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Understanding pattern scaling errors across a range of emissions pathways

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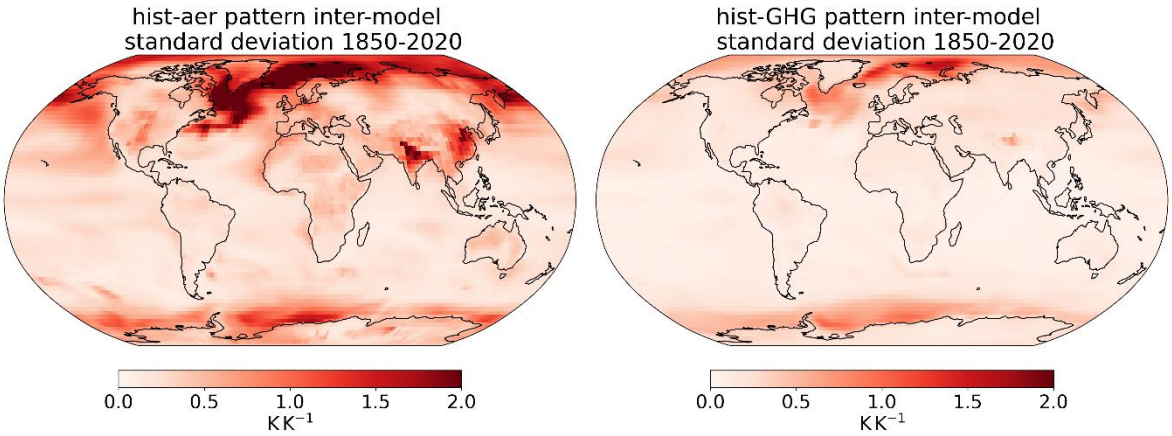
NorESM2-LM	hist-aer (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	hist-GHG (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
EC-Earth3-Veg	ssp119 (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	ssp126 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1
	ssp245 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1
	ssp370 (4)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1
	ssp585 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1
MIROC6	hist-aer (6)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r5i1p1f1 r7i1p1f1 r8i1p1f1
	hist-GHG (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	ssp119 (1)	r1i1p1f1
	ssp126 (50)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r26i1p1f1 r27i1p1f1 r28i1p1f1 r29i1p1f1 r2i1p1f1 r30i1p1f1 r31i1p1f1 r32i1p1f1 r33i1p1f1 r34i1p1f1 r35i1p1f1 r36i1p1f1 r37i1p1f1 r38i1p1f1 r39i1p1f1 r3i1p1f1 r40i1p1f1 r41i1p1f1 r42i1p1f1 r43i1p1f1 r44i1p1f1 r45i1p1f1 r46i1p1f1 r47i1p1f1 r48i1p1f1 r49i1p1f1 r4i1p1f1 r50i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp245 (33)	r1i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r26i1p1f1 r27i1p1f1 r28i1p1f1 r29i1p1f1 r2i1p1f1 r30i1p1f1 r31i1p1f1 r32i1p1f1 r33i1p1f1 r34i1p1f1 r35i1p1f1 r36i1p1f1 r37i1p1f1 r38i1p1f1 r39i1p1f1 r3i1p1f1 r40i1p1f1 r41i1p1f1 r42i1p1f1 r43i1p1f1 r44i1p1f1 r45i1p1f1 r46i1p1f1 r47i1p1f1 r48i1p1f1 r49i1p1f1 r50i1p1f1
	ssp370 (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	ssp585 (50)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r26i1p1f1 r27i1p1f1 r28i1p1f1 r29i1p1f1 r2i1p1f1 r30i1p1f1 r31i1p1f1 r32i1p1f1 r33i1p1f1 r34i1p1f1 r35i1p1f1 r36i1p1f1 r37i1p1f1 r38i1p1f1 r39i1p1f1 r3i1p1f1 r40i1p1f1 r41i1p1f1 r42i1p1f1 r43i1p1f1 r44i1p1f1 r45i1p1f1 r46i1p1f1 r47i1p1f1 r48i1p1f1 r49i1p1f1 r4i1p1f1 r50i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
FGOALS-g3	hist-aer (1)	r1i1p1f1
	hist-GHG (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	ssp119 (1)	r1i1p1f1
	ssp126 (4)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1
	ssp245 (4)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1
	ssp370 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	ssp585 (4)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1

IPSL-CM6A-LR	hist-aer (10)	r10i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	hist-GHG (10)	r10i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp119 (6)	r14i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1
	ssp126 (6)	r14i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1
	ssp245 (11)	r10i1p1f1 r11i1p1f1 r14i1p1f1 r1i1p1f1 r22i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1
	ssp370 (11)	r10i1p1f1 r14i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp585 (6)	r14i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1
EC-Earth3	ssp119 (51)	r101i1p1f1 r102i1p1f1 r103i1p1f1 r104i1p1f1 r105i1p1f1 r106i1p1f1 r107i1p1f1 r108i1p1f1 r109i1p1f1 r110i1p1f1 r111i1p1f1 r112i1p1f1 r113i1p1f1 r114i1p1f1 r115i1p1f1 r116i1p1f1 r117i1p1f1 r118i1p1f1 r119i1p1f1 r120i1p1f1 r121i1p1f1 r122i1p1f1 r123i1p1f1 r124i1p1f1 r125i1p1f1 r126i1p1f1 r127i1p1f1 r128i1p1f1 r129i1p1f1 r130i1p1f1 r131i1p1f1 r132i1p1f1 r133i1p1f1 r134i1p1f1 r135i1p1f1 r136i1p1f1 r137i1p1f1 r138i1p1f1 r139i1p1f1 r140i1p1f1 r141i1p1f1 r142i1p1f1 r143i1p1f1 r144i1p1f1 r145i1p1f1 r146i1p1f1 r147i1p1f1 r148i1p1f1 r149i1p1f1 r150i1p1f1 r4i1p1f1
	ssp126 (7)	r11i1p1f1 r13i1p1f1 r15i1p1f1 r1i1p1f1 r4i1p1f1 r6i1p1f1 r9i1p1f1
	ssp245 (22)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r4i1p1f1 r6i1p1f1 r7i1p1f1 r9i1p1f1
	ssp370 (7)	r11i1p1f1 r13i1p1f1 r15i1p1f1 r1i1p1f1 r4i1p1f1 r6i1p1f1 r9i1p1f1
	ssp585 (58)	r101i1p1f1 r102i1p1f1 r103i1p1f1 r104i1p1f1 r105i1p1f1 r106i1p1f1 r107i1p1f1 r108i1p1f1 r109i1p1f1 r110i1p1f1 r111i1p1f1 r112i1p1f1 r113i1p1f1 r114i1p1f1 r115i1p1f1 r116i1p1f1 r117i1p1f1 r118i1p1f1 r119i1p1f1 r11i1p1f1 r120i1p1f1 r121i1p1f1 r122i1p1f1 r123i1p1f1 r124i1p1f1 r125i1p1f1 r126i1p1f1 r127i1p1f1 r128i1p1f1 r129i1p1f1 r130i1p1f1 r131i1p1f1 r132i1p1f1 r133i1p1f1 r134i1p1f1 r135i1p1f1 r136i1p1f1 r137i1p1f1 r138i1p1f1 r139i1p1f1 r13i1p1f1 r140i1p1f1 r141i1p1f1 r142i1p1f1 r143i1p1f1 r144i1p1f1 r145i1p1f1 r146i1p1f1 r147i1p1f1 r148i1p1f1 r149i1p1f1 r150i1p1f1 r15i1p1f1 r1i1p1f1 r3i1p1f1 r4i1p1f1 r6i1p1f1 r9i1p1f1

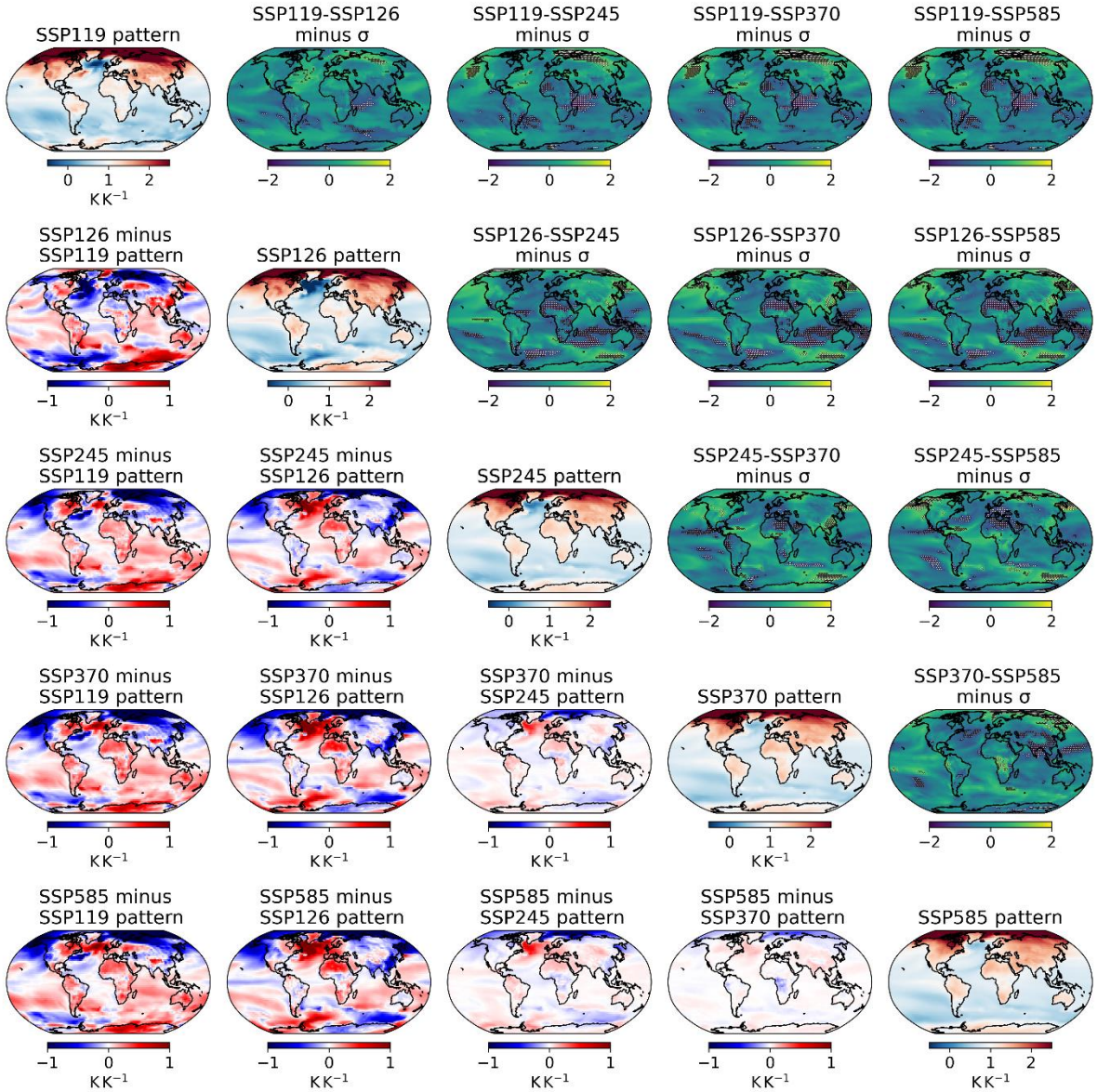
CanESM5	hist-aer (15)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	hist-GHG (25)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp119 (25)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp126 (25)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp245 (25)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp370 (25)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
	ssp585 (25)	r10i1p1f1 r11i1p1f1 r12i1p1f1 r13i1p1f1 r14i1p1f1 r15i1p1f1 r16i1p1f1 r17i1p1f1 r18i1p1f1 r19i1p1f1 r1i1p1f1 r20i1p1f1 r21i1p1f1 r22i1p1f1 r23i1p1f1 r24i1p1f1 r25i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1 r6i1p1f1 r7i1p1f1 r8i1p1f1 r9i1p1f1
MRI-ESM2-0	hist-aer (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	hist-GHG (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	ssp119 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	ssp126 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	ssp245 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	ssp370 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
	ssp585 (5)	r1i1p1f1 r2i1p1f1 r3i1p1f1 r4i1p1f1 r5i1p1f1
BCC-CSM2-MR	hist-aer (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	hist-GHG (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
ACCESS-ESM1-5	hist-aer (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	hist-GHG (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
ACCESS-CM2	hist-aer (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	hist-GHG (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
GFDL-ESM4	hist-aer (1)	r1i1p1f1
	hist-GHG (1)	r1i1p1f1
	ssp119 (1)	r1i1p1f1

	ssp126 (1)	r1i1p1f1
	ssp245 (3)	r1i1p1f1 r2i1p1f1 r3i1p1f1
	ssp370 (1)	r1i1p1f1
	ssp585 (1)	r1i1p1f1

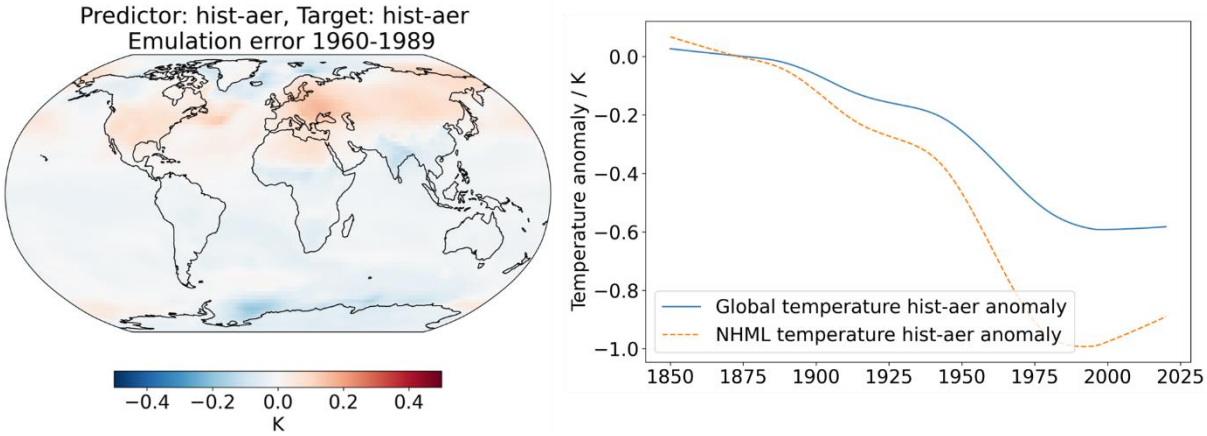
Supplementary Table S1: the 12 ESMs used in the analysis, and the members used for each experiment. All ESMs with at least one member of the default initialisation, physics, and forcings (i1p1f1) in the cmip6-ng database were used. Eight ESMs had all five SSP experiments while 10 had both DAMIP experiments.



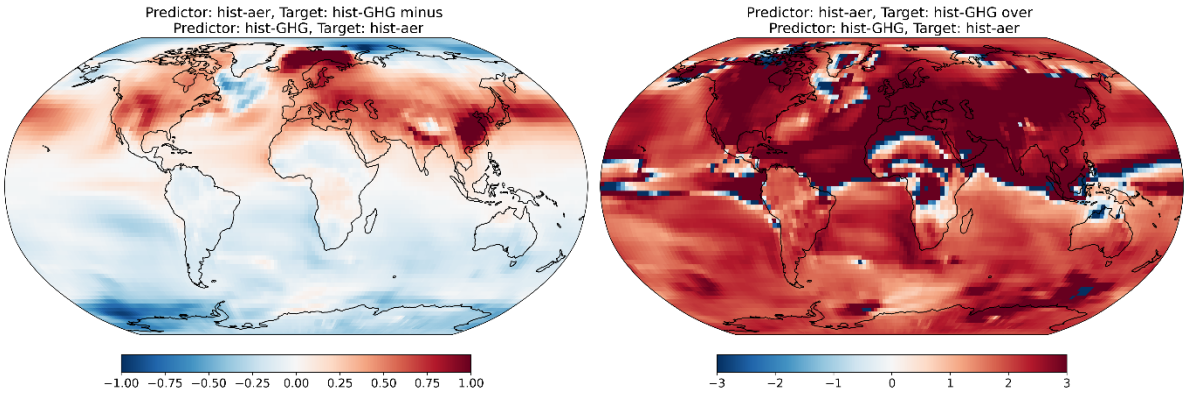
Supplementary Figure S1: inter-model standard deviation in the temperature response pattern in hist-aer and hist-GHG. Calculated between the 10 ESMs in Supplementary Table S1, with linear regression applied at each gridcell in MESMER.



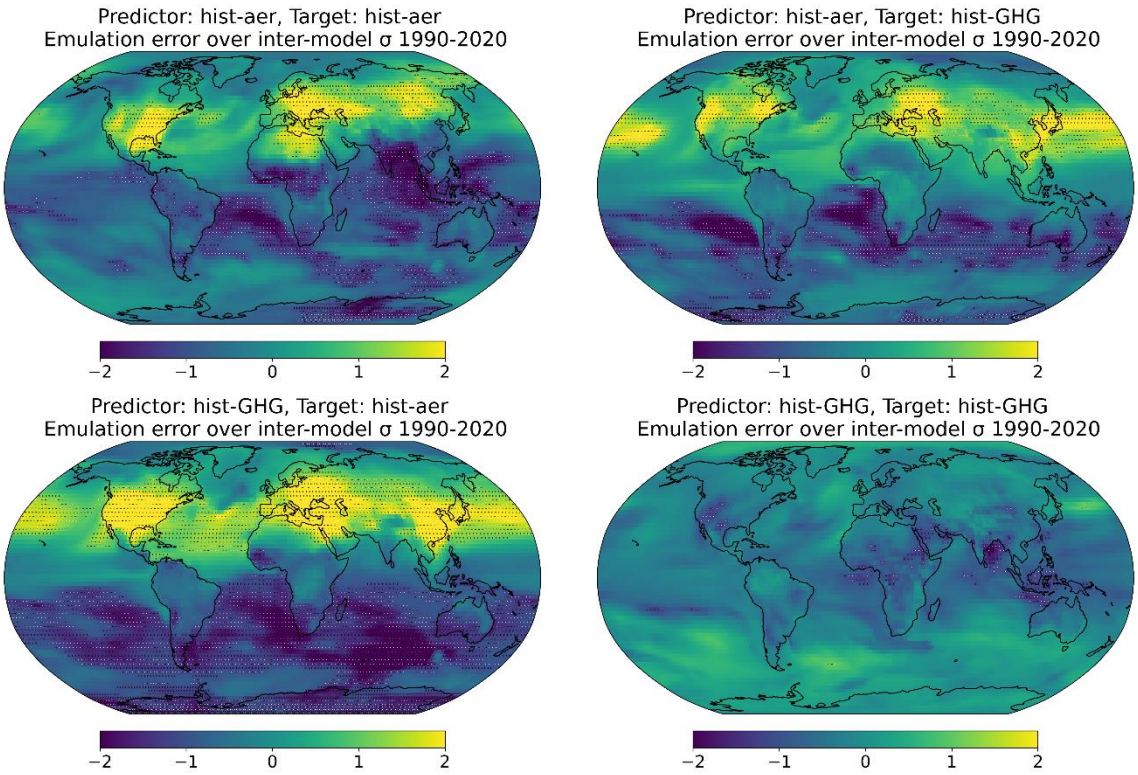
Supplementary Figure S2: as per Figure 3 but for all combinations of the five SSP scenarios analysed in this study. The diagonal shows the temperature patterns from each individual scenario. The bottom left section shows the pattern differences between each scenario pair. The top right section shows the difference divided by the inter-model standard deviation, with differences greater than one standard deviation stippled, for each pair.



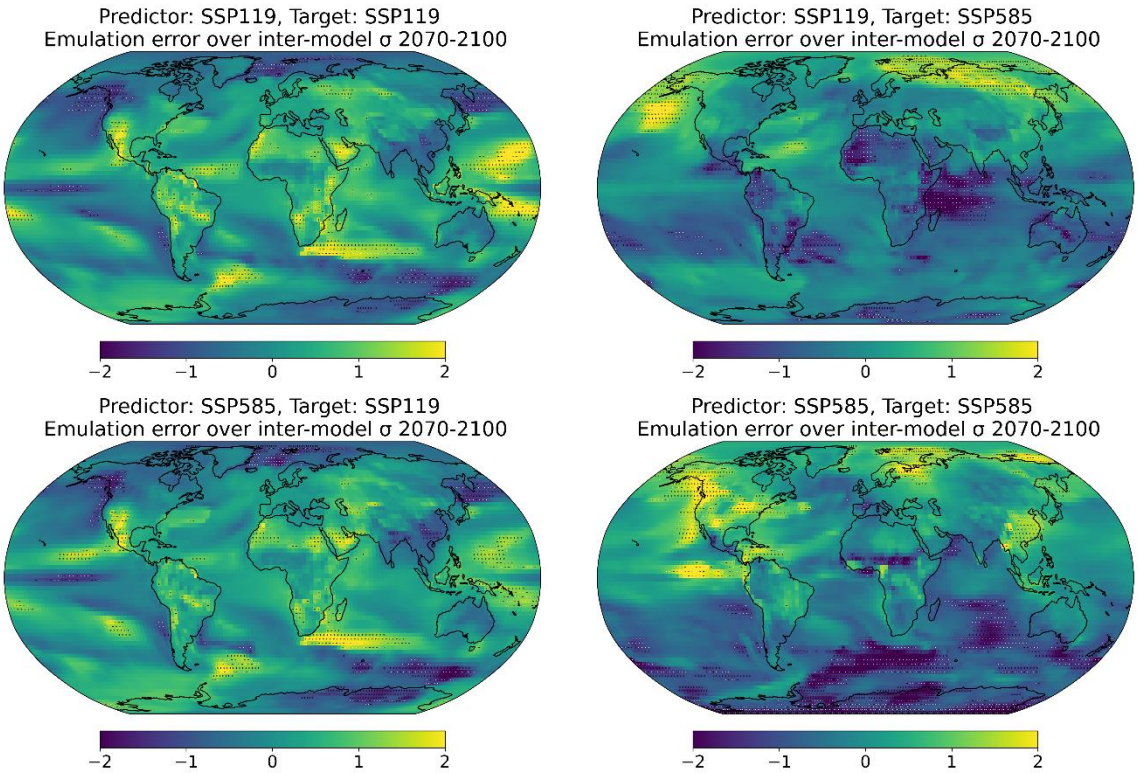
Supplementary Figure S3: hist-aer self-emulation error in 1960-1989 (left) and timeseries of global and NHML hist-aer temperature response (right). Both plots are averaged across all 10 ESMs used for the DAMIP analysis.



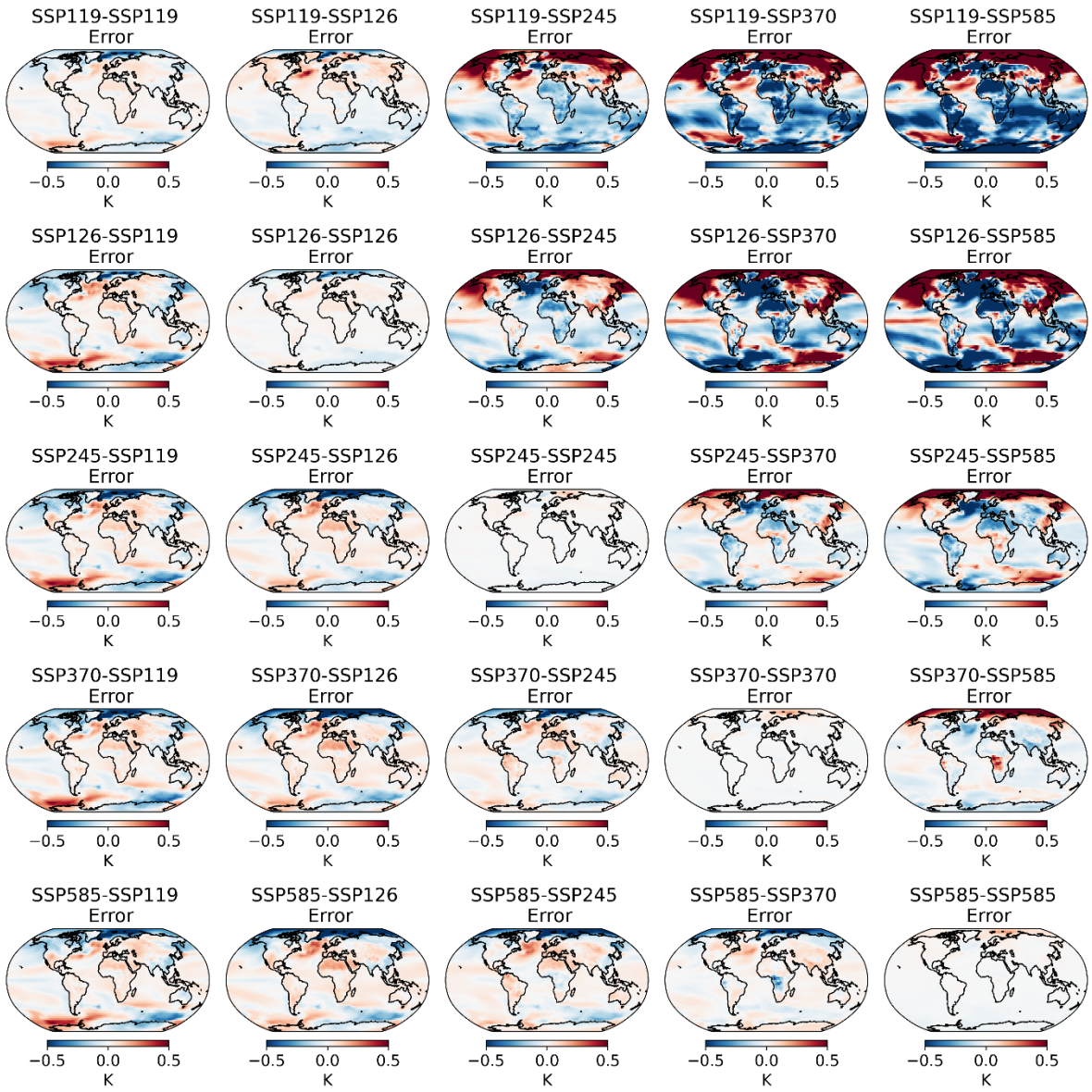
Supplementary Figure S4: difference (left) and ratio (right) between panels b) and c) of Figure 4 in the main text.



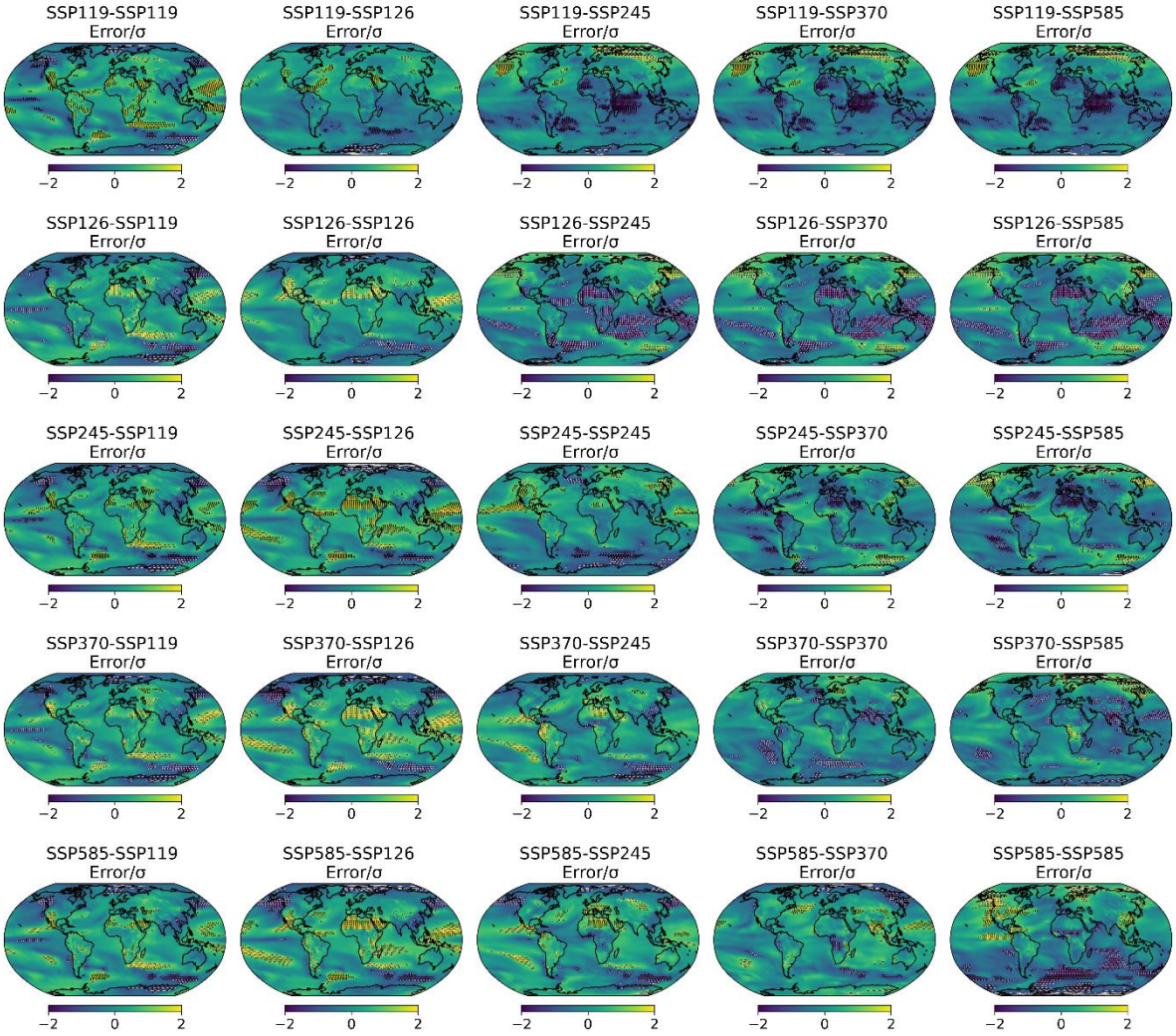
Supplementary Figure S5: The 1990-2020 DAMIP multi-model mean pattern scaling errors as shown in Figure 4 divided by the inter-model standard deviation in these errors. Differences greater than one standard deviation are stippled.



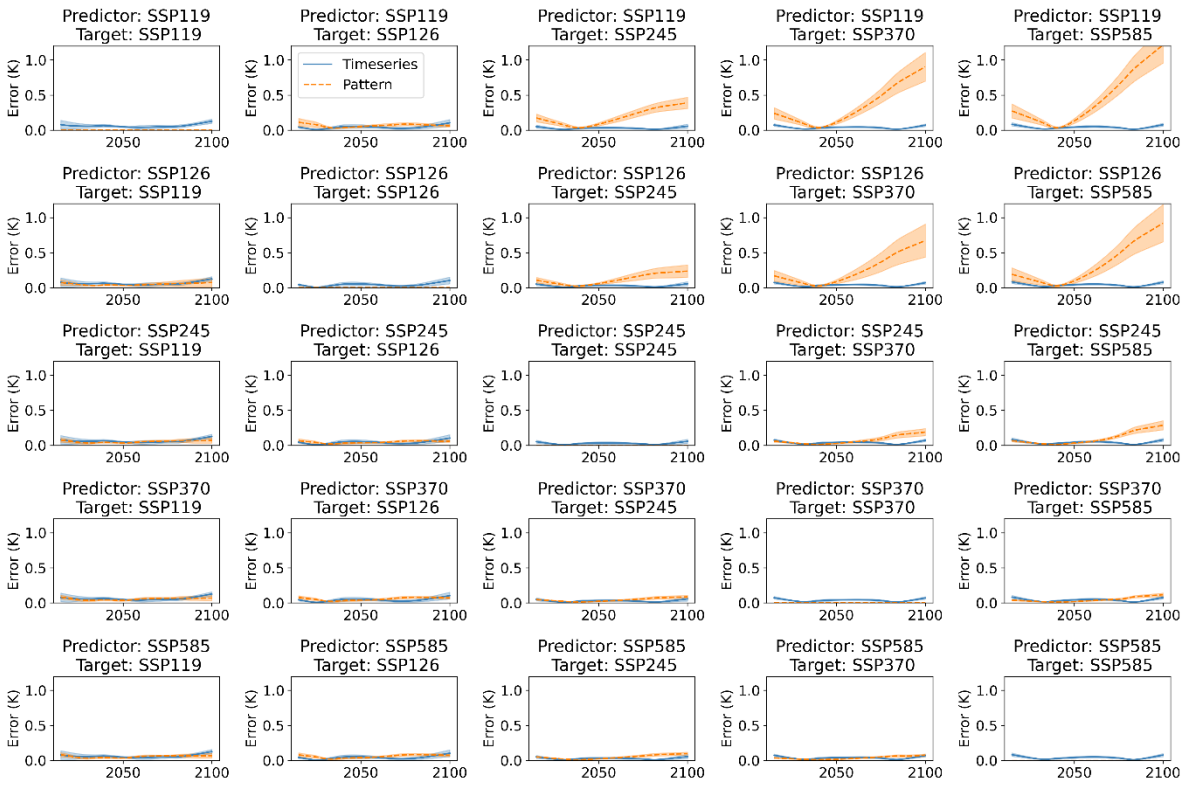
Supplementary Figure S6: 2070-2100 SSP multi-model mean pattern scaling errors as shown in Figure 5, divided by the inter-model standard deviation in these errors. Differences greater than one standard deviation are stippled.



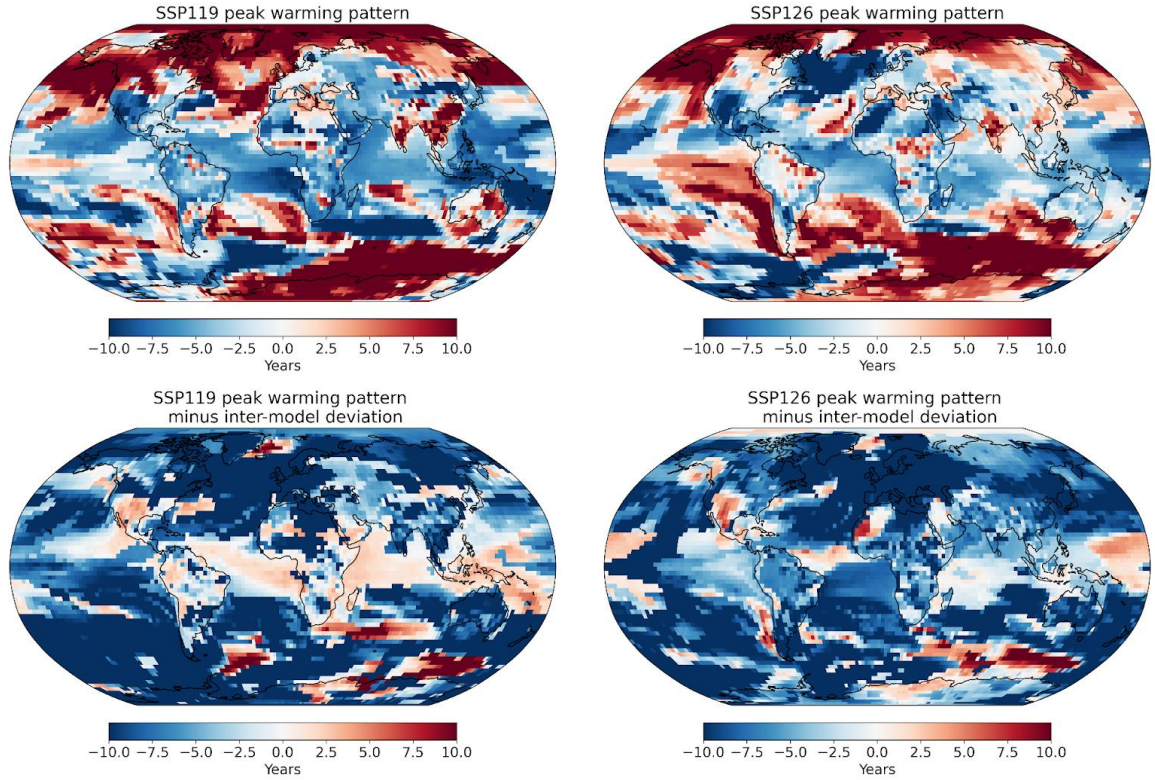
Supplementary Figure S7: As Figure 5 of the main text, but for every pair of the five SSP scenarios analysed here.



Supplementary Figure S8: As Figure S6, but for every pair of the five SSP scenarios analysed here.

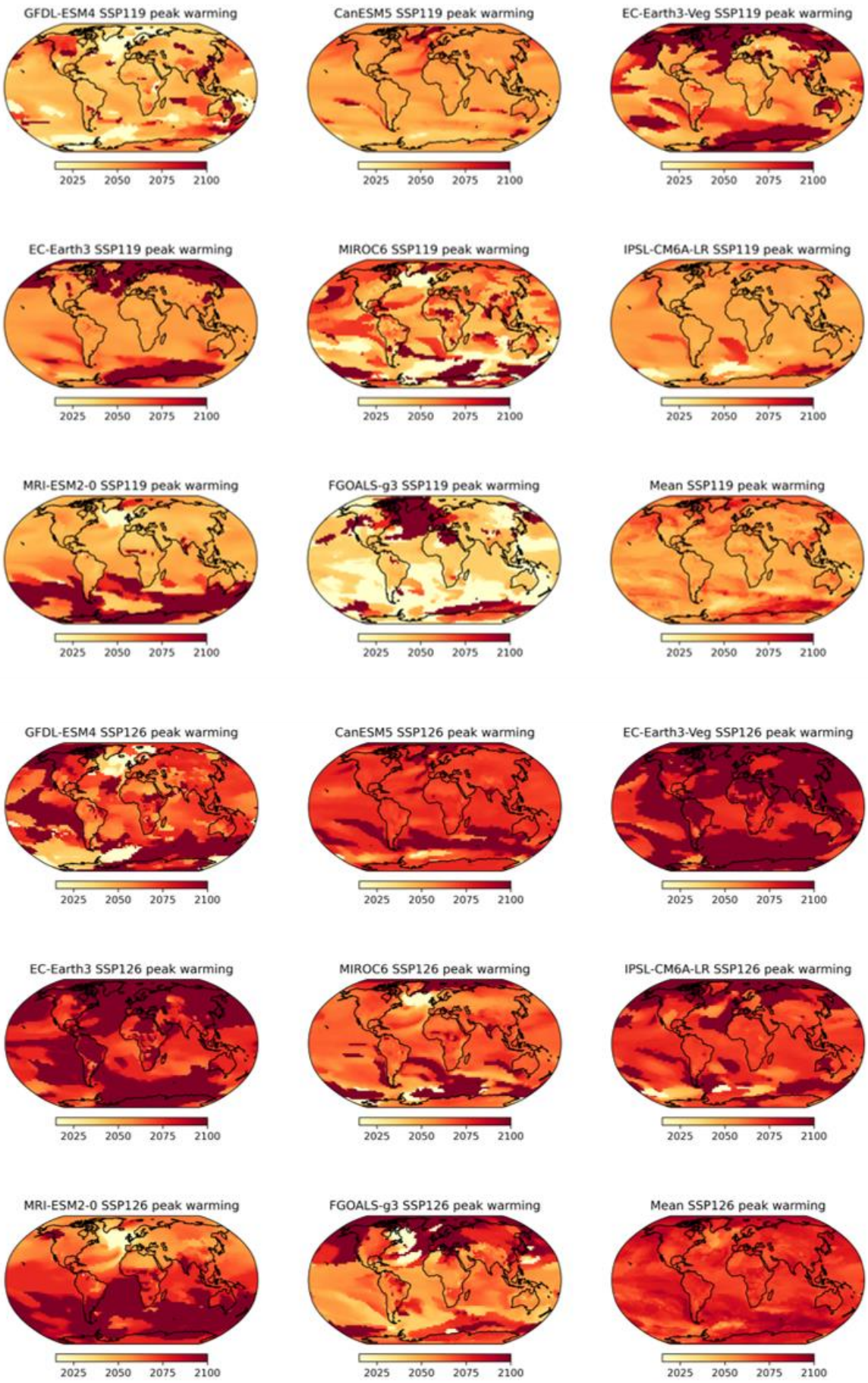


Supplementary Figure S9: as Figure 6 in the main text but for every pair of the five SSP scenarios and with identical scales to allow for comparison of error magnitudes between pairs of scenarios.

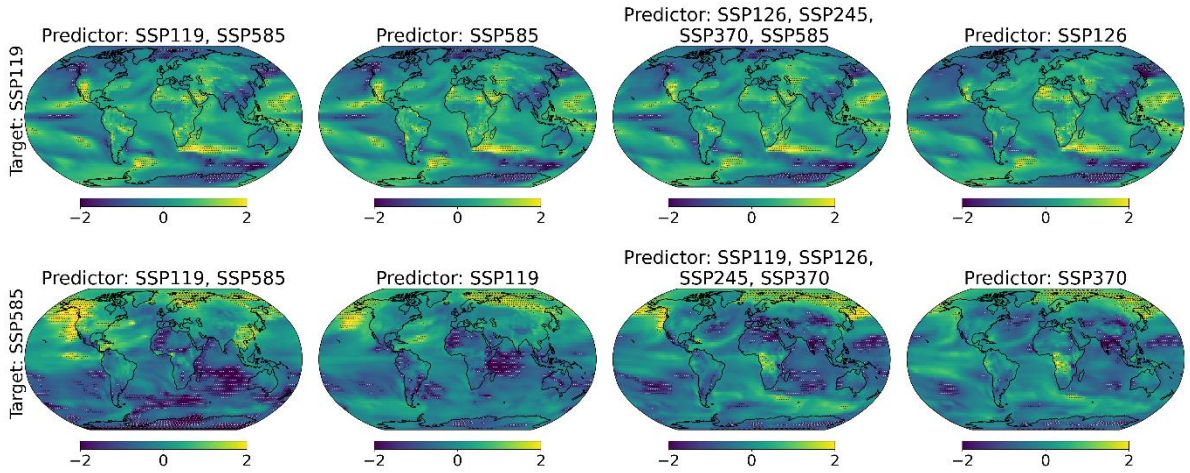


Supplementary Figure S10: deviation in local peak warming year from global average (of local warming year) averaged across 8 ESMs in SSP119 (top left) and SSP126 (top right), and the magnitude of this deviation minus one inter-model standard deviation (bottom). Note that the

deviation is with respect to the global weighted average of the local peak temperature year, not the peak year of the global average temperature, which are not necessarily the same.


GFDL-ESM4 SSP119 peak warming
CanESM5 SSP119 peak warming
EC-Earth3-Veg SSP119 peak warming
EC-Earth3 SSP119 peak warming
MIROC6 SSP119 peak warming
IPSL-CM6A-LR SSP119 peak warming
MRI-ESM2-0 SSP119 peak warming
FGOALS-g3 SSP119 peak warming
Mean SSP119 peak warming
GFDL-ESM4 SSP126 peak warming
CanESM5 SSP126 peak warming
EC-Earth3-Veg SSP126 peak warming
EC-Earth3 SSP126 peak warming
MIROC6 SSP126 peak warming
IPSL-CM6A-LR SSP126 peak warming
MRI-ESM2-0 SSP126 peak warming
FGOALS-g3 SSP126 peak warming
Mean SSP126 peak warming
2025 2050 2075 2100

Supplementary Figure S11: peak warming year - calculated as the peak in the LOWESS-smoothed timeseries at each gridcell - in each of the eight ESMs studied in the SSP analysis here, along with the multimodal year, for SSP119 (top) and SSP126 (bottom).



Supplementary Figure S12: The 2070-2100 pattern scaling errors divided by the inter-model variability in the errors, when projecting SSP119 (top) and SSP585 (bottom) for patterns using four sets of predictors - see main text for details. Differences greater than one standard deviation are stippled.