Response to Anonymous Reviewer #1

The authors would like to express their sincere gratitude to the reviewer for his/her insightful comments which will surely enhance the paper. We have revised the paper based on your suggestions. Our responses (in black) to the questions (in blue) are described below.

- General comments

''The manuscript studied a conceptual scheme of the interaction between unsaturated and saturated zones of the MOBIDIC hydrological model which is applicable to shallow water table conditions. This is an interesting topic. However, it will still need some clarification. The results and discussion section needs further improvement, compare your findings with the other author's findings, Please add a clear statement of what is the objective of this study at the end of the introduction part and novelty of this work should be clearly explained.''

Thank you for your great suggestion. We have revised the introduction part to better explain the objective and novelty of this study:

Considering the limitations associated with the application of the MOBIDIC-MODFLOW in the very shallow water table regions (type 3), the objective of this study is to propose a series of modifications to the original conceptualization of the hydrological processes of the MOBIDIC-MODFLOW to extend its potential applicability for these cases.

To this aim, a novel methodology for revisiting the calculation of the groundwater recharge in MOBIDIC, specific yield in MODFLOW, and the interaction between the unsaturated and saturated zone in MOBIDIC-MODFLOW was developed. The developed methodology is based on the premise that the ''expected'' response of a shallow water table system is given by MIKE SHE a fully coupled surface-subsurface model taken as the reference model of this study. Using Water Table Fluctuation (WTF) method (Healy and Cook, 2002), the water table rises of a shallow water table system under different sets of rainfall intensity, soil property and depth to water table were simulated using MIKE SHE. The simulated responses were then used to reformulate the groundwater recharge of MOBIDIC based on the hydrostatic equilibrium interaction between the unsaturated and saturated zones. The accuracy of the proposed changes is first tested in a two-dimensional case where subsurface water is simulated in a vertical plane with a constant slope. A constant rainfall rate is applied and the rise in groundwater levels is affected by groundwater recharge and by the lateral interaction between the saturated computational grids. In a second numerical experiment, the accuracy of the approach is further evaluated at the catchment scale and under unsteady rainfall where the simulated water table levels of the two models (MIKE SHE as the reference model and MOBIDIC-MODFLOW) are compared.

The comparison of the simulated water table responses of the MOBIDIC-MODFLOW against those of MIKE SHE allows us to evaluate how the externally coupled models such as MOBIDIC-MODFLOW in our study can be modified for applications in very shallow water tables.

The discussion regarding the comparison of the findings of this study with others is given in page 3 of this document.

- *Specific comments*

1- Page 3, Line 20: The "evapotranspiration from groundwater ($\Delta S_{GW} = R + Q_u - Q_u - ET_{GW}$) is not clear for all the readers. Please add an explanation of this concept.

Thanks for your suggestion. The description of the evapotranspiration from the groundwater was added in the revised version of the paper:
The evapotranspiration from groundwater is the direct root water uptake from the saturated zone. Unlike the deep water table conditions, the groundwater evapotranspiration can be much greater than the evapotranspiration from the unsaturated zone as discussed by (Shah et al., 2007).

2- Page 4, Line 10: I feel this is not clear what are the differences between the MIKE-SHE and the MOBIDIC hydrological model. You may use a table to show the differences or what you have improved or changed.

Thanks for your great suggestion. The following table describing the differences between the two models was added to the revised manuscript:

Table 1. Comparison of the subsurface flow processes in MOBIDIC-MODFLOW and MIKE SHE.

Model/Process	Unsaturated zone	Saturated zone	UZ-SZ coupling	Applications in humid regions
MIKE SHE	1D Richards	3D finite difference	Iterative water table correction in each UZ time steps	Applicable in both deep and shallow water table regions. The dynamic variations of the specific yield in shallow water table regions are handled using the UZ-SZ coupling approach. However, the iterative process increases the computational burden of the model.
MOBIDIC-MODFLOW	Dual reservoir	3D finite difference	Sequential[1] coupling	Since it uses a constant specific yield, it has limitations in modelling of the water table fluctuations of the humid regions. The simplified UZ-SZ coupling approach makes the model computationally efficient.

[1] Sequential coupling means the solution of the water table from the previous time step is used as the boundary condition for the solution of the MODFLOW (Guzha 2008)

3- Page 8, line 15: You may use a flowchart here to show the methods you used or the model setup processes.

Thank you for the suggestion. The following flowchart describing the step-by-step of the procedure was added to the revised manuscript:

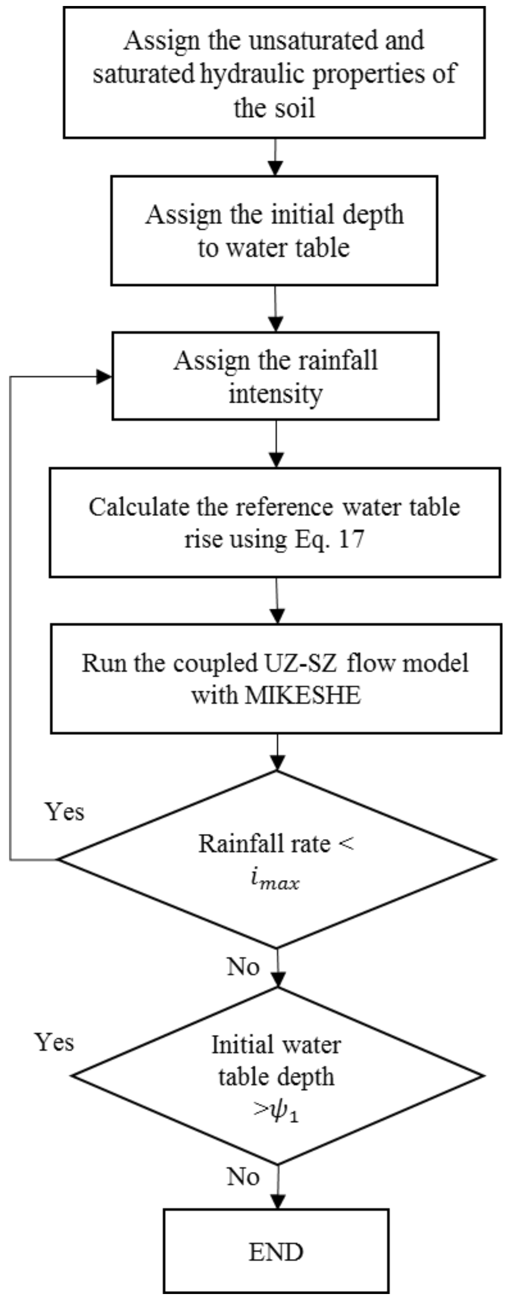

Figure 4. Flowchart describing the step-by-step procedure of water table fluctuation method in MIKE SHE. i_{max} is the maximum rainfall rate below which the infiltration excess runoff doesn't occur. ψ_1 is the soil bubbling pressure given in Table 2.

4- Page 14, line 20: I suggest the author add some paragraphs to compare this study and the previous similar studies.

The authors are very thankful for this comment. The discussion part of the manuscript was revised as to include the comparison with the previous studies:

The quick rise of the shallow water table in response to the precipitation was also observed in the experimental work of (Abdul and Gillham 1984). In their study, the water table response of a sandy soil packed in a 160 ×120 × 8 cm (surface slope 12°) box with different initial water table level under a uniform rainfall rate was investigated. The objective of the experiment was to evaluate the effect of the capillary fringe on the rise in water table and streamflow generation. The results revealed that when the water table is very shallow, that is for the downhill regions of the slope in which the capillary fringe extended to the soil surface, the small amount of rainfall can result in a water table rise much greater than what would be expected by the specific yield of the soil. The uphill regions with deeper water table depth, however, showed a delayed response due to the presence of the moisture deficit in the unsaturated zone. The simulated responses using MIKE SHE and MOBIDIC-MODFLOW (Figure 8) are consistent with the findings of the (Abdul and Gillham 1984) attesting their capability in capturing the effect of capillary fringe on the water table rise. Note that the coefficient of ω in MOBIDIC-MODFLOW (Equation 19) changes as the water table level rise/falls and therefore, each computation grid in Figure 8 has a different value for ω at each time step.

The quantitative comparison of the simulated water table rises of MIKE SHE and MOBIDIC-MODFLOW against the observations of (Abdul and Gillham 1984) is not possible since the soil types (sandy soil in their experiment and sandy soil for which the coefficient of ω in Equation 19 (please refer to the Table 2 and Figure 7).

The Borden catchment has also been in experimental (Abdul and Gillham 1989) and modelling studies (VanderKwaak 1999; Jones et al. 2006). However, the exact comparison of the simulation results of this work with the aforementioned studies is not possible since different soil properties are different.

5- You mentioned that the efficiency of the new model is better than MIKE-SHE, but what about the uncertainty of the new model than MIKE-SHE? Because you added new parameters here.

Thank you for raising this very important issue. The modified MOBIDIC-MODFLOW doesn't have any additional parameters, thereby the parameter uncertainties of the model remain unchanged. Comparison of the original and modified calculation of the groundwater recharge in MOBIDIC (Equations 12 and 19) shows that the two equations have only one calibration parameter (γ in Equation 12 and ω in Equation 19).
The proposed modifications, however, eliminates the specific yield from the calibration parameters of MODFLOW using the water table dependent expression given in Equation 18. The required soil hydraulic parameters for application of the Equation 18 is derived based on (Rawls and Brakensiek 1989) soil database.
Therefore, the modified MOBIDIC-MODFLOW has one less calibration parameter (specific yield) compared to the original structure of the MOBIDIC-MODFLOW.

6- Figure 9: What about the situation after 31 days. Also, do you have observation of the spatial distribution water tables?

Thank you for the question. The comparison of the water table rises of the two models shows the water table is rising during the 31 days of simulation (see Figure 11) as they would eventually reach to the soil surface since. This is because the evapotranspiration process was not included in neither of the models. Note that we ran the models for a month since the simulations with MIKE SHE was already very time consuming (about 30 hours).
Unfortunately, we did not have any observations of the water table level to evaluate the accuracy of the predictions with the two models. In fact, the idea of this work was to propose changes in the structure of the MOBIDIC-MODFLOW to become as an alternative tool to the physically based model (such as MIKE SHE in our study) for shallow water table applications.

7- Figure 10: Do you have observations of water depth to compare with the model simulations?

Thanks for your question. We did not have any observations of the water depths to evaluate the accuracy of the predictions with the models. In fact, we used MIKE SHE as the reference model to evaluate the accuracy of the predictions with MOBIDIC-MODFLOW. Also, the generated saturated excess runoff was removed from the soil surface since the surface water routing process was not considered in this work.

References

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