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Acoustic-Seismic Coupling of Broadband Signals - Analysis of Potential Disturbances during CTBT On-Site Inspection Measurements

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For the verification of the Comprehensive Nuclear Test Ban Treaty (CTBT) the precise localisation of possible underground nuclear explosion sites is important. During an on-site inspection (OSI) sensitive seismic measurements of aftershocks can be performed, which, however, can be disturbed by other signals. To improve the quality and effectiveness of these measurements it is essential to understand those disturbances so that they can be reduced or prevented. In our work we focus on disturbing signals caused by airborne sources: When the sound of aircraft (as often used by the inspectors themselves) hits the ground, it propagates through pores in the soil. Its energy is transferred to the ground and soil vibrations are created which can mask weak aftershock signals.
The understanding of the coupling of acoustic waves to the ground is still incomplete. However, it is necessary to improve the performance of an OSI, e.g. to address potential consequences for the sensor placement, the helicopter trajectories etc. We present our recent advances in this field.

We performed several measurements to record sound pressure and soil velocity produced by various sources, e.g. broadband excitation by jet aircraft passing overhead and signals artificially produced by a speaker. For our experimental set-up microphones were placed close to the ground and geophones were buried in different depths in the soil. Several sensors were shielded from the directly incident acoustic signals by a box coated with acoustic damping material. While sound pressure under the box was strongly reduced, the soil velocity measured under the box was just slightly smaller than outside of it. Thus these soil vibrations were mostly created outside the box and travelled through the soil to the sensors. This information is used to estimate characteristic propagation lengths of the acoustically induced signals in the soil.
In the seismic data we observed interference patterns which are likely caused by the superposition of acoustically induced seismic waves with reflections at a layer boundary. Their frequencies of increased/decreased amplitudes depend on the angle of incidence of the acoustic signal. So these patterns can be used to estimate the path(s) of propagation of acoustically induced soil vibrations. The frequency-dependent phase offset between different sensors is used to estimate the propagation velocity of soil.
The research aims to deliver a better understanding of the interaction of acoustic waves and the ground when hitting the surface, the transfer of energy from sound waves into the soil and the possible excitation of seismic surface waves. The goal is to develop recommendations for sensitive seismic measurements during CTBTO on-site inspections to reduce disturbing vibrations caused by airborne sources.