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Research Article

Impact of seasonal variations of ambient seismic noise level on the number of registered earthquakes in the Arctic regions

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Abstract

Researchers at the Seismological Laboratory of the Institute of Geodynamics and Geology of the Federal Center for Integrated Arctic Research of the Russian Academy of Sciences (FCIARctic) have been engaged in the seismological monitoring of the European Arctic sector since 2011. In this paper, we present a comparative assessment of the earthquakes spatial distribution in this region based on the data from the International Seismological Centre (ISC) and the FCIARctic's Arkhangelsk Seismic Network (ASN) obtained in 2012–2016. The paper presents the waveforms of earthquakes occurred at the Gakkel Ridge and the Svalbard archipelago processed with the use of a Russian software package WSG (Windows Seismic Grafer) recommended by the Unified Geophysical Service of the Russian Academy of Sciences. A standard 4–8 Hz bandpass filter was used for the processing of regional Arctic earthquakes. The impact of seasonal variations on the quality of earthquakes registration was analysed based on the seismograms recorded by the ASN's island-based Arctic stations from 2012 to 2014 The same analysis was done for the central broadband sensor SPA0 of the Norwegian NORSAR-owned SPITS group installed at the Svalbard archipelago. A correlation has been established between the number of earthquakes recorded by the ASN's island Arctic stations and SPA0 station. The number of regional earthquakes, recorded by ASN's island Arctic stations is is smaller in summer-autumn periods than in winter periods. Forthe SPA0 station, which is part of SPITS group, there is not seasonality in the number of registered earthquakes. Generally, earthquakes are recorded uniformly, exception on January. This might be due to the increased seismic activity in the Svalbard archipelago during that period.

Keywords

Svalbard archipelago, seismic station, earthquakes, seismological monitoring

Introduction

Russia, Norway, Sweden, Finland, Denmark, and Poland are involved in the seismological monitoring of the European Arctic sector. These countries have their seismic stations on the territory of Scandinavia, the Kola Peninsula, the Arctic archipelagos Svalbard, Franz Joseph Land, Severnaya Zemlya, and Greenland. A broad range of data obtained by various seismological services is compiled into a single International Seismological Centre (ISC) catalogue. Since late 2011, the data, collected by Arkhangelsk Seismic Network (ASN) of FCIARctic, is used by the ISC for the global consolidated processing of the earthquakes occurred in the Arctic. Figure 1 shown comparison of the spatial distribution of earthquakes occurred above 70 degrees north latitude for five years from 2012 to 2016 according to the ISC combined catalogue data that includes the ASN data (Fig. 1a), and according to the ASN catalogue data only (Fig. 1b) (The unique research platform "Arkhangelsk Seismic Network").

Figure 1 demonstrates that the most of earthquake epicentres are located at the mid-arctic ridges of Gakkel, Knipovich, Mohn, and the Svalbard archipelago. Every year ISC processes more than 2,000 earthquakes occurred in the European Arctic. Typically up to ten strong (M ≥ 5.0 magnitude) earthquakes are recorded every year. All the earthquakes are crustal, i.e. have a depth no more than the Mohorovichich border depth (h = 33 km).

The following ASN stations operated in the Arctic region above 70 degrees north: Franz Joseph Land (ZFI), Omega (OMEGA) and Severnaya Zemlya (SVZ) (Fig. 1b). The catalogue contains data from 200 to 500 earthquakes recorded by the ASN annually.

On the Figure 1 one can see some inconsistency in terms of the location of some Arctic earthquakes. This may be caused by the fact that the ISC catalogue contains information about earthquakes recorded at least by three stations. The ASN catalogue includes data about all the earthquakes, including those recorded only by a single seismic station. These events were processed with using of the Event Locator (EL) software package provided by the Kola Branch of the United Geophysical Service of the Russian Academy of Sciences (KB UGS RAS). This package helps to approximate the most likely area of the epicentre location.

A comparative analysis of the seismic monitoring data presented in Fig. 1 proves that the ASN allows to significantly improve the results of the seismic monitoring of the Barents-Kara region and surrounding territories. We should point out, however,

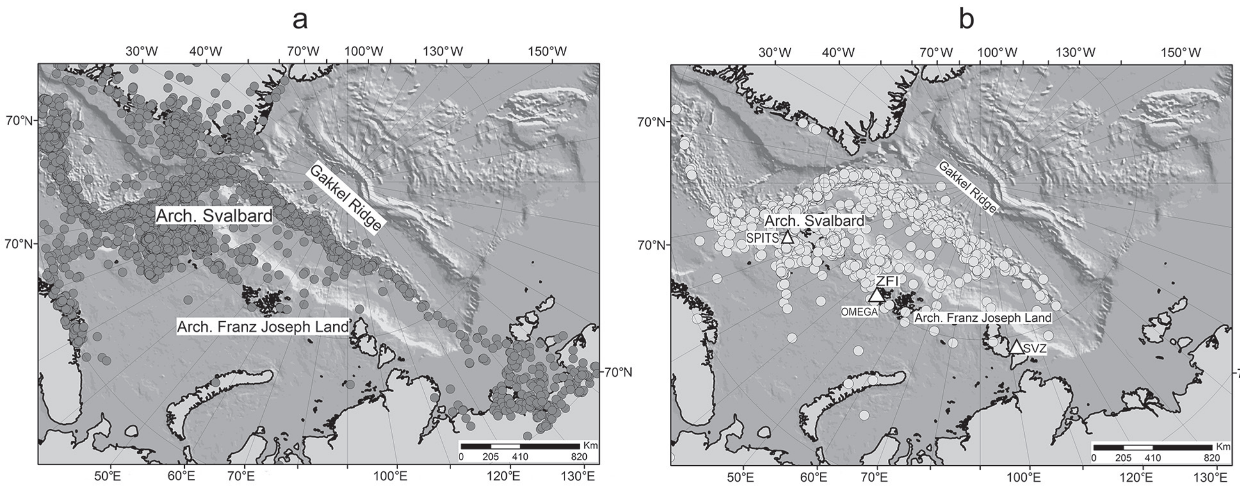

Fig. 1. Spatial distribution of earthquakes: a – according to ISC data for 2012–2016 (http://www.isc.ac.uk/) including ASN's contributions; b – according to data provided solely by ASN for 2012–2017

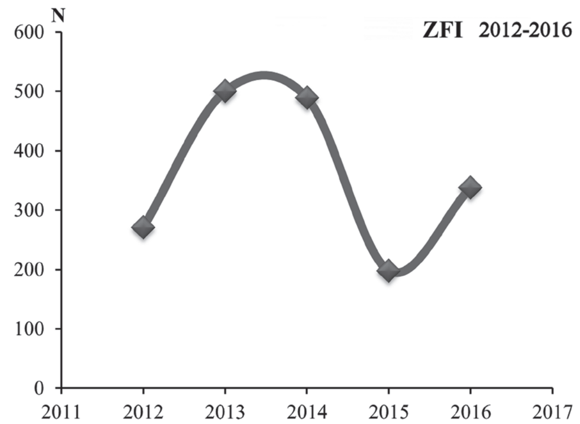

Fig. 2. Distribution of the number of earthquakes recorded by the ZFI station in 2012–2016

that the number of earthquakes recorded by ASN stations varies significantly from year to year. Fig. 2, shows the distribution of the number of earthquakes recorded by the ZFI seismic station from 2012 to 2016. Variation of ambient seismic noise level is one of the most important factors, which directly impact on the seismic monitoring quality and the number of recorded earthquakes. Relatively high level of ambient seismic noise makes problems on seismic data processing. . In this regard, this paper is aimed to quantify the impact of seasonal variations of background seismic noiseon the number of recorded earthquakes in the Arctic.

Data and methods

For the analysis of the impact of seasonal variations on the quality of earthquake registration we compared the ASN island Arctic stations data from 2012–2018 with the data obtained in 2012–2014 by the central broadband sensor SPA0 of the Norwegian NORSAR-owned SPITS group (International Registry of Seismograph Stations), installed in the Svalbard archipelago in 1992. The SPITS group is equipped with broadband seismological equipment; its borehole central sensor SPA0 makes it possible to register earthquakes of different energy classes by the SPITS sensor group. That is way the SPA0 data may be used as reference for the analysis of the operation of the Arctic stations.

The earthquakes were detected and processed with using of the WSG (Windows Seismic Grafer) software package developed by the Geophysical Service of the Russian Academy of Sciences (GS RAS) (Poigina and Krasilov 2019). For this, the standard 4–8 Hz bandpass filter was applied and the resection method was used.

Results

Generally, a record of a regional Arctic earthquake has a typical appearance with a sharp amplitude entry for both longitudinal and transverse waves. Fig. 3 presents a typical earthquake record from the western region of the Gakkel Ridge (magnitude M = 3) that occurred on February 7, t_0 = 03:15:28 and June 25, t_0 = 15:46:00 in 2013. It is evident that in the summer period (the lowest three waveforms) the records was noisier, despite on applying the standard 4–8 Hz bandpass filter. This complicates the processing of events.

According to (Spivak et al. 2004), the level of microseismic noise is affected by such factors as the region of registration, presence and nature of the distribution of local sources of microoscillations, nature of the propagation of the seismic waves in real medium, random ground movements and local conditions on the site at which the seismic measurements are made. Moreover, background microoscillations depend on resonance properties and relaxation processes of a particular rock mass. Prior studies (Asming et al. 2009) have shed some light on the issue of the impact seasonal factors have on the registration of low-magnitude events (ML < 2.2) in the Svalbard archipelago, aligned with the occurrence of glacial events whose frequency increases during the summer months.

According to our experience, NORSAR's seismic catalogues often omit to reflect earthquakes occurred north-east and east of the Svalbard archipelago. This is due to the priorities set by this company. Because of this, we re-processed the SPA0 seismic station re-

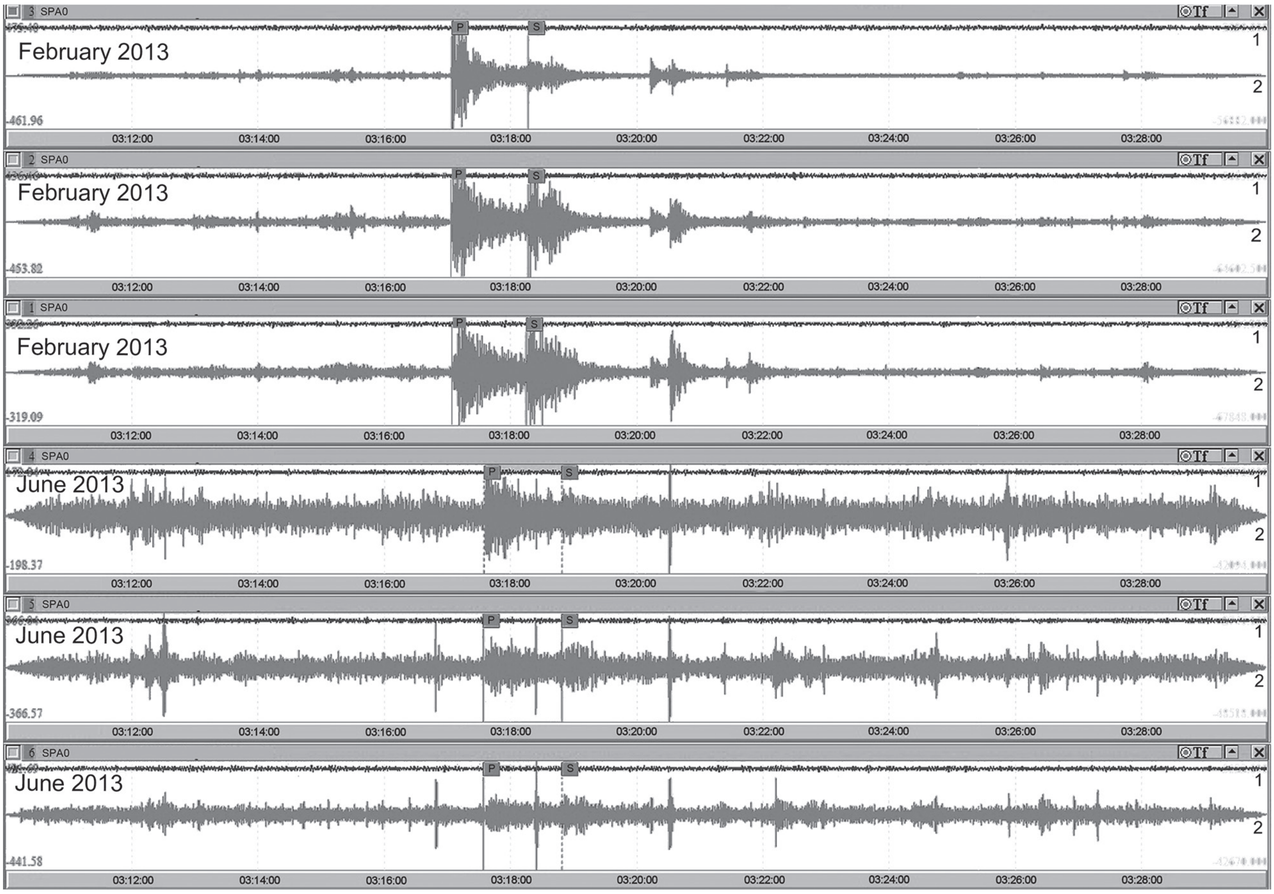

Fig. 3. Earthquake record example from western part of Gakkel Ridge recorded in February and June 2013: 1 – source signal; 2 – signal after bandpass filtering 4–8 Hz

cords. We analysed the three years (2012–2014) of the station operation and calculated distribution of the earthquakes recorded by SPITS (Fig. 4c). The data was compared to the records of the stations ZFI and SVZ (Fig. 4d, e) included in the ASN. For the ZFI station we have analysed the 2012–2018 period. Since the SVZ station started operation in 2017, we only had the opportunity to analyse the 2017–2018 data from SVZ.

The distribution diagram of the number of earthquakes recorded by the stations in various networks (Fig. 4) demonstrates that there is no apparent seasonality in the earthquake registration for the central SPA0 sensor. The number of recorded earthquakes, in general, remains the same, with the exception of January. This might be due to the increase of seismic activity in the Svalbard archipelago during this period. The conclusion that the records of higher magnitude events (ML > 2.4) have no seasonality has been suggested by Asming et al. 2009.

We would like to point out that the processing of ASN island Arctic stations seismic records resulted in an observation that in the summer-autumn period the number of recorded regional earthquakes is less than that in the winter period (Fig. 4 a, b). This might be due to an increased level of ambient seismic noise(Frantsuzova et al. 2014). This, in turn, might be caused by various external factors – an increasing of the anthropogenic environmental impact near the stations (vigorous economic activity, construction work, industrial equipment operation, etc.) and

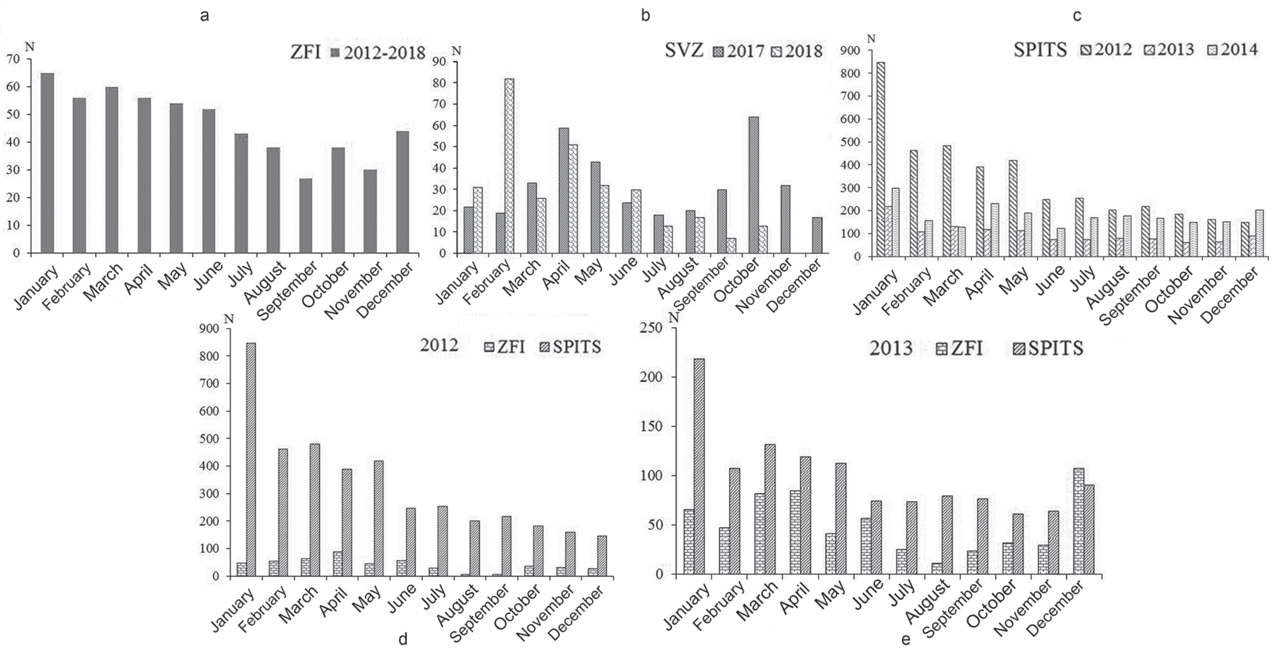

Fig. 4. Distribution of number of earthquakes recorded by different stations: a – average number of earthquakes in 2012–2018 recorded by ZFI; b – 2017–2018 – by SVZ; c – 2012–2014 – by SPITS; g – 2012 – by ZFI and SPITS; d – 2013 – by ZFI and SPITS

maintenance work at the stations themselves during which the equipment is turned off (Antonovskaya et al. 2018).

Discussion

It is a known fact that earthquakes are the markers of tectonic processes occurring in the Barents-Kara region (Verba et al. 2016). This determines the importance of seismic monitoring in this region. In our opinion, the almost total lack of seasonality in the registration of earthquakes by the SPA0 station (the apparent uniform temporal distribution of earthquakes during the year) is associated with the highest seismic activity of the arch-block rise of the Svalbard archipelago denying the opportunity of the detection of seasonal variations.

In addition, the types of seismic equipment and the quality of itsinstallation also may have an impact on the number of recorded earthquakes. For example, the SPA0 central station of the SPITS group is equipped with a three-component borehole seismometer installed at a depth of 2 m. The entire SPITS group is located away from human settlements.

Due to technical limitations, the ASN (ZFI, OMEGA, and SVZ) equipment was installed at a depth of no more than 80 cm; moreover, the seismic stations themselves are located near anthropogenic noise sources. This ultimately affects the number of recorded events. The principles and issues of the installation of ASN Arctic stations have been described in detail by Danilov et al. 2013.

Conclusion

The study suggested that the seasonal variations of ambient seismic noise level registered by the ASN stations, caused by technological factors, namely – the difficulty of subtracting an event against a background of anthropogenic noise, rather than natural causes. Installing seismic arrays instead of single stations is a solution that increases sensitivity of each registration point; in addition, it would be advisable to attempt reproducing the Norwegian success in installing seismic stations in the Arctic. We would also like to point out that putting the ASN Arctic stations in operation resulted in new data received on the seismicity of the entire Arctic region and the Barents-Kara area in particular.

Acknowledgments

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