Investigation to the relation between meteorological drought and hydrological drought in the upper Shaying River Basin using wavelet analysis

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CONTENTS

PART ONE

Background

01 Background

- With the global climate and environment changes, droughts occur **more frequently** and also cause **greater loss**.
- It is difficult to forecast hydrological drought by using hydrologic model in China, because the data of streamflow is **not publicly published.**
- To get enough time to cope with water supply shortage, using the propagation time from meteorological drought to hydrological drought to give an **early warning** of hydrological droughts is an effective method.

Therefore, more detailed investigation was required to well understanding the relation between meteorological drought and hydrological drought.

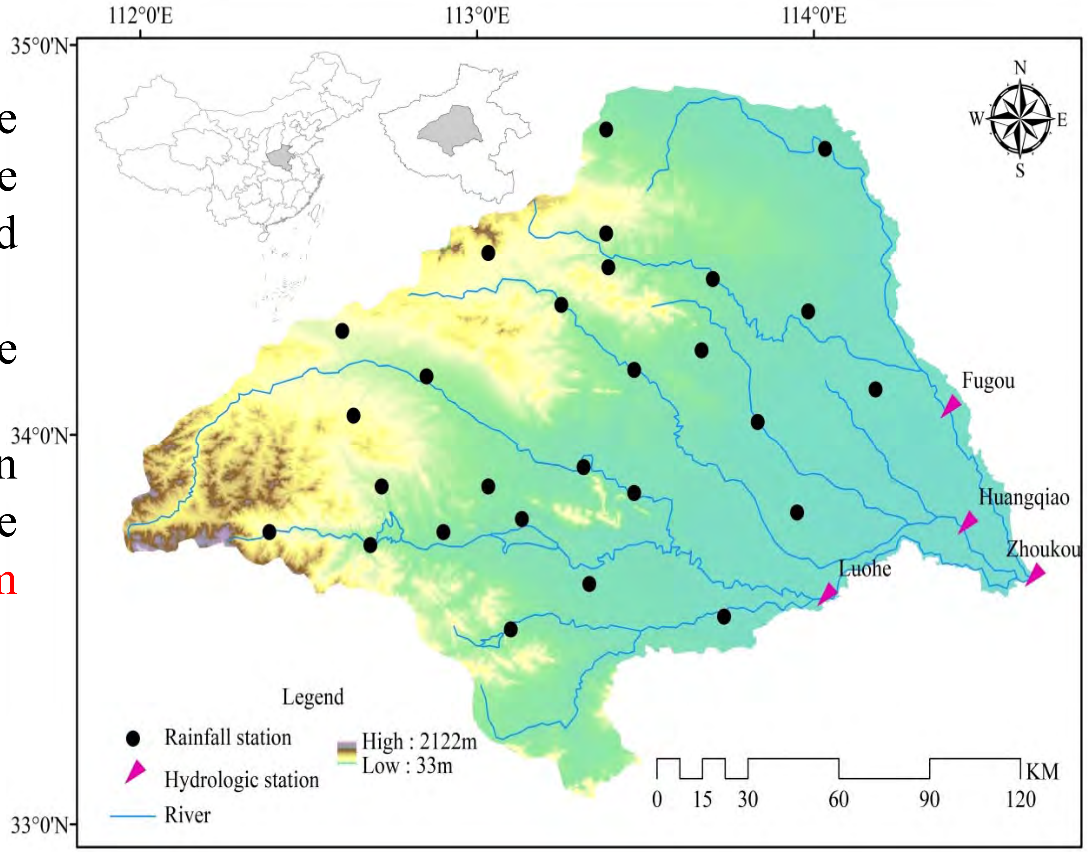
PART **TWO**

Study Site

02 Study Site

◆ The Shaying River is the biggest tributary of the Huaihe River.

- The basin is characterized by more precipitation and higher temperature in summer, and less precipitation and lower temperature in winter.
- The multi-year average temperature is about 14–15 ° C
- The multi-year average precipitation falls within 700 to 1000mm in the western hilly area and 600 to 800mm in the eastern plain area,



02 Study Site

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The hydrologic stations

Main stream

- The Zhoukou station, control catchment area 25,800 km^2

Tributaries

- The Luohe station, 12150 km^2
- The Huangqiao station, 6807 km^2
- The Fugou station, 5710 km^2

Facts

- ✓ The intra-annual distribution of the precipitation is very uneven with more than 60% of annual precipitation in flood season (from June to September).
- ✓ The inter- and intra-annual variation characteristics of precipitation lead to frequent occurrence of droughts

PART THREE

Data & Methodology

Data

- **Time Series：** daily precipitation time series from 27 rainfall stations and daily avereage streamflow time series from 4 hydrologic stations, 1964~2016
- **Data Sources：** Hydrology and Water Resources Bureau of Henan Province, China

Methodology ①

◆ **The monthly Standardized Precipitation Index (SPI) was selected to represent meteorological drought, and the monthly Standardized Streamflow Index (SSI) for hydrological drought.**

- The heuristic segmentation method was utilized to detect the possible change points of the annual precipitation and runoff time series.
- With the Kolmogorov-Smirnov (K-S) test at a 5% significance level, four different distributions (Pearson III , Log-normal, General Extreme Value, and Generalized Logistic distribution) were identified for the goodness-of-fit test of monthly streamflow time series.
- The SSI values were obtained by use of standardized normal distribution function based on the best cumulative probability of monthly streamflow time series at different hydrological stations.

Methodology ②

- **The Pearson correlation analysis between monthly SPI accumulated periods of 1–24 months and monthly SSI was applied to detect the propagation time between meteorological drought and hydrological drought**

  - The Pearson correlation coefficients between SPI accumulated periods of 1–24 months and SSI-1 series for every month.
  - The Pearson correlation coefficients between the SPI and the SSI-1 time series of 1964-2016.

Methodology ③

◆ Wavelet analysis Application:

- ✓ The continuous wavelet transform, cross wavelet transform, wavelet coherence and wavelet cross-correlation were utilized to depict the links between meteorological drought and hydrological drought in specific time-frequency bands.

PART FOUR

Results & Discussions

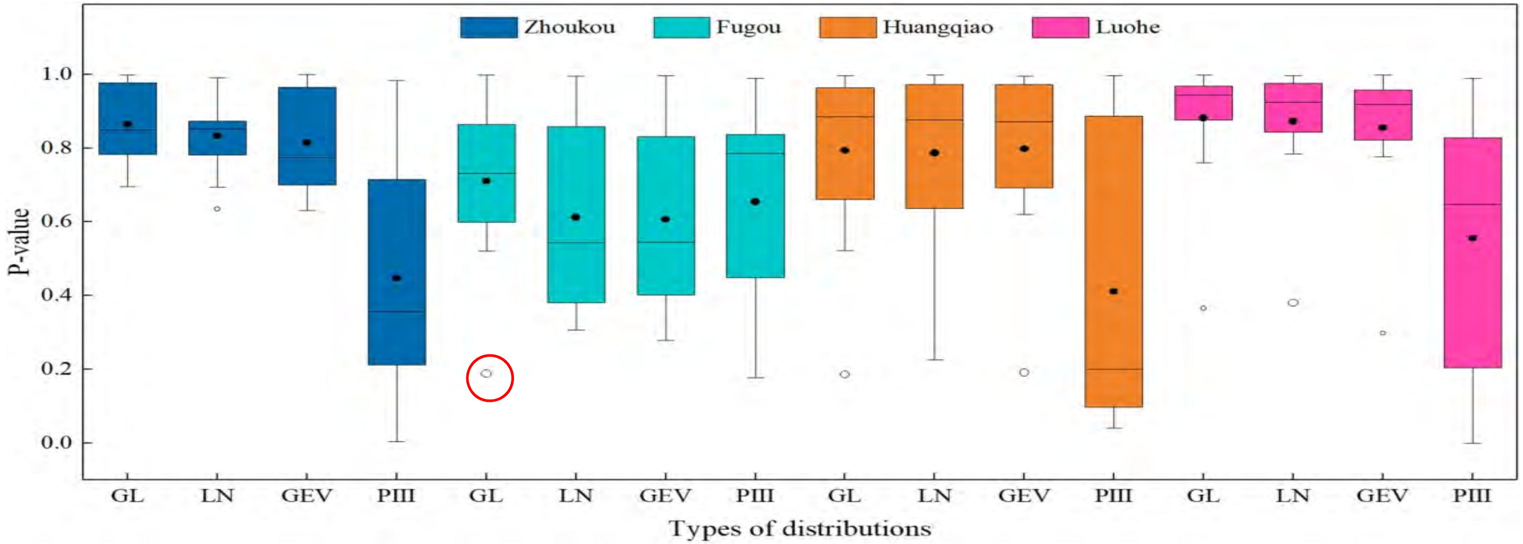
◆ 4.1 Goodness-of-fit test of monthly streamflow distributions

Station	Orders of iteration	Precipitation			Runoff		
		T_{max}	$P(T_{max})$	Chang point (year)	T_{max}	$P(T_{max})$	Chang point (year)
Zhoukou	First	2.19	0.8	1965	4.4	1	1965
	Second				2.15	0.8	2015
Fugou	First	1.82	0.64	1965	4.34	1	1965
	Second				4.24	1	2003
	Third				2.79	0.95	1986
Huangqiao	First	1.91	0.69	1965	4.6	1	1965
	Second				1.8	0.64	1986
Luohe	First	2.13	0.78	1965	3.76	1	1965
	Second				2.62	0.92	2013

Change points identification of annual precipitation and runoff in the upper Shaying River Basin.

- ✓ No change point existed in the annual precipitation series.
- ✓ Change points existed in all annual runoff series.
- ✓ We proved that the non-stationarity of annual runoff series could hardly affect the selection of the same probability distribution of annual runoff series.

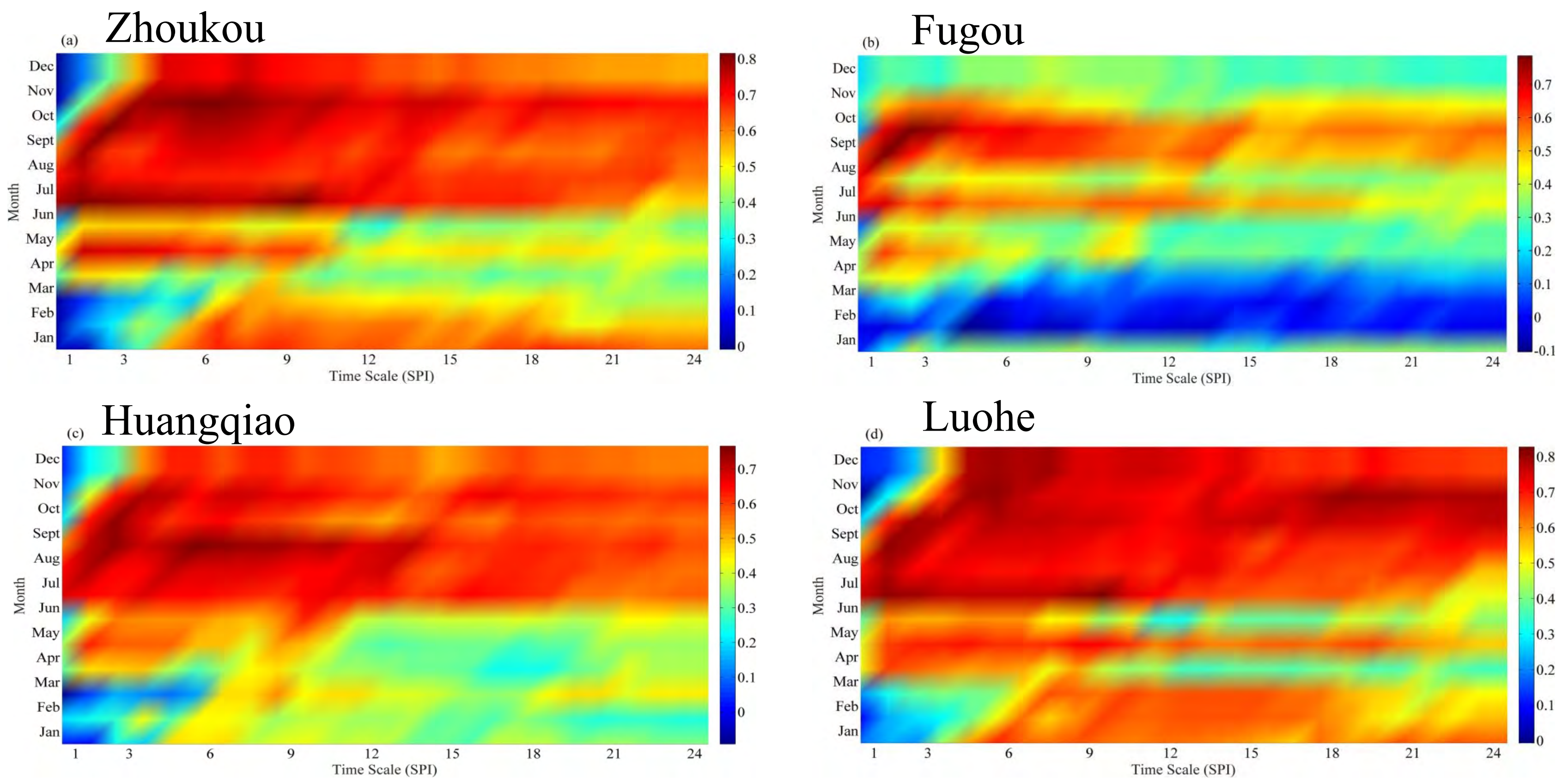
◆ 4.1 Goodness-of-fit test of monthly streamflow distributions



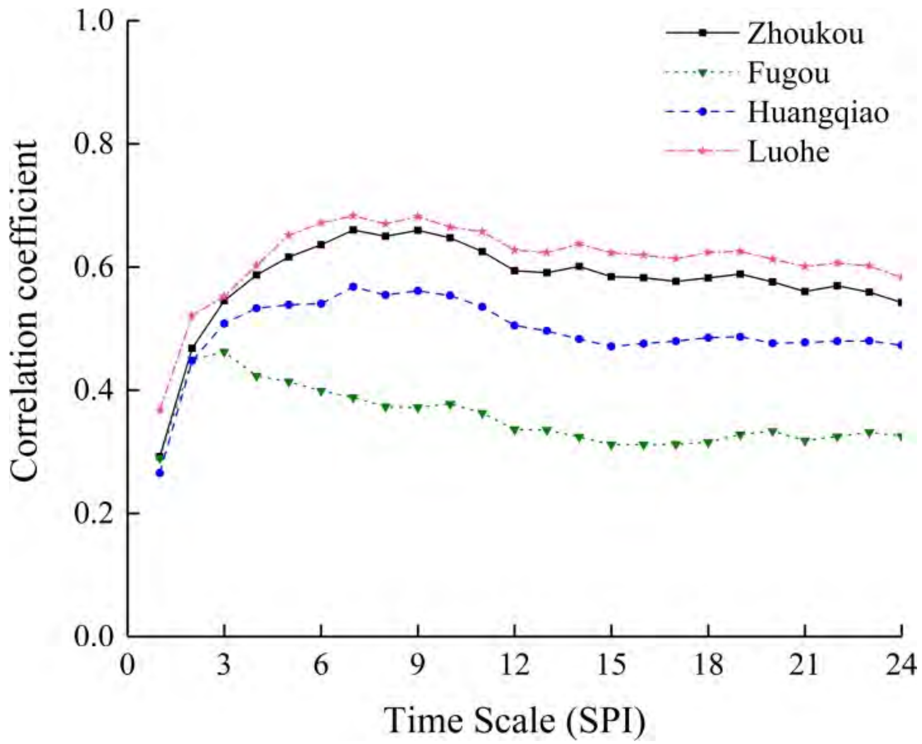
P-values for the different types of distributions fitting monthly streamflow data

- At Fugou station, since the mean and minimal values of the P-value for the GL are higher than those for the LN, GEV and PIII, and the only one outlier was greater than 0.05, the GL was regarded as the best fit to its streamflow data.
- The best-fit distribution for Zhoukou, Huangqiao, Luohe stations was determined as the GEV, the GL and the GL.

◆ 4.2 Propagation time from meteorological drought to hydrological drought



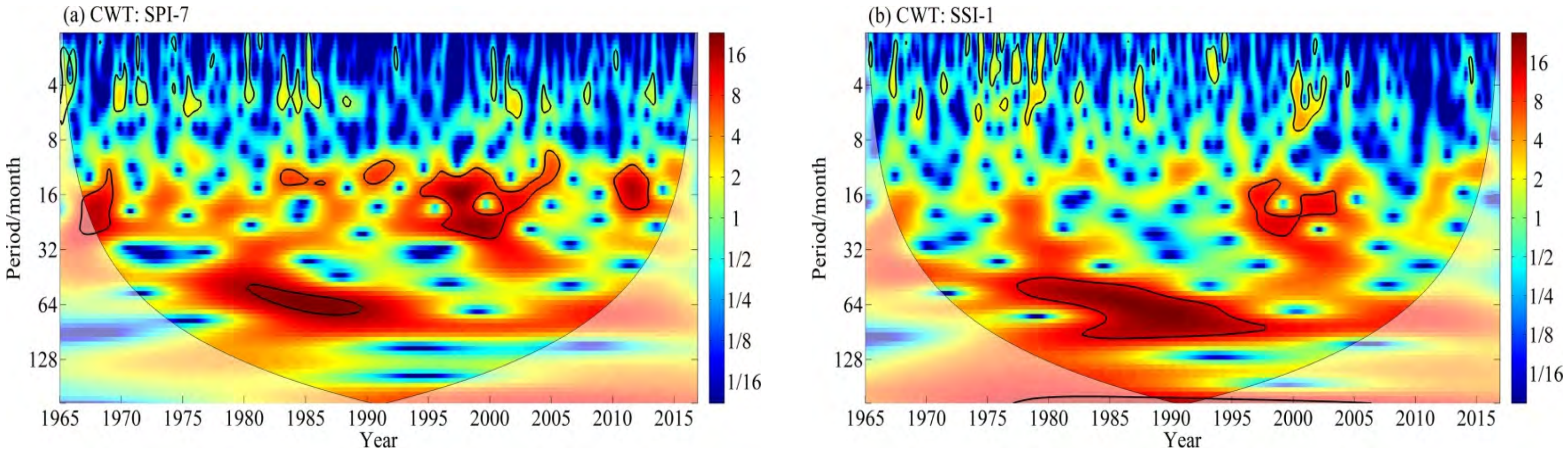
- The propagation time from meteorological drought to hydrological drought notably varied with seasons, the longer in spring and winter and the shorter in summer and autumn.



The correlation coefficients between the SPI and the SSI-1

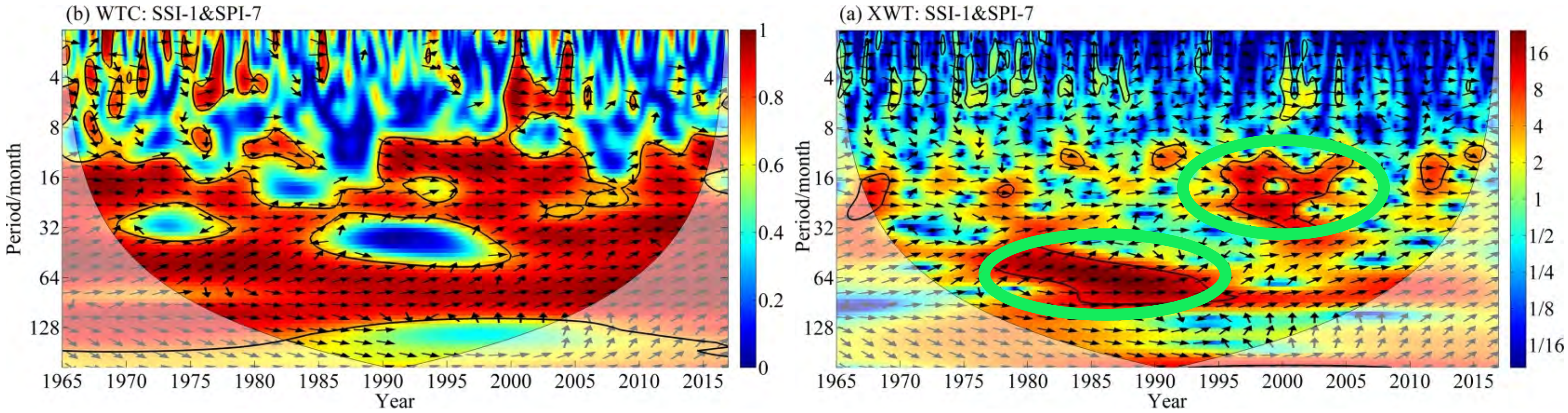
- The biggest correlation coefficient was 0.66, 0.46, 0.57 and 0.68 respectively at Zhoukou, Fugou, Huangqiao and Luohe, and the propagation time at Zhoukou, Fugou, Huangqiao and Luohe was 7, 3, 7, and 7 months respectively.

◆ 4.3 Relationship between hydrological and meteorological droughts



Continuous Morlet wavelet power spectrum of the SPI-7(a) and the SSI-1(b).
The thick contours denoting a 95% confidence level against red noise,
and the thin lines being cone of influence (COI) in which the effect of zero padding may distort the picture.

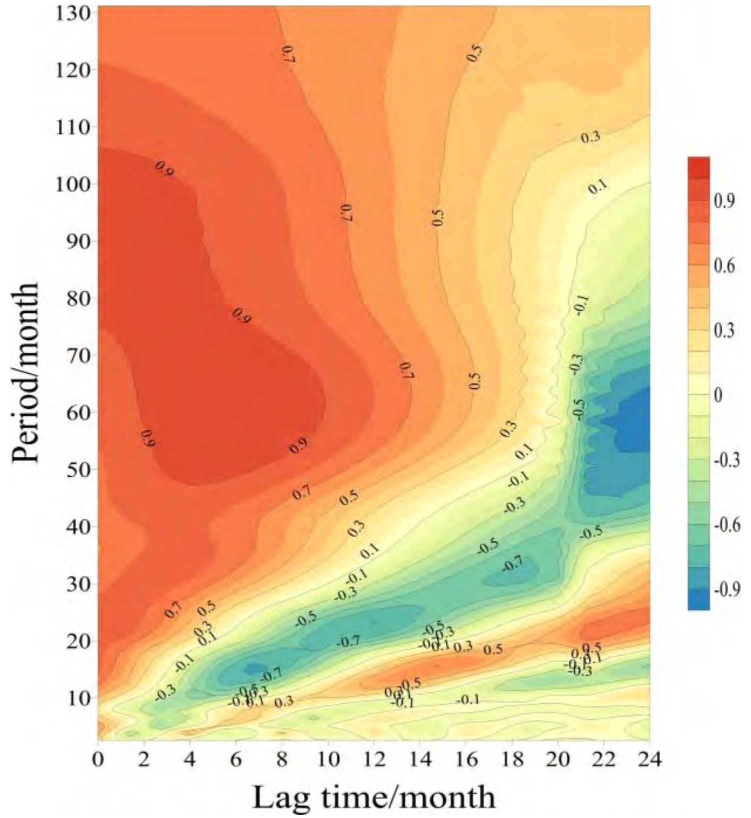
- ✓ The SPI-7 and the SSI-1 at a 95% confidence level had a 14- to 26-month band around 1997–2004.



Cross wavelet power spectra (a) and wavelet coherence (b) of the SSI-1 and the SPI-7.

- ✓ There was a significant relationship between the SSI-1 and the SPI-7 in a 12- to 40-month period mainly during 1995–2006, and a 48- to 108-month period from 1977 to 1992.
- ✓ A significant in-phase relationship between the SSI-1 and the SPI-7 was illustrated in the most part of the area.

◆ 4.3 Relationship between hydrological and meteorological droughts



Wavelet cross-correlation of the SSI-1 and the SPI-7

- ✓ Highest cross-correlation coefficient was 0.98 with a periodic scale of 62- month, and the lag time was 6 months.
- ✓ Lowest cross-correlation coefficient was -0.93 with a period of 58-month and the lag time was 24 months.

PART FIVE

Conclusion

05 Conclusion

01 Different probability distributions were suitable for the SSI at different gauging stations;

02 The propagation time from meteorological drought to hydrological drought notably varied with seasons, the longer in spring and winter and the shorter in summer and autumn;

03 Hydrological drought and meteorological drought presented the similar patterns in term of phase shift;

04 Close correlation existed between hydrological drought and meteorological drought with high absolute maximum and minimum wavelet cross-correlation coefficients;

05 It provided an effective and efficient approach to quantifying propagation from meteorological drought to hydrological drought, and implementing the early warning of hydrological drought by using meteorological drought.

Thank You

for Your Attention !