BROWN
Public Health

Air Pollution and Cardiovascular Disease: From Air Quality Data to Policy

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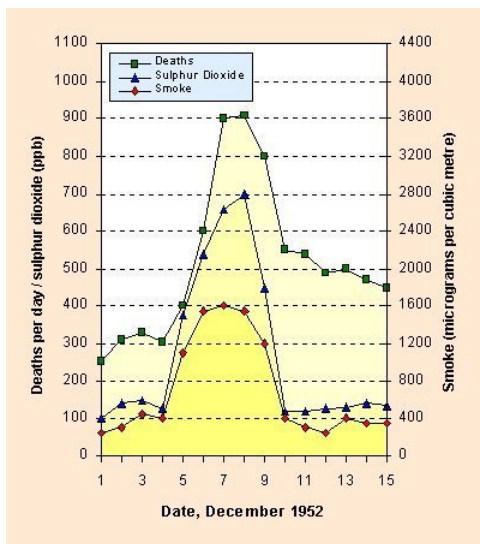Brown University
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EPA AQS Conference: 8/22/2012

London Smog, 1952

A couple wearing smog masks
take an afternoon stroll along
The Embankment

Greater London
Authority, 2002

London Smog, 1952

www.portfolio.mvm.ed.ac.uk

Boston, MA

www.hazecam.net

Boston, MA

www.hazecam.net

Estimated PM$_{10}$ Levels in Large Cities

PM10
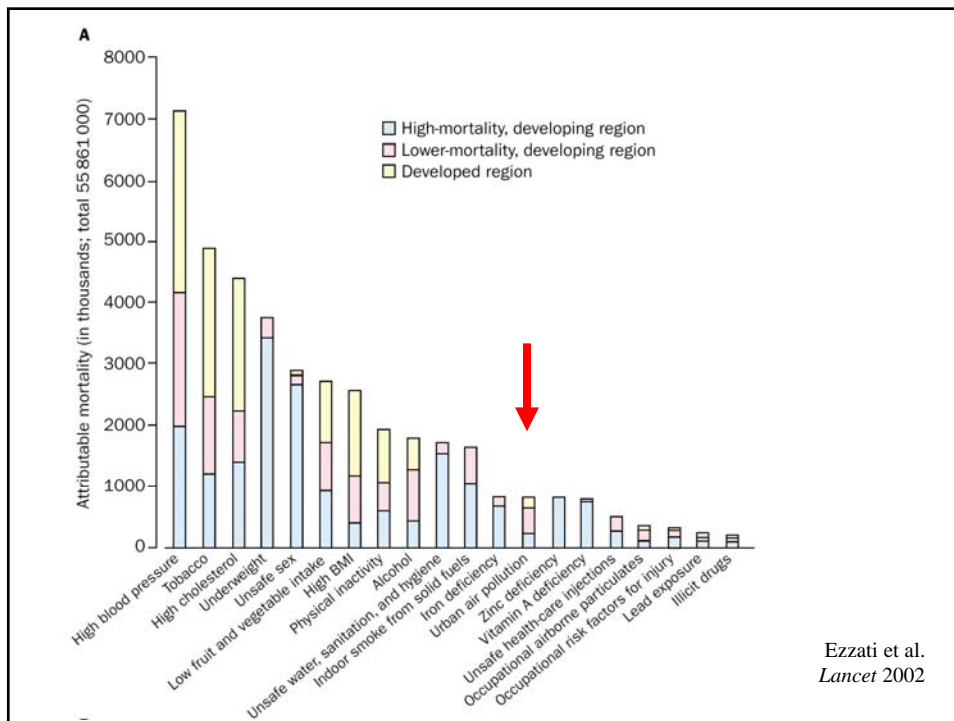(quintiles)
- I (low)
- II
- III
- IV
- V (high)
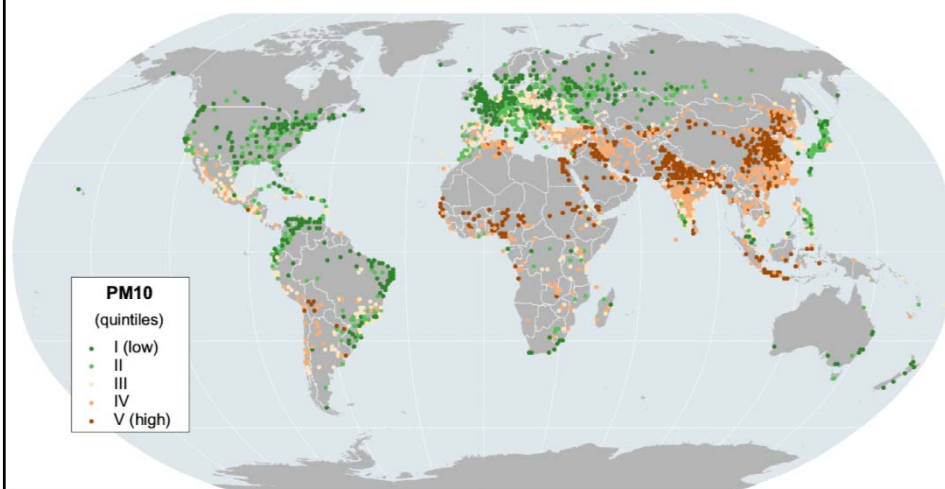
Cohen et al. *GBD* 2002

Annual Mortality Attributable to Outdoor Air Pollution

| Environmental risks	Global estimate	Asian estimate (S, SE Asia + W Pacific)
Unsafe water	1,730,000	730,000
Urban outdoor air	799,000	487,000
Indoor air	1,619,000	1,025,000
Lead	234,000	88,000

Cohen et al. 2005

Ezzati et al. *Lancet* 2002

Estimated Annual Global Deaths Attributable to Outdoor Air Pollution

Table 5. Estimated annual global $PM_{2.5}$ mortalities (mean ± 1 SD) using alternative CRFs with and without LCTs and HCTs (×1,000).

	Mortality		
	All causes	Cardiopulmonary	Lung cancer
Krewski et al. (2009)	3,381 ± 986	3,499 ± 864	222 ± 80
LCT = 5.8 µg/m³	2,378 ± 876 (−29.7%)	2,506 ± 816 (−28.4%)	164 ± 68 (−26.1%)
LCT = 7.5 µg/m³	2,077 ± 822 (−38.6%)	2,201 ± 780 (−37.1%)	146 ± 64 (−34.2%)
HCT = 30 µg/m³	3,059 ± 774 (−9.5%)	3,205 ± 676 (−8.4%)	201 ± 68 (−9.5%)
HCT = 50 µg/m³	3,338 ± 940 (−1.3%)	3,464 ± 826 (−1.0%)	219 ± 78 (−1.4%)
Pope et al. (2002), 1979–1983[a]	2,333 ± 1,196 (−31.0%)	1,800 ± 742 (−48.6%)	139 ± 72 (−37.4%)
Laden et al. (2006)[b]	7,714 ± 2,736 (+128.2%)	4,549 ± 1,439 (+30.0%)	336 ± 198 (+51.4%)

Anenberg et al. *EHP* 2010

Estimated Annual Excess Cardiopulmonary Mortality Rate Attributable to $PM_{2.5}$
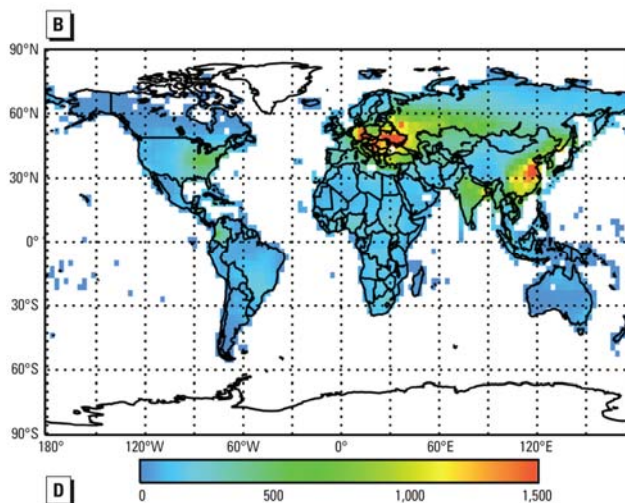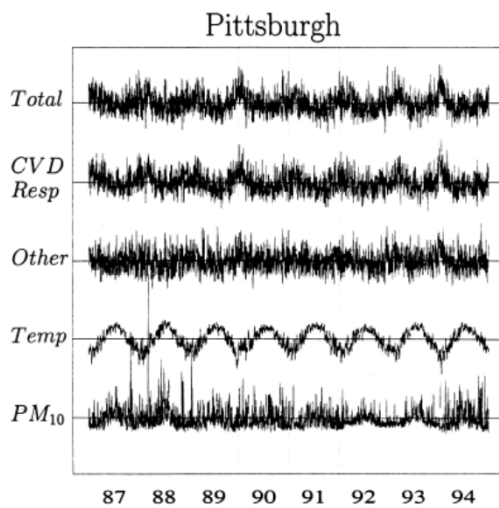

Anenberg et al. *EHP* 2010

What Are People Dying Of?

Cause of death	Percent of total deaths	Estimated RR per 50 $\mu g/m^3$ increase in $PM_{2.5}$	Percent of excess deaths due to PM exposure
All Causes	100	1.07	100
Respiratory	8	1.25	28
Cardiovascular	45	1.11	69
Other	47	1.04	3

Pope *EHP* 2000

Cardiovascular Effects of Short-Term Exposure

The Problem

Pittsburgh

Total

CVD
Resp

Other

Temp

PM_{10}

87 88 89 90 91 92 93 94

Dominici et al. *AJE* 2003

PM_{10} and All-Cause Mortality in 20 US Cities

% Change in All-Cause Mortality

Los Angeles
New York
Chicago
Dallas–Fort Worth, Tex.
Houston
San Diego, Calif.
Santa Ana–Anaheim, Calif.
Phoenix, Ariz.
Detroit
Miami
Philadelphia
Minneapolis
Seattle
San Jose, Calif.
Cleveland
San Bernardino, Calif.
Pittsburgh
Oakland, Calif.
Atlanta
San Antonio, Tex.
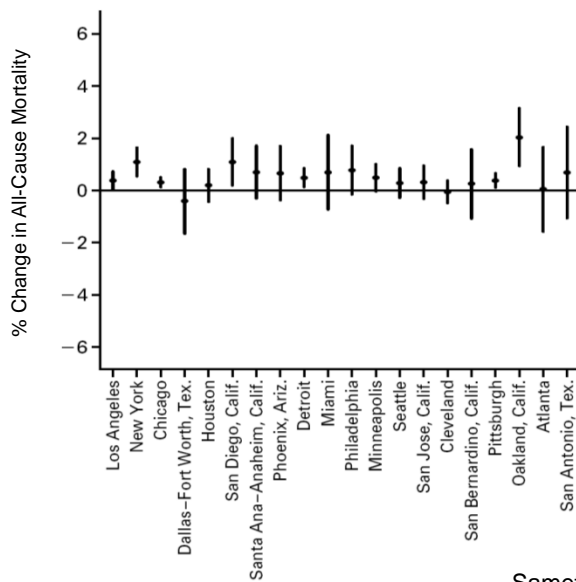
Samet et al. *NEJM* 2000

NMMAPS: Percent Change in Daily Mortality for a 10-ppb Increase in O_3

Bell et al. *JAMA*. 2004
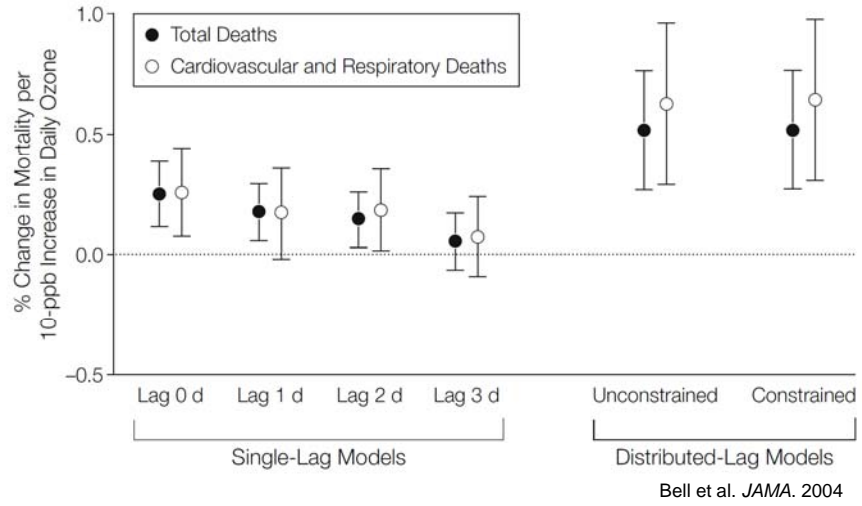
Medicare Cohort Air Pollution Study (MCAPS), 1999–2002

Dominici et al. *JAMA*. 2006

Dominici et al. *JAMA.* 2006

Percent Increase in CVD Hospital Admissions per 10 µg/m³ Increase in PM$_{2.5}$

- • < -5.0%
- • -5.0% to 0.0%
- • 0.0% to 1.5%
- • 1.5% to 5.0%
- • > 5.0%

Bell et al. *AJRCCM.* 2009
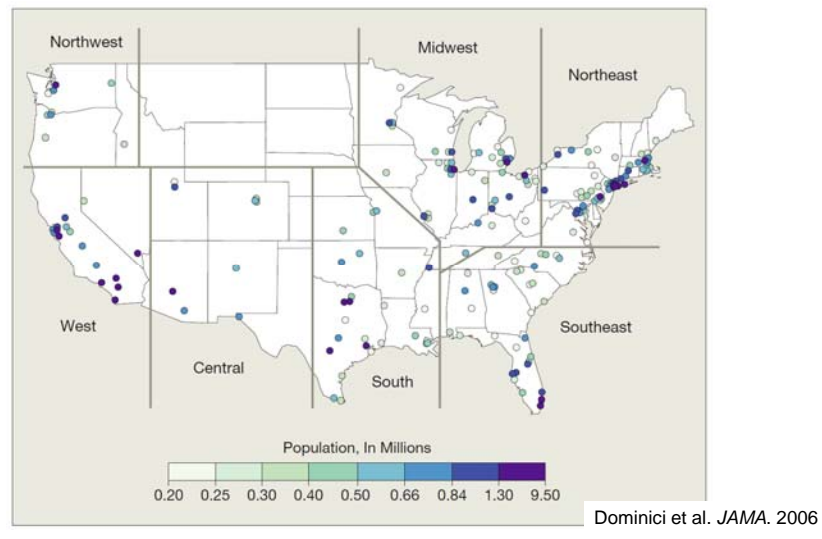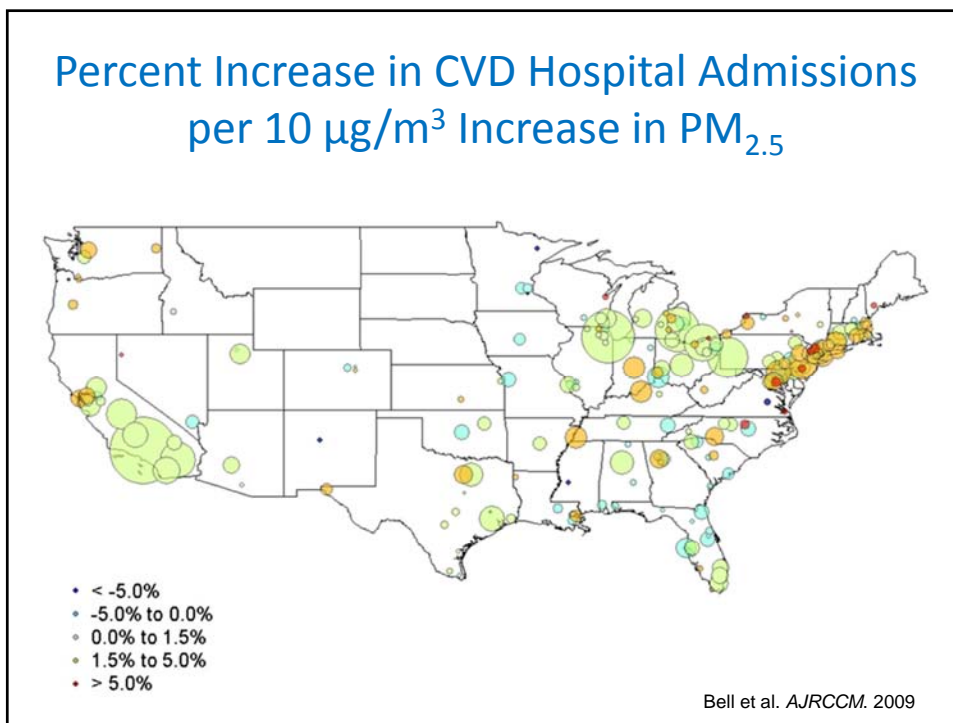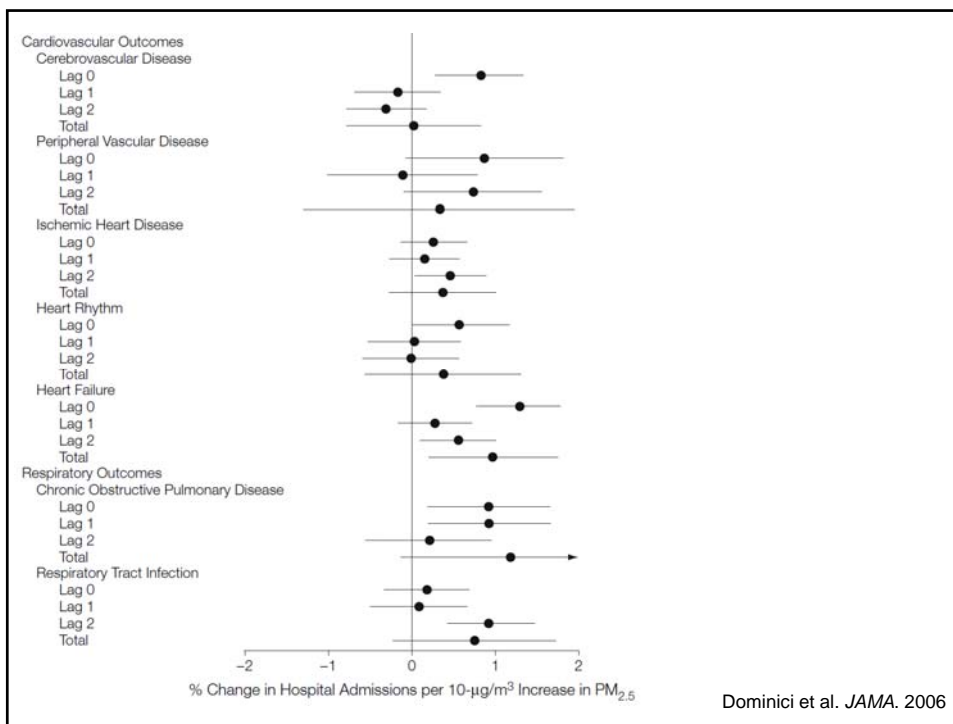
Percent Increase in CVD Hospital Admissions per IQR Increase in Each Component

Bell et al. *AJRCCM.* 2009

www.airnow.gov

Air Quality Index for PM$_{2.5}$
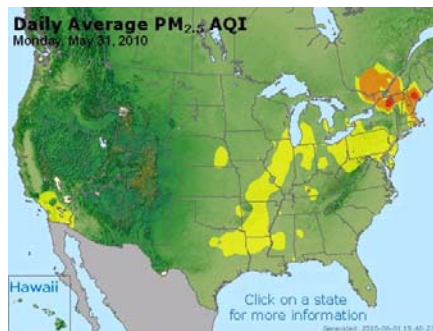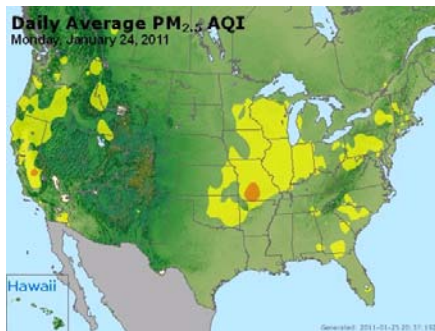
www.airnow.gov

AQI and Risk of Ischemic Stroke Onset
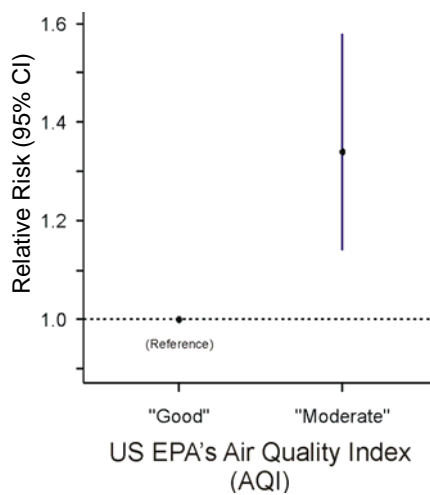
Wellenius et al. *Arch Intern Med* 2012

Public health importance of triggers of myocardial infarction: a comparative risk assessment

Tim S Nawrot, Laura Perez, Nino Künzli, Elke Munters, Benoit Nemery
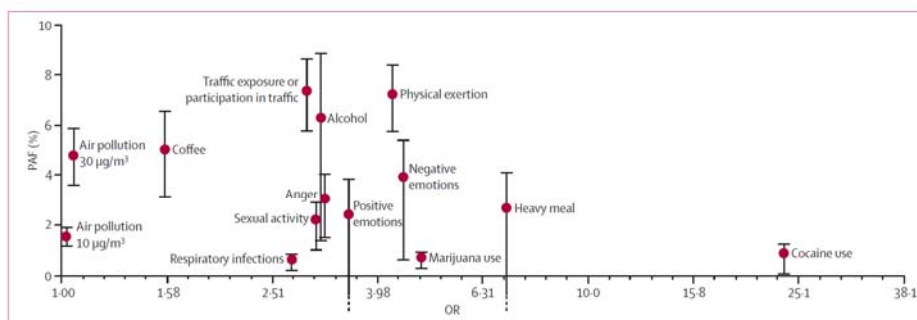
Figure 2: Relation between OR and the PAF for each studies trigger
PAFs were calculated and reported with their 95% CI (error bars). Not significant triggers show 95% CIs that are lower than 0%. X-axis is log scale, and ORs are given as anti-logs. OR=odds ratio. PAF=population attributable fraction.

Nawrot et al. *Lancet.* 2011

Cardiovascular Effects of Long-Term Exposure

Harvard Six-Cities Study
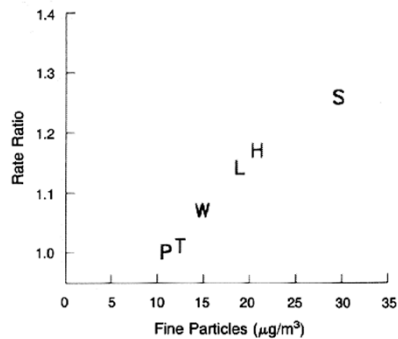
- 8111 adults in 6 cities recruited between 1974 and 1977
- 14-16 year follow-up for mortality

Dockery *NEJM* 1993

Women's Health Initiative
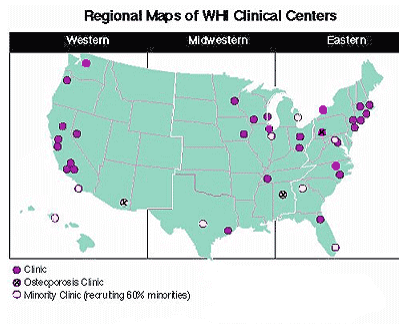
- 65,000 women recruited from 49 centers in 36 US Metropolitan areas between 1994 and 1998
- Followed prospectively through 2002
- Exposure estimated based on average $PM_{2.5}$ levels in 2000 at nearest EPA monitor

Women's Health Initiative

Table 3. Estimated Hazard Ratios for the Time to the First Cardiovascular Event or Death Associated with an Exposure Increase of 10 μg per Cubic Meter in the Level of Fine Particulate Matter ($PM_{2.5}$).*

Outcome	No. of Events	Hazard Ratio (95% CI)		
		Overall	Between Cities	Within Cities
First cardiovascular event				
Any cardiovascular event†	1816	1.24 (1.09–1.41)	1.15 (0.99–1.32)	1.64 (1.24–2.18)
Coronary heart disease‡	1268	1.21 (1.04–1.42)	1.13 (0.95–1.35)	1.56 (1.11–2.19)
Cerebrovascular disease§	600	1.35 (1.08–1.68)	1.20 (0.94–1.54)	2.08 (1.28–3.40)
Myocardial infarction	584	1.06 (0.85–1.34)	0.97 (0.75–1.25)	1.52 (0.91–2.51)
Coronary revascularization	949	1.20 (1.00–1.43)	1.14 (0.93–1.39)	1.45 (0.98–2.16)
Stroke	554	1.28 (1.02–1.61)	1.12 (0.87–1.45)	2.08 (1.25–3.48)
Death from cardiovascular cause				
Any death from cardiovascular cause	261	1.76 (1.25–2.47)	1.63 (1.10–2.40)	2.28 (1.10–4.75)
Coronary heart disease				
Definite diagnosis	80	2.21 (1.17–4.16)	2.22 (1.06–4.62)	2.17 (0.60–7.89)
Possible diagnosis	59	1.26 (0.62–2.56)	1.20 (0.54–2.63)	1.57 (0.29–8.51)
Cerebrovascular disease	122	1.83 (1.11–3.00)	1.58 (0.90–2.78)	2.93 (1.03–8.38)

Miller et al. *NEJM.* 2007

Nurses' Health Study
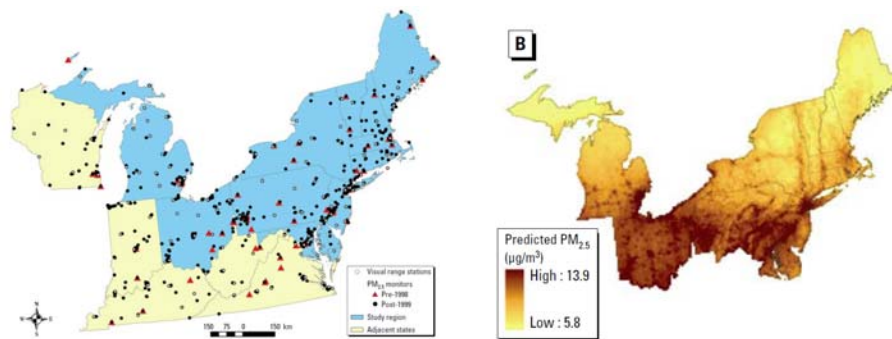
Yanosky et al. *Env Health Perspect.* 2008

Nurses' Health Study
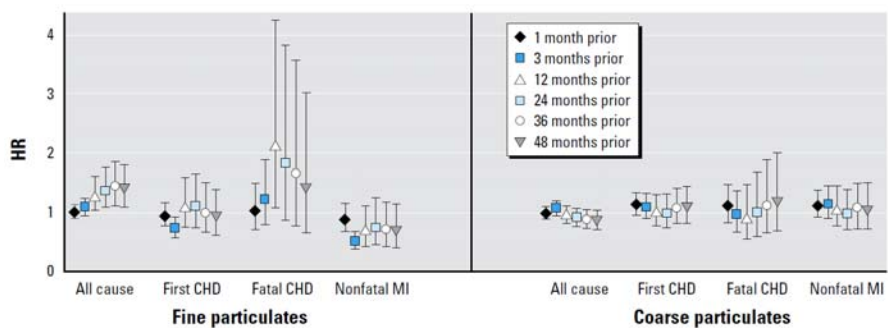
Puett et al. *Env Health Perspect.* 2009

Combining Ground and Satellite Data
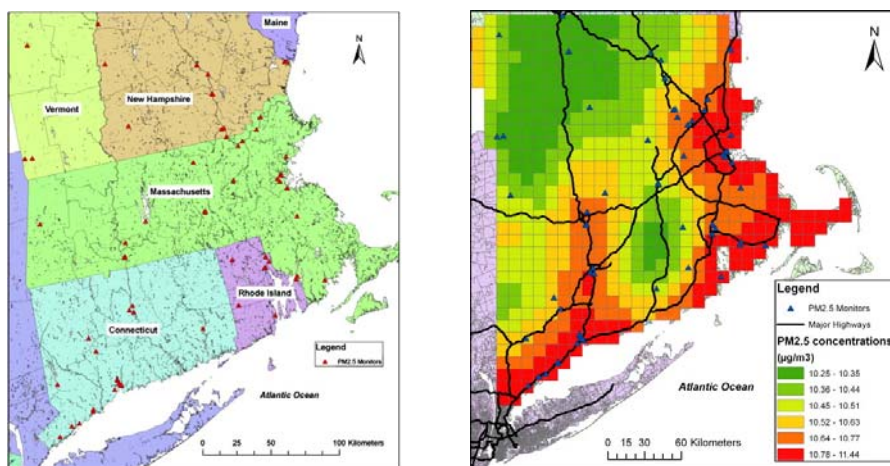
Lee et al. *Environ Res.* 2012

Combining Ground and Satellite Data

Lee et al. *Environ Res.* 2012

Kloog et al. *PLoS One.* 2012
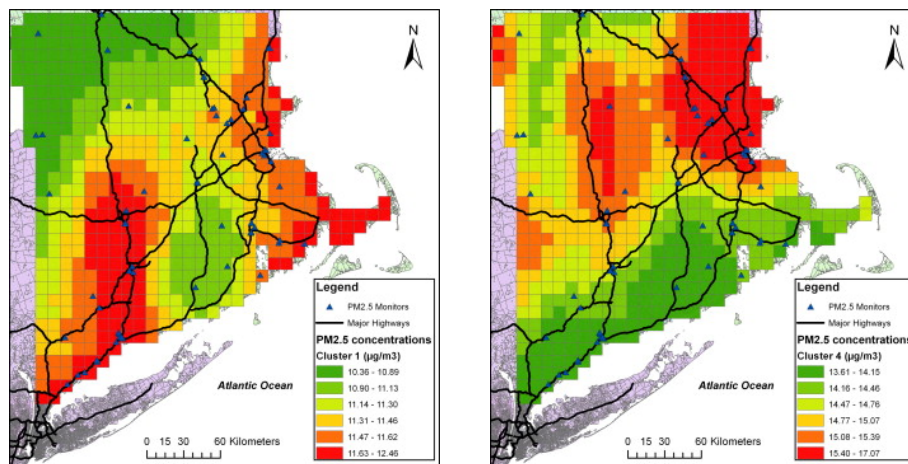
Acute and Chronic Effects of Particles on Hospital Admissions in New-England

Itai Kloog[1,*], Brent A. Coull[2], Antonella Zanobetti[1], Petros Koutrakis[1], Joel D. Schwartz[1]

PM$_{2.5}$ exposure type	All Respiratory	CVD
	Percent increase [a]	Percent increase [a]
Short term PM$_{2.5}$ exposure	0.70 (0.35–0.52)	1.03 (0.69–0.45)
Long term PM$_{2.5}$ exposure	4.22(1.06–4.75)	3.12(0.30–4.29)

Note: [a]Values are percent.
doi:10.1371/journal.pone.0034664.t003

Kloog et al. *PLoS One.* 2012

Cardiovascular Health Effects of Particulate Air Pollution

Chronic effects
- Clinical events
- Atherosclerosis
- Hemodynamics
- Oxidative stress
- Inflammation

Acute effects
- Clinical events
- Autonomic nervous system function
- Hemodynamics
- Inflammation
- Oxidative stress
- Hemostasis
- Endothelial cell function

Connection to Policy

Summary of NAAQS Promulgated for PM, 1971-2006

Year (Final Rule)	Indicator	Avg Time	Level	Form
1971 (36 FR 8186)	TSP (Total Suspended Particulates)	24 h	260 µg/m^3 (primary) 150 µg/m^3 (secondary)	Not to be exceeded more than once per yr
		Annual	75 µg/m^3 (primary)	Annual geometric mean
1987 (52 FR 24634)	PM$_{10}$	24 h	150 µg/m^3	Not to be exceeded more than once per yr on average over a 3-yr period
		Annual	50 µg/m^3	Annual arithmetic mean, averaged over 3 yr
1997 (62 FR 38652)	PM$_{2.5}$	24 h	65 µg/m^3	98th percentile, averaged over 3 yr
		Annual	15 µg/m^3	Annual arithmetic mean, averaged over 3 yr[1]
	PM$_{10}$	24 h	150 µg/m^3	Initially promulgated 99th percentile, averaged over 3 yr; when 1997 standards were vacated in 1999, the form of 1987 standards remained in place (not to be exceeded more than once per yr on average over a 3-yr period)
		Annual	50 µg/m^3	Annual arithmetic mean, averaged over 3 yr
2006 (71 FR 61144)	PM$_{2.5}$	24 h	35 µg/m^3	98th percentile, averaged over 3 yr
		Annual	15 µg/m^3	Annual arithmetic mean, averaged over 3 yr[2]
	PM$_{10}$	24 h	150 µg/m^3	Not to be exceeded more than once per yr on average over a 3-yr period

Note: When not specified, primary and secondary standards are identical.

Connection to Policy

TABLE 4—TOTAL COSTS, MONETIZED BENEFITS AND NET BENEFITS IN 2020 [a] (MILLIONS OF 2006$) [b] FULL ATTAINMENT

Alternate PM$_{2.5}$ standards (annual/24-hour, in μg/m³)	Total costs		Monetized benefits [b]		Net benefits [b]	
	3% Discount rate	7% Discount rate	3% Discount rate	7% Discount rate	3% Discount rate [c]	7% Discount rate
13/35	$2.9	$2.9	$88 to $220	$79 to $200	$85 to $220	$76 to $200
12/35	69	69	2,300 to $5,900	2,100 to $5,400	2,300 to $5,900	2,000 to $5,300
11/35	270	270	9,200 to $23,000	8,300 to $21,000	8,900 to $23,000	8,000 to $21,000
11/30	390	390	14,000 to $36,000	13,000 to $33,000	14,000 to $36,000	13,000 to $33,000

Open Research Questions

- Who is most susceptible to these effects?
- Other health effects?
- What are the key components or sources of $PM_{2.5}$ that elicit these effects?
- Interactions with other pollutants?
- Interactions with meteorological factors?
- Interactions with population/housing characteristics?
- Many more….

Summary

- Ambient $PM_{2.5}$ is associated with a wide range of adverse cardiovascular health effects
- Many important research questions remain unanswered
- This research has direct relevance to public policy and public health
- EPA's ambient air quality data has been (and will continue to be) central to health effects research

Thank You!