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## Supplementary appendix

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# Supplementary appendix

## Global, regional and national burden of mortality associated with non-optimal ambient temperatures from 2000 to 2019: a three-stage modelling study

## 1. Updated information of the MCC data set

The Multi-Country Multi-City (MCC) Collaborative Research Network has been collecting time-series data on daily deaths and environmental variables (e.g. daily mean temperature, relative humidity and air pollution) since 2014. It is an international collaboration of research teams working on a program aiming to produce epidemiological evidence on associations between environmental stressors, climate, and health (http://mccstudy.lshtm.ac.uk/). The earliest MCC data set collected data from 306 locations in 12 countries/territories: Australia (3 cities during 1988–2008), Brazil (18 cities during 1997–2011), Thailand (62 provinces during 1999–2008), mainland China (6 cities during 2002–2011), Taiwan (3 cities during 1994–2007), South Korea (7 cities during 1992–2010), Japan (7 cities during 1972–2009), Italy (10 cities during 1987–2010), Spain (51 cities during 1990–2010), United Kingdom (10 regions during 1993–2006), United States (108 cities during 1987–2000), and Canada (21 cities during 1986–2009).

The MCC Collaborative Research Network has developed during the years, with the data set extended frequently. In the latest version of data set, data from 1364 locations in 43 countries/territories during different periods has been included. In this study, the data set with more locations or more recent data set is selected for each country. After removing data from 612 locations due to duplication and two locations due to quality issue, a total of 130,217,521 deaths from 750 locations in 43 countries or territories are finally included in the analysis: Argentina (3 cities during 2005–2015), Australia (3 cities during 1988–2009), Brazil (18 cities during 1997–2011), Canada (26 cities during 1986–2015), Chile (4 cities during 1986–2015), mainland China (15 cities during 1996–2015), Colombia (5 cities during 1998–2013), Costa Rica (1 city during 2000–2017), Czech Republic (4 cities/regions during 1994–2015), Ecuador (2 cities during 2014–2018), Estonia (5 cities during 1997–2015), Finland (1 city during 1994–2014), France (18 cities during 2000–2014), Germany (12 cities during 1993–2015), Greece (1 city during 2001–2010), Guatemala (1 city during 2009–2016), Iran (1 city during 2004–2013), Ireland (6 cities during 1984–2007), Italy (18 cities during 2006–2015), Japan (47 cities during 1972–2015), Kuwait (1 city during 2000–2016), Mexico (10 cities during 1998–2014), Moldova (4 cities during 2001–2010), Netherlands (5 cities during 1995–2016), Norway (1 city during 1969–2016), Panama (1 city during 2013–2016), Paraguay (1 city during 2004–2016), Peru (18 cities during 2008–2014), Philippines (4 cities during 2006–2010), Portugal (5 cities during 1980–2018), Puertorico (1 city during 2009–2016), Romania (8 cities during 1994–2016), South Africa (52 cities during 1997–2013), South Korea (36 cities during 1997–2018), Spain (52 cities during 1990–2014), Sweden (3 cities during 1990–2016), Switzerland (8 cities during 1995–2013), Taiwan (3 cities during 1994–2014), Thailand (62 provinces during 1999–2008), United Kingdom (70 cities during 1990–2016), Uruguay (1 city during 2012–2016), United States (211 cities during 1973–2006), and Vietnam (2 cities during 2009–2013). The longitudes and latitudes of the 750 locations vary between -157.9 to 153.0 and -38.7 to 61.2, respectively. Basic characteristics of these locations have been summarized in Table S1 by country or territory, and listed according to the average latitude from high to low within each continent.

## 2. Predicting the temperature-mortality association for each grid

In this study, we estimated the temperature-related mortality burden at a spatial resolution of $0{\cdot}5^{\circ}\times0{\cdot}5^{\circ}$. The key methodological innovation of this study is to predict the temperature-mortality association for areas without daily time-series data on mortality and weather conditions. Numerous studies have indicated a strong geographic variation in the temperature-health association, which is linked with climatological, socio-economic and demographic factors of each location.[1-3] This observation provides the theoretical solution for predicting temperature-mortality association in areas without daily mortality data. We applied a three-stage analysis strategy to achieve this:

First stage: We estimated the temperature-mortality association for each of the 750 locations from MCC network.

Second stage: We collected location-specific predictors that could explain the majority of heterogeneity in the temperature-mortality associations across locations. We selected predictors (including the continents, indicators for Köppen-Geiger climate classification, GDP per capita, yearly average of daily mean temperature, and range of daily mean temperature) based on our previous studies published by The Lancet and The Lancet Planetary Health.[4,5] We then built a meta-regression between location-specific temperature-mortality association and those location-specific predictors. Continents included Americas, Europe, Africa, Asia and Oceania. Indicators for Köppen-Geiger climate classification had five categories: group A for tropical climates, group B for dry climates, group C for temperate climates, group D for continental climates, group E for polar and alpine climates.

Third stage: We collected data on predictors aforementioned at the grid level and used the coefficients of each predictor from the meta-regression of the second stage to predict the grid-specific temperature-mortality association. Then the predicted grid-specific temperature-mortality association, grid-specific daily temperature

and grid-specific mortality are combined to calculate the grid-specific mortality burden attributable to non-optimal temperatures.

### 3. Temperature-mortality relationship: seven GBD countries VS the rest 36 countries

The GBD 2019 study estimate the global burden of mortality associated with non-optimal temperatures using mortality data from eight countries – Brazil, Chile, Colombia, Guatemala, Mexico, the United States, China and New Zealand. The latest MCC network covers data from all these GBD countries except for New Zealand. Here we divided MCC data into two groups: the seven GBD countries and the remaining 36 countries, and then performed a straightforward comparison using a classic two-stage time-series analysis strategy.[6,7] Briefly, in the first stage the association between temperature and mortality was estimated for each location using a quasi-Poisson regression with distributed lag non-linear model over lag 0-21 days, with controlling for long-term trend, seasonality and day of the week. In the second stage, the location-specific estimates were pooled using meta-analysis to get a 'global view'. Considering the various temperature ranges across locations, we used a relative scale for temperature (i.e. temperature percentage for each location) for the first and second stages. All other parameterizations followed the main analysis of this study. The pooled results are provided in Figure S3. As shown, the pooled effect estimates of low and high temperatures were both lower for GBD group than for the group of the remaining 36 countries.

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## Table

**Table S1 Descriptive statistics of the 750 locations by continent and country/territory.**

| | No. of locations | Study period | Total deaths | Temperature |
|---|---|---|---|---|
| **Americas** | | | | |
| USA | 211 | 1973-2006 | 38040638 | 13·9 (3·2, 24·8) |
| Canada | 26 | 1986-2015 | 3733749 | 6·9 (2·7, 10·8) |
| Panama | 1 | 2013-2016 | 11457 | 28·1 (28·1, 28·1) |
| Guatemala | 1 | 2009-2016 | 62715 | 19·4 (19·4, 19·4) |
| Puerto Rico | 1 | 2009-2016 | 26564 | 26·8 (26·8, 26·8) |
| Mexico | 10 | 1998-2014 | 2980086 | 18·8 (13·9, 23·3) |
| Chile | 4 | 2004-2014 | 325462 | 13·7 (11·5, 15·4) |
| Uruguay | 1 | 2012-2016 | 153554 | 18·6 (18·6, 18·6) |
| Argentina | 3 | 2005-2015 | 686333 | 18·1 (17·8, 18·5) |
| Paraguay | 1 | 2004-2016 | 39713 | 23·2 (23·2, 23·2) |
| Brazil | 18 | 1997-2011 | 3401136 | 24·6 (17·7, 27·4) |
| Peru | 18 | 2008-2014 | 633137 | 17·9 (4·6, 27·0) |
| Ecuador | 2 | 2014-2018 | 112264 | 20·9 (15·5, 26·3) |
| Colombia | 5 | 1998-2013 | 956539 | 23·4 (13·9, 28·0) |
| Costa Rica | 1 | 2000-2017 | 31117 | 22·7 (22·7, 22·7) |
| **Europe** | | | | |
| Netherlands | 5 | 1995-2016 | 453395 | 10·6 (10·5, 10·7) |
| UK | 70 | 1990-2016 | 6167130 | 10·5 (9·0, 11·4) |
| Ireland | 6 | 1984-2007 | 1058215 | 9·7 (9·1, 10·6) |
| Sweden | 3 | 1990-2016 | 717294 | 8·6 (7·8, 9·1) |
| Estonia | 5 | 1997-2015 | 146347 | 6·2 (5·6, 6·7) |
| Norway | 1 | 1969-2016 | 263448 | 4·6 (4·6, 4·6) |
| Finland | 1 | 1994-2014 | 153308 | 6·2 (6·2, 6·2) |
| Romania | 8 | 1994-2016 | 951146 | 10·8 (8·3, 12·7) |
| Moldova | 4 | 2001-2010 | 59906 | 10·7 (10·2, 11·3) |
| Switzerland | 8 | 1995-2013 | 243638 | 10·4 (8·6, 12·9) |
| France | 18 | 2000-2014 | 1639262 | 12·6 (10·8, 16·3) |
| Czech Republic | 4 | 1994-2015 | 711910 | 9·1 (8·3, 9·9) |
| Germany | 12 | 1993-2015 | 3105865 | 10·3 (9·6, 11·0) |
| Greece | 1 | 2001-2010 | 287969 | 18·7 (18·7, 18·7) |
| Portugal | 5 | 1980-2018 | 1750670 | 15·8 (14·7, 16·7) |
| Spain | 52 | 1990-2014 | 3017110 | 15·5 (10·9, 21·6) |
| Italy | 18 | 2006-2015 | 804278 | 16·1 (12·9, 18·5) |
| **Africa** | | | | |
| South Africa | 52 | 1997-2013 | 8509130 | 18·1 (12·4, 22·8) |
| **Asia** | | | | |
| Kuwait | 1 | 2000-2016 | 73748 | 27·1 (27·1, 27·1) |
| Iran | 1 | 2004-2013 | 121585 | 16·0 (16·0, 16·0) |
| Mainland China | 15 | 1996-2015 | 1201670 | 15·0 (7·4, 23·7) |
| Japan | 47 | 1972-2015 | 39917611 | 15·1 (8·9, 22·9) |
| South Korea | 36 | 1997-2018 | 3070357 | 13·2 (9·1, 17·1) |
| Philippines | 4 | 2006-2010 | 274516 | 28·2 (28·0, 28·8) |
| Vietnam | 2 | 2009-2013 | 108173 | 27·1 (25·7, 28·5) |
| Thailand | 62 | 1999-2008 | 1827853 | 27·6 (25·1, 29·3) |
| Taiwan | 3 | 1994-2014 | 1209573 | 24·0 (23·1, 25·3) |
| **Oceania** | | | | |
| Australia | 3 | 1988-2009 | 1177950 | 18·1 (15·7, 20·3) |

**Table S2 Average daily mean temperature (°C) and change per decade (°C) between 2000–2019 by continent and region.**

| | Average daily mean temperature (°C) | Increase in daily mean temperature per decade (°C) |
|---|---|---|
| **Global** | 15·23±10·40 | 0·26±0·44 |
| **Americas** | 14·87±9·83 | 0·28±0·43 |
| Northern America | 7·32±6·95 | 0·21±0·43 |
| Latin America and the Caribbean | 21·63±6·58 | 0·34±0·43 |
| **Europe** | 4·58±6·31 | 0·37±0·41 |
| Northern Europe | 4·73±4·76 | 0·11±0·40 |
| Southern Europe | 14·07±3·21 | 0·40±0·41 |
| Western Europe | 12·23±5·26 | 0·33±0·29 |
| Eastern Europe | 2·36±5·06 | 0·43±0·40 |
| **Africa** | 24·40±3·74 | 0·26±0·42 |
| Northern Africa | 24·03±3·85 | 0·04±0·47 |
| Sub-Saharan Africa | 24·50±3·70 | 0·32±0·39 |
| **Asia** | 16·97±9·55 | 0·17±0·45 |
| Central Asia | 9·28±5·17 | 0·05±0·39 |
| Southern Asia | 21·40±7·22 | -0·16±0·53 |
| Western Asia | 21·25±6·56 | 0·47±0·43 |
| Eastern Asia | 8·93±7·49 | 0·26±0·29 |
| South-eastern Asia | 26·35±2·19 | 0·26±0·36 |
| **Oceania** | 20·15±6·10 | 0·28±0·52 |
| Australia and New Zealand | 16·34±4·69 | 0·14±0·61 |
| Other regions in Oceania | 26·05±1·90 | 0·48±0·23 |

**Table S3 Excess deaths ratio (%) and deaths per 100,000 residents (with 95% empirical CIs) due to non-optimal temperatures (overall and cold/heat components) between 2000–2019 by the indicators of Köppen-Geiger climate classification.**

| Climate classification | Excess death ratio (%) | | | Excess deaths per 100,000 residents | | |
|---|---|---|---|---|---|---|
| | Overall | Cold-related | Heat-related | Overall | Cold-related | Heat-related |
| Group A: Tropical climates | 7·22 (3·23, 10·95) | 6·68 (2·43, 10·56) | 0·54 (0·30, 0·86) | 57 (25, 86) | 52 (19, 83) | 4 (2, 7) |
| Group B: Dry climates | 8·78 (7·03, 10·34) | 7·85 (5·55, 9·82) | 0·94 (0·50, 1·50) | 64 (51, 75) | 57 (40, 72) | 7 (4, 11) |
| Group C: Temperate climates | 10·88 (9·96, 11·78) | 9·95 (8·64, 11·11) | 0·93 (0·60, 1·35) | 84 (77, 91) | 77 (67, 86) | 7 (5, 10) |
| Group D: Continental climates | 10·68 (9·51, 11·69) | 9·24 (8·31, 10·22) | 1·44 (1·00, 2·02) | 97 (87, 106) | 84 (76, 93) | 13 (9, 18) |
| Group E: Polar and alpine climates | 16·27 (-9·17, 57·31) | 1·04 (-0·23, 2·84) | 15·24 (-10·90, 56·10) | 117 (-66, 412) | 7 (-2, 20) | 109 (-78, 403) |

**Table S4 Excess death ratio due to non-optimal temperatures by continent and region during different period.**

| | 2000-2003 | 2004-2007 | 2008-2011 | 2012-2015 | 2016-2019 |
|---|---|---|---|---|---|
| **Global** | 9·53 (7·62, 11·21) | 9·50 (7·63, 11·14) | 9·43 (7·57, 11·09) | 9·48 (7·62, 11·13) | 9·23 (7·49, 10·79) |
| **Americas** | 6·51 (5·82, 7·26) | 6·45 (5·74, 7·17) | 6·66 (5·95, 7·40) | 5·95 (5·35, 6·61) | 6·08 (5·51, 6·74) |
| Northern America | 7·28 (6·29, 8·26) | 7·02 (6·05, 8·04) | 7·40 (6·39, 8·44) | 6·72 (5·78, 7·73) | 6·78 (5·82, 7·82) |
| Latin America and the Caribbean | 5·90 (5·32, 6·73) | 5·99 (5·41, 6·81) | 6·09 (5·51, 6·92) | 5·35 (4·87, 6·01) | 5·52 (5·04, 6·17) |
| **Europe** | 10·10 (8·94, 11·21) | 10·52 (9·34, 11·68) | 10·28 (9·11, 11·42) | 9·96 (8·78, 11·08) | 10·47 (9·21, 11·69) |
| Northern Europe | 9·24 (8·06, 10·41) | 9·57 (8·39, 10·71) | 9·46 (8·31, 10·59) | 9·13 (7·98, 10·26) | 9·71 (8·46, 10·92) |
| Southern Europe | 10·75 (9·77, 11·70) | 11·50 (10·53, 12·48) | 11·32 (10·30, 12·32) | 10·93 (9·93, 11·90) | 11·23 (10·14, 12·28) |
| Western Europe | 9·43 (8·38, 10·44) | 10·39 (9·33, 11·49) | 9·80 (8·76, 10·84) | 9·14 (8·11, 10·12) | 9·85 (8·69, 10·97) |
| Eastern Europe | 10·35 (9·04, 11·56) | 10·43 (9·10, 11·65) | 10·29 (8·98, 11·49) | 10·15 (8·78, 11·40) | 10·64 (9·20, 11·94) |
| **Africa** | 12·18 (1·67, 21·98) | 11·79 (1·42, 21·46) | 11·80 (1·36, 21·52) | 11·72 (1·26, 21·47) | 11·34 (1·12, 20·81) |
| Northern Africa | 10·01 (2·21, 16·48) | 9·72 (2·06, 16·10) | 9·74 (2·12, 16·05) | 9·57 (2·00, 15·85) | 9·61 (2·09, 15·77) |
| Sub-Saharan Africa | 12·49 (1·60, 22·68) | 12·09 (1·33, 22·11) | 12·09 (1·25, 22·18) | 12·03 (1·16, 22·15) | 11·58 (0·98, 21·40) |
| **Asia** | 9·06 (8·13, 9·86) | 9·04 (8·10, 9·85) | 8·94 (8·02, 9·75) | 9·29 (8·34, 10·12) | 8·79 (7·84, 9·67) |
| Central Asia | 10·60 (9·49, 11·56) | 10·15 (9·03, 11·13) | 10·31 (9·18, 11·32) | 10·50 (9·34, 11·53) | 10·45 (9·30, 11·42) |
| Southern Asia | 8·11 (7·12, 9·02) | 8·31 (7·31, 9·22) | 8·08 (7·10, 8·97) | 8·76 (7·74, 9·69) | 8·42 (7·39, 9·35) |
| Western Asia | 10·81 (9·68, 11·85) | 10·96 (9·85, 12·05) | 10·69 (9·55, 11·70) | 10·26 (9·14, 11·25) | 10·29 (9·08, 11·40) |
| Eastern Asia | 10·96 (10·09, 11·67) | 10·91 (10·04, 11·65) | 10·96 (10·09, 11·71) | 11·34 (10·46, 12·08) | 10·63 (9·75, 11·39) |
| South-eastern Asia | 5·83 (4·91, 6·58) | 5·17 (4·34, 5·88) | 5·08 (4·31, 5·79) | 4·57 (3·80, 5·28) | 3·95 (3·13, 4·73) |
| **Oceania** | 10·55 (6·64, 15·11) | 10·16 (6·44, 14·51) | 10·03 (6·23, 14·56) | 9·75 (6·04, 14·18) | 10·12 (6·25, 14·78) |
| Australia and New Zealand | 11·43 (7·02, 16·45) | 11·17 (6·74, 16·47) | 11·13 (6·66, 16·42) | 10·61 (6·32, 15·84) | 11·43 (6·81, 17·00) |
| Other regions in Oceania | 8·33 (4·44, 11·77) | 7·60 (4·20, 10·93) | 7·23 (3·64, 10·81) | 7·56 (3·85, 11·13) | 6·81 (3·42, 10·00) |

**Table S5 Excess death ratio due to cold temperatures by continent and region during different period.**

| | 2000-2003 | 2004-2007 | 2008-2011 | 2012-2015 | 2016-2019 |
|---|---|---|---|---|---|
| **Global** | 8·70 (6·35, 10·65) | 8·63 (6·31, 10·56) | 8·54 (6·19, 10·49) | 8·57 (6·22, 10·52) | 8·19 (5·89, 10·11) |
| **Americas** | 5·71 (5·02, 6·57) | 5·58 (4·91, 6·41) | 5·77 (5·10, 6·64) | 4·99 (4·39, 5·78) | 5·01 (4·41, 5·80) |
| Northern America | 6·67 (5·81, 7·61) | 6·33 (5·50, 7·25) | 6·66 (5·81, 7·59) | 5·97 (5·18, 6·85) | 5·89 (5·10, 6·78) |
| Latin America and the Caribbean | 4·96 (4·08, 5·91) | 4·98 (4·13, 5·93) | 5·08 (4·23, 6·02) | 4·23 (3·45, 5·09) | 4·32 (3·53, 5·17) |
| **Europe** | 8·11 (7·22, 8·94) | 8·48 (7·59, 9·33) | 8·18 (7·31, 9·01) | 7·74 (6·88, 8·55) | 7·84 (6·96, 8·65) |
| Northern Europe | 7·68 (6·74, 8·42) | 7·98 (7·07, 8·78) | 7·99 (7·08, 8·80) | 7·67 (6·75, 8·41) | 7·86 (6·91, 8·64) |
| Southern Europe | 8·54 (7·75, 9·24) | 9·41 (8·62, 10·16) | 8·82 (8·03, 9·53) | 8·51 (7·73, 9·20) | 8·34 (7·56, 9·03) |
| Western Europe | 7·70 (6·89, 8·43) | 8·58 (7·77, 9·36) | 8·10 (7·30, 8·84) | 7·49 (6·69, 8·21) | 7·53 (6·72, 8·25) |
| Eastern Europe | 8·23 (7·19, 9·18) | 8·20 (7·16, 9·16) | 8·01 (7·00, 8·94) | 7·59 (6·58, 8·49) | 7·78 (6·76, 8·71) |
| **Africa** | 11·96 (1·37, 21·81) | 11·54 (1·09, 21·30) | 11·53 (1·00, 21·35) | 11·46 (0·91, 21·31) | 11·09 (0·78, 20·66) |
| Northern Africa | 9·47 (1·50, 16·12) | 9·16 (1·31, 15·73) | 9·12 (1·31, 15·66) | 9·00 (1·25, 15·48) | 9·12 (1·45, 15·47) |
| Sub-Saharan Africa | 12·31 (1·35, 22·57) | 11·88 (1·06, 21·98) | 11·88 (0·96, 22·05) | 11·82 (0·87, 22·02) | 11·38 (0·69, 21·28) |
| **Asia** | 8·34 (7·59, 9·14) | 8·29 (7·55, 9·09) | 8·17 (7·45, 8·96) | 8·53 (7·80, 9·37) | 7·93 (7·22, 8·69) |
| Central Asia | 10·04 (9·16, 11·03) | 9·42 (8·60, 10·33) | 9·57 (8·72, 10·53) | 9·77 (8·89, 10·76) | 9·80 (8·92, 10·77) |
| Southern Asia | 7·22 (6·47, 8·04) | 7·44 (6·68, 8·30) | 7·15 (6·41, 7·98) | 7·89 (7·08, 8·82) | 7·44 (6·67, 8·30) |
| Western Asia | 10·13 (9·21, 11·22) | 10·39 (9·45, 11·54) | 9·98 (9·06, 11·06) | 9·52 (8·63, 10·55) | 9·35 (8·46, 10·37) |
| Eastern Asia | 10·32 (9·62, 11·15) | 10·20 (9·51, 11·01) | 10·24 (9·56, 11·04) | 10·66 (9·96, 11·49) | 9·86 (9·19, 10·67) |
| South-eastern Asia | 5·38 (4·60, 6·14) | 4·64 (3·92, 5·32) | 4·66 (3·93, 5·36) | 3·94 (3·31, 4·54) | 3·22 (2·68, 3·75) |
| **Oceania** | 9·33 (5·78, 12·80) | 8·59 (5·40, 11·93) | 8·22 (5·21, 11·53) | 8·03 (5·06, 11·31) | 8·09 (5·15, 11·27) |
| Australia and New Zealand | 10·16 (6·57, 14·27) | 9·66 (6·23, 13·67) | 9·63 (6·17, 13·63) | 9·15 (5·80, 13·09) | 9·56 (6·19, 13·40) |
| Other regions in Oceania | 7·21 (3·84, 10·59) | 5·88 (3·07, 8·69) | 4·66 (2·46, 7·07) | 5·20 (2·72, 7·83) | 4·38 (2·28, 6·69) |

**Table S6 Excess death ratio due to hot temperatures by continent and region during different period.**

| | 2000-2003 | 2004-2007 | 2008-2011 | 2012-2015 | 2016-2019 |
|---|---|---|---|---|---|
| **Global** | 0·83 (0·52, 1·25) | 0·87 (0·54, 1·30) | 0·89 (0·55, 1·34) | 0·91 (0·57, 1·36) | 1·04 (0·64, 1·55) |
| **Americas** | 0·80 (0·42, 1·32) | 0·87 (0·46, 1·44) | 0·89 (0·47, 1·48) | 0·96 (0·50, 1·58) | 1·07 (0·55, 1·76) |
| Northern America | 0·61 (0·27, 1·07) | 0·69 (0·30, 1·21) | 0·74 (0·33, 1·28) | 0·75 (0·31, 1·34) | 0·89 (0·39, 1·57) |
| Latin America and the Caribbean | 0·95 (0·50, 1·56) | 1·01 (0·56, 1·63) | 1·01 (0·54, 1·66) | 1·12 (0·63, 1·80) | 1·20 (0·66, 1·97) |
| **Europe** | 1·99 (1·58, 2·54) | 2·04 (1·62, 2·60) | 2·10 (1·67, 2·67) | 2·21 (1·76, 2·82) | 2·63 (2·10, 3·35) |
| Northern Europe | 1·57 (1·16, 2·13) | 1·59 (1·17, 2·15) | 1·47 (1·08, 1·99) | 1·45 (1·07, 1·97) | 1·84 (1·37, 2·49) |
| Southern Europe | 2·21 (1·82, 2·78) | 2·09 (1·71, 2·62) | 2·50 (2·06, 3·12) | 2·42 (1·99, 3·03) | 2·89 (2·37, 3·61) |
| Western Europe | 1·73 (1·33, 2·25) | 1·81 (1·40, 2·36) | 1·70 (1·31, 2·21) | 1·65 (1·28, 2·15) | 2·32 (1·80, 3·02) |
| Eastern Europe | 2·12 (1·71, 2·68) | 2·23 (1·79, 2·81) | 2·28 (1·84, 2·88) | 2·56 (2·07, 3·23) | 2·86 (2·31, 3·58) |
| **Africa** | 0·22 (0·14, 0·33) | 0·25 (0·15, 0·36) | 0·26 (0·16, 0·39) | 0·26 (0·16, 0·39) | 0·24 (0·14, 0·37) |
| Northern Africa | 0·54 (0·37, 0·75) | 0·56 (0·38, 0·79) | 0·63 (0·40, 0·90) | 0·57 (0·38, 0·81) | 0·49 (0·32, 0·71) |
| Sub-Saharan Africa | 0·18 (0·11, 0·27) | 0·20 (0·12, 0·30) | 0·21 (0·13, 0·32) | 0·21 (0·13, 0·33) | 0·21 (0·12, 0·32) |
| **Asia** | 0·72 (0·37, 1·19) | 0·75 (0·38, 1·22) | 0·77 (0·39, 1·26) | 0·76 (0·38, 1·24) | 0·86 (0·43, 1·40) |
| Central Asia | 0·56 (0·20, 1·04) | 0·73 (0·26, 1·36) | 0·74 (0·27, 1·38) | 0·73 (0·27, 1·37) | 0·66 (0·24, 1·22) |
| Southern Asia | 0·89 (0·50, 1·38) | 0·87 (0·48, 1·35) | 0·93 (0·52, 1·44) | 0·87 (0·49, 1·35) | 0·98 (0·54, 1·53) |
| Western Asia | 0·69 (0·27, 1·25) | 0·56 (0·22, 1·02) | 0·71 (0·28, 1·28) | 0·74 (0·29, 1·34) | 0·94 (0·37, 1·70) |
| Eastern Asia | 0·65 (0·29, 1·14) | 0·72 (0·32, 1·25) | 0·72 (0·32, 1·27) | 0·68 (0·30, 1·20) | 0·77 (0·35, 1·34) |
| South-eastern Asia | 0·45 (0·20, 0·77) | 0·53 (0·25, 0·89) | 0·42 (0·19, 0·72) | 0·63 (0·29, 1·08) | 0·73 (0·30, 1·27) |
| **Oceania** | 1·22 (0·29, 2·58) | 1·57 (0·39, 3·29) | 1·81 (0·47, 3·76) | 1·72 (0·45, 3·57) | 2·03 (0·53, 4·23) |
| Australia and New Zealand | 1·27 (0·21, 2·89) | 1·51 (0·25, 3·46) | 1·50 (0·24, 3·45) | 1·46 (0·24, 3·35) | 1·87 (0·29, 4·33) |
| Other regions in Oceania | 1·11 (0·41, 2·05) | 1·73 (0·62, 3·20) | 2·57 (0·90, 4·73) | 2·35 (0·87, 4·32) | 2·43 (0·90, 4·48) |

**Table S7 Results of sensitivity analyses on global excess death ratio.**

| | Overall | Cold-related | Heat-related |
|---|---|---|---|
| Main model | 9·43 (7·58, 11·07) | 8·52 (6·19, 10·47) | 0·91 (0·56, 1·36) |
| Knots for exposure-response: 25th, 75th, and 90th | 9·69 (7·73, 11·52) | 8·75 (6·32, 10·88) | 0·95 (0·62, 1·38) |
| Knots for exposure-response: 25th, 50th, and 75th | 8·91 (8·21, 9·78) | 7·59 (6·46, 8·60) | 1·32 (0·85, 1·95) |
| Knots for exposure-response: 10th, 50th, and 90th | 8·13 (7·39, 9·09) | 6·97 (5·60, 8·17) | 1·16 (0·67, 1·76) |
| Df for lag-response: 6 | 9·39 (7·52, 11·02) | 8·50 (6·19, 10·45) | 0·89 (0·56, 1·34) |
| Lag period: 24 days | 9·70 (7·86, 11·43) | 8·87 (6·56, 10·96) | 0·83 (0·48, 1·30) |
| Lag period: 28 days | 10·67 (8·08, 13·01) | 9·90 (6·84, 12·54) | 0·77 (0·43, 1·28) |
| Df/year for seasonal control: 6 | 8·41 (7·13, 9·49) | 7·43 (5·94, 8·75) | 0·98 (0·73, 1·31) |
| Df/year for seasonal control: 10 | 9·68 (6·51, 12·56) | 8·93 (5·36, 12·09) | 0·76 (0·43, 1·17) |

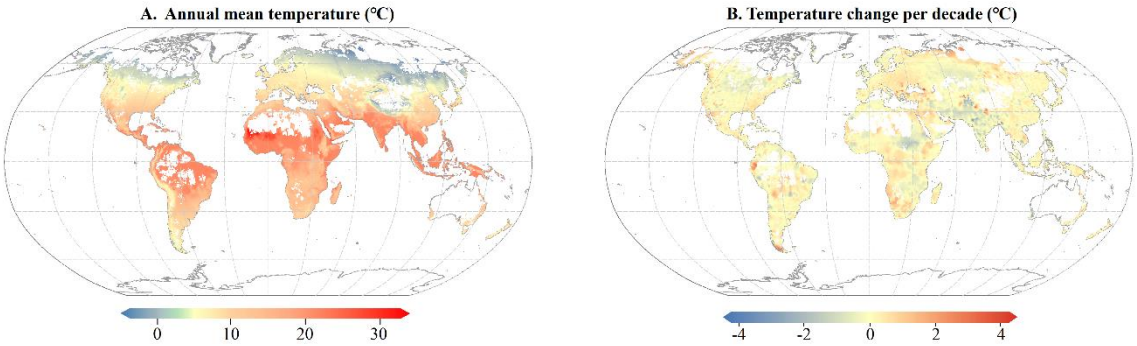


**Figure S1 Average daily mean temperature and change per decade between 2000–2019 at a spatial resolution of 0·5°×0·5˚.** Only grids with at least one annual death were included. The colors represent ranges of average daily mean temperature.

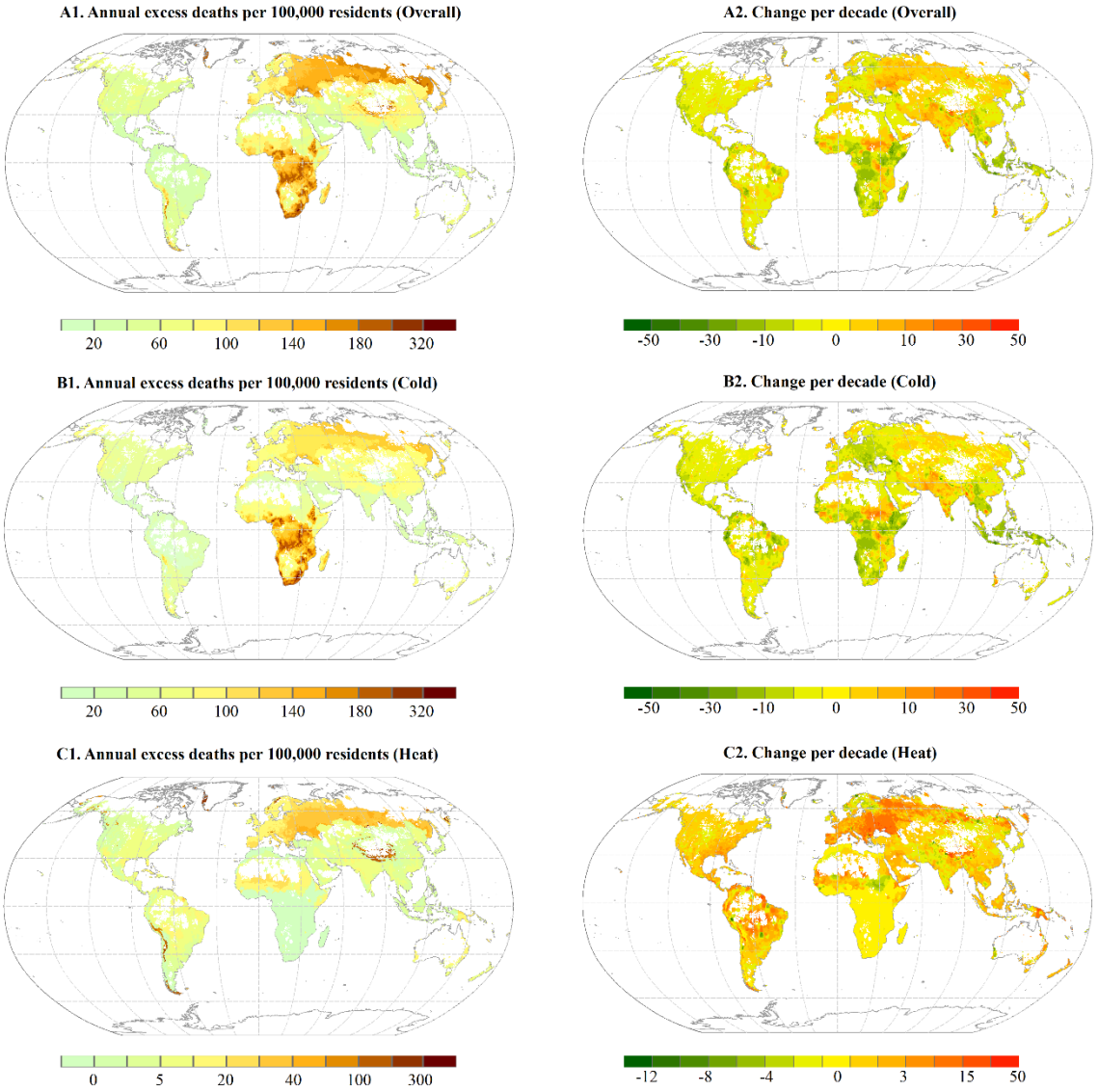


**Figure S2. Average annual excess deaths per 100,000 residents and change per decade due to non-optimal temperatures (total and cold/heat components) between 2000–2019 at a spatial resolution of 0·5°×0·5˚.** Only grids with at least one annual death were included.

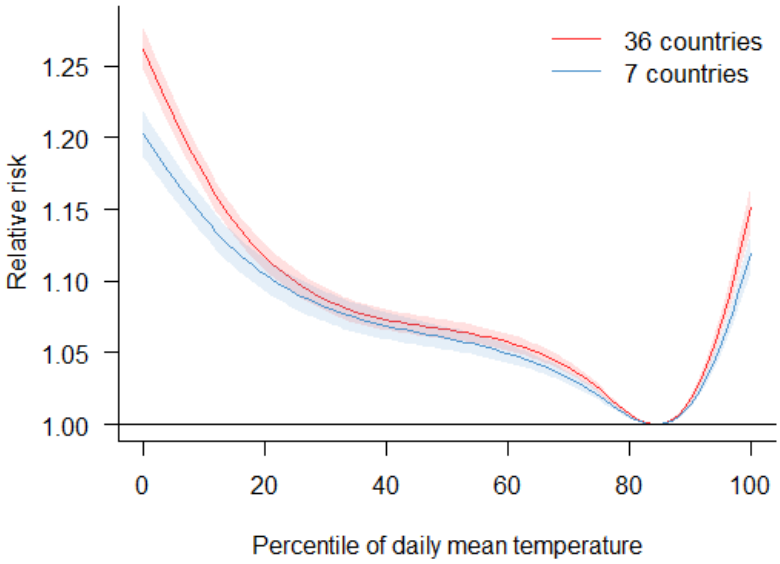


**Figure S3. The pooled association between temperature percentile and mortality across locations in the 7 countries included in GBD 2019 and the remaining 36 countries.**