

Supporting Information for

“Narrowing of the ITCZ in a warming climate: physical mechanisms”

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S1. CMIP5 models

The models analyzed are ACCESS1-0, ACCESS1-3, BCC-CSM1-1, BCC-CSM1-1-M, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-ES, INMCM4, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, MIROC-ESM, MIROC-ESM-CHEM, MRI-CGCM3, MRI-ESM1, NorESM1-M.

The models used for the clear-sky radiative flux analysis are ACCESS1-0, BCC-CSM1-1, CNRM-CM5, CSIRO-Mk3-6-0, GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR, IPSL-CM5A-MR, IPSL-CM5B-LR, MIROC5, MIROC-ESM, MIROC-ESM-CHEM, MRI-CGCM3, NorESM1-M.

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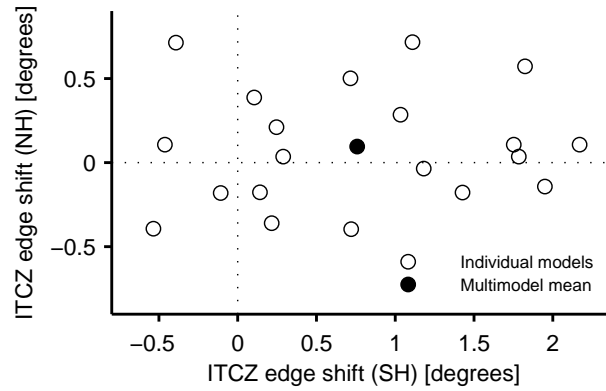


Figure S1. Changes in the latitudes of the northern hemisphere (y-axis) and southern hemisphere (x-axis) edges of the annual-mean mass ITCZ for individual models (open black circles) and for the multimodel mean (solid black circle).

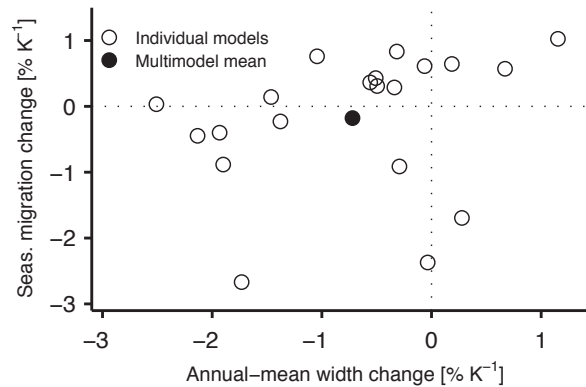


Figure S2. Changes in the seasonal migration of the ITCZ location vs changes in annual-mean ITCZ width for individual models (open black circles) and for the multimodel mean (solid black circle). The seasonal migration of the ITCZ is defined as the area between the average June-July-August (JJA) and December-January-February (DJF) locations of the ITCZ, with the ITCZ location defined as the latitude closest to the equator where the mass streamfunction, vertically averaged between 700 hPa and 300 hPa, passes through zero. The correlation coefficient is $r = 0.26$.

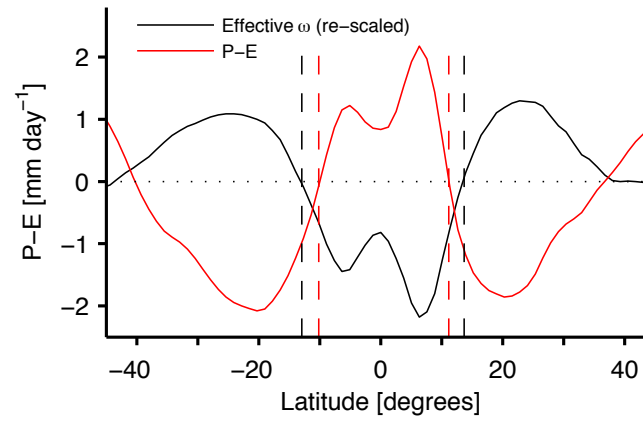


Figure S3. The zonal-, annual- and multimodel-mean historical precipitation minus evaporation (solid red line) and the effective vertical velocity (solid black line) averaged between 300 hPa and 700 hPa. The effective vertical velocity is defined as $\omega_{\text{eff}} = -\partial\Psi/\partial\phi$, and has been re-scaled so that it roughly matches the magnitude of precipitation minus evaporation. Dashed black lines denote the edges of the mass ITCZ and dashed red lines show the moisture ITCZ (see section 2.3 for details of the ITCZ definitions).

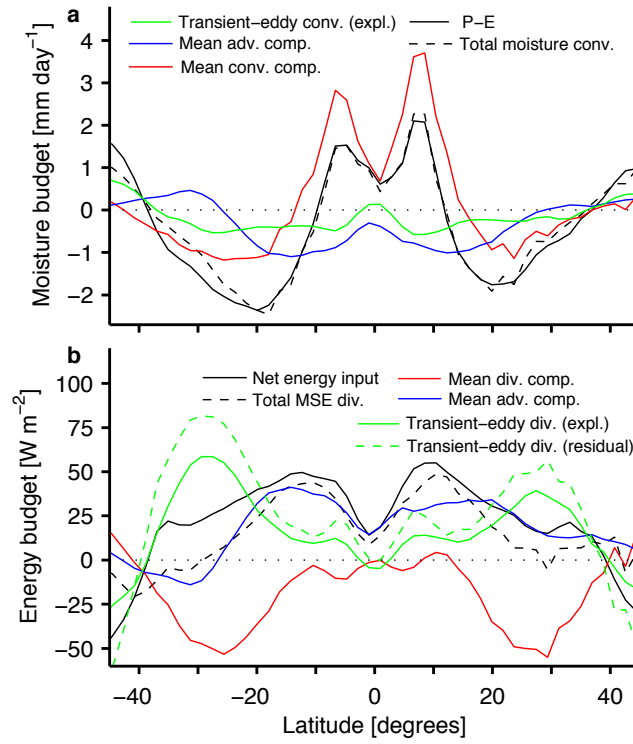


Figure S4. Terms in the annual-mean atmospheric (a) moisture (A.1) and (b) energy budgets (B.1) in the historical simulation for the IPSL-CM5A-LR model. The zonal-mean of each term is shown. For the energy budget, two estimates of the transient-eddy component are plotted: (i) Calculated explicitly using daily-mean temperatures, specific humidities, geopotentials, and horizontal winds (solid green line), and (ii) calculated as a residual from the atmospheric energy budget (dashed green line).

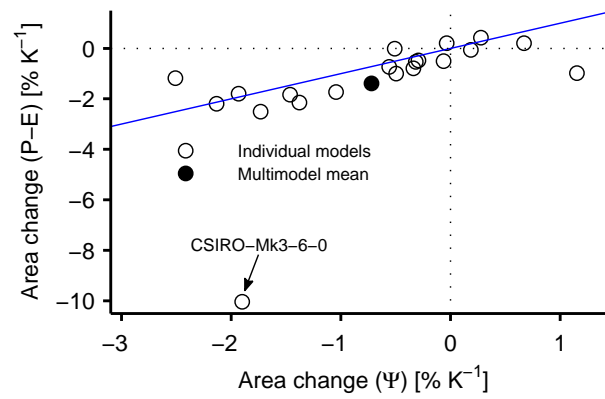


Figure S5. Fractional changes in the area of the ITCZ for individual models (open black circles) and for the multimodel mean (solid black circle) for two definitions of the ITCZ width (the mass and moisture ITCZs, see section 2.3 for details). The blue line shows the one-to-one relationship and the fractional area changes have been normalized by the global-mean change in surface-air temperature for each model. The correlation coefficient is $r = 0.54$ for all models and $r = 0.75$ when the CSIRO-Mk3-6-0 model is excluded.

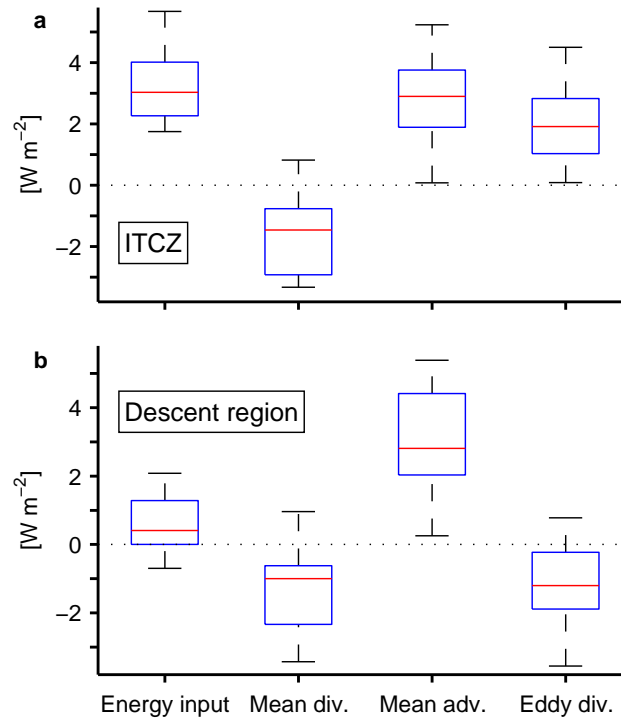


Figure S6. Changes in the various terms in the atmospheric energy budget (B.1) between the historical and RCP8.5 simulations averaged (a) over the ITCZ and (b) over the descent region. The red lines show the multimodel median for each term, the blue boxes show the interquartile ranges, and the whiskers show the full model ranges.

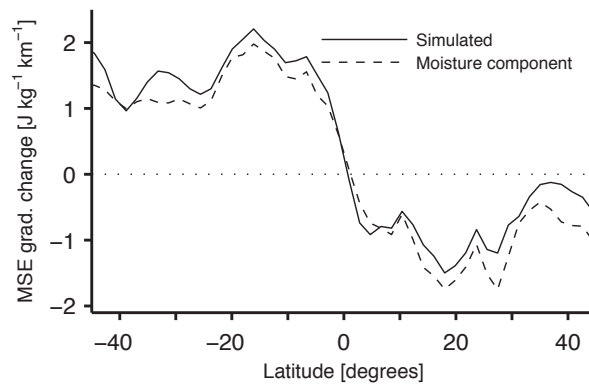


Figure S7. Multimodel-mean change in the surface-air meridional moist static energy gradient. The simulated change (solid black line) along with the component of the change due solely to changes in surface-air specific humidity (dashed black line) are shown.

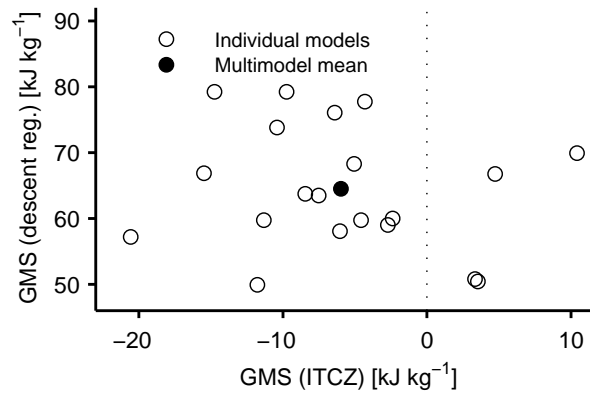


Figure S8. The historical gross moist stability (GMS) in the ITCZ and the descent region for each individual model (open black circles) and for the multimodel mean (solid black circle). See appendix B for the definition of GMS.