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Supplementary appendix

This appendix formed part of the original submission and has been peer reviewed. We post it as supplied by the authors.

Supplement to: Timonin S, Shartova N, Wen B, et al. The differential effect of ambient temperature on age-specific and sex-specific mortality in 300 largest cities of Russia, 2000–19: a first national time-series study. *Lancet Planet Health* 2025; **9:** e410–20.

SUPPLEMENTARY MATERIALS

Differential impact of ambient temperature on age- and sex-specific mortality in 300 largest cities of Russia, 2000-19: a first national time-series study

Sergey Timonin, Natalia Shartova, Bo Wen, Yao Wu, Evgeny Andreev, Yuming Guo, Joan Ballester

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A. Additional information on data

A.1. Cities and regions under the study

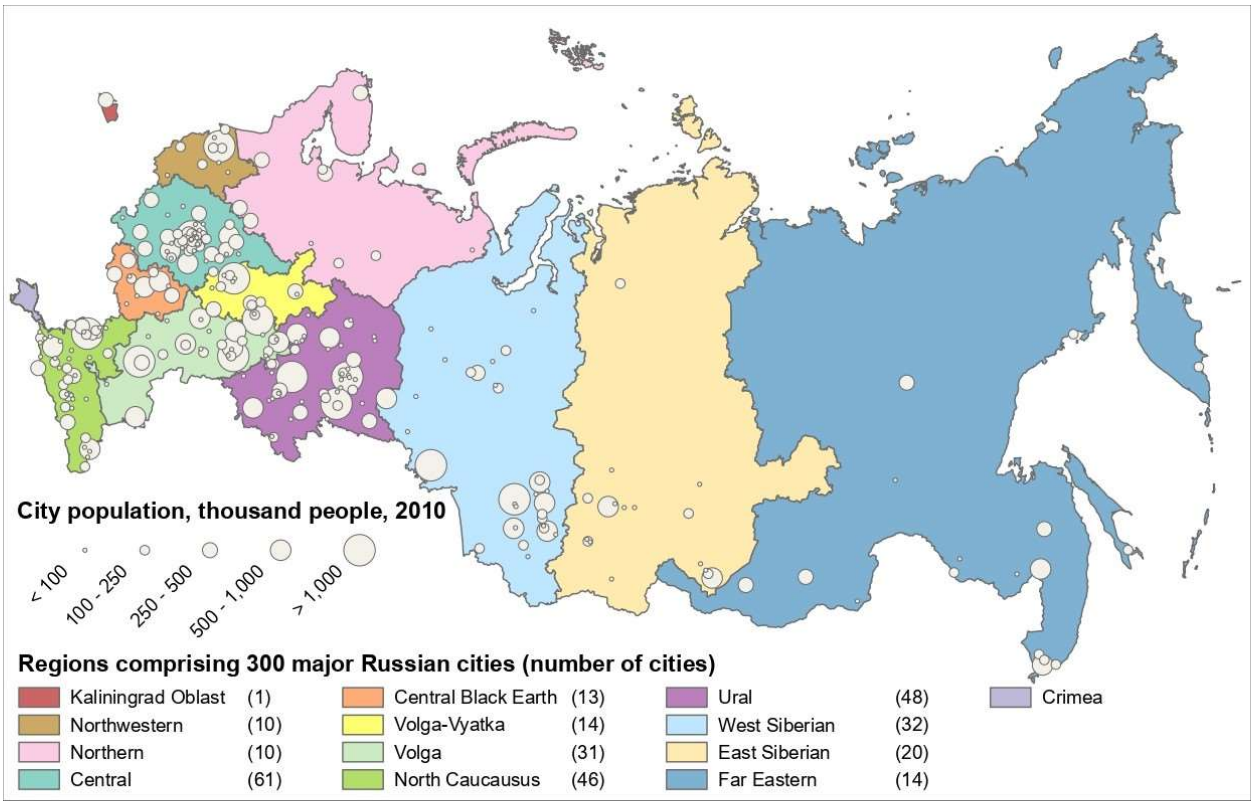


Figure S1: Reference map: cities and regions on the map of Russia

***Note**: Here and hereafter the borders of Russia are shown according to the 2019 delineations as defined by the Russian government.*

A.2. Mortality data

Collection and processing of mortality data

We used anonymised individual death records provided by the Russian Federal State Statistics Service (Rosstat) for each calendar year from 2000 to 2020 to create a harmonised dataset covering all deaths in Russia's 300 largest cities between the 1st of January 2000 and 31st of December 2019. We used the detailed information on the Russian Classification of Objects of Administrative Division ("OKATO") and the Russian Classification of Territories of Municipal Formations ("OKTMO") to construct the series of time-consistent death records for the Russian cities with population size more than 50 thousand people. Both "OKATO" and "OKTMO" were included in the death records and referred to the place of residence (as indicated in the passport) of a deceased person. There were several changes in the 'OKATO' and 'OKTMO' classifications during the study period, so we used correspondence tables to account for these changes. The time series of daily deaths for each city were subjected to a robust check. For 22 cities, we were unable to ensure temporal consistency, and they were excluded from further consideration. The final dataset comprised Russia's 300 largest cities.

According to the normative documents, a death in Russia can be registered at the civil registry office located either in the city where the death occurred or in the place of residence. However, Rosstat makes annual adjustments to redistribute (reassign) deaths to the place of residence, when necessary. In addition to the place of residence, death records also contained information on the date of death, age, sex and underlying cause of death according to the International Classification of Diseases, 10th Revision. We only included deaths from natural causes (ICD-10 codes: A00 - P99) in our analysis; external causes of death (injuries and poisonings) were excluded.

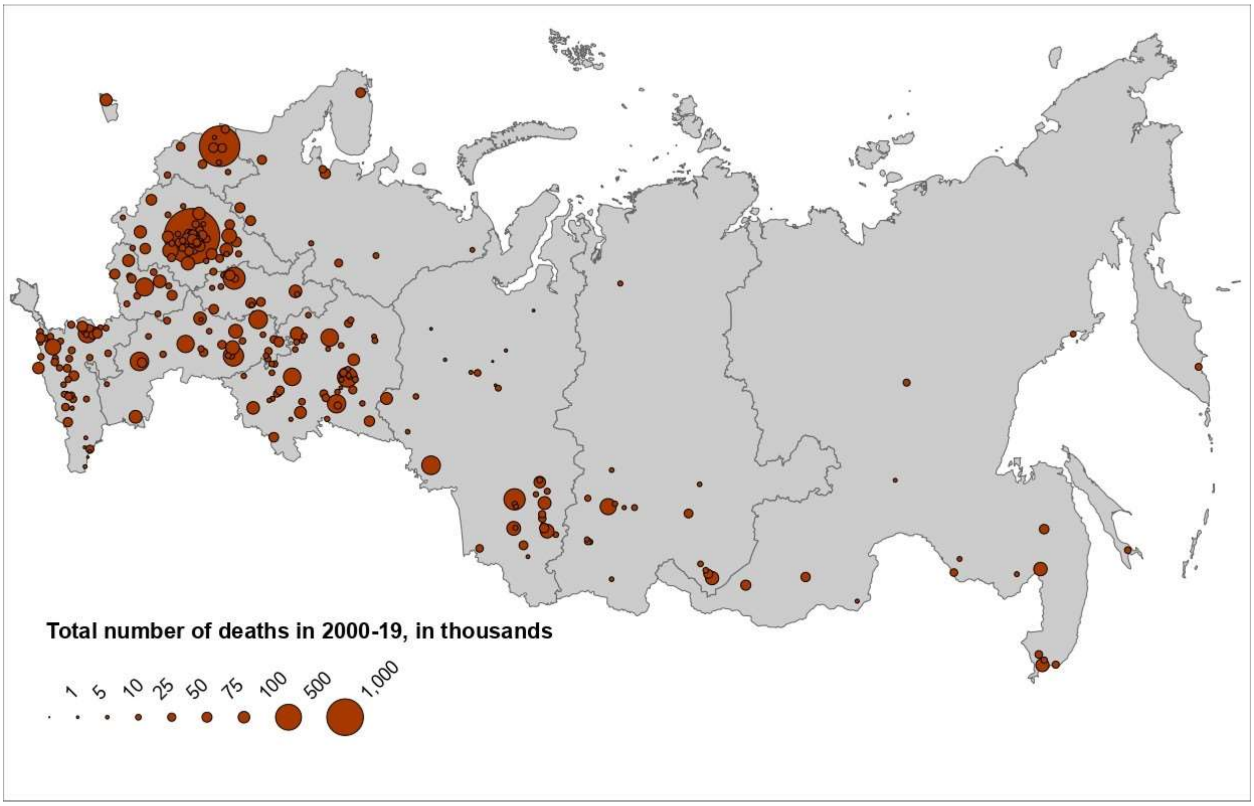


Figure S2: Total number of deaths from natural causes, both sexes, all ages, total for 2000-2019.

Note: *The circles on this map are proportional to the total number of deaths, unlike all other maps where the circles are proportional to the logarithm of the population of the cities in 2010 (according to the census).*

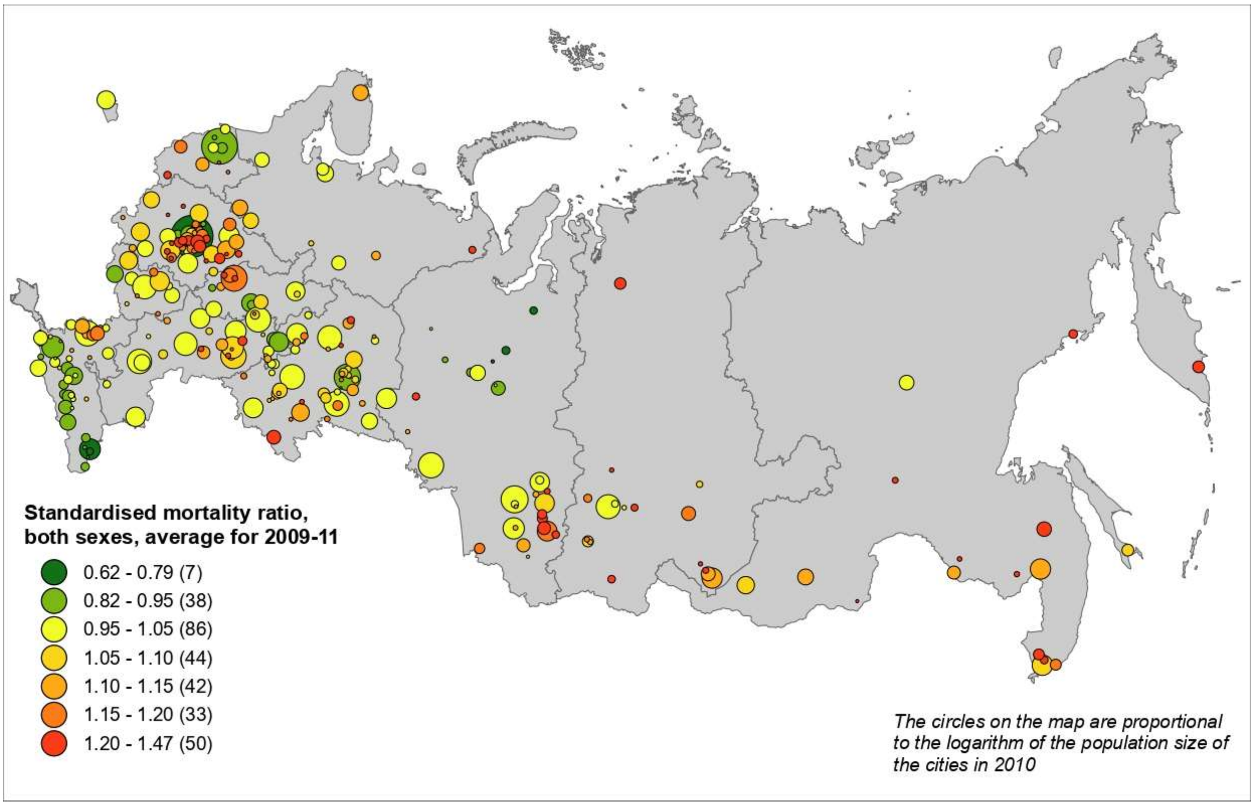


Figure S3a: Standardised mortality ratio (SMR), both sexes, all ages, average for 2009-2011.

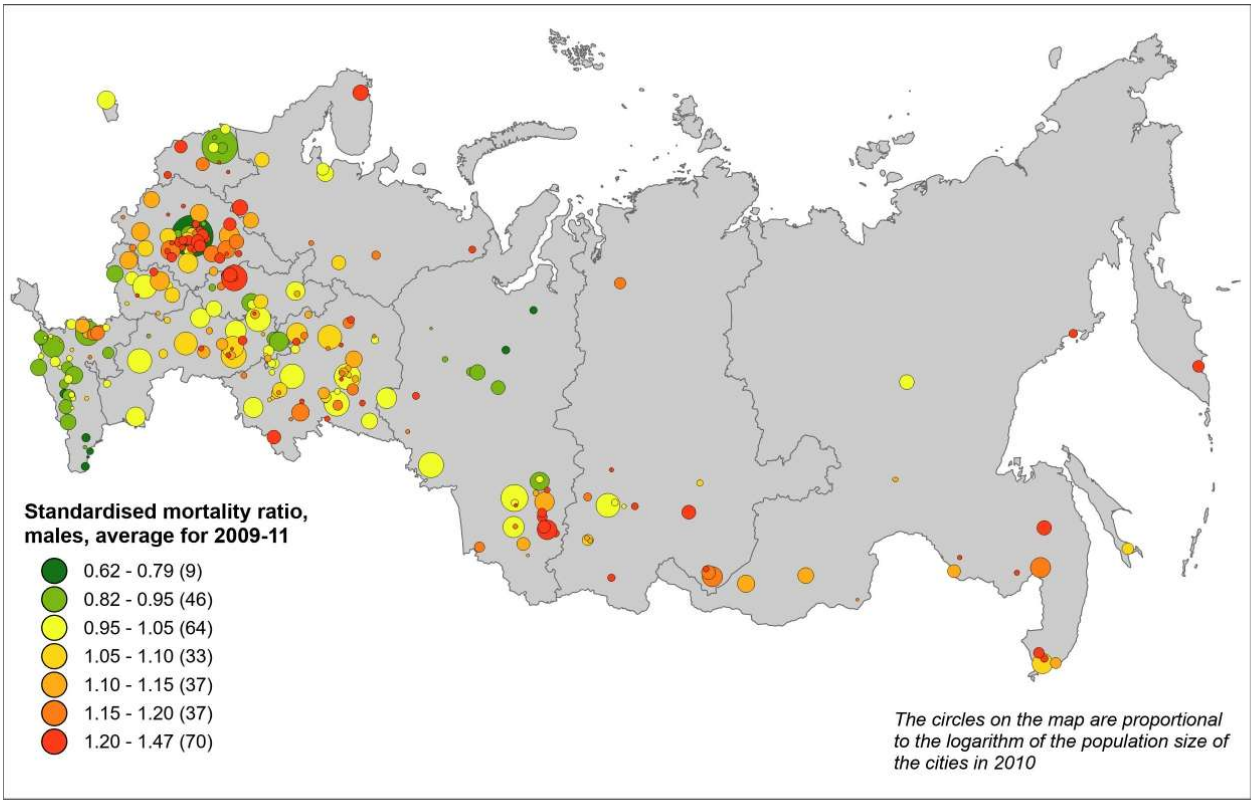


Figure S3b: Standardised mortality ratio (SMR), males, all ages, average for 2009-2011.

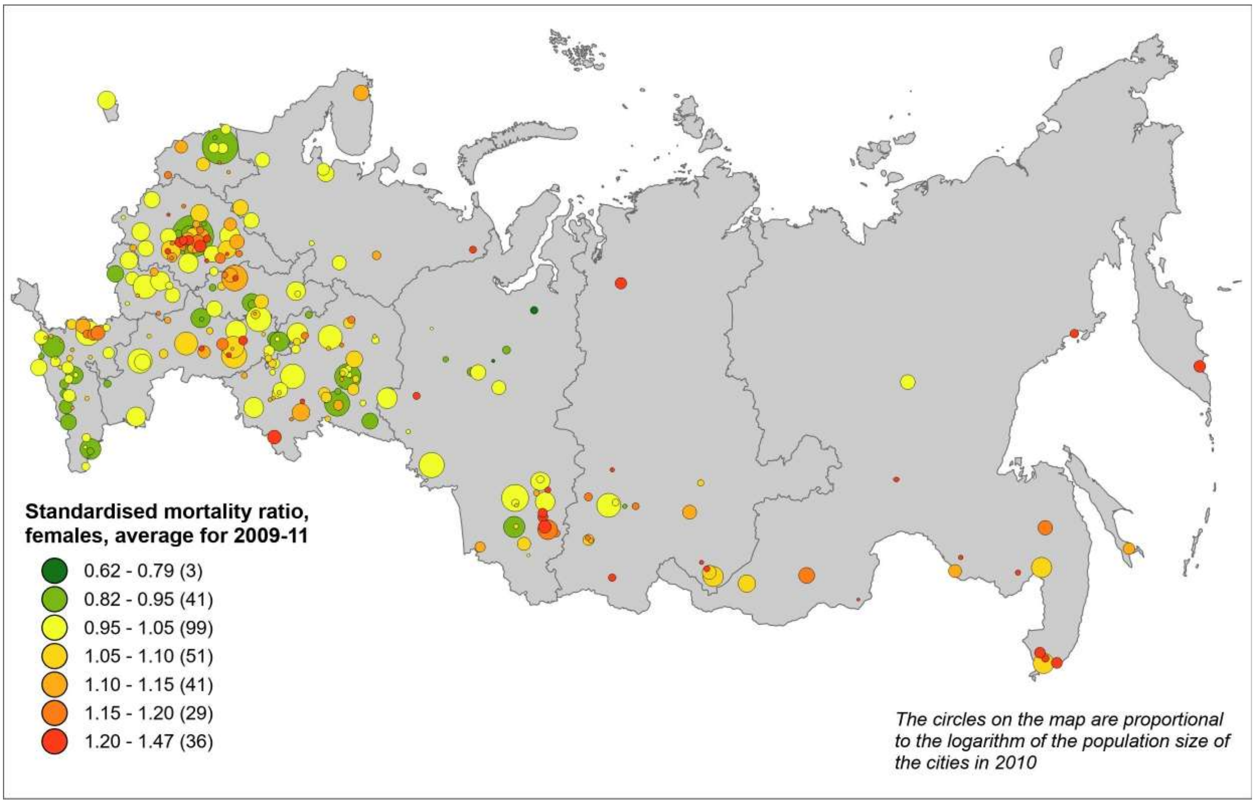


Figure S3c: Standardised mortality ratio (SMR), females, all ages, average for 2009-2011.

Note: *The Standardised Mortality Ratio (SMR) is determined by dividing the observed number of deaths in a city by the expected number of deaths. The expected number of deaths is calculated by multiplying the age distribution of the city's population by the average age-specific death rates across all cities. An SMR greater than 1 indicates higher-than-average mortality, while an SMR less than 1 suggests lower-than-average mortality compared to all cities.*

A.3. Temperature data

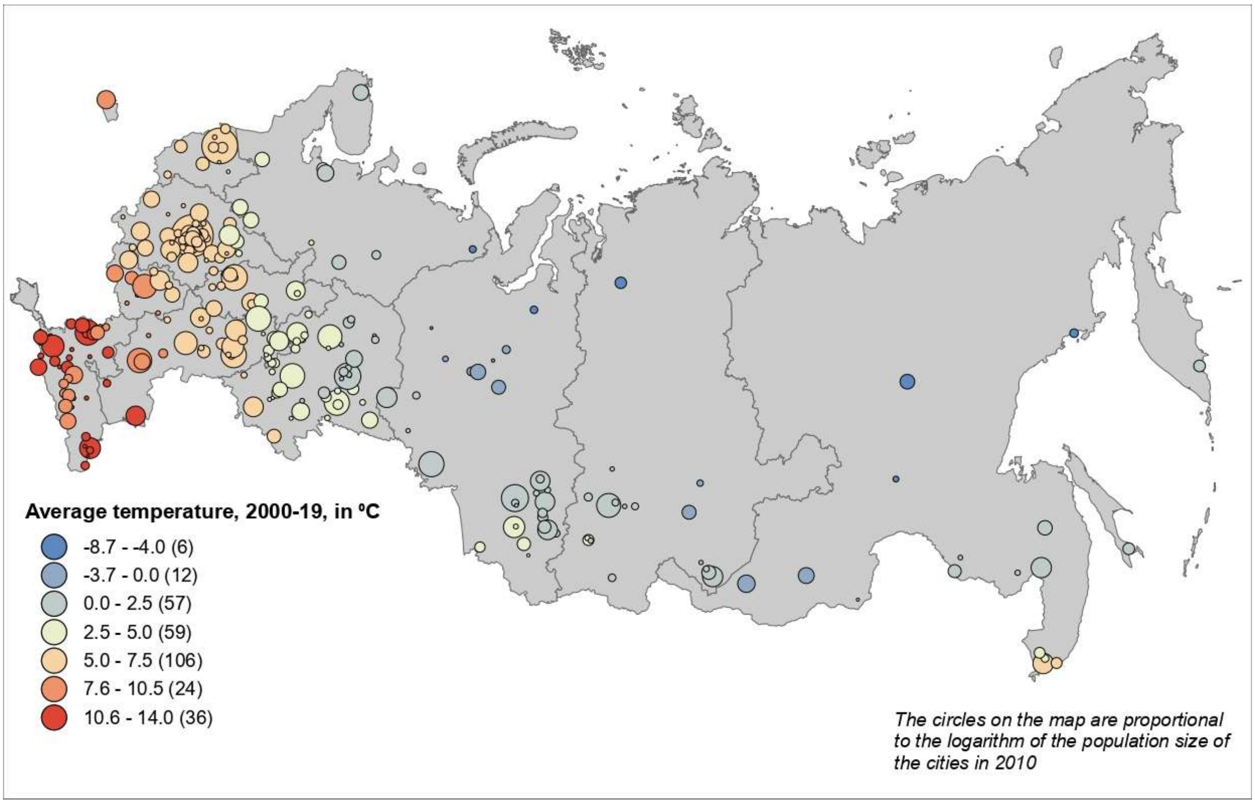


Figure S4: Mean annual temperature, average for 2000-2019.

Source: ERA5-Land reanalysis

A.4. Geographical distribution of meta-predictors

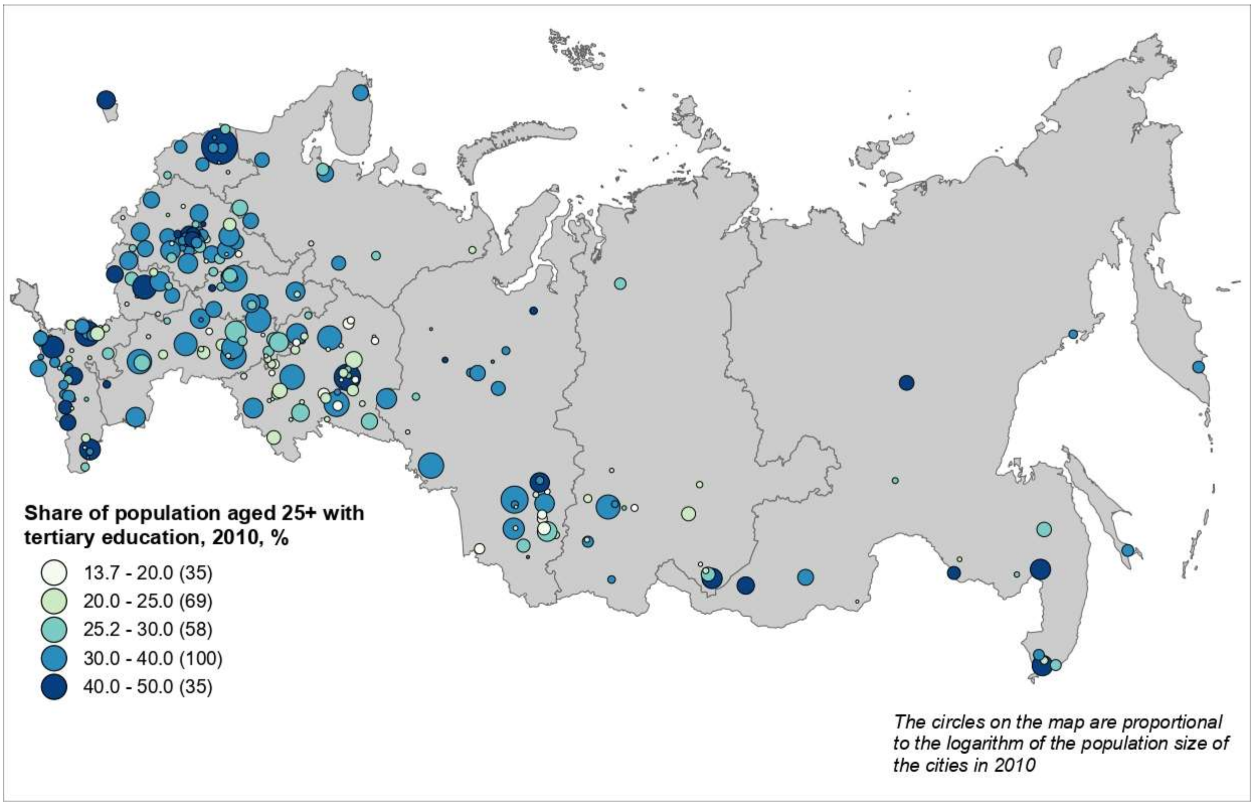


Figure S5: Share of population aged 25+ with tertiary education, both sexes, 2010.

Source: *2010 Russian population census*

Figure S6: Share of population aged 65 and over, both sexes, 2010.

***Source**: 2010 Russian population census*

B. Additional information on modeling

Table S1: First-stage sensitivity analysis.

Model		MMT (ºC)	Percentile of MMT	Akaike Information Criterion
Baseline model		19.23	88	9 576 057
Model with quadratic B-spline		20.64	92	9 577 012
Percentiles of temperature distribution	10, 25, 75, 90	19.57	88	9 577 075
	10,50,90	17.07	84	9 577 355
	10, 90	15.83	85	9 579 268
	25,75	15.51	84	9 579 390
Maximum lag	28	19.23	88	9 566 520
Model adjusted to relative humidity		19.23	88	9 576 856
Model adjusted to PM2.5		19.23	88	9 576 373
Model adjusted to ozone		19.23	87	9 576 231

Data source: Daily relative humidity was extracted from the ERA5-Land reanalysis. Daily concentrations of PM2.5 and ozone were extracted from the following dataset: "Xu, R., Ye, T., Yue, X. et al. (2023). Global population exposure to landscape fire air pollution from 2000 to 2019. Nature 621, 521–529".

Multilevel random-effect meta-analysis

The city-level results were transformed into regional-level aggregates using an approach that extends model to account nested levels of hierarchy[1,2]. The grouping factor was represented by economic regions and expressed a hierarchical structure of random effects, allowing for the consideration of risk variations across two nested levels: cities within economic regions. Best Linear Unbiased Predictions (BLUP) borrow information across units within the same hierarchical level, providing more accurate estimates, particularly in locations with small daily mortality counts or short time series.[3]

References:

1 Sera F, Gasparrini A. Extended two-stage designs for environmental research. *Environ Health* 2022; 21: **41**.

2 Sera F, Armstrong B, Blangiardo M, Gasparrini A. An extended mixed-effects framework for meta-analysis. *Statistics in Medicine* 2019; **38**: 5429–44.

3 Vicedo-Cabrera AM, Sera F, Liu C, et al. Short term association between ozone and mortality: global two stage time series study in 406 locations in 20 countries. *BMJ* 2020; : m108.

Table S2: Significance test for predictors (p-value) and I-square statistic in multivariate random-effect meta-regression models

Model	**Predictor**	**P-value test for predictor**	**I-square statistic**
Intercept only	--	--	43.7%
Single predictor	Mean annual temperature	<0.001	29.1%
	Temperature interquartile range	0.003	42.5%
	Population	0.19	43.1%
	Population in age over 65 (%)	0.003	40.9%
	Population with higher level of education (%)	0.002	42.6%
	GDP	0.07	42.6%
Baseline model	Intercept	<0.001	23%
	Mean annual temperature	<0.001	
	Temperature interquartile range	<0.001	
	Population	0.07	
	Population in age over 65 (%)	0.01	
	Population with higher level of education (%)	0.04	
Baseline model with GDP	Intercept	<0.001	23.2%
	Mean annual temperature	<0.001	
	Temperature interquartile range	<0.001	
	Population	0.29	
	Population in age over 65 (%)	0.84	
	Population with higher level of education (%)	0.01	
	GDP	0.94	
Baseline model with GDP and without population	Intercept	<0.001	23.4%
	Mean annual temperature	<0.001	
	Temperature interquartile range	<0.001	
	Population in age over 65 (%)	0.025	
	Population with higher level of education (%)	0.03	
	GDP	0.27	
Baseline model without GDP and population	Intercept	<0.001	23.9%
	Mean annual temperature	<0.001	
	Temperature interquartile range	<0.001	
	Population in age over 65 (%)	0.006	
	Population with higher level of education (%)	0.02	

B.1. Sensitivity analysis to heat wave 2010

For the calculation of the exposure-lag-response associations of the main analyses, we excluded deaths in European Russia in July and August 2010 due to the high sensitivity of results to an extensive, intense and persistent heat wave observed during this period.[1] However, the mortality associated with this event was included in the calculation of attributable fractions and numbers.

The cities to be excluded were defined according to the temperature anomaly (more than 1.5 ºC) in July-August 2010 compared to average for the same months in 1961-1990. In total, the data for 231 cities in European Russia were excluded from the main analysis.

We show here the comparison of some results obtained with July and August 2010 remaining in the analysis.

References:

1 Dole R, Hoerling M, Perlwitz J, *et al.* Was there a basis for anticipating the 2010 Russian heat wave?: THE 2010 RUSSIAN HEAT WAVE. *Geophys Res Lett* 2011; **38**: n/a-n/a

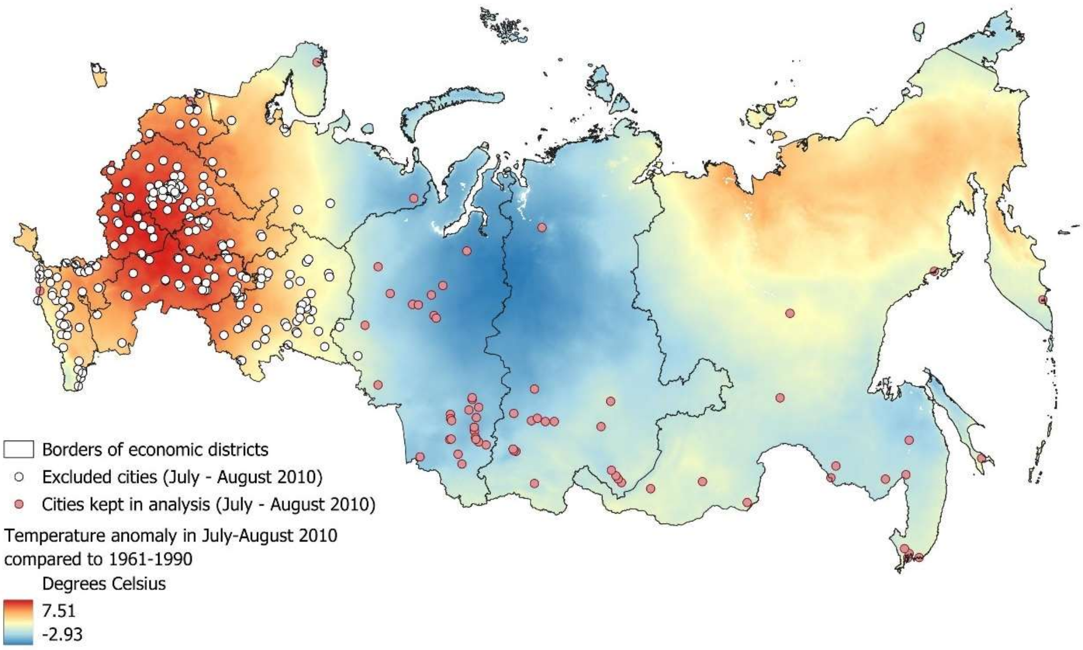


Figure S5: Map of cities excluded from main analysis for the period July-August 2010

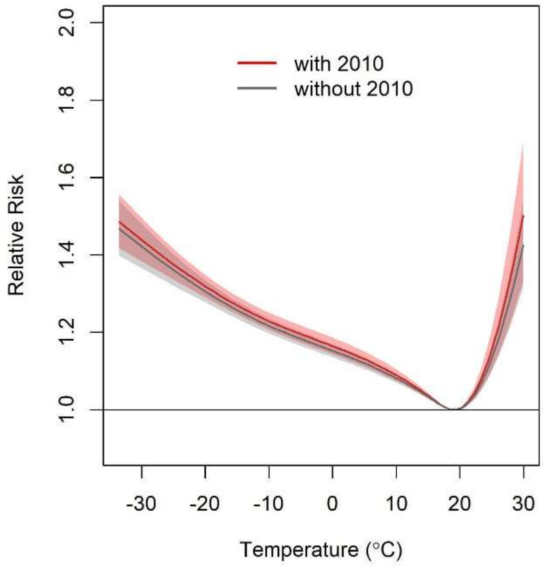
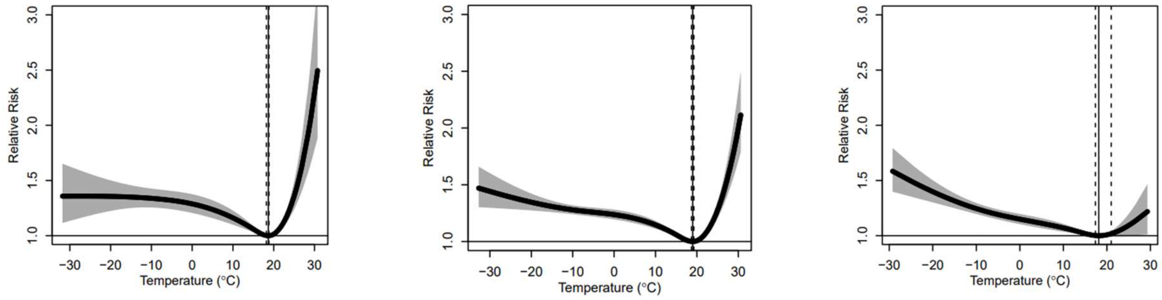


Figure S6: Pooled associations between daily temperature and non-accidental mortality, with and without July and August 2010 in the model

Note: Shaded areas denote 95% confidence interval of relative risks (RRs)

Moscow Nizhniy Novgorod St. Petersburg

With July and August 2010 in the model



Without July and August 2010 in the model

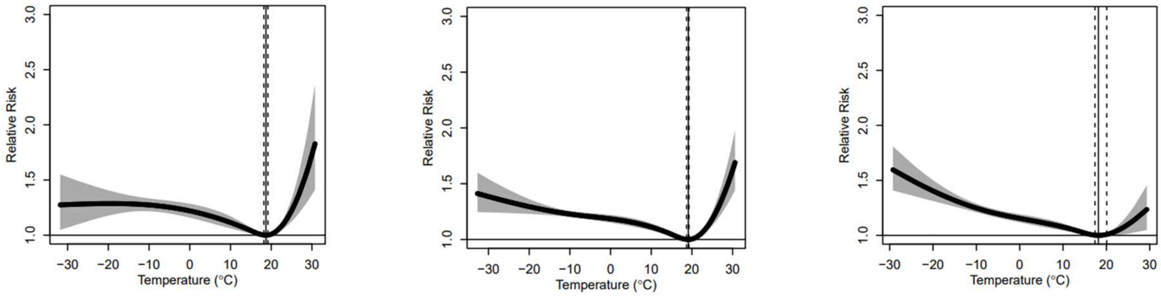
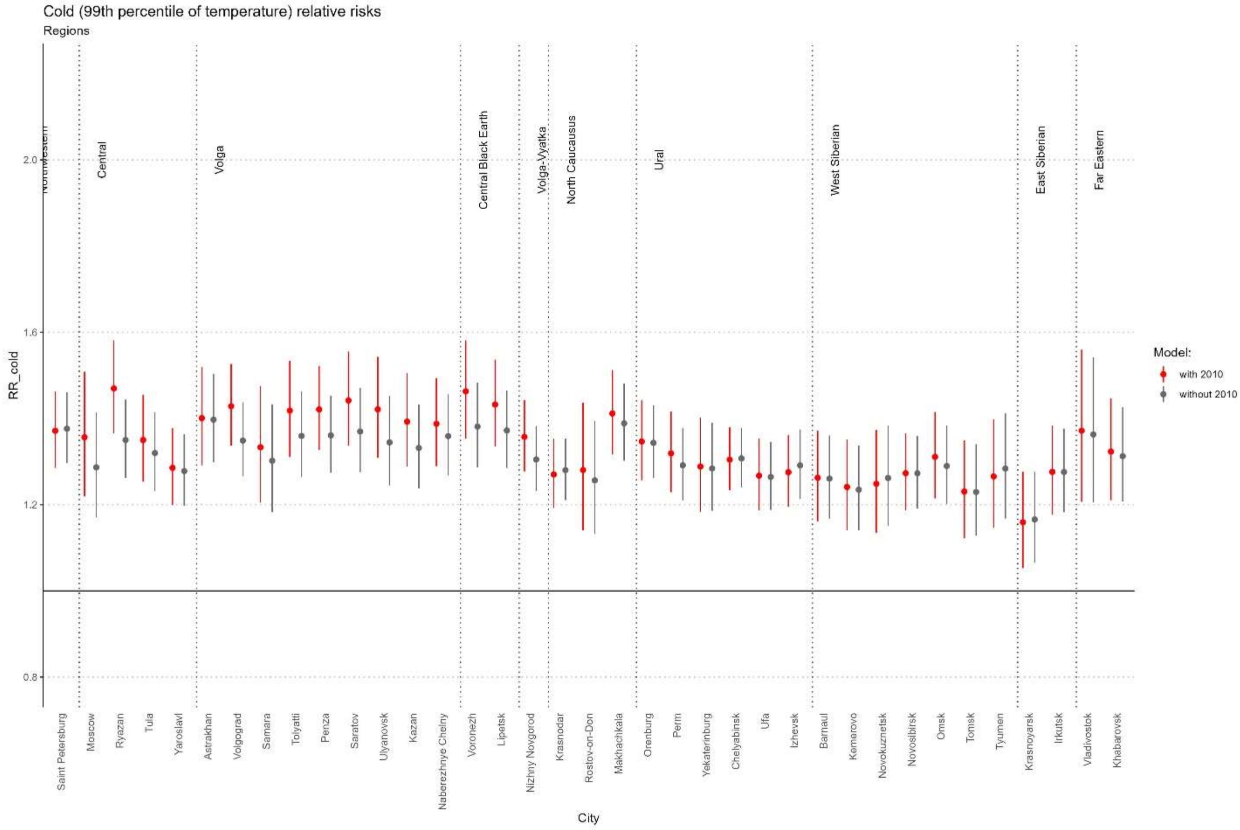


Figure S7: Pooled associations between daily temperature and non-accidental mortality in some major cities most affected by the heat wave 2010 (Moscow, Nizhniy Novgorod) and those less affected (St. Petersburg)

Note*: Solid vertical lines denote minimum mortality temperature (MMT) and dashed vertical lines denote 95% eCI of MMT for the subgroups. Shaded areas denote 95% confidence interval of relative risks (RRs)*

A



B

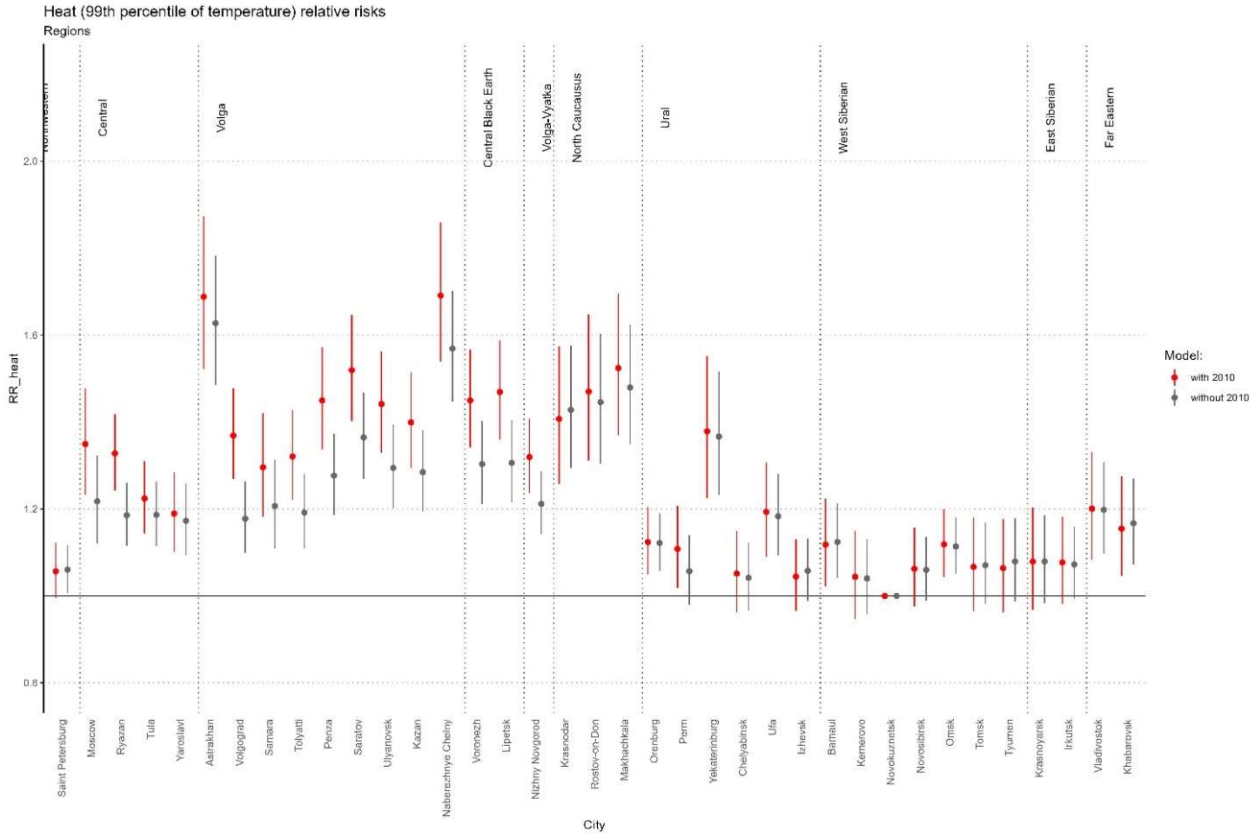


Figure S8: Cold (first percentile of temperature) (A) and heat (99th percentile of temperature) relative risks (RRs) (B) in most populated cities (more than 500,000 population), with and without July and August 2010 in the model

Table S3: Total mortality attributable fractions (AF) of deaths to the heat and cold in cities divided by different regions of Russia, with and without July and August 2010 in the model

Region	Cold, % (95% CI)		Heat, % (95% CI)	
	Without July and August 2010 in the model	**With July and August 2010 in the model**	**Without July and August 2010 in the model**	**With July and August 2010 in the model**
All cities	10.47 (8.80, 11.99)	11.51 (9.19, 13.78)	0.67 (0.42, 0.88)	0.81 (0.49, 1.14)
Northwestern	9.84 (7.55, 11.96)	9.69 (7.14, 12.20)	0.18 (-0.00, 0.35)	0.17 (-0.02, 0.38)
Central	10.78 (9.11, 12.24)	12.67 (9.62, 15.87)	0.66 (0.49, 0.80)	0.90 (0.60, 1.21)
West Siberian	9.73 (7.91, 11.56)	9.84 (8.55, 11.03)	0.24 (-0.05, 0.49)	0.23 (-0.07, 0.53)
North Caucausus	9.25 (7.27, 10.91)	9.66 (6.81, 12.65)	1.36 (1.05, 1.60)	1.39 (0.94, 1.85)
East Siberian	10.42 (8.13, 12.60)	10.51 (8.04, 12.80)	0.33 (-0.04, 0.66)	0.34 (-0.07, 0.76)
Far Eastern	12.52 (10.15, 14.85)	12.97 (11.19, 14.70)	0.59 (0.26, 0.88)	0.58 (0.15, 1.01)
Northern	14.01 (10.54, 17.50)	14.19 (10.51, 17.61)	0.08 (-0.08, 0.22)	0.10 (-0.07, 0.27)
Volga	10.82 (9.25, 12.35)	12.89 (10.49, 15.31)	1.24 (0.97, 1.46)	1.59 (1.27, 1.93)
Central Black Earth	10.35 (7.76, 12.54)	12.47 (9.95, 15.11)	1.02 (0.69, 1.30)	1.35 (1.05, 1.66)
Volga-Vyatka	10.51 (8.31, 12.53)	12.33 (10.13, 14.68)	0.75 (0.41, 1.04)	1.05 (0.74, 1.36)
Kaliningrad	8.03 (4.99, 10.80)	8.90 (5.51, 12.10)	0.28 (-0.13, 0.62)	0.34 (-0.08, 0.76)
Ural	10.13 (8.82, 11.42)	10.30 (8.18, 12.20)	0.43 (0.20, 0.62)	0.45 (0.10, 0.82)

Table S10: Total attributable numbers (AN) of deaths to the heat and cold in cities divided by different regions of Russia, with and without July and August 2010 in the model

Region	Cold, deaths		Heat, deaths	
	Without July and August 2010 in the model	**With July and August 2010 in the model**	**Without July and August 2010 in the model**	**With July and August 2010 in the model**
All cities	99631 (83731, 114145)	109543 (87522, 131142)	6376 (4014, 8345)	7724 (4629, 10893)
Northwestern	7440 (5711, 9038)	7325 (5396, 9226)	140 (-0, 265)	131 (-19, 288)
Central	28558 (24148, 32422)	33585 (25495, 42045)	1757 (1294, 2112)	2379 (1594, 3193)
West Siberian	8746 (7112, 10391)	8843 (7682, 9916)	216 (-44, 443)	206 (-63, 476)
North Caucausus	8036 (6317, 9476)	8389 (5912, 10988)	1177 (915, 1390)	1207 (815, 1605)
East Siberian	4546 (3546, 5495)	4585 (3504, 5584)	143 (-18, 288)	147 (-30, 332)
Far Eastern	4056 (3288, 4811)	4202 (3628, 4763)	191 (83, 285)	187 (48, 328)
Northern	3526 (2653, 4407)	3573 (2645, 4434)	21 (-19, 55)	25 (-18, 68)
Volga	12353 (10556, 14101)	14711 (11978, 17480)	1411 (1110, 1666)	1818 (1449, 2201)
Central Black Earth	4200 (3151, 5089)	5061 (4038, 6133)	414 (282, 526)	548 (426, 673)
Volga-Vyatka	4817 (3812, 5746)	5651 (4643, 6732)	344 (189, 477)	479 (340, 624)
Kaliningrad	433 (269, 583)	480 (297, 653)	15 (-7, 33)	18 (-5, 41)
Ural	12919 (11248, 14563)	13139 (10429, 15557)	547 (256, 791)	580 (125, 1043)

C. Additional results

C.1. Exposure–response associations

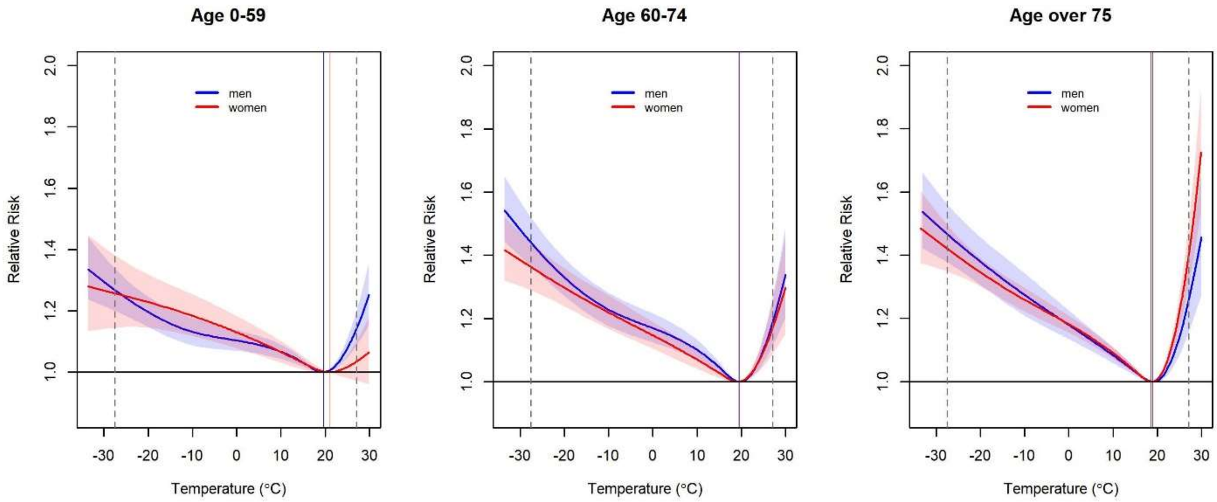


Figure S11: Pooled overall cumulative exposure–response relationship predicted for women and men at different ages

Note: Here and throughout dashed vertical lines denote the 1st and 99th percentiles of the temperature distributions. Solid vertical lines denote minimum mortality temperature (MMT) for the subgroups. Shaded areas denote 95% confidence interval of relative risks (RRs)

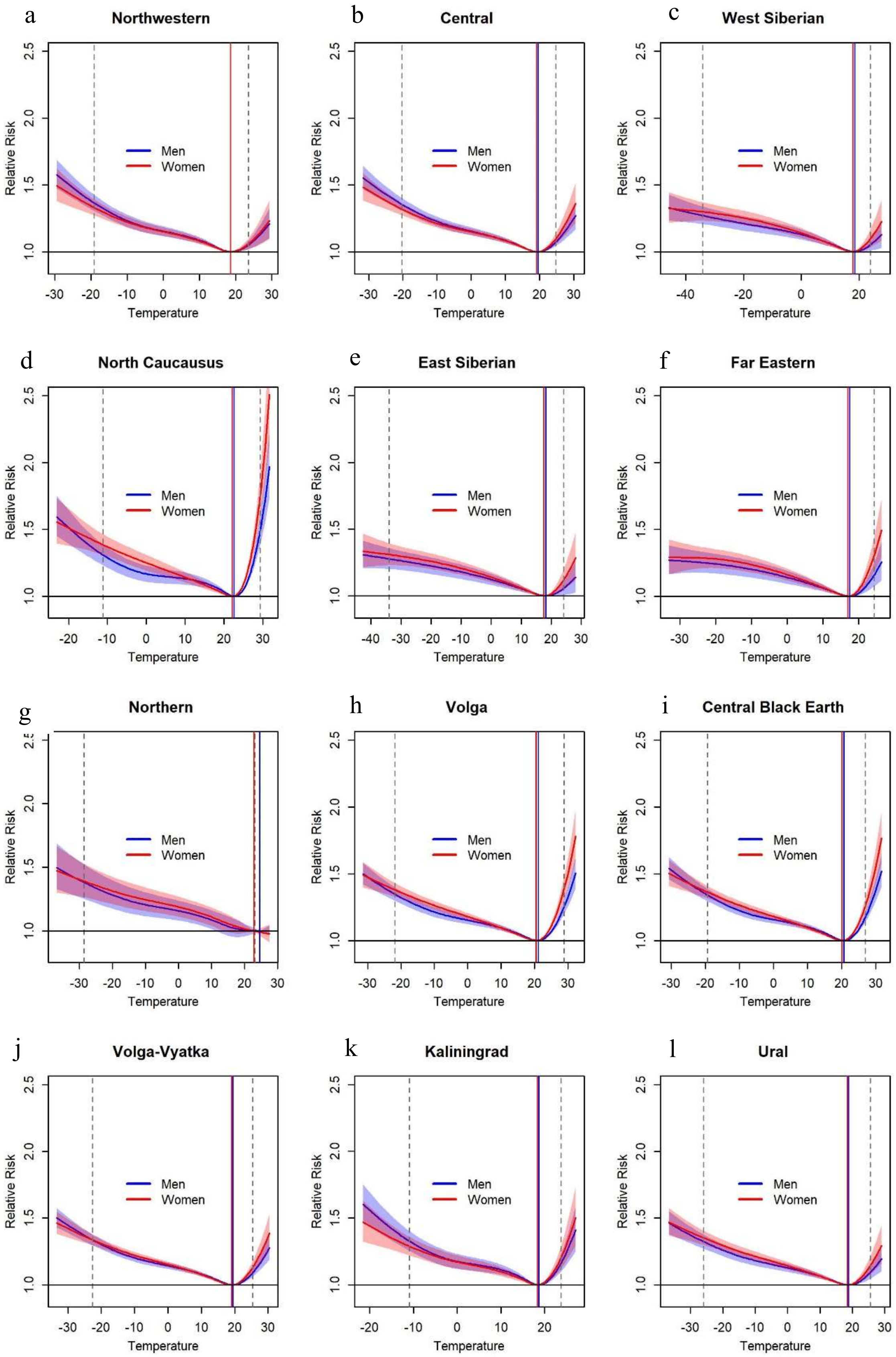


Figure S12: Pooled overall cumulative exposure–response relationship predicted for women and men at all ages according to various regions. *Note: European part – a, g (north and northwest); b, h, i, j (central), d (south); k – Kaliningrad (exclave between Lithuania and Poland). Ural – l. Siberia – c, e. Far East – f.*

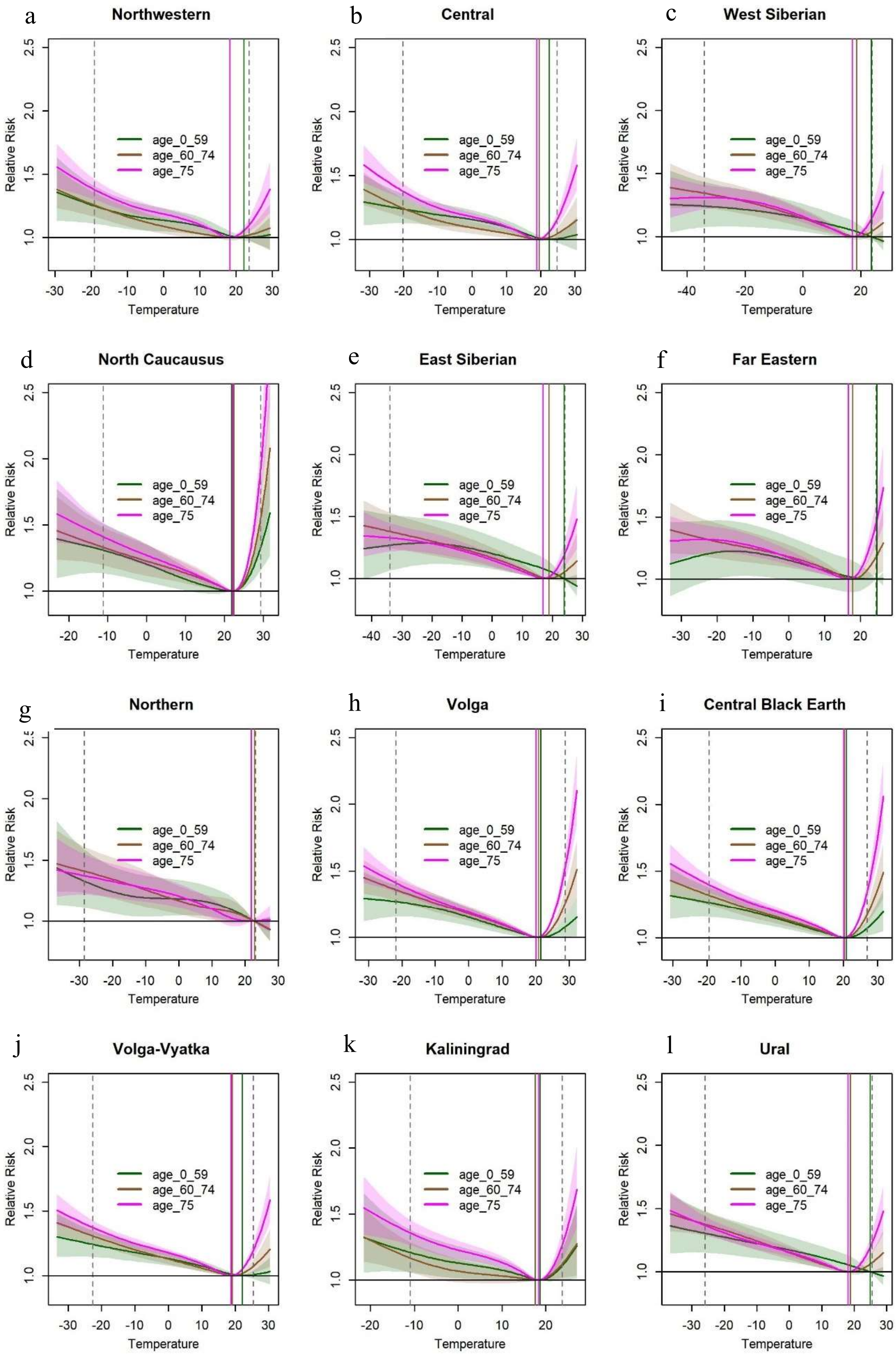


Figure S13: Pooled overall cumulative exposure–response relationship predicted for women at different age groups according to various regions. *Note: European part – a, g (north and northwest); b, h, i, j (central), d (south); k – Kaliningrad (exclave between Lithuania and Poland). Ural – l. Siberia – c, e. Far East – f.*

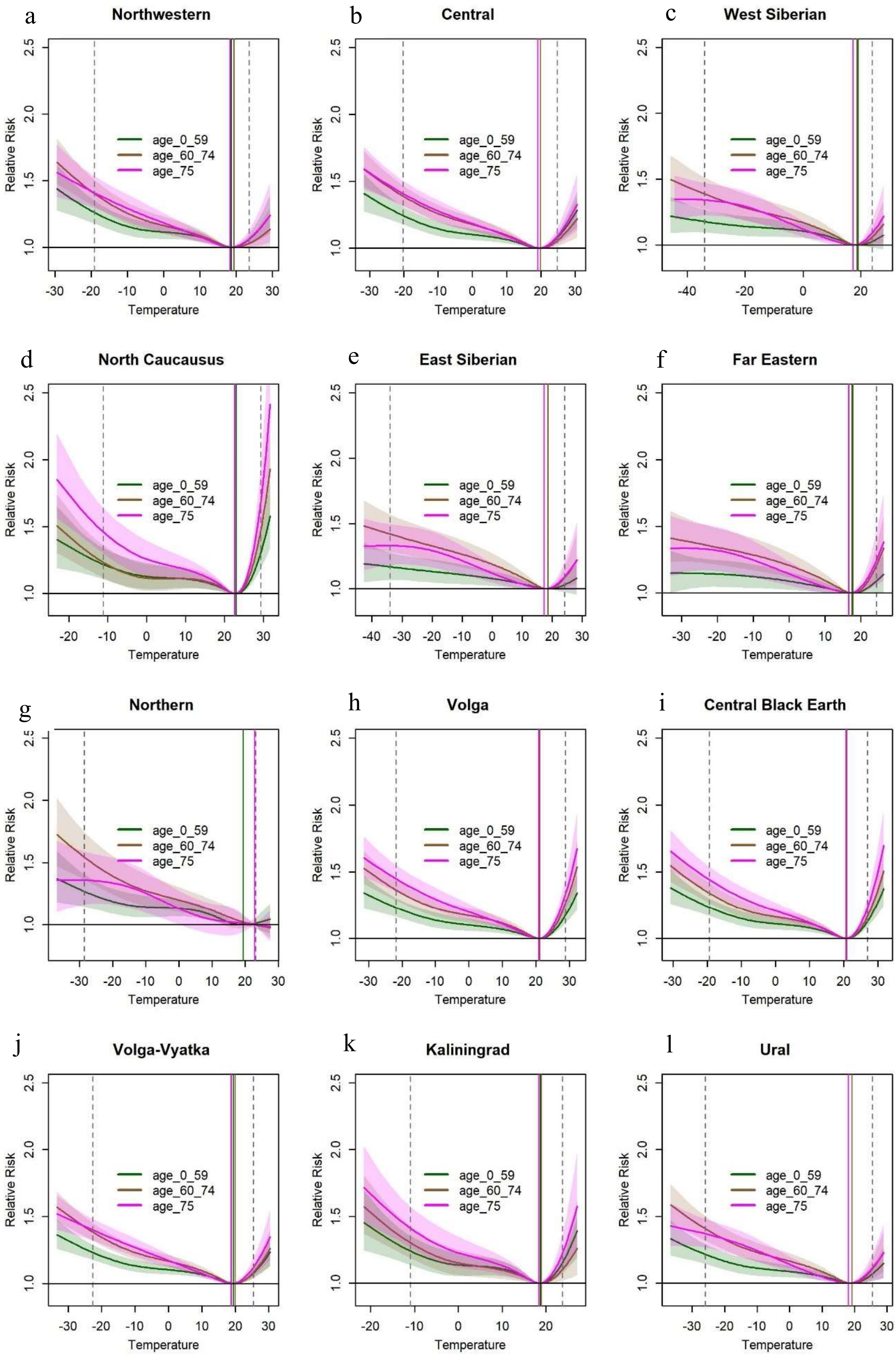


Figure S14: Pooled overall cumulative exposure–response relationship predicted for men at different age groups according to various regions. *Note: European part – a, g (north and northwest); b, h, i, j (central), d (south); k – Kaliningrad (exclave between Lithuania and Poland). Ural – l. Siberia – c, e. Far East – f.*

C.2. Minimum Mortality Temperature

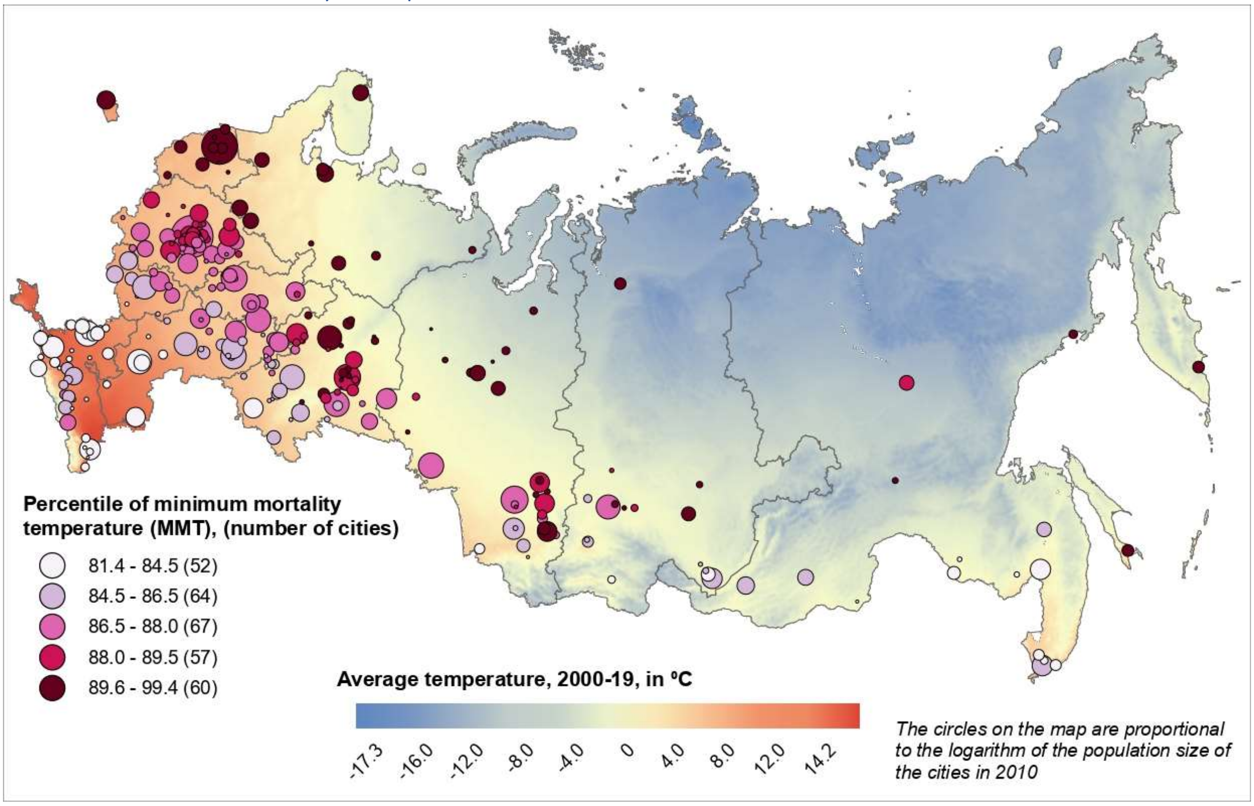


Figure S15: Percentile of MMT for both sexes at all ages across the 300 major Russian cities, 2000-19

C.3. Relative risk ratios

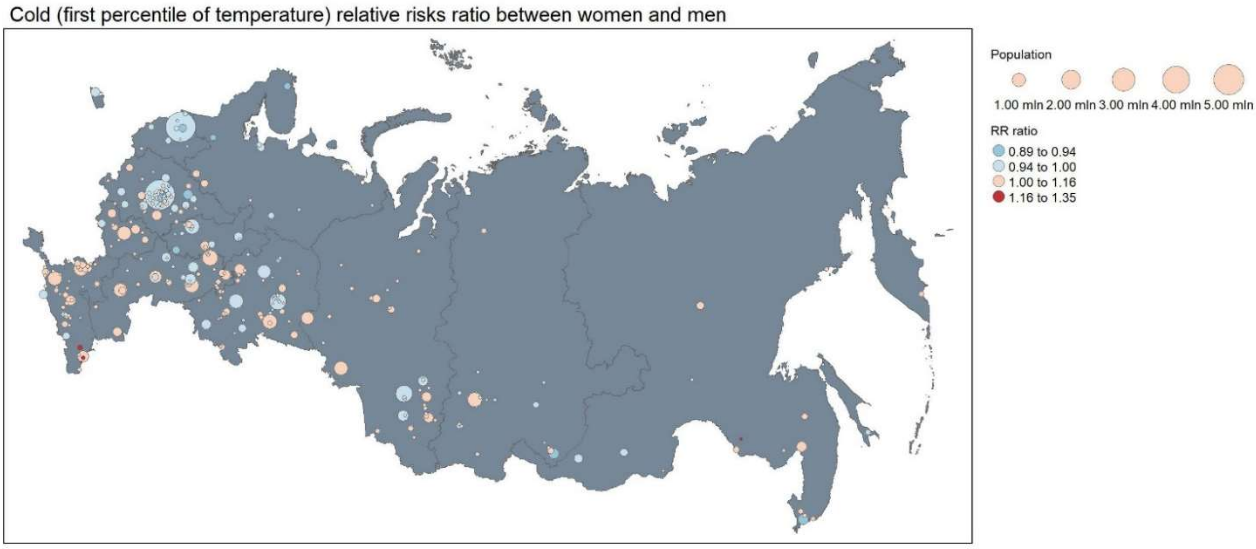


Figure S16: Cold-related relative risk ratio (first percentile of temperature distribution), males to females, all ages, 2000-19

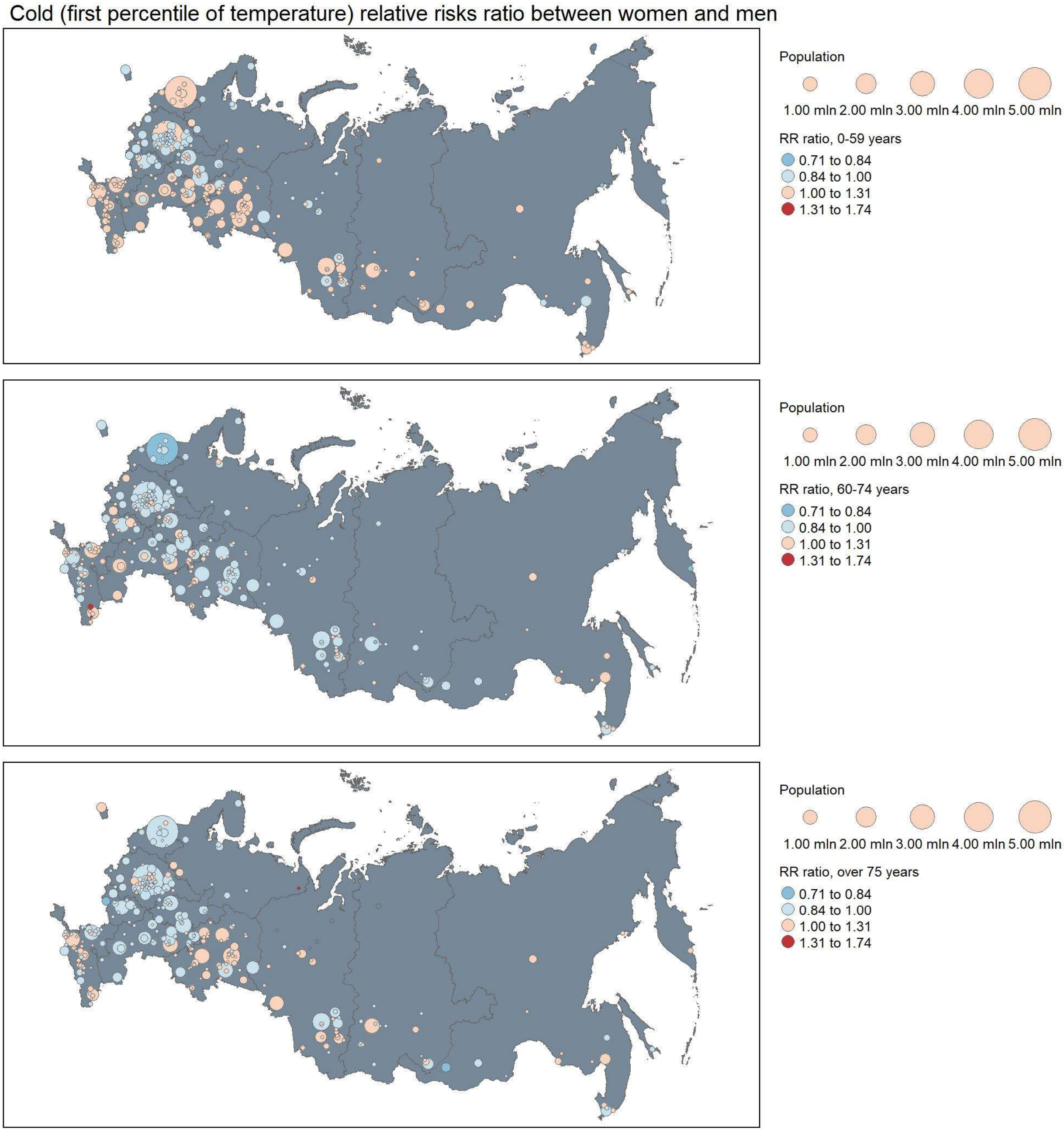


Figure S17: Cold-related relative risk ratio (first percentile of temperature distribution), males to females, different age groups, 2000-19.

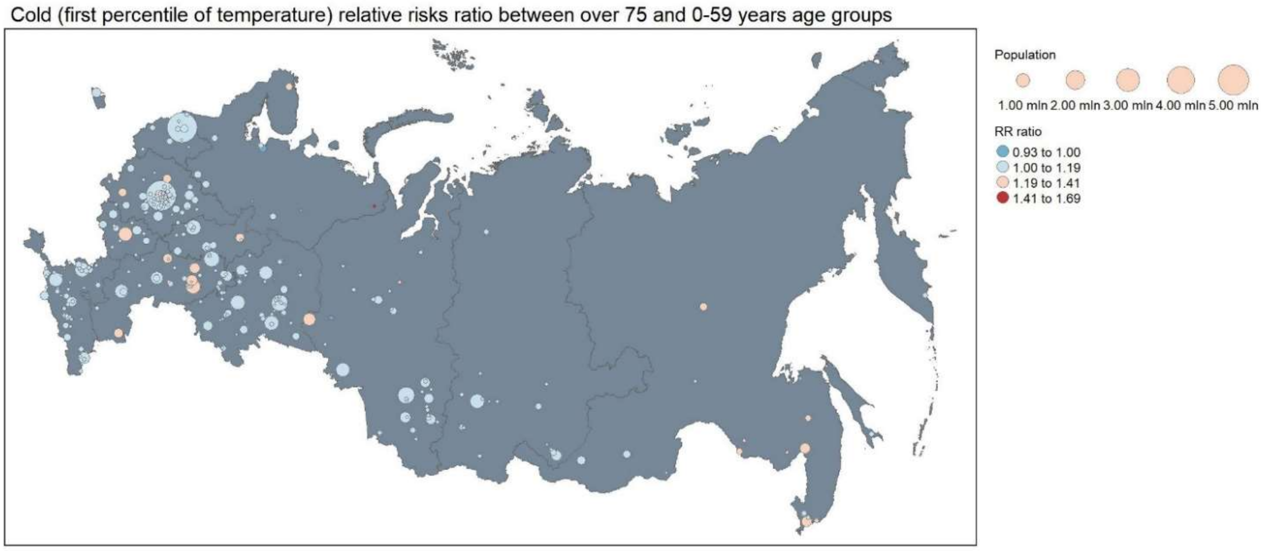


Figure S18: Cold-related relative risk ratio (first percentile of temperature distribution), 75+ to 0-59 years, 2000-19.

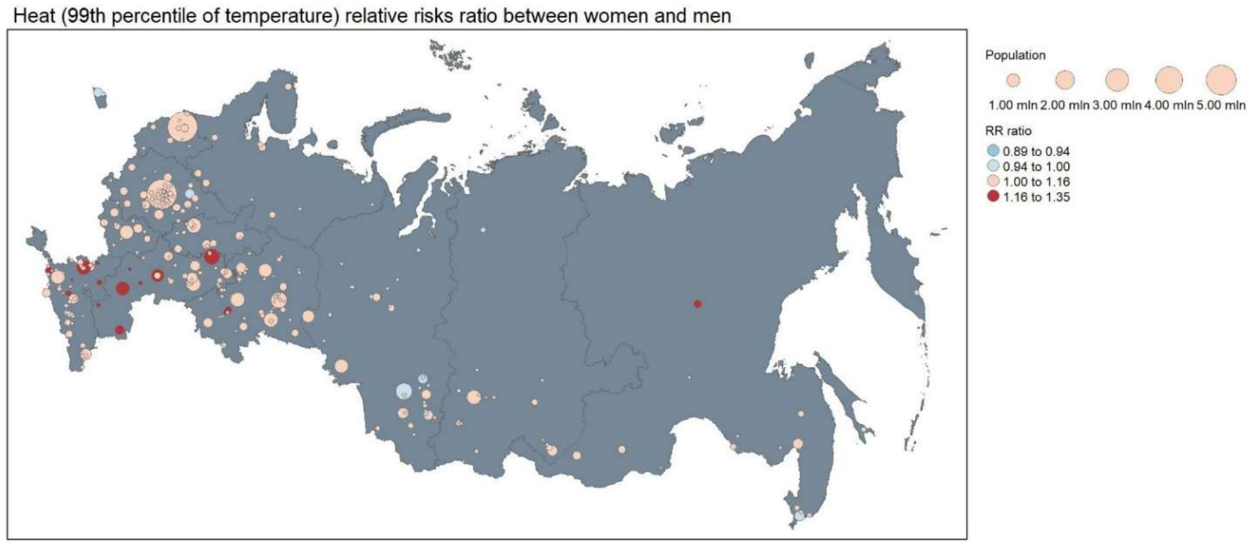


Figure S19: Heat-related relative risk ratio (99th percentile of temperature distribution), males to females, all ages, 2000-19.

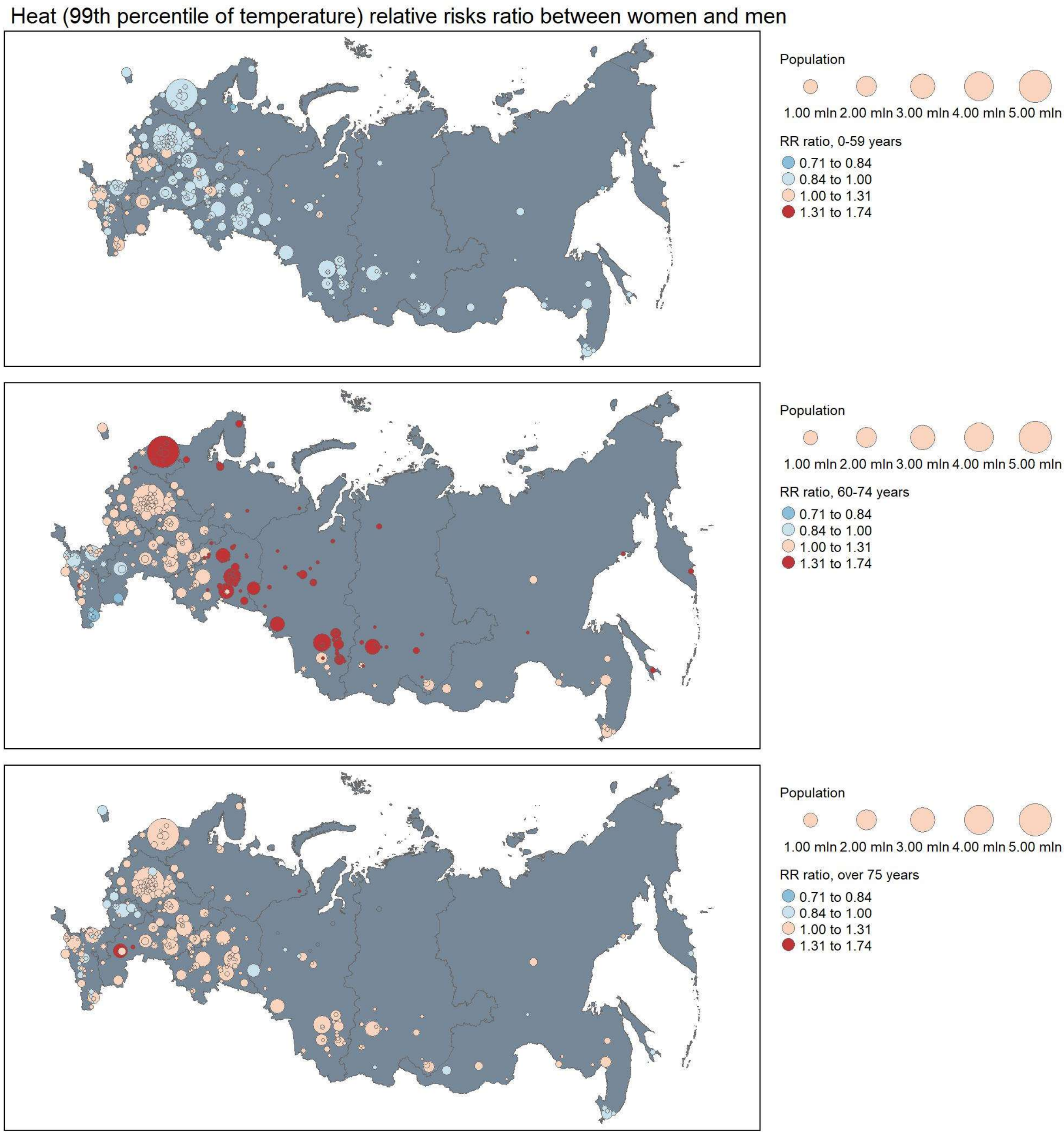


Figure S20: Heat-related relative risk ratio (99th percentile of temperature distribution), males to females, different age groups, 2000-19.

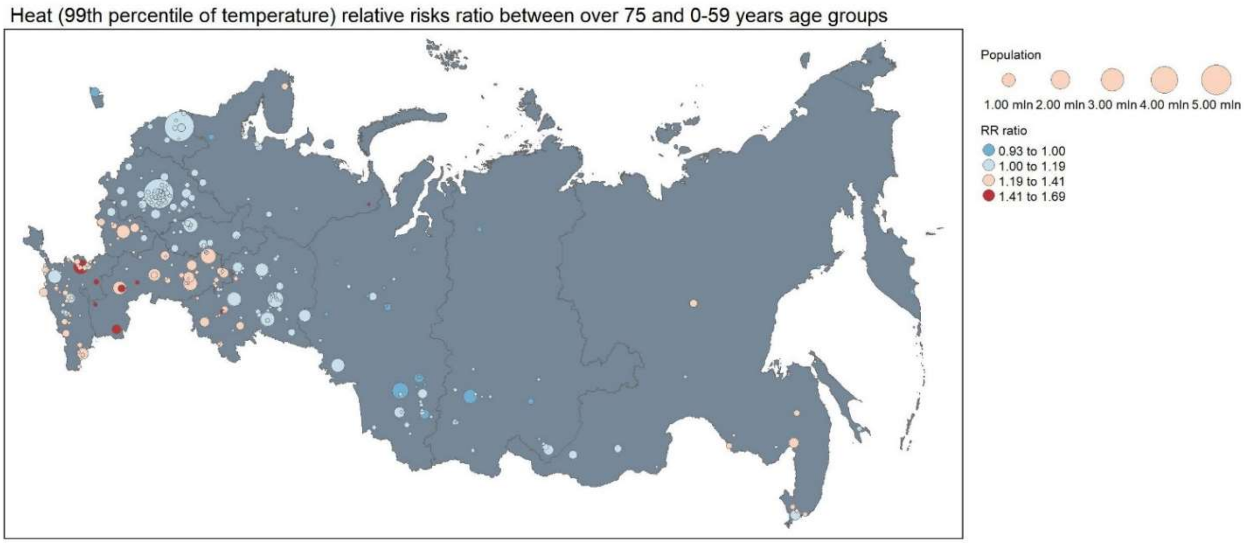


Figure S21: Heat-related relative risk ratio (99th percentile of temperature distribution), 75+ to 0-59 years, 2000-19

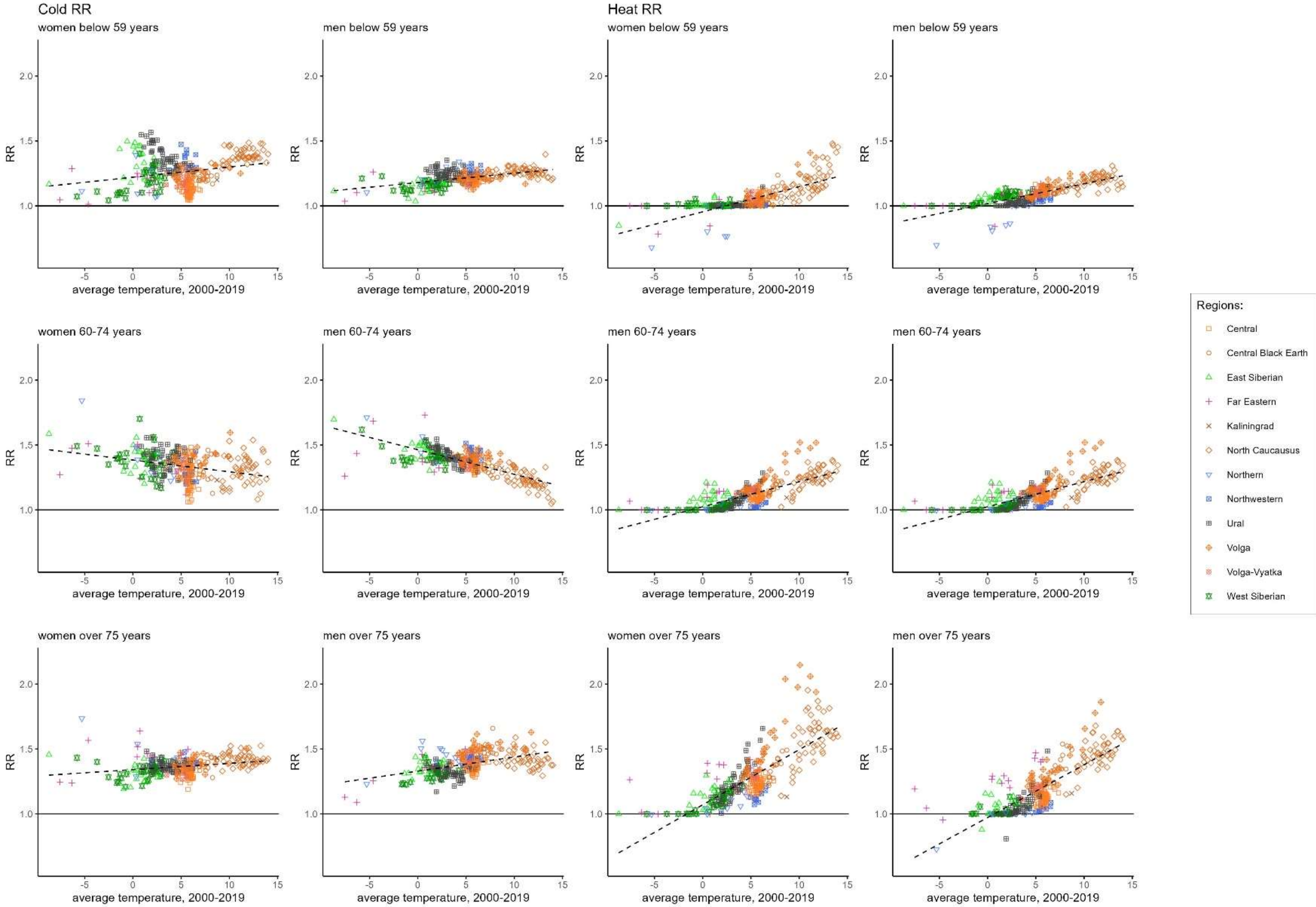
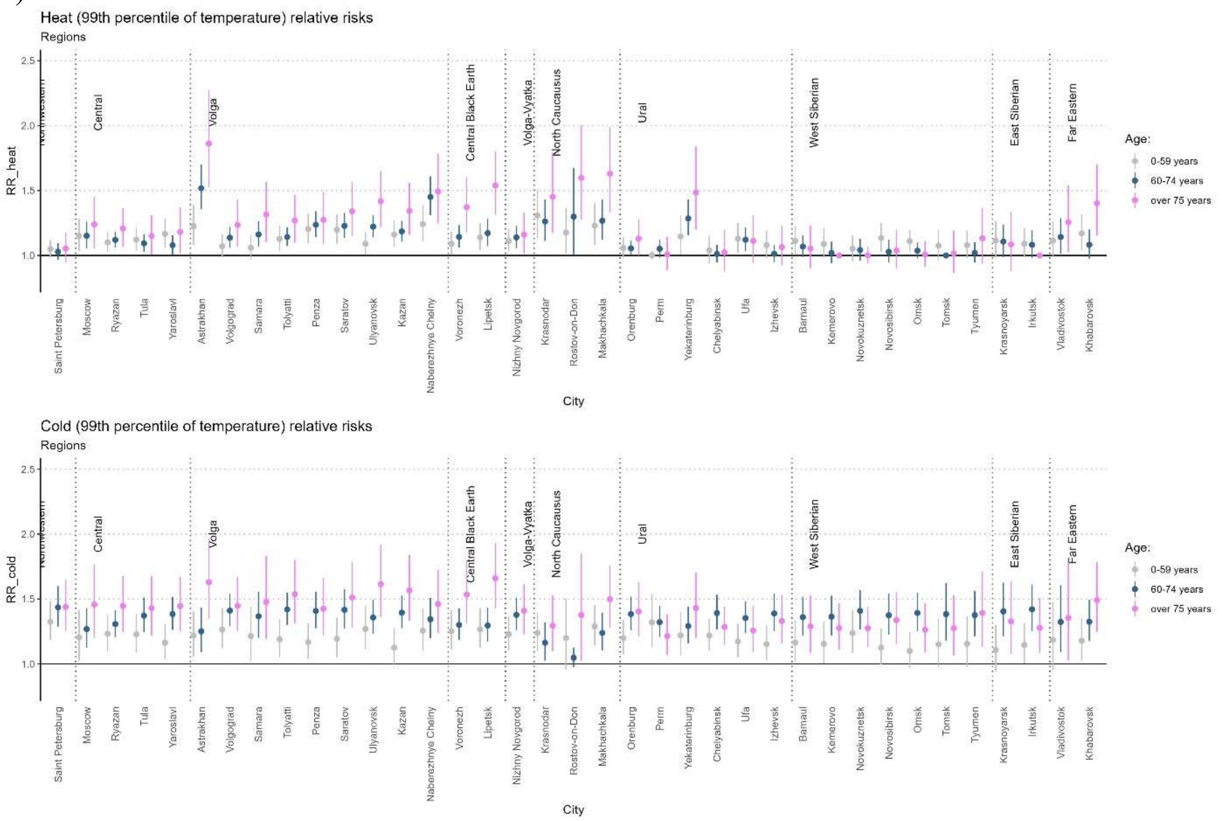


Figure S22: Relative risks (RRs) for temperature associated mortality for women and men at all ages across different ages in 300 major Russian cities, 2000-19

C.4. Relative risks in most populated cities

a)



b)

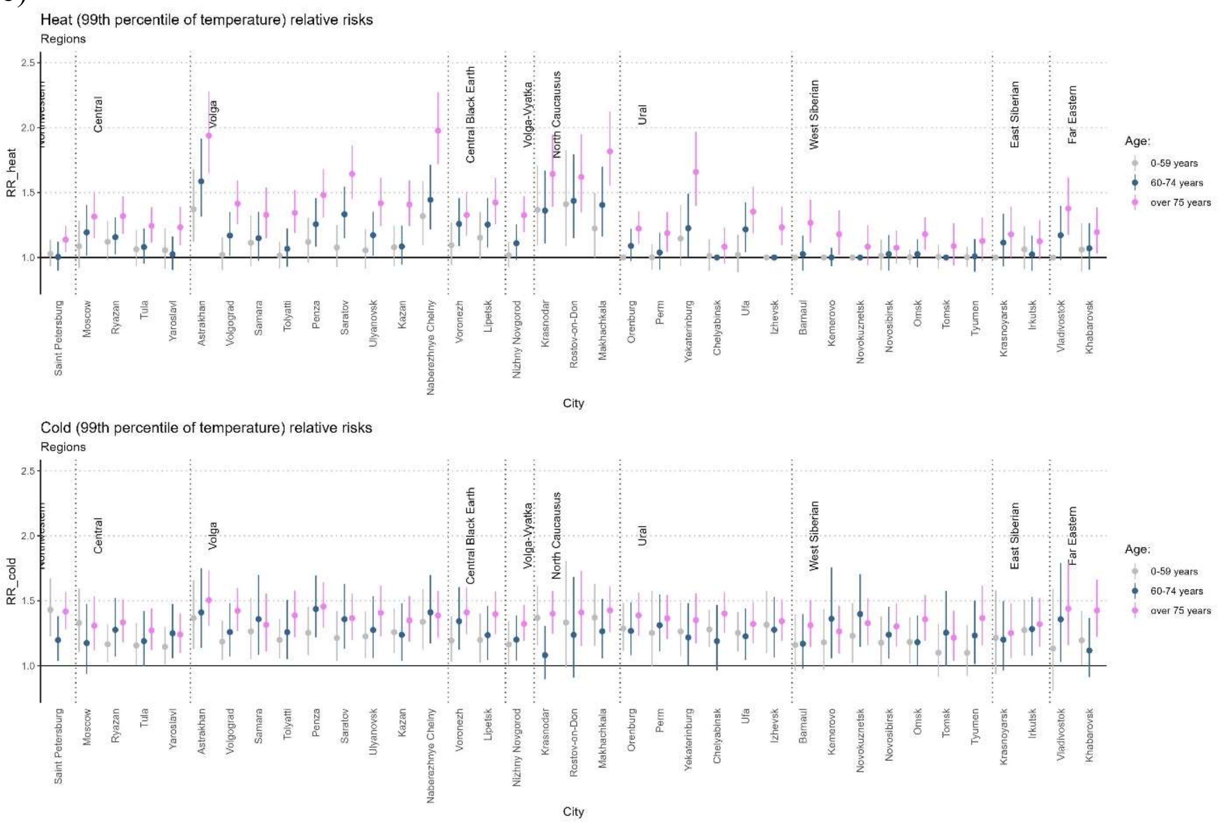


Figure S23: Relative risks (RRs) for temperature associated mortality for most populated cities (more than 500,000 population) for men (a) and women (b) at all ages

C.5. Attributable fractions and attributable numbers of deaths

Table S11: Region-level attributable fractions for cold and heat for the population across different age groups, 2000-19

	Cold			Heat		
Region	**Women (95%CI)**	**Men (95%CI)**	**Ratio**	**Women (95%CI)**	**Men (95%CI)**	**Ratio**
All ages						
All cities	10.63 (8.72, 12.62)	10.30 (7.26, 13.13)	1.03	0.81 (0.67, 0.94)	0.51 (0.22, 0.78)	1.59
Northern	13.42 (8.60, 17.85)	13.72 (9.84, 17.43)	0.98	0.11 (-0.10, 0.33)	0.04 (-0.11, 0.18)	2.75
Northwestern	9.47 (7.24, 11.66)	10.35 (6.94, 13.63)	0.91	0.25 (0.10, 0.40)	0.11 (-0.07, 0.28)	2.27
Kaliningrad	8.00 (4.84, 11.24)	9.41 (4.94, 13.53)	0.85	0.35 (-0.19, 0.88)	0.40 (-0.00, 0.76)	0.88
Central	10.70 (8.00, 13.25)	10.98 (7.00, 14.68)	0.97	0.78 (0.43, 1.07)	0.53 (0.23, 0.80)	1.47
Central Black Earth	10.50 (8.09, 12.99)	9.58 (6.21, 12.68)	1.10	1.16 (0.72, 1.57)	0.72 (0.48, 0.96)	1.61
Volga	11.03 (9.41, 12.70)	10.61 (8.00, 13.03)	1.04	1.58 (1.37, 1.77)	0.90 (0.58, 1.17)	1.76
Volga-Vyatka	10.39 (8.37, 12.50)	10.45 (6.91, 13.83)	0.99	0.87 (0.45, 1.26)	0.55 (0.19, 0.86)	1.58
North Caucasus	10.27 (7.82, 12.70)	8.43 (6.19, 10.48)	1.22	1.63 (1.34, 1.88)	1.08 (0.75, 1.38)	1.51
Ural	10.33 (8.43, 12.13)	9.78 (6.88, 12.51)	1.06	0.57 (0.43, 0.68)	0.29 (-0.04, 0.60)	1.97
West Siberian	10.51 (7.98, 12.97)	9.04 (5.54, 12.33)	1.16	0.24 (-0.00, 0.47)	0.23 (-0.12, 0.56)	1.04
East Siberian	10.80 (8.02, 13.38)	10.82 (7.37, 14.26)	1.00	0.38 (-0.10, 0.84)	0.27 (-0.11, 0.61)	1.41
Far Eastern	12.69 (9.49, 15.86)	11.68 (7.79, 15.48)	1.09	0.64 (0.13, 1.15)	0.55 (0.19, 0.88)	1.16
ages 0-59 years						
All cities	10.52 (3.33, 16.42)	7.70 (4.39, 10.66)	1.37	0.19 (-0.35, 0.69)	0.37 (-0.01, 0.71)	0.51
Northern	5.86 (-3.13, 12.88)	4.21 (1.26, 6.92)	1.39	-0.74 (-4.10, 2.42)	-1.25 (-3.73, 0.87)	0.59
Northwestern	11.13 (4.14, 17.40)	8.45 (4.62, 12.23)	1.32	0.06 (-0.20, 0.32)	0.14 (-0.06, 0.32)	0.43
Kaliningrad	7.37 (-0.23, 14.52)	8.23 (3.60, 12.84)	0.90	0.20 (-0.50, 0.86)	0.46 (0.00, 0.86)	0.43
Central	9.61 (6.52, 12.29)	9.11 (6.51, 11.40)	1.05	0.24 (-0.36, 0.81)	0.48 (0.13, 0.81)	0.50
Central Black Earth	7.75 (3.49, 12.03)	6.99 (4.10, 9.82)	1.11	0.54 (-0.29, 1.33)	0.44 (0.10, 0.74)	1.23
Volga	9.48 (4.58, 14.07)	6.69 (3.20, 10.26)	1.42	0.48 (-0.24, 1.17)	0.60 (0.25, 0.91)	0.80
Volga-Vyatka	8.57 (2.08, 14.44)	7.61 (4.76, 10.41)	1.13	0.13 (-0.35, 0.60)	0.43 (0.06, 0.77)	0.30
North Caucasus	9.95 (4.50, 14.38)	7.91 (3.23, 12.36)	1.26	0.86 (-0.20, 1.87)	0.83 (0.21, 1.36)	1.04
Ural	13.52 (-0.77, 24.68)	6.84 (2.89, 10.27)	1.98	0.03 (-0.20, 0.25)	0.22 (-0.16, 0.55)	0.14
West Siberian	10.68 (-2.01, 20.96)	7.42 (3.39, 11.31)	1.44	0.01 (-0.22, 0.24)	0.35 (-0.08, 0.73)	0.03
East Siberian	14.48 (0.24, 25.52)	7.83 (2.91, 12.43)	1.85	0.01 (-0.40, 0.38)	0.32 (-0.23, 0.80)	0.03
Far Eastern	11.08 (-2.03, 20.61)	6.60 (0.96, 11.49)	1.68	-0.18 (-1.12, 0.74)	0.13 (-0.37, 0.59)	1.38
ages 60-74 years						
All cities	8.83 (4.49, 12.69)	11.15 (7.96, 13.78)	0.79	0.50 (-0.08, 1.04)	0.45 (0.16, 0.71)	1.11
Northern	11.23 (-1.54, 20.05)	13.44 (6.82, 19.25)	0.84	0.02 (-0.20, 0.22)	0.12 (-0.11, 0.32)	0.17
Northwestern	4.47 (-0.13, 8.55)	12.45 (6.98, 17.29)	0.36	0.04 (-0.41, 0.50)	0.08 (-0.09, 0.24)	0.50
Kaliningrad	4.25 (-2.27, 9.93)	9.25 (1.57, 15.69)	0.46	0.46 (-0.38, 1.29)	0.30 (-0.18, 0.70)	1.53
Central	7.64 (2.97, 11.85)	10.68 (7.95, 13.10)	0.72	0.52 (-0.10, 1.11)	0.41 (0.14, 0.67)	1.27

Central Black Earth	9.08 (4.27, 13.34)	9.25 (4.87, 13.05)	0.98	0.86 (0.19, 1.49)	0.60 (0.29, 0.87)	1.43
Volga	10.27 (5.68, 14.34)	13.21 (9.58, 16.30)	0.78	1.00 (0.28, 1.67)	0.90 (0.60, 1.17)	1.11
Volga-Vyatka	8.82 (4.25, 12.90)	12.76 (8.17, 16.85)	0.69	0.49 (-0.17, 1.11)	0.52 (0.23, 0.78)	0.94
North Caucasus	6.93 (1.21, 11.78)	5.18 (-1.00, 10.48)	1.34	1.15 (0.29, 1.92)	1.03 (0.39, 1.59)	1.12
Ural	10.60 (3.69, 15.87)	11.11 (8.38, 13.66)	0.95	0.27 (-0.17, 0.68)	0.24 (0.01, 0.45)	1.13
West Siberian	10.18 (1.74, 16.39)	11.22 (6.68, 15.32)	0.91	0.04 (-0.27, 0.34)	0.12 (-0.07, 0.29)	0.33
East Siberian	12.17 (7.59, 16.22)	15.11 (8.90, 20.36)	0.81	0.27 (-0.40, 0.90)	0.33 (-0.06, 0.70)	0.82
Far Eastern	11.25 (6.06, 15.74)	13.38 (8.25, 17.63)	0.84	0.36 (-0.39, 1.02)	0.39 (0.02, 0.73)	0.92
ages over 75 years						
All cities	11.73 (9.09, 14.31)	12.21 (5.64, 17.89)	0.96	1.09 (0.67, 1.47)	0.73 (0.20, 1.20)	1.49
Northern	14.45 (9.09, 19.48)	14.42 (4.77, 22.17)	1.00	0.24 (-0.03, 0.48)	0.00 (-0.32, 0.31)	"--"
Northwestern	11.84 (9.44, 14.07)	11.48 (4.91, 17.20)	1.03	0.39 (0.09, 0.67)	0.15 (-0.22, 0.52)	2.60
Kaliningrad	12.21 (7.61, 16.44)	12.07 (3.49, 19.09)	1.01	0.42 (-0.19, 0.94)	0.50 (-0.33, 1.27)	0.84
Central	11.98 (8.85, 15.23)	13.32 (5.60, 20.14)	0.90	0.99 (0.45, 1.45)	0.65 (0.11, 1.15)	1.52
Central Black Earth	11.29 (8.58, 14.18)	13.95 (7.12, 20.11)	0.81	1.35 (0.77, 1.89)	1.47 (0.86, 2.06)	0.92
Volga	11.62 (9.16, 13.92)	13.21 (7.52, 18.29)	0.88	2.02 (1.57, 2.45)	1.39 (1.00, 1.79)	1.45
Volga-Vyatka	11.00 (8.35, 13.76)	11.88 (4.85, 18.19)	0.93	1.12 (0.61, 1.54)	0.69 (-0.03, 1.35)	1.62
North Caucasus	11.56 (7.77, 14.92)	11.96 (3.08, 19.34)	0.97	2.01 (1.36, 2.63)	1.56 (0.72, 2.33)	1.29
Ural	11.18 (8.09, 14.18)	10.42 (4.91, 15.16)	1.07	0.92 (0.51, 1.31)	0.32 (-0.03, 0.63)	2.88
West Siberian	11.21 (8.32, 14.03)	10.03 (3.10, 16.08)	1.12	0.52 (0.13, 0.90)	0.10 (-0.34, 0.51)	5.20
East Siberian	11.55 (6.99, 15.79)	10.51 (3.13, 16.92)	1.10	0.55 (-0.04, 1.12)	0.17 (-0.45, 0.75)	3.24
Far Eastern	13.73 (9.24, 17.33)	13.00 (3.87, 20.59)	1.06	1.05 (0.51, 1.53)	1.15 (0.17, 2.10)	0.91

Table S12: Total mortality attributable fractions (AF) and attributable numbers (AN) of deaths to the heat and cold in 300 major Russian cities stratified by age and sex, 2000-19

	Cold			**Heat**		
Age group	**Women (95%CI)**	**Men (95%CI)**	**Both (95%CI)**	**Women (95%CI)**	**Men (95%CI)**	**Both (95%CI)**
			Attributable fraction			
all ages	10.63 (8.72, 12.62)	10.30 (7.26, 13.13)	10.47 (8.80, 11.99)	0.81 (0.67, 0.94)	0.51 (0.22, 0.78)	0.67 (0.42, 0.88)
0-59 years	10.52 (3.33, 16.42)	7.70 (4.39, 10.66)	8.48 (6.70, 10.04)	0.19 (-0.35, 0.69)	0.37 (-0.01, 0.71)	0.33 (-0.04, 0.71)
60-74 years	8.83 (4.49, 12.69)	11.15 (7.96, 13.78)	10.16 (8.56, 11.67)	0.50 (-0.08, 1.04)	0.45 (0.16, 0.71)	0.47 (0.19, 0.74)
over 75 years	11.73 (9.09, 14.31)	12.21 (5.64, 17.89)	11.81 (8.20, 15.41)	1.09 (0.67, 1.47)	0.73 (0.20, 1.20)	0.99 (0.51, 1.46)
			Attributable number			
all ages	52256 (42865, 62024)	47421 (33412, 60447)	99631 (83731, 114145)	3982 (3276, 4606)	2370 (1003, 3573)	6376 (4014, 8345)
0-59 years	7648 (2421, 11938)	12581 (7184, 17422)	20022 (15820, 23721)	141 (-251, 498)	598 (-18, 1154)	791 (-104, 1680)
60-74 years	11259 (5722, 16172)	19067 (13618, 23559)	30322 (25548, 34840)	638 (-105, 1324)	773 (281, 1213)	1404 (558, 2205)
over 75 years	34179 (26508, 41726)	15363 (7098, 22509)	49296 (34232, 64317)	3185 (1948, 4297)	913 (252, 1503)	4125 (2134, 6082)

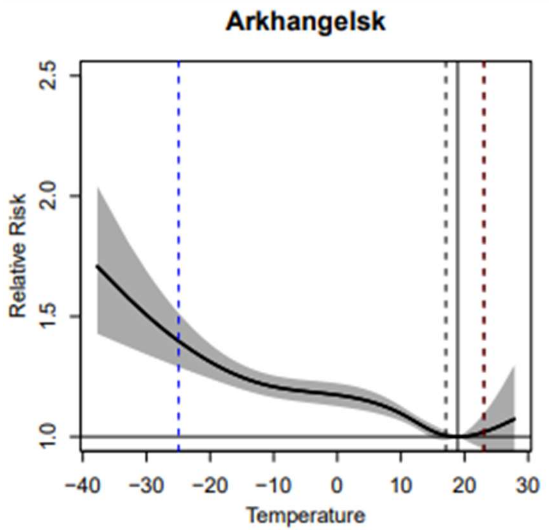
Table S13: Total mortality attributable fractions (AF) and attributable numbers (AN) of deaths to the heat and cold, including extreme cold and heat, in 300 major Russian cities stratified by regions, 2000-19

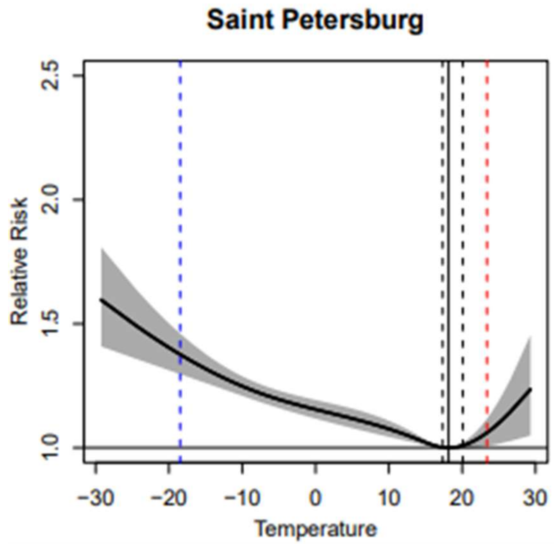
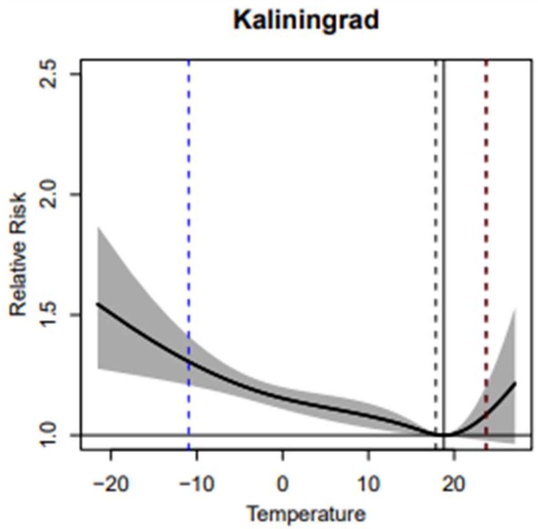
Region		**Attributable fraction**				**Attributable number**			
		Cold, % (95% CI)	**Extreme cold, % (95% CI)**	**Heat, % (95% CI)**	**Extreme heat, % (95% CI)**	**Cold, deaths**	**Extreme cold, deaths**	**Heat, deaths**	**Extreme heat, deaths**
All cities		10.47 (8.80, 11.99)	0.65 (0.51, 0.78)	0.67 (0.42, 0.88)	0.40 (0.25, 0.52)	99631 (83731, 114145)	6226 (4871, 7408)	6376 (4014, 8345)	3793 (2414, 4940)
The European part of Russia	Northern	14.01 (10.54, 17.50)	0.80 (0.62, 0.96)	0.08 (-0.08, 0.22)	0.07 (-0.03, 0.15)	3526 (2653, 4407)	201 (156, 242)	21 (-19, 55)	18 (-8, 39)
	Northwestern	9.84 (7.55, 11.96)	0.75 (0.61, 0.86)	0.18 (-0.00, 0.35)	0.15 (0.01, 0.27)	7440 (5711, 9038)	565 (465, 652)	140 (-0, 265)	112 (9, 204)
	Kaliningrad	8.03 (4.99, 10.80)	0.65 (0.47, 0.81)	0.28 (-0.13, 0.62)	0.20 (-0.06, 0.41)	433 (269, 583)	35 (25, 44)	15 (-7, 33)	11 (-3, 22)
	Central	10.78 (9.11, 12.24)	0.60 (0.45, 0.74)	0.66 (0.49, 0.80)	0.45 (0.33, 0.53)	28558 (24148, 32422)	1594 (1188, 1951)	1757 (1294, 2112)	1186 (879, 1413)
	Central Black Earth	10.35 (7.76, 12.54)	0.69 (0.54, 0.83)	1.02 (0.69, 1.30)	0.63 (0.43, 0.80)	4200 (3151, 5089)	280 (218, 337)	414 (282, 526)	255 (176, 323)
	Volga	10.82 (9.25, 12.35)	0.70 (0.55, 0.83)	1.24 (0.97, 1.46)	0.68 (0.53, 0.81)	12353 (10556, 14101)	799 (625, 949)	1411 (1110, 1666)	776 (607, 919)
	Volga-Vyatka	10.51 (8.31, 12.53)	0.61 (0.47, 0.72)	0.75 (0.41, 1.04)	0.48 (0.27, 0.65)	4817 (3812, 5746)	278 (216, 332)	344 (189, 477)	220 (126, 299)
	North Caucasus	9.25 (7.27, 10.91)	0.75 (0.60, 0.87)	1.36 (1.05, 1.60)	0.69 (0.53, 0.82)	8036 (6317, 9476)	647 (524, 753)	1177 (915, 1390)	598 (457, 711)
Ural	Ural	10.13 (8.82, 11.42)	0.66 (0.55, 0.76)	0.43 (0.20, 0.62)	0.24 (0.11, 0.35)	12919 (11248, 14563)	843 (701, 973)	547 (256, 791)	309 (142, 442)
Siberia	West Siberian	9.73 (7.91, 11.56)	0.58 (0.46, 0.68)	0.24 (-0.05, 0.49)	0.14 (-0.02, 0.28)	8746 (7112, 10391)	518 (411, 611)	216 (-44, 443)	127 (-17, 247)
	East Siberian	10.42 (8.13, 12.60)	0.54 (0.35, 0.70)	0.33 (-0.04, 0.66)	0.19 (-0.01, 0.36)	4546 (3546, 5495)	237 (155, 304)	143 (-18, 288)	83 (-4, 158)

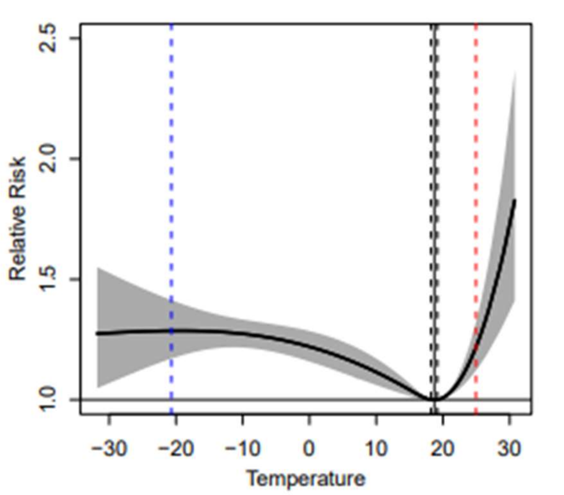
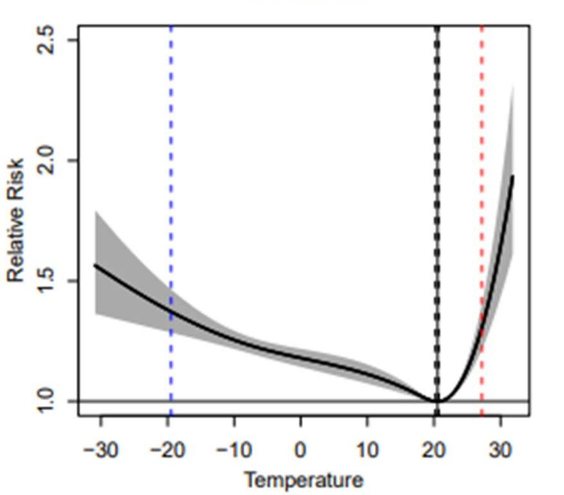
The Far East	Far Eastern	12.52 (10.15, 14.85)	0.70 (0.46, 0.92)	0.59 (0.26, 0.88)	0.31 (0.14, 0.45)	4056 (3288, 4811)	228 (149, 298)	191 (83, 285)	100 (46, 145)

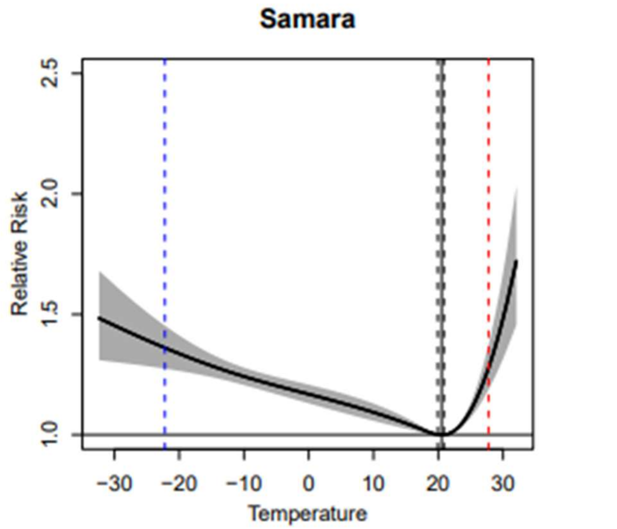
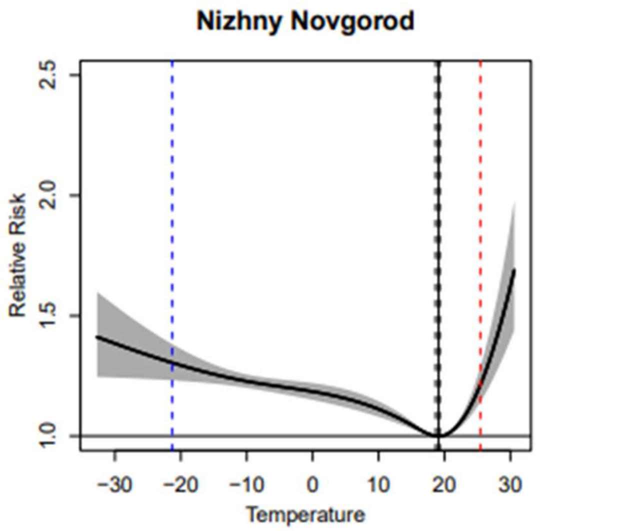
Note: extreme cold and heat defined as temperatures lower than 2.5th location-specific percentile (extreme cold) and higher that 97.5th location-specific percentiles (extreme heat)

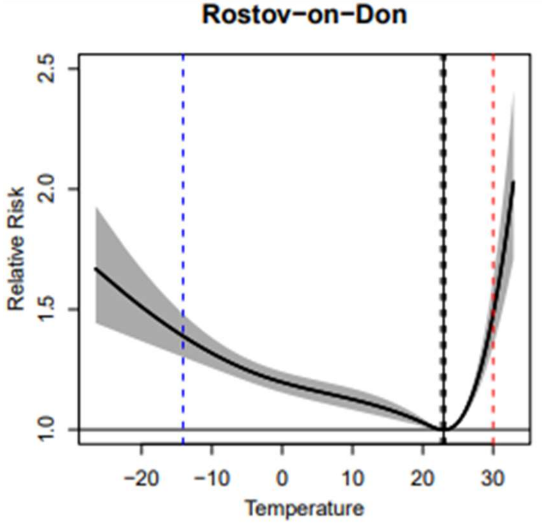
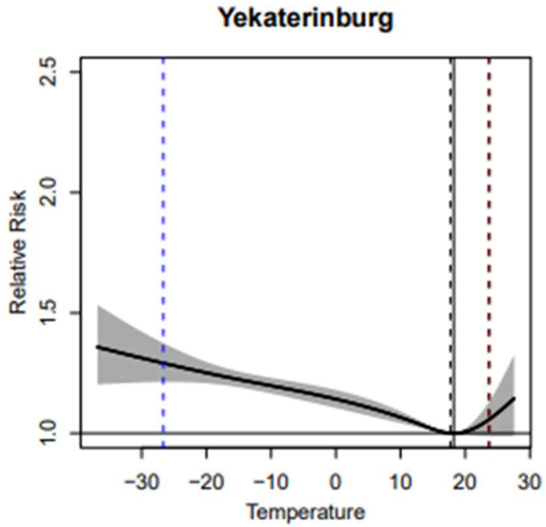
Table S14: Temperature-mortality associations according to the heat and cold exposure in most populated cities of the regions in 2000-2019, including minimum mortality temperature (MMT), relative risks (RRs) to cold and heat, attributable fractions (AF) and attributable numbers (AN) of deaths to the heat and cold, including extreme cold and heat

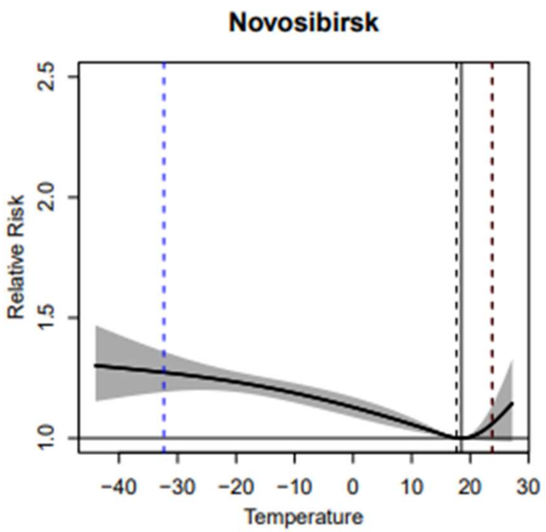
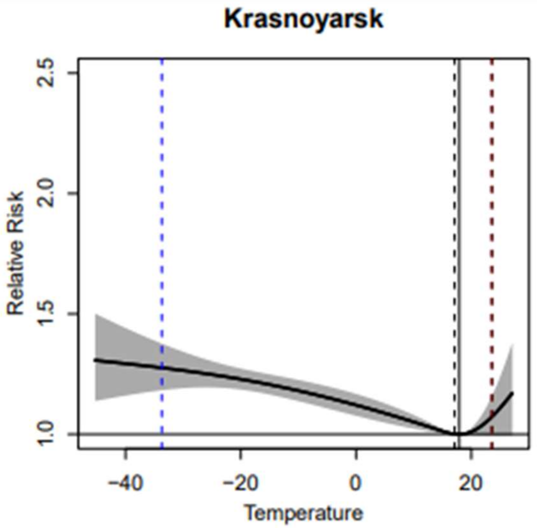
Region	Temperature-mortality associations	MMT (95% eCI)	RRs cold (95% CI)	RRs heat (95% CI)	AF (%) / AN (deaths) cold (95% eCI)	AF (%) / AN (deaths) heat (95% eCI)
Northern		*18.92 (17.07, 23.05)*	*1.38 (1.29, 1.51)*	*1.02 (0.95, 1.10)*	*AF total: 12.21 (9.80, 14.72) AF Extreme: 0.78 (0.62, 0.92) AN total: 473 (380, 571) AN Extreme: 30 (24, 36)*	*AF total: 0.05 (-0.17, 0.24) AF Extreme: 0.05 (-0.14, 0.21) AN total: 2 (-7, 9) AN Extreme: 2 (-6, 8)*
Northwestern		18.14 (17.35, 20.08)	1.38 (1.30, 1.46)	1.06 (1.01, 1.12)	*AF total:* 9.82 (7.63, 11.85) *AF Extreme 0.76 (0.63, 0.87):*	*AF total: 0.17 (0.00, 0.32) AF Extreme: 0.14 (0.02, 0.25)*

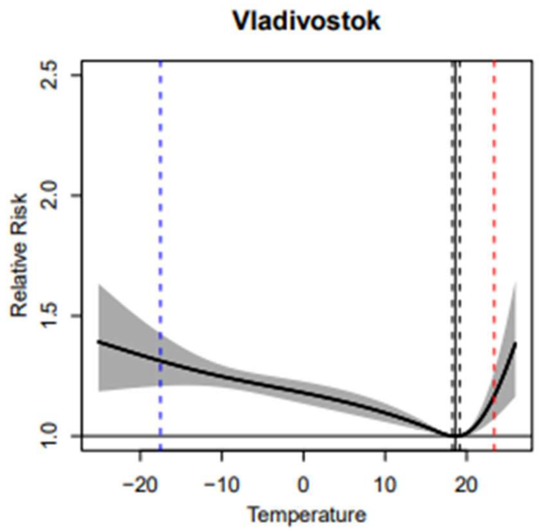
					*AN total:* 5961 (4631, 7193)	*AN total:* *103* *(1, 193)*
					AN Extreme: *461* *(381, 531)*	*AN Extreme:* *84* *(10, 150)*
Kaliningrad		18.79 (17.86, 23.72)	1.31 (1.21, 1.41)	1.09 (0.98, 1,21)	*AF total:* 8.03 (4.99, 10.80)	*AF total:* 0.28 (-0.13, 0.62)
					AF Extreme: 0.65 (0.47, 0.81)	*AF Extreme:* 0.20 (-0.06, 0.41)
					AN total: 433 (269, 583)	*AN total:* 15 (-7, 33)
					AN Extreme: 35 (25, 44)	*AN Extreme:* 11 (-3, 22)

Central	Moscow 	18.72 (18.20, 19.19)	1.29 (1.17, 1.41)	1.22 (1.12, 1.32)	*AF total:* 12.16 (8.82, 14.89) *AF Extreme:* *0.60* *(0.38, 0.79)* *AN total:* 13949 (10119, 17076) *AN Extreme:* 690 (433, 911)	*AF total:* 0.80 (0.46, 1.08) *AF Extreme:* 0.55 (0.32, 0.73) *AN total:* 922 (530, 1244) *AN Extreme:* 629 (372, 841)
Central Black Earth	Voronezh 	20.54 (20.19, 20.75)	1.37 (1.29, 1.46)	1.31 (1.21, 1.40)	*AF total:* 10.36 (8.26, 12.25) *AF Extreme:* 0.74 (0.60, 0.87) *AN total:* 1238 (986, 1463) *AN Extreme:* 88 (72, 104)	*AF total:* 1.13 (0.84, 1.38) *AF Extreme:* 0.69 (0.52, 0.84) *AN total:* 135 (101, 165) *AN Extreme:* 82 (62, 100)

Volga		20.54 (19.92, 20.87)	1.36 (1.27, 1.45)	1.28 (1.19, 1.37)	*AF total:* 10.25 (8.18, 12.04)	*AF total:* 1.06 (0.76, 1.31)
					AF Extreme: 0.70 (0.56, 0.82)	*AF Extreme:* 0.61 (0.44, 0.76)
					AN total: 1578 (1259, 1854)	*AN total:* 162 (117, 202)
					AN Extreme: 108 (86, 127)	*AN Extreme:* 94 (68, 117)
Volga-Vyatka		19.11 (18.67, 19.28)	1.30 (1.23, 1.38)	1.21 (1.14, 1.29)	*AF total:* 11.03 (9.20, 12.79)	*AF total:* 0.81 (0.56, 1.05)
					AF Extreme: 0.63 (0.49, 0.75)	*AF Extreme:* 0.53 (0.38, 0.67)
					AN total: 1974 (1646, 2288)	*AN total:* 146 (101, 187)
					AN Extreme: 113 (89, 135)	*AN Extreme:* 5 (-0, 10)

North Caucasus		22.97 (22.59, 23.19)	1.39 (1.30, 1.48)	1.48 (1.35, 1.62)	*AF total:* 10.05 (7.72, 12.12) *AF Extreme:* 0.79 (0.65, 0.92) *AN total:* *1280* *(984, 1544)* *AN Extreme:* 101 (83, 117)	*AF total:* 1.63 (1.28, 1.92) *AF Extreme:* 0.84 (0.67, 0.99) *AN total:* *208* *(163, 245)* *AN Extreme:* 108 (85, 127)
Ural		18.23 (17.70, 23.69)	1.29 (1.21, 1.37)	1.06 (0.99, 1.13)	*AF total:* 10.03 (8.19, 11.76) *AF Extreme:* 0.60 (0.45, 0.72) *AN total:* 1455 (1187, 1706) *AN Extreme:* 86 (66, 105)	*AF total:* 0.21 (-0.09, 0.47) *AF Extreme:* 0.14 (-0.03, 0.28) *AN total:* 30 (-13, 68) *AN Extreme:* 20 (-5, 41)

West Siberian		18.50 (17.67, 23.76)	1.27 (1.19, 1.36)	1.06 (0.99, 1.14)	*AF total:* 9.36 (7.26, 11.33)	*AF total:* 0.24 (-0.08, 0.53)
					AF Extreme: 0.56 (0.41, 0.69)	*AF Extreme:* 0.14 (-0.03, 0.29)
					AN total: 1572 (1220, 1904)	*AN total:* 40 (-13, 89)
					AN Extreme: 94 (69, 116)	*AN Extreme:* 24 (-4, 49)
East Siberian		17.90 (17.09, 23.56)	1.28 (1.18, 1.38)	1.07 (0.99, 1.16)	*AF total:* 9.26 (6.90, 11.45)	*AF total:* 0.29 (-0.06, 0.61)
					AF Extreme: 0.57 (0.39, 0.71)	*AF Extreme:* 0.17 (-0.02, 0.35)
					AN total: *893* *(666, 1104)*	*AN total:* 28 (-6, 59)
					AN Extreme: 55 (38, 69)	*AN Extreme:* 17 (-2, 33)

Far Eastern		18.61 (18.27, 19.17)	1.31 (1.21, 1.43)	1.17 (1.07, 1.27)	*AF total:* 10.76 (8.54, 12.77)	*AF total:* 0.67 (0.28, 1.01)
					AF Extreme: 0.65 (0.45, 0.81)	*AF Extreme:* 0.35 (0.16, 0.52)
					AN total: 673 (534, 799)	*AN total:* 42 (17, 63)
					AN Extreme: 40 (28, 51)	*AN Extreme:* 22 (10, 32)

Note: extreme cold and heat defined as temperatures lower than 2.5th location-specific percentile (extreme cold) and higher that 97.5th location-specific percentiles (extreme heat. Dashed vertical lines denote the 1st (blue) and 99th (red) percentiles of the temperature distributions. Solid vertical lines denote minimum mortality temperature (MMT) and dashed vertical lines denote 95% eCI of MMT. Shaded areas denote 95% confidence interval of relative risks (RRs)

Table S15: Total mortality attributable fractions (AF) and attributable numbers (AN) of deaths to the cold, including extreme cold, in ten cities with the highest values of cold-related RRs (first percentile of temperature), 2000-19

Region	**City**	**RRs cold (95% CI)**	**AF (%) cold (95% eCI)**	**AN (deaths) cold (95% eCI)**	**AF (%) extreme cold (95% eCI)**	**AN (deaths) extreme cold (95% eCI)**
Northern	Vorkuta	1.70 (1.40, 2.06)	31.11 (20.26, 40.62)	262 (171, 342)	1.12 (0.80, 1.39)	9 (7, 12)
Northern	Murmansk	1.57 (1.39, 1.77)	22.27 (16.40, 27.96)	767 (565, 963)	1.00 (0.79, 1.19)	35 (27, 41)
Far Eastern	Petropavlovsk- Kamchatsky	1.56 (1.36, 1.78)	20.94 (13.36, 28.32)	371 (237, 502)	0.95 (0.71, 1.15)	17 (13, 20)
Far Eastern	Magadan	1.54 (1.35, 1.75)	22.08 (16.84, 26.93)	253 (193, 309)	0.93 (0.70, 1.13)	11 (8, 13)
North Caucasus	Kamensk-Shakhtinsky	1.47 (1.35, 1.61)	9.46 (6.43, 12.05)	129 (87, 164)	0.93 (0.74, 1.10)	13 (10, 15)
North Caucasus	Gukovo	1.46 (1.33, 1.60)	9.58 (6.25, 12.42)	101 (66, 131)	0.87 (0.68, 1.03)	9 (7, 11)
Far Eastern	Artyom	1.46 (1.32, 1.62)	11.81 (9.06, 14.15)	166 (127, 199)	0.94 (0.70, 1.14)	13 (10, 16)
North Caucasus	Yeysk	1.46 (1.33, 1.59)	9.64 (6.80, 12.10)	179 (126, 225)	0.86 (0.67, 1.01)	16 (12, 19)
Ural	Berezniki	1.45 (1.28, 1.64)	17.27 (8.78, 25.66)	381 (193, 566)	0.79 (0.59, 0.99)	17 (13, 22)

Table S16: Total mortality attributable fractions (AF) and attributable numbers (AN) of deaths to the heat, including extreme heat, in ten cities with the highest values of heat-related RRs (99th percentile of temperature), 2000-19

Region	City	RRs heat (95% CI)	AF (%) heat (95% eCI)	AN (deaths) heat (95% eCI)	AF (%) extreme heat (95% eCI)	AN (deaths) extreme cold (95% eCI)
Volga	Volzhsky	1.66 (1.49, 1.85)	2.38 (1.96, 2.72)	81 (66, 92)	1.17 (0.96, 1.34)	40 (33, 45)
Volga	Elista	1.64 (1.46, 1.84)	2.18 (1.80, 2.57)	19 (16, 23)	1.02 (0.83, 1.21)	9 (7, 11)
Volga	Astrakhan	1.63 (1.49, 1.78)	2.25 (1.94, 2.57)	136 (118, 156)	0.93 (0.80, 1.07)	57 (49, 65)
Volga	Volgograd	1.57 (1.45, 1.70)	2.03 (1.71, 2.30)	259 (219, 294)	1.02 (0.88, 1.16)	131 (112, 148)
Volga	Kamyshin	1.53 (1.35, 1.73)	1.97 (1.47, 2.39)	30 (23, 37)	1.03 (0.77, 1.24)	16 (12, 19)
North Caucasus	Volgodonsk	1.52 (1.33, 1.74)	2.06 (1.50, 2.52)	33 (24, 41)	0.97 (0.70, 1.19)	16 (11, 19)
North Caucasus	Anapa	1.51 (1.31, 1.73)	1.97 (1.39, 2.45)	15 (11, 19)	0.98 (0.68, 1.22)	8 (5, 9)
North Caucasus	Derbent	1.49 (1.32, 1.69)	1.96 (1.45, 2.48)	11 (8, 14)	0.89 (0.65, 1.11)	5 (4, 7)
North Caucasus	Yeysk	1.49 (1.31, 1.68)	1.89 (1.36, 2.32)	35 (25, 43)	0.86 (0.61, 1.06)	16 (11, 20)
North Caucasus	Bataysk	1.48 (1.30, 1.69)	1.60 (1.14, 1.98)	22 (16, 28)	0.81 (0.57, 1.00)	11 (8, 14)