1. Motivation

Management of groundwater contaminant risks and effective design of remediation strategies require a good understanding of field-scale subsurface transport processes. Investigating field-scale transport is challenging! Can electrical surveys be used to non-invasively monitor transport and provide quantitative estimates of transport parameters?

Improvements in imaging technology have created a tomographic ‘image’. Great for research, but who has this well field? Use electrodes instead of wells?

2. Rethinking Data Fusion

- After processing, treat geophysics as ‘hydric’ data. - Takes advantage of current inversion/processing methods. - Forced to rely on prior assumptions regarding spatial continuity. - Requires large volumes of data for time-lapse imaging (i.e., slow).

Integrated Data Fusion:

- Use geophysical data to directly constrain transport parameters.
- Avoid bias problems introduced by the geophysical ‘imaging’ step.
- Takes advantage of spatial patterns imposed by transport physics.
- More efficient use of data allows high-speed, adaptive surveys.

3. Synthetic Study

Goal: Determine if low-density electrical resistivity measurements can be used to monitor a tracer test and constrain hydraulic conductivity and dispersivity values due their control on the location of the tracer plume.

Modeling Details:

- Coupled fluid, transport, and resistivity models in COMSOL Multiphysics (FEM).
- Plume source (0.5kg NaCl) located 0.5m below surface.
- Assumed uniform flow and non-reactive transport.
- Tracer Model Parameters:
  - Hydraulic conductivity, $K = 10^{-4}$ m/s
  - Longitudinal dispersivity, $L_s = 1$ m
  - Transverse dispersivity, $L_t = 1$ m
- Injected current using a single electrode pair.
- Monitored voltage with 231 potential electrodes located on the ground surface (11 x 21 electrode grid).

4. Results

- Voltage patterns are observed to be highly sensitive to hydraulic conductivity and dispersivity values due their control on the location of the tracer plume.
- Parameter Optimization: Integrated data fusion:
  - Results in an over/underestimated parameter estimation problem.
  - Does not rely on prior information other than the physics driving transport.
  - Produces a distinct global minimum in the objective function.
- Avoids bias in parameters introduced by smoothing of geophysical images in sequential data fusion.
- Transient data improves our ability to obtain good parameter estimates.

5. Conclusions

Electrical measurements are powerful tools for monitoring transient subsurface processes and estimating transport parameters, leading to better predictive modeling and contaminant management strategies. Linking geophysics directly to transport parameters using integrated data fusion is a promising approach to joint inversion.

Integrated Data Fusion:

- Takes advantage of our understanding of transport processes for inverting geophysical data.
- Results in better formulated inverse problems than sequential data fusion avoiding the need for prior information.
- Requires significantly less data than tomographic methods and easily integrates multiple data types.
- Can produce high resolution concentration images for risk assessment based on high resolution transport simulations.

Needs for future research:

- Can a small number of resistivity measurements be used to map heterogeneous permeability fields using prior knowledge on K?
- What are the practical considerations for a field application (e.g., noise, mineral conductivity, real-time adaptive data collection)?