



Supplement of

A global perspective on past and future change in regional seasonal cycle shape

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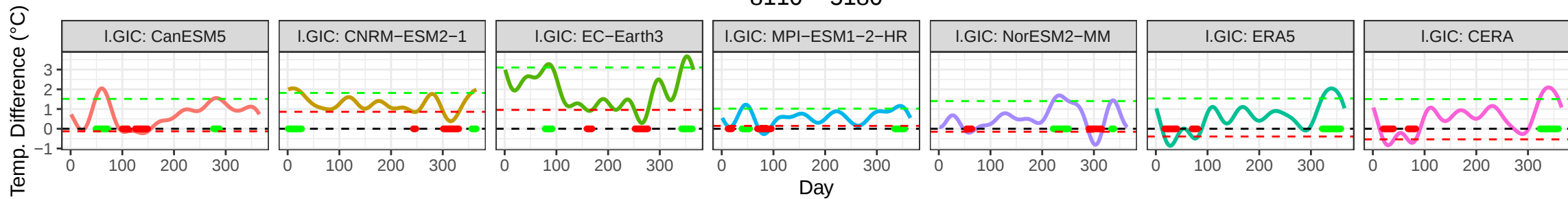
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Table S1: Annual mean, global mean temperature changes for both historical and future periods and all datasets used in present study. Global mean values, as well as values averaged separately over oceanic and land areas are listed.

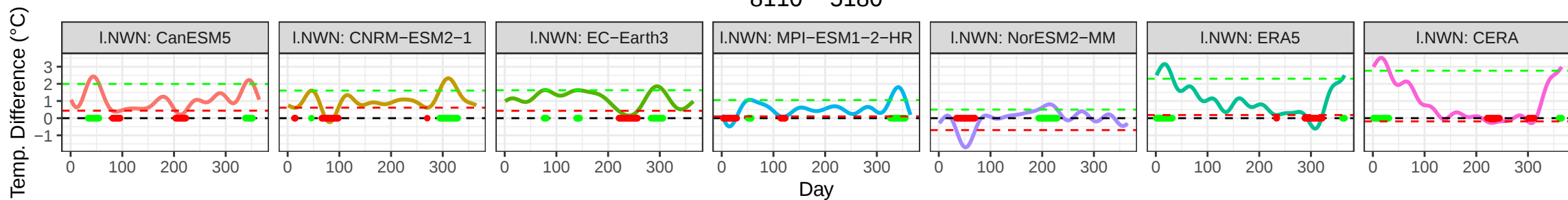
Dataset	Changes between the two historical periods 1951-1980 and 1981-2010			Changes between the future time period 2071-2100 and the reference period 1961-1990		
	Global	Land	Ocean	Global	Land	Ocean
NorESM2-MM	0.3	0.4	0.2	2.8	4.1	2.3
CanESM5	0.6	0.8	0.5	5.1	6.9	4.4
CNRM-ESM2-1	0.4	0.6	0.4	3.6	4.8	3.1
EC-Earth3	0.6	0.8	0.5	4.1	5.5	3.6
MPI-ESM1-2-HR	0.3	0.4	0.3	2.8	3.7	2.4
ERA5	0.4	0.7	0.3			
CERA20	0.5	0.6	0.4			

Figure S1: The distances between the smoothed annual cycle curves in the two historical periods 1981-2010 and 1951-1980. Plots for five selected CMIP6 ESMs and two reanalyses are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. The red dashed line represents the 10th percentile, and the green dashed line represents the 90th percentile. For all values below/above the 10th/90th percentile-threshold, the time periods of the year when these values occur are shown in red/green. The results shown in this figure are summarized in Fig. 3 in the manuscript.

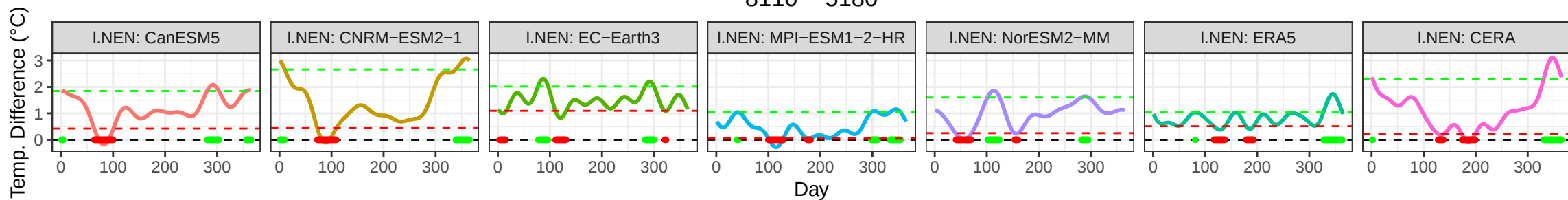
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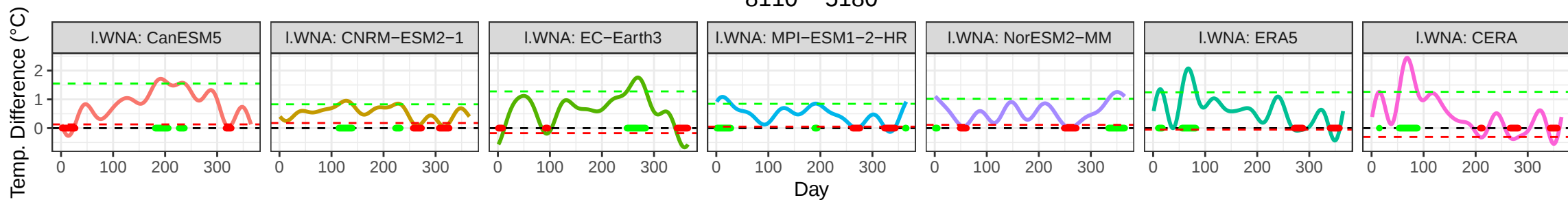
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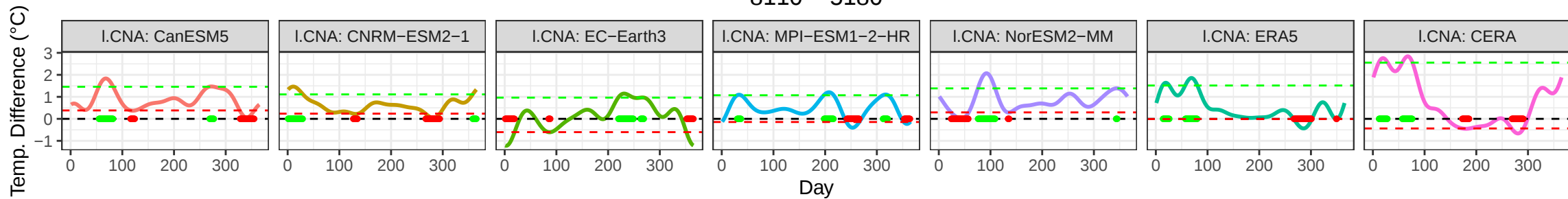
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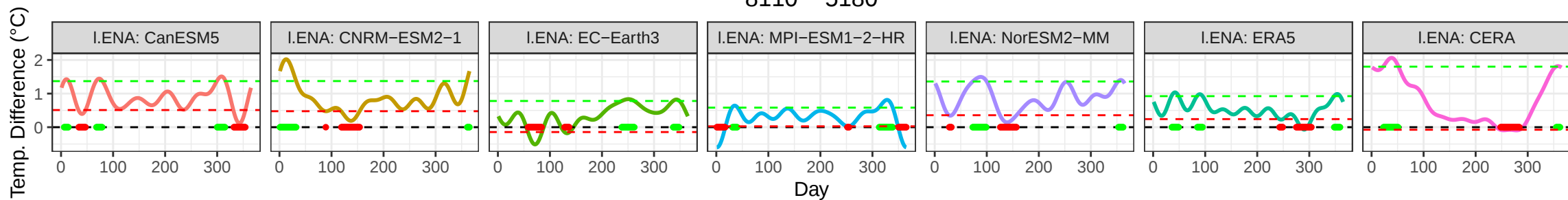
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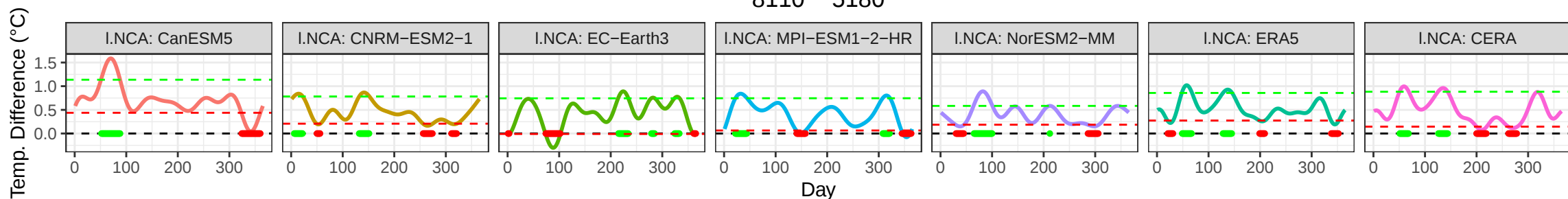
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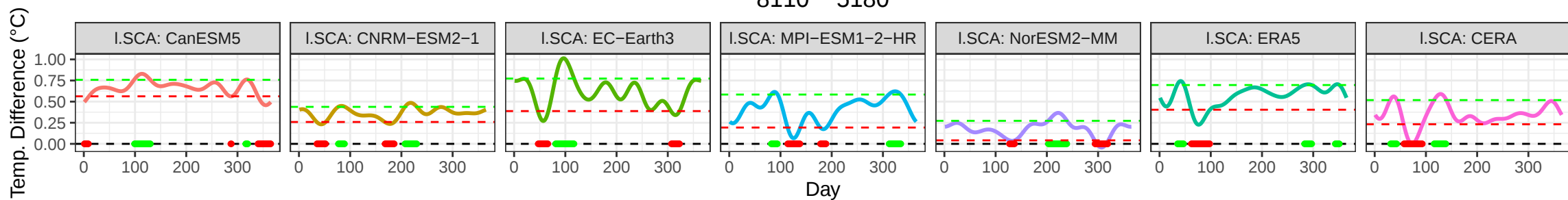
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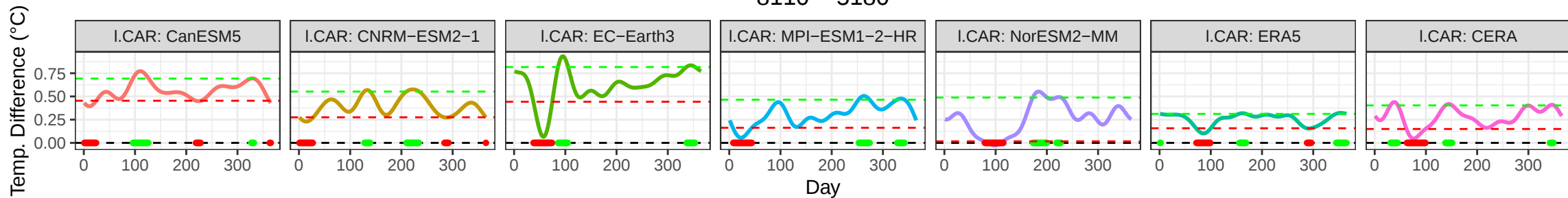
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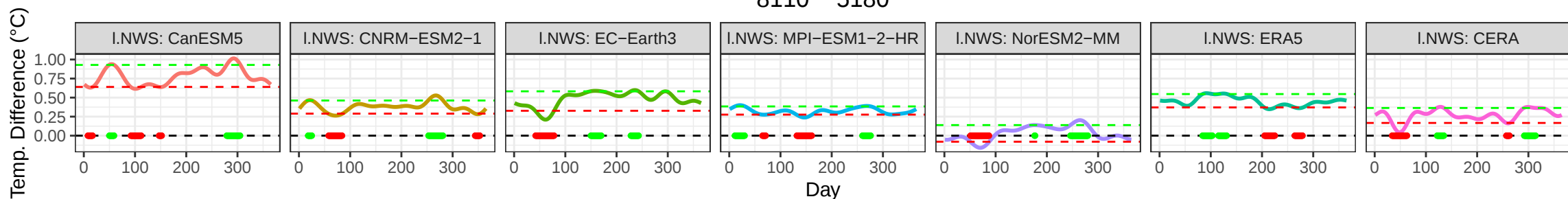
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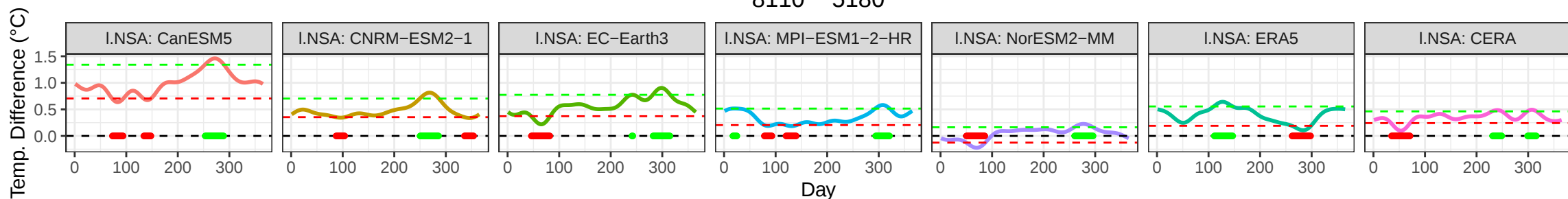
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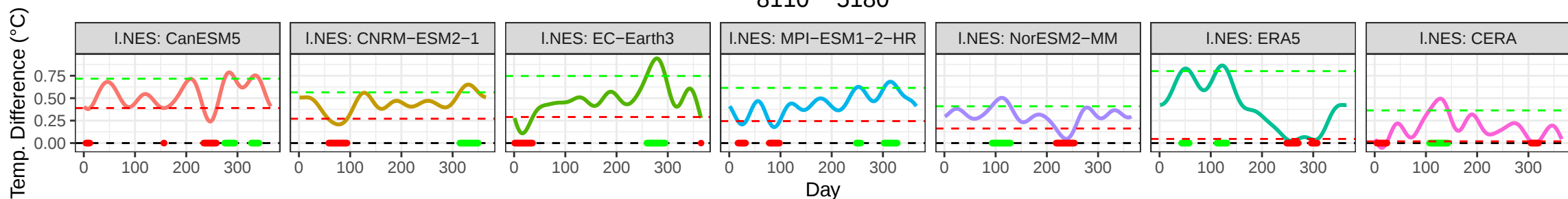
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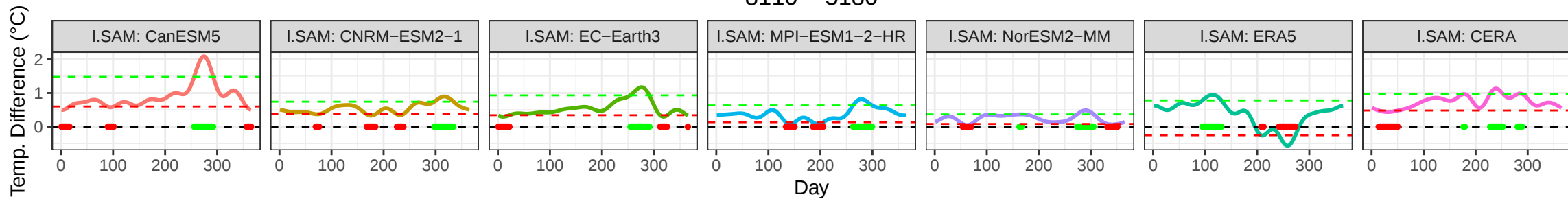
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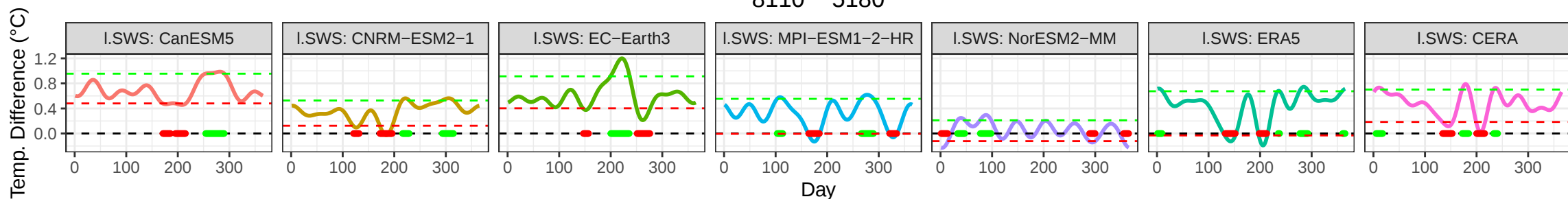
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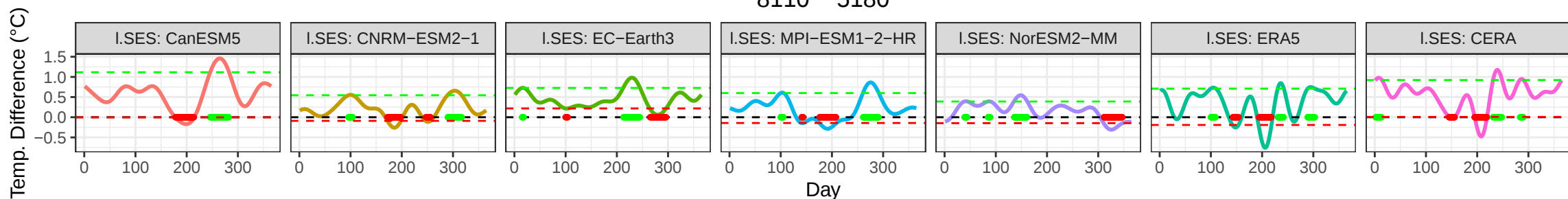
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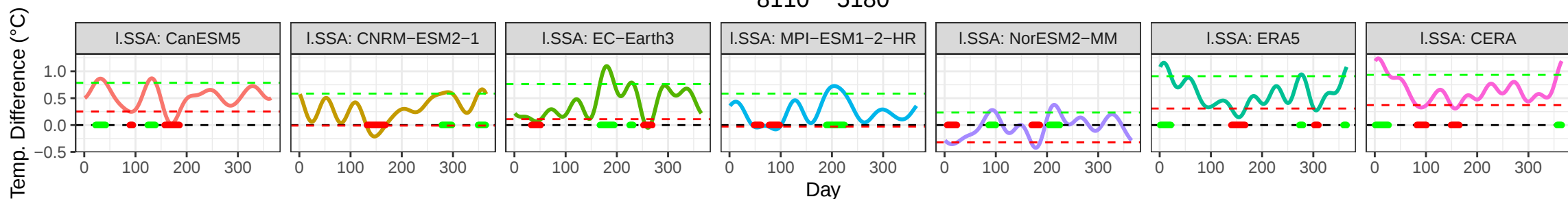
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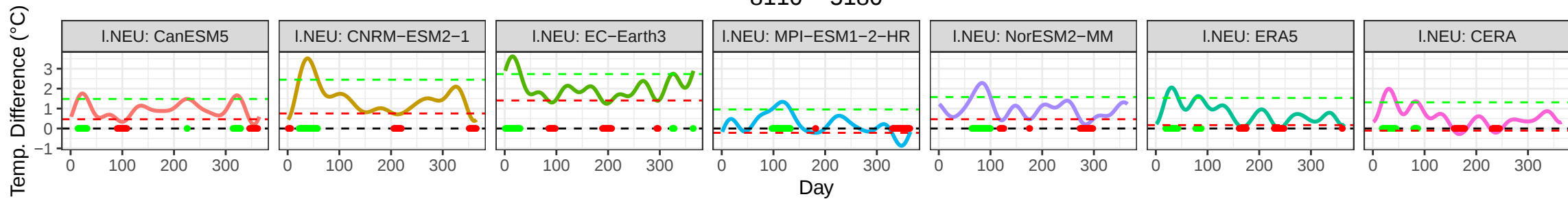
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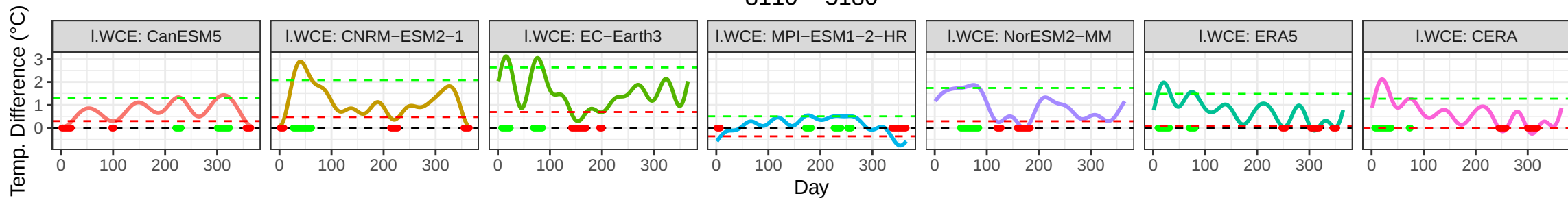
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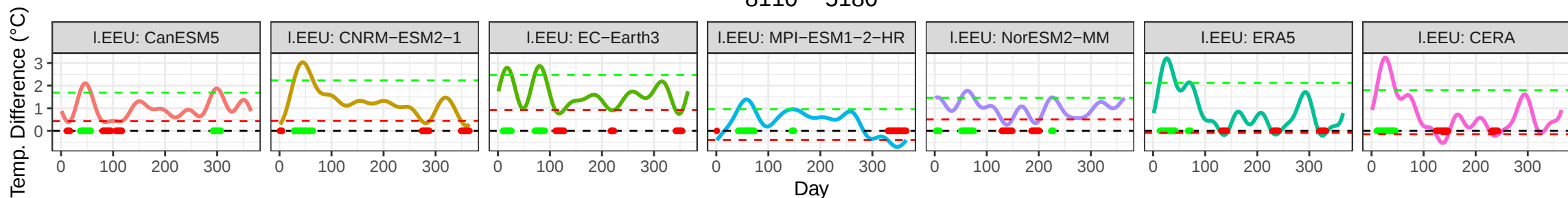
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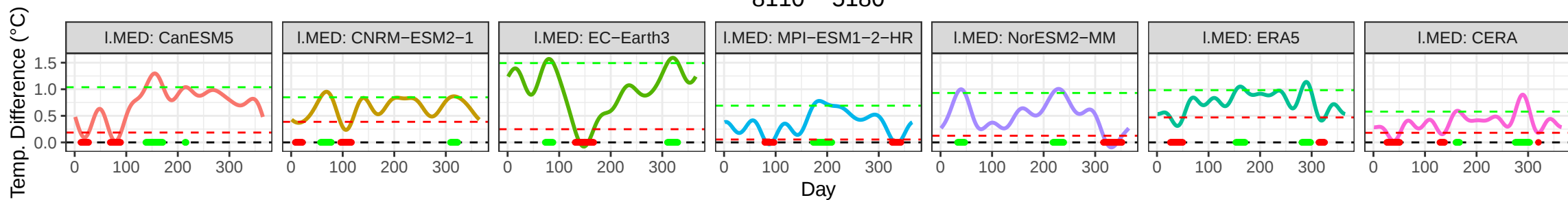
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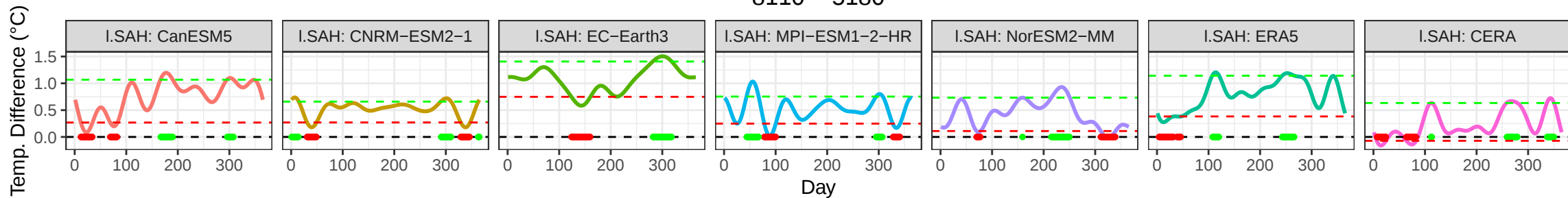
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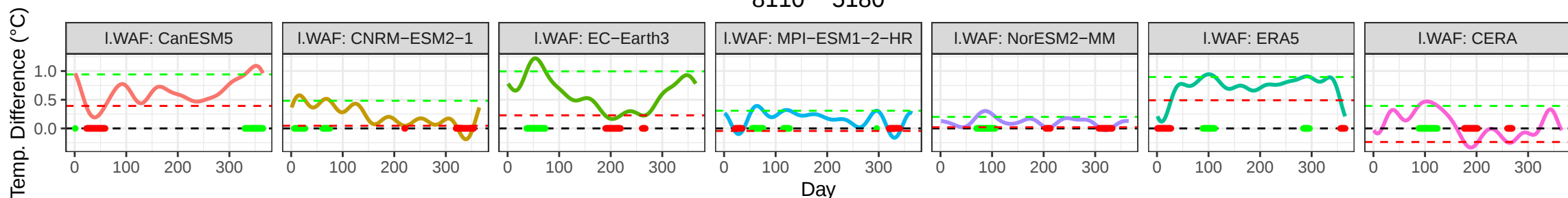
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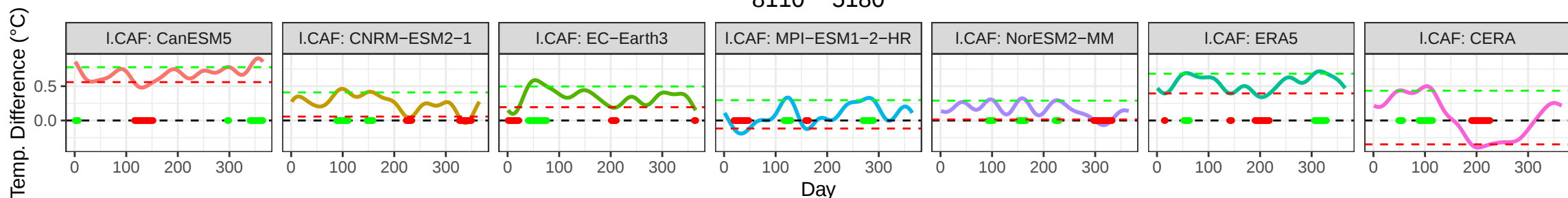
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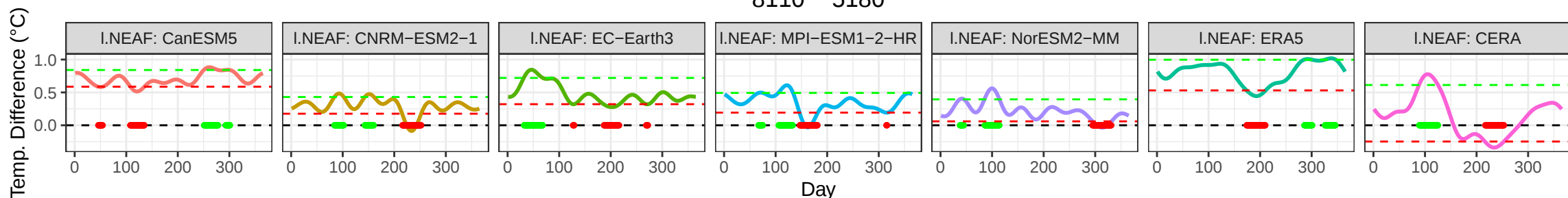
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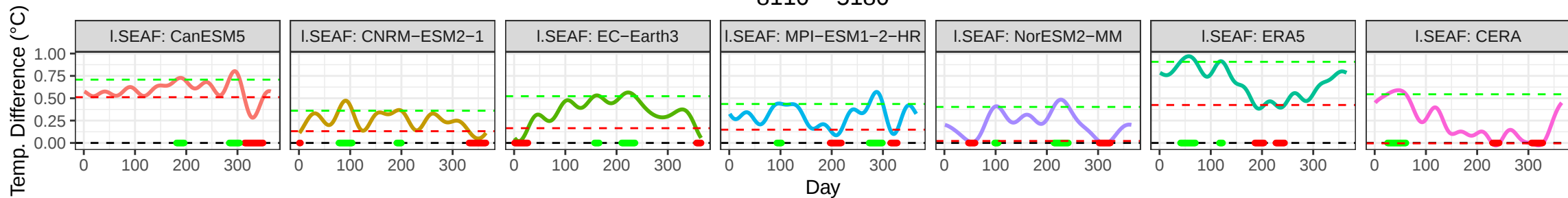
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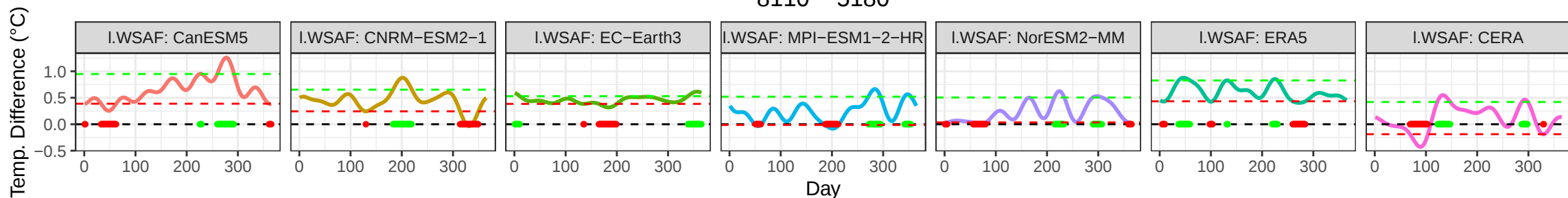
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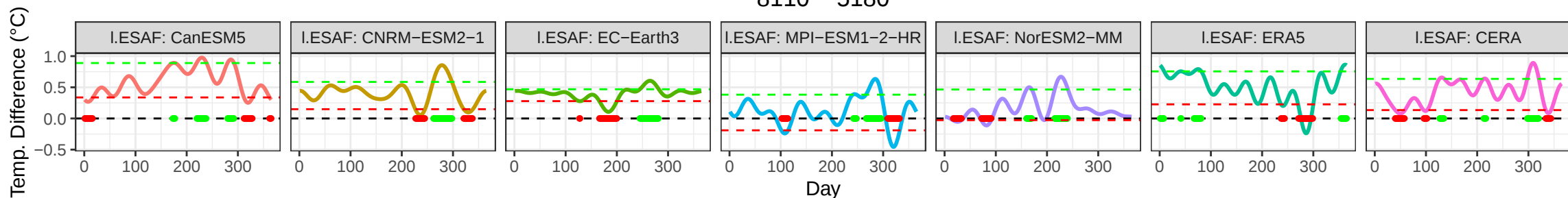
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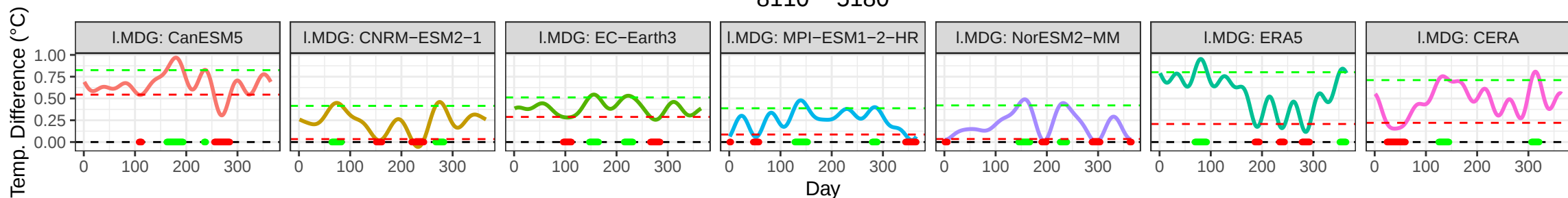
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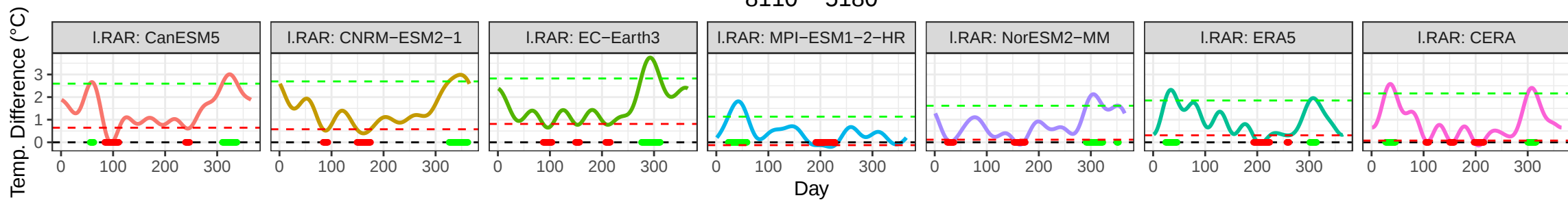
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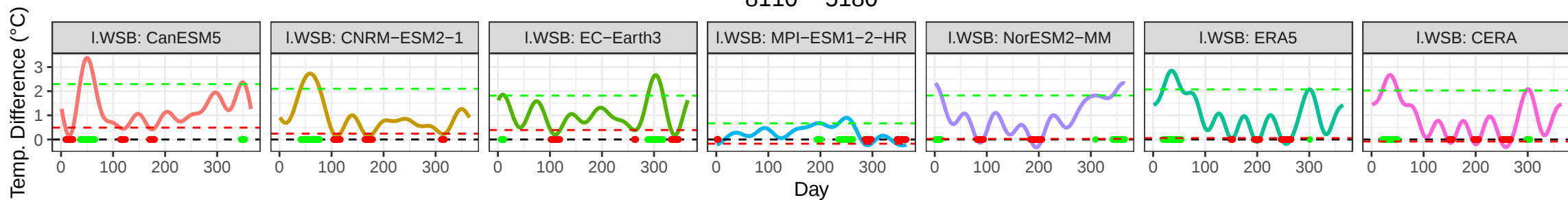
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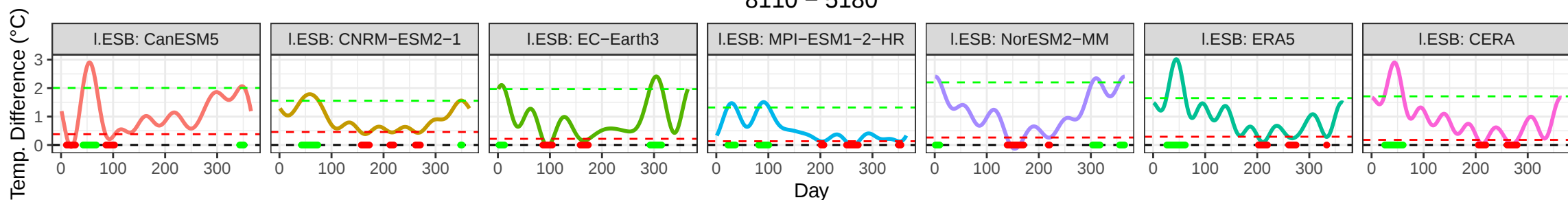
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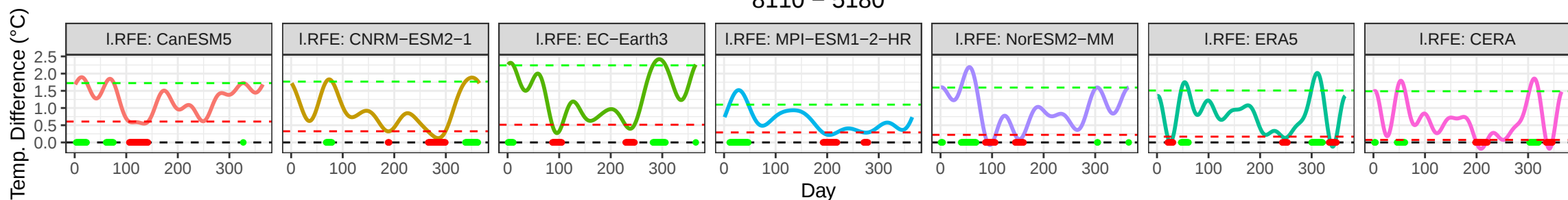
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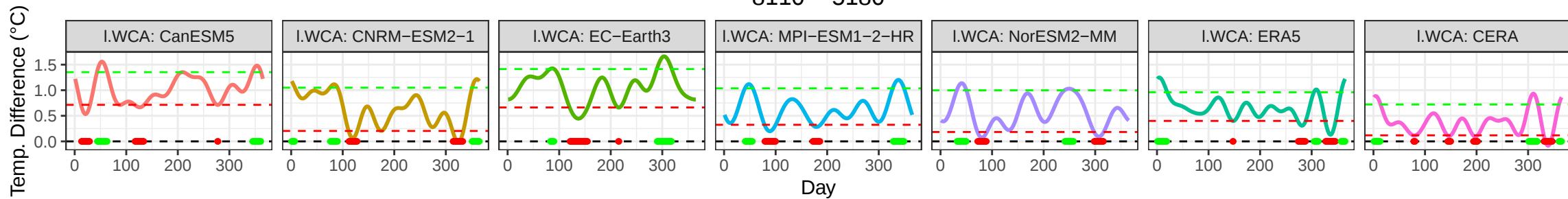
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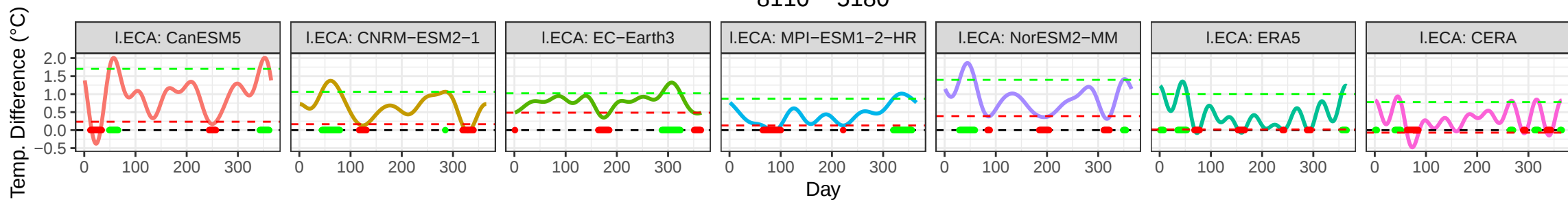
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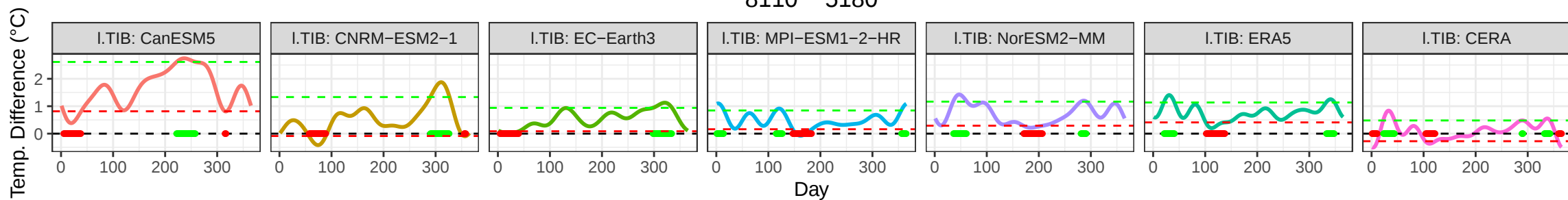
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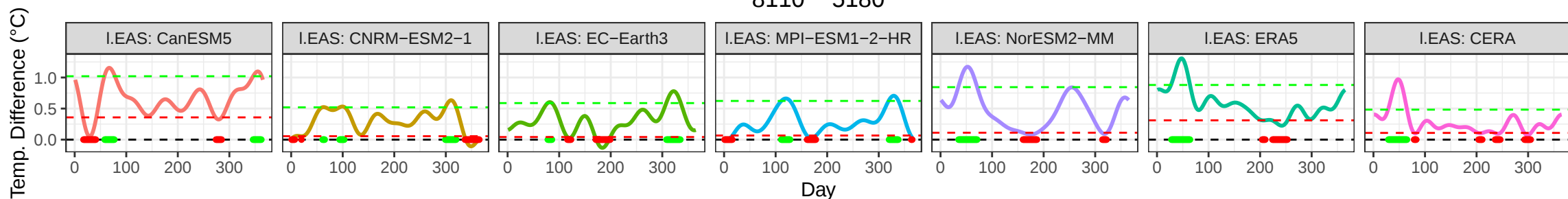
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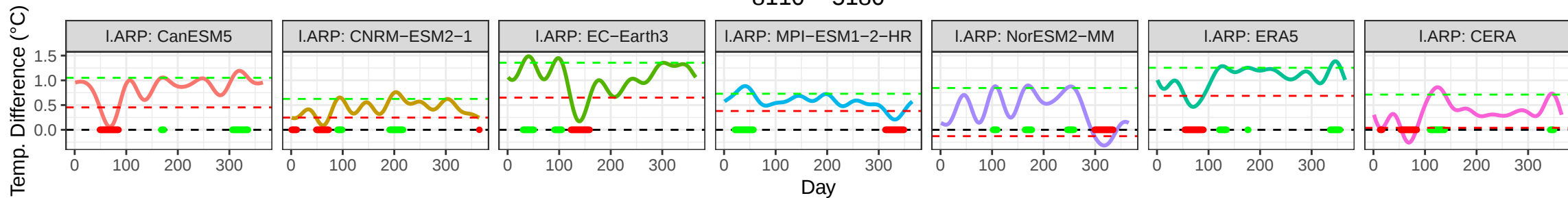
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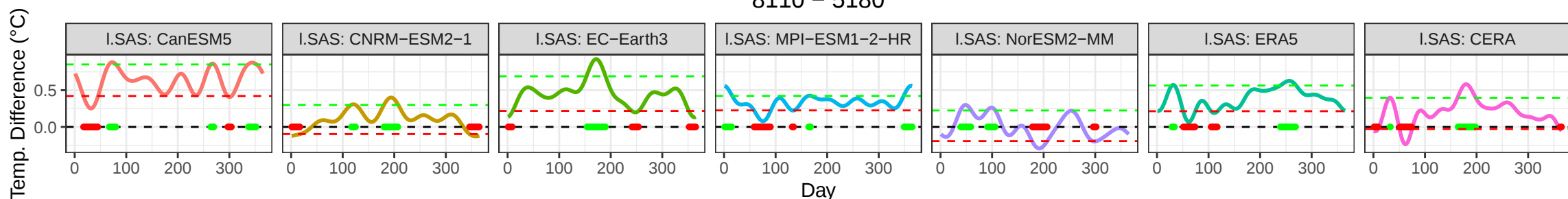
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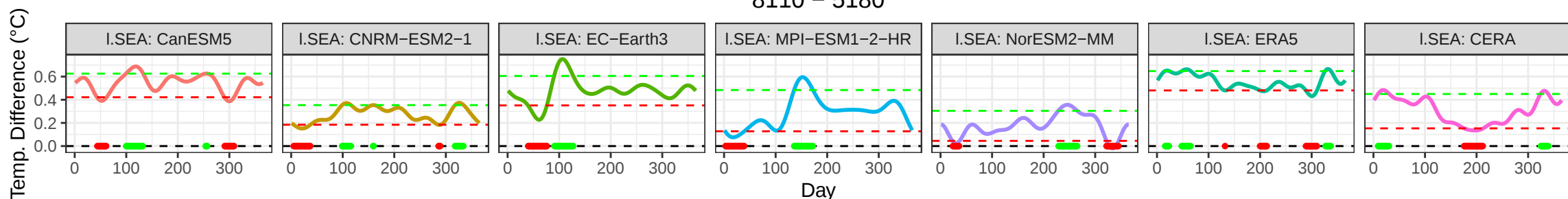
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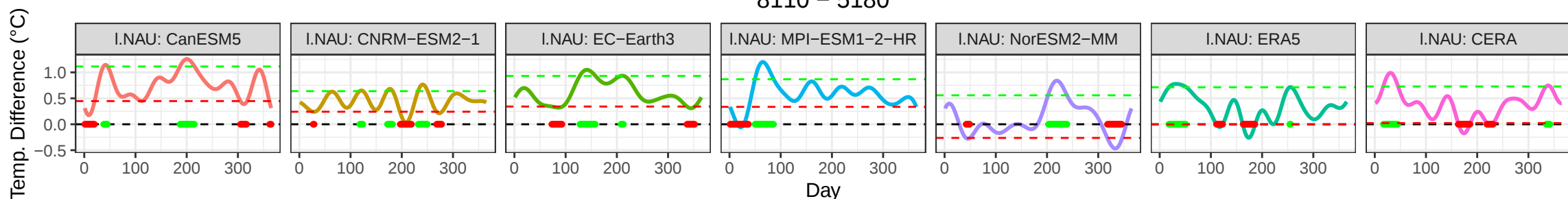
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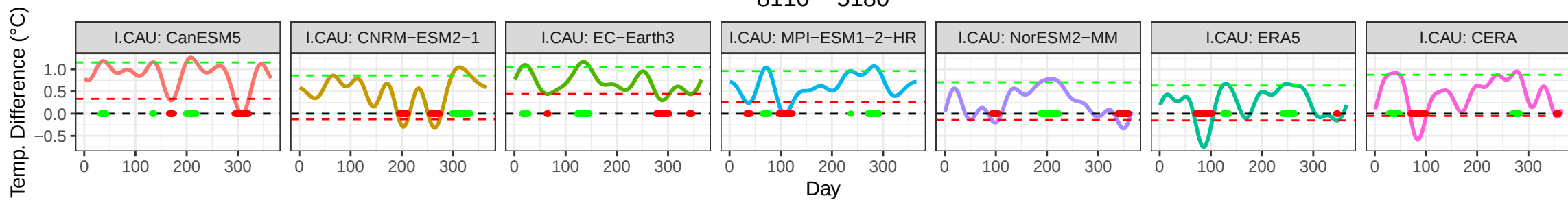
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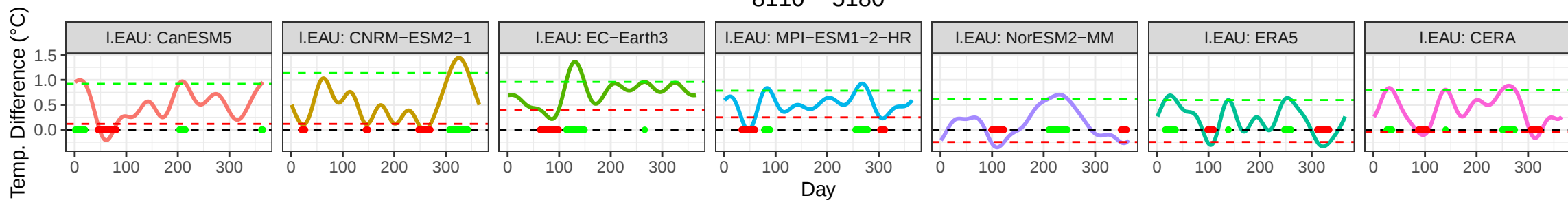
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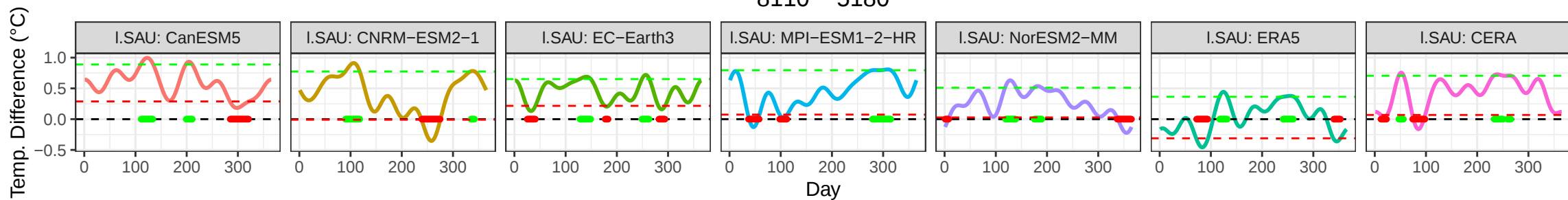
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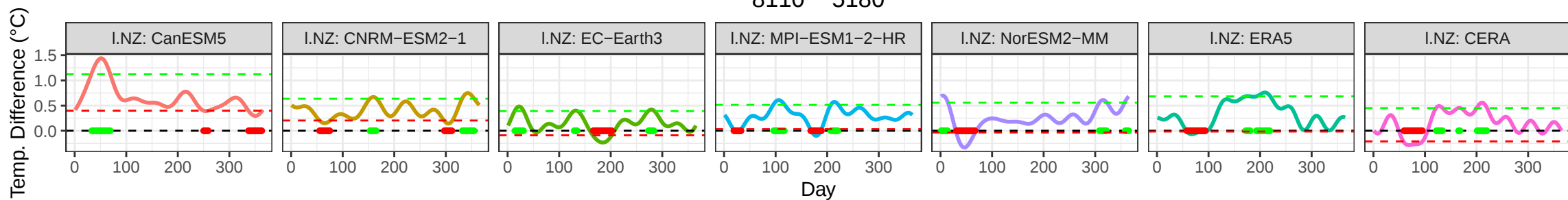
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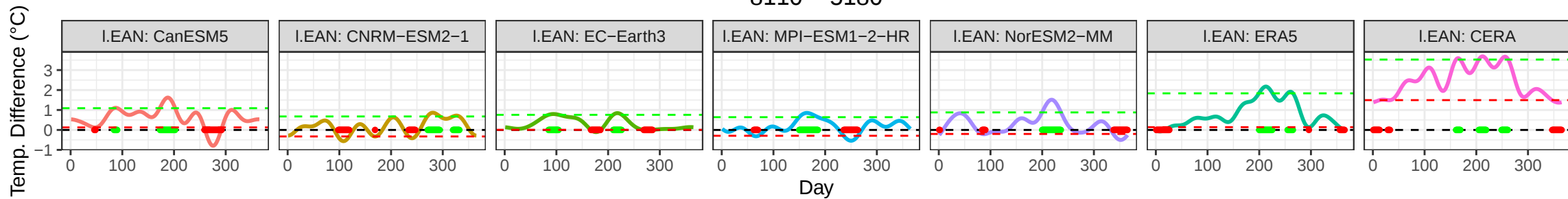
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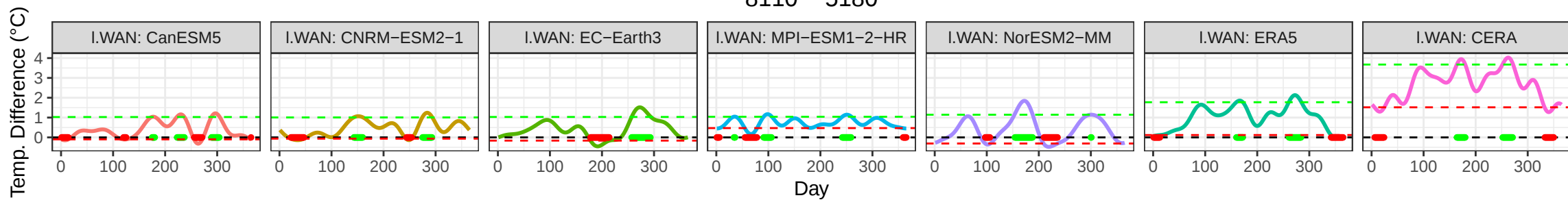
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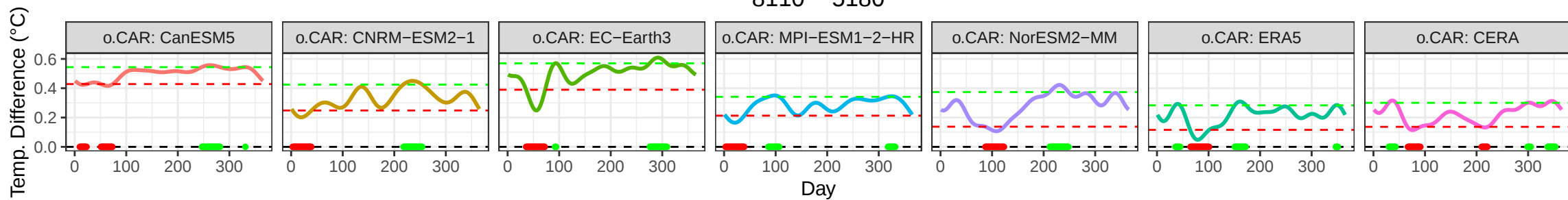
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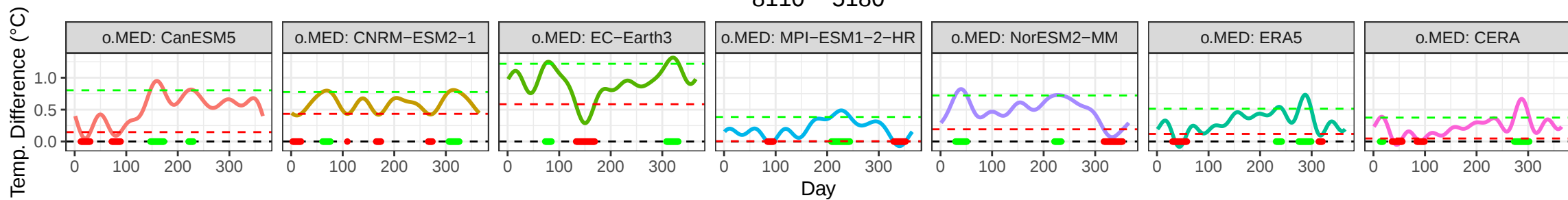
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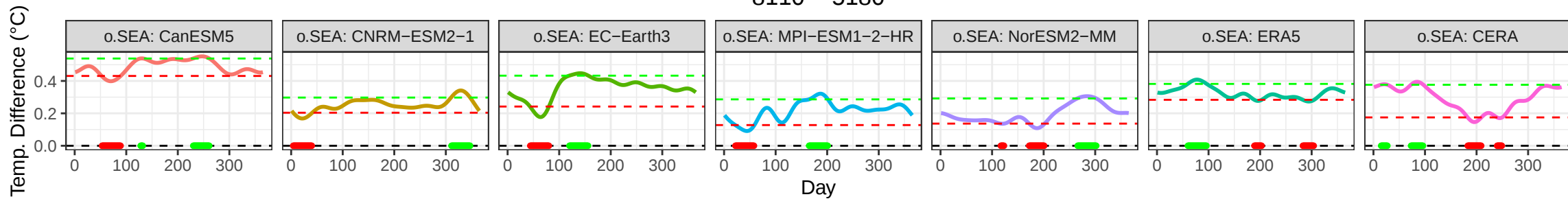
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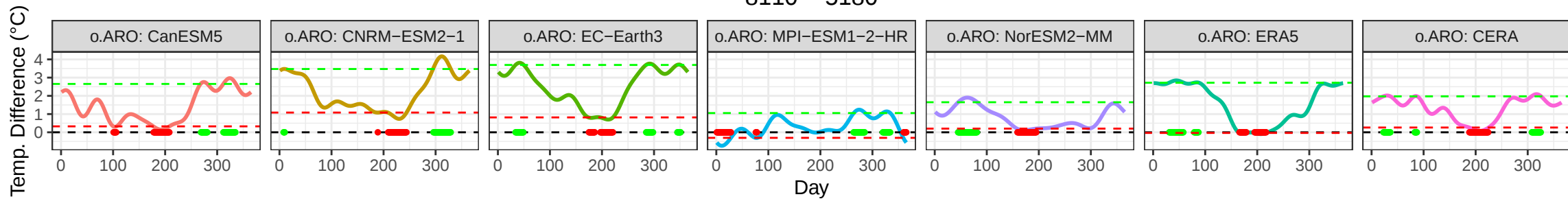
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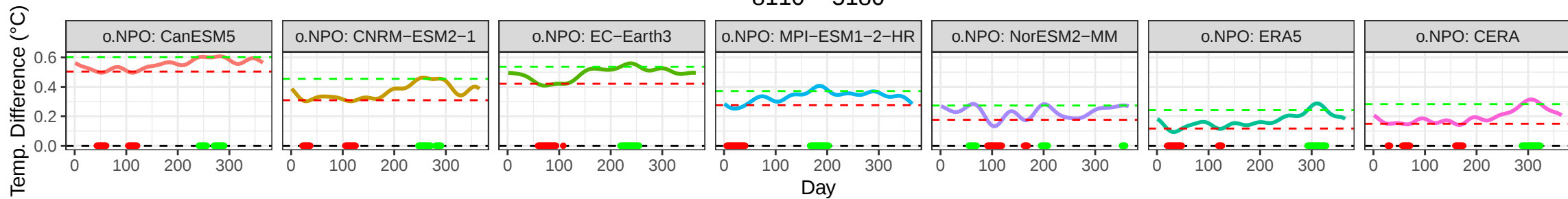
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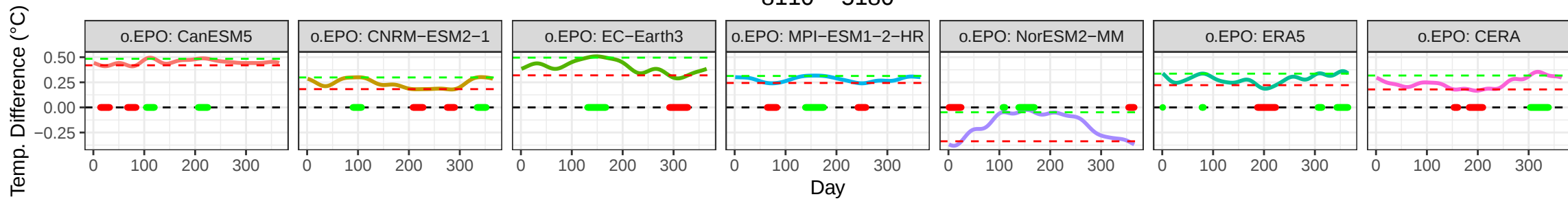
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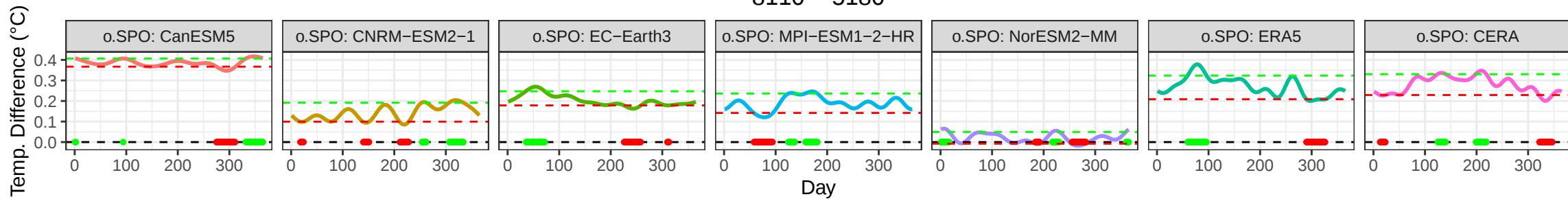
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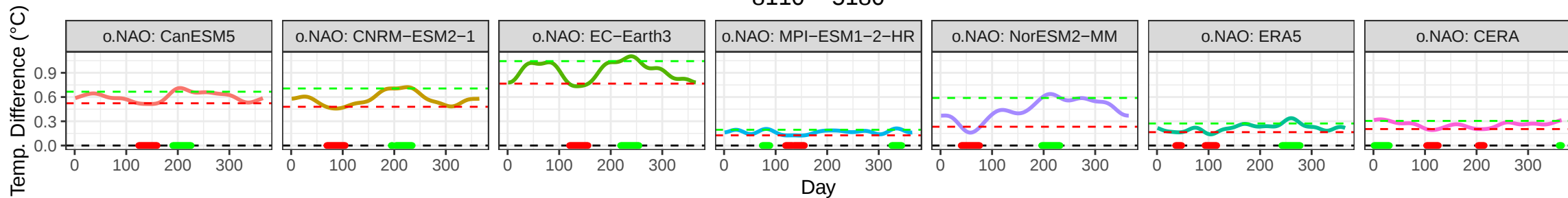
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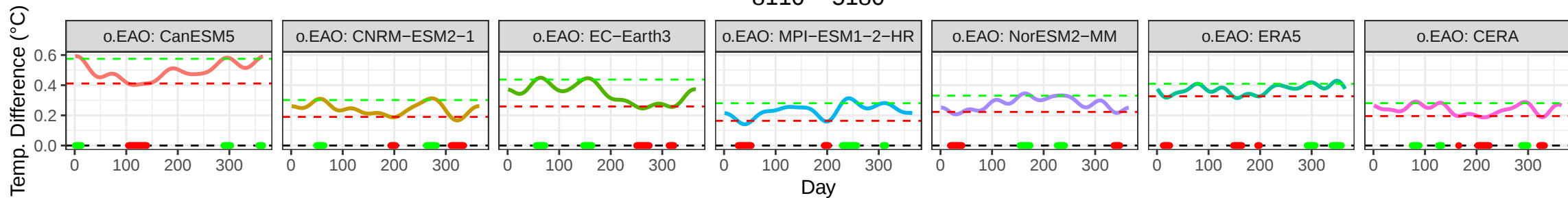
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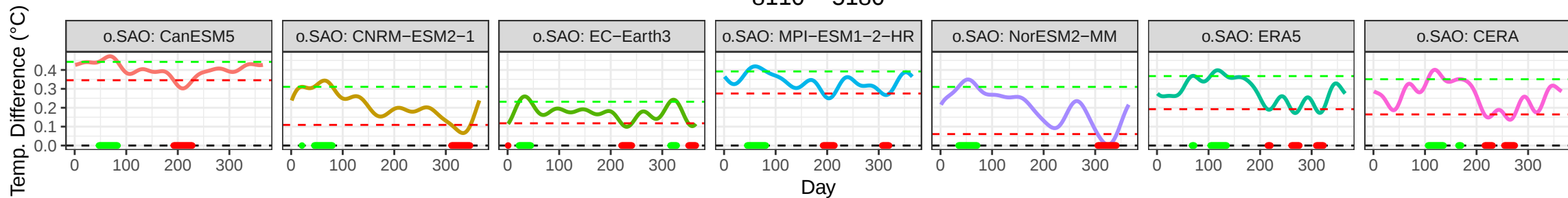
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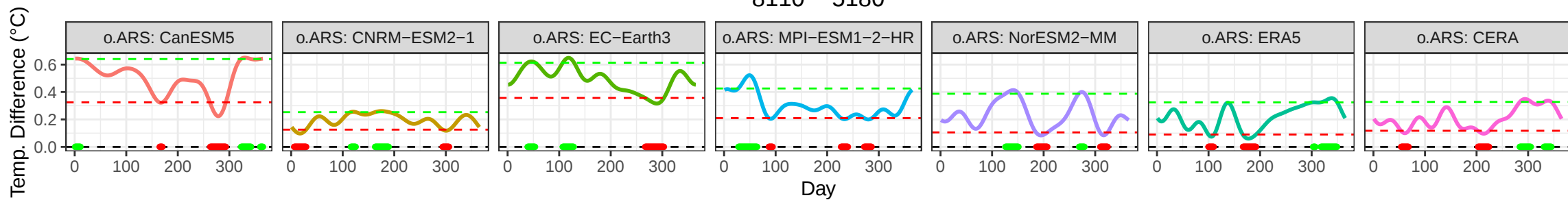
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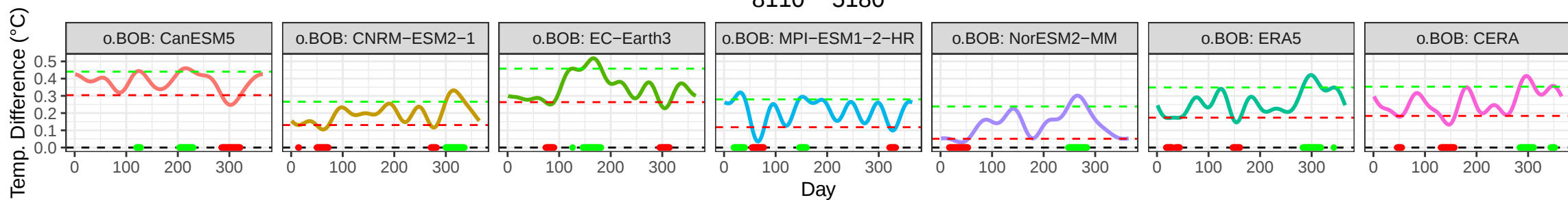
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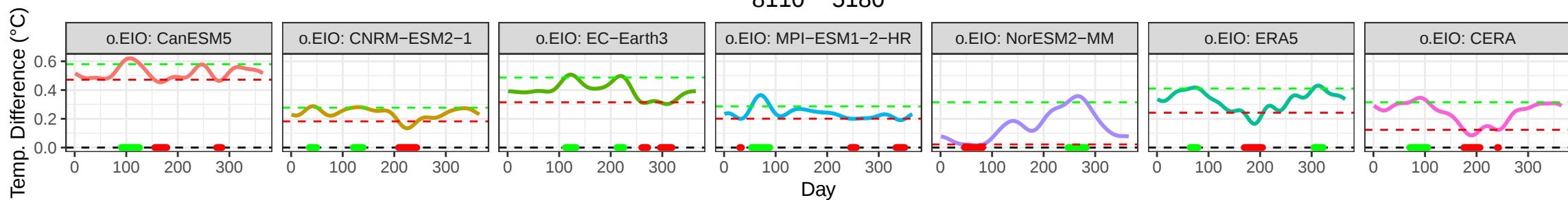
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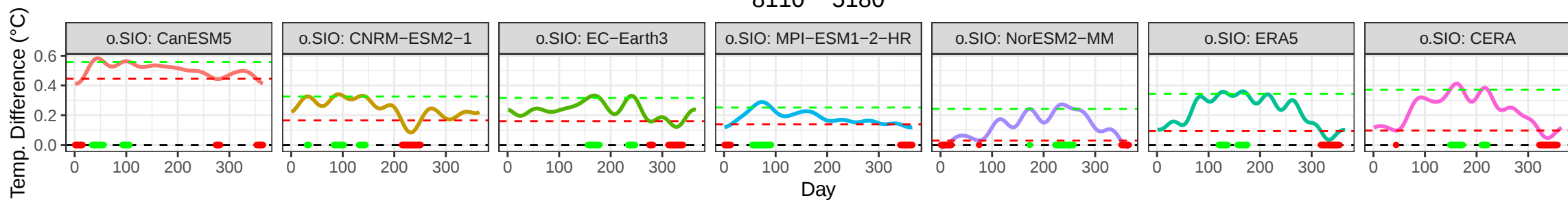
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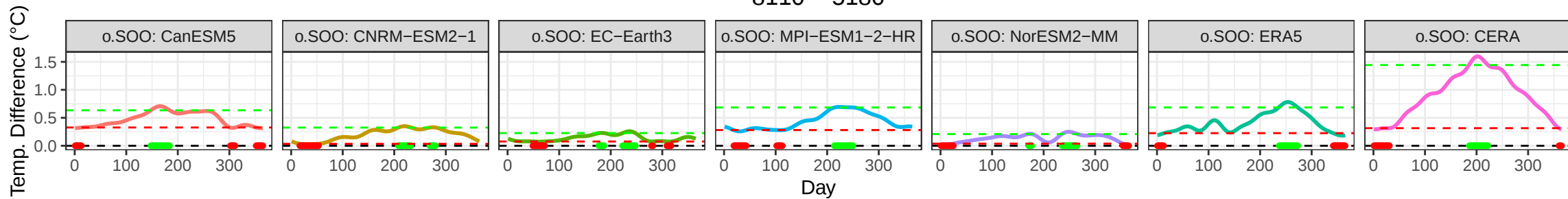
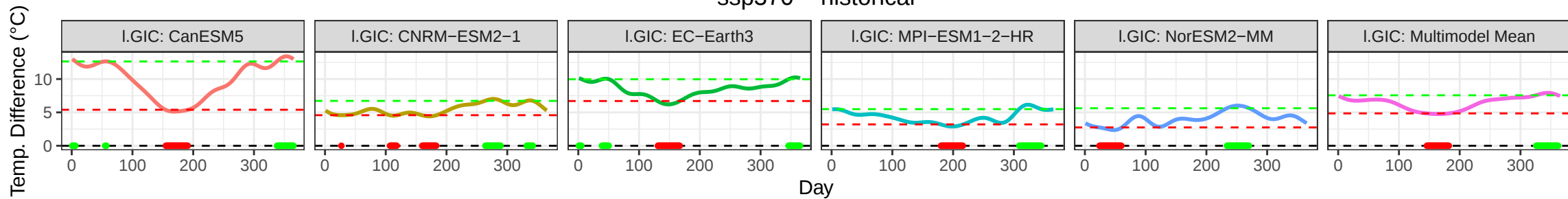
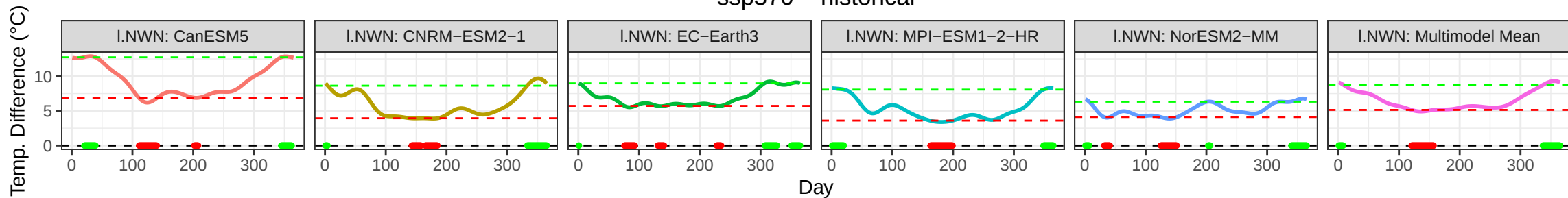


Figure S2: The distances between the smoothed annual cycle curves in the future and reference periods 2071-2100 and 1961-1990. Plots for five selected CMIP6 ESMs and their multi-model mean are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. The red dashed line represents the 10th percentile, and the green dashed line represents the 90th percentile. For all values below/above the 10th/90th percentile-threshold, the time periods of the year when these values occur are shown in red/green. The results shown in this figure are summarized in Fig. 4 in the manuscript.

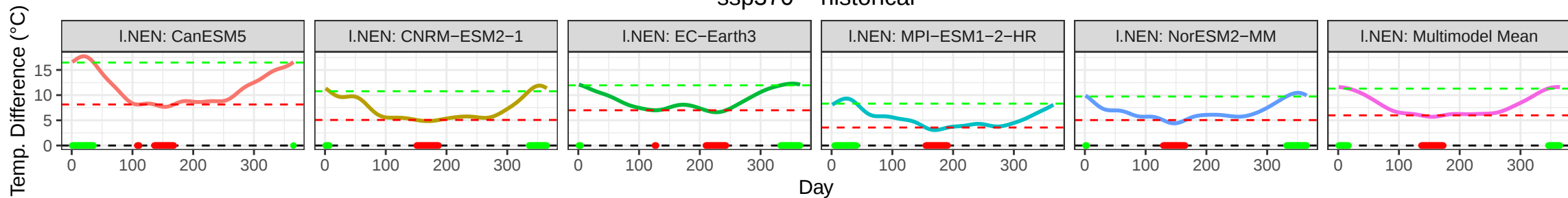
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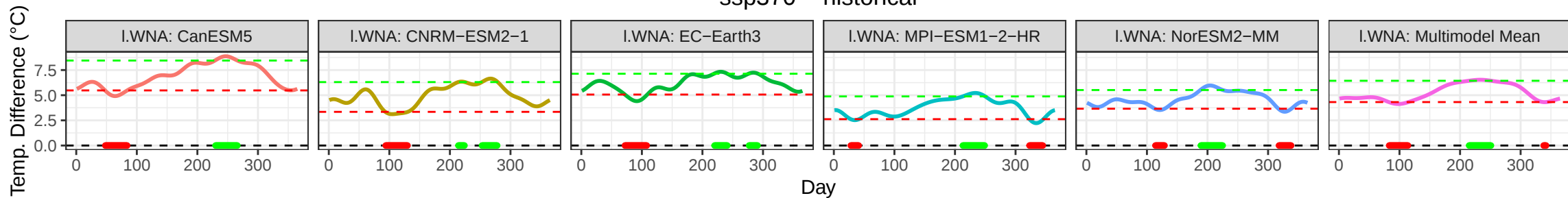
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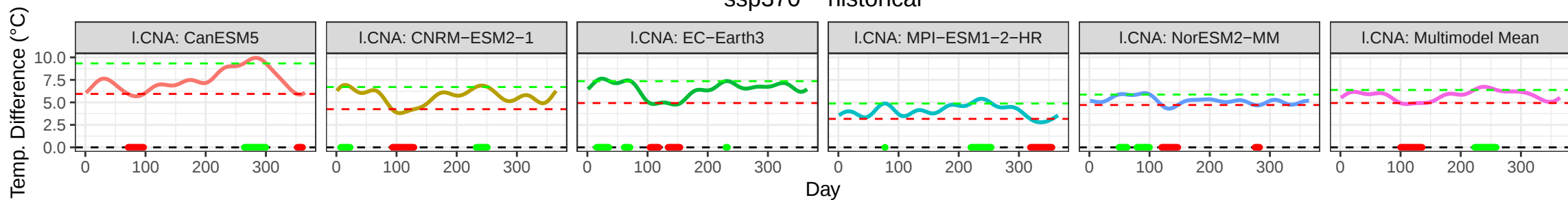
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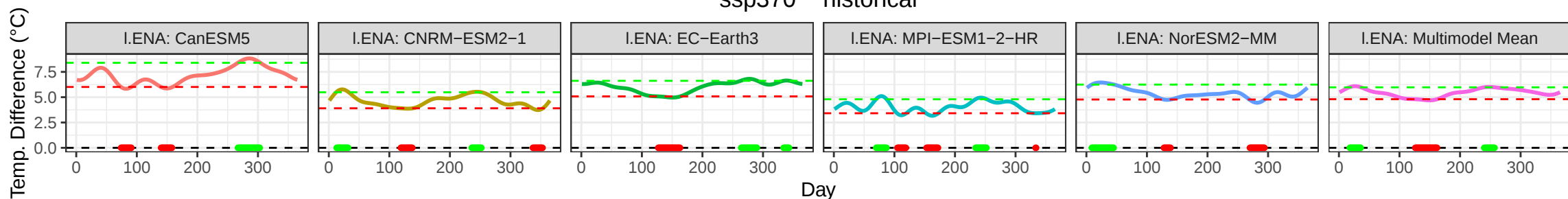
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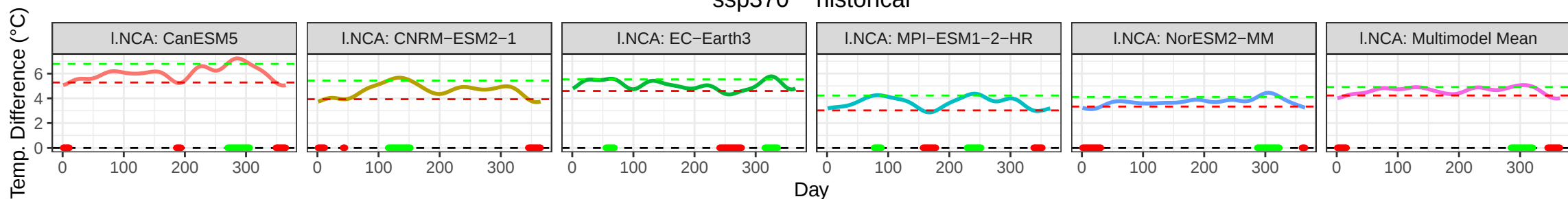
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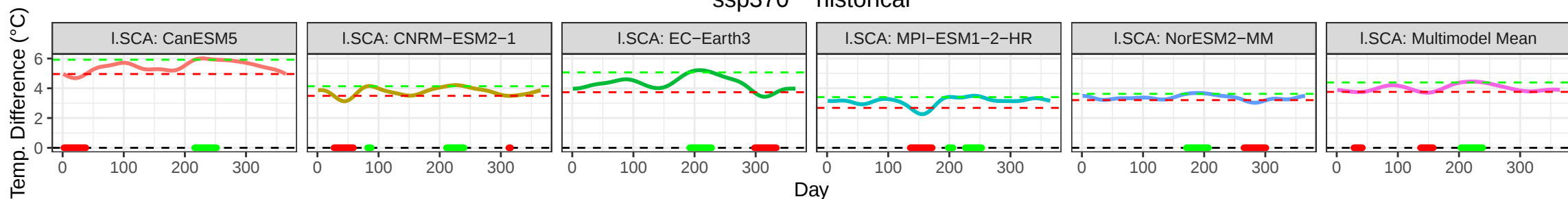
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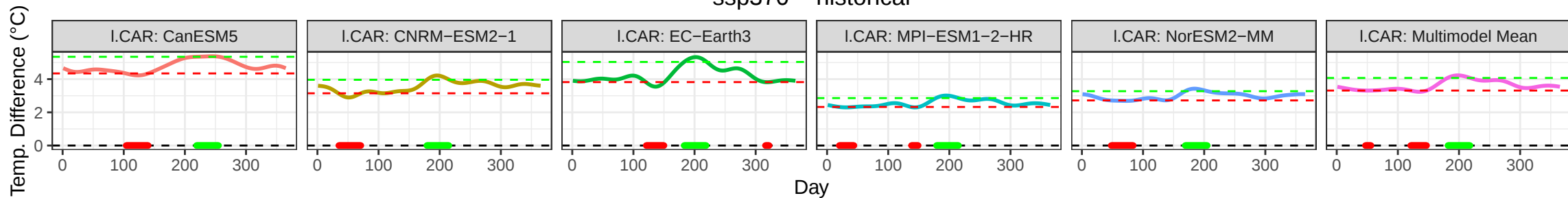
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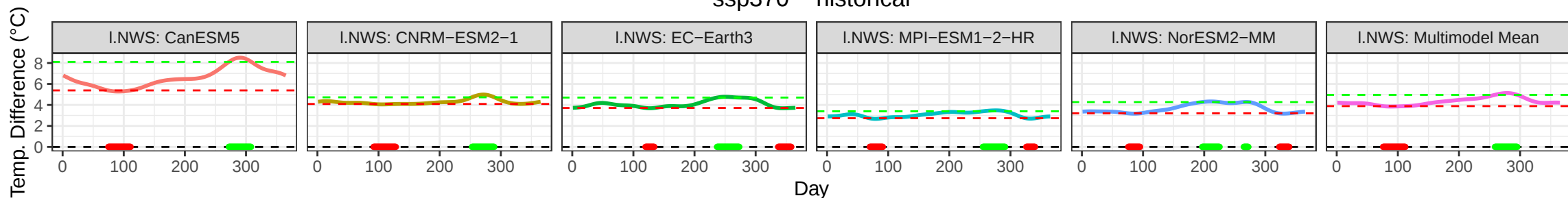
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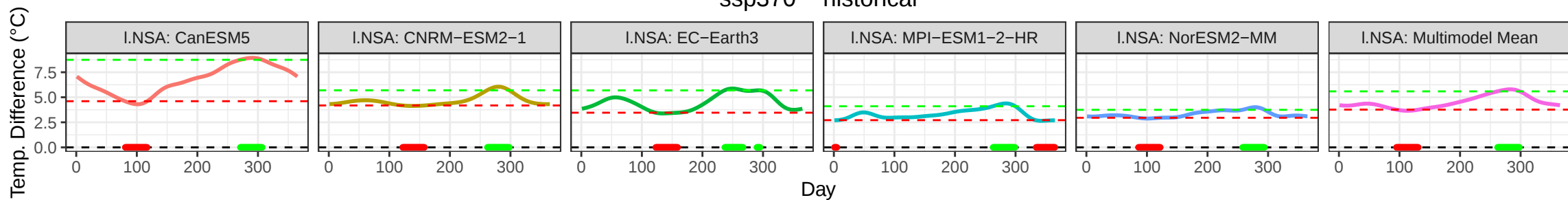
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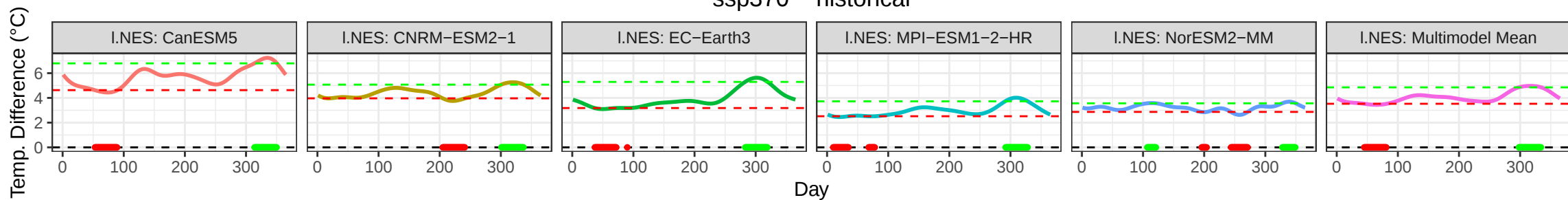
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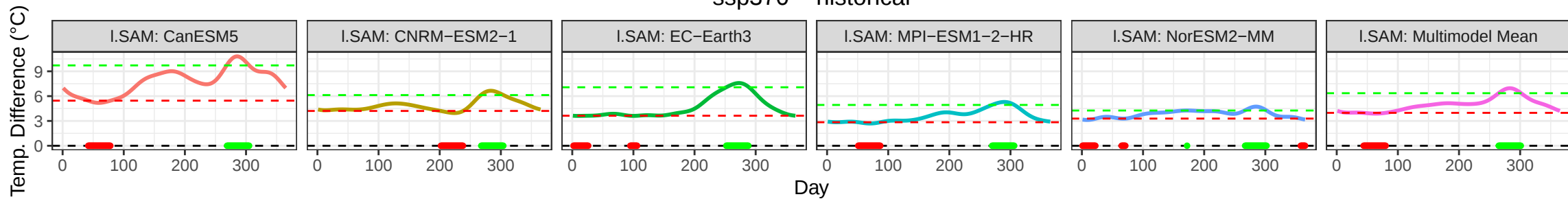
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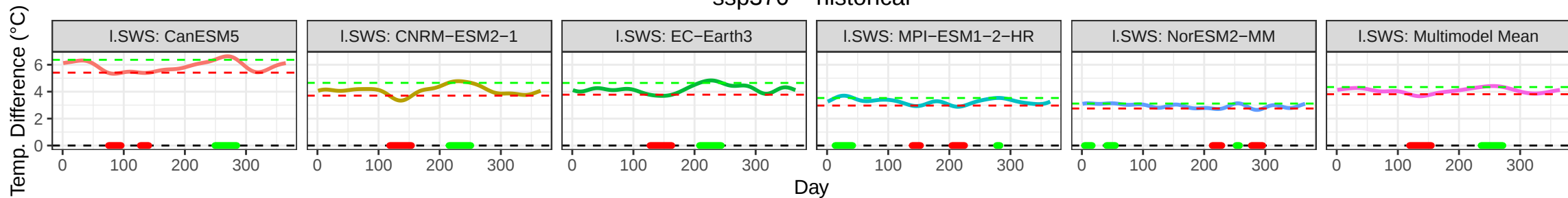
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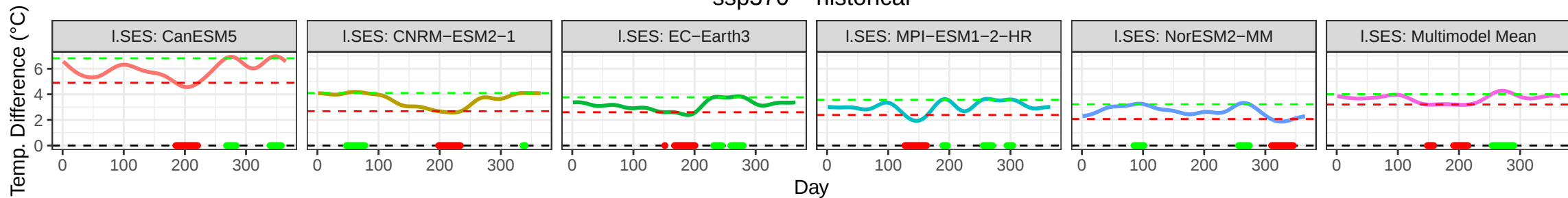
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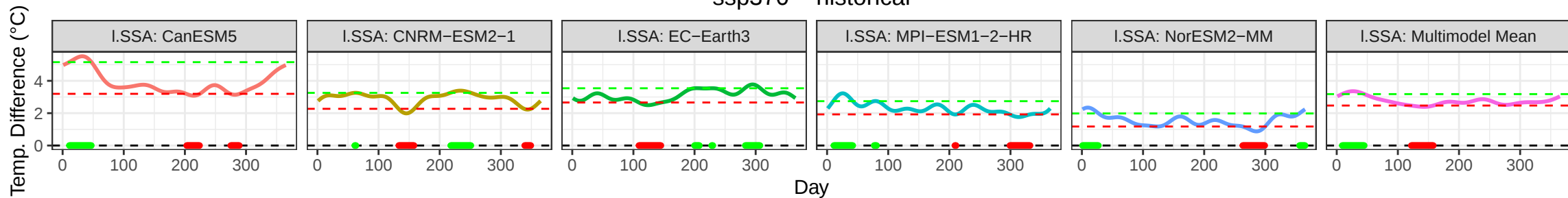
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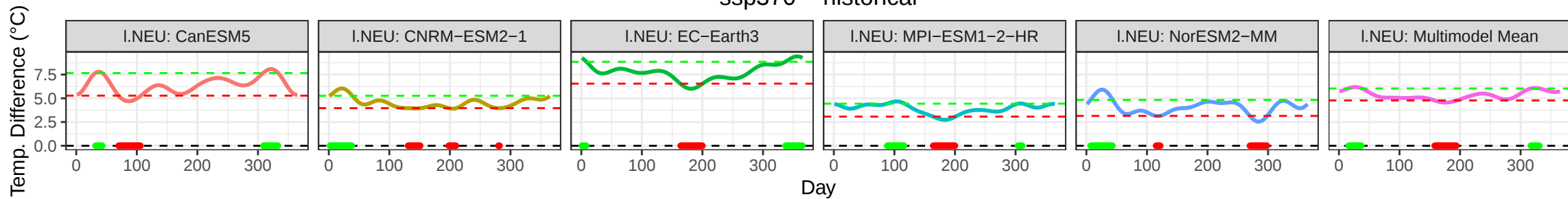
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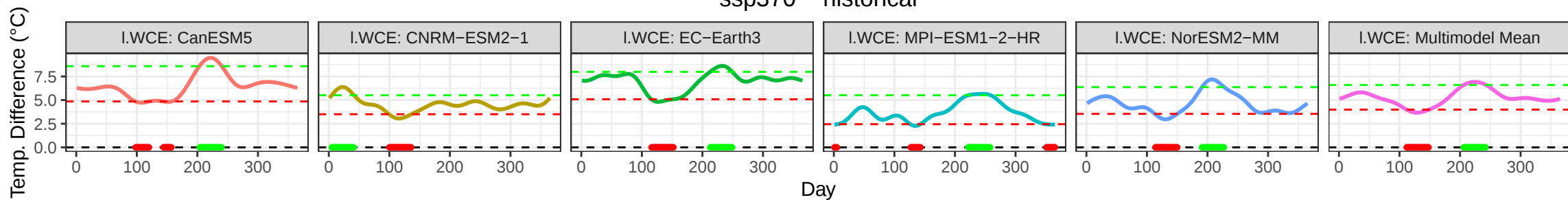
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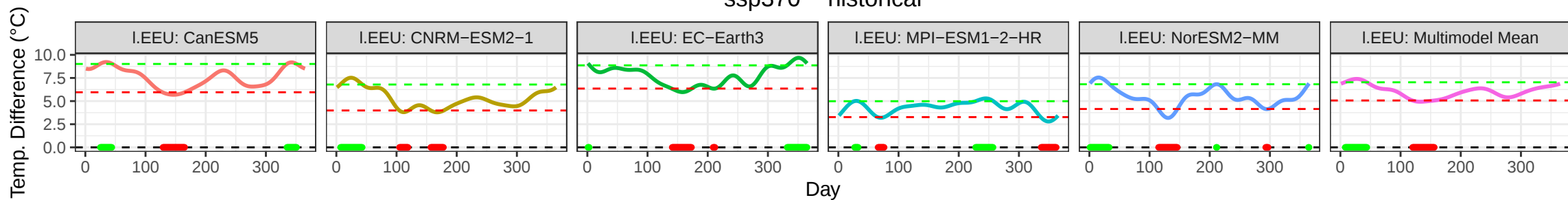
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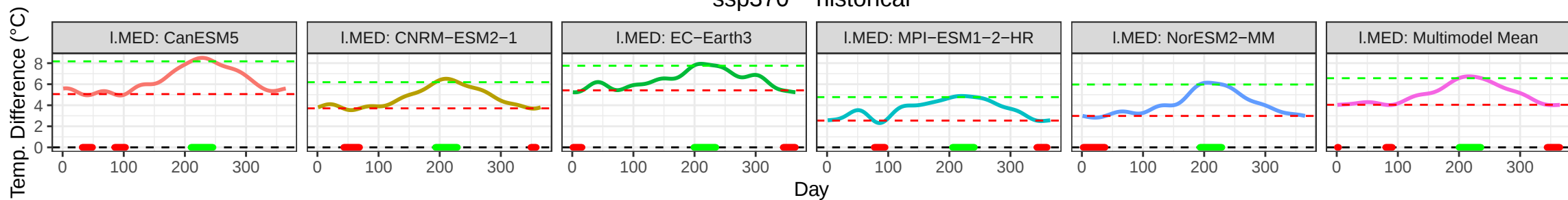
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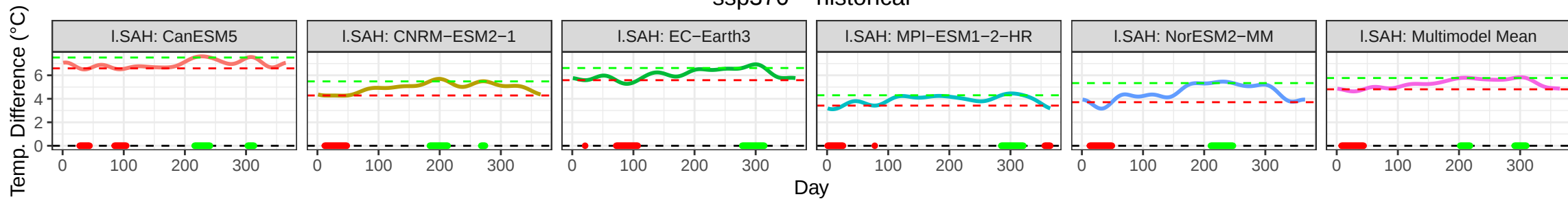
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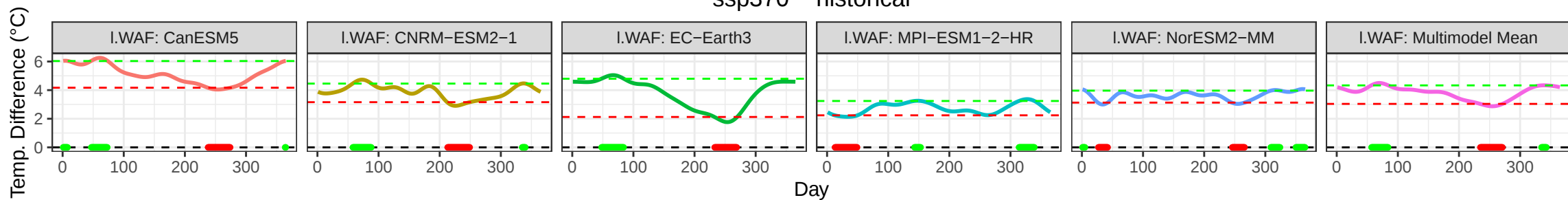
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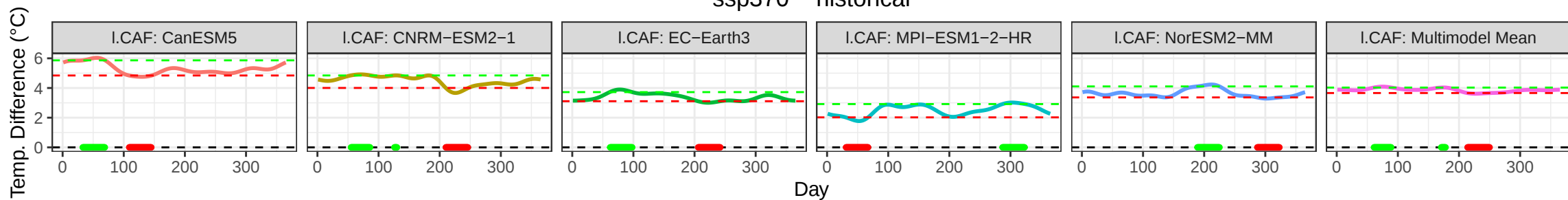
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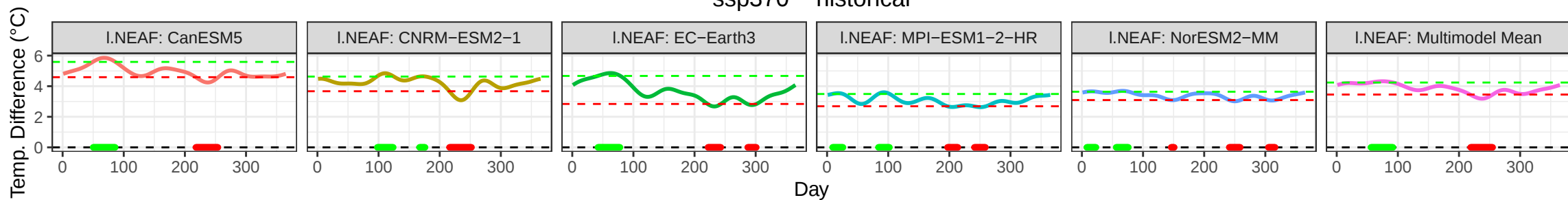
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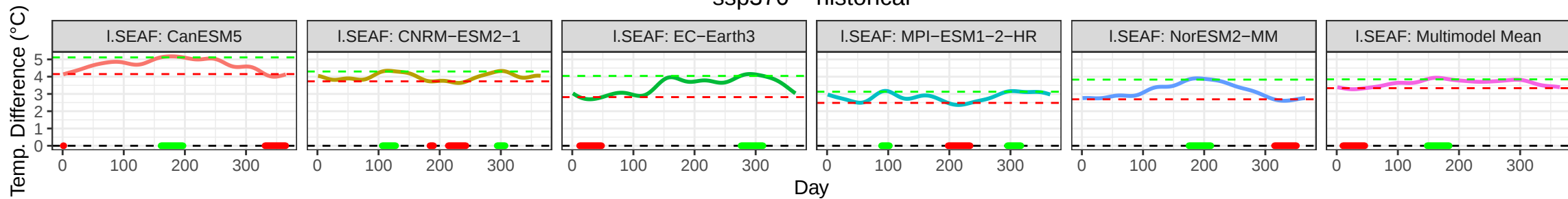
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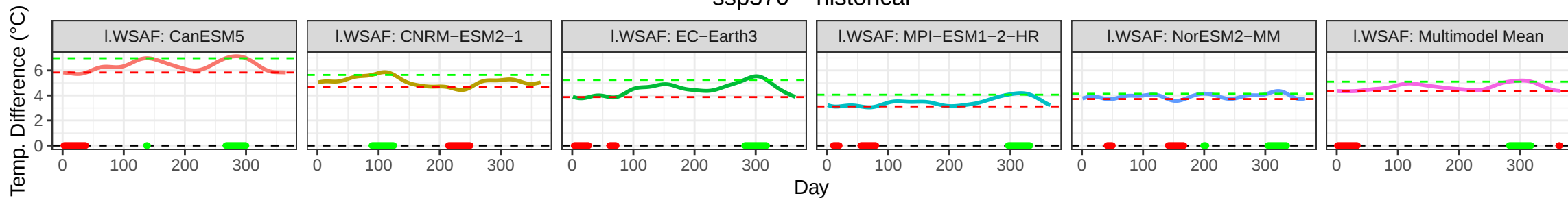
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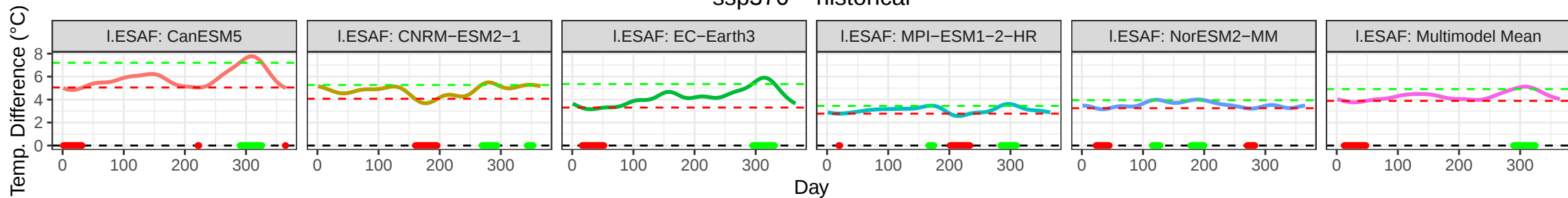
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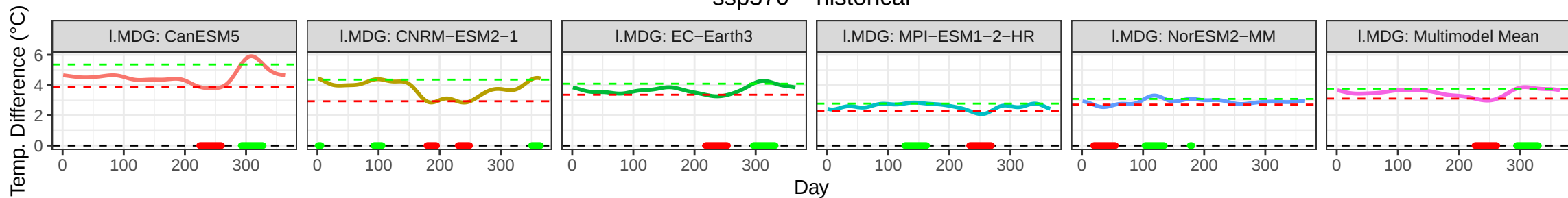
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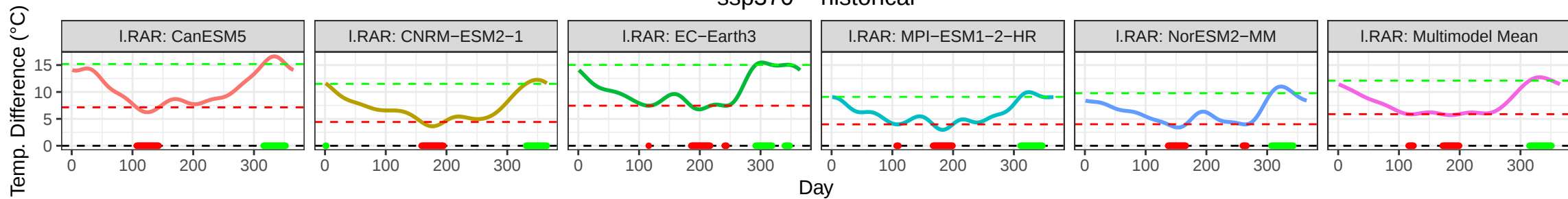
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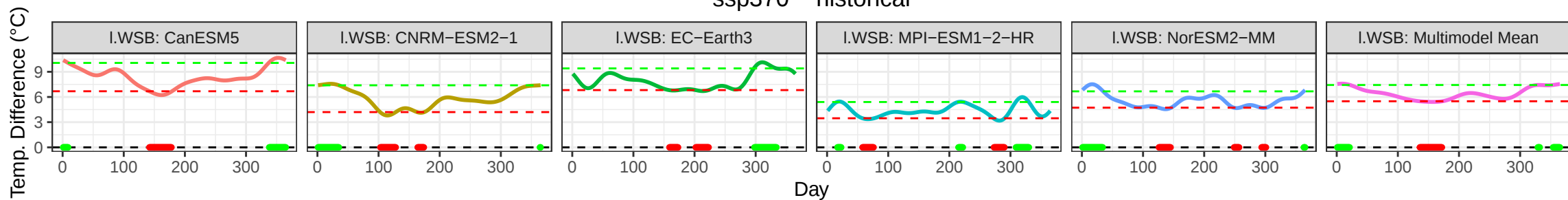
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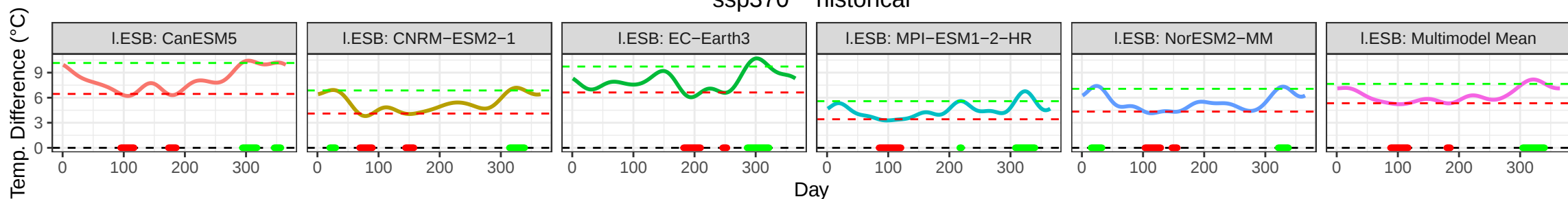
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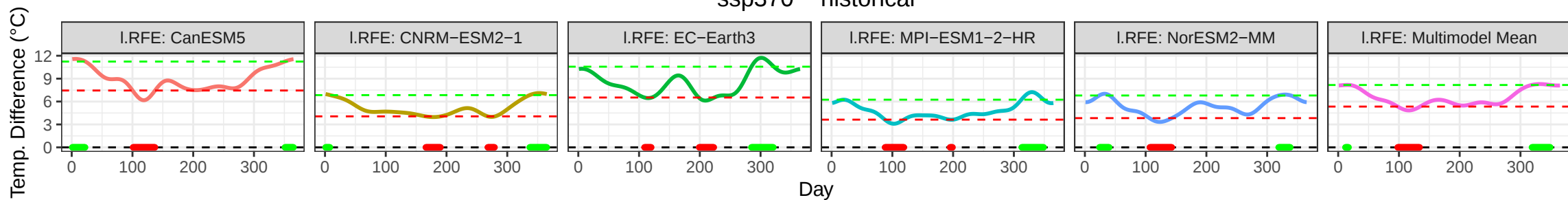
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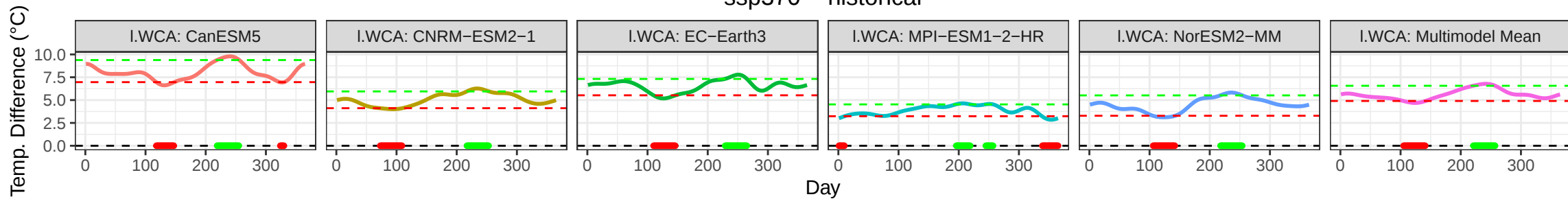
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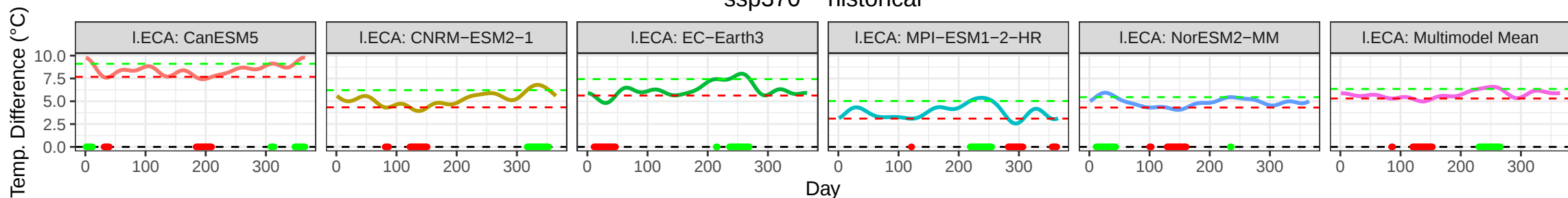
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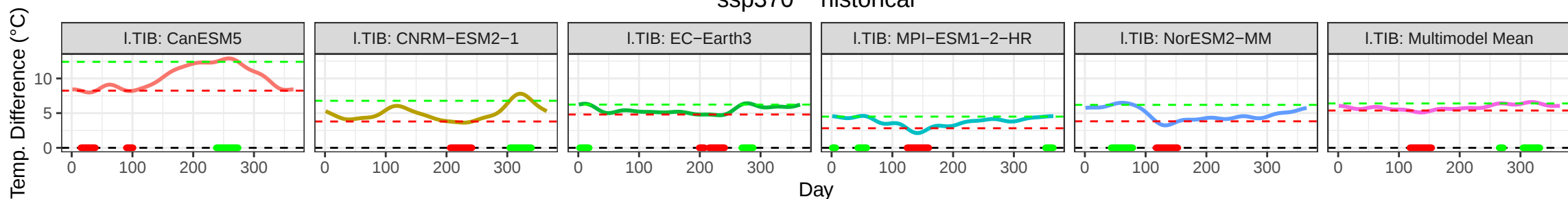
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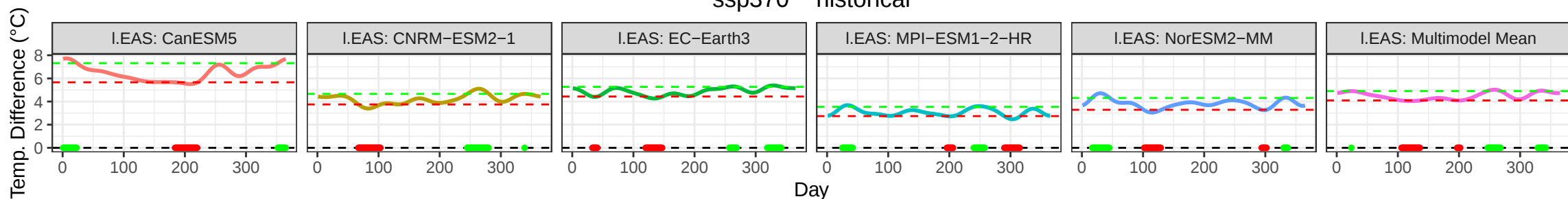
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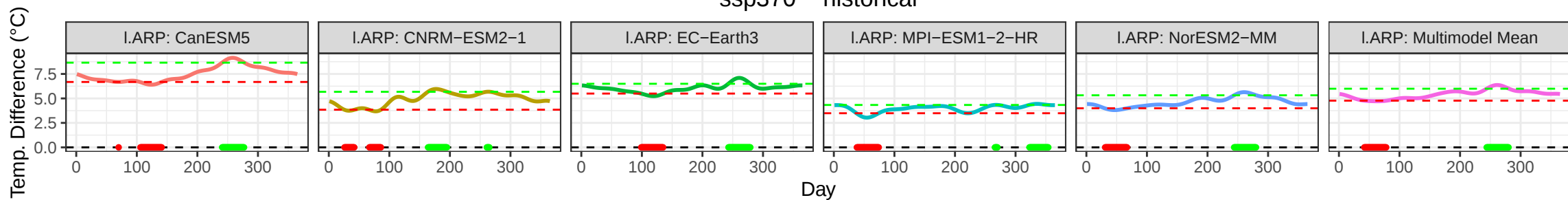
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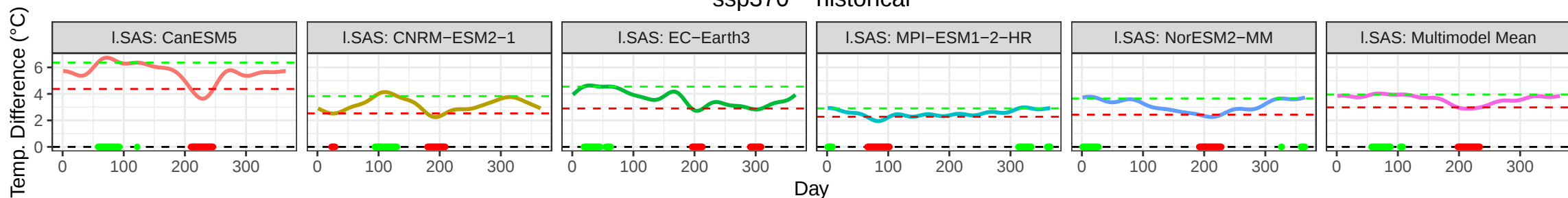
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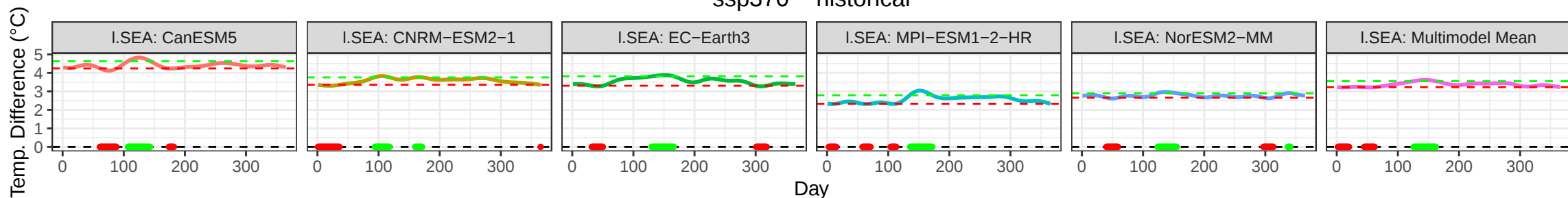
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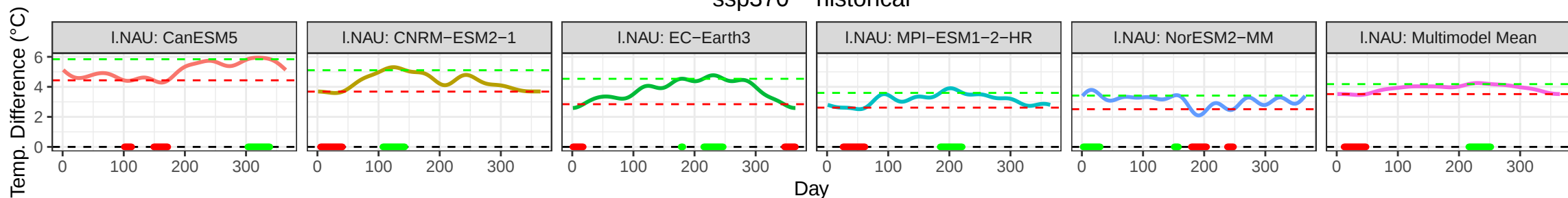
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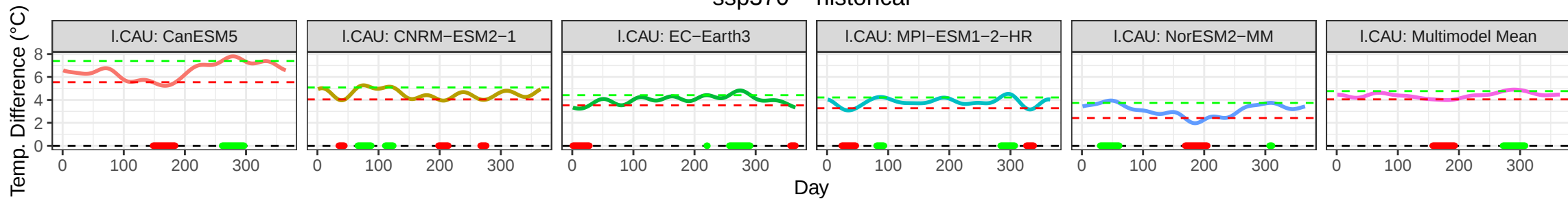
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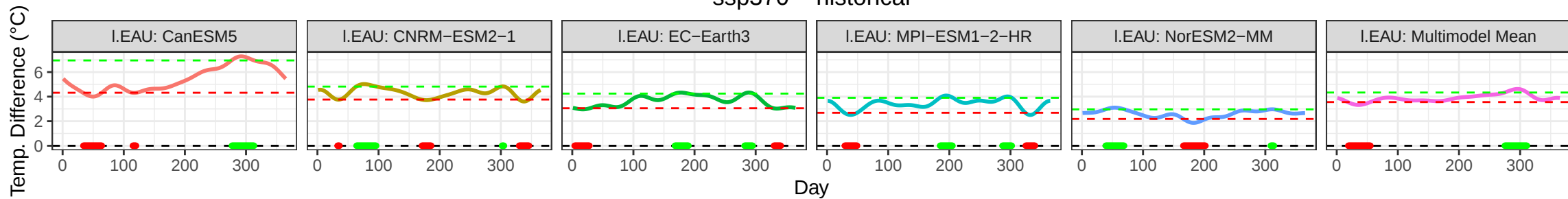
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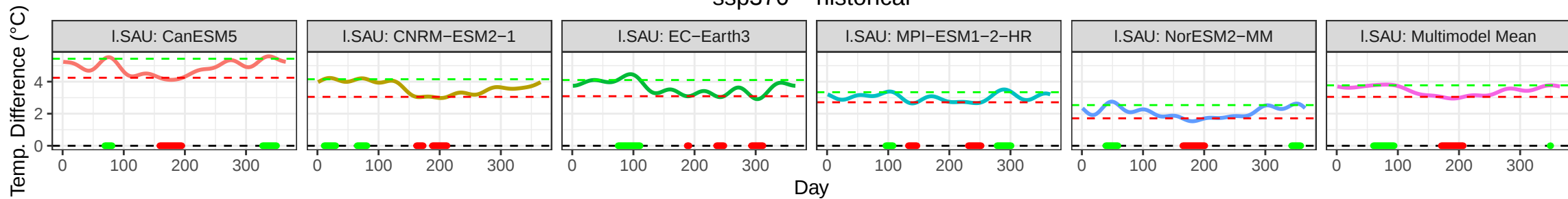
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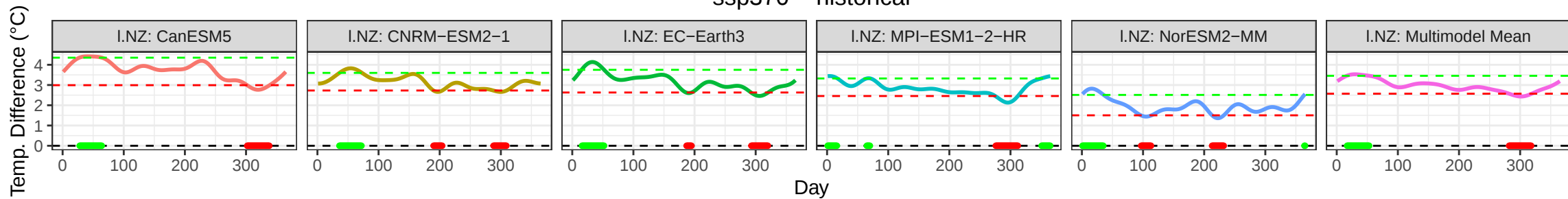
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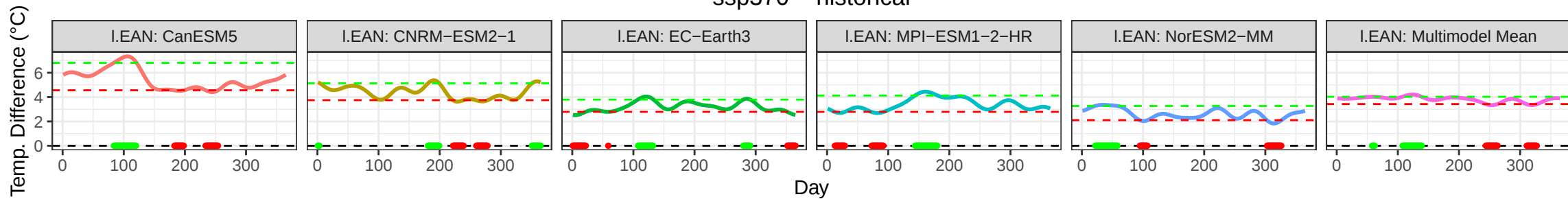
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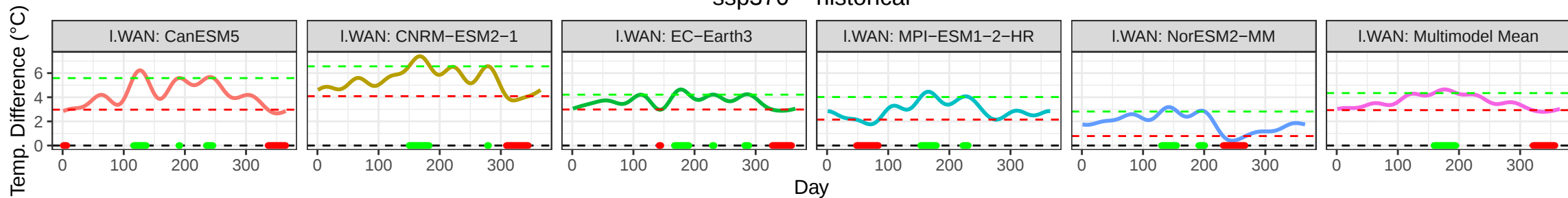
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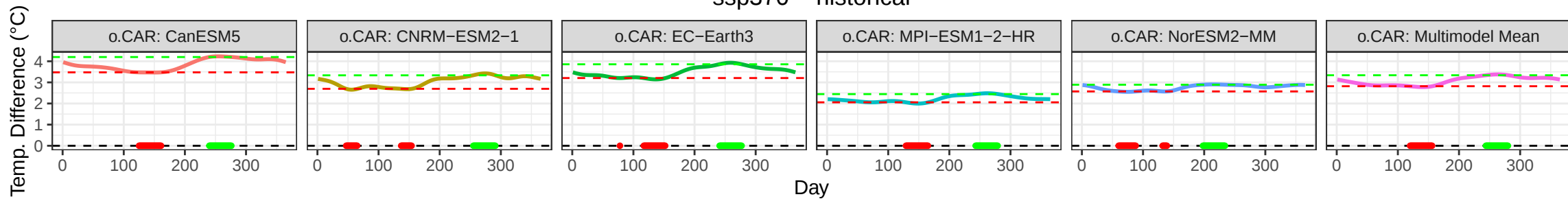
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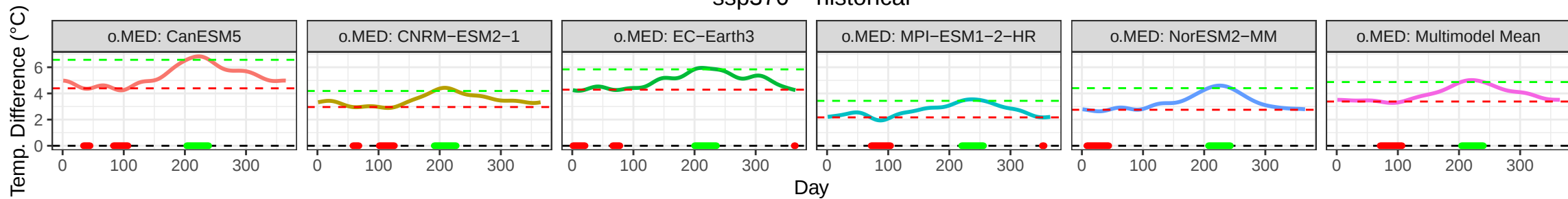
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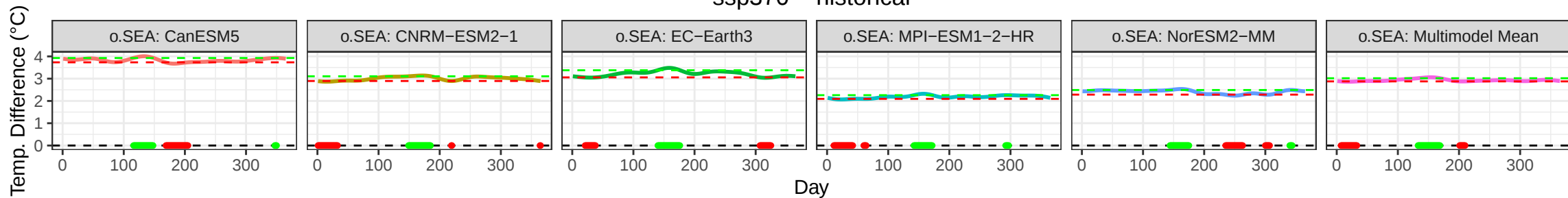
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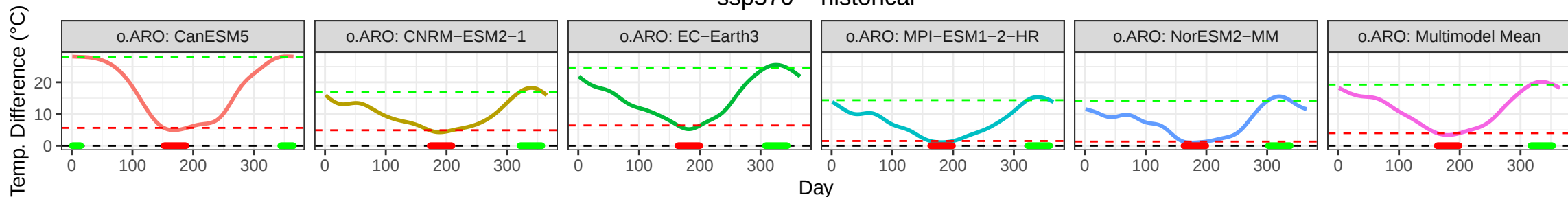
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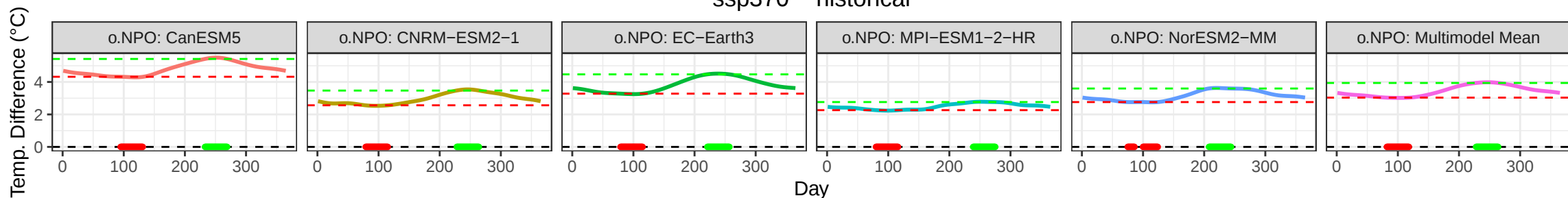
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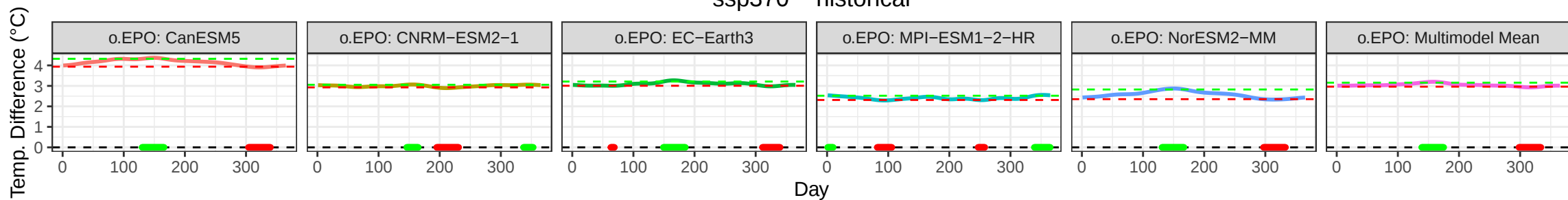
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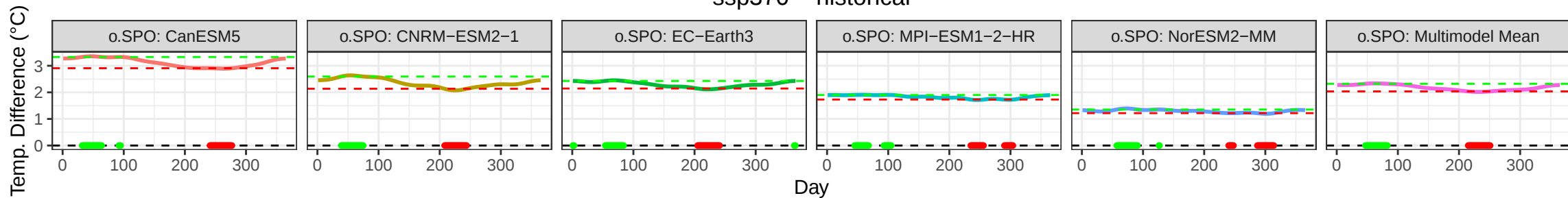
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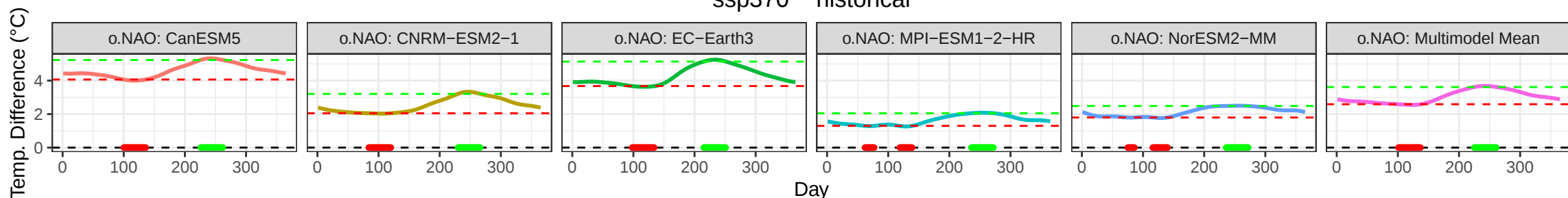
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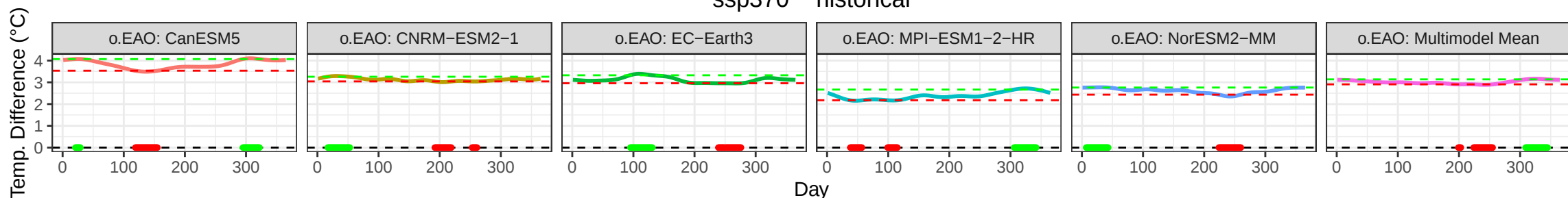
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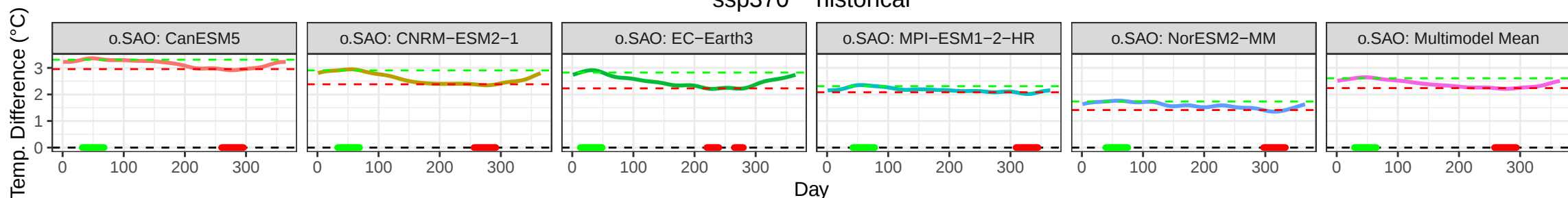
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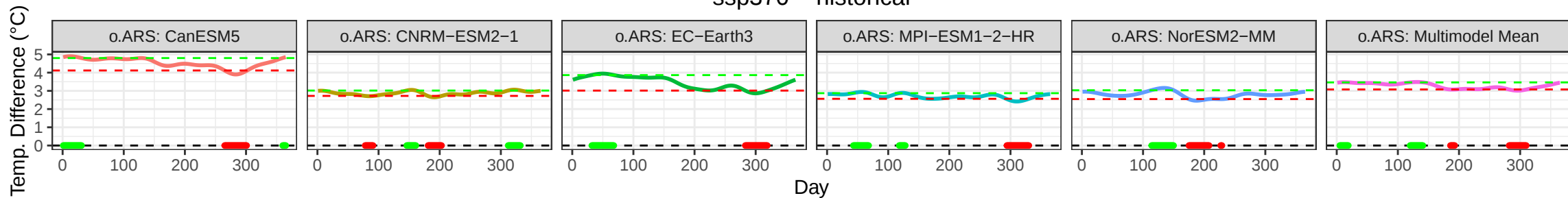
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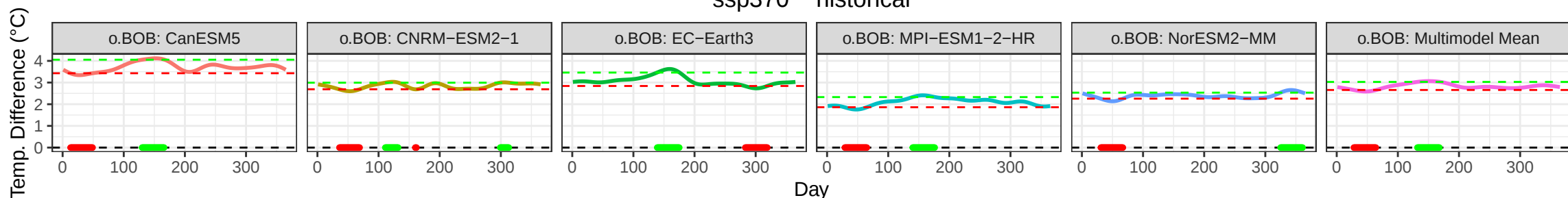
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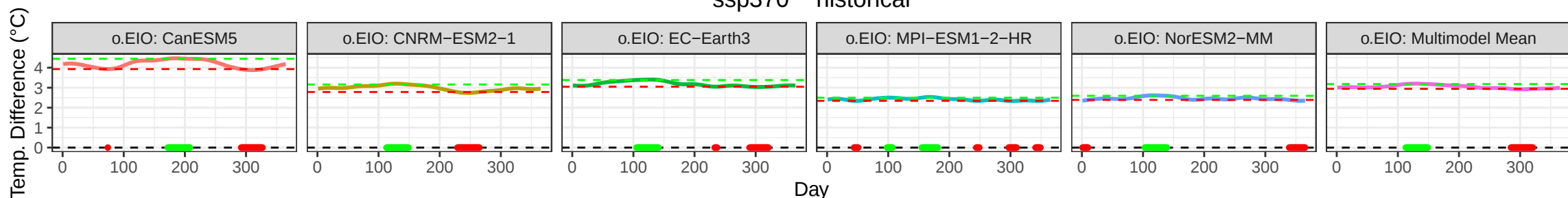
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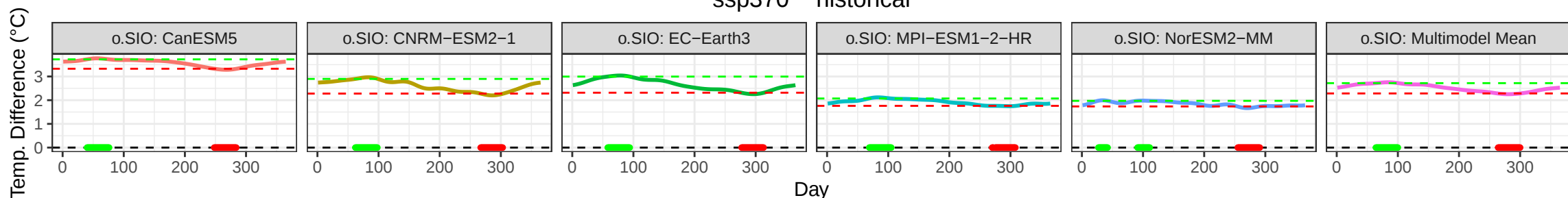
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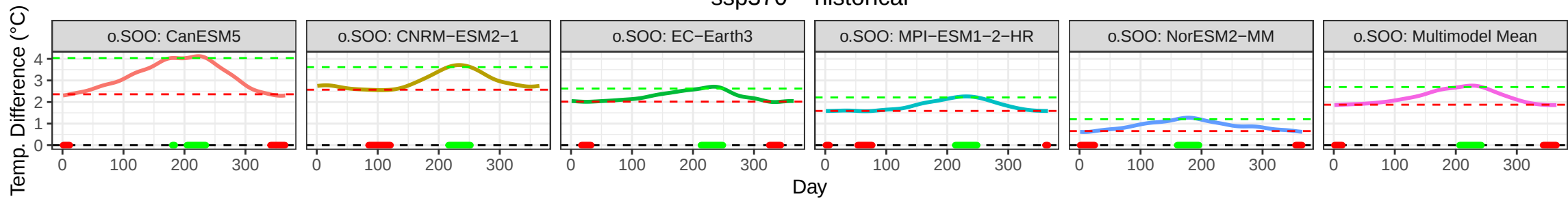
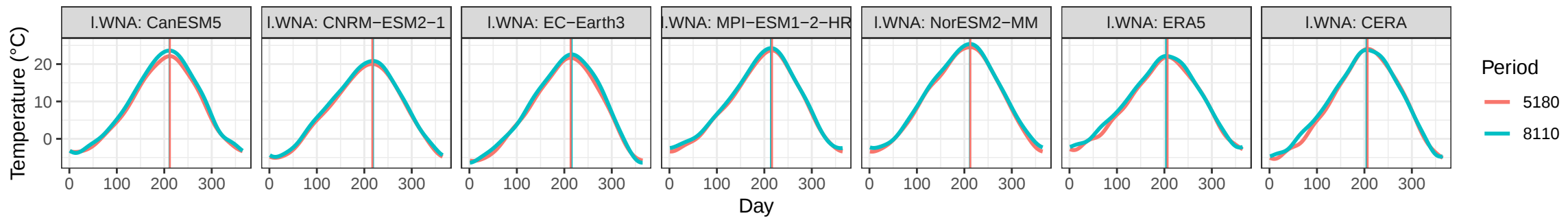
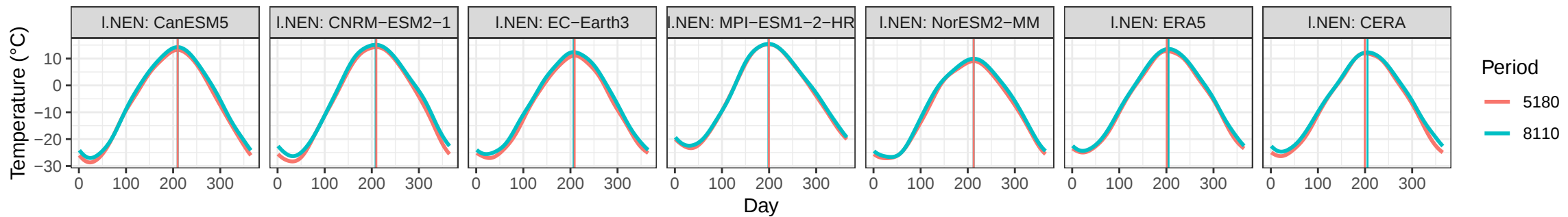
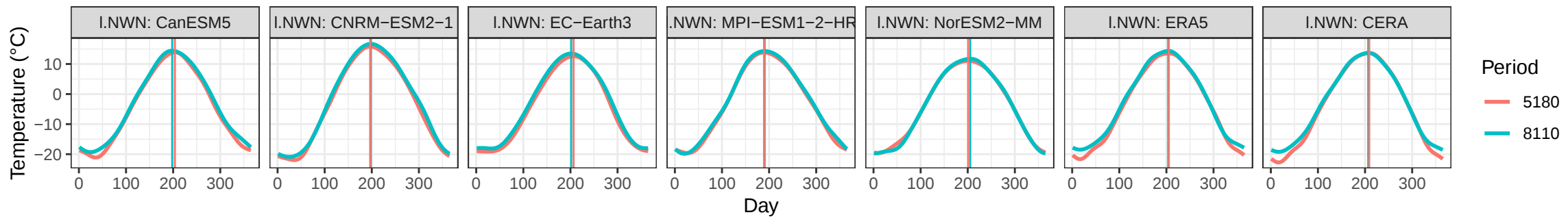
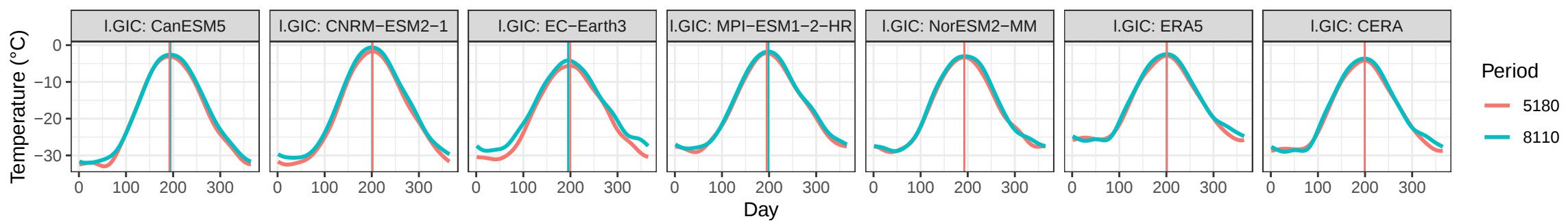
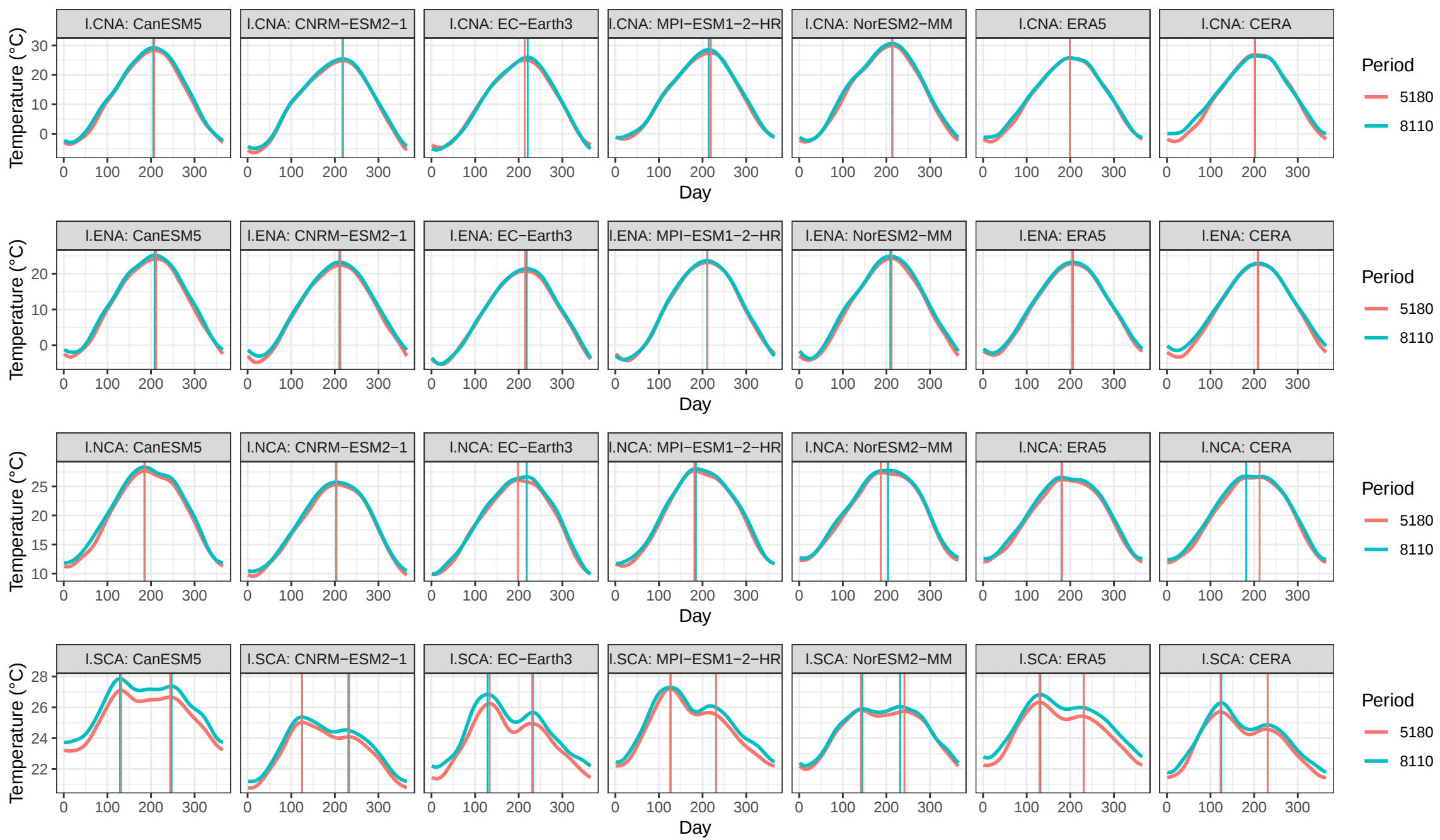
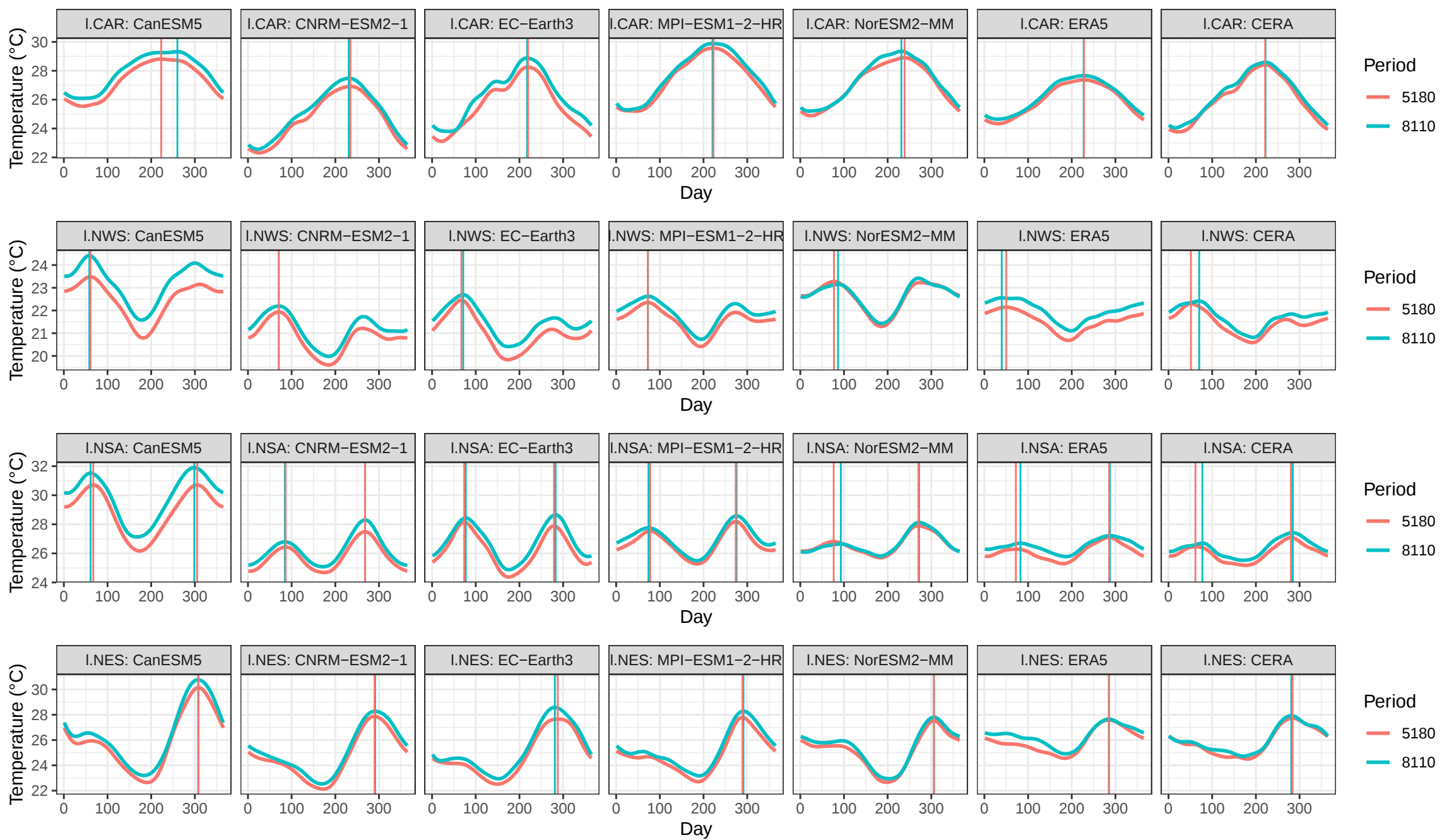
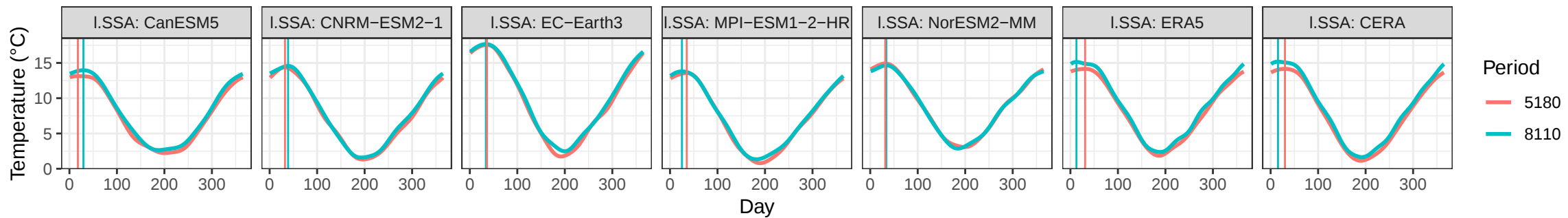
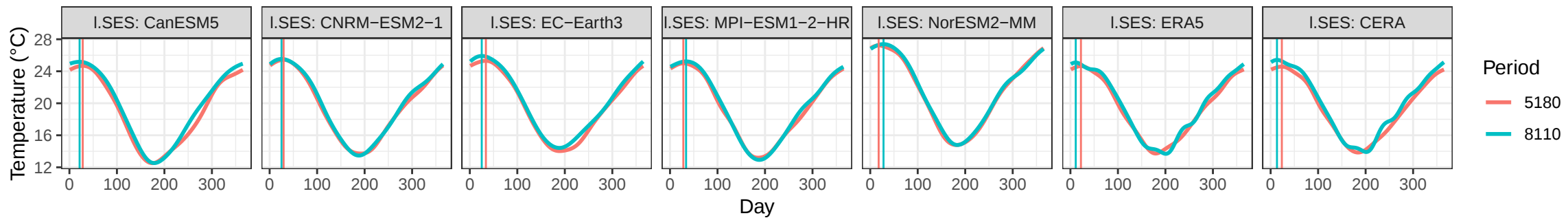
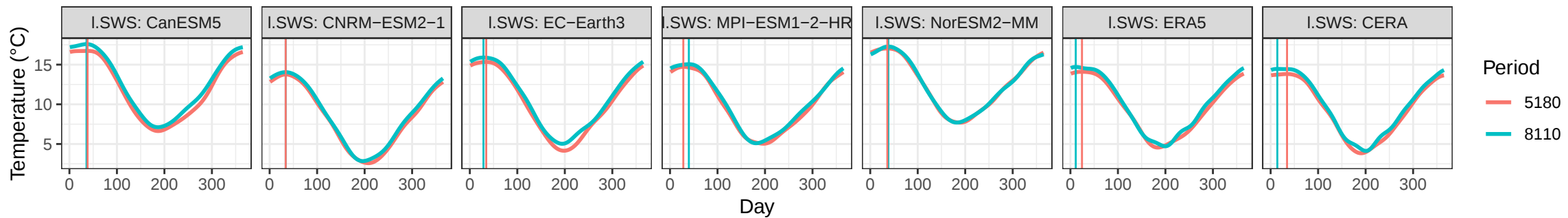
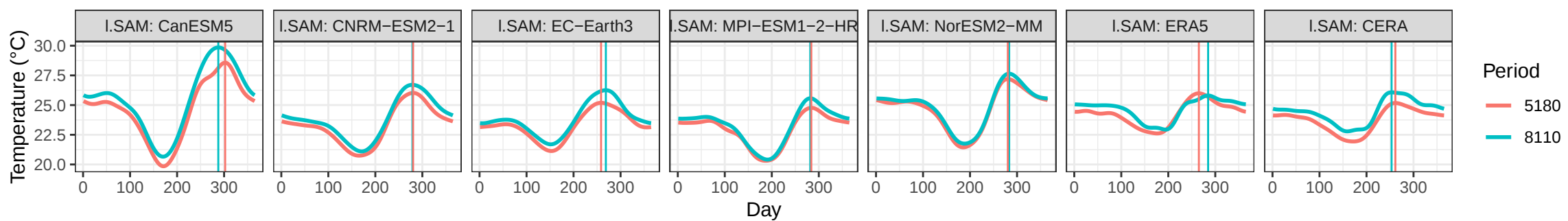


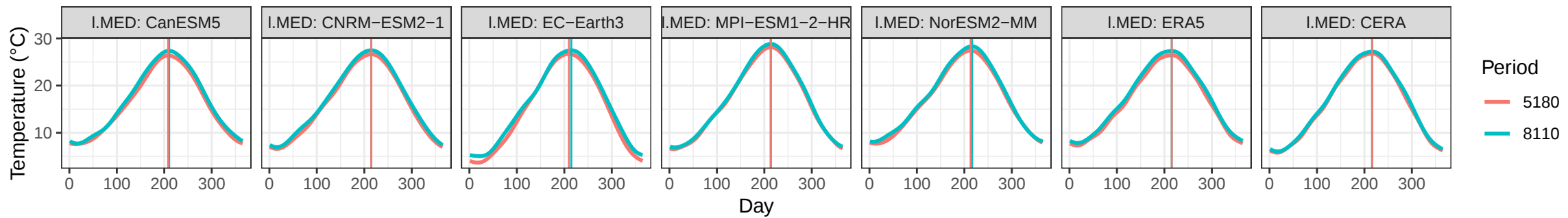
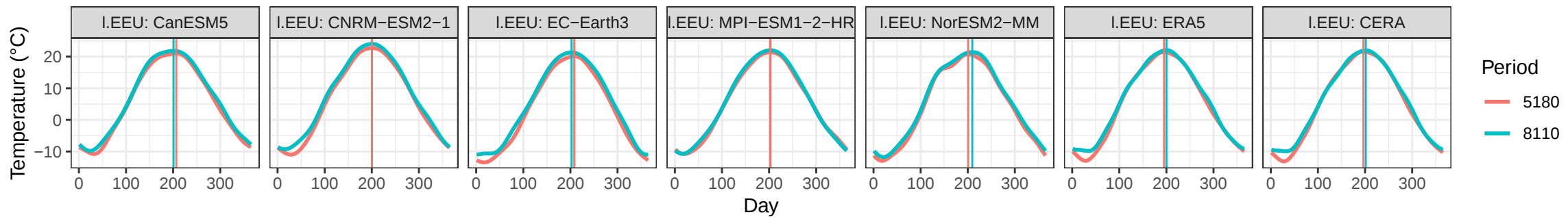
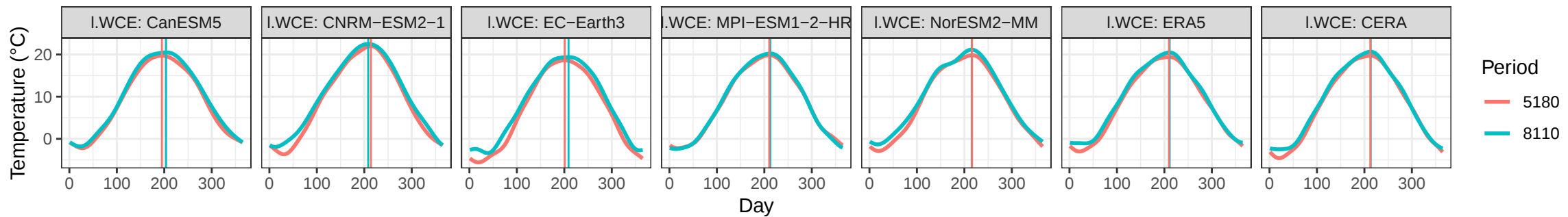
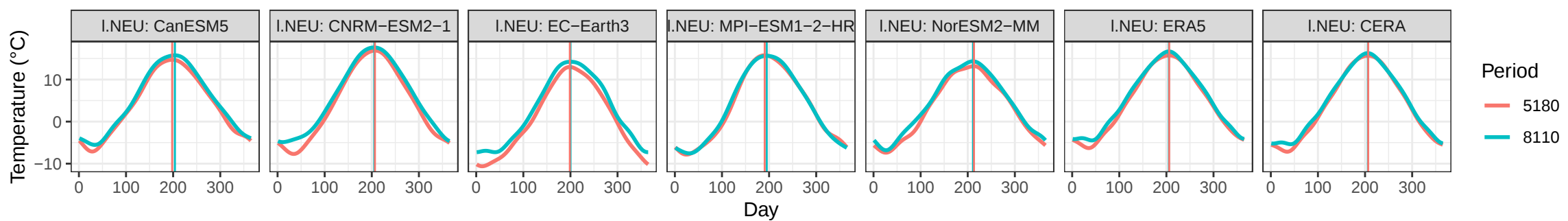
Figure S3: The smoothed annual cycle curves in the two historical periods 1981-2010 (8110, blue curve) and 1951-1980 (5180, red curve). Plots for five selected CMIP6 ESMs and their multi-model mean are shown in different columns, plot for different geographical regions are depicted in different rows of the figure. Positions of the annual cycle maxima in the two periods are denoted by the vertical lines. The results shown in this figure are summarized in Fig. 5 in the manuscript.

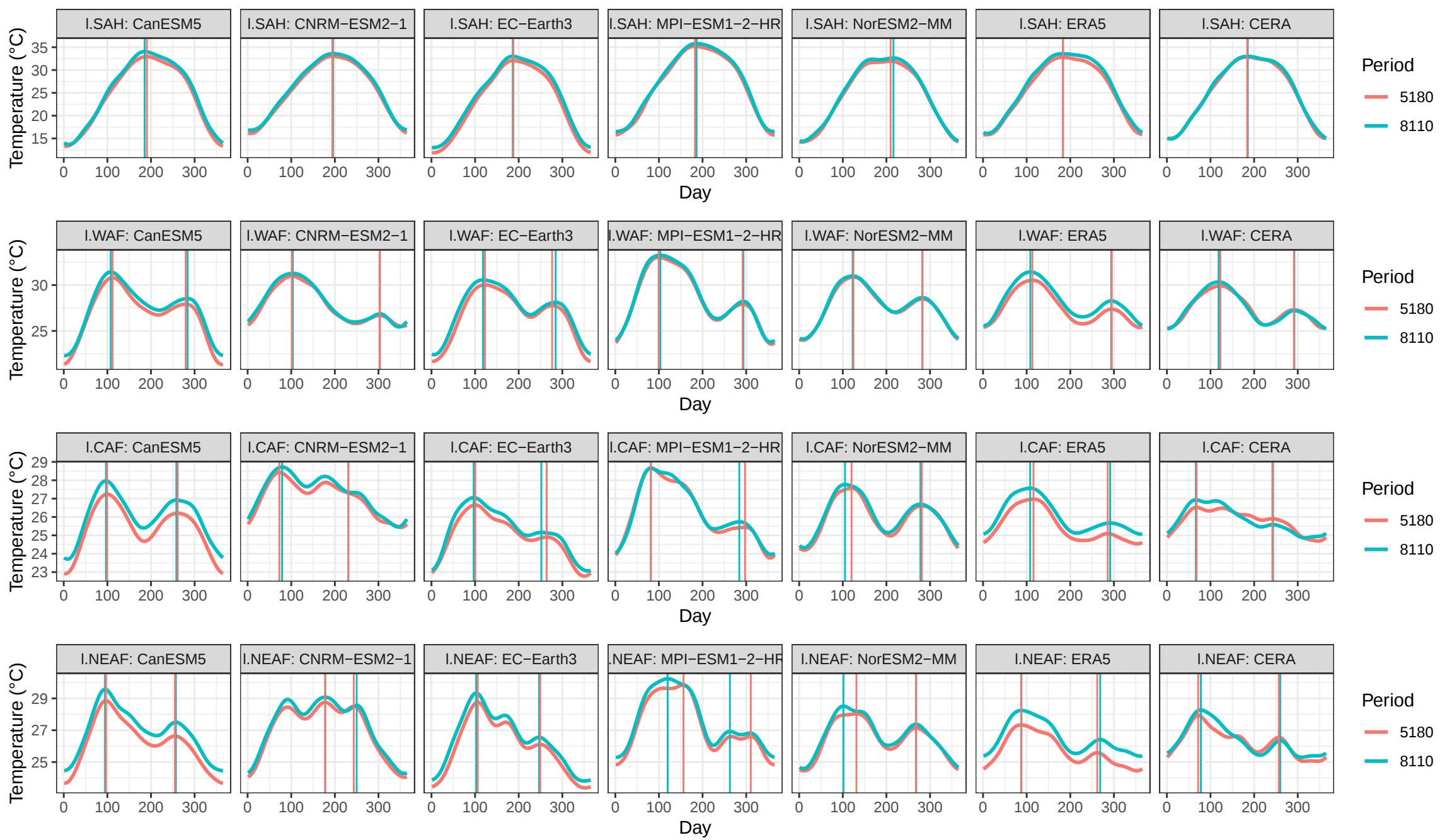


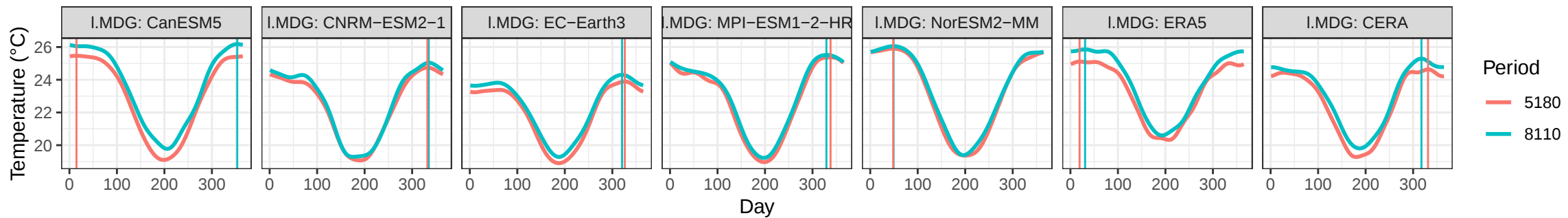
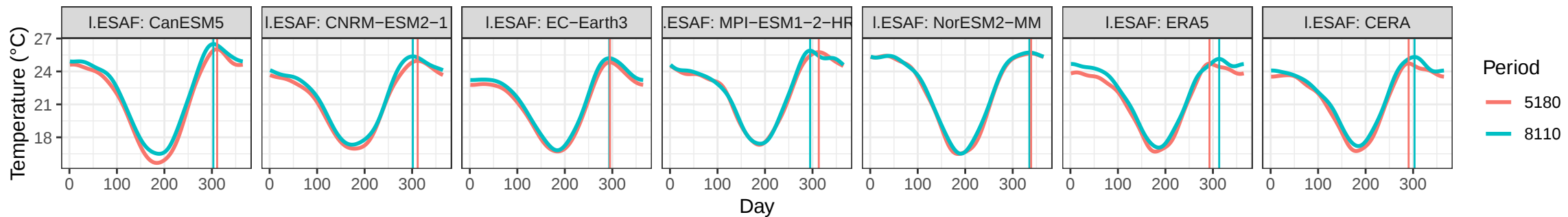
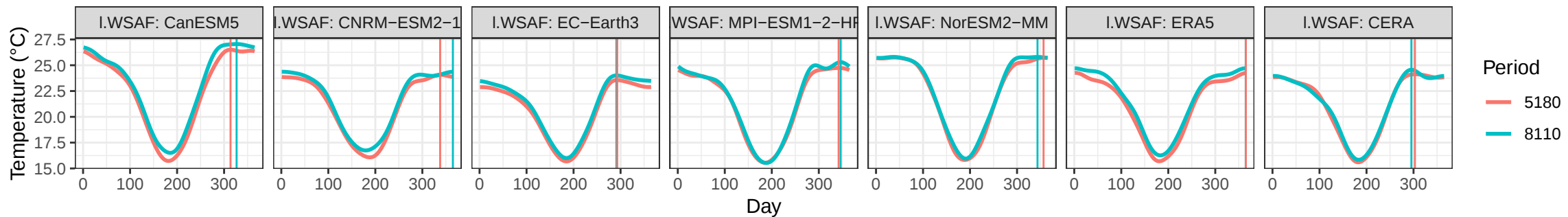
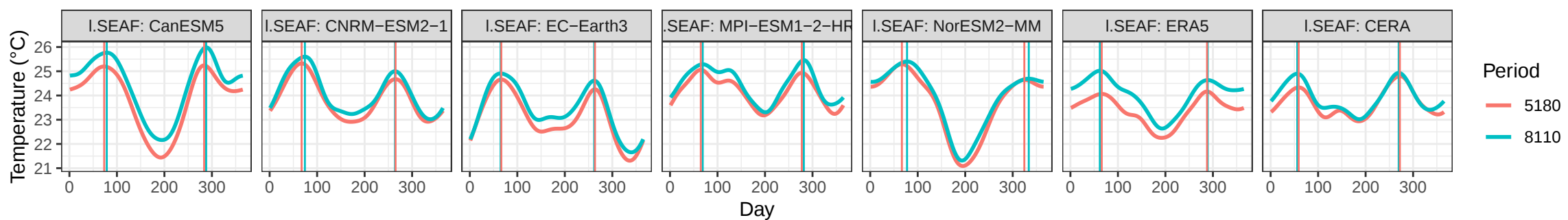


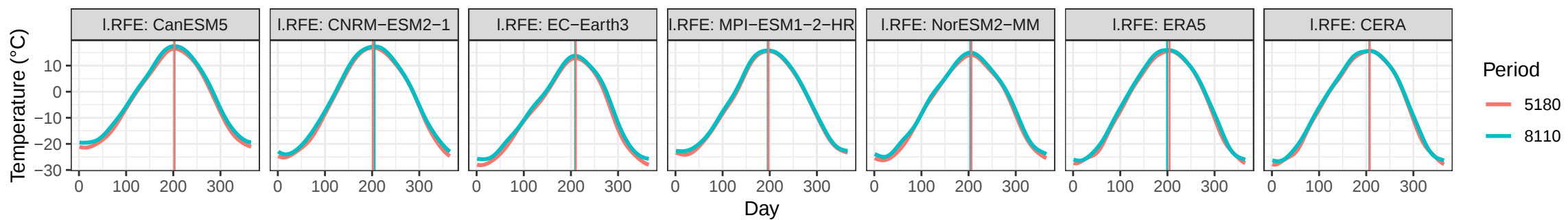
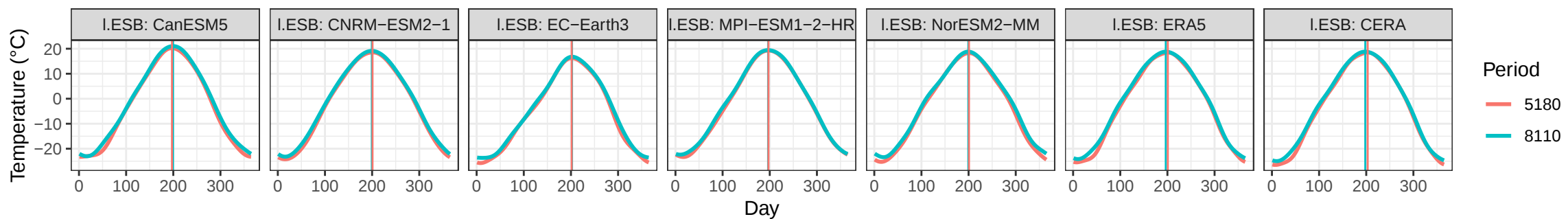
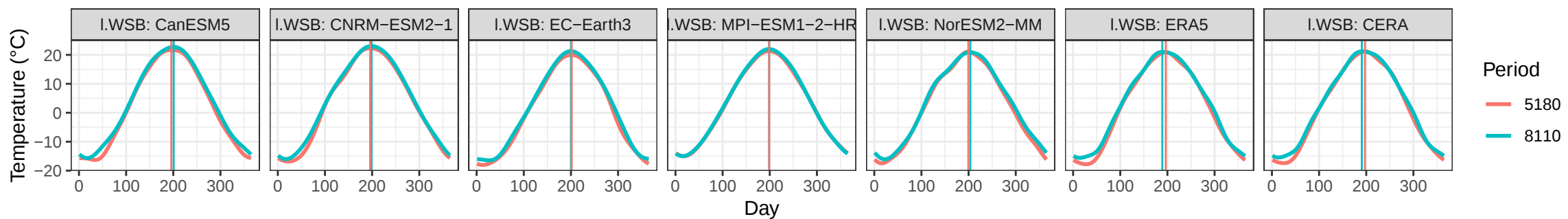
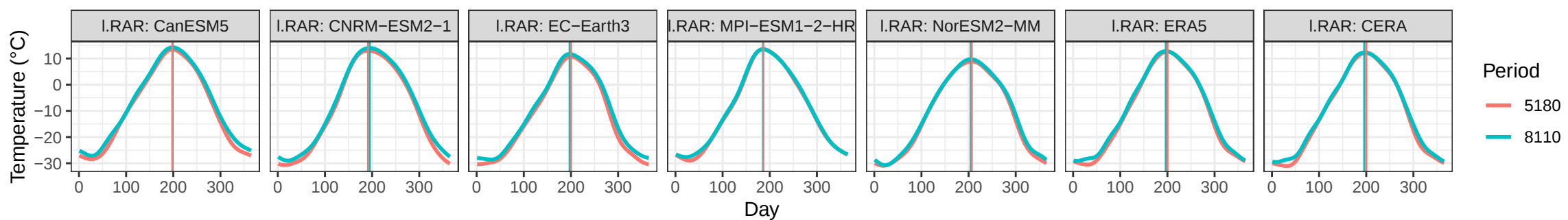


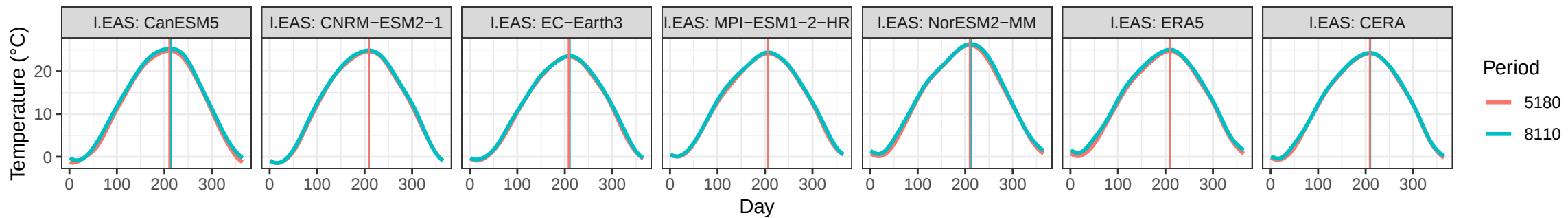
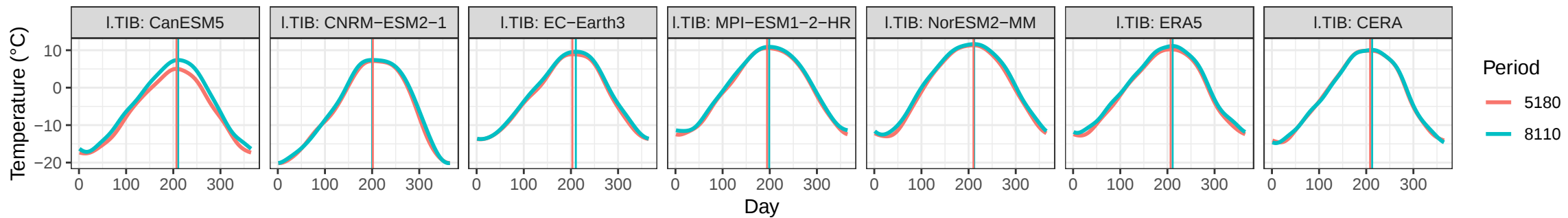
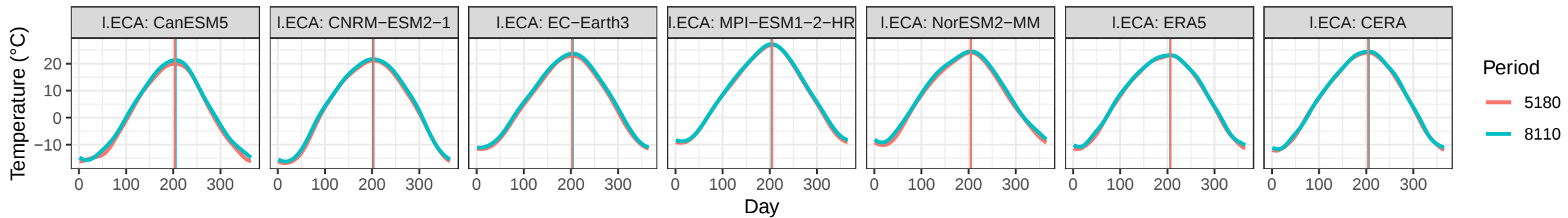
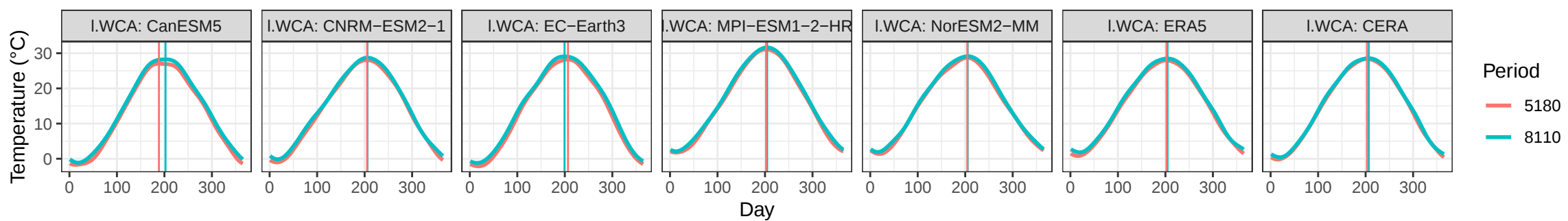


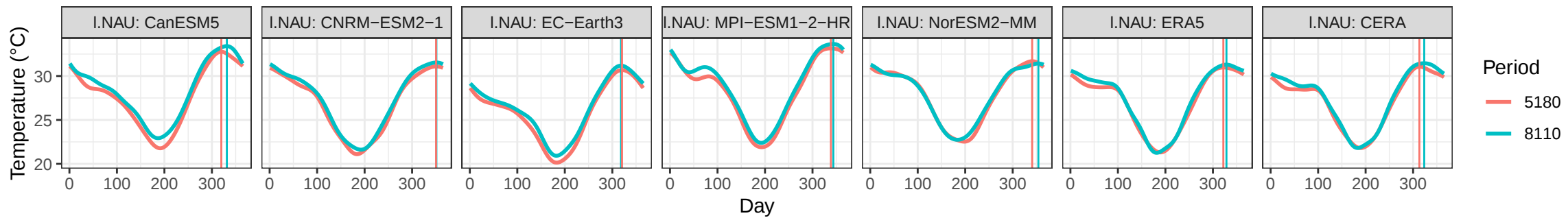
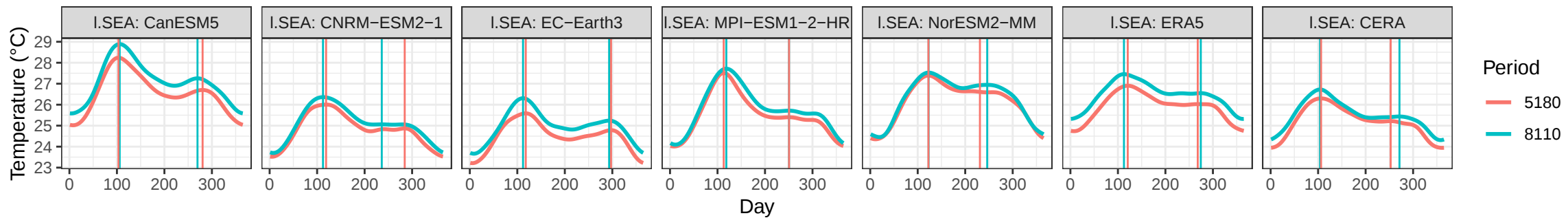
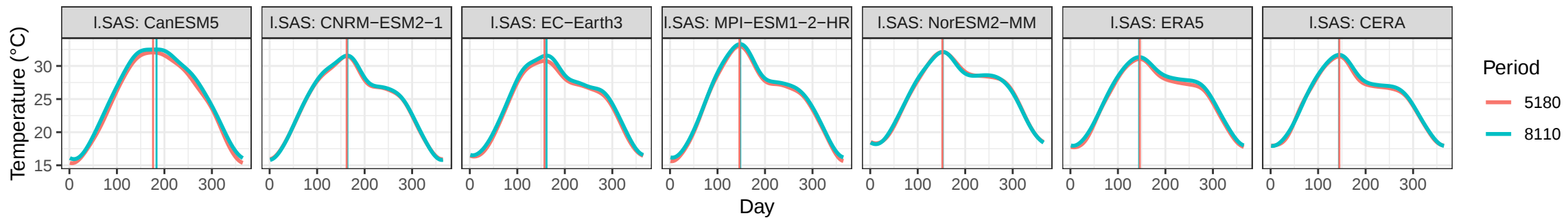
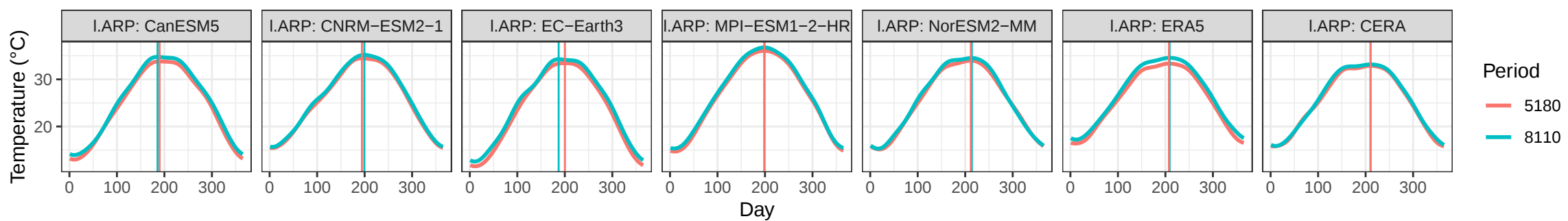


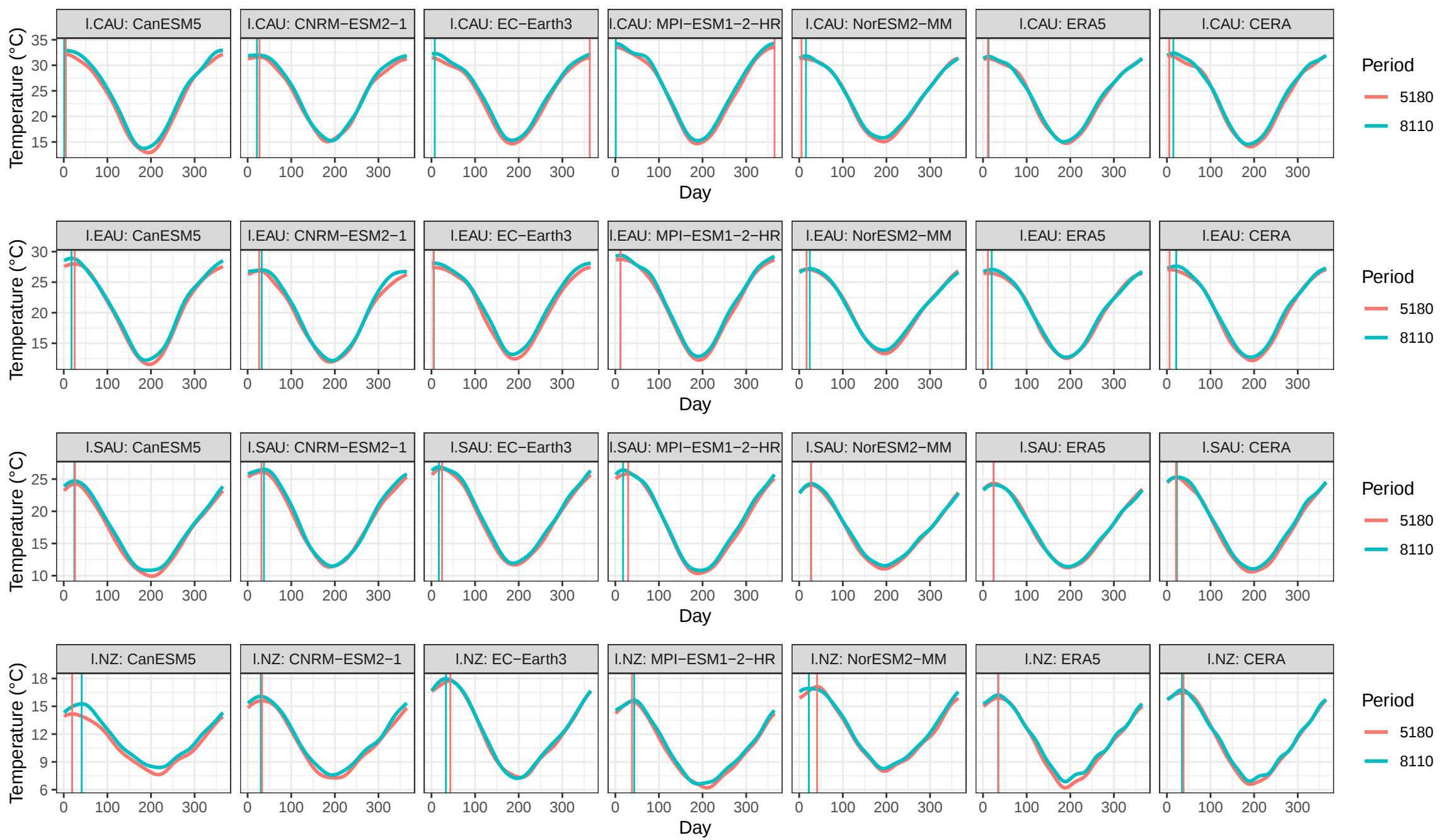


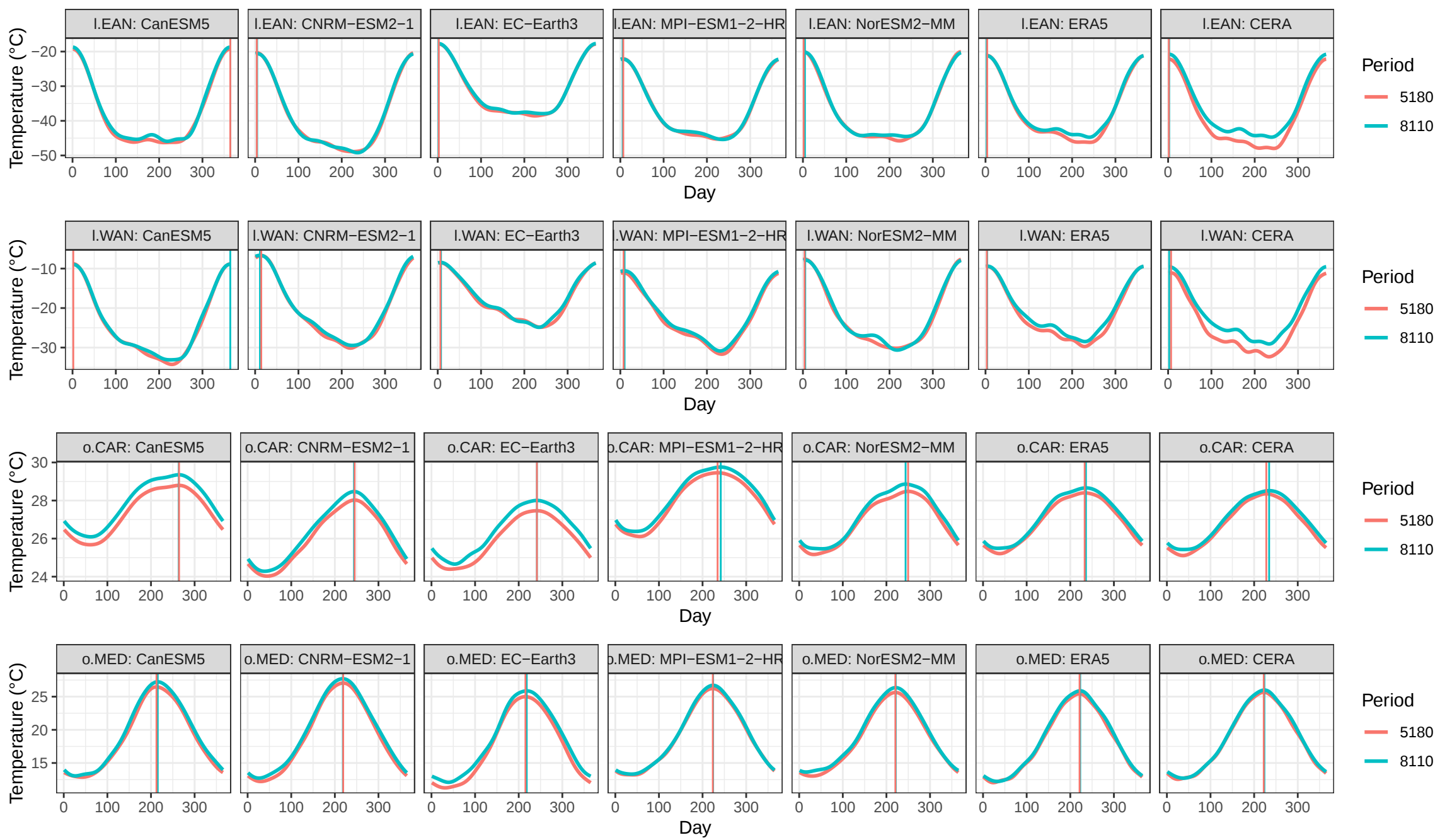


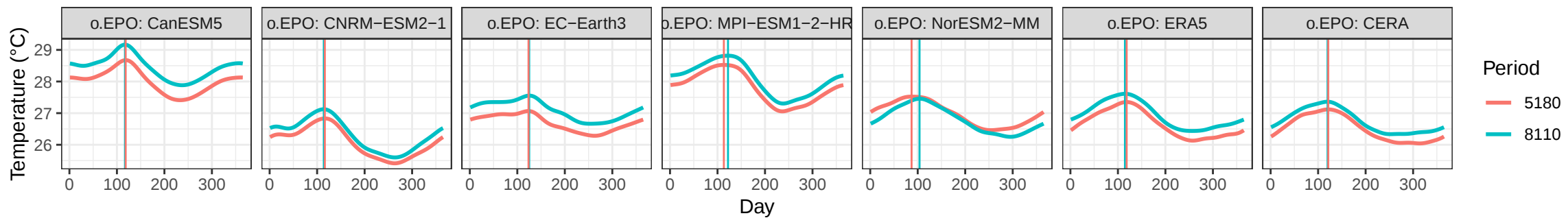
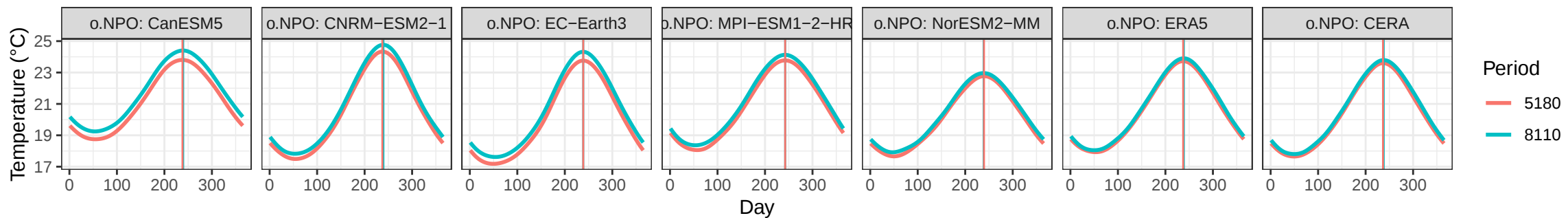
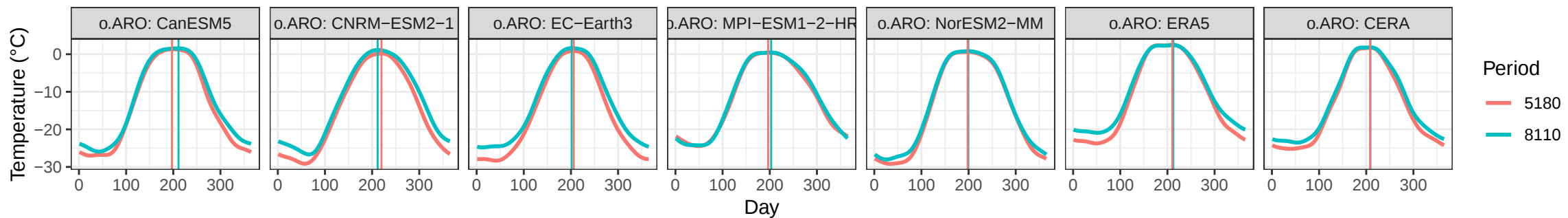
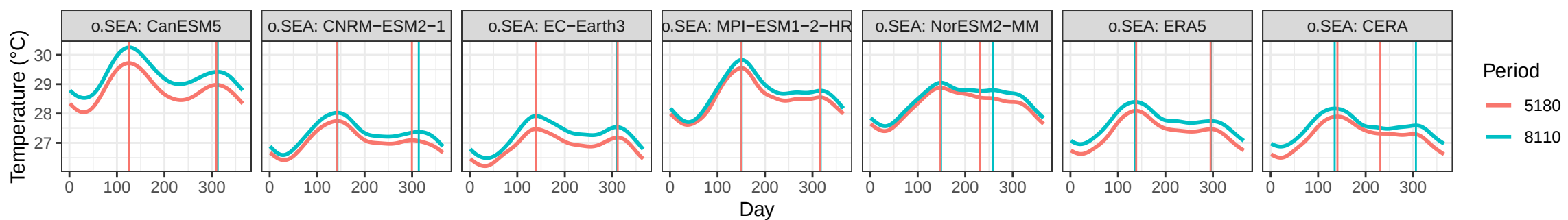


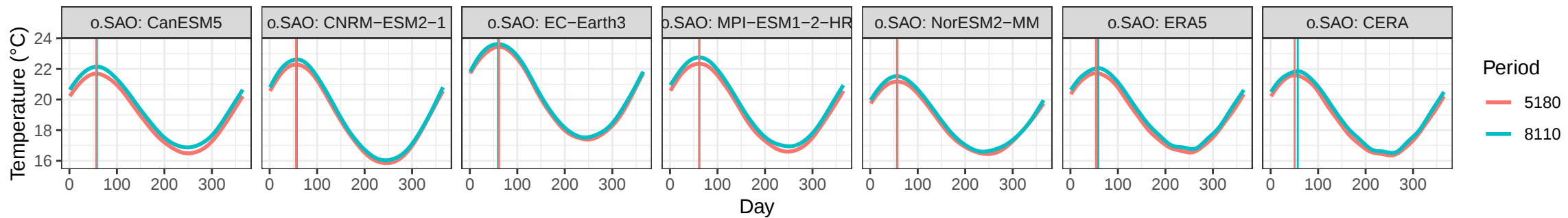
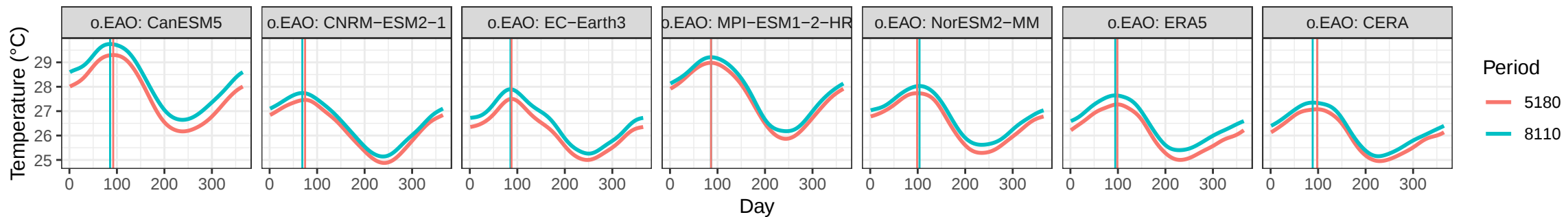
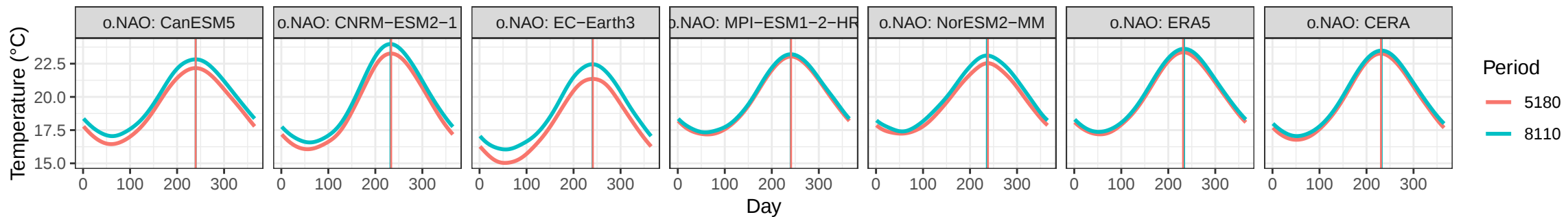
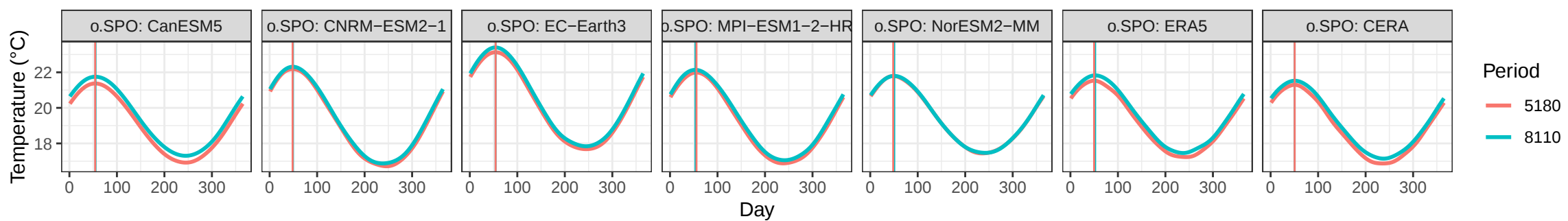


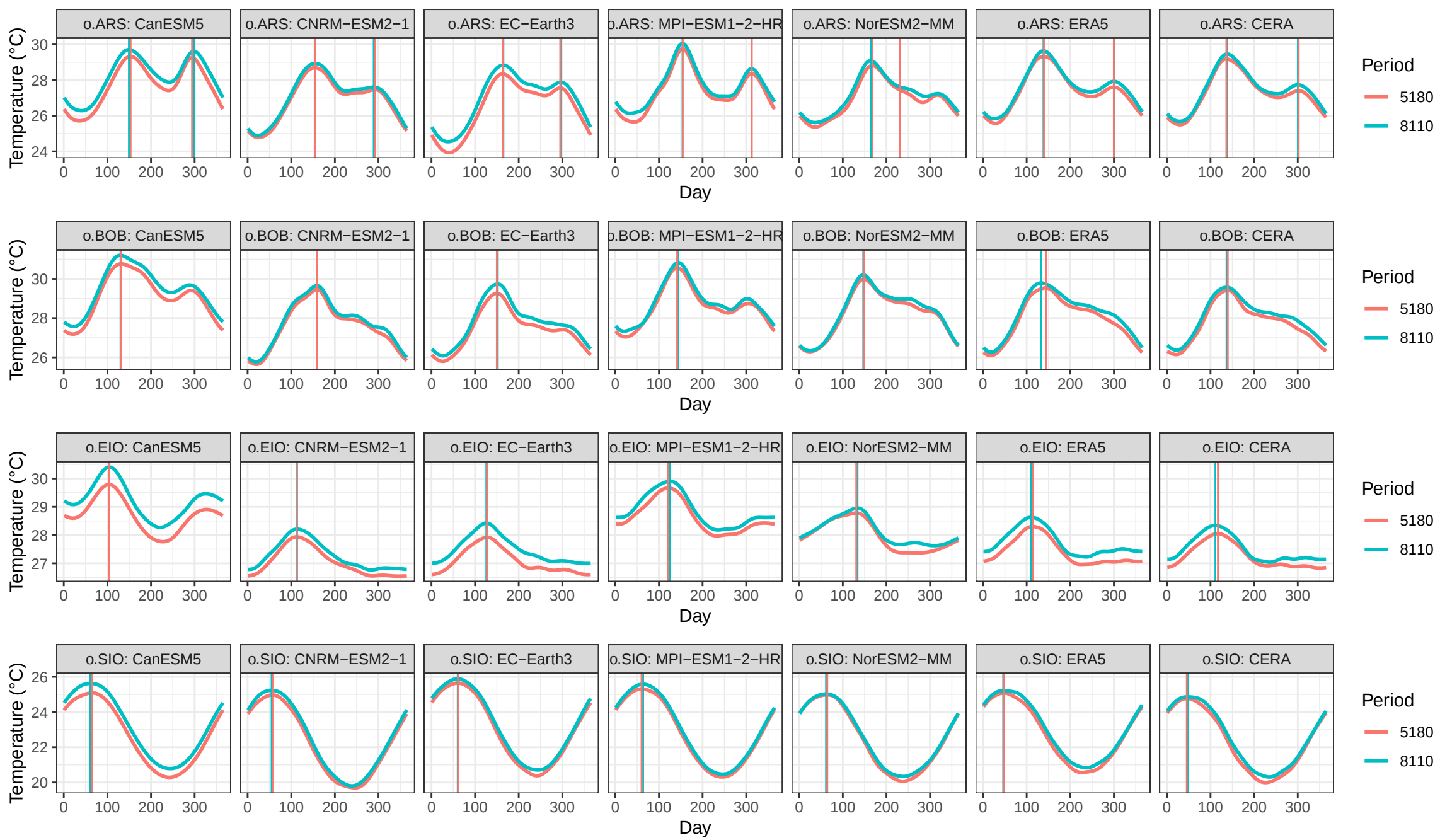












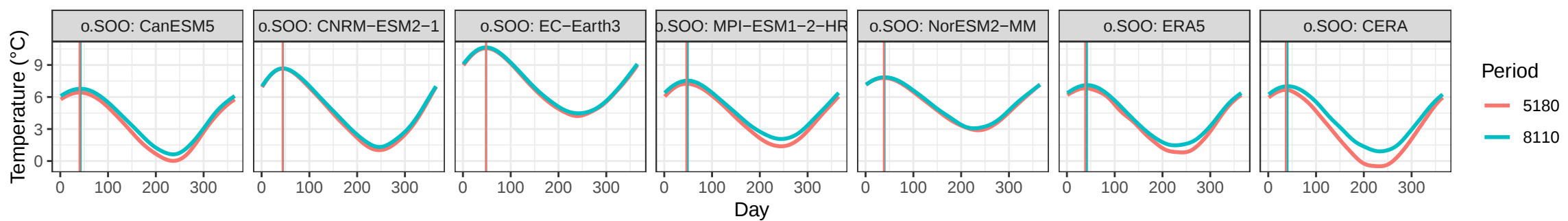
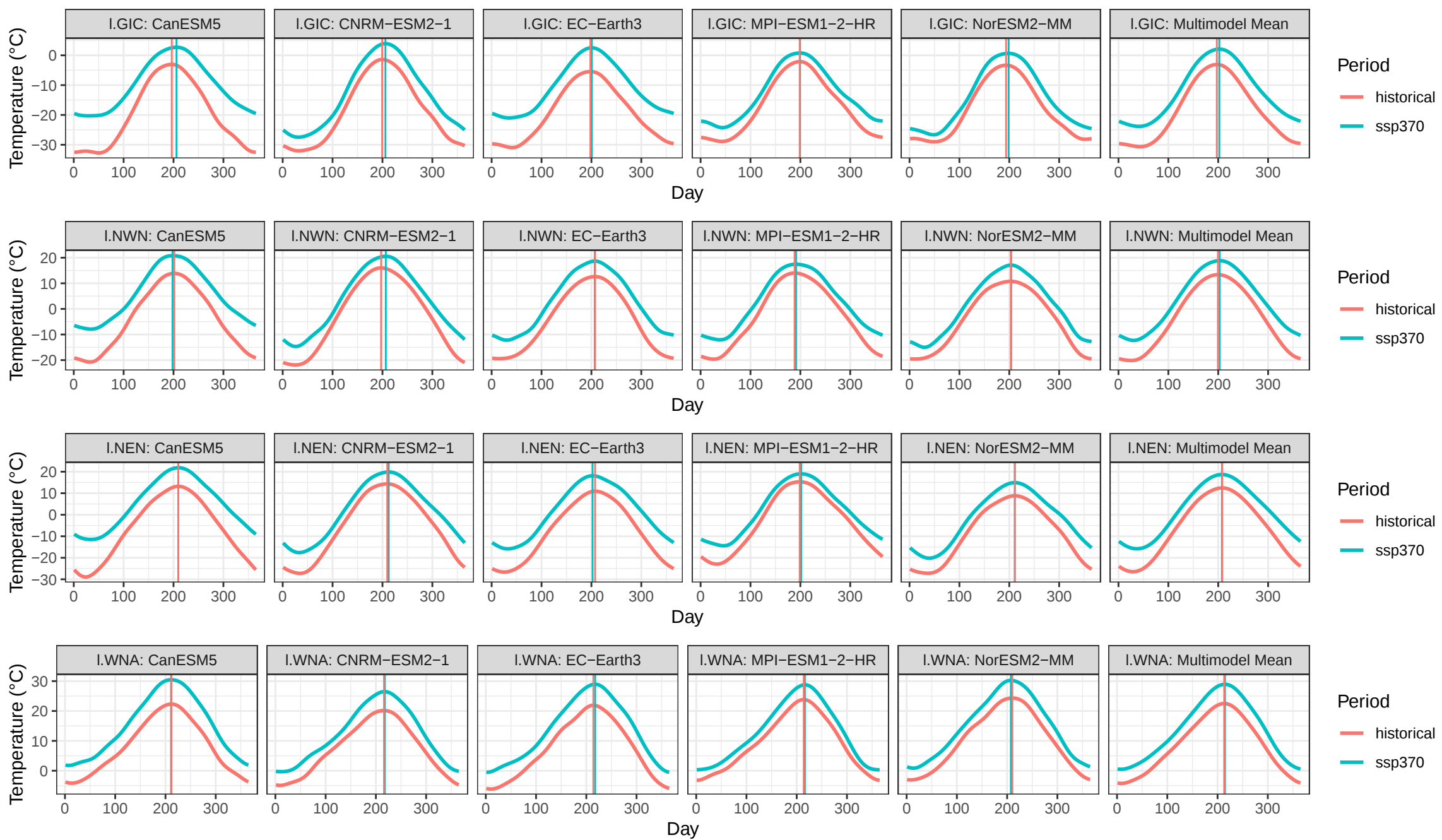
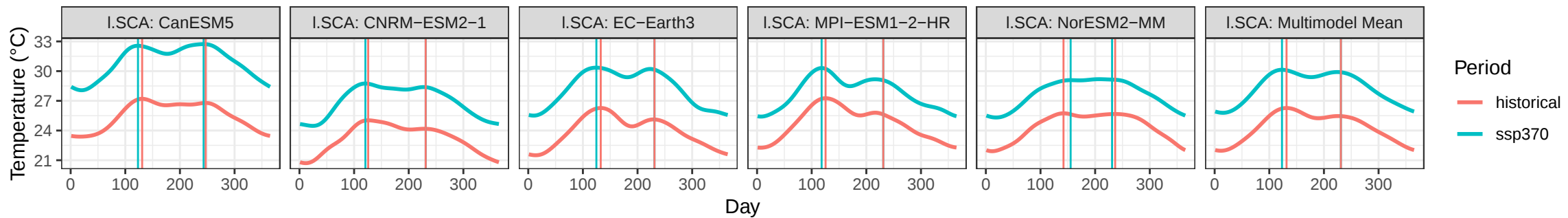
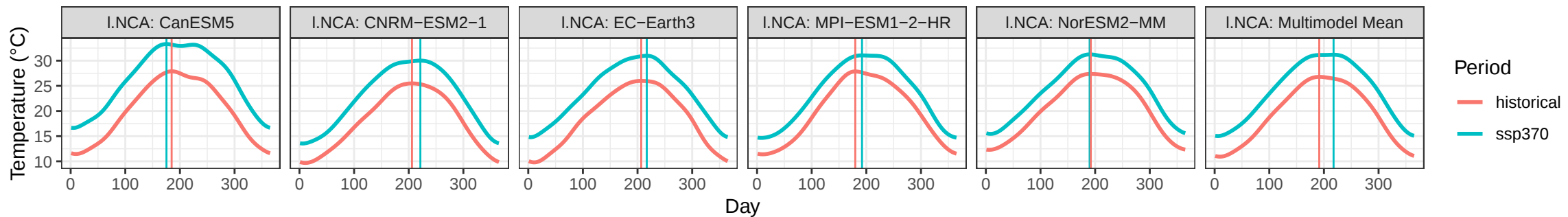
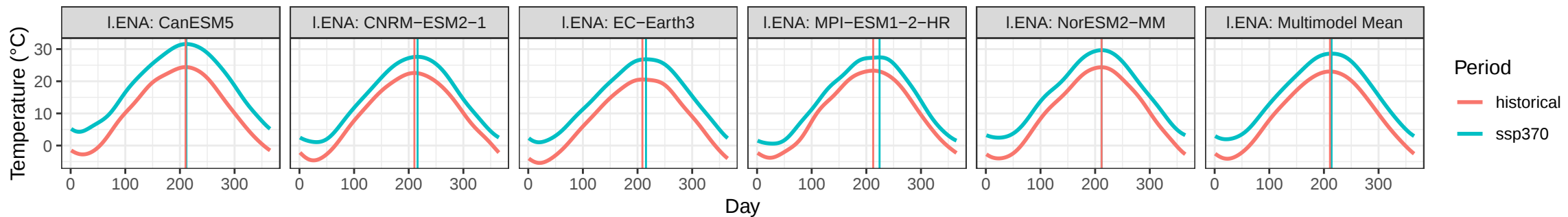
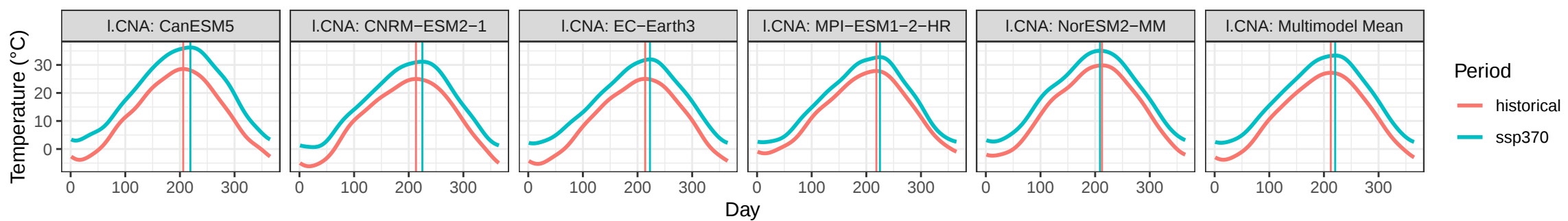
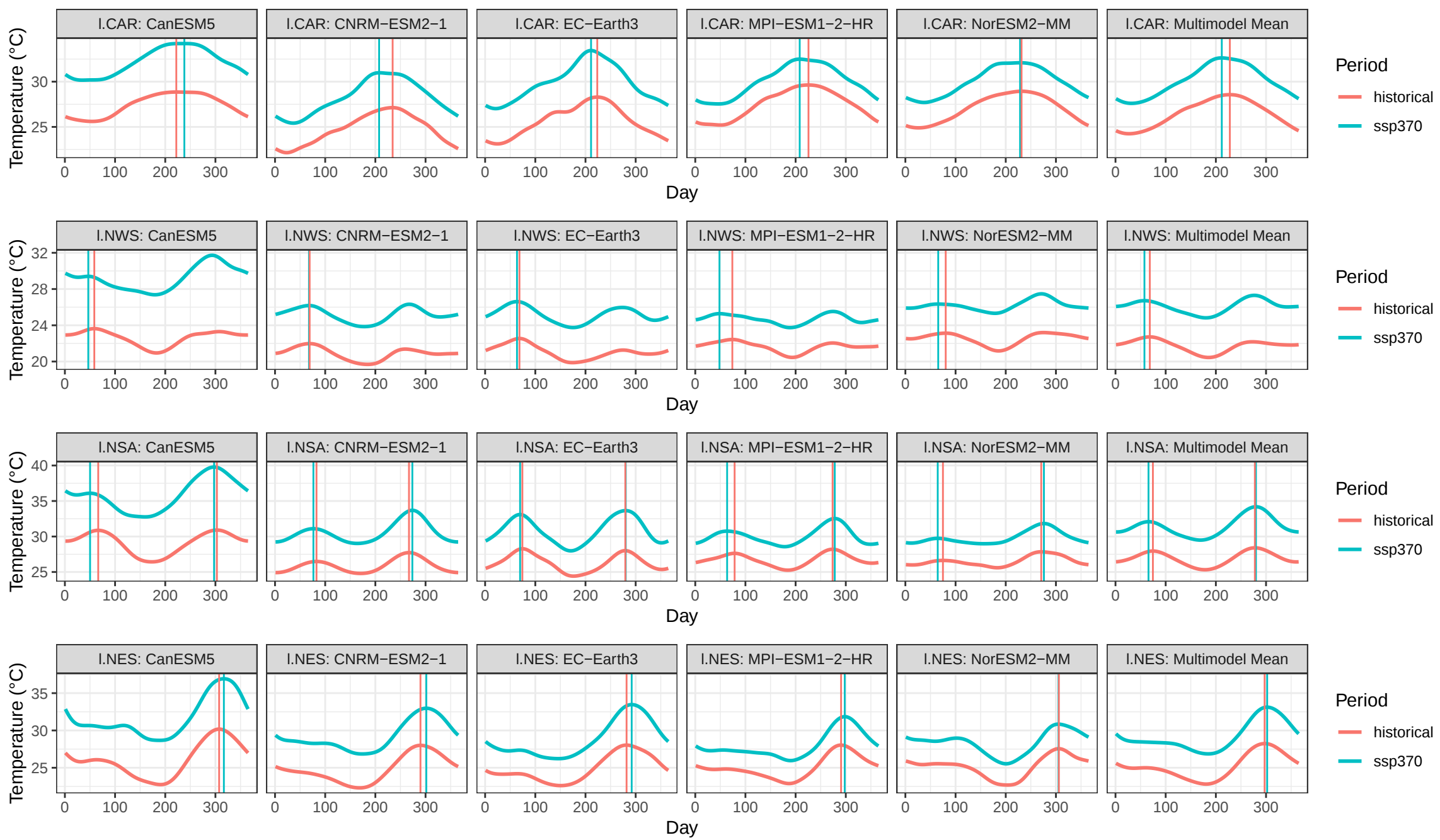
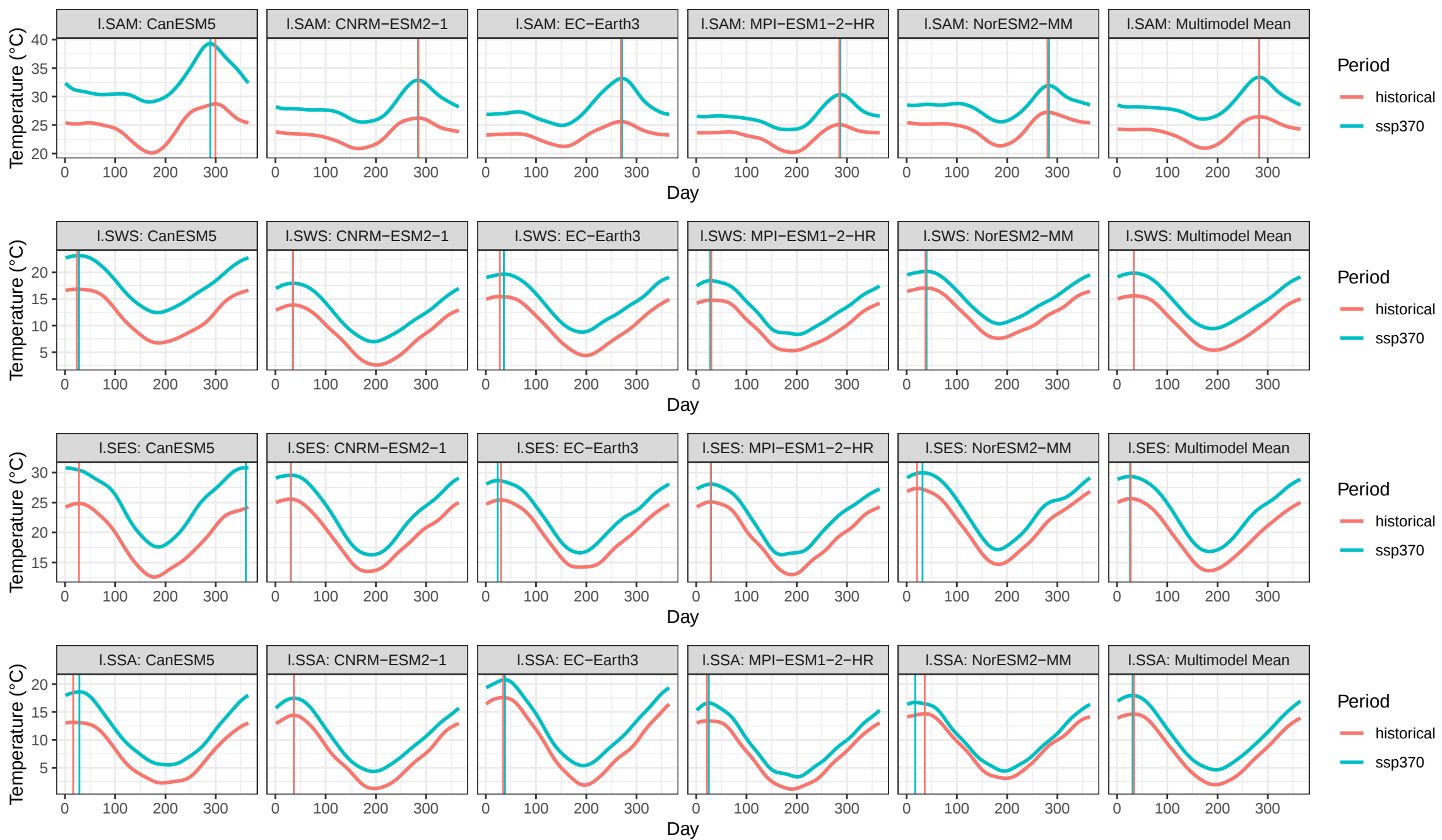


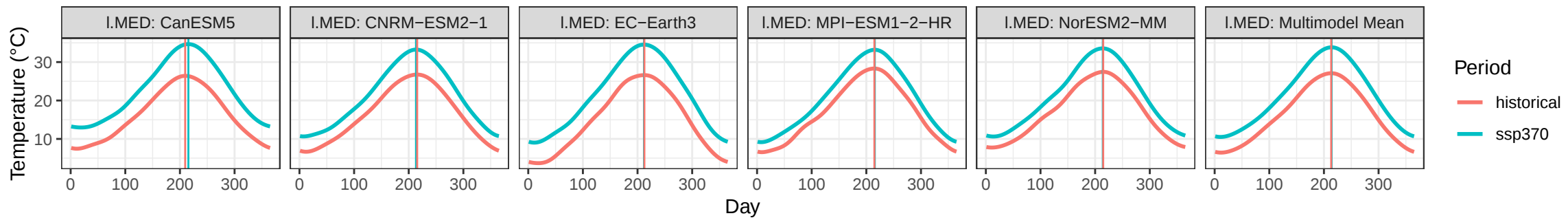
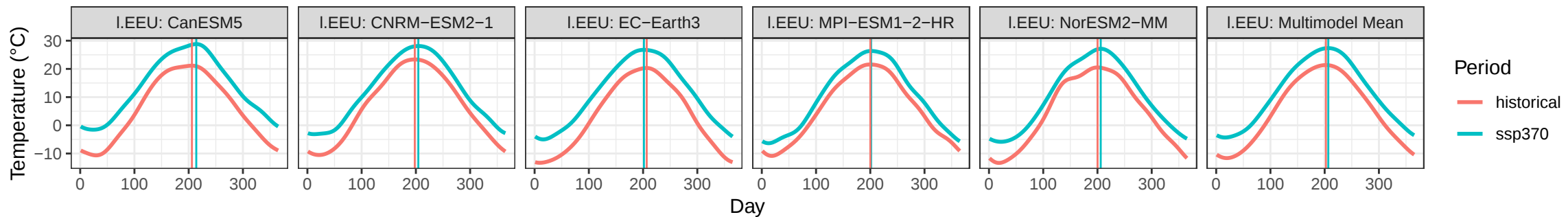
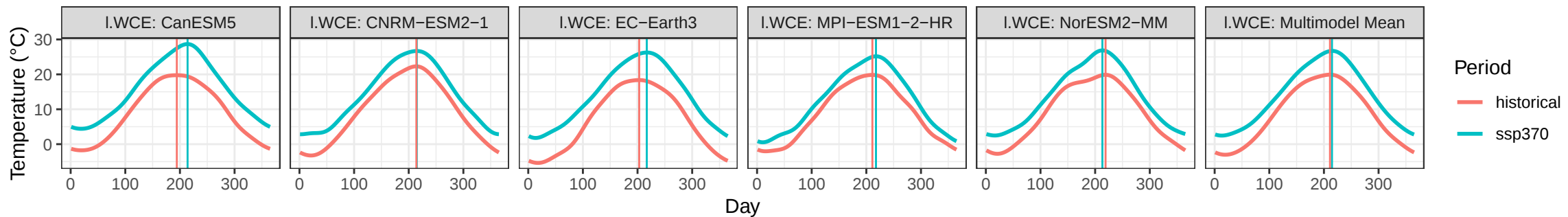
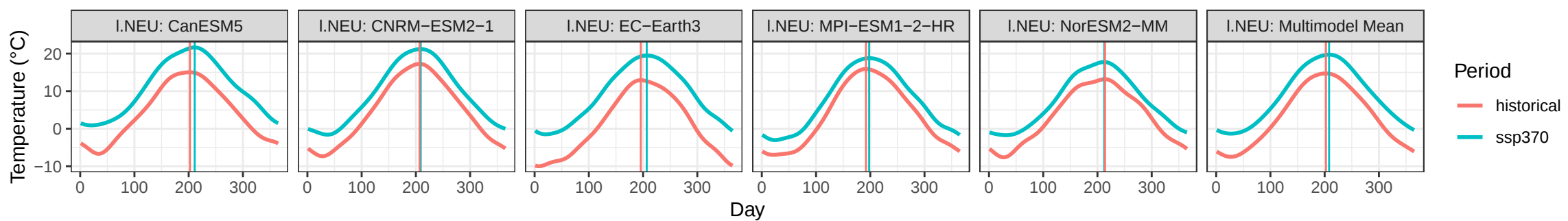
Figure S4: The smoothed annual cycle curves in the future and reference periods of 2071-2100 (ssp370, blue curve) and 1961-1990 (historical, red curve). Plots for five selected CMIP6 ESMs and their multi-model mean are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. Positions of the annual cycle maxima in the two periods are denoted by the vertical lines. The results shown in this figure are summarized in Fig. 6 in the manuscript.

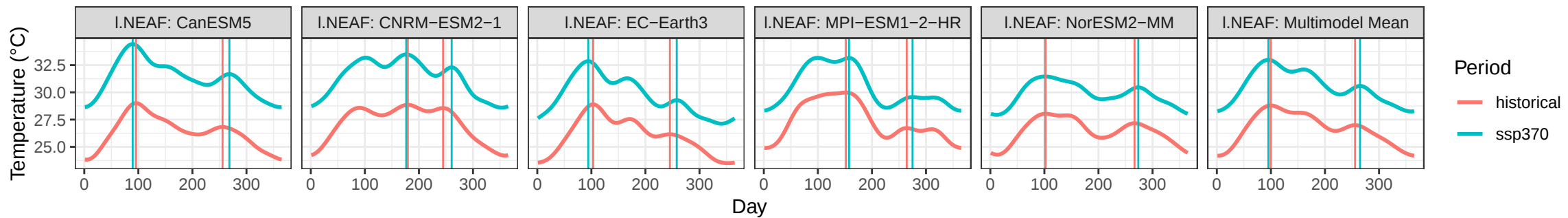
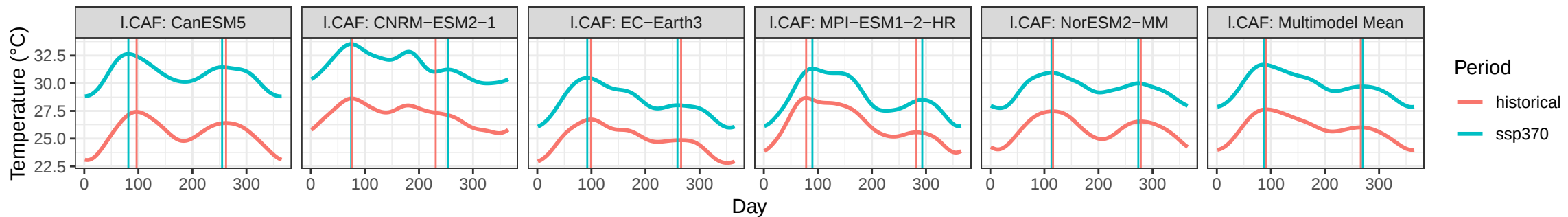
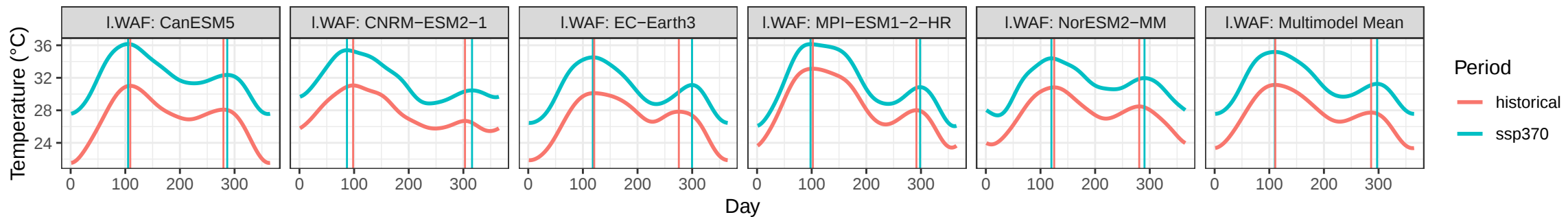
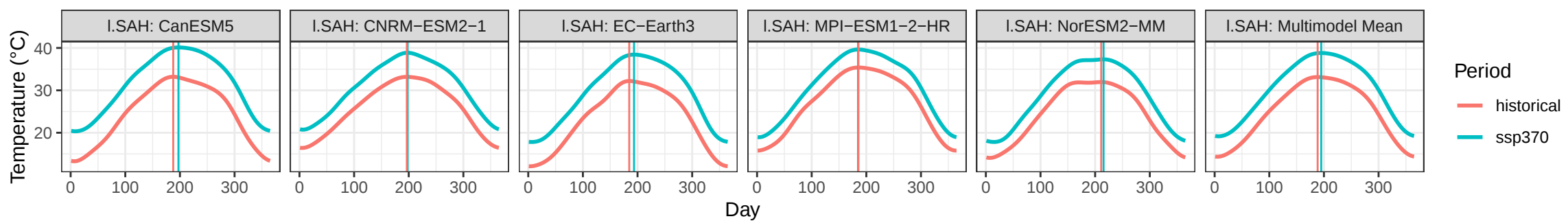


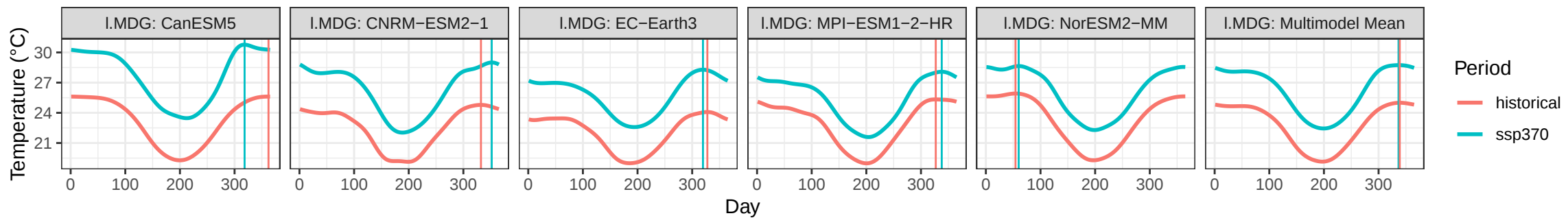
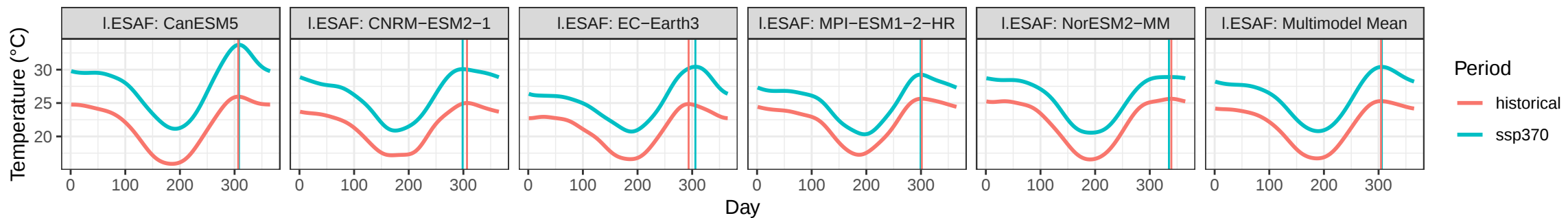
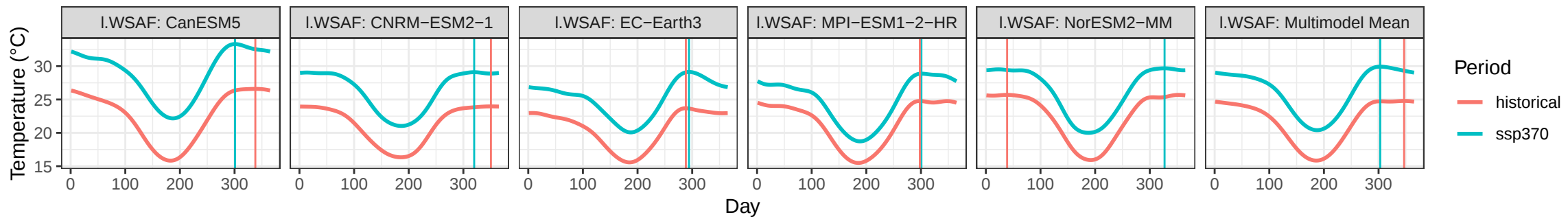
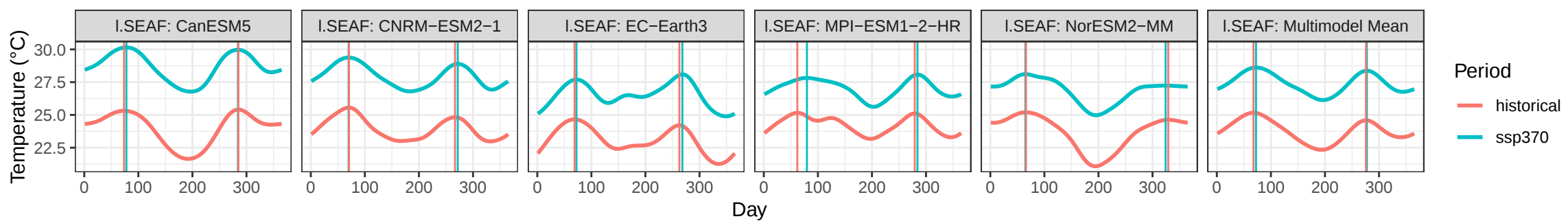


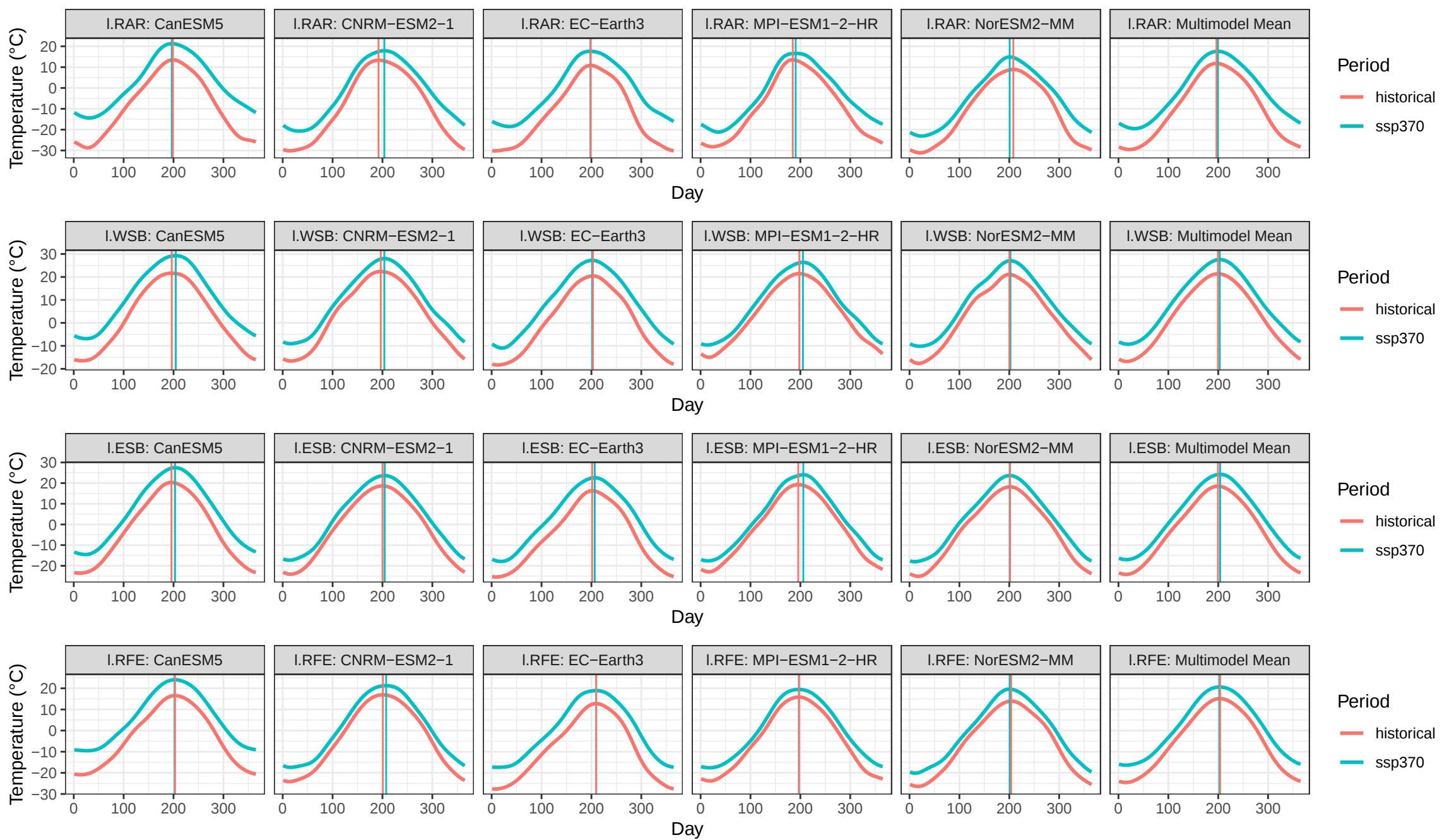


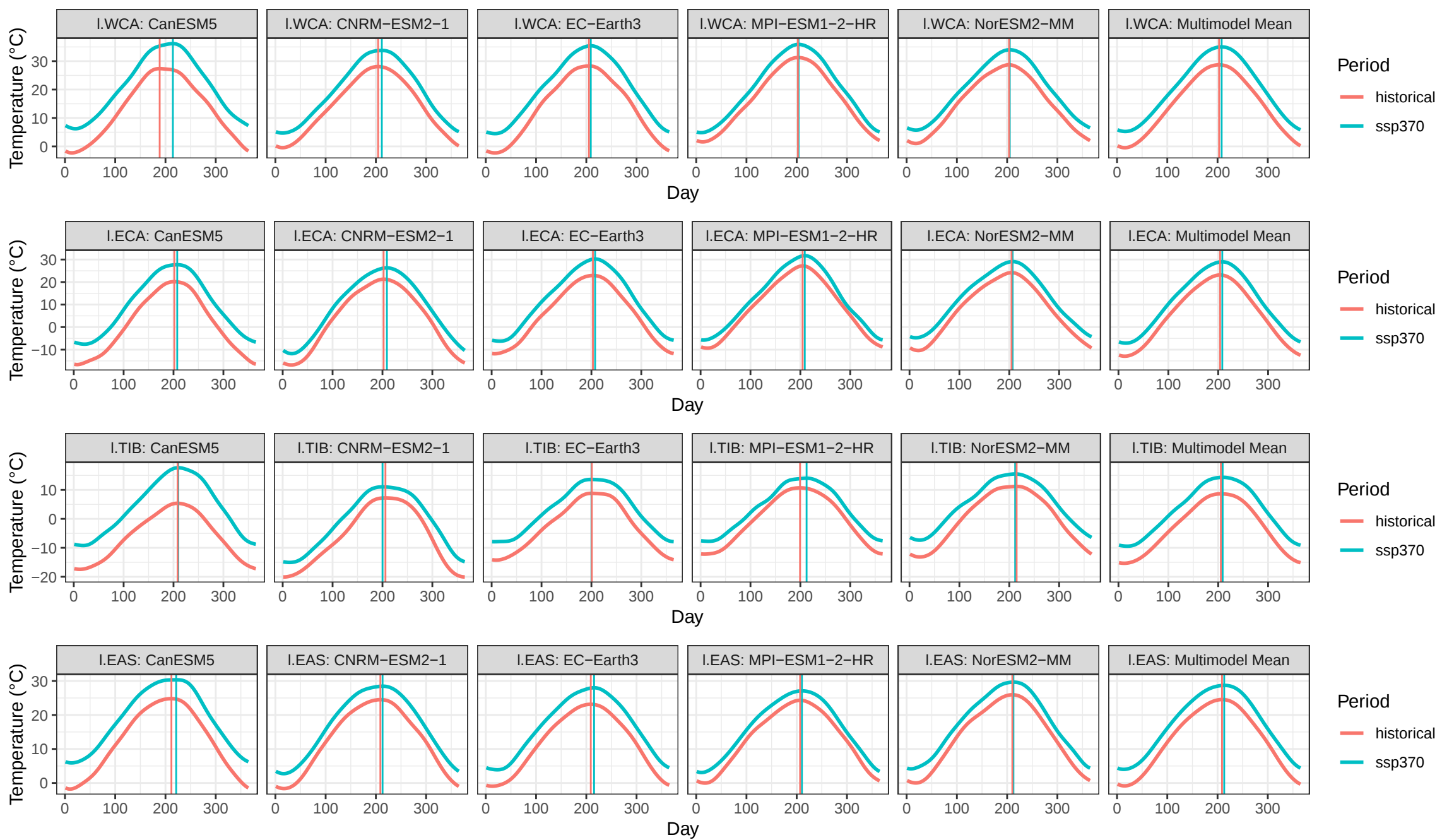


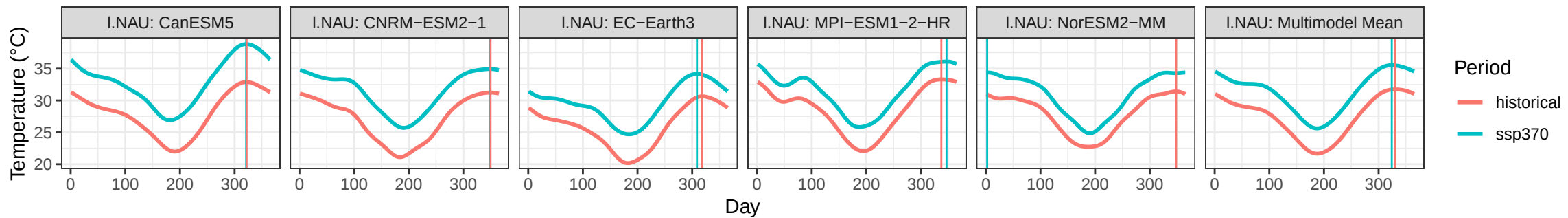
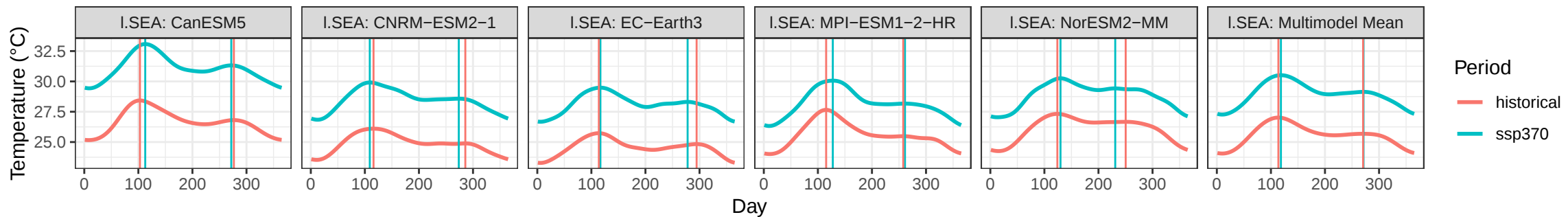
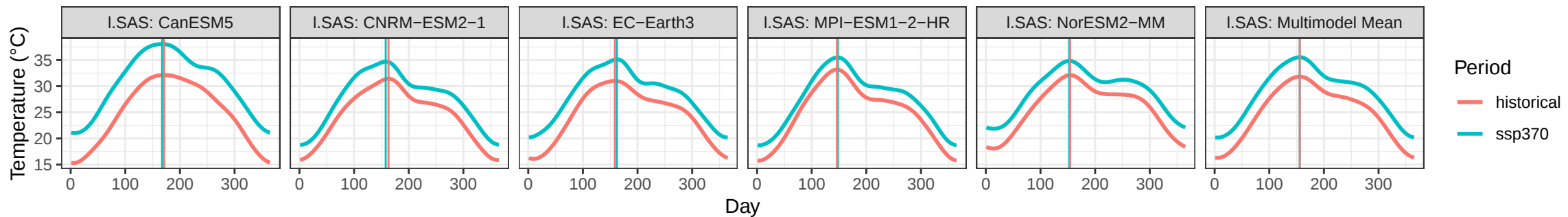
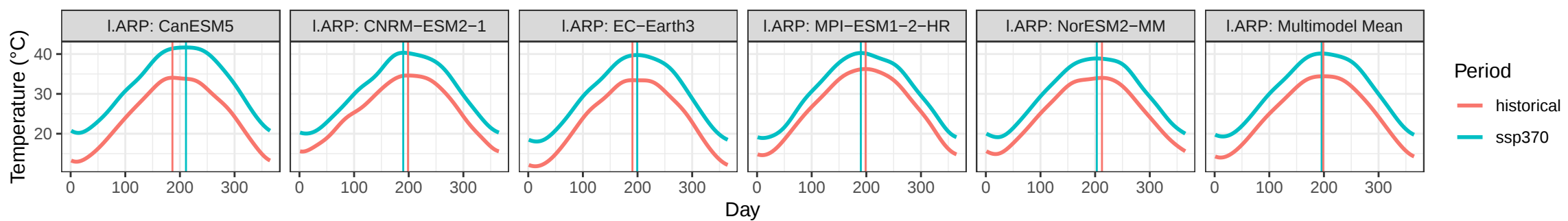


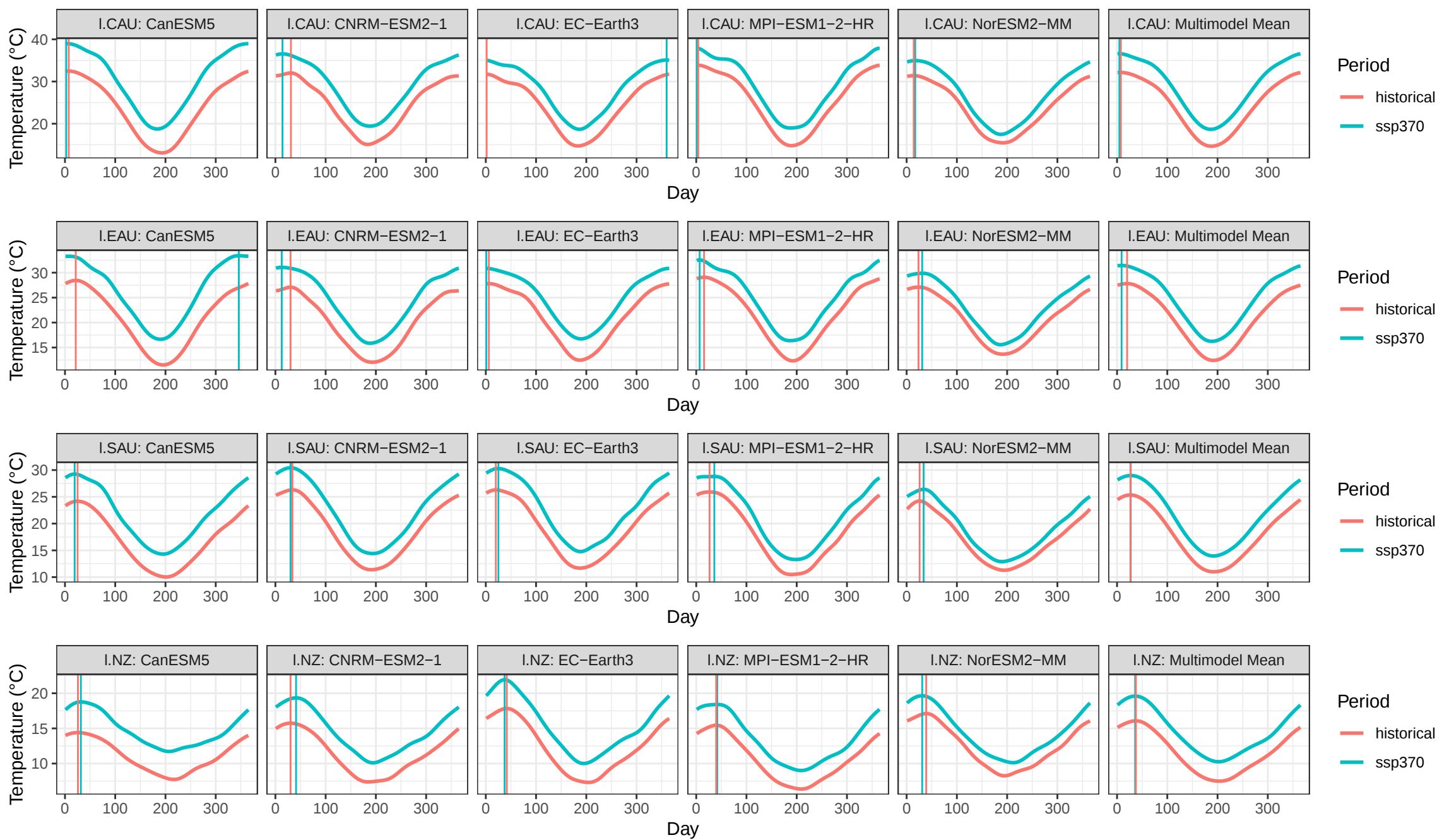


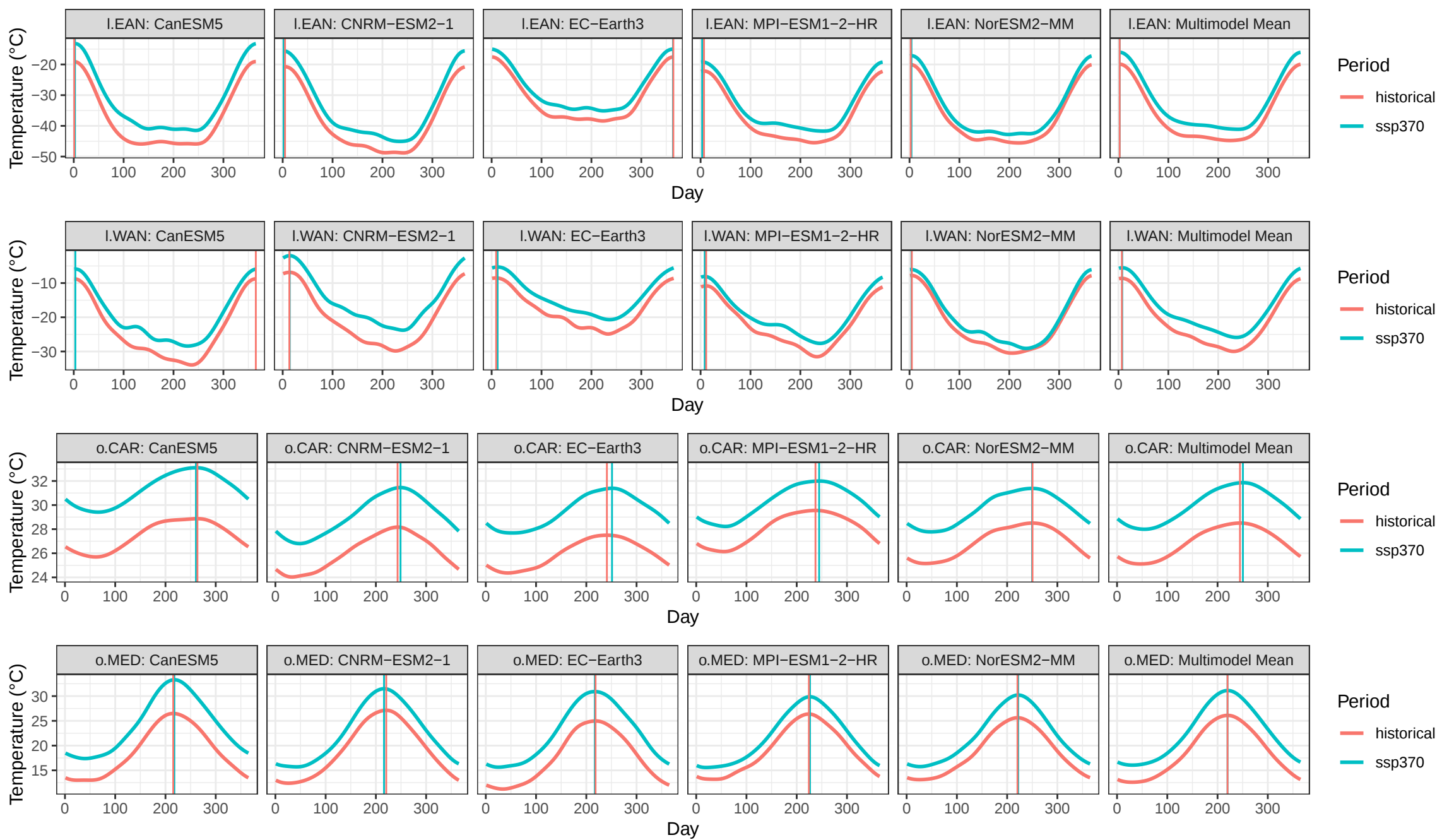


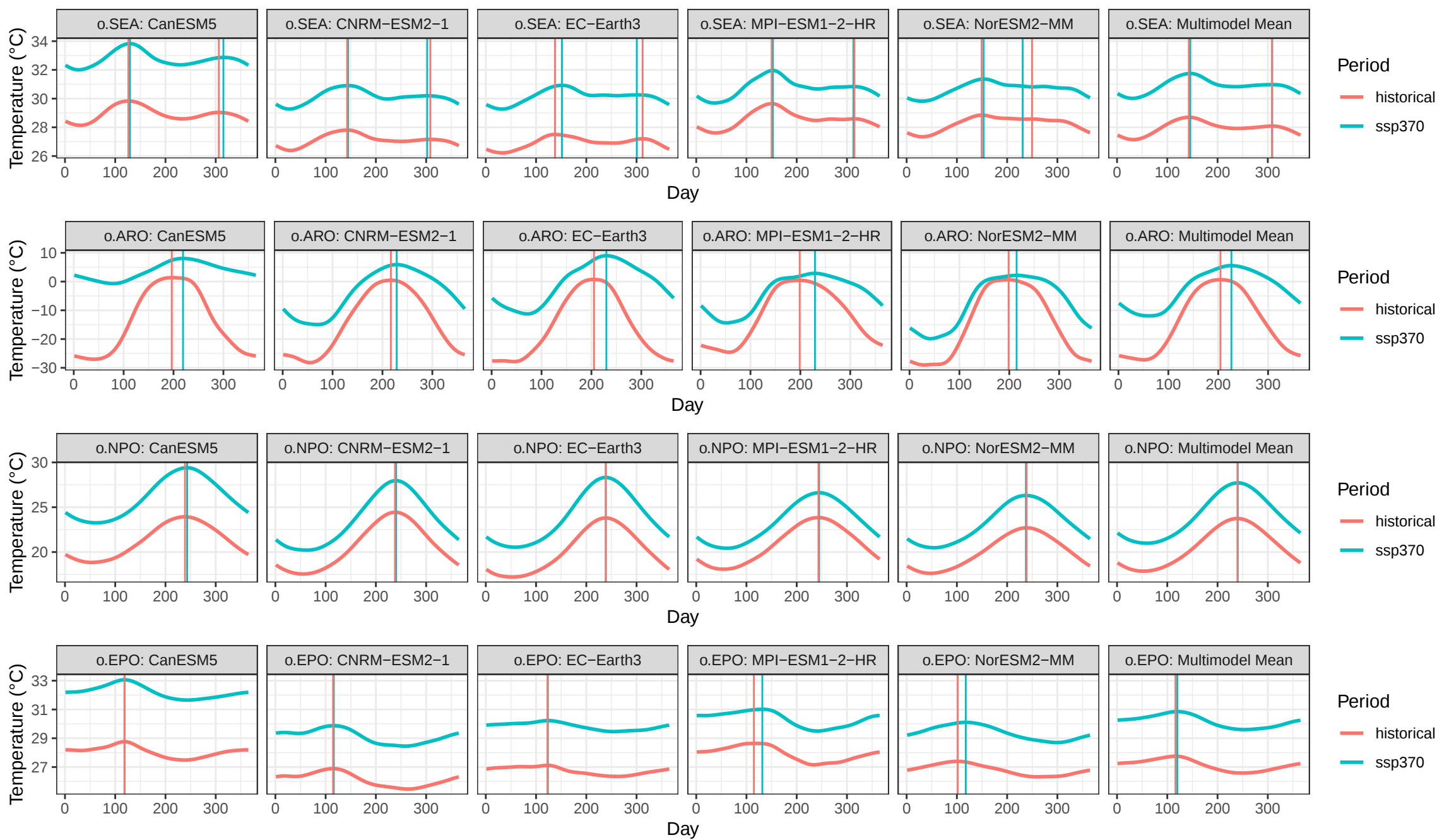


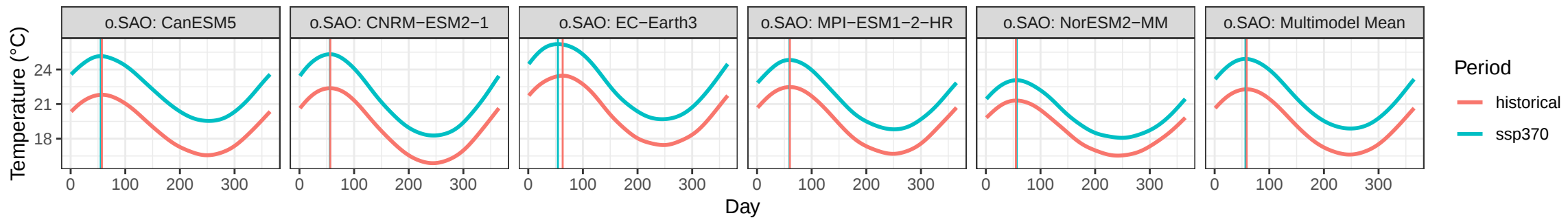
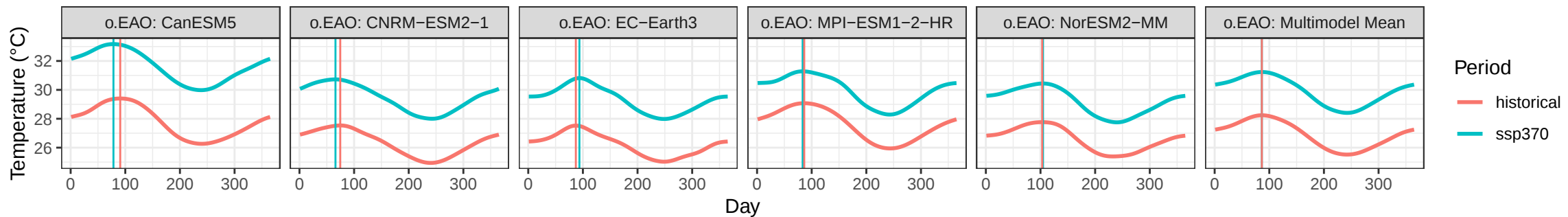
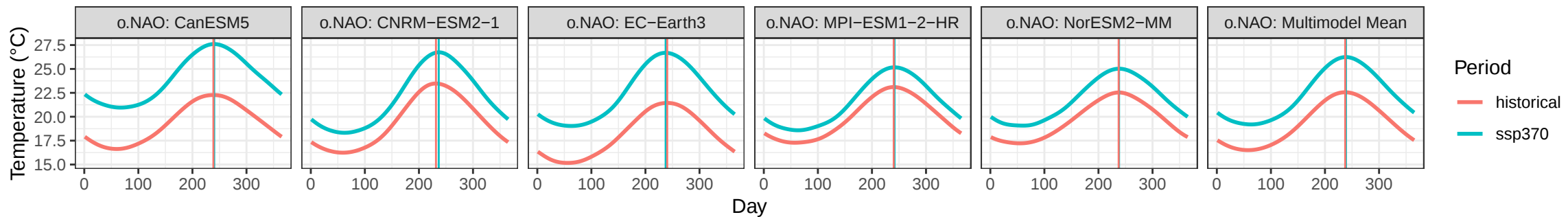
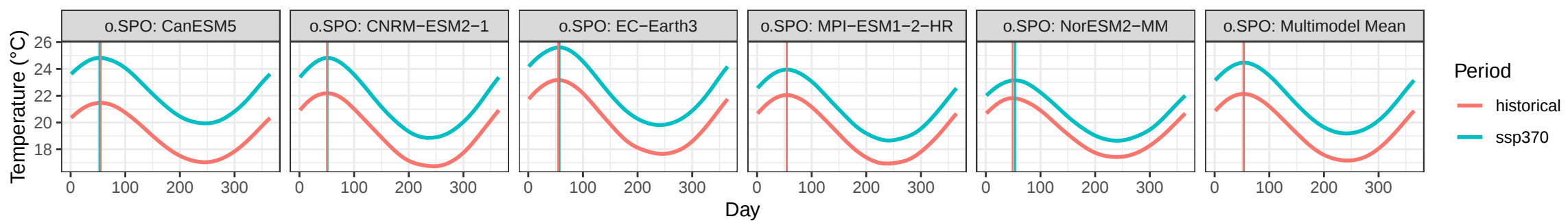


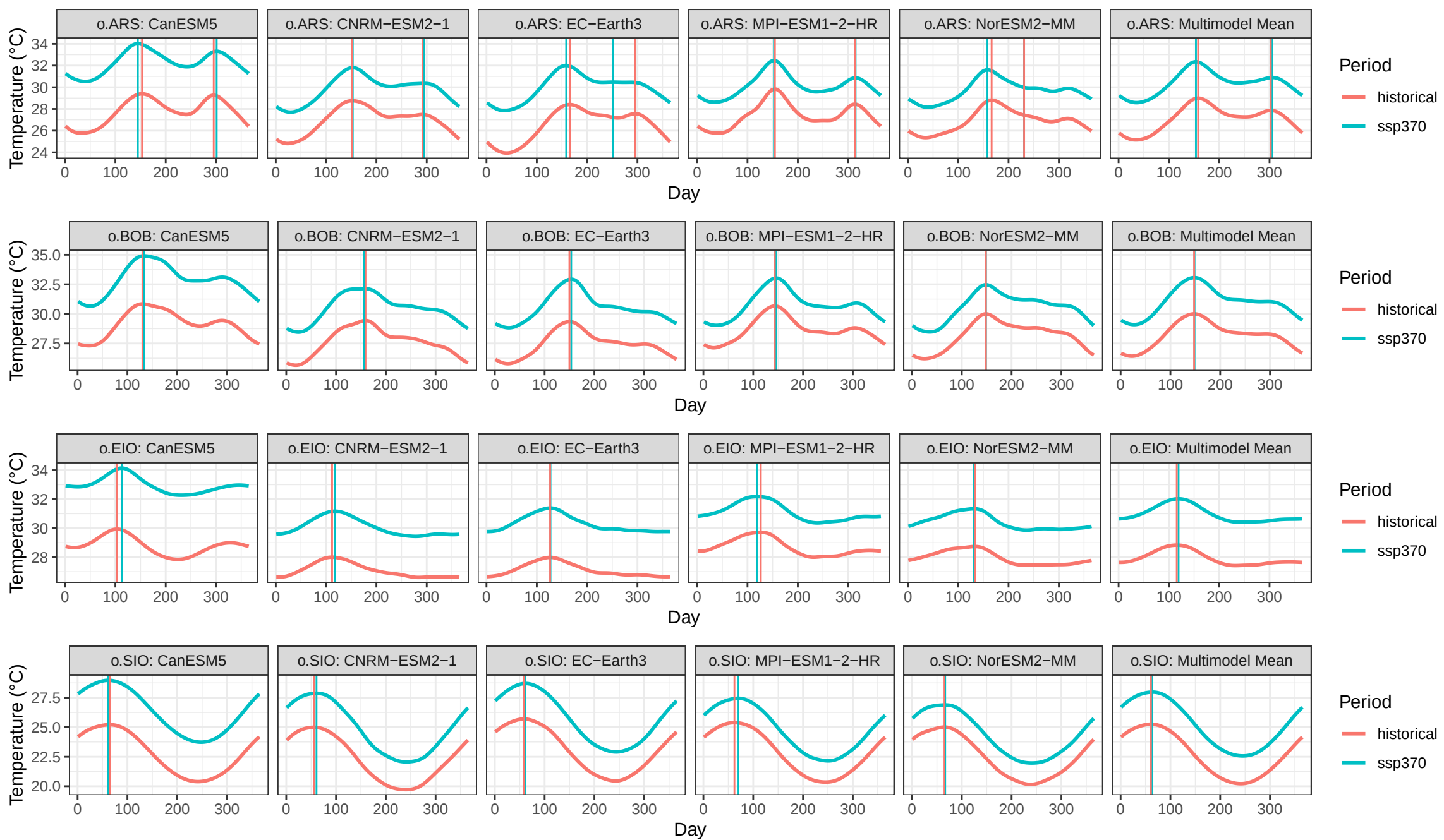












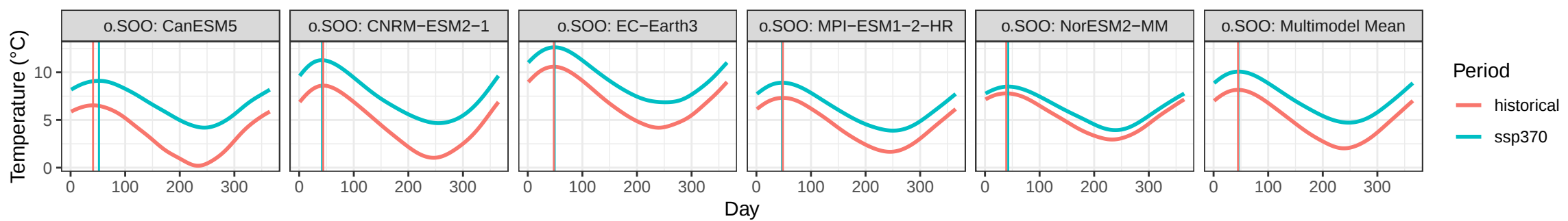
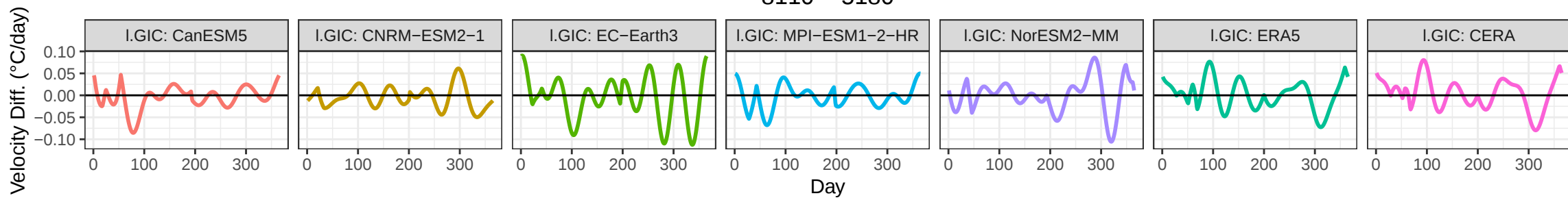
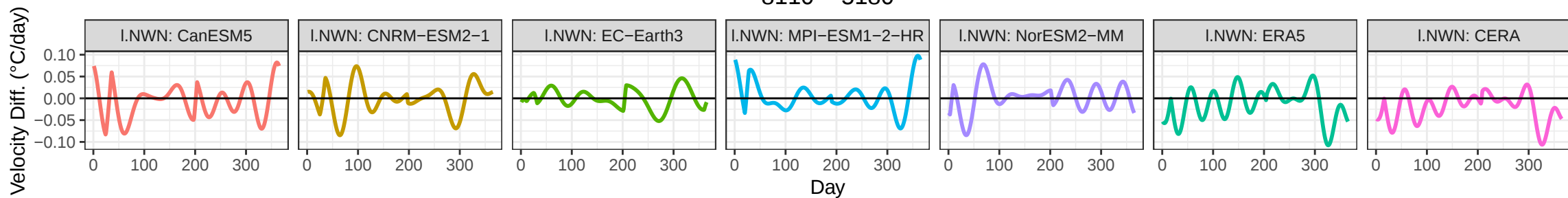


Figure S5: The distances between the first derivatives of the smoothed annual cycle curves in the two historical periods 1981-2010 and 1951-1980. Plots for five selected CMIP6 ESMs and two reanalyses are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. The results shown in this figure are summarized in Fig. 7 in the manuscript.

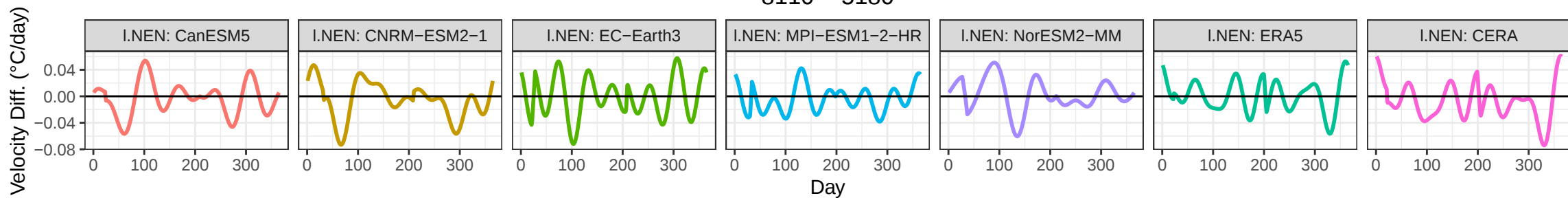
8110 – 5180



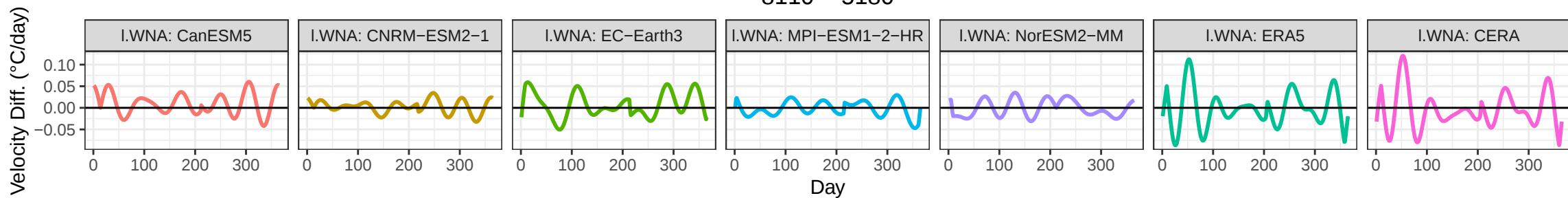
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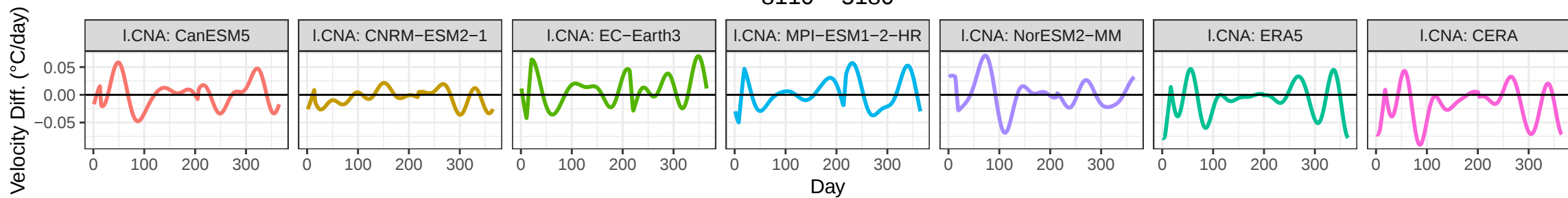
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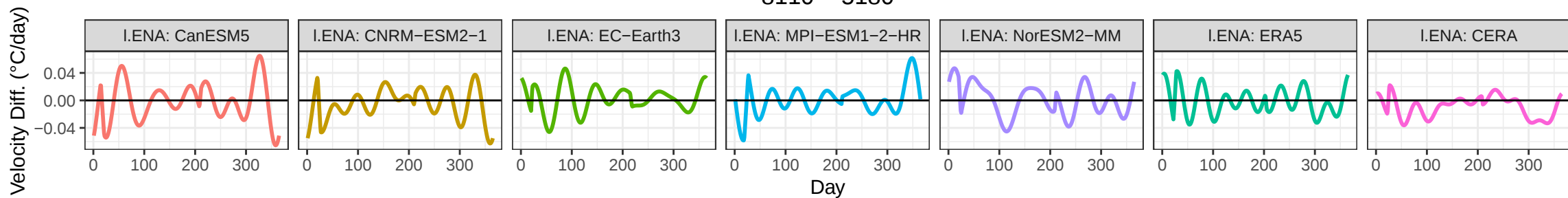
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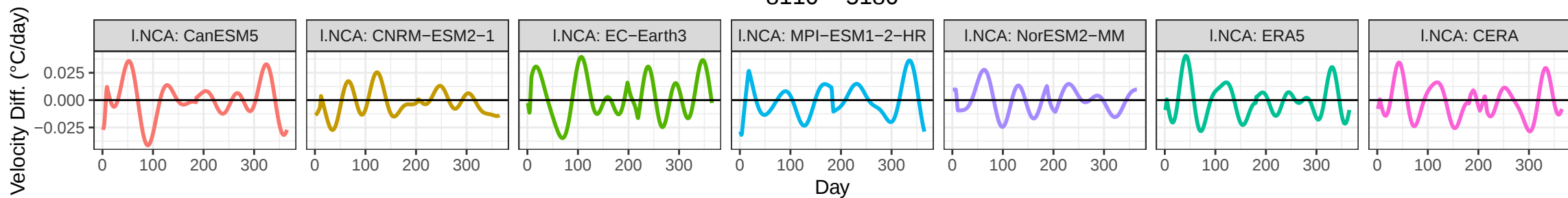
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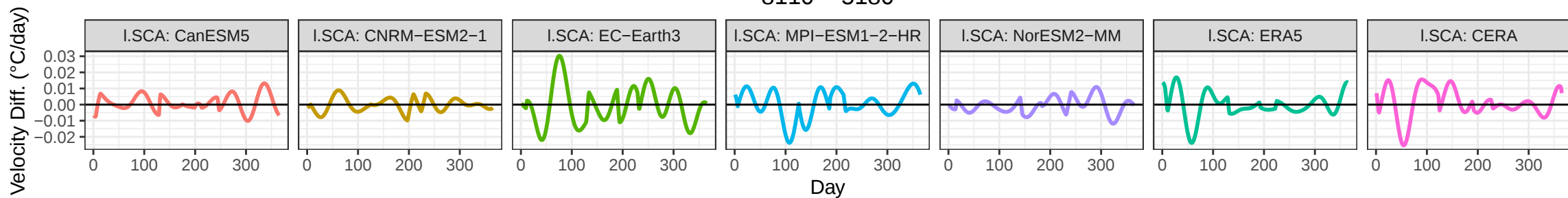
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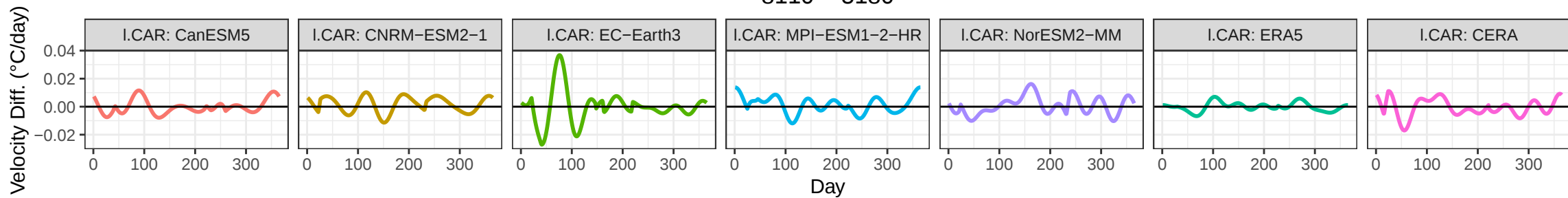
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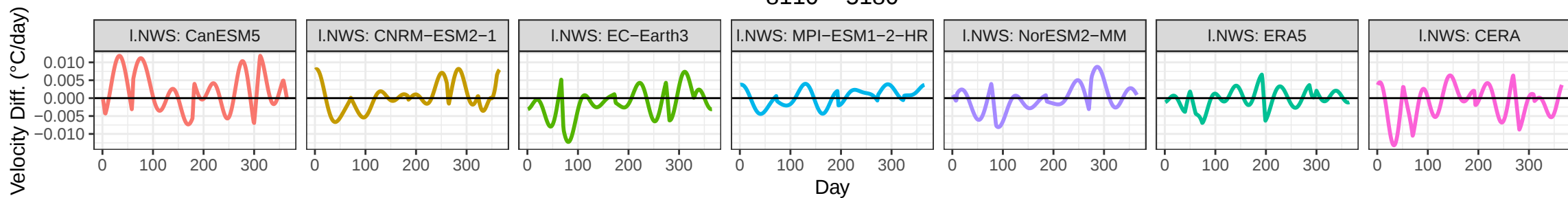
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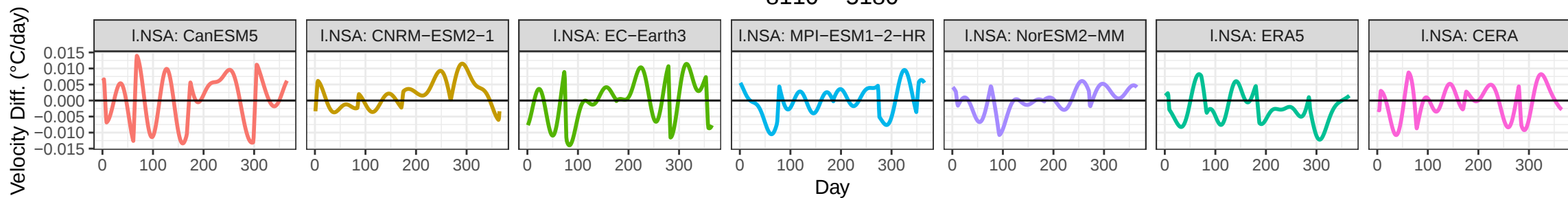
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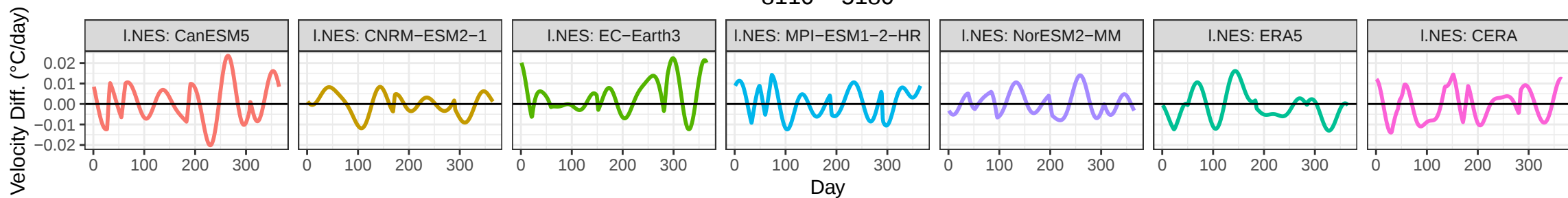
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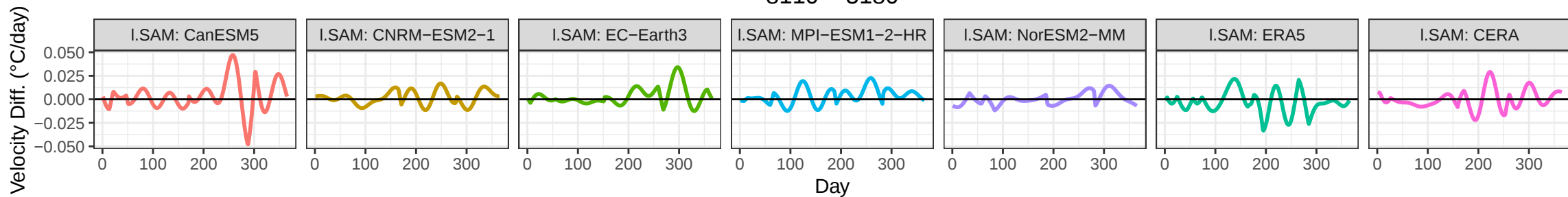
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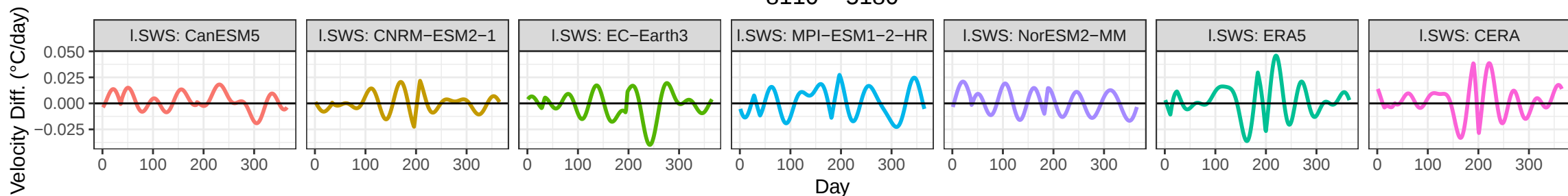
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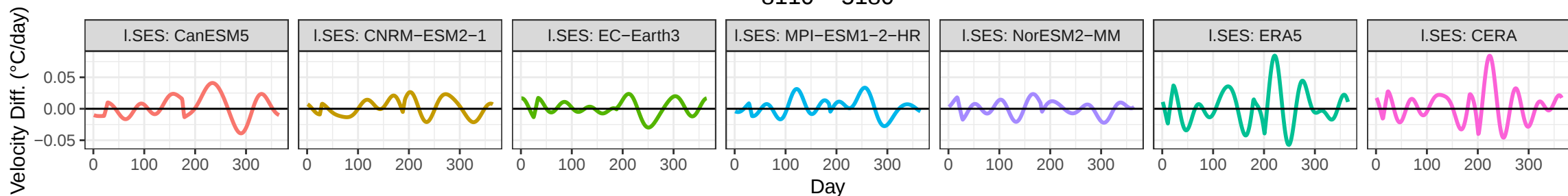
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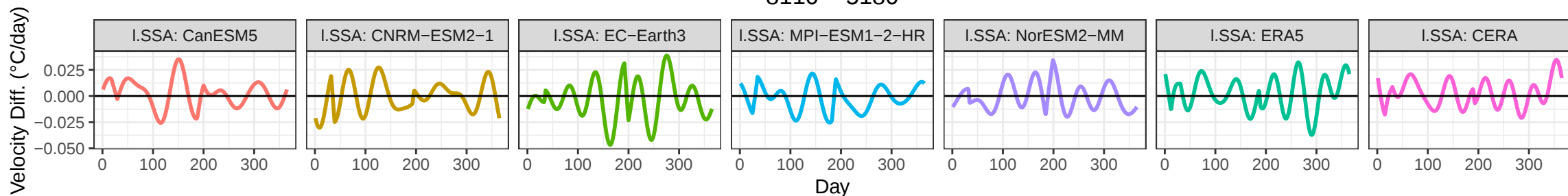
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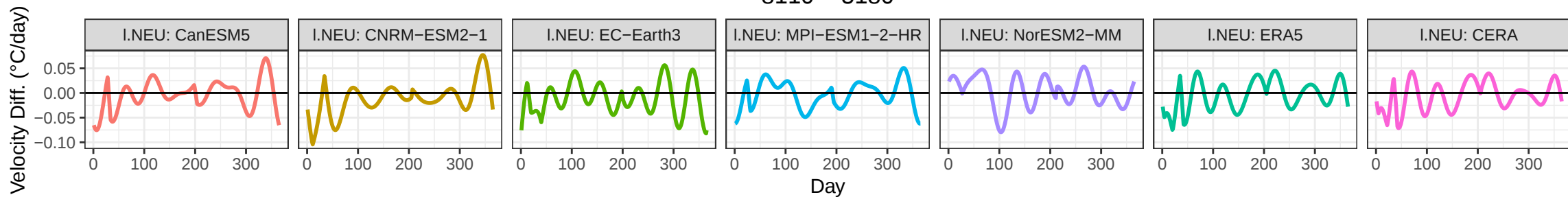
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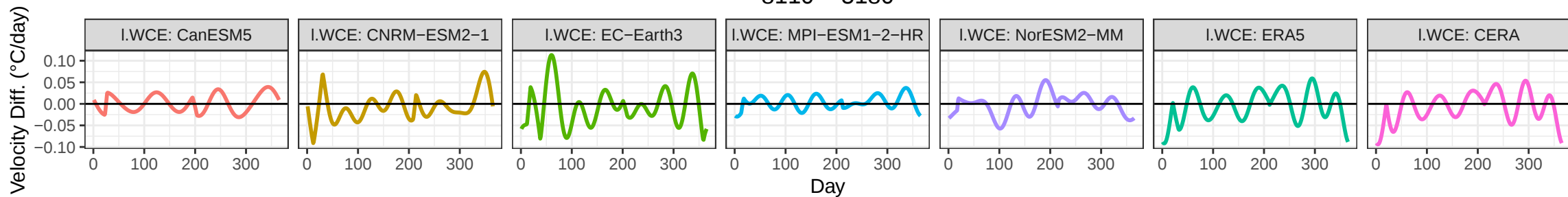
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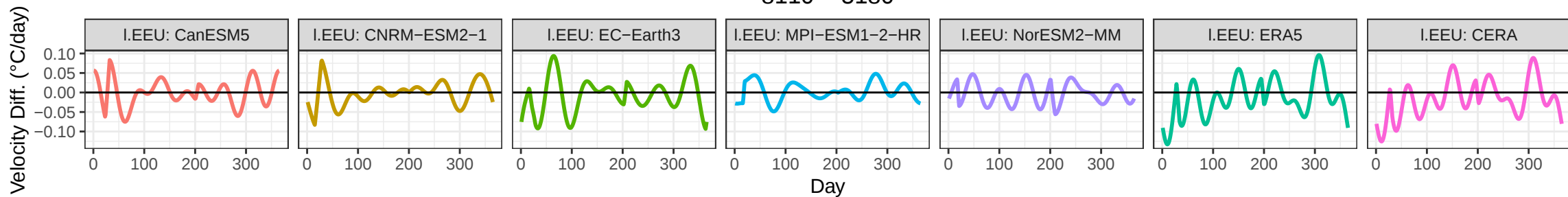
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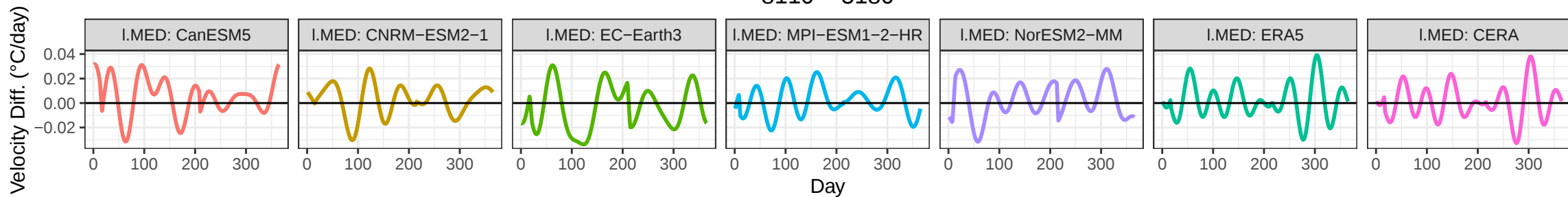
8110 – 5180



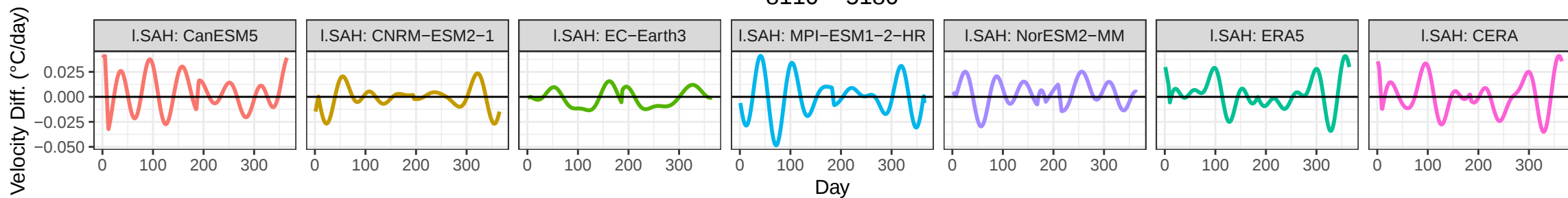
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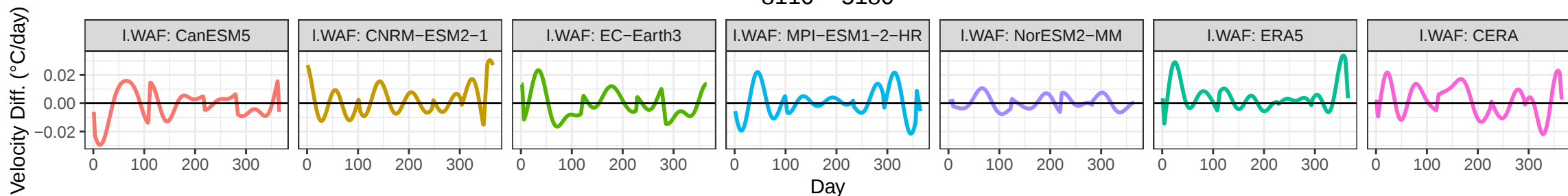
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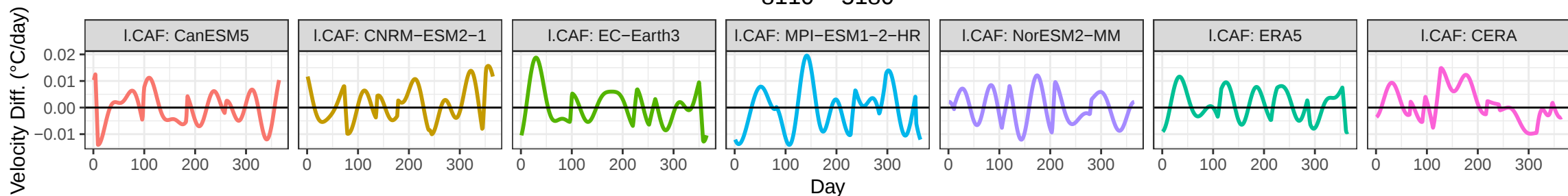
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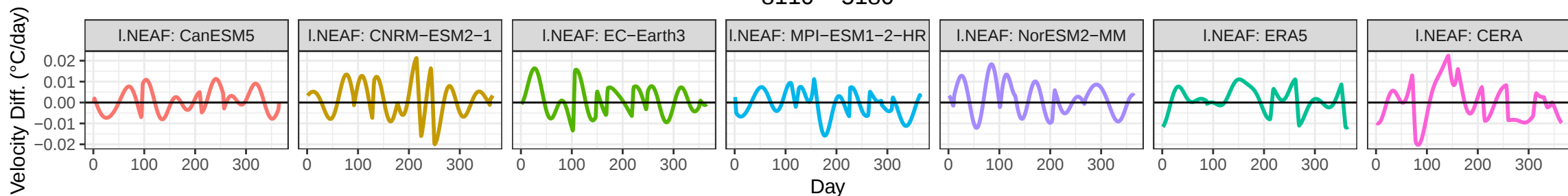
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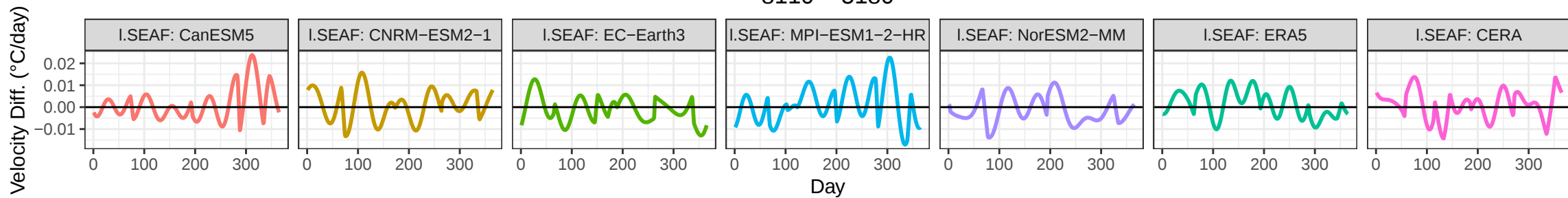
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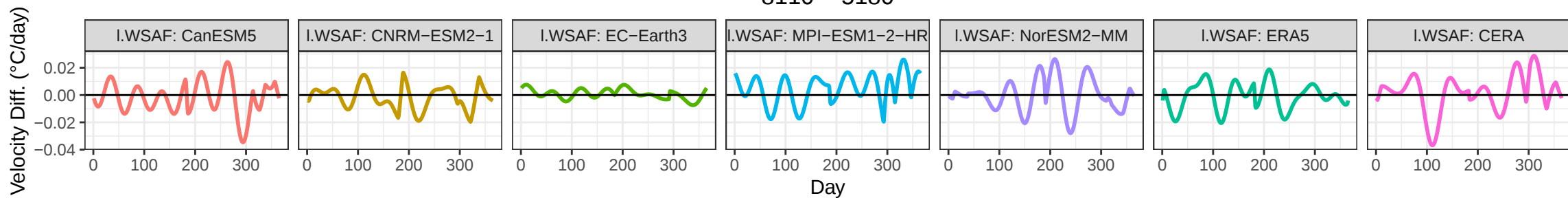
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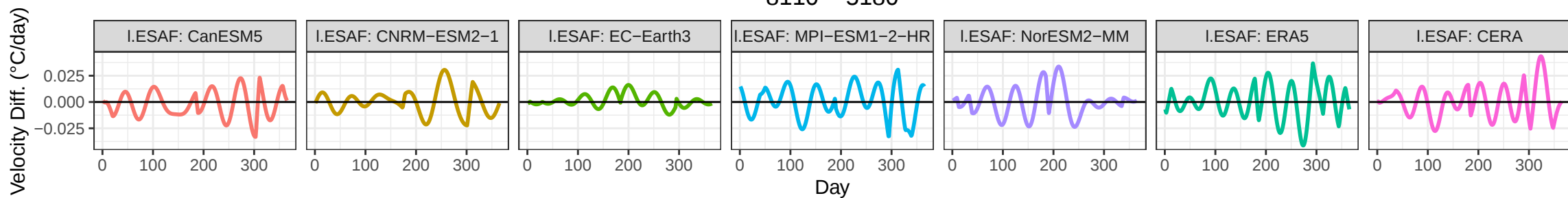
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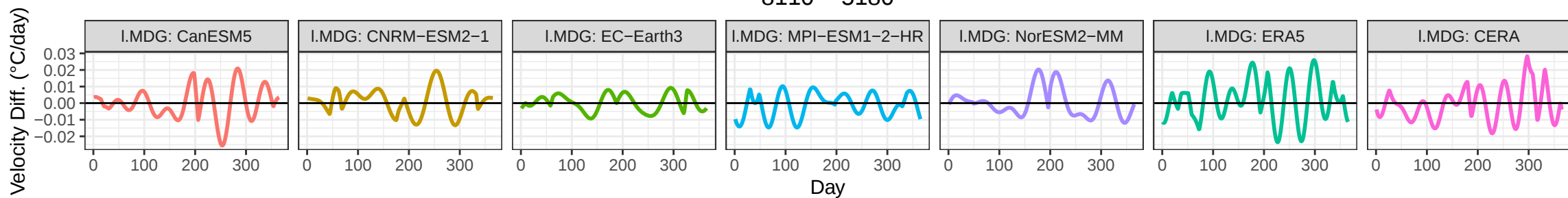
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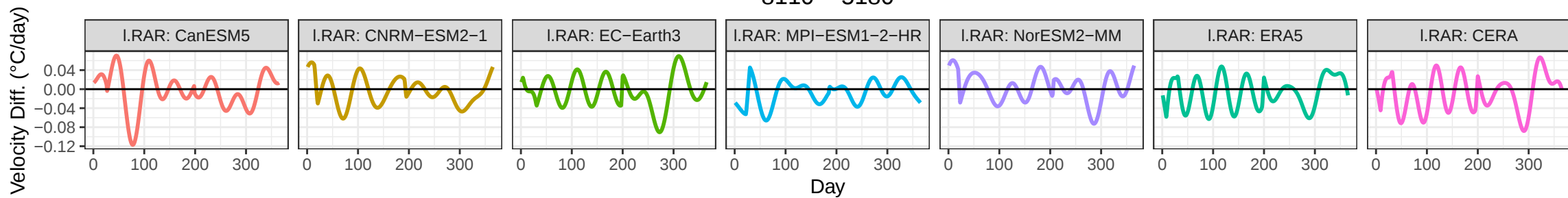
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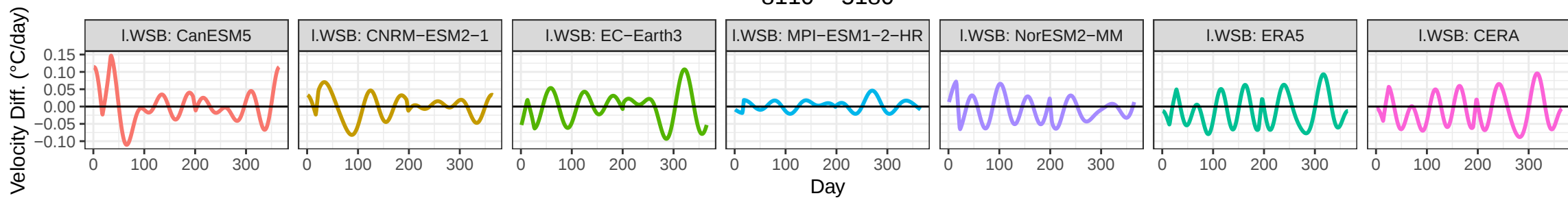
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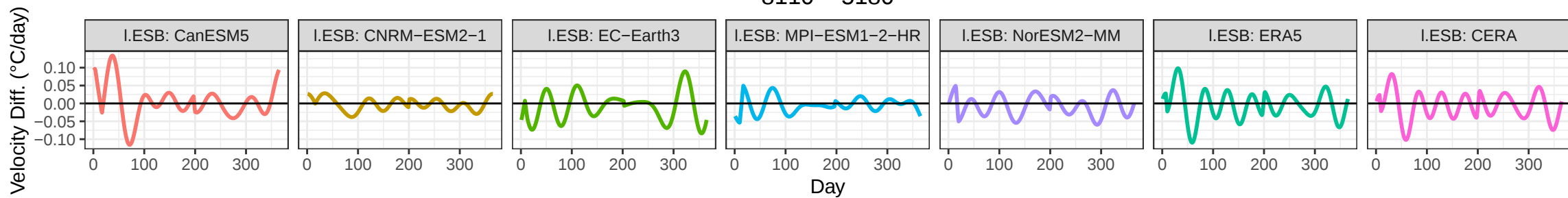
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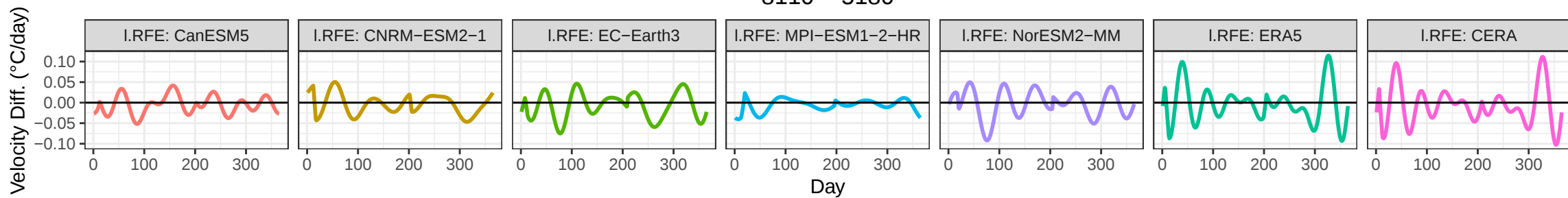
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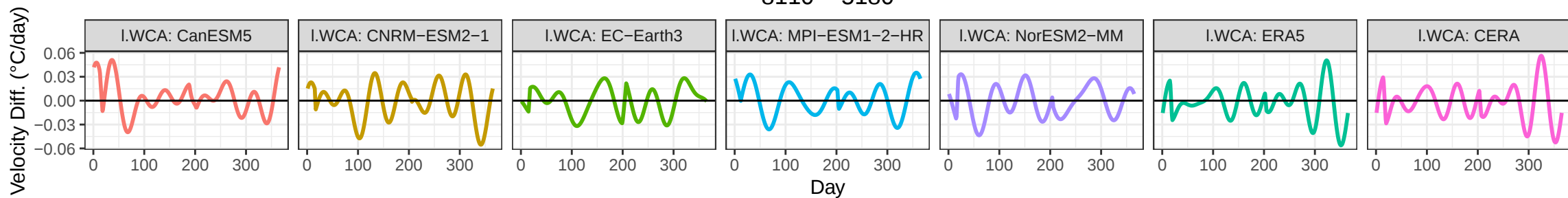
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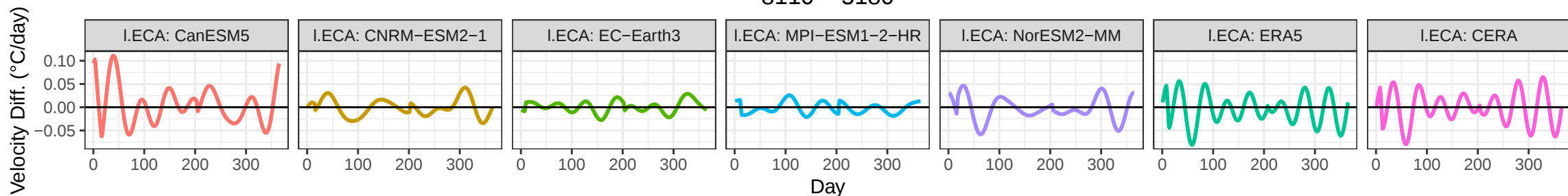
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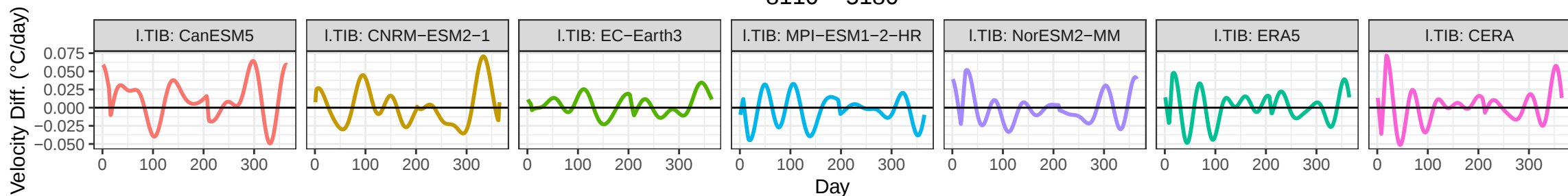
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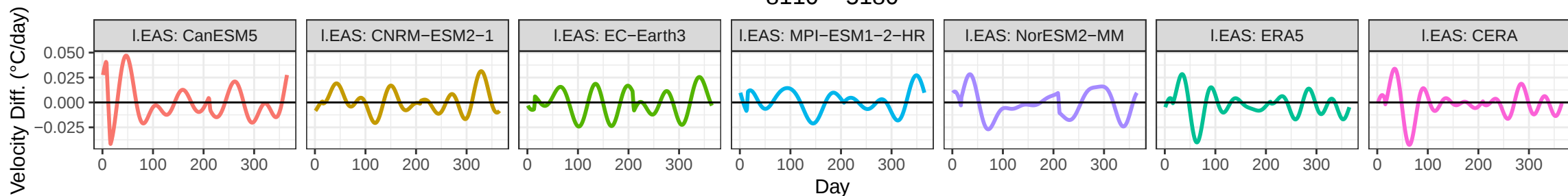
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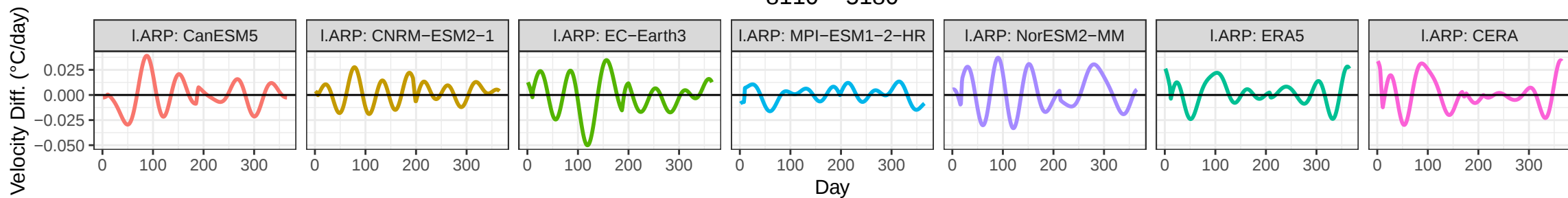
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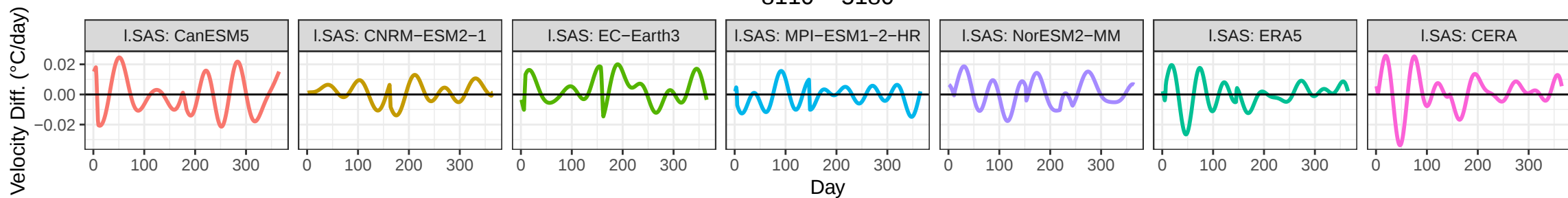
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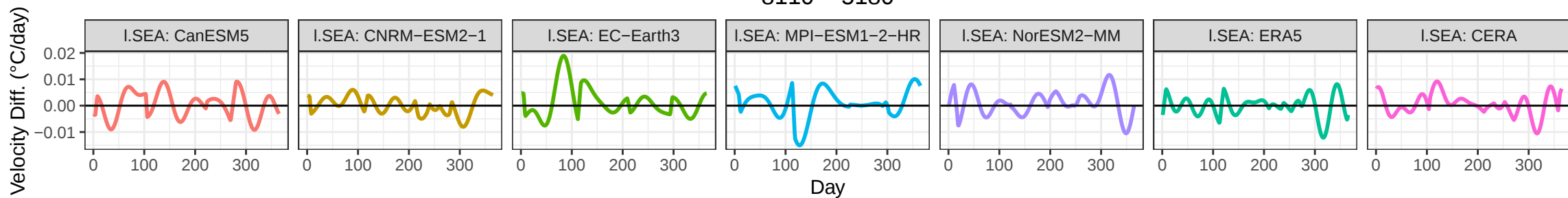
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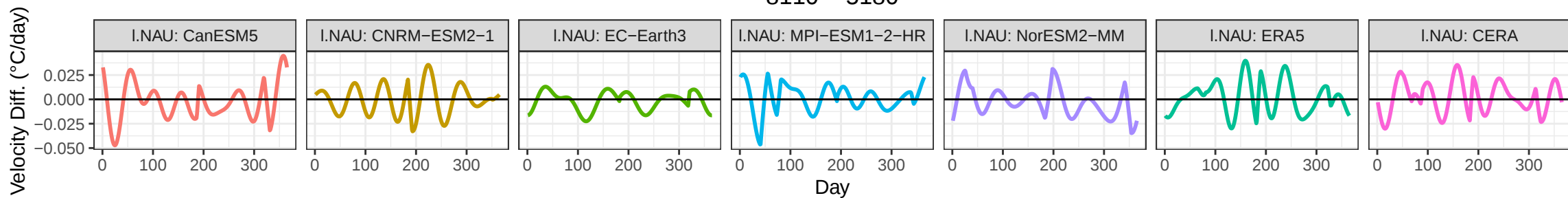
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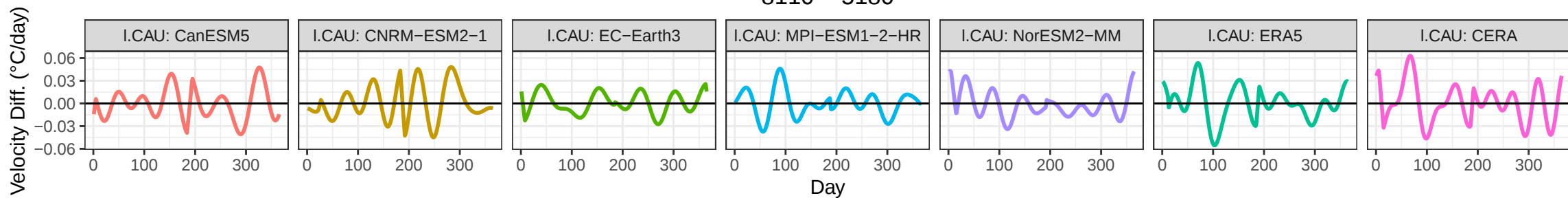
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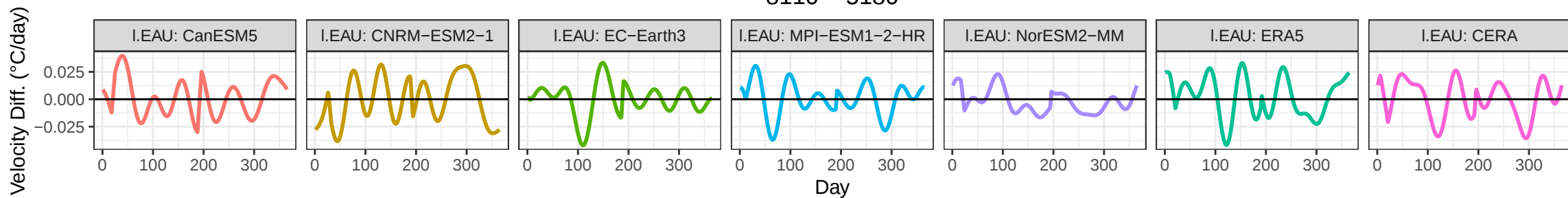
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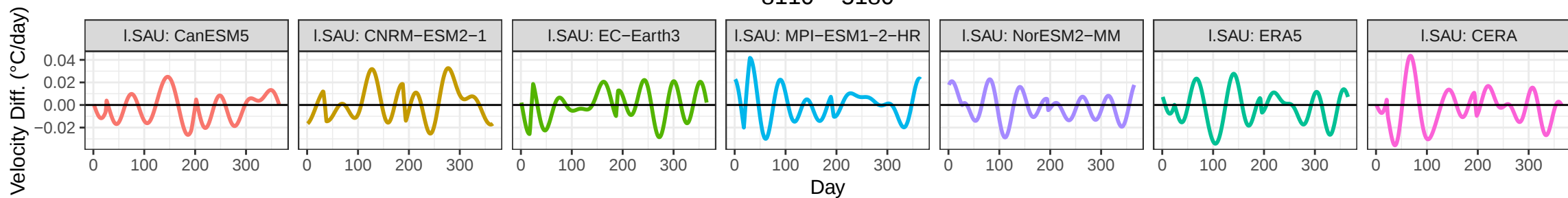
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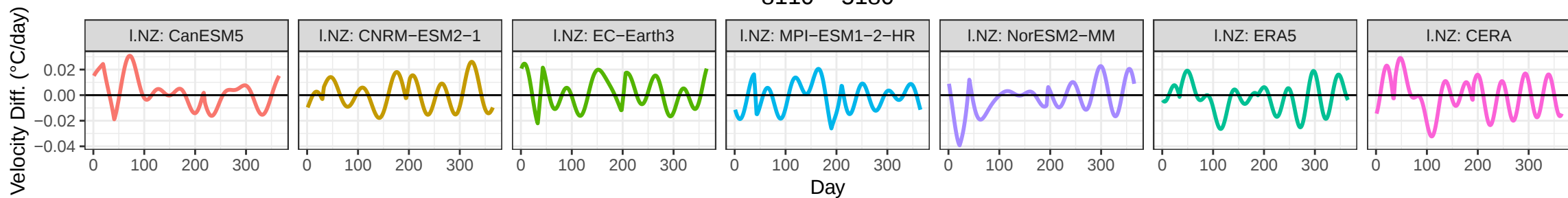
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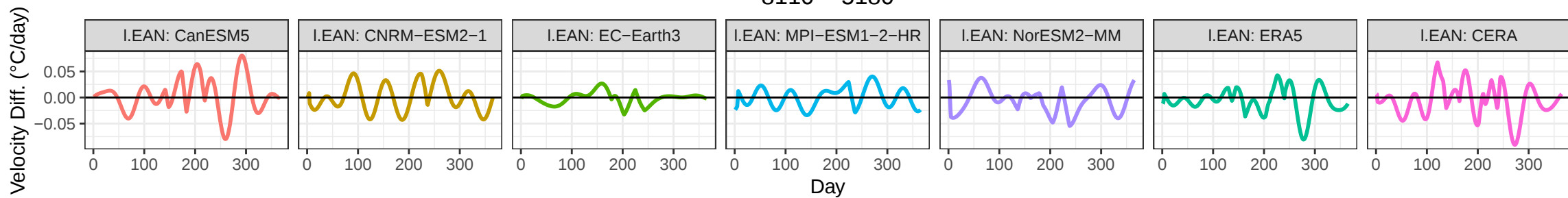
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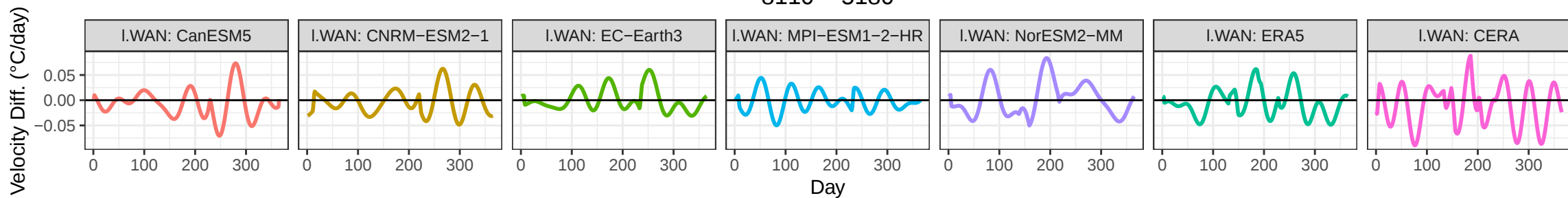
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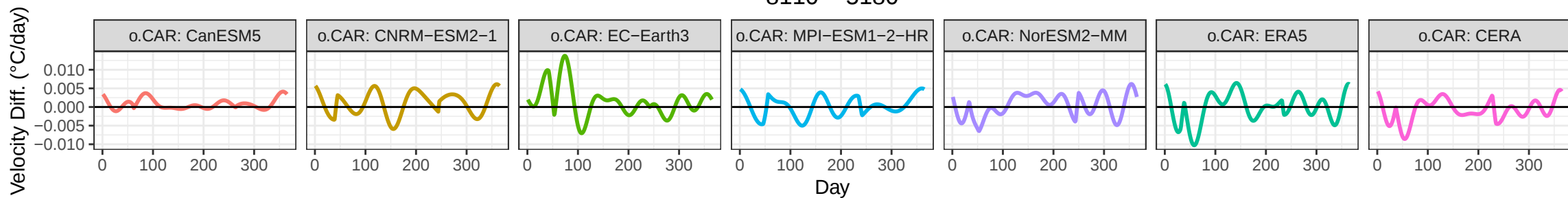
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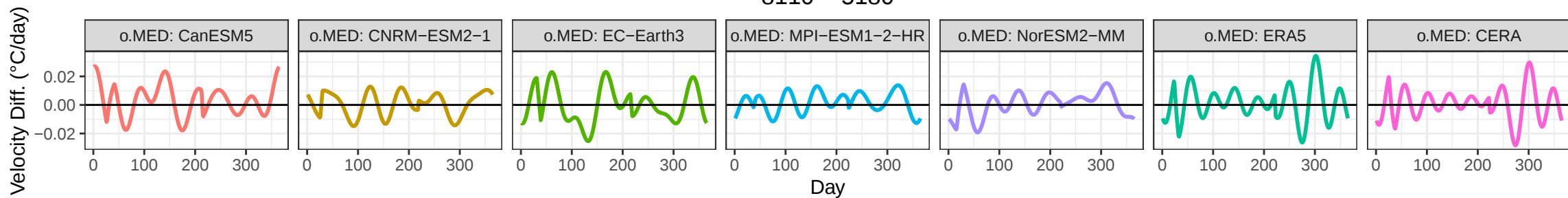
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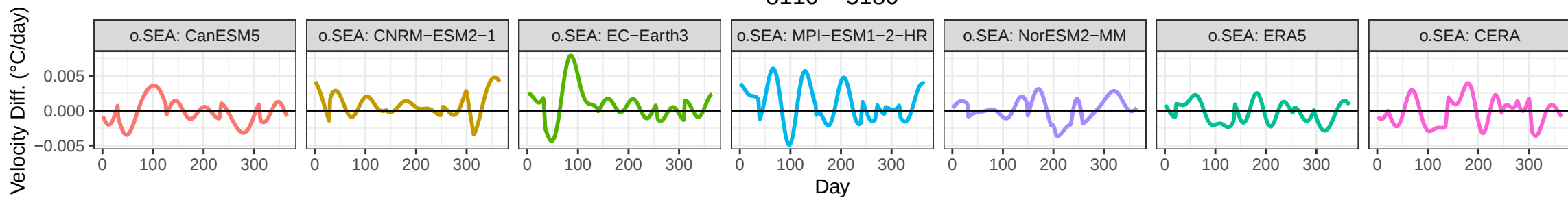
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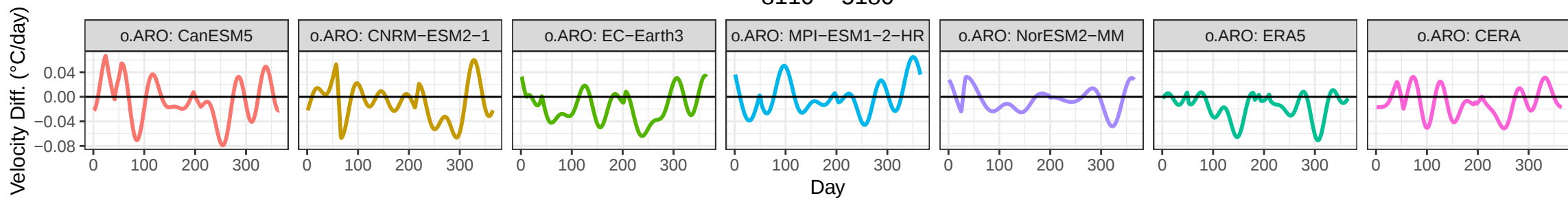
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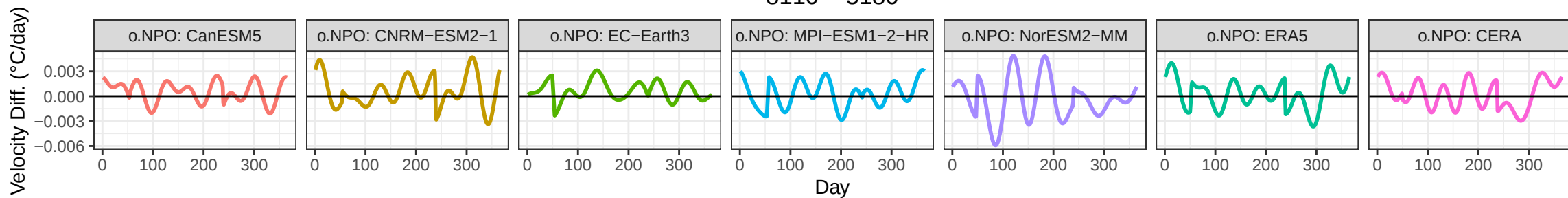
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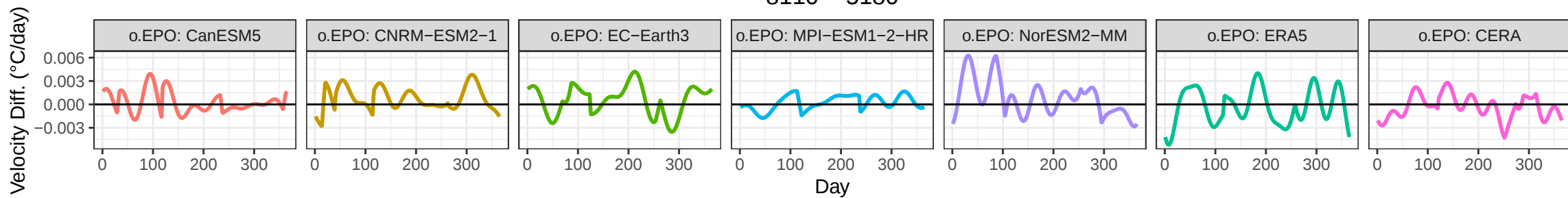
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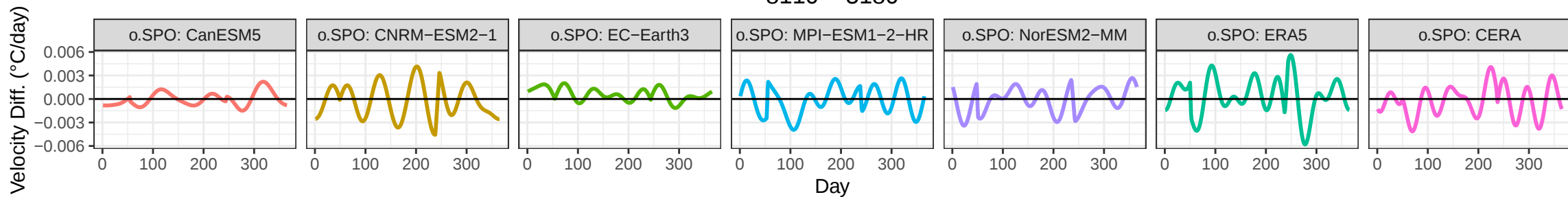
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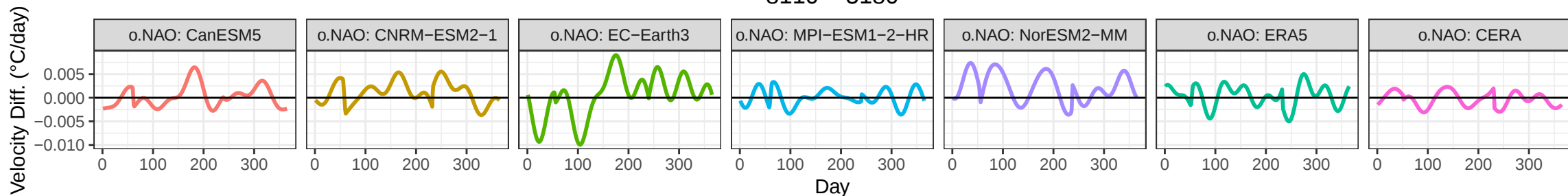
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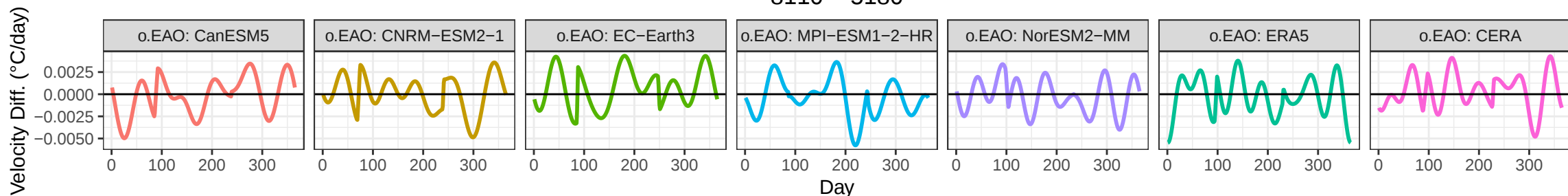
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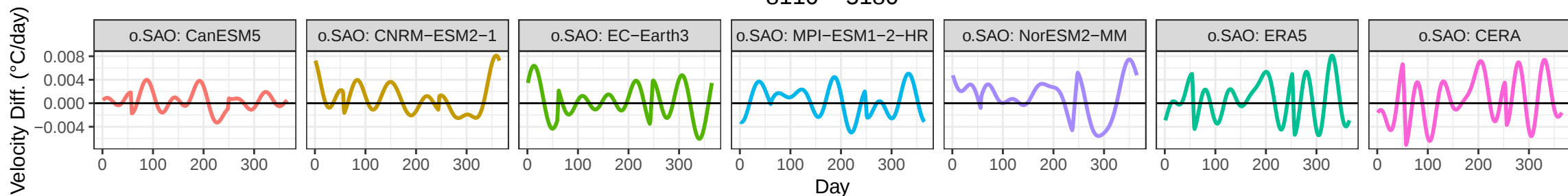
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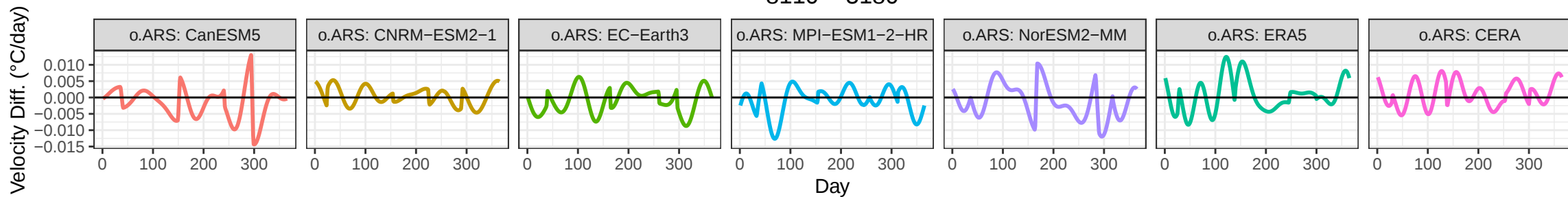
8110 – 5180



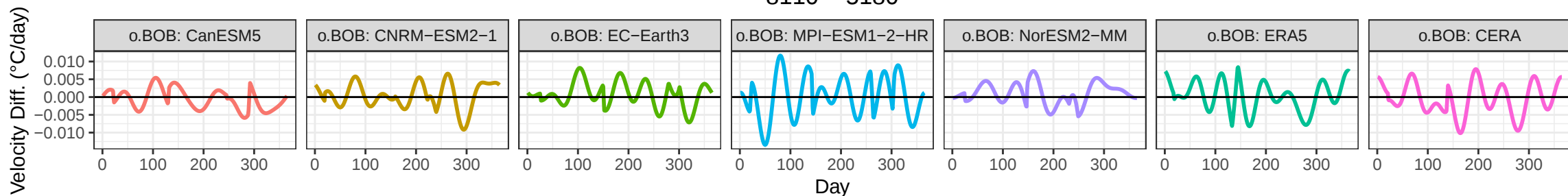
8110 – 5180



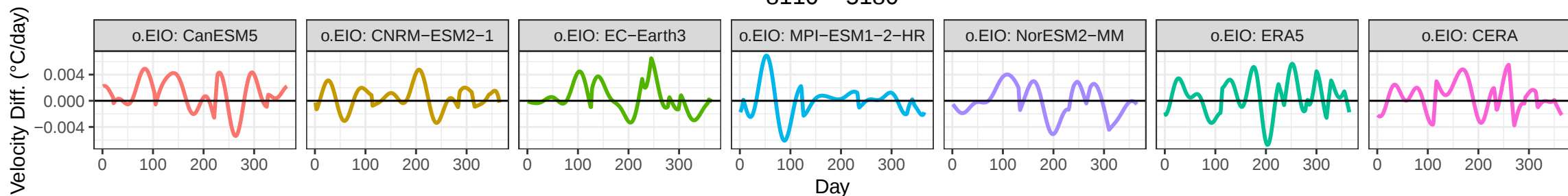
8110 – 5180



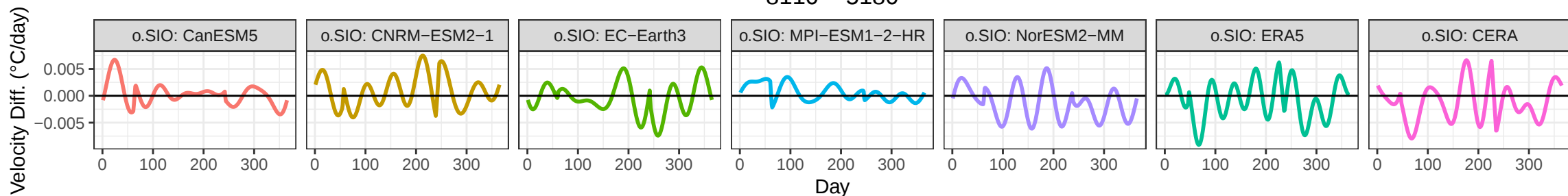
8110 – 5180



8110 – 5180



8110 – 5180



8110 – 5180

Velocity Diff. (°C/day)

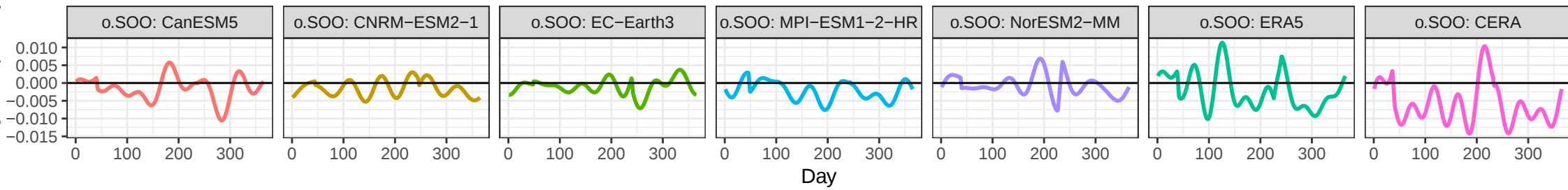
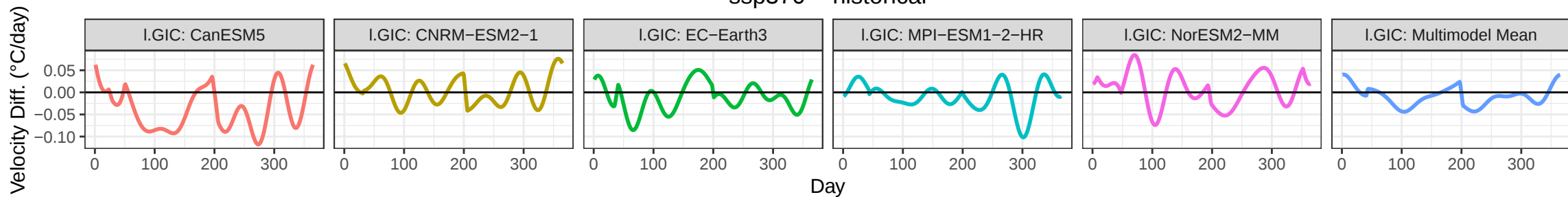
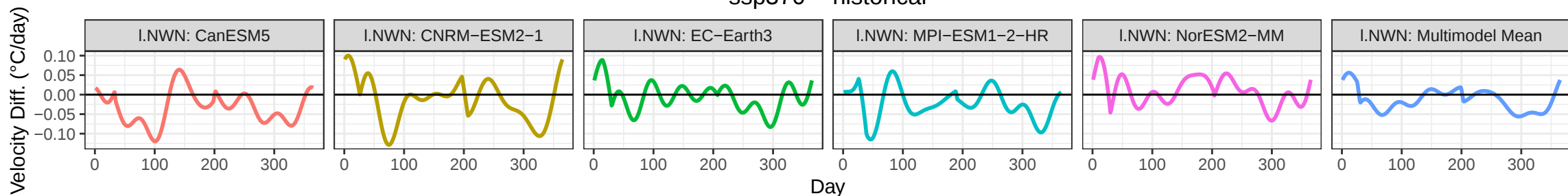


Figure S6: The distances between the first derivatives of the smoothed annual cycle curves in the future and reference periods 2071-2100 and 1961-1990. Plots for five selected CMIP6 ESMs and their multi-model mean are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. The results shown in this figure are summarized in Fig. 8 in the manuscript.

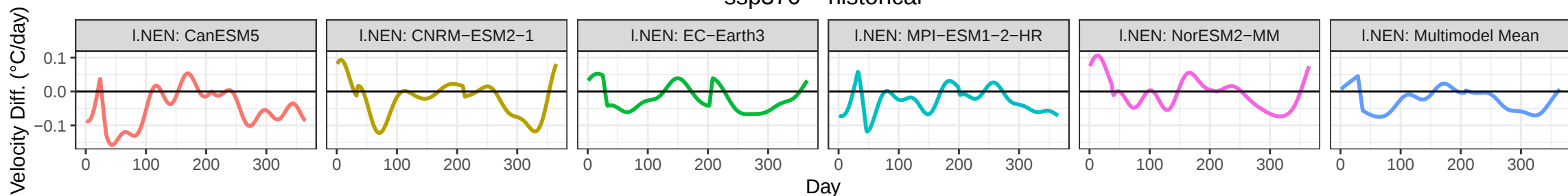
ssp370 – historical



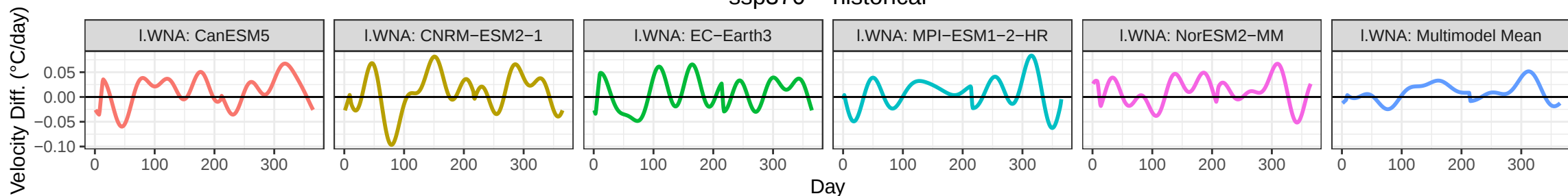
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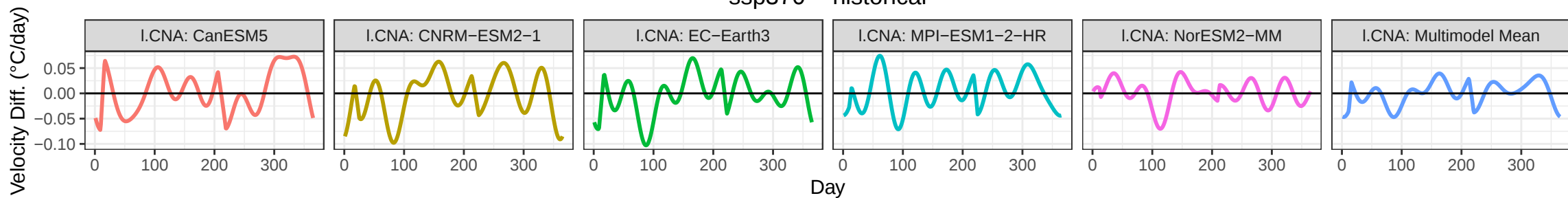
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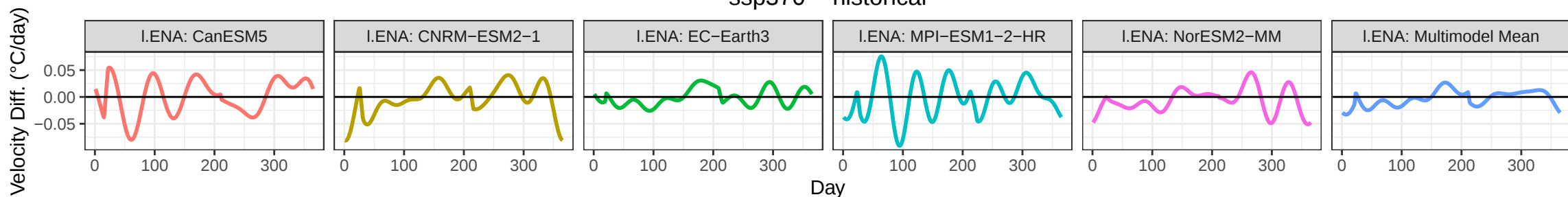
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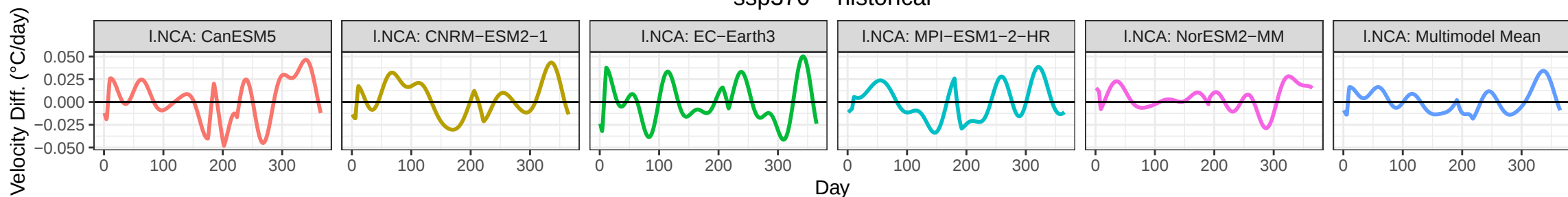
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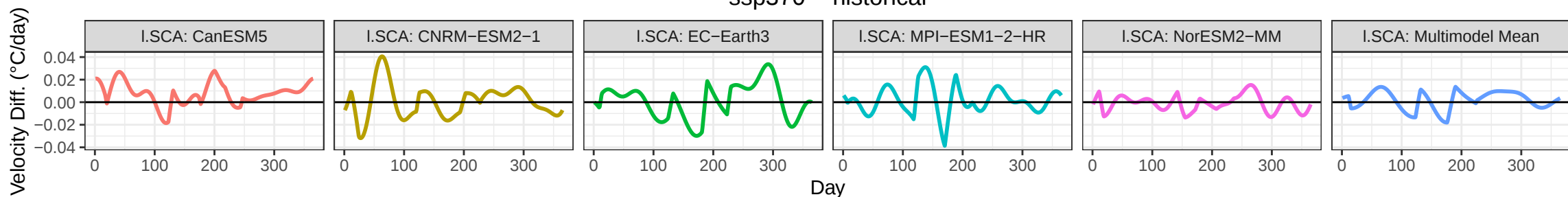
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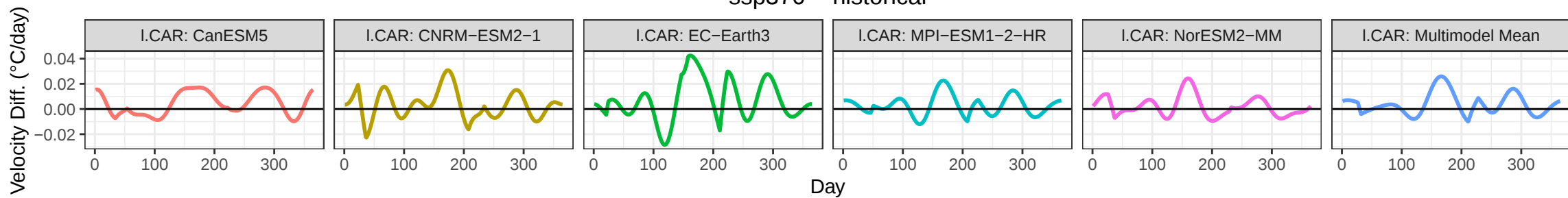
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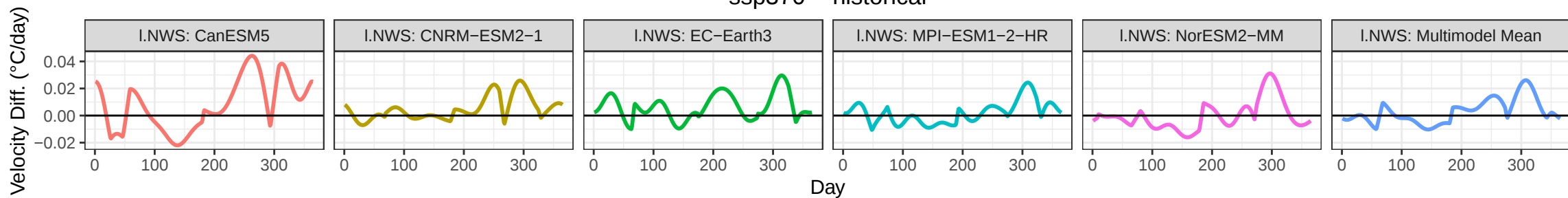
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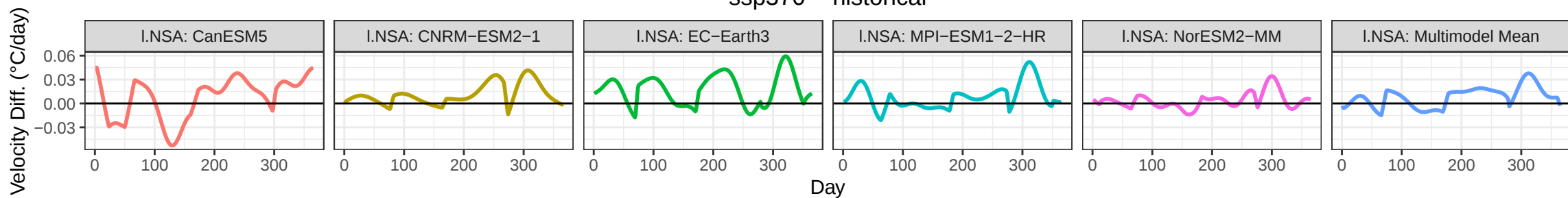
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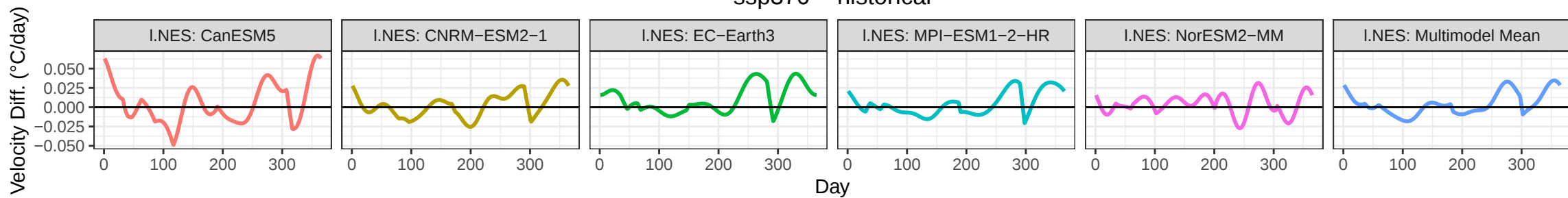
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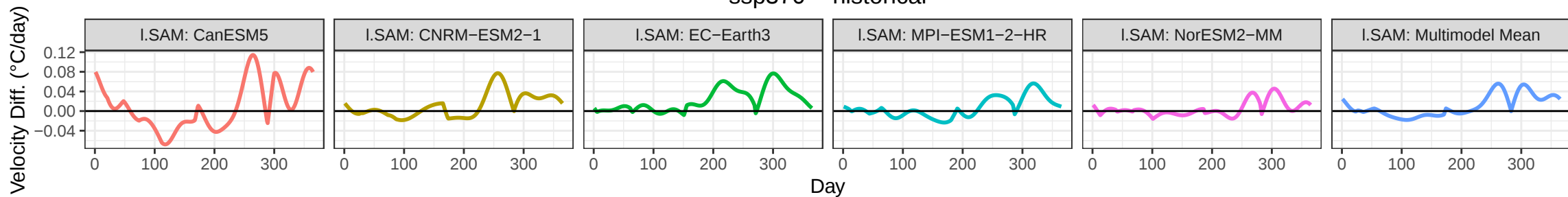
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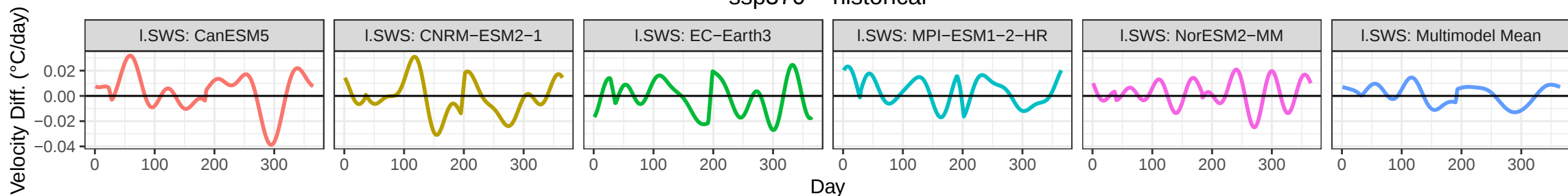
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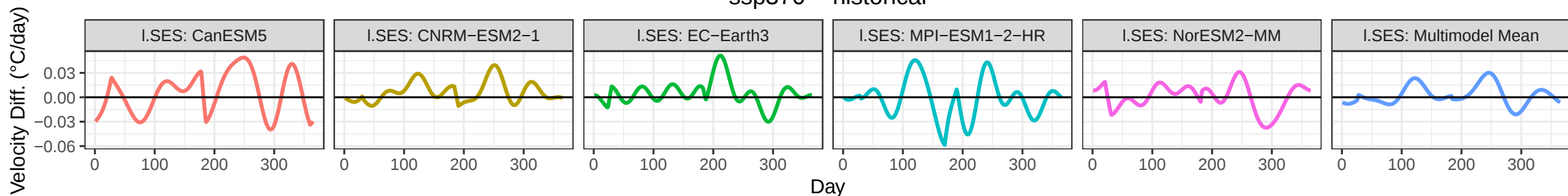
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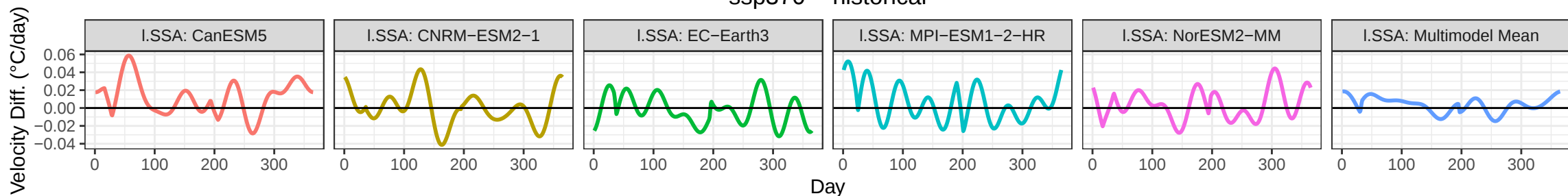
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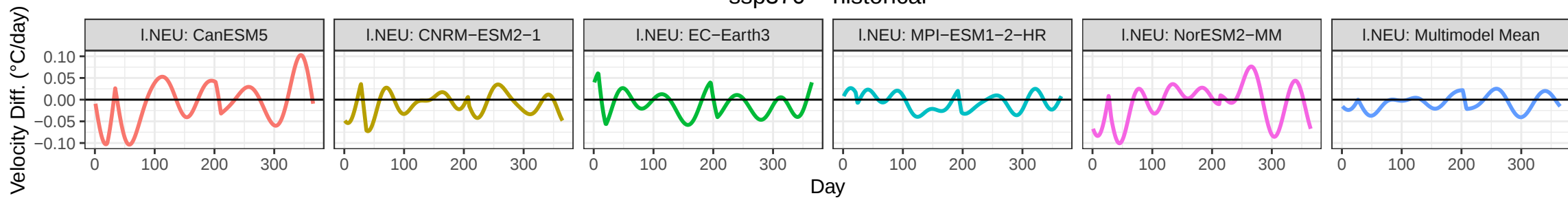
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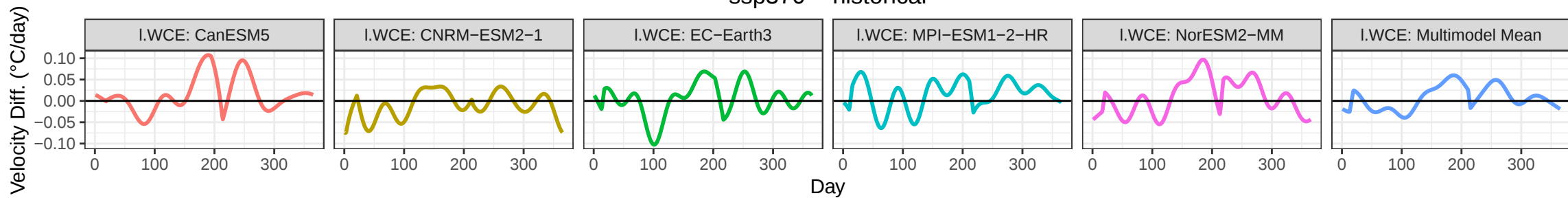
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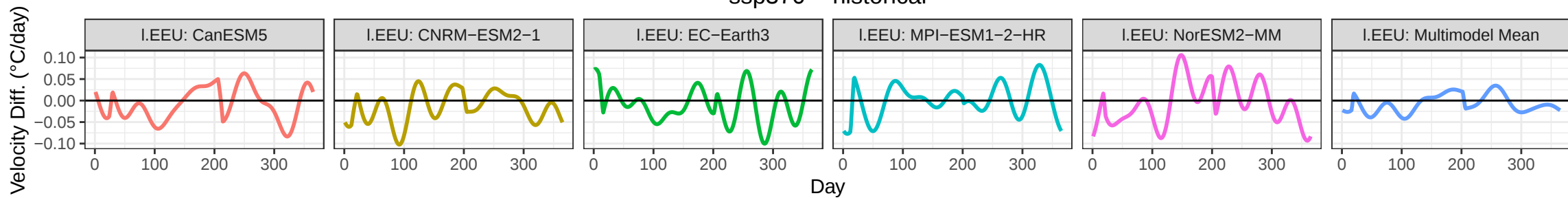
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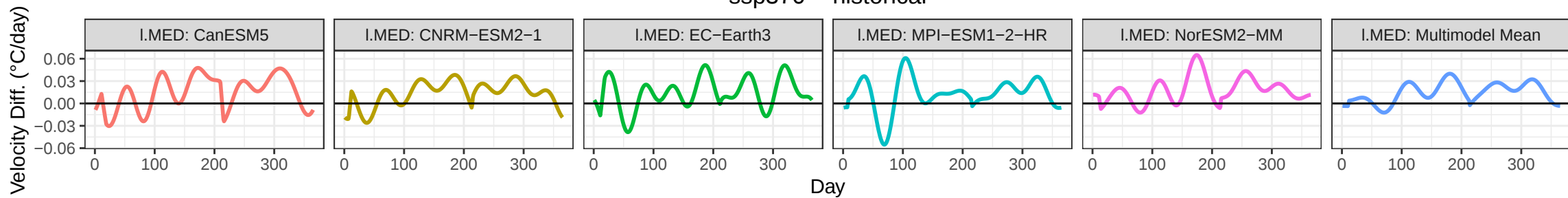
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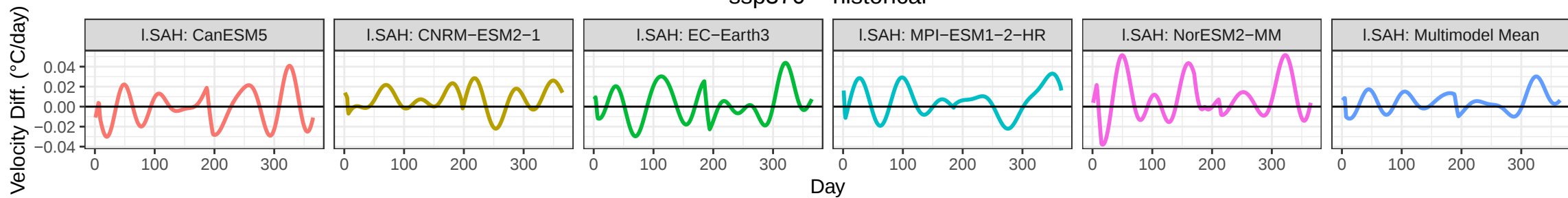
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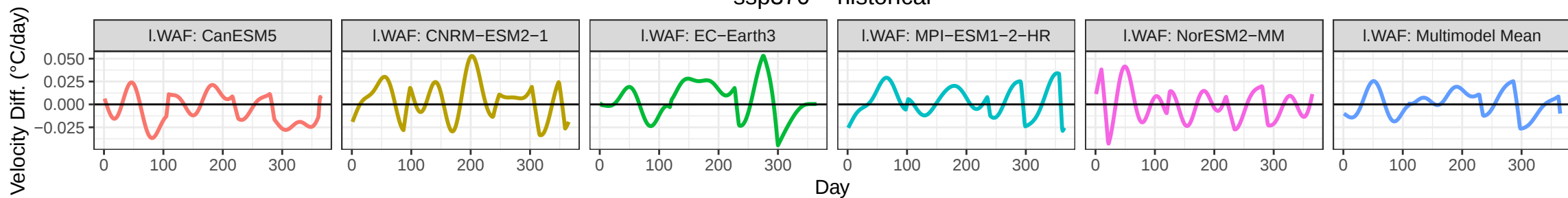
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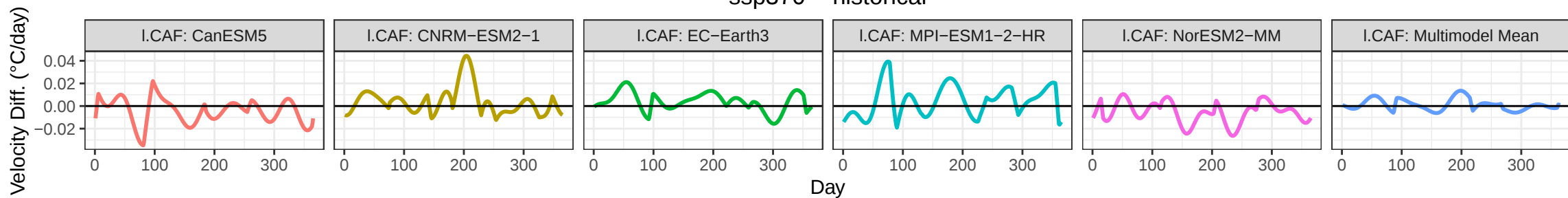
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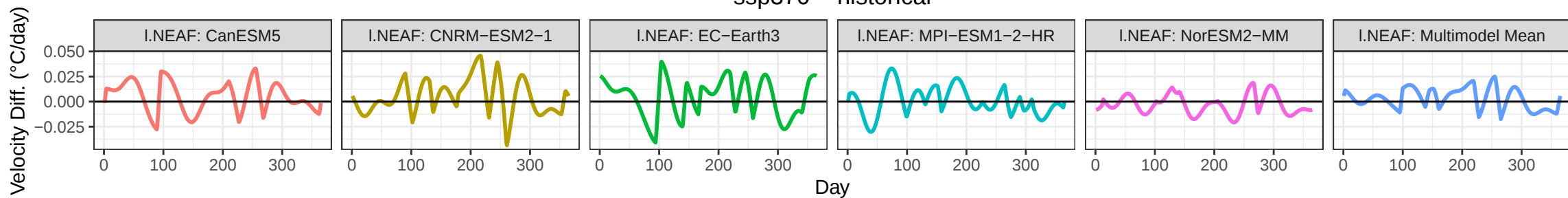
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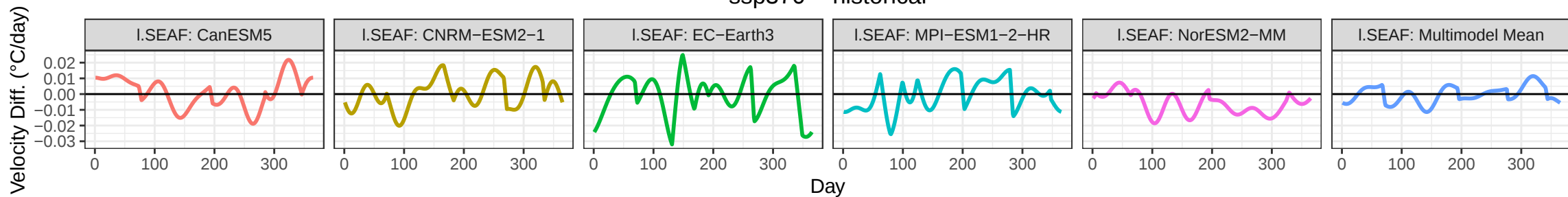
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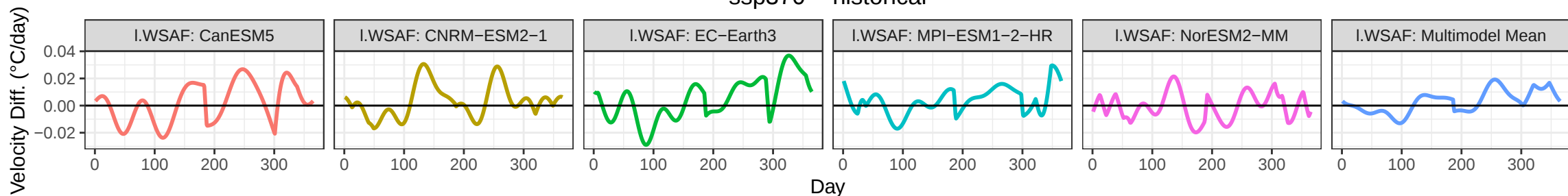
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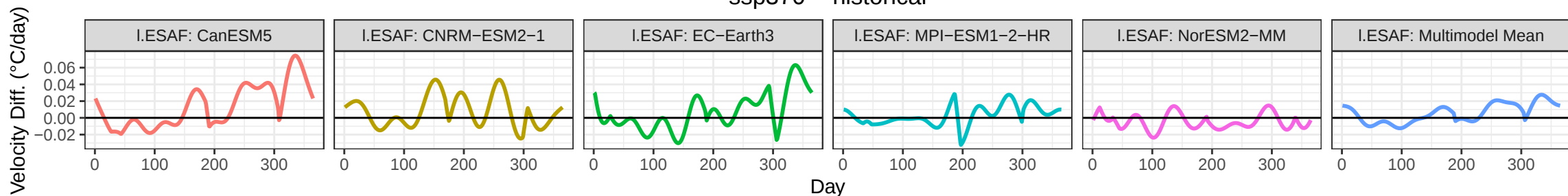
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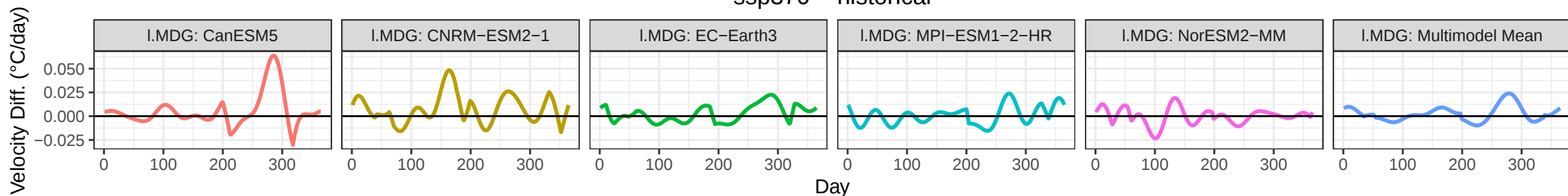
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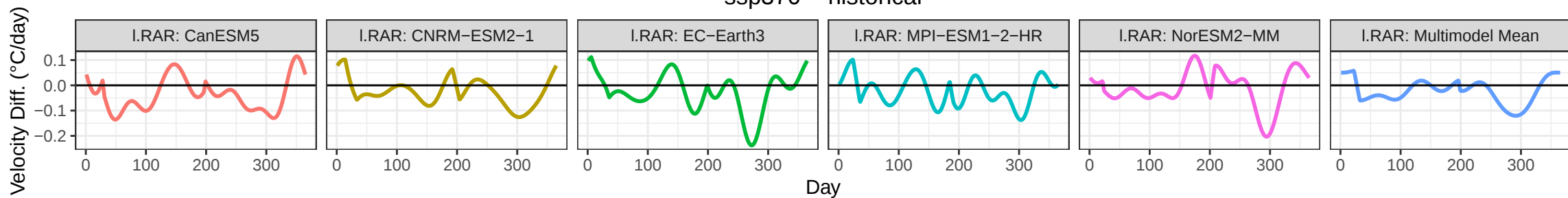
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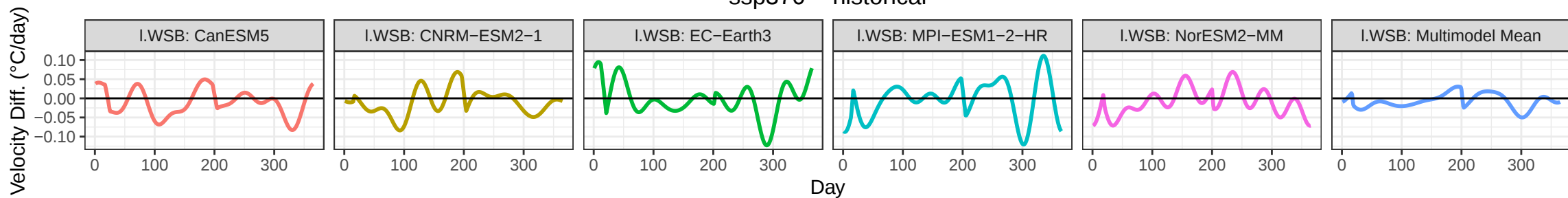
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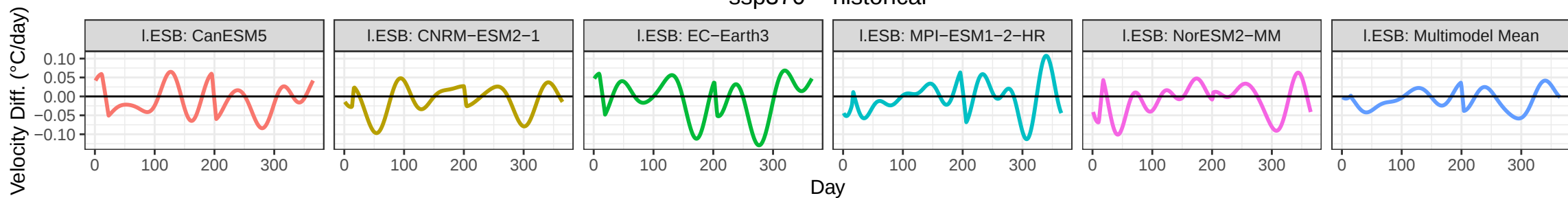
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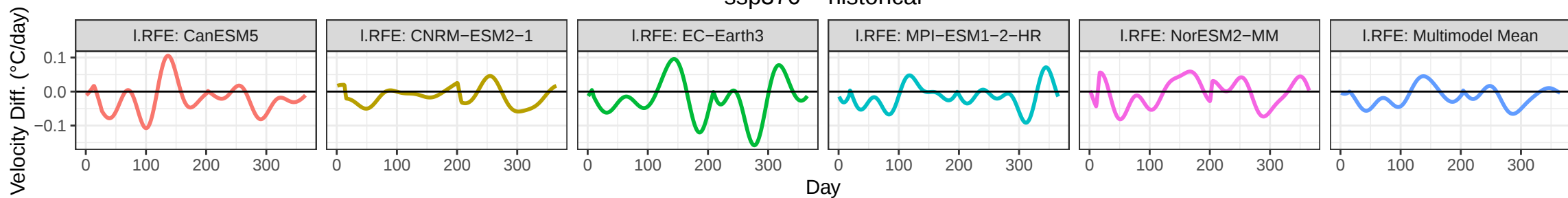
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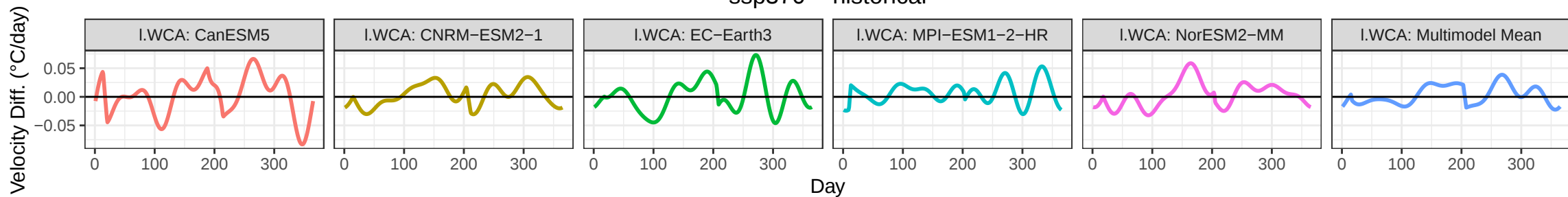
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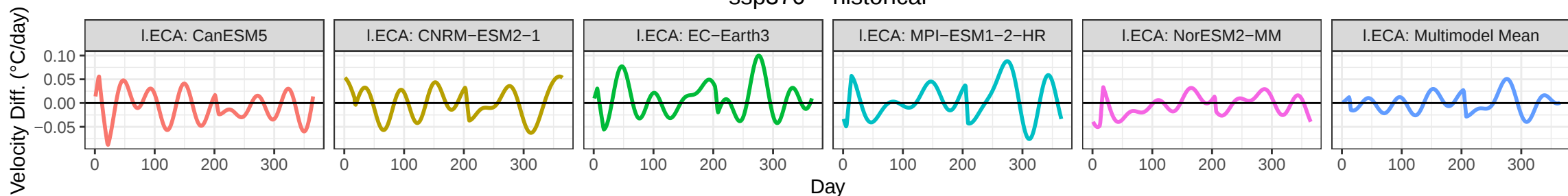
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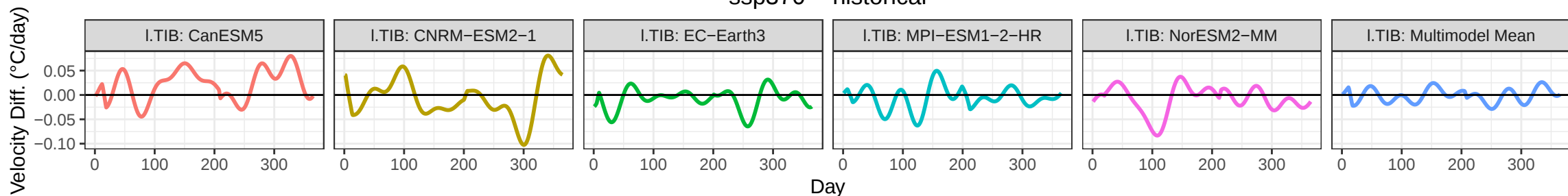
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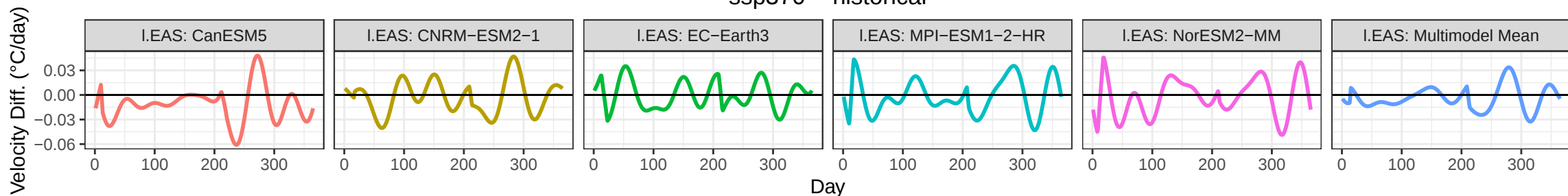
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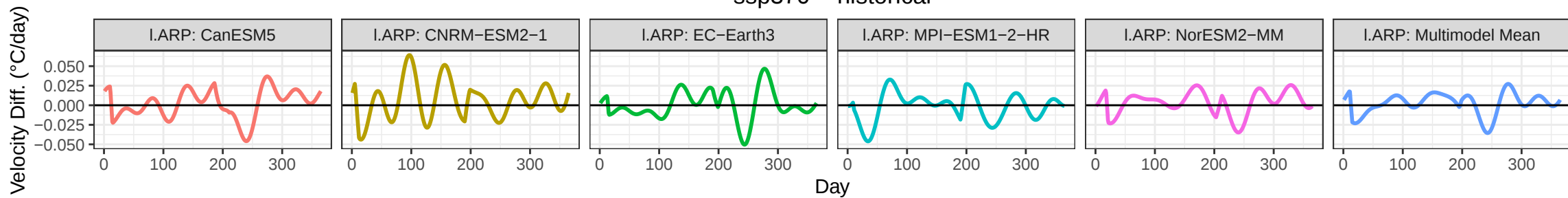
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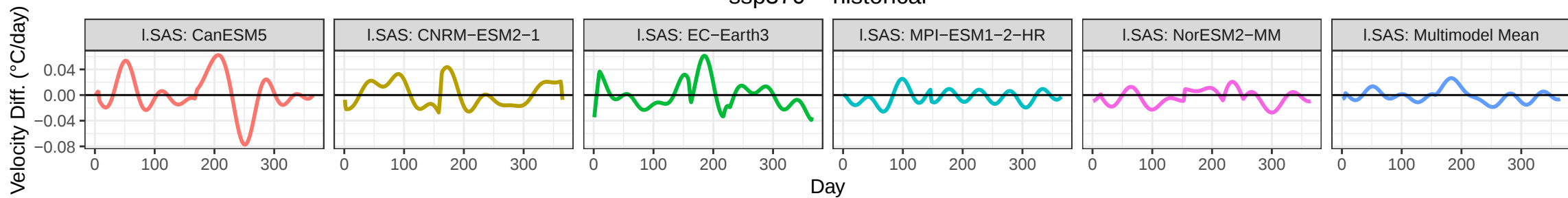
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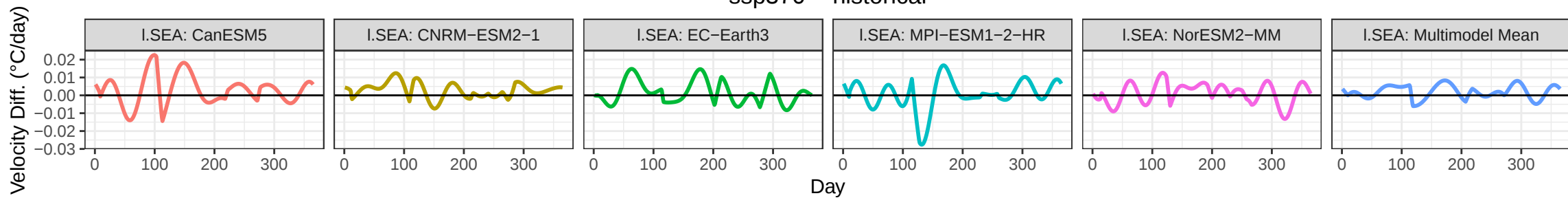
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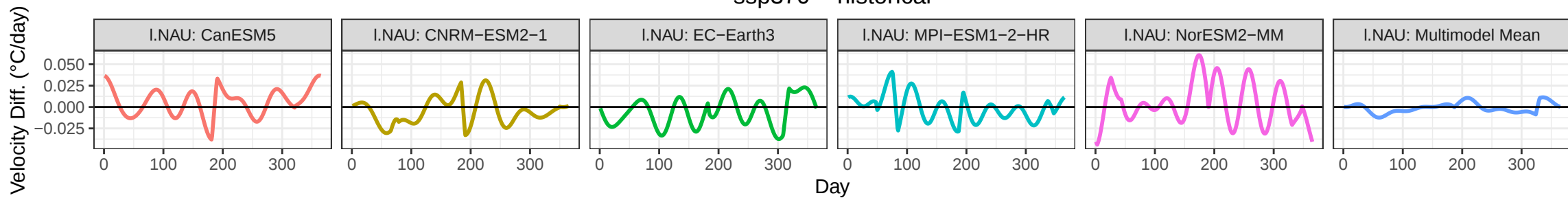
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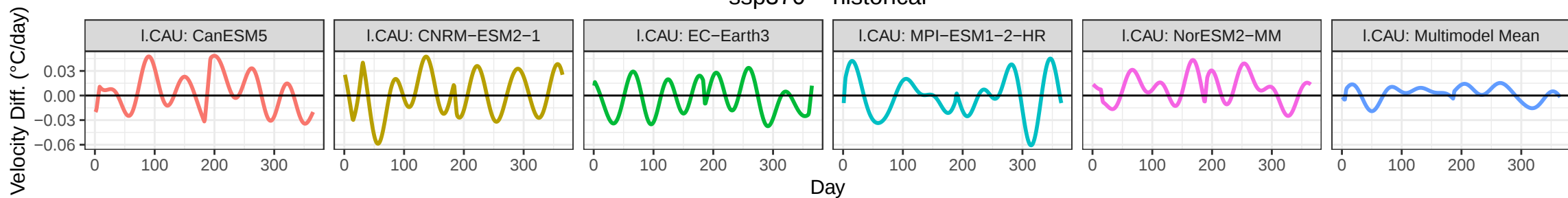
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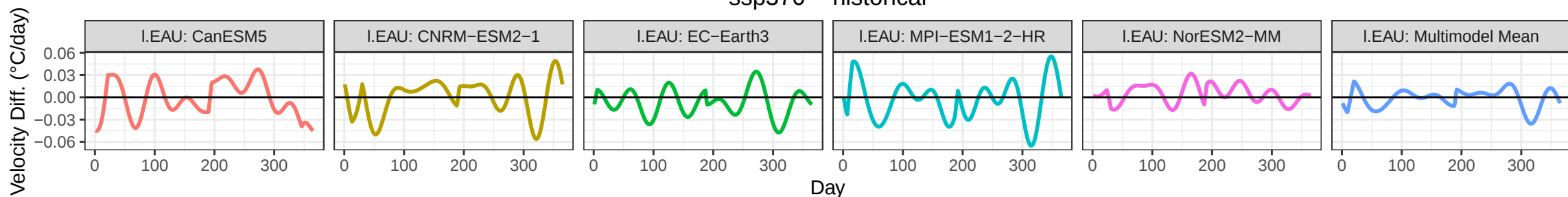
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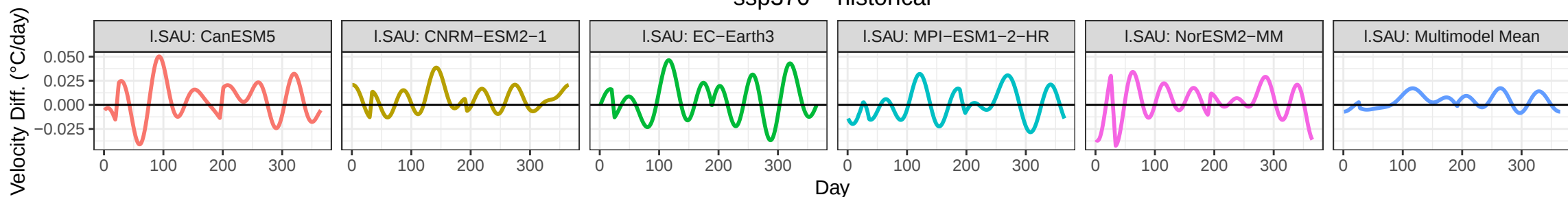
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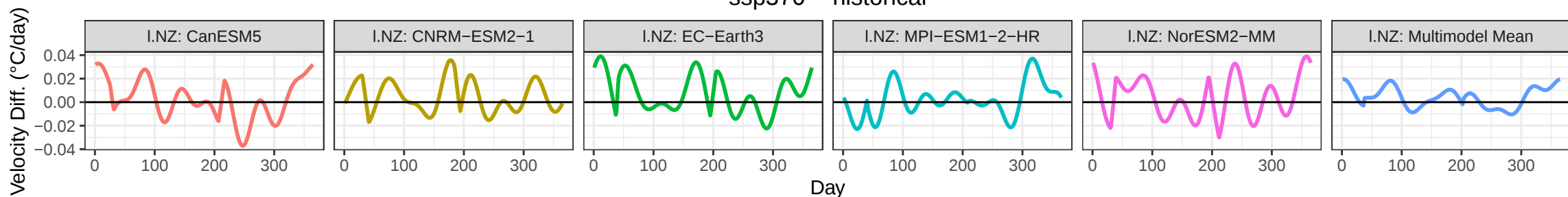
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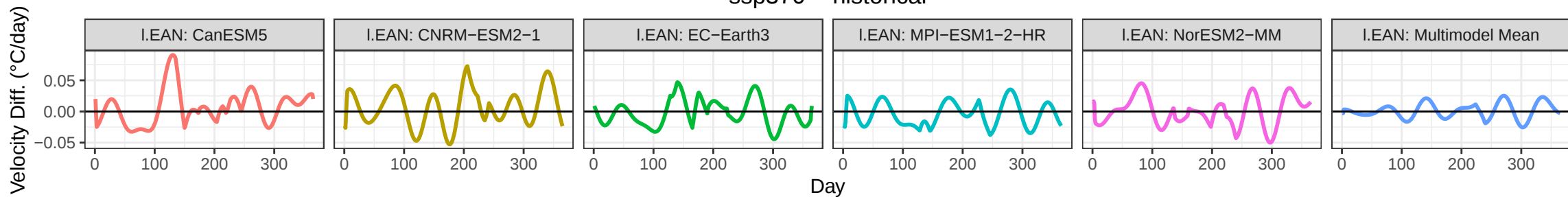
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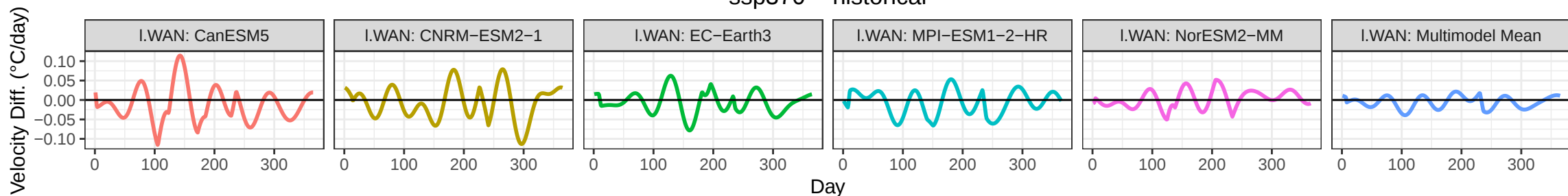
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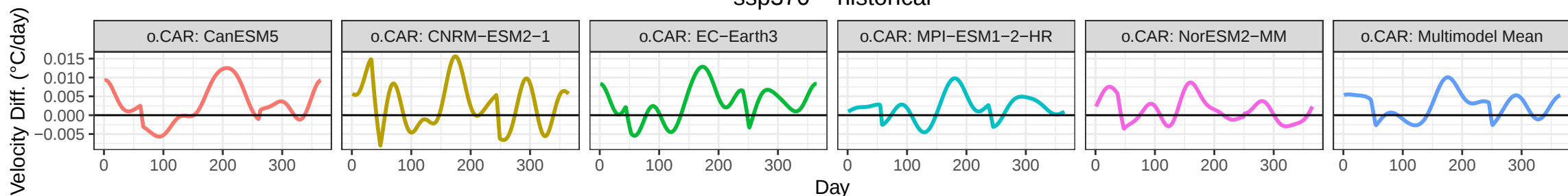
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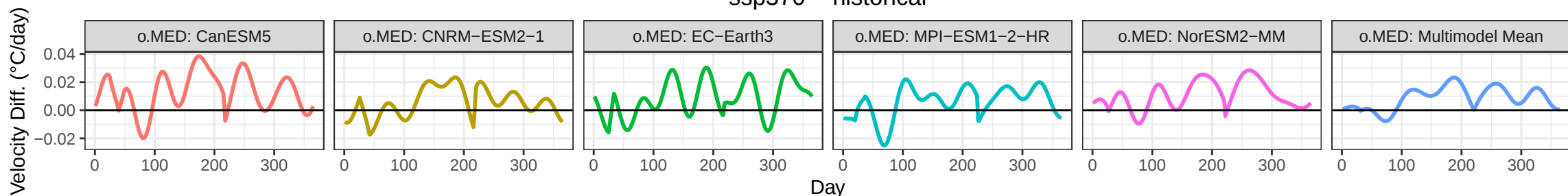
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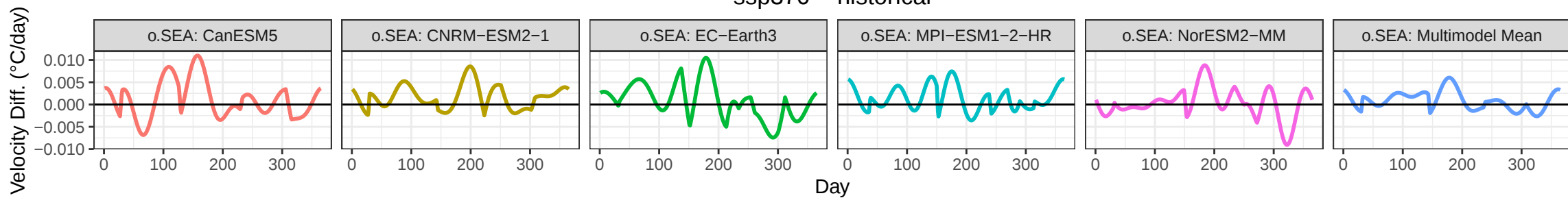
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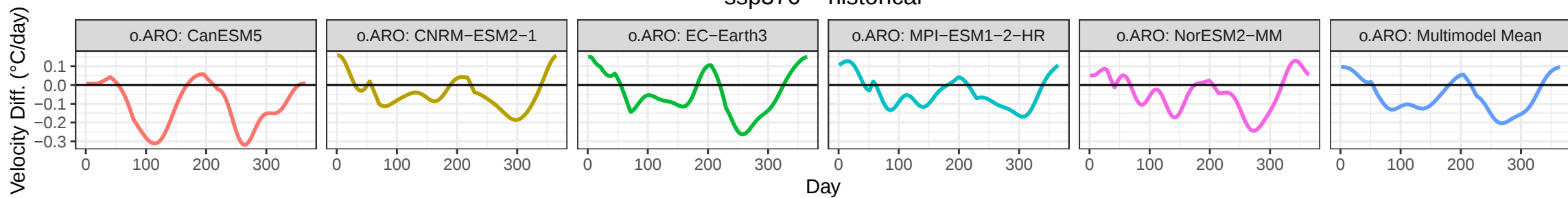
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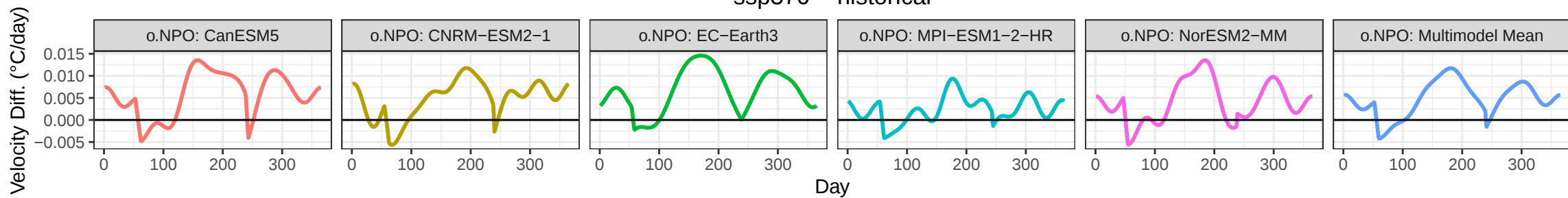
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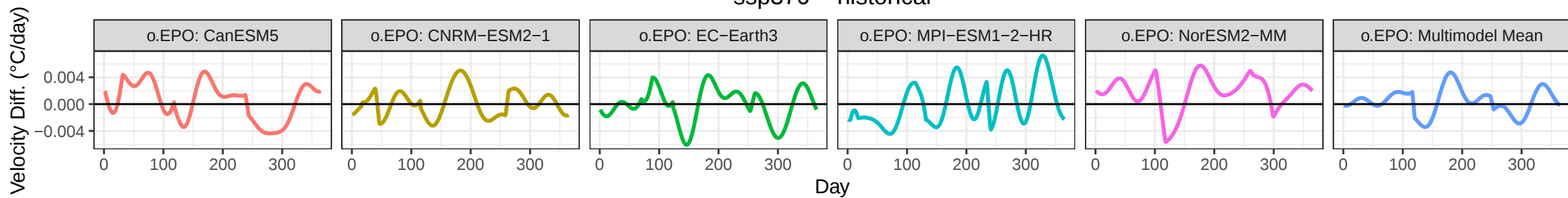
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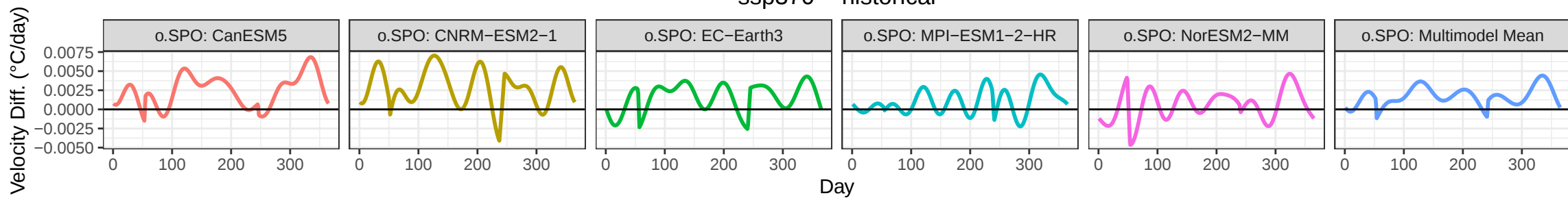
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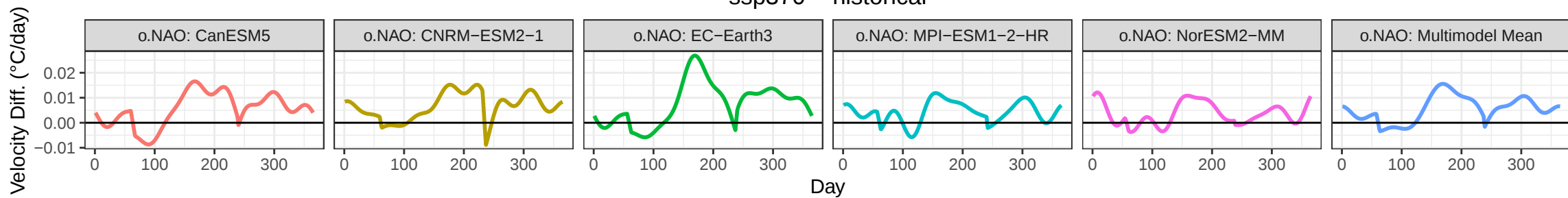
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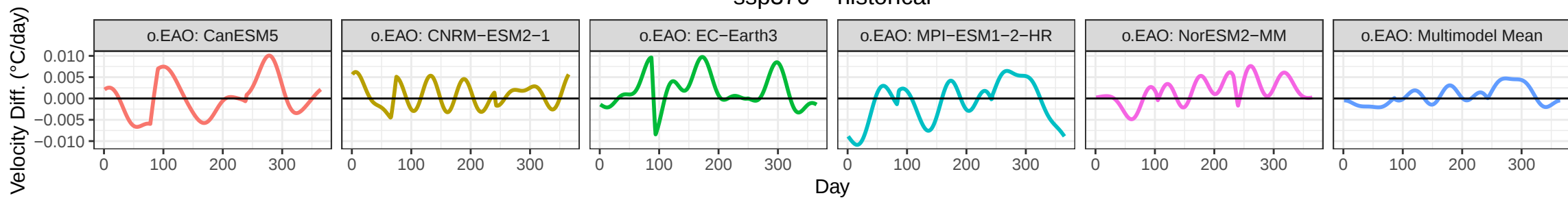
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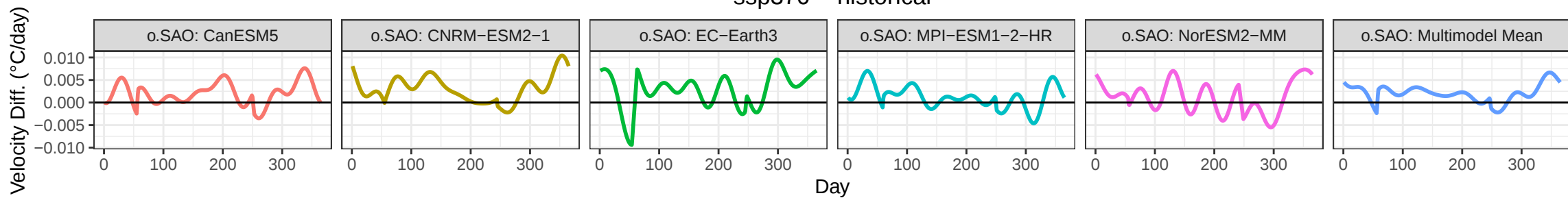
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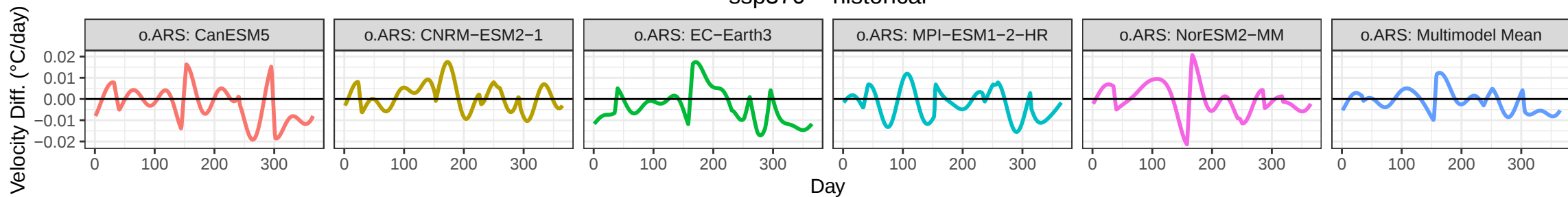
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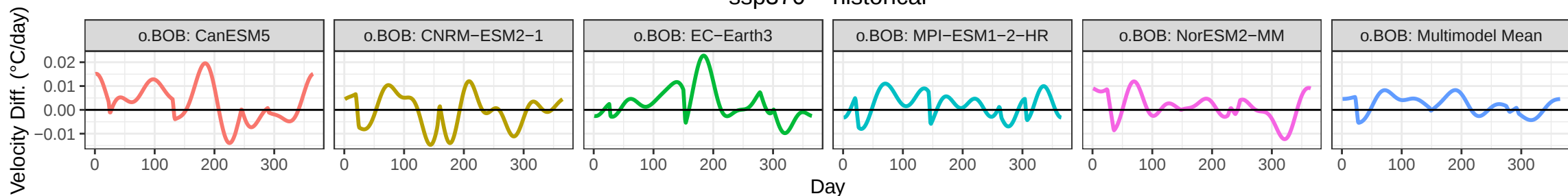
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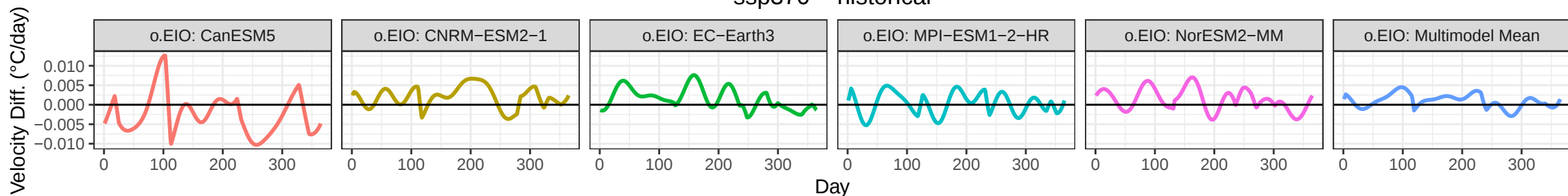
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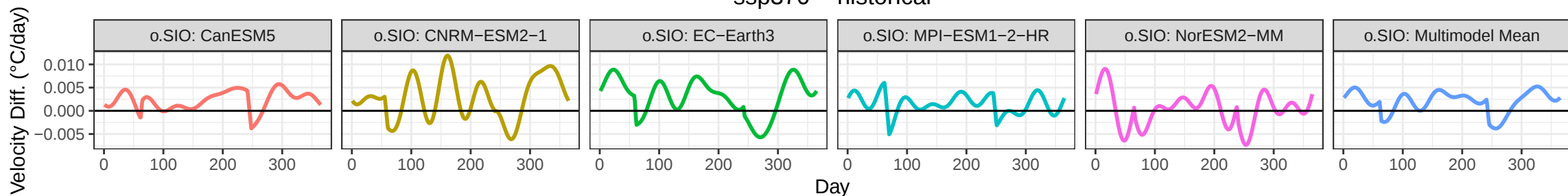
ssp370 – historical



ssp370 – historical



ssp370 – historical



ssp370 – historical

Velocity Diff. (°C/day)

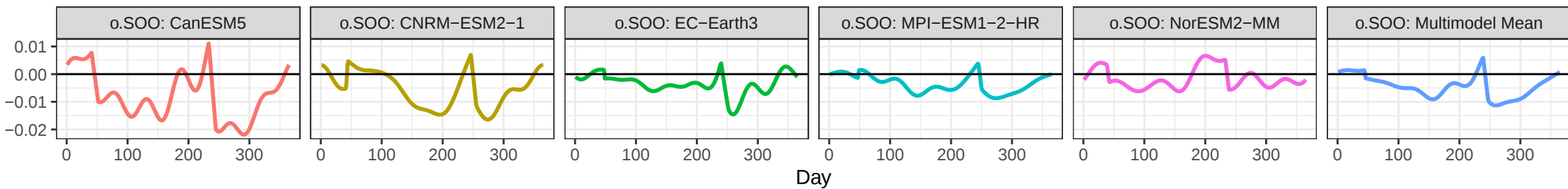
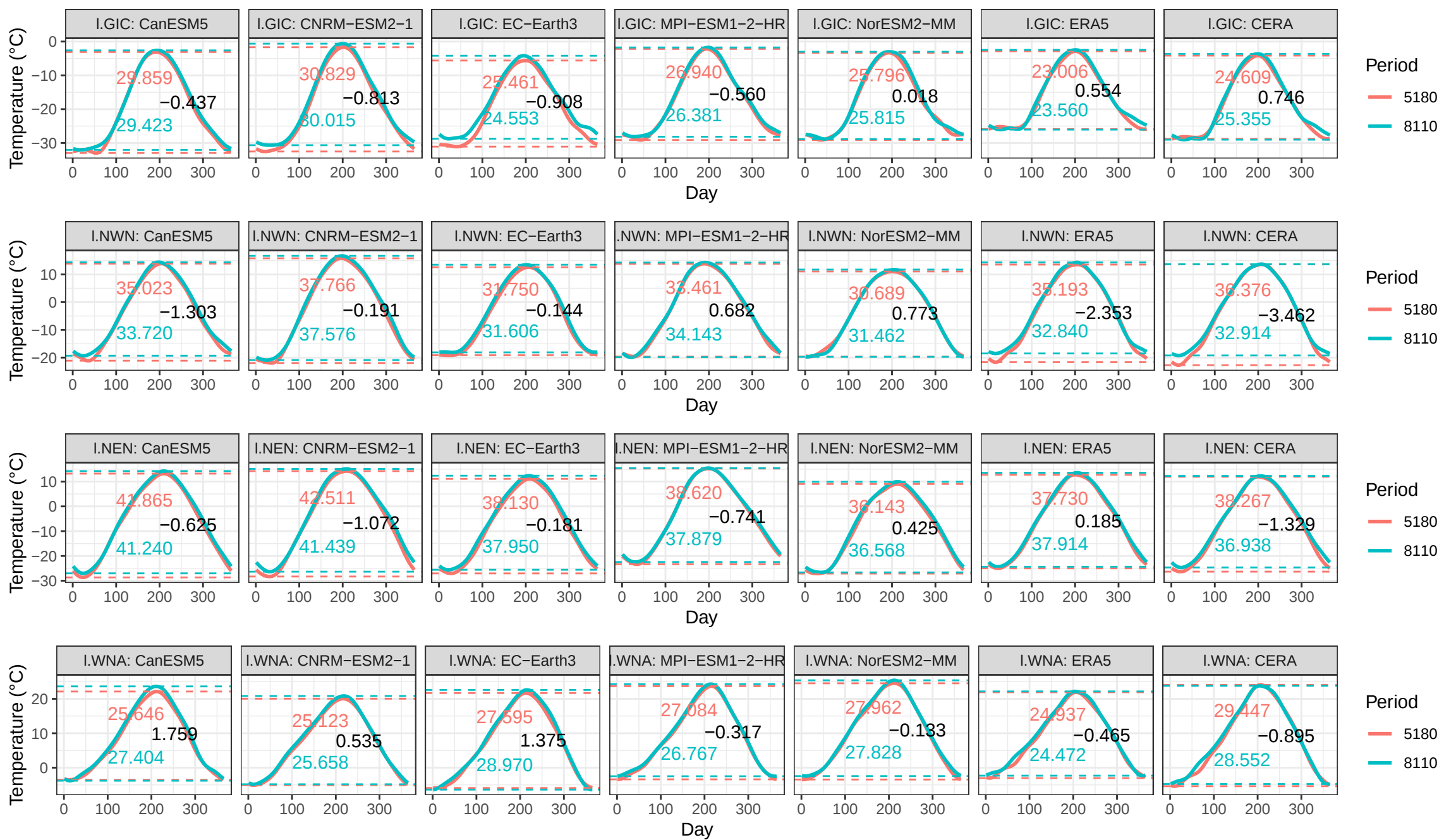
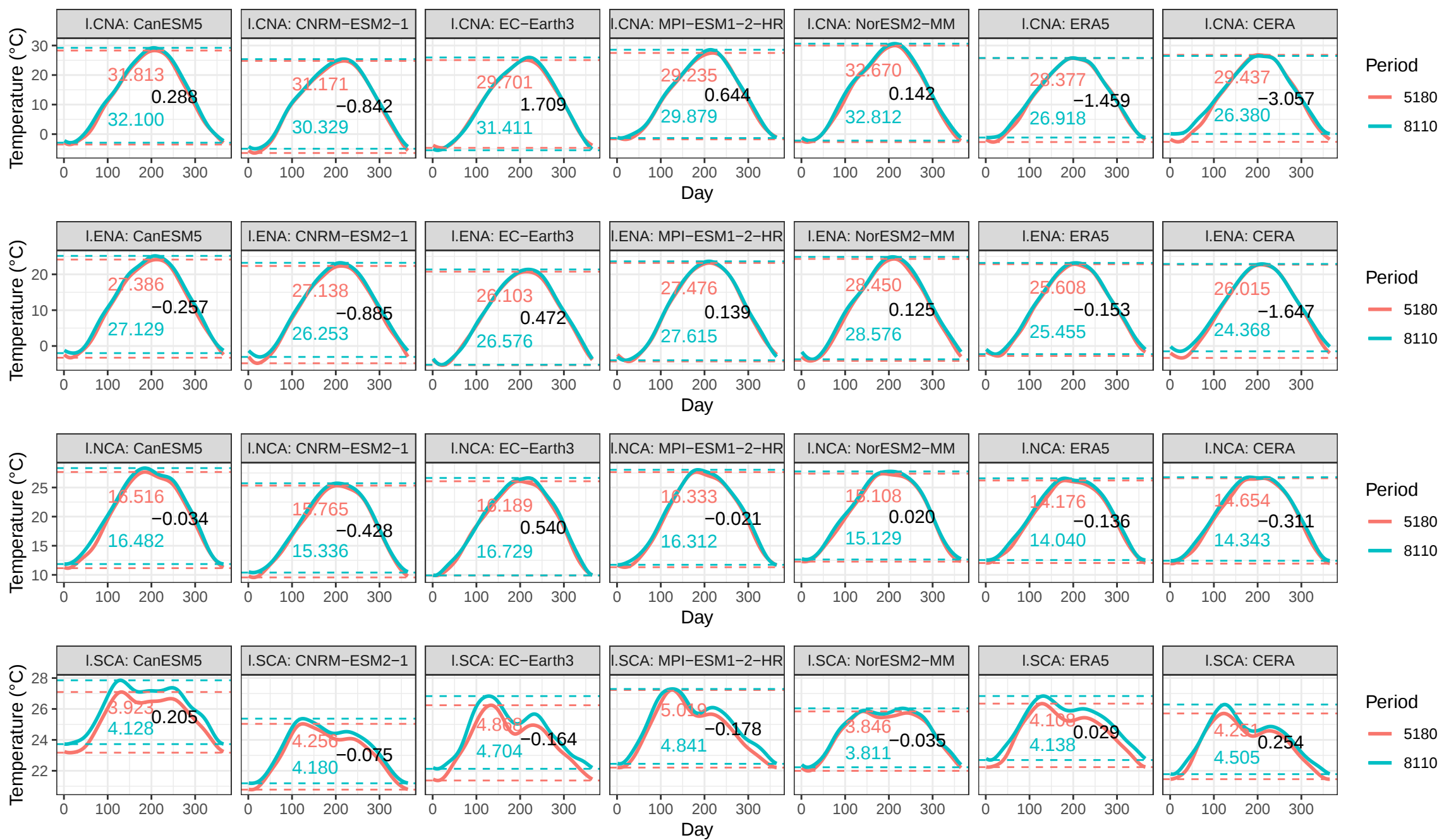
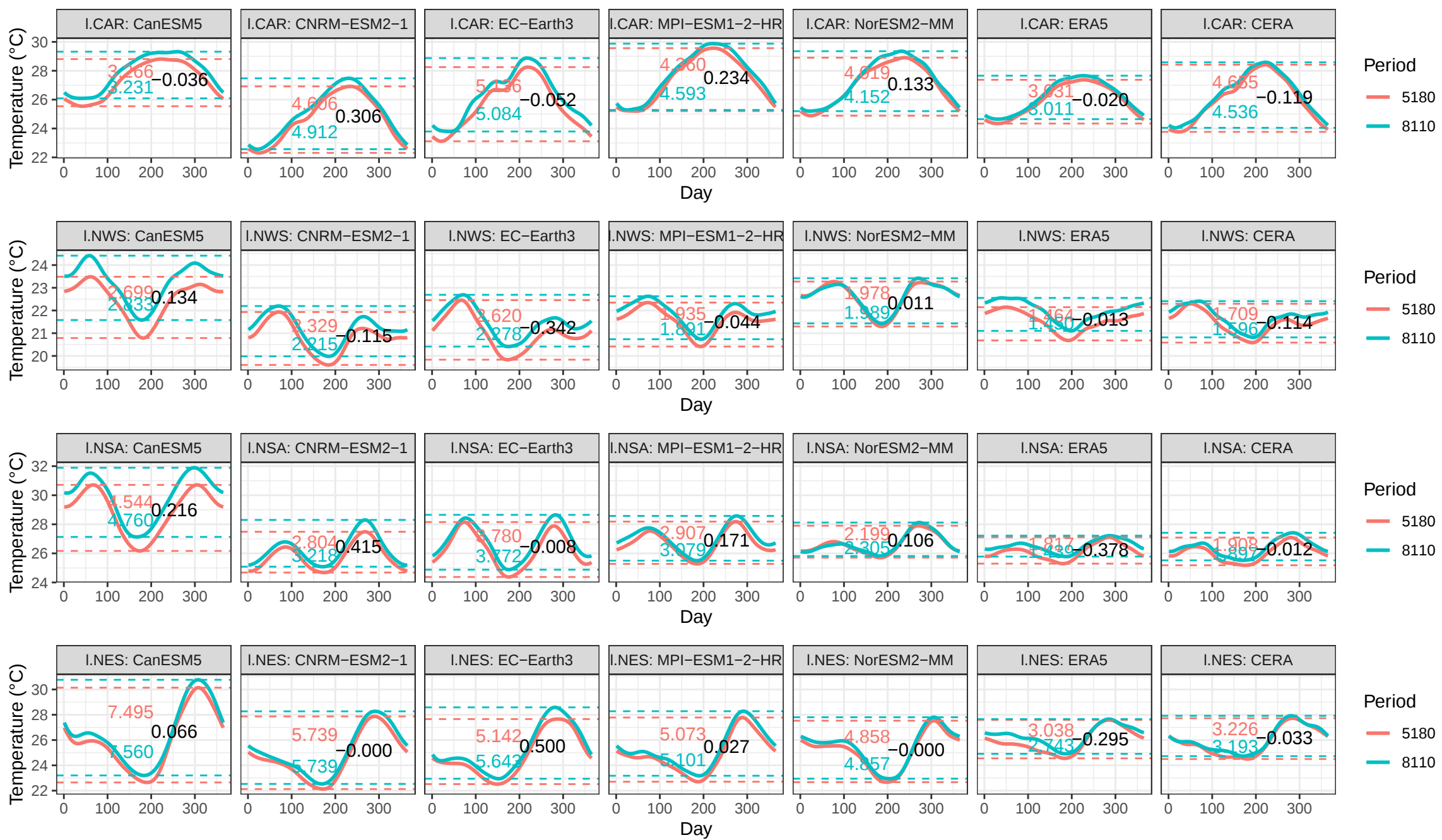
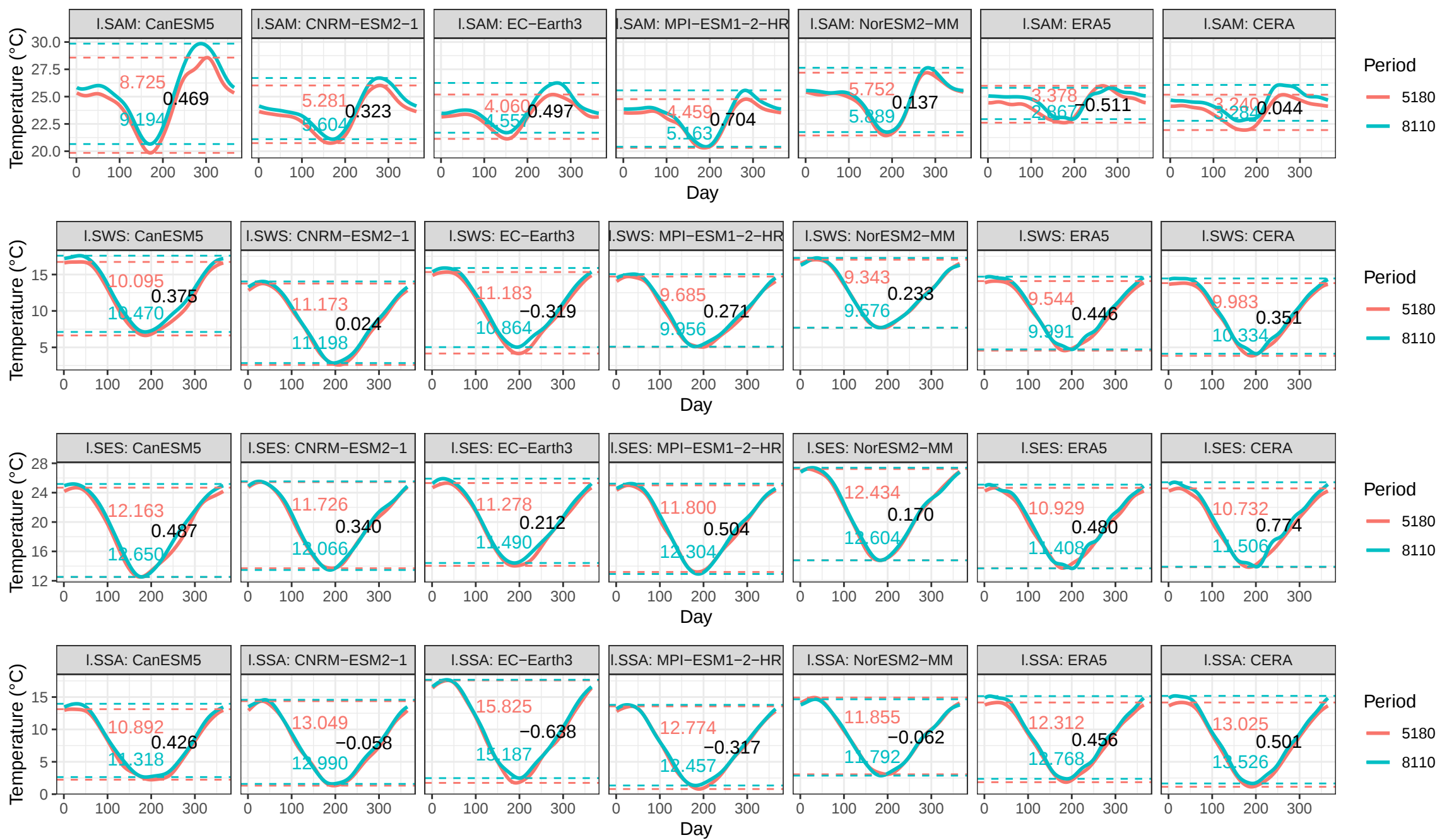


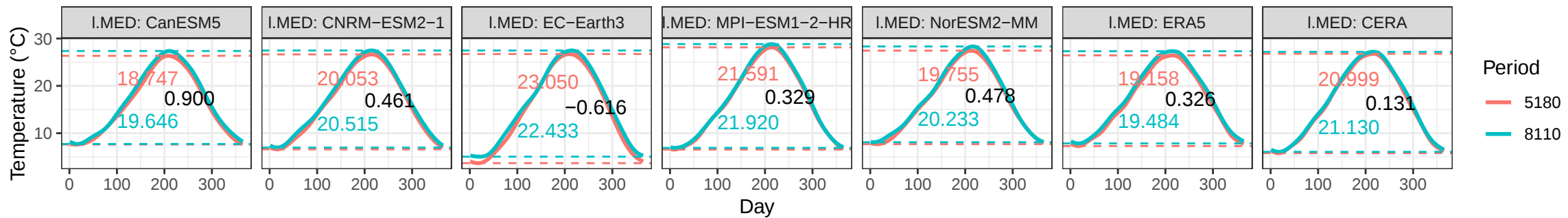
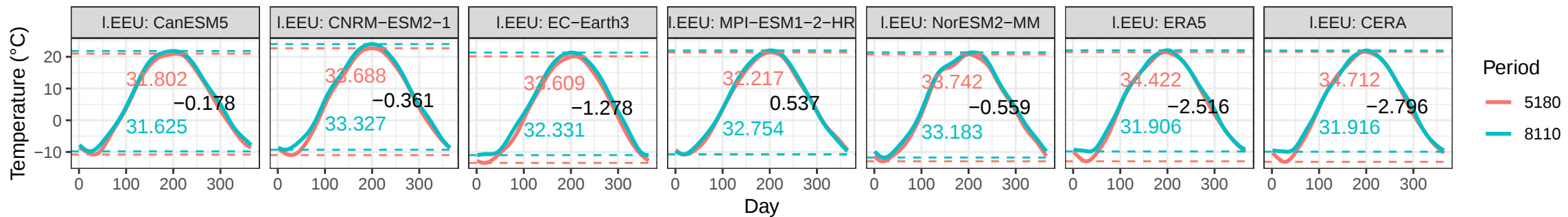
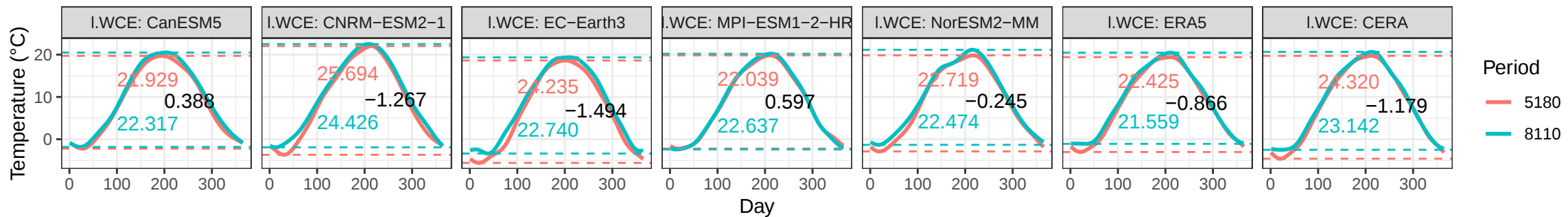
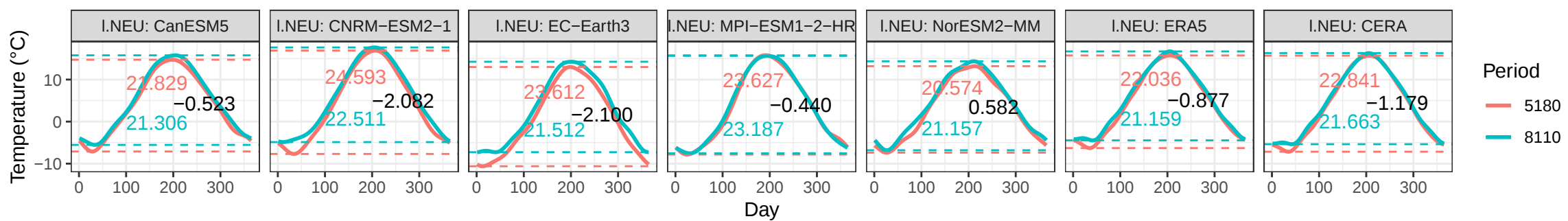
Figure S7: The smoothed annual cycle curves in the two historical periods 1981-2010 (8110, blue curve) and 1951-1980 (5180, red curve). Plots for five selected CMIP6 ESMs and their multi-model mean are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. The horizontal dashed lines denote annual minimum and maximum temperatures in the two periods. The blue and red numbers describe the amplitudes of the annual cycle in the two periods. The black number in each plot says the differences between the amplitudes in the two periods. The results shown in this figure are summarized in Fig. 9 in the manuscript.

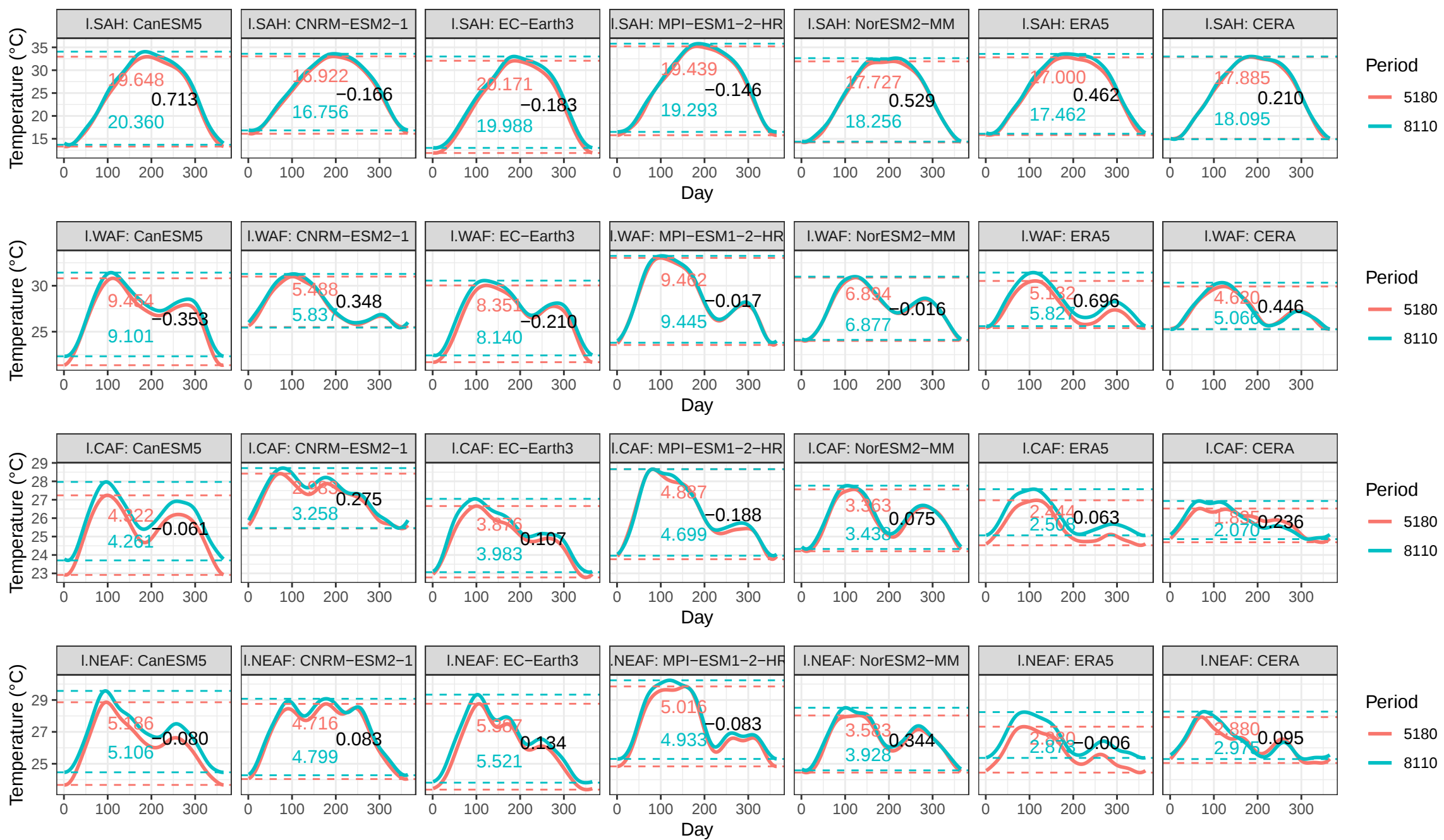


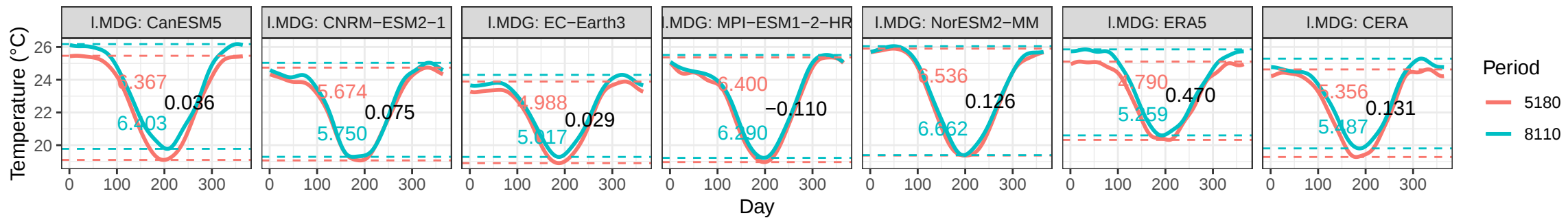
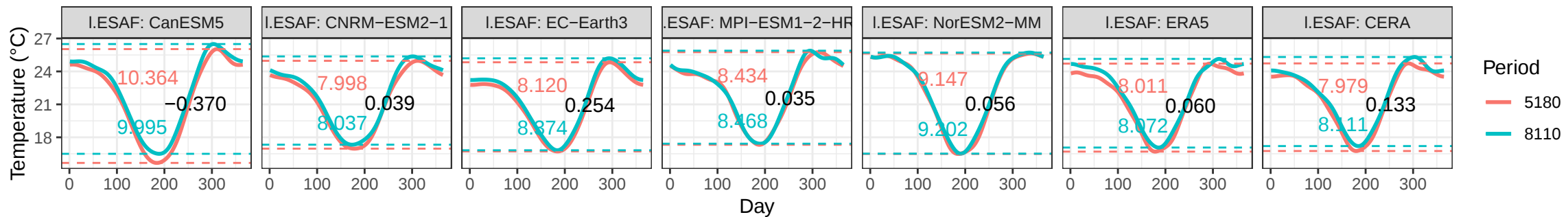
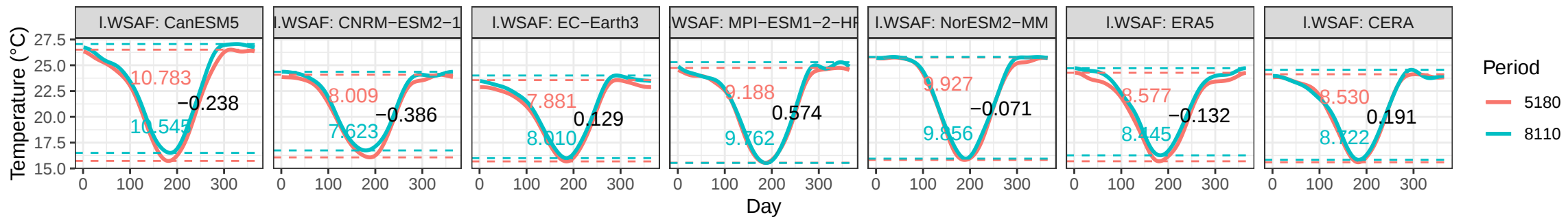
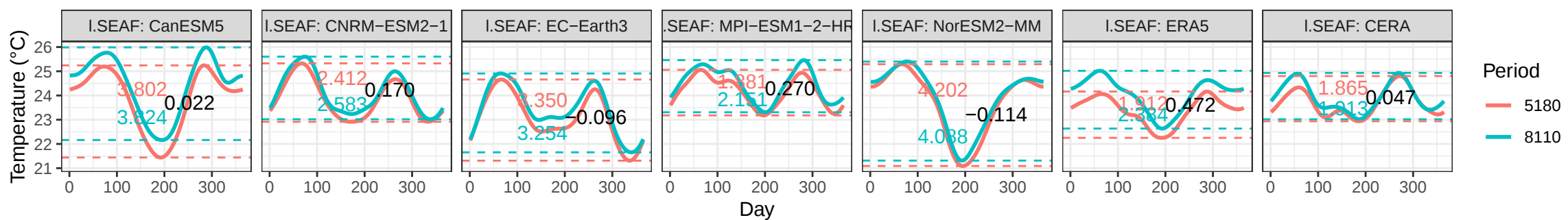


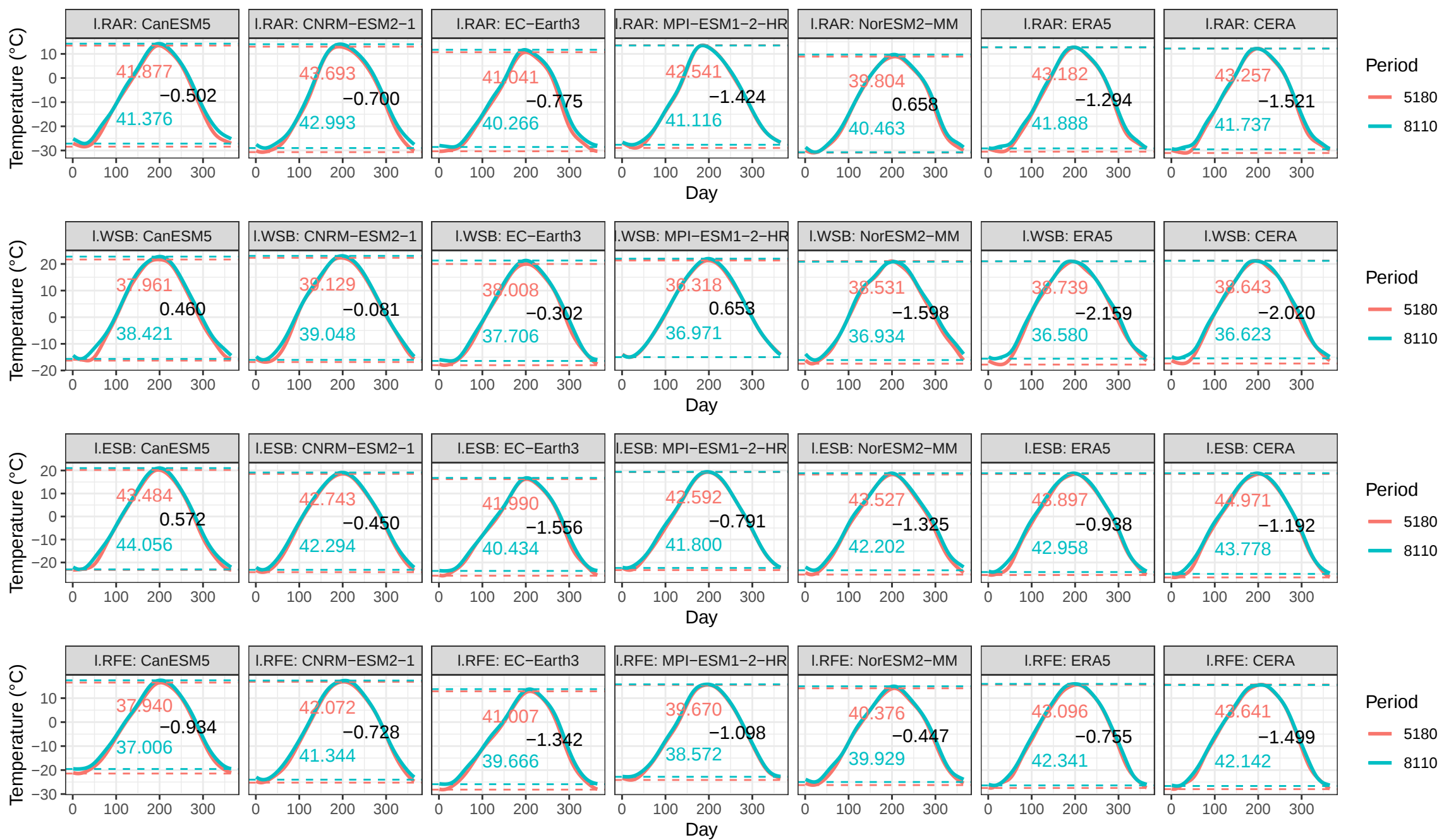


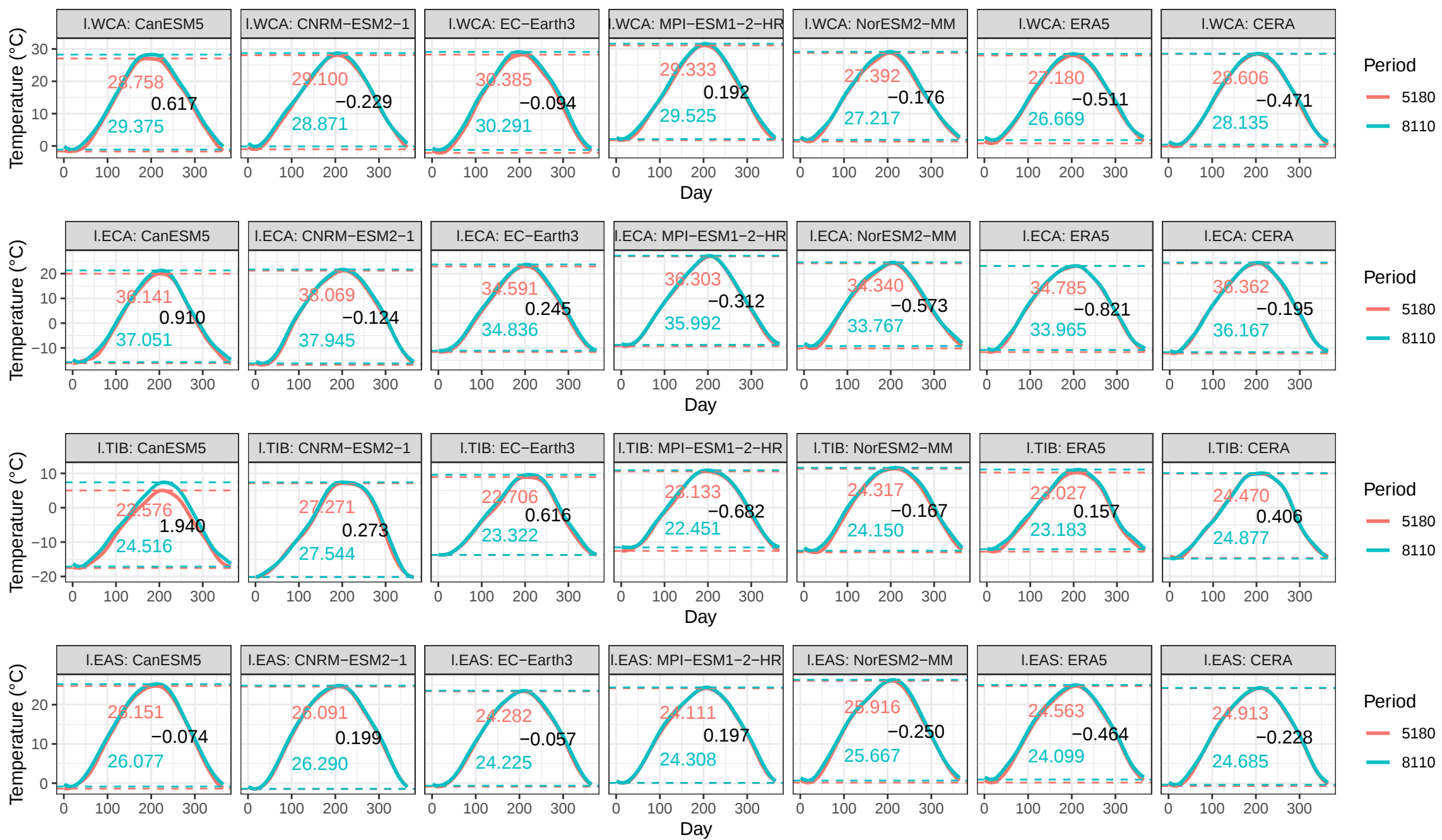


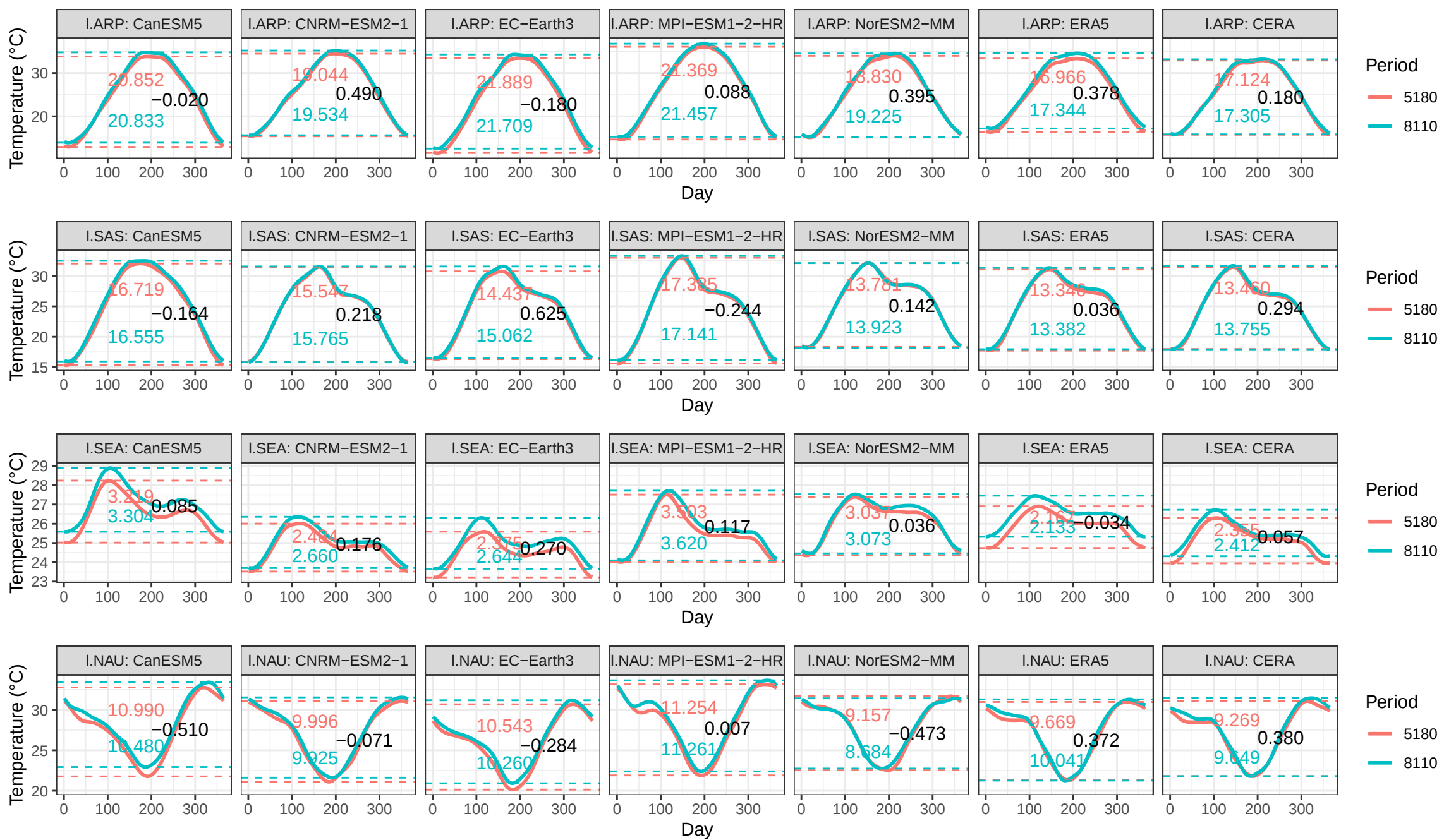


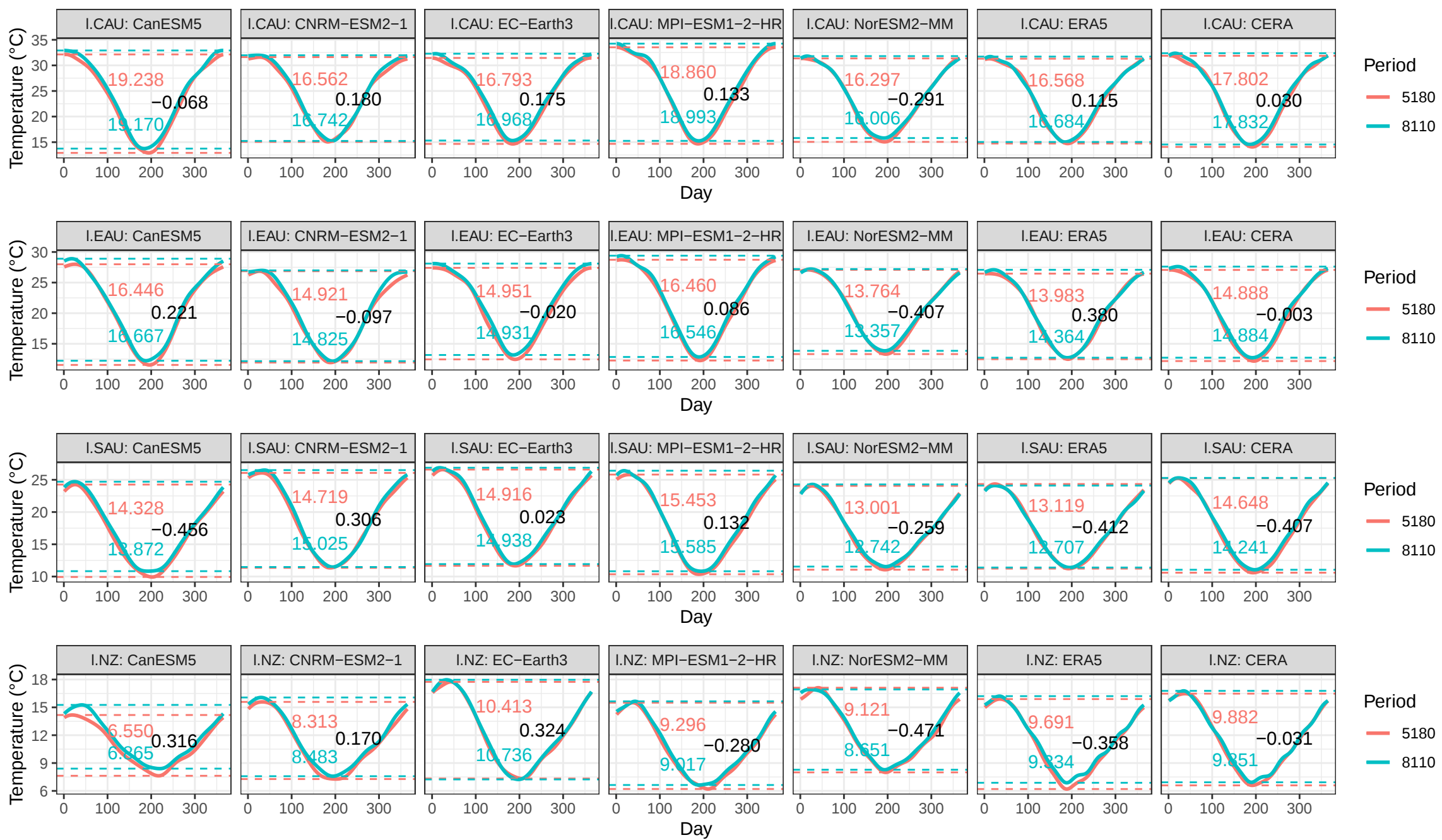


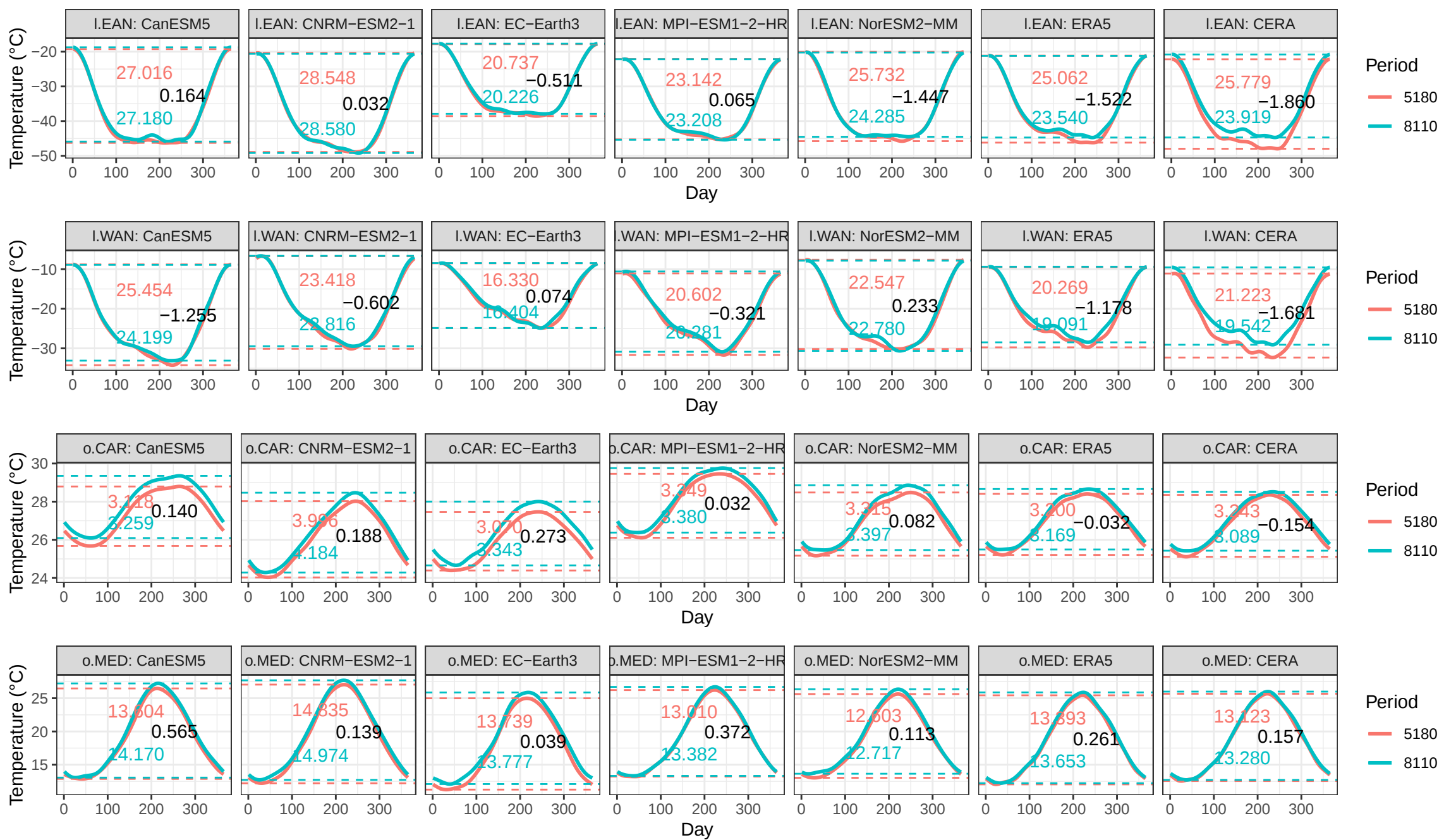


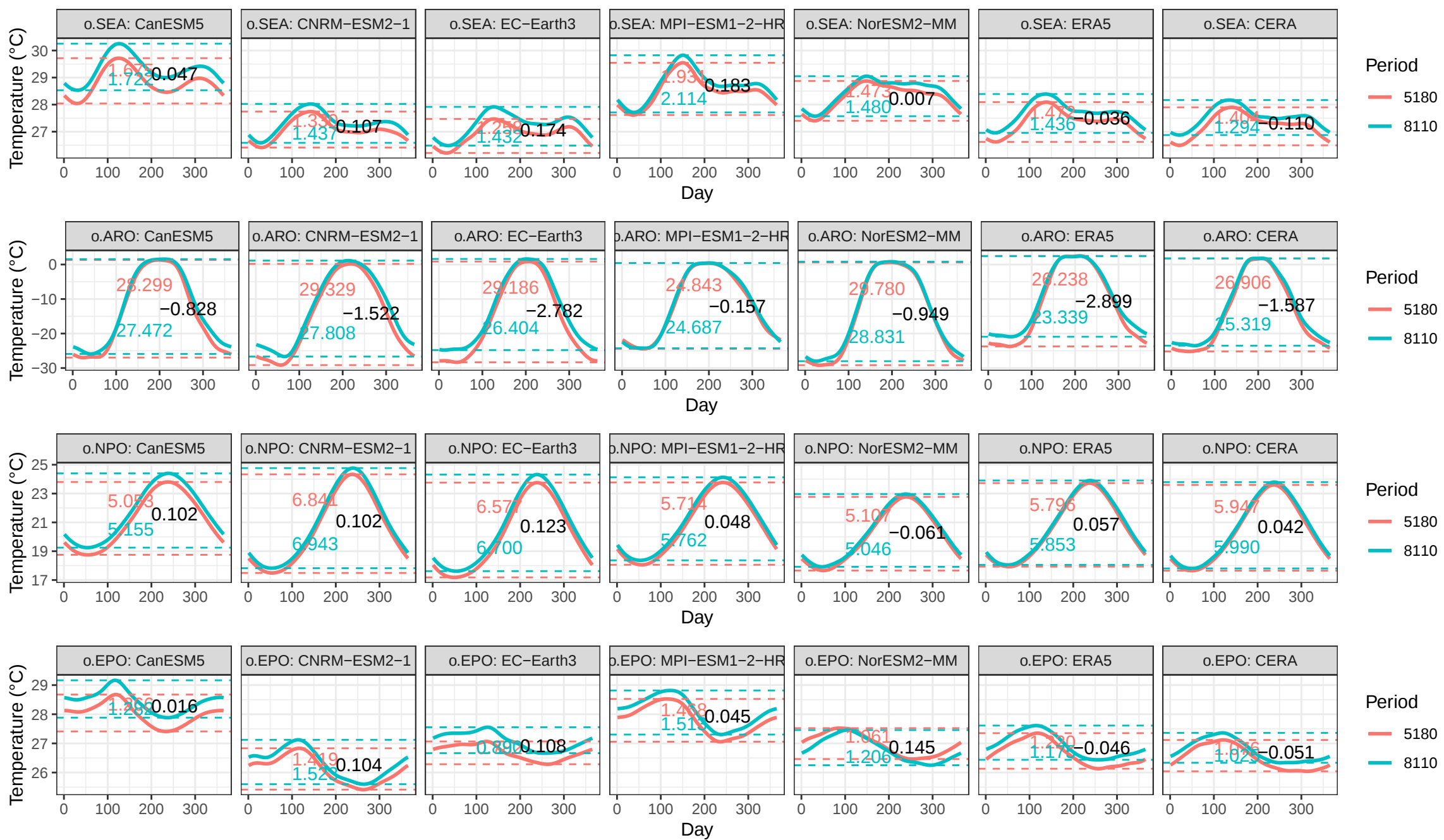


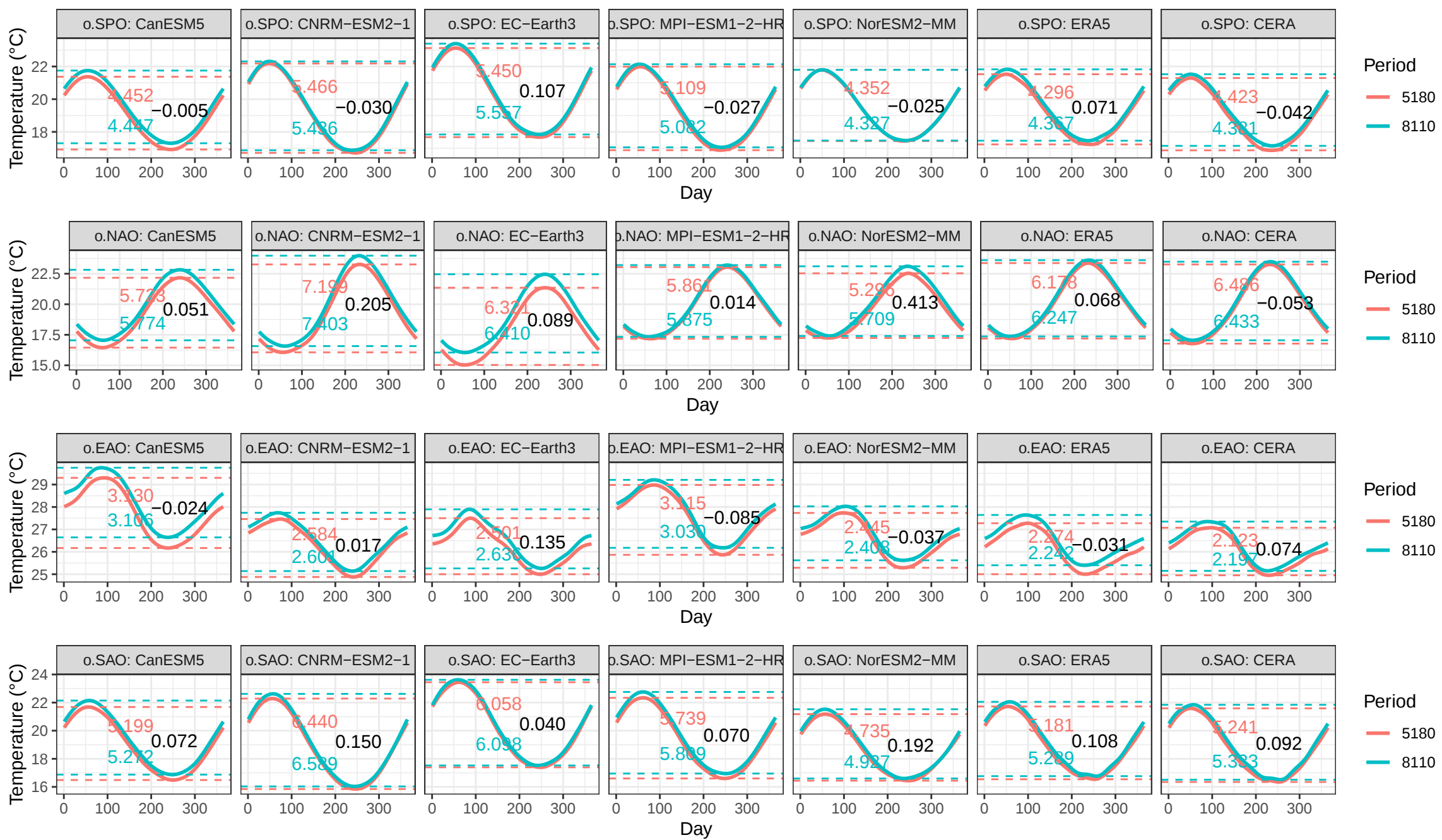


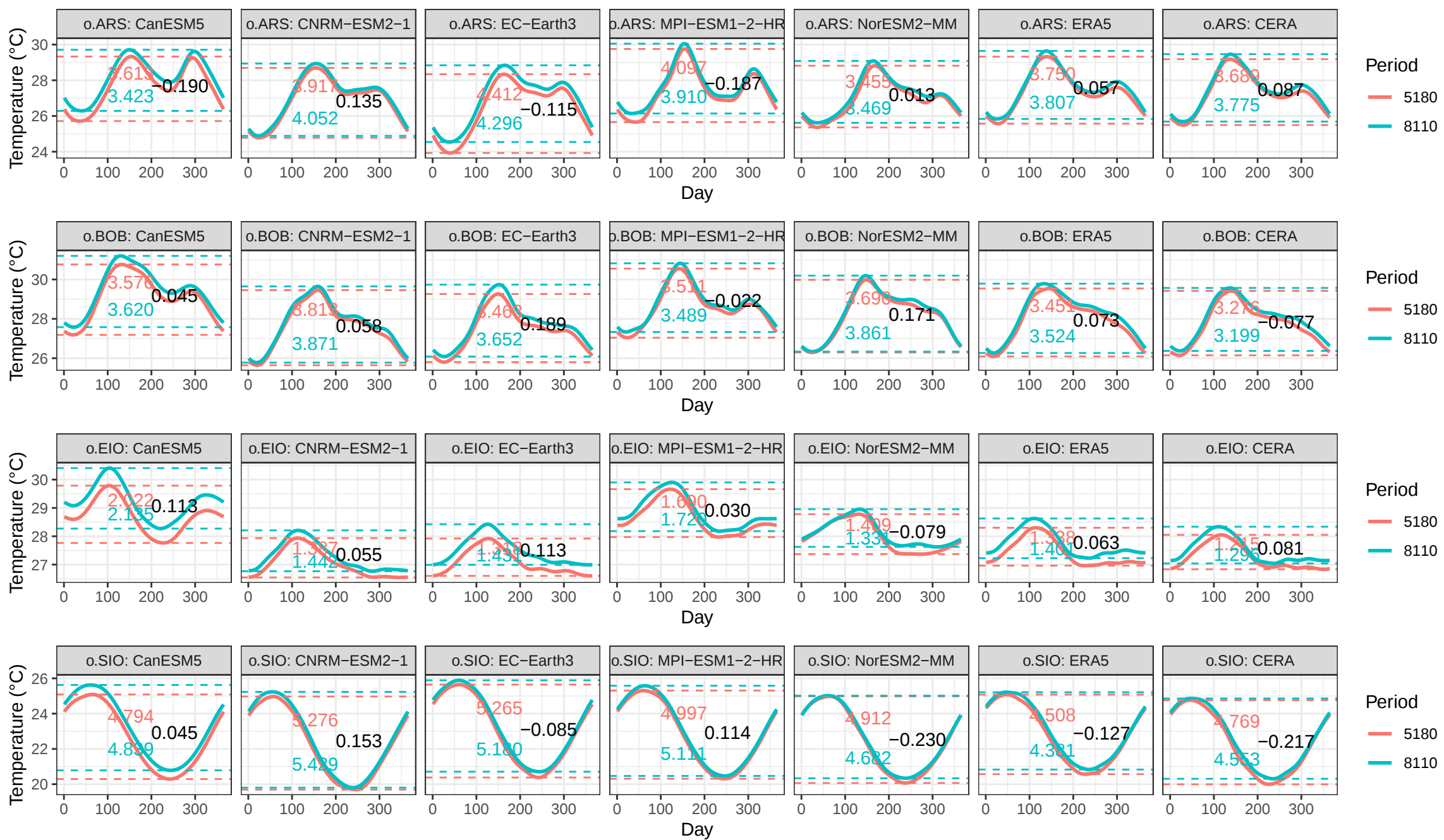












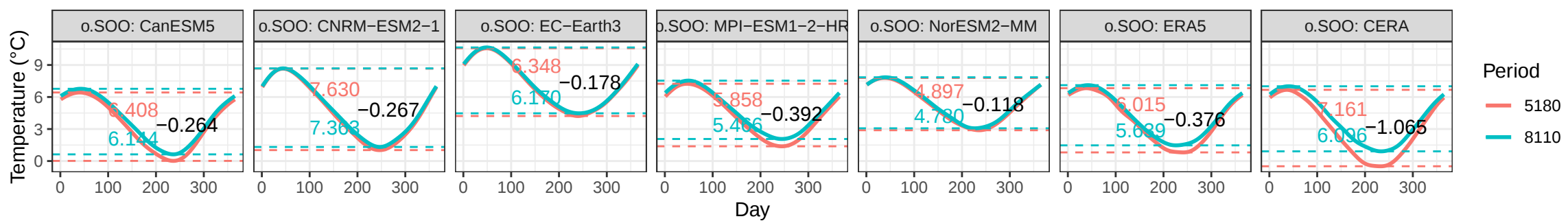


Figure S8: The smoothed annual cycle curves in the future and reference periods of 2071-2100 (ssp370, blue curve) and 1961-1990 (historical, red curve). Plots for five selected CMIP6 ESMs and their multi-model mean are shown in different columns, plots for different geographical regions are depicted in different rows of the figure. The horizontal dashed lines denote annual minimum and maximum temperatures in the two periods. The blue and red numbers describe the amplitudes of the annual cycle in the two periods. The black number in each plot says the differences between the amplitudes in the two periods. The results shown in this figure are summarized in Fig. 10 in the manuscript.

