High Resolution Spatial and Temporal Mapping of Air Pollution in Detroit

Detroit Sustainability Indicators Integrated Assessment Workshop
Graham Environmental Sustainability Institute

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Outline

Review of Objectives

Air Quality Models
   AERMOD
   AERLINE

Air Quality Modelling
   AERMOD : Point Sources, Road Sources
   AERLINE : Sensitivity Analysis
Objectives of project

Map and analyze ambient air pollutant concentrations for Detroit at high spatial and temporal resolution

Provide a database containing this information to Data Driven Detroit (DDD), allowing its use for a wide variety of purposes.

• Use state-of-the-art simulation models

• Predict concentrations of two key pollutants, particulate matter under 2.5 μm aerodynamic diameter (PM$_{2.5}$) and nitrogen oxides (NO$_x$)

• Use spatially dense grid and daily basis for calendar year 2010
Modeling approach

Regional Background concentrations of pollutants

Meteorological conditions

Source data: -site description -emission rate

Model options: -receptor grid -dispersion parameters

Local topographical features

Atmospheric dispersion model

Prediction of ground level concentration of pollutants

Assessment of potential environmental and health factors

Field Measurements

Model/Measurement Synthesis

Refined Concentration estimates
Atmospheric Dispersion models - AERMOD

- Steady state Gaussian plume model
- Uses Planetary Boundary Layer (PBL) technology
- Estimates the impacts from a variety of industrial sources
- Improvement over the ISC model
- Pre-processors – AERMET and AERMAP
- Rural and urban areas
- Simple as well as complex terrain
- Accounts for different source types: (i) Surface and elevated sources (ii) Multiple sources – point, area and volume sources
- Concentration distribution in stable boundary layer (SBL): Gaussian in both vertical and horizontal directions
- Concentration distribution in convective boundary layer (CBL): horizontal distribution is assumed Gaussian but vertical distribution is described with bi-Gaussian function
- Plume penetrates through the elevated boundary layer and re-enters into the boundary layer.
- This model accounts for the vertical inhomogeneity of the PBL
AERMOD – Inputs for Point Sources

- Source data: Point Source Emission Inventory (NEI2008)
- Receptor and Terrain data: Receptor grid as specified (26 * 26 = 676 receptors at 500m spacing. Terrain conditions are assumed as ‘flat’.
- Meteorological data: Detroit Airport Data for 2010
Number of Point Sources – 399. Maximum Annual Average Concentration = 114.37ug/m³
AERMOD – Point Sources (PM2.5)

Number of Point Sources – 837. Maximum Annual Average Concentration = 5.84 ug/m³
AERMOD – Point Sources (PM2.5)
Atmospheric Dispersion models - AERLINE

- Steady state Gaussian plume model
- Uses PBL technology similar to AERMOD
- Estimates the impacts from a variety of road sources
- Improvement over the AERMOD
- Pre-processors – AERMET and AERMAP
- Additional algorithms used in AERLINE for predicting concentrations from road sources
- Uses an additional component of ‘meandering’ to predict concentrations for both ‘upwind’ and ‘downwind’ conditions
- The AERLINE model is capable of handling different types of road (at grade, below grade, elevated)
- It is still a research model being further evaluated by EPA
Sensitivity Analysis of Model for following conditions were carried out:

1. Road Gradient at -6 m (below grade), 0 m (at grade) and +6 m (above grade)

2. Wind Speeds of 1, 2, 4, 6, 8, 10 and 12 m/s

3. Wind Direction of 0-90 degrees in 10 degrees interval
Receptors placed at 10 m distances up to 500 m on either side of road.
Input Data for Modelling

- Road Source Coordinates of (0, -500, 1) to (0, 500, 1)
- Receptor Coordinates of (10, 0, 1.8) to (500, 0, 1.8)
- Emission factor of 1 gm/km (0.001 gm/m)
- Distance from C/L = 0
- Initial Dispersion = 1.00 (after discussion with EPA)
- Height of barrier = -1 (same value as used by EPA)
- Distance of barrier = 0
- Depth of Depression = -6 (below gradient), -3 (below gradient), 0 (road at grade)
- Width at top of Depression = 50 (below gradient), 0 (at grade)
- Width at bottom of Depression = 40 (below gradient), 0 (at grade)
- Heat flux = -41
- Friction Velocity = 0.1*wind speed
- Convective Velocity = 0
- Vertical potential temperature gradient = -9
Input Data for Modelling (Continued)

- Height of Convectively generated boundary layer = -999
- Height of Mechanically generated boundary layer = 2300*(WS)^1.5
- Monin-Obhukov Length = 1000m
- Surface Roughness Length = 0.25
- Bowen Ratio = 1.4
- Albedo = 1
- Wind Speed = 4 m/s
- Wind direction = 90 degrees
- Height at which WS was measured = 6.1m
- Temperature = 284K
- Height at which temp was measure = 2.0m
- Sigma-z (Vertical Dispersion Curve) = PG
- Wind Speed Profiling - A
- Meandering - Y
Predicted Concentrations on Road Transect

AERLINE_Grade

- At grade
- below grade_6_50_40
- below grade_3_50_40
Predicted Concentrations on Road Transects

Concentrations vs. Distance from road for various transects labeled as WS_1 to WS_12.
Predicted Concentrations on Road Transect

AERLINE_WD_M

Concentrations vs Distance from road

WD_90
WD_80
WD_70
WD_60
WD_50
WD_40
WD_30
WD_20
WD_10
WD_0
Two Atmospheric Dispersion Models (AERMOD and AERLINE) have been considered.

The AERMOD model has been set-up to calculate contributions from point sources. Trial runs have already been conducted with predicted concentrations in ‘reasonable ranges’.

The AERMOD model has been set up for predicting concentrations from road sources

Sensitivity Analysis of AERLINE model has been carried out.

Further studies are being conducted on AERLINE model to refine the model predictions.
Partners

Arab Community Center for Economic and Social Services (ACCESS)
Community Health and Social Services Center (CHASS)
Detroit Department of Health and Wellness Promotion
Detroit Hispanic Development Corporation (DHDC)
Detroiter Working for Environmental Justice
Friends of Parkside
Henry Ford Health System
Latino Family Services
Warren Conner Development Coalition
University of Michigan School of Public Health (EHS, HB/HE, Biostatistics)
University of Michigan School of Medicine (Pediatrics)
Thank You