

The SMART CLUSTER METHOD – adaptive earthquake cluster analysis and declustering

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Earthquake declustering is an essential part of almost any statistical analysis of spatial and temporal properties of seismic activity with usual applications comprising of probabilistic seismic hazard assessments (PSHAs) and earthquake prediction methods. The nature of earthquake clusters and subsequent declustering of earthquake catalogues plays a crucial role in determining the magnitude-dependent earthquake return period and its respective spatial variation. Various methods have been developed to address this issue from other researchers. These have differing ranges of complexity ranging from rather simple statistical window methods to complex epidemic models.

This study introduces the smart cluster method (SCM), a new methodology to identify earthquake clusters, which uses an adaptive point process for spatio-temporal identification. Hereby, an adaptive search algorithm for data point clusters is adopted. It uses the earthquake density in the spatio-temporal neighbourhood of each event to adjust the search properties. The identified clusters are subsequently analysed to determine directional anisotropy, focussing on a strong correlation along the rupture plane and adjusts its search space with respect to directional properties. In the case of rapid subsequent ruptures like the 1992 Landers sequence or the 2010/2011 Darfield-Christchurch events, an adaptive classification procedure is applied to disassemble subsequent ruptures which may have been grouped into an individual cluster using near-field searches, support vector machines and temporal splitting. The steering parameters of the search behaviour are linked to local earthquake properties like magnitude of completeness, earthquake density and Gutenberg-Richter parameters.

The method is capable of identifying and classifying earthquake clusters in space and time. It is tested and validated using earthquake data from California and New Zealand. As a result of the cluster identification process, each event in the dataset receives a unique cluster-ID which links it to its respective cluster. Utilising the knowledge of cluster classification, the method has been adjusted to provide an earthquake declustering algorithm, which is compared to common existing methods used for declustering in PSHA in detail.

The SCM provides a significantly more reliable declustering method in comparison to existing approaches. Instead of simply removing events from the dataset, it first identifies clusters and analyses them to avoid artefacts and non-physical implications. Furthermore, the SCM is the foundation of a more detailed analysis of global earthquake cluster activity. Using the knowledge of identified clusters, a detailed analysis of cluster properties can be undertaken.