Monitoring induced seismicity with a single seismic station by combining coda wave interferometry with distance geometry solvers

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Microseismic monitoring networks are nowadays extensively used, in combination with risk analysis tools, to ensure the safety of the industrial operations which may trigger or induce earthquakes. However, in many cases the lack of dense enough microseismic monitoring networks affects the performance of the routine data analysis procedures limiting the application of adequate risk mitigation strategies. In this work we propose a novel approach based on the combination of Coda Wave Interferometry (CWI) and Distance Geometry Solvers (DGS) that allow to locate microseismic events by using a single seismic station. The use of CWI allows to determine, for pairs of earthquakes characterized by high similarity of waveforms (i.e. with similar location and focal mechanism), the absolute inter-event distance of each pair (Snieder and Vrijlandt, 2005), while DGS allow to determine their location based only on the given values of the distances between member pairs. Microseismic events can be classified in different families by combining a waveform correlation analysis and a clustering technique. Clustered events are characterized by a high similarity of waveforms, which implies a similarity in both source mechanism and location. In these conditions, the analysis of seismic coda recorded at a single receiver can be used to infer a measure of the spatial separation between two seismic sources. Coda waves are radiated in all directions with a radiation pattern determined by the source mechanism and a small change in the source position affects the interference pattern of the scattered waves that constitute the coda. This change in the coda waves is used to constrain the inter-event distance for each events pair. Absolute locations can be then retrieved by using DGS and considering all inter-event distances, a procedure which requires at least four reference locations. In order to show the potential of this approach we firstly validated the method with a synthetic dataset, then we applied it to the September-October 2013 induced seismicity sequence associated to the underground gas storage operations performed in the offshore Spain. The largest event of the sequence, a magnitude Mw 4.3 earthquake occurred on 2013 October 4th, was preceded by about 1000 seismic events, mostly with magnitude below 2. However, the poor monitoring network in the area (the closest seismic station was located at about ~20 km distance from the platform) did not allow to properly locate these small events. In this work we relocate these low magnitude events, showing that our approach provides better results than those obtained by using standard location methods, making this method particularly useful in poorly monitored areas where only a limited number of stations is available.

References:

Snieder, R., and Vrijlandt, M., 2005. Constraining the source separation with coda wave interferometry: Theory and application to earthquake doublets in the Hayward fault, California, J. Geophys. Res., doi:10.1029/2004JB003317

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