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Acoustic-Seismic Coupling in Porous Ground - Measurements and Analysis for On-Site-Inspection Support

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During on-site inspections (OSI) of the Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO) a local seismic network can be installed to measure seismic aftershock signals of an assumed underground nuclear explosion. These signals are caused by relaxation processes in and near the cavity created by the explosion and when detected can lead to a localisation of the cavity. This localisation is necessary to take gas samples from the ground which are analysed for radioactive noble gas isotopes to confirm or dismiss the suspicion of a nuclear test. The aftershock signals are of very low magnitude so they can be masked by different sources, in particular periodic disturbances caused by vehicles and aircraft in the inspection area. Vehicles and aircraft (mainly helicopters) will be used for the inspection activities themselves, e.g. for overhead imagery or magnetic-anomaly sensing. While vehicles in contact with the ground can excite soil vibrations directly, aircraft and vehicles alike emit acoustic waves which excite soil vibrations when hitting the ground. These disturbing signals are of periodic nature while the seismic aftershock signals are pulse-shaped, so their separation is possible.
The understanding of the coupling of acoustic waves to the ground is yet incomplete, a better understanding is necessary to improve the performance of an OSI, e.g. to address potential consequences for the sensor placement, the helicopter trajectories etc.

In a project funded by the Young Scientist Research Award of the CTBTO to one of us (ML), we investigated the acoustic-seismic coupling of airborne signals of jet aircraft and artificially induced ones by a speaker. During a measurement campaign several acoustic and seismic sensors were placed below the take-off trajectory of an airport at 4 km distance. Therefore taking off and landing jet aircraft passed nearly straightly above the setup. Microphones were placed close to the ground to record the sound pressure of incident acoustic signals and geophones were buried in different depths to measure the soil velocity.
Additionally, a wooden box coated with acoustic damping foam was placed over some acoustic and seismic sensors to reduce the power of incident acoustic signals and thus the locally created seismic vibrations (under the box). The reduced soil velocity measured by geophones under the box corresponds mainly to vibrations created by acoustic-seismic coupling outside the box which travel through the soil and reach the sensor. Under certain conditions of frequency and incident angle of acoustic signals an increased seismic response was observed. This might indicate the excitation of seismic surface waves and is of special interest for the evaluation.
The project aims to deliver a better understanding of the interaction of acoustic waves with the ground when hitting the surface. Recommendations for sensitive seismic measurements during CTBTO on-site inspections will be developed to reduce disturbing vibrations caused by airborne sources.