Near-Roadway Exposures: Land-Use Regression and SHEDS Exposure Modeling

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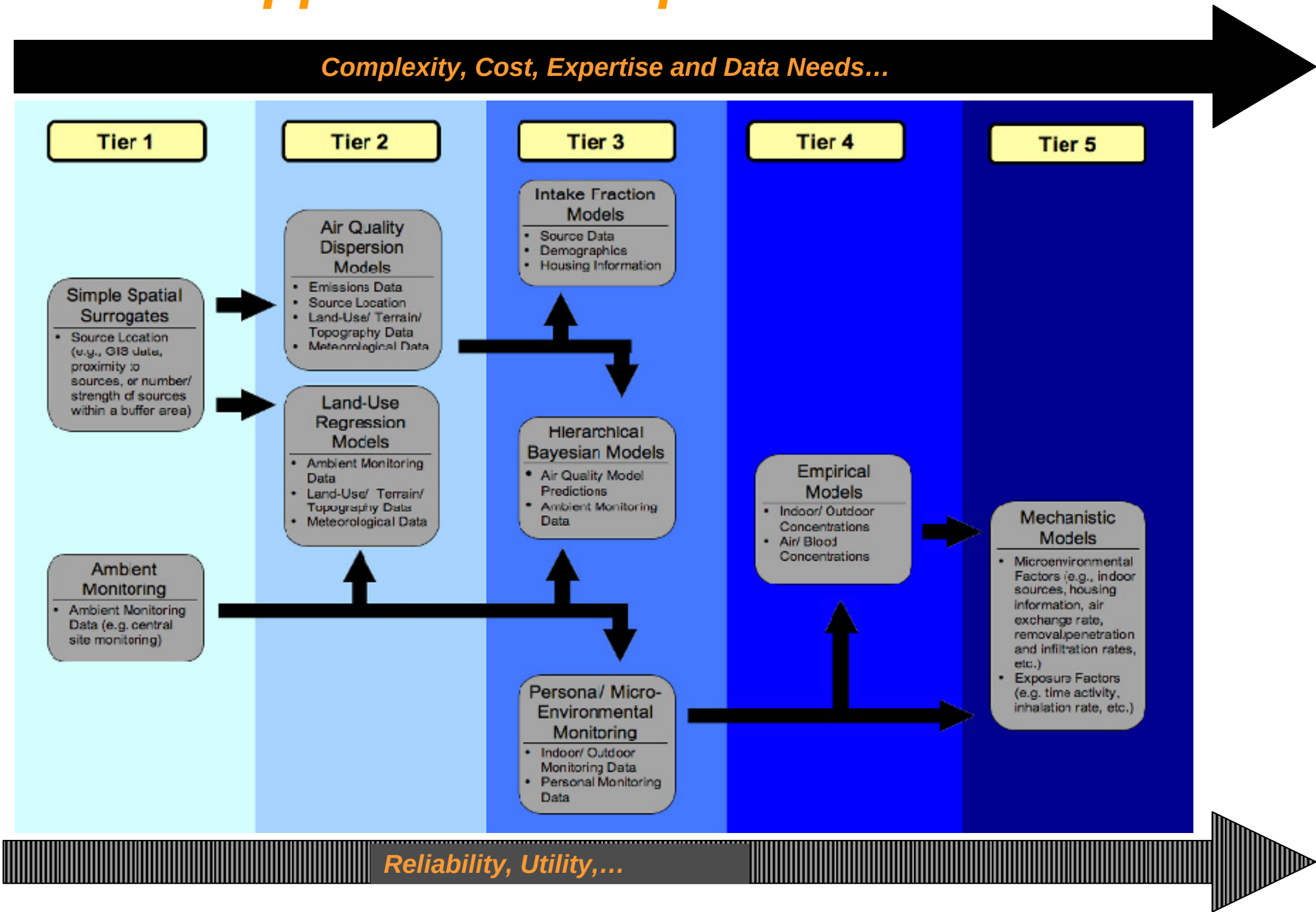
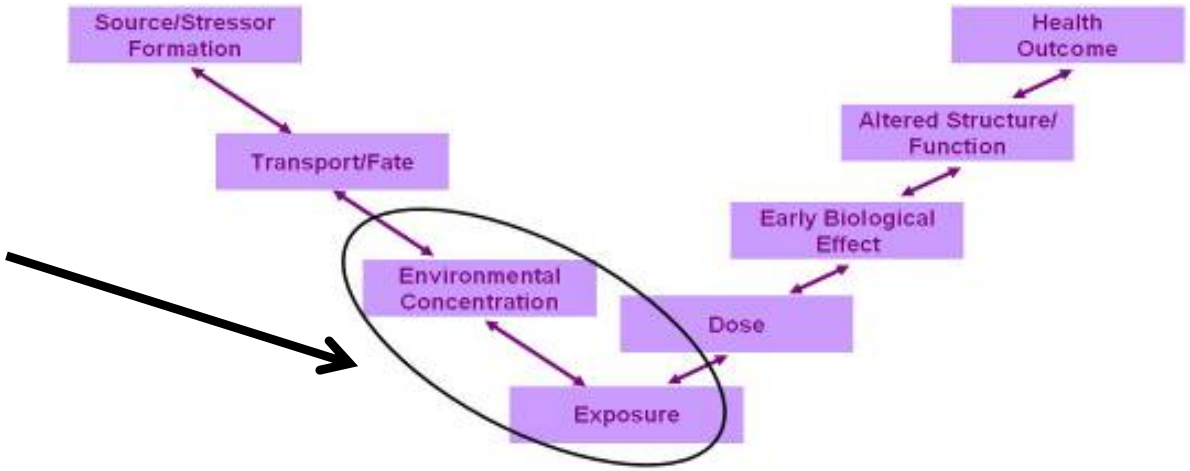
U.S. Environmental Protection Agency

EPA/CDC Symposium on Air Pollution Exposure and Health
September 19-20, 2006

Tiered Approach to Exposure Assessment



Predicting Exposures from Modeled Concentrations



Why is this important?

- **To increase the accuracy and precision of exposure assignments made to study subjects or populations groups of concern**
- **To improve the design of community health studies and the interpretation of findings derived from them**
- **To assist in the development of optimum risk mitigation strategies:**
  - ✓ **Target emissions reductions towards principal sources of pollutants**
  - ✓ **Identify exposure mitigation strategies that reduce personal or population exposures in the relevant microenvironments**
- **To support environmental health accountability programs that demonstrate the public health benefits from emissions controls**

Estimators of Ambient Concentrations

- **County-level roadway density**
- **Assignment to nearest monitor**
- **Interpolation of urban monitors**
- **Self-perceived exposure**
- **Univariate proximity measures**
- **Emission-based diffusion models**
- **Land-use regression models**
- **Personal / residential exposure measures**
- **Exposure biomarkers**

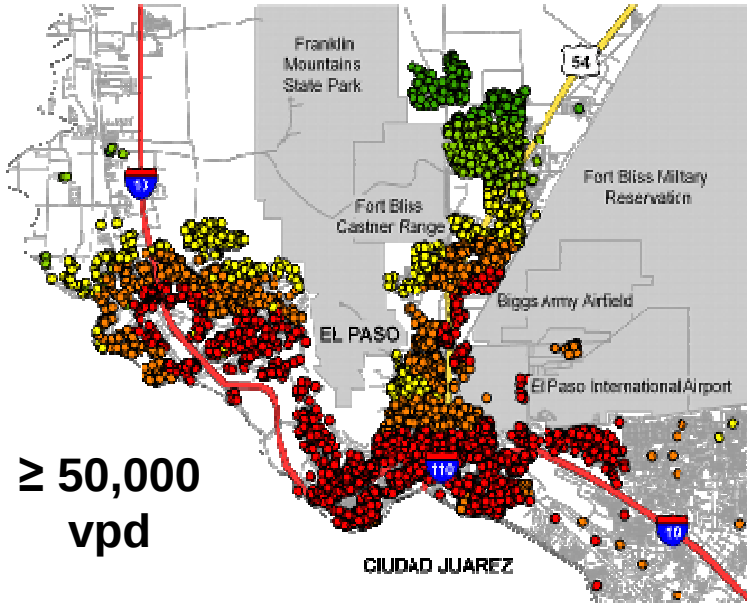
Univariate Proximity Measures

- **Proximity of residence to "major" road**
  - **Distance (m) to nearest road with Y+ vehicles / day**
  - **Residence within X m of nearest road with Y+ vehicles / day**
- **Traffic volume / intensity**
  - **Vehicles / day for nearest road with Y+ vehicles / day**
  - **Total vehicles / day of major roads within X m circular buffer**
- **Traffic density**
  - **Weighted average of volume of all roads within X m buffer**
- **Roadway density**
  - **Total length of roads within X m circular buffer**
  - **Total surface area of roads within X m circular buffer**

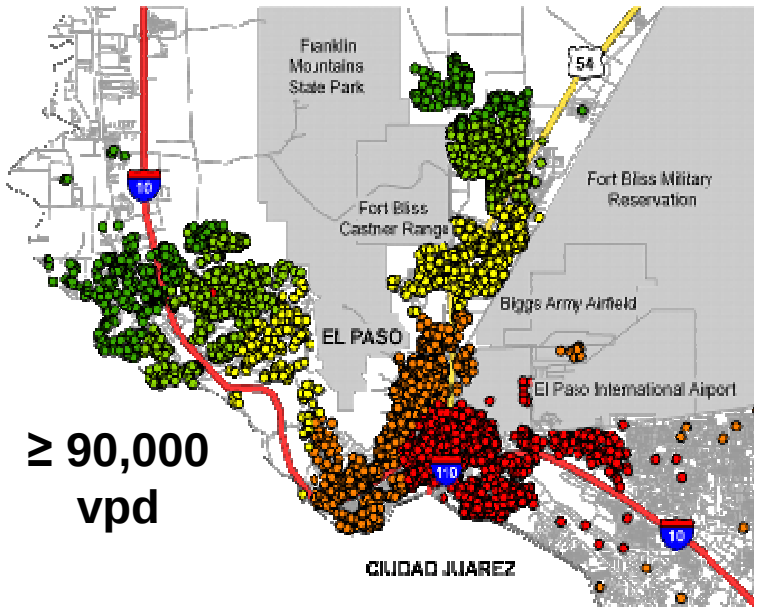
Refinements: Total vehicles / cars / trucks
Continuous / quantiles / dichotomous

Univariate Measures in El Paso

Traffic Proximity

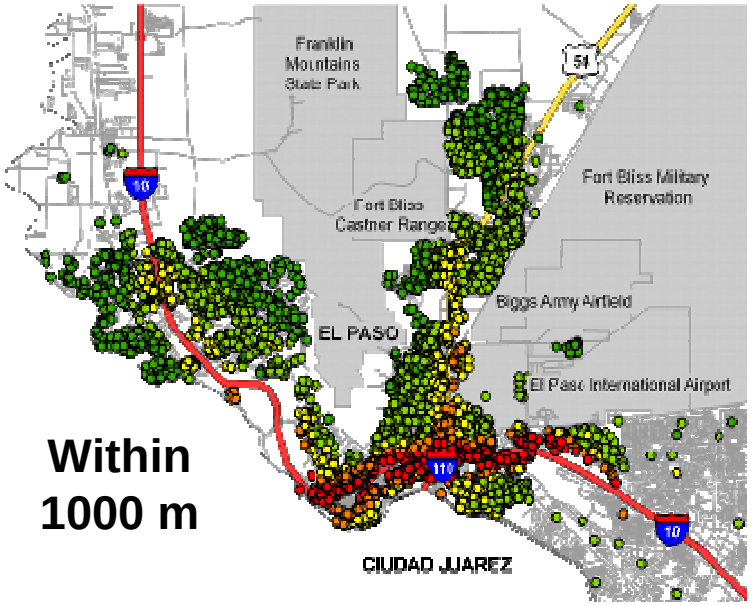


≥ 50,000 vpd

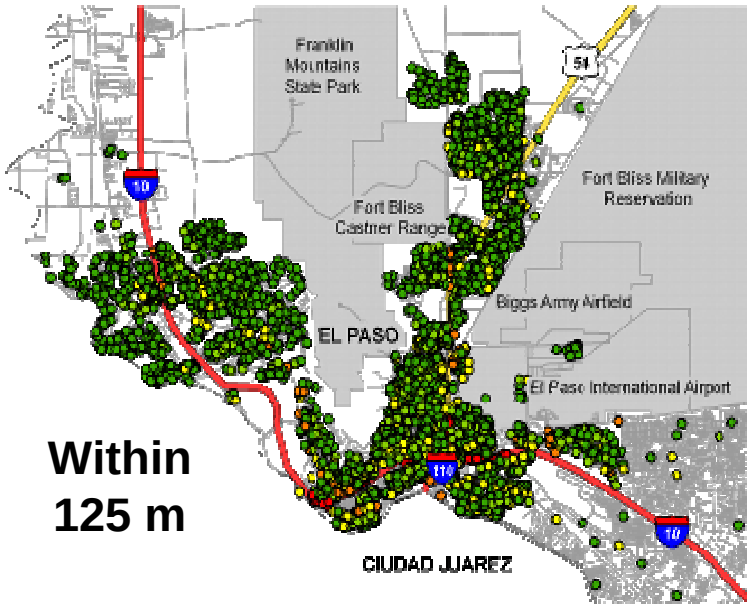


≥ 90,000 vpd

Traffic Intensity

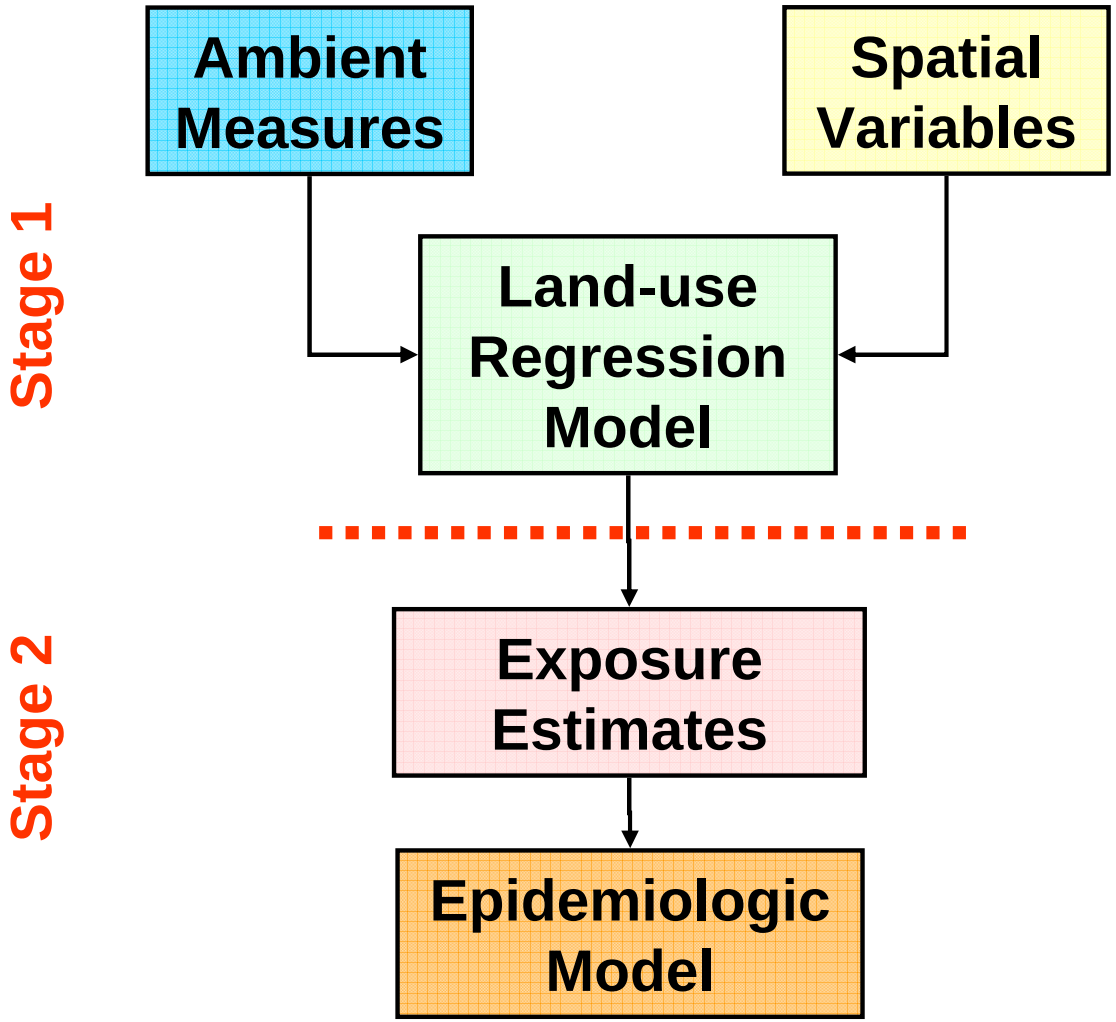


Within 1000 m

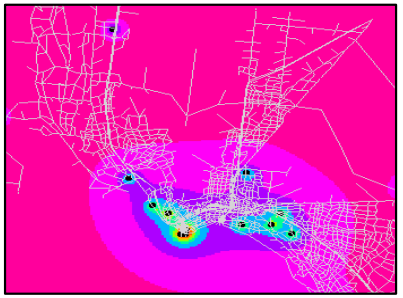


Within 125 m

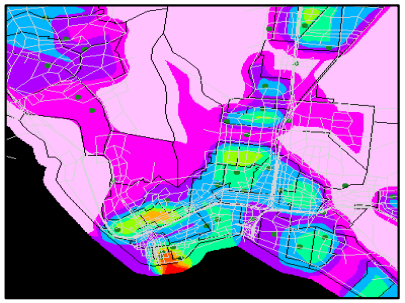
Land-Use Regression Modeling



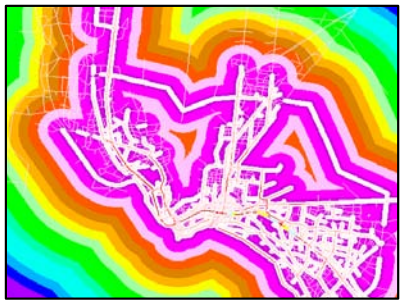
Point Sources



Area Sources



Line Sources



Land-use Regression Example: El Paso Model

Linear variables:

- **Elevation**
- **Distance to road with ≥ 90,000 vpd**
- **Traffic intensity within 1000 m**

Toluene

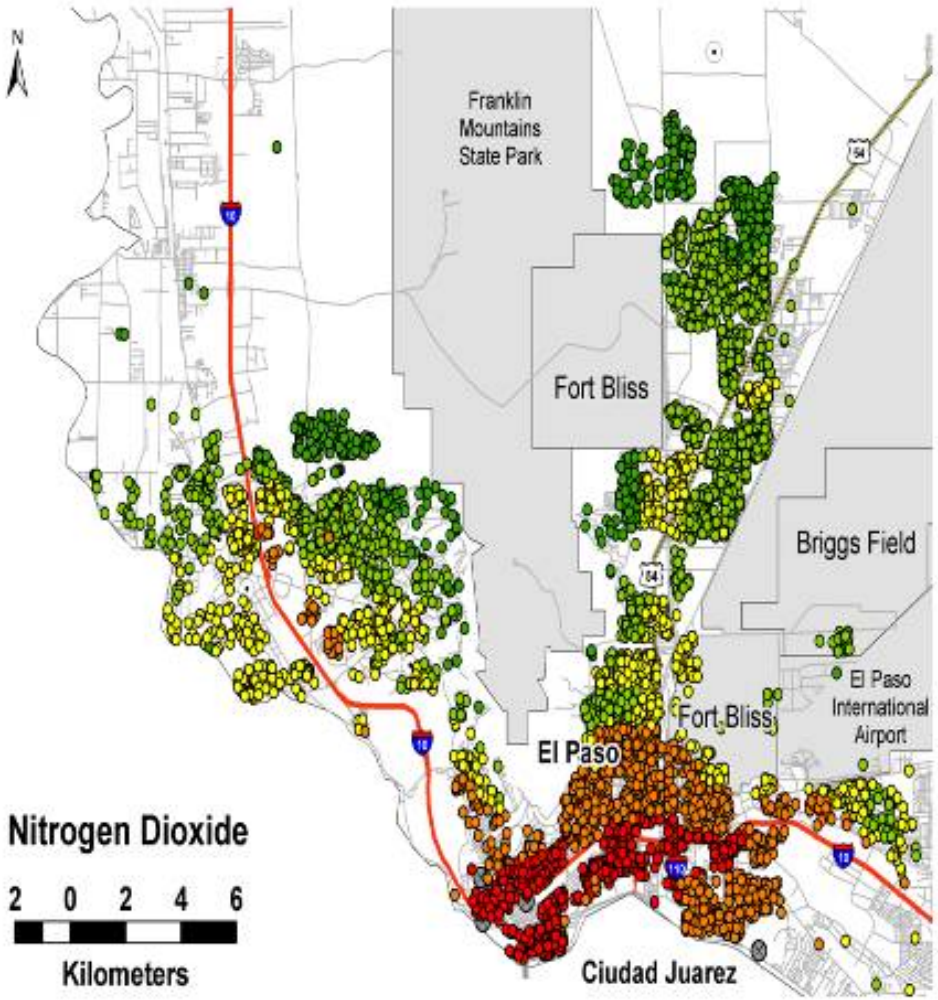
NO_2

Non-linear variables (LOESS):

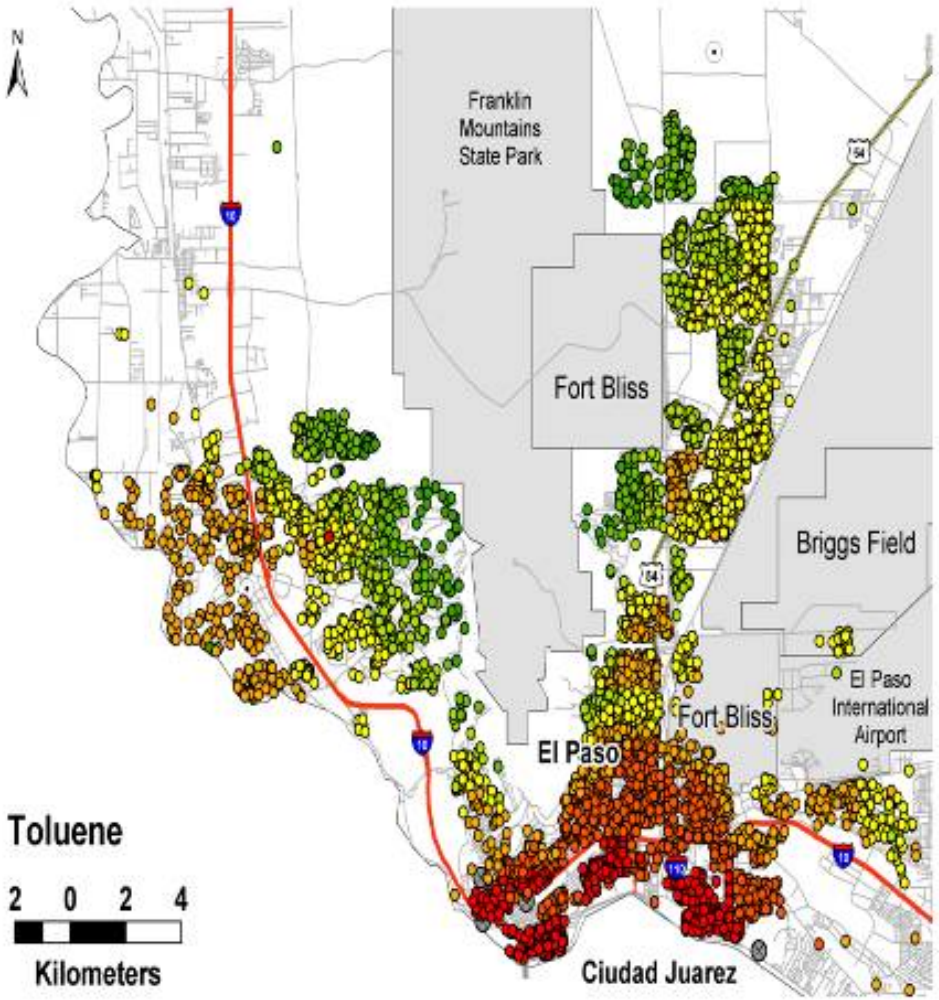
- **Population density (minor roads)**
- **Distance to nearest border crossing**
- **Distance to petroleum refinery**

NO_2 R^2 = 0.97 **Toluene R^2 = 0.93**

Estimated Ambient Concentrations

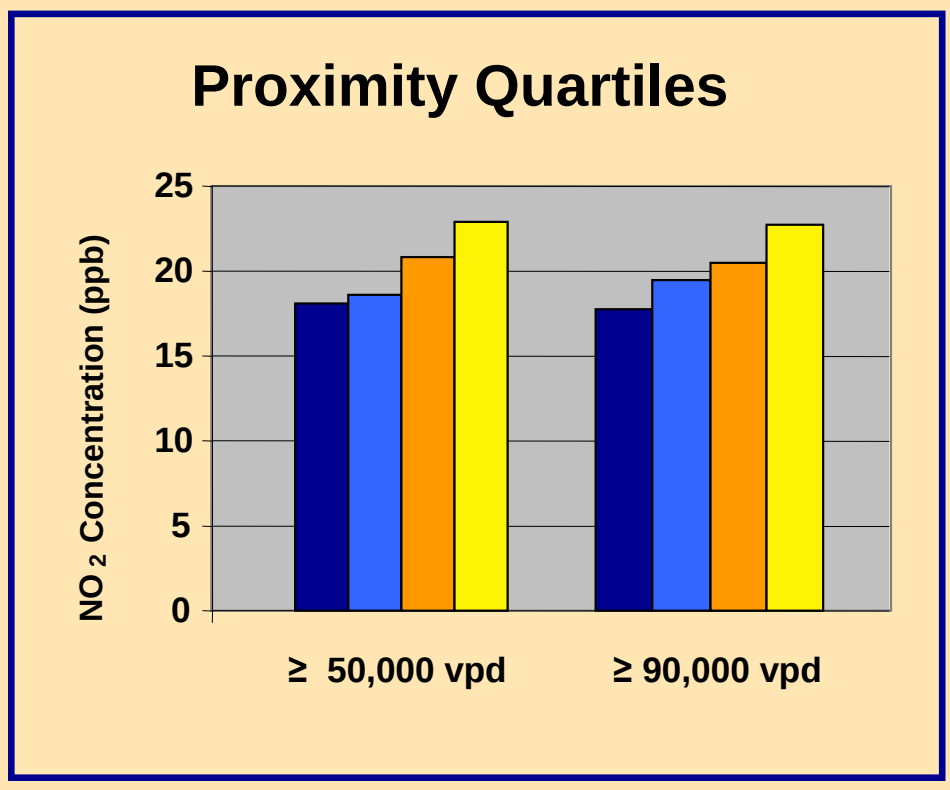


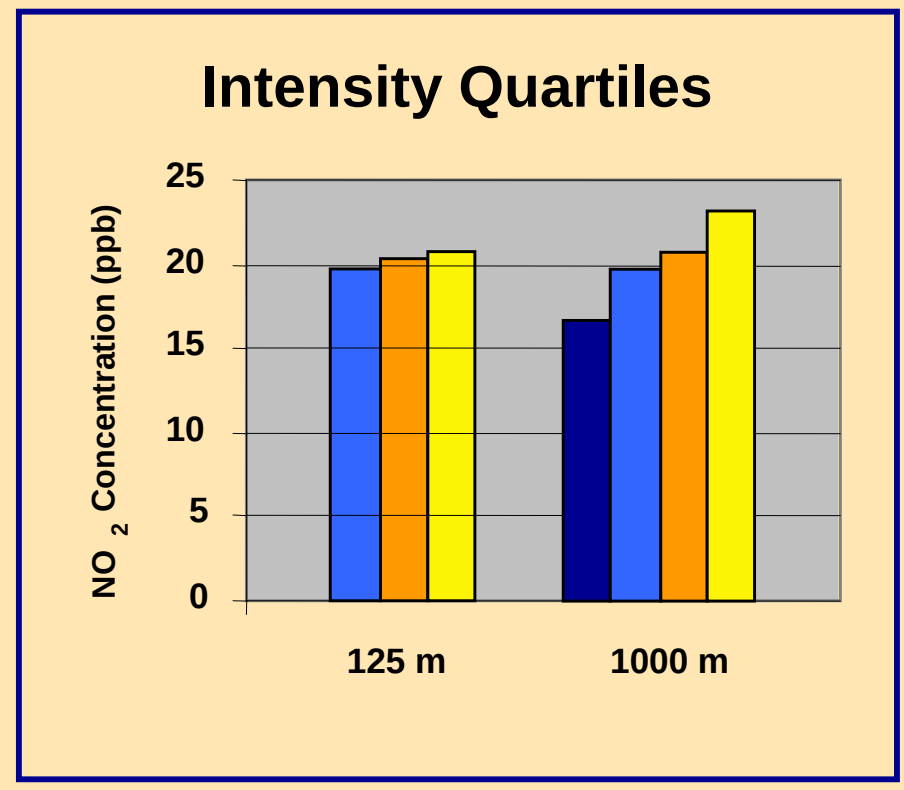
Combustion



Petroleum

Estimated NO_2 by Traffic Quartiles In El Paso





As expected from their inclusion in the LUR model, estimated NO_2 co-varies with proximity and intensity.

Future of LUR Models

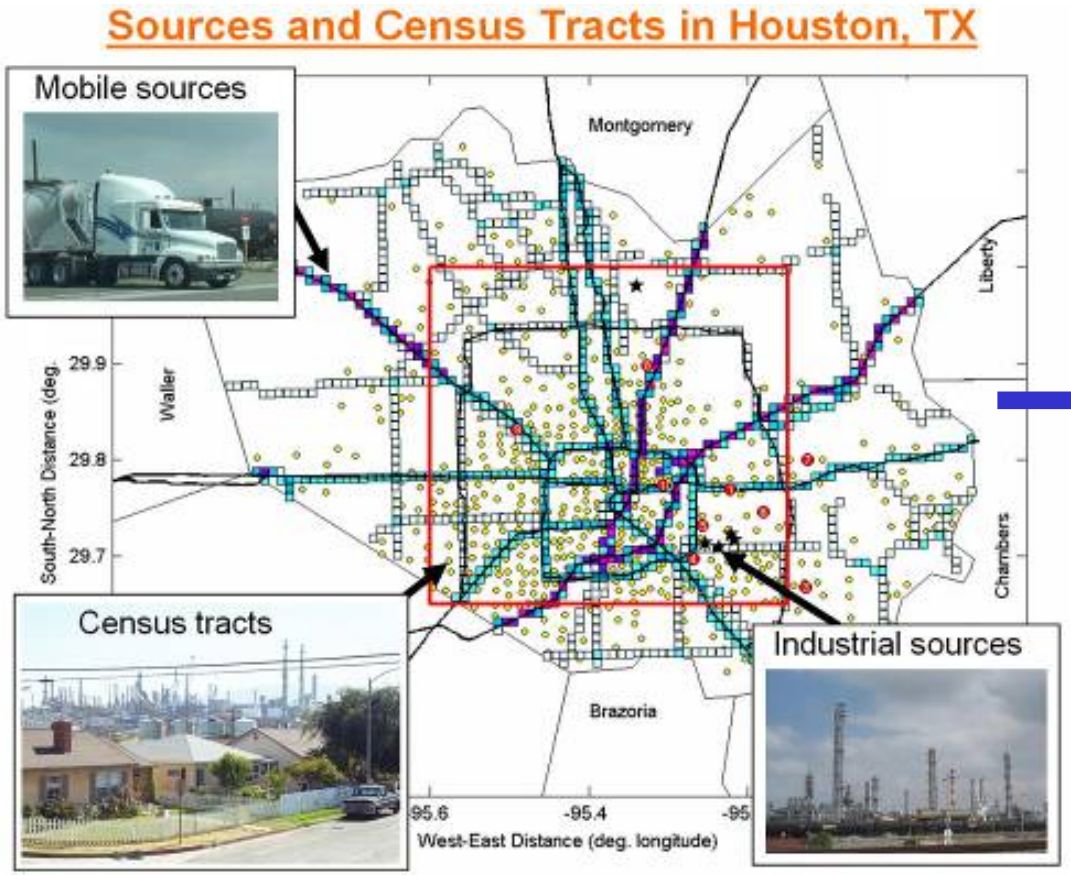
Exposure Assessment

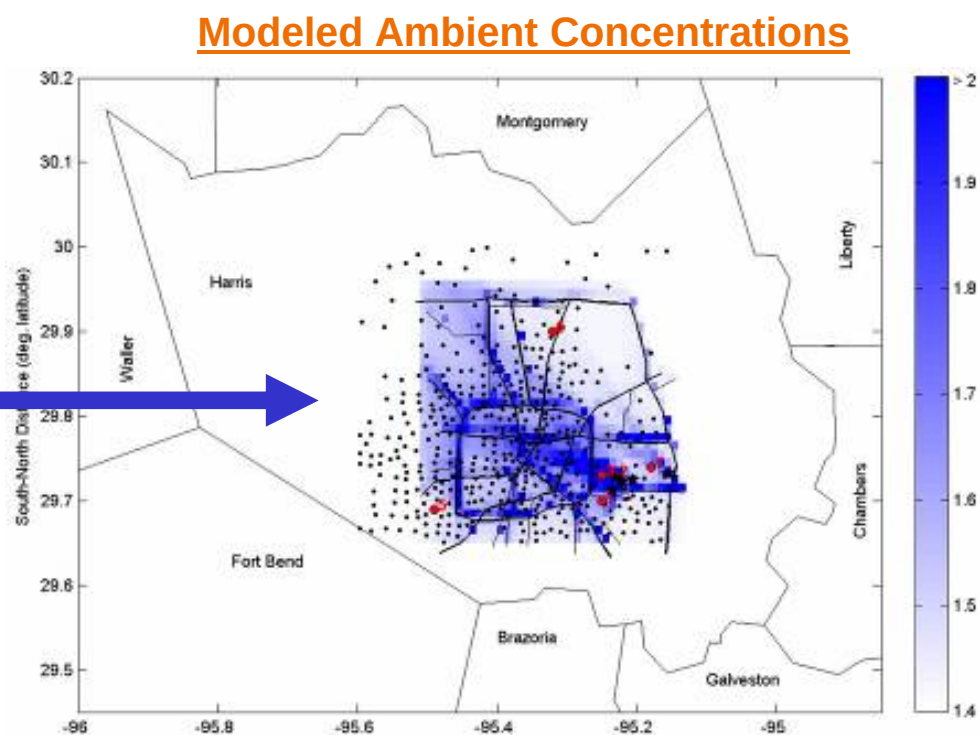
- **Standardization of traffic metrics?**
- **Are LUR models transferable to other cities?**
- **Comparison with diffusion models?**

Epidemiology

- **Meta-analysis of traffic metrics?**
- **What is the causal agent (latent variable)?**
- **Two-stage modeling approach?**
- **Health effects beyond tight roadway buffer?**

Modeling Ambient Concentrations



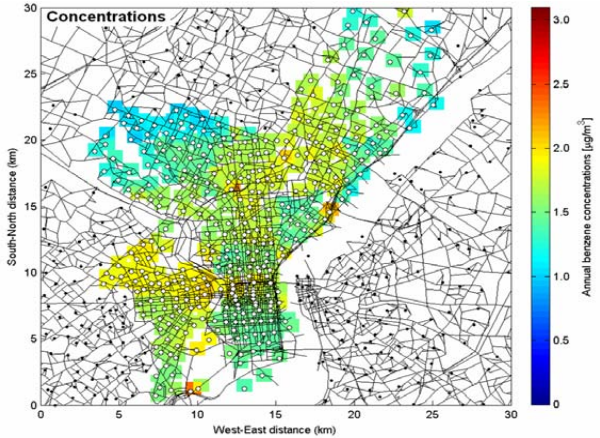


Input Needs

- ***Detailed emissions inventories and meteorological data***
- ***Modeling tools to resolve local scale features and chemical transformations***

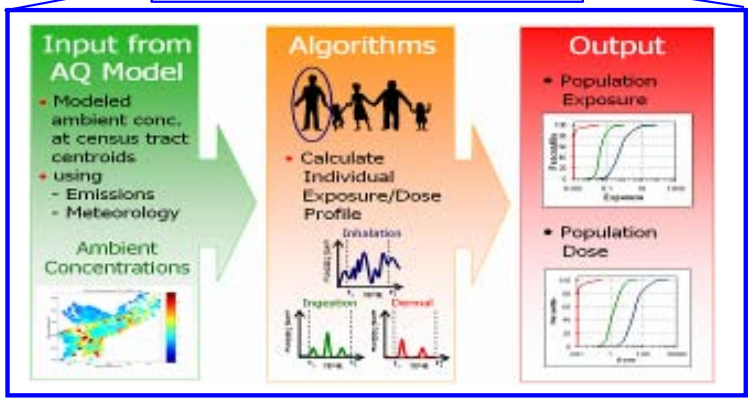
Modeling Population Exposures

Ambient Concentrations

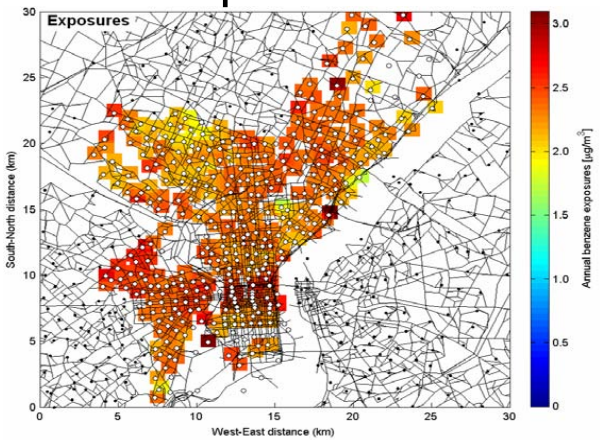


Exposure Modeling

- Indoor Penetration
- Personal Sources
- Human Activity



Exposures



Input Needs

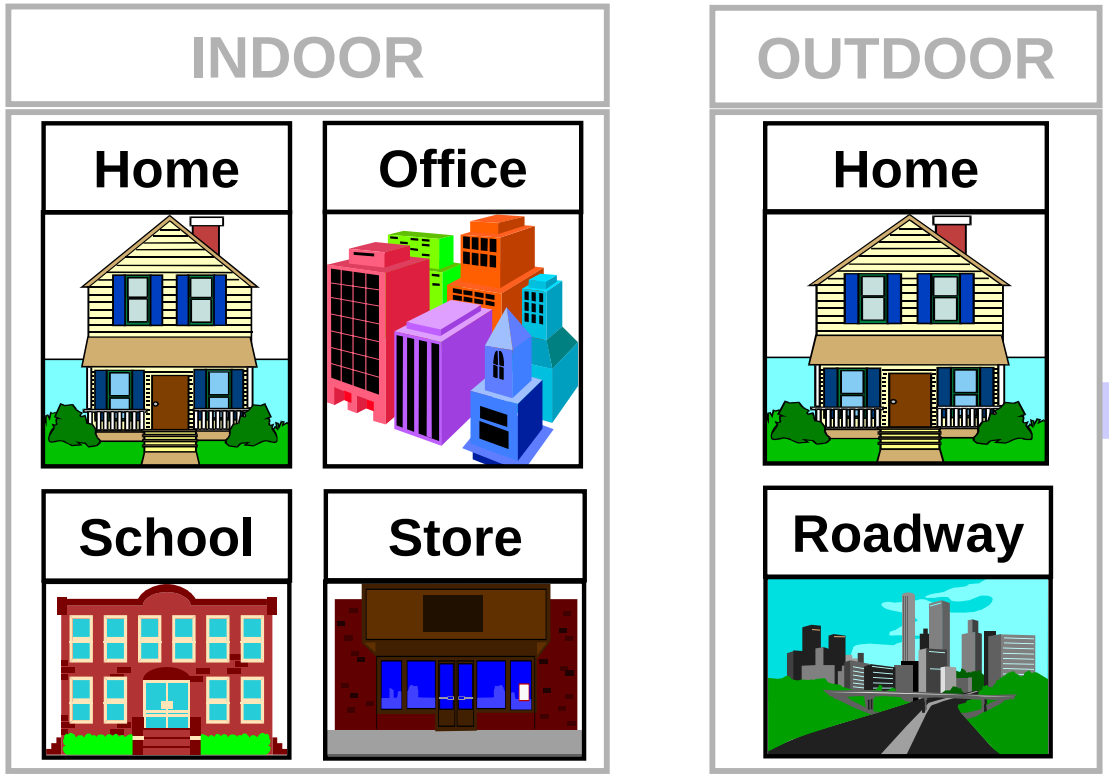
- ***Spatially and temporally resolved concentrations***
- ***Demographics and commuting data, human time-activity, physical factors and information on source strengths and concentration relationships for the different microenvironments***
- ***Modeling algorithms and computational tools to estimate exposures***

Modeling PM Exposures: SHEDS

Outdoor PM Sources

Indoor PM Sources

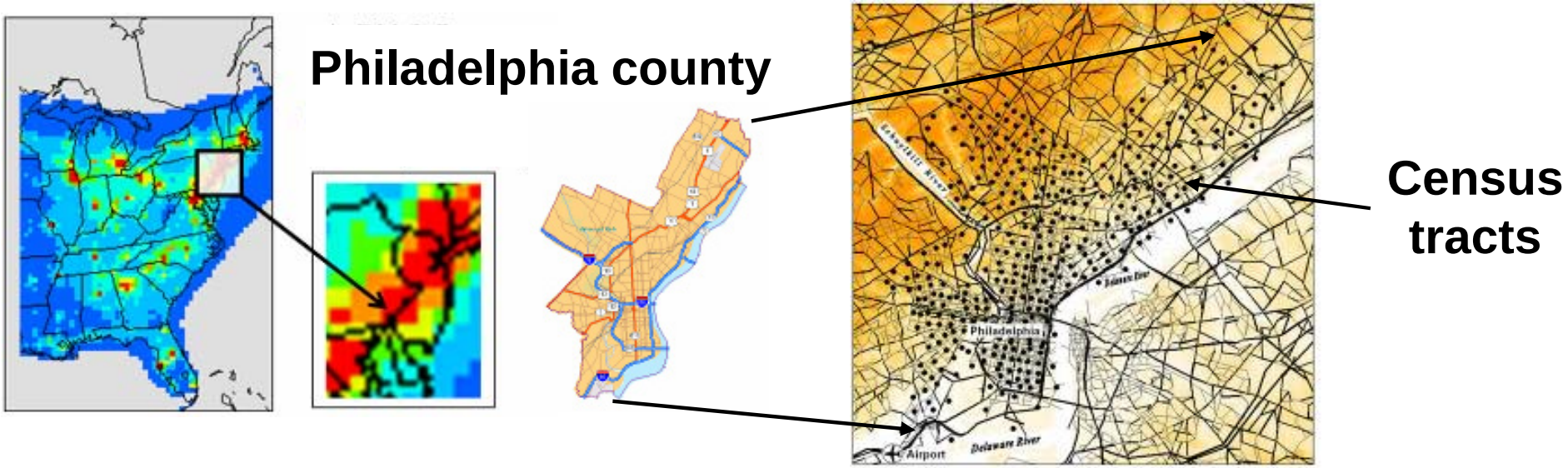
Microenvironmental PM Concentrations

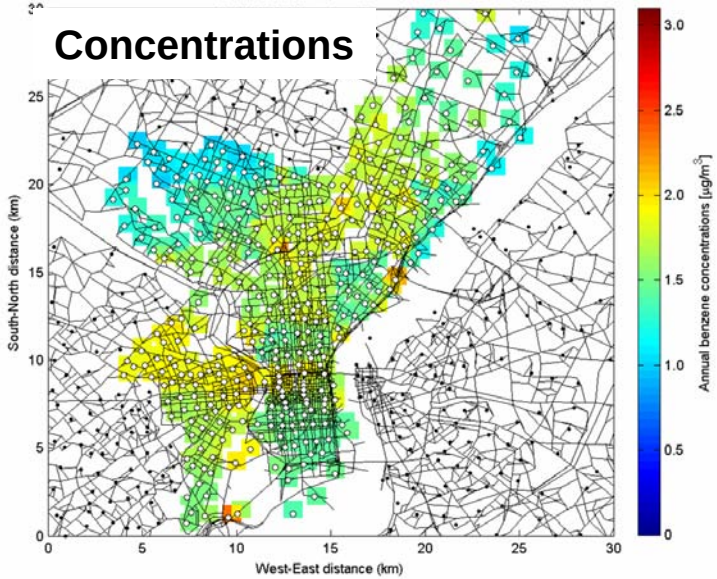


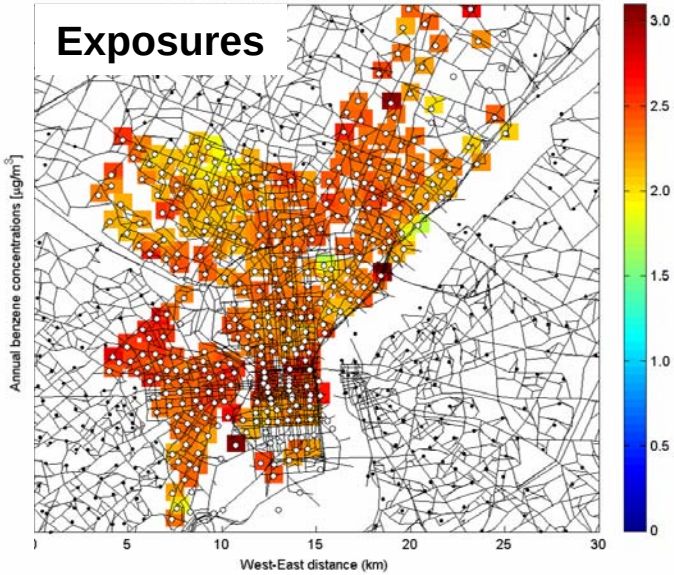
Exposure

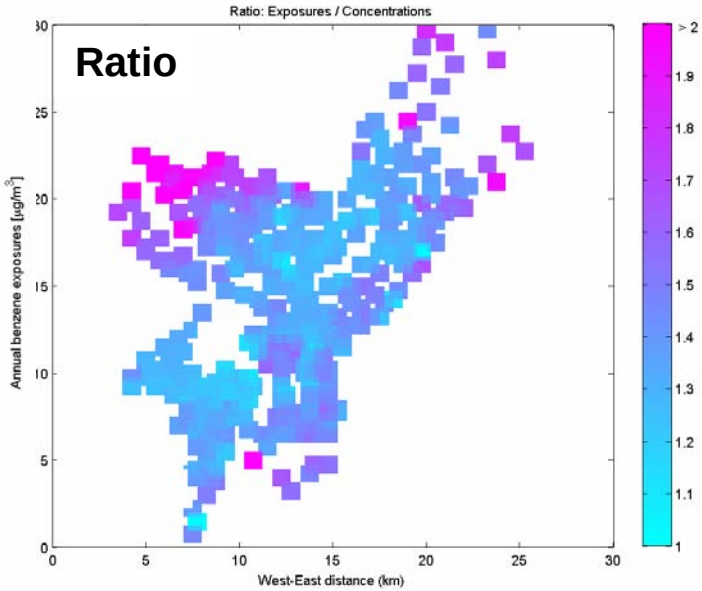
Calculated using outdoor PM concentration in mass-balance or land-use regression equations developed from measurement data

Benzene Exposure Modeling Example in Philadelphia, PA



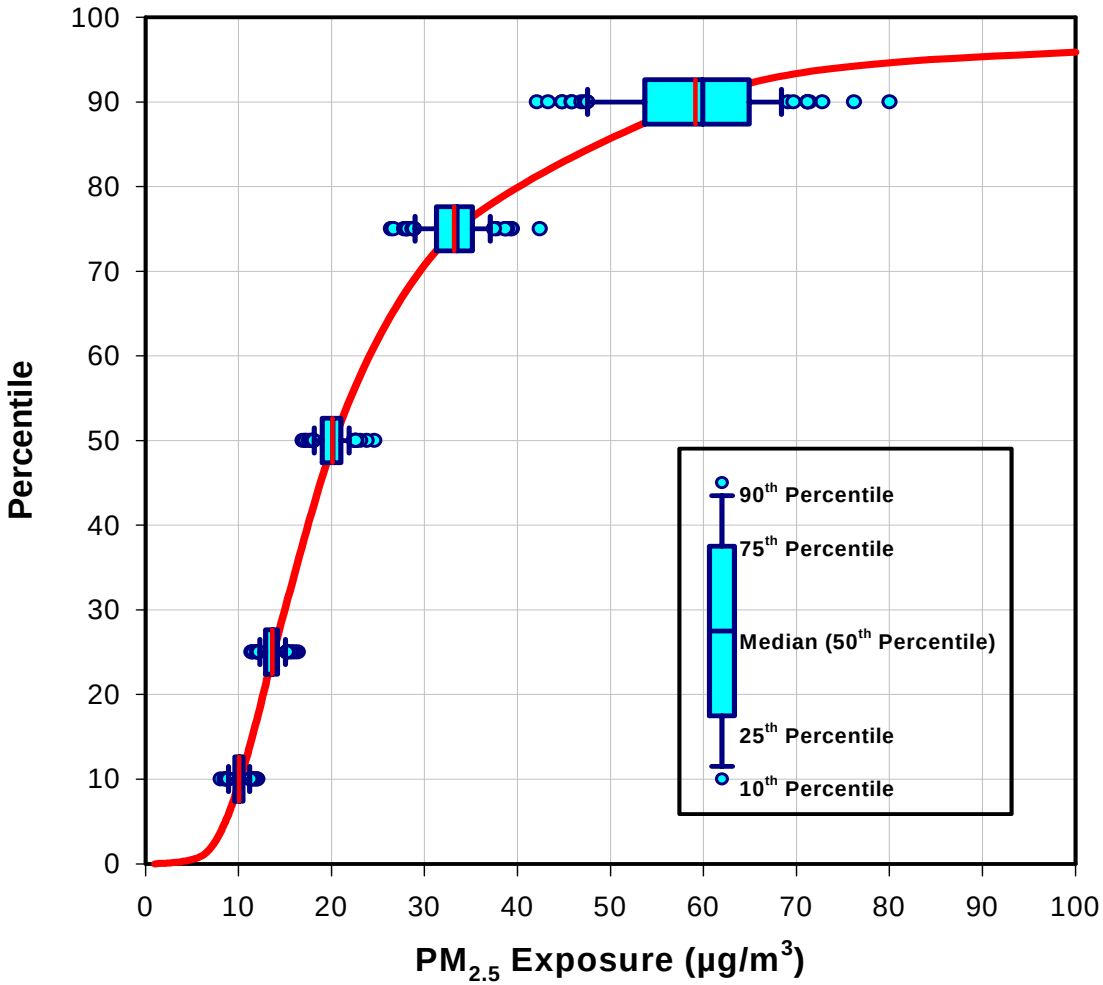






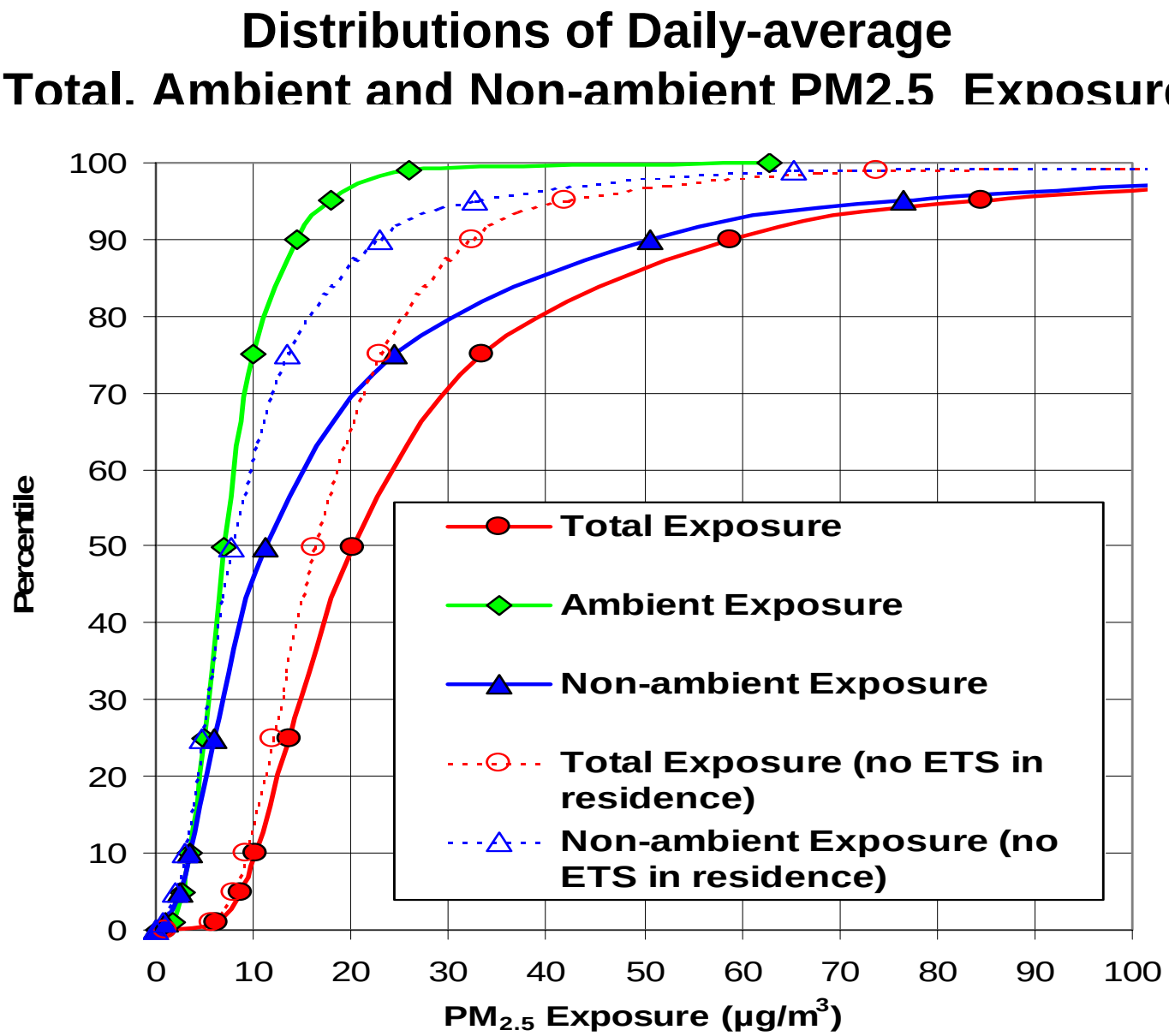
SHEDS-PM Philadelphia $PM_{2.5}$

Distribution of Daily-average Total $PM_{2.5}$ Exposure and Uncertainty for Selected Percentiles



Source: Burke et al. 2001

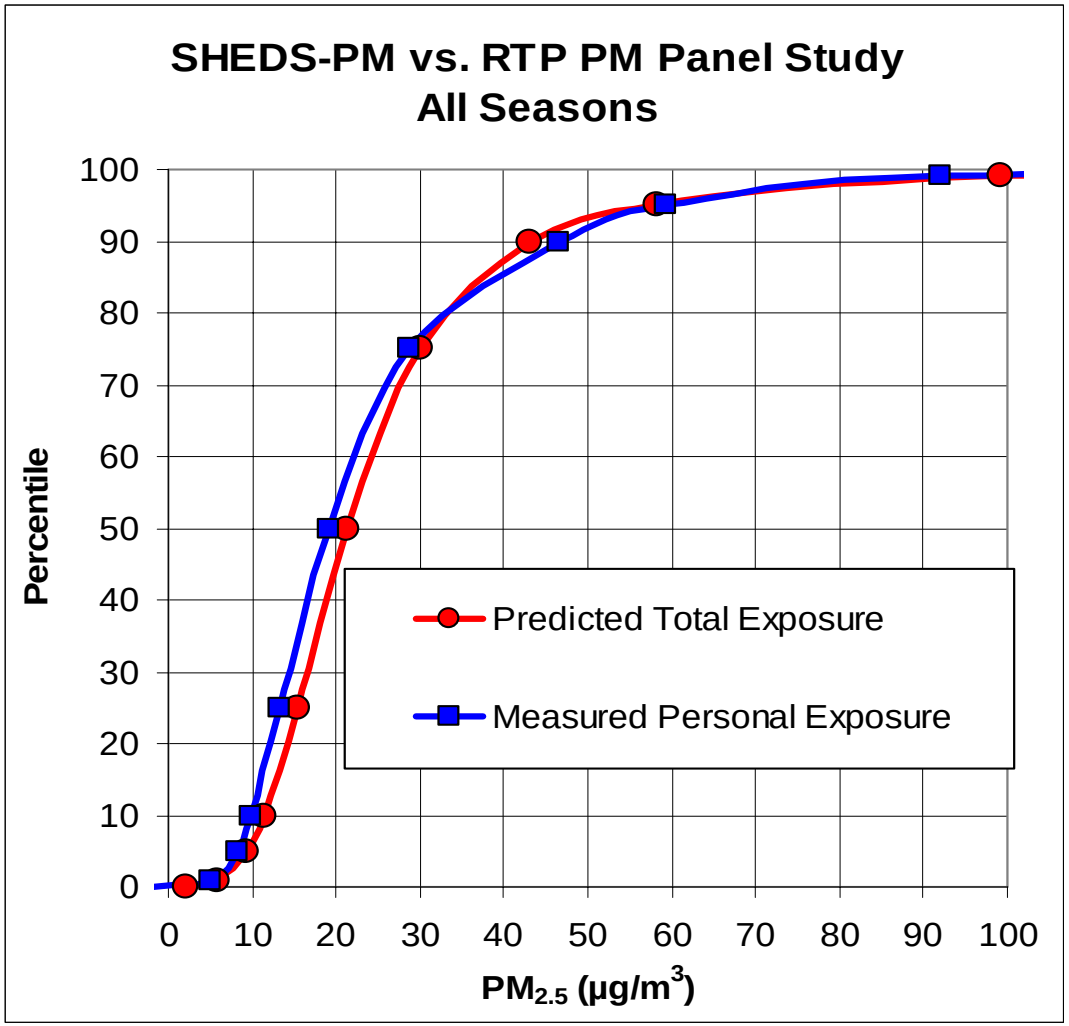
SHEDS-PM Philadelphia $PM_{2.5}$



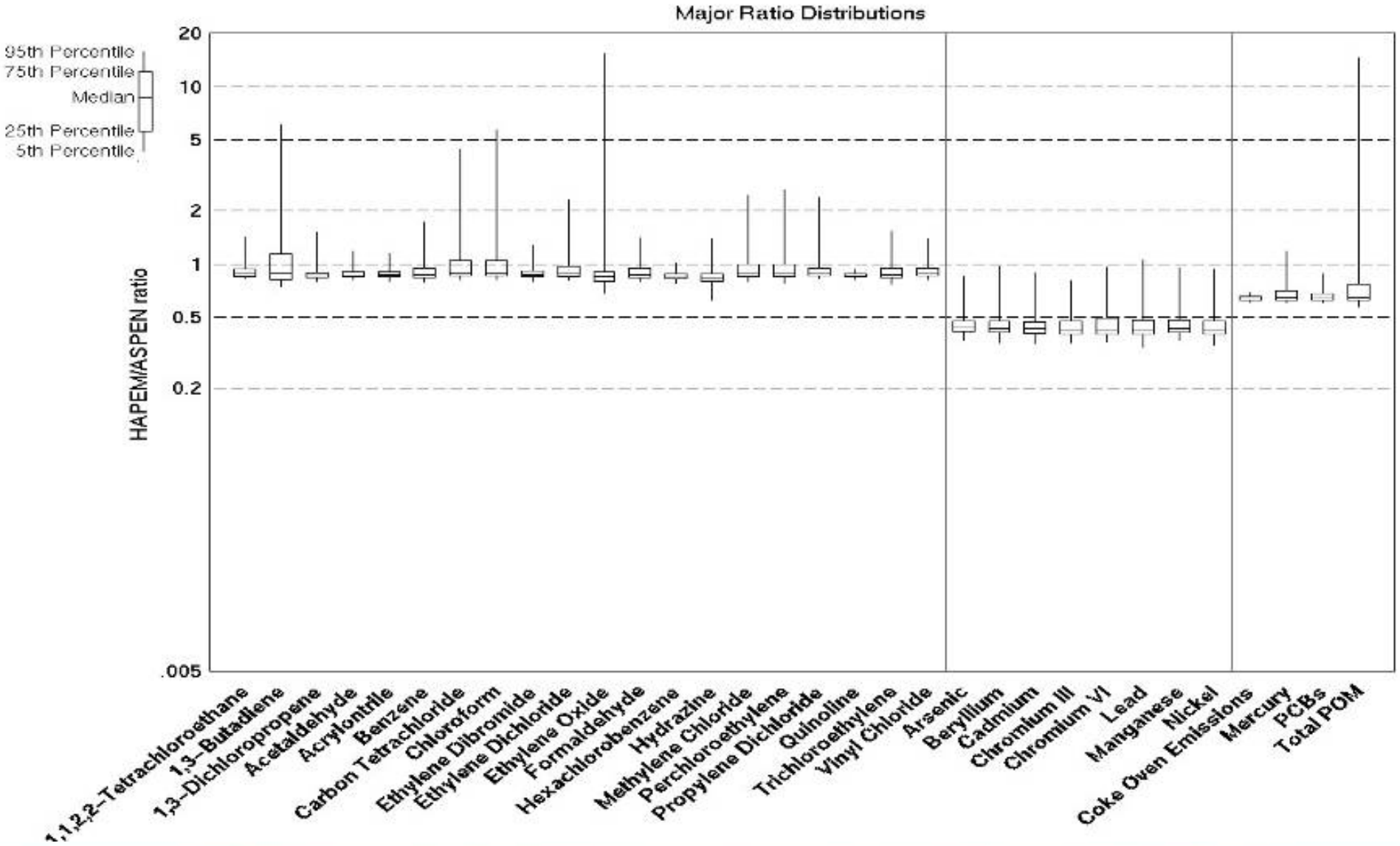
SHEDS-PM Evaluation

NERL's RTP PM Panel Study

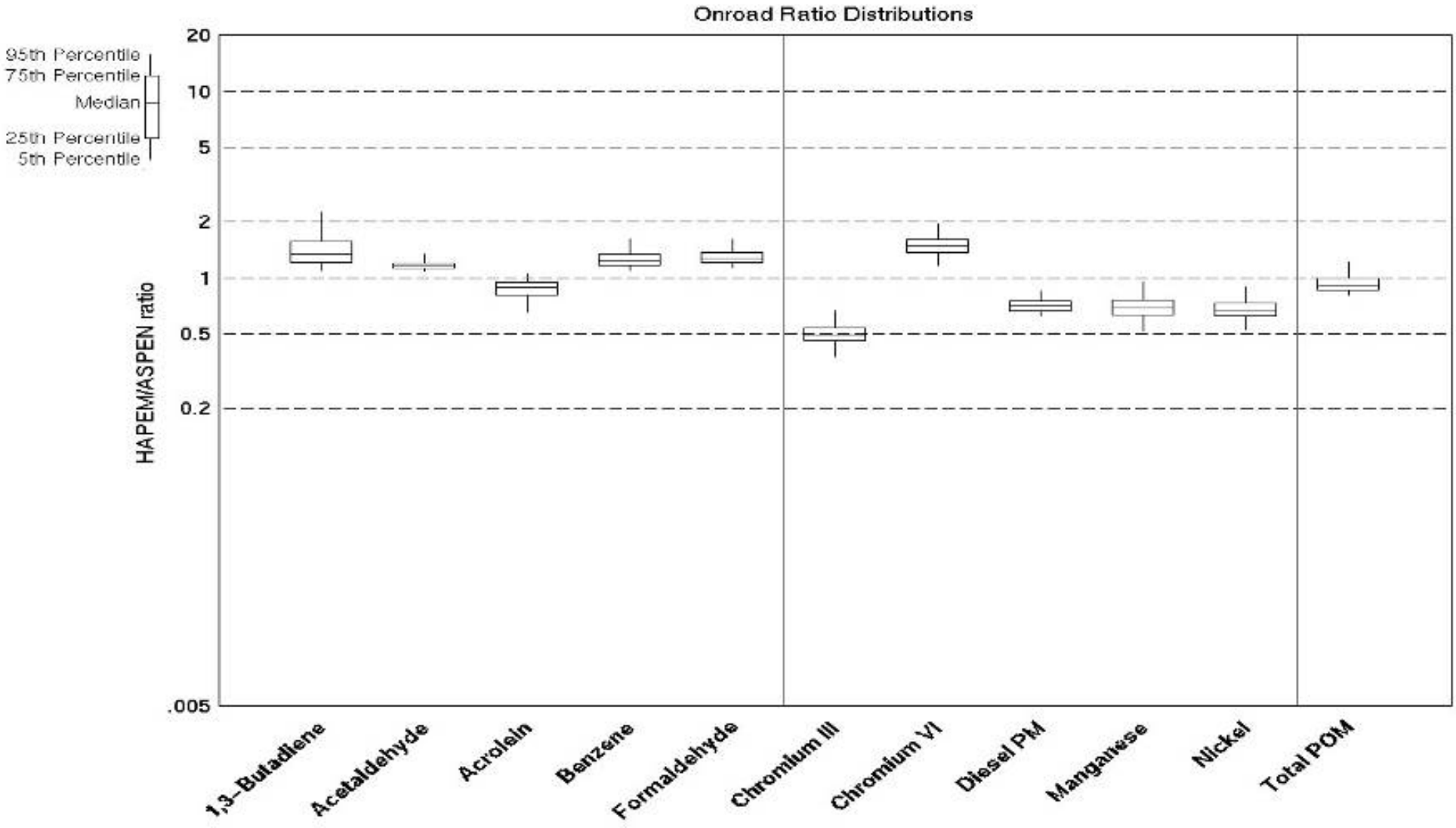
- 37 non-smoking subjects age 55 or older
- 24-hr $PM_{2.5}$ measurements, 1 week during 4 seasons (June 2000 - May 2001)
- Personal and ambient (central site) $PM_{2.5}$
- 24-hr air exchange rates in residences
- Human activity diaries



HAPEM to ASPEN Ratios: Major Sources



HAPEM to ASPEN Ratios: On-Road Sources



Concentration-Exposure Modeling

Strengths

- Broad geographical coverage of data, on: emissions, demographics, housing, HVAC & building information, time-activity and commuting surveys, etc.
- Recently developed regional and local-scale fate/transport and exposure models: CMAQ, AERMOD, SHEDS, APEX, HAPEM
- Capability to model source-specific and multi-pollutant impacts
- Demonstrated utility of models by the EPA/CDC PHASE program

Weaknesses

- Limitations of longitudinal/temporal information for: emissions, time-activity, commuting, etc.
- Challenges in modeling fine-scale ambient concentrations
- Need for further model evaluations

Planned or Anticipated Activities

- **LUR, CMAQ/AERMOD and SHEDS applications in Detroit (EPA/ORD DCHS & DEARS)**
- **Concentration-exposure modeling applications in different community health (e.g., proposed Harvard EJ study in the Boston and Chicago areas) and accountability (EPA/ORD New Haven, CT) studies**
- **EPA/AMI project on ozone health effects and benefits linked to recent NOx SIP rule in the Northeast (EPA/ORD,NYSDOH and Columbia Univ.)**
- **Anticipated support to various extramural epidemiology investigations on PM and roadway pollution health effects**