Dear Editor,

In their interesting paper, “Changes of Nonlinearity and Stability of Streamflow Recession Characteristics under Climate Warming in a Large Glaciated Basin of the Tibetan Plateau”, the authors examine changes in the parameters *a* and *b* of the power law recession equation given by $-\mathrm{d}Q/\mathrm{d}t = aQ^b$. Between two periods of years (1980-1996 and 1997-2015), they calculate an increase in *b* in five basins and a decrease in *a* in four of five basins. To the overall decrease in *a*, or log(*a*), they ascribe a physical significance: a decrease in “streamflow stability”.

However, no such physical significance to be ascribed to changes in *a* alone when *b* also changes. The problem arises from the units *a*, which change as *b* changes. The authors are making a nonsensical comparison of two values with different units and claiming one value is less than another.

A consequence of the scale dependence of *a* is that the reported change in *a* over time is dependent on the units the authors use for discharge *Q*. If they were to use different units (in other words, rescale *Q*), not only might the absolute and relative magnitudes of the change in *a* be different, so could the sign of the change (and zero change is also possible given the precise rescaling).

We can take basin YBJ as an example. Table 3 shows values of *a* decreasing from 0.043 to 0.034 when *Q* has units of mm/day. At the same time, *b* increases from 1.79 to 1.90. Converting units of *Q* to m/day, and keeping *b* at 1.79 and 1.90, results in values of *a* of 9.41 and 17.04, respectively (assuming the relationship $-\mathrm{d}Q/\mathrm{d}t = aQ^b$ holds exactly). Converting units from mm/day to m/day doesn’t simply change the values of *a*, but results in an *increase* in *a* instead of a *decrease* over time. Certainly, if the reported changes in *a* had a physical significance, simply changing the units wouldn’t change the physical interpretation.

The same general problem of misinterpretation exists in their examination of *a* as a function of temperature.

I recommend that the authors be very careful in their interpretation of changes in *a* under simultaneous changes in *b*. I also recommend the authors look to Dralle et al. (2015) and Biswal (2021) for further discussion on the relationship between the power law coefficients.

Lastly, on the more general topic of the role of climate on the variability of the *b* parameter, the authors could look to Jachens et al. (2020) for additional discussion.

Sincerely,
David E. Rupp

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Reply: We thank Dr. Rupp for his comments and suggestions that help us to reevaluate the recession methodology used in our study.

We agree with his comment that "A consequence of the scale dependence of a is that the reported changes in a over time is dependent on the units for discharge Q." The scatterplot of the values of log(a) and b according to Eq. (1) in our original manuscript is shown in Fig. r1 (a)-(e). It shows strong and significant correlation between log(a) and b values. Their correlation coefficient r ranges from 0.78 to 0.89 for the five sub-basins in YRB.

We recalculated the parameter a' after scaling a with q_0 and a'' for fixed b in each sub-basin based on the recession approaches in the two articles recommended by Dr. Rupp (Dralle et al., 2015 and Biswal 2021). We found that the exponential decrease of a' and a'' in response to the rise of temperature still exists for the sub-basins except for LS which is affected by reservoir regulations. We interpret our recalculation procedures and results as the follows.

(1) The rescale method

According to Dralle et al. (2015), we rescaled discharge Q by $Q = k\hat{Q}$ and obtained a power law relationship for the rescaled discharge $\hat{Q}$

$$\frac{d\hat{Q}}{dt} = -ak^{b-1}\hat{Q}^b = -a'\hat{Q}^b \tag{1}$$

where k is a constant and $a' = ak^{b-1}$ is a new recession parameter independent of b, and the unit of a' is day^{-1} (Dralle et al. 2015).
In order to minimize the correlation of the fitted recession exponents and log-transformed fitted recession scale parameters for a unique value of q_0, we use the following equation to compute the scaling factor q_0 (Bergner and Zouhar, 2000):

$$q_0 = \exp\left(-\frac{\sum_{i=1}^{n}(b_i-\bar{b})(log(a_i)-\overline{\log(a)})}{\sum_{i=1}^{n}(b_i-\bar{b})^2}\right) \tag{2}$$

where $\bar{b}$ and $\overline{\log(a)}$ are the arithmetic means of annually fitted recession exponents $\{b_1, b_2, \dots, b_n\}$ and log-transformed fitted recession intercepts $\{\log(a_1), \log(a_2), \dots, \log(a_n)\}$, respectively, and i is the number of annual values from 1980 to 2015.

The calculated q_0 from (2) is 0.527, 0.602, 0.740, 0.594, and 0.611 mm·day^{-1} for the sub-basins of NGS, YC, NX, YBJ, and LS, respectively. After scaling with q_0, the scatterplot of log(a') and b is shown in Fig. r1 (f)-(j). As expected, there are no correlations between the two recession parameters for the study sub-basins.

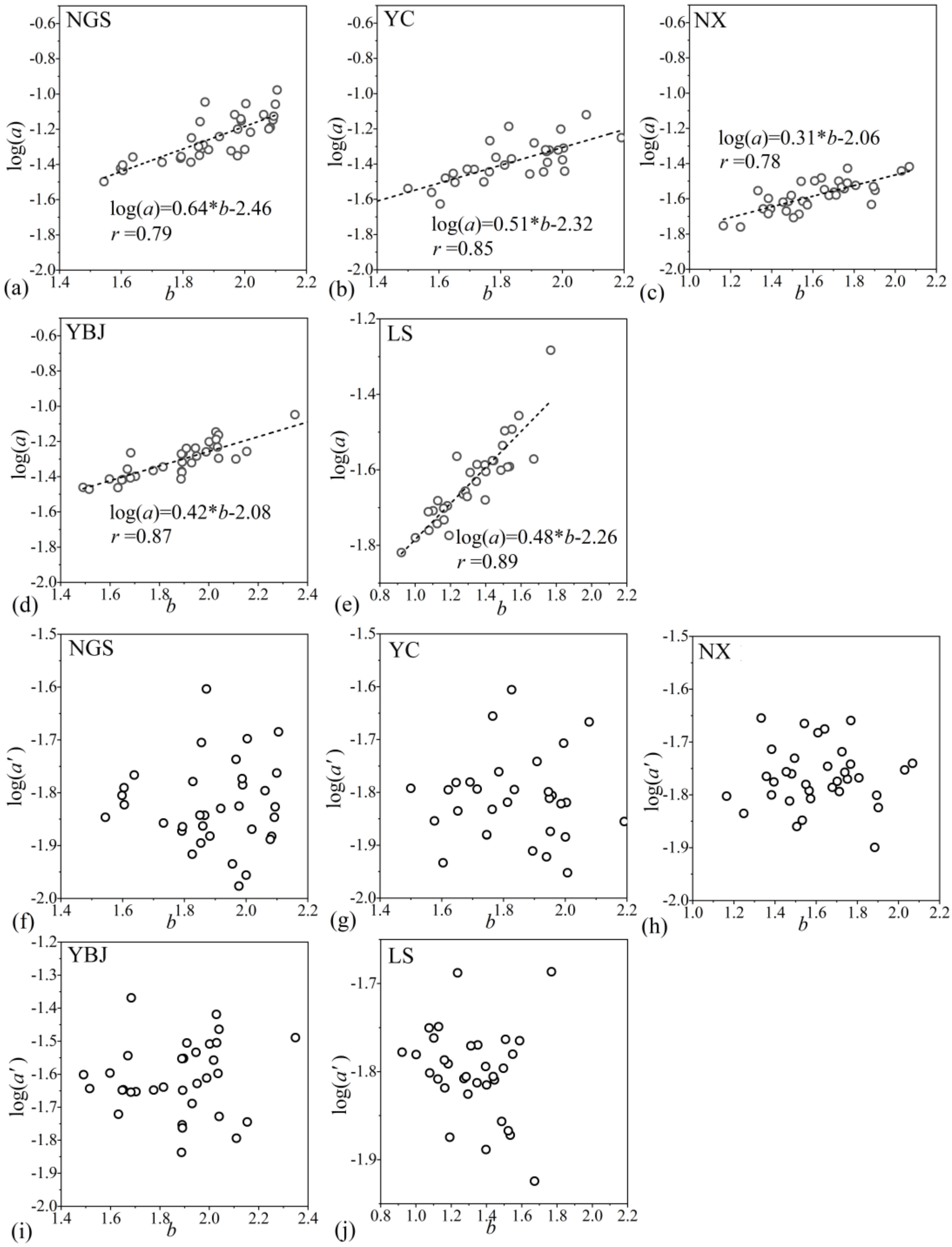

Figure r1: (a)-(e) Scatterplots of the values of log(a) and b, and (f)-(j) scatterplots of log(a') (after scaling with q_0) and b in years from 1980 to 2015 for the sub-basins of NGS, YC, NX, YBJ, and LS.

However, the scatterplot of a' (after scaling with q_0) and mean temperature (T_{re}) during recession period (Fig. r2) shows that a' still decreases exponentially with rising T_{re} for the sub-basins except for LS with reservoir regulations. Also, the mean a' values in the recent warmer period of 1997–2015 are smaller than those in the previous period of 1980–1996 for the sub-basins NGS, YC, NX, and YBJ as listed in Table A1.

After transforming into the correlation free representation, the b values do not change as stated by

Dralle et al. (2015). So, *b* exponentially increases with the rise of T_{re} for the five sub-basins as shown in our original manuscript.

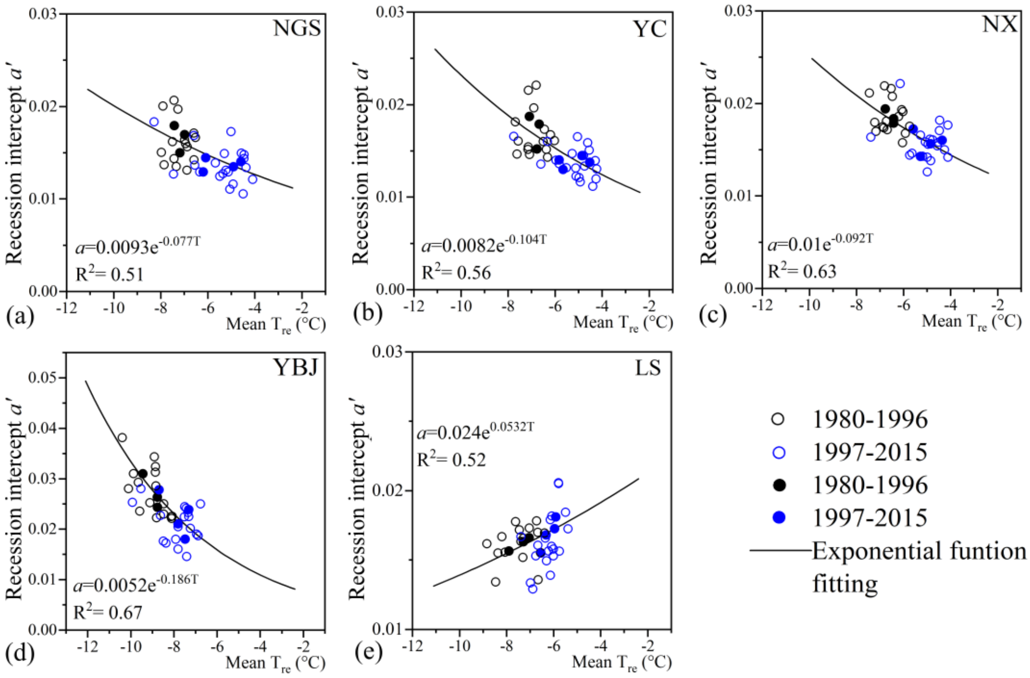

Figure r2: The exponential function of *a′* (after scaling with q_0) with mean temperature (T_{re}) during recession period. The solid and open circles represent 4-year average and annual value, respectively.

(2) The fixed *b* method

According to the approach proposed by Biswal (2021), we selected the median of annual *b* in the period of 1980-2015 as the fixed *b* value for each sub-basin (Table A1), and then fitted the values of annual *a* (i.e. *a″* in Table A1) using the method in our original manuscript (Section 3.2).

The scatterplot of *a″* (under fixed *b*) and the mean temperature (T_{re}) during recession period (Fig. r3) also shows that *a″* decreases exponentially with the rising T_{re} for the sub-basins except for LS. The mean *a″* values in the recent warmer period of 1997-2015 are smaller than those in the previous period of 1980-1996 for the sub-basins of NGS, YC, NX, and YBJ as listed in Table A1.

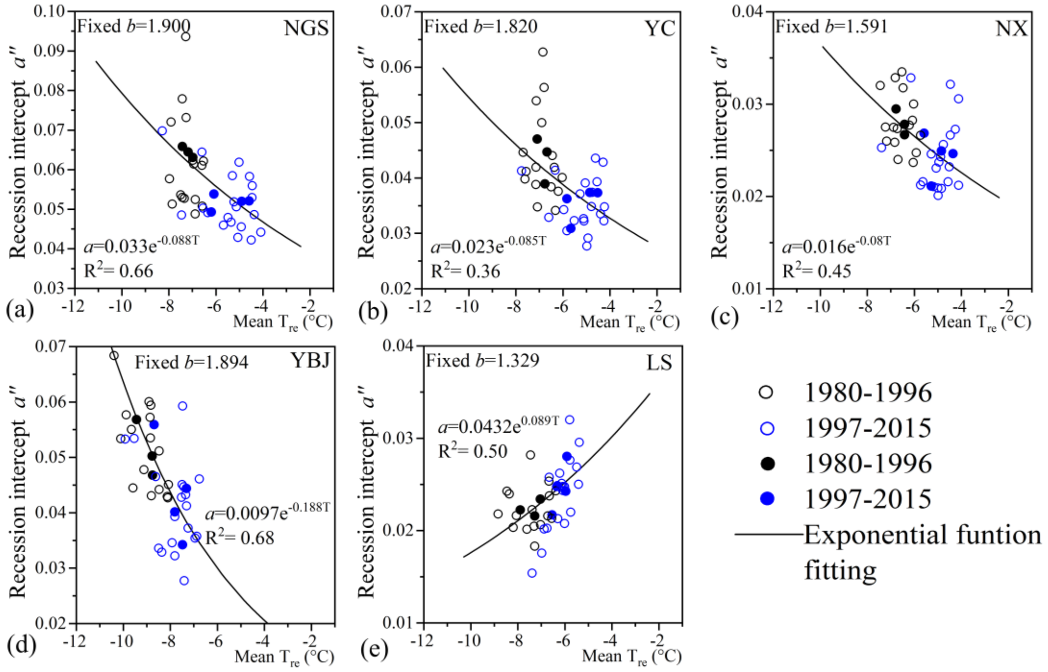

Figure r3: The exponential function of a'' (under fixed b) with mean temperature (T_{re}) during recession period. The solid and open circles represent 4-year average and annual value, respectively.

(3) The physical interpretations

The exponential decrease of annual values of a, a' (after scaled with q_0), and a'' (under fixed b), and the increase of b with the rise of T_{re} in the study sub-basins reflect a physical significance of the recession behavior due to climate warming in our study region.

We will revise the manuscript and add detail as follows: the accelerated glacier melting and permafrost thawing have increased the effective hydraulic properties (Lamontagne-Hallé et al., 2018) and the soil active layer thickness (ALT) for groundwater storage. The increase of hydraulic conductivity reduces the buffering effect of soils on streamflow variability and thereby increases the baseflow recession rate. This phenomenon can be identified from the observed hydrographs which suggest that the initial recessions are faster in the warmer period of 1997-2015 for the sub-basins of NGS, YC, NX, and YBJ (Fig. r4). On the other hand, the increase of ALT strengthens aquifer regulations on groundwater flow and slows down the recession rate. This phenomenon can be distinguished in the late slow recession period as shown in Fig. r4. The decrease of a and a' and the increase of b with the rise of temperature suggest a decrease in streamflow stability and an increase of nonlinearity in time in the study region.

As to the report by Jachens et al. (2020), they suggested that the recession parameters assessed by considering the average (or median) values of a and b do not represent watershed properties as much as they represent the climate, and proper evaluation of watershed properties is only ensured by considering independent individual recession events. In our study sub-basins, however, since there is a single hydrograph in a year, the discharge recedes in a long period of time (from September to February of the following year). Thus, the annual variations of the a or a' and b values from 1980 to 2015 in our study sub-basins can represent both the watershed properties and the climate.

Table A1: The median value of a (calculated from the data of the original manuscript), and mean annual parameters of a', a'', and b during different sub-periods. Here the parameters a' and a'' calculated by methods from Dralle et al. (2015) and Biswal (2021). The asterisk indicates significance with $p< 0.05$. The values in parentheses refer to the range of annual value.

Index	Period	Sub-basin				
		NGS	YC	NX	YBJ	LS
a	1980–2015	0.042 (0.033~0.060)	0.032 (0.025~0.043)	0.022 (0.019~0.027)	0.038 (0.025~0.052)	0.024 (0.018~0.032)
	1980–1996	0.046	0.035	0.023	0.043	0.022
	1997–2015	0.039	0.029	0.021	0.034	0.025
	Δa	-0.007	-0.006	-0.002	-0.009	0.003
a'	1980–2015	0.015 (0.011~0.025)	0.015 (0.011~0.025)	0.017 (0.013~0.022)	0.025 (0.015~0.043)	0.017 (0.012~0.022)
	1980–1996	0.017	0.017	0.019	0.027	0.015
	1997–2015	0.014	0.014	0.015	0.023	0.017
	$\Delta a'$	-0.003*	-0.003*	-0.004*	-0.004*	0.002
a''	1980–2015	0.056 (0.042~0.094)	0.039 (0.028~0.063)	0.026 (0.020~0.034)	0.047 (0.028~0.089)	0.023 (0.015~0.032)
	1980–1996	0.062	0.044	0.028	0.052	0.022
	1997–2015	0.051	0.035	0.024	0.043	0.024
	$\Delta a''$	**-0.011***	**-0.008***	**-0.004***	**-0.009***	**0.002**
b	1980–2015	1.85 (1.645~1.990)	1.70 (1.506~1.992)	1.54 (1.297~1.789)	1.85 (1.607~1.979)	1.36 (1.117~1.783)
	1980–1996	1.81	1.67	1.48	1.78	1.25
	1997–2015	1.89	1.73	1.59	1.90	1.37
	Δb	**0.08***	**0.06**	**0.11***	**0.11***	**0.12***
	Median	**1.900**	**1.820**	**1.591**	**1.894**	**1.329**

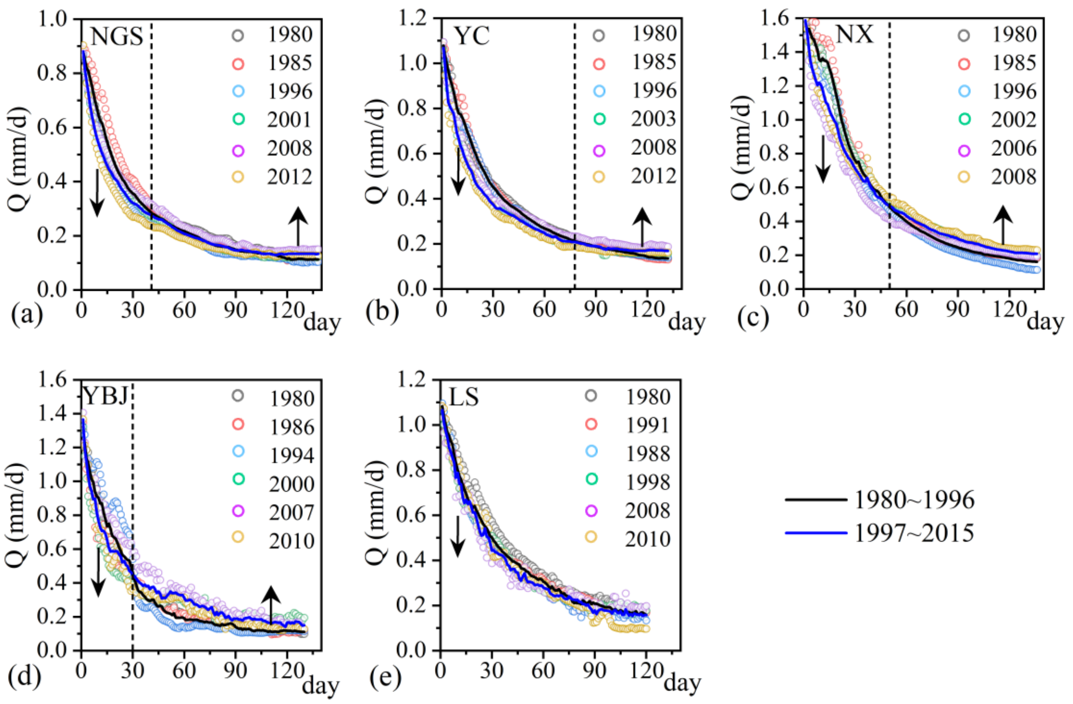

Figure r4: The discharge recession for the selected years with approximately the same initial discharge Q_0 in each sub-basin.

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