Using Magnetotellurics to Detect CO_2 and Brine Leakage in Underground Sources of Drinking Water

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Xianjin Yang, Yunwei Sun, Kayyum Mansoor, Thomas Buscheck and Susan Carroll
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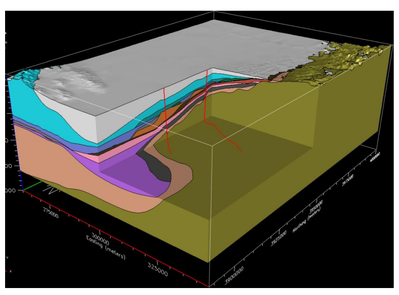
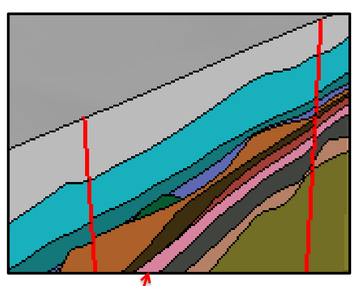
Introduction

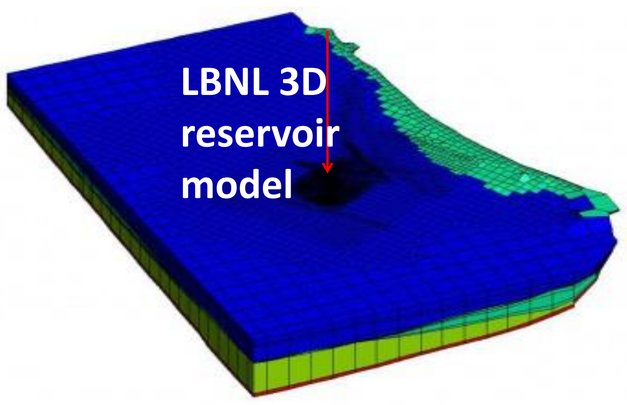
We assessed the effectiveness of the magnetotelluric (MT) method in detecting CO_2 and brine leakage through a wellbore, which penetrates a CO_2 storage reservoir, into overlying aquifers, 0 to 1720 m in depth, in support of the USDOE National Risk Assessment Partnership (NRAP) program. Synthetic datasets based on the Kimberlina site in the southern San Joaquin Basin, California were created using CO_2 storage reservoir models, wellbore leakage models, and groundwater-geochemical models of the overlying aquifers. The species concentrations simulated with the groundwater/geochemical models were converted into bulk electrical conductivity (EC) distributions as the MT model input. Brine and CO_2 leakage into the overlying aquifers increases ion concentrations, and thus results in an EC increase, which may be detected by the MT method. Our objective was to maximize the probability of leakage detection using the MT method.

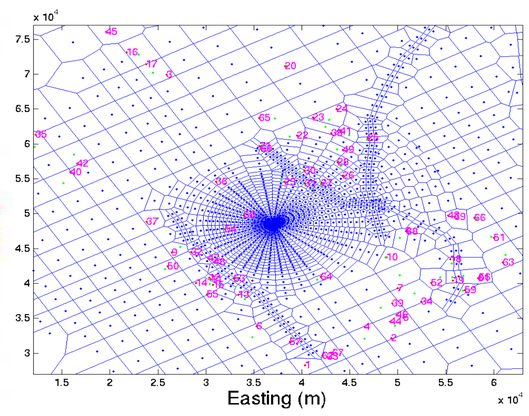
Geology-Reservoir-Wellbore-Groundwater Models





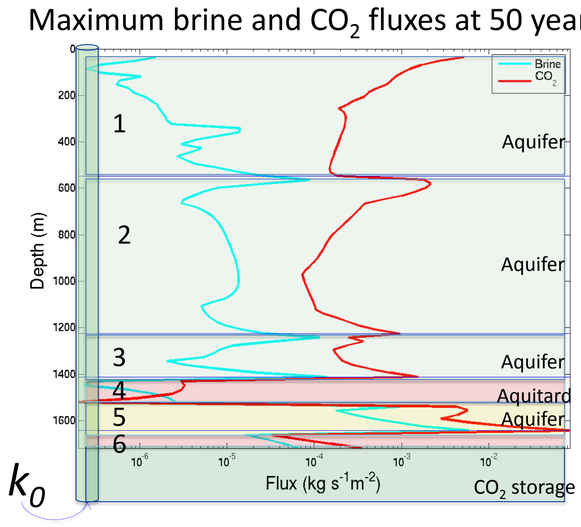
Geologic model: Heterogeneous caprock layers, wells and a storage reservoir at Kimberlina, CA

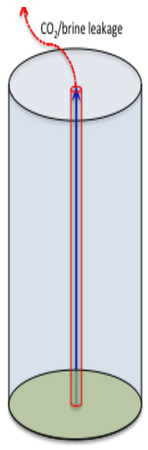




Reservoir model: 11 input parameters, 200 samples

Maximum brine and CO_2 fluxes at 50 years



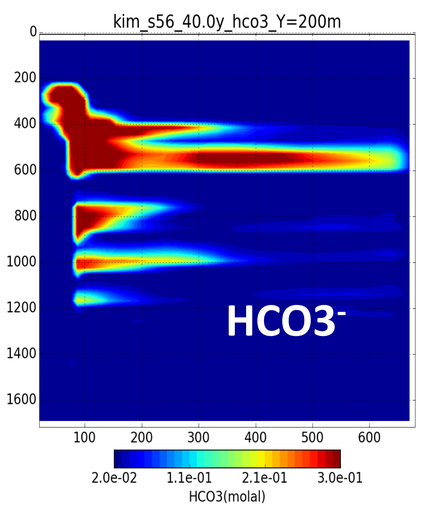


Wellbore leakage model:

- 9 input parameters
- 1000 samples
- 69 wells

Groundwater/geochemical model:

- 10 input parameters
- 1 leaking well,
- 1000 samples



$$Na^+ + Cl^- = NaCl$$

$$CO_2(g) = CO_2(aq)$$

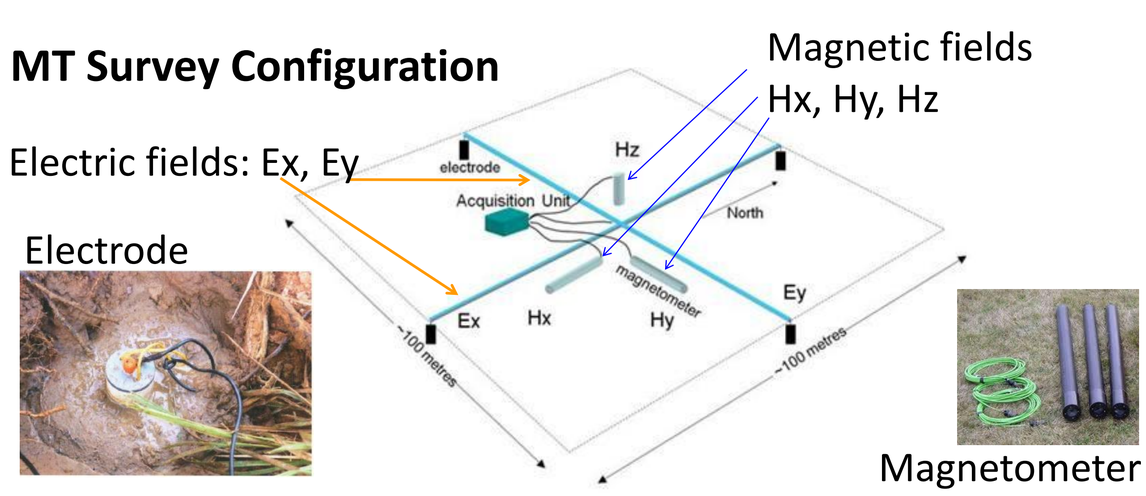
$$CO_2(aq) + H_2O = HCO_3^- + H^+$$

$$CaCO_3(calcite) + H^+ = Ca^{2+} + HCO_3^-$$

Magnetotelluric (MT) Method

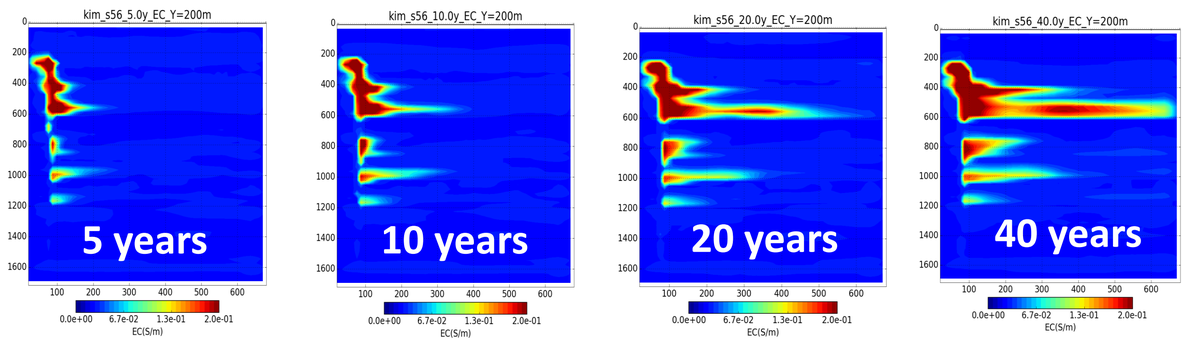
- Magnetotelluric (MT) method is an electromagnetic geophysical technique that images the electrical conductivity (EC) distribution of the earth by measuring natural electric and magnetic fields
- The two sources of the MT electromagnetic field are (1) micro-pulsations (< 1 Hz) due to the interaction of solar wind with the geomagnetic field, and (2) global lightning activities (> 1 Hz)
- MT frequency range: 0.01 Hz to 1 kHz
- ModEM software is used for MT modeling

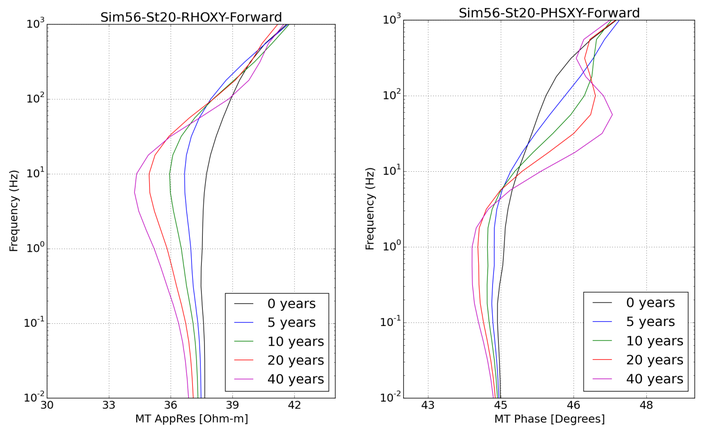
MT Survey Configuration



MT Synthetic Data

The electrical conductivity (EC) plume grows with time





Apparent Resistivity

Phase

MT detects apparent changes due to the brine and CO_2 plume growth with time. Year 0 indicates the baseline data.

Future Work

- MT inverse models with noise contaminated data
- Optimization of monitoring system design to maximize the probability of leakage detection
- Value of information analysis to link brine and CO_2 leakage to economic outcome

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