

Vadose Zone Hydrological Processes

Modeling Soil and Groundwater systems using the
HYDRUS and **STANMOD** Software Packages

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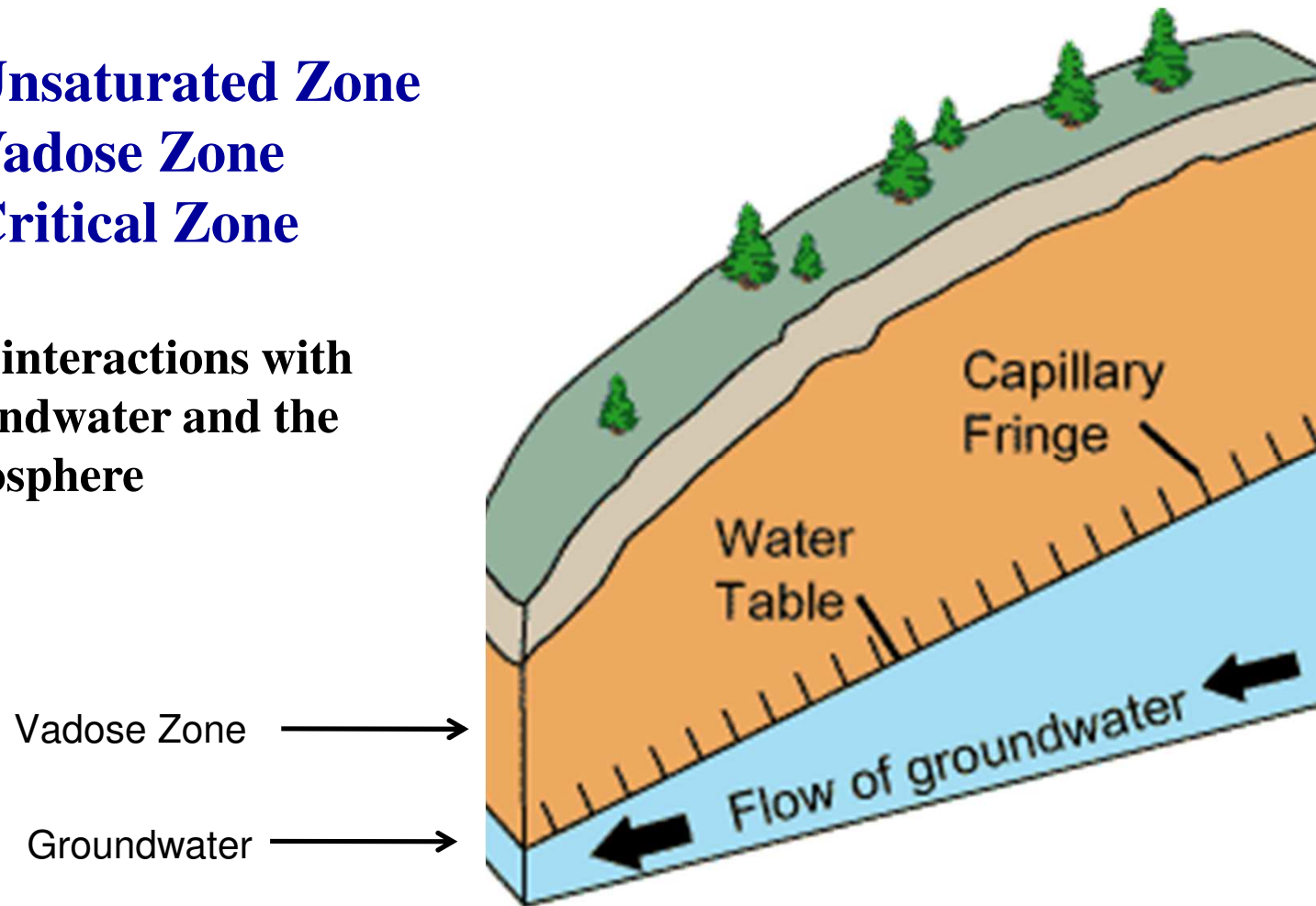
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Mirek Sejna, PC-Progress, Prague, Czech Republic

The Near-Surface Environment

- **Unsaturated Zone**
- **Vadose Zone**
- **Critical Zone**

Plus interactions with groundwater and the atmosphere



Governing Equations

Variably-Saturated Water Flow (**Richards Equation**)

$$\frac{\partial \theta(h)}{\partial t} = \frac{\partial}{\partial z} \left[K(h) \frac{\partial h}{\partial z} - K(h) \right] - S(h)$$

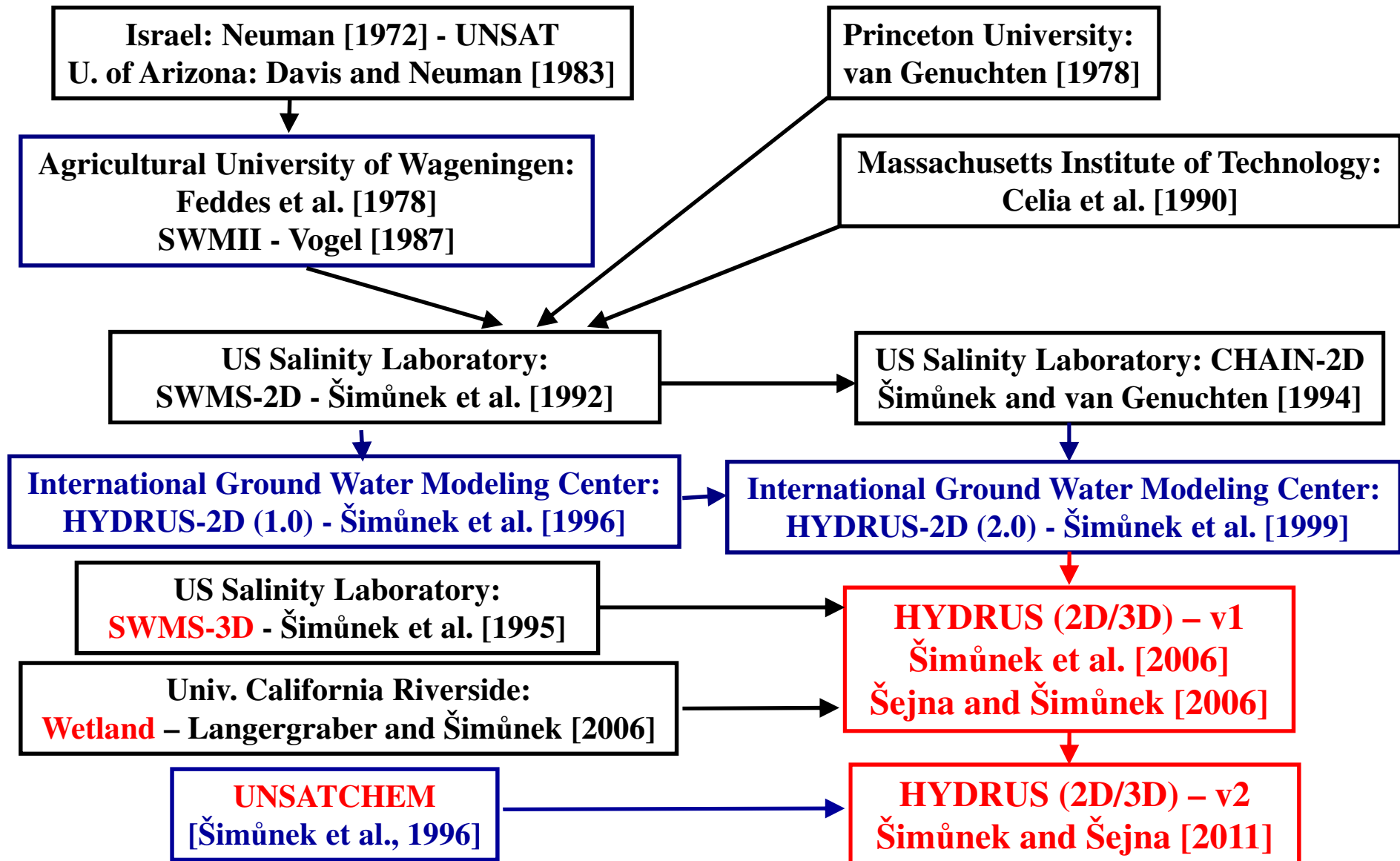
Solute Transport (**Advection-Dispersion Equation**)

$$\frac{\partial(\rho s)}{\partial t} + \frac{\partial(\theta c)}{\partial t} = \frac{\partial}{\partial z} \left(\theta D \frac{\partial c}{\partial z} - qc \right) - \phi$$

Heat Movement

$$\frac{\partial C_p(\theta)T}{\partial t} = \frac{\partial}{\partial z} \left[\lambda(\theta) \frac{\partial T}{\partial z} \right] - C_w \frac{\partial qT}{\partial z} - C_w ST$$

HYDRUS - History of Development



HYDRUS – Main Processes

Water Flow:

- ◆ Richards equation for variably-saturated water flow
- ◆ Various models of soil hydraulic properties
- ◆ Hysteresis
- ◆ Sink term to account for water uptake by plant roots
(uncompensated and compensated, reduced due to osmotic and pressure stress)
- ◆ Isothermal and thermal liquid and vapor flow
- ◆ Preferential flow

Heat Transport:

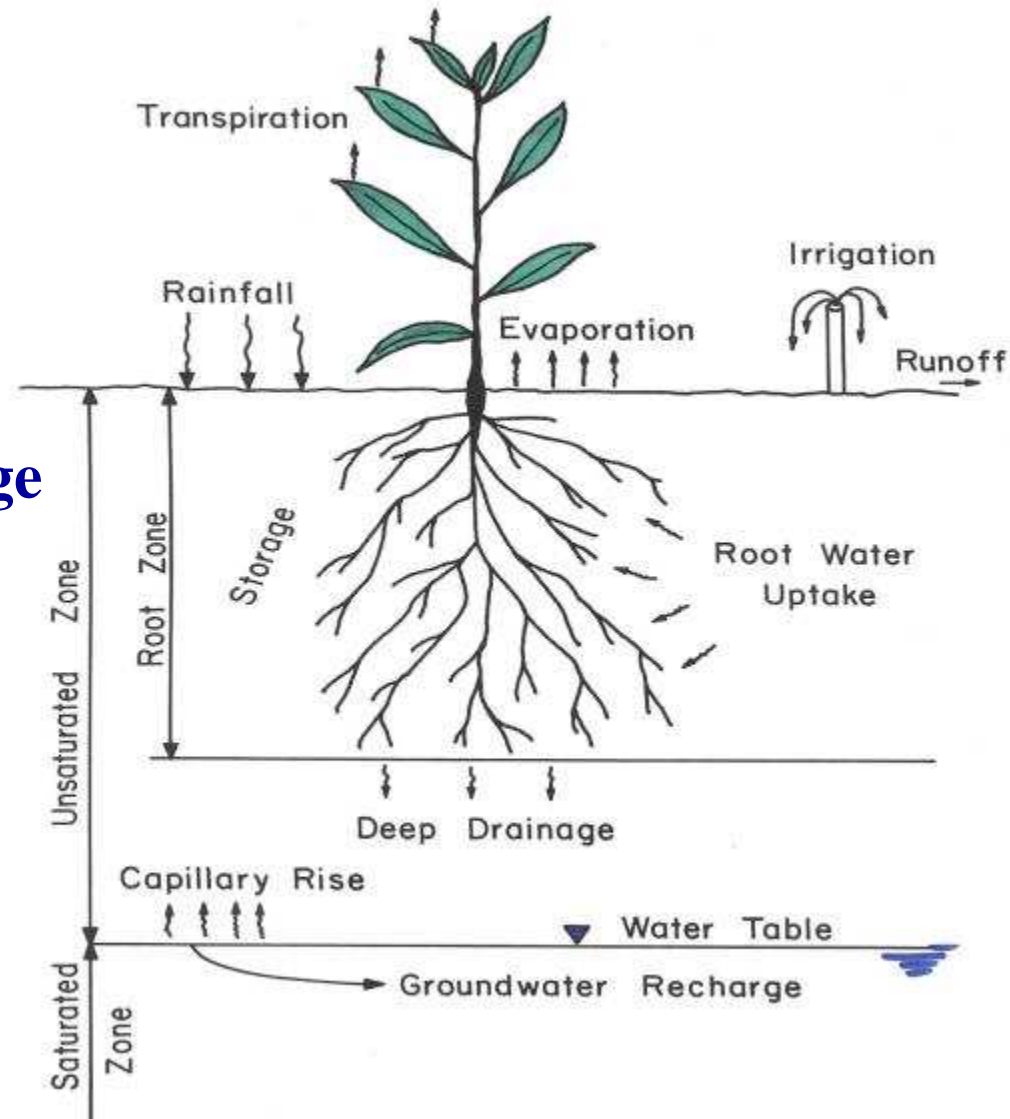
- ◆ Conduction and convection with flowing water (transport of latent heat)

Solute Transport:

- ◆ Advective-dispersive transport in the liquid phase
- ◆ Diffusion in the gaseous phase
- ◆ Linear and nonlinear reactions between the solid and liquid phases
- ◆ Linear equilibrium reactions between the liquid and gaseous phases
- ◆ Zero-order production; First-order degradation
- ◆ Physical nonequilibrium solute transport
- ◆ Chemical nonequilibrium solute transport
- ◆ Sink term to account for (active and passive) nutrient uptake by plant roots

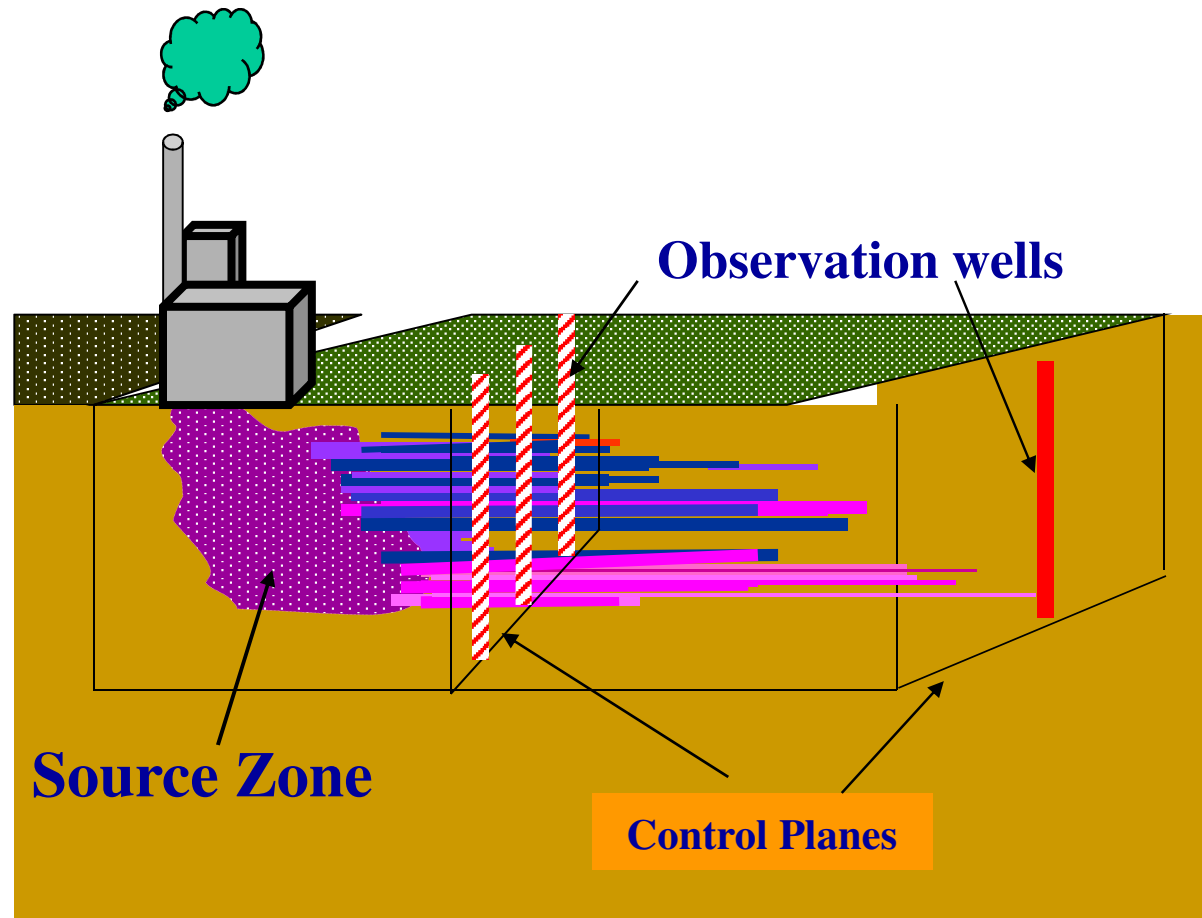
Agricultural Applications

- ◆ Precipitation
- ◆ Irrigation
- ◆ Runoff
- ◆ Evaporation
- ◆ Transpiration
- ◆ Root Water Uptake
- ◆ Capillary Rise, Drainage
- ◆ Salinity
- ◆ Nutrients
- ◆ Pesticides
- ◆ Fumigants
- ◆ Colloids
- ◆ Pathogens
- ◆ Nanoparticles
- ◆ ...



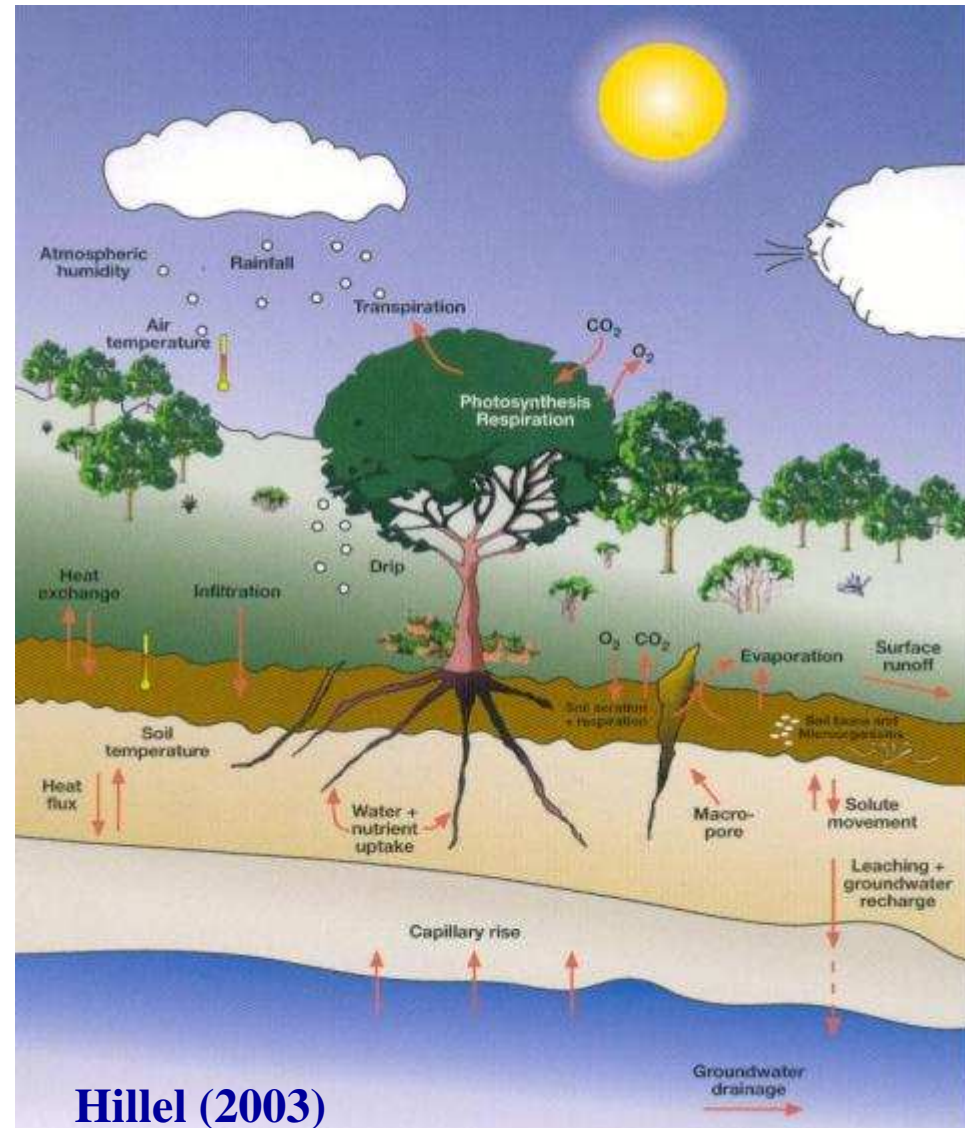
Industrial Applications

- ◆ Industrial Pollution
- ◆ Municipal Pollution
- ◆ Landfill Covers
- ◆ Waste Repositories
- ◆ Radioactive Waste Disposal Sites
- ◆ Remediation
- ◆ Brine Releases
- ◆ Contaminant Plumes
- ◆ Seepage of Wastewater from Land Treatment Systems



Environmental Applications

- ◆ Ecological Applications
- ◆ Carbon Storage and Fluxes
- ◆ Heat Exchange and Fluxes
- ◆ Nutrient Transport
- ◆ Soil Respiration
- ◆ Microbiological Processes
- ◆ Effects of Climate Change
- ◆ Riparian Systems
- ◆ Stream-Aquifer Interactions
- ◆ ...



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Practical Courses

HYDRUS-1D

- 
- Infiltration into 1D profile (water flow, solute transport)
 - Flow and Transport in a multilayered soils profile
 - PCE decay chain transport: PCE → TCE → DCE → VC → E
 - Inverse problems

**Linear sorption, constant unidirectional flow,
homogeneous profile → 1,2,3D ADE analytical solutions**

STANMOD

- Equilibrium and nonequilibrium contaminant transport
- Inverse problems (BTCs)

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Our core products

▶ [HYDRUS 2D/3D](#) - software package for simulating water, heat, and solute transport in variably saturated porous media.

▶ [Hydrus-1D](#) - one-dimensional free version of HYDRUS, developed in cooperation with University of California, Riverside, USA.

▶ [DREAM Suite](#) - software package for inverse modeling (parameter estimation, data assimilation, model averaging, etc.) using Bayesian inference methods. The rapid development of applications based on Markov Chain Monte Carlo (MCMC) and Differential Evolution Adaptive Metropolis methods.

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