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S. J. Kollet, R. M. Maxwell

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S.J. Kollet and R.M. Maxwell

Atmospheric, Earth, and Energy Department, Lawrence Livermore National Laboratory (L-206), 7000 East Avenue, Livermore, CA 94550 USA

Models incorporating interactions between surface and subsurface flow are commonly based on the conductance concept that presumes a distinct interface at the land surface, separating the surface from the subsurface domain. In these models the subsurface and surface domains are linked via an exchange flux that depends upon the magnitude and direction of the hydraulic gradient across the interface and a proportionality constant (a measure of the hydraulic connectivity). Because experimental evidence of such a distinct interface is often lacking in the field, a more general coupled modeling approach would be preferable.

We present a more general approach that incorporates a two-dimensional overland flow simulator into the parallel three-dimensional variably saturated subsurface flow code ParFlow developed at LLNL. This overland flow simulator takes the form of an upper, free-surface boundary condition and is, thus, fully integrated without relying on the conductance concept. Another advantage of this approach is the efficient parallelism of ParFlow, which is exploited by the overland flow simulator.

Several verification and simulation examples are presented that focus on the two main processes of runoff production: excess infiltration and saturation. The usefulness of our approach is demonstrated in an application of the model to an urban watershed. The influence of heterogeneity of the shallow subsurface on overland flow and transport is also examined. The results show the uncertainty in flow and transport predictions due to heterogeneity. This is important in determining, for example, total maximum daily loads of surface water systems.

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