



The Ever Expanding Knowledge-Base of Air Pollution's Health Effects

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Conflict of Interest Statement

Wayne Cascio, MD

- *No conflicts of interest*
- *The presentation represents the opinions of the speaker and does not necessarily represent the policies of the US EPA*



Air Pollution: A Leading Cause of the Global Burden of Disease

In 2015 ambient PM_{2.5} was the fifth-ranking global mortality risk factor -

Exposure to PM_{2.5} caused:

- 4.2 million deaths (7.6% of total deaths)
- 103.1 million disability-adjusted life-years (4.2% of DALYs)

Between 1990 and 2015 deaths increased in association with PM_{2.5} exposure from:

- 3.5 million to 4.2 million

Ozone exposure contributed to morbidity and mortality -

In 2015 ozone exposure is estimated to have accounted for:

- 254,000 deaths
- 4.1 million DALYs from chronic obstructive pulmonary disease

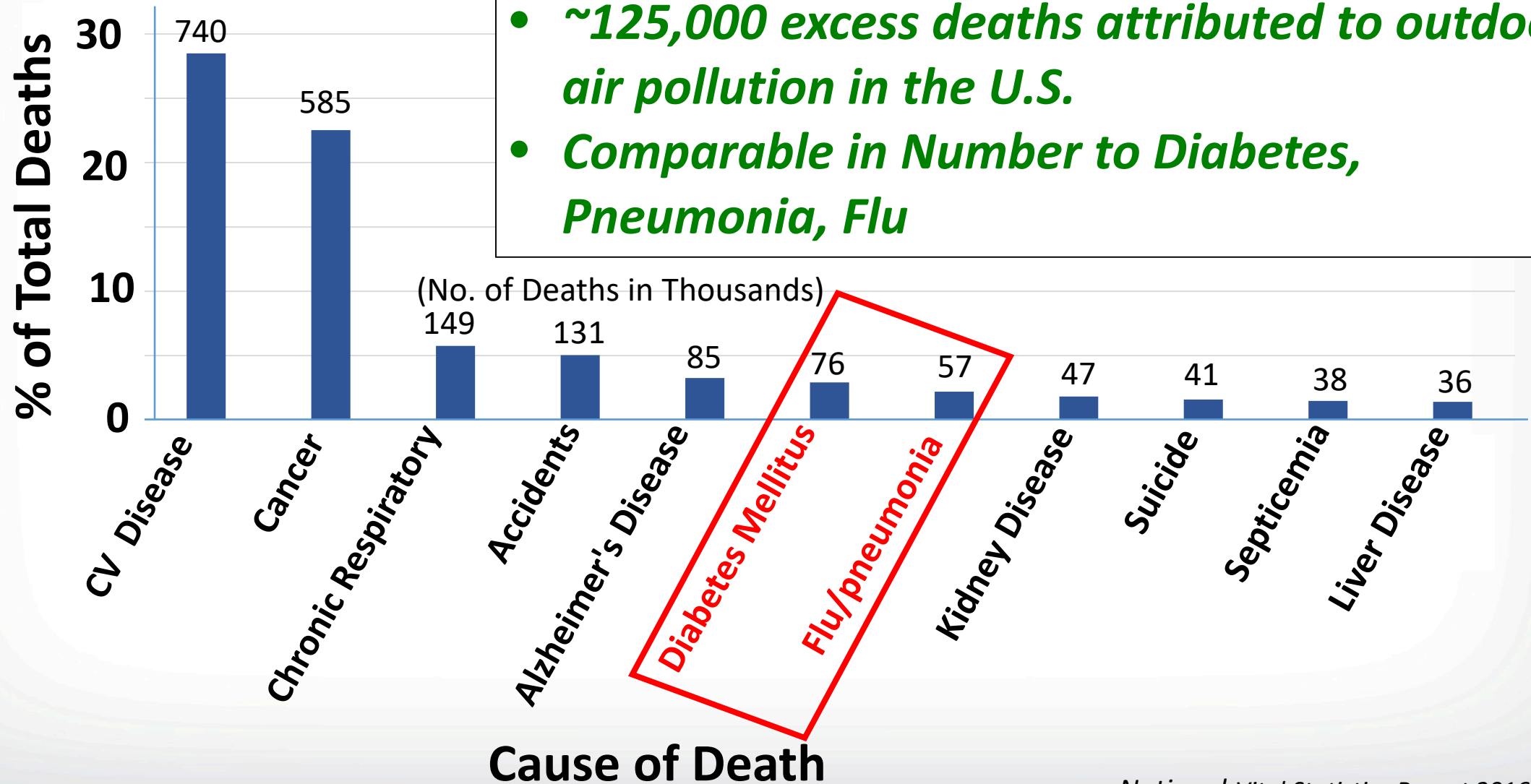


Despite Phenomenal Progress U.S. Air Pollution Continues to Impact Population Health

Air pollution remains a significant U.S. Public Health Concern

- Estimated excess mortality **125,000 deaths/year**
- Over **20 million school days and work days lost**
- Over **1 million life-years lost**
- **122.5 million people living in counties with one or more pollutants exceeding the NAAQS in 2016**



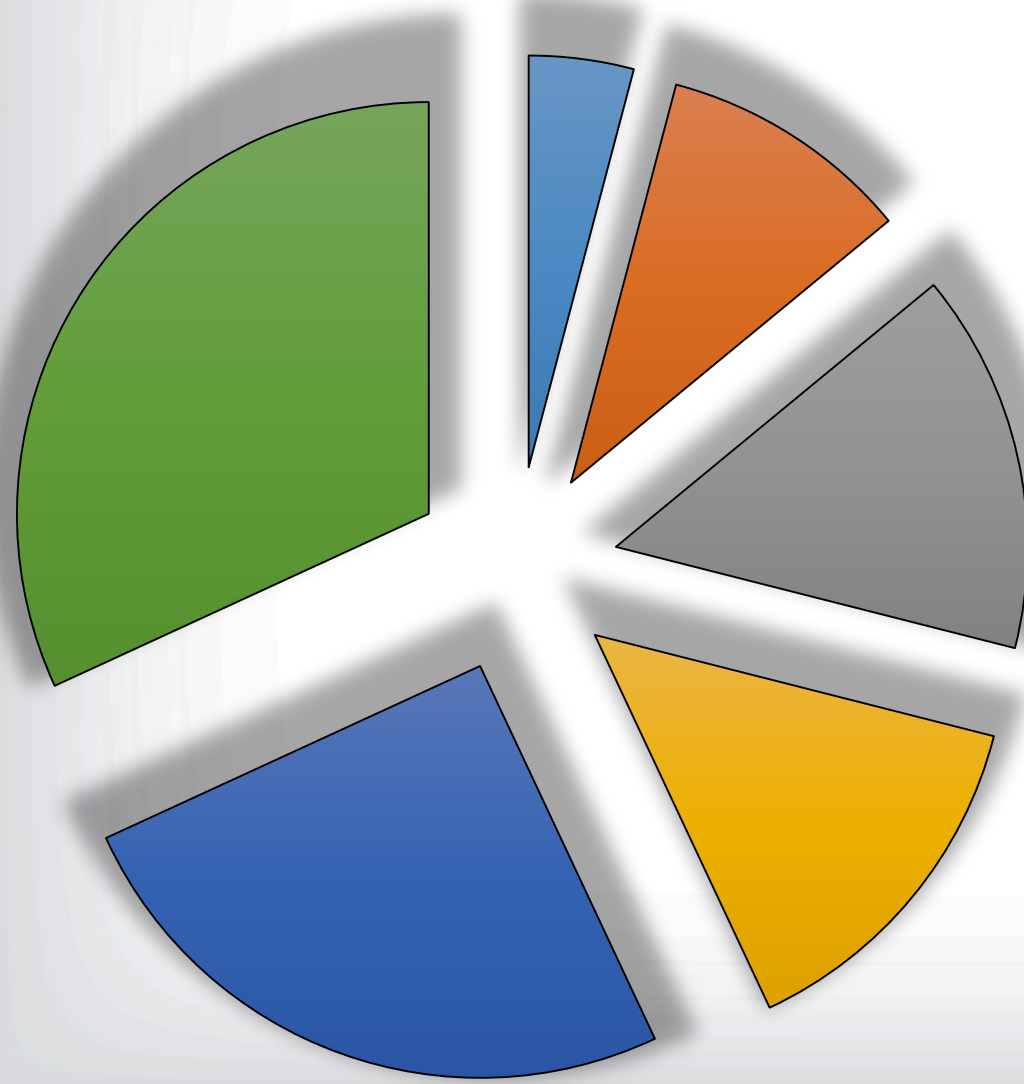


- ~125,000 excess deaths attributed to outdoor air pollution in the U.S.
- Comparable in Number to Diabetes, Pneumonia, Flu



Environmental Health Scientists Continue to Study Air Pollution and Human Health

2,894 Publications on “Air Pollution and Human Health” in PubMed since 2016



Topic Area	# of Publications	Maturity of Field
■ Central Nervous System	119	New
■ Birth Outcomes	287	Growing
■ Cardiovascular	432	Growing
■ Cancer	407	Stable
■ Respiratory	727	Stable
■ Other	922	

- ***Benefits of NAAQS on Mortality in the U.S.***
- ***Health Effects of Air Pollution***
 - **Cardiovascular**
 - **Central Nervous System**
 - **Human Development**
- ***Emerging Issues, Technology & Opportunities***
 - **Wildfire Smoke**
 - **Sensors and Citizen Science**
 - **Public Health and Clinical Interventions**



Fall in Air Pollution Related Deaths Over Time

Fraction of Total All-Cause Deaths Attributed to PM_{2.5}

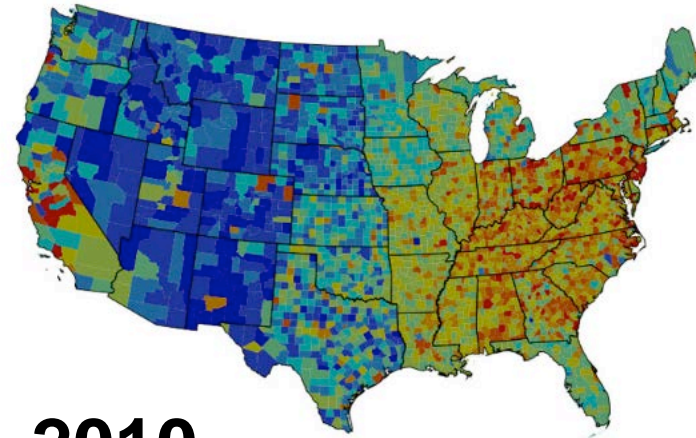
After the implementation of local, state, and federal air quality policies

- PM_{2.5} precursor emissions declined over the course of several decades

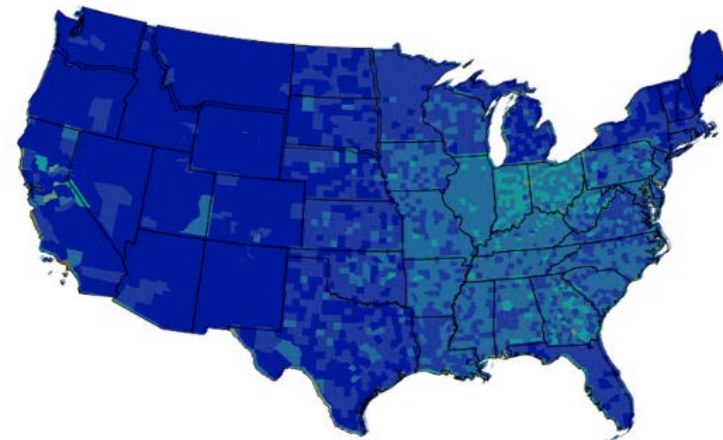
Between 1980 - 2010, PM_{2.5} exposures fell by about half, and estimated excess deaths decreased by about a third

- California, Virginia, New Jersey, and Georgia had some of the largest estimated reductions in PM_{2.5}-attributable deaths

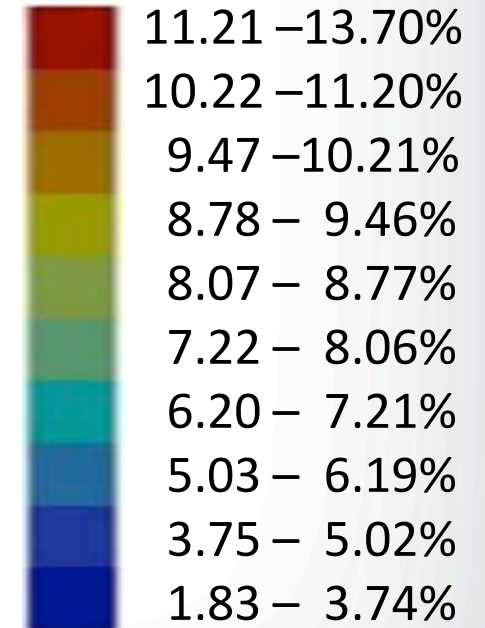
1980



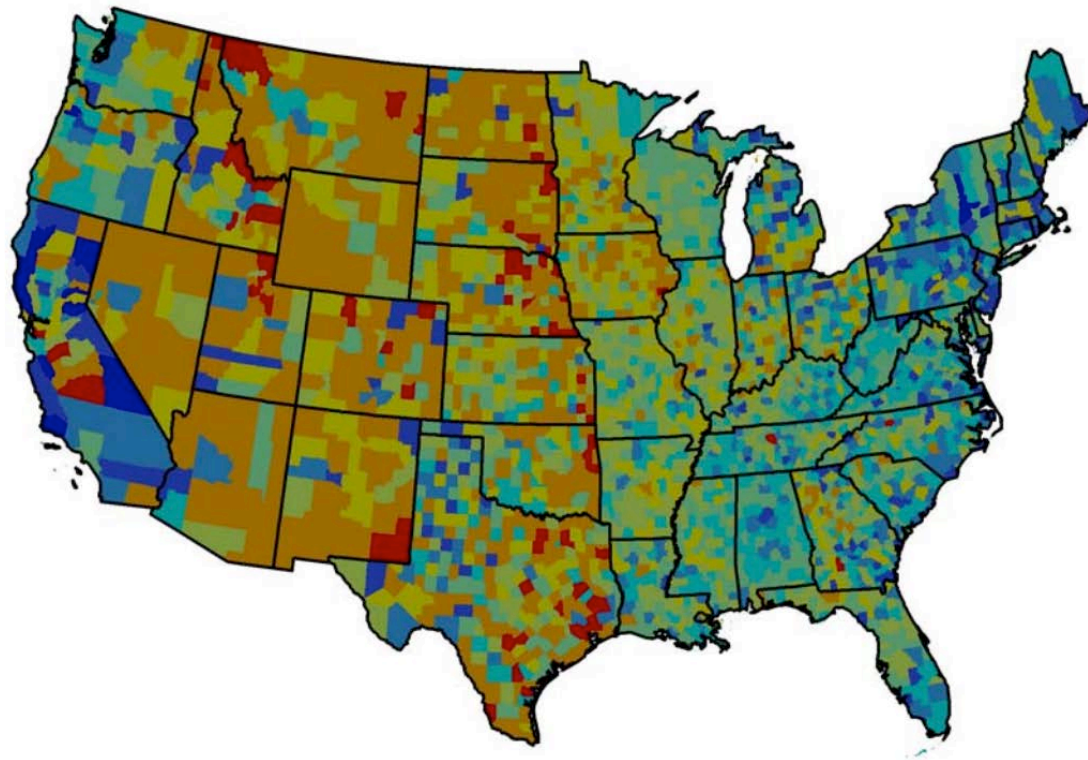
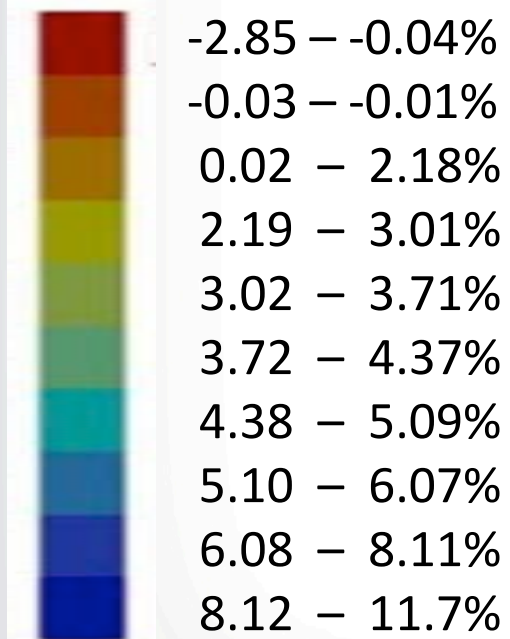
2010



% of Total All-Cause Deaths Due to PM_{2.5} Between 1980 & 2010



Change in the %
of Death Due to PM_{2.5}
Between 1980 - 2010



*Relative to a
hypothetical population
with exposures held
constant at 1980 levels*

- people born in 2050 would live about 1 year longer
- there would be a cumulative gain of 4.4 million life years among adults ≥30 years of age

Health Effects of Air Pollution

Cardiovascular



Long-term Health Effects of Air Pollution

PM_{2.5} Exposure and Post-MI Survival in Ontario, Canada

Post-Myocardial Infarction Survival Ontario, Canada 1999-2011

- 8,873 patients with 4,016 non-accidental deaths
- Mortality follow-up through 2011
- Cumulative time-weighted exposures to PM_{2.5} were derived from satellite observations
- **For each 10-µg/m³ increase in PM_{2.5} non-accidental mortality increased by 22%**

Conclusions:

- Long-term air pollution exposure adversely affects the survival of Heart Attack patients

Post-Stroke Survival London, England 1995-2006

- 3,320 patients with 1,856 deaths
- Stroke follow-up to mid-2006
- Outdoor NO₂ and PM₁₀ modeled for 2002
- HRs were adjusted for relevant factors
- **10-µg/m³ increase in NO₂ and PM₁₀ was associated with a 28% and 52% increase in risk of death, respectively**

Conclusions:

- Improvements in outdoor air quality might contribute to better survival after stroke
- A 10 µg/m³ reduction in NO₂ exposure is expected to reduce mortality comparable to that for stroke units



Air Pollution and Mortality

Effect of PM on Survival and Subsequent Clinical Events

Zanobetti A & Schwartz J.
Environ Health Perspect 2007

Mortality
CHF hospitalization
MI hospitalizations

Koton et al.
Prev Med 2013

MI, CHF, Stroke
Mortality

Tonne et al.
Eur Heart J 2013

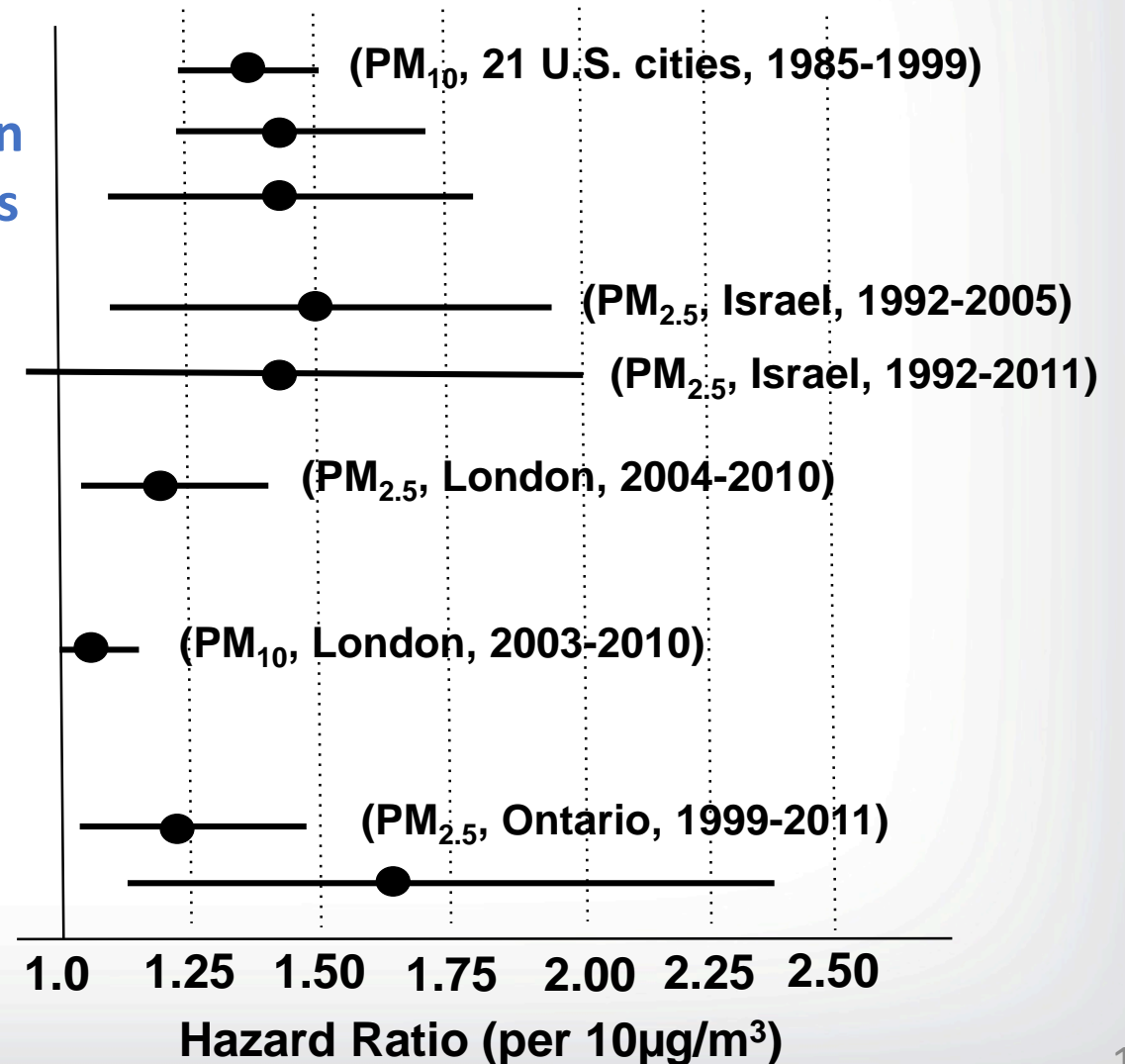
Mortality

Tonne et al.
Int J Hyg Envir Health 2016

Mortality

Chen et al. EHP 2016
Environ Health Perspect 2016

Mortality
MI Mortality

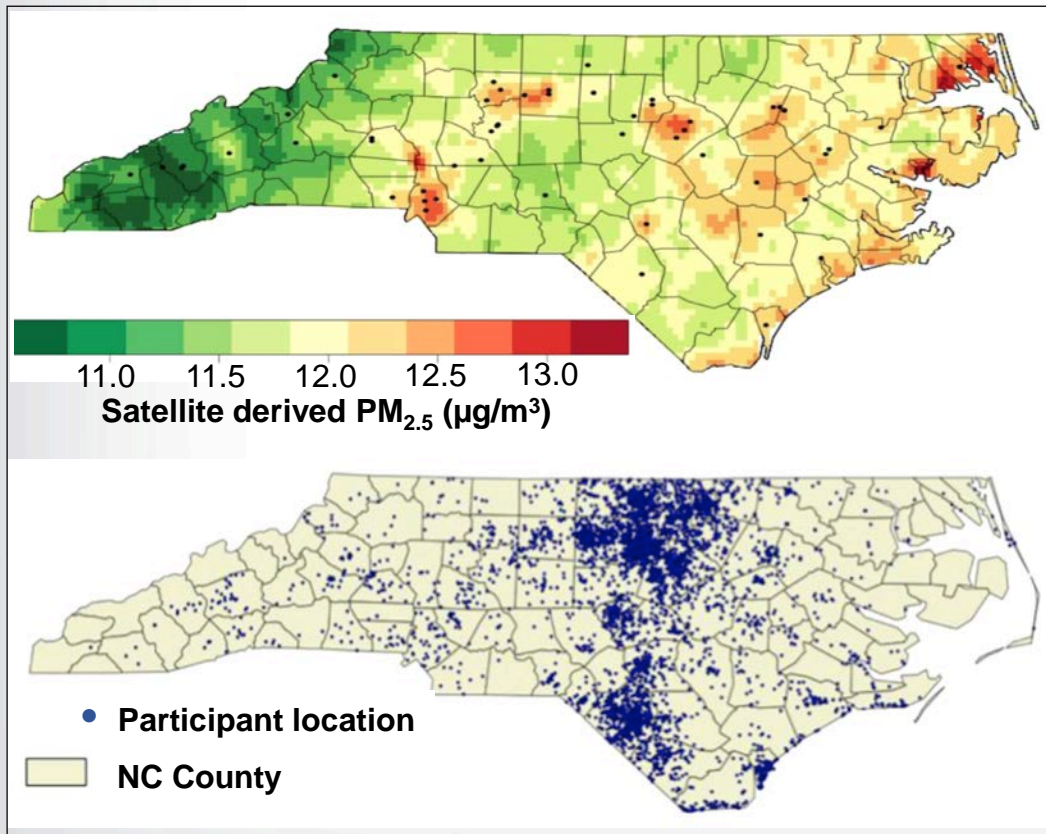




Health and Long-term Air Pollution Exposure

Association between PM and Coronary Artery Disease

5,679 patients who underwent coronary angiography at Duke University between 2002–2009 and resided in North Carolina*



1 µg/m³ increase in annual average PM_{2.5} was associated with an:

- 11.1% relative increase in the odds of significant coronary artery disease
- 14.2% increase in the odds of having had a heart attack during the previous year

6,575 Ohio residents undergoing elective diagnostic coronary angiography**

1 µg/m³ increase in annual average PM_{2.5} was associated with an:

- 17% relative increase in the odds of 1-2 vessel, and a 24% increase in ≥ 3 vessel coronary artery disease
- 14% increase in the odds of having a heart attack within 3 years

*McGuinn LA, et al. *Environ Res* 2016

**Hartiala J, et al. *J Am Heart Assoc* 2016



Cardiovascular Disease Risk Calculators

Predictive Models for Cardiovascular Outcomes

AMERICAN COLLEGE of CARDIOLOGY ASCVD Risk Estimator Plus

Estimate Risk | Therapy Impact | Advice

Current 10-Year ASCVD Risk ~% | Previous 10-Year ASCVD Risk ~%

Patient Demographics

Current Age: [dropdown] | Sex: Male | Female | Race: White | African American | Other

Age must be between 40-79

Current Labs/Exam

Total Cholesterol (mg/dL): [dropdown] | HDL Cholesterol (mg/dL): [dropdown] | LDL Cholesterol (mg/dL): [dropdown] | Systolic Blood Pressure (mm of Hg): [dropdown]

Value must be between 130 - 320 | *Value must be between 20 - 100* | *Value must be between 30-300* | *Value must be between 90-200*

Personal History

History of Diabetes? Yes | No | On Hypertension Treatment? Yes | No | Smoker: Yes | Former | No

On a Statin? Yes | No | On Aspirin Therapy? Yes | No

ACC AHA 10-Year ASCVD Risk

- Age
- Gender
- Race
- Smoker
- HDL cholesterol
- Systolic blood pressure
- Diastolic blood pressure
- Treatment for high blood pressure
- Diabetes
- Statin therapy
- Aspirin therapy
- Total cholesterol

Reynolds Risk Calculator

- CRP: Inflammation

<http://www.reynoldsriskscore.org>

MESA Cardiovascular Risk Calculator

- Calcium Score

<https://www.mesa->

nlbi.org/MESACHDRisk/MesaRiskScore/RiskScore.aspx



Air Pollution Worsens Vascular Risk Factors

Risk Factors for Atherosclerosis and Air Quality

AMERICAN COLLEGE of CARDIOLOGY ASCVD Risk Estimator Plus

Estimate Risk Therapy Impact Advice

Current 10-Year ASCVD Risk ~% Previous 10-Year ASCVD Risk ~%

Patient Demographics

Current Age Sex Male Female Race White African American Other

Age must be between 40-79

Current Labs/Exam

Total Cholesterol (mg/dL) HDL Cholesterol (mg/dL) LDL Cholesterol (mg/dL) Systolic Blood Pressure (mm of Hg)

Value must be between 130 - 320 Value must be between 20 - 100 Value must be between 30-300 Value must be between 90-200

Personal History

History of Diabetes? Yes No On Hypertension Treatment? Yes No Smoker: Yes Former No

On a Statin? Yes No On Aspirin Therapy? Yes No

Poor Air Quality:

Age – might accelerate aging

Ward-Caviness et al. Octotarget 2016
McCracken et al. EHP 2010

Total Cholesterol – increases cholesterol

Shanley et al. Epidemiology 2016

HDL – decreases HDL particle number

Bell et al. Arterioscler Thromb Vasc Biol 2017

LDL – oxidizes LDL and ox-LDL receptor

Gong et al. Genome Biol. 2007
Wu et al. Chemosphere 2015

Systolic BP – increases blood pressure

Giorgini et al. Curr Pharm Des. 2016

Diabetes – associated with type II diabetes

Renzi et al. Environ Int 2017

Statin Therapy – protective

O'Neill et al. Occup Environ Med 2007
Alexeeff et al. Environ Health Perspect 2011



Coronary Artery Calcium Confers Increased Cardiovascular Risk

Summary of the Coronary Artery Calcium (CAC) and absolute long-term Cardiovascular Risk

CAC Score	FRS Equivalent	10-Year Event Rate, %
0	Very low	1.1 - 17
1 - 100	Low	2.3 - 5.9
101 - 400	Intermediate	12.8 - 16.4
> 400	High	22.5 - 28.6
> 1,000	Very high	37.0

Normal



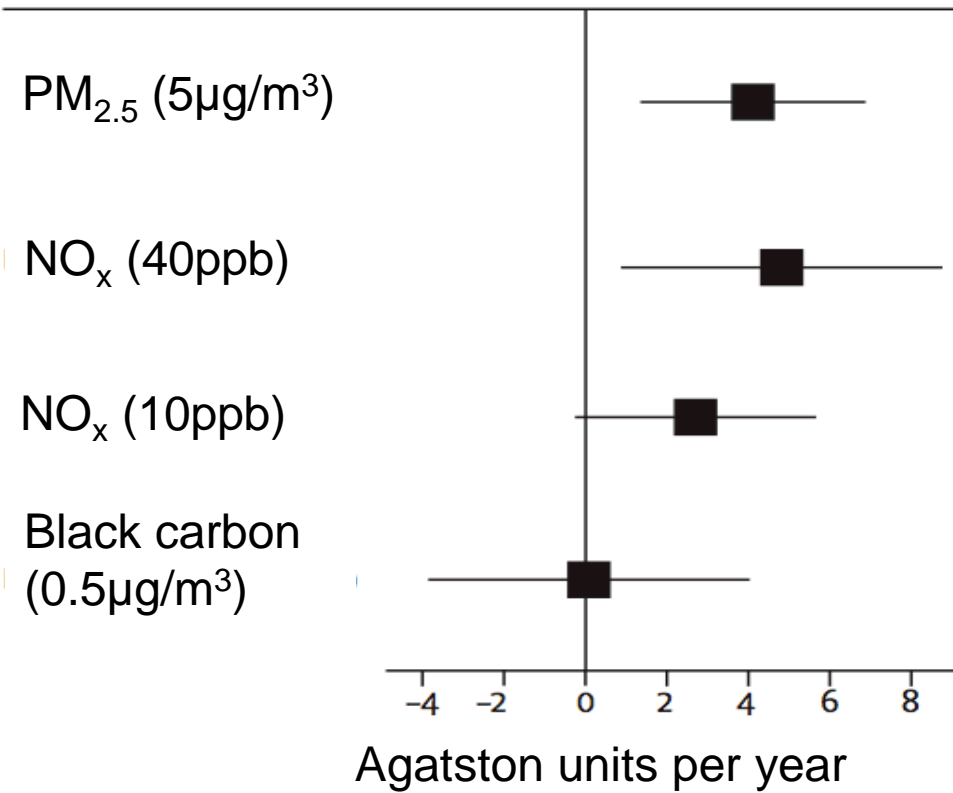
Severe Calcification



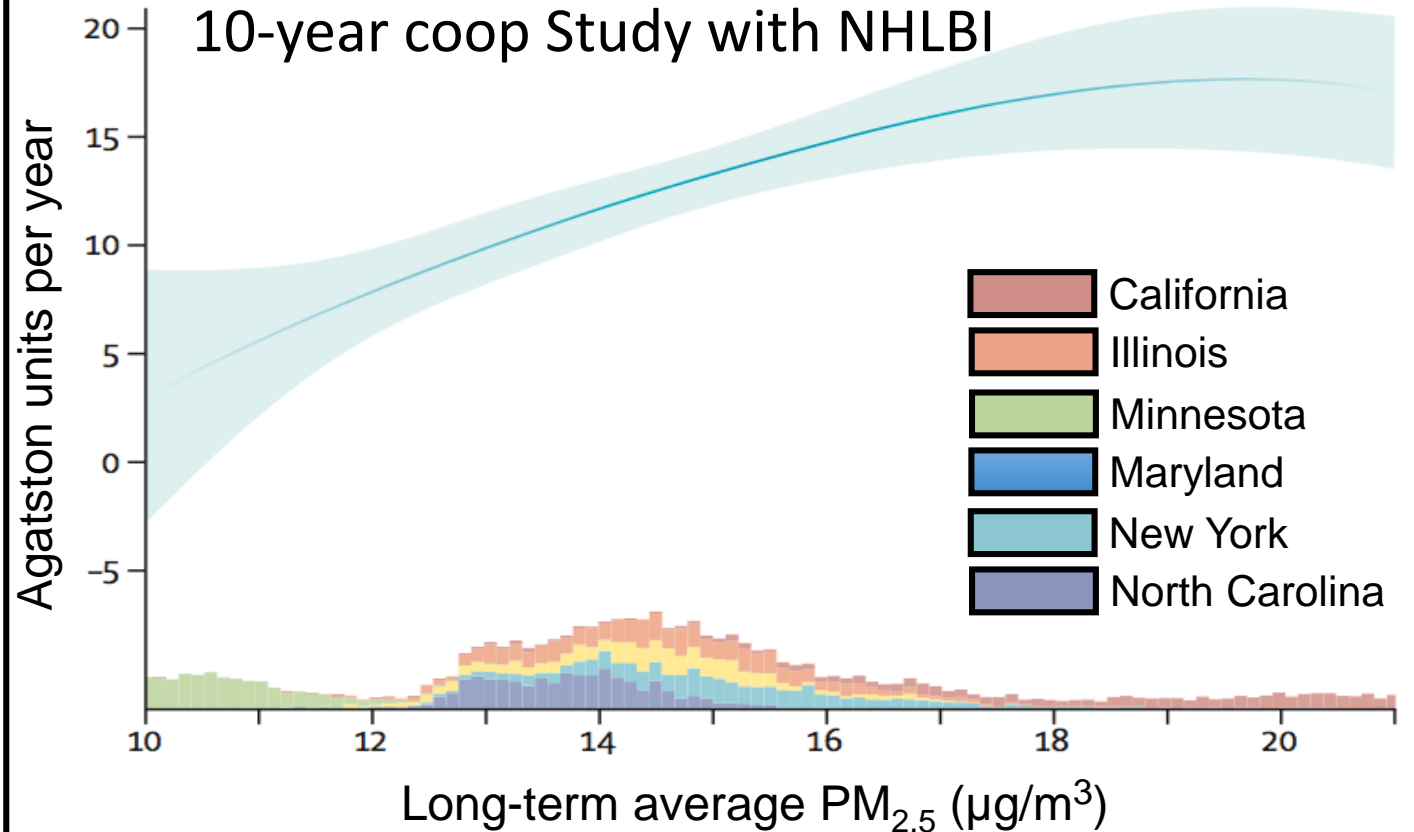


Long-Term $PM_{2.5}$ & NO_2 Exposure Increases Coronary Artery Calcium

Air Pollutants



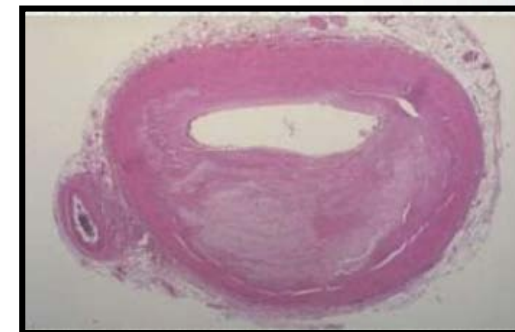
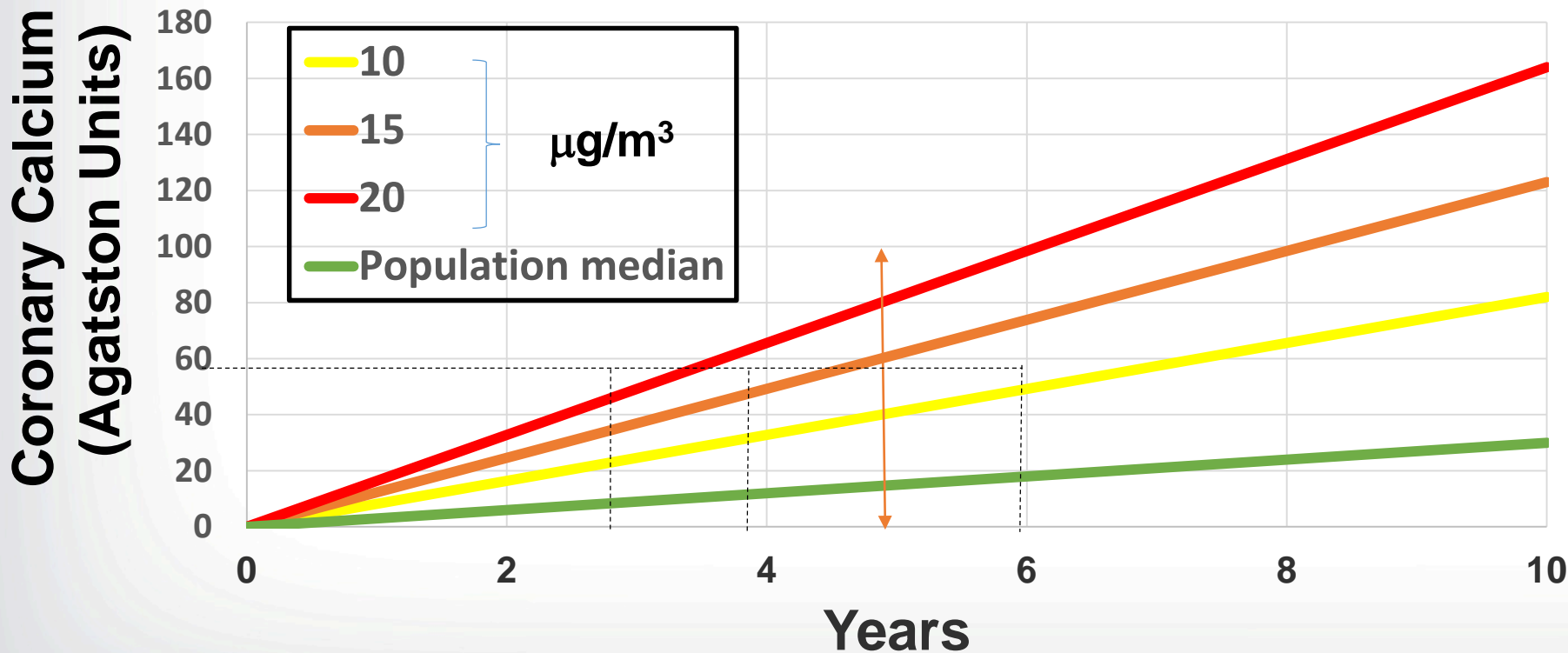
Multi Ethnic Study of Atherosclerosis - Air: 10-year coop Study with NHLBI



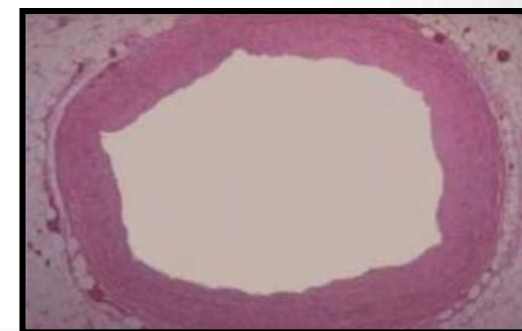
**Long-term $PM_{2.5}$ and NO_2 increased coronary calcium,
an indicator of atherosclerosis**

MESA Air Study – Led by University of Washington

$PM_{2.5}$ and Coronary Calcium



Uncertainty for
15 $\mu\text{g}/\text{m}^3$ case





Coronary Artery Calcium Confers Increased Cardiovascular Risk

Possible Shift in 10-Year Event Rate due to Increases in Coronary Artery Calcium (CAC) Associated with Exposure to 15 $\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$ for 10 years = 120 Agatston Units

CAC Score	FRS Equivalent	10-Year Event Rate, %
0	Very low	1.1 – 1.7
1 - 100	Low	2.3 – 5.9
101 - 400	Intermediate	12.8 – 16.4
> 400	High	22.5 – 28.6
> 1,000	Very high	37.0

ACC AHA 10-Year ASCVD Risk Calculator does not consider environmental factors

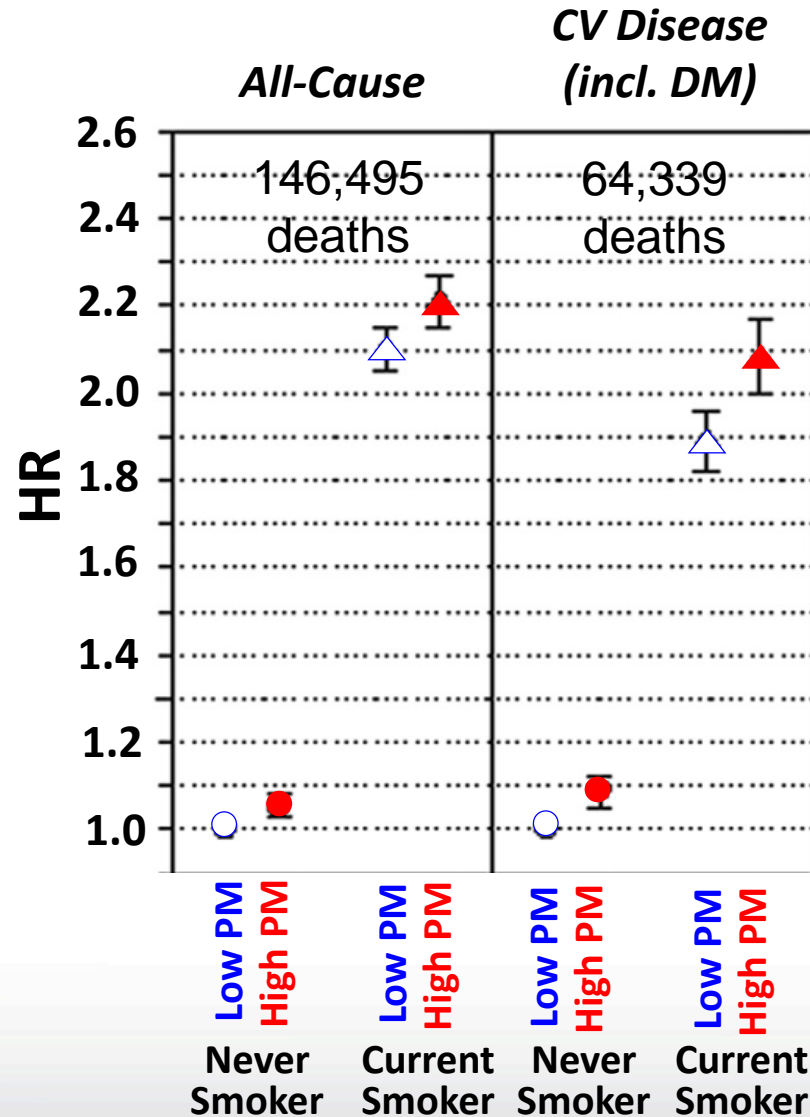
ASCVD Risk Calculators might be refined by including long-term exposure to air pollution



Smoking-Air Pollution Interaction & Mortality

Interaction of Smoking Cigarettes and Air Pollution

- ACS Cancer Prevention Study-II with modeled $PM_{2.5}$ levels
- Examined interactions for all-cause & cardiovascular mortality among 429,406 current or never smoking participants and PM
- High (>14.44) vs. low (≤ 10.59) $PM_{2.5}$ $\mu g/m^3$ exposure



Number of Additional Deaths Per 100,000 Person Years (95% CI)

	All Cause	Cardiovascular Disease (plus diabetes)
High $PM_{2.5}$ vs. Low $PM_{2.5}$	44 (5, 83)	36 (9, 63)
Current vs. Never Smoker	1,080 (1,034, 1,250)	318 (288, 347)
High $PM_{2.5}$ * Current Smoker	56 (-3, 115)	32 (-6, 71)

- Reductions in smoking will reduce all-cause & cardiovascular death the most
- Reductions in $PM_{2.5}$ will prevent a proportion of mortality attributed to smoking

Health Effects of Air Pollution

Central Nervous System



Emerging Areas of Health Effects Research

Neurological and Neurodegenerative

Air Pollution & Neurotoxicity in Adults

- **Effects on Neurodegenerative Disorders**
 - *Parkinson's*
(Liu R et al. Environ Health Perspect 2016; Palacios et al. Rev Environ Health 2017)
 - *Multiple sclerosis*
- **Non-Specific Neurological Symptoms**
 - *Cognitive Function*
(Tallon et al. Environ Internat 2017)
 - *Fatigue*
 - *Anxiety and Depression*
(Szyszkowicz M et al. Environ Health insights 2016; Pun EHP 2016; Vert Intern J Hygiene Envir Health 2017)

Air Pollution & Neurotoxicity in Children

- **Effects on Child Neurodevelopment**
 - *Prenatal exposure to air pollution*
 - *Childhood exposure to air pollution*
- **Neurodevelopmental Disorders**
 - *Autism Spectrum Disorder*
 - *Attention-Deficit Hyperactivity Disorder*

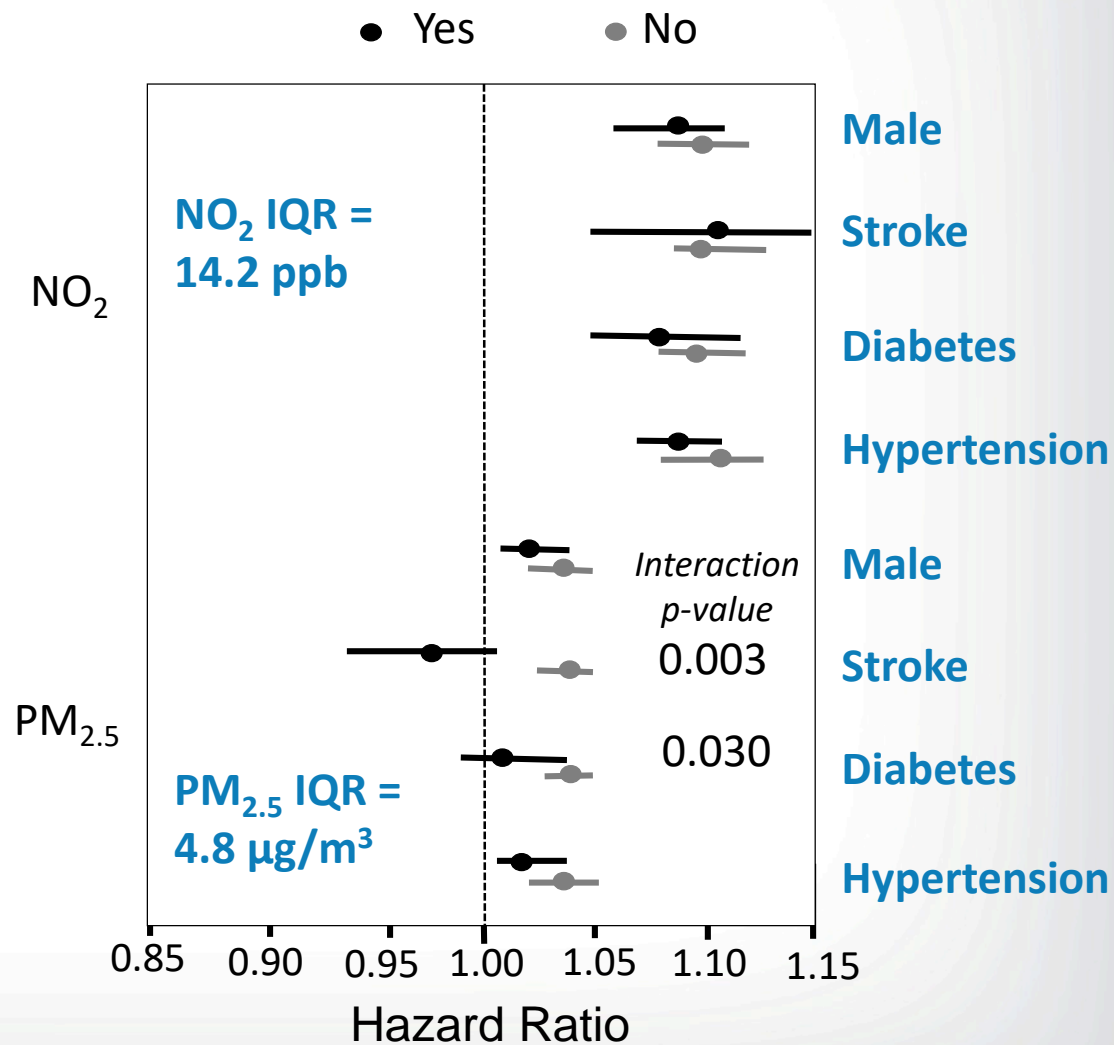


Air Pollution: Cognition and Dementia

- 257,816 cases of dementia in 2001–2013 in Ontario
- Positive association between air pollutants and dementia incidence
- The incidence of dementia increased for every interquartile-range increase in exposure to:
 - PM_{2.5} the hazard ratio (HR) was 1.04 (95% CI: 1.03–1.05)
 - NO₂ the HR was 1.10; (95% CI: 1.08–1.12)

Estimated attributable fraction and the number of incident dementia attributable to exposure to PM_{2.5} and NO₂ among a cohort in Ontario, during the follow-up period 2001–2013 (total number of incident cases = 257,816)*.

Exposure	Attributable fraction (95% uncertainty level) [†]	Number of dementia attributable to exposure to air pollutant (95% uncertainty level)
PM _{2.5} [‡]	2.4% (1.8–3.0%)	6278 (4738–7816)
NO ₂ [‡]	5.4% (4.4–6.6%)	13,962 (11,428–16,910)
PM _{2.5} + NO ₂ [§]	6.1% (4.8–7.5%)	15,813 (12,374–19,464)



Health Effects of Air Pollution
Human development



Emerging Areas of Health Effects Research

Reproductive and Developmental

Infertility

- **Menstrual cycle** (Merklinger-Gruchala et al. *Internat J Environ Res Public Health* 2017)
- **Gametogenesis** (Carré J et al. *Environmental Health* 2017)

Fetal Growth

- exposure to PM₁₀, PM_{2.5} and NO₂ was associated with reductions in measurements at birth and biparietal diameter from late second trimester onwards. (Clemens T et al. *Environ Internat* 2017)

Stillbirth

- ambient air pollution suspected of increasing stillbirth (Siddika et al. *Occup Environ Med.* 2016)

Preterm Delivery

- PM_{2.5} constituents and preterm delivery were observed for Blacks and Asians, older mothers, and those with some college education compared to their reference groups (Basu R et al. *Ped Perinatal Epi* 2017)

Low Birth Weight

- exposure to PM_{2.5} is associated with low birth weight. (Rosa MJ et al. *Environ Internat* 2017)

Accelerated Biological Aging

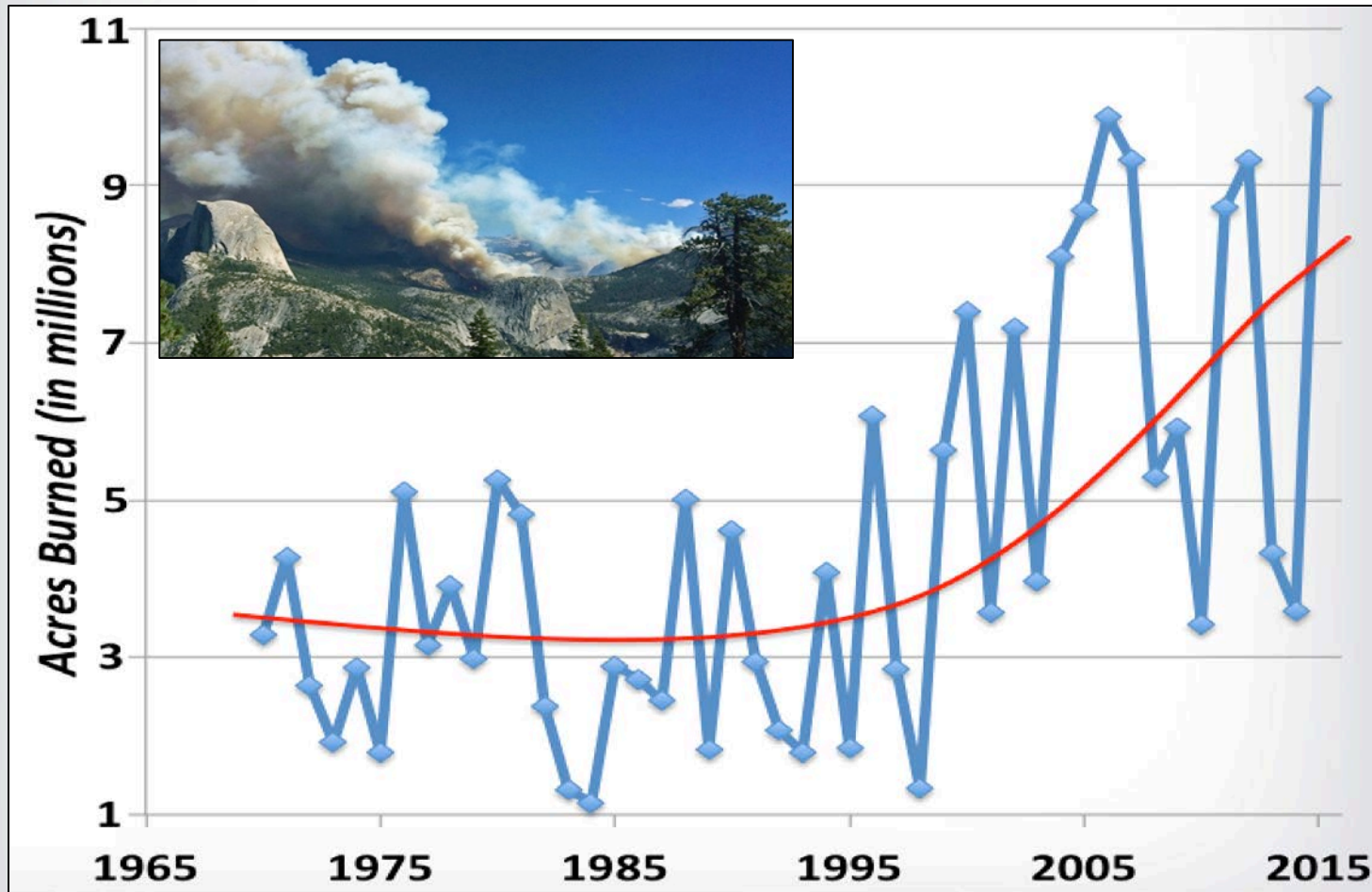
- exposure to PM_{2.5} shortened telomeres measured at birth, an indicator of biological aging (Martens DS et al. *JAMA Pediatrics* 2017)

- **Wildfire Smoke**
- **Low cost sensors**
- **Public health and clinical interventions**



Wildfire: An Issue of Concern for the States

Impacts of Local and National Importance



- **Wildland fires accounted for 38% of $PM_{2.5}$ emissions in 2014**
- **2017 was substantially worse than the average of the last 10 years**
- **Between 2001 - 2010 over 40% of the country's large wildfires occurred in the Southeast**
- **U.S. spends more than \$2 billion each year to fight wildfires**

Adapted from https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html



Health Effects of Wildfire Smoke

Systematic Reviews are Now Available

Environmental Research 136 (2015) 120–132

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres



Review

A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke

Jia C. Liu ^{a,*}, Gavin Pereira ^b, Sarah A. Uhl ^a, Mercedes A. Bravo ^a, Michelle L. Bell ^a

^a School of Forestry and Environmental Studies, Yale University, 195 Prospect Street, New Haven, CT 06511, USA

^b Center for Perinatal Pediatric and Environmental Epidemiology, School of Medicine, Yale University, New Haven, CT 06511, USA



Reid et al. *Environ Res.*
2015 Jan;136:120-32

Liu et al. *Environ Health Perspect.*
2016; 124:1334–1343

Review

Critical Review of Health Impacts of Wildfire Smoke Exposure

Colleen E. Reid,^{1,2} Michael Brauer,³ Fay H. Johnston,^{4,5} Michael Jerrett,^{1,6} John R. Balmes,^{1,7} and Catherine T. Elliott^{3,8}

¹Environmental Health Sciences Division, School of Public Health, University of California, Berkeley, Berkeley, California, USA; ²Harvard Center for Population and Development Studies, Harvard T.H. Chan School of Public Health, Cambridge, Massachusetts, USA; ³School of Population and Public Health, University of British Columbia, Vancouver, British Columbia, Canada; ⁴Menzies Institute of Medical Research, University of Tasmania, Hobart, Tasmania, Australia; ⁵Environmental Health Services, Department of Health and Human Services, Hobart, Tasmania, Australia; ⁶Department of Environmental Health Sciences, Fielding School of Public Health, University of California, Los Angeles, Los Angeles, California, USA; ⁷Department of Medicine, University of California, San Francisco, San Francisco, California, USA; ⁸Office of the Chief Medical Officer of Health, Yukon Health and Social Services, Whitehorse, Yukon, Canada

A Section 508–conformant HTML version of this article is available at <http://dx.doi.org/10.1289/ehp.1409277>.



Health Effects Linked to Smoke from Wildland Fires

Health effects known or suspected to be caused by wildland fire smoke

- ***All-cause mortality***
- ***Asthma & chronic obstructive pulmonary disease (COPD) exacerbations***
- ***Bronchitis & pneumonia***
- ***Cardiovascular outcomes***
- ***Childhood respiratory disease***
- ***Adverse birth outcomes***
- ***Symptoms such as eye irritation, sore throat, wheeze and cough***





California 2015 Wildfire Study

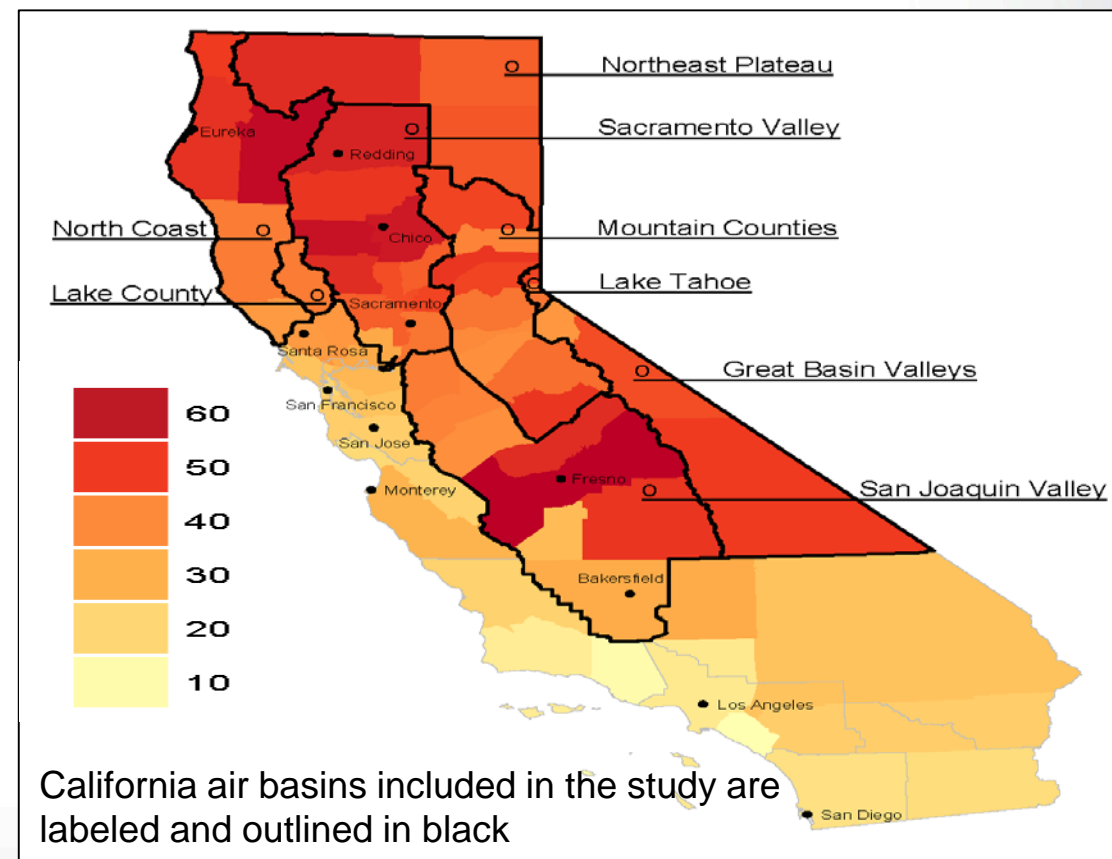
Problem: Cardiovascular health effects of wildfire smoke are uncertain

Approach:

- Epidemiology study during the 2015 California wildfire season
- Associate wildfire-PM_{2.5} exposure with emergency department visits for cardiovascular and respiratory diagnoses
- Collaborative study partners:
 - California Dept. of Public Health
 - Univ. of California at San Francisco
 - US EPA/ORD/NHEERL

Measuring the Health Effects of Wildfire Smoke

Smoky days/county during the study:
May through September 2015



Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al.
(in review, 2018)



Wildfire-PM_{2.5} Increases Heart Attack & Stroke

California 2015 Wildfire Study

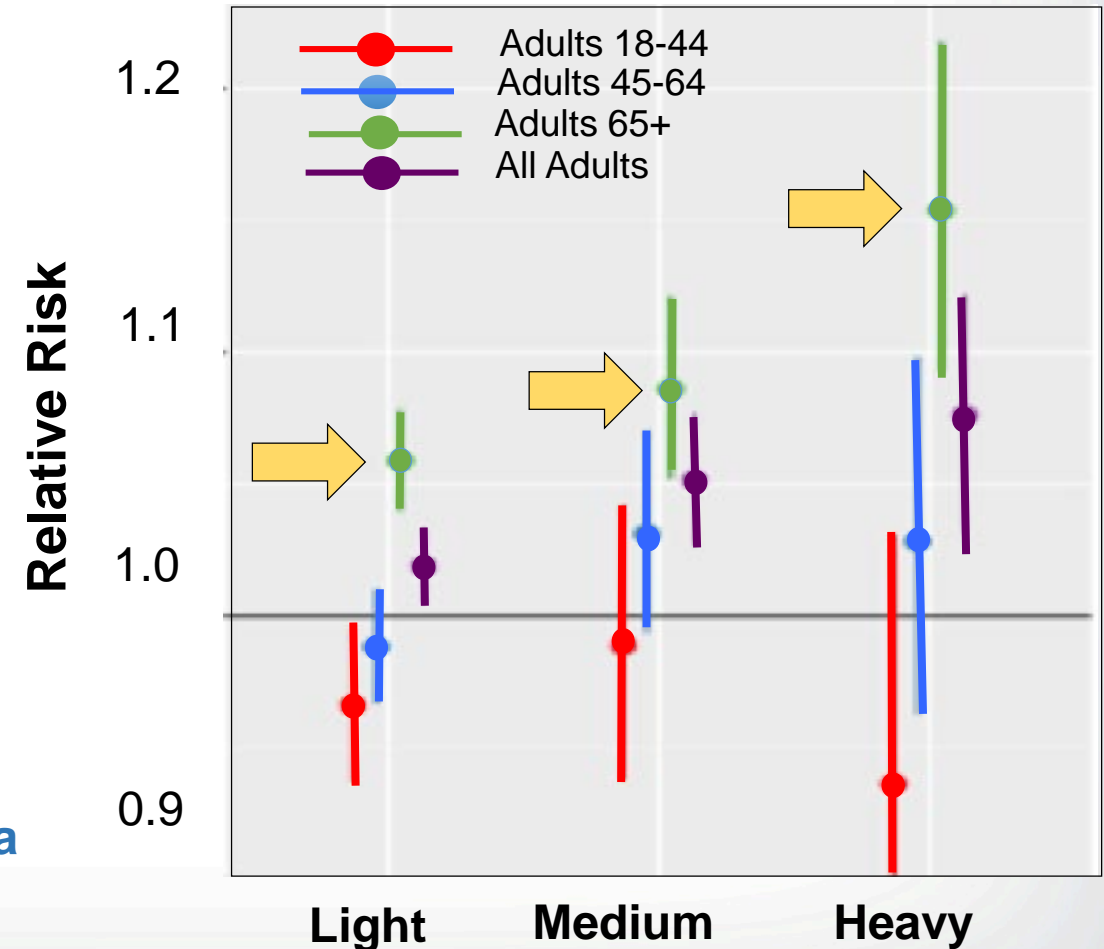
Results: Wildfire-PM_{2.5} associated with **heart attacks** and **strokes** for all adults, particularly for those over **65 years old**

- Increase in risk the day after exposure:
 - All cardiovascular, 12%
 - Heart attack, 42%
 - Abnormal heart rhythm, 24% (same day)
 - Heart failure 16%
 - Stroke 22%
 - All respiratory causes 18%

Impact: Highlights the importance of decreasing exposure in at-risk populations

Data to be presented as a Late-Breaking Study at the **American Public Health Association Conference in Atlanta** - November 2017

All Cardiovascular Causes



Wettstein Z, Hoshiko S, Cascio WE, Rappold AG et al.
(in review, 2018)



Moving to the Future

ENVIRONMENTAL Science & Technology

Policy Analysis

pubs.acs.org/est

Forecast-Based Interventions Can Reduce the Health and Economic Burden of Wildfires

Ana G. Rappold,^{*,†} Neal L. Fann,[‡] James Crooks,[†] Jin Huang,[§] Wayne E. Cascio,[†] Robert B. Devlin,[†] and David Diaz-Sanchez[†]

Forecast-based interventions predicted to reduce the health and economic burden of wildfires

Rappold AG, et al.
Environ Sci Technol 2014

Cost effectiveness is improved by intervening only in the homes of those at highest risk, e.g. older persons

Health benefits and costs of filtration interventions that reduce indoor exposure to PM_{2.5} during wildfires

Indoor Air 2017; 27: 191–204
wileyonlinelibrary.com/journal/ina
Printed in Singapore. All rights reserved

Abstract Increases in hospital admissions and deaths are associated with increases in outdoor air particles during wildfires. This analysis estimates the health benefits expected if interventions had improved particle filtration in homes in Southern California during a 10-day period of wildfire smoke

W. J. Fisk, W. R. Chan

Indoor Environment Group, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Fisk WJ, Chan WR *Indoor Air* 2017

VIEWPOINT

The Global Threat of Outdoor Ambient Air Pollution to Cardiovascular Health Time for Intervention

Robert D. Brook, MD

Anthropogenic ambient fine particulate matter less etal air pollution problem appears to be

“... we believe that the time is ripe to definitively test the efficacy of personal-level interventions...”

Brook RD, et al.
JAMA Cardiol. 2017

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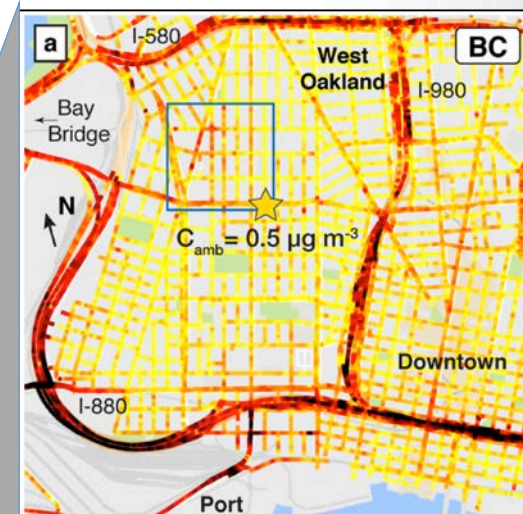
Article

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ENVIRONMENTAL
Science & Technology

Oakland, CA

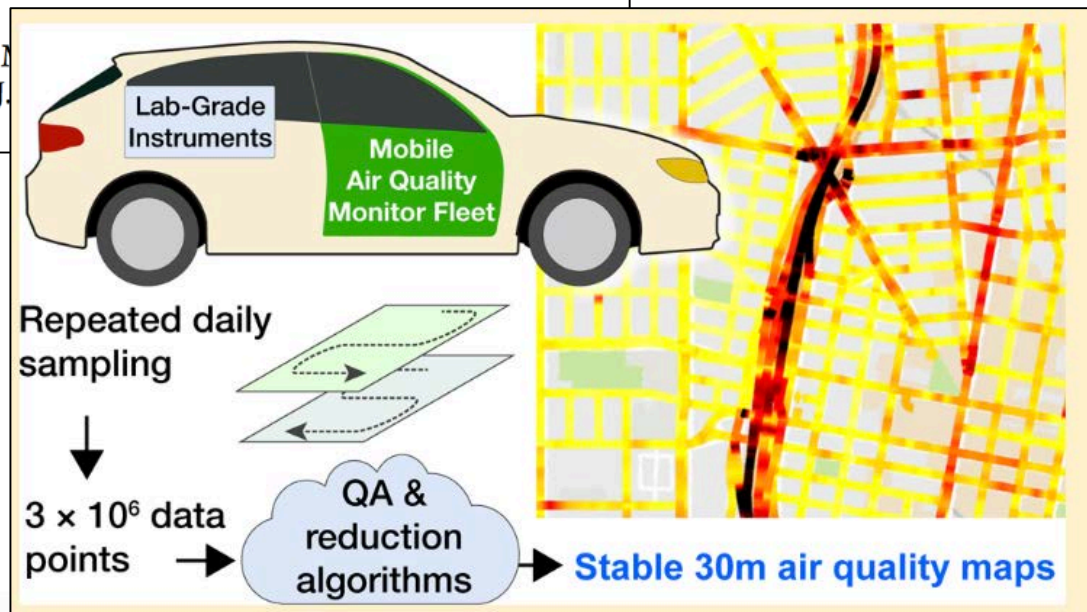
Spatial distribution of Black Carbon (BC)



High-Resolution Air Pollution Mapping with Google Street View Cars: Exploiting Big Data

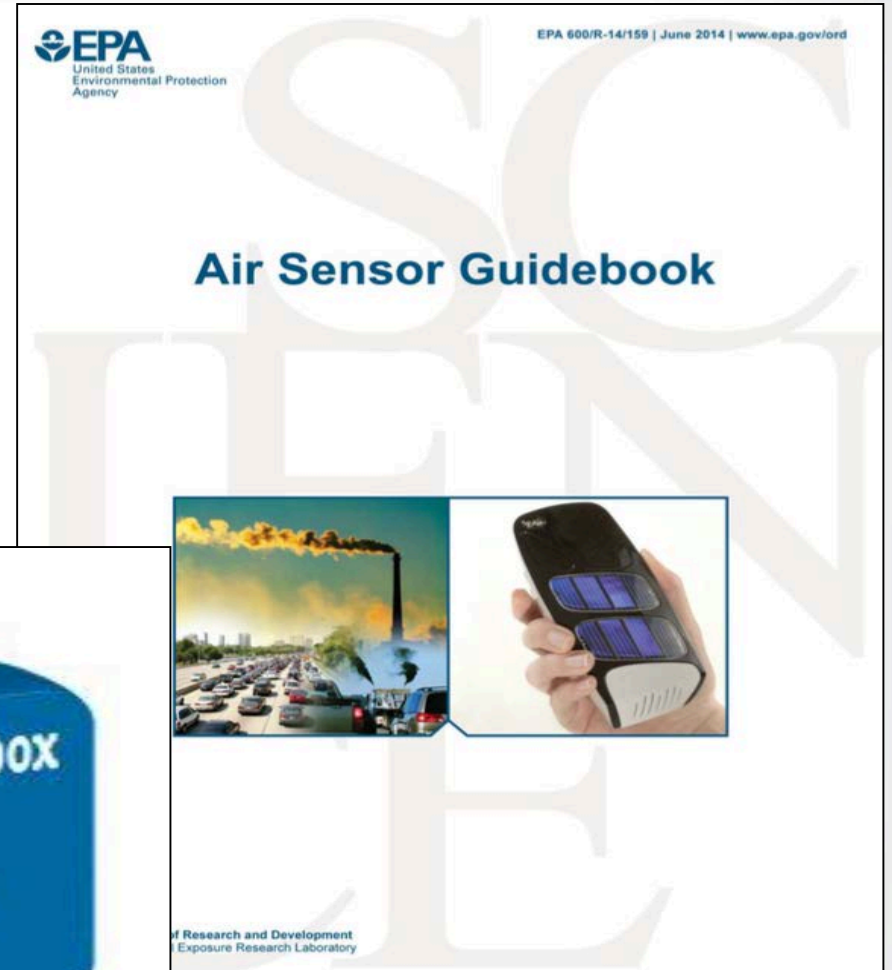
Joshua S. Apte,^{*,†,⊕} Kyle P. Messier,^{†,‡} Shahzad Gani,[†] Melissa M. Lunden,[‡] Julian D. Marshall,[#] Christopher J. and Steven P. Hamburg[‡]

Apte JS et al. Environ Sci Technol 2017



Hankey S et al. Population-Level Exposure to Particulate Air Pollution during Active Travel: Planning for Low-Exposure, Health-Promoting Cities. Environmental Health Perspectives 125:527–534, 2017

- EPA actively engaged in new sensor technologies for:
 - *personal use*
 - *community engagement*
 - *research*

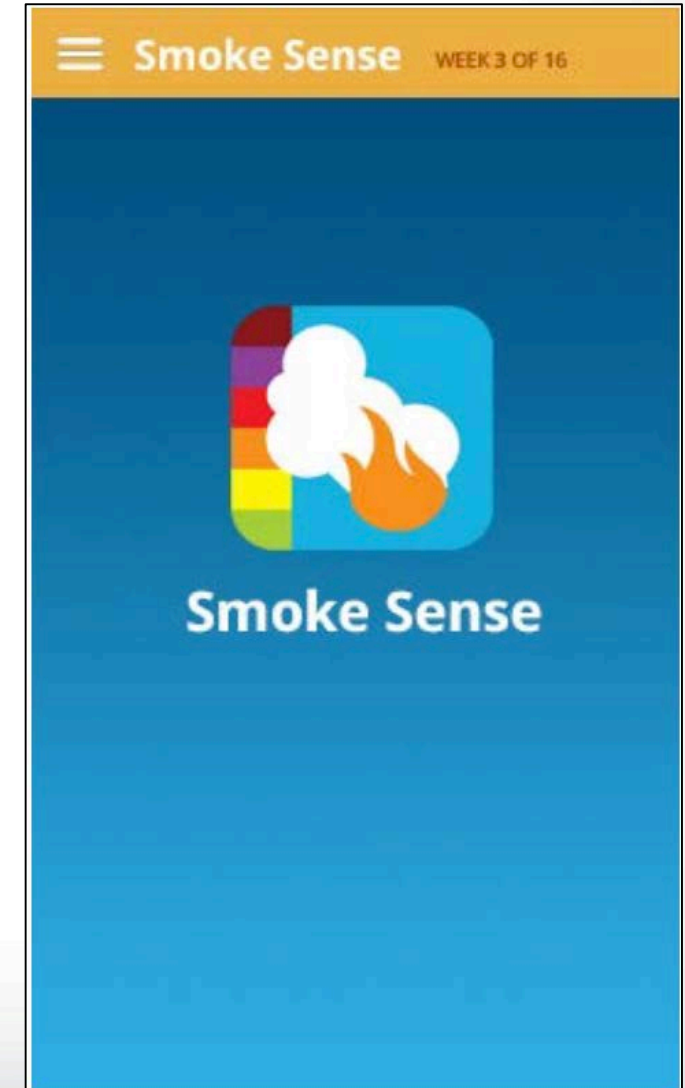


- ***Aims of Smoke Sense:***

- Measure the effect of wildfire smoke exposure on health and productivity
- Develop health risk communication strategies to improve public health outcomes

- ***As part of this, researchers have developed a Smoke Sense mobile phone application to:***

- Collect user input on how smoke events impact their health and daily activities
- Provide information about the smoke exposure and recommended health risk messages

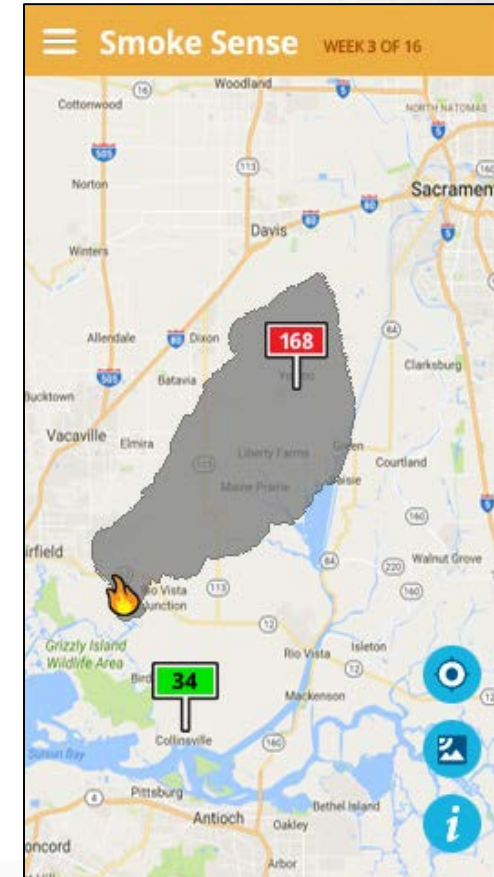




Air Quality & Smoke Plume Information



- Smoke Sense provides current and future air quality
- Forecasted smoke plumes can be visualized
- Less time outside during smoke episodes to decrease exposure, and protect health
- Smoke Sense helps collect information about who, when, and how frequently people are impacted by smoke
- Information about smoke in the air and symptoms experienced in the past week will be logged



Thank you

Wayne E. Cascio, MD, FACC
Acting Director, National Health and Environmental Effects Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency

Email: cascio.wayne@epa.gov

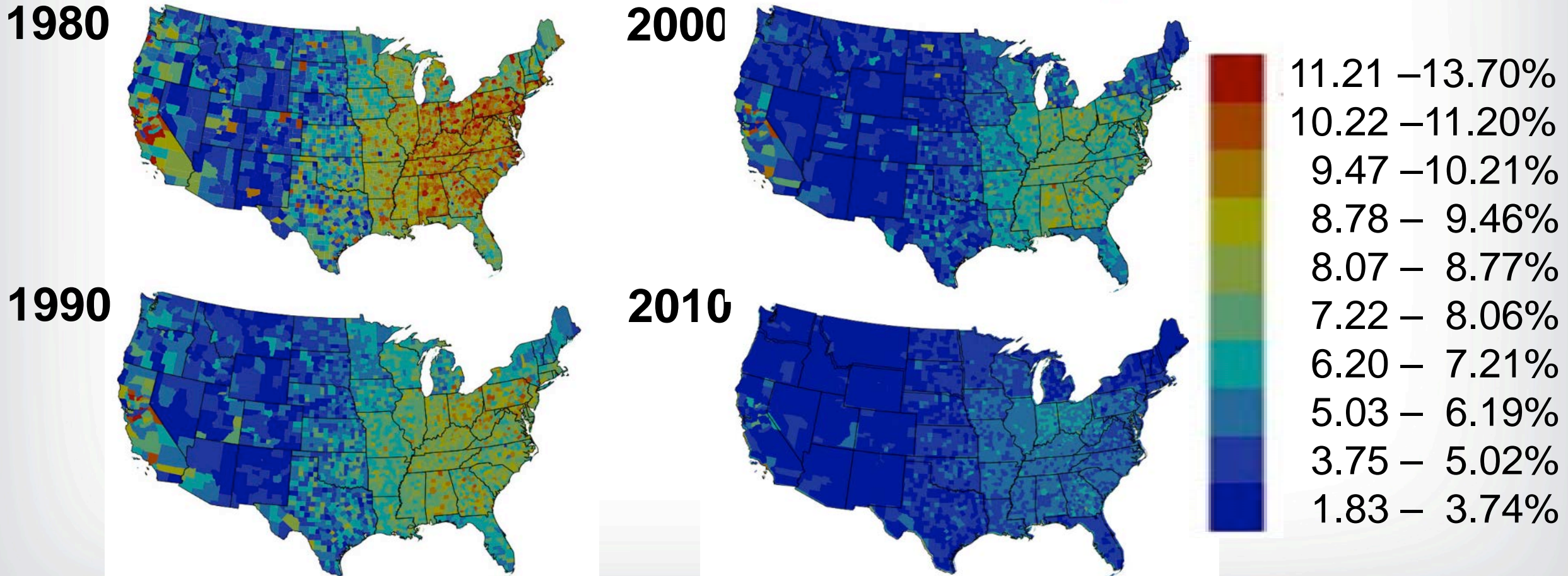


Fall in Air Pollution Related Deaths Over Time

Fraction of Total All-Cause Deaths Attributed to PM_{2.5}

After the implementation of local, state, and federal air quality policies –

- PM_{2.5} precursor emissions declined over the course of several decades





Lee EY et al. Traffic-Related Air Pollution and Telomere Length in Children and Adolescents Living in Fresno, CA: A Pilot Study. J Occup Environ Med. 2017 May;59(5):446-452.

Exposure to ambient PAH may play a role in telomere shortening.

Berhane K, et al. Association of Changes in Air Quality With Bronchitic Symptoms in Children in California, 1993-2012. JAMA. 2016 Apr 12;315(14):1491-501.

Decreases in ambient pollution levels were associated with statistically significant decreases in bronchitic symptoms in children.

Keet CA, et al. Long-term Coarse PM Exposure is Associated with Asthma Among Children in Medicaid. Am J Respir Crit Care Med. 2017 Dec 15. doi: 10.1164/rccm.201706-1267OC

Exposure to higher average coarse PM levels is associated with increased asthma prevalence and morbidity.



Improving Air Quality

An Important Priority to Achieve the EPA's Mission

“...promoting and protecting a strong and healthy environment is among the lifeblood priorities for the government, and EPA is vital to that mission.”

E. Scott Pruitt, Senate Confirmation Hearing January 18, 2017

EPA Administrator's Priorities:

- Cooperative Federalism: Environmental law, policy, and progress are all based on cooperation: cooperation between the States, cooperation between the States and EPA, and cooperation between the regulators and the public.
 - **Improving air quality**
 - Restoring the role of States in the regulation of water
 - Cleaning up contaminated land to revitalize communities
 - Ensuring the safety of chemicals in commerce

E. Scott Pruitt, Testimony before US Senate Committee on Appropriations:
Subcommittee on Interior, Environmental and Related Agencies July 17, 2017