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Efficient 1.5-D hillslope model using 1D Richards' and 1D Boussinesq equations coupled by the Method Of Lines

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Abstract

Modeling lateral subsurface flow at the hill slope scale by considering the full 2D or 3D spacial domain can be quite complex from a computational point of view. To reduce simulation times a new prototype model consisting of a set of 1D Richards' equations linked with the Boussinesq equation is presented.

The Method Of Lines approach to solving the Richards' equation has already been shown to be an efficient and stable alternative to established solution methods, such as low-order finite difference and finite element methods applied to the mixed form of Richards' equation. Besides its beneficial properties in numerical challenging scenarios, the Method Of Lines approach allows for easier integration of additional differential equations which proves advantageous here, when integrating the Boussinesq equation into the combined model. In the combined model it is assumed that lateral flow primarily happens at soil layer interfaces. The Boussinesq equation is than used to link the 1D columns at these soil layer interface nodes in the lateral direction. Thus enabling water transport between adjacent columns and therefor along the hillslope. In an analog procedure it would be possible to extend the presented model to also simulate for surface runoff.

Simulations for several synthetic setups have been carried out and compared to solutions to the

full 2D problem from the software Hydrus. The results show good agreement between the two approaches, with the benefit of reduced simulation times and increased numerical stability of the presented model.