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Hydrology and Earth System Sciences Discussions

Interactive comment on "Is the groundwater reservoir linear? Learning from data in hydrological modelling" *by* F. Fenicia et al.

B. Schaefli (Referee)

bettina.schaefli@a3.epfl.ch

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General comments:

The paper investigates the question whether the low flow components of a hydrograph can be modelled by a linear reservoir. The authors identify a master recession curve that represents the long-term recession of a given catchment. Using a conceptual model with 4 reservoirs, they reproduce this master recession curve without an a priori determination of the storage-discharge (S-D) relationship of the slow reacting reservoir. This S-D function is inferred from the master recession curve during the model calibration process. The method is applied to 8 catchments in Luxemburg and the authors show that a linear reservoir approach can reproduce de master recession curve for 7 of the 8 case studies.

The question whether low flow can be modelled by a linear reservoir approach is inter-

esting and a prerequisite to the application of any conceptual reservoir-based model. The paper does however not sufficiently discuss the case study-specificity of the obtained results (even if the question is raised in the paper) . Based on their 7 case studies, the authors make the strong assumption that "in general the groundwater reservoir of the catchment is linear" and give a few arguments without sufficient reference to their own or previous scientific work that would underpin their assumption.

In general, the authors should better reference their assertions. It should be better identified what contributions are new, in the present form, the reader cannot judge whether there is something new (e.g.: is this study the first comparable attempt to quantify the linear behaviour of the ground water?).

The title of the paper is eye-catching but it suggests a general study with general results whereas the obtained results hold only for the presented case studies. The authors try to show whether the ground water can be "modelled" by a linear reservoir and not whether the reservoir "is" linear. This difference should at least be pointed out once (even if the difference between natural processes and model representation is generally well emphasized in the paper).

The paper should discuss the question whether the results are conditioned by the used model, i.e. the used interconnections between the reservoirs. Namely the influence of preferential recharge (that is often not included in such models) on the linear behaviour should be analysed. It should at least be mentioned that all results depend on the chosen model structure. It would also be interesting to show how the other model parameters (the ones that are not related to the slow reservoir) influence the low flow simulation, namely the parameters that condition the recharge of the slow reservoir. Would different (equifinal) parameter sets lead to the same simulations / conclusions? The reader has no idea about the parameter values; do they vary a lot during the different recalibration steps?

The paper should be restructured; the introduction section is very long (15 % of the

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paper length) and not quite concise. I also suggest including section 2 in the introduction section (section 2 is a very brief overview). The conclusion section is rather a summary of the work. Reorganize the discussion and the conclusion section. The conclusion should add some further information (i.e. an outlook, potential further research). The abstract does not seem to correspond to the same paper. Especially the first paragraph of the abstract seems to introduce a paper on model calibration strategies. The mean question underlying the research appears only at the end. I suggest rewriting the abstract.

The first part of the paper is well written, but the quality of the language decreases towards the end (except the conclusion section). The language and grammar should be carefully reviewed for the entire paper (see also the detailed comments hereafter). There are different wrong references to figures and equations. Some of the figures do not add substantial information to the paper and should be removed.

Detailed comments:

* Introduction section: It would improve the readability to state first the two different modelling approaches (top-down, bottom-up) before discussing further details.

* Introduction section: The two explanations given for weak low flow simulation should be kept on a more general level. Hydrological models are generally not able to reproduce several discharge characteristics simultaneously. As most models are not designed for low flow prediction, they often do a poor job during low flow. Several reasons can be invoked: 1) parameterisation not adapted; 2) calibration strategy not adapted; 3) data not appropriate (e.g. low flow measurements in temporarily frozen rivers).

* Introduction section: In general, try to make more precise statements (e.g., why is the catchment response more regular and better identifiable during low flow?)

* P. 1720, line 28: add "the" in "the system response", check this omission in the entire

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paper.

* P. 1724, line 21 - 24: redundant, please remove this paragraph

* P. 1725, line 25: what means CRP-GL?

* P. 1726: Model description is not clear: not the excess water from UR is partitioned into Rs and Rf but the difference between Re and Ru; the partitioning between Rs and Rf is not described in any equation and the reference to equation 4 and 5 is wrong at p. 1727, line 6

* P. 1727, line 16: Wrong reference to fig. 1

* P. 1728, line 3: wrong reference to figure 2

* P. 1729: Master recession curve: Minimum length of the retained recession periods? As shown by Lamb and Beven, 1997, this influences the S-D relationship.

* P. 1730, line 21: what means SM?

* P. 1731, line 21 - 28: This paragraph should be moved to the beginning of section 5.2. The reader inevitably ask himself how one can assume that the MRC is generated by the outflow of the SR only and why fig. 5 stops at 0.10 mm/h. How is the "lower parts" of the recession defined/identified? For the Petrusse catchment, this "lower part" corresponds obviously to specific discharges that are more than twice higher than for the first example, why?

* P. 1732, line 11: rephrase the sentence "AlsoĚ initially." Suggestion: "This figure shows that the SR reservoir has to empty faster than initially estimated to match the MRC."

* P. 1732, line 5: please add a reference for the parameter equifinality concept

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* P. 1732, line 7: replace "2 and 3" by "2nd and 3rd"

* P. 1732, line 8: write *"For all other catchments"*

* P. 1732, line 14 - 19: after removing fig. 9 (see comment on fig. 9), add this paragraph on p. 1731, line 20.

* P. 1732, line 24: change to "and can therefore be considered"

* P. 1732, line 25: rephrase: "In this case, there would be no recharge to SR during recession periods"

* P. 1732, line 29: what do you mean by "consent"?

* P. 1733, line 21 and p. 1735 line 16: try to be concise and avoid statements like "quite high" and "really very small".

* P. 1733, line 8: I suggest replacing "table 3 summarizes" by adding at the end of next sentence "(see Table 3)"

* P. 1733, line 12: the sentence is not complete (no finite verb) and not understandable

* P. 1733, line 13: "that takes into account the capillary"

* P. 1733 lines 13 - 20: I suggest rewriting this paragraph starting with "For all studied catchments, the downward flux has been shown to be predominating over upward fluxe".

* P. 1733, line 14: chose whether you spell deeply-rooted or deeply rooted

* P. 1733, lines 21 following: add to the first paragraph of this section.

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* P. 1734, section 7: how do the parameter values change during recalibration ? Could you give any quantitative measure for the improvement of the simulation quality during high flow or quality decrease during low flow?

* P. 1734, line 6: "that represents well flow recessionĚ"

* P.1734, line 18: the sentence is difficult to understand, rather write "it became negligible during calibration"

* P. 1735, line 7 and following: replace image by graph

* P. 1735, line 16: could and not can

* P. 1736, line 3: turn the sentence: "Considering the limited amount of case studies"

* P. 1736, line 5: add references

* P. 1736, line 6: you show that percolation does not lead to non-linear behaviour!

* P. 1736, line 8: what do you mean by utility?

* P. 1736: line 11: understand not understanding

* P. 1736, line 12 following: it is not the groundwater reservoir that behaves in a particular way but the behaviour of the natural system enables its modelling in a particular way

* P. 1736, line 27-28: I suggest rephrasing (e.g. "We strongly believe that")

* P. 1737, line 16-17: add a reference

* P. 1737, line 19: "using only discharge data"

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* Following paragraph: add a reference

* P. 1737, line 27: add a reference for the concept of self-organisation

* P. 1738, line 11: the working hypothesis is that the low flow can be modelled by a linear groundwater reservoir; the expression "tends to be linear" has to be followed by an explanation (under which conditions?)

* P. 1738, line 18/19 following: add "we assume" to show that this is a hypothesis

* Conclusion section: has the linearity under upward flux been tested?

* Conclusion section: I suggest writing " our hypothesis is that in general the low flow can be modelled by a linear groundwater reservoir"

* Remove the comma before the relative pronoun "that" (e.g. p. 1720, line 16, p. 1721 line 5, p. 1731, line 10)

* Check the use of the word endings "-ise" resp. "-isation" and "-ize" resp. "-ization". Do not mix up the forms for the same words (e.g. p. 1722 line 10 and 12: conceptualised but conceptualization, e.g. characterise p. 1736 line 26 but characterize p. 1723 line 28, but also emphasize and emphasise

Equations:

* Eq. 8: Please indicate what the variables stand for

References:

* Reggiani and Rientjes, 2005: please add the doi-number

* Gupta et al., 1998 : use the correct abbreviation : Water Resour. Res.

Tables:

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* Table 1: use the same number of significant digits for all values in a column

* Table 2: I suggest adding the possible value ranges for the different parameters (e.g. the physical limits)

* Table 3: modify the legend, add that it shows the coefficient of determination

Figures:

* Fig. 3: does not add any information. I suggest removing it and indicating instead the range of possible values for the parameter beta (that conditions whether the functional relationship is S-shaped or not)

* Fig. 4 - Fig.8: please specify the name of the catchment in the legend

* Fig. 5: add the coefficient of determination

* Fig. 6 and fig. 8: please replace "exchange" by "inflow"; add a comment to clearly show that the two figures do not show the same (the legend is exactly the same!)

* Fig. 9 please remove; this figure does not add any information except the equation of the polynomial that could be added in Figure 7 or be placed in the text.

* Fig. 11: please enlarge the figure (put two in a row); the current figure is not readable in paper format. I suggest changing the representation; choose for example dots for the simulated discharge rather than a thick line covering the underlying observed discharge. Add the name of the catchment. Please add a more explicit legend (general rule: if possible, the figure has to be understandable without reading the text). Why the logarithmic scale in the third graph?

Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 1717, 2005.