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Ground Water and Frost Induced Seismic Velocity Changes in Ketzin (Germany)

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The principle of Seismic Interferometry (SI) is that the correlation of a random wave field like seismic noise recorded by distant receivers can be used to infer the Green function (or at least part of it) of the medium between the receivers. Beside tomographic inversion for the subsurface velocity it can also be used to detect small temporal changes in the propagation of the seismic wave field.
As these changes can be related to changes of elastic properties in the propagation medium, SI can characterize dynamic processes in the earth's crust. This technique was successfully applied, inter alia, to monitor seasonal variations in response to environmental influences, shaking caused by earthquakes or material changes due to the eruption of volcanoes.
We work with data acquired with a seismic network in Ketzin (Brandenburg, Germany), where CO_2 is injected into a saline aquifer at a depth of about 650 m. We calculated daily cross-correlation functions (CCFs) of the ambient noise field for a time period of about 4 years from the beginning of the injection. Spectra showed that the frequency band between 1 and 3.5 Hz does neither show an annual periodicity (like for microseism) nor temporal shifts of peak frequencies.
For this frequency band we estimated the noise propagation direction over two years and found a predominant direction from north-east. This direction matches with the location of a large wind park a few km away from the array. The direction of the noise wave field shows a good stability, which excludes variations of the noise source distribution as a cause of spurious velocity variations.
To analyze possible velocity changes for each day, we computed stretched versions of a reference CCF and calculated correlation values between different time windows in the coda part of the stretched traces and the reference trace. We can observe velocity variations with a period of approx. one year that are not caused by the CO_2 injection. Due to the almost continuous injection of CO_2 we would expect a monotonic decrease of the seismic velocities if caused by the CO_2.
Based on an amplitude decrease when using time windows in the later part of the coda, we show that the variations must be generated in the shallow subsurface. A comparison to ground water level data reveals a direct correlation between the depth of the ground water level and the seismic velocity. The influence of ground frost on the seismic velocities is documented in a sharp increase of velocity when the maximum daily temperature does not exceed 0°C.