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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Evaluating the effect of partial contributing storage on storage–discharge function from recession analysis" *by* X. Chen and D. Wang

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Hydrograph recession as a maturing field of mathematical hydrology

1. Introduction

I enjoy reading in an open forum the discussion paper by Chen and Wang (2013). From a personal perspective of what may be called the "mathematical hydrology" or mathematics of hydrology, I would like to offer comment on their recession analysis methodology described in their Sect. 2.1

2. Methodology

They start their equation (Eq. 1) from the Brutsaert-Nieber recession flow model, $-dQ/dt = aQ^b$ (e.g., Brutsaert, 2005). Integrating Eq. (1) yields:

$1/Q^{b-1}(t) = 1/Q^{b-1}(0) + (b-1)at$, ...(D1)

and in a conventional form:

$Q(t) = [Q^{-(b-1)}(0)+(b-1)at]^{-1/(b-1)}$. ....(D2)

Equation (D2) in fact is an "Eve" of most nonlinear baseflow models (e.g., Ding, 1966; Brutsaert, 2005). This is an analytical solution of the Boussinesq equation representing an outflow hydrograph from a cross section, perpendicular to a stream, of an unconfined aquifer. It is thus most applicable to hillslopes and zero-order catchments, and then to first-order streams, i.e. small watersheds.

Equation (D1) represents a linear relation between the inverse fractional power (IFP) transformed discharge $1/Q^{b-1}(t)$ and the elapsed time t, so that the recession curve appears as a straight line on a semi-IFP plot (Ding, 1966, 2012). Being a linear form, the IFP transformed recession line is independent of the size of time step (Δt), compared to the Δt- dependent $(-dQ/dt)$ term in the recession plot.

The storage can be inferred from observed baseflow by integrating an elementary volume, Qdt, from time t to infinite:

$S(t) = \int_t^{\infty} Qdt = S(0) + [1/(2-b)][1/a]Q^{2-b}(t)$. ....(D3)

This form is identical to their Eqs. (5a) and (5b).

Their Eq. (3), based on reasoning on physical grounds, can be derived backward by differentiating Eq. (D3),(5a) or (5b).

3. Effect of evaporation

In the derivations outlined above, evaporation has not been considered. Thus recession parameters a and b are independent of it, and need not be estimated at the lower envelop where the impact of evaporation is minimal (cf., page 5772, lines 18-19).

Evaporation is accounted for in their water balance equation (Eq. 2): $dS/dt = -Q - E$. This implies there are more flux pathways to the storage than the flow one alone. Among others, evaporation is thought to deplete or reduce the in-stream flow which in turn depletes the feeding or contributing aquifer storage. The flow is measured or measurable, but the storage is not, but inferable from flow measurements. The storage thus inferred is part of the contributing storage and need be adjusted upward for evapotranspiration loss.

For the purpose of this comment, the evaporation term (E) is considered in my view to represent the channel evaporation. In Tables 2a and 2b for the Spoon River (4,237 km^2) and Nodaway River (1,972 km^2), respectively, both not small in size by any measure, the estimated (channel) evaporation is all higher than the corresponding observed baseflow, thus not negligible (both rates mostly between 0.5 to 2 $mm.d^{-1}$).

4. Supplement

Figures 1 and 1S together show the recession plots of $log(-dQ/dt)$ vs. $logQ$ for all nine study watersheds.

I notice each of the data clouds can be fitted, objectively, by an additional linear regression line. This would simplify considerably the evaporation estimation procedure.

It may be beyond the current scope of Chen and Wang (2013) paper, but I encourage them to explore this statistical, regression alternative of fitting recession parameters.

Additional references

Brutsaert W.: Catchment-wide base flow parameterizations, Sec. 10.6 of "Hydrology: An Introduction," Cambridge Univ. Press, 2005. ISBN-10 0-521-82479-6.

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