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A new root water uptake sink term including root-rhizosphere hydraulic architecture

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Water and nutrient uptake are essential for plant productivity. Therefore, the development of precise functional-structural root models will enable better agricultural management in particular in resource limited environments. In such models water movement is of special importance since the rhizosphere's biochemical reactions are strongly influenced by water content and water movement. We present a general sink term for larger scale root water uptake models that includes the root-rhizosphere hydraulic architecture.

We derive the new aggregated sink term from a more complex model that describes the rhizosphere around each root segment in dependence of a hydraulic root system model. We use CPlantBox (Schnepf et al. 2018) to represent root architecture, and calculate water movement within the root system using the hybrid analytical solution of Meunier et al. (2017). Around each root segment we represent water movement within the rhizosphere by a 1D axisymmetric model. Such models are flexible in the way the rhizosphere is represented (Mai et al. 2019). They are able to accurately describe water depletion and redistribution, but are computationally expensive.

To simplify the model we use the analytical solution of the steady rate approximation following (Schröder et al. 2008) for water movement in the 1D axisymmetric models. The analytic solution depends on the matric potentials of the macroscopic soil (which is calculated in 1D, 2D or 3D) and the hydraulic root architecture model, root radial conductivity, and radius of the rhizosphere domain. We use fixed-point iteration to determine the matric potential at the soil root interface and store the solutions in a look up table for speedup.

Moving to larger scales it is generally not useful to keep track of all root system architectures. Therefore, we aim for a coarser approximation of the root architecture by representing it as detached parallel root segments. Parallel segment conductivities are based on standard uptake fraction (SUF) and root system conductivity (Krs) of the original topology (Couvreur et al. 2012), which was shown by Vanderborght et al. (2021) to be a close approximation of the uptake by the original root topology. This approach makes the computation of the full root hydraulic architecture model superfluous, leading to a stable and performant sink term.

This new sink term increases the accuracy of water uptake in a suite of larger scale models

including crop modes, earth system models, and hydrological models. Using the presented approach, the sink term can be derived directly from 3D root hydraulic architecture. This avoids parameterizations based on proxy information about root system hydraulics and can acknowledge age dependent axial and radial root segment hydraulic conductances. Finally, information about rhizosphere hydraulic properties, which may differ from bulk soil hydraulic properties can be injected effectively in this sink term model.

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