Misfortunes Never Come Singly: Consecutive Weather Shocks and Mortality in Russia

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Outline:

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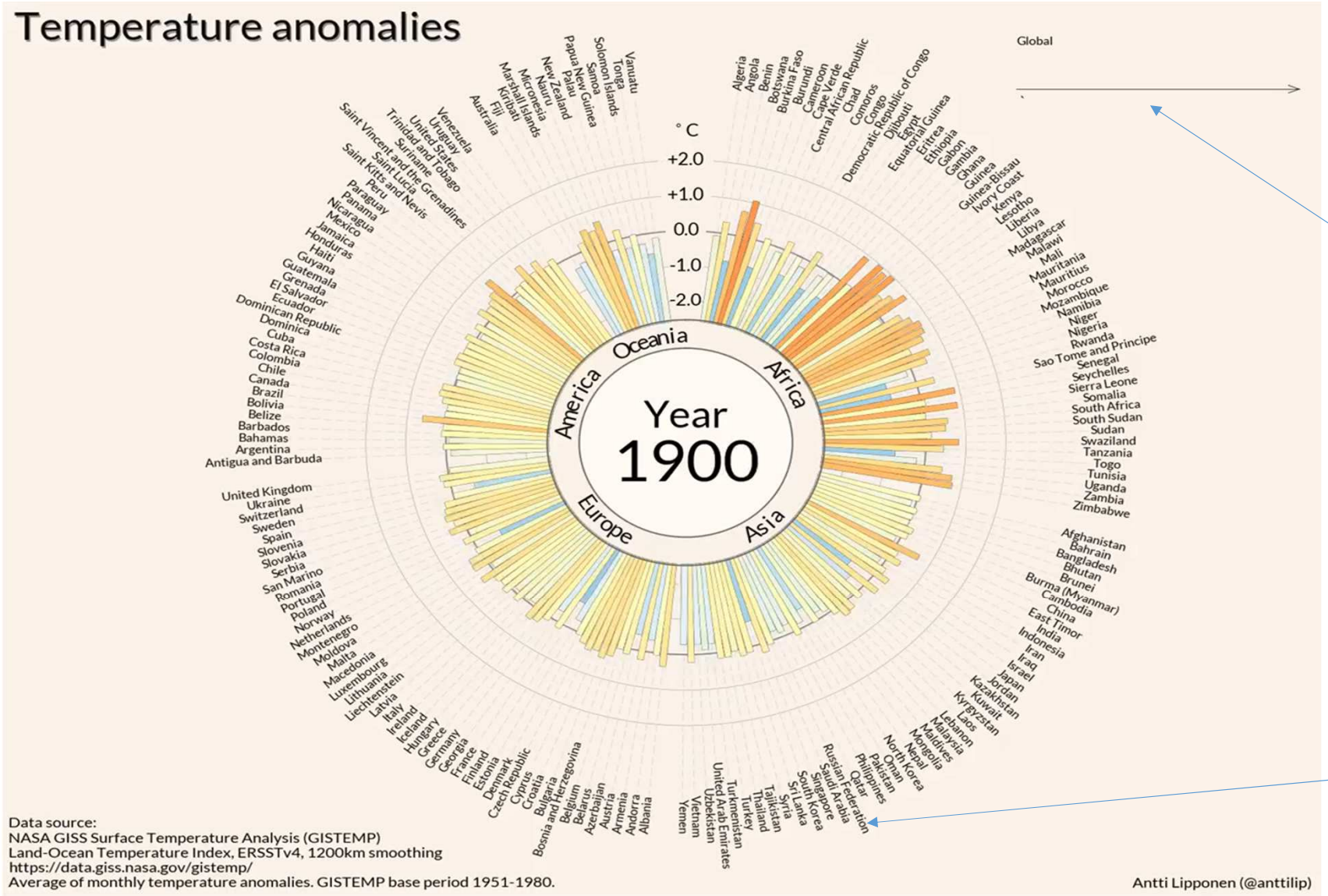
Introduction and Motivation

- Extreme weather events become more frequent and severe, contributing to excess mortality worldwide (IPCC, 2014)

- In this study extreme weather events imply hot and cold temperatures

- Consecutive extreme days (heat waves and cold spells) are especially harmful. This threat is well documented in epidemiological literature, but is yet overlooked in economic studies (Basu and Samet, 2002; Samet, 2009)

- An increasing number of studies assess the impacts of climate change to design mitigation policies



Global Trend

Russia

Introduction and Motivation: Gender Dimension

Most economic studies assume a similar impact of weather on gender health:

- there is a substantial heterogeneity in mortality and life expectancy between genders (Clark and Peck, 2012; Deschênes and Moretti, 2009)

Russian context:

- One of the highest gaps in life expectancy at birth (64.7 for males and 76.3 for females in 2015), which persists until both genders reach 55 years
- In relative terms, the highest impact of hot temperature days is on mortality of the 30-39 year olds, the most economically productive group, which is also in the reproductive age (Otrachshenko et al., 2017)

Research Question and Contribution

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We suggest an econometric model that analyzes the impact of single and consecutive days simultaneously

We examine and quantify the impact of single and consecutive days with extreme temperature on females' and males' mortality in Russia

- All-cause mortality of different age groups for each gender

We examine the impact of both hot and cold extremes

We estimate the economic cost of single and consecutive days with extreme temperatures in terms of foregone years of life

Literature

Epidemiology:

- Heat waves and cold spells
- Case studies (Basu & Samet, 2002; Deschenes, 2014)
- Mortality increases due to heat waves and cold spells
- Elderly are more susceptible

Economics:

- A one-day impact of a specific cold or hot temperature on mortality, using countrywide regional panel data

Hot temperatures:

- Days with extremely hot temperatures increase mortality in the U.S., India, Mexico, and Russia (Deschenes & Moretti, 2009; Barreca et al., 2015 and 2016; Burgess et al. 2014; Otrachshenko et. al., 2017; Cohen & Dechezlepretre, 2017)

- The impact of hot weather differs by age groups (Deschenes & Greenstone, 2011; Otrachshenko et. al., 2017)

Literature

- Economics: Cold temperatures are studied less:
  - Cold temperature (10°F or ca. -12.2°C) ↑ all-cause mortality (Deschenes & Moretti, 2009; IPCC, 2014)
  - Cold and dry weather (0°F or ca. -17.8°C) ↑ all-cause mortality (Barecca, 2012)
  - Cold temperature ↑ all-cause and cause-specific mortality, but extremely cold temperature (below -30°C) may ↓ mortality (Otrachshenko et al., 2017)
  - Definition of cold is study-specific

Mechanism: Extreme Temperatures

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Comfortable ambient air temperature (Burroughs & Hansen, 2011)

- Winter: between 68°F to 74°F (20-23.3°C)
- Summer: between 73°F to 78°F (22.3-25.6°C)

Air temperature beyond these limits is a thermal stress

- induces physiological adjustment and thermoregulation to avoid hypothermia and hyperthermia (Basu & Samet, 2002)

- risk of death for people with cardiovascular diseases and ↑ susceptibility to respiratory infections (Dell et al., 2014; Martens, 1998)

- "harvesting" or advanced displacement of death (Basu & Samet, 2002; Deschênes & Moretti, 2009)

Mechanism: Consecutive Days

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- Harmful effects of heat waves and cold spells are well documented in epidemiology (reviews by Basu and Samet, 2002; Deschênes, 2014)

- No studies in economics, except for Cohen and Dechezlepretre (2017) who find no impact of consecutive extremely hot (>32°C) and cold days (<10°C) on mortality in Mexico

Mechanism: Gender Health Differences

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- Differences in thermoregulation: Women have higher body temperature, heart rates, and blood pressure (Havenith, 2005)

- Behavioral differences: Women have less risky health behavior (Macey & Schneider, 1993; Courtenay, 2000)

Econometric Model

$$Mortality_{it} = \sum_{j} \alpha_{j=1}^{18} TempBin_{jit} + \sum_{k} \beta_{k=1}^{2} ConsecBin_{kit}$$

$$\sum_{n} \delta_{n=1}^{3} PrecBin_{nit} + \gamma_i + \mu_t + \Theta' \boldsymbol{Region} * Trend + \varepsilon_{it}$$

where *t* - year*; i* – region; *j* - temperature bin*; k* - precipitation bin

- $\boldsymbol{Mortality}_{it}$- mortality rate per 1,000,000
- $\boldsymbol{TempBin}_{jit}$ - # of days in year *t* on which the daily mean temperature fell in the *j*th of the 18 bins
- $\boldsymbol{ConsecBin}_{\boldsymbol{kit}}$ - # of days in year *t* for at least 3 consecutive days with a particular daily mean temperature and fells in the *j*th of the 2 bins (1st bin below -23°C and 2nd bin above 25°C)
- $\boldsymbol{PrecBin}_{nit}$ - # of days in year *t* on which the daily mean precipitation fell in the *k*th of the 3 bins
- $\boldsymbol{\gamma_i}\ and\ \boldsymbol{\mu_t}$– regional and time fixed effects
- $\boldsymbol{Region} * Trend$ – region-specific linear time trends
- ε_t - stochastic disturbance

Methodology: Temperature Bins

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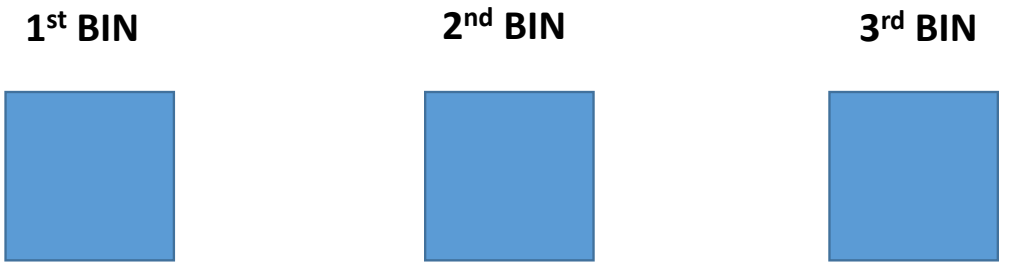
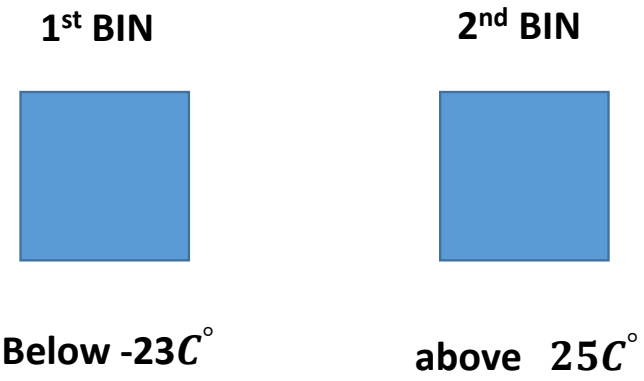


- Assume a day with the average temperature +3C°. Then this day fells into the 1st bin
- Assume a day with the average temperature +26C°. Then this day fells into the 3rd bin

Methodology: Consecutive Day Bins



- Assume <u>three consecutive days</u> with the average daily temperature +26C°. Then these 3 days fell into the 2nd bin.

Data

- Daily data on precipitation and temperature from meteorological stations in Russia for the period 1989-2014
  - Number of Meteostations is 518
  - Data are aggregated to the regional level
  - For each meteostation we find the nearest settlements (cities, towns, villages of city type) within 200 km and use the population of this settlement as weights
  - For each year for each region, 18 bins are calculated for the temperature, 3 bins for the precipitation, and 2 bins for the consecutive days with extreme temperatures
- Yearly data on all-cause and cause-specific mortality for 79 regions during 1989-2014

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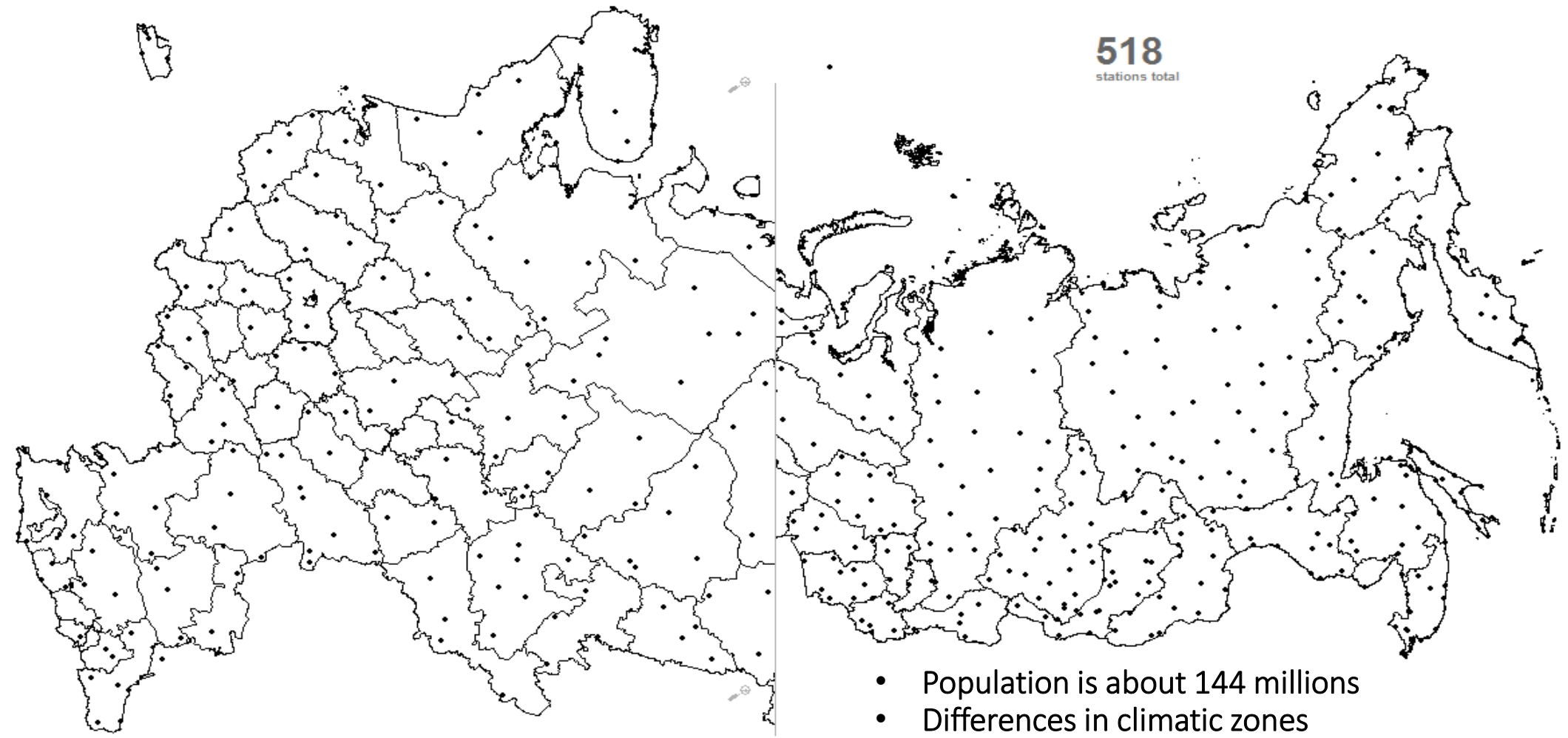
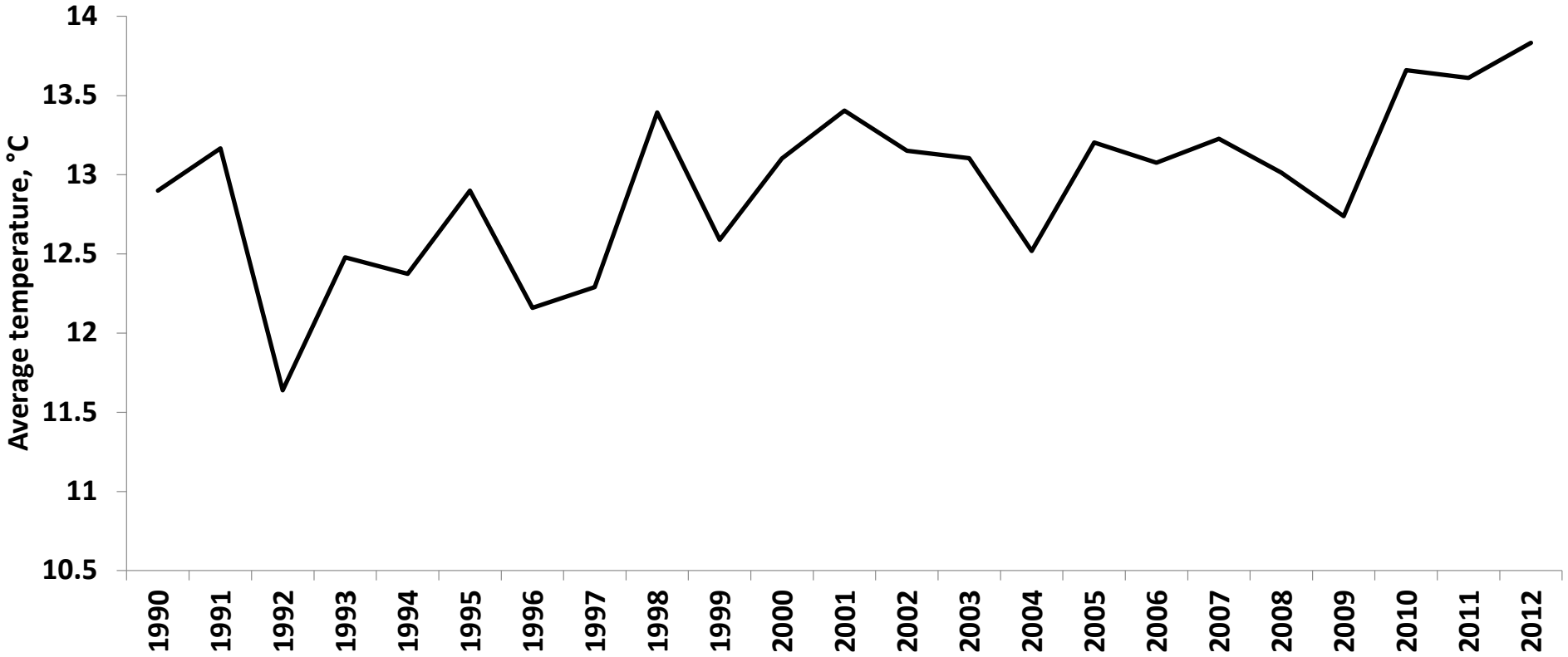
Map of meteo stations in Russia



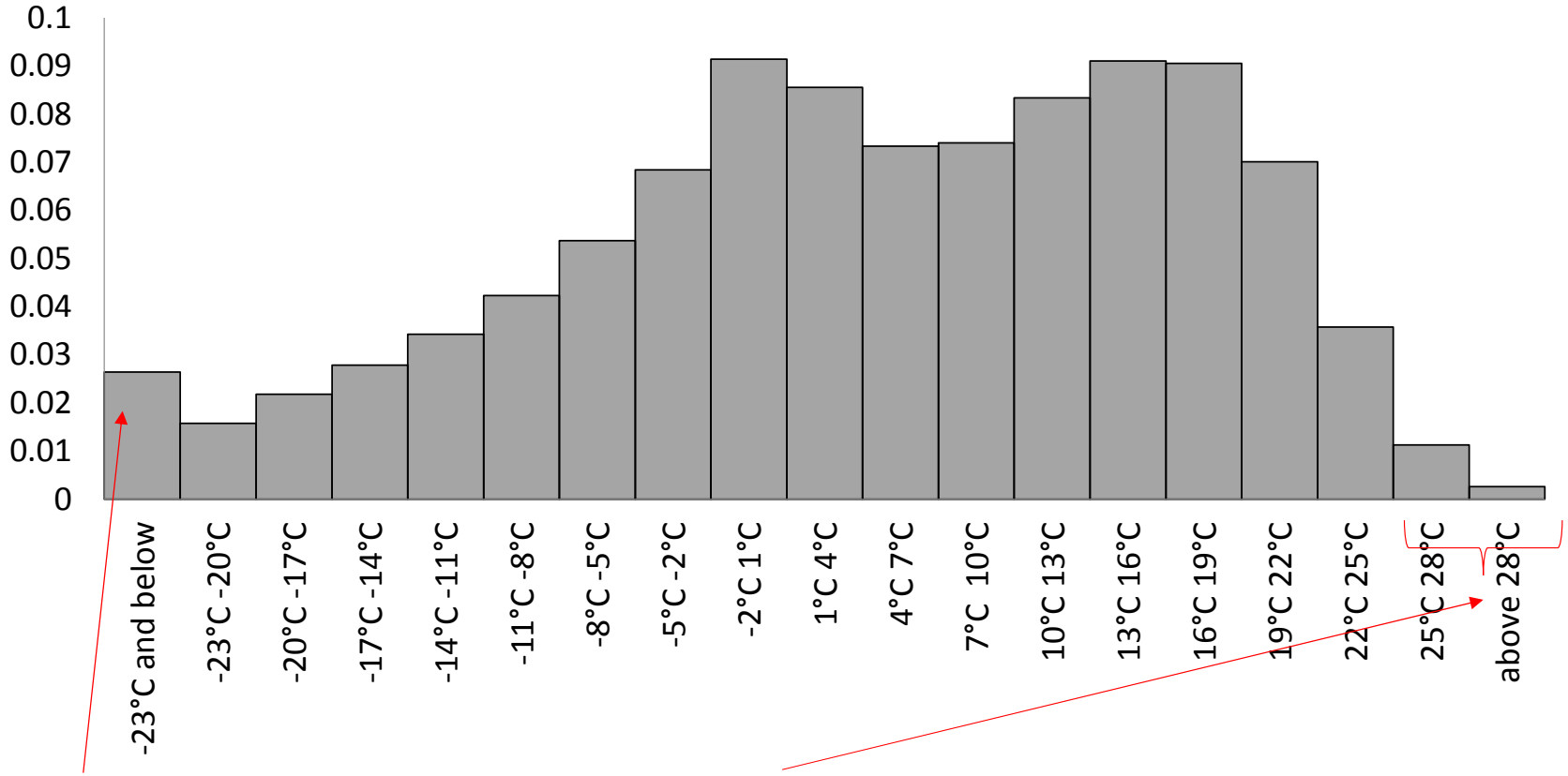
Meteo stations coordinates: (http://meteo.ru/data/155-meteostations)
R map template: (https://github.com/Sobach/R.rus.map.zoom)

- Population is about 144 millions
- Differences in climatic zones
- Largest territory

Average monthly temperature in June-August for Russia from 1990-2012 (°C).



The distribution of days with a particular temperature, 1989-2014



Cold day is below -23°C

Hot day is above 25°C

Estimation Results: Total all-age mortality by gender

Model:	(1a)			(1b)			(2a)			(2b)		
Dependent Variable:	FEMALE			MALE			FEMALE			MALE		
Mortality	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.
Conseq.(below -23°C]	-			-			15.57	***	2.85	20.20	***	5.49
(below -23°C]	16.06	***	3.16	25.51	***	6.78	-3.84		4.80	-3.85		9.11
(-23°C, -20°C]	6.03		4.54	-6.08		9.07	7.78	*	4.37	-5.67		9.25
(-20°C, -17°C]	13.44	**	3.35	14.37	**	6.80	12.20	***	3.56	10.38		6.84
(-17°C, -14°C]	15.53	***	3.03	20.41	***	6.83	13.80	***	2.93	15.57	**	6.17
(-14°C, -11°C]	12.35		3.84	12.88		8.42	10.78	**	3.85	8.38		7.98
(-11°C, -8°C]	10.40	**	2.81	14.05	**	5.23	8.84	***	2.58	10.07	*	5.06
(-8°C, -5°C]	12.82	***	3.09	17.97	***	5.86	11.26	***	3.32	14.11	**	6.04
(-5°C, -2°C]	12.27	**	3.20	15.29	**	6.50	10.88	***	3.08	11.61	*	6.19
(-2°C, 1°C]	9.53	***	2.10	17.88	***	5.46	8.58	***	2.22	14.97	**	5.80
(1°C, 4°C]	4.29		2.87	4.56		5.00	3.18		3.08	1.59		5.33
(4°C, 7°C]	5.38		2.57	7.38		5.08	4.13		2.51	4.36		4.91
(7°C, 10°C]	9.47	***	2.11	16.54	***	4.06	8.74	***	2.15	14.41	***	4.15
(10°C, 13°C]	3.50	**	1.54	7.86	**	3.16	2.98	*	1.58	6.22	*	3.15
(13°C, 16°C]	5.07	*	1.96	8.76	*	4.49	4.73	**	2.07	7.73		4.70
(16°C, 19°C]	2.87	*	1.90	8.41		6.34	2.18		2.03	6.73		6.57
(22°C, 25°C]	7.27	**	2.45	16.00	**	6.37	6.99	**	2.75	15.18	*	6.80
(above 25°C]	12.32	***	2.68	20.86	***	4.85	13.70	**	6.09	24.77	*	15.01
Conseq.(above 25°C]	-			-			10.49	***	2.91	17.29	***	5.00
[10mm, 20mm)	-0.26		4.82	-9.43		8.49	-0.39		4.83	-9.28		8.61
[above 20mm)	10.83		9.61	24.34		24.17	10.88		9.63	24.61		24.03
Regional Fixed Effects	Yes			Yes			Yes			Yes		
Time Fixed Effects	Yes			Yes			Yes			Yes		
Regional Linear Trends	Yes			Yes			Yes			Yes		
R^2_{within}	0.89			0.88			0.89			0.88		
Nr. Of Obs.	2,047			2,047			2,047			2,047		

Estimation Results: Impacts of Single and Consecutive Days

Impacts of Single and Consecutive Days with Temperature above 25°C on Mortality by Age Groups

	FEMALE						MALE					
	Impact of a Single Day			Impact of a Consec. Day			Impact of a Single Day			Impact of a Consec. Day		
Age Groups:	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.
20-29	-0.31		2.18	0.82		0.74	7.67		8.45	5.21	*	2.94
30-39	2.37		2.78	4.47	***	1.32	9.18		15.39	16.40	***	4.23
40-49	15.91	***	5.43	7.94	***	1.86	43.90	**	20.48	28.20	***	7.15
50-59	24.55	***	8.90	12.69	***	3.35	69.43	**	29.92	41.69	***	9.39
60-69	39.56	***	14.40	21.65	***	4.96	61.51		44.92	49.51	***	13.67
70 and above	-13.29		44.05	71.98	***	16.58	44.73		52.10	66.29	***	16.65

Impacts of Single and Consecutive Days with Temperature below -23°C on Mortality by Age Groups

	FEMALE						MALE					
	Impact of a Single Day			Impact of a Consec. Day			Impact of a Single Day			Impact of a Consec. Day		
Age Groups:	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.	Coeff.		S.E.
20-29	-0.91		1.61	-0.57		1.06	-2.62		6.16	-5.49		3.39
30-39	-4.82		3.01	2.65		2.20	-13.58		8.33	8.85		5.83
40-49	-6.36		4.85	6.81		3.04	-13.05		12.33	22.21	**	8.81
50-59	-13.47		8.59	7.82		4.95	0.50		19.36	25.56	**	11.91
60-69	-7.34		10.96	-0.29		7.62	-40.72		24.87	48.54	**	19.31
70 and above	-31.87		30.89	73.35	***	18.27	-3.87		40.86	102.73	***	21.80

Estimated Number of Deaths and Years of Life Lost due to a Single and to a Consecutive Hot Day

		(1)	(2)	(3)	(4)	(5)	(6)
		Estimated Number of Death		Years of Life Lost		Total Years of Life Lost	
Impact of a Single Day above 25°C	Age Groups	Female	Male	Female	Male	Female	Male
	20-29	14	70	52.3	41.1	732	2,877
	30-39	30	201	43.0	33.0	1,290	6,633
	40-49	107	338	33.9	25.3	3,627	8,551
	50-59	156	413	25.2	18.1	3,931	7,475
	60-69	217	295	17.2	12.3	3,732	3,629
	70 and above	405	195	13.4	9.9	5,427	1,931
	Total	929	1,512			18,740	31,096
Impacts of Single and Consecutive Days above 25°C a Single Day	Age Groups	Female	Male	Female	Male	Female	Male
	20-29	-3[a]	84[a]	52.3	41.1	-157	3,452
	30-39	26[a]	101[a]	43.0	33.0	1,118	3,333
	40-49	171	438	33.9	25.3	5,797	11,081
	50-59	241	558	25.2	18.1	6,073	10,100
	60-69	327	330[a]	17.2	12.3	5,624	4,059
	70 and above	-79[a]	115[a]	13.4	9.9	-1,059	1,139
	Total	739	996			17,495	21,181
Impacts of Single and Consecutive Days above 25°C a Consecutive Day	Age Groups	Female	Male	Female	Male	Female	Male
	20-29	9[a]	57	52.3	41.1	471	2,343
	30-39	50	180	43.0	33.0	2,150	5,940
	40-49	85	282	33.9	25.3	2,882	7,135
	50-59	125	335	25.2	18.1	3,150	6,064
	60-69	179	265	17.2	12.3	3,079	3,260
	70 and above	427	170	13.4	9.9	5,722	1,683
	Total	866	1,289			16,982	26,423

Estimated Number of Deaths and Years of Life Lost due to a Single and to a Consecutive Cold Day

		(1) Estimated Number of Death	(2)	(3) Years of Life Lost	(4)	(5) Total Years of Life Lost	(6)
Impact of a Single Day below -23°C	Age Groups	Female	Male	Female	Male	Female	Male
	20-29	-8[a]	-66	52.3	41.1	-418	-2,713
	30-39	29[a]	87[a]	43.0	33.0	1,247	2,871
	40-49	68[a]	272	33.9	25.3	2,305	6,882
	50-59	29[a]	314	25.2	18.1	731	5,683
	60-69	-52[a]	161[a]	17.2	12.3	-894	1,980
	70 and above	307	245	13.4	9.9	4,114	2,426
	Total	307	765			4,114	12,278
Impacts of Single and Consecutive Days below -23°C — a Single Day	Age Groups	Female	Male	Female	Male	Female	Male
	20-29	-10[a]	-29[a]	52.3	41.1	-523	-1,192
	30-39	-54[a]	-149[a]	43.0	33.0	-2,322	-4,917
	40-49	-68[a]	-130[a]	33.9	25.3	-2,305	-3,289
	50-59	-132[a]	4[a]	25.2	18.1	-3,326	72
	60-69	-61[a]	-218[a]	17.2	12.3	-1,049	-2,681
	70 and above	-189[a]	-10[a]	13.4	9.9	-2,533	-99
	Total	0	0			0	0
Impacts of Single and Consecutive Days below -23°C — a Consecutive Day	Age Groups	Female	Male	Female	Male	Female	Male
	20-29	-6[a]	-60[a]	52.3	41.1	-314	-2,466
	30-39	29[a]	97[a]	43.0	33.0	1,247	3,201
	40-49	73[a]	222	33.9	25.3	2,475	5,617
	50-59	77[a]	205	25.2	18.1	1,940	3,711
	60-69	-2[a]	260	17.2	12.3	-34	3,198
	70 and above	436	264	13.4	9.9	5,842	2,614
	Total	436	951			5,842	15,139

Adaptation to Weather Shocks

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People adapt to hot and cold weather (Barreca et al., 2015 and 2016; Otrachshenko et al., 2017)

Impacts of a Single Day and a Consecutive Day with a Specific Temperature on the Total All-age Mortality in Warm Regions

Dependent Variable: Mortality	Female Coeff.		Female S.E.	Male Coeff.		Male S.E.
Consec.(below -23°C]	22.85	***	5.98	24.85	*	13.85
(below -23°C]	2.17		8.75	8.59		15.08
(above 25°C]	-0.61		4.93	12.40		12.05
Consec.(above 25°C]	5.54		3.63	10.92		9.97
Regional Fixed Effects	Yes			Yes		
Time Fixed Effects	Yes			Yes		
Regional Linear Trends	Yes			Yes		
R^2_{within}	0.90			0.93		
Nr. Of Obs.	1,008			1,008		

Adaptation to Weather Shocks

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People adapt to hot and cold weather (Barreca et al., 2015 and 2016; Otrachshenko et al., 2017)

Impacts of a Single Day and a Consecutive Day with a Specific Temperature on the Total All-age Mortality in Cold Regions

Dependent Variable: Mortality	Female Coeff.		Female S.E.	Male Coeff.		Male S.E.
Consec.(below -23°C]	11.47	***	3.38	9.62		6.66
(below -23°C]	-2.19		5.25	-5.50		9.77
(above 25°C]	0.90		9.24	-13.19		23.94
Consec.(above 25°C]	19.46	***	3.60	29.54	***	7.49
Regional Fixed Effects	Yes			Yes		
Time Fixed Effects	Yes			Yes		
Regional Linear Trends	Yes			Yes		
R^2_{within}	0.90			0.93		
Nr. Of Obs.	1,014			1,014		

Average mortality rate from 1989 to 2014 (per 1,000,000 inhabitants)

Age Groups:	Female	Male
20-29	1,152	4,438
30-39	2,181	7,922
40-49	4,212	13,963
50-59	8,894	26,080
60-69	19,788	48,406
above 70	78,141	106,106

- One day above 25°C increases the mortality of the 30-39 yrs. old females and males by 0.74% and 0.42%, respectively

Robustness Check:

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- Check “harvesting effect”
- Redefine a sequence of consecutive days
- Confirm our results on cardiovascular mortality

Summary:

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- We estimate the impacts of single and consecutive hot/cold days on mortality by gender and age group
- The impact of consecutive days matters and result in substantial losses of lives
- Single hot days increase mortality while single cold days do not affect mortality
- Males suffer more than females
- Cold regions suffer from hot days
- Hot regions suffer from cold days

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Thank you!!!

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Correlation Matrix between Temperature Bins and Consecutive Day Bins

		Consecutive Day Bins		
		below -23°C	25-28°C	above 28°C
Temperature Bins	below -23°C	0.97		
	25-28°C		0.93	
	above 28°C			0.95