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Cluster analysis and relative relocation of mining-induced seismicity using HAMNET data

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Longwall mining activity in the Ruhr-coal mining district leads to mining-induced seismicity. For detailed studies seismicity of the single longwall panel S 109 beneath Hamm-Herringen in the eastern Ruhr area was monitored between June 2006 and July 2007. More than 7000 seismic events with magnitudes $-1.7 \leq M_L \leq 2.0$ are localized in this period. 70% of the events occur in the vicinity of the moving longwall face. Moreover, the seismicity pattern shows spatial clustering of events in distances up to 500 m from the panel which is related to remnant pillars of old workings and tectonic features.

Two sources with common location and rock failure mechanism are expected to show identical waveforms. Hence, similar waveforms suggest similarity of source properties. Waveform similarity can be quantified by cross-correlation. Similarity matrices have been established and build the basis of a cluster analysis presented here.

We compare two approaches for cluster definition: a single-linkage approach and excerpting clusters by visual inspection of the sorted similarity matrices. Clusters are found as areas of high inter-event similarity in the depicted matrix. In contrast, the single-linkage approach assigns an event to the cluster if the similarity threshold $\vartheta_{sl} = 0.9$ is exceeded to at least one other member. This method is more restrictive and, in general, leads to clusters with less members than visual inspection.

Both methods exhibit clusters which show the same properties. The largest clusters are built by low-magnitude events (around $M_L \approx -0.6$) directly at the longwall face at the mining level. Other clusters include events with magnitudes as large as $M_{L,max} = 1.8$. Their locations tend to lie above or below the mining level in load-bearing sandstone layers. Mining accompanying events show face-parallel near vertical fault planes whereas more distant clusters have typical solutions of remnant pillar failure with a medium dip angle.

Relative relocation of the events is done using lag times from the cross-correlation procedure. The relative location accuracy within the clusters is increased to some meters. We find that most of the seismicity within the longwall panel concentrates on two narrow bands.