Increasing potential for intense tropical and subtropical thunderstorms under global warming:
Supplementary material

Martin S. Singh
School of Earth, Atmosphere & Environment
Monash University, Victoria, Australia

Zhiming Kuang
Department of Earth & Planetary Sciences
Harvard University, Massachusetts, USA

Eric D. Maloney
Department of Atmospheric Sciences
Colorado State University, Colorado, USA

Walter M. Hannah
Lawrence Livermore National Laboratory
California, USA

Brandon O. Wolding
Department of Atmospheric Sciences
Colorado State University, Colorado, USA

	ΔCAPE^{95} (% K^{-1})		DTE days (% K^{-1})		ΔT_s (K)	
Model	all	land	all	land	all	land
ACCESS1-3	10.6	9.0	24.6	9.6	3.6	4.9
BNU-ESM	13.0	14.1	35.1	30.4	3.4	4.1
CNRM-CM5	13.9	13.2	34.1	27.3	3.0	3.8
GFDL-CM3	10.7	10.9	18.8	16.5	4.5	5.6
HadGEM2-CC	10.5	11.7	22.0	18.7	4.1	5.5
IPSL-CM5A-LR	6.1	8.7	9.4	15.0	4.6	5.5
IPSL-CM5B-LR	6.9	7.9	11.8	17.8	3.1	3.9
MIROC5	8.4	9.7	18.4	16.5	3.2	4.1
MIROC-ESM	7.0	7.2	25.7	18.4	4.2	5.5
MIROC-ESM-CHEM	7.6	7.8	27.2	19.7	4.4	5.7
MRI-CGCM3	9.1	9.6	28.8	25.8	2.9	3.7
MRI-ESM1	9.0	9.5	28.5	20.1	3.0	3.8
ensemble mean	**9.4**	**9.9**	**23.7**	**21.2**	**3.7**	**4.7**

Table S1: Projected future changes in CAPE^{95}, frequency of damaging thunderstorm environment (DTE) days, and surface air temperature (T_s) according to CMIP5 models. Changes calculated as difference from the current climate (1981-2000) to the future climate (2081-2100) under the RCP8.5 scenario for 12 CMIP5 models and shown as area-weighted mean of all points or land points in the region 36°S-36°N. Changes in CAPE^{95} and DTE days are expressed as a percentage and normalised by the area-weighted mean change in surface air temperature over the same region.

α	CAPE^{95} (J kg^{-1})
0.0	580
0.2	1120
0.4	1600
0.6	1900

Table S2: Area-weighted mean of CAPE^{95} over the region 36°S-36°N in GCM simulations with varying entrainment parameter α.

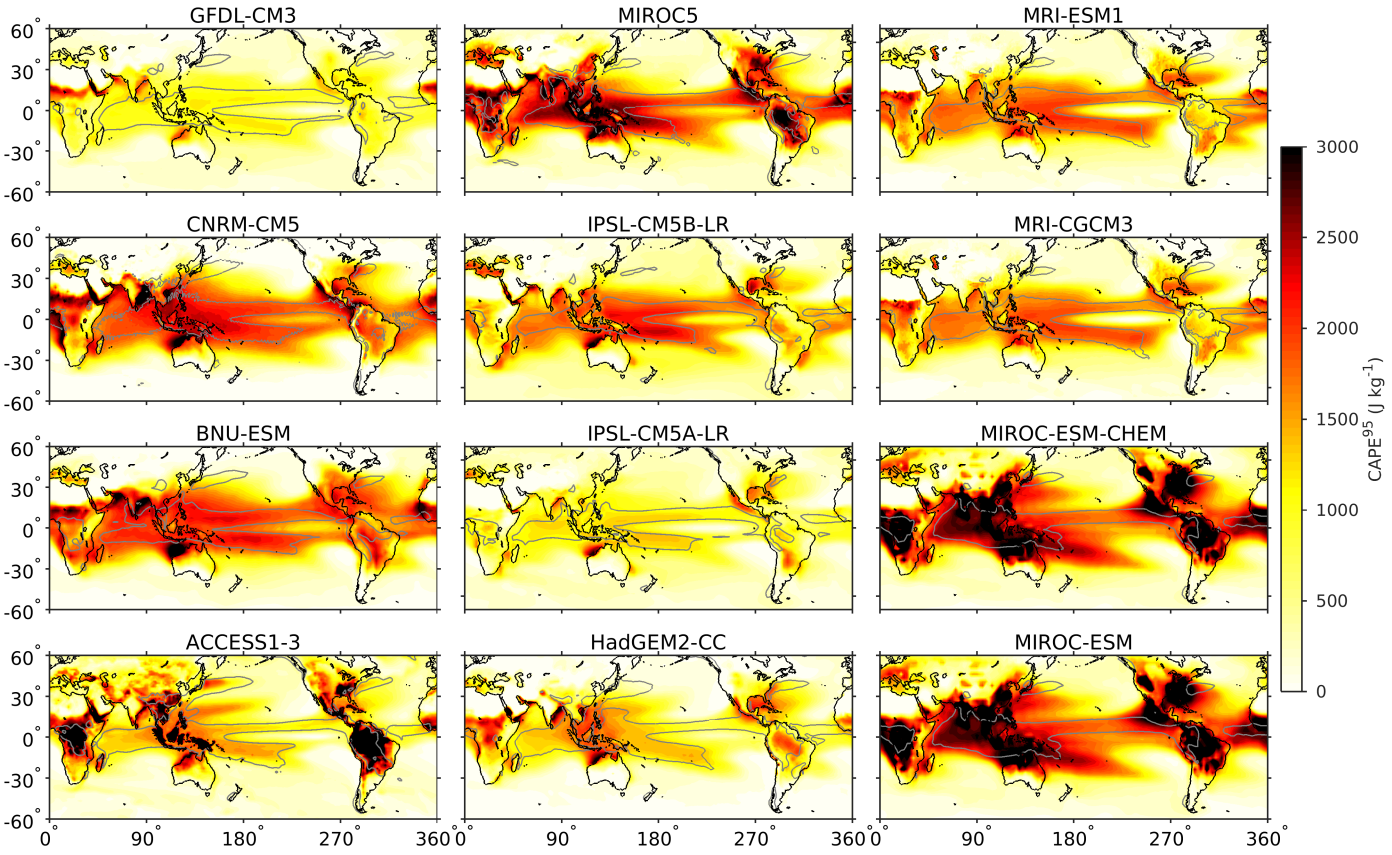

Figure S1: As in Fig. 1a, but for each of the 12 CMIP5 models used to construct the ensemble mean.

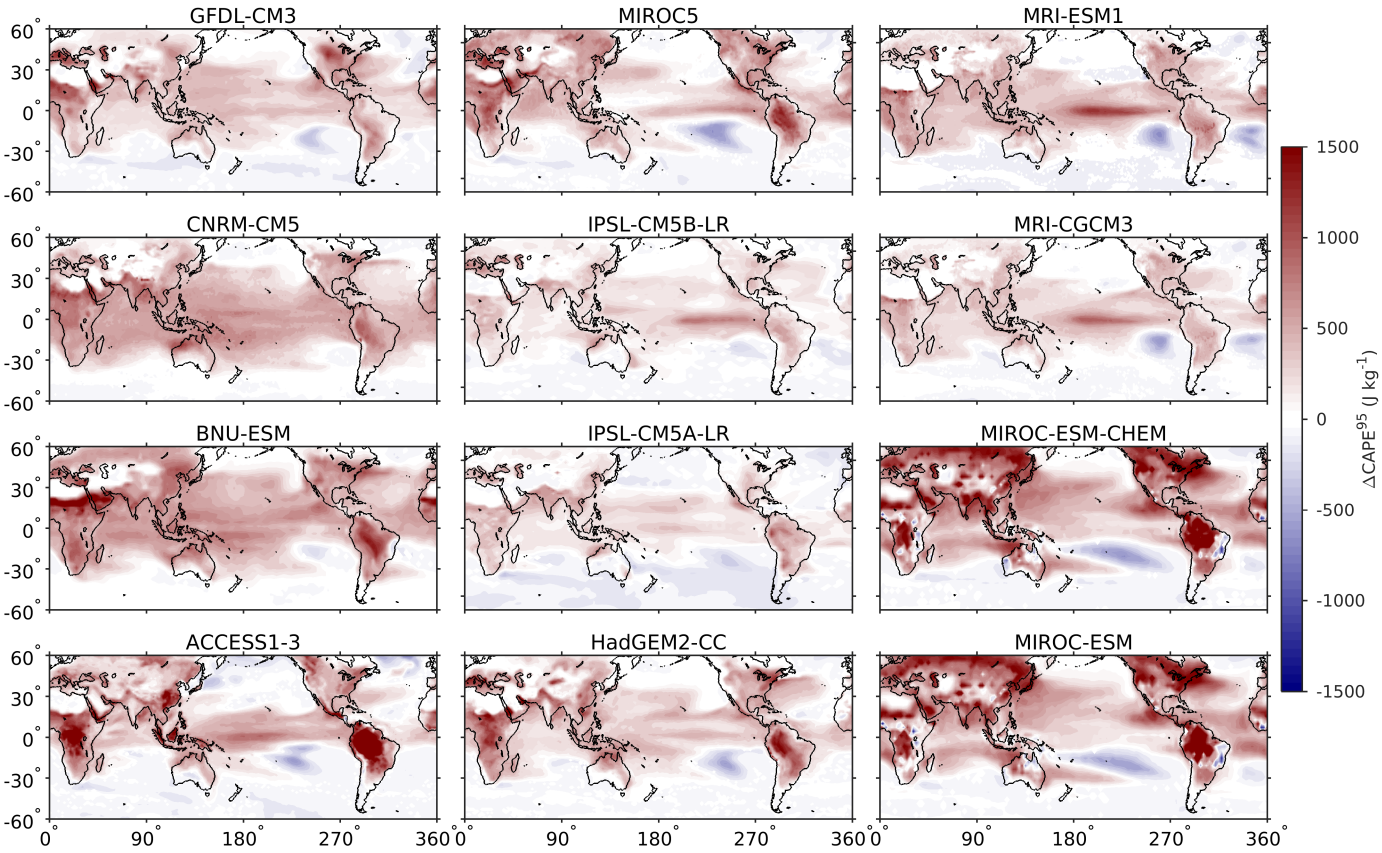

Figure S2: As in Fig. 1b, but for each of the 12 models used to construct the ensemble mean. Only regions in which the change in CAPE^{95} is significant to 95th percentile confidence according to a bootstrap estimate are coloured.

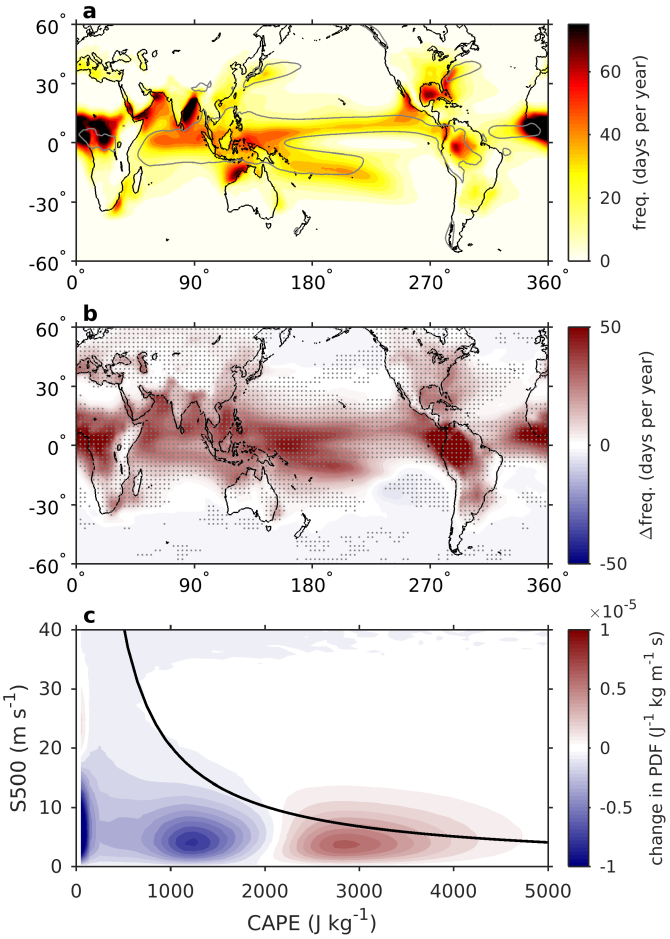

Figure S3: (a) Ensemble-mean frequency of damaging thunderstorm environment (DTE) days in 12 CMIP5 models for the period 1981-2000 and ensemble-mean change in (b) the frequency of DTE days and (c) the joint probability distribution function (PDF) of CAPE and surface to 500 hPa wind shear magnitude (S500) from the current climate (1981-2000) to the future climate (2081-2100) under the RCP8.5 scenario. Stippling in (b) indicates regions where 11 of the 12 models agree on the sign of the response. Solid line in (c) shows the ensemble-mean threshold defining damaging thunderstorm environments given by CAPE×S500 = 20 300 J kg^{-1} m s^{-1}.

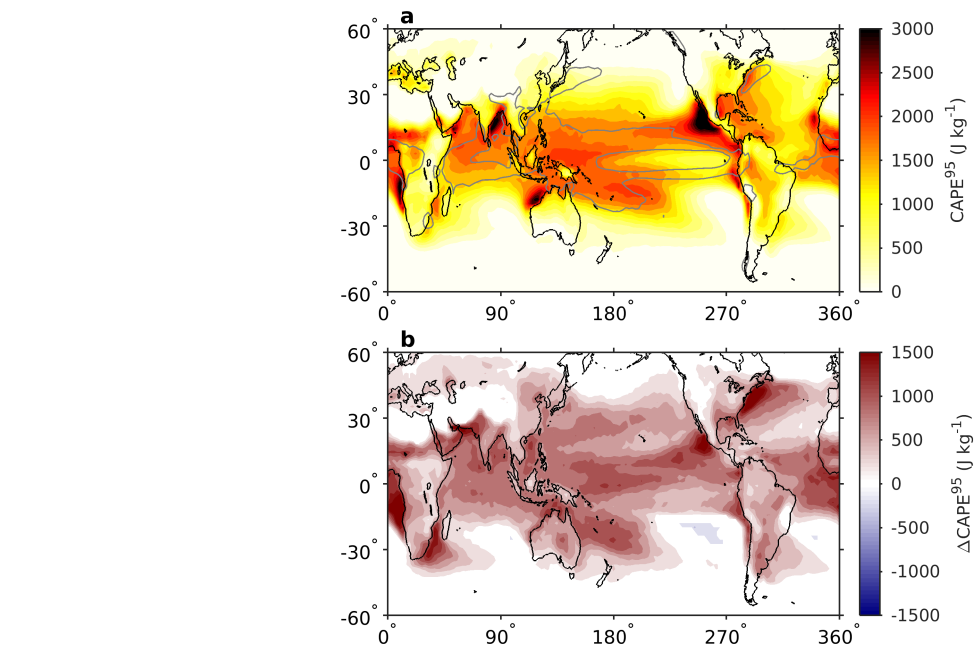

Figure S4: CAPE^{95} in simulations with a superparameterised GCM. (a) CAPE^{95} (colours) and 5 mm day^{-1} contour of time-mean precipitation (grey) in simulation of preindustrial CO_2 concentration. (b) Change in CAPE^{95} from the preindustrial simulation to the quadrupled CO_2 simulation; only regions in which the change in CAPE^{95} is significant to 95th percentile confidence according to a bootstrap estimate are coloured.

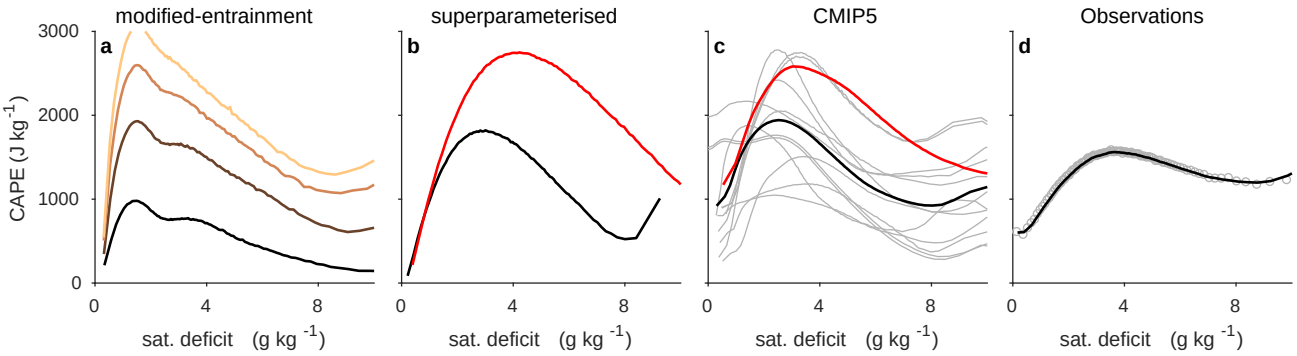

Figure S5: As in Fig. 3a-d, but considering all regions in the latitude band 36°S-36°N rather than only strongly precipitating regions.

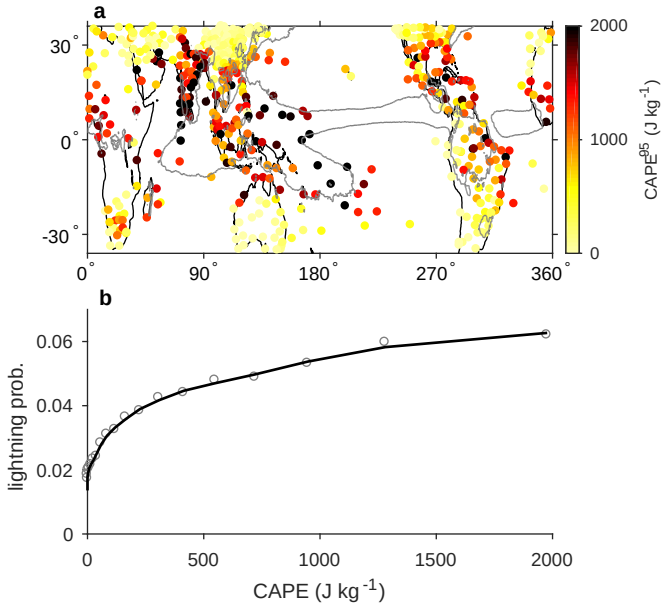

Figure S6: (a) $CAPE^{95}$ for stations in the IGRA database located in the region 36°S-36°N and with at least 100 CAPE observations (colours), and contour of mean daily precipitation according to the TRMM 3B42 (v7) estimate. (b) Probability of lightning occurrence in strongly precipitating regions as a function of CAPE (Methods); black line is smoothed with a five-point Lowess filter and grey symbols give unsmoothed data.

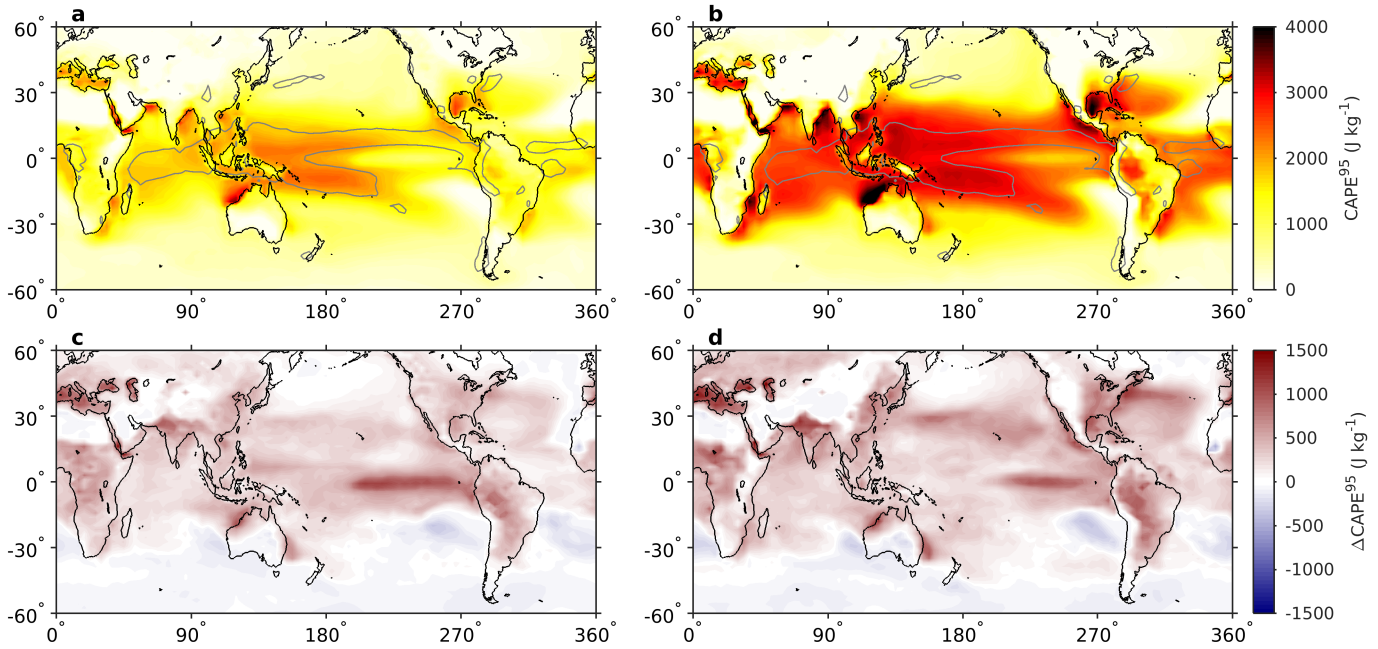

Figure S7: $CAPE^{95}$ climatology (top row) and response to warming (bottom row) calculated using (a,c) monthly surface pressure and atmospheric profiles at standard pressure levels as used for CMIP5 simulations in all other figures and (b,d) daily surface pressure and atmospheric profiles at model levels as used for superparameterised and modified-entrainment simulations. Response to warming given as difference between current climate (1981-2000) and future climate (2081-2100) under the RCP8.5 scenario. Grey line in panels (a) and (b) shows the 5 mm day^{-1} mean precipitation contour.