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In the Antarctic Peninsula region a number of research stations are measuring seismic and infrasound signals and some are also part of the CTBTO IMS. The region is exposed to earthquakes, tsunamis and cyclonic activity. The measurements are ongoing for a long time allowing an assessment of climate change. Satellite observations have made a tremendous breakthrough in the study of the continent but ground-based measurements are still lagging behind. There are perennial datasets of microseismic and acoustic noise, which are associated, for example, with cyclonic activity in the region and the presence of ice cover in the water area. Additional local monitoring of cryoseismic over the years can also contribute to climate research.

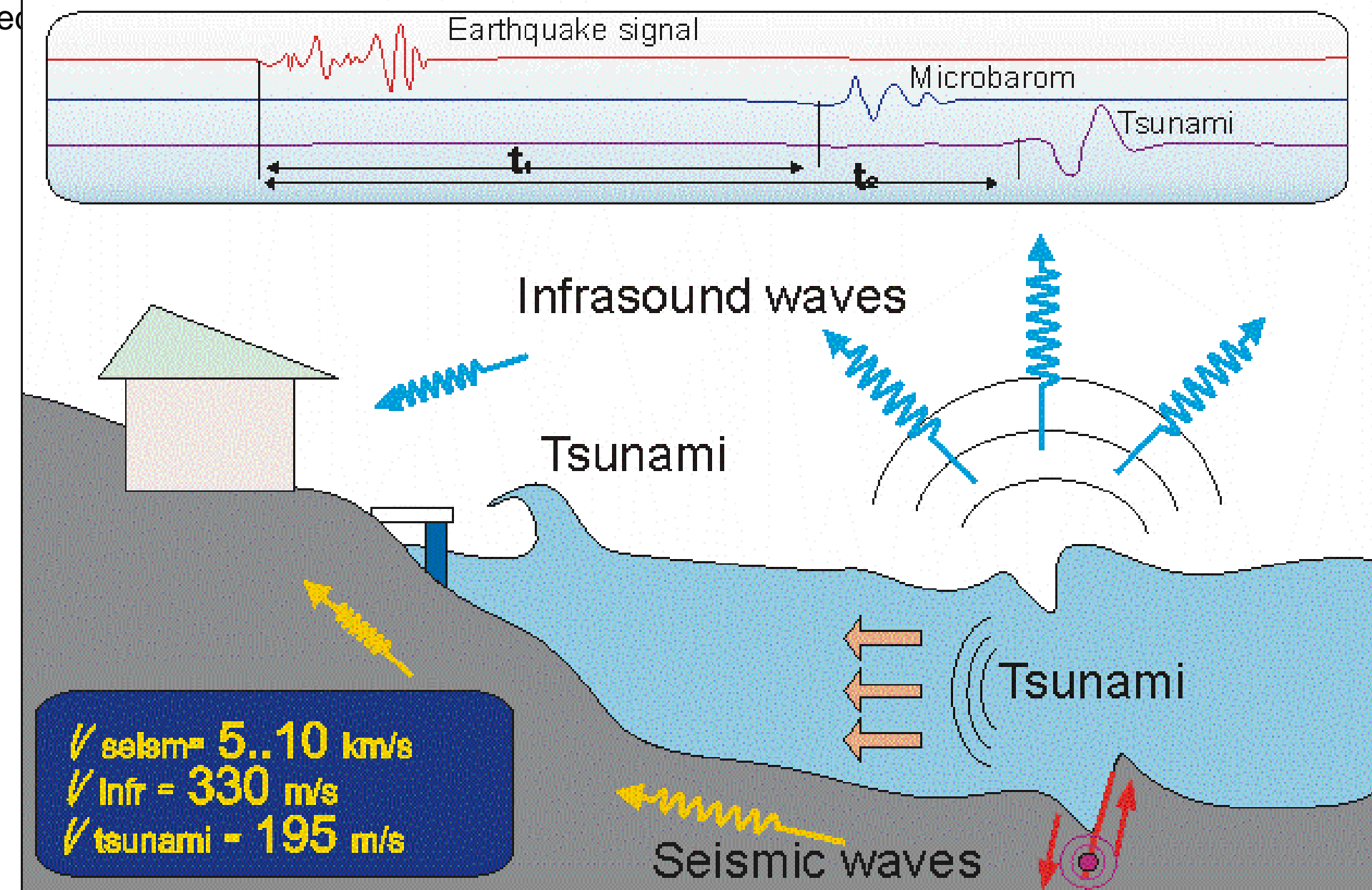
GEOPHYSICAL ANOMALIES BEFORE EARTHQUAKES (TSUNAMI)

Vernadsky Station is located near the Antarctic Peninsula. Station have complex set of geophysical equipment. In addition, geophysical stations located near CTBTO - (Palmer, Neumayer, Ushuaia), which made it possible to study geophysical event using regional network. Several powerful earthquakes Scotia Sea region triggered tsunami waves that repeatedly recorded tide station. Tsunami waves recorded on station from other strong earthquakes in the world (Sumatra, 2004, Japan 2011, Chile, 2010 (2014)). The official website of BAS reported, the possible destruction of Wordie House in 40 of the last century it was the tsunami wave. One of the possible reasons for this shift in the destruction of a large mass of water ice near the station due to shock waves of the tsunami.

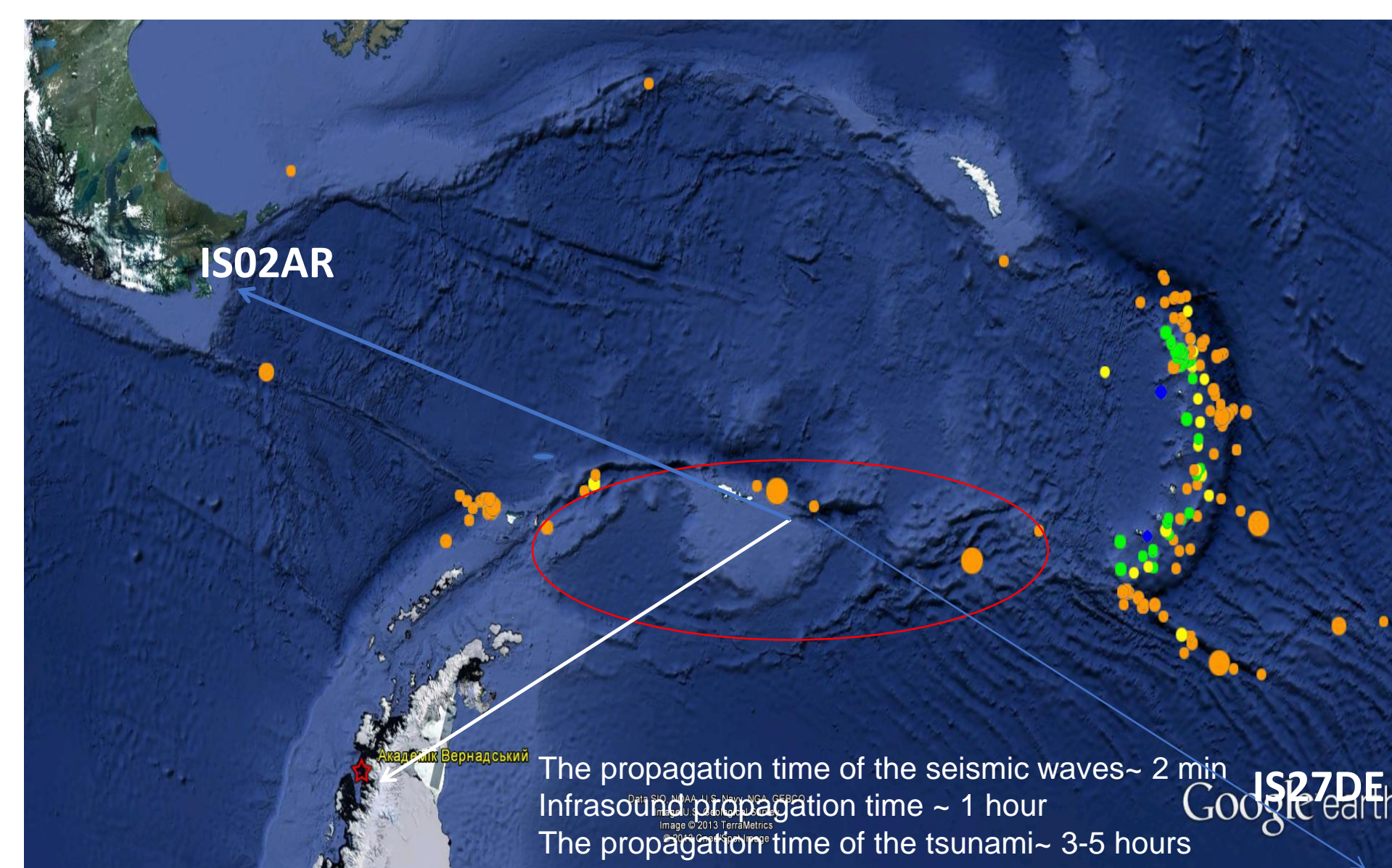
In the area of placing Vernadsky station greatest impact causes seismically dangerous zone of South Antilles arc that encircles the Scotia Sea and the Drake Passage. The average distance from the station earthquakes is 1000-2000 km. During the year in the specified region is about 50 earthquakes of magnitude 5 and more. The closest station earthquakes during instrumental observations recorded at a distance of 200 km ($M = 5.4$). Earthquakes of this region can cause a tsunami will be felt for station.

Since geophysical fields are interrelated, we can expect reactions to high-energy phenomena such as earthquakes all the geosphere. Tsunamis occur only after those earthquakes that are associated with rapid formation on the ocean discharges, mudslides, landslides. This shift, acting on the basis of the piston, pushing water, causing the formation of a tsunami. In addition a "piston" pushes not only water but also air, which leads to the generation of infrasound waves.

Infrasound waves can bend around obstacles easily good spreading in the air over long distances with little loss of energy as the absorption of infrasound in the atmosphere is small. However, the velocity of infrasound is about 1100 km/h, the speed of propagation of the tsunami. This fact can be used



The scheme tsunami warning using infrasound



For working methods of using infrasound as an alarm of an impending tsunami used infrasound stations of the CTBT and IS02AR IS27DE

SEISMOACOUSTIC MONITORING OF THE CRYOSPHERE

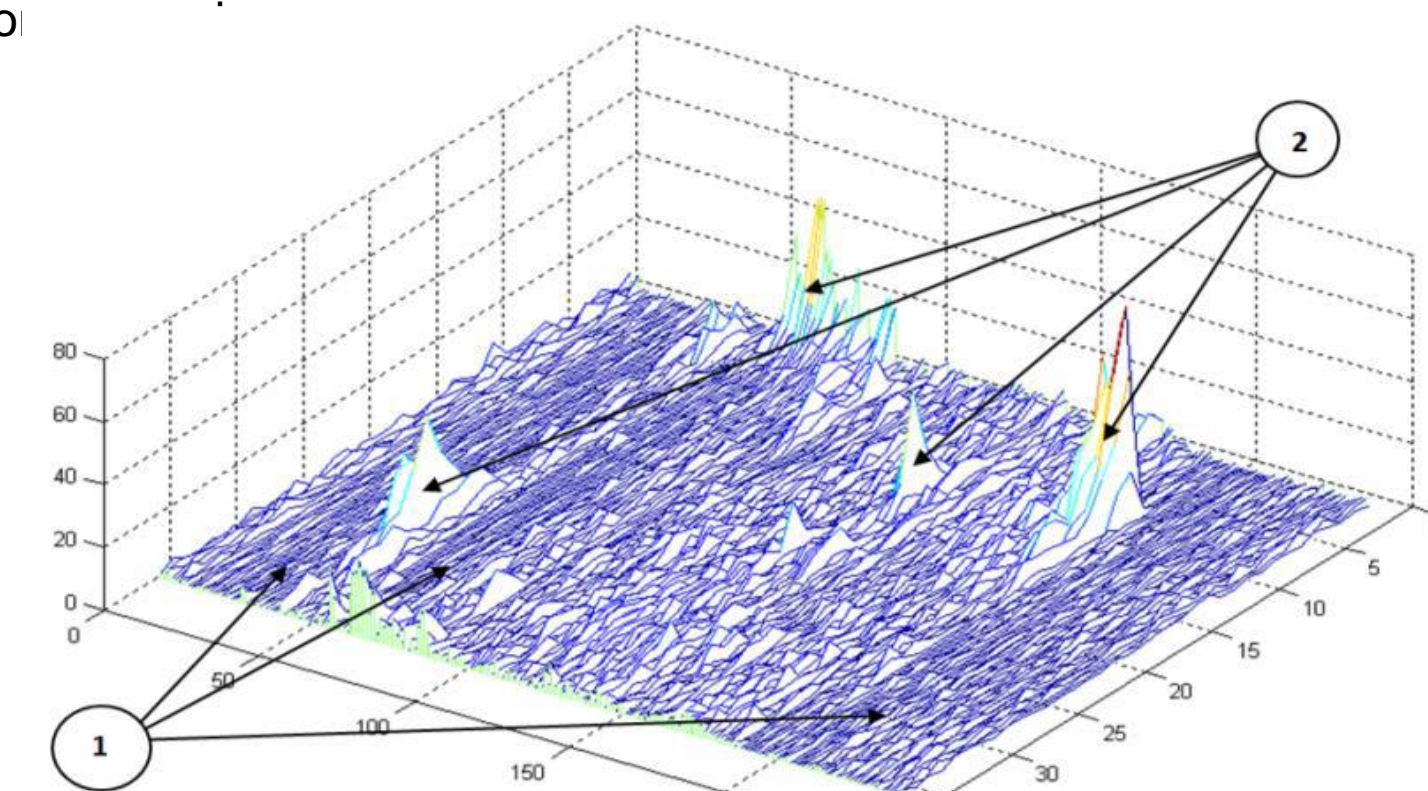
Continuous seismoacoustic observations at the Ukrainian Antarctic Station (UAS) "Academician Vernadsky" have been held since 2000. On average, up to several hundred seismic signals are recorded per year, the sources of which are earthquakes around the globe. The seismic region closest to the station is the Scotia Sea region, the nearest earthquakes were registered at a distance of 150 kilometers to the station. At the same time, there is a huge number of high-frequency seismic signals, the sources of which are local in nature. This is due to the peculiarities of the location of the Argentine Islands Archipelago, where the UAS is located. First of all, the archipelago is surrounded by a marine water area, which is frozen by ice during the winter season and causes a seasonal change in microseismic noise. In addition, on the large islands of the archipelago lie glaciers, covering up to 50% of their area. East of the archipelago is the Antarctic Peninsula and the very nearest part - the peninsula of Kiev. Mountain peaks are covered with snow, between them there are glaciers with access to the sea, the main of which are the glaciers Wiggins, Truz, Bassey, Ley. In addition, on the eastern side of the Antarctic Peninsula, the Larsen C ice shelf is located. It has been observed that the processes of glacier dynamics, can generate seismic signals. In addition, such signals can generate avalanches coming down from the nearest peaks of the peninsula and blowing formed icebergs into the seabed as a result of the surf. The greatest interest in observing variations in the rates of destruction of glaciers in the polar regions can be used to assess the impact of short-and medium-term climate changes on the planet on the environment

Method and/or Theory

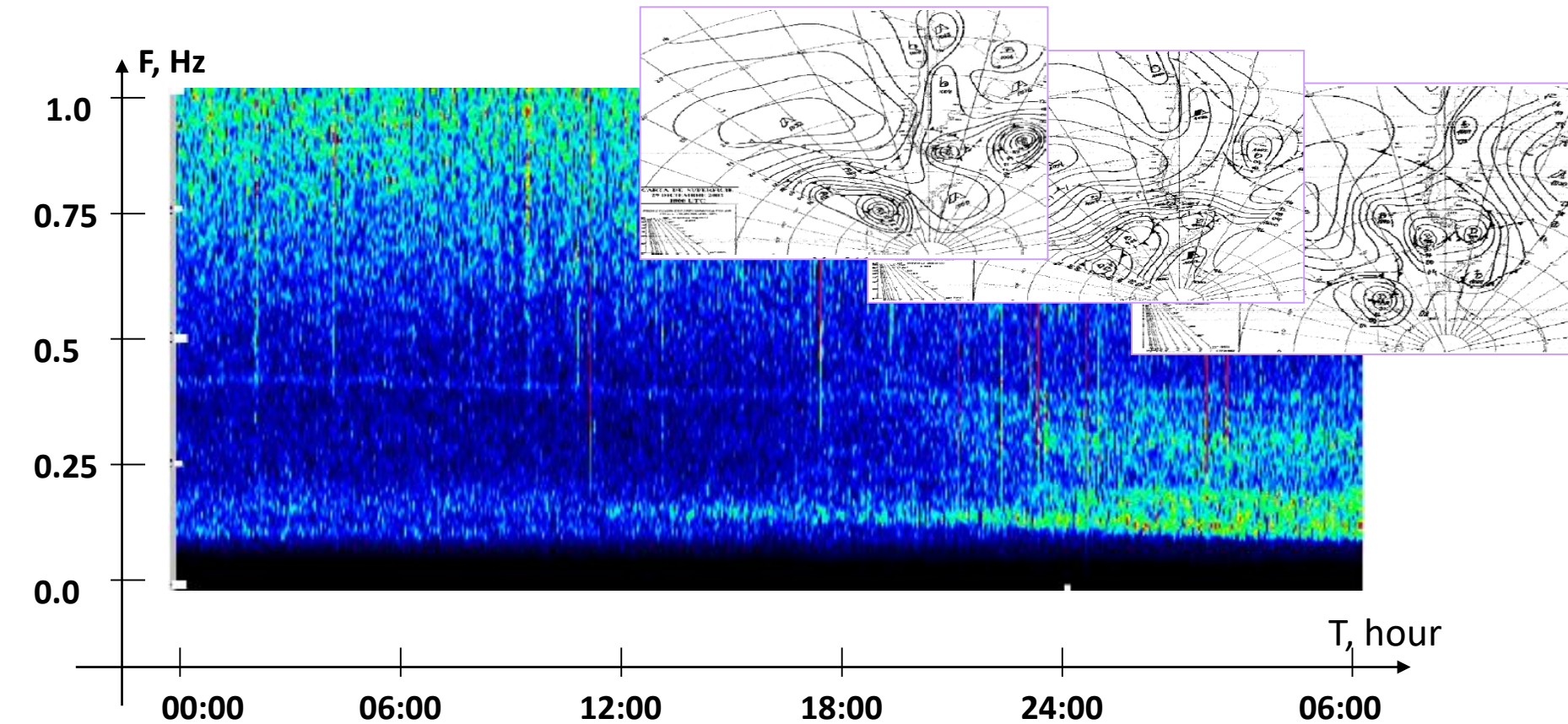
The seismic data collection in the region is carried out around the clock with the help of the digital three-component seismic stations. Data format - miniSEED. Local signals are high-frequency, lie in the band 2-20 Hz, but we limited the band 2-7 Hz for each component. After filtration, useful signals are detected by the amplitude detector, the determination of the direction of the signal source by the polarization filter, the calculation of their number, and the creation of a database containing information on the spatial-temporal distribution of the detected signals. The algorithm LTA/STA was used to detect signals.

Results and discussion

After automatic detection of signals and determination of azimuths on the source of excitation of seismic waves, they are grouped by time and azimuthal signs. The space around the station is divided into 36 10-degree sectors. During each time there is an accumulation of the number of signals for each sector. Thus, for a day, azimuthal time array is created, in the cells of which is the number of signals received from the sector at a specific time (Fig. 1). The zones marked as "1" refer to the moments when there is a significant decrease in the level of the microseismic background. The low-level value is observed in the range of units to dozens of hours. Zones marked as "2" refer to the moments of a general increase in seismic background. To verify the adequacy and correctness of the assessment, 8 reference signals from icebergs to the seabed with known values of azimuths per source (determined by visual observations) were selected from 0 to 270 degrees fo



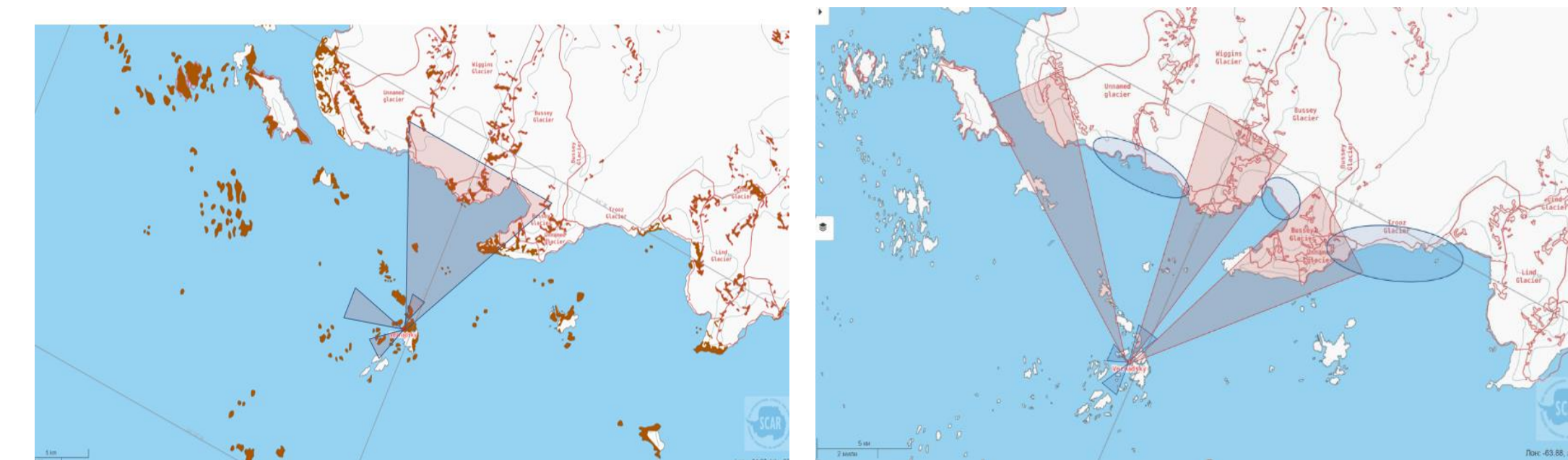
Azimuthal-time signal distribution within 10 days. Beginning September 9, 2016 at 00:00 UTC, end of September 18, 2016 at 24:00 UTC. Vertical axis - number of signals, left horizontal axis - time in hours, right horizontal axis - number of azimuth sector. One unit of the right horizontal axis corresponds to 10 azimuthal degree



Monitoring the passage of the cyclone using seismic

In our opinion, for the local seismicity, there are three main sources of signals. Firstly, it is the process of icebergs formation as a result of the dynamics of the Wiggins, Bassey, and Truz glaciers. The process of destruction of the leading edge of the glacier and the collision of a large mass of ice with the seafloor is accompanied by excitation of seismic waves. Azimuth signals within 40-120 degrees, waveforms and duration allow them to be identified. Also, the destruction of already existing icebergs in shallow waters generates similar fluctuations. Secondly, the icebergs themselves, moving along the sea between the islands, face the strut on their way and generate seismic waves hitting the seabed.

Confirmation can be a map of islands with azimuths (Fig. 2). Visually, in parts of the water area near the islands of the archipelago in the specified corner sectors, there was a cluster of icebergs. Depending on the direction of the wind and the flow of icebergs, they moved (drift) and seismic signals were generated by rocking into the seabed. Third, it's a sea surf. Parts of the adjacent islands, on the sides of which the wind blows, can create places where the great waves rotate on the coast. These waves can endure (bring to shore) broken ice and icebergs of various sizes. In contact with the surface, surface ice waves can in some cases create seismic signals but are smaller than the magnitude of large icebergs.

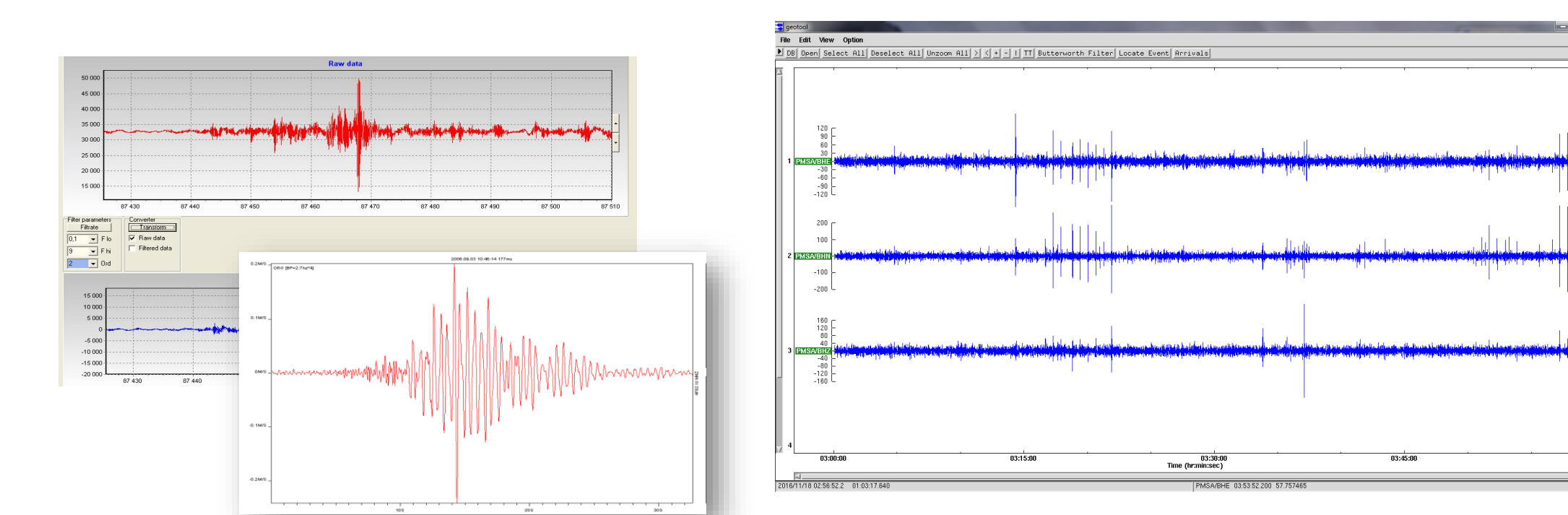


Sectors of generation of seismic signals during the intensive movement of icebergs and ice surf (blue triangles), avalanches (pink triangles), formation of icebergs (blue ovals)

It should be noted separately about such a generator of local seismic signals such as snowstorms and avalanches from the mountain peaks of the peninsula, which is determined by the orographic features of the mainland, the seasons and the amount of snowfall. During the season there are about 300 signals from powerful snow avalanches. The main directions are 30-40, 80-120 and 140-150 degrees, which corresponds to the directions on the main avalanche discharges on the continental part of the Antarctic Peninsula. Seismic signals differ in duration and frequency, can be identified and separated from the main part of local signals.

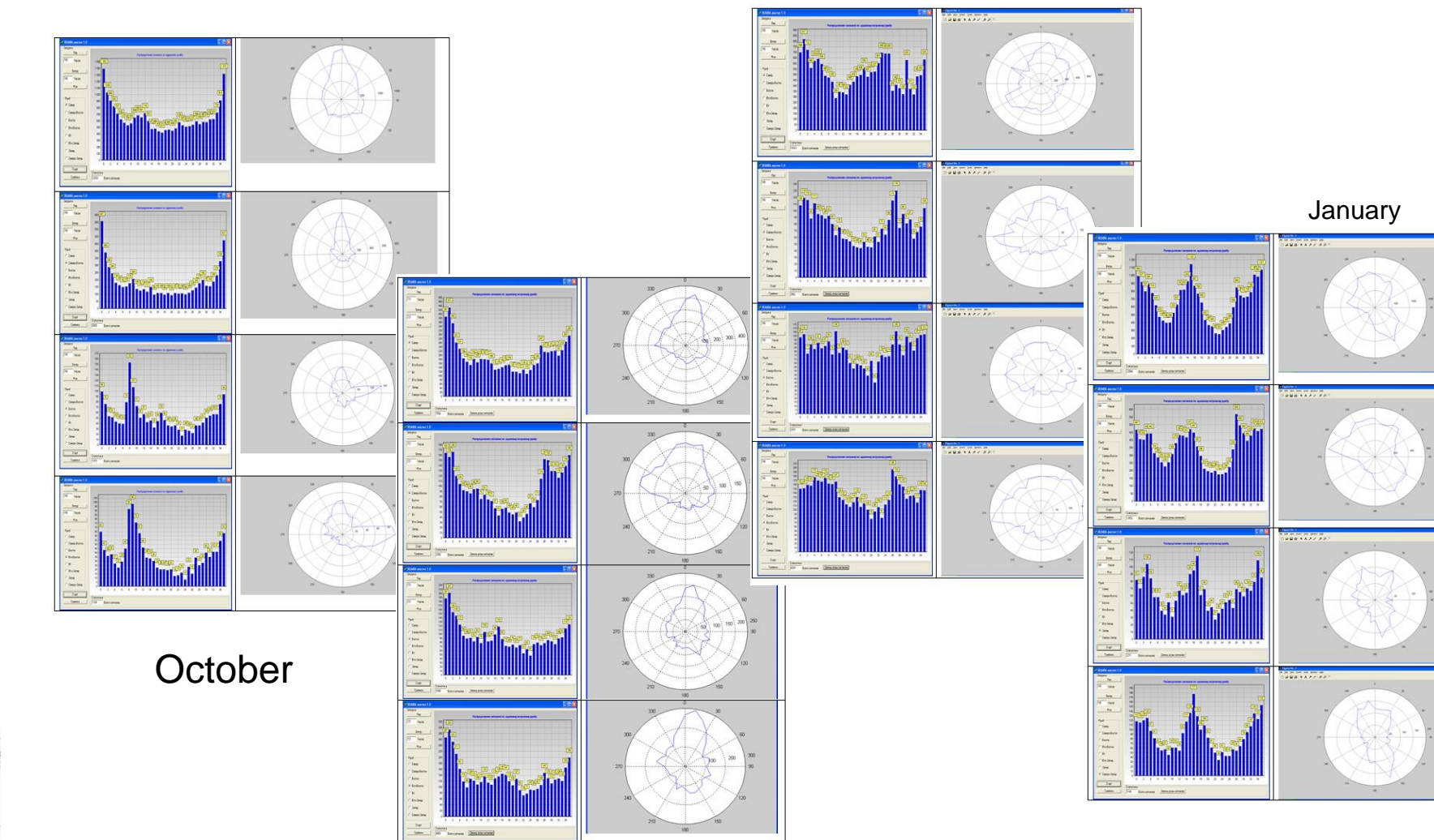
Conclusions

The Antarctic Peninsula and adjoining territory demonstrate one of the most breathtaking changes observed in glacial systems in recent decades. Events include the decomposition of shelf glaciers, the acceleration and thinning of glaciers, the retreat of glacial fronts. However, there are no systematic observations of glacial systems in the region of the UAS. The work demonstrates the possibility of monitoring the cryosphere of the region by the seismic method. Under existing conditions, such observations may be made in real-time. The developed algorithm for estimating azimuth on a source of a seismic signal involves the use of at least one three-component seismic station. At the same time, expanding the region of observation and attracting additional seismic stations in the future will allow to localize and identify seismic events. In the course of seismic monitoring in the region, the location of the Ukrainian Antarctic station has revealed that a significant number of seismic signals is not related to tectonic processes. The reason for local seismicity is the processes of iceberg formation and destruction of glaciers, avalanches, possibly ice break on glacier shelves. It is established that the level of microseismic noise in the region depends essentially on the ice cover of the water area, the dynamics of which depends on changes in the environment. All this can be used to monitor such changes.

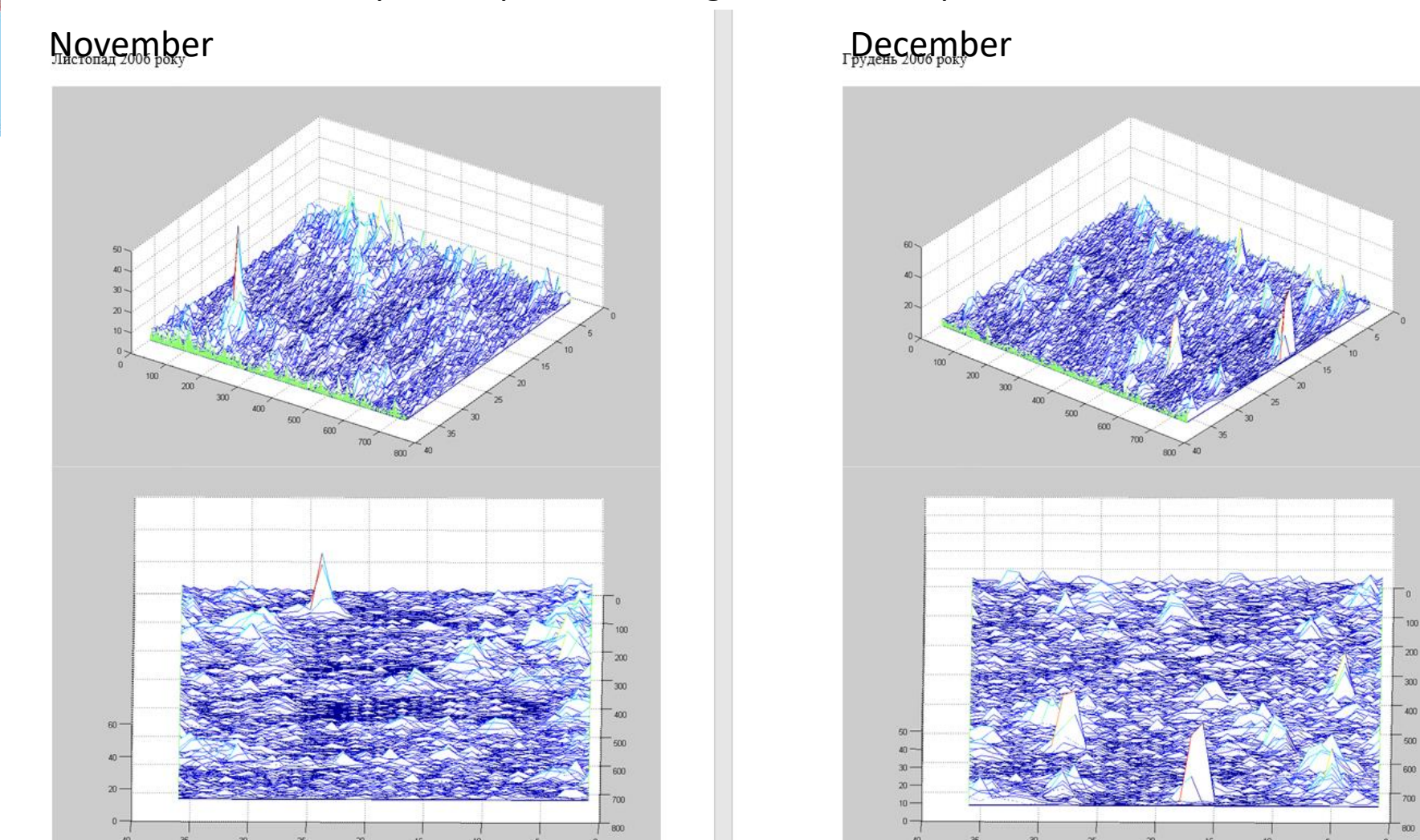


Examples of infrasound and seismic signals from avalanches (left). Seismic signals from the iceberg formation process (right).

DISTRIBUTION OF SEISMIC SIGNALS IN DEPENDENCE FROM THE WIND



Azimuth - temporal separation of signals from the process of ice formation



Antarctic station Vernadsky on the background of the Wiggins Glacier (Antarctic Peninsula)