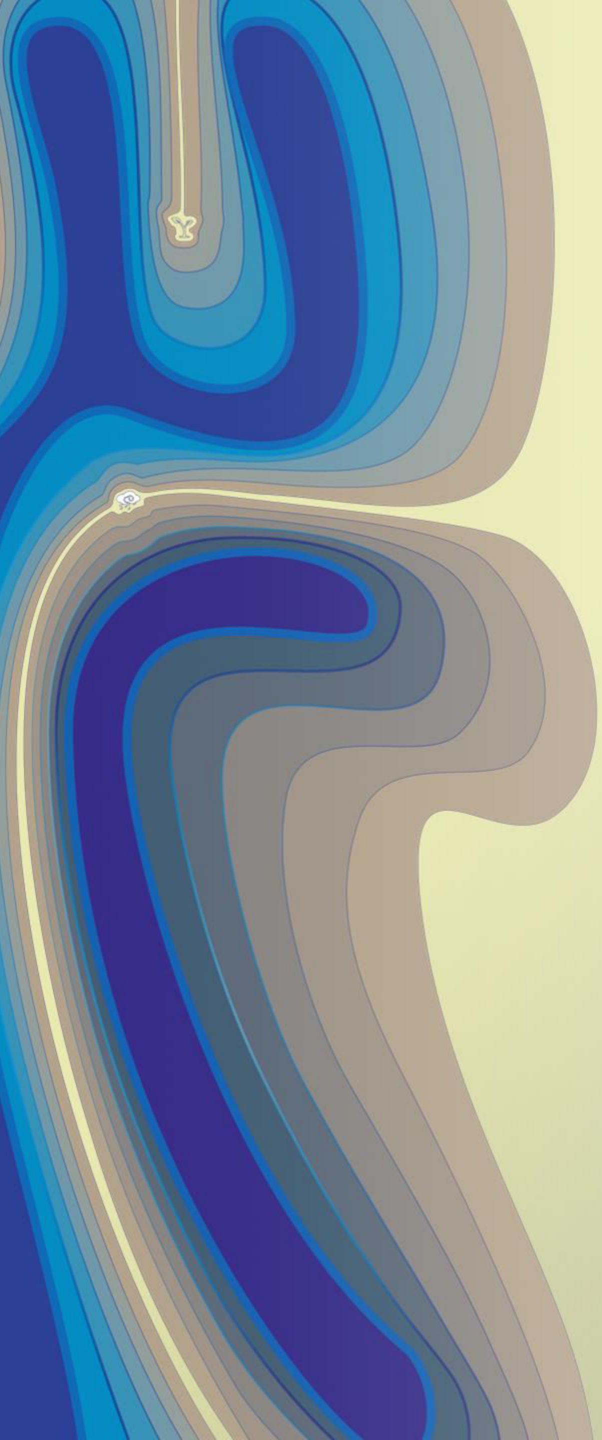
XVIII
World Water Congress
International Water Resources Association (IWRA)

Spatiotemporal variation of potential evapotranspiration and its dominant factors in Southwest, China

Qingzhou Zheng

Chongqing Meteorology Bureau

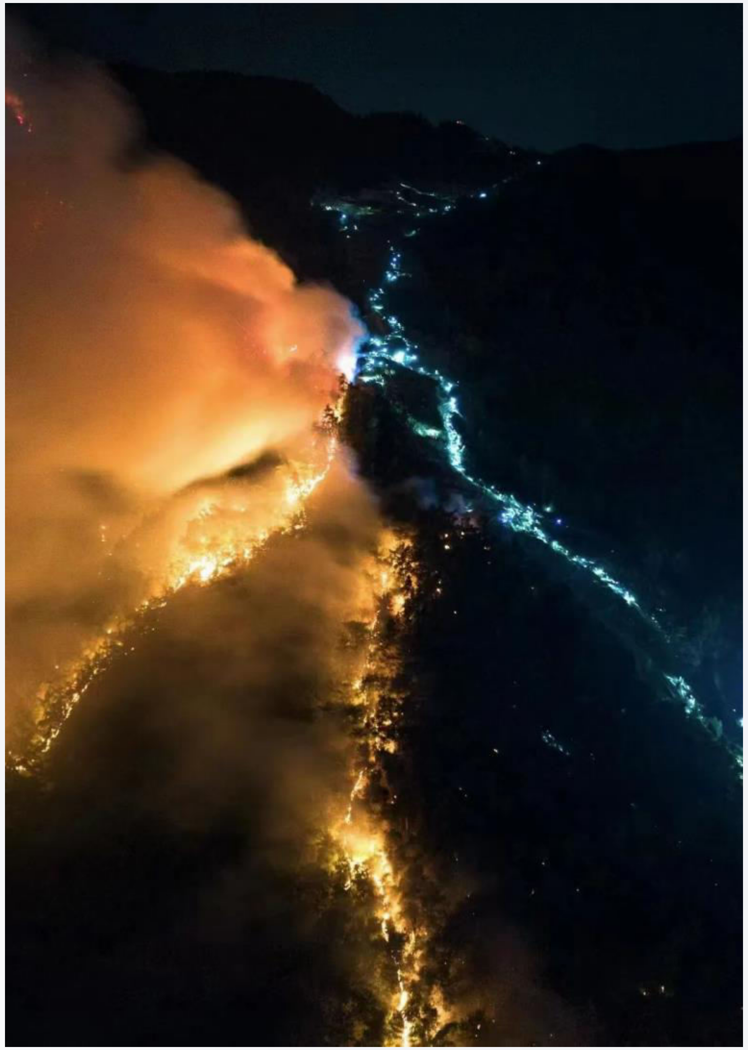
XVIII
WORLD WATER CONGRESS
Water for All
Harmony between Humans and Nature
第18届
世界水资源大会
水与万物：
人与自然和谐共生



Content

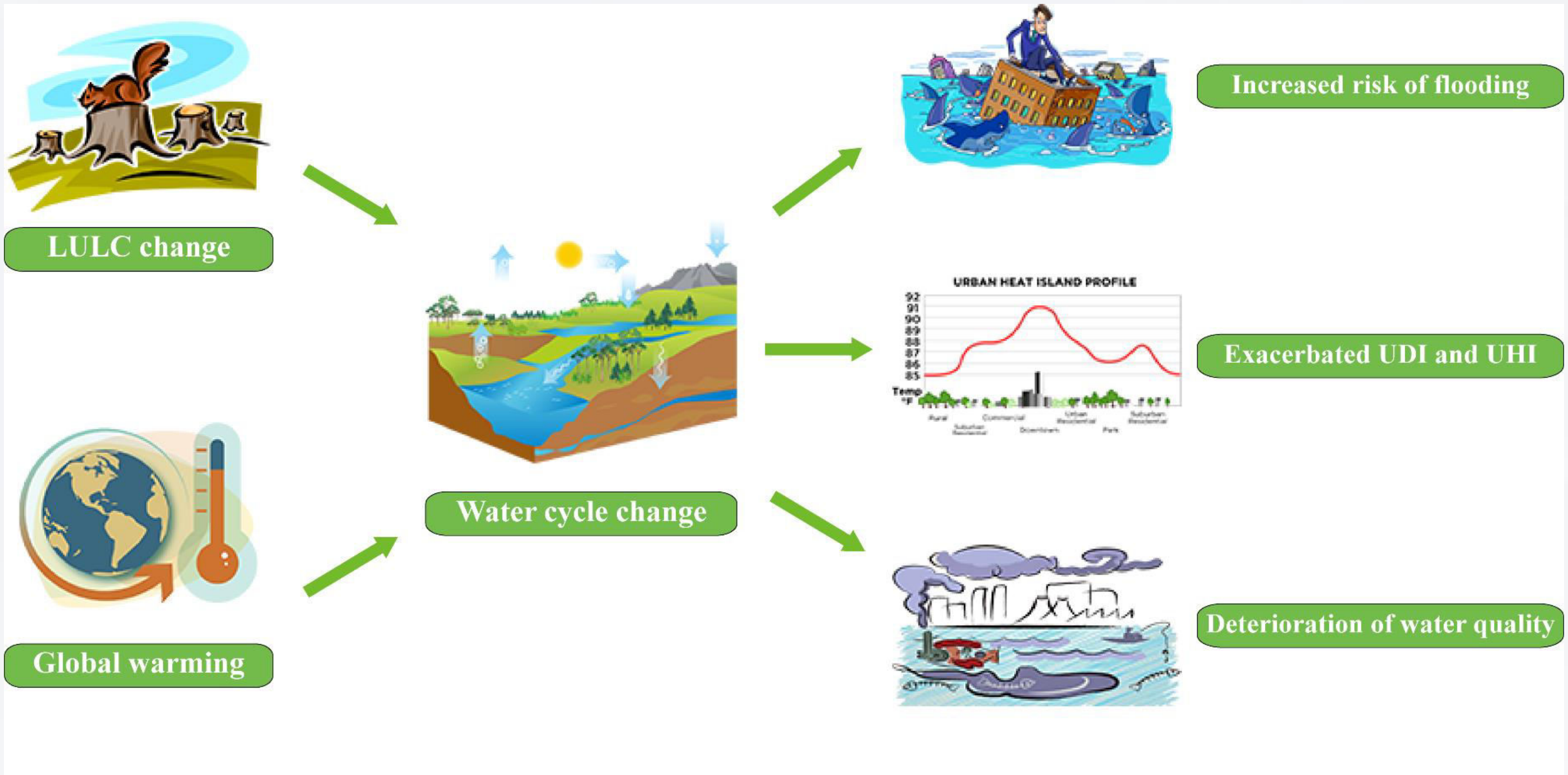
- Background
- Methods
- Results
- Conclusions

Background



Extreme climatic events become more frequent and more intense with ongoing climate change!!

Background



LULC change

Global warming

Water cycle change

Increased risk of flooding

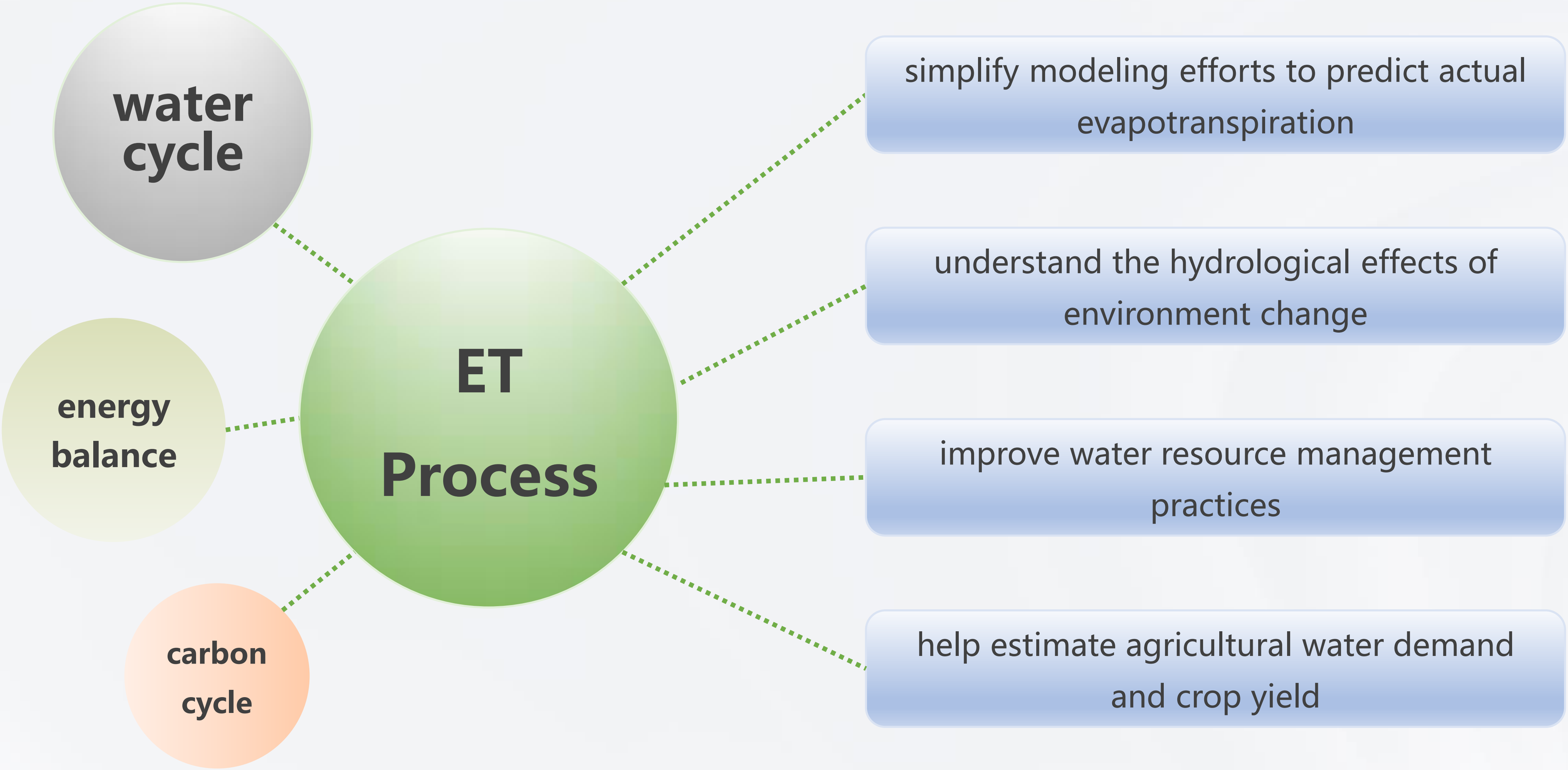
Exacerbated UDI and UHI

Deterioration of water quality

Warning： Regional water energy and balances are altered！！！！

Background

WHY PET ?



water cycle

energy balance

carbon cycle

ET Process

simplify modeling efforts to predict actual evapotranspiration

understand the hydrological effects of environment change

improve water resource management practices

help estimate agricultural water demand and crop yield

……

Background

Table. Dominant factors and trends of potential evapotranspiration (PET) in different regions of the world.

Region	Period	PET trend	Dominant factors	Reference
Jiangsu, China	1960–2019	Increase in 1960–1989	Increased vapor pressure deficit and decreased relative humidity	Qin et al. (2021)
		Decrease in 1990–2019	Decreased wind speed	
Yangtze river basin, China	1960–2000	Decrease	Decreased net radiation	Xu et al. (2006)
East, south and northwest China	1960–2005	Decrease	Decreased net radiation in east and south China; Increased relative humidity in northwest China	Zhang et al. (2011)
Canadian Prairies	1971–2000	Decrease	Decreased wind speed	Burn and Hesch (2007)
Bet Dagan, Israel	1964–1998	Stable	Increased vapor pressure deficit and wind speed were offset by decreased solar radiation	Cohen et al. (2002)
West Iran	1966–2005	Increase	Increased air temperature	Tabari et al. (2011)
Slovenia, Europe	1961–2016	Increase	Increased solar radiation	Maček et al. (2018)

Questions Asked:

- Seasonal differences of PET changes and their driving forces?
- Spatial heterogeneity for PET trends and corresponding dominant drivers?

Background

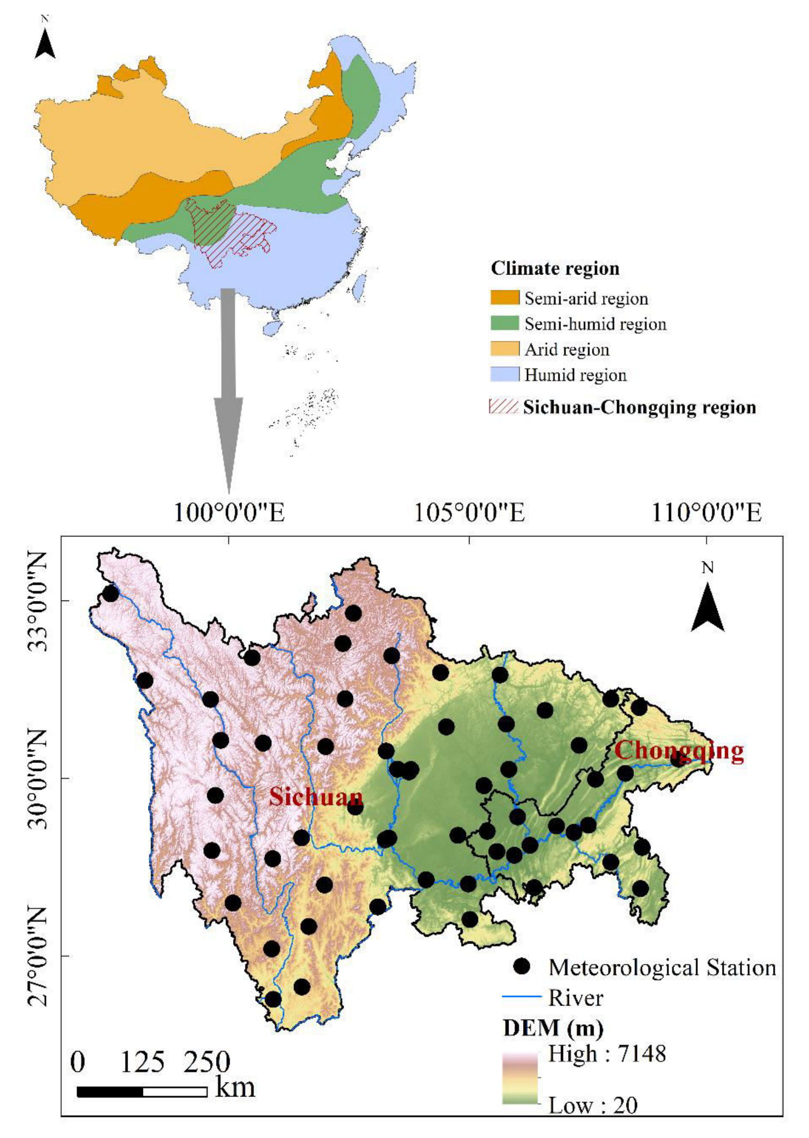


Fig. Location of the Sichuan-Chongqing (SC-CQ) region

Economic Development:

- national strategies
- the core growth area of Southwest China
- massive changes in land use and population

- shortage of local water resource
- Increasingly vulnerable to the effects of environmental changes

Terrain Features and Geographic Locations:

- located in the east of the Qinghai–Tibet Plateau
- uneven distributions of climate elements and natural resources
- distinct seasonal changes in meteorological factors
- “abundant water+ basin” → primary rice-producing area

- enhance our understanding of seasonal and spatial patterns of PET changes and their underlying causes

Methods

Specific objectives:

- Identifying temporal and spatial variation in PET across the SC-CQ region from 1970 to 2020
- Exploring spatial and seasonal differences in the driving factors of PET
- Quantifying the contributions and sensitivity of dominant climate factors to PET changes

Methods:

- FAO-56 Penman-Monteith model for estimating PET
- Nonparametric Mann-Kendall test to detect the parameter trends
- Stepwise regression was adopted to quantitatively analyze the contributions of each meteorological variable to variation in PET
- "Sensitivity Coefficient" to compare the sensitivity of PET to changes in climatic variables.

Results-annual scale

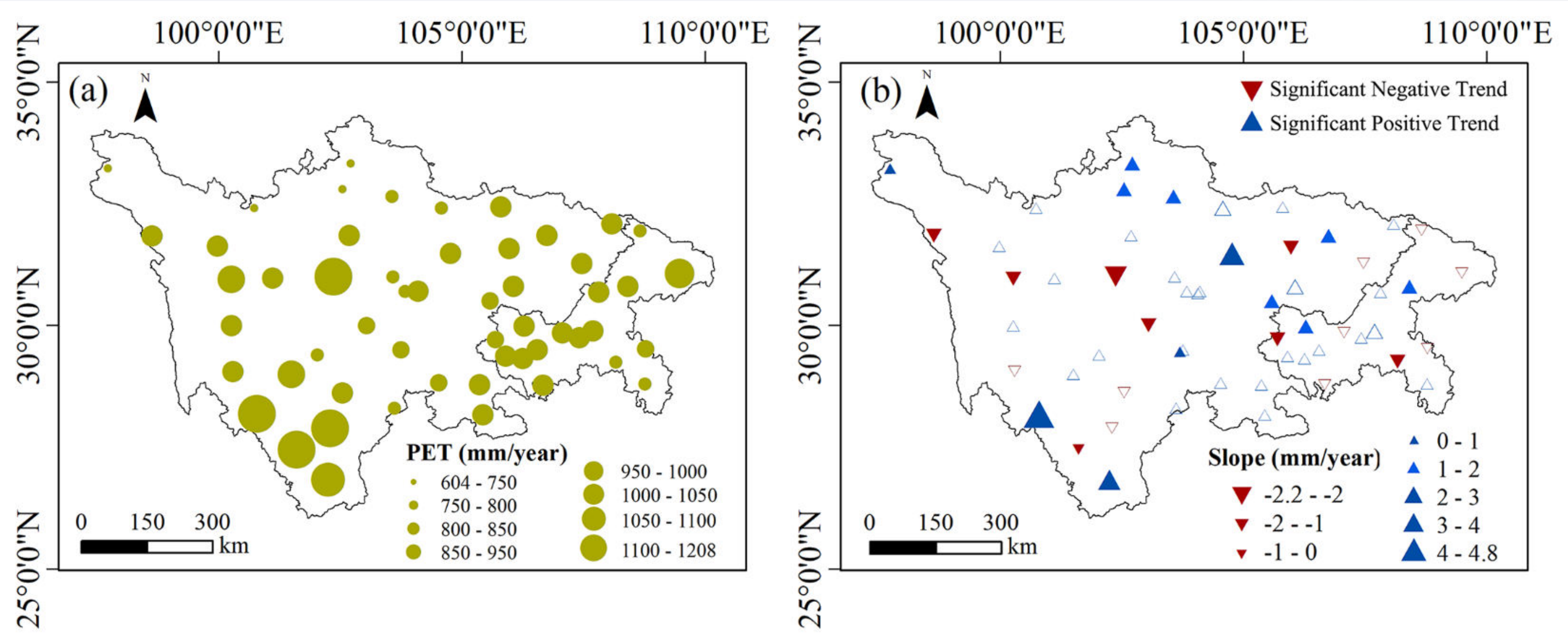


Fig. Spatial distributions of (a) mean annual PET, and (b) its trends slopes and the MK test results ($p < 0.05$)

- Multiyear average PET across the entire SC-CQ region in 1970–2020 ranged from 600 to1200 mm.
- Annual PET showed a positive trend at 33 stations (58.9%), mainly in the northern part of the area; the trend was significant at 12 stations at a 95% confidence level.
- A negative trend in PET was found at 23 stations (41.1%); the trend was statistically significant at eight stations (14.3%) at a 95% confidence level.

Results-seasonal scale

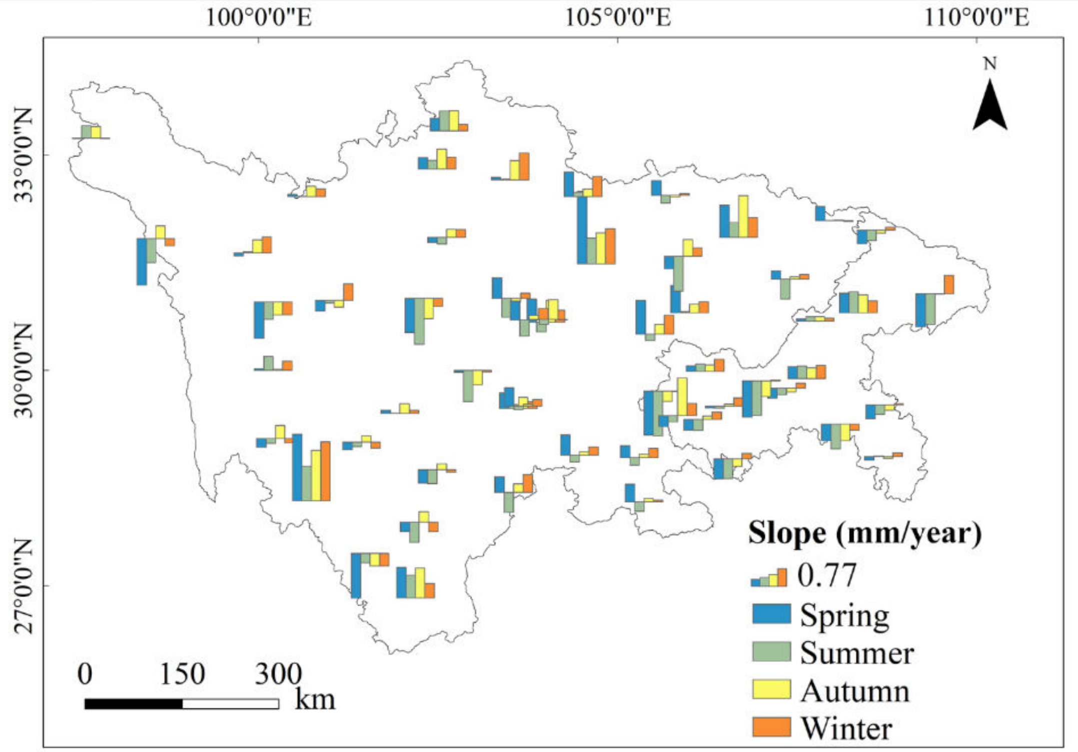
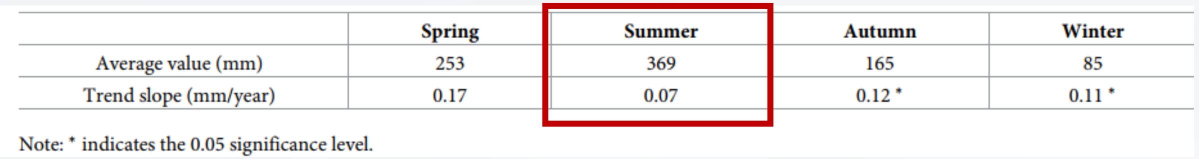


Fig. Seasonal trends of potential evapotranspiration at each station

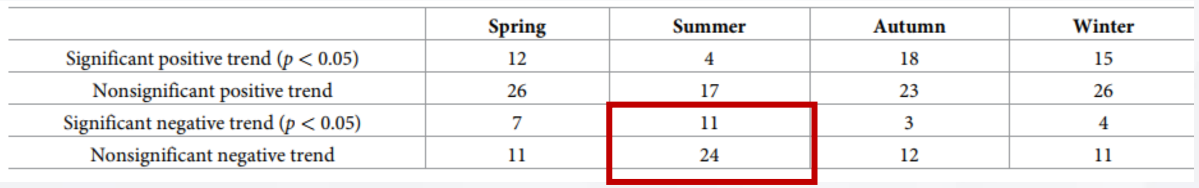
Table. Analysis of seasonal and annual PET throughout the entire SC-CQ region from 1970 to 2020 using the Mann-Kendall test.



	Spring	Summer	Autumn	Winter
Average value (mm)	253	369	165	85
Trend slope (mm/year)	0.17	0.07	0.12 *	0.11 *

Note: * indicates the 0.05 significance level.

Table. Numbers of stations with different trends of PET by season



	Spring	Summer	Autumn	Winter
Significant positive trend ($p < 0.05$)	12	4	18	15
Nonsignificant positive trend	26	17	23	26
Significant negative trend ($p < 0.05$)	7	11	3	4
Nonsignificant negative trend	11	24	12	11

- The evaporation paradox phenomenon occurred more frequently in summer.
- Consideration only of average regional PET is inadequate to reveal the dominant factors of PET variation.

Results-contribution analysis

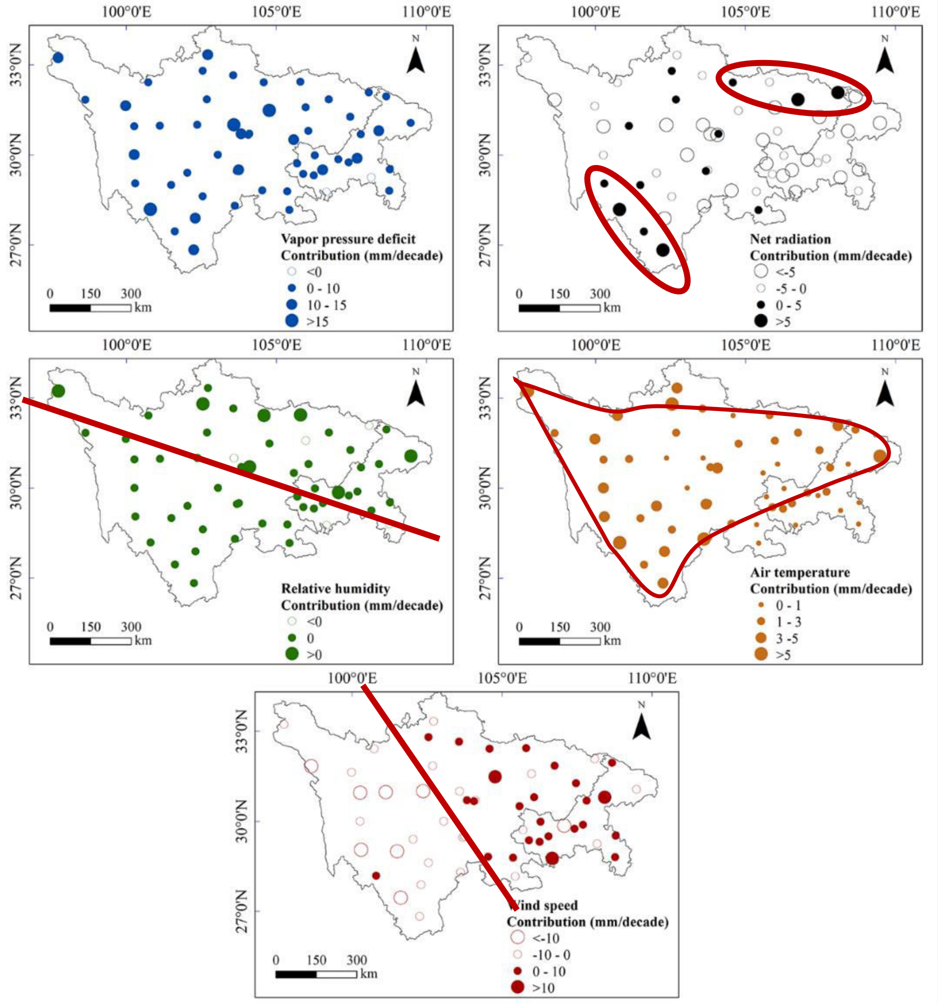
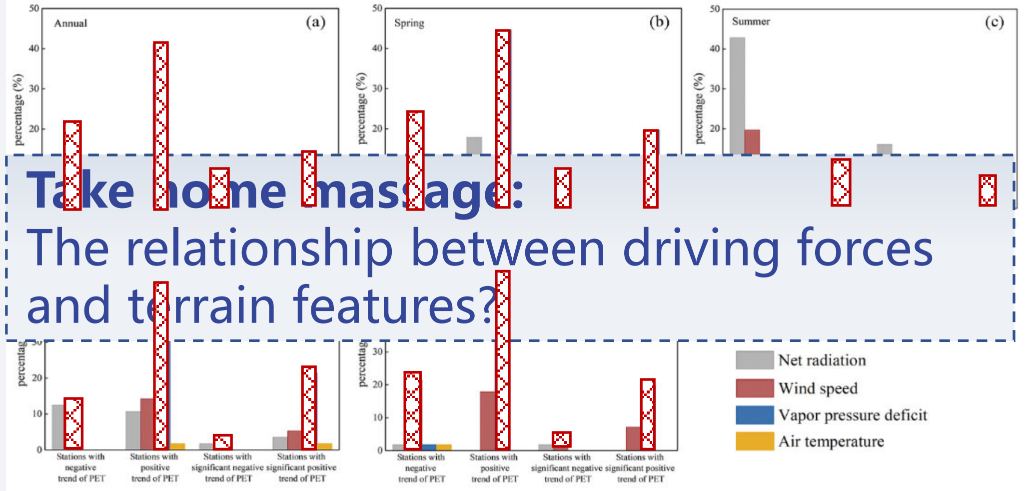
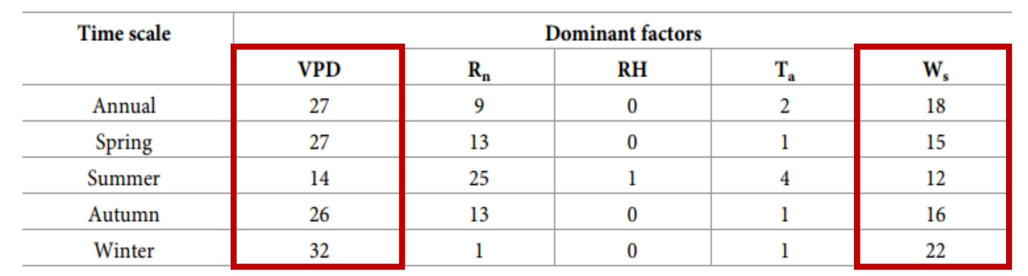


Fig. Spatial distributions of contributions of five basic meteorological factors to PET trends at an annual scale.



Take home message:
The relationship between driving forces and terrain features?

Fig. Dominant factors are shown as percentages for stations with negative, positive, significantly negative ($p < 0.05$) and significantly positive ($p < 0.05$) trends of PET



Time scale	Dominant factors				
	VPD	R_n	RH	T_a	W_s
Annual	27	9	0	2	18
Spring	27	13	0	1	15
Summer	14	25	1	4	12
Autumn	26	13	0	1	16
Winter	32	1	0	1	22

Table. Number of stations with dominant factors of PET trends

Results-sensitivity analysis

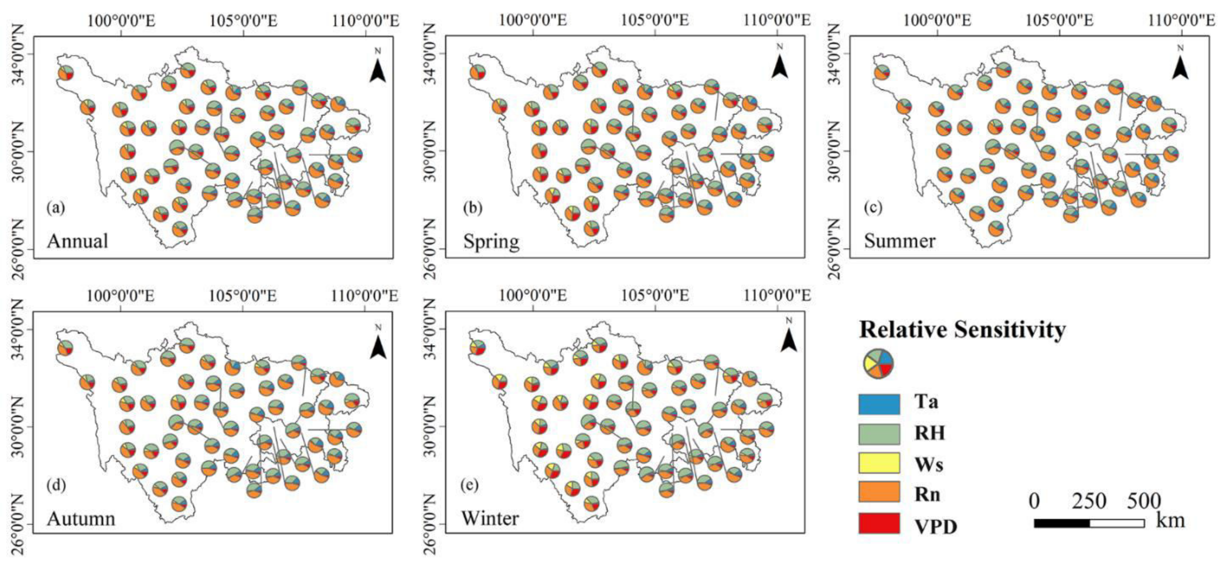
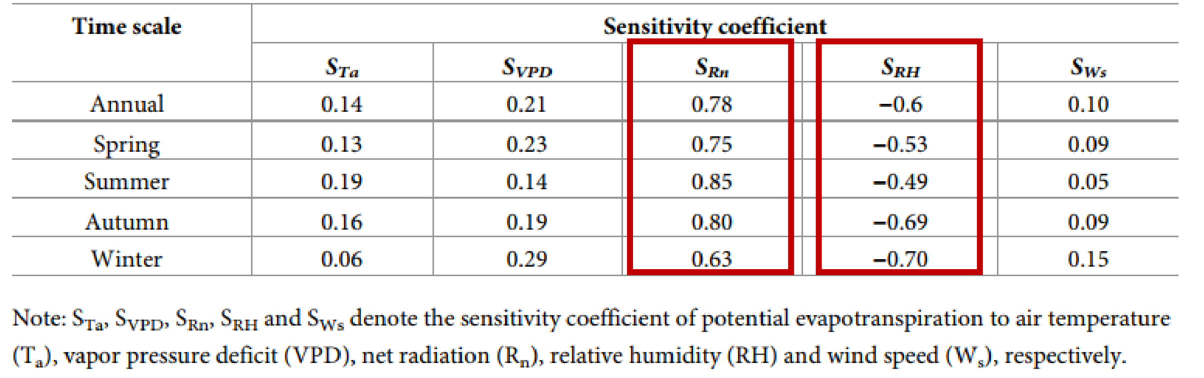


Fig. The relative sensitivity of the PET to five basic meteorological variables

Table. The sensitivity coefficient of the PET to the five basic meteorological variables.



Time scale	Sensitivity coefficient				
	S_{Ta}	S_{VPD}	S_{Rn}	S_{RH}	S_{Ws}
Annual	0.14	0.21	0.78	−0.6	0.10
Spring	0.13	0.23	0.75	−0.53	0.09
Summer	0.19	0.14	0.85	−0.49	0.05
Autumn	0.16	0.19	0.80	−0.69	0.09
Winter	0.06	0.29	0.63	−0.70	0.15

Note: S_{Ta}, S_{VPD}, S_{Rn}, S_{RH} and S_{Ws} denote the sensitivity coefficient of potential evapotranspiration to air temperature (T_a), vapor pressure deficit (VPD), net radiation (R_n), relative humidity (RH) and wind speed (W_s), respectively.

Annual scale

- Rn and RH were the two most sensitive elements on PET throughout the whole study region in general, followed by VPD. The least sensitive variable was Ws.

Seasonal scale

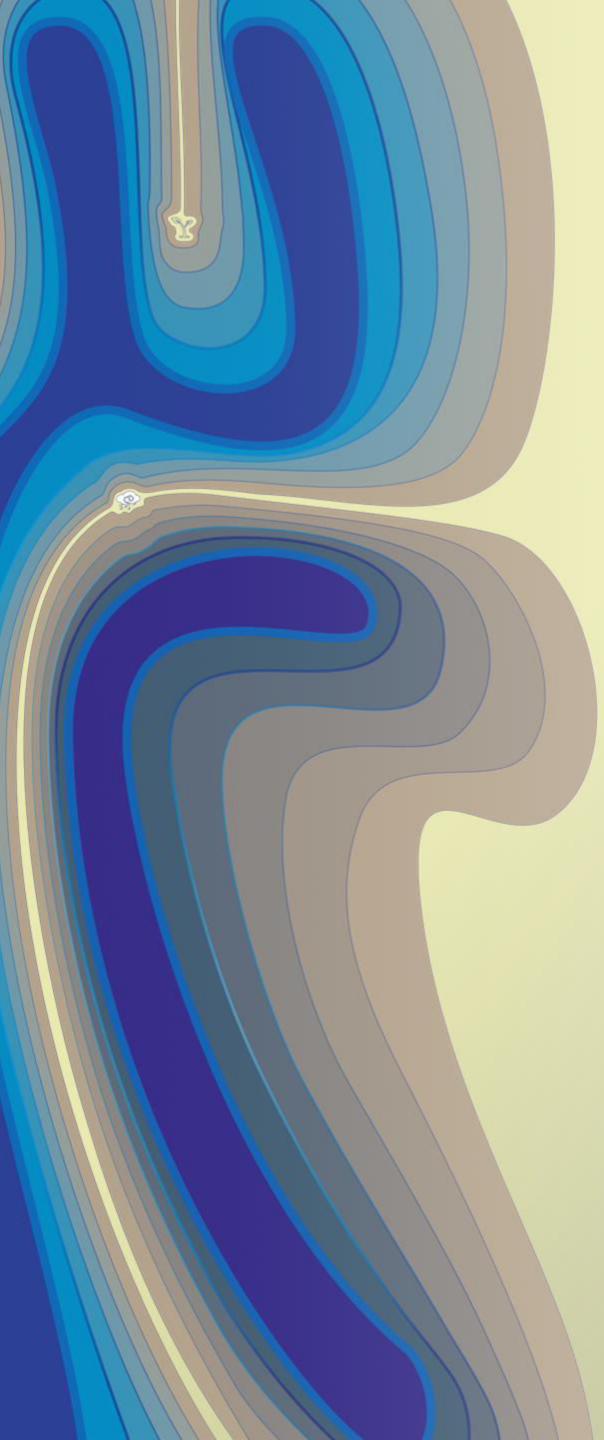
- The most sensitive variable on spring (0.75), summer (0.85) and autumn (0.80) PET was Rn.
- During winter, the greatest sensitivity of PET was for RH (−0.70).

Conclusions

- Seasonal and regional differences in PET and their associated meteorological variables are bound to exist. Approximately 58%, 68%, 38%, 73% and 73% of all surveyed weather stations produced an increasing trend in PET in annual, spring, summer, autumn and winter, respectively. The distinct seasonal and regional characteristics of changes in PET and their causes showed the importance of estimating the hydro-meteorological processes at fine spatiotemporal resolution.

- Climate change has greatly impacted local hydrology. A comparative analysis illustrated that the effects of meteorological factors are influenced by not only the sensitivity of PET to meteorological factors but also the change magnitude of the meteorological factors.

- This research fills the knowledge gap on the changes in PET and controlling factors in Southwest China, which is a substantial step in the process of understanding the water cycle and improving agricultural water management. Further work could improve the accuracy of agricultural water requirements and crop yield estimation by exploring the change mechanism through climate modelling techniques based on high-quality remote sensing products.



Thank you! Questions?

Contact me:
zhengqzvillage@163.com