Effectiveness of Multiple Monitoring Methods for Detection of Brine and CO_2 Leakage

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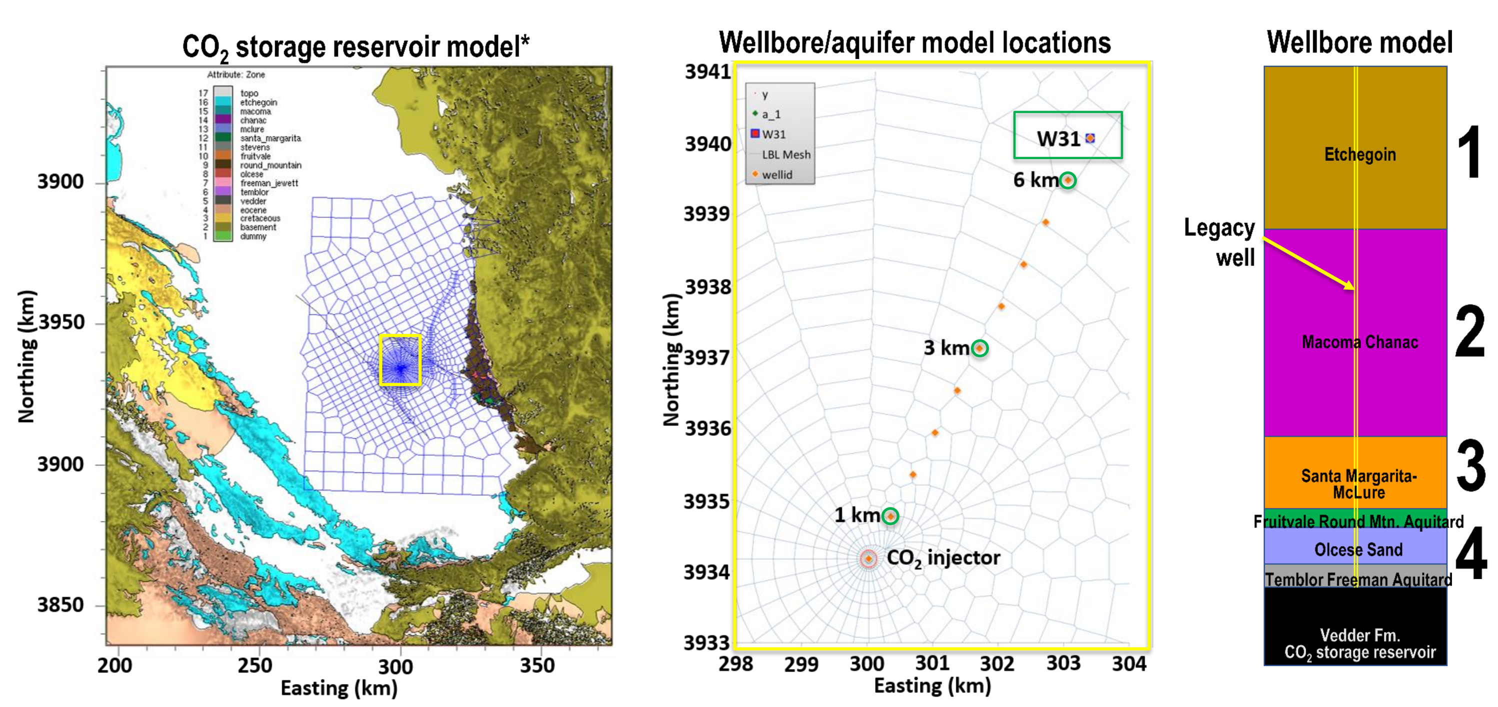
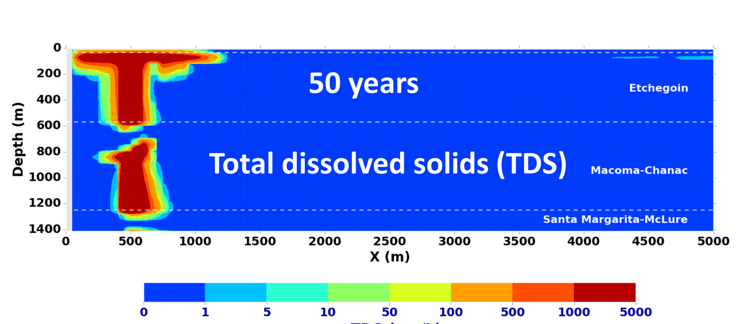
Introduction

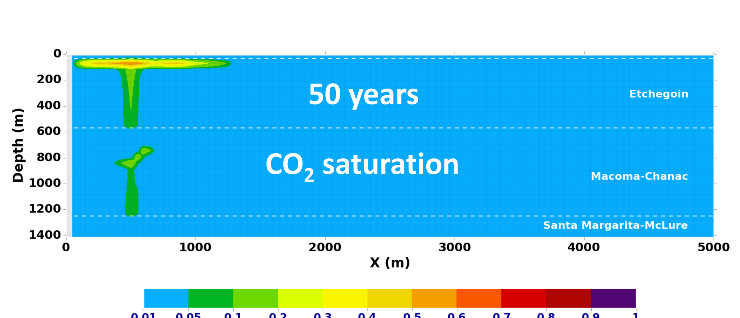
The US DOE National Risk Assessment Partnership (NRAP), funded through the Office of Fossil Energy and NETL, is developing methods to evaluate the effectiveness of monitoring techniques to detect brine and CO_2 leakage from legacy wells into underground sources of drinking water (USDW) overlying a CO_2 storage reservoir. As part of the NRAP Strategic Monitoring task group, we have generated Kimberlina Rev. 1.1 of the simulated aquifer impact data from a model framework based on a hypothetical, compartmentalized, CO_2 storage reservoir in the Vedder Formation near Kimberlina in the southern San Joaquin Basin, California. Brine and CO_2 leakage results in subsurface changes in pressure, CO_2 saturation and total dissolved solids (TDS). CO_2 buoyancy allows a significant fraction of leaked CO_2 to reach shallower permeable zones, which is more detectable with surface geophysical sensors. We are using this simulated data set to evaluate effectiveness of electrical resistivity tomography (ERT) and magnetotellurics (MT) for leakage detection. The evaluation of additional monitoring methods such as pressure, seismic and gravity is underway through a multi-lab collaboration.

Kimberlina V1.1 Simulated Aquifer Impact Data

Reservoir and wellbore multi-phase flow models



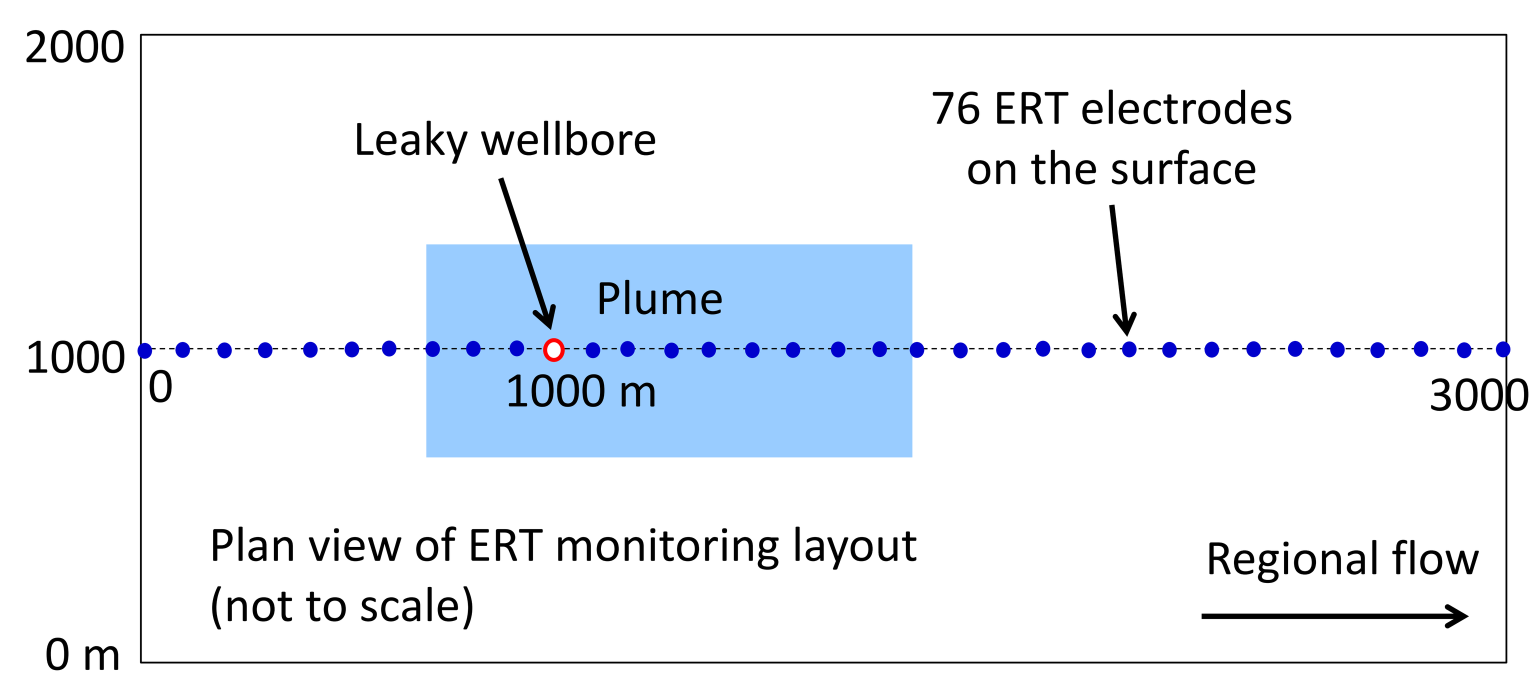




- 140 data sets are generated by sampling pressure & CO_2 saturation in the wellbore, injector-wellbore distance, wellbore permeability and location of leaky intervals
- Key factors affecting plume size and detectability are wellbore permeability and location of leakage intervals along the wellbore
- CO_2 leakage dominates leakage plume size and detectability

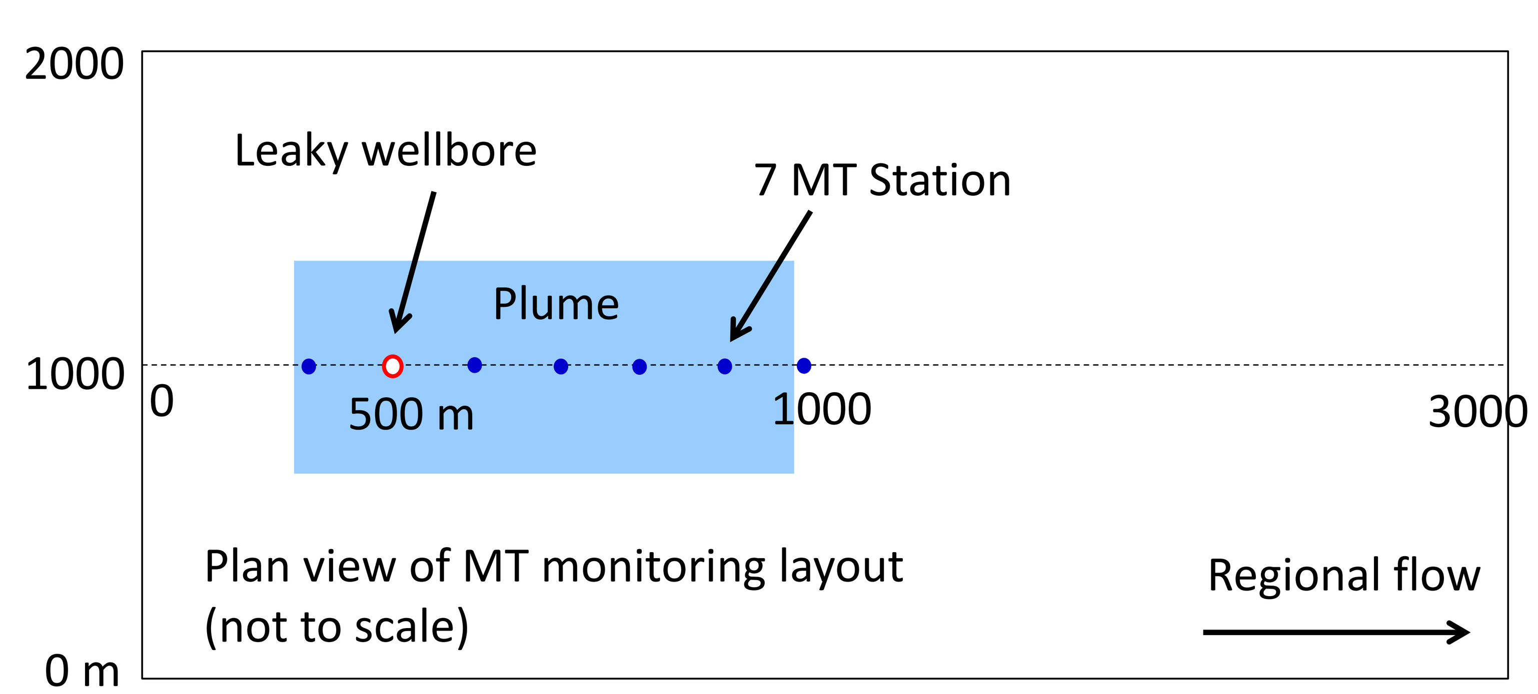
Electrical Resistivity Tomography (ERT)

- ERT is sensitive to changes in both TDS and gas-phase CO_2 saturation, and its penetration depth is < 600 m
- Deployed 76 electrodes at 40 m spacing on the surface
- Generated 980 ERT data sets (140 simulations x 7 time steps)
- Generated 5,847 data points per ERT data set using a dipole-dipole array with multiple dipole lengths
- The pre-leakage baseline ERT model consists of three layers of TDS concentration: 500 mg/L (0-200 m), 1,000 mg/L (200 – 500 m) and 2,000 mg/L beyond 500 m depth



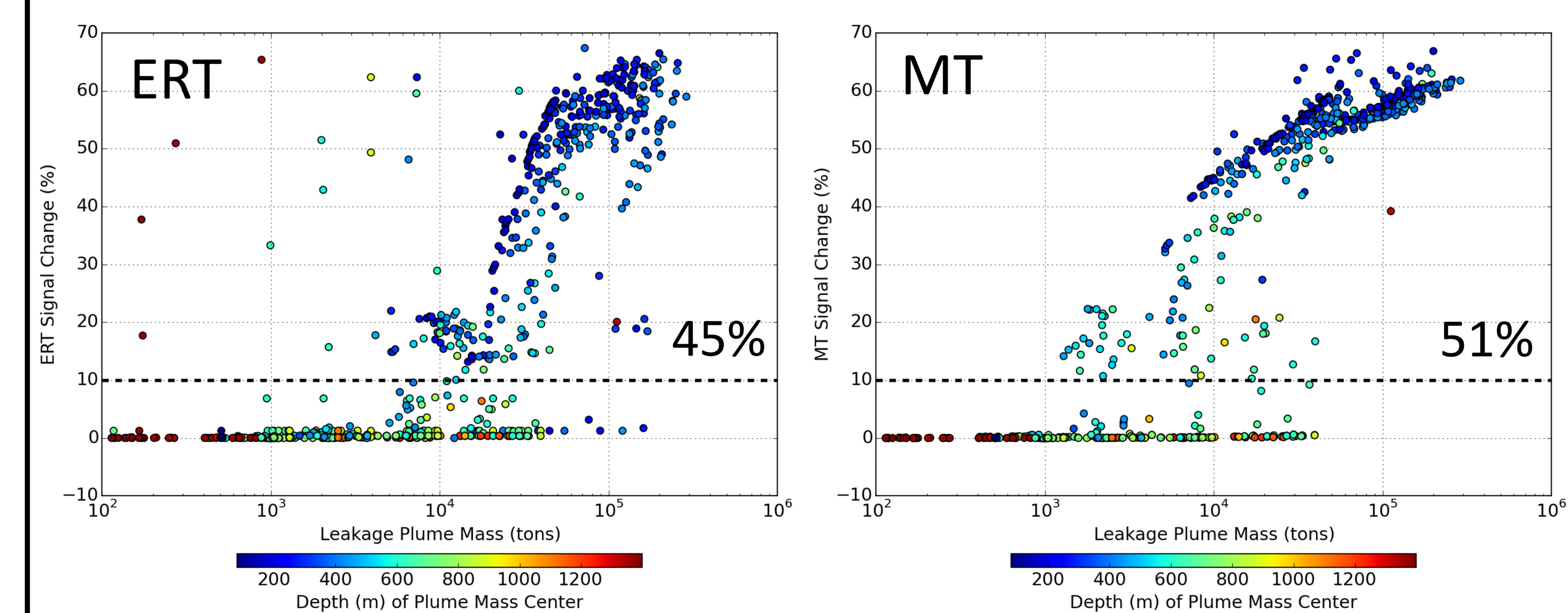
Magnetotellurics (MT) Method

- MT is sensitive to changes in both TDS and gas-phase CO_2 saturation and its penetration depth is > 2 km
- Deployed 7 MT stations at 200 m spacing on the surface
- 17 MT signal frequencies from 1 Hz to 10 kHz
- The pre-leakage baseline MT model consists of three layers of TDS concentration: 500 mg/L (0-200 m), 1,000 mg/L (200 – 500 m) and 2,000 mg/L beyond 500 m depth
- Electrical conductivity models from simulated aquifer impact data at 7 time steps: 0, 10, 20, 50, 100, 150 and 200 years

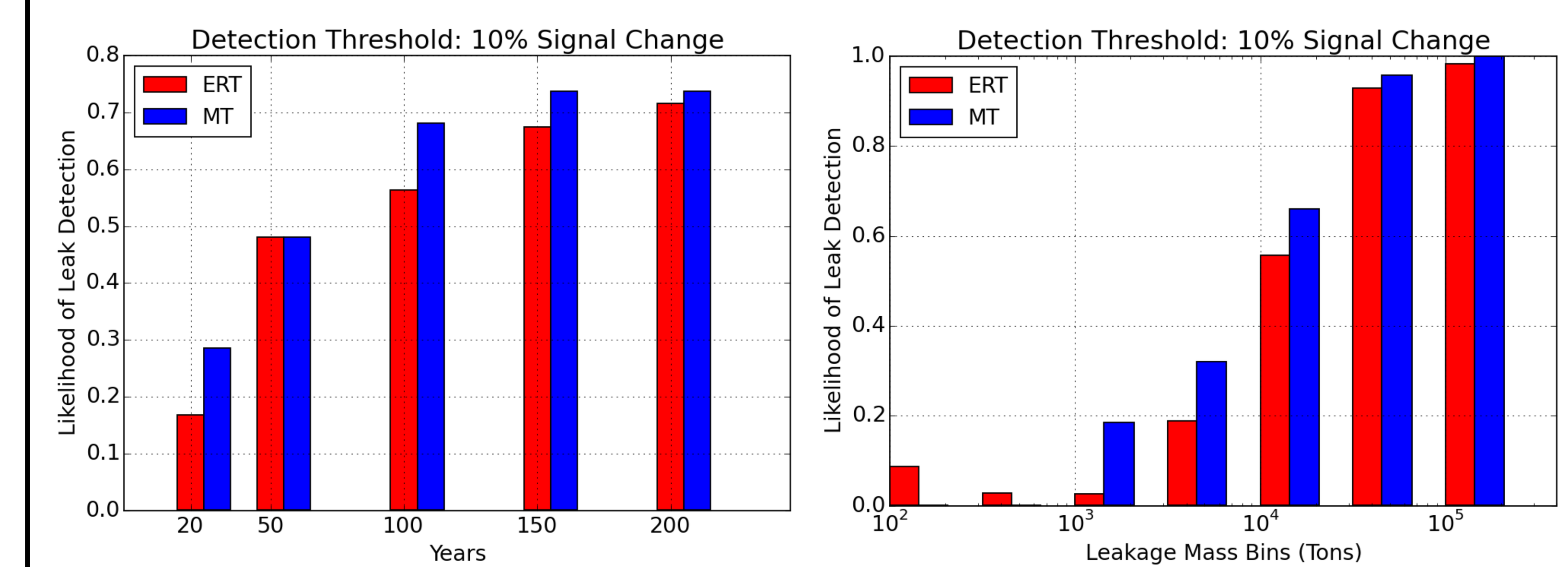


Likelihood of Leakage Detection

ERT/MT Signal Change from the Pre-Leak Baseline



Likelihood of Leakage Detection by ERT/MT wrt Time and Mass



Summary and Future Work

- Both ERT and MT methods can detect the shallow plumes driven by CO_2 buoyancy
- The likelihood of leakage detection increases with time and leakage mass. Both MT and ERT have about a 50% chance to detect a leak at 50 years. A sure detection (>95%) is predicted when the leakage mass is over 30,000 tons
- The MT method is slightly more effective than ERT
- Our predictions are based on many assumptions. For example, (1) 140 simulations which sampled a very limited number of model parameters; (2) A known leaky wellbore location for optimal ERT/MT monitoring configuration
- Pressure, gravity and seismic methods will be evaluated for leakage detection using Kimberlina V1.1 data sets. The effectiveness of multiple monitoring techniques will be ranked

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