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Source localization from seismic noise: a methodology applied to seismic exploration.

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The main objective of the present study is to develop a methodology for source localization in seismic exploration contexts, using seismic noise data, which integrates methodologies optimized from acoustics and seismology.
Passive imaging from noise cross-correlation is now applied at continental and regional scale. Its use at local scale for seismic exploration purposes is still uncertain.
The development of passive imaging using cross-correlated data classically consists in two different tasks, the first one being the extraction of the Green's function from seismic noise and the second one consisting in modelling the velocity field from these observations.
All the correlation methods are based on the concept that seismic noise is randomly distributed in space, in other words noise sources are azimuthally distributed around the recording stations. In practice, however, this never happens, especially at local scale and frequency above 1 Hz. A consequence is that the shape of the causal and anti-causal part of noise correlation function differs, which makes ambiguous the extraction of travel times for imaging purposes. Another consequence is that a third task should be added to the first two presented above that consists in the localization of the noise sources when it appears that the noise source distribution is heterogeneous.
In our work we used data acquired in Northern America (Canada) on a 1-km side square seismic network. Five days of seismic noise data were collected on a total of 397 stations.
Since exploration purposes need to obtain high resolution images and since noise correlation vanishes as frequency increases, we introduce a multistep procedure permitting to start our analysis from low to high frequency content.
The seismic noise correlation function performed on the seismic network at low frequency [2-5 Hz] shows a large spatial coherence but also reveals a difference in amplitude for the causal and anti-causal parts of noise-correlated traces.
Capitalizing on the strong coherence between station pairs, a methodology was developed, using both linear and non-linear techniques, to localize the seismic noise source(s).
The linear technique is based on the minimization, as L2 norm, of the travel-times information extracted from the correlation functions and synthetic travel-times obtained from a local source at depth.
Matched-Field Processing (MFP) non-linear techniques developed in ocean acoustics (and analogous to Capon's algorithm used in seismic) were used to further constraint the localization of the noise source on sub-wavelength dimensions. MFP results show that noise sources are quite stable on the 5 days of recording and source localization is well constrained in the low frequency range of interest.