EPA United States Environmental Protection Agency

EPA Tools & Resources Webinar: Air Pollution and Heart Disease

Wayne E. Cascio, MD, FACC

Director, Center for Public Health and Environmental Assessment

US EPA Office of Research and Development

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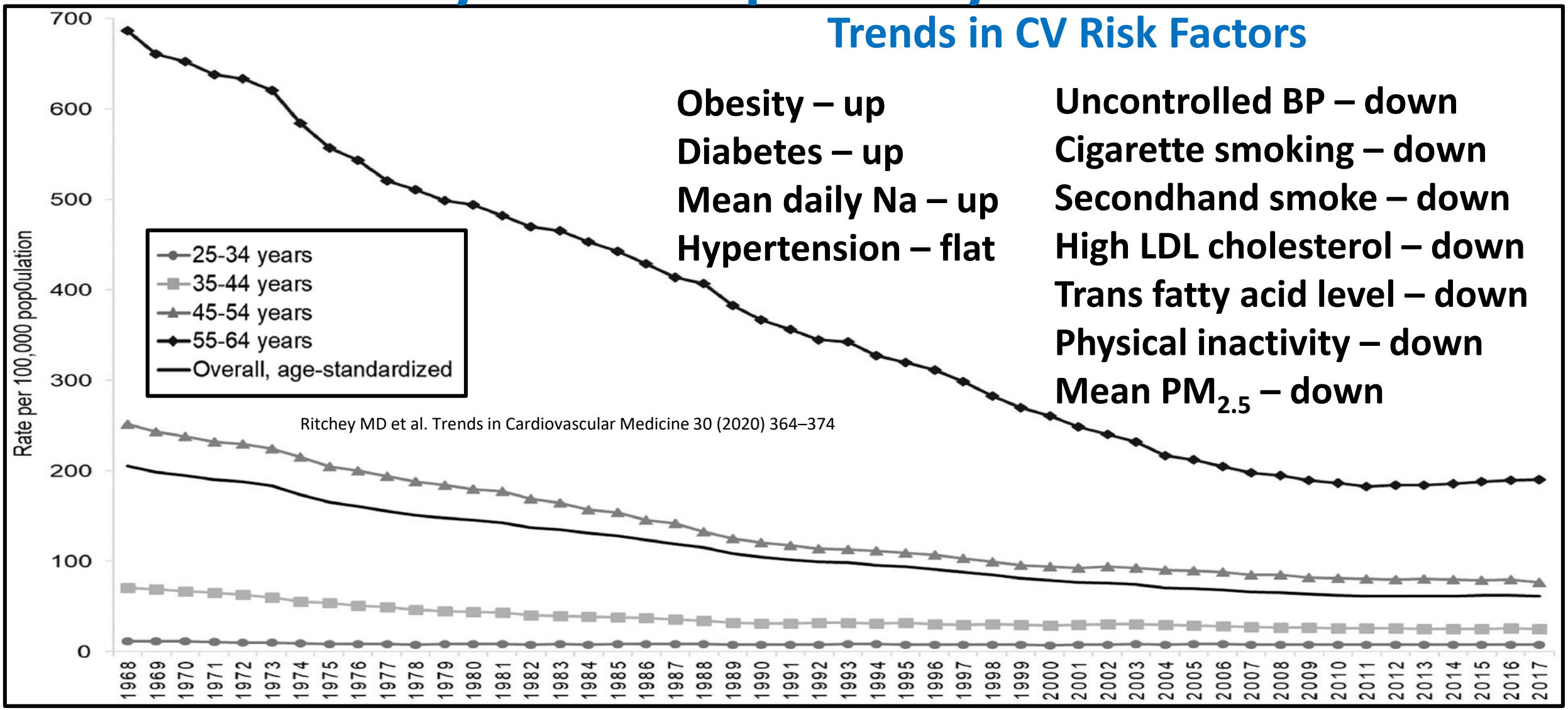
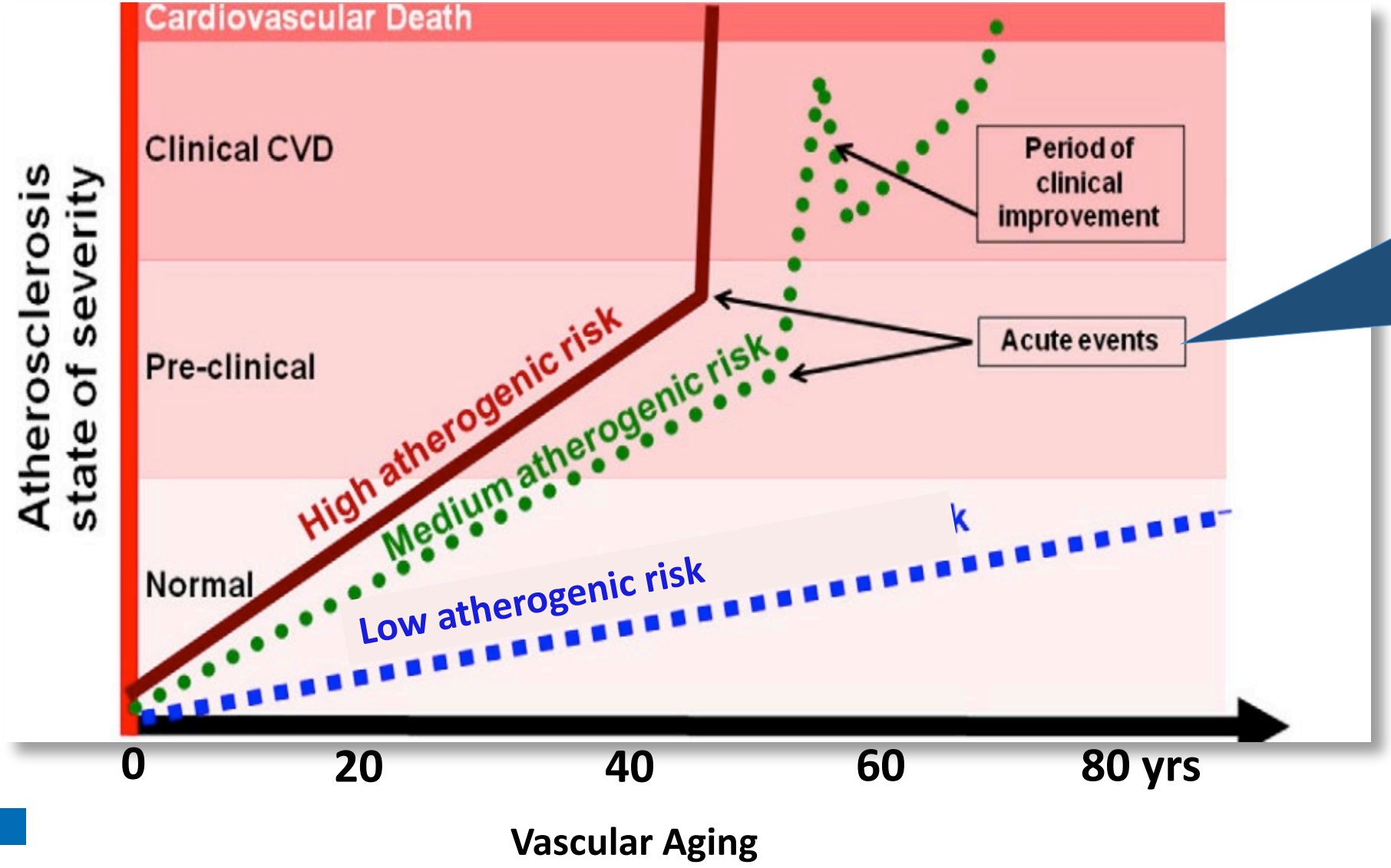
US Trends in Premature Heart Disease: Mortality over the past 50 years



Ambient Air Particle Pollution Exposures Can Trigger Acute Cardiovascular Events

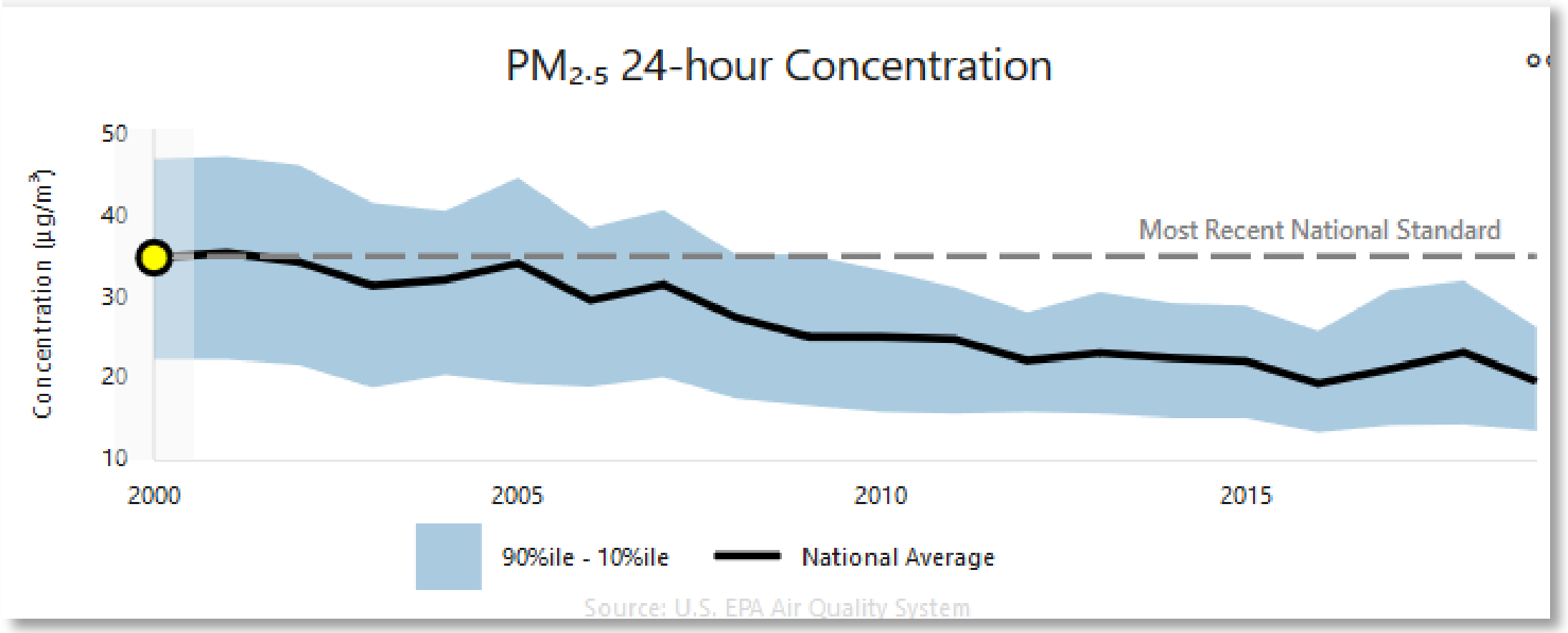


Short-term Health Effects

- **Triggering of clinical events**
- **Precipitate organ dysfunction**

N. Künzli et al. *Progress in Cardiovascular Diseases* 53 (2011) 334–343

Criteria Pollutant Trends Show Clean Air Progress

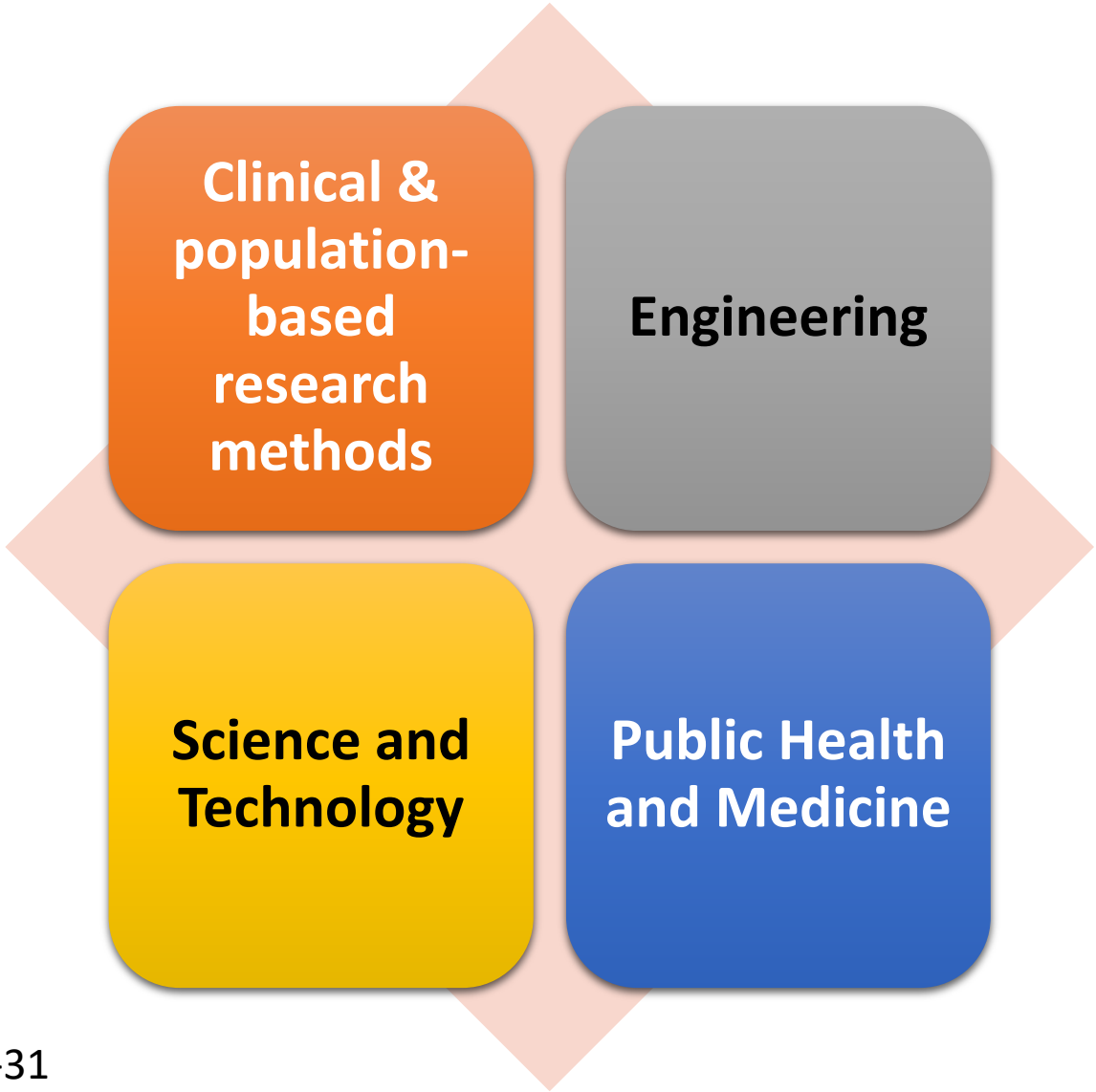


Our Nation's Air Integrative Report: https://gispub.epa.gov/air/trendsreport/2020/#home

Improved Life Expectancy with Declining $PM_{2.5}$ Concentrations

Recent epidemiologic studies examining long-term $PM_{2.5}$ exposure and mortality provide evidence of increased life expectancy as $PM_{2.5}$ concentrations decline

- Pope et al. (2009) Decreased $PM_{2.5}$ from 1980-2000 associated with increased in expectancy life of ~0.61 year
- Correia et al. (2013) Decreased $PM_{2.5}$ from 2000-2007 associated with increased in life expectancy of ~0.35 year



Correia et al. (2013), Epidemiology 24(1): 23-31
Pope et al. (2009), NEJM 360:376-86

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Air Pollution and Cardiovascular Health-Nexus over 50 Years

Final Rule	Primary	Indicator	Averaging Time	Level mg/m^3	PM ISA	PM-induced Cardiovascular Health Effects
1971	Primary	TSP	24-hour	260		
			Annual	75	1986 AQCD	Not mentioned
1987	Primary	PM_{10}	24-hour	150		
			Annual	50	1996 AQCD	Descriptive
1997	Primary	$PM_{2.5}$	24-hour	65		
			Annual	15		
		PM_{10}	24-hour	150		
			Annual	50	2004 AQCD	Descriptive
2006	Primary	$PM_{2.5}$	24-hour	35		
			Annual	15		
		PM_{10}	24-hour	150	2009 ISA	Causative
2012	Primary	$PM_{2.5}$	24-hour	35		
			Annual	12		
		PM_{10}	24-hour	150	2019 ISA	Causative

Scientific, Technical and Clinical Progress Strengthens the Link between Air Pollution and Heart Disease

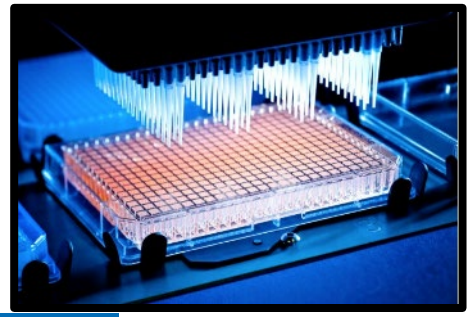
Animal Models

Rat

Mouse

Zebrafish

Cellular studies



Science Disciplines

Anatomical
Histological
Biochemical

Toxicological

Physiological

Genetics
Epigenetics

"omics"

Human Studies

Occupational Cohorts

Clinical Cohorts

Panel Studies

Challenge Studies

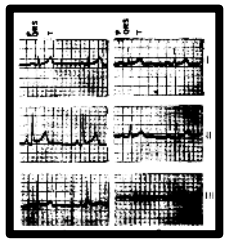
Federal Administrative Health Databases (CMS)

Electronic Health Records

1970

2020

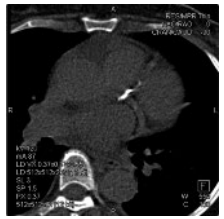
Clinical Methods



BP, ECG, m-mode echo & Chest Radiograph

Coronary Angiogram

Heart Rate Variability
Flow Mediated Dilation



Cardiac CT Angiography
MRI, & Ca Scoring

Biomarkers

WBCs
SED rate
LDH/SGOT
Glucose
CPK
Catecholamines
CRP - IL-1beta, IL-6

Fibrinogen, D-dimer, PAI-1, prothrombin

Lipids (LDL, HDL, Triglycerides)

BNP, NT-proBNP

Troponin
hs-Troponin T

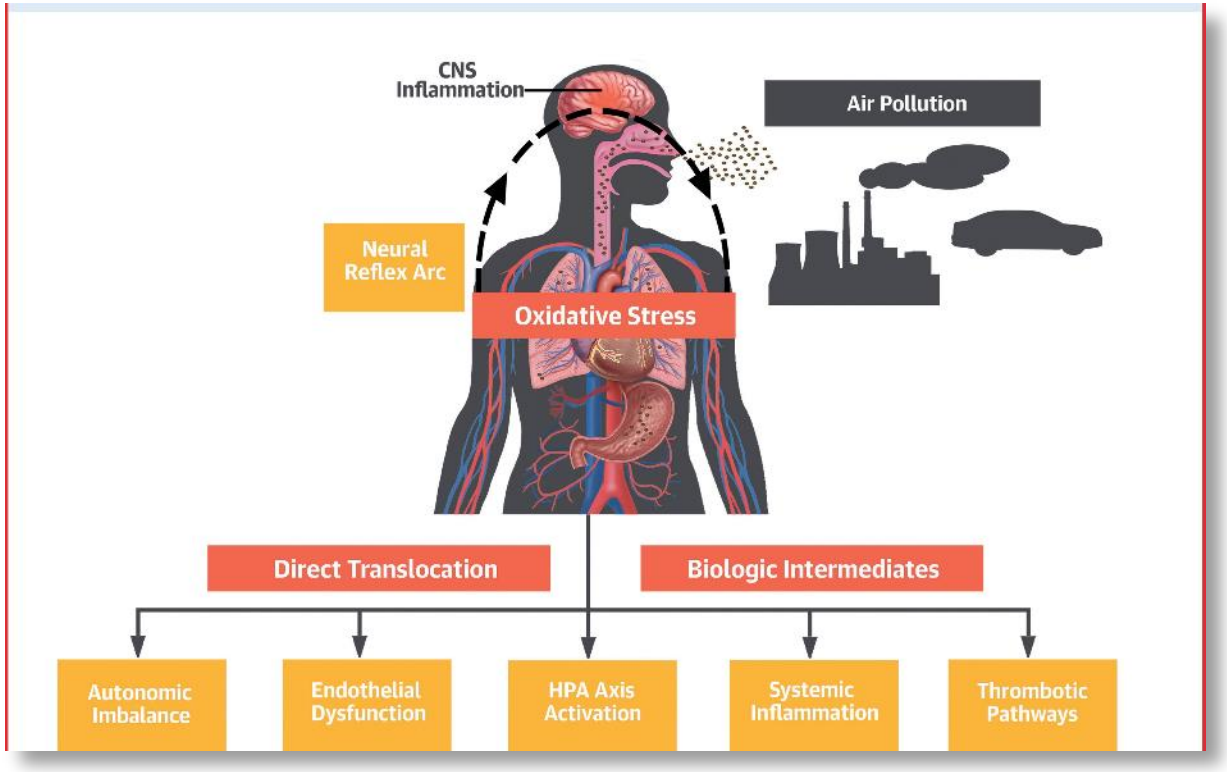
Epidemiological Methods

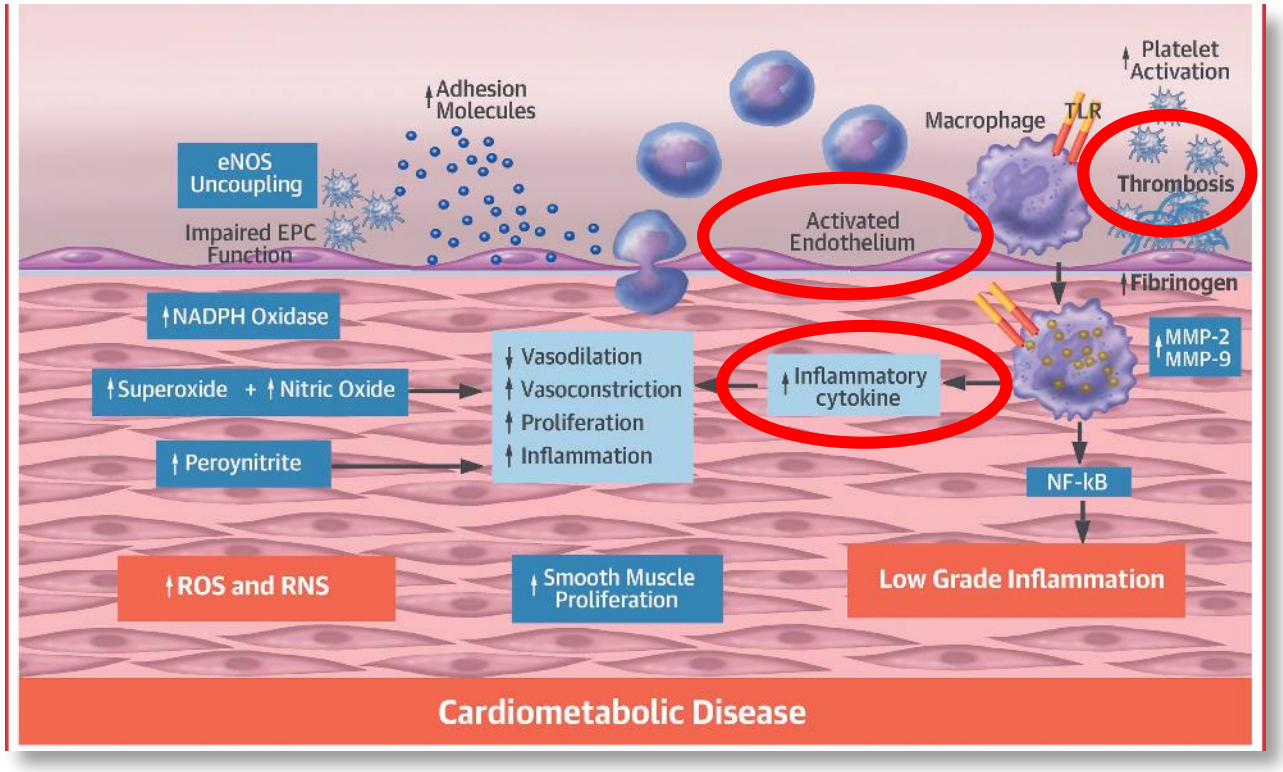
GLM with parametric splines
GAM with non-parametric smoothers
Case-Crossover

Meta-Analysis
Systematic Review

Biological Plausibility for $PM_{2.5}$ Causing Cardiovascular Disease and Clinical Events

Biological pathways through which $PM_{2.5}$ promotes cardiovascular events

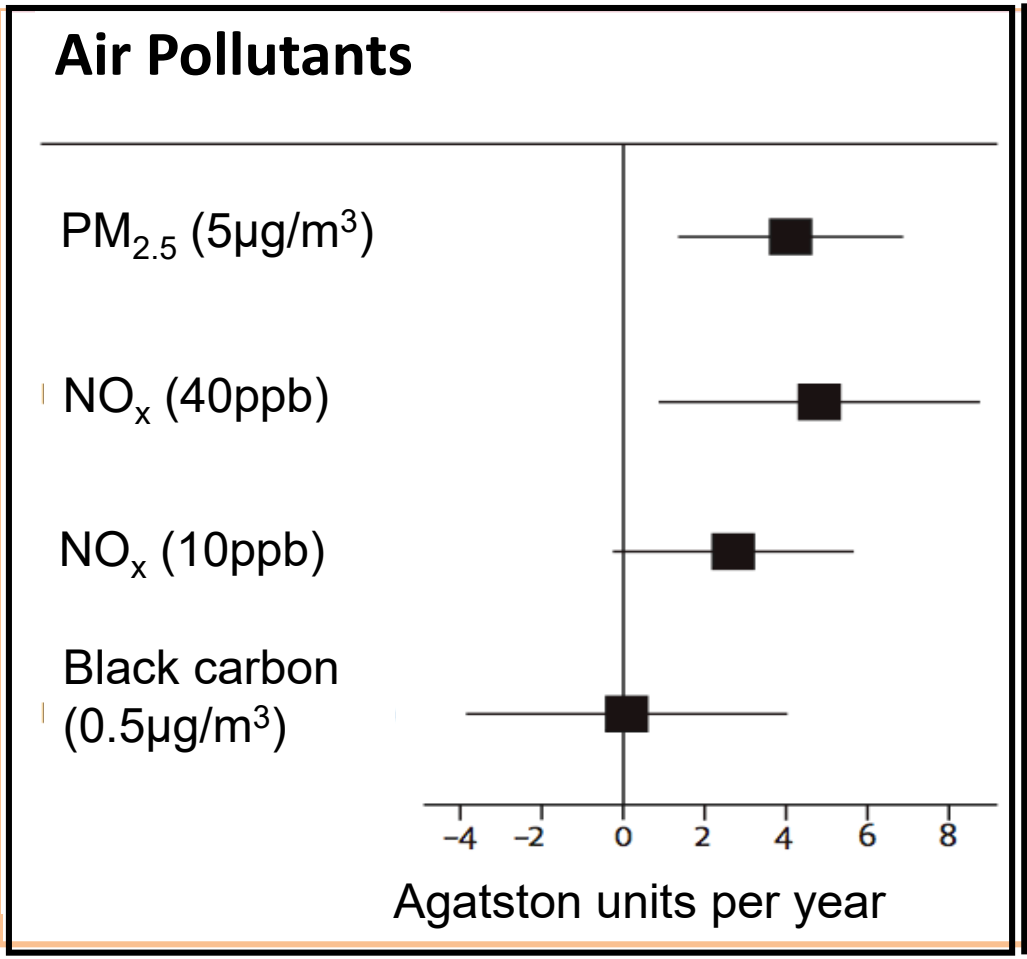


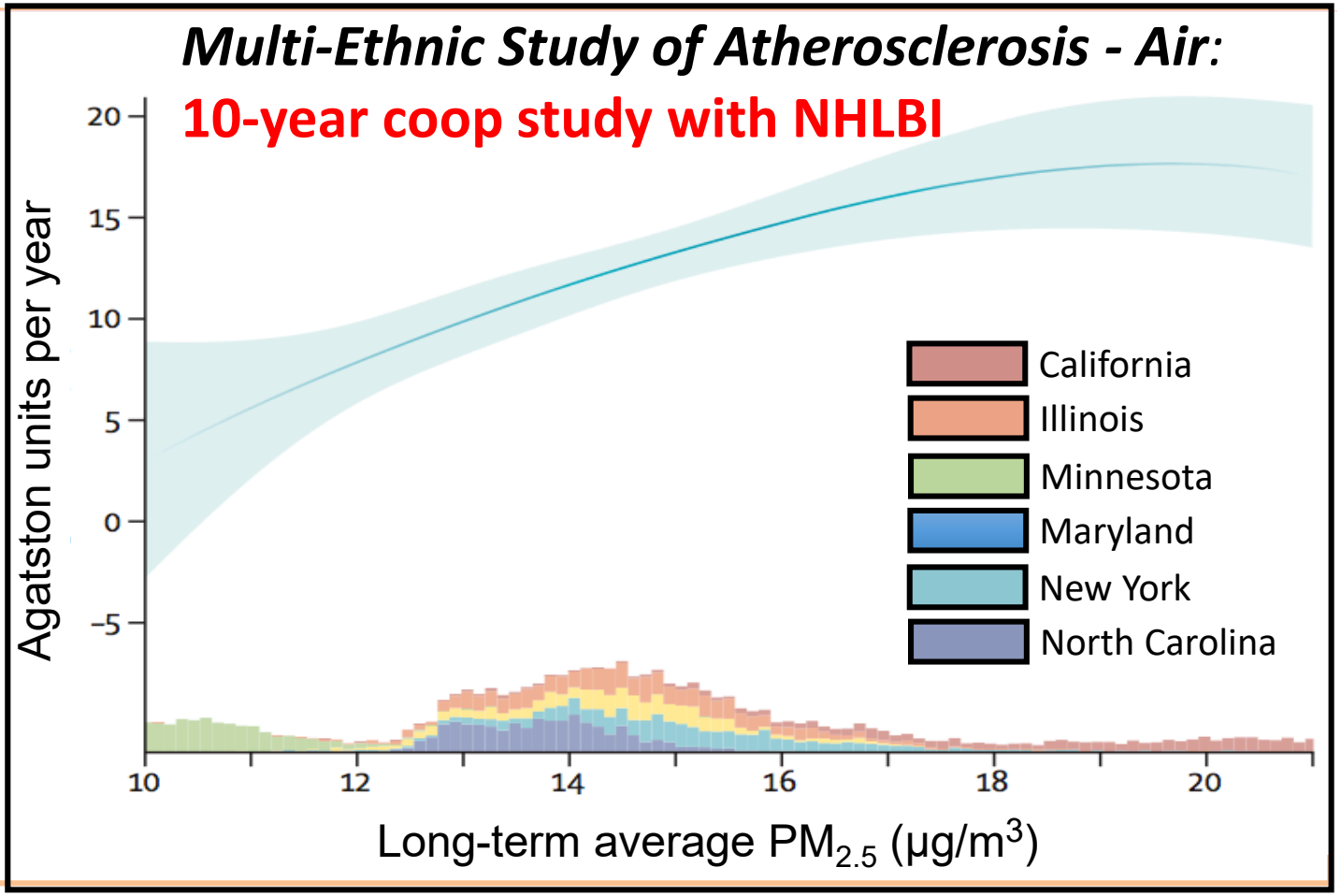


JACC

Rajagopalan S, et al. J Am Coll Cardol. 2018;72(17):2054-70.

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



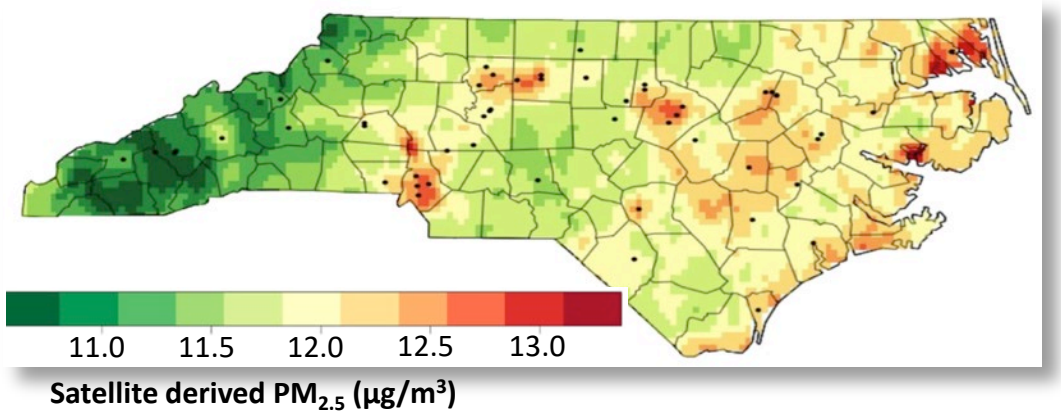


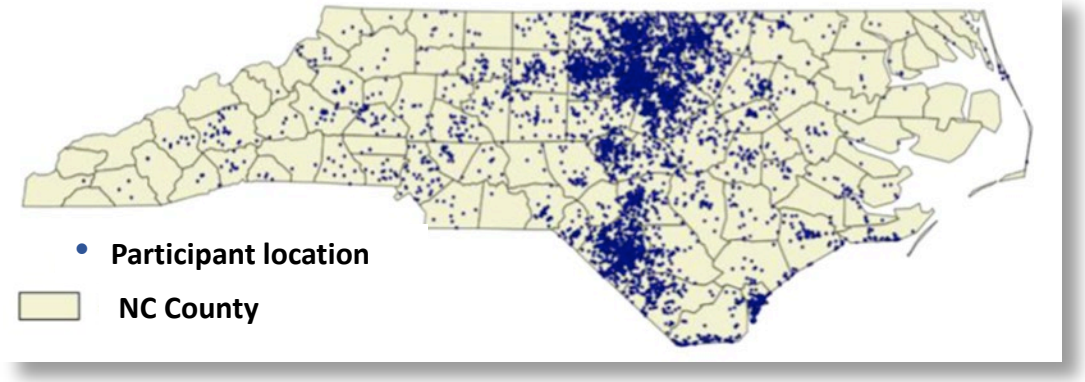
Long-term $PM_{2.5}$ and NO_2 increased coronary calcium, an indictor of atherosclerosis

Kaufman JD et al. Lancet 2016

Health & 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 odds of significant Coronary Artery Disease**
- **14.2% increase in the odds of having had a heart attack during the previous year**

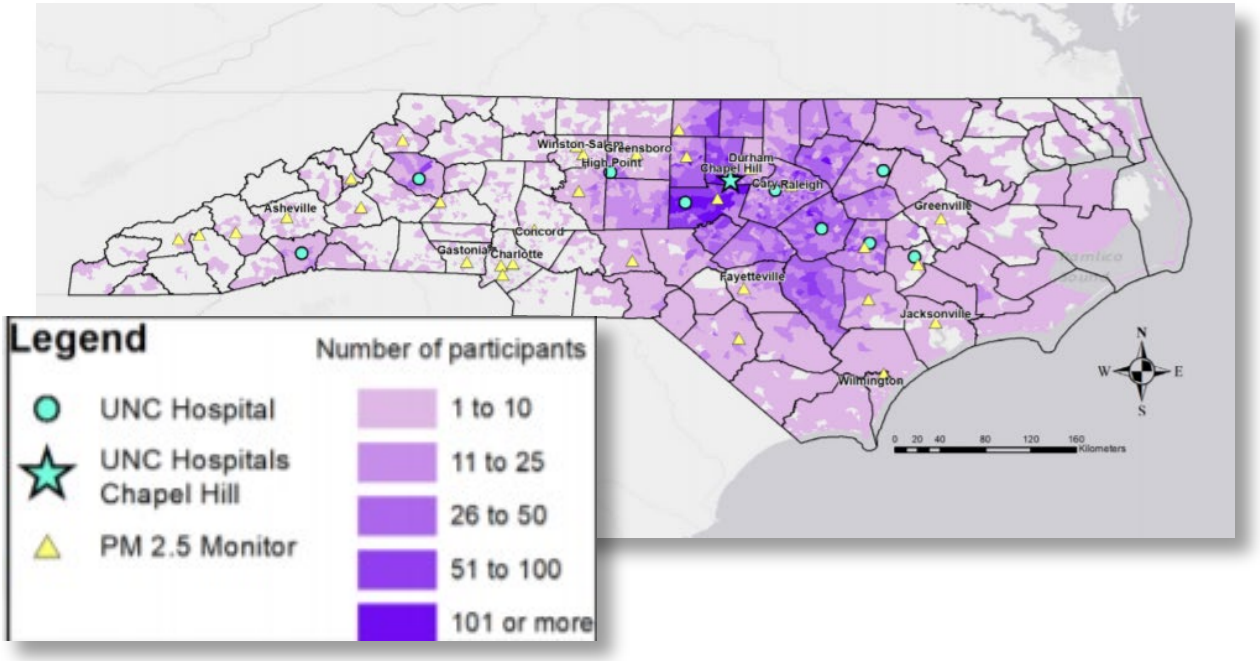
6,575 Ohio residents undergoing elective diagnostic coronary angiography found the same relationship**

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

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

Air Pollution and Heart Failure Mortality Association with Age and Annual $PM_{2.5}$ Concentration

Map of Heart Failure Patients in CARES (purple)



UNC-affiliated hospitals (blue circles) with the flagship hospital, located in Chapel Hill, NC, given as a blue star. EPA $PM_{2.5}$ monitors are represented as yellow triangles.

Risk per 1 μg/m³ increase in $PM_{2.5}$

All Individuals	
HR (95% CI)	N (Deaths)
1.13 (1.10-1.15)	23,012 (4,444)
Diastolic HF	
HR (95% CI)	N (Deaths)
1.09 (1.05-1.13)	6,315 (1,449)
Systolic HF	
HR (95% CI)	N (Deaths)
1.07 (1.03-1.11)	7,041 (1,055)

Ward-Caviness C et al. JAHA 2020

Air Pollution Worsens Vascular Risk Factors
Risk Factors for Atherosclerosis and Air Quality

Poor Air Quality:

Age – might accelerate aging

Total Cholesterol – increases cholesterol

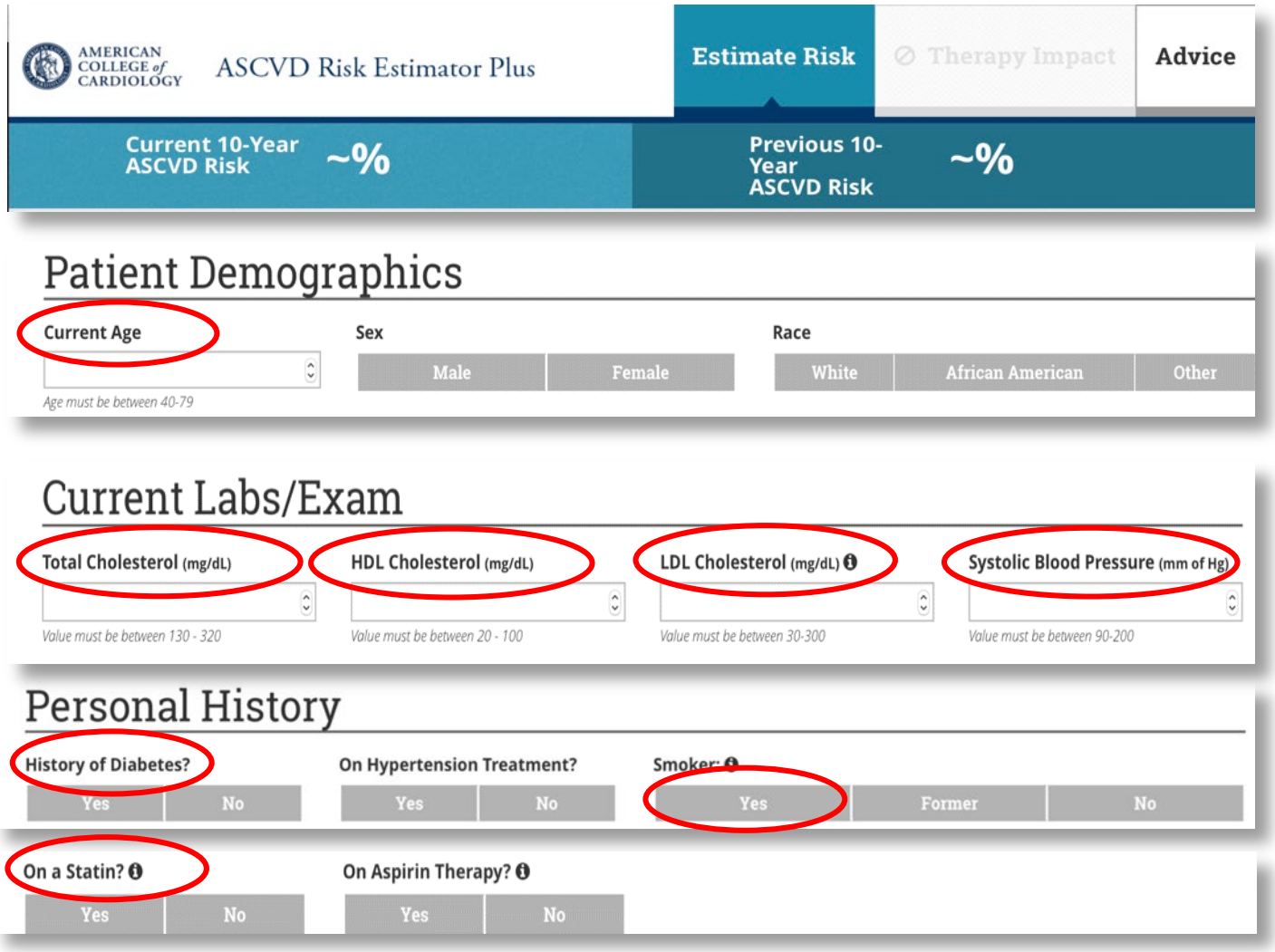
HDL – decreases HDL particle number

LDL – oxidizes LDL and ox-LDL receptor

Systolic BP – increases blood pressure

Diabetes – associated with Type II diabetes

Statin Therapy – might protective



http://tools.acc.org/ASCVD-Risk-Estimator-Plus/#!/calculate/estimate/

The Environmental "Buckets" of Prevention Framework

Total Population Community-Wide Prevention

NAAQS

Built Environment

Health Literacy

- Attain & maintain NAAQS standards
- Improve built environment:
  - Places for physical activity
  - Create healthier near-road environments
- Improve overall CV health status

Traditional Clinical Prevention

"Evidence-based" clinical prevention management strategies

- Long-term indoor air filtration lowered markers of oxidative stress and inflammation (*Chuang H-C, et al. Environ International 2017*)

Modified from Auerbach J. *J Pub Health Manag Pract*, *22*: 215-218, 2016

The Environmental "Buckets" of Prevention Framework

Total Population Community-Wide Prevention

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- Attain & maintain NAAQS standards
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Innovative Clinical Prevention

?

- Optimize clinical care of the at-risk priority population
- Increase awareness of health effects of PM among physicians, health care professionals and the at-risk population
- Provide guidance to lower exposure & associated risk

Traditional Clinical Prevention

~~"Evidence-based" clinical prevention management strategies~~

- Long-term indoor air filtration lowered markers of oxidative stress and inflammation (*Chuang H-C, et al. Environ International 2017*)

Public Health — **Health Care**

Modified from Auerbach J. *J Pub Health Manag Pract*, *22*: 215-218, 2016

EPA's Healthy Heart Program
Increasing Environmental Health Literacy

EPA's Healthy Heart program aims to prevent heart attacks and strokes by:

- Raising public awareness about the role outdoor air pollution plays in cardiovascular health, and
- Steps individuals can take to reduce their pollution exposure

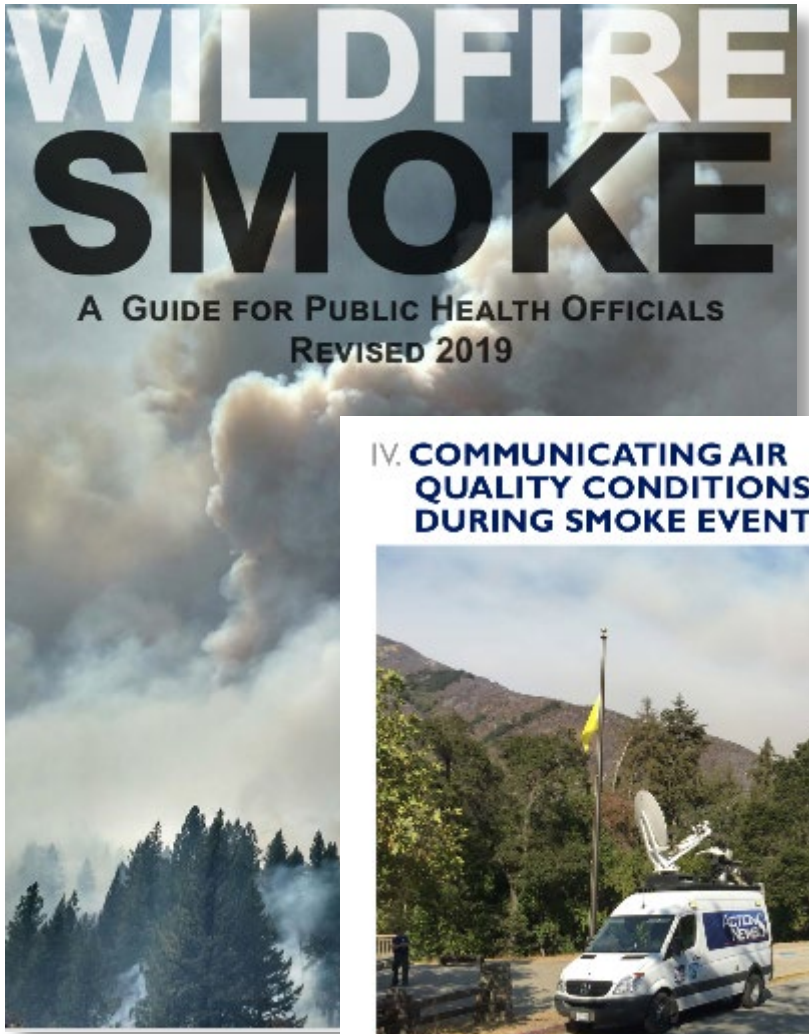
http://www.epa.gov/healthyheart/

Particle Pollution and Your Patients' Health

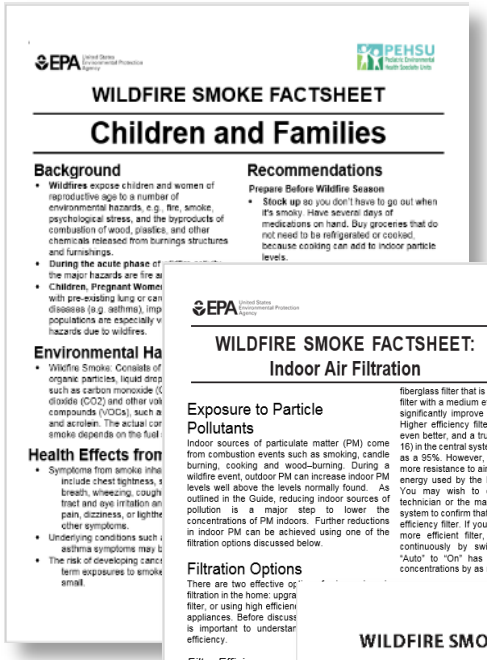
Web Course for Healthcare Professionals and Educators

Evidence-based training for healthcare professionals that provides knowledge they can share with patients to help reduce their overall risk of particle pollution health effects. **Free CME, CNE, and CEU upon completion**.

Wildfire Smoke Guide for Public Health Officials *Revised 2019*



- Interagency collaboration
- Smoke vs. urban particles
- Addition of ozone
- Added sections
  - PM web course
  - Ash cleanup
  - Sensors
- Stand alone fact sheets
  - Children
  - Older adults
  - Pets/livestock
  - Preseason preparedness
  - Exposure reduction
  - Know when to evacuate
  - Older adults
  - Respirator use
  - Ash cleanup


WILDFIRE SMOKE FACTSHEET

Children and Families

Background

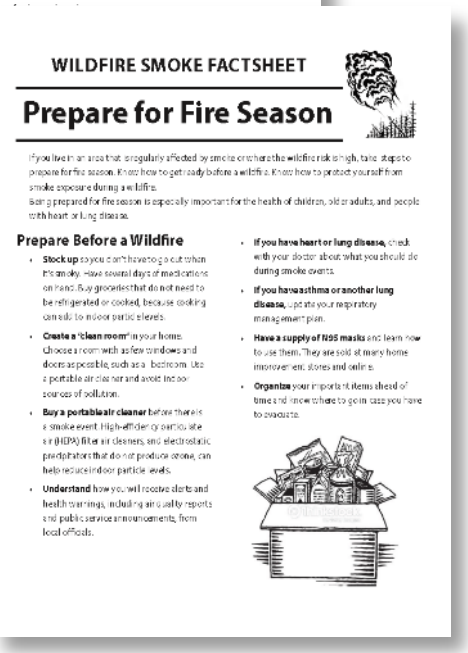
Recommendations

Prepare Before Wildfire Season

WILDFIRE SMOKE FACTSHEET: Indoor Air Filtration

Exposure to Particle Pollutants

Filtration Options


WILDFIRE SMOKE FACTSHEET

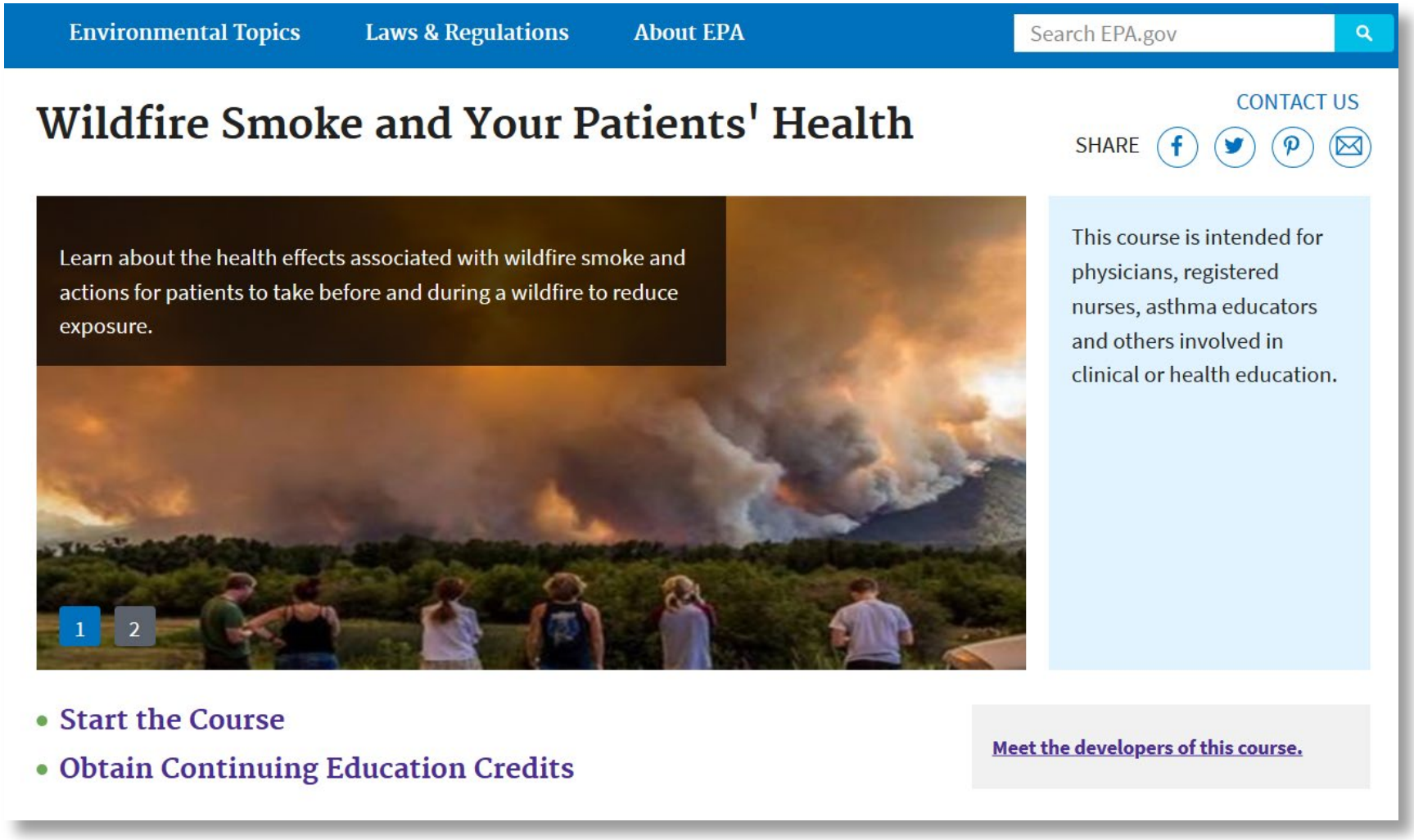
Prepare for Fire Season

Prepare Before a Wildfire

https://airnow.gov/index.cfm?action=topics.smoke_wildfires_guide_factsheets

Wildfire Smoke and Your Patients' Health

Web Course for Healthcare Professionals and Educators



Developed for healthcare practitioners, the **Wildfire Smoke and Your Patients' Health course** is a trimmed down, tailored version of the **Wildfire Guide,** focusing on health effects, populations at greater risk of health effects, air quality, and actions to reduce exposure.

EPA's Healthy Heart Program
Increasing Environmental Health Literacy

A health literacy program that provides a collection of web-based resources about the health effects of air pollution.

A national initiative, co-led by CDC and CMS, that aims to prevent 1 million heart attacks by 2022.

Healthy Heart & Million Hearts

Total Population Community-Wide Prevention	Innovative Clinical Prevention	Traditional Clinical Prevention
PM NAAQS 24-hour Standard: 35 µg/m³ Annual Standard 12 µg/m³	Healthy Heart A healthier environment for healthier hearts Million Hearts®	Currently no traditional "evidence-based" clinical prevention management strategies

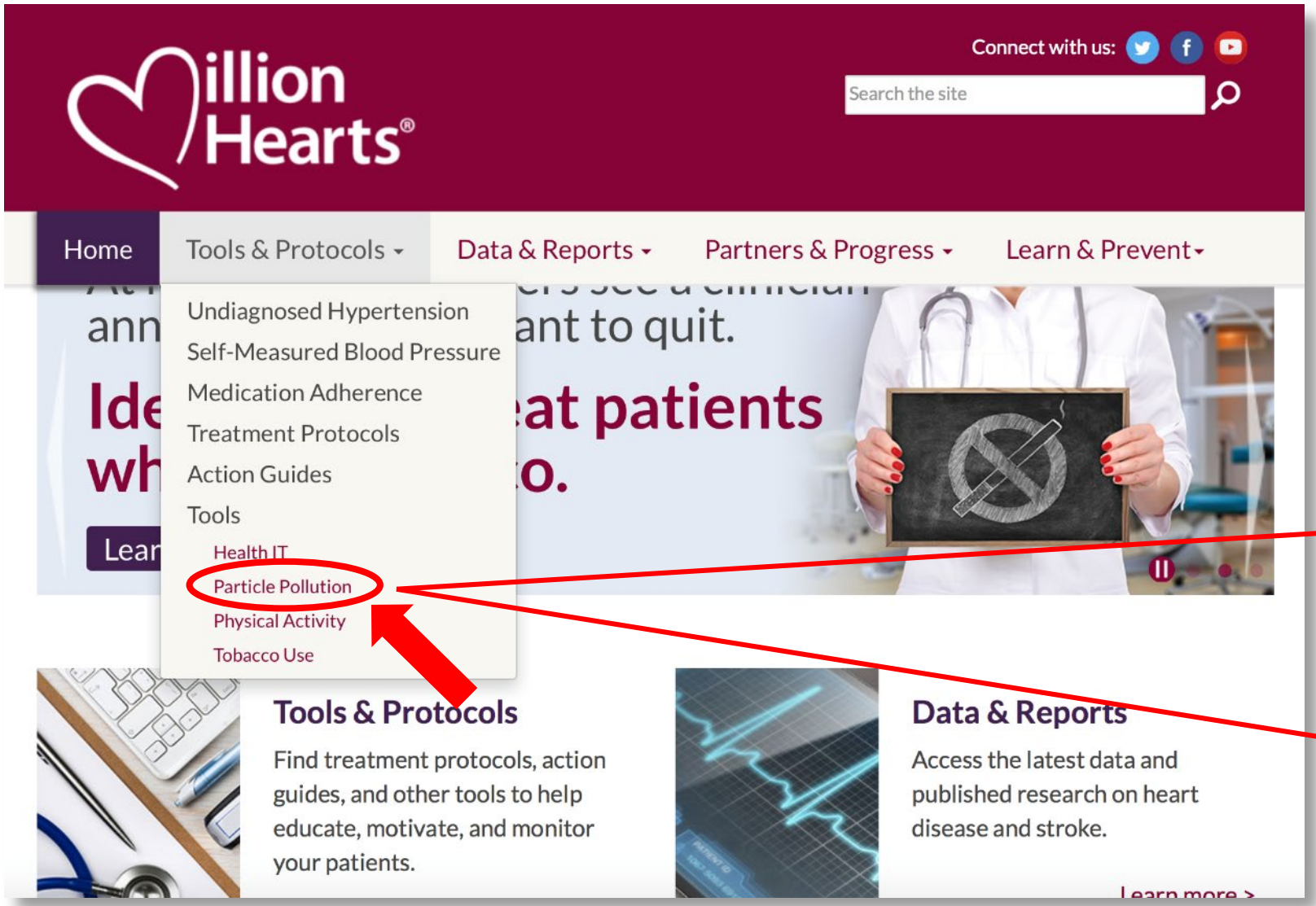
Public Health → **Health Care**

Modified from Auerbach J. *J Pub Health Manag Pract*, *22*: 215-218, 2016

Million Hearts® 2022 Aim:
Prevent a Million Heart Attacks and Strokes in 5 Years

Joint initiative of CDC and CMS

Million Hearts®
Provides Educational Tools on Particle Pollution



https://millionhearts.hhs.gov

Optimizing Care

Support includes: Counseling on risks of particulate matter

Goals	Effective Health Care Strategies
Improve ABCS* Targets: 80%	***High Performers Excel in the Use of…*** • **Teams**—including pharmacists, nurses, community health workers, and cardiac rehab professionals • **Technology**—decision support, patient portals, e- and default referrals, registries, and algorithms to find gaps in care • **Processes**—treatment protocols; daily huddles; ABCS scorecards; proactive outreach; finding patients with undiagnosed high BP, high cholesterol, or tobacco use • **Patient and Family Supports**—training in home blood pressure monitoring; problem-solving in medication adherence; counseling on nutrition, physical activity, tobacco use, risks of particulate matter; referral to community-based physical activity programs and cardiac rehab
Increase Use of Cardiac Rehab Target: 70%	
Engage Patients in Heart-Healthy Behaviors Targets: TBD	

*Aspirin when appropriate, Blood pressure control, Cholesterol management, Smoking cessation

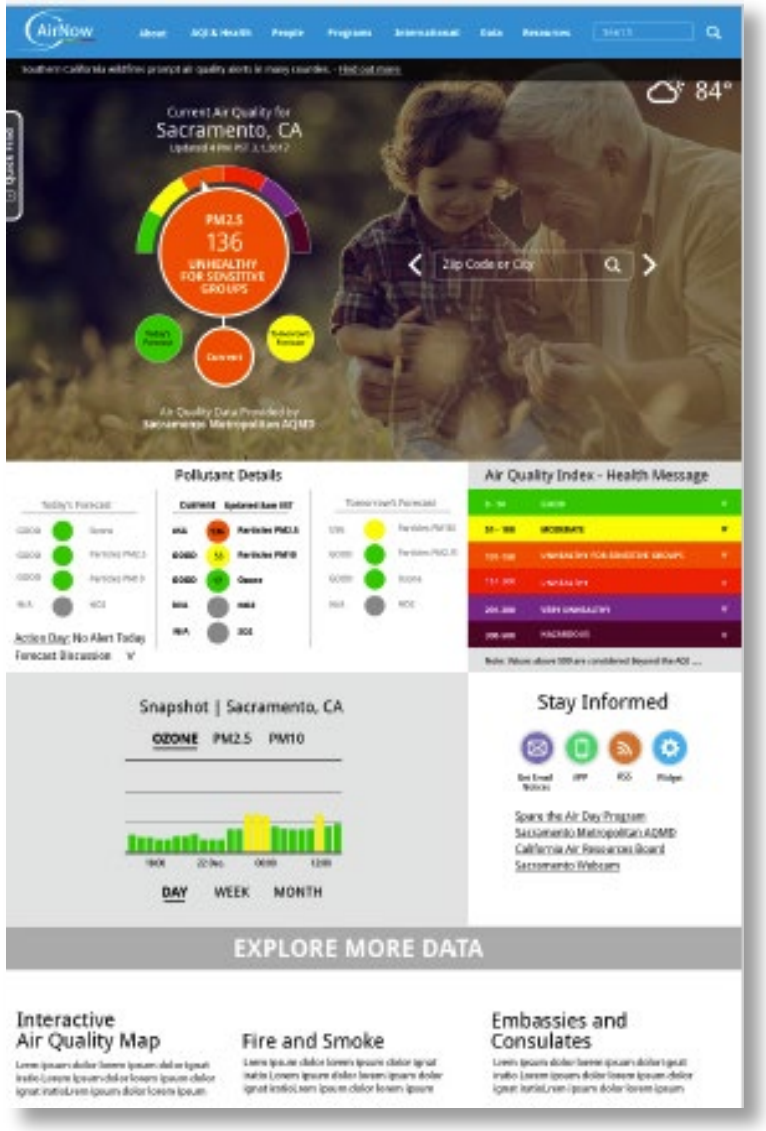
EPA United States Environmental Protection Agency

Improving Outcomes for Priority Populations

Priority Populations	Major Strategies
Blacks/African Americans	Improving hypertension control
35- to 64-year-olds, because event rates are rising	• Improving hypertension control and statin use • Increasing physical activity
People who have had a heart attack or stroke	• Increasing cardiac rehab referral and participation • Avoiding exposure to particulate matter
People with mental illness or substance use disorders	Reducing tobacco use

Informing the Public www.airnow.gov via the Internet

- *AirNow.gov Redesign Now Active*
  - **Updated look: Focus on local conditions**
  - **Mobile-friendly website**
  - **Same great information**
    - Health Care Provider page
    - Fires: Current Conditions page
  - **Better display of temporal changes in air quality**



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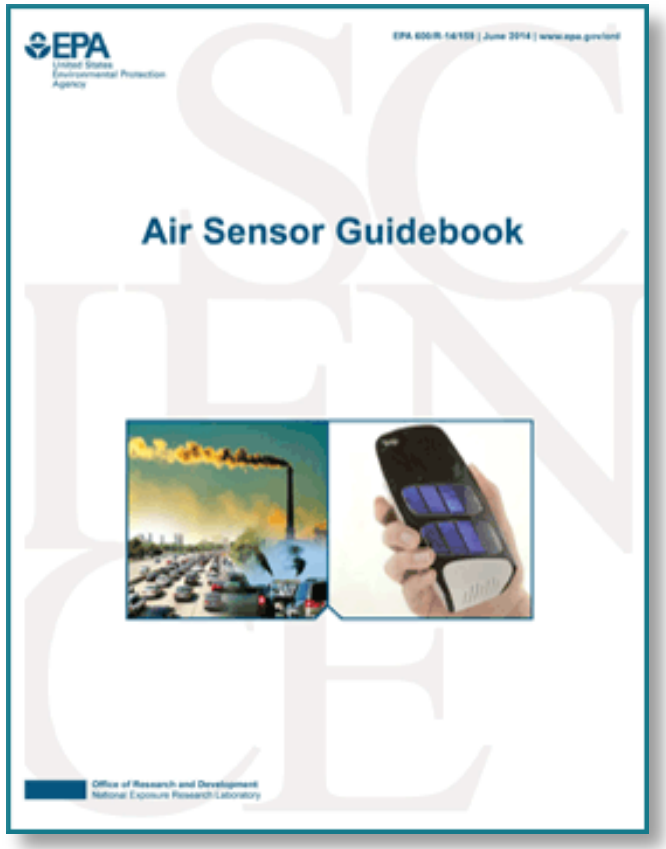
EPA ORD Air Quality Tools: Engaging Individuals and Communities

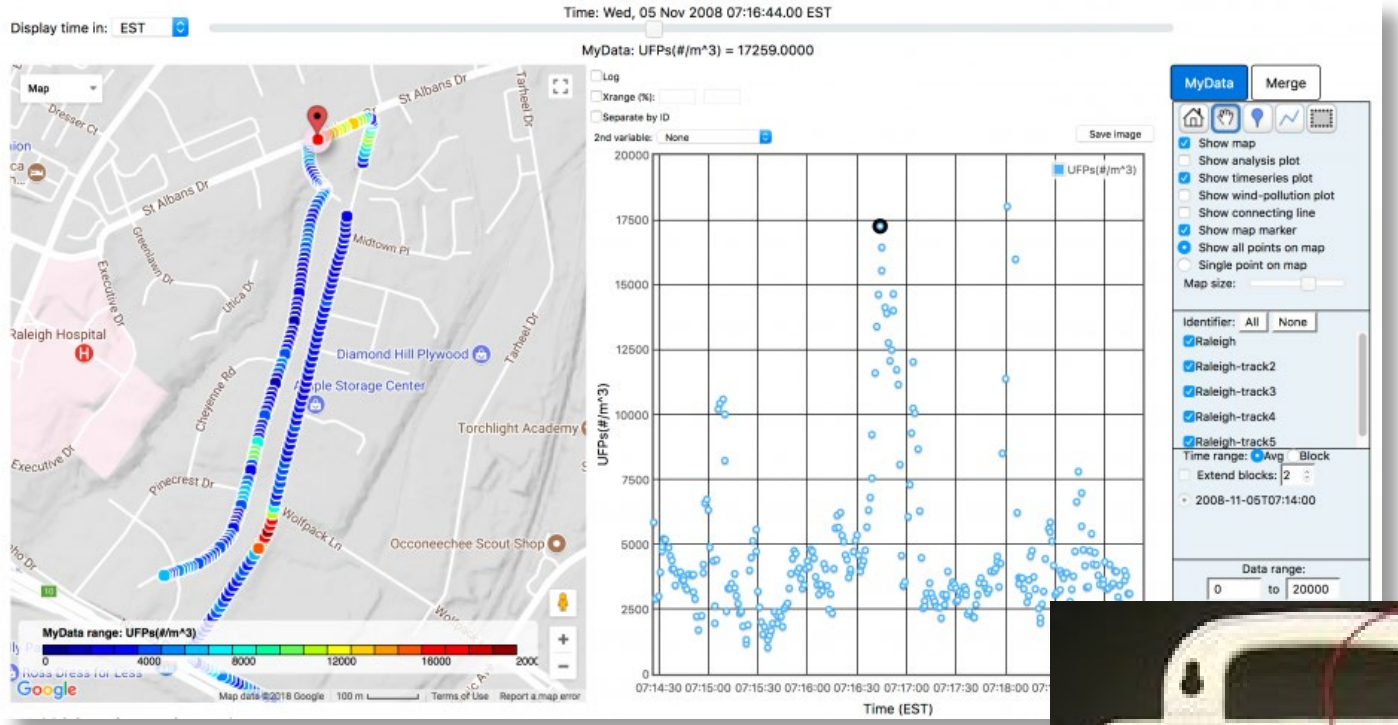
TracMyAir App

Air Sensor Toolbox: Goals

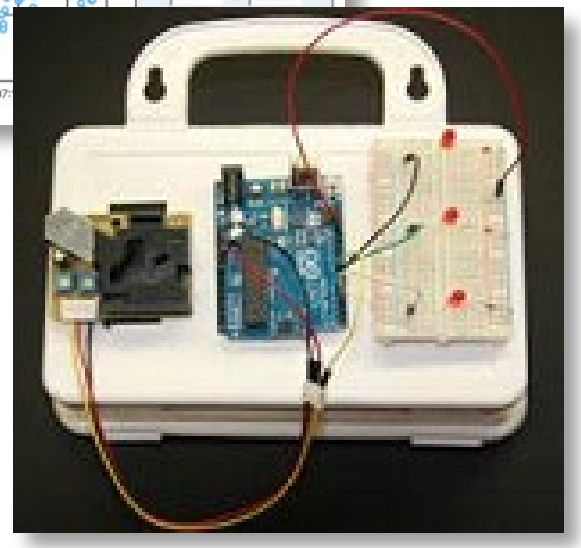
EPA's Air Sensor Toolbox provides the latest science on the performance, operation and use of air sensor monitoring systems for technology developers, air quality managers, citizen scientists and the public.

Air Sensor Toolbox: Approaches





REal TIme Geospatial Data Viewer (RETIGO)



Build your own particle sensor kit

https://www.epa.gov/air-sensor-toolbox

Air Sensor Toolbox: Impact

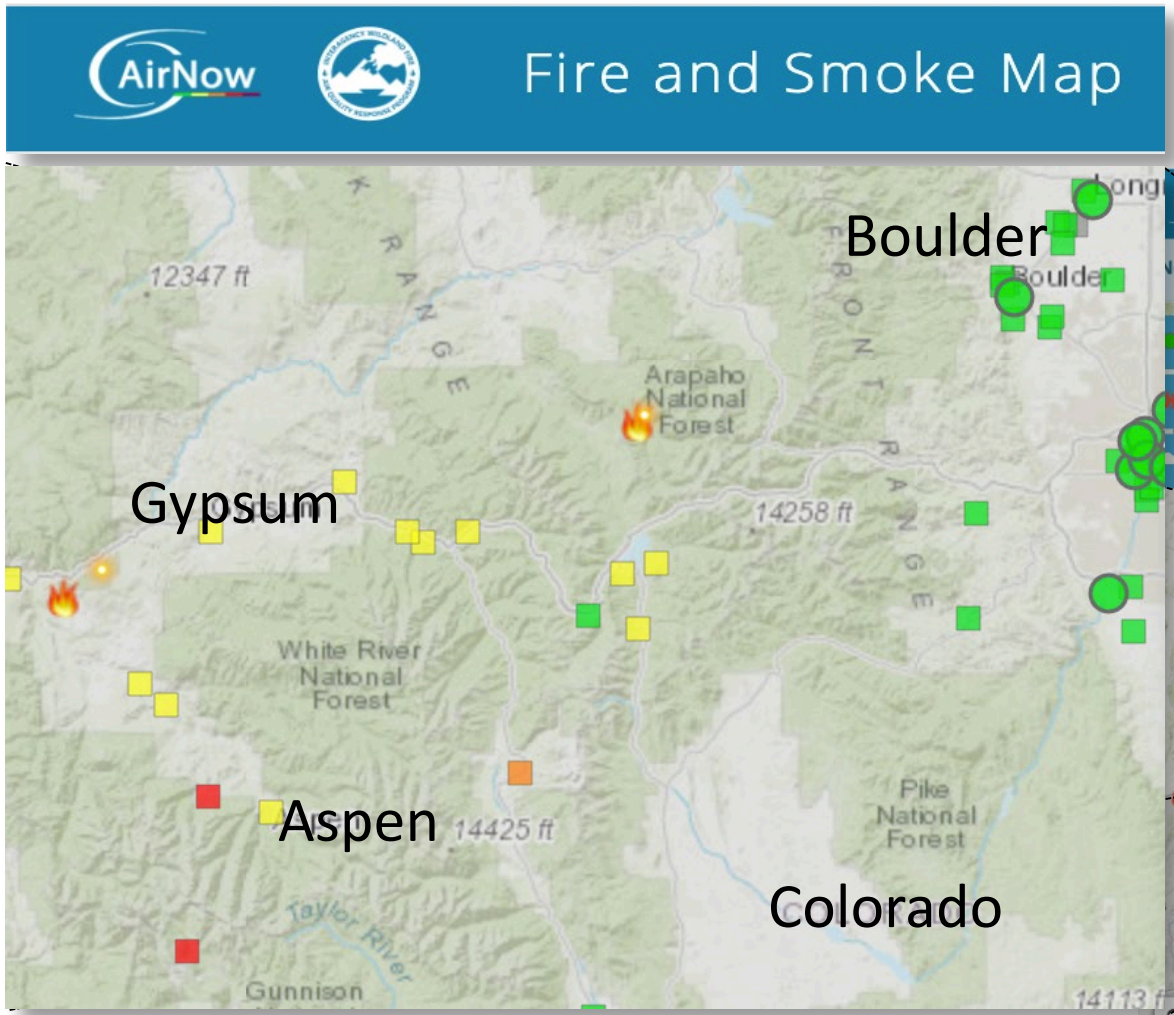
EPA and partners from the Eastern Band of Cherokee Indians review the assembly of a weather shelter for low-cost sensors.

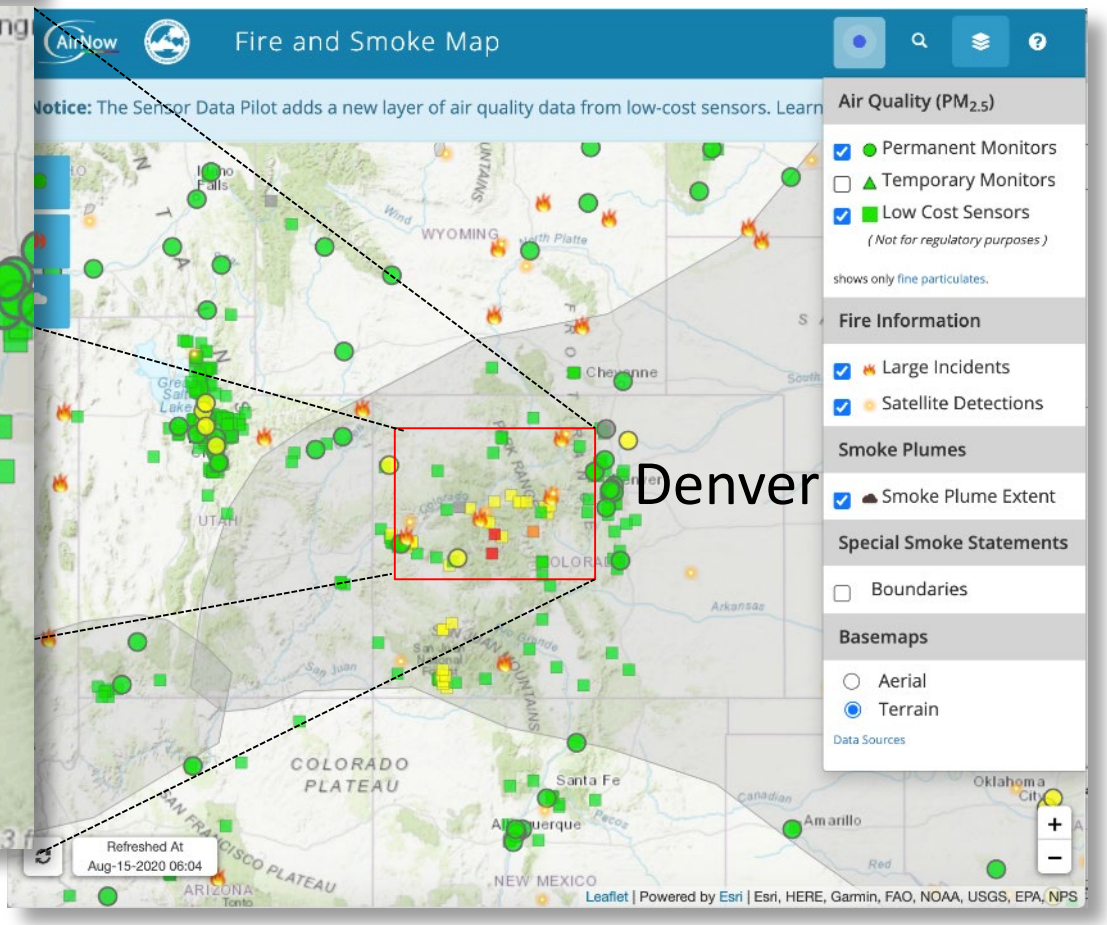
Over 50K visits to Toolbox webpage this past year

Enhanced Ambient Air Quality ($PM_{2.5}$) Data PurpleAir now displayed on AirNow

Air Quality ($PM_{2.5}$) Layers: Monitors and sensors reporting $PM_{2.5}$ data

- Permanent Monitors: Federal, State, Tribal
- Temporary Monitors: Typically government agencies
- Low Cost Sensors: Currently from Purple Air

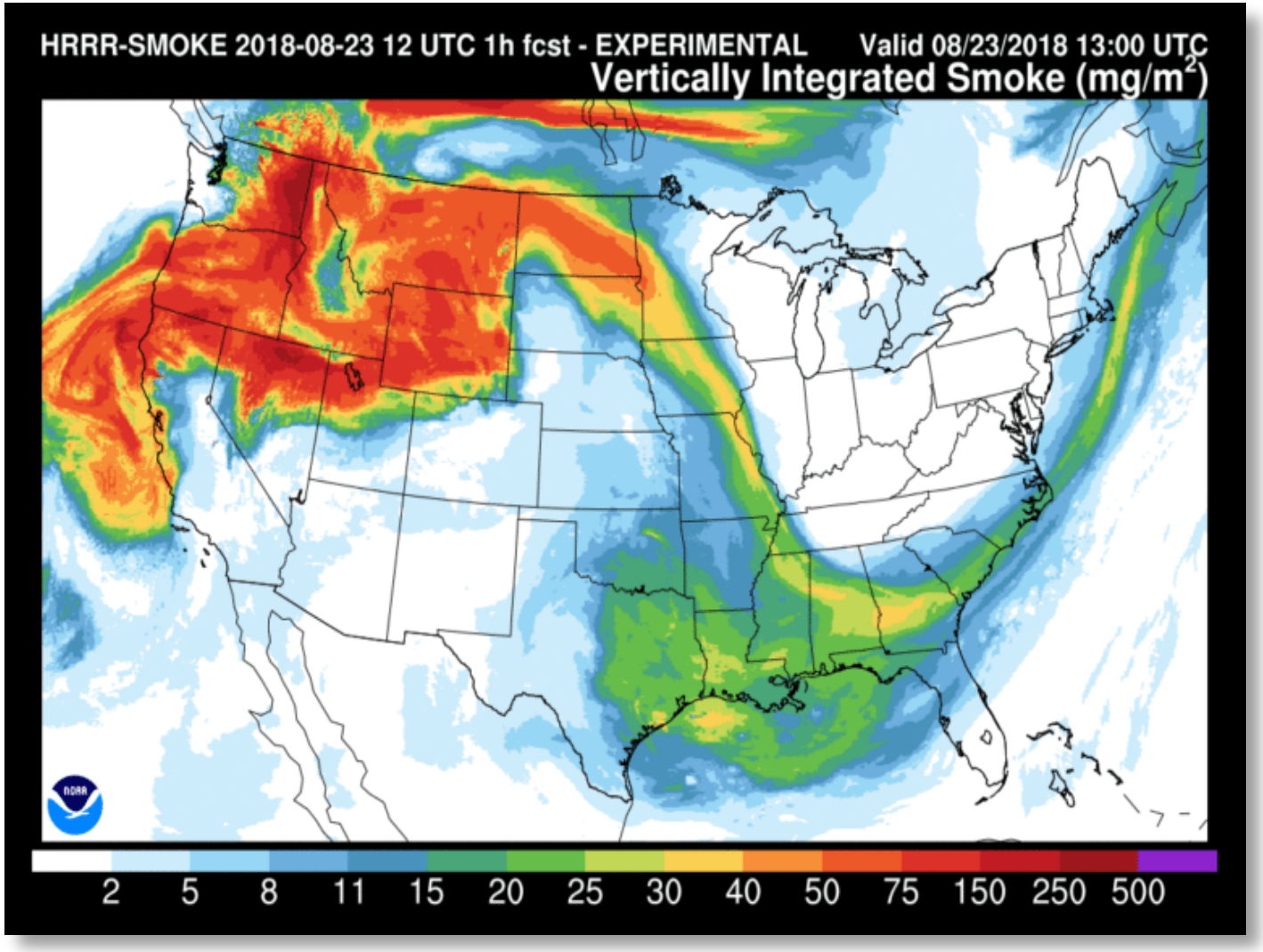




https://fire.airnow.gov/

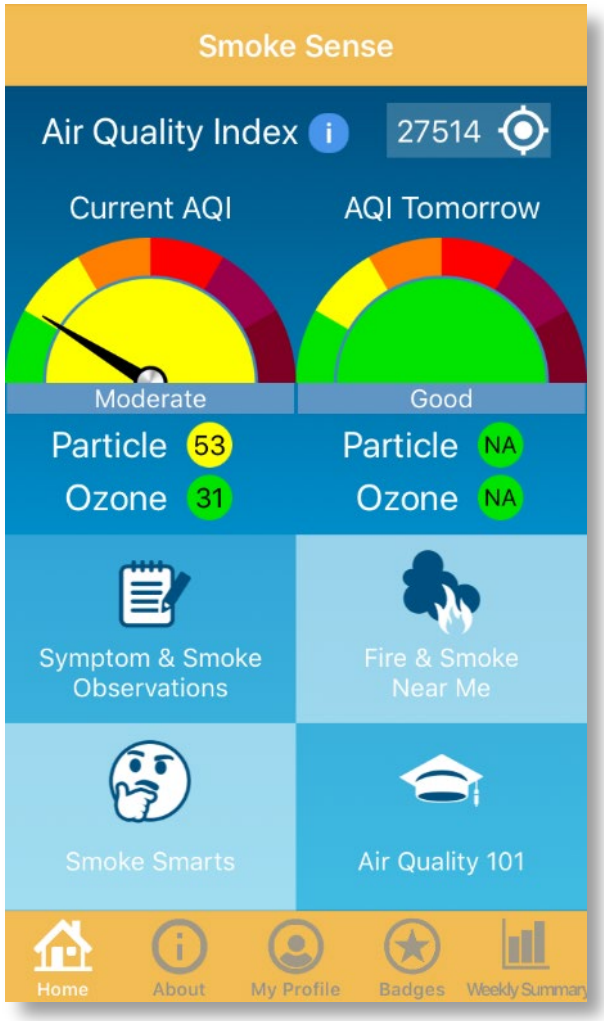
Smoke Sense: Goals

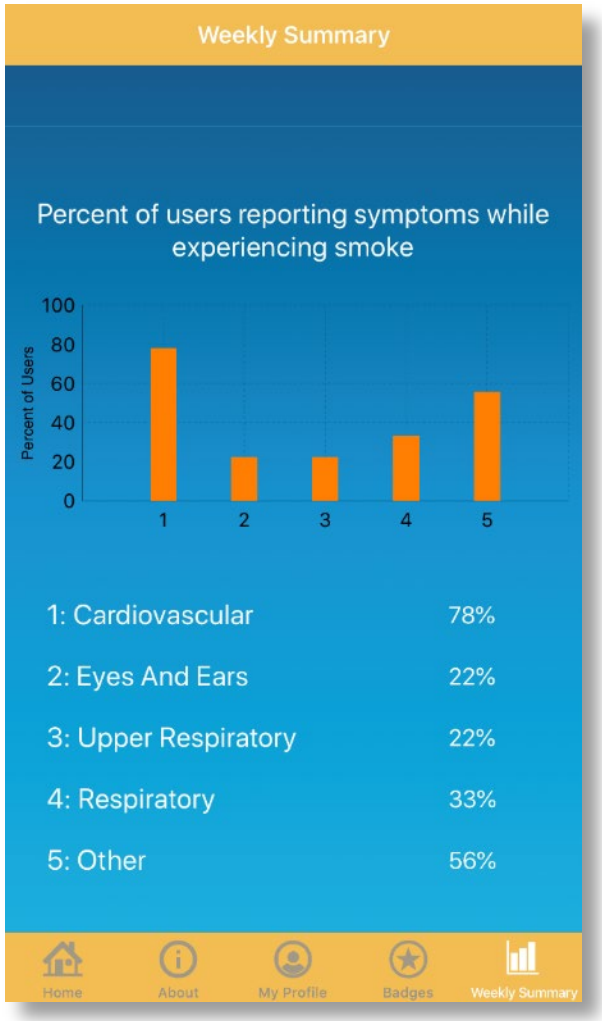
- Understand the gap between what we know about risk and ways to protect our health and the observed public health outcomes
- Increase issue engagement so people can take action to protect health
- Inform ways to improve effectiveness of health risk messaging and communication strategies



Smoke Sense: Approaches

Smoke Sense





www.epa.gov/air-research/smoke-sense

Smoke Sense: Impact

- Develops entry points for members of the public to contribute to ***research, engage and access*** data
- ***Mutually beneficial*** – it helps EPA answer questions, and it also serves as an educational/data resource that communities can leverage to address issues related to air quality and health in their communities
- Allows for ***two-way communication*** framework in problem formulation and dissemination of knowledge
- ***Data sharing and fostering change***

Over 31K users in all 50 states

TracMyAir: Goals

TracMyAir App

- Develop smartphone exposure model to estimate real-time individual-level exposures and inhaled doses to $PM_{2.5}$ and ozone
- Facilitate and expand use of exposure metrics for epidemiological studies and public health applications
- Inform ways to reduce exposures so people can take action to protect health

EPA science in ACTION

www.epa.gov/research

INNOVATIVE RESEARCH FOR A SUSTAINABLE FUTURE

EPA's TracMyAir App: Using smart phones to predict near real-time air pollution exposures

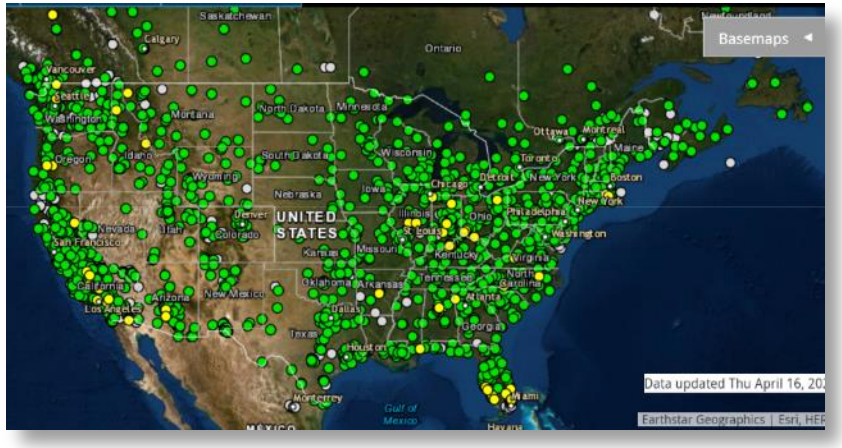
Background

To better understand people's contact with air pollutants and their potential for adverse health effects, it's important to estimate how much time they spend in different locations and what the air pollutant concentrations are in those locations. Using currently available personal air monitors to collect this information has several limitations, including burden on participants, cost, and need for substantial technical expertise.

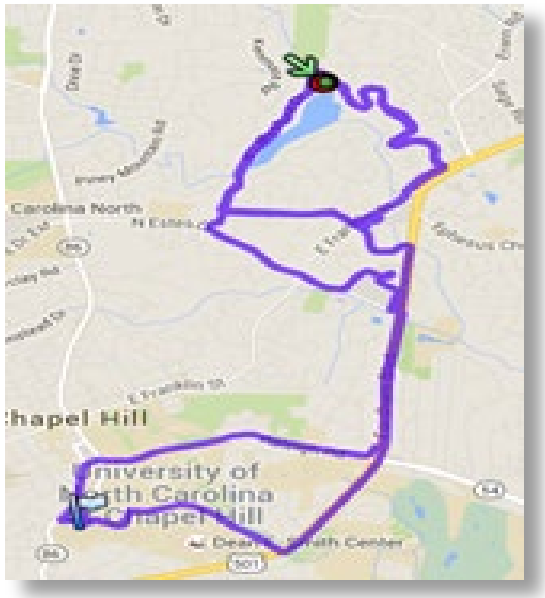
TracMyAir: Approaches

TracMyAir App

- Tracks user's nearest $PM_{2.5}$ and ozone monitors to determine outdoor levels
- Estimates building-specific infiltration of $PM_{2.5}$ and ozone to determine indoor levels (accounts for open windows, window fans, home air cleaners)
- Tracks user's location and corresponding microenvironment (e.g., outdoors, in-vehicle, indoors at home, work) to determine exposure
- Tracks user's physical activity level (e.g., step counts) to determine inhaled dose



AirNow $PM_{2.5}$, ozone monitors



User's location tracks

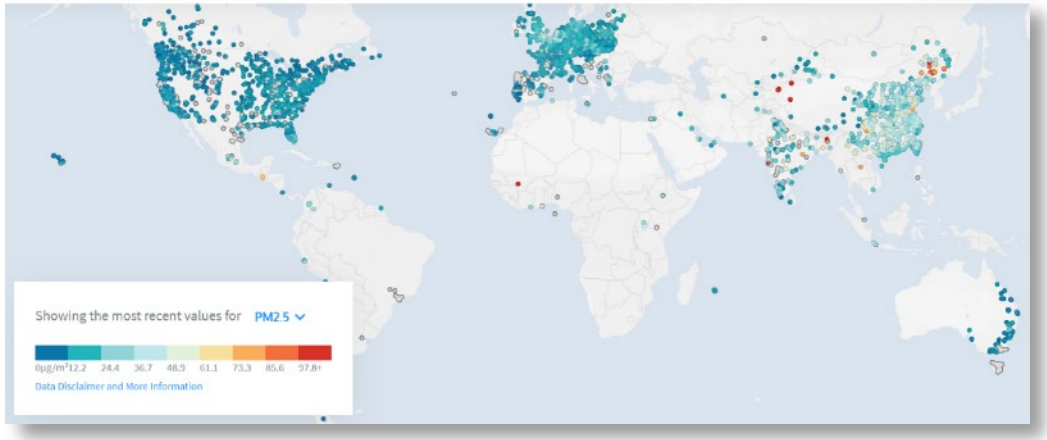
User's step counts

TracMyAir: Impact

TracMyAir App

- Integrates with network of low-cost $PM_{2.5}$ monitors (PurpleAir) for community applications
- Integrates with global network of ambient monitors (OpenAQ) for international applications
- Integrates with real-time air quality models for exposures to additional air pollutants (e.g., NO_2)
- Determines microenvironment-specific exposures and dose to help identify strategies to reduce levels (e.g., scheduling time spent outdoors and at higher physical activity levels, closing home windows, operating home air cleaners)

PurpleAir – network of low-cost $PM_{2.5}$ monitors



OpenAQ – global network of $PM_{2.5}$, O_3 monitors

Solutions-Driven Research Pilot: Creating Cleaner Air Spaces

Focus: Measuring the effectiveness of air cleaning filtration systems in wildfire smoke conditions

- **Stakeholders identified research priorities including:**
  - How effective are portable air cleaners (PACs) or central air filtration systems during smoke events?
  - Under what operating and maintenance conditions and in what building types?
- **Laboratory and field studies**
- **Partnering with:**
  - Missoula City-County Health Department, Climate Smart Missoula, University of Montana
  - Hoopa Valley Tribe

Collocation of PurpleAir sensors with reference monitors at the USFS Fire Science Lab

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High Resolution Air Pollution Mapping Small Scale Variability due to Local Sources

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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 and Steven P. Hamburg[‡]

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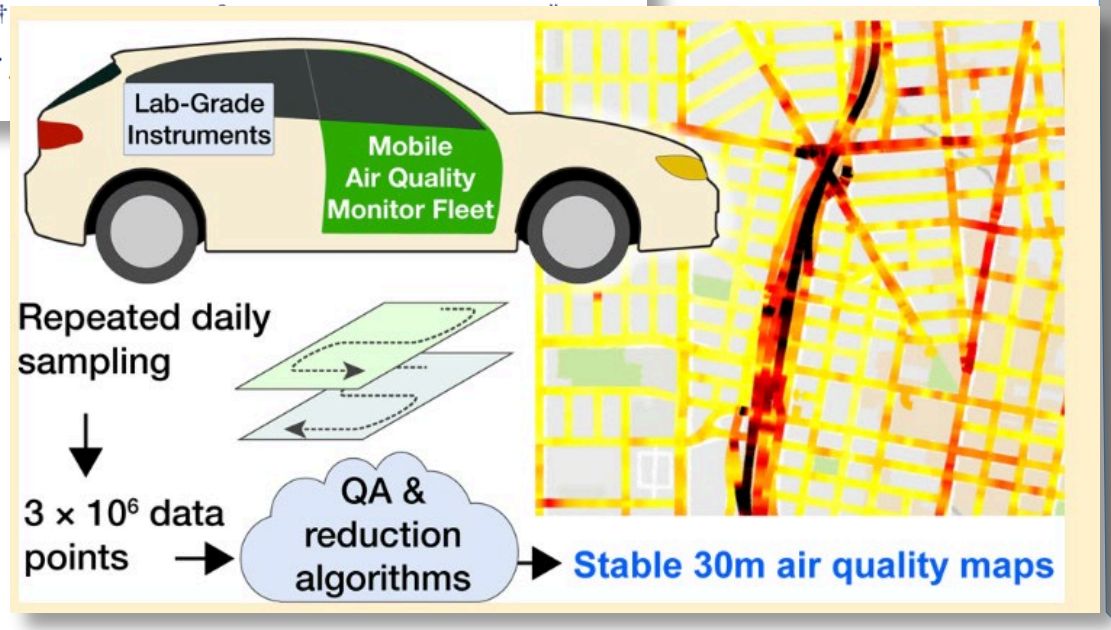
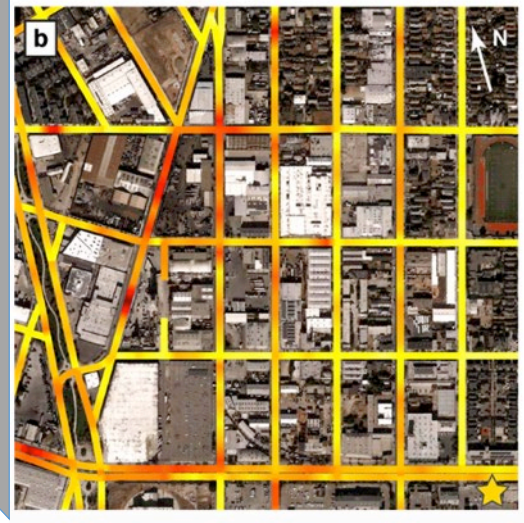


Oakland, CA

Spatial distribution of Black Carbon (BC)



EPA United States Environmental Protection Agency

COVID-19, Air Pollution and Heart Disease

Highly infectious through an aerosol route

- Uses the ACE2 receptor to attach and infect cells
- ACE2 receptors are present on cells of the respiratory and cardiovascular systems

Wide spectrum of disease severity

- Pulmonary effects - pneumonia
- Cardiovascular effects including increased risk of thrombosis, e.g. heart attack and stroke
- Massive inflammatory response (cytokine storm)

Vulnerable populations include many who are sensitive to particulate air pollution

- Chronic lung, heart and kidney disease
- Obesity and Type II diabetes
- Older adults and lower socioeconomic status
- African-Americans, Native Americans and non-White Hispanics

Early epidemiology research suggests that exposure to particulate air pollution increases the severity and mortality of COVID-19

EPA COVID-19 Research to Benefit Public Health

Detecting and Monitoring SARS-CoV-2 in Wastewater

- Standardize methods to assess virus in sewage
- Monitor virus levels in sewage to assess community infection rate

Evaluating SARS-CoV-2 Cleanup and Disinfection Practices

- Surface sampling efficiency
- Alternative disinfection devices
- Longer-term SARS-CoV-2 disinfection evaluation
- Real-world surface disinfection
- Rapid viability
- PPE disinfection

Develop a Salivary Antibody Assay

- Salivary antibody assay to assess community exposure

Early epidemiology research suggests that exposure to particulate air pollution increases the severity and mortality of COVID-19

Looking to the Future
Mid-term Goals for Decreasing Cardiovascular Disease

- **Continue to apply state-of-the-art methods to conduct research to inform EPA regulatory and policy decisions**
- **Continue to develop research to better define those at higher risk from environmental exposures and find ways to mitigate risks in the most vulnerable**
- **Support HHS' goals for Million Hearts, and Healthy People 2020 and 2030**
  - Aims to decrease the prevalence of cardiovascular risk factors in the population
  - Educate clinicians, patients and family members that patients with heart disease should avoid exposure to air pollution
- **Increase cooperation between public health, healthcare systems, insurers and healthcare professionals to protect population and individual health**
  - Look at novel ways to coordinate education and healthcare to limit exposure
  - Especially among those most vulnerable

Looking to the Future
Mid-term Goals for Decreasing Cardiovascular Disease

- **Continue to work with our federal partners to provide consistent and useful guidance on environmental health issues**
  - Increase environmental health literacy through improved communication of environmental health topics, risk and decision-making
- **Increase quality and access to health data for research and public health decision-making**
  - Increase access to and integration of electronic health records data
- **Encourage the incorporation of advances in science and technology to:**
  - Improved exposure assessment to air pollutants
    - Satellite, Ground-based measurement and monitoring
  - Ongoing improvements in air pollution modeling
  - Improve personal exposure measurement and monitoring as well as health effects
    - e.g. TracMyAir app, Smoke Sense app

Contact

Wayne Cascio, MD, FACC
Director, Center for Public Health and Environmental Assessment
US EPA Office of Research and Development
cascio.wayne@epa.gov

For More Information

- Science Matters Newsletter: https://www.epa.gov/sciencematters
- Follow us on Twitter at @EPAresearch and Facebook at U.S. EPA Research
- EPA's Air Research: www.epa.gov/air-research
- EPA's Healthy Heart Toolkit: www.epa.gov/air-research/healthy-heart-toolkit-and-research
- Smoke Sense Project: www.epa.gov/air-research/smoke-sense
- Village Green Project: www.epa.gov/air-research/village-green-project

Thank You!

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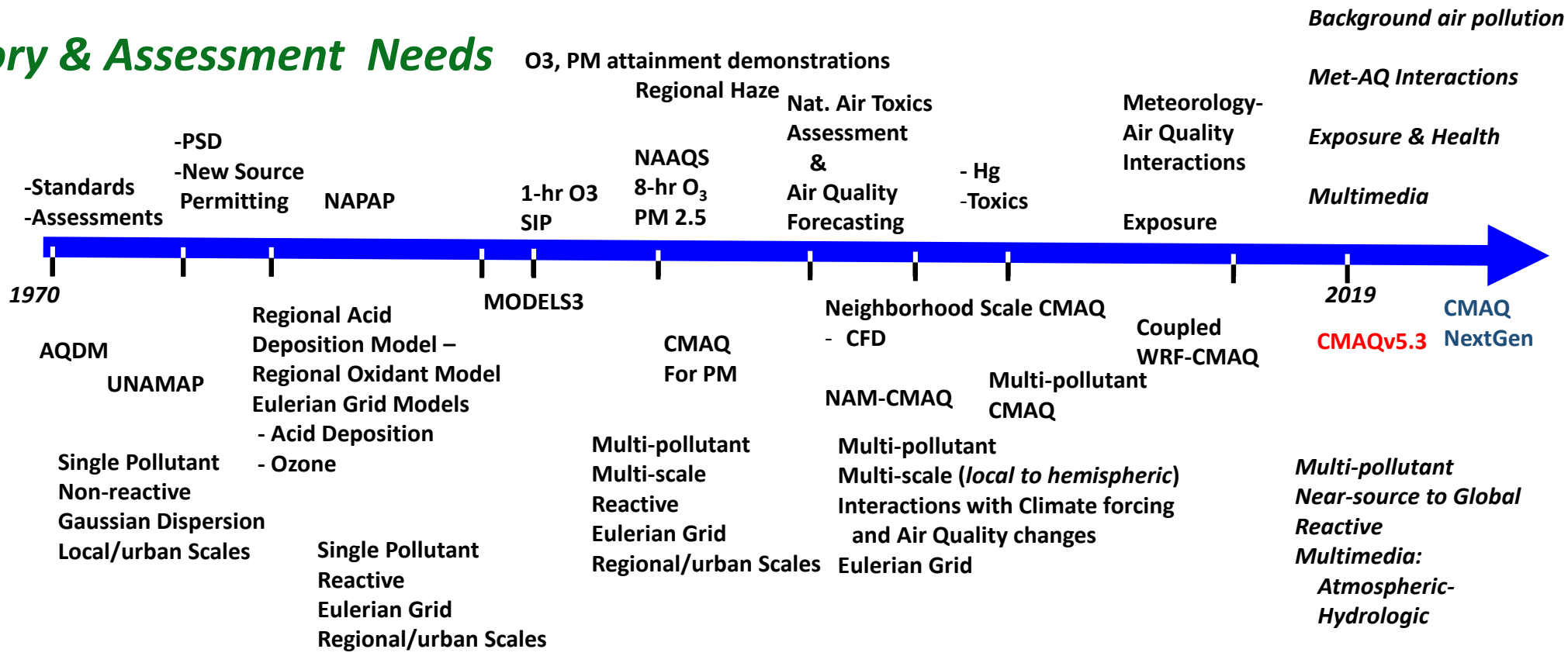
Solutions-Driven Research and Communications

Disclaimer: The views expressed do not necessarily reflect the views or policies of the US EPA.

EPA's Air Quality Models
Vital for implementing the Clean Air Act

Evolution of models guided by increasingly complex application and assessment needs