EGU25-6036, updated on 19 Jan 2026
https://doi.org/10.5194/egusphere-egu25-6036
EGU General Assembly 2025

Three-dimensional Distributed Acoustic Sensing to monitor geothermal fields in Munich, Germany

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Distributed Acoustic Sensing (DAS) transforms optical fibers into extensive arrays of sensing points, making it particularly well-suited for seismic array processing techniques. Compared to arrays of seismometers, DAS has the potential for significantly higher spatial density of measurement points. A limitation of DAS is, however, its directional sensitivity, where the response of individual sensing points is influenced by the orientation of the fiber optic cable. In this study, we use a fiber optic cable that was installed by design with multiple cable orientations to record and analyze the seismic wavefield in three dimensions. This work investigates the capabilities of the DAS station, installed in the Munich region (Germany), for seismic monitoring of a nearby geothermal field. The DAS station consists of two controlled fiber-optic cable sections: a near-surface loop providing various azimuthal strain-rate measurements, which is extended into a 250-metre-deep vertical monitoring well for vertical sensing. The setup is complemented on the surface by a 3C-broadband seismometer for the validation of the results. In this study, we describe the design, installation and characterization of the DAS station, as well as the seismic event processing workflow. We demonstrate the ability of the 3D-DAS to analyze wavefield directionality, including back-azimuth, incidence and slowness components. In addition, we highlight the role of the vertical borehole in converting DAS strain-rate data into acceleration, which allows estimating source characteristics such as moment magnitude and stress drop estimation. These capabilities are demonstrated for a local seismic event relevant to the monitoring objective. Quality control procedures confirm the consistency and reliability of the DAS station measurements in comparison to 3C seismometer results. Extending the analysis to a broader event catalogue reveals spatial resolution limitations inherent to the station's array geometry. These results highlight the potential and challenges of using DAS for seismic monitoring in geothermal contexts.