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Microseismic monitoring of a future CO_2 storage site in the Arctic (Svalbard) – Suppression and utilization of seismic noise

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Since 2007, CO_2 Capture and Storage (CCS) research has been carried out in the Longyearbyen CO_2 lab (hosted by University Centre in Svalbard, UNIS, and UNIS CO_2-lab AS). Due to its remoteness, the CO_2 lab injection site presents a unique opportunity to demonstrate the entire CO_2 value chain based on the closed energy system including coal mines, a coal fuelled power plant and geological structures suited for CO_2 sequestration.

The reservoir at a depth of 670 – 970 m consists of Triassic and Jurassic sandstone formations. The primary caprock is formed by a 400 – 500 m thick layer of organic rich shale, whereas the impermeable near-surface layer of permafrost currently constitutes a secondary top-seal. Eight wells were drilled down to a maximum of about 1000 m depth in order to analyse composition and structure of the reservoir, to perform injection tests and to deploy instruments close to the reservoir. Although the reservoir sandstone exhibits a low primary permeability and porosity, injection test campaigns demonstrate a good injectivity, indicating an unconventional reservoir strongly impacted by tectonic fractures.

To perform microseismic monitoring, a high-frequency geophone network surrounding the injection well has been established. During the first water injection in 2010, a microseismic event ($M \sim 1$) was recorded and located close to the injection well, followed by a series of 7 aftershocks identified using a matched filter method. Later injection tests did not generate any detectable microseismic events; nevertheless, pressure and flow rate showed a pattern characteristic for fracture opening, potentially indicating “aseismic” fracture propagation or slow slip.

Prior to data analysis, signals resulting from local mining operations, degassing, icequakes and regional earthquakes have to be separated from seismicity induced by (water) injection. In addition, recorded signals are strongly corrupted by electronic noise. Especially for correlation and stacking methods, the signal can be swamped easily by even low-power electronic interference. Hence, noise cancellation methods, like e.g. the Widrow algorithm, have to be applied prior to analysis. Transient signals (e.g. microseismicity) are almost completely unaffected by the cancellation operation.

The application of passive methods in the context of stimulating geothermal systems has recently shown that monitoring the evolution of reservoir properties using the ambient seismic field provides critical observables, which are complementary to microseismic approaches. We explore the potential applicability of noise-based imaging and monitoring techniques using continuous records from the pilot injection experiment. Our feasibility study focuses on the frequency-dependent wave field properties, the spatial and temporal distribution of noise sources and the distance-dependent coherency of the wave field, which is related to systematic variations of the signal-to-noise ratio in vertical and horizontal directions. Assessment of the corresponding noise correlation function properties can improve network geometries for an optimal resolution of subsurface dynamics associated with the targeted injection experiment in summer 2014.