PM Progress: Looking Back and Looking to the Future at EPA

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Mind Map

- A breeze through PM history…
- What lies ahead?
  - Lingering questions
  - Achieving clarity

- Perspectives
  - o Looking forward / taking action
    - Implementation
    - New air pollution monitoring paradigm
    - Systematic approaches – public health
    - Power to the people: citizen science
  - o Climate – ***mīlle viae dūcunt hominēs per saecula Rōmam***

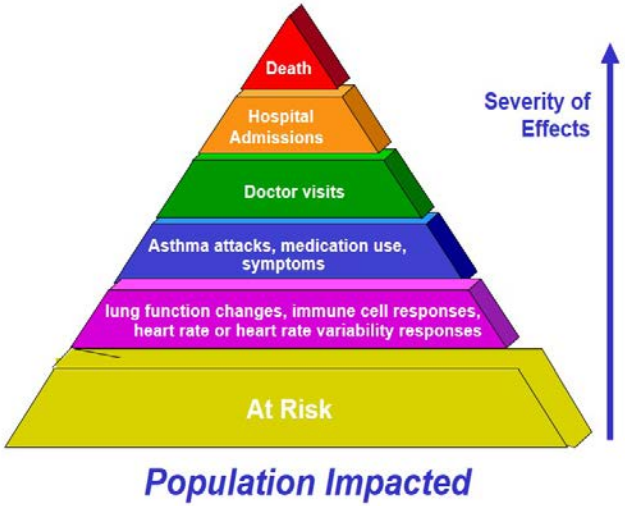
- Summary / conclusions

Air Pollution has a Compelling History

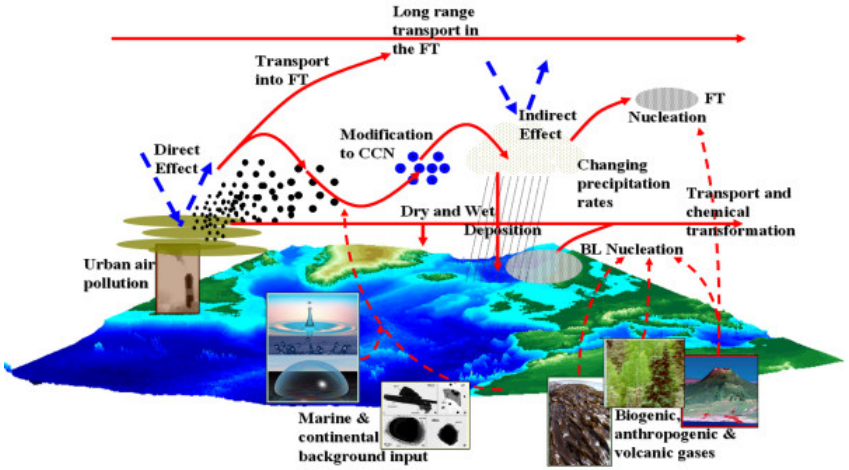
...Recovery is also Compelling

Translating the Science into Regulation

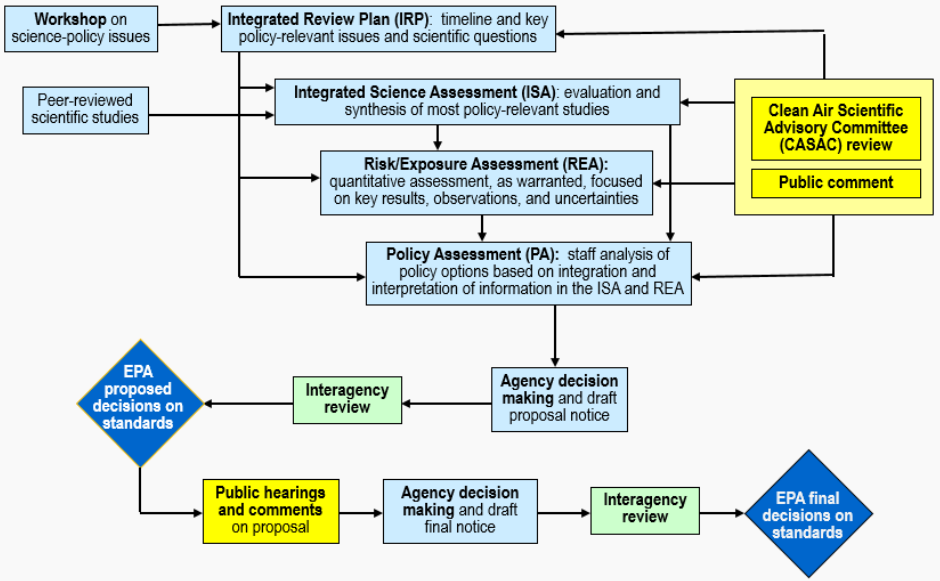
Pyramid of Health Effects for NAAQS

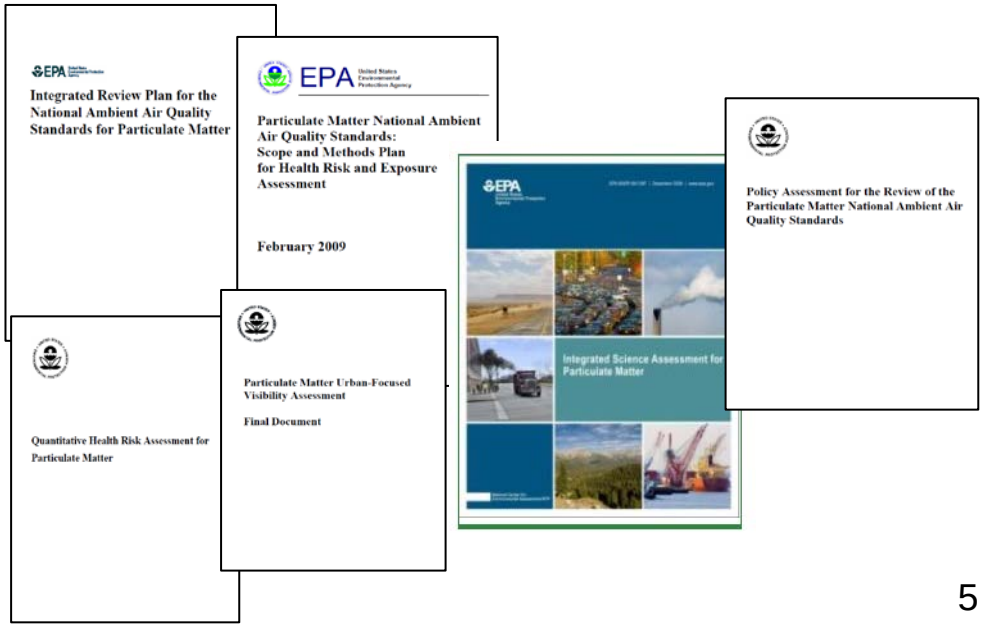


Atmospheric Sciences



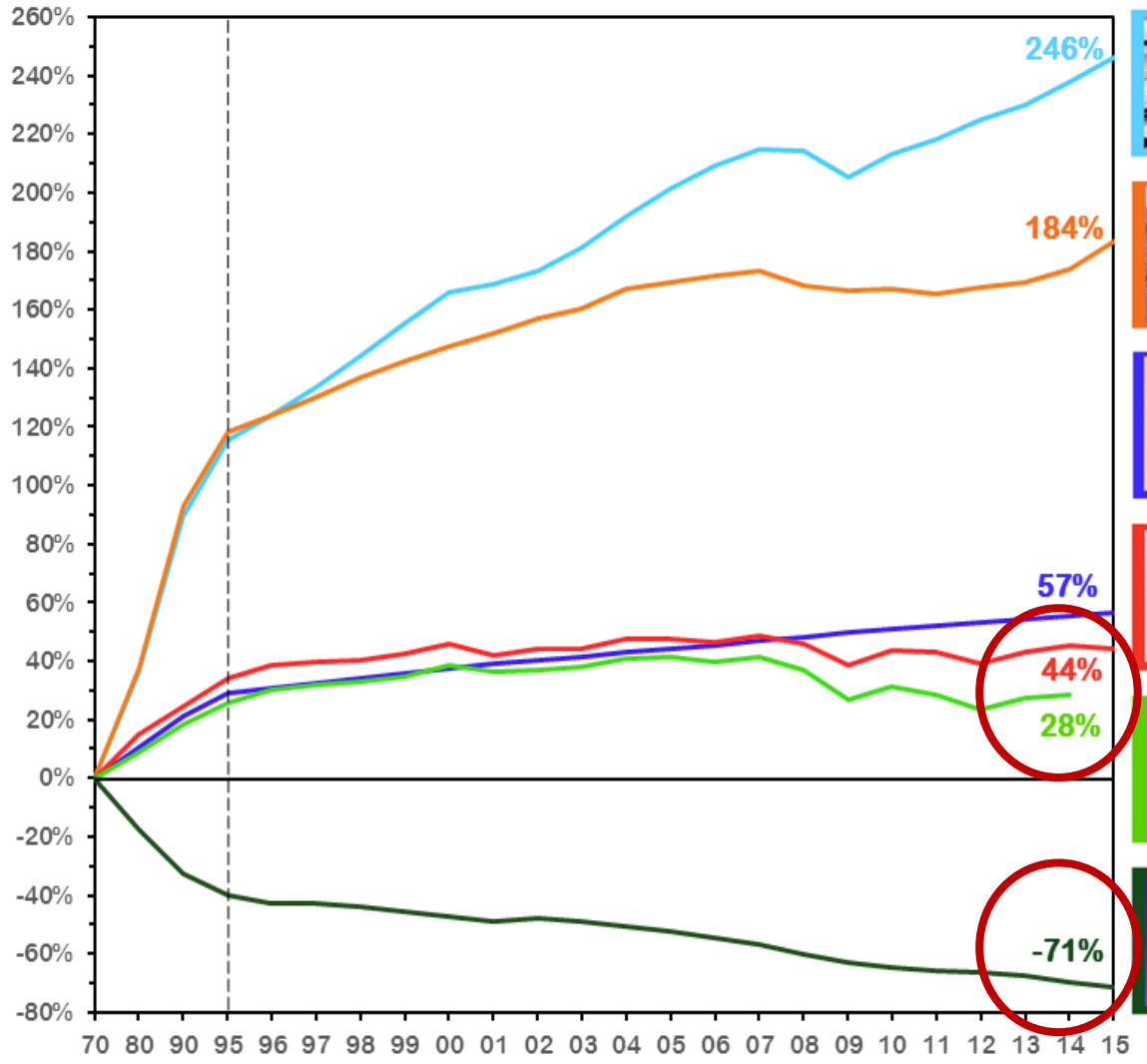
NAAQS Review Process





Final Rule	Indicator	Ave. Time	Level	Form
1971	TSP - Total Suspended Particles (≤ 25-45 µm)	24-hour	260 µg/m^3 (primary) 150 µg/m^3 (secondary)	Not to be exceeded more than once per year
		Annual	75 µg/m^3 (primary) 60 µg/m^3 (secondary)	Annual geometric mean
1987	PM_{10}	24-hour	150 µg/m^{3*}	Not to be exceeded more than once per year
		Annual	50 µg/m^3	Annual arithmetic mean, avg. over 3 years
1997	$PM_{2.5}$	24-hour	65 µg/m^3	98th percentile, avg. over 3 years
		Annual	15 µg/m^3	Annual arithmetic mean, avg. over 3 years
	PM_{10}	24-hour	150 µg/m^3	Initially promulgated 99th percentile, avg. over 3 years; when 1997 standards were vacated, form of 1987 standards remained in place (not to be exceeded more than once per year on avg. over a 3-year period))
		Annual	50 µg/m^3	Annual arithmetic mean, avg. over 3 years
2006	$PM_{2.5}$	24-hour	35 µg/m^3	98th percentile, avg. over 3 years
		Annual	15.0 µg/m^3	Annual arithmetic mean, avg. over 3 years
	PM_{10}	24-hour	150 µg/m^3	Not to be exceeded more than once per year on avg. over a 3-year period
2006	$PM_{2.5}$	24-hour	2012	98th percentile, avg. over 3 years
		Annual	12.0 µg/m^3	Annual arithmetic mean, avg. over 3 years
	PM_{10}	24-hour	150 µg/m^3	Not to be exceeded more than once per year on avg. over a 3-year period

A Good News Story…



Gross Domestic Product

Vehicle Miles Traveled

Population

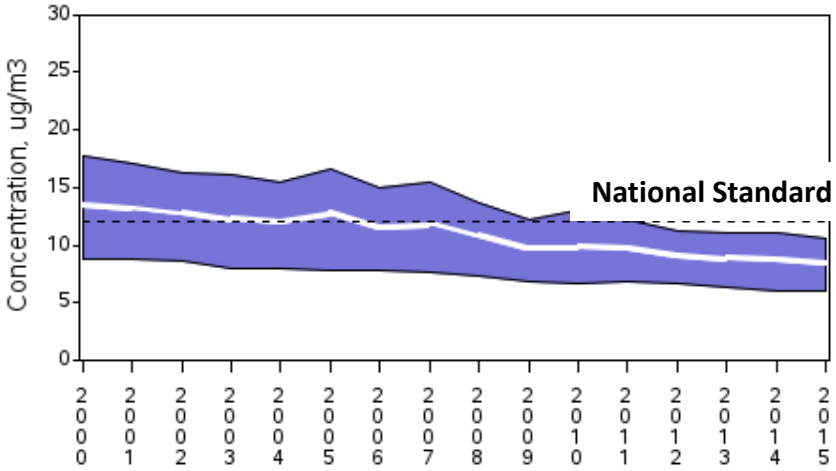
Energy Consumption

CO_2 Emissions

Aggregate Emissions (Six Common Pollutants)

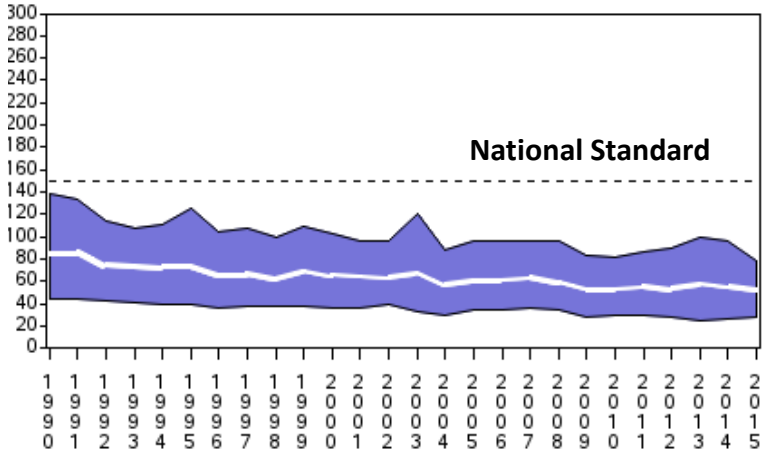
Particulate Matter (PM) Trends

PM2.5 Air Quality, 2000 - 2015
(Seasonally-Weighted Annual Average)
National Trend based on 480 Sites



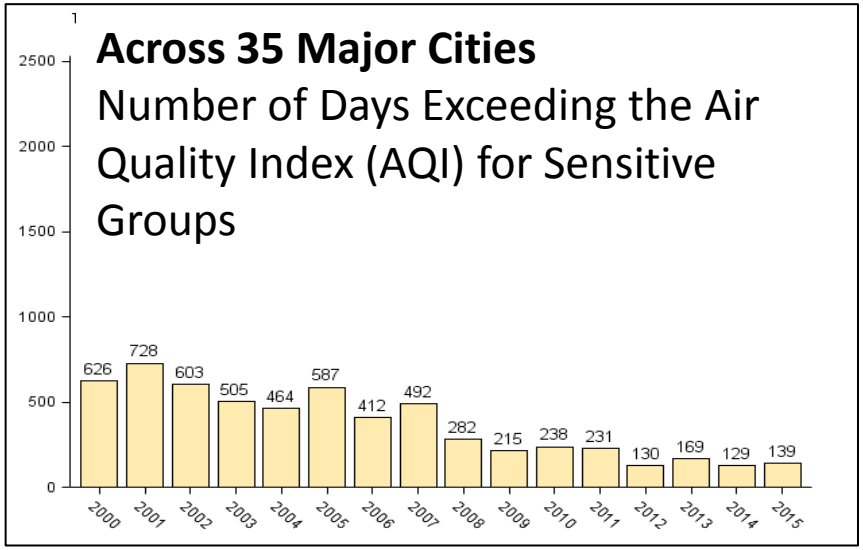
2000 to 2015 : 37% decrease in National Average

PM10 Air Quality, 1990 - 2015
(Annual 2nd Maximum 24-Hour Average)
National Trend based on 171 Sites

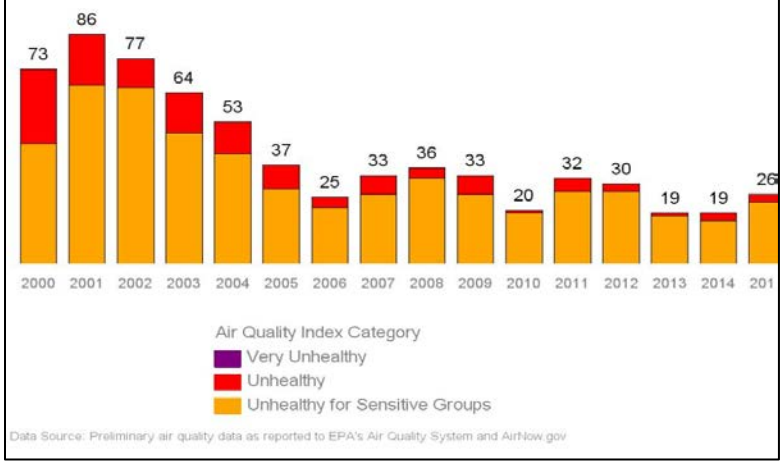


1990 to 2015 : 39% decrease in National Average

Across 35 Major Cities
Number of Days Exceeding the Air Quality Index (AQI) for Sensitive Groups

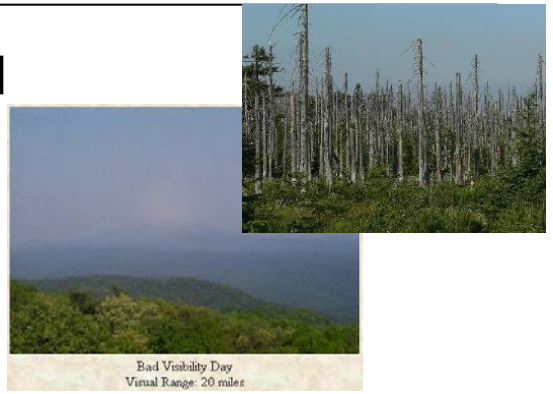


Los Angeles Long Beach - AQI



Highlight: The PM Issue of the ’70s/80s was Acid Aerosols

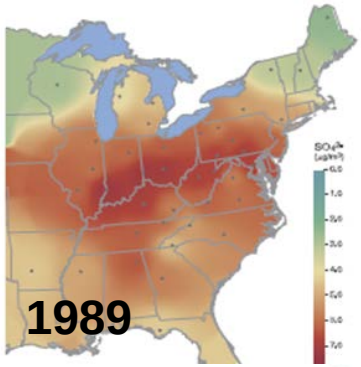
- Visibility impairment caused by fine particles formed from precursors transported over 100's of miles
- Acid aerosols damaged forests
- Acid (H_2SO_4) was thought to be a major pulmonary irritant, but:
  - By itself was not as potent as thought - except in asthmatics
  - Conventional epidemiology not very revealing

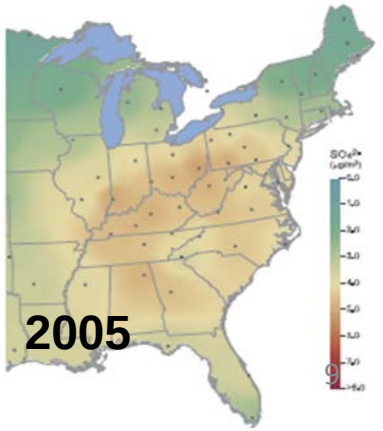


The Clean Air Act Amendments of 1990

- Targeted smoke reduction & lower sulfur coal and oil
- CAP & TRADE on sulfur had a dramatic effect

Ozone seemed to be the looming problem

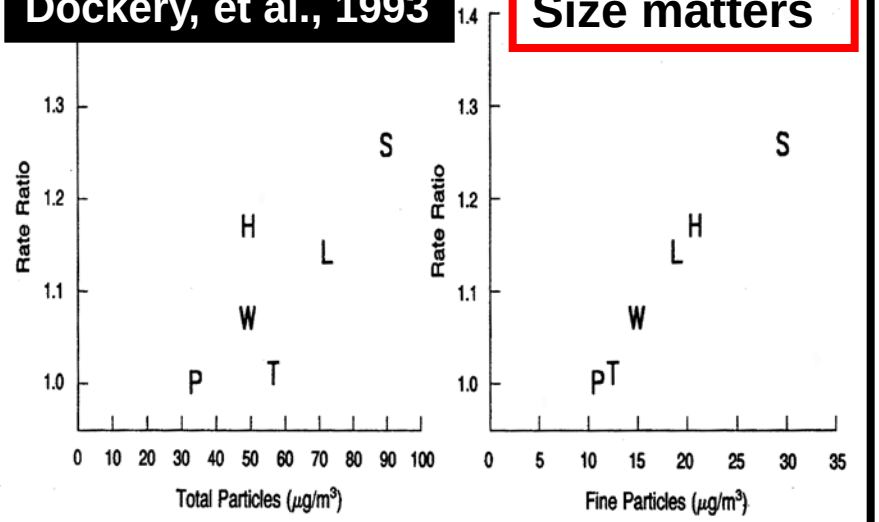




PM Problem was thought… Solved!

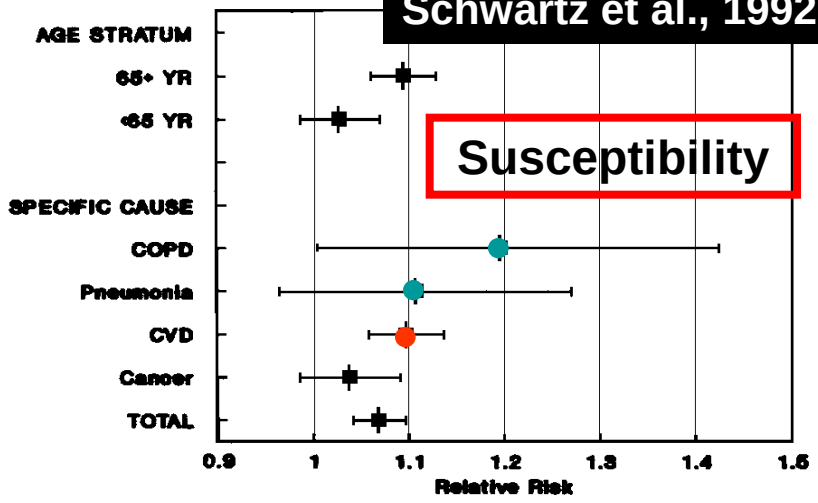
Dockery, et al., 1993

Size matters



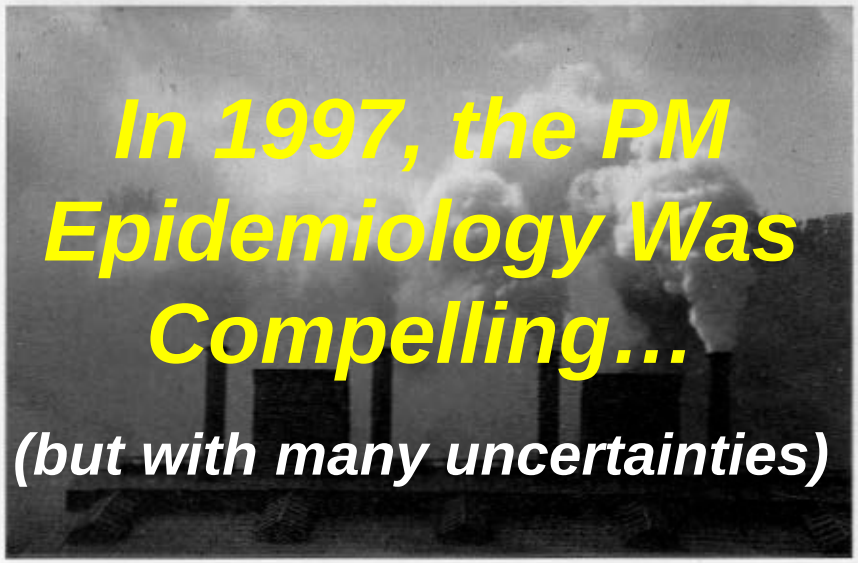
Schwartz et al., 1992

Susceptibility



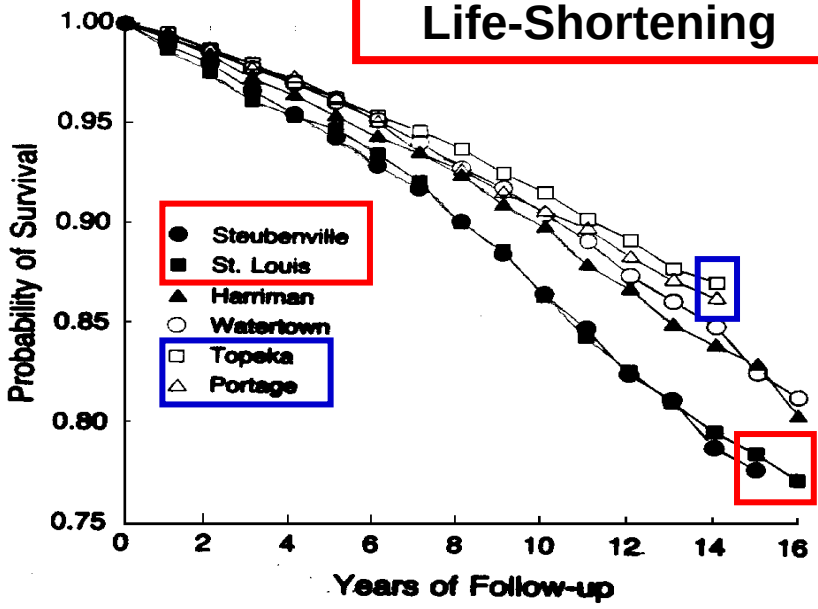
In 1997, the PM Epidemiology Was Compelling…

(but with many uncertainties)



Foundry along Ohio River near Stubenville, OH.
Photo: J. Spengler or D. Dockery

Life-Shortening



EPA United States Environmental Protection Agency

Weight of Evidence for Causal Determination

… doses or exposures generally within 1-2 orders of magnitude of recent concentrations

. . . chance, confounding, and other biases could be ruled out with reasonable confidence

. . . multiple high-quality studies by multiple research groups

Table II Weight of evidence for causal determination.

	Health Effects	Ecological and Welfare Effects
Causal relationship	Evidence is sufficient to conclude that there is a causal relationship with relevant pollutant exposures (e.g., doses or exposures generally within one to two orders of magnitude of recent concentrations). That is, the pollutant has been shown to result in health effects in studies in which chance, confounding, and other biases could be ruled out with reasonable confidence. For example: (1) controlled human exposure studies that demonstrate consistent effects; or (2) observational studies that cannot be explained by plausible alternatives or that are supported by other lines of evidence (e.g., animal studies or mode of action information). Generally, the determination is based on multiple high-quality studies conducted by multiple research groups.	Evidence is sufficient to conclude that there is a
Likely to be a causal relationship	Evidence is sufficient to conclude that a causal relationship is likely to exist with relevant pollutant exposures. That is, the pollutant can result in health effects in studies that cannot be explained by chance, confounding, or other biases, but uncertainties remain in the overall. For example: (1) observed an association, but copollutant confounding is difficult to address and/or other lines of evidence (e.g., human exposure, animal, or mode of action information) are limited or inconsistent; or (2) toxicological evidence from multiple studies by different laboratories demonstrates effects, but limited or no human data are available. Generally, the determination is based on multiple high-quality studies.	Evidence is sufficient to conclude that there is a likely causal association with relevant pollutant
Suggestive, but not sufficient, to infer a causal relationship	Evidence is suggestive of a causal relationship with relevant pollutant exposures but is limited, and chance, confounding and other biases cannot be ruled out. For example, (1) when the body of evidence is relatively small, at least one high-quality epidemiologic study shows an association with a given health outcome and/or at least one high-quality toxicological study shows effects relevant to humans in animal species; or (2) when the body of evidence is relatively large, evidence from studies of varying quality is generally supportive but not entirely consistent, and there may be coherence across lines of evidence (e.g., animal studies or mode of action information) to support the determination.	Evidence is suggestive of a causal relationship with relevant pollutant exposures, but chance, confounding, and other biases cannot be ruled out. For example, at least one high-quality study shows an effect, but the results of other studies are inconsistent.
Inadequate to infer a causal relationship	Evidence is inadequate to determine that a causal relationship exists with relevant pollutant exposures. The available studies are of insufficient quantity, quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.	The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of an effect.
Not likely to be a causal relationship	Evidence indicates there is no causal relationship with relevant pollutant exposures. Several adequate studies, covering the full range of levels of exposure that human beings are known to encounter and considering at-risk populations and lifestages, are mutually consistent in not showing an effect at any level of exposure.	Several adequate studies, examining relationships with relevant exposures, are consistent in failing to show an effect at any level of exposure.

Preamble to the Integrated Science Assessments (ISAs): https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310244

AHA Scientific Statement

Particulate Matter Air Pollution and Cardiovascular Disease

An Update to the Scientific Statement From the American Heart Association

Robert D. Brook, MD, Chair; Sanjay Rajagopalan, MD; C. Arden Pope III, PhD; Jeffrey R. Brook, PhD; Aruni Bhatnagar, PhD, FAHA; Ana V. Diez-Roux, MD, PhD, MPH; Fernando Holguin, MD; Yuling Hong, MD, PhD, FAHA; Russell V. Luepker, MD, MS, FAHA; Murray A. Mittleman, MD, DrPH, FAHA; Annette Peters, PhD; David Siscovick, MD, MPH, FAHA; Sidney C. Smith, Jr, MD, FAHA; Laurie Whitsel, PhD; Joel D. Kaufman, MD, MPH; on behalf of the American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism

"The overall evidence is consistent with a causal relationship between $PM_{2.5}$ exposure and cardiovascular morbidity and mortality."

Brook RD, et al. Circulation 2010; 121: 2331-78

Last Decade of Research Provided Impetus for:

- Importance of raising awareness among health care providers
- Providing specific recommendations for clinical practice

What are the Benefits – Costs?

The U.S. Office of Management and Budget estimated in 2006 that the EPA's air pollution regulations save between $63 and 430 billion annually. (Costs $25-28 billion)*

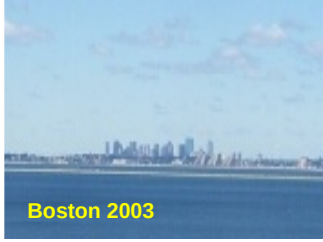
Reality Check…

In 2015, Americans spent roughly $1.2 trillion for energy.

EPA's investment from 1998-2015 in air pollution research amounts to less than 1/1,000 of that energy expenditure.

*No longer available on the OMB website

US Benefits Achieved with Pollution Reduction since 1970



- One of the most successful public health programs in American history with a return of more than $30 in benefits for every dollar invested in pollution (PM) reductions
- In 2010 alone, reductions in fine particle and ozone pollution under the Clean Air Act prevented:
  - 160,000 cases of premature mortality
  - 130,000 heart attacks and 86,000 hospital visits
  - 13 million lost work days
  - 1.7 million asthma attacks
- Life expectancy improvements ~7 months over 10 years
- Reduction in acid deposition in lakes, streams & forests
- Improved visibility

Information gathered from Clean Air Act where you live:
http://www.epa.gov/cleanairactbenefits/whereyoulive/

What lies ahead?

Many Issues Remain Unresolved and New Emerging Issues Appear Even More Complex

Lingering Health Questions

Carry-over uncertainties

- Accountability – Can we show regulations are making a difference?
- What is the shape of the C-R* curve at low concentrations?
  - A potentially greater accountability challenge
- The challenge of multipollutant exposures?
  - How do we begin to think of AIR cumulatively across media?
- How do we best handle spatial variation / indoor exposures?
- With cardiovascular outcomes now a strong driver of assessments, what's up with new nervous system impacts?
- Are there other unappreciated organ system impacts? (e.g., reproductive)
- What underlies susceptibility; becoming susceptible?

*C-R = concentration-response

"Embedded" Health Questions

Related questions worth pondering?

- Does the causality mode hold across concentration - low concentrations?
- Components…causality? What about ultrafine particles Is $PM_{2.5}$ adequate?
- Are PM and O_3 enough for dealing with multipollutants?
- Does there come a point where lowering the NAAQS is not possible?
  - No threshold but is there a <u>when / do</u> we say "low enough"?
  - Are there alternative approaches to attain the desired health protection goals?
- Will we have to "justify" the standards for PM in the new reality?

"The interest in air pollution is inversely proportional to its concentration."

Sir Patrick Lawther, circa, 1981

Protection of public and environmental health

Some thoughts and reflections moving forward …

Don't let what you cannot do interfere with what you can do

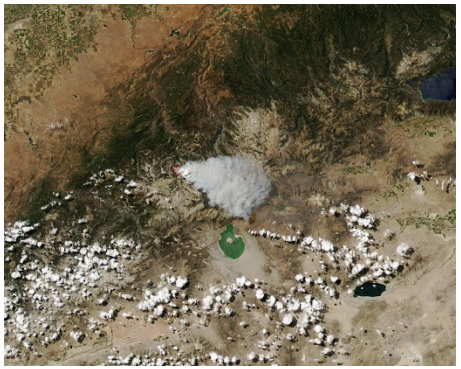
John Wooden

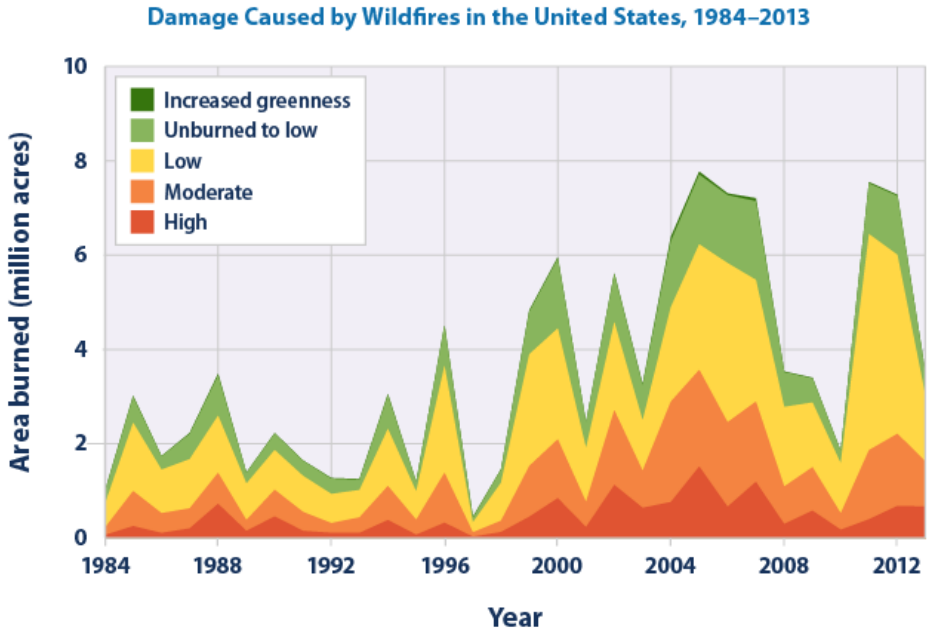
On the surface things look great…

BUT….

Not all problems are solved nor adequately addressed

Some Issues are of National Concern





- The United States spends more than $1 billion every year to fight wildfires
- According to National Interagency Fire Center data, of the 10 years with the largest acreage burned, nine have occurred since 2000 (as of 2012)
- This period coincides with many of the warmest years on record nationwide

Taking the Long View

- Great progress made to date – is it time to reflect upon our approach?
  - Strong defensible NAAQS have been our primary tool
  - Hammering locales with a club may not work indefinitely into the future
  - If we want solutions – we need systems-based strategies
- There is a technology revolution in measurement systems – sensors
  - There are new sensors (good ones) to measure emissions – getting better
  - Soon local & personal sensors will be everywhere – improving rapidly

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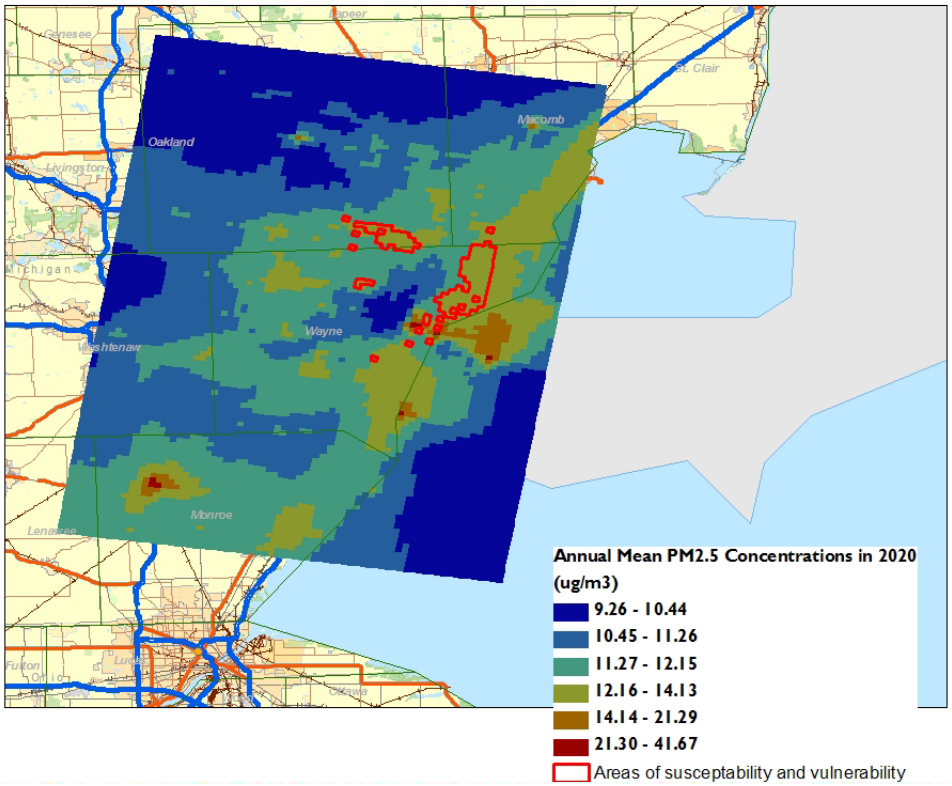
- Think a bit more creatively to utilize emission sensors as they evolve
- As for other sensors, we need to:
  - Promote affordable and reasonably (tiered?) accurate sensors
  - Develop messaging / translational tools for the public
  - Network sensors (Weather Underground has started)
  - Analytical methods to leverage lots of weak data into something useful (Weibel's lung structure model – "do more less well")

Taking the Long View

- "Public health" is the true moniker of the Clean Air Act 1970
  - A national standard may not be enough to get to where we want to be
  - Is it time for regions to address issues specific to themselves?
- Public health is inherently a systems-approach
  - Public health involves the "regulator" and the "public" – indeed the "person"
  - People make personal decisions on beliefs and information
    - Having the right – and actionable - information… (translation)
    - Social science is integrated into all of aspects of public health
    - Develop a strategy to blend sensor advances into public health
  - Public health approaches encompass susceptibility / vulnerability
  - Embrace empowerment of the public – educate them as well
    - Community science is growing – can we take advantage through partnerships?
    - Promote educated interventions and innovation by all parties

A Step in the Right Direction



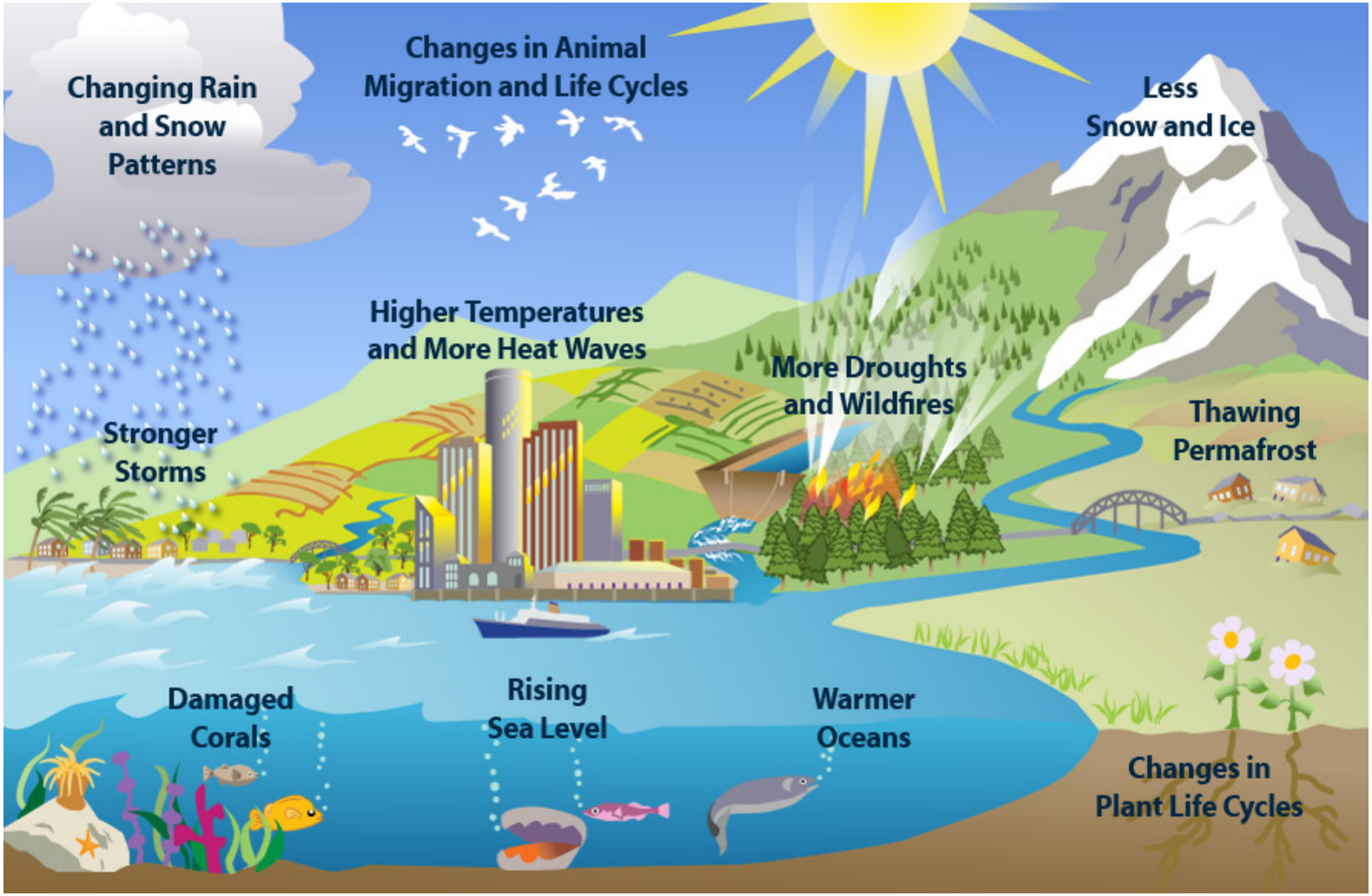
Identifying and locating at-Risk and Highly Exposed Populations

Maximizing Health Benefits and Minimizing Inequality: Incorporating Local-Scale Data in the Design and Evaluation of Air Quality Policies

Neal Fann,[1,*] Henry A. Roman,[2] Charles M. Fulcher,[1] Mikael A. Gentile,[2] Bryan J. Hubbell,[1] Karen Wesson,[1] and Jonathan I. Levy[3]

Risk Analysis (2011)

All Roads Lead to Rome…



Climate Impacts Are Here & Now

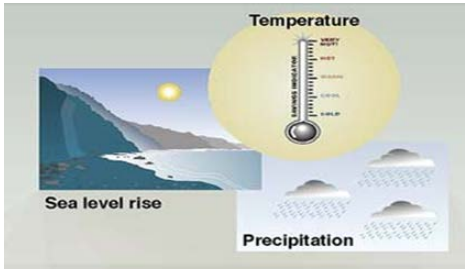
Source: http://www.epa.gov/climatestudents/scientists/clues.html

Potential Public Health Impacts of Climate Change

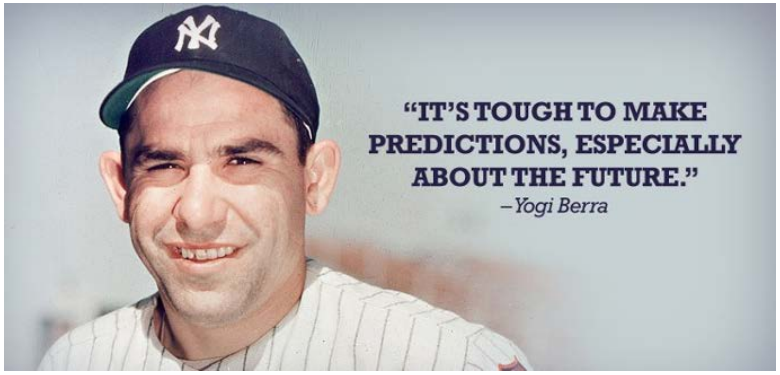
INDIRECT

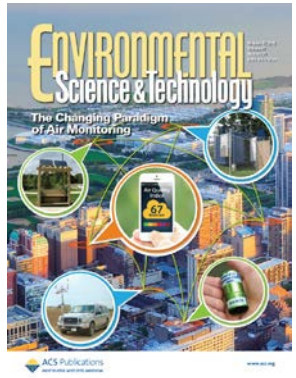
DIRECT

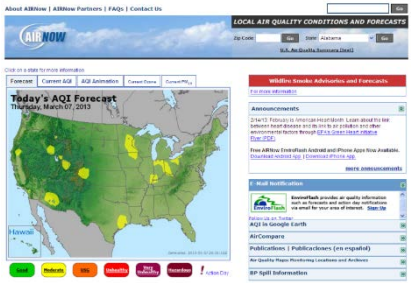
- **Temp. rise**
- **Sea level rise**
- **Changes in Precipitation**



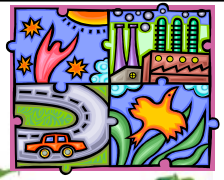
HEAT	Heat stress, cardiovascular failure
SEVERE WEATHER	Injuries, fatalities
AIR POLLUTION	Asthma, cardiovascular disease
ALLERGIES	Resp allergies, poison ivy
VECTOR-BORNE DISEASES	Malaria, dengue, hantavirus, encephalitis, Rift Valley fever
WATER-BORNE DISEASES	Cholera, cryptosporidiosis, campylobacter, leptospirosis
WATER AND FOOD SUPPLY	Malnutrition, diarrhea, harmful algal blooms
MENTAL HEALTH	Anxiety, post-traumatic stress, depression, despair
ENVIRONMENTAL REFUGEES	Forced migration, civil conflict

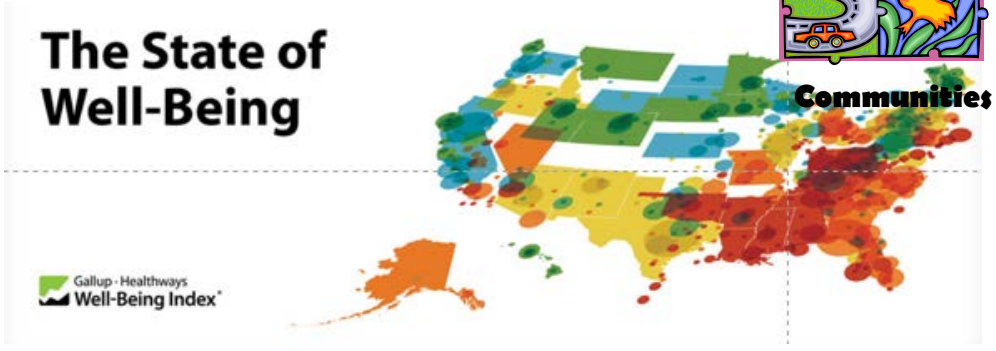


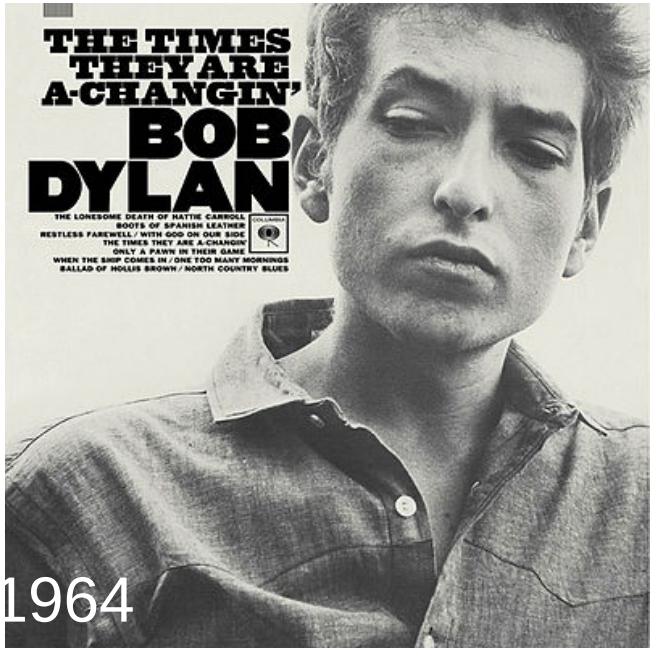




"Never, ever, think outside the box"







Summary / Perceptions

- Regulation-directed reductions in PM levels have had significant public health and economic benefits
- Air pollution continues to present significant impacts on public health – especially in certain at-risk populations and life-stages
- Can we continue to proceed with the a “business as usual” approach to addressing the impacts of air pollution?
- Social science tied to public health (not just health) strategies should be explored and exploited
- Innovative integration of public health “thinking” with the emergent sensor technologies offers opportunities we just cannot ignore
- Public health drivers promote cooperation and partnerships between the public and private sector
- The changing energy landscape and climate change pose new challenges

Putting the Health of Our Planet and Life on It in Perspective

Earth taken from Mars by Curiosity, Aug 2012