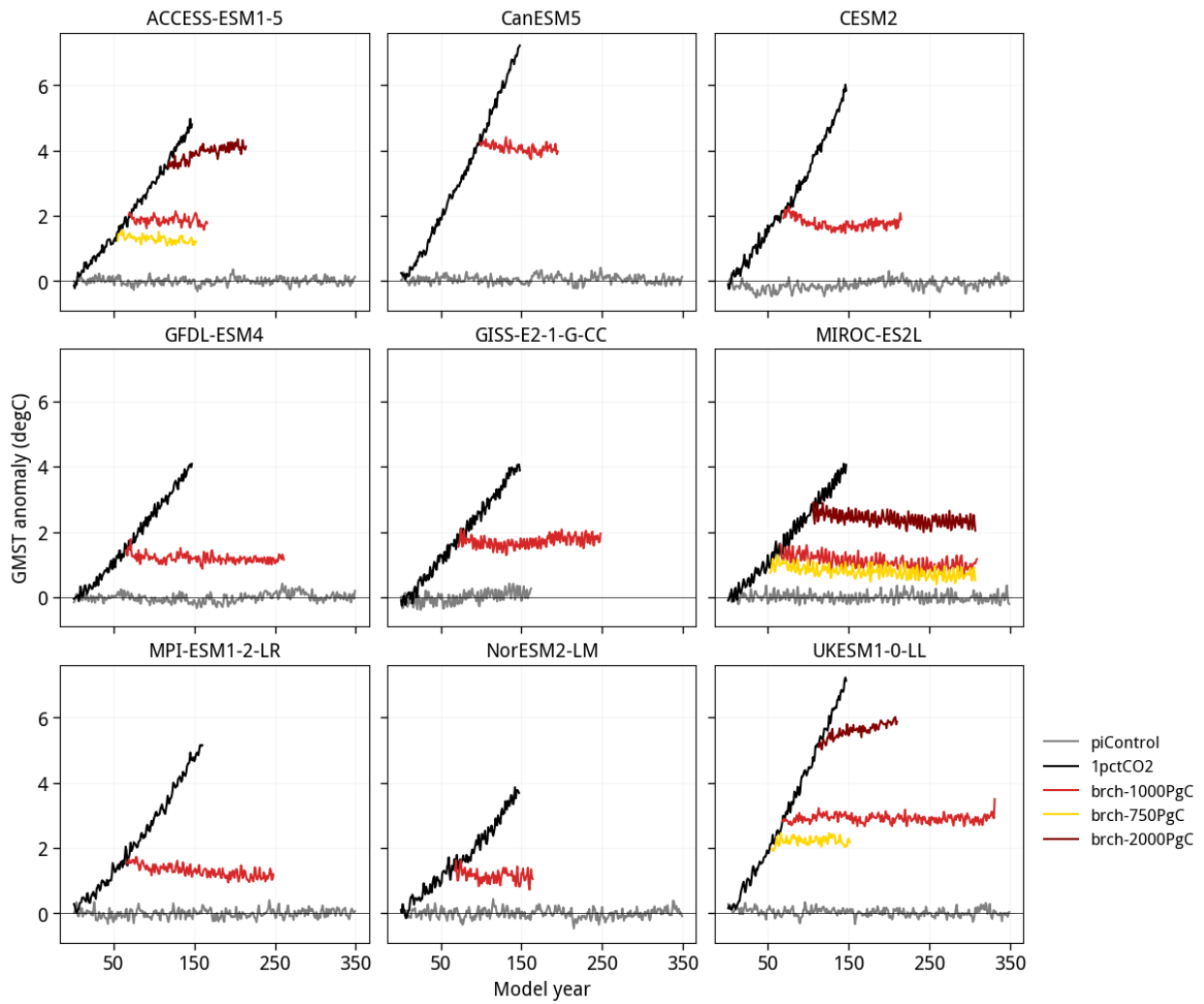
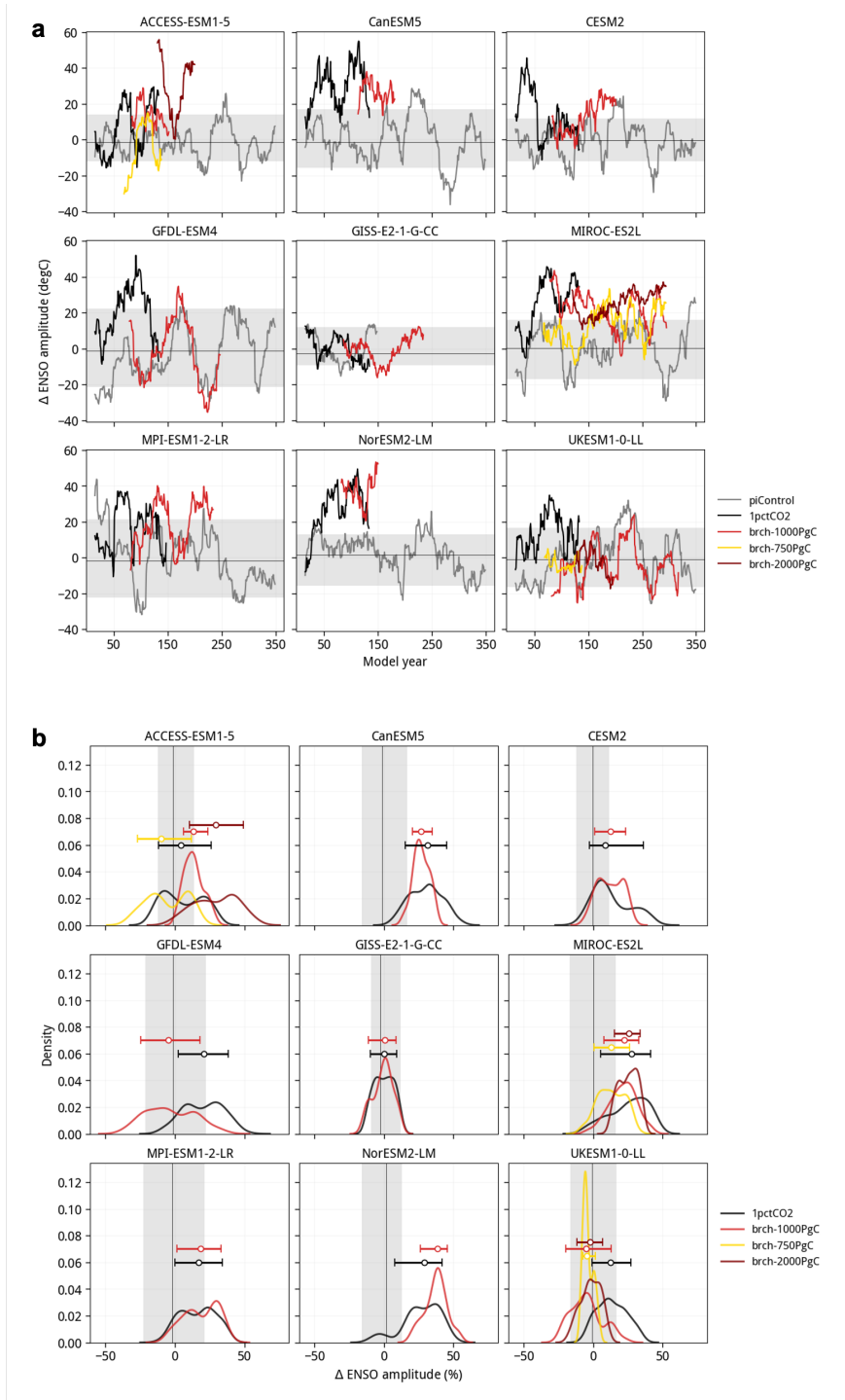


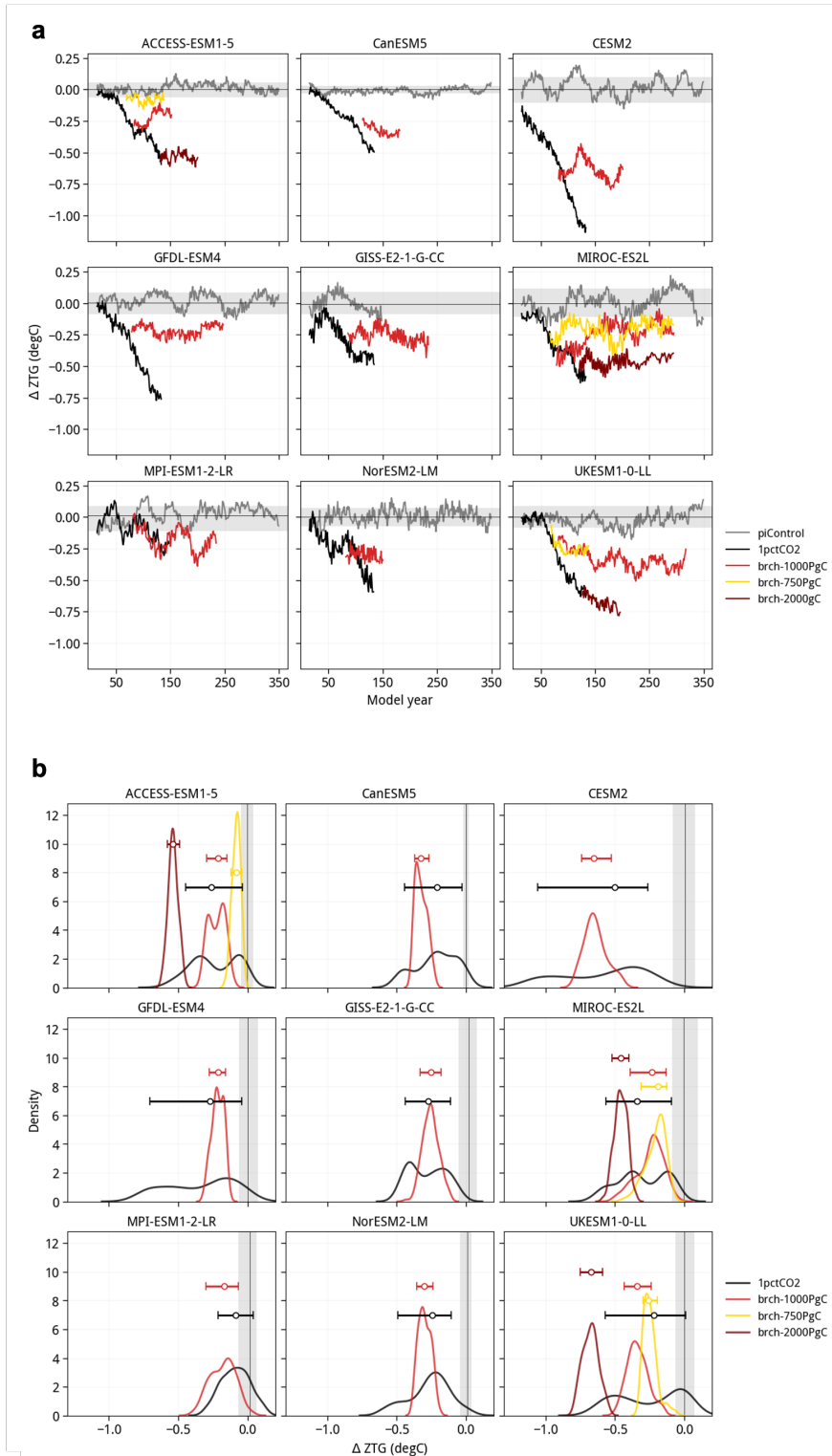
Supplementary Material



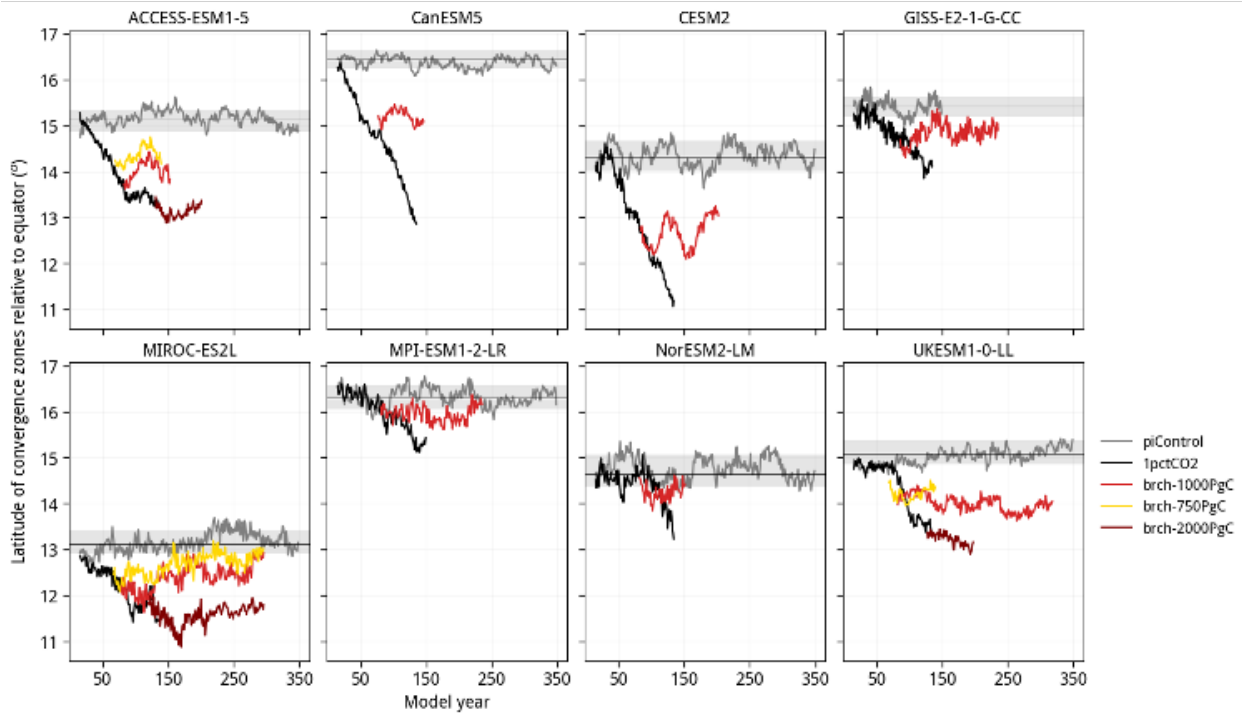
Supplementary Figure S 1. GMST anomaly changes in individual models in ZECMIP Tier-1 experiment. The changes are shown in 1pctCO₂ (black), ZECMIP brch-1000PgC (red), and brch-750PgC (gold) and brch-2000PgC (maroon) experiments for different models. The low and high emission cessation experiments were only available for three models: ACCESS-ESM1-5, MIROC-ES2L and UKESM1-0-LL.



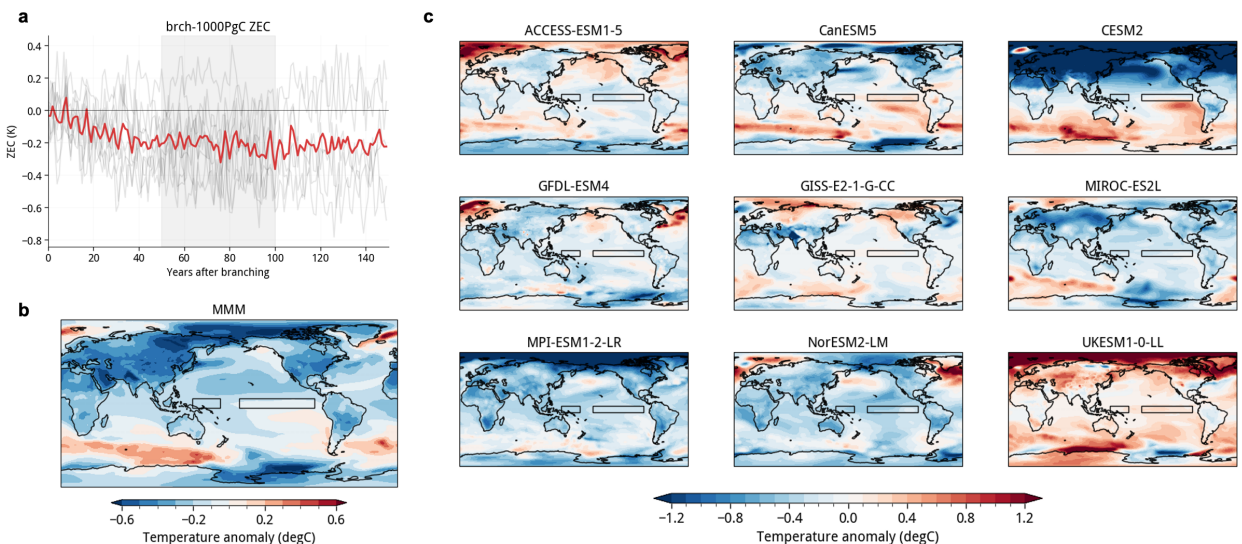
Supplementary Figure S 2. ENSO amplitude changes in individual models in ZECMIP experiments. **a**, Changes in ENSO amplitude, calculated as the 30-year rolling standard deviation of Niño3 index, in the 1pctCO₂ (black), ZECMIP brch-1000PgC (red), and brch-750PgC (gold) and brch-2000PgC (maroon) experiments for different models. The low and high emission cessation experiments were only available for three models: ACCESS-ESM1-5, MIROC-ES2L and UKESM1-0-LL. **b**, The kernel density estimate of ENSO amplitude for different models in the 1pctCO₂ and ZECMIP branching experiments. The inset whisker plots represent the median, 10th and 90th percentile of the temporal distributions. Gray line represents the change in ENSO amplitude in the piControl experiment. The thin black line is the piControl temporal average, while the grey shading represents the 10th–90th percentile range of the temporal distribution.



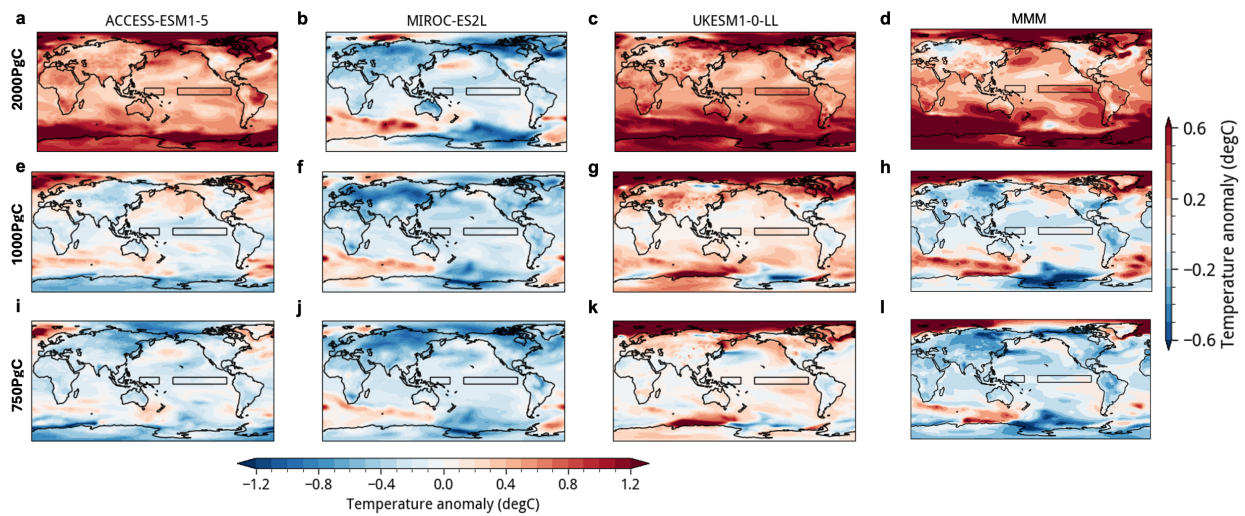
Supplementary Figure S 3. ZTG changes in individual models in ZECMIP experiments. Same as Supplementary Fig.2 but for ZTG anomaly changes



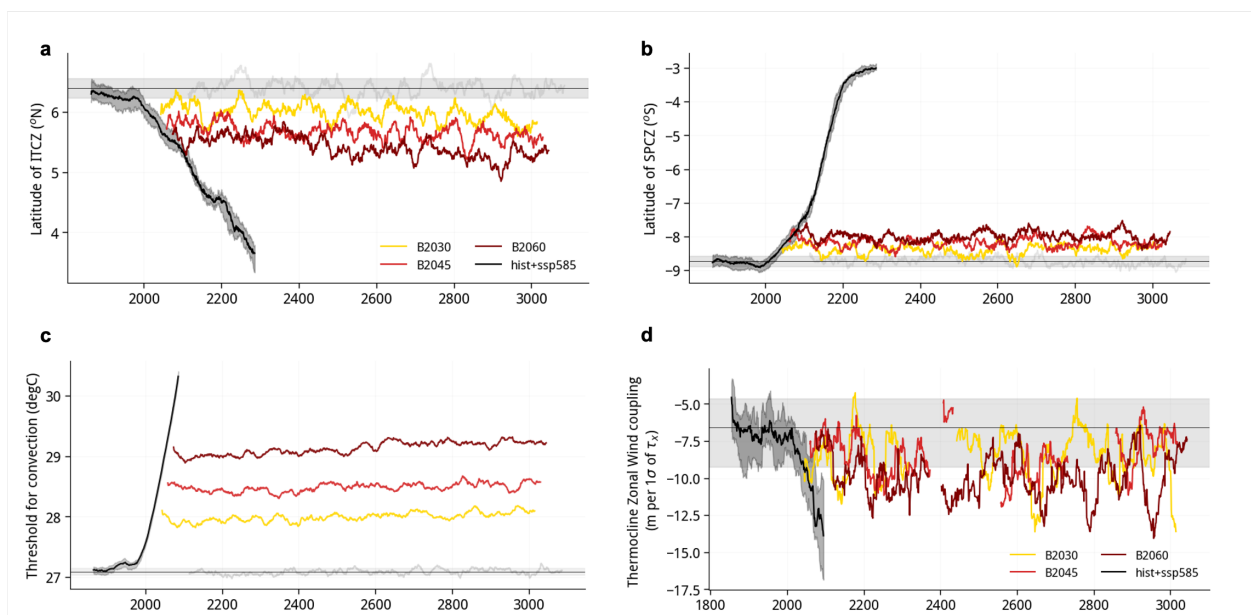
Supplementary Figure S 4. Evolution of the location of the convergence zones: ITCZ and SPCZ relative to the equator (see Methods) in the ZECMIP experiments. Changes shown for 1pctCO₂ (black), ZECMIP brch-1000PgC (red), and brch-750PgC (gold) and brch-2000PgC (maroon) experiments for different models. The low and high emission cessation experiments were only available for three models: ACCESS-ESM1-5, MIROC-ES2L and UKESM1-0-LL. The gray line represents the relative location, in the piControl experiment. The thin black line is the piControl average across time, while the grey shading represents the 10th–90th percentile range.



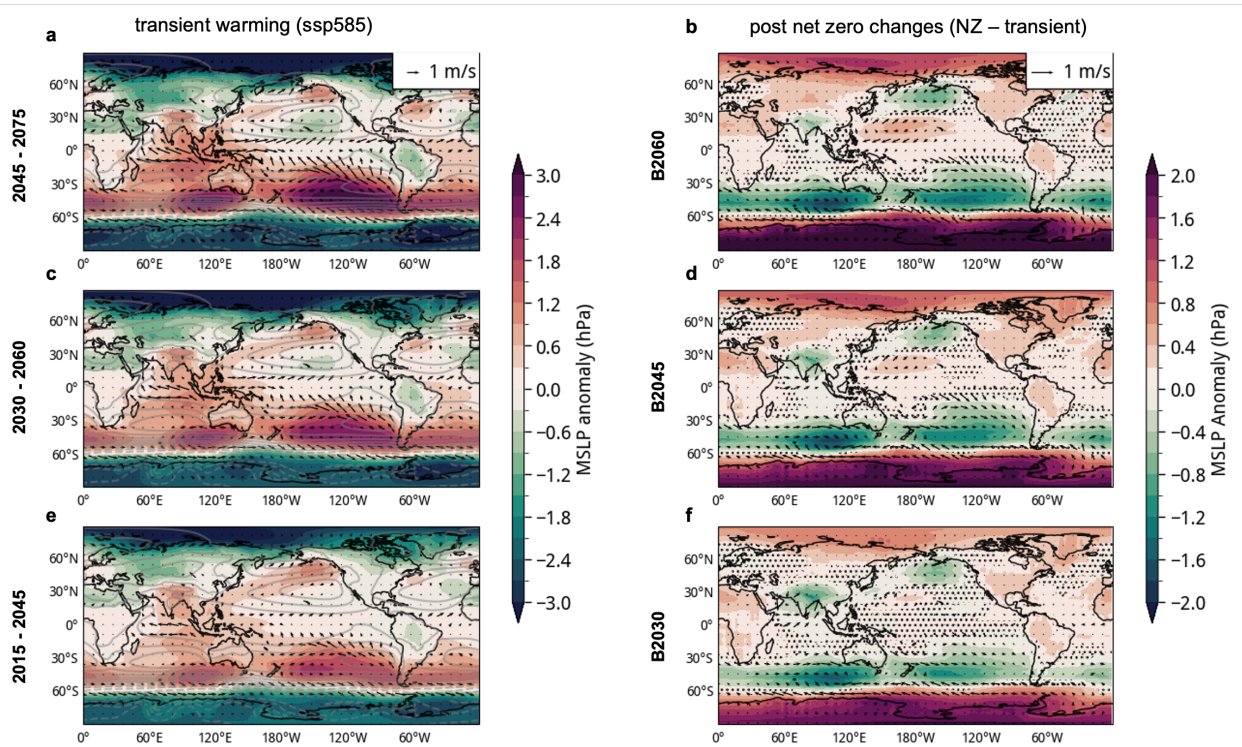
Supplementary Figure S 5. GMST and regional temperature changes post emission cessation in ZECMIP Tier-1 brch-1000PgC experiment. **a**, Post net-zero GMST change in individual models (shown in gray) and multimodel mean (MMM) change (shown in red). **b**, MMM of the regional surface temperature changes in the 50–100 year period (shown in gray shading in **a**) post emission cessation in the brch-1000PgC run compared to the 50-year baseline centred at the year of branching in each model. **c**, Regional surface temperature changes in each individual model.



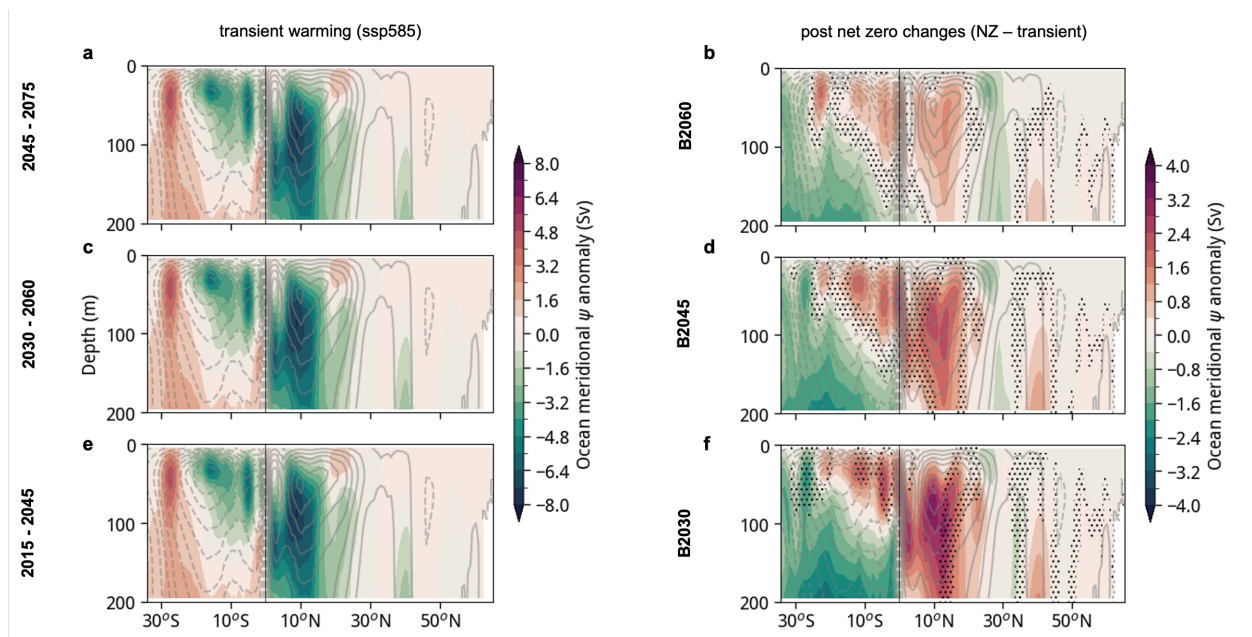
Supplementary Figure S 6. Regional surface temperature changes in ZECMIP experiments at different levels of cumulative emissions. **a–d**, Regional surface temperature change in ACCESS-ESM1-5 (**a**), MIROC-ES2L (**b**) and UKESM1-0-LL (**c**) and the MMM (**d**) in the 50-100 year period post emission cessation in brch-2000PgC run, compared to the 50-year baseline centred at the year of branching. **e–h** and **i–l**, Same as **a–d**, but for the branching runs brch-1000PgC and brch-750PgC, respectively.



Supplementary Figure S 7. Persistence in the shift of ITCZ and SPCZ, SST threshold for convection and tropical Pacific thermocline-wind coupling strength in the tropical Pacific in ACCESS-ESM1-5 net-zero runs. **a, b**, Evolution of the location of ITCZ (**a**) and SPCZ (**b**) relative to the equator, during historical and transient warming (black) and under net-zero branching runs: B2030 (gold), B2045 (red) and B2060 (maroon). **c**, Same as **a**, but for the SST threshold for convection (see Methods) in the tropical Pacific. **d**, Same as **a**, but for tropical Pacific thermocline slope and zonal wind stress coupling strength (see Methods). The gray line in panels **a–c** represents the temporal variation in the ACCESS-ESM1-5 piControl experiment. The thin black line in each panel is the piControl average across time except panel **d** where the line represents the 1850–1900 average, while the grey shading represents the 10th–90th percentile range.



Supplementary Figure S 8. MSLP and surface wind changes under transient warming and post net-zero in ACCESS-ESM1-5 net-zero runs. a, b, MSLP anomaly (shading) and surface wind anomalies (vectors) under transient warming, compared to historical, during 2045–2075 (**a**) and the changes post net-zero in the branching run B2060 compared to transient warming (**b**). The gray contours represent the MSLP values ranging from 980 to 1020hPa with a gradient of 4hPa from the historical run during 1850–1900. **c, d** and **e, f** Same as **a, b** but for transient warming period 2030–2060; net-zero B2045 and transient warming period 2015–2045; net-zero B2030, respectively. Stippling represents those points where the post net-zero changes are statistically insignificant (see Methods)



Supplementary Figure S 9. Asymmetric changes in the Indo-Pacific shallow overturning circulation in ACCESS-ESM1-5 net-zero runs. **a, b**, Indo-Pacific Ocean meridional stream function anomaly under transient warming, compared to historical, during 2045–2075 (**a**) and changes in stream function post net-zero in the branching run B2060 compared to transient warming (**b**). The solid (dashed) gray contours represent the positive (negative) stream function values from the historical run during 1850–1900. **c, d** and **e, f** Same as **a, b** but for transient warming period 2030–2060; net-zero B2045 and transient warming period 2015–2045; net-zero B2030, respectively. Stippling represents those points where the post net-zero changes are statistically insignificant (see Methods).