An Index-based Assessment of Perceived Climate Risk and Vulnerability for the Urban Cluster in the Yangtze River Delta Region of China

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Supporting Information: Projection of the extreme climate indices for the middle of the 21st century

We employ the high-resolution WRF and PRECIS2.0 models driven by IPSL and HadGEM respectively to simulate the precipitation extremes over Eastern China. Based on the evaluation of simulations in the reference period (1981–2000), the possible climate changes are projected by RCMs under the RCP4.5 Scenario for the near future (2041-2060).

S-1. Precipitation Extremes

The precipitation extreme indices used in this study are adopted from the ETCCDI (Expert Team on Climate Change Detection and Indices, http://cccma.seos.uvic.ca/ETCCDI). These indices have been widely used in characterizing precipitation extremes (Li et al., 2013; Qin 2016; Sillmann et al., 2013a, 2013b; You et al., 2011). We employ a set of 5 precipitation indices from ETCCDI and 4 custom indices including wet days, V95p, R95d and R95t (Table S-1). These indices are calculated respectively in each stations and model's grid, then the indices result are interpolated to a common 0.5×0.5 grid using a bilinear interpolation scheme.

Table S-1. Information of the climate extreme indices.

Index	Descriptive name	Definition	Units
PRCPTOT	Wet day precipitation	Annual total precipitation in wet days (RR>1 mm)	Mm
Wet days	Wet days	Annual total days when RR>=1.0 mm	Days
SDII	Simple daily intensity index	Average precipitation on wet days	mm/day
R10mm	Heavy precipitation Days	Annual count of days when RR>10 mm	Days
Rx5day	Maximum 5-day precipitation	Annual maximum consecutive 5-day precipitation	Mm
R95p	Very wet day precipitation	Annual total precipitation when RR > 95th percentile daily rainfall	Mm
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days
V95p	Extreme precipitation value	Value when RR>95th percentile?	Mm
R95d	Days of Extreme precipitation	Annual total days when RR>=V95p	Days
R95t	Heavy precipitation fraction	Fraction of annual total precipitation events exceeding the 1981–2000 95th percentile	%

Note: RR refers to daily precipitation. PRCPTOT is the annual total precipitation.

Figures S-1 and S-2 present an overview of projected changes of the eight precipitation extreme indices over 2041-2060 under RCP4.5 Scenario, relative to the baseline period of 1981-2000. For IPSL and WRF, large values of increase in PRCPTOT are shown in YRB, NC and NEC (Figures S-1a and S-1b). A general increase of PRCPTOT of HadGEM simulations can be found over Eastern China

(Figure S-1c). The PRECIS2.0 simulations project an increase of PRCPTOT value in YRB, NC and NEC, while a decrease in SC (Figure S-1d). As shown in Figures S-1f and S-1h, WRF and PRECIS simulations project a decrease of wet days over SC and YRB. Similar results also can be found in HadGEM simulations. However, the IPSL simulation mainly presents an increase in most areas. The spatial pattern of changes in R10mm is similar to PRCPTOT, but with different magnitude. For SDII, an increase in projected change dominates almost all of study areas of each model. In SC, both IPSL and WRF present a no more than 10% decrease in most area (Figures S-1m and S-1n). A decrease by less than 10% is projected in NEC, as shown in Figure S-1o.

For R95d, WRF simulation projects an increase over the eastern China even by more than 40% in some area. IPSL projects a greater increase than WRF in YRB, NC and NEC, with a maximal value exceeding 70%. HadGEM also projects a larger increase of R95d in SC, YRB and NC than PRECIS2.0 does.

The spatial patterns of simulated R95t are different across models. Increased change of R95t is mainly distributed in NWC by IPSL and mainly distributed in SC and NEC by PRECIS2.0. The most of increased changes in study area exceed 80% of WRF, HadGEM and PRECIS simulations.

For Rx5day, IPSL and WRF show similar simulated features. They all detected a general increase in NC and NWC, whereas a decrease in YRB. WRF shows greater increase than IPSL. HadGEM also presents an increase over most area and the PRECIS simulation projects a mixed increase and decrease over the eastern China, as shown in Figure S-2i. The same pattern is also found for Rx5day and R95d, suggesting that changes of R95d and Rx5day are consistent under RCP4.5 scenario.

For CDD, HadGEM simulation projects a dominated decrease over eastern China, while IPSL simulation projects an increase over the area. PRECIS2.0 simulation projects increase change in SC and decrease change in NC and NEC. Increased change of IPSL is mainly distributed in SC, YRB and SC.

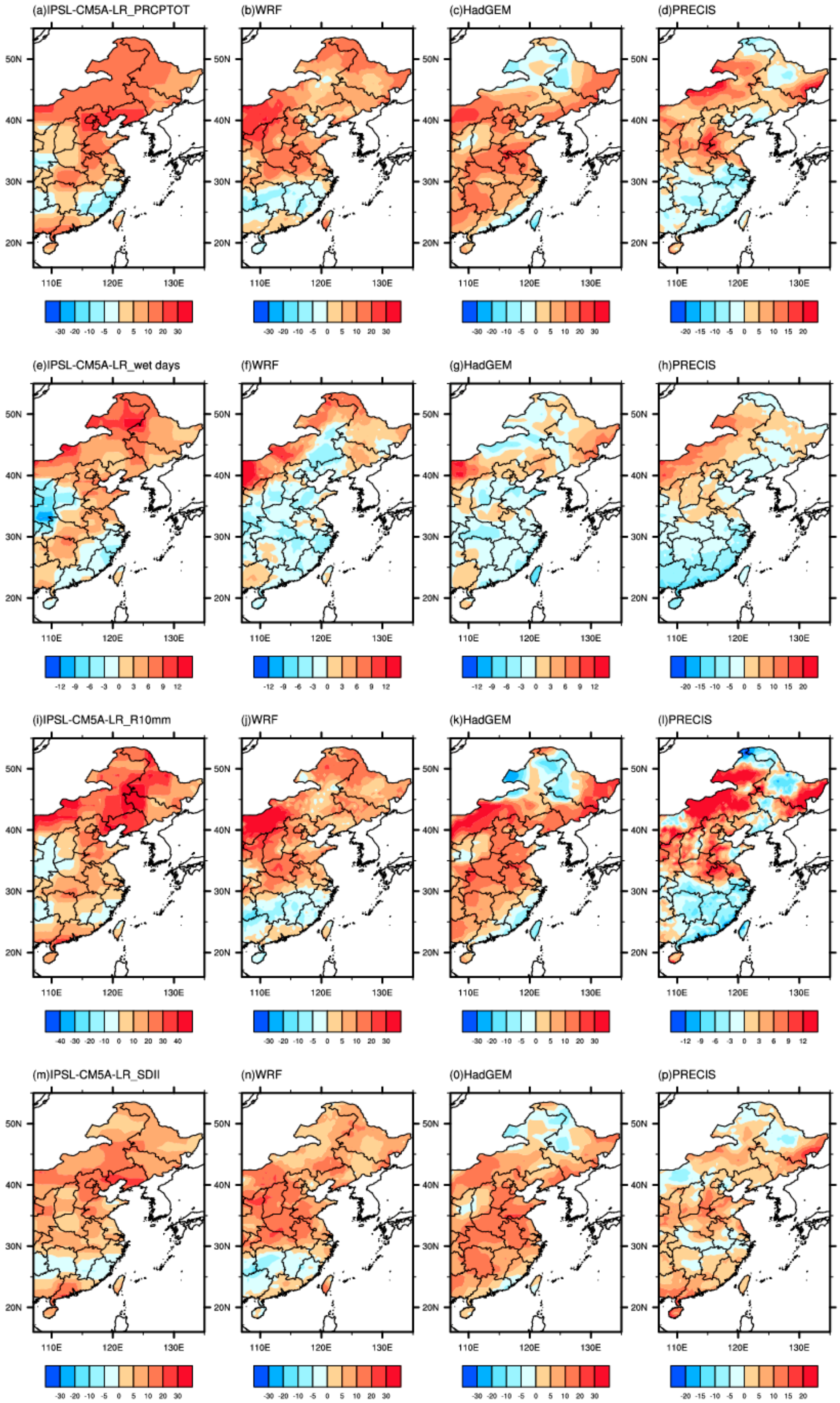


Figure S-1. Changes in the annual mean state of precipitation indices between 2041–2060 and 1981–2000 under RCP4.5: PRCPTOT (a, b, c, d, e), wet days (f, g, h, i, j), R10mm (k, l, m, n, o) and SDII (p, q, r, s, t).

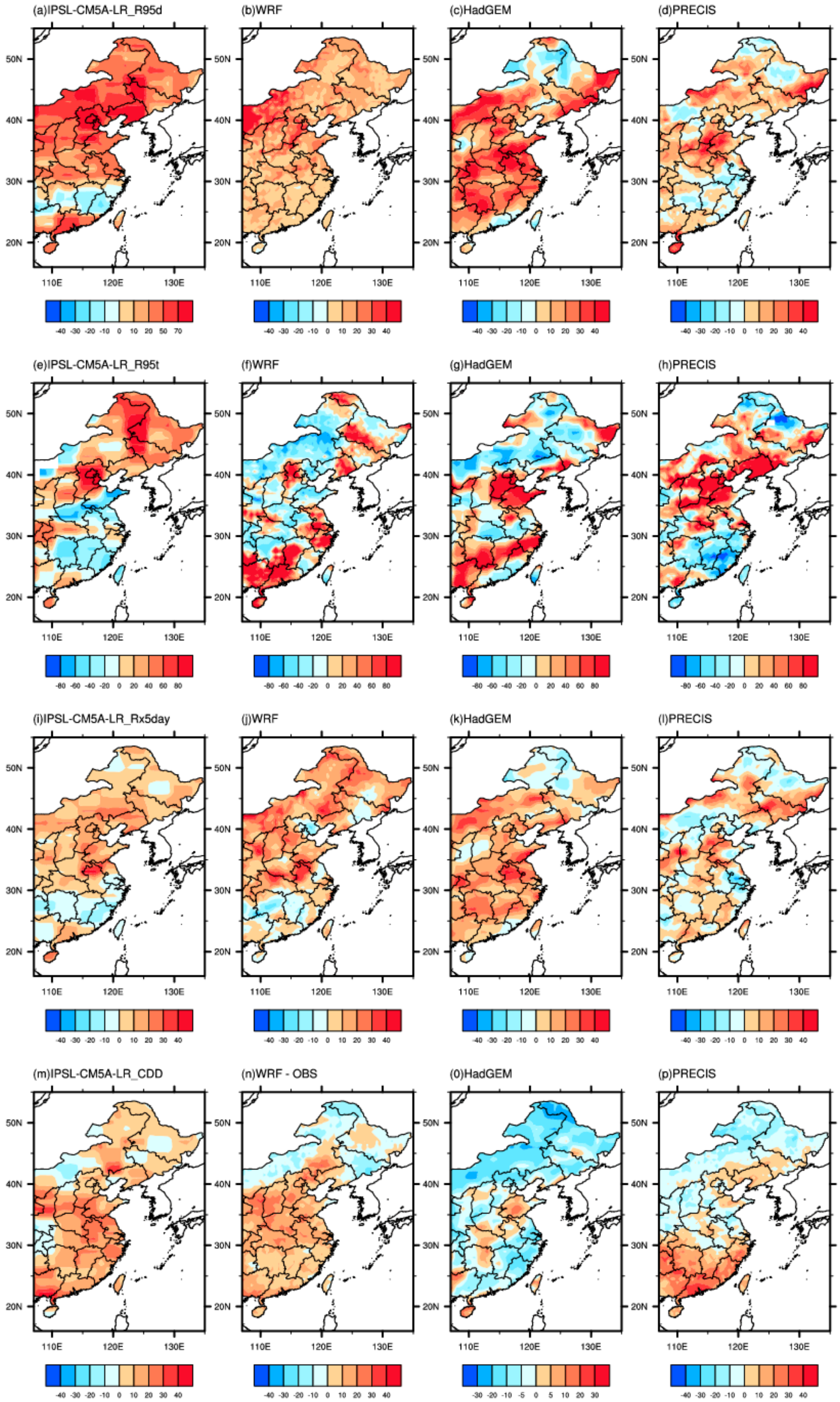
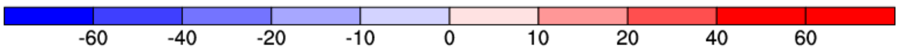


Figure S-2. As in Figure 10, but for indices of V95p (a, b, c, d, e), R95t (f, g, h, i, j), Rx5day (k, l, m, n, o) and CDD (p, q, r, s, t).

To have a general appreciation of models' projected changes for extreme precipitation indices, averaged projected changes over sub-regions between 2041–2060 and 1981–2000 under RCP4.5 is shown in Table S-2. For PRCPTOT, two GCMs simulations project an increase changes in each subregion, and PRECIS2.0 and WRF present a decrease change in SC. Furthermore, all climate model simulations project an increase of R95d in an interval of 1.12% to 47.22%. Here, IPSL projects a large change in NC and NEC. Except HadGEM, the other models project relatively larger increase of change in NC and NEC than in SC and YRB. However, the change of R95t doesn't correspond to R95d. For example, PRECIS2.0 and IPSL simulations project a decrease of R95t in SC and YRB. Particularly, the change of R95t is -53.81% while the changes of R95d is 47.22% in the same region of NC. It is likely because that IPSL simulation projects much weak rainfall days in NC. For SDII, almost all sub-regions present increasing changes, except for SC with -0.92% change projected by WRF. Increasing/positive changes also dominate almost all sub-regions. WRF simulation projects an obvious increase by more than 10% for all indices, except wet days by -0.2%. The decrease of wet days is mainly distributed in SC, YRB and NC.

Table S-2 Projected Changes (%) of precipitation indices averaged over sub-regions between 2041–2060 and 1981–2000 under RCP4.5

Model_SubRegion	prcptot	wet days	R10mm	SDII	R95d	R95t	Rx5day	CDD
HadGEM_SC	5.13	-0.77	2.97	5.69	15.53	24.63	9.18	-1.76
HadGEM_YRB	8.3	-1.63	7.52	10.32	27.15	10.69	17.71	-3.91
HadGEM_NC	9.47	-8.02	-3.82	1.8	2.21	22.06	12.87	-5.65
HadGEM_NEC	3.24	0.8	5.24	2.48	7.54	-22.41	2.53	-12.16
PRECIS_SC	-2.56	-8.02	-2.55	6.36	4.09	-24.65	2.65	21.82
PRECIS_YRB	-2.28	-3.82	-2.12	1.75	1.12	-10.99	-0.89	6.18
PRECIS_NC	6.3	1.8	5.17	4.74	10.45	35.7	4.44	-3.61
PRECIS_NEC	5.05	2.21	5.16	2.81	7.78	-16.75	5.84	-7.4
IPSL_SC	2.97	-0.46	9.28	3.3	16.51	-4.95	0.18	17.04
IPSL_YRB	2.88	-0.03	7	3.09	9.62	-6.46	0.63	12.61
IPSL_NC	9.93	0.67	12.54	9.55	47.22	-53.81	12.73	12.67
IPSL_NEC	13.44	5.41	26.96	7.82	40.24	42.53	8.96	4.91
WRF_SC	-1.18	-0.82	-2.32	-0.92	7.05	15.67	-1.18	9.79
WRF_YRB	1.8	-2.19	1.1	4.98	8.74	-6.53	5.53	11.3
WRF_NC	11.18	-0.2	11.65	11.91	18.61	10.05	12.96	11.69
WRF_NEC	7.95	2.32	8.28	6.46	12.69	0.04	14.79	-2.79



S-2. Temperature Extremes

The extreme temperatures are analyzed using the following indicators: the annual mean maximum temperature (Tmax), annual mean minimum temperature (Tmin), 95th percentile of the maximum temperature (TX95) and 5th percentile of the minimum temperature (TN5), which are the thresholds for the extreme high and low temperature days; they would also allow highlighting the projected changes in the temperature extremes of each grid cell by comparing the average temperature over future RCPs scenarios to that in Baseline. The high-temperature days (HTD) and low-temperature days (LTD) show how usual extreme temperature events based on present-day levels might become in the future. Detailed descriptions of the indices are provided in Table S-3.

Table S-3. Definition of extreme temperature indices.

Index	Descriptive name	Definition	Units
TX95	Threshold of extreme hot days	95th percentile of all of the maximum temperature	℃
TN5	Threshold of extreme cold days	5th percentile of all of the daily minimum temperature	℃
HTD	High-temperature days index	Number of days in a year with the daily maximum temperature exceeding TX95 (over 1971-2000)	day
LTD	Low-temperature days	Number of days in a year with the daily minimum temperature below TN5 (over 1971-2000)	day

Figure S-3 shows that, by the mid and end of the 21st century, the annual Tmax and Tmin would significantly increase over the baseline level within Eastern China's boundary, and the Tmax would increase more than Tmin under same scenario and time-slice. Under RCP4.5 scenario, the annual Tmax and Tmin will increase slightly by the mid of 21st century, with a magnitude of 1.3-2.8℃. While there are nearly same magnitude between RCP8.5 scenario by the mid of 21st century and RCP4.5 scenario by the end of 21st century, with a magnitude of 2.5-3.7℃ and 2.8-4.0℃ respectively. And under RCP8.5 scenario by the end of 21st century, the magnitude of warming will be 4.5-6.0℃.

The high-temperature days (HTD) characterized by the present-day threshold show a significant increase by the mid and end of 21st century compared to baseline (i.e. 1971-2000), as shown in Figure S-4. The HTD would increase more and more significant from north of Eastern China to the south of China with the largest magnitude under the RCP8.5 scenario by the end of 21st century. Under RCP4.5 scenario by the mid of 21st century, the magnitude of increase will be 10-40 days, nearly 155-320% of the baseline. The magnitudes of increase under RCP4.5 scenario by the end of 21st century and RCP8.5 scenario by the mid of 21st century are similar at 20-60 days, nearly 160-430% of the baseline. The changes of annual Tmax and Tmin show a similar story, with the most warming magnitude under RCP8.5 scenario by the end of 21st century.

By the mid/end of the 21st century, the low-temperature days based on the present-day level would decrease significantly under RCP4.5 and RCP8.5 scenarios (Figure S-5). A larger decrease in LTD appears in the south part of Eastern China than those in the north part. Also A most significant changes appear in the RCP8.5 scenario by the end of 21st century, with a reduction by 15-18 days. It means that there would be no Low-temperature day in the whole year by using the present-day Low-temperature threshold in the RCP8.5 scenario by the end of 21st century. The extent of decrease under the RCP8.5 scenario by the mid of 21st century will be larger than that under the RCP4.5 scenario by the end of 21st century.

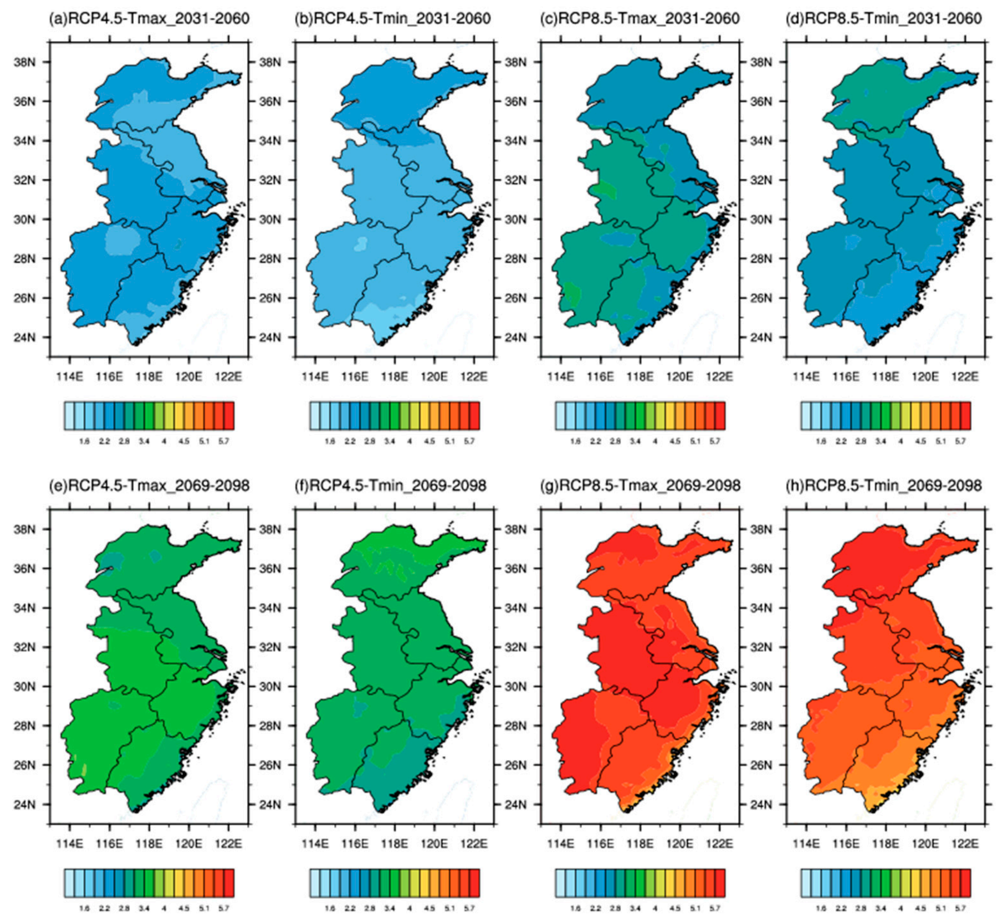


Figure S-3. Changes of the annual maximum and minimum temperatures compared with the baseline period levels under the RCP4.5 and RCP8.5 scenarios by the mid and end of the 21st century: (a) changes in maximum temperature under the RCP4.5 scenario by the mid of 21st century; (b) changes in minimum temperature under the RCP4.5 scenario by the mid of 21st century; (c) changes in maximum temperature under the RCP8.5 scenario by the mid of 21st century; (d) changes in minimum temperature under the RCP8.5 scenario by the mid of 21st century; (e) changes in maximum temperature under the RCP4.5 scenario by the end of 21st century; (f) changes in minimum temperature under the RCP4.5 scenario by the end of 21st century; (g) changes in maximum temperature under the RCP8.5 scenario by the end of 21st century; (h) changes in minimum temperature under the RCP8.5 scenario by the end of 21st century. Unit: ℃.

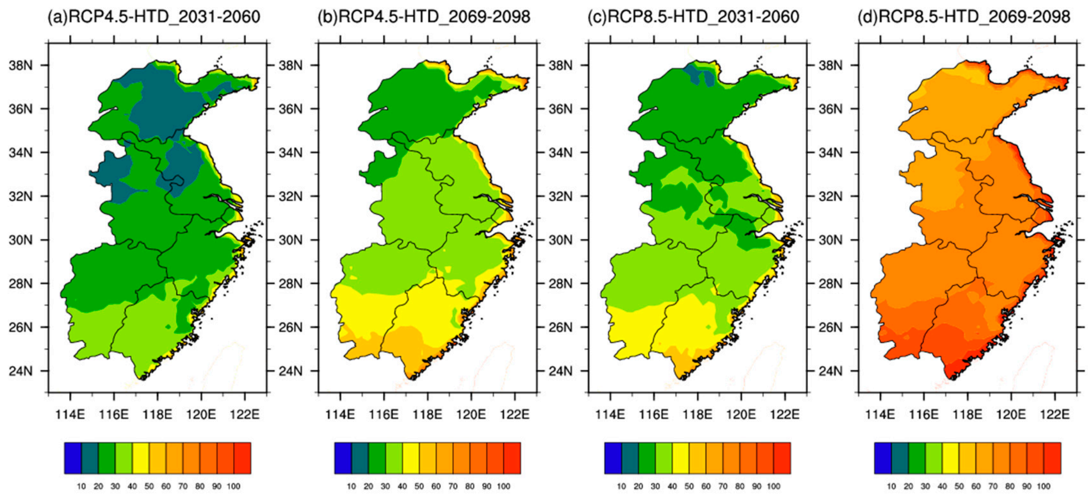


Figure S-4. Changes of the High-temperature days (HTD) compared with the baseline period levels under the RCP4.5 and RCP8.5 scenarios by the mid and end of the 21st century: (a) changes in HTD under the RCP4.5 scenario by the mid of 21st century; (b) changes in HTD under the RCP4.5 scenario by the mid of 21st century; (c) changes in HTD under the RCP8.5 scenario by the mid of 21st century; (d)changes in HTD under the RCP8.5 scenario by the mid of 21st century. Unit: day.

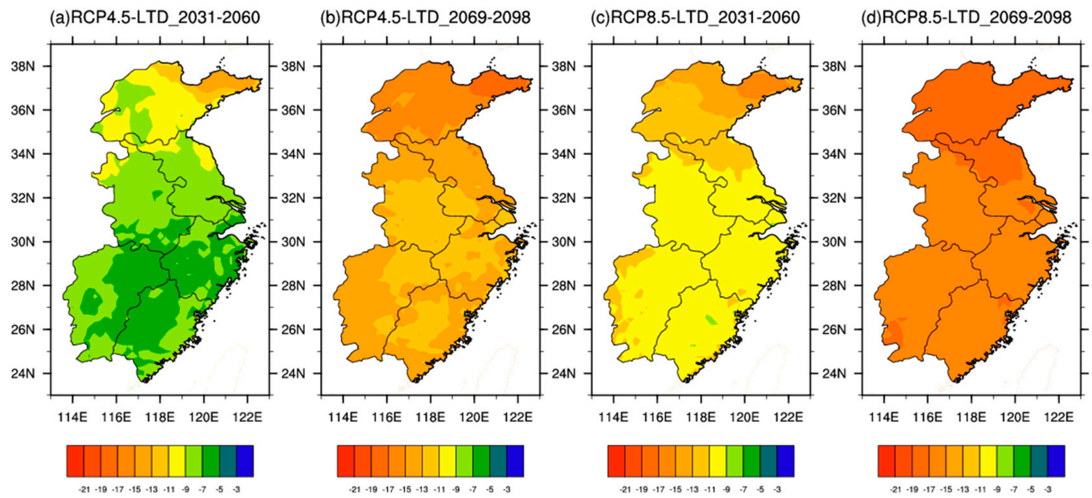


Figure S-5. Same as Fig. 25 but for Low-temperature days (LTD). Unit: day.