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*Supplement of*

# High-resolution downscaled CMIP6 drought projections for Australia

**Rohan Eccles et al.**

*Correspondence to:* Rohan Eccles (rohan.eccles@gmail.com)

# Sect. S1 NRM Super-clusters

Table S1. Climate and ecological characteristics used to define the NRM super-clusters (CSIRO and Bureau of Meteorology, 2015).

| NRM super-cluster | Area (1000 km$^2$) | Climate Zone | Ecoregions |
|---|---|---|---|
| Eastern Australia | 767 | Subtropical (north)<br>Temperate (south)<br>Grassland (west) | Temperate broadleaf and mixed forests<br>Temperate grasslands, savannas and shrublands<br>Tropical and subtropical grasslands, savannahs and shrublands |
| Northern Australia | 2084 | Equatorial (north east)<br>Tropical (north)<br>Subtropical (far east)<br>Grassland (south) | Tropical and subtropical grasslands, savannahs and shrublands<br>Tropical and subtropical moist broadleaf forests |
| Rangelands | 4888 | Grassland (scattered)<br>Desert (majority) | Deserts and xeric shrublands (majority)<br>Mediterranean forests, woodlands and scrubs (south west & far south)<br>Temperate grasslands, savannas and shrublands (east)<br>Tropical and subtropical grasslands, savannahs and shrublands (north east) |
| Southern Australia | 1464 | Subtropical (west coast)<br>Temperate<br>Grassland | Mediterranean forests, woodlands and scrubs<br>Temperate broadleaf and mixed forests<br>Temperate grasslands, savannas and shrublands<br>Montane grasslands and shrublands |

# Sect. S2 Goodness of fit

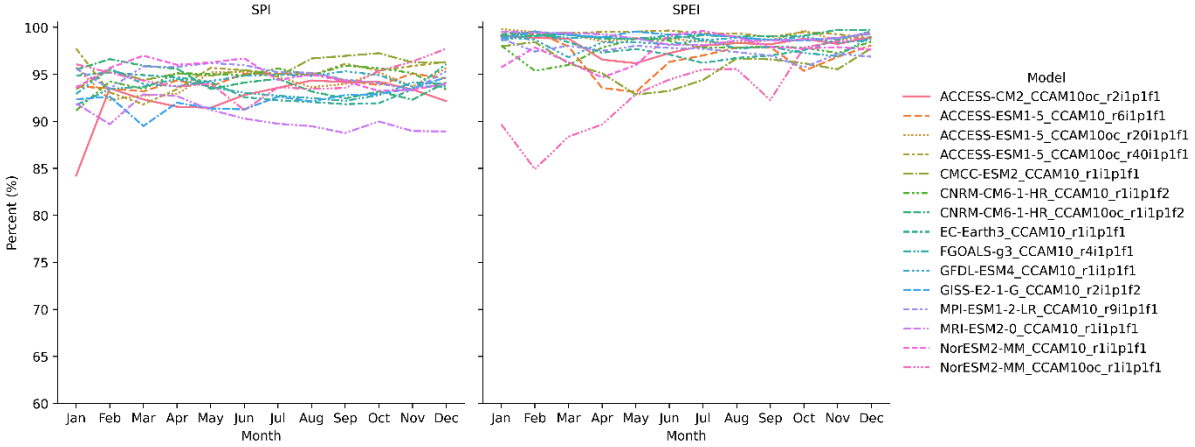



***Figure S1****. Percentage of cells which pass the Shapiro-Wilk test at the 95% confidence level for normality following application of the Gamma distribution for SPI and the Log-logistic distribution for SPEI. Each month is fitted separately using data in the calibration period (1981-2010).*

## Sect. S3 Changes to precipitation and PET

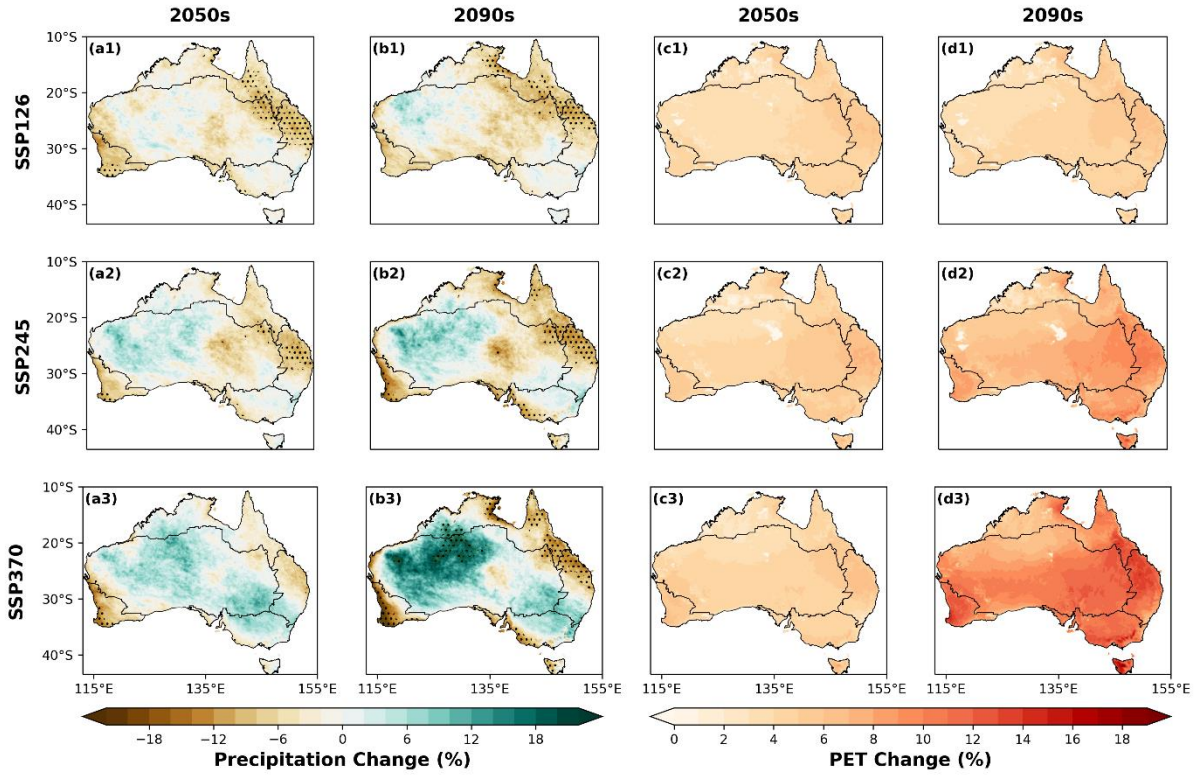



***Figure S2****. Maps showing changes to the precipitation (columns a and b) and PET (columns c and d) for the 2050s and 2080s relative to the baseline period under SSP126 (row 1), SSP245 (row 2), and SSP370 (row 3). Hatching shows where the signal-to-noise ratio > 1.0. For PET the signal-to-noise ratio > 1.0 in all grid cells, so the stippling is not shown.*

# Sect. S4 Changes to SPI and SPEI

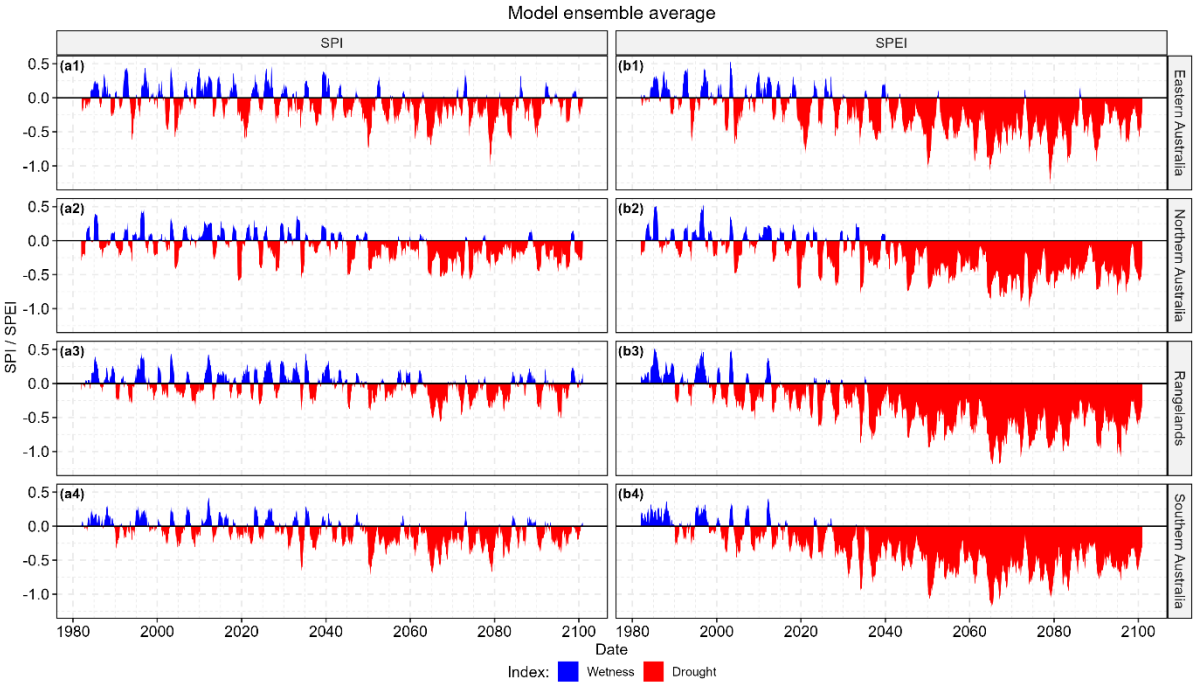



***Figure S3***. *Timeseries of the multi-model ensemble average SPI and SPEI results for the four NRM regions considered under SSP126.*

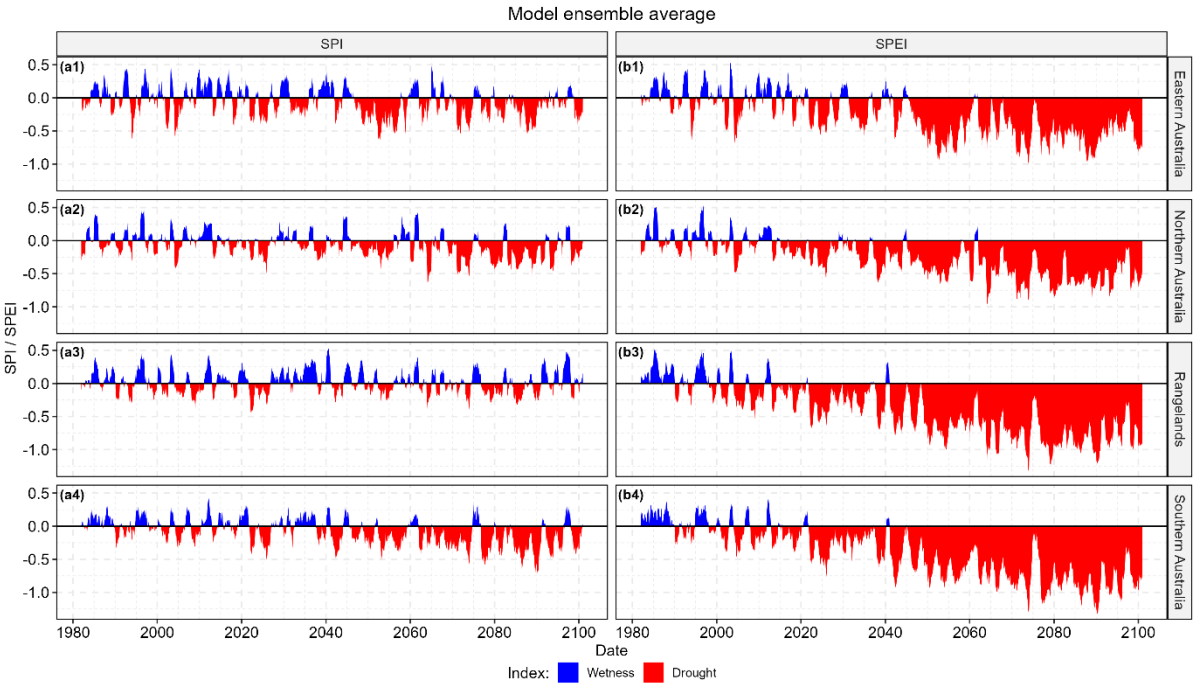



***Figure S4***. *Timeseries of the multi-model ensemble average SPI and SPEI results for the four NRM regions considered under SSP245.*

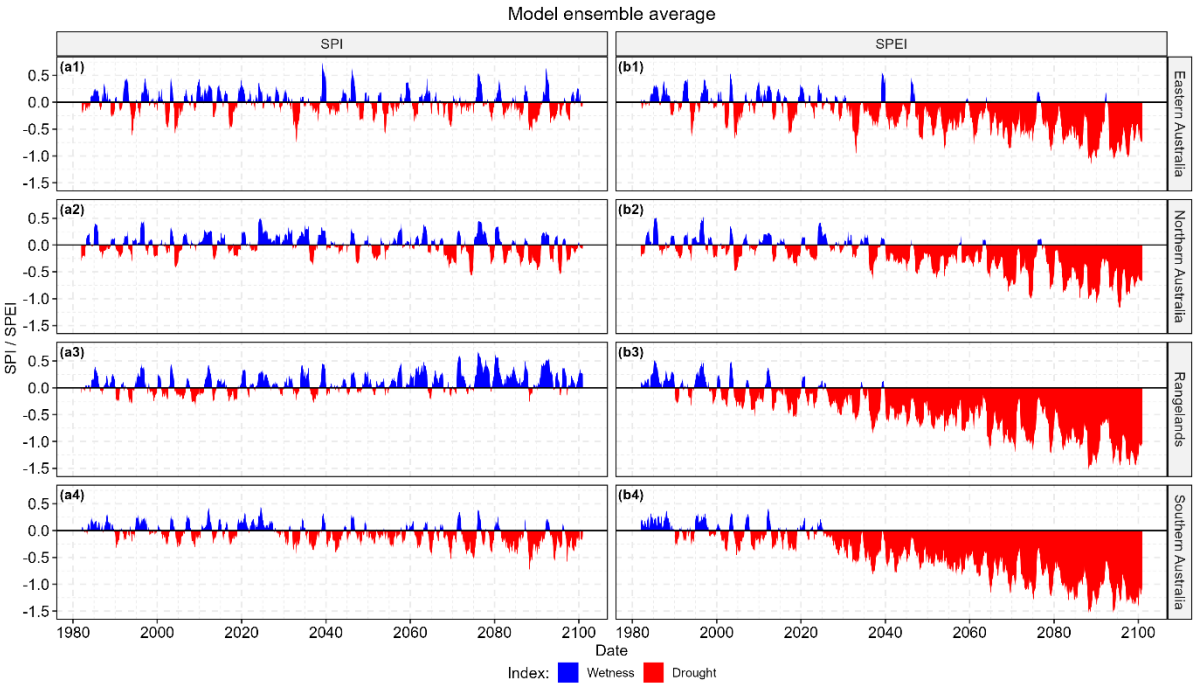



***Figure S5***. *Timeseries of the multi-model ensemble average SPI and SPEI results for the four NRM regions considered under SSP370*

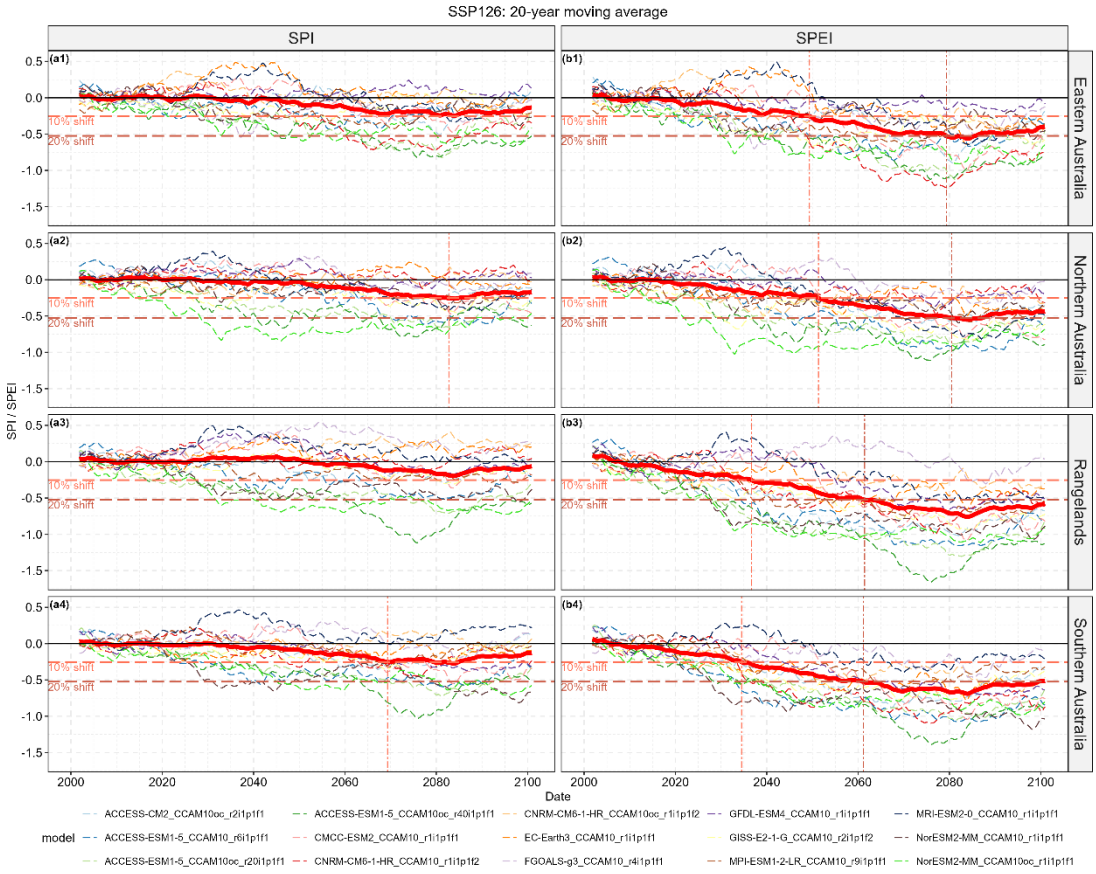



***Figure S6***. *Timeseries results for SPI and SPEI calculated as a 20-year moving average for each climate model considered with the model average shown in red for each of the regions under the SSP126 scenario. Dotted lines show the time taken for the ensemble average value to shift by 10% and 20% (according to the Z-score).*

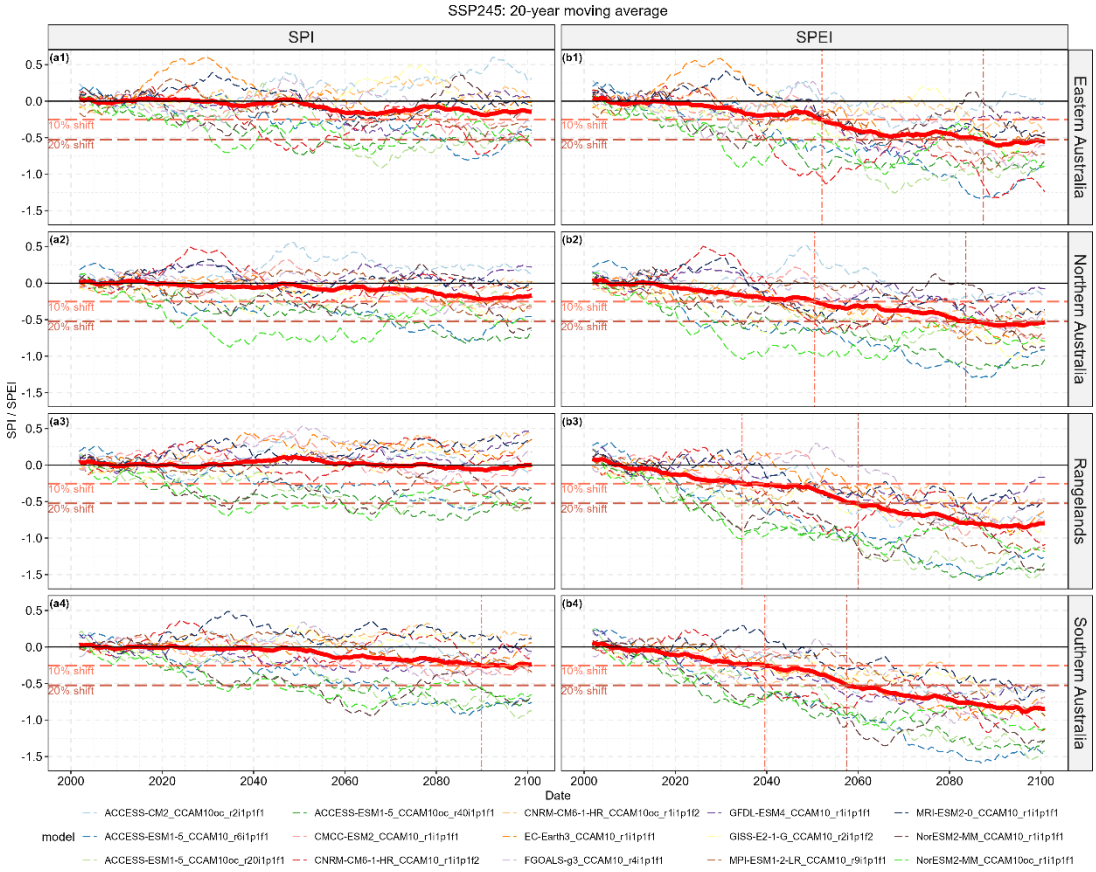



***Figure S7****. Timeseries results for SPI and SPEI calculated as a 20-year moving average for each climate model considered with the model average shown in red for each of the regions under the SSP245 scenario. Dotted lines show the time taken for the ensemble average value to shift by 10% and 20% (according to the Z-score).*

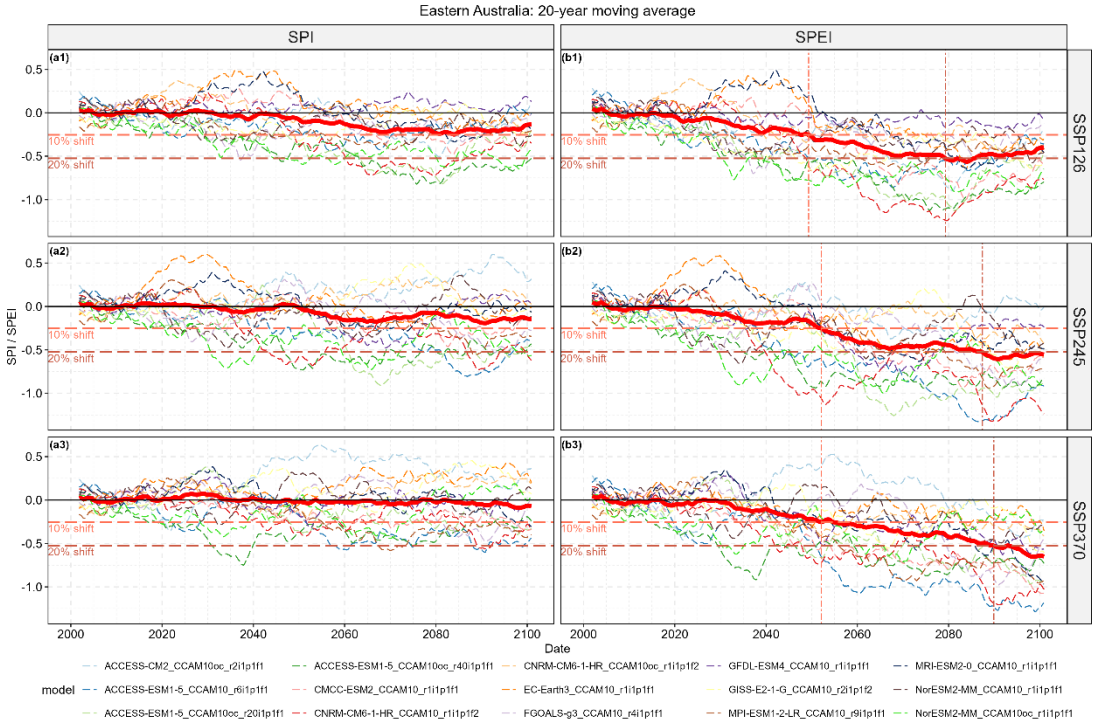



***Figure S8**. Timeseries results for SPI and SPEI calculated as a 20-year moving average for each climate model considered with the ensemble average shown in red for each of the emissions scenarios for Eastern Australia. Dotted lines show the time taken for the ensemble average value to shift by 10% and 20% (according to the Z-score).*

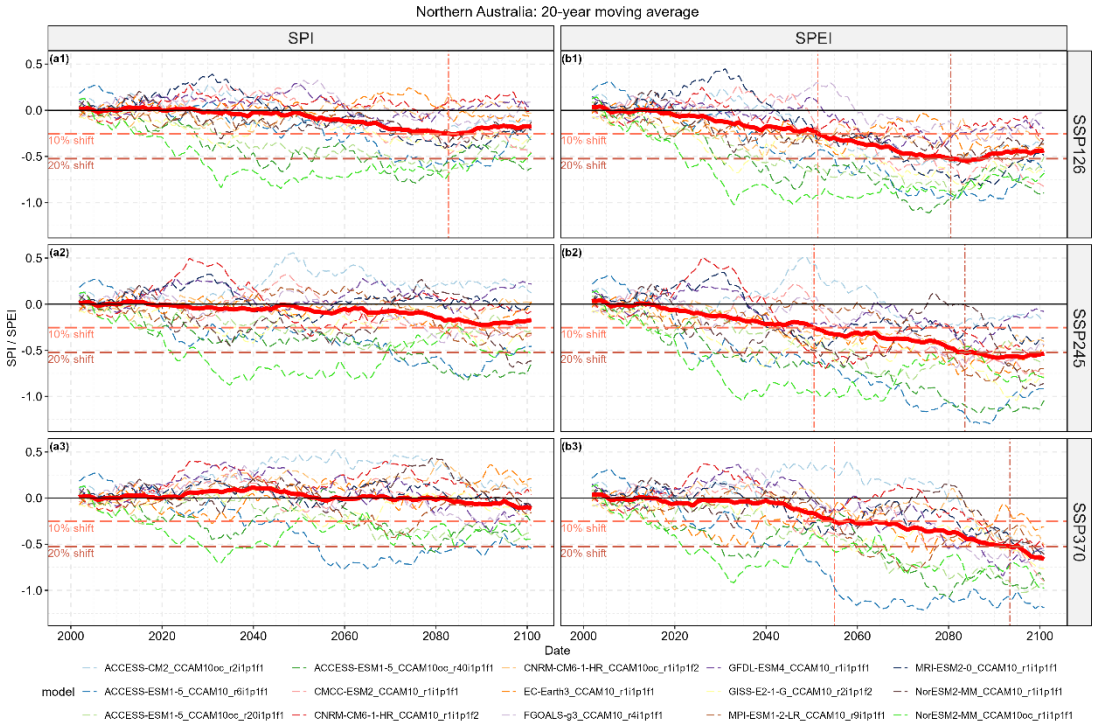



***Figure S9**. Timeseries results for SPI and SPEI calculated as a 20-year moving average for each climate model considered with the ensemble average shown in red for each of the emissions scenarios for Northern Australia. Dotted lines show the time taken for the ensemble average value to shift by 10% and 20% (according to the Z-score).*

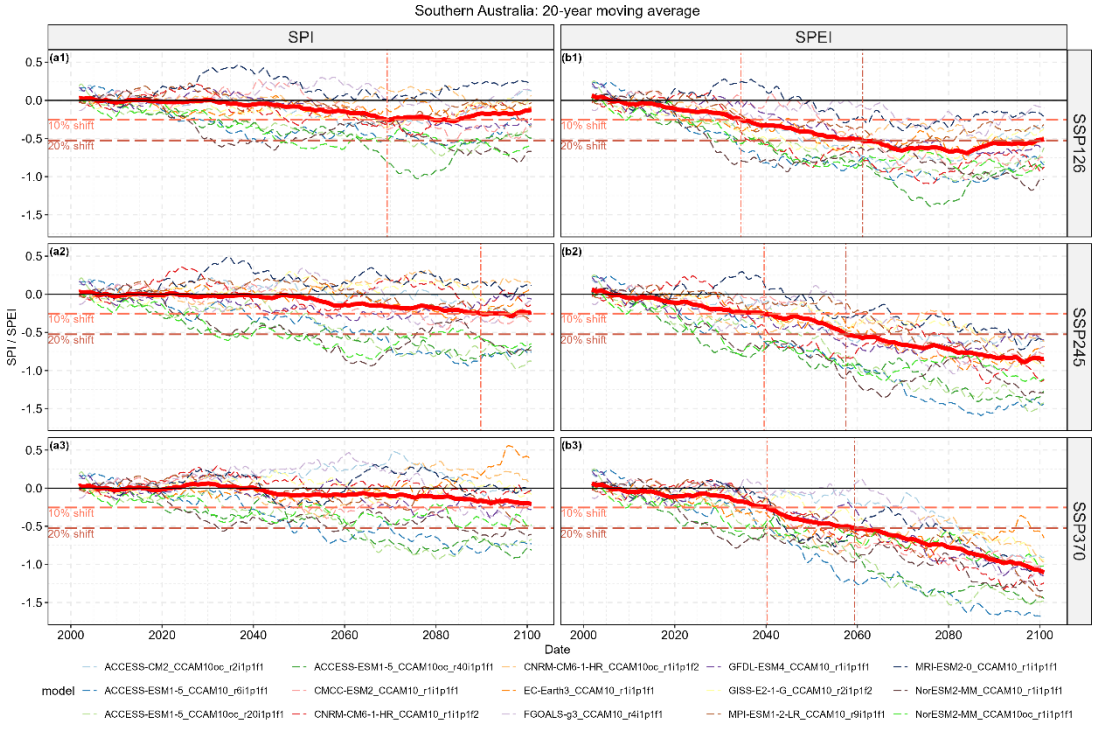



***Figure S10****. Timeseries results for SPI and SPEI calculated as a 20-year moving average for each climate model considered with the ensemble average shown in red for each of the emissions scenarios for Southern Australia. Dotted lines show the time taken for the ensemble average value to shift by 10% and 20% (according to the Z-score).*

# Sect. S5 Changes to drought extent

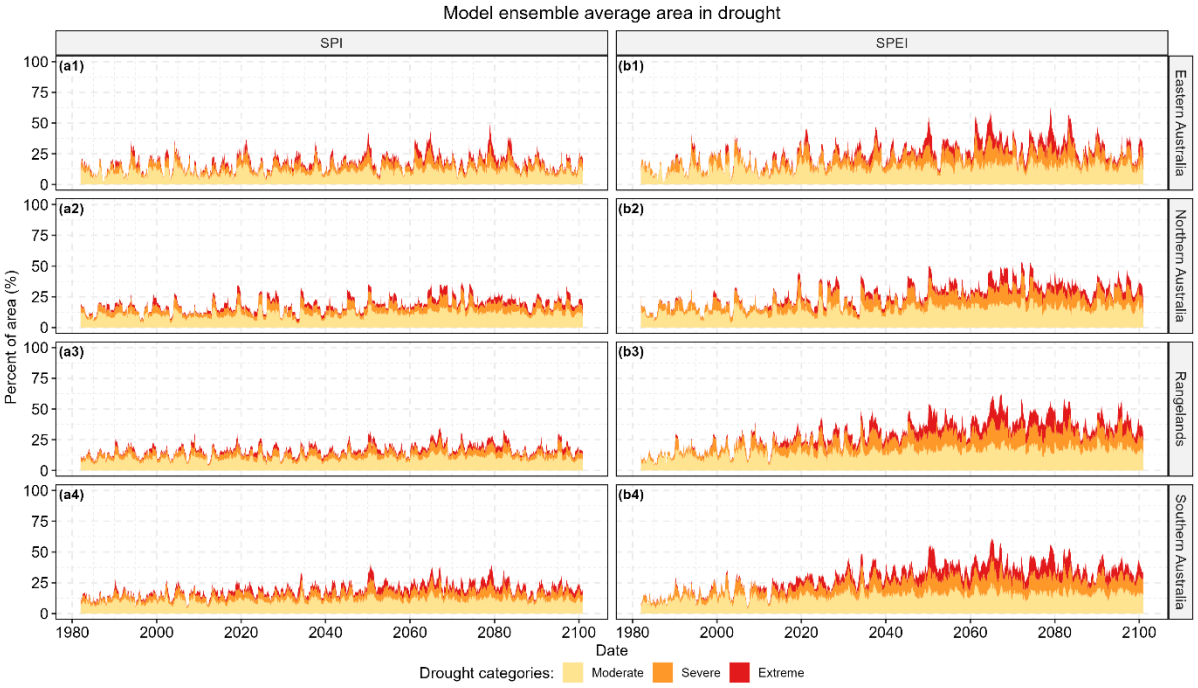



***Figure S11***. *Timeseries of the multi-model ensemble area in drought for SPI and SPEI results for the four NRM regions considered under SSP126.*

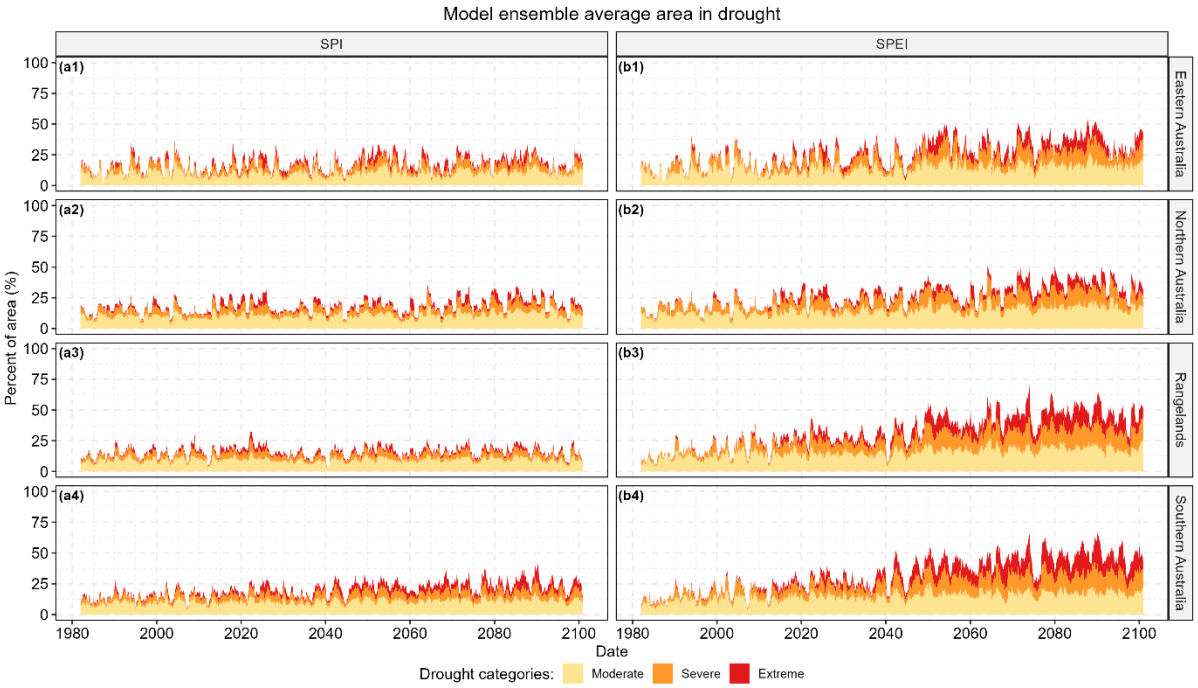



***Figure S12***. *Timeseries of the multi-model ensemble area in drought for SPI and SPEI results for the four NRM regions considered under SSP245.*

Table S2. Projected absolute percent change to the percent of time spent in different drought and wetness categories by the 2050s and 2090s compared to the reference period (1995-2014) using the ensemble average under SSP245. Red colours denote larger increases, while green colours denote decreases.

| | | Eastern Australia | | Northern Australia | | Rangelands | | Southern Australia | |
|---|---|---|---|---|---|---|---|---|---|
| Index | Category | 2050s | 2090s | 2050s | 2090s | 2050s | 2090s | 2050s | 2090s |
| SPI | Extreme drought | 1.86 | 1.65 | 0.74 | 1.77 | 0.55 | 0.46 | 2.97 | 4.05 |
| | Severe drought | 1.35 | 1.53 | 0.72 | 2.22 | 0.48 | 0.65 | 2.17 | 2.75 |
| | Moderate drought | 1.26 | 1.53 | 0.76 | 3.1 | 0.08 | 0.55 | 1.71 | 2.55 |
| | Near normal | -0.38 | -1.27 | -0.53 | -4 | -1.9 | -2 | -6.17 | -7 |
| | Moderate wetness | -2.5 | -2.13 | -1.22 | -2.4 | -0.45 | -1.01 | -1.35 | -2.27 |
| | Severe wetness | -1.28 | -1.08 | -0.67 | -0.94 | 0.06 | -0.1 | -0.3 | -0.81 |
| | Extreme wetness | -0.32 | -0.23 | 0.2 | 0.25 | 1.19 | 1.45 | 0.97 | 0.73 |
| SPEI | Extreme drought | 4.06 | 6.28 | 2.49 | 5.28 | 6.66 | 11.64 | 7.73 | 13.39 |
| | Severe drought | 3.73 | 6.04 | 3.45 | 6.69 | 6.1 | 9.36 | 6.04 | 9.16 |
| | Moderate drought | 3.91 | 5.01 | 3.06 | 6.12 | 3.6 | 5.86 | 4.36 | 5.85 |
| | Near normal | -3.54 | -7.6 | -2.52 | -9.12 | -8.95 | -17.09 | -11.03 | -18.14 |
| | Moderate wetness | -4.59 | -5.34 | -3.58 | -5.64 | -4.74 | -6.63 | -4.6 | -6.49 |
| | Severe wetness | -3.12 | -3.66 | -2.59 | -3.03 | -2.85 | -3.42 | -2.72 | -3.76 |
| | Extreme wetness | -0.6 | -0.97 | -0.34 | -0.42 | -0.05 | -0.25 | -0.04 | -0.52 |

Table S3. Projected absolute percent change to the percent of time spent in different drought and wetness categories by the 2050s and 2090s compared to the reference period (1995-2014) using the ensemble average under SSP126. Red colours denote larger increases, while green colours denote decreases.

| | | Eastern Australia | | Northern Australia | | Rangelands | | Southern Australia | |
|---|---|---|---|---|---|---|---|---|---|
| Index | Category | 2050s | 2090s | 2050s | 2090s | 2050s | 2090s | 2050s | 2090s |
| SPI | Extreme drought | 1.15 | 1.18 | 1.05 | 1.84 | 0.73 | 1.05 | 2.27 | 2.08 |
| | Severe drought | 1.46 | 0.8 | 1.37 | 1.97 | 0.85 | 1 | 1.97 | 1.6 |
| | Moderate drought | 1.19 | 0.86 | 1.81 | 2.3 | 0.75 | 0.97 | 1.96 | 1.55 |
| | Near normal | 0.17 | 2.42 | -1.67 | -2.51 | -2.1 | -1.53 | -4.6 | -3.39 |
| | Moderate wetness | -2.18 | -2.65 | -1.78 | -2.45 | -0.93 | -1.45 | -1.82 | -1.86 |
| | Severe wetness | -1.35 | -1.75 | -0.8 | -1.15 | -0.22 | -0.5 | -0.63 | -0.82 |
| | Extreme wetness | -0.44 | -0.86 | 0.02 | 0 | 0.92 | 0.47 | 0.85 | 0.84 |
| SPEI | Extreme drought | 3.59 | 3.64 | 3.05 | 4.5 | 6.12 | 6.88 | 6.83 | 6.38 |
| | Severe drought | 3.43 | 3.38 | 4.12 | 5.17 | 5.75 | 7.07 | 5.84 | 5.65 |
| | Moderate drought | 3.1 | 3.6 | 4.21 | 4.71 | 3.99 | 5.22 | 4.23 | 4.91 |
| | Near normal | -2.68 | -1.14 | -5.21 | -6.85 | -9.47 | -11.13 | -10.42 | -9.57 |
| | Moderate wetness | -3.97 | -5.09 | -3.66 | -4.6 | -4.22 | -4.9 | -4.28 | -4.81 |
| | Severe wetness | -3.05 | -3.63 | -2.32 | -2.78 | -2.42 | -2.95 | -2.61 | -2.86 |
| | Extreme wetness | -0.56 | -0.9 | -0.25 | -0.28 | 0.05 | -0.39 | 0.18 | 0.15 |

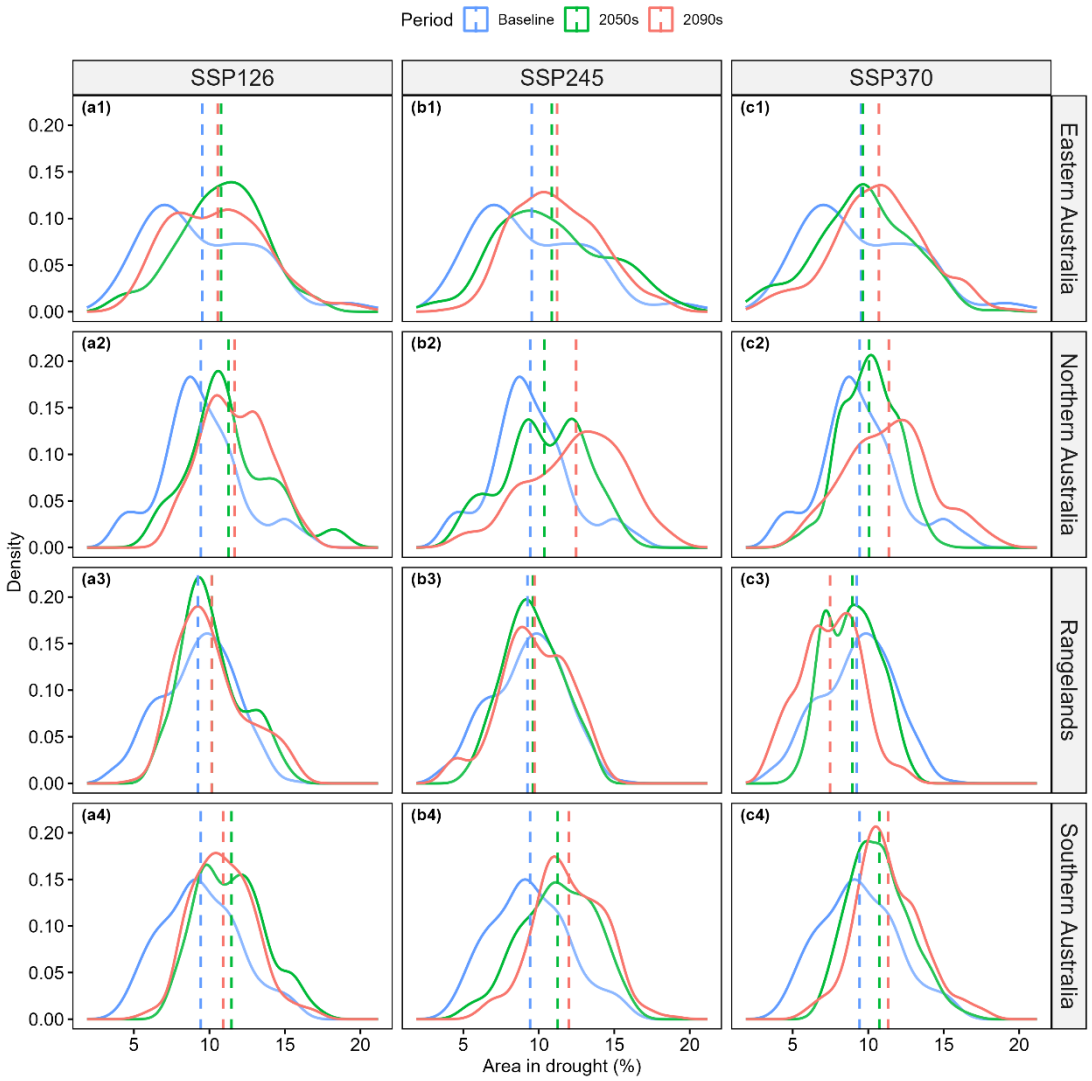



***Figure S13***. *Probability density function plot the percent area under moderate drought using SPI values from the weighted averaged of the model ensemble for the baseline (1995-2014), 2050s (2041-2060), and 2090s (2081-2100). Results are shown for the three SSPs in the four NRM regions considered. Dotted lines show mean values and percents show the difference in the overlap between the future and baseline densities.*

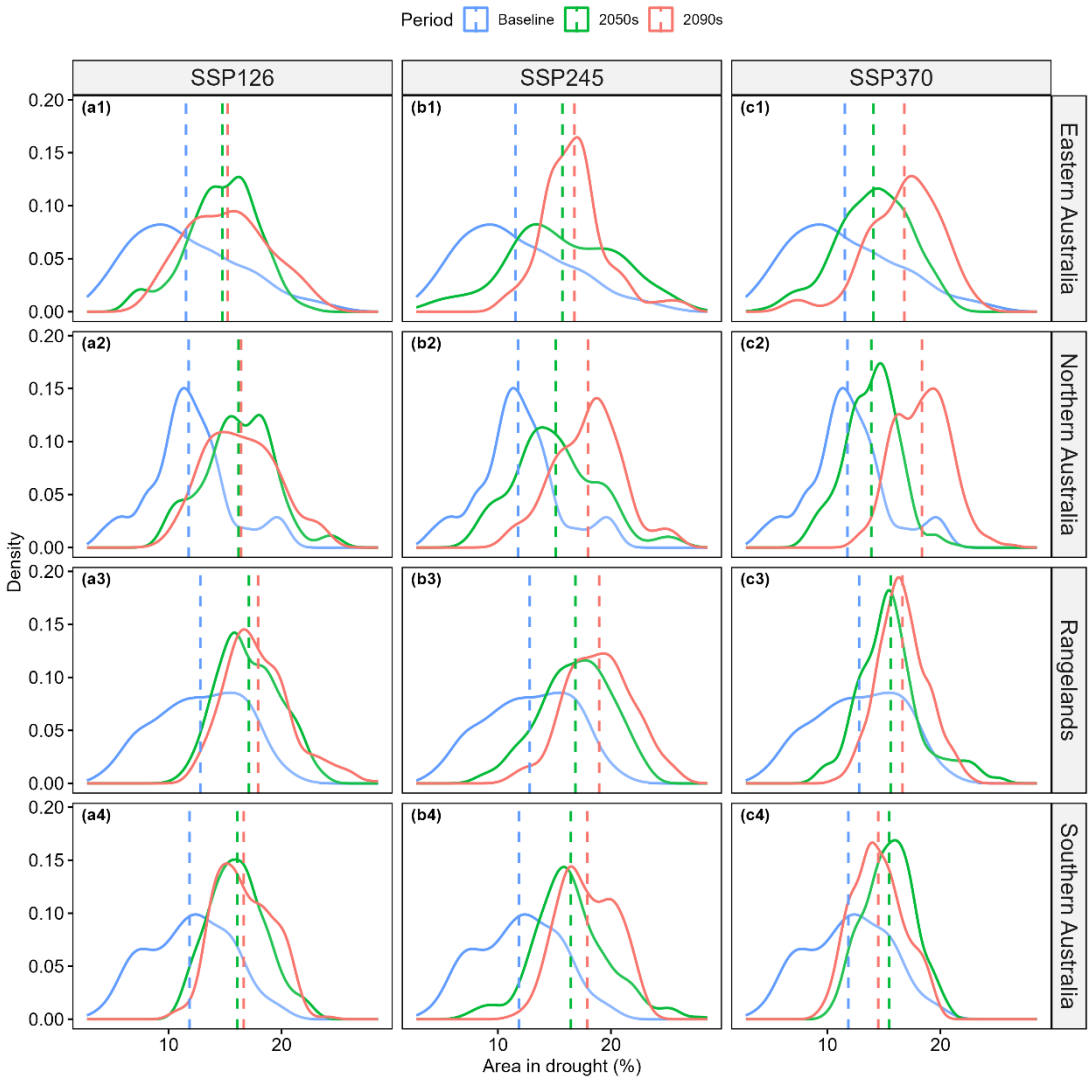



***Figure S14***. *Probability density function plot the percent area under moderate drought using SPEI values from the weighted averaged of the model ensemble for the baseline (1995-2014), 2050s (2041-2060), and 2090s (2081-2100). Results are shown for the three SSPs in the four NRM regions considered. Dotted lines show mean values and percents show the difference in the overlap between the future and baseline densities.*

# Sect. S6 Changes to drought metrics

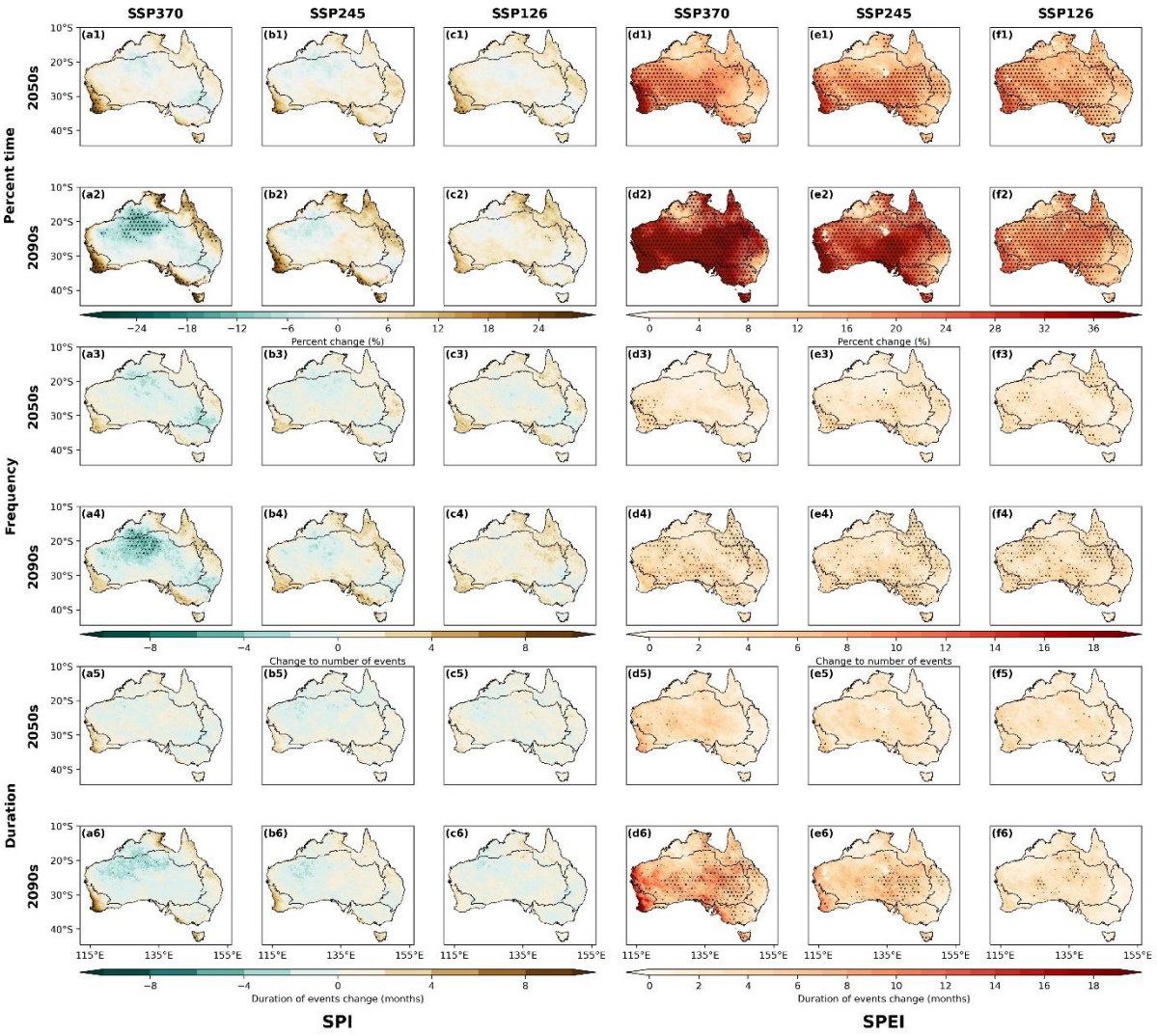



***Figure S15****. Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows 5 to 6) of moderate to extreme droughts according to SPI (columns a, b, and c) and SPEI (column d, e, and f) for the 2050s and 2080s relative to the baseline period. Hatching shows where the signal-to-noise ratio > 1.0.*

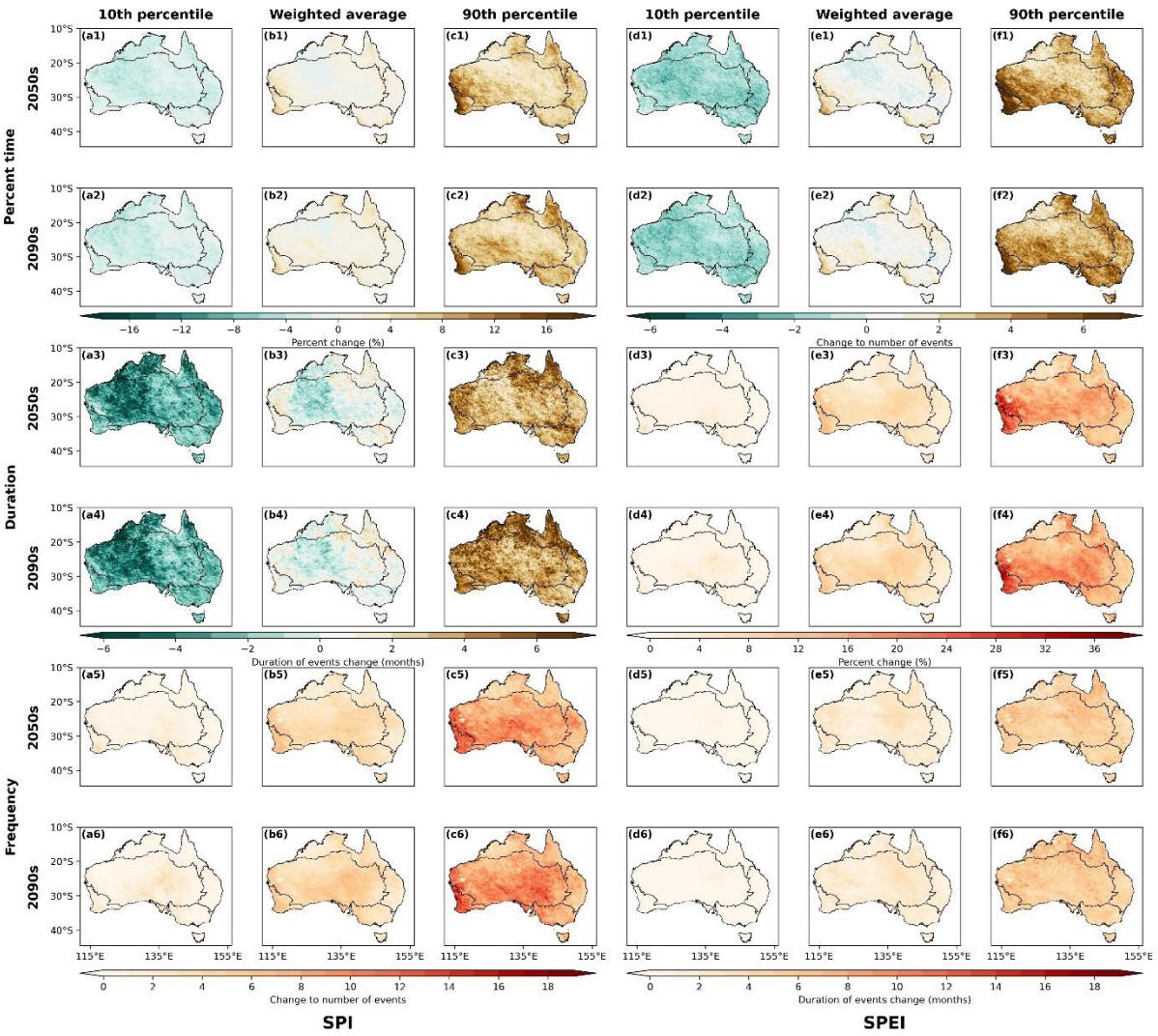
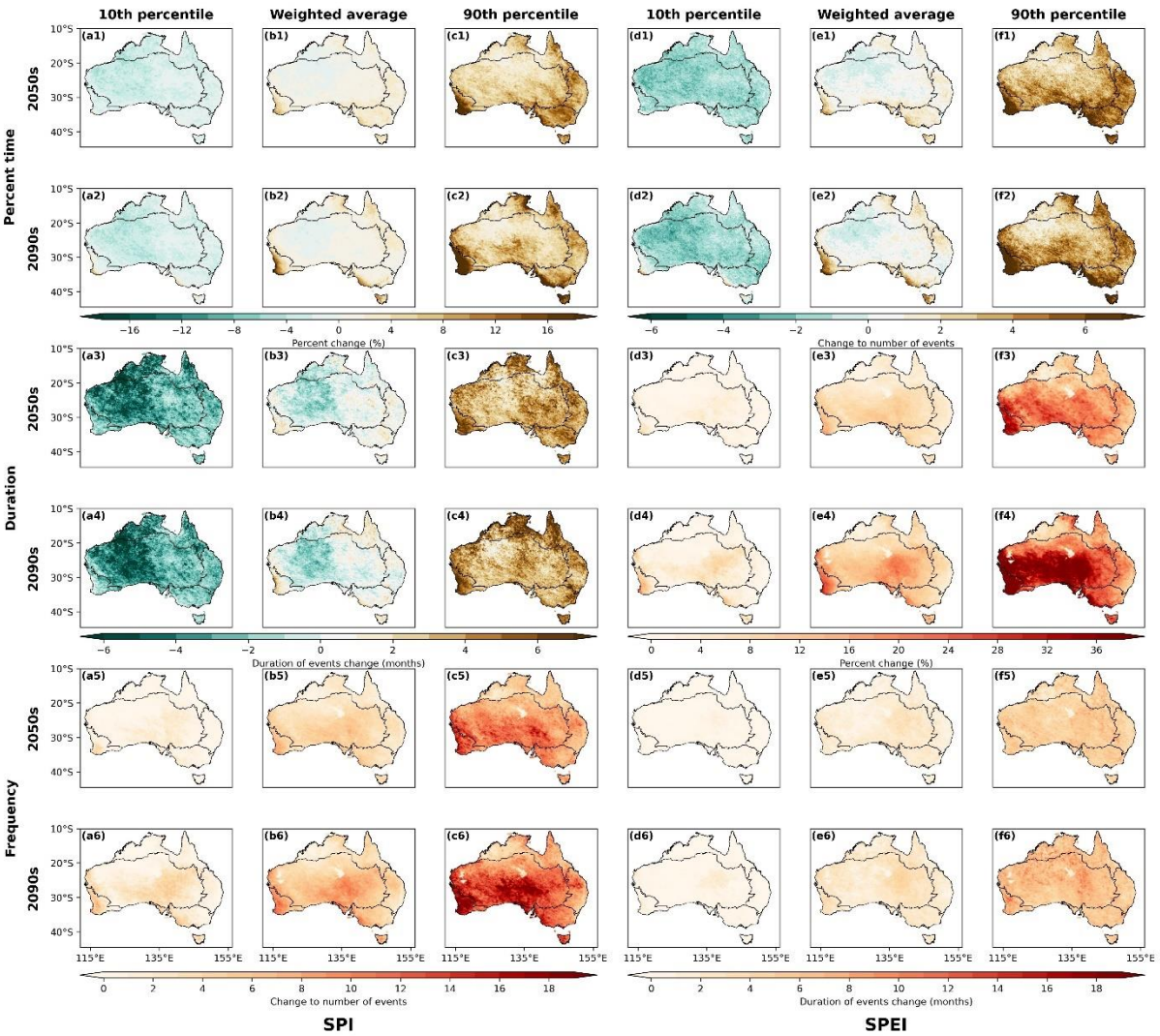



***Figure S16****. Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows 5 to 6) of extreme droughts under SSP126 according to SPI (columns a, b, and c) and SPEI (column d, e, and f) for the 2050s and 2080s relative to the baseline period. The multi-model ensemble average is shown with the 10-90$^{th}$ percentile.*




115
116 ***Figure S17****. Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows*
117 *5 to 6) of extreme droughts under SSP245 according to SPI (columns a, b, and c) and SPEI (column d, e, and f) for*
118 *the 2050s and 2080s relative to the baseline period. The multi-model ensemble average is shown with the 10-90$^{th}$*
119 *percentile.*

120

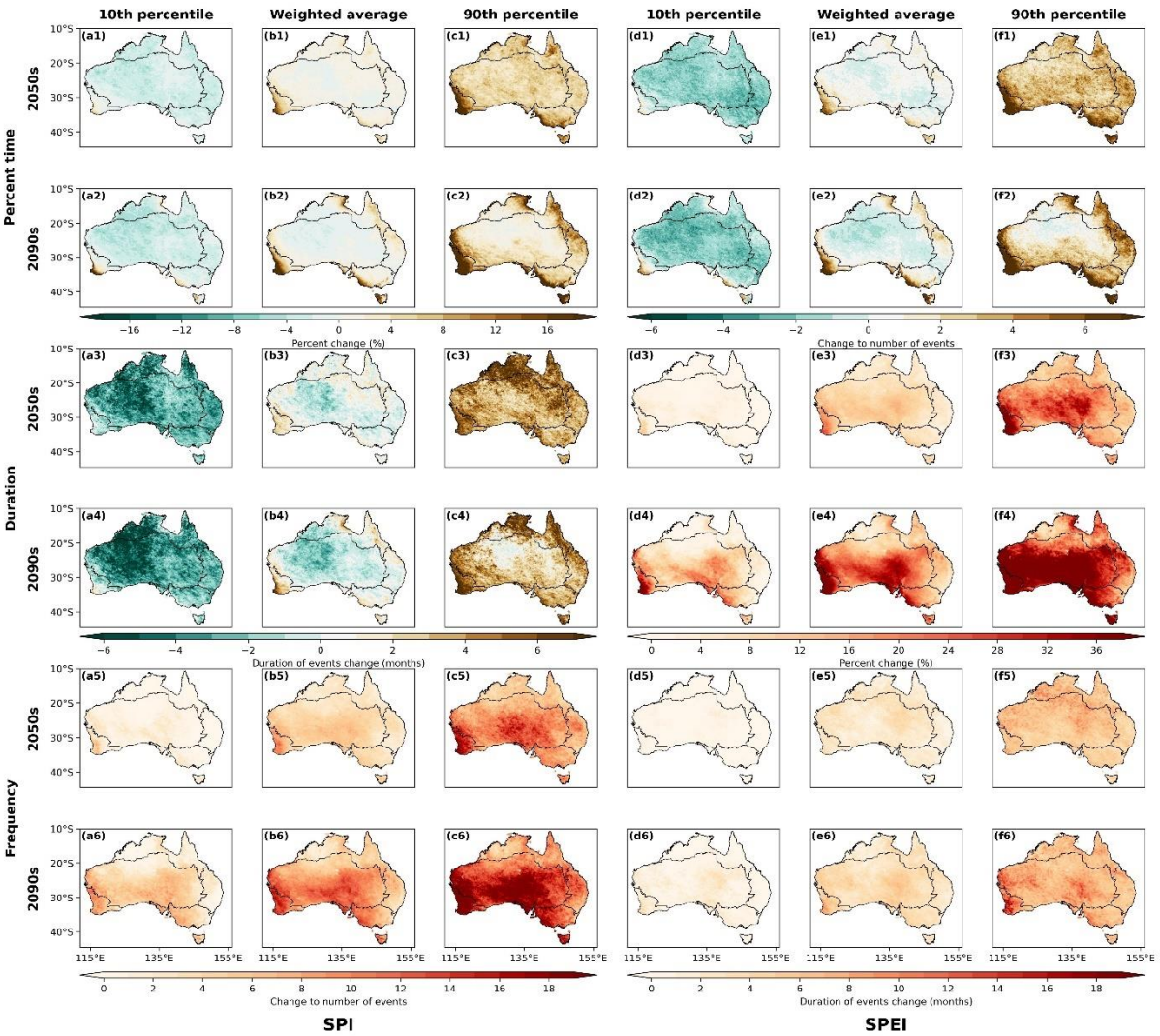



*Figure S18. Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows 5 to 6) of extreme droughts under SSP370 according to SPI (columns a, b, and c) and SPEI (column d, e, and f) for the 2050s and 2080s relative to the baseline period. The multi-model ensemble average is shown with the 10-90$^{th}$ percentile.*

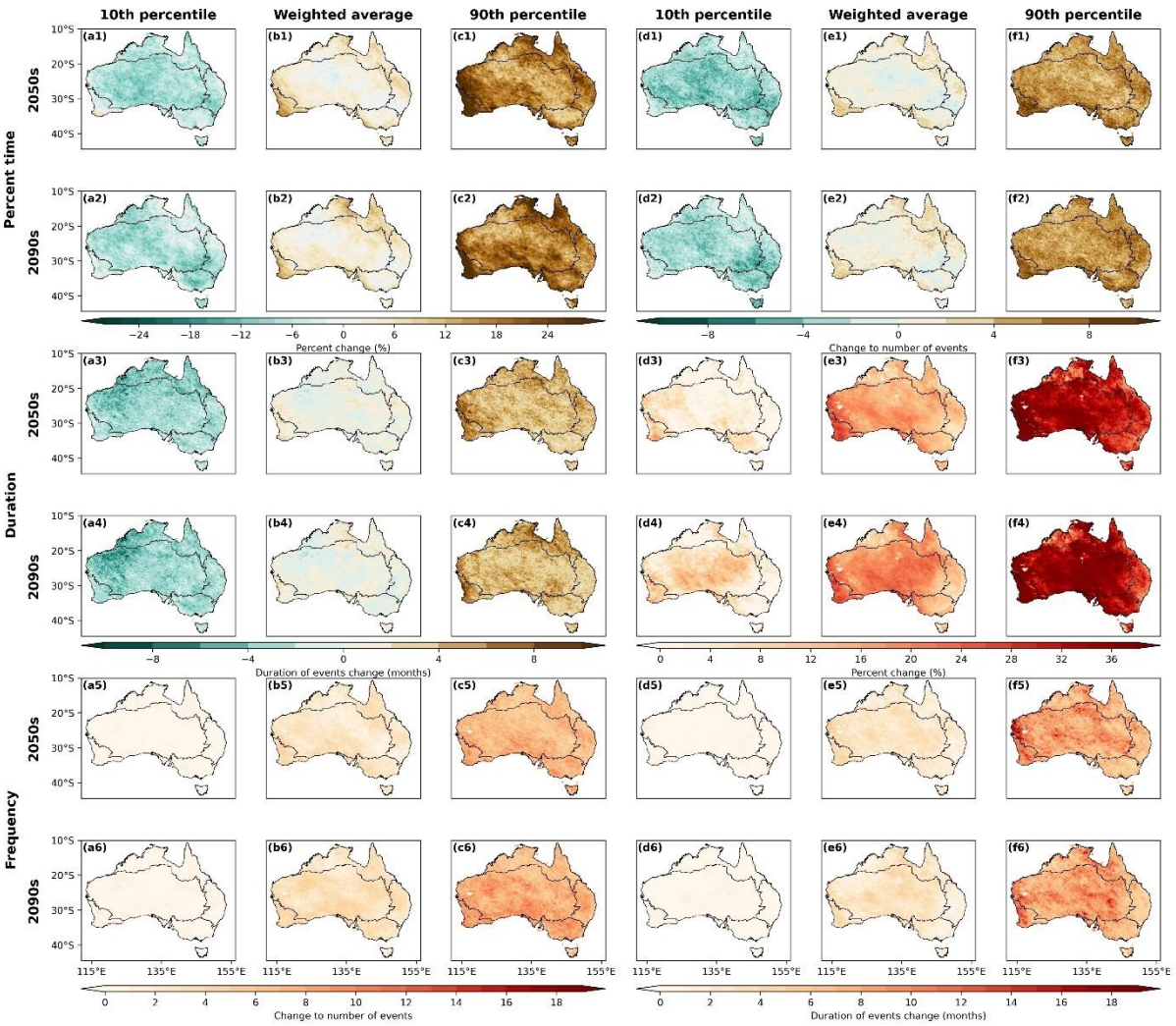



*Figure S19*. *Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows 5 to 6) of moderate to extreme droughts under SSP126 according to SPI (columns a, b, and c) and SPEI (column d, e, and f) for the 2050s and 2080s relative to the baseline period. The multi-model ensemble average is shown with the 10-90$^{th}$ percentile.*

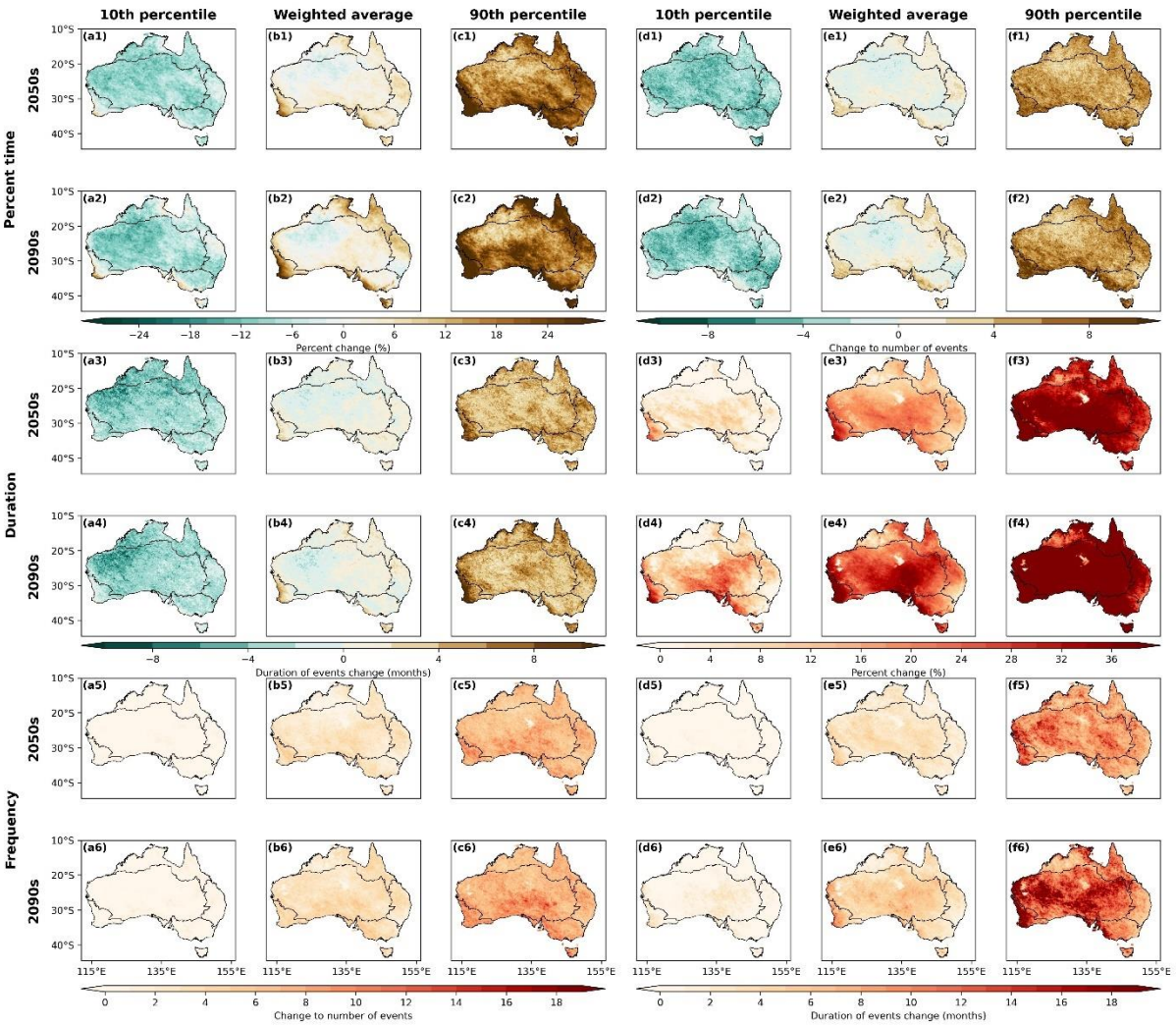
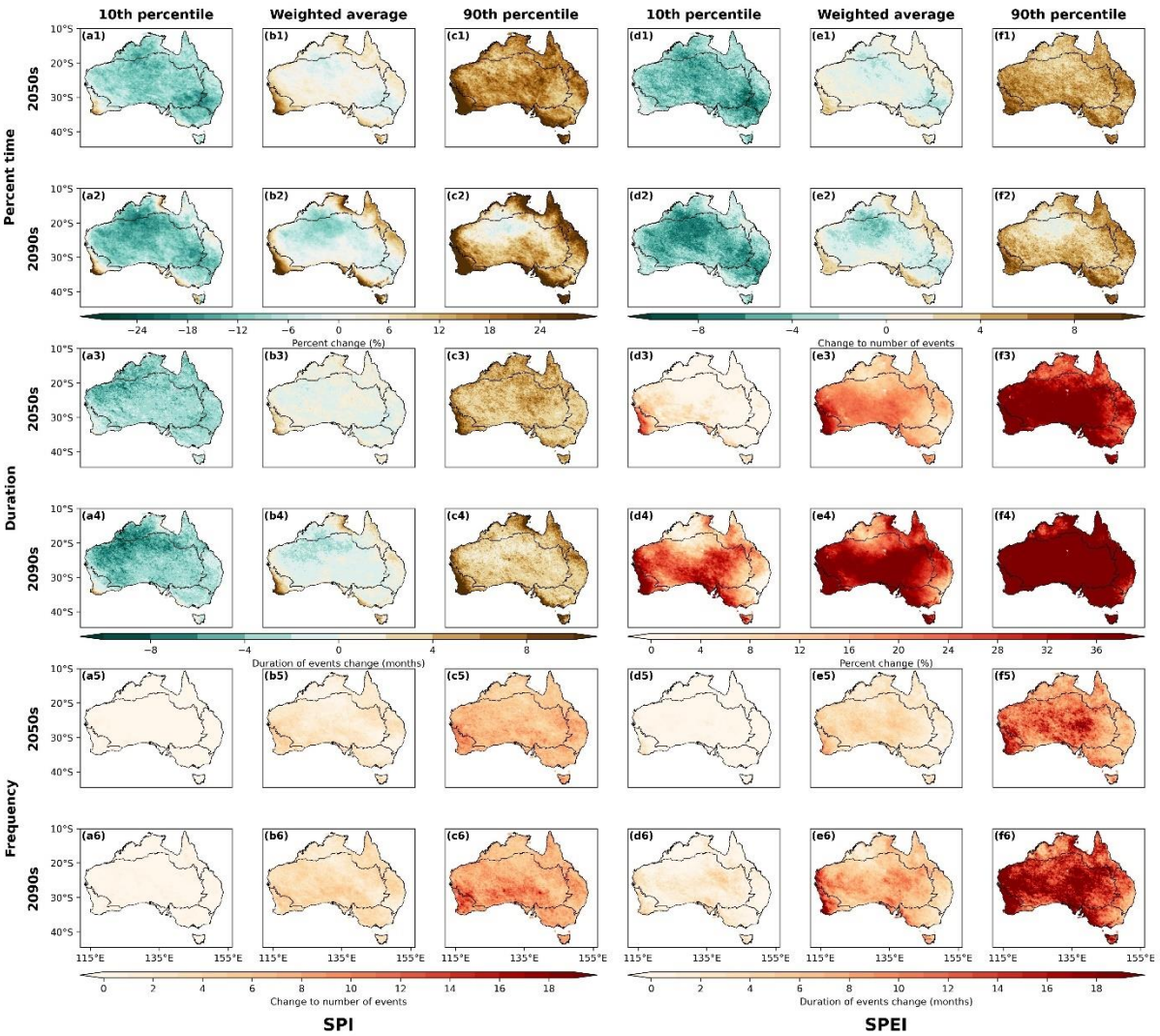



*Figure S20. Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows 5 to 6) of moderate to extreme droughts under SSP245 according to SPI (columns a, b, and c) and SPEI (column d, e, and f) for the 2050s and 2080s relative to the baseline period. The multi-model ensemble average is shown with the 10-90$^{th}$ percentile.*




139
140 ***Figure S21***. *Maps showing changes to the percent time (rows 1 to 2), frequency (rows 3 to 4), and duration (rows*
141 *5 to 6) of moderate to extreme droughts under SSP370 according to SPI (columns a, b, and c) and SPEI (column d,*
142 *e, and f) for the 2050s and 2080s relative to the baseline period. The multi-model ensemble average is shown with*
143 *the 10-90$^{th}$ percentile.*

144

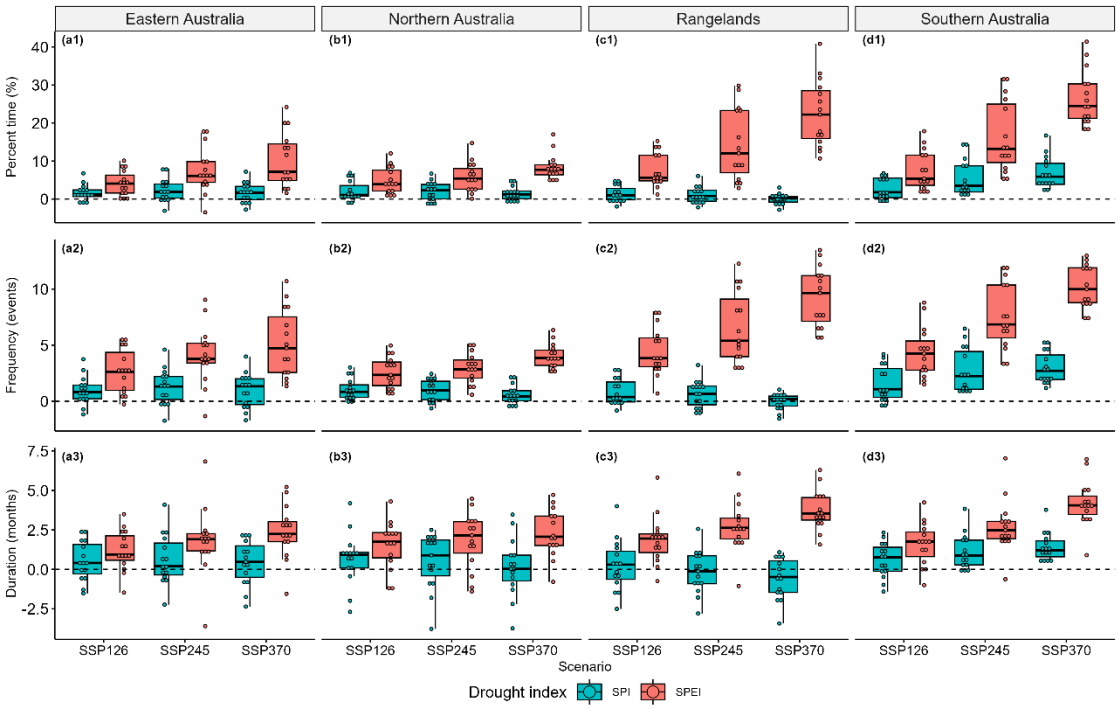



***Figure S22***. *Changes to the percent time, frequency, and duration of extreme droughts using SPI and SPEI in the 2090s compared to the baseline period. The box and whisker plot shows the interquartile range (box), and the median (bar), while the whiskers extend from the box to the furthest datapoint within 1.5x the interquartile range. Dots show projections for each of the climate models.*

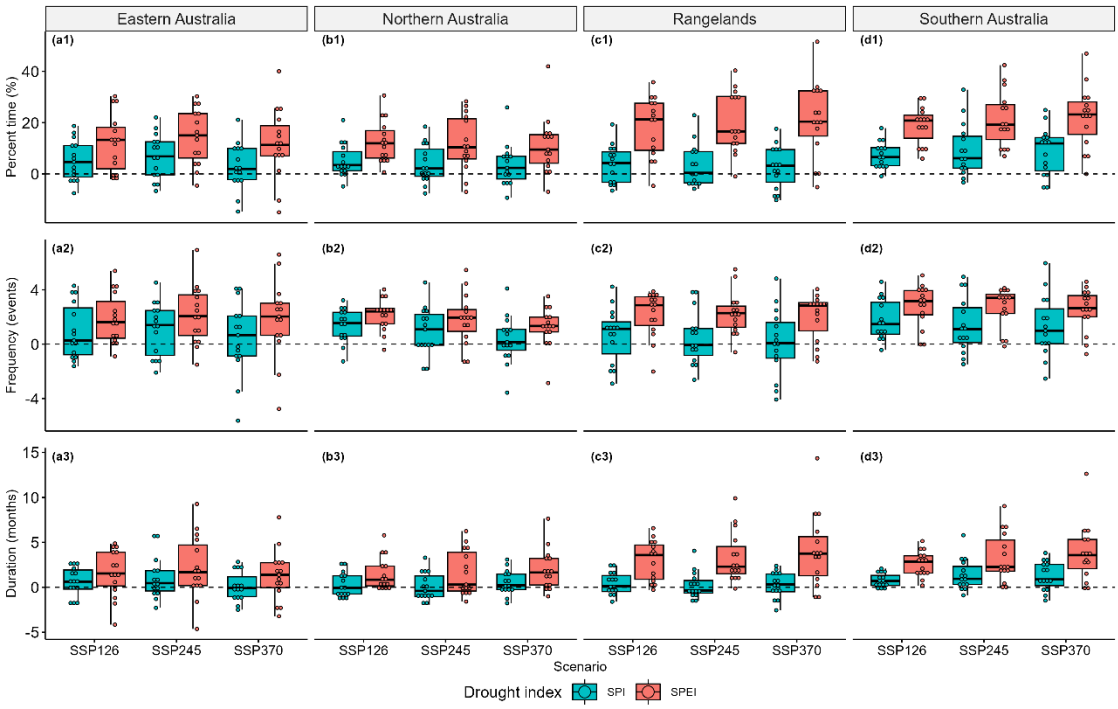



***Figure S23***. *Changes to the percent time, frequency, and duration of moderate to extreme droughts using SPI and SPEI in the 2050s compared to the baseline period. The box and whisker plot shows the interquartile range (box), and the median (bar), while the whiskers extend from the box to the furthest datapoint within 1.5x the interquartile range. Dots show projections for each of the climate models.*

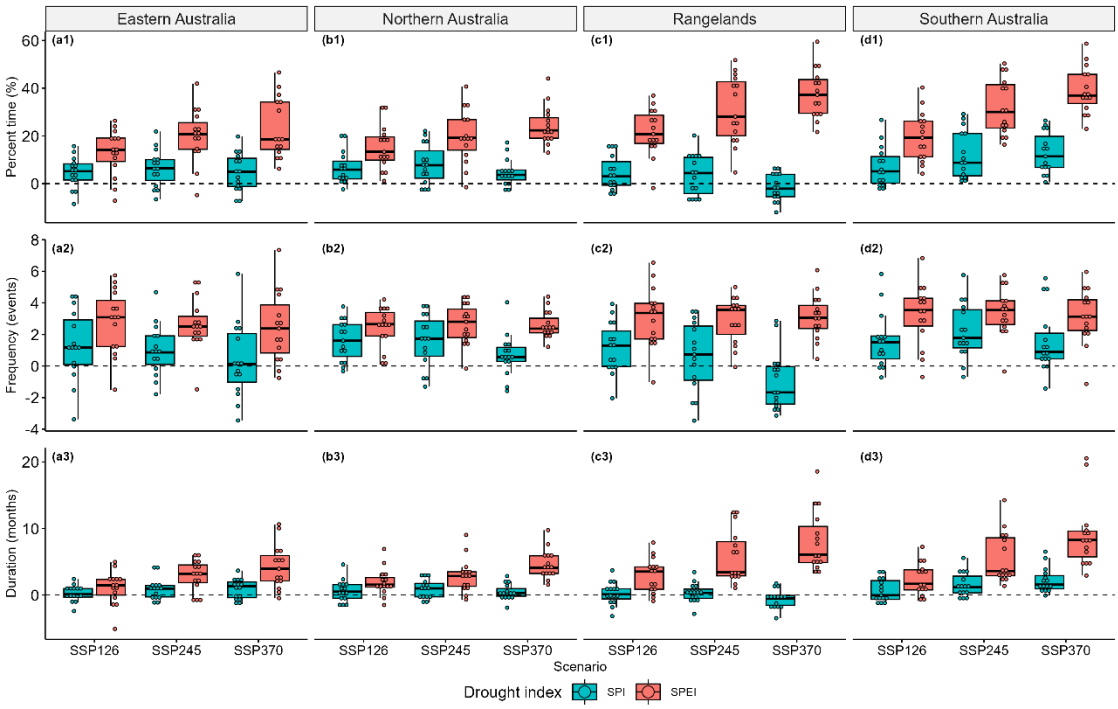



***Figure S24***. *Changes to the percent time, frequency, and duration of moderate to extreme droughts using SPI and SPEI in the 2090s compared to the baseline period. The box and whisker plot shows the interquartile range (box), and the median (bar), while the whiskers extend from the box to the furthest datapoint within 1.5x the interquartile range. Dots show projections for each of the climate models.*

# Sect. S7 SPI and SPEI Interannual Variability

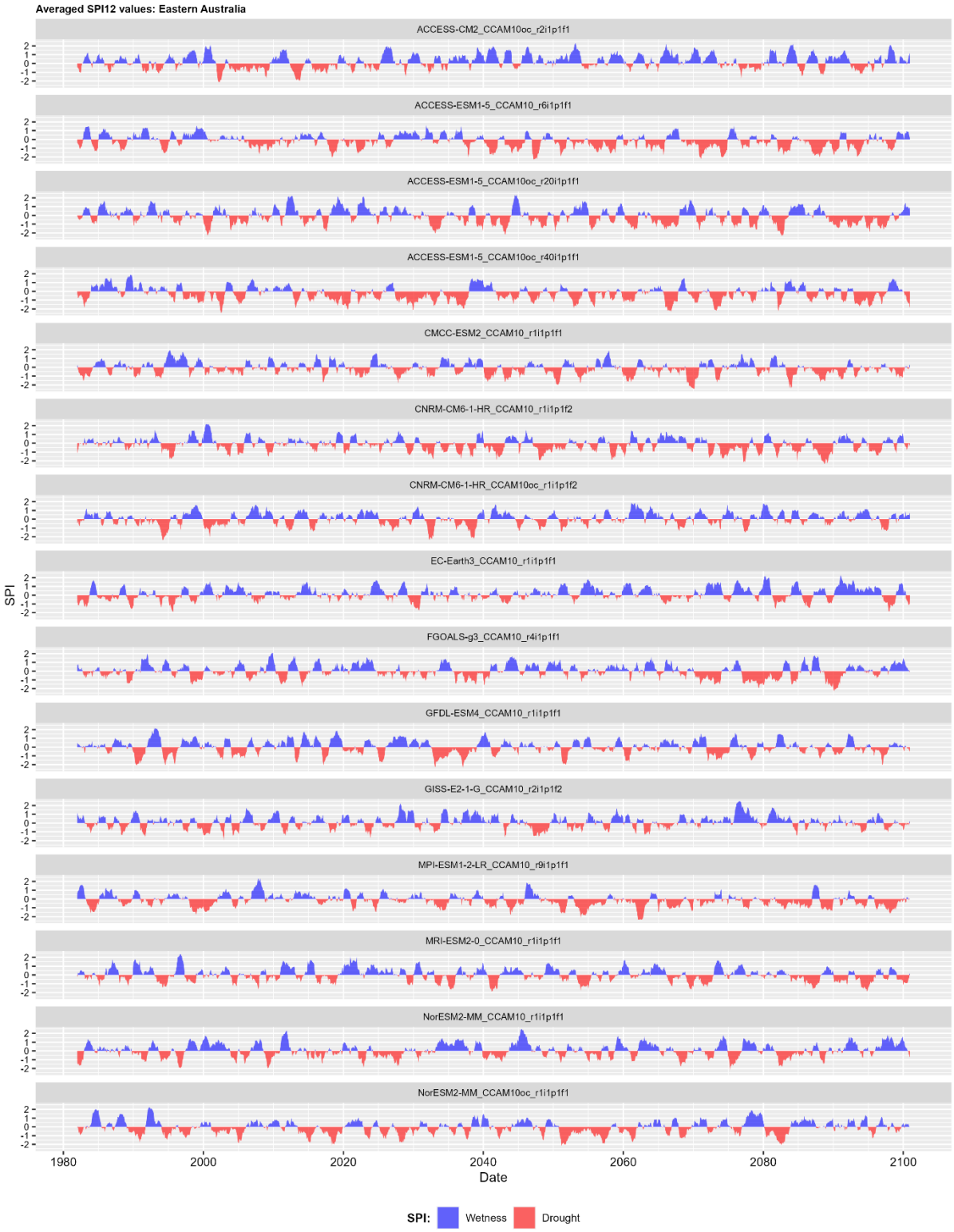



***Figure S25***. *Interannual variability of SPI values in Eastern Australia for all climate models under SSP370.*

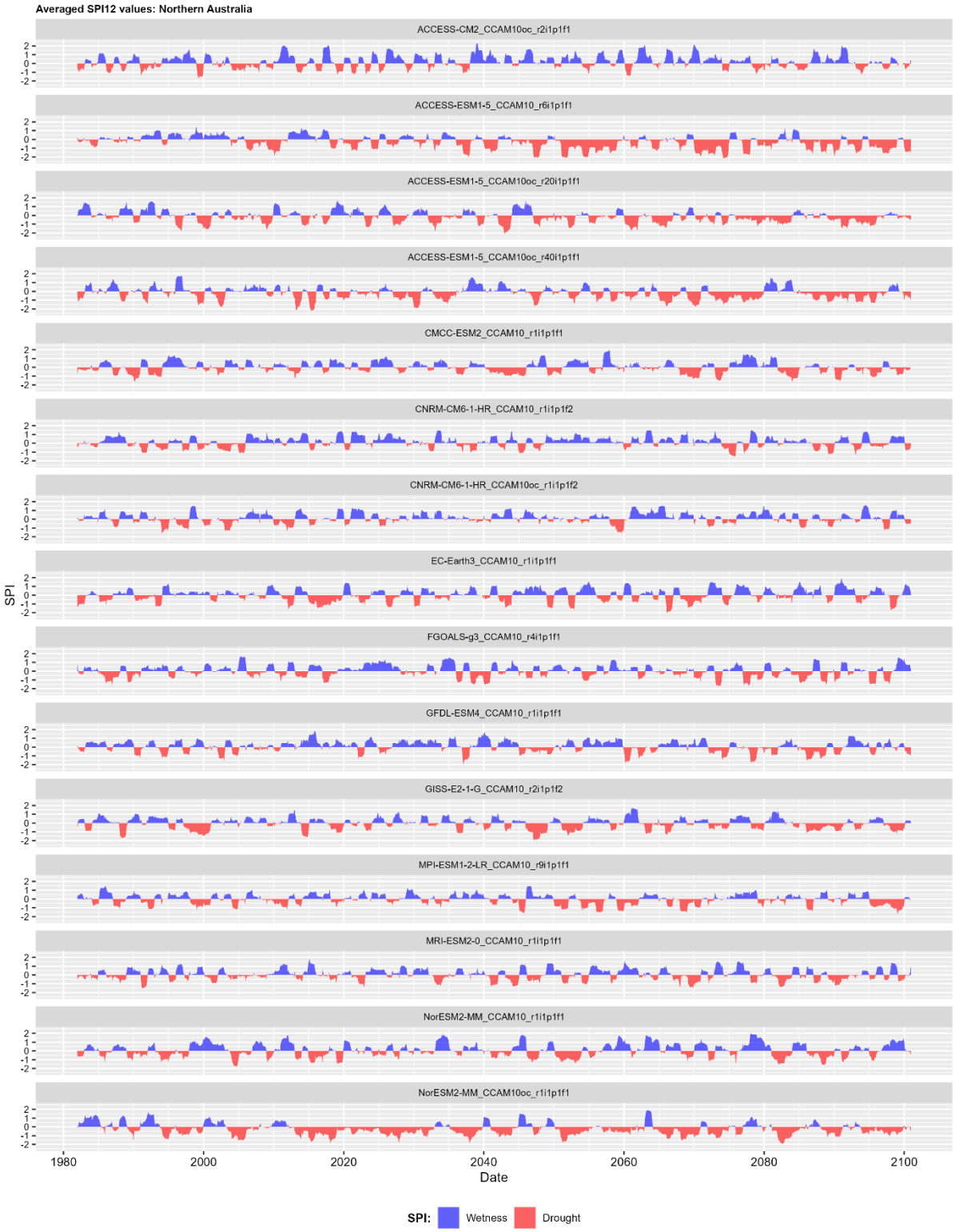



***Figure S26**. Interannual variability of SPI values in Northern Australia for all climate models under SSP370.*

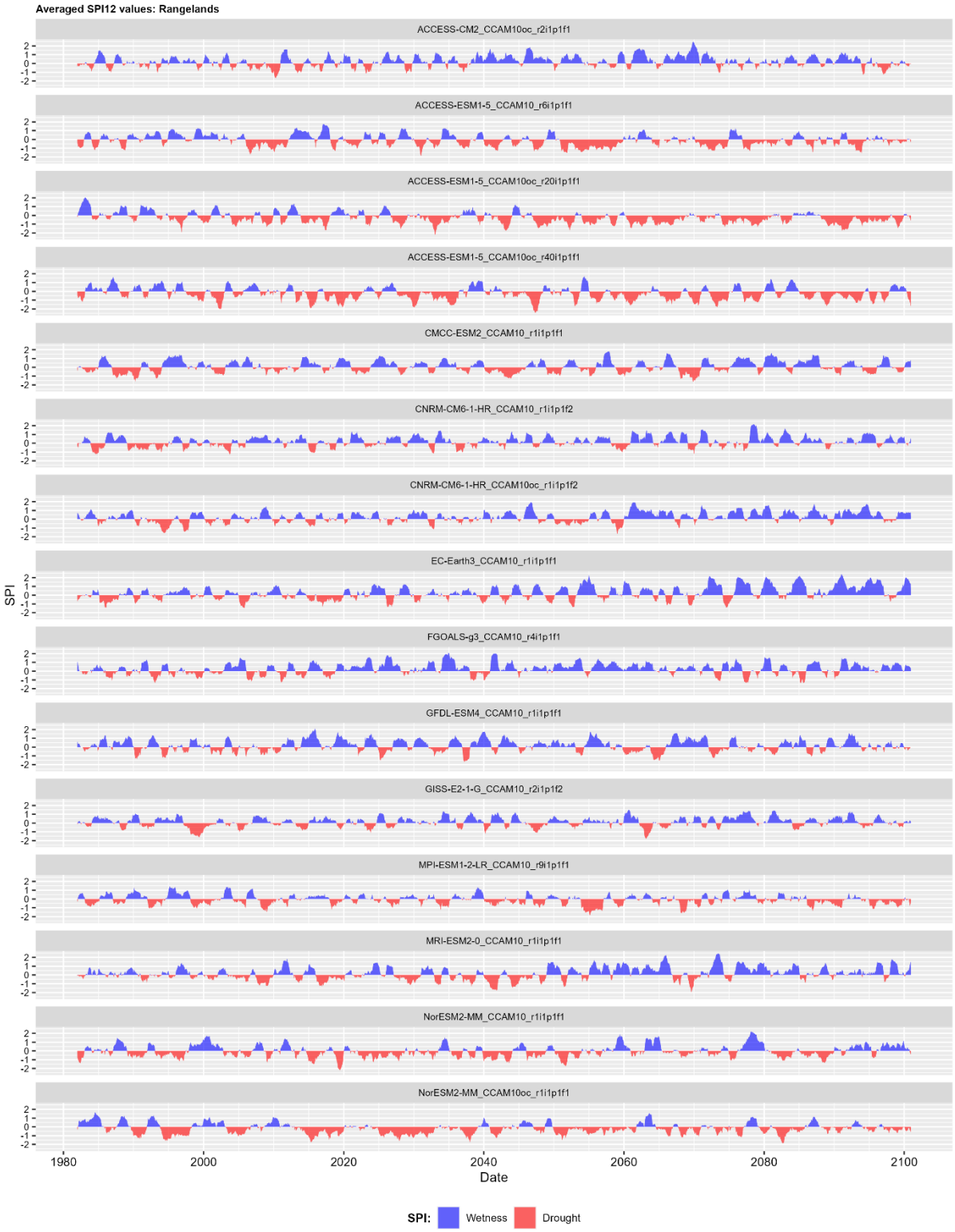



***Figure S27**. Interannual variability of SPI values in Rangelands for all climate models under SSP370.*

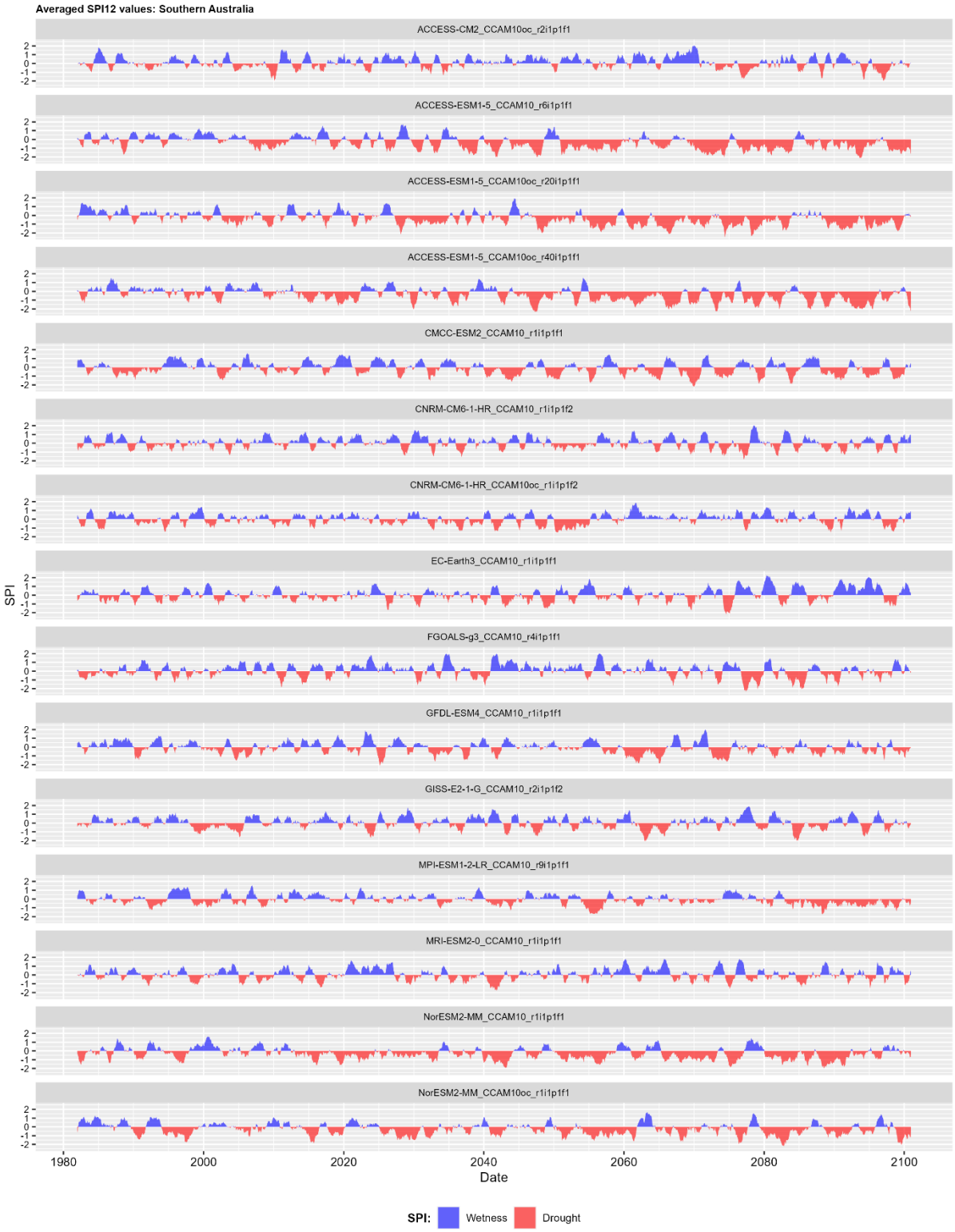



***Figure S28**. Interannual variability of SPI values in Southern Australia for all climate models under SSP370.*

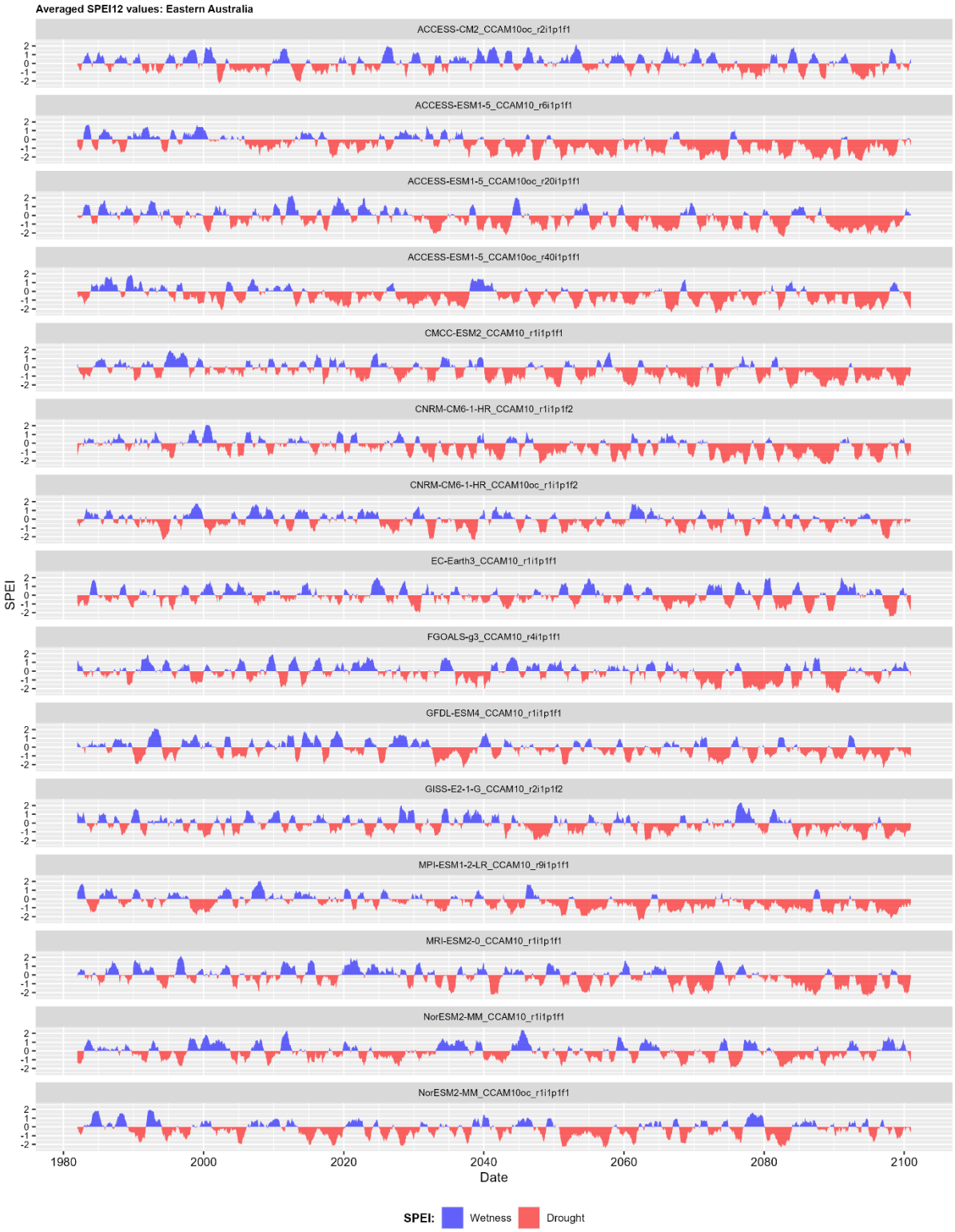



***Figure S29**. Interannual variability of SPEI values in Eastern Australia for all climate models under SSP370.*

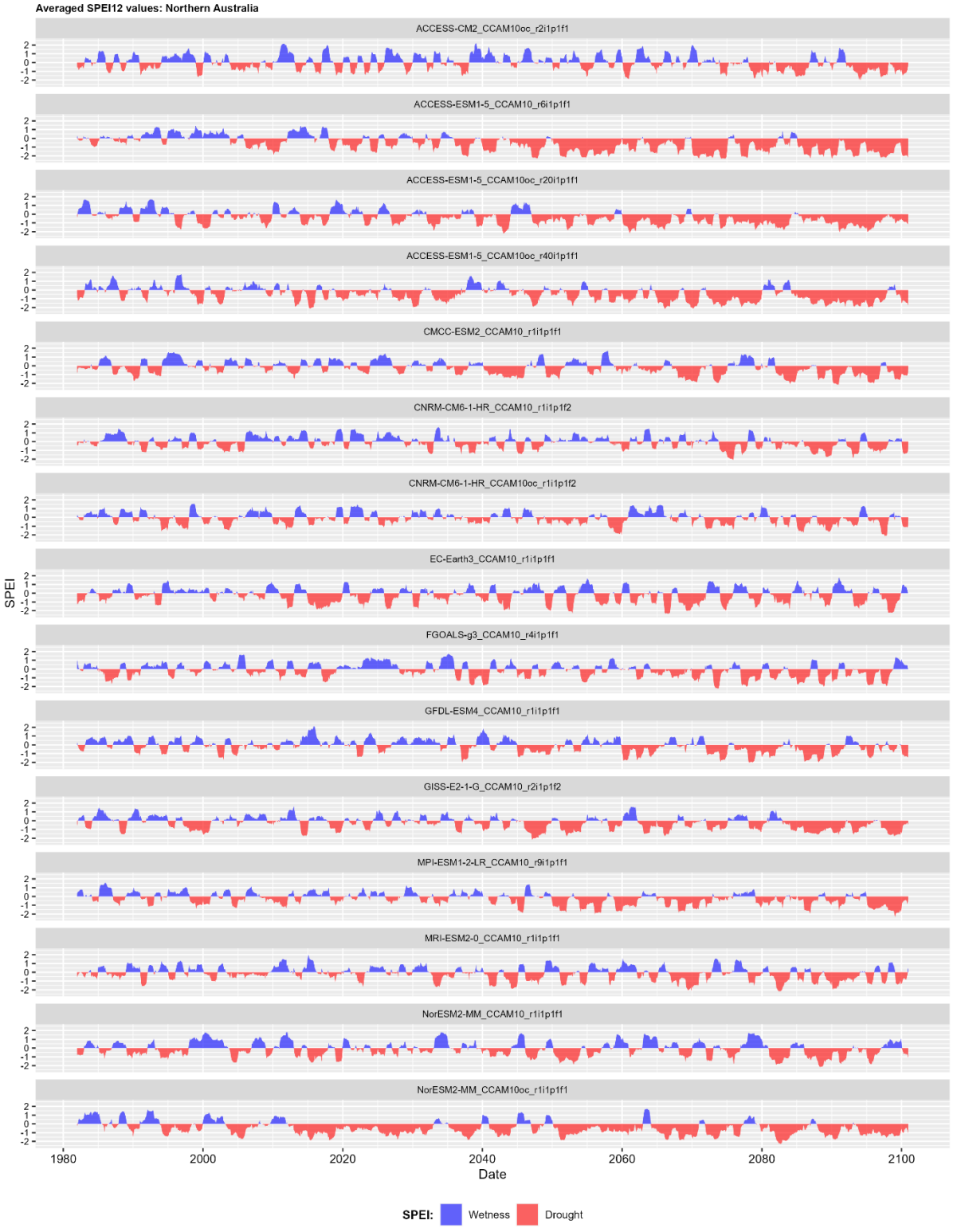



***Figure S30**. Interannual variability of SPEI values in Northern Australia for all climate models under SSP370.*

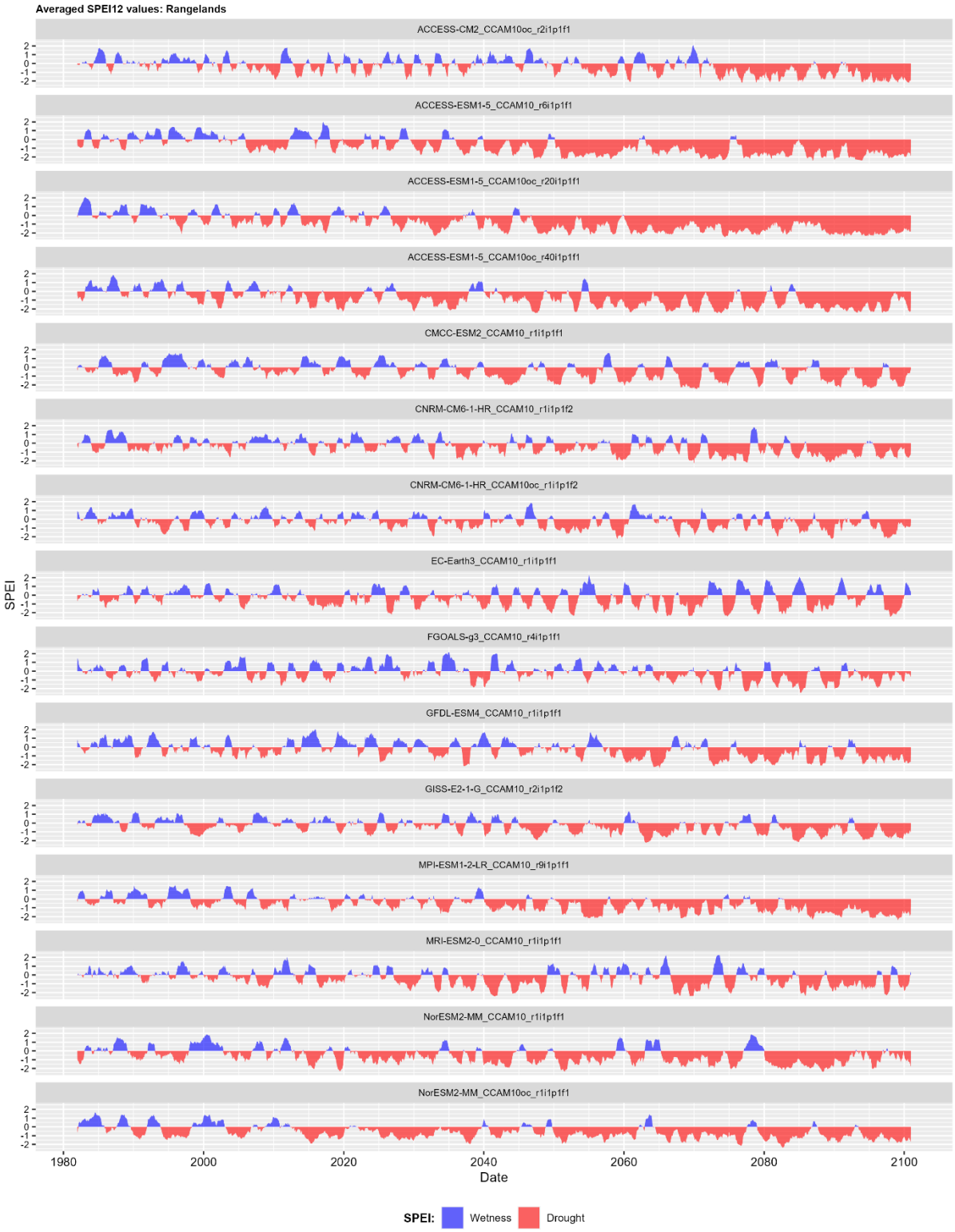



***Figure S31**. Interannual variability of SPEI values in Rangelands for all climate models under SSP370.*

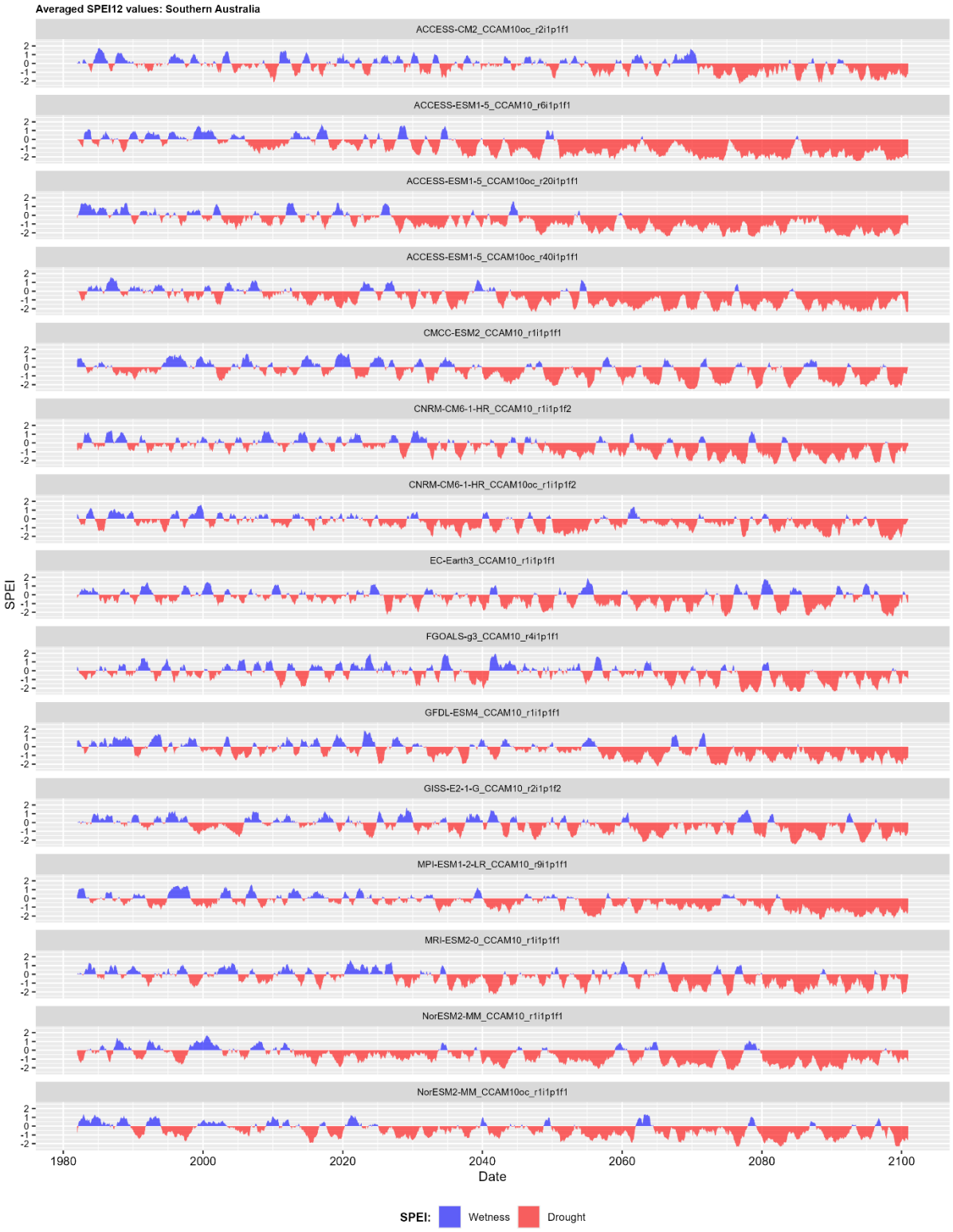



***Figure S32***. *Interannual variability of SPEI values in Southern Australia for all climate models under SSP370.*

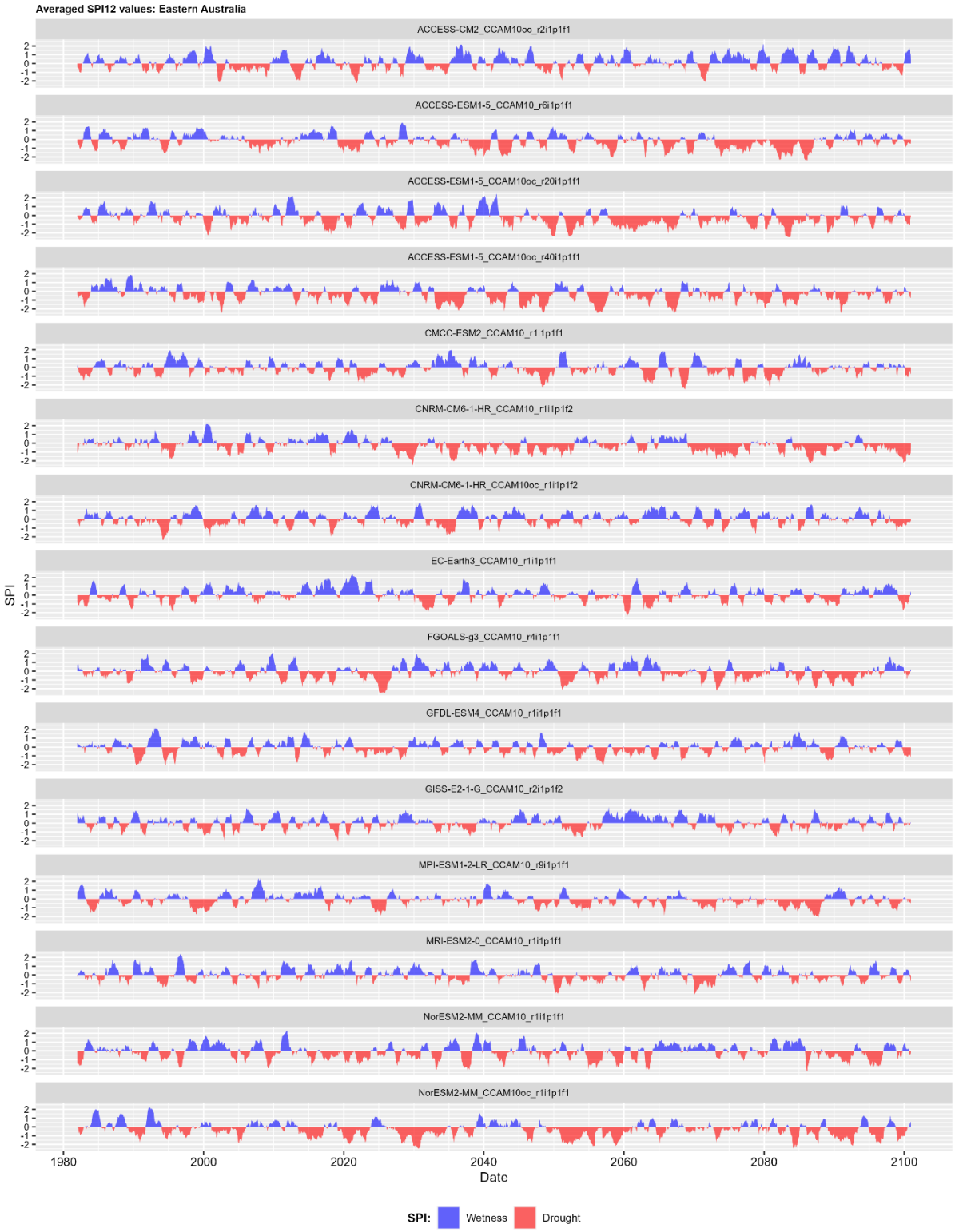
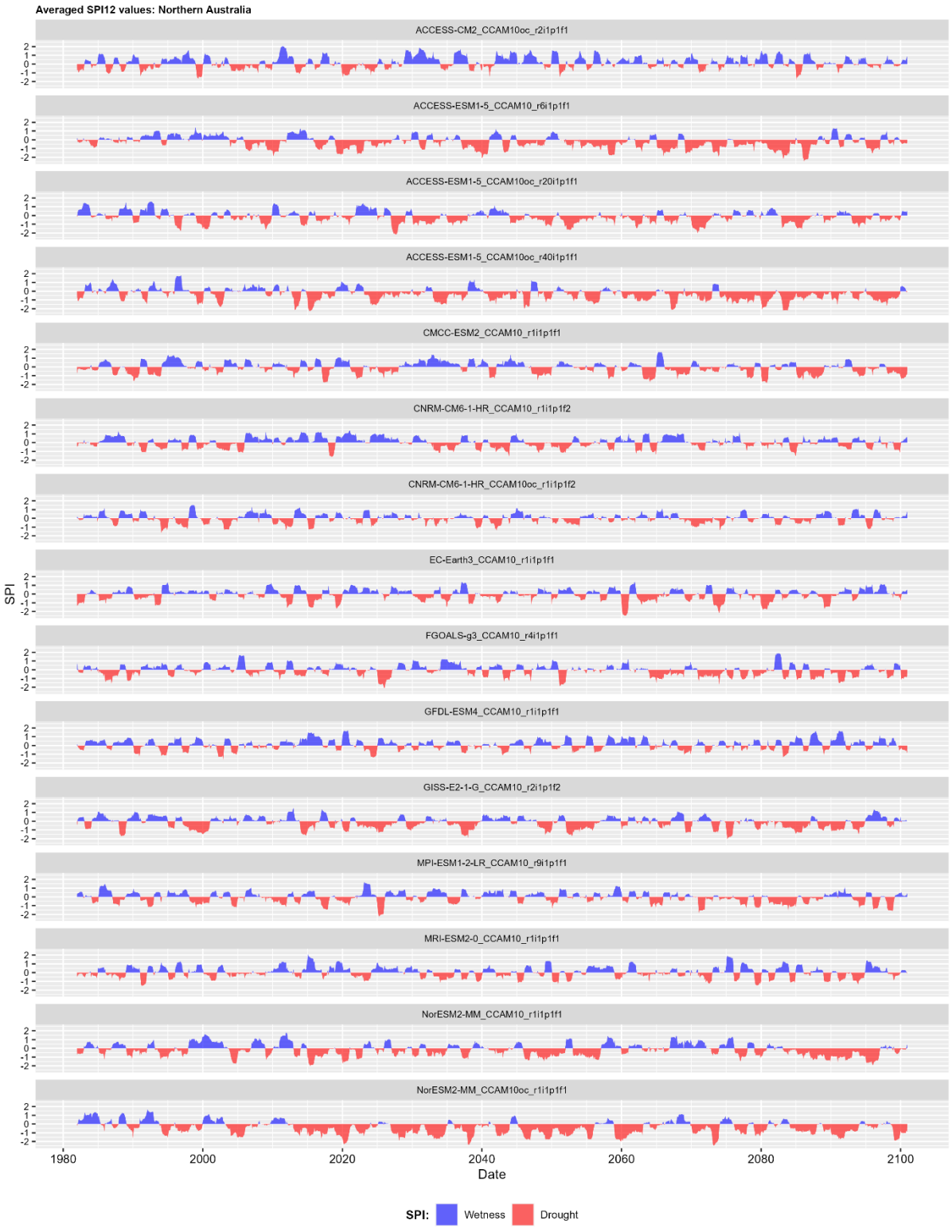



***Figure S33***. *Interannual variability of SPI values in Eastern Australia for all climate models under SSP245.*

188




189

190 ***Figure S34***. *Interannual variability of SPI values in Northern Australia for all climate models under SSP245.*

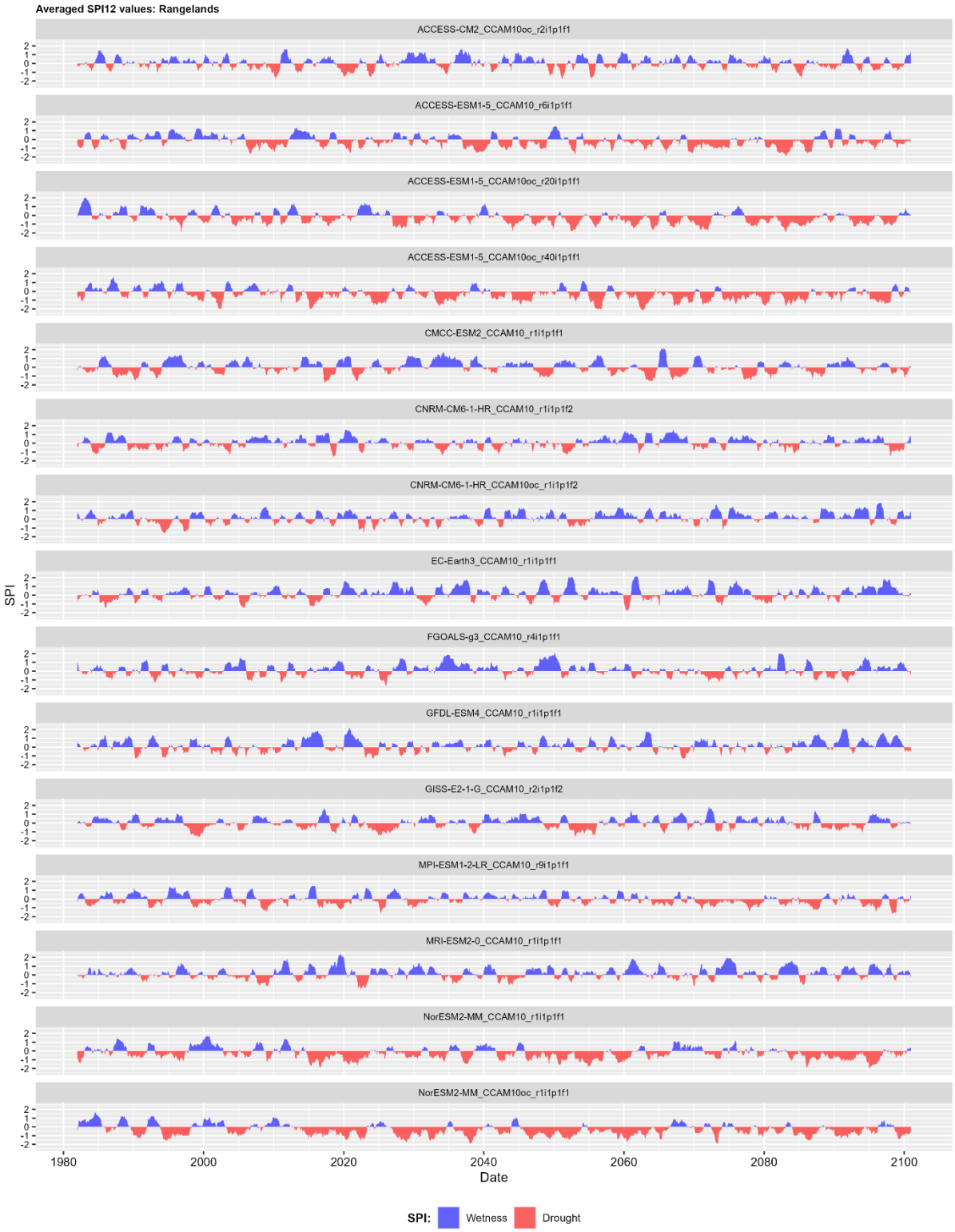



***Figure S35***. *Interannual variability of SPI values in Rangelands for all climate models under SSP245.*

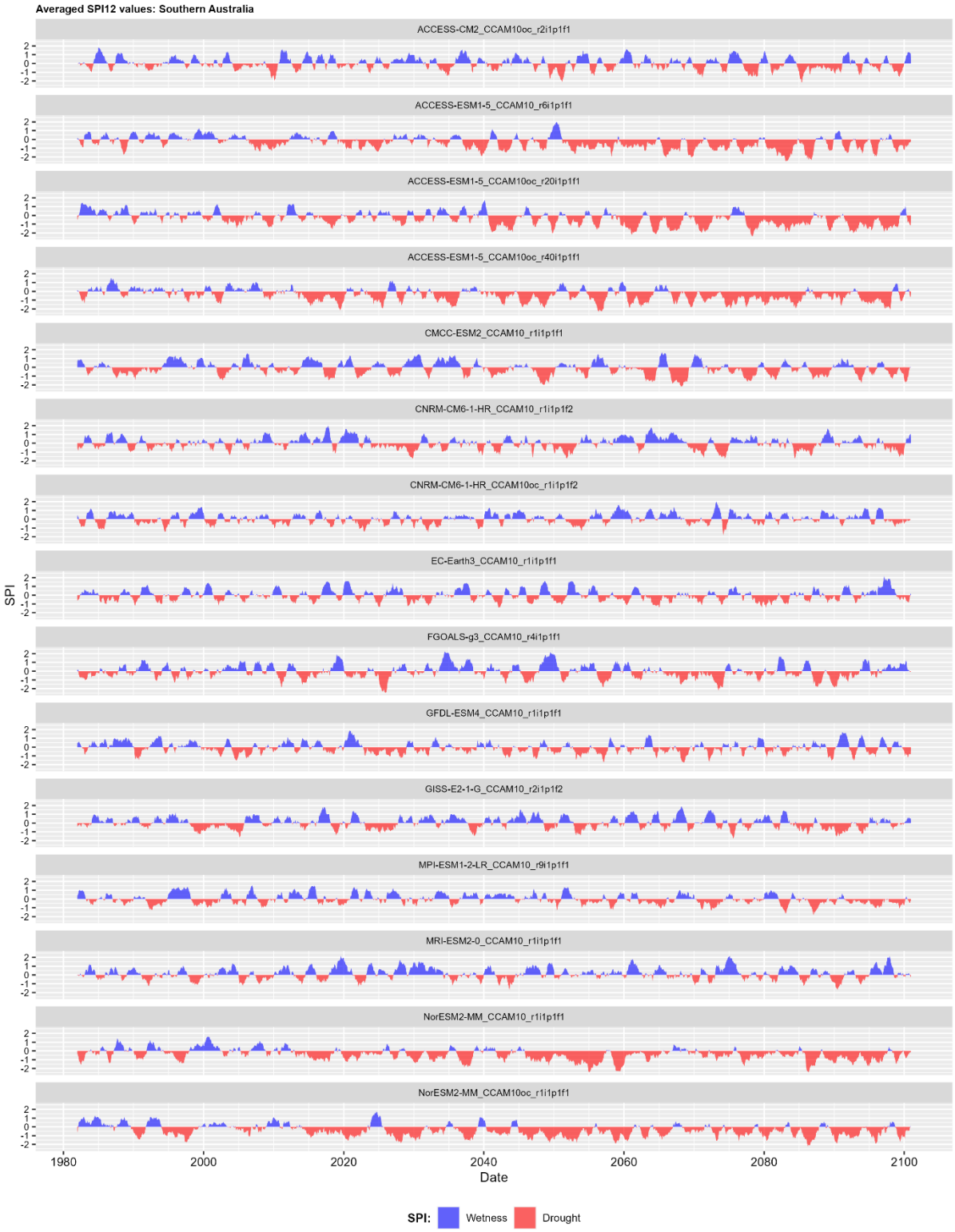



***Figure S36**. Interannual variability of SPI values in Southern Australia for all climate models under SSP245.*

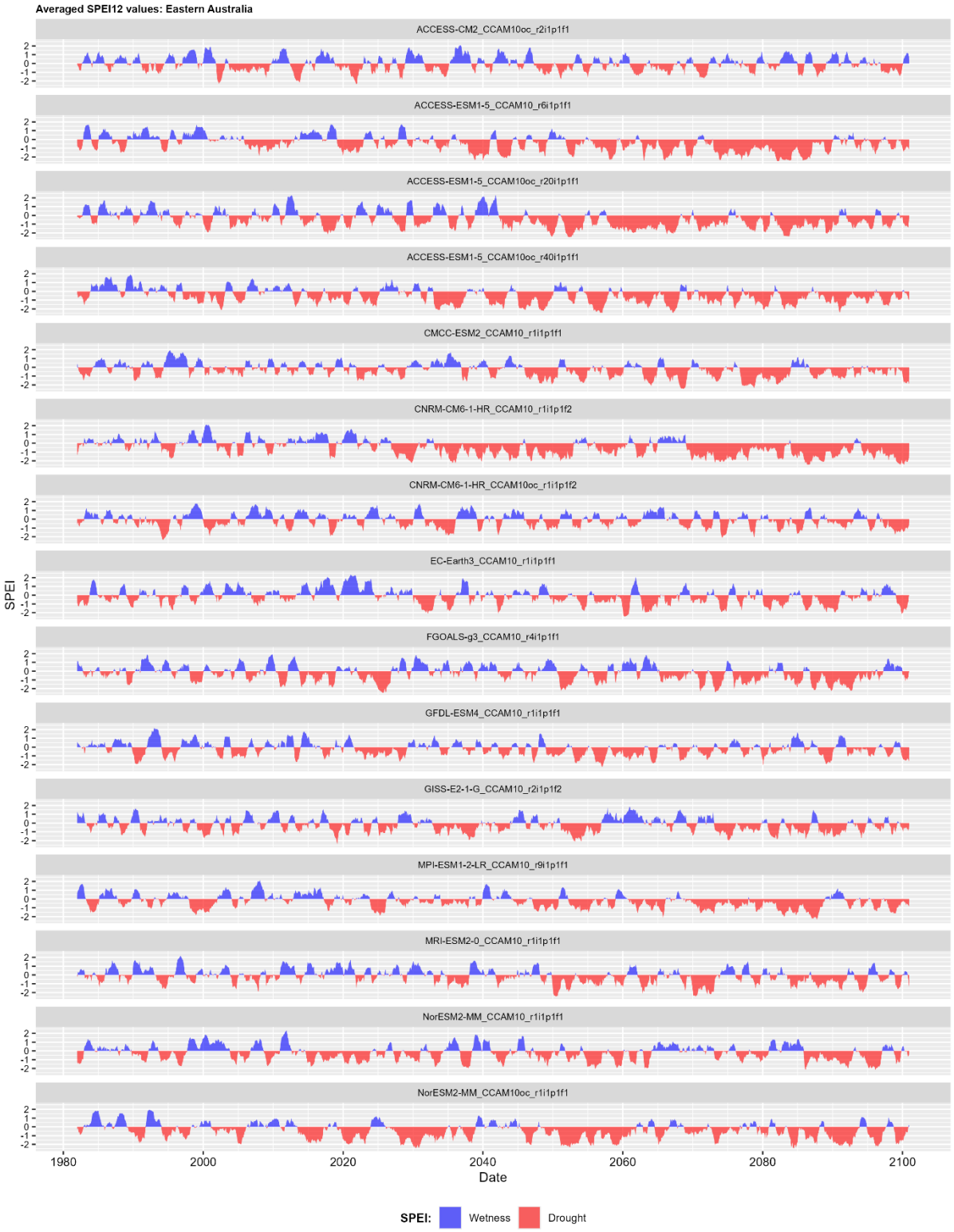



***Figure S37****. Interannual variability of SPEI values in Eastern Australia for all climate models under SSP245.*

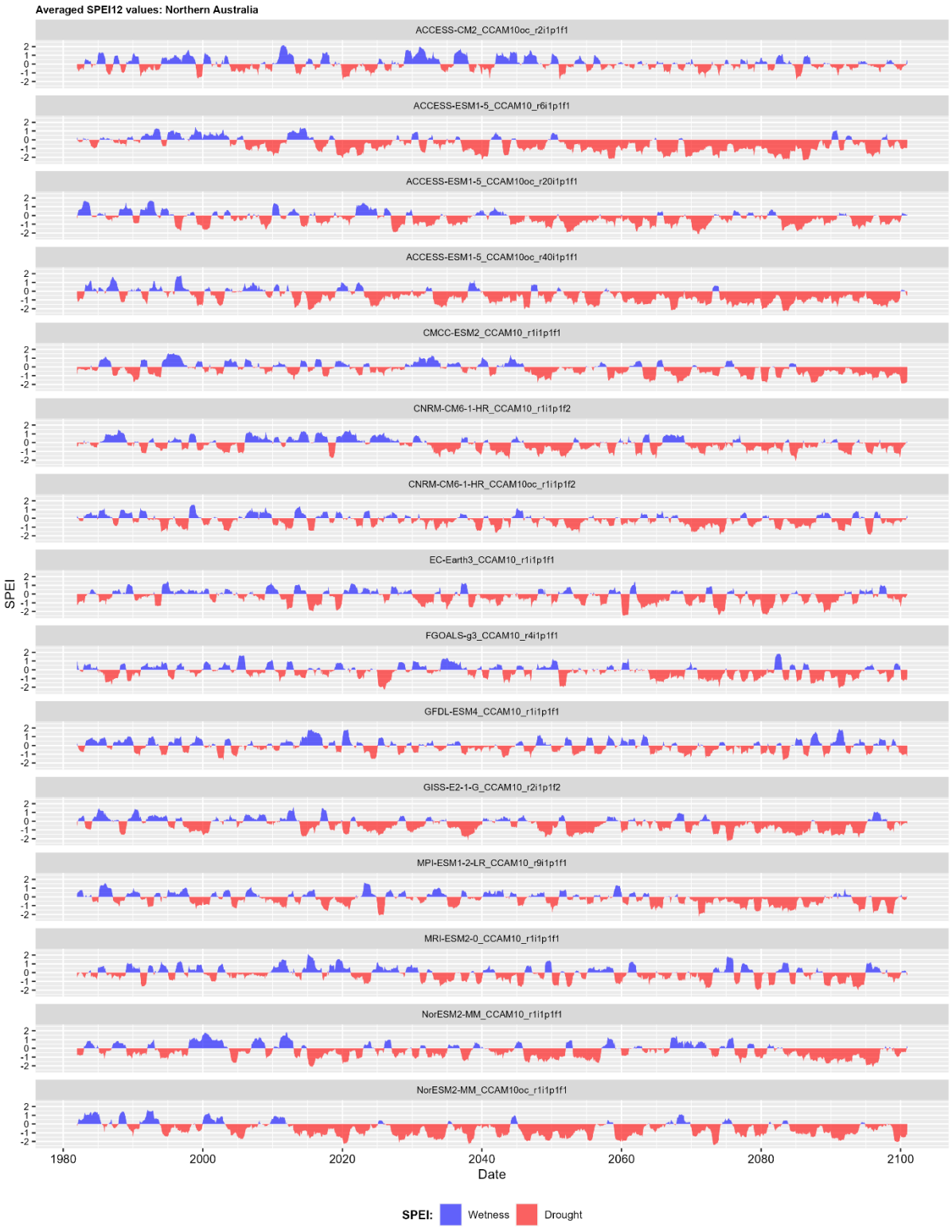



***Figure S38***. *Interannual variability of SPEI values in Northern Australia for all climate models under SSP245.*

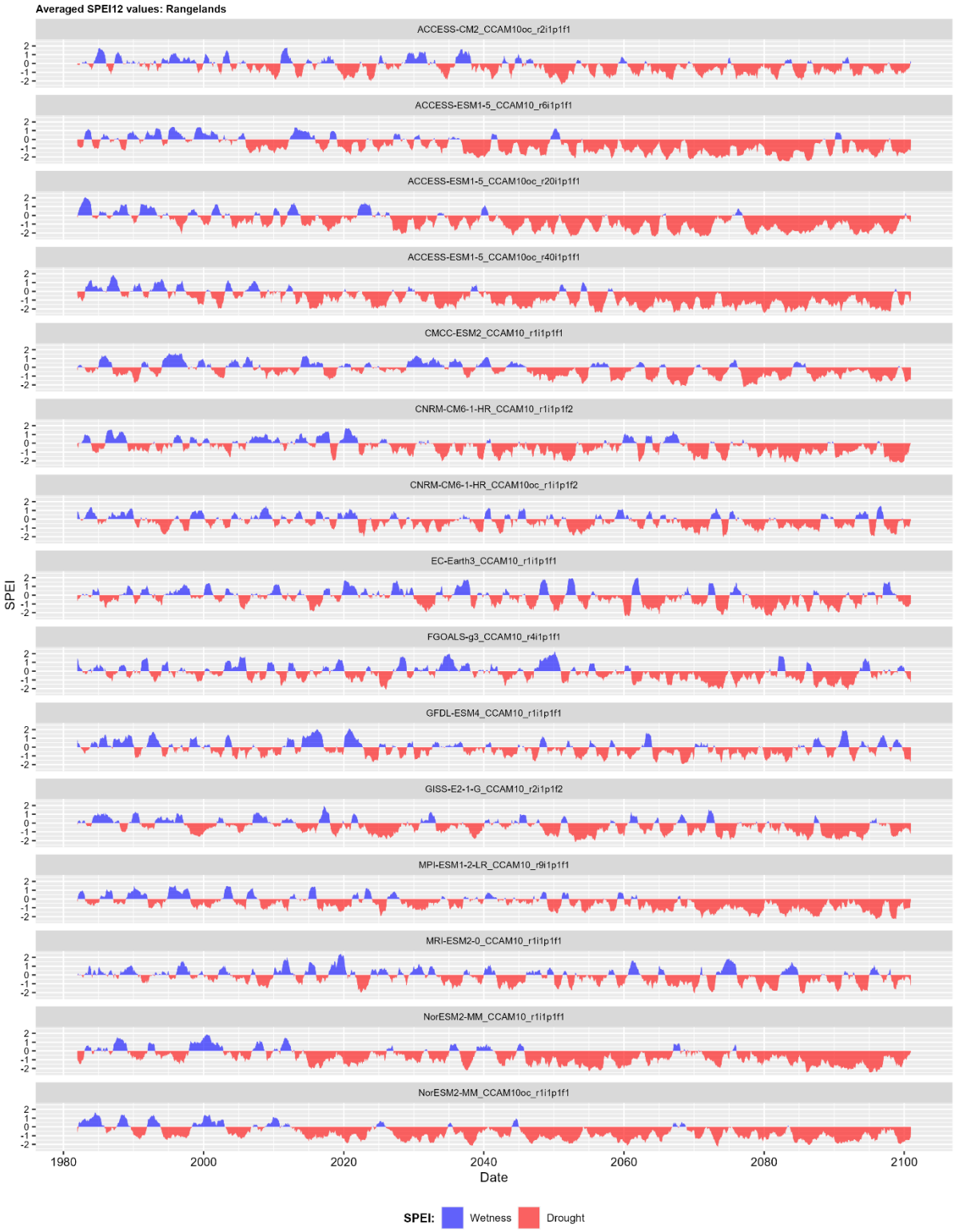



***Figure S39***. *Interannual variability of SPEI values in Rangelands for all climate models under SSP245.*

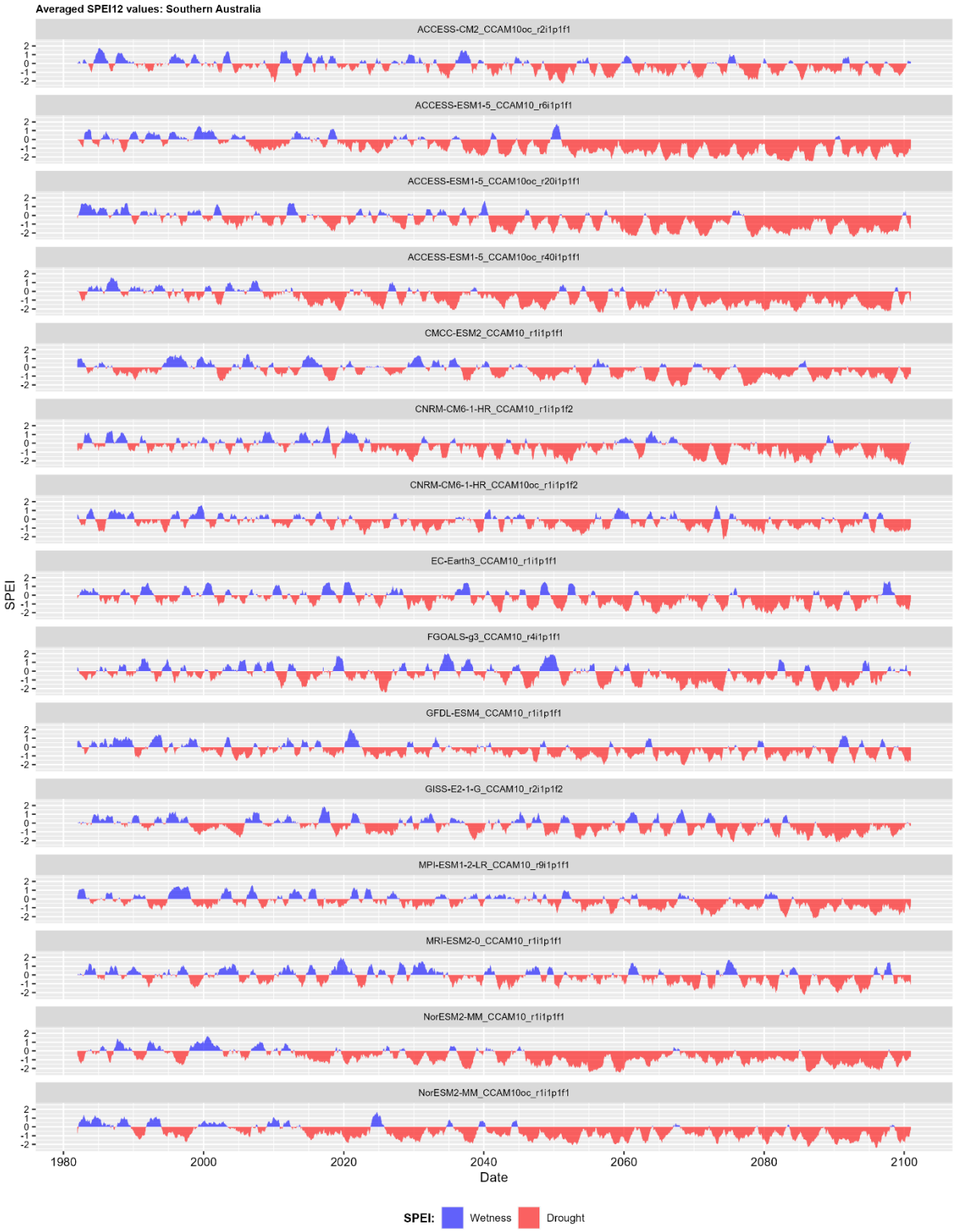
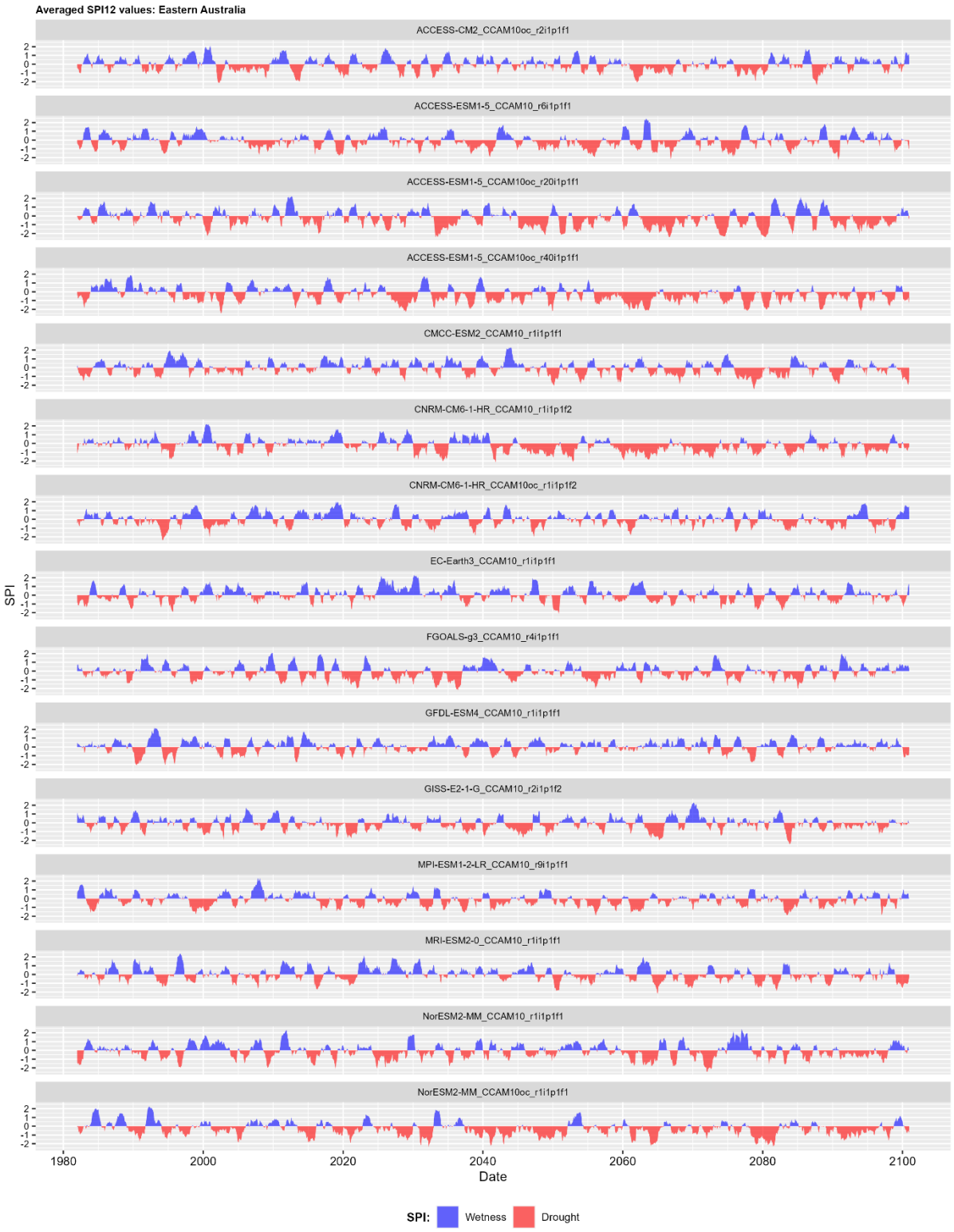



***Figure S40**. Interannual variability of SPEI values in Southern Australia for all climate models under SSP245.*

208




209
210 ***Figure S41***. *Interannual variability of SPI values in Eastern Australia for all climate models under SSP126.*

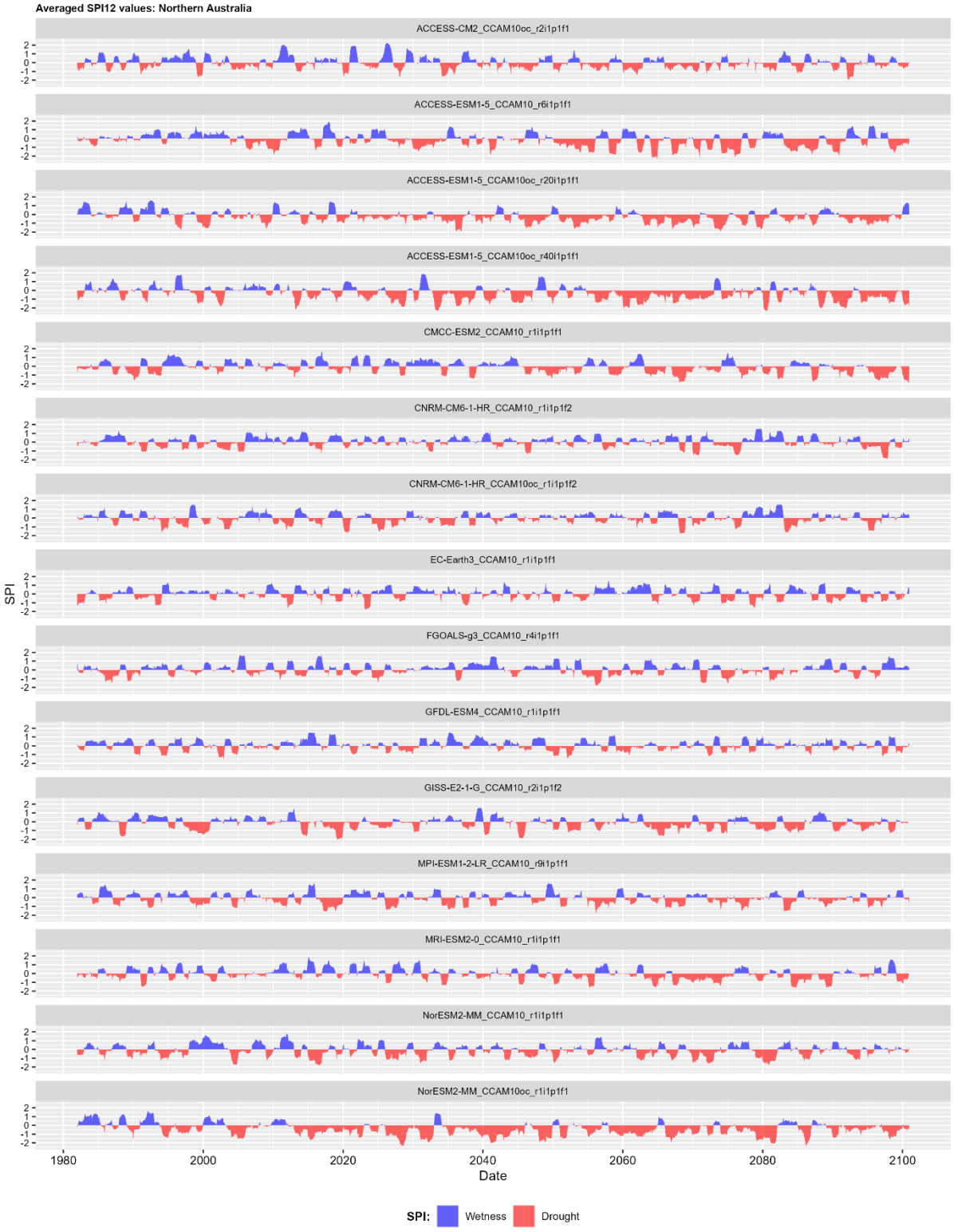



***Figure S42***. *Interannual variability of SPI values in Northern Australia for all climate models under SSP126.*

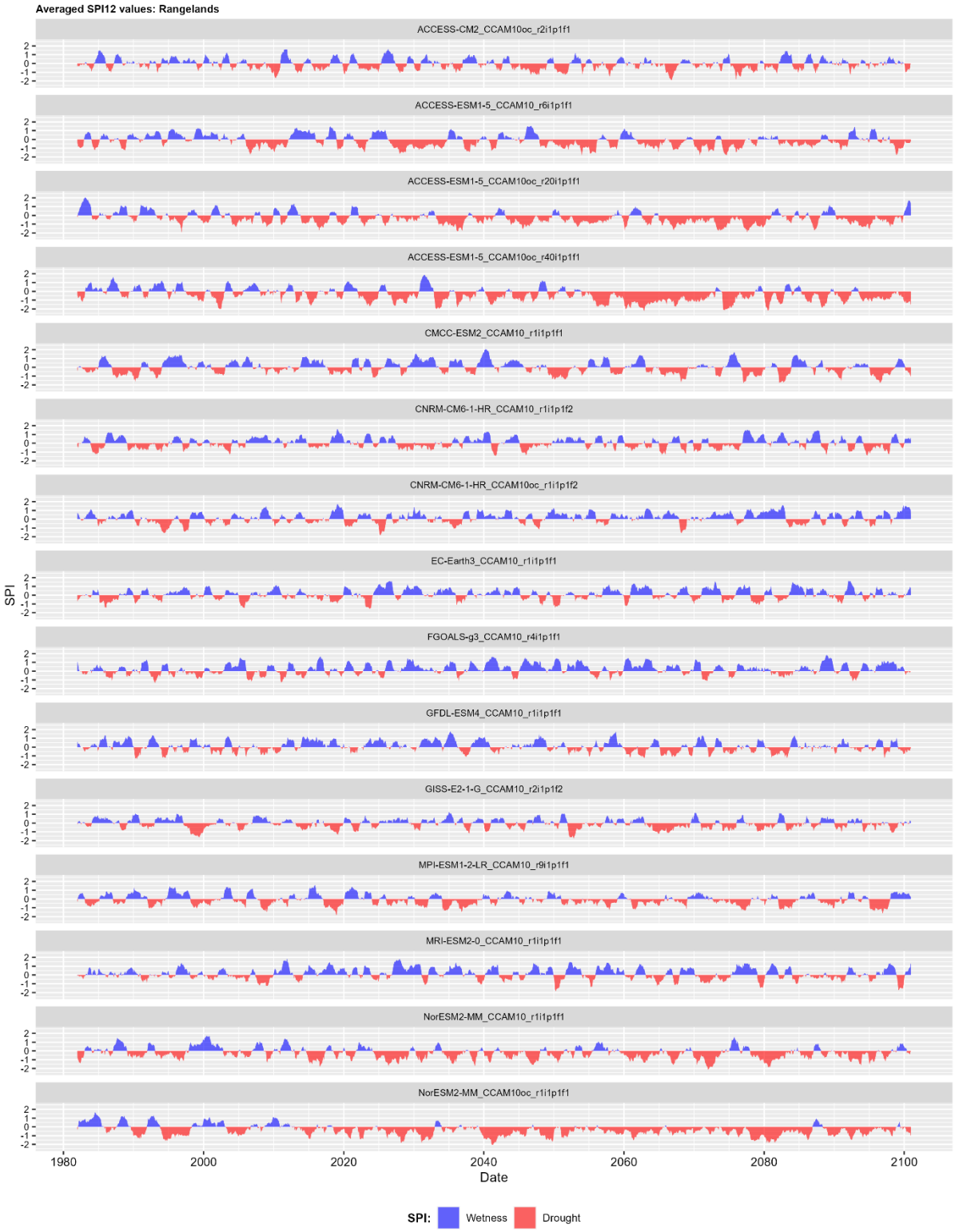



***Figure S43***. *Interannual variability of SPI values in Rangelands for all climate models under SSP126.*

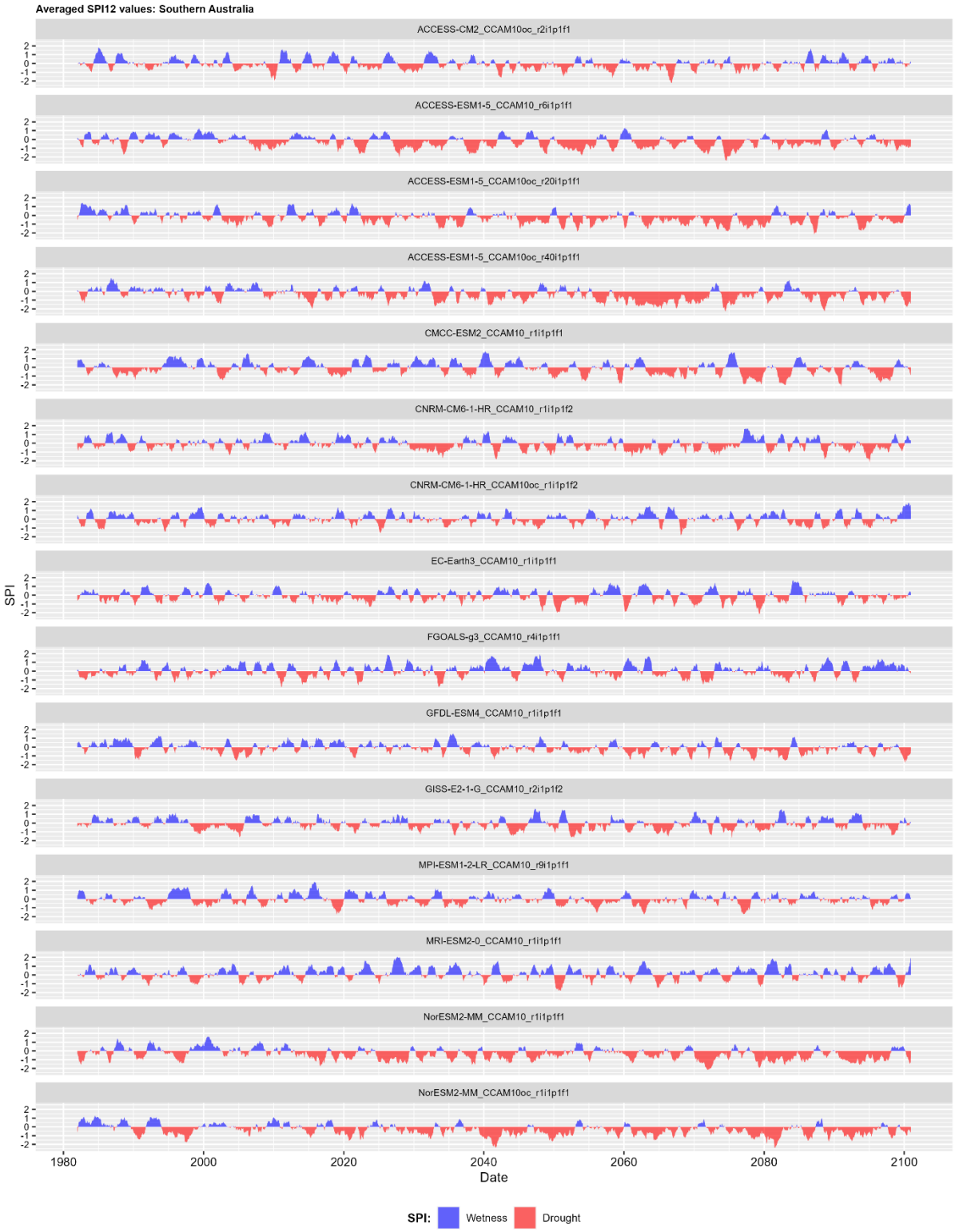



***Figure S44***. *Interannual variability of SPI values in Southern Australia for all climate models under SSP126.*

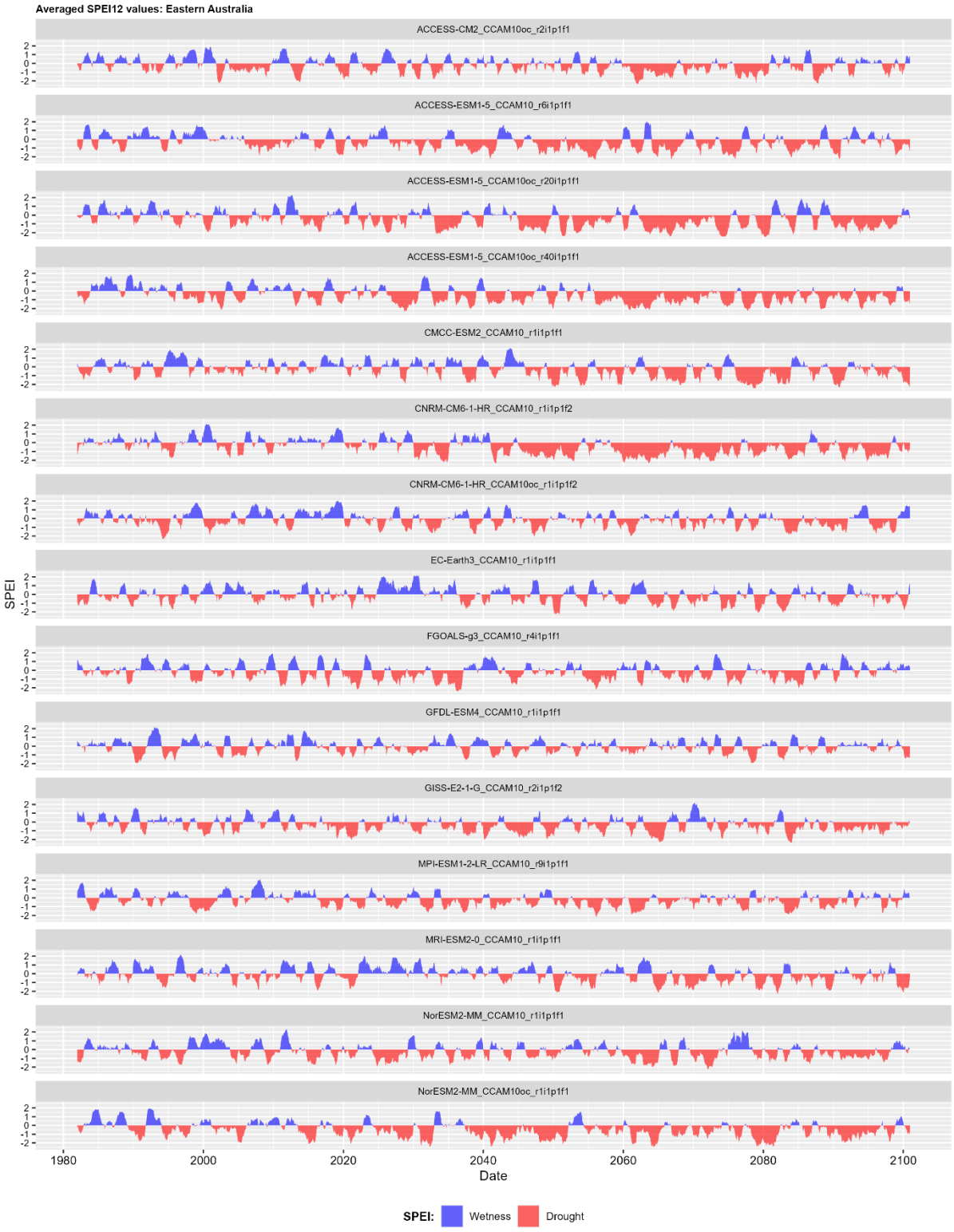



***Figure S45***. *Interannual variability of SPEI values in Eastern Australia for all climate models under SSP126.*

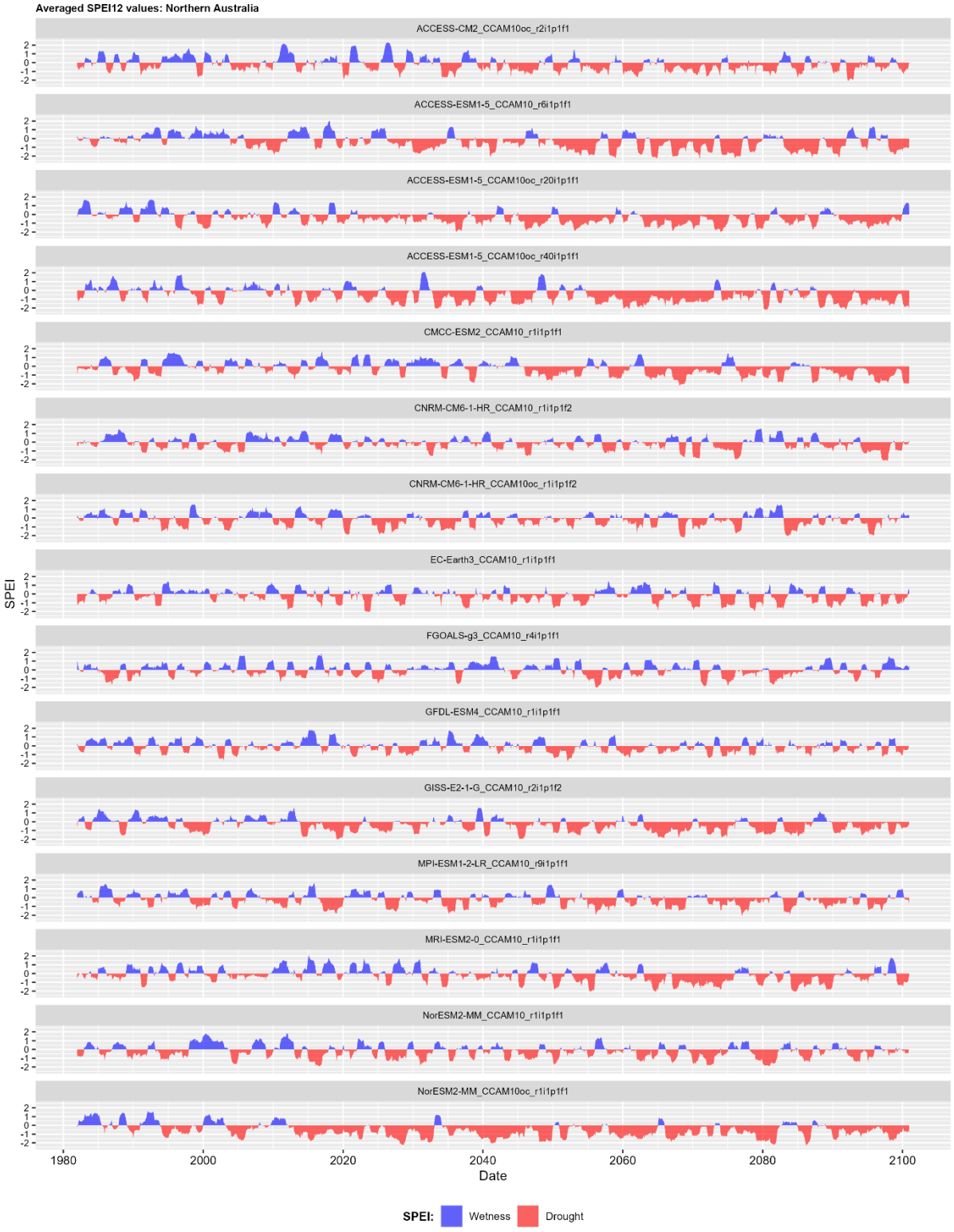



***Figure S46***. *Interannual variability of SPEI values in Northern Australia for all climate models under SSP126.*

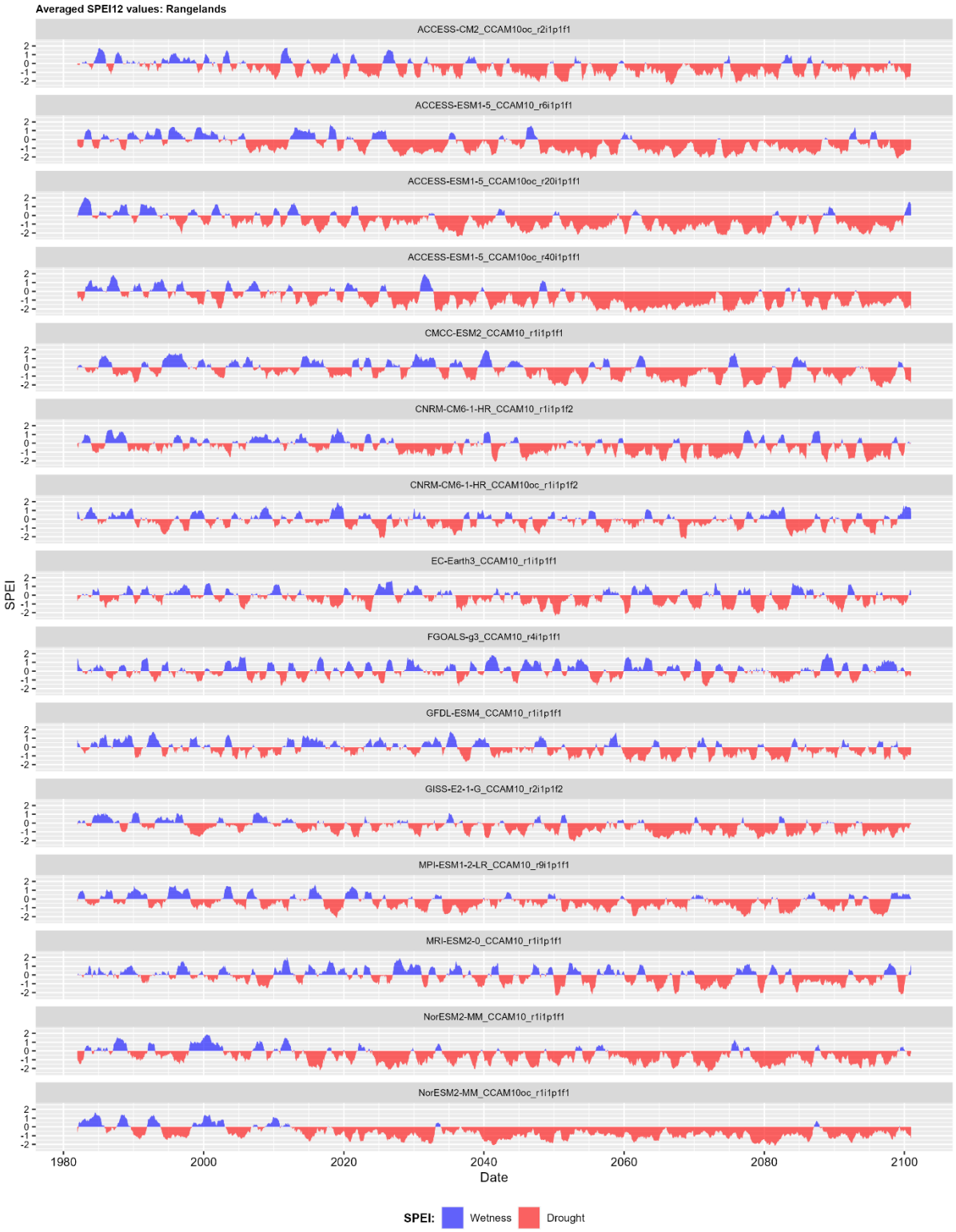



***Figure S47**. Interannual variability of SPEI values in Rangelands for all climate models under SSP126.*

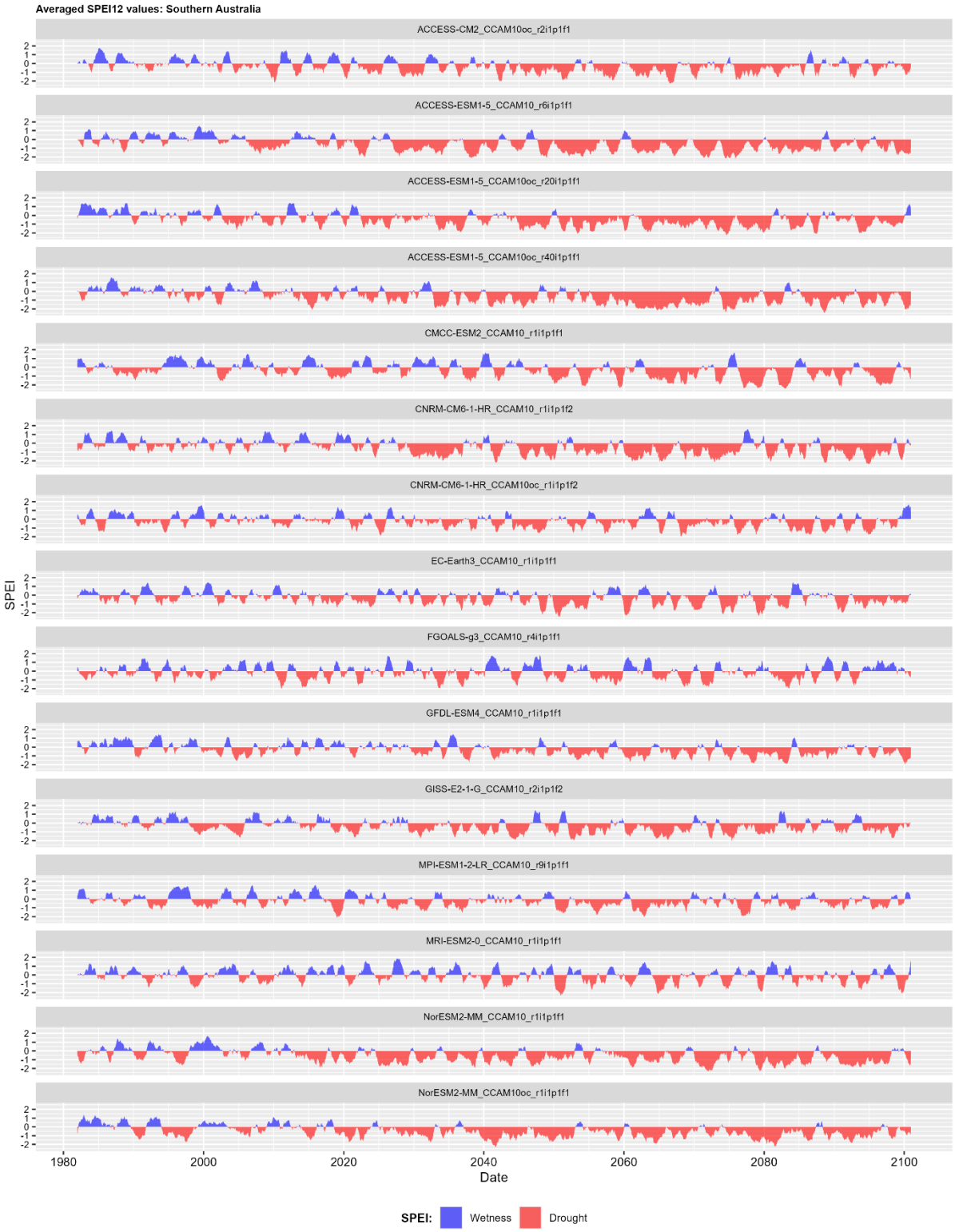



***Figure S48**. Interannual variability of SPEI values in Southern Australia for all climate models under SSP126.*