Feasibility of 4D microgravimetric monitoring of a CO_2 flood in a depleted gas reservoir

Martha Lien, Alex Goertz, Siri Catherine Vassvåg (OCTIO), Chris Ward, Mark Ackers, Thierry Pujol, Anna Fletcher (Spirit Energy)

In this paper we present the feasibility of long-term CO_2 storage monitoring in depleted gas fields with time-lapse seafloor gravity measurements, using the South Morecambe field as a case study. We model the injection of CO_2 into the depleted gas reservoir at injection rates of between 7 to 10 Mt per year. Our study shows that the annual changes in the gravitational field at the seabed due to CO_2 injection amount to more than 10 µGal. For comparison, the estimated measurement uncertainty is on the order of 1 µGal.

The North Morecambe and South Morecambe depleted gas reservoirs in the East Irish Sea Basin are candidates for conversion into a gigaton-scale CO_2 storage site. The structural crests of the Triassic Sherwood Sandstone reservoir are relatively shallow (both <1 km) and are overlain by a thick succession of the Triassic Mercia Mudstone Group consisting of alternating layers of halite and mudstones.

The shallow water depths, presence of residual gas, existing infrastructure and planned offshore wind farm developments impose challenges for using seismic methods to monitor a CO_2 flood in the storage site. However, the density difference between injected CO_2 and in-situ methane at this comparatively shallow reservoir depth provides good potential for using seafloor time-lapse gravity measurements as an alternative to seismic for monitoring.

The study shows that time-lapse gravity was able to map the progression of a CO_2 saturation front across the storage site as well as to detect leakage into the overburden. In addition, time-lapse gravity could identify a phase change of in-situ CO_2 from the gaseous phase to supercritical as it represents a significant density increase.

The reservoir can be monitored with repeat surveys, including short periods of less than 1 year, using a relatively sparse grid (ca. 500 m) of measurement locations through ROV-based deployment. As a result, time-lapse gravity not only provides a technical solution for monitoring the CO_2 flood in a depleted gas field but is also very cost-efficient and highly compatible with the presence of infrastructure, including platforms and offshore wind farms.

In summary, the South Morecambe study shows that time-lapse gravity can provide quantitative measurements of the distribution of mass changes within the subsurface with sufficient spatial and temporal resolution for CO_2 monitoring. Hence, the technology is shown to be suitable for conformance (understanding of CO_2 phase behaviour), containment (ensuring the CO_2 storage is controlled), and contingency (detecting and addressing significant anomalies) monitoring.