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ESTIMATION OF HYDRAULIC CONDUCTIVITY FOR AN HETEROGENEOUS UNSATURATED SOIL USING ELECTRICAL RESISTIVITY AND LEVEL-SET METHODS

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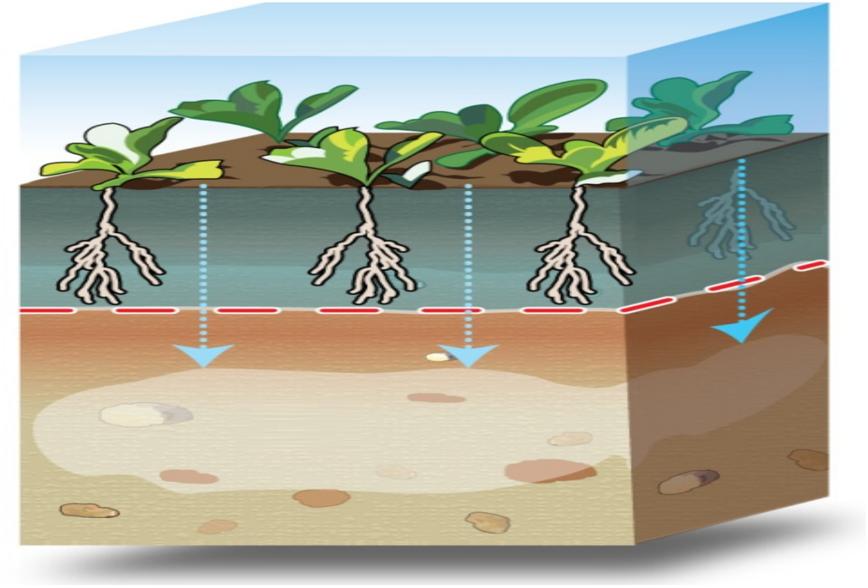
POLYTECHNIQUE MONTRÉAL
LE GÉNIE EN PREMIÈRE CLASSE

ÉTS
Le génie pour l'industrie

Objectives



Hydraulic properties?
Preferential flow of fluids in porous medium

Objectives

Conventional ways to determine K_S:

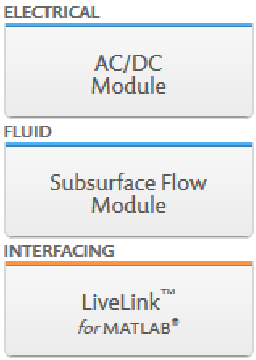
- Constant head method
- in-situ soil analysis

- **provide quality data points**
- limited by sparse data sampling and scale
- lack of spatial resolution

Objectives

Propose an iterative scheme for estimating Ks:

- non-destructive
  - water infiltration method
  - monitoring flow front with ERT method
  - Interpolate flow front level-set method



- cost effective
- works for most type of mediums
- concentrate on unsaturated and heterogeneous mediums

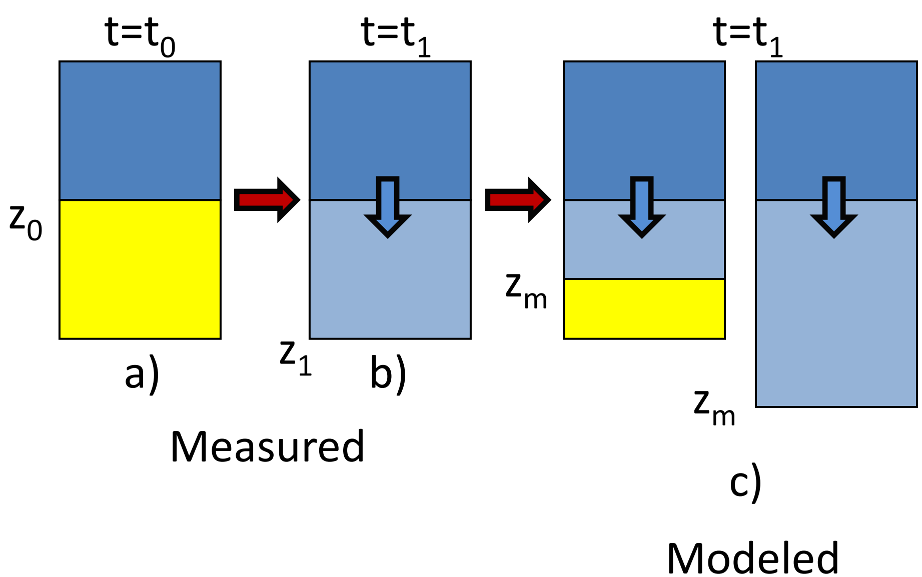
Outline

- Methodology of the iterative scheme
- 1D Hypothetical Hydrology model
- 2D Hypothetical Hydrology model
- Electrical Resistivity Tomography
- Conclusion

Methodology

Iterative scheme for estimating K_S

- a & b: Determine the speed of the measured flow front $V_0 = (z_1 - z_0) / \Delta t$
- c: Determine the speed difference $\Delta V = (z_1 - z_m) / \Delta t$



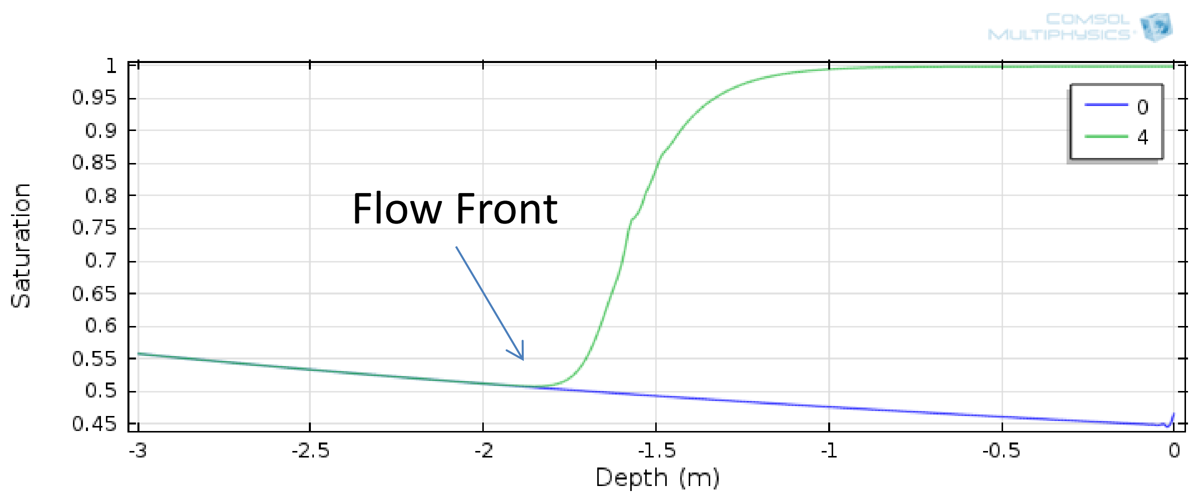
- *Suppose* $K_0 = V_0$
- *Then* $Z_m \rightarrow \Delta V$
- *While* $\Delta V \neq 0$
  $K_{i+1} = K_i + \Delta V$
- *If $\Delta V = 0$* $K_i = K_{S\,real}$

Hypothetical Hydrology 1D model

- Richard's equation
  - Fluid Flow
    - Porous Media and Subsurface Flow
      - Richards' Equation (dl)
- van Genuchten retention model
- Water table (Hydraulic Head = - 7 m)
- ***Mass Flux of 1000 kg/(m²s)***

Table 1. van Genuchten parameters (Wosten et al., 2001)

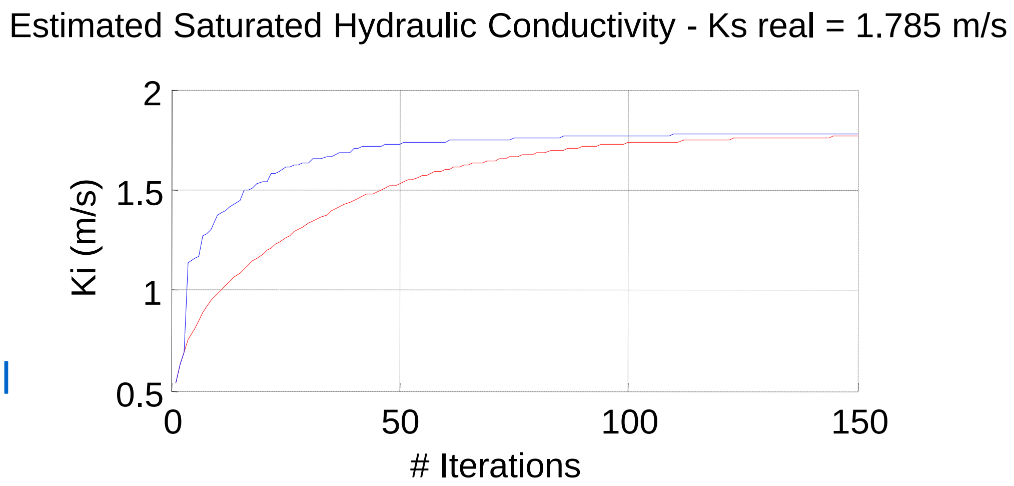
Soil Type	Loamy Sand
Ks (m/s)	1.785E-06
Simulated Ks (m/s)	***1.785***
$\theta_{RESIDUAL}$	0.02
$\theta_{SATURATED}$	0.46
α (m^{-1})	1.44
n	1.534
l	-0.215



Hypothetical Hydrology 1D model

- Numerical iterative scheme
- (K_i , i) ≈ type 2 sigmoidal Weibull
  - Faster convergence

$$y = A - (A - B)e^{-(Cx)^D}$$



Scheme	Iterations	Ks (m/s)	MPE
Iterative	150	1.7635	1.20%
Weibull Type 2	150	1.7826	0.13%

Hypothetical Hydrology 2D model

- Richard's equation
  - Fluid Flow
    - Porous Media and Subsurface Flow
      - Richards' Equation (dl)
- van Genuchten retention model
- Water table (Hydraulic Head = - 10 m)
- ***Mass Flux of 1000 kg/(m²s)***
- Concrete is assume impermeable

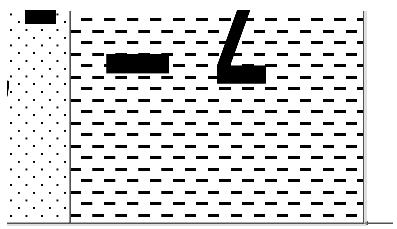
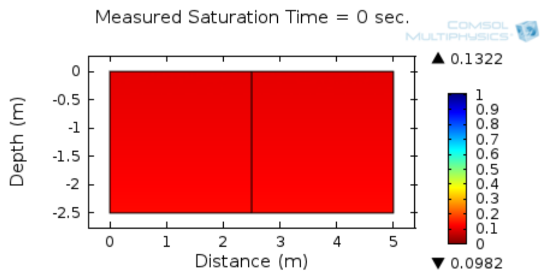


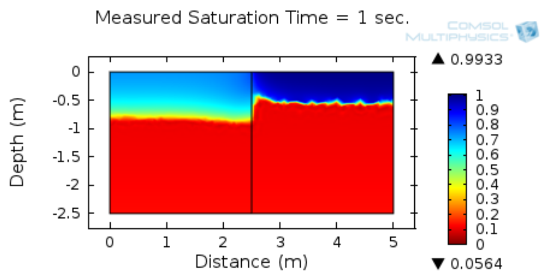
Table 2. van Genuchten parameters (Wosten et al., 2001)

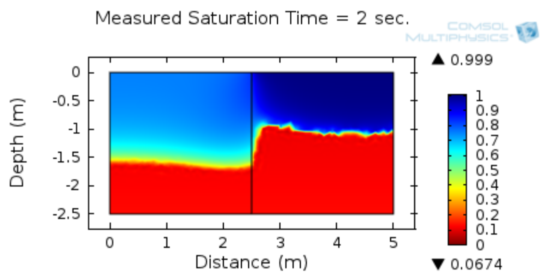
Soil Type	Sand	Subsoil
Ks (m/s)	1E-05	1E-06
Ks_simulated (m/s)	***10***	***1***
$\Theta_{RESIDUAL}$	0.01	0.01
$\Theta_{SATURATED}$	0.5	0.5
α (m^{-1})	1	1
n	2	2
l	0.5	0.5

Hypothetical Hydrology 2D model

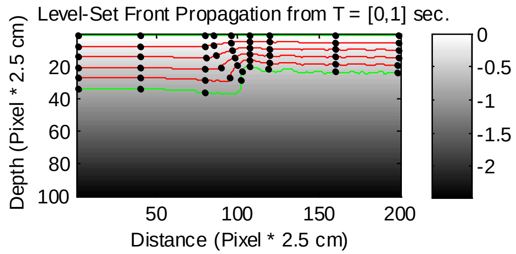
Level-Set method

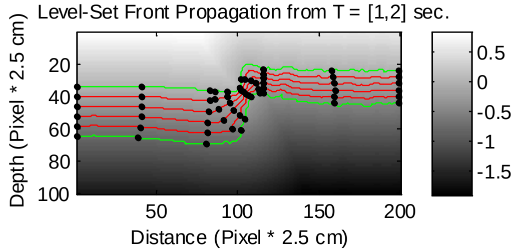


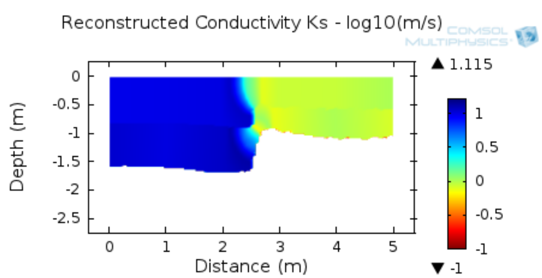




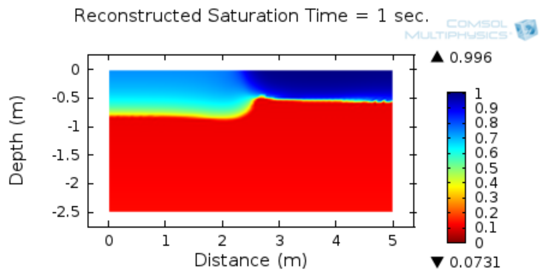
Measured Saturation

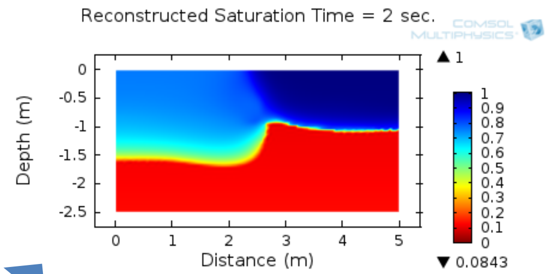






MPE < 3%

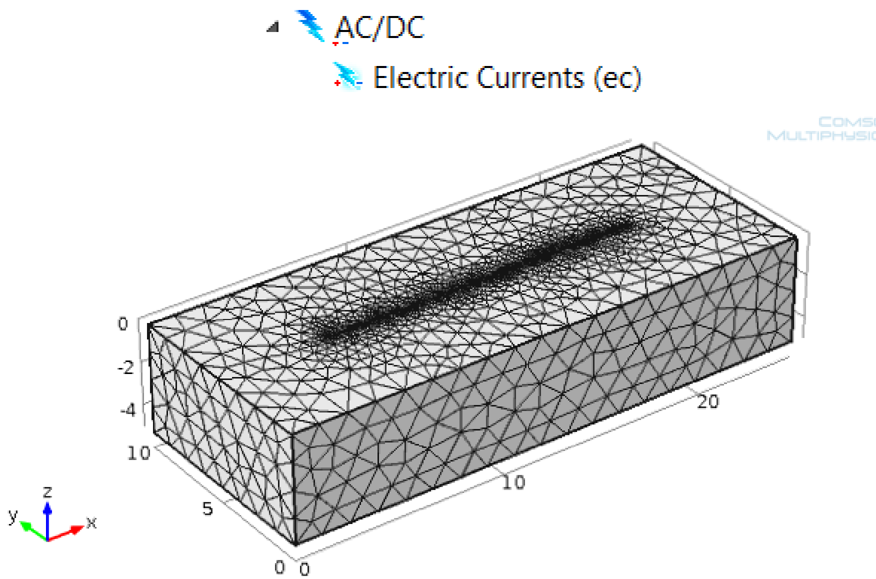


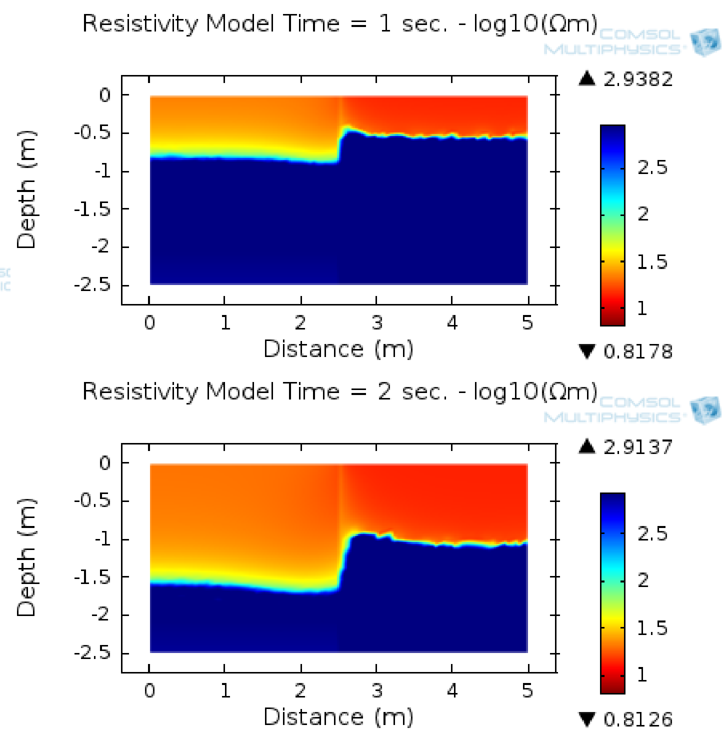


Modeled Saturation
(MPE 1.92% and 2.29%)

Electrical Resistivity Tomography

- Dipole-Dipole Array





Conclusion

Proposed a non-destructive and cost effective method for estimating the saturated hydraulic conductivity of an heterogeneous and unsaturated medium.

The limitation:

- Geophysical method: vertical and horizontal resolutions, sounding depth, depends on electrodes configurations.

- Done by using COMSOL Multiphysics (AC/DC, Porous Medium and Matlab Livelink modules)