Temporal variability of catchment storage-discharge characteristics and their driving mechanisms in cold region

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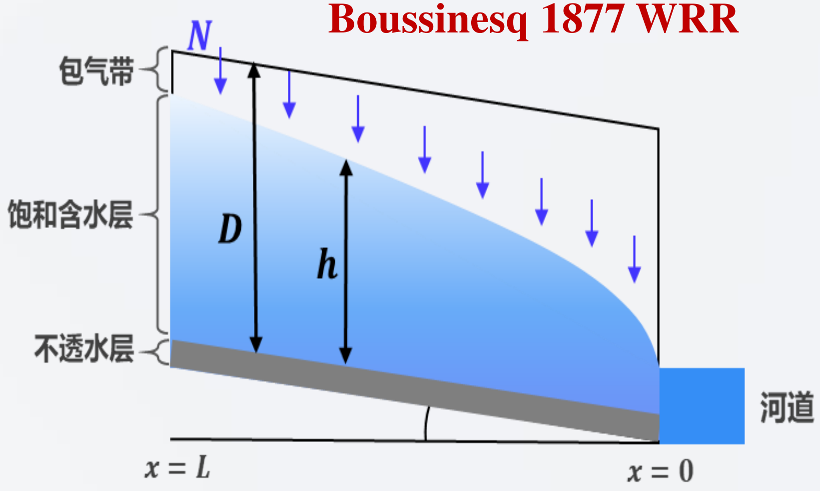
Motivations and Issues

- Storage-discharge relationship (SDR) is the description between catchment storage and baseflow
- The pow-law SDR has been widely used in many hydrological model (e.g., TOPMODEL, VIC)

Boussinesq 1877 WRR



$$Q_b = \alpha S^{\beta_e}$$

Q_b baseflow

S storage

Huang 2013 JOH

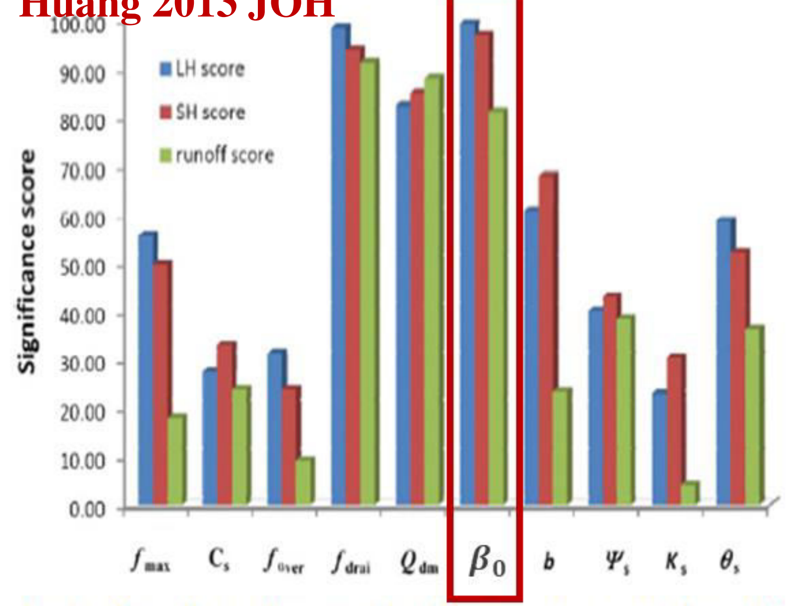
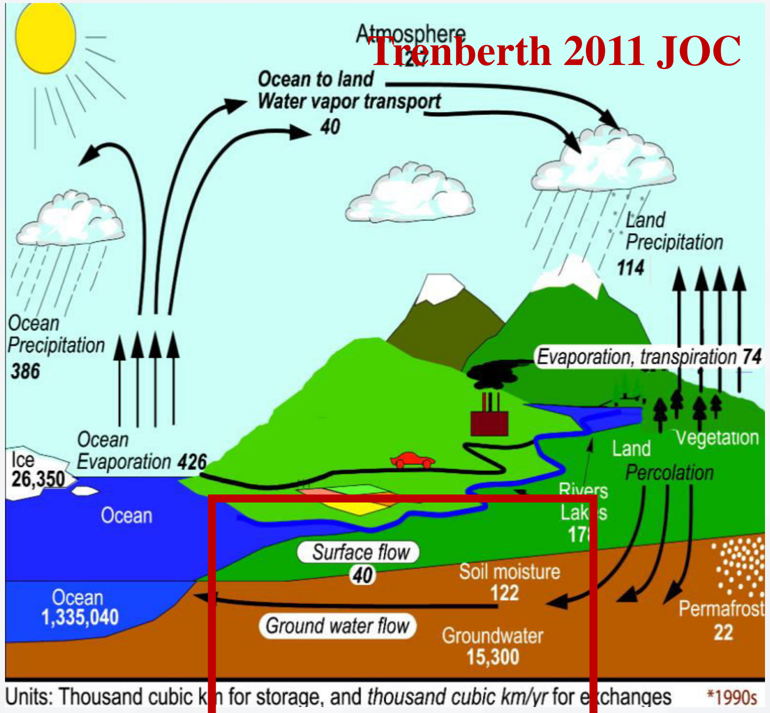


FIG. 3. Overall significance of the 10 parameters on total runoff and fluxes.

Trenberth 2011 JOC



storage-discharge relationship

high-sensitive of pow-law parameter (β_e)

Baseflow (or groundwater flow) in water cycle

- A deeply understanding of β_e is necessary precondition of baseflow simulation

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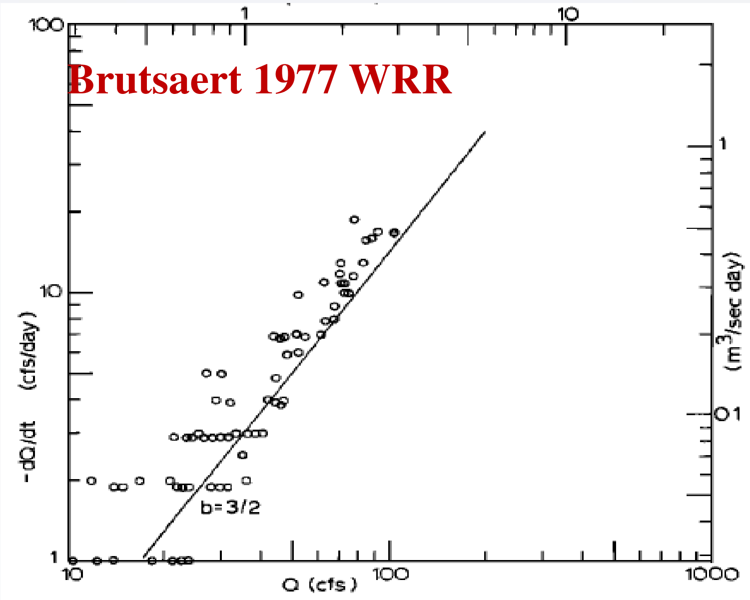
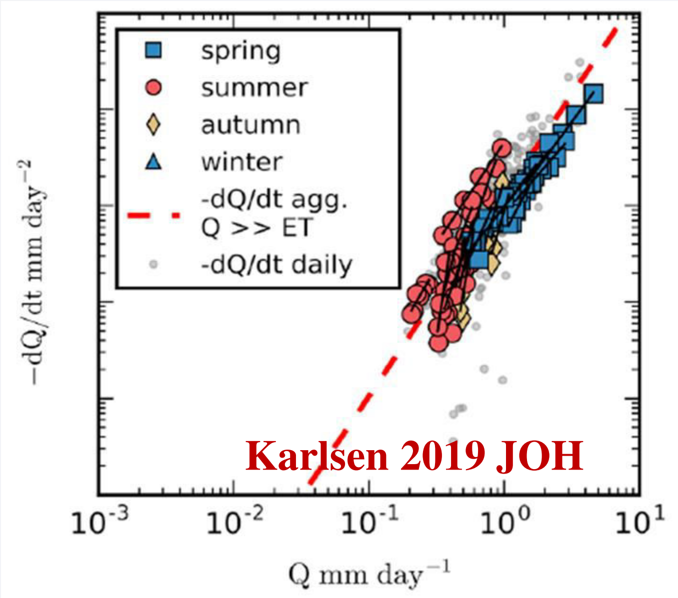
Motivations and Issues

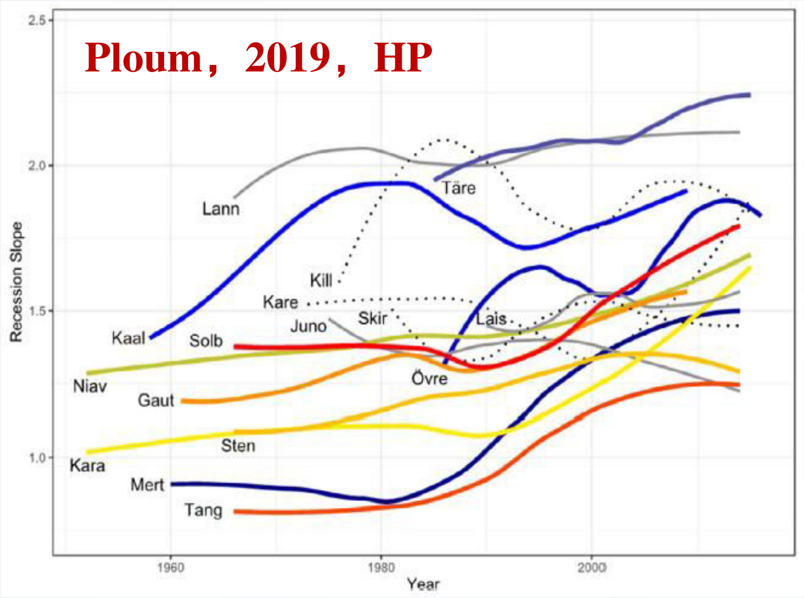
- The paramter (β_e) was generally regarded as a constant
- However, many recent studies have found time-varying β_e, espcially in the cold region



assumption of constant β_e



time -varying β_e in seasonal scale



inconsistent annual variation of β_e in cold region

Objectives

- In the cold region, What`s the temporal characteristic of β_e
- What`s the mechanism of time-varying β_e

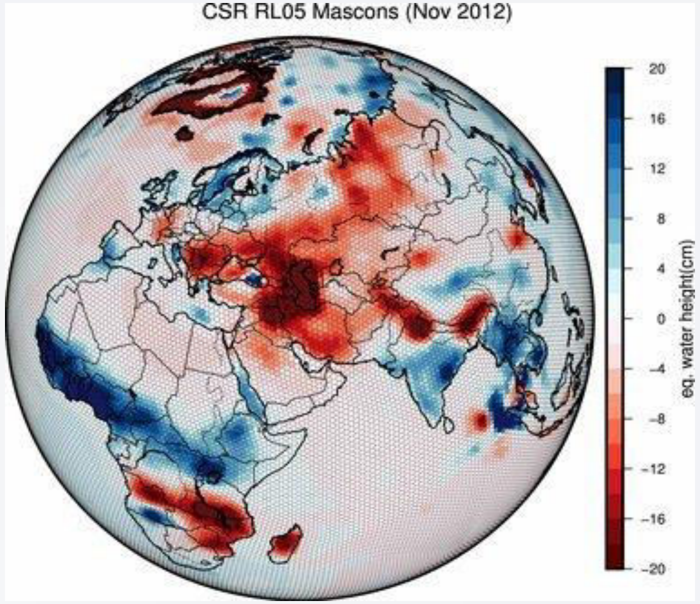
Methodology

- **Recession analysis, proposed by Brutsaert and Nieber (1977), is an effective method for β_e**

[Tashie 2022 WRR; Wang 2019 WRR; Jachens 2019 HESS; Karlsen 2019 JOH]

$$Q_b = \alpha S^{\beta_e}$$

Direct fitting: data missing of S



The scale of estimated S from GRACE satellite too large for most catchment

Recession analysis: In recession period, catchment recharge (N) can be neglect. Only streamflow record required

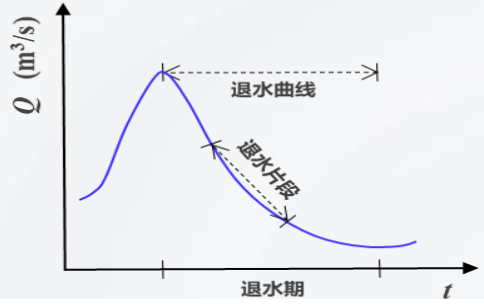
$$N - Q = dS/dt$$

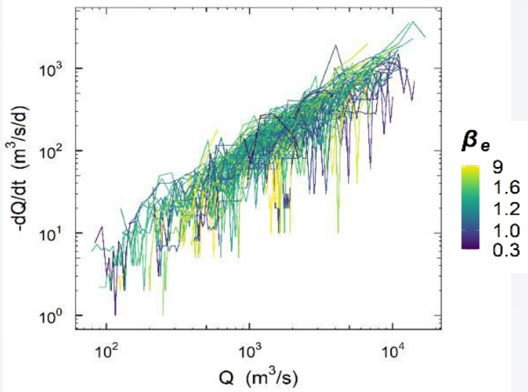
$$\frac{dS}{dt} = \frac{d}{dt}\left[\left(\frac{Q}{\alpha_0}\right)^{1/\beta_0}\right] = \frac{Q^{1/\beta_0 - 1}}{\beta_0 \alpha_0^{1/\beta_0}} \frac{dQ}{dt}$$

$$\alpha_0 = \left[\alpha(2-\beta)\right]^{1/(2-\beta)}$$

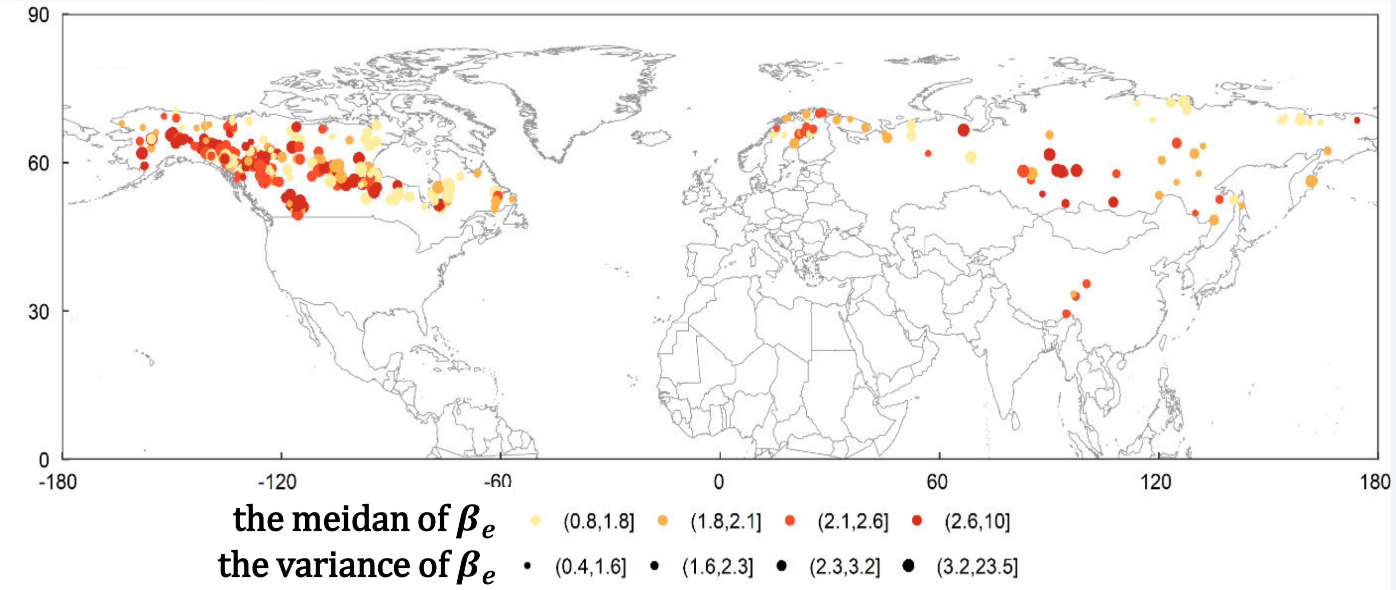
$$\beta_0 = \frac{1}{2-\beta}$$

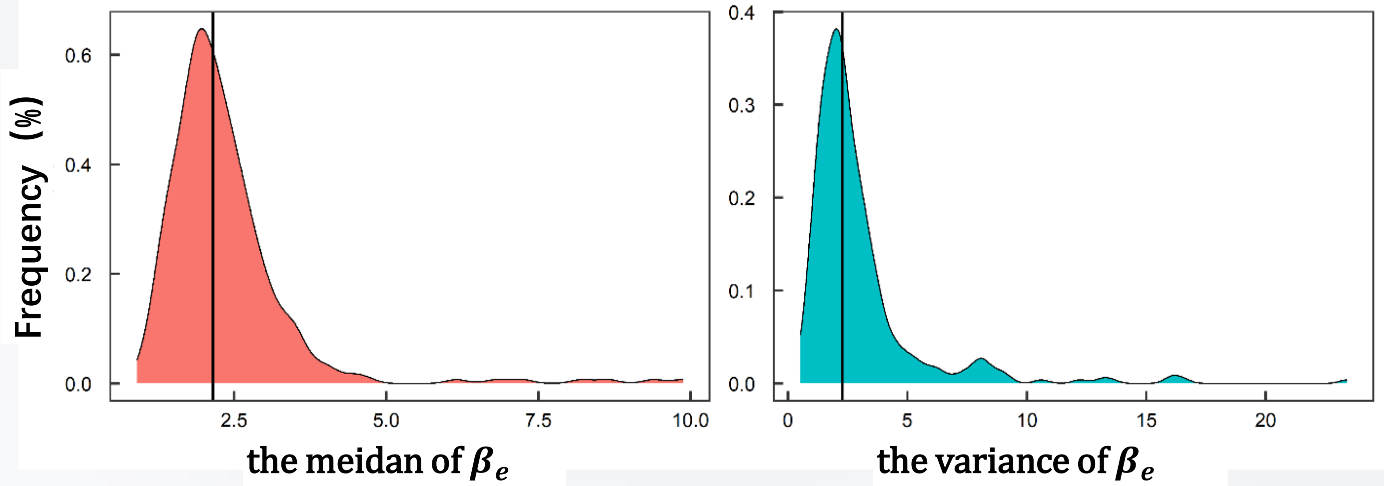
$$-\frac{dQ}{dt} = \beta_0 \alpha_0^{1/\beta_0} Q^{2-1/\beta_0} = \alpha Q^{\beta_e}$$





Results and Discussion

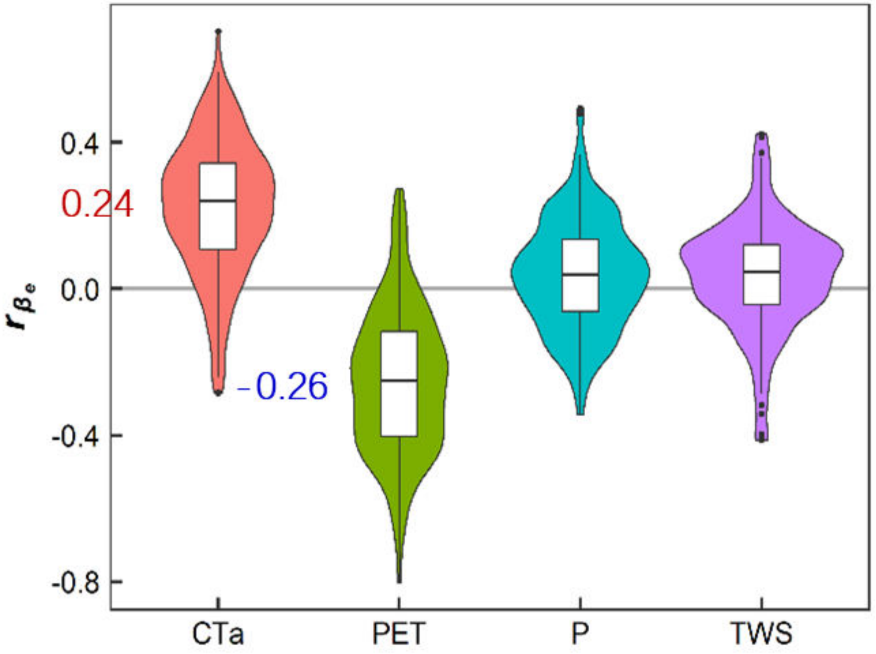


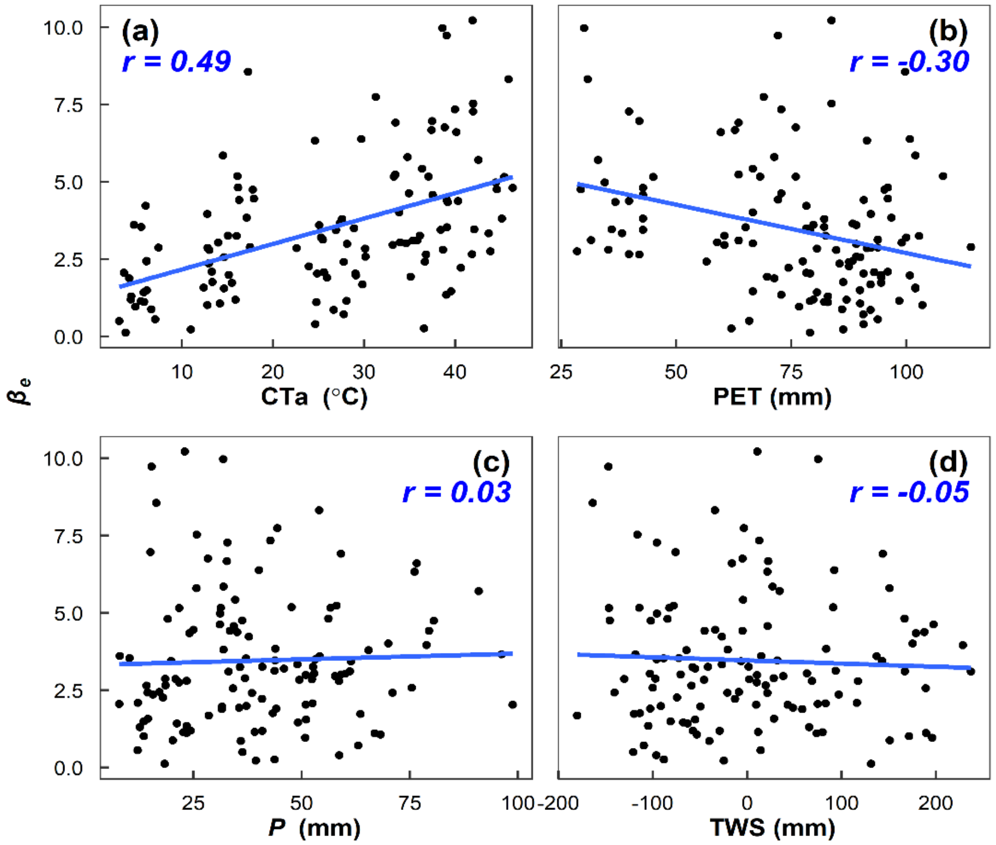


- In 315 cold catchment
  - the meidan of β_e is among 1.8~2.6
  - the median of β_e variance is 2.3

β_e varies greatly among the recession events, showing obvious time-varying feature in cold region

Results and Discussion





CTa: cumulative temperature

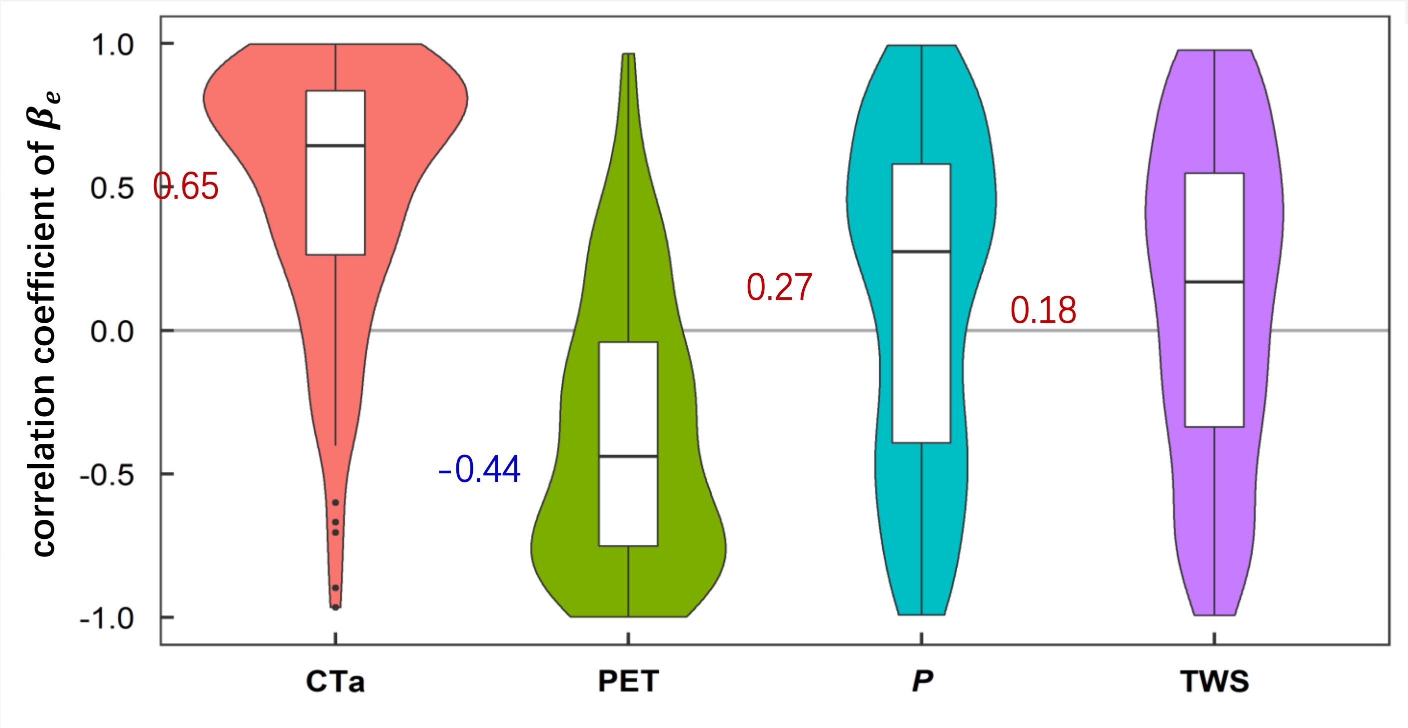
TWS: water storage

PET: potential evapotranspiration

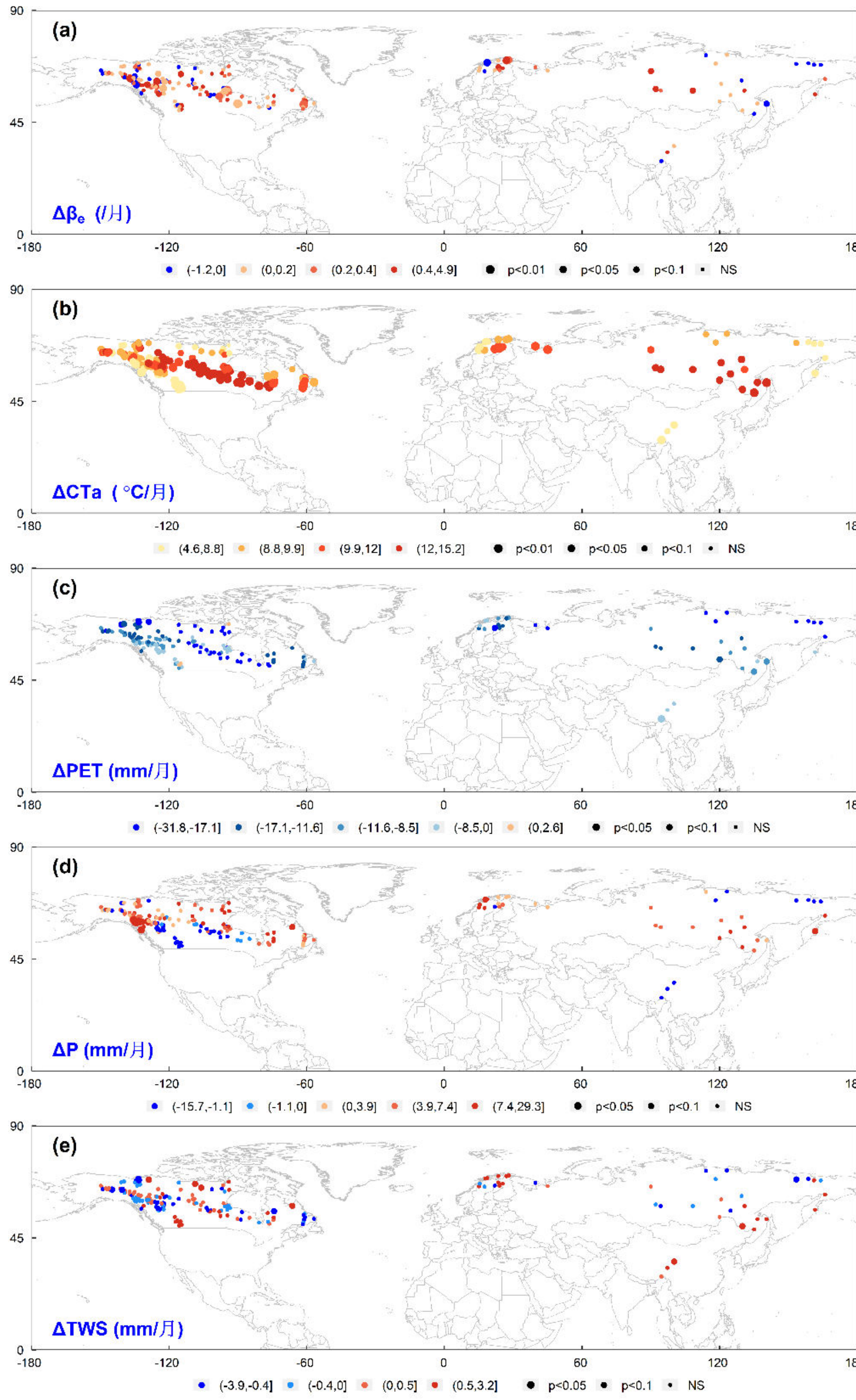
P: precipitation

In events: β_e is positively correlated with CTa (Permafrost), TWS and P, and negatively correlated with PET. β_e is mainly controlled by PET, followed by CTa, and slightly correlated by TWS and P.

Results and Discussion



- **In warm period**
  - β_e increases in most (78%) cold catchments
  - Permaforst degradation (CTa) is the foremost postive driver of β_e, followed by negative Potential evapotranspiration (PET)



Results and Discussion

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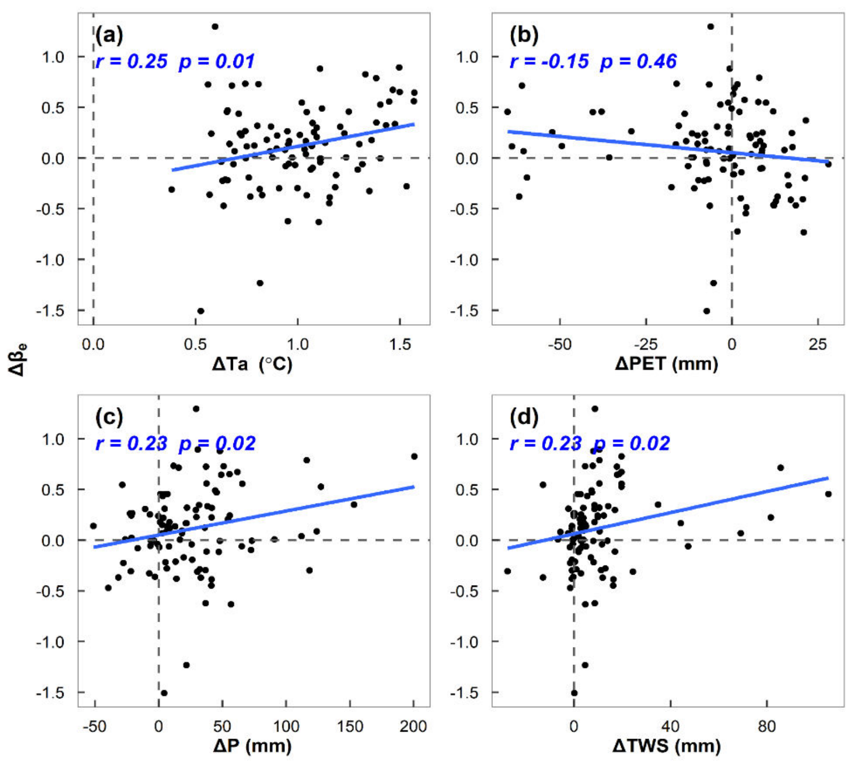
Decade change of β_e、Ta、PET、P & TWS in cold region

Variables	Statistic Feature					Percent of increasing catchment
	Min	25%	50%	75%	max	
$\Delta\beta_e$	−1.5	−0.1	0.1	0.3	1.3	63%
ΔTa	0.4	0.8	1.0	1.2	1.6	100%
ΔPET	−65.3	−9.9	−0.7	8.1	28.1	47%
ΔP	−51.2	2.8	21.4	43.0	200.6	77%
ΔTWS	−27.5	0.7	4.8	11.5	105.5	77%



- **In decade**
  - β_e **increases in many (63%) cold catchments**
  - **Increase of all permaforst degradation、climate wetting and water storage increase take effects on β_e increase.**

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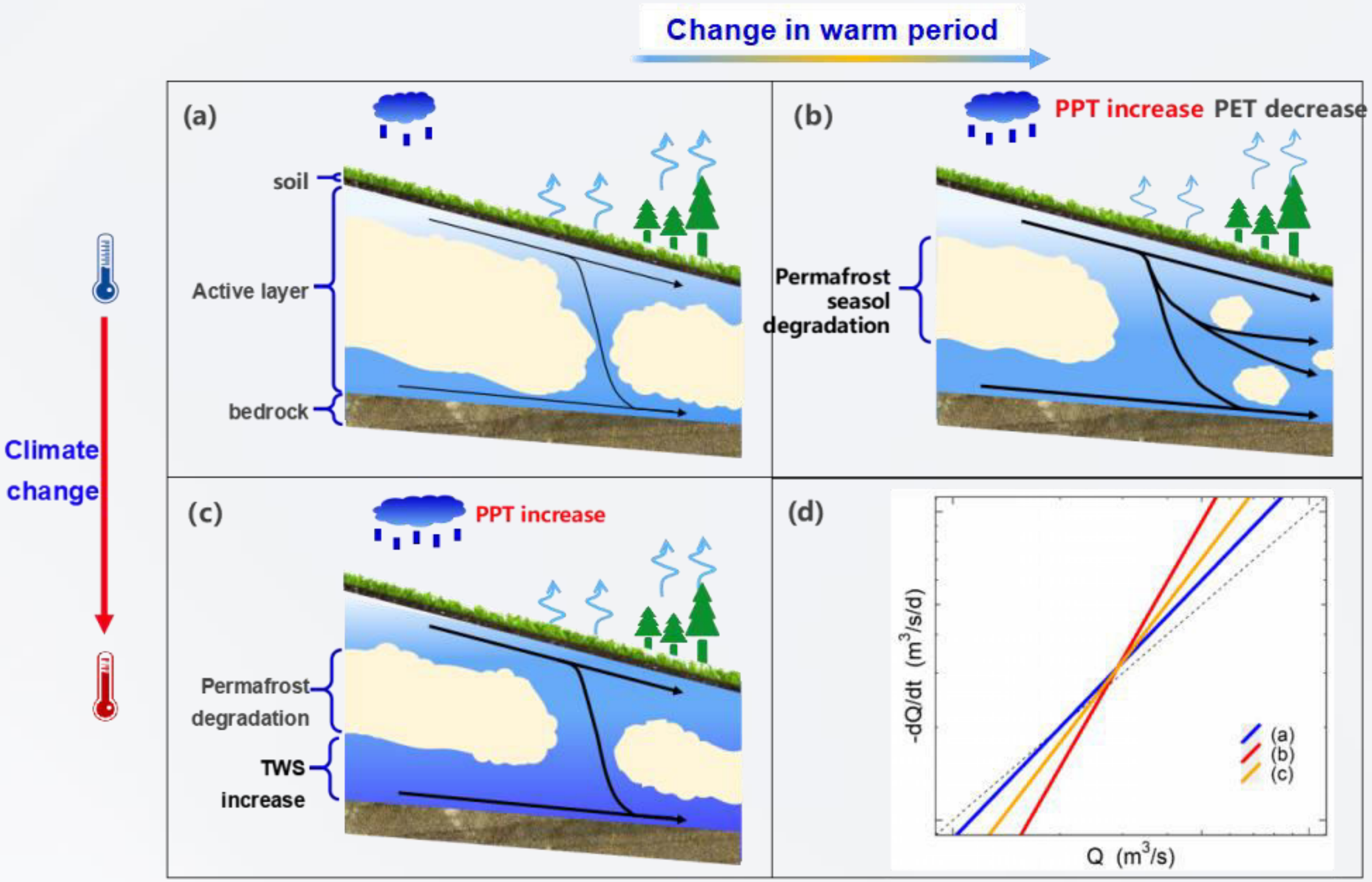

- The greater permafrost degradation (PD), due to more significant temperature changes in the **warm season**, results in a **more significant β_e increase than decadal** permafrost degradation

- The **positive effect of PD** on β_e possibly caused by **increasing storage capacity** and **underground water transfer capacity** after PD.

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Conclusions

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- In cold region, the pow-law parameter of storage-discharge relationship (β_e) varies greatly among the recession events in 315 cold catchments, showing obvious time-varying feature

- The β_e increases in both warm period and decade scale in most catchment, which mainly positive controlled by permafrost degradation and negative controlled by PET increase

- The possible mechanism is permafrost degradation in the cold area under the warming climate, coupled with the increase in water storage caused by climate wettness, makes the β_e of the cold area generally increase

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