Supplementary of

A new precipitation emulator (PREMU v1.0) for lower complexity models

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Figure S1. The corresponding results from the PCA of the gridded temperature in July between 1901 and 1950 from GSWP3: **a**) The cumulative variance explanation rate of the top ten principal components. **b-k**) Coefficients of the top ten principal components.

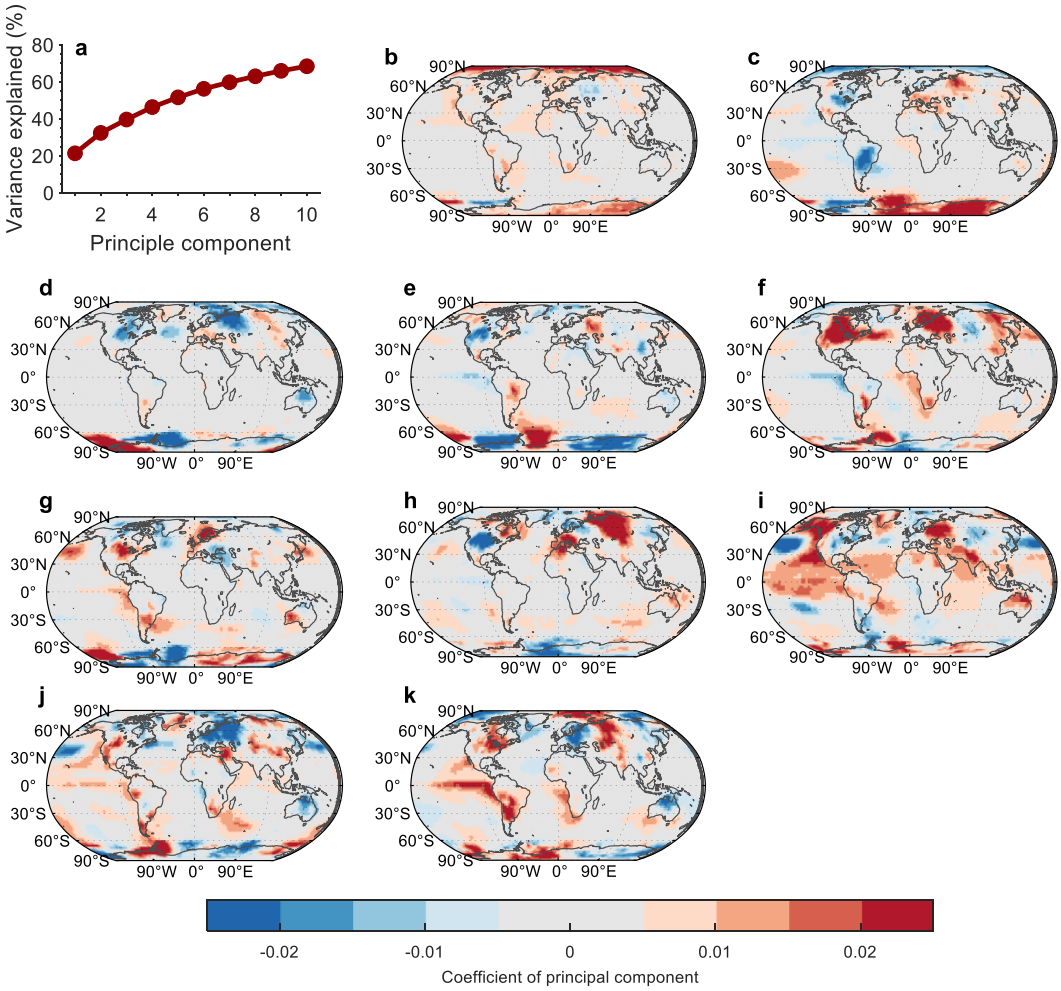

Figure S2. The corresponding results from the PCA of the gridded temperature in January between 2016 and 2100 from ESMs under SSP5-8.5 scenario: **a**) The cumulative variance explanation rate of the top ten principal components. **b-k**) Coefficients of the top ten principal components.

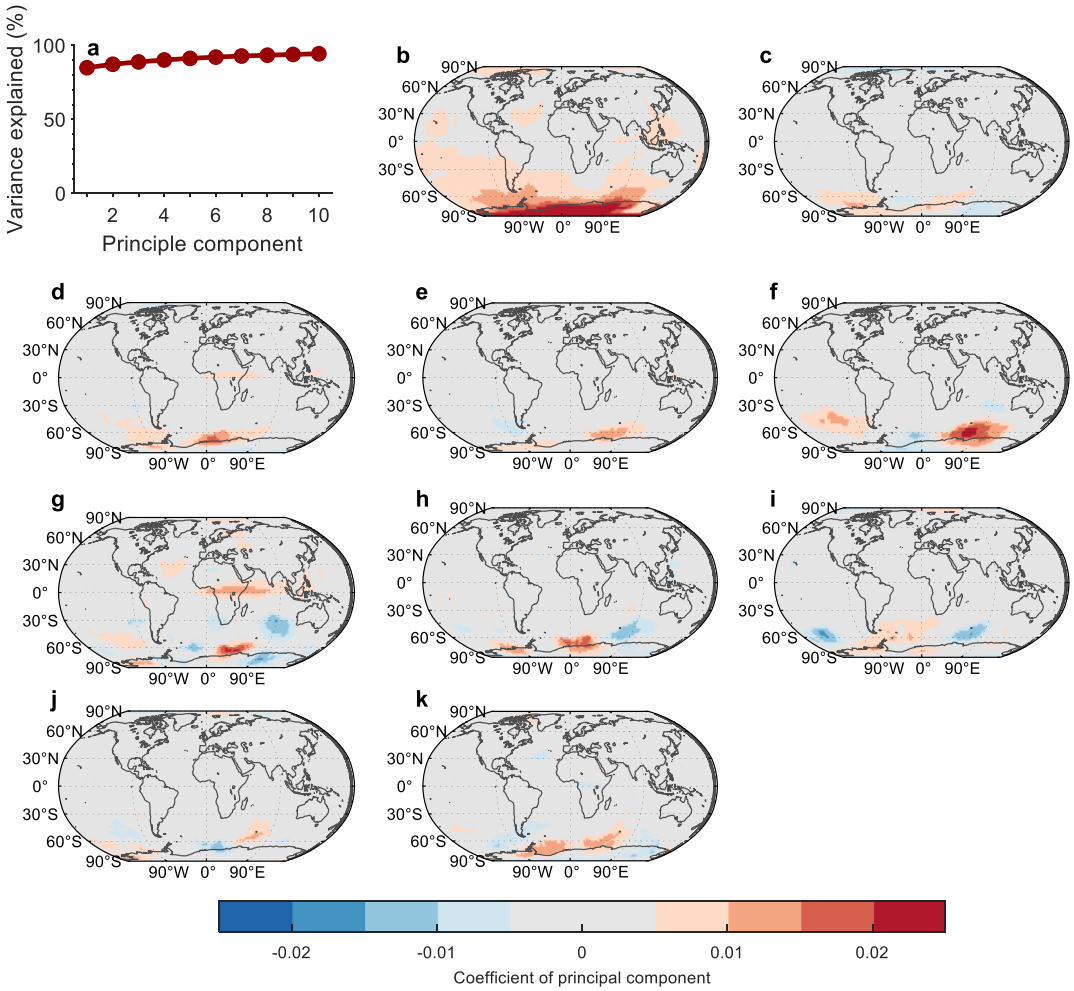

Figure S3. The corresponding results from the PCA of the gridded temperature in July between 2016 and 2100 from ESMs under SSP5-8.5 scenario: **a**) The cumulative variance explanation rate of the top ten principal components. **b-k**) Coefficients of the top ten principal components.

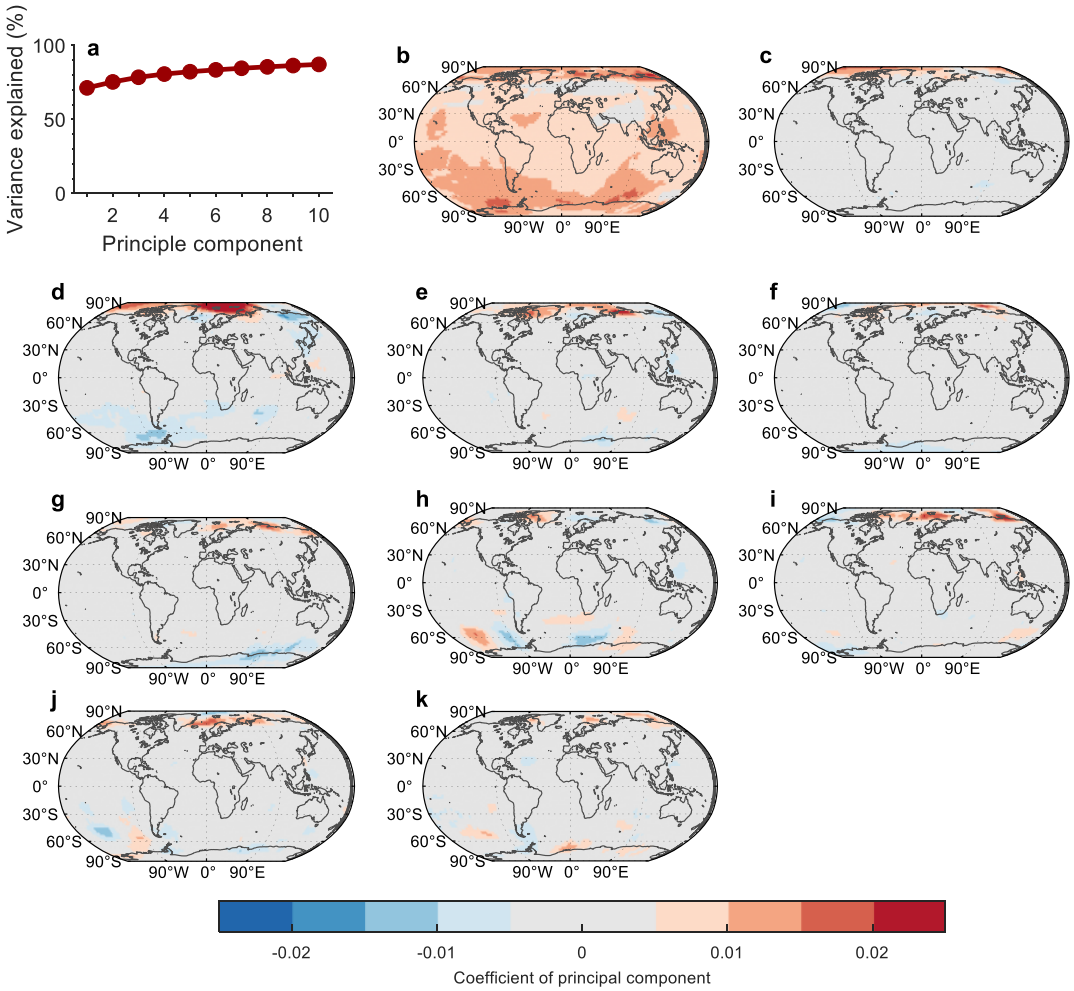

Figure S4. The anomaly of GLAP from each ESM under the SSP2-4.5 scenario: **a**) UKESM1-0-LL; **b**) MPI-ESM1-2-LR; **c**) MIROC6; **d**) IPSL-CM6A-LR; **e**) GFDL-ESM4; **f**) EC-Earth3; **g**) CanESM5; **h**) CESM2; **i**) ACCESS-ESM1-5.

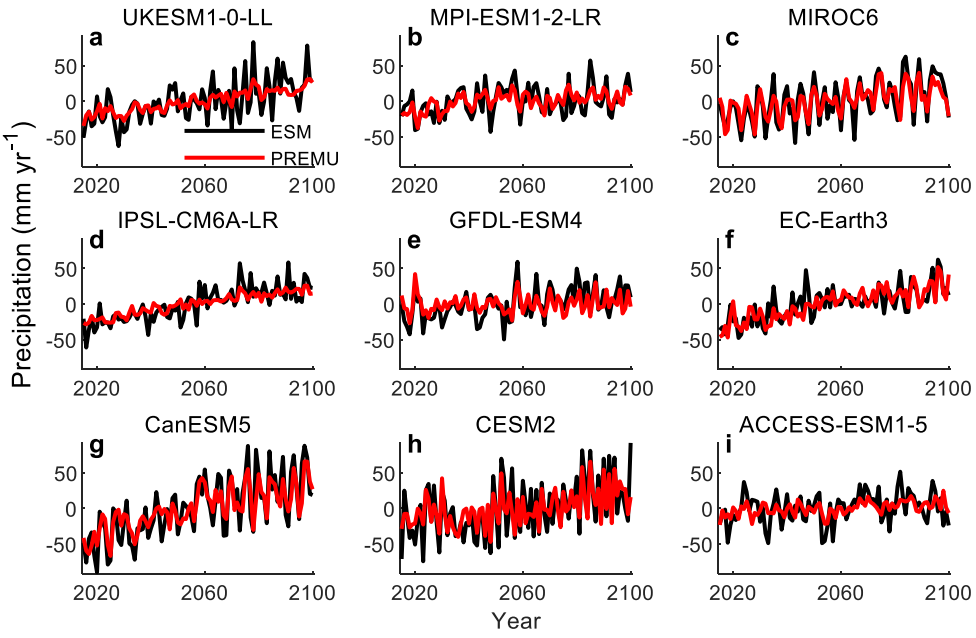

Figure S5. The anomaly of GLAP from each ESM under the SSP3-7.0 scenario: **a**) UKESM1-0-LL; **b**) MPI-ESM1-2-LR; **c**) MIROC6; **d**) IPSL-CM6A-LR; **e**) GFDL-ESM4; **f**) EC-Earth3; **g**) CanESM5; **h**) CESM2; **i**) ACCESS-ESM1-5.

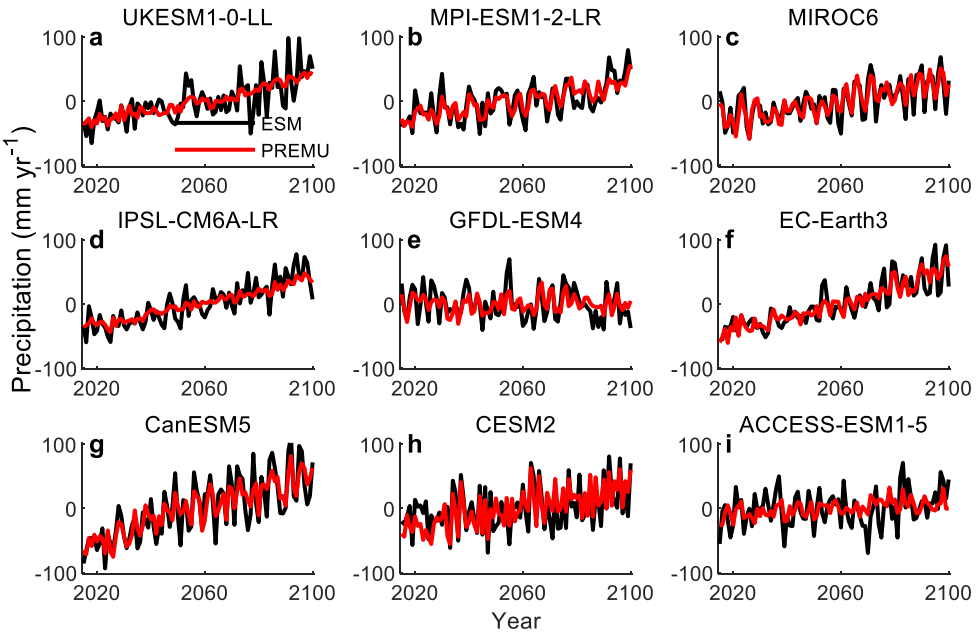

Figure S6. The anomaly of GLAP from each ESM under the SSP5-8.5 scenario: **a**) UKESM1-0-LL; **b**) MPI-ESM1-2-LR; **c**) MIROC6; **d**) IPSL-CM6A-LR; **e**) GFDL-ESM4; **f**) EC-Earth3; **g**) CanESM5; **h**) CESM2; **i**) ACCESS-ESM1-5.

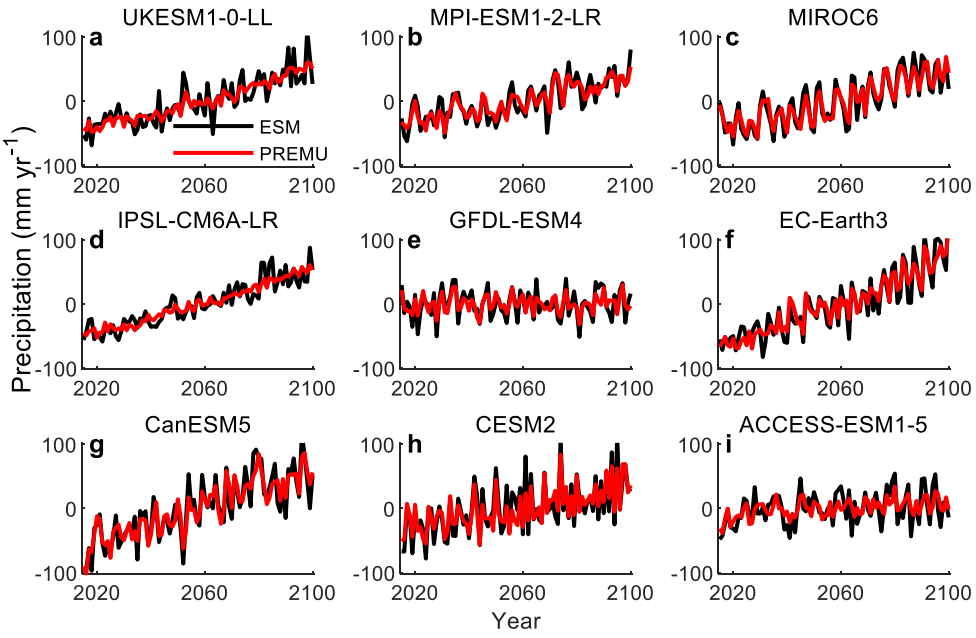

Figure S7. The spatial pattern of error of the MAP in 2071-2100 between each ESM and our emulation under the SSP2-4.5 scenario: **a**) UKESM1-0-LL; **b**) MPI-ESM1-2-LR; **c**) MIROC6; **d**) IPSL-CM6A-LR; **e**) GFDL-ESM4; **f**) EC-Earth3; **g**) CanESM5; **h**) CESM2; **i**) ACCESS-ESM1-5.

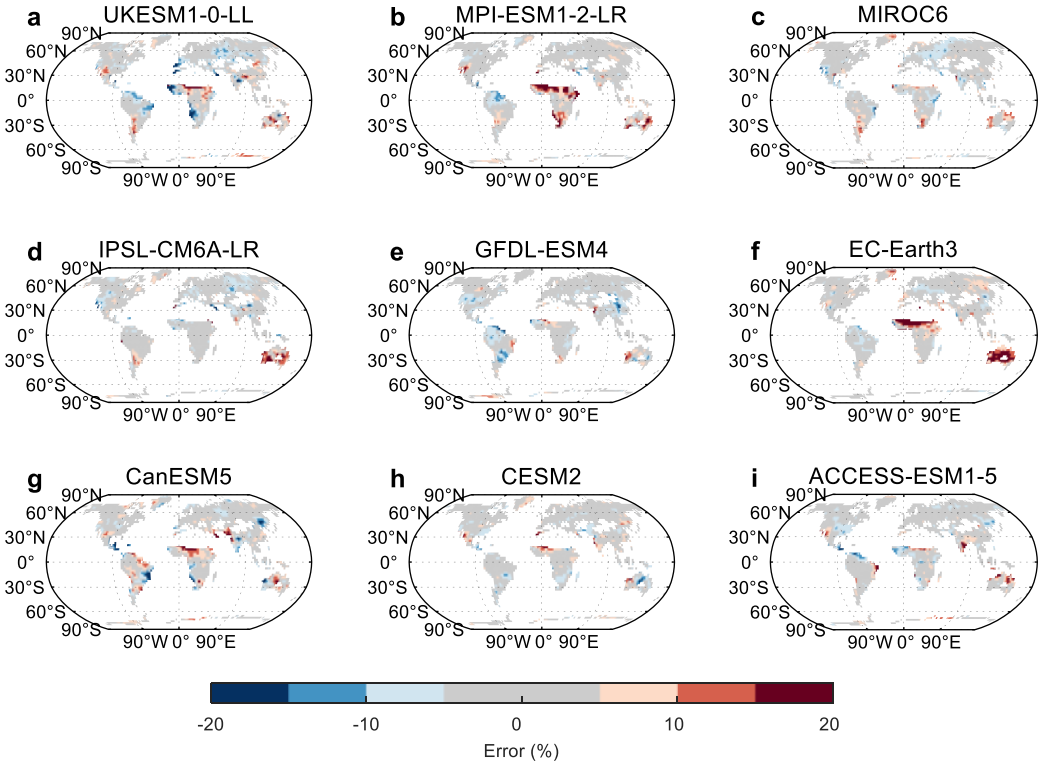

Figure S8. The spatial pattern of error of the MAP in 2071-2100 between each ESM and our emulation under the SSP3-7.0 scenario: **a**) UKESM1-0-LL; **b**) MPI-ESM1-2-LR; **c**) MIROC6; **d**) IPSL-CM6A-LR; **e**) GFDL-ESM4; **f**) EC-Earth3; **g**) CanESM5; **h**) CESM2; **i**) ACCESS-ESM1-5.

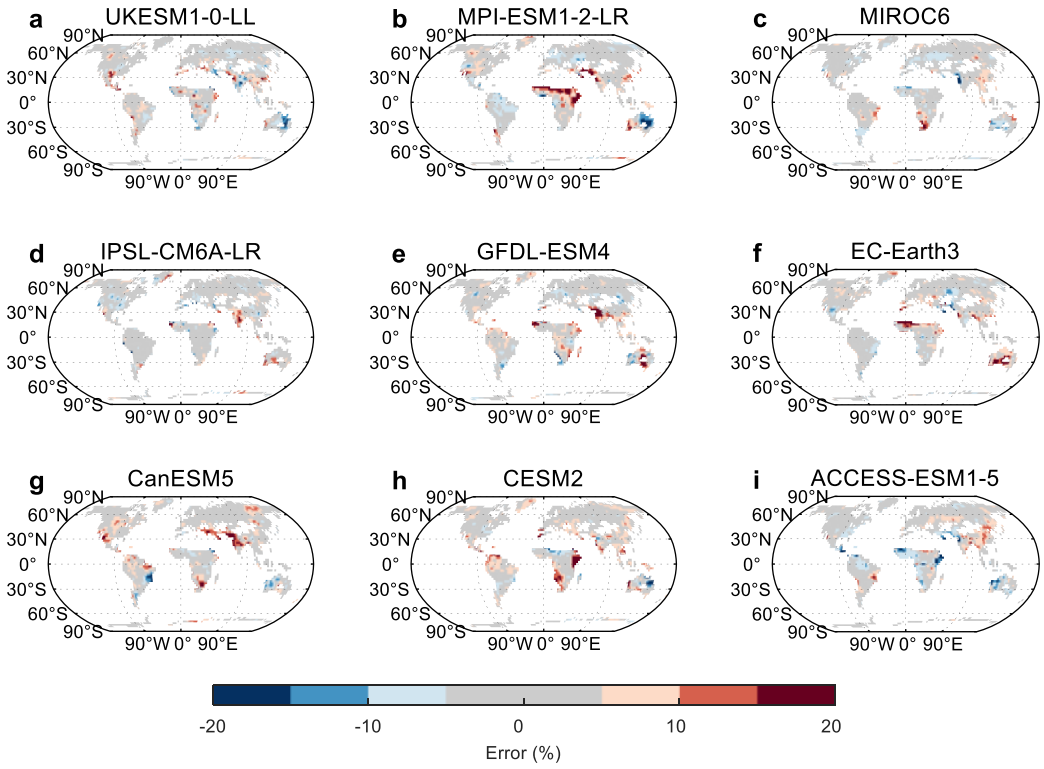

Figure S9. The spatial pattern of the MAP in 2071-2100 between each ESM and our emulation under the SSP5-8.5 scenario: **a**) UKESM1-0-LL; **b**) MPI-ESM1-2-LR; **c**) MIROC6; **d**) IPSL-CM6A-LR; **e**) GFDL-ESM4; **f**) EC-Earth3; **g**) CanESM5; **h**) CESM2; **i**) ACCESS-ESM1-5.

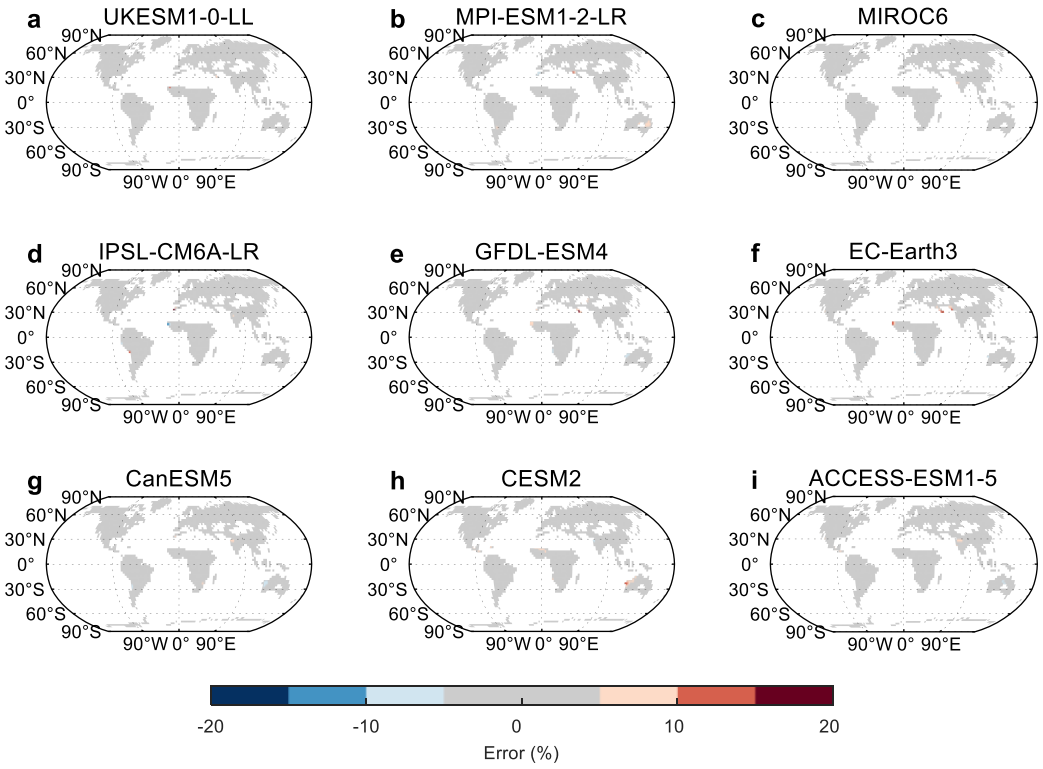

Figure S10. The spatial pattern of change in MAP between the period of 2016-2045 and 2071-2100 from **a**) UKESM1-0-LL and **b**) our emulation under SSP1-2.6 scenario. **c-d**) MPI-ESM1-2-LR; **e-f**) MIROC6; **g-h**) IPSL-CM6A-LR; **i-j)** GFDL-ESM4; **k-l**) EC-Earth3; **m-n**) CanESM5; **o-p**) CESM2; **q-r**) ACCESS-ESM1-5.

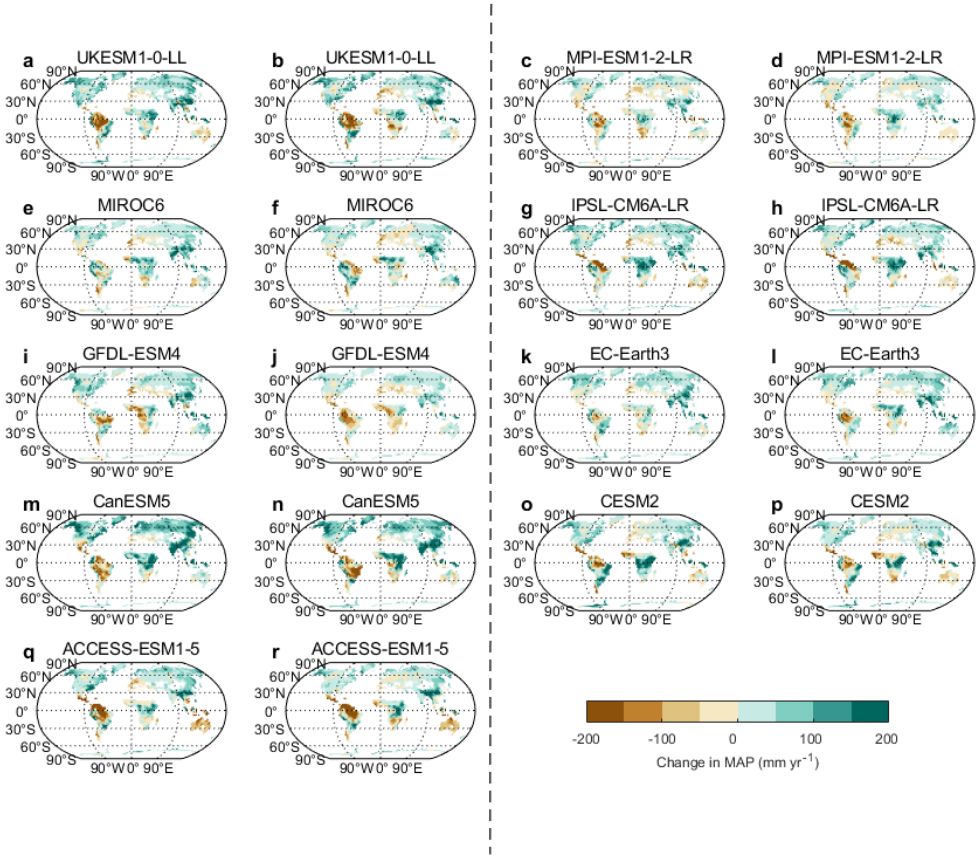

Figure S11. The spatial pattern of change in MAP between the period of 2016-2045 and 2071-2100 from **a**) UKESM1-0-LL and **b**) our emulation under SSP1-2.6 scenario. **c-d**) MPI-ESM1-2-LR; **e-f**) MIROC6; **g-h**) IPSL-CM6A-LR; **i-j)** GFDL-ESM4; **k-l**) EC-Earth3; **m-n**) CanESM5; **o-p**) CESM2; **q-r**) ACCESS-ESM1-5.

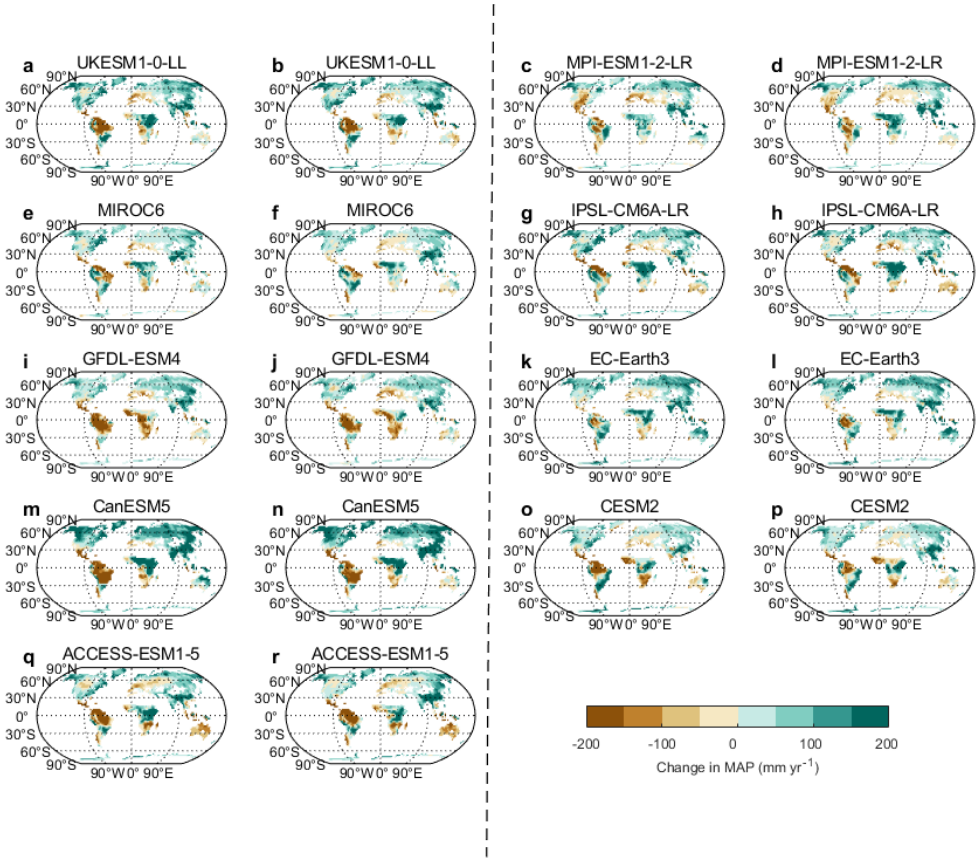

Figure S12. The spatial pattern of change in MAP between the period of 2016-2045 and 2071-2100 from **a**) UKESM1-0-LL and **b**) our emulation under SSP1-2.6 scenario. **c-d**) MPI-ESM1-2-LR; **e-f**) MIROC6; **g-h**) IPSL-CM6A-LR; **i-j)** GFDL-ESM4; **k-l**) EC-Earth3; **m-n**) CanESM5; **o-p**) CESM2; **q-r**) ACCESS-ESM1-5.

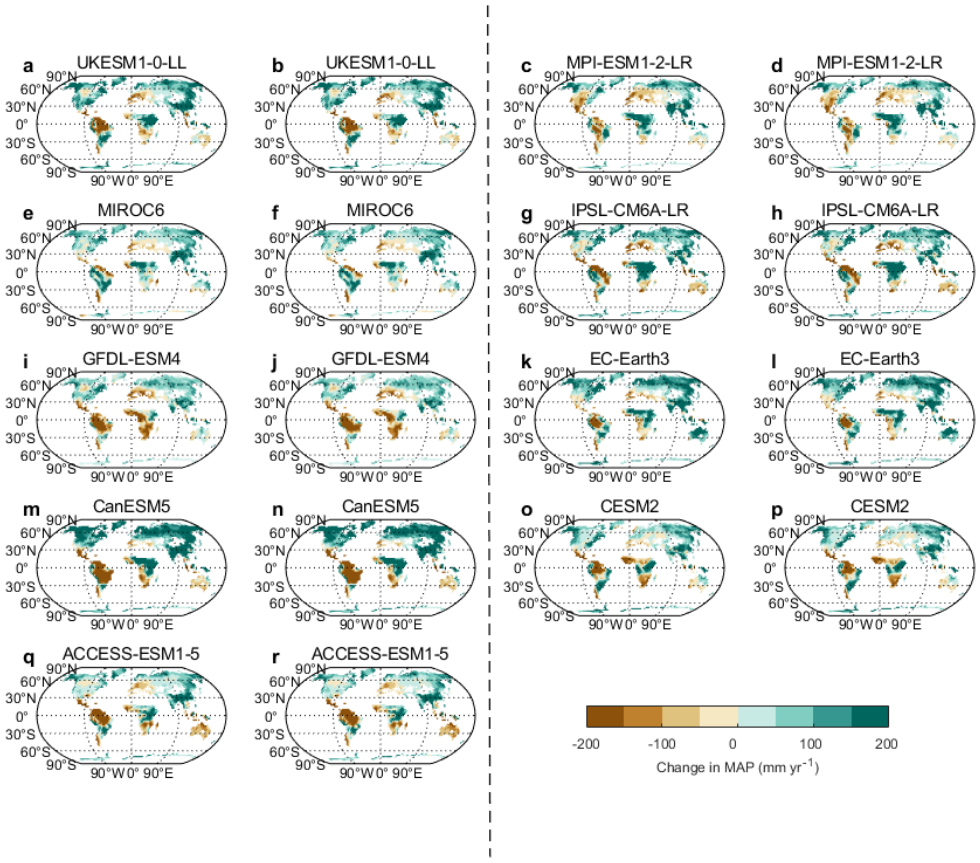

Figure S13. The corresponding results from the PCA of the gridded temperature in January between 2016 and 2100 from ESMs under SSP1-2.6 scenario: **a**) The cumulative variance explanation rate of the top ten principal components. **b-k**) Coefficients of the top ten principal components.

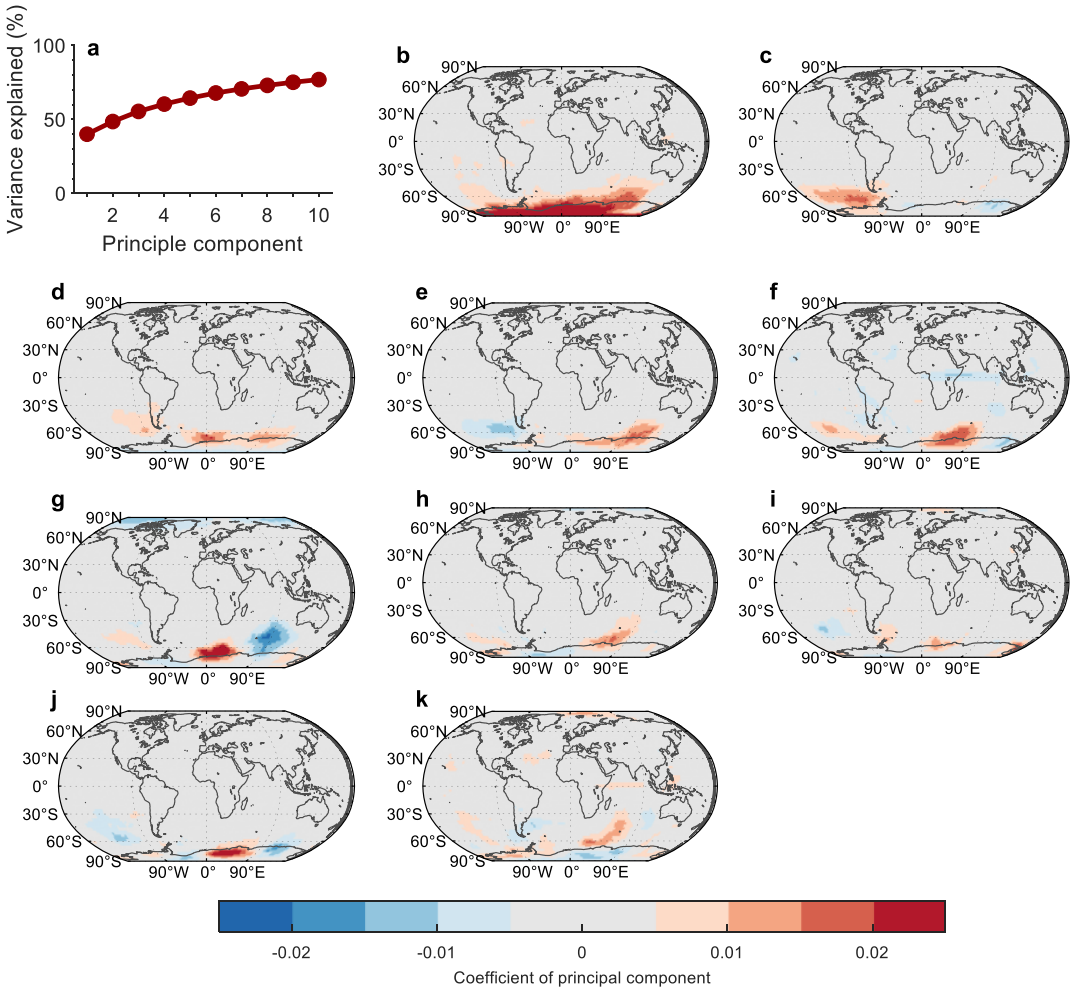

Figure S14. The corresponding results from the PCA of the gridded temperature in July between 2016 and 2100 from ESMs under SSP1-2.6 scenario: **a**) The cumulative variance explanation rate of the top ten principal components. **b-k**) Coefficients of the top ten principal components.

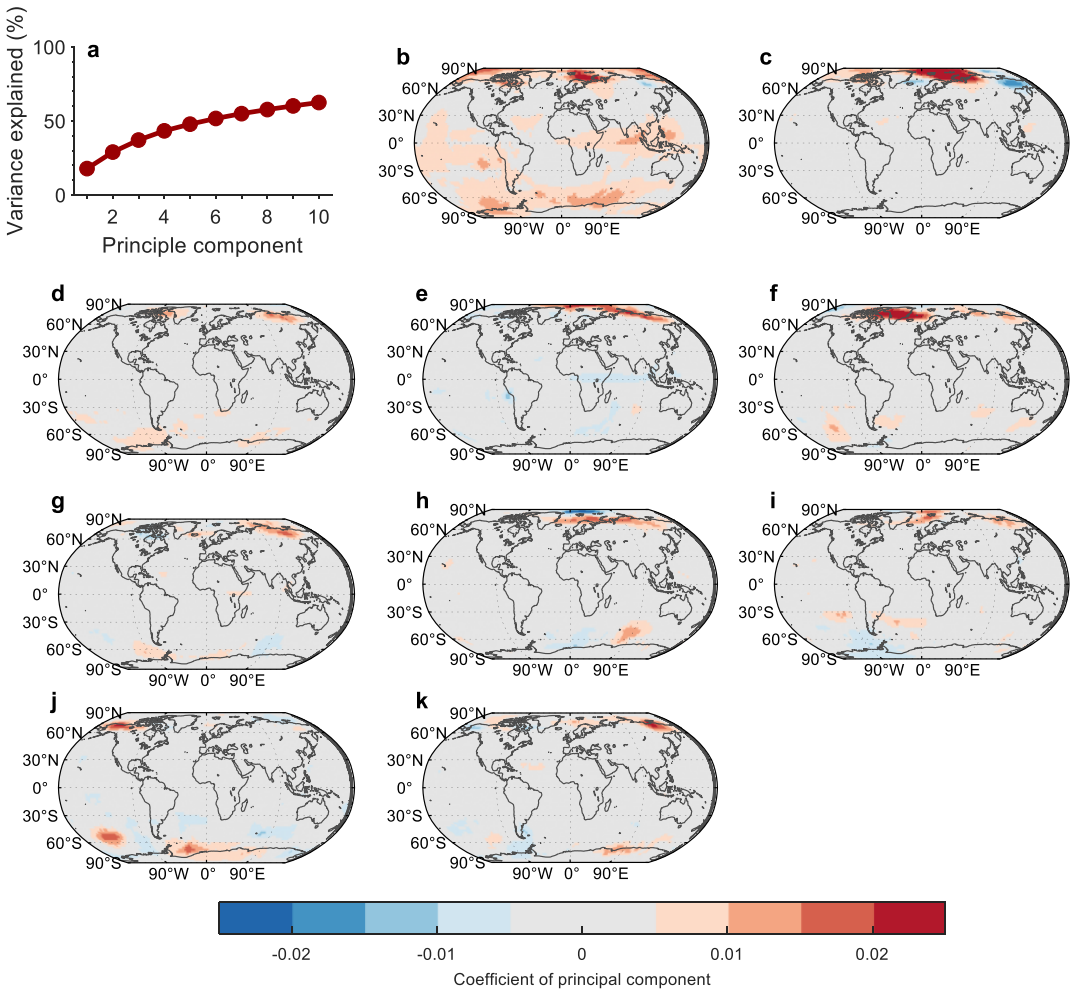

Figure S15. The GLAP in GSWP3 and the estimations from emulators based on monthly temperature (emulator-mon), 3-month average temperature (This study) and 6-month average temperature (emulator-6mon) in 1901-2016.

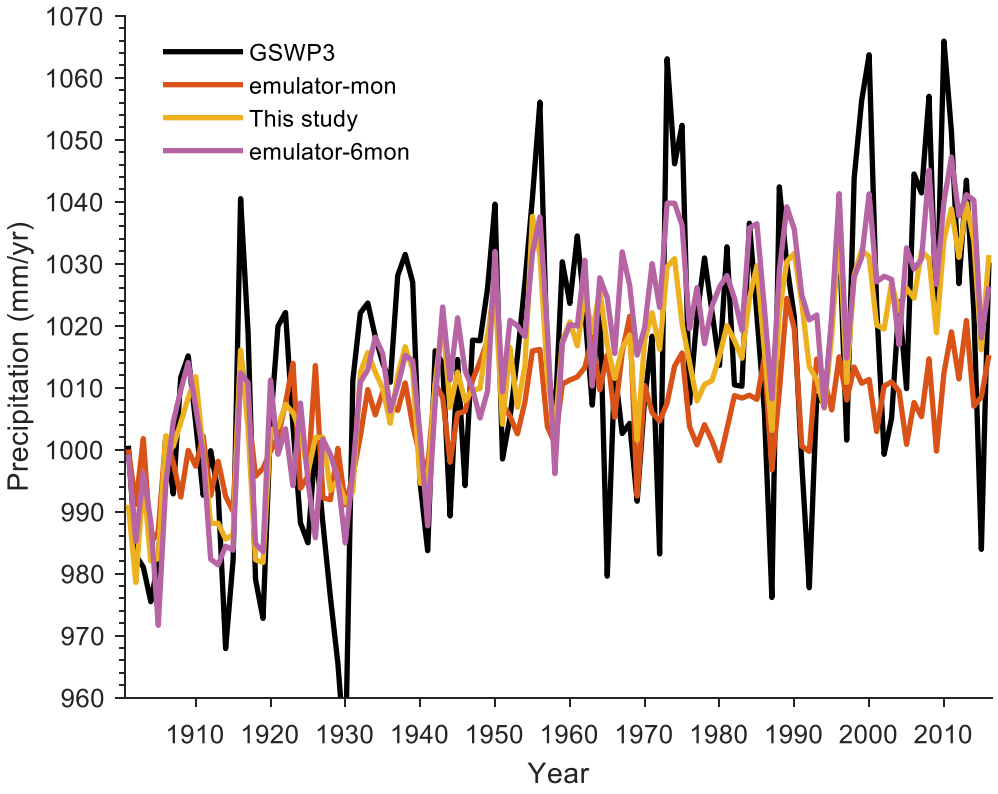

Figure S16. The emulation on future precipitation: **a**) multi-model mean GLAP in 9 ESMs from CMIP6 (CMIP (9)), and the precipitation prediction by the emulator-1mon (Emulator-mon) in 2015-2100 under the SSP5-8.5 scenario. The shaded area represents the mean±std. **b**) The spatial pattern of error in MAP during 2071-2100 between multi-model mean and our emulator. **c-d**) SSP1-2.6; **e-f**) SSP2-4.5; **g-h**) SSP3-7.0.

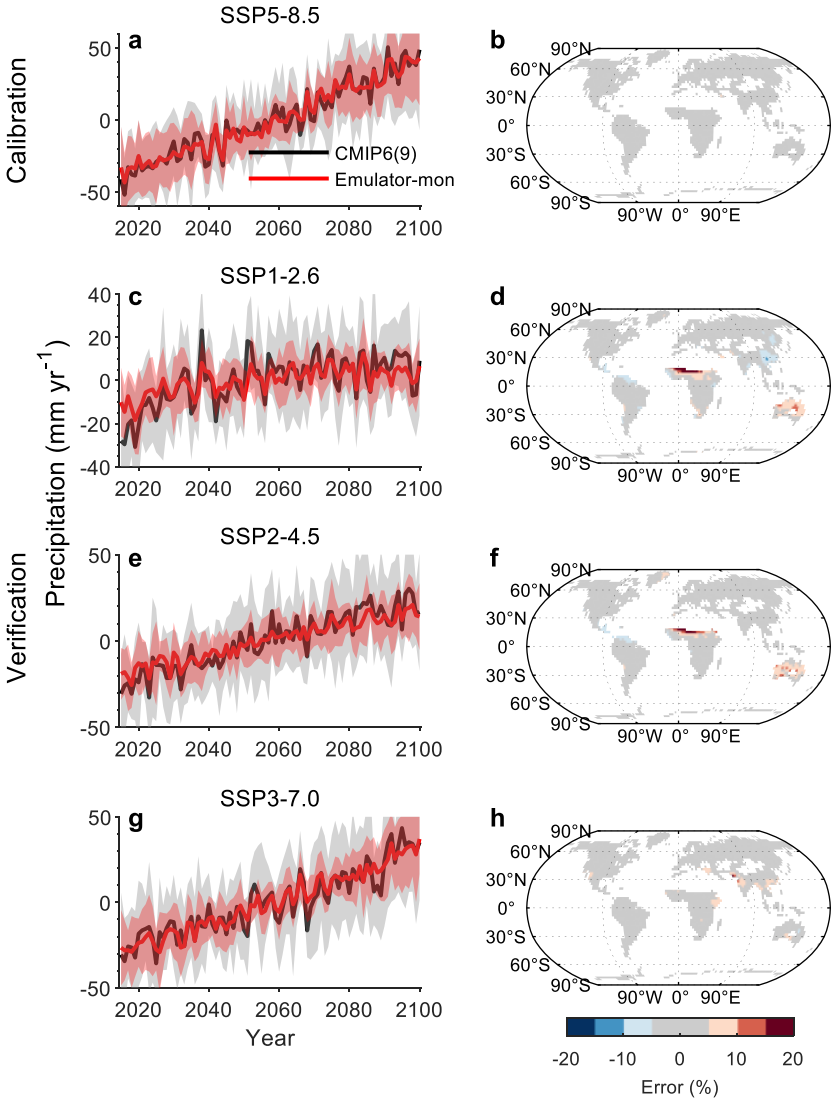

Figure S17. The emulation on future precipitation: **a**) multi-model mean GLAP in 9 ESMs from CMIP6 (CMIP (9)), and the precipitation prediction by the emulator-6mon (Emulator-6mon) in 2015-2100 under the SSP5-8.5 scenario. The shaded area represents the mean±std. **b**) The spatial pattern of error in MAP during 2071-2100 between multi-model mean and our emulator. **c-d**) SSP1-2.6; **e-f**) SSP2-4.5; **g-h**) SSP3-7.0.

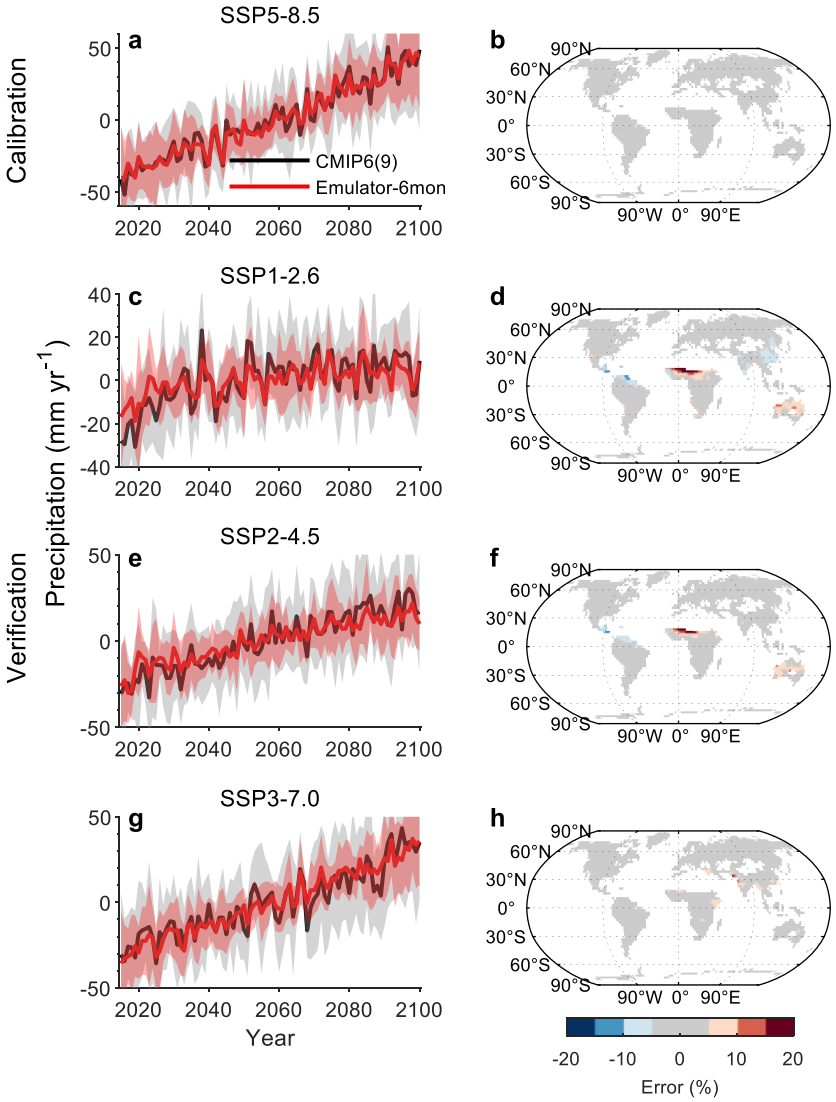

Figure S18. The emulation on future precipitation by emulator-land: **a**) multi-model mean GLAP in 9 ESMs from CMIP6 (CMIP (9)), and the precipitation prediction by emulator-land (Emulator-land) in 2015-2100 under the SSP5-8.5 scenario. The shaded area represents the mean±std. **b**) The spatial pattern of error in MAP during 2071-2100 between multi-model mean and our emulator. **c-d**) SSP1-2.6; **e-f**) SSP2-4.5; **g-h**) SSP3-7.0.

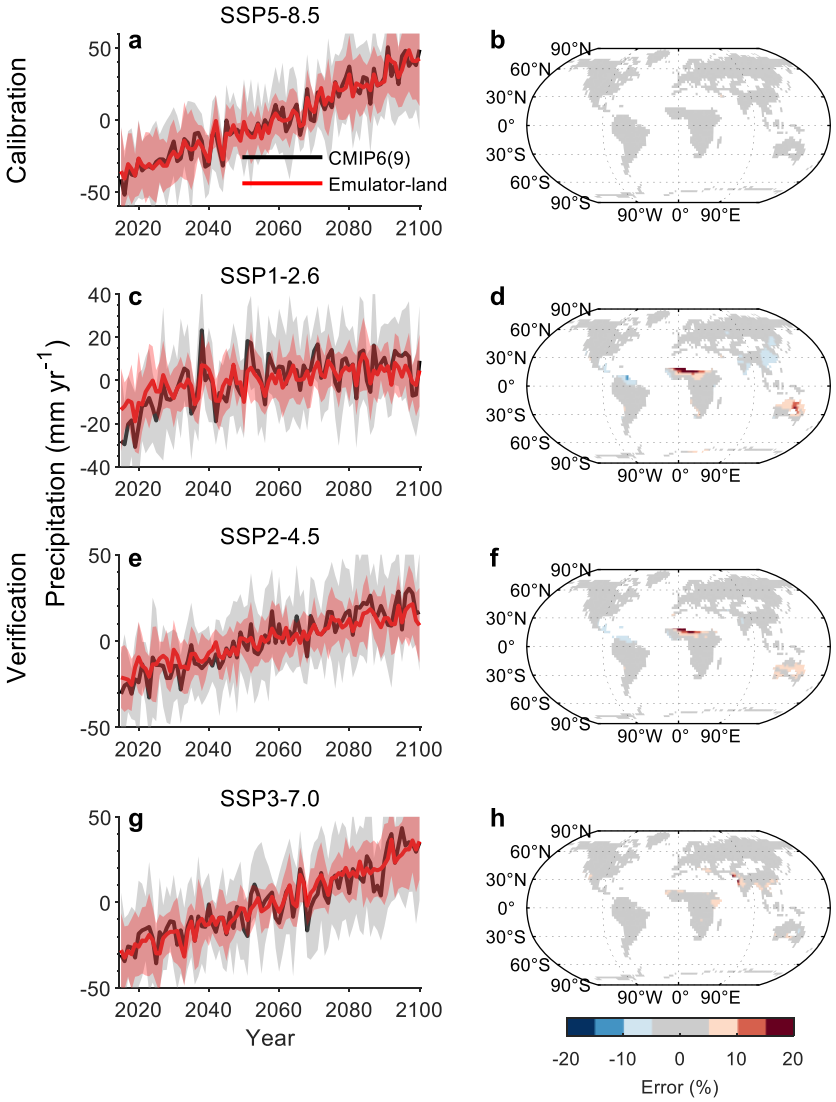

Figure S19. The spatial pattern of change in MAP in 2071-2100 from **a**) ESMs and **b**) emulation from emulator-land under SSP5-8.5 scenario. **c-d**) SSP1-2.6; **e-f**) SSP2-4.5; **g-h**) SSP3-7.0.