Hydrol. Earth Syst. Sci. Discuss., 2, S746–S750, 2005
www.copernicus.org/EGU/hess/hessd/2/S746/
European Geosciences Union

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.

Anonymous Referee #1

Received and published: 27 September 2005

General Comments

The paper attempts two tasks. Firstly it proposes a calibration technique that, within a given model structure and using specified measures of fit to observed data, develops an optimal parameter set and an optimal derivation of the storage-discharge (S-D) relationship within the slow reacting reservoir. Secondly the results of applying this methodology to eight catchments within Luxembourg are used to trigger a discussion as to the general suitability of the use of a linear S-D relationship in conceptual hydrological models. While the paper goes some way to achieving both these tasks the work has caveats that are not acknowledged, these are discussed in the Specific Comments section. The standard of English and Figures used within the paper is generally good, though some aspects are in need of revision (see the Technical Comments section). The review of groundwater and its' modelling currently presented is inadequate

to justify the title.

Specific Comments

Section 1 (Introduction) and Section 2 (The representation of the groundwater reservoirĚ) should be combined and shortened. The discussion (Pg 1719 - 1721 line 11) in the Section 1 is worthy (though inadequately referenced) and the demonstrable examples offered in Section 2 would illustrate the topics raised. The discussion; particularly that relating to “top-down” and “bottom-up” modelling methodologies; should be focused towards the rest of the paper. The terms “top-down” and “bottom-up” also require a specific definition. The methodology chosen should be contrasted with those already published. For example is the methodology used really “top-down” compared to that used in the derivation of Data Based Mechanistic (DBM) models [1, 2] or more of an iterative process of model improvement [3, 4]. Also multistep calibration procedures should be mentioned since the methodology presented (if the selection of the S-D component is removed) is close to that presented within the MACS procedure [5], though implemented to a different model.

The presentation of the model structure could be improved (see the Technical Comments). The calibration procedure is placed in an optimisation framework, as such the sentence “The value of 10

While the S-D relationship of the slow response reservoir is initially derived from the Master Recession Curve (MRC) the iterative procedure of optimising the fit then the recalculating the relationship (Steps 3 4, Pg 1730-1731) means that the relationship can no longer be considered independent of the rest of the model structure, a point that does not appear to be explicitly made and crucial to the later discussion as to the general applicability of the use of a linear S-D relationship discovered in most of the catchments. The derivation of MRC should also be fully explained, particularly in the case where input to the slow response reservoir is included. The sensitivity of the MRC to the selection of appropriate time periods (recession curves) requires comment. The

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method used for fitting the parametric relationship (e.g. the initial polynomial in Figure 5) requires explanation and justification. The length of data (three years) appears short when compared to the return period of many low flow events.

The presentation of the results in Section 6 suggests that the S-D relationship within the slow response reservoir has become more linear. The extent of this change is hard to gauge from the R-squared statistics presented. No comment is made about how the iterative process in the derivation of the S-D relationship for the slow response reservoir affects the fit to the observed hydrograph. Further to this a simple graphical presentation of the respective contribution to flow from the slow and fast reservoirs would clarify the relative importance of these in characterising the receding limb of the hydrographs. No mention is made of the effects of the nesting of the study catchments.

The statement that the interception parameters best identified during periods of low flow requires referencing and justification (Pg 1734 line 23-25). Surely the start of rainfall events (whatever the flow conditions) is crucial in determining the size of the interception store?

Section 8 contains some interesting discussion as to the interpretability of the conceptual hydrological model in terms of the groundwater. However many of the important points are lost due to a lack of clarity in the text. Section 8 is also inadequately referenced. An idea that may be of help in the presentation of this section is to consider two topics: “is a linear representation of ground water adequate for reproducing the observed data (both in the study presented and other studies)? If so why?” and “how representative is the model of the real world? (i.e. does it reproduce only the observed dynamics or the ‘true’ physical processes resulting in them)”. Some of the statements made in Section 8 also cause concern. The statement “..., by calibrating low-flows and high-flows separately,...” (Pg 1737 line 6) does not reflect the methodology which (from my interpretation of the method section) calibrates first with a bias to low flow fit (but not fitting only the low flows), then recalibrates some parameters with a bias towards fitting the high flows. Also the use of conceptual models may limit the interpretability of the

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results (in contrast to the statement on Pg 1737 line 22) either on a spatial scale or due to fact that there area multiple interpretations of physical processes each component of the conceptual model represents.

The conclusion (Section 9) does not offer anything further to the paper, such as suggestions for further work. Any response to the above comments needs to be reflected within the abstract.

Technical Comments

Reviewer B. Schaefi has provided a detailed list of technical comments. To these the following may be added: - delete “result to” Pg 1722 line 1
- The results are presented in the introduction Pg 1722 line 21.
- Su and Sfr are not present in Figure 2 (Pg 1727 line 3)
- How does D operate (Pg 1727 line 4)
- “Lp is the ratio of Sfr” (Pg 1727 line 15) The ratio of Sfr to what?
- I doubt you “were somehow forced” to use “a parsimonious model with few calibration parameters” (Pg 1737 line 20). However you did make the sensible decision to use such a model given the quantity of data available as suggested in the previous sentence (Pg 1737 line 19).
- Table 2. I suggest adding parameter definitions.

References

1. Young, P., Time-Series methods and recursive estimation in hydrological systems analysis, in River Flow Modelling and Forecasting, D.A. Kraijenhoff and J.R. Moll, Editors. 1986, D. Reidel Publishing Company. p. 129-180.
2. Young, P.C., Advances in real-time flood forecasting. Philosophical Transactions of the Royal Society of London Series a-Mathematical Physical and Engineering Sciences, 2002. 360(1796): p. 1433-1450.
3. Nash, J.E. and J.V. Sutcliffe, River flow forecasting through conceptual models part I – A discussion of principles. Journal of Hydrology, 1970. 10(3): p. 282-290.

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4. Wagener, T., et al., A framework for development and application of hydrological models. Hydrology and Earth System Sciences, 2001. 5(1): p. 13-26.
5. Hogue, T.S., et al., A multistep automatic calibration scheme for river forecasting models. Journal Of Hydrometeorology, 2000. 1(6): p. 524-542.

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