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Hydrology and Earth System Sciences Discussions

Interactive comment on "Catchment-scale non-linear groundwater-surface water interactions in densely drained lowland catchments" *by* Y. van der Velde et al.

Anonymous Referee #2

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General Comments

The manuscript focuses on an important and relevant topic – the modelling of lowland catchments – and uses an interesting approach to do so: The thickness of the unsaturated zone is assumed to be normally distributed, and all dependences (groundwater discharge, tile drain discharge etc.) are built around this assumption. After a very informative introduction into the topic, the development of the model and the underlying assumptions are described in detail. Then, the groundwater model Modflow is applied to a small catchment to derive a PDF of the thickness of the unsaturated zone and to

test the main underlying assumption of the model. After passing this test, the newly developed model is successfully applied. Despite its simplifications, the model works very well, but it has to be admitted that it relies on the results of a more detailed model to derive the PDF parameters. Nonetheless, the approach is innovative and the paper should definitely be published. Overall, the manuscript is, due to a detailed description of the model structure, rather long and contains 19 (!) figures. Thus, some suggestions to shorten the manuscript will be given below.

Specific Comments

Introduction:

Page 3754/ line 44 Please replace "deltas" by "lowland areas" or "lowland landscapes" as the term delta seems too restrictive here.

Theory:

Page 3758/ line 22 Figure 1 can be omitted for sake of the length of the paper. The variability of the groundwater level is later discussed in detail so that this figure does not add anything really new here.

Page 3760/ line 2 ff You write (correctly) that it is not possible to apply the model to a catchment with discontinuities with in stream network densities. Yet, the Hupsel catchment has artificially drained and undrained areas, which surely have different stream network densities (especially if you consider the tile drainage network as a part of the stream network). Furthermore, there will be different drainage spacings and depths, which both influence the groundwater level. How do you deal with these existing discontinuities?

Page 3760/ line 13 I was getting confused here (and elsewhere in the manuscript) with the term lsurf. Perhaps you should say already at this point that this term comprises both overland flow, tile drain discharge and flow in the ditches and brooks. Later, on page 3761, it is stated that "lsurf comprises lateral fluxes of water both over the land

surface, and through drain tubes". If lsurf comprises qdr, why are then both term in Eq. 5? Please try to re-write paragraph 2.2 (Mass balance equation) to make it easier to understand.

Page 3762/ lines 18ff I don't understand why you want the unsaturated zone to act as an amplifier of the atmospheric conditions (again, the capability of the model to do so is discussed on page 3768, line 9ff). On contrary, I would expect the unsaturated zone to attenuate the atmospheric boundary conditions. In the case of evapotranspiration, plant roots will (at least partially) abstract water from the unsaturated zone, thus creating a time lag until a new equilibrium forms and the groundwater table recedes. In the case of precipitation, there might be some kind of piston effect (or preferential flow paths), which will convey rainfall directly towards the groundwater table. But even in areas with a shallow groundwater table, there will still be some delay until the groundwater table reacts on precipitation and thus also a possibility for plants to remove water from the unsaturated zone before it reaches the groundwater table

Page 3770/ line 8ff I've got a problem with understanding here again. You write that the infiltration is zero when the surface storage increases (I understand this part) and equal to the change in surface storage when the surface storage decreases. Where does any overland flow go then?

Page 3773/ line 10ff Although the evapotranspiration estimates average out on the catchment scale and will thus result in a smooth temporal distribution, I'm not very happy with the representation of the actual transpiration. It is suddenly switched off at one point, which seems to be unnecessarily far from reality. A representation similar to the Feddes function might have been a better solution here.

Materials and methods

Page 3776/ line 21 Figure 6 is not really needed and could be sacrificed to a more concise manuscript.

Page 3776/ line 22f Which water levels? Were they used as initial water levels or as a "plausibility check"?

Results and discussion

Page 3777/ line 20 There seem to be systematic errors in the Modflow results. Did you calibrate the Modflow model at all? Is the missing overland flow really the reason for the bias in the Modflow results, or could the parameterisation also be part of the problem? In figures 15 and 17, I can't discover any overland flow when you separate the flow components (what is the contribution of the overland flow, by the way?). As the groundwater levels are too high and the discharges to low, the connection between these two does not seem to work very well. Perhaps the missing representation of the tile drains in Modflow might be a reason, as they cause a groundwater drawdown while increasing or at least accelerating the discharge.

Page 3780/ line 22 You probably mean "Hortonian overland flow and saturation excess overland flow", as the first one is already infiltration excess overland flow.

Page 3781/ line 2ff Parts a and b of Figure 10 can be omitted to shorten the paper a little. As the active drainage network cannot be validated from other sources (e.g. remote sensing), this information is not that important here.

Page 3784/ line 21ff Although I don't really see hysteresis in figures 15 and 17, there might be further explanations of the overestimation of the discharge in autumn and the underestimation in spring. First of all, the general representation of the evapotranspiration is slightly questionable (see above). Apart from that, the actual evapotranspiration is always quite difficult to estimate, and thus a slightly wrong calculation of the evapotranspiration (you did not take into account the spatial variability of the evapotranspiration due to different land covers) might not only explain the above mentioned problems, but also some of the problems associated with low flow periods. The assumption of an instantaneous equilibrium might also add to the above problems, for example if, in spring, the soils were immediately before the onset of the discharge event wetter than

assumed by equilibrium conditions.

Conclusions

Page 3786/ line 2ff Please also discuss (here or in the discussion section) the prerequisites for applying you model approach. It seems that you will either need a large and spatially well distributed number of groundwater measurements or another model to derive the distribution of the unsaturated zone thickness to be able to fix the accordant parameters of the PDF. In your case, you could fix these parameters, and thus avoiding some equifinality problems, but in your catchment, you had good stratigraphic data, which won't be necessarily available elsewhere. Thus I think the necessity to apply another model – with all its uncertainties and a larger data demand than you straightforward approach – beforehand unfortunately limits the applicability of your approach. Implicitly, this would mean that some simplification you made are not really feasible as you "outsourced" the data demand and related problems to Modflow.

Technical Corrections

Generally, the paper is very well written. The English is fluent, precise and without any major errors (some minor typos and suggestions are listed below). The figures are well prepared and the references are well-chosen and up to date.

- The term "tube drain" is not very common in hydrological or agricultural literature. I would suggest to replace it with "tile drain" (even though plastic pipes were used) or with "subsurface drains". - Page 3766/ line 4: "and", not "an" - Page 3766/ line 14: Add a space before "and" - Page 3772/ line 6ff: There is something missing in this sentence. - Figure 18 and 19: Please add somewhere in the heading of these figures that they refer to the validation period.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 3753, 2009.