Acoustic Ground Coupling Experiment

Dataset description

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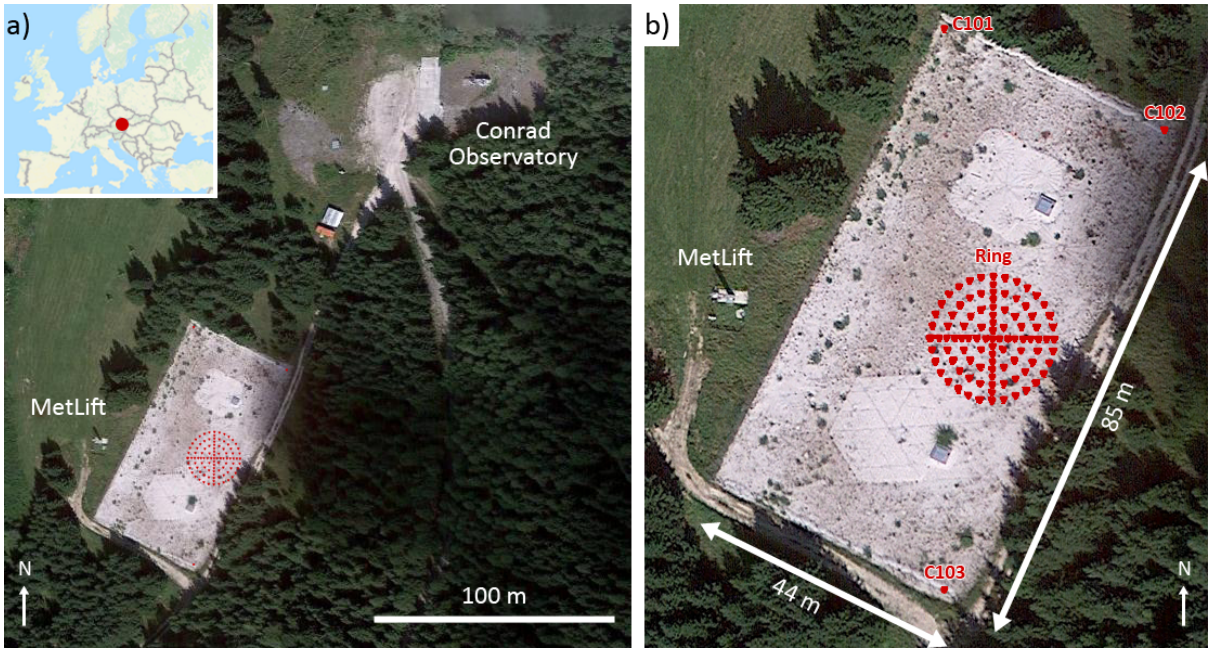


Figure 1: a) Aerial view of the experiment site near the Conrad Observatory, Austria. The location is also highlighted on the inset. b) Close-up view showing the locations of the seismic nodes in the corners (C101, C102, C103) and in the ring.

Dataset

This is the description of the 2019 seismic/acoustic dataset with FDSN network code 6A (Fuchs et al., 2019). Data was acquired in the context of a dense, small-scale temporary (one-day) deployment to investigate acoustic-to-seismic coupling of sound waves created by controlled firework sources.

The experiment was performed on May 14, 2019 at Trafelberg near the Conrad Observatory in Austria (coordinates: 47.9270, 15.8582, 1046 m altitude), on the grounds of a former test site for infrasound wind-noise reduction systems (see Fig. 1). The ground material at the experiment site is limestone-rich thumb-sized breccia (see Fig. 4).

Data is available from 99 autonomous geophones (Fairfield ZLand Gen2 3C 5Hz) - hereafter called nodes - with a corner frequency of 5 Hz that recorded ground velocity in three directions (vertical, horizontal N-S, horizontal E-W) at a continuous sampling rate of 2000 samples per second. Timing on all nodes is GPS synchronized. Four nodes were co-located with Hyperion IFS-5111 seismically decoupled (<0.08 Pa s^2/m)) infrasound sensors - hereafter called Hyperions - that recorded dynamic air pressure changes at a continuous sampling rate of 1000 samples per second. All Hyperions were equipped with the standard Hyperion high-frequency shroud for wind-noise reduction. The Hyperion sensors have a usable calibrated frequency response in the range of 0.001 – 1000 Hz. All Hyperions were connected to the same 6-channel Reftek 130-01 data logger with a Garmin GPS receiver. Hyperion infrasound sensors with station names HYP01, HYP02 and HYP03 were digitized by a Reftek 130-01 type board, whereas HYP04 was digitized by a Reftek 130S type board with different sensitivity - please carefully refer to the station metadata for details (Fuchs et al., 2019).

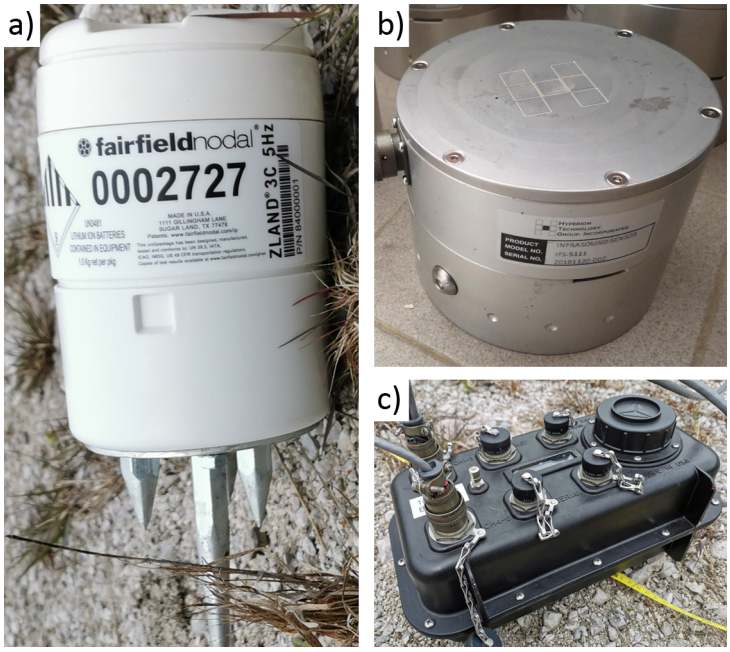


Figure 2: Instruments used in the experiment. a) Fairfield ZLand Gen2 3C 5Hz geophone node with metal spikes at the bottom. b) Hyperion IFS-5111 infrasound sensor with high-frequency shroud. c) Reftek 130-01 data logger.

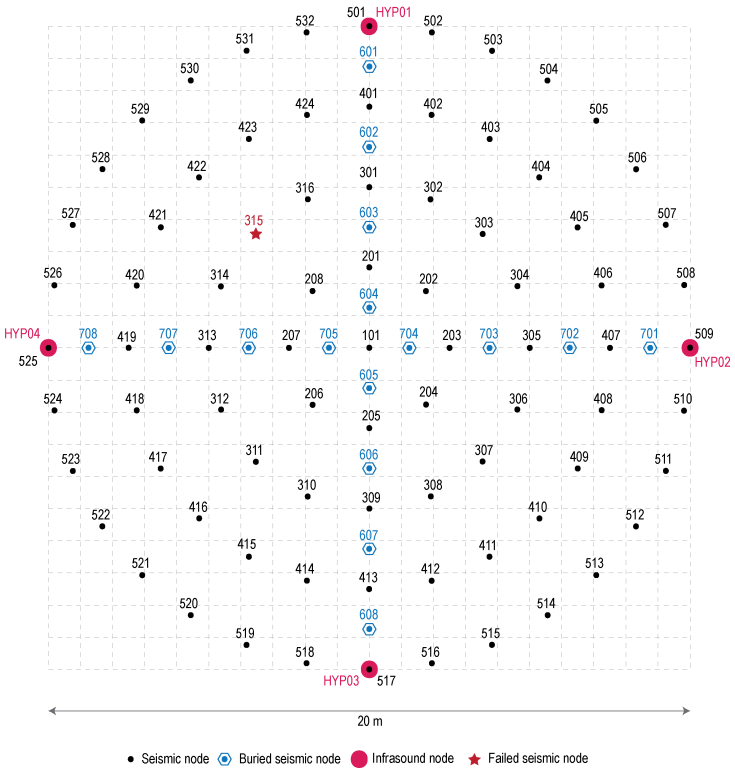
All infrasound channels were recorded with unity gain settings. See Figure 2 for photographs of the instruments used.

The main part of the deployment is an array of 97 seismic nodes (one of which was not functional) arranged in a concentric ring layout of 20 m diameter (see Fig. 3). Four rings were deployed around a central node. The in-ring spacing of the nodes is 2 meters and neighboring rings are separated by 2.5 meters. All ring nodes and the central node were deployed at the ground surface using metal spikes that are attached to them (see Figs. 2 and 4). Additional nodes were installed along N-S and E-W lines in between the rings (8 nodes in each N-S and E-W line, see Fig. 3). These nodes were installed inside holes of 15–20 cm depth and 12–15 cm diameter so the top of each node was at surface level (see Fig. 4). Space around the nodes was filled up with the excavated soil. Three surface nodes (C101, C102, C103) were deployed at 40–45 m distance from the central ring node in the corners of the experiment site (see Fig. 1).

The four nodes at the North, South, East and West side of the ring array are each co-located with one of the Hyperion infrasound sensors (R501-HYP01, R509-HYP02, R517-HYP03, R525-HYP04, see Fig. 4). The infrasound sensors were put on the ground and covered with plastic buckets with holes on the top for wind, rain and dirt protection (see Fig. 4). The spacing between co-located nodes and Hyperions is approximately 20 cm.

The array was operating for approximately 1.5 hours on May 14, 2019. The seismic nodes recorded data simultaneously between 12:45:00 UTC and 14:28:00 UTC. The infrasound sensors were operating between 12:56:05 UTC and 14:29:23 UTC.

Air temperature, air humidity, air pressure and wind speed were recorded on a measuring tower (MetLift) 43 m from the central node at heights of 1, 2, 3, 4 and 5 meters at a sampling rate of 1 sample per minute. Throughout the experiment air temperature varied between 1.5–3.5° Celsius, air



Description	Node naming
Central node	R101
Inner ring	R201 - R208
2nd inner ring	R301 - R316
2nd outer ring	R401 - R424
Outer ring	R501 - R532
N-S line buried	R601 - R608
E-W line buried	R701 - R708

Figure 3: Left: Detailed view of the ring layout and co-located infrasound sensors. Right: Node naming scheme.

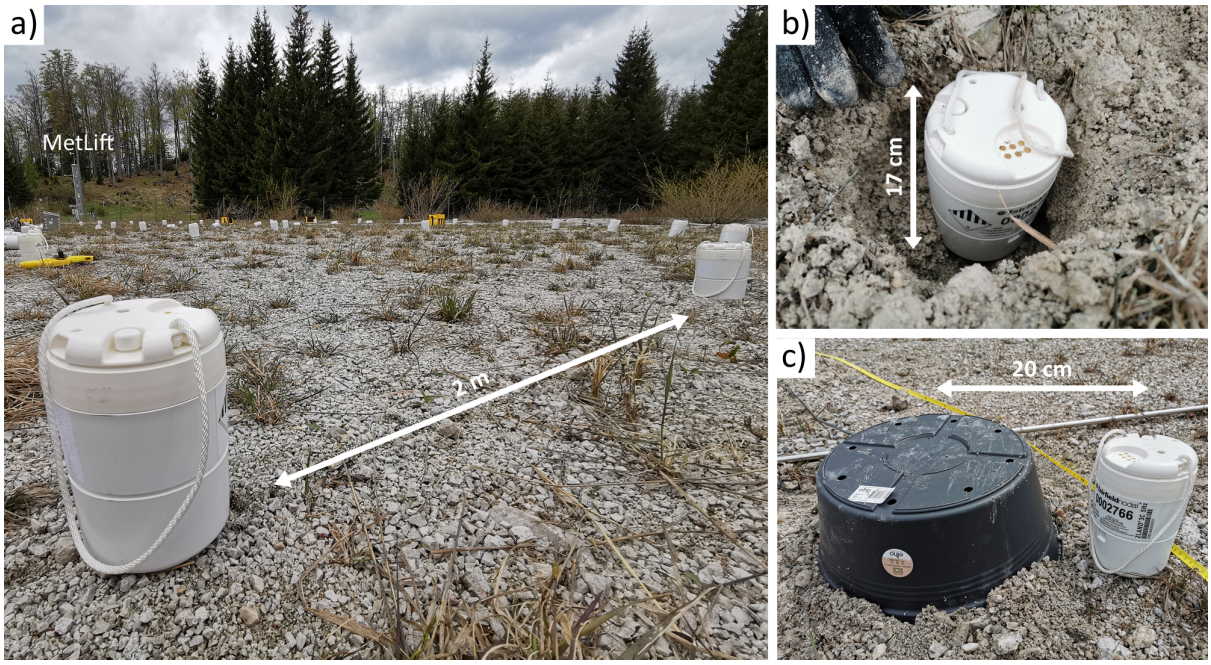


Figure 4: a) Photograph of experiment site and surface node deployment. b) Example of buried node deployment. c) Example of co-located seismic node and infrasound sensor. The infrasound sensor is placed underneath the black plastic bucket.

pressure was approximately 903 hPa and air humidity varied between 45–70%. Wind was blowing in gusts from irregular directions with peak speeds up to 5 m/s.

Data access

All seismic and pressure data from this experiment are freely available. Seismic and pressure waveform data and metadata are available from the European Integrated Data Archive (EIDA) using FDSN webservices (`http://orfeus-eu.org/data/eida/webservices/`, last accessed April 2020) or a website with graphical user interface (`http://orfeus-eu.org/webdc3/`, last accessed April 2020). Please use the network code 6A in 2019 when requesting the data. Any use of the data should properly reference this document as well as the data itself (Fuchs et al., 2019).

Meteorological data (wind direction, wind speed, air temperature, air humidity, air pressure) are available at `https://github.com/IMGW-univie/ground-coupling`.

Acoustic and seismic sources

Several acoustic and seismic sources were shot during the experiment: sequences of hammer beats, firecrackers above ground, firecracker slightly buried, flying rockets and rockets slightly buried. Table 1 lists all information about all active source shots. A text file containing the same information is also available at `https://github.com/IMGW-univie/ground-coupling`. In between shots people were moving around at the experiment site so data in between shots is impacted by foot step signals. Wind gusts occurred repeatedly and irregularly. These also effect the records of the seismic nodes.

Hammer

Hammer beats were performed at several locations around the edge of the seismic node ring and at the corners of the experiment site. At each location approximately 10 hammer beats were performed in quick succession. Please refer to Figure 5a and Table 1 for location and timing details.

Firecrackers

Firecrackers (Fig. 5b-e) of three different charge sizes (L,M,S) were fired. The charge size is taken from the net explosive mass (NEM) specified on the cracker packaging. Firecrackers were shot at five different locations above ground (placed on top of poles or a tripod) and at one location where the crackers were buried at approximately 5 cm depth (see Fig. 5a and Tab. 1). At each location near the ring the same sequence of firecrackers was shot: 1x L charge (= 7.5g NEM, Fig. 5c), 1x M charge (= 6.75g NEM, Fig. 5d) and 4x S charge (= 0.8g NEM, Fig. 5e). The respective shot heights

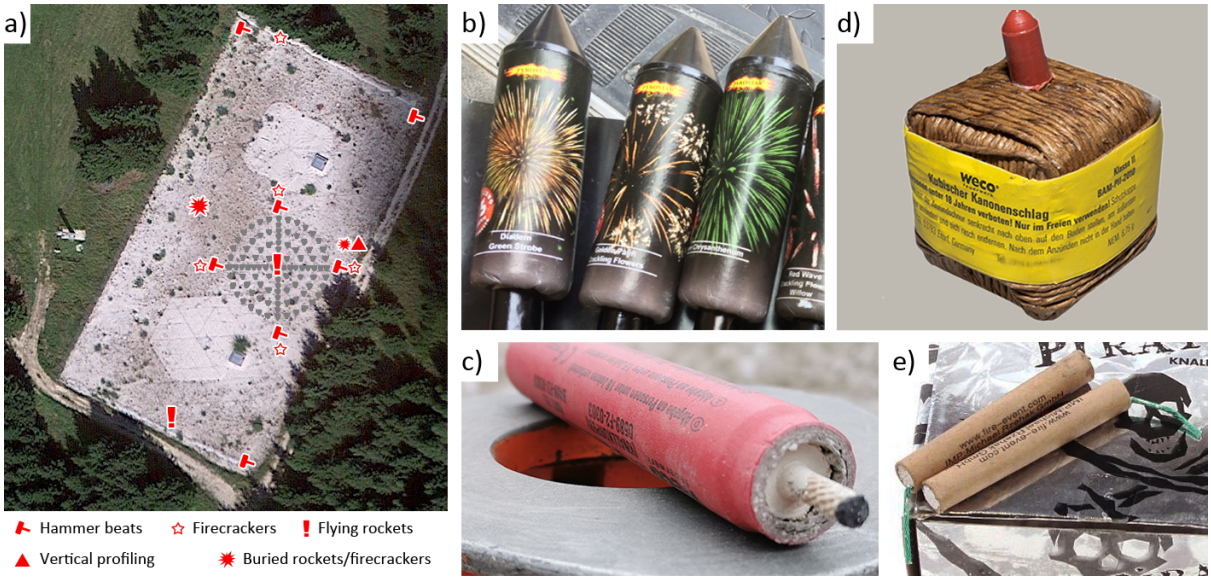


Figure 5: a) Map of active source shot locations. b) Rockets with different effect heads, 75g NEM. c) Firecracker charge L, 7.5g NEM. d) Firecracker charge M, 6.75g NEM. e) Firecracker charge S, 0.8g NEM. NEM = net explosive mass.

above ground are listed in Table 1. At one location offset from the ring only a single L charge was fired (see Fig. 5a and Tab. 1). Several charges of size S were shot at different heights east of the ring (labelled vertical profiling in Fig. 5a). Please refer to Table 1 for the respective height parameters.

Rockets

Rockets (Fig. 5b) were fired from two different locations. Three rockets were fired at the center of the ring, next to the central seismic node. Two rockets were launched south of the ring (see Fig. 5a and Tab. 1). Two rocket heads were buried at approximately 5 cm depth and fired north-west of the ring layout (see Fig. 5a and Tab. 1). All rockets contained 75g NEM which includes fuel and effect explosive mass. The explosion height of the rocket head is approximately 40–60 m above surface (according to the vendor).

Acknowledgments

We are very grateful to Roman Leonhardt from ZAMG for providing access to the experiment site and for granting the permission to use it for our purposes. Thanks to Manfred Dorninger for providing meteorological data from the Metlift. We also thank all helpers in the field: Petr Kolínský, Sven Schippkus, Gerrit Hein, Irene Bianchi, Tommaso Pivetta, Stefan Weginger, Galina Simeonova, Ghazaleh Shirdel, Fatemeh Naeimi.

Table 1: Complete list of active sources fired during the experiment. Note that for hammer sources only the beginning of each 10-strokes hammer sequence is listed. NEM is net explosive mass.

Source type	NEM (g)	Latitude	Longitude	Time (UTC)	Height
Hammer		47.92743	15.85815	12:47:07	
Hammer		47.92728	15.85863	12:45:13	
Hammer		47.92663	15.85819	12:49:35	
Hammer		47.92699	15.85841	12:52:03	
Hammer		47.92699	15.85809	12:53:48	
Hammer		47.92688	15.85824	12:56:53	
Hammer		47.92710	15.85825	12:58:25	
Rocket	75	47.92699	15.85825	13:05:00.08	
Rocket	75	47.92699	15.85825	13:14:53.95	
Rocket	75	47.92699	15.85825	13:16:20.62	
Rocket	75	47.92672	15.85799	14:07:22.40	
Rocket	75	47.92672	15.85799	14:08:17.80	
Buried rocket	75	47.92699	15.85804	14:15:58.98	-5 cm
Buried rocket	75	47.92699	15.85804	14:18:29.20	-5 cm
Buried firecracker	7.5	47.92699	15.85841	13:53:51.89	-5 cm
Buried firecracker	6.75	47.92699	15.85841	13:54:32.72	-5 cm
Buried firecracker	0.8	47.92699	15.85841	13:55:39.77	-5 cm
Firecracker	0.8	47.92699	15.85841	14:21:59.94	70 cm
Firecracker	0.8	47.92699	15.85841	14:22:57.45	90 cm
Firecracker	0.8	47.92699	15.85841	14:23:50.13	120 cm
Firecracker	0.8	47.92699	15.85841	14:24:20.92	130 cm
Firecracker	0.8	47.92699	15.85841	14:25:00.63	150 cm
Firecracker	0.8	47.92699	15.85841	14:25:36.96	170 cm
Firecracker	7.5	47.92699	15.85844	13:21:56.92	2.1 m
Firecracker	6.75	47.92699	15.85844	13:23:42.29	2.1 m
Firecracker	0.8	47.92699	15.85844	13:24:42.02	2.1 m
Firecracker	0.8	47.92699	15.85844	13:26:02.18	2.1 m
Firecracker	0.8	47.92699	15.85844	13:26:34.47	2.1 m
Firecracker	0.8	47.92699	15.85844	13:28:14.33	2.1 m
Firecracker	7.5	47.92686	15.85824	13:35:27.25	1.65 m
Firecracker	6.75	47.92686	15.85824	13:36:12.54	1.65 m
Firecracker	0.8	47.92686	15.85824	13:36:42.17	1.65 m
Firecracker	0.8	47.92686	15.85824	13:37:08.56	1.65 m
Firecracker	0.8	47.92686	15.85824	13:37:32.48	1.65 m
Firecracker	0.8	47.92686	15.85824	13:37:54.95	1.65 m
Firecracker	7.5	47.92699	15.85805	13:40:38.48	1.65 m
Firecracker	6.75	47.92699	15.85805	13:41:09.89	1.65 m
Firecracker	0.8	47.92699	15.85805	13:41:56.06	1.65 m
Firecracker	0.8	47.92699	15.85805	13:42:18.59	1.65 m
Firecracker	0.8	47.92699	15.85805	13:42:47.82	1.65 m
Firecracker	0.8	47.92699	15.85805	13:43:07.69	1.65 m
Firecracker	7.5	47.92712	15.85825	13:47:07.70	1.65 m
Firecracker	6.75	47.92712	15.85825	13:47:43.82	1.65 m
Firecracker	0.8	47.92712	15.85825	13:48:19.59	1.65 m
Firecracker	0.8	47.92712	15.85825	13:48:59.56	1.65 m
Firecracker	0.8	47.92712	15.85825	13:49:32.02	1.65 m
Firecracker	0.8	47.92712	15.85825	13:49:49.81	1.65 m
Firecracker	7.5	47.92741	15.85827	14:01:43.79	2.1 m

References

F. Fuchs, A. Novoselov, and G. Bokelmann. Acoustic ground coupling experiment: The dataset. department of meteorology and geophysics, university of vienna, hosted by orfeus and the international federation of digitial seismograph networks. dataset/seismic network. 2019. doi: 10.7914/SN/6A_2019.