Analysis on Climate Anomalies and Causations in summer 2016

WANG Dong-Qian, YUAN Yuan, KE Zong-Jian

Beijing Climate Center/CMA

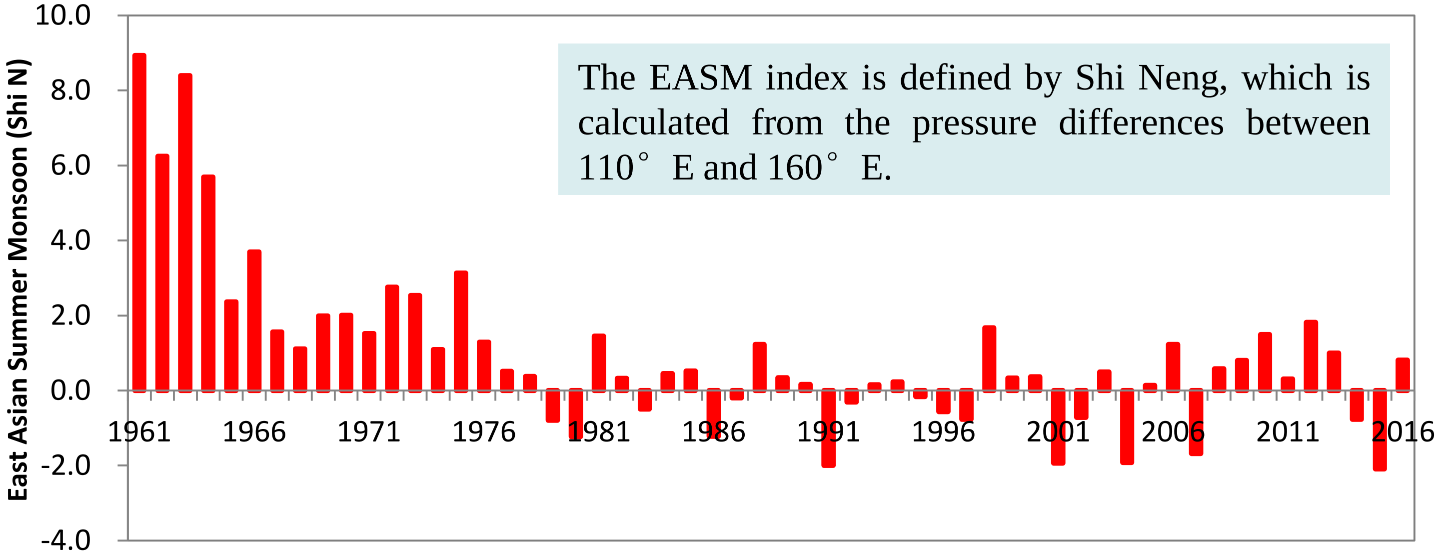
8 November 2016

Outline

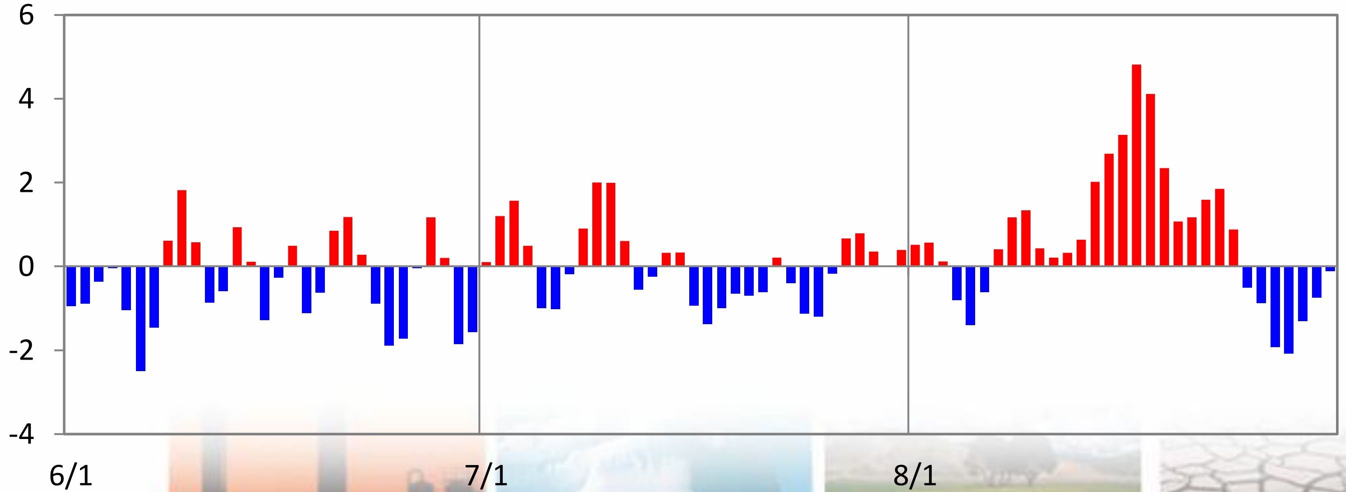
- Features of Summer Monsoon
- Climate Characteristics over China
- Causes of the Precipitation Anomalies
- Summary

Features of Summer Monsoon

East Asian Summer Monsoon

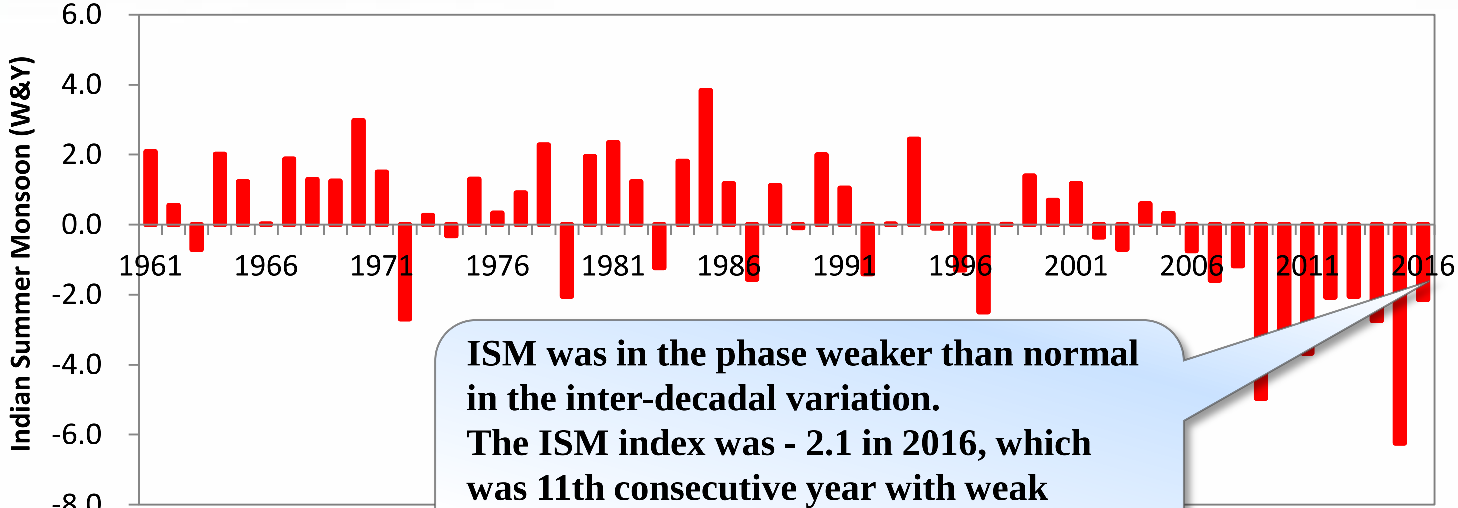


0.81

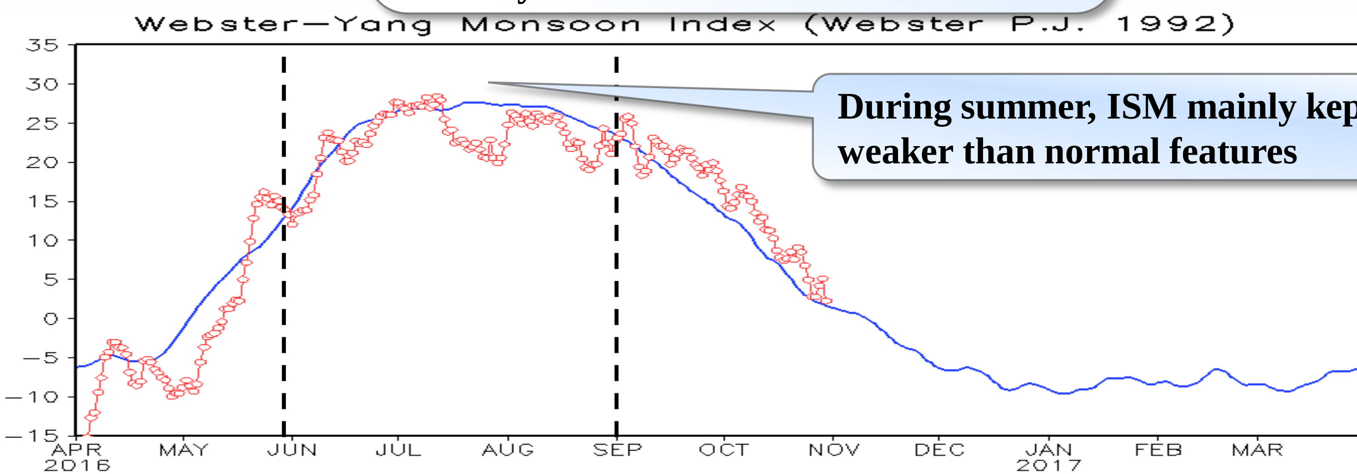


For intra-seasonal timescale, the EASM exhibited strong intra-seasonal variations, especially during June and July. While in August, EASM mainly kept stronger than normal features

Indian summer monsoon

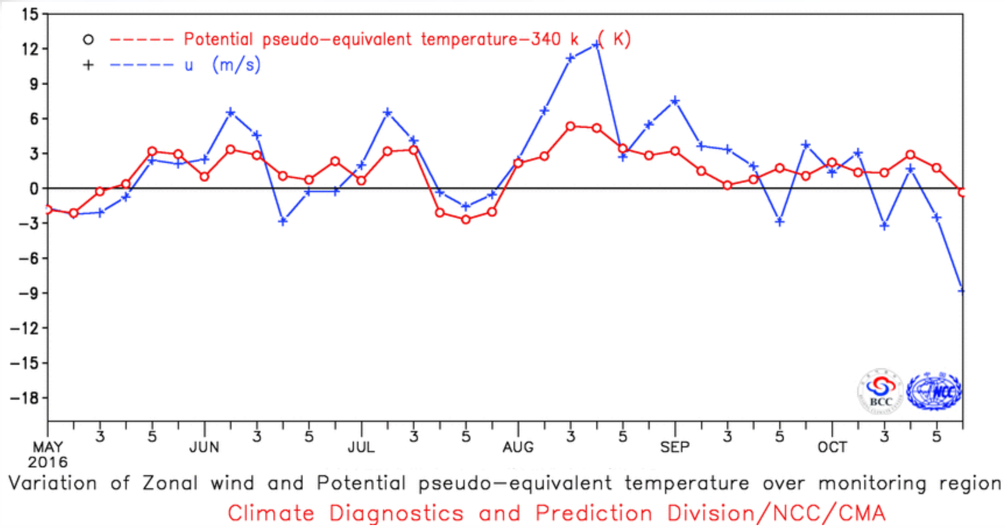


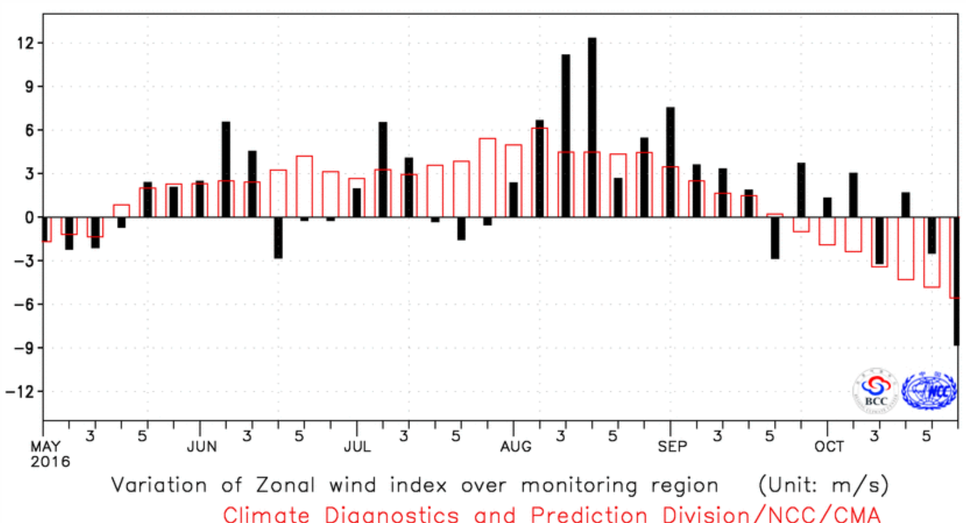
ISM was in the phase weaker than normal in the inter-decadal variation.
The ISM index was - 2.1 in 2016, which was 11th consecutive year with weak intensity.



During summer, ISM mainly kept weaker than normal features

South China Sea Summer Monsoon





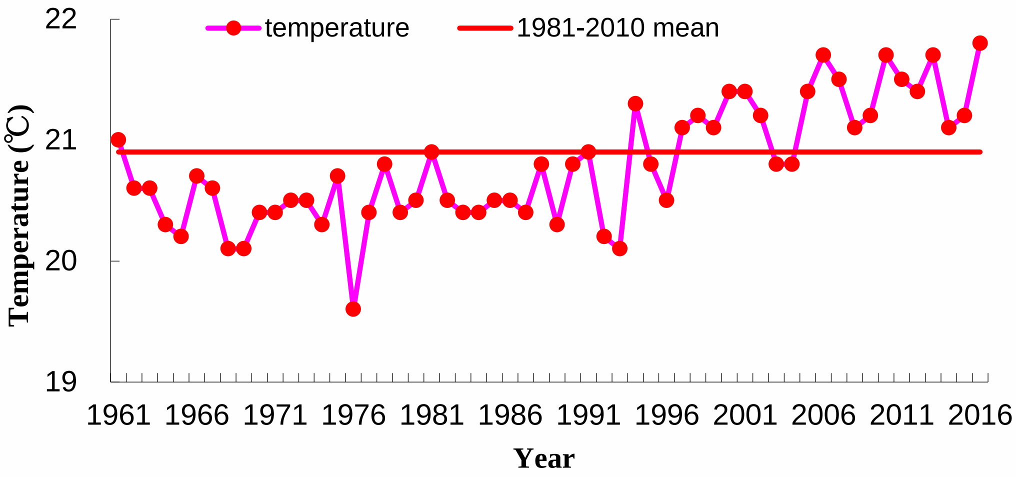
South China Sea (SCS) summer monsoon (SCSSM) in 2016 broke out in the 5th pentad of May, which was near normal.

The latest monitoring in the Beijing Climate Center (BCC) showed that during the 6th pentad of October, the zonal wind at 850hPa changed into easterly wind, and the θse (pseudo-equivalent potential temperature) dropped greatly. The SCS summer monsoon ended in the 6th pentad of October, which is 6 pentads later than the climate (the 6th pentad of September), and is also **the latest years in history.**

The pentad evolution of the intensity index indicated that the SCS summer monsoon was strong in 9 pentads out of 18 pentads in summer. SCSSM was significantly stronger than normal during 3rd pentad to 4th pentad of August, weaker than normal during 4th pentad to 6th pentad of June and 4th pentad to 6th pentad of July.

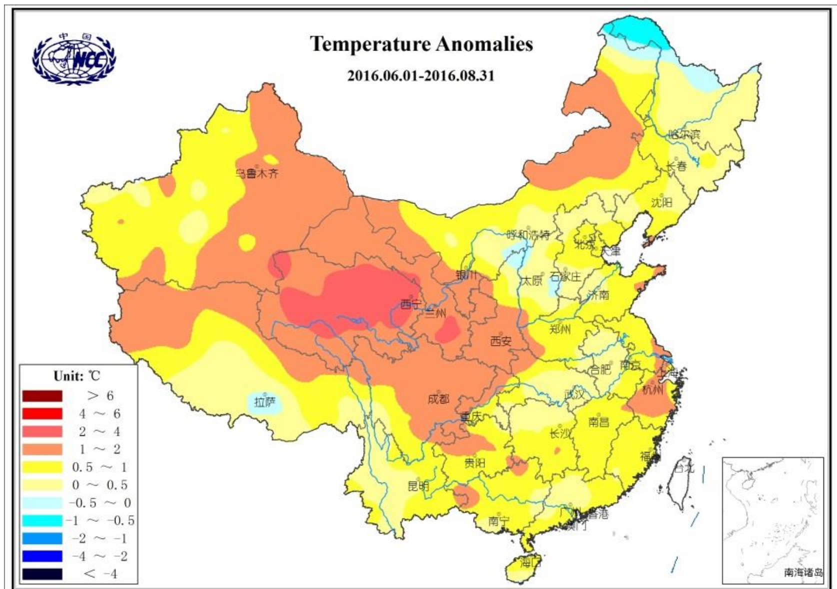
Climate Characteristics over China

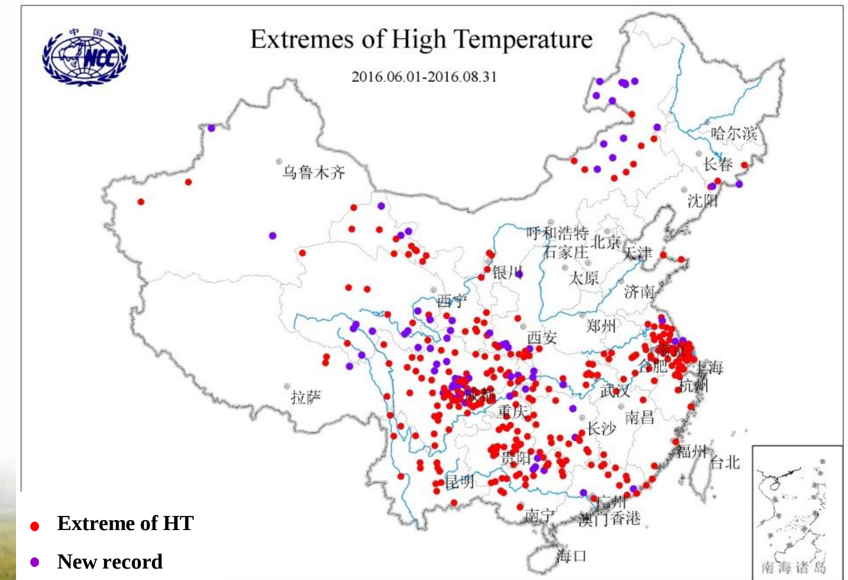
The mean temperature over China was general higher than normal



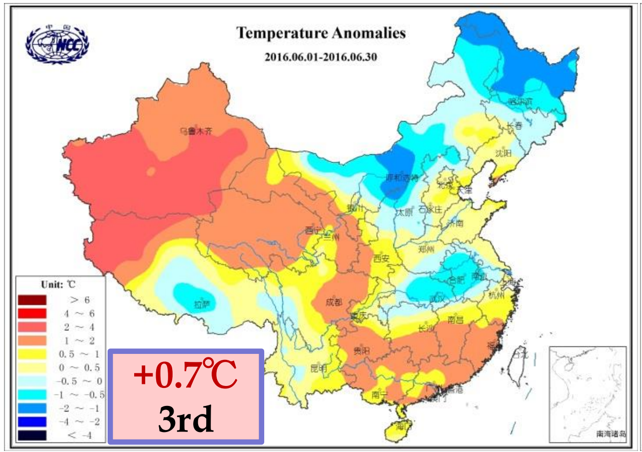
In the summer of 2016, the monthly mean surface air temperature of China was 21.8 ℃, which was 0.9℃ higher than normal. It is the warmest summer since 1961. The temperatures were near and above normal in most China, with temperatures 1~2℃ above normal in most Northwest China.

During the season, extremes of High Temperature occurred in 370 stations, with 73 stations hitting new records.

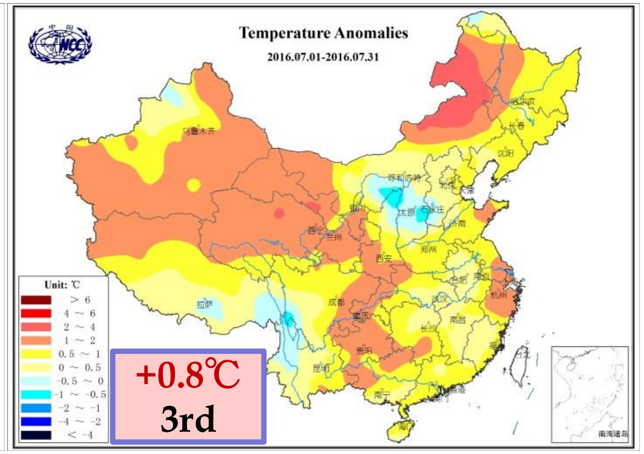




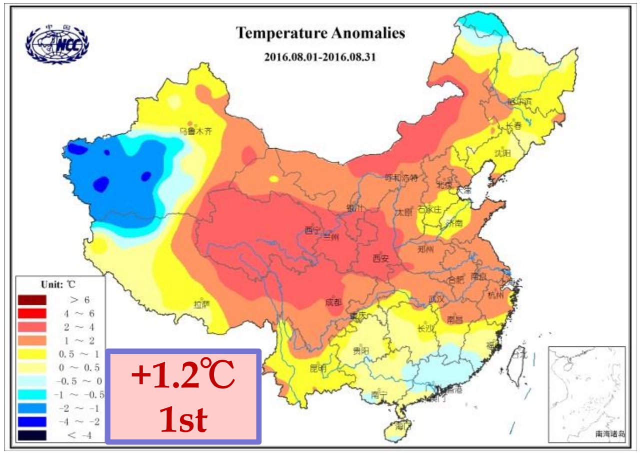
June

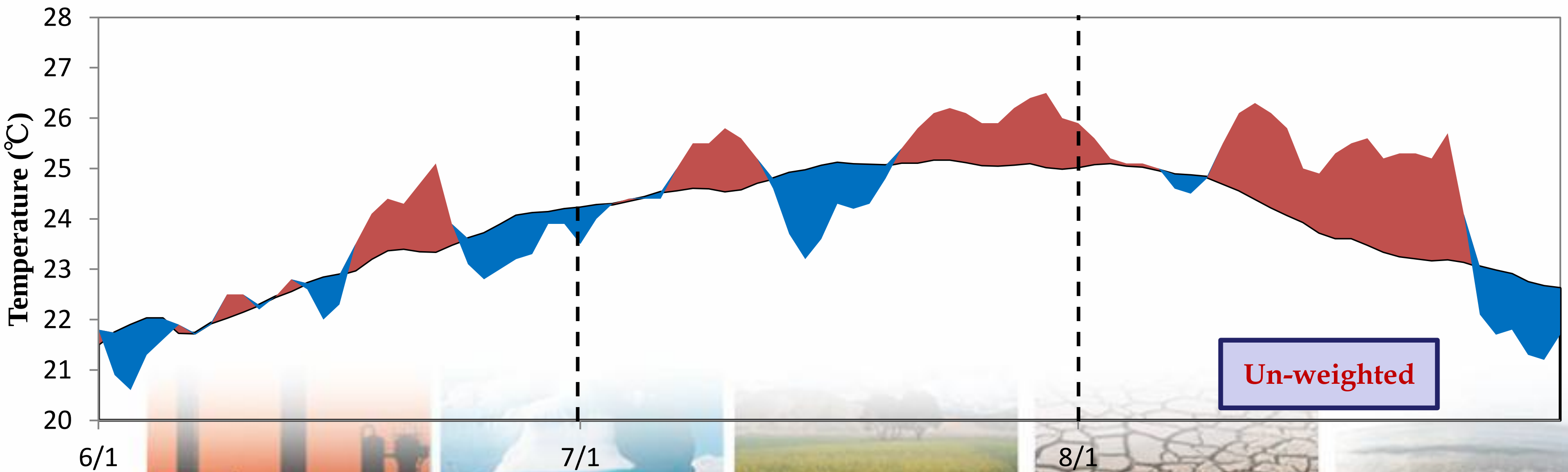


July

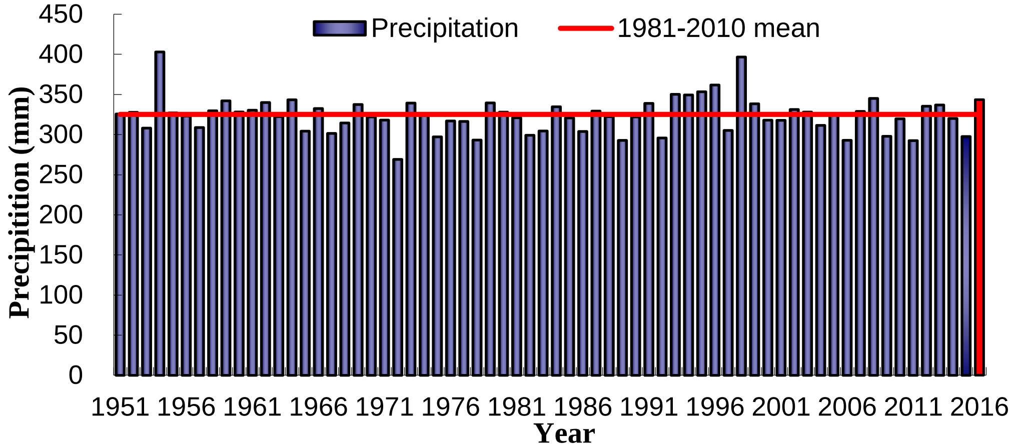


August

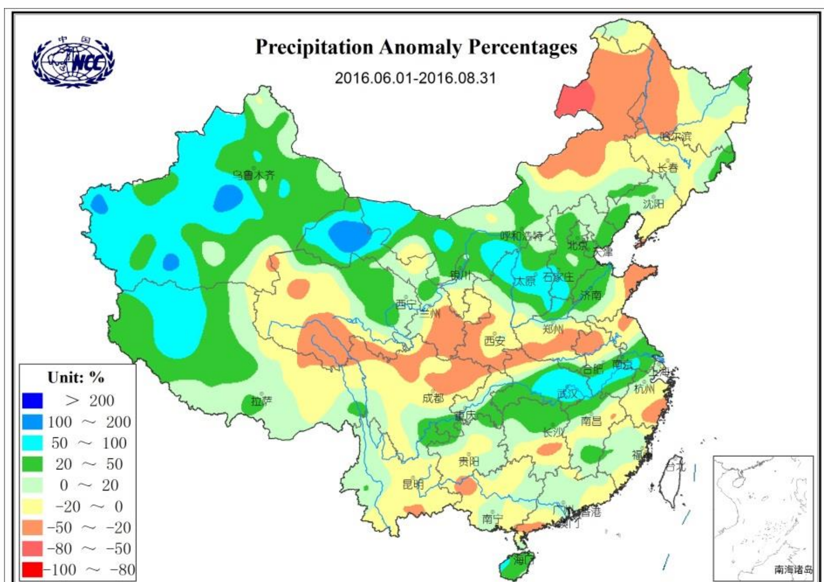


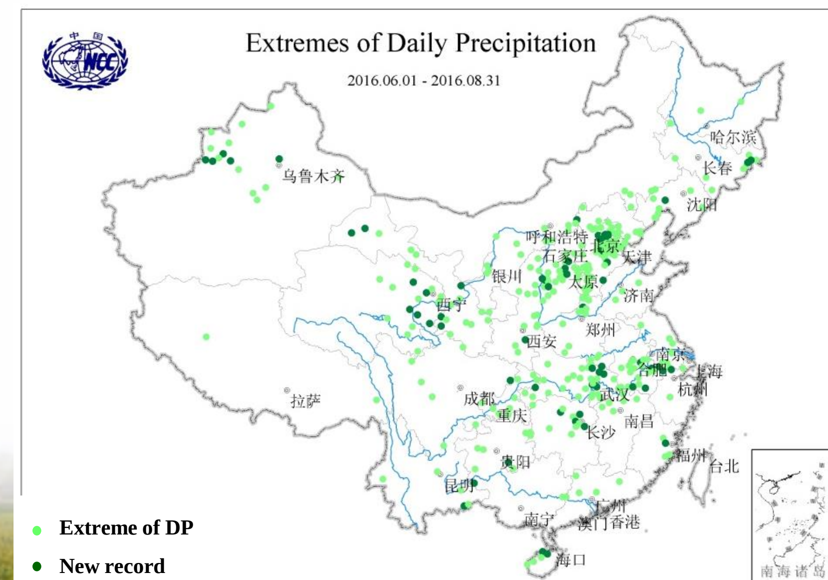


The precipitation over China was slightly more than normal

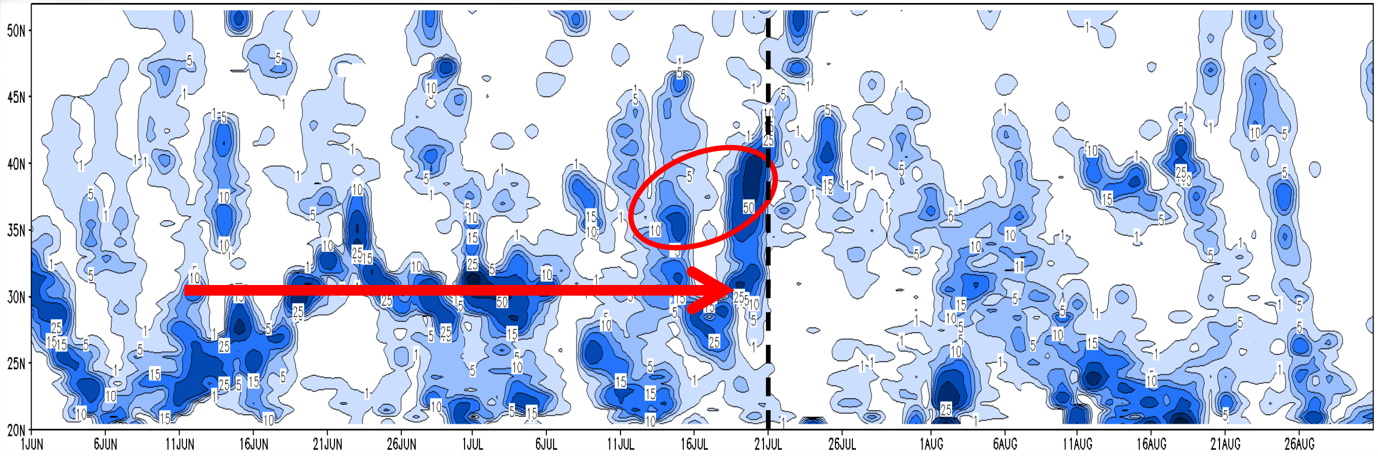


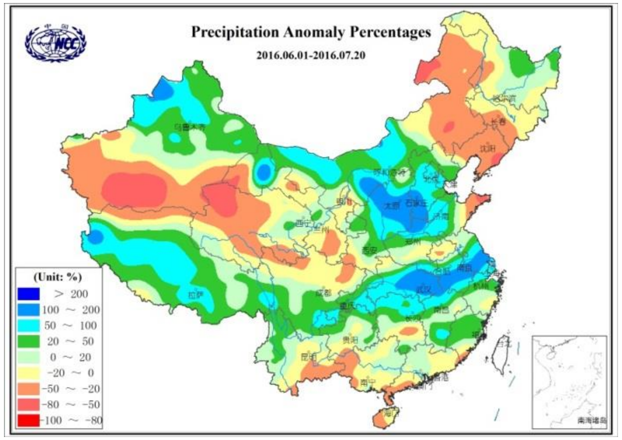
In the summer of 2016, average precipitation of China was 343.4 mm, with 5.6% more than normal (325.2mm). Two rainfall belts were observed over eastern China, located over Yangtze River valley (YRV) and North China. **During the season, extremes of Daily Precipitation occurred in 351 stations, with 73 stations setting new records.**

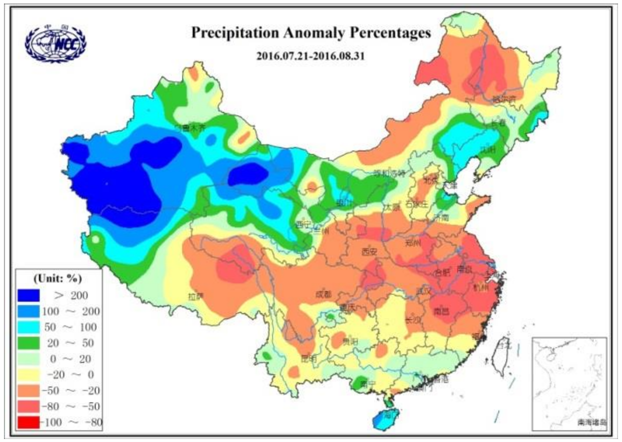




Precipitation Section Alone 110-120° E



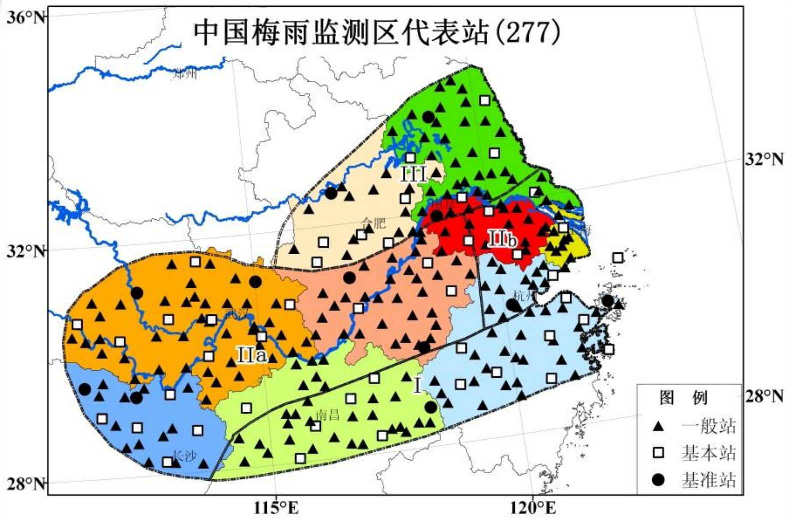




In June and early and middle July, precipitation occurred mainly in the YRV.

In late July and August, however, precipitation was below normal in most part of eastern China, except for more precipitation over South China.

Mei-Yu



	I_jiangnan			II_changjiang			III_jianghuai		
	ave	>0.1	sign	ave	>0.1	sign	ave	>0.1	sign
20160521	10.6	98.5	*	14.2	87.3	*	28.2	98.2	*
20160522	1.3	55.4		0.5	42.0		2.5	90.9	*
20160523	0.9	43.1		0.3	40.8		0.3	58.2	
20160524	1.8	92.3		0.4	52.2		0.1	36.4	
20160525	8.2	96.9	*	4.6	43.3	*	0.0	1.8	
20160526	12.4	95.4	*	22.9	100.0	*	3.3	90.9	*
20160527	2.2	73.8	*	8.5	91.0	*	27.3	100.0	*
20160528	16.3	98.5	*	11.2	91.7	*	14.2	98.2	*
20160529	27.6	100.0	*	6.6	87.9	*	1.1	78.2	
20160530	1.3	67.7		0.1	2.5		0.0	5.5	
20160531	1.2	33.8		1.2	41.4		4.4	96.4	*
20160601	29.6	93.8	*	35.5	96.2	*	33.2	100.0	*
20160602	28.5	96.9	*	14.6	79.0	*	0.6	36.4	
20160603	35.8	100.0	*	16.5	95.5	*	3.7	100.0	*
20160604	0.4	67.7		0.6	47.1		2.8	85.5	*
20160605	0.0	0.0		0.0	5.7		1.3	34.5	
20160606	0.3	4.6		1.5	19.7		1.9	61.8	
20160607	2.5	24.6		2.1	48.4	*	0.6	23.6	
20160608	4.6	53.8	*	2.8	60.5	*	7.1	74.5	*
20160609	1.0	29.2		0.1	19.7		0.0	3.6	
20160610	1.4	18.5		0.5	22.3		0.0	0.0	
20160611	10.4	81.5	*	5.4	83.4	*	1.3	5.5	
20160612	12.7	100.0	*	28.3	95.5	*	5.9	69.1	*
20160613	2.1	56.9	*	0.2	27.4		0.7	12.7	
20160614	0.0	0.0		0.0	1.3		0.0	3.6	
20160615	41.6	100.0	*	11.6	80.3	*	1.3	43.6	
20160616	15.3	84.6	*	0.6	39.5		0.0	18.2	
20160617	0.0	15.4		0.0	0.0		0.0	0.0	
20160618	9.5	84.6	*	0.6	11.5		0.0	0.0	
20160619	19.8	89.2	*	41.4	82.8	*	0.5	10.9	
20160620	4.5	50.8	*	31.7	90.4	*	7.4	50.9	*
20160621	0.0	15.4		3.8	67.5	*	41.7	100.0	*
20160622	0.8	16.9		14.3	56.7	*	24.9	98.2	*
20160623	0.0	3.1		1.2	20.1		12.6	35.3	*
20160624	0.4	10.8		8.3	70.1	*	26.0	100.0	*
20160625	11.7	72.3	*	26.4	97.5	*	5.7	69.1	*
20160626	33.0	92.3	*	7.1	75.8	*	0.3	20.0	
20160627	3.2	63.1	*	19.6	92.4	*	18.1	100.0	*
20160628	6.8	83.1	*	44.6	84.7	*	1.0	63.6	
20160629	54.9	98.5	*	5.3	66.9	*	0.0	12.7	
20160630	3.8	69.2	*	6.0	62.2	*	0.4	5.5	
20160701	1.7	66.2		60.4	100.0	*	89.9	100.0	*
20160702	4.2	66.2	*	64.3	98.7	*	16.6	65.5	*
20160703	13.4	73.8	*	52.5	100.0	*	19.3	65.5	*
20160704	11.9	50.8	*	45.1	99.4	*	49.5	100.0	*
20160705	9.3	66.2	*	21.8	91.1	*	27.2	100.0	*
20160706	3.3	55.4	*	26.3	84.7	*	8.1	98.2	*
20160707	1.4	27.7		4.4	60.3	*	19.3	90.9	*
20160708	1.2	29.2		1.0	17.3		0.4	10.9	
20160709	4.4	64.6	*	0.4	17.8		0.0	3.6	
20160710	9.0	86.2	*	1.6	38.2		0.7	29.1	
20160711	5.4	86.2	*	6.0	49.0	*	2.9	43.6	*
20160712	4.4	49.2	*	2.0	27.4		0.0	5.5	
20160713	4.7	49.2	*	9.7	79.0	*	9.6	90.9	*
20160714	4.3	53.8	*	13.5	90.4	*	16.8	72.7	*
20160715	1.4	32.3		14.2	91.7	*	22.2	100.0	*
20160716	29.9	95.4	*	5.9	60.5	*	0.1	36.4	
20160717	3.1	36.9	*	4.6	24.8		0.0	3.6	
20160718	9.2	69.2	*	8.3	55.4	*	1.6	14.5	
20160719	1.3	32.3		17.6	59.9	*	5.0	67.3	*
20160720	0.2	7.7		15.0	45.9	*	0.3	16.4	
20160721	0.2	3.1		1.0	23.6		1.2	21.8	
20160722	0.3	6.2		0.0	0.6		0.0	0.0	

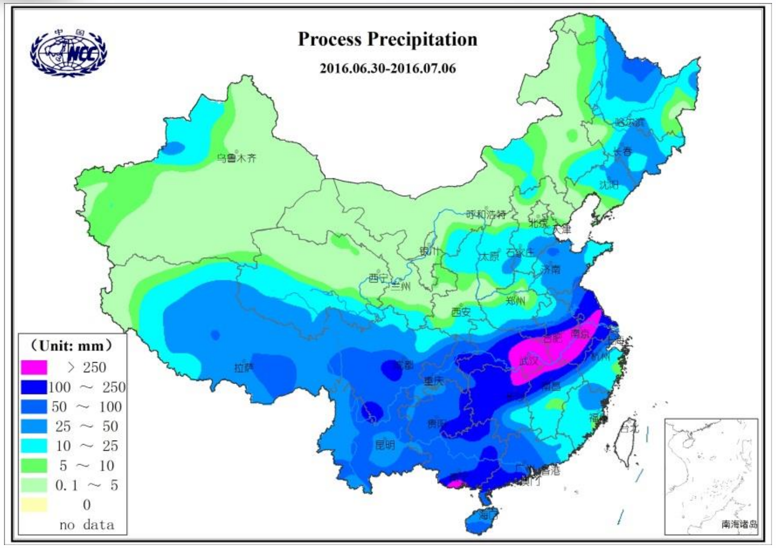
Three precipitation patterns are analyzed respectively.

The South Meiyu (I. regions south of the Yangtze River) began at 25 May, which was 14 days earlier than normal, ended at 19 July, 11 days later than normal, total rainfall amount was 526.0mm, with 44.0% more than normal (365.4mm).

The Yangtze Meiyu (II. the middle and lower reaches of the YRV) began at 19 June, which was 5 days later than normal, ended at 21 July, 8 days later than normal, total rainfall amount was 584.3mm, with 108.0% more than normal (281.0mm).

The Yangtze-Huaihe Meiyu (III. Yangtze-Huaihe River valley) began at 20 June, which was 1 days earlier than normal, ended at 16 July, 8 days later than normal, total rainfall amount was 420.6mm, with 59.1% more than normal (264.4.4mm).

Major Climate Event

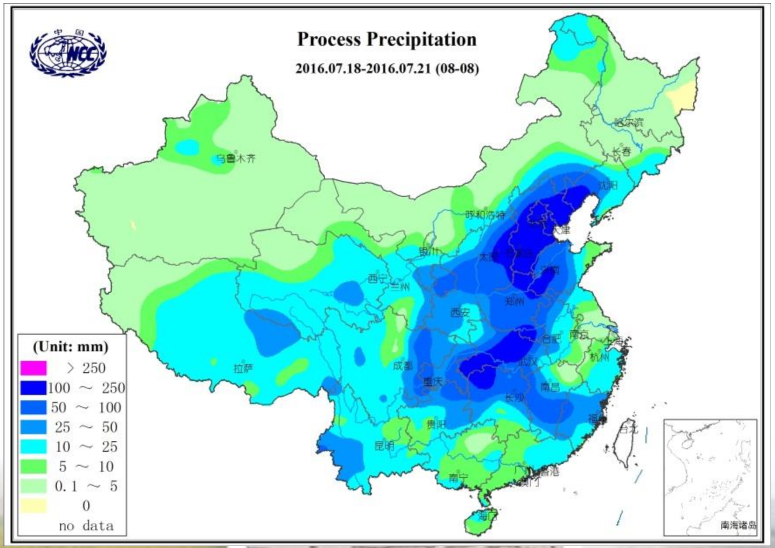


During 30 June – 6 July, continued intensive rainfall attacked middle and lower reaches of the YRV.

During the process, rainfall amount over 500mm were observed in 20 stations, with over 600mm in 6 stations. Hubei, Anhui, Jiangxi, Jiangsu province experienced flooding, and geological disasters.

During 18 July – 21 July, the extreme rainfall attacked Central China, southeastern North China.

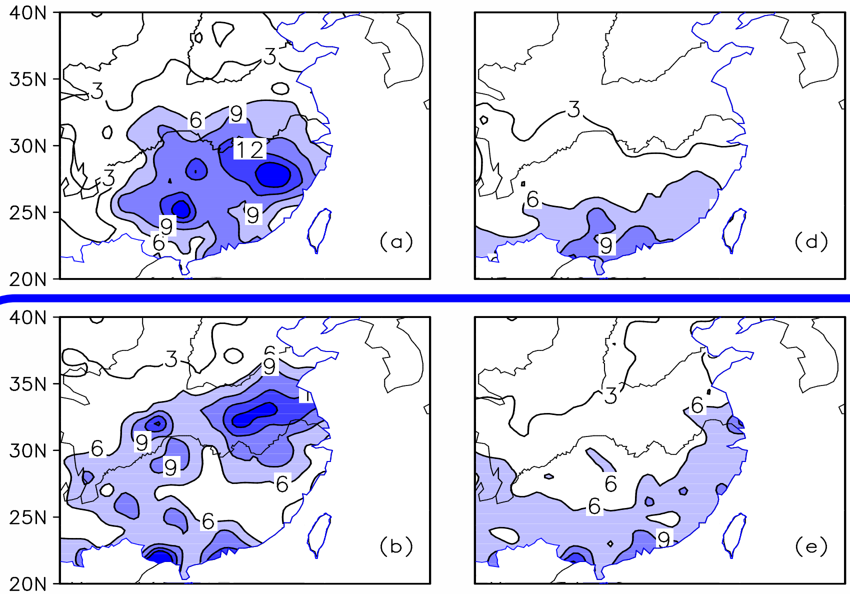
During the process, maximum daily precipitation of linzhou county was 703mm, set new record. The extreme rainfall caused local severe flooding, geological disasters.



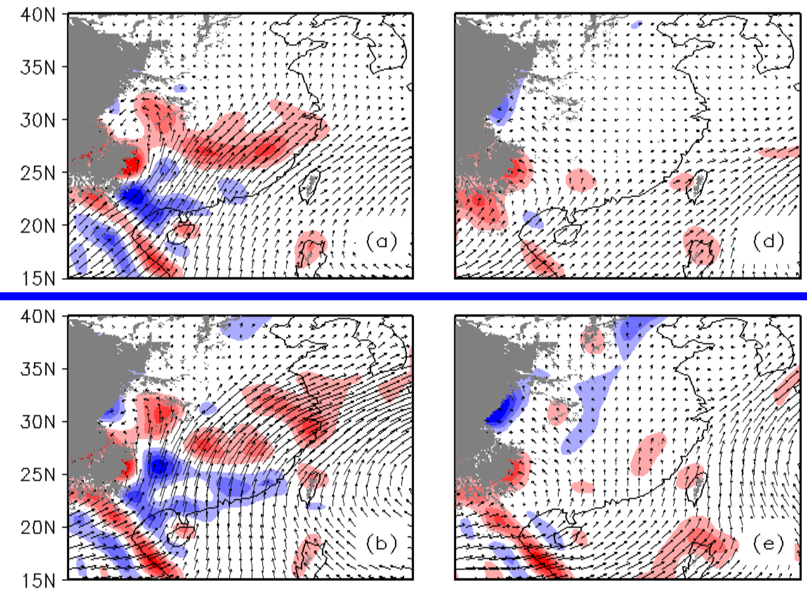
Causes of the Precipitation Anomalies

Low Level Jet

The observed precipitation averaged during the period of LLJ events and non-LLJ events



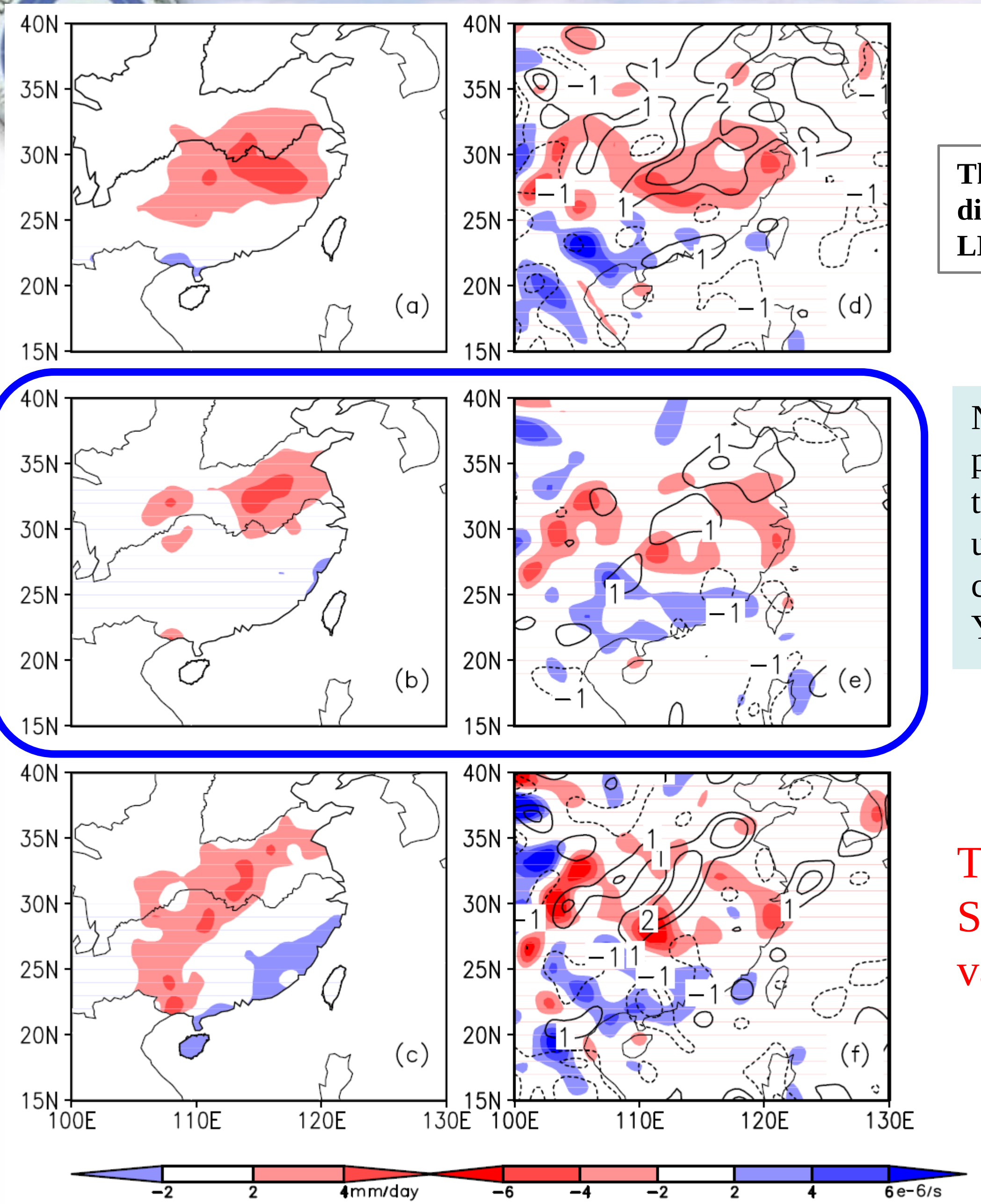
Moisture flux at 850hPa (vector) and moisture flux divergence (shaded) vertically integrated from 925hPa to 600hPa averaged during the period of LLJ events and non-LLJ events



The precipitation of LLJ periods shows a maximal center with the intensity over 12 mm/d located over the Yangtze-Huaihe River valley, while during the non-LLJ periods, the precipitation mainly occurs over the south coastal regions of Southeast China.

The LLJ plays an important role in moisture transport.

The moisture was transported northward by the strong winds along the axis of the LLJ supplies the water vapor for the precipitation formation over the Yangtze-Huaihe River Valley. In the non-LLJ, the moisture flux is quite weak and there is no obvious moisture flux convergence over East China.

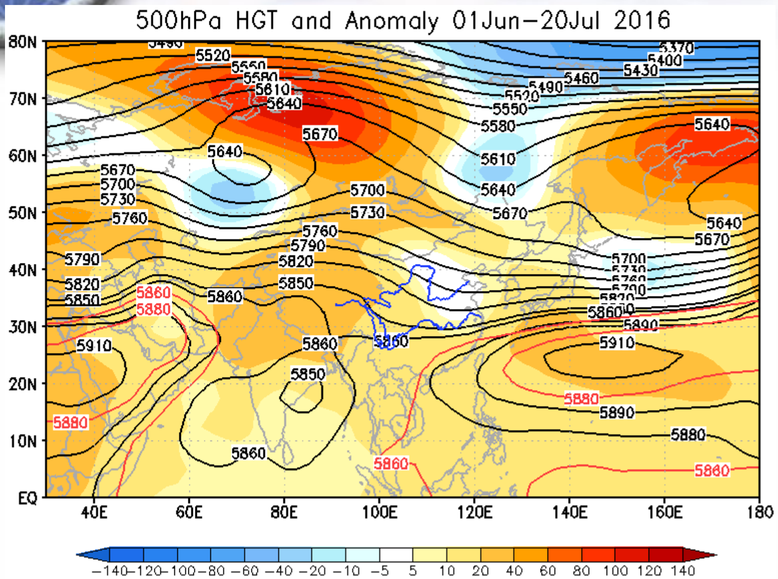


The anomalies of the precipitation and the wind divergence at 850hPa (shaded) and 200hPa (contour) of the LLJ periods compared to the climatology

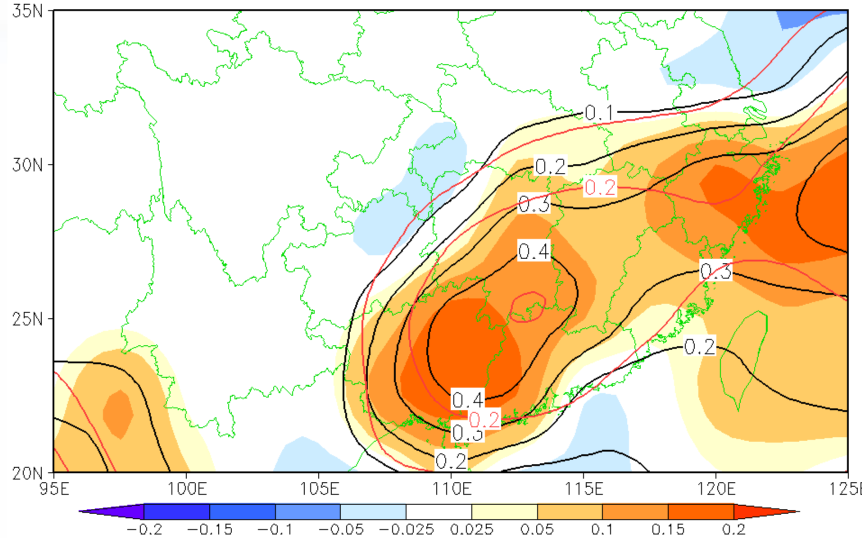
Negative wind divergence anomalies at 850hPa and positive wind divergence anomalies at 200hPa over the Yangtze-Huaihe River Valley strengthen the upward motion over this region, which are conductive to produce more precipitation over the Yangtze-Huaihe River Valley.

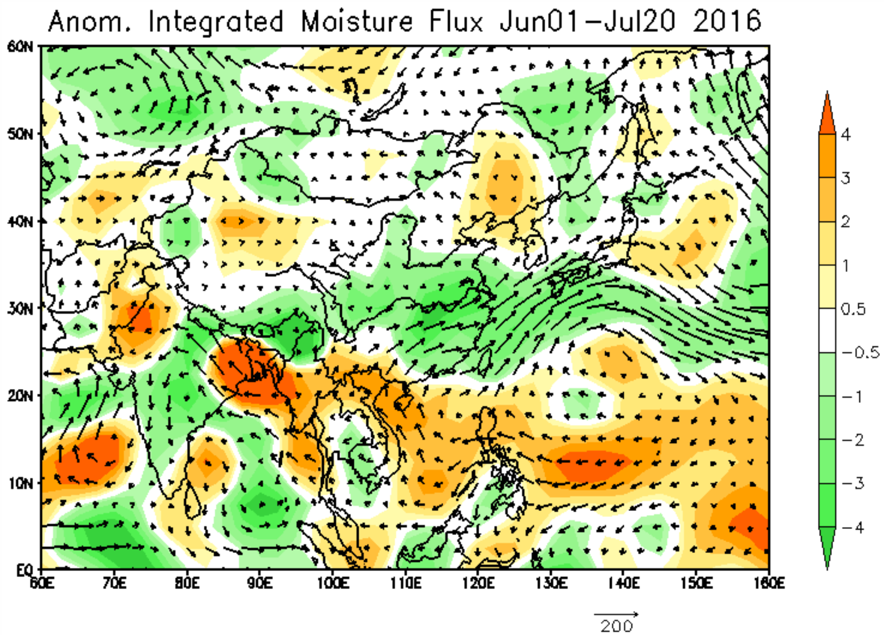
The LLJ affects the precipitation over Southeast China by transporting water vapor and triggering upward motion.

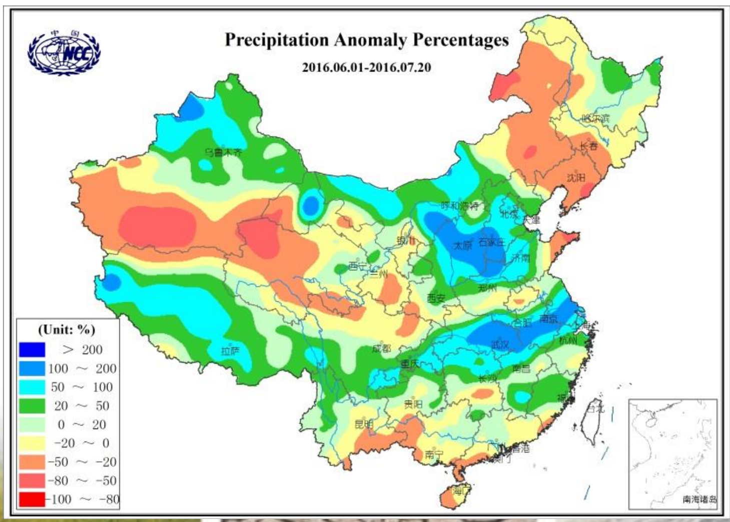
Wang D Q, *APJAS*, 2013



The occurrence frequency of LLJ







GEFA (Generalized Equilibrium Feedback Assessment)

$$X_t = \begin{pmatrix} x_1(t) \\ x_2(t) \\ \vdots \\ x_i(t) \end{pmatrix}$$

The variability of atmospheric Xt consists of a stochastic part associated with the internal variability Nt and a feedback part response of sea surface temperature (SST) B×Yt

$$X_t = BY_t + N_t$$

B is the response sensitivity matrix measuring the impact of the SST and Yt is the variability of SST

$$Y_t = \begin{pmatrix} y_1(t) \\ y_2(t) \\ \vdots \\ y_j(t) \end{pmatrix}$$

$$B_J = \left| b_{ij} \right|_J$$

$$X_t = BY_t + N_t$$

$$\langle X_t, Y_{t-\tau} \rangle = \langle BY_t + N_t, Y_{t-\tau} \rangle$$

$$= \langle BY_t, Y_{t-\tau} \rangle + \langle N_t, Y_{t-\tau} \rangle$$

$$= \langle BY_t, Y_{t-\tau} \rangle + \langle N_t, Y_{t-\tau} \rangle$$

⇧

SST cannot be forced by internal atmospheric variability of later times

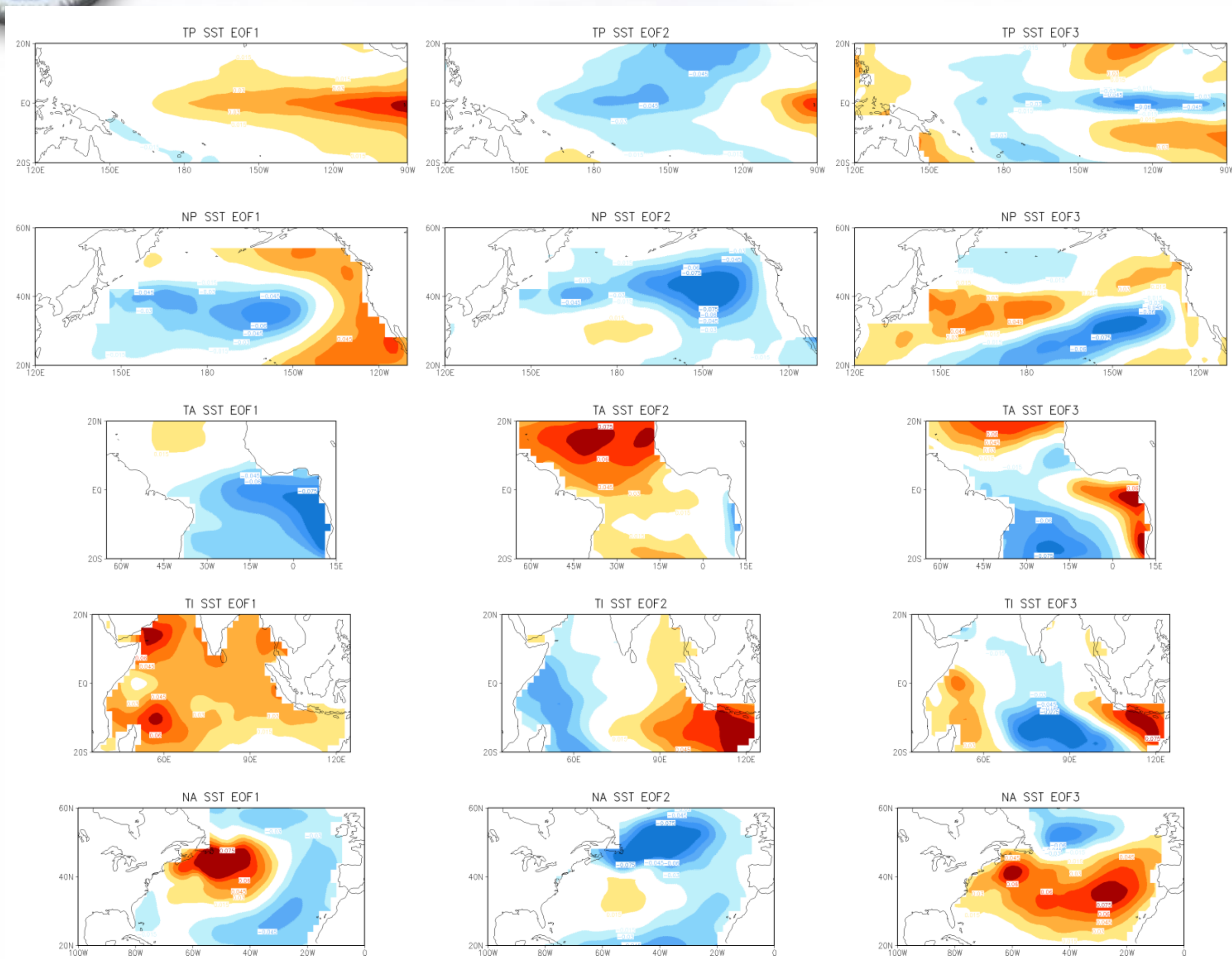
$$= B\langle Y_t, Y_{t-\tau} \rangle + 0$$

$$C_{XY}(\tau) = BC_{YY}(\tau)$$

$$B = C_{YY}^{-1}(\tau) C_{XY}(\tau) \quad (\tau = 1)$$

Liu Z Y, et al. *J. Climate*,2008

Forcing Factors



Tropical Pacific (20ºS–20ºN, 100ºE–80ºW)

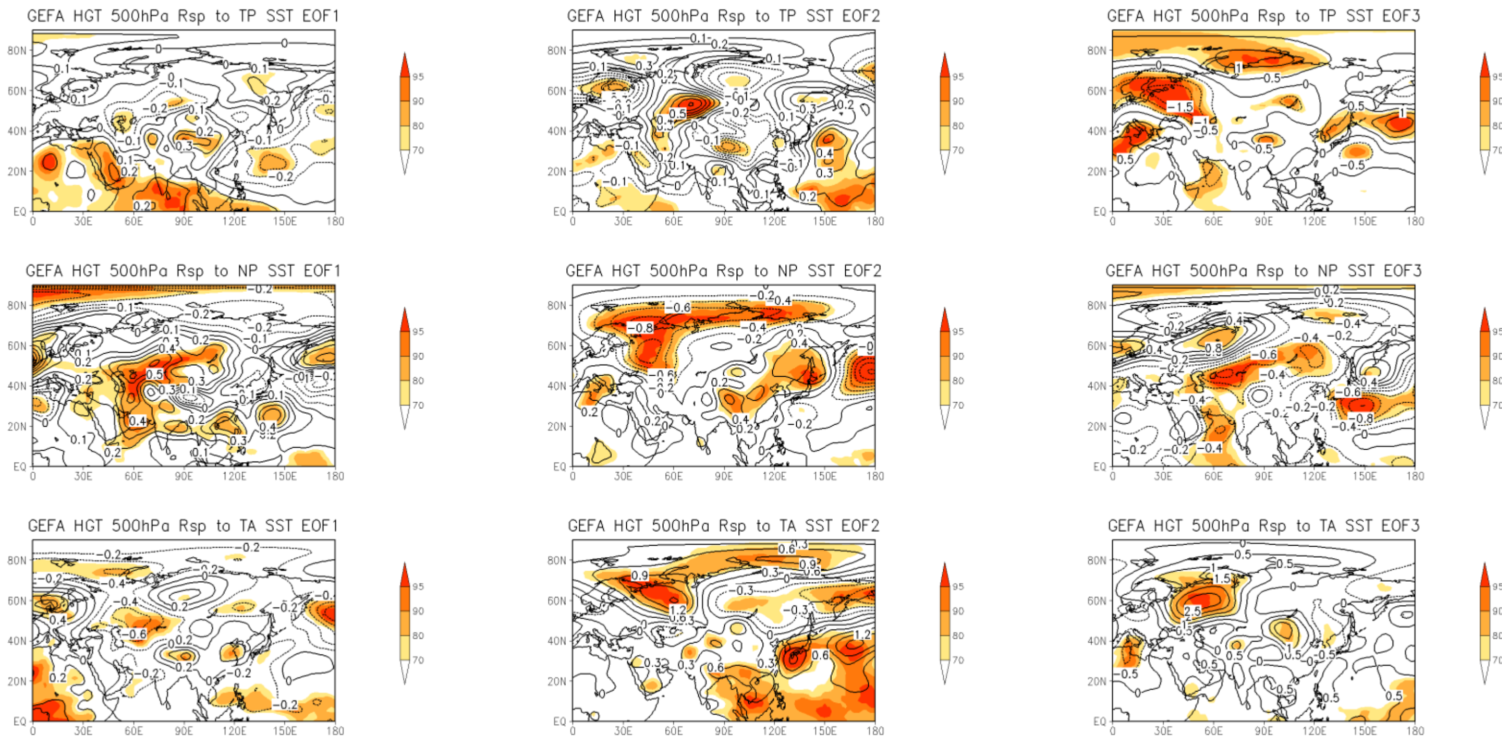
North Pacific (20º–60ºN, 120ºE–80ºW)

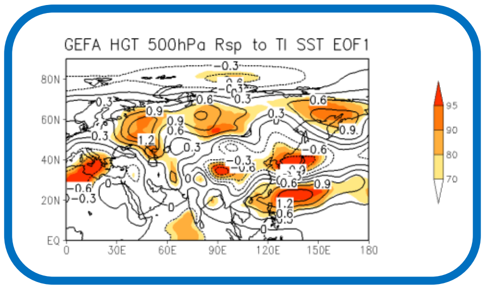
Tropical Atlantic (20ºS–20ºN, 70ºW–20ºE),

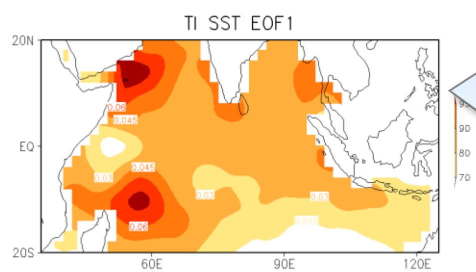
Tropical Indian Ocean (20ºS–20ºN, 35º–120ºE)

North Atlantic (20º–60ºN, 70ºW–20ºE)

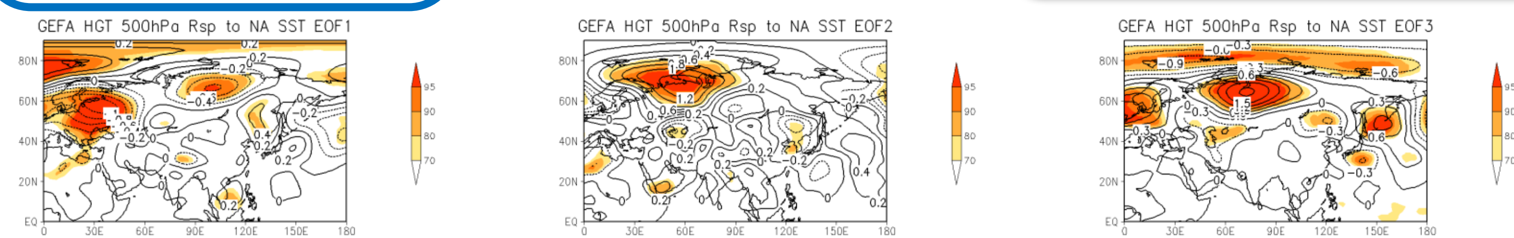
Response Sensitivity of 500hPa HGT to SST Forcing

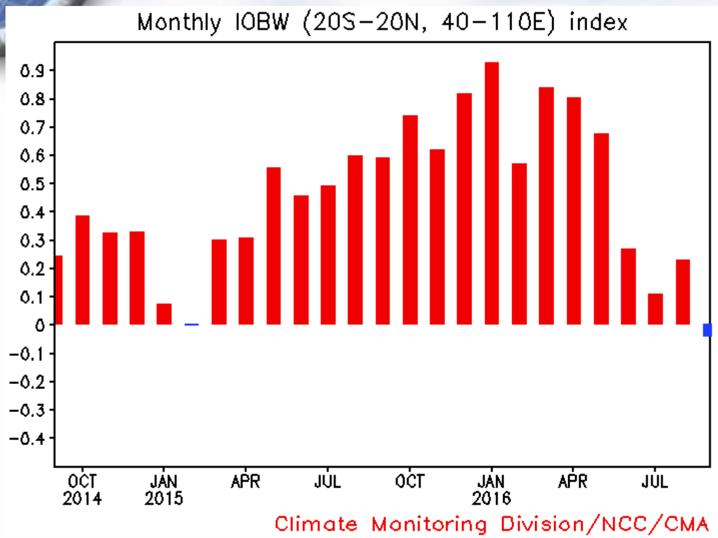




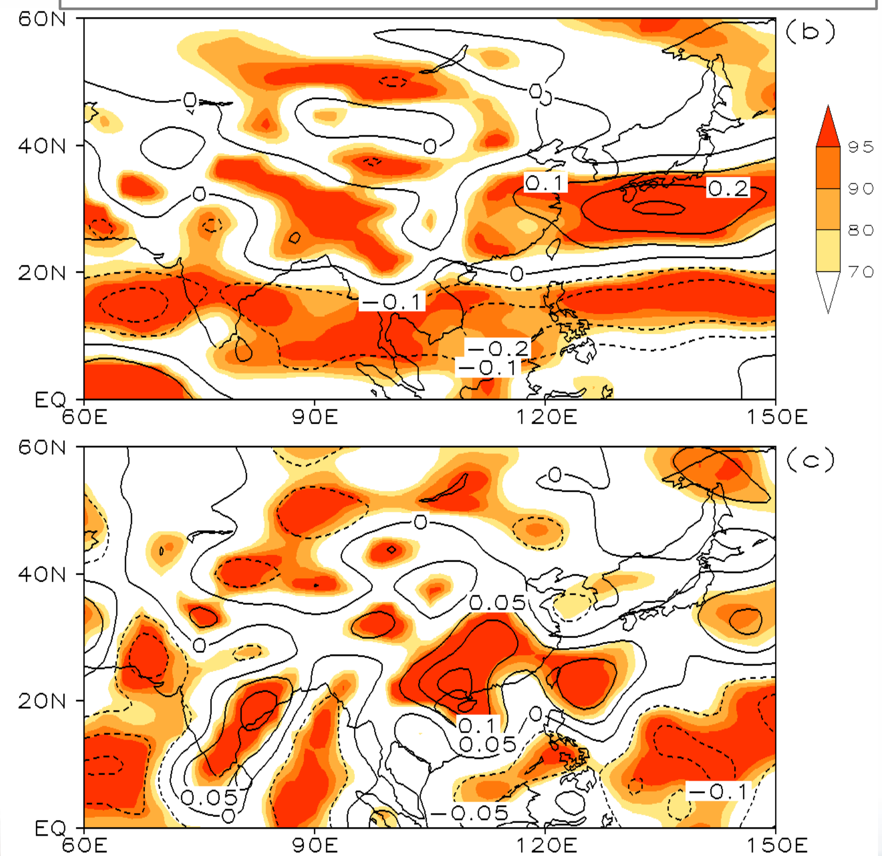


The Tropical Indian Ocean IOBW mode was an important external forcing for East Asia atmospheric circulation anomalies.

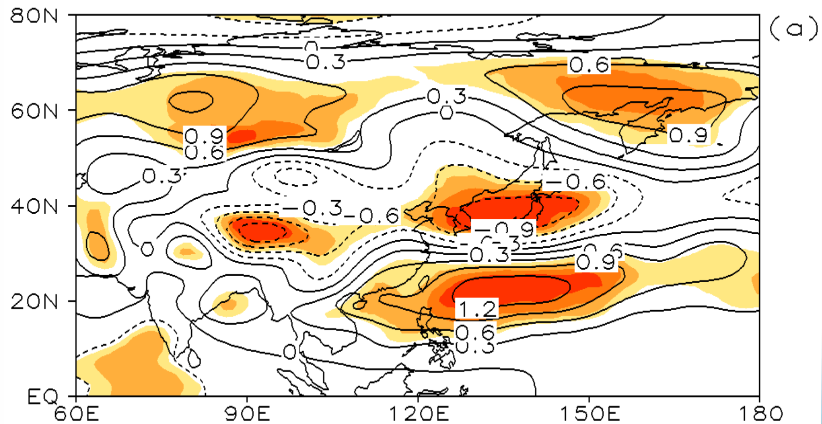




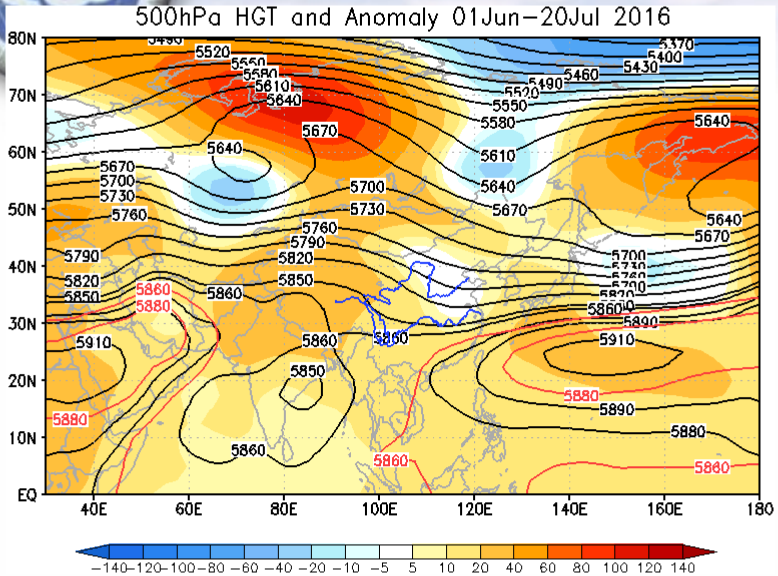
Distribution of the response coefficient (black lines) and Monte Carlo test (shaded)of 850hPa zonal winds (b) and 850hPa meridional winds(c) to Indian Ocean basin-wide mode (IOBW) forcing



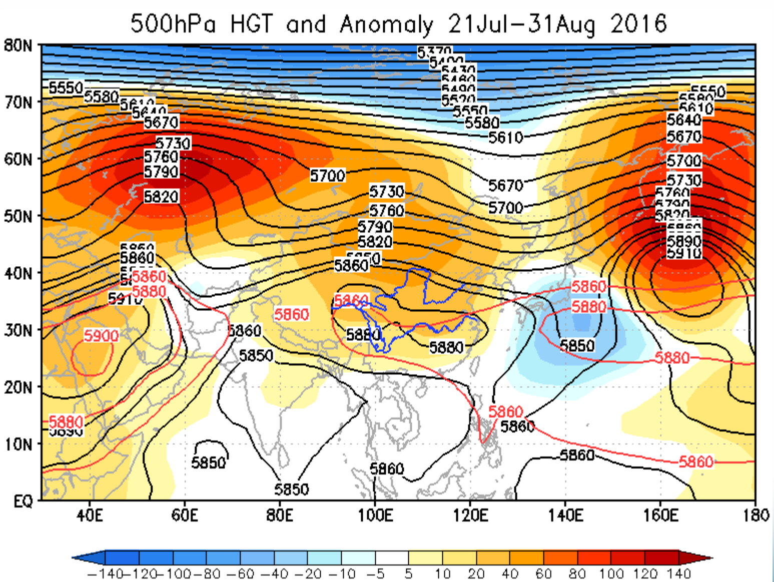
Distribution of the response coefficient (black lines) and Monte Carlo test (shaded)of 500hPa geopotential heights to Indian Ocean basin-wide mode (IOBW) forcing

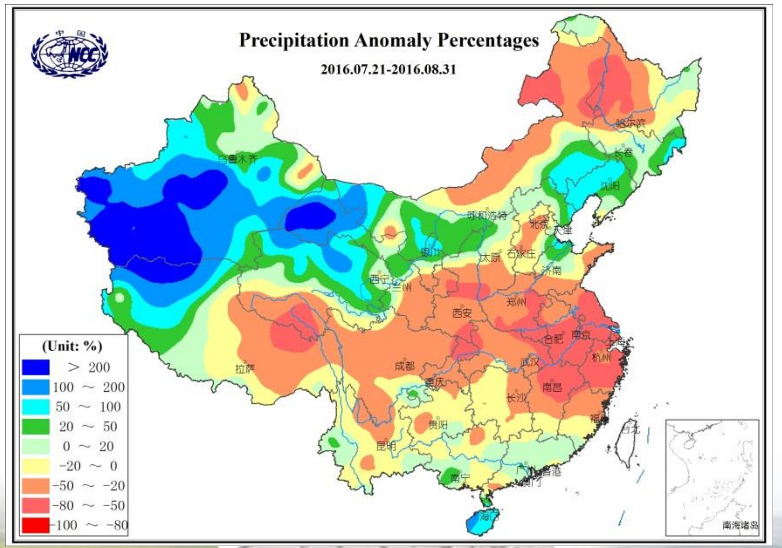


The WPSH fractured after late July



After late July, the WPSH fractured, with the eastern part retreating eastward and the western part combining with the continental high pressure. Anomalous low-level cyclone controlled the northwestern Pacific, which caused anomalous divergence of moisture flux over most part of eastern China. Therefore, high temperature and little precipitation occurred in the middle and lower reaches of the YRV.

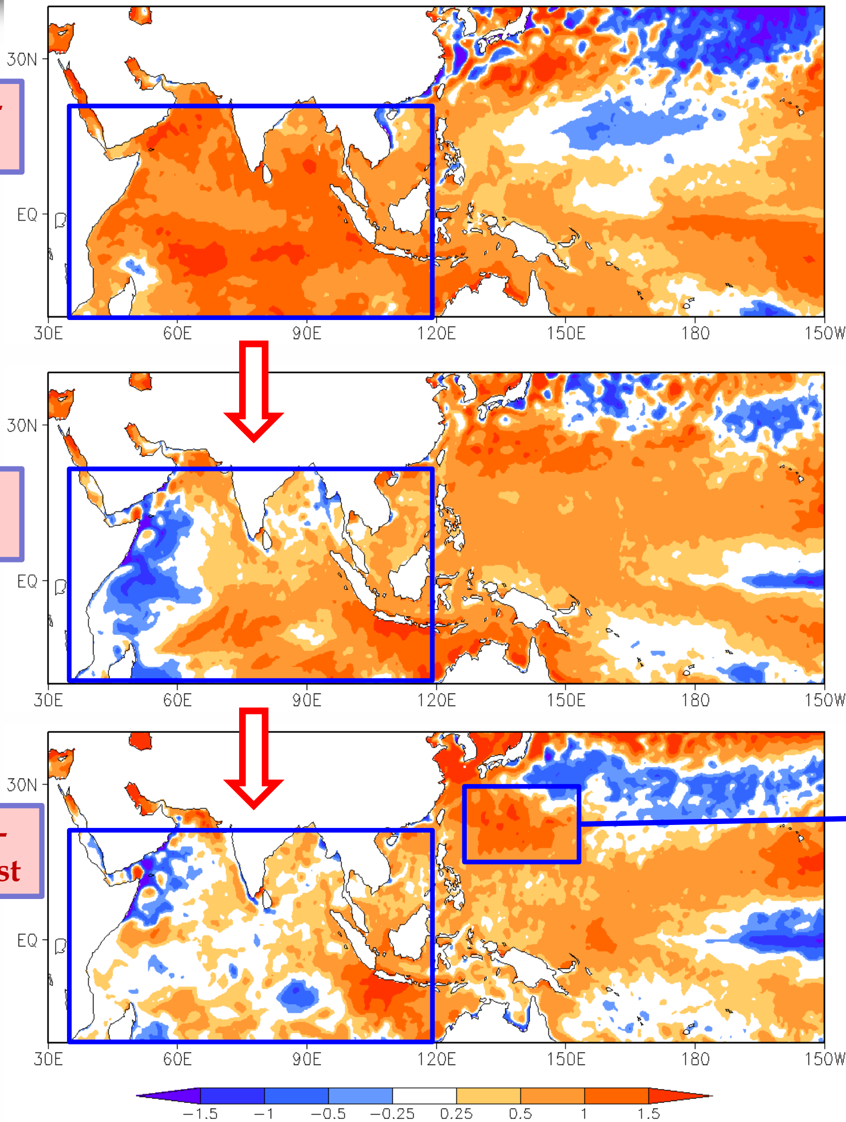




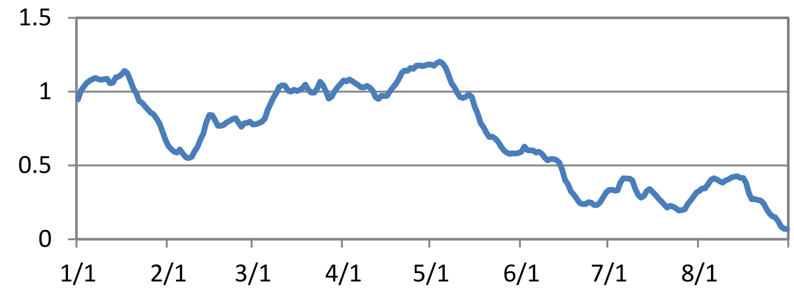
April - May

June - July

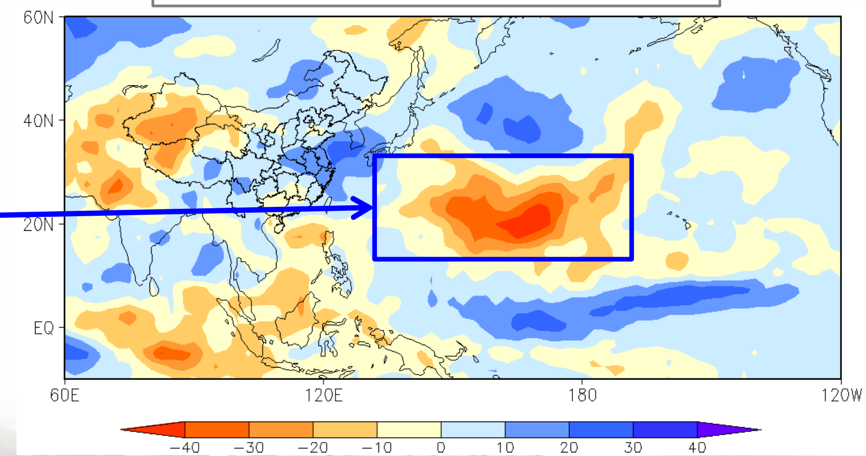
21 July - 31 August

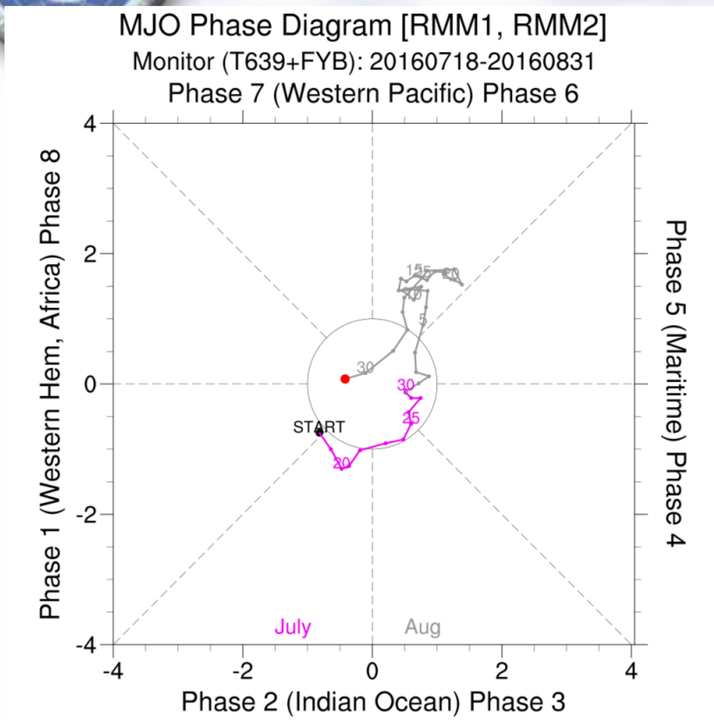


Variation of SST anomalies (20° S - 20° N, 35° - 120° E average)



OLR anomalies (21 July – 31 August)





21 July to 31 August, there were 10 tropic cyclones formed (No.2 – No.11), among those 7 cyclones moved northward.

Under that condition, the unusually active MJO played as a important cause for the significant turning of the tropical and subtropical circulations. After late July, MJO transferred eastward to the western Pacific and stayed there for 25 days. It excited active tropical cyclone activities in the northwestern Pacific and thereby influenced the fracture of the WPSH in August 2016.

Summary

The EASM was stronger than normal, while the ISM was weaker than normal.

In the summer of 2016, the average temperature of China was 21.8 ℃, which was **0.9℃ higher** than normal, while the average precipitation was 343.4 mm, **5.6% more** than normal. **Two rainfall belts** were observed over eastern China, located over YRV and North China, respectively.

The **more intensified and more westward-extending WPSH** acted as one of the most important circulation factors for the southern rainfall belt over the YRV in June and July.

The **higher occurrence frequency of LLJ** was also favorable to strengthen the precipitation over YRV by transporting water vapor and triggering upward motion.

The **persistent warming in the entire basin of the tropical Indian Ocean**, which was generated by the decaying procedure of a strong El Nino event, was an important external forcing for the above tropical and subtropical circulation anomalies.

The **infrequent activity of MJO** excited active tropical cyclone activities and thereby influenced the fracture of the WPSH, lead to the hotter and less rainfall over YRV in August.

Thanks for your attention!