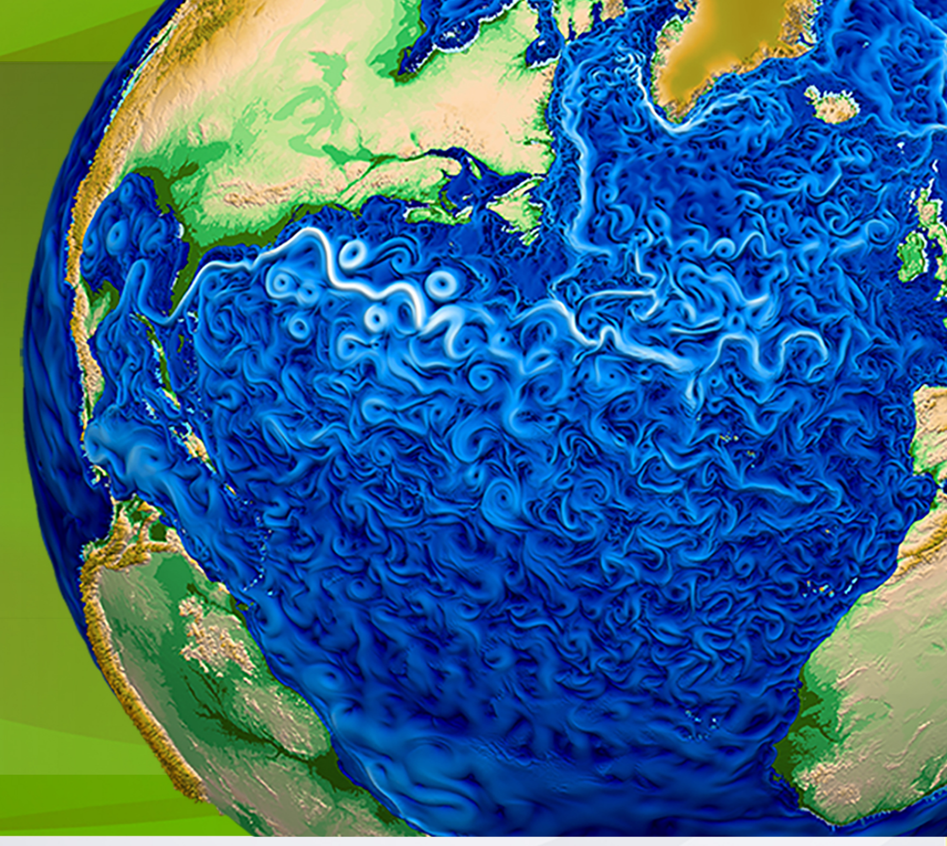
R: Unified treatment of hydrologic processes in the unsaturated-saturated zone within ALM



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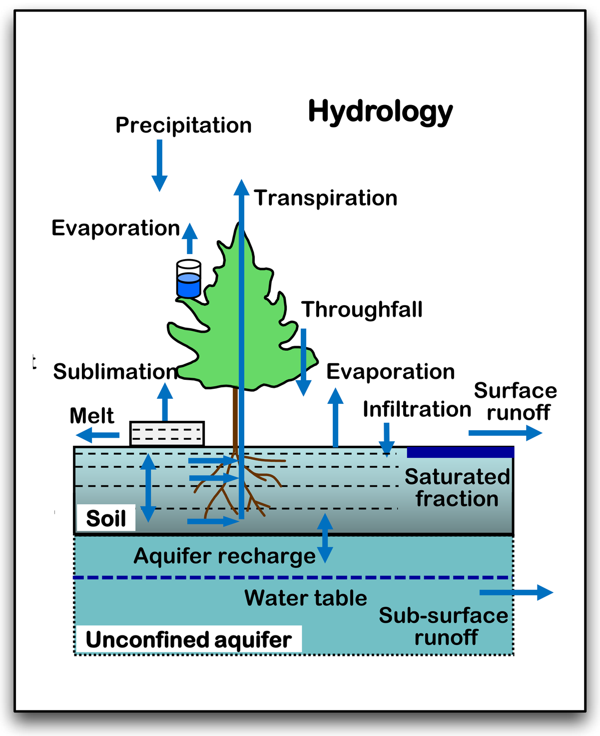
Objective

- Numerous modeling and observation studies have shown a positive soil moisture-rainfall feedback.
- Groundwater, which accounts for 30% of freshwater reserves globally, is expected to be impacted in quantity and quality by climate change.
- The current version of the ACME Land Model (ALM) employs a non-unified treatment of hydrologic processes in the subsurface.
- To overcome above-mentioned issue a variably saturated flow model (VSFM) is developed that uses Portable, Extensible Toolkit for Scientific Computation (PETSc) library.



Approach

- The governing equatons for flow in porous media are given by:

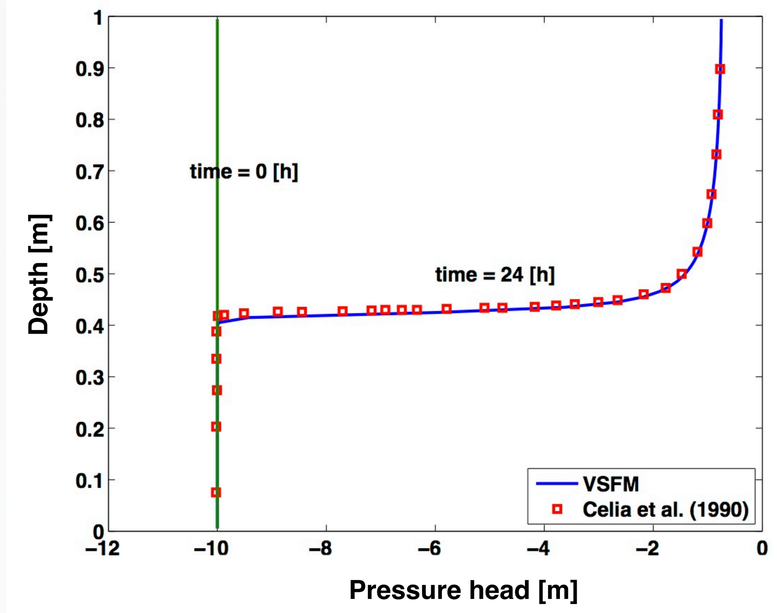
$$\frac{\partial(\phi s_w \rho)}{\partial t} = \nabla \bullet \left(\rho \vec{q}\right) + Q \qquad \text{and} \qquad \vec{q} = -\frac{k k_r}{\mu}\nabla\left(P + \rho g z\right)$$

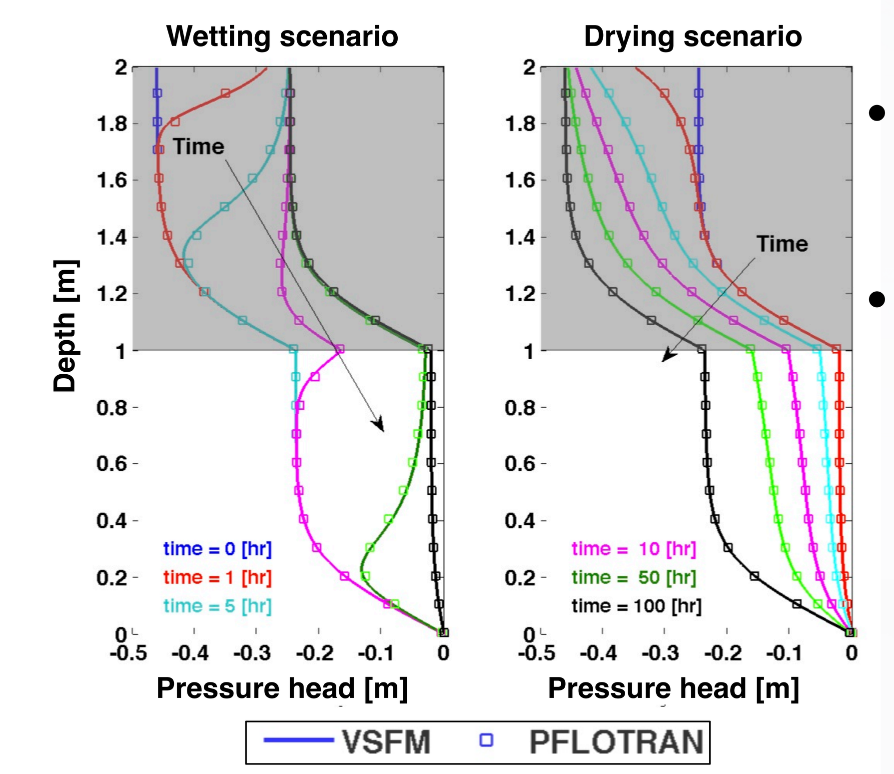
where ϕ is the soil porosity [-], s_w is water saturation [-], ρ is water density [kg m^{-3}], q is Darcy flux [ms^{-1}], Q is a source of water [kgm^{-3}s^{-1}], k is intrinsic permeability [m^2], ϕ is relative permeability [-], μ is viscosity of water [Pa s], k_r is liquid pressure [Pa], g is the accelaration due to gravity [ms^{-2}], and z is the elevation [m].

- In order to close the system of equation, we choose van Genucten [1980] and Maulem [1976] constitutive relationship.
- Finite volume spatial discretization and backward euler temporal integration is used in the VSFM.
- The set of resulting non-linear equations are solved using PETSc.

Results

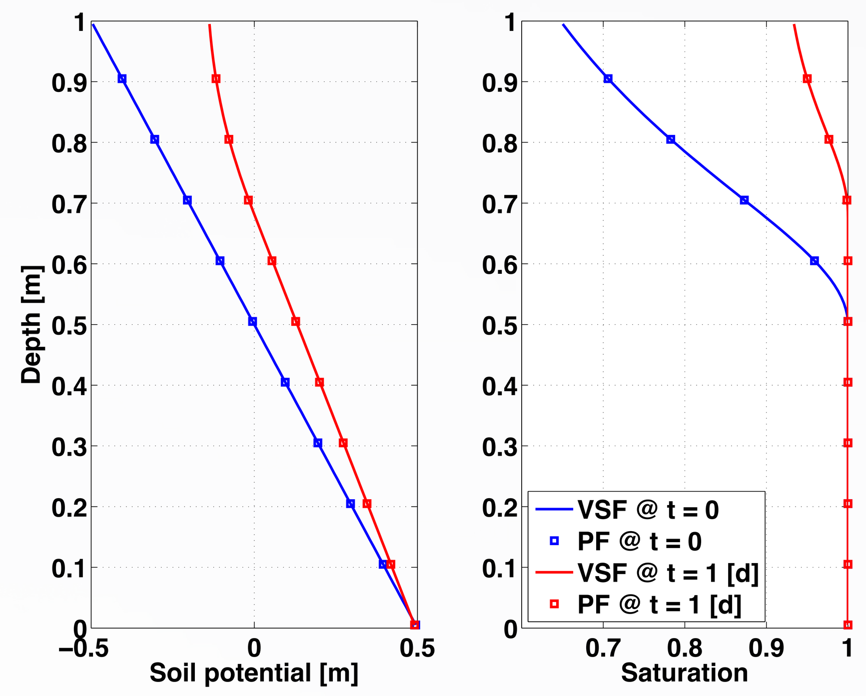
- Evolution of a wetting front within a dry 1[m] deep soil column as reported in Celia et al. (1980).
- VSFM captures the sharp wetting profile at t = 24[hr] and agrees well with reported data.

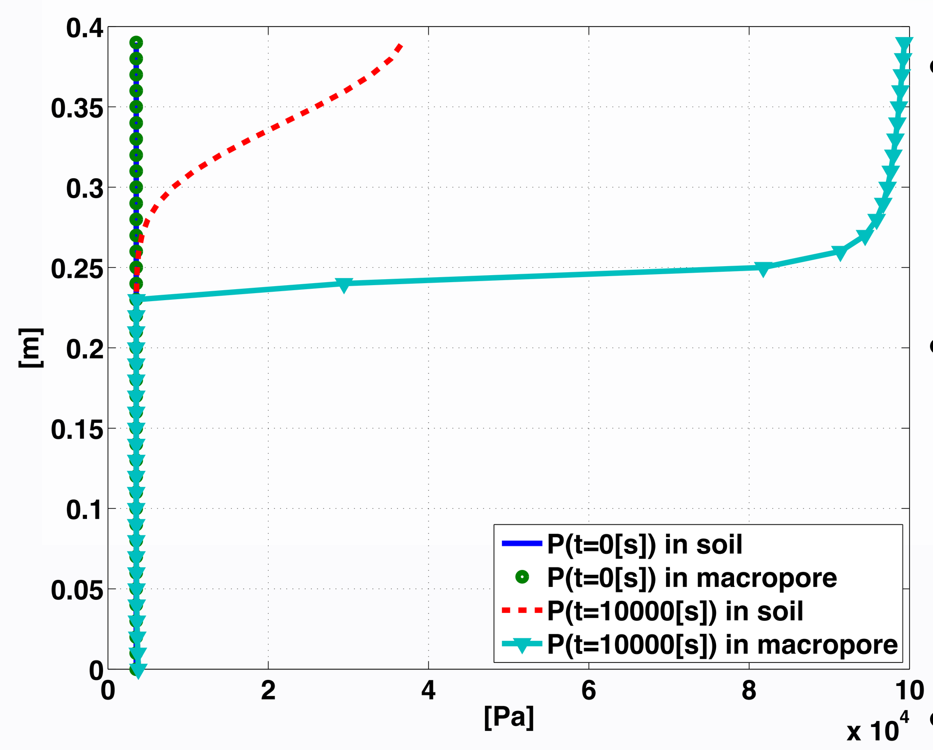




- Evolution of pressure profile between two stead conditions for layered soils.
- The top soil layer, with higher hydraulic conductivity responds quickly to change in top boundary condition as compared to bottom soil layer.

- The numerical experiment demonstrates the unified treatment of saturated and unsaturated zone in the VSFM for a constant infiltration flux.
- The water table rises by 0.2 [m] at the end of simulation.





- Macropore flow simulation performed using a Dual Continuum Connected Matrix approach.
- A constant infiltration flux is applied only to the macropore, which accounts for 5% of the total volume and has K_{sat} 2000 times larger than bulk soil.
- VSFM results agree with PFLOTRAN.

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