Finding Leaks Using Hydrogeophysical Data and Numerical Models

al. et Stefan Finsterle

Earth Sciences Division
Lawrence Berkeley National Laboratory
University of California, Berkeley, USA

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Outline

- Role of Modeling in Support of Leak Detection
- Hydrogeophysics
  - Identification of soil structure and system state
  - Modeling supporting geophysical imaging
- ASCEM
- Concluding Remarks

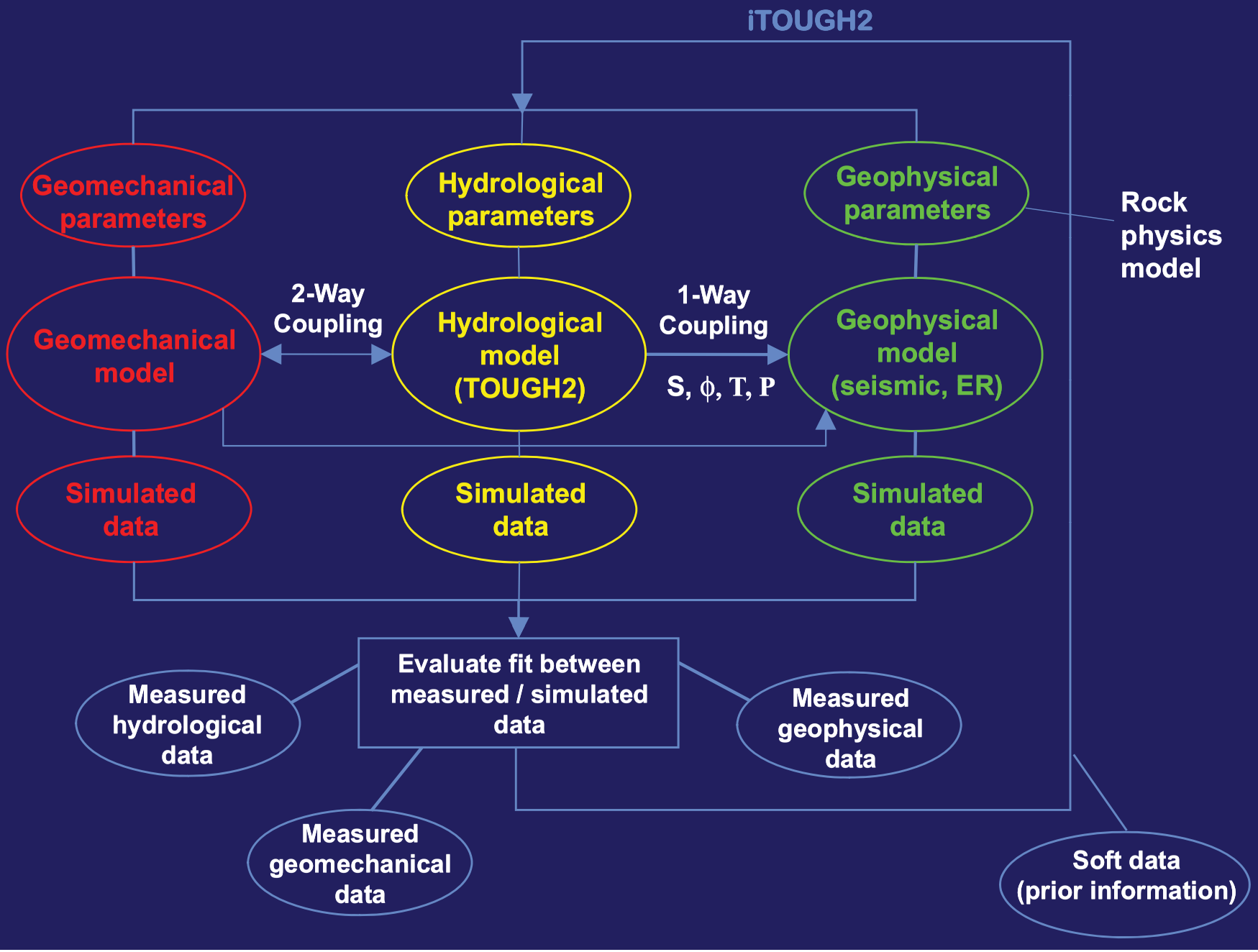
- Defect
- Pathway
- Plume
- Impact
- Action
- Failure scenario
- Characterization
- Monitoring
- Prediction
- Engineering
- Conceptualization
- Parameter estimation
- Data analysis
- Risk assessment
- Decision support

Modeling plays key role in all tasks related to leak detection and remedial actions

Joint Hydrological-Geophysical Inversion

- *Geophysical* data provide *high-resolution* information on soil *structure* and state
- *Hydrological* data provide *process-specific* information on soil *properties* and state
- The hydrological forward model provides *physical regularization* to geophysical imaging
- Joint hydrogeophysical data analysis *reduces ill-posedness* of inverse problem
- Joint estimation of geometry and properties *reduces estimation and prediction bias*

Coupled Hydrogeophysical-Geomechanical Inverse Modeling

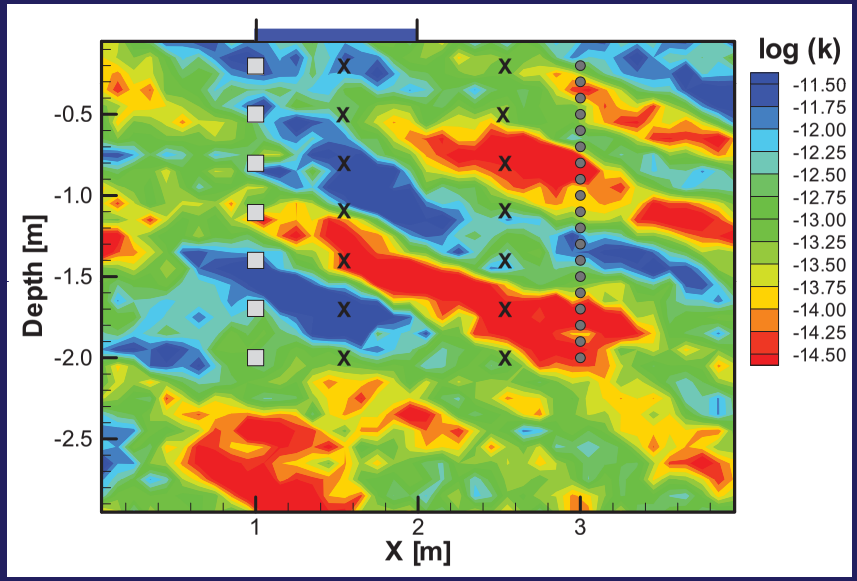


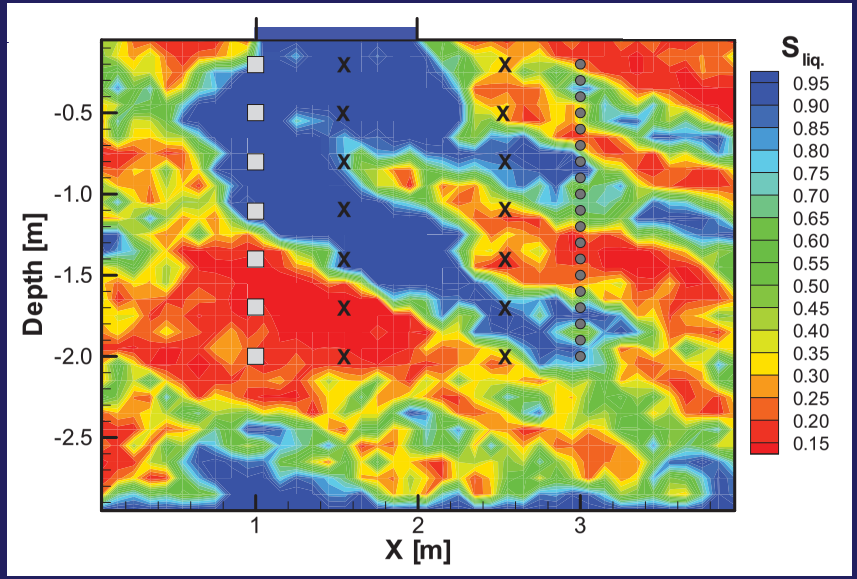
Identification of…

Soil Structure

and

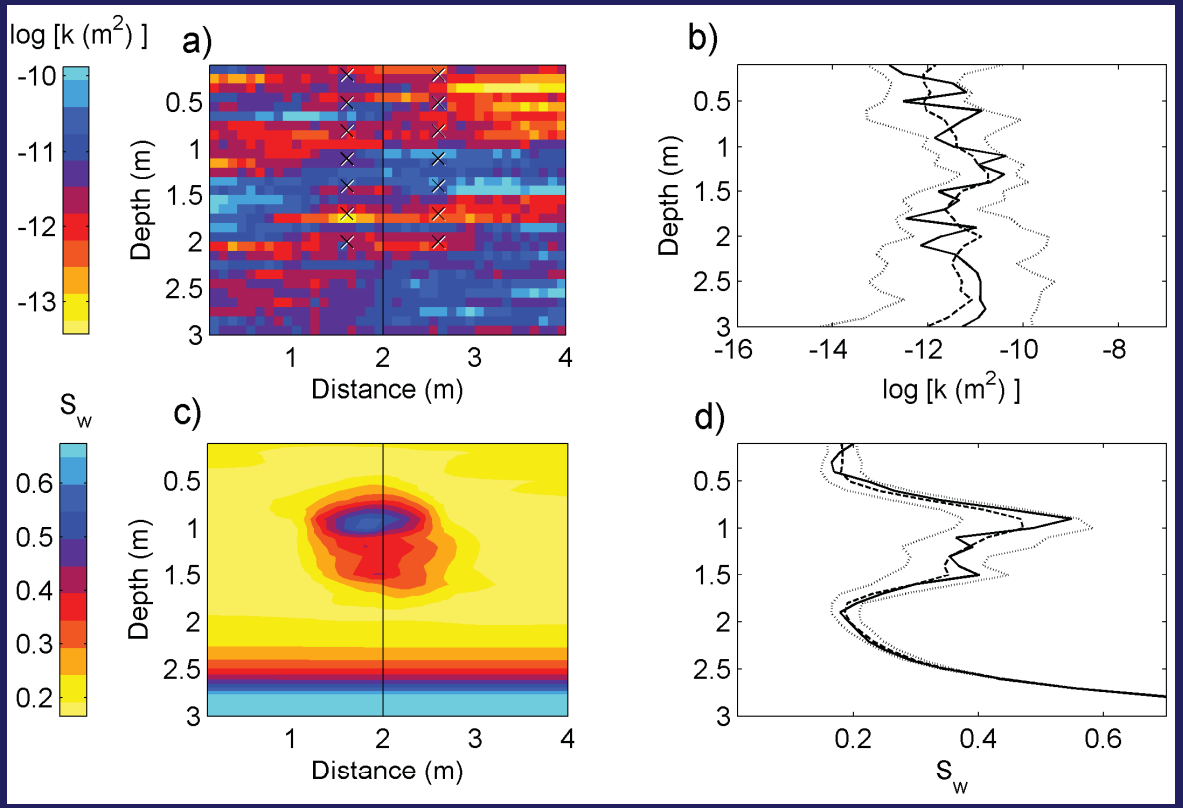
System State





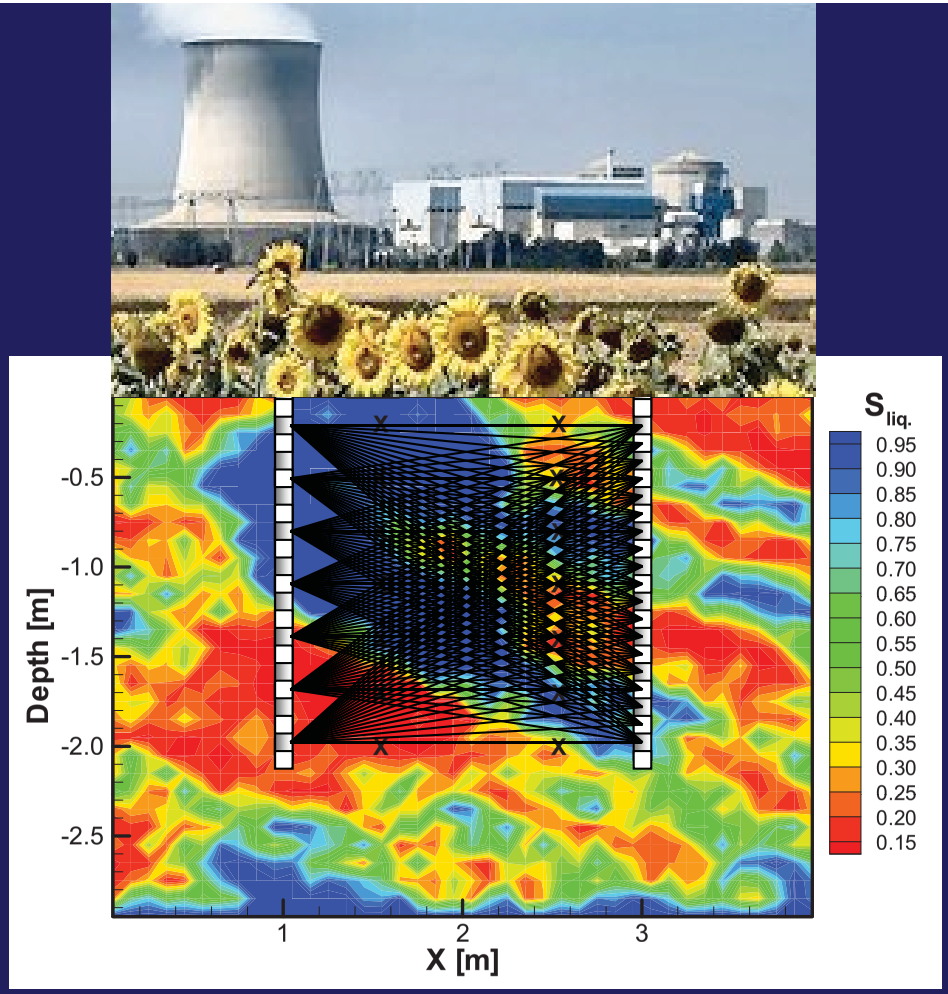
Joint Inversion

- *Geophysical data* contain high-resolution information about soil structure
- *Hydrogeological data* contain information about flow and transport processes
- *Jointly invert* geophysical and hydrogeological data
- Infer both *properties* and *system state*



Illustration

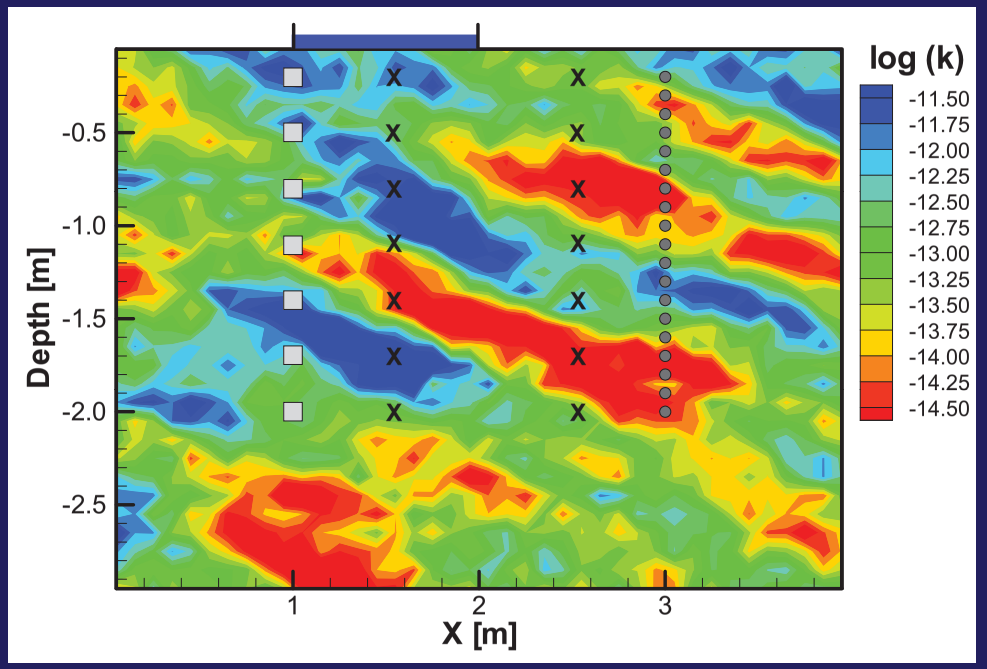
- Scenario:
  2 days leaking
  3 days redistribution
- 2 Boreholes:
  Time-lapse GPR
  Neutron probes
- Data (1 set every day):
  1 Infiltration rate (σ = 0.1 L/day)
  40 Water content (σ = 0.02)
  133 GPR travel times (σ = 0.5 ns)



Total: $6 \times 174 = 1044$ observations

Parameterization

- Soil structure:
  - Variance
  - Correlation length
  - Anisotropy
  - Orientation
- Petrophysical model:
  - Dielectric constant for solids κ_s
  - Mixing exponent n
- Hydrogeological parameters:
  - Porosity: ϕ
  - Reference permeability: k_h, k_v
  - Permeability modifiers at 14 pilot points
  - Two-phase flow parameters: α, n, m, $S_{lr,RP}$, $S_{lr,PC}$, ε, η



$$\kappa = \left[(1-\varphi)\kappa_s^n + S_w\varphi\kappa_w^n + (1-S_w)\varphi\kappa_a^n\right]^{\frac{1}{n}}$$

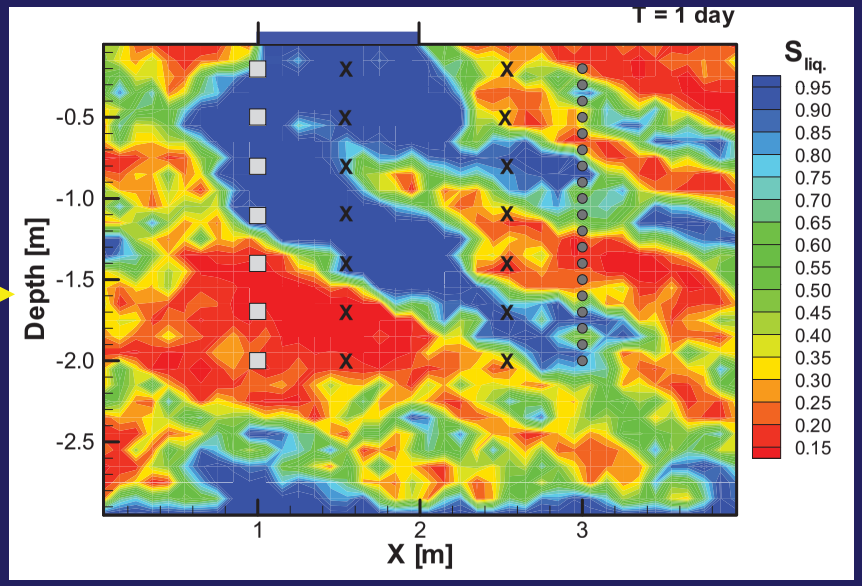
Total 30 parameters

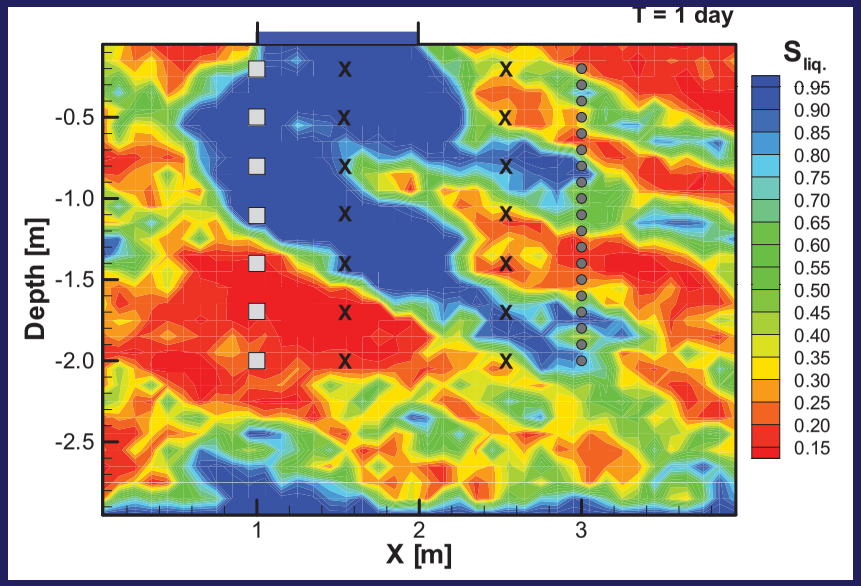
True

Estimated

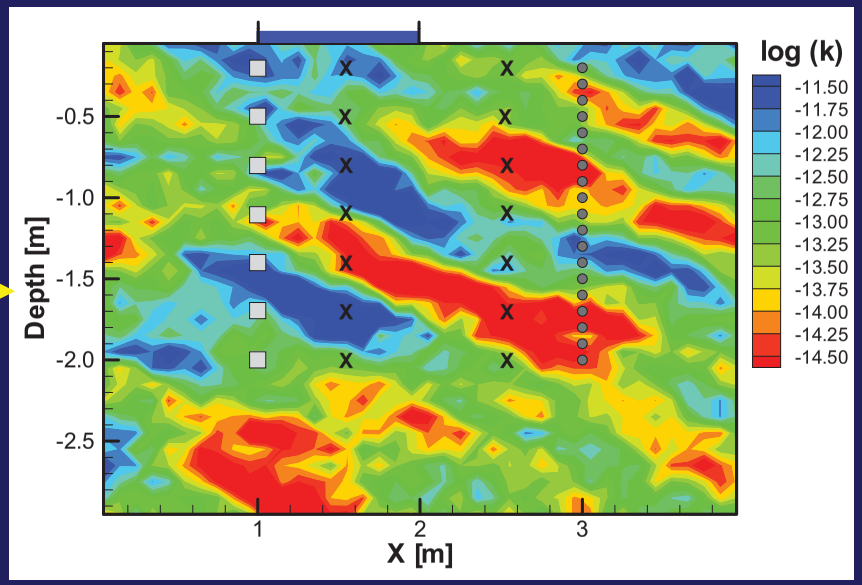
Iteration 14 Obj. Fun.: 1,200

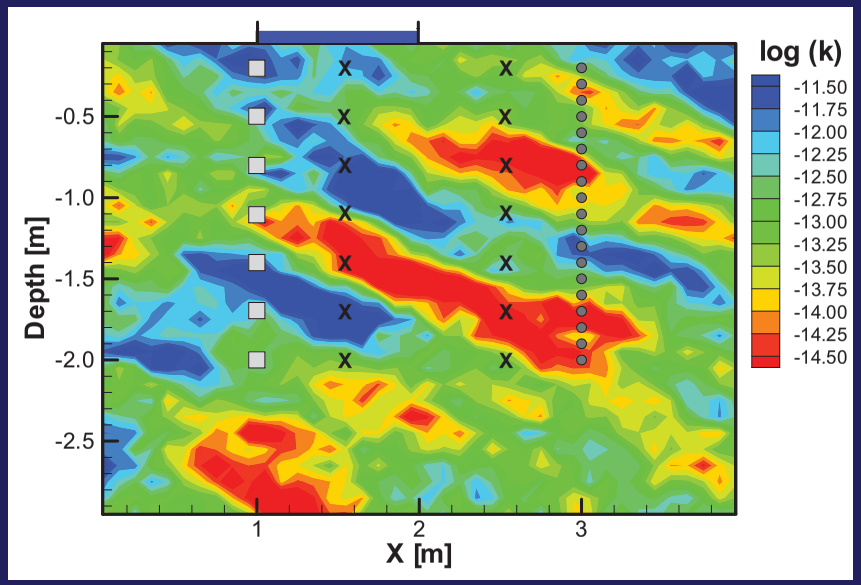
Saturation ▶





Permeability ▶





Ensemble Average