

Supplement for 'Tropical Precipitation Response to Anthropogenic Climate Change in Recent Decades'

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1 Materials

The monthly precipitation data are obtained from the Global Precipitation Climatology Project (GPCP) version 2.3 [1], which provides merged satellite and gauge-based estimates on a global scale. Monthly air temperature data are sourced from the Berkeley Earth Temperature dataset [2], combined with air temperature over sea ice regions. Sea surface temperature data are taken from the NOAA Optimum Interpolation SST (OISST) version 2 [3], which blends satellite and in situ measurements. The 850-hPa and 200-hPa wind fields are obtained from the NCEP–DOE Reanalysis 2 (NCEP2) [4], and the 200-hPa velocity potential fields are computed from the 200-hPa winds using the Windspharm Python package[5]. All datasets are analyzed for the period 1979–2024, ensuring consistency with the satellite era.

Table 1 List of CMIP6 models and institutions used in this study.

Model Name	Institution
ACCESS-CM2	CSIRO-ARCCSS
ACCESS-ESM1-5	CSIRO
BCC-CSM2-MR	BCC
CAMS-CSM1-0	CAMS
CESM2-WACCM	NCAR
CESM2	NCAR
CMCC-CM2-SR5	CMCC
CNRM-CM6-1-HR	CNRM-CERFACS
CNRM-CM6-1	CNRM-CERFACS
CNRM-ESM2-1	CNRM-CERFACS
CanESM5	CCCma
EC-Earth3-Veg-LR	EC-Earth-Consortium
EC-Earth3-Veg	EC-Earth-Consortium
EC-Earth3	EC-Earth-Consortium
FGOALS-g3	CAS
GFDL-CM4	NOAA-GFDL
GFDL-ESM4	NOAA-GFDL
HadGEM3-GC31-LL	MOHC
IITM-ESM	CCCR-IITM
INM-CM4-8	INM
INM-CM5-0	INM
IPSL-CM6A-LR	IPSL
KACE-1-0-G	NIMS-KMA
KIOST-ESM	KIOST
MIROC-ES2L	MIROC
MIROC6	MIROC
MPI-ESM1-2-HR	MPI-M
MPI-ESM1-2-LR	MPI-M

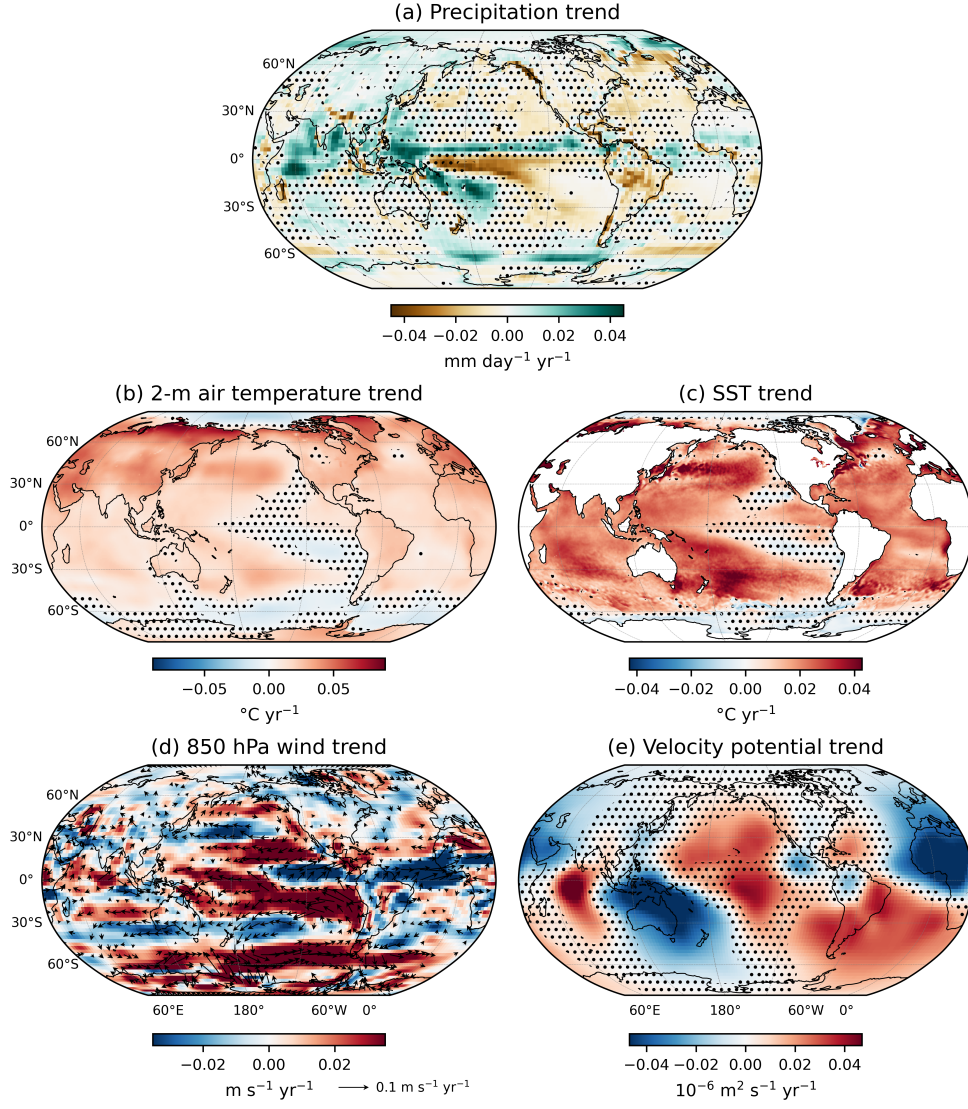


Fig. 1 Global climate trends (1979-2024) in (a) precipitation (GPCP), (b) 2-meter air temperature (Berkeley Earth), (c) sea surface temperature (OISST), (d) 850-hPa wind vectors (arrows) and speed (shading) from NCEP2, and (e) 200-hPa velocity potential (NCEP2). Dots represent regions with statistically insignificant trends at 90% confidence level. Wind vectors in panel (d) are plotted only if at least one component of the wind trend is statistically significant.

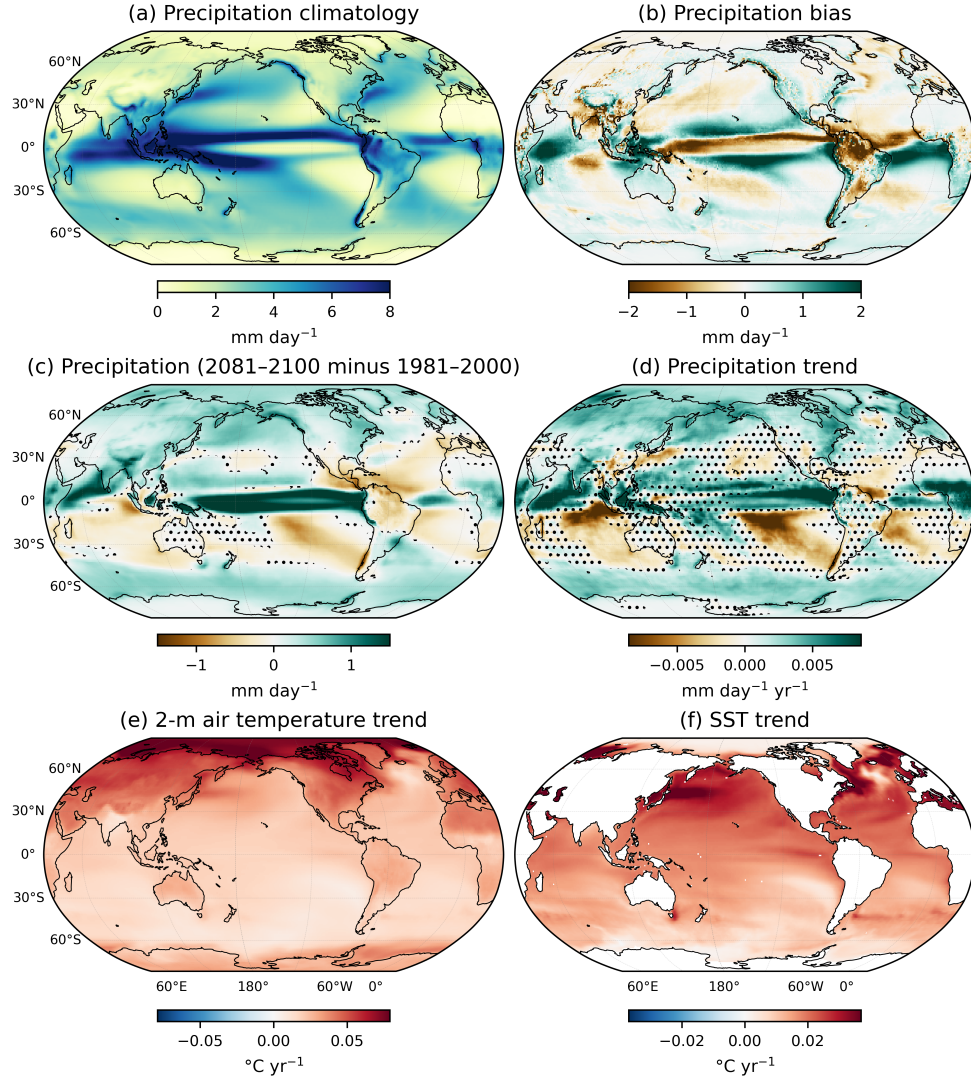


Fig. 2 Climatology, bias, future changes, and trends in CMIP6 in (a) precipitation MME climatology computed from the 1979-2014 period from CMIP6 historical simulations, (b) precipitation bias in CMIP6 MME compared to ERA5 climatology during the 1979-2014 period, (c) projected future changes in precipitation (2081-2100 (SSP585) minus 1981-2000 (historical)) from CMIP6 simulations and projections, (d) precipitation trend, (e) 2-m air temperature trend, and (f) SST trend. In panels (d), (e) and (f), the trends are computed over the 1979-2024 period combining CMIP6 historical and SSP245 simulations. Dots represent regions with statistically insignificant trends at 90% confidence level.

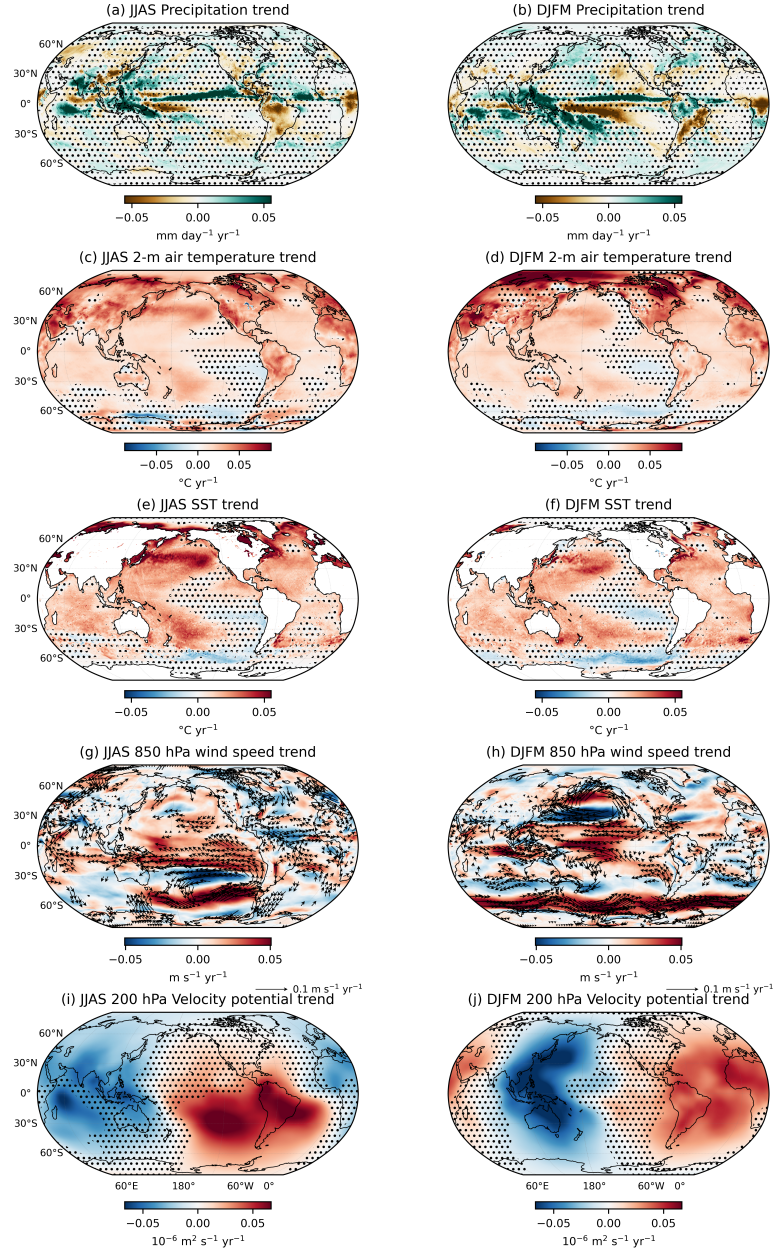


Fig. 3 Seasonal climate trends (1979–2024). Left column: boreal summer (JJAS); right column: boreal winter (DJFM). Shading shows linear trends per year for (a,b) precipitation (GPCP; $\text{mm day}^{-1} \text{yr}^{-1}$), (c,d) 2-meter air temperature (Berkeley Earth; $^{\circ}\text{C yr}^{-1}$), (e,f) sea-surface temperature (OISST; $^{\circ}\text{C yr}^{-1}$), (g,h) 850-hPa wind speed with wind-vector trends overlaid (NCEP2; $\text{m s}^{-1} \text{yr}^{-1}$), and (i,j) 200-hPa velocity potential (NCEP2; $10^{-6} \text{m}^2 \text{s}^{-1} \text{yr}^{-1}$). Dots mark grid points where the trend is not significant at 90% confidence level. Arrows in (g,h) denote trends in the 850-hPa wind vectors and are drawn only where at least one wind component is significant.

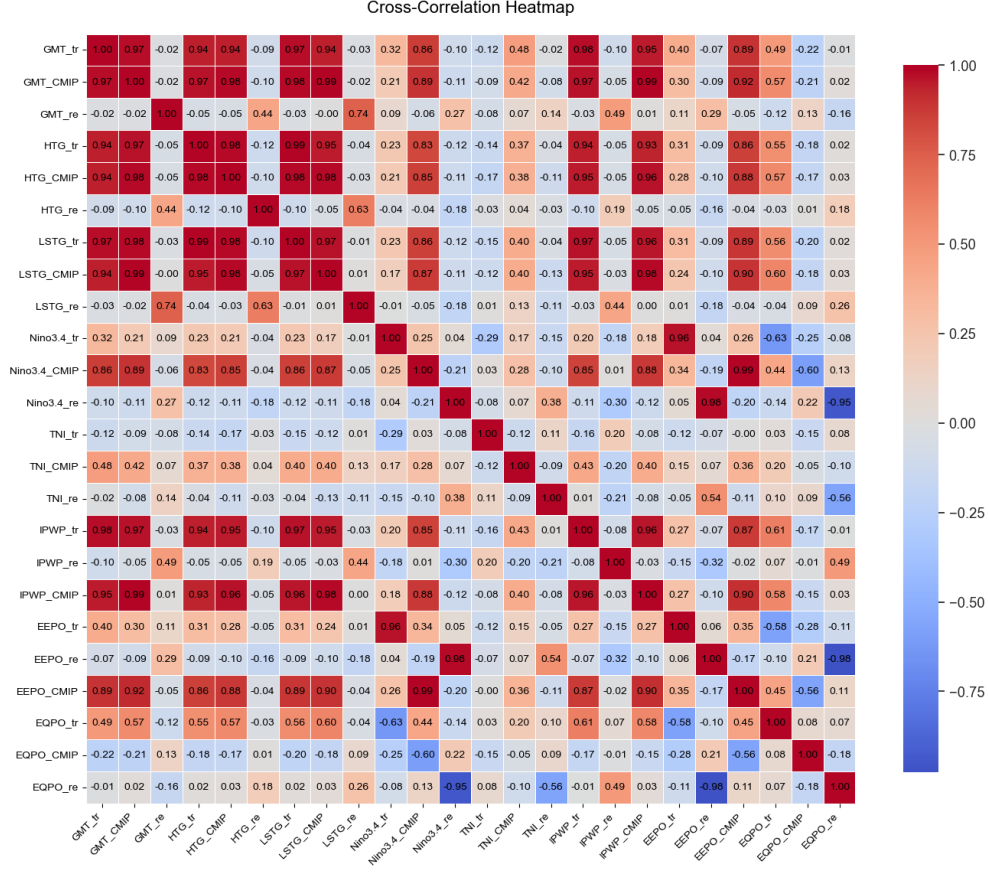


Fig. 5 Cross-correlation between trend (tr) and residual (re) components (extracted with LOESS; see the Data and Methods section in the main manuscript) of time series for different climate variables from ERA5 and CMIP6 MME. GMT denotes global mean temperature, HTG the interhemispheric thermal gradient, LSTG the land-sea thermal gradient, IPWP the Indo-Pacific warm pool SST, EEPO the equatorial eastern Pacific SST, and EQPO the equatorial Pacific SST gradient (IPWP-EEPO). Full definitions of all variables are provided in the Data and Methods section in the main manuscript.

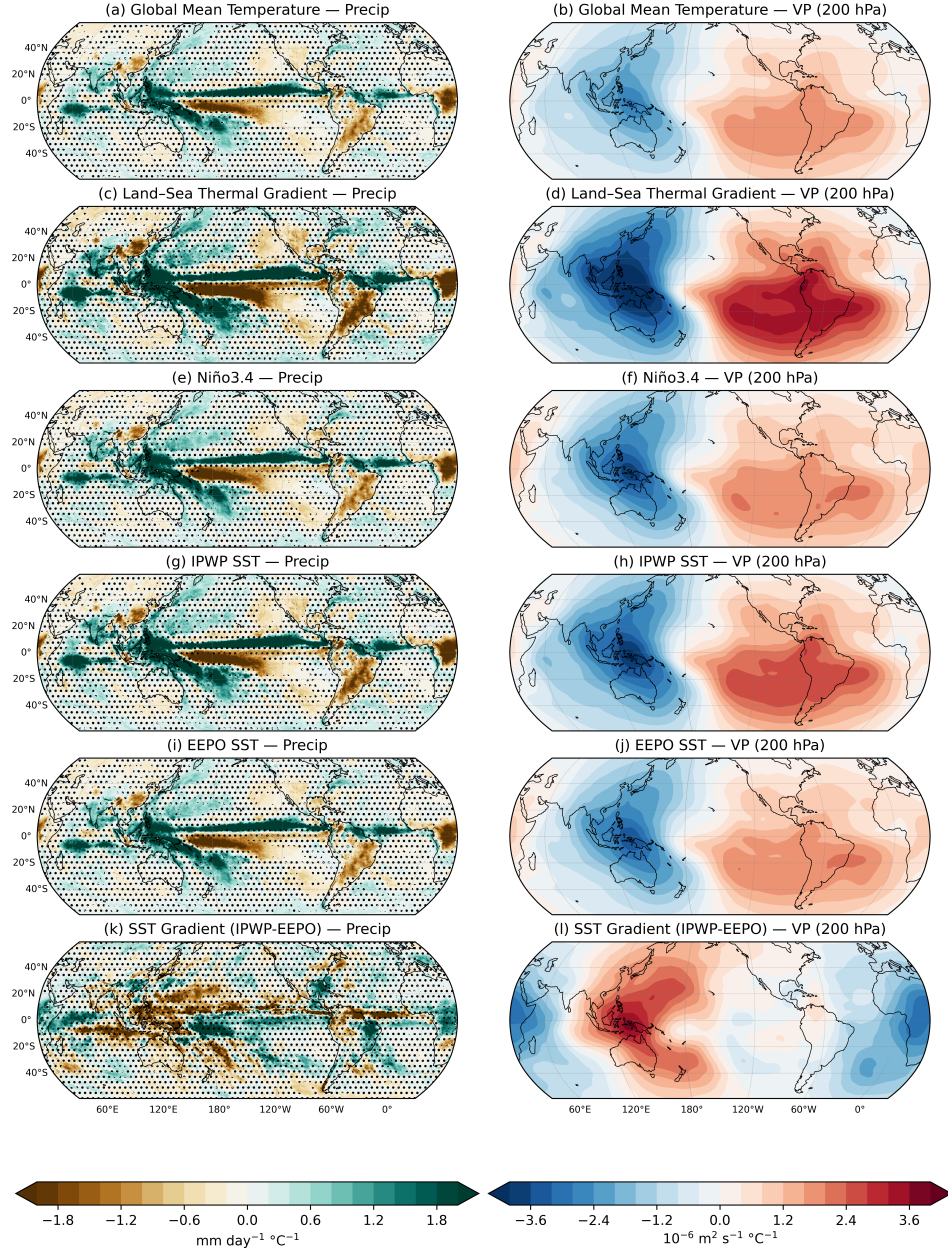


Fig. 6 Spatial regressions of annual anomalies (1979–2024). Left column: precipitation ($\text{mm day}^{-1} \text{ }^{\circ}\text{C}^{-1}$); right column: 200-hPa velocity potential ($10^{-6} \text{ m}^2 \text{ s}^{-1} \text{ }^{\circ}\text{C}^{-1}$), both derived from ERA5. Fields are regressed onto six climate indices derived from the CMIP6 MME: (a,b) GMT, (c,d) land–sea thermal gradient, (e,f) Niño 3.4, (g,h) IPWP SST, (i,j) EEPO SST, and (k,l) equatorial Pacific SST gradient. Colours show regression coefficients; stippling marks grid points where the coefficient is not significant at 90% confidence level.

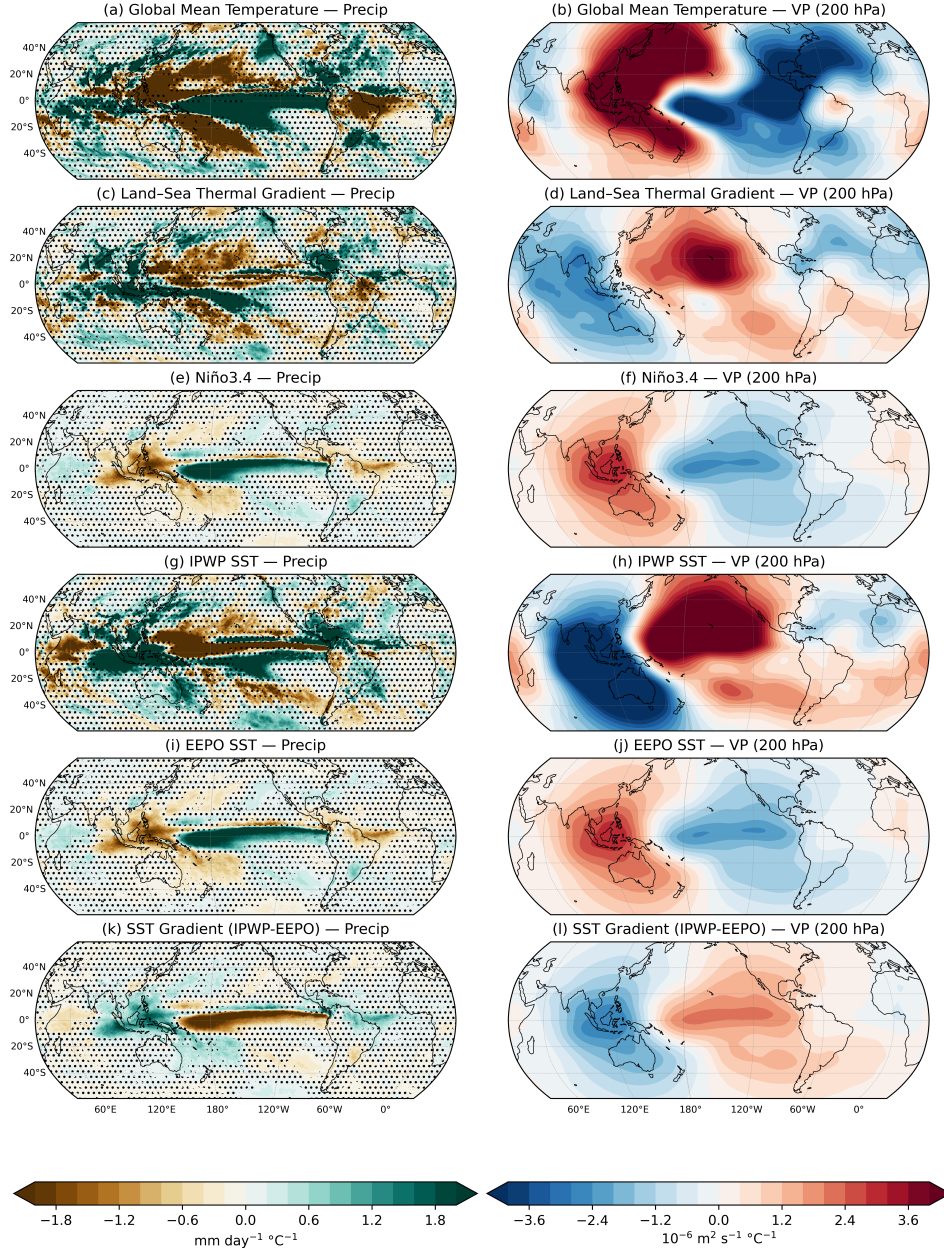


Fig. 7 Spatial regressions of annual anomalies (1979–2024). Left column: precipitation ($\text{mm day}^{-1} \text{ }^{\circ}\text{C}^{-1}$); right column: 200-hPa velocity potential ($10^{-6} \text{ m}^2 \text{ s}^{-1} \text{ }^{\circ}\text{C}^{-1}$), both derived from ERA5. Fields are regressed onto the residual component of the six temperature-related indices derived from the ERA5: (a,b) GMT, (c,d) land–sea thermal gradient, (e,f) Niño 3.4, (g,h) IPWP SST, (i,j) EEPO SST, and (k,l) equatorial Pacific SST gradient (IPWP-EEPO). Colours show regression coefficients; stippling marks grid points where the coefficient is not significant at 90% confidence level.

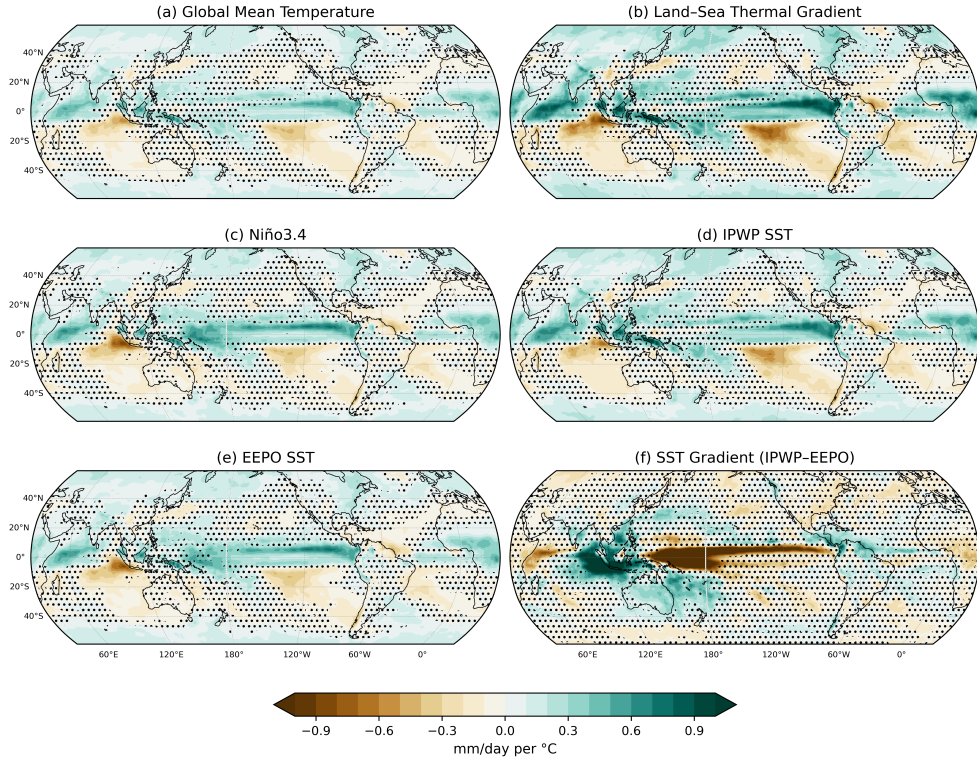


Fig. 8 Spatial regressions of annual precipitation anomalies ($\text{mm day}^{-1} \text{ }^{\circ}\text{C}^{-1}$) from CMIP6 MME. Fields are regressed onto the six temperature-related indices derived from the CMIP6 MME: (a) GMT, (b) land-sea thermal gradient, (c) Niño 3.4, (d) IPWP SST, (e) EEPO SST, and (f) equatorial Pacific SST gradient (IPWP-EEPO). Colours show regression coefficients; stippling marks grid points where the coefficient is not significant at 90% confidence level.

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