New multiscale model unifies physical laws of water flow to span all scales

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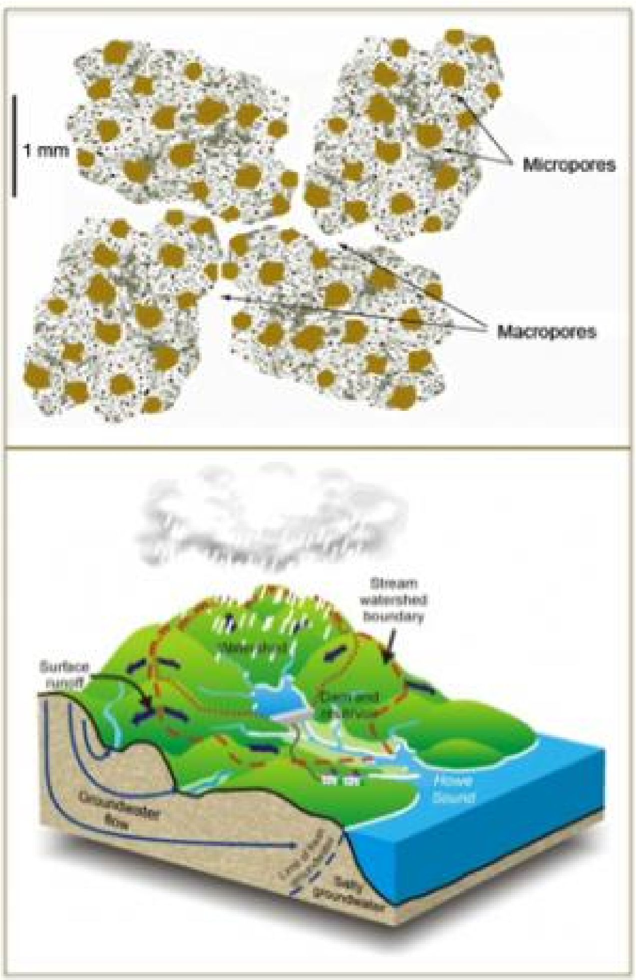

The unified multiscale model developed at PNNL couples water transport equations in such a way that this one model can represent transport at both pore (top) and watershed (bottom) scales.

(Phys.org) —Water moves through multifaceted physical boundaries. This poses a significant challenge for scientists who must simulate water flow across many domains. Scientists at Pacific Northwest National Laboratory (PNNL) conquered this barrier by merging different physical laws. Their new approach can describe any type of water flow in soils and the terrestrial ecosystem, in soil pores, streams, lakes, rivers and oceans, and in mixed media of pores and solids for soil and aquifer. The versatile properties of the new approach allow cross-domain simulation of water flow at different scales. The research was published in the *Soil Science Society of America Journal*.

From stream flow, to soil and irrigation saturation, to underground aquifers, understanding how water travels through many varied regions is important for understanding water cycling and its effect on agriculture, water conservation, and climate changes. For scientists, the challenge is simulating water's travels through many different domains in ways that are efficient and effective. Soil is a complex system consisting of large spaces (macropore) where water easily flows and small spaces (micropore) where water drains and saturates slowly. Two different domains mean different calculations for the physical trail. Simulation of pore-scale water flow in soils is traditionally described by coupling Navier-Stokes equations in macropore and Darcy's law in porous domain containing micropore, and then repeating the calculations continuously at these interfaces. The researchers in this paper developed a new approach to eliminate the repeated calculations at the domain interfaces, significantly simplifying water flow simulations for ecosystems.

A multidisciplinary team at PNNL developed the unified theory and unified multiscale model (UMSM) that simulates water flow at all scales. The new set of coupled mathematical equations unifies the Navier-Stokes equations and Darcy's law to describe water flow at different scales and across different physical domains. The team performed extensive numerical verifications to evaluate the new model under both saturated and unsaturated conditions. Using water flow in a soil core from Rattlesnake Mountain in south-central Washington State as an example, they validated the new model. Their numerical and experimental validation confirmed that the unified model performs the same as the Navier-Stokes equations where these equations are applicable and becomes Darcy's law in porous media.

"By solving a single set of equations in all ecosystem components, UMSM presents a system-scale approach to analyze water cycling," said Dr. Chongxuan Liu, biogeochemist and corresponding author of the paper. "This approach will facilitate integration of ecosystem water flow in large, climate-scale modeling."

UMSM directly simulates water flow across scales and physical domains in soils and ecosystems. The PNNL researchers are now extending UMSM to describe biogeochemical processes in soils and ecosystems that are coupled with water flow.

More information: Yang X, C Liu, J Shang, Y Fang, and VL Bailey. 2014. "A Unified Multi-Scale Model for Pore-Scale Flow Simulations in Soils." *Soil Science Society of America Journal* 78(1):108-118. DOI: 10.2136/sssaj2013.05.0190

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