

Supplementary Information for 'Widespread heat stress will become the norm in a warming Southeast Asia'

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This document contains results for additional models and scenarios not shown in the main text.

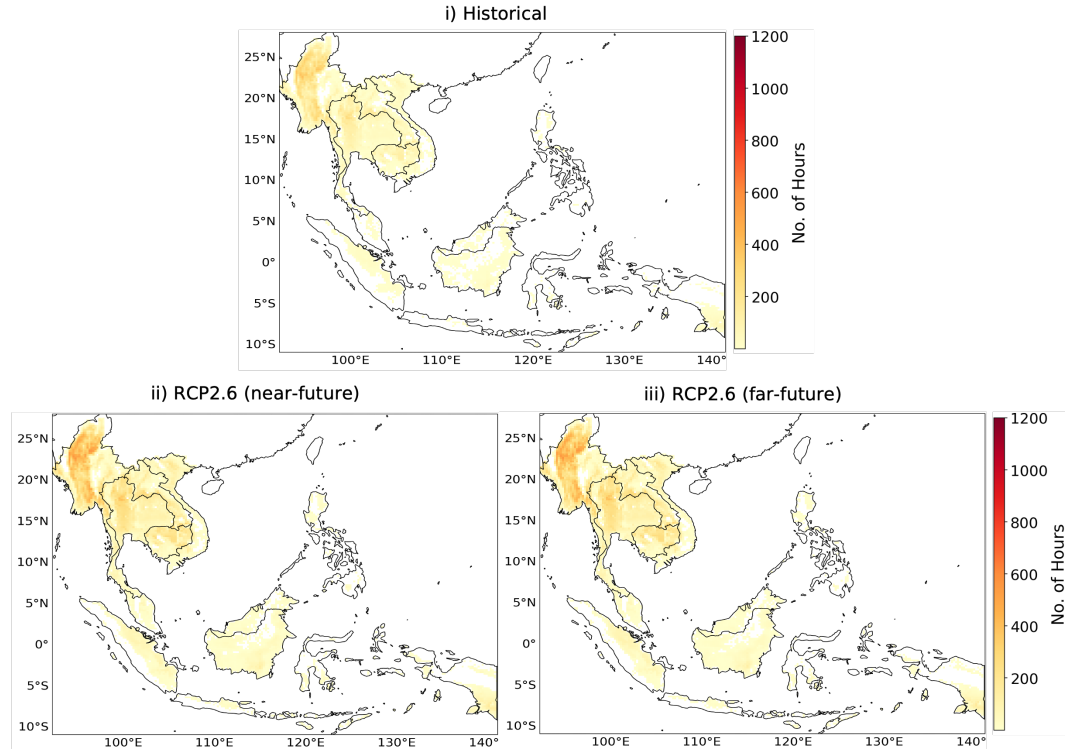
Exposure

Table S1: Metrics of annual exposure to extreme heat stress computed with UTCI and WBGT, with results presented for each constituent GCM used in REMO RCM and the mean across GCMs.

Extreme heat stress indices ¹	Scenario	MOHC-HadGEM2-ES	NCC-NorESM1-M	MPI-M-MPI-ESM-LR	Mean
UTCI					
Weighted avg. total annual hours in extreme heat	Baseline	59.7	52.9	32.0	48.2
	RCP2.6 (2030–2059)	73.6	55.9	37.9	55.8
	RCP8.5 (2030–2059)	104.8	71.6	58.5	78.3
	RCP2.6 (2070–2099)	72.5	45.8	34.9	51.1
	RCP8.5 (2070–2099)	309.1	137.5	208.6	218.4
Population exposed ≥ 3 days (millions)	Baseline	27.1	24.8	12.1	21.3
	RCP2.6 (2030–2059)	71.1	62.5	33.6	55.7
	RCP8.5 (2030–2059)	99.3	80.4	34.4	71.4
	RCP2.6 (2070–2099)	64.5	43.4	21.2	43.0
	RCP8.5 (2070–2099)	245.6	100.0	139.4	161.7
Population exposed ≥ 7 days (millions)	Baseline	11.8	13.7	0.2	8.6
	RCP2.6 (2030–2059)	40.0	20.3	9.5	23.3
	RCP8.5 (2030–2059)	50.9	28.4	3.9	27.8
	RCP2.6 (2070–2099)	35.1	15.5	4.2	18.3
	RCP8.5 (2070–2099)	126.8	68.4	65.0	86.7
Total annual person-hours exposure (billions)	Baseline	10.0	9.3	5.5	8.3
	RCP2.6 (2030–2059)	32.7	21.6	16.3	23.5
	RCP8.5 (2030–2059)	55.3	30.1	29.4	38.3
	RCP2.6 (2070–2099)	26.0	13.8	11.8	17.2
	RCP8.5 (2070–2099)	162.7	60.6	105.2	109.5
WBGT					
Weighted avg. total annual hours in extreme heat	Baseline	32.2	28.0	29.6	29.9
	RCP2.6 (2030–2059)	92.7	50.3	63.1	68.7
	RCP8.5 (2030–2059)	158.8	75.6	116.1	116.8
	RCP2.6 (2070–2099)	89.2	43.3	52.8	61.8
	RCP8.5 (2070–2099)	623.3	233.1	460.6	439.0
Population exposed ≥ 3 days (millions)	Baseline	19.4	6.9	15.5	13.9
	RCP2.6 (2030–2059)	178.7	65.8	88.1	110.9
	RCP8.5 (2030–2059)	208.5	115.9	117.0	147.1
	RCP2.6 (2070–2099)	137.7	53.6	52.6	81.3
	RCP8.5 (2070–2099)	417.2	206.9	311.0	311.7
Population exposed ≥ 7 days (millions)	Baseline	0.0	0.1	0.3	0.1
	RCP2.6 (2030–2059)	13.8	4.7	1.3	6.6
	RCP8.5 (2030–2059)	42.2	4.6	3.9	16.9
	RCP2.6 (2070–2099)	11.6	1.7	0.5	4.6
	RCP8.5 (2070–2099)	250.8	109.0	122.8	160.8
Total annual person-hours exposure (billions)	Baseline	10.8	8.8	10.0	9.9
	RCP2.6 (2030–2059)	62.0	32.5	42.0	45.5
	RCP8.5 (2030–2059)	106.5	49.5	77.6	77.9
	RCP2.6 (2070–2099)	49.6	23.2	28.9	33.9
	RCP8.5 (2070–2099)	343.9	128.1	253.0	241.7

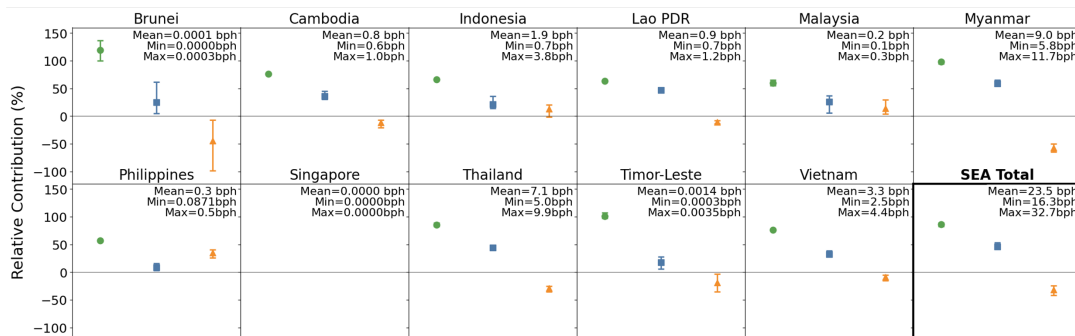
UTCI

a) Annual cumulative hours > 46°C UTCI



b) Decomposition of exposure effects

i) RCP2.6 (near-future)



ii) RCP2.6 (far-future)

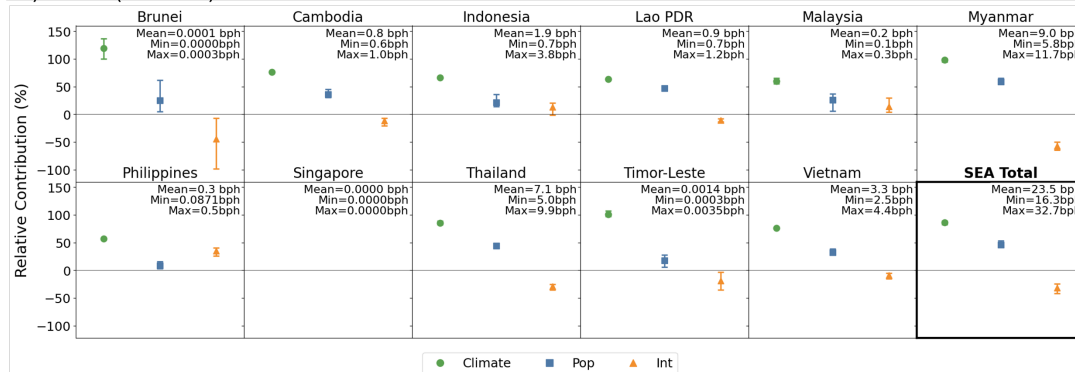
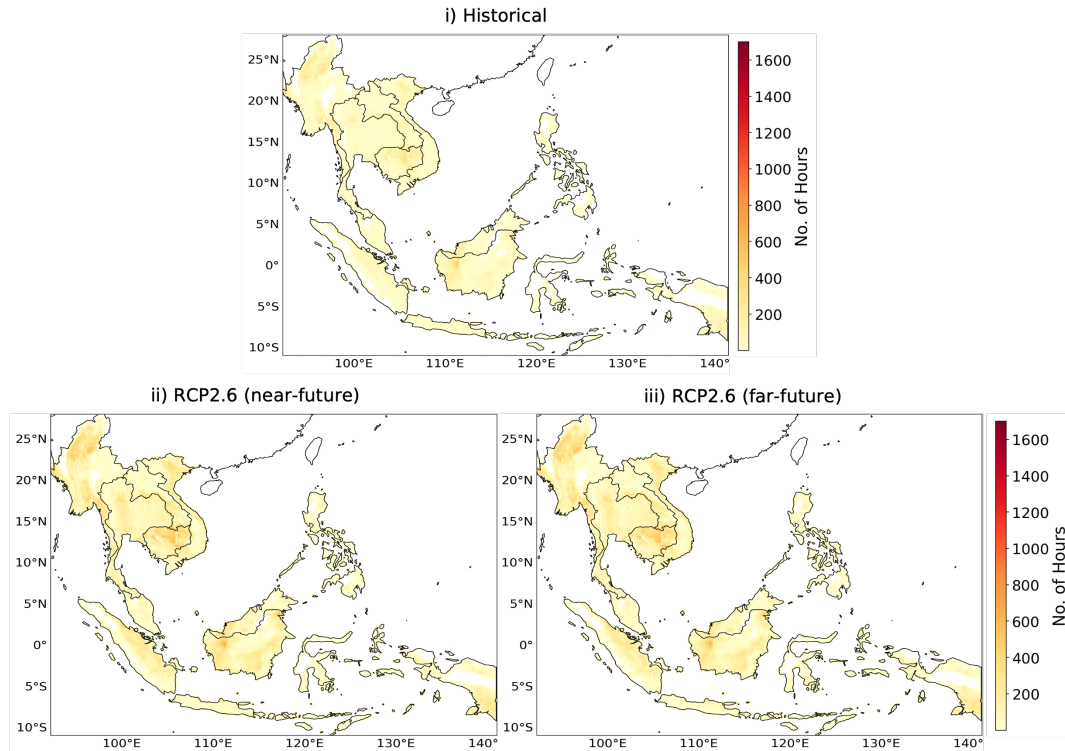


Figure S1: Exposure to extreme heat stress in Southeast Asia, as computed by UTCI for RCP2.6. a) Maps of annual cumulative hours > 46°C UTCI (Extreme Heat Stress) in the (i) historical, (ii) near-future and (iii) far-future time periods; b) Decomposition of the relative contribution of climate, population and interaction effects to total person-hours exposure to > 46°C UTCI (Extreme Heat Stress) in the (i) near-future (ii) far-future time periods, for Southeast Asia as a whole and each country. Symbols show the ensemble mean of the REMO RCM; whiskers indicate the min–max range. Panel annotations also report the mean and range of total exposure in billion person-hours (bph) across the ensemble. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).

WBG

a) Annual cumulative hours > 33°C WBG



b) Decomposition of exposure effects

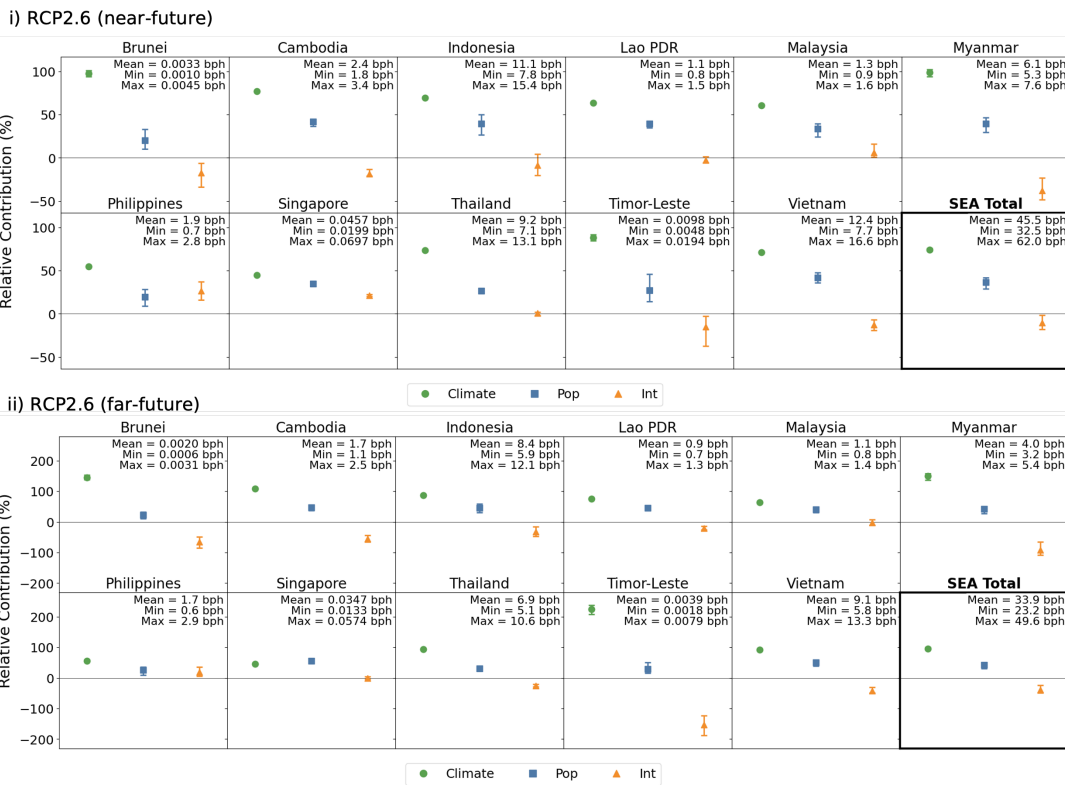


Figure S2: Exposure to extreme heat stress in Southeast Asia, as computed by WBG for RCP2.6. a) Maps of annual cumulative hours > 33°C WBG (Resting workload) in the (i) historical, (ii) near-future and (iii) far-future time periods; b) Decomposition of the relative contribution of climate, population and interaction effects to total person-hours exposure to > 33°C WBG (Resting workload) in the (i) near-future (ii) far-future time periods, for Southeast Asia as a whole and each country. Symbols show the ensemble mean of the REMO RCM; whiskers indicate the min-max range. Panel annotations also report the mean and range of total exposure in billion person-hours (bph) across the ensemble. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).

Spatial patterns

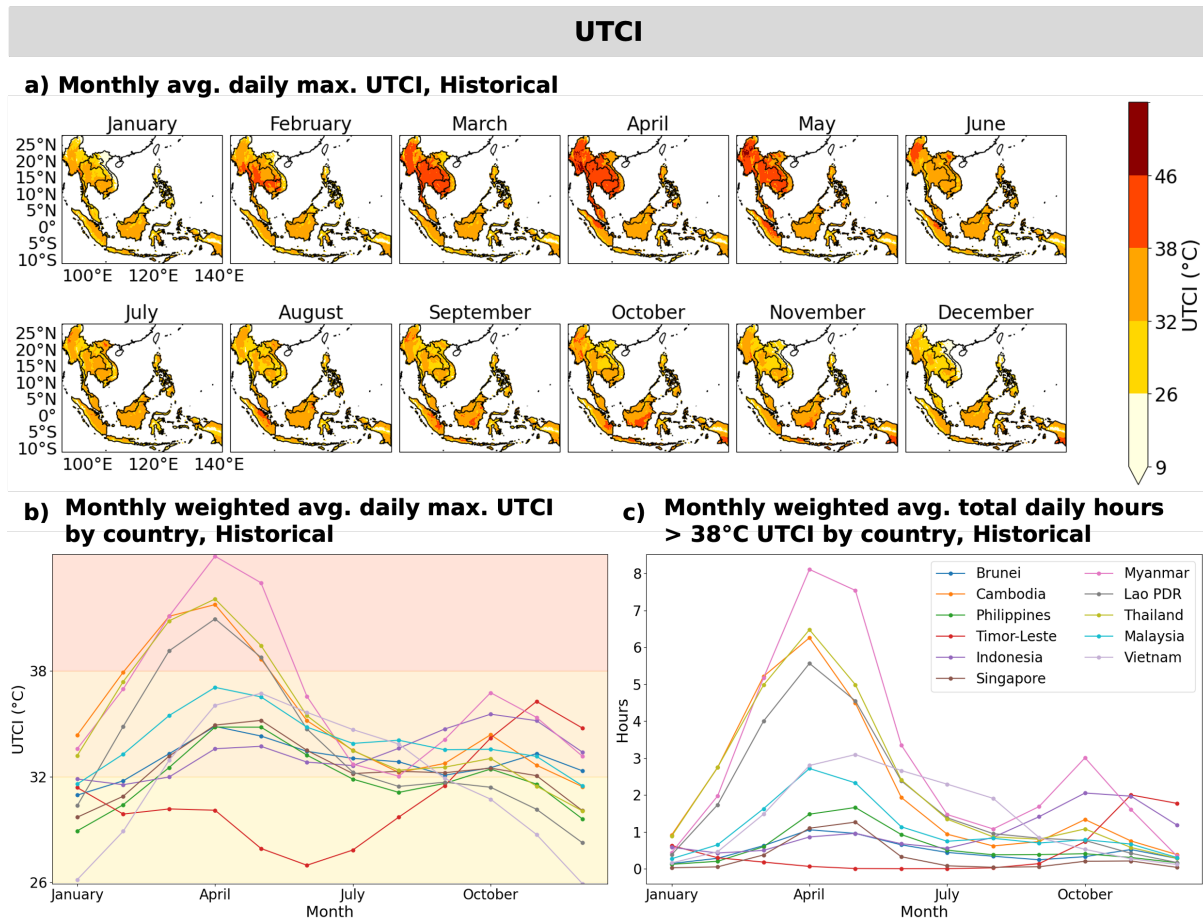
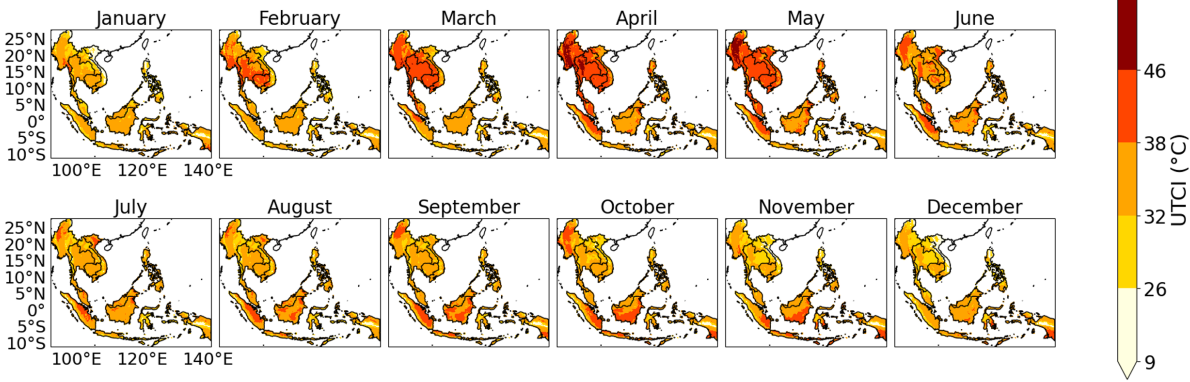


Figure S3: Spatial patterns of heat stress in Southeast Asia, as computed by UTCI for the historical baseline. a) Maps of monthly average daily maximum UTCI in the (i) near-future and (ii) far-future; b) Line plots of monthly average daily maximum UTCI, weighted by population, for each country in the (i) near-future and (ii) far-future; c) Line plots of monthly average total daily hours > 38°C UTCI (i) (Very Strong Heat Stress), weighted by population, for each country in the (i) near-future and (ii) far-future. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).

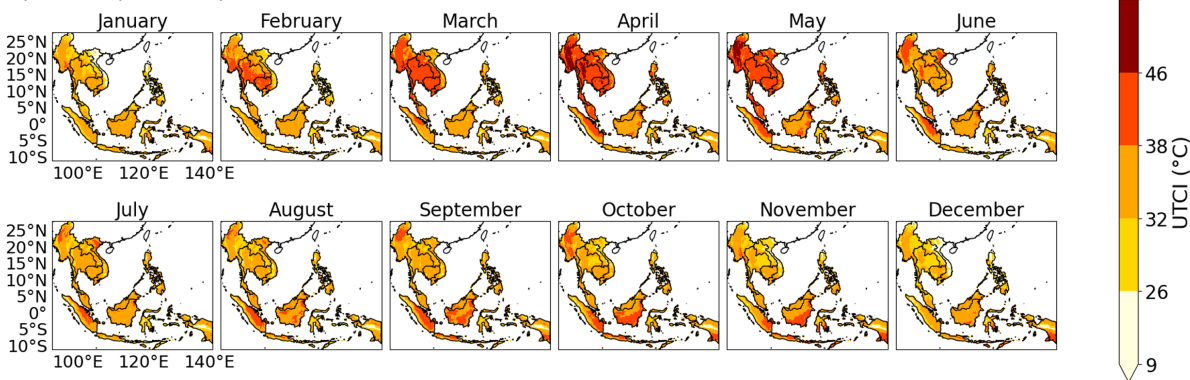
UTCI

a) Monthly avg. daily max. UTCI

i) RCP2.6 (near-future)

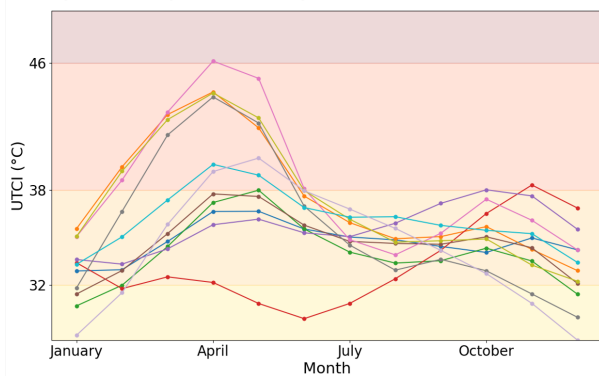


ii) RCP2.6 (far-future)

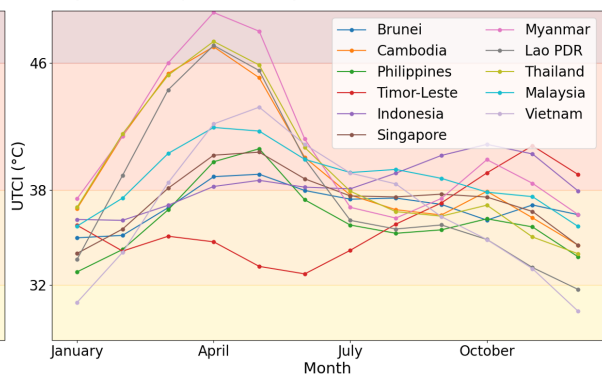


b) Monthly weighted avg. daily max. UTCI by country

i) RCP2.6 (near-future)

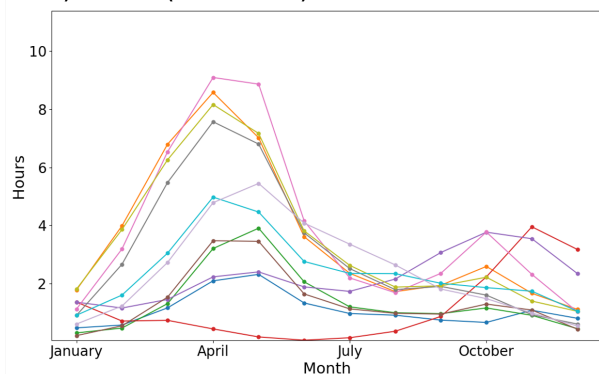


ii) RCP2.6 (far-future)



c) Monthly weighted avg. total daily hours > 38°C UTCI by country

i) RCP2.6 (near-future)



ii) RCP2.6 (far-future)

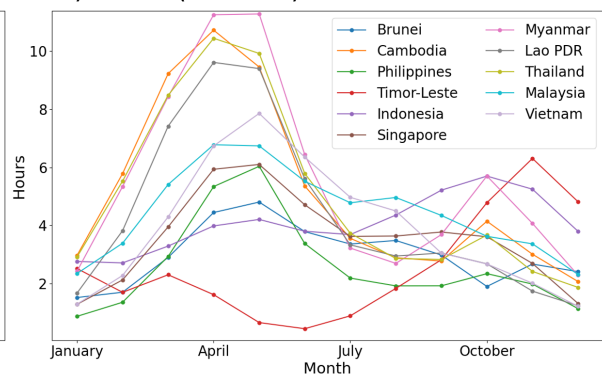
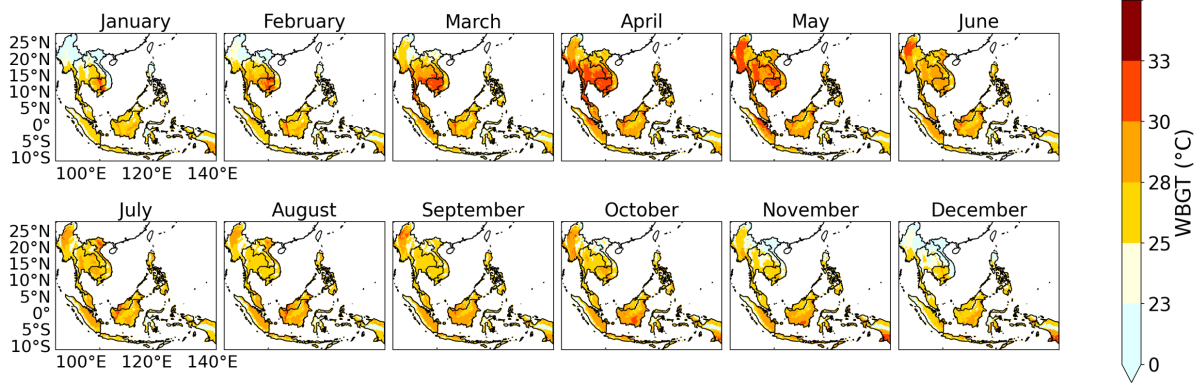


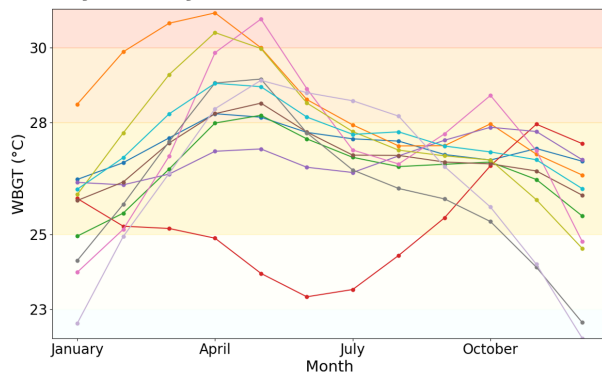
Figure S4: Spatial patterns of heat stress in Southeast Asia, as computed by UTCI for RCP2.6. a) Maps of monthly average daily maximum UTCI in the (i) near-future and (ii) far-future; b) Line plots of monthly average daily maximum UTCI, weighted by population, for each country in the (i) near-future and (ii) far-future; c) Line plots of monthly average total daily hours > 38°C UTCI (i) (Very Strong Heat Stress), weighted by population, for each country in the (i) near-future and (ii) far-future. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).

WBGT

a) Monthly avg. daily max. WBGT, Historical



b) Monthly weighted avg. daily max. WBGT by country, Historical



c) Monthly weighted avg. total daily hours > 30°C WBGT by country, Historical

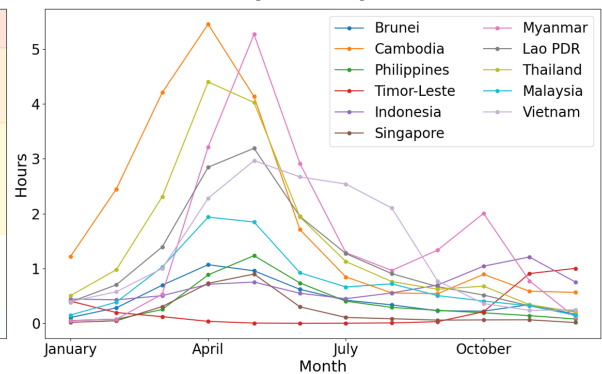
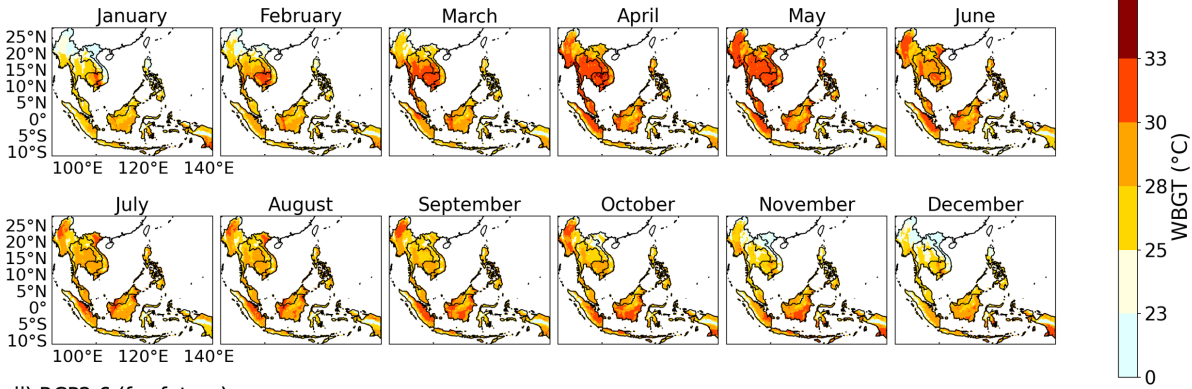


Figure S5: Spatial patterns of heat stress in Southeast Asia, as computed by WBGT for the historical base-line. a) Maps of monthly average daily maximum WBGT in the (i) near-future and (ii) far-future; b) Line plots of monthly average daily maximum WBGT, weighted by population, for each country in the (i) near-future and (ii) far-future; c) Line plots of monthly average total daily hours > 30°C WBGT (Light workload), weighted by population, for each country in the (i) near-future and (ii) far-future. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).

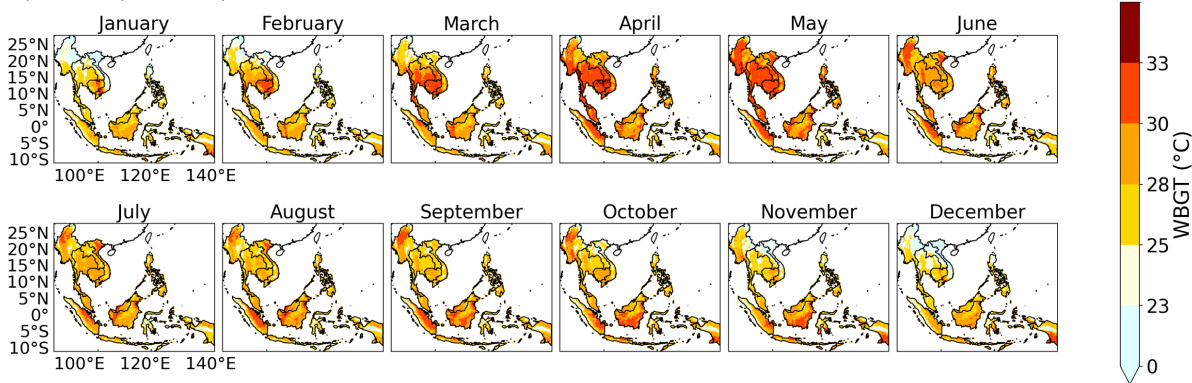
WBGT

a) Monthly avg. daily max. WBGT

i) RCP2.6 (near-future)

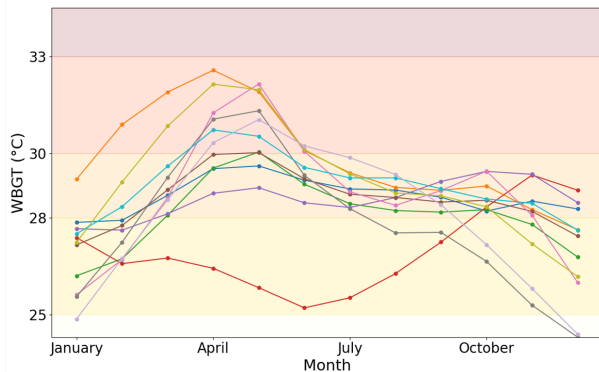


ii) RCP2.6 (far-future)

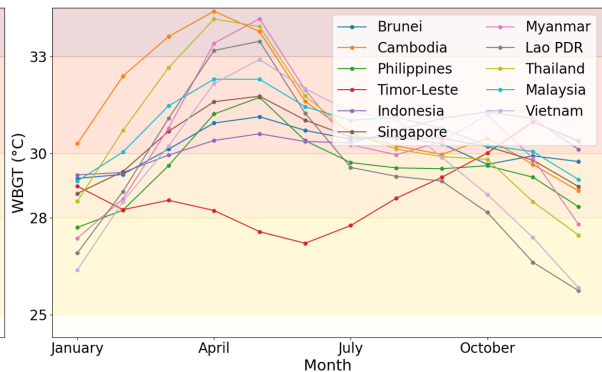


b) Monthly weighted avg. daily max. WBGT by country

i) RCP2.6 (near-future)

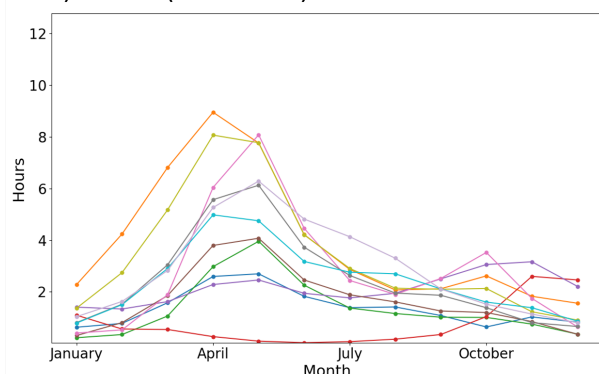


ii) RCP2.6 (far-future)



c) Monthly weighted avg. total daily hours > 30°C WBGT by country

i) RCP2.6 (near-future)



ii) RCP2.6 (far-future)

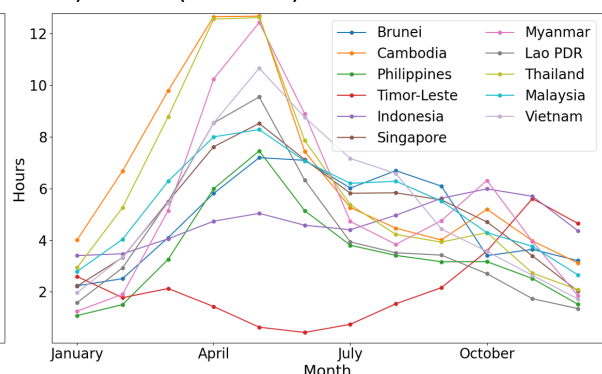


Figure S6: Spatial patterns of heat stress in Southeast Asia, as computed by WBGT for RCP2.6. a) Maps of monthly average daily maximum WBGT in the (i) near-future and (ii) far-future; b) Line plots of monthly average daily maximum WBGT, weighted by population, for each country in the (i) near-future and (ii) far-future; c) Line plots of monthly average total daily hours > 30°C WBGT (Light workload), weighted by population, for each country in the (i) near-future and (ii) far-future. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).

Bias

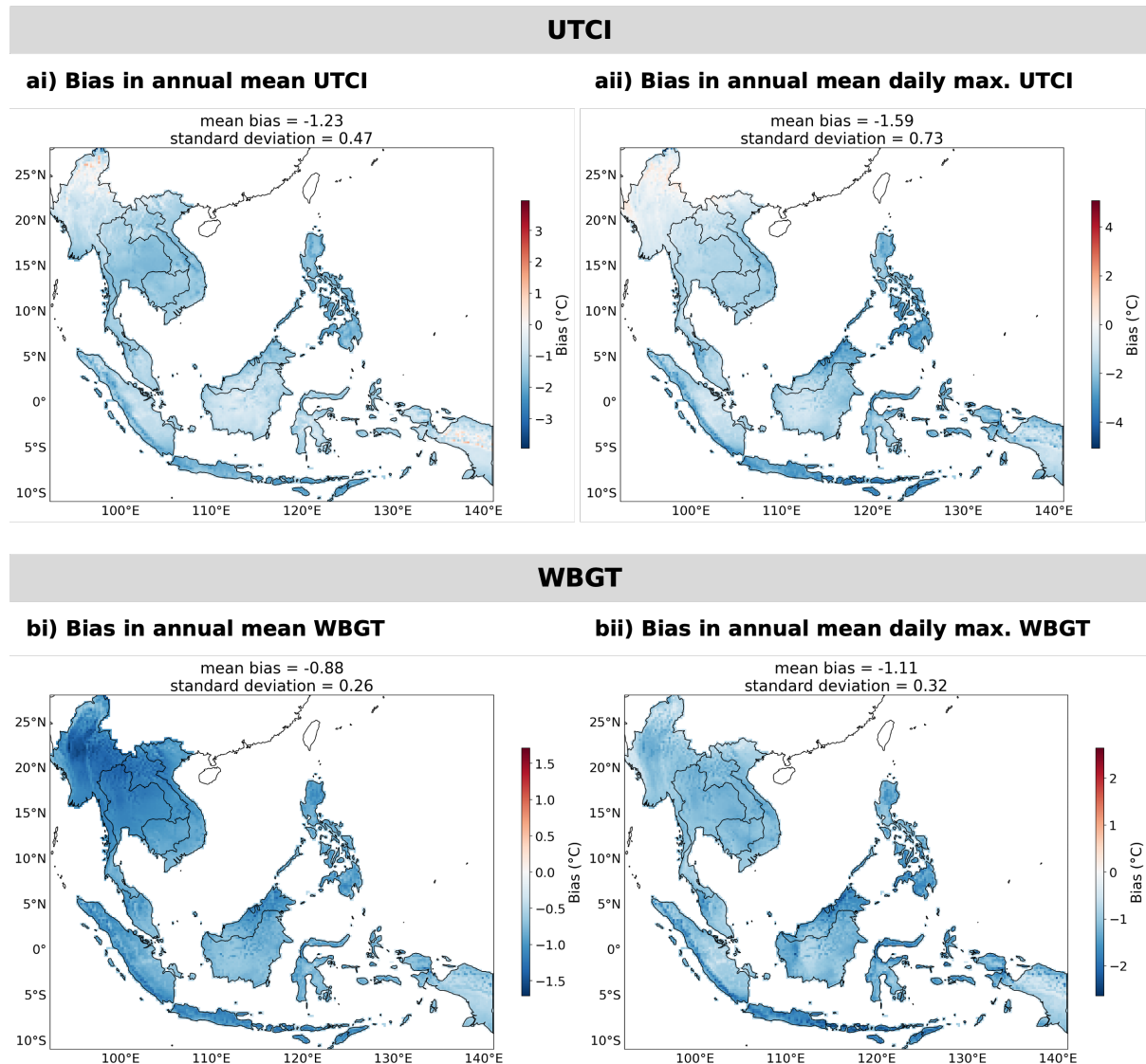


Figure S7: Maps of bias in annual mean ai) UTCI, aii) daily maximum UTCI, bi) WBGT and bii) daily maximum WBGT. This is computed by comparing the heat indices computed with the RCM to ERA-Interim reanalysis data. The mean and standard deviation of these bias values are printed at the top of each map. Maps created in Python (v3.12.4) using Matplotlib (v3.9.0) and Cartopy (v0.23.0). Coastlines and borders from Natural Earth (public domain).