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Efficient mixed-dimensional models for root water uptake

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Root water uptake efficiency and robustness to varying soil water distribution depend on the three-dimensional root system architecture.
Roots can also redistribute soil water through the root system. However, roots are numerous and thin which is why modeling root water uptake with three-dimensionally resolved roots is a numerical challenge. Moreover, soil hydraulic conductivity nonlinearly decreases with soil water content resulting in a large conductivity drop in the vicinity of roots which may require local grid refinement around roots to resolve pressure gradients in dry soils.

We first present several approaches to overcome these challenges. We show that a rather coarse-grained approximation of the solution locally around the roots can be combined with local analytical approaches to reconstruct accurate root-soil interface conditions. We discuss the difference between time-independent and time-dependent approximations.
We then demonstrate many challenging numerical tests including a recent benchmark study that compares models from different research groups.
We briefly discuss the implementation of mixed-dimensional schemes in the open-source simulator DuMux.

Finally, we discuss some open questions regarding the inclusion of more complex interface physics in such mixed-dimensional models and detail the challenges stemming from the construction of the interface reconstruction model.

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