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Simplified subsurface modelling: data assimilation and violated model assumptions

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Integrated models are gaining more and more attention in hydrological modelling as they can better represent the interaction between different compartments. Naturally, these models come along with larger numbers of unknowns and requirements on computational resources compared to stand-alone models. If large model domains are to be represented, e.g. on catchment scale, the resolution of the numerical grid needs to be reduced or the model itself needs to be simplified. Both approaches lead to a reduced ability to reproduce the present processes. This lack of model accuracy may be compensated by using data assimilation methods. In these methods observations are used to update the model states, and optionally model parameters as well, in order to reduce the model error induced by the imposed simplifications. What is unclear is whether these methods combined with strongly simplified models result in completely data-driven models or if they can even be used to make adequate predictions of the model state for times when no observations are available.

In the current work we consider the combined groundwater and unsaturated zone, which can be modelled in a physically consistent way using 3D-models solving the Richards equation. For use in simple predictions, however, simpler approaches may be considered. The question investigated here is whether a simpler model, in which the groundwater is modelled as a horizontal 2D-model and the unsaturated zones as a few sparse 1D-columns, can be used within an Ensemble Kalman filter to give predictions of groundwater levels and unsaturated fluxes. This is tested under conditions where the feedback between the two model-compartments are large (e.g. shallow groundwater table) and the simplification assumptions are clearly violated. Such a case may be a steep hill-slope or pumping wells, creating lateral fluxes in the unsaturated zone, or strong heterogeneous structures creating unaccounted flows in both the saturated and unsaturated compartments. Under such circumstances, direct modelling using a simplified model will not provide good results. However, a more data driven (e.g. grey box) approach, driven by the filter, may still provide an improved understanding of the system. Comparisons between full 3D simulations and simplified filter driven models will be shown and the resulting benefits and drawbacks will be discussed.