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Widespread deoxygenation in warming rivers

In the format provided by the authors and unedited

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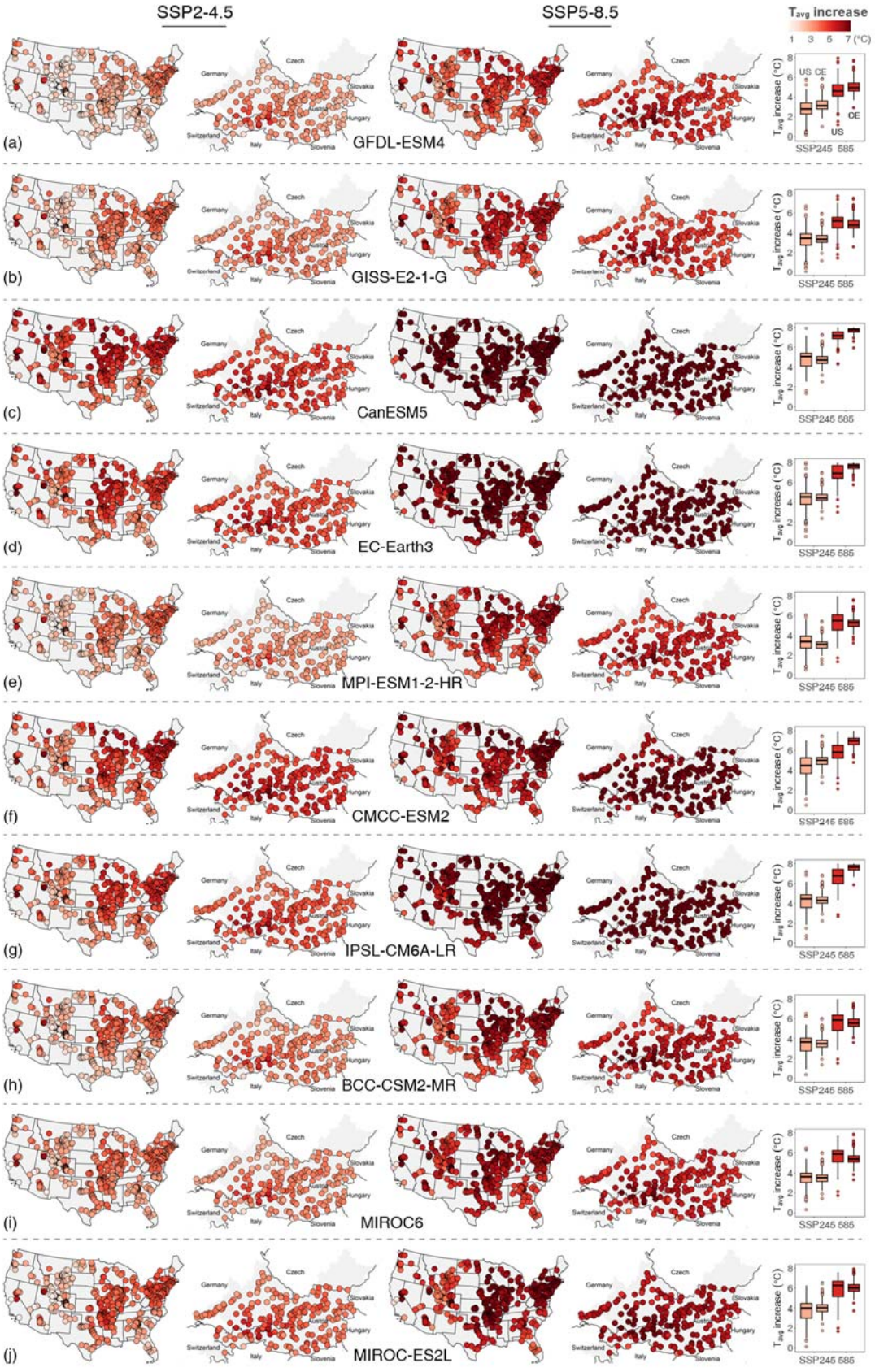
SSP2-4.5
SSP5-8.5
Tavg increase
1 3 5 7 (°C)
(a) GFDL-ESM4
(b) GISS-E2-1-G
(c) CanESM5
(d) EC-Earth3
(e) MPI-ESM1-2-HR
(f) CMCC-ESM2
(g) IPSL-CM6A-LR
(h) BCC-CSM2-MR
(i) MIROC6
(j) MIROC-ES2L
Tavg increase (°C)
US CE
CE
US
SSP245 585
Germany
Czech
Slovakia
Switzerland
Italy
Slovenia
Hungary

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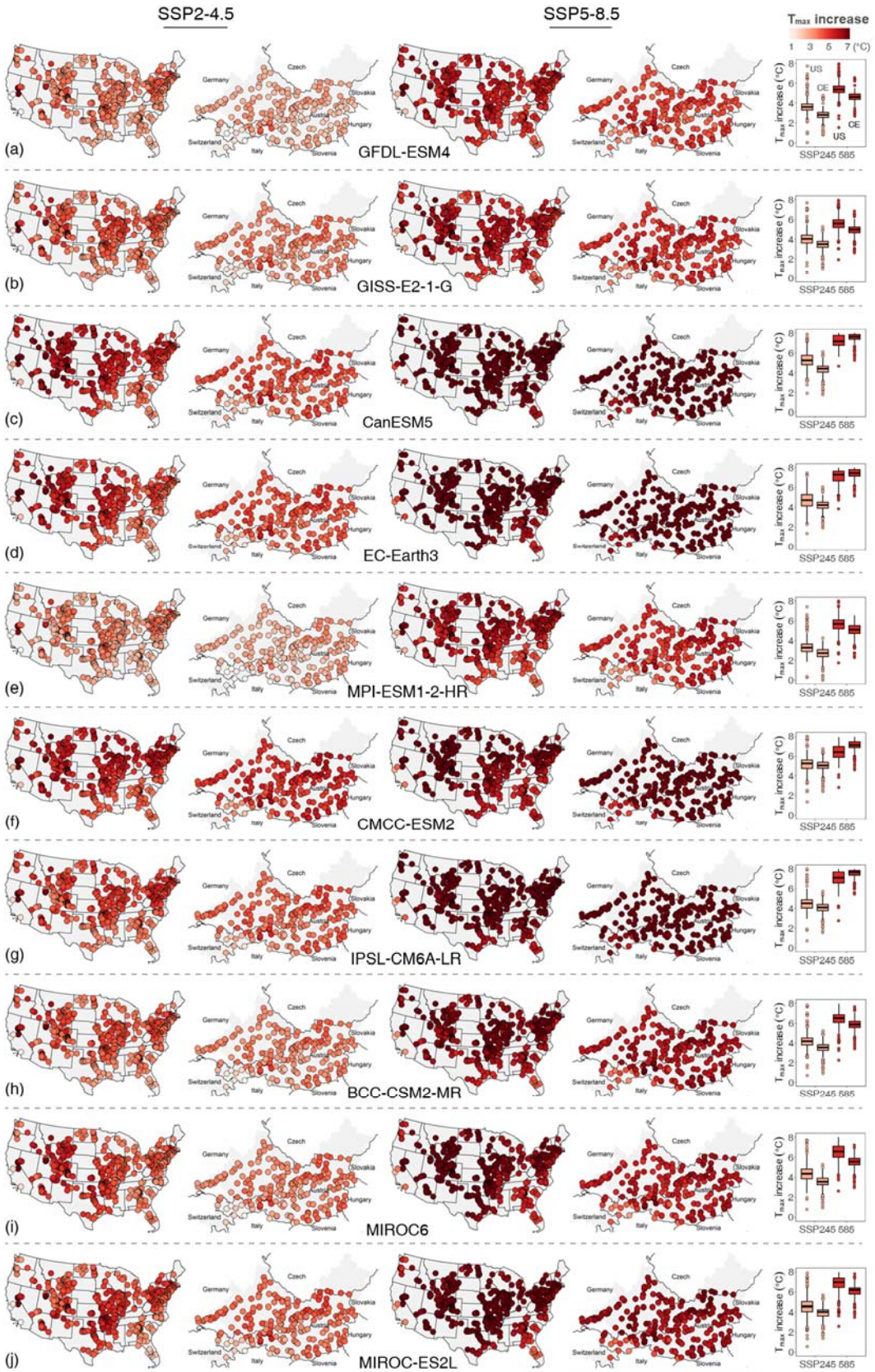
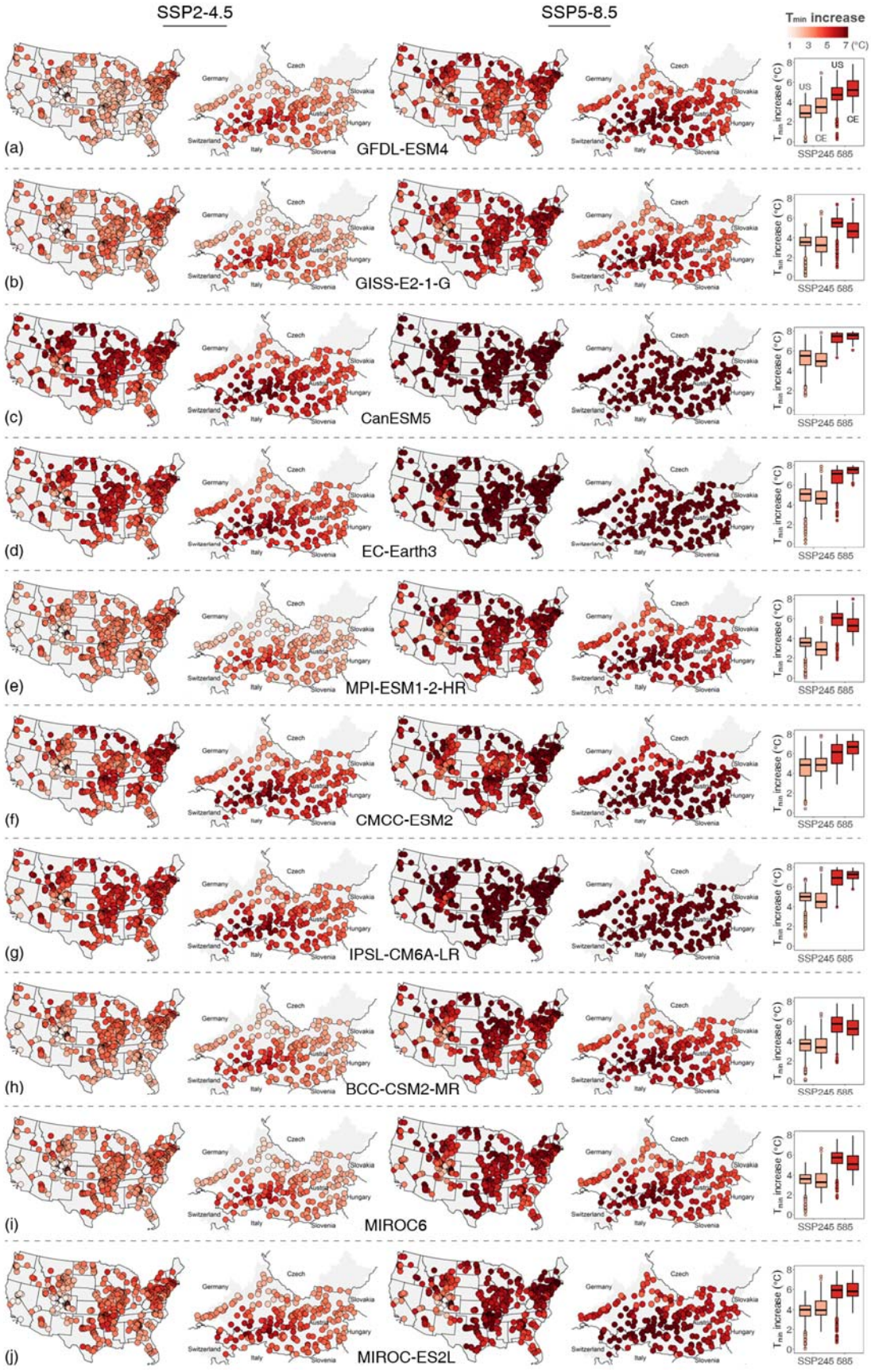
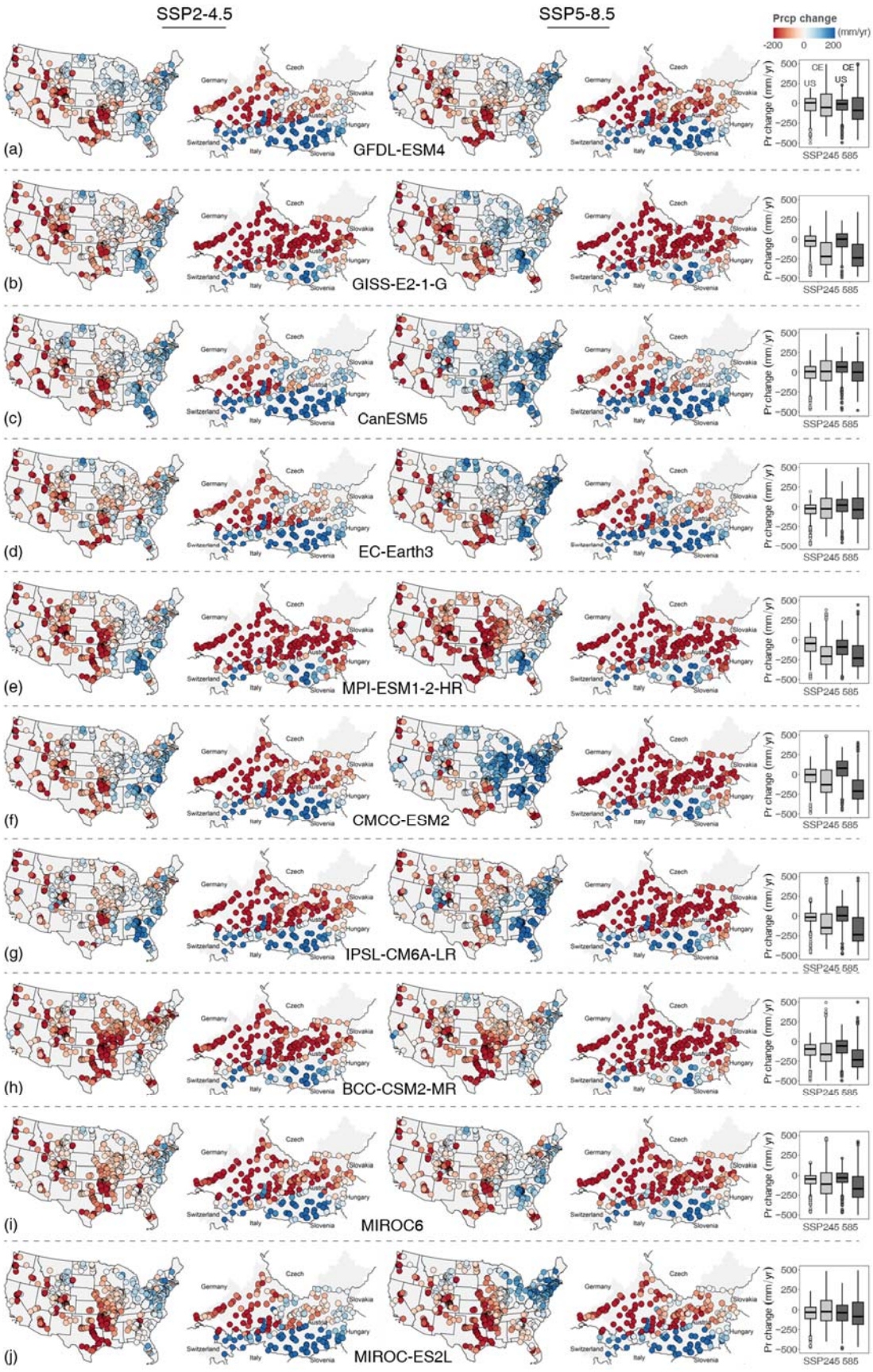
Supplementary Fig. 1 | Daily average temperature (T_{avg}) increases under SSP2-4.5 and SSP5-8.5 scenarios. The panels of (a) to (j) represent 10 CMIP models. T_{avg} increase was calculated as the 20-year average of the daily difference between the historical period of 1981-2000 and the projected period of 2081-2100. The boxes on the side show the median values (middle line) and the interquartile range (IQR), which is the range between the first quartile (Q1) and third quartile (Q3). The lower and upper whiskers extend to Q1 − 1.5 × IQR and Q3 + 1.5 × IQR, respectively. For detailed information on the 10 CMIP6 models, please refer to the Method section.


SSP2-4.5
SSP5-8.5
Tmax increase
1 3 5 7 (°C)
(a) GFDL-ESM4
(b) GISS-E2-1-G
(c) CanESM5
(d) EC-Earth3
(e) MPI-ESM1-2-HR
(f) CMCC-ESM2
(g) IPSL-CM6A-LR
(h) BCC-CSM2-MR
(i) MIROC6
(j) MIROC-ES2L
US
CE
SSP245 585
Tmax increase (°C)

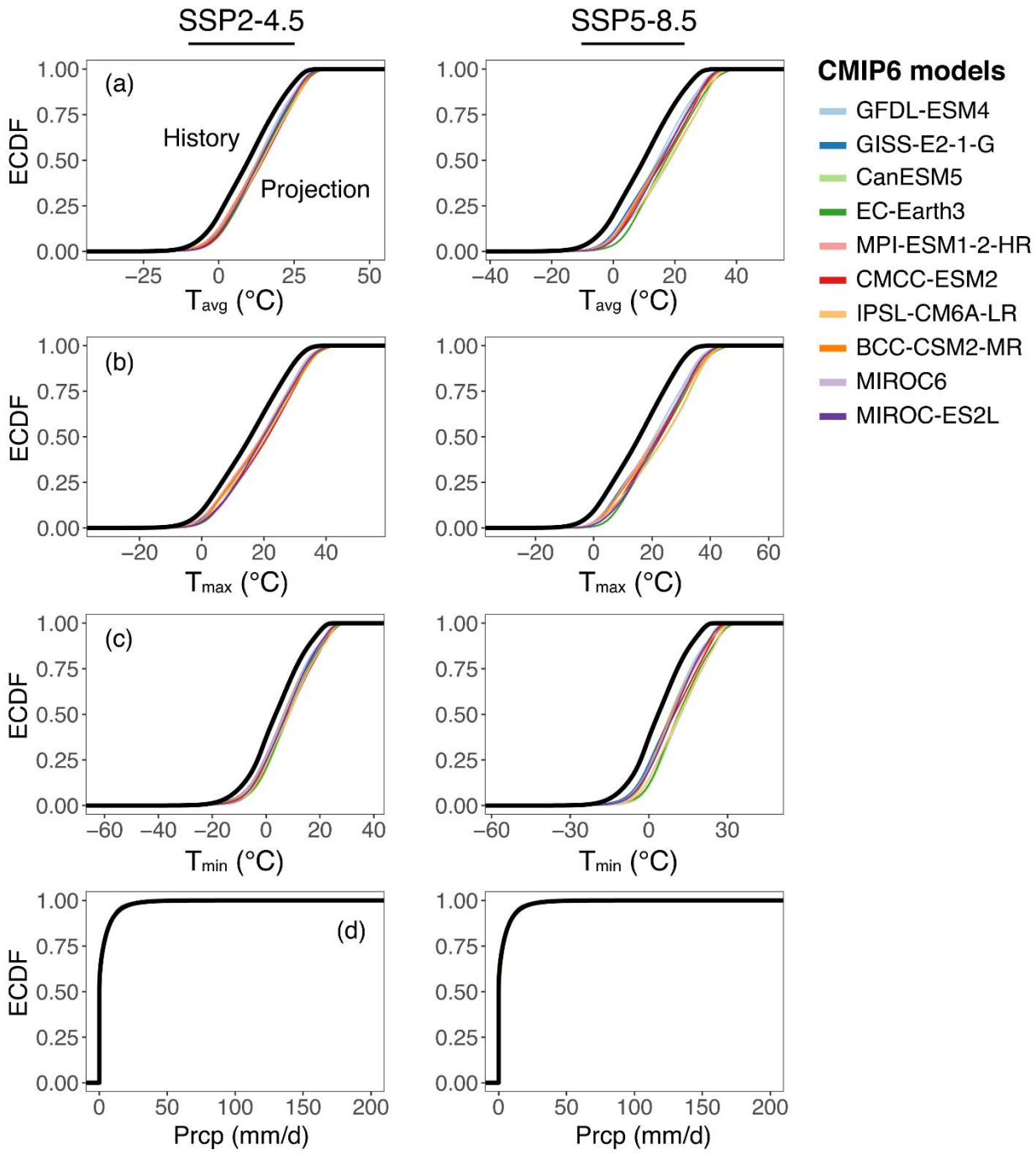
Supplementary Fig. 2 | Daily maximum temperature (T_{max}) increases under SSP2-4.5 and SSP5-8.5 scenarios. The panels of (a) to (j) represent 10 CMIP models. T_{max} increase was calculated as the 20-year average of the daily difference between the historical period of 1981-2000 and the projected period of 2081-2100. The boxes on the side show the median values (middle line) and the interquartile range (IQR), which is the range between the first quartile (Q1) and third quartile (Q3). The lower and upper whiskers extend to Q1 − 1.5 × IQR and Q3 + 1.5 × IQR, respectively. For detailed information on the 10 CMIP6 models, please refer to the Method section.


SSP2-4.5
SSP5-8.5
Tmin increase
1 3 5 7 (°C)
(a) GFDL-ESM4
(b) GISS-E2-1-G
(c) CanESM5
(d) EC-Earth3
(e) MPI-ESM1-2-HR
(f) CMCC-ESM2
(g) IPSL-CM6A-LR
(h) BCC-CSM2-MR
(i) MIROC6
(j) MIROC-ES2L
US
CE
SSP245 585
Tmin increase (°C)

Supplementary Fig. 3 | Daily minimum temperature (T_{min}) increases under SSP2-4.5 and SSP5-8.5 scenarios. The panels of (a) to (j) represent 10 CMIP models. T_{min} increase was calculated as the 20-year average of the daily difference between the historical period of 1981-2000 and the projected period of 2081-2100. The boxes on the side show the median values (middle line) and the interquartile range (IQR), which is the range between the first quartile (Q1) and third quartile (Q3). The lower and upper whiskers extend to Q1 − 1.5 × IQR and Q3 + 1.5 × IQR, respectively. For detailed information on the 10 CMIP6 models, please refer to the Methodology section.

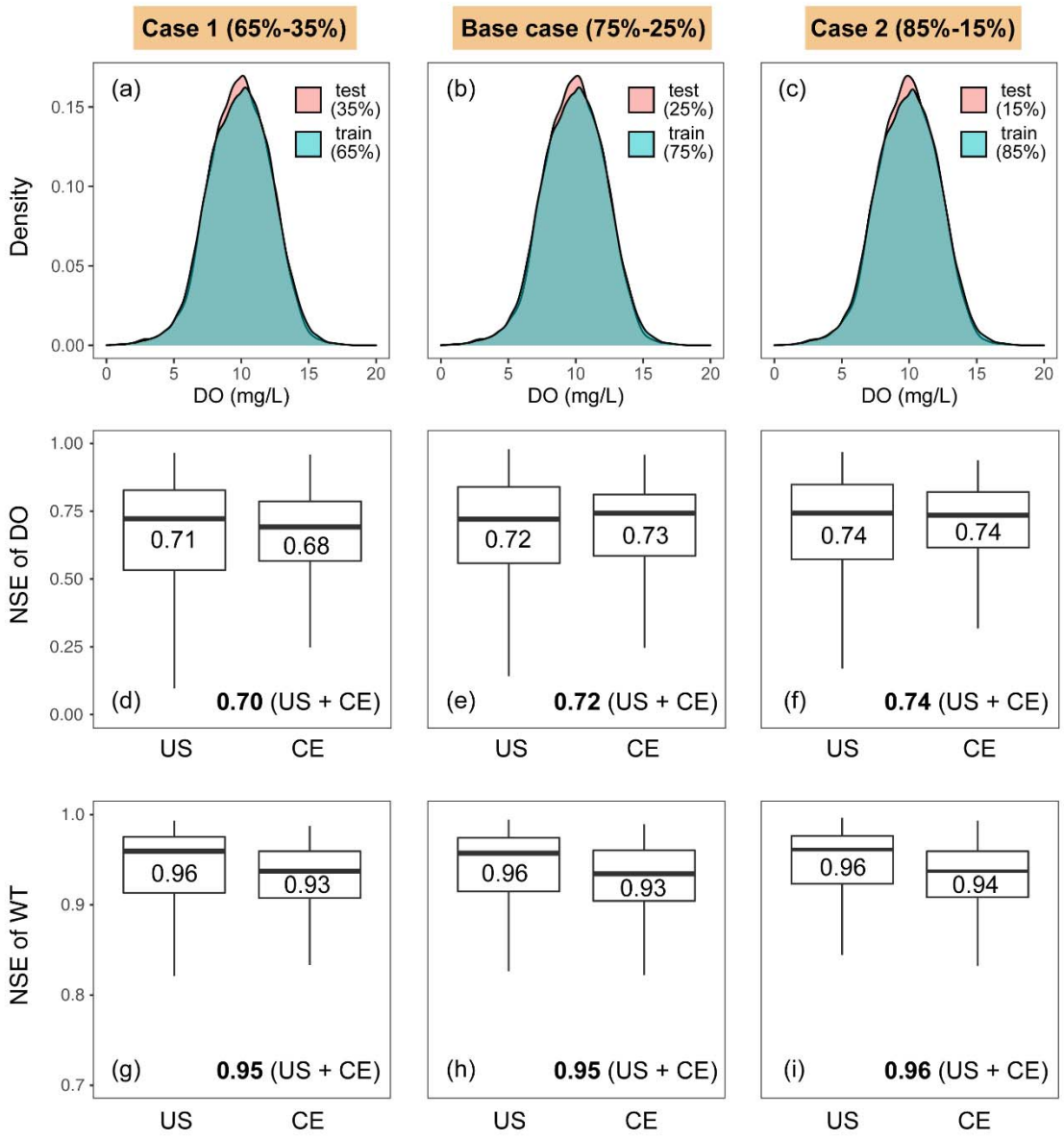

SSP2-4.5
SSP5-8.5
Prcp change
(mm/yr)
-200
0
200
(a) GFDL-ESM4
(b) GISS-E2-1-G
(c) CanESM5
(d) EC-Earth3
(e) MPI-ESM1-2-HR
(f) CMCC-ESM2
(g) IPSL-CM6A-LR
(h) BCC-CSM2-MR
(i) MIROC6
(j) MIROC-ES2L
Germany
Czech
Slovakia
Austria
Hungary
Switzerland
Italy
Slovenia
Pr change (mm/yr)
500
250
0
−250
−500
CE
US
SSP245 585

Supplementary Fig. 4 | Annual precipitation changes under SSP2-4.5 and SSP5-8.5 scenarios. The panels of (a) to (j) represent 10 CMIP models. Precipitation change was calculated as the 20-year average of the annual difference between the historical period of 1981-2000 and the projected period of 2081-2100. The boxes on the side show the median values (middle line) and the interquartile range (IQR), which is the range between the first quartile (Q1) and third quartile (Q3). The lower and upper whiskers extend to Q1 − 1.5 × IQR and Q3 + 1.5 × IQR, respectively. Overall, red color indicates future drier conditions, and blue indicates future wetter conditions. Information on 10 CMIP6 models are detailed in the Method section.



Supplementary Fig. 5 | Empirical Cumulative Distribution Function (ECDF) of historical and projected forcing variables. Variables include temperature (a-c) and precipitation (d) under SSP2-4.5 and SSP5-8.5 scenarios. Compared to the historical period, noticeable distribution shifts can be observed in the projected temperature variables (a-c). Kolmogorov-Smirnov tests conducted on all 10 CMIP6 models under the two SSP2-4.5 and SSP5-8.5 scenarios demonstrated distinct distributions. Although the

historical and projected precipitation curves overlapped (d), the statistical analysis indicated different underlying distributions.



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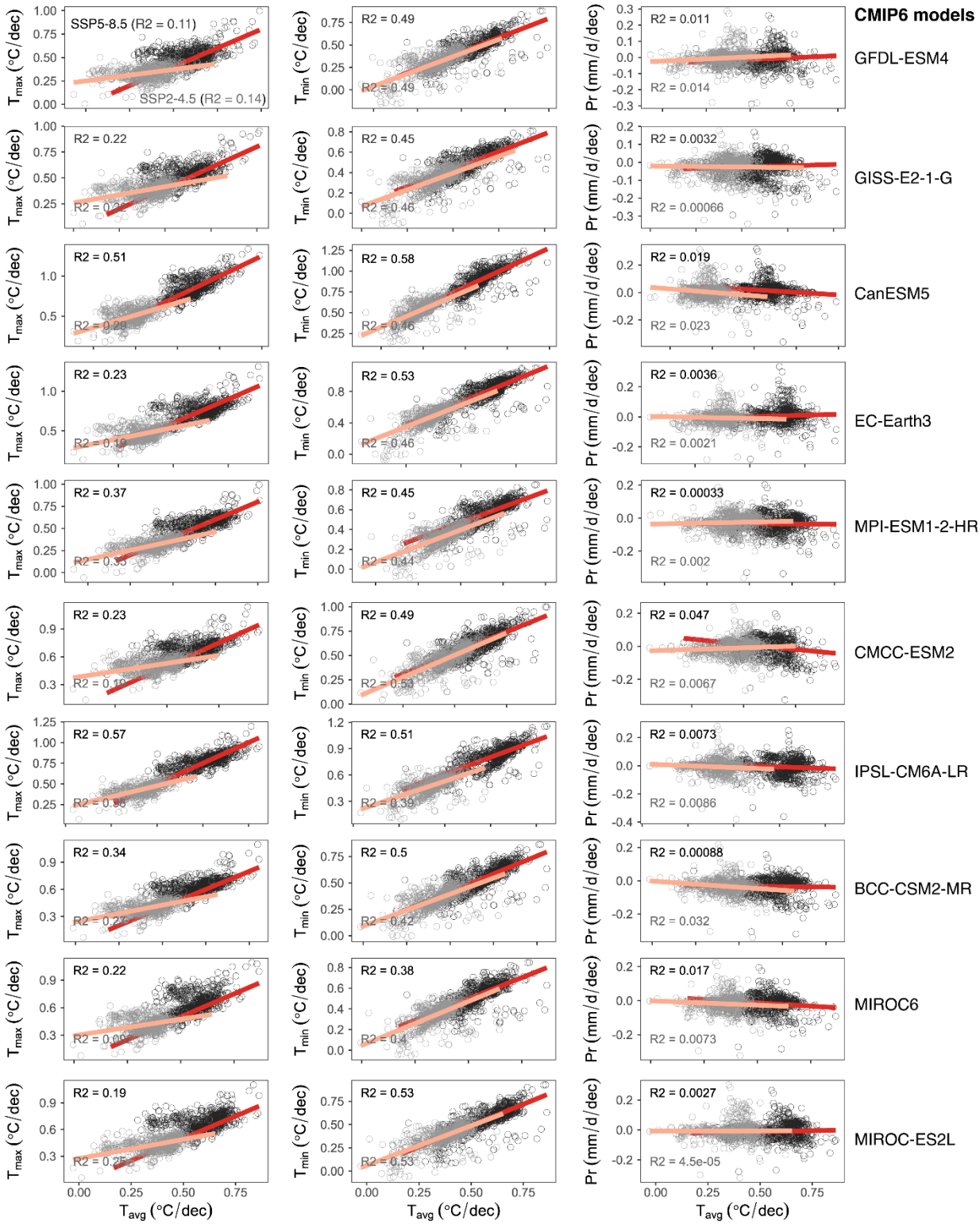
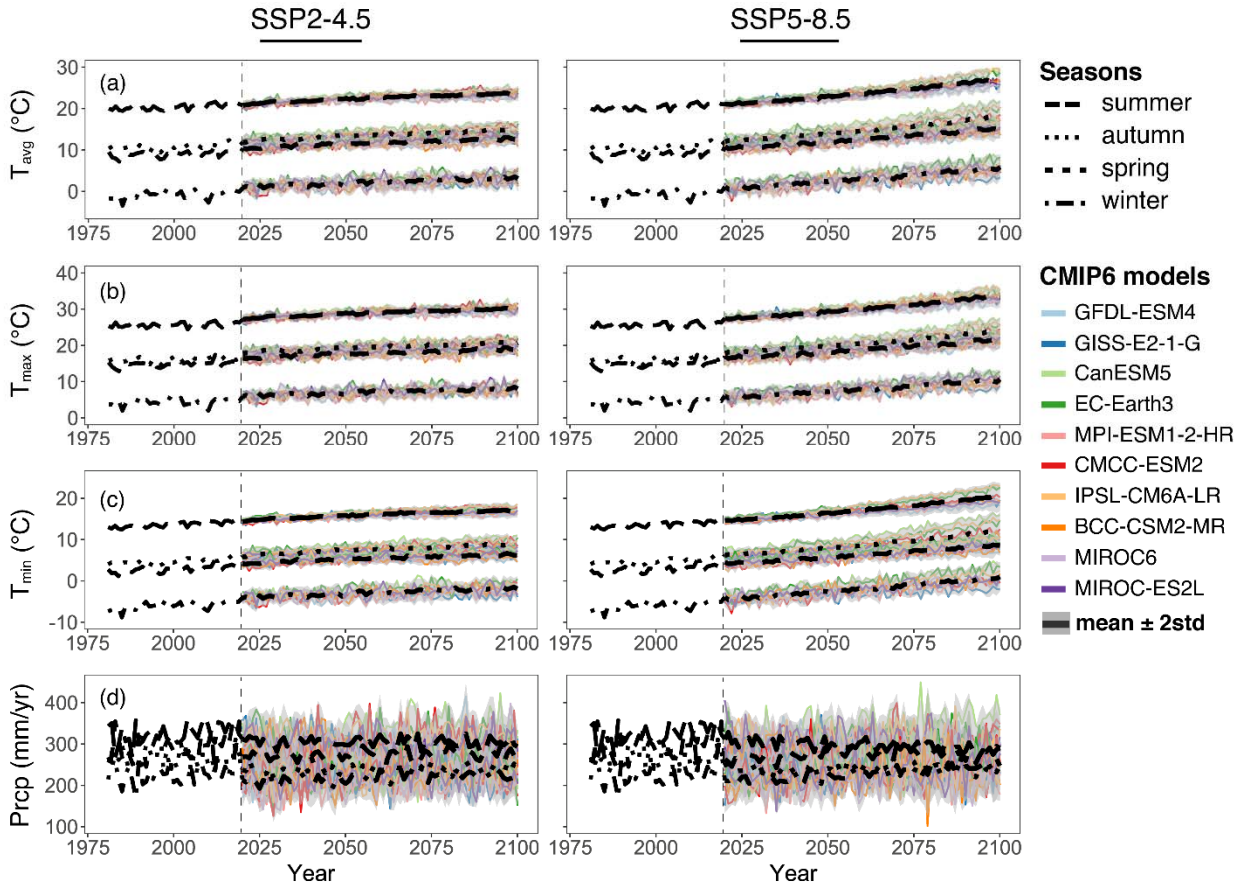
67 **Supplementary Fig. 6 | Data distribution and model performance under different**
68 **splitting schemes**. In comparison to the base case, Case 1 and 2 varied in training-
69 testing data volumes by ± 10%. The top row is the distribution of training vs. testing data
70 while the middle and bottom rows are NSE performances of DO and WT, respectively.
71 Numbers in the middle and bottom rows are median NSE performances for US and CE
72 with bold numbers are for all basins in the US and CE. The boxes show the median values
73 (middle line) and the interquartile range (IQR), which is the range between the first quartile
74 (Q1) and third quartile (Q3). The lower and upper whiskers extend to Q1 − 1.5 × IQR and
75 Q3 + 1.5 × IQR, respectively.



Supplementary Fig. 7 | Correlations among projected changes in temperature and precipitation. Each panel represents one of the 10 CMIP6 models for correlations between T_{avg} and T_{max} (left), T_{min} (middle), and Prcp (right). In the figure, each dot

represents the decadal rates of one basin with lighter and darker colors indicating the SSP2-4.5 and SSP5-8.5 scenarios. The numbers in the top and bottom corners are linear fitting (R^2) under the SSP2-4.5 and SSP5-8.5 scenarios, respectively.



Supplementary Fig. 8 | Projected seasonal trends of temperature and precipitation variables under SSP2-4.5 and SSP5-8.5 scenarios. Variables include daily average (a), maximum (b), and minimum (c) temperature and precipitation (d). The historical period covers 1981 to 2019 with the solid line as the average of all 796 basins. The projection period spans from 2020 to 2100 with thin color lines from the 10 CMIP6 models and bold black lines as the model mean ± 2 std. In each panel, the long-dash, dotted, dashed, and dot-dash lines represent the seasons of summer, autumn, spring, and winter, respectively. Temperature (a-c) shows consistent warming trends while the projected precipitation (d) generally exhibits stable but decreased trends compared to the historical period.