Contributions of Interstate Transport of Air Pollutants to Air Pollution-related Mortality in the Mid-Atlantic U.S.

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Overview

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Background

- Exposure to ground-level ozone could cause adverse human health effects
- Ground-level ozone is created by chemical reactions of NOx and VOCs in the presence of sunlight
- A 10-ppb increase in the previous week's ozone concentrations is associated with a 0.52% increase in daily mortalities (Bell Ml, 2004)
- In some cases, NOx reductions in one hemisphere could led to long-term increases in mortalities in the opposite hemisphere (West et al., 2009)

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Methods

- Health Effect Function (or C-R Function)

$$\Delta y = y_0\left(1 - e^{-\beta \Delta x}\right) POP$$

  - y_0= baseline incidence rate of the health outcome
  - β = coefficient of association between ozone concentration and health outcome
  - Δx = the estimated air pollution change
  - POP = the size of exposed population
  - Δy = the estimated change in the health outcome due to the change in ozone exposure

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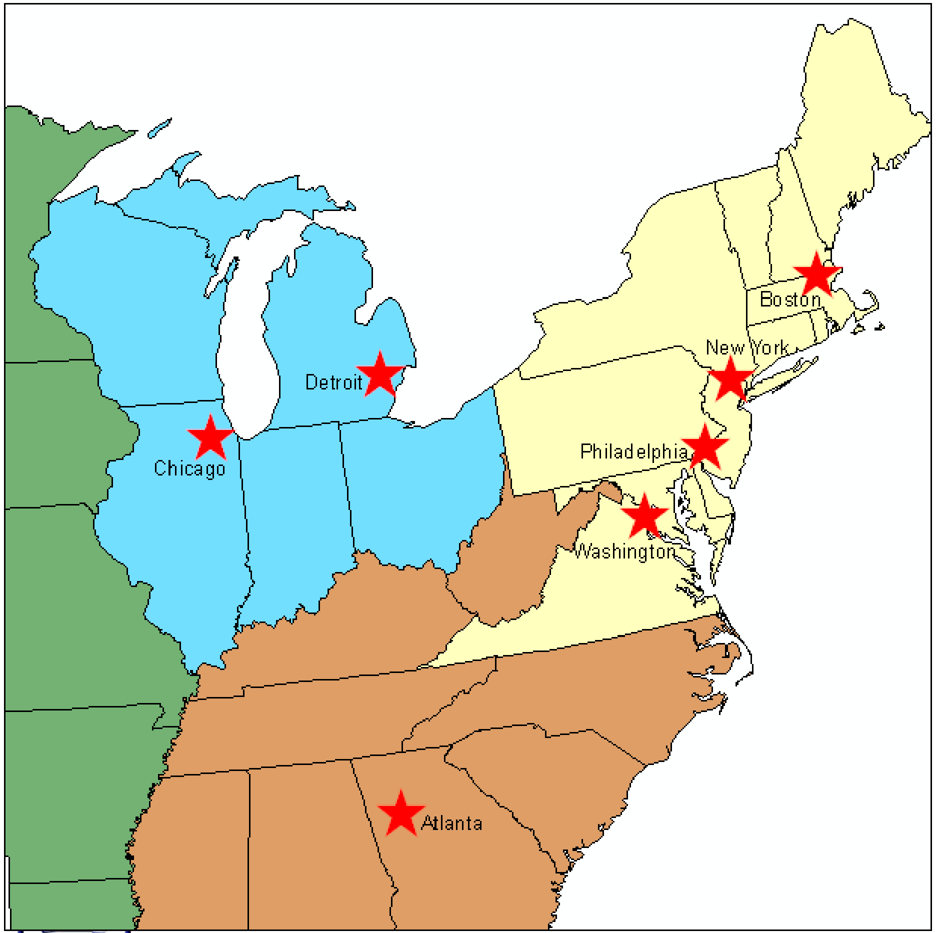
Major Cities in the Eastern U.S.



Metropolitan Statistical Area	2007 Estimate Populations*
New York-Northern New Jersey-Long Island, NY-NJ-PA	18,815,988
Chicago-Naperville-Joliet, IL-IN-WI	9,524,673
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	5,827,962
Washington-Arlington-Alexandria, DC-VA-MD-WV	5,306,565
Atlanta-Sandy Springs-Marietta, GA	5,278,904
Boston-Cambridge-Quincy, MA-NH	4,482,857
Detroit-Warren-Livonia, MI	4,467,592

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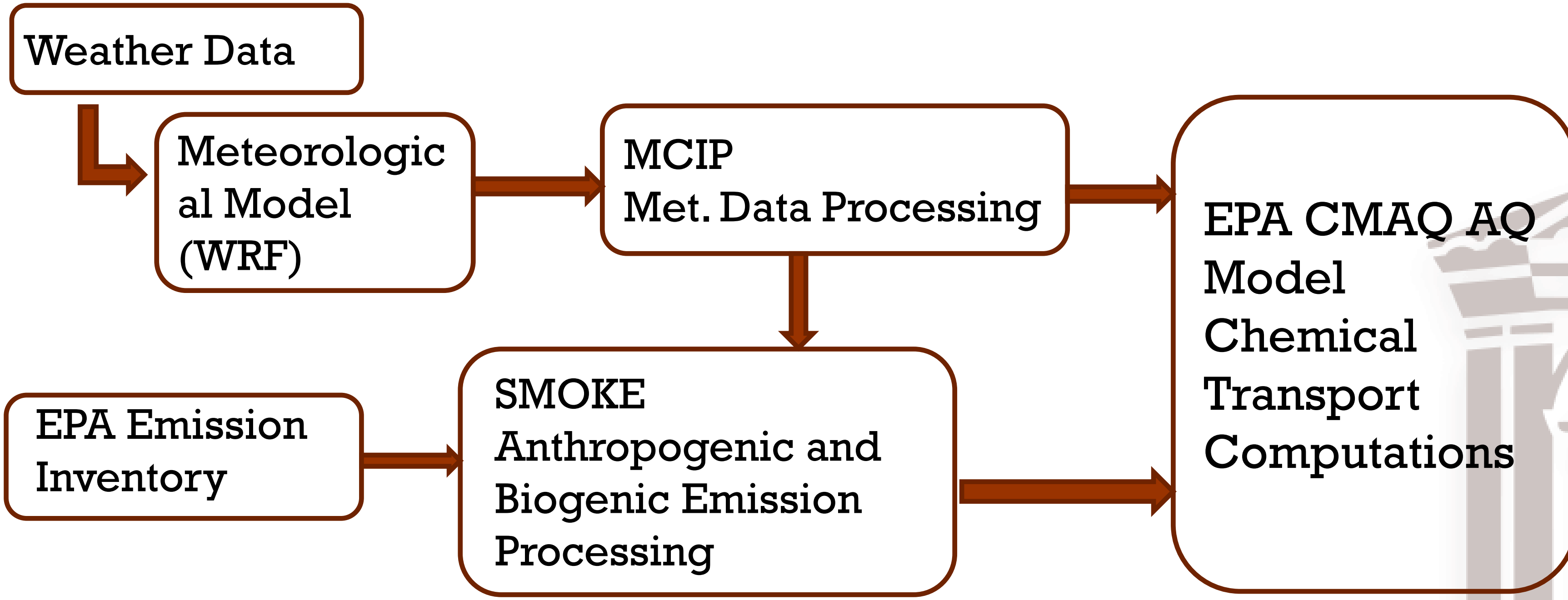
Figure 1. Modeling study domain, four emission regions (i.e., Central Regional Air Planning Association (CENRAP)(Green), Lake Michigan Air Directors Consortium (LADCO) (Blue), Ozone Transport Region (OTR) (Yellow), Southeastern Modeling, Analysis, and Planning (SEMAP) regions (Orange)

* http://www.census.gov/popest/data/historical/2000s/vintage_2007/metro.html



EPA CMAQ was used to calculate Daily Maximum 8-Hour Ozone Concentration as well as ZOC for the sensitivity analysis

Feature	Description
Air Quality Model	U.S. EPA CMAQ-DDM v4.7.1
Meteorological Model	WRF
Emission Model	SMOKE
Horizontal Resolution	12*12 km
Vertical Layer	34 Layers
Simulation Period	May 25th ~ August 31st, 2007

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Data Inputs: Contribution of Emissions to Ozone Air Pollution

- ZOC (zero-out source contribution) to estimate the overall air pollution related risk by multi-pollutant emissions reduction (Cohan et al., 2005).

$$ZOC(E_i, E_j) = \left(S_i^{(1)} - \frac{1}{2}S_{i,i}^{(2)}\right) + \left(S_j^{(1)} - \frac{1}{2}S_{j,j}^{(2)}\right) - S_{i,j}^{(2)}$$

- First-order sensitivities: $S_i = \frac{\partial C}{\partial E_i}$, $S_j = \frac{\partial C}{\partial E_j}$

pollutant concentrations (*C*) to source emissions *i* (*E*)

- Second-order: $S_i^{(2)} = \frac{\partial^2 C}{\partial E_i^2}$, $S_j^{(2)} = \frac{\partial^2 C}{\partial E_j^2}$, $S_{i,j}^{(2)} = \frac{\partial^2 C}{\partial E_i \partial E_j}$
- Anthropogenic NOx and VOC emissions as the main ozone precursors

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Data Inputs: C-R Function and Health Data

- CR Function

Health Effect	Age Group	Acute of Chronic Exposure Metric	Effect Estimate	Study Location	Source of Effect Estimate
Non-Accidental Premature Mortality	All ages	Acute Daily 8-hour maximum	0.261% increase in mortality per 10 ppb increase in ozone level over the previous week	95 US urban cities	Bell et al. 2004

- MSA-specific bas
- Monthly county-l rate in summertim obtained from CD(Disease Control ar WONDER databas
- Age-weighted m (per 100 people in

New York* Age Group	Population	Death	Pop Proportion* Mortality Rate (per 100 people in summer time)
< 1 year	251056	302	0.001605018
1-4 years	980622	28	0.00014881
5-14 years	2408102	50	0.000265731
15-24 years	2526940	104	0.000552721
25-34 years	2444443	244	0.00129677
35-44 years	2922840	774	0.004113523
45-54 years	2798932	2024	0.01075681
55-64 years	2061471	3298	0.017527647
65-74 years	1232706	4748	0.02523386
75-84 years	827942	8449	0.044903302
85+ years	360934	9735	0.051737916
Total	18815988	29756	Age-weighted mortality rate (per 100 people in summer time) 0.158142108

*http://www.census.gov/popest/data/historical/2000s/vintage_2007/metro.html

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Modeled and Observed Ozone Air Quality

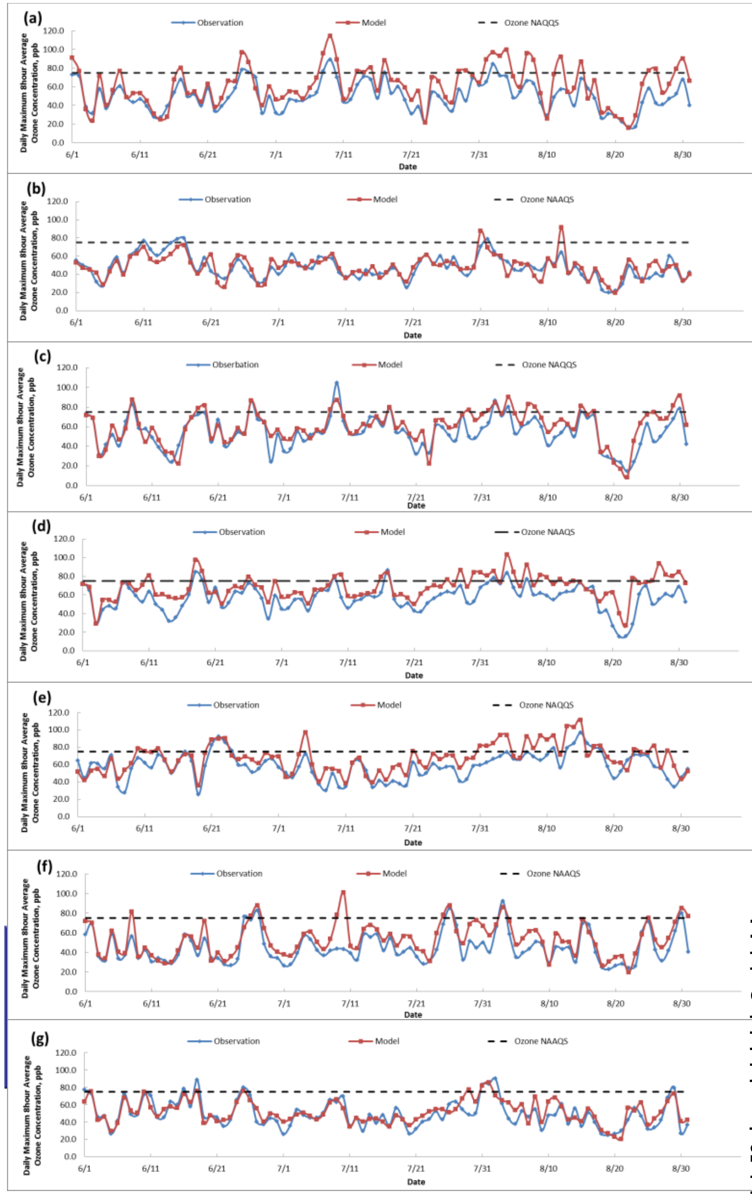
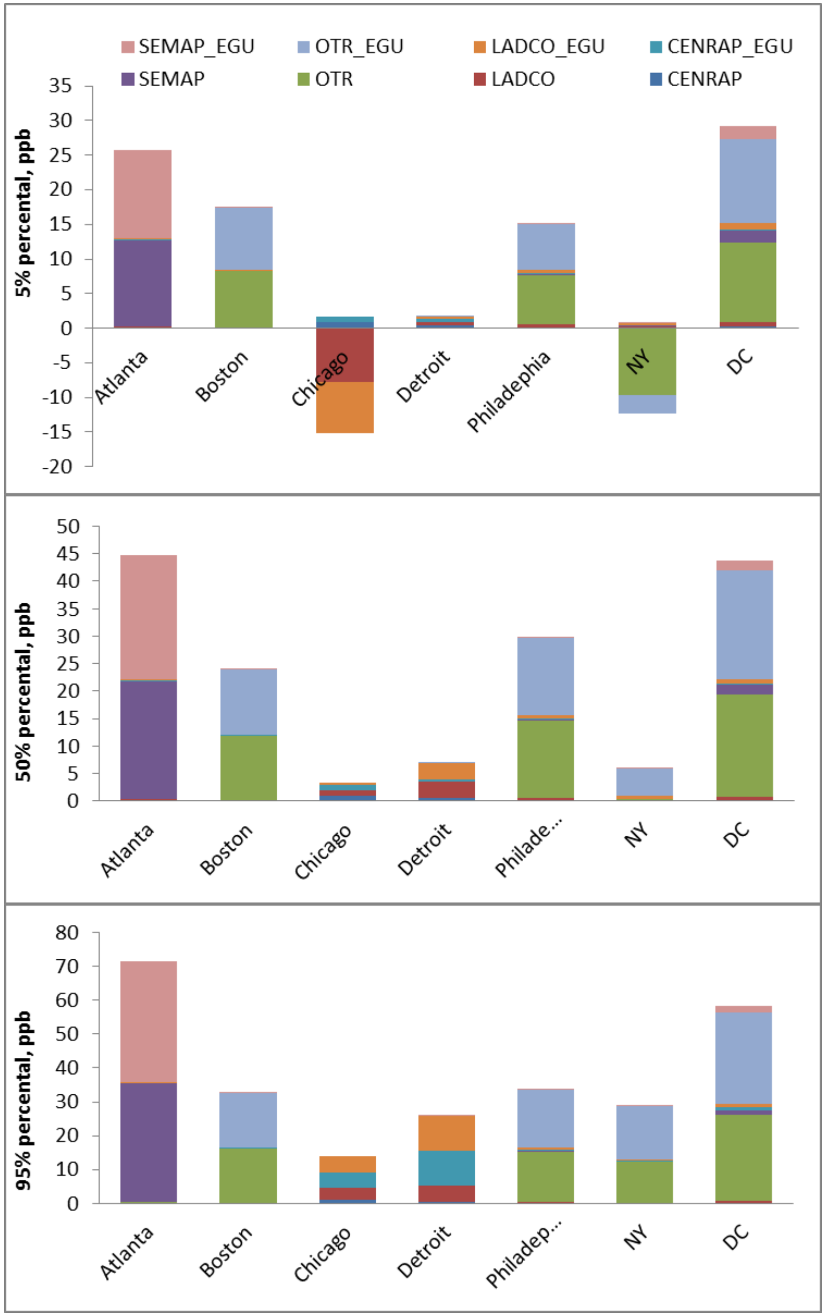


Figure 2. Time series for modeled and observed Daily Maximum 8-hour Average Ozone concentrations during the 2007 summer for (a)New York-Northern New Jersey-Long Island, NY-NJ-PA, (b)Chicago-Naperville-Joliet, IL-IN-WI, (c)Philadelphia-Camden-Wilmington, PA-NJ-DE-MD, (d)Washington-Arlington-Alexandria, DC-VA-MD-WV, (e)Atlanta-Sandy Springs-Marietta, GA, (f)Boston-Cambridge-Quincy, MA-NH and (g)Detroit-Warren-Livonia, MI.

- Observed daily ozone concentrations were used to compare with the CMAQ-modeled daily maximum 8-hour ozone concentrations.
- Observations of ozone concentrations were retrieved from the U.S. EPA's Air Quality System (AQS)
- 5-by-5 grid cells in the urban areas
- 5^{th}, 50^{th}, 95^{th} percentiles were selected to represent the low, base, high scenarios
- DM8-hour ozone concentrations in (a)NYC and (d) DC were overestimated.



- ZOC in this study refers to estimate the effect on ozone concentration of removing anthropogenic NOx and VOC emissions.
- A positive ZOC corresponds to an ozone decrease at a receptor upon removal of the source interested.
- The impact of anthropogenic NOx and VOC emissions reduction on high level concentrations more obvious.

Figure 3. Three scenarios of zero-out source contribution to 5% (top), 50% (middle), and 95% (bottom) percentiles of 8-hour ozone

MSA Specific Estimated Changes of Ozone-Related Premature Mortality (no. of incidence) (Mean Estimates and 5th and 95th Percentiles of Confidence Levels)

	Atlanta			Boston			Chicago			DC			Detroit			New York			Philadelphia		
	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th	5th	50th	95th
Total	33	86	134	48	65	78	-62	14	33	62	94	118	5	16	39	-27	74	276	45	105	125
CENRAP	1	1	1	0	0	0	4	5	5	1	1	1	2	2	2	1	1	1	1	1	1
LADCO	1	1	1	1	2	1	-35	1	10	3	3	3	0	6	11	7	7	6	4	4	4
OTR	2	1	1	19	27	33	0	0	0	15	32	45	1	1	1	-75	-12	100	10	37	47
SEMAP	11	38	64	1	1	1	1	0	0	7	7	6	1	1	1	10	10	11	5	5	4
CENRAP _EGU	1	1	1	0	0	0	5	5	5	1	1	1	2	2	2	1	2	1	1	1	1
LADCO _EGU	1	1	1	2	2	2	-37	1	12	4	4	4	-2	3	20	10	10	10	5	5	5
OTR _EGU	2	2	2	23	31	38	0	0	0	24	40	53	1	1	1	9	47	138	15	48	59
SEMAP _EGU	15	41	63	1	2	1	1	1	1	8	7	7	1	1	1	9	10	10	5	5	5

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Summary

- Sensitivity analysis is useful for estimating the contribution of transported air pollutants to peak ozone formation and premature mortality incidences.
- Reductions in cross-region transport of emissions could decrease ozone-related mortalities in MSAs in the eastern U.S.
- The mortality results for NYC and DC could be overestimated since ozone concentrations were over-predicted in those two cities.
- The method and results used in this study can be applied to develop effective regional air quality management strategies that protect human health.

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Acknowledgement

This work was supported by the U.S. EPA STAR grant R835218, and the Maryland Department of the Environment for providing meteorological and emission data used in air quality modeling.

The authors acknowledge the Texas Advanced Computing Center (TACC) at The University of Texas at Austin for providing HPC resources that have contributed to the research results reported within this study. URL: http://www.tacc.utexas.edu

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