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Hydrology and Earth System Sciences Discussions

Interactive comment on "A measure of watershed nonlinearity: interpreting a variable instantaneous unit hydrograph model on two vastly different sized –watersheds" *by* J. Y. Ding

Anonymous Referee #4

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1. General Comments.

The paper uses a generalisation of the unit hydrograph to examine non-linearity of the catchment response for catchments of different sizes. I am sympathetic to this approach as the unit hydrograph is a good way to represent non-linearity in a form that can be easily interpreted from a hydrological perspective. The unit hydrograph a one of hydrology's founding concepts and is easily understood and visualised by all hydrologists.

The first part of the paper presents the underlying mathematical development. It shows how the variable instantaneous unit hydrograph (VIUH) (dependent on inputs - rainfall excess intensity) can be derived from a non-linear storage model. This part of the

paper is well presented and interesting. One of the good parts of the paper is that it provides enough mathematical detail to enable you to do the end-to-end calculations, without reference to other texts.

The next part of the paper applies the mathematical model developed to Minshall and Childs' unit hydrograph research. The paper uses the "shape factor method" to determine the non-linearity and scale parameters from the shapes of the IUHs derived by Minshall and Childs. In this approach the non-linearity parameter of the VIUH is solely determined by the time to peak and peak of the unit hydrograph. I have considerable misgivings about this approach because I don't believe that the shape of a catchment's unit hydrograph has anything to do with non-linearity. Non-linearity is how the unit hydrograph shape changes with varying inputs (ie rainfall excess intensity) not the actual shape of the unit hydrograph. For example see the work of Valdes et al. (1979), and Wang et al. (1981). Based on this, which I consider a fundamental problem; I would not feel comfortable in recommending publication of the paper at this stage. However, I feel there is potential to rework the analysis of this paper to better examine non-linearity of catchment response. Specific comments follow.

2. Mathematical Development

The mathematical development is well presented in sections 2 to 6. I found this part of the paper well organised and easy to read. I liked the numerical examples and the provision of a solution of the Bakhmeteff varied-flow function. These will make it easier for future researcher to apply the methods developed in this paper. Some comments that the author may want to consider are as follows:

(i) It may be useful to reinforce the basic IUH concepts of "time invariance and superposition", and how these assumptions are relaxed in the VIUH.

(ii) The author emphasises a "hydraulic" interpretation for the non-linearity parameter N, which is a good alternative to the typically arbitrary interpretations in hydrological practice. The author may want to include the examples of the N values recommended

HESSD
2, S919–S924, 2005

EGU

in standard rainfall-runoff models used in Engineering practice.

(iii) It would be useful to have some plots showing the shape of the VIUH and how it changes with the non-linearity parameter N and rainfall excess intensity.

3. The shape factor method for estimating catchment non-linearity

As mentioned in the general comments, my major concern with this paper is the use of the shape factor method to estimate catchment non-linearity. The author may wish to argue this point, and perhaps I have misunderstood the theoretical application of the model. In either case, I feel it is necessary for this issue to be further investigated and for the author to provide better justification for the approach adopted. My concerns are as follows:

(i) From a physical perspective the shape of a catchment's unit hydrograph is due to number of physical factors: shape of the catchment, stream network structure, type of runoff processes etc. A whole variety of IUH shapes are possible, whether the response is linear or not. Therefore, I disagree with the proposition that you can derive a measure of non-linearity by examining a single unit hydrograph. Instead, one must look at a number of unit hydrographs and examine how they change with varying inputs.

(ii) For the linear case (N=1) the corresponding VIUH is an exponential pdf, which is a very unlikely shape for IUH derived from data. As N increases the time to peak and the dispersion of VIUH increases, which makes the hydrograph shapes more reasonable. Thus, I feel that N, as applied in this paper is more of a measure of the shape of the unit hydrograph rather than non-linearity.

(iii) One of the critical findings of the paper is that the larger catchment (Naugatuck) was much more non-linear than the smaller catchment (Edwardsville). The author provides little discussion of this finding, despite it being contrary to the generally accepted view that non-linearity decreases with catchment size (Wang et al., 1981).

Despite these issues, I feel that there is potential to use the theoretical development

HESSD
2, S919–S924, 2005

presented in this paper to examine non-linearity. I would recommend that the author explore using the relationship between the VIUH peak and the rainfall excess intensity presented in equation (15). Using this equation, one could derive a value for the non-linearity parameter N based on how the peaks of the IUHs derived from the data vary with rainfall excess intensity.

4. Source Data

The paper uses the data presented in the work of Minshall and Child. This work is close to 50 years old, and while it is interesting to look back at these classic papers, I would recommend that the author provide some new and original data. This would enable the author to do more detailed analysis and would provide an additional data source on the scientific record.

5. Verification of calibration parameters

In the verification section of the paper, the author attempts to reproduce the observed flood events by convoluting the VIUH's with the observed rainfall. This section of the paper is then extended by detailed discussion of the sensitivity of the approach to the time-step used in the convolution.

I found this part of the paper a distraction from the main focus of the paper. As the author points out, the "principles of superposition don't strictly apply to non-linear system Ĕ and the model parameters are only applicable to the size of time step for which they are calibrated". Therefore, I do not feel it is a useful exercise to examine the issue of trying to make the VIUH work as a conventional unit hydrograph. The introduction of adjustment factors just clouds issues further.

I would recommend the author remove these sections of the paper (7.3-7.4), and simply validate the VIUHs by providing plots, which compare the original data derived IUH's with the new theoretically derived VIUHs. This would provide an adequate verification of the model, for the purpose of this paper.

HESSD

2, S919–S924, 2005

Interactive Comment

6. Summary and Conclusions

The summary and conclusions section of the paper is well written and presented. It provides a clear summary and is consistent with the discussion presented in the paper.

7. Appendix A

The templates presented in this section are unnecessary.

8. Cosmetic Issues.

(i) Writing style is a personal preference, and the academic style used by the author is satisfactory. However, I would recommend the author use simpler language to make the paper accessible to a larger audience. For example the paper begins with “The paper reviews the use of an input-dependent kernel in a linear convolution integral as a quasi-nonlinear approach to unify non-linear overland flow, channel routing and catchment runoff processes”, this could be simplified to: “The paper uses an input dependent generalisation of the unit hydrograph to examine non-linearity of the catchment rainfall-runoff process”

(ii) There are very few figures in the paper. It would be good if there were a few more figures that show the shapes of the unit hygrographs derived using the author’s theoretical model.

(iii) Some issues with consistency of units. The Edwardsville catchment has its area given in ha, while the Naugatuck catchment has its area given in km2.

(iv) It may be better to use the notion of Instantaneous Response Function (IRF), rather than VIUH.

References: Valdes, J.B., Y. Fiallo, and I. Rodriguez-Iturbe, A rainfall-runoff analysis of the geomorphic IUH, Water Resour. Res., 15(6), 1421-1434, 1979 Wang, C.T., V.K Gupta, and E. Waymire, A geomorphic Synthesis of Nonlinearity in Surface Runoff.. Water Resour. Res., 17(3), 545-554, 1981

HESSD

2, S919–S924, 2005

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