Spatio-temporal influence of ENSO on terrestrial water storage change in the Yangtze River basin

Taoyong Jin[1], Zhongwei Jin[1], Jiancheng Li[1], Zuansi Cai[2]

[1] School of Geodesy and Geomatics, Wuhan University

[2] School of Engineering and the Built Environment, Edinburgh Napier University

July 26, 2018

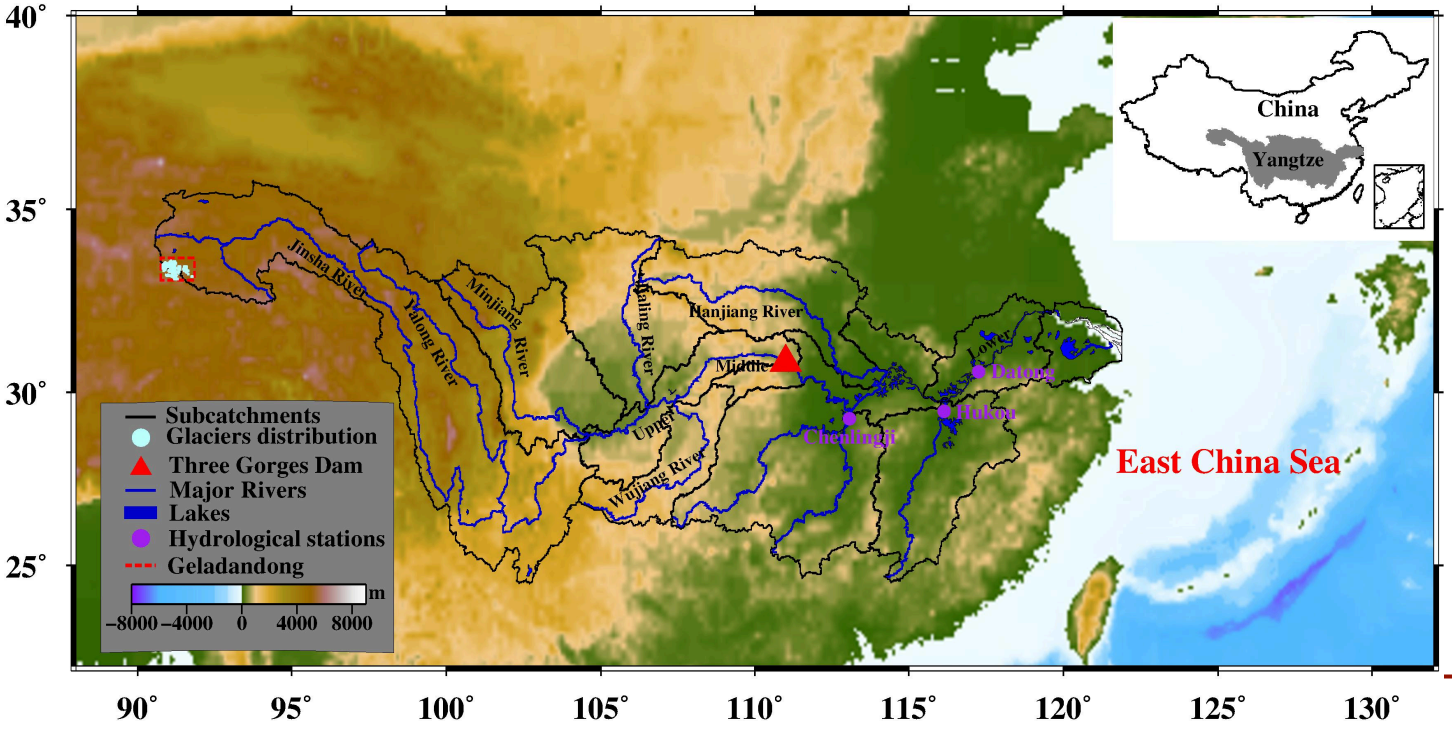
Contents

- Motivations
- Data and Methods
- Results
- Discuss and Conclusions

Motivations

» The Yangtze River Basin (YRB)

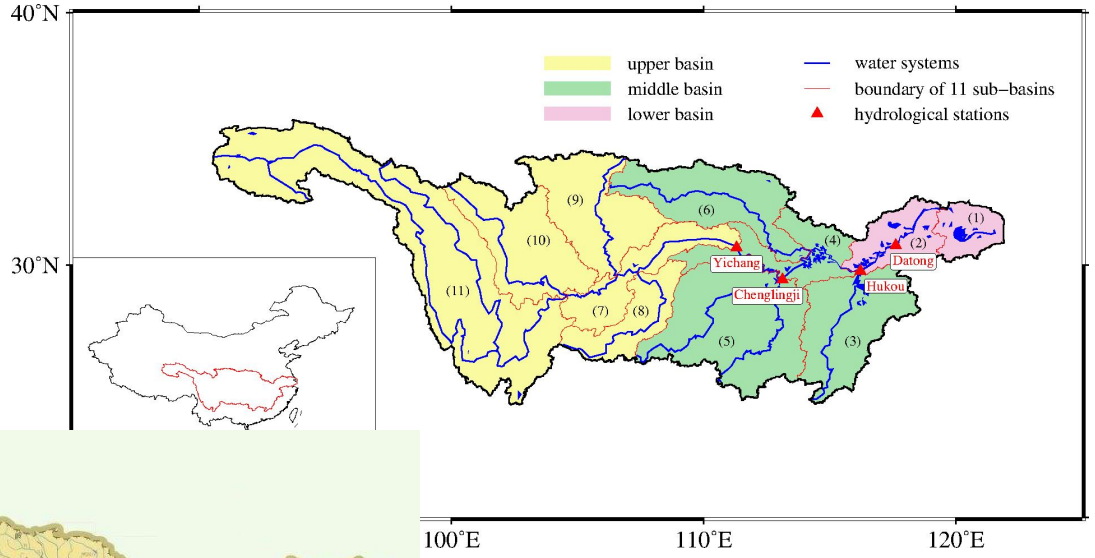
- the longest river in China, with a total length of 6300km
- originates in the Qinghai-Tibet Plateau, terminates at the East China Sea
- mainly controlled by a subtropical and temperate monsoon



Motivations

» The Yangtze River Basin (YRB)

- 3 reaches and sub-basins
- 8 hydrological systems
- 11 sub-basins



Motivations

» The extreme weather events in YRB

2006 Chongqing

2010 Wenchuan

2011 Poyang Lake

2016 Wuhan

Motivations

- How does the total water storage change in YRB
- How about the relations between TWSC and ENSO
- How does the ENSO influence TWSC in YRB

Data and Methods

» Data used

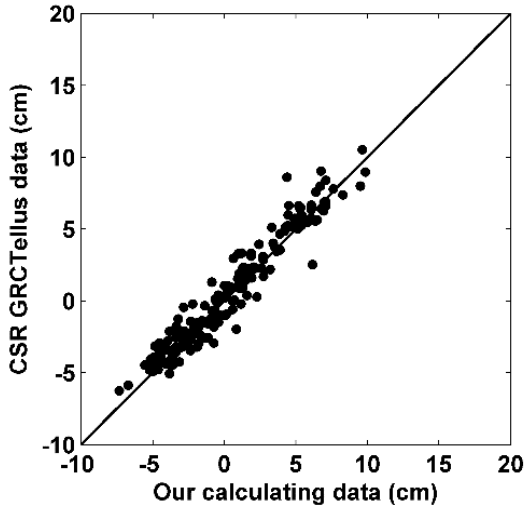
Data type	Data sources	Version	Resolution		Span
			Spatial	Temporal	
ET	GLEAM	V3.0b	0.5°×0.5°	daily	2003.1~2017.6
TWSC	GRACE CSR	RL05	-	monthly	2002.7~2017.6
	GRCTellus	CSR	1°×1°	monthly	2002.7~2017.6
Land surface model	GLDAS_Noah	V2.1	1°×1°	monthly	2002.7~2017.6
River discharge	Chenglingji	-	-	daily	2002.7~2017.6
	Datong	-	-	daily	2002.7~2017.6

Data and Methods

» Terrestrial water storage change (TWSC) from GRACE

- degree 1 and C20 replaced
- fan filter with 250km
- decorrelation filter from Swenson
- scale factors by Landerer

$$\mathrm{TWSC}(\theta,\lambda)=\frac{r\rho_a}{3\rho_w}\sum_{l=0}^{60}\sum_{m=0}^{l}W_{lm}\bar{P}_{lm}(cos\theta)\frac{2l+1}{k_l+1}\left(\Delta\bar{C}_{lm}cosm\lambda+\Delta\bar{S}_{lm}sinm\lambda\right)$$



Compared to the CSR GRCTellus results

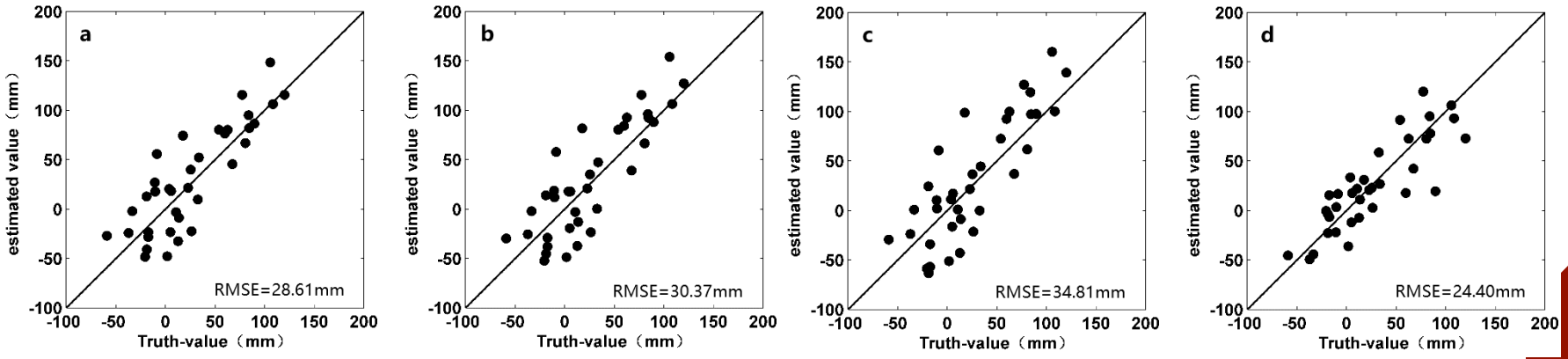
- R^2, 0.93
- RMSE, 1.06cm

Data and Methods

» The missing monthly data interpolation

Year	2002 (Jul. – Dec.)	2003	2004-2010	2011	2012	2013	2014	2015	2016	2017 (Jan. – Jun.)
Missing months	-	Jun.	-	Jan., Jun.	May, Oct.	Mar., Aug., Sept.	Feb., Jul.	Jun., Oct., Nov.	May, Sept., Oct.	Feb.

- based on 72 months (Jan 2005 to Dec 2010)
- 36 months are interpolated and compared to the truth (37 - 72)



a) Linear interpolation

b) Cubic Hermite interpolation

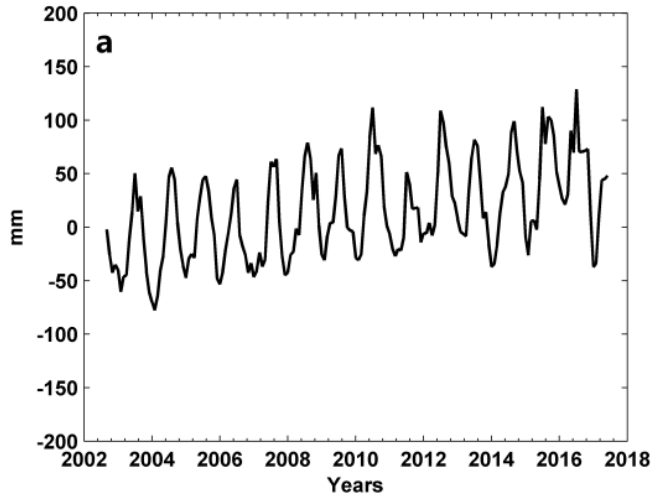
c) Spline interpolation

d) SSA method

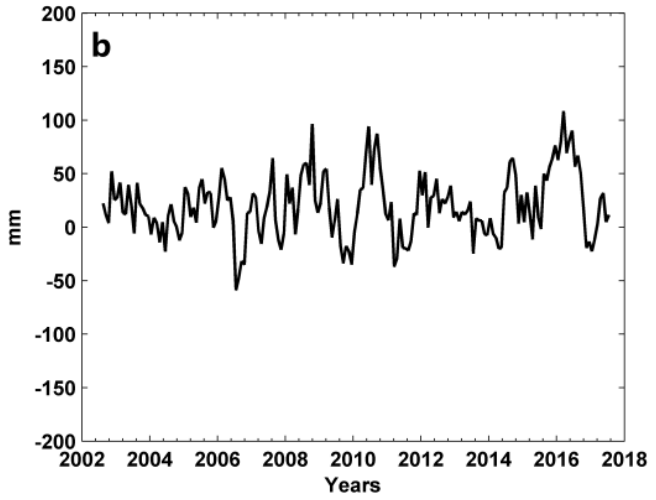
Data and Methods

» De-trended, de-seasoned monthly TWSC time series

- use SSA method to remove the non-linear trend
- use LSE method to remove the seasonal cycles



a) de-trended TWSC



b) de-seasoned TWSC （TWSA）

Results

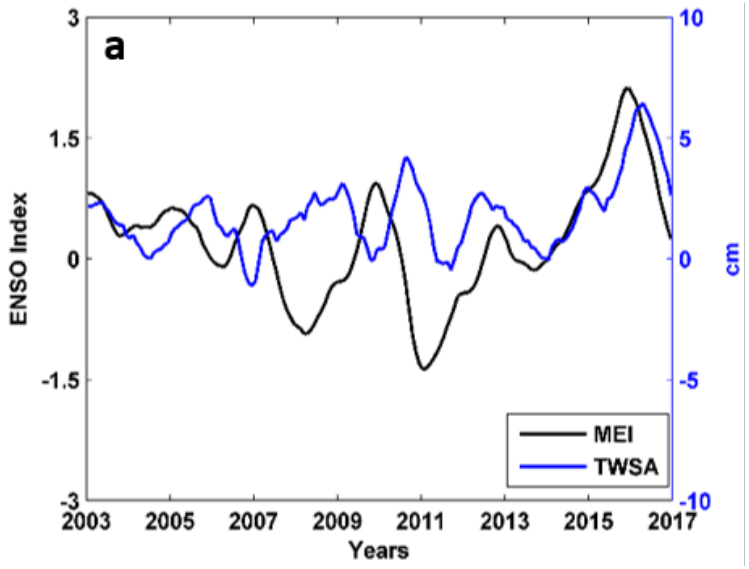
» The relations between TWSA and ENSO

- MEI is selected to indicate the ENSO index
- 13-month moving-average filter applied
- different scales
  - Basin scale (the whole YRB)
  - Sub-basin scale (3 sub-basins or 11 sub-basins)
  - 1°×1° grid scale

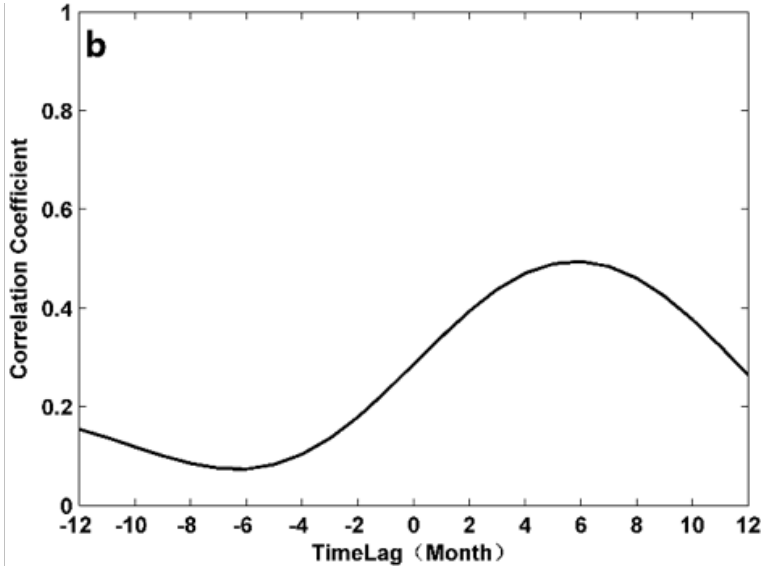
Results

» The relations between TWSA and ENSO

- Basin scale
  - R is 0.29
  - peak R is 0.53, with 6-month time lag



a) correlation coefficient



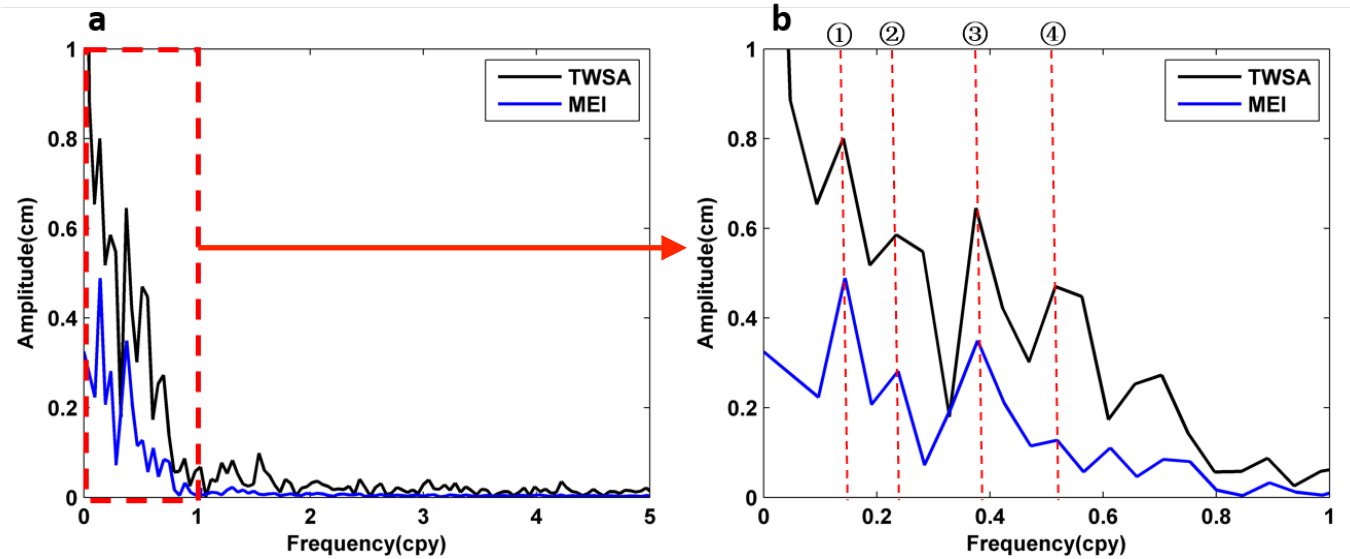
b) time lags

Results

» The relations between TWSA and ENSO

- Basin scale
  - FFT spectrum analysis

Type of time series	Number of significant periodic signals	Frequencies of all the significant signals in descending order of amplitude (cpy)			
MEI	4	①0.15	③0.35	②0.28	④0.52
TWSA	4	①0.15	③0.35	②0.28	④0.52



Results

» The relations between TWSA and ENSO

- Sub-basin scale
  - upper, middle and lower basins

Correlation with ENSO

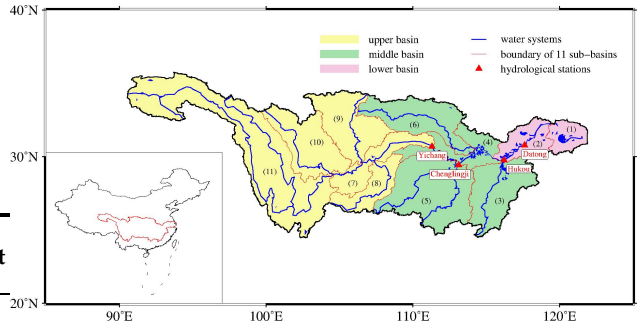
Sub-basins	Correlation coefficient	Cross-correlation peak value	ENSO-TWSA time lag	Correlation test
Upper YRB	0.29	0.51	8 months	Passed
Middle YRB	0.33	0.57	6 months	Passed
Lower YRB	0.28	0.58	6 months	Passed

Results

» The relations between TWSA and ENSO

- Sub-basin scale
  - 11 hydrological systems

	Sub-basins	Correlation coefficient	Cross-correlation peak value	ENSO-TWSA time lag	Correlation test
	(1) Taihu Lake	0.32	0.65	5 months	Passed
lower	(2) The lower reaches of the Yangtze River	0.31	0.57	5 months	Passed
	(3) Poyang Lake	0.51	0.61	6 months	Passed
middle	(4) The middle reaches of the Yangtze River	0.43	0.63	6 months	Passed
	(5) Dongting Lake	0.41	0.57	8 months	Passed
	(6) Hanjiang River	-0.12	0.20	9 months	Failed
	(7) The upper reaches of the Yangtze River	0.11	0.42	10 months	Passed
upper	(8) Wujiang River	0.39	0.55	8 months	Passed
	(9) Jialing River	-0.13	0.16	9 months	Failed
	(10) Mintuo River	-0.02	0.31	10 months	Passed
	(11) Jinsha River	-0.11	0.32	11 months	Passed



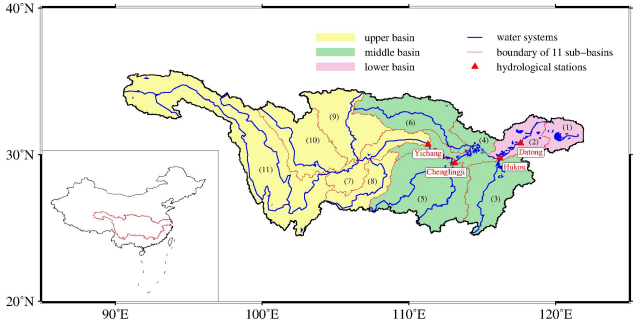
From downstream to upstream

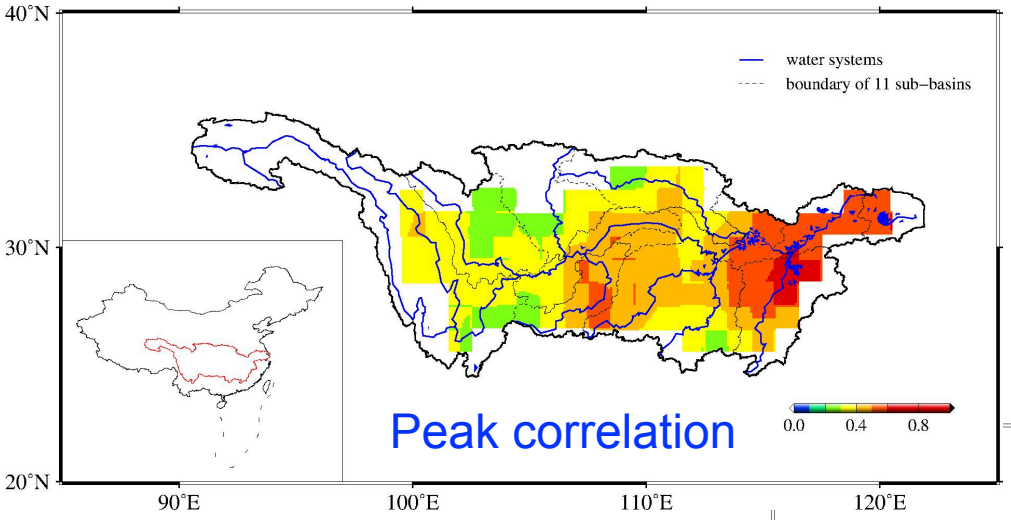
- peak R decrease
- time lag increase

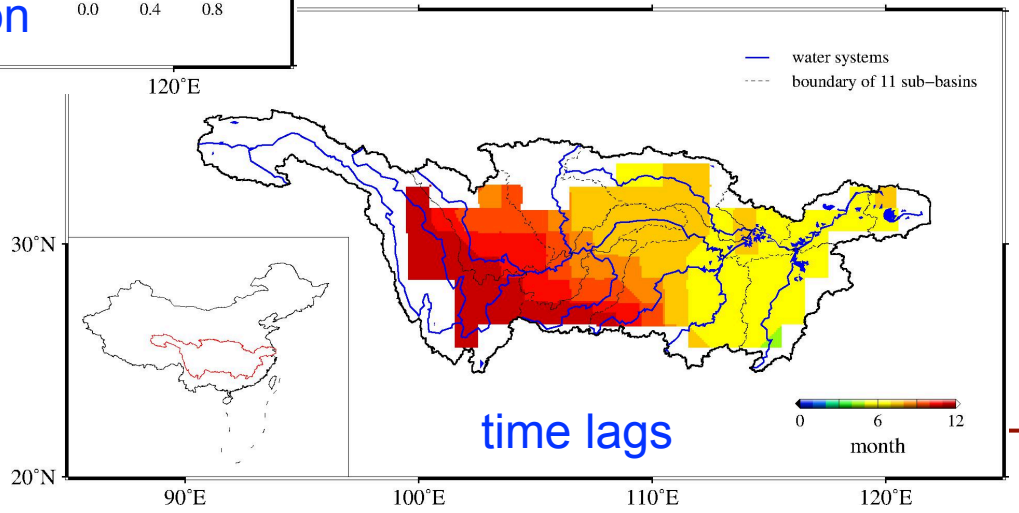
Results

» The relations between TWSA and ENSO

- 1°×1° grid analysis







The grid cells failed to pass the correlation test had been eliminated

Discussions

» The lower links between ENSO and upper YRB

- the Jialing River, the Hanjiang River
- part of Mintuo River and Jinsha River
- Indian Ocean Dipole (Dipole Mode Index)

Correlation between TWSA and IOD

YRB and its sub-basins	Correlation coefficient	Cross-correlation peak value		IOD-TWSA time lag	Correlation test
The YRB	-0.38	-0.41	**0.53**	2 months	Passed
The upper YRB	-0.47	-0.51	**0.51**	2 months	Passed
The middle YRB	-0.15	-0.19	**0.57**	2 months	Failed
The lower YRB	-0.13	-0.17	**0.58**	2 months	Failed

ENSO

Discussions

» The lower links between ENSO and upper YRB

- the Jialing River, the Hanjiang River
- part of Mintuo River and Jinsha River

Correlation between TWSA and IOD in the upper YRB

Sub-basins	Correlation coefficient	Cross-correlation peak value		IOD-TWSA time lag	Correlation test
(6) Hanjiang River	-0.23	-0.32	**0.20**	2 months	Passed
(7) The upper reaches of the Yangtze River	-0.44	-0.50	**0.42**	2 months	Passed
(8) Wujiang River	-0.37	-0.41	**0.55**	2 months	Passed
(9) Jialing River	-0.39	-0.43	**0.16**	2 months	Passed
(10) Mintuo River	-0.59	-0.67	**0.31**	2 months	Passed
(11) Jinsha River	-0.42	-0.47	**0.32**	2 months	Passed

ENSO

Discussions

» The links between ENSO and TWSA

- water balance equation: $d(TWSC)/dt = P - ET - R$
- same processing to P, ET and R with TWSA

Correlations with ENSO

YRB and its sub-basins	Hydroclimatic data anomalies	Correlation coefficient	Cross-correlation peak value	Time lag	Correlation test
The YRB	P	0.42	0.54	5 months	Passed
	R	0.04	0.31	6 months	Passed
	ET	-0.02	-0.11	4 months	Failed
The upper YRB	P	0.18	0.30	7 months	Passed
	R	-0.10	0.19	8 months	Failed
	ET	-0.11	-0.12	3 months	Failed
The middle YRB	P	0.47	0.58	5 months	Passed
	R	0.24	0.43	6 months	Passed
	ET	0.06	-0.08	7 months	Failed
The lower YRB	P	0.37	0.40	5 months	Passed
	R	0.04	0.31	6 months	Passed
	ET	-0.01	-0.07	5 months	Failed

Discussions

» The links between ENSO and TWSA

- water balance equation: $d(TWSC)/dt = P - ET - R$
- same processing to P, ET and R with TWSA

Summary of time lags relations

YRB and its sub-basins	ENSO-TWSA	ENSO-precipitation	ENSO-runoff	Precipitation-TWSA	Runoff-TWSA
The YRB	6 months	5 months	6 months	1 month	0 months
The upper YRB	8 months	7 months	8 months	1 month	0 months
The middle YRB	6 months	5 months	6 months	1 month	0 months
The lower YRB	6 months	5 months	6 months	1 month	0 months

Discussions

» Possible links between ENSO and extreme weather

- four typical extreme weather events

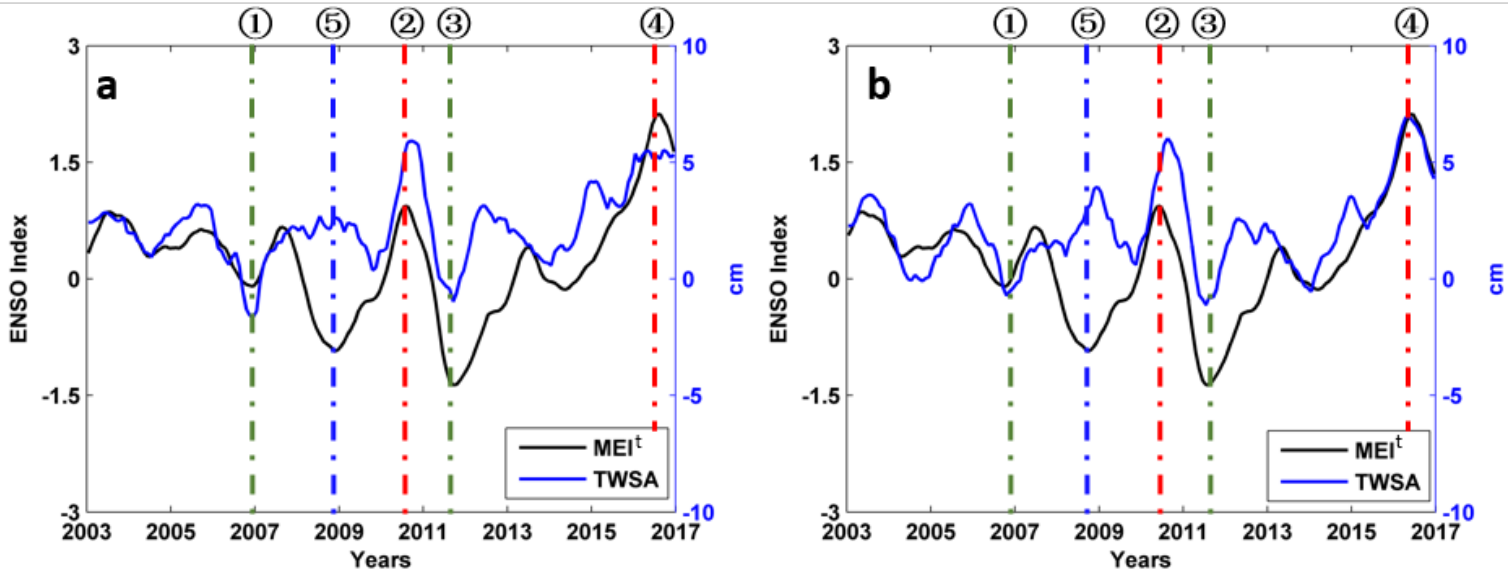
Type of the extreme weather event	Occurrence time	Location
①Drought	Summer of 2006	Upper YRB
②Flood	Summer of 2010	Mid-lower YRB mainly
③Drought	Summer of 2011	Mid-lower YRB mainly
④Flood	Summer of 2016	Mid-lower YRB

Discussions

» Possible links between ENSO and extreme weather

- four typical extreme weather events
- time lags and 13-month moving-average filter are applied on MEI (MEI^t)

Correlation between TWSA and MEI^t



a) in the upper YRB

b) in the mid-lower YRB

Conclusions

- ENSO has a significant influence on the TWSA in the YRB and its sub-basins but has time lags
- The influence of ENSO on TWSA decreases and the time lags increase from east to west and south to north in the YRB
- The precipitation and runoff changes, through the monsoon circulation changes, are found to be affected by ENSO, and explaining the influence of ENSO on TWSA
- The sub-basins in the upper YRB and the northwest corner of the middle YRB that are not significantly affected by ENSO have clear correlation with IOD

Thank you!