HWRS 505: Vadose Zone Hydrology

Lecture 25

12/5/2023

Today:
- Final project presentation
- Review for the final exam

Student Course Survey (Reminder)

1 combined section has a SCS that is currently in progress.

SCS Start/End	Term-Session	Combined Section Members	Enrolled	Instructors	Response Rate
2023-11-09 **2023-12-06***	2234-1	**0522 HWRS 405/505 001** HWRS-405-001-50914-LEC HWRS-505-001-50915-LEC	7	Bo Guo	42.86%

**To encourage participation*: Everyone who fills out the survey gets 1/100 bonus point in the final grade.

Review (List of concepts from mid-term review)

- The concept of vadose zone
- Steady-state saturated flow: Darcy’s law; permeability; hydraulic conductivity.
- Transient saturated flow: Deriving the governing equation (3D groundwater flow)
- Solute transport under saturated flow: Advection, mechanical dispersion, molecular diffusion.
- Air-water system: Interfacial tension; wettability; capillary pressure; bundle of tubes model (triangular vs. cylindrical).
- Macroscopic descriptions of two-phase systems: pc-s (SWC); kr-s. Mathematical descriptions of these curves (VG, BC). The idea of scaling (Leverett-J function and Miller-Miller scaling).
- Two-phase flow: two-phase extended Darcy’s law; governing equations; unknowns vs. # of equations.
- Unsaturated flow: Richards’ assumption; Richards’ equation (different forms).
- Steady-state unsaturated flow: physical understanding; numerical solution; impact of heterogeneity.
- Transient unsaturated flow: water infiltration models; physical understanding; numerical solution; impact of heterogeneity.

Review (List of additional concepts)

- Measurement methods and inverse modeling
  - ✓ Laboratory methods
    - SWC (Tempe cell method)
    - Ksat (Constant head permeameter; Falling head permeameter)
    - K(θ) (Steady-state flux method; Instantaneous profile method)
  - ✓ Field methods
    - Water content (Neutron probes; Time domain reflectometry)
    - Water pressure head (Tensiometer)
    - K(θ) (Instantaneous profile method)
    - Porewater chemistry (porewater sampling suction lysimeter)

Review (List of additional concepts)

- PFAS
  - ✓ Unique transport properties of PFAS
  - ✓ Conceptual and mathematical models for variably saturated flow and the transport of PFAS in the vadose zone
    - Formulating surfactant-induced flow
    - Formulating adsorption at solid-water and air-water interfaces
    - Mass partitioning among the different phases (aqueous phase, solid-phase adsorption, and air-water interfaces)
    - Short-chain vs. long-chain
- Measurement of fluid-fluid interfacial area in porous media
  - Methods to measure interfacial area
  - Interfacial tracer methods vs. PFAS transport

Comments on HW 5

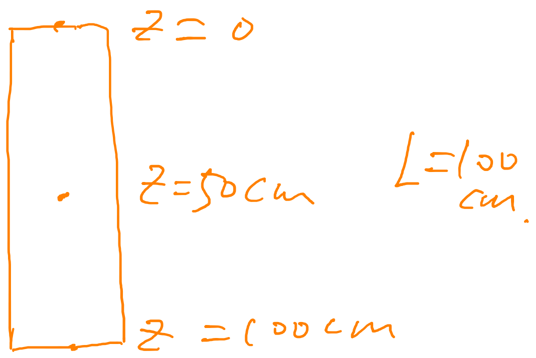
1. (10 points) Use HYDRUS 1D to construct a model of a 1 m long profile of sand using the default parameters in HYDRUS. The profile is initially fully saturated with a constant pressure head of 0 cm. There is a water table at the bottom of the domain. At time = 0 s, a zero flux top boundary condition is applied. Simulate 10000 s of time. Include an observation node at 50 cm depth.

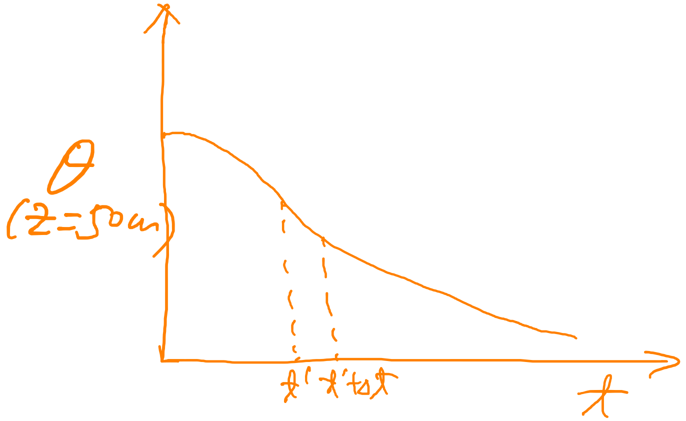
   (1) Plot the water content (at 50 cm depth) as a function of time.

   (2) Assuming that the water content is always uniform in the domain. Based on mass balance, use the water content time series (at 50 cm depth) to estimate a flux at the bottom of the column over time. Plot the flux as a function of time. Then, on the same axes, plot the flux out of the bottom of the domain as calculated by HYDRUS.

   (3) Assuming that there is a unit gradient during drainage, compute K as a function of θ for the soil using each of the two fluxes from (2). Plot the two K vs. θ functions. On the same axes, plot the correct K vs. θ for the soil (using the hydraulic parameters for sand used for the forward model in HYDRUS). Comment on the differences among the three K vs. θ functions.

   Hint: You are not allowed to use any of the parameters you use in HYDRUS to do your calculations. Think of the HYDRUS calculation as an "experiment" that someone else did it for you, thus you should not know any of the parameters that went into the HYDRUS calculation. You should only compare to the true K vs. θ after you finish your calculations.

① 



$$q = \frac{\theta(t'+\Delta t) - \theta(t')}{\Delta t} \cdot L$$

② $q = -K(\theta)\left(\cancel{\frac{\partial h}{\partial z}}^{\,0} + 1\right) \Rightarrow K(\theta)$

1° Based on your estimated q

2° Based on Hydrus computed q.

Comments on HW 5

2. (10 points) As a follow-up of problem 1.
   (1) Fix K_s to 0.00825 cm/s and the θ_r to 0.045 cm^3/cm^3. Fit the Mualem form of the van Genuchten relationship to the K vs. θ measurements determined for problem 1 using the flux from the base of the column. Report your best fit n value. Compare your value to the values used in the forward model and plot K vs. θ for your fit and for the actual soil. Comment on the difference.
   (2) Now plot paired measurements of the pressure head and water content at the observation point. Fit the van Genuchten model to these data to determine α and n. Compare the α and n values that you fit to the correct values and plot θ vs. ψ for your fit and for the actual soil. Comment on the differences.

Fitting $K(\theta)$ to M-VG (K(θ)) $\Rightarrow$ n

Fitting $\psi(\theta)$ to M-VG (SWC) $\Rightarrow$ α, n

Comments on HW 5

3. (15 points) Read the following article: Guo, B., Zeng, J. and Brusseau, M.L., 2020. A Mathematical Model for the Release, Transport, and Retention of Per- and Polyfluoroalkyl Substances (PFAS) in the Vadose Zone. *Water Resources Research*, 56(2), e2019WR026667.
   (1) Write a summary of the major findings. It would be best if you use bullet points rather than long paragraphs.
   (2) Write down a list of at least three *transport* (i.e., relevant to their migration in soils and groundwater) properties that distinguish PFAS from other more traditional contaminants in the subsurface. For each of the properties you list, propose a mathematical model to represent the relevant transport process. You can use the models developed by the authors in the article, but if you do so, you will need to present them in your own language. Whatever models you propose, explain their assumptions and potential limitations.
   (3) Building upon the work reported in the article, come up with a *new* research question that you think would be worth investigating. Explain the significance of this question (i.e., why is it important?). Outline the approach you think you can take to tackle it (Note: You do not need to execute the approach—you only need to outline the necessary steps)