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Space-time distribution of foreshock, aftershock and swarm activity in and near Bulgaria

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Examination of the space-time distribution of earthquakes is of fundamental importance for understanding the physics of the earthquake generation process. One challenge in applying statistical methods to study the earthquake occurrence is to distinguish objectively the nonrandom from the random.
Fore-shocks (rarely observed) are those earthquakes that occur immediately prior to the main event in the same area. They are of substantial importance in the possibility of predicting earthquakes. Fore-shocks cannot be positively identified as fore-shocks until after the main shock has occurred. Even then, the "main shock" sometimes proves to be a large fore-shock of an even bigger earthquake, which will then assume the position as the "main shock".
Aftershocks occur after the main shock and their frequency decays through time with approximately reciprocal of time elapsed since the main earthquake. The spatial and temporal clustering of aftershock activity is the dominant non-random element of seismicity. When fore and aftershocks are removed, the remaining seismic activity can be modeled (as first approximation) as a Poisson process.
The temporal decay of aftershocks is interesting because it contains information about the seismogenic process and physical conditions in the source region. The decay of aftershock sequences usually follows the modified Omori formula. The power-low decay represented by the modified Omori relation is an example of temporal self-similarity of the earthquake source process. Aftershock decay rate may contain information about the mechanisms of stress relaxation and frictional strength heterogeneity. On the assumption that aftershocks are distributed in time as a non-stationary Poisson process the maximum likelihood method for estimating the parameters (K, c and p) of the modified Omori formula is usually used. The properties of aftershock sequences (distinct cluster in space and time) allow time-dependent prediction of aftershock probabilities. Consideration of recent earthquake sequences suggests that large aftershocks although they are still, by definition, smaller events, can be very damaging and should be addressed in emergence planning scenarios. Because of the factors such as location and radiation pattern and the cumulative nature of building damage, aftershocks can cause more damage than the main shock.
Some earthquake sequences may not have obvious main shock - the so called swarms. Swarms are sequences of earthquakes that are clustered in space and time and are not associated with an identifiable main shock.
The present study was aimed at presenting the peculiarities in the space-time distribution of the fore-shock, aftershock, and swarm activity on the territory in Bulgaria. Statistical analysis is applied to examine spatial and temporal pattern of earthquakes in the fore-aftershock and swarm sequences. Differences in the space-temporal distribution of events in the sequences are highlighted.