PRAGMA 20

Hong Kong

Quantification of Variability Change in Terrestrial Hydrological Processes over the Pearl River Basin in South China

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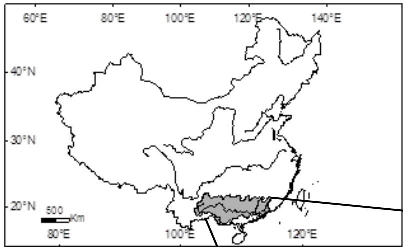
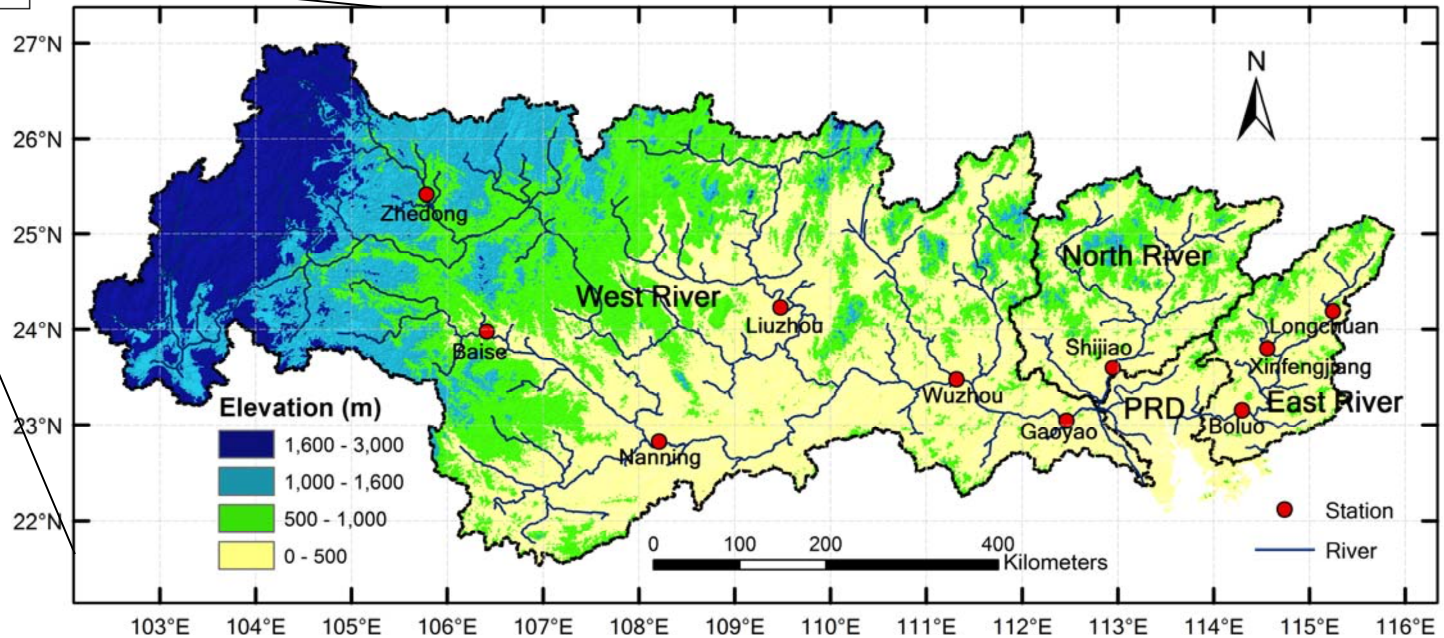
Mar. 3, 2011

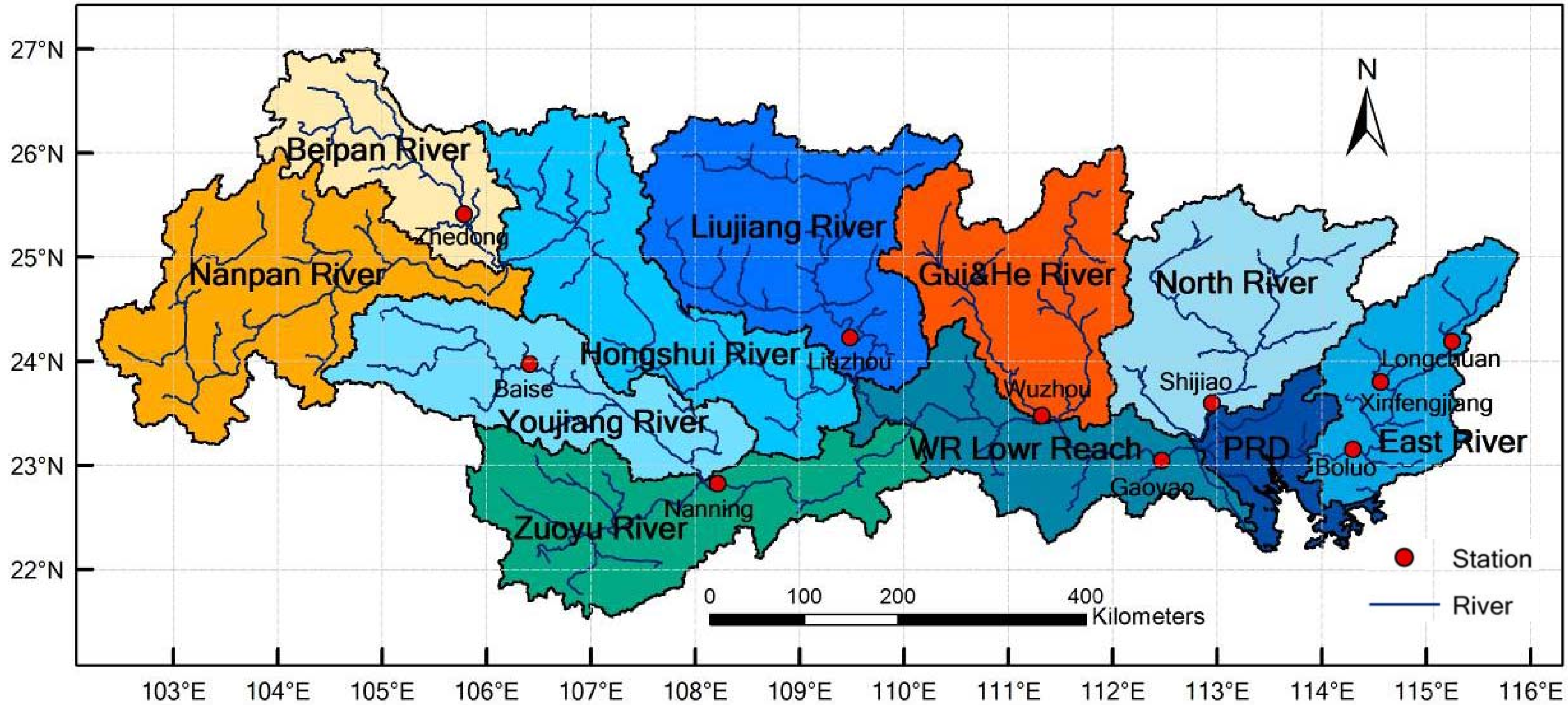


The Pearl River basin



- Total basin area 453,690 km^2
- Average Annual precipitation 1477mm
- Four river systems: West River, North River, East River, Pearl River Delta
- Annual runoff generation 0.74 million m^3/km^2
- $(Q_{wet}/Q_{dry})_{max}$=6~7 (inter-annual)
- $Q_{Apr\text{-}Sep} \approx 80\% Q_{annual}$

10 sub-basins for the Pearl River basin



- Comparable basin area;
- Available observation data;
- Discriminative geographic features.

Flood events in the Pearl River basin

Whole Basin Floods: 1968.6-8, 1994.6, 2005.6

The East River Floods: 1959.6, 1966.6, 1979.7

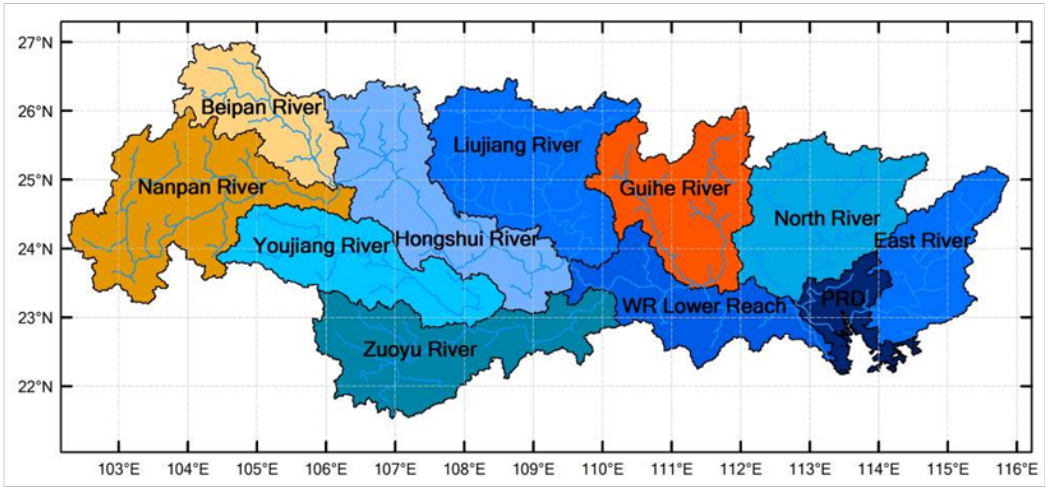
The North River Flood: 1982.5

The West River Floods: 1976.7, 1988.8, 1997, 1998.6

The Nanpan&Beipan Floods: 1991.7

The Zuoyu Floods: 1986.7, 2001.7

The Liujiang Flood:1996.7



Jun. 2005

Wuzhou, Guangxi Province:

Peak Flood Level: 26.75m

Q_{peak}: 53,900 m^3/s

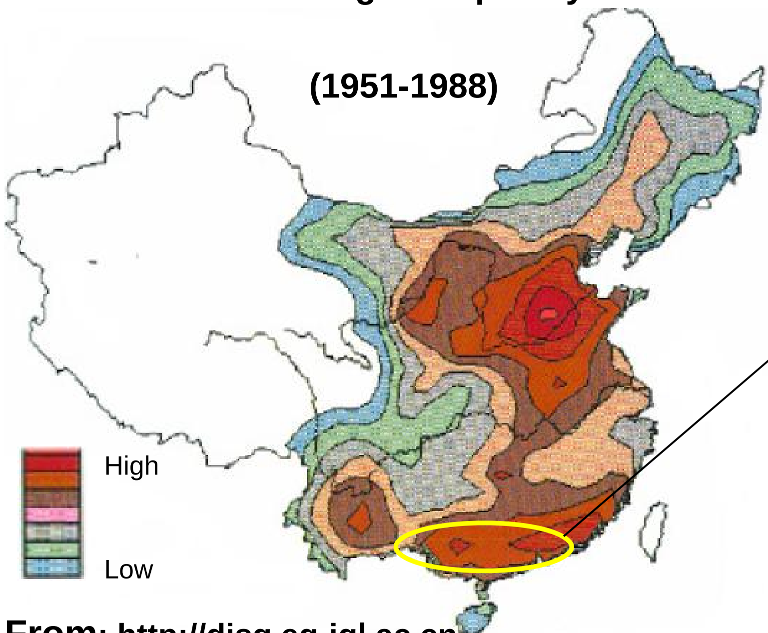
Return Period: 100 years for West River
10 years for North River
20 years for East River

Population affected: 12.6 million

Economic loss: 13.6 billion RMB

Drought condition in the Pearl River basin

Distribution of drought frequency in China



From: http://disg.eq-igl.ac.cn

The severest drought event:

1963

Other drought events:

1954, 1955, 1956, 1957, 1960, 1977

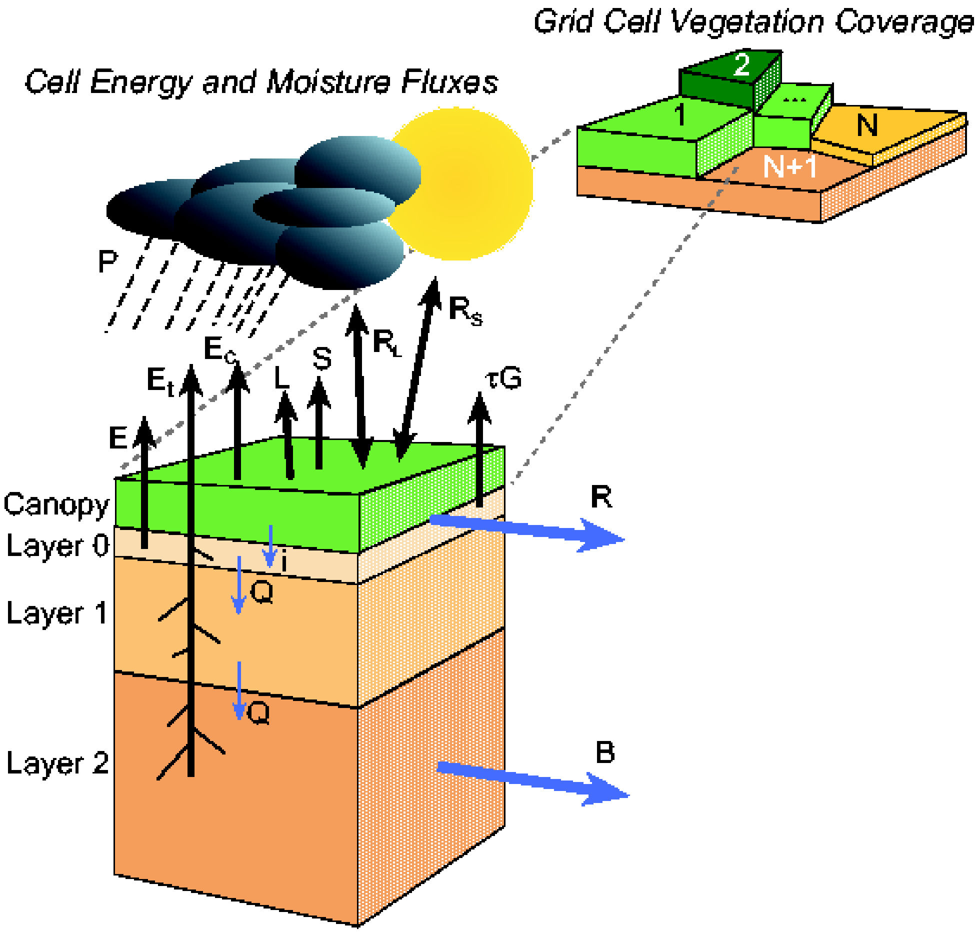
Drought Disaster Area of Pearl River Basin

Unit: 10^3 hectare

Year \ River basin	Pearl River	West River	North River	East River	Pearl River Delta
1963	2216.11	1621.63	183.05	137.31	274.11
1977	1691.81	1044.21	166.55	125.29	355.77
1956	1543.84	1126.07	97.85	59.42	260.49
1960	1254.99	815.21	41.07	45.17	353.53
1955	820.26	497.69	150.00	60.56	112.25
1957	775.61	648.17	26.25	20.65	80.54
1954	684.41	550.91	83.83	5.89	43.78

From: Pearl River Hydraulic Research Institute. (2007) Drought monitor and assessment report

Variable Infiltration Capacity (VIC) Macroscale Hydrological Model



Washington University

Princeton University

From: http://www.hydro.washington.edu/Lettenmaier/Models/VIC

- The VIC-NL model represents surface and subsurface hydrologic processes on a spatially distributed (grid cell) basis.
- Energy and water balance terms are computed independently for each coverage class (vegetation and bare soil) present in the model.
- Processes governing the flux and storage of water and heat in each cell-sized system of vegetation and soil structure include

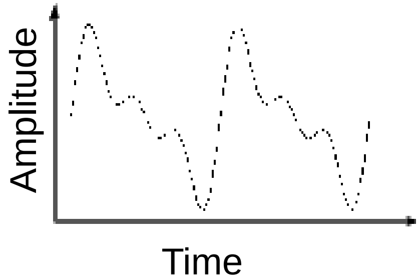
evaporation from the soil layers (E)
evapotranspiration (E_t)
canopy interception evaporation (E_c)
latent heat flux (L)
sensible heat flux (S)
longwave radiation (R_L)
shortwave radiation (R_S)
ground heat flux (G)
infiltration (i) **percolation (Q)**
runoff (R) **baseflow (B)**

Validation of streamflow simulation

Station	Number of months*	Mean(O) (mm/mon)	Mean(S) (mm/mon)	*RB*	*RRMSE*	*NS*
Zhedong	360	46.14	45.02	-0.02	0.59	0.72
Baise	355	32.65	36.43	0.12	0.52	0.78
Nanning	372	43.34	54.56	0.26	0.45	0.80
Liuzhou	360	71.24	64.91	-0.09	0.32	0.90
Wuzhou	264	51.53	53.21	0.03	0.23	0.93
Gaoyao	212	54.35	56.64	0.04	0.16	0.96
Shijiao	240	96.13	81.90	-0.18	0.32	0.85
Boluo	420	77.35	77.17	-0.01	0.52	0.56
Xinfengjiang	84	76.03	71.77	-0.06	0.39	0.85
Longchuan	252	77.28	61.29	-0.21	0.41	0.82

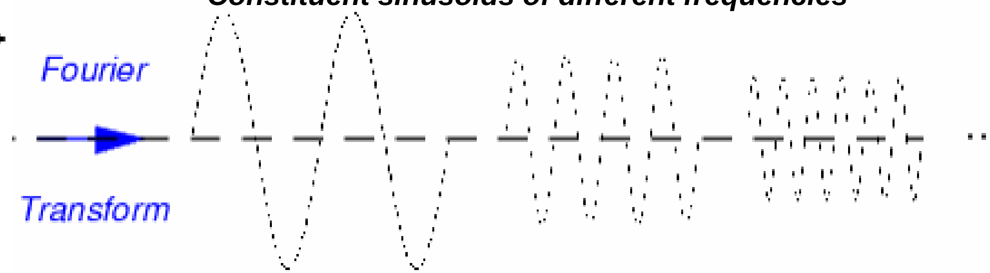
* Number of available monthly flow observations in the period of 1952-1988.

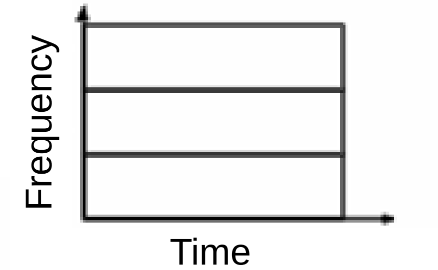
Spectral analysis: Fourier transform & Wavelet transform



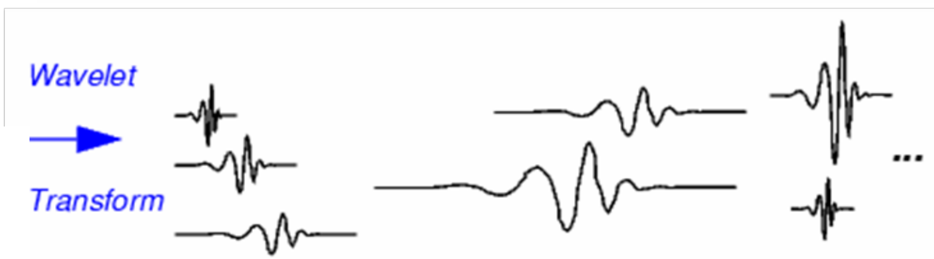
$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt$$

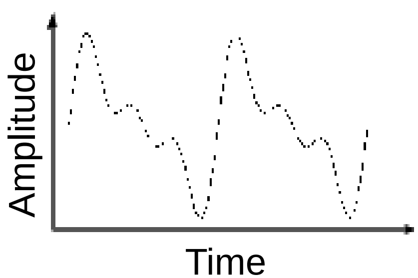
Constituent sinusoids of different frequencies





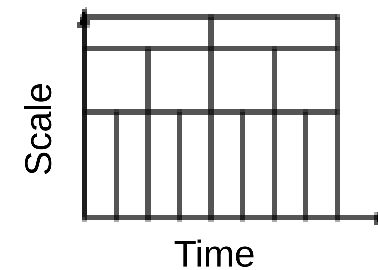
Fourier Transform





Constituent wavelets of different scales and positions

$$C(scale, position) = \int_{-\infty}^{\infty} f(t) \psi(scale, position, t) dt$$



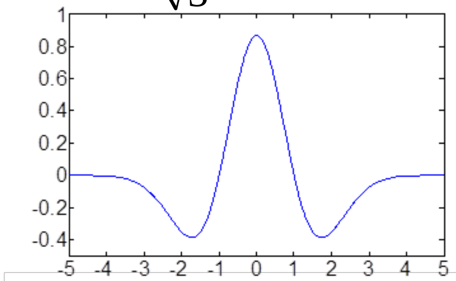
Wavelet Transform

- Low scale a $\Rightarrow$ Compressed wavelet $\Rightarrow$ Rapidly changing details $\Rightarrow$ High frequency ω
- High scale a $\Rightarrow$ Stretched wavelet $\Rightarrow$ Slowly changing coarse features $\Rightarrow$ Low frequency ω

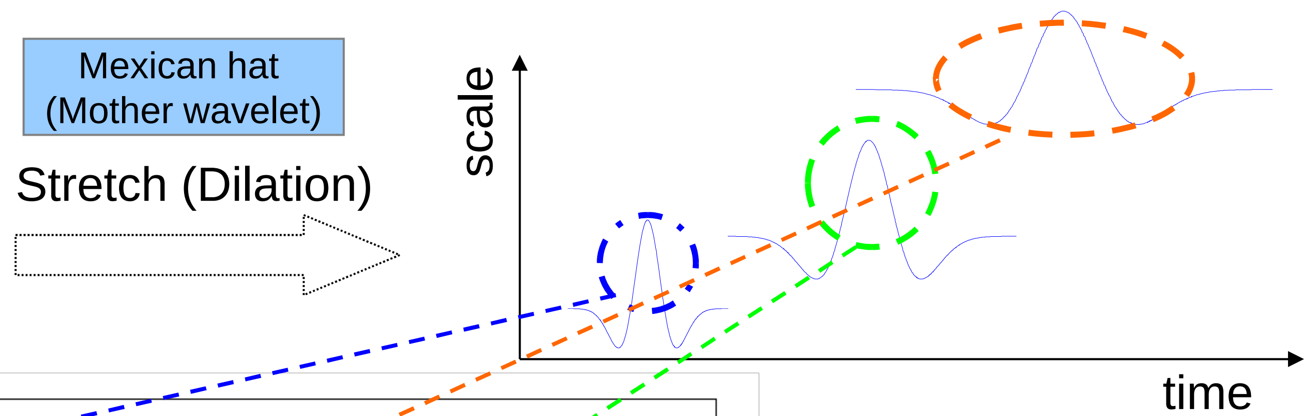
Reference: Wikipedia & MATLAB

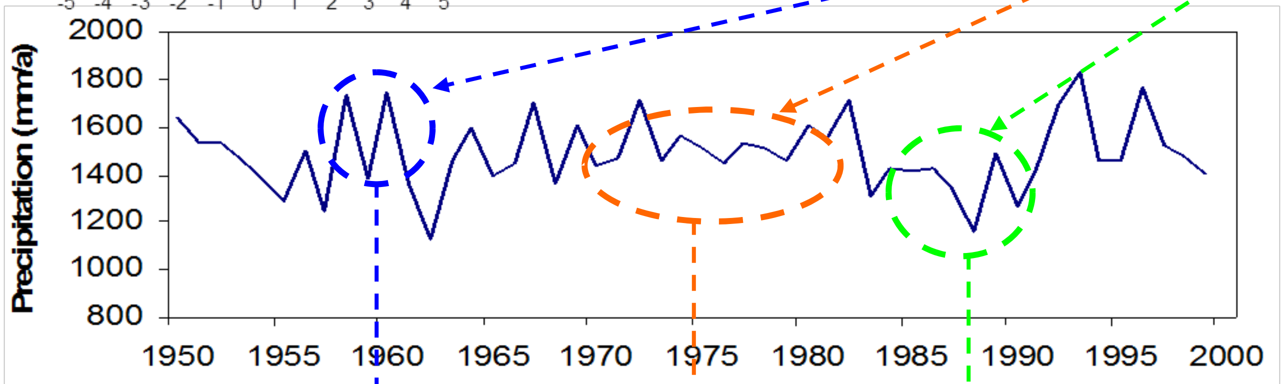
Example: wavelet transform of annual precipitation

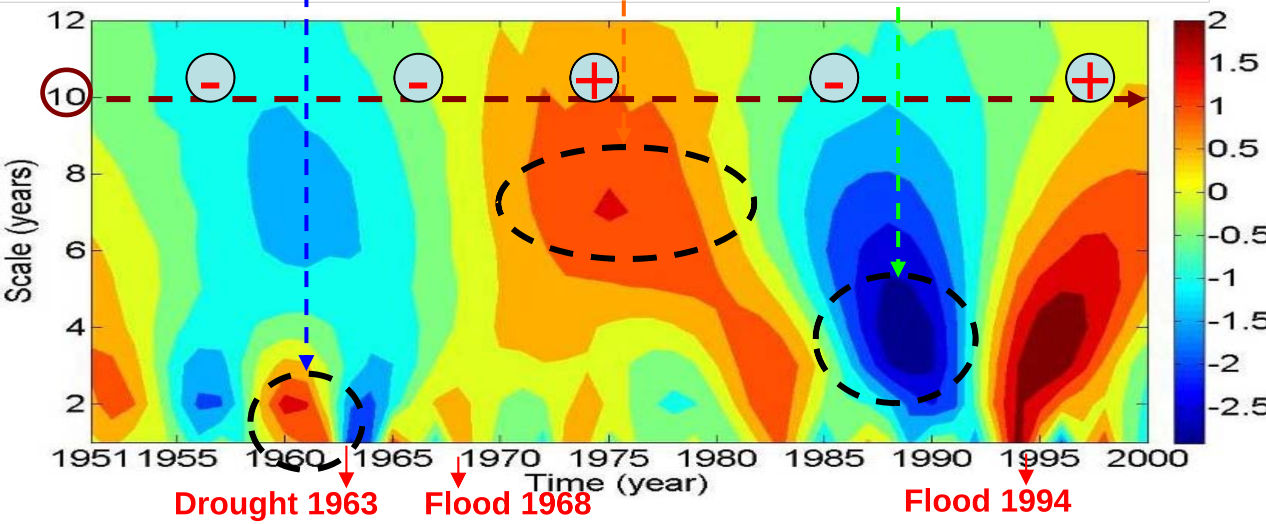
$$\psi(x) = \left(\frac{2}{\sqrt{3}}\pi^{-1/4}\right)(1-x^2)e^{-x^2/2}$$



Mexican hat
(Mother wavelet)



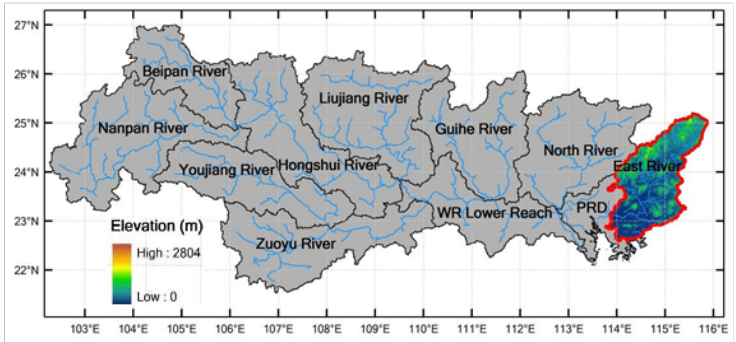




Annual precipitation decadal anomalies in the Pearl River basin during 1951-2000

Year	Anomaly (mm)	Percentage (%)
50s	-16.09	-1.08
60s	-7.48	-0.50
70s	+22.61	+1.52
80s	-41.78	-2.81
90s	+42.75	+2.87

Whole basin floods	1968 1994
The severest drought	1963

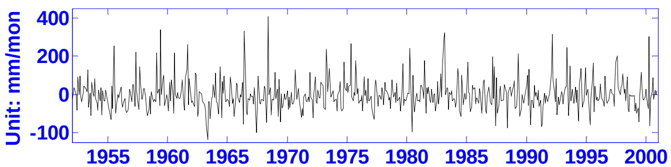


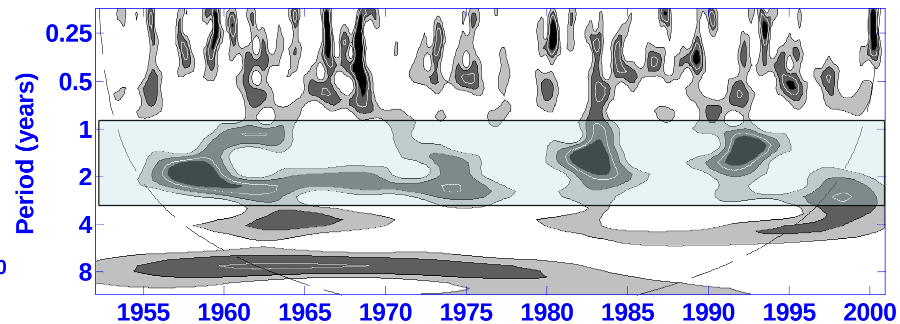
Variability transfer in East River

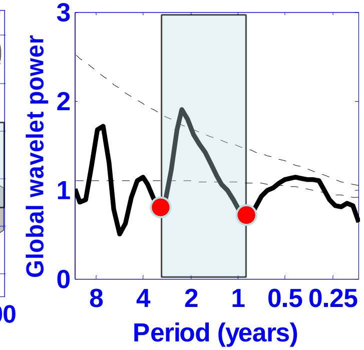
Local spectrum

Global spectrum

Precipitation

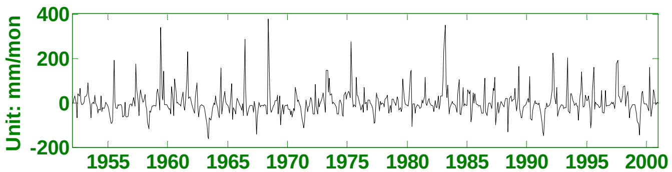


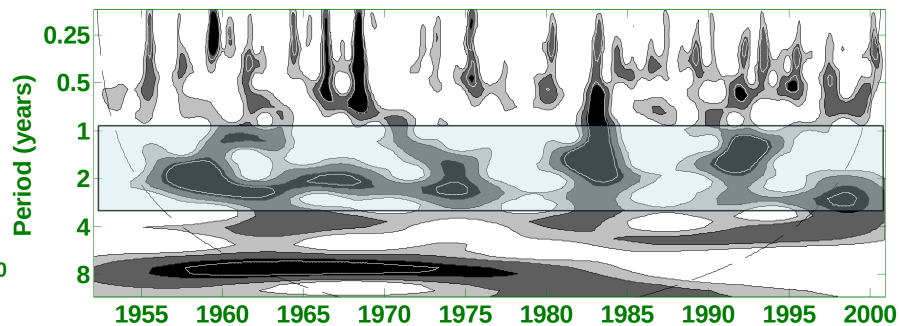


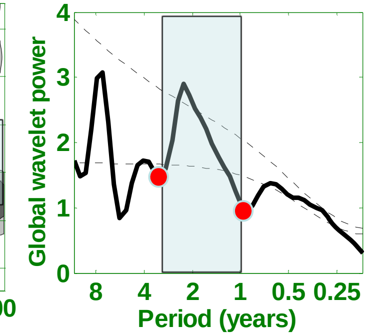


VIC model

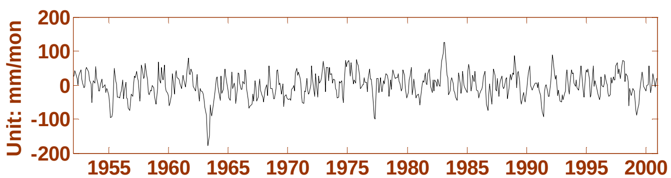
Streamflow

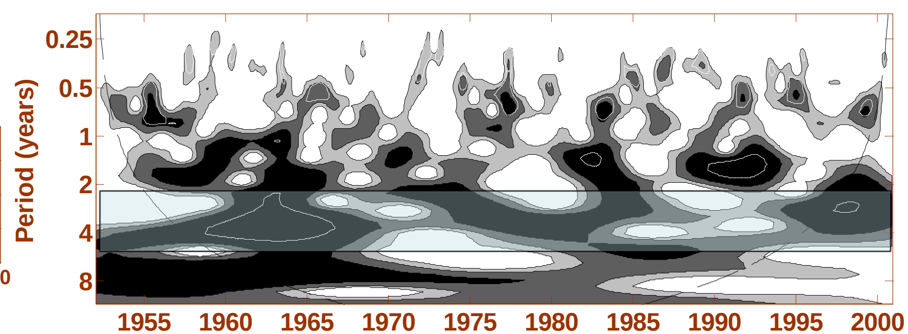


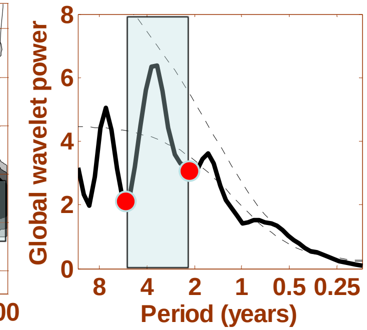




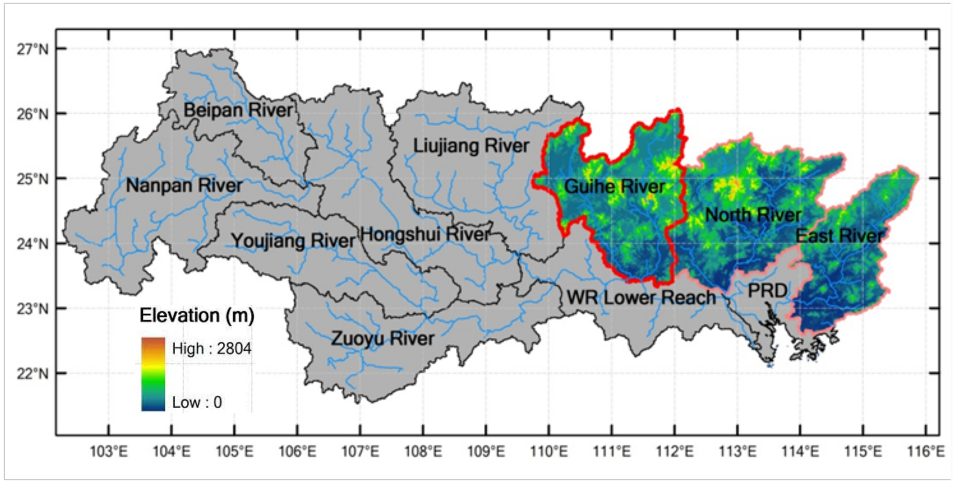
Soil moisture

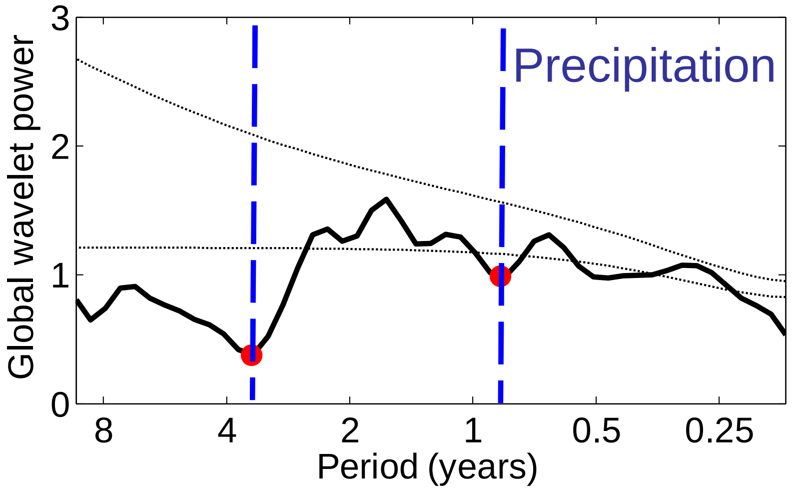


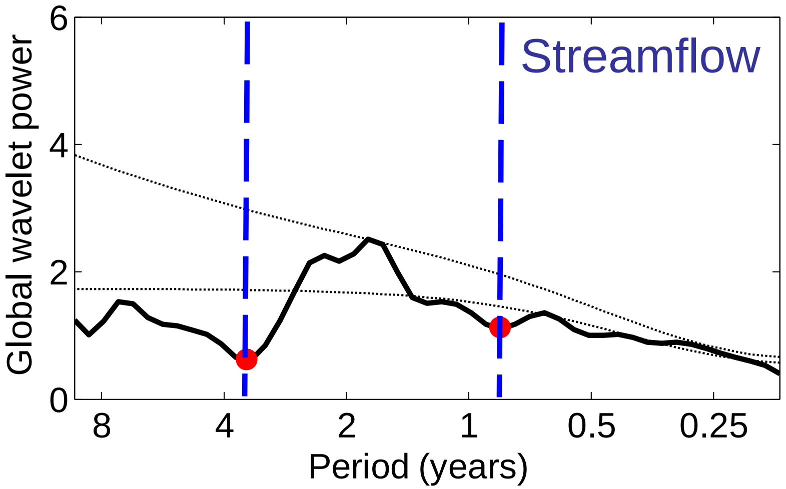


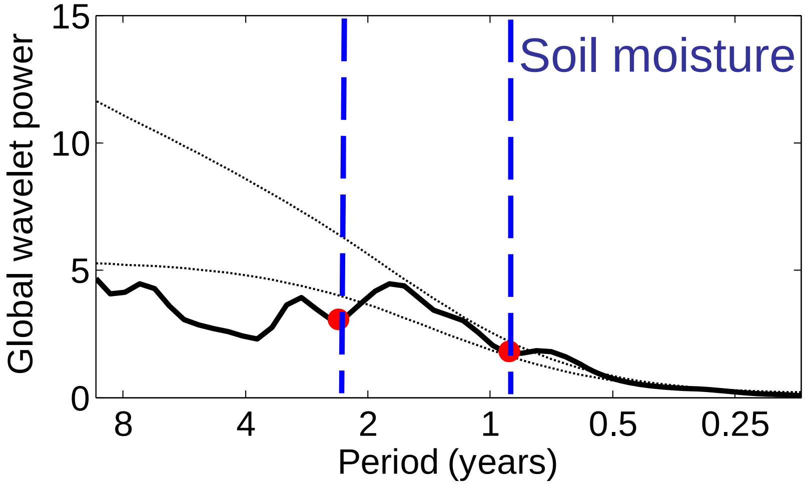


Northeastern Region
(e.g.,Guihe River)

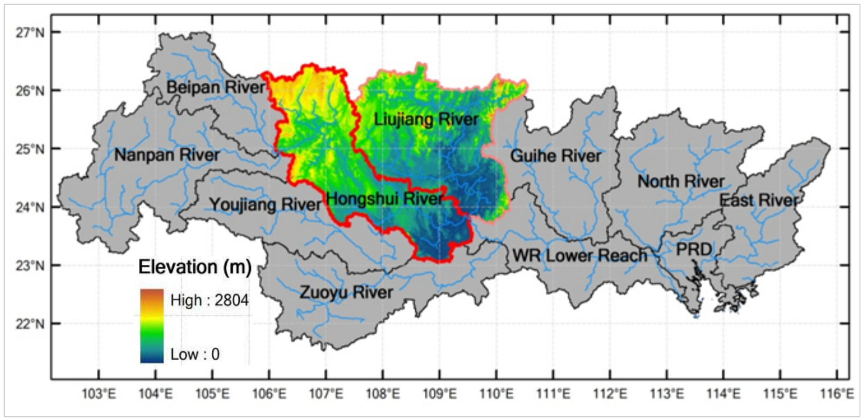


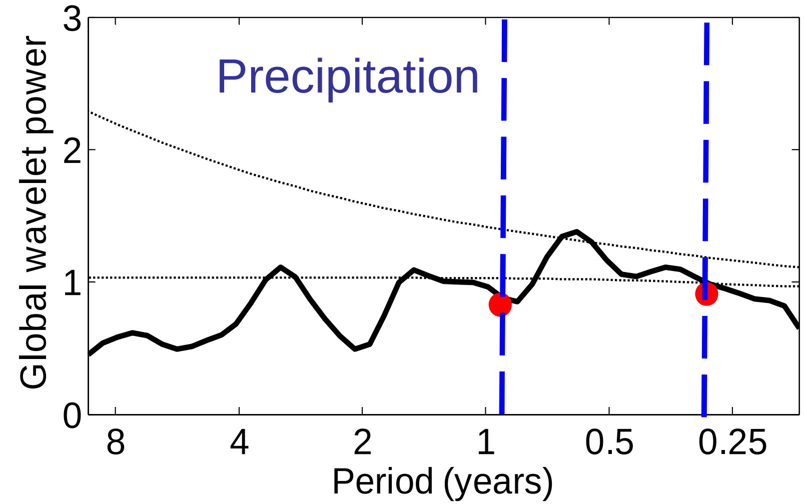


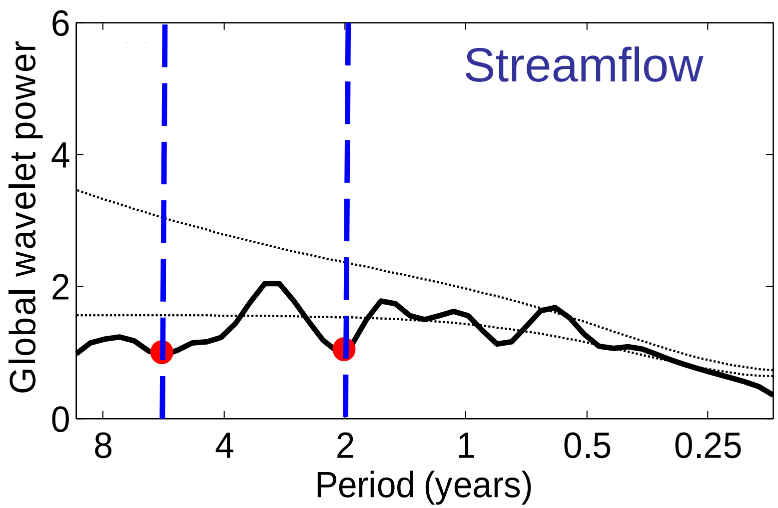


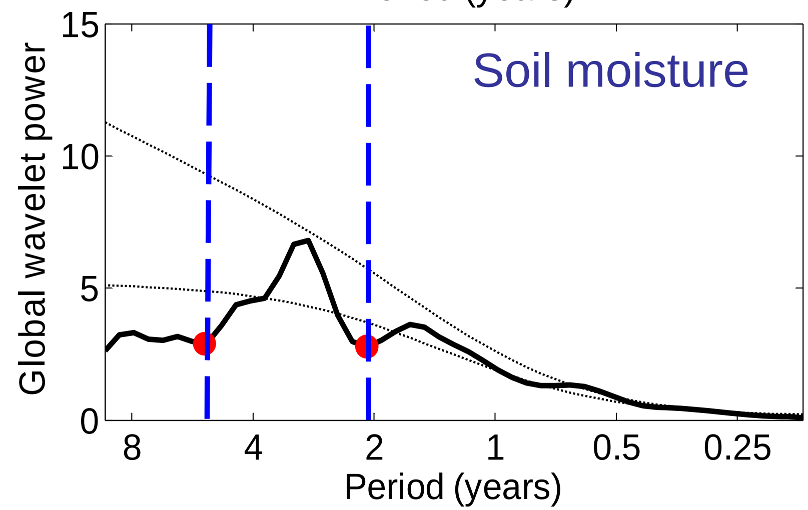


Middle Region
(e.g.,Hongshui River)



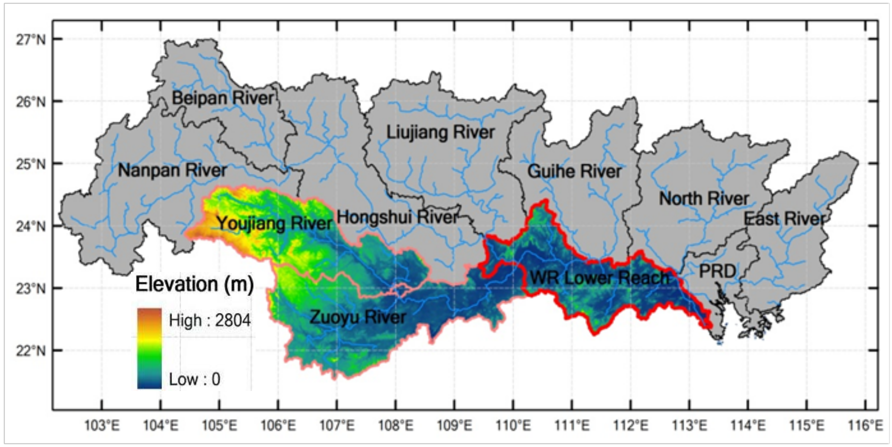


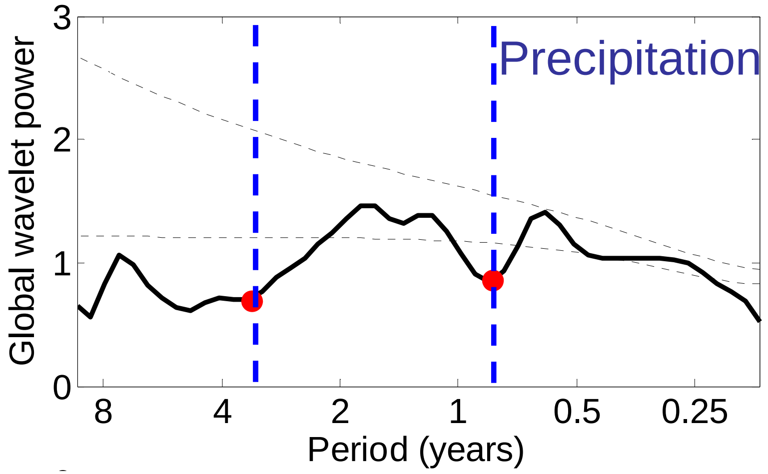


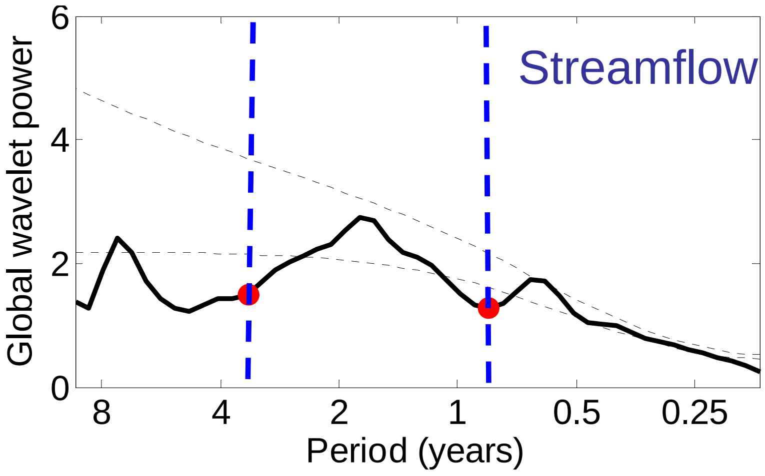


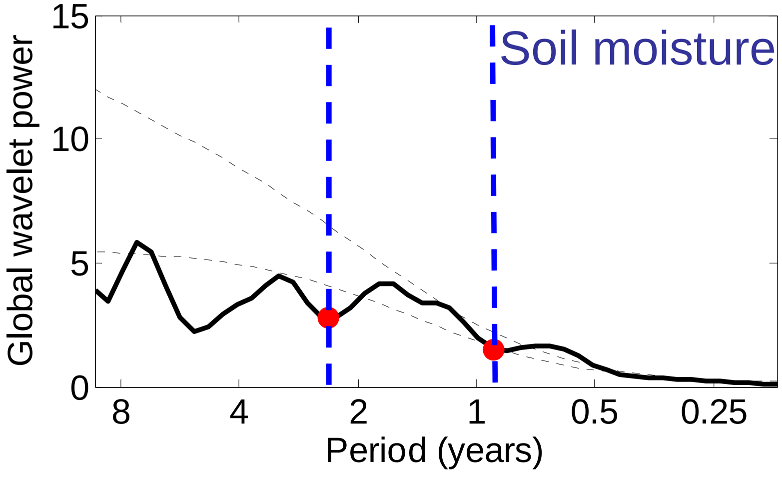
Southern Region

(e.g.,WR Lower Reach)

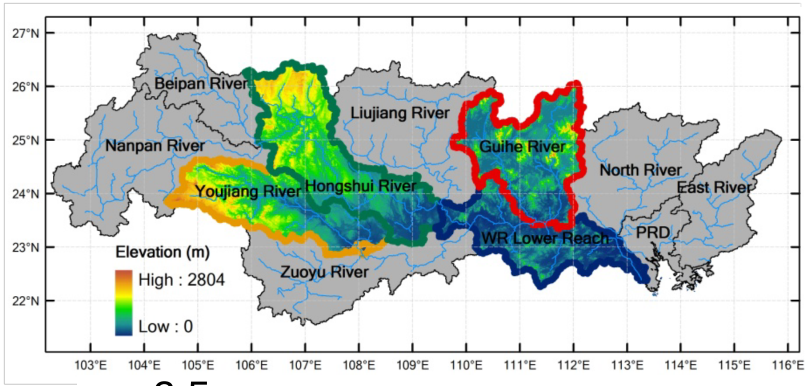


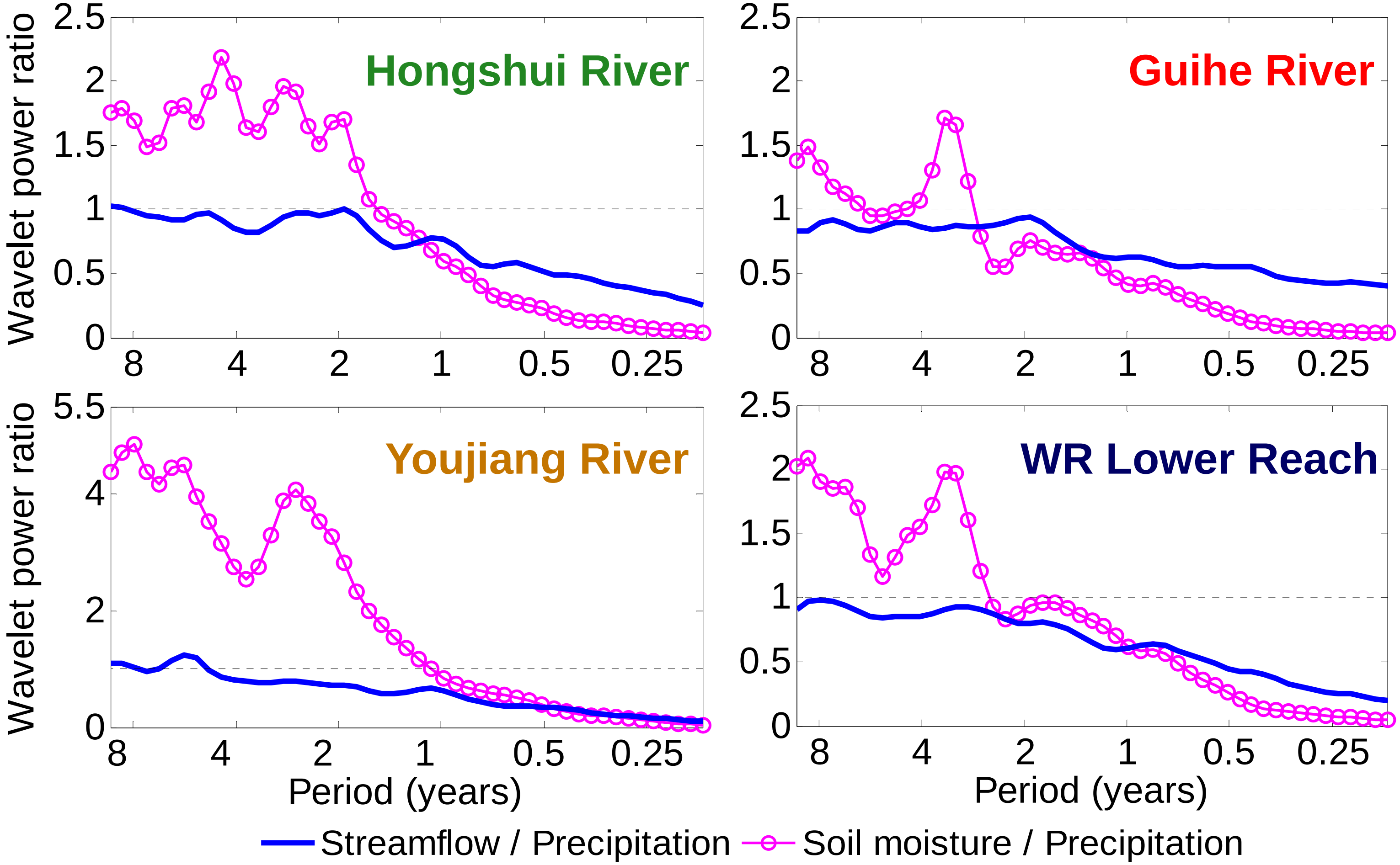






Multi-scale wavelet power ratio





Variability relationships

- ✓ The streamflow variability can be reflected by the precipitation variability at long timescales (longer than 2-year periods for most of the subbasins in the Pearl River basin).

- ✓ The soil moisture variability can reflect even longer timescales of precipitation variability than the streamflow, and may further extend precipitation variability at much longer timescales due to the terrestrial system memory for precipitation variability.

- ✓ The above variability relationships vary for different subbasins, which can be partly attributed to their geographic characteristics.

Thank you!