USING OF IMS INFRASOUND STATIONS FOR TSUNAMI WARNING IN THE ANTARCTIC PENINSULA

ABSTRACT. Since geophysical fields are interconnected with each other, it is possible to expect a response to earthquakes in all geospheres. Tsunamis occur only after those earthquakes that are associated with the rapid formation on the bottom of the ocean of discharges, avalanches, landslides. This shift acts on the principle of the piston and pushes the water, causing the formation of a tsunami. In addition, this "piston" can push not only water, but also air, which leads to the generation of infrasound. Infrasound propagation velocity exceeds the speed of propagation of tsunamis, so it can be used for tsunami early warning. This fact has been used in the Ukrainian Antarctic Station "Akademik Vernadsky" for developing techniques for early warning of a tsunami in the region of the Antarctic Peninsula (Scotia Sea). For developing of methodology infrasound, seismic and oceanographic data of Vernadsky stations geophysical complex and infrasound data from IMS stations (Ushuaia, Neumeier) has been used. The essence of the procedure was limited to the detection of a strong earthquake in a given region, estimating of travel times and azimuths for infrasound waves and confirmation of the tsunami by a tide gauge. A positive result was obtained for earthquakes with a magnitude of more than 7.

A series of powerful earthquakes in the Skotia Sea region has caused a wave of tsunami that has been repeatedly recorded by the Tide gauge at the Ukrainian Antarctic Station "Academician Vernadsky" (UAS). The tsunami waves have also been recorded from other major earthquakes in the world (Sumatra, 2004, Japan, 2011, Chile, 2010 and 2014). The amplitude of the tsunami wave from the recorded earthquakes did not exceed the values of 50 cm. However, it should be noted that the waves of even such an amplitude can cause negative consequences at a significant distance from the epicenter of the event. After the earthquake near the coast of Japan in March 2011, a tsunami that reached the Antarctic coast, the amplitude of the waves did not exceed 30 cm. This proved to be sufficient to cause a blow to the shelf glacier, which resulted in the split iceberg Sulzberger, which is larger than the size of Manhattan . Known facts (1958, Aleutian Islands), when the earthquake and the subsequent tsunami caused a flood Lituya bay displacement of the glacier of the same name into the sea, resulting in a near-closed space of the bay formed a wave height of several hundred meters. The BAS official website reports that the possible destruction of Wordie House in the 40s of the last century was the very wave of the tsunami (https://www.bas.ac.uk/about/about-bas/our-history/british-research-stations- And-refuges / faraday-f /). One of the possible causes of such a destruction is a shift in the water of a large mass of ice near the station due to a tsunami wave impact

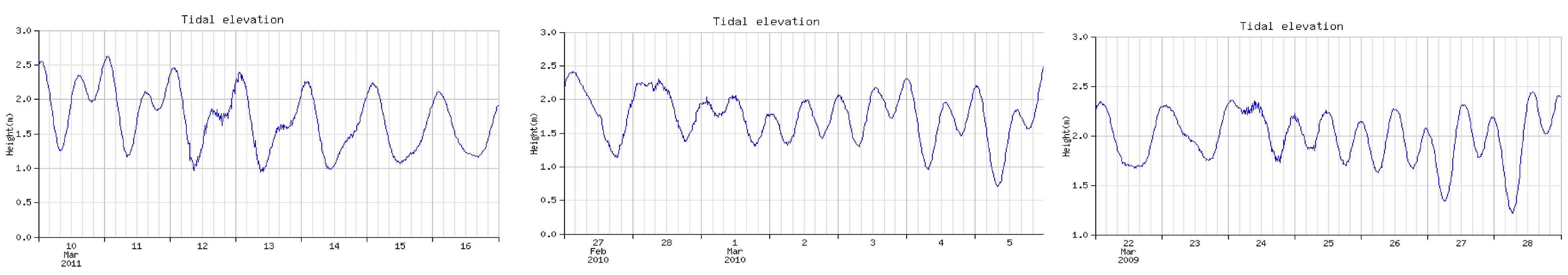

Fig.1 Weekly tidal records with a frequency of 15 minutes. From the left to the right are shown in the tsunami from the earthquake in Japan (11.03.2011) M ~ 9, the earthquake in Chile (02/27/2010) M ~ 8.6, the Scotia Sea earthquake (24.03.2009) M ~ 6.6. The amplitude does not exceed 30 centimeters.

There are a number of international tsunami warning systems in the world (Pacific Tsunami Warning Center, Tsunami Warning System in the Indian Ocean) and regional systems (Russia, Japan, Tsunami Warning System in the Caribbean). Each system is based on a network of sensors registering a tsunami (Tide gauge on the coast) and communications network, which warning of danger.
Although the Antarctic Peninsula region does not fit into the action of warning systems, nevertheless conducted by a group of New Zealand scientists from the University of Canterbury modeling [2] indicate that the tsunami waves in the Antarctic Peninsula region are and can be quite high. A large number of scientific stations are located in the peninsula, most of which are equipped with tidal stations, which gave grounds for such conclusions.

The greatest impact on UAS is caused by the seismically dangerous area of the South Antilles arc, which surrounds the Scotia Sea and the Drake Strait, includes the islands of South George, South Sandwich, South Shetland, South Orkney Islands. The average distance of earthquakes from the station is 1000-2000 km. During the year in the indicated region about 50 earthquakes with a magnitude of 5 or more. Nearest earthquakes from the station during instrumental observations are recorded at a distance of 200 km (M = 5.4), which corresponds to a calculated intensity of 3-4 points on the MSC scale (can be felt by station personnel). Earthquakes from this region can cause a tsunami that will be felt in the UAS.

Because of the long wavelength of more than 100 km per kilometer of depth, the tsunami can pass almost without reducing thousands of kilometers. Confirmation of this is the registration of the UAS tsunami from the coast of Chile, Japan, Indonesia. The tsunami speed in the ocean is 700 ÷ 800 km / h, and the coast is already lowering to 30-40 km / h.

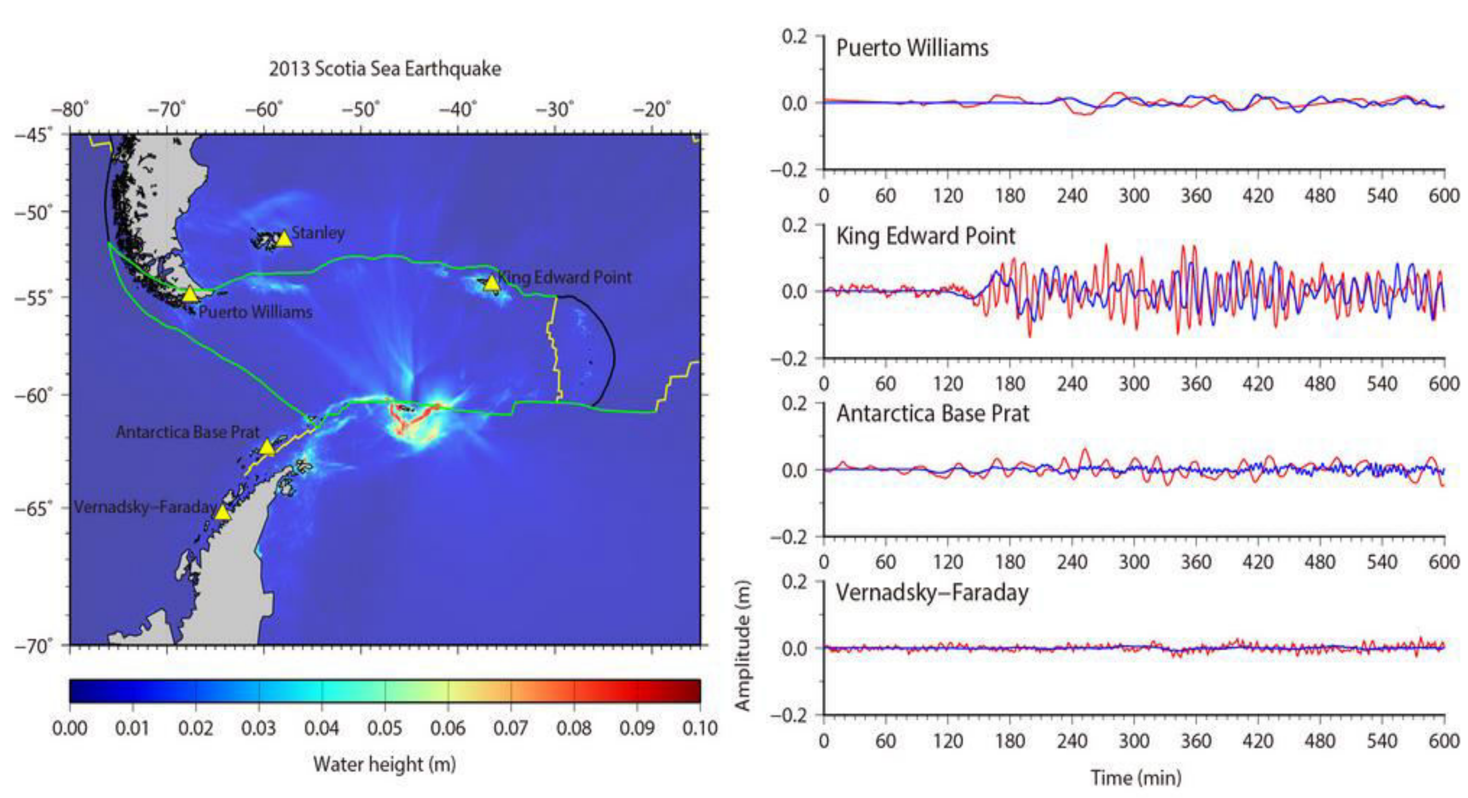

Fig.2 Maximum Height of Tsunami and Tsunami Waveforms
(http://iisee.kenken.go.jp/staff/fujii/Scotia2013/tsunami.html and http://www.tsunami.gov/previous.events/?p=11-17-13)

Since geophysical fields are interconnected, one can expect a reaction to such high-energy phenomena as an earthquake in all geospheres. Tsunami arises only after the earthquakes that are associated with rapid formation at the bottom of the ocean discharges, landslides. This bias, acting on the principle of a piston, pushes water, causing the formation of a tsunami. In addition, such a "piston" pushes not only water, but also atmospheric air, which leads to the generation of infrasonic waves.

A characteristic feature of the infrasound is the large wavelength and low frequency oscillation. In this case, infrasonic waves can freely bend the barriers well spreading in the air over long distances with a slight loss of energy, as the absorption of infrasound in the atmosphere is small. At the same time, the rate of infrasound distribution is about 1,100 km / h, which exceeds the speed of tsunami proliferation. This fact can be used to warn of a tsunami in the region/

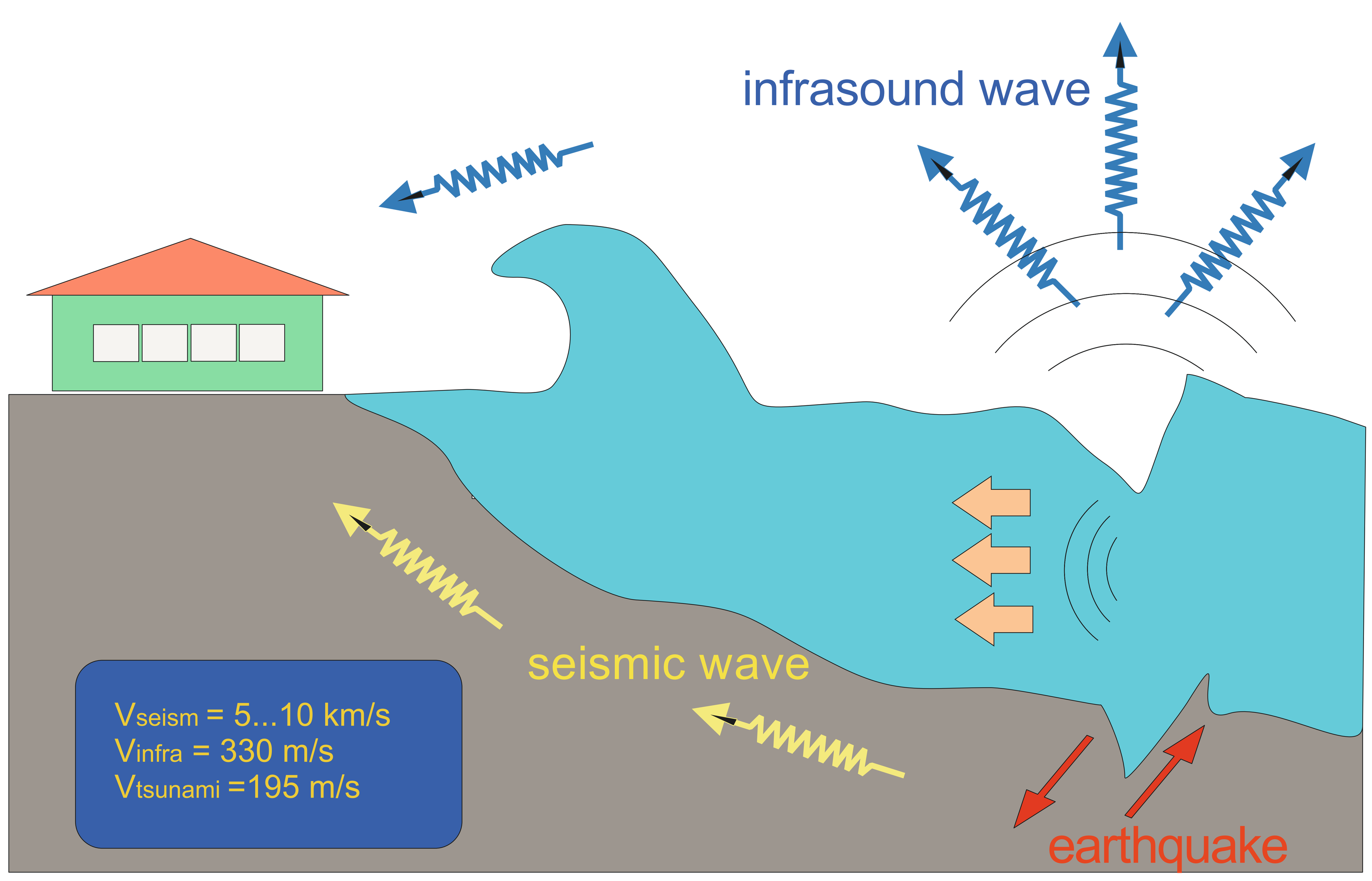

Fig.3 Model of wave propagation as a result of tsunamigenic earthquake

During the last decade of the region, there were 2 strongest in the history of instrumental observations earthquakes with magnitudes 7.3 (08.04.2003) and 7.7 (17.11.2013), which caused a wave of tsunami. Infrasonic response is registered for both phenomena.

For an earthquake in 2003, the infrasound background was more favorable, so the registered acoustic signal is clearly allocated on the spectrogram (Fig. 4). In the first lower part of the spectrum there is a strong wind, which gradually disappears, and further, in the absence of interference, comes the infrasonic signal from the earthquake. The time for infrasound transmission was 67 minutes. The amplitude of the wave on the gauge was 10 cm.

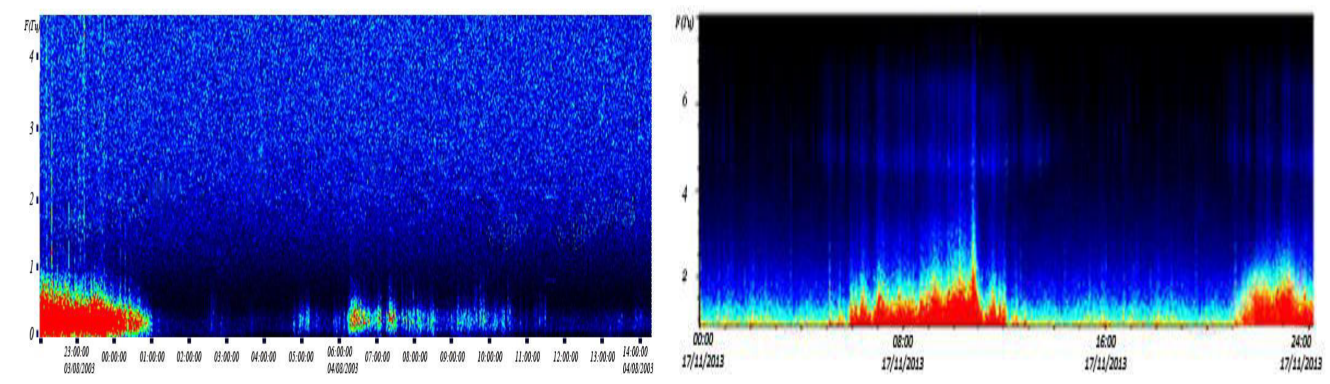

Fig.4 Spectrograms of infrasound from earthquakes in the Scotia Sea

In 2013, a clear detection of the infrasonic signal from the earthquake was hampered by the presence of wind noise during the arrival of the signal (Fig. 6). Nevertheless, at the level of acoustic noise, a useful signal is extracted, which can be visually detected. The infrasound propagation time was 53 minutes. At the tide gauge, the wave is at the background level.

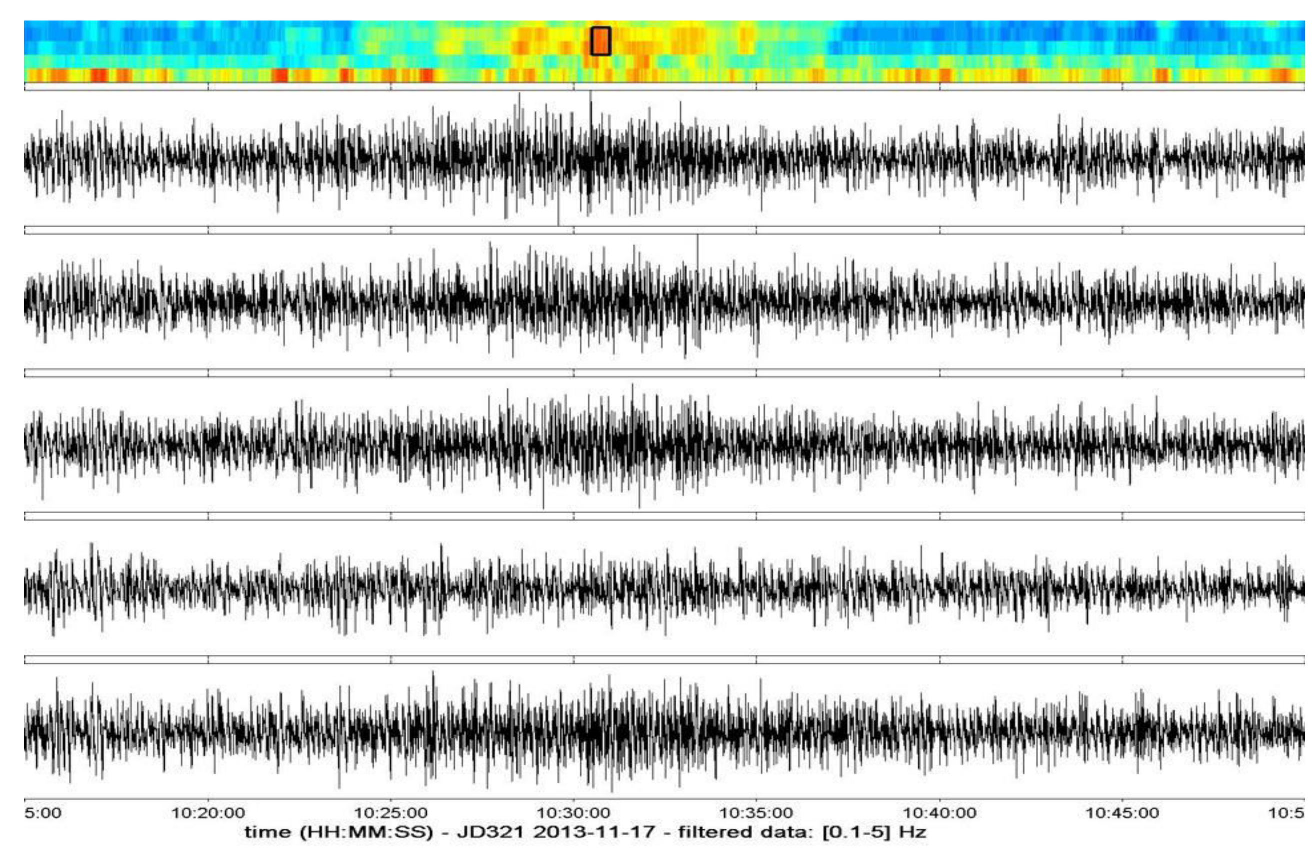

Fig.5 Infrasound wave forms of with a signal from an earthquake in the Scotia Sea

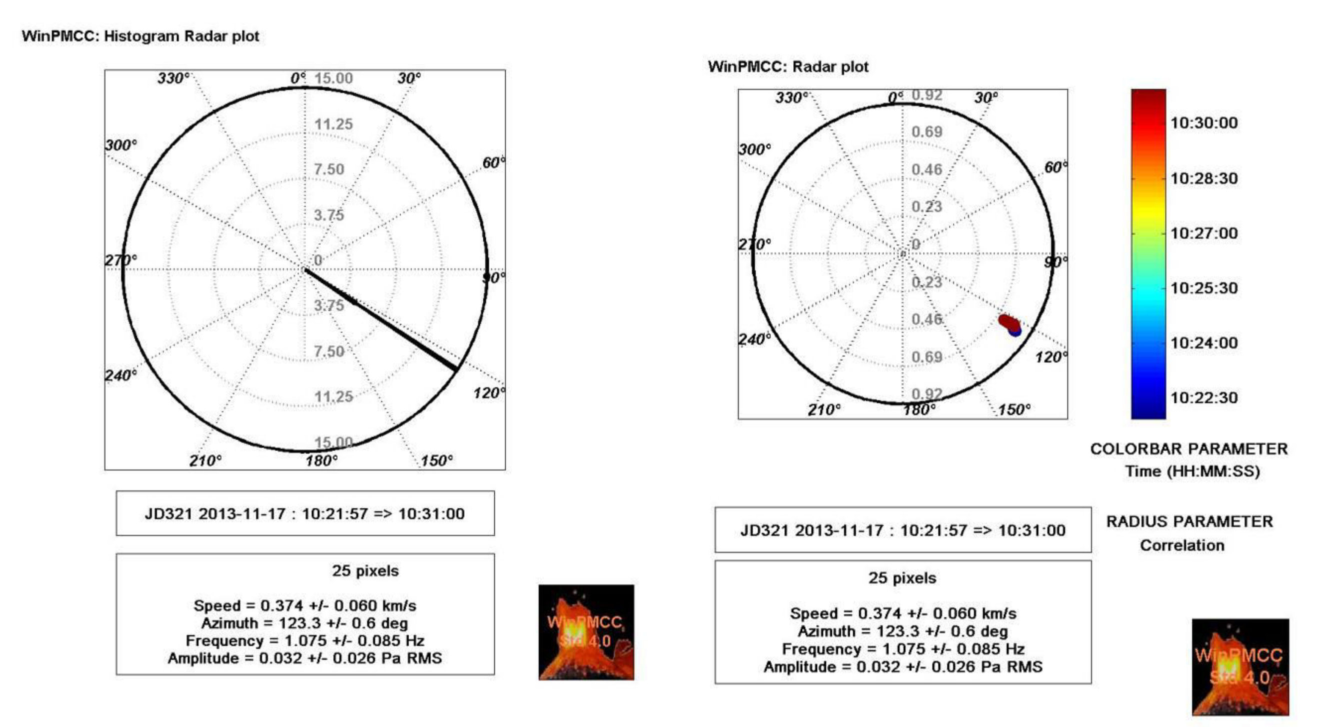

Fig.6 The result of processing infrasonic data of MSM stations IS02AR in WinPMCC

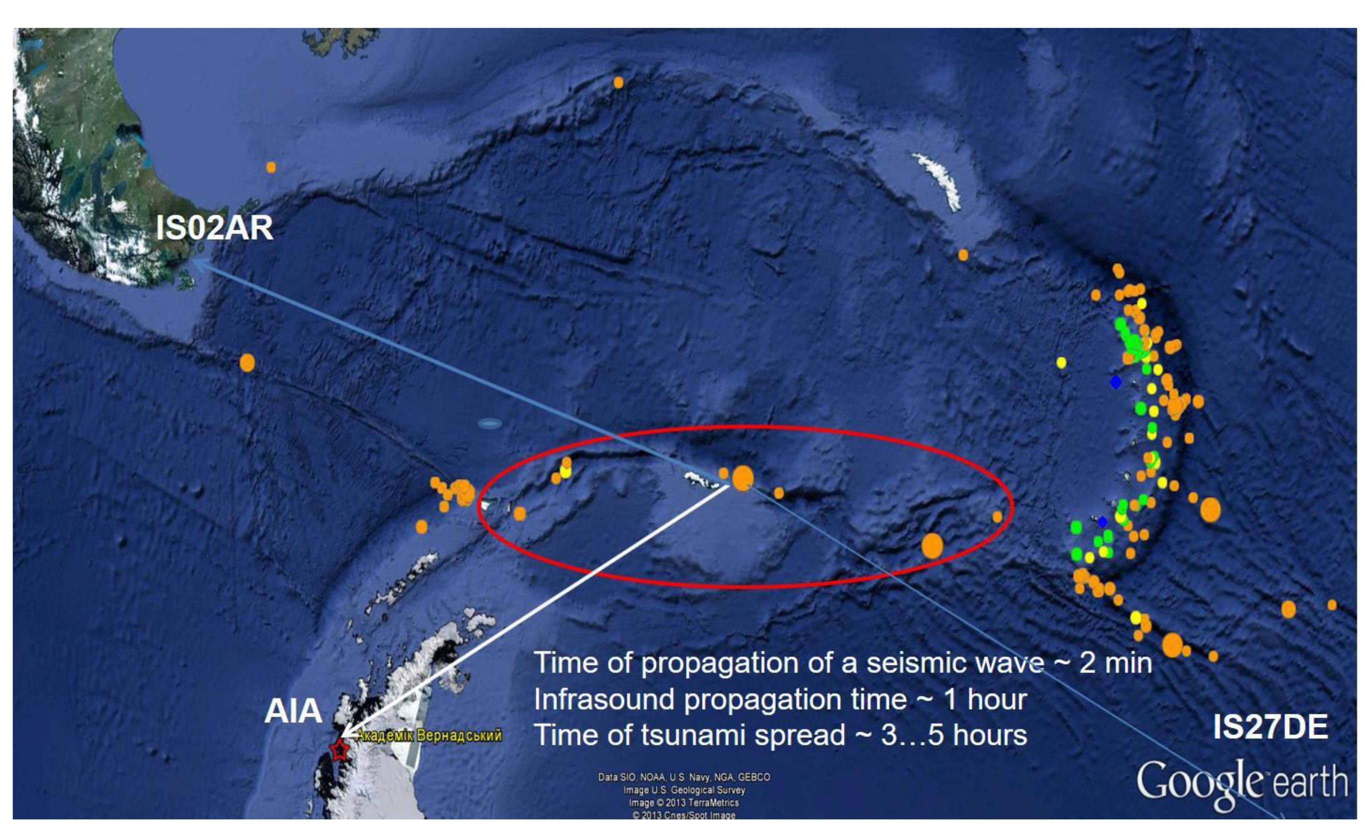

Fig.7 Map of the Scotia Sea Region with check-in points

To test the idea, the infrasound stations of the International Monitoring System CTBTO were also involved. In the Scotia Sea region, the closest stations are IS02 (Argentina) and IS27 (Antarctica, Germany). At the indicated time for the second earthquake (2013), the infrasonic signal is present only at the IS02 station. At the IS27 station a large noise level, which did not detect the signal.

Nevertheless, the use of the proposed methodology has shown its promise and requires in the future a set of additional data.

Links:
1. (https://www.bas.ac.uk/about/about-bas/our-history/british-research-stations-and-refuges/faraday-f/
2. COMNAP Preliminary Research Report: Understanding Risk to Antarctic Program Operations and Personnel in Coastal Antarctica fromTsunami Events. SCAR Papers to ATCM XXXV and CEP XV 2012, Hobart, Tasmania.
3. http://iisee.kenken.go.jp/staff/fujii/Scotia2013/tsunami.html
4. http://www.tsunami.gov/previous.events/?p=11-17-13

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