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Earthquake catalogue enhancement through template matching: an application to the Southern Apennines (Italy)

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Improving the capability of seismic networks to detect small-magnitude seismicity, commonly near or below the detectability threshold, is the prerequisite to characterize the seismotectonics of an area in terms of fault geometry, kinematics and mechanics, thus leading to an improved comprehension on the physical mechanisms that generate small and large earthquakes. In this work, we apply *template-matching*, a cross-correlation based technique for the detection of hidden earthquakes, at the scale of the Southern Apennines (Italy). Here, the ongoing extension of the Mio-Pliocene Apennine thrust-belt poses a major seismic risk, as testified by several Mw~7 earthquakes that struck this area in the past 300 years. No clear consensus exists on the seismotectonic models related to such events, particularly in terms of characterization of the fault structure and crustal rheology that can thus largely benefit from the application of *template-matching*.

As template events, we use ~9000 earthquakes occurring between 2009 and 2015, recorded by 181 stations from the INGV National Seismic Network. Six years-long (2009-2015) continuous recordings are scanned by the *template-matching* algorithm. Of about 3 million new detections, around 3% (~88.000 events) comply with the minimum quality thresholds we set (at least four P and S picks, recorded at least at five stations). For determining earthquake locations we used the fully-probabilistic non-linear code NonLinLoc, with an ad-hoc 1D velocity model and corrections for station residuals.

By accounting for the quality of the hypocenter location, the final catalog comprises ~50.000 new seismic events with a mean horizontal and vertical error of 1.4 and 2.5 km, respectively, and a mean RMS of 0.13 s, parameters that are similar to those of the template catalog. Given the small magnitude (Mw<1) of the majority of the newly detected events, the new catalog shows a decrease in magnitude of completeness from 2.5 to 1.9, assessed through the Lilliefors' goodness-of-fit test.

The spatial and temporal pattern of seismicity unravelled by the enhanced catalog provide new insights especially for those seismogenic structures that are poorly known. For the main seismic sequences that occurred in the analyzed period (i.e., Pollino and Matese Mw5+ sequences) the aftershocks as well as the foreshock phases appear particularly enriched. Main NW-SE trending seismogenic structures of the axial zone of chain are illuminated by abundant microseismicity, with evident gaps delineating the boundary of such structures. In addition, the new catalog

unravels distinct E-W oriented clusters in the external zone of the seismic belt, likely related to shear zones developed in the deeper crystalline crust of the Adria plate.