Dear Editor,

On behalf of my co-authors, we thank you very much for giving us the opportunity to revise the manuscript (Manuscript ID: **hess-2022-196**). We appreciate the comments on our manuscript entitled "*Attributing trend in naturalized streamflow to temporally explicit vegetation change and climate variation in the Yellow River Basin of China*" by Zhihui Wang, Qiuhong Tang, Daoxi Wang, Peiqing Xiao, Runliang Xia, Pengcheng Sun, Feng Feng.

Great thanks to the reviewers and editors, we have revised the manuscript carefully according to the comments. All the changes were high-lighted in the revised manuscript and the point-by-point response to the comments of the reviewers is also listed below. Please let me know if you require any additional information on our paper.

Looking forward to hearing from you soon.

Best regards,

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Response to Comments from Reviewer 2

General comments:

Based on the Variable Infiltration Capacity (VIC) model prescribed with continuously dynamic leaf area index (LAI) and land cover, this study attributed the trend of naturalized streamflow to temporally explicit vegetation change and climate variation over the Yellow River Basin of China. They found that the effect of climate variation on streamflow is slight, while the change of underlying surface has imposed a substantial trend on naturalized streamflow. This research is of significance for understanding the underlying mechanisms of natural streamflow reduction, which can provide guidelines for local water resources management.

Response: Great thanks for your encouragement and recognition to our manuscript.

Specific comments:

Point 1: Equation 7: In scenario S3 ($f(C_{inter}, P_{intra})$), all climate variables and intra-annual temporal pattern of monthly precipitation vary according to observation records, while in scenario S2 ($f(C_{inter})$), only specific climate variable varied according to observation records, why the intra-annual temporal pattern of precipitation on the annual streamflow trend (Q_{Pintra}) can be calculated with equation 7? Maybe you should add a scenario (S2-1), in which all the interannual change of climate variables vary according to observation records while other variables vary according to control conditions in the S1. With this scenario, you can also check whether climate variables affect each other.

Response: Great thanks for this great comment. Here is an unclear description about original Equation 7 where $f(C_{inter})$ represents simulated streamflow trend induced by interannual change of different climate variables, which make readers confused about scenario S2. Hence, three separated equations are shown in the revised description to illustrate how to calculate individual impact of precipitation, temperature and wind speed on the streamflow trend. In addition, we have checked the interactive effects of different climate variables on streamflow trend, and these effects are nearly close to the zero. Therefore, we adopted calculation formula that can make impacts of different four climate variables closed to the total impact of climate change. Hence according to your comments, corresponding description and equations have been revised, and the details are shown below.

To isolate the effect of climate variables on streamflow trend, we designed two scenarios. In Scenario S2, annual value of climate variable (precipitation, temperature and wind speed) varied one by one according to observation records while other variables vary according to control conditions in the S1. In Scenario S3, annual values of all climate variables and intra-annual temporal pattern of monthly precipitation vary according to observation records while other variables vary according to control conditions in the S1. The impacts of climate variables were calculated as follows:

$$Q_{P_{inter}} = f(P_{inter}) - f(control) \tag{6}$$

$$Q_{T_{inter}} = f(T_{inter}, P_{inter}) - f(P_{inter}) \tag{7}$$

$$Q_{WS_{inter}} = f(WS_{inter}, T_{inter}, P_{inter}) - f(T_{inter}, P_{inter}) \tag{8}$$

$$Q_{P_{intra}} = f(WS_{inter}, T_{inter}, P_{inter}, P_{intra}) - f(WS_{inter}, T_{inter}, P_{inter}) \tag{9}$$

$$Q_C = Q_{P_{inter}} + Q_{T_{inter}} + Q_{WS_{inter}} + Q_{P_{intra}} = f(WS_{inter}, T_{inter}, P_{inter}, P_{intra}) - f(control) \tag{10}$$

Where $Q_{P_{inter}}$, $Q_{T_{inter}}$ and $Q_{WS_{inter}}$ are impacts of interannual change of precipitation, temperature and windspeed, respectively, and $Q_{P_{intra}}$ is impact of intra-annual temporal pattern of precipitation. Q_C represents the total impacts of all climate variables. $f(control)$and $f(P_{inter}, T_{inter}, WS_{inter}, P_{intra})$ are the simulated streamflow trends in the S1 and S3, and $f(P_{inter})$, $f(T_{inter}, P_{inter})$, and $f(WS_{inter}, T_{inter}, P_{inter})$ are the simulated streamflow trends in the S2.

2. It seems that the VIC simulations don't match well with the observations, and the Nash–Sutcliffe efficiency (NSE) of monthly streamflow is only 0.44 and 0.46 over TNH-TDG and LM-HYK during validation periods (Fig. 8). To ensure the accuracy of this research, it may be necessary to recalibrate the model parameters.

Response: Great thanks for this great comment. In the process of model calibration, we have used an optimization algorithm of MOCOM-UA, and the automatic calibration was carried out by running the VIC model 1000 times over calibration period (1980-1993), of which the first two years (1980–1981) used for warm up, and the period of 1994-1999 is the validation period. We have run the calibration program many times, and the optimal result was employed in this study. Therefore, we think these model parameters already are the best ones calibrated by the algorithm, and model parameters also have been shown in the Table 3. It can be seen that from Table 4, NSE in the TNH-TDG and LM-HYK in the calibrate period is very high, merely NSE is slightly lower than the value of 0.5 in the validation period, which might be acceptable for model simulation.

There are some reasons for this. Actually, it is very difficult to accurately acquire naturalized streamflow due to high uncertainties of human water use data, especially from irrigation, which could explain the NSE slightly lower than 0.5 in the validation period in the TNH-TDG and LM-HYK where there are large irrigated areas. In the future, the high-quality naturalized data and hydrological simulation considering irrigation should be used to mitigate uncertainties of model parameters. The corresponding descriptions have been added in the section Uncertainties as below.

Table 3. Calibrated parameters of VIC model for different drainage areas over YRB

Drainage areas	b	D_s	D_{smax}	W_s	b_1	b_2	b_3
TNH	0.374	0.514	23.559	0.671	0.091	0.100	1.021
TNH-TDG	0.313	0.454	18.686	0.771	0.102	0.172	0.497
TDG-LM	0.135	0.056	7.427	0.354	0.264	0.824	1.107
LM-HYK	0.151	0.123	18.973	0.530	0.134	0.465	0.812

It is difficult to accurately acquire naturalized streamflow due to some uncertainties of human water use data, especially from irrigation, which could explain the NSE lower than 0.5 in the validation period (Table 4) in the TNH-TDG and LM-HYK where there are large irrigated areas. In addition, all grid cells of sub-region were characterized with constant parameter dataset based on an idealized assumption. Hence further calibration should be conducted in more subbasins by collecting high-quality naturalized hydrological data and using hydrological model considering irrigation to mitigate uncertainties of model parameters.

3. Why only the results over TDG-LM and LM-HYK are shown in Fig. 12, and what's the streamflow trend over other regions?

Response: Great thanks for this great comment. In this Section, we just want to discuss the discrepancy of simulated annual streamflow trend based on VIC considering and without considering continuous LAI dynamics to demonstrate the implication of considering temporally explicit vegetation change on runoff simulation using VIC. Therefore, in order to demonstrate this discrepancy clearly and obviously we just only selected two typical sub-regions (TDG-LM and LM-HYK) in the Middle Reaches, where large-scale and intensive ecological restoration has been implemented since 1999 instead of Upper Reaches with slight vegetation change.

To explore the discrepancy in evaluating the hydrological effect of vegetation using VIC considering and without considering temporally explicit LAI change, we calculated the annual streamflow trend change by differencing simulation of scenario S1 and simulation with dynamic annual LAI observations while other variables varied under control conditions in the S1, and then calculated the streamflow trend change using the combination of scenario S1 and simulation where annual LAI during 1982-1999 and 2000-2018 were fixed into the multi-year averages of corresponding periods respectively, while other variables varied same as S1. Likewise, the annual streamflow trend changes simulated by continuous and noncontinuous change of intra-annual temporal pattern of LAI were also calculated using same way.

It should be emphasized for peer review expert here that Figure 12 illustrates the simulated annual streamflow using VIC considering and without considering continuous dynamics of interannual LAI and intra-annual temporal pattern of LAI in the TDG-LM (Figure 12(a)~(b)) and LM-HYK (Figure 12(c)~(d)) instead of the original naturized annual streamflow trend, which can be seen in the Figure 3. Corresponding figure has been revised as below.

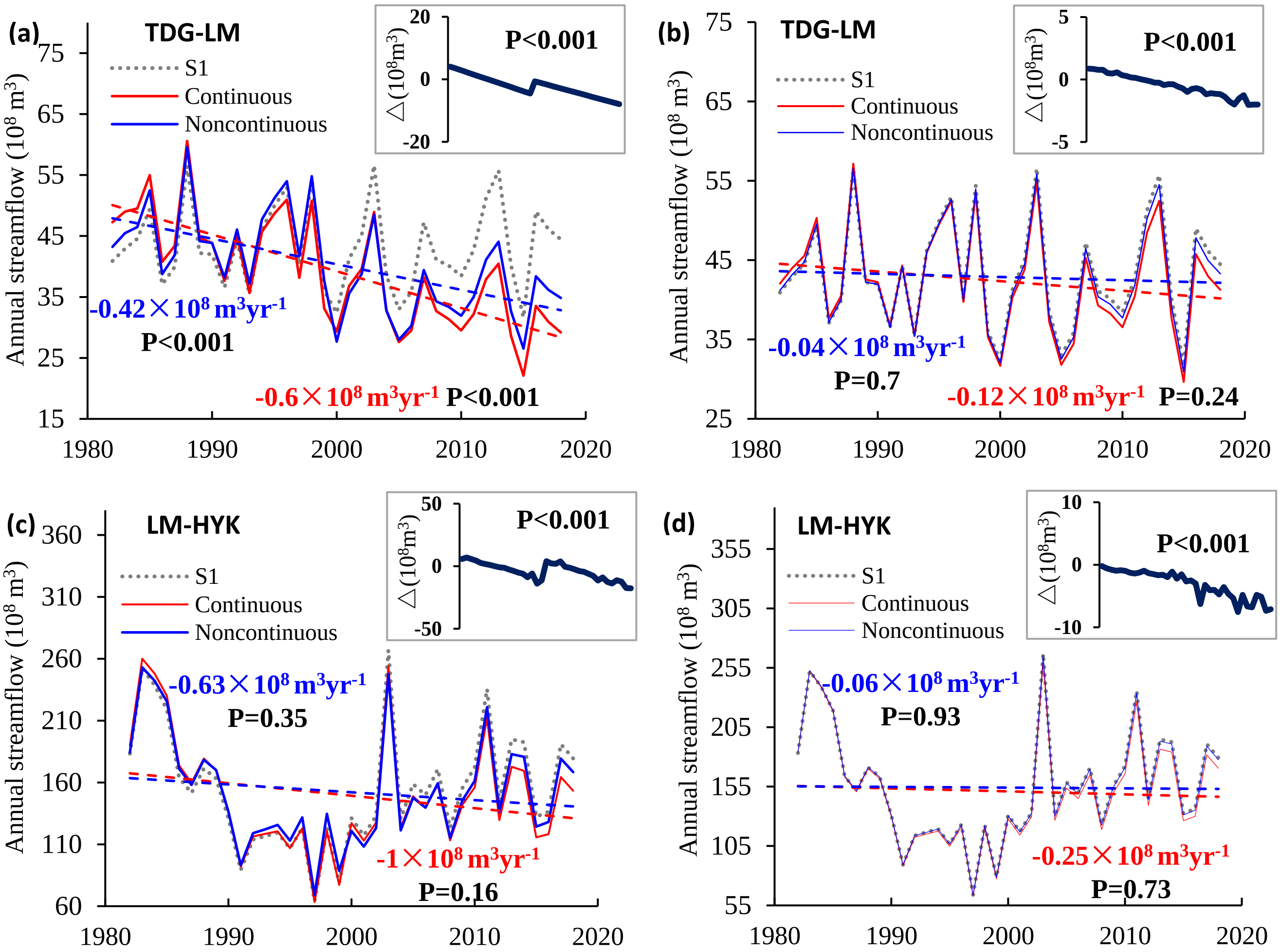


Figure 12. The comparison of simulated annual streamflow trend using VIC considering and without considering continuous dynamics of interannual LAI (a and c) and intra-annual temporal pattern of LAI (b and d) in the TDG-LM and LM-HYK. The insets show the time-series of difference between simulated annual streamflow with VIC considering and without considering continuous LAI dynamics, and its significance level of change trend.

4. To reduce the uncertainty of this research, it's better to show the multi-years average evapotranspiration and soil moisture in Fig. 13, rather than a specific year. In addition, please explain the meaning of these line charts in the manuscript.

Response: Great thanks for this great comment. Let me explain for you. Figure 13 is not annual ET and soil moisture simulated by VIC, but the difference between VIC simulations with dynamic LAI and with fixed multi-year average LAI during 2000-2018. This difference was calculated in order to demonstrate the implication of considering temporally explicit vegetation change on ET and soil moisture simulation using VIC. In the Figure 13, the reason why we selected three specific years of 2000 with low LAI, 2010 with medium LAI, and 2018 with high LAI is that we just want to clearly show the discrepancy between ET and soil moisture simulated by VIC considering LAI dynamics and without considering LAI dynamics. According to the discrepancy in different year with different level of LAI shown in the Figure 13, the model using dynamic LAI tends to predict lower (higher) evapotranspiration and higher (lower) soil moisture than the model using static multi-year average LAI in the year when LAI was lower (higher). This could explain the less intense reduction in runoff when continuous LAI increase was not considered in the hydrological simulation. Corresponding figure has been revised as below.

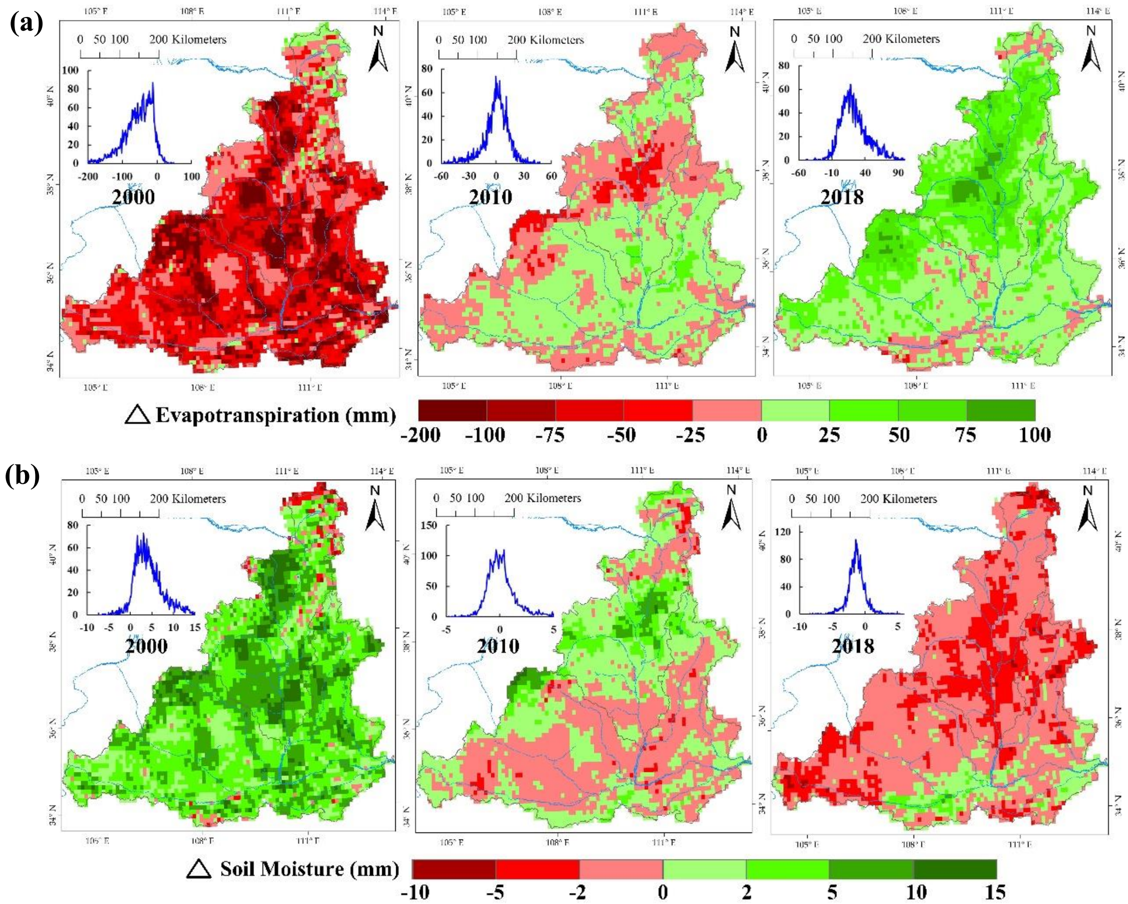


Figure 13. The difference between two simulations by VIC with dynamic LAI and fixed multi-year average LAI during 2000-2018 for annual total evapotranspiration (a) and annual average soil moisture (b) in the

middle reaches in the year of 2000, 2010 and 2018. The insets show the statistical histogram of the difference value.

Minor Comments

5. Line 29: "the effect climate variation on streamflow" should be changed to "the effect of climate variation on streamflow".

Response: Great thanks for this great comment. According to your suggestion, corresponding description has been revised, and the details are shown below.

Overall, the effect of climate variation on streamflow is slight because positive effect from precipitation and wind speed changes was offset by the negative effect from increasing temperature.

6. Line 129: "hman" should be changed to "human".

Response: Great thanks for this great comment. According to your suggestion, corresponding description has been revised, and the details are shown below.

Naturalized runoff at the target gauge was estimated by adding human water use data from irrigation, industrial and domestic sectors over the drainage area of the target gauge back to the observed runoff at the target gauge (Yuan et al., 2017; Zhang et al., 2020)

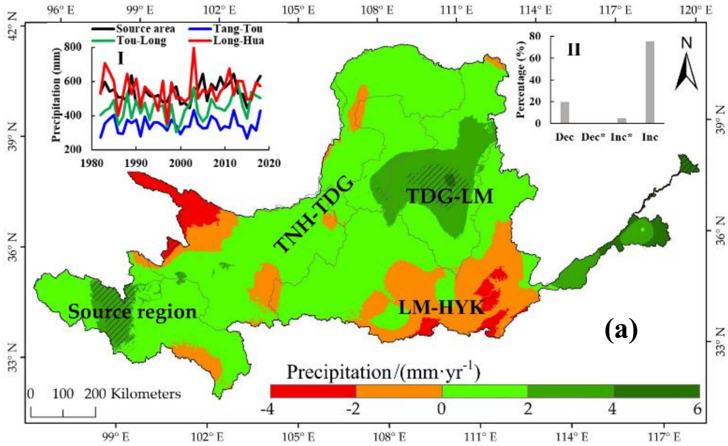
7. Line 267: "HKY" should be changed to "HYK".

Response: Great thanks for this great comment. According to your suggestion, corresponding description has been revised, and the details are shown below.

Temporally, all monthly streamflow experienced negative trends at HYK station, with a greatest reduction (18.6%) was found in August.

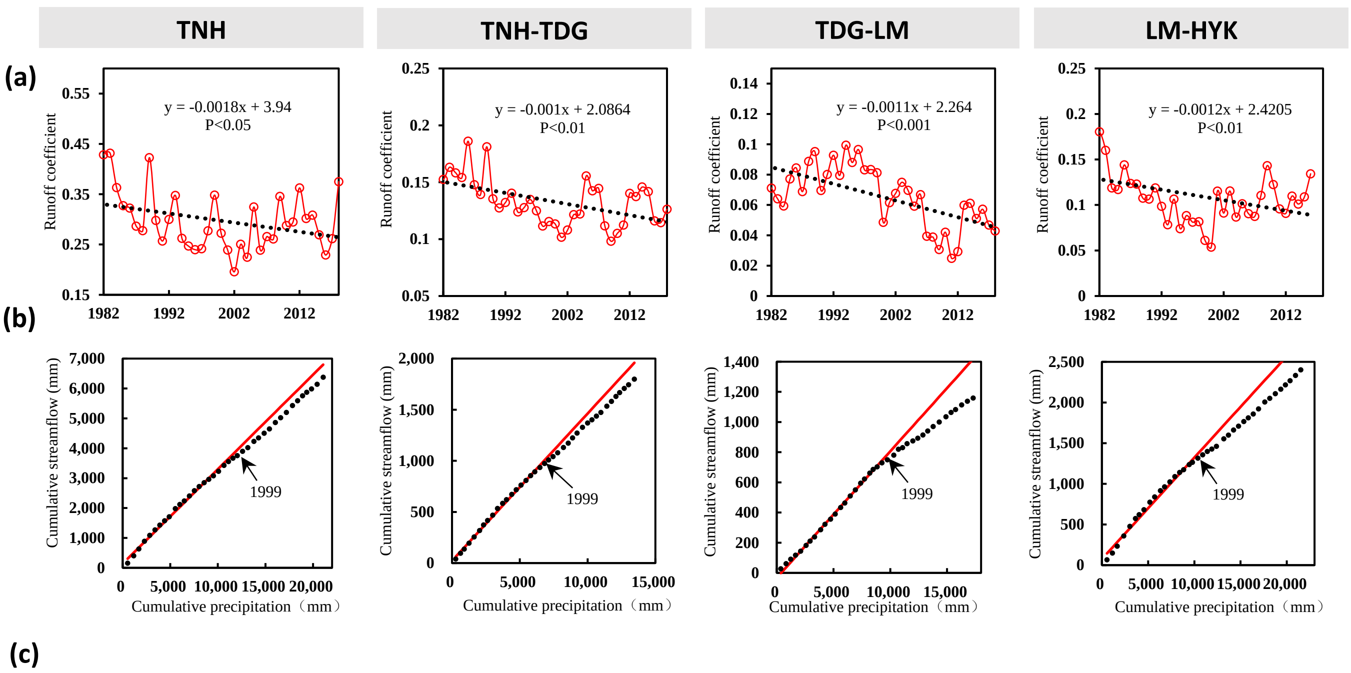
8. Fig. 4a: The label of the colorbar is incorrect. "-6" should be changed to "6".

Response: Great thanks for this great comment. According to your suggestion, corresponding figure has been revised, and the details are shown below.



9. Are the trends in Fig. 7, 10, and 12 significant? It's better to add the confidence interval in the figures.

Response: Great thanks for this great comment. The trends in the Figure 7 are all significant. The △P25 annual time-series at most meteorological stations in the Figure 10 show significant change trend. It should be noted that although the change trends of simulated annual streamflow (Figure 12(b)~(d)) are insignificant due to original interannual fluctuations were reserved in the scenario simulations, these trends become more significant when continuous LAI dynamics were considered in VIC simulation, and time-series of difference between simulated annual streamflow with VIC considering and without considering LAI dynamics show extremely significant change trend (P<0.001). To make the figures more clear, understandable and scientific, the significance level of the trends in the Figure 7, 10 and 12 were added in the original figures, and the details are shown below.



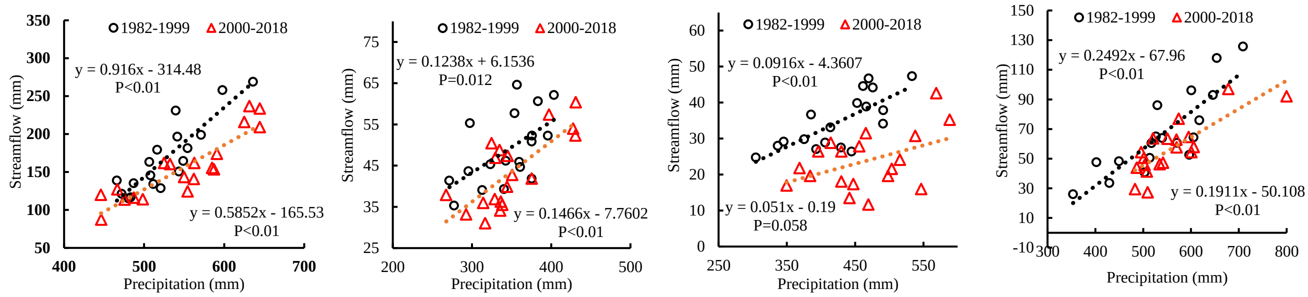


Figure 7. (a) The interannual change trend of annual runoff coefficiencts for 4 sub-regions, (b) precipitation-streamflow double mass curves for different sub-regions, and (c) precipitation-streamflow relationships in the two periods of 1982-1999 and 2000-2018 for 4 sub-regions.

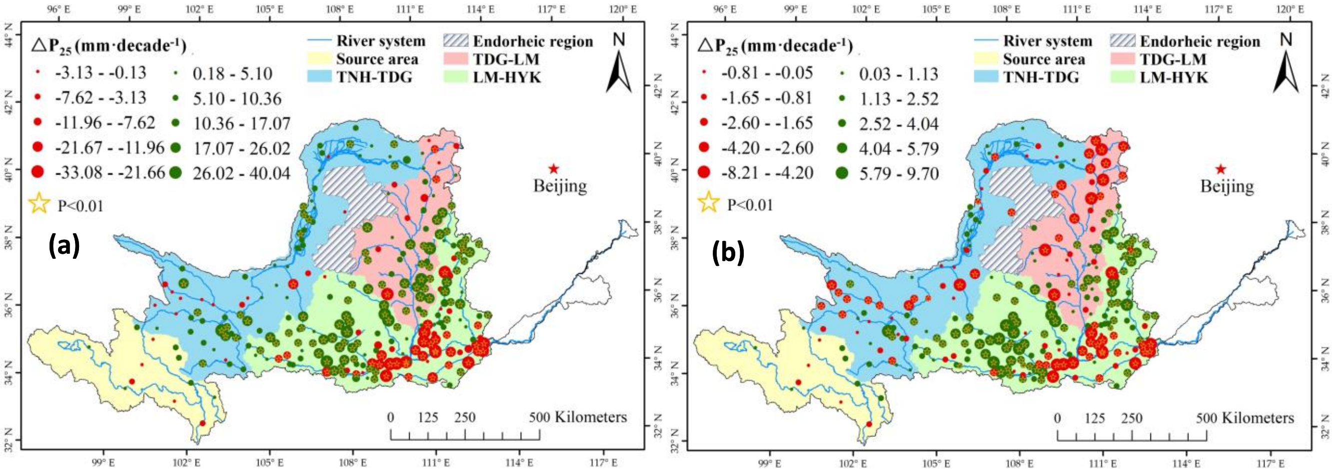
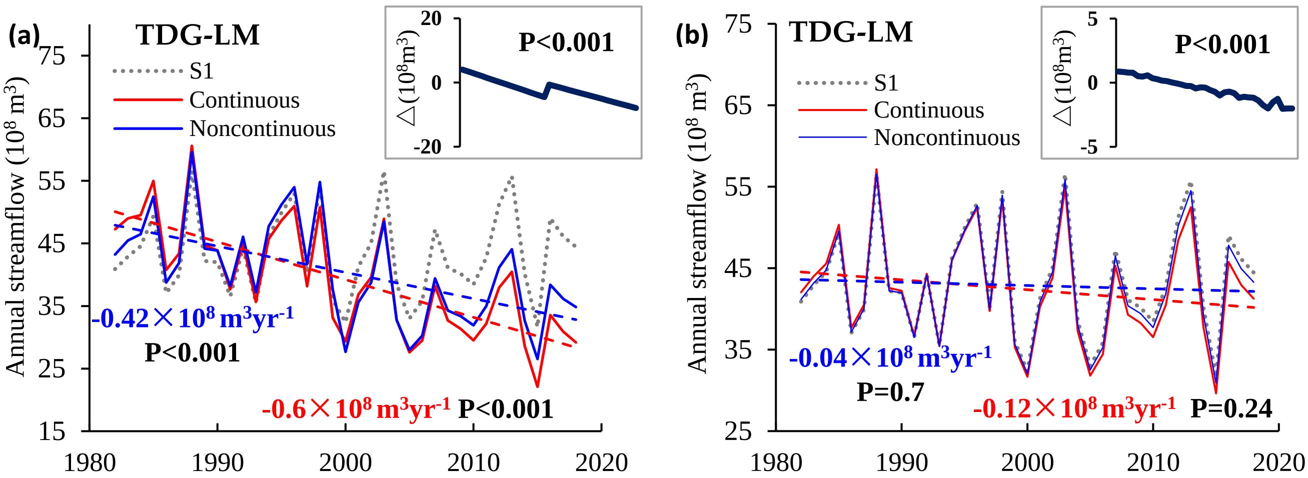


Figure 10. The impacts (△P25) of changes in interannual precipitation (a) and intra-annual monthly to annual precipitation ratio (b) on the P25 trend of each station. Hollow stars show △P25 time-series with statistically significant trends (P<0.01)



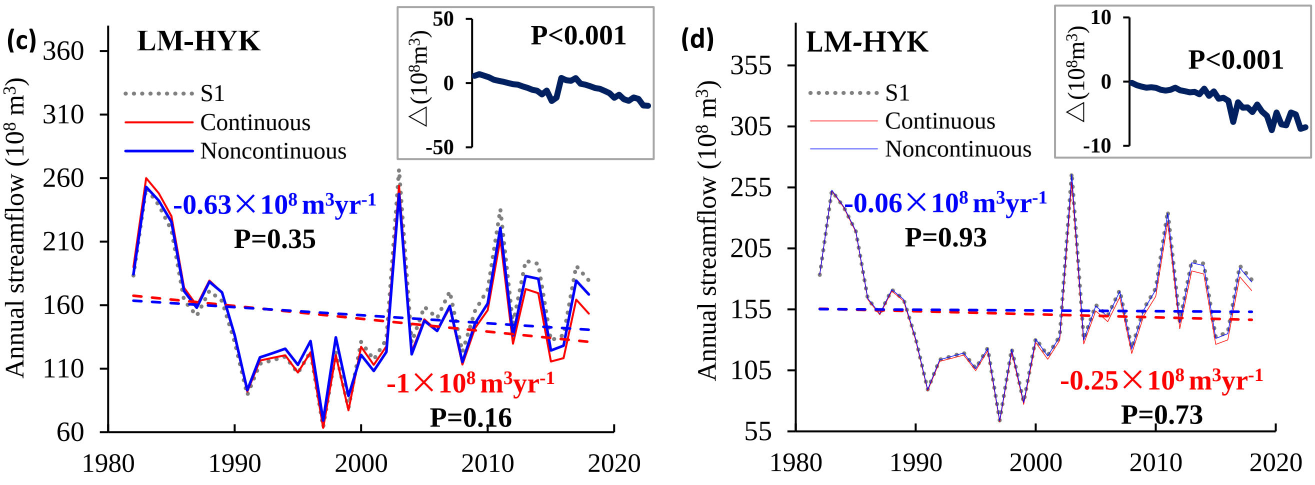


Figure 12. The comparison of simulated annual streamflow trend using VIC considering and without considering continuous dynamics of interannual LAI (a and c) and intra-annual temporal pattern of LAI (b and d) in the TDG-LM and LM-HYK. The insets show the time-series of difference between simulated annual streamflow with VIC considering and without considering continuous LAI dynamics, and its significance level of change trend.

10. Fig. 12: "LM-TDG" should be changed to "LM-HYK" in the figure caption.

Response: Great thanks for this great comment. According to your suggestion, corresponding caption has been revised, and the details are shown below.

Figure 12. The comparison of simulated annual streamflow trend using VIC considering and without considering continuous dynamics of interannual LAI (a and c) and intra-annual temporal pattern of LAI (b and d) in the TDG-LM and LM-HYK. The insets show the time-series of difference between simulated annual streamflow with VIC considering and without considering continuous LAI dynamics, and its significance level of change trend.