Do surface lateral flows matter for land data assimilation?: Implication for hyper-resolution land modeling and observation

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Hyper-resolution land modeling is expected to innovate the simulation of terrestrial water, energy, and carbon cycles. One of the major advantages of existing hyper-resolution land models against conventional 1-demensional land surface models is that surface and subsurface lateral water flows can be explicitly simulated. Despite a lot of efforts on assimilating hydrological observations into the hyper-resolution integrated surface-groundwater land models, how and in what case topography-driven surface water flows matter for data assimilation of soil moisture observations has yet to be clarified. In this study, I perform a minimalist synthetic numerical experiment, in which shallow soil moisture observations are assimilated into an integrated surface-groundwater land model by an ensemble Kalman filter. Propagation of a background error due to surface lateral water flows is crucially important to adjust the unobserved model state and parameter variables by horizontally propagating the information of soil moisture observations. However, the non-Gaussianity of the background error induced by the nonlinear dynamics of topography-driven surface flows harms the performance of an ensemble Kalman filter and the efficiency of data assimilation strongly depends on soil characteristics. The new capability of data assimilation with the hyper-resolution land models found in this study may improve the monitoring and prediction of flash floods caused by local severe rainfalls.

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