Diffusivity analysis of clustered seismicity in Central-Southern Apennines

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Seismic swarms are defined as a set of clustered earthquakes with high spatio-temporal variability and with the absence of a main shock. They can originate in different tectonic contexts related to the migration of deep fluids that can alter the stress field (Roland et al., 2009). In particular, the diffusivity parameter, defined by Shapiro et al. (1997) and linked to the migration of the hypocenters over time, allows us to associate the swarms' temporal duration with the rocks' permeability characteristics. Swarms characterized by long durations (years) and low diffusivity values (10^{-3}-10^{-2} m^2/sec) are associated with low permeability fault systems. On the contrary, shorter durations (days) and high diffusivity values (0.5-1 m^2/sec or greater) indicate the presence of highly permeable systems in which seismicity is induced by the rise of fluids at high pressures (Amezawa et al., 2021). We focus on the clustered seismicity in the central-southern Apennines, which extends from the south of L'Aquila to Benevento, to analyze the spatio-temporal characteristics of the swarms and the relationship between their temporal duration and diffusivity.

Compared to the rest of the chain, this sector is characterized by (1) low seismicity rates, which do not allow us to follow the evolution of seismicity and the mechanisms underlying it, and (2) a high seismic risk, as demonstrated by the strongest and most destructive sequences recorded within the historical catalogs which magnitude M ~ 7.

We analyzed the seismicity reported in the catalog of absolute locations CLASS (Latorre et al., 2022), which describes Italian seismic activity over the past 37 years (1981-2018). Additionally, we augmented the catalog within a 7-year time window (2012-2018) using a template matching technique (Vuan et al., 2018). This choice was made based on the optimal distribution and operation of the seismic network. The initial catalog is improved, lowering the completeness magnitude by more than one degree (+ 20,000 events with $-1.5<M<5.0$). This approach allowed the analysis and comparison of clustered seismicity in two catalogs with different time extensions and resolutions.

Clustered seismicity is defined relative to the background using a nearest-neighbor technique (Zaliapin & Ben-Zion, 2020). Due to the great spatio-temporal variability of the seismic phenomenon, no univocal methods in the literature can establish the spatial dimension and duration of the single cluster. The low seismicity rates of this area require a very detailed analysis on a small space-time scale and different methodological approaches. For the spatial definition, we used the Kernel Density calculation to determine an event's density probability in each radius. The time duration is defined using the approach described by Roland et al. 2009 based on the evaluation of the percentage of seismicity rate.

We identified 53 polyphasic seismic clusters in the complete catalog (37-year time window), and 30 in the improved catalog (7-year time window). The clusters were subsequently divided into swarms and sequences. The diffusivity was calculated for each cluster using the Shapiro et al. (1997) relationship.

Most of the seismicity is expressed as swarm-type and characterized by high diffusivity values (≥ 1m^2/sec) with short temporal durations (days-months). This result confirms that the clustered seismicity is linked to highly permeable fault zones and the natural injection of fluids under pressure. The swarms present in this sector of the Apennine chain can, therefore, be linked to the deep migration of CO_2-rich fluids (Chiodini et al., 2004), which exploit pre-existing fault zones as a preferential path.

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