Ozone, Air Pollution and Sprawl

a perspective (and analysis tools) from the
Ozone Research Center
and the
Center for Exposure and Risk Modeling
at EOHSI

Presented at the
Science of Sprawl (SOS) Conference
May 1, 2003 • Trenton, NJ

by
Panos G. Georgopoulos

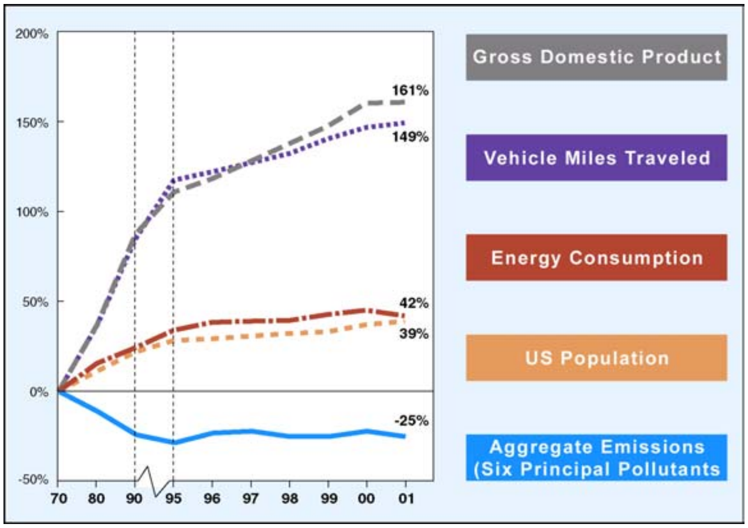
Computational Chemodynamics Laboratory
(www.ccl.rutgers.edu)
Environmental and Occupational Health Sciences Institute (EOHSI)
A joint project of UMDNJ – RW Johnson Medical School and Rutgers University
170 Frelinghuysen Road, Piscataway, NJ 08854

Sprawl, Environmental Quality, and Public Health Issues

Low-density/segregated land use:

- Stresses environmental resources
  - *Release, transport/mixing/fate of contaminants over multiple spatial scales*
  - *"Diffuse" resources use of (e.g. drinking water) makes quality control difficult*
  - *Changes in land cover expand urban heat island effects*
- Increases reliance on automobiles for transportation
  - *Increased Vehicle Miles Traveled (VMTs) and congestion/delays*
    - Additional contaminant releases (offset technology gains)
  - *Loss of useful time in commuting, increase of commuting stress*
  - *Changes in human activity patterns (e.g. less walking)*
  - *Increased risks for accidents (crashes, pedestrian): no sidewalks, wide roads*
- Creates inequities
  - *Loss of economic opportunity for some groups (especially inner cities)*
  - *Environmental justice issues*

USEPA Comparison of Critical Trends, Including VMTs



Between 1970 and 2001, gross domestic product increased 161 percent, vehicle miles traveled increased 149 percent, energy consumption increased 42 percent, and U.S. population increased 39 percent. At the same time, total emissions of the six principal air pollutants decreased 25 percent. (Source: USEPA, 2001)

Sprawl Affects Air Quality in Multiple Ways

Via the increase in VMTs and congestion (most obvious)

- Increased emissions of pollutants and greenhouse gases
  - *Primary criteria pollutants (e.g. CO)*
  - *Many air toxics (e.g. benzene, formaldehyde)*
  - *Precursors (VOCs and NOx) to secondary pollutants such as ozone and photochemical aerosol*

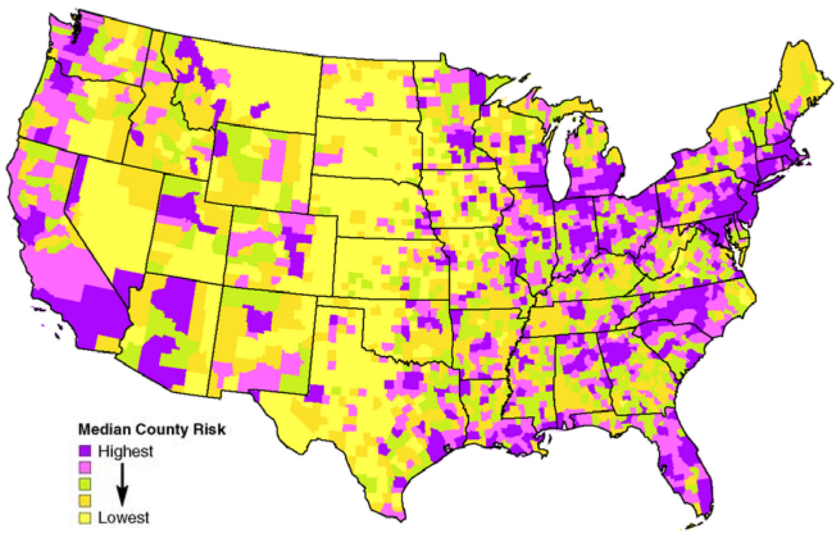
By providing extended spatial temporal scales for air chemistry

- Secondary pollutants are formed in the air through chemical reactions involving precursors and solar radiation
  - *Lower reactivity precursors are given enough time to "cook"*
  - *Mixing of "fresh" and "aged" contamination complicates control*
  - *Everybody gets to be "downwind"…*

Via positive feedbacks with heat island effects

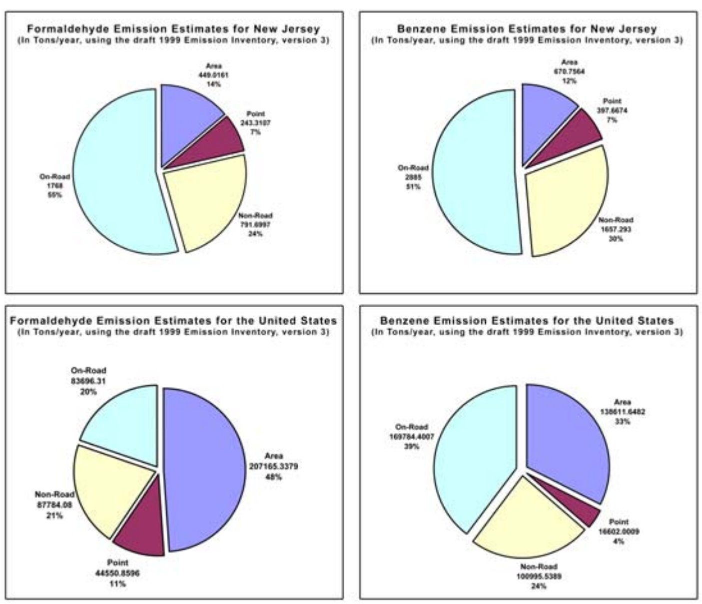
- Higher temperatures both affect chemistry and raise energy use and therefore emissions…

County Level Comparison of Risk for Air Toxics Estimated by USEPA's National Scale Assessment (1996 NTI)



Source:
USEPA, 2002

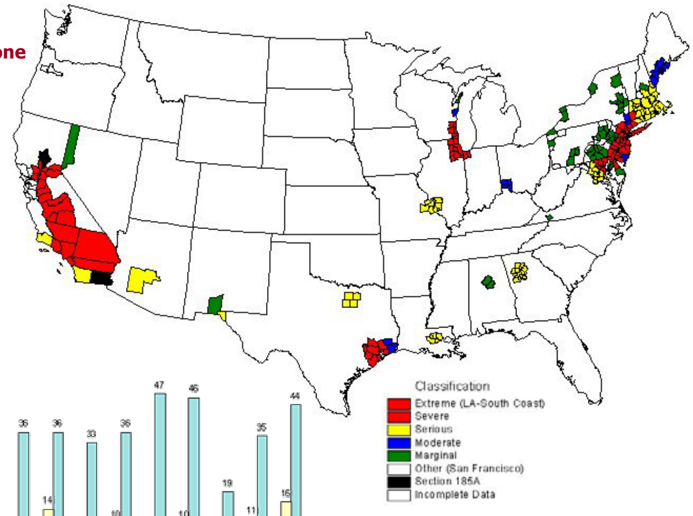
Contribution of Mobile Sources to Emissions of Air Toxics

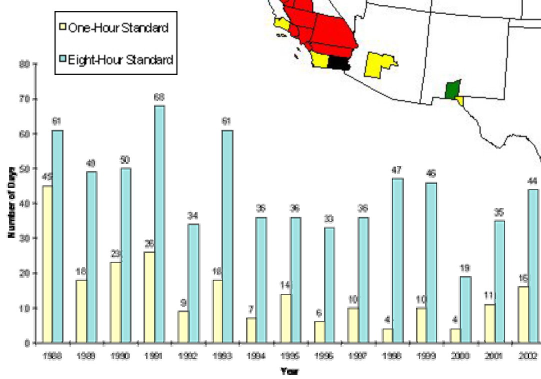


Ozone, Air Pollution and Sprawl
Computational Chemodynamics Laboratory

The Ozone Problem is Persistent Across the US – Particularly Critical for New Jersey (Statewide Nonattainment of the Standard)

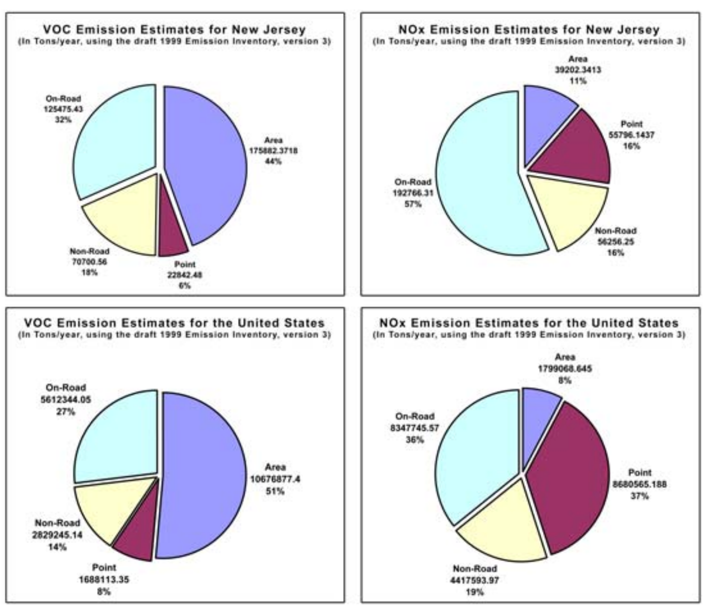
Counties Designated Nonattainment for Ozone (Source, USEPA, 2002)



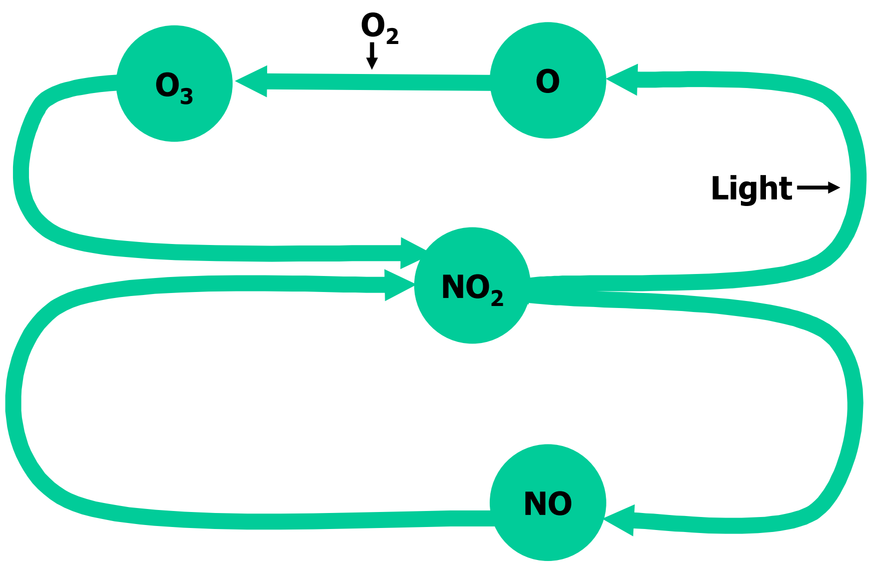


Days of Exceedances of the Ozone Standard in New Jersey, 1988-2002 (Source: NJDEP, 2003

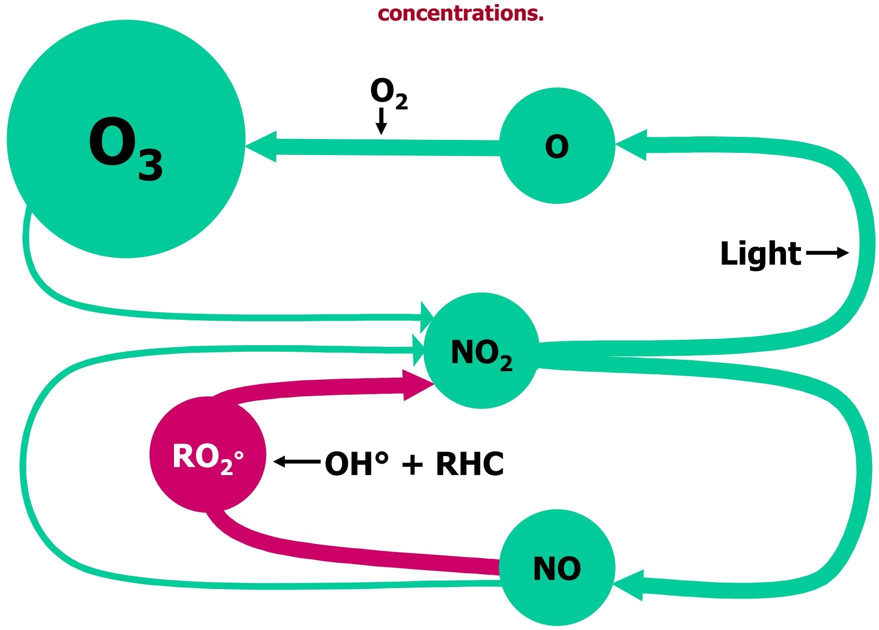
Contribution of Mobile Source Emissions to Ozone Precursors



Photochemistry 000: Dissociation of nitrogen dioxide by sunlight forms equal numbers of nitric oxide molecules and oxygen atoms which convert oxygen to ozone. Ozone and nitric oxide react to reform nitrogen dioxide.



In air contaminated with reactive hydrocarbons and hydroxyl radicals, peroxy radicals are formed. These oxidize nitric oxide to nitrogen dioxide. This process leaves very little of the nitric oxide to react with ozone and in this way ozone builds up to large concentrations.



A Framework for Assessing Exposure to Ozone, PM, and Air Toxics over Multiple Scales:Models-3/CMAQ and MENTOR - OPERAS

Emissions: NEI (NET, NTI), State; Processing with SMOKE, (EMS-HAP, MOBILE, NONROAD, FAAED, BEIS), etc.
Meteorology: NWS, NCDC; Modeling MM5, RAMS, CALMET
Land Use/Land Cover: NLDC (USGS); Demographics: USCB

Emissions: EMS-HAP
Meteorology - Local Effects: RAMS, FLUENT

1. Estimate background levels of air pollutants through either:
   a. multivariate spatiotemporal statistical analysis of monitor data
   b. emissions-based air quality modeling (typically with regional, grid-based model such as Models-3/CMAQ)

2. Estimate local outdoor pollutant levels that characterize the ambient air of an administrative unit (such as a census tract) or a conveniently defined grid through either
   a. spatiotemporal statistical analysis of monitor data
   b. application of urban scale model at high resolution
   c. physical "correction" of the estimates of the regional model

3. Estimate levels and temporal profiles of pollutants in various microenvironments (streets, residences, offices, restaurants, vehicles, etc.) through either
   a. regression of observational data
   b. simple linear mass balance
   c. detailed (nonlinear) gas/ aerosol chemistry models
   d. detailed combined chemistry & CFD models.

Calculate Potential Outdoor Exposures

7. Combine intake rates and microenvironmental concentrations for each activity event to assess exposures

4. Characterize relevant attributes of populations (geographic density, age, gender, race, income, etc.)
   a. select fixed-size sample population that statistically reproduces essential demographics or
   b. divide population of interest into exhaustive set of cohorts

5. Develop activity event (or exposure event) sequences for each member of the sample population or for each cohort for the exposure period through either:
   a. existing databases based on composites of questionnaire information from past studies, or
   b. study-specific information, if available

6. Calculate appropriate inhalation rates for the members of the sample population combining the physiological attributes of the study subjects and the activities pursued during the individual exposure events

US Census, US Housing Survey, Local Data

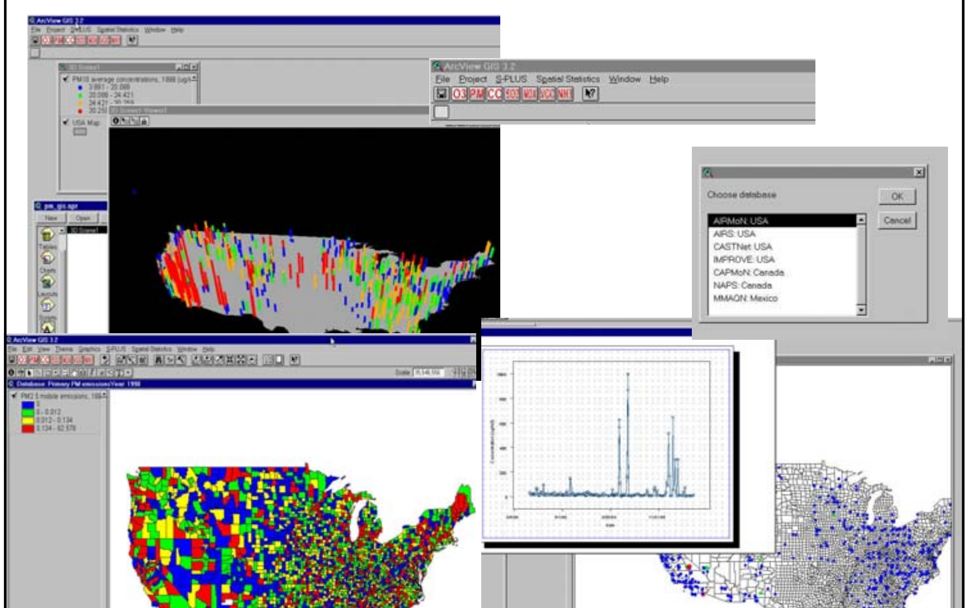
CHAD, NHAPS

ICRP and Other Physiological & METS Databases

MENTOR: Modeling Environment for Total Risk studies; OPERAS: Ozone and Particle Exposure and Risk Analysis Systems; CMAQ: Community Multiscale Air Quality model; NEI: National Emissions Inventory

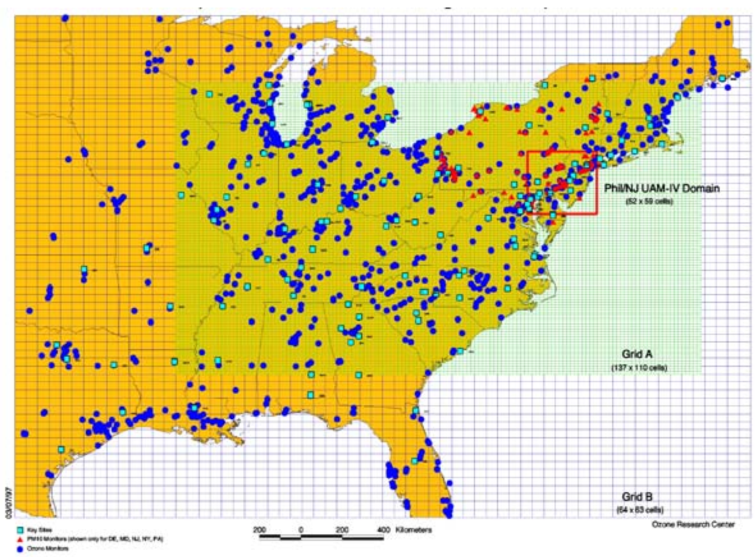
Ozone, Air Pollution and Sprawl — Computational Chemodynamics Laboratory

Example Screens of MENTOR-OPERAS (previous release)

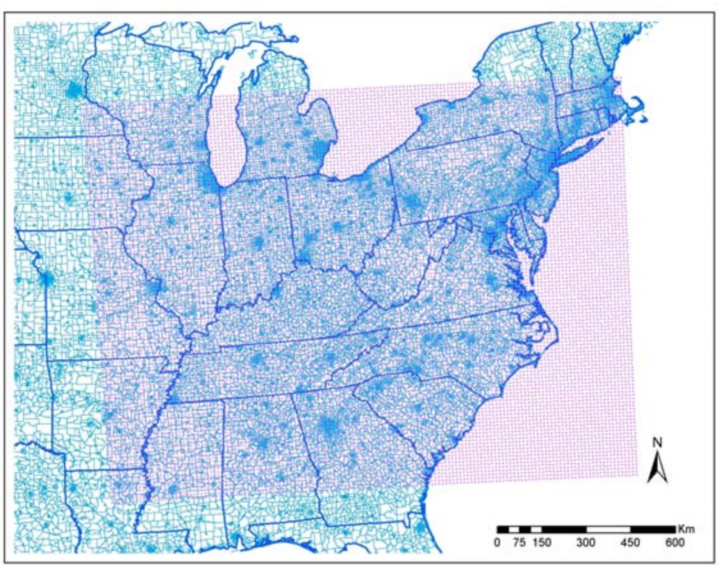


Ozone, Air Pollution and Sprawl — Computational Chemodynamics Laboratory

Nested OTAG (Ozone Transport Assessment Group) Modeling Domains: Efforts in the Mid-Late '90s Applied Mostly UAM-V to Ozone Episodes from 1988 to 1995; Currently we are Focusing on the Summer of 1999 Using CMAQ



Census Tracts within the "Intermediate" Grid of CMAQ/MENTOR: The "NE Corridor" (Boston-Washington) Area "Behaves" as One Sprawling Metropolis

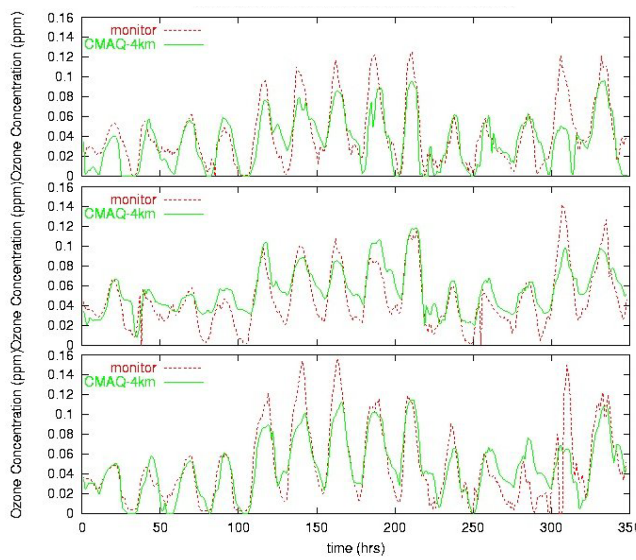


Example Comparisons of CMAQ Predictions with Hourly Observations of Ozone in New Jersey for July 11 - 24, 1999

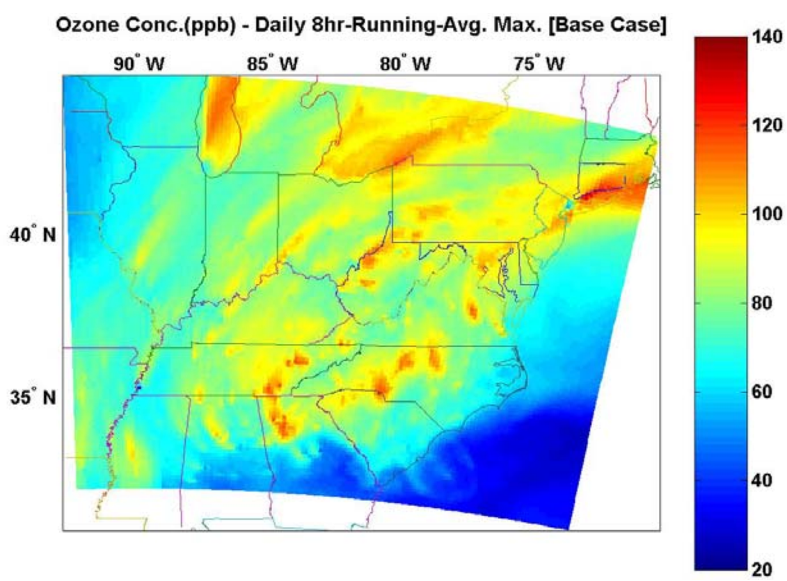
Camden 1

Camden 2

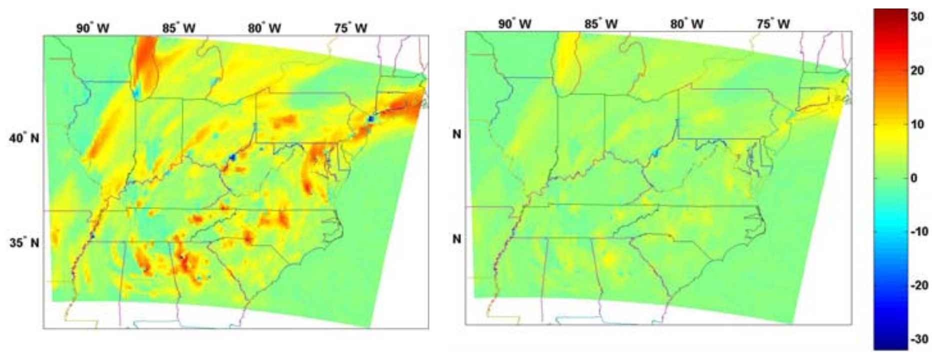
Middlesex



Example: Daily Maxima of 8-hr Average Ozone Concentrations (7/16/1999) for the Inner OTAG Domain (Calculated Using Models-3/CMAQ)



Relative Effectiveness of VOC vs NOx Intensive Controls in Reducing Daily Maxima of 8-hr Average Ozone Concentrations: NOx Controls More Effective



Difference of base case results minus NOx-intensive strategy

Daily maxima of 8-hr average ozone concentrations (ppb)

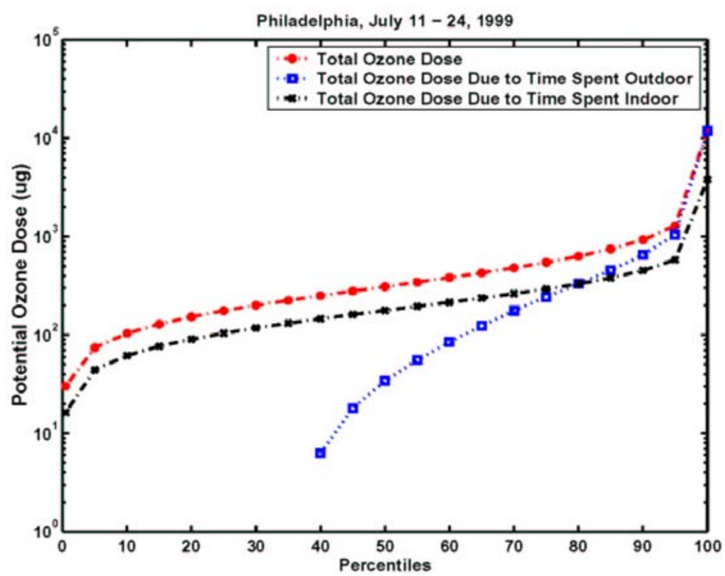
(CMAQ calculations for 7/16/1999)

Difference of base case results minus VOC-intensive strategy

Daily maxima of 8-hr average ozone concentrations (ppb)

(CMAQ calculations for 7/16/1999)

Example of a Source-to-Dose Application of CMAQ/MENTOR: Calculated Cumulative Distributions of O_3 Doses for 482 Census Tracts in Philadelphia (Information Needed to Support and Interpret Health Studies)



Some of the General Findings for New Jersey (and the Northeast)

The Eastern United States are one airshed

- Only regional strategies can work

The NE Corridor (Boston-Washington) is one sprawling metropolis

- Managing sprawl and emissions must consider multiple MSAs simultaneously

New Jersey is always downwind

- Even if all anthropogenic emissions were eliminated NJ would still be in non-attainment

NOx controls are more effective regionally than VOC controls

- But must be implemented carefully regionally/locally

Different subregions respond differently to the same controls

- E.g., a strategy that benefits NJ may worsen air quality in NYC

Acknowledgements

NJDEP

- Base funding for the Ozone Research Center (ORC) at EOHSI

USEPA

- Base funding for the Center for Exposure and Risk Modeling (CERM) at EOHSI
  - *Development of MENTOR (Modeling Environment for Total Risk studies) and MENTOR-OPERAS (Ozone and Particles Exposure and Risk Analysis Systems)*
- Funding for OTAG Regional Analysis; Development of Uncertainty Analysis Tools for Models-3; NARSTO-NEOPS, and other studies

NIEHS

- Base funding for the Center of Excellence in Environmental Health Sciences at EOHSI