Seasonal-to-Annual Forecasts of Heavy Precipitation in Southern China

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Acknowledgement

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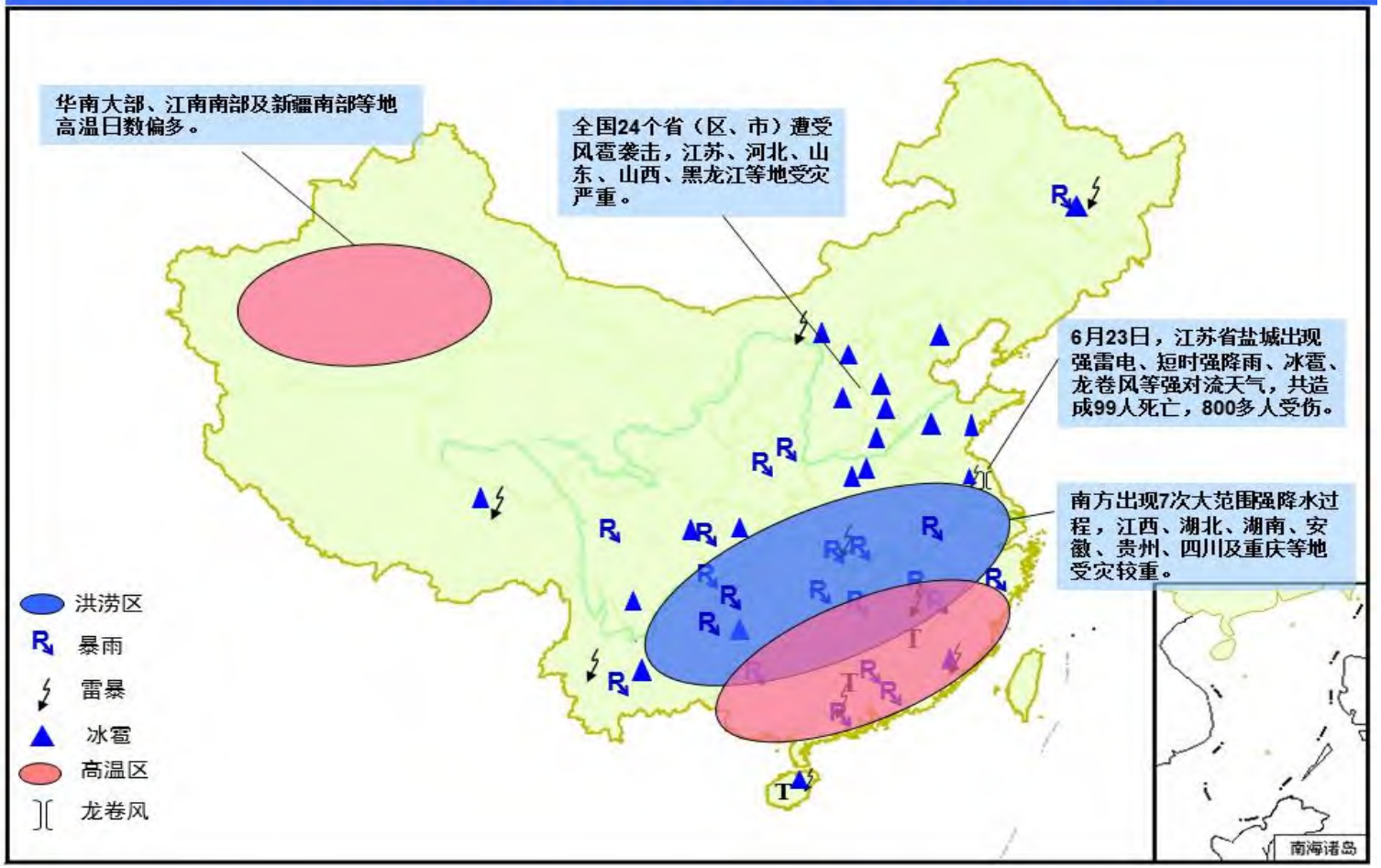
Previous forecast attempts in China

- Previous forecast attempts in China have not been successful (Chen, 2008; Yang et al. 2011).
- Zhang (2006) used data from the global Array for Real-time Geostrophic Oceanography (ARGO) to forecast summer precipitation in southern China, but were only able to get correlation coefficients ranging from 0.2 to 0.6.

The Climate Prediction Center of the US National Weather Service uses a collection of forecast models, but only able to provide qualitative probabilistic precipitation outlooks (such as dryer or wetter) up to 12.5 months into the future, underscoring the extreme challenging situation of predicting seasonal-to-annual precipitation.

2016年6月全国主要气象灾害分布图



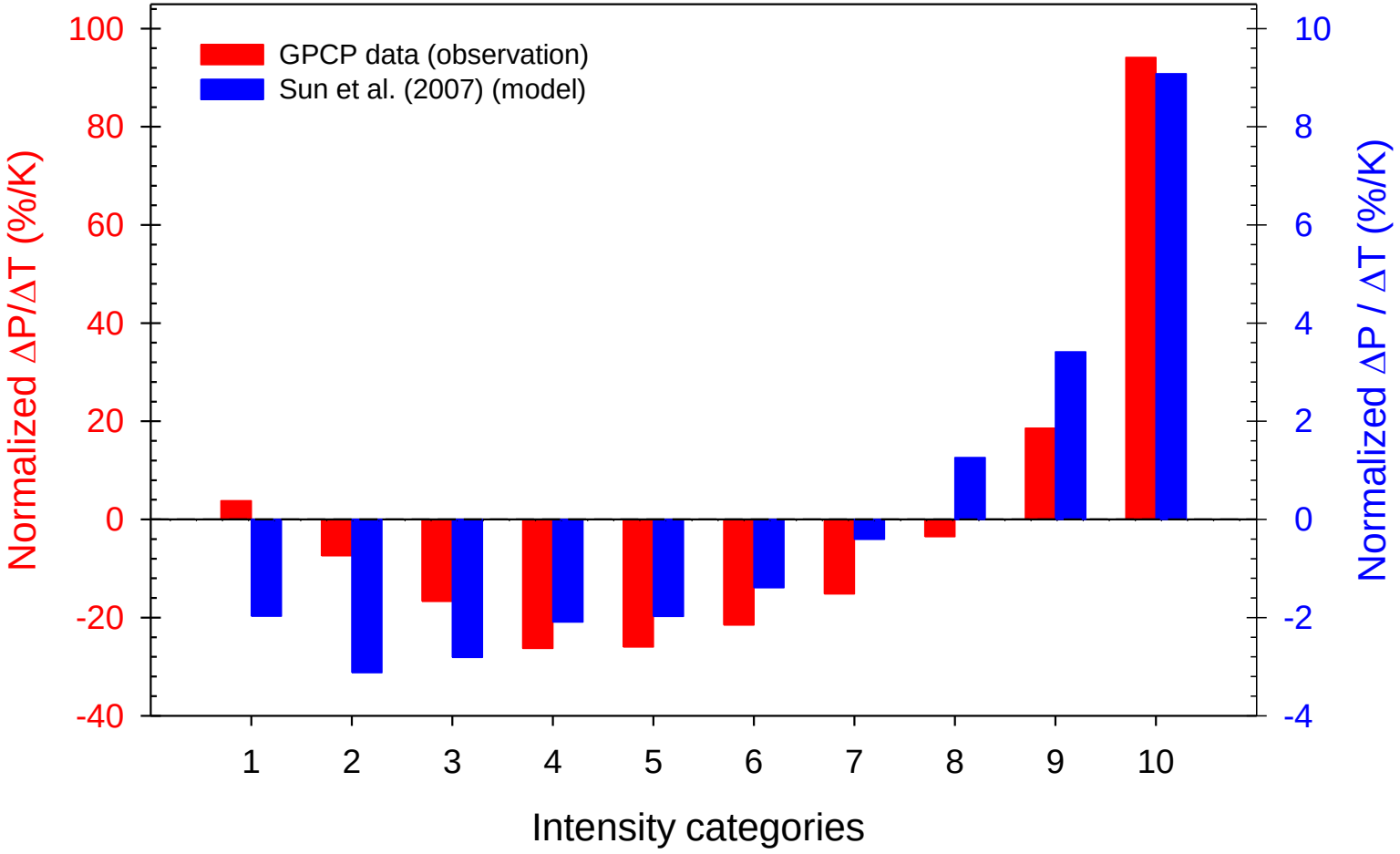
Heavy rain (>50mm/day) in southern China

1964-1968 average 322mm

2010-2014 average 424mm

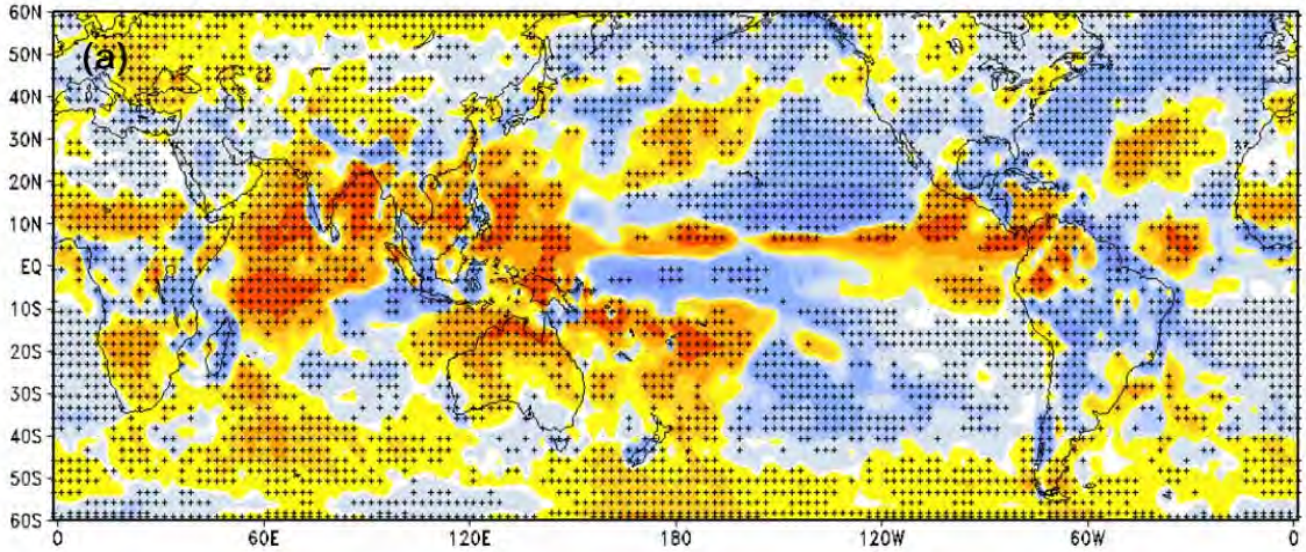
Increased by 31.67%

Changes in global precipitation intensity from climate models and observations (mostly from satellites) for one degree warming in global temperature (Liu et al. GRL2009)

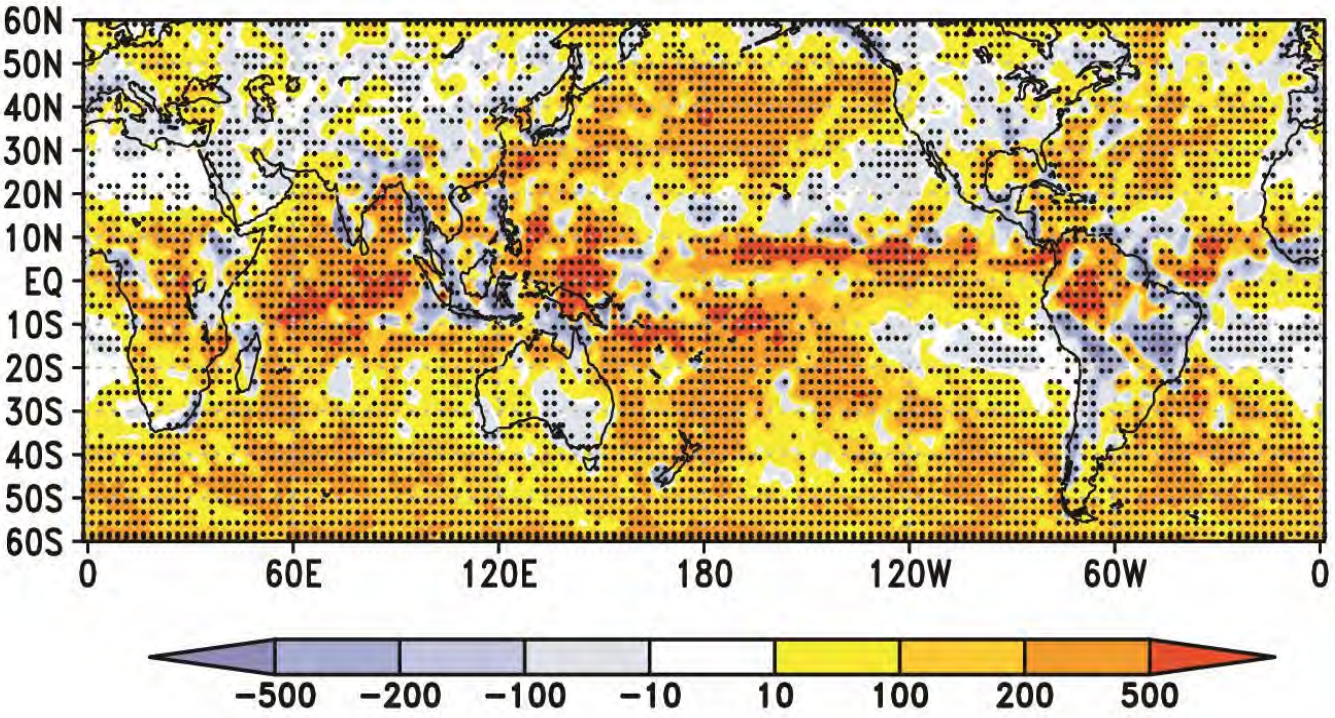


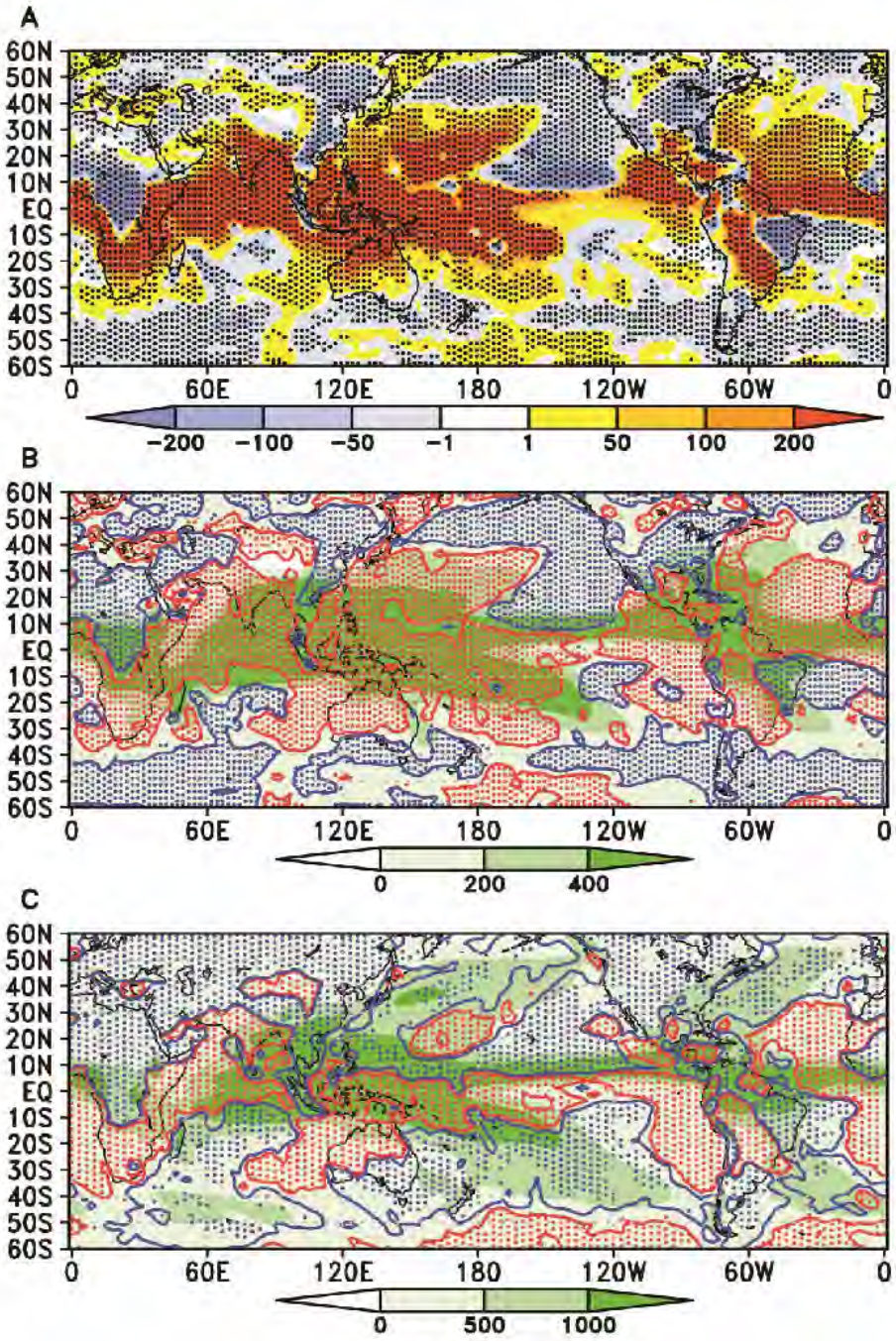
Liu et al. 2016

Changes in annual total precipitation due to 1 Degree warming



Changes in annual top 10% heavy precipitation due to 1 degree warming





From MERRA

Trends of upward moist convective mass flux (UMCMF) at 700 hPa
對流上升水氣通量的趨勢

Trends of UMCMF in +-20% overlaid on the average UMCMF

Same as (B), except for annual total precipitation

Meteorological processes (MPs) affecting precipitation in southern China

Arctic Oscillation

Gong, et al., **2001**

Global Temperature

Hansen, et al., **2006**

Pacific Decadal Oscillation

Mantua, et al., **2002**

ENSO

Wang B，et al., **2000**

Indian ocean dipole

Saji, et al., **2003**；
Chakravorty, et al.，**2013**

South China monsoon

姚才等, **2011**

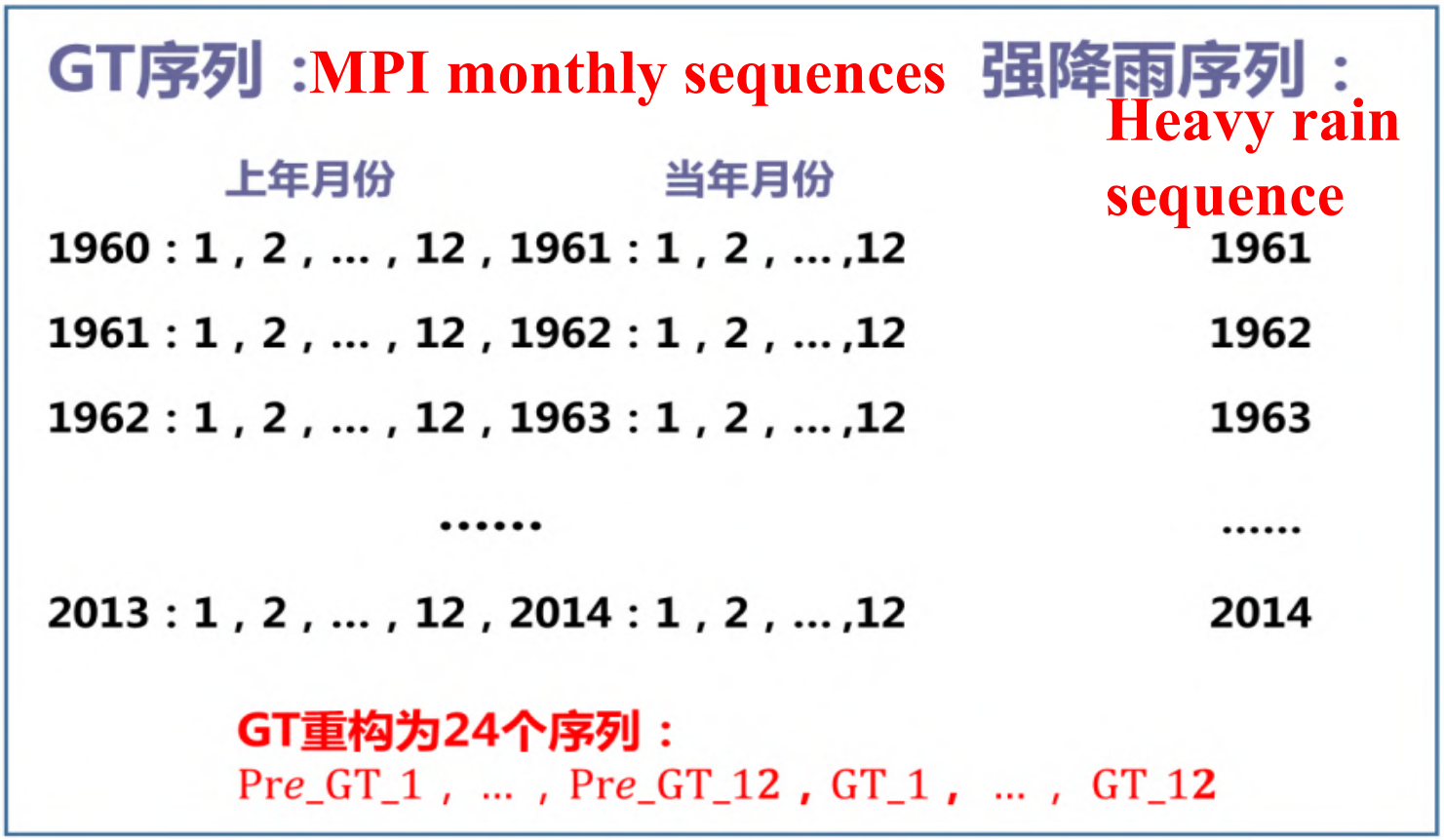


图 2-3 气候指数序列重构

Fig. 2-3 the reconsitution of climate index

1) True forecast: use 12 MPI monthly sequences of previous year.
2) 6-month forecast: use 6 MPI monthly sequences of current year and 12 MPI monthly sequences of previous year.
3) Hindcast: use 24 monthly MPIs of current year and previous year.

Comparison of true forecast (green), 6-month forecast (yellow) and hindcast (blue) to observations (red)

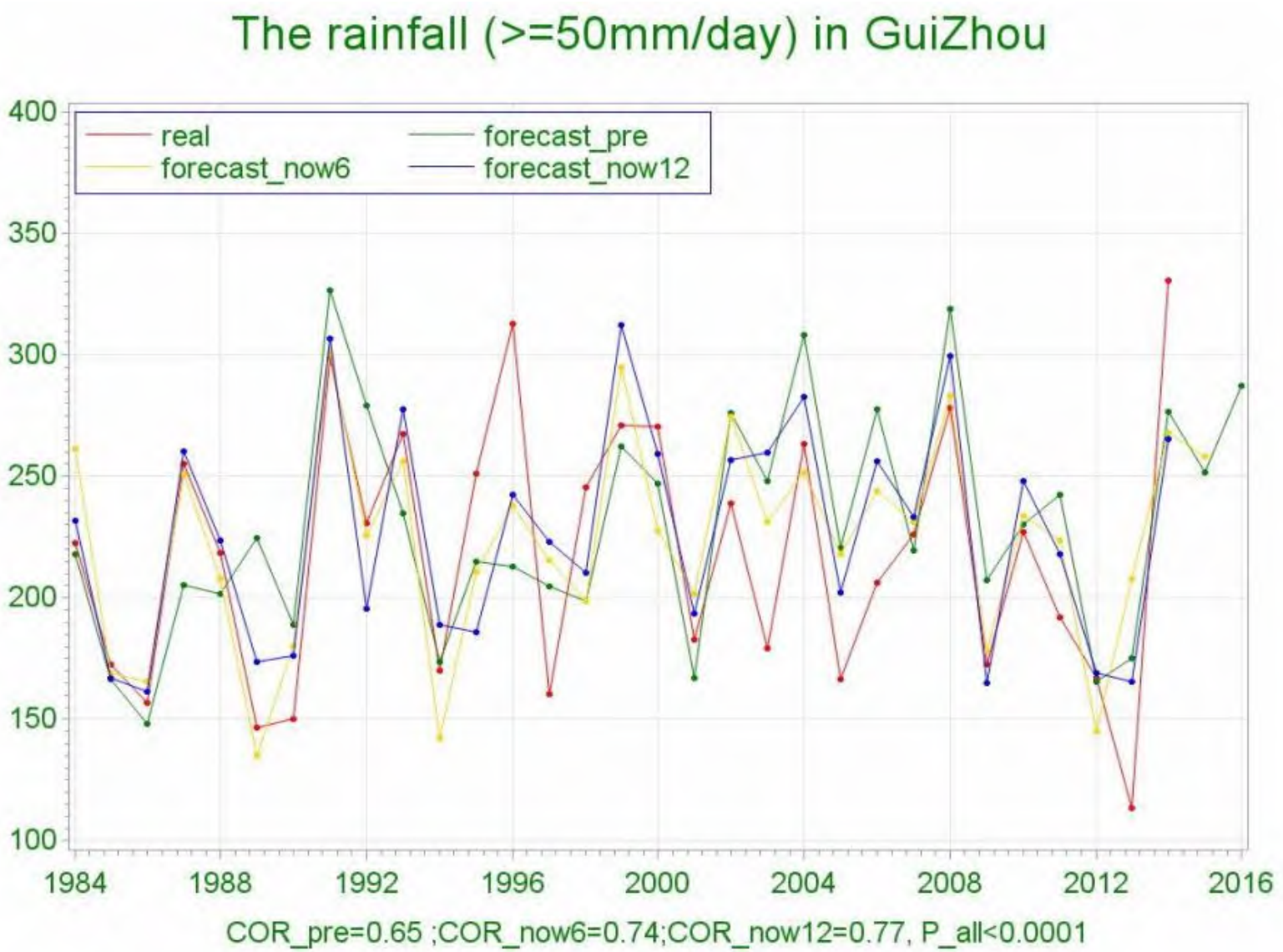
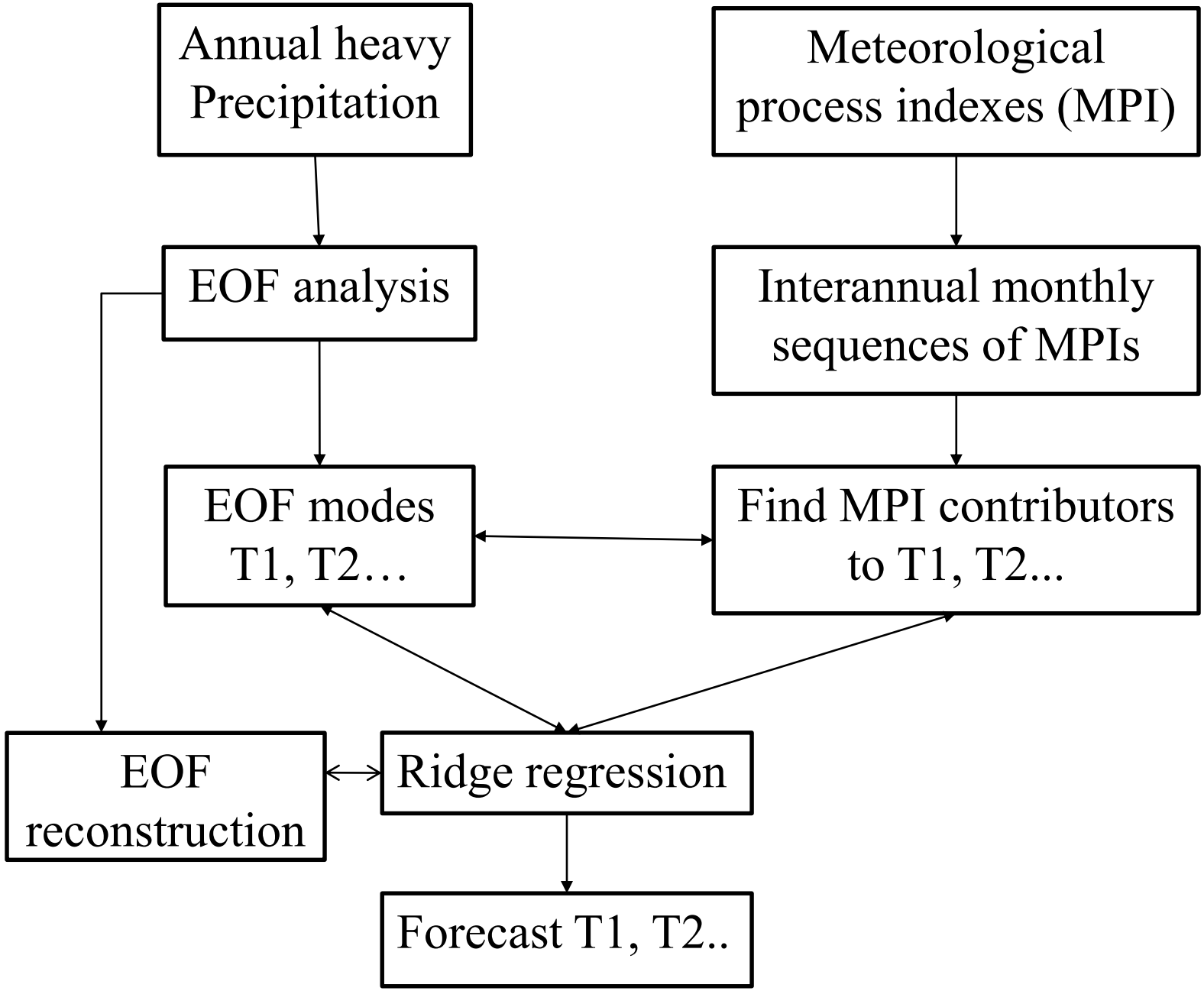


图 5-9：不同时期对中国南方地区贵州省强降雨量(>=50mm/day)预报结果。

Predictability of heavy precipitation

- Large interannual variability, i.e. large signal to noise ratio.
- Time lags between heavy precipitation and most meteorological process indexes (MPIs) are a few weeks to a year.
- Storms, moisture and temperature are strongly coupled by the convection-moisture-latent heat feedback cycle (Trenberth et al. 2003).
- Mr. Wenhui Liao's knowledge and experience in statistics.


Annual heavy Precipitation
Meteorological process indexes (MPI)
EOF analysis
Interannual monthly sequences of MPIs
EOF modes T1, T2…
Find MPI contributors to T1, T2...
EOF reconstruction
Ridge regression
Forecast T1, T2..

EOF modes of heavy precipitation: T1, T2…

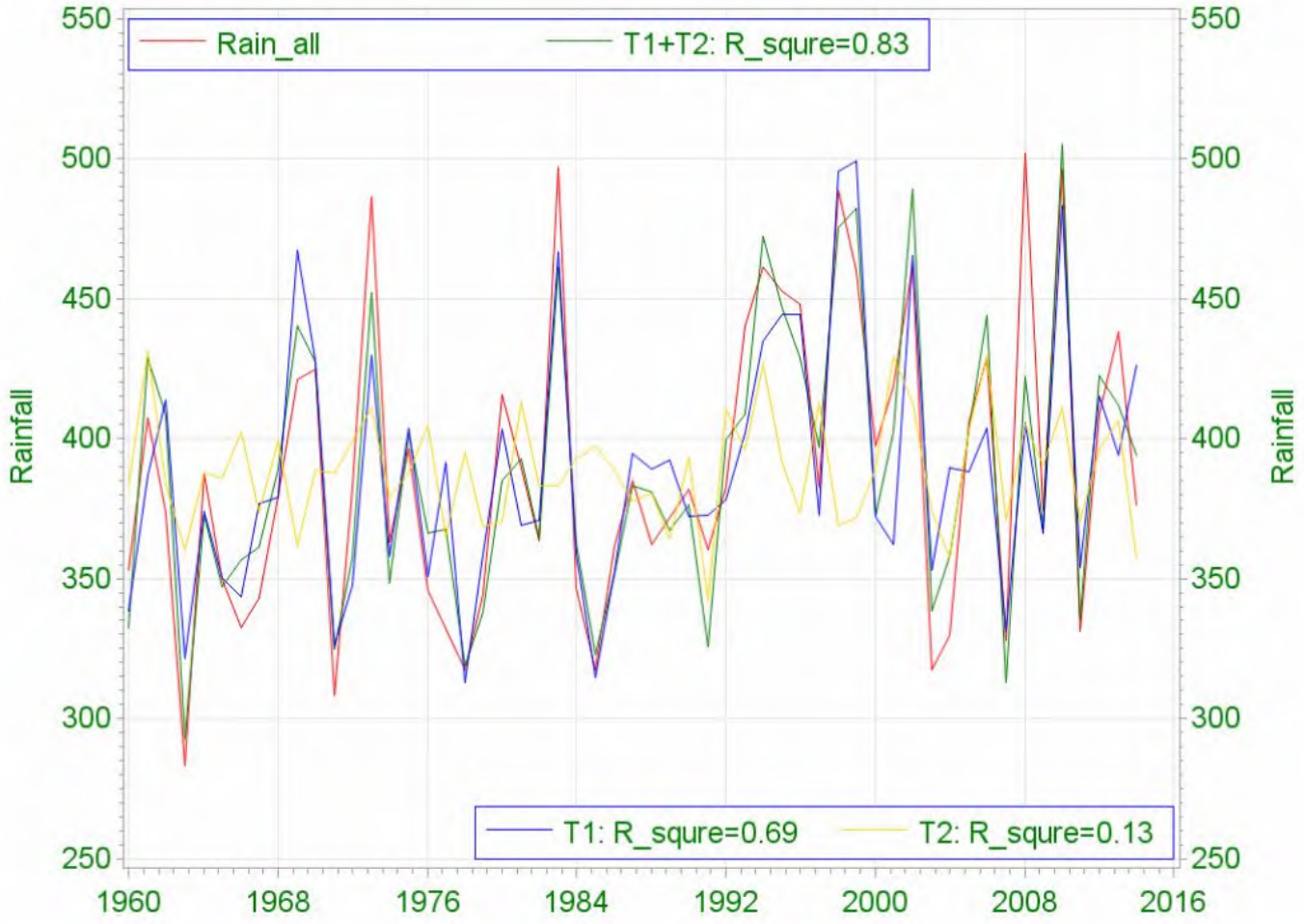
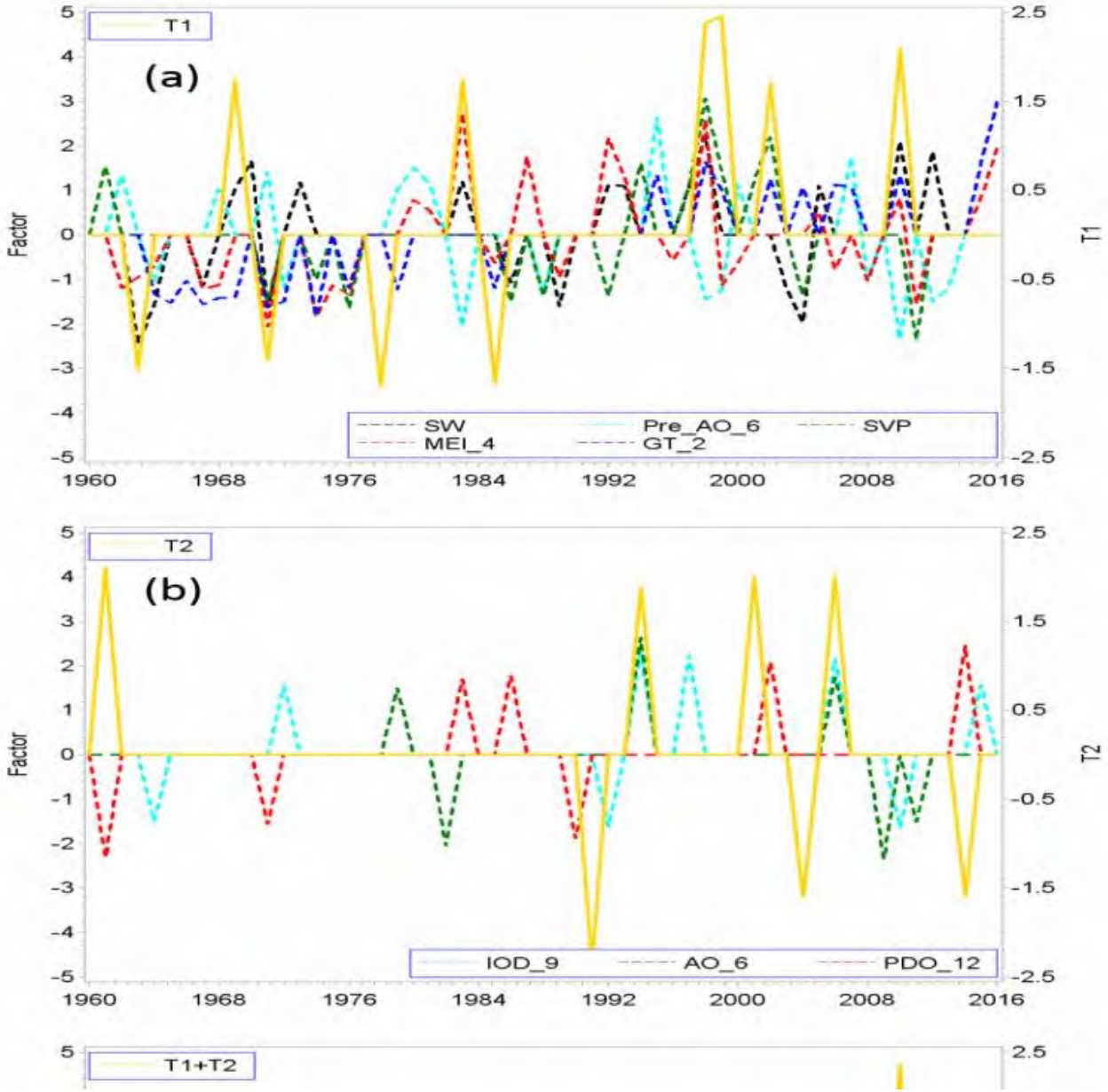


图5-3：中国南方地区年强降雨量和T1、T2以及T1+T2的拟合结果。

Figure 5-3: Mid-severe rainfall in southern China and T1, T2 and T1 + T2 fitting results.


T1
(a)
Factor
T1
SW
MEI_4
Pre_AO_6
GT_2
SVP
T2
(b)
Factor
T2
IOD_9
AO_6
PDO_12
T1+T2
1960
1968
1976
1984
1992
2000
2008
2016

15 out of the 19 extreme precipitation years coincide with high absolute values of two or more MPIs

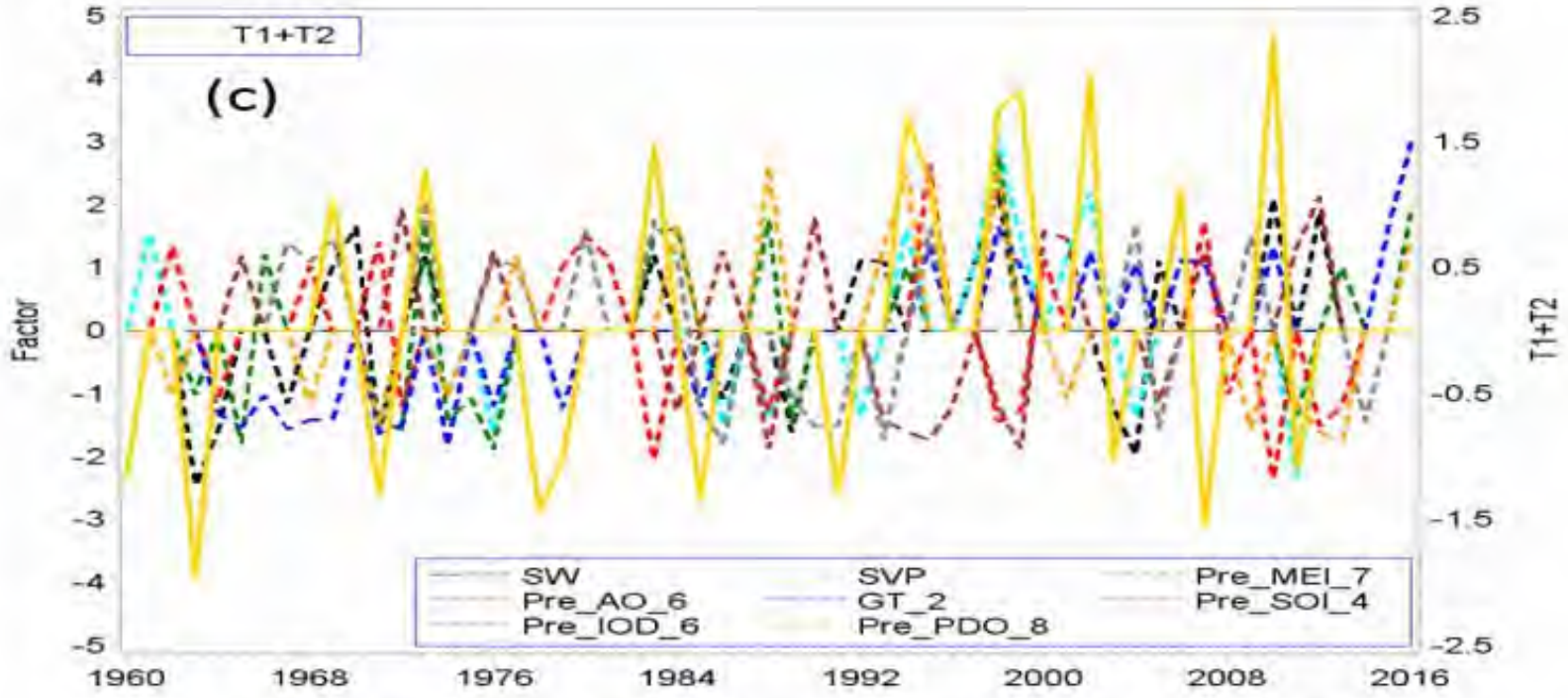


图5-4：T1、T2和T1+T2与各种指数在时间序列上的比较分析图。

Figure 5-4: T1, T2 and T1 + T2 and various indices in the time series of comparative analysis.

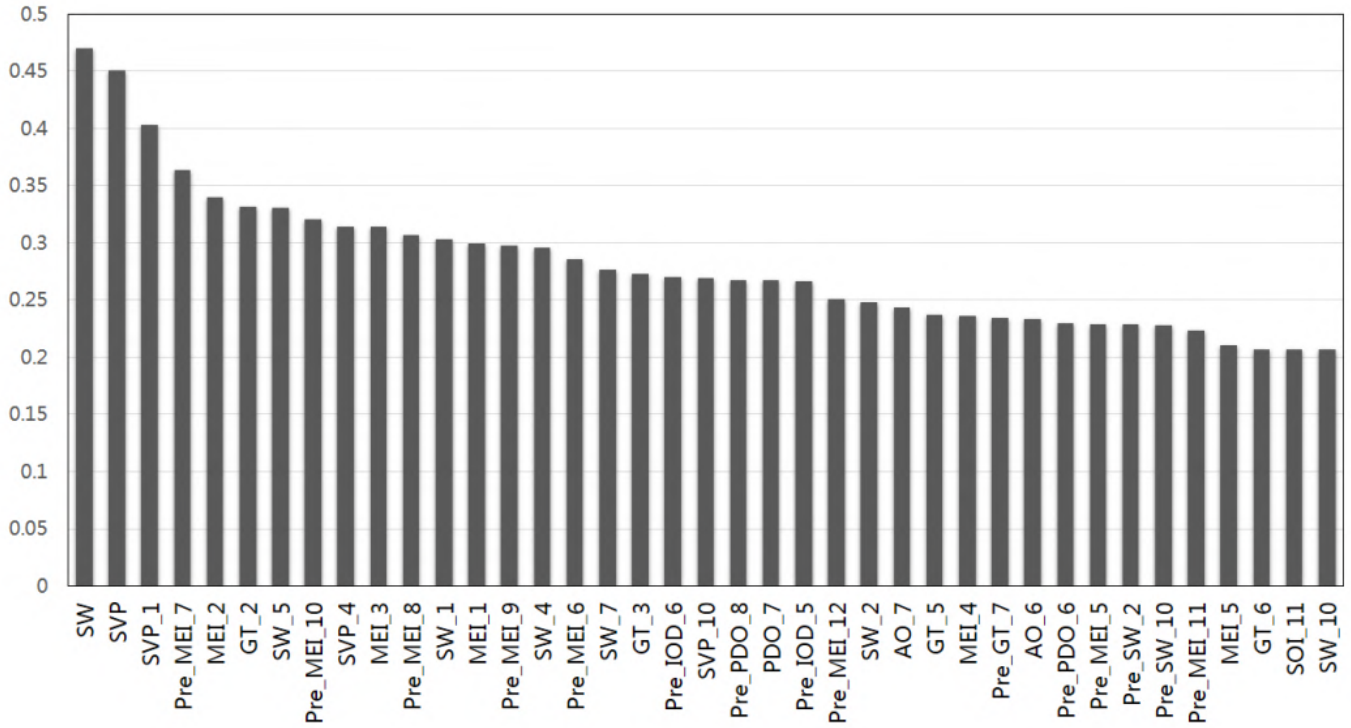
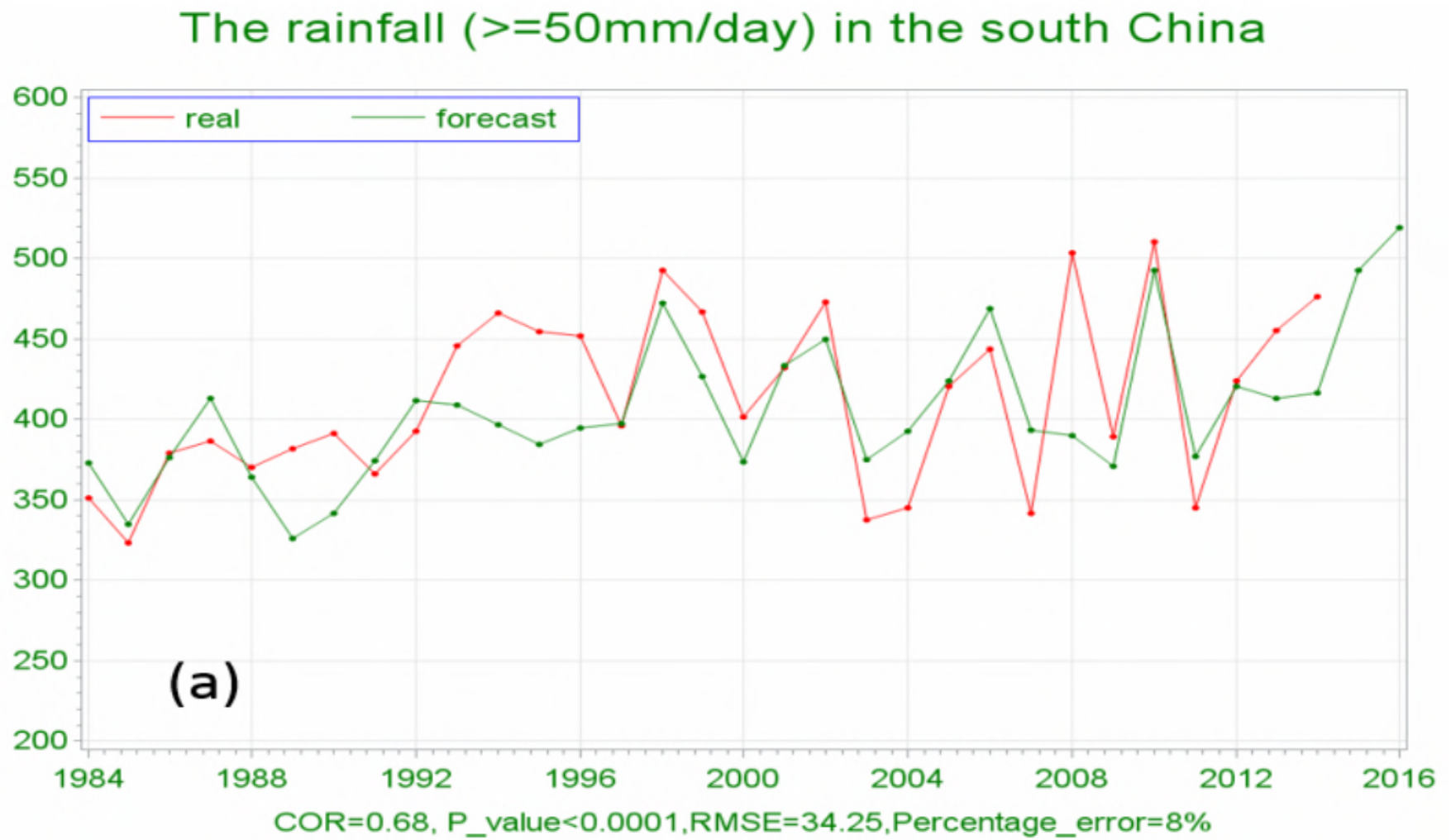


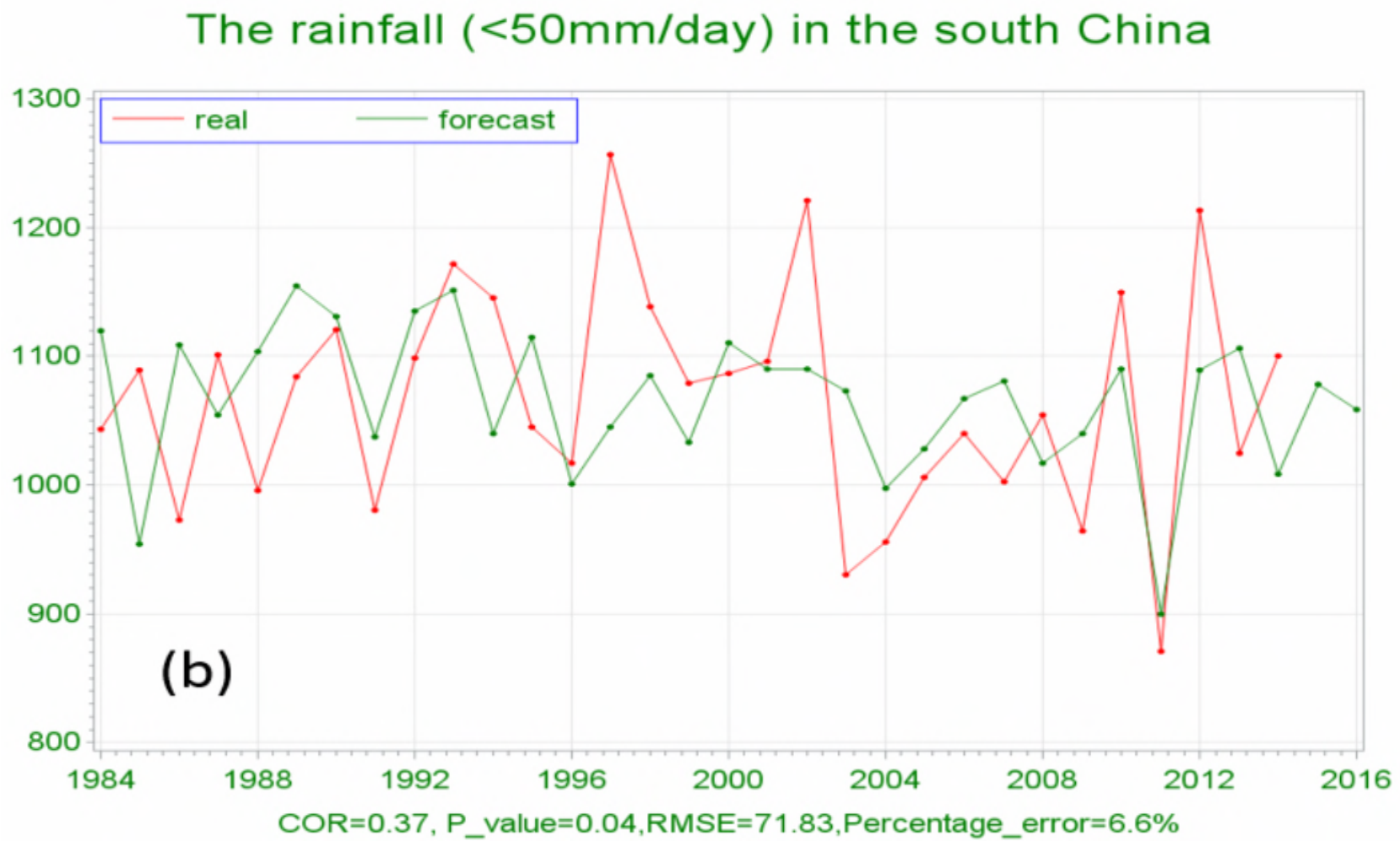
图 5-5：气候指数重构后的月均值序列与 T1+T2 的相关分析。

Fig. 5-5: Correlation analysis of monthly mean sequence with T1 + T2 after reconstructed climate index.

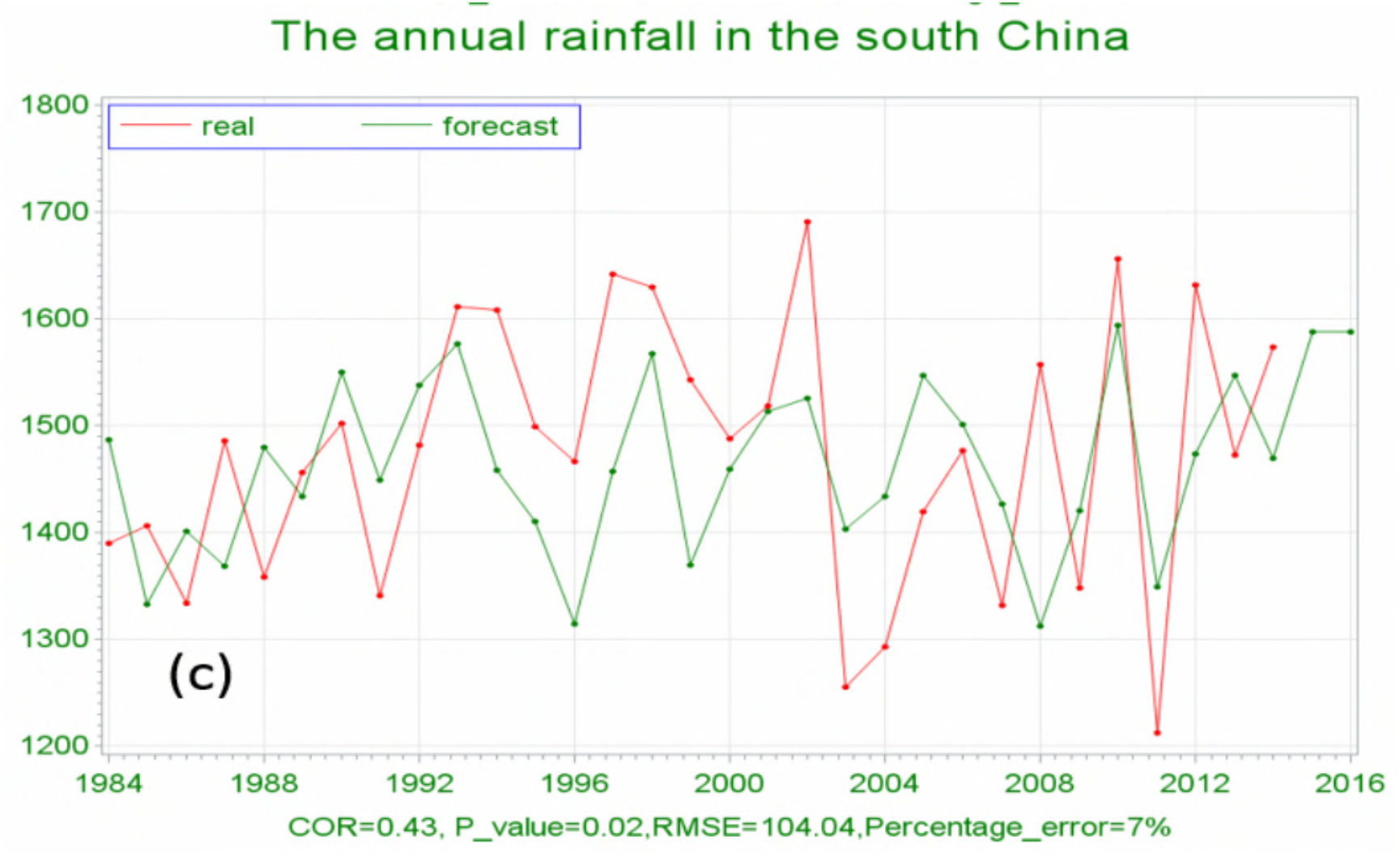
Compare forecasted heavy precipitation (>50mm/day) in southern China (green) to observations (red)



Compare forecasted light and moderate precipitation (<50mm/day) in southern China (green) to observations (red)



Compare forecasted annual total precipitation in southern China (green) to observations (red)



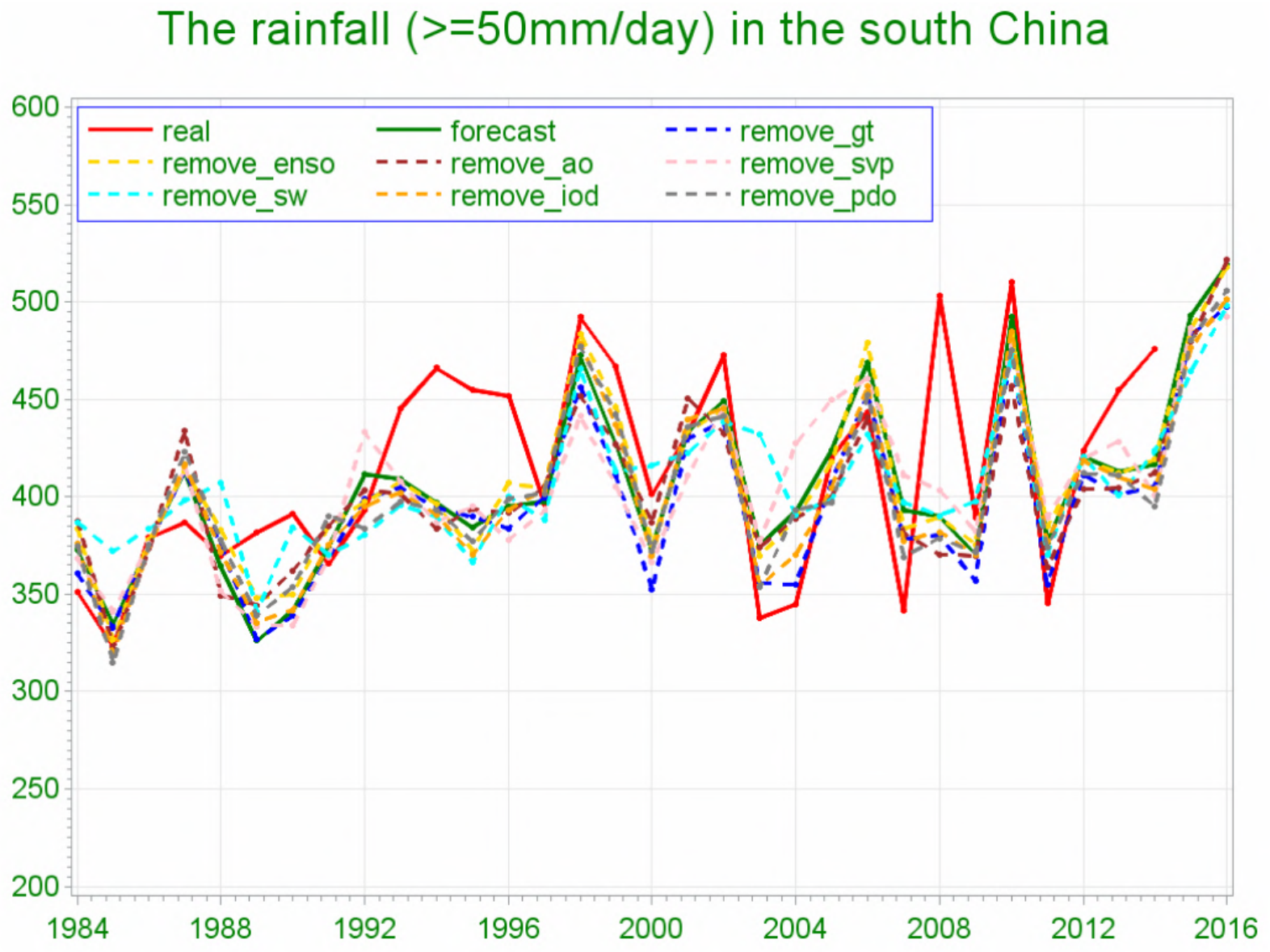


图 5-7：中国南方地区年强降雨量(>=50mm/day)预报值与观测值在预报模式中分别剔除 SW、SVP、GT、ENSO(MEI,SOI)、IOD、PDO 和 AO 相关变量后的预报效果。

表5-2：中国南方地区年强降雨量(>=50mm/day)预报值与观测值的统计结果。

Remove Variable	The South China			
	Corr	P_value	RMSE	Percentage_error
	0.68	<.0001	34.26	8.26%
GT	0.72	<.0001	34.85	8.40%
ENSO	0.69	<.0001	32.68	7.88%
IOD	0.70	<.0001	33.56	8.09%
PDO	0.68	<.0001	34.59	8.03%
AO	0.63	0.0002	37.83	9.12%
SVP	0.54	0.0017	40.21	9.70%
SW	0.52	0.0025	39.14	9.44%

5.3.2 不同地区预报比较分析

Forecasts of heavy rain for four southern provinces

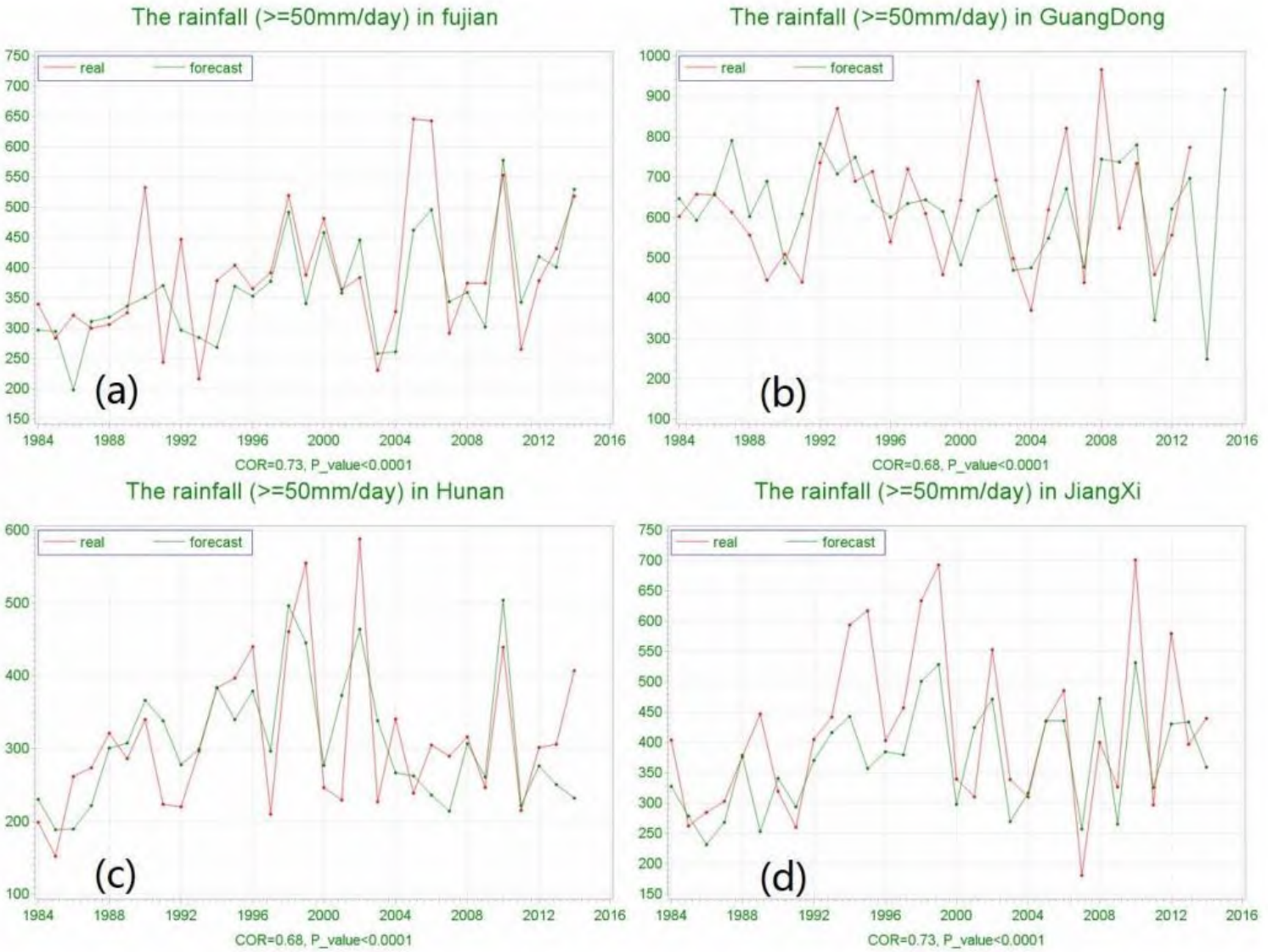


图 5-8：对中国南方地区强降雨量(>=50mm/day)的预报：(a)福建，(b)广东，(c)湖南，(d)江西。

Summary

- The statistical/empirical model has the capability (at the level of R~0.7 and RMSE~10%) to forecast annual heavy precipitation >50 mm/day in southern China with a lead time of six months to one year.
- Model results suggest that south China monsoon, global temperature and ENSO are the primary processes influencing the interannual variance in annual heavy precipitation in southern China.
- The model probably can be used to forecast annual heavy precipitation in other regions where heavy precipitation from convective storms is significant.

Thank you!

Comparison of changes in heavy precipitation in southern China downscaled from a climate model (CCSM) with the observed value

Difference in heavy precipitation between 2046-2050 and 2010-2014 divided by difference in global temperature (from CCSM)

RCP4.5: (218-179)mm/1.4K = 39 mm/K

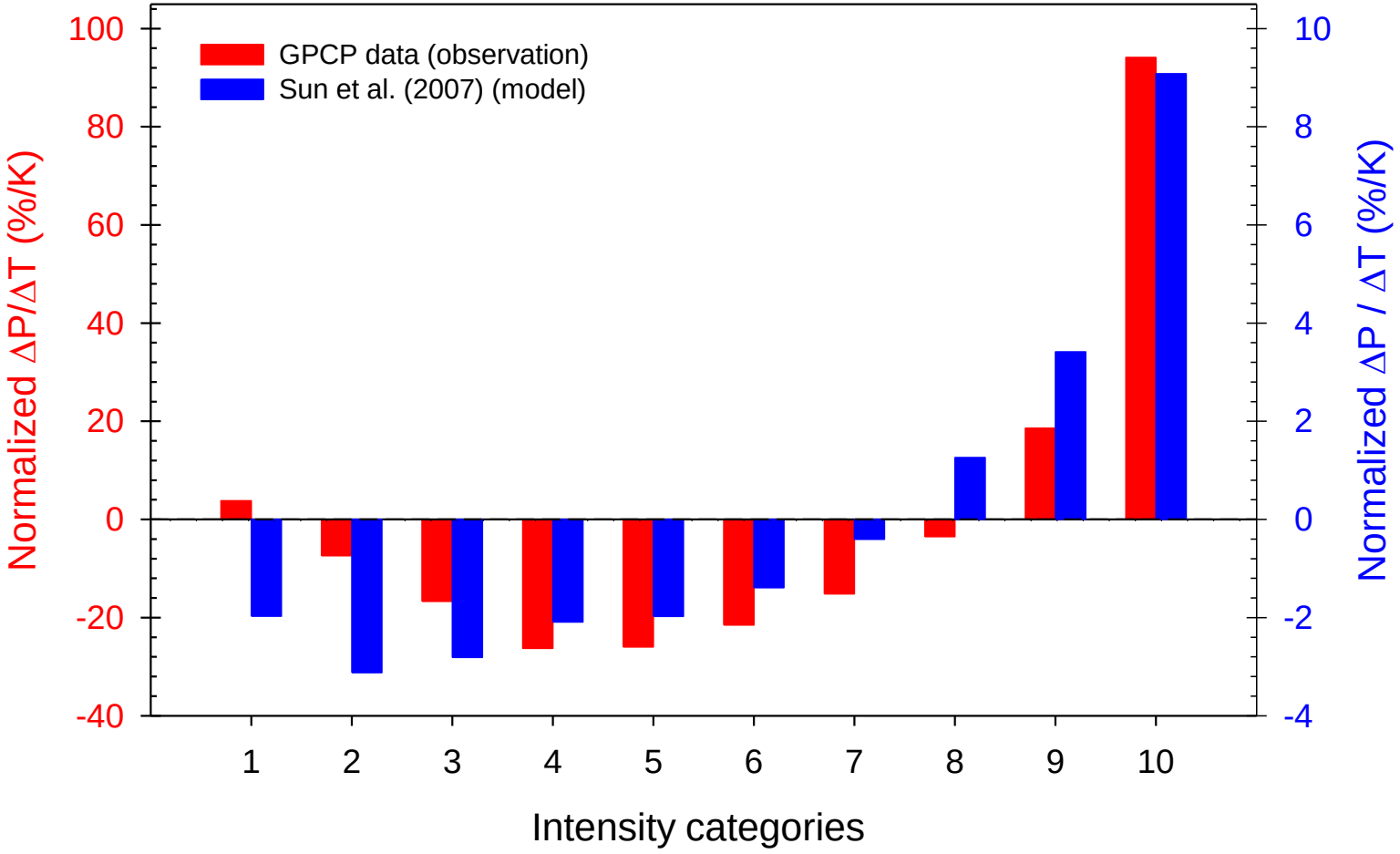
RCP8.5: (204-132)mm/2K = 36 mm/K

Observed difference in heavy precipitation between 2010-2014 and 1964-1968 divided by difference in global temperature

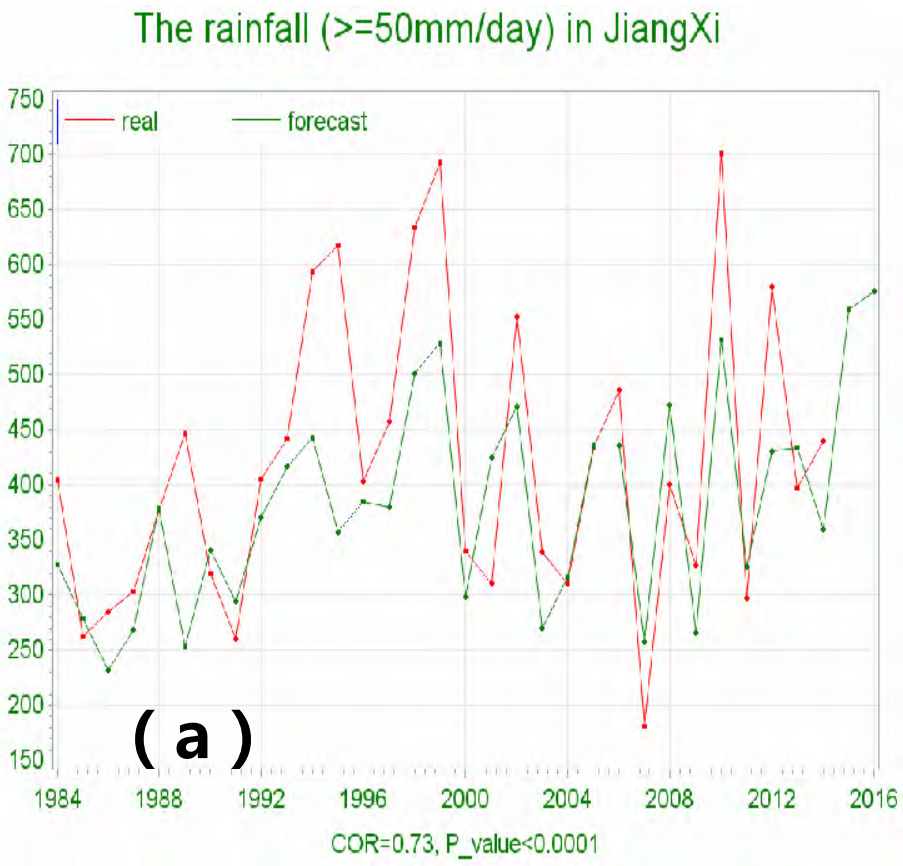
Observed: (424-322)/0.5 = 204 mm/K

The observed value is more than 5 times higher than those of CCSM.

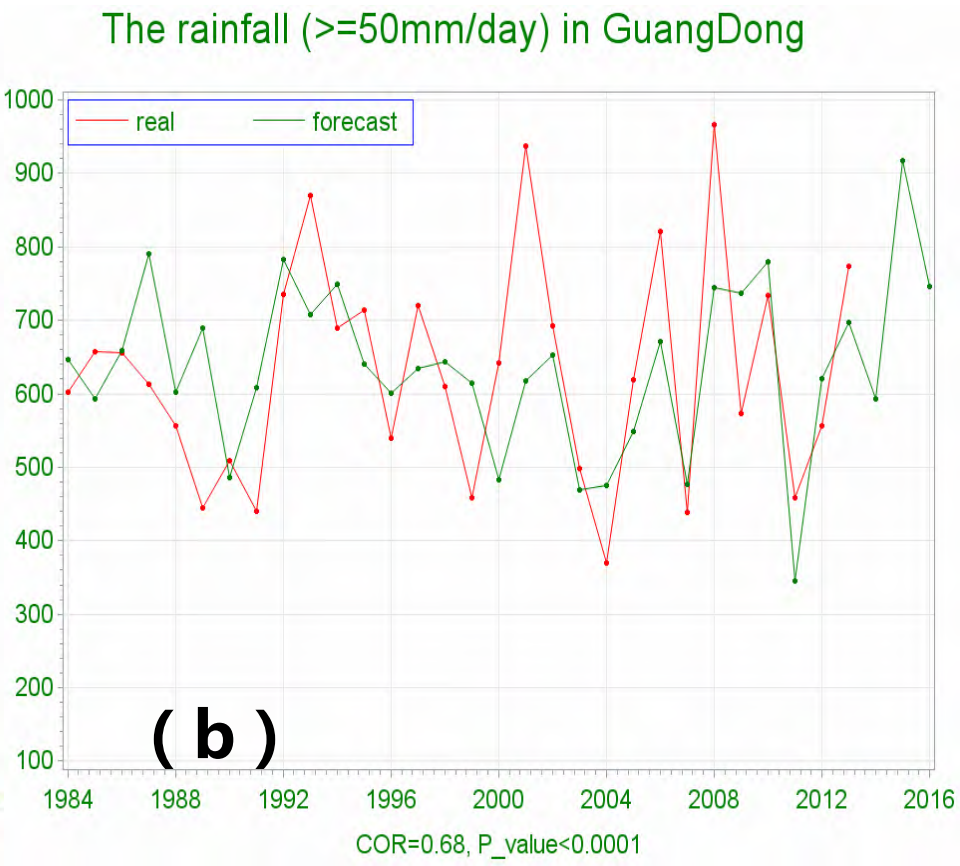
Changes in global precipitation intensity from climate models and observations (mostly from satellites) for one degree warming in global temperature (Liu et al. GRL2009)



4. 统计模式对南方地区强降雨预报



（a）



（b）

在江西和广东预报值和真实值相关性为0.73和0.68，**证明有较好的稳定性。**

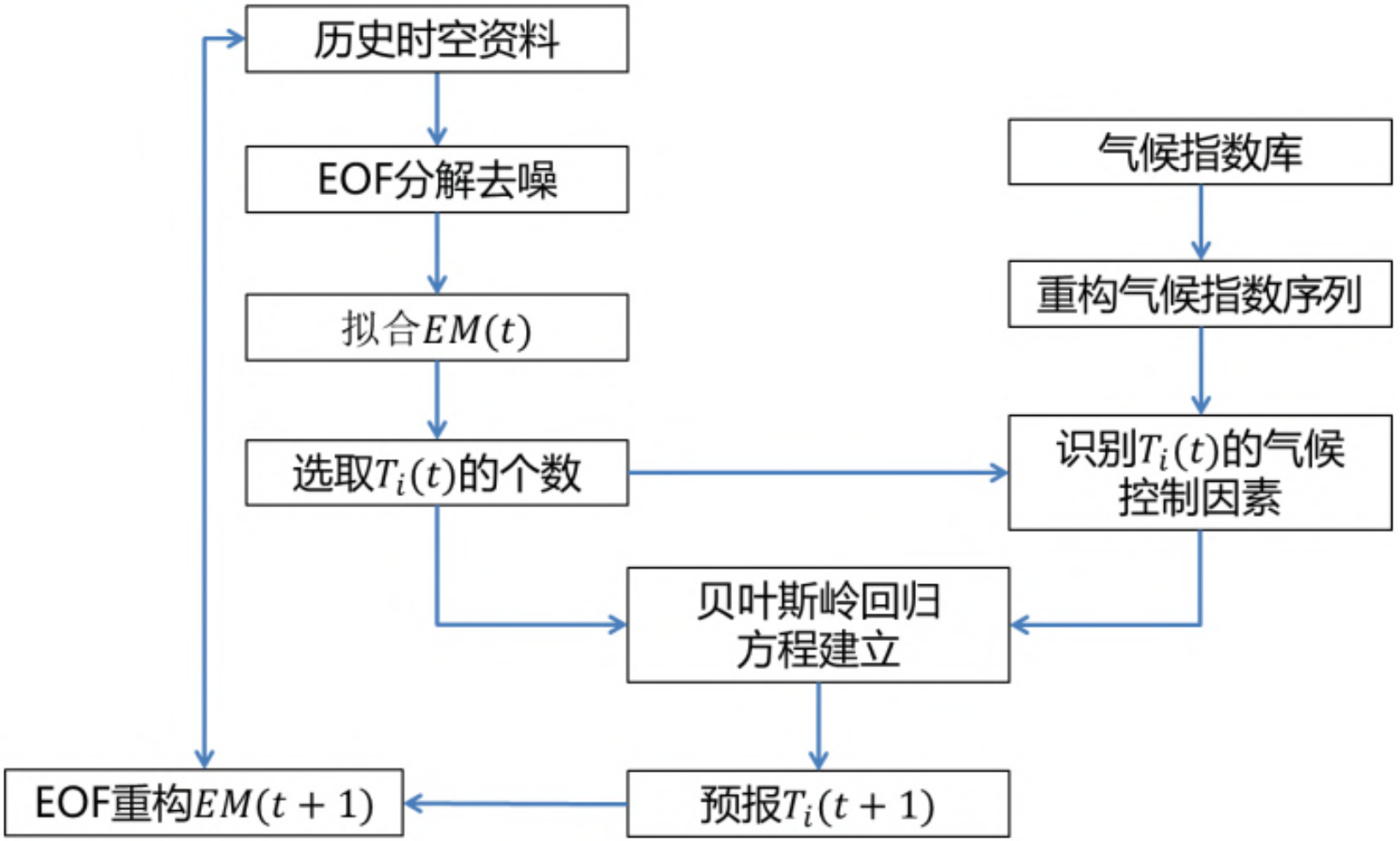


图 2-4 预报方法框架

Fig 2-4 the framework of Forecast method

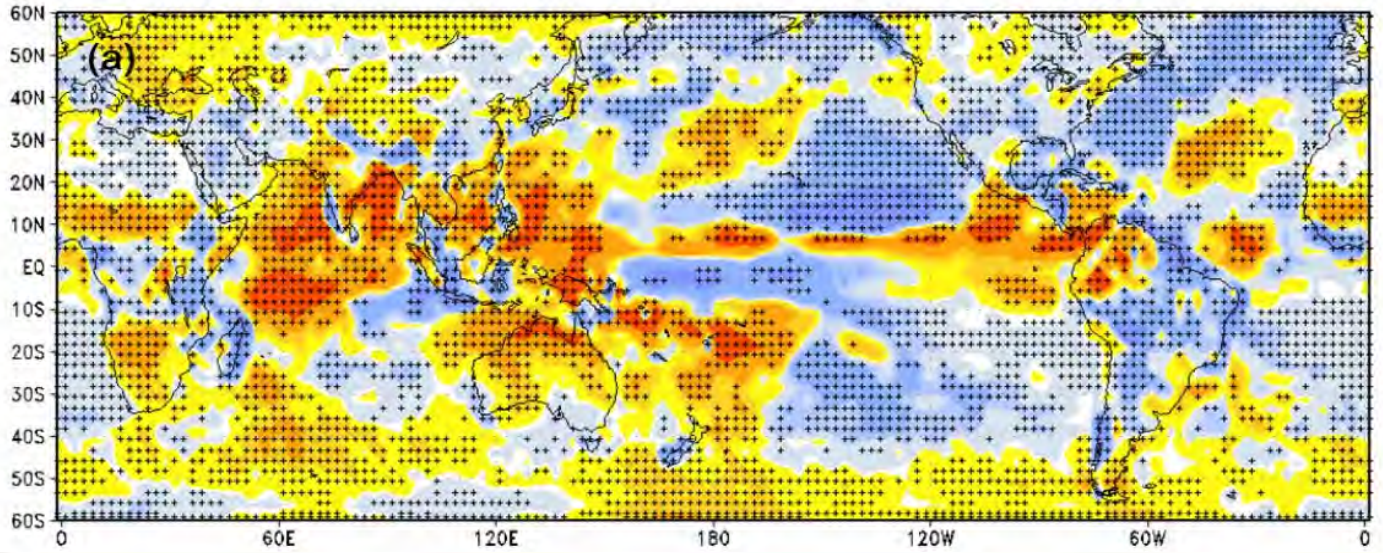
表7-3： 强降雨（单位：mm）比例变化结果。

范围	观测 1964-1968			观测 2010-2014			GT 上升
	年降雨量	暴雨量	比例	年降雨量	暴雨量	比例	
D01	764	153	20%	813	183	23%	0.5
D02	1342	322	24%	1514	424	28%	0.5

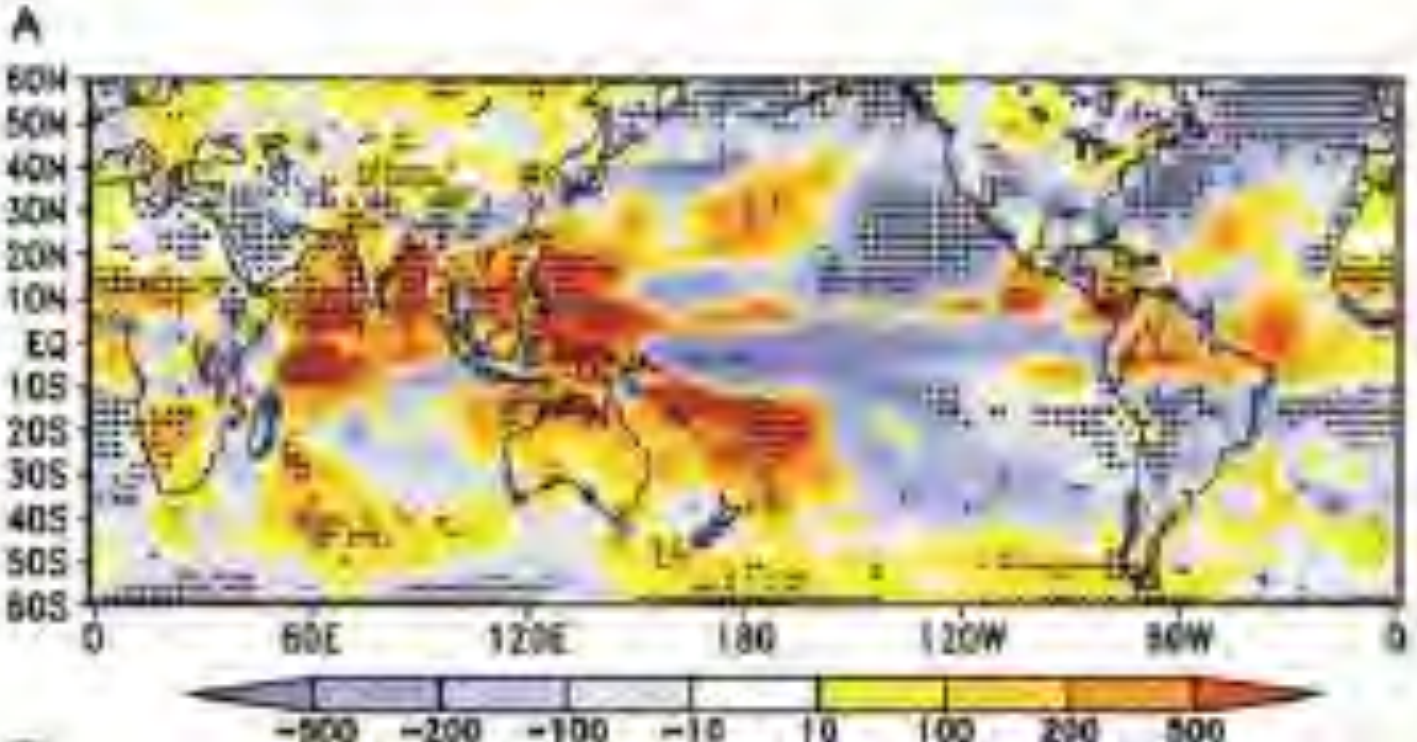
表7-4：强降雨（单位：mm）比例变化模拟结果。

情景类型	范围	模拟 2010-2014			模拟 2046-2050			GT 上升
		年降雨量	暴雨量	比例	年降雨量	暴雨量	比例	
RCP4.5		724	93	13%	704	108	15%	1.4
RCP6.0	D01	773	93	12%	588	81	14%	
RCP8.5		724	73	10%	642	103	16%	2.0
RCP4.5		862	179	21%	937	218	23%	1.4
RCP6.0	D02	992	175	18%	730	161	22%	
RCP8.5		823	132	16%	820	204	25%	2.0

IDM


(a)
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
60S
0
60E
120E
180
120W
60W
0

LTSM


A
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
60S
0
60E
120E
180
120W
60W
0
-500
-200
-100
-10
10
100
200
500