

## Supporting Information for

**On the enhancement of the Indian summer monsoon drying by Pacific multidecadal variability during the latter half of the 20th century**M. Salzmann<sup>1</sup> and R. Cherian<sup>1</sup>

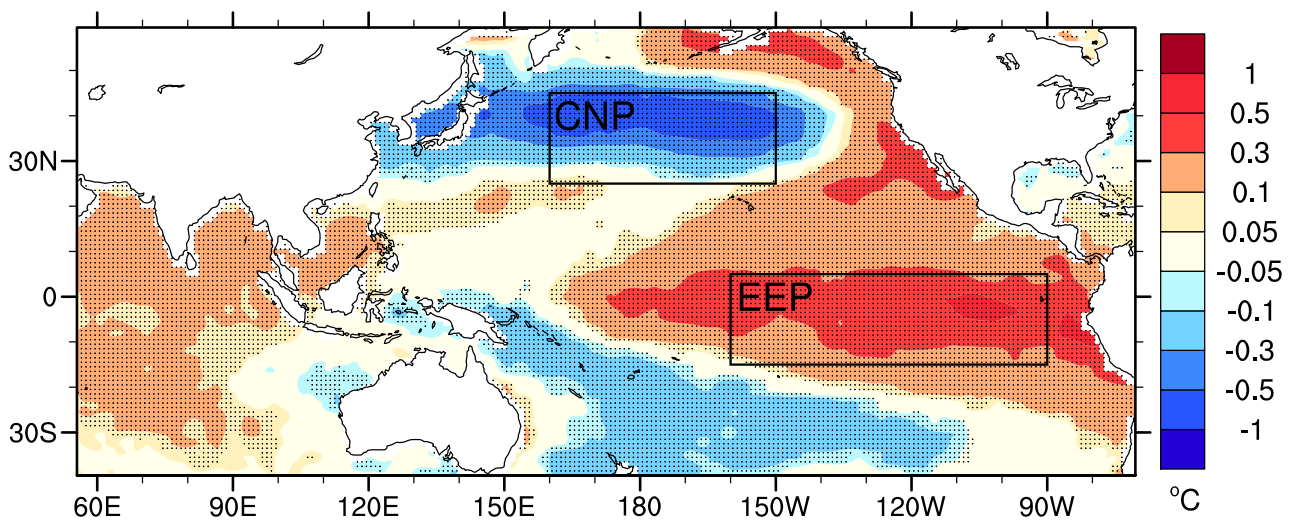
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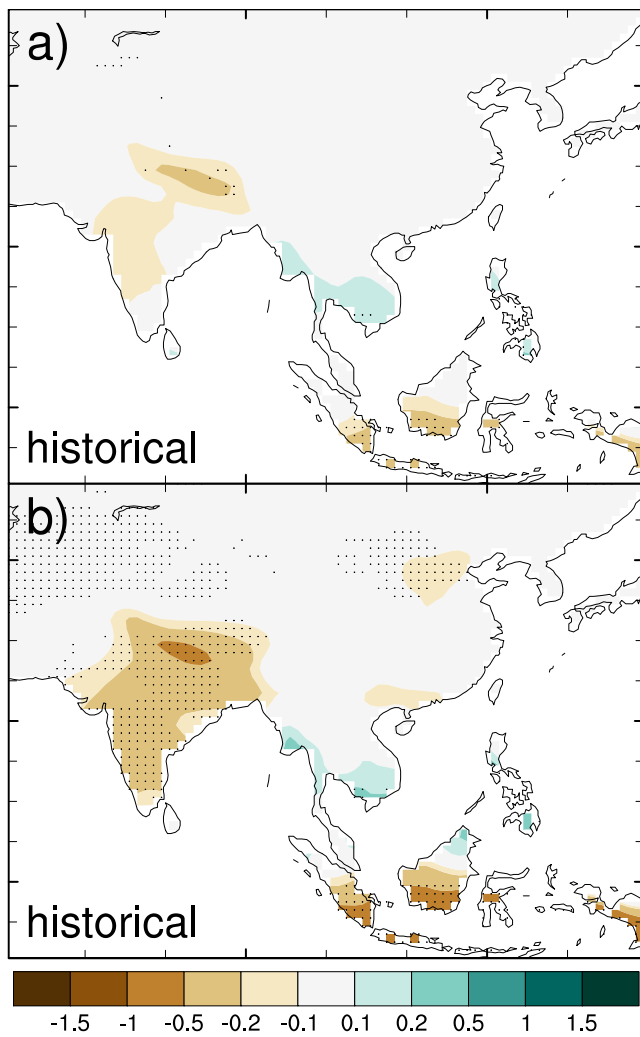
1. Figures S1 to S15
2. Table S1

**Introduction**

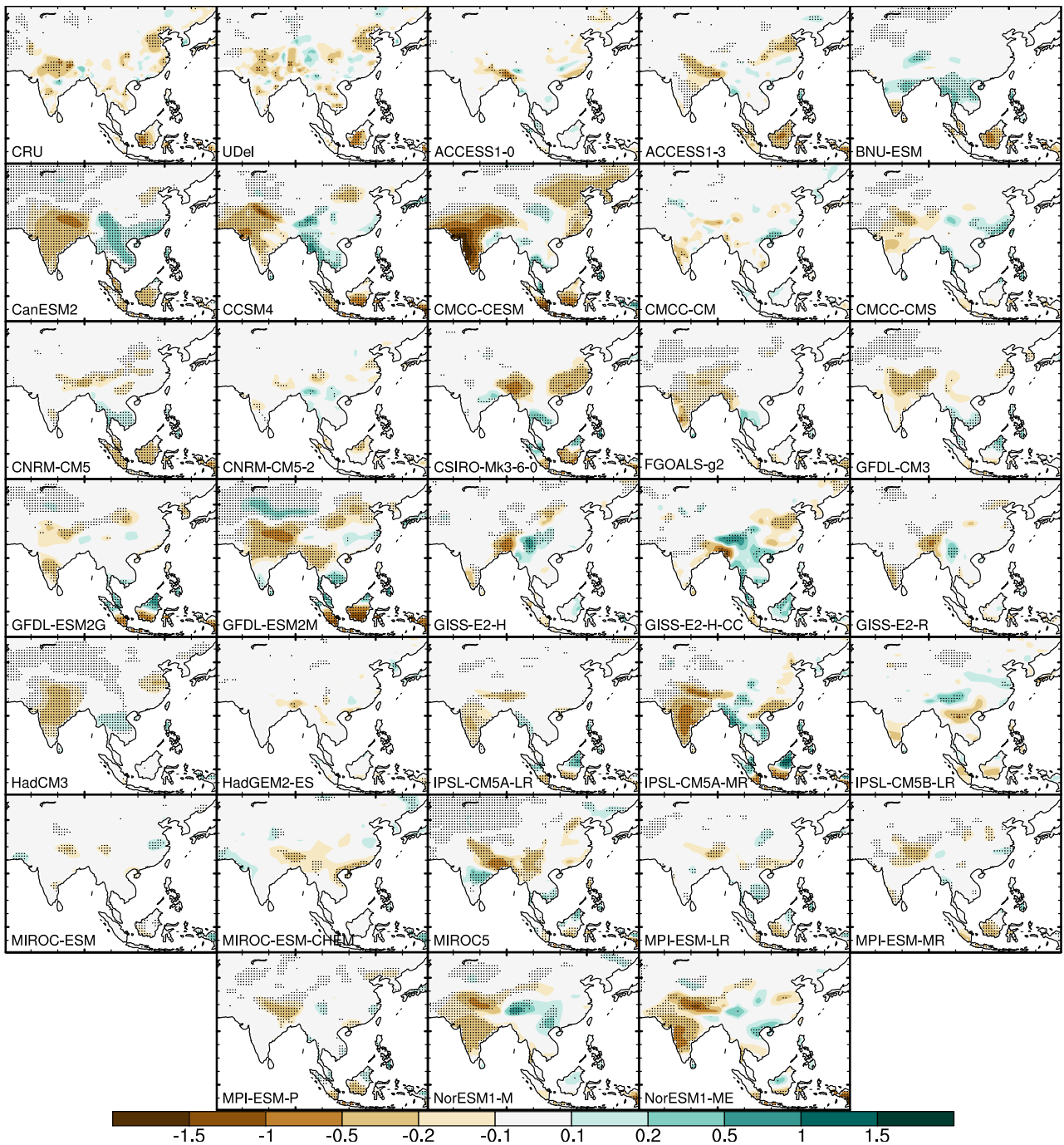
The supporting information contains additional figures and a table. Figure S1 is similar to Figure 2 but uses the PDO-JJAS index instead of the canonical NDJFM PDO definition. Figure S2 corresponds to Figure 4c and f, but shows results for the historical instead of the piControl experiment. The regression coefficients for individual models in Figure S3 and S4 also complement the multi-model averages in Figure 4c and f. Figure S5 corresponds to Figure 5, but the PDO index instead of S1 was used for adjusting the trends. The multi-run averages from individual models in Figures S6 to S8 complement the multi-run multi-model averages in Figure 5a,c, and d. Figure S9 is identical to Figure 9a except that it shows results for all India instead of NCI. Figures S10 and S11 correspond to Figure 5, but use different SST indices. Figure S12 shows ISMR time series based on CRU and UDel data. Figure S13 corresponds to Figure 12 but uses the S1-JJAS instead of the S1 index. Figures S14 and S15 correspond to Figure 14, but they show the PDO and the S2 index instead of the S1 index. Table S1 provides the values plotted in Figure 10.



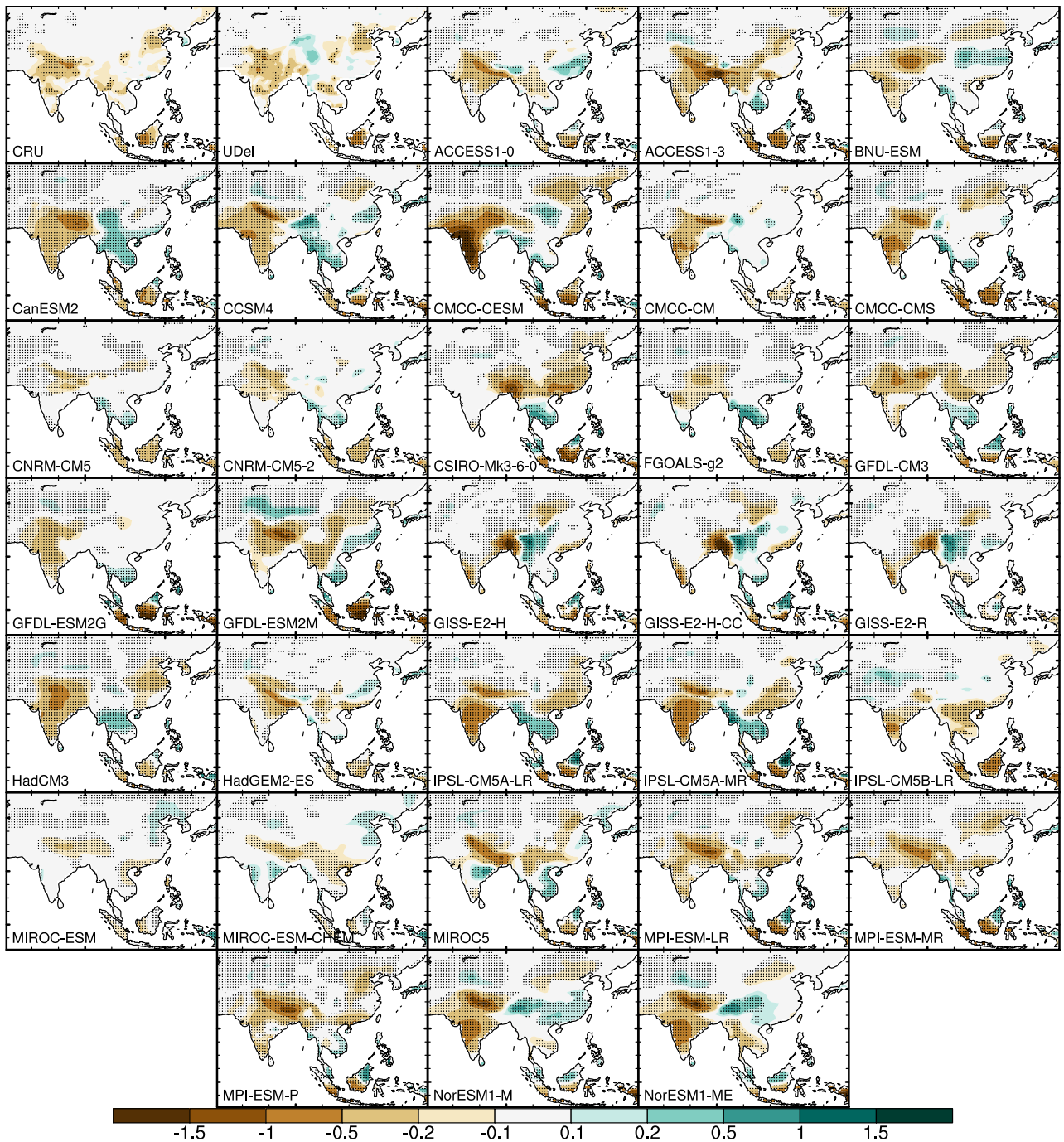
**Figure S1.** June-September (JJAS) sea surface temperature (SST) regressed onto the PDO-JJAS index (based on HadISST 1.1 data). Stippling indicates significance at the 95% confidence level. CNP and EEP denote the regions that are used to define S1 (see text for details).



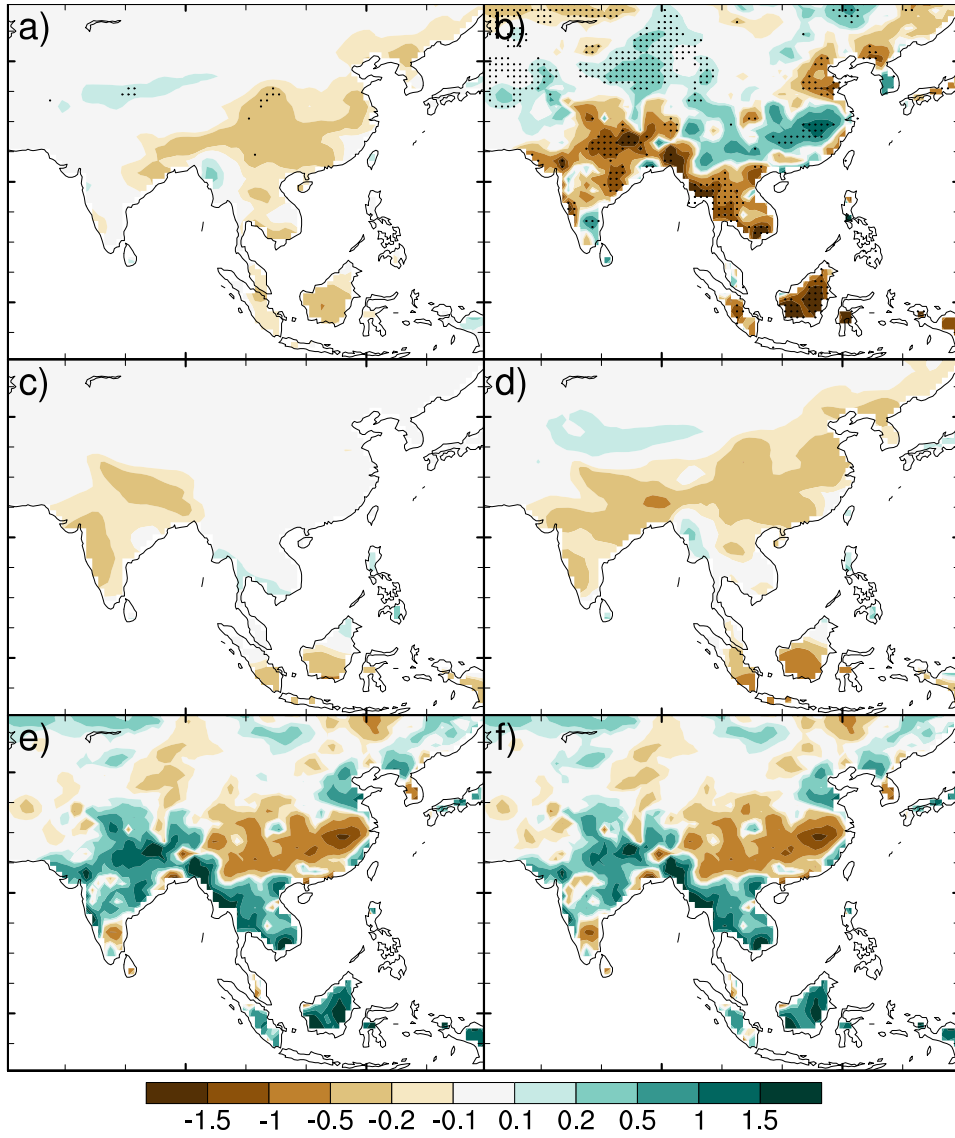
**Figure S2.** June-September (JJAS) surface precipitation over land in mm day<sup>-1</sup> regressed onto (a) the PDO index and (b) onto S1 based on CMIP5 historical runs.



**Figure S3.** June-September (JJAS) rainfall over land in  $\text{mm day}^{-1}$  regressed onto the PDO index. The first two panels are based on CRU and UDel precipitation and HadISST. The remaining panels are for the piControl run from various CMIP5 models.

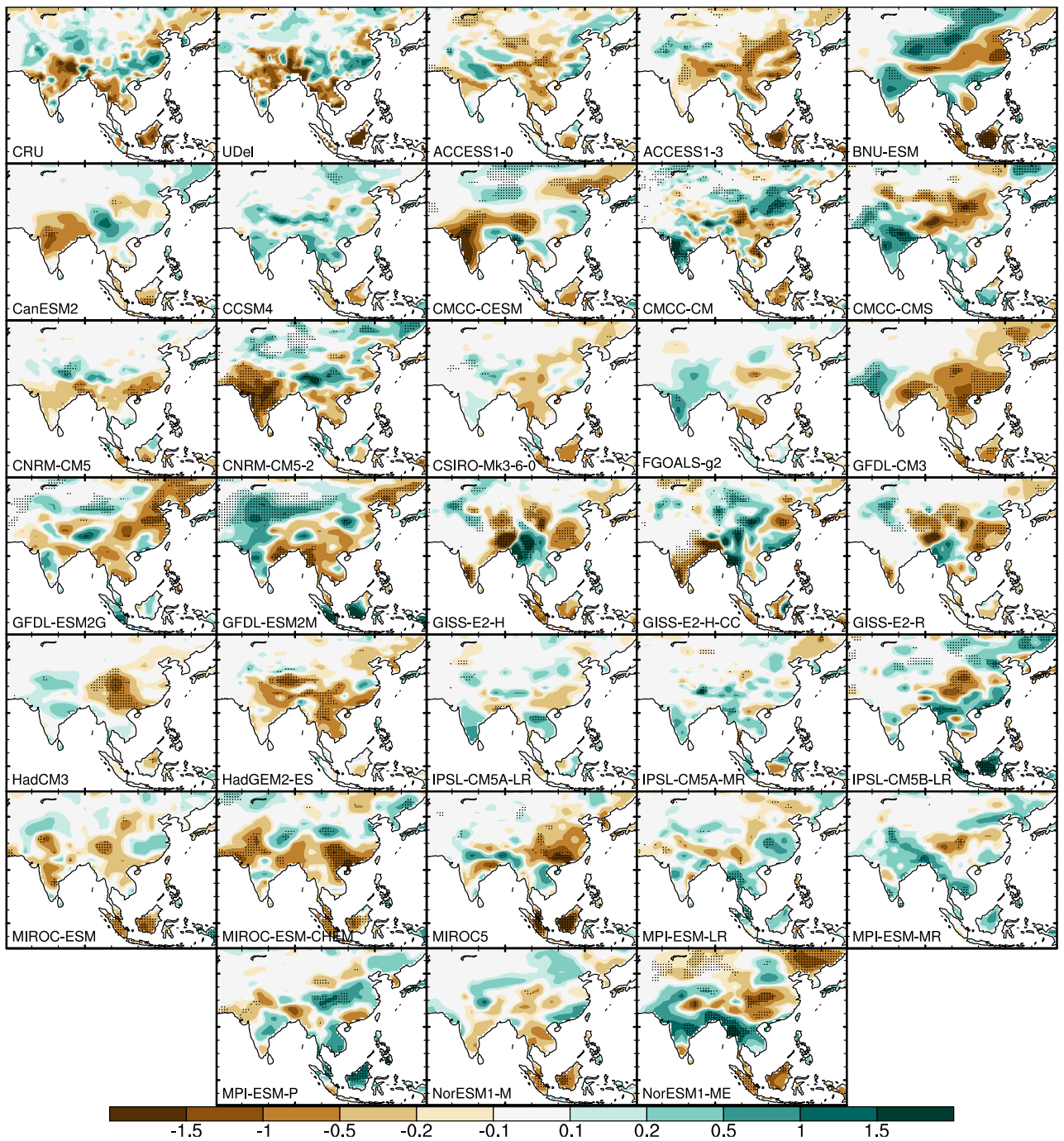


**Figure S4.** June-September (JJAS) rainfall over land in  $\text{mm day}^{-1}$  regressed onto S1. First two panels are based on CRU and UDel precipitation and HadISST. The remaining panels are for the the piControl run from various CMIP5 models.

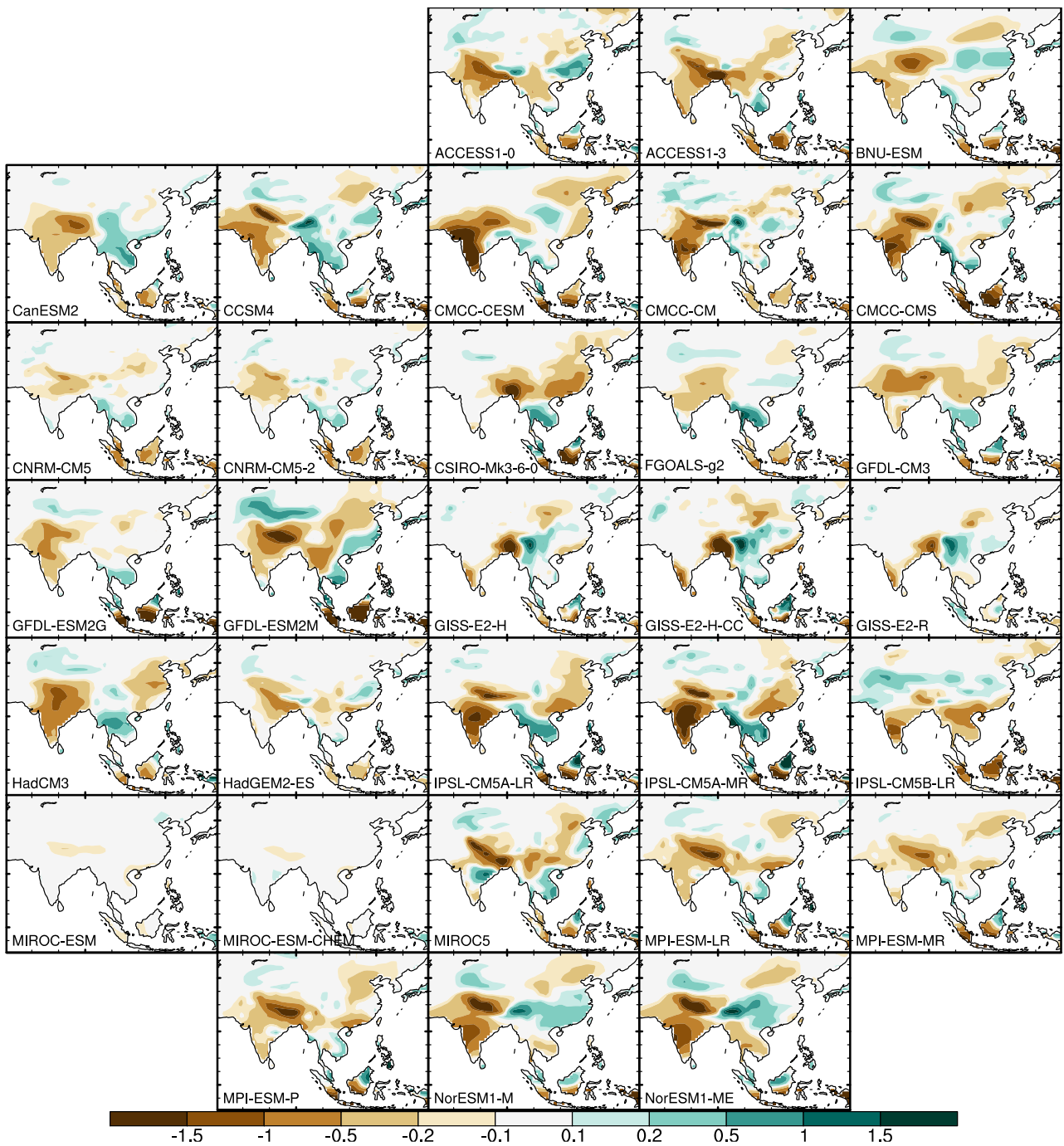


**Figure S5.** (a,b) JJAS surface precipitation trend ( $t_{pr}$ ) for 1950 to 1999 in  $\text{mm day}^{-1} (50 \text{ years})^{-1}$  (a) multi-model mean from CMIP5 historical runs ( $\bar{t}_{pr,mod}$ ), and (b) average from CRU and UDel data ( $\bar{t}_{pr,obs}$ ). (c) Multi-model average of the adjustment terms  $a_{pr} = -r_{pr,PDO} (t_{PDO,mod} - t_{PDO,obs})$  where  $t_{PDO,mod}$  is the 1950 to 1999 trend of the PDO index from a historical model run,  $t_{PDO,obs}$  is from the HadISST data, and  $r_{pr,PDO}$  is the regression coefficient from Figure 5c. (d) Precipitation plus adjustment term ( $t_{pr,adj} = t_{pr,mod} + a_{pr}$ ) multi-model average. (e,f) Multi-model averages of the differences (e)  $t_{pr,mod} - \bar{t}_{pr,obs}$  and (f)  $t_{pr,adj} - \bar{t}_{pr,obs}$ .



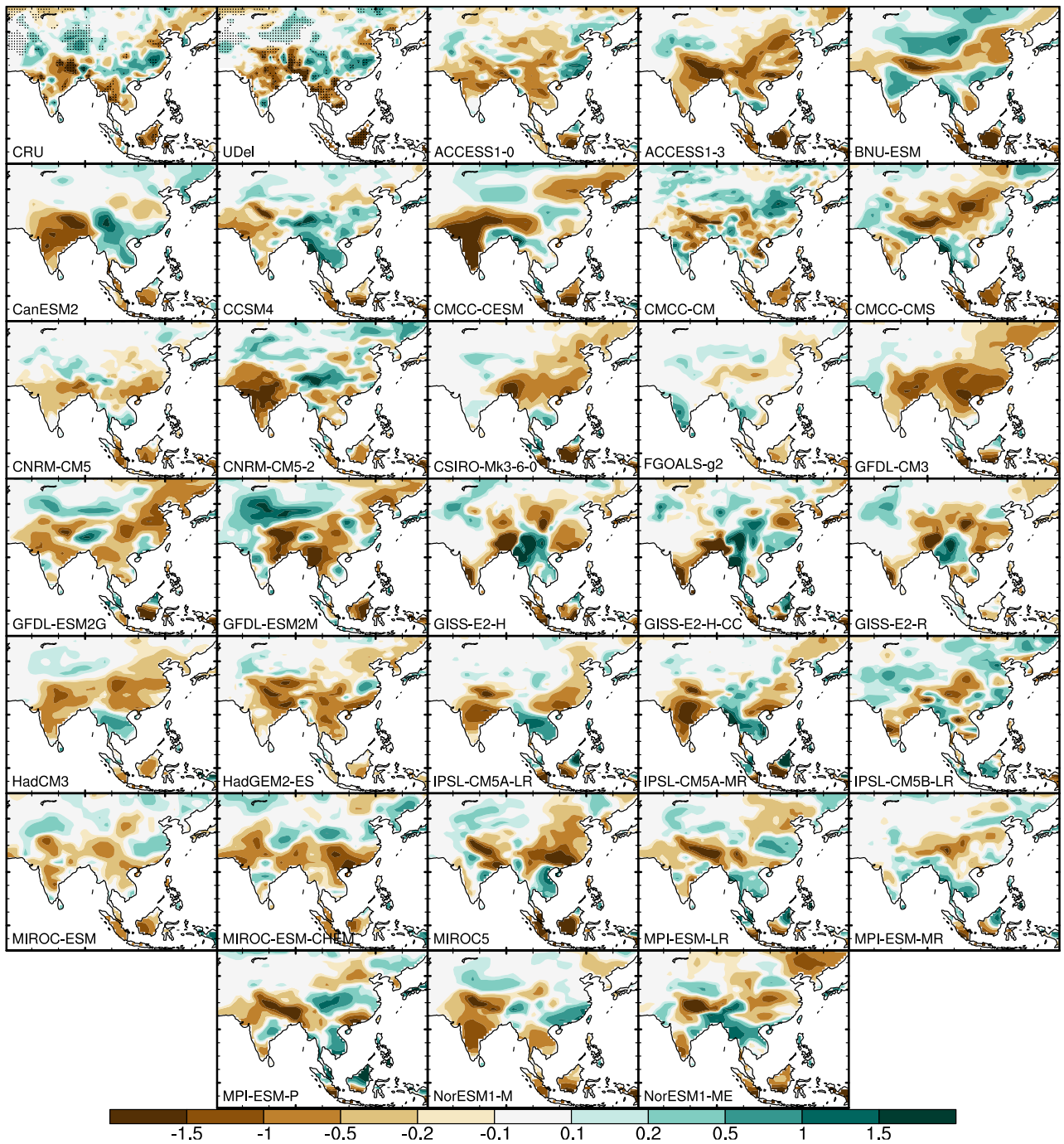


**Figure S6.** June-September (JJAS) rainfall trend over land for 1950 to 1999 in  $\text{mm day}^{-1}$  ( $50 \text{ years}$ )<sup>-1</sup>. First two panels are based on CRU and UDel precipitation. The remaining panels are for the the historical run from various CMIP5 models.

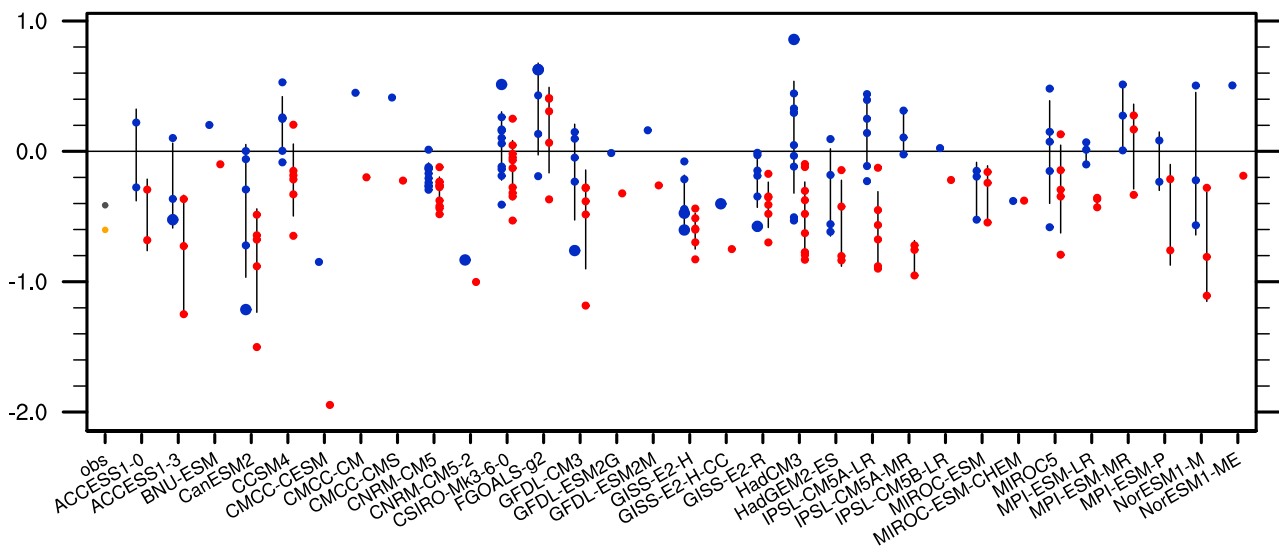


**Figure S7.** Adjustment terms based on S1 adjustment ( $\text{mm day}^{-1} (50 \text{ years})^{-1}$ ).

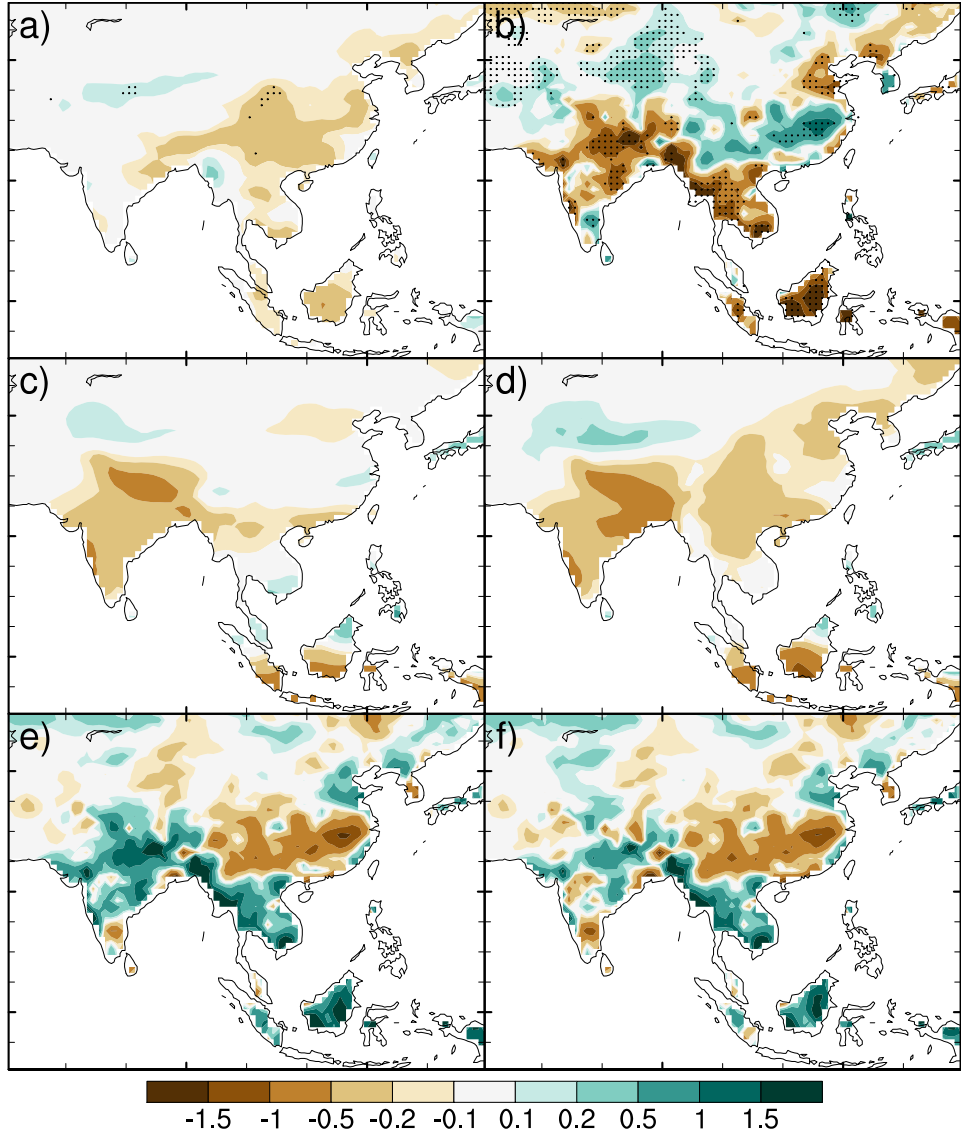




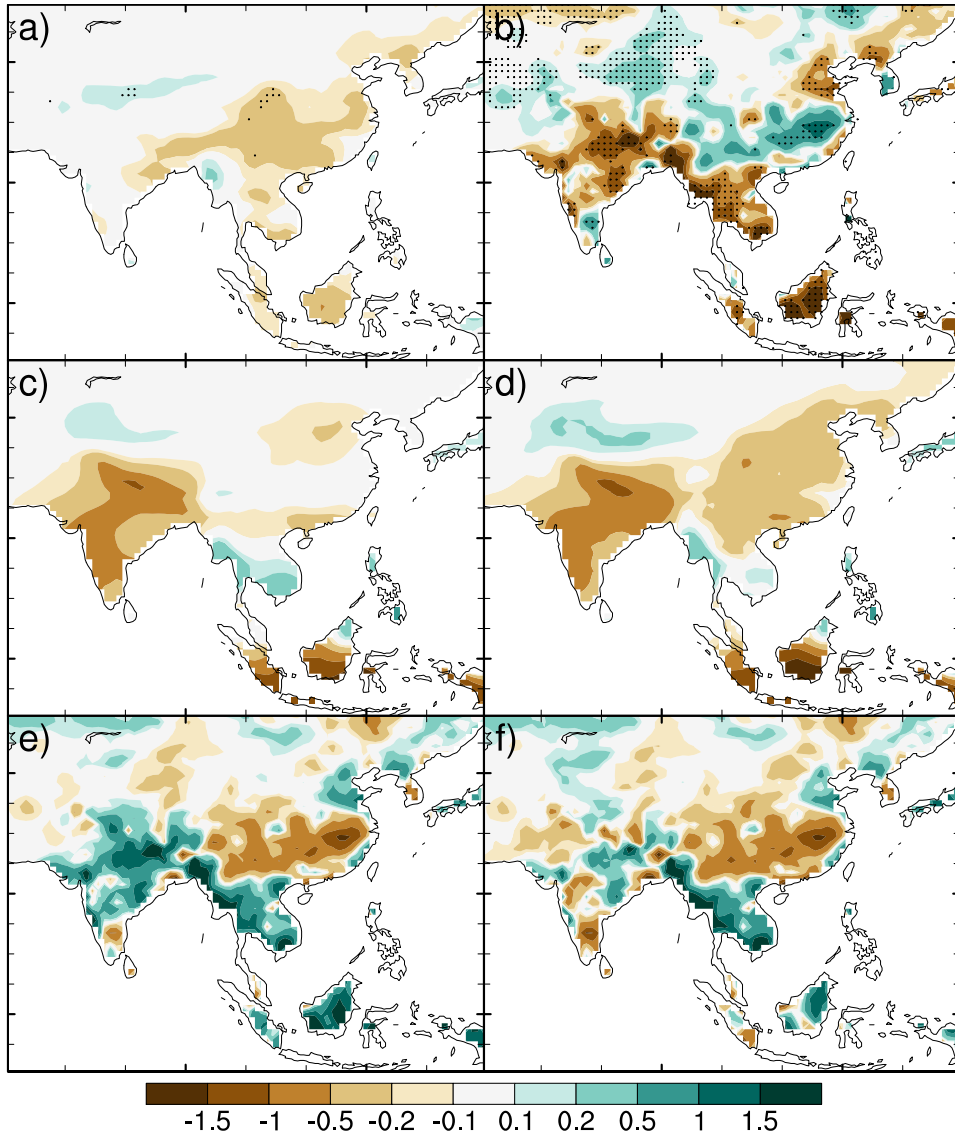
**Figure S8.** S1-adjusted June-September (JJAS) rainfall trend over land for 1950 to 1999 in mm day<sup>-1</sup> (50 years)<sup>-1</sup>. First two panels are based on CRU and UDel precipitation (for comparison). The remaining panels are for the the historical run after adjusting for S1.



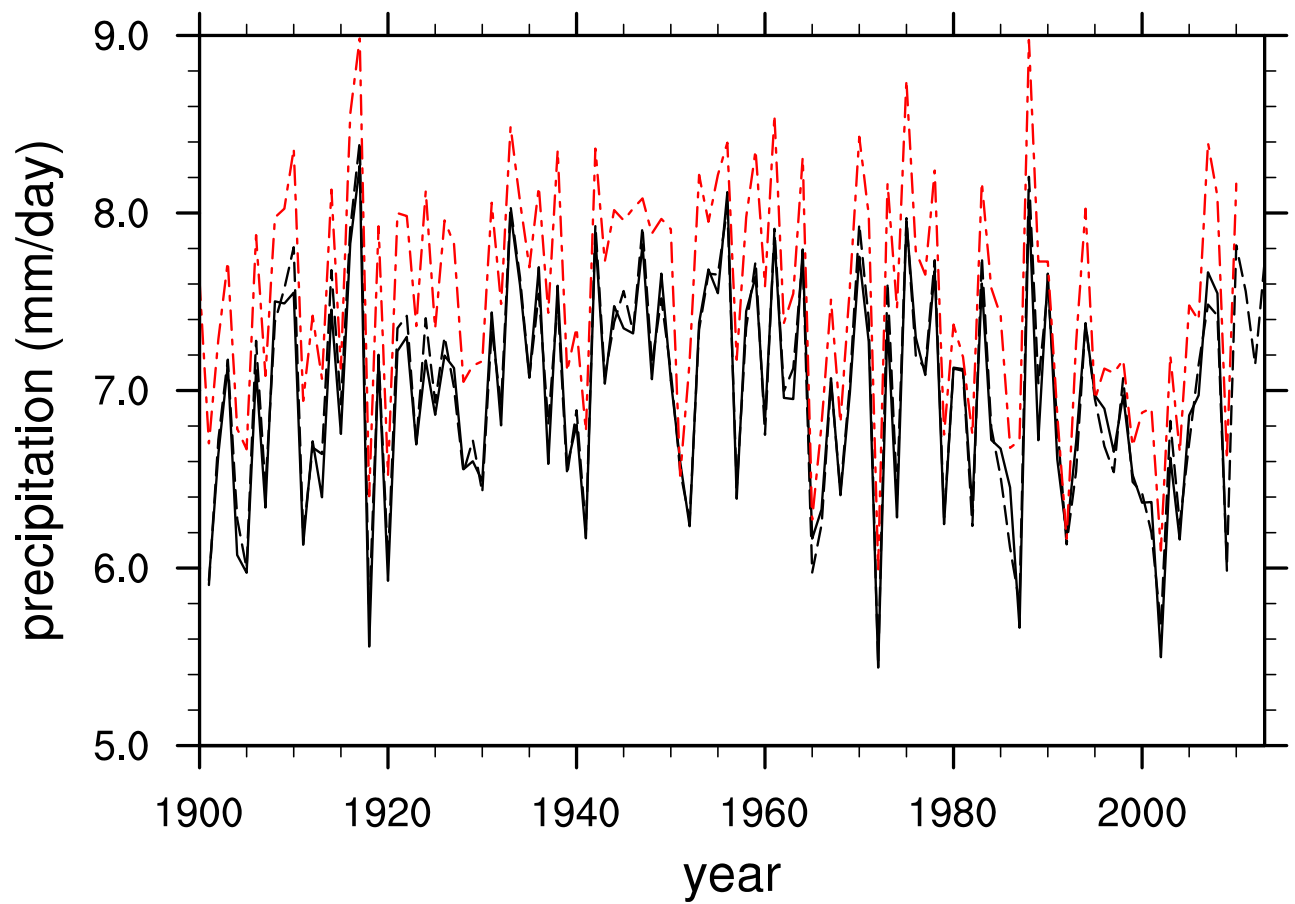
**Figure S9.** Trends of JJAS land-only rainfall for India in  $\text{mm day}^{-1} (50 \text{ years})^{-1}$  for individual model runs from the historical experiment. Observations are from CRU (gray) and UDeI (orange). Blue dots represent simulated (unadjusted) trends and red dots adjusted trends. Vertical bars indicate multi-run averages  $\pm$  one standard deviation. Large dots indicate statistical significance at the 95% level.



**Figure S10.** Same as figure S5 but for the PDO-JJAS index.

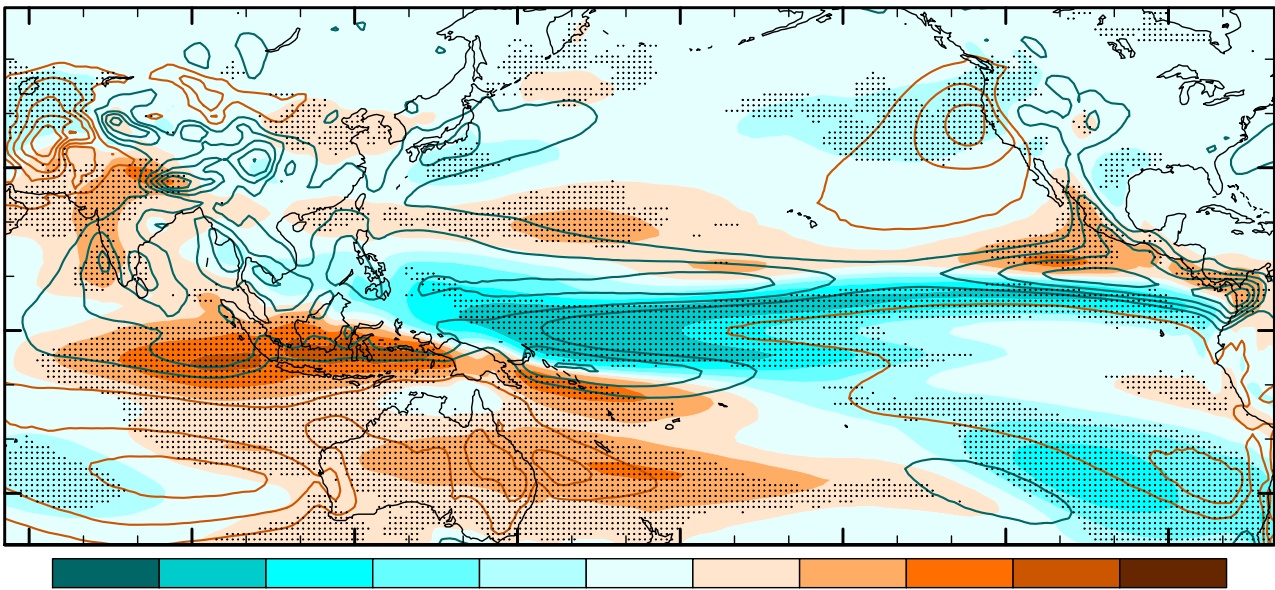


**Figure S11.** Same as figure S5 but for the S1-JJAS index.



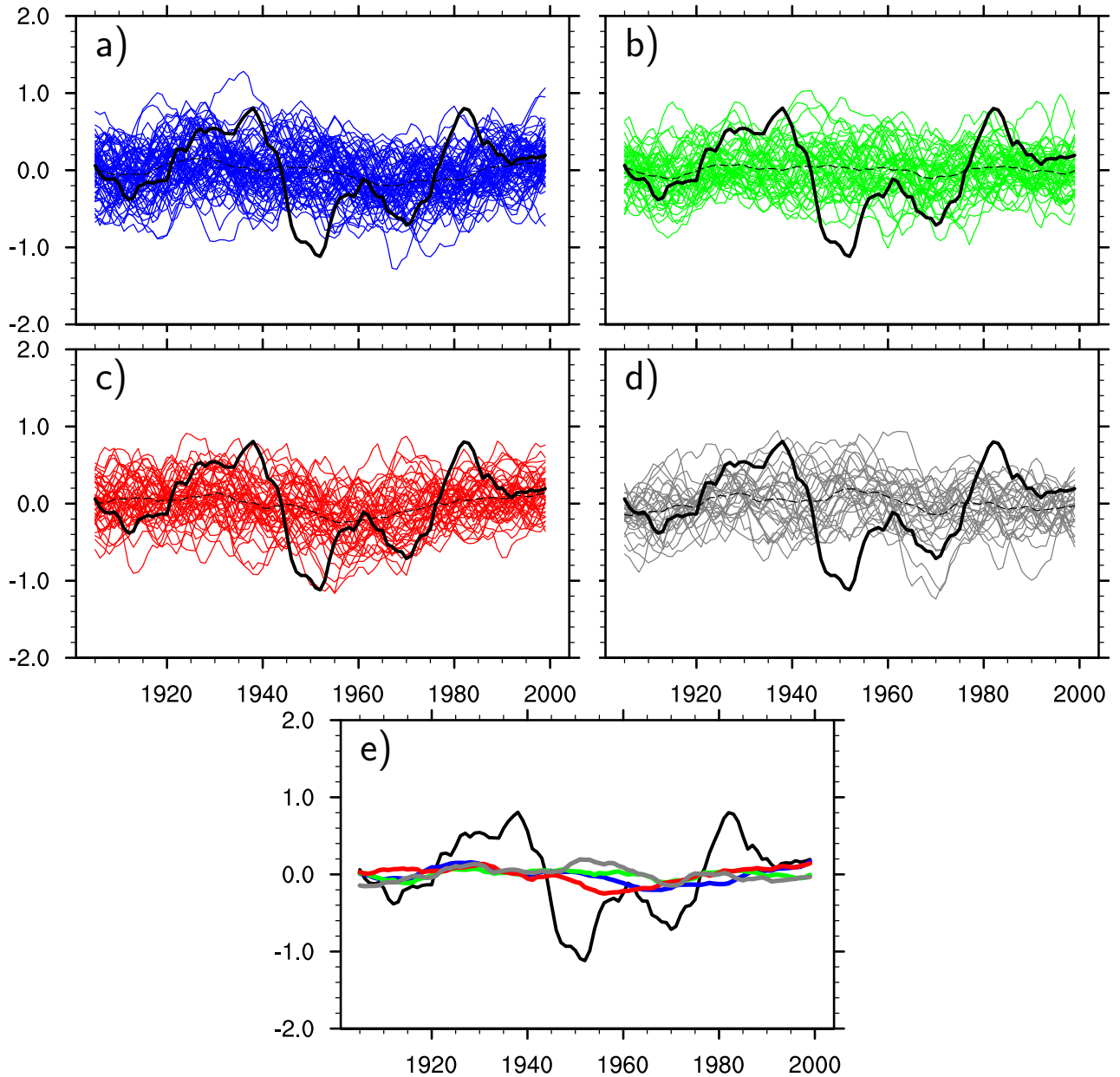
**Figure S12.** Land-only JJAS rainfall for India from CRU v3.10.01 1901 to 2001 (black solid line) CRU v3.22 1901 to 2013 (black dashed line ) UDel v3.01 1900 to 2010 (red dashed line).



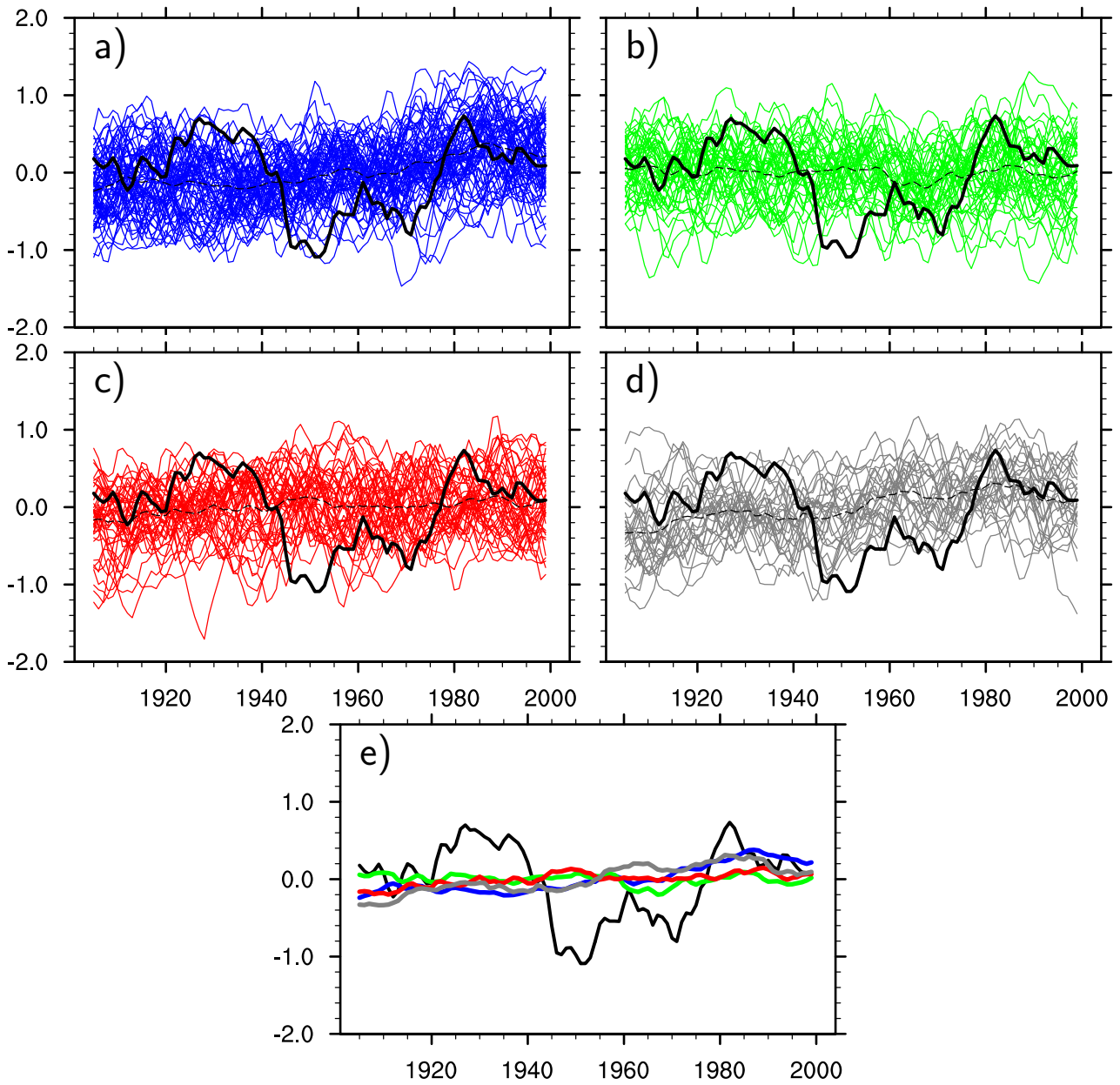


-0.02 -0.01 -0.006 -0.003 -0.001 0.001 0.003 0.006 0.01 0.02

**Figure S13.** Filled contours: 500 hPa pressure vertical velocity  $\omega$  regressed onto S1-JJAS. Stippling indicates that 80% of model families (as defined in the text) agree on the sign of the regression coefficient. Contour lines:  $\omega$  in 500 hPa from -0.1 to -0.02 (bluegreen) and from 0.02 to 0.1 (orange) in steps of  $0.02 \text{ Pa s}^{-1}$ . Based on JJAS averages from the piControl runs.



**Figure S14.** Ten-year running mean time series of the PDO index from HadISST (solid black line) and for (a) historical, (b) historicalNat, (c) historicalGHG, and (d) historicalIAA runs. (e) ensemble averages from (a,b,c,d) combined in a single plot.



**Figure S15.** Same as Figure S14 but for the S2 index.

**Table S1.** 1950-1999 JJAS rainfall trend for all India from the historicalGHG and the historical experiment for unfiltered and for 11 year time filtered data. Also historical trend after adjusting for PDO, PDO-JJAS, S1, S1-JJAS, and IPO as defined in the text. UDel and CRU trends are from unfiltered data. The 1955-1994 JJAS rainfall trend after adjusting for PDO-JJAS based on 11-year filtered rainfall and SST data is also shown.

	mean	median	stddev	lower quartile	upper quartile
historical GHG	0.26	0.25	0.20	0.16	0.27
historical	-0.05	0.01	0.29	-0.30	0.11
hist. filtered	-0.14	-0.12	0.27	-0.40	0.06
PDO adjusted	-0.22	-0.11	0.40	-0.36	-0.05
PDO-JJAS adj.	-0.39	-0.34	0.34	-0.58	-0.18
S1 adj.	-0.45	-0.35	0.41	-0.60	-0.25
S1-JJAS adj.	-0.52	-0.47	0.38	-0.78	-0.28
IPO adj.	-0.31	-0.36	0.32	-0.47	-0.15
CRU, UDel	-0.51		0.11		
PDO-JJAS adj. filtered	-0.41	-0.35	0.39	-0.66	-0.14