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Catchment tomography - An approach for spatial parameter estimation in catchment hydrology

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Though forecast accuracy of hydrological models has improved in the last decades due to the development of more powerful and distributed models, uncertainties in forcings and model parameters are still challenging issues limiting the forecast reliability. As the number of unknown model parameters is generally large for distributed models, batch calibration methods usually lead to different parameter sets resulting in the same model accuracy. Catchment tomography presents an approach to reduce this non-uniqueness problem in hydrological parameter estimation by applying a moving transmitter-receiver concept on a catchment. Radar based precipitation fields serve as the transmitters and stream water gauge observations, the receivers, are sequentially assimilated into the model. The integrated stream gauge signals are resolved by a joint state-parameter update with the Ensemble Kalman Filter. The uncertain parameters are continuously constrained by sequentially integrating new information. Forward simulations are performed with the variably saturated subsurface and overland flow model ParFlow, which has been coupled to the Parallel Data Assimilation Framework (PDAF). In a first step in developing the method, catchment tomography was applied in a synthetic study of a simplified two dimensional catchment with pure overland flow (no subsurface flow) to estimate the spatially distributed Manning's roughness coefficient. The roughness coefficient was distributed in two and four zones and was updated applying different real radar precipitation time series and different initial parameter distributions. The parameters were successfully estimated with only 64 realizations over a simulation period of 30 days with hourly state and parameter updates. The error in the ensemble mean estimated parameters was reduced from up to 500% to less than 4% for all zones of both scenarios, independent from the initial ensemble mean value, if an appropriate initial ensemble spread was applied. While parameters of areas close to observations are correctly estimated within less than 200 updates, the parameter estimates of areas distant from observation locations continuously improve until the end of the simulation and may benefit from longer simulation times. We show that even the parameter of a zone mostly located in the neighboring watershed distant from all stream gauges is efficiently estimated by catchment tomography. In this case increasing the initial ensemble spread by a factor of three reduces the estimation error from 110% at the end of the time series to 0.7%. Applying two different precipitation time series it is shown that the distributed precipitation as the moving transmitter is the key component of catchment tomography, clearly initiating ensemble convergence towards the reference parameters with the commencement of precipitation events.