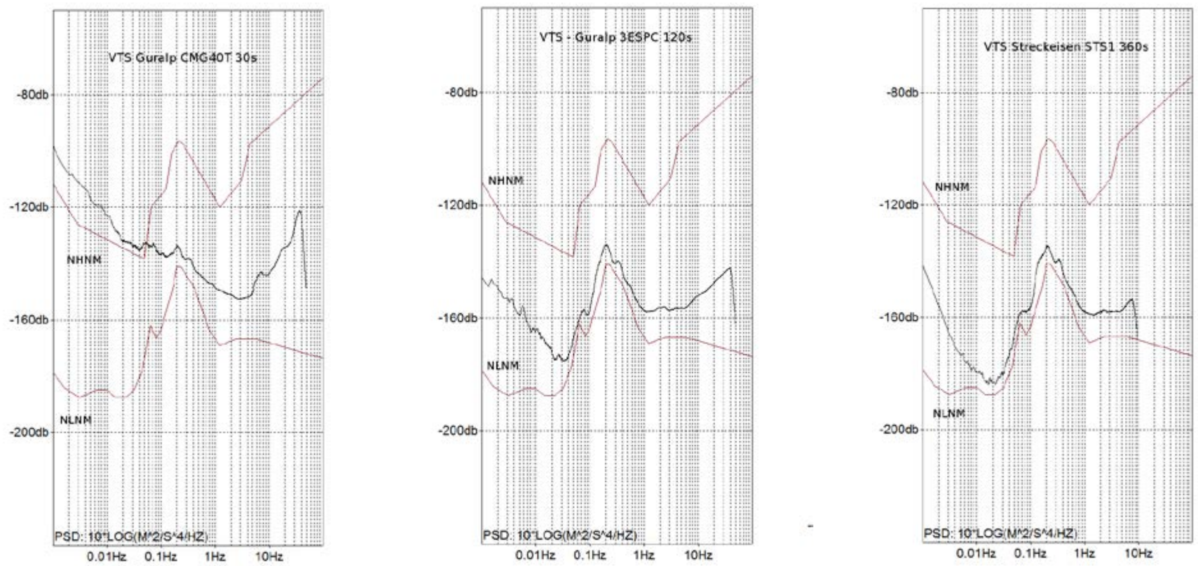


(a) Provadya (b) Malo Peshtene

Fig.3. Annual distribution of the PSD at stations PRV (a) and MPE (b).

The registration of the microseisms depends strongly on the frequency response of the sensors. The distribution of PSD of three seismometers (one BB and 2 VBB) is presented in Fig. 4 as a function of frequency. –The BB seismometer Guralp CMG40T, with typical response from 30 s to 50 Hz, records well the double frequency peak (Fig. 4a), while the VBB seismometer CMG 3ESPC with lower corner frequency 120 s and VBB seismometer STS1 whit lower frequency 360 s record both the double and the single peaks (Figs. 4b and 4c).

Despite of lack of human activity on Livingston Island, we plan to install the seismic station one kilometer far from Bulgarian Antarctic Base in order to avoid as much as possible the anthropoid noise. It is expected to register seismic noise produced exclusively by natural phenomena like moving glacier, falling icebergs, earthquakes, and etc.



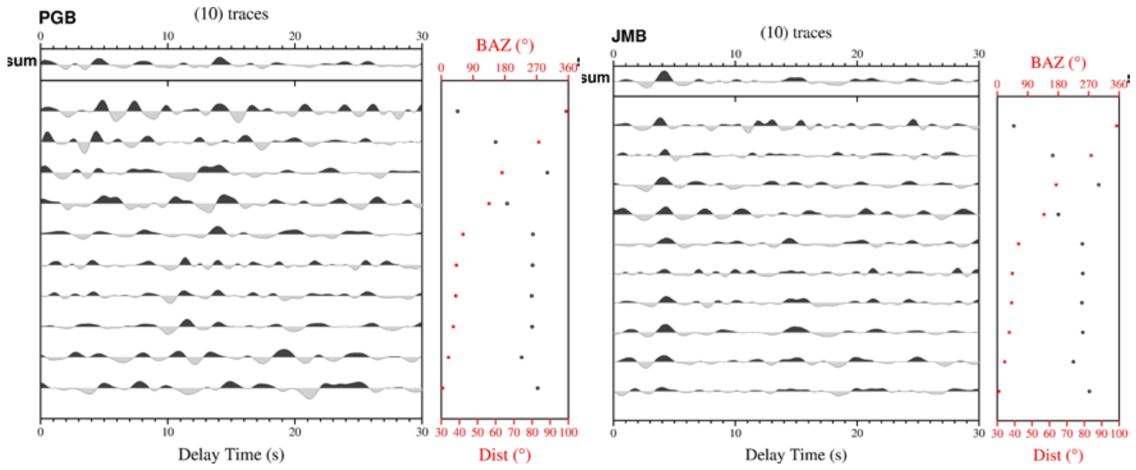
(a) CMG40T (b) CMG3ESPC (c) STS1

Fig.4. Registration of the microseisms at the station Vitosha (VTS) by three types of seismometers: (a) BB Guralp CMG40T, (b) VBB Guralp CMG3ESPC (120s), and (c) VBB STS1 (360s).

Ambient noise registered by BB seismometer in frequency range between 10 Hz to 0.5 Hz is 10 dB higher than the noise registered by both VBB seismometers as it is seen by three PSD distributions, presented in Fig. 4. The main part of the resulting increment of the level of the noise is caused by weather conditions outside of the building. Such effect and behavior of the BB seismometer should be expected on Livingston Island. We should found a quiet place without strong wind and more thermal isolation should be added in the seismometer installation in order to reduce the noise level in frequency range around 1 Hz.

Receiver function technique

One of the best techniques to study Earth's structure in areas with small number of seismic stations is receiver function technique. It was successful applied to the data from 11 seismic stations of Bulgarian Digital Seismological Network (Georgieva and Nikolova, 2013). We plan to apply this technique to data from the station on Livingston Island. A small number of seismic events with epicentral distance in range 30-95^o and magnitudes between 5,5 and 7,5 are enough to obtain the crustal and mantle structure beneath the station. To demonstrate the possibilities of receiver function technique 10 earthquakes recorded by stations PGB and JMB are selected. Both seismic stations are equipped with Guralp 40T seismometer and digitizer DAS 130, identical to the equipment to be used on the Livingston Island. Figs. 5a and 5b show receiver functions for selected earthquakes. Clear Ps phase from Moho boundary (Fig.5b) for station JMB is observed, even the small number of the used events. Ps phase for station PGB is difficult to distinguish, because of the complex structure obtained beneath this station.



(a) (b)

Fig.5. The receiver functions from 10 earthquakes, registered at stations PGB (a) and JMB (b).

Conclusions

Livingston Island is prone to three type seismicity – volcanic, tectonic and iced related seismicity. Bulgarian Antarctic Base on Livingston Island gives opportunity to explore these natural phenomena. The installation of broadband seismometer in the vicinity of Bulgarian Antarctic Base will give possibility to register some local, low magnitude earthquakes and seismic activity of the Scotia subduction zone. Registration of the events from Pacific-Indian ridge zone will give the possibility to use the surface wave analysis to explore the crustal and upper mantle structure of Antarctic continent. Exploring the ambient noise will answer questions related to the behavior of the glaciers, ice cover and sea ice which is in close dependence on the climate changes. Some methods and techniques to study of the seismic records from Livingston Island were tested for small number of events and in heavy weather conditions. The provided preliminary tests in Bulgaria proved the suitability of the selected seismic equipment for the purposes of the research.

Acknowledgment

The presented paper and the test results of seismological equipment are part of the project DFNI I02/11/2014 “Creating an information base for exploration of seismicity and Earth structure of Livingston island and surroundings by complex research in the Bulgarian Arctic Base area” supported by the Science Research Fund to Bulgarian Ministry of Education and Science for a period of 2 years.

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