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Hydrology and Earth System Sciences Discussions

Interactive comment on "Catchment classification: empirical analysis of hydrologic similarity based on catchment function in the eastern USA" *by* K. Sawicz et al.

Anonymous Referee #3

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The authors present preliminary results to support the use of available streamflow, temperature and precipitation data for classification of watershed (basin) function. The goal of watershed function classification is a current and active subject of research. The basic premise of this work, that existent hydrologic data can be used to provide clues for the underlying 'watershed classification' framework, is original and is carefully tested using up-to-date methodologies of data analysis and classification techniques.

Two conjectures (or hypothesis) emerge form their analysis: (**C1**) Streamflow elasticity with respect to precipitation is modified by the soil characteristics of a catchment. (**C2**)

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Spatial proximity is a good first indicator of hydrologic similarity because of the strong control climate exerts on catchment function, and because it varies slowly in space.

Several concerns regarding the validity of the conclusions reached on this paper arise. First, the analysis presented mixes basins of different size. Although, a histogram of the distribution of basin areas is not presented (and it should be), it is clear from Figure 2 that basin size varies significantly between the watersheds being considered. The authors do provide the range of basin areas (67 km^2 to 10,096 km^2), but it cannot be deduced from the available figures and results the role that total watershed area plays in the final classification results. There seems to be an implicit assumption throughout the analysis that the indexes used in the classification scheme are scale independent (or that they vary in the same fashion as a function of scale). My initial reaction is that this implicit assumption may be incorrect, rendering the two major conclusions of the paper (i.e. **C1** and **C2**) invalid.

In order to support (and explain) the argument above consider the physical processes occurring at a fix spatial scale: the hillslope scale. `Reviewer-3_Figure-1.png` illustrates how two of the indexes (F_{QP} and I_{BF}), can be strongly affected by hillslope/bedrock shape. Here, similar changes in the water table levels (from H1 to H2) can lead to very different ratios in the partition of subsurface and surface runoff due to uneven changes in the saturated area (variable source area). Notice, that nothing prevents two hillslopes with such different shapes to occur nearby to each other. Making the conjecture **C2** invalid at this scale. This example is only a conceptual illustration, but a more detailed study of the relation between the three dimensional shape of the hillslope/bedrock can be found in Troch et al (2003) and Hilberts et al (2004).

As watershed area increases, the number of hillslopes increases as well in a linear fashion (e.g. Gupta 2004), which tends to smooth out local effects, and watershed scale controls begin to dominate the basin response (e.g. soil types). What is the scale where those watershed characteristics begin to appear? This question is not addressed in this paper, nor it's demonstrated that the scales considered there are appropriate. But most importantly it is unclear that scale effects disappear at a given scale.

Consider the indicator R_{LD} used to quantify the 'flashiness' of a given watershed. This index provides a time scale (average slope) for the rising limb of the hydrograph. When comparing two basin of identical size, the index provides a good indicator of which of the two responds more rapidly to precipitation inputs. The index is strongly controlled by the topology and geometry of the river network and the spatial distribution of hillslope shapes. However, this index is not scale independent, which can create difficulties when comparing geographical distinct regions. In order to illustrate this issue, consider two basin of different size, thus having different concentration times (t_c), and assume that the unit hydrograph for those two basins can be given by a triangular hydrograph (see `Reviewer-3_Figure-2.png`). For the basin with t_c = 1 hr R_{LD} = 2, while for the basin with t_c = 10 hr R_{LD} = 0.2. Even though, the two basin exhibit the same slope for the rising limb they exhibit different values of R_{LD}. Thus, given that basins are a system of embedded watersheds, the class assigned based on this index would only apply to one scale on a geographical region. A similar argument can be developed for other indexes used in the analysis, that invalidate conjecture **C2**.

My final comment is in regards to conjecture **C1**. Here streamflow elasticity with respect to precipitation is evaluated at the annual scale. Although, the index provides a good measure of basin response for large scale basins ($>$ 10,000 km^2) where annual precipitation totals provide a good indicator of rainfall over the basin, for smaller scales, timing and intensities of storm events can be masked by this index (i.e. A basin will react differently to 100 mm of rain if they fall over 24 hours or over 1 hour). Thus two years with equal value dP/P and have widely different values of dQ/Q. The measure E_{QP} would be less robust for small watersheds than for large watersheds, where the effects of individual storm properties are smoothed out by the transit of the runoff on the river network (e.g. Rinaldo et al. 1991). I have conducted and independent study for the quantity E_{QP} for basins in Iowa to determine the extent of the effect of scale and the validity of the conjecture **C1**. in this geographical setting. My results reveal values of E_{QP} varying from -1 to 5, changing in a very random fashion from basin to basin and with very little geographical consistency, and no apparent correlation with soil types in Iowa. Also the results show more variability of the quantity for smaller basin than it does for large basin. Since, the manuscript does not report the range of values found by the authors (only the histogram of the normalized values are given) it is difficult for us to determine is the range of variability found in Iowa basins is small or large relative to the results observed for the dataset used by the authors. The file `Reviewer-3_Figure-3.png` shows the variability of the index as a function of area. (Note: we can prepare the results for sharing with the authors if they consider it would contribute to convey my opinion more clearly).

The current manuscript can be improved by addressing the issues raised above, and the authors are encouraged to describe in a more through fashion the underlying physical mechanisms described by selected classification indexes. The validity of the conjectures reached on this paper are pending on a detailed analysis of scale independence of the indexes in consideration. This issue needs to be clearly assessed and demonstrated before this work can be accepted for publication.

In addition to these major comments I suggest that the manuscript be thoroughly revised for consistency of the referenced material. Most of my concerns were already pointed out by the other reviewers, so I will not include them here to avoid duplication.

References:

Gupta. Emergence of statistical scaling in floods on channel networks from complex runoff dynamics. Chaos Soliton Fract (2004) vol. 19 (2) pp. 357-365

Hilberts et al. The hillslope-storage Boussinesq model for non-constant bedrock slope. J. Hydrol. (2004) vol. 291 (3-4) pp. 160-173

Rinaldo et al. Geomorphological Dispersion. Water Resour. Res. (1991) vol. 27 (4)

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Troch et al. Hillslope-storage Boussinesq model for subsurface flow and variable source areas along complex hillslopes: 1. Formulation and characteristic response. Water Resour. Res. (2003) vol. 39 (11) pp. 1316

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 4495, 2011.

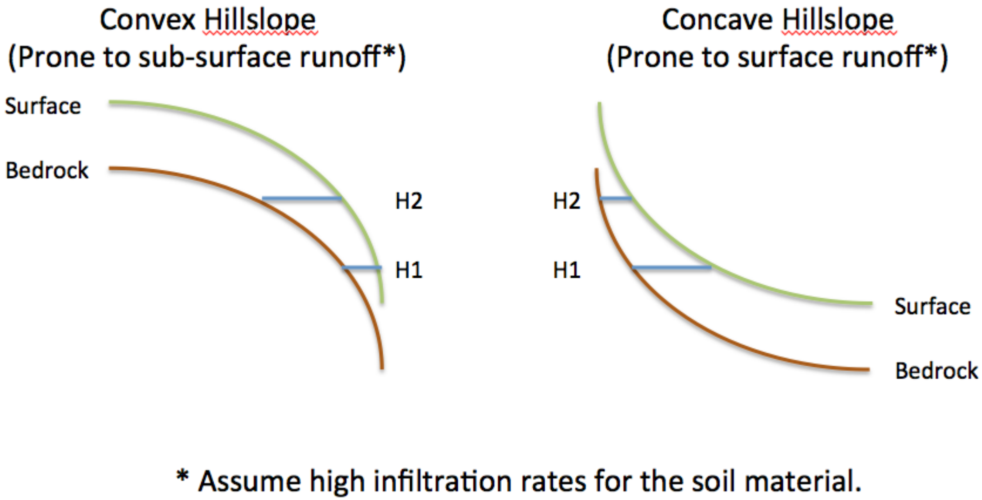
Convex Hillslope
(Prone to sub-surface runoff*)
Surface
Bedrock
H2
H1
Concave Hillslope
(Prone to surface runoff*)
H2
H1
Surface
Bedrock
* Assume high infiltration rates for the soil material.

Fig. 1.

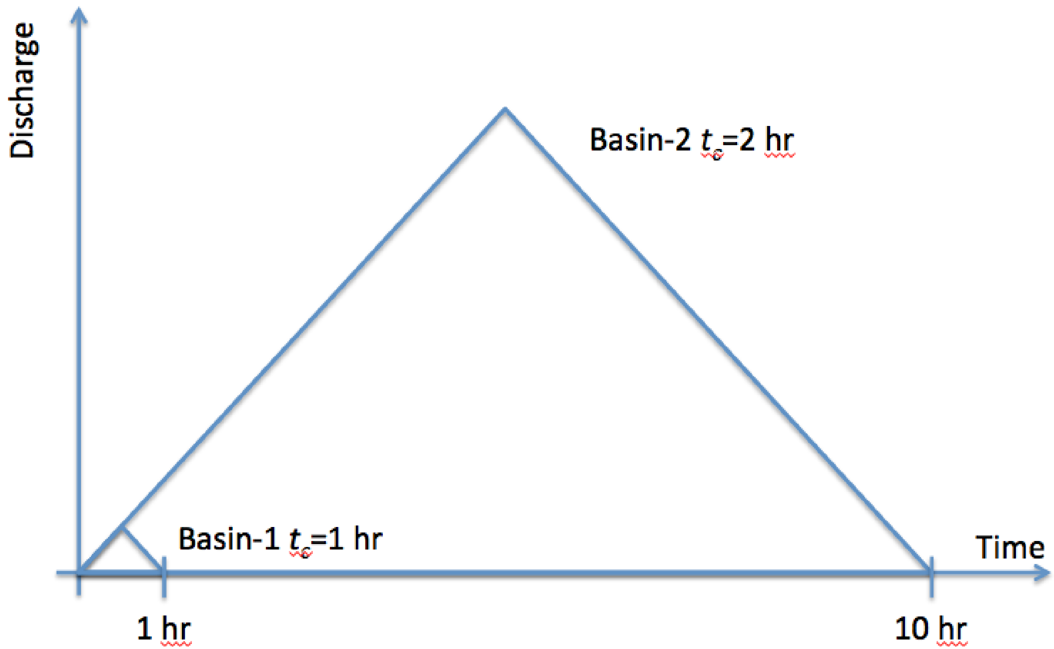

Fig. 2.

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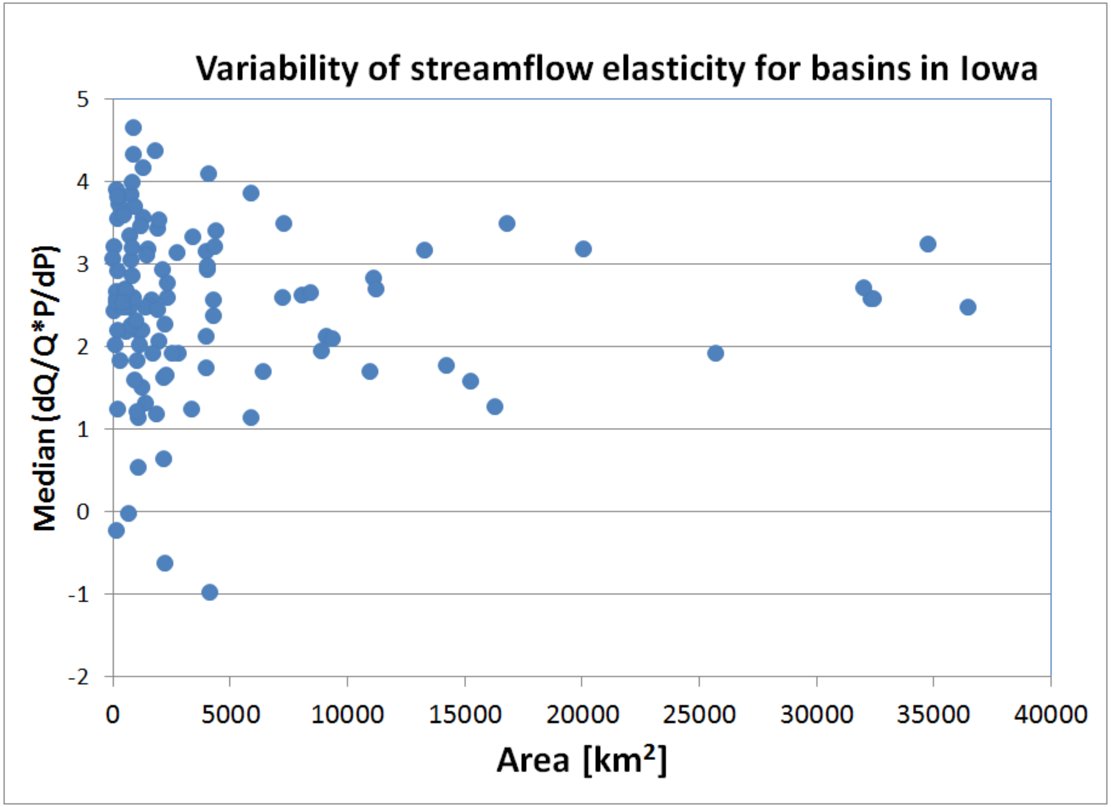

Fig. 3.

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