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

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A fraction of the acoustic wave energy (from the atmosphere) may couple into the ground, and it can thus be recorded as ground motion using seismometers. We have investigated this coupling, with two questions in mind, a) how strong it is for small explosive sources and offsets up to a few tens of meters, and b) what we can learn about the shallow subsurface from this coupling. 25 firecracker explosions and 5 rocket explosions were analyzed using co-located seismic and infrasound sensors; we find that around 2% of the acoustic energy is admitted into the ground. Recording dynamic air pressure together with ground motion at the same site allows identification of different waves propagating in the shallow underground, notably the seismic expression of the direct airwave, and the later air-coupled Rayleigh wave. We can reliably infer shallow ground properties from the direct airwave, in particular the two Lame constants and the Poisson-ratio.

During most of its history, seismology has regarded elastic and pressure waves, propagating below and above ground, separately, calling the former waves "seismic" and the latter "acoustic". This was in part due to an intellectual boundary, but it was also for convenience: the assumption of a traction-free surface (and of seismic displacements that are discontinuous across it) provided a simple and convenient upper boundary condition for seismic modeling.

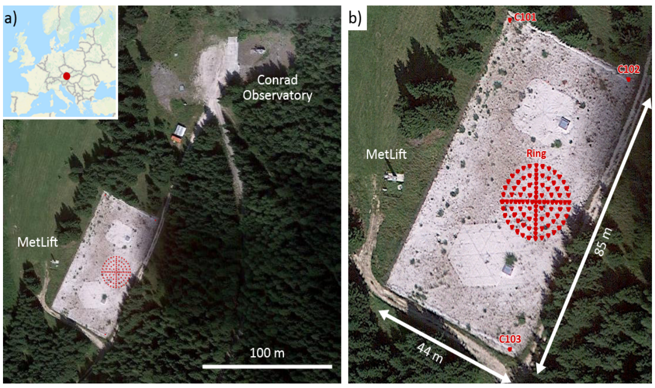

Figure 1: a) Aerial view of the experiment site near the Conrad Observatory, Austria. The location in Europe is highlighted on the inset. b) Close-up view showing the position of the ring array.

The experiment was performed on May 14, 2019, near the Conrad Observatory on the Trafelberg mountain in Austria (see Figure 1). The core of the experiment is a seismic array of 97 geophone nodes (Fairfield ZLand Gen2, 3-components, 5Hz corner period) arranged in a concentric ring layout of 20 m diameter. To study acoustic-to-seismic coupling, we have analyzed 25 firecracker explosions and 5 rocket explosions using the ring array and co-located infrasound sensors.

The spectrograms and waveforms show that the co-located seismic and infrasound sensors have recorded energy in a similar frequency band for the first arrival, which is followed on the seismic trace (and only there) by a prolonged wavetrain with a narrow-band spectrum. For more details please refer to the publication Novoselov et. al 2020 (https://doi.org/10.1093/gji/ggaa304).

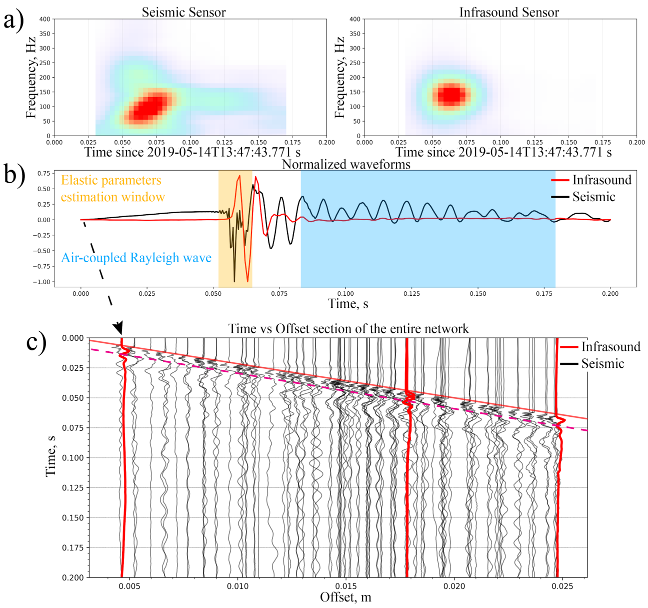

Figure 2: Explosion Experiment: infrasound and seismic measurements of a "large" charge explosion at co-located seismic (R501) and infrasound (HYP01) sensors (data is not filtered). a) Spectrograms for corresponding seismic and infrasound records. b) Normalized and overlaid, on top of each other, seismic and infrasound wave-forms. The background shows the time window of the direct airwave used for determining elastic parameters, and that of the air-coupled Rayleigh wave. c) Section plot (time versus distance). Seismic traces are shown in black (vertical components), infrasound in red. Red solid line indicates picked acoustic velocity. Purple dashed line indicates air-coupled Rayleigh wave. The acoustic wave propagates with a velocity of around 0.3 km/s; coherent phases of the subsequent air-coupled Rayleigh wave suggest a similar phase velocity.

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