



# Decadal northward shift of the Meiyu belt and the possible cause

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# Outline

- 1. Weakening of the Asian summer monsoon and inter-decadal shift of summer precipitation pattern**
- 2. Decadal northward shift of the Meiyu belt**
- 3. Possible cause and conclusions**





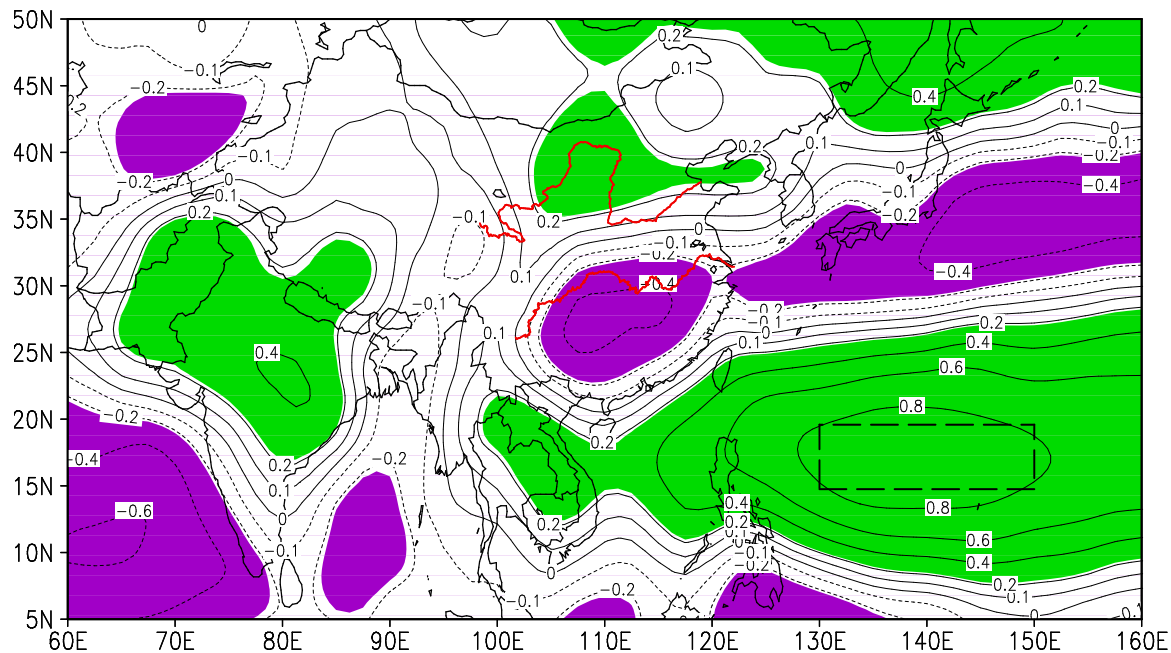
# **1. Weakening of the Asian summer monsoon and inter-decadal shift of summer precipitation pattern**





## 亚洲-太平洋季风降水的相关分布

# Correlation patterns of Asian-Pacific summer (JJA) monsoon



西北太平洋关键区6~8月降水与亚洲-太平洋季风区降水的相关





1870-2003东亚季风指数长期变化 ( IPCC,2007 )

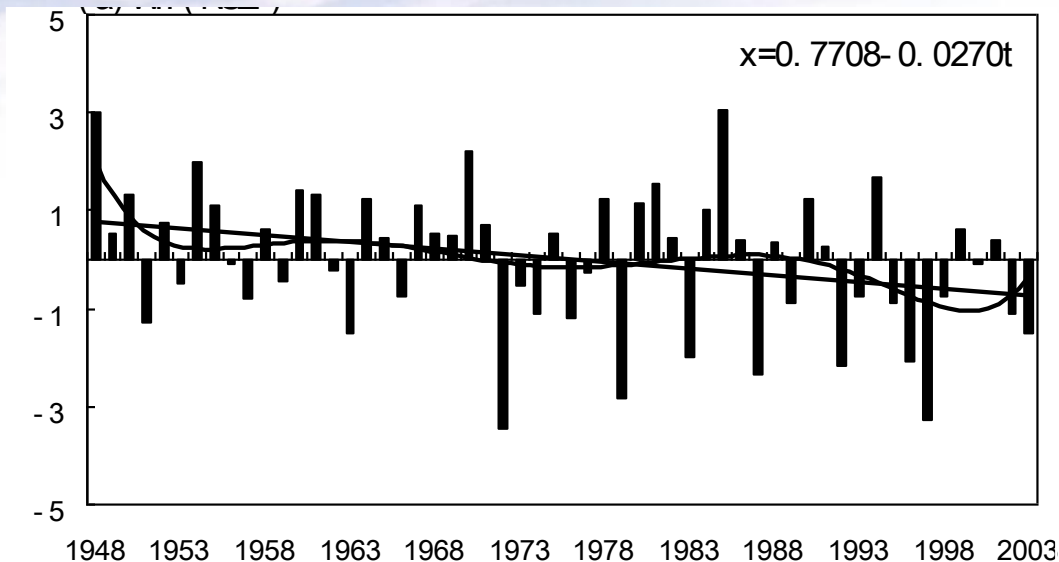
**Long-term variation of East Asian summer index since 1870 (based on GUO)**





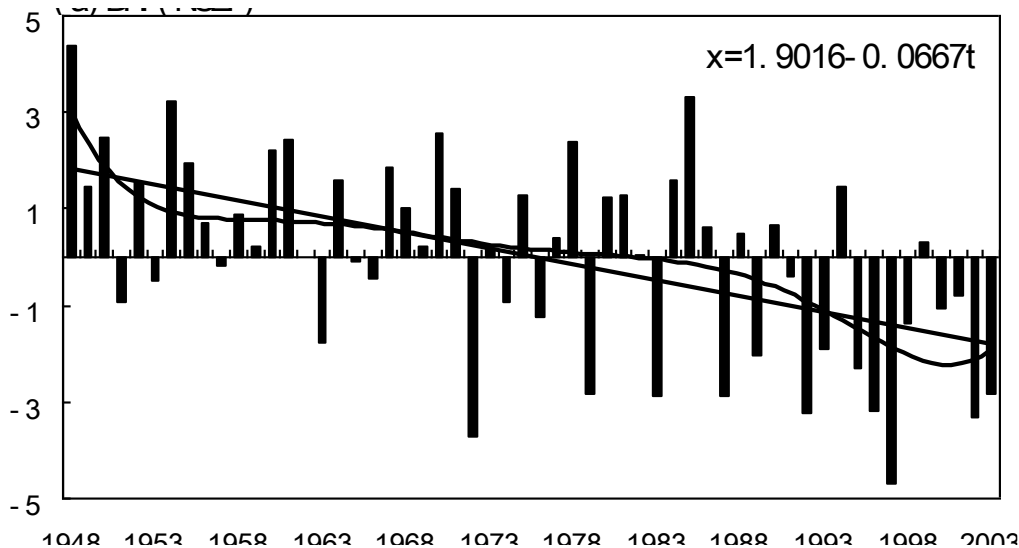
ERA

# 主要是由于亚洲季风减弱所致



(a)

NCEP



(b)

**Long-term variation of summer monsoon index for 1948-2003**



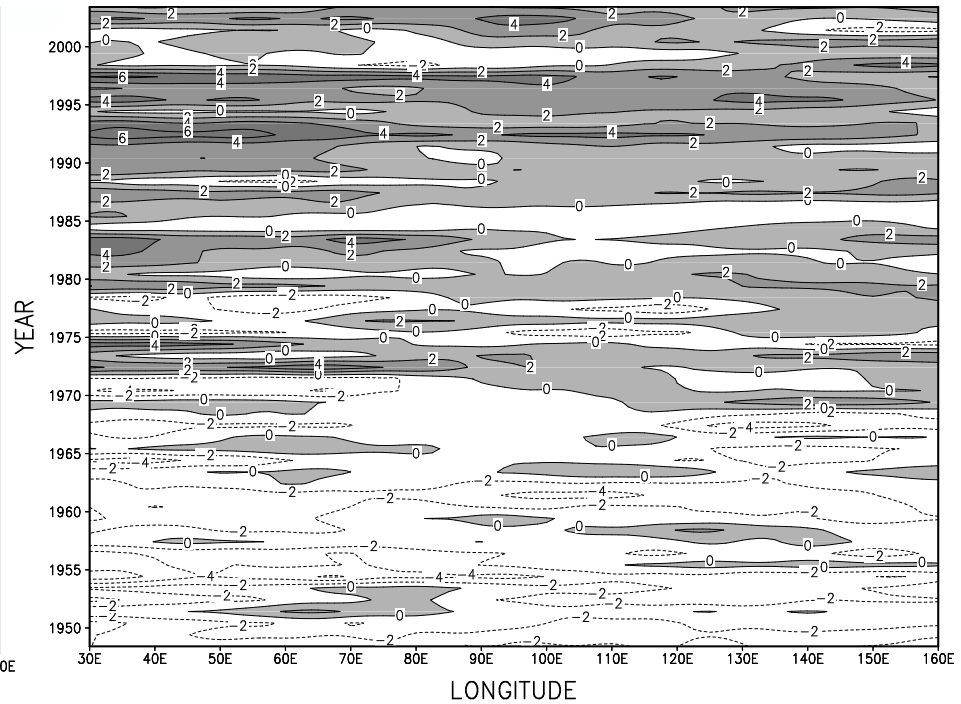
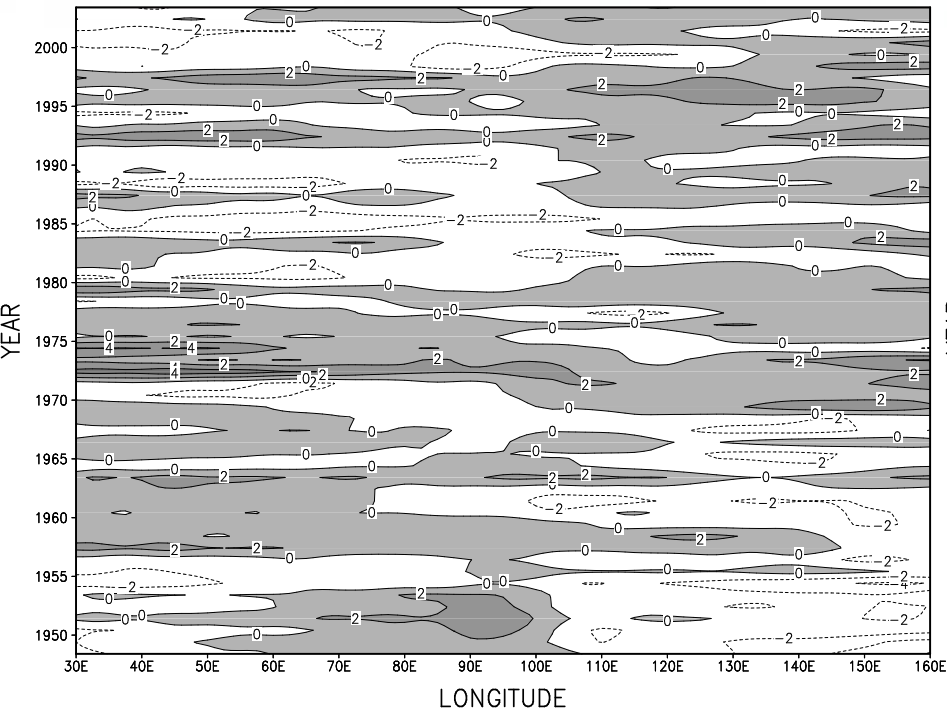
# Tropical Easterly Jet at 150-100 hpa has decreased since mid-1970's

(a)

(b)

200hPa U Anomaly (JJA) (10–20N) NCEP

100hPa+150hPa U Anomaly (JJA) (10–20N) NCEP

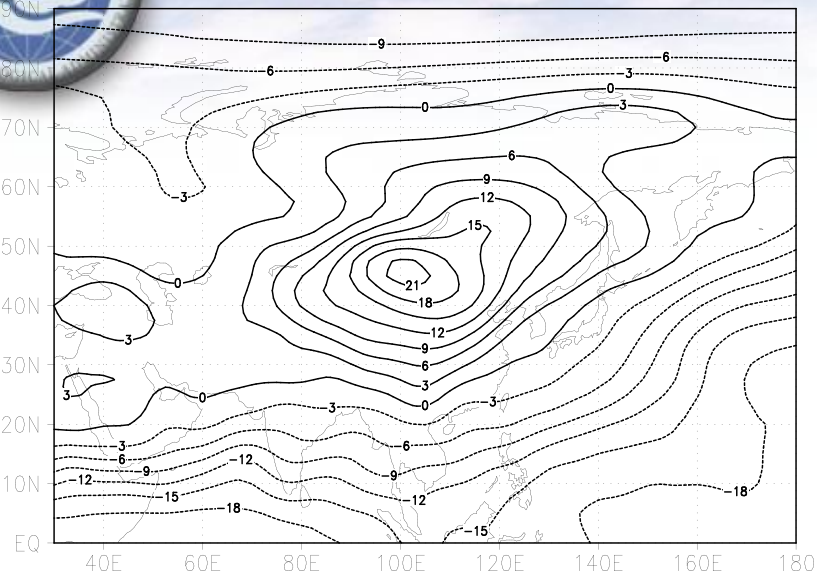


**Latitude-time cross-sections of 200 hPa U-component (a) and 150-100 hPa layer U-component (b) averaged for 10°-20°N in summer (June-August). Unit: ms<sup>-1</sup>. Data source: NCEP Reanalysis datasets. Anomalous westerly wind is shaded.**

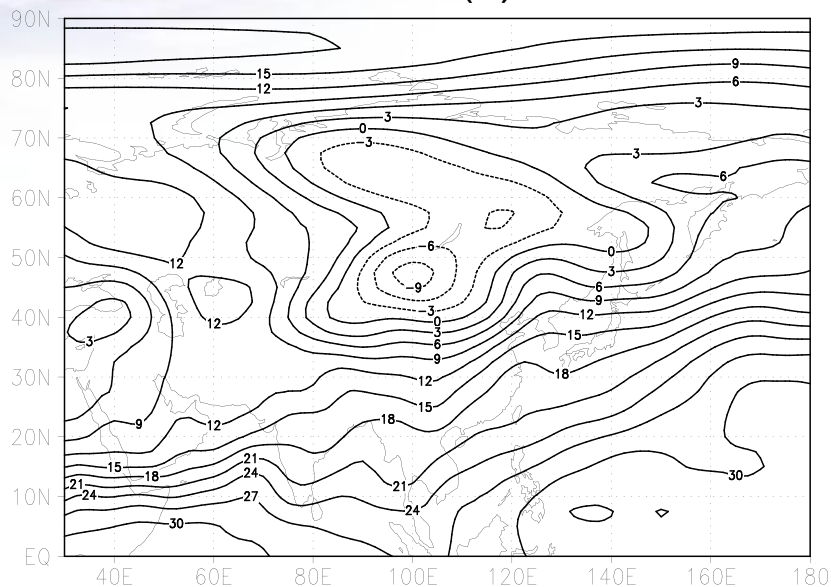




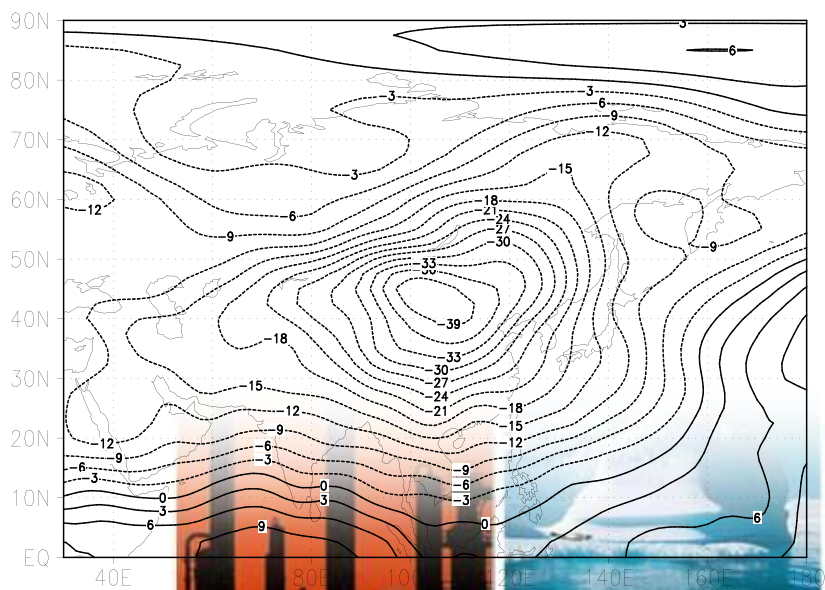
(a)



(b)



(c)



## Cooling over the Asian continent since 1979

100-500hPa厚度异常的长期变化

(a) 1951-1978;

(b) 1979-1992;

(c) 1991-2004

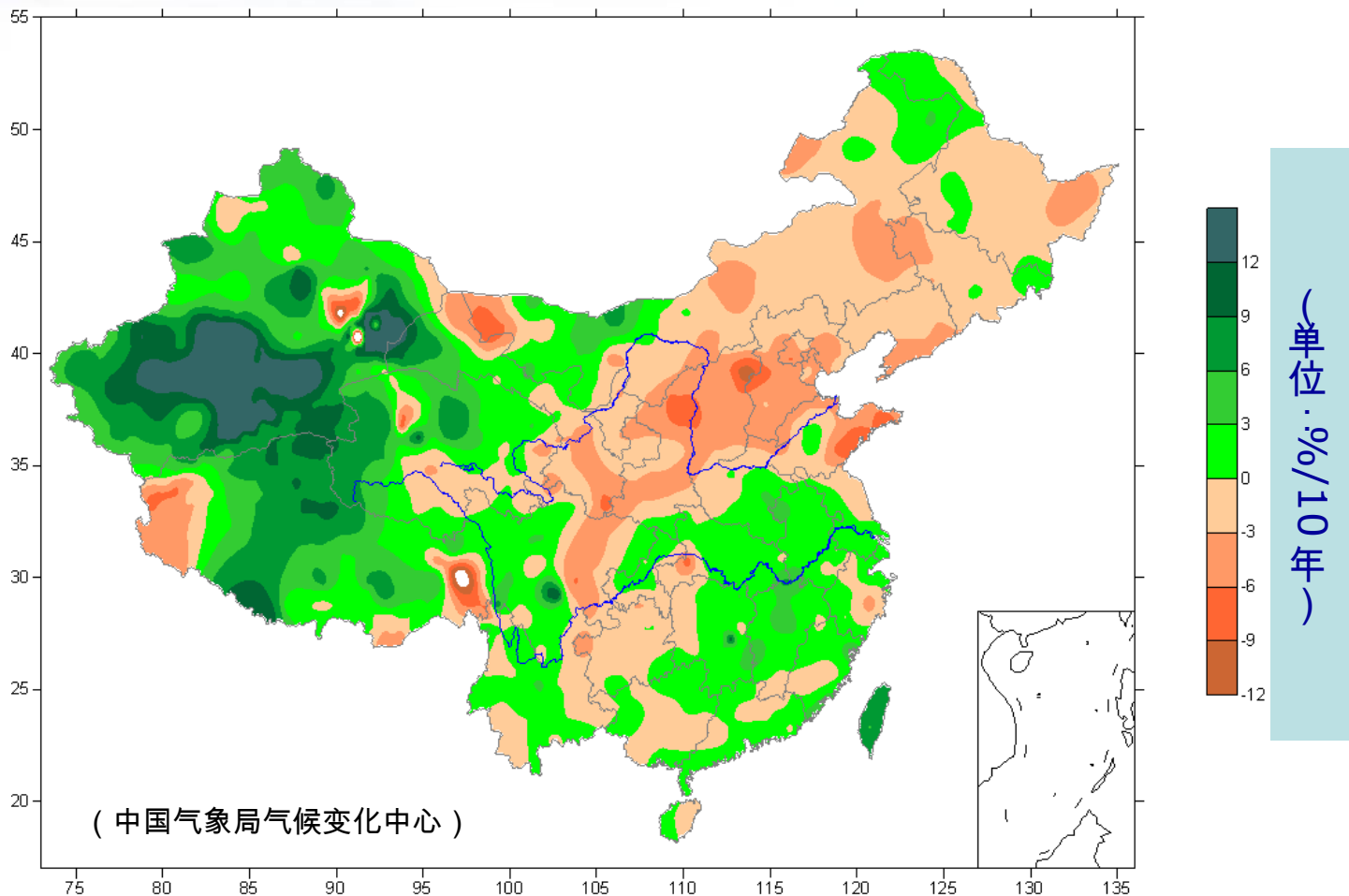
**Long-term change in**

**100-500 hpa layer thickness anomaly.**



# 我国降水分布发生了明显变化

## Significant change in summer precipitation pattern in China (1958-2007) unit:%/10yrs

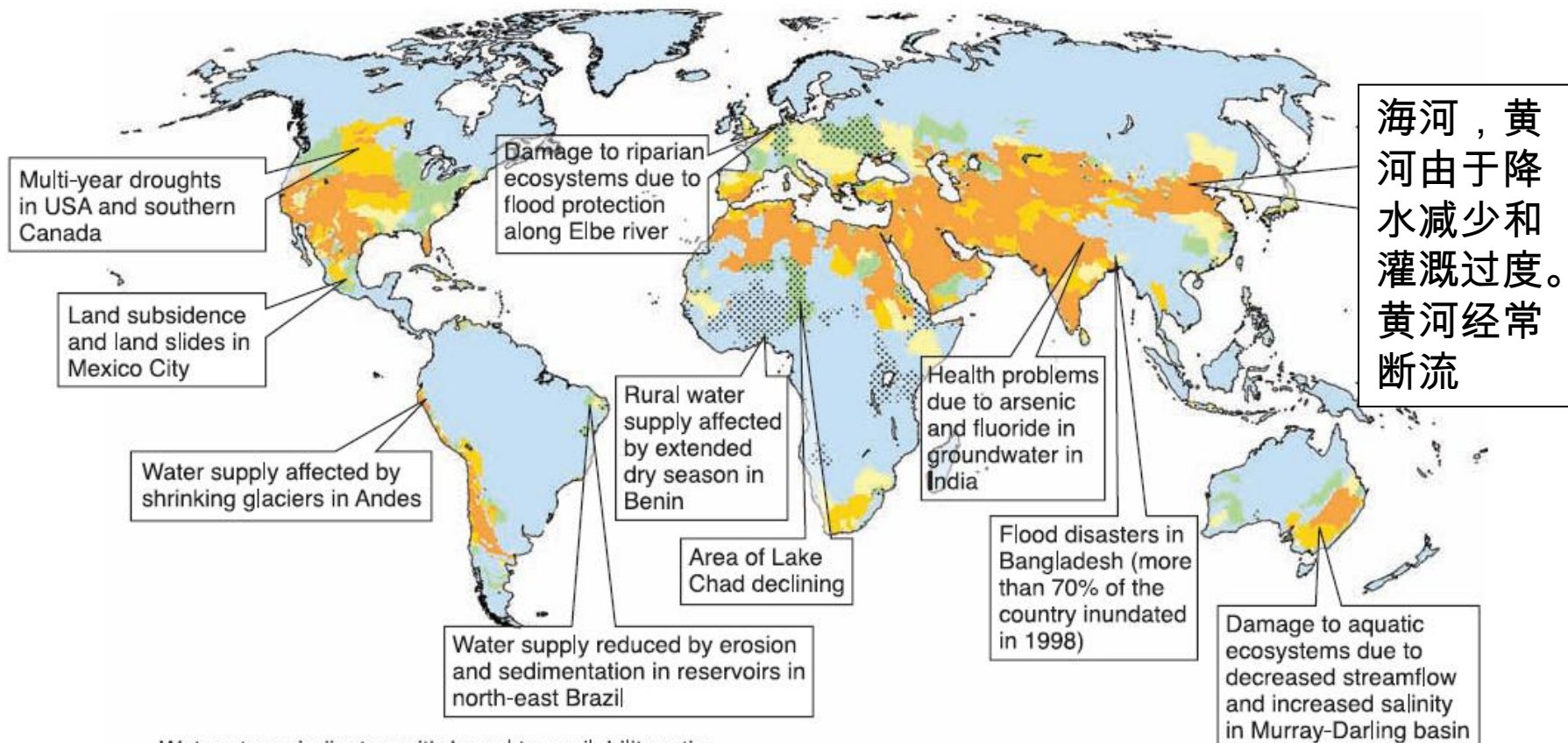


近50年来，西部地区降水约增加15%—50%；东部地区频繁出现“南涝北旱”，华南地区降水约增加5%—10%，而华北和东北大部分地区约减少10%—30%。（图：1958-2007年我国年降水量变化幅度）



气候变化下，全球现代淡水资源的脆弱性和他们的管理

# Vulnerability of fresh water resources in the context of global climate change (high stress region in North China)



Water stress indicator: withdrawal to availability ratio

no stress low stress mid stress high stress very high stress

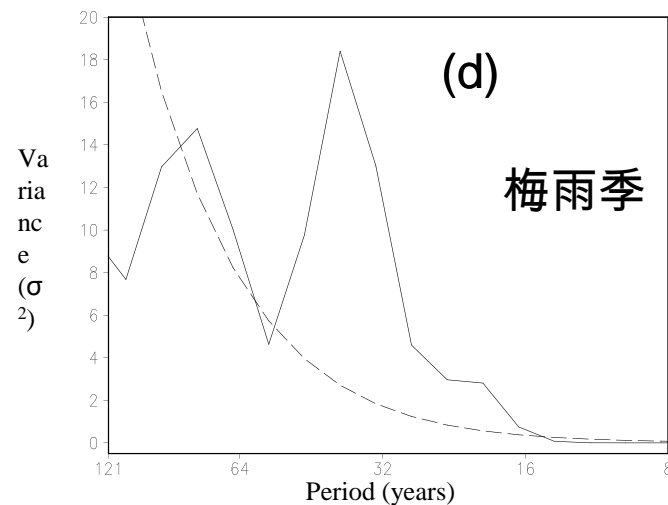
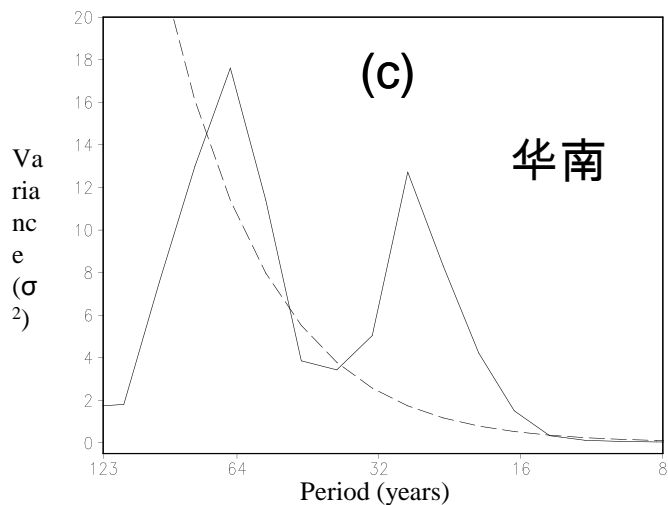
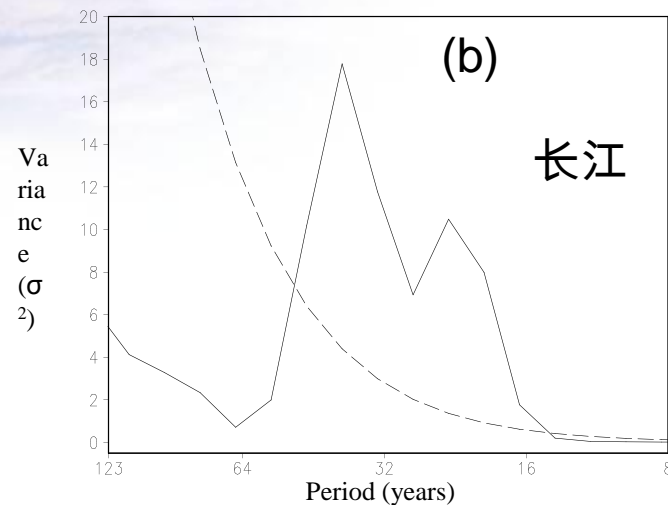
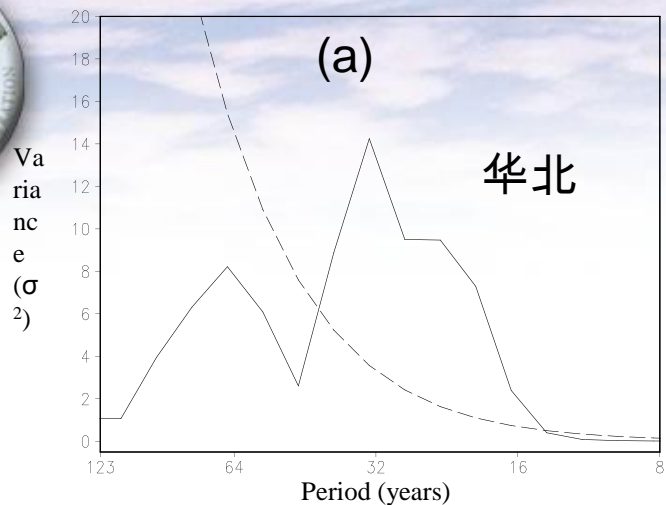


No/low stress and per capita water availability <math>< 1,700\text{m}^3/\text{yr}</math>

Water withdrawal: water used for irrigation, livestock, domestic and industrial purposes (2000)

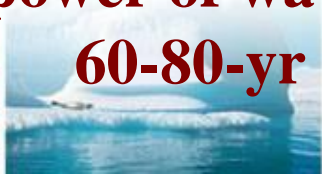
Water availability: average annual water availability based on the 30-year period 1961-90





小波分析功率谱：30-40年与80年周期趋势变化分析：1978和1992是两个突变点

**Spectrum power of wavelet analysis: 30-40-yr and 60-80-yr oscillations**





## 中国东部不同分区夏季降水的主要周期

# Major periods of summer precipitation in different subregions of East China

subdivision 分区	A时段 ( 123年 )	B时段 ( 54年 )
华南 <b>South China</b>	4, 14*, 30*, 80*	2*, 7, 30*
长江中下游 <b>Yangtze</b>	2*, 7*, 20*, 40*	2*, 7, 14, 40*
华北 <b>North China</b>	3, 9, 18*, 40*, 80	3*, 9, 18
长江中下游5站 (121年) <b>Meiyu Season</b>	2, 7, 12, 40*, 80*	2, 7*, 12, 40*

\*代表超过50%信度





## 中国东部三个地区夏季降水的突变点检验

# Detection of abrupt change points for different subregions in East China

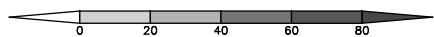
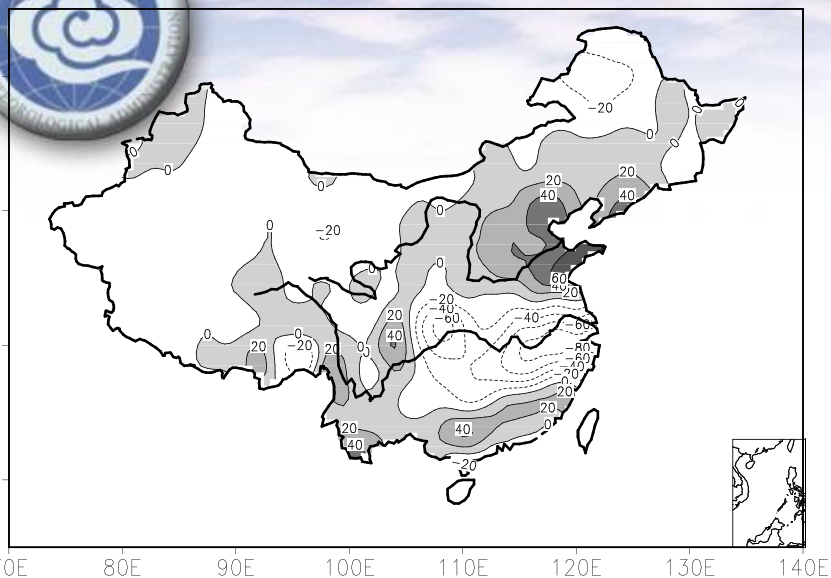
<b>Methods</b> 方法	<b>South China</b> 华南	<b>Yangte</b> 长江中下游	<b>North China</b> 华北	<b>Meiyu</b> 梅雨期长江中下游5站
Running Test	1980, 1992	1978	1965, 1979	1978
Yamamoto et al., (1986)	1980, 1992	1979	1964, 1980	1980
Mann-Kendall (1945; 1975)	1993	1982	1975	1978

所有的突变点都超过95%的信度

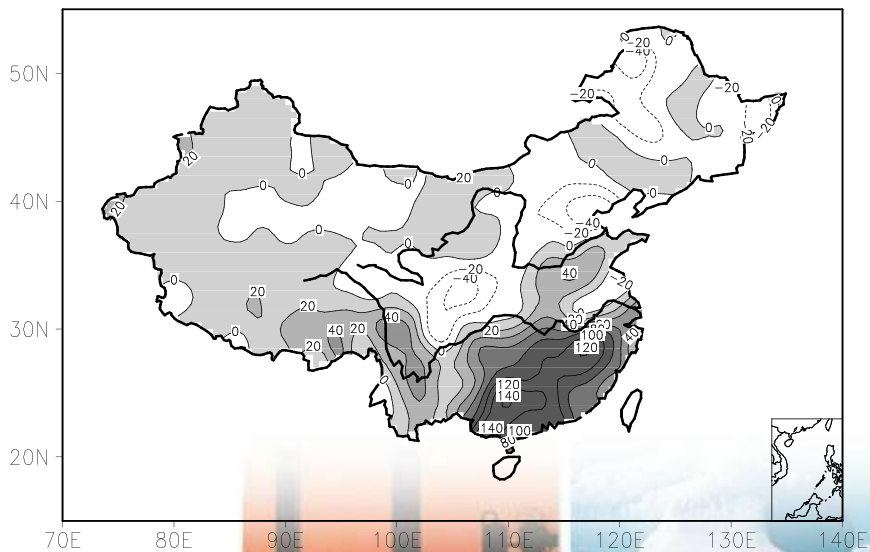




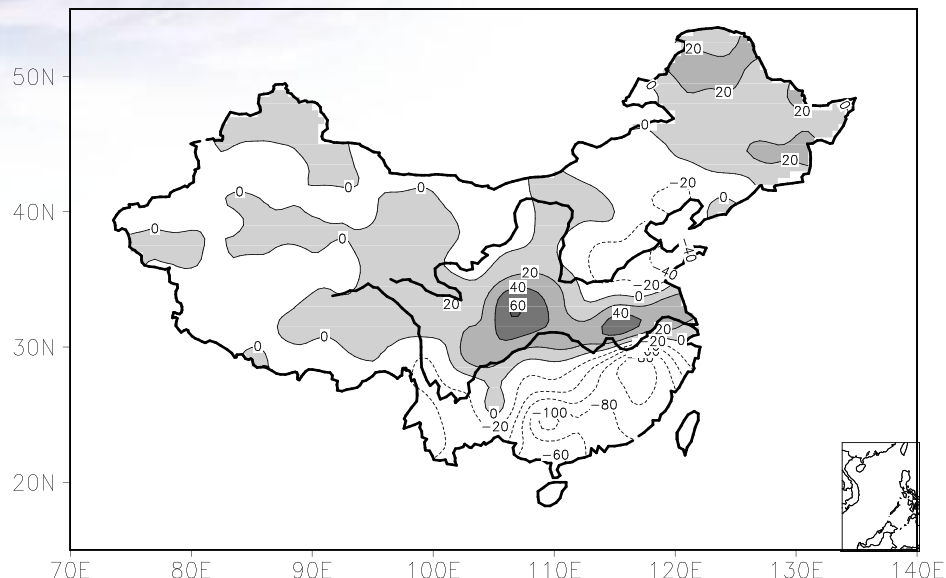
1951-1978



1993-2004



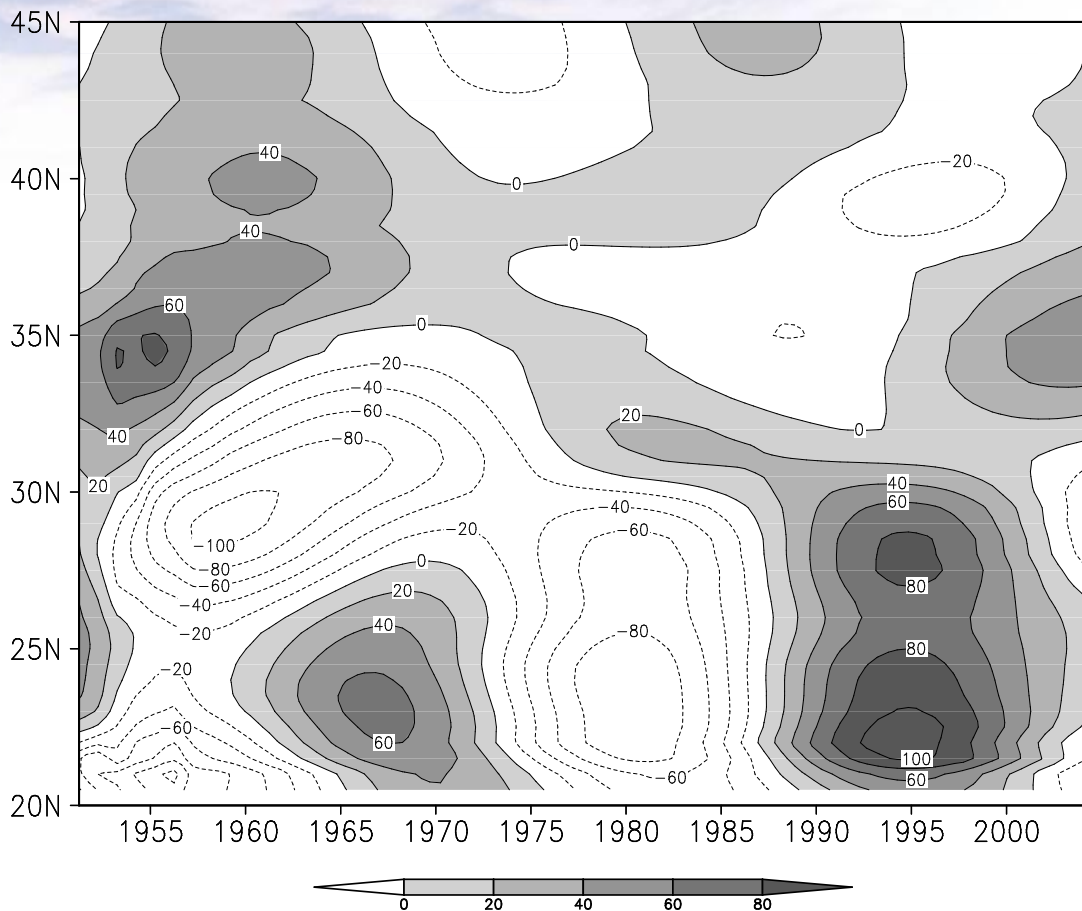
1979-1992



中国不同时段，夏季降水距平百分比分布的变化。(阴影区是正距平，相对于1971-2000年平均值)

**In-decadal shifts of summer monsoon patterns in China**  
**shading: positive anomaly percentage**

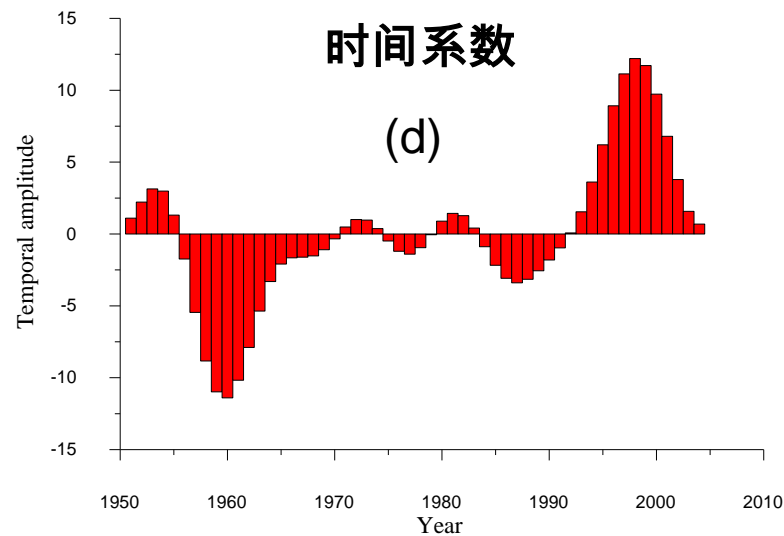
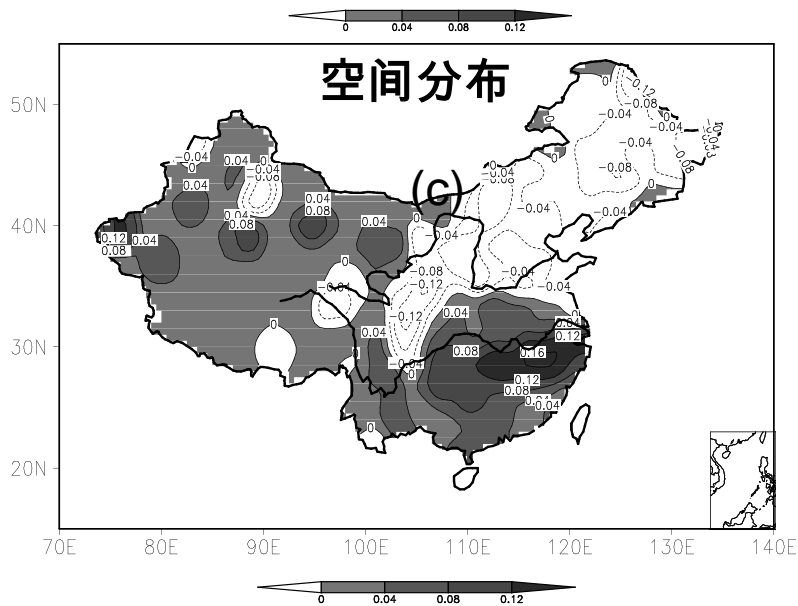
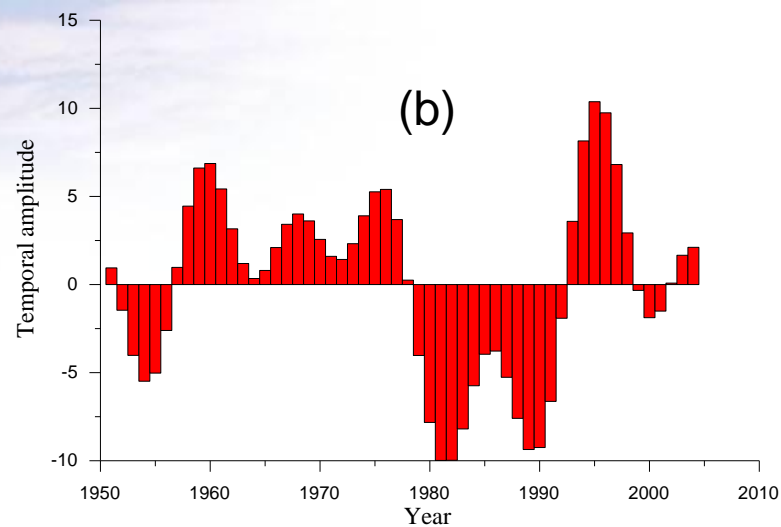
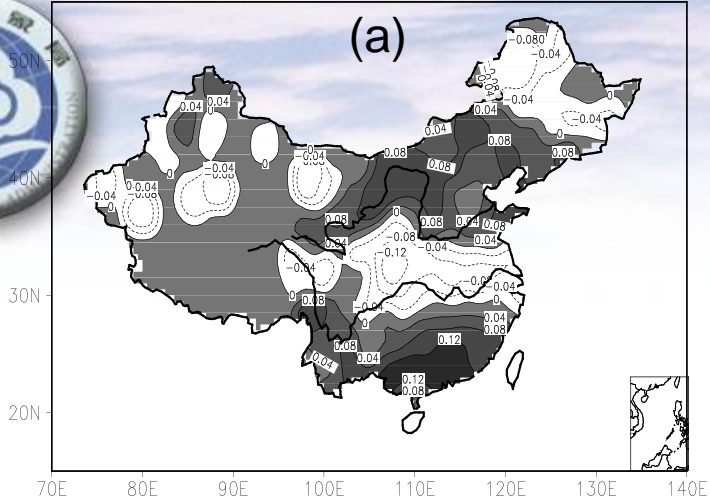




1951-2004中国东部(107.5-130°E)平均夏季异常降水纬度-时间剖面图。单位: mm

**Latitude-time cross-section of summer precipitation departure(107.5-130°E)**

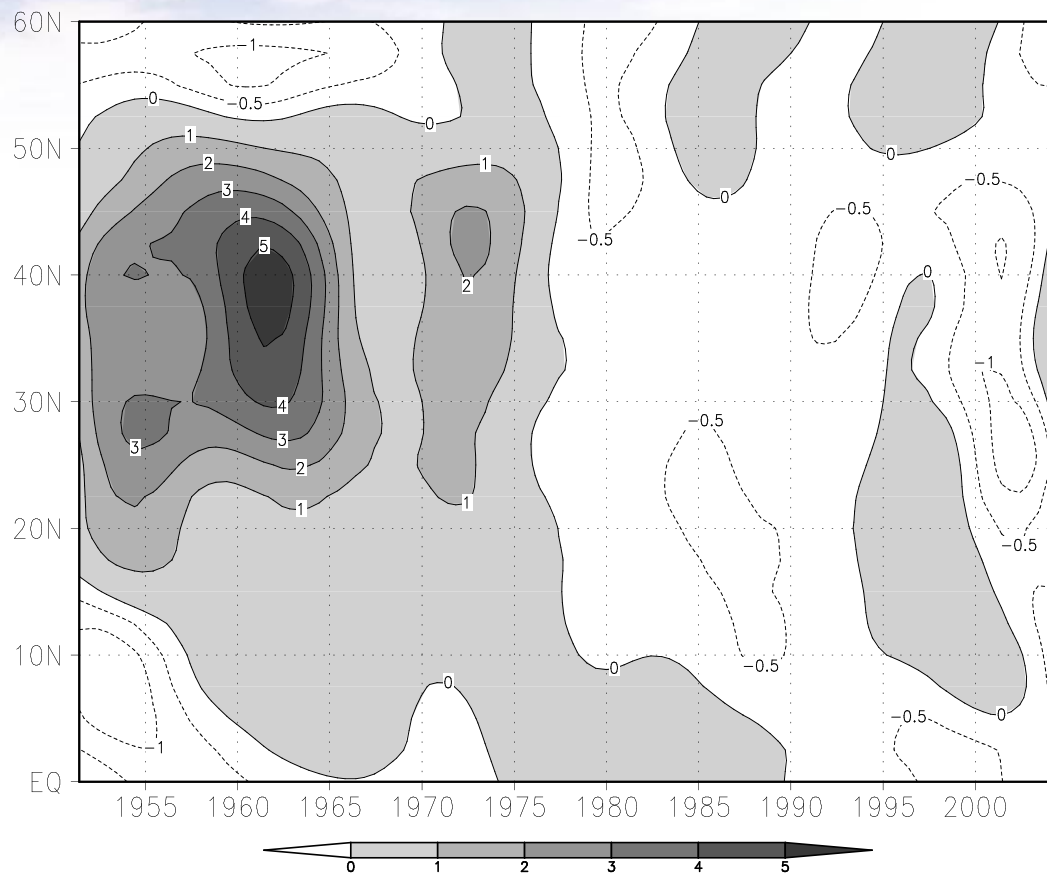




中国夏季降水的EOF分析 ( 1951-2004 )

**EOF modes of summer precipitation (JJA) for 1951-2004**

**(a)(c): EOF1 ; (b)(d): EOF2**



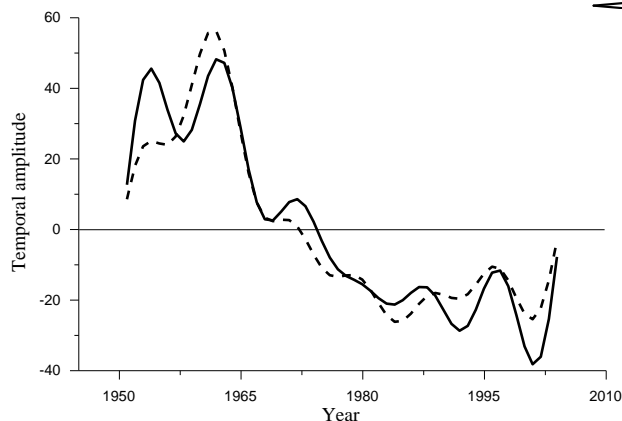
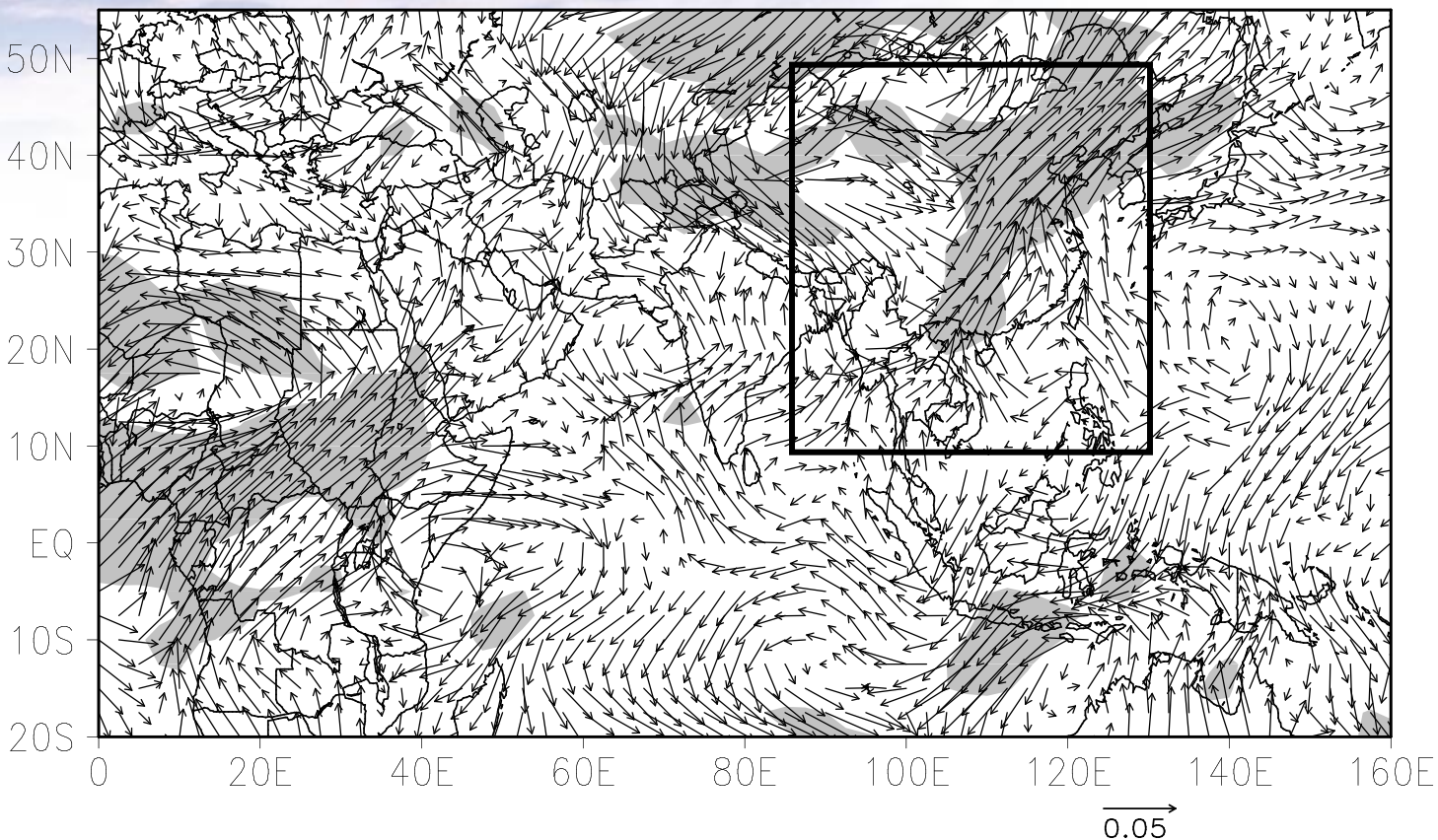
850 hPa平均经向风纬度时间剖面图 ( unit:  $\text{ms}^{-1}$  )。阴影区是异常南风。  
**Latitude-time cross-section of 850hpa V-component departures, shading: South wind**





# 夏季风 水汽输 送向量 的EOF 分析

下图是  
时间系  
数



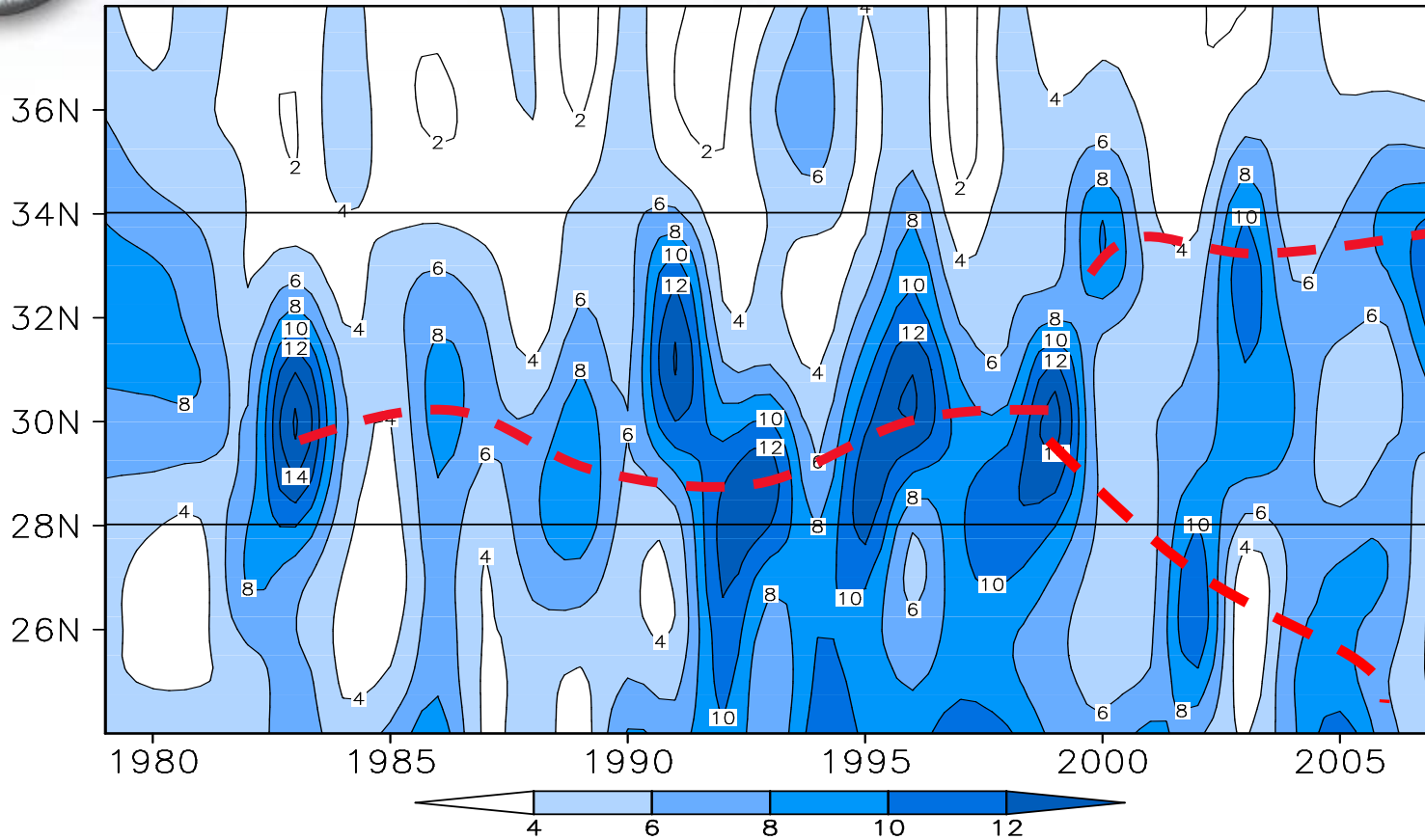
**Leading EOF model of  
moisture transport for  
Asian summer monsoon**





## 2. Decadal northward shift of the Meiyu belt



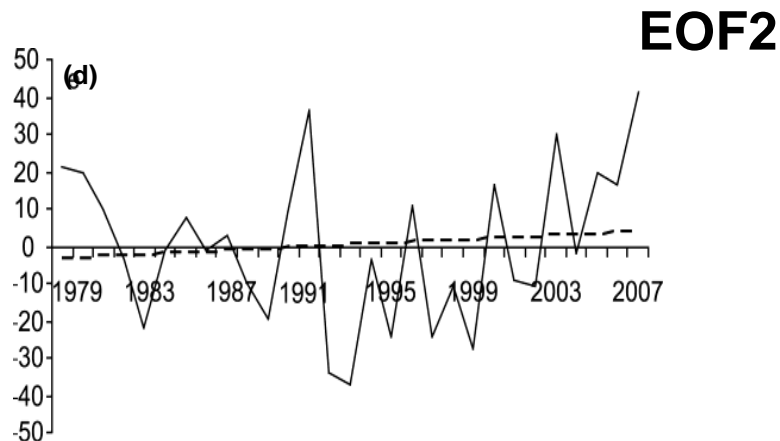
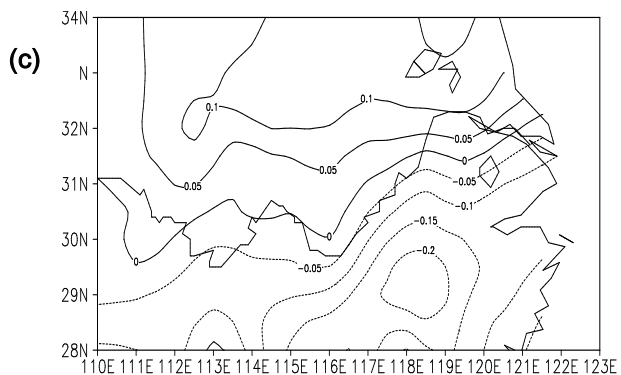
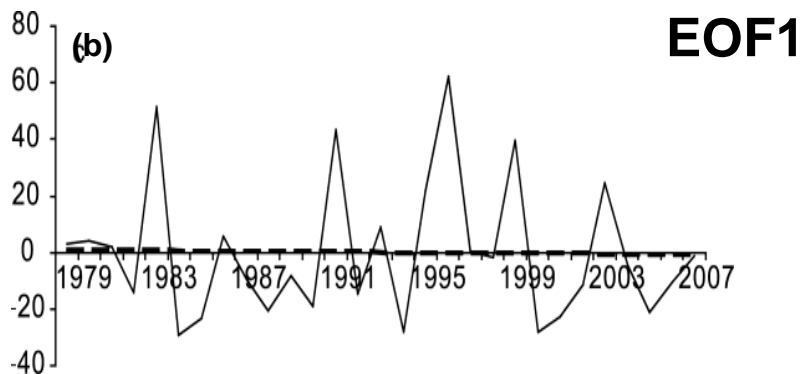
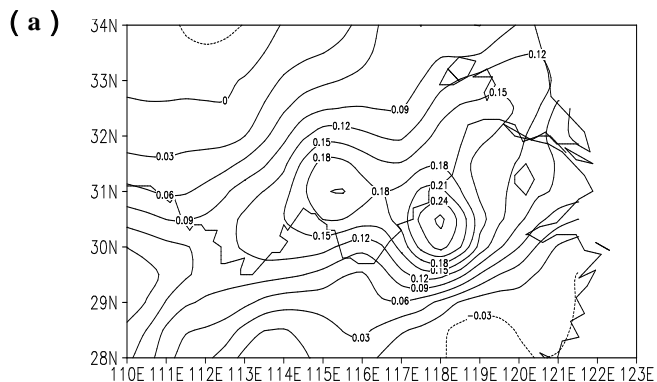


**Temporal evolution of the observed Meiyu precipitation averaged over 110°—122°E from 1979 to 2007 (unit: mm/d).**

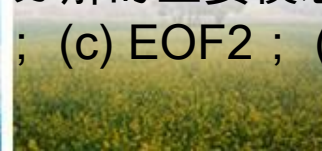




# EOF modes of Meiyu precipitation for 1990-2007

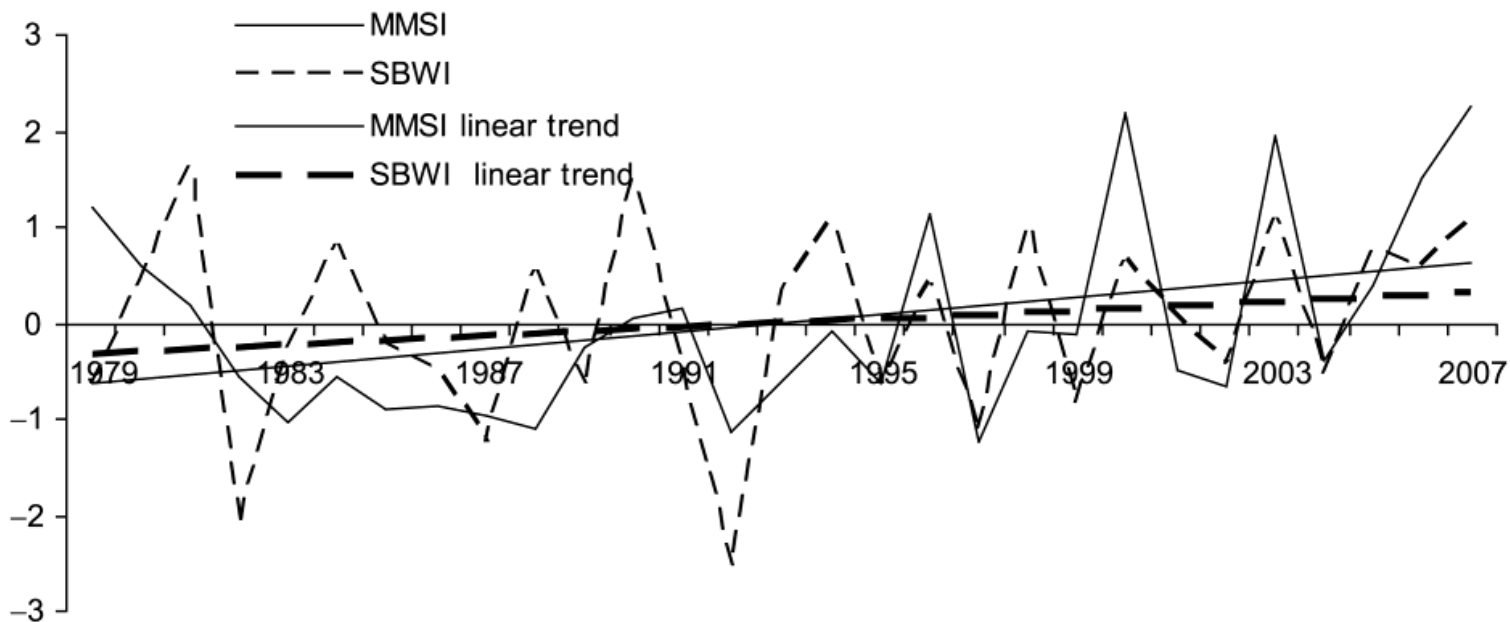


1990~2007年梅雨期降水距平EOF分解的主要模态及其对应的时间系数  
(a) EOF1 ; (b) EOF1时间系数 ; (c) EOF2 ; (d) EOF2时间系数



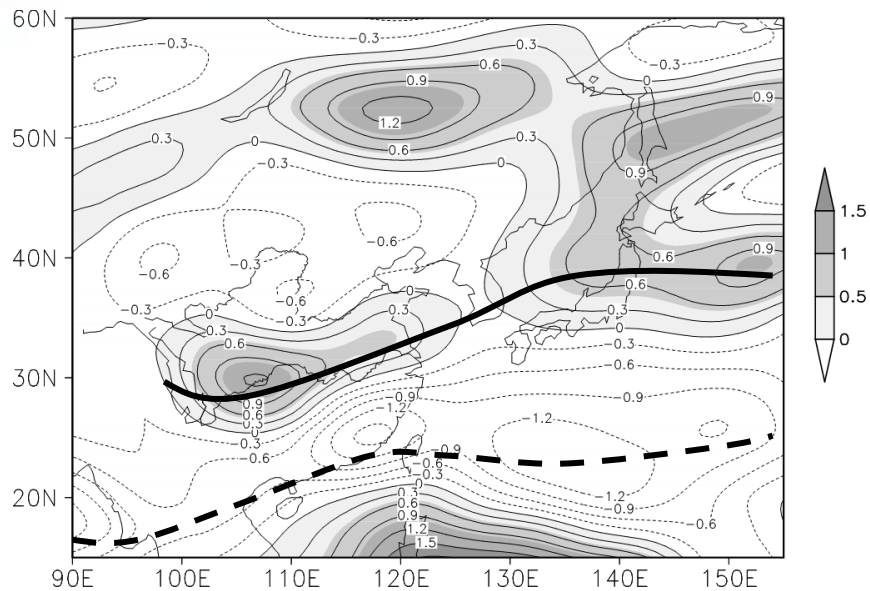
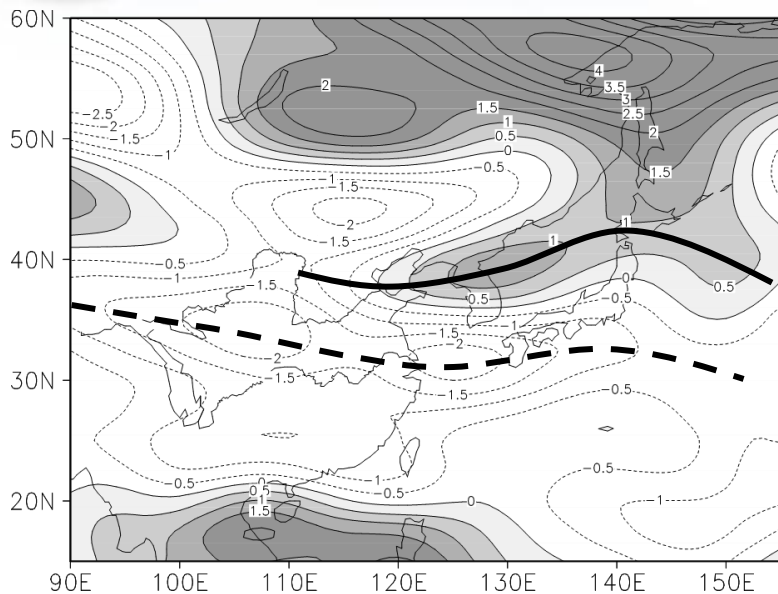


# Time series of Meiyu index and northern boundary of subtropical high



1990~2007年MMSI指数 ( 实线 ) 及SBWI ( 虚线 ) 指数的时间序列





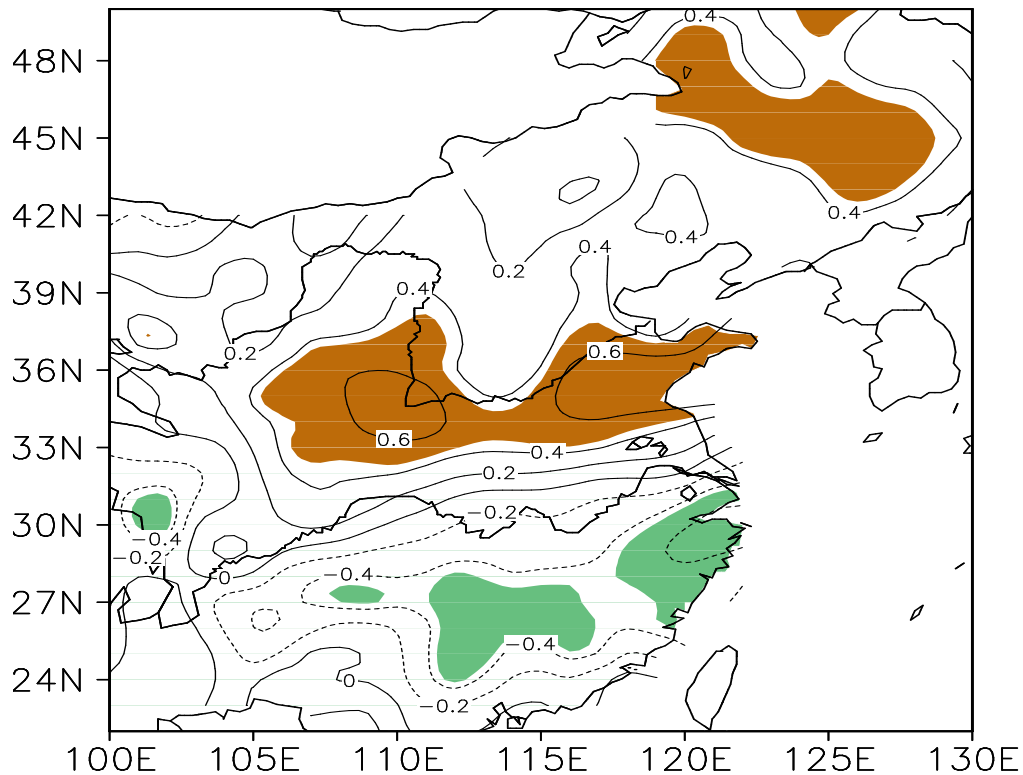
## Differences of 300hpa and 850hpa zonal wind between 2000-2007 and 1990-1999

2000~2007年平均与1990~1999年平均的梅雨期300hPa ( a , 单位 : m/s ) 和850hPa ( b , 单位 : m/s ) 纬向风的差值





# Correlation coefficient of Meiyu precipitation and SBWI for 1990-2007



1990~2007年东亚副热带扩张指数 ( SBWI ) 与逐年梅雨期降水量的相关系数分布 ( 阴影区表示相关通过了95%的信度检验 )



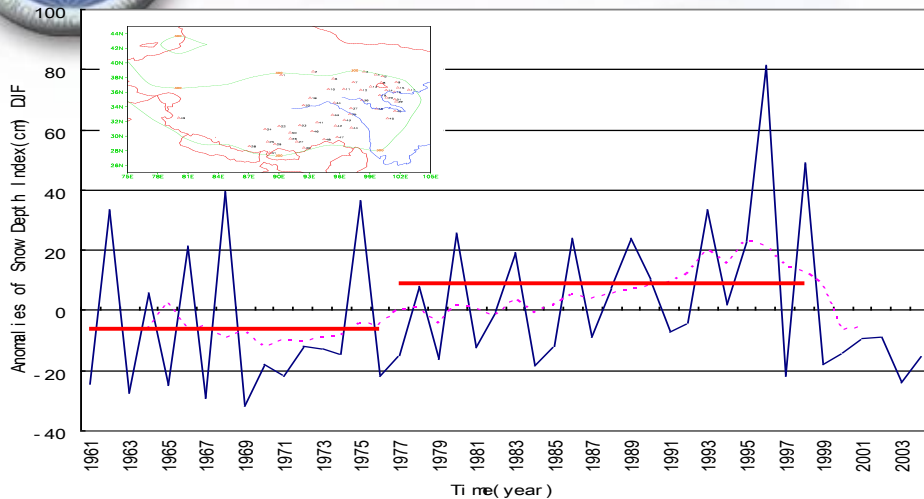


# 3. Possible cause and conclusions

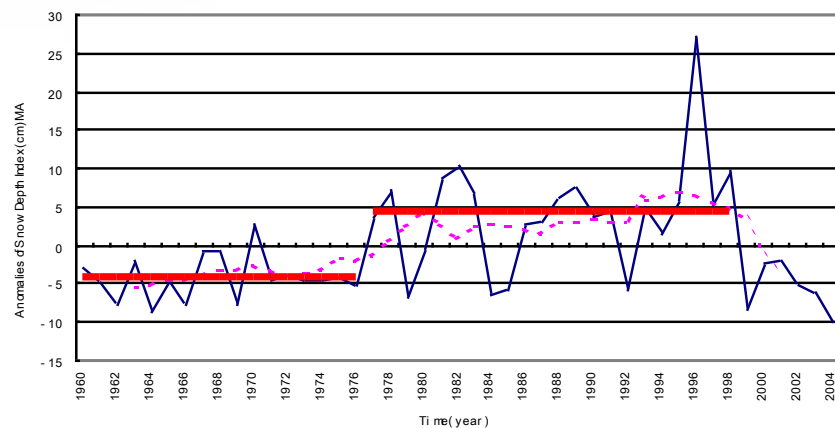




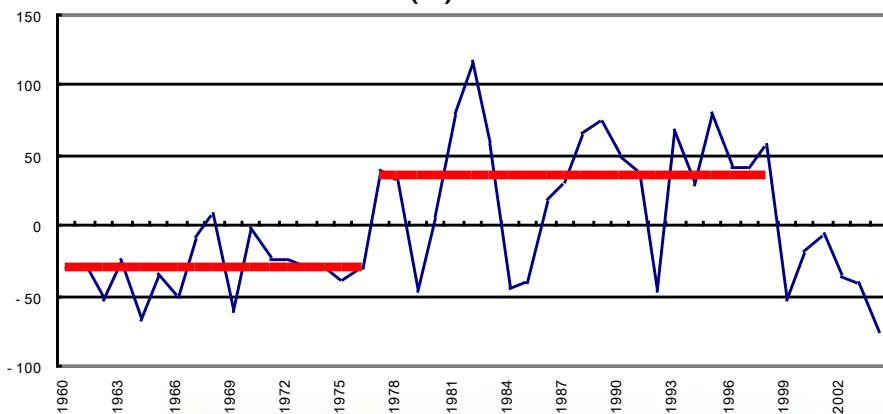
(a)



(b)



(c)



青藏高原50个台站冬春季雪深时间变化曲线。(a) 春季；(b) 冬季；(c) EOF 1 模态时间系数。Unit: mm.

**Time series of snow depth for (a) spring and (b) winter; (c) EOF1 modes time coefficient.**

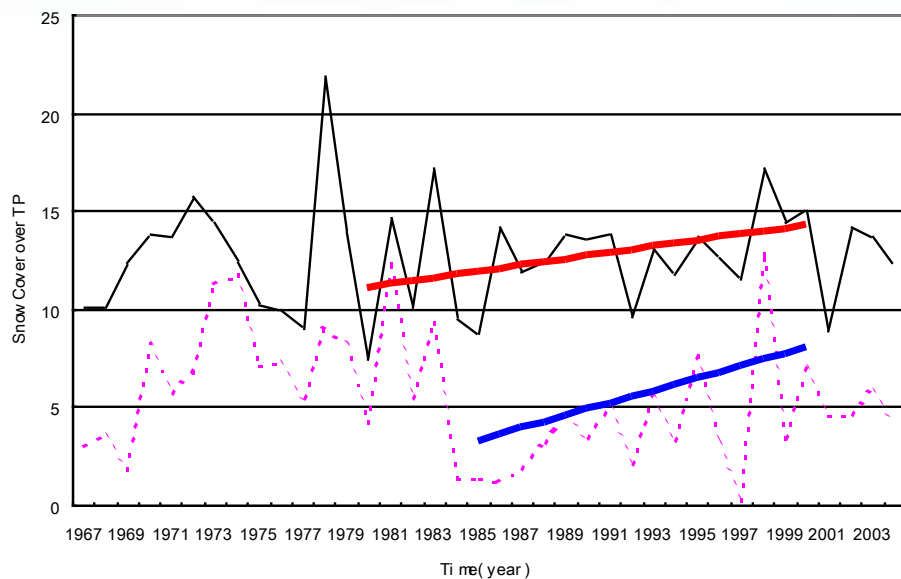
**Inserted**

**diagram: station distribution**

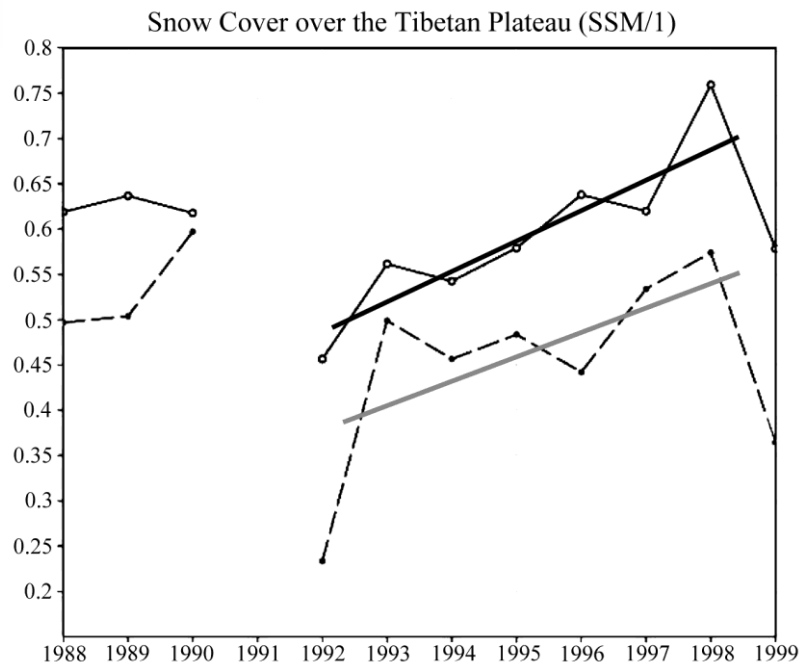




(a)



(b)



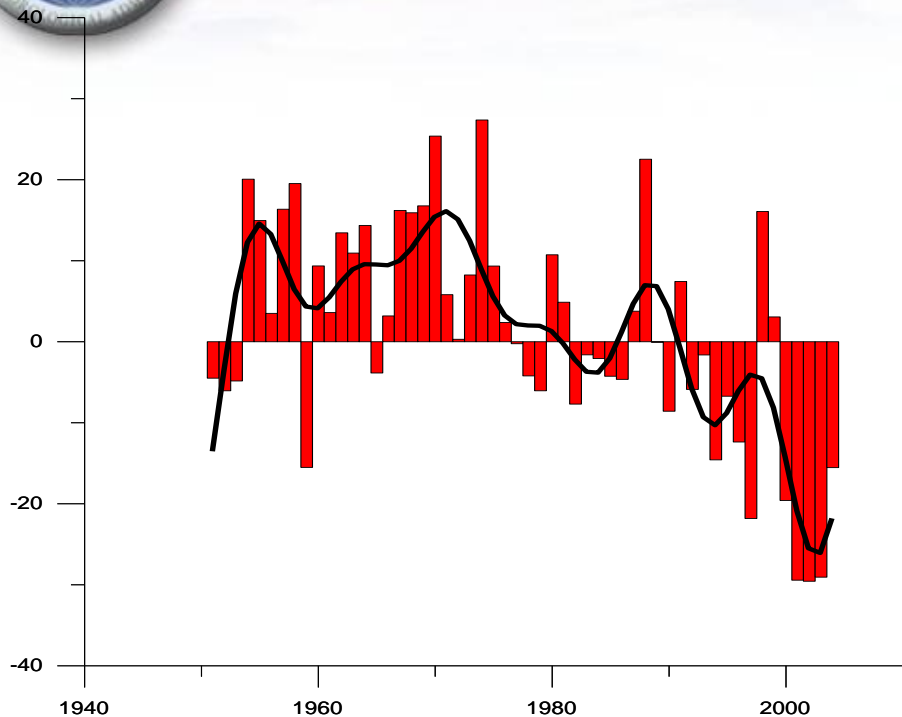
(a)青藏高原卫星雪盖资料(1966-2004) ; (b)高原卫星微波雪盖资料 ( SSM/I ) (1986-2000).

**Satellite- measured snow coverage (a) VHR data, red: winter, blue: spring ,(b) SSM/I (from Robinson, 2005)**

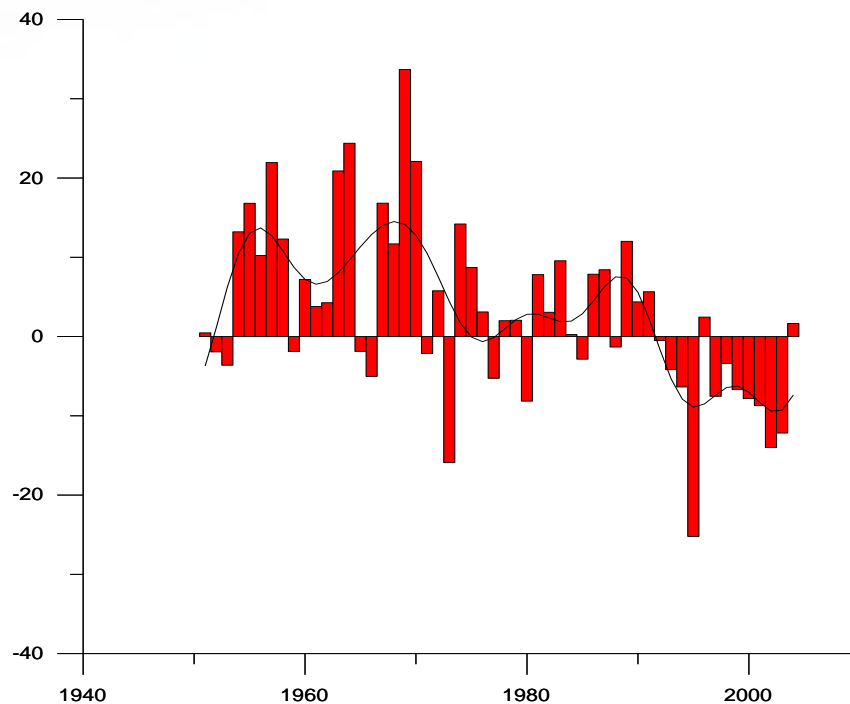




(a)

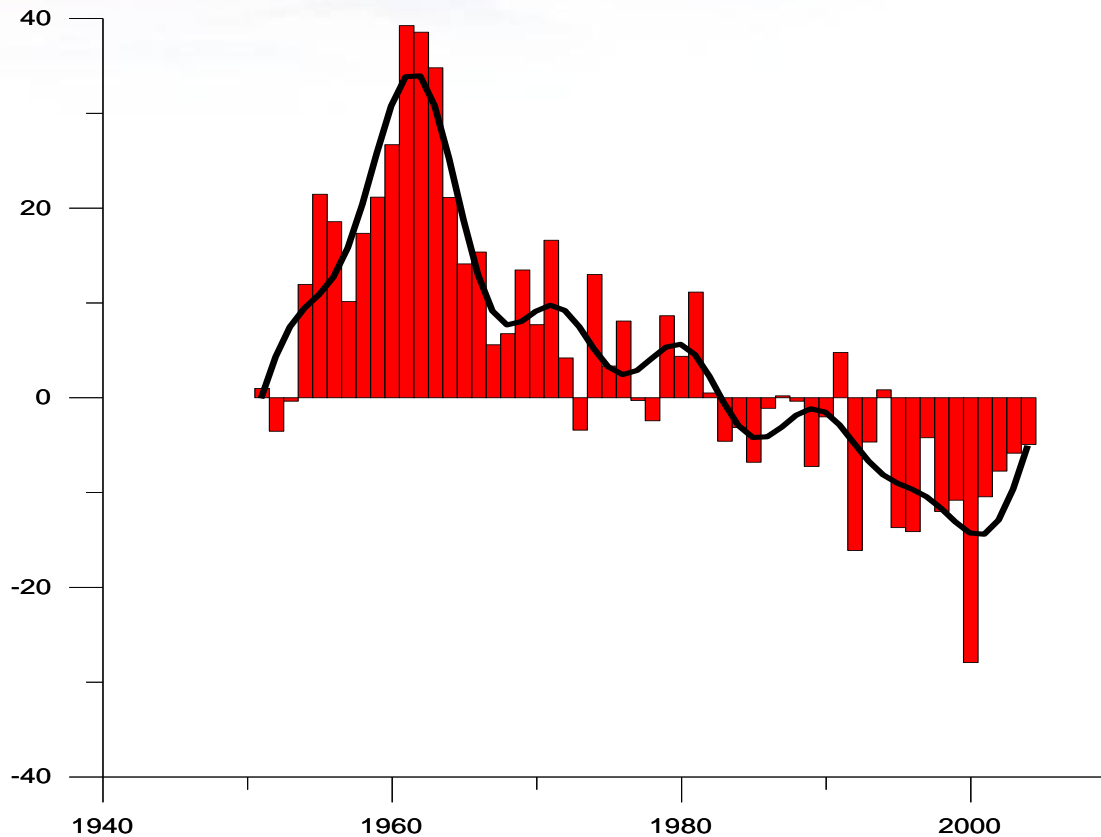


(b)



**Time series of the anomalous vertically integrated (from surface to 100hPa) apparent heat source ( $Q1$ ) averaged for all Tibetan Plateau ( $75 \sim 105^{\circ}\text{E}$  ,  $27.5 \sim 42.5^{\circ}\text{N}$  ) for summer (a), and spring (b). Solid lines denote 9-yr running mean curves. Unit:  $\text{Wm}^{-2}$**





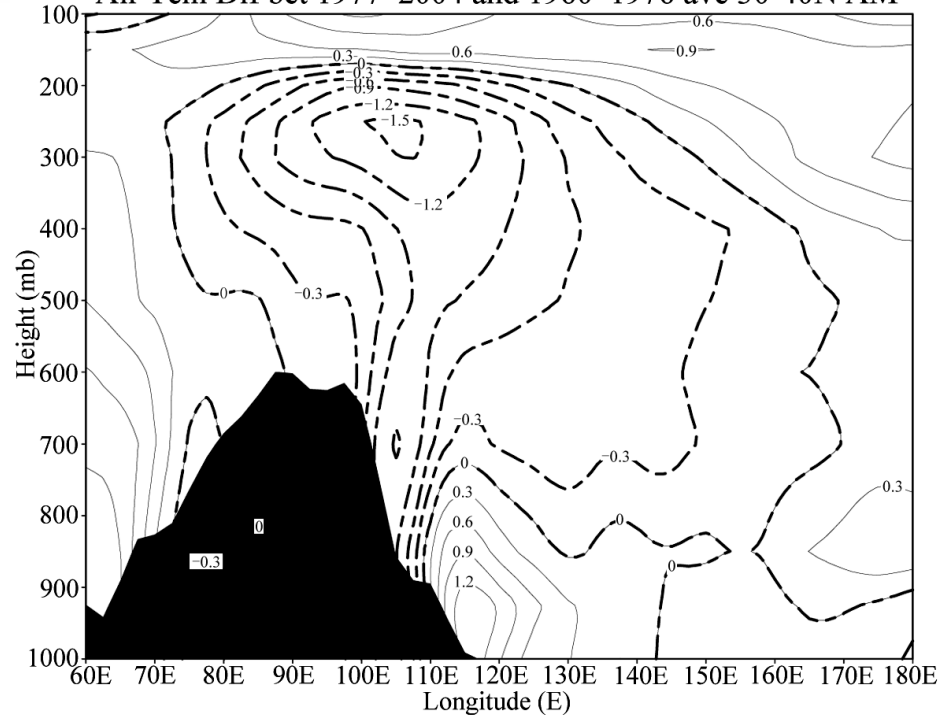
**Time series of Q1 difference between land areas (547 grid points) and oceanic areas (668 grid points) in the Asian monsoon and neighbouring oceanic regions (30°-140°E, 20°S-45°N). The solid line is the 9-yr running average. Unit:  $\text{w m}^{-2}$**





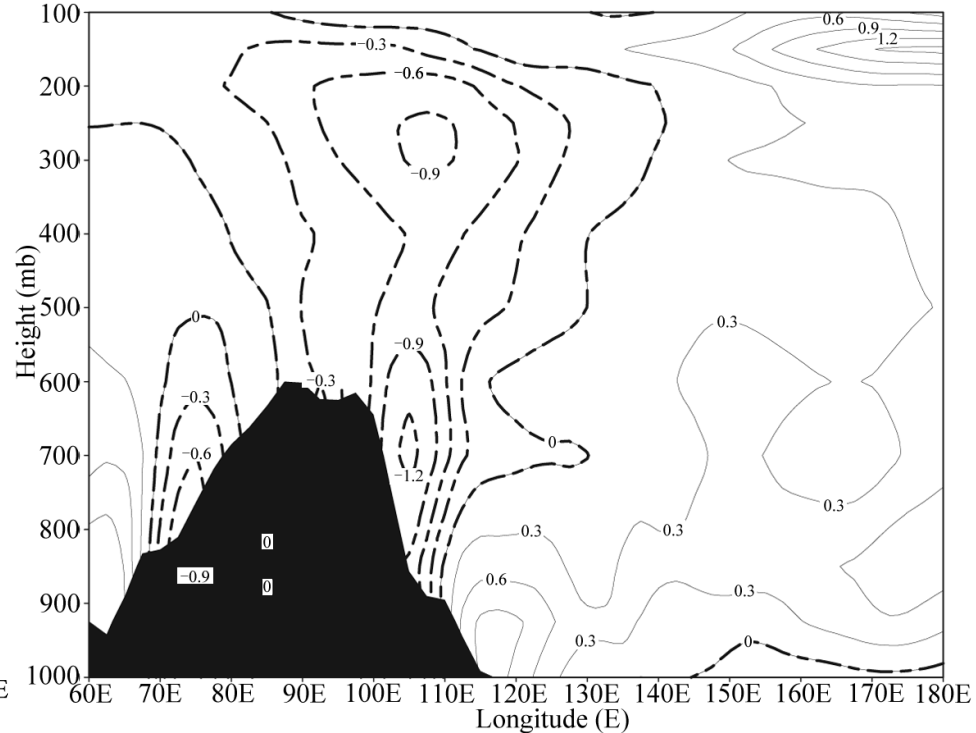
(a)

Air Tem Dif bet 1977-2004 and 1960-1976 ave 30-40N AM



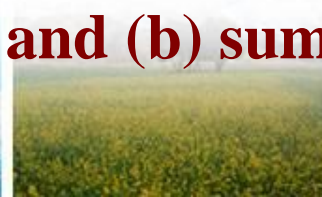
(b)

Air Tem Dif bet 1977-2004 and 1960-1976 ave 30-40N JJA



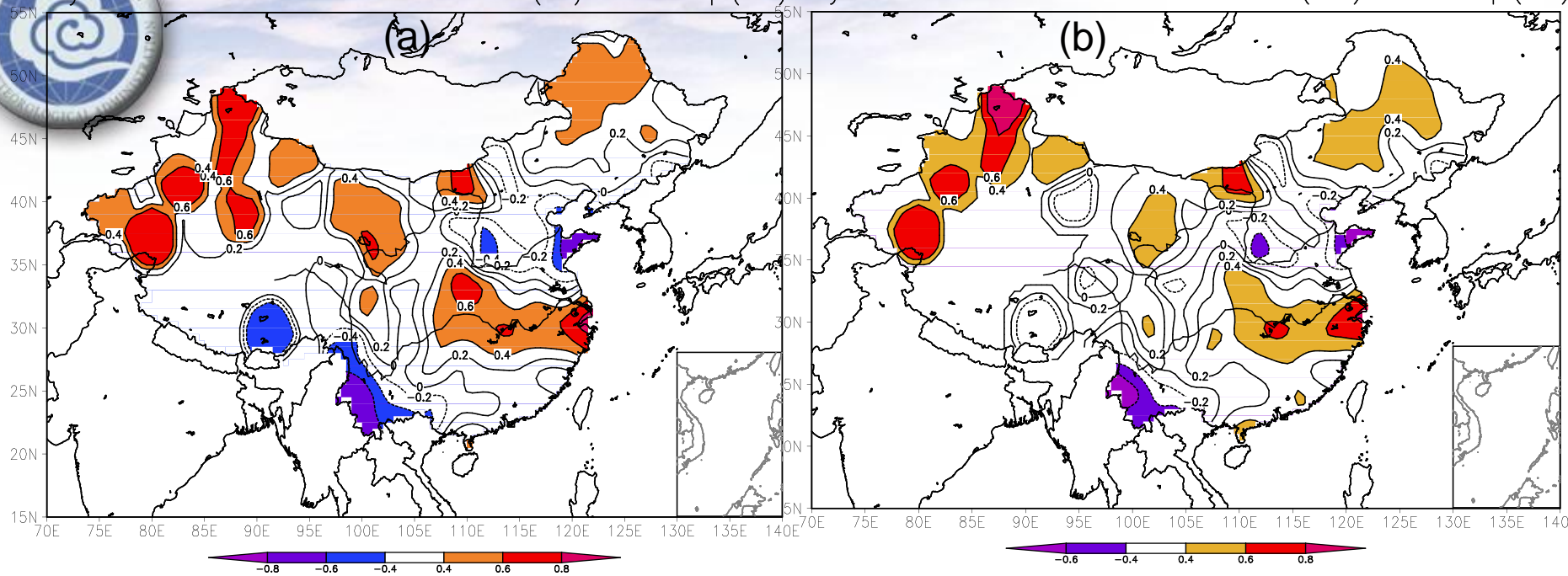
1977-2004平均温度减1960-1976平均温度的剖面图。30-45N平均: (a) 春天 ; (b) 夏天 ( °C )

**Height –longitude of temperature differences between 1977-2004 and 1960-1976 (a) spring and (b) summer**





9 yr move mean correlation between SDI(MA) and Precip.(JJA) 9 yr move mean correlation between SDI(DJF) and Precip.(JJA)



高原冬春雪深与中国夏季降水的相关分布(a)冬天 ; (b)春天

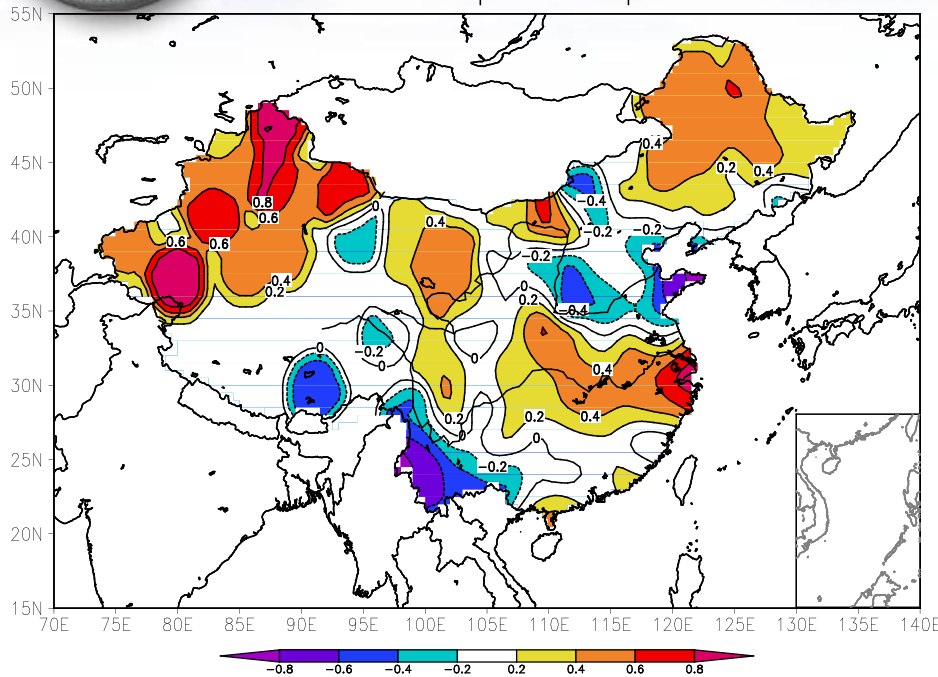
**Correlation patterns between summer precipitation and snow depth over TP. (a )preceding winter and (b) spring**





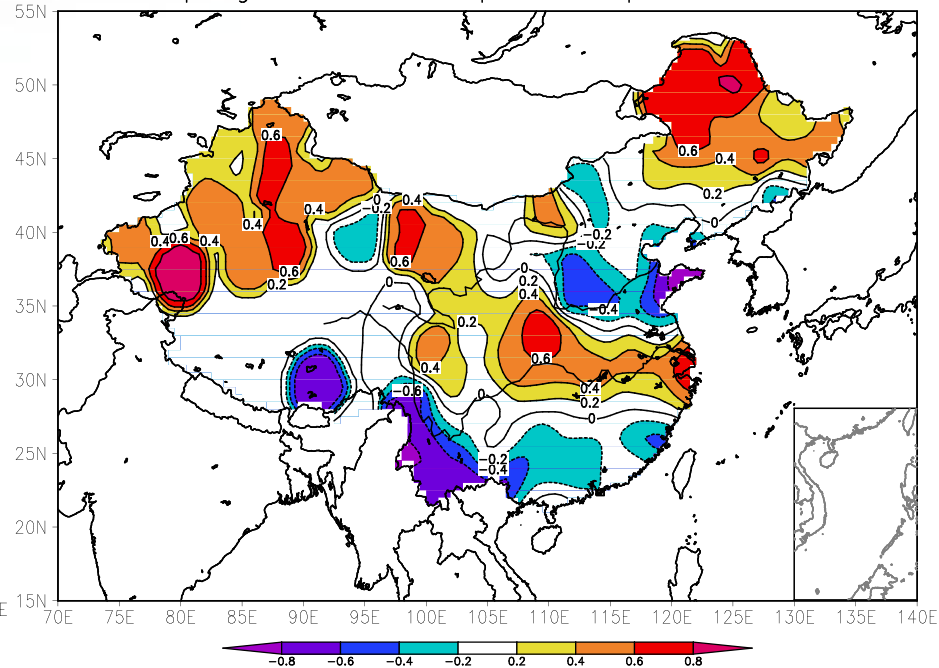
(a)

winter snow-summer preci SVD prec mode 2



(b)

spring snow-summer preci SVD prec mode 1



夏季降水和高原雪深的SVD分析 (a) 冬季, (b) 春季. 平方方差分别是35.77% and 40.46% , 相关系数分别是0.97 and 0.96.

**SVD analysis between summer precipitation and snow depth over TP (a) preceding winter and (b) spring**





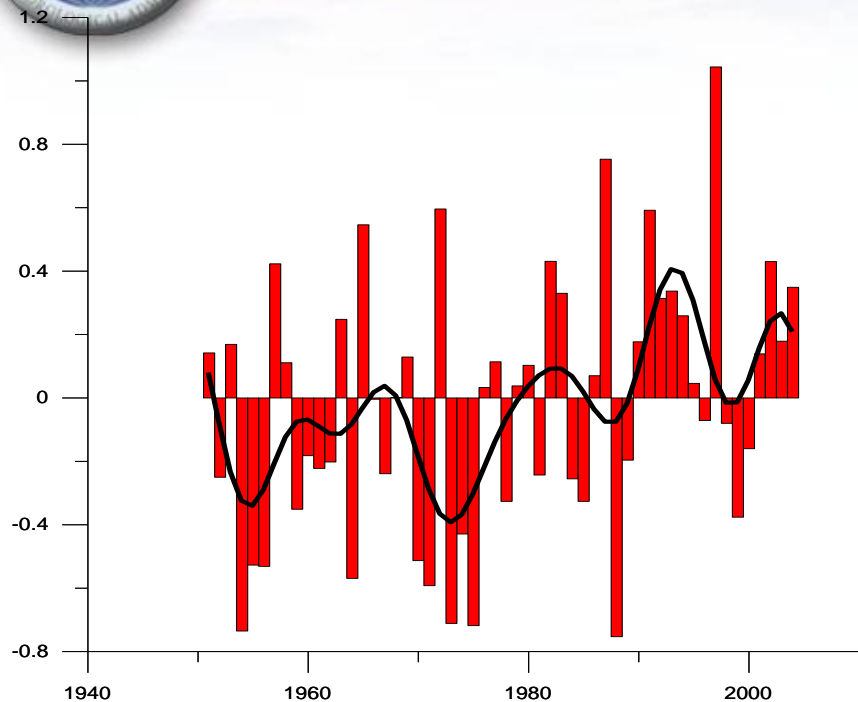
# 与热带太平洋海温影响的比较

## Comparison with effect of the tropical Pacific SSTA

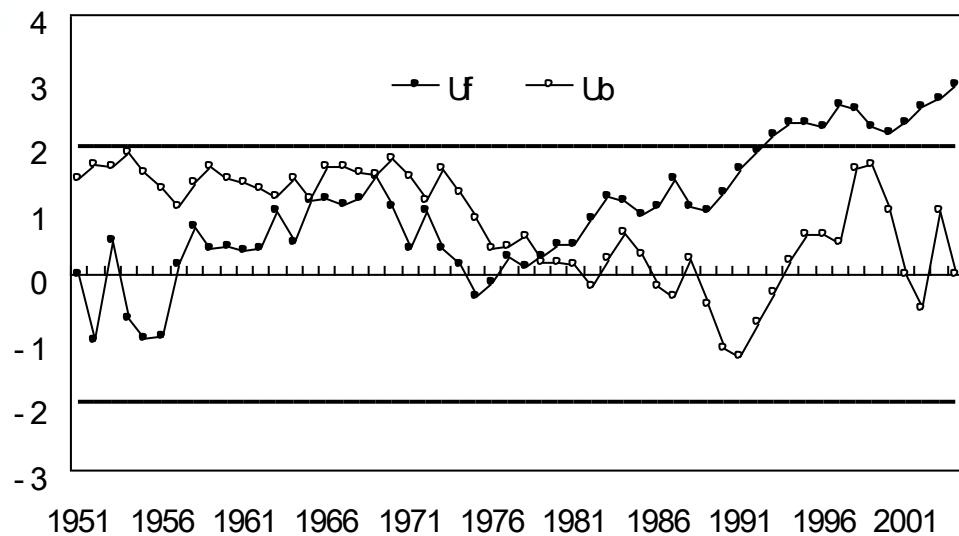




(a)

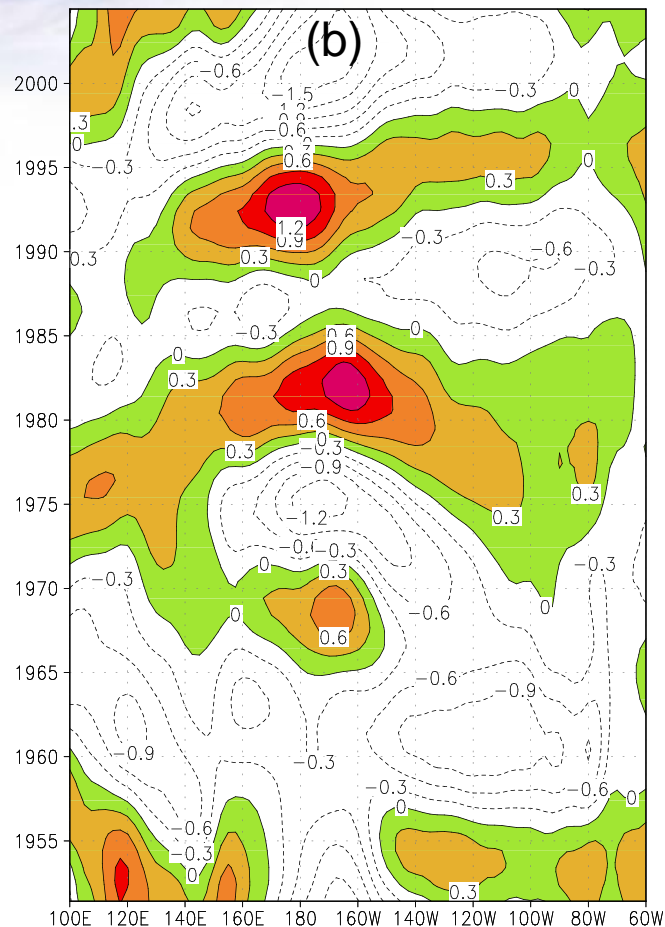
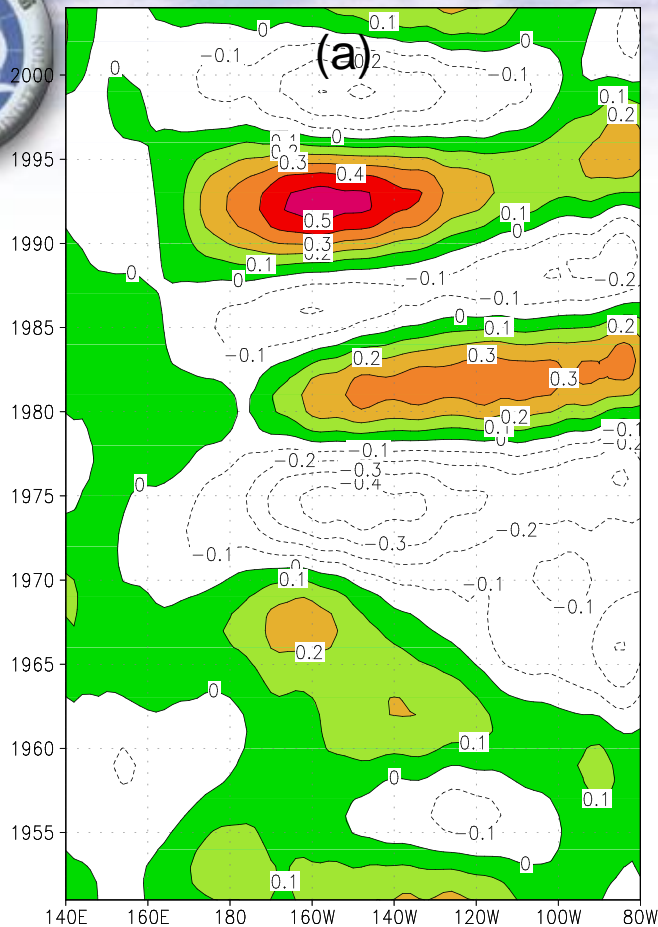


(b)

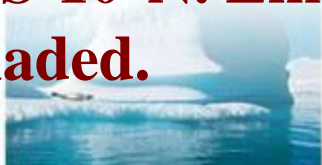


**(a) Time series of SSTA of 1951-2004 averaged for tropical central and eastern Pacific ( $160^{\circ}\text{E}$ - $100^{\circ}\text{W}$ ,  $10^{\circ}\text{S}$ - $10^{\circ}\text{N}$ ) in summer. Solid line is the linear trend. (b) Mann-Kendall test of SSTA in the central and eastern Pacific ( $160^{\circ}\text{E}$ - $100^{\circ}\text{W}$ ,  $10^{\circ}\text{S}$ - $10^{\circ}\text{N}$ ). Bold horizontal bars are critical levels of significant level of  $\alpha=0.05$**





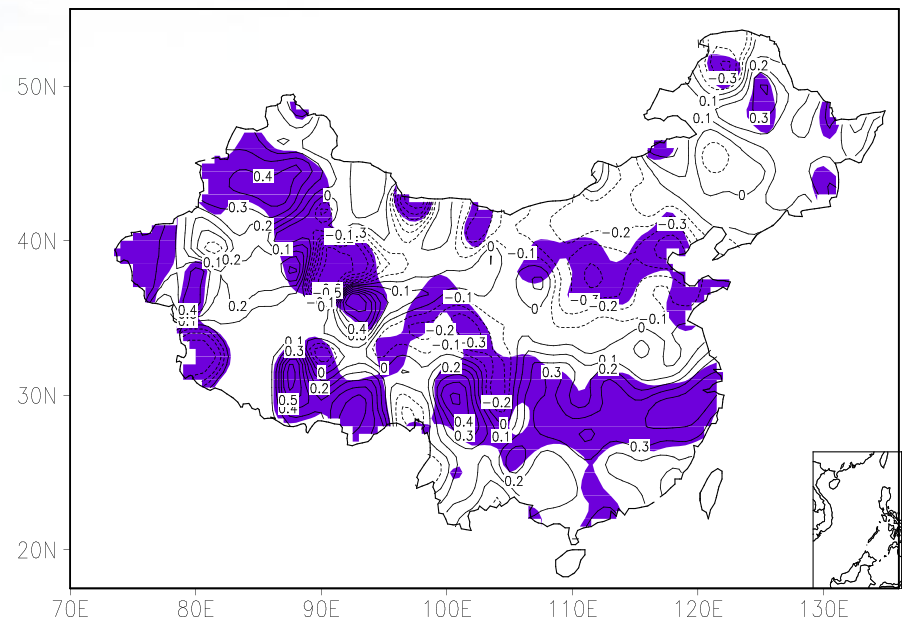
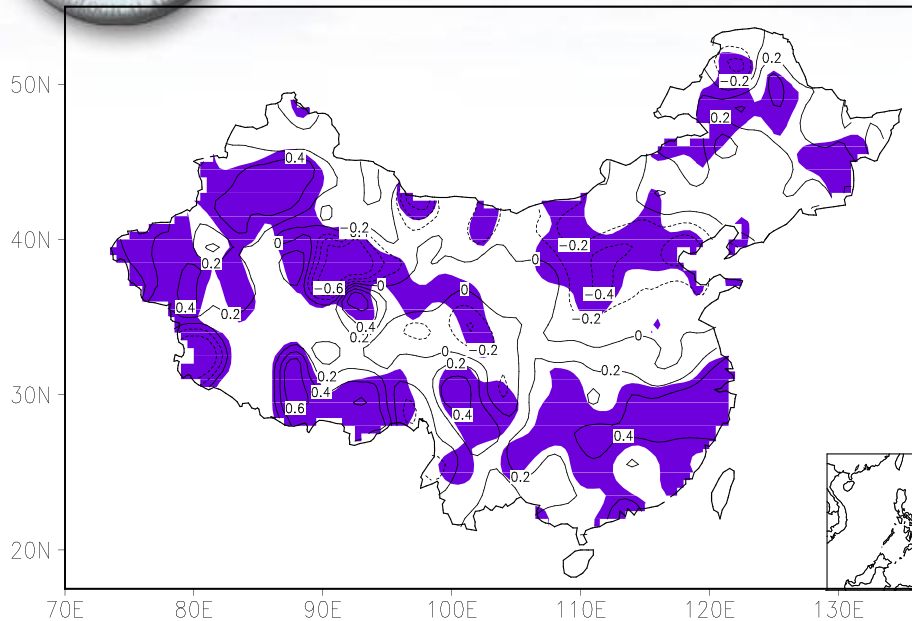
**Longitude-time cross-sections of SSTA decadal component (a) (unit:  $^{\circ}\text{C}$ ) and 850 hPa zonal wind (b) (unit:  $\text{ms}^{-1}$ ), averaged for  $10^{\circ}\text{S}$ - $10^{\circ}\text{N}$ . Linear trend is removed. Positive anomalies are shaded.**





(a)

(b)



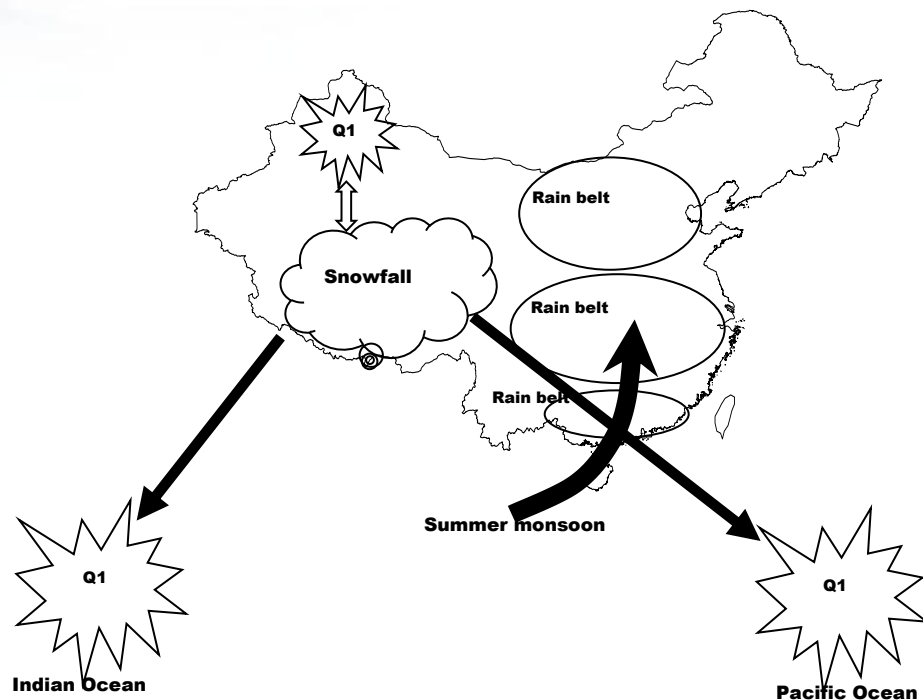
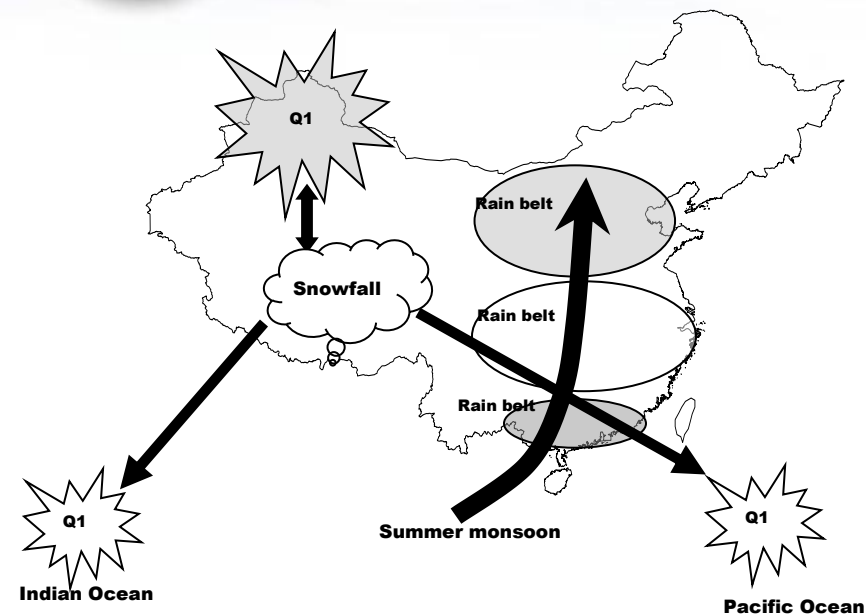
**Correlation fields between spring SSTA in the central and eastern Pacific and the summer precipitation in China (a), and the summer SSTA and the summer precipitation in China (b). Shaded areas denote those areas exceeding 95% confidence level.**





(a)

(b)



季风减弱和中国降水年代际变化的可能原因示意图(a) 夏季风强盛期；(b) 季风减弱期

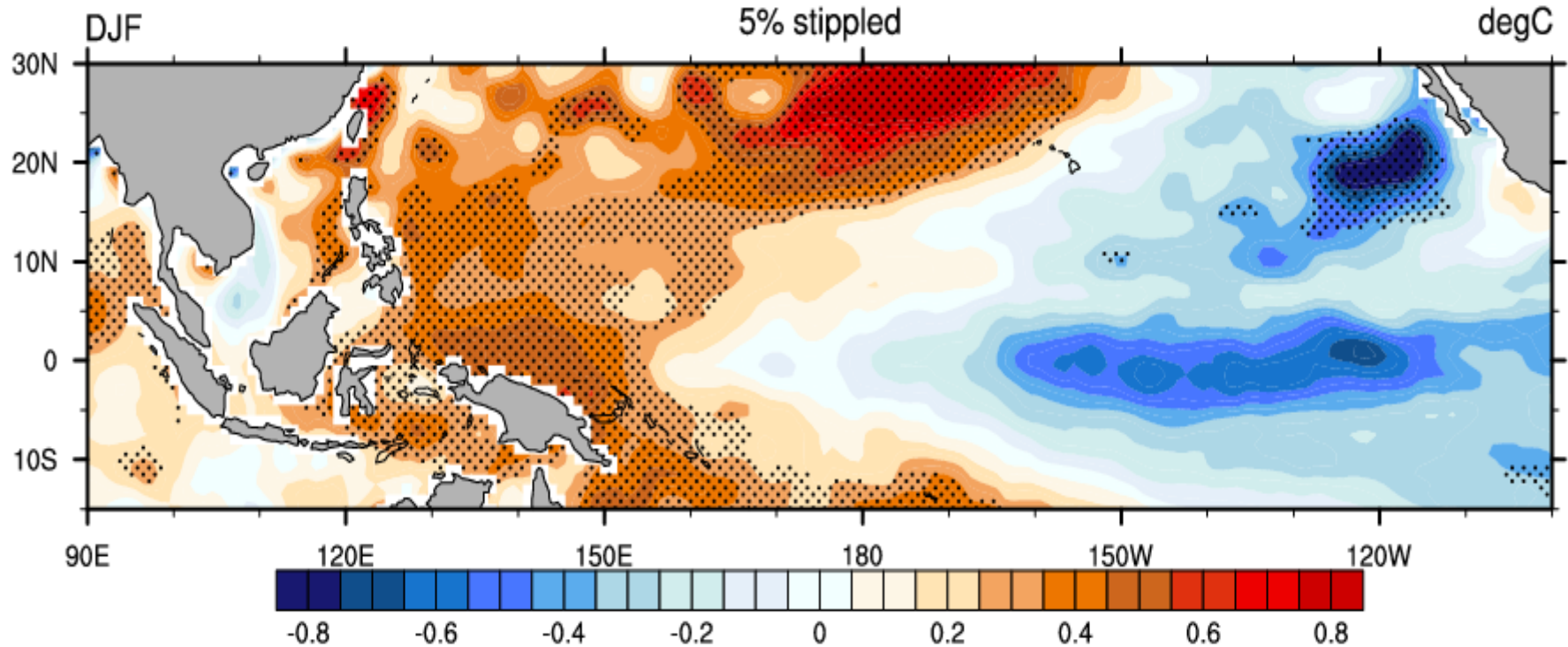
**Schematic of possible causes of inter-decadal monsoon weakening and summer precipitation pattern shift in China**

**(a) strong summer monsoon (b) weak summer monsoon**





SST Difference: 2000-2008 minus 1982-1999

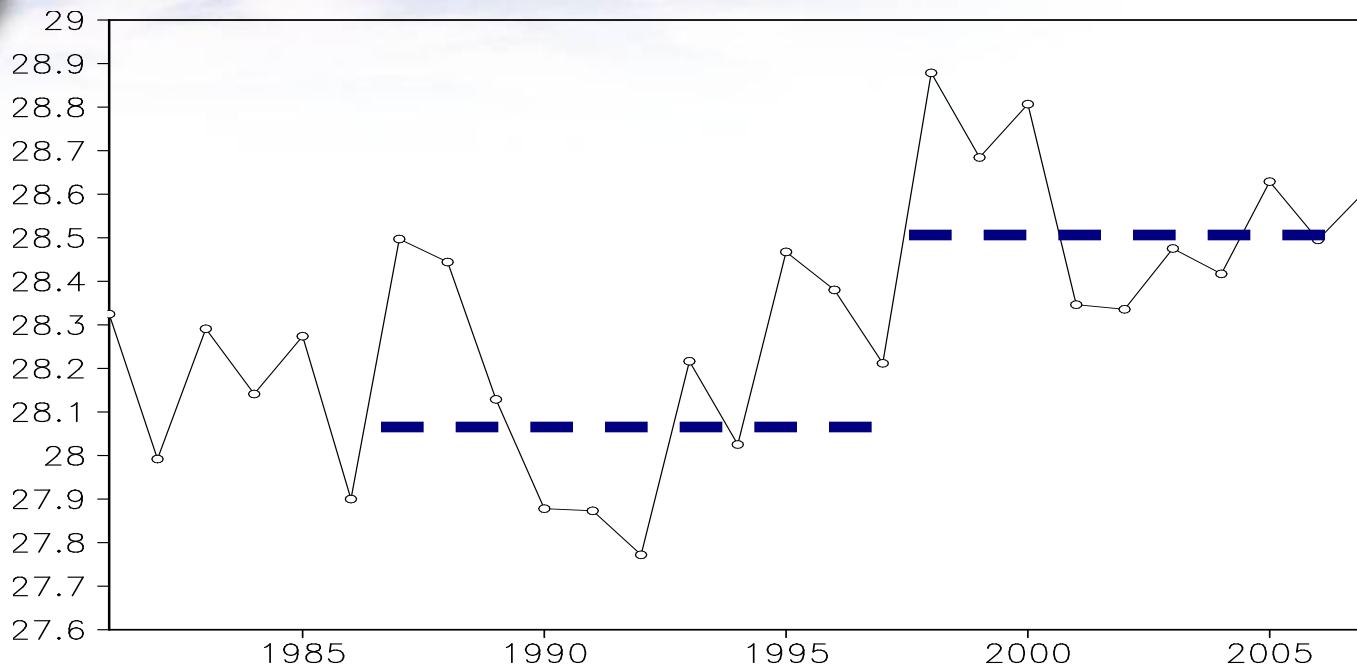


2000-2008年与1982-1999年 冬季 ( DJF ) 平均海  
表温度的差值场





# SST (DJF) variation for 1982-2008 over west Pacific



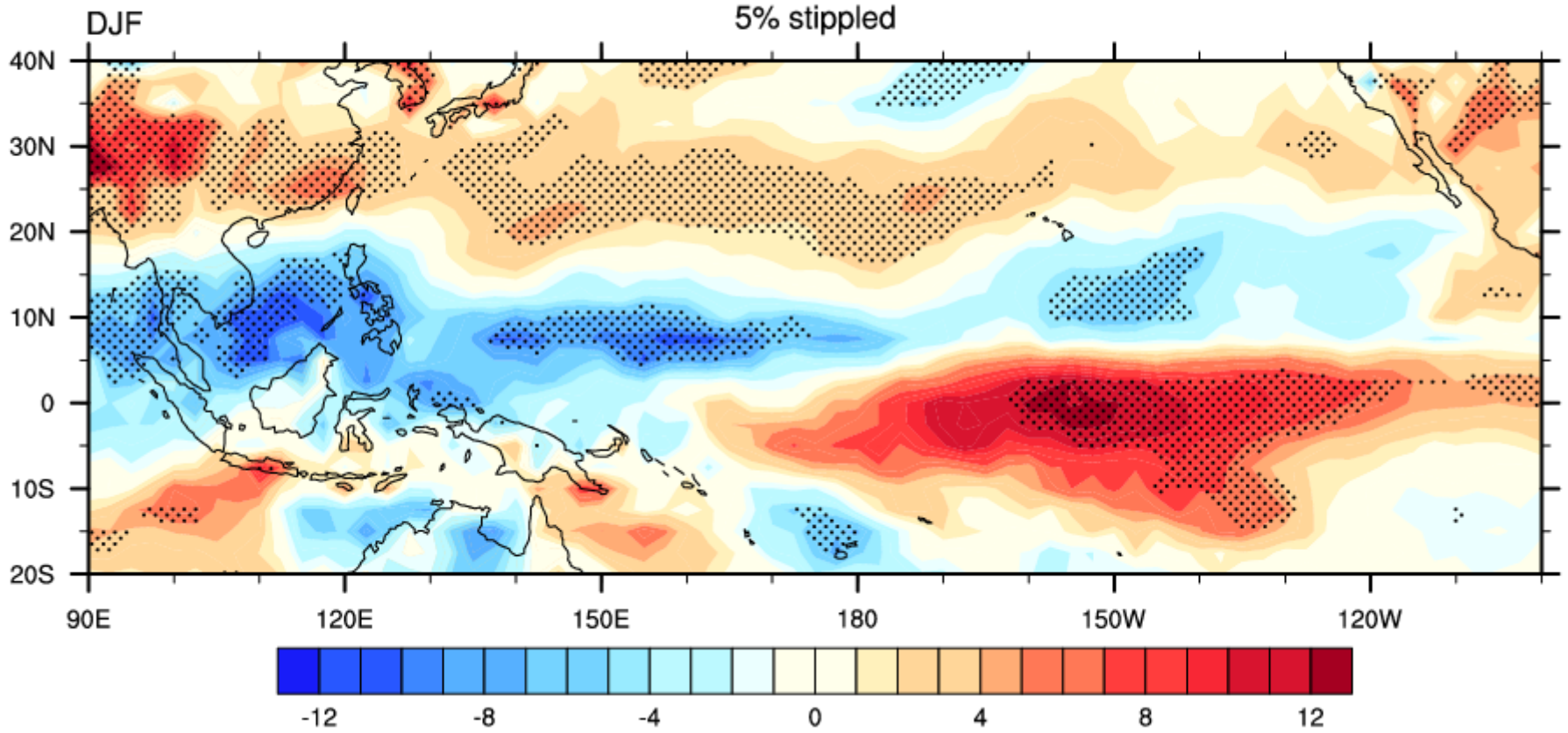
1982-2008年冬季 ( DJF ) 热带西太平洋 (  $120^{\circ}\sim 160^{\circ}\text{E}$  ,  $0\sim 25^{\circ}\text{N}$  )  
区域平均海温的时间序列 ( 单位 :  $^{\circ}\text{C}$  )

**上世纪90年代末梅雨雨带的北移是否  
与热带西太平洋的增温有关呢？**





## OLR Difference: 2000-2008 minus 1982-1999

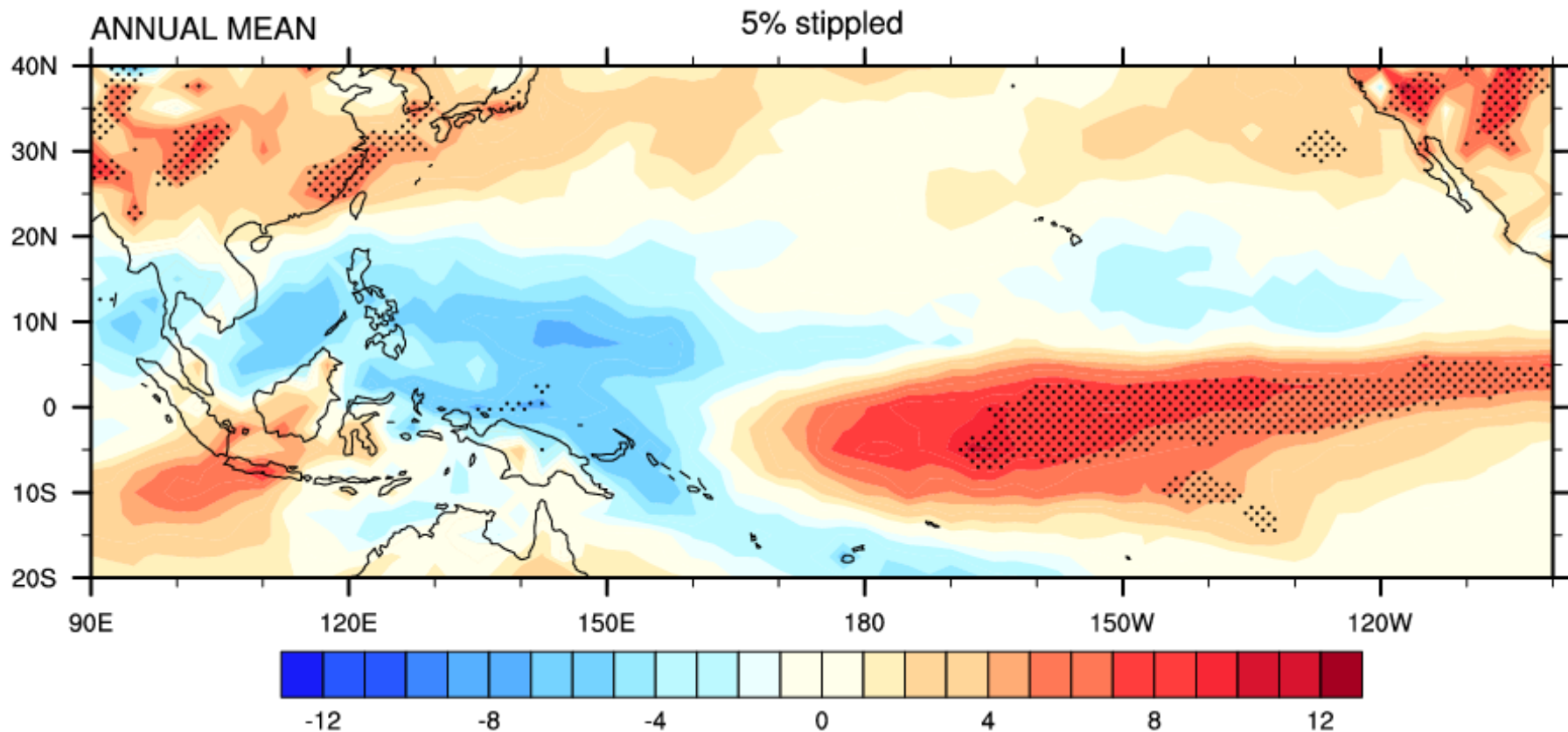


2000-2008年与1982-1999年 冬季 ( DJF ) 平均OLR  
的差值场





## OLR Difference: 2000-2008 minus 1982-1999



2000-2008年与1982-1999年 年平均OLR的差值场





***Thank you!***

