Monitoring Subsurface Energy Storage with Ambient Noise Tomography

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Introduction
There are important economic, environmental and societal reasons for underground monitoring of Energy storage site as well as it is the case for all the other use of subsurface (Oil & gas, Geothermal, CO2 sequestration, etc.). Among the existing techniques already implemented for underground monitoring, a new technique called "Ambient Noise Tomography" can be added to the toolbox. This makes use of naturally occurring seismic signals from waves, oceans, etc., as well as of entropic sources, such as train, car traffic, etc.

Key features of the ambient noise method
- Inexpensive – simple 3C or 1C seismic stations are required at surface
- Quick to deploy
- Environmentally friendly
- No active sources required
- Can be used for imaging or time-lapse monitoring

![Diagram showing ambient noise crosscorrelation](image)

Example showing a reconstructed virtual source:
Move-out of virtual source signal across the array, obtained from ambient noise crosscorrelation. The location of the sensor that was used as virtual source is indicated by the black square (G. Olivier & al., 2018).

Case study: Groningen gas field - The Netherlands (Brenguier & al., 2019)

Example showing ambient noise crosscorrelation:
![Image](image)

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Tools
- Cross correlation to obtain pseudo Greens function and Virtual Source
- Correlation of body waves
- Coda wave Interferometry

Conclusion and the way forward
"Ambient Noise Tomography" (ANT) is a monitoring method that can added to the growing family of the passive seismic monitoring techniques. ANT is a great complement to Microseismic monitoring.

Since the raw data required for all the passive seismic methods is very similar, all those methods should be combined (P. Hansen, 2011) using a single monitoring data acquisition platform rather than being implemented separately. Main advantage is reducing the uncertainty and thus increasing the value of the monitoring at a marginal supplemental cost.

In the near future, new pilot projects should be launched in view of validating the economic of the method for monitoring energy storage site. Such pilots should:
- Integrate the different passive seismic methods
- Add new technical enablers such as Distributed Acoustic Sensing (DAS)
- Implement real-time monitoring capability such as in microseismic

Technical references on the Ambient Noise method
Shapiro and Campillo, 2004; Roux et al, 2005; Campillo, 2006; Snieder, 2007; Brenguier et al, 2016; Boué et al, 2013; Mordret et al. 2014, Nakata et al., 2015; Nakata et al., 2016