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A new numerical method to approximate root water uptake fluxes in a mixed-dimensional 1D-3D setting

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1D-3D methods are used to describe root water and nutrient uptake in complex root networks. Root systems are described as networks of line segments embedded in a three-dimensional soil domain. Particularly for dry soils, local water pressure and nutrient concentration gradients can be become very large in the vicinity of roots. Commonly used discretization lengths (for example 1cm) in root-soil interaction models do not allow to capture these gradients accurately. We present a new numerical scheme for approximating root-soil interface fluxes. The scheme is formulated in the continuous PDE setting so that is it formally independent of the spatial discretization scheme (e.g. FVM, FD, FEM). The interface flux approximation is based on a reconstruction of interface quantities using local analytical solutions of the steady-rate Richards equation. The local mass exchange is numerically distributed in the vicinity of the root. The distribution results in a regularization of the soil pressure solution which is easier to approximate numerically. This technique allows for coarser grid resolutions while maintaining approximation accuracy. The new scheme is verified numerically against analytical solutions for simplified cases. We also explore limitations and possible errors in the flux approximation with numerical test cases. Finally, we present the results of a recently published benchmark case using this new method.