EGU22-8729
https://doi.org/10.5194/egusphere-egu22-8729
EGU General Assembly 2022

Bayesian parameter inference in hydrological modelling using a Hamiltonian Monte Carlo approach with a stochastic rain model

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Conceptual models are indispensable tools for hydrology. In order to use them for making probabilistic predictions, they need to be equipped with an adequate error model, which, for ease of inference, is traditionally formulated as an additive error on the output (discharge). However, the main sources of uncertainty in hydrological modelling are typically not to be found on the output, but on the input (rain) and in the model structure. Therefore, more reliable error models and probabilistic predictions can be obtained by incorporating those uncertainties directly where they arise, that is, into the model. This, however, leads us to stochastic models, which render traditional inference algorithms such as the Metropolis algorithm infeasible due to their expensive likelihood functions. However, thanks to recent advancements in algorithms and computing power, full-fledged Bayesian inference with stochastic models is no longer off-limit for hydrological applications. We demonstrate this with a case study from urban hydrology, for which we employ a highly efficient Hamiltonian Monte Carlo inference algorithm with a time-scale separation.