

Report

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$$R^2(y, \hat{y}) = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2}, \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \quad (1)$$

$$T(t) = \frac{T_{RAW}(t) - \bar{T}_{RAW, train}}{\sigma_{RAW, train}} \quad (2)$$

$$T_{BC}(t) = T_{RAW} - (\bar{T}_{REF} - \bar{O}_{REF}) + \frac{\sigma_{O, REF}}{\sigma_{T, REF}} (T_{RAW}(t) - \bar{T}_{RAW}) \quad (3)$$

$$T_i(t) = \frac{\sum_{i=1}^n (w_i \cdot T_i(t))}{\sum_{i=1}^n w_i} \quad (4)$$

$$P_{BC}(t) = \frac{\sum_{i=1}^{42} P_{Obs}}{\sum_{i=1}^{42} P_{GCM}} P_{GCM}(t) \quad (5)$$

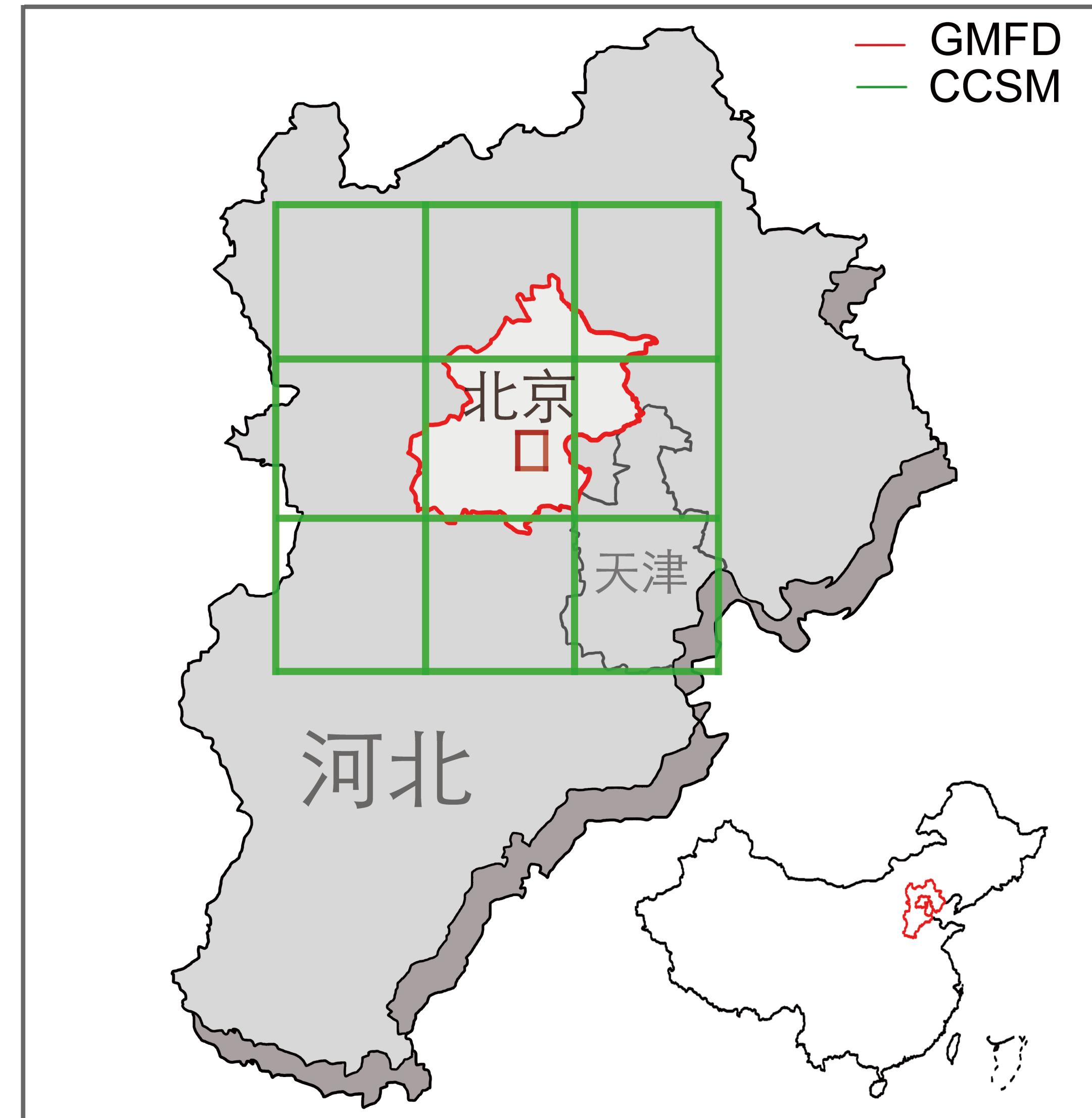


图 1 全球气候模式和观测数据分辨率对比

Fig. 1 The Comparison of CCSM4 and GMFD's resolution

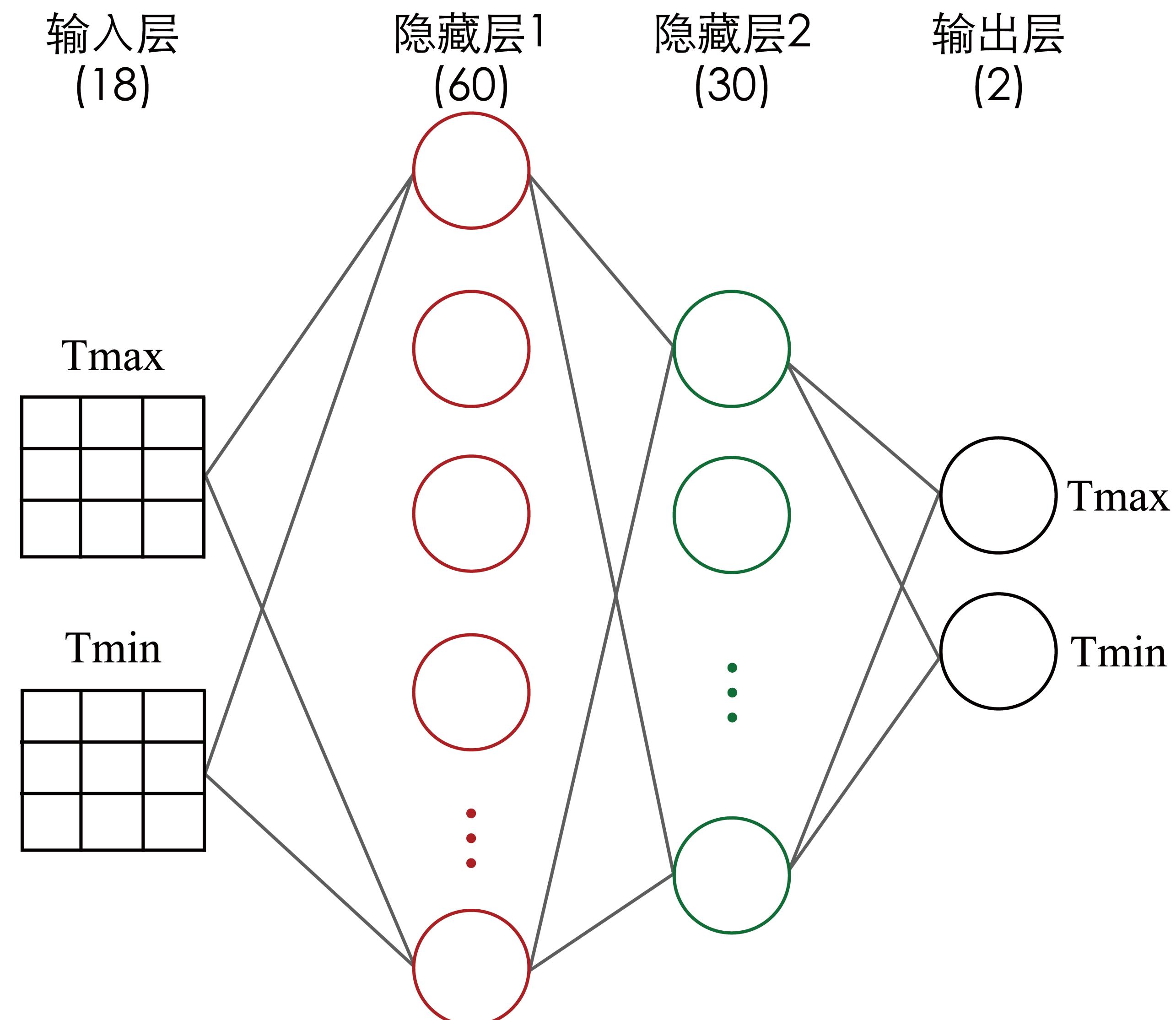
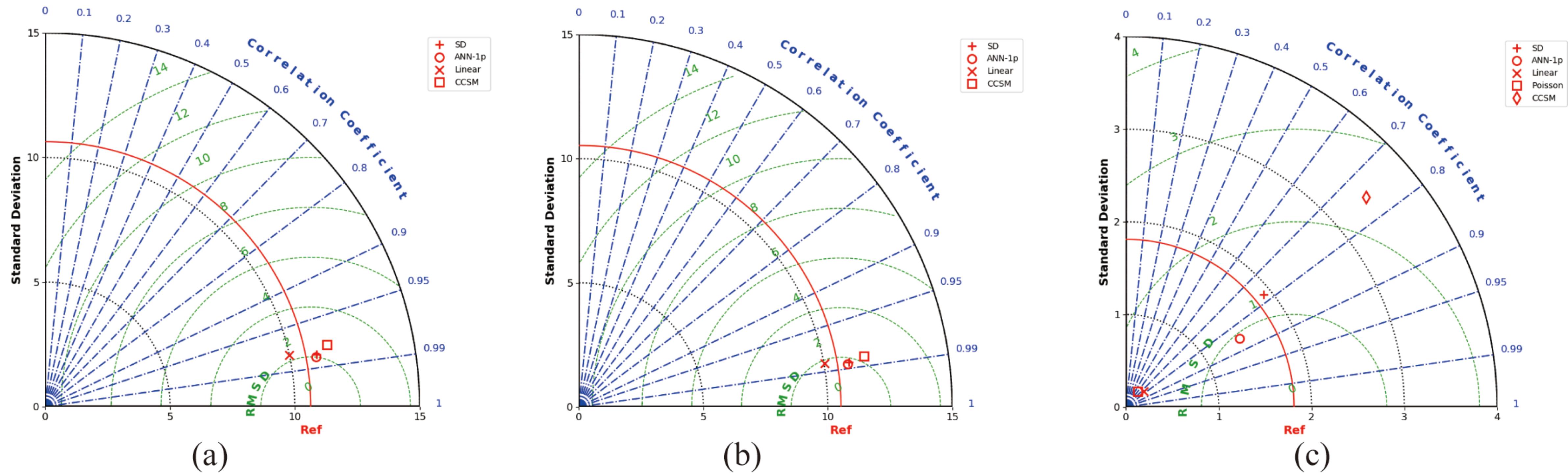


图 2 多层感知器神经网络结构

Fig. 2 The Architecture of MLP Regressor



(a) 七月日最高温，不同统计降尺度方法在北京地区的表现，十字代表SD方法，圆代表ANN仅使用1个CCSM4格点输入并进行偏差校正的方法，斜十字代表多元线性回归方法，正方形代表原始的CCSM4数据；(b) 一月日最低温，不同统计降尺度方法在北京地区的表现，十字代表SD方法，圆代表ANN仅使用1个CCSM4格点输入并进行偏差校正的方法，斜十字代表多元线性回归方法，正方形代表原始的CCSM4数据；(c) 七月日降水，不同统计降尺度方法在北京地区的表现，十字代表SD方法，圆代表ANN仅使用1个CCSM4格点输入的方法，斜十字代表一元线性回归方法，正方形代表泊松回归方法，菱形代表原始的CCSM4数据

图 3 日最高温、日最低温和日降水在北京格点的不同统计降尺度方法泰勒图

Fig. 3 Taylor diagram for Tmax, Tmin and Pr in Beijing

表 1 日最高温、日最低温和日降水在验证集上的表现

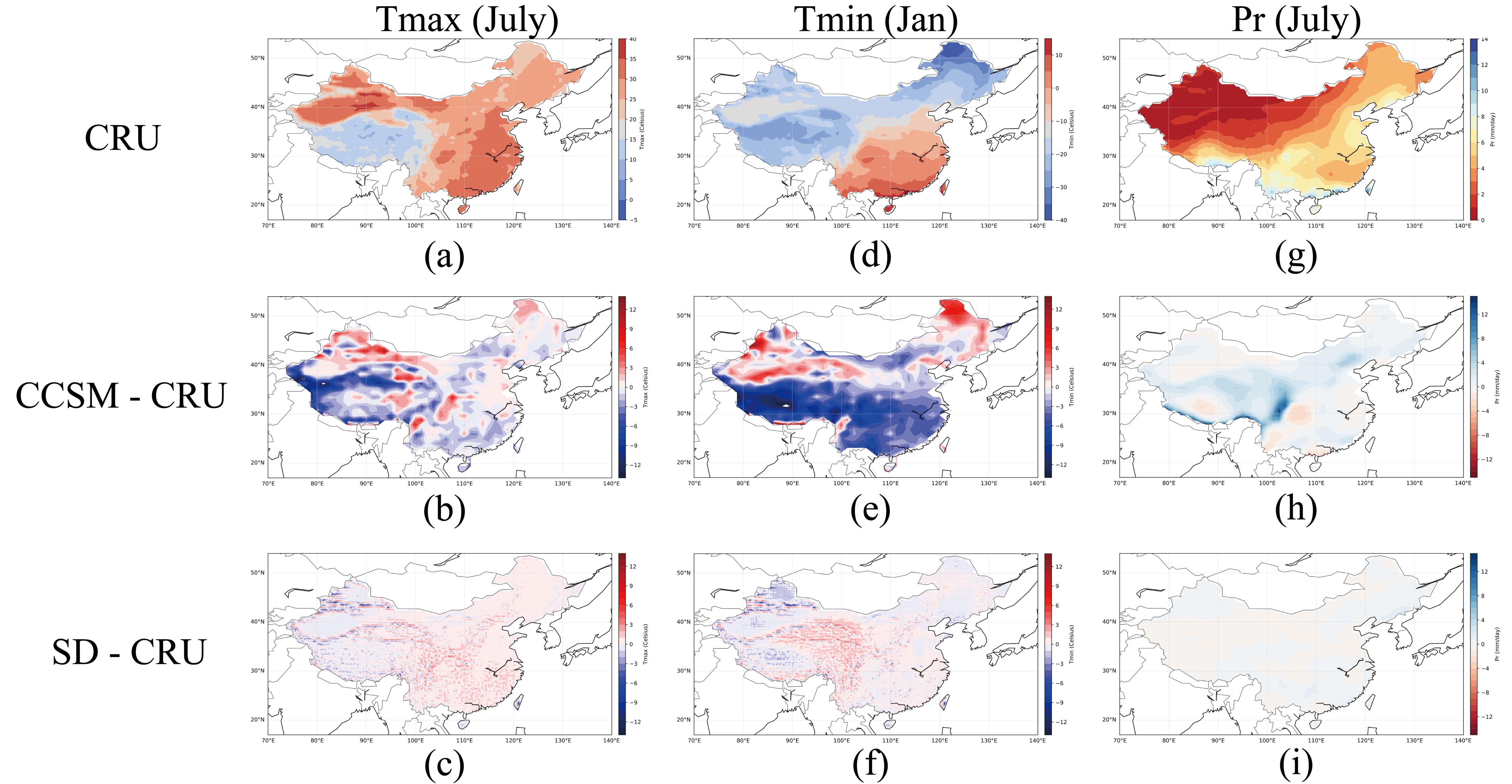
Table 1 The quantities during training period of Tmax, Tmin and Pr (China)

Tmax (July)			Tmin (Jan)			Pr (July)			
	Obs	CCSM4	SD	Obs	CCSM4	SD	Obs	CCSM4	SD
Mean	25.05	24.56	25.25	-13.79	-16.38	-13.62	3.66	4.64	3.67
StdDev	0.43	0.73	0.66	1.10	1.12	0.86	0.33	0.47	0.42
RMSE		0.91	0.73		2.98	1.28		1.17	0.59

表 2 日最高温、日最低温和日降水在验证集上的表现

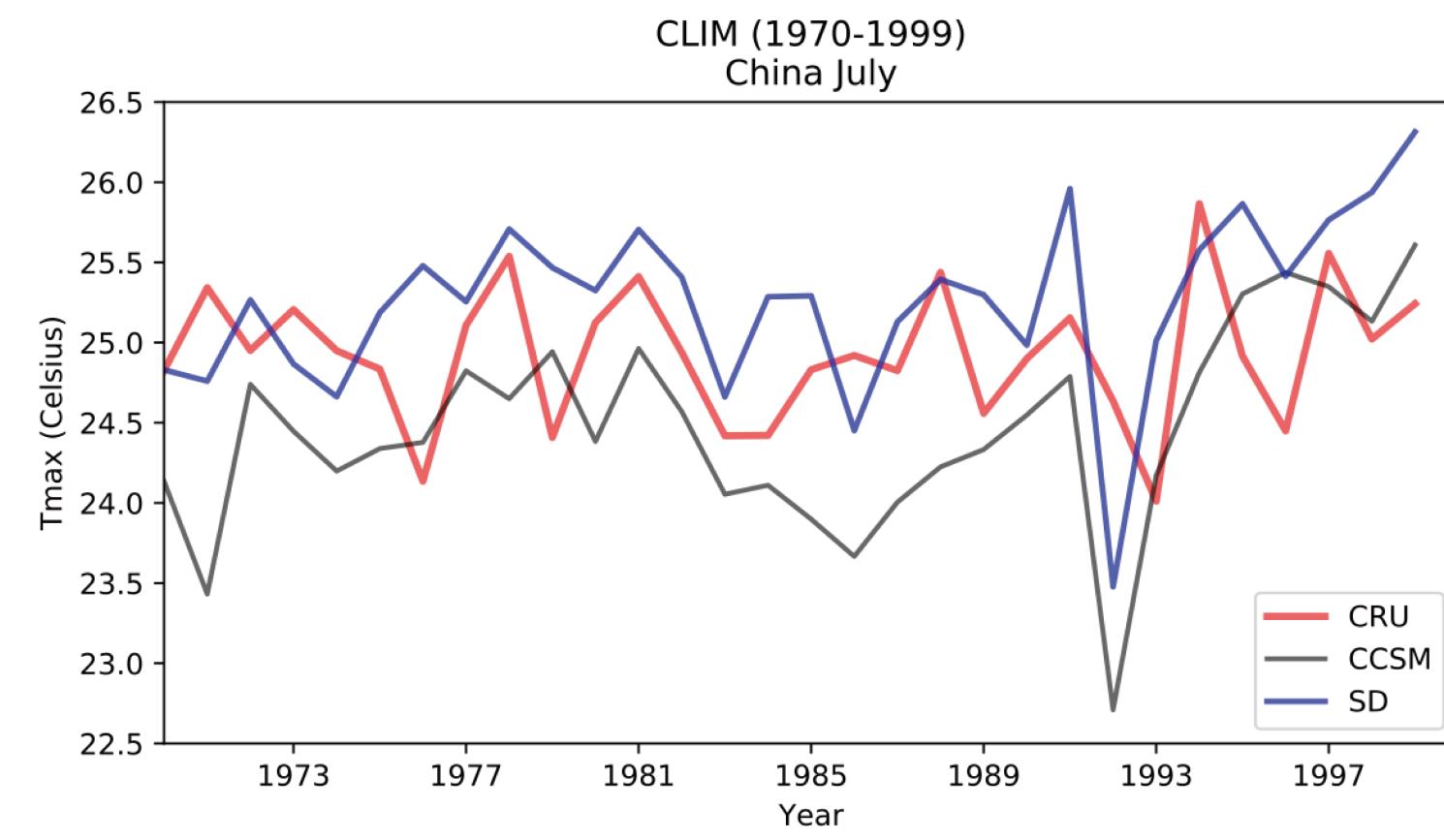
Table 2 The qualities during validation period of Tmax, Tmin and Pr (China)

Tmax (July)			Tmin (Jan)			Pr (July)			
	Obs	CCSM4	SD	Obs	CCSM4	SD	Obs	CCSM4	SD
Mean	25.17	24.52	25.21	-13.89	-16.17	-13.70	3.69	4.68	3.74
StdDev	0.56	0.69	0.59	0.85	0.88	0.71	0.22	0.40	0.34
RMSE		0.89	0.55		2.49	1.01		1.09	0.44

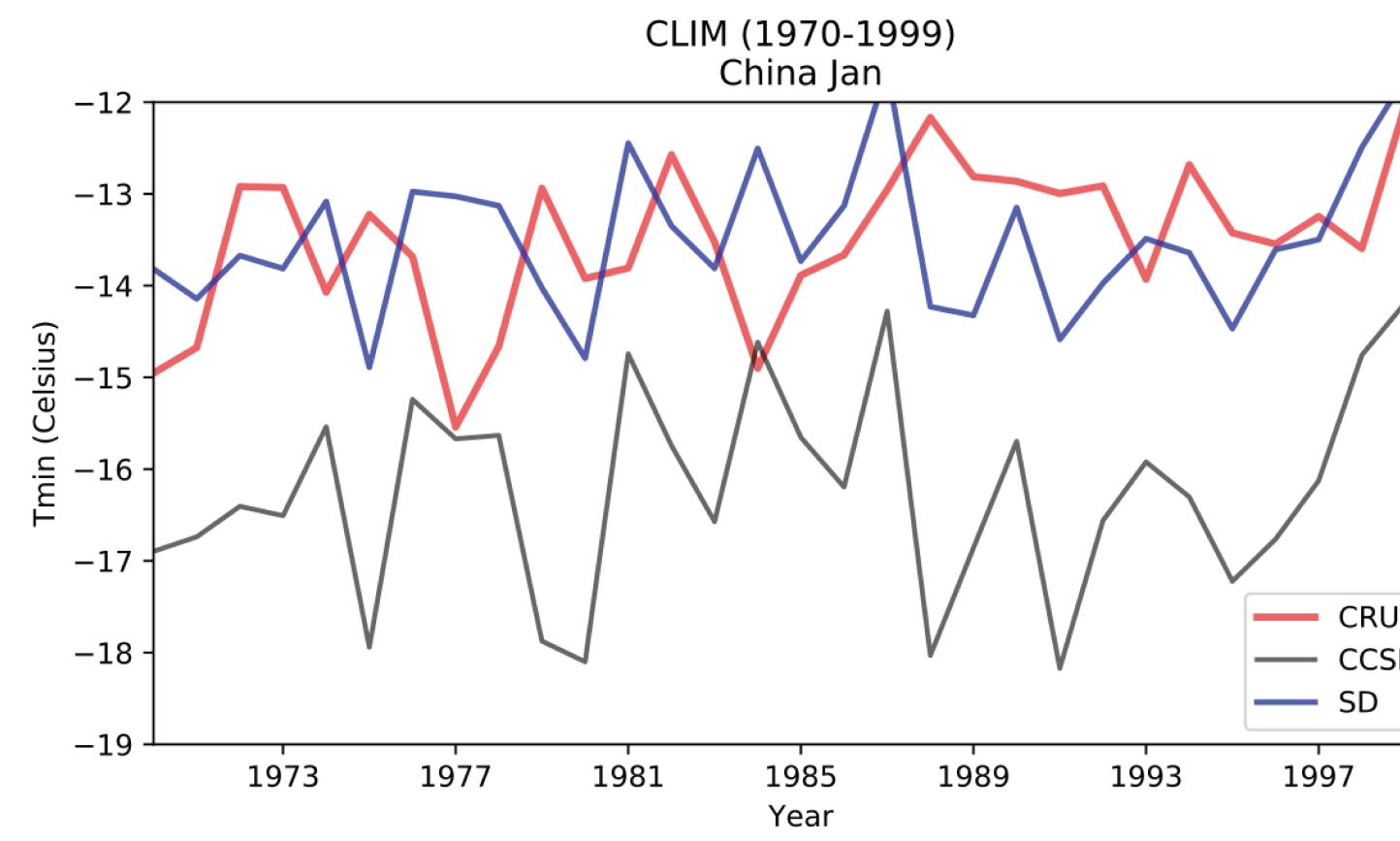


(a)-(c) 七月日最高温; (d)-(f) 一月日最低温; (g)-(i) 七月日降水; (a), (d)和(g) 1970-1999 CRU空间分布; (b), (e)和(h) 1970-1999 CCSM4和CRU的差值; (c), (f)和(i) 1970-1999 SD和CRU的差值

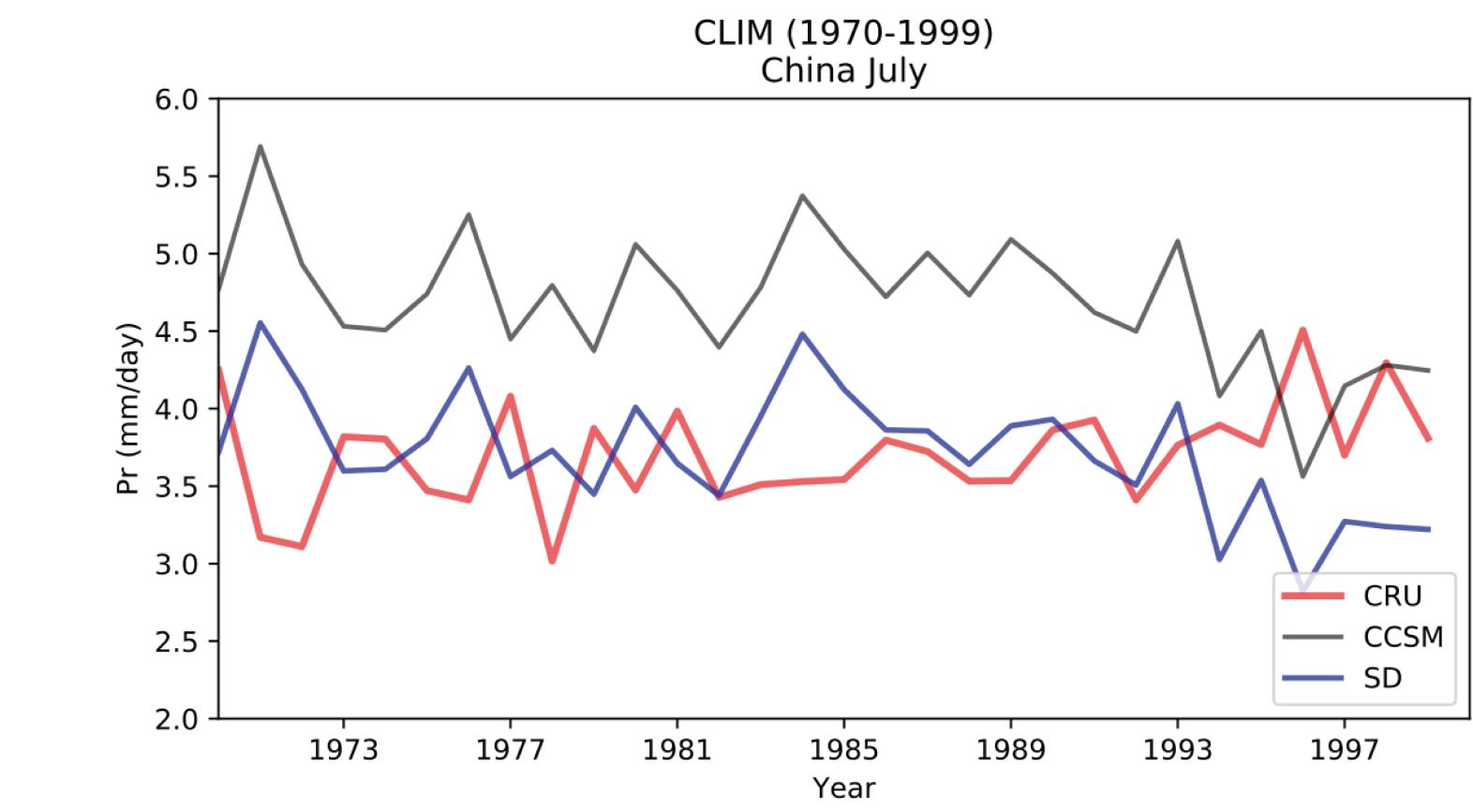
图 4 1970-1999 日最高温、日最低温和日降水平均值空间分布对比
Fig. 4 Tmax, Tmin and Pr's mean value in 1970-1999 in spatial



(a)



(b)



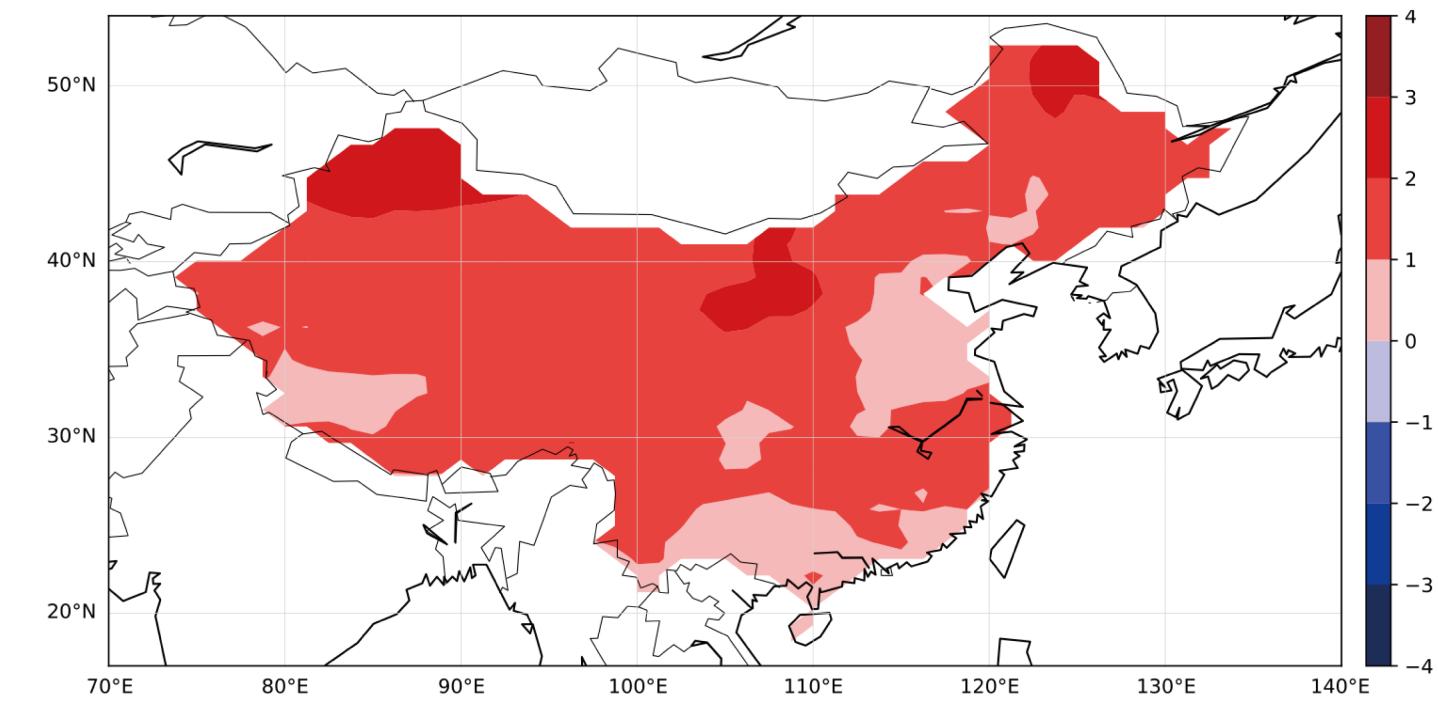
(c)

(a)-(c) 红色实线代表CRU，黑色实线代表CCSM4，蓝色实线代表SD；(a) 1970-1999中国所有格点七月日最高温做加权平均后的时间序列；
(b) 1970-1999中国所有格点一月日最低温做加权平均后的时间序列；(c) 1970-1999中国所有格点七月日降水做加权平均后的时间序列

图 5 1970-1999中国日最高温、日最低温和日降水时间序列对比
Fig. 5 The comparison of Tmax, Tmin and Pr in 1970-1999 in time series (China)

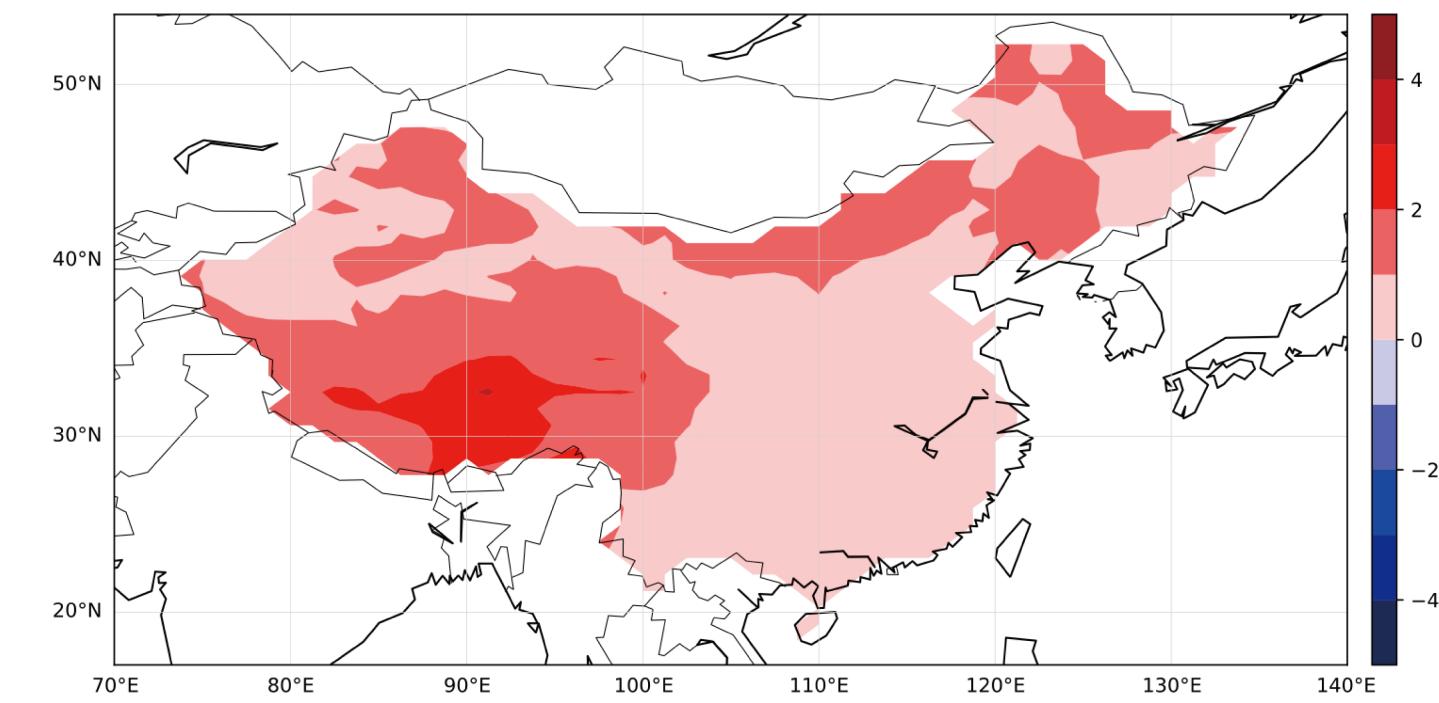
CCSM

Tmax (July)



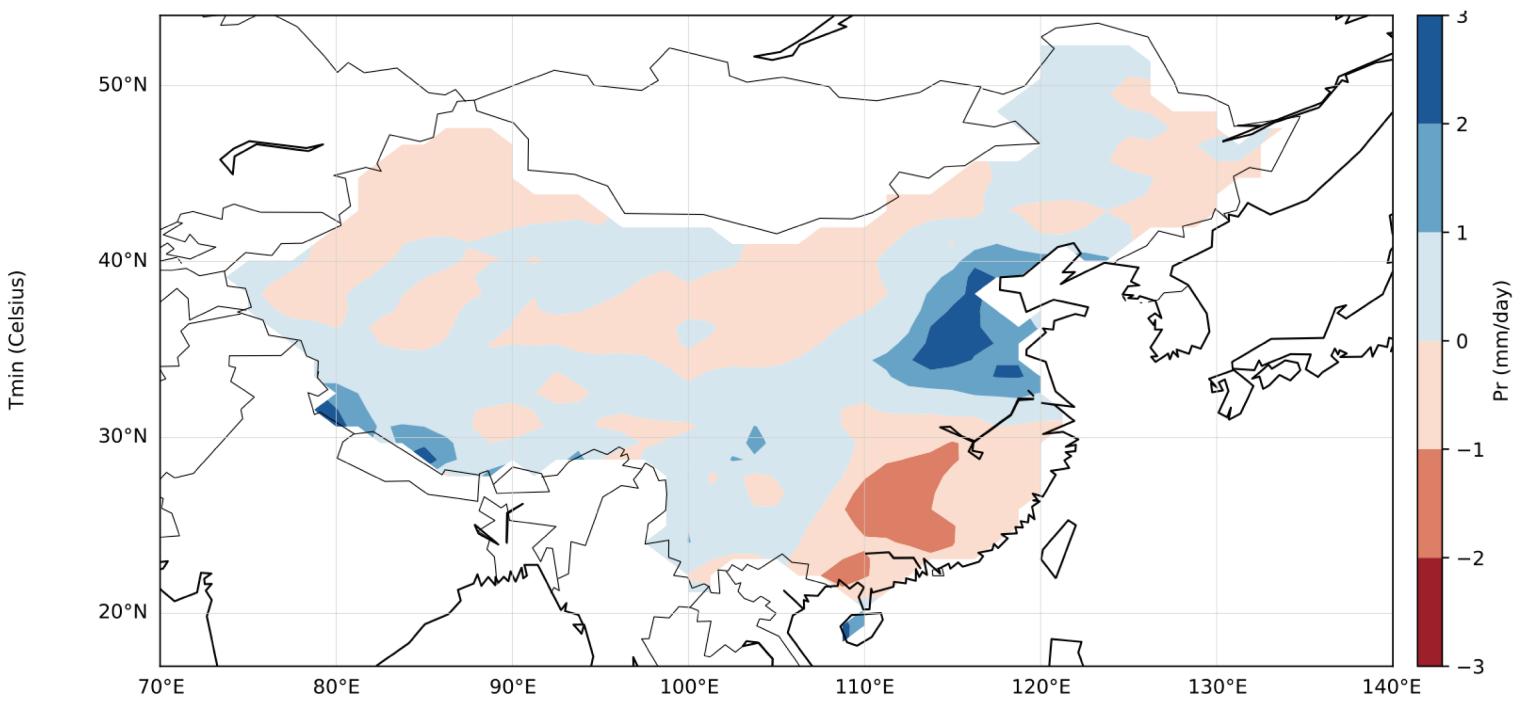
(a)

Tmin (Jan)



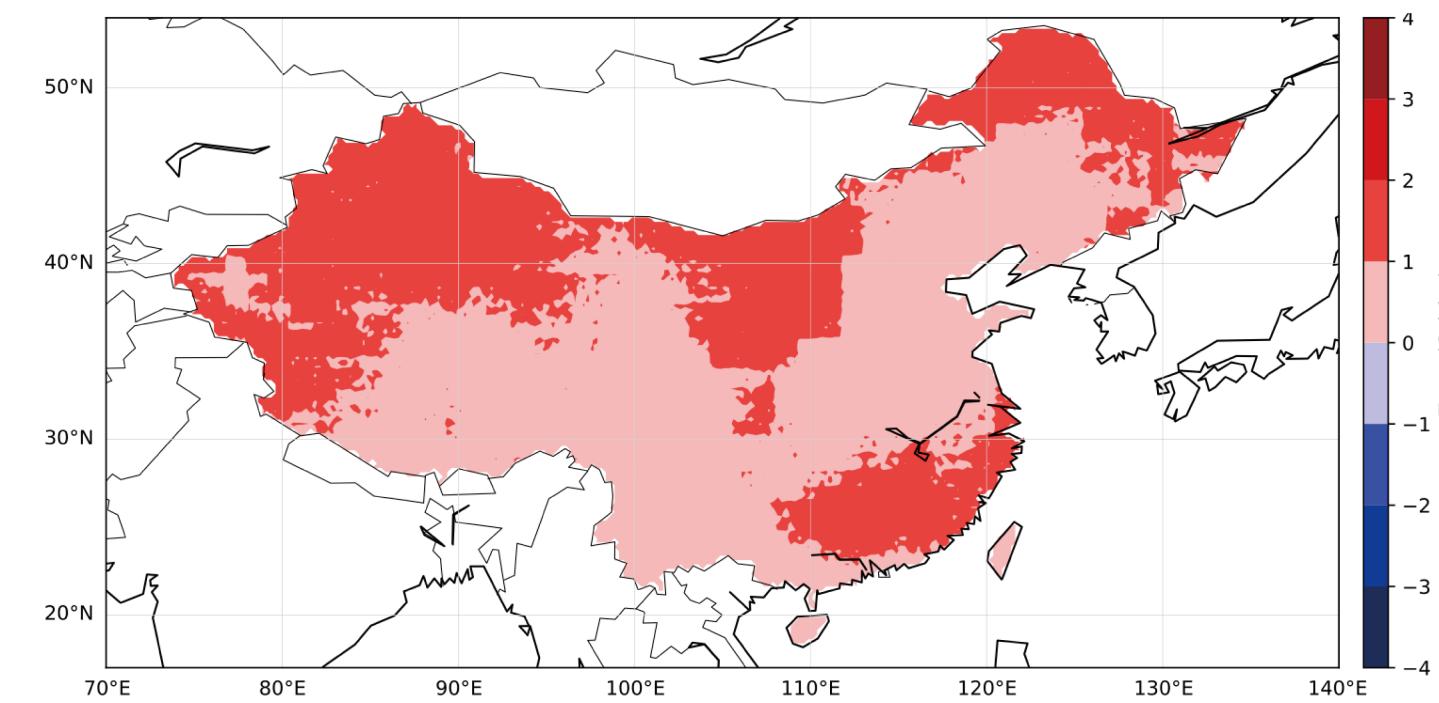
(c)

Pr (July)

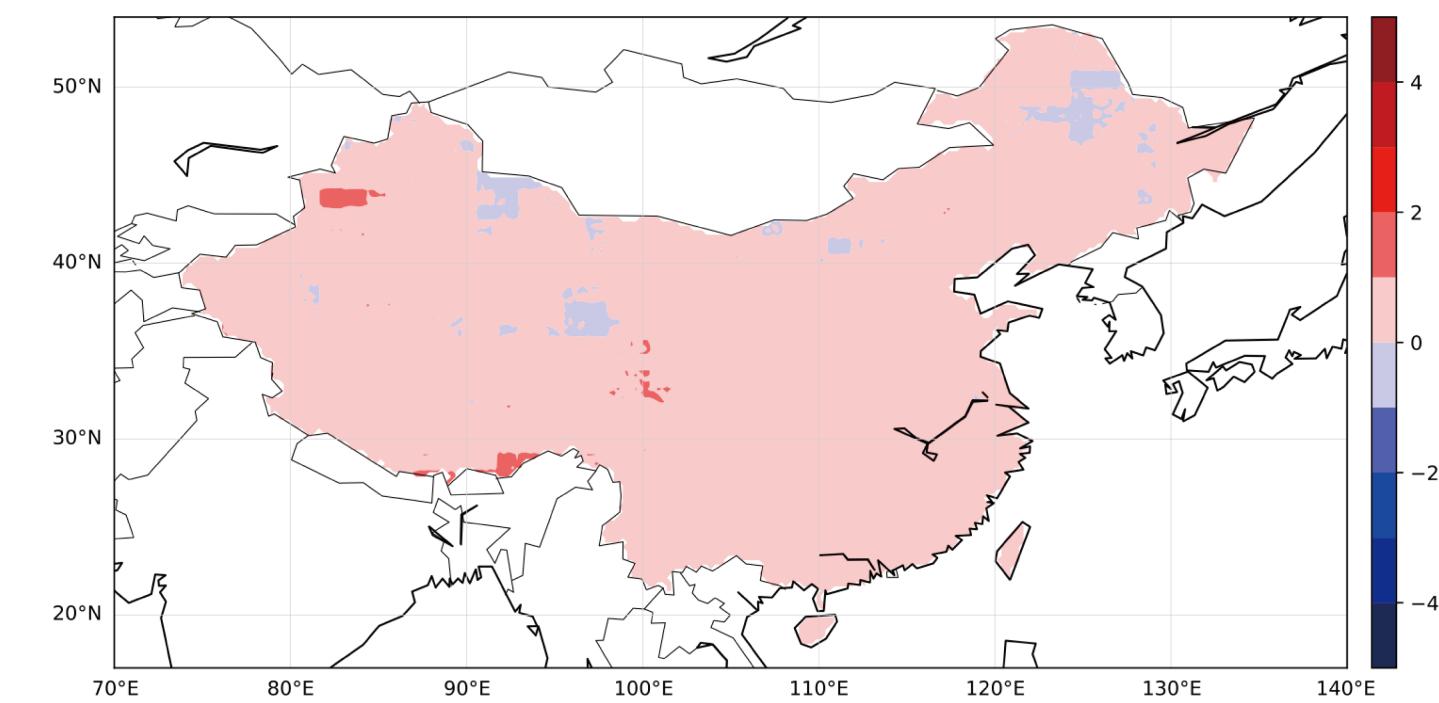


(e)

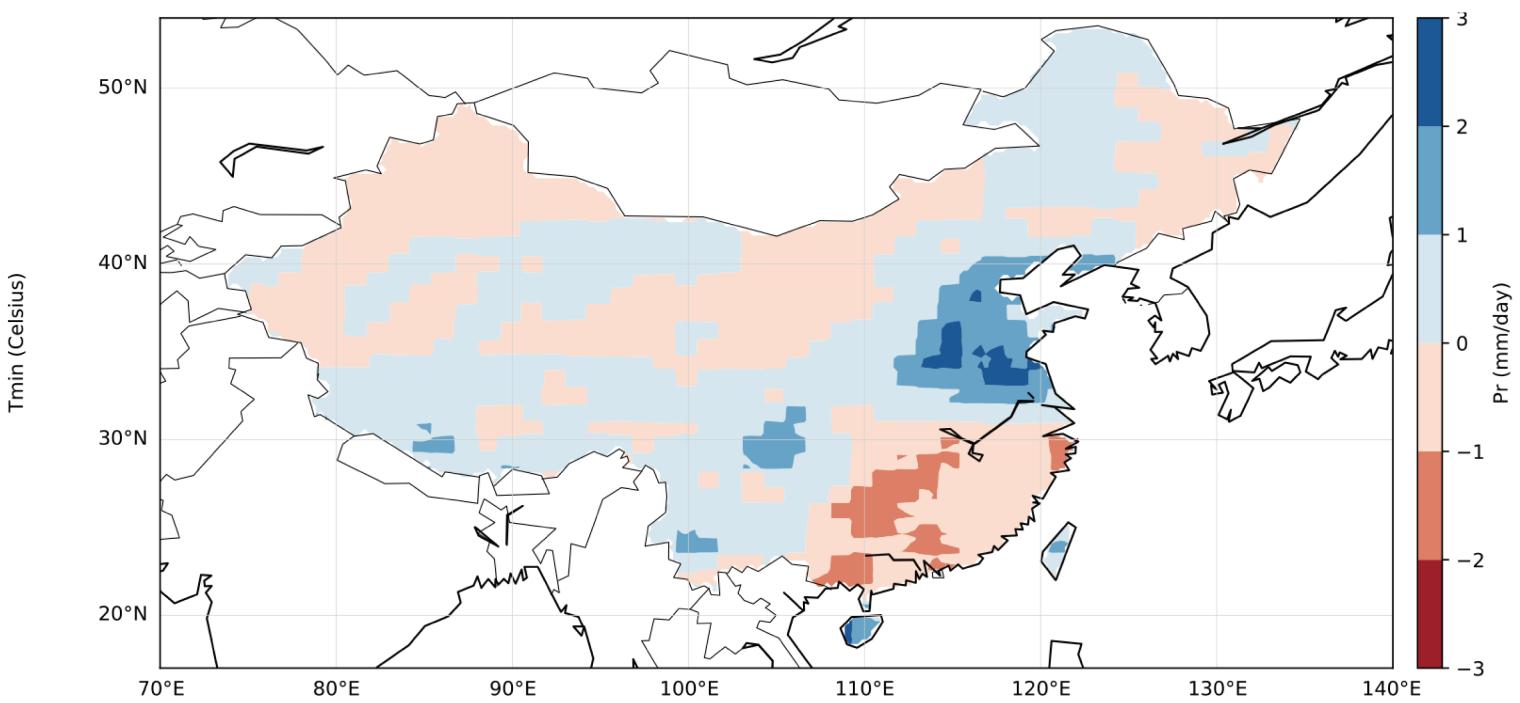
SD



(b)



(d)



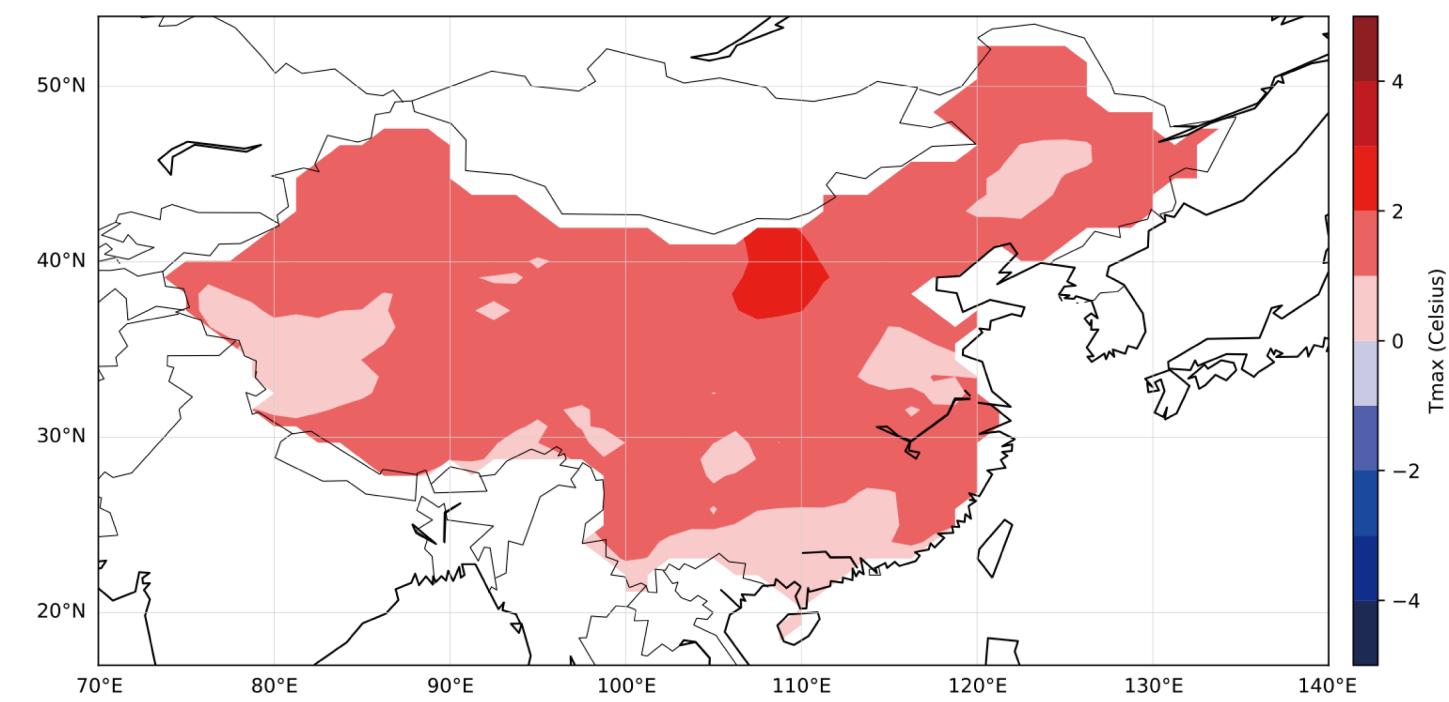
(f)

(a)-(b) 七月日最高温; (c)-(d) 一月日最低温; (e)-(f) 七月日降水; (a), (c)和(e) RCP2.6情境下2020-2049 CCSM4相较于1979-1999 CCSM4的差值; (b), (d)和(f) RCP2.6情境下2020-2049 SD相较于1970-1999 SD的差值

图 6 RCP2.6情景下2020-2049日最高温、日最低温和日降水气候变化空间分布
Fig. 6 RCP2.6 scenario's Tmax, Tmin and Pr's climate change in 2020-2049 in spatial

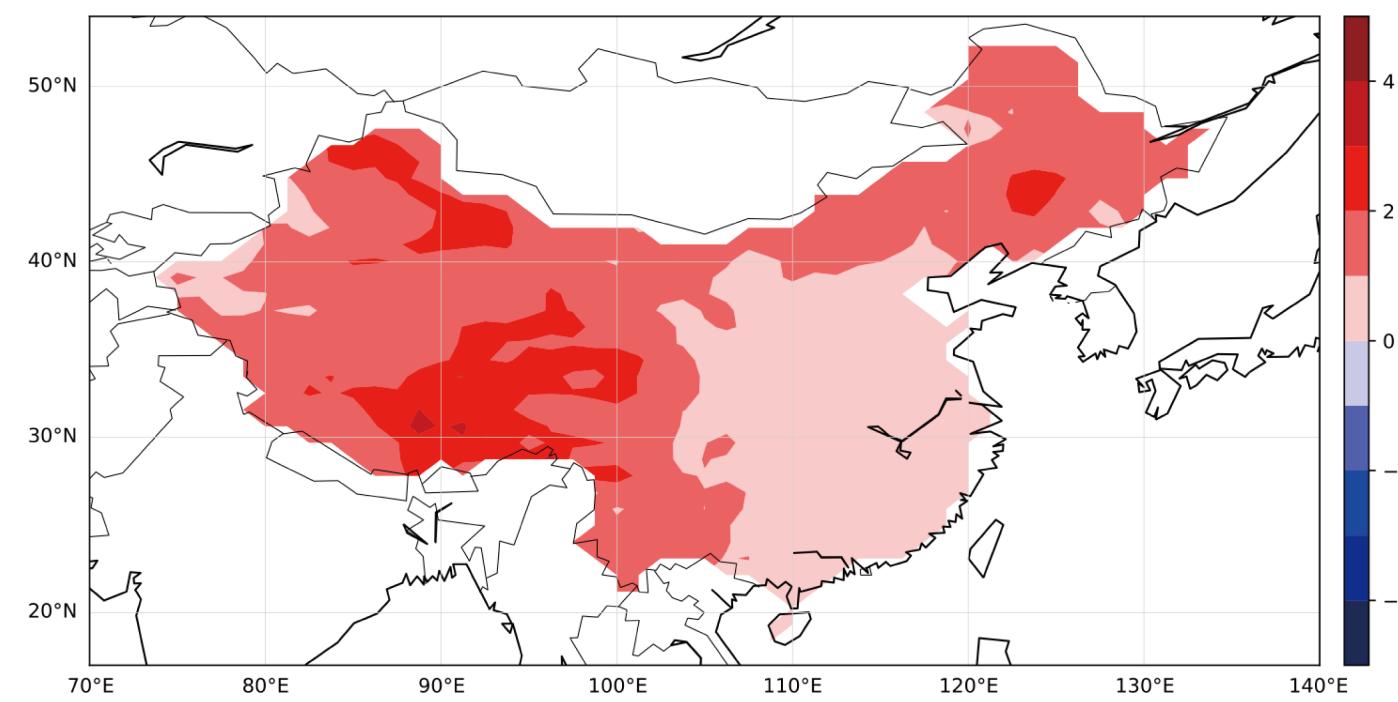
CCSM

Tmax (July)



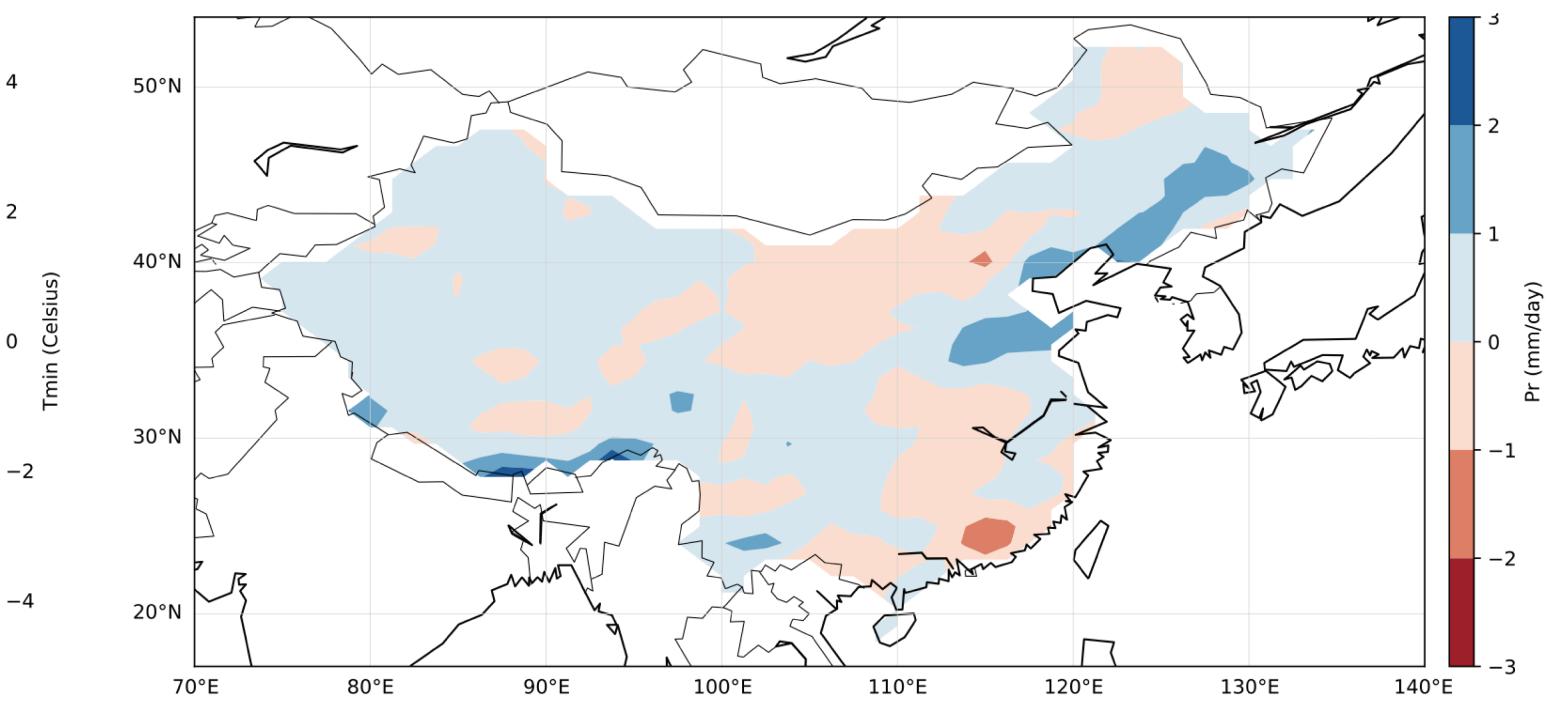
(a)

Tmin (Jan)



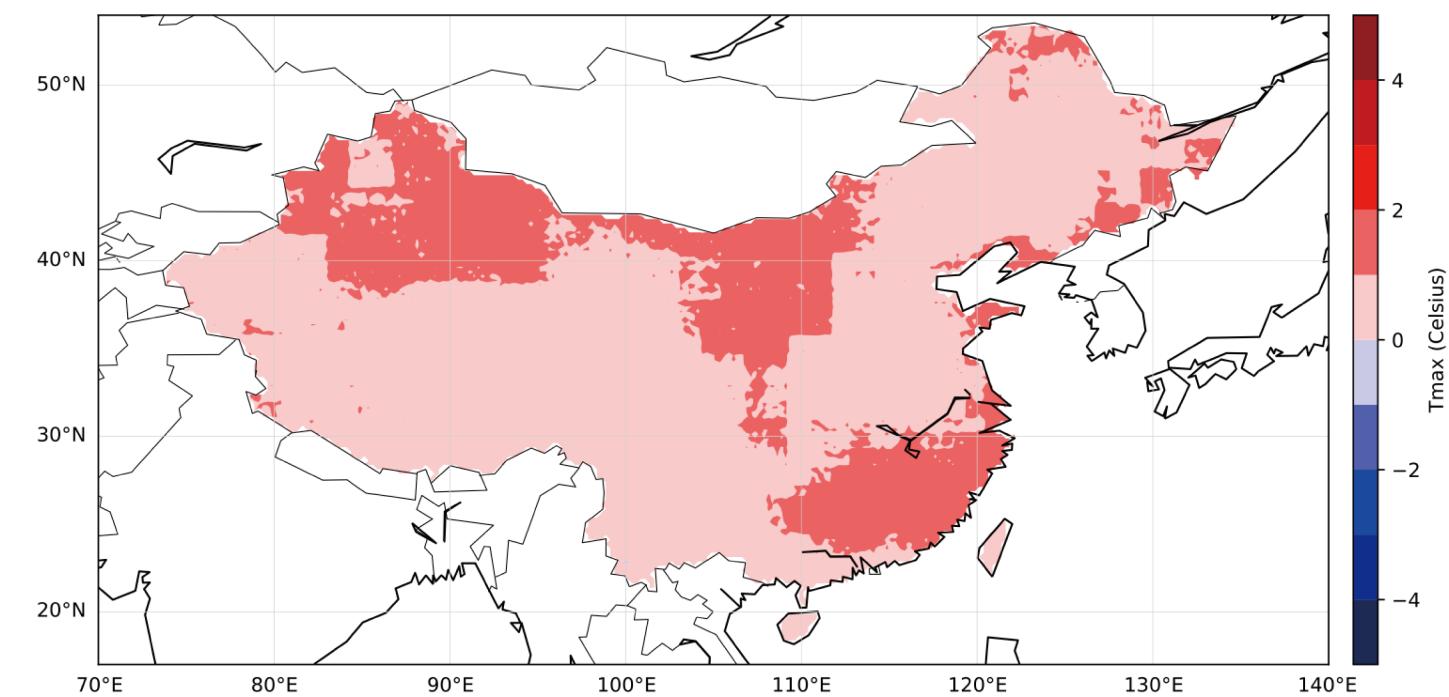
(c)

Pr (July)

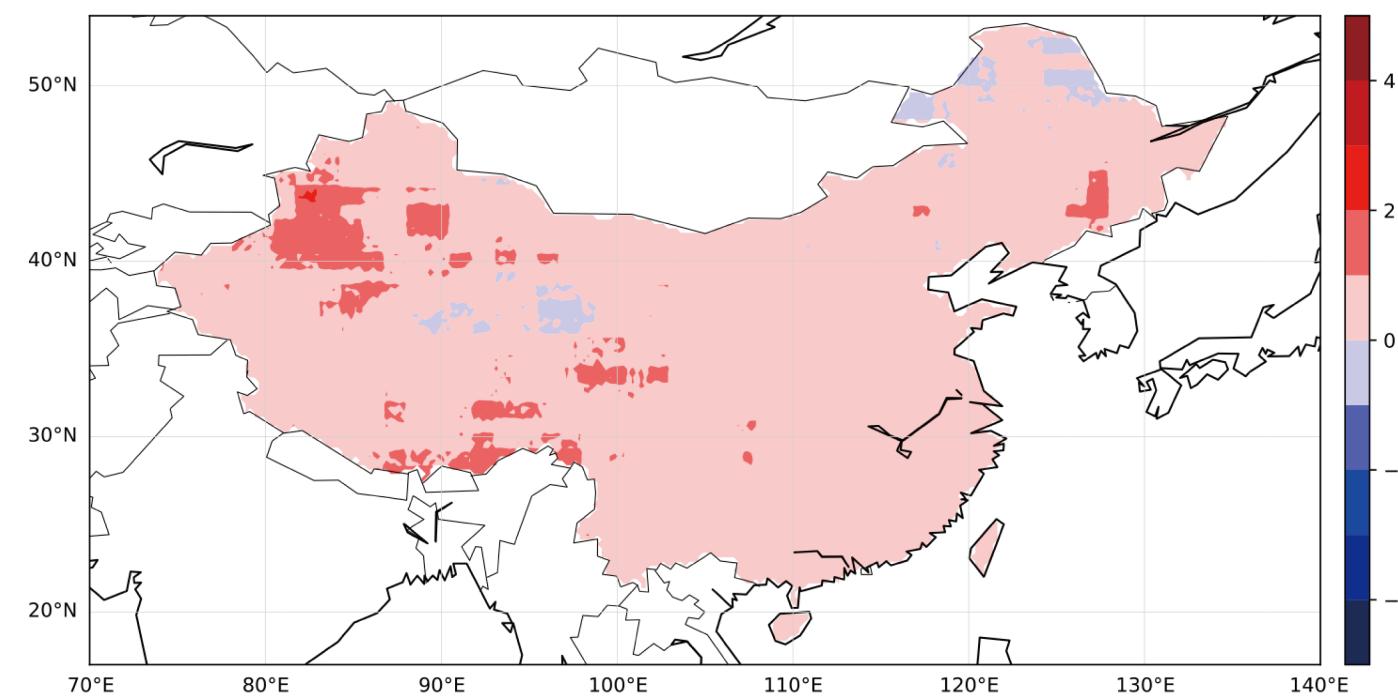


(e)

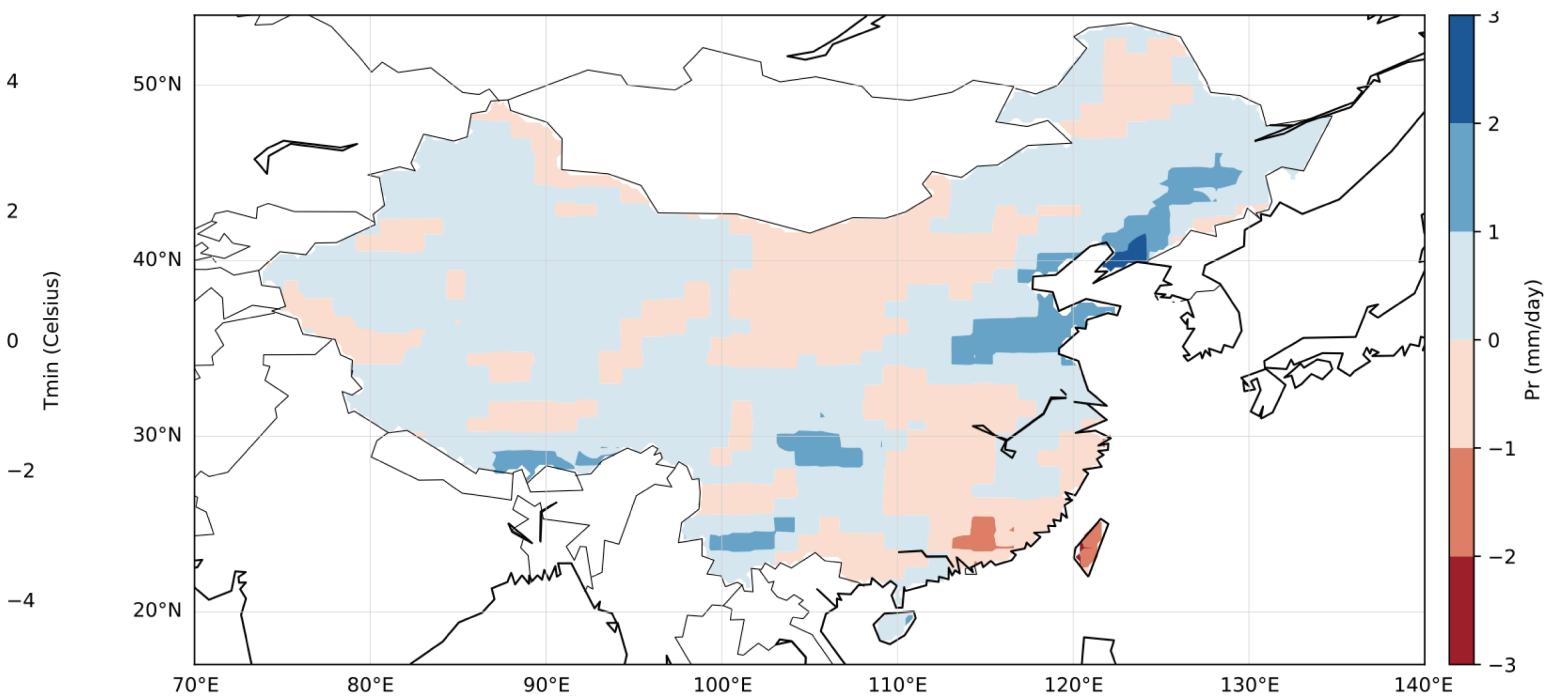
SD



(b)



(d)



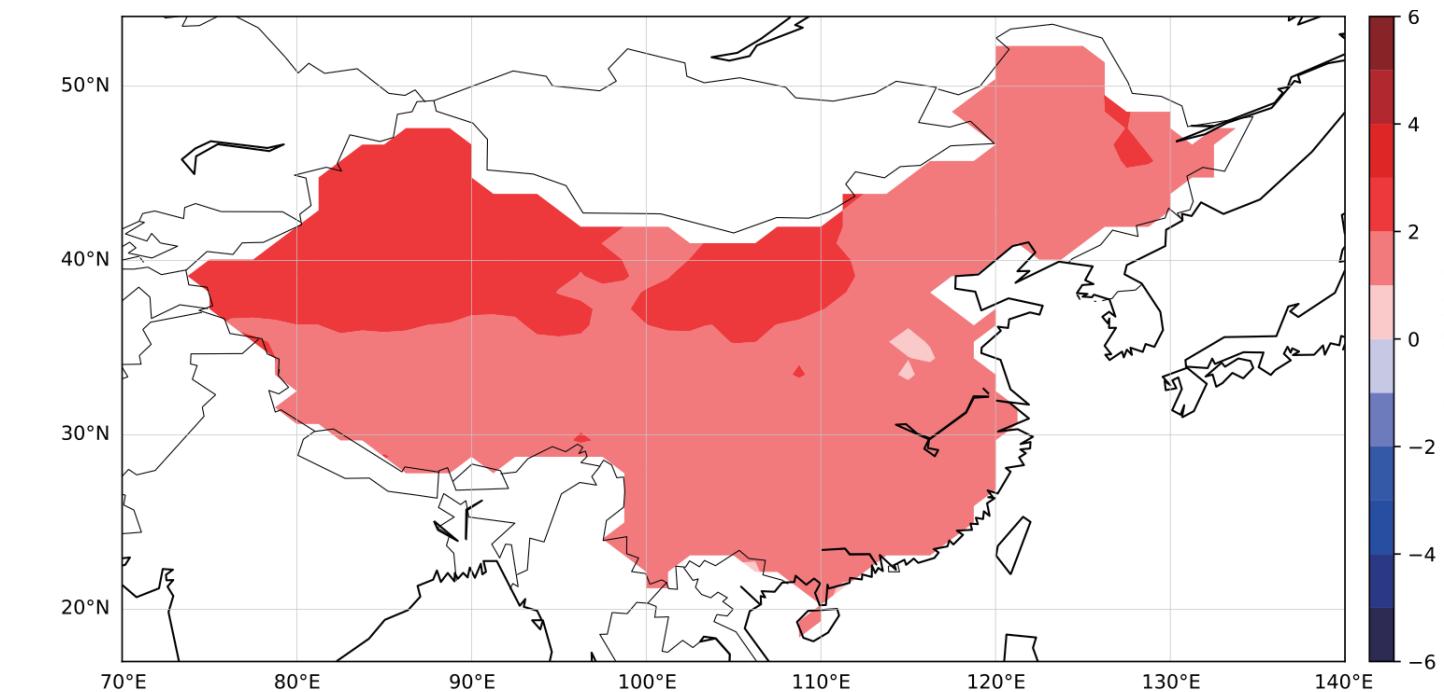
(f)

(a)-(b) 七月日最高温; (c)-(d) 一月日最低温; (e)-(f) 七月日降水; (a), (c)和(e) RCP2.6情境下2070-2099 CCSM4相较于1979-1999 CCSM4的差值; (b), (d)和(f) RCP2.6情境下2070-2099 SD相较于1970-1999 SD的差值

图 7 RCP2.6情景下2070-2099日最高温、日最低温和日降水气候变化空间分布
Fig. 7 RCP2.6 scenario's Tmax, Tmin and Pr's climate change in 2070-2099 in spatial

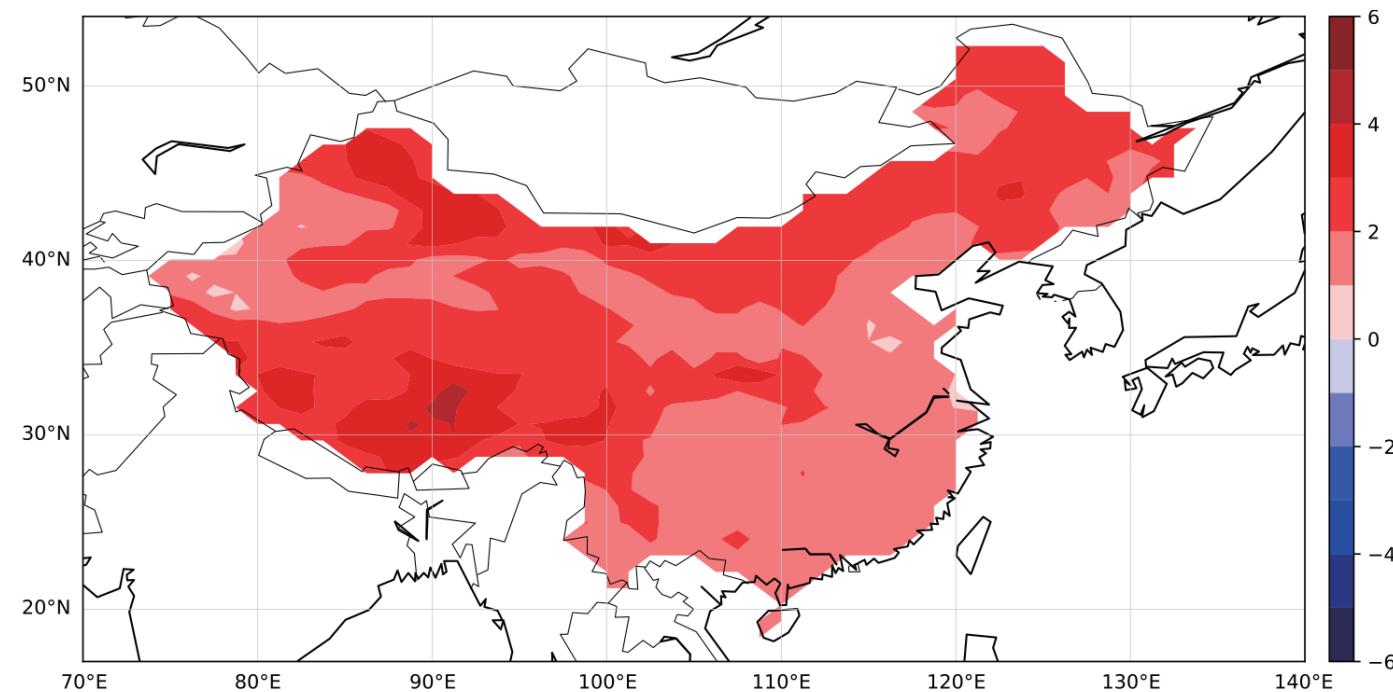
CCSM

Tmax (July)



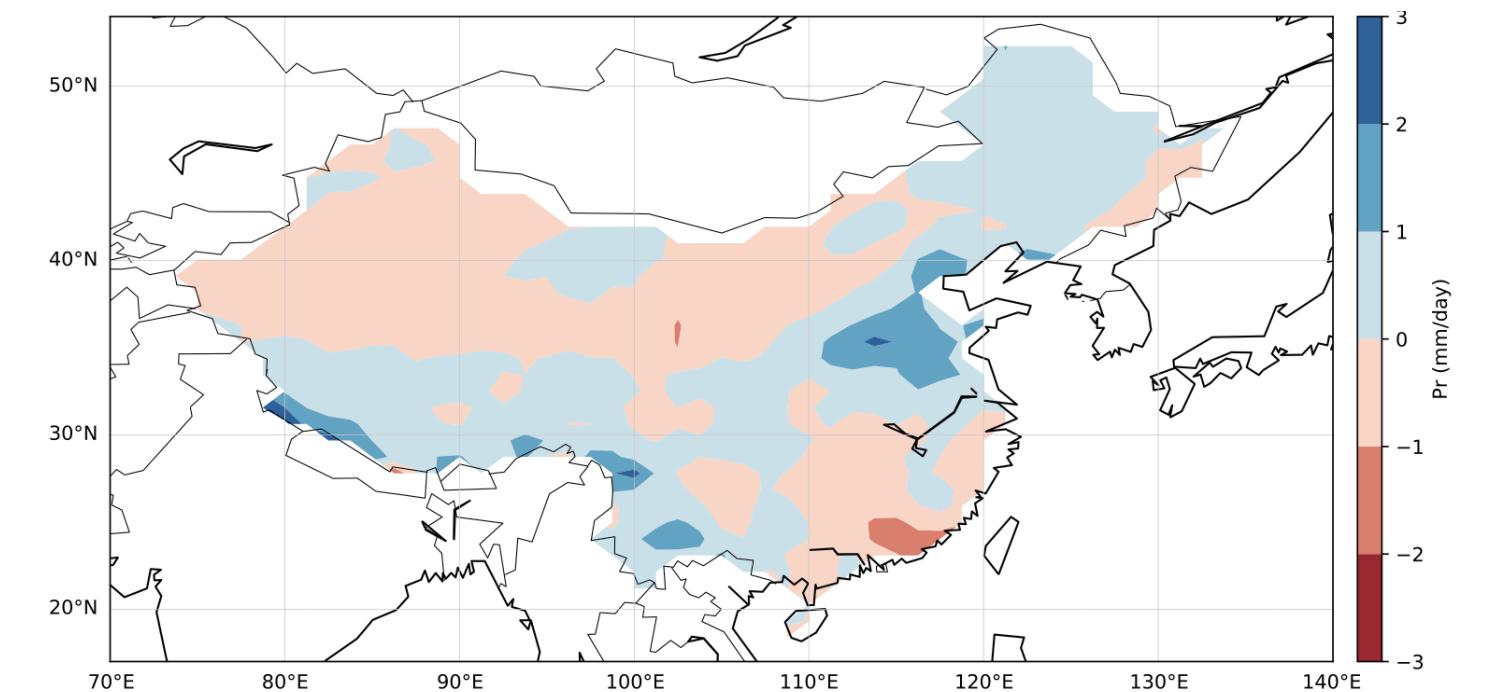
(a)

Tmin (Jan)



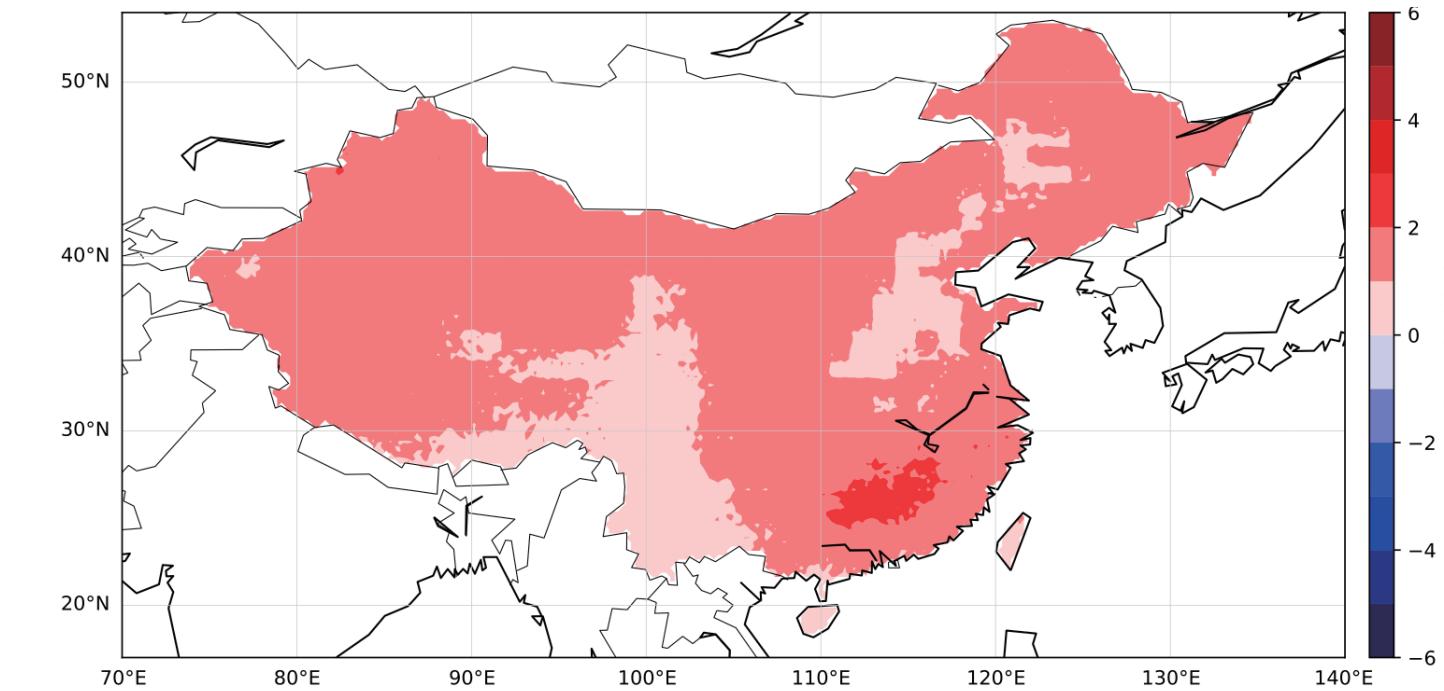
(c)

Pr (July)

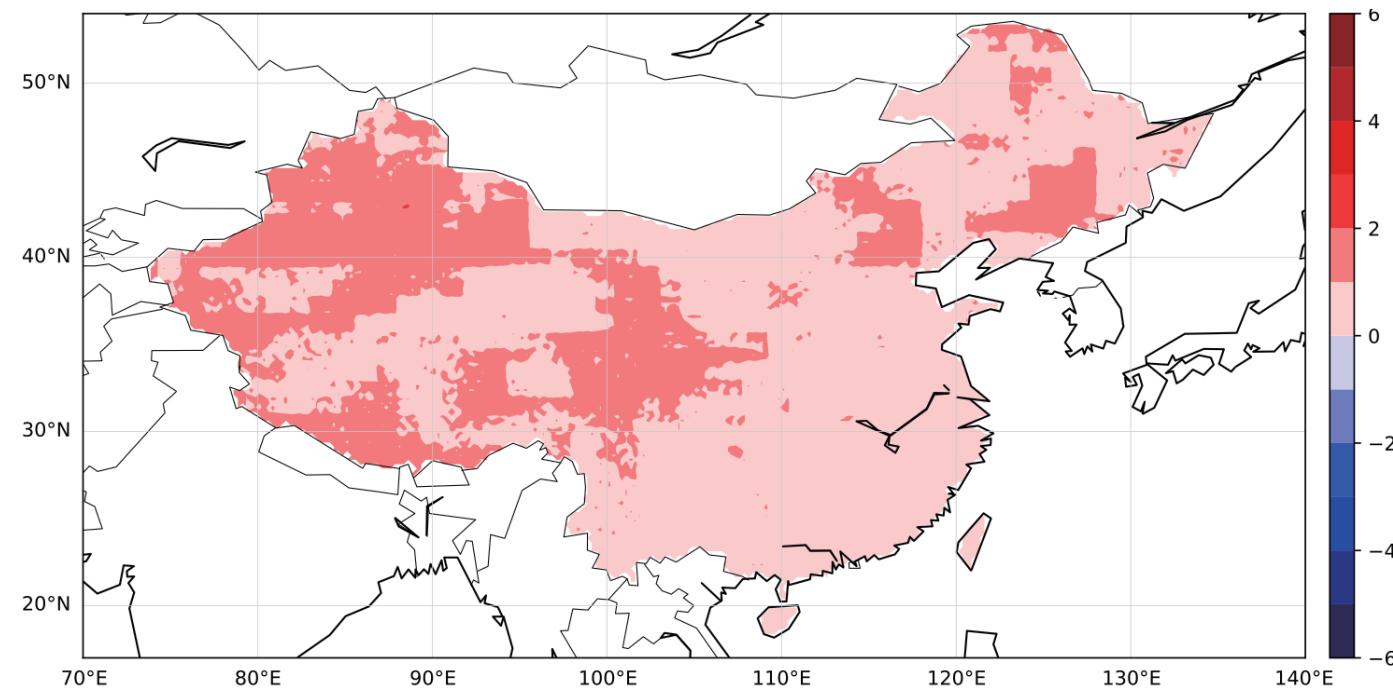


(e)

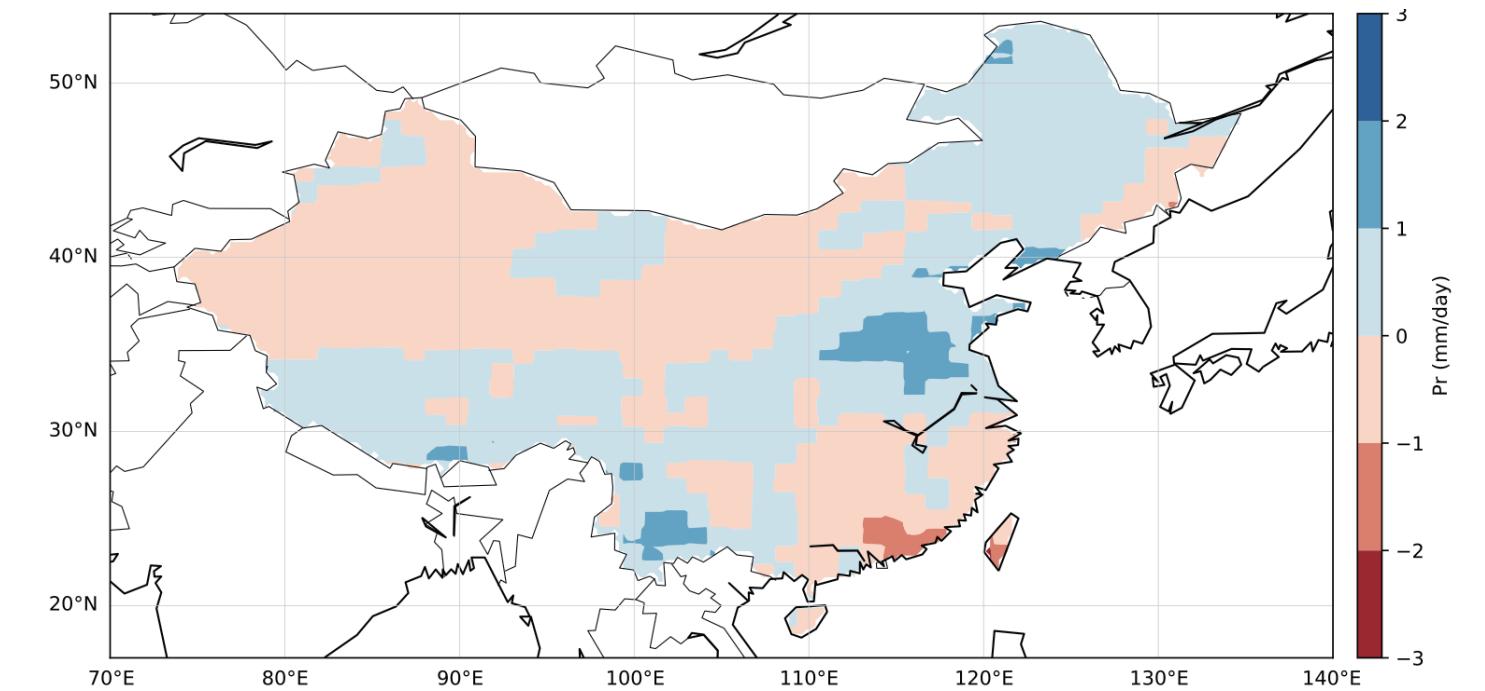
SD



(b)



(d)



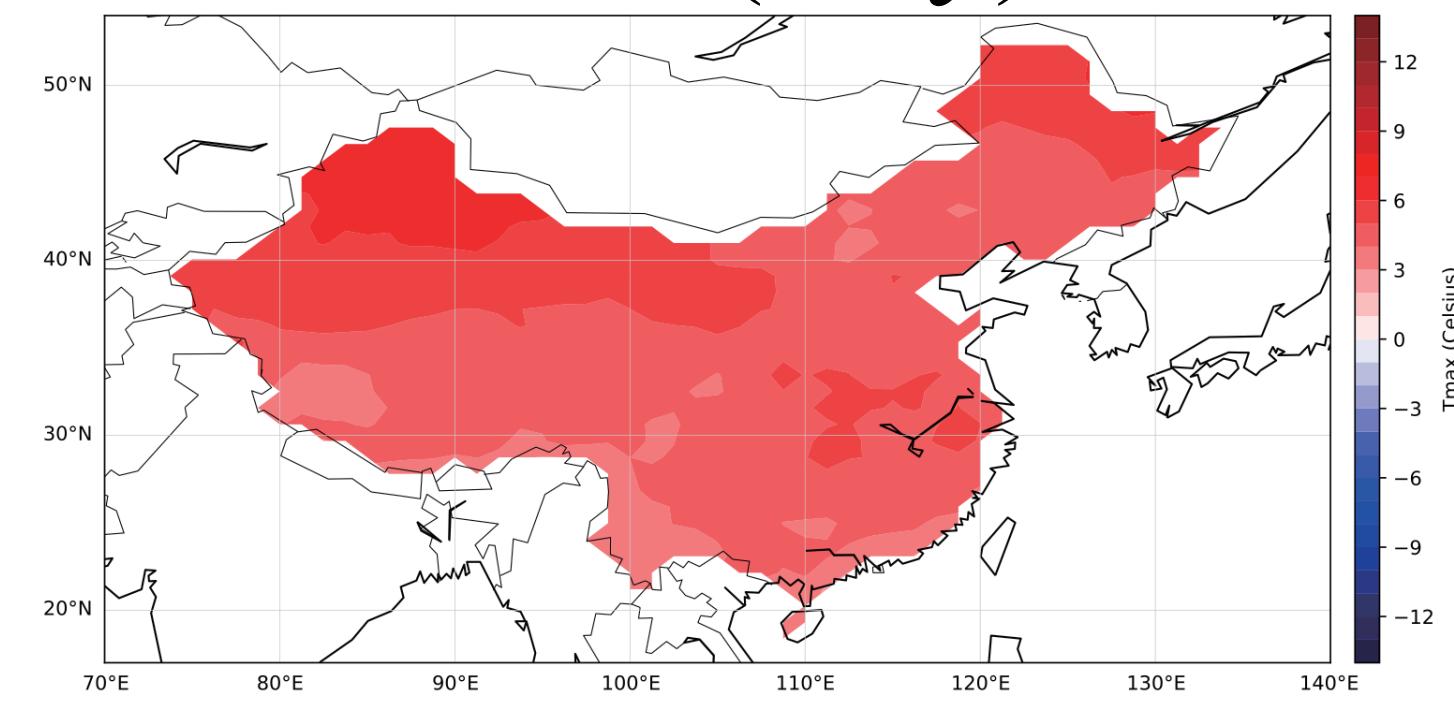
(f)

(a)-(b) 七月日最高温; (c)-(d) 一月日最低温; (e)-(f) 七月日降水; (a), (c)和(e) RCP8.5情境下2020-2049 CCSM4相较于1979-1999 CCSM4的差值; (b), (d)和(f) RCP8.5情境下2020-2049 SD相较于1970-1999 SD的差值

图 8 RCP8.5情景下2020-2049日最高温、日最低温和日降水气候变化空间分布
Fig. 8 RCP8.5 scenario's Tmax, Tmin and Pr's climate change in 2020-2049 in spatial

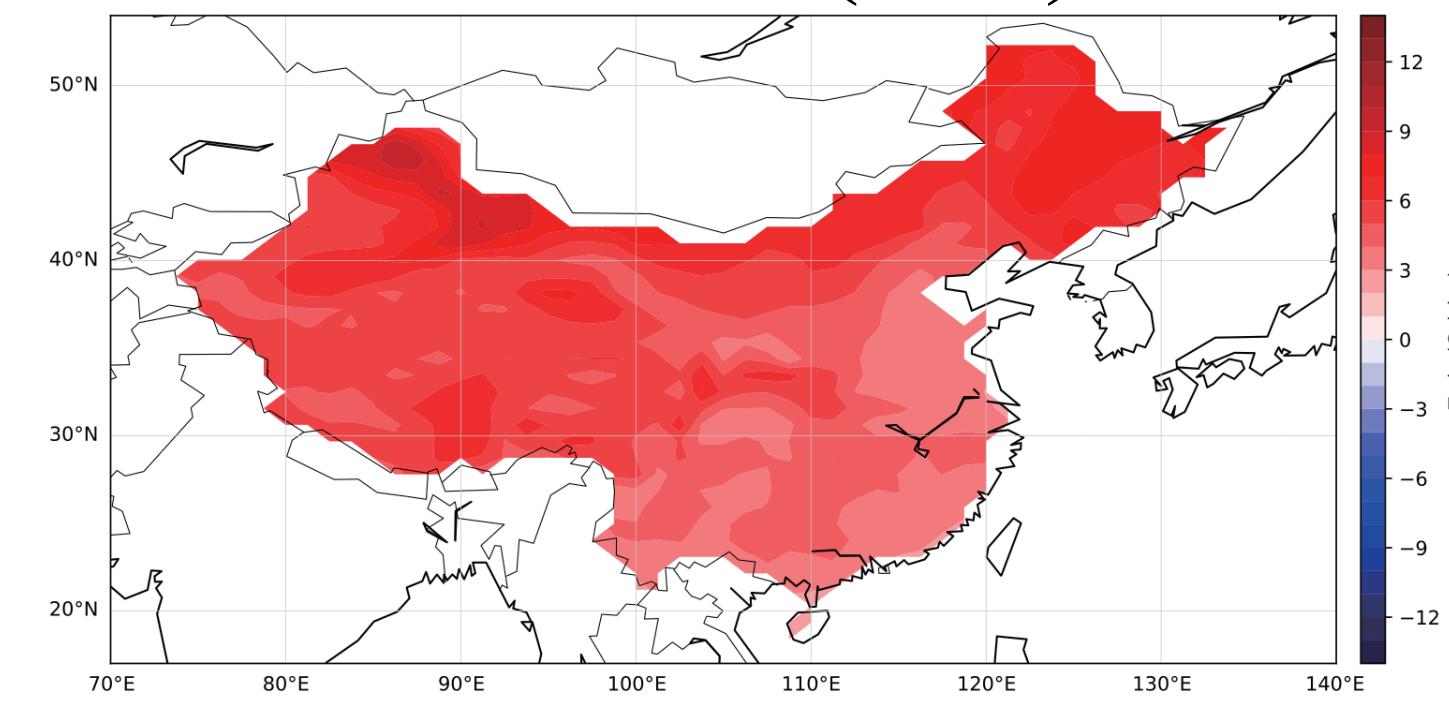
CCSM

Tmax (July)



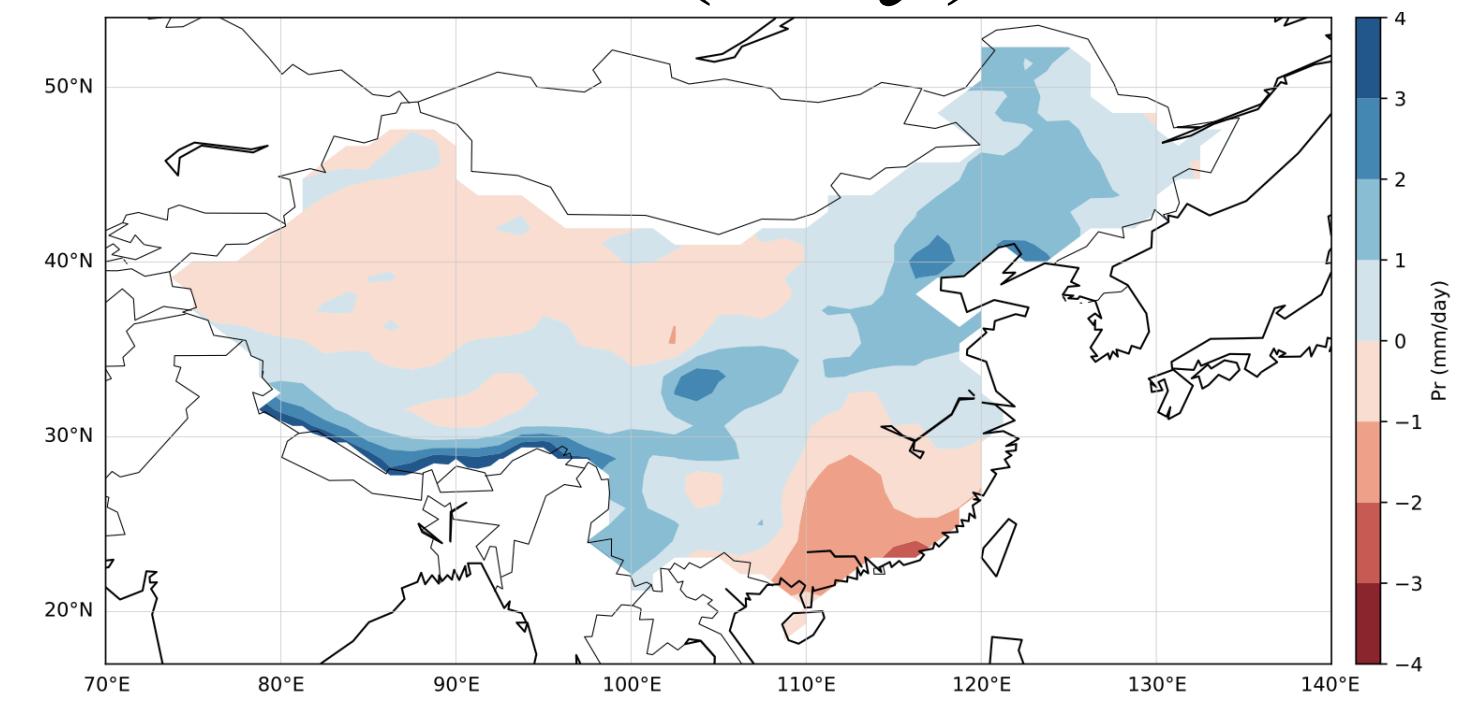
(a)

Tmin (Jan)



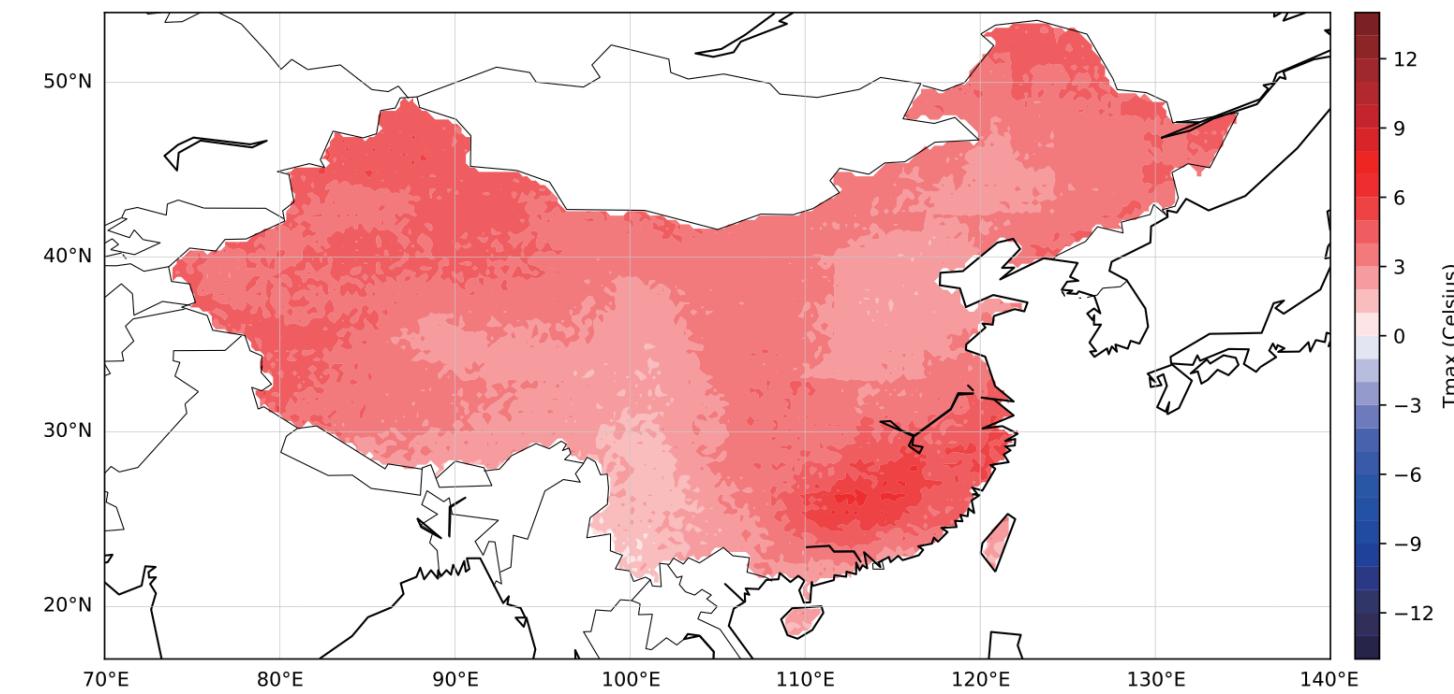
(c)

Pr (July)

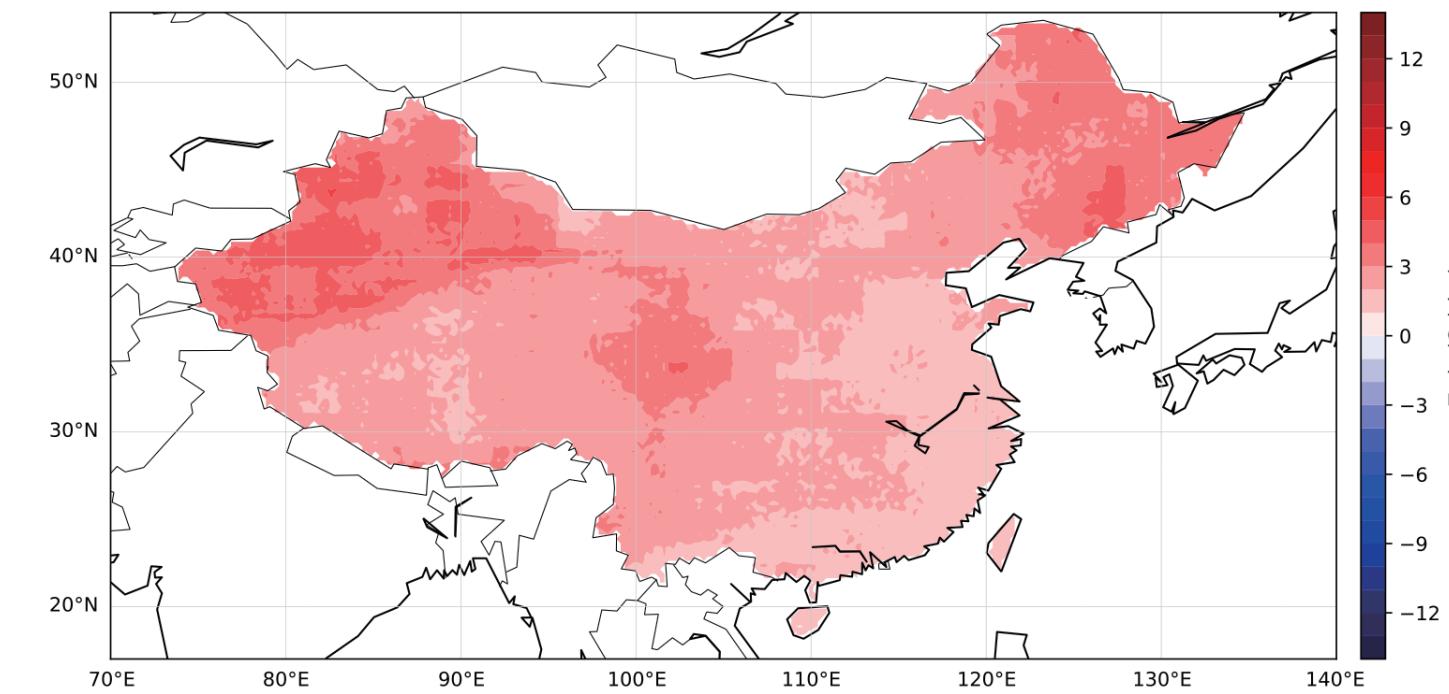


(e)

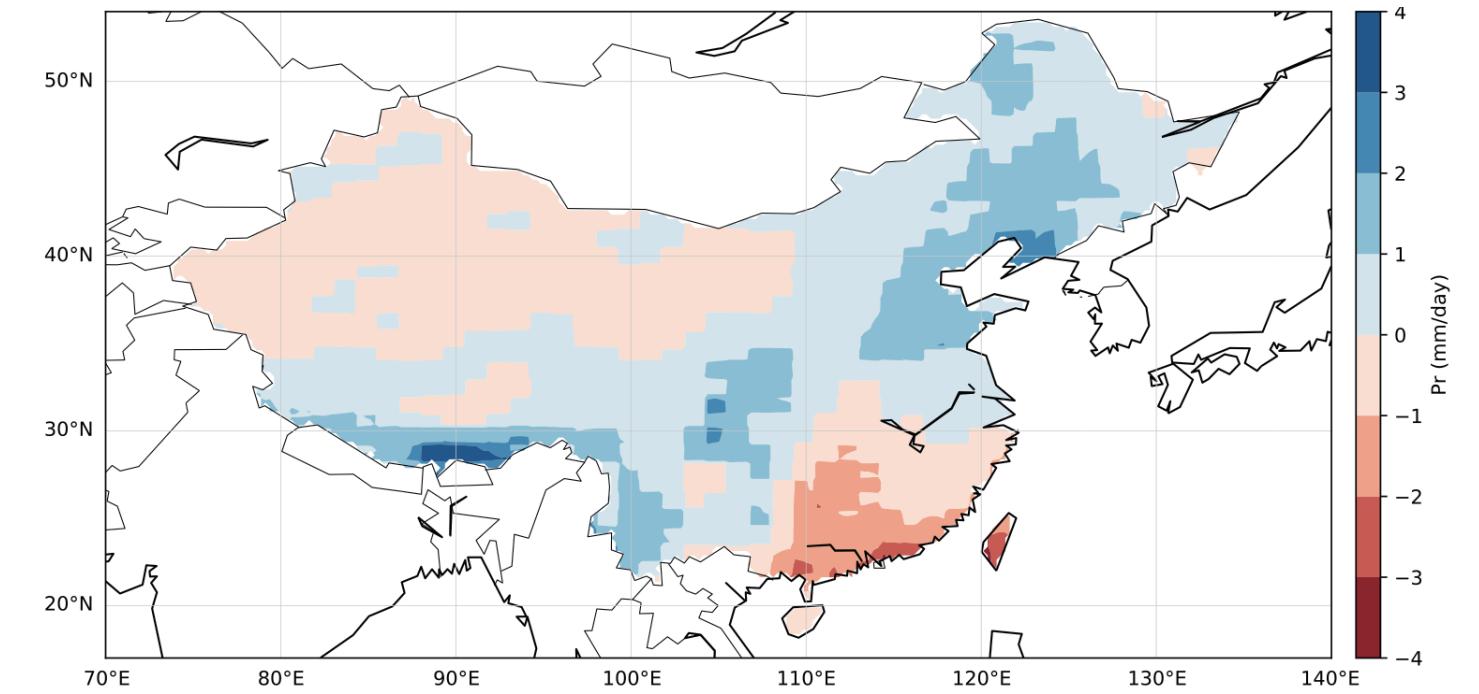
SD



(b)



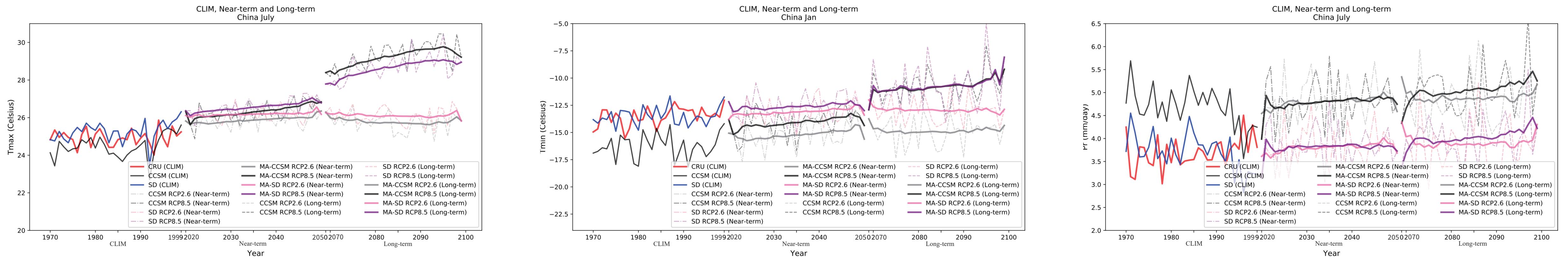
(d)



(f)

(a)-(b) 七月日最高温; (c)-(d) 一月日最低温; (e)-(f) 七月日降水; (a), (c)和(e) RCP8.5情境下2070-2099 CCSM4相较于1979-1999 CCSM4的差值; (b), (d)和(f) RCP8.5情境下2070-2099 SD相较于1970-1999 SD的差值

图 9 RCP8.5情境下2070-2099日最高温、日最低温和日降水气候变化空间分布
Fig. 9 RCP8.5 scenario's Tmax, Tmin and Pr's climate change in 2070-2099 in spatial



(a)

(b)

(c)

(a)-(c) CLIM(1970-1999): 红色实线代表CRU，黑色实线代表CCSM4，蓝色实线代表SD; Near-term(2020-2050): 灰色粗实线代表RCP2.6情景CCSM4滑动平均，黑色粗实线代表RCP8.5情景CCSM4滑动平均，灰色细虚线代表RCP2.6情景CCSM4原始数据，黑色细虚线代表RCP8.5情景CCSM4原始数据，粉色粗实线代表RCP2.6情景SD滑动平均，紫色粗实线代表RCP8.5情景SD滑动平均，粉色细虚线代表RCP2.6情景CCSM4原始数据，紫色细虚线代表RCP8.5情景CCSM4原始数据; Long-term(2070-2100): 与Near-term图例相同;

(a) 1970-1999(CLIM), 2020-2050(Near-term)和2070-2100(Long-term)中国所有格点七月日最高温做加权平均后的时间序列;

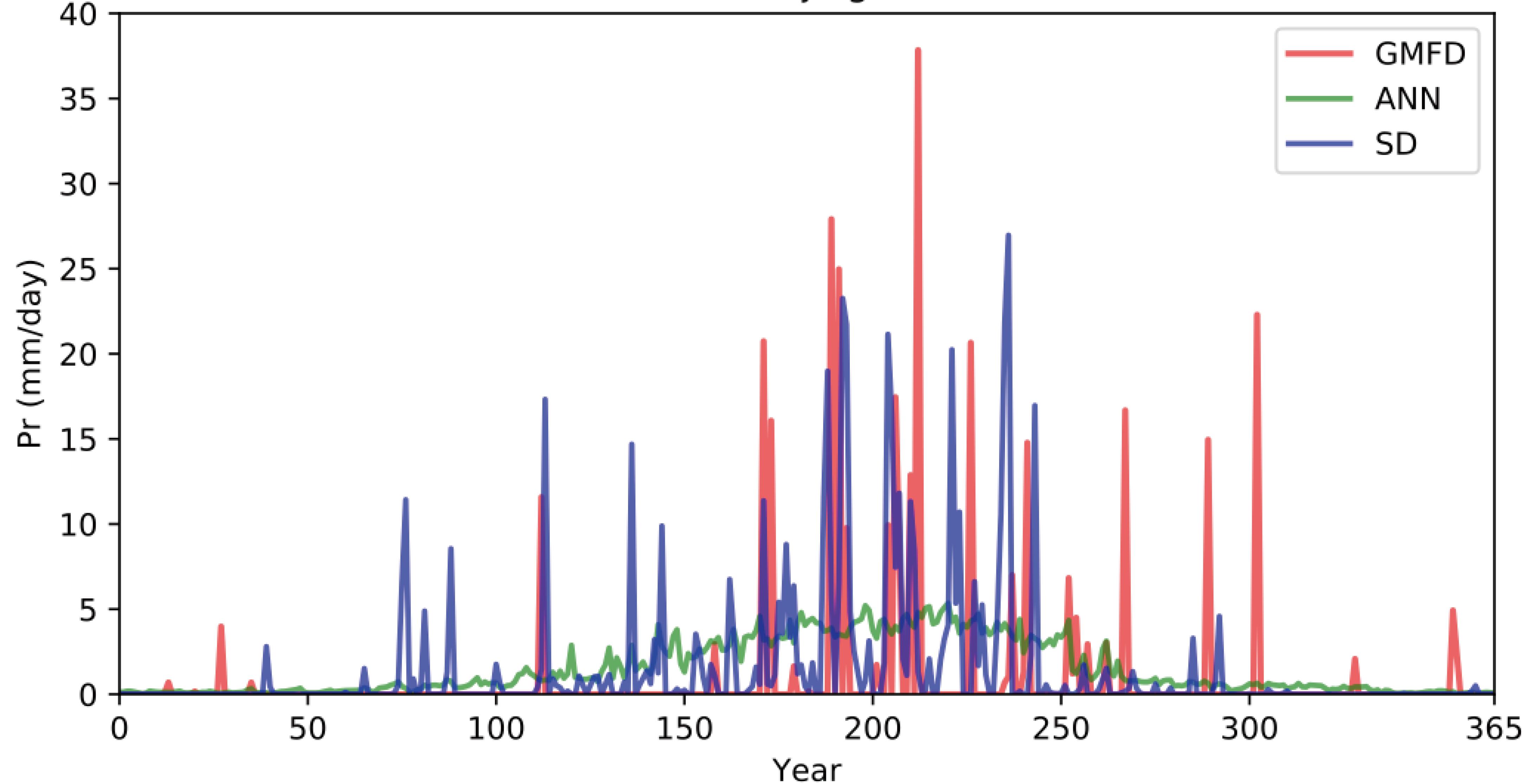
(b) 1970-1999(CLIM), 2020-2050(Near-term)和2070-2100(Long-term)中国所有格点一月日最低温做加权平均后的时间序列;

(c) 1970-1999(CLIM), 2020-2050(Near-term)和2070-2100(Long-term)中国所有格点七月日降水做加权平均后的时间序列;

图 10 中国日最高温、日最低温和日降水气候变化时间序列

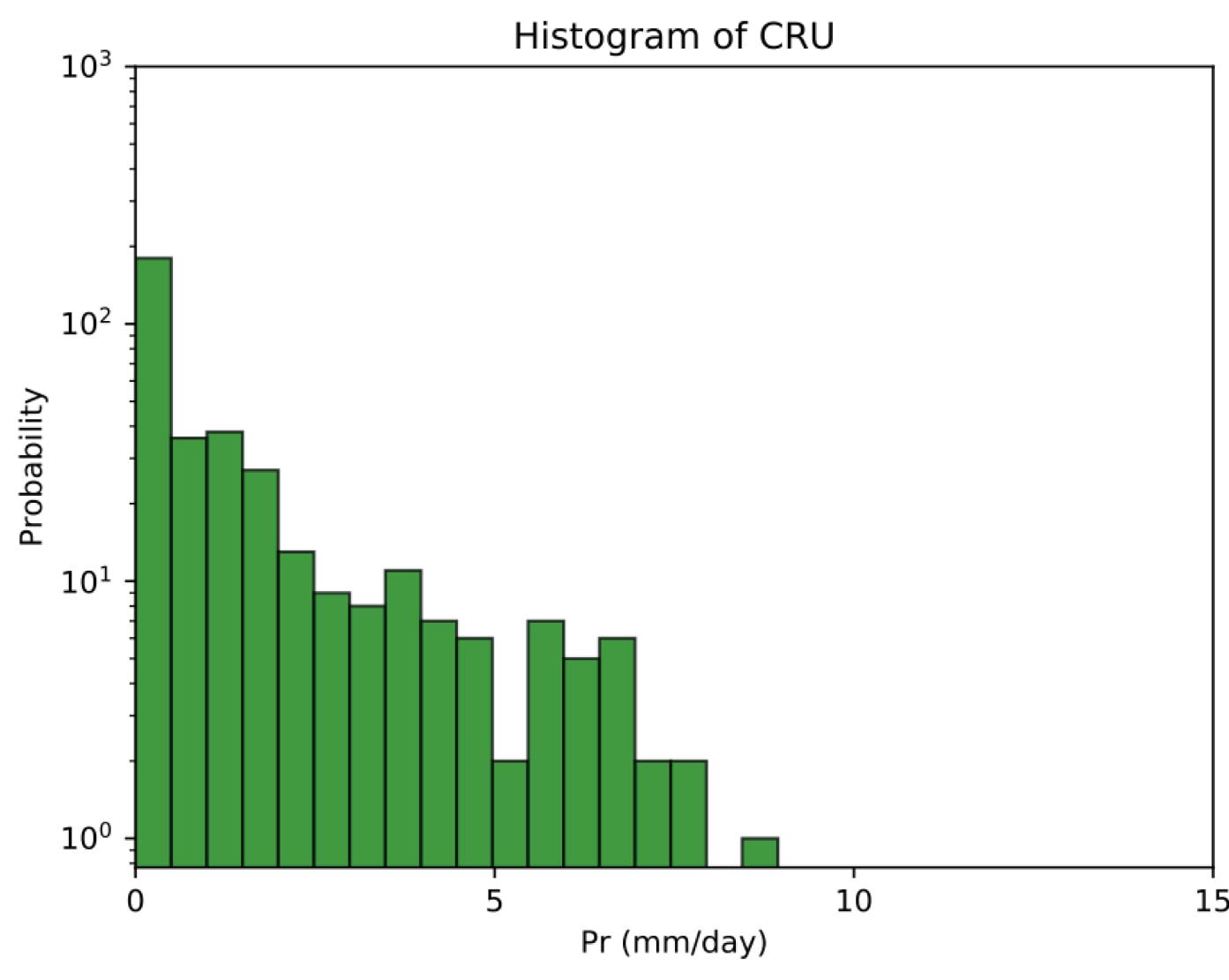
Fig. 10 Climate change of Tmax, Tmin and Pr in time series (China)

1997
Beijing

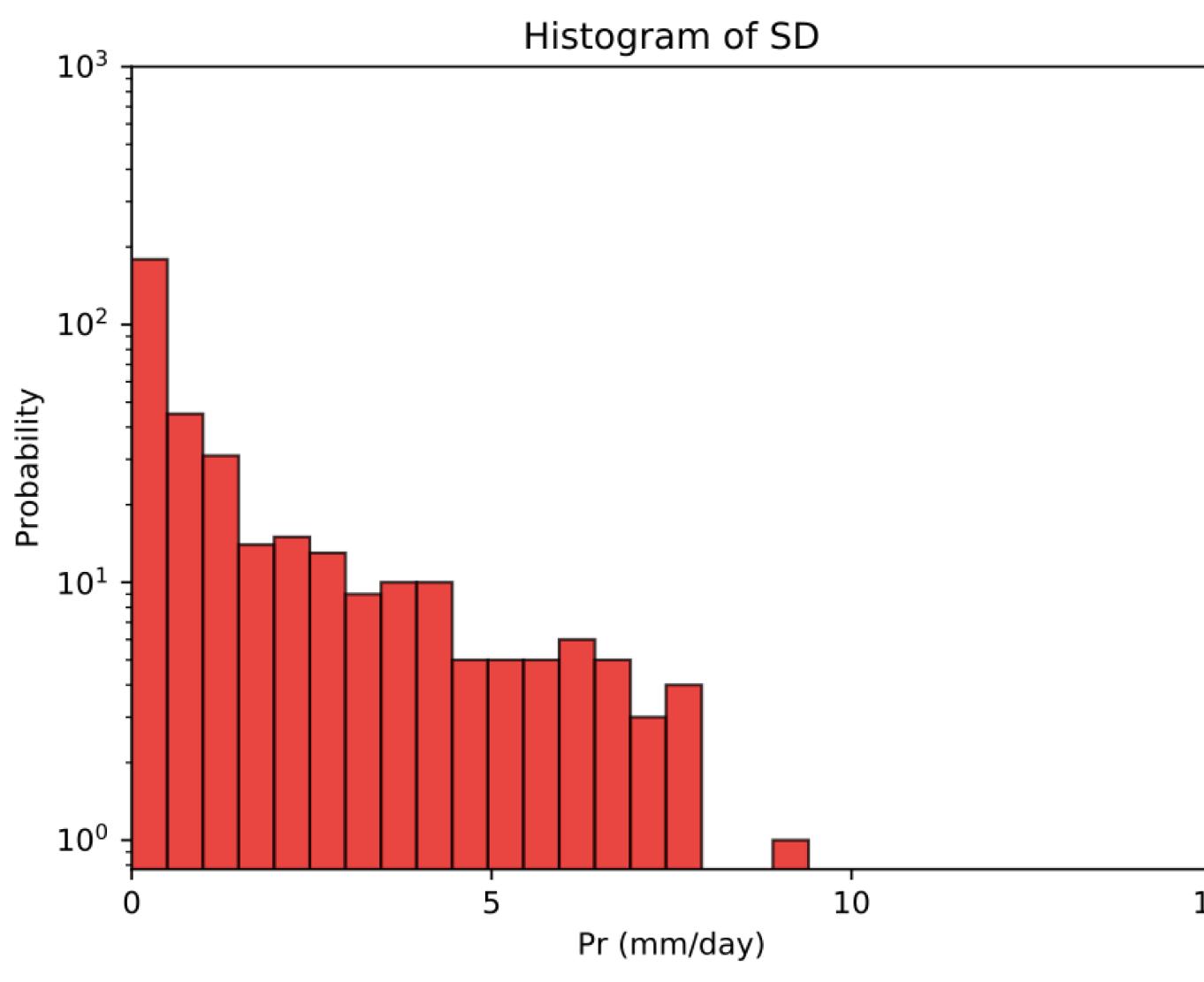


附录图 1 日降水变量GMFD, ANN, SD数据的验证集(1997年)时间序列

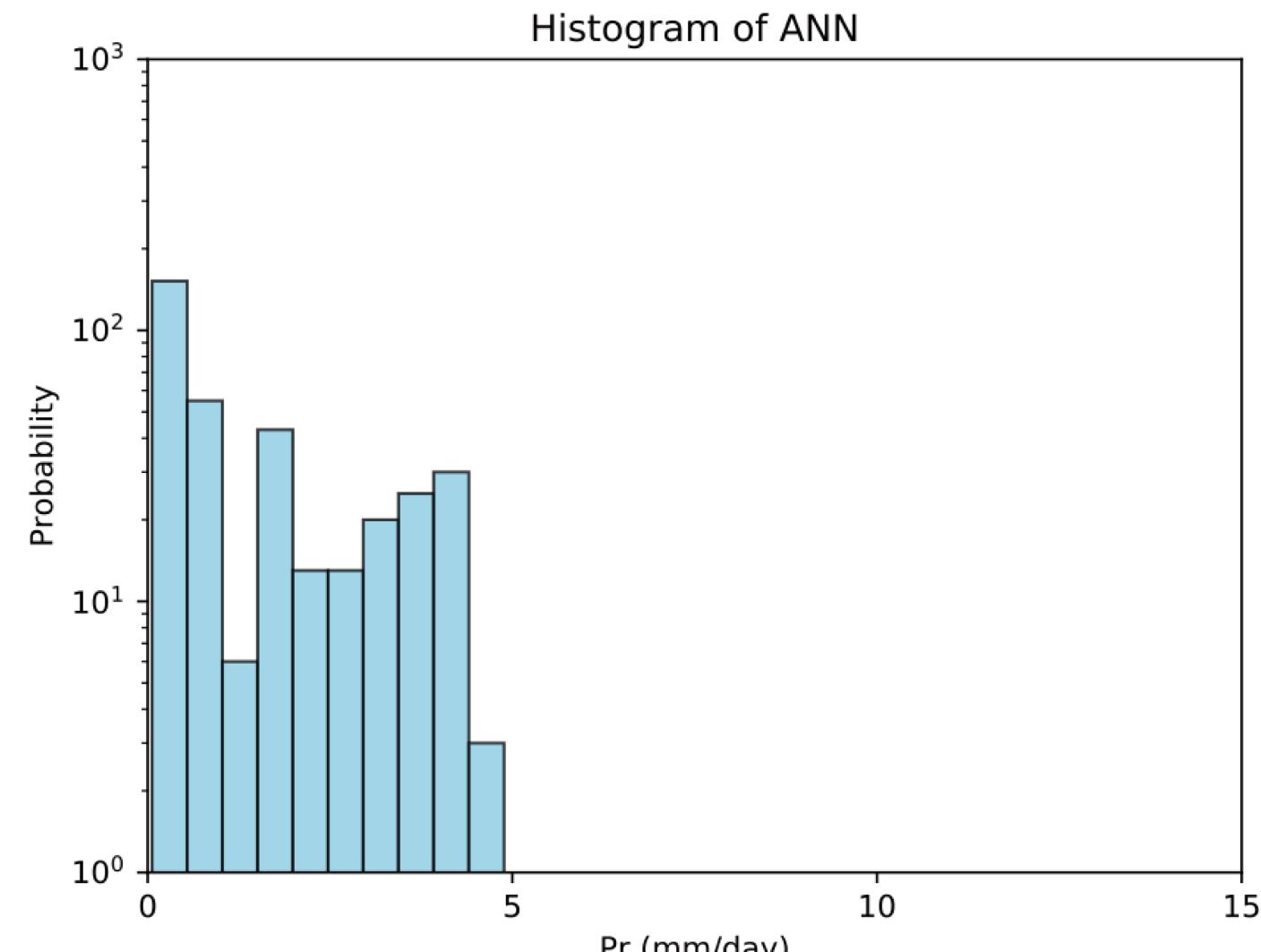
Appendix fig. 1 1997's GMFD, ANN and SD data of Pr in time series



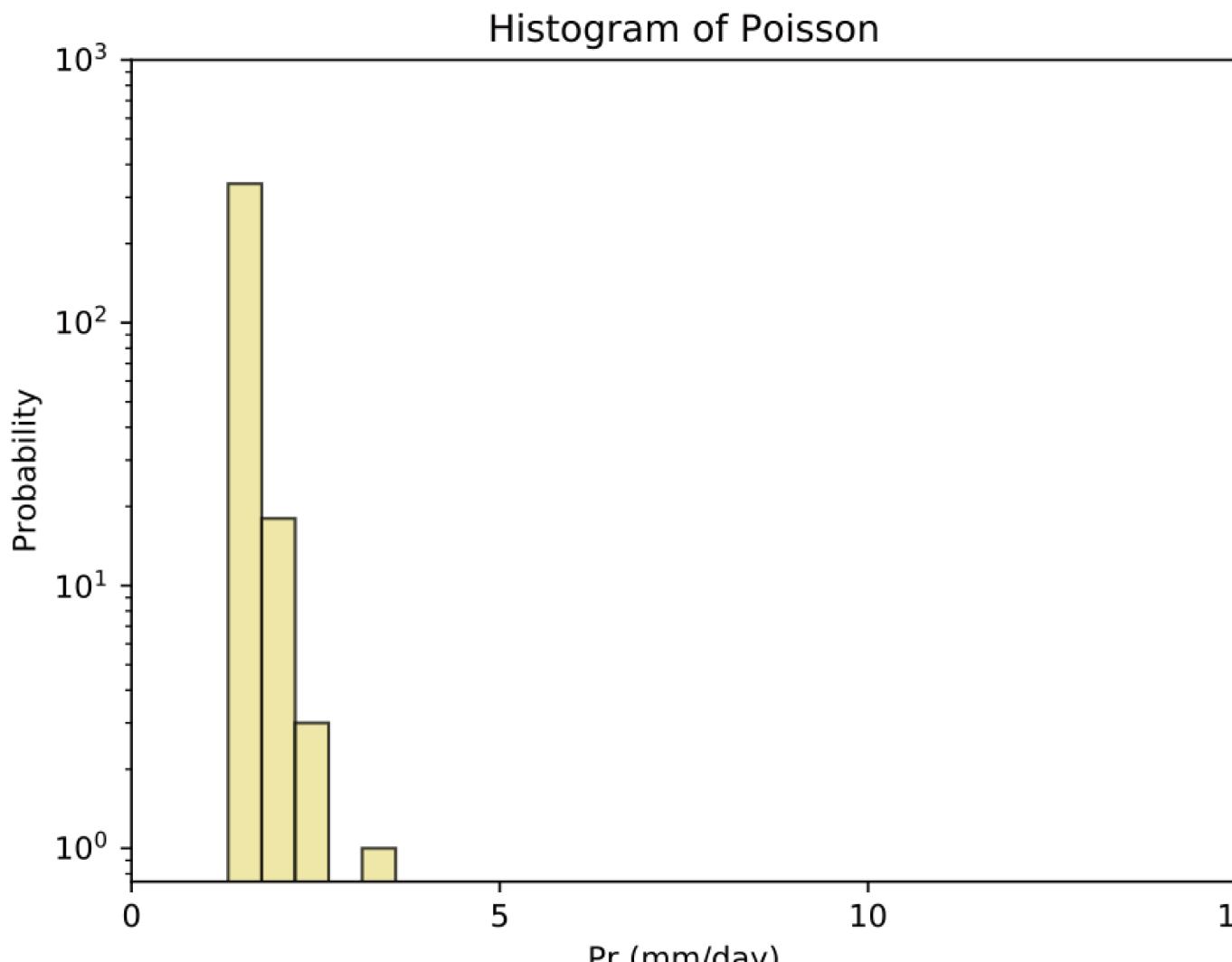
(a)



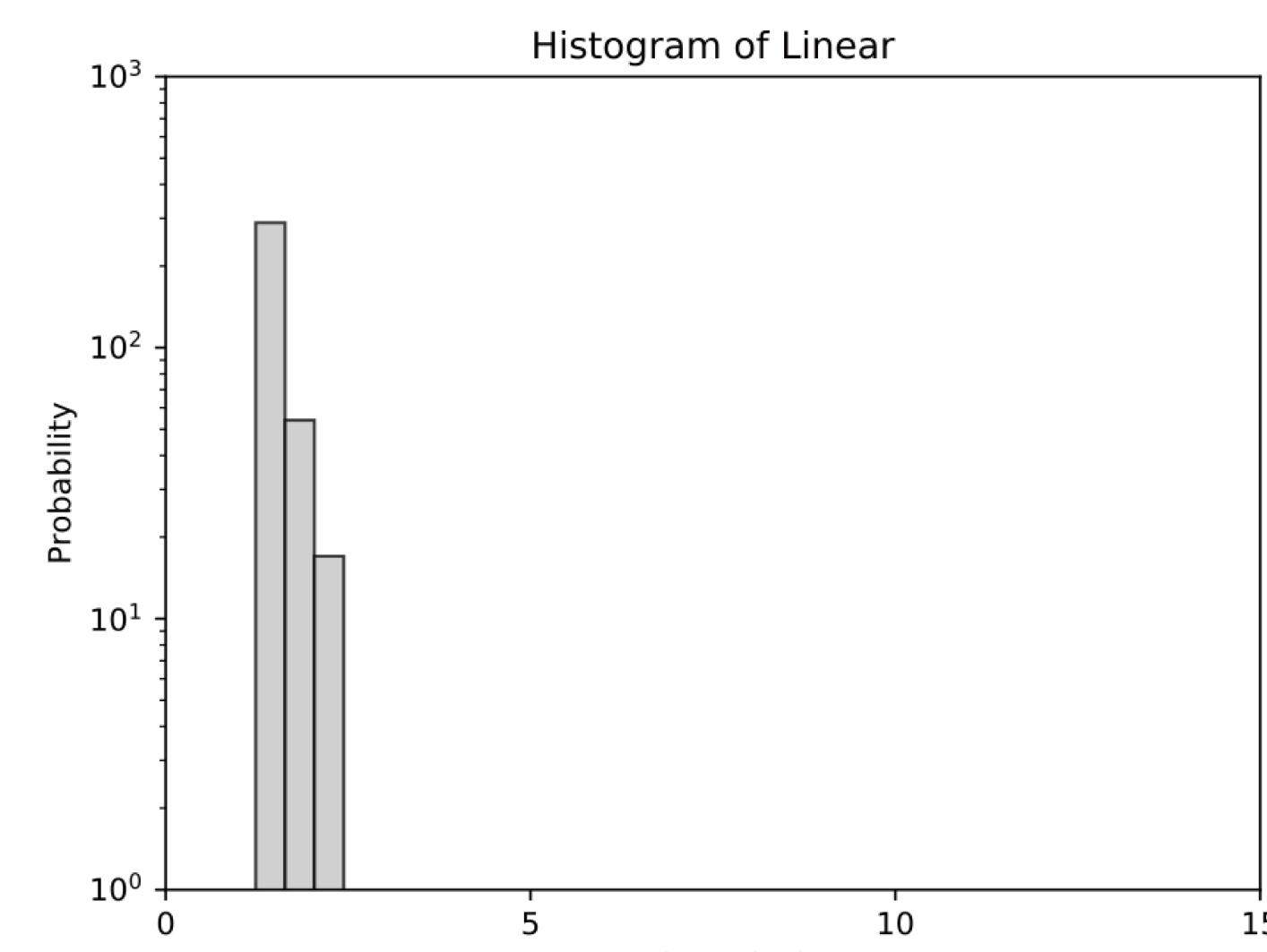
(b)



(c)



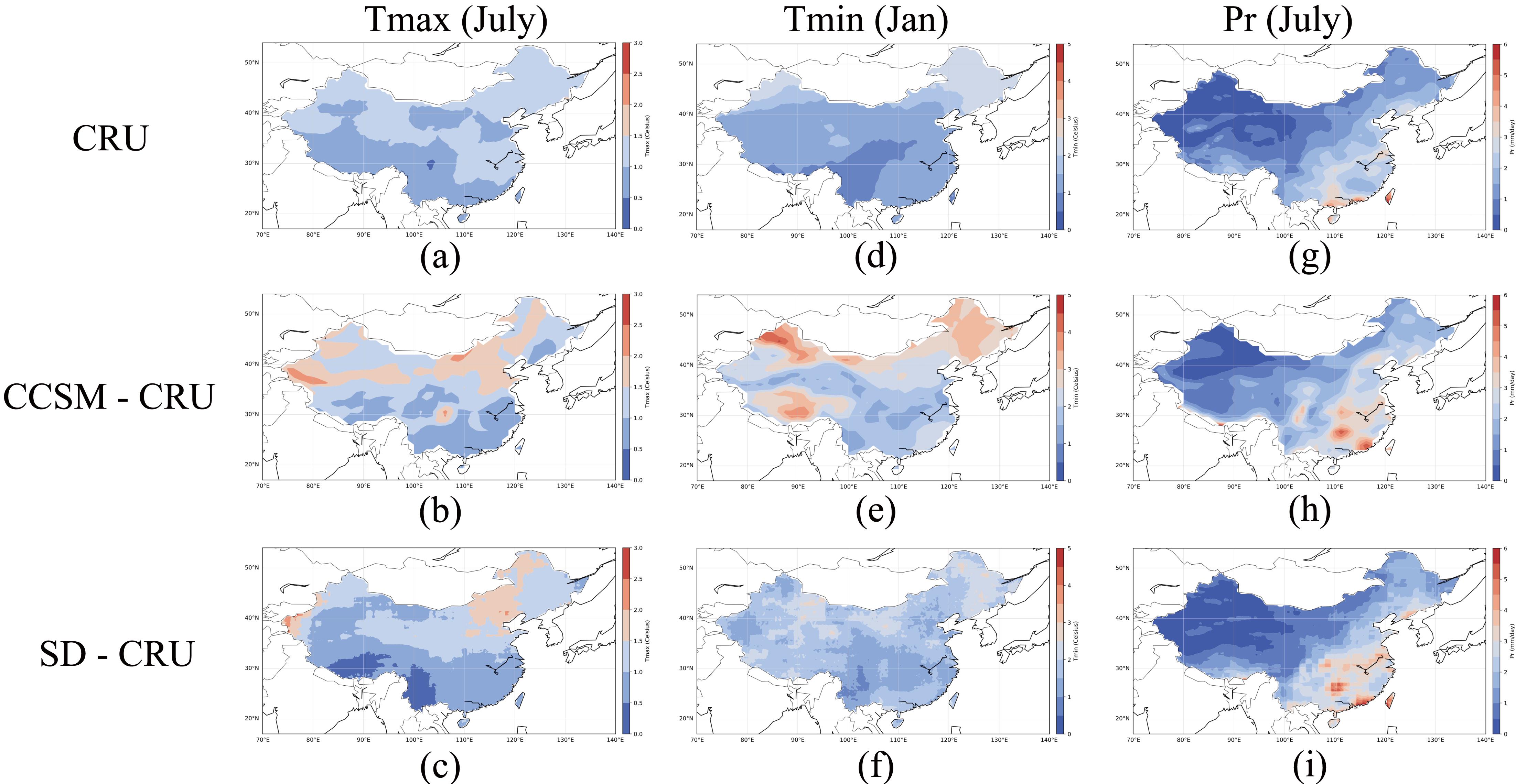
(d)



(e)

附录图 2 日降水变量直方图方法比较

Appendix fig. 2 The comparison of different statistical downscaling methods of Pr



(a)-(c) 七月日最高温; (d)-(f) 一月日最低温; (g)-(i) 七月日降水; (a), (d)和(g) 1970-1999 CRU空间分布; (b), (e)和(h) 1970-1999 CCSM4和CRU的差值; (c), (f)和(i) 1970-1999 SD和CRU的差值

附录图 3 1970-1999日最高温、日最低温和日降水标准差空间分布

Appendix fig. 3 Tmax, Tmin and Pr's standard deviation in 1970-1999 in spatial

謝謝