A feasibility study of the CSEM method for CO_2 storage monitoring of the deep Aquistore reservoir

SeyedMasoud Ansari[1], James Craven[1] and Don White[1]
[1]Natural Resource Canada, Geological Survey of Canada, Ottawa, seyedmasoud.ansari@nrcan-rncan.gc.ca, jim.craven@nrcan-rncan.gc.ca, don.white@nrcan-rncan.gc.ca

SUMMARY

The geological strata of the storage reservoir at the Aquistore CO_2 storage site in Canada comprise clastic units with subordinate carbonate layers that are generally saturated with highly saline brines. As the main storage units, the Winnipeg and Deadwood formations at a depth of 3200 m directly overlie crystalline Precambrian basement rocks and are capped by a minor shale member. The injection of supercritical CO_2 into this highly conductive aquifer is expected to reduce the electrical conductivity of the formation causing a contrast related to the saturation levels. The purpose of this study is to evaluate the detection capability of geophysical time-lapse EM response to the evolved CO_2 plume and its possible leakage to the surrounding geological layers with a detailed synthetic model. Using drill-hole resistivity logs we designed a 9-layer base model and then considered various injection and CO_2 leakage scenarios of varying saturation. The model includes two steel cases (9 inch in diameter and 3400 m in length) that were meshed into the layering using unstructured tetrahedral meshes. Despite the large number of cells in the meshed domain, i.e., 8 million cells, we successfully adopted a finite-element E-field solution of the Helmholtz equation to compute the electromagnetic signal of a long grounded wire source on the surface. The EM signal is calculated with source excitation scenarios where the grounded wire is in the inductive proximity of the steel cases or is galvanically connected to the casing. Figure 1 shows the calculated responses of layered Earth model. The resistivity of the sandstone brine layer is 2 ohm-m and extends from 3120 m to 3350 m at depth. This layer with a porosity of 20% is assumed to be saturated with 30% CO_2 after injection. This according to Archie's law produces a resistive anomaly of 100 ohm-m that according to in-situ saturation models, has evolved into a disk of 500 m with a thickness of 150 m. For this isolated target in a low saturation regime, we realized a relatively weak response of the scattered in-line electric field and phase. We investigate various leakage scenarios to the upper resistive and near surface layers subject to different saturation levels. We also calculate the EM responses for the realistic resistivity models built based on saturation models as the injection program has progressed.

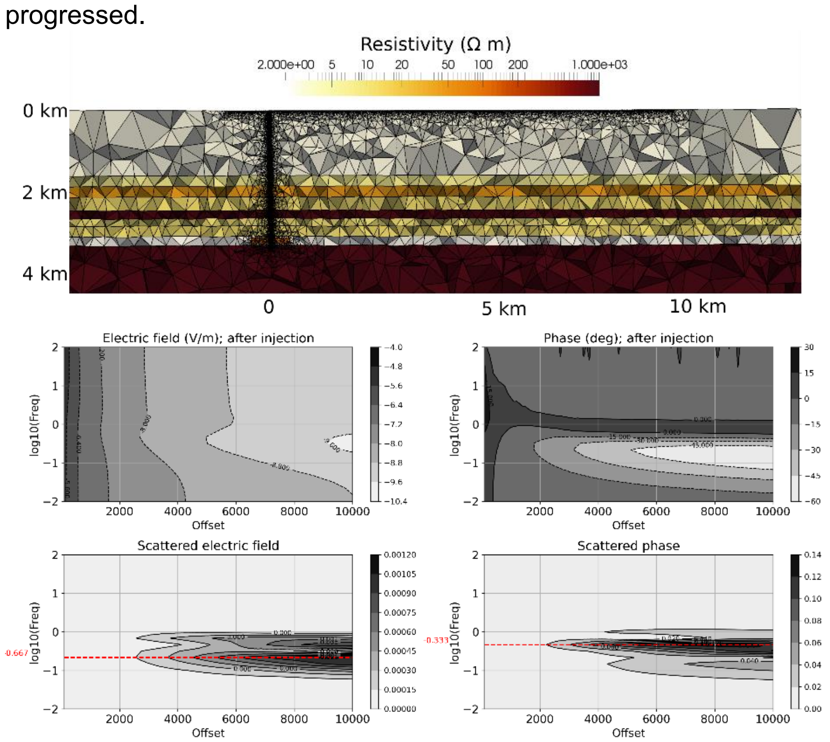

Figure 1: Top: The 9-layer Earth resistivity model and the mesh (zoomed view) of the Aquistore site. Inclusion of the steel case produced significant refinement at the zero offset down to a depth of 3400m in the basement. The conductivity of steel case is 5.e6 S/m. One end of the 1200 m grounded wire source is connected to the top of the steel case at the origin. The mesh consists of 5 million cells.
Bottom: The in-line electric field, phase and their scattered values calculated for this Earth model. The ideal frequencies that measure the maximum scattered signals are shown in red (dotted line).

Keywords: CO_2 sequestration, CSEM method, time-lapse signals, scattered fields, and phases