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Preliminary catalog of quarry blasts in Hungary recorded by the PSZI infrasound array

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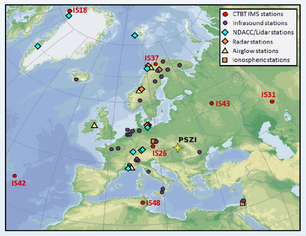
Introduction

The first Hungarian experimental infrasound array started operation in May 2017.
Hungary is characterized by moderate seismicity where more than a third of the seismically recorded events are anthropogenic events, such as quarry blasts and mine explosions. Hence, to study the natural seismicity of the country and produce reliable seismic hazard estimates, it is important to identify and separate natural events from anthropogenic ones. Explosions not only generate seismic waves, but the shock wave propagates to large distances in the atmosphere in the form of infrasound waves. The infrasound array in Piszkés-tető was intentionally designed so that it is co-located with a seismic station. Combined with well-established seismic discrimination techniques, the infrasound records will help us to routinely distinguish earthquakes (that typically do not generate infrasound) from explosions (that do).

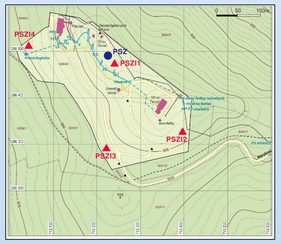


The map of the ARISE and IMS infrasound network. Yellow star shows the location of PSZI array (modified after [1])

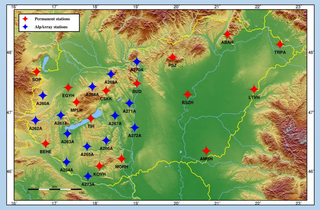
Hungary joined the Atmospheric Research InfraStructure in Europe (ARISE) in 2016, when the Geodetic and Geophysical Institute of the Hungarian Academy of Sciences has won national funding for the deployment of the first Hungarian infrasound station. The ARISE project is a collaboration of more than 25 European universities and research institutes and aims to provide a new atmosphere model with a high spatio-temporal resolution by integrating different techniques - including infrasound. The ARISE infrasound network consists of the CTBTO IMS network and several European experimental infrasound arrays. In the Eastern-European region the ARISE network is sparse, hence the Piszkés-tető array will improve the coverage of the infrasound network in the region.

The PSZI array

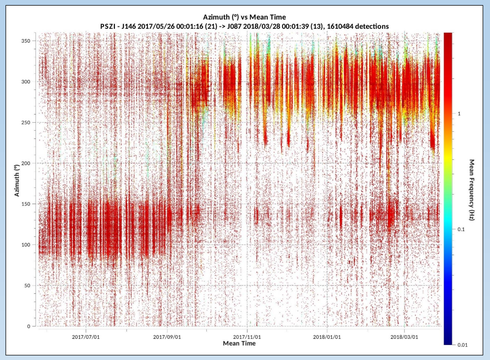
- The Piszkés-tető infrasound array is located in Northern Hungary, in the Mátra Mountains, at approximately 930 m above sea level.
- The array consists of 4 elements and has an aperture of approximately 300 m.
- Each element of the array is equipped with a SeismoWave MB3d microbarometer with built-in digitizer.
- All the instrumentation is placed in a waterproof plastic container.
- The station site is covered with forest that helps to reduce environmental noise.
- For further noise reduction the sensors are equipped with a star array wind-noise filtering system made of porous hoses.
- The data is forwarded real-time, and collected with SeisComp3 in the data centre of the Kövesligethy Radó Seismological Observatory.
- The central element of the infrasound array (PSZI1) is co-located with a permanent broadband seismological station (PSZ).
- For data processing we use the CTBTO NDC-in-a-box software package that includes PMCC [2].
- The waveform data are available at GEOFON. Network code: HN, doi: 10.14470/UA114590



The map of the PSZI array. Red triangles mark the location of the microbarometers, and the blue circle marks the PSZ broadband seismological station.



The stations of the Hungarian National Seismological Network. The broadband seismometers detect hundreds of quarry blasts every year.



The detections of the PSZI array from June 2017 to March 2018. The most characteristic signals are the high frequency noise from the Mátra Power Plant in the summer between 100-150°, and the microbaroms from the North Atlantic, appearing in mid-September at 300°.

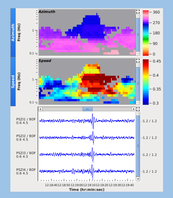
Quarry blasts

Since May 2017 the Hungarian National Seismological Network has recorded more than 300 quarry blasts from more than 30 quarries located in Hungary and Slovakia. In present study we analyze 125 events from 10 selected Hungarian mines in different distances from PSZI array. The nearest locations (Recsk and Kisnána) produce seismic signal that is detectable by the PSZ seismic station, co-located with the infrasound array, the seismic signals from the further locations are detected by the other elements of the Hungarian National Seismological Network, but not by PSZ.
The table shows a summary about the detectability of the events from different sources.

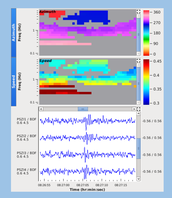
Location	Distance from PSZI (km)	Azimuth (°)	Number of blasts recorded seismically	Number of blasts recorded by infrasound array	Proportion of blasts recorded by infrasound array
Recsk	14	85	4	4	100,00%
Kisnána	21	106	10	7	70,00%
Bercel	36	265	6	5	83,33%
Vác	58	260	7	7	100,00%
Dabas	92	208	8	4	50,00%
Tatabánya	118	251	10	2	30,00%
Gánt	128	242	30	0	0,00%
Iszkaszentgyörgy	140	240	23	0	0,00%
Komló	228	212	13	5	38,46%
Bükkösd	245	216	14	5	35,71%

Tatabánya, Gánt, Iszkaszentgyörgy

Iszkaszentgyörgy, Gánt and Tatabánya are located in the Transdanubian Mountains, roughly 140 km from PSZI. They are all very active mines, our seismological network records explosions almost every week from one of them. 63 events from these 3 mines were analyzed during this study, and only two of them are recorded by the infrasound array, both from Tatabánya. These detections are not as clear as the ones from other locations. This is probably because these mines are located in the acoustic shadow zone of the PSZI array. This assumption will be later verified by ray tracing studies.



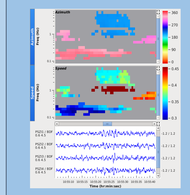
Tatabánya, 2018.01.11. M=1,2



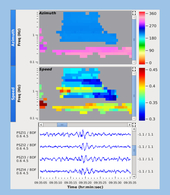
Tatabánya, 2017.09.22. M=1,3

Komló and Bükkösd

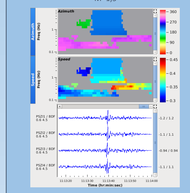
Komló and Bükkösd are quarries located in the South Transdanubia, in the Mecsek mountains, 240 km distance from PSZI. 27 quarry blasts were detected seismically from these locations and 10 of them also by the infrasound station. The detected signal is probably the tropospheric phase of the wave, this will be later confirmed by ray tracing studies.



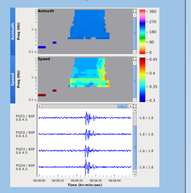
Komló, 2017.11.17. M=1,3



Komló, 2017.10.14. M=1,1



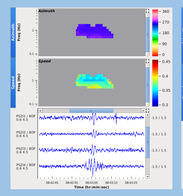
Bükkösd, 2018.02.19. M=1,1



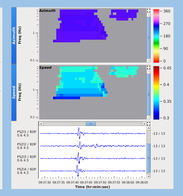
Bükkösd, 2017.09.25. M=1,3

Vác and Bercel

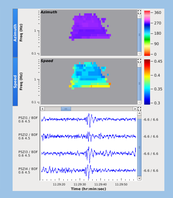
Bercel and Vác are in 36 and 58 km distance from PSZI. In these locations 13 explosions were carried out during in the last 9 months. The infrasound array detected all the explosions except one. The high apparent velocities imply that from these mines PSZI records reflected phases of the infrasound wave.



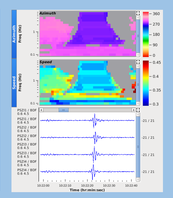
Vác, 2017.10.10. M=1,4



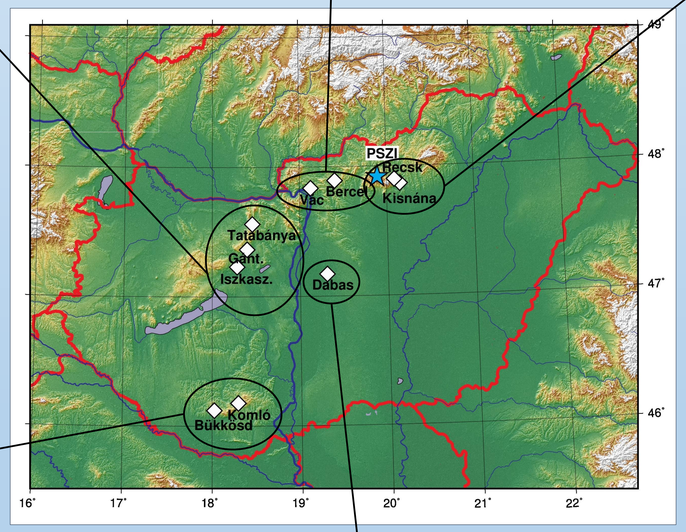
Vác, 2017.09.07. M=1,4



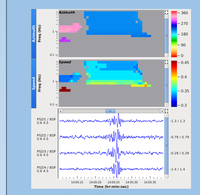
Bercel, 2017.11.20. M=1,8



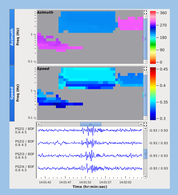
Bercel, 2017.12.13. M=1,3



Dabas



Dabas, 2017.09.25. M=1,6



Dabas, 2017.09.26. M=1,1

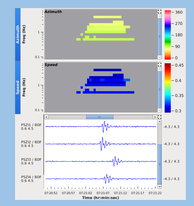
Dabas is a special one among the investigated locations because this seismo-acoustic source is not a mine but a military training area where explosives are regularly neutralized. Similarly to mines, these explosions are also regularly detected by the seismological network and the half of them also by the infrasound array. It is located 92 km from PSZI, so probably on the boundary of the shadow zone of the array and the infrasonic detection of the explosions depends on the current weather conditions.

Future plans

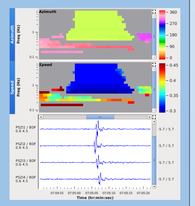
- We continue analyzing explosions from further mines and quarries that were not covered by this study. These include explosions from neighboring countries.
- We will perform ray tracing to better understand the various ray paths and infrasound phases originating from each location. Ray tracing will also be used to confirm infrasound arrivals from the quarry blasts.
- Our near future objective is to produce a catalog of seismo-acoustic events that will include not only explosions but also confirmed sprite, bolide and other natural infrasound events.

Recsk and Kisnána

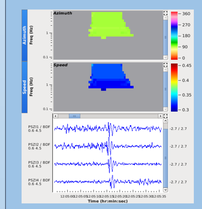
Recsk and Kisnána mines are in the close vicinity of PSZI (14 and 21 km) thus it is not surprising to detect direct arrivals of the generated infrasound wave. These events were recorded by the seismometer co-located with the infrasound array (PSZ), and most of them were detected also by the infrasound array. The apparent propagation velocities imply horizontal propagation of the direct waves.



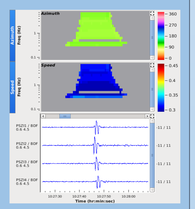
Recsk, 2017.08.30. M=1,6



Recsk, 2017.11.09. M=1,6



Kisnána, 2018.01.09.



Kisnána, 2017.10.06.

Acknowledgements

We thank Pierrick Mialle, Julien Vergoz for their help in setting up PMCC, Elizabeth Blanc and the ARISE2 project for their support.

References

[1] www.arise-project.eu
[2] Cansi, Y. (1995): An automatic seismic event processing for detection and location: The P.M.C.C. method; Geophysical Research Letters, vol. 22, No. 9, pages 1021-1024.