Challenges and Opportunities in Estimating the Direct Effects of Climate on Health

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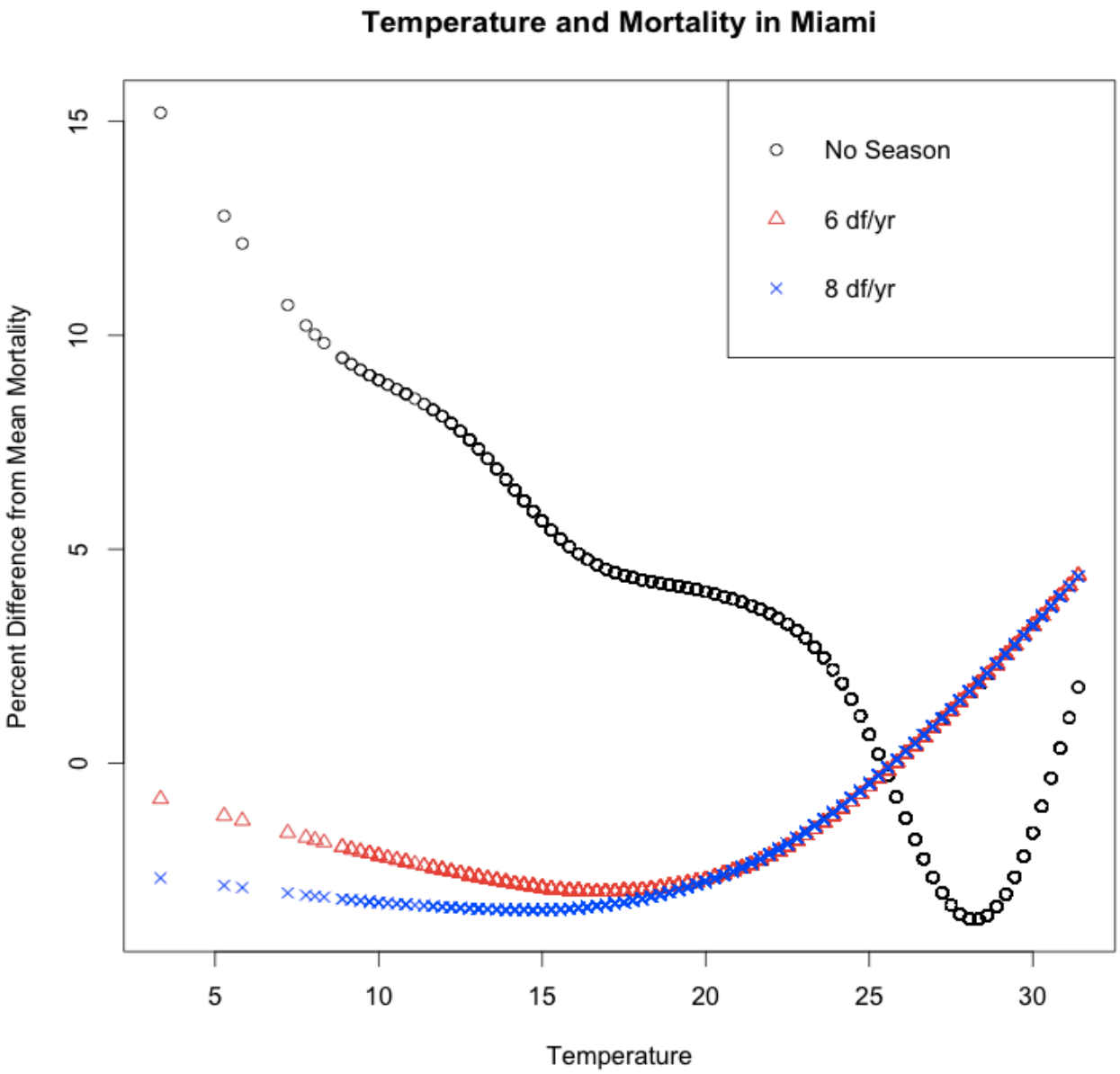
What do we know about the Direct Effects of Temperature?

- More people die when it gets hot
- More people die when it gets cold
- More surprisingly, more people seem to die when it is only moderately hot and when it is only moderately cold
- Could these effects at less extreme temperature by confounded?

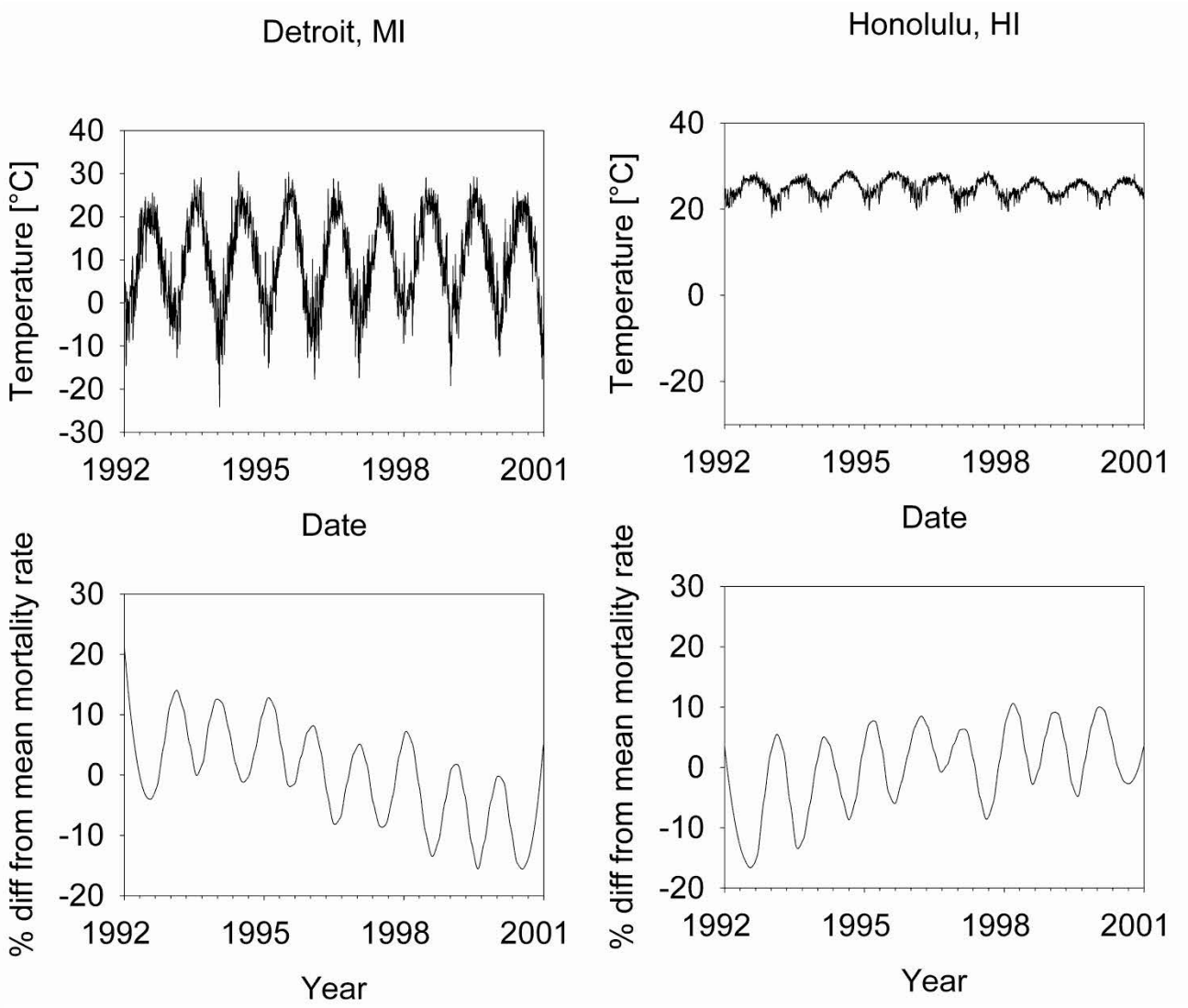
Miami with and without control for Season

Cold effects sensitive to degrees of freedom

But should we control for season?



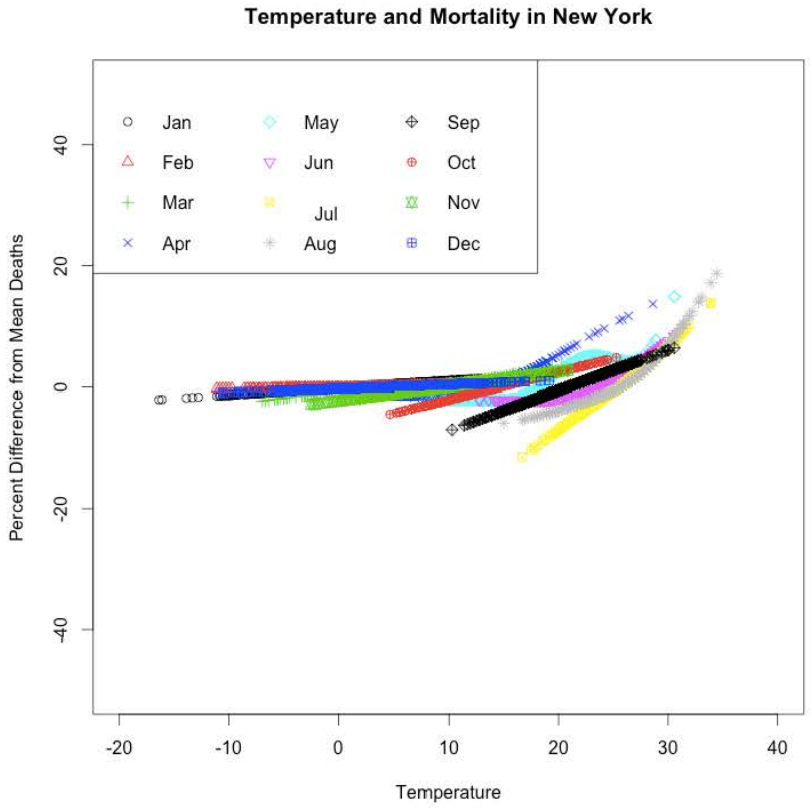
Schwartz J et al.

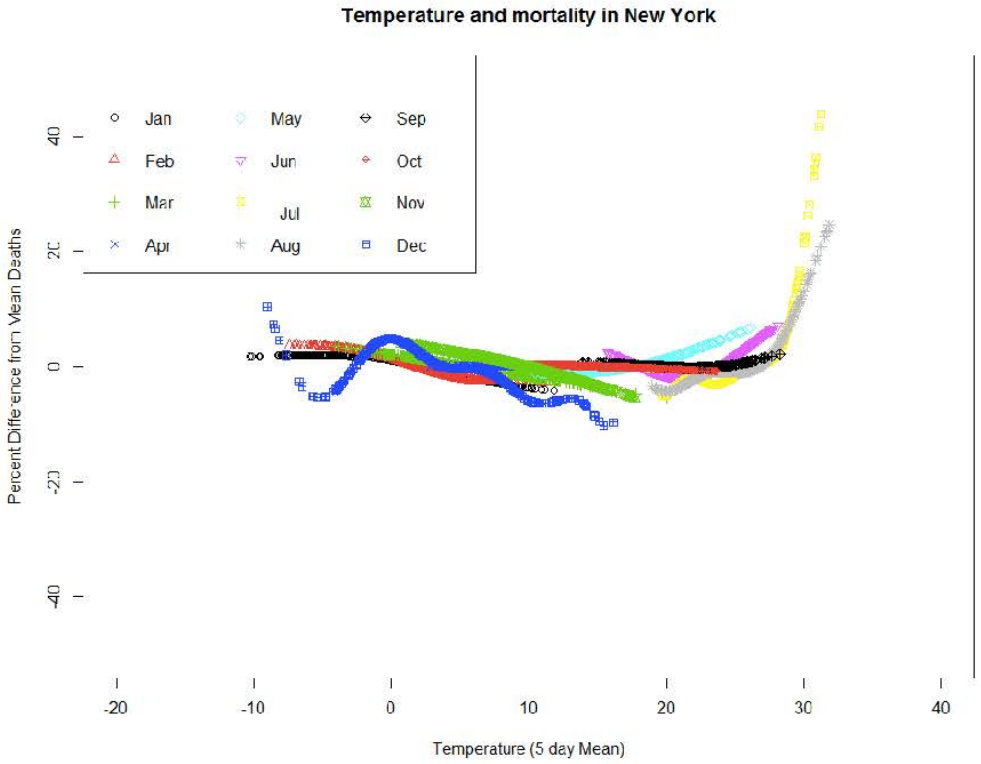


Von Klot and Schwartz, Environ Health 2012

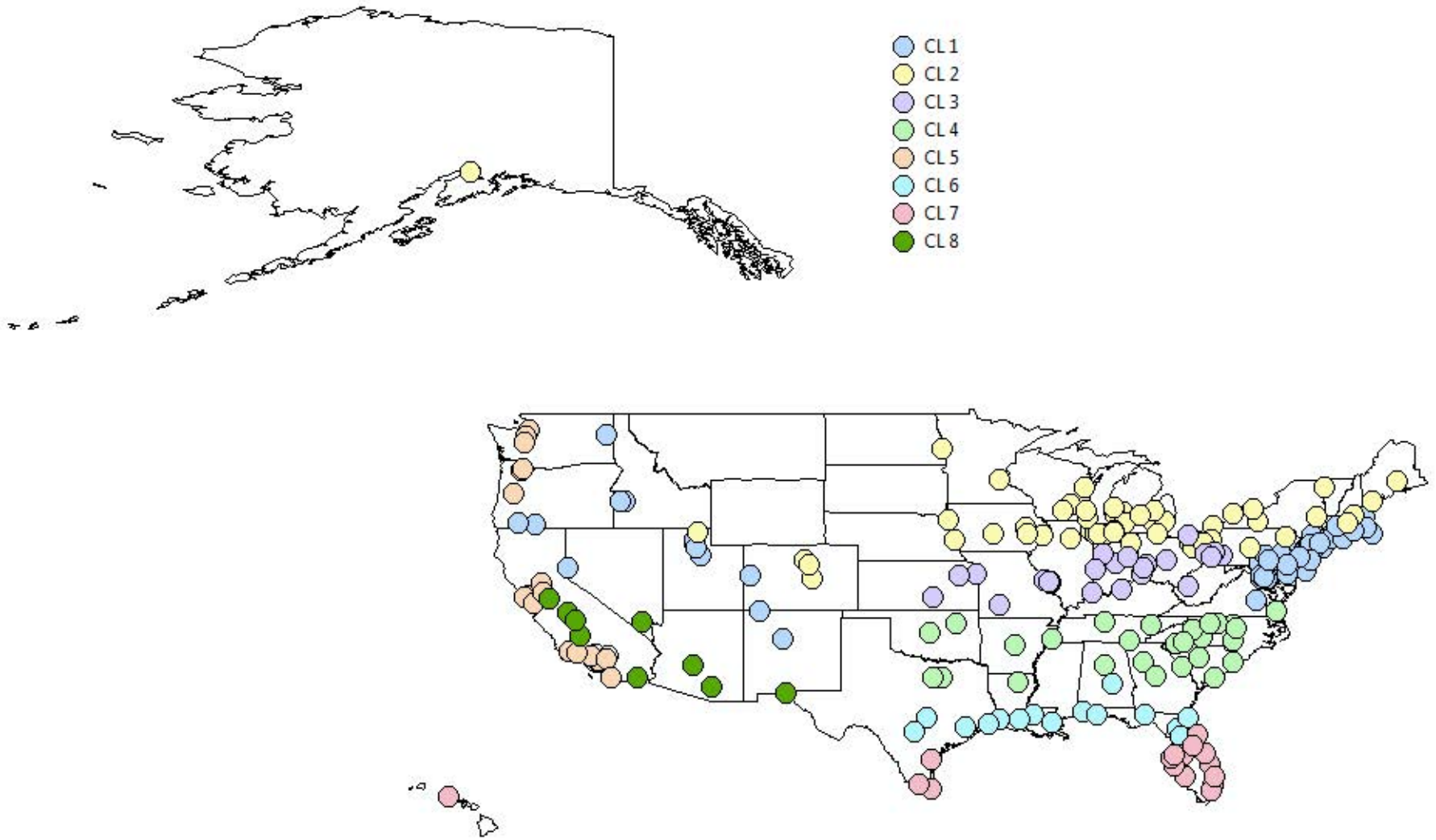
A Standard Approach in Epidemiology

- Is Stratified Analyses
- What if we look at effects of temperature within month?
- Also addresses the question of whether the effect of a given temperature is independent of when it occurs (60 ° in December Vs in May)

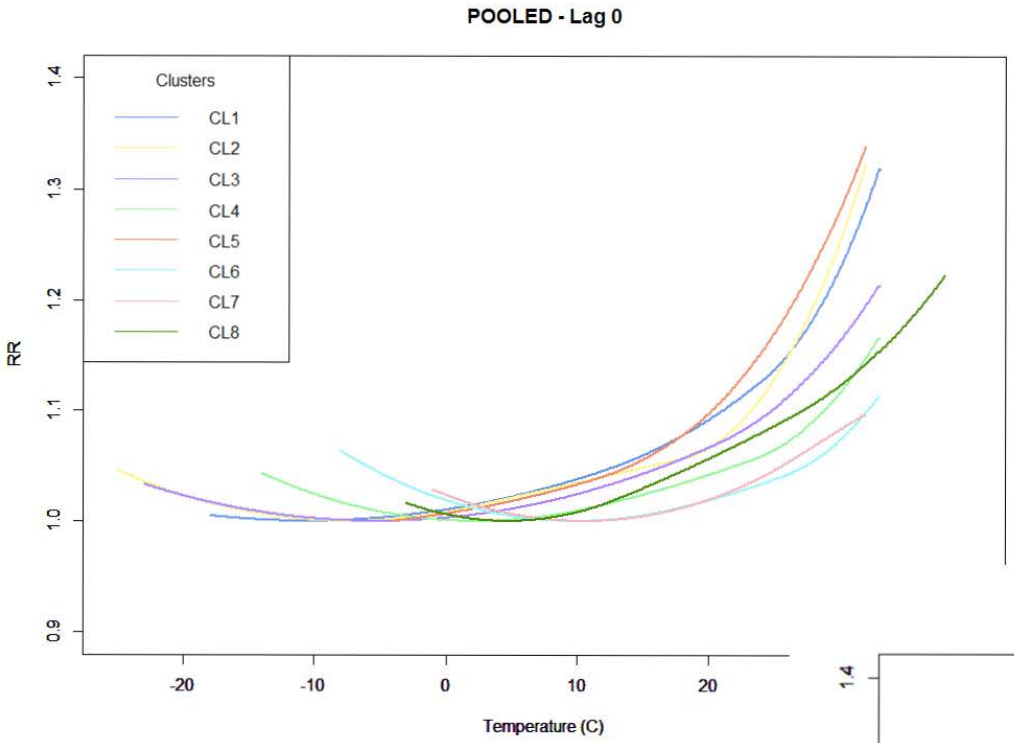


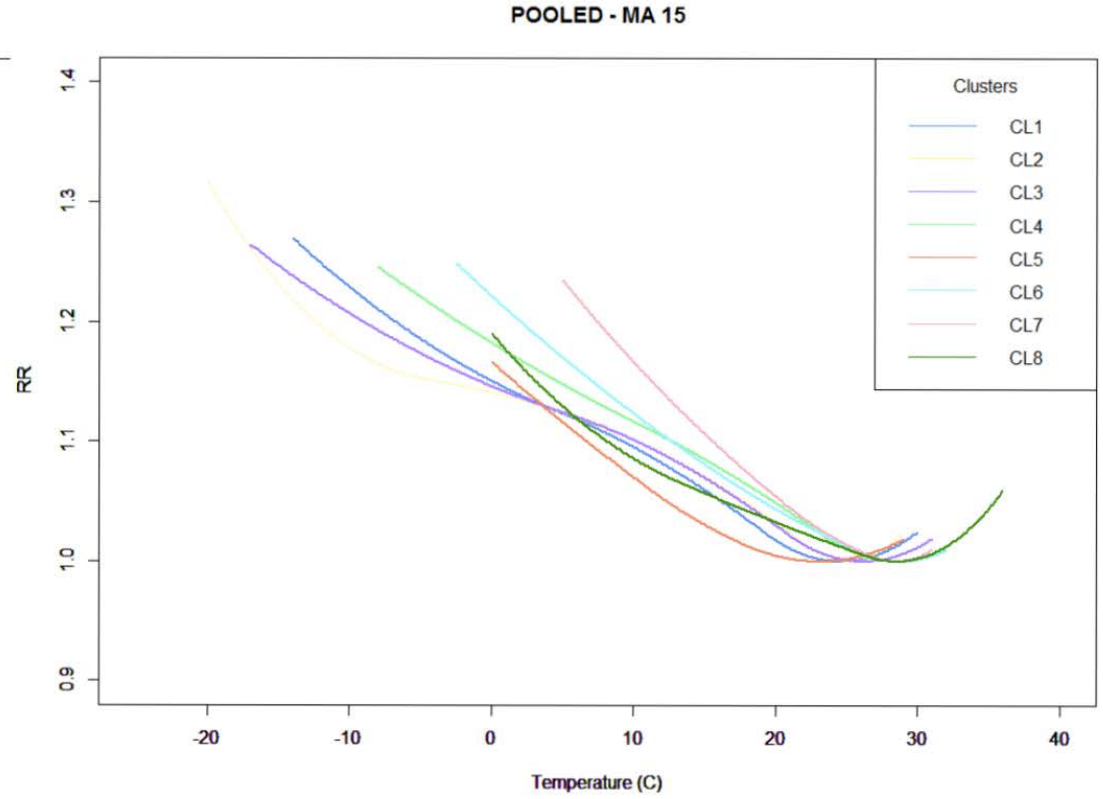


Schwartz J et al.



We clustered 200 cities based on Temperature and its standard deviation


POOLED - Lag 0
Clusters
CL1
CL2
CL3
CL4
CL5
CL6
CL7
CL8
RR
0.9
1.0
1.1
1.2
1.3
1.4
-20
-10
0
10
20
Temperature (C)


POOLED - MA 15
Clusters
CL1
CL2
CL3
CL4
CL5
CL6
CL7
CL8
RR
0.9
1.0
1.1
1.2
1.3
1.4
-20
-10
0
10
20
30
40
Temperature (C)

What about Exposure

- What is the connection between airport temperature and temperature where you live?
- What is the connection to temperature you are exposed to?
- We used satellite remote sensing of radiance on a 1 km grid and calibrated it with air temperature readings

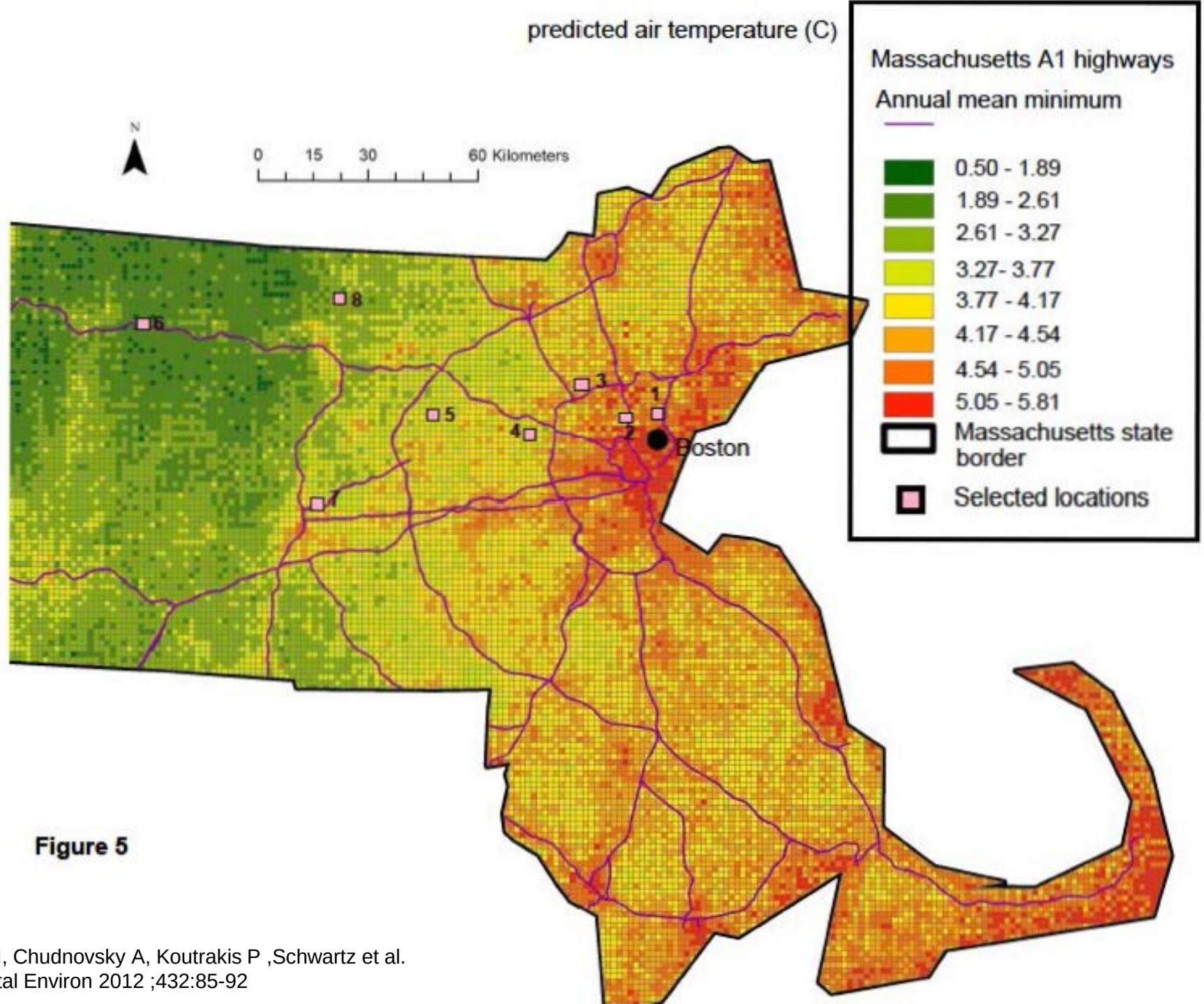
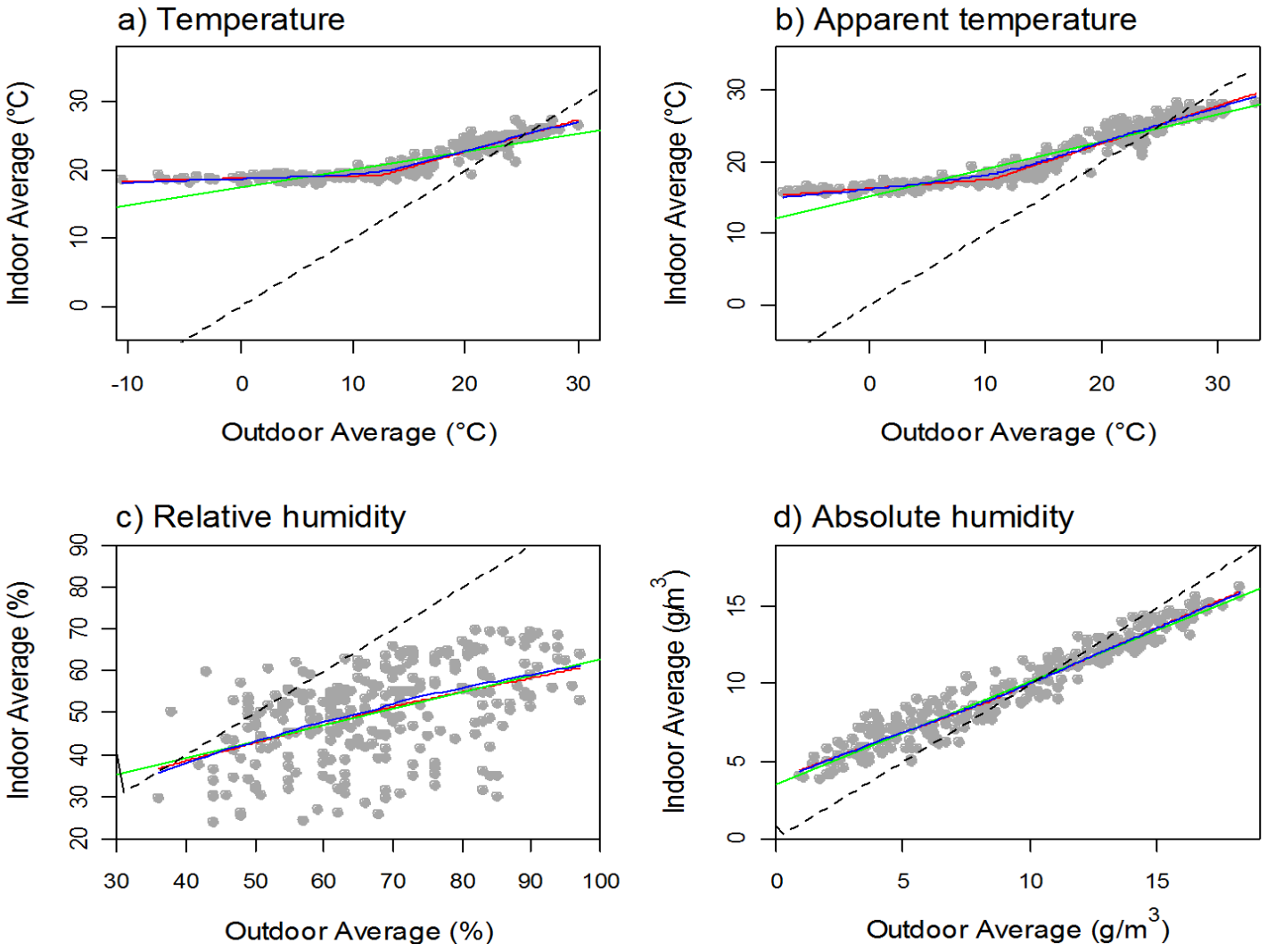


Figure 5

Kloog I, Chudnovsky A, Koutrakis P ,Schwartz et al.
Sci Total Environ 2012 ;432:85-92

Scatterplot and regression results relating indoor to outdoor (a) temperature, (b) apparent temperature, (c) relative humidity, and (d) absolute humidity from May 2011 – April 2012, Greater Boston, Massachusetts. Red line, piecewise linear regression for (a) and (b) and linear regression for (c) and (d); black solid line, reference line placed at knot value; black dashed line, y=x (45 degree) reference line.

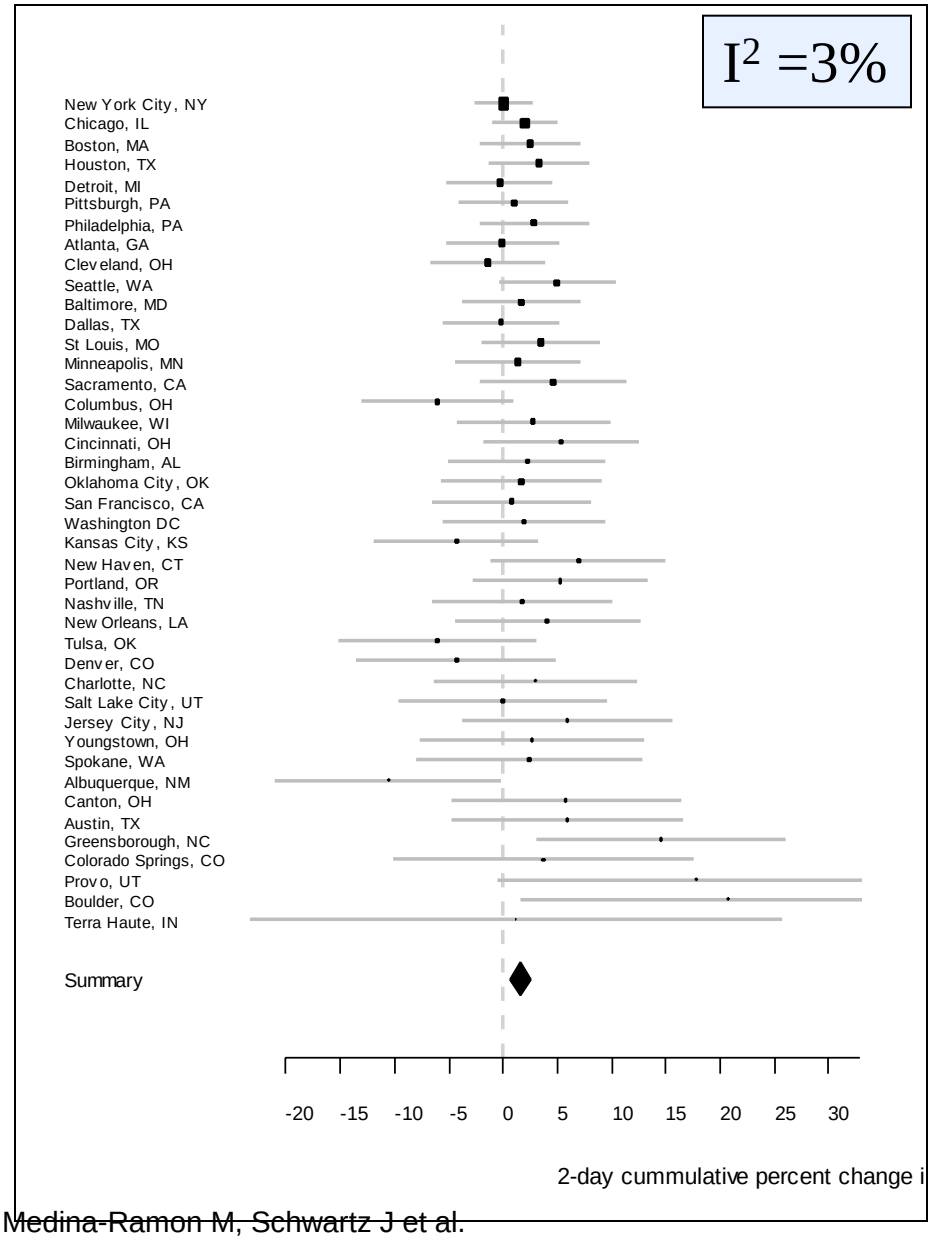


Nguyen J, Schwartz J, Dockery D

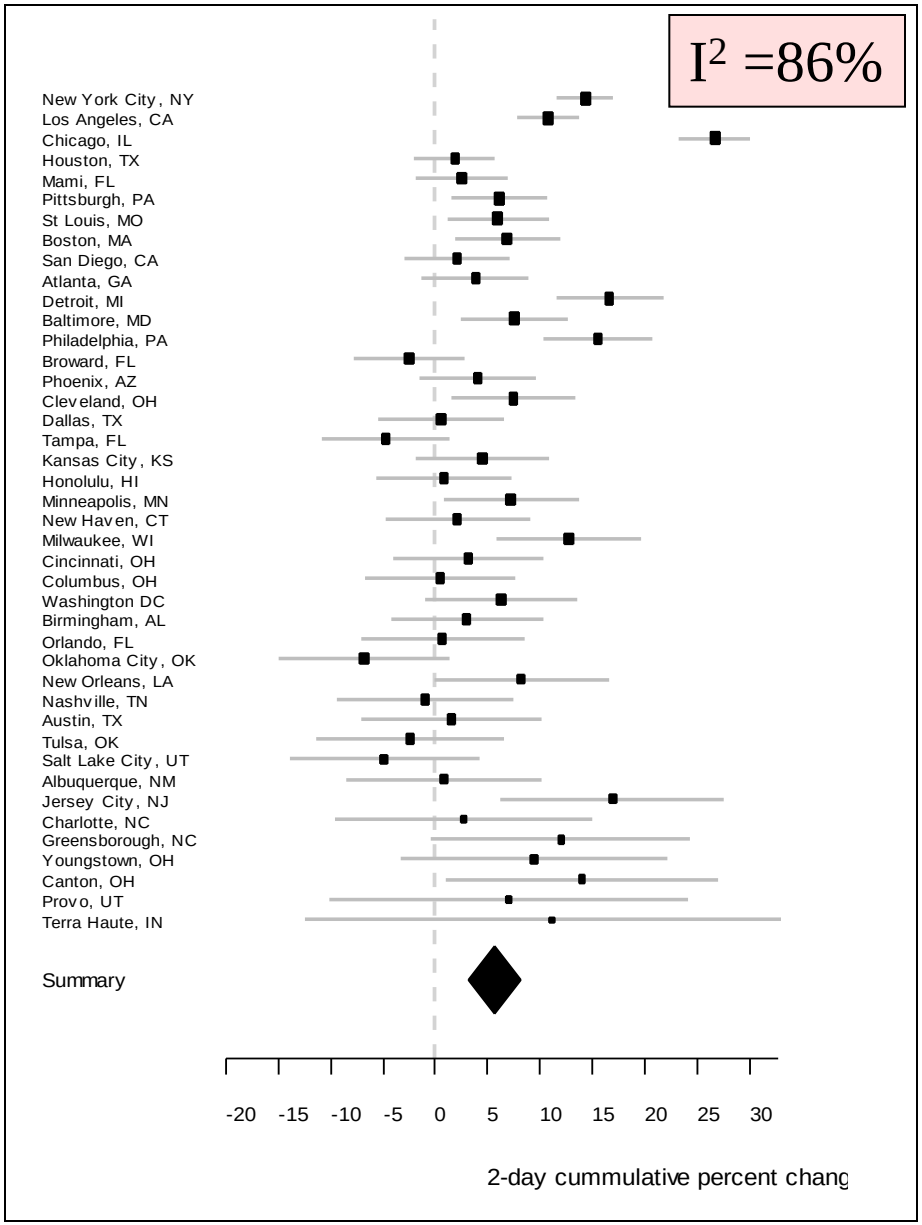
How can we examine Acclimatization?

- If weak acclimatization to cold is true
  - We expect the same effect of an unusually cold day (say at the 1st percentile of temperature) in all cities, since it is equally unusual
  - If absolute temperature matters, the effect at the 1st percentile should vary with temperature
  - May also vary with other characteristics
  - Same for unusually hot days (99th percentile)

Extreme cold effect



Extreme heat effect

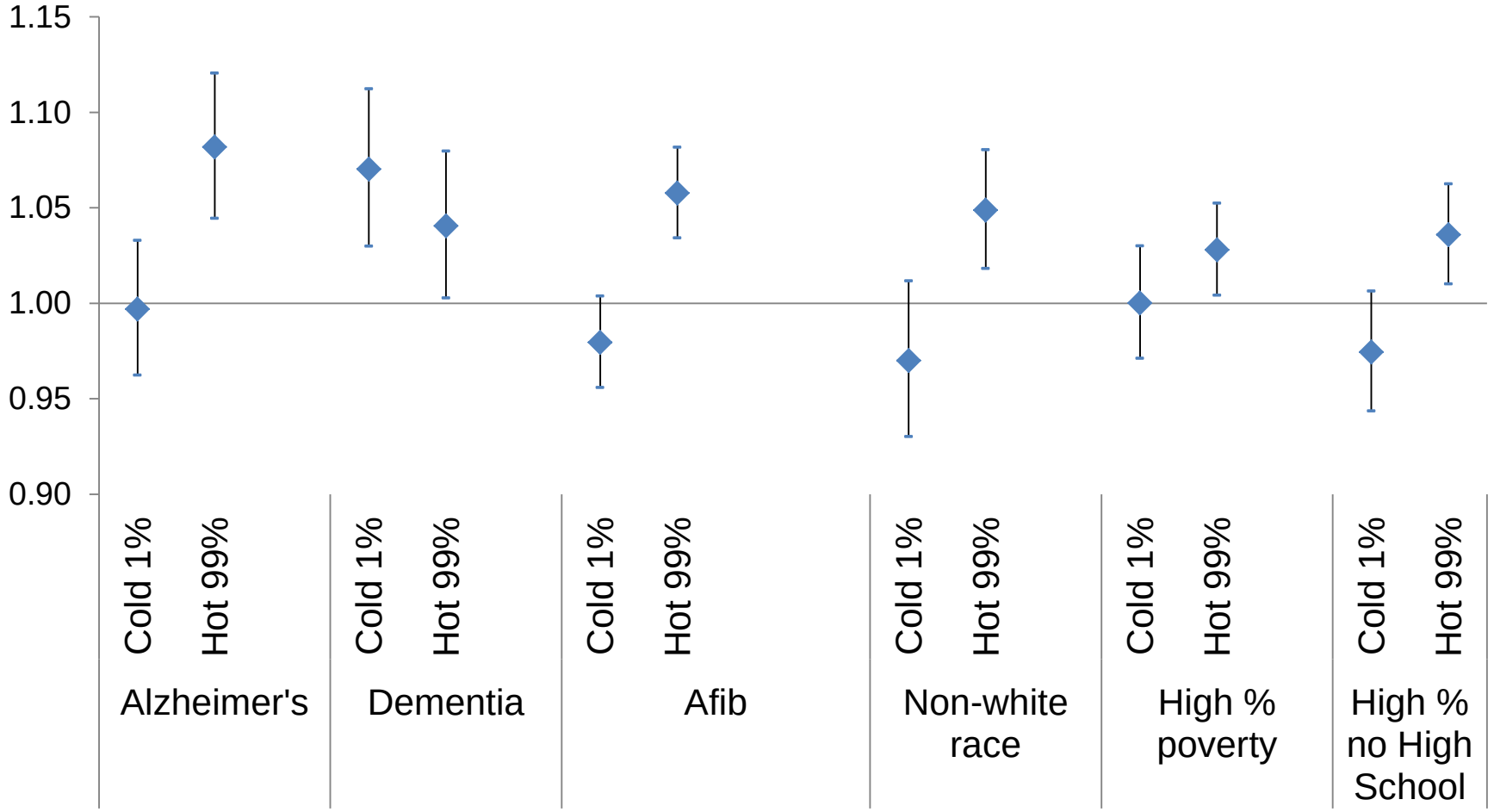


Medina-Ramon M, Schwartz J et al.

So it looks like

- The effects of the coldest 1% of days are the same everywhere in the US
- So warming the winter is unlikely to reduce deaths
- The effects of the hottest 1% of days differs substantially across US cities
- So even if we use the dose-response from city A which already has the predicted temperature for city B, we will expect changes in mortality

Effect modification by medical condition and subject and area level characteristics of the effect of extreme hot and extreme cold temperature (1th and 99th percentiles of temperature) on total mortality: meta-analysis of 123 and 111 U.S. cities respectively during the period 1985–2006, among Medicare enrollees.



Zanobetti A, O' Neill M, Gronlund C, Schwartz J, ATS conference, 2012

Cohort Study of Medicare Participants in 135 US Cities

- Follow a population over time and look at life expectancy
- What is the Exposure?
  - *Problem*
  - Life expectancy in Finland and Greece is about the same
  - *Possible Answer*
  - Variability of summer temperature predicts mortality differences

Hazard Ratio (HR) and 95% Confidence Intervals (CI) for a 1 °C increase in yearly summer temperature standard deviation across the 135 U.S. cities in four cohorts

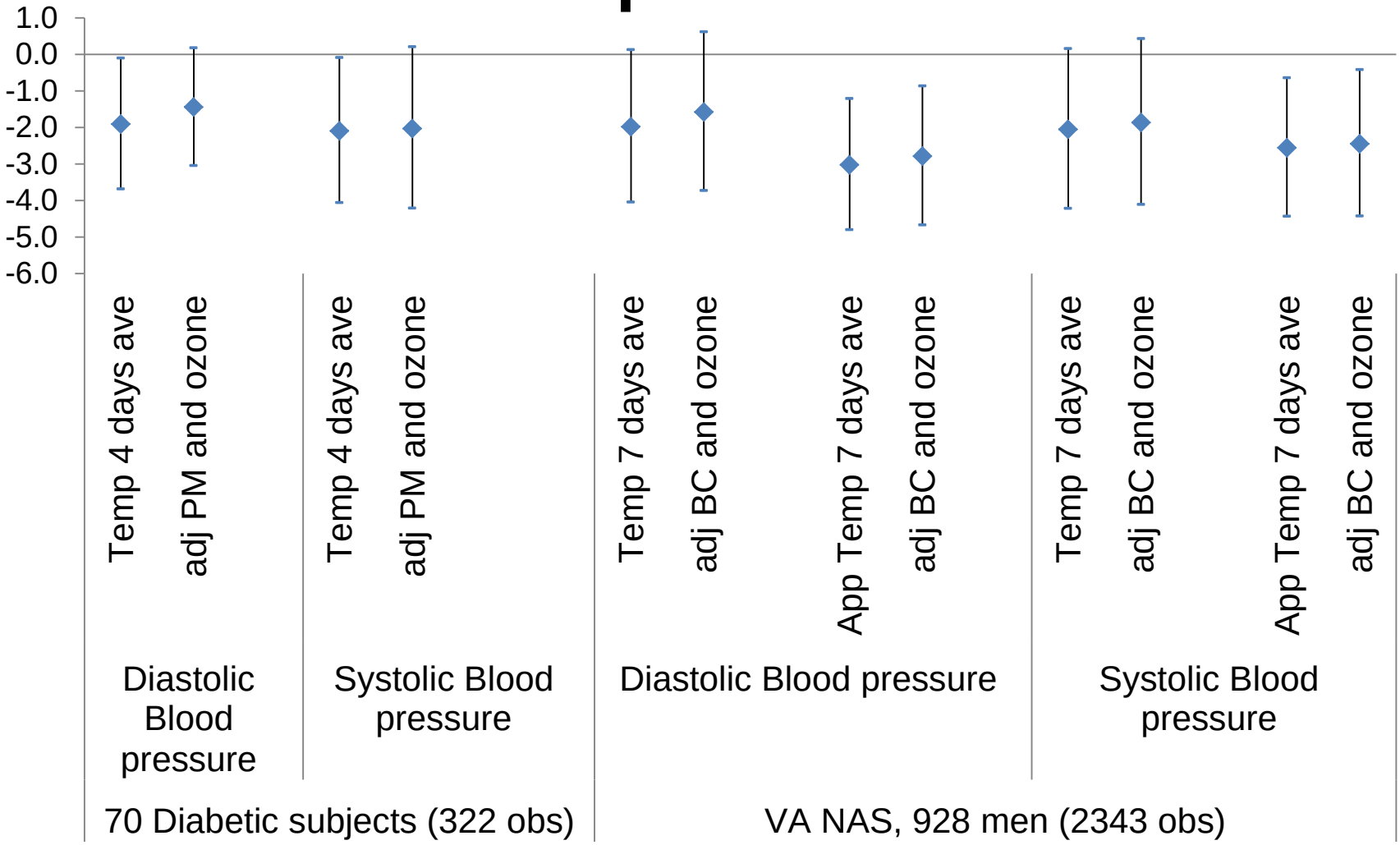
	Summer (June-August)		
	HR	95% CI	
Adjusting for ozone			
COPD	1.037	1.019	1.055
Diabetes	1.040	1.022	1.059
MI	1.038	1.021	1.055
CHF	1.028	1.013	1.042

Zanobetti A, O' Neill M, Gronlund C, Schwartz J, Proc Natl Acad Sci USA, 2012, 24;109(17):6608-13

What are potential Mechanisms

- Particularly at less extreme temperatures?

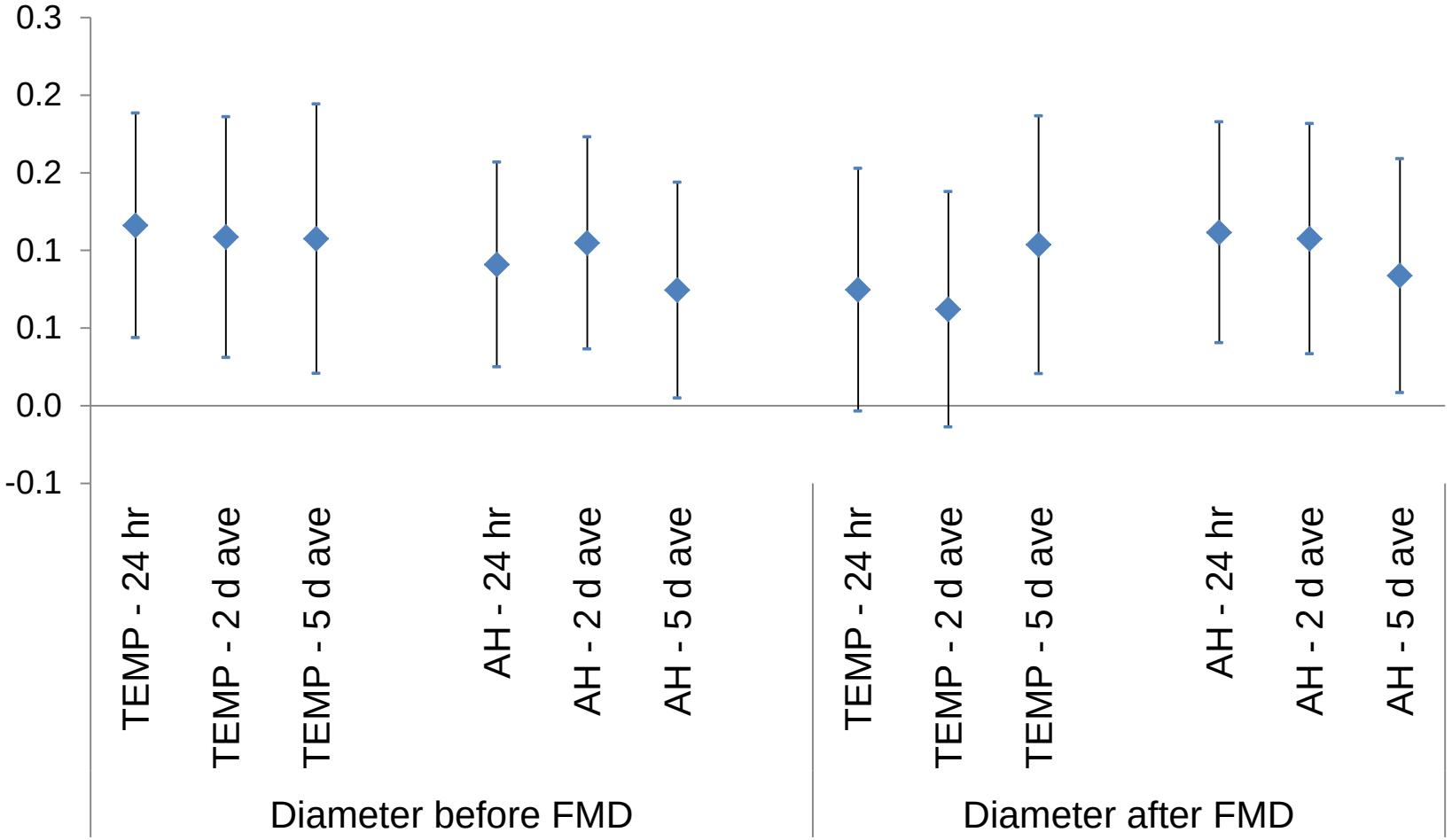
Percent increase in blood pressure for 10 degree increase in temperature and apparent temperature



Hoffmann B, Gold DR, et al. Environ Health Perspect, 2012;120(2):241-6

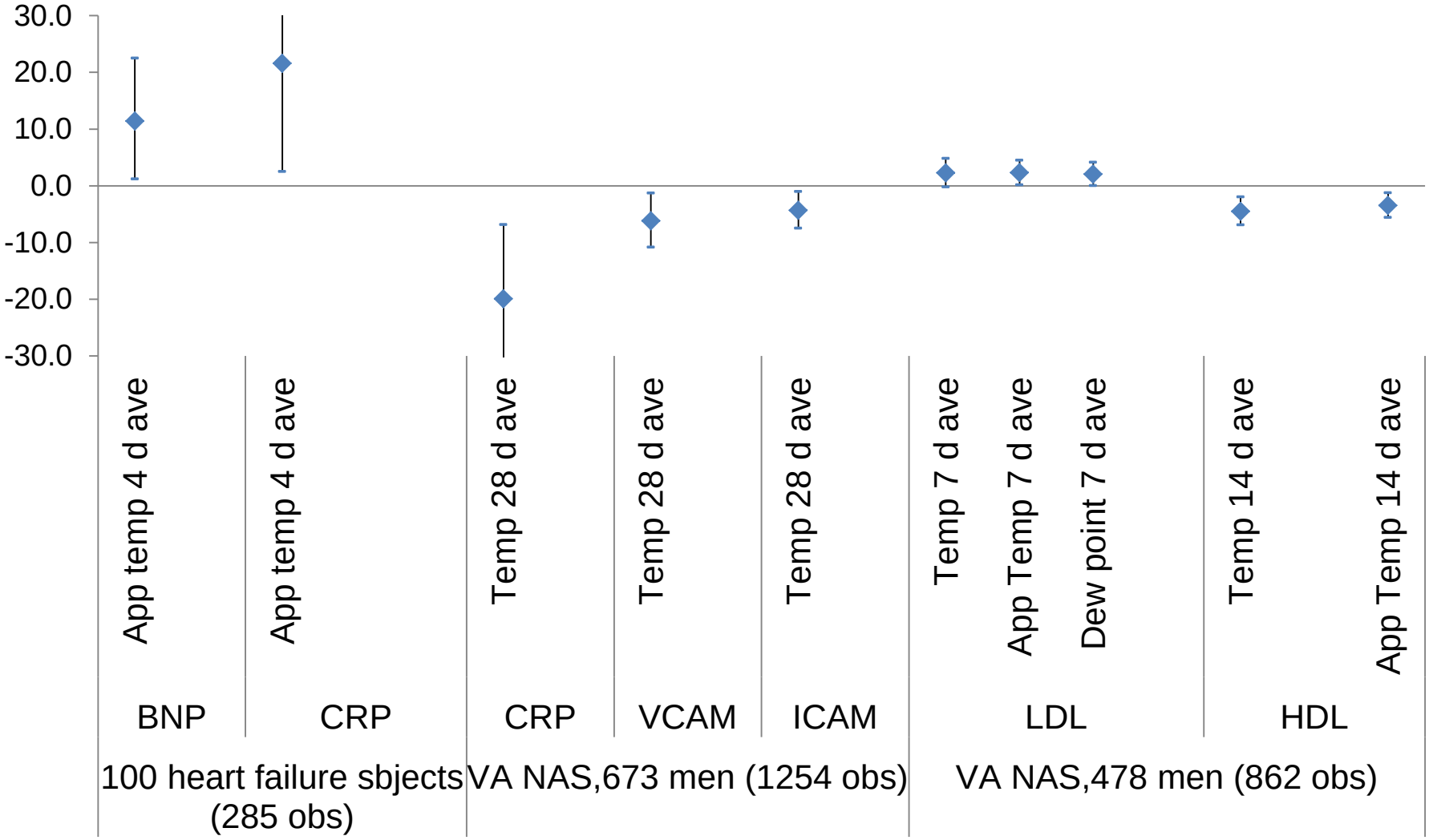
Halonen JI, Zanobetti A, Sparrow D, Vokonas PS, Schwartz J Occup Environ Med. 2011;68(4):296-301

Changes in mm (95% CI) in brachial artery diameter (BAD) before and after occlusion, for an IQR increase in the prior 24 hours, 2-day and 5-day average temperature (TEMP) and absolute humidity (AH) in diabetic subjects.



Zanobetti, Gold DR, et al. , Am J Respir Critic Care Med Vol 185. pp. A3203

Risk factors for cardiovascular disease



Wilker E, et al. Environ Health Perspec 2012, 120(8):1083-7 Halonen J, et al. Environ Res, 2011;111(2):281-7. Halonen J, et al. Environ Health; 2010: 9:42.

Impact of Meteorological Variables on Atrial Fibrillation

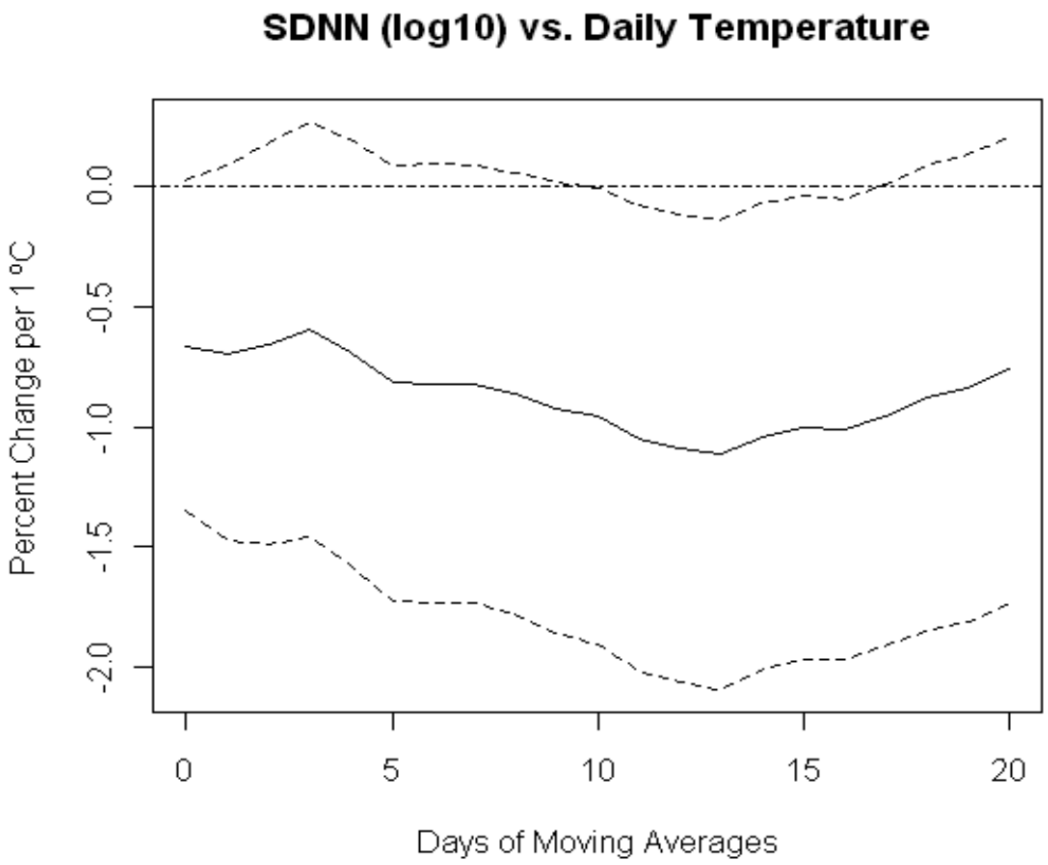
Parameters included in model	Adjusted for:	Matched IQR	Odds Ratio (95% CI)	*P*
Outdoor temperature	---	6.3°C	1.13 (0.89, 1.43)	0.32
	Indoor Temperature	6.3°C	1.01 (0.75, 1.37)	0.93
	Absolute Humidity	6.3°C	0.96 (0.72, 1.28)	0.79
Absolute Humidity	---	3.5 g/m^3	1.33 (1.02, 1.74)	0.037
	Outdoor Temperature	3.5 g/m^3	1.37 (0.98, 1.90)	0.061
	Indoor Temperature	3.5 g/m^3	1.28 (0.96, 1.70)	0.093

IQR, interquartile range; CI, confidence interval.

* All models were adjusted for the 24-hour moving average barometric pressure, 2-hour moving average particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) concentration, and matched on month, day of the week, and hour.

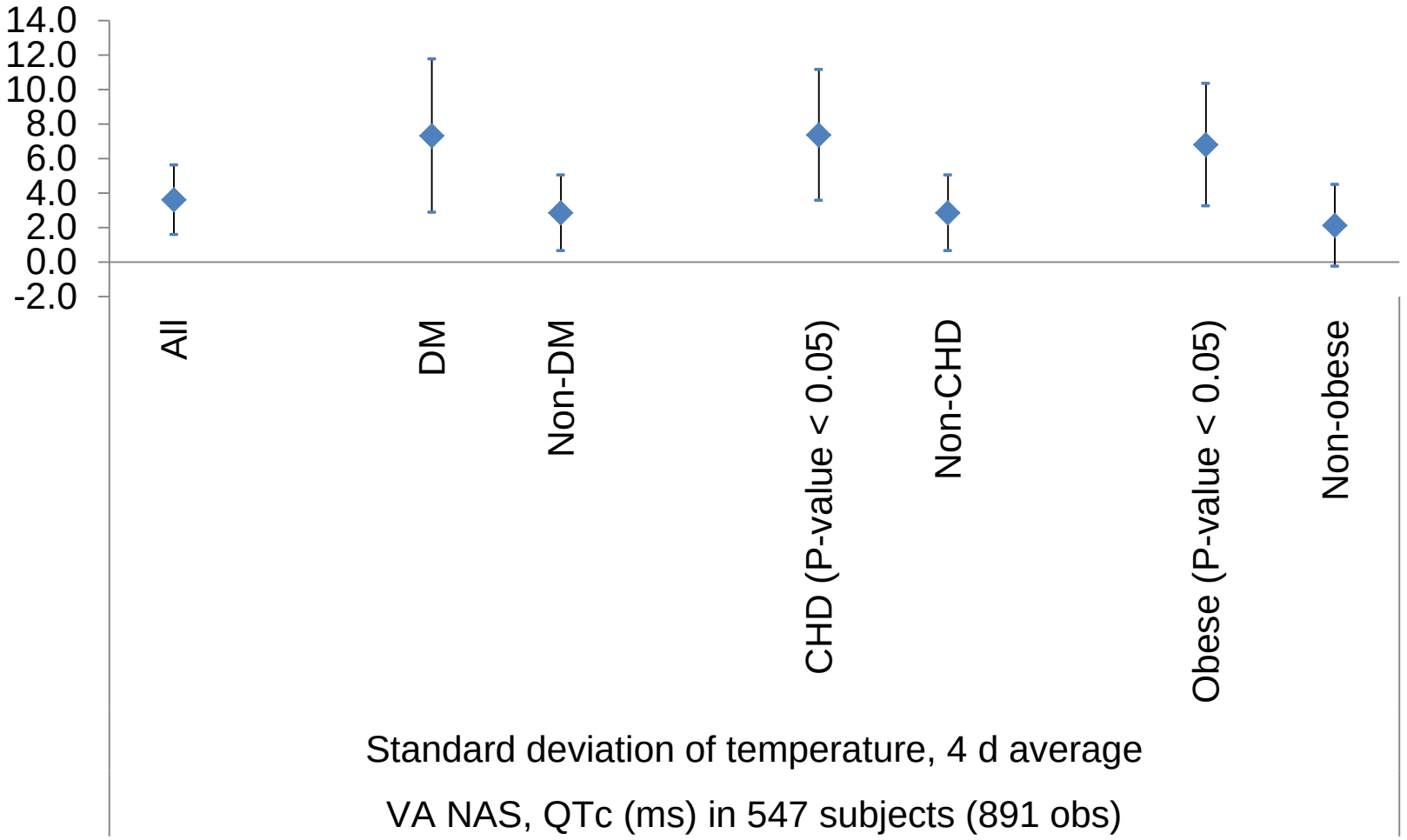
Nguyen J, Dockery D, et al

Effect of temperature on Heart Rate Variability and



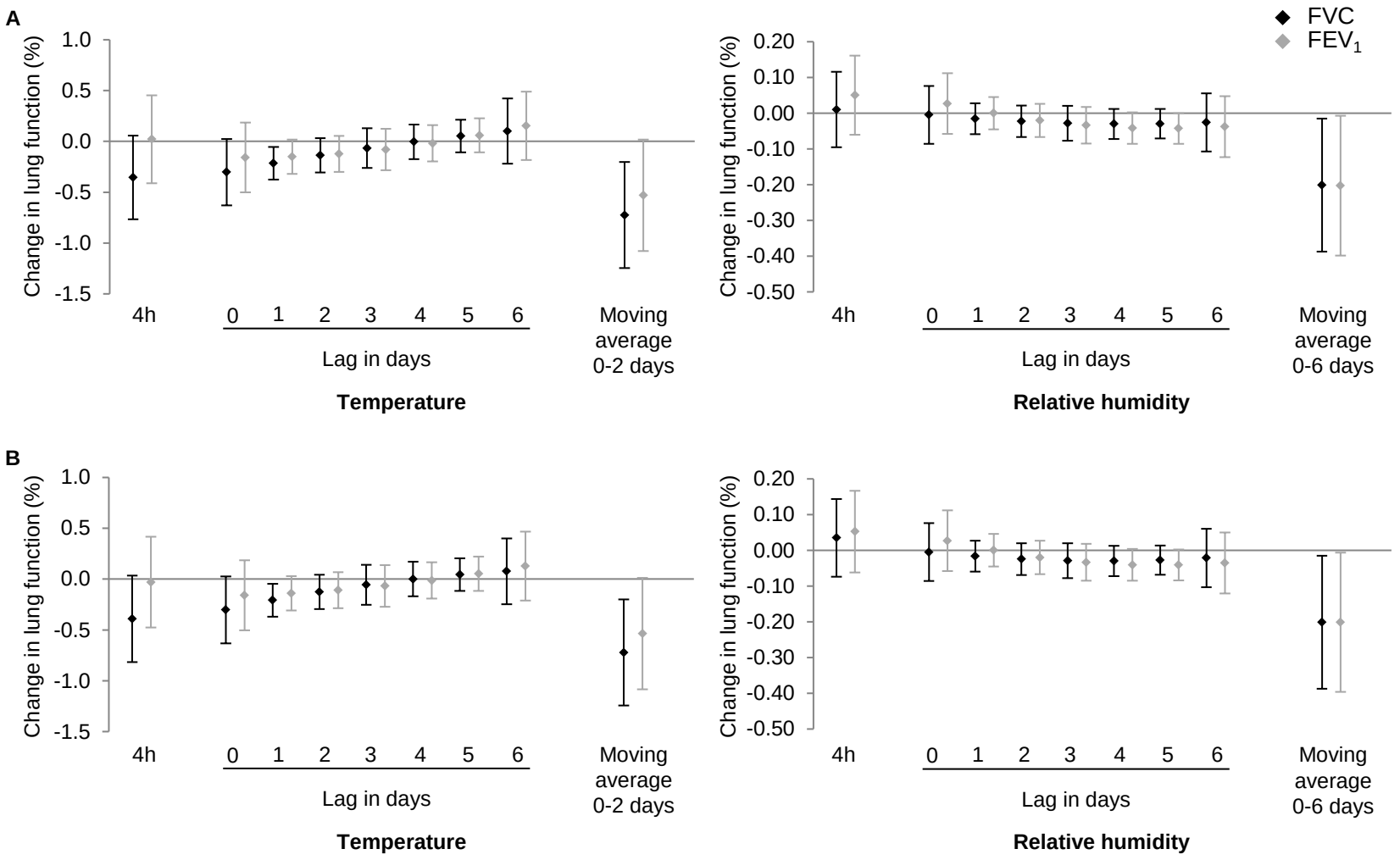
Ren C, et al. Am J Epidemiol 2011;173(9):1013-21

Effects of temperature variability on QTc (ms)



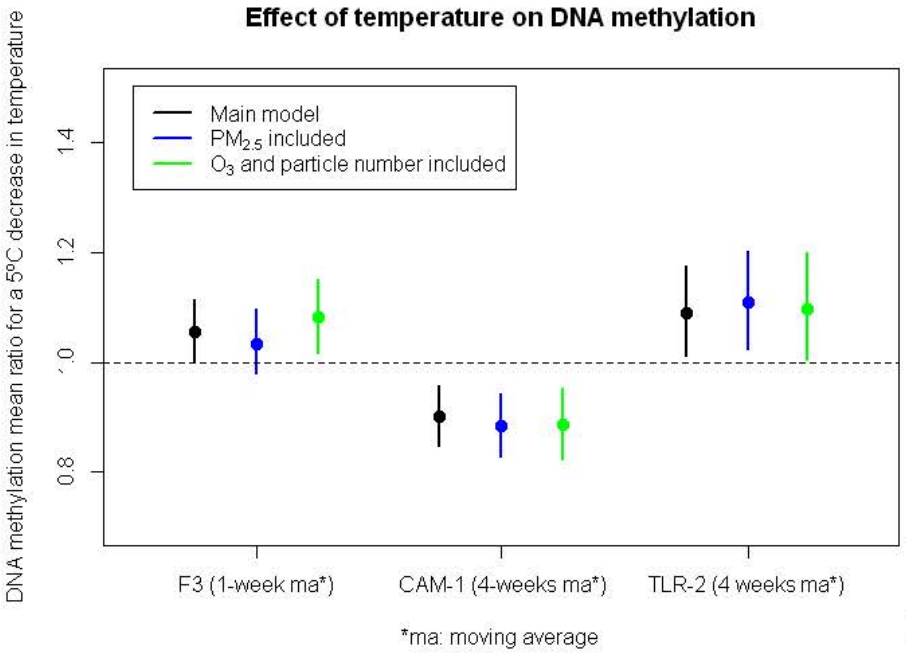
Mehta A, Schwartz J, Zanobetti A, et al.

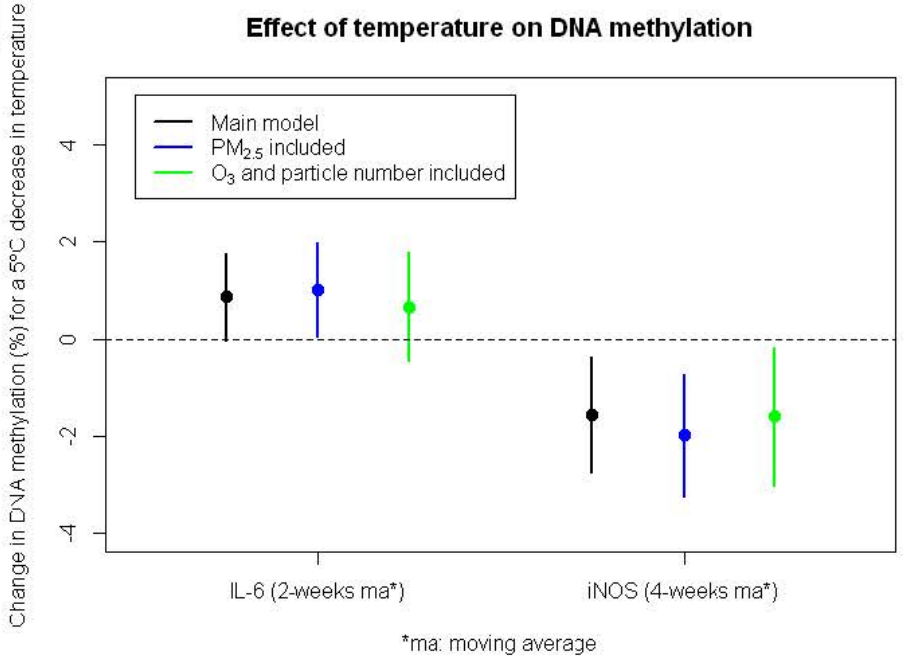
Effect of Meteorology on Lung Function



Lepeule J, Schwartz J

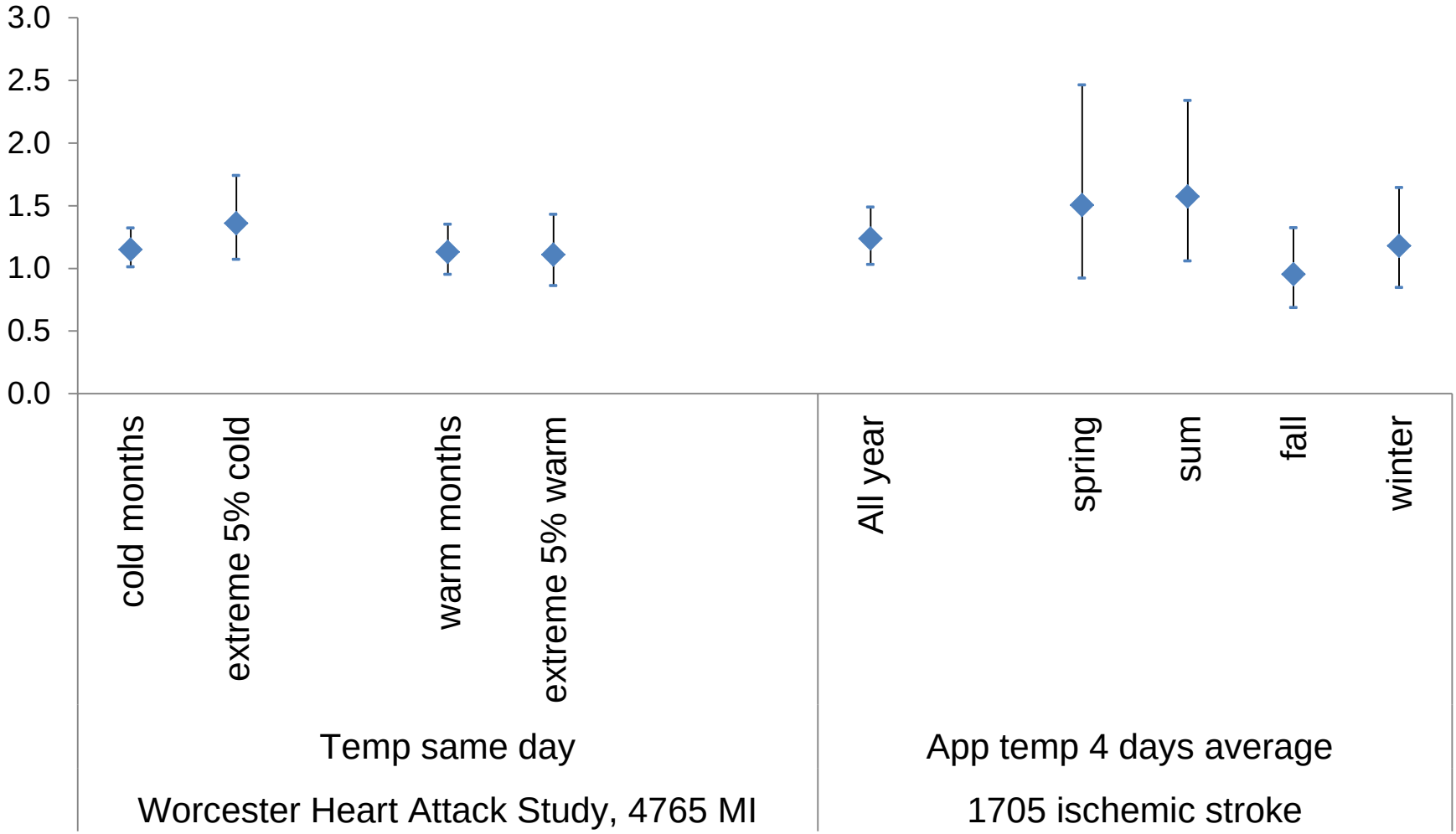
Effect of temperature on DNA Methylation





Bind MA, Schwartz J, et al

Decrease in Temperature and MI Incidence and ischemic stroke

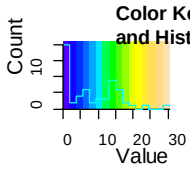


Madrigano J, Schwartz J, et al.Epidemiol, in press

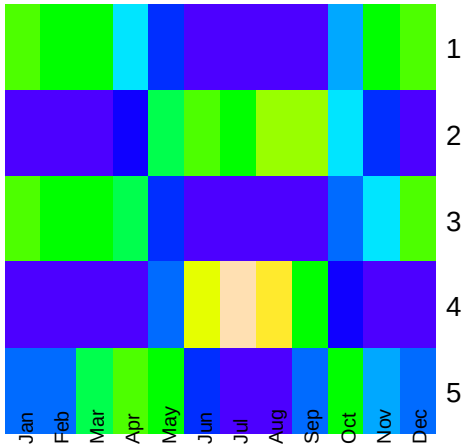
Mostofsky E, Mittleman M, et al. International Stroke conference 2013

Clustering days according to weather parameters

	1 *Mean (SD)*	2 *Mean (SD)*	3 *Mean (SD)*	4 *Mean (SD)*	5 *Mean (SD)*
# of days	1523	1308	1145	946	834
max T today (C)	**6 (5)**	**19 (4)**	**8 (6)**	**29 (3)**	**20 (6)**
SD Hourly Temp (C)	**2 (1)**	**2 (1)**	**2 (1)**	**3 (1)**	**4 (1)**
Water Vapor Pressure (mbar)	**5 (2)**	**14 (4)**	**6 (3)**	**20 (4)**	**9 (3)**
Sea-Level Pressure (mbar)	**1022 (6)**	**1016 (6)**	**1007 (7)**	**1013 (5)**	**1017 (7)**
Ozone (ppb)	18 (9)	22 (9)	24 (9)	35 (12)	27 (11)
Wind Speed (m/s)	**5 (1)**	**4 (1)**	**7 (2)**	**5 (1)**	**5 (1)**
PM2.5 TEOM (ug/m3)	10 (5)	10 (5)	7 (4)	16 (9)	10 (5)
Sulfur Dioxide (ppb)	7 (4)	3 (2)	4 (3)	3 (2)	4 (3)



Monthly



Monthly Distribution

Austin E, Koutrakis P, Zanobetti A, Gold D, Schwartz J, et al

Citations

- Zanobetti A, et al. Summer temperature variability and long-term survival among elderly people with chronic disease. Proc Natl Acad Sci USA, 2012, 24;109(17):6608-13.
- Hoffmann B, et al. Opposing Effects of Particle Pollution, Ozone and Ambient Temperature on Arterial Blood Pressure. Environ Health Perspect, 2012;120(2):241-6.
- Halonen J, et al. Outdoor temperature is associated with serum HDL and LDL. Environ Res, 2011;111(2):281-7.
- Halonen J, et al. Relationship between outdoor temperature and blood pressure. Occup Environ Med. 2011;68(4):296-301
- Halonen J, et al. Associations between outdoor temperature and markers of inflammation: a cohort study. Environ Health; 2010: 9:42.
- Ren C, et al. Ambient Temperature, Air Pollution, and Heart Rate Variability in an Aging Population. Am J Epidemiol 2011;173(9):1013-21.
- Wilker E, et al. Ambient temperature and biomarkers of heart failure: a repeated measures analysis. Environ Health Perspec 2012 Aug;120(8):1083-7.
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- Zanobetti A et al. Effects Of Temperature And Water Vapor Pressure On Vascular Function In People With Diabetes, ATS conference, Am J Respir Critic Care Med Vol 185. pp. A3203
- Mostofsky E et al. Short-Term Changes in Ambient Temperature and Risk of Ischemic Stroke. Abstract submitted to the International Stroke conference 2013
- Zanobetti A, et al. Assessing Effect Modification By Zipcode Area Level Characteristic, Personal Characteristics And Specific Cause Of Admission In A Multi-City Case-Only Analysis. Abstract to ATS conference, 2012
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- Madrigano J et al. Temperature, Myocardial Infarction, and Mortality: Effect Modification by Individual and Area-Level Characteristics, Epidemiol, in press

Acknowledgments

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- NIEHS R21 AG040027-01
- NIEHS R21 ES020194
- NIEHS PO1 ES-09825
- NIEHS P30 ES000002-49
- US EPA grant RD 83479801

- Our Climate Change R21s led to:
  - an RO1 proposal to evaluate indoor and outdoor temperature/humidity and land use effects on cardiovascular and sleep outcomes in the longitudinal Jackson (Mississippi) Heart Study.
  - An R21 proposal to identify the chronic effects associated with long-term exposure to fluctuations in temperature and absolute humidity, adaptation, and to investigate the health consequences of increasing variability of summertime temperatures with different future scenarios