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Supplemental Information

Global excess deaths associated with heatwaves in 2023 and the contribution of human-induced climate change

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Supplemental Information

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Materials and Methods

Description of the climate scenarios datasets used for the study.

We utilized two climate scenarios: one representing historical (factual) climate conditions and the other a counterfactual scenario approximating a hypothetical world without anthropogenic climate change. The temperature data for these scenarios (near-surface air temperature) were extracted from the Detection and Attribution Model Intercomparison Project (DAMIP) climate database[1], which is part of CMIP6. DAMIP is specifically designed to assess the individual contributions of various external factors to past and future changes in global and regional climates. This study incorporated ensemble member simulations from four general circulation models (CanESM5, IPSL-CM6A-LR, MIROC6, and NorESM2-LM) within CMIP6, drawn from two different experiments for which relevant data were available at the time of analysis. Details about the models and selected simulations can be found in Table S2. For the factual scenario, we used historical climate simulations ('hist') of mean daily temperatures available up to 2014, combined with simulations of ssp2rcp45 for the subsequent years until 2023[2]. These simulations account for all types of natural and anthropogenic forcing, effectively mimicking the actual historical climate[1]. In contrast, the counterfactual climate data were derived from the 'hist-nat' experiment, which considers only natural forcing. This counterfactual dataset approximates a hypothetical climate devoid of human influences since the early twentieth century, allowing for a clear distinction between natural and anthropogenic climate change. Daily mean temperature series (near-surface air temperature—tas) were extracted from globally gridded datasets and bias-corrected using ERA5 data. In summary, the ERA5 temperature series was employed to bias-correct the factual scenario, and the same correction factors were applied to the modelled series of the counterfactual scenario.

Table S1. Summary of location-specific deaths and temperatures by country/territory and period.

Country/territory	Locations	Period	All-cause mortality (yearly average)	Temperature, annual average (ºC)*
Argentina	3	2005–2015	18767	23·7 (23·6, 23·9)
Australia	341	2009–2019	46785	21·8 (12·8, 32·5)
Bangladesh	1	2005–2016	124	26·8 (26·.8, 26·8)
Brazil	494	1996–2019	350094	24·5 (18·9, 28·9)
Bulgaria	5	2000–2019	8034	21·6 (19·5, 22·8)
Burkina Faso	3	1998–2015	880	29·3 (29·2, 29·4)
Canada	288	1986–2015	77431	15·1 (-0·2, 20·7)
Chile	15	2016–2019	33099	14·0 (7·1, 17·4)
China	15	1996–2015	124360	24·5 (17·6, 28·0)
Colombia	5	1998–2013	20348	23·8 (14·0, 28·7)
Costa Rica	1	2000–2017	580	22·7 (22·7, 22·7)
Cyprus	5	2004–2019	1534	26·1 (24·4, 27·6)
Czech Republic	4	1994–2019	10313	17·5 (16·6, 18·5)
Ecuador	2	2014–2018	7485	21·1 (15·5, 26·7)
Estonia	5	1997–2019	2414	15·1 (14·7, 15·7)
Ethiopia	4	2006–2015	437	18·3 (17·0, 19·5)
Finland	1	1994–2014	2356	15·1 (15·1, 15·1)
France	20	2000–2017	35938	18·8 (16·2, 22·8)
French Guiana	1	2000–2015	154	27·0 (27·0, 27·0)
Germany	15	1993–2019	49871	17·3 (16·3, 18.5)
Ghana	1	1994–2014	310	27·9 (27·9, 27·9)
Greece	1	2001–2010	9418	26·7 (26·7, 26·7)
Guadeloupe	1	2000–2015	568	27·7 (27·7, 27·7)
Guatemala	1	2009–2016	2639	20·3 (20·3, 20·3)
Iceland	1	2000–2018	423	10·0 (10·0, 10·0)
India	1	2009–2016	149	30·2 (30·2, 30·2)
Iran	2	2002–2015	26865	26·4 (25·7, 27·1)
Ireland	6	1984–2007	13494	13·6 (13·1, 14·0)
Israel	4	1985–2019	5130	25·4 (23·6, 26·7)
Italy	18	2006–2015	28083	23·1 (20·9, 24·9)
Ivory Coast	1	2009–2016	142	25·2 (25·2, 25·2)
Japan	47	1973–2019	293752	23·1 (18·1, 27·1)
Kenya	2	2003–2015	263	21·7 (19·6, 23·8)
Kuwait	1	2000–2016	1336	37·3 (37·3, 37·3)
Malawi	1	2003–2016	90	23·7 (23·7, 23·7)
Malta	1	1995–2019	963	24·5 (24·5, 24·5)
Martinique	1	2000–2015	435	27·9 (27·9, 27·9)
Mexico	11	1998–2019	59717	21·9 (14·5, 28·2)
Moldova	4	2001–2010	2354	20·6 (20·1, 21·1)
Mozambique	1	2010–2015	222	26·4 (26·4, 26·4)
Netherland	5	1995–2016	6562	16·3 (15·9, 16·7)
New Zealand	66	2000–2018	9170	14·5 (9·7, 17·9)
Nigeria	1	2011–2014	970	27·8 (27·8, 27·8)
Norway	1	1973–2018	1718	13·4 (11·4, 14·4)

Panama	1	2013–2016	970	28·3 (22·3, 29·3)
Paraguay	1	2004–2019	937	27·2 (25·2, 29·2)
Peru	18	2008–2014	29193	18·9 (5·5, 27·2)
Philippines	13	2006–2019	30700	28·8 (28·4, 29·5)
Portugal	6	1980–2018	14958	20·7 (18·1, 22·3)
Puerto Rico	1	2009–2016	1100	27·8 (27·8, 27·8)
Reunion	1	2000–2015	292	26·2 (26·2, 26·2)
Romania	8	1994–2016	13090	20·3 (17·4, 21·7)
Senegal	3	1990–2016	194	27·4 (26·4, 28·5)
Serbia	1	1995–2019	6460	21·9 (20·1, 23.9)
South Africa	55	1997–2013	158685	22·1 (14·6, 27·6)
South Korea	36	1997–2018	44553	22·5 (19·0, 24·0)
Spain	52	1990–2014	37643	21·4 (16·7, 26·0)
Sweden	3	1990–2016	8377	15·9 (15·8, 15·9)
Switzerland	8	1969–2018	4311	17·3 (15·3, 19·7)
Taiwan	6	2000–2018	29701	24·3 (21·5, 26·0)
Tanzania	3	1994–2014	567	25·4 (22·3, 27·3)
Thailand	62	1999–2008	62582	28·5 (26·7, 29·8)
Gambia	1	1990–2015	84	27·8 (23·8, 27·9)
UK	112	1990–2019	69241	15·3 (13·9, 16·7)
USA	211	1973–2006	354003	22·2 (13·4, 32·4)
Uruguay	1	2012–2016	9116	24·0 (24·0, 24·0)
Vietnam	3	2004–2013	9568	28.6 (27·7, 29·4)

*Average (range)

Table S2. Description of the climate models used for human-induced climate change attribution.

Climate Model	Member (variant label)	Citation
CanESM5	r1i1p1f1	Swart, N. C. et al. The Canadian Earth System Model version 5 (CanESM5.0.3). Geosci. Model Dev. Discuss. (2019) doi:10.5194/gmd-2019-177
MIROC6	r1i1p1f1	Tatebe, H. et al. Description and basic evaluation of simulated mean state, internal variability, and climate sensitivity in MIROC6. Geosci. Model Dev. (2019) doi:10.5194/gmd-12-2727-2019
IPSL-CM6A-LR	r1i1p1f1	Boucher, O., Servonnat, J., Albright, A. L., Aumont, O. & Balkanski, Y. Presentation and evaluation of the IPSL-CM6A-LR climate model. J. Adv. Model. Earth Syst. (2020) doi:10.1029/2019MS002010.
NorESM2-LM	r1i1p1f1	Seland, Ø. et al. The Norwegian Earth System Model, NorESM2 – Evaluation of the CMIP6 DECK and historical simulations. Geosci. Model Dev. Discuss. (2020) doi:10.5194/gmd-2019-378.

Daily mean temperature series (near-surface air temperature—tas) simulated by these models for both factual and counterfactual scenarios were extracted from the Detection and Attribution Model Intercomparison Project (DAMIP) (http://damip.lbl.gov/)

Table S3. Second-stage random-effects meta-regression models examining heatwave definitions at the 95th percentile threshold for ≥2 days, including Cochran's Q test p-values and I^2 for residual heterogeneity.

Model	**Predictor**	***I^2* (%)**	***p-value* for Q test**
Intercept only	No predictor	34.3	<0.0001
Full Model	Annual average Temperature		
	Temperature range		
	Climate classifications	20.7%	<0.0001
	GDP per capita		
	Period		
	Regions		
	Annual average temperature: Climate classifications		
	Temperature range: Annual average temperature		
Model with Relative Humidity	Relative Humidity	21.0%	<0.0001
	Annual average Temperature		
	Temperature range		
	Climate classifications		
	GDP per capita		
	Period		
	Regions		
	Annual average temperature: Climate classifications		
	Temperature range: Annual average temperature		

I^2 (%) indicates the percentage of residual heterogeneity. p-value for Q test refers to Cochran's Q test for heterogeneity.

Table S4. Sensitivity analysis on the degrees of freedom (df) for exposure-response and different lag dimensions.

	Excess death ratio (%) (95% eCI)	Excess death rate per million people (95% eCI)
Main model	0·73 (0·65–0·83)	23 (20–26)
Df for lag response: 6	0·72 (0·65–0·88)	21 (17–25)
The lag period of 14	0·74 (0·71–0·83)	22 (16–26)
A lag period of 21	0·75 (0·63–0·79)	24 (19–37)
Using heatwave definition of 97·5th percentile and ≥ 2days	0·75 (0·66–0·88)	21 (18–24)
Adjusting for both greenness (NDVI) and the proportion of the population above 65 years	0·73 (0·52–0·99)	23 (16–31)
Using minimum temperature for the heatwave definition	0·75 (0·48–1·11)	23 (15–36)
Using maximum temperature for the heatwave definition	0·74 (0·68–0·81)	23 (21–25)

eCI=empirical confidence interval

Table S5. Heatwave-related mortality based on periods of ≥2 days with daily mean temperatures above 97.5th percentiles for each location.

	Number of excess deaths (95% eCI)	Excess death ratio (%) (95% eCI)	Excess death rate per million people (95% eCI)
Global	165,894 (145,773–193,431)	0·75 (0·66–0·88)	20·92 (18·38–24·39)
Africa	2,135 (924–5,306)	0·03 (0·01–0·08)	1·50 (0·65–3·72)
Northern Africa	1,543 (804–3,133)	0·17 (0·09–0·34)	5·93 (3·09–12·05)
Sub-Saharan Africa	592 (119–2,172)	0·01 (0·00–0·04)	0·51 (0·10–1·86)
Americas	27,878 (2,4497–33,152)	0·58 (0·51–0·69)	26·06 (22·9–30·99)
Latin America and the Caribbean	8,782 (7,239–12,026)	0·33 (0·27–0·45)	13·12 (10·81–17·96)
Northern America	19,096 (17,259–21,126)	0·91 (0·82–1·01)	47·72 (43·13–52·80)
Asia	70,316 (58,722–85,331)	0·37 (0·31–0·44)	15·17 (12·67–18·41)
Central Asia	1,087 (874–1,313)	0·46 (0·37–0·55)	15·96 (12·83–19·28)
Eastern Asia	45,255 (37,937–53,051)	0·63 (0·53–0·74)	28·82 (24·16–33·79)
South-eastern Asia	550 (496–1,565)	0·02 (0·02–0·06)	0·81 (0·73–2·31)
Southern Asia	17,456 (14,970–21,729)	0·21 (0·18–0·26)	8·70 (7·46–10·82)
Western Asia	5,968 (4,445–7,673)	0·64 (0·48–0·82)	19·24 (14·33–24·73)
Europe	65,508 (61,592–69,537)	1·27 (1·2–1·35)	86·97 (81·77–92·32)
Eastern Europe	28,128 (26,240–30,055)	1·24 (1·15–1·32)	99·87 (93·17–106·72)
Northern Europe	3,150 (2,765–3,547)	0·52 (0·46–0·59)	28·65 (25·14–32·26)
Southern Europe	23,179 (22,153–24,233)	2·23 (2·13–2·33)	142·93 (136·6–149·43)
Western Europe	11,051 (10,434–11,702)	0·91 (0·86–0·96)	55·4 (52·31–58·66)
Oceania	57 (43–100)	0·03 (0·02–0·05)	1·24 (0·93–2·18)
Australia and New Zealand	55 (41–85)	0·04 (0·03–0·06)	1·57 (1·18–2·45)
Other regions in Oceania	2 (1.6–15)	0·002 (0·001–0·034)	0·19 (0·15–1·34)

eCI = empirical Confidence Interval. Note: Regional groupings in this table are defined according to the UN Statistics Division regional groupings. *Other regions in Oceania are defined as all areas in Oceania excluding Australia and New Zealand. Only grids with at least one annual death were included.

Table S6. Comparison of Heatwave-related mortality estimates based on different heatwave definitions, adjusted for green space and population proportion.

	Excess death (95% eCI)	***P*-value for difference**
Temperatures used for heatwave definition Daily minimum temperature	184,363 (119,250–274,216)	0.234
Daily maximum temperature	181,591 (166,223–198,341)	0.523
Daily mean temperature	178, 486 (159, 892–204, 147)	Reference
Adjusting for both greenness (NDVI) and the proportion of the population above 65 years	179,428 (131,637–252,983)	0.537

eCI: empirical Confidence Interval, p-value for the difference is from the t-test comparing heatwave-related mortality estimates derived from heatwave definitions based on daily minimum and maximum temperatures and including additional meta-predictors (greenness defined as NDVI) and the proportion of the population above 65 years compared to the mean temperature (main results).

Table S7. Heatwave-related mortality burden estimated under the Factual scenario using varying numbers of climate models.

	Heatwave-related mortality (95% eCI)		
	4 GCMs	**3 GCMs**	**2 GCMs**
Global	178072 (160232-203765)	182696 (165735-208474)	180970 (165021-206848)
Americas	25385 (22853-29763)	20492 (18371-24658)	20704 (18706-24736)
Europe	67778 (63834-71902)	79002 (74465-83650)	82290 (78219-86508)
Africa	4777 (3495-8364)	1523 (598-4761)	1620 (618-5086)
Asia	79842 (69786-93364)	81555 (72218-95153)	76241 (67399-90279)
Oceania	289 (68-367)	124 (86-246)	115 (81-234)

GCM = Global Climate Model; eCI: empirical Confidence Interval

Table S8. Global and regional average temperature and number of heatwave days during the hottest months in 2023.

	Annual mean temperature (ºC) (±SD)	Median heatwave days (IQR)
Global	21 ±8	18 (11, 25)
Australia and New Zealand	19 ±5	11 (7, 16)
Central Asia	21 ±8	25 (21, 30)
Eastern Asia	19 ±8	22 (15, 29)
Eastern Europe	15 ±6	19 (15, 23)
Latin America and the Caribbean	23 ±6	17 (11, 26)
Northern Africa	29 ±5	24 (17, 32)
Northern America	17 ±7	18 (12, 25)
Northern Europe	13 ±5	16 (13, 20)
Other regions in Oceania	25 ±3	9 (4, 17)
South-eastern Asia	26 ±2	14 (8, 22)
Southern Asia	27 ±8	17 8, 25)
Southern Europe	21 ±5	25 (22, 31)
Sub-Saharan Africa	26 ±4	6 (0, 17)
Western Asia	28 ±8	25 (19, 30)
Western Europe	18 ±4	19 (16, 23)

Note: Regional groupings in this table are defined according to the UN Statistics Division regional groupings. *Other regions in Oceania are defined as all areas in Oceania excluding Australia and New Zealand. Only grids with at least one annual death were included. SD= Standard Deviation, IQR= Interquartile Range

Supplemental Figures

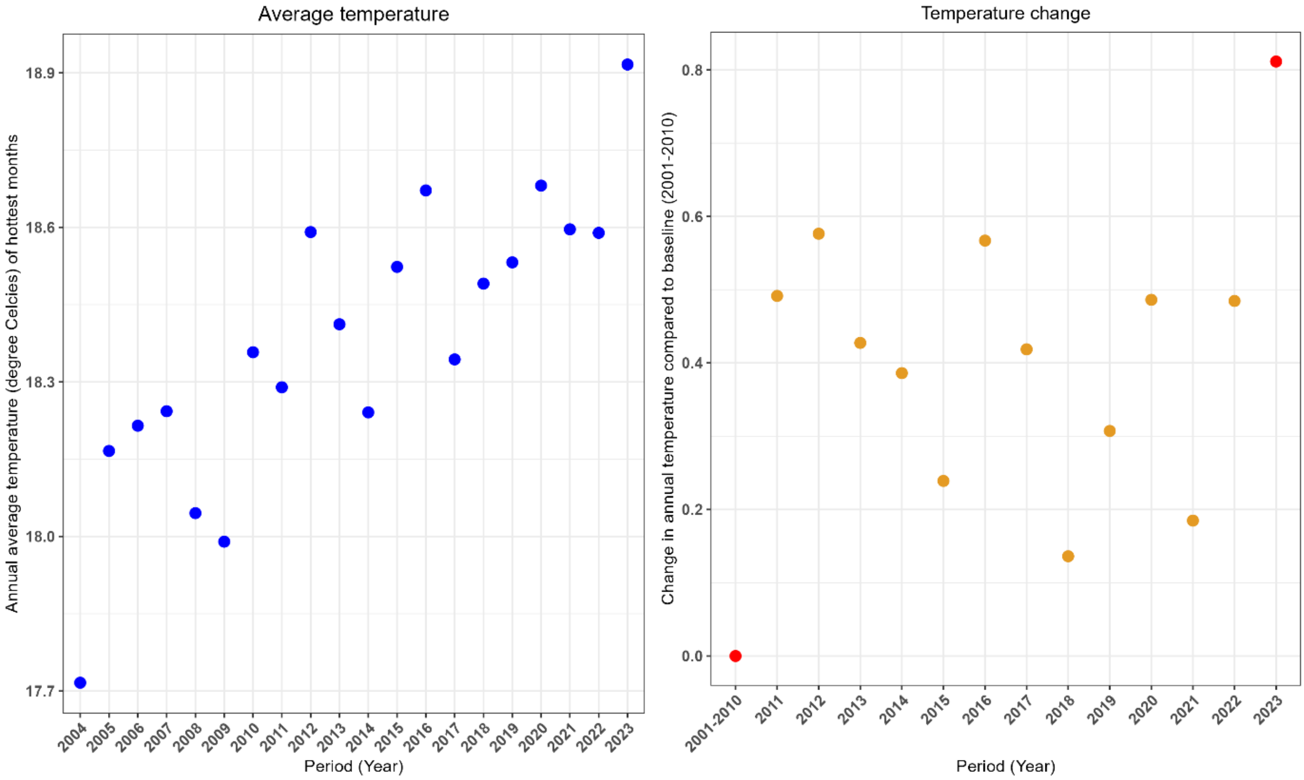

Figure S1. Average temperature of the hottest months during 2004-2023 (left) and annual changes compared to the 2004-2010 average (right). The red dot at the top right corner indicates the change in 2023.

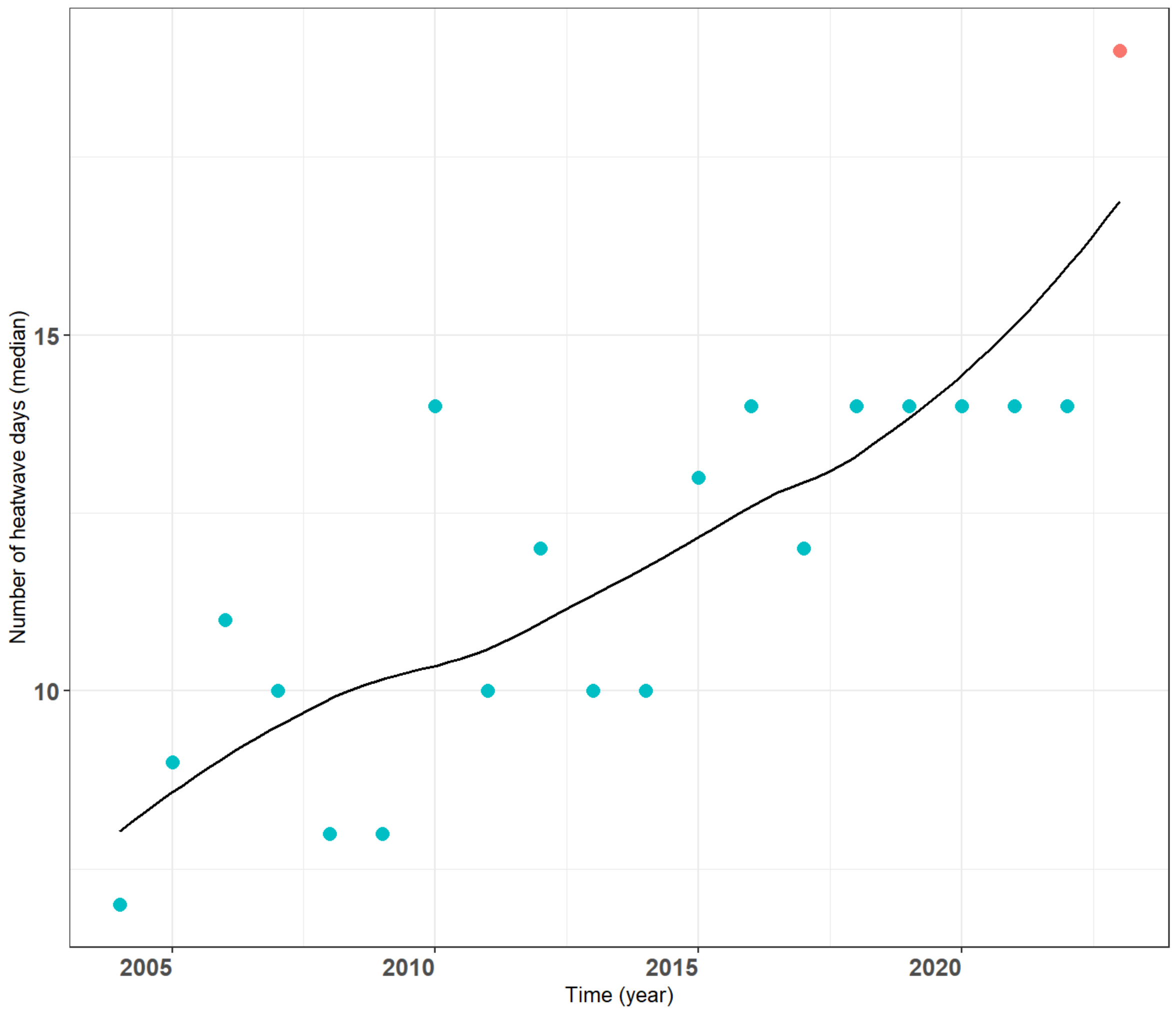

Figure S2. Trends in the number of heatwave days (median) during 2004-2023. The blue dots indicate the median number of heatwave days per year from 2004 to 2022, while the straight line shows the linear trend. The red dot indicates the median number of heatwave days in 2023.

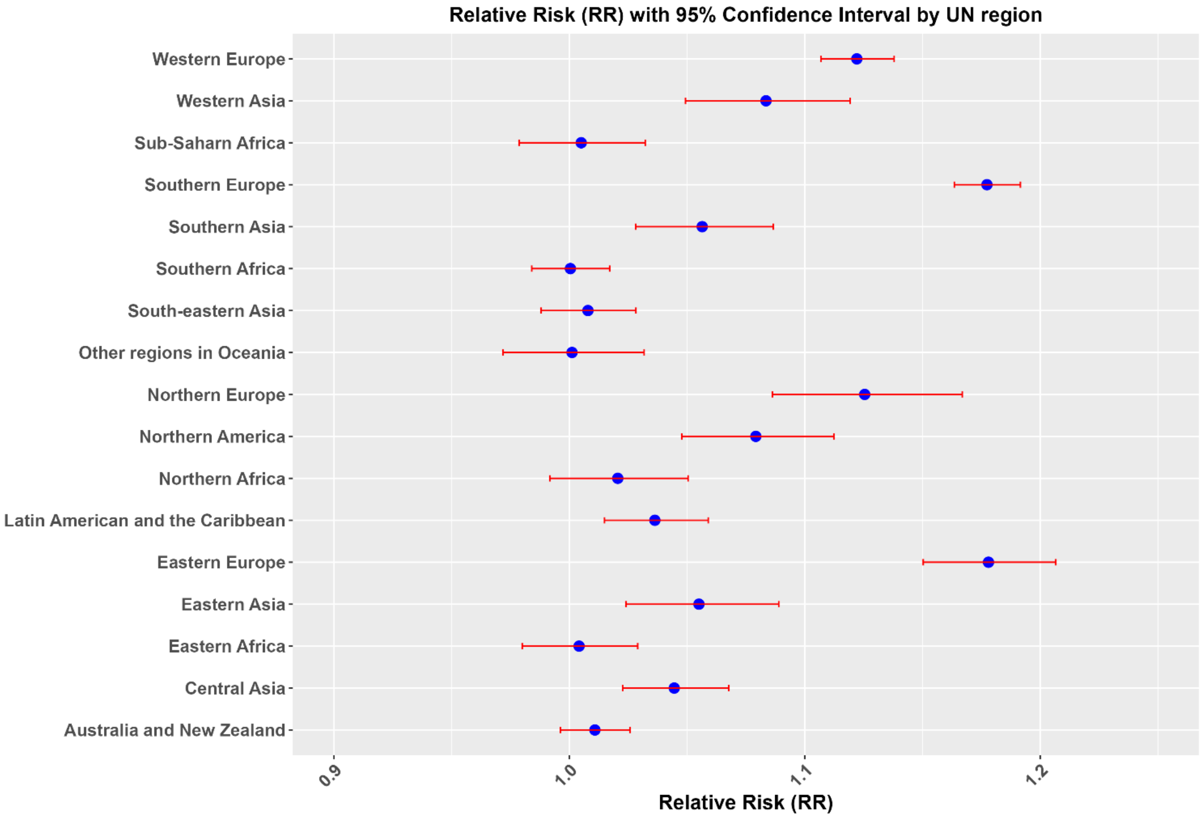

Figure S3. Regional estimates of heatwave mortality risk (RR) with 95% empirical confidence intervals. Regional groupings in this table are defined according to the UN Statistics Division regional groupings. *Other regions in Oceania are defined as all areas in Oceania excluding Australia and New Zealand. Only grids with at least one annual death were included.

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References

1. Gillett NP, Shiogama H, Funke B, et al. The detection and attribution model intercomparison project (DAMIP v1. 0) contribution to CMIP6. *Geoscientific Model Development*. 2016;9:3685-3697.
2. Vicedo-Cabrera AM, Scovronick N, Sera F, et al. The burden of heat-related mortality attributable to recent human-induced climate change. *Nat Clim Chang*. 2021;11:492-500.