Institute of Fluid Mechanics
and Environmental Physics
in Civil Engineering

Master's Thesis Topic- Bias Aware Ensemble Kalman Filter in Coupled-Subsurface-Flow Modeling

First Examiner: Prof. Dr. Insa Neuweiler
Supervisor: M.Sc. Bastian Waldowski

Motivation / Outline

Reliable forecasts of water availability are becoming increasingly important. Numerical models that simulate variably saturated flow can be a useful tool for such forecasts. However, they are often prone to uncertainties due to simplifying assumptions within their core concepts as well as insufficient knowledge of their parameters and their initial and boundary conditions. Consequently, it is common practice to make use of information provided by measurements to improve predictions of a numerical model.
In Data assimilation, the measurement information is used sequentially to update the forecast of a numerical model during the simulation. Figure 1 shows a schematic overview of the procedure, where the state of interest x (within this thesis this would be the soil moisture or the water table height) is shown over time. Predictions of the numerical model (blue line) are updated based on the measurements (red stars) at the times t_1 to t_3 and the model uncertainty (grey dashed lines) is reduced. Within this thesis, the Ensemble Kalman Filter (EnKF), a widely used DA method introduced by Evensen in 1994, shall be used. It approximates the distribution function of the model error by an ensemble (which means multiple simultaneous runs of the same numerical model with slightly altered conditions such as altered parameters) and utilizes measurements to reduce the model error. This model error is assumed to be unbiased, which rarely actually is the case. A way of dealing with that issue is by using a bias aware EnKF, which, in addition to the conventional state updates, introduces bias terms that are updated alongside the states. This work should build on the work of Erdal et al. (2014), who used a bias aware EnKF with a 1D-unsaturated-zone model. Within this work, a coupled model should be used that couples 1D-unsaturated-flow models with a 2D-groundwater-flow model. Source codes of both the coupled, as well as the unsaturated-zone model are written in Matlab and both will be shared with you. You should then transfer the bias correction framework from the 1D model to the coupled model and test it.

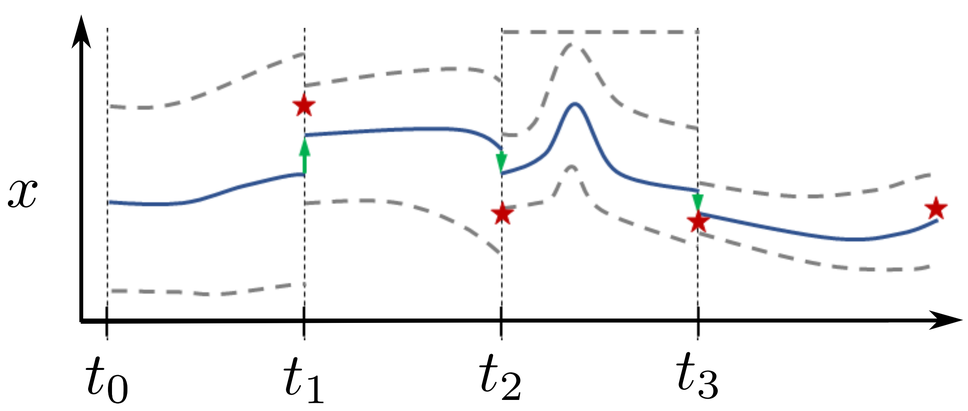

Figure 1: Exemplary sketch of the EnKF, modified after Brandhorst (2022).

Main Goals

- Transfer the bias correction framework from the unsaturated flow model (Matlab) into the coupled model (Matlab).
- Set up a test cases similar to those by Erdal et al. (2014).
- Investigate if the findings by Erdal et al. (2014) can be reproduced with a coupled model.

Required Skills

- Basic knowledge in statistics
- Basic knowledge with partial-differential-equation-based models
- Decent Matlab skills

Beneficial courses

If you have heard (and enjoyed!) some of these courses (or similar ones), this topic might be a good fit for you.

- Prozesssimulation
- Hydrosystemmodellierung
- Numerische Strömungsmechanik / Numerical Methods in Fluid Mechanics
- Environmental Hydraulics

Additional Information

This work intended as a Master's thesis, but the extent could also be scaled down for a Bachelor's thesis or an Interdisciplinary Project if the required skills are met. For the most part, the project should be worked on continuously with regular meetings with the supervisor where preliminary results should be discussed and questions can be asked. **The thesis can be written in German or in English.**

Interested?

Feel free to contact me (even if you are still undecided) and we can have a meeting (online or in person) where we can further discuss the topic and your concerns and ideas.

- waldowski@hydromech.uni-hannover.de

References

[1] N. Brandhorst. *Data assimilation with parameter updates for unsaturated flow problems*. PhD thesis, Univ., Inst. für Strömungstechnik u. Umweltphysik im Bauwesen, 2022.

[2] D. Erdal, I. Neuweiler, and U. Wollschläger. Using a bias aware enkf to account for unresolved structure in an unsaturated zone model. *Water Resources Research*, 50(1):132–147, 2014.

[3] 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.