Applicability of long-range seismic noise correlation for CO2 geological storage monitoring

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Abstract

In addition to non-emitting and renewable energy production among others, Carbon dioxide Capture and Storage (CCS) is considered as a tool to ensure the necessary decrease of CO2 anthropogenic emissions. This technic industrial development is above all conditioned by its safety demonstration. Within the safety global strategy, the role of monitoring is essential as it should ensure a proper detection of potential irregularities. For this purpose, conventional geophysics methods are and will be implemented; newer ones are developing as well.
For about ten years, seismologists have demonstrated the possibility of using ambient seismic noise to recover the Green's functions, i.e. the medium impulse responsethrough the long range cross-correlation between two broadband stations. Literature shows that both Rayleigh and body waves can be extracted opening up new possibilities for seismological objects monitoring. Current studies are focusing on improving the temporal resolution to propose an alternative continuous monitoring method.
Correlation of seismic ambient noise is currently considered by various pilot projects for CO_2 geological storage (Hontomin for example). This method offers serious advantages: an easy implementation and deployment, a continuous monitoring (unlike the microseismicity monitoring that requires events to observe), and a strong background experience in seismology. However, the applicability of this method to geological CO_2 storage field needs to be proven. Our work then aims at evaluating the sensitivity of long range seimic noise correlation to CO_2 presence. For this purpose, we consider different ways to use seismic noise correlation. We first explore the different possibilities of using a surface broadband network including the measurement of direct Rayleigh waves, of coda shifts and of direct P-waves arrivals. We then explore explore the possibility to use downhole geophones in continuous mode as receptors for studying Stoneley waves travelling on the caprock interface. The validity of these methods in the purpose of monitoring the CO_2 presence is assessed through a theoretical work and modeling based on the Ketzin pilot injection site test case. The results obtained for the surface broadband network are confirmed on the field through a network installed at Ketzin during a couple of years.

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Our study reveals that the direct use of Rayleigh wave speed measurements does not appear as a suitable solution to monitor the CO2 plume. CO2 has indeed a small influence on Rayleigh wave speed dispersion explained by the fact that CO2 has a small impact on S wave speed.
Another option, explored by Wegler and Sens-Schönfelder, uses the coda shifts to infer general speed changes in the considered area. Although successful on the Merapi volcano, we show that this method is not suited for tracking leakages but is best used as a complementary measurement of the main CO2 bubble envisioned for large-scale storages. A last option regarding surface seismic noise cross-correlation was suggested by Roux et al; they retrieved P waves from ambient noise. As P waves are strongly affected by CO2 presence, this method is likely to be more sensible than using Rayleigh waves; however, the needed geological features for a good storage site (a strong caprock over a soft reservoir layer) forbid P waves going through the reservoir to surface again, unless a strong layer exists below ; this method is therefore not suited for every site we show that it requires specific conditions that may not be met for every site.

Finally, we explore the possibility of performing noise correlation from downhole sensors. Downhole geophones are likely to be deployed in order to measure the microseismicity associated with the injection ; set to continuous mode, they may be able to measure Stoneley waves, especially at the upper border of the caprock. These Stoneley waves are susceptible We show in this study the sensitivity of possible Stoneley waves to the caprock integrity and the CO2 presence, thus leading the way to possible new experimentations and instrumentations.