geoconvention
Calgary • Canada • May 15-17 2023

Measurement, Monitoring and Verification (MMV) for large-scale geological carbon storage projects

Don C. Lawton and Kirk G. Osadetz

Carbon Management Canada and the University of Calgary

Summary

As geological CO_2 storage becomes commercially viable, the current state of technologies for subsurface monitoring and measurement will not be sufficient to monitor the large volumes of CO_2 that will be injected and permanently stored. Geophysical and geochemical methodologies are key technologies to monitor the expanding CO_2 plume and verify containment and conformance. However, once we reach large storage volumes, the injected CO_2 plume will be too large for detailed repeated surveys to be feasible from both a cost and logistics perspective. We are developing a new sparse approach for measurement, monitoring and verification (MMV) for large-scale CO2 storage projects. This approach will be cost-effective and reliable to maintain public and regulatory confidence in the secure containment of CO_2.

Theory / Method / Workflow

Carbon Capture, Utilization and Storage (CCUS) is considered a vital technology for reducing emissions of greenhouse gases into the atmosphere and is included in the energy transition plans in many countries. In Alberta, implementation of CCS was started with the Shell Quest Project which has already injected over 6 million tonnes of CO_2 in the Basal Cambrian Sand northeast of Edmonton (https://www.shell.ca/en_ca/about-us/projects-and-sites/quest-carbon-capture-and-storage-project.html). Recent estimates suggest that global investment in CCUS between 2023 and 2030 will be at least $256 billion (https://energynow.ca/2023/03/carbon-capture-utilization-and-storage-ccus-will-spearhead-energy-transformation/). Within the last few months, the Government of Alberta has permitted 25 CCS projects to advance to the evaluation stage, which enables teste wells, capacity, containment and injectivity to be evaluated in the area of interest (AOI) for each project.

Carbon Management Canada (CMC), in collaboration with the University of Calgary, has developed a comprehensive Field Research Station in southern Alberta, now known as the Newell County Facility. It is located 200 km southeast of Calgary. At this site we are focused on the development of new, continuous and discrete monitoring technologies necessary to verify containment and conformance of geological CO_2 storage. This is particularly important during the early stages of injection and when there may be unexpected outcomes or trigger events that will require hub operators to adapt their injection strategies.

Novel approaches to MMV

The project team is developing the concept of a sparse nodal network for monitoring technologies to map the CO_2 plume development in the subsurface. We will develop methodologies for field data acquisition, processing and analysis that can be rapid and automated. Figure 1 shows a schematic diagram of a data node. It consists of a permanent seismic source and buried geophones or DAS fibre that can be repeated on a rapid time basis to capture the arrival of the CO_2 plume at the location of the note. Each node may have observation wells drilled to the base of groundwater protection for monitoring groundwater and potentially record other types of geophysical data.

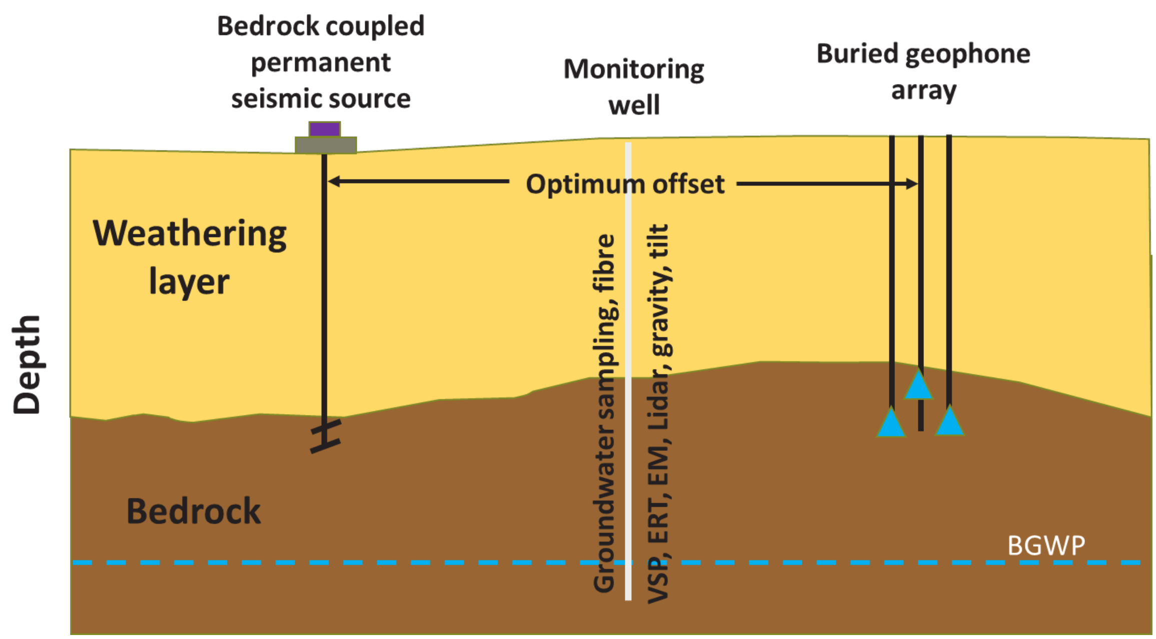

Figure 1: Schematic diagram of a sparse node for monitoring GCS.

Geophysical monitoring

A challenge for surface sources and receivers used for time-lapse land seismic data is separating time delays caused by seasonal changes in the near surface to 4D effects related to CO_2 injection (Henley and Lawton, 2020). To overcome this, we have been testing permanent sources (GPUSA orbital vibe and a 'Squid' 3P Technology impulsive plasma source) mounted on large helical screw piles (pedestals) that are screwed into the ground into bedrock below the weathering layer (Spackman and Lawton, 2019) and recording into an array of geophone cemented into the observation well. Surface orbital vibrators mounted on concrete foundations have been developed with good results shown from Otway (Australia). The concept of single source and a single or a small number of receivers has been implemented previously (e.g. Brun et al. 2021). In this paper we propose an advancement by designing the survey using an optimum offset approach (Hunter and Pullan, 1989) where the source – receiver offset is selected to that the reflection is captured at an offset that is beyond the arrival times of surface waves and inside the first arrival times of headwaves and associated reverberations.

At each node, other geophysical borehole or surface measurements can also be made, such as electrical resistivity tomography (ERT), vertical seismic profiles (VSP), electromagnetic (EM) and geodetic surveys etc. as shown in Figure 1. This project work is being undertaken by CMC staff in collaboration with the CREWES Project at the University of Calgary, under the leadership of Dr. Kris Innanen.

Geochemical monitoring

Geophysical monitoring at the Newell County Facility is augmented by geochemical and hydrogeological activities performed in collaboration with numerous public and corporate groups, including, faculty, post-doctoral and student researchers, resulting in the formation of a new generation of subsurface geoscientists who will implement commercial scale CCS projects in the basin. Key among our collaborators are Dr. Bernhard Mayer and Dr. Cathy Ryan at the University of Calgary who both participate in the geochemical monitoring of Newell County Facility soil and atmospheric gas emissions. Dr. Stuart Gilfillan and his research group at the University of Edinburgh works in collaboration with Dr. Nicholas Utting of Natural Resources Canada/CanMET Energy Devon. They performed baseline studies and continuing monitoring of both free and dissolved, natural gases, including their noble gas components, both emitted and dissolved gases. Hydrogeological studies by Dr. Utting and Dr. Mayer are significantly augmented by the construction of multilevel water wells at the FRS by Dr. Elizabeth (Beth) Parker of the University of Guelph. Dr. Utting is working on the development of continuous monitoring technologies for both CCS storage complexes and emitting wells with construction integrity issues. Atmospheric GHG monitoring is also performed in co-operation with the Dr. Robert Davies of the Southern Alberta Institute of Technology, Prof. Kyle Daun and his students from the University of Waterloo, Dr. Greg Rieker of the University of Colorado Boulder and Dr. Jerome Genest of Universite Laval in Quebec. Several industrial collaborators have been testing their monitoring technologies, particularly oriented toward methane emissions using controlled releases at the NCF. These companies include, GHGSat of Montreal, Questor Technology Inc. of Calgary, and Kuva Systems Inc. of Boston and Calgary. This component of work has increased significantly since 2022, with many of the technologies funded by the Alberta Methane Emission Program choosing to test at the NCF. The general results so far indicated that the injected CO_2 plume has not yet arrived at any of our wells (1 injector, 2 observation; 6 water) at the site. Likewise, there is no indication that the injection program has contaminated either the groundwater protection zone, nor the soils and near surface environments. However, we do see carbon dioxide in the soils, but these are clearly linked to plant respiration rather than the injected plume. We have detected and continue to monitor long-term changes in both geochemical and hydrogeological characteristics of the site. Some of these, like biofouling of one a well interior, and changes in the rate and composition at surface casing vent emissions appear related to our engineering interventions at the site. In addition to providing monitoring for the injected carbon dioxide that serves as a model for future commercial CCS projects, we have tested new tools and techniques that can be applied generally to the common problems of well integrity, and the use of noble gases and other geochemical tracers to better understand subsurface migration processes, while improving the post-glacial hydrogeological environment in the Alberta subsurface.

Acknowledgements

We thank CaMI.FRS JIP subscribers and University of Calgary CREWES sponsors for their support for this research. We also acknowledge financial support from Canada First Research

Excellence Fund program: The Global Research Initiative in Sustainable Low-Carbon Unconventional Resources at the University of Calgary.

References

Victoria Brun, Elodie Morgan, Brad Gerl, Luis Cardozo, Richard Habiak, 2021, Light time-lapse seismic monitoring for SAGD: a new approach & operational model. GeoConvention, Calgary. https://spotlight-earth.com/geoconvention-2021-x-paper-5/

David C. Henley and Donald C. Lawton (2021), Time-lapse detection using raypath interferometry, GEOPHYSICS 86: Q27-Q36. https://doi.org/10.1190/geo2020-0562.1

Hunter, J.A., and Pullan, S.E, 1989, The shallow seismic optimum offset shallow technique. SEG Annual General Meeting.

Tyler W. Spackman, Donald C., Lawton and Malcolm B. Bertram, 2019, Seismic data acquired with a novel, permanently-installed borehole seismic source. SEG Annual General Meeting. https://doi.org/10.1190/segam2019-3214836.1