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On the problem of earthquake correlation in space and time over large distances

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A quick examination of geographical maps with the epicenters of earthquakes marked on them reveals a strong tendency of these points to form compact clusters of irregular shapes and various sizes often traversing with other clusters. According to [Saleur et al. 1996] "earthquakes are correlated in space and time over large distances". This implies that seismic sequences are not formatted randomly but they follow a spatial pattern with consequent triggering of events. Seismic cluster formation is believed to be due to underlying geological natural hazards, which: a) act as the energy storage elements of the phenomenon, and b) tend to form a complex network of numerous interacting faults [Vallianatos and Tzanis, 1998]. Therefore it is imperative to "isolate" meaningful structures (clusters) in order to mine information regarding the underlying mechanism and at a second stage to test the causality effect implied by what is known as the Domino theory [Burgman, 2009]. Ongoing work by Konstantaras et al. 2011 and Katsifarakis et al. 2011 on clustering seismic sequences in the area of the Southern Hellenic Arc and progressively throughout the Greek vicinity and the entire Mediterranean region based on an explicit segmentation of the data based both on their temporal and spatial stamp, following modelling assumptions proposed by Dobrovolsky et al. 1989 and Drakatos et al. 2001, managed to identify geologically validated seismic clusters. These results suggest that that the time component should be included as a dimension during the clustering process as seismic cluster formation is dynamic and the emerging clusters propagate in time. Another issue that has not been investigated yet explicitly is the role of the magnitude of each seismic event. In other words the major seismic event should be treated differently compared to pre or post seismic sequences. Moreover the sometimes irregular and elongated shapes that appear on geophysical maps means that clustering algorithms such as the well known k-means that tend to form "well-shaped" clusters may not suffice for the problem at hand and other families of unsupervised pattern recognition methods might be a better choice. One such algorithm is the DBSCAN algorithm which is based on the notion of density. In this proposed version the density is not estimated solely on the number of seismic events occurring at a specific spatio-temporal area, but also takes into account the size of the seismic event. A second method proposes the use of a modified measure of proximity that will also account for the size of the earthquake along with traditional clustering schemes such as k-means and agglomerative clustering (k-means is seeded with a quite large number for k and the results are fed to the hierarchical algorithm in order to alleviate the memory requirements on one hand and also allow for irregular shapes on the other hand). Preliminary results of seismic cluster formation using these algorithms appear promising as they are in agreement with geophysical observations on distinct seismic regions, such as those of the neighbouring regions in the Ionian sea and that of the southern Hellenic seismic arc; as well as by the location and orientation of the mapped network of underlying natural hazards beneath each clusters vicinity.

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