DAS Deployed at Seabed for 4D Active Seismic Monitoring of CO₂ Storage

Vincent Brémaud\textsuperscript{a}, Estelle Rebel\textsuperscript{a}, Enrico Zamboni\textsuperscript{a}, Corinne Sagary\textsuperscript{b}

\textsuperscript{a}TotalEnergies S.A., CSTJF, Avenue Larribau, Pau, France  
\textsuperscript{b}Alcatel Submarine Network, Route de Villejust, Nozay, France

Abstract

Capture and Storage of CO₂ is part of a range of solutions to reduce greenhouse gases in the atmosphere (9\% following IEA following Technology Report 2019). In order to be efficient, CCS technologies will have to be deployed at large scale, with the goal of storing Giga Tons of CO₂. The safety of these operations will be ensured by appropriate monitoring techniques which have to be deployed to verify both conformance and containment of the storage. Conformance is shown when outputs of numerical simulations of CO₂ injections are matching the monitoring attributes. Containment is shown when no signs of leaks are detected. Among the different techniques put in place to monitor the CO₂ injection, 4D seismic is one of the most precise to follow the spatio-temporal plume evolution or ensure no CO₂ is leaking to shallower formations. Therefore, 4D seismic is also one of the techniques the most frequently used for CCS monitoring.

As fiber optic cables are more mature technology to acquired 3D/4D seismic data when deployed at borehole, there are still some uncertainties whether this technology is sensitive and repeatable enough to be able to detect tiny changes induced by the CO₂ injection within the subsurface. In this paper we are investigating the capabilities of fiber optic cables deployed at seabed to acquire and process 4D seismic data. A data set acquired with a Permanent Reservoir Monitoring (PRM) system installed at seabed has been analyzed. Four-component (4C) optical sensors are interconnected by optic fiber cable along a 2D line and active seismic shots located above this optical cable have been simultaneously recorded by the 4C sensors and by DAS along the optical cable connecting these 4C sensors (Figure 1). This data set is ideal to compare the sensitivity of DAS versus the one of conventional sensors.

In a first step, the goal was to understand what is physically recorded by these optical cables. In the simple case of this straight cable deployed horizontally, the amplitudes of seismic waves should be proportional to the cosine square of the incidence angle (the incidence angle is defined as the angle between the direction of propagation of the seismic wave and the direction of the cable). Amplitudes of direct arrival and its multiples have been picked on all types of sensors (conventional and DAS) in order to check that the measurements follow this simple theory.

In a second step, the same PP processing sequence has been applied to the PZ summation (combination of hydrophone and vertical component of accelerometer), the radial component of accelerometer and the DAS (Figure 2). The stacked image obtained from the DAS processing data is very encouraging with a quality still lower than the PZ summation stack but better than the radial component stack. Most of the strong events are correctly recovered, and structures as deep as 3sec are recovered.
In the future, the processing sequence will be optimized in order to take into account full advantage of the dense spatial sampling offered by the DAS (5m versus 50m for conventional sensors). This step will probably allow better noise reduction and further improve the quality of the final image. Another aspect of this work is to repeat this specific acquisition to estimate the repeatability offered by this specific technology and determine if in the future, fiber optic cables can be used for time-lapse seismic monitoring of CO₂ storage.

![Figure 1: Acquisition design of the active seismic experiment](image1)

![Figure 2: 2D stack obtained from the processing of the PZ summation (left), radial accelerometer (middle) and DAS (right).](image2)

**Keywords:** CO₂ storage monitoring; DAS; surface optical fibers;