THE NEW METHODIC FOR CRIOSPHERE CONTROL BY INFRASOUND AND SEISMIC DATA

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ABSTRACT

The paper provides results of experiment for seismo-infrasound monitoring of glaciers situated on the northern coast of Isfjorden bay, Spitsbergen Archipelago. The experiment showed that the glaciers produce seismic emission which enhances since the second part of July till the end of September. Diurnal variation of the seismic emission is close to the behavior of air temperature near the Earth surface. The seismo-infrasound events produced by the glaciers destruction were revealed in Spitsbergen for the warm time of year (Y.A. Vinogradov et al. (2012)). To detect and localize the seismo-infrasound events the methods based on the joint use of seismic records and data of infrasound monitoring was suggested. The experiment showed a convincing evidence of a possibility of monitoring glaciers destruction processes and iceberg formation by means seismo-infrasound methods.

Key words: Spitsbergen, glaciers destruction, seismic monitoring, infrasound monitoring, seismo-infrasound events.

INTRODUCTION

Since 2000 the Geophysical Survey, Kola Branch, Russian Academy of Sciences (GS KB RAS) has continually monitored the seismicity of the Spitsbergen archipelago. On the basis of seismic observation at a continental part of archipelago during the period 2000-2013 seasonal periodicity of weak seismic events has been revealed. The maximum number of seismic events is registered in the warmest months in a year - August and September. We have assumed that this increase is connected with increase of activity glaciers movement. We suppose that the annual variations of seismicity deal with processes in cryosphere which are controlled by seasonal fluctuations of the air temperature. During the period of positive temperatures Svalbard glaciers melt creating appropriate conditions for ice crevassing, appearing surging glaciers, and calving of tide glaciers. These processes in ice-cap generate seismic emission which is recorded by seismometers as a seismic event. It is known that during a glaciers movement it bursts producing sharp sounds. Registration of these acoustic waves and their comparison with seismic signals also was the primary goal of the research. For detecting infrasound signals an infrasound station has been installed near the seismic station BRBB in November 2010. The stations are located on a distance 4 km from settlement Barentsburg in order to reduce the level of human-made noise. The infrasound station consists of 3 low-frequency microphones. Each microphone is established in the wind-reduce filter.

132 glaciers are located in the central and northern part of Spitsbergen archipelago, more than 90 from them are surging. Two nearest for our seismic station surging glaciers – Esmark glacier and Nansen glacier – are located at distance 24 and 26 km to the north and north-east from the stations. These glaciers are rather small on capacity but in 2007 and in 2010 a lot of seismic events have been registered under them.

It was supposed that the infrasound station will allow registering the signals arising at cleaving of glaciers and the seismic station will register the signals caused by glaciers movement.

THE HARDWARE EQUIPMENT

The BRBB station was installed stationary on the northern outskirts of the Barentsburg settlement (coordinates 78.094° N and 14.208° E)(more detail information at Asming et al.(2013)). We use polar version of compact broadband Guralp CMG- 3ESP seismometer and Guralp DM24 digitizer. The system has next specifications:

Frequency range: 1/60 Hz – 50 Hz
Sensitivity: 2 x 1000 V/m/s
Gain: 3.18 microV/count
Sampling frequency : 40 Hz.

A small aperture infrasound micro-array was installed stationary near a broadband seismic station BRBB (figure 1). The micro-array consists of three microphones which are placed at the vertices of an isosceles triangle. The length of the long edge is ~230 meters and the length of the short edge is ~150 m.

The seismic and infrasound data is collected in a central cabin and transmitted to the Kola branch of the Geophysical Survey of the RAS by Internet. Currently it is a unique station for all-year-round joint seismic and infrasound observations in this zone of the Arctic.

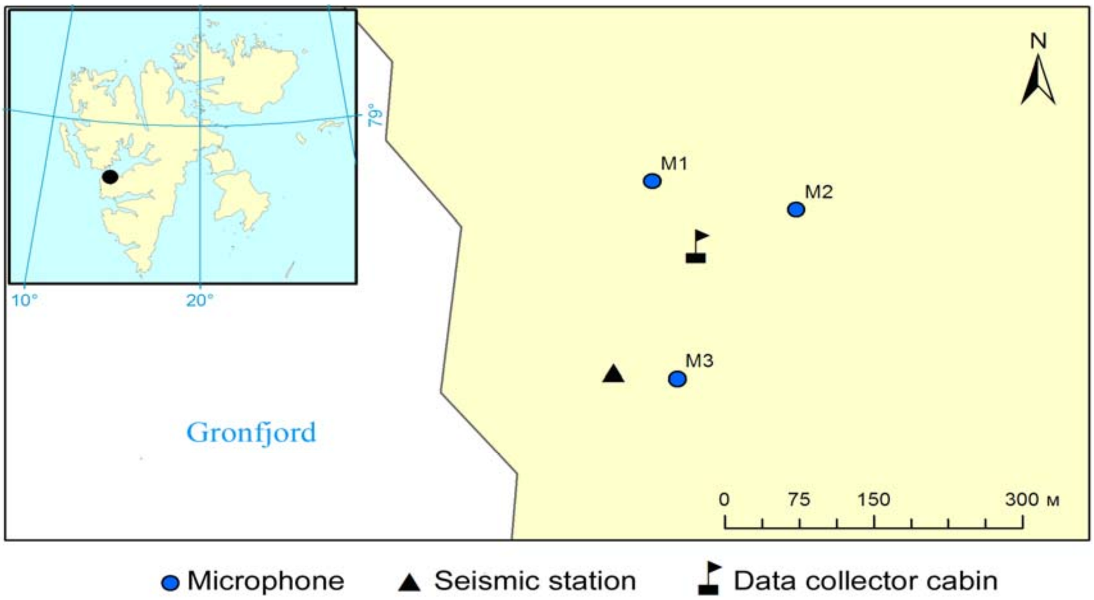

Figure 1. Position of BRBB infrasound micro-array

As infrasound sensors we used a Microphone MP-201 (BSWA Corporation) and the 24-bit 4-channel analog-to-digital converter (ADC) E 24 made by L Card Corporation with next specifications:

Class of accuracy: 1
Sensitivity : 50 mV/Pa
Frequency response: 6Hz-20kHz
Operating temperature (°C): -30 ~ 80
Sampling frequency : 40 Hz

A temporary 3-C seismic station was installed near the Esmark glacier. It was in operation only at summer time 2012-2013. As sensor we use digital Guralp-6TD seismometer with next specifications:

Frequency range: 1/30 Hz – 50 Hz

Sensitivity: 2 x 2000 V/m/s
Sampling frequency : 100 Hz.

PRELIMINARY RESULT OF DATA PROCESSING AND DISCUSSION

The infrasound micro-array can record infrasound events of different origins and frequencies:
1) Calving of glaciers (1-15 Hz)
2) Microbaroms (<1Hz)
3) Man-caused signals like helicopter flights (>10 Hz)
Distribution of the number of infrasound events by the month of year shows that the majority of events occurred from July to October and have a maximum on August. The temperature plot shows that the period of above-zero temperature coincides with the increase in infrasonic events with a short time delay (Figure 2).
Also, the time of above-zero temperatures coincides with the period of glacial acceleration associated with active glacier destruction
The majority of events of natural origin are detected in two frequency bands: 1-5Hz and 5-15Hz. Most infrasonic events have been recorded from northerly directions where the closest active glaciers are situated and there is no human activity.

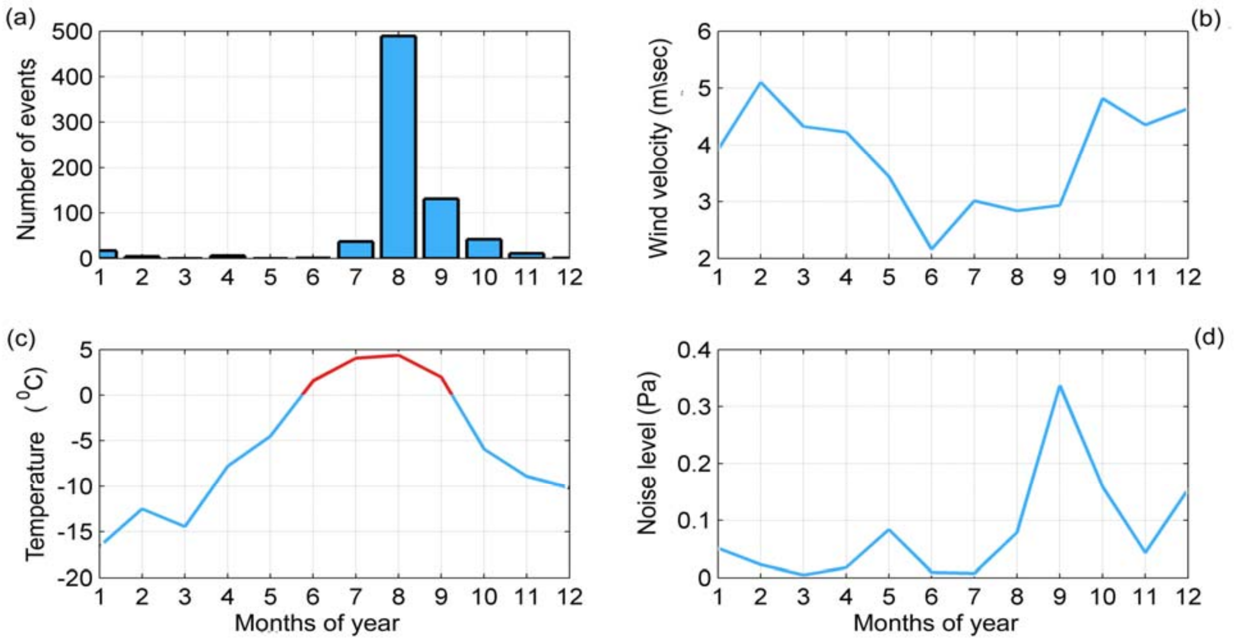

Figure 2. *a* – distribution of number of events by months; *b* – wind velocity diagram; *c* – temperature diagram; *d* – noise level diagram

To reveal seismic events recorded by ESM station we used STA/LTA detector. In this way we detected 16136 signals with STA/LTA > 2.5. The use of such simple technique for signal detection is reasonable because ESM station is far from anthropogenic noise sources. In order to satisfy Gutenberg-Richter (G-R) Law we restrict ourselves considering the signals for which the logarithms of their amplitudes are greater than 2.5 and less than 4.2 (Fig. 3a). This condition is fulfilled for 13% records.

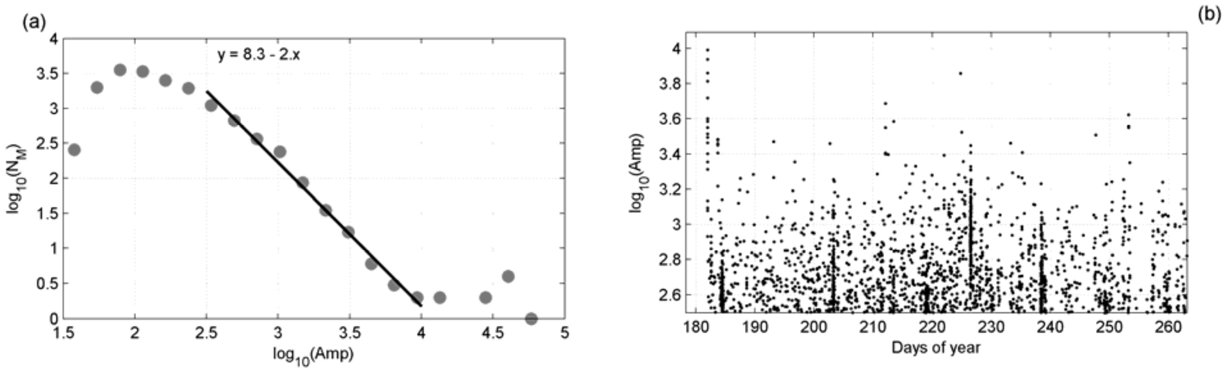

Figure 3. Seismic emission recorded by ESM station. (a) – Dependence of number of revealed signals with STA/LTA detector on logarithm of their amplitudes (records with the amplitudes from [3, 4.2] obey G-R Law). (b) – Logarithms of amplitudes of revealed events which obey G-R Law.

The dynamics of seismic events from the glaciers in the northern part of Isfjorden is shown in Fig. 3b. One can see that there are some periods (182, 202, 226, 238, 253 days of 2013) during which seismic activity increased. According to Amundson et al. (2010) research conducted in Iceland glaciers such seismicity pattern is observed just after a calving event. Thus we suppose that the observed seismicity increases (Fig. 3b) were caused by calving events.

Also we have made joint location by seismic P-S and infrasound back azimuths and used polarization by ESM station for some events. Most of the events were located to the Esmark glacier border and a few to the Nansen and Harriet glaciers. The results of locations are shown on Figure 4. So we can conclude that increase of number of infrasound events in summer-autumn time is connected with glacial destruction.

We suggest that during the period of positive temperatures Svalbard glaciers melt creating appropriate conditions for ice crevassing, appearing surging glaciers, and calving of tide glaciers. Melt water penetrate through cracks and faults in the upper part of the lithosphere as a kind of "grease" that promotes tectonic processes. In summer time speed of the surge glaciers are increased, the movement of it can cause seismic events. These processes in ice-cap generate acoustic and seismic emission which is recorded by seismic and infrasound stations.

CONCLUSIONS AND ACKNOWLEDGEMENTS

The first results of observations showed the following:

1. A registration of infrasound signals in difficult weather conditions on Svalbard is possible.
2. Most part of recorded infrasound events came from close distances and were associated with processes on a nearest glaciers.
3. The joint analysis of seismic and infrasound data may provide new information about the glaciers destruction and surging.
4. The complex seismic-infrasound observation for glacier destruction can get new information about climate changing and also can increase shipping safety by providing data about the creation of large icebergs.

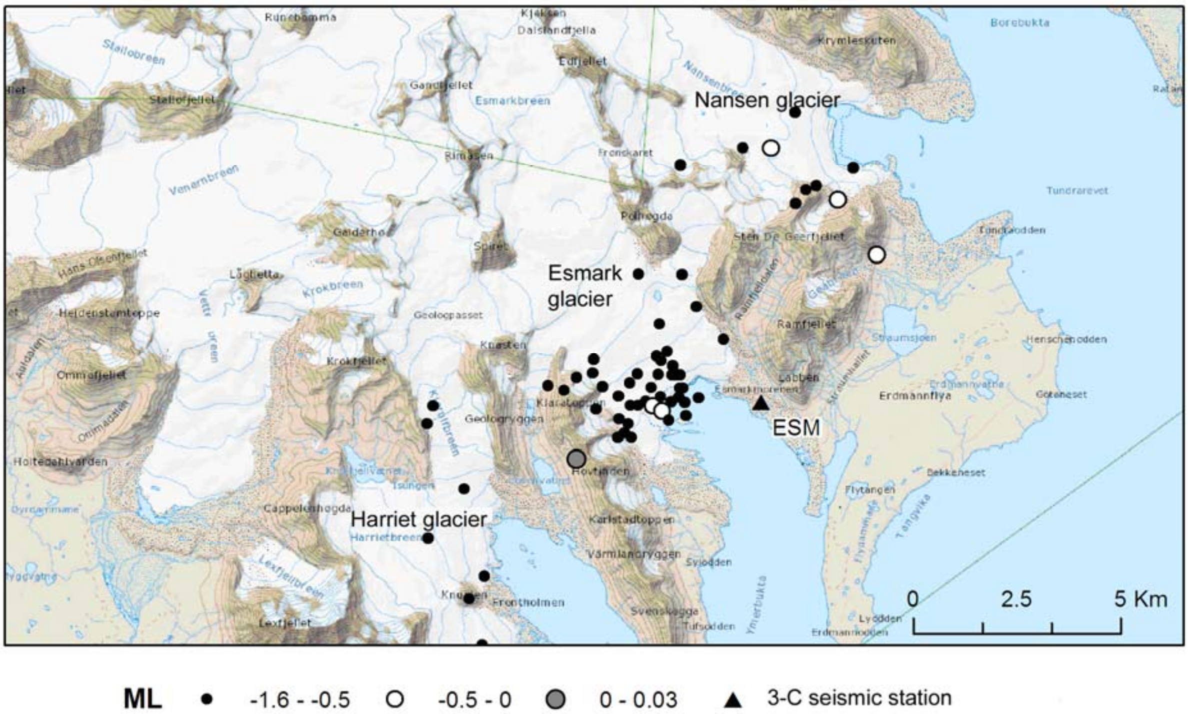

Figure 4. Map of glacier events by joint seismic and infrasound location

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