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Parameter estimation in physically-based integrated hydrological models with the ensemble Kalman filter: a practical application.

Anna Botto and Matteo Camporese

Department of Civil, Environmental and Architectural Engineering, University of Padova, Italy (anna.botto@unipd.it)

Hydrological models allow scientists to predict the response of water systems under varying forcing conditions. In particular, many physically-based integrated models were recently developed in order to understand the fundamental hydrological processes occurring at the catchment scale. However, the use of this class of hydrological models is still relatively limited, as their prediction skills heavily depend on reliable parameter estimation, an operation that is never trivial, being normally affected by large uncertainty and requiring huge computational effort.
The objective of this work is to test the potential of data assimilation to be used as an inverse modeling procedure for the broad class of integrated hydrological models.
To pursue this goal, a Bayesian data assimilation (DA) algorithm based on a Monte Carlo approach, namely the ensemble Kalman filter (EnKF), is combined with the CATchment HYdrology (CATHY) model. In this approach, input variables (atmospheric forcing, soil parameters, initial conditions) are statistically perturbed providing an ensemble of realizations aimed at taking into account the uncertainty involved in the process. Each realization is propagated forward by the CATHY hydrological model within a parallel R framework, developed to reduce the computational effort. When measurements are available, the EnKF is used to update both the system state and soil parameters. In particular, four different assimilation scenarios are applied to test the capability of the modeling framework: first only pressure head or water content are assimilated, then, the combination of both, and finally both pressure head and water content together with the subsurface outflow.
To demonstrate the effectiveness of the approach in a real-world scenario, an artificial hillslope was designed and built to provide real measurements for the DA analyses. The experimental facility, located in the Department of Civil, Environmental and Architectural Engineering of the University of Padova (Italy), consists of a reinforced concrete box containing a soil prism with maximum height of 3.5 m, length of 6 m and width of 2 m. The hillslope is equipped with six pairs of tensiometers and water content reflectometers, to monitor the pressure head and soil moisture content, respectively. Moreover, two tipping bucket flow gages were used to measure the surface and subsurface discharges at the outlet. A 12-day long experiment was carried out, during which a series of four rainfall events with constant rainfall rate were generated, interspersed with phases of drainage. During the experiment, measurements were collected at a relatively high resolution of 0.5 Hz.
We report here on the capability of the data assimilation framework to estimate sets of plausible parameters that are consistent with the experimental setup.