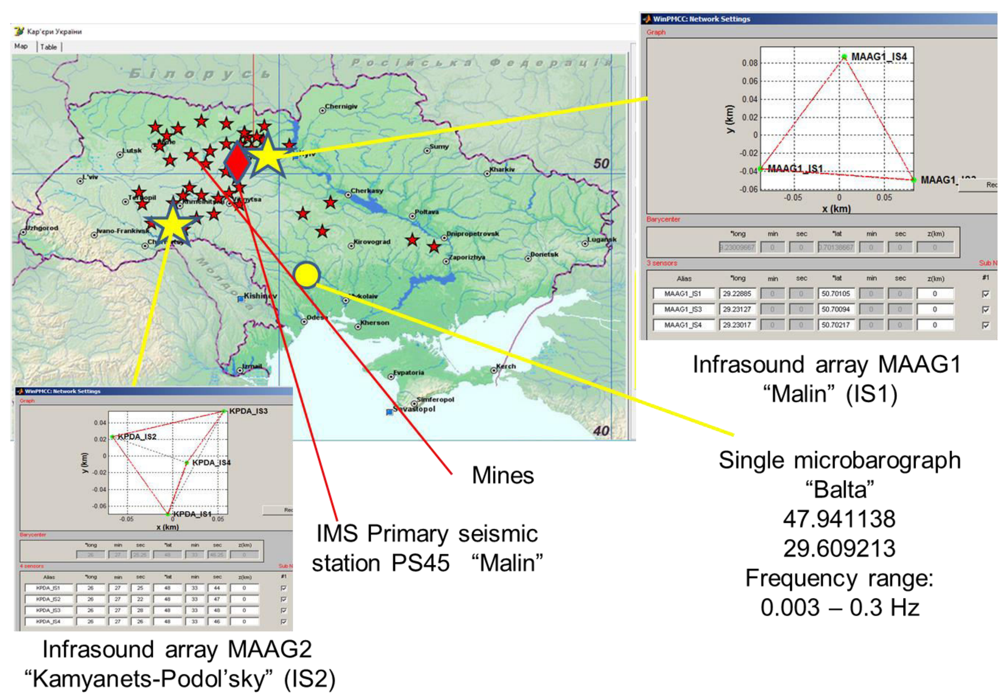
CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

(T3.5-P23)

IDENTIFICATION OF EXPLOSIONS AND EARTHQUAKES USING INFRASOUND AND SEISMIC DATA

Right-Bank Ukraine, especially its north-western part, densely covered by a network of mining companies that in course of business actively generate seismic signals. This creates a problem in identifying signals from earthquakes and industrial explosions and is one of the key problems of seismic observations. The ability to distinguish chemical explosion seismic recording write-earthquake based on the characteristics of these sources as a mechanism, zone size, time and depth. There are a number of criteria to identify the source of the seismic signal. In Main center of special monitoring (MCSM) developed additional criteria that have shown to be effective. However, they are not absolute, and many seismic events so far impossible to determine what was an event: an earthquake or explosion left an analysis based seismic data. MCSM network in addition to seismic observations is equipped with a number of other geophysical methods, including infrasound. Continuous monitoring is performing by infrasonic technical means placed at the Zhytomyr, Khmelnytsky and Odessa regions. Infrasound means have also been established at Ukrainian Antarctic Station "Academic Vernadsky". Small absorption in different environments is specific characteristic of infrasound. The result is the ability to register signals from atmospheric events that occurred on a large distance from the point of observation. The range of natural and man-made phenomena that generate infrasound wide enough. The main sources of generating infrasound is the aurora, launching rockets, volcanoes, falling celestial bodies, storms, hurricanes, earthquakes, avalanches, fires, nuclear and chemical explosions else.

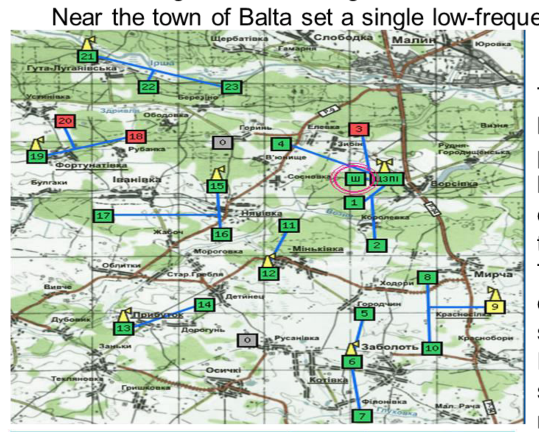
Seismic and infrasound complex



Two small aperture infrasound arrays and seismic station PS45 allow to conduct more high-quality analysis of events in earthly and air spheres, and also to find connection between them. The IS1 infrasound array is next to the primary station PS45.

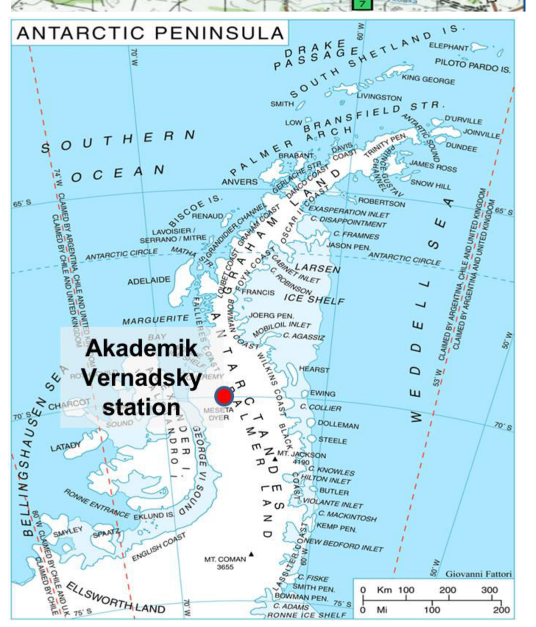
Both infrasound arrays equipped by broadband microbarometers K-304-A. The arrays configuration is the isosceles triangle with side length around 150 – 160 meters. The distance between arrays is 262 kilometers.

Near the town of Balta set a single low-frequency microbarograph.



The PS45 IMS Primary Seismic Station is consist of 23 borehole's elements equipped by CMG-3ESP vertical short period seismometers and one vault equipped by CMG-3TD broadband seismometer. Data from seismometers collecting on the Central Facility of the Station and sanding by VSAT to the IDC and by radio modem to the NDC for data processing. The data transmission inside seismic array is mixing and organized used radio links and cable modems via copper signal lines.

In future, the configuration of the data transmission sub-system will be change to optical and copper cables. The radio links will be removed, because the reliability of the radio links in the location of PS45 Station is low.



Also, a set of seismoacoustic equipment placed on the Ukrainian Antarctic station Akademik Vernadsky (West Antarctica, Antarctic peninsula, Argentine islands). The set includes a three-component seismic station Guralp CMG40T and broadband microbarograph K-304-A with noise reducer. This set of equipment used in the research program studying global climate. Also, the seismoacoustic complex registered number of natural phenomena. These phenomena may be of a global nature (meteors, earthquakes, tsunamis, cyclones, storms, auroral phenomena, etc.) and local character (the movement of glaciers, icebergs drift and genesis, avalanches, tides, etc.)

At the station, an important object of study is the earthquake in the ocean, and especially - the associated tsunami. Due to the fact that the station is based on a small island on the coast, at a height of about 1.5 meters, a tsunami poses a real threat to the people living at the station.

In the near future, for the protection of personnel and the prevention of a possible tsunami, the plant set of equipment will be deployed. This kit will consist of seismic and infrasonic groups. Seismic Group will record a powerful earthquake in the open ocean, to evaluate the position and magnitude, and infrasound group will confirm the presence of high waves associated with the epicenter of the earthquake.

Registration of infrasonic signals in MCSM is performing by using systems of infrasound small-aperture groups (MAAG). Each such infrasound group is a complex of three or more space distributed independent mikrobarograph (acoustic station K-304A), systems of data collection and transmission, processing and storing. Frequency range of MAAG is below the threshold of human hearing and is in the range 0.003 - 12 Hz. Stations sensitivity modes - 1, 10, 100 Pa. The value of spatial diversity reception points acoustic pressure depends on the nature of the meteorological conditions of the area, where the group and its purpose (targeting certain signals) and range from tens of meters to several kilometers.

In MCSM observation points acoustic stations spaced one another at a distance of 100-200 meters apart. Aperture size and shape of its limited territory, available to the institution. Usually, if the three elements of trying to put on the tops of an imaginary equilateral triangle, the fourth element is placed in the center of the triangle or change the configuration of the square. It should be noted that the aperture determines the frequency group registration. The larger the base, the lower the frequencies available for processing, and the greater the distance registration.

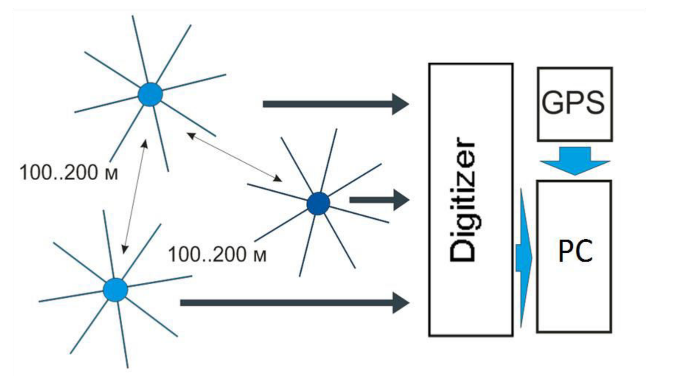
In the present time the MCSM infrasound monitoring system includes two small-aperture infrasound groups.

During processing of the recorded infrasound signals must first distinguish the signal of man-made or natural origin from wind noise.

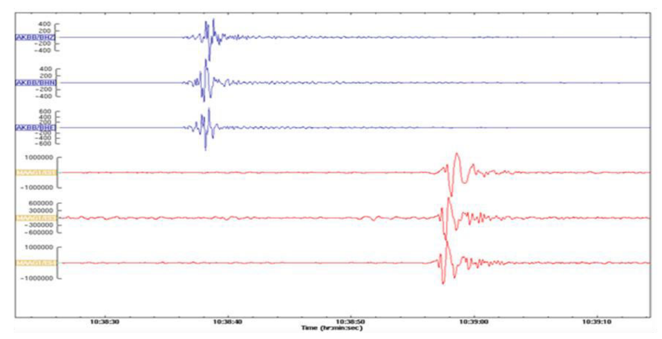
The main features of useful signals and their difference from wind noise:

- - Useful signal is recorded on all the elements of groups almost simultaneously. Time difference on channels of MAAG1 and MAAG2 not exceed 1-2 seconds. The signal from the wind noise has much greater time difference of arrivals between channels.
- - Useful signals have almost the same envelope, character of writing and filling the envelope. Wind noise differ in recording on different channels.

If the explosion is held at short distances from MAAG (5 - 20 km), the infrasound waveform does not change significantly, and to its spectrum additional harmonics are not added. Figure shows the infrasound record of industrial explosion in Granite Malyn district, Zhytomyr region (06 Feb 2015 T_0 = 10:38:56, φ = +50,81º, λ = +29,31º) recorded MAAG1. Infrasound group confidently records such signals. Interchannel correlation within the whole frequency range 0.5 - 10 Hz is not lower than 0.9.



Typical structure schema of small-aperture infrasound group

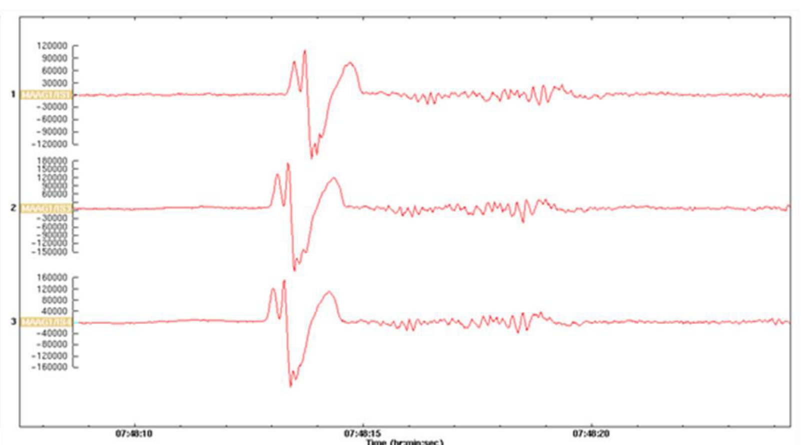


Seismic and infrasound records of industrial explosion in Granite Malyn district, Zhytomyr region (06 Feb 2015 T_0 = 10:38:56, φ = +50,81º, λ = +29,31º)

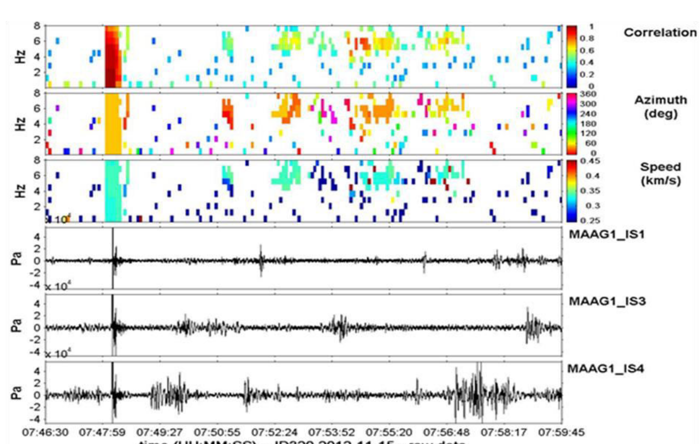
During propagation of infrasound must take into account the structure of the atmosphere and the fact that there are several waveguides. A large range of infrasound propagation caused by sound energy concentration layer near the minimum temperature and due to the lack in the way of noise.

The axis of the main waveguide is located at an altitude of 10-15 km, the axis of the second waveguide is located at an altitude of 75-80 kilometers. Various combinations of vertical changes in temperature and wind speed can cause the formation of additional waveguides in the atmosphere, which complicates the picture infrasound propagation in the atmosphere.

As an example in Figure shows an infrasound record from industrial explosion in the village Granitne, Zhytomyr region on 15 November 2012. After passing the entry signal and phase compression, liquefaction there are several typical amplitude bursts.



Infrasound record of industrial explosion in Granite Malyn district, Zhytomyr region (15 Nov 2012 T_0 = 07:58:13, φ = +50,81º, λ = +29,31º)



Result of processing by WinPMCC

For explosions at distances from 20 to 100 kilometers there is one reflection from tropospheric layer at an altitude of 20 km. If the wave front propagating opposite to direction of the wind, it is possible front reflection from mesosphere layer at a height of 60 - 80 km. Waveform signal partially changed. In the spectrum of the signal appear more harmonic. Interchannel correlation decreases to 0,75..0,8.

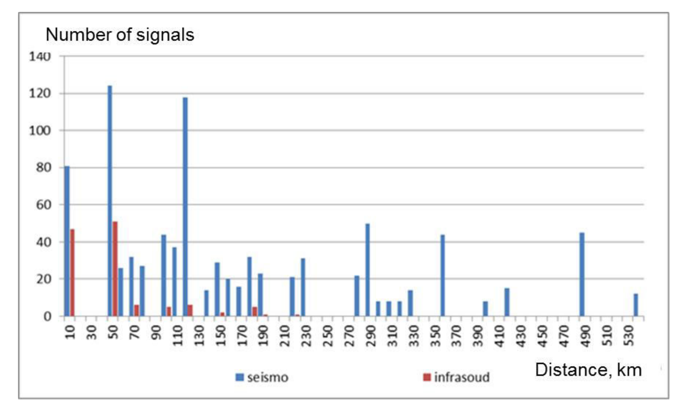
In most cases at these distances begins dead zone where registration is improbable This zone is caused by refraction in a warm layer of air, when the beam deviates infrasonic waves up and do not reach the point of observation. When cooled surface air at night, and day and night in the cold season, this area may not occur.

When registering signals from explosions at a distance of 100-300 km there is one or more reflections from tropospheric layer at a height of 16 - 20 km and one or more reflections from mesosphere layer at a height of 60 - 80 km. In the spectrum of the signal appear more harmonic.

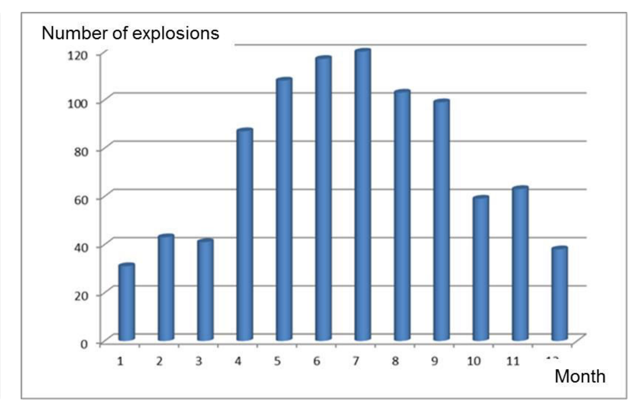
According to statistics of infrasound systems during the year nearly thousands of useful signals are registered. Basically these signals were from explosions at industrial mines. In addition, operating experience has shown that MAAG can register signals from accidental explosions, in gas pipelines and military warehouses.

For evaluation of infrasound complex on certain algorithm the database of registered seismic and infrasound signals were analyzed in MCSM during 2014. During this time 909 industrial explosions that occurred mainly in northwestern Ukraine were registered by seismic equipment. For 437 of them there were confirmed information about the number of planted explosives that used in MCSM for calibration of network.. During the same time were confirmed by infrasonic means 124 explosions. The azimuth of the sound source identified with an accuracy of 0,1 ° to 3,8 °, due to the distance to the source and the state of the atmosphere at the time of measurement.

Quality of registration improving in the winter months and gets worse in the summer. During the day better quality registration at night and evening and is degrading as a result of heating of the atmosphere around noon. However, the main production takes place in summer (Figure 7), during the day, which is not conducive detection of infrasonic signals from low-power explosions.



Distribution number of signals in relation to distance from observation site



Distribution number of explosions in relation to month

It is established that the main type of registered infrasound signals has explosive nature and an explosive shape of the envelope. This is due primarily to the peculiarity of the location of registration points in areas where the mining industry is developed and a large number of explosions are conducted.

The results of infrasound observations can be used as an additional criteria for identifying the nature of seismic events with certain limitations concerning the power of the charge, the distance to the signal source. Registration of infrasound from industrial explosions is conducted by small-aperture groups at distances up to 200 kilometers, with sufficient power (at least 20 tons of TNT). The quality of recording infrasound signals also depends on the meteorological conditions on the path of propagation.

Also, the use of these infrasound data measurements in a near-real time mode allows to apply this method for monitoring of the environment, operative evaluation of an event that occurred, to provide information in case of emergency events (explosions of warehouses, gas pipelines, etc.) to emergency services.

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