Source-to-Dose Analysis of Population Exposures to Particulate Matter
Case Study: Philadelphia Region.

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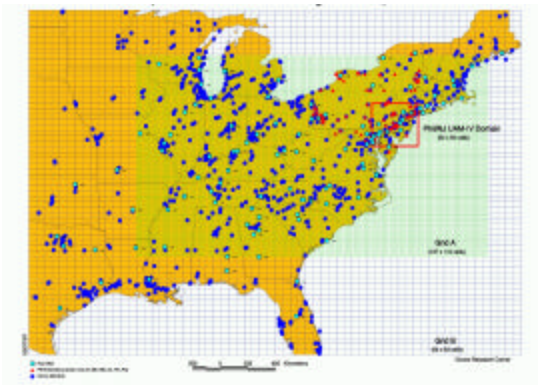
Modeling Steps in the Source-to-Dose Analysis

- **Regional Air Quality Modeling**
  - **Meteorological modeling using MM5**
  - **Emissions processing using SMOKE**
  - **Photochemical Modeling using CMAQ and MAQSIP**
- **Spatiotemporal interpolation using STRF (Application of Bayesian methods is in progress)**
- **Population exposure and dosimetry modeling using PM-SHEDS2**
- **Model reduction and uncertainty analysis using HDMR is being investigated**

The Philadelphia Region Case Study

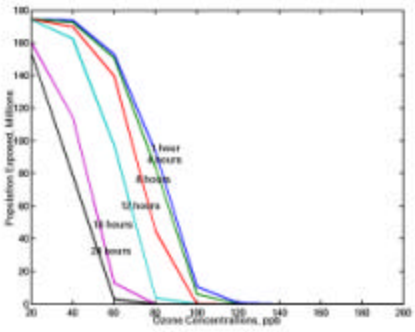
- **The case study focuses on a two-week episode between 11 July 1999 and 24 July 1999**
- **482 census tracts were selected in and adjacent to City of Philadelphia. Selection of the census tracts was based on population density and housing characteristics**
- **1990 Census data were used to obtain demographic and housing characteristics**

Domain for Regional Meteorological and Air Quality Modeling

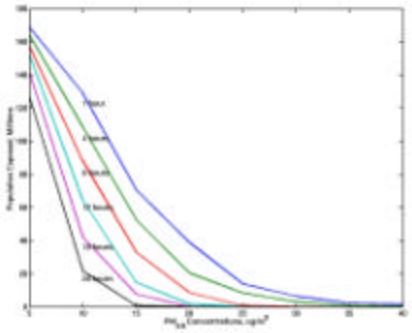


- **The modeling study used one -way nested grids with resolution of 36 km, 12 km, and 4km**
- **Outermost grid domain corresponds to the Ozone Transport and Assessment Group (OTAG) domain**
- **14 layers in the vertical direction were used**

Potential Population Exposure to $PM_{2.5}$ and Ozone: 15 July 1999, over the OTAG Domain

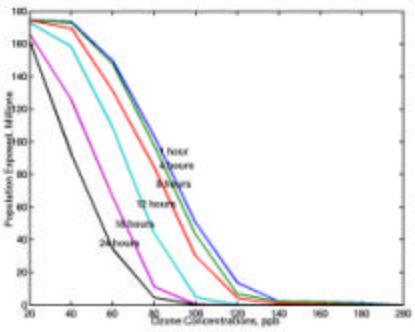


For Ozone

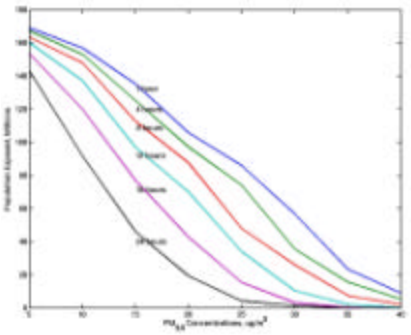


For $PM_{2.5}$

Potential Population Exposure to $PM_{2.5}$ and Ozone: 18 July 1999, over the OTAG Domain



For Ozone

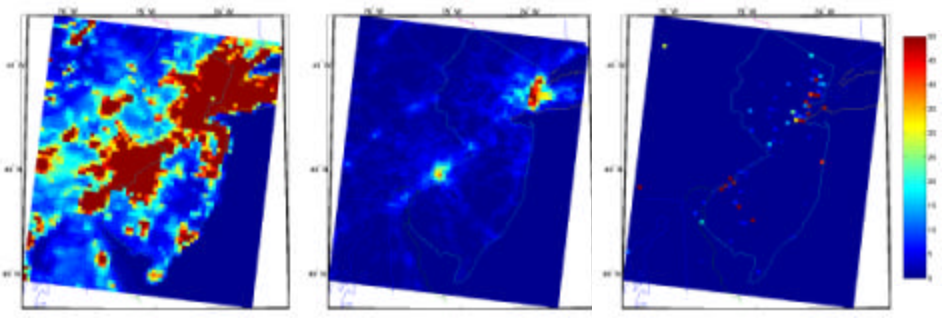


For $PM_{2.5}$

Meteorological Modeling

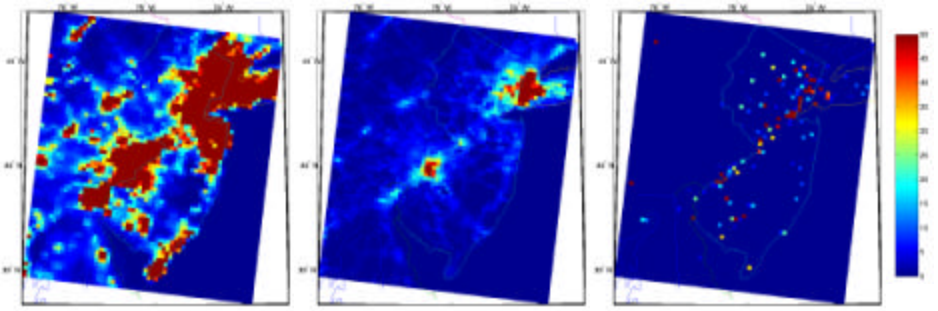
- **MM5 Version 3 was used to model the regional meteorology**
- **Surface and upper-atmosphere data archived at National Center for Atmospheric Research (NCAR) were used as inputs to MM5**
- **The model used the following schemes:**
  - **High resolution Blackadar scheme for Planetary Boundary Layer (PBL) characterization**
  - **Grell's scheme for cumulus parameterization**
  - **Mixed phase (Reisner) scheme for explicit moisture parameterization**
  - **Cloud radiation scheme**

Primary $PM_{2.5}$ Emissions Processed Using SMOKE



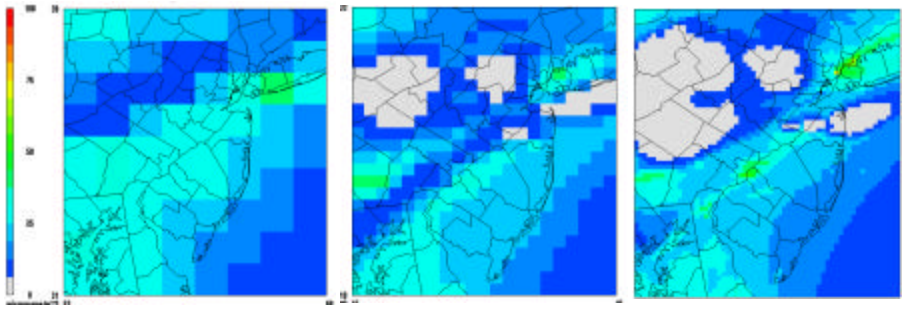
Area Sources **Mobile Sources** **Point Sources**

SO_2 Emissions Processed Using SMOKE



Area Sources **Mobile Sources** **Point Sources**

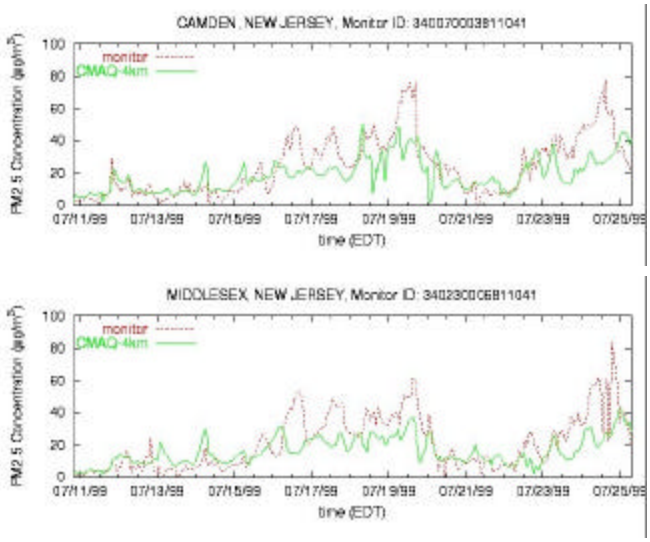
Photochemical Air Quality Modeling Using CMAQ



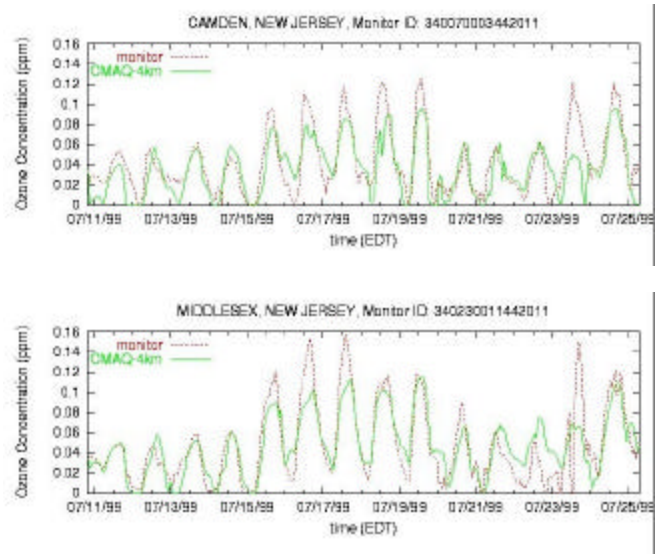
a b c

CMAQ output: $PM_{2.5}$ concentrations ($\mu g/m^3$) at 8:00 AM EDT, 18 July 1999: (a) for 36km x 36 km (b) for 12 km x 12 km and (c) for 4 km x 4 km

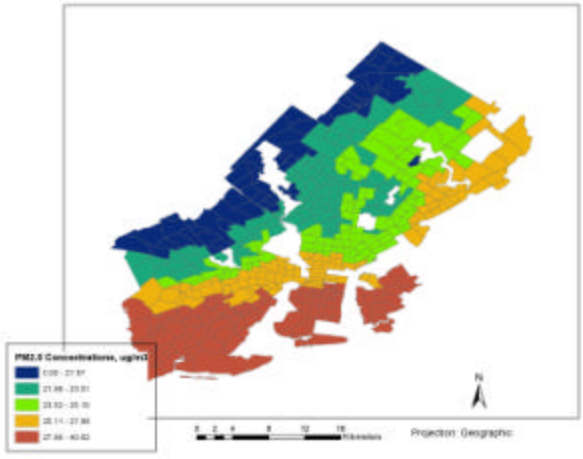
Comparison of Observed and Predicted $PM_{2.5}$ Concentrations



Comparison of Observed and Predicted Ozone Concentrations



Spatiotemporal Interpolation Using STRF



$PM_{2.5}$ concentrations ($\mu g/m^3$) for each census tract at 8:00 AM EDT, 18 July 1999

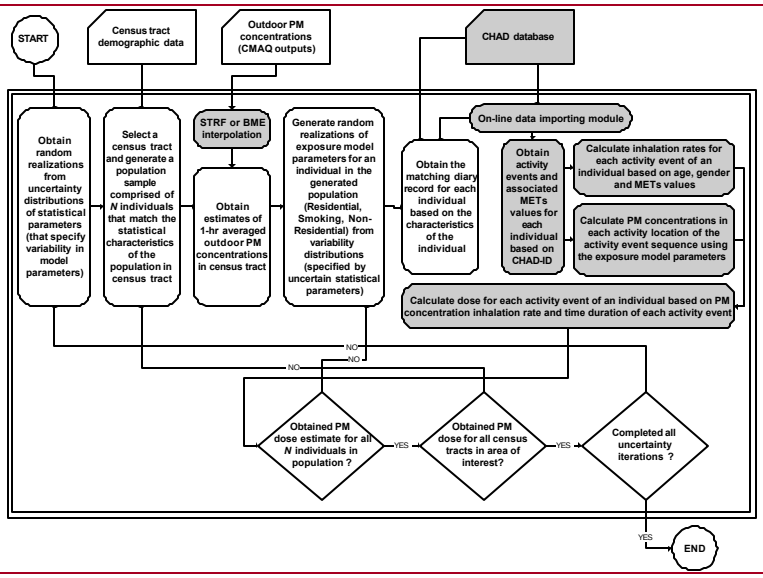
Bayesian Maximum Entropy (BME) Methods for Spatiotemporal Interpolation

- BME offers a general and versatile mapping and analysis framework for steady-state as well as dynamic data. It can use prior information in the form of hard data (measurements), probability law descriptors (type of distribution, mean and variance), interval information (maximum and minimum values) and physical laws. It also offers a complete uncertainty analysis by providing confidence sets to quantify the uncertainty associated with estimates.
- There are three basic stages to BME analysis (Serre, 1999):
  - The prior stage seeks to maximize prior information in the form of general information G, obtained from general principles and laws, summary statistics, and background information.
  - The meta-prior or pre-posterior stage considers the specific information S, obtained from actual expert judgment, secondary information on geologic formation, etc.
  - The integration or posterior stage, in which the information bases considered in stages 1 and 2 are integrated into total prior information K, and the posterior probability density function (pdf) of the estimates is maximized.
  - The posterior pdf is defined as $f_K(Y_K) = A^{-1} \lfloor Y_{soft} \cdot Y_G(Y_{map}) \rfloor$

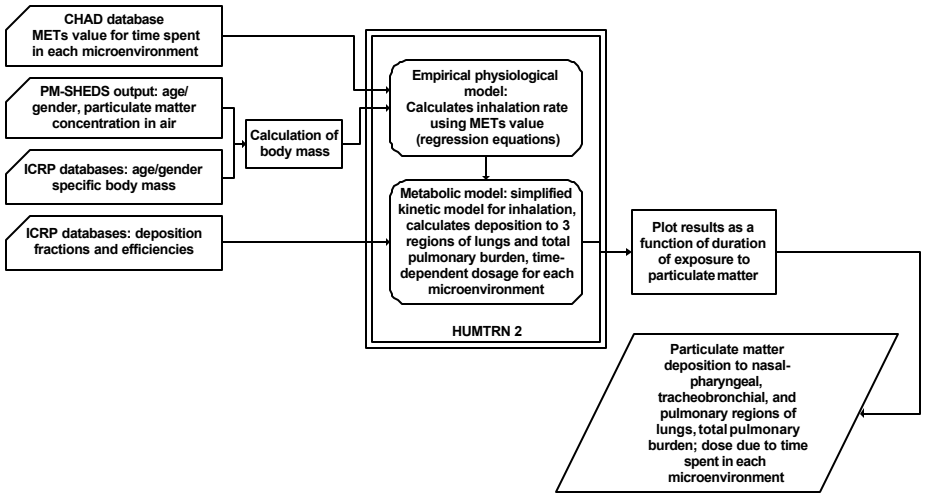
    where $Y_G = \sum_{k=1}^{N} \lambda_k(p_{map}) g^k(X_{map})$

    and the Lagrange multipliers are given by $\lambda_k(\theta) = \ldots$

Enhancements to PM-SHEDS in PM-SHEDS2



HUMTRN/ICRP-Based Dosimetry Model Implemented in PM-SHEDS2



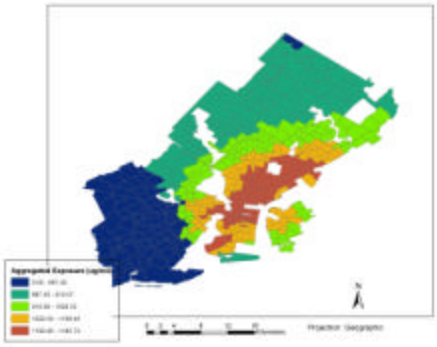
95th Percentiles of 24-Hour Aggregated Total Exposure and Dose, 18 July 1999

Dose (µg)

Exposure (µg/m³)

95th Percentiles of 24-Hour Aggregated Dose and Exposure due to Outdoor Sources, 18 July 1999

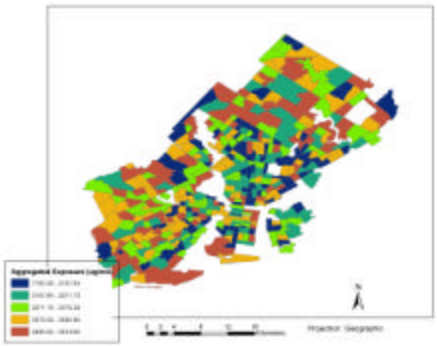
Dose (µg)



Exposure (µg/m³)

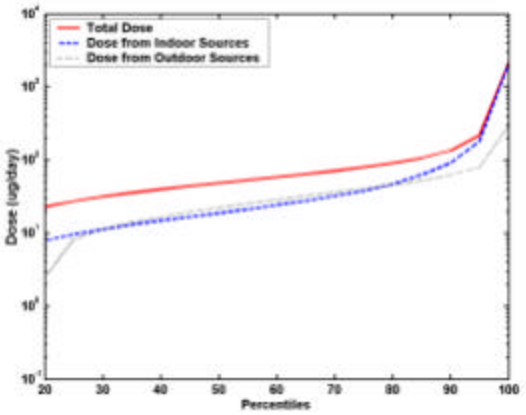
95th Percentiles of 24-Hour Aggregated Dose and Exposure due to Indoor Sources, 18 July 1999.

Dose (µg)

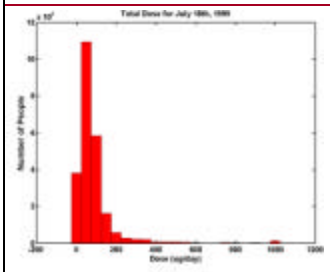


Exposure (µg/m³)

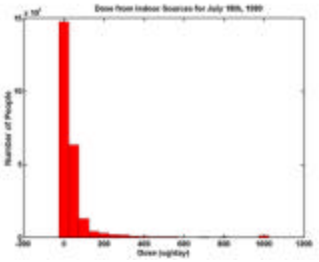
Percentile Plot for 24-Hour Aggregated Total Dose, Dose due to Outdoor Sources, and Dose due to Indoor Sources (All Days).



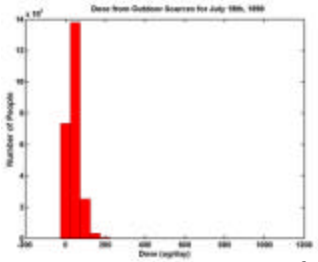
24-Hour Aggregated Total Dose, Dose due to Outdoor Sources, and Dose due to Indoor Sources on 18 July 1999



Total Dose (µg)



Dose due to Indoor Sources, (µg/m^3)



Dose due to Indoor Sources, (µg/m^3)

Ongoing Work

- **Runs of the MAQSIP model with sectional aerosol dynamics for the same domain and time period, for comparison with the CMAQ results**
- **Application of the Bayesian Maximum Entropy (BME) method for comparison with STRF results**
- **Refined simulations with improved inventories (MARAMA, NEI)**
- **Refined simulations with improved meteorological inputs**

Acknowledgements

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