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Cluster analysis of earthquake swarms - results from West Bohemia and South-West Iceland

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Earthquake swarms are specific type of seismic activity when strain energy is released in numerous mostly shallow earthquakes, which are missing a single large event; instead a few dominant earthquakes reach similar magnitudes so that smaller events are not associated with any identifiable mainshock. Earthquake swarms distinctively cluster in time and space and last from several hours to several months. They occur at boundaries of the lithospheric plates (interplate), within the plates (intraplate), and they are very often related to the volcanic areas, geothermal fields and ocean ridges. In our study we explored the behaviour of earthquake swarms within a tectonic plate, in a boundary of tectonic plates and in volcanic areas in order to understand why the energy is released successively by sequences of small events in contrast to mainshock-aftershock earthquakes.

We used catalogue data from West Bohemia-Vogtland region (WB) situated within a tectonic plate, and three different tectonic basis in South-West Iceland (SWI), namely boundary of tectonic plates (Krísuvík), the edge of a zone where typically mainshock-aftershock earthquakes occur (Olfus, South Iceland Sesmic Zone) and the volcanic area (Hengill). In case of WB we analyzed two swarms, 2000 and 2008, which occurred on the same fault segments.

We analyzed distribution of events in a view of a spatial metric obtained from relative locations and time metric (in case of WB and SWI), and a focal mechanism metric based on double couple (DC) solutions (in case of WB). For this purpose we used clustering method by Cesca et al. (2014). The results are strongly affected by the subjective choice of two parameters which describe the desired density of points to infer a cluster. For the tested applications, we repeated the clustering several times to decide the best combination of these parameters.

The cluster analysis applied to the double-difference locations disclosed several separate clusters in each area investigated which indicates that in all such different tectonic environments the swarms activate a number of smaller fault segments rather than one main fault.
The time clustering discovered several separate phases in time which are characterized by abrupt increase of activity in a view of number of events and their magnitude.

In case of WB, both 2000 and 2008 swarms show the same pattern. One significant and several smaller clusters appeared by processing of locations. From the analysis based on focal mechanisms we obtained three main mechanisms (oblique-normal, oblique-thrust and thrust faulting). For 2008 we got one additional mechanism appearing on a fault segment which was not activated in 2000 (thrust faulting with different strike). Strikes and dips of the focal mechanisms correspond to geometry of fault segments which are identified by the clustering method applied to the locations. The main fault segment is characterized by the most frequent mechanism (oblique-normal with strike and dip of about 170° and 80°). However, in its northern part, on its edge and sometime even inside the segment focal mechanisms differ significantly. This supports an idea that earthquake swarms occur on short fault segments with heterogeneous stress.

References:
Cesca S, Sen AT, Dahm T (2014) “Seismicity monitoring by cluster analysis of moment tensors”, Geophys. J. Int., 196 (3):1813-1826