US EPA ARCHIVE DOCUMENT

Translating Air Quality Model Predictions to Health Impacts

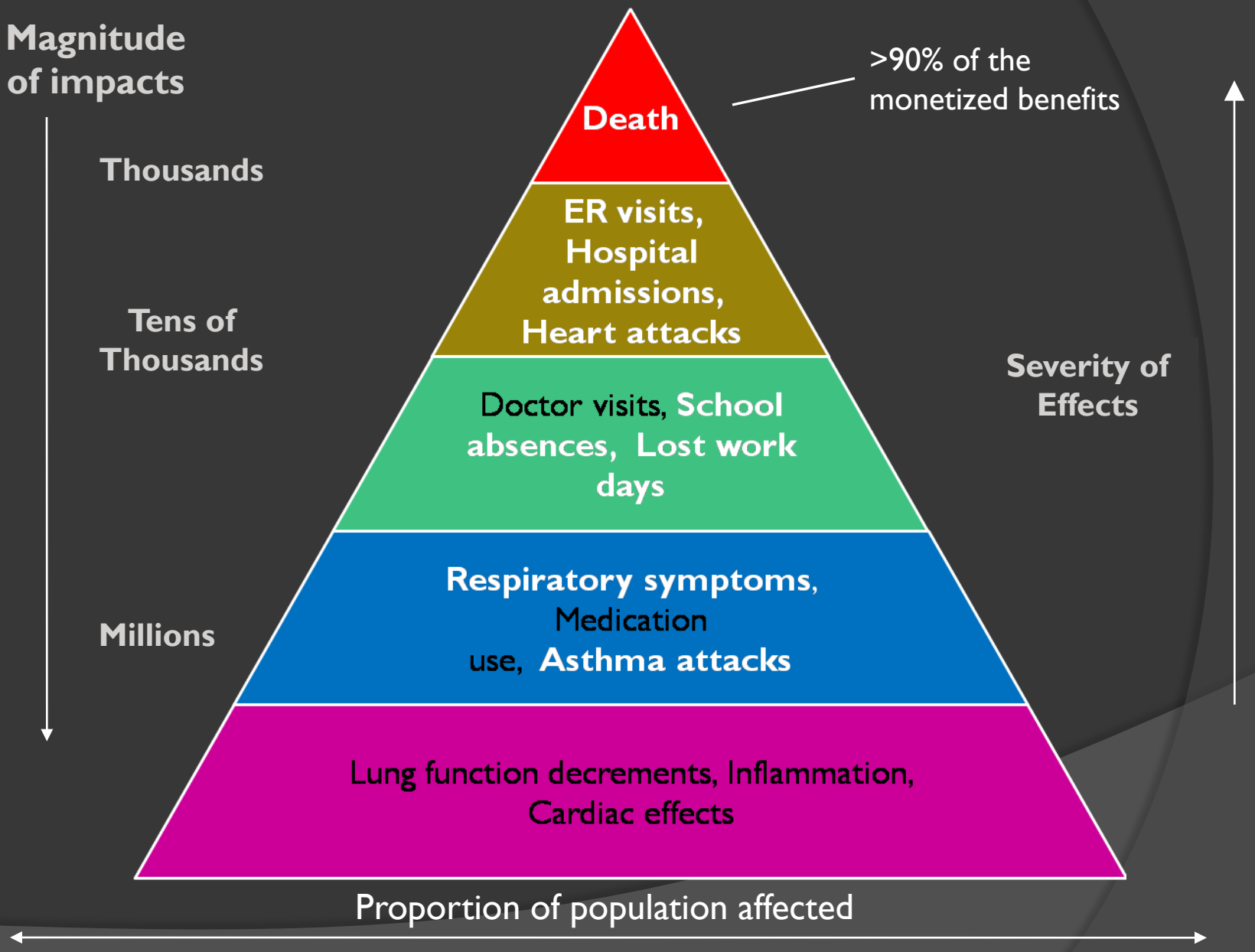
Understanding how the Agency uses air quality modeling results to estimate health benefits

Dynamic Air Quality Modeling Kick-Off
November 8th, 2012

Overview

- First principles—the relationship between air pollution and health
- Using the BenMAP tool to quantify air pollution health impacts
- Benefits assessments supporting regulatory impact analyses
- Health burden assessments
- Characterizing cumulative air pollution risk
- Future air quality modeling needs

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	✓	✓
Upper & lower respiratory symptoms	✓	
Asthma attacks	✓	✓
Work loss days	✓	
School absence rates		✓

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

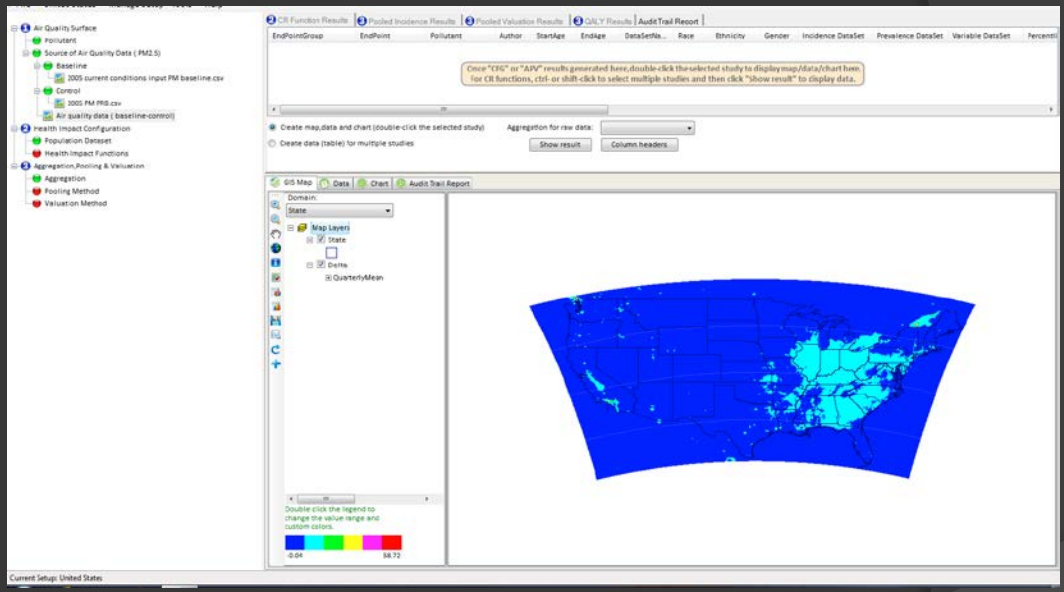
What Health Endpoints do we Include in Our Sensitivity Analyses?

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

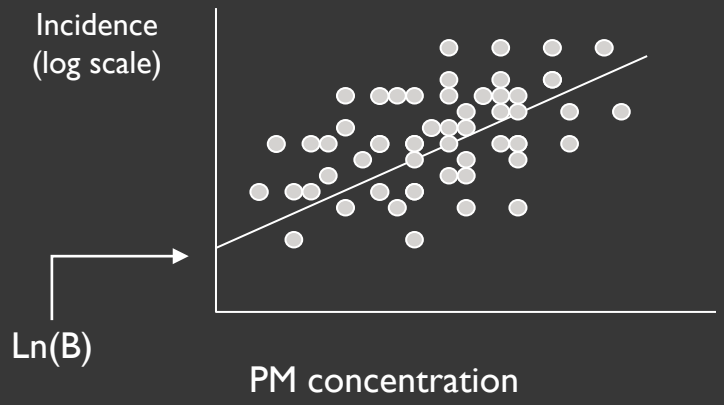
What is BenMAP?

- 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
- Open-source version available for beta testing **Spring 2013**



Step One: Derive Health Impact Functions from Epidemiology Literature

Epidemiology Study



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

Health impact function

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

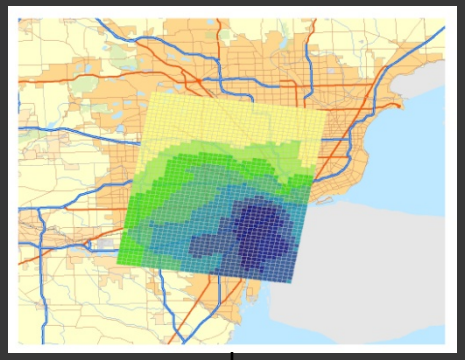
Yo – Baseline Incidence

β – Effect estimate

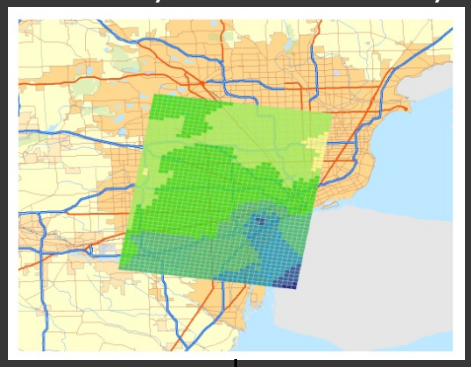
ΔPM – Air quality change

Pop – Exposed population

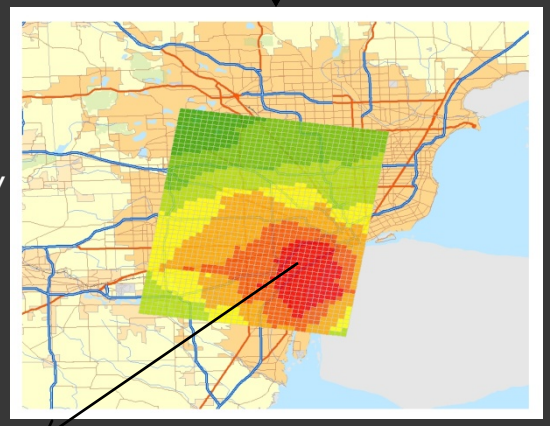
Baseline Air Quality



Post-Policy Scenario Air Quality

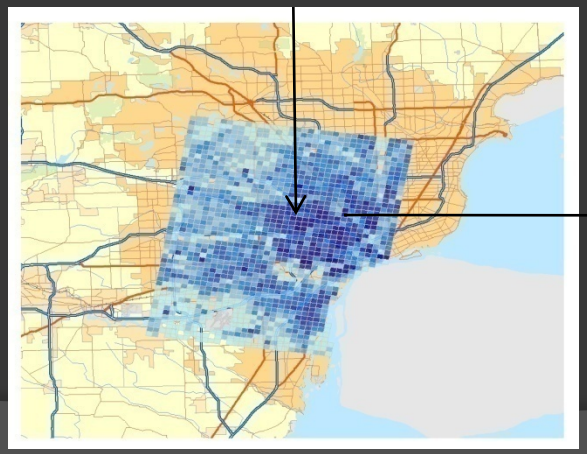


$$\Delta Y = Yo\ (1\text{-}e^{-\beta \Delta PM}) * Pop$$

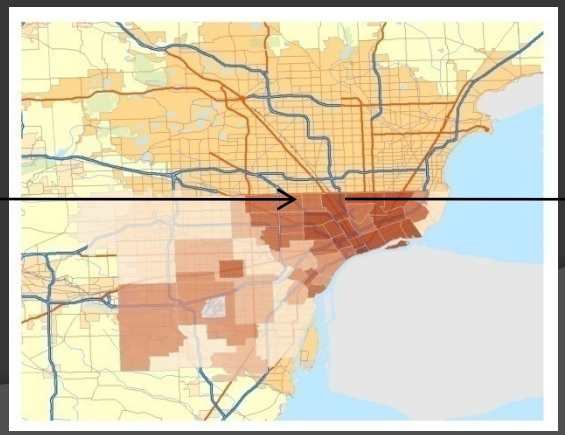


Incremental Air Quality Improvement

$PM_{2.5}$ Reduction



Population Ages 18-65



Background Incidence Rate

Effect Estimate

Mortality Reduction

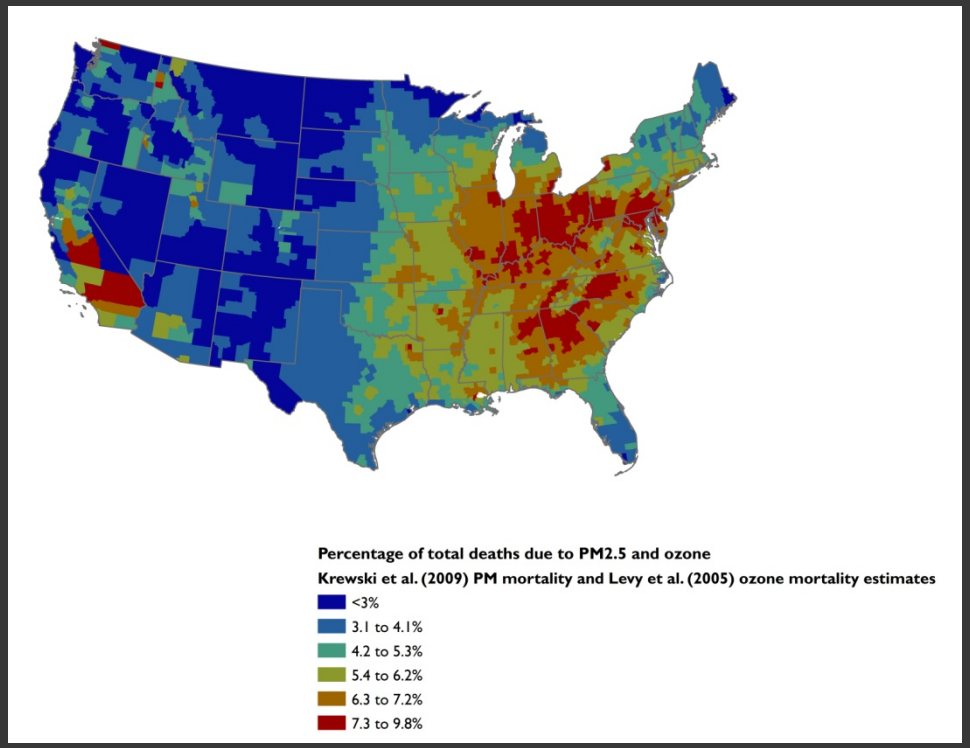
U.S. Version

BenMAP

Environmental Benefits Mapping and Analysis Program

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

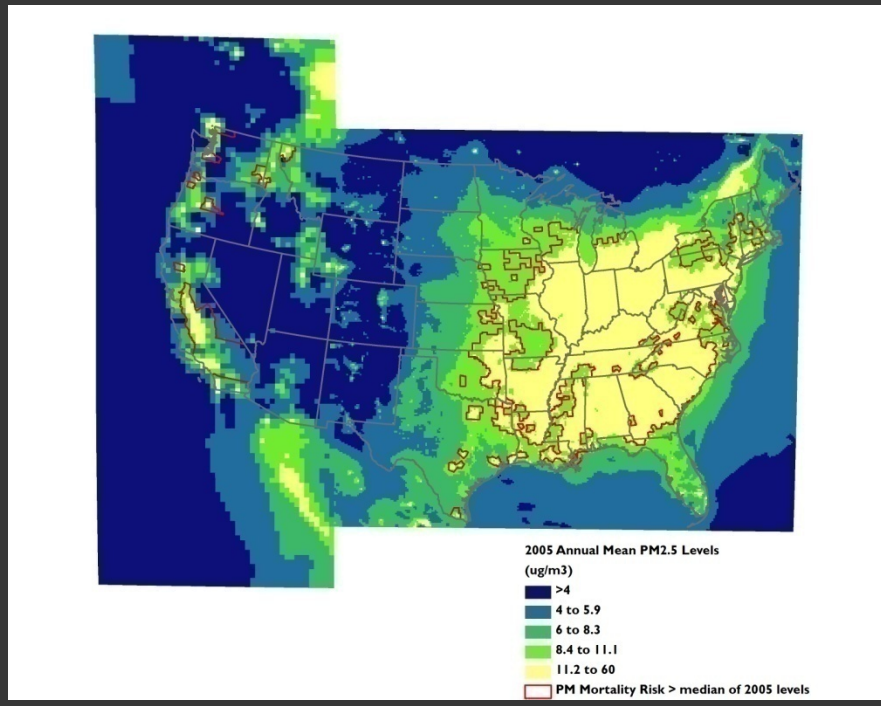
Source: Fann N, Lamson A, Wesson K, Risley D, Anenberg SC, Hubbell BJ. Estimating the National Public Health Burden Associated with Exposure to Ambient $PM_{2.5}$ and Ozone. Risk Analysis; 2012a

[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

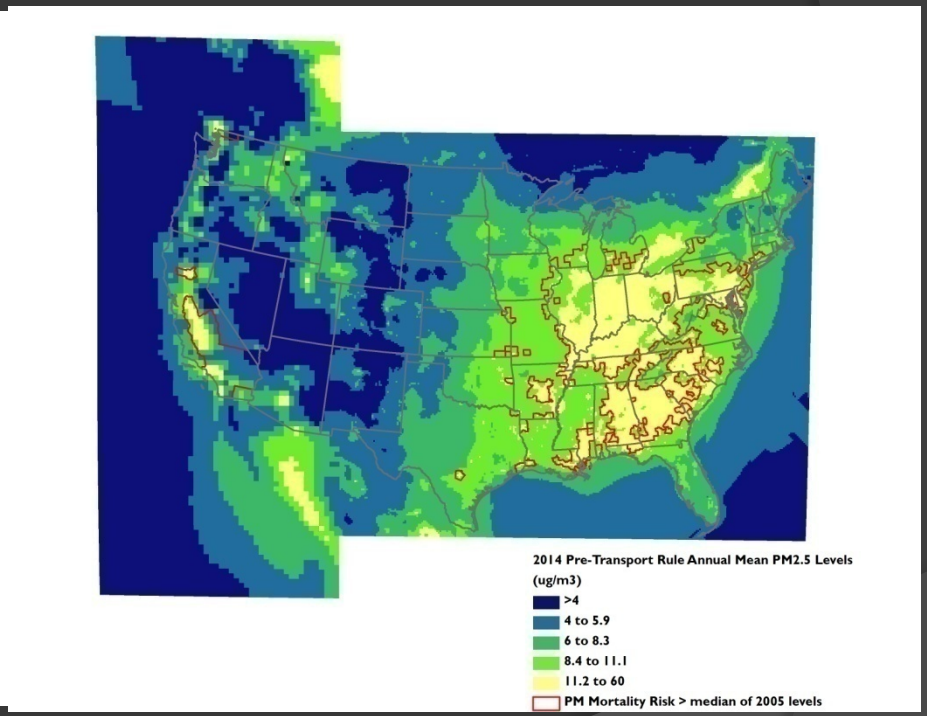
Existing rules reduce the number of counties with elevated PM mortality risk between 2005 and 2014…

2005



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

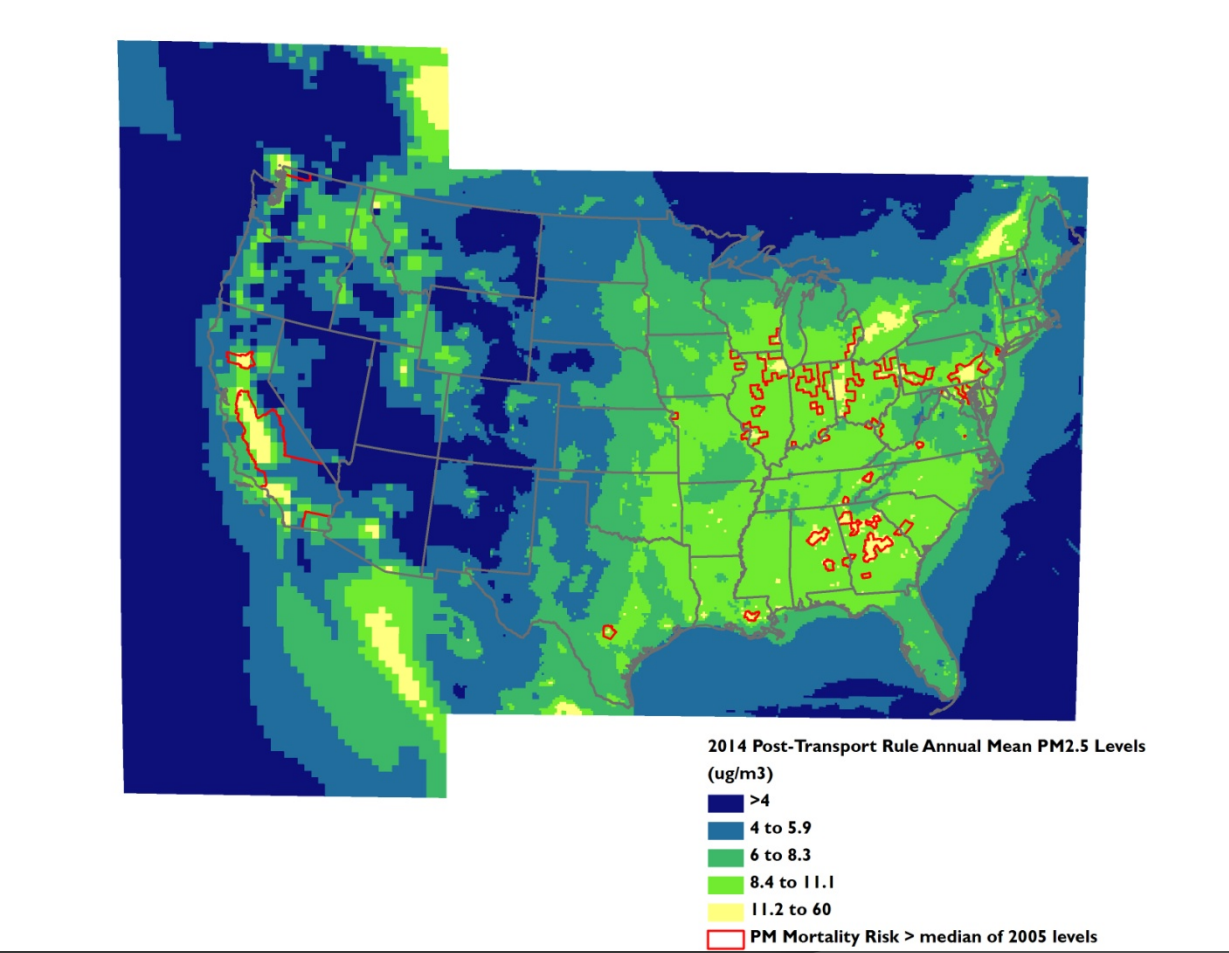
2014 Pre-Transport Rule



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

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

Identifying Populations Susceptible and Vulnerable to $PM_{2.5}$ Air Pollution in Detroit

Populations susceptible to $PM_{2.5}$ impacts

Asthma hospital visits

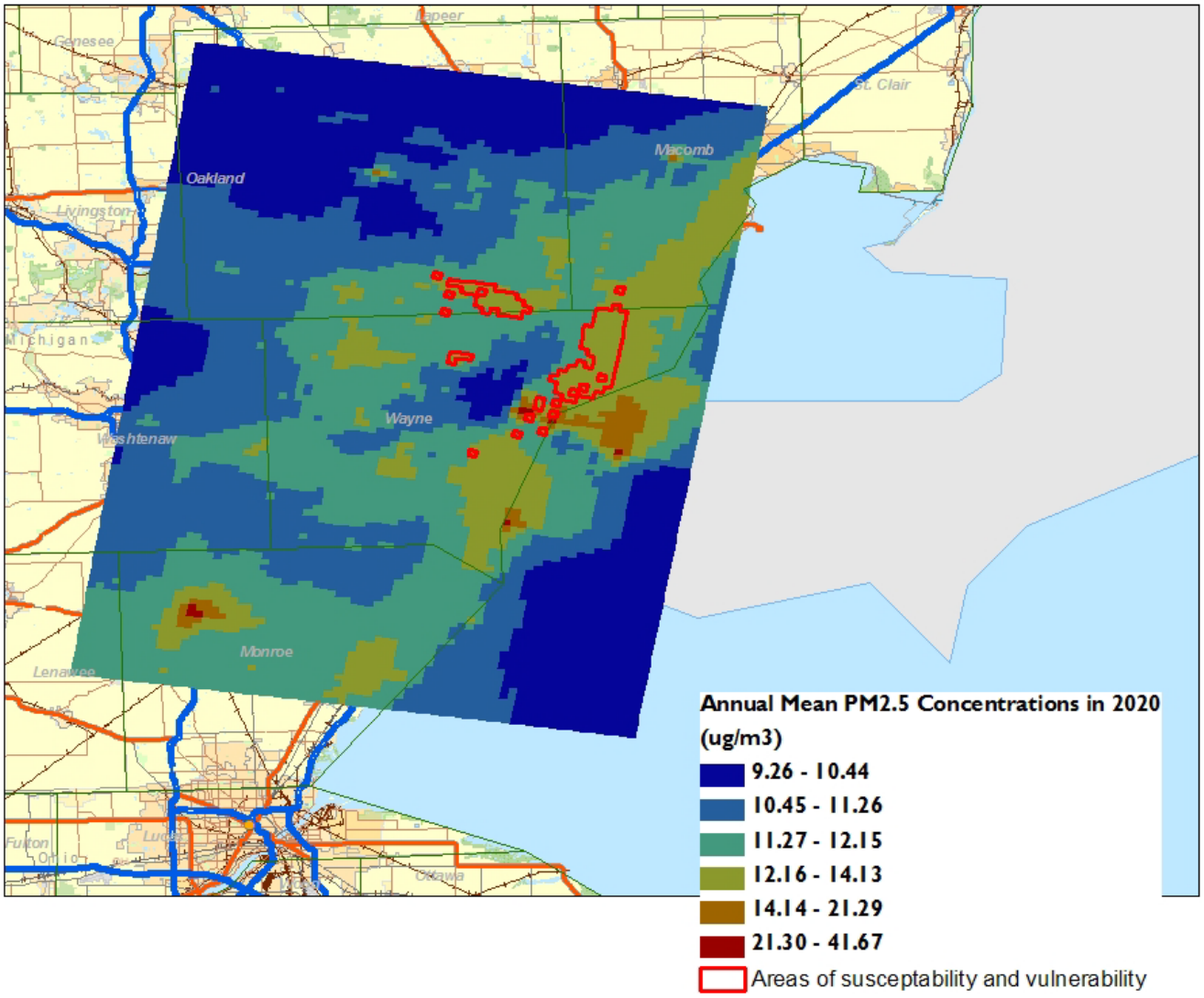
↓

Populations vulnerable to $PM_{2.5}$ impacts

Annual mean $PM_{2.5}$ air quality levels

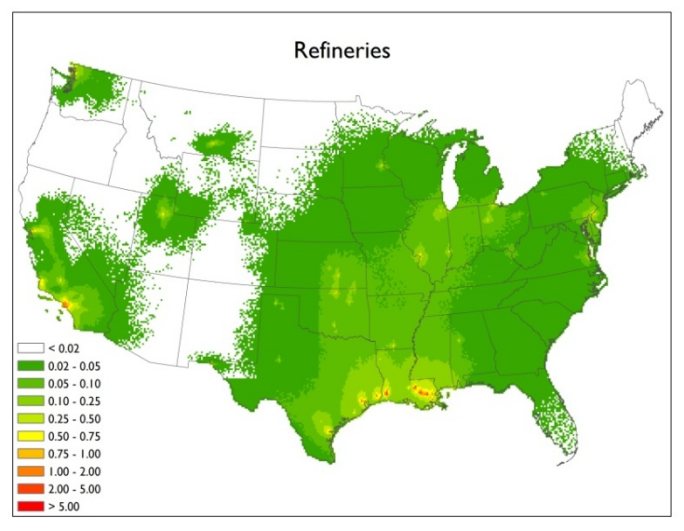
↓

Populations susceptible and vulnerable to $PM_{2.5}$ impacts

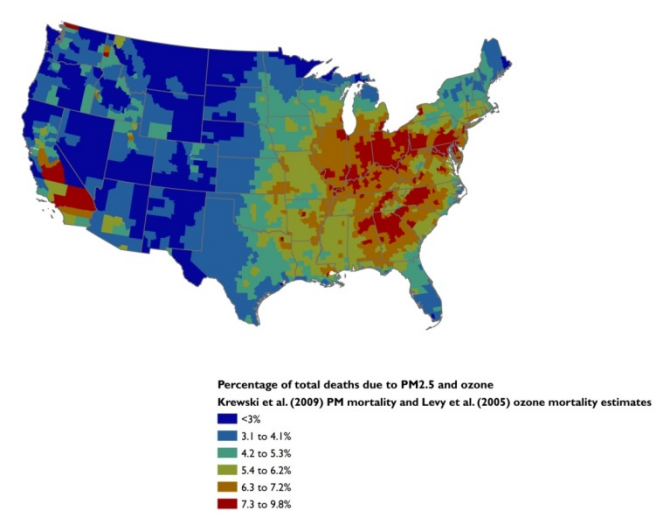


Estimating and Applying Benefit per Ton Estimates

(1) Model source contribution



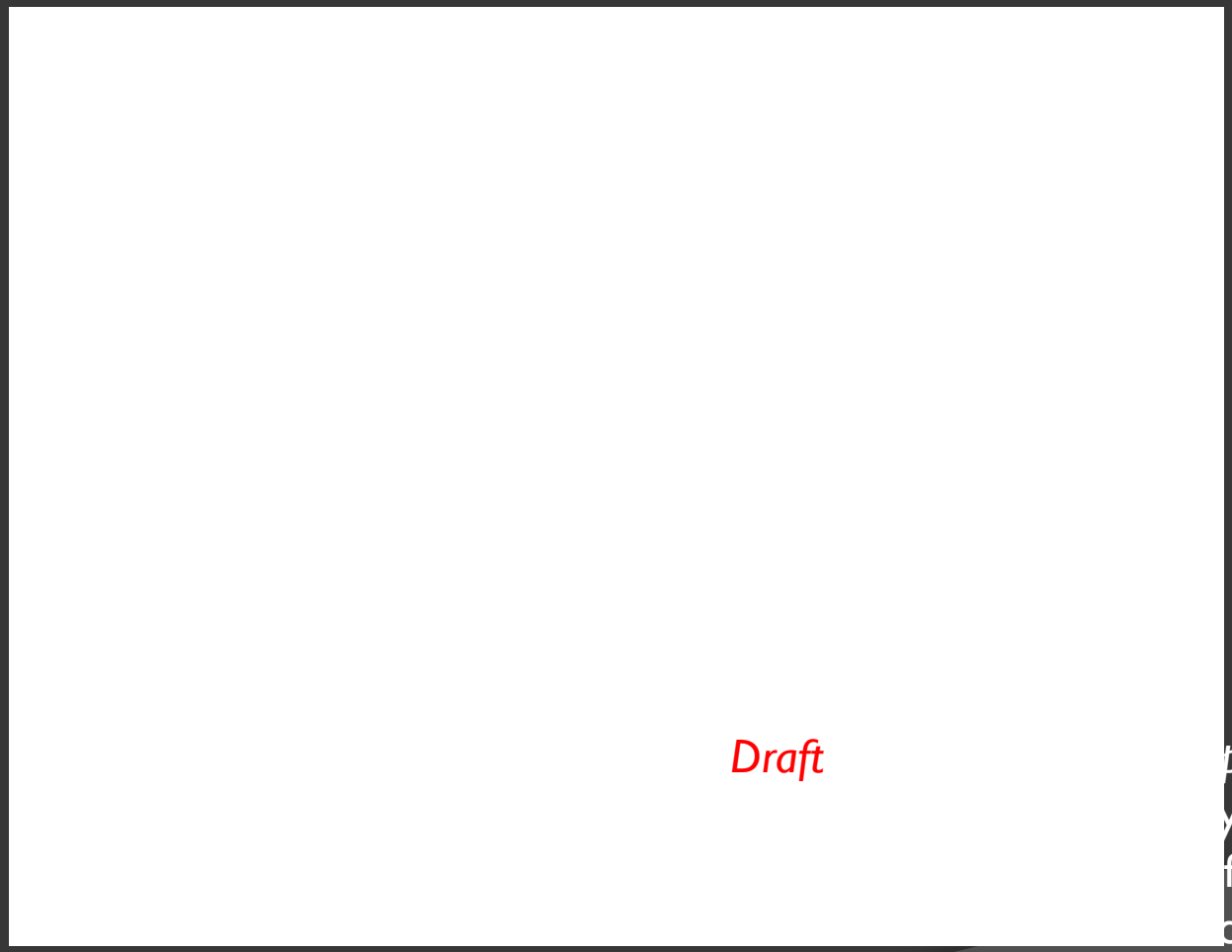
(2) Estimate health benefits



(3) Calculate benefit/ton

$$\frac{Human\ health\ benefits}{Sector\ emissions} = {Benefit}/{1\ ton}$$

Nexus of Secondary $PM_{2.5}$ Mortality Risk and Secondary HAP Cancer Risk



proach

y due to secondary $PM_{2.5}$

fferentiated by specie)

condary HAPs

3. Upper 80th percentile of both distributions

Nexus of Direct $PM_{2.5}$ Mortality Risk and Metal HAP Cancer Risk

roach

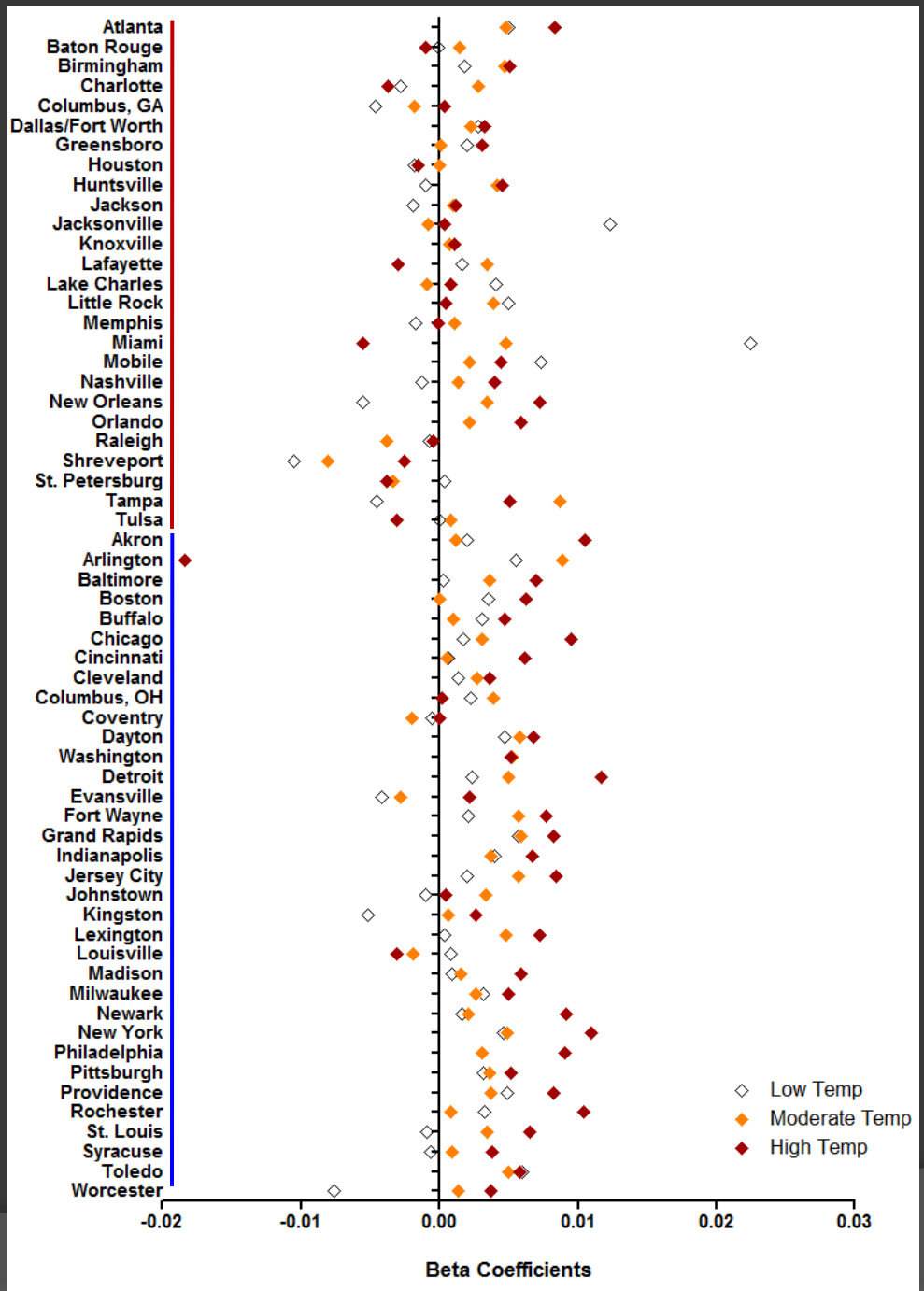
due to directly emitted

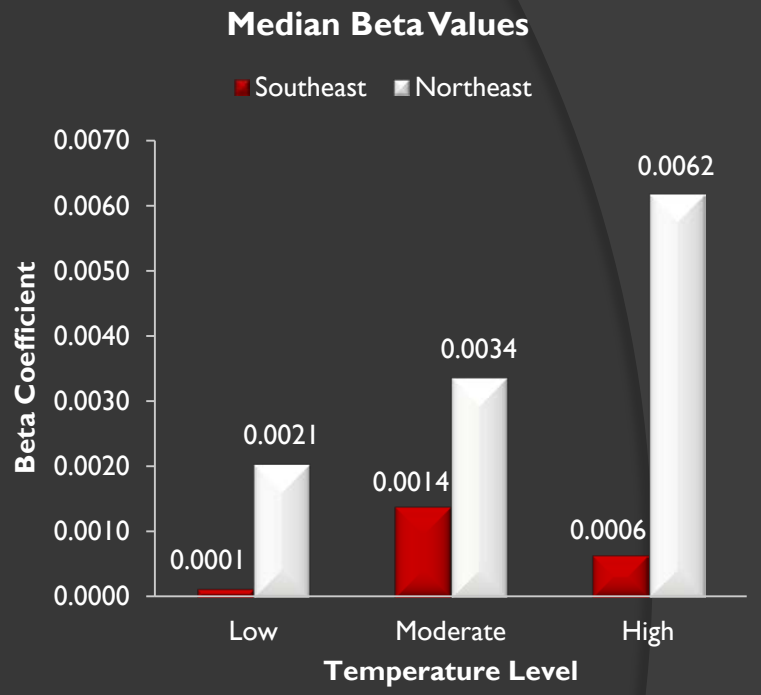
ot differentiated by

2. Cancer risk due to metal HAPs
3. Upper 80th percentile of both distributions

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

What Are Our Future Air Quality Modeling Needs for Benefits Assessment?

- More time and resource efficient forward and backward looking sensitivity tools
- Better characterization of source-to-receptor relationship at design value monitors
- Improved temporal and spatial resolution of pollutants and stressors (e.g. temperature)

Contact Information

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References

Abt Associates, Inc. Environmental Benefits and Mapping Program (Version 4.0), 2010. Bethesda, MD. Prepared for U.S. Environmental Protection Agency Office of Air Quality Planning and Standards. Research Triangle Park, NC. Available on the Internet at <http://www.epa.gov/air/benmap>

Fann N, Roman HR, Fulcher CF, 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; 2012a.

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; 2012b.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, Turner C, Pope CA, Thurston G, Calle EE, Thunt MJ. Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. HEI Research Report, 140, 2009; Health Effects Institute, Boston, MA.

Levy JI, Greco SL, Spengler JD. The Importance of Population Susceptibility for Air Pollution Risk Assessment: A Case Study of Power Plants Near Washington, DC. Environmental Health Perspectives, 2002 110(12): 1253—1260.

Wesson KH, Baker K, Nopmongcol U, Yarwood G, Sakulyanontvittaya T, Strum M, Thurman J, Camalier L , Ensley D, Timin B, Phillips S and Fox T. "Comparing Models/Methods for Estimating Multi-pollutant Fine-scale Air Quality Concentrations" in Air Pollution Modeling and Application XX. Ed. By DG Steyn and ST Rao.

Wesson K, Fann N, Morris M, Fox T, Hubbell B. A Multi-Pollutant, Risk-based Approach to Air Quality Management: Case Study for Detroit. Atmospheric Pollution Research, 2010 1: 296—304.