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Data features and observations from a network to monitor the 2018 EGS stimulation in Espoo/Helsinki, Finland

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We discuss several data features and observations associated with an EGS stimulation experiment in the Helsinki, Finland, area. In June and July 2018 the St1 Deep Heat company stimulated a rock mass between 6 km and 7 km depth beneath the Aalto University campus in Otaniemi/Espoo, Finland, to establish an Enhanced Geothermal System (EGS) to support district heating. We report on the response to the induced seismicity received from the population in the neighborhoods around the drill site. We present results from the analysis of seismic data collected by a heterogeneous seismic network consisting of borehole and surface stations and arrays. Borehole data have been made available to the Institute of Seismology from the University of Helsinki (ISUH) by the St1 Deep Heat company that installed 12 semi-permanent 3-component borehole instruments between 238 m and 1620 m depth. ISUH has been operating 7 semi-permanent broadband stations and installed a temporary network consisting of nominally 100 4.5-Hz 3-component geophones. The stations were organized in 3 large arrays of 25 stations designed to resolve propagation properties of P and S waves excited by earthquakes in the M$\sim$0.5 to M$\sim$2 range, 3 small 4-station arrays to enhance detection capabilities, and 8 single stations. Source mechanisms from selected large M>1, manually-picked events are investigated as a function of sensor and array configuration. We evaluate hypocenter locations using travel times and array- or beamforming-based backprojection methods. We compare location estimates obtained with a regional velocity model to solutions based on a 1-D model obtained from surface wave inversion. These surface waves are reconstructed from ambient noise correlations in the 0.5 to 5 Hz range. We apply double-beamforming to this noise correlation database to analyze the properties of P waves propagating between arrays and to evaluate the potential for monitoring the rock properties above the stimulated volume. We show time series of seismic velocity changes dv/v obtained with noise-based or passive monitoring techniques and compare them to stimulation parameters and properties of the induced seismicity. The diverse range of approaches demonstrates the versatility of the network configuration and has thus important implications for future deployments for studying EGS responses in hard-rock environments.