Seismo-Acoustic Shockwave Isolation for Low-Yield Local Explosions

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Seismic and acoustic recordings have long been used for the forensic analysis of various natural and anthropogenic events, especially in the realm of nuclear treaty monitoring. More recently, multi-phenomenological analysis has been applied to these signals with great success, providing unique constraints for studying a broad range of source events, including man-made noise, earthquakes and explosions. In particular, the fusion of seismic and infrasonic data has proven valuable for the analysis of explosive yield, significantly improving on the yield estimates obtained from either seismic or acoustic analysis alone.

Unfortunately, the seismo-acoustic analysis of local explosions is complicated by the fact that the two phenomena are potentially co-dependent. Large seismic waves displace the earth like a piston, potentially inducing acoustic waves into the atmosphere as they pass. Similarly, large acoustic waves can couple into the earth, inducing ground motion along their path. This co-dependence can be problematic, particularly when the passing acoustic shockwave couples into the earth coincident with a seismic phase arrival, thereby corrupting the signal.

To address this problem, we present a method for isolating the shockwave response of a seismic sensor, such that any underlying seismic phase arrivals can be recovered. This is accomplished by employing the adaptive noise cancellation model, where a co-located infrasound sensor is used as a reference measurement for the shockwave. In this model, the adaptive filter learns the transform between the relative atmospheric pressure (as recorded by the infrasound sensor), and the resulting ground motion (as recorded by the seismometer). In this way, the filtered infrasound recording approximates the seismic shockwave response, and can be subtracted from the seismograph to recover the phase arrivals.

The experimental data comes from a set of three low-yield near-surface chemical explosions conducted by LLNL as part of a field experiment, known as FE2. The explosions were recorded at eight stations, located at varying distances from the source (between 64m and 2km), with each station consisting of a co-located three-component seismic velocity transducer and differential infrasound sensor. The adaptive technique is demonstrated for recovering seismic arrivals in both the vertical and horizontal channels across all eight stations, and evaluated using leave-one-out cross-validation across the three explosions.