Summary

This study aims to demonstrate the importance of bedrock conductivity pattern, bedrock slope, and soil-bedrock conductivity contrast on streamflow recession using a theoretical (numerical) experiment. The authors conducted scenario analyses to explore how conductivity contrast at soil-bedrock interface, soil thickness, and porosity as well as bedrock slope impact the parameter "b" of recession analysis which shows the nonlinearity of recession response. They explored under which circumstances the homogeneous theory derived from the Boussinesq solution deems appropriate to interpret recession analysis.

Assessment

I enjoyed reading this manuscript. Bedrock conductivity pattern and soil-bedrock conductivity contrast could strongly control how catchments store, partition and release water and solute and thus they could control vertical distribution of flow-path and ultimately recession behavior. These controls are poorly understood and lack of consideration of such controls could lead to a misleading interpretation of recession analysis if one only relies on the homogeneous theory derived from the Boussinesq solution. This paper could be a very nice addition to HESS after some revisions and clarification.

Major suggestion:

This study conducted a set of analyses on the importance of parameter alpha (the rate at which Bedrock K declines exponentially) and D (upper compartment thickness or soil thickness) on recession non-linearity. But we cannot see figure or discussion on the importance of these parameters in the paper (except one fig in the appendix for max(b) only). There is one short statement in the paper that these two have had negligible impact on "*b*". I have hard time justifying this statement. Soil thickness and rate of exponential decline in K were showed to significantly control the way catchments partition and release water, particularly during low flow (see below citations). Some of the co-authors of the paper also previously showed that these two factors control recession non-linearity, using analytical solutions. I suggest that the authors further evaluate the impacts of these two and show some figures on these two parameters impact on *b*. Specifically, these two might be important at certain level of bedrock slope (beta) and soil-bedrock K contrast (rk). A sub-section of discussion can then discuss why and how the results of this paper are similar or different from previous literature. Knowing those levels of slope and rk that exaggerate the impacts of alpha and D on recession non-linearity could be very interesting.

Suggested citations: Below studies focused on the importance of soil-bedrock conductivity contrast and bedrock vertical conductivity pattern (and/or soil thickness) on how catchments store, partition and release water and solute. The authors may find it helpful to use some of these citations in the introduction to further emphasize the importance of their work.

[*Ameli et al.*, 2015; *Ameli et al.*, 2016; *Ameli et al.*, 2018; *Ameli et al.*, 2021; *Ameli et al.*, 2017; *Bishop*, 1991; *Cardenas and Jiang*, 2010; *Hopp and McDonnell*, 2009; *Janssen and Ameli*, 2021; *Jiang et al.*, 2010]

Other suggestions:

Line 16: "Responsible" is a strong word. We probably cannot safely declare that yet.
Line 28-29: I don't think Tashie et al and Jachens et al suggested "*strong* dependencies".
Figure 1c. Unit is not correct

Line 119. Are results (and final conclusions) sensitive to the initial value of KL and porosity

Line 124: Identical porosity across the interface is not a conservative assumption. Could you explain/discuss how it could impact the final result and conclusions

Line 182: I think figure 4 shows as rk increases, the recessions transition from lower values of -dQ/dt to higher values. Am I missing something?

Line 290: The evidence of "compartmentalized aquifer" can lead to anomalous b values is a solid conclusion obtained from this paper. But in real world, proving that anomalous b is due to "compartmentalized aquifer" could be tricky. I suggest to revise this sentence

Line 300: But this threshold of rk was obtained given other parameters such as D and porosity and etc remained constant. So, we cannot generalize it to other situation and the threshold of rk can only be generalized for certain values of other parameters. I mean, for different D or porosity, rk might be smaller or larger than 16.

Line 305: If I am not mistaken Fig 3 conveys different message. At later time b goes toward 1 (become smaller than earlier recession). Early recession is about 1.5 and late recession is around 1.

Ameli, A. A., J. Craig, and J. McDonnell (2015), Are all runoff processes the same? Numerical experiments comparing a Darcy-Richards solver to an overland flow-based approach for subsurface storm runoff simulation, *Water Resources Research*, *51*(12).
Ameli, A. A., J. J. McDonnell , and K. Bishop (2016), The exponential decline in saturated hydraulic conductivity with depth and its effect on water flow paths and transit time distribution, *Hydrological Processes*, *30*(14), 12.
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Bishop, K. H. (1991), Episodic increases in stream acidity, catchment flow pathways and hydrograph separation, University of Cambridge.

Cardenas, M. B., and X.-W. Jiang (2010), Groundwater flow, transport, and residence times through topography-driven basins with exponentially decreasing permeability and porosity, *Water Resources Research*, *46*(11), n/a-n/a.
Hopp, L., and J. J. McDonnell (2009), Connectivity at the hillslope scale: Identifying interactions between storm size, bedrock permeability, slope angle and soil depth, *Journal of Hydrology*, *376*(3-4), 378-391.
Janssen, J., and A. A. Ameli (2021), A hydrologic functional approach for improving large-sample hydrology performance in poorly-gauged regions, *Water Resources Research*, *57*(9), e2021WR030263.
Jiang, X.-W., L. Wan, M. B. Cardenas, S. Ge, and X.-S. Wang (2010), Simultaneous rejuvenation and aging of groundwater in basins due to depth-decaying hydraulic conductivity and porosity, *Geophysical Research Letters*, *37*(5), n/a-n/a.