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A novel physical eco-hydrological model concept for preferential flow based on experimental applications.

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Preferential flow through macropores often determines hydrological characteristics - especially regarding runoff generation and fast transport of solutes. Macropore settings may yet be very different in nature and dynamics, depending on their origin. While biogenic structures follow activity cycles (e.g. earth worms) and population conditions (e.g. roots), pedogenic and geogenic structures may depend on water stress (e.g. cracks) or large events (e.g. flushed voids between skeleton and soil pipes) or simply persist (e.g. bedrock interface).
On the one hand, such dynamic site characteristics can be observed in seasonal changes in its reaction to precipitation. On the other hand, sprinkling experiments accompanied by tracers or time-lapse 3D Ground-Penetrating-Radar are suitable tools to determine infiltration patterns and macropore configuration. However, model representation of the macropore-matrix system is still problematic, because models either rely on effective parameters (assuming well-mixed state) or on explicit advection strongly simplifying or neglecting interaction with the diffusive flow domain.

Motivated by the dynamic nature of macropores, we present a novel model approach for interacting diffusive and advective water, solutes and energy transport in structured soils. It solely relies on scale- and process-aware observables.
A representative set of macropores (data from sprinkling experiments) determines the process model scale through 1D advective domains. These are connected to a 2D matrix domain which is defined by pedo-physical retention properties. Water is represented as particles. Diffusive flow is governed by a 2D random walk of these particles while advection may take place in the macropore domain. Macropore-matrix interaction is computed as dissipation of the advective momentum of a particle by its experienced drag from the matrix domain.

Through a representation of matrix and macropores as connected diffusive and advective domains for water transport we open up double domain concepts linking porescale physics to preferential macroscale fingerprints without effective parameterisation or mixing assumptions. Moreover, solute transport, energy balance aspects and lateral heterogeneity in soil moisture distribution are intrinsically captured. In addition, macropore and matrix domain settings may change over time based on physical and stochastic observations. The representativity concept allows scaleability from plotscale to the lower mesoscale.