Handling uncertainty of soil hydraulic parameters using the ensemble Kalman filter

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Model predictions of flow in the unsaturated zone require knowledge of the soil hydraulic parameters. For prediction of flow in the unsaturated zone, field observations of soil moisture are often used to determine soil parameters. However, it is difficult to determine these parameters, in particular if observations cover only a small range of possible states. Correlation of parameters or their correlation in the range of states that are observed is a problem, as different parameter combinations may reproduce approximately the same measured states. In such a case, the parameters are unidentifiable and highly uncertain. In a data assimilation framework, where observations are used sequentially to make predictions, this uncertainty needs to be accounted for. Using the ensemble Kalman filter (EnKF, [1]), the standard approach is to include the parameters in the update in an augmented state vector formalism. This allows not only for reducing the model error induced by the uncertain parameters, but also for estimating these parameters. It has been shown in several studies that the EnKF is well able to estimate parameters decently if the observations contain enough information. Yet, in the field, this is usually not the case and the parameters are not identifiable. Under such conditions, aiming for estimating the parameters is pointless. Under such conditions, other approaches to deal with the parameter uncertainty might be better or equally well suited.

In this presentation, we compare different ways of assigning and reducing parameter uncertainty within the EnKF in an 1D unsaturated flow model. Apart from performing a joint update of states and parameters, we consider updating only states with and without bias correction. The parameter uncertainty/error is introduced by either using an ensemble of parameters or by assigning a fixed, but wrong, set of parameters. The purpose of the model is to predict soil moisture and the different methods are evaluated according to criteria related to this. Besides, all numerical test cases are carried out as identical twin experiments using synthetic observations to offer full knowledge of the true parameter set and model states. Since general conclusions on that matter cannot be made due to the high nonlinearity of Richards equation, multiple test cases (varying in soil type and structure) are used and designed in such a way to allow for as general as possible conclusions. We find that taking measures to account for parameter uncertainty in the EnKF improves predictions and that the best performance in terms of soil moisture prediction is achieved with the augmented state approach, where parameters are continuously updated.

References

[1] G. Evensen. Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics. *Journal of Geophysical Research: Oceans*, **99(C5)**:10143-10162, (1994).