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Research Article

The contribution of the seismic station "Severnaya Zemlya" to the study of arctic seismicity

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Abstract

At present, a relevant task consists in understanding the seismicity of the European Arctic sector in general and the Barents-Kara region in particular. Due to the small number of seismic stations installed in the Arctic region our understanding of the seismicity of the Arctic is still not properly investigated. However, as a consequence of the operationalisation of the seismic station SVZ Severnaya Zemlya on the Severnaya Zemlya archipelago since 2016, it has become possible to record and process an increased number of seismic events. Data from the Arkhangelsk seismic network were compared with a map of the spatial distribution of earthquake epicentres in the Barents-Kara region and adjacent waters for 2017–2018 created by various seismological agencies. The distribution of the number of earthquakes by magnitude and location registered by the Arkhangelsk seismic network for 2012–2018 are presented. The greatest number of earthquakes is associated with the Gakkel, Knipovich and Mohn Ridges, while the lowest number is associated with the St. Anne trough We compared the number of earthquakes recorded by the Arkhangelsk seismic network in 2017–2018 with those recorded by the Severnaya Zemlya station in the same period. The increased number of recorded earthquakes indicates the importance of opening the Severnaya Zemlya station in Arctic region. The microseismic background level was considered and charts drawn up comparing the daily power spectra of SVZ for the "best" and the "worst" months in terms of seismogram quality. Using an earthquake recorded in the eastern part of the Gakkel ridge as an example, the effective processing of the earthquake record in the WSG software package including the operation of the new SVZ station is demonstrated.

Keywords

Severnaya Zemlya archipelago, seismic station, earthquakes

Introduction

In order to be able to accurately assess the level of seismic hazard of the Arctic territories, it is necessary to advance the understanding of the contemporary geodynamics of the Arctic zone of the Russian Federation. However, the insufficient number of seismic stations in the Russian Arctic for carrying out detailed studies results in a need to develop new stations as a priority task (Antonovskaya et al. 2017). In the present work, we consider the contribution made by the Severnaya Zemlya seismic station to the regional monitoring of the Barents-Kara region and adjacent territories. This seismic facility was installed on Bolshevik Island in the Severnaya Zemlya archipelago on the territory of the research base of the Arctic and Antarctic Research Institute (AARI).

Current state of the Arkhangelsk seismic network (ASN)

At present, the Arkhangelsk regional network of seismic observations consists of 9 stations (International Seismological Centre 2019). The network was established in 2003 when the Arkhangelsk and Klimovskaya stations were opened within the framework of the Institute of Environmental Problems of the North, affiliated with the Ural Branch of the Russian Academy of Sciences (currently the N. Laverov Federal Centre for Integrated Arctic Research Federal State Budgetary Research Institution (FPFIS FCIAR RAS)) with the support of the Geophysical Service of the Russian Academy of Sciences (currently the Federal Research Centre “United Geophysical Service of the Russian Academy of Sciences” (FRC UGS RAS) (Yudakhin et al. 2012). From 2011 to 2017, the following stations were installed by FPFIS FCIAR RAS employees: Amderma (AMDE), Zemlya Franca-Iocifa (ZFI), Omega (OMEGA) and Severnaya Zemlya (SVZ). In 2014, an agreement on mutual collaboration was concluded with the International Seismological Centre (ISC, UK); since then, FCIAR RAS seismology laboratory employees have compiled regular teleseismic and local events bulletins, with a particular focus on the Arctic (Morozov et al. 2015).

Currently, the configuration of the Arkhangelsk Seismic Network (ASN) supports seismological monitoring of the Barents-Kara region and adjacent waters. Figure 1 shows the number of recorded events in the European sector of the Arctic by ASN stations compared to other seismological networks for 2017–2018 (information taken from the ISC database). The map is drawn using the ArcGIS 10 software package. As can be seen, the ASN makes a significant contribution to the study of Arctic seismicity, primarily in terms of the location of events. ASN stations record a large number of earthquakes occurring around the Gakkel ridge and shelf area, as well as in the Barents-Kara region.

Materials and methods

In this paper, an analysis of the data recorded by the Severnaya Zemlya seismic station is presented. This station was opened at the end of 2016 thanks to the joint efforts of the seismology laboratory of the N. Laverov Federal Centre for Integrated Arctic Research of the Russian Academy of Sciences (FPFIS FCIAR RAS) and the Ice Physics Laboratory of the Arctic and Antarctic Research Institute (AARI, St. Petersburg). The seismic vault, which houses the seismic equipment (digital velocimeter CMG-6TD, Guralp, UK), is a hydro- and heat-insulated metal box. Digital seismic data from the velocimeter are transmitted to a local computer installed in the building of the AARI research base. The transfer of seismic data from the SVZ station computer is carried out subsequently by synchronising them on the AANII server through the internal virtual network. After being synchronised via the Internet on the server of the seismology laboratory of FCIAR RAS and converted for processing in the WSG software package (developed by the Federal Information Centre of United Geophysical Service of the Russian Academy of Sciences (FIC UGS RAS) and LLC “NPP Geotech”), the data from the AANII server are then stored in the archive (Antonovskaya 2018).

The waveforms of earthquakes are processed using the resection method using the WSG software package. After manually selecting the filtering mode in

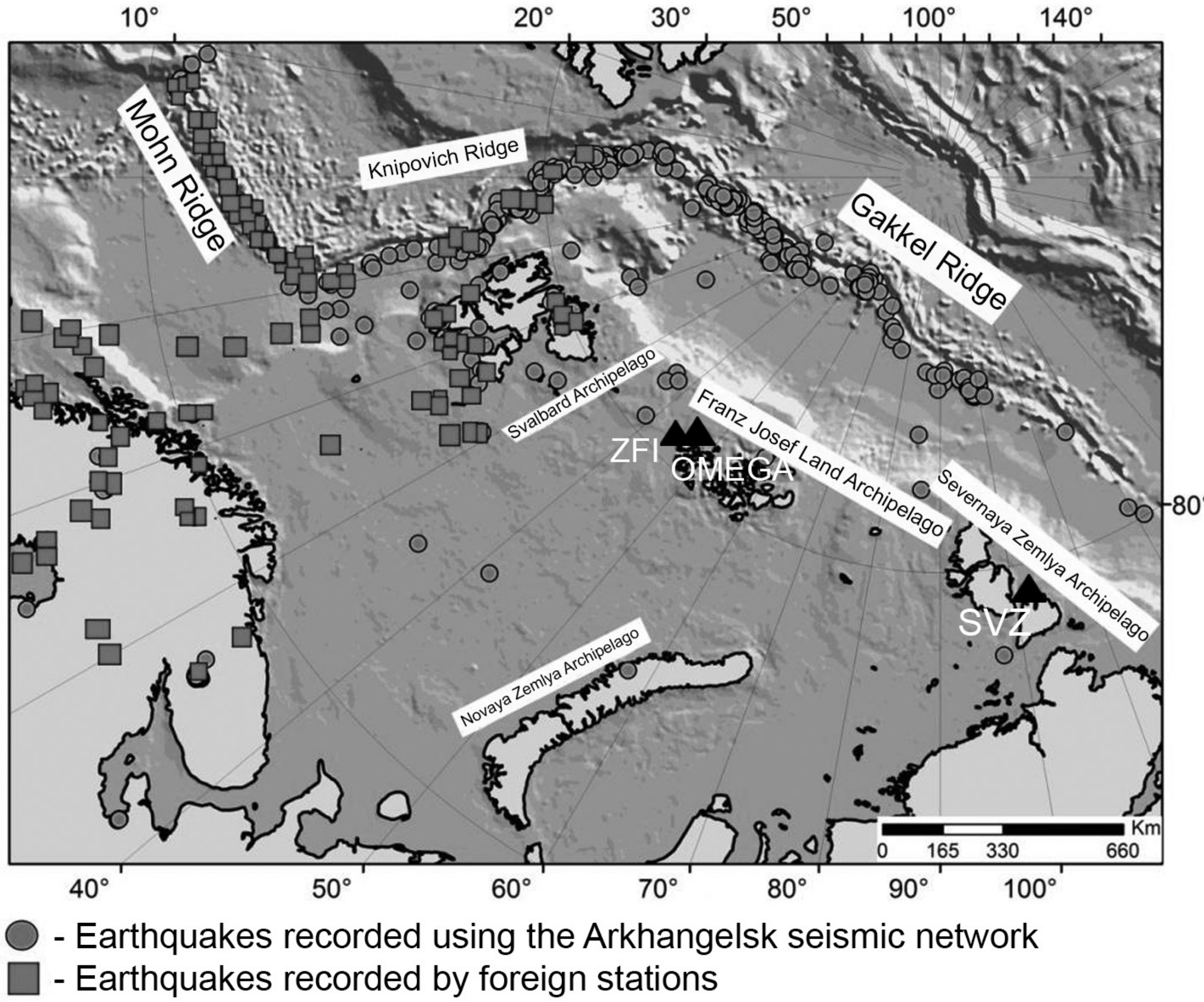

Fig. 1. Map of the spatial distribution of earthquake epicentres in the Barents-Kara region and adjacent waters for 2017–2018 recorded by various seismological agencies (according to ISC data) and compared with the results obtained by the Arkhangelsk seismic network

which the earthquake appears most clearly along with the main phases of seismic waves and hodograph, the earthquake epicentre is determined automatically. The same procedure is performed for each station that registered a seismic event. The epicentre of the earthquake is then visually displayed via the WSG software package's built-in mapping function.

Table 1 presents the distribution of the number of earthquakes recorded by the ASN for 2012–2018 by region. The magnitude range of recorded events over the same years is shown in Figure 2.

An analysis of Table 1 shows that an increase in the number of recorded earthquakes in the Barents-Kara region since 2017 is directly related to the opening of the Severnaya Zemlya seismic station. The maximum number of earthquakes recorded by ASN occurs in the Knipovich and Gakkel Ridge areas due to the rifting processes taking place in these zones, while the lowest number of earthquakes is registered near Bely Island and the St. Anne Trench, indicating the relatively tectonically stable nature of these structures.

Table 1. Magnitude distribution of the number of earthquakes recorded by the Arkhangelsk seismic network for 2012–2018

Structures and objects	Years						
	2012	2013	2014	2015	2016	2017	2018
Knipovich Ridge	72	156	154	64	100	113	114
Svalbard Archipelago	27	98	68	50	106	74	37
Gakkel Ridge	91	106	169	46	82	120	132
Mohn Ridge		3	4	4	15	7	5
St. Anne Trough	4				1		3
Bely and Victoria Rise	2	1	9	2		2	
Novaya Zemlya Archipelago		1	1			1	1
Severnaya Zemlya Archipelago		1			1	1	1
Iceland		3	45			1	
Franz-Victoria Trough	3	4	6	3	5	2	3
Bely Island		2			2		
Barents Sea		1		7	8	4	5
Greenland Sea		1	3	3	3		6
Total:	199	377	459	179	323	325	307

In particular, the Severnaya Zemlya station allows the recording of events from the eastern part of the Gakkel Ridge (Antonovskaya et al. 2019)

Results

Figure 2 shows the magnitude distribution diagrams of the earthquakes recorded by the Arkhangelsk network for 2012–2018.

An analysis of Figure 2 reveals an overall decrease in the number of recorded events having magnitudes below 3.5, while the number of registered earthquakes with magnitudes from 3.5 to 5 has increased. Earthquakes of a magnitude greater than 5 rarely occur in the Arctic region. One of the possible reasons for the decrease in the number of low-magnitude earthquakes is a change in the seismicity development trend of the region. A similar assessment was carried out for ASN stations operating on the Franz Josef Land archipelago. (Antonovskaya et al. 2019) The second, equally significant reason is related to the beginning of operation of the seismic station OMEGA in 2015. Meanwhile, it is possible to evaluate the contribution of the SVZ station to the overall monitoring of the Arctic on the basis of information presented in Table 2, which clearly indicates an increase in the total number of recorded events following the opening of this station.

Let us examine the analysis of the diurnal power spectra of microseisms recorded by the SVZ seismic station. Figure 3a shows a comparison between the diurnal power spectra of microseisms recorded by SVZ for different months of 2017 with a generalisation according to Peterson’s models (Peterson J. Observation and modelling of seismic background noise, 1993). Here, it can be seen that the increase in the microseismic background level occurs between July and September, which is probably associated with a general increase in economic activity in the summer Arctic period, open sea and melting snow cover, reducing the influence of exogenous factors (Antonovskaya et al. 2018). Due to the power spectra of the microseisms of this station not exceeding the limits of microseismic noise, as generalised by (Peterson J. Observation and modelling of seismic background noise, 1993, high-quality seismic records of recorded earthquakes can be obtained.

The “best” month for earthquake registration in 2017 for SVZ station is October, while the “worst” is August; this is due to the influence of exogenous factors, as explained above (Antonovskaya et al. 2018). Figure 3b, c show a comparison of the daily microseismic power spectra of the SVZ station for the “best” and “worst” months. As can be seen from the graphs, although the daily power spectra of microseisms in August have a greater variation than in October, they do not exceed the limits of low and high microseismic noise models.

Table 2. The number of earthquakes recorded by ASN with and without the contribution of SVZ in 2017–2018

Years	Number of recorded earthquakes	
	Arkhangelsk seismic network without SVZ station	Arkhangelsk seismic network, including the results of the SVZ station
2017	281	340
2018	215	314

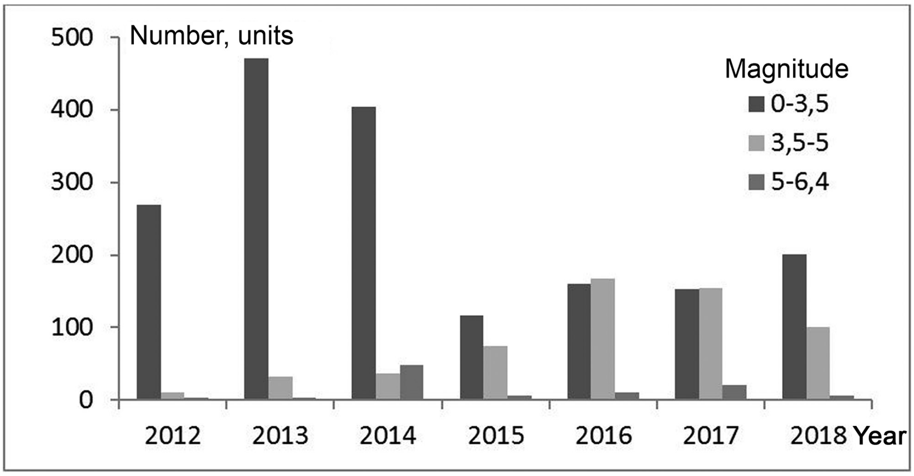

Fig. 2. Distribution of the number of the earthquakes recorded by the Arkhangelsk network by magnitudes for 2012–2018

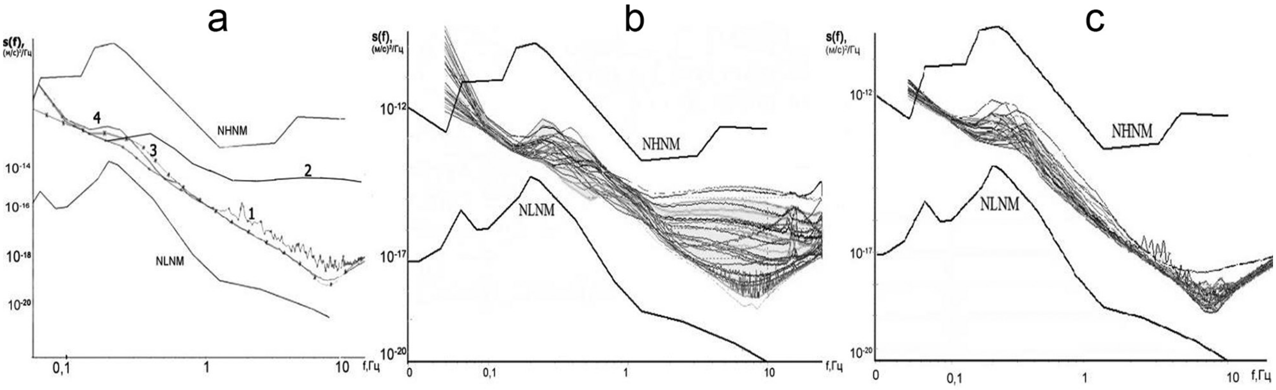

Fig. 3. Comparison of the daily power microseismic spectra of SVZ station for different months of 2017 with a generalisation by Peterson models: **a** – NLNM and NHNM – low and high microseismic noise models, respectively; 1 – May, 2 – August, 3 – October; 4 – December; **b** – diurnal power microseismic spectra in August; **c** – daily power microseismic spectra in October

An analysis of seismic events on SVZ station records. Figure 4 demonstrates the processing of an earthquake that occurred on 23rd December 2017 in the eastern part of the Gakkel Ridge: latitude – 84.98°; longitude – 88.47°; t_0 = 22:13:05; magnitude – 5.20. The data for processing the earthquake signal were gathered from eight seismic stations of various seismic services, including SVZ station. The event was processed in the WSG software package using a bandpass filter of 3–6 Hz for a better resolution.

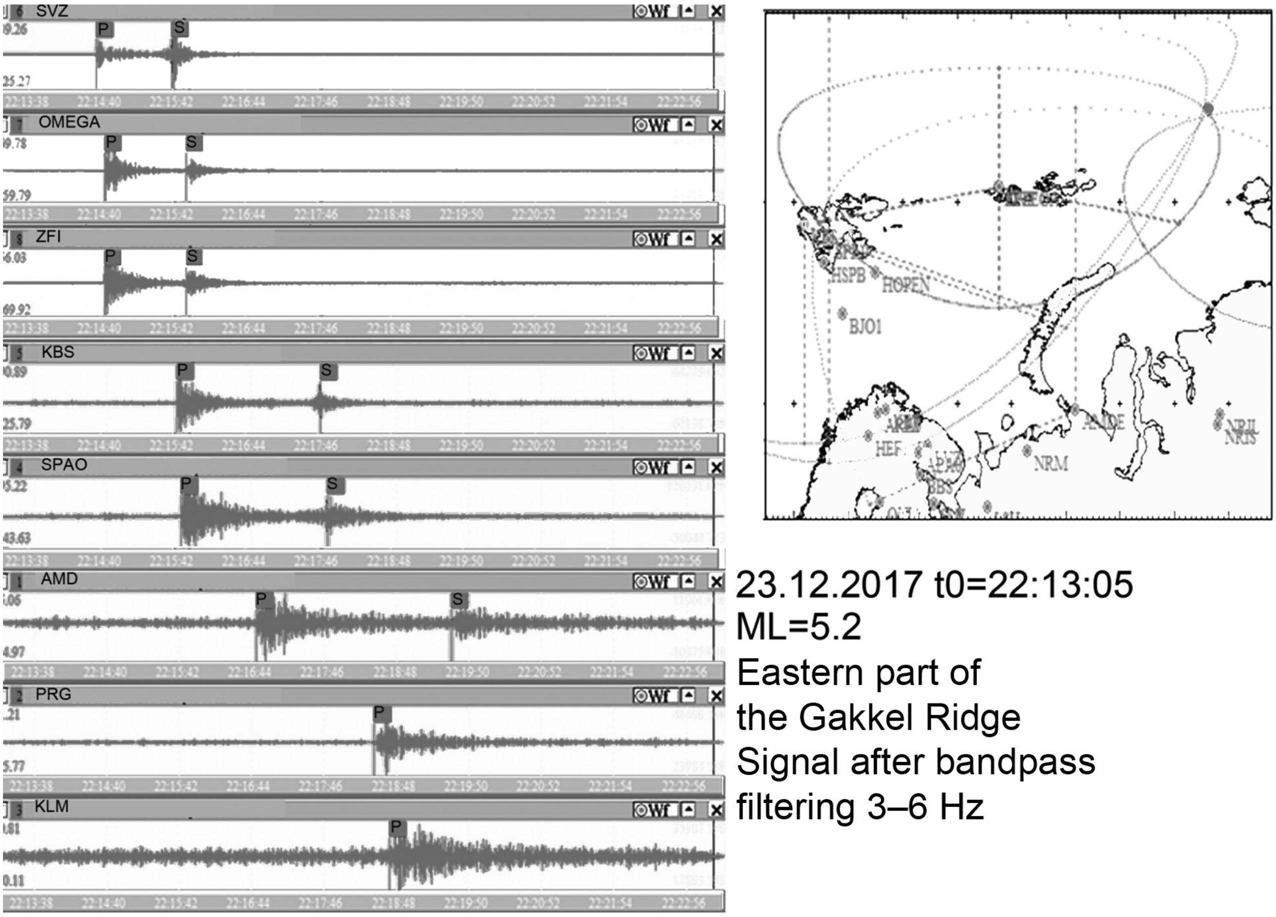

Fig. 4. Example of an earthquake recorded in the eastern part of the Gakkel Ridge, including the data collected by SVZ station

Discussion

The opening of the Severnaya Zemlya station – which became part of the Arkhangelsk seismic network under the code SVZ – resulted in an expansion of the monitoring geography in the Barents-Kara region to 100° East and an increase in the sensitivity of the network at the magnitude range above 3.5 for the entire region (Antonovskaya et al. 2019). Previously, the representative magnitude value for the Barents Sea region was estimated in the domain up to 60°E and amounted to 3.0. (Antonovskaya et al. 2019) On average, ACC began to register 70 earthquakes more in the Arctic region, which is important in the light of current plans on its future development and further study. Station SVZ mainly records earthquakes confined to the Gakkel Ridge, the Severnaya Zemlya archipelago and surrounding waters.

We would like to note that the predominant part of earthquakes recorded by the SVZ station is not included in the seismological catalogue since those events are recorded only by this station. It is known that, in order to determine the coordinates of the epicentre of the earthquake, it is necessary to use the records of at least three seismic stations. Nevertheless, it can be noted that these events are most likely to be confined to the Gakkel Ridge. This fact confirms the relevance of the development of seismic networks in the Russian Arctic.

Conclusion

The presented results demonstrate the importance of opening the Severnaya Zemlya archipelago seismic station for the purpose of broadening the perspective on the seismicity of the European Arctic sector generally and the Barents-Kara region in particular. Despite notable progress in monitoring the seismicity of the Arctic, further improvement of the observation system is necessary, which is in turn associated with the installation of new seismic stations.

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