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Event-driven approach to 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 petroleum-exploration industry. One application of SI is the retrieval of the Earth's reflection response from cross-correlation of ambient seismic noise. In general, no information is available beforehand on the noise sources. For this reason, the ambient noise is assumed to originate from spatially uncorrelated, stationary noise sources that illuminate the recording array from all directions. To ensure this in the field, one wants to use recording times as long as possible. Correlating these long noise recordings would result in obtaining the best possible estimate of the complete Green's function including reflections and surface waves.

The assumption of the spatially uncorrelated, stationary noise sources is not necessarily fulfilled, especially with measurements in the field taken during a limited time span. Results from different studies of ambient-noise SI for surface-wave tomography on global and regional scale have shown that when energy is used in the primary- and double-frequency-microseism bands, approximately between 0.07 Hz and 0.5 Hz, the majority of the recorded noise represents surface waves. After cross-correlation, such noise would result in the retrieval of only surface waves. For this reason one can choose to follow an alternative approach – to look in the ambient-noise data for parts of the noise that can be identified as body-wave arrivals (events). Such parts of the noise are then extracted and only they are used for SI. In this way, the correlated energy is manipulated to boost the contributions to the retrieval of body-wave reflections and, at the same time, minimize the contribution of those parts of the noise records that would retrieve surface waves.

We apply the event-driven approach to about 11 hours of ambient seismic noise recorded by Shell in Libya. The noise, recorded by the vertical-component geophones, is stored in about 900 panels with a length of 47 s each. We look in the noise for identifiable body-wave arrivals and extract them. There are about 100 noise panels that contain visually identifiable events, which appear to travel (close to) vertically. We conclude that these are P-wave arrivals and we correlate the event panels and then sum the correlated results to obtain virtual common-source gathers. For the short-to-medium offsets, the so-retrieved reflections are superior to the ones obtained from the correlation of all noise panels. On the other hand, we see that in our case the event-driven approach has caused the events at larger offsets to loose their hyperbolic curvature. As a result, we cannot use the retrieved reflections in velocity analysis. We compensate this by using the velocities picked from the retrieved reflections when all the noise is correlated. We then proceed with a standard exploration-industry processing sequence to obtain a time-migrated stacked section of the subsurface that exhibits better reflectors compared to the results when all the noise is used without combining it with the event-driven approach.