Analysis of seismic signals generated by vehicle traffic with application to derivation of subsurface Q values

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Motivation

- Ground motions induced by human activities are commonly considered as background noise.
- These can cause difficulties for detecting small earthquakes and tremors.
- The vehicle-induced signals show distinguishing features in the time-frequency domain that can be modeled with source spectra and wave propagation & attenuation.

Data

- 5 Hz ZLand nodal arrays
- Controlled experiments at SGB site using a SUV and a compact sedan.

Analysis

- Car moves with constant speed along a straight road.
- Car can be represented by a point source.
- Primarily radiates Rayleigh waves with a source spectrum $A_0(f)$.
- Radiation pattern is nearly isotropic in all azimuth directions.
- Considering geometrical spreading and attenuation:

$$A(f, t') = \frac{A_0(f)}{\sqrt{r}} \exp\left(-\pi f \frac{r}{Q(f)c(f)}\right)$$

Where

$$r = \sqrt{l^2 + (v_0t)^2}$$

$$t = (t' - t_0) - \sqrt{l^2 + [v_0(t' - t_0)]^2}$$

$$c(f) = l/(Q(f)c(f))$$

By taking the natural logarithm

$$\ln(A(f, t')) + \frac{1}{4} \ln(l^2 + (v_0t)^2) = -\pi f \sqrt{l^2 + (v_0t)^2} \cdot \ln(A_0(f))$$

Results

Controlled Experiment at SGB site with known moving speed.

- Vertical waveforms recorded by 4 sensors at the SGB site during an experiment with a mid-size SUV moving at 40 km/hr.
- Corresponding spectrograms. The white dashed boxes denote data incorporated in the inversion.
- Resolved source spectrum of the moving car.
- Derived Q values for paths between the car and sensors.
- Model results using the resolved source spectrum and Q values in (c) and (d).

Car event at RA site with unknown moving speed: grid search.

- An event in RA site. Same as Figure 3 but the moving speed is grid searched to minimize the misfit of the observed and modeled spectrograms in (c).

Discussion

- A simple analytical solution for propagation and attenuation of surface waves is developed to quantify the spatiotemporal and frequency variations of seismic waveforms.
- The model reproduces well bell-shaped spectrograms of car signals close to roads and it allows estimating frequency-dependent Q values of the subsurface.
- The data analysis indicates Q values of 3 to 40 up to 150 Hz for road-receiver paths at the two sites.
- Possible further applications in signal classification and monitoring temporal variations of attenuation factor.

References


