

Hydrol. Earth Syst. Sci. Discuss., referee comment RC1
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Comment on hess-2021-28

Jasper Vrugt (Referee)

Referee comment on "Numerical daemons of hydrological models are summoned by extreme precipitation" by Peter T. La Follette et al., Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2021-28-RC1>, 2021

The present paper is another attempt to make the surface hydrologic community aware of the problems associated with the use of poor numerics. This is always important, and the present hook is climate change (increased precipitation). The work presented in this paper is standard material for a numerics class - how to solve differential equations. I certainly appreciate the topic and second its importance, yet, do like to articulate that a need for more publications on this topic highlights a fundamental flaw in hydrologic education. Proper awareness/knowledge of mathematics, numerics and, also, statistics.

The paper is well written and generally well prepared. Nevertheless, the paper would benefit from a careful read by a native speaker. I will give some examples in my review below. What is more, at a number of different places in the manuscript, I believe the authors do not use the 'right' technical language. I will also provide some examples of this. Altogether, I believe this paper should be published after some moderate, perhaps major revision, if they deem some of the comments important enough and/or worthy of further exploration. I list my comments in random order - as I wrote them down when scrolling through the pdf.

1. Is it possible to express the numerical error as percentage of the rainfall error? If you make some simple assumptions about the rainfall error. Then you can use this as metric and show how it increases with rainfall intensity/duration. Same question about discharge measurement error. If one makes an assumption about 10% error (heteroscedastic) then one can express the numerical error as percentage of the discharge measurement error. One can show how this error evolves with time.
2. Then on a related note, can you investigate the relationship between numerical error and flow level (=discharge) ? May be interesting to see - as this, I believe, is not explicitly addressed in earlier studies. This should show that numerical errors are relatively large during rainfall events, and these errors dissipate during a subsequent drying period. This, dissipation is one reason numerics has not got the attention it deserves from the

community. I will revisit this point in a later comment.

3. Did you consider midpoint methods? Why/why not? Similar question for Runge-Kutta methods by the Carl Runge and Wilhelm Kutta? They developed a whole toolbox of explicit/implicit/fixed/variable time step integration methods. What about backward Euler? I know this implies more work, nevertheless, maybe there was a reason not to include these methods in your analysis - then, it would be good to know the reasons.

4. When it comes to Heun and Euler some papers are cited but the original inventors of these solution methods are not mentioned! I would include a reference to Leonhard Euler (*Institutionum calculi integralis*) and Karl Heun, among others.

5. One reason proper numerics receives little attention among surface hydrologists is the nature of hydrologic systems. Negative feedback loops ameliorate differences in initial states and promote convergence to a stable state. Indeed, for such systems one can simply use a spin-up period (as you use in the paper) to prepare the initial states of the model for subsequent simulation. In systems with positive feedback, numerical errors will have a devastating effect on long term behavior as model runs will diverge rapidly and suggest a very different system behavior later on. Thus, one reason that numerical errors have historically received relatively little attention is the nature of hydrologic systems, that is, negative feedback loops induce stable attractor states - hence, why we can solve poor knowledge of the initial states with a spin-up period. Note, in some fields, differential equations are so incredibly sensitive to numerics that these small errors can induce chaos (example: two-predator-two-prey systems).

6. The paper of Schoups et al: doi:10.1029/2009WR008648 draws similar conclusions as herein, that is, the use of a second-order integration methods is preferred. I believe the text should address this earlier paper and those possibly related to it more properly. The paper is cited, but the text does not address that similar findings have been reported elsewhere. On a related note, there are more surface hydrologic model codes that use proper numerics. For example, the hmodel of Schoups et al. (same paper) has been used in various publications. This model uses 2nd order adaptive Heun for its numerical solution.

7. You may want to emphasize in the paper that poor numerics not only affects the simulated discharge, but compromises tasks such as parameter estimation, prediction, simulation of related state variables (groundwater table, soil moisture), etc. Those familiar with proper numerical procedures are aware, but not all those others reading this manuscript.

8. I do not see anything else that is wrong with this paper (see my written comments on pdf), except that the questions listed above may help find a second hook to 'sell' this work. Climate change is an interesting hook, yet, one may argue that the precipitation intensities as used herein are a bit exaggerated. Maybe a more detailed investigation into

how numerical errors behave in a simulation may be interesting, their dependence on simulated flow level and simulated state variables. Perhaps even better, can you pinpoint which process in the model contribute most to the numerical error during precipitation extremes. This must be the most nonlinear process - or that process (its flux) that changes most rapidly in a time step.

Please see the attached supplement for other comments.

Please also note the supplement to this comment:

<https://hess.copernicus.org/preprints/hess-2021-28/hess-2021-28-RC1-supplement.pdf>