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The benefit of capturing groundwater for soil moisture predictions with subsurface flow data assimilation

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Soil moisture predictions can be made using models that describe the flow processes in the unsaturated zone. If sequential observations are available, they can be integrated into the prediction model using data assimilation methods, such as the Ensemble Kalman Filter. In general, data assimilation uses observations to reduce uncertainty and improve predictive power of the model. In an unsaturated zone model, parameters and boundary conditions are usually uncertain. A source of the uncertainty of boundary conditions is due to the fact that the compartments are cut at the boundaries to neighboring compartments, which means for the unsaturated zone the model is cut at the groundwater table and at the soil surface. Using coupled models that describe flow in all compartments, it is possible that the boundary conditions can be captured in a better way and thus predictions can be improved. On the other hand, data assimilation in a stand-alone unsaturated model might already sufficiently reduce the model error caused by neglected interaction with neighboring compartments. Then, using an integrated model, which comes along with a large number of additional unknowns and an increased demand of computational resources, could deteriorate predictions.

We compare soil moisture predictions with data assimilation in a stand-alone unsaturated zone model to data assimilation in a coupled soil – groundwater model. The coupled model for data assimilation is a simplified (2.5D) model coupling a 2D depth averaged horizontal groundwater model to multiple 1D unsaturated soil columns. For data assimilation the ensemble Kalman filter is used. We investigate the benefit of including the groundwater model and/or its observations for predictions of soil moisture. Observations are taken from forward runs of a fully coupled 3D soil – groundwater model. The model for data assimilation has thus a model error compared to the 'true' model generating the observations, as lateral fluxes in the soil are not considered. In this study we demonstrate that, in general, coupled modeling and observations from both systems, groundwater and soil, are beneficial for shallow groundwater tables where lateral fluxes occur and flow in the unsaturated zone is strongly influenced by the changing groundwater table. In case of deep groundwater tables, predictions of soil moisture with the coupled model using groundwater observations leads to worse predictions of soil moisture than using the soil model alone.