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Discussions

Interactive comment on "Minimum dissipation of potential energy by groundwater outflow results in a simple linear catchment reservoir" *by* Axel Kleidon and Hubert H J. Savenije

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The manuscript by Axel Kleidon and Hubert H. G. Savenije presents a concept for explaining why catchments could behave like linear reservoirs. The theory assumes two coupled reservoirs draining into one catchment and consists of two parts. First it is shown that it is energetically favorable if both reservoirs are on the same groundwater level with respect to their river. Then it is shown that they behave like a single linear reservoir under this condition, and the resulting characteristic time scale is computed.

While I find the overall concept interesting and enjoyed reading the manuscript, I found some critical aspects among which one might even question the concept as a whole. In principle, my concerns addressed in the following have already been mentioned by the contributors to the discussion, Martijn Westhoff, Wouter Berghuijs, Sebastian Gnann, and Basudev Biswal.

Linearity of the catchment: There has been discussion to what extent real catchments behave like linear reservoirs. This point has also been pointed out by Basudev Biswal. I share the opinion that linear behavior is not a universal property, at least not at all time scales. There should indeed be more discussion on this aspect. However, even if I am personally not convinced of linear catchment behavior, this aspect does not question the merit of this study in my opinion. Explaining why some catchments are more linear than one might expect would also be valuable.

Linearity of the two reservoirs: As already pointed out by Martijn Westhoff, the authors assume that both reservoirs are already linear, which should be clarified.

Energy dissipation of the flow between the two reservoirs: This point was already raised by Martijn Westhoff. They authors neglect the energy consumed for the flow between the two coupled reservoirs. I guess that the total energy dissipation would be constant if this component was taken into account, so that there would be nothing left to minimize. The explanation given in the paper is indeed somewhat weak. On the other hand, models involving optimization often minimize only some components where the reasons are sometimes not straightforward. So this point would also require more explanation, but would not be crucial in my opinion.

Time scale of the flow between the two reservoirs: The authors assume that the optimization holds for all times, so that the two reservoirs are at the same groundwater level at each time. This implies that flow between the reservoirs takes place instantaneously and without any limitation. In other words, the time scale of this flow must be zero or at least be much smaller than the time scale of the faster of the two reservoirs. This point was raised by Sebastian Gnann, and the question about stationarity asked by Wouter Berghuijs goes into the same direction.

This assumption appears to be unrealistic to me. What could be a structure of two reservoirs where the communication between both is much faster than their drainage to the river? If we release this restriction, i.e., if we only assume that the two reservoirs always want to be in an optimized state, but adjustment involves a finite time scale τ_{ab}, the entire result would be lost. We would then get stuck at a superposition of two exponential recession curves where the two time scales are determined by the eigenvalues of the matrix

$$A = \begin{pmatrix} \frac{1}{\tau_a} + \frac{1}{\tau_{ab}} & -\frac{1}{\tau_{ab}} \\ -\frac{1}{\tau_{ab}} & \frac{1}{\tau_b} + \frac{1}{\tau_{ab}} \end{pmatrix}.$$

Then the optimization would not change anything on the behavior that two linear reservoirs yield a superposition of two exponential recession functions, only with different characteristic time scales.

And if we accept that this time scale must be zero, so that the reservoirs are always at the same groundwater level? Would we still consider them as two distinct reservoirs? Or is it not rather a single reservoir then? In this case, the results would not be very surprising.

The last aspect seems to be critical to me as it might challenge the whole concept. I hope that there will be more contributions to the discussion about this point as I may also be wrong with this concern.

Best regards,

Stefan Hergarten

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