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Propagating subsurface uncertainty to the atmosphere using fully-coupled, stochastic simulations

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Abstract Feedbacks between the land surface and the atmosphere, manifested as mass and energy fluxes, are strongly correlated with soil moisture under dry conditions, making soil moisture an important factor in land–atmosphere interactions. We show that uncertainty in subsurface properties propagate into atmospheric variables, and therefore reduction of uncertainty in hydraulic conductivity will propagate through land–atmosphere feedbacks to yield more accurate weather forecasts. Using ParFlow-WRF, a fully-coupled groundwater-to-atmosphere model, we demonstrate responses in land–atmosphere feedbacks and wind patterns due to subsurface heterogeneity. An idealized domain with heterogeneous subsurface properties is used in ensembles of coupled-simulations. These ensembles are generated by varying the spatial location of the subsurface properties, while honouring the global statistics and correlation structure, an approach common to the hydrologic sciences but never-before used in atmospheric simulations. We clearly show that different realizations of hydraulic conductivity produce variation in soil moisture, latent heat flux and wind for both point and domain-averaged quantities. A single random field is chosen as the “actual” case and varying amounts of hydraulic conductivity data are sampled from this realization. Using these conditional Monte Carlo simulations, we incorporate subsurface data into the ensemble of realizations. We also show that the difference between the ensemble mean prediction and the actual saturation, latent heat flux and wind speed are reduced significantly via conditioning of hydraulic conductivity. By reducing uncertainty associated with land–atmosphere feedback mechanisms, we also reduce uncertainty in both spatially distributed and synoptic wind speed magnitudes, thus improving our ability to make more accurate forecasts important for many applications such as wind energy.

Key words uncertainty; land–atmosphere feedbacks; wind; heterogeneity