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Ensemble Kalman filter vs. Newtonian nudging for a coupled model of surface and subsurface flow: a comparison of data assimilation approaches

M. Camporese (1), C. Paniconi (1), M. Putti (2), P. Salandin (2)
(1) INRS-ETE, Université du Québec, Canada (matteo.camporese@ete.inrs.ca), (2) Università di Padova, Italy

Data assimilation in the geophysical sciences refers to a methodology to optimally merge model predictions and observations. The Kalman Filter (KF) is a statistical and sequential data assimilation technique that updates the system state based on the relative magnitudes of the covariances of both the observations and the model state estimate. KF is optimal for linear dynamics and measurement processes with Gaussian error statistics, while for nonlinear filtering problems the Ensemble Kalman Filter (EnKF) has been demonstrated to be a suitable alternative. EnKF is based on the approximation of the conditional probability densities of interest by a finite number of randomly generated model trajectories. In Newtonian relaxation or nudging (NN), which can be represented as a special case of KF, model variables are driven towards observations by a forcing term added to the model equations. The forcing term is proportional to the difference between simulation and observation (relaxation component) and contains four-dimensional weighting functions that can incorporate prior knowledge about the spatial and temporal variability and characteristic scales of the state variable(s) being assimilated. In this study both EnKF and NN have been implemented in a relatively complex hydrological model, which couples a three dimensional finite element Richards equation solver for variably saturated porous media and a finite difference diffusion wave approximation based on a digital elevation data for surface water dynamics. We report on the numerical and hydrological performance of the two assimilation schemes in a syntethic test case represented by a small hypothetical catchment. In particular, we focus on the comparison between the performance of the two approaches and evaluate how EnKF can help parameterize the parameters controlling NN weighting functions, in order to better define the spatial and temporal

characteristic scales of the state variable(s) and thus optimize NN as a valid alternative when ENKF proves to be not favourable due to its high computational burden.