16th International Conference on Greenhouse Gas Control Technologies **GHGT-16**

23-27th October 2022, Lyon, France

Time-lapse pressure tomography of a migrating CO_2 plume at the Otway Stage 3 site

Samuel J. Jackson[a*], James Gunning[a], Tess Dance[b], Mohammad Bagheri[c], Paul Barraclough[c], Roman Pevzner[d], Jonathan Ennis-King[a], Charles Jenkins[e]

a CSIRO, Clayton, Melbourne Australia
b CSIRO, Kensington, Perth, Australia
c CO2CRC, 11-15 Argyle Pl S, Carlton VIC 3053
d Curtin Centre for Exploration Geophysics, Curtin University, Perth, Australia
e CSIRO, Black Mountain, Canberra, Australia

Abstract

We present results from the field tests of active pressure tomography at the CO2CRC Otway International Test Centre, Stage 3 site. Active pressure tomography involves cross-well pressure tests performed at multiple subsurface wells to build a coarse-grained map of subsurface petrophysical properties, e.g., diffusivity-thickness and porosity-thickness. When performed in a time-lapse manner before and after the injection of CO_2 in the formation, the change in pressure response can also be used to infer the CO_2 plume location. We utilise a Bayesian inversion technique to infer the spatial distribution of properties/CO_2 from a tomographic survey – a series of water injections and measured pressure response at six wells, completed at ~1500m in the Paaratte formation in the Otway Basin, Victoria, Australia.

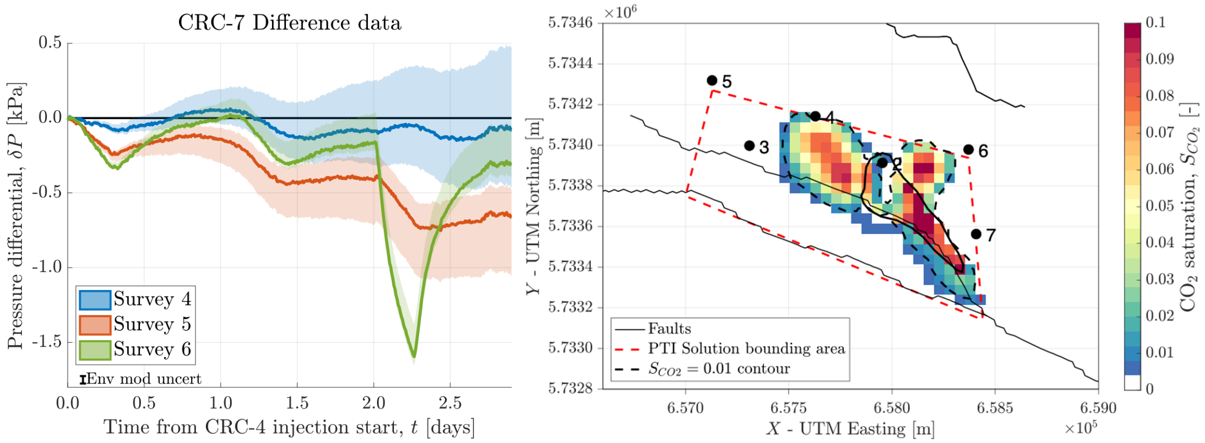

Figure 1 (left) Time-lapse pressure differential (taken from the baseline response) monitored at well CRC-7. Survey 4, 5 and 6 are after 5kt, 10kt and 15kt of CO_2 injection, respectively. Shaded areas represent the uncertainty in the data processing pipeline. CRC-4 water injection starts at $t = 0$, CRC-5 at $t = 1$, CRC-6 at $t = 2$ in the graph. (right) Example Bayesian inversion result for Survey 6 showing coloured CO_2 saturation and footprint contour. The thick black line shows the in-situ Stage 2 CO_2 plume footprint from seismic imaging.

Baseline environmental monitoring results and aquifer characterisation were presented at GHGT-15. Several baseline water injections were performed at the site, and used in the Bayesian inversion approach to infer aquifer properties, and obtain a base pressure signal from which to normalise any repeat injection. In this current work, we present results from three repeat water injection surveys performed after 5kT, 10kT and 15kT of CO_2 injection, allowing the time-lapse tracking of the CO_2 migration. The previously acquired baseline signal is subtracted from the pressure monitored at each well during the survey to produce a differential pressure response - a response caused by CO_2 saturation changes in the domain. The monitored pressure responses require processing to remove superposed pressure signals from the CO_2 injection itself, so that the processed response arises solely from the water injections. An example differential pressure signal obtained at CRC-7 is shown in Figure 1 left, with data processing uncertainty. With each successive survey, we see a reduction in the pressure signal resulting in a more negative differential when compared to the baseline without CO_2. This reduction is due to the compressibility and diffusivity impact of the CO_2 plume 'absorbing' the pressure from the cross-well water injections. The absorbing effect is increased as the mass (and volume) of CO_2 increased in-between the wells.

From the difference signal, we use the Bayesian inversion scheme to invert for the spatial location of the CO_2 plume. We produce depth-averaged maps of the CO_2 saturation evolution – an example inversion is shown in Figure 1 right for Survey 6. To match the difference signal, the inversion places CO_2 in specific regions to cause the desired pressure reduction and minimise the misfit in experimental and modelled pressures. This is particularly evident in the south-east migration of CO_2 near CRC-7, which causes the sharp reduction in pressure during the CRC-6 water injection (see the green line at t = 2.25 days, Figure 1 left). We also see that the plume centred around CRC-2 from the previous Otway Stage 2 operations has likely merged with the new CO_2 plume emanating from CRC-3, due to the south-east topography and fault driven migration. We compare the CO_2 plume migration to the results of active seismic monitoring using several downhole acquisition geometries, such as time-lapse offset VSP and 4D VSP. We discuss the ability of the pressure tomography to provide risk-based monitoring at a CCS site, and how the technology can be scaled up to industrial injection rates.

Keywords: CCS monitoring; pressure tomography; Bayesian inversion; time-lapse