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Application of a dense network cross-correlation event detector to seismicity induced by hydraulic stimulations in Espoo/Helsinki, Finland

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We have developed a cross-correlation based event detector with the primary application focus on dense, surface-installed temporary seismic networks monitoring the seismicity from a set target area. The event detector is capable of handling a terabytes-sized, noisy multi-channel dataset with hundreds of stations on a regular desktop PC. The detector works in 4 steps: 1. Generate templates from known events in a database. 2. Run cross-correlation for templates on continuous data. 3. Filter initial detections based on the surface network geometry. 4. Relocate the events in the filtered dataset applying correlation time delays and amplitude based magnitude corrections. The detector is accompanied with an event viewer designed to rapidly browse the resulting catalogue. We apply the detector on the induced seismicity of a planned Enhanced Geothermal System (EGS) doublet in Espoo, Finland. The company St1 Oy performed two hydraulic stimulations at around 6 kilometer depth beneath the Aalto University campus in Otaniemi, Espoo, Finland, in June-July 2018 and in May 2020. For both stimulations, the Institute of Seismology, University of Helsinki, installed a temporary ~100 geophone network to monitor the stimulation and post-stimulation stages. The network consisted of three-component 4.5 Hz geophones, mostly DATA-CUBE3s recording at 400 Hz. The geophone stations were organized into large arrays consisting of up to 25 stations, smaller 3-4 station arrays, and additional single stations for better azimuthal coverage. We present here the results from applying the detector on the datasets collected from the Otaniemi-EGS. The anatomy, such as magnitude of completeness, of the resulting event catalogue consisting of thousands of induced events will be discussed with the goal of publishing the finalized catalogue in near future. We also briefly discuss the impact of adding sub-surface borehole stations, and applying the detector to a sparser surface station network to broaden the scope of usefulness.