Reflections on/from noise:
Continuous versus event-driven ambient-noise seismic interferometry

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During the last decade Seismic Interferometry, or SI, has gained rapidly in popularity among academia and the industry (Wapenaar et al., 2008; Schuster, 2009). One application of SI is the retrieval of the Green's function from the crosscorrelation of ambient seismic noise. Theory tells us that if uncorrelated noise sources illuminate the recording stations from all directions and if the noise generation is an ergodic random process, then the complete Green's function, including the body-wave reflection response and surface waves, is retrieved from the crosscorrelation-and-summation operation.
If the noise is generated mainly by noise sources at or close to the Earth's surface, then the crosscorrelation-and-summation operation will only retrieve the surface-wave part of the Green's function. This is the case, for example, in many global and regional studies of surface-wave tomography with ambient noise when energy in the primary- and double-frequency-microseism bands, approximately between 0.07 Hz and 0.5 Hz, is used for correlations.

For seismic exploration, the retrieval of body-wave reflections is more desirable, as they afford the construction of subsurface velocity models and subsurface reflection images with higher resolution than can be provided by surface-wave tomography. However, the retrieval of the reflection part of the Green's function has proven much more challenging as the surface-wave noise normally drowns out the subtler body-wave noise. In order to retrieve the reflection response, one needs to correlate noise from sources located in the deeper subsurface. These sources may be primary sources or secondary (Huygens) sources generated by scattering due to heterogeneity.

In general, we have no information on the sources, so we assume they are spatially uncorrelated, stationary noise sources. In this case, we use recording times as long as possible in order to obtain the best possible estimate of the Green's function.

Another approach is to look in the data for coherent events, select them and correlate only the selected events. By manipulating the energy that is crosscorrelated, we can minimize the contribution of those parts of the noise records that would not contribute to the desired part of the Green's function.

We compare these approaches on data from a passive experiment in which Shell recorded approximately 11 hours of ambient noise in the northeasterly part of the Sirte Basin, East of Ajdabeya, Libya. Our aim is to retrieve body-wave reflections.

The noise was stored in about 900, 47-seconds-long receiver station panels. The field geometry consisted of 8 parallel lines with 50 m station spacing and 500 m spacing between the lines. The recorded noise is dominated by strong surface waves, concentrated mainly below 6 Hz, which were caused by a traffic road that crossed the survey at its Northern section. First, we assume that the noise sources are continuous. To bring forward the weaker body-wave arrivals, we suppress the surface-wave energy before crosscorrelation. After crosscorrelation, the data are identified as retrieved common-shot gathers. We use all the retrieved common-shot gathers in a standard processing sequence including interactive velocity analysis, normal-moveout correction, stacking, and time migration. The so obtained time migrated sections show several laterally coherent events. We compare these sections with sections obtained from an active reflection survey along the same lines. The comparison shows that several shallow events have been adequately reconstructed from the noise.

Next, we selectively window visually identifiable events in the noise records which appear to travel (close to) vertically. Draganov et al. (2006) argue that such arrivals have contributed to the retrieved reflections in their results. From all the 900 noise panels, we find about 100 panels that contain such arrivals. We use only these panels in the correlation process. Draganov (2007) used this approach and showed that the retrieved reflections are enhanced when compared to retrieved results using all the recorded noise. We then apply to the retrieved results from the approximately 100 selected noise panels the same processing steps to obtain poststack time-migrated sections and compare these results to those obtained from the first described approach.

References
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