Reply to Editor's Comment

Dear Authors,
unfortunately quite a few of your recent corrections in response to the reviewer's comments still require some work. In several instances it is not really possible to understand the meaning of what you are trying to say.
I have added some comments in your response as well as at the beginning of the track changes document, but please also go over the remaining changes and clarify and correct the english where necessary. Some of my comments appear only in the response but also apply to the manuscript.
Please also make sure that the corrections are made not only in the one line the reviewer references but also in the other instances throughout the manuscript.
Please note that you need to download the pdf to see all the comments as not all of them appear when viewing the pdf in the browser
Once these things have been clarified and corrected I will review the manuscript again.
All the best,
Theresa

Reply:
Dear Theresa,

We extend our gratitude for your meticulous review of our manuscript. We have addressed all the comments you highlighted in our previous communication and made necessary revisions to the manuscript. We thoroughly revised the manuscript and clarified the ambiguous sentences. Mainly revisions are in the abstract, landscape variable [L82-92], and discussion 4.2.1 [L279-289]. Also, Table S3 which illustrated the definitions and calculations of hydrologic-event and landscape variables was clarified and revised. We have also ensured that all responses in the manuscript are correspond to the appropriate corrections.

Best regards,
Jr-Chuan (River) Huang

SPECIFIC COMMENTS

(in response)

"*Also, we conducted a comprehensive review of the vocabulary and grammar throughout the entire manuscript.*"

This still needs to be improved, especially in the newly added text.

Reply: We have diligently refined the revised manuscript and engaged a native speaker to further enhance the precision of our text.

"*Without considering this contrasting response, which is contingent upon landscape structure, it leads to a misjudgment of the recession nonlinearity in response to rainfall amount and needs further clarification, particularly for use in assessing regional recession in ungauged catchments under climate change.*"

This sentence is not clear and needs to be rephrased.

Reply: In this version, we rephrased the abstract thoroughly and highlighted our three new findings. For the last two sentences, now it reads, "Our finding that *L*/*G* and drainage area might regulate the contrasting response of recession along rainfall amounts requires additional validation in different regions since recession response is crucial when assessing regional recession in ungauged catchments under the influence of climate change." [L20-24]

"*For example, it is not enough to only state that the value of b decreases as L/G increases. What is the significance of L/G? What does it represent with regards to what influences the flow of water through the catchment What does it imply in terms of subsurface flow that b decreases as L/G increases?*"

This should be answered in the manuscript and explained in more detail.

Reply:

To clarify the composite L/G ratio, we have revised several sections of the manuscript, including the abstract, material and methods, and discussion.

In the abstract [L16-17], we added a short definition of *L* and *G*. Now it reads, "(*L*: median of flow-path lengths within a catchment; *G*: median of flow-path gradients within a catchment)".

In the material and methods [L82-92], we rewrote the paragraph to provide a clear definition, explanation, and simple calculation of flow path variables. It is, "In addition to the primary landscape variables described above, we incorporated flow path associated variables into our study, as flow path is an explicit proxy for aquifer systems. Within a gridded DEM, the flow path is defined as the route followed by water from a grid cell, following the surface flow direction towards the channel cell (see detail in Tetzlaff et al., 2009). Specifically, flow path length *L* [m] is the length of this route, flow path height *H* [m] is the elevation difference between a specific cell to the channel cell, and *G* is the flow-path gradient [-], defined as defined as the flow path height divided by flow path length. As such,

every grid cell possesses distinct values for *L*, *H* and *G*. Within a catchment, the medians of the *L*, *H*, and *G* distributions serve as representative flow path characteristics. Note that *G* can also be regarded as a surrogate of flow velocity (most equations used for estimating flow velocity needs gradient to represent the conversion from potential to kinetic energy). Therefore, the composite ratio, *L*/*G* [m], can be a proxy for residence time (McGuire et al., 2005; Tetzlaff et al., 2009) and as a means to comprehend the interplay between landscape features and climate impacts on residence time (Seybold et al., 2017). The detailed definition and calculation of the flow path associated variables are illustrated in Table S3 in the supplement."

In discussion 4.2.1 [L279-289], now it reads, "Our variable *H*, which exhibits a negative correlation with the recession coefficient, likely suggests that our groundwater flow paths possess greater depth and length, consequently leading to slower drainage rates. Although flow path height, *H*, denoting potential energy is a component of gradient, it does not necessarily correspond to hydraulic gradient due to the geologic and soil settings varying across regions (Karlsen et al., 2019). Besides, high *DD* and short *L* indicate shorter flow paths and thus lead to a higher recession coefficient. In our cases, Type C catchments are characterized by short *L* and very small *H* and thus have high *L*/*G* ratios and recession coefficients (solid orange dots in Fig. 7c). Individually, extended *L* or gentle *G* is conducive to flow accumulation. Thus, the *L*/*G* ratio, which integrates both length and gradient, serves as a good proxy for estimating residence time (McGuire et al., 2005; Asano and Uchida, 2012). While the equivalent composite ratio can result from either *L* or *G*, the relationship between recession parameters and *L*/*G* has the potential to establish a further linkage between recession parameters and water residence time."

Hope the revised text expresses the intended meaning more effectively.

"*landscape structure*"

Not clear.

Reply: Landscape structure in our study is interpreted by hillslope hydraulics (L/G) and inter-hillslope heterogeneity (A). While we have introduced this term in the introduction to convey the general concept, we employed the terms L/G and A in the main body of the text to provide specific emphasis.

"*Therefore, we addressed it in L81-88 and added a new Table S3 in supplementary for describing the definition and calculation of landscape and rainstorm variables.*"

Not enough.

Reply: Please see reply above. Besides, Table S3 has been revised.

"*Specifically, from the aspect of aquifer hydraulics (Rupp and Selker, 2006), spatial heterogeneity (Harman et al., 2009) and drainage network (Biswal and Marani, 2010) have been observed that these*

recession parameters are influenced by the aforementioned factors."

Sentence does not work, needs to be fixed.

Reply: We have removed this sentence since the following sentences explained the works.

"*Additionally, theoretical works have shown that the dependence of streamflow recession parameters on antecedent storage or rainstorms.*"

Needs to be fixed.

Reply: Fixed. Now it reads, "Additionally, theoretical studies have demonstrated that streamflow recession parameters are subject not only to the influences of landscape and aquifer systems but also to the interplay with antecedent storage and rainfall events" [L39-40]

"*the downstream*"

Not a noun.

Reply: We replaced "the downstream" with "the downstream channel" [L44] and [L45].

"*Replied above.*"

Where? should be stated in the manuscript text

Reply: In the introduction section of this version, paragraph #2 and #3 demonstrated the theoretical works and paragraph #4 expressed the empirical studies.

"point-cloud"

this also needs to be explained in the methods section, where you suddenly switch from single recession curves to the so-called point cloud.

Reply: In the methods section, we have revised the sentence introducing the term "point-cloud": "One approach involves fitting the lower envelope of a collection of multiple recession curves, which is referred to as point-cloud (Brutsaert and Nieber, 1977)."[L150-151]

"The flow path is defined as the hillslope grid point following the surface flow direction toward channel."

Not clear. A point cannot be a path

Reply: Please see reply above. We rephrased the paragraph [L82-92] to interpret the definition and calculation of flow path associated variables.

"*Among them, the composite ratio of L/G, which represent the distance effect of flow-path under different gradient holds hydrologic significance as it can serve as a proxy for water residence time (McGuire et al., 2005; Tetzlaff et al., 2009).*"

Explain why this can serve as a proxy for residence time and what you mean by composite ratio.

Reply: We rephrased the sentences in [L88-91]: "Note that *G* can also be regarded as a surrogate of

flow velocity (most equations used for estimating flow velocity needs gradient to represent the conversion from potential to kinetic energy). Therefore, the composite ratio, *L/G* [m], can be a proxy for residence time (McGuire et al., 2005; Tetzlaff et al., 2009) and as a means to comprehend the interplay between landscape features and climate impacts on residence time (Seybold et al., 2017)."

"detailed"

Reply: Revised as suggested [L92].

Table S3: This table contains errors in units and definitions. The explanations for how variables are calculated are often not clear and need to be improved.

Reply: Revised thoroughly. Please see the new Table S3.

"the supplement"

Reply: Revised as suggested [L92].

"Is G = H/L? Is L/G, therefore, simply L/(H/L) = L^2/H? If so, what does L^2/H say about landscape structure that simply G (or 1/G = L/H) alone does not?"

I have the same question and don't feel that you answer it below. We need a better explanation for the calculation and meaning of L/G.

Reply:

L and G are the length and gradient of the flow path. Since the gradient is an important variable for estimating velocity, the composite L/G ratio could be imagined as a kind of time due to distance over velocity. Therefore, L/G represent the hillslope hydraulics and it explained why L/G is a good proxy for water residence time at catchment scale.

For variable selection, the variables of H, L, L/G and DD shown in Fig. 7 are highly correlated with recession parameters. Our focus on the composite L/G ratio aims to underscore its potential in establishing a linkage between recession parameters and water residence times.

"The composite L/G ratio represents the distance effect of flow path under different gradient"

I don't understand this.

Reply: Replied above.

"Given how much of the discussion on the results centers on L/G, it is important that its geomorphic/hydrologic/hydraulic significance be stated. Reply: Replied."

Need a better explanation than what you gave above

Reply: Replied above.

How does a large value of L/G imply a "short-and-gentle" hillslope?

This does not answer the question and the correction in the ms is missing.

Reply: Apologies for the unclear interpretation. The large L/G value certainly is derived from a long flow path or gentle G. However, our Type C catchments are characterized by short *L* (Fig. 7b) and very small *H* (Fig. 7a) and thus have high *L/G* ratios (Fig. 7c). We have rewritten this paragraph [L279-289] for clarification.

"*Actually, "b" is the slope in a plot of log(-dQ/dt) vs log(Q).*"

This should be corrected throughout the ms and not just in this one line!

Reply: Our apologies. This time, we have checked throughout the manuscript and made the necessary corrections [L31].

"*Reply: We observed that when the drainage area larger than 800 km2, the point-cloud derived coefficients become similar to the third quantile of the coefficient distribution from individual segments [L197].*"

Explanation should be added to ms.

Reply: We had added the following sentence to the manuscript in [L201-202]: "Notably, when the catchment size exceeds approximately 500 km^2 (W19), the point-cloud-derived coefficients become similar to the third quantile of the coefficient distribution from individual segments."

"*described the calculation methods*"

Needs to be improved and in part corrected

Reply: We improved Table S3. We modified the gridlines of Table S3, correcting the unit of DD to [km km-2], changing the "meaning" column to "definition and meaning." We have also rephrased the calculation methods for each variable.

"*the superimposition of recession events on antecedent flows*"

Not clear, please rephrase

"*The negative correlation between b and peak flow does not necessarily imply a consistent response across all catchments.*"

I don't understand this

Reply: We rephrased in [L328-332]: "Across all catchments, we observed an augmentation of exponent *b* with antecedent flows, but a decline with peak flow (Fig. 5). This augmentation can be attributed to the overlay of recession event flows onto antecedent flows, amplifying the value of *b* (Jachens et al., 2020). The inverse correlation between *b* and peak flow suggests that in the majority of catchments, the existence of active fast flow paths could potentially reduce the recession nonlinearity.".

Replace “than” with “compared to those derived from”

Reply: Revised as suggested [L235]. Thank you.

“*we have a deeper and longer groundwater flow system and thus drainage slowly*”

English needs to be fixed, also groundwater flow systems cannot really be long, only flow paths.

Reply: We rephrased it as “our groundwater flow paths possess greater depth and length, consequently leading to slower drainage rates.” [L280-281]

(in the track change document)

L10: are these supposed to be two different things? Not clear.

Reply: We rephrased it as “landscape structures and rainstorms are recognized as drivers of recession response” [L10].

L10-11: needs to be rephrased.

L11: Logical flow not clear. Why "yet"?

Reply: We rephrased the first two opening sentences. Now it reads, “Streamflow recession reflects hydrological functioning, runoff dynamics, and storage status within catchments and landscape structures and rainstorms are recognized as drivers of recession response. However, the documented recession responses to landscape structure and rainstorms are inconsistent, and there are fewer studies that concurrently investigate the combined effects of these two factors on recession.” [L9-12].

L13: be is the exponent in the equation, I don't think it is called "the nonlinearity"

Reply: Checked. In this version, when talking about equation or parameter, we used exponent b. For describing the recession behavior, nonlinearity is used.

L16: not clear, this is not quantitative and therefore it is not clear how something increases with structure. It is also completely unclear what you mean by landscape structure.

Reply: As suggested, we only used the term “landscape structure” to convey the general concept, but used specific variables like L/G and A to express the relationships. Now it reads, “Our finding that *L*/*G* and drainage area might regulate the contrasting response….” [L21].

L18: the exponent of the recession model and therefore

L19: replace “Without” with “Not”

L19-21: not clear. Are you saying we normally are just guessing recession model parameters for ungauged basins? Why and under which circumstances would we do that? Not clear what you are trying to say here.

Reply: We rewrote the abstract to increase its readability. Now it reads, “Our finding that *L*/*G* and drainage area might regulate the contrasting response of recession along rainfall amounts requires

additional validation in different regions since recession response is crucial when assessing regional recession in ungauged catchments under the influence of climate change." [L20-24]

L24: not clear. Runoff does not exist in plural form. What do you mean by different runoffs?
L24: the streamflow recession and its link with flow
Reply: We replaced "runoff" with "flow paths" and rephrased as suggested [L26]. Thank you.

L26: why is this equation different to the one in the abstract?
Reply: The recession parameters of the equation in the abstract were decorrelated, which differs from the equation in the original Brutsaert and Nieber (1977) version. For simplification, we eliminated the equation in the abstract.

L26: not the correct term
Reply: We replaced "streamflow declines" with "the rate of change in streamflow" [L28]

L26: describe the recession
Reply: Revised as suggested [L28].

L28-29: this is something that the reviewer corrected (see line 125), Why did you only correct it there but not here?
Reply: Apologies for only revising [L116] earlier. This time, we have checked throughout the manuscript and corrected it [L31].

L32-34: sentence needs to be fixed
Reply: We removed this sentence since the meaning of the sentence had already been explained in the previous statement.

L50: The exponent b slightly increases...
Reply: Revised as suggested [L43].

L52: downstream is not a noun
Reply: We replaced "the downstream" with "the downstream channel" [L44] and [L45].

L59-60: Most previous studies aggregated long-term data to a point-cloud, a collection of multiple recession curves *to* retrieve representative recession parameters
Reply: Revised as suggested [L51-52].

L67: streamflow

Reply: Revised as suggested [L57]

L69: I would not use this as a synonym for b

Reply: We replaced "nonlinearity" with "exponent" [L60]

L124: what is the difference to a?

Reply: $\hat{a} = ak^{b-1}$. We have elaborated on the rationale for this relationship in [L163-167]: "An important concern in recession parameter estimation is the dependence between $\hat{a}$ and b, which confounds the interpretation of parameters (Dralle et al., 2015). The decorrelation method assumes that the observed flow, Q, consists of a scale-free flow $\hat{Q}$ and a constant k ($Q = k\hat{Q}$). Thus, the power law formula can be rewritten as $-dQ/dt = ak^{b-1}\hat{Q}^b$, where a is the scale-free recession coefficient [h^{-1}]. For correcting $\hat{a}$ to a, the observed flow Q was divided by a constant Q_0 (which is ideally equal to $1/k$, see detail in Dralle et al., 2015)".