XVIII World Water Congress
International Water Resources Association (IWRA)

Integrated assessment of multiple characteristics for extreme climatic events under climate change

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XVIII WORLD WATER CONGRESS
Water for All
Harmony between Humans and Nature

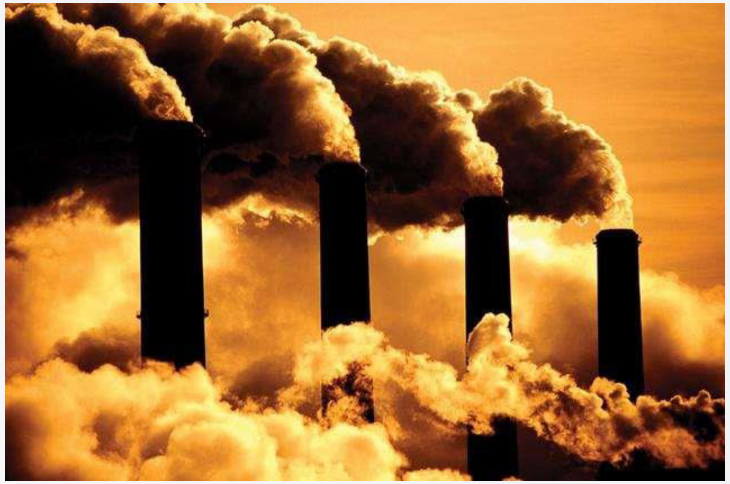
第18届世界水资源大会
水与万物：人与自然和谐共生

Content

- Motivation
- Material and methods
- Results and discussion
- Innovation and limitation

Motivation

- In the context of global warming, regional climate change has become one of the top concerns of human society due to its complex uncertainties and the severity of disasters.
- The Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change stated that climate change would continue to intensify in all regions of the world in the coming decades, and that climate disasters will become more frequent and severe. (IPCC Core Writing Team, 2021)



Human activities

Cause →

Global warming

Lead →

Extreme climatic event

Regional dry and wet change

It is of great significance to study the occurrence and development of extreme climates from multiple scales, dimensions, and perspectives.

Material and methods

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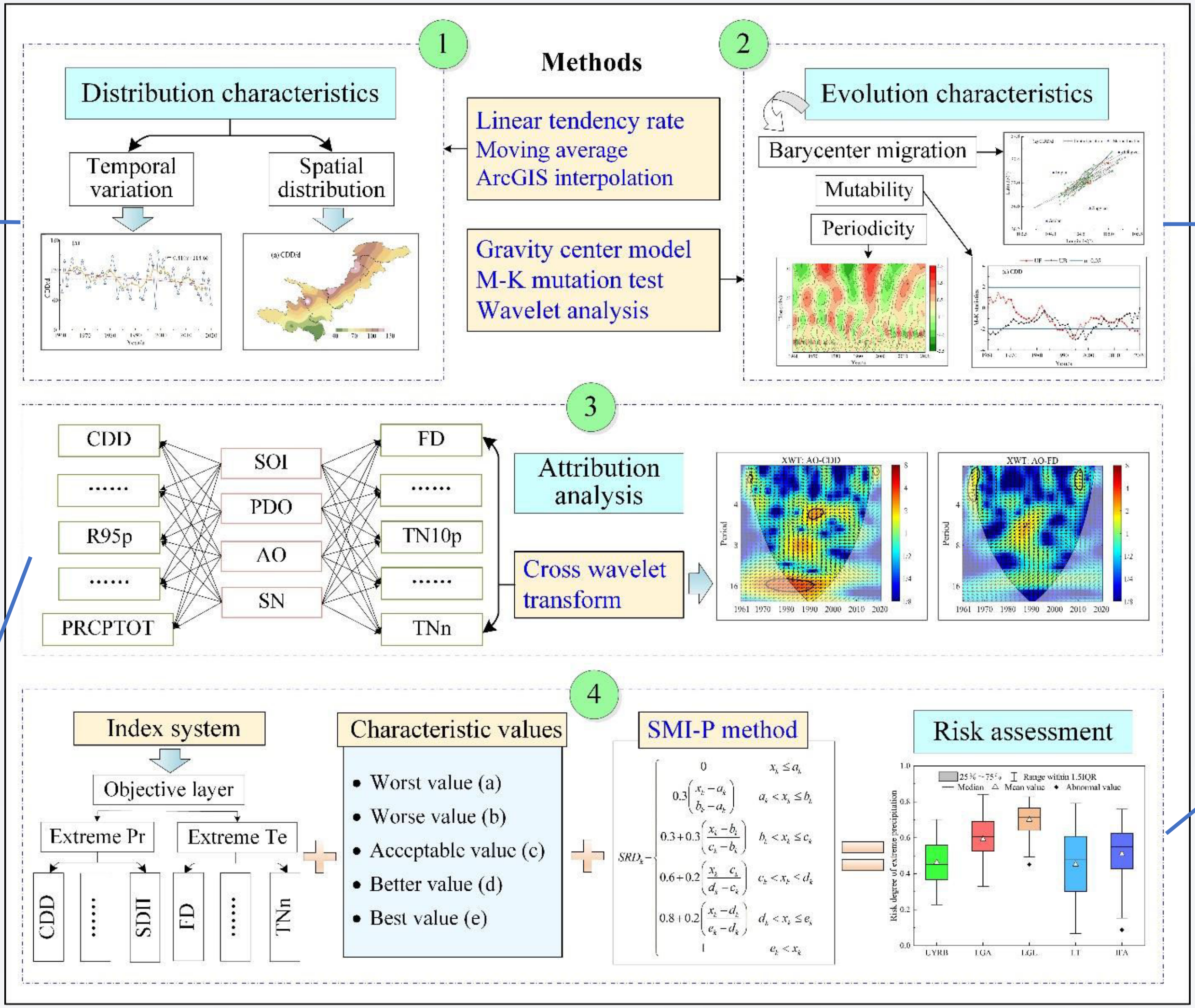
➢ Concrete content

Temporal variation and spatial distribution of extreme climate events, which is a direct analysis of extreme climate conditions.

To explore the tele-connection between atmospheric circulation, solar activity and extreme climate change, and to identify the main drivers.



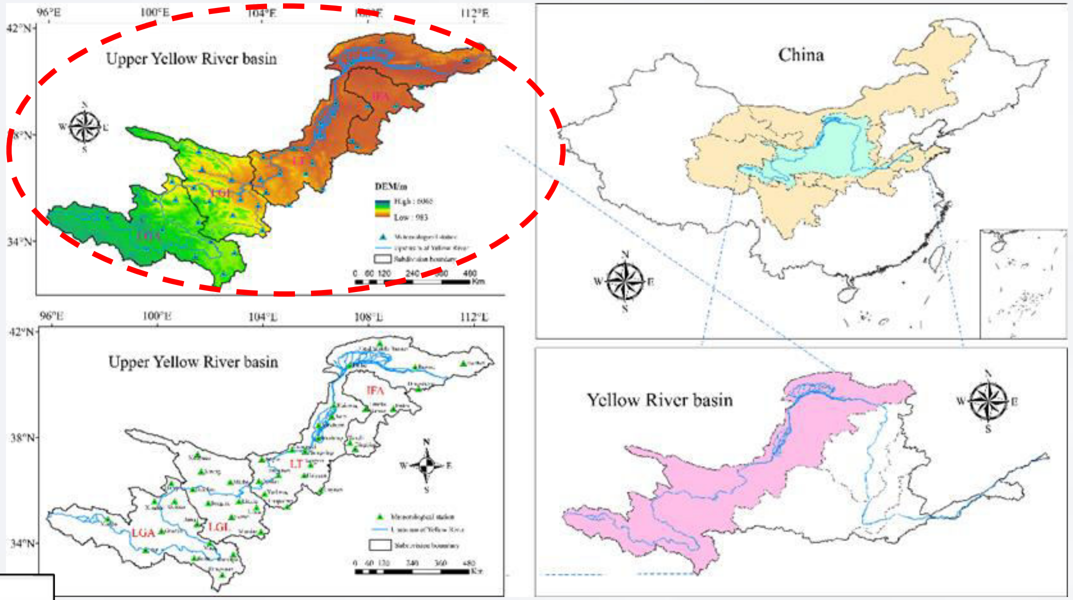
Mutability and periodicity of extreme climate events, a reanalysis of extreme climate conditions.

Combining two aspects of extreme Pr and Te, to assess the risk degree and level of climatic extremes.

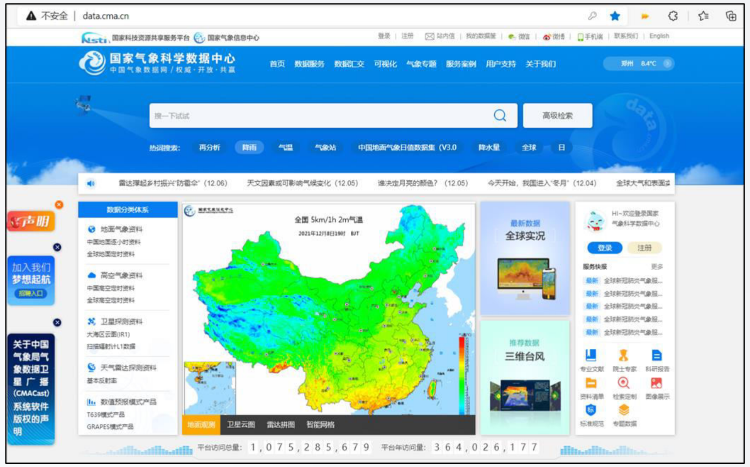
Material and methods

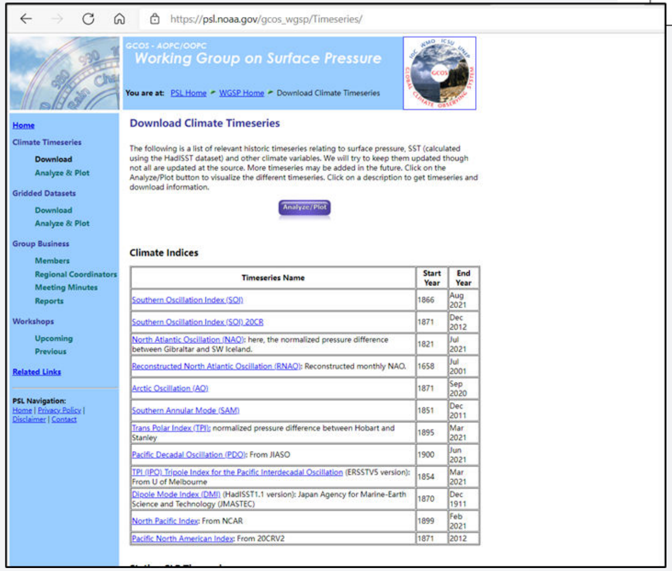
➢ Material

- The upper reaches of the Yellow River are about 3,472 kilometers long, the Upper Yellow River basin (UYRB) covers an area of 417.4 thousand km^2.
- Four secondary watersheds: Longyang Gorge above (LGA), Longyang Gorge to Lanzhou (LGL), Lanzhou to Toudaoguai (LT) and Inner flow area (IFA).



Study period: 1961-2020





http://data.cma.cn https://psl.noaa.gov/gcos_wgsp/Timeseries/

- Daily precipitation and temperature data are derived from China Surface Climatological Dataset of the China Meteorological Data Network.
- Atmospheric circulation factor and sunspot data from the National Oceanic and Atmospheric Administration (NOAA).

Material and methods

➢ Methods

The first step: Selection and calculation of extreme climate indices

7 extreme Pr indices and 9 extreme Te indices were selected from perspectives of absolute threshold, relative threshold and extreme value; the calculations were made using the RclimDex software.

	Precipitation (Pr)	Temperature (Te)
Absolute threshold index	**Consecutive dry days (CDD, d)** Maximum number of consecutive days with Pr < 1mm **Consecutive wet days (CWD, d)** Maximum number of consecutive days with Pr ≥ 1mm **Heavy precipitation days (R10, d)** Annual count of days when Pr ≥ 10mm	**Frost days (FD, d)** Annual count when TN (daily minimum) < 0°C **Ice days (ID, d)** Annual count when TX (daily maximum) < 0°C **Summer days (SU25, d)** Annual count when TX > 25°C
Relative threshold index	**Very wet days (R95p, mm)** Annual total Pr when daily Pr > 95th percentile	**Cool days (TX10p, d)** Number of days when TX < 10th percentile **Cool nights (TN10p, d)** Number of days when TN < 10th percentile **Warm days (TX90p, d)** Number of days when TX > 90th percentile **Warm nights (TN90p, d)** Number of days when TN > 90th percentile
Extreme value index	**Max 5-day Pr amount (RX5, mm)** Monthly maximum consecutive 5-day Pr **Simple daily intensity index (SDII, mm/d)** Annual total Pr divided by the number of wet days (Pr ≥ 1mm) **Annual total wet day Pr (PRCPTOT, mm)** Annual total Pr in wet days (Pr ≥ 1mm)	**Max Tmax (TXx, °C)** Yearly maximum value of daily maximum Te **Min Tmin (TNn, °C)** Yearly minimum value of daily minimum Te

The second step: The application of various methods

Content	Methods
1. Spatial and temporal distribution features	a) Climate tendency rate; b) Moving average method; c) Kriging interpolation method
2. Evolution characteristics in time history	a) Mann-Kendall mutation test (Mutability); b) wavelet analysis (Periodicity)
3. Attribution analysis of extreme climatic events	Cross wavelet transform (Achieved by *MATLAB*, http://grinsted.github.io/wavelet-coherence/)
4. Assessment of the risk degree and level	Single index quantification and Multiple index synthesis and Poly-criteria integration (Propose)

Results and discussion

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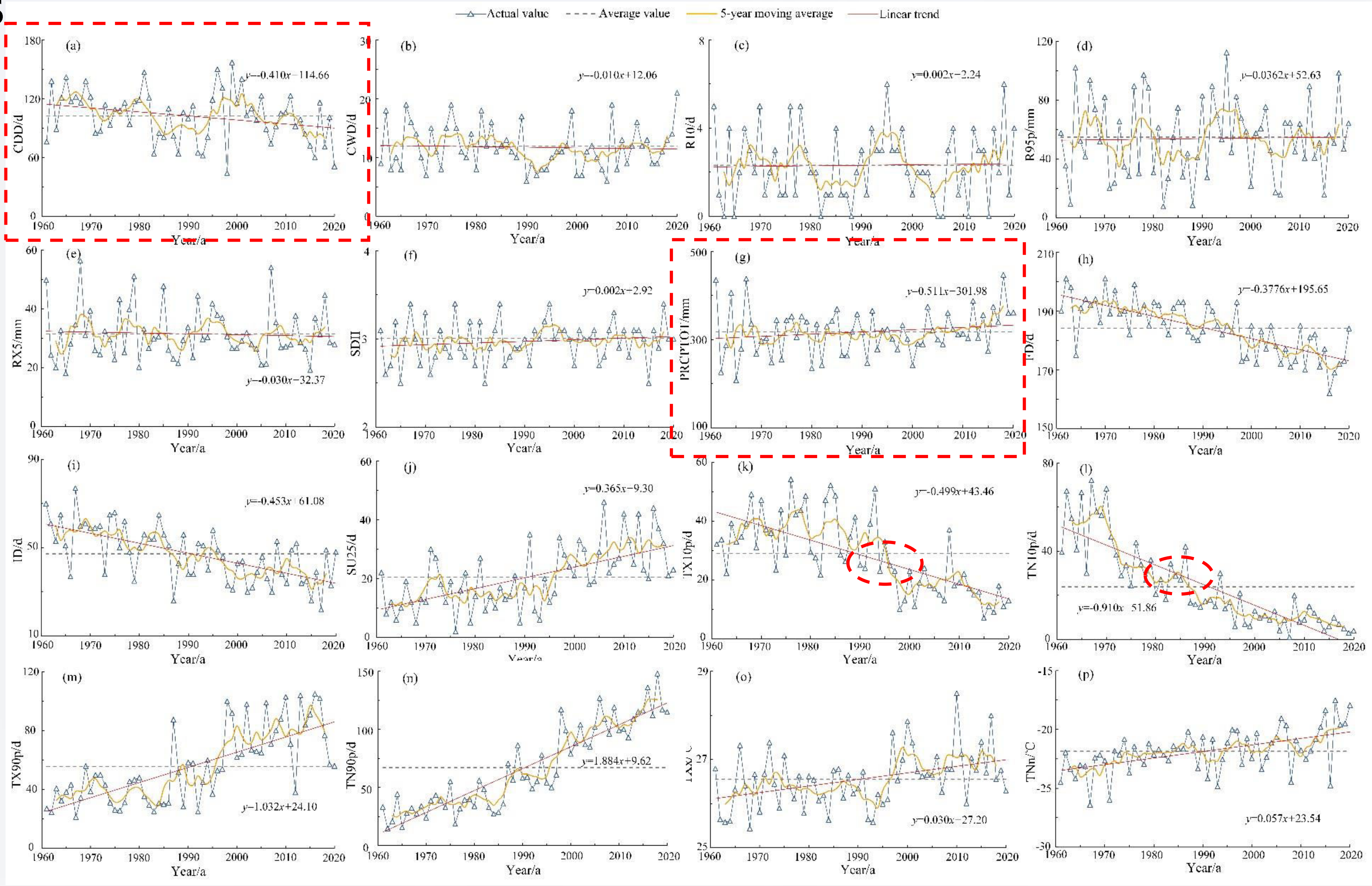
➢ Distribution features

1. Temporal variation

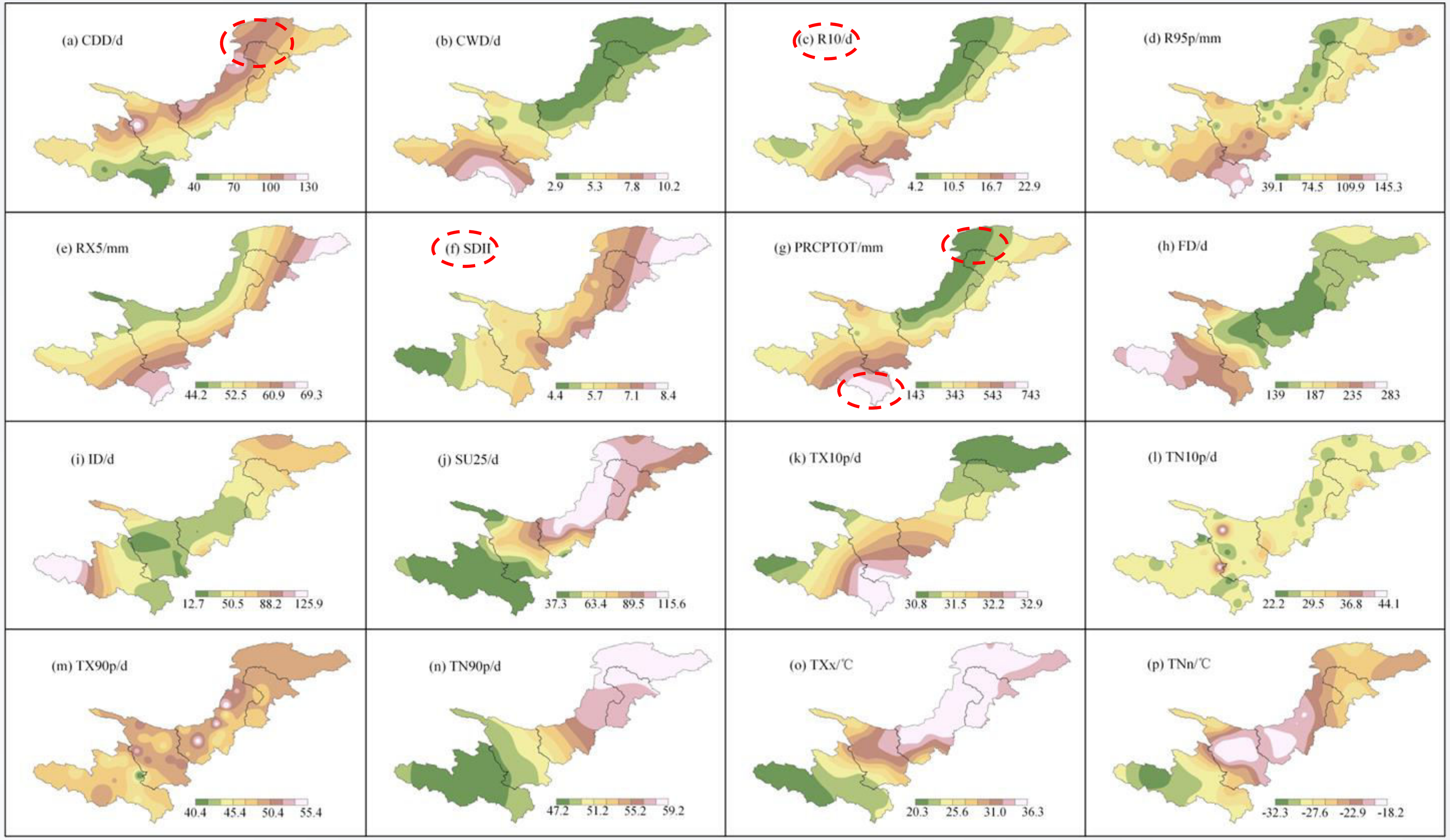
- The interannual variation of consecutive dry days (CDD) and annual Pr (PRCPTOT) is evident, while the other indices show only a slight trend of variation. The concentration and influence of Pr is increasing.
- The trend of extreme Te index is more significant than that of extreme Pr index. The intensity and frequency of extreme high Te events have increased significantly.



Results and discussion

2. Spatial distribution

Showing the intensity of extreme weather in different regions



- The southeast of the basin is wetter than the northwest, where the number of continuous dry days even reaches 100-130.
- The number of days with heavy Pr is lower, but the intensity of Pr is higher in the eastern region, which is more prone to extreme Pr disasters.
- The spatial distribution of extreme Te events is quite different due to the apparent spatial differences in the topography and the intensity of human activity.

Results and discussion

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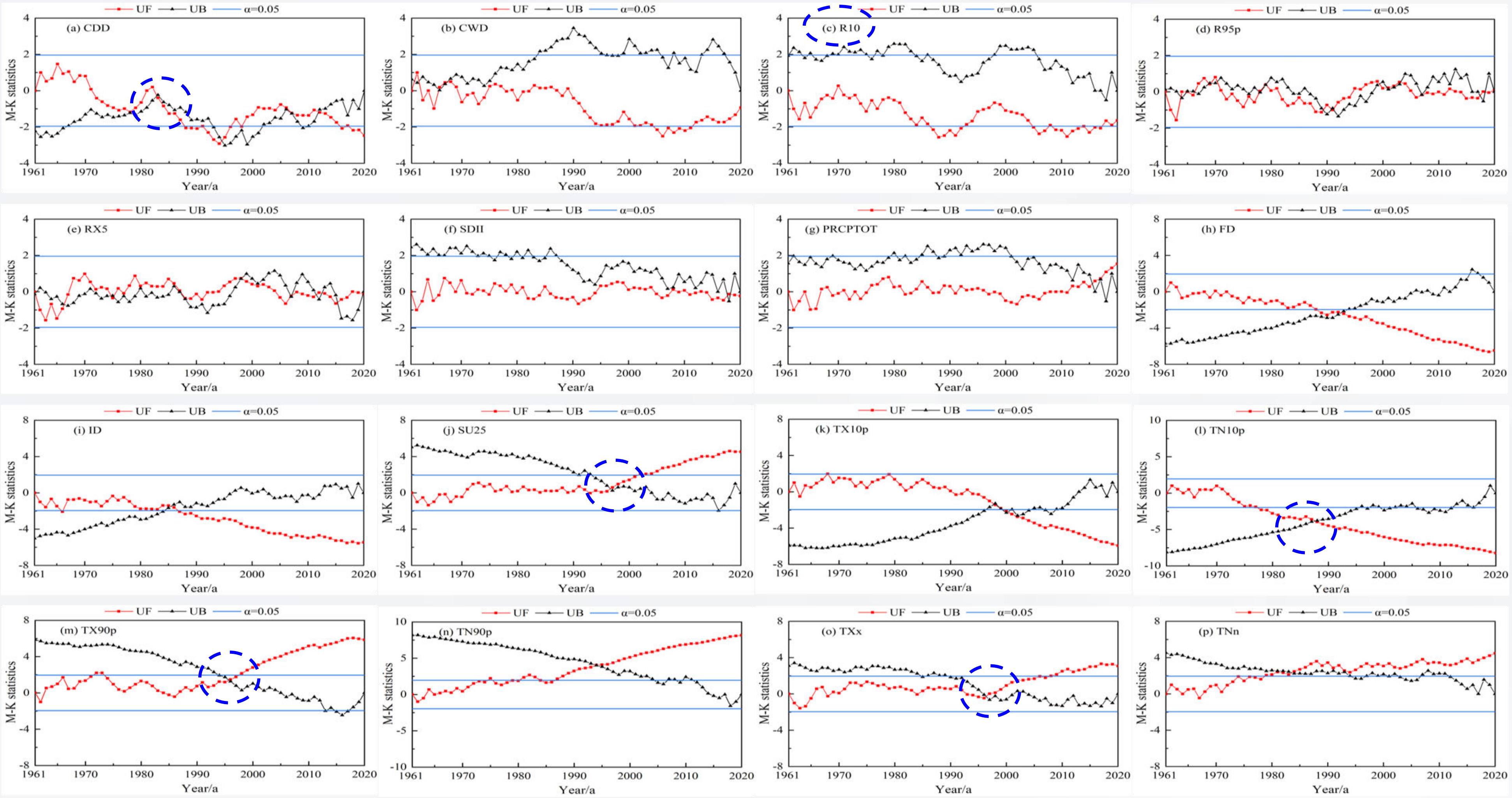
➢ Evolution features

1. Mutability test

- In general, except for the heavy Pr days (R10) index, the UF and UB curves of all indices have at least one intersection.

- According to the number of intersections, it can be classified into three types: zero, one, and multiple intersections.
- The mutation features of the extreme Pr indices are more complicated than those of the extreme Te indices.
- The years of the index's abrupt changes vary widely, but most occurred in the 1980s and 1990s.



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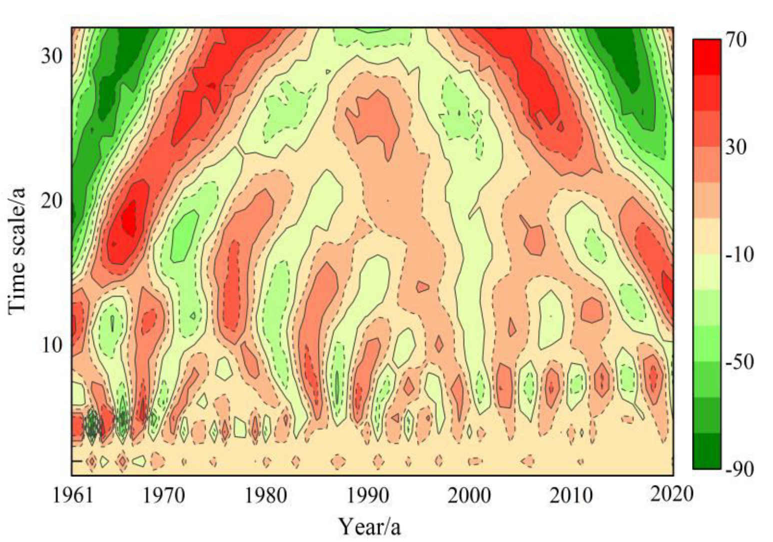
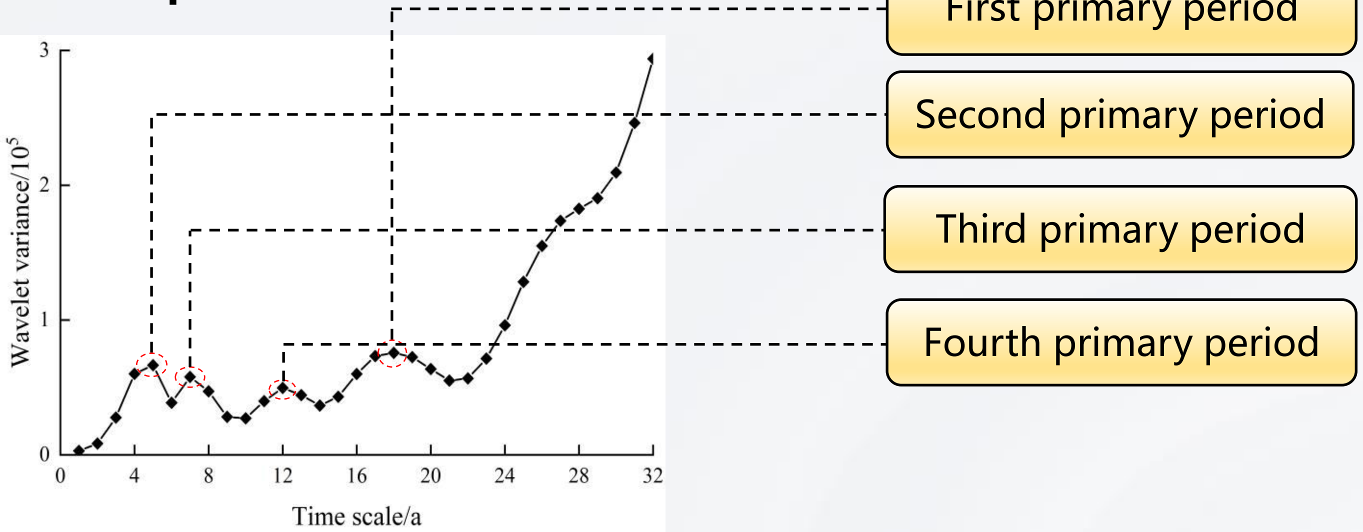
2. Periodic analysis



Example: PRCPTOT



Primary periods of extreme climate indices

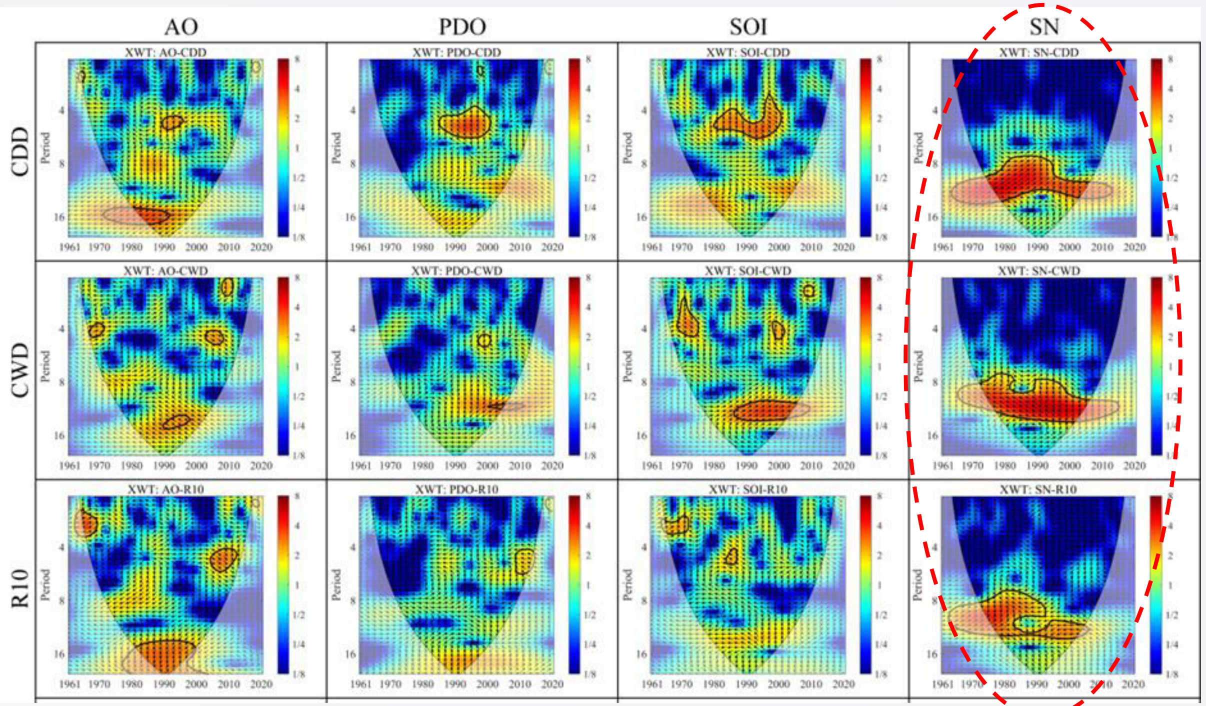
Primary period	CDD	CWD	R10	R95p	RX5	SDII	PRCPTOT	FD
First	22	11	22	20	21	7	18	13
Second	7	16	8	13	12	5	5	4
Third	3	7	12	8	8		7	
Fourth		3	4	4	5		12	

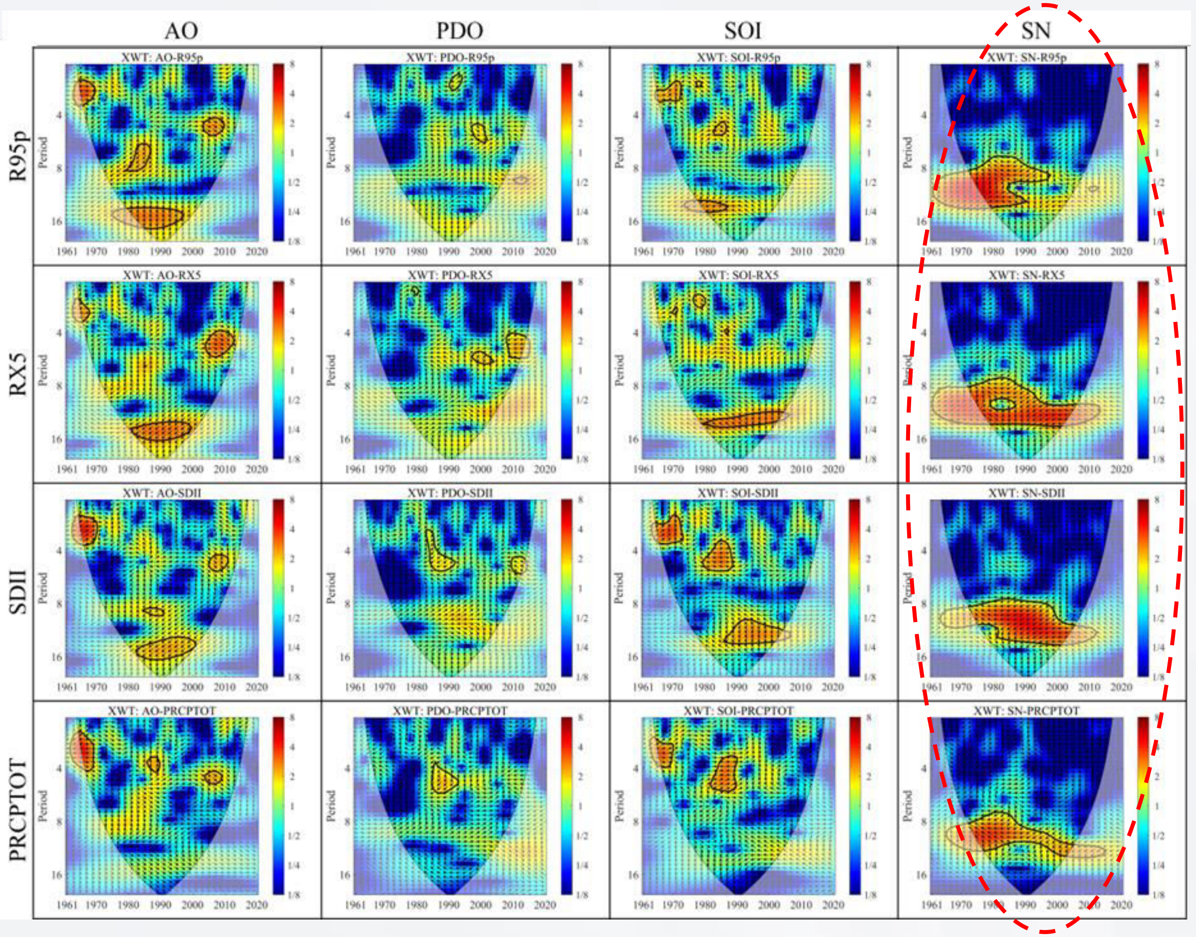
Primary period	ID	SU25	TX10p	TN10p	TX90p	TN90p	TXx	TNn
First	27	8	28	22	14	14	10	28
Second	22	5	18	12	21	6	7	14
Third	12	14	20	4	6		4	6
Fourth	5	22	7					4

- The annual Pr has four primary periods (18a, 12a, 7a, 5a), but oscillations do not occur throughout the study period.
- With the exception of SDII, FD, and TN90p, almost all extreme climate indices have more than two primary periods, showing trends of interannual and interdecadal oscillations.
- Most indices generally have three types of periods, large, medium, and small, showing consistency, but their time domain, frequency, and oscillation intensity are quite different.

Results and discussion

➢ Attribution analysis 1. Teleconnection between driving forces and Pr extremes



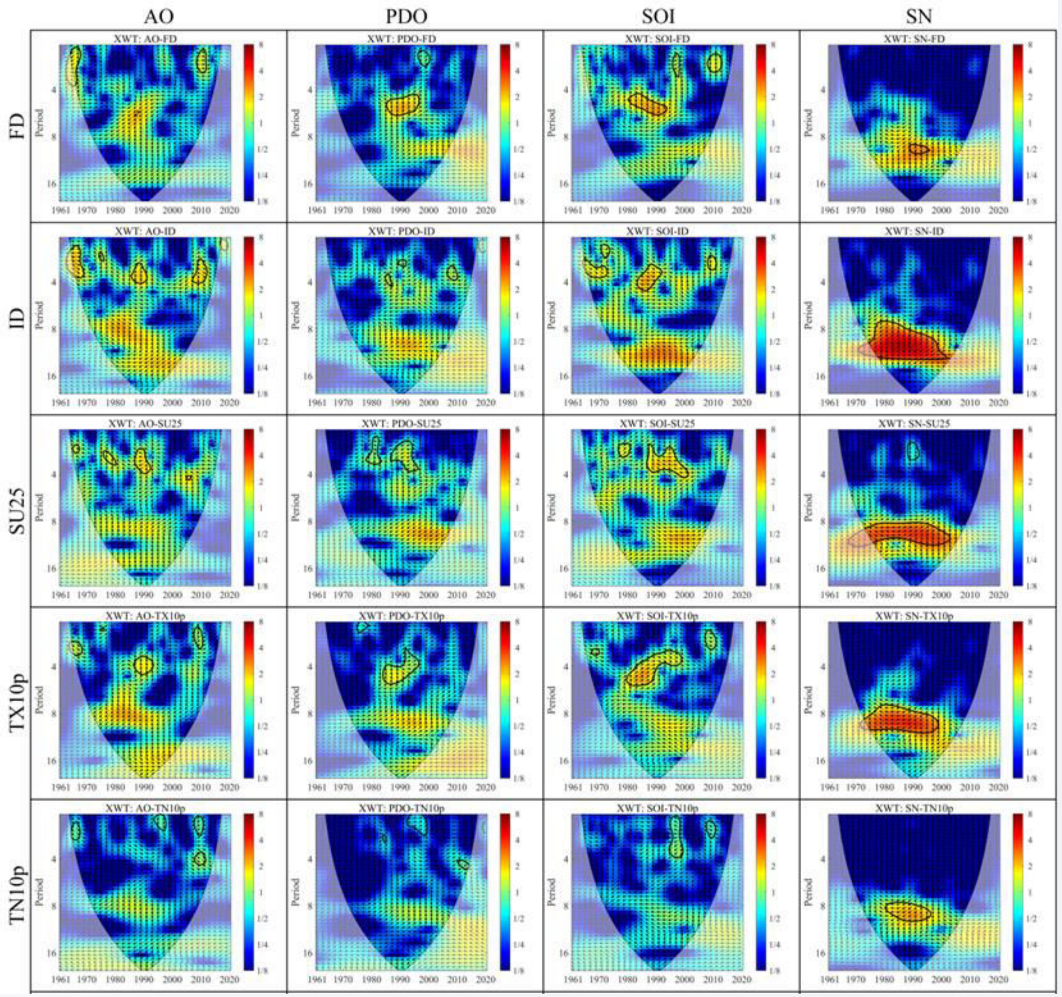


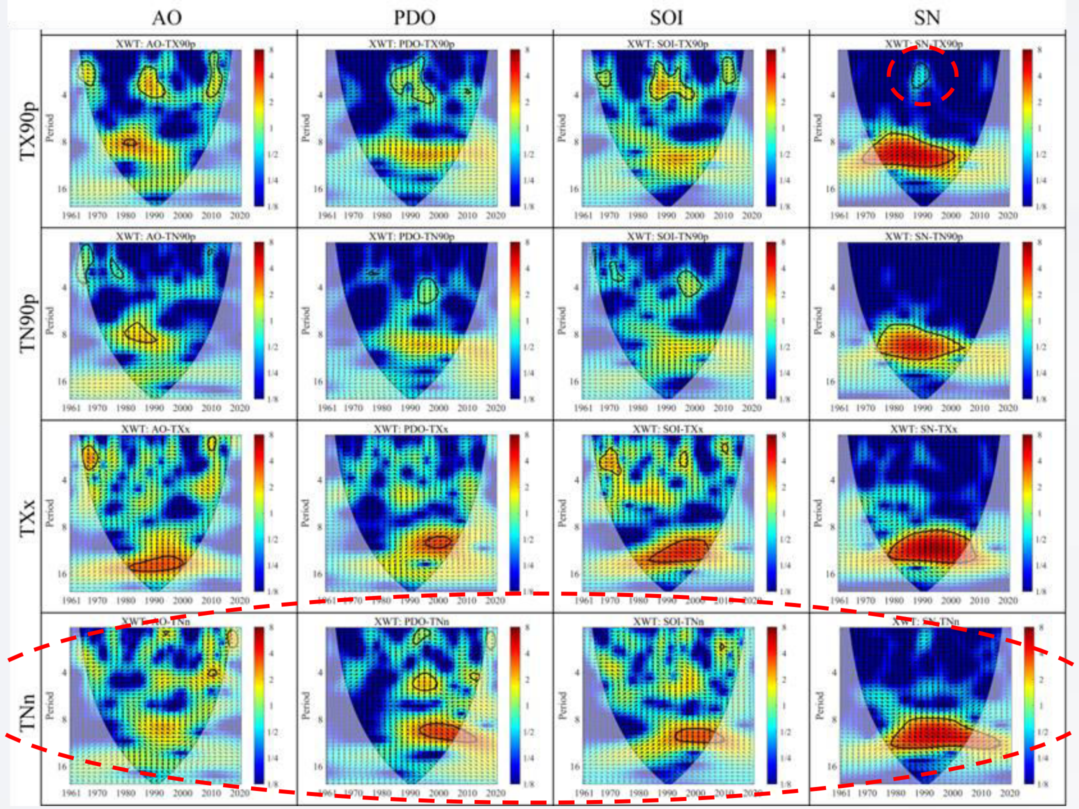
- The response relation between the selected driving force and the extreme Pr index differs significantly in terms of index category, resonance intensity, time domain, and phase relation.

- In terms of driving forces, almost all indices with AO and SOI have larger resonance periods and intensities than PDO, and exhibit features of multiple time scales and long time domains.
- There is a correlation between the SN and the extreme Pr index on scales 8-14a, which is related to the mean period of solar activity at 11a.

Results and discussion

2. Teleconnection between driving forces and Te extremes





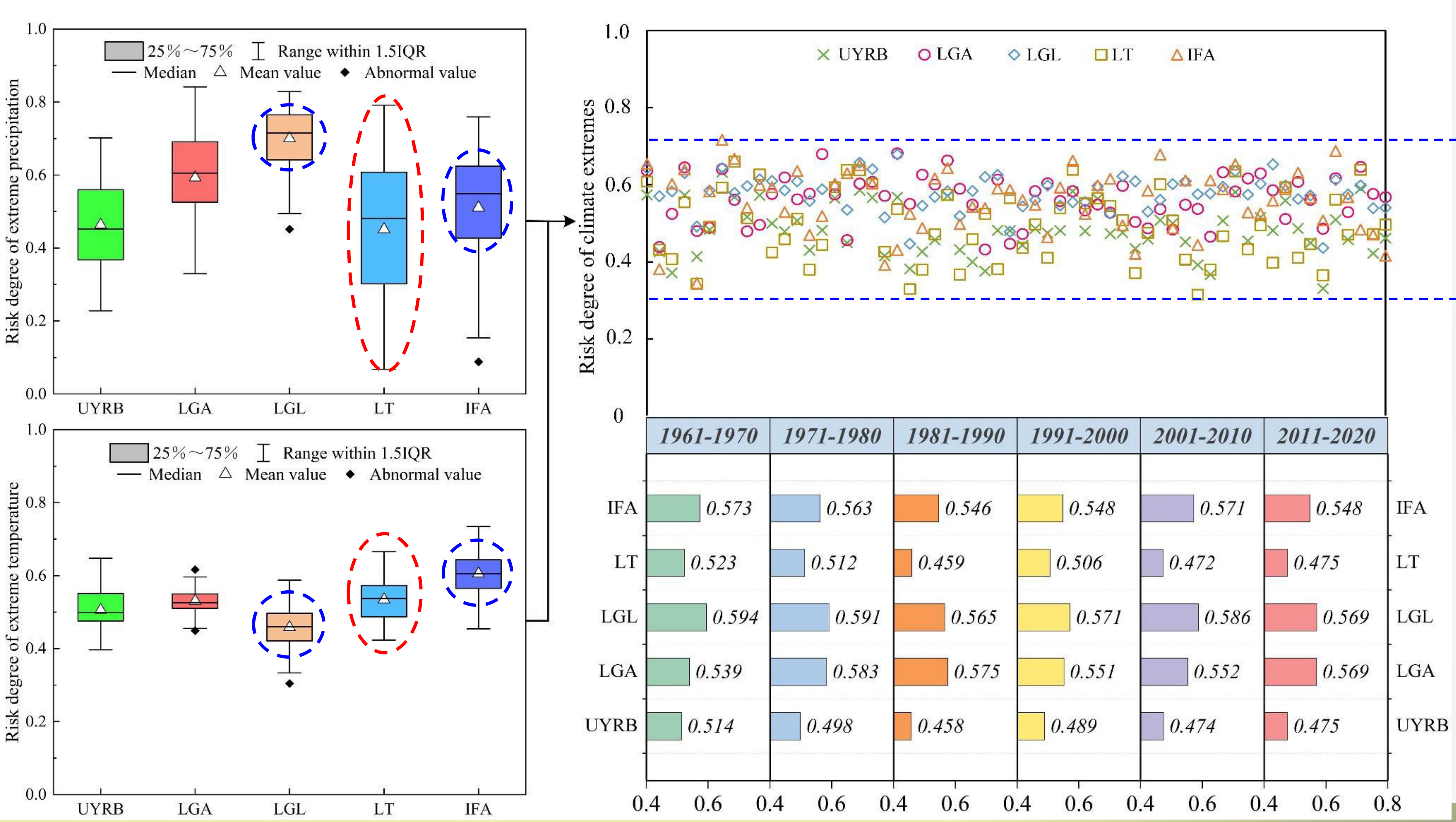
- Similar to the extreme Pr index, the correlation between AO and SOI is stronger than PDO for almost all extreme Te indices except for the minimum temperature (TNn).

- There is also a significant correlation between the SN and the most extreme Te indices at large scale period.
- The correlation between the extreme Te index and the selected driving force is weaker than that of the extreme Pr index, indicating that the Pr extremes is more strongly and more complexly affected by atmospheric circulation.

Results and discussion

➢ Risk analysis

- The risk degree of extreme Pr and Te is diverse among subbasins. The overall risk degree of extreme Pr in the same region is larger than that of extreme Te, and its variation range is also larger, mainly due to the complex uncertainty of Pr.



The overall risk of extreme climate is in the range of 0.3 to 0.7, with a fluctuating trend from 1961 to 2020.

- Regions with a high risk of extreme Pr may have a lower risk of extreme Te, while the situation is different for the Inner flow area (IFA).
- The occurrence of extreme Pr and Te events is not spatially and temporally synchronized, so coping strategies should be formulated based on the actual situation.

Innovation and limitation

➢ Innovation

- An Distribution-Evolution-Attribution-Risk (DEAR) framework was developed.
- A novel risk assessment idea for climatic extremes was proposed with the SMI-P method.
- The DEAR framework was applied to a real case of Upper Yellow River basin, China.
- Extreme climatic events were examined with multiple scales, dimensions and aspects.
- Findings can help clarify the occurrence and development laws of climate extremes.

➢ limitation

1. The occurrence and variation of climatic extremes are influenced by multiple factors. An all-sided attribution analysis involving many factors should be carried out.

2. The characteristic values applied in the risk assessment are determined by the percentile of the data series. Universal standard should be explored further.