EPA's Approach to Quantifying the Benefits of Air Rules

Understanding how and why the Agency estimates the quantity and economic value of health and welfare impacts

9/28/12

Overview

- First principles—the relationship between air pollution and health
- The role of the benefits analysis in the Regulatory Impact Assessment
- Using the BenMAP tool to quantify benefits
- Approaches to characterizing uncertainty
- Directions for future research

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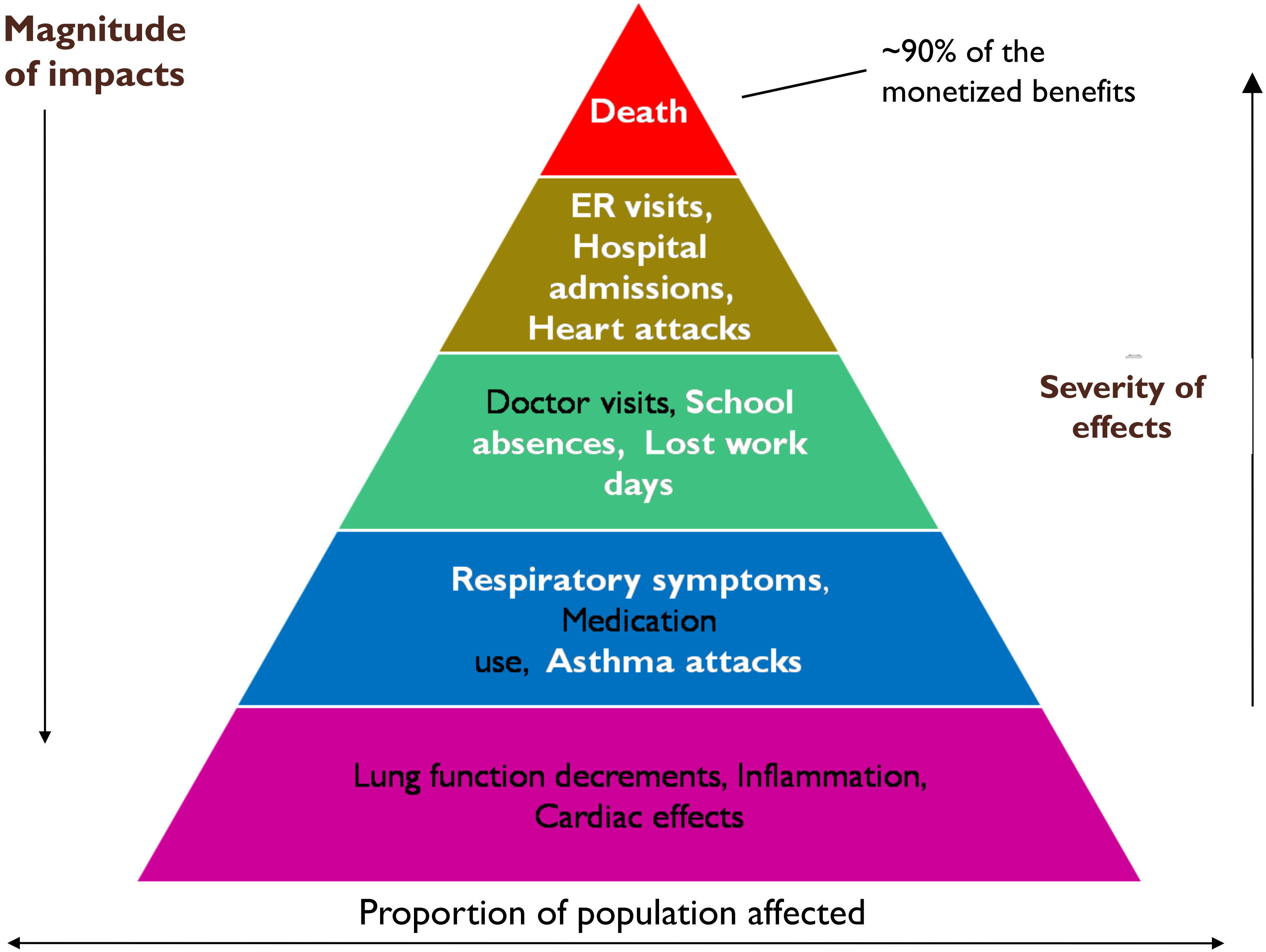
AIR POLLUTION AND HEALTH

A "Pyramid of Effects" from Air Pollution



What Health Endpoints do we Include in Our Central Benefits Estimate?

Health Endpoint	***$PM_{2.5}$***	***Ozone***
Premature mortality*	✓	✓
Nonfatal heart attacks	✓	
Hospital admissions	✓	✓
Asthma ER visits	✓	✓
Acute respiratory symptoms	✓	✓
Asthma attacks	✓	✓
Work loss days	✓	
School absence rates		✓

*Long term $PM_{2.5}$-related mortality and short-term O_3-related mortality

What Health Endpoints do we Include in Our Sensitivity Analyses?

Health Endpoint	*$PM_{2.5}$*	*Ozone*
Long- Term Premature mortality*		✓
Education-modified premature mortality	✓	
Ischemic and hemorrhagic stroke	✓	
Cardiovascular emergency department visits	✓	
Worker productivity		✓
Chronic bronchitis	✓	

*Long term O_3-related mortality

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THE ROLE OF THE HEALTH BENEFITS ASSESSMENT

Key Messages on Health Benefits Analyses

- What policy questions are we trying to answer?
  - How can we organize, describe, and monetize the positive consequences of a rule?
  - How can we inform the regulatory decision and help justify a rule?
- Executive Order 12866 directs EPA to quantify the benefits and costs of regulatory actions
  - We cannot quantify or monetize all benefits
  - Only need a benefits analysis for an RIA
  - Benefits can trigger an RIA even if costs do not
  - Co-benefits and disbenefits are important considerations
- EPA's methods for characterizing the human health benefits of air quality improvements have received extensive external review from the National Academies of Science and the Independent Science Advisory Board among other bodies.

Benefits and "Co-Benefits"

- RIA goal is to provide as comprehensive an estimate of benefits of rule as possible (given time, resources, etc)
  - Such an estimate should account, as completely as possible, for the complete benefits and costs of a regulatory action
  - Co-benefits accrue as a result of meeting the policy goal of the rule—but are not central
- The value of $PM_{2.5}$-related co-benefits can be substantial, and frequently represent the only monetized benefit
  - Typically quantify co-benefits of reductions in $PM_{2.5}$ precursors (e.g. metals)
  - While toxics-related benefits are important, the Agency has not yet developed a systematic approach to monetizing these benefits

Why Don't We Always Estimate Co-Benefits for Other Criteria Pollutants?

- Ozone formation is governed by complex non-linear chemistry and greatly influenced by localized conditions
  - We do not have a "reduced-form" approach to estimating ozone impacts like we do for PM
  - Ozone benefits requires air quality modeling
  - Ozone benefits tend to be smaller than $PM_{2.5}$ benefits
- We could generate benefits for other criteria pollutants (NO_2, SO_2, CO, and Pb)
  - Generally, we do not have the necessary air quality data
  - Generally, these benefits are much smaller than $PM_{2.5}$ benefits because only estimating non-fatal health effects

Why don't we always estimate HAP benefits?

- The health-related benefits of reducing air toxics are real, but difficult to estimate
- However, we generally lack studies characterizing population-level human health risk to air toxics
  - Large-scale epidemiological studies are most useful for benefits assessments, as they can provide a reliable central estimate of risk across the population
  - Epidemiological studies for criteria pollutants tend to be easier to develop because of the ubiquity of these pollutants and the broader population exposure
- Risk analyses (such as for Risk and Technology Reviews) are designed to estimate maximum risk, while a monetized benefits analysis is expected to estimate most likely risk
- In 2009, an EPA workshop addressed inherent complexities, limitations, and uncertainties in current methods to quantify the benefits of reducing HAPs. Recommendations from this workshop included
  - Identifying research priorities
  - Focusing on susceptible and vulnerable populations
  - Improving dose-response relationships

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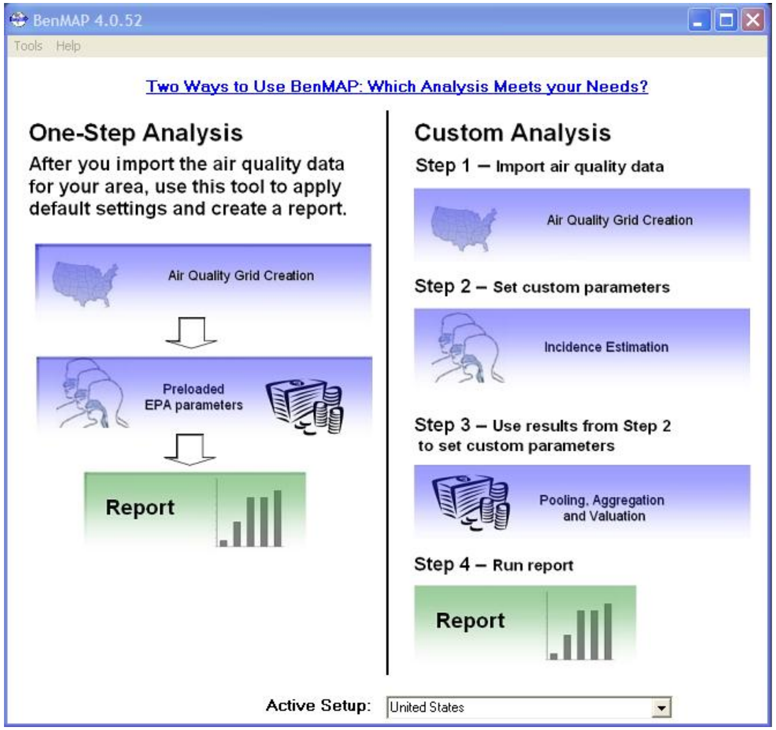
QUANTIFYING BENEFITS IN BENMAP

What is BenMAP?

- The "environmental Benefits Mapping and Analysis Program"
- The principal tool EPA uses to quantify the benefits criteria air quality improvements
- A PC-based and graphic user interface-driven software program
- Program estimates the incidence and economic value of adverse health outcomes
- www.epa.gov/air/benmap



BenMAP Community Software (BenMAP CS)

- Written in C#
  - More broadly used code
  - Distribute uncompiled code freely. EPA will retain regulatory version.
  - Multi-threading processes promises to decrease computation time
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  - GIS will continue to interact with a database of population and health impact functions to calculate impacts
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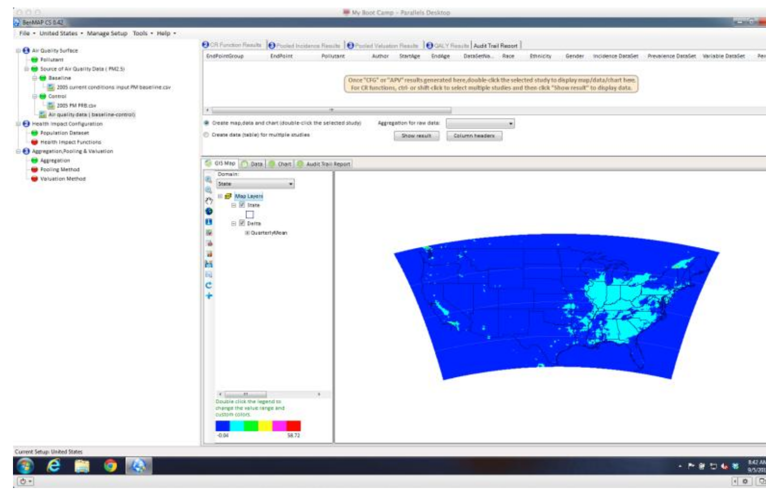
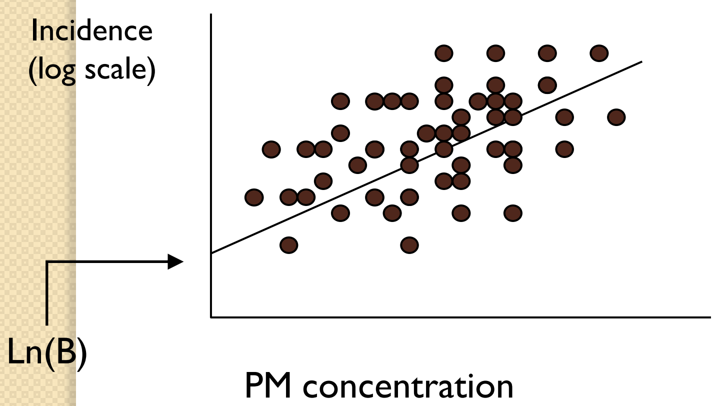


Step One: Derive Health Impact Functions from Epidemiology Literature

Epidemiology Study



$$\ln(y) = \ln(B) + \beta(PM)$$

Health impact function

$$\Delta Y = Y_o\,(1 - e^{-\beta \Delta PM}) * Pop$$

Yo – Baseline Incidence

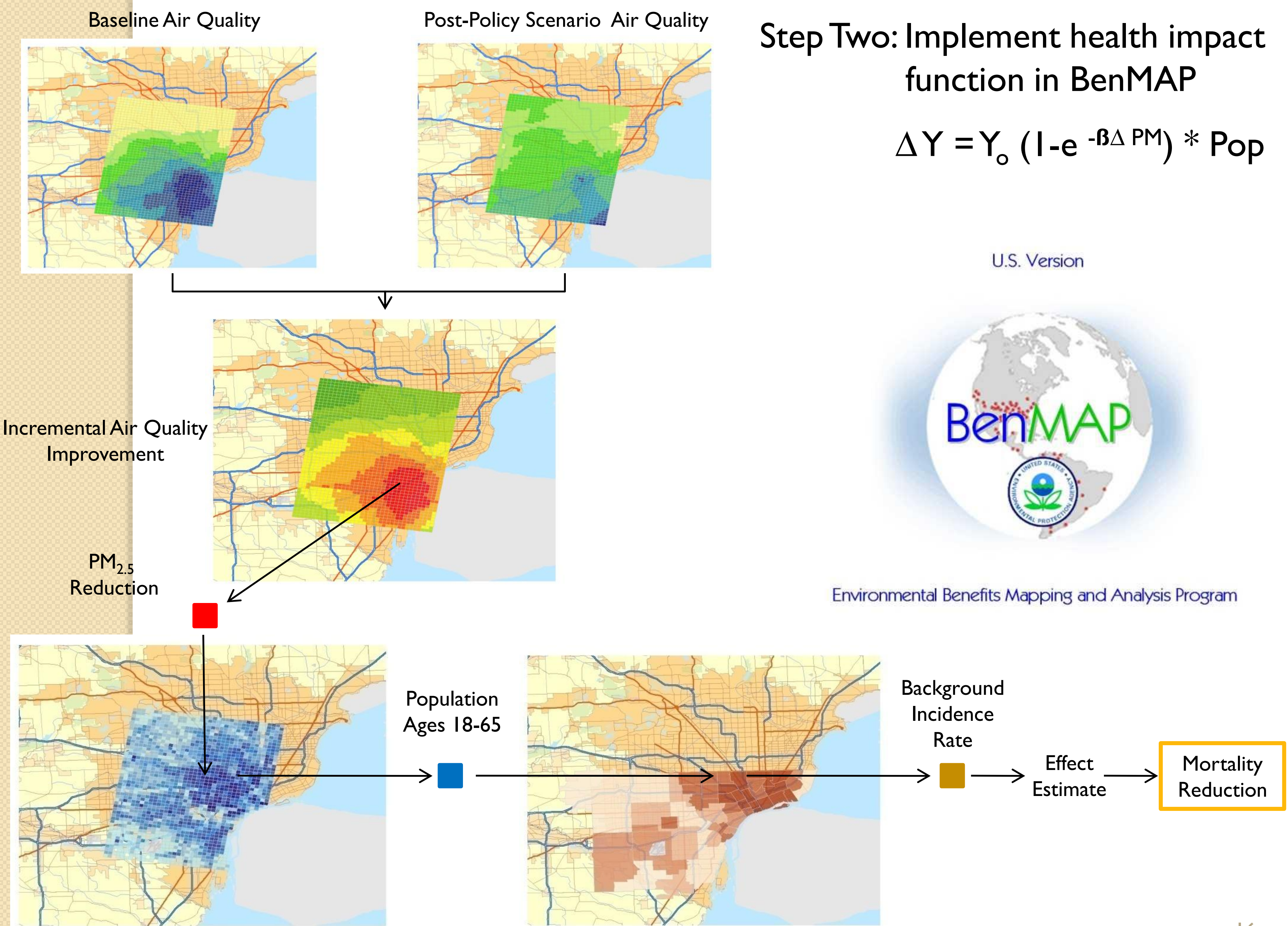
ß - Effect estimate

ΔPM – Air quality change

Pop – Exposed population

Step Two: Implement health impact function in BenMAP

$$\Delta Y = Y_o \left(1 - e^{-\beta \Delta PM}\right) * Pop$$



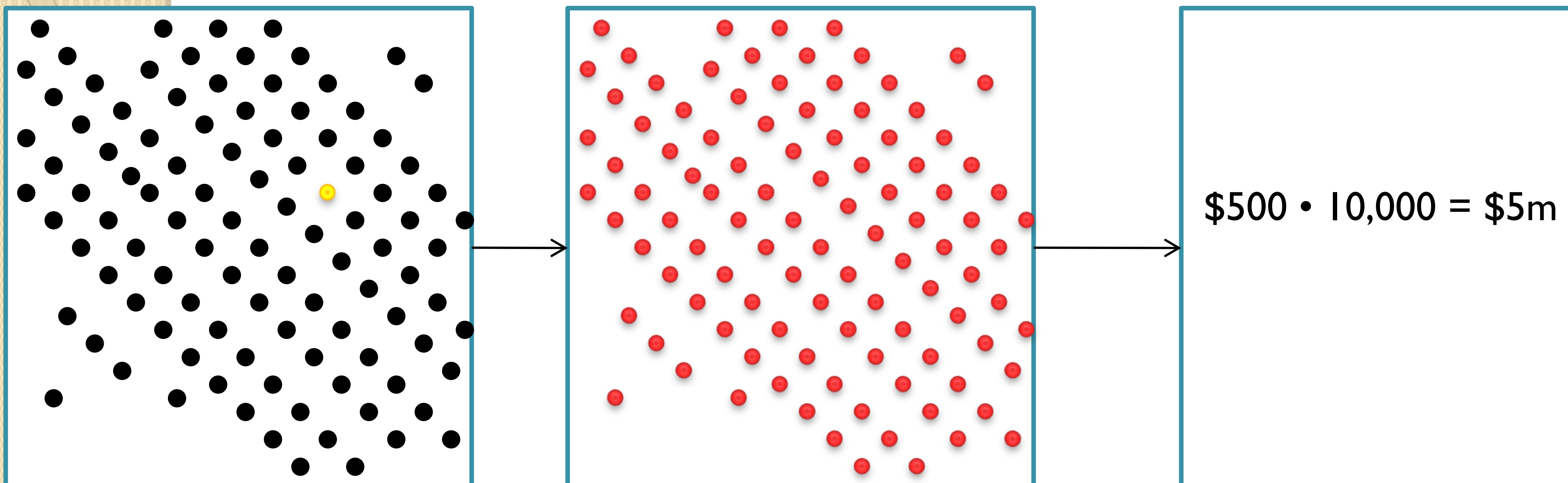
Step Three: Assign a $ Value

- Cost of Illness (COI)
  - Medical expenses for treatment of illness
  - Captures the money savings to society of reducing a health effect
  - Ignores the value of reduced pain and suffering

- Willingness To Pay (WTP)
  - Lost wages, avoided pain and suffering, loss of satisfaction, loss of leisure time, etc.
  - Measures the complete value of avoiding a health outcomes

- OMB requires that we report monetized benefits at discount rates of 3% and 7%

Step Three: Assign a $ Value—How do we Calculate VSL?



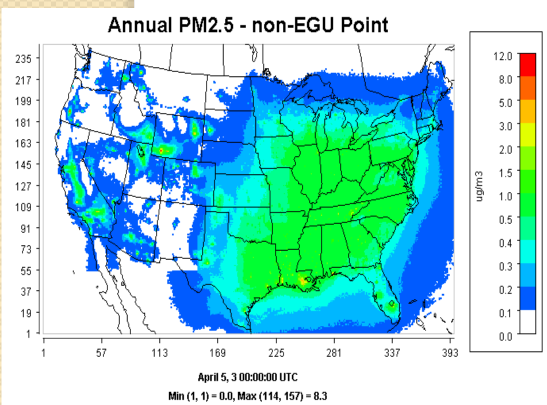
In a population of 10,000, reducing pollution would avoid one premature death (i.e. reduce risk by $\frac{1}{10,000}$)

Each of 10,000 are willing to pay $500 to reduce risk of death by

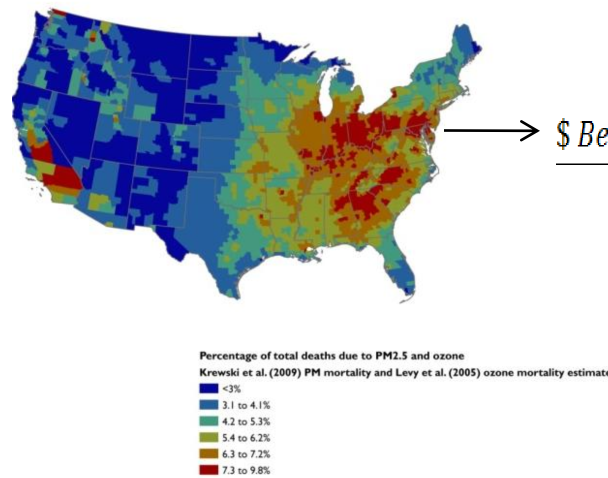
$$\frac{1}{10,000}$$

VSL is then WTP multiplied by the inverse of the risk reduction

Overview of Approach to Calculating $PM_{2.5}$ Benefit Per-Ton Estimates



$PM_{2.5}$ air quality change for a given sector



Human health benefits

$$\frac{\$\ Benefits\ and\ avoided\ impacts}{Scenario\ emissions} = Benefit/ton$$

Benefit-per-ton calculation

Estimating Other Benefits

Likelihood of being able to quantify for rules

- Climate benefits – based on "social cost of carbon" determined by interagency group
- Visibility benefits – based on WTP studies for change in visual range due to light extinction
- Mercury health benefits – based on mercury deposition and lost earnings due to IQ loss
- Aquatic acidification benefits – based on WTP for recreational fishing for change in lake acidification
- Ozone biomass benefits – based on exposure-response relationships for different species

Why Do We Present Ranges of Benefits?

- Each step in the benefits analysis process has inherent uncertainty
- We report a range of benefits representing different estimates of the relationship between premature deaths and pollution exposure from the epidemiology literature
- Many unquantified sources of uncertainty, and even the range estimates have additional unquantified uncertainty
- When data are available, we also report confidence intervals for each estimate based on the standard errors in the health functions and uncertainty in the valuation functions

- Key assumptions in $PM_{2.5}$ benefits
  - National average benefit-per-ton estimates are representative of emission reductions from the rule
  - All PM species are equally toxic
  - Linear relationship between PM exposure and health effects down to very low levels

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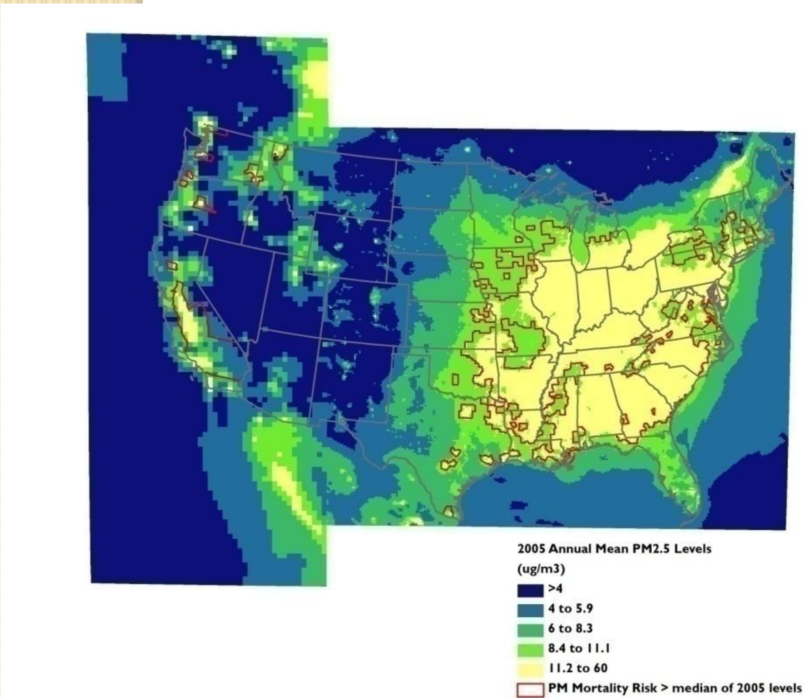
FUTURE DIRECTIONS FOR EPA BENEFITS ANALYSES

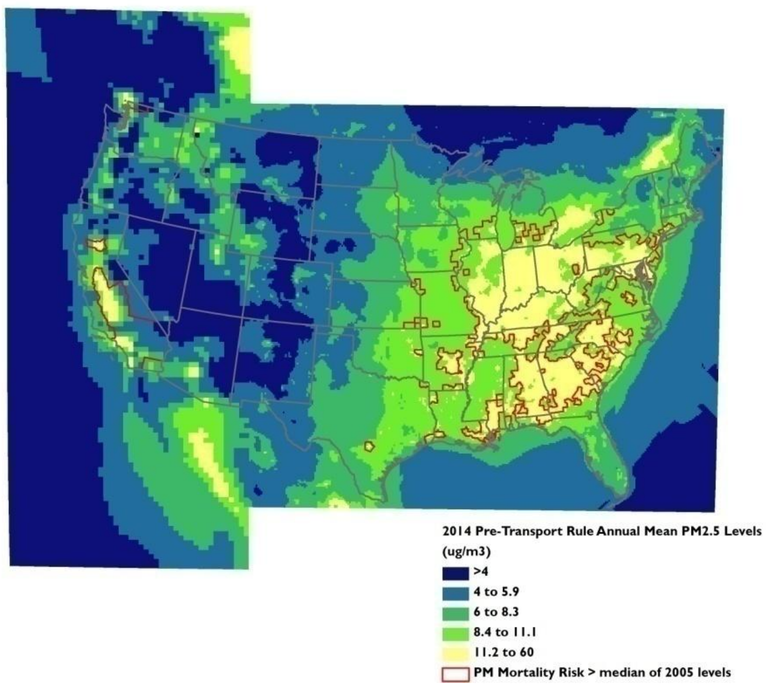
Existing rules reduce the number of counties with elevated PM mortality risk between 2005 and 2014…

2005



1,550 total high risk counties, of which 1,525 are in the East.

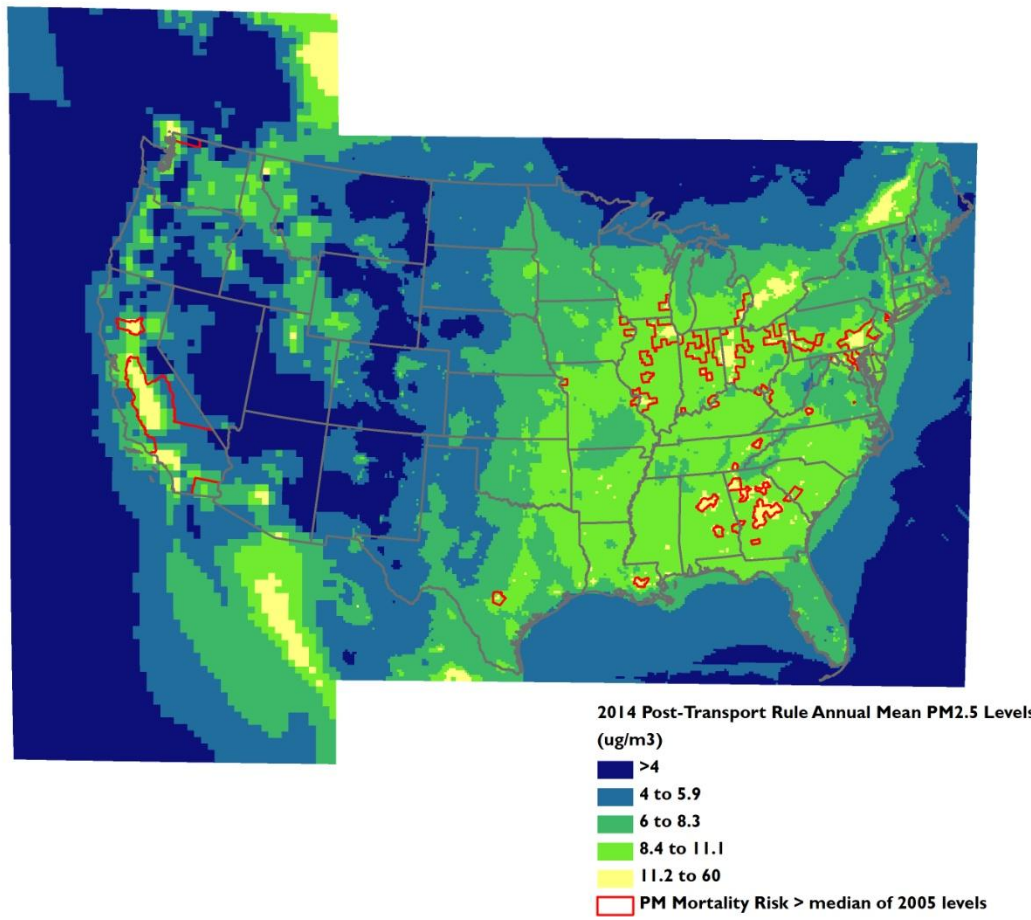
2014 Pre-Transport Rule



958 total high risk counties. of which 942 are in the East.

Red outline identifies counties at or above the 2005 median risk level

…and this number drops further under the 2014 Proposed Transport Rule

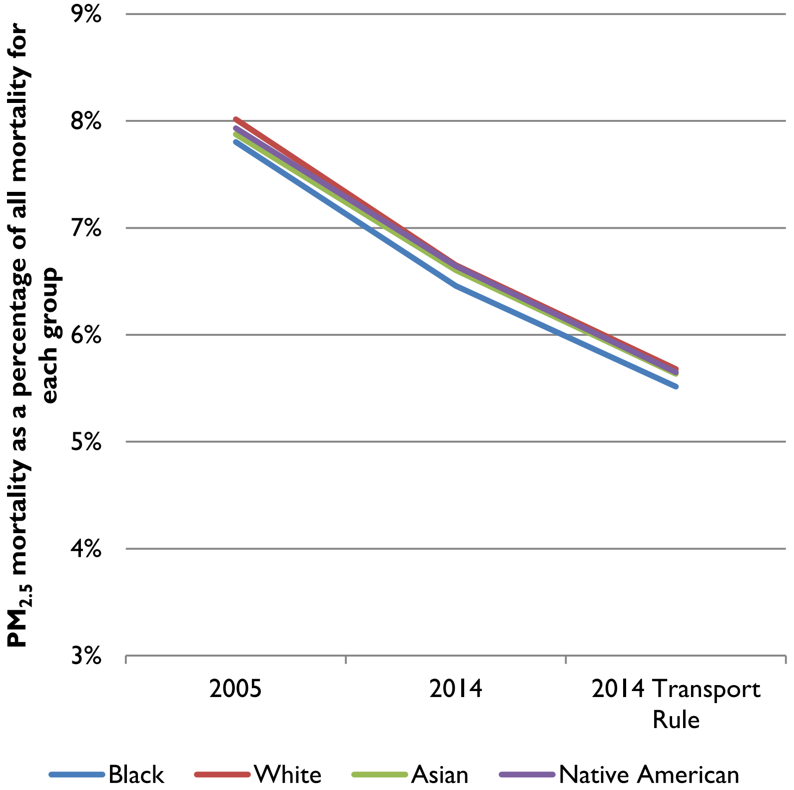


180 total high risk counties, of which 164 are in the East.

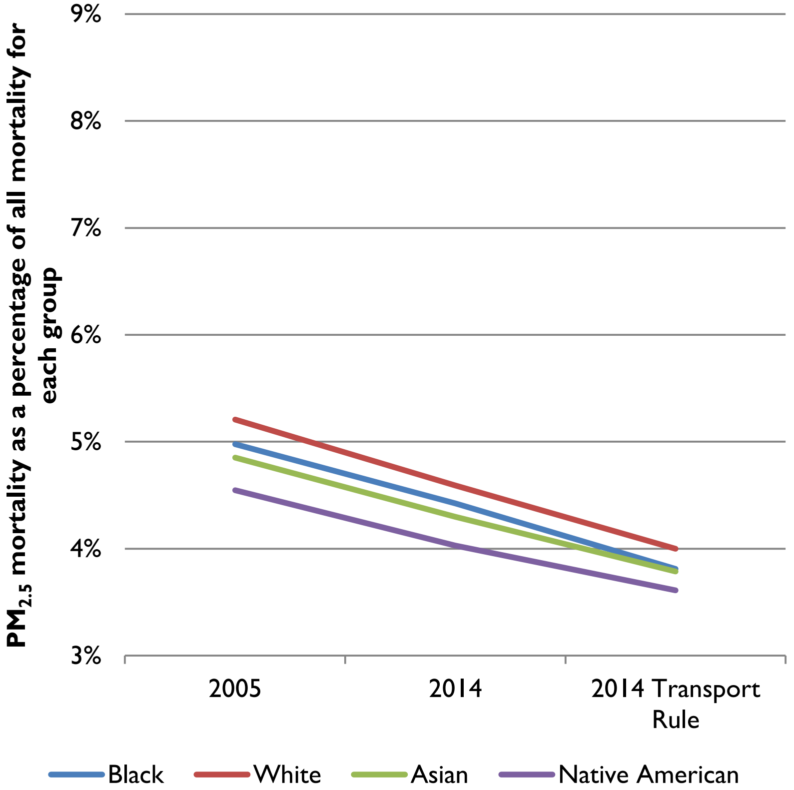
Red outline identifies counties at or above the 2005 median risk level

National Environmental Justice Analyses: 2014 Proposed Transport Rule

Among populations living in counties at greatest risk of air pollution*



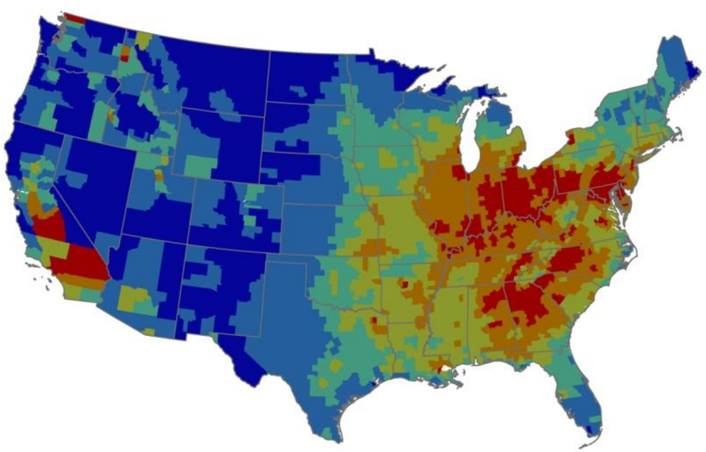
Among populations living in all other counties



*Data are not sensitive enough to delineate relative PM mortality among races with confidence. However, we are more confident that populations, irrespective of race, receive a substantial health benefit.

Burden Assessments: Estimating the Risk Attributable to Recent $PM_{2.5}$ and Ozone Levels

Percentage of O_3 and $PM_{2.5}$ related deaths due to 2005 air quality levels by county



Summary of National $PM_{2.5}$ & O_3 impacts due to 2005 air quality	
Excess mortalities (adults)[A]	130,000 to 340,000
Percentage of all deaths due to $PM_{2.5}$ and O_3[B]	6.1%
Impacts among Children	
ER visits for asthma (age <18)	110,000
Acute bronchitis (age 8-12)	200,000
Exacerbation of asthma (age 6-18)	2,500,000

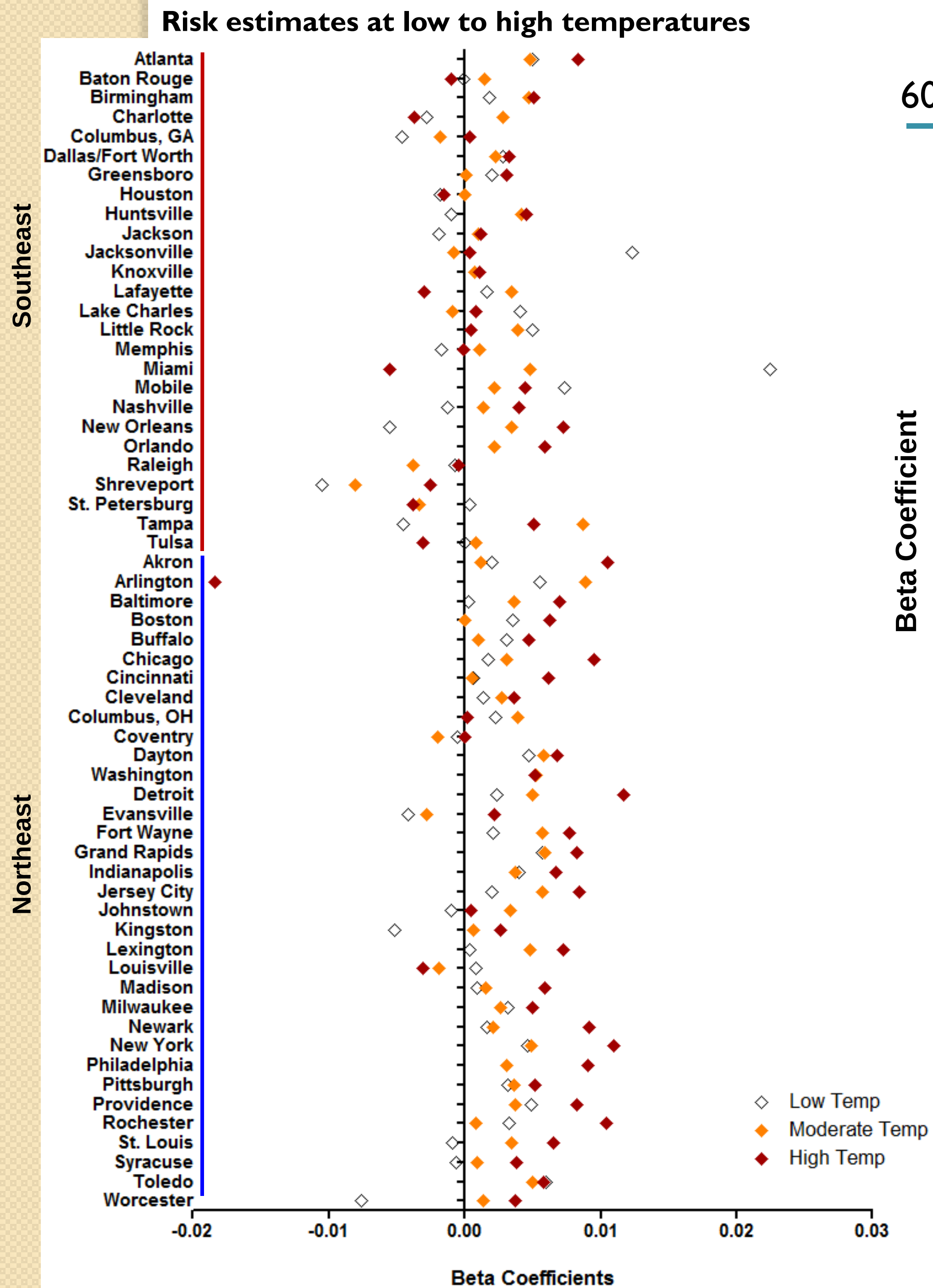
[A] Range reflects use of alternate PM and ozone mortality estimates

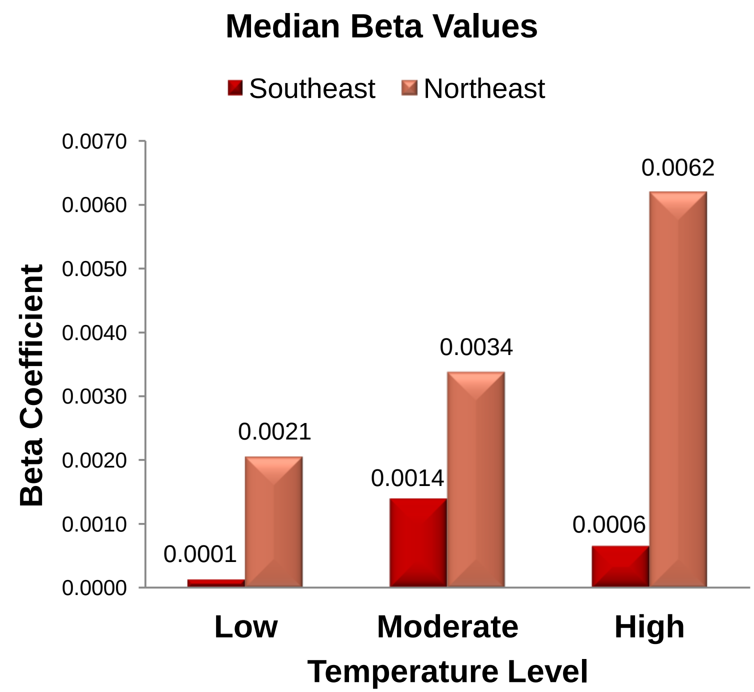
[B] Population-weighted value using Krewski et al. (2009) PM mortality and Levy et al. Ozone mortality estimates

Source: Fann N, Lamson A, Wesson K, Risley D, Anenberg SC, Hubbell BJ. Estimating the National Public Health Burden Associated with Exposure to Ambient $PM_{2.5}$ and Ozone. Risk Analysis; 2011. In Press.

Temp-Modified O_3 Mortality

60 Eastern NMMAPS Cities (1987-2000)





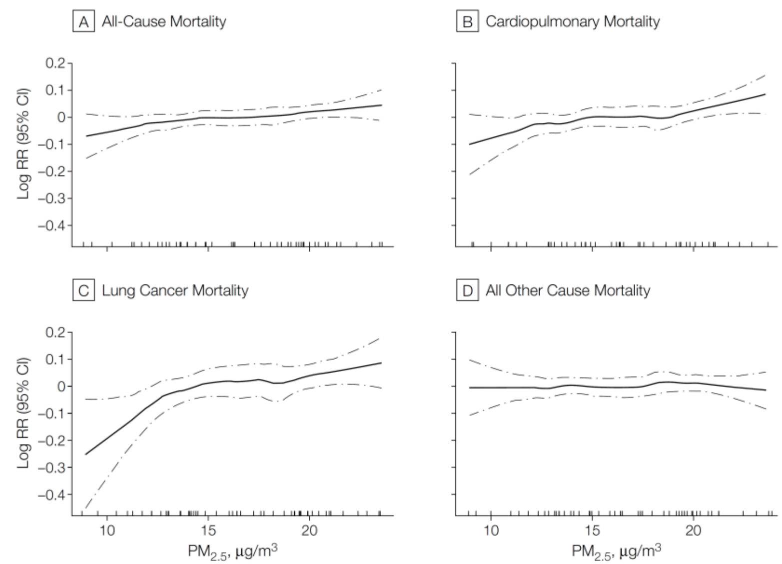
- Greater beta coefficients = greater risk of death from O_3 exposure
- 1 national effect estimate vs 3 per city
- Regional differences in magnitude and direction of change in beta values
- Regional difference possibly due to physiological, behavioral adaptation

Analysis performed by Iny Jhun, HSPH
Raw data received from Cizao Ren

Continuing Methodological Issues in Benefits Analysis

- Calculating effects at low concentrations
- Accounting for potential differences in $PM_{2.5}$ toxicity by species and season
- Incorporating information about population susceptibility
- Characterizing multi-pollutant impacts

Figure 2. Nonparametric Smoothed Exposure Response Relationship



Vertical lines along x-axes indicate rug or frequency plot of mean fine particulate pollution; $PM_{2.5}$, mean fine particles measuring less than 2.5 µm in diameter; RR, relative risk; and CI, confidence interval.

Pope et al., 2002

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APPENDIX

EPA Regulatory Analyses: Health Benefits of 2014 Cross-State Air Pollution Rule

Summary of health impacts avoided

Health endpoint	Value
$PM_{2.5}$-related mortality (Pope et al. 2002)	13,000 (5,200—21,000)
$PM_{2.5}$-related mortality (Laden et al. 2006)	34,000 (18,000—49,000)
O_3-related mortality (Bell et al. 2004)	27 (11—42)
O_3-related mortality (Levy et al. 2005)	120 (90—160)
$PM_{2.5}$-related chronic bronchitis	8,700 (1,600—16,000)
$PM_{2.5}$-related non-fatal heart attacks	15,000 (5,600—24,000)
$PM_{2.5}$ and O_3-related respiratory hospitalizations	2,900 (1,300—4,300)
$PM_{2.5}$ and O_3-related emergency department visits	9,900 (5,800—14,000)

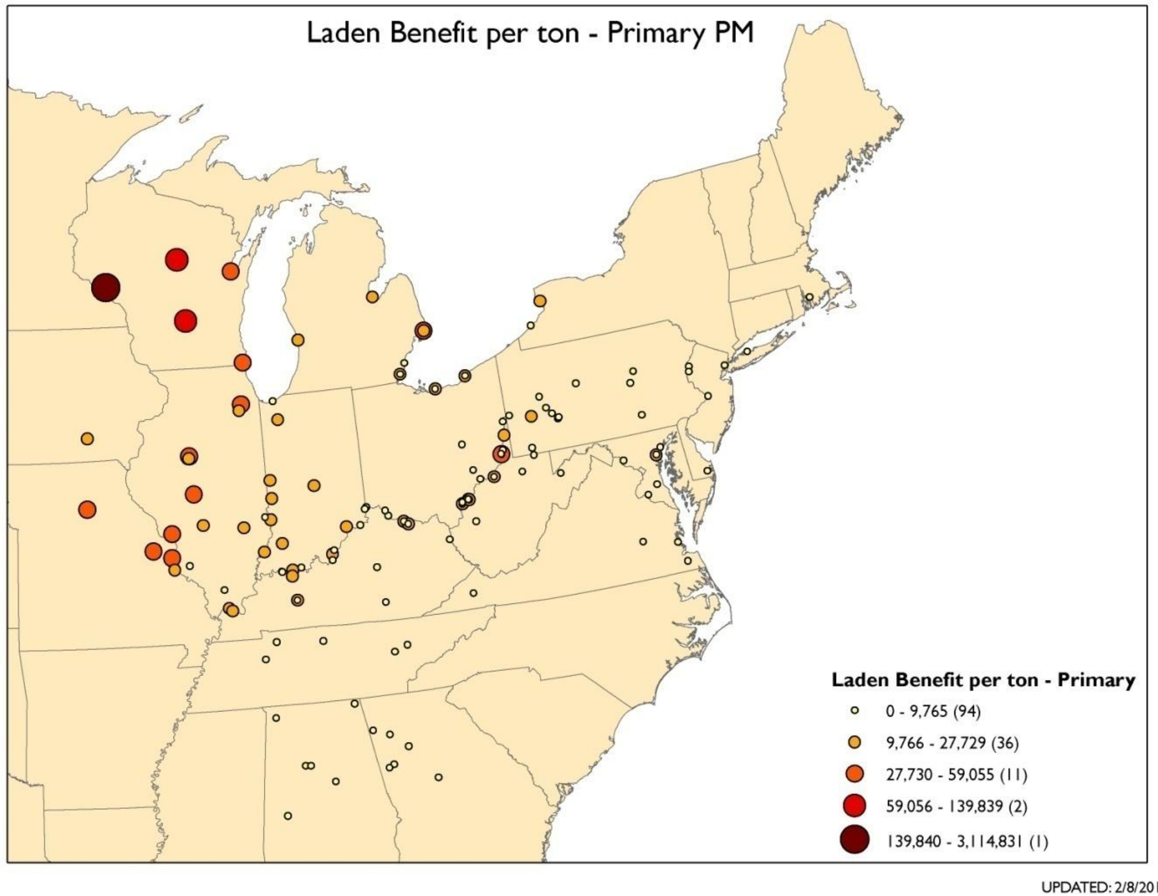
Monetized health and welfare benefits[A]

Endpoint	Value (billions of 2006$)
Human health[B]	
Pope et al. 2002 $PM_{2.5}$ and Bell et al. 2004 O_3 mortality estimates	$120 ($14—$350)
Laden et al. 2006 $PM_{2.5}$ and Levy et al. 2005 O_3 mortality estimates	$280 ($29—$810)
Visibility	$3.6
Total	
Pope et al. 2002 $PM_{2.5}$ and Bell et al. 2004 O_3 mortality estimates	**$120 ($10—$360)**
Laden et al. 2006 $PM_{2.5}$ and Levy et al. 2005 O_3 mortality estimates	**$290 ($26—$850)**

[A] All values rounded to two significant figures
[B] Discounted at 3%

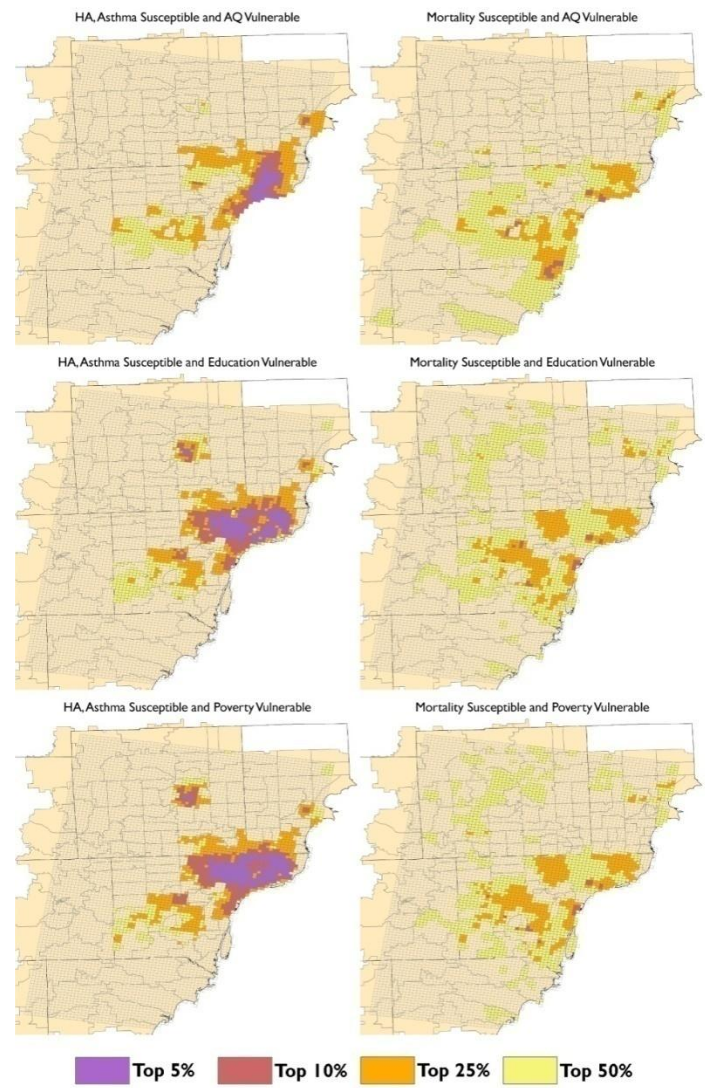
Source: http://www.epa.gov/airtransport/pdfs/FinalRIA.pdf

Benefit per ton estimates



Detroit Multi-pollutant Pilot Project: EJ Assessment

- Analysts can consider alternate variables to identify susceptible and vulnerability populations
  - Susceptibility:
    - Hospital Admissions
    - Mortality
  - Vulnerability
    - Annual mean $PM_{2.5}$ levels
    - Educational attainment
    - Poverty
- Irrespective of variables used, the multi-pollutant risk-based approach provides greatest reductions in $PM_{2.5}$ exposure



Source: Fann N, Roman HR, Fulcher C, Gentile M, Wesson K, Hubbell BJ, Levy JI. Maximizing Health Benefits and Minimizing Inequality: Incorporating Local Scale Data in the Design and Evaluation of Air Quality Policies, *Risk Analysis*, 2011; in press.

Supporting Methods Development and State Analyses

- CDC Environmental Public Health Tracking Program
- NYC Health Burden Assessment
- WA State Health Burden Assessment
- Assessment of Climate-Induced Heat Mortality

Redeveloping the Model to Address Future Policy Questions

- Rebuilding the model from the ground up
  - Improve computational efficiency
  - Address bugs and user interface issues
- Transition from proprietary to open-source framework
  - Code maintained by the contractor
  - Open-source framework may facilitate broader ownership of the model
- Implement a modern codebase
  - Current BenMAP written in Delphi, which is familiar to a more limited audience

BenMAP Community Software (BenMAP CS)

- Written in C#
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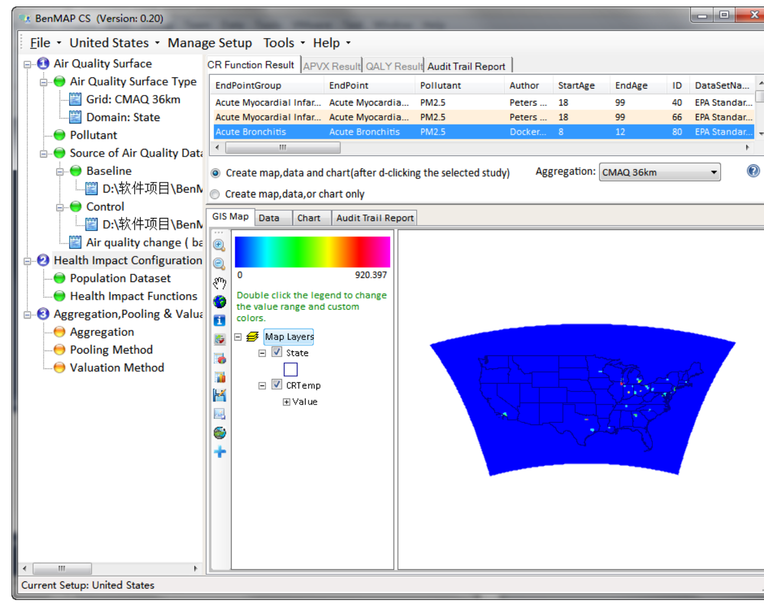

Future BenMAP CS Enhancements and Modules

- Explore the feasibility of incorporating ecological endpoints
  - Recreational and residential visibility
- Multi-pollutant
  - Assess the impacts from multiple pollutants jointly
  - Incorporate variance/co-variance matrices to quantify uncertainty
- Environmental Justice
  - Calculate inequality metrics (Gini coefficient and Atkinson Index)
  - Use race-specific health data when calculating impacts
- Climate
  - Characterize temperature-modified air pollution effect estimates
  - Include ICLUS-based population projections that account for climate change scenarios
- International
  - Include new health impact functions for indoor cookstove pollution
  - Include health impact functions from non-U.S. studies
- Local-scale assessments
  - More easily assess city-specific impacts
- More easily quantify the benefits of EPA enforcement cases

Key terms

- Discounting – method for calculating how much future benefits and costs are worth today
- Cost of Illness (COI) - total costs of treatment and time lost due to illness, which often excludes pain and suffering
- Willingness to pay (WTP) - maximum amount of money an individual would pay to obtain an improvement in the environmental effects of concern
- Value of a Statistical Life (VSL) - aggregate dollar amount that a large group of people would be willing to pay for a small reduction in their individual risks of dying in a year
- Disbenefits – increase in pollution emissions, frequently as a secondary impact
- Net benefits – calculated by subtracting total costs from total monetized benefits.