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Clustering of seismic events in equivalent dimension hyperspaces – premonitory effects of M8.8 Chile earthquake of February 27, 2010

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Seismic events are described by their parameterizations. Specific parameters values linked to every particular event define a point in the parameter space that represents that event. Hence, to assess clustering among seismic events one must be able to compare objectively distances between these points. Metric of most of the seismic parameters is, however, complex and non-Euclidean and neither the Euclidean distance can be used, nor any other pre-defined metric can be readily applied in the multidimensional parameter space.

An equivalent dimension concept has been worked out to investigate, in a non-speculative way, clustering of events in the spaces built by any combinations of the seismic event parameterizations. Let earthquake parameters X_1,...,X_p be continues and have the cumulative distributions $F_{X1}(X_1)$,..., $F_{Xp}(X_p)$, respectively. We accept that for every X_k, X_l: $k, l \in$ {1,...,p},$k \neq l$ or$k = l$, two intervals of the parameter values, Δx_k, Δx_l are equivalent if Prob($X_k \in \Delta x_k$) = Prob($X_l \in \Delta x_l$). Since the transformations $X_k - > \quad U_k = F_{Xk}(X_k)$, k=1,..,p return $U_k$uniformly distributed in [0, 1] the defined equivalency condition is fulfilled for the same length intervals of U_k, U_l, k,l = 1,..,p. We call U_1,..., U_p equivalent dimensions of seismic parameterizations. An earthquake is represented by the vector **U**(U_1,..., U_p) in the Euclidean metric hypercube [0,1].

In general the probabilistic models for earthquake parameters, $F_{Xk}(X_k)$, are not known. We therefore replace $F_{Xk}(X_k)$, k=1,..,p with their model-free, data-driven estimators. Suppose that we have a series of seismic events from a certain seismogeneic region and a certain time period. As long as we do not have new data this series of events is the entire information on the seismic process from the region and time under study, which means that it is a population of seismic events. Such a population is used to estimate $F_{Xk}(X_k)$ by means of the non-parametric kernel estimation method (e.g. Silverman, 1986 and the references therein). We apply adaptive kernel estimators with the Gaussian kernel function.

The transformation to equivalent dimensions is applied to investigate clustering of smaller seismic events before the giant M8.8 Chile earthquake of February 27, 2010. 5930 seismic events of $M \geq$3.5 that occurred in the Flinn-Engdahl region #135 from the beginning of 1991 until the main rupture are regarded as the background population to estimate parameters' distributions. Time-varying patterns of seismic events are observed in moving time-windows of various combinations of equivalent dimension parameters. The most significant results are obtained for the equivalent hyperspace of {*dt*, *dr*, M}, where *dt* and *dr* are the time and epicentral distance between every two consecutive events and M is magnitude of the second event. Systematic event clustering process began some 2.5 year before the main rupture. Formation of two distinct clusters is visible on {*dt*, *dr*}-equivalent plane. Some events tend to group close to the point (0,0) – simultaneous shortening the interevent time and distance, whereas the other organize themselves around the point (1,1) – both *dt* and *dr* simultaneously elongated. In the last year before the main rupture magnitude of events building both clusters is distinctly increased.

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