Seismo-acoustic ground coupling: Wave types, transfer efficiency, and near-surface structure

Results from a small-scale
acoustic ground coupling experiment

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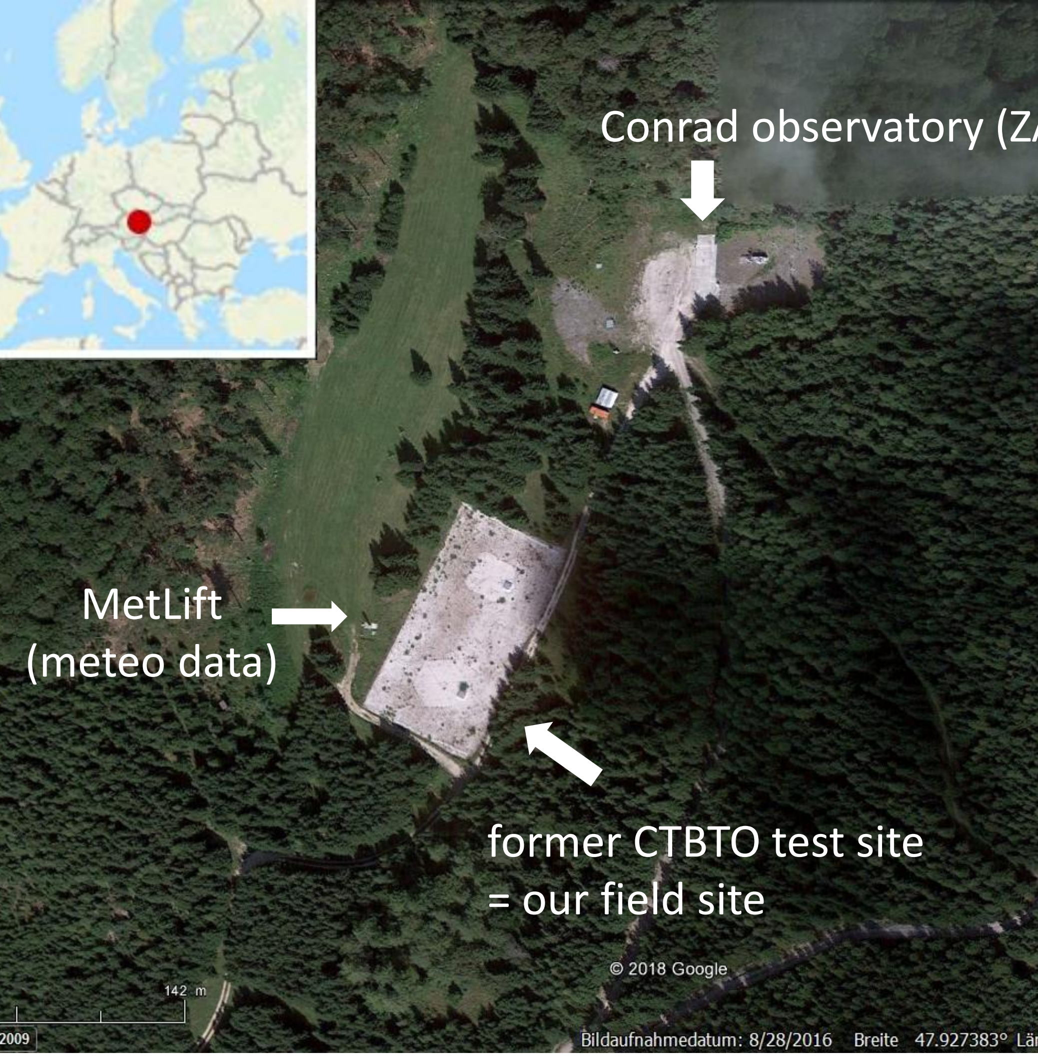
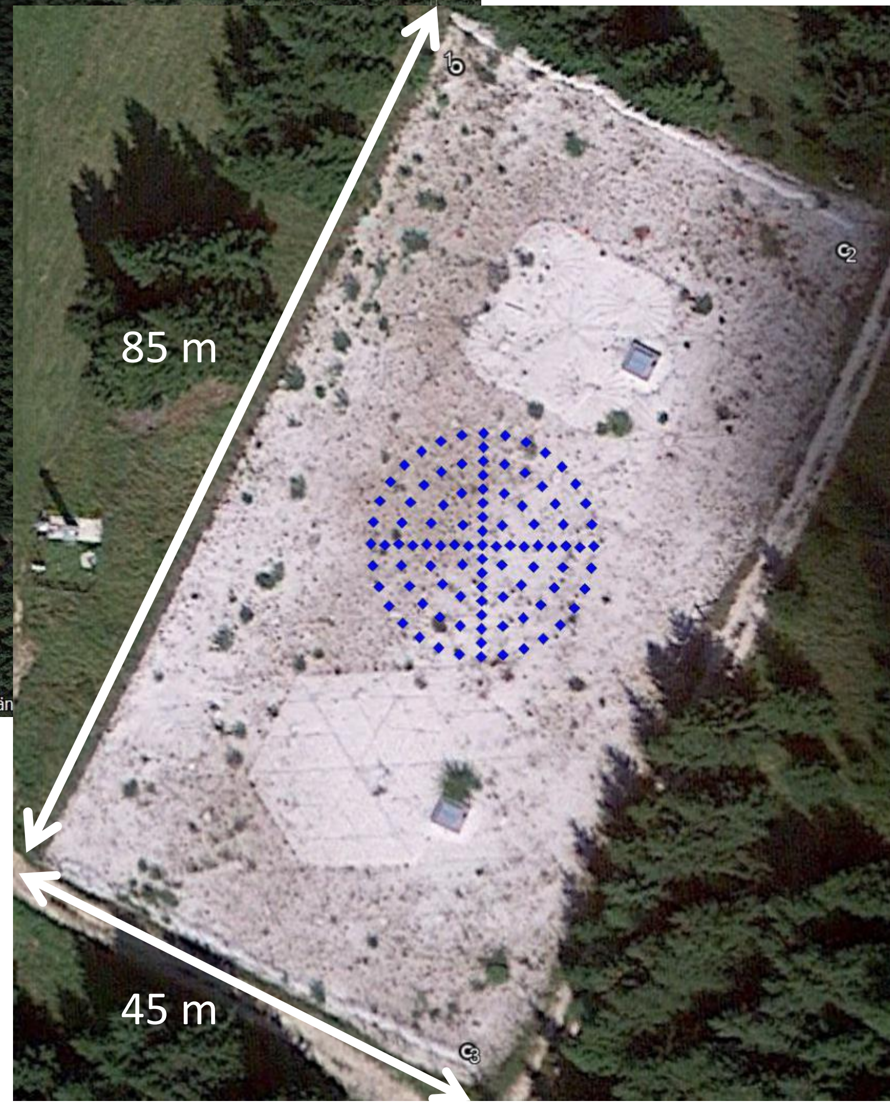


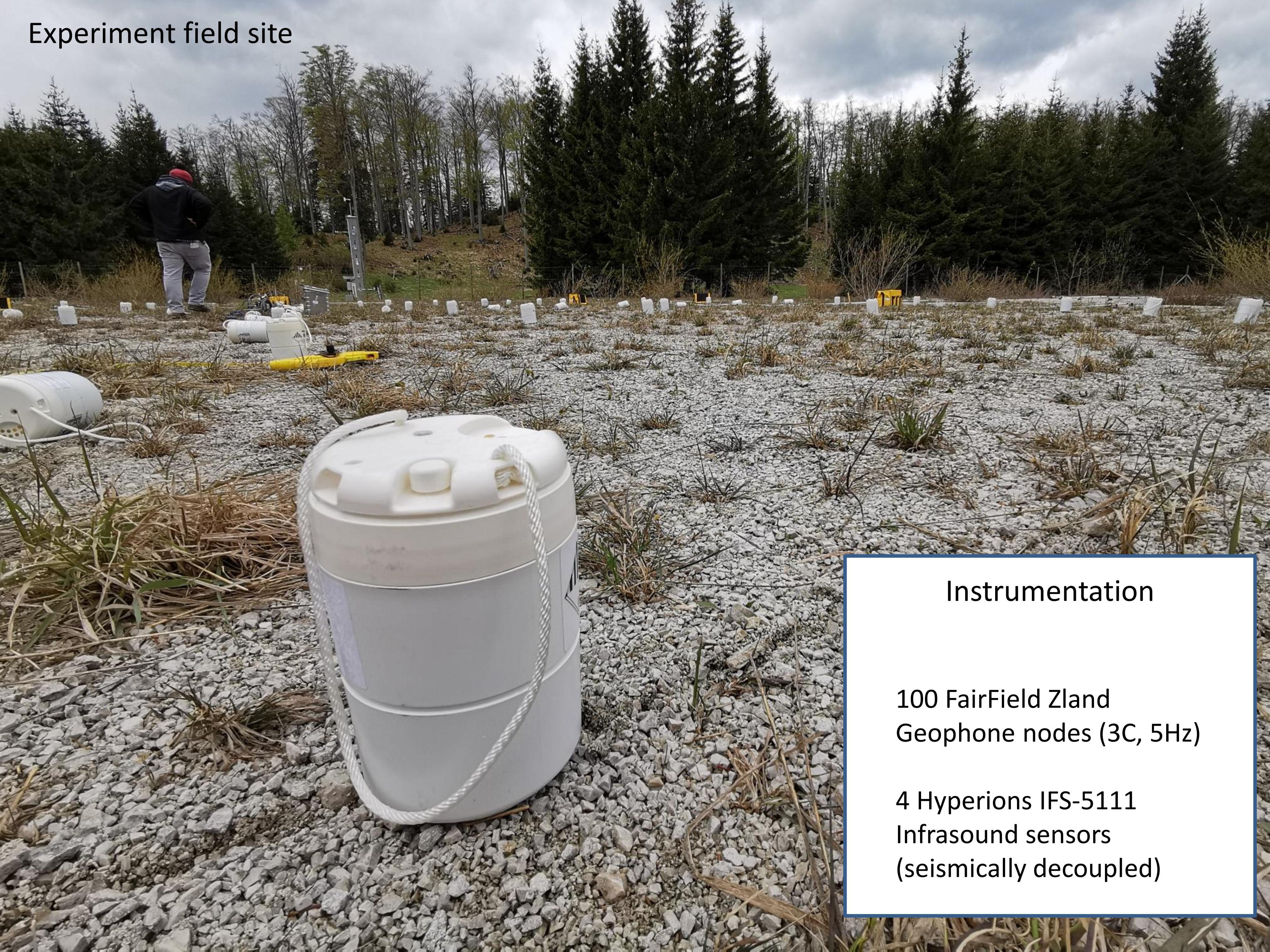
Experiment setup



Motivation

- How sensitive are geophone nodes to acoustic perturbations?
- Can we use them to locate acoustic sources at height?

Experiment field site


Experiment field site
Instrumentation
100 FairField Zland
Geophone nodes (3C, 5Hz)
4 Hyperions IFS-5111
Infrasound sensors
(seismically decoupled)

Hyperion IFS-5111
Infrasound sensor below bucket

Wind noise
reduction „system“

Design 1

Wind noise
reduction „system“

Design 2

Co-located seismic & infrasound sensors

Acoustic Sources

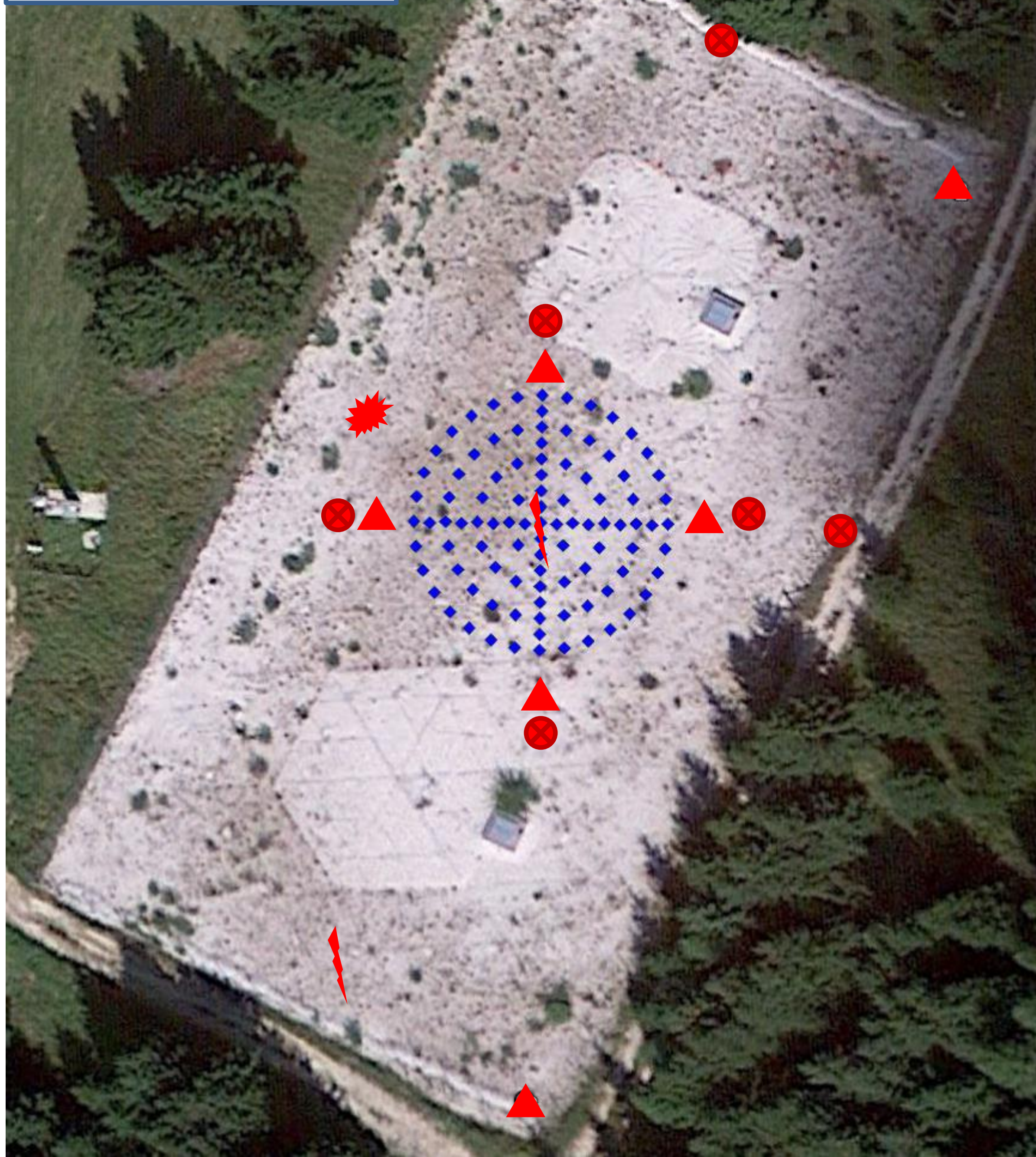
= hammer beats

= flying rockets

= buried rockets

= firecrackers

75 g NEM



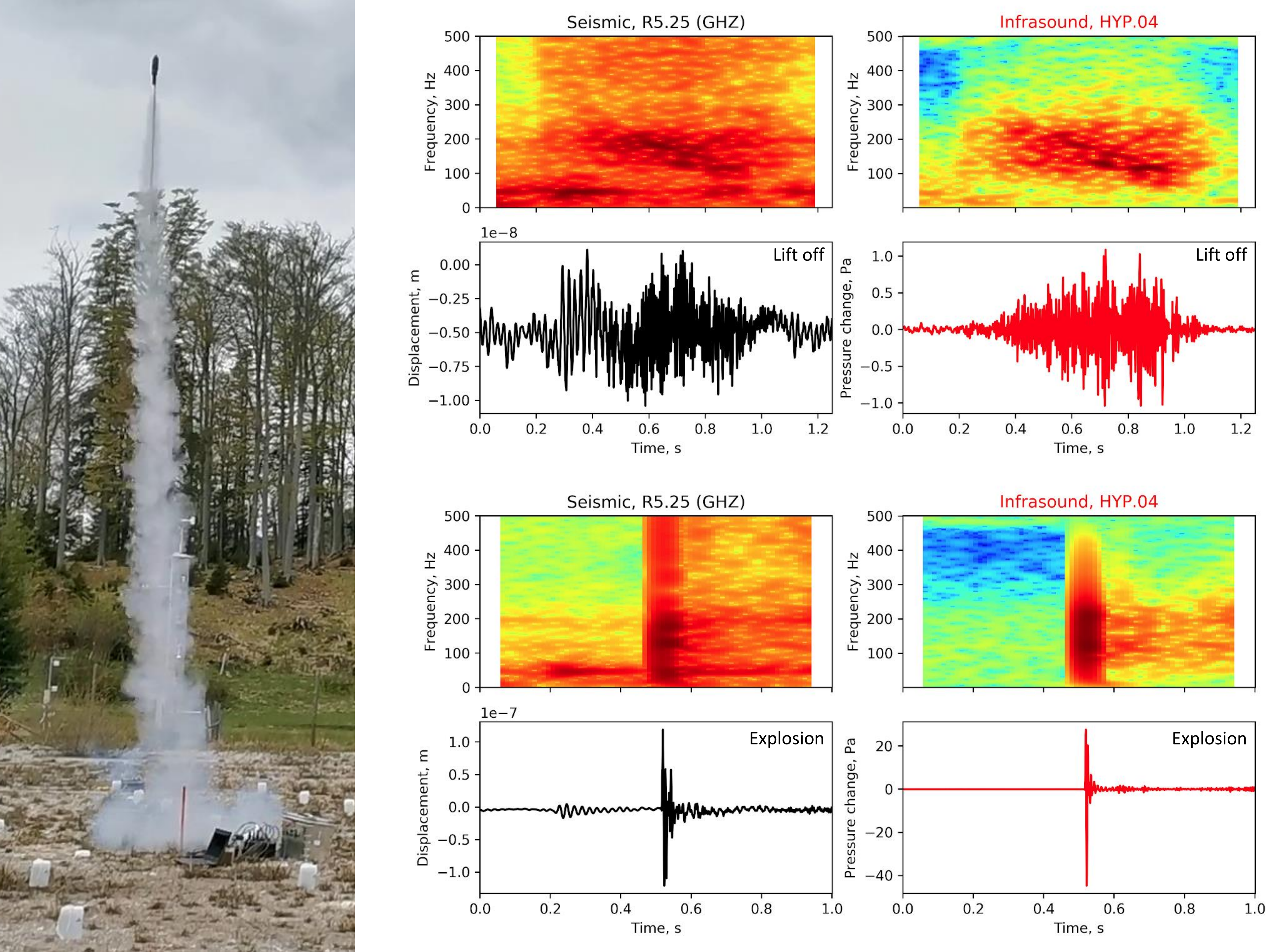
Why look at rocket signals?

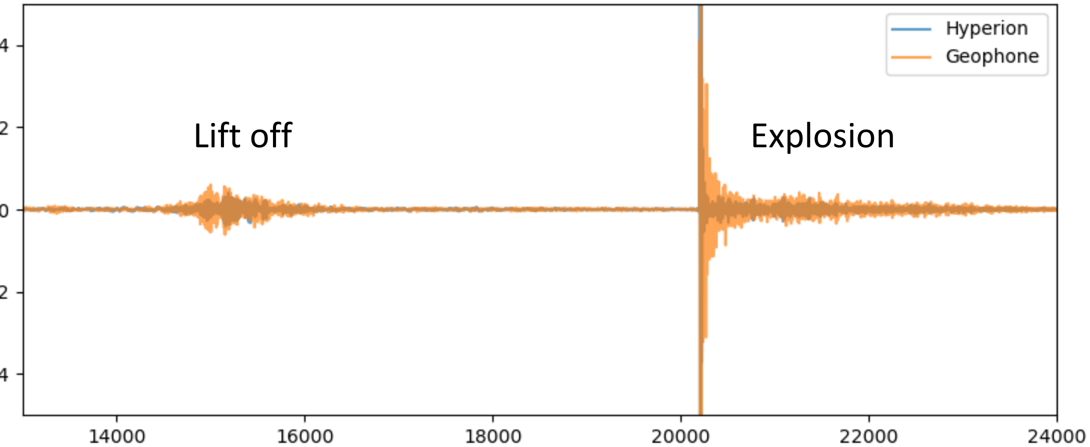
75g NEM (fuel + head)

Moving source - can we track it acoustically using geophone nodes ?

- Test run for thunder analysis with geophone nodes

- Can we locate/separate sources along lightning strike?

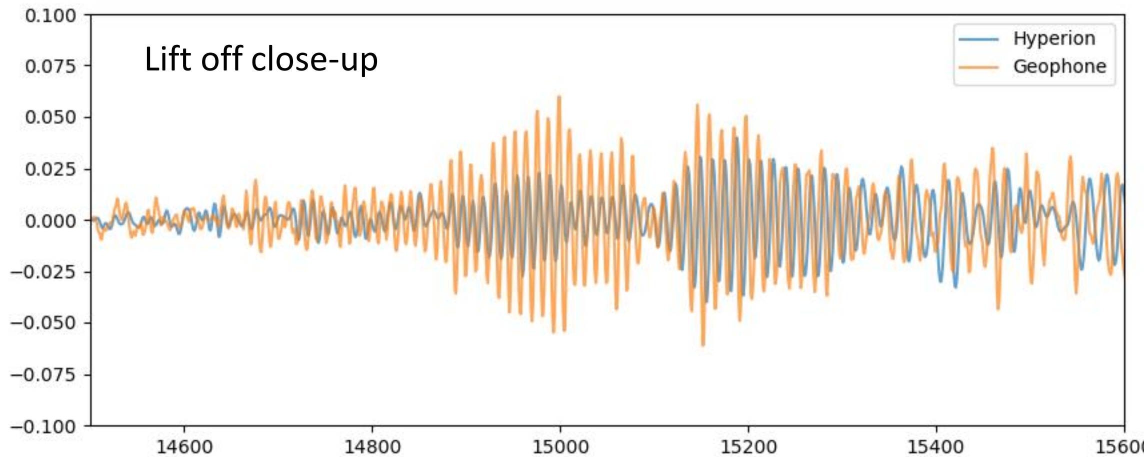

Seismic, R5.25 (GHZ)
Infrasound, HYP.04
Frequency, Hz
1e−8
Displacement, m
Lift off
Pressure change, Pa
Lift off
Time, s
Time, s
Seismic, R5.25 (GHZ)
Infrasound, HYP.04
Frequency, Hz
1e−7
Displacement, m
Explosion
Pressure change, Pa
Explosion
Time, s
Time, s

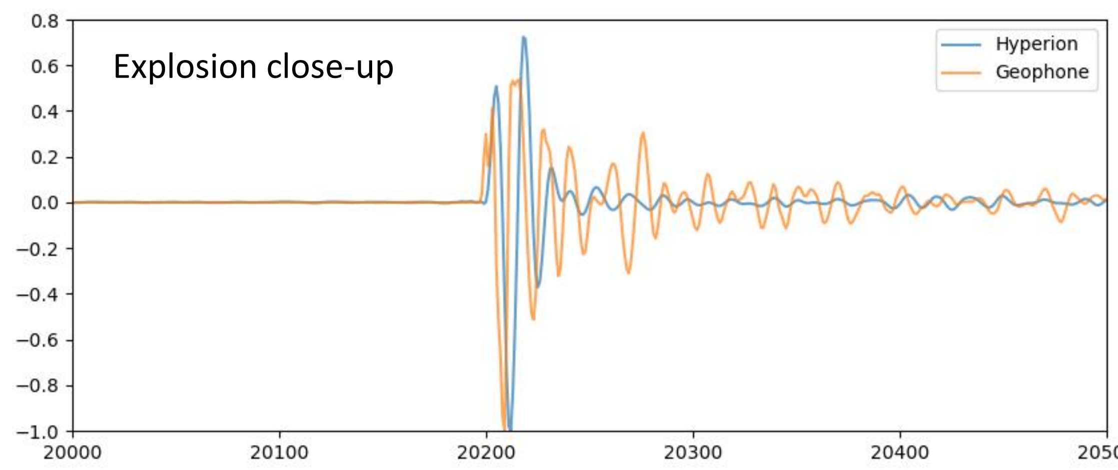


Surface geophone

(beware geophone polarity:
positive values = DOWNward motion)

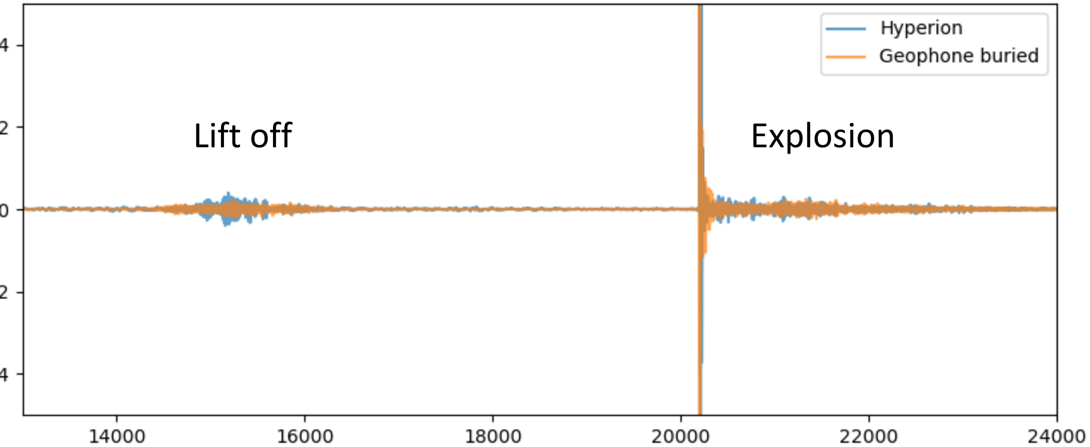
amplitudes are normalized





Waveforms are strikingly similar !

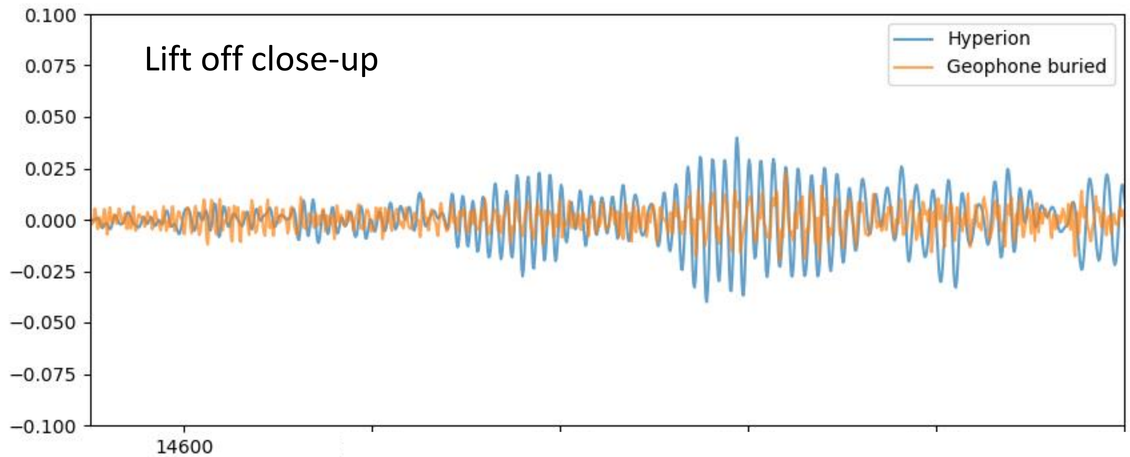
1.7 µm/s per Pa

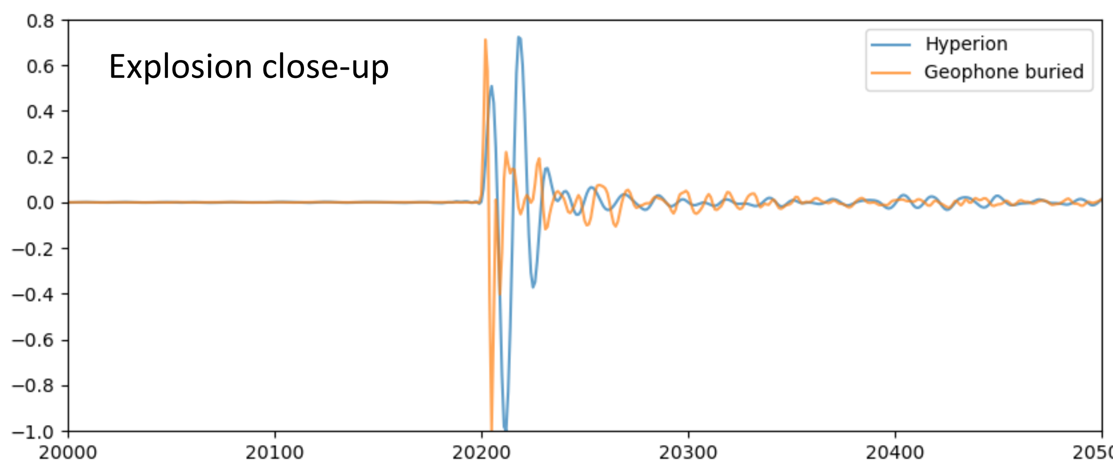


Buried geophone

(beware geophone polarity:
positive values = DOWNward motion)

amplitudes are normalized



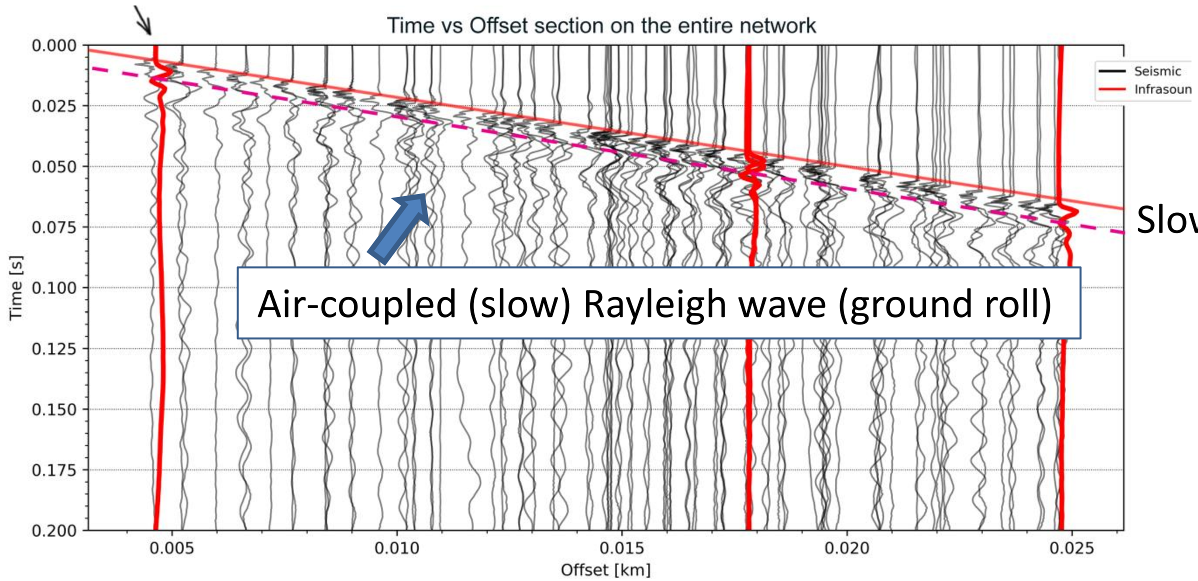


Waveforms are still very similar !

Wave types:

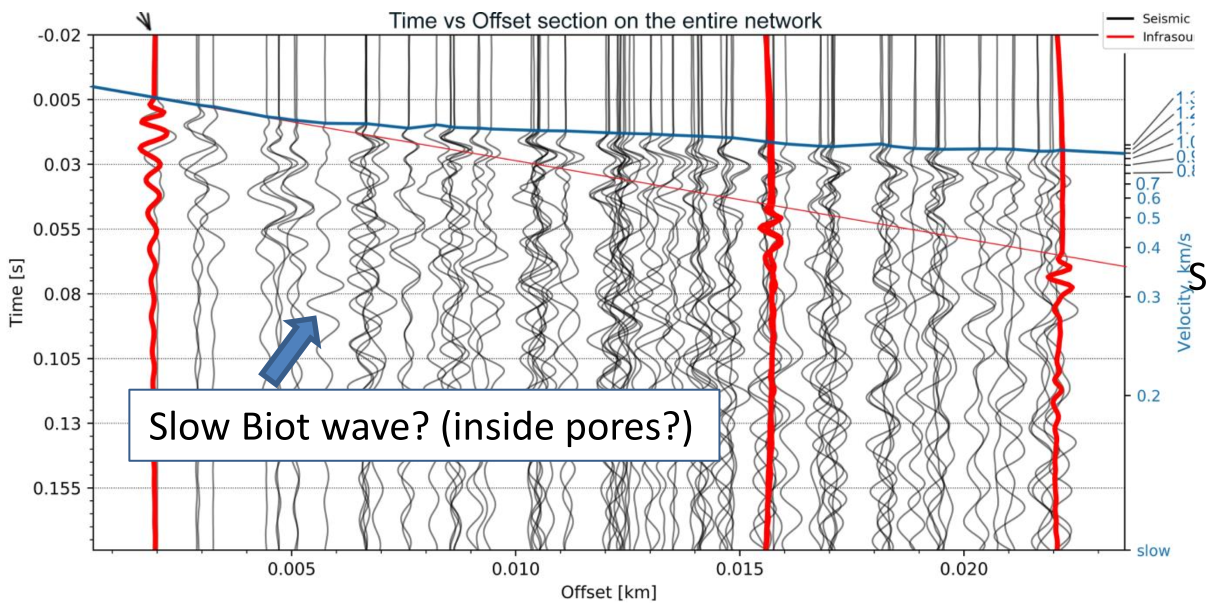
What kind of wave types do acoustic sources induce in the ground?

Acoustic source at height (firecracker)



Slow acoustic arrival

Seismic source at surface (hammer beat)

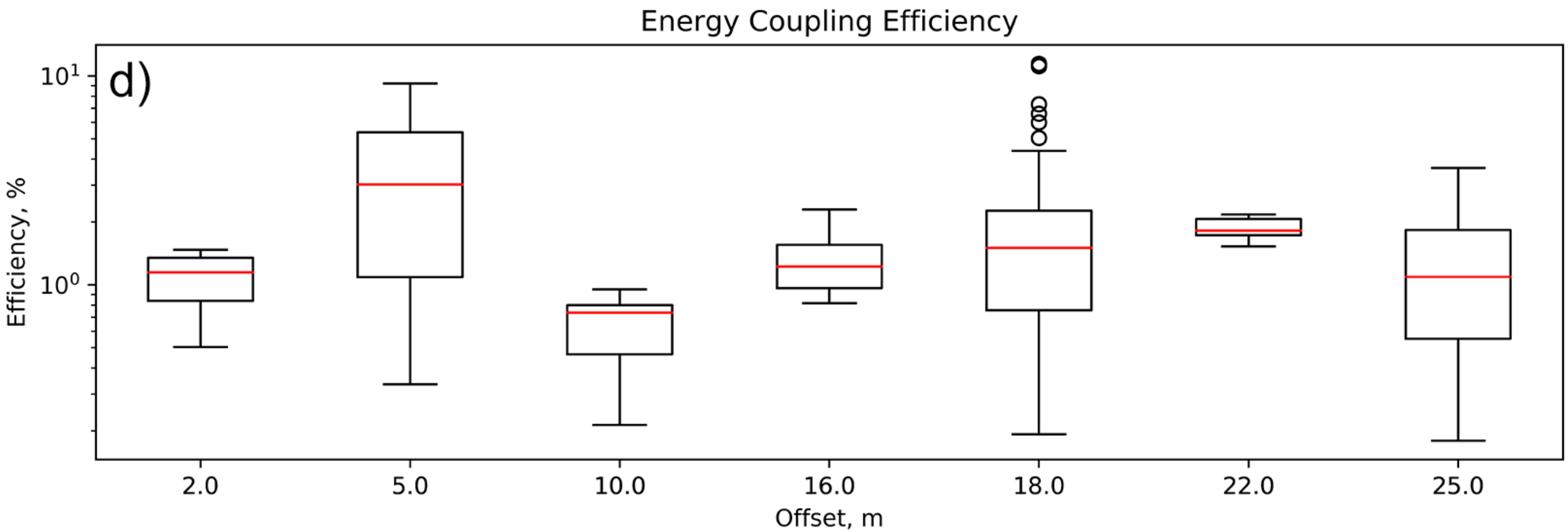


Fast seismic arrival

Slow acoustic arrival

Coupling efficiency:

Having co-located seismic and infrasound sensors we can calculate the energy transmission into the ground:



Conversion from acoustic energy to seismic energy ~ 1%

Estimating soil parameters:

Having co-located seismic and infrasound sensors we can infer near surface elastic parameters:

Acoustic velocity

Seismic horizontal displacement

$$U_x = \frac{-iV_{\mathrm{air}}p_0}{2\omega(\lambda+\mu)}$$

Dynamic pressure on infrasound sensor

Seismic vertical displacement

$$U_z = \frac{-V_{\mathrm{air}}p_0}{2\omega(\lambda+\mu)}\left(\frac{\lambda+2\mu}{\mu}\right)$$

Lamé parameters

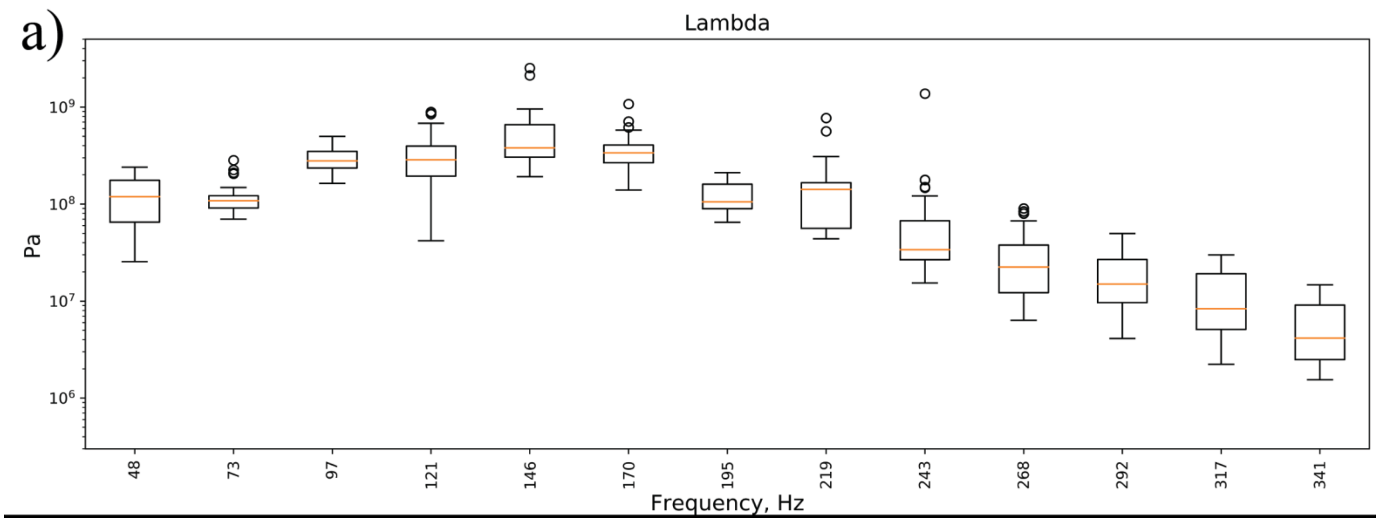
Ben-Menahem, A. & Singh, S. J., 1981. Seismic Waves and Sources, Springer, New York, NY.

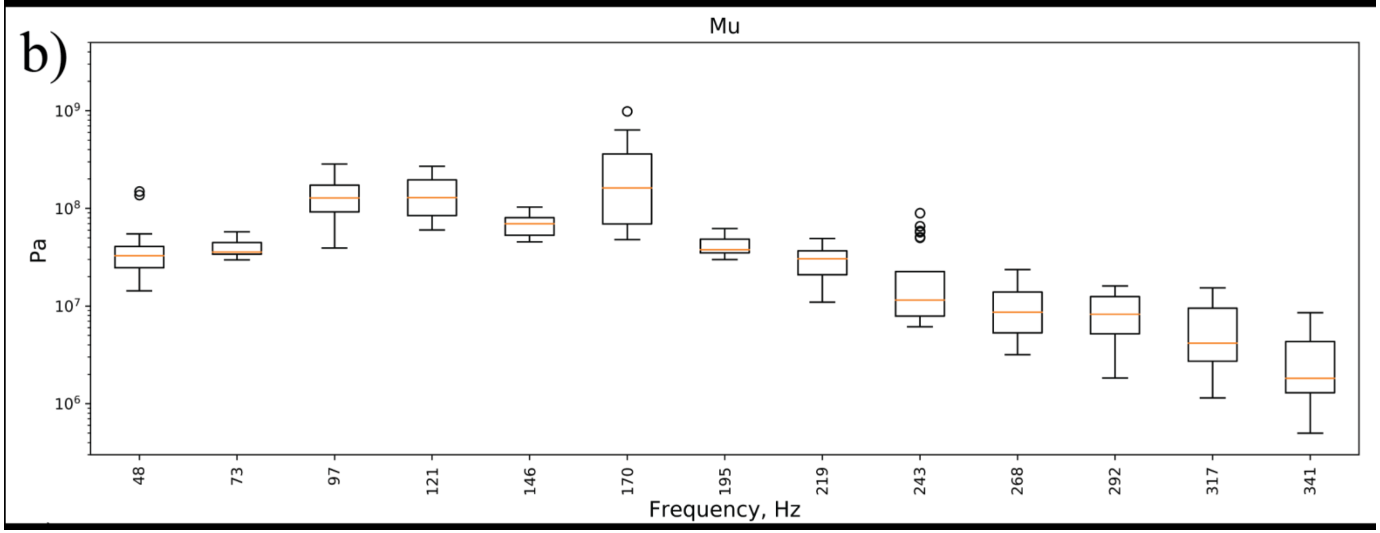
Measuring dynamic air pressure, and 3D seismic displacement allows to infer Lamé parameters!

Doing this for different frequencies allows for a depth profile!

Estimating soil parameters:

Results:





This was only a brief preview …

Got interested?

Await the upcoming paper in **GJI** (submitted):

Acoustic-to-seismic ground coupling: coupling efficiency and inferring near-surface properties

Artemii Novoselov, Florian Fuchs, Goetz Bokelmann

Check out the comprehensive dataset and experiment description document:

https://doi.org/10.25365/PHAIDRA.111

Watch out for waveform data soon being made available at EIDA, using network code 6A (2019)

https://www.orfeus-eu.org/data/eida/