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High-Performance Numerical Simulation of Coupled Surface-Subsurface Flow

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The simulation of coupled surface subsurface flow is a topic of high scientific and social relevance for flood protection, agriculture and weather prediction. An essential part is the efficient and accurate simulation of coupled surface/subsurface flow. Most existing numerical models use a kinematic wave approximation for the simulation of the surface runoff. We present an approach based on the more accurate diffusive wave approximation for surface and Richards' equation for subsurface flow.

The implementation uses state-of-the-art numerical schemes and techniques from high-performance computing: An operator splitting approach is used with a kind of Dirichlet Neumann coupling for surface and subsurface flow. Spatial discretization of both flow equations is done with a Weighted Interior Penalty Discontinuous Galerkin scheme, while for the temporal discretization a semi-implicit scheme is used for the surface runoff and a diagonally implicit Runge-Kutta scheme for the subsurface flow. We present results obtained with the parallel numerical solver based on DUNE-PDELab and advanced in computational efficiency within the scope of EXA-DUNE project, including sum-factorisation, vectorisation and matrix-free computing to obtain a nearly optimal performance.