Low-SNR Microseismic Detection Using Direct P-Wave Arrival Polarization

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Detection and analysis of small magnitude events are valuable for better characterization and understanding of reservoirs in addition to developing strategies for mitigating induced seismicity. Three-component (3C) receivers, which are now widely used, are commonly deployed in boreholes to provide continuous seismic data amenable to novel and powerful analysis. Using multicomponent continuous records of ground motion, we utilize two principal features of the direct P-wave arrival: (1) linearity and (2) polarization in the direction along the ray path to the source region to detect small magnitude events undetectable by conventional methods. We evaluate the linearity of polarization and direction of arrival in the time and frequency domains by introducing the spectral matrix analysis method and combine them into a scalar characteristic function that is thresholded for event detection purposes. We boost the signal-to-noise ratio by stacking characteristic functions obtained at different 3C receivers along an empirical moveout of a master event known to have occurred in an area of interest. This allows us to detect smaller events and spatially tie them to a relatively small area around the large event. We apply our method to field data recorded at the Groningen gas field in the Netherlands. Our method detects all catalog events as well as several previously undetected events.