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Coupled surface-groundwater flow modeling: comparison of two physics-based numerical models

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Problems involving strong interactions between surface water and groundwater, as well as investigations of conjunctive water management issues, necessitate coupled simulation of surface and subsurface flow regimes. Within these regimes, individual modeling of flow processes is well established, but characterization of exchange fluxes between them remains a great challenge in hydrology, at both small (e.g., streambed, hillslope) and large (watershed to global) scales. To resolve these interactions in conjunctive groundwater-surface water models, a variety of coupling approaches are currently used. In this study we compare the treatment of the exchange term, as well as other features, in two physics-based numerical models that use a 3D Richards equation representation of subsurface flow. In one model, surface flow is represented by a quasi-2D diffusive wave approximation to the Saint-Venant equations, and surface runoff follows a rill flow conceptualization. In the second model, surface routing is performed via a fully 2D kinematic formulation with a sheet flow conceptualization. The coupling term between the land surface and the subsurface is handled very differently in the two models: an explicit exchange term resolved by continuity principles in one case and special treatment of atmospheric boundary conditions in the other. The comparison of the two models was carried out for a series of test-cases involving a 1D sloping plane and a 2D tilted V-catchment. These tests focused on overland flow and integrated surface-subsurface processes. The two main mechanisms of runoff production (excess saturation and excess infiltration) were studied under homogeneous conditions as well as in the presence of heterogeneities in the shallow subsurface. We explore the mechanisms for any differences and similarities in the responses of the models, and we discuss the pros and cons of the two approaches for dealing with the coupling term, emphasizing the role played by factors such as grid discretization

(especially vertical) and time-step size.