# Peer review report on "Unsaturated zone model complexity for the assimilation of evapotranspiration rates in groundwater modeling" (*Gelsinari et al. 2020*)

## Overview and General Remarks

In this work, the authors assess the impact of assimilating evapotranspiration rates in the simulations of weakly-coupled unsaturated zone and groundwater flow numerical models. The authors tested two different unsaturated zone models, UnSAT and SWAP, coupled to MODFLOW. The settings of both configurations were defined in a way that the numerical simulations resemble the processes observed at a forest plantation located at south-east Australia. The authors first calibrated the models using a multiobjective function that considers evapotransipiration and water table data. Afterwards, evapotranspiration data from the study area was assimilated using the ensemble Kalman filter, and finally the effects of the assimilation in model states simulations such as soil water content and groundwater tables were assessed.

The study of the effects of data assimilation in cross-compartmental settings (e.g. surface-subsurface compartments) is currently in the interest of the hydro(geo)logical community. Even though powerful numerical models capable of coupling different compartments of the earth's system are being developed, it is still unclear to which extent we can benefit from using certain type of data to improve model simulations, and how do these improvements propagate through the different compartments. For this reason, I find the topic of this work of very high relevance and of interest for the HESS readers. I have some major concerns that I would like to discuss with the authors before the work can be accepted for publication. I have also some editorial remarks that may help improve the fluency of the written work and make it easier to read.

## Major Comments

1. I consider that the results of the data assimilation are not conclusive. The model seems to lack the ability to reproduce the different type of available observations. The improvements of the simulations are marginally improved even for the assimilated variable (ET). However, there is not enough information in the manuscript to really have an idea on what were the settings used in the filter, and hence is hard to identify what was the main reason for the lack of improvement in the simulations.

2. In the same line, and without knowing the specific filter settings, it seems that the simulations are highly influenced by the boundary conditions. This is most likely a consequence of the model setup. Why did you choose to not further extend the model domain if it was somewhat hinted that the fixed boundary conditions are dominating the model behavior? What are the general run times of the coupled system? Given the number of cells in the model I suppose that MODFLOW does not take long, and I am not sure how compute-intensive are UnSAT and SWAP, however I am positive that modern computers would be able to handle numerical models with a better discretization.

3. I do not agree with the authors that an ensemble of 32 members is appropriate for the study. The strong non-linearities of the system under study will be better addressed if a larger ensemble size is used. I do not think that compute time is the limitation, since the models being used are coarse and with very few cells. A larger ensemble size would also give the possibility to increase the ensemble spread, which I also consider to be too small in this work. The EnKF benefits strongly if the observations are within the ensemble spread. This might help to improve both the assimilation of ET and the additional model states updates.

4. I suggest to elaborate in the theory of the filter and the settings applied during the assimilation, I recognize the authors want to avoid a strong overlap with the related publication, however, important information is missing in the text and it does not stand by itself as it is presented.

5. Have the authors considered using the ensemble Kalman filter for updating also model parameters? This is mentioned throughout the text, e.g. line 180 kind of hints that this was actually tried out, however is not clear. I consider that a large enough ensemble, and a large enough spread (which can be produce by perturbing the model parameters) would allow the filter to improve the model simulations not only by updating the model states, but also by calibrating the model parameters. If that is the case this would contradict the first conclusion of the work, which is that the calibration using a multi-objective function is needed prior to data assimilation.

6. I thought only ET was actually assimilated, and used to update all the model estates. However, in line 322 it is said ″the assimilation for actual ET, WT levels, and SM contents of the upper and lower soil layers″. Could you please clarify?

## Editorial Comments

1. I suggest the authors to undergo a thorough proofread of the paper. While I am not a native speaker, and would argue that the work is not necessarily wrong from the language perspective, it is sometimes hard to read.

2. I recommend subtle modifications to the text to make it easier to read. I apologize the emphasis on this but I hope the authors can understand what I mean when I say the work is hard to read. In the following, I list a couple of examples in which I slightly modified the text. This might help the authors to understand my viewpoint:

> Line 91. The Morton equation (Donohue et al., 2010) and the Budyko curve (Donohue et al., 2007) classify the area as dominated by ET or water-limited (Jackson et al., 2009; Benyon et al., 2006). another example l104. We used remotely sensed data of actual ET from the CSIRO MODIS reflectance-based scaling evapotranspiration (CMRSET) algorithm (Guerschman et al., 2009). Subtle changes but makes it much easier to read.
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> Line 110. We tested two different configurations of coupled groundwater-unsaturated zone models. Figure 2 describes the UZMs conceptualization and the groundwater model coupling. In the following we detail in the description of the models used in this work as well as the coupling framework.