AGU PUBLICATIONS

Earth's Future

Supporting Information for

Projected Changes and Time of Emergence of Temperature Extremes over Australia in CMIP5 and CMIP6

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Table S1. Models and simulations in CMIP6 used in this study.

Model	Historical	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
1. ACCESS-CM2	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
2. ACCESS-ESM1-5	r1i1p1f1	-	r1i1p1f1	r1i1p1f1	r1i1p1f1
3. AWI-CM-1-1-MR	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
4. AWI-ESM-1-1-LR	r1i1p1f1	-	-	-	-
5. BCC-CSM2-MR	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
6. BCC-ESM1	r1i1p1f1	-	-	-	-
7. CanESM5	r1i1p1f1 ~ r25i1p1f1	r1i1p1f1 ~ r25i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1 ~ r25i1p1f1
8. CMCC-ESM2	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
9. CNRM-CM6-1	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2
10. CNRM-CM6-1-HR	r1i1p1f2	r1i1p1f2	-	-	r1i1p1f2
11. CNRM-ESM2-1	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2
12. FGOALS-f3-L	r1i1p1f1	-	-	-	-
13. FGOALS-g3	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
14. GFDL-CM4	r1i1p1f1	-	r1i1p1f1	-	r1i1p1f1
15. GFDL-ESM4	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
16. GISS-E2-1-G	r1i1p1f1	-	-	-	-
17. HadGEM3-GC31-LL	r1i1p1f3	r1i1p1f3	r1i1p1f3	-	r1i1p1f3
18. HadGEM3-GC31-MM	r1i1p1f3	r1i1p1f3	-	-	r1i1p1f3
19. INM-CM4-8	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
20. INM-CM5-0	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
21. IPSL-CM6A-LR	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
22. MIROC-ES2L	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2
23. MIROC6	r1i1p1f1 ~ r50i1p1f1	r1i1p1f1 ~ r50i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1 ~ r50i1p1f1
24. MPI-ESM-1-2-HAM	r1i1p1f1	-	-	-	-
25. MPI-ESM1-2-HR	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
26. MPI-ESM1-2-LR	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
27. MRI-ESM2-0	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
28. NorCPM1	r1i1p1f1	-	-	-	-
29. NorESM2-LM	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
30. NorESM2-MM	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1	r1i1p1f1
31. SAM0-UNICON	r1i1p1f1	-	-	-	-
32. UKESM1-0-LL	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2	r1i1p1f2
Number of models	32	23	23	21	25

Table S2. Models and simulations in CMIP5 used in this study.

Model	Historical	RCP2.6	RCP4.5	RCP8.5
1. ACCESS1-0	r1i1p1	-	r1i1p1	r1i1p1
2. ACCESS1-3	r1i1p1	-	r1i1p1	r1i1p1
3. bcc-csm1-1	r1i1p1	r1i1p1	r1i1p1	r1i1p1
4. BNU-ESM	r1i1p1	r1i1p1	r1i1p1	r1i1p1
5. CanESM2	r1i1p1	r1i1p1	r1i1p1	r1i1p1
6. CCSM4	r1i1p1	r1i1p1	r1i1p1	r1i1p1
7. CESM1-BGC	r1i1p1	-	r1i1p1	r1i1p1
8. CMCC-CM	r1i1p1	-	r1i1p1	r1i1p1
9. CNRM-CM5	r1i1p1	r1i1p1	r1i1p1	r1i1p1
10. CSIRO-Mk3-6-0	r1i1p1	r1i1p1	r1i1p1	r1i1p1
11. FGOALS-g2	r1i1p1	-	r1i1p1	r1i1p1
12. GFDL-ESM2G	r1i1p1	r1i1p1	r1i1p1	r1i1p1
13. GFDL-ESM2M	r1i1p1	r1i1p1	r1i1p1	r1i1p1
14. GISS-E2-R	r6i1p1	-	r6i1p1	r2i1p1
15. HadGEM2-CC	r1i1p1	-	r1i1p1	r1i1p1
16. HadGEM2-ES	r1i1p1	r1i1p1	r1i1p1	r1i1p1
17. IPSL-CM5A-LR	r1i1p1	r1i1p1	r1i1p1	r1i1p1
18. IPSL-CM5A-MR	r1i1p1	r1i1p1	r1i1p1	r1i1p1
19. IPSL-CM5B-LR	r1i1p1	-	r1i1p1	r1i1p1
20. MIROC5	r1i1p1	r1i1p1	r1i1p1	r1i1p1
21. MIROC-ESM	r1i1p1	r1i1p1	r1i1p1	r1i1p1
22. MIROC-ESM-CHEM	r1i1p1	r1i1p1	r1i1p1	r1i1p1
23. MPI-ESM-LR	r1i1p1	r1i1p1	r1i1p1	r1i1p1
24. MPI-ESM-MR	r1i1p1	r1i1p1	r1i1p1	r1i1p1
25. MRI-CGCM3	r1i1p1	r1i1p1	r1i1p1	r1i1p1
26. NorESM1-M	r1i1p1	r1i1p1	r1i1p1	r1i1p1
Number of models	26	18	26	26

Table S3. Extreme temperature indices used in this study.

Label	Index Name	Description	Unit
TXx	Hottest day	Annual maximum value of daily maximum temperature	°C
TXn	Coldest day	Annual minimum value of daily maximum temperature	°C
TNx	Warmest night	Annual maximum value of daily minimum temperature	°C
TNn	Coldest night	Annual minimum value of daily minimum temperature	°C
DTR	Diurnal temperature range	Annual mean difference between daily maximum and minimum temperature	°C
TX90p	Warm days	Percentage of time when daily maximum temperature is greater than 90th percentile (using running 5-day window)	%
TX10p	Cold days	Percentage of time when daily maximum temperature is less than 10th percentile (using running 5-day window)	%
TN90p	Warm nights	Percentage of time when daily minimum temperature is greater than 90th percentile (using running 5-day window)	%
TN10p	Cold nights	Percentage of time when daily minimum temperature is less than 10th percentile (using running 5-day window)	%
WSDI	Warm spell duration index	Annual count when at least six consecutive days of maximum temperature is greater than 90th percentile (using running 5-day window)	days
CSDI	Cold spell duration index	Annual count when at least six consecutive days of minimum temperature is less than 10th percentile (using running 5-day window)	days
SU	Summer days	Annual count when daily maximum temperature is greater than 25°C	days
TR	Tropical nights	Annual count when daily minimum temperature is greater than 20°C	days
FD	Frost days	Annual count when daily minimum temperature is less than 0°C	days

Table S4. Latitude and longitude boundaries of Australian regions.

Label	Region	Lat (°S)	Lon (°E)
1. AUS	Australia	10-45	110-155
2. NA	Northern Australia	10–26	110–155
3. SA	Southern Australia	26–45	110–155
4. SEA	South East Australia	32.5–45	140–155
5. MEA	Middle Eastern Australia	20–32.5	140–155
6. TA	Tropical Australia	10–20	110–155
7. SWA	South West Australia	27.5–40	110–127.5
8. SSA	Southern South Australia	30–40	127.5–140
9. CAU	Central Australia	20–30	127.5–140
10. MWA	Mid-Western Australia	20–27.5	110–127.5

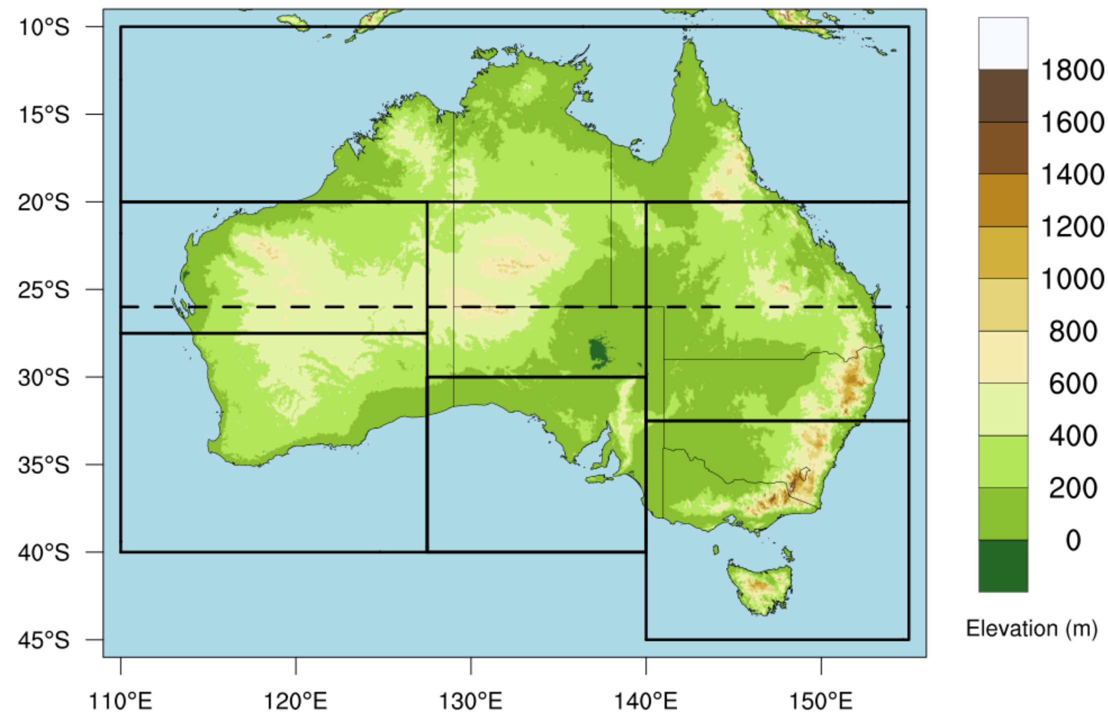


Fig. S1. Regions used in the study. Northern Australia (NA) and Southern Australia (SA) are divided by the dashed line at 26°S, and solid lines denote the boundaries of other Australian subregions.

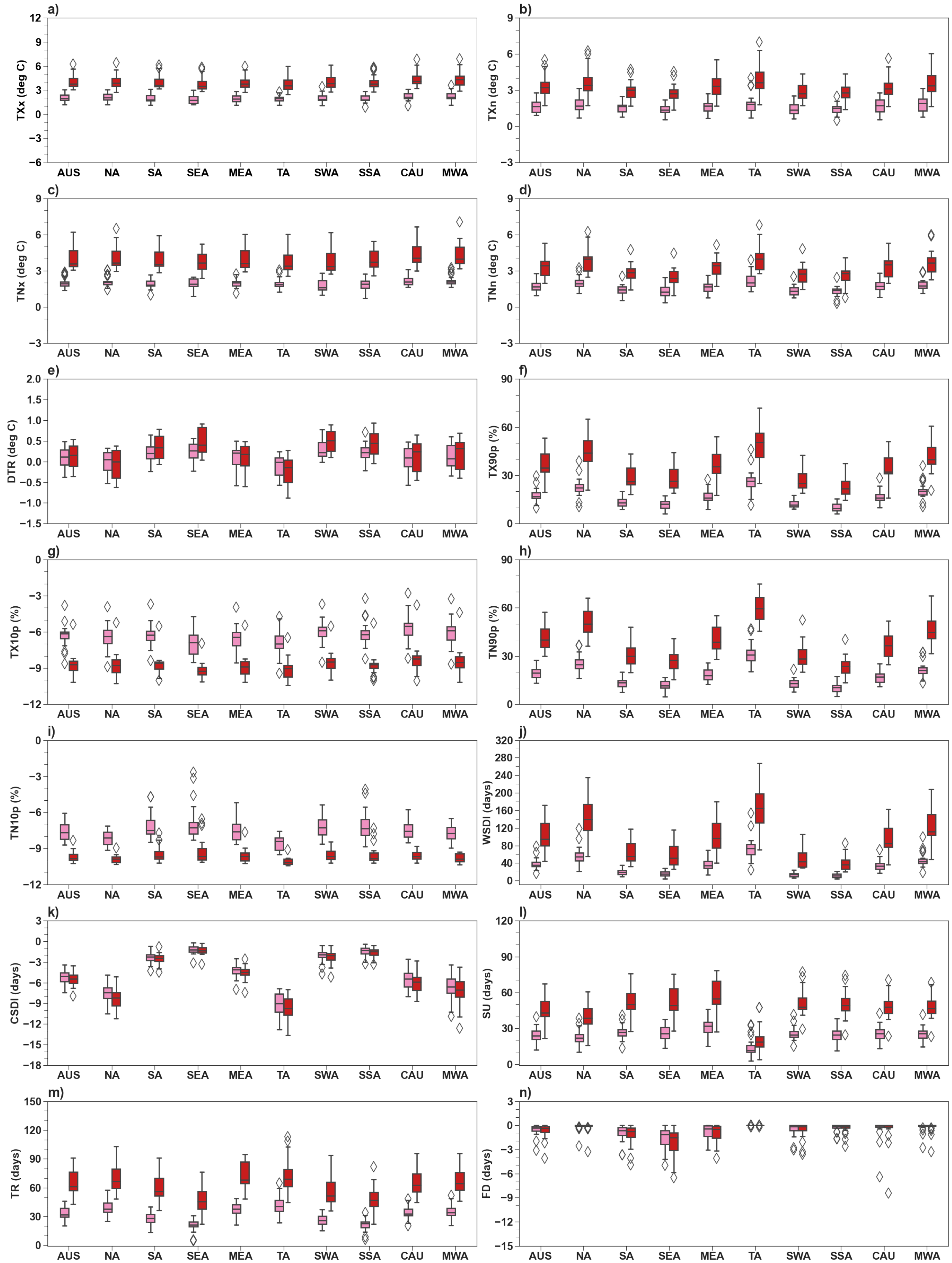


Fig. S2. Boxplots of projected changes in the 14 ETCCDI indices over 2071–2100 (bold color) and 2031-2060 (light color) relative to the base period 1961–1990 across 10 Australian regions, under SSP3-7.0 (red). The boxes indicate the interquartile spreads (ranges between the 25th and 75th percentiles), the black lines within the boxes are the multi-model medians, the whiskers extend to the edges of 1.5 × interquartile ranges and "outliers" outside of the whiskers are denoted by diamonds.

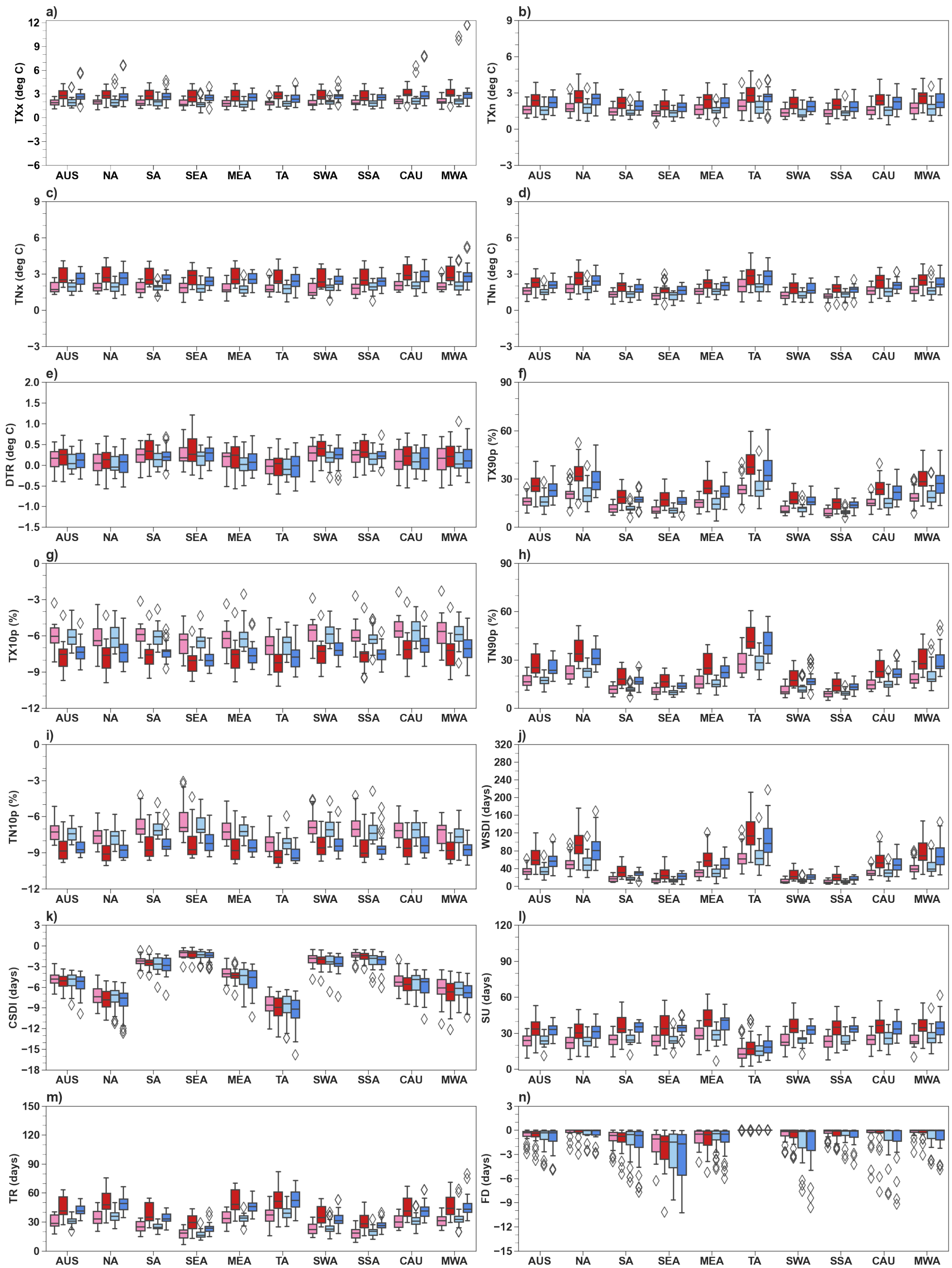


Fig. S3. Same as Fig. S2, but for SSP2-4.5 (red) and RCP4.5 (blue).

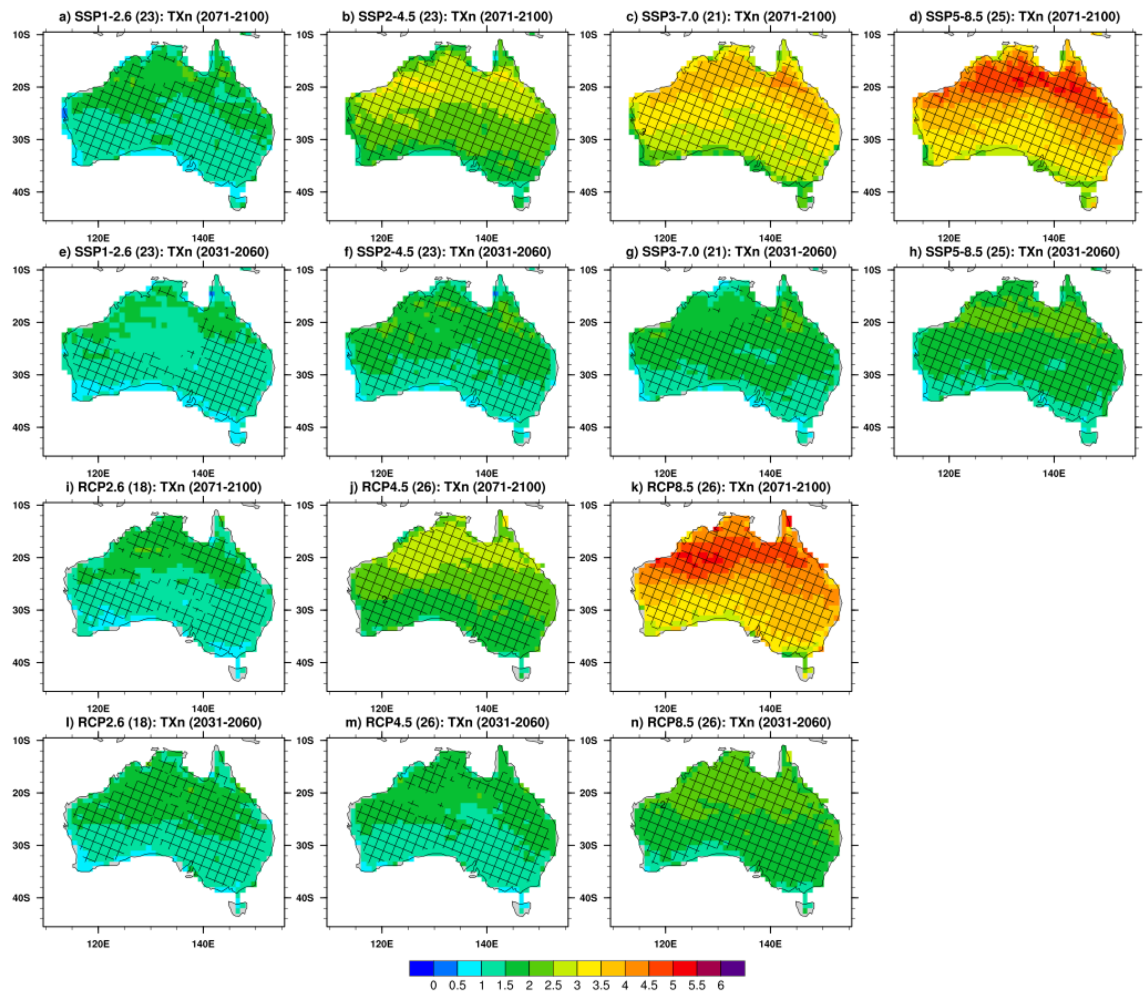


Fig. S4. Multi-model median changes in TXn for 2071–2100 (a-d; i-k) and 2031–2060 (e-h; l-n) relative to the base period 1961–2010, under different future scenarios in CMIP6 (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5) and CMIP5 (RCP2.6, RCP4.5 and RCP8.5). Hatching indicates that at least 75% of the models for each future scenario project significant changes at 95% level, based on the two-tailed Student's t-test.

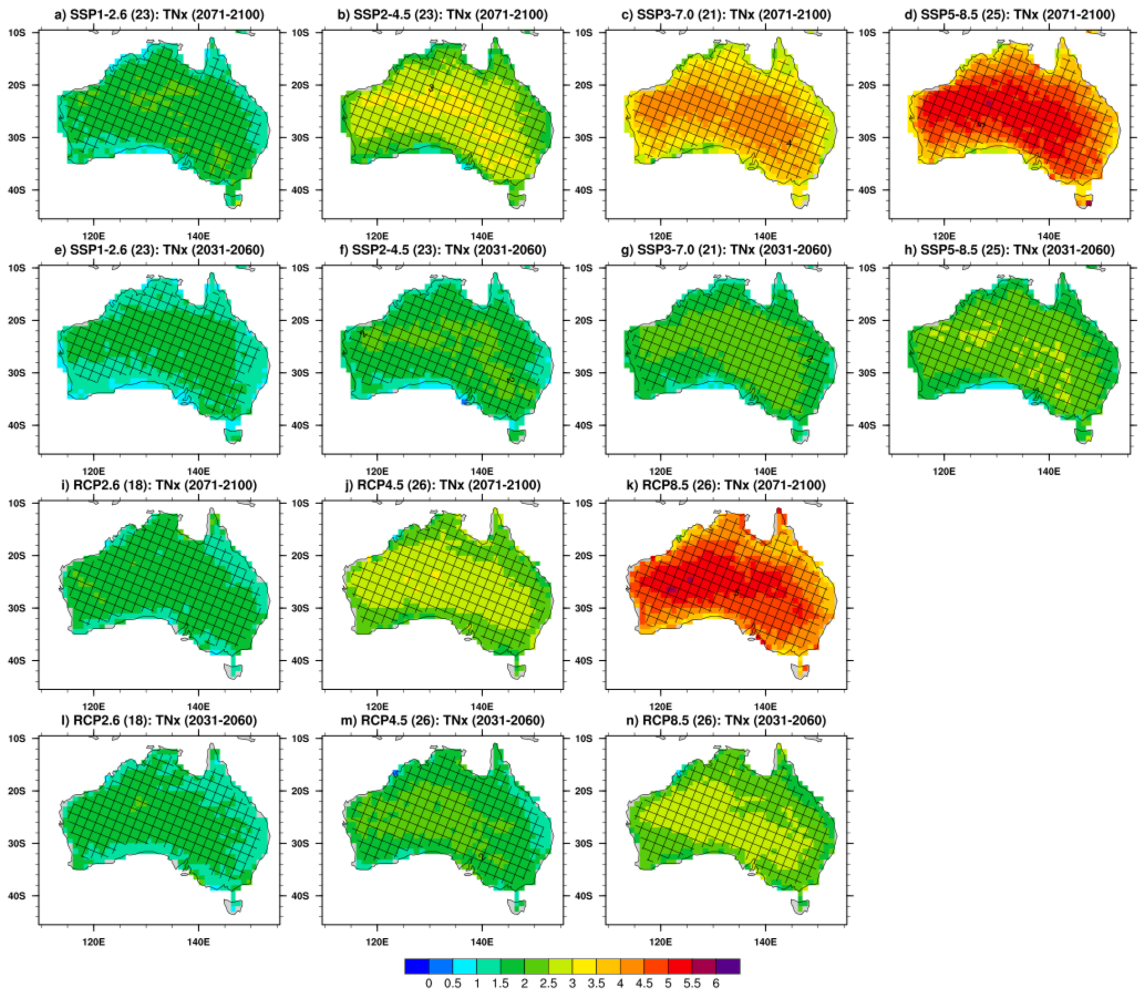


Fig. S5. Same as Fig. S4, but for TNx.

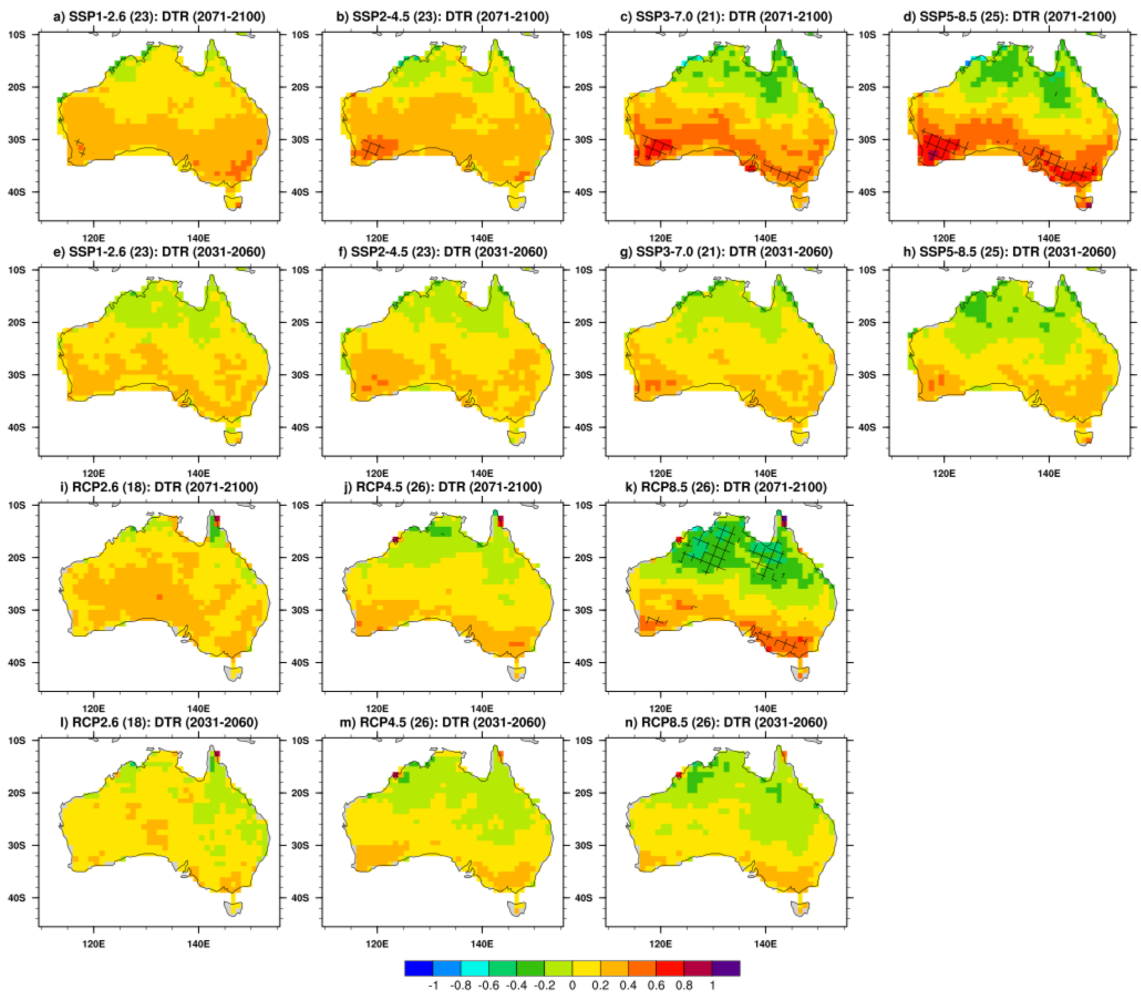


Fig. S6. Same as Fig. S4, but for DTR.

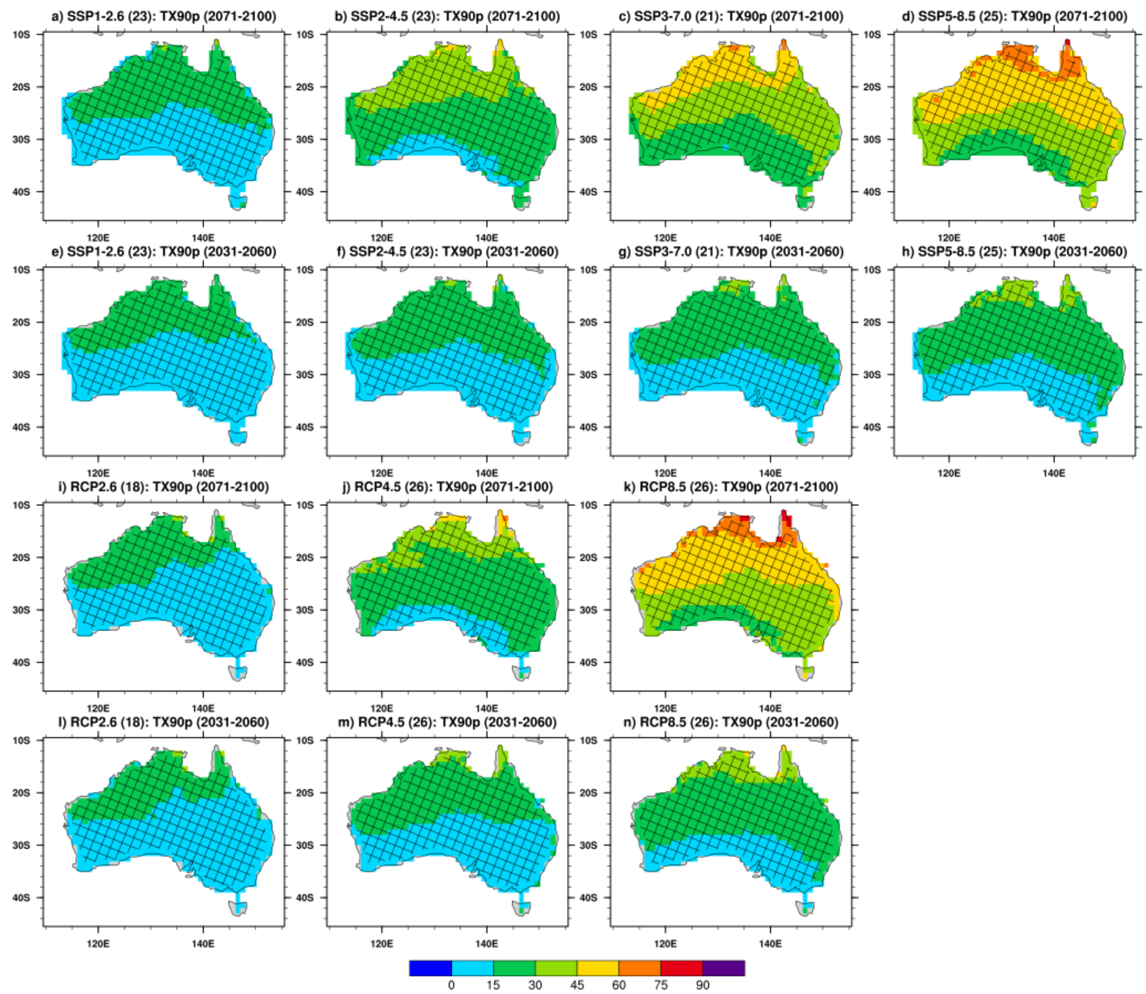


Fig. S7. Same as Fig. S4, but for TX90p.

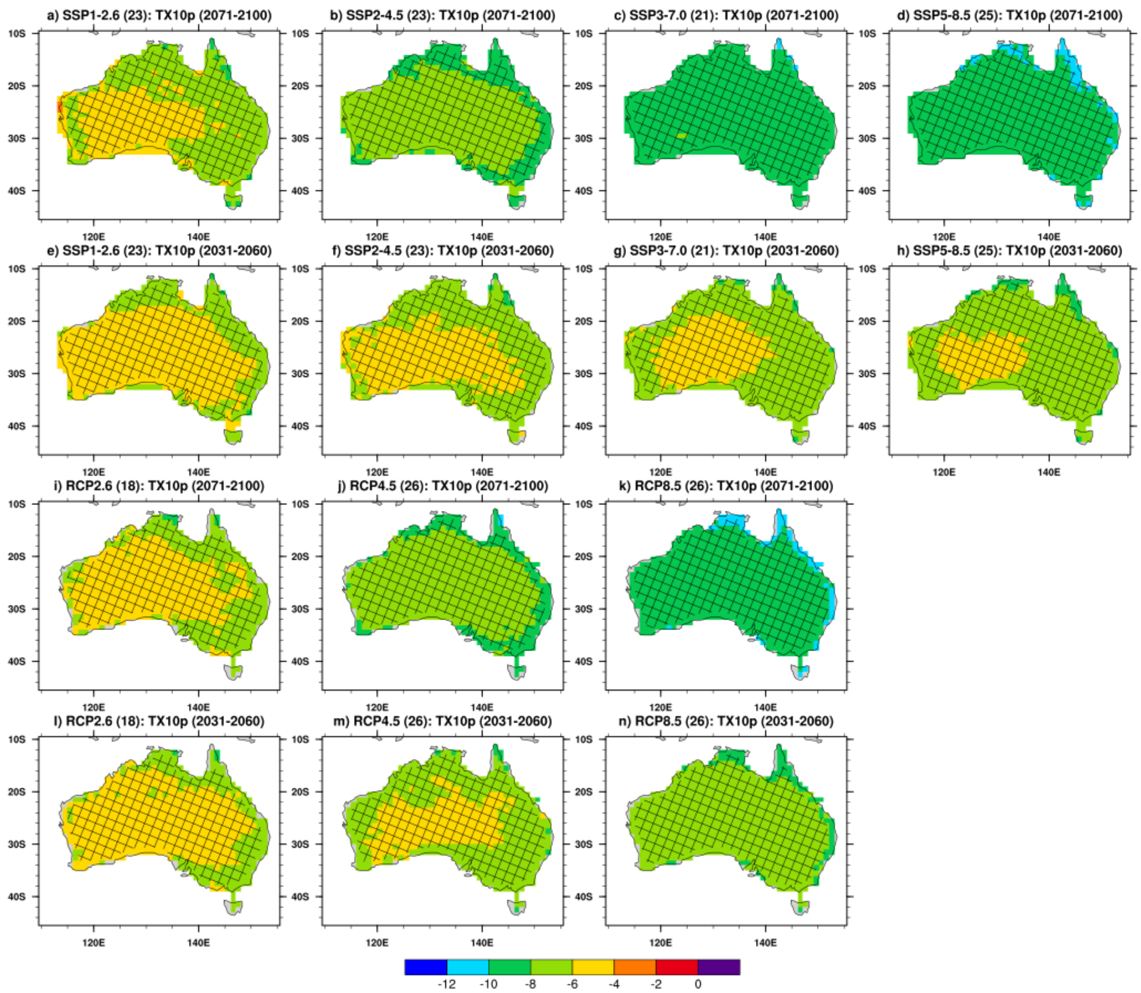


Fig. S8. Same as Fig. S4, but for TX10p.

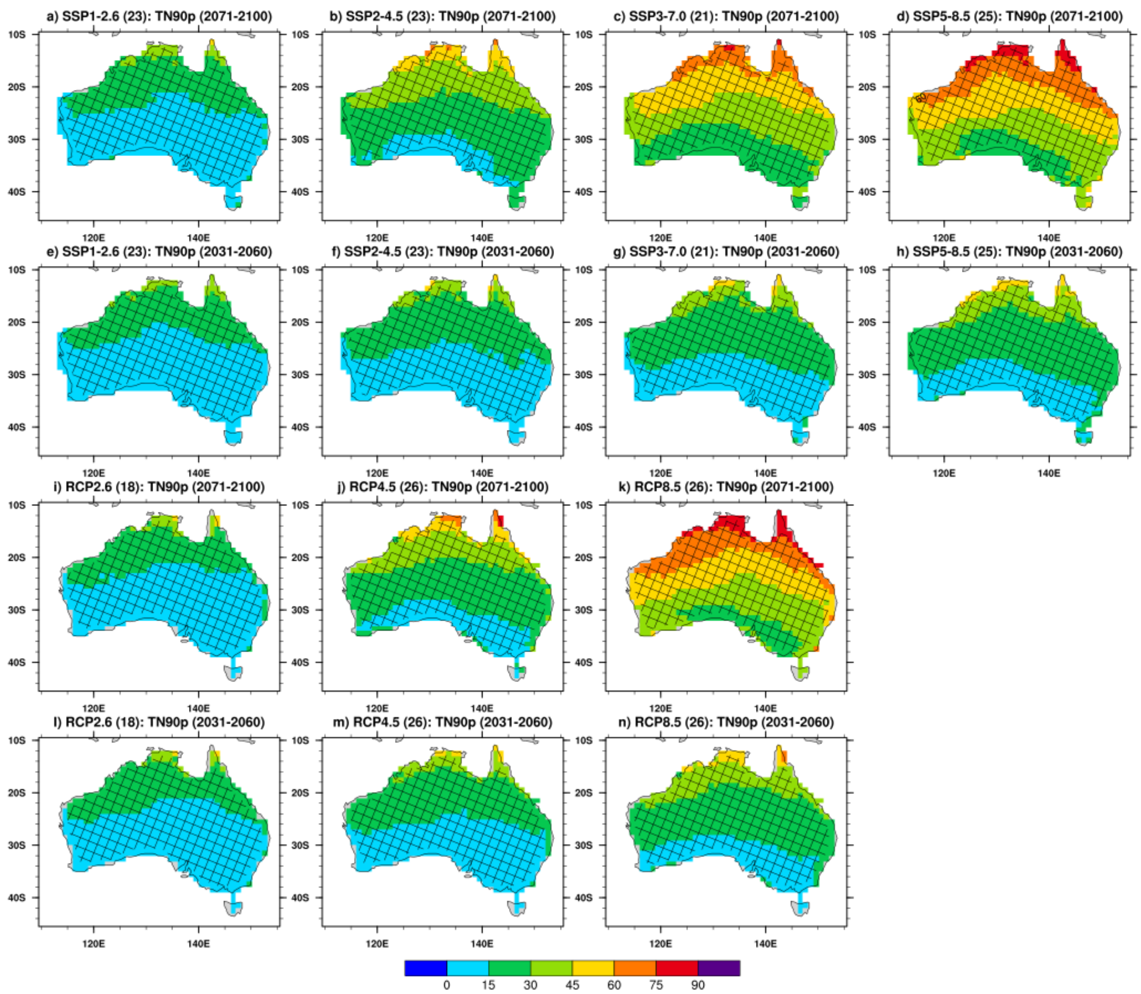


Fig. S9. Same as Fig. S4, but for TN90p.

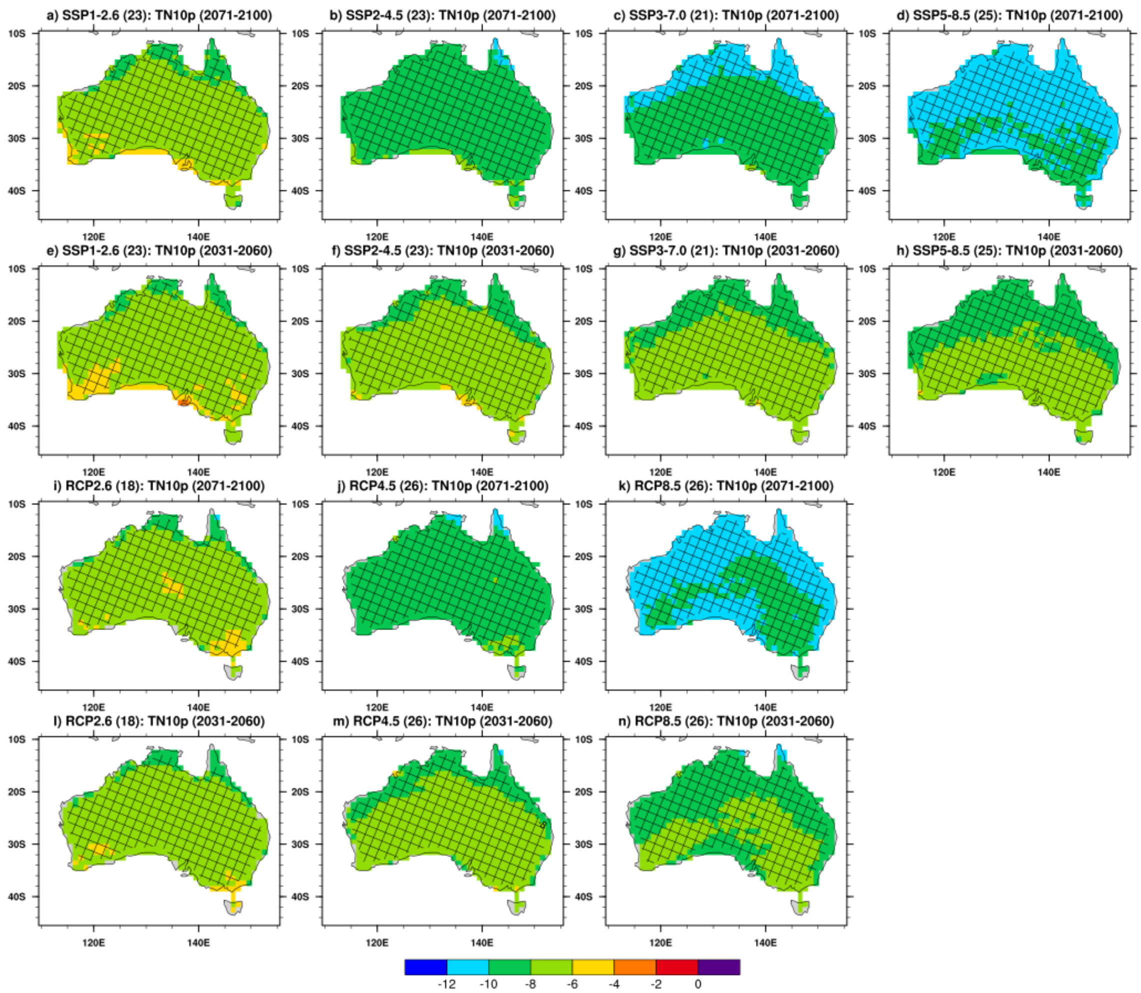


Fig. S10. Same as Fig. S4, but for TN10p.

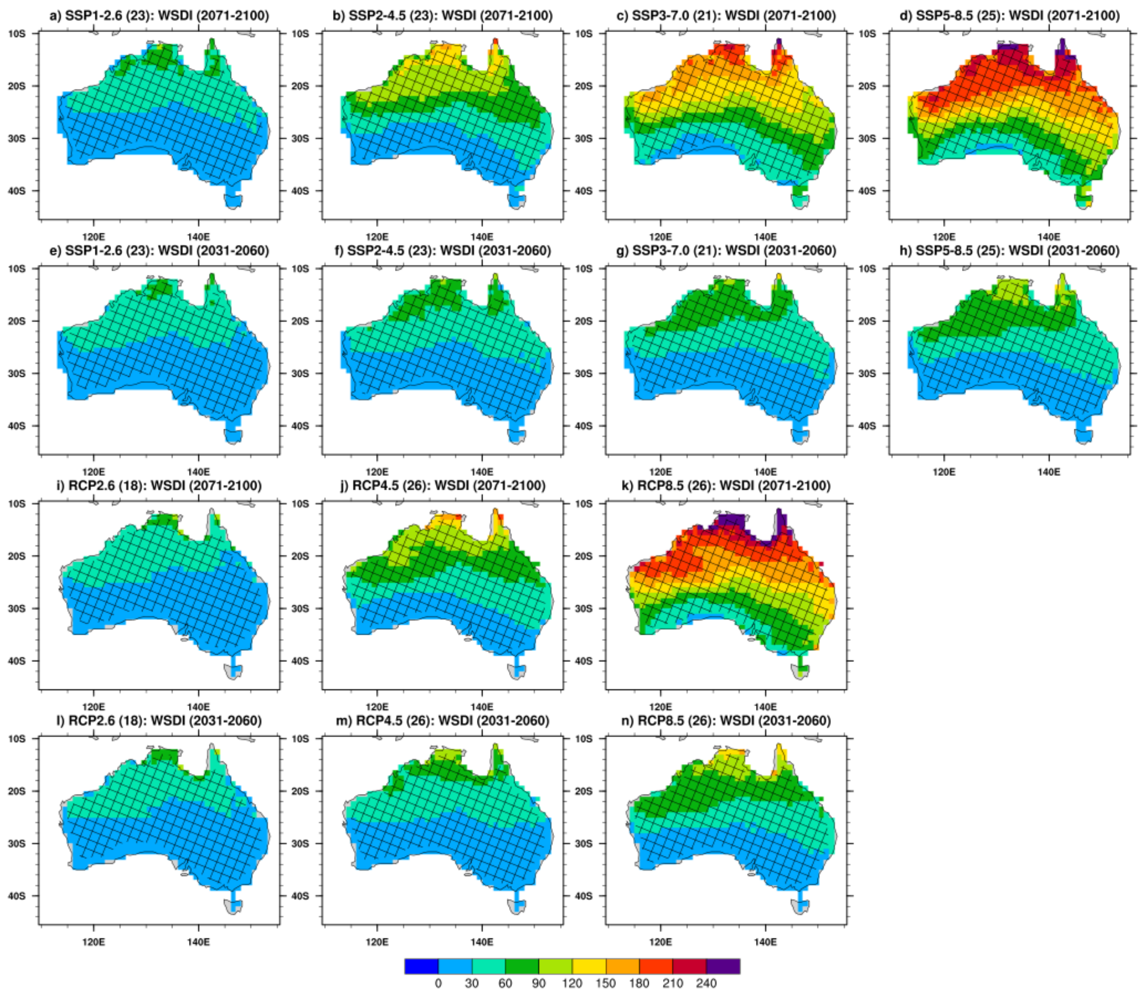


Fig. S11. Same as Fig. S4, but for WSDI.

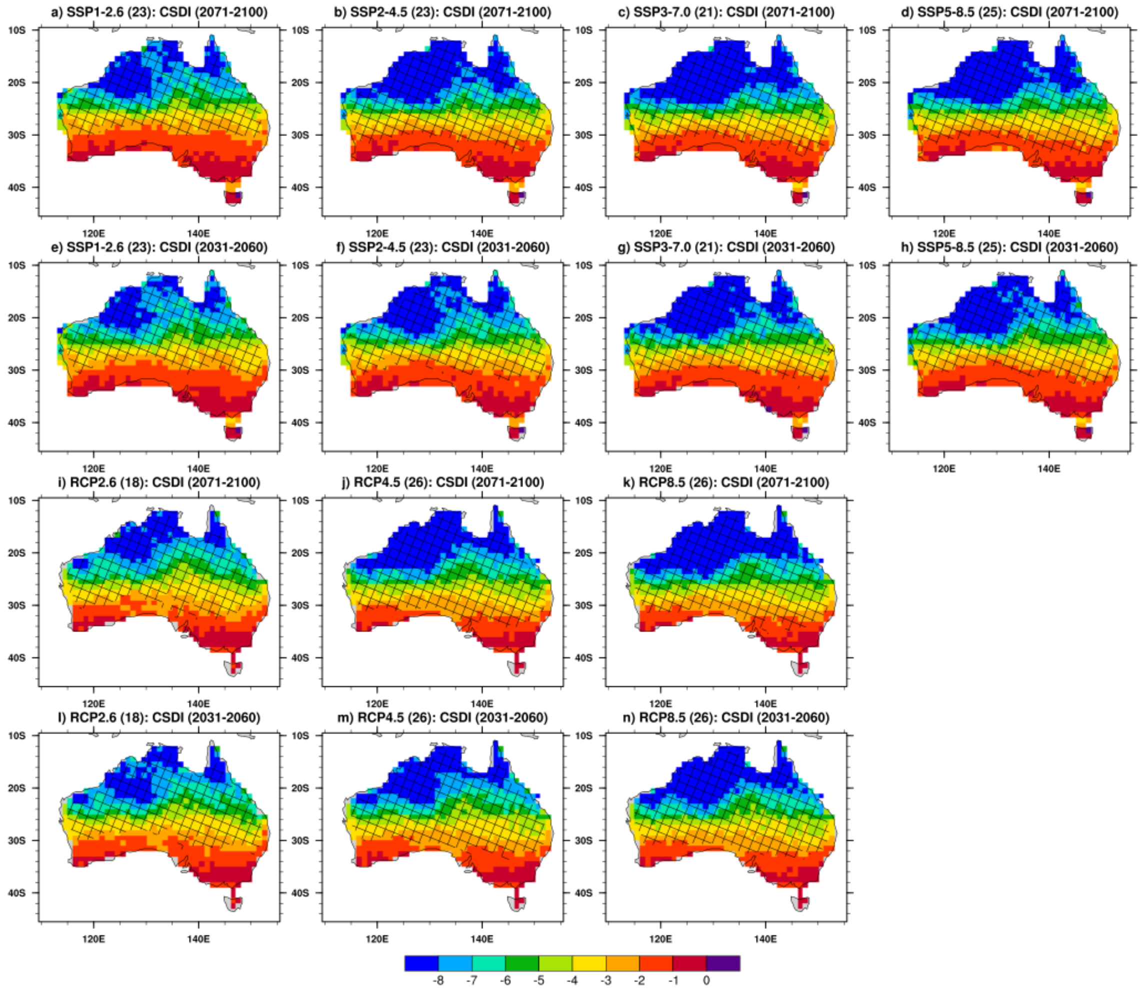


Fig. S12. Same as Fig. S4, but for CSDI.

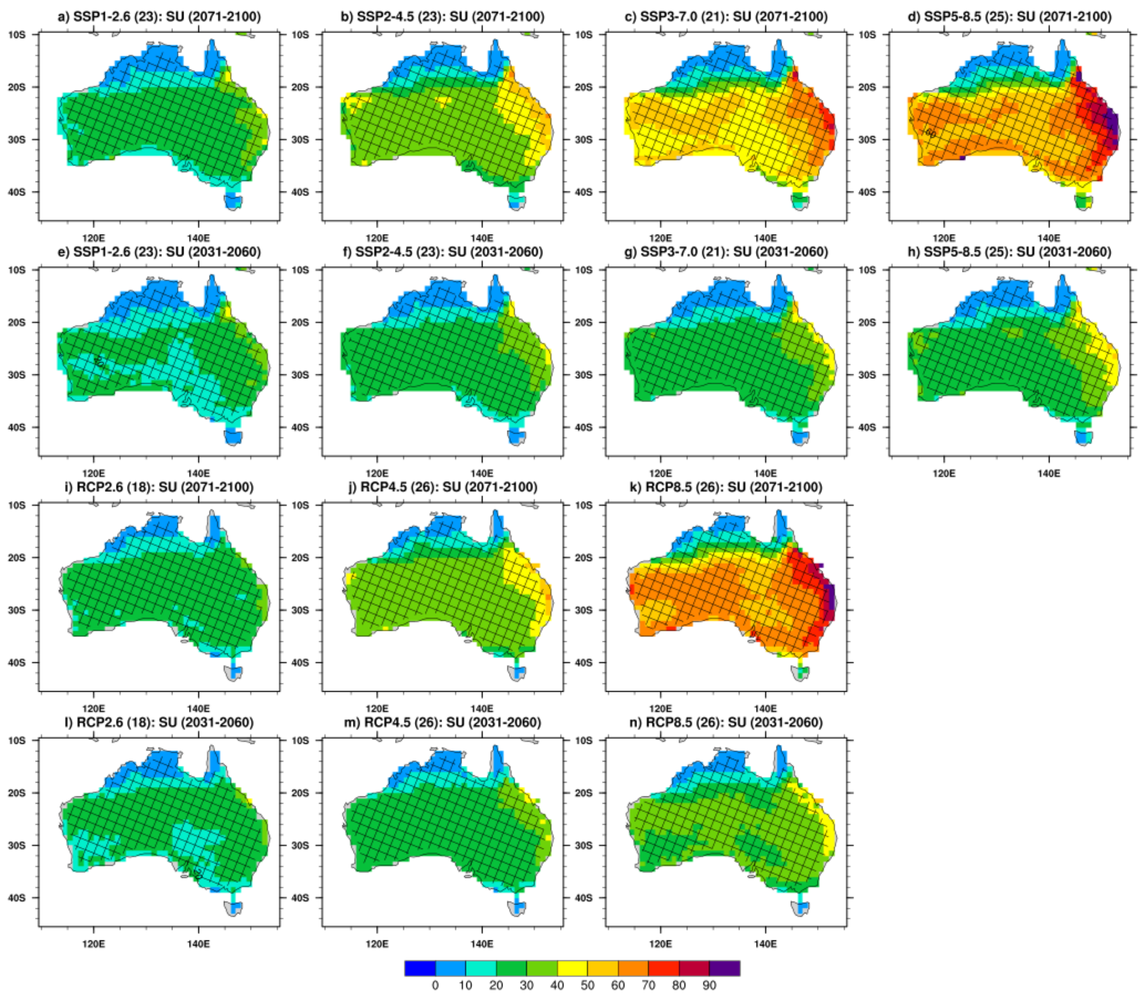
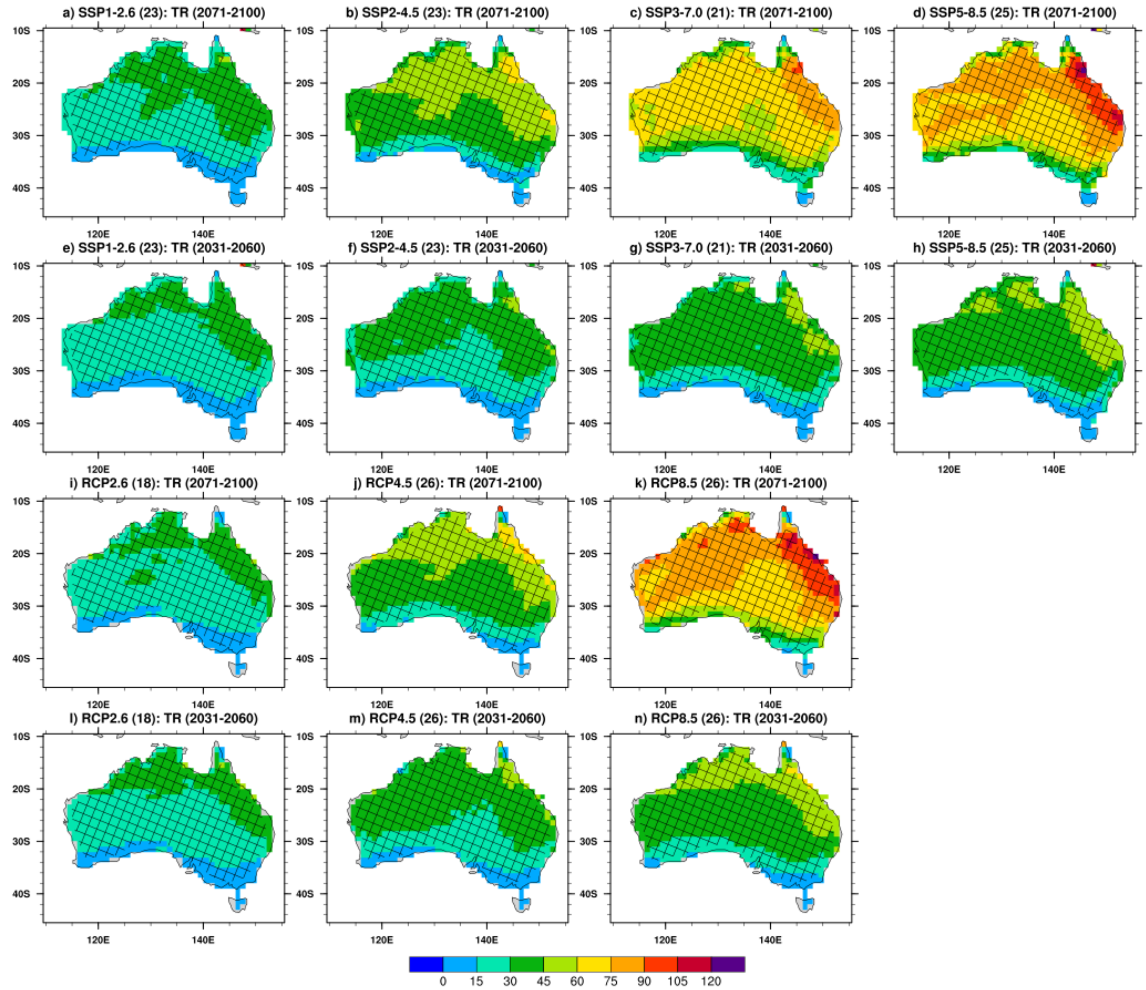


Fig. S13. Same as Fig. S4, but for SU.



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151 **Fig. S14.** Same as Fig. S4, but for TR.

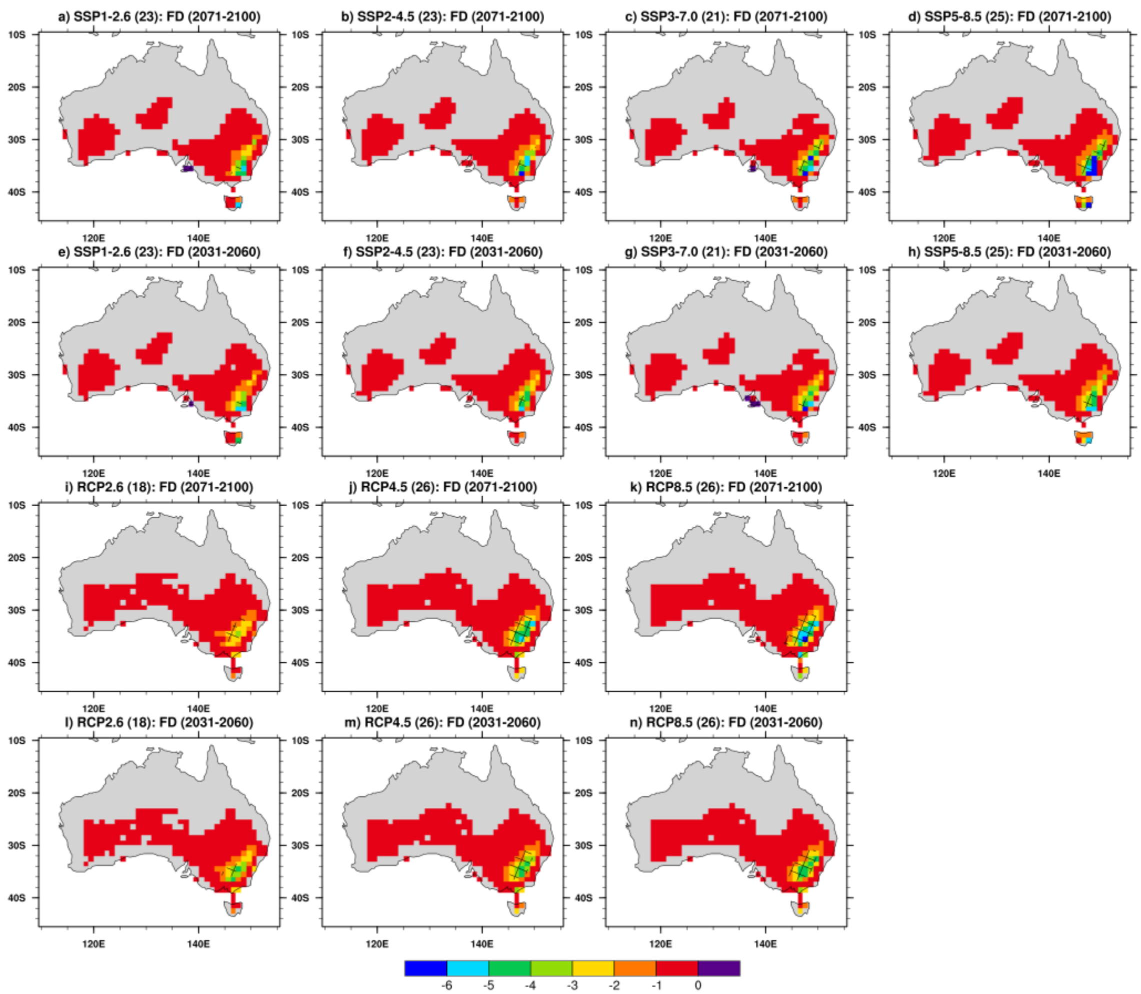

Fig. S15. Same as Fig. S4, but for FD.

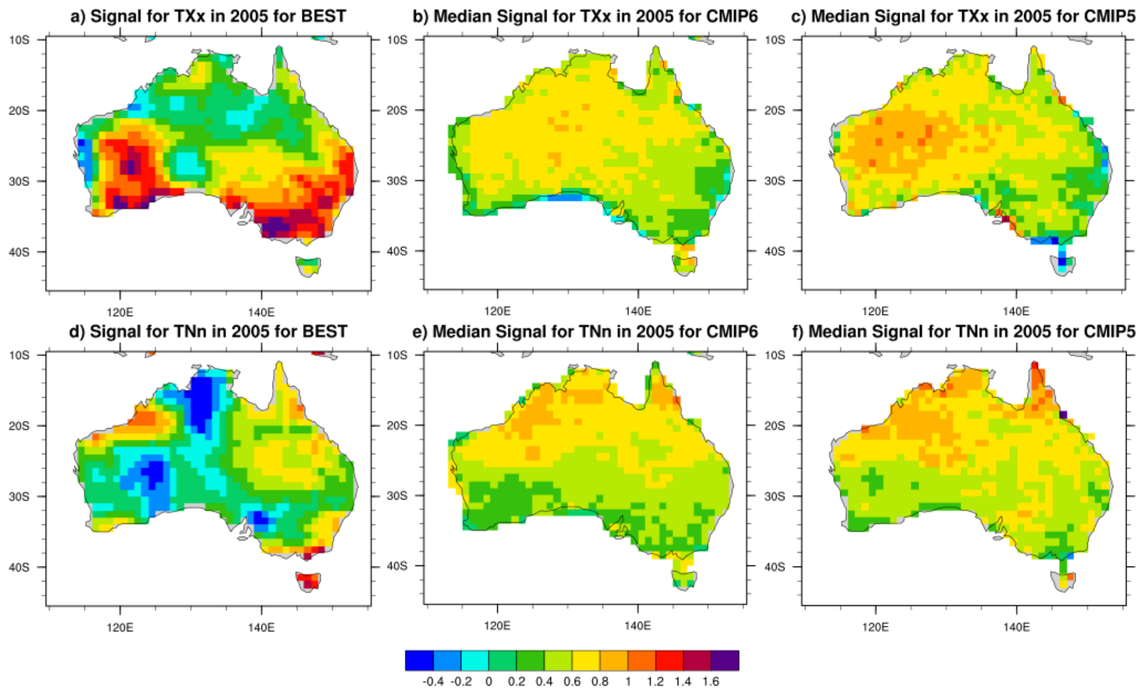

Fig. S16. Signal (unit: K) in the year 2005 for temperature extremes in BEST, CMIP6 and CMIP5. (a) Signal in TXx for BEST; (b) Signal in TXx for the multi-model medians in CMIP6; and (c) Signal in TXx for the multi-model medians in CMIP5. (d-f) Same as (a-c), but for TNn.

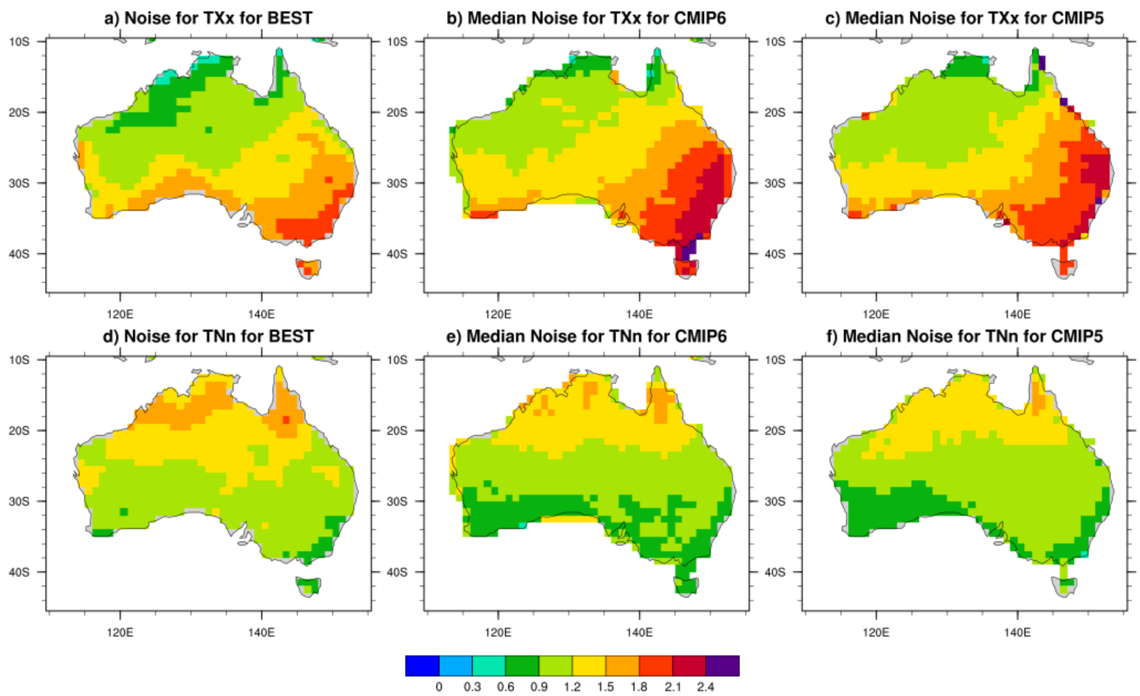

Fig. S17. Sane as Fig. S16, but for noise (unit: K).

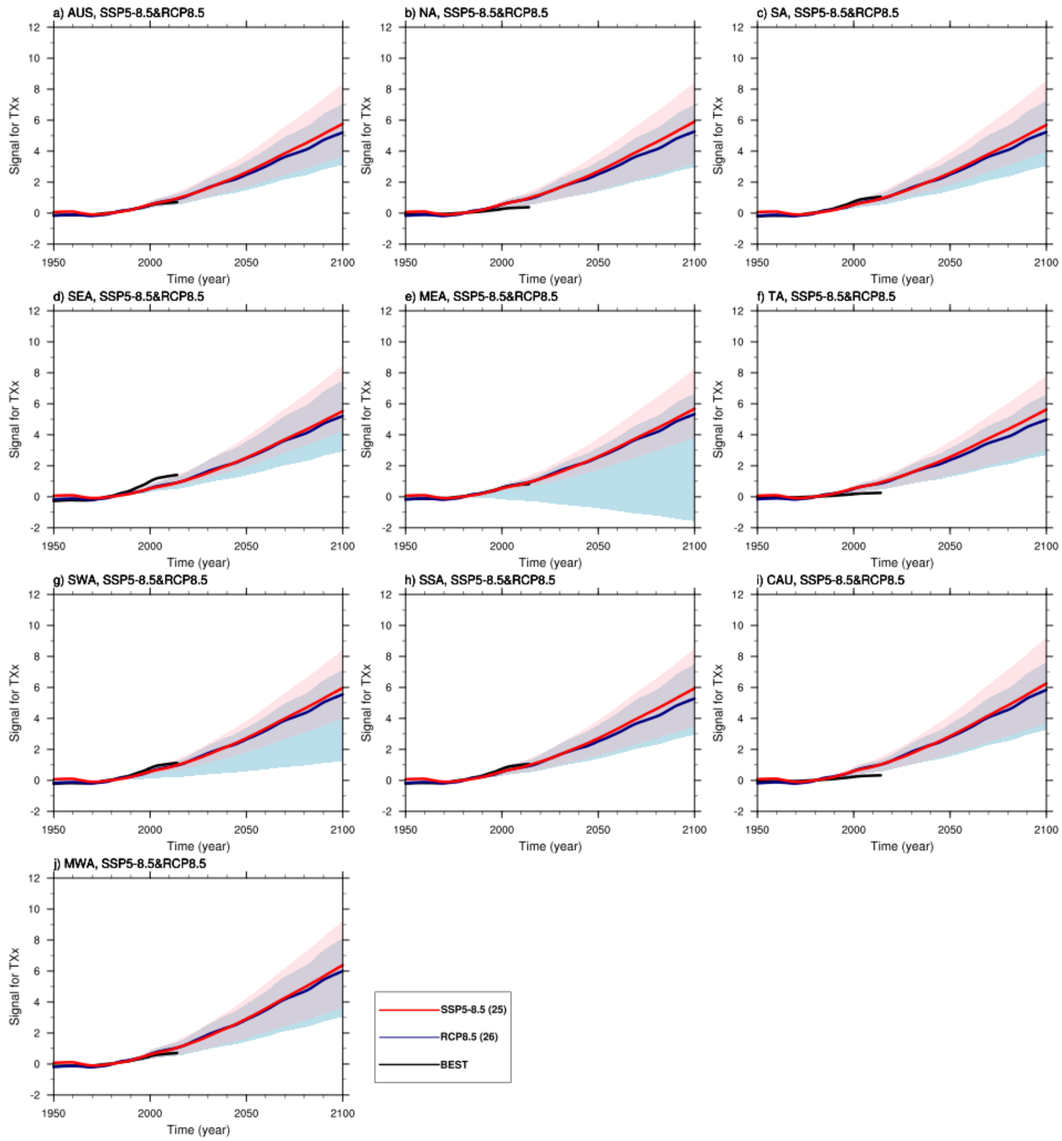

Fig. S18. Time series of signal (unit: K) in TXx from 1950-2100 over 10 Australian regions under SSP5-8.5 for BEST (black), CMIP6 (red) and CMIP5 (blue) (the number of models indicated in parentheses in the legend). Solid lines represent the multi-model medians and shading indicates the full range across the models for each experiment.

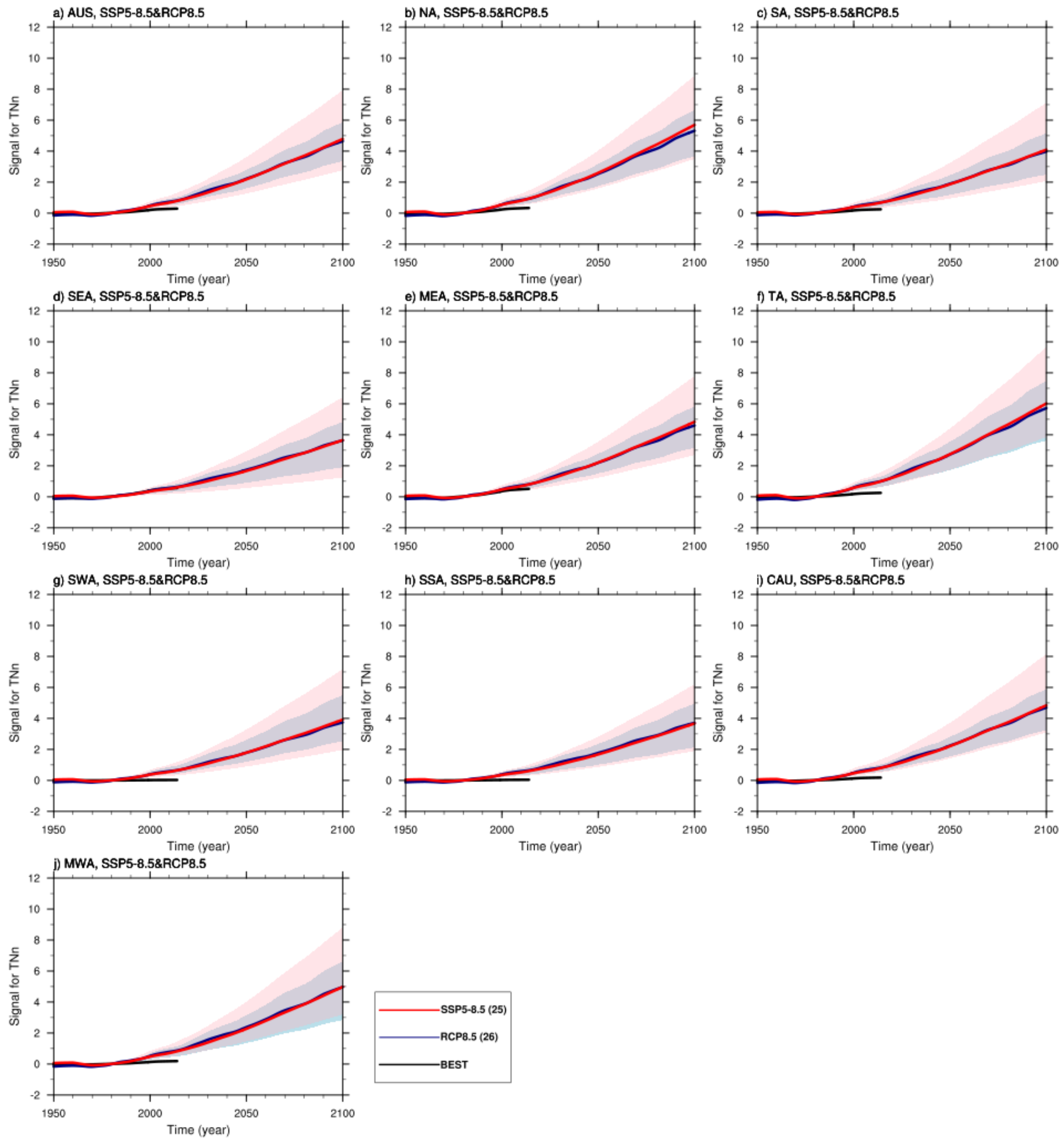

Fig. S19. Same as Fig. S18, but for TNn.

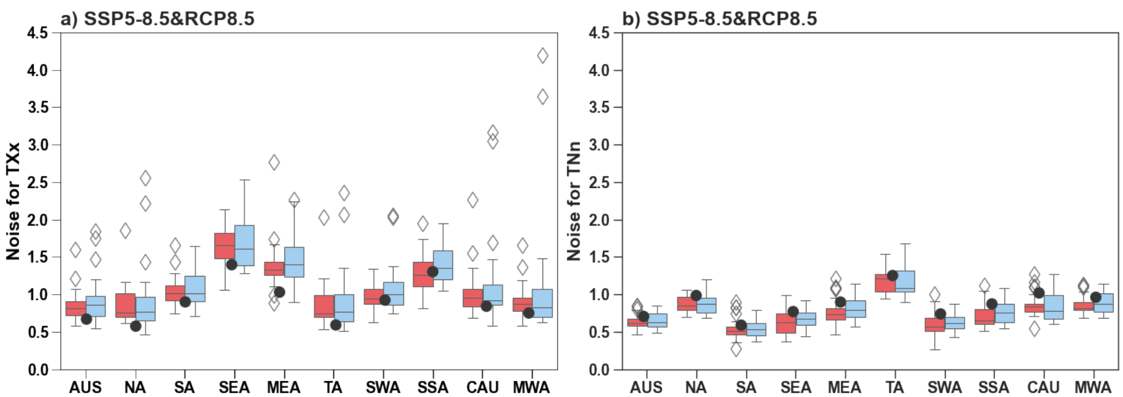

Fig. S20. Boxplots of noise (unit: K) in TXx (a) and TNn (b) calculated over the period 1950-2005 across 10 Australian regions, under SSP5-8.5 (red) and RCP8.5 (blue). The boxes indicate the interquartile spreads (ranges between the 25th and 75th percentiles), the black lines within the boxes are the multi-model medians, the whiskers extend to the edges of 1.5 × interquartile ranges and "outliers" outside of the whiskers are denoted by diamonds.

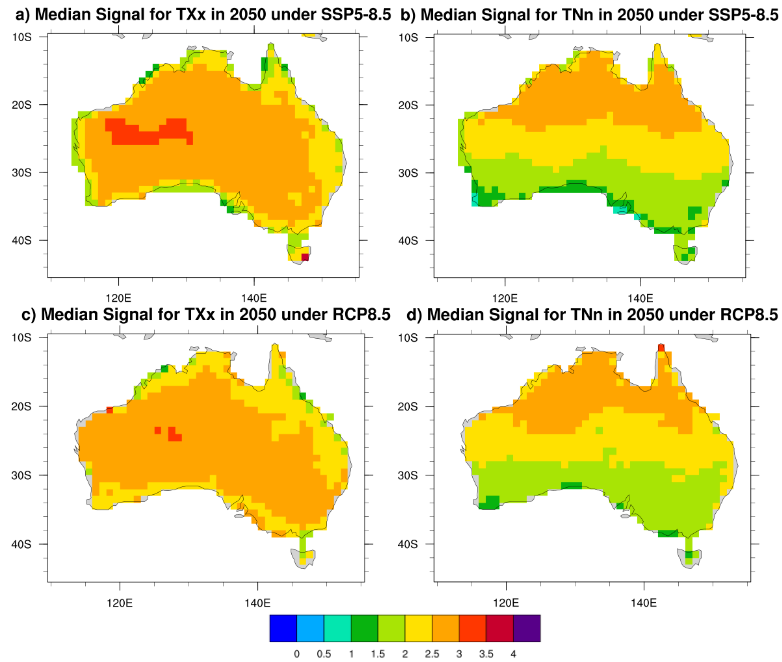

Fig. S21. Median signal (unit: K) for TXx and TNn under SSP5-8.5 and RCP8.5 in the years 2050. (a) Signal for TXx under SSP5-8.5 in the year 2050; (b) Signal for TNn under SSP5-8.5 in the year 2050; (c, d) same as (a) and (b), but for RCP8.5.

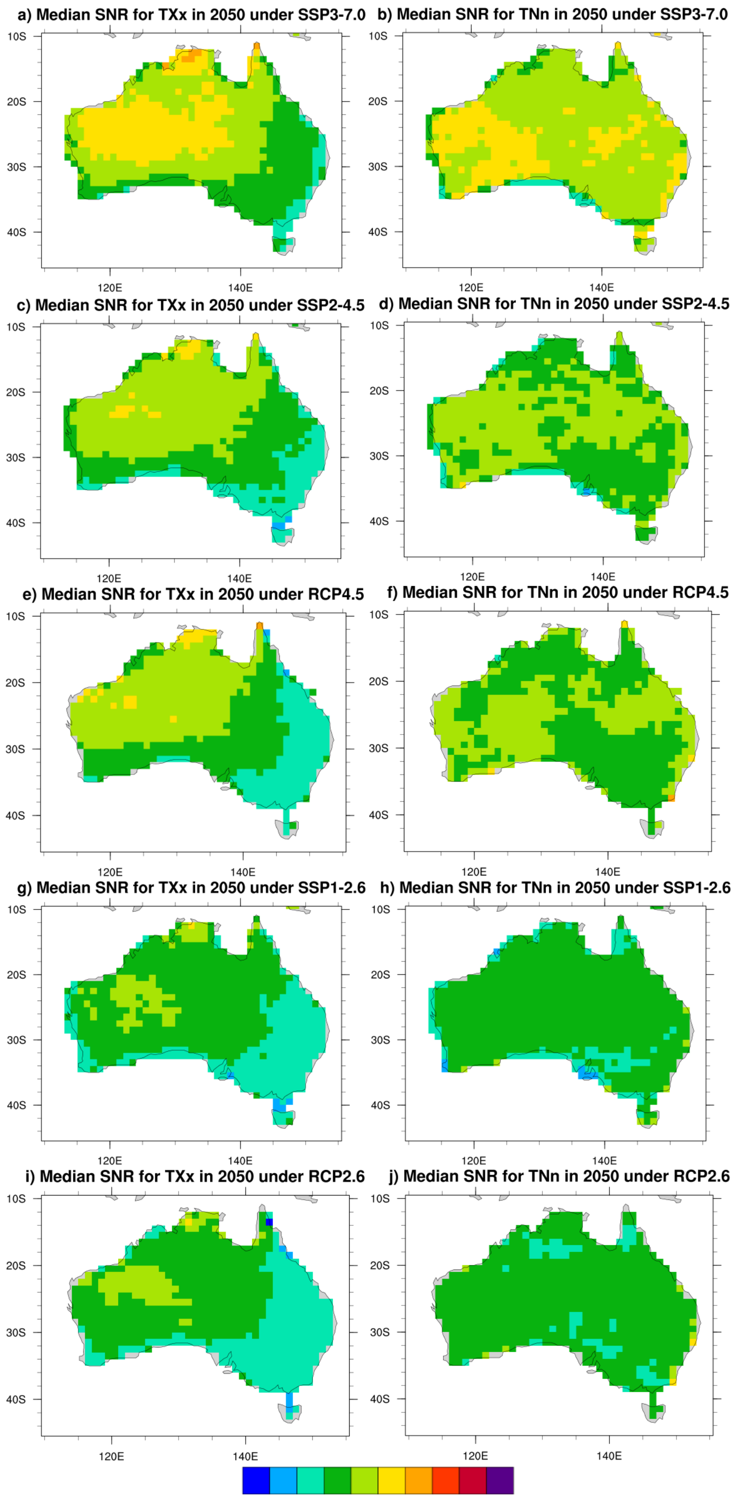

Fig. S22. Median signal-to-noise ratio (SNR) for TXx and TNn under SSP3-7.0, SSP2-4.5&RCP4.5, and SSP1-2.6&RCP2.6 in the year 2050. (a) SNR for TXx under SSP3-7.0 in the year 2050; (b) SNR for TNn under SSP3-7.0 in the year 2050; (c, d) same as (a) and (b), but for SSP2-4.5; (e, f) same as (a) and (b), but for RCP4.5; (g, h) same as (a) and (b), but for SSP1-2.6; (i, j) same as (a) and (b), but for RCP2.6.

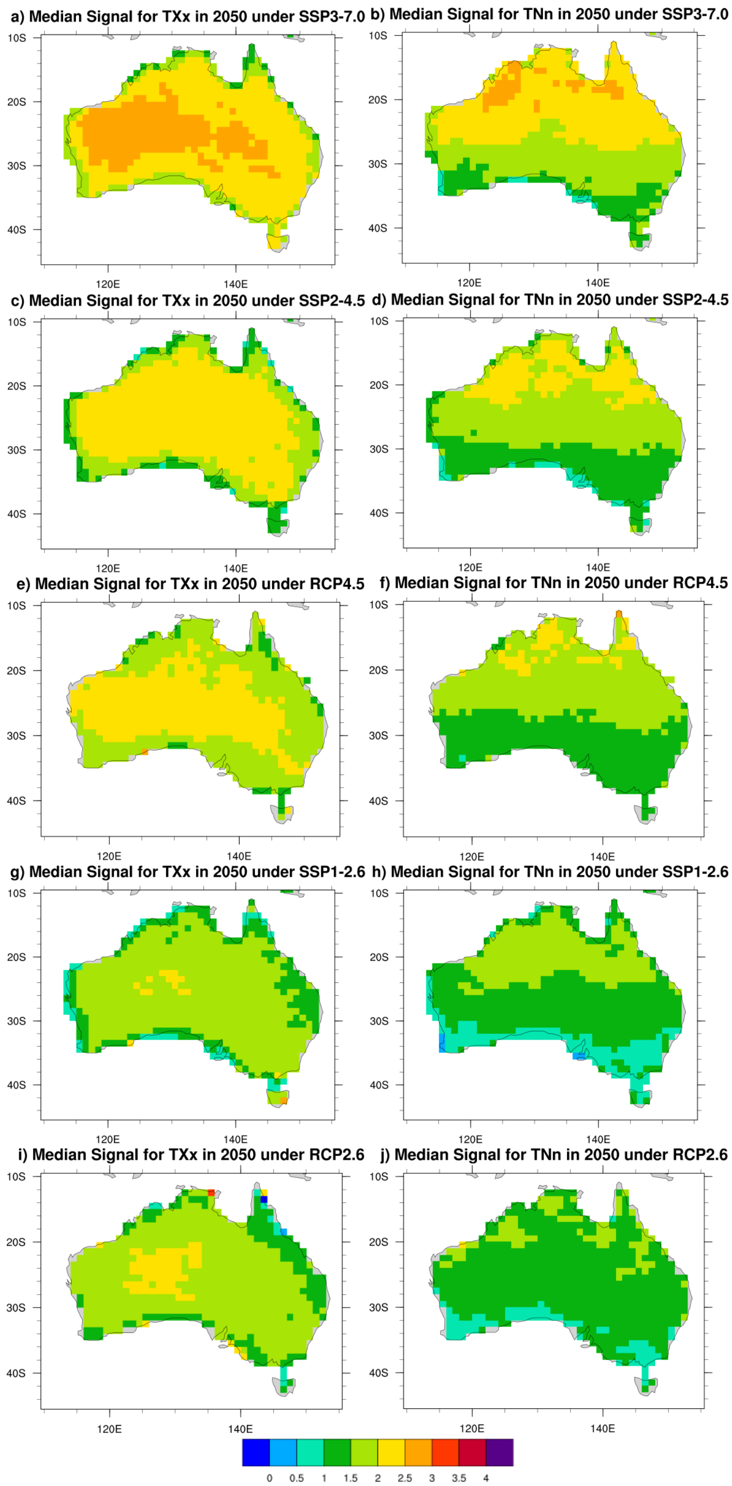

Fig. S23. Same as Fig. S22, but for the signal (unit: K).

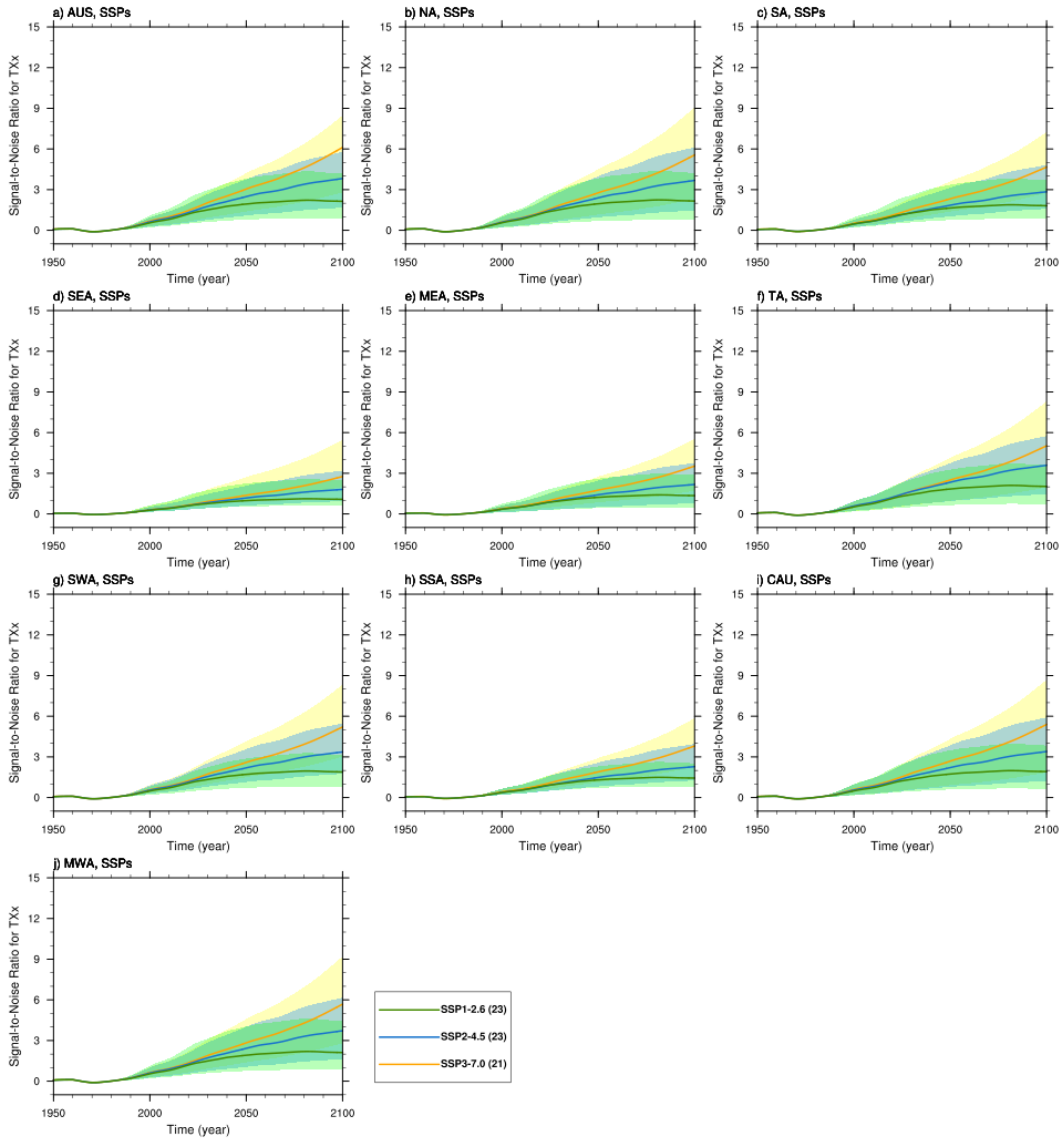

Fig. S24. Time series of signal-to-noise ratio (SNR) in TXx from 1950-2100 over 10 Australian regions under SSP1-2.6 (green), SSP2-4.5 (blue), SSP3-7.0 (yellow) (the number of models indicated in parentheses in the legend). Solid lines represent the multi-model medians and shading indicates the full range across the models for each experiment.

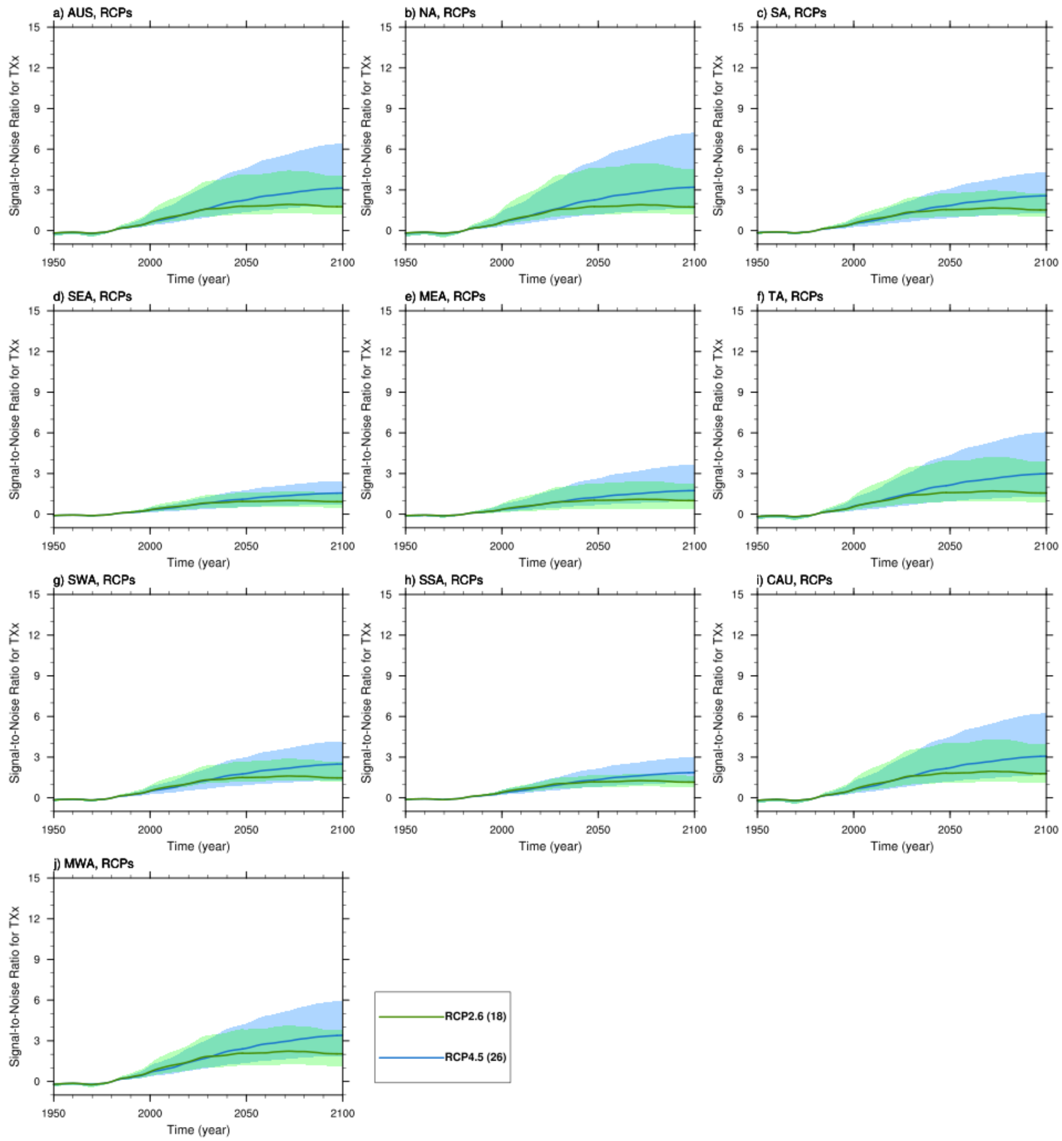

Fig. S25. Same as Fig. S24, but for RCP2.6 (green), RCP4.5 (blue).

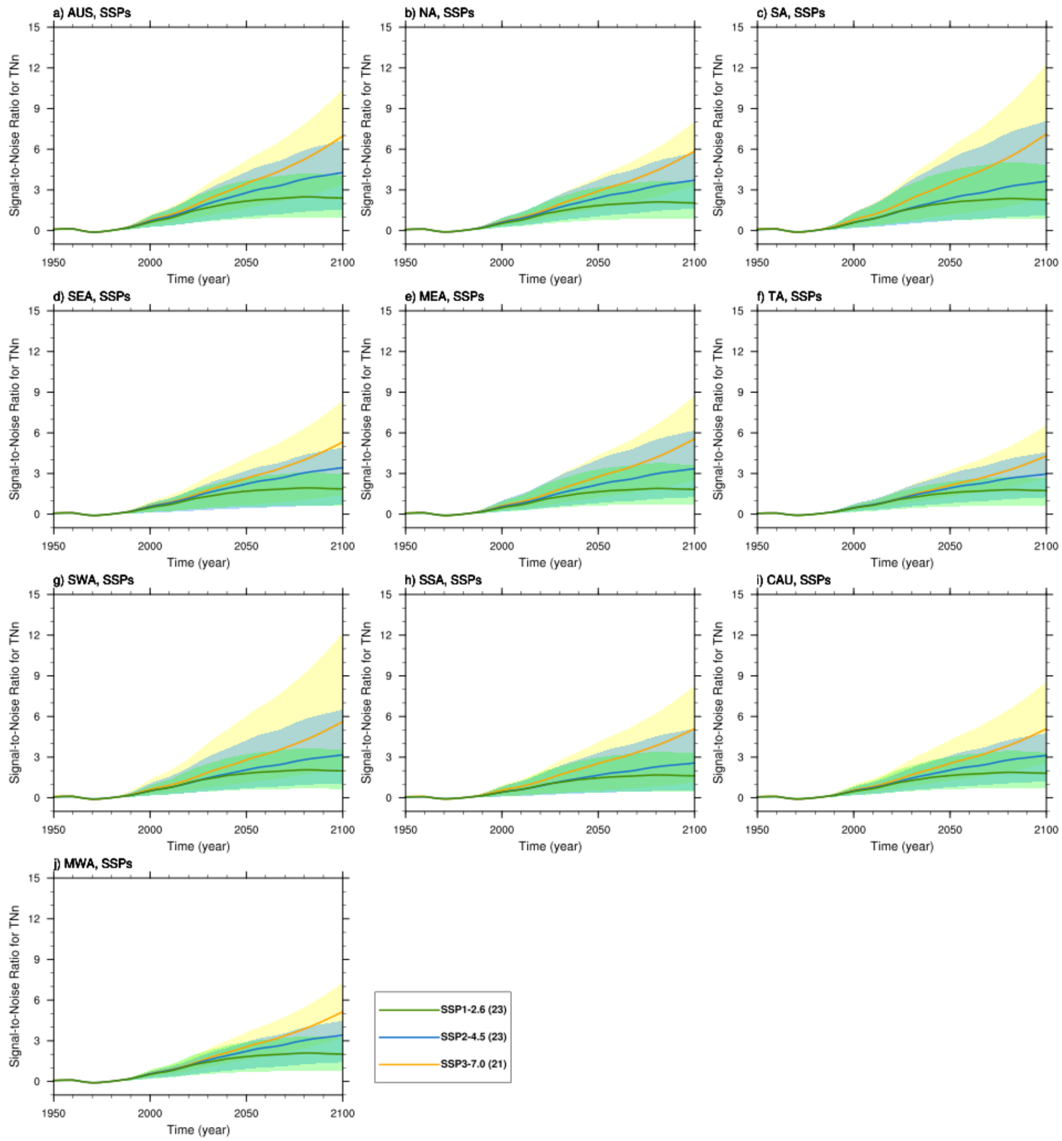

Fig. S26. Same as Fig. S24, but for TNn.

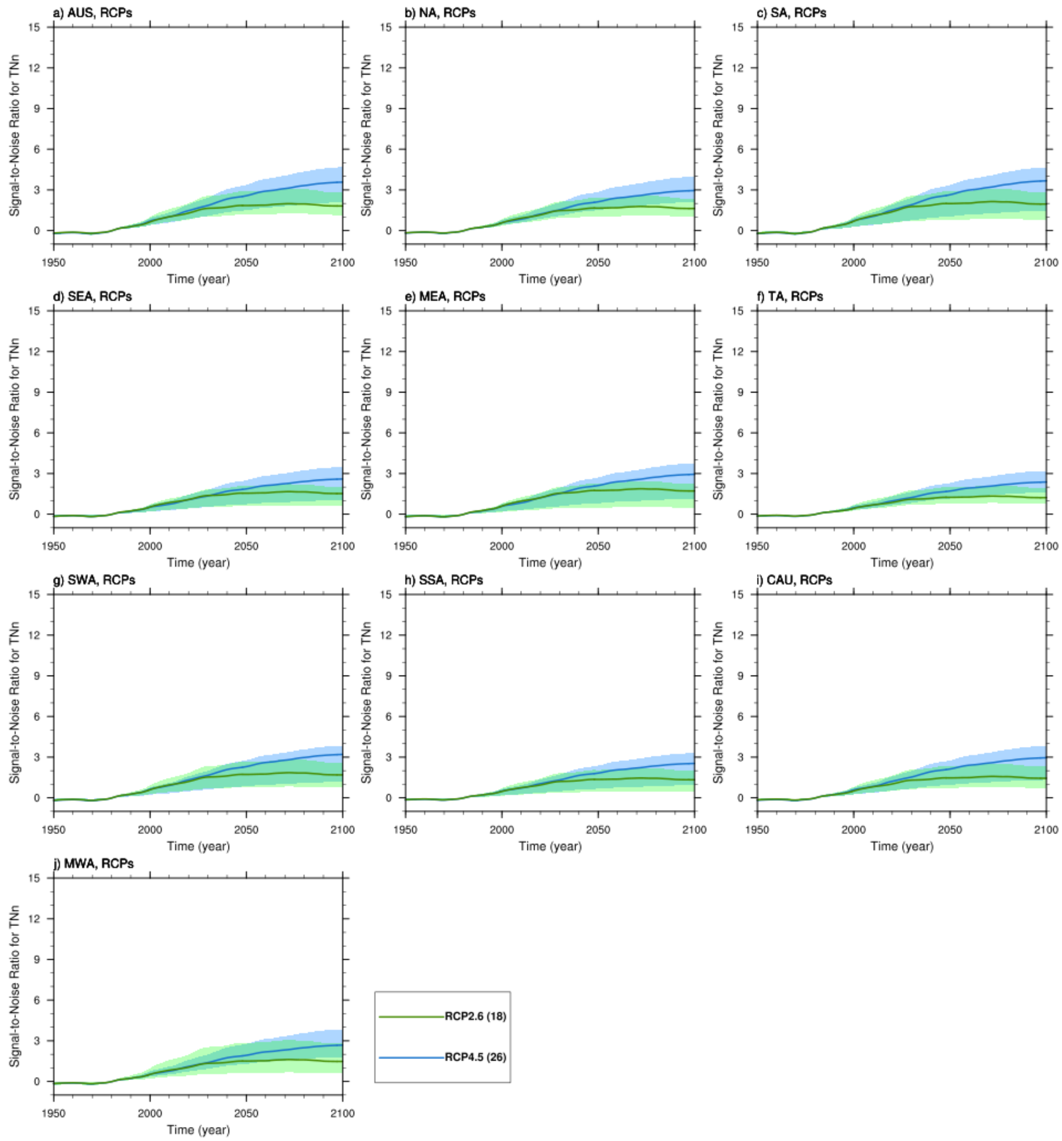

Fig. S27. Same as Fig. S24, but for TNn under RCP2.6 (green), RCP4.5 (blue).

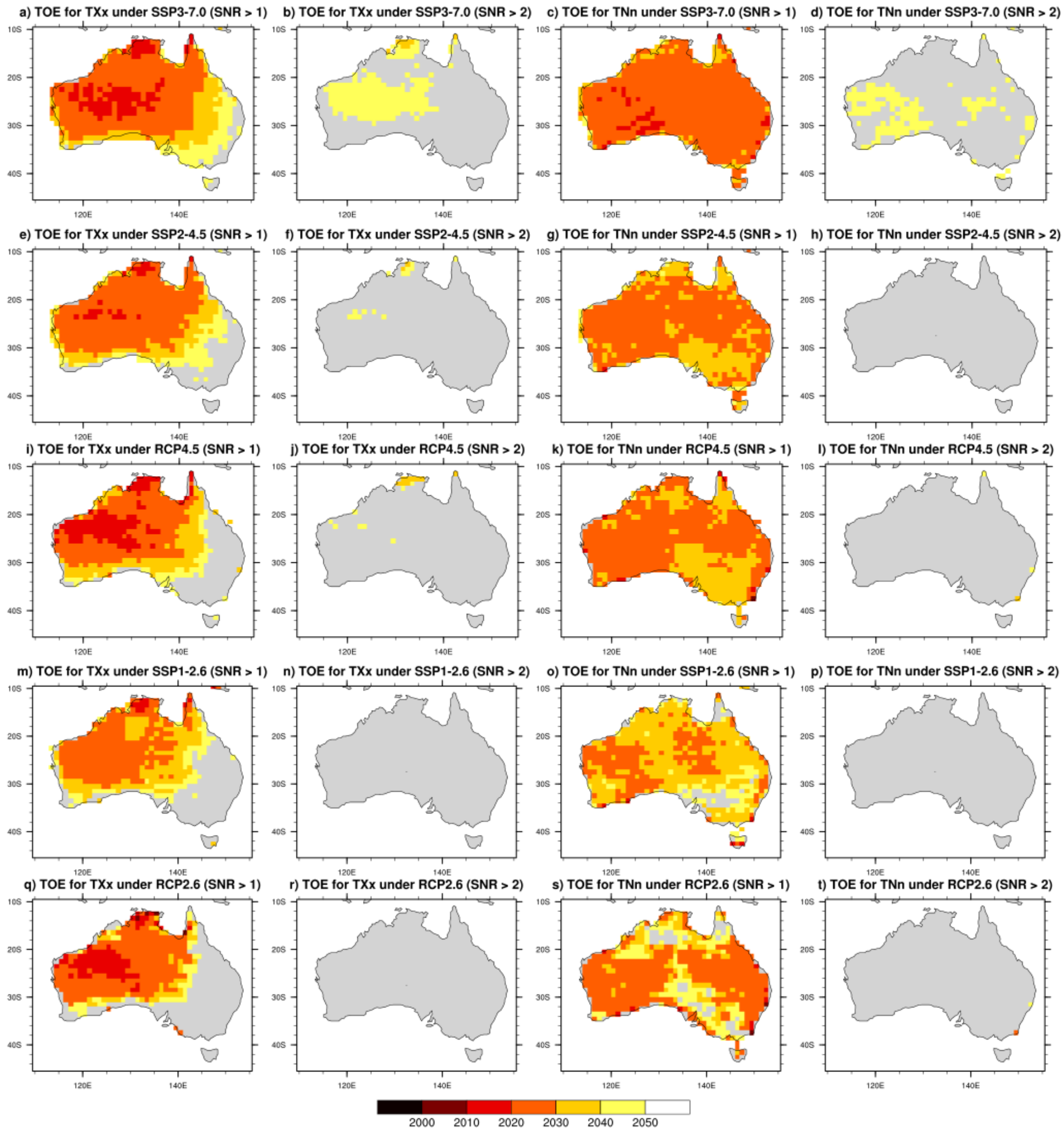

Fig. S28. Median time of emergence (TOE) for TXx and TNn based on SNR thresholds under SSP3-7.0, SSP2-4.5&RCP4.5, and SSP1-2.6&RCP2.6. (a) TOE for TXx under SSP3-7.0 when SNR > 1; (b) TOE for TXx under SSP3-7.0 when SNR > 2; (c, d) same as (a) and (b), but for TNn; (e-h) same as (a-d), but for SSP2-4.5; (i-l) same as (a-d), but for RCP4.5; (m-p) same as (a-d), but for SSP1-2.6; (q-t) same as (a-d), but for SSP1-2.6.

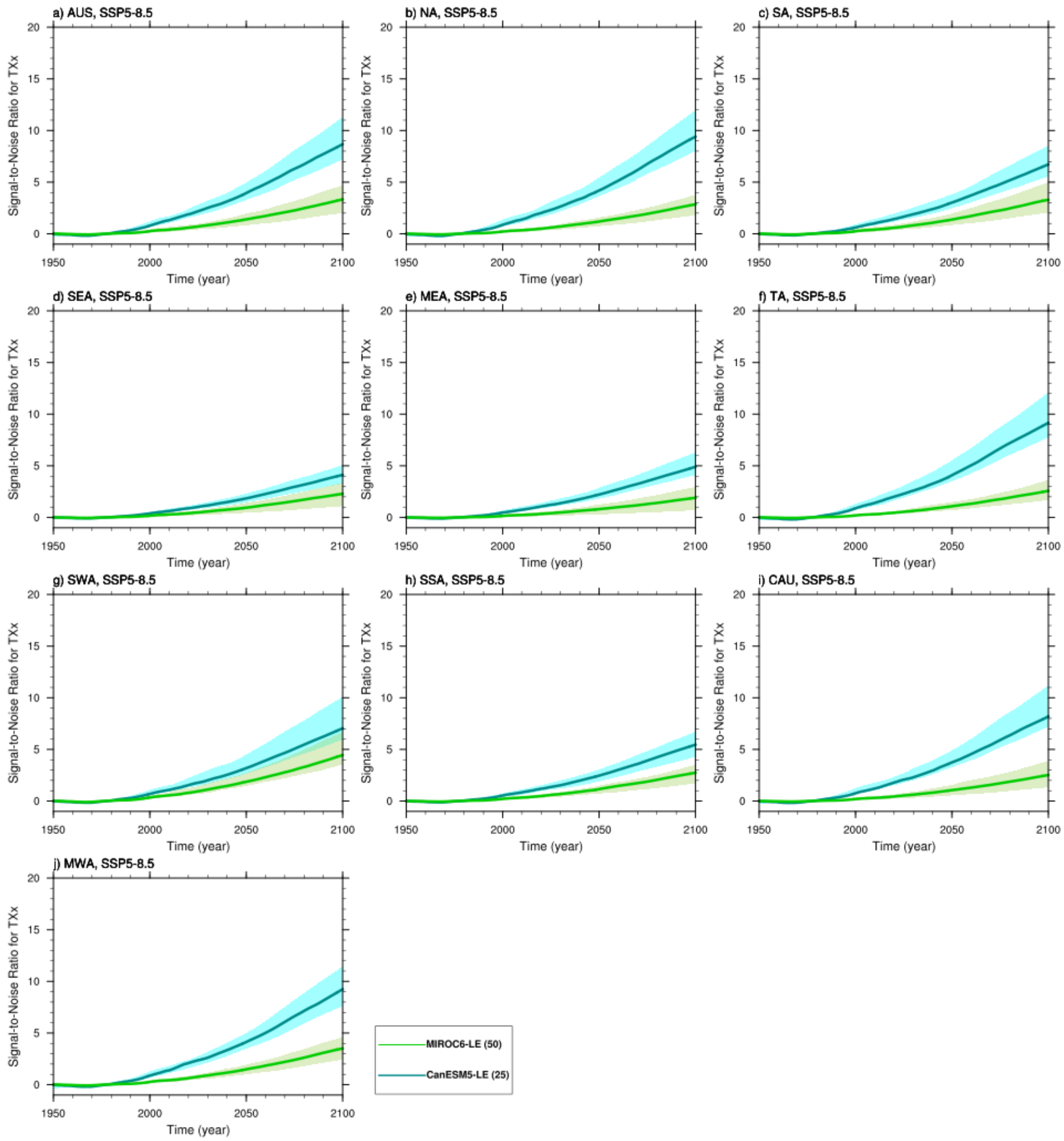

Fig. S29. Time series of signal-to-noise ratio (SNR) in TXx from 1950-2100 over 10 Australian regions under SSP5-8.5 for CanESM5-LE (cyan) and MIROC6-LE (green) (the number of members indicated in parentheses in the legend). Solid lines represent the multi-member medians and shading indicates the full range across the members for each LE.

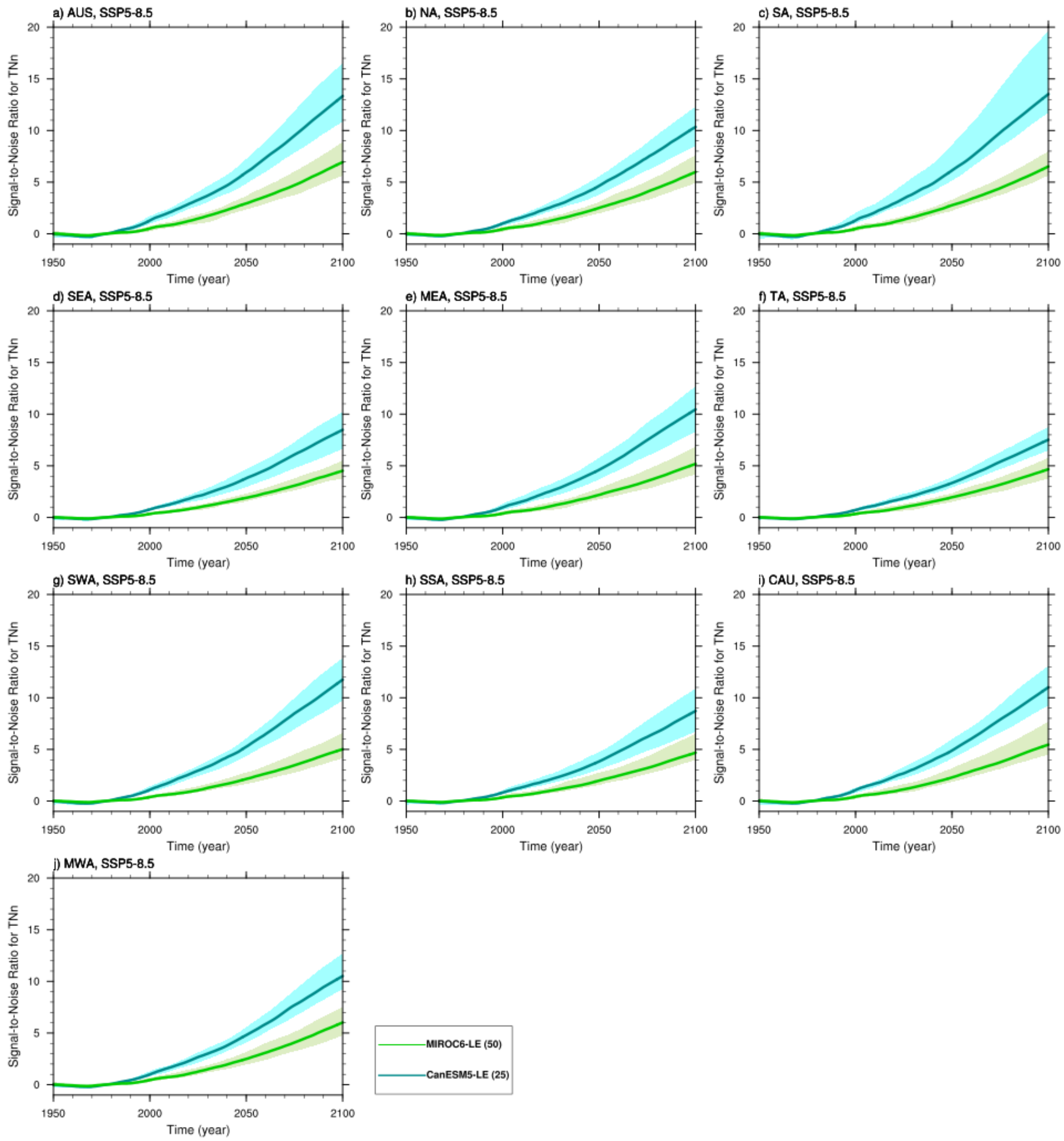

Fig. S30. Same as Fig. S29, but for TNn.

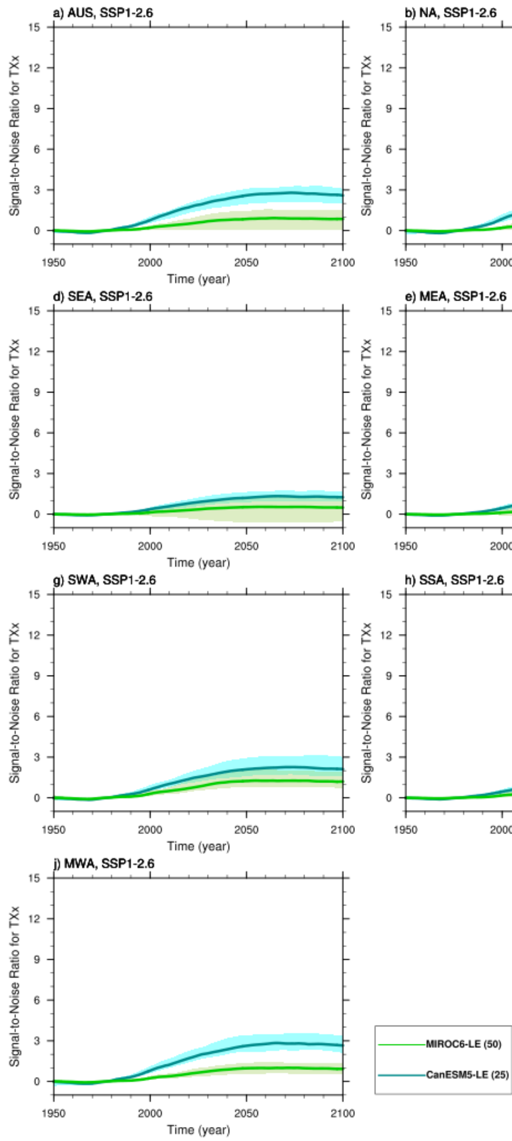

Fig. S31. Same as Fig. S29, but for SSP1-2.6.

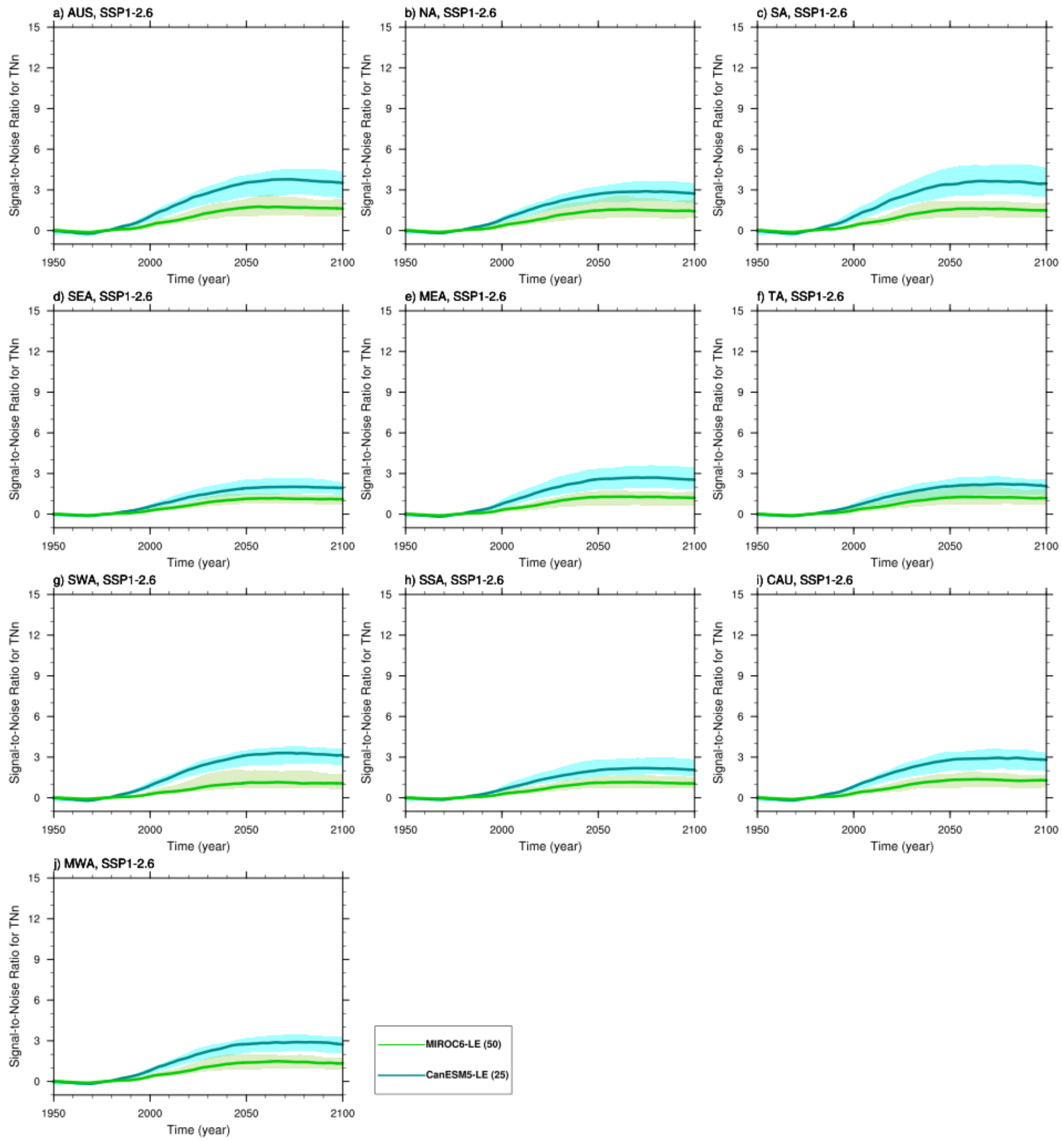

Fig. S32. Same as Fig. S29, but for TNn under SSP1-2.6.

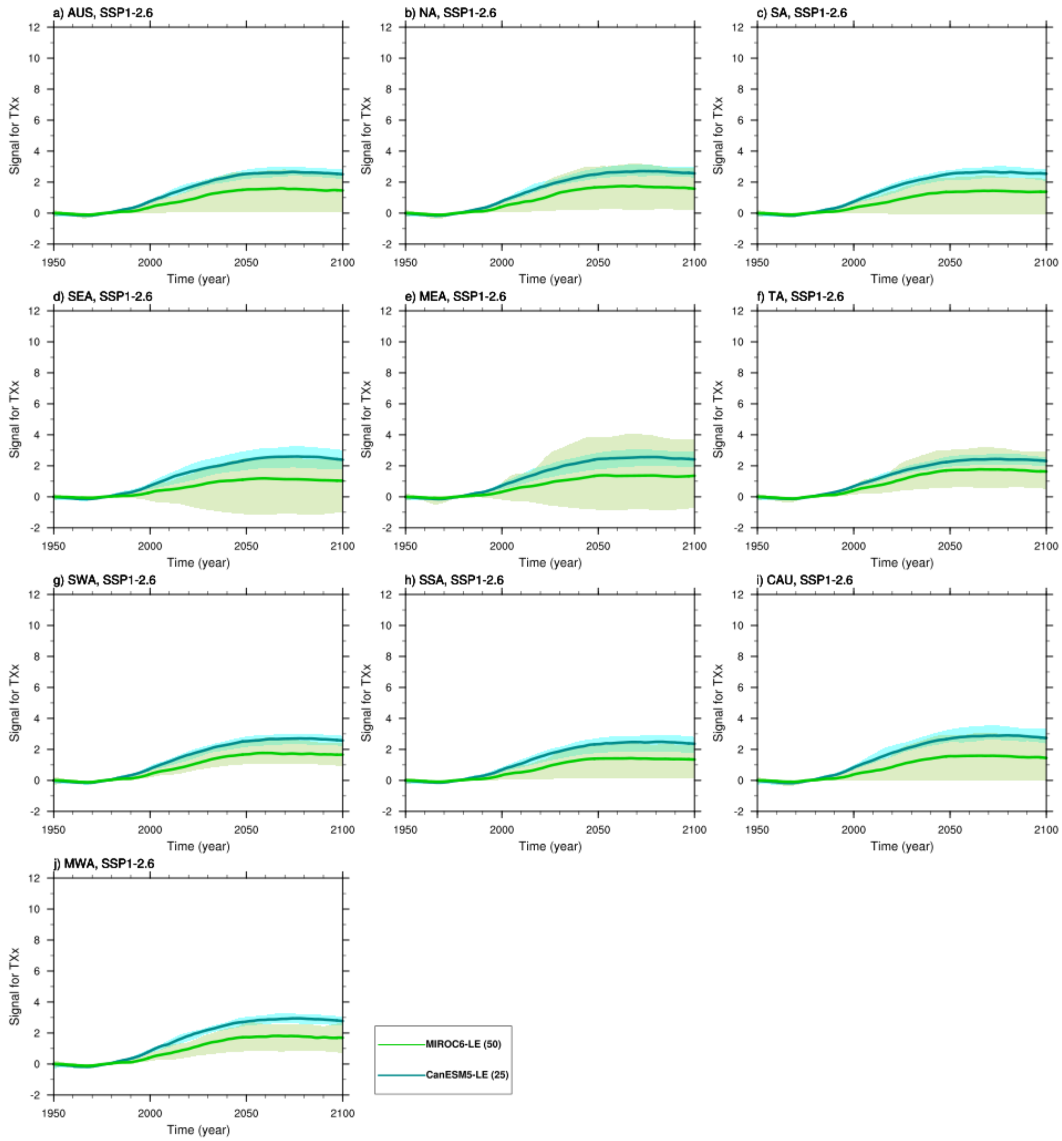

Fig. S33. Same as Fig. S29, but for signal under SSP1-2.6.

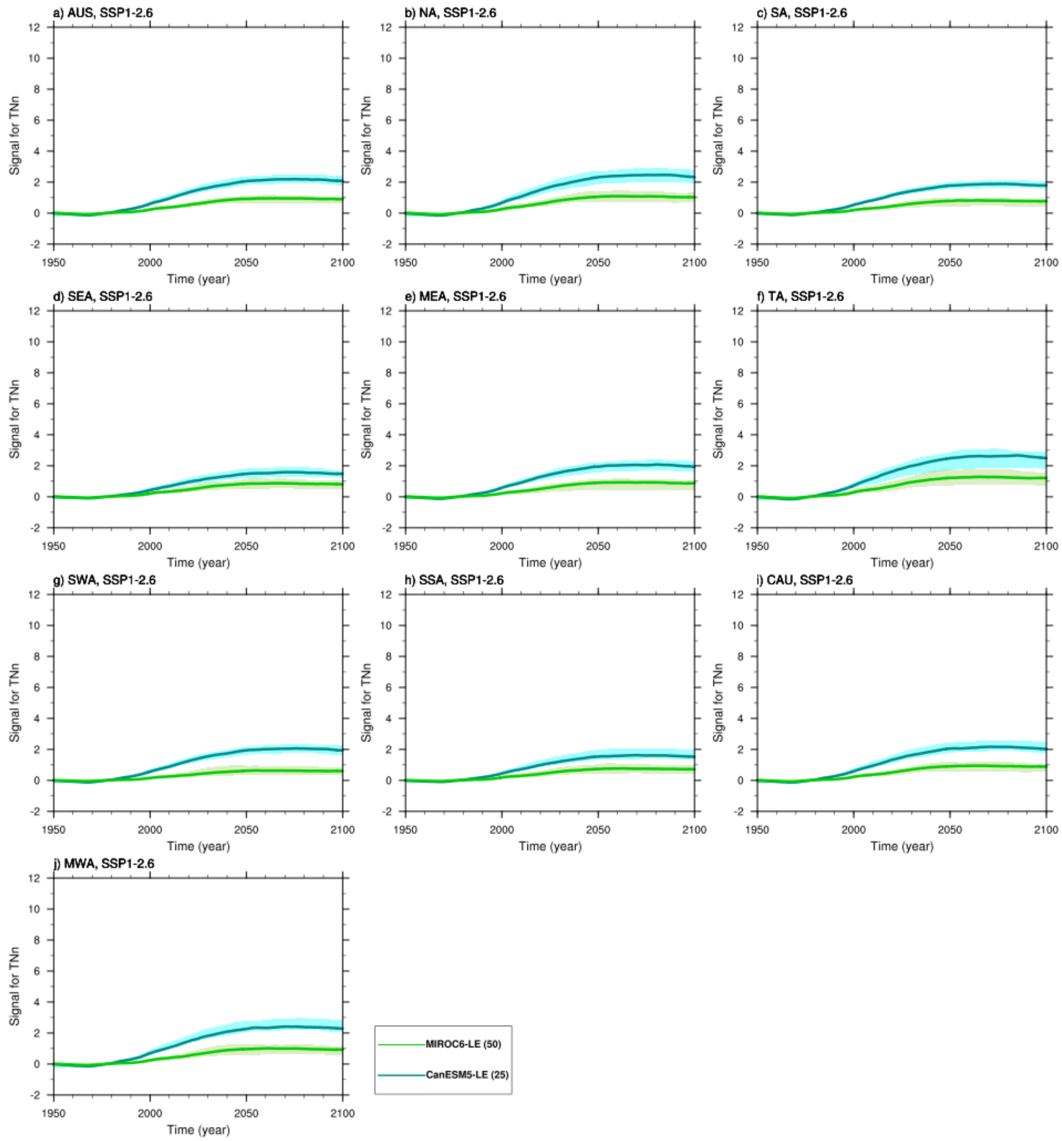

Fig. S34. Same as Fig. S29, but for signal in TNn under SSP1-2.6.