

Supplementary Information for Forced Changes in Modes of Variability in E3SM and CESM as Diagnosed in the CVD Pv6

John T. Fasullo¹, Julie M. Caron¹, Adam S. Phillips¹, Nicola Maher^{2,3,4}, Clara Deser¹,

Jiwoo Lee⁵

¹*NSF National Center for Atmospheric Research, Boulder, CO, 80301, USA*

²*Australian National University, Canberra, Australia*

³*Cooperative Institute for Research in Environmental Sciences, University of Colorado
at Boulder, 80309 USA*

⁴*ARC Centre of Excellence for Weather of the 21st Century, Canberra, Australia*

⁵*Lawrence Livermore National Laboratory, Livermore, California*

17 Feb 2026

Ensemble	E3SM1	CESM1	E3SM2	CESM2	CESM1HR	CESM1SR
T_{2m} σ	0.86	0.84	0.92	0.85	0.73	0.88
P σ	0.84	0.90	0.91	0.79	0.69	0.87
El Niño T_{2m}	0.74	0.72	0.83	0.76	0.50	0.71
El Niño P	0.88	0.86	0.92	0.73	0.35	0.83
El Niño HOV	0.88	0.91	0.94	0.76	0.69	0.93
La Niña T_{2m}	0.60	0.78	0.63	0.71	0.59	0.58
La Niña P	0.75	0.86	0.73	0.80	0.40	0.80
La Niña HOV	0.73	0.85	0.83	0.82	0.64	0.93
IOD	0.67	0.47	0.93	0.17	0.94	0.91
PDV	0.81	0.65	0.88	0.03	0.48	0.75
NPMM	0.43	0.59	0.93	0.85	0.17	0.86
SAM	0.53	0.59	0.86	0.43	0.30	0.57
AMV	0.75	0.68	0.84	0.71	0.54	0.69
PNA	0.52	0.49	0.92	0.45	0.67	0.79
NAO	0.55	0.85	0.84	0.89	0.52	0.78

Table S1: Pattern correlations of ensemble-mean future changes from the piC versus the multi-ensemble mean future change pattern. Minimum correlations for each mode are in bold.

Ensemble	E3SM1	CESM1	E3SM2	CESM2	CESM1HR	CESM1SR
T_{2m} σ	0.009	0.009	0.008	0.017	0.011	0.008
P σ	0.015	0.011	0.006	0.005	0.015	0.012
El Niño T_{2m}	0.07	0.08	0.07	0.04	0.06	0.11
El Niño P	0.07	0.06	0.06	0.04	0.09	0.09
El Niño HOV	0.02	0.02	0.02	0.02	0.05	0.02
IOD	0.03	0.02	0.02	0.02	0.01	0.01
PDV	0.23	0.15	0.10	0.02	0.04	0.04
NPMM	0.36	0.03	0.03	0.22	0.05	0.02
SAM	0.03	0.02	0.03	0.05	0.01	0.04
AMV	0.07	0.07	0.09	0.07	0.07	0.12
PNA	0.03	0.02	0.02	0.02	0.03	0.03
NAO	0.02	0.03	0.03	0.03	0.06	0.02

Table S2: Standard deviation ranges of PC for each mode pattern against observations for the ensembles considered.

Mode	E3SM1			CESM1			E3SM2			CESM2			CESM1HR			CESM1SR		
	LIN	QUA	30y	LIN	QUA	30y	LIN	QUA	30y	LIN	QUA	30y	LIN	QUA	30y	LIN	QUA	30y
Niño 34 (C)	0.43 ±0.0 0	0.29 ±0.0 0	0.28 ±0.0 0	0.36 ±0.0 0	0.26 ±0.0 0	0.26± 0.00	0.33± 0.00	0.23± 0.00	0.23± 0.00	0.34± 0.00	0.22± 0.00	0.23± 0.01	0.31± 0.00	0.25± 0.00	0.25± 0.01	0.37± 0.00	0.30± 0.00	0.31± 0.00
IOD (C)	0.19 ±0.0 0	0.18 ±0.0 0	0.19 ±0.0 1	0.14 ±0.0 0	0.14 ±0.0 0	0.16± 0.00	0.18± 0.00	0.19± 0.00	0.20± 0.00	0.12± 0.00	0.12± 0.00	0.14± 0.01	0.20± 0.00	0.19± 0.00	0.20± 0.00	0.28± 0.00	0.29± 0.00	0.29± 0.00

PDV (C)	1.53	0.43	0.40	1.52	0.34	0.36±	1.31±	0.28±	0.34±	1.17±	0.33±	0.31±	1.29±	0.44±	0.45±	1.47±	0.37±	0.42±
	±0.0	±0.1	±0.0	±0.0	±0.0	0.02	0.12	0.02	0.02	0.11	0.03	0.02	0.23	0.03	0.03	0.13	0.02	0.04
	6	8	4	6	4													
NPMM (C)	0.87	0.37	0.39	0.51	0.31	0.35±	0.66±	0.24±	0.30±	0.52±	0.28±	0.37±	0.55±	0.34±	0.38±	0.78±	0.38±	0.44±
	±0.0	±0.1	±0.1	±0.0	±0.0	0.02	0.05	0.01	0.01	0.05	0.03	0.06	0.09	0.02	0.02	0.10	0.03	0.03
	7	4	1	3	2													
AMV (C)	0.47	0.15	0.10	0.42	0.14	0.09±	0.23±	0.07±	0.06±	0.21±	0.11±	0.08±	0.23±	0.10±	0.07±	0.22±	0.08±	0.07±
	±0.0	±0.0	±0.0	±0.0	±0.0	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0	0	1	0	0													
SAM JJA (hPa)	0.27	0.28	0.33	0.25	0.27	0.31±	0.20±	0.20±	0.24±	0.17±	0.18±	0.22±	0.36±	0.36±	0.38±	0.33±	0.33±	0.36±
	±0.0	±0.0	±0.0	±0.0	±0.0	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
	1	1	2	1	1													
PNA DJF (hPa)	0.28	0.29	0.32	0.24	0.25	0.28±	0.21±	0.22±	0.26±	0.18±	0.19±	0.22±	0.37±	0.38±	0.38±	0.34±	0.35±	0.37±
	±0.0	±0.0	±0.0	±0.0	±0.0	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
	1	1	2	1	1													
NAO DJF (hPa)	0.24	0.25	0.29	0.24	0.25	0.28±	0.19±	0.21±	0.24±	0.17±	0.19±	0.23±	0.38±	0.38±	0.41±	0.34±	0.35±	0.38±
	±0.0	±0.0	±0.0	±0.0	±0.0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
	1	2	2	1	1													

Table S3: Root-mean-squared error in mode indices using various approximations of removing forced signals including a linear fit (LIN), quadratic fit (QUA), and 30-yr running mean (30y) versus removal of the ensemble mean, shown by ensemble and mode. Best performing approaches are shown in bold.

Pattern Correlations

	ENSO TAS (DJF ⁻¹)	ENSO PSL (DJF ⁻¹)	El Niño Hovmöller	La Niña Hovmöller	AMV Low-Pass	PDV	NAO (JFM)	PNA (DJF)	SAM (DJF)	SST std dev (Ann)	PR std dev (Ann)	Mean Score
E3SM1 (10%)	0.60	0.71	0.83	0.72	0.21	0.67	0.91	0.92	0.98	0.60	0.85	0.82
E3SM1 (Avg)	0.70	0.79	0.88	0.77	0.30	0.75	0.94	0.95	0.98	0.64	0.85	0.84
E3SM1 (90%)	0.75	0.84	0.90	0.81	0.38	0.83	0.95	0.96	0.99	0.66	0.86	0.86
CESM1 (10%)	0.55	0.75	0.88	0.86	0.15	0.82	0.88	0.89	0.95	0.72	0.87	0.83
CESM1 (Avg)	0.60	0.80	0.90	0.88	0.26	0.85	0.92	0.93	0.96	0.73	0.88	0.85
CESM1 (90%)	0.65	0.84	0.92	0.90	0.36	0.88	0.95	0.94	0.97	0.74	0.88	0.85
E3SM2 (10%)	0.63	0.76	0.91	0.75	0.23	0.70	0.88	0.91	0.98	0.58	0.88	0.85
E3SM2 (Avg)	0.72	0.82	0.93	0.81	0.34	0.80	0.91	0.94	0.98	0.61	0.89	0.86
E3SM2 (90%)	0.76	0.87	0.94	0.86	0.43	0.85	0.94	0.96	0.99	0.63	0.89	0.86
CESM2 (10%)	0.68	0.81	0.90	0.86	0.06	0.85	0.90	0.95	0.94	0.75	0.91	0.87
CESM2 (Avg)	0.73	0.87	0.91	0.88	0.21	0.87	0.94	0.96	0.96	0.77	0.91	0.88
CESM2 (90%)	0.77	0.90	0.93	0.90	0.32	0.88	0.96	0.97	0.97	0.78	0.91	0.89
CESM1HR (10%)	0.52	0.70	0.71	0.63	-0.08	0.77	0.90	0.92	0.95	0.60	0.86	0.80
CESM1HR (Avg)	0.62	0.77	0.77	0.76	0.16	0.84	0.94	0.95	0.97	0.67	0.87	0.83
CESM1HR (90%)	0.71	0.84	0.81	0.82	0.28	0.87	0.95	0.96	0.98	0.73	0.88	0.84
CESM1LR (10%)	0.48	0.66	0.82	0.78	0.08	0.80	0.89	0.91	0.97	0.69	0.85	0.82
CESM1LR (Avg)	0.60	0.73	0.85	0.81	0.26	0.83	0.95	0.92	0.98	0.70	0.86	0.84
CESM1LR (90%)	0.68	0.78	0.87	0.84	0.38	0.86	0.97	0.93	0.98	0.72	0.86	0.85

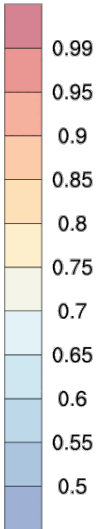


Table S4: Ensemble summary scores for the observational evaluation cases (1950-2023 except for PR, 1979-2023) based on CVDPv6 summary metrics.

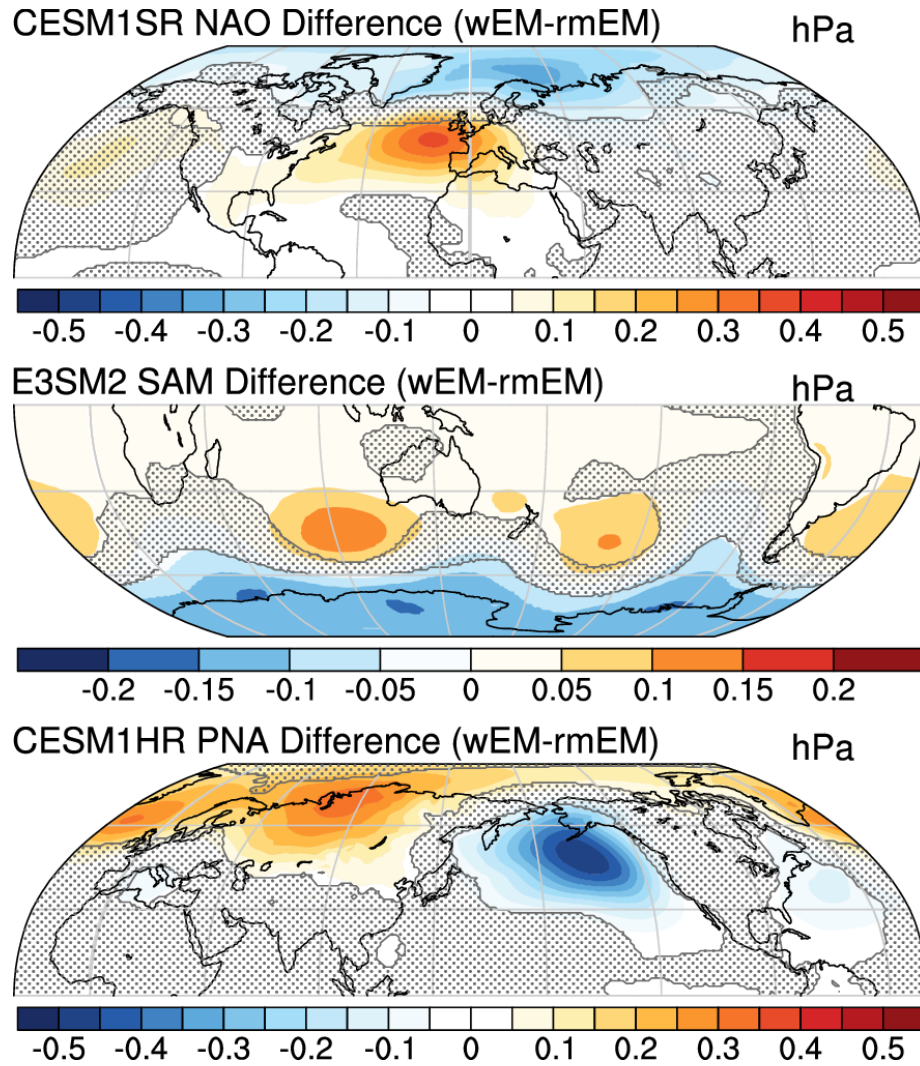


Figure S1: Differences between mode patterns computed using fields with (wEM) and without (rmEM) the ensemble mean. The mode differences are for the NAO in Dec. through Feb. in CESM1SR (top), the SAM in June through Aug. in E3SM2 (middle), and the PNA in Dec. through Feb. in CESM1HR (bottom).

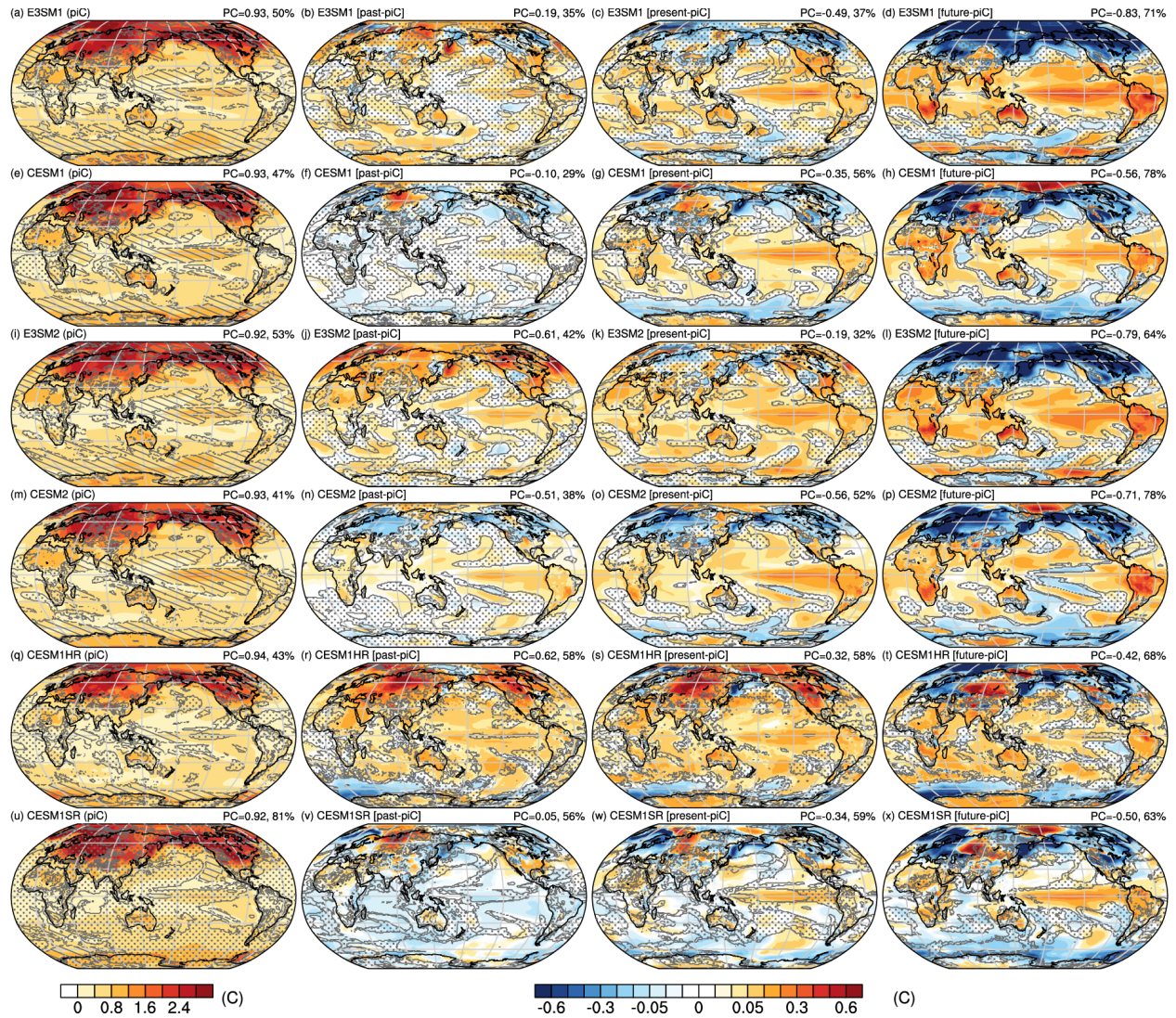


Figure S2: As in Figure 2 but for December through February average near-surface air temperature.

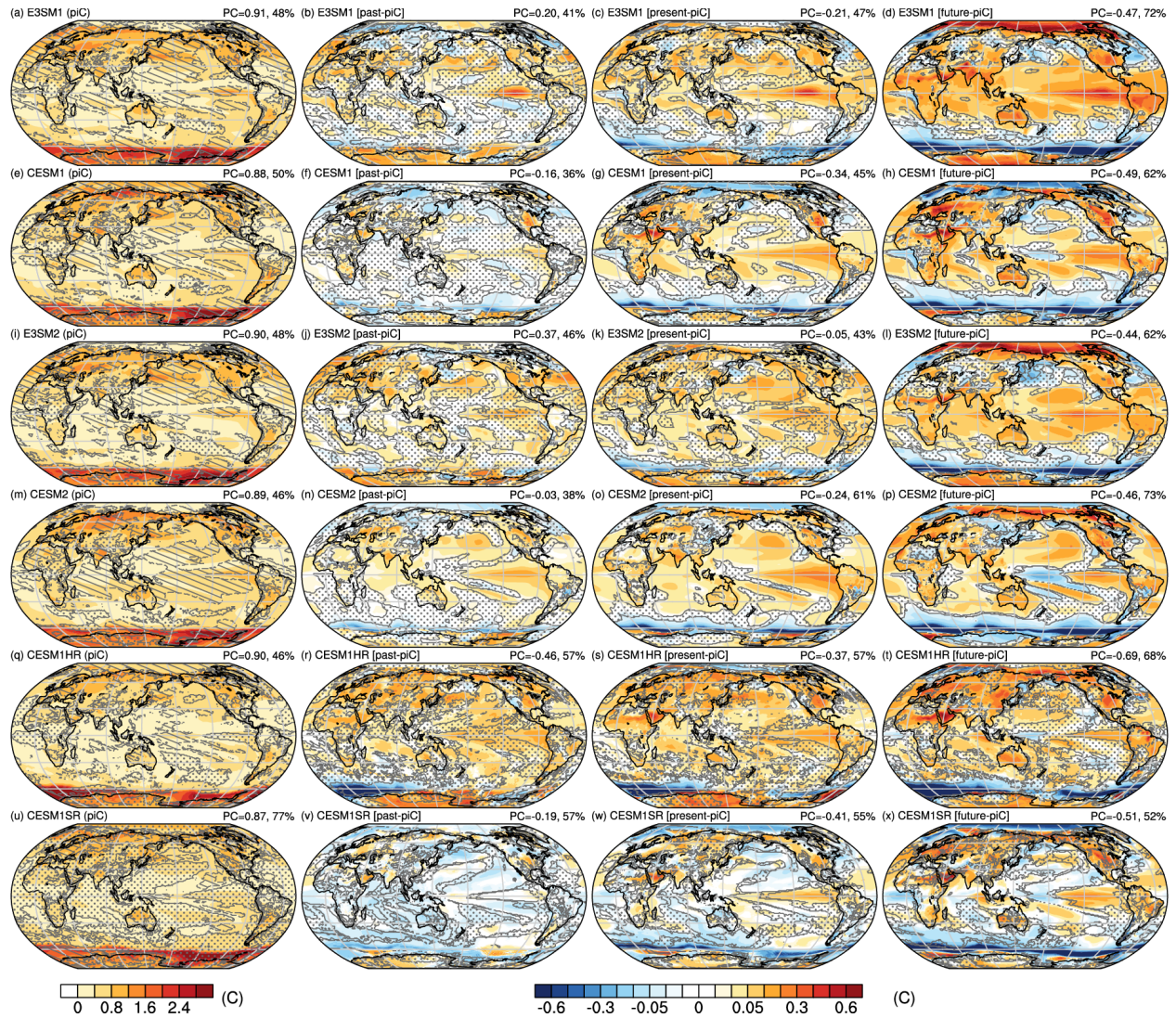


Figure S3: As in Figure 2 but for June through August average near-surface air temperature.

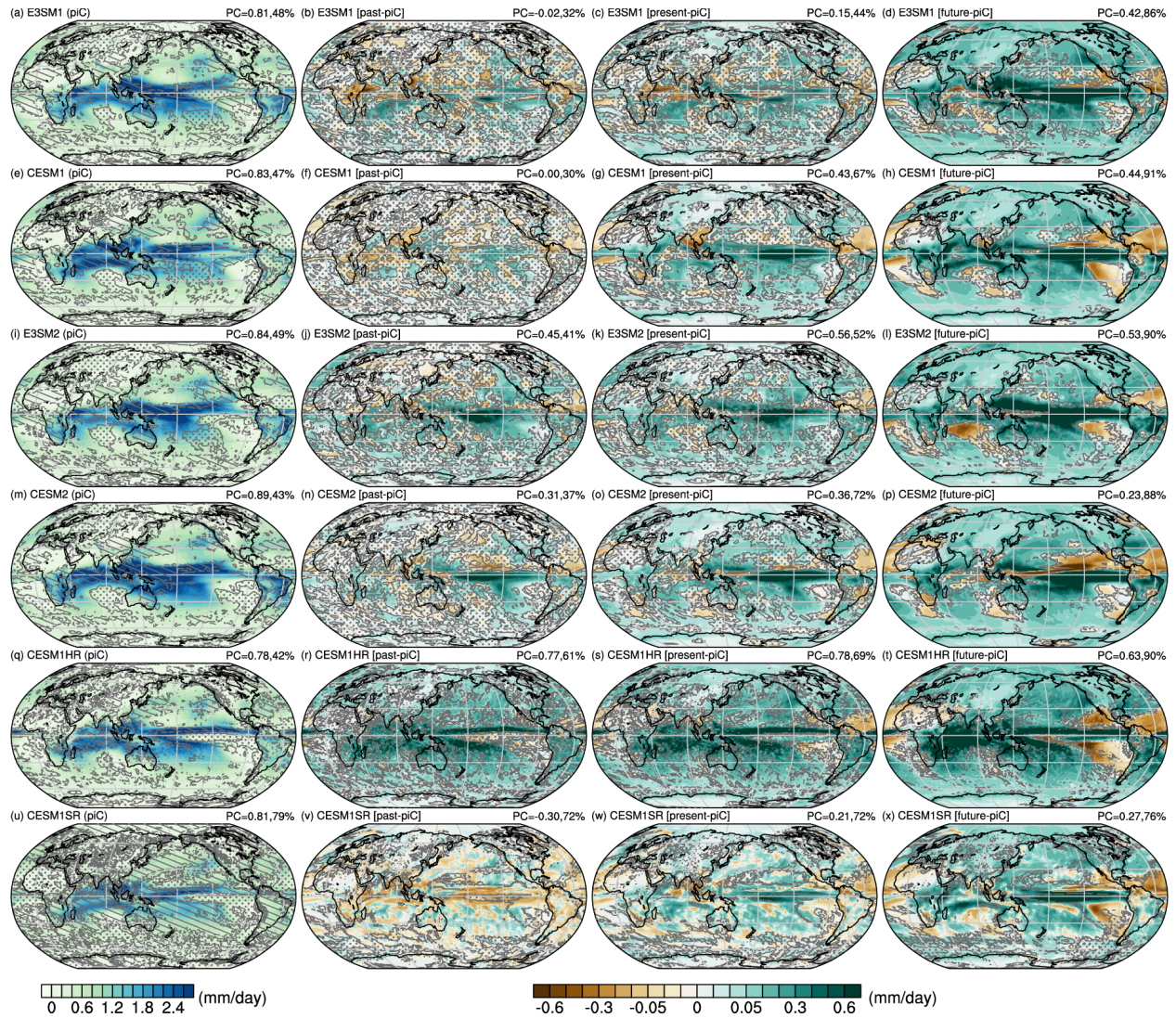


Figure S4: As in Figure 3 but for December through February average precipitation.

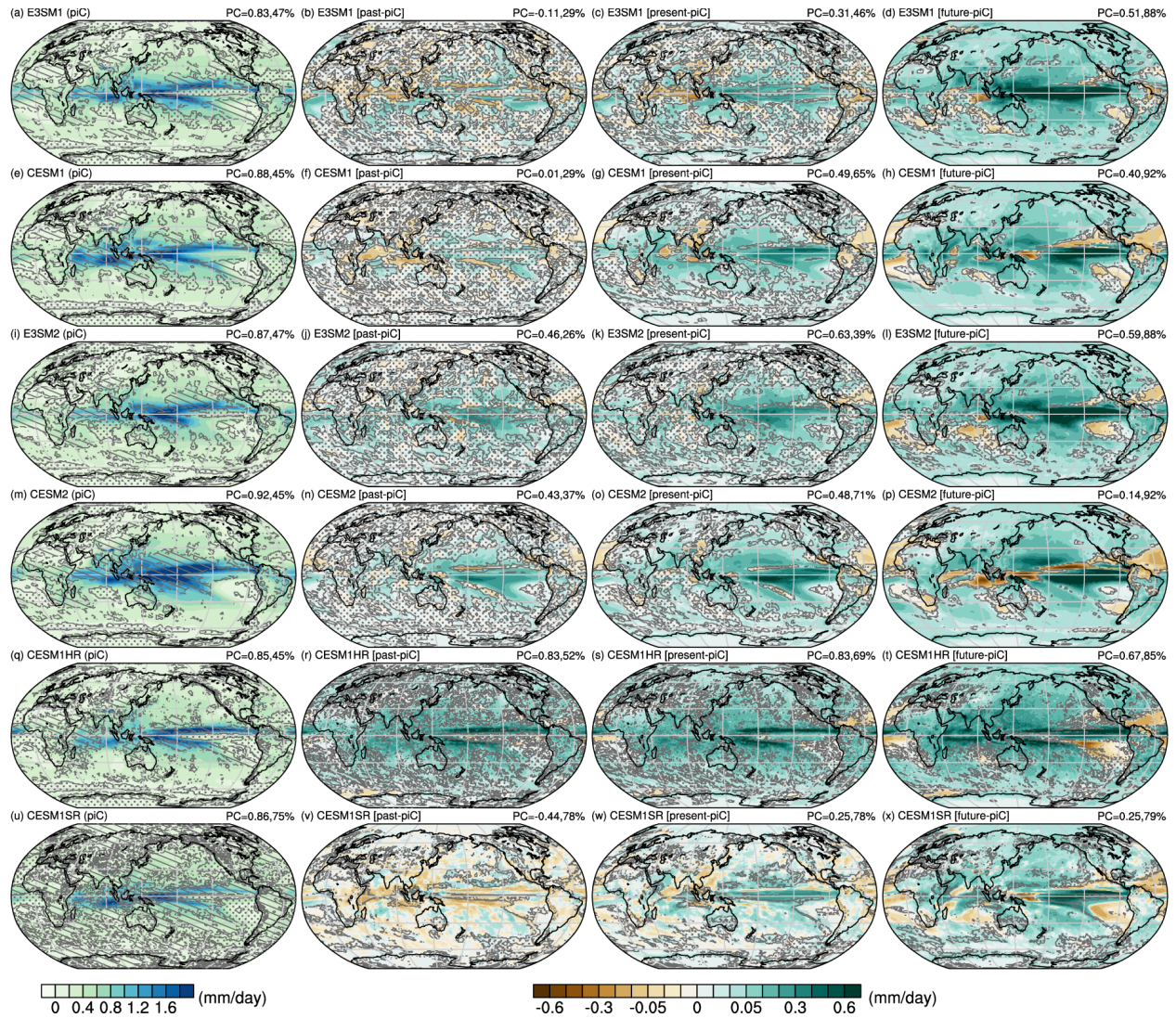


Figure S5: As in Figure 3 but for June through August average precipitation.

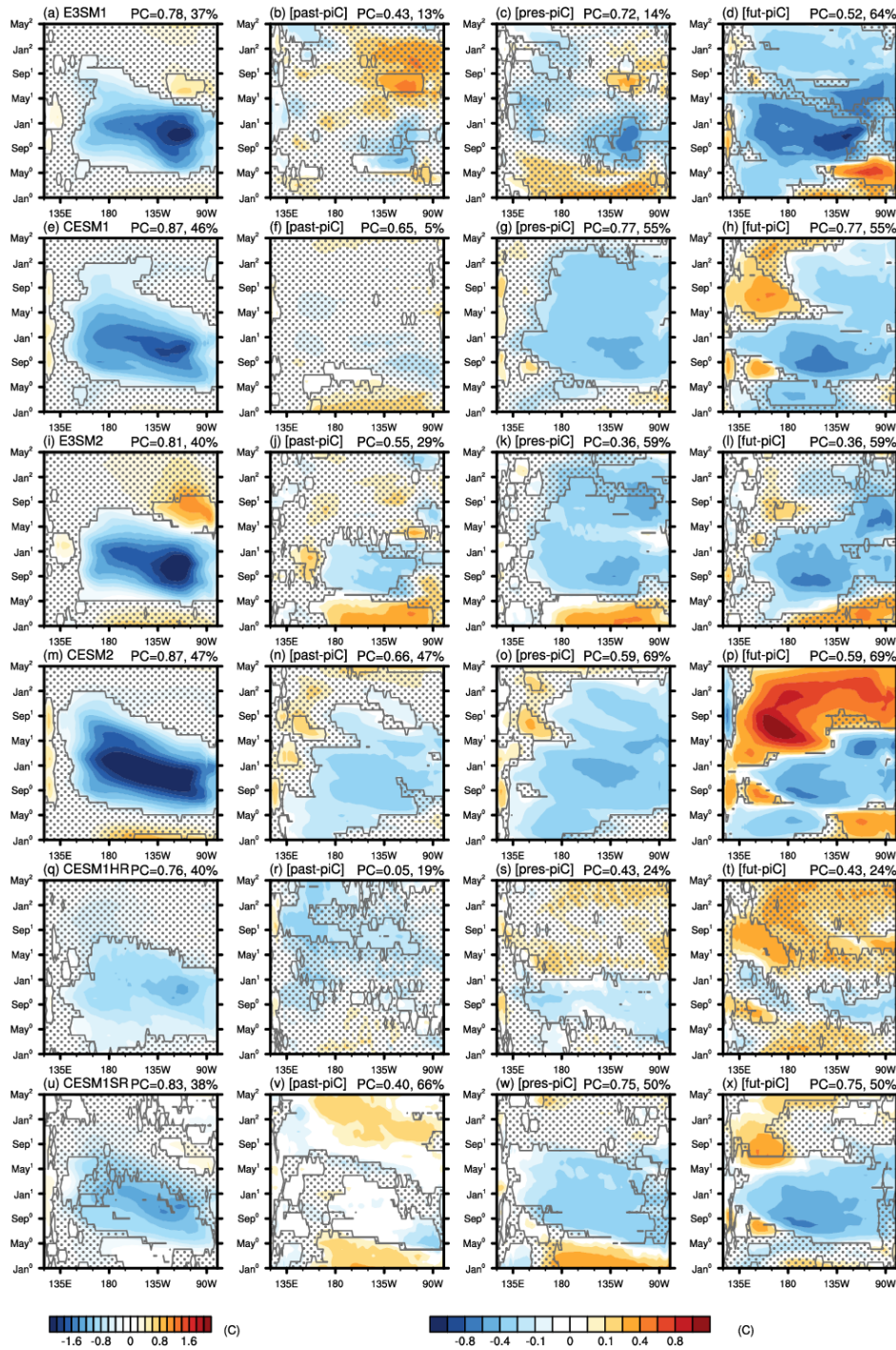


Figure S6: Mean La Niña hovmoellers of sea surface temperature (SST) composite for the piC (left column), and the relative changes from the piC in past (center-left column), present (center-right column), and future (right column). Models shown include E3SM1 (a-d), CESM1, (e-h), E3SM2 (i-l), CESM2 (m-p), CESM1HR (q-t), and CESM1SR (u-x). Regions of insignificant anomalies (left column) and differences (other columns) are stippled, except in the bottom row where they denote insignificant differences with CESM1HR.

