Sensitivity Analysis of Dispersion Model Results in the NEXUS Health Study Due to Uncertainties in Traffic-Related Emissions Inputs

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Presentation Outline

- NEXUS Design and Objectives
- Modeling Mobile Sources using a Dispersion Model and Emissions.
- Sensitivity of Line Source Dispersion Model to Emissions Inputs
- Preliminary Modeling Results
- Conclusions

NEXUS Design & Objectives

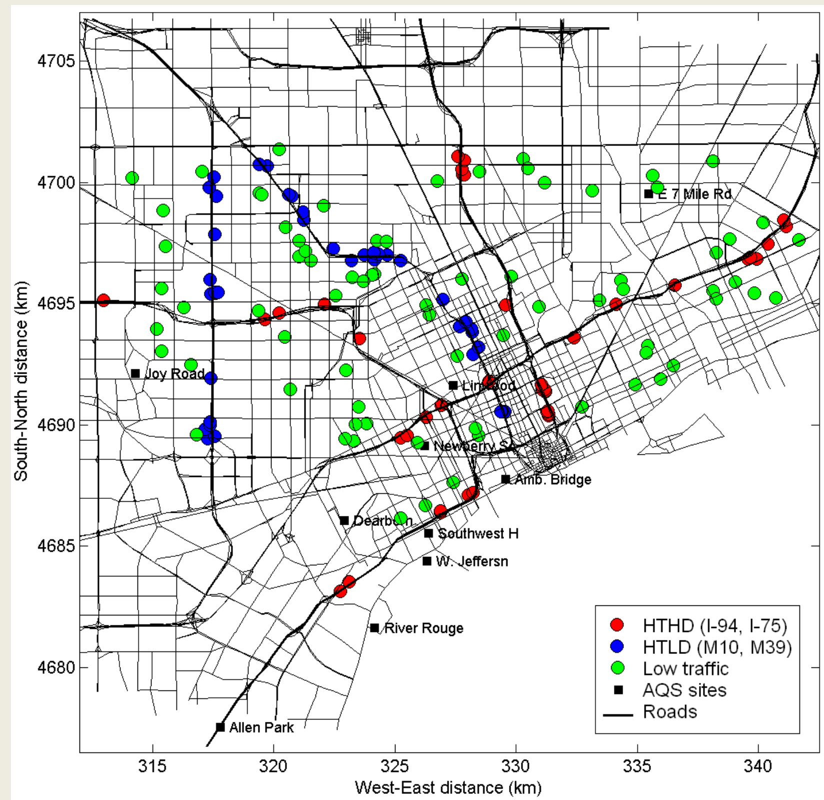
Objective: ***Study effects of traffic-related air pollution on the respiratory health of asthmatic children in Detroit.***

Primary research question: Do children with asthma living near major roadways with high traffic have greater health impacts associated with air pollutants than those living farther away, particularly for those living near roadways with high diesel traffic?

Health outcomes:
Aggravation of asthma symptoms, inflammation and other biological responses, and respiratory viral infections.

Modeling objective: Provide pollutant surfaces capturing spatial and temporal variability across health study domain for all participants for each hour of the 29-month period. This includes background, stationary source and ***mobile source*** estimates.

NEXUS Participant Locations



Vette, A., Burke, J., Norris, G., Landis, M., Batterman S., Breen, M., Isakov, V., Lewis, T., Gilmour, M. I., Kamal, A., Hammond, D., Vedantham, R., Bereznicki, S., Tian, N. & Crogan, C. 2013. The Near-Road Exposures and Effects of Urban Air Pollutants Study (NEXUS): Study design and methods. *Science of The Total Environment, 448*, ***38-47.***

Modeling Mobile Sources: RLINE – Research LINE source model

RLINE is EPA -ORD's research dispersion modeling tool for near roadway assessments.

- based on a steady-state Gaussian formulation
- currently formulated for near-surface releases
- contains new formulations for the vertical and lateral dispersion rates
- includes treatment of receptors very near line sources
- accounts for low wind meander
- includes M-O similarity profiling of winds near the surface
- uses the surface meteorology provided by AERMET
- includes user-friendly input requirements for road network

Snyder, M. G., Venkatram, A., Heist, D. K., Perry, S. G., Petersen, W. B. & Isakov, V. RLINE: A Line Source Dispersion Model for Near-Surface Releases. *Atmospheric Environment (in press, 2013).*

Combining Emissions and Dispersion Modeling for Mobile Sources

The total emission factors (EF_i) and traffic activity (A_i) inputs are combined to create hourly emissions, (E_i) for each roadlink (*i*) in the Detroit road network.

$$E_i = EF_i \text{ x } A_i$$

$$EF_i = \Sigma_{\text{veh.class}}\, ef_i(\text{poll., speed, month, temp.}) \text{ x } fleetmix(\text{veh.class})$$

$$A_i = AADT_i \text{ x } TAF_i(\text{hour, day, month})$$

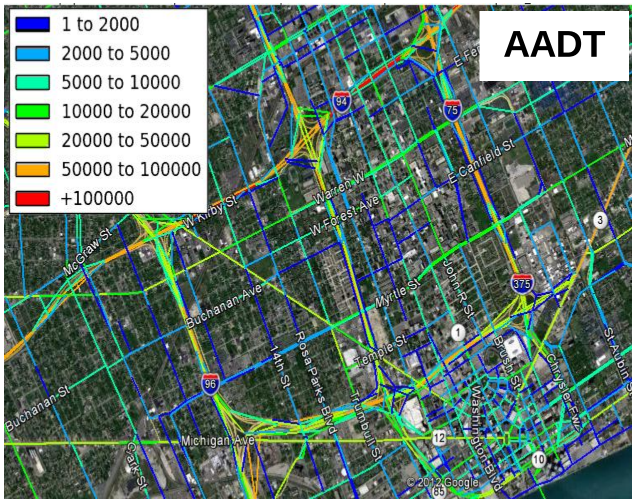
The concentration is found by $C = \Sigma_i E_i \text{ x } X_i$, where X_i is the dispersion from each roadlink, *i*, to each receptor generated by RLINE with unit emission rate.

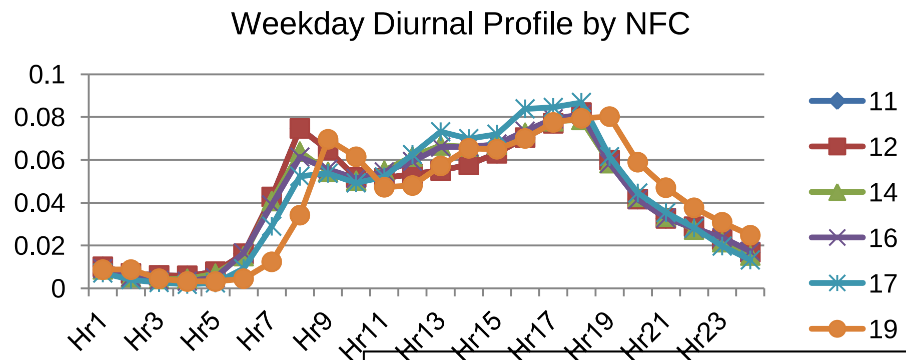
This two step process is used so the most time intensive step, the dispersion model, would only need to be run once, then the emissions could be applied and emissions can be easily modified.

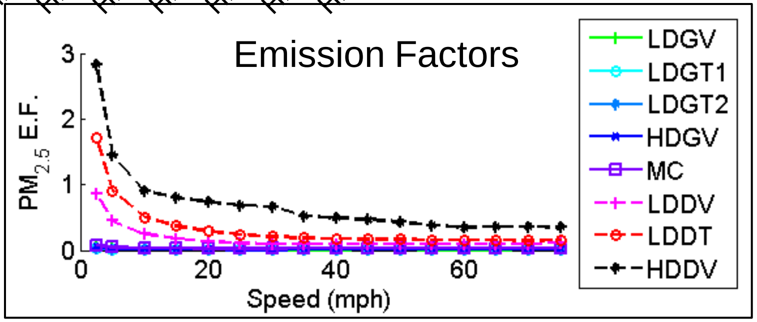
Cook, R., V. Isakov, J. S. Touma, W. Benjey, J. Thurman, E. Kinnee, and D. Ensley, 2008: Resolving Local-Scale Emissions for Modeling Air Quality near Roadways. *Journal of the Air & Waste Management Association*, **58,** 451-461.

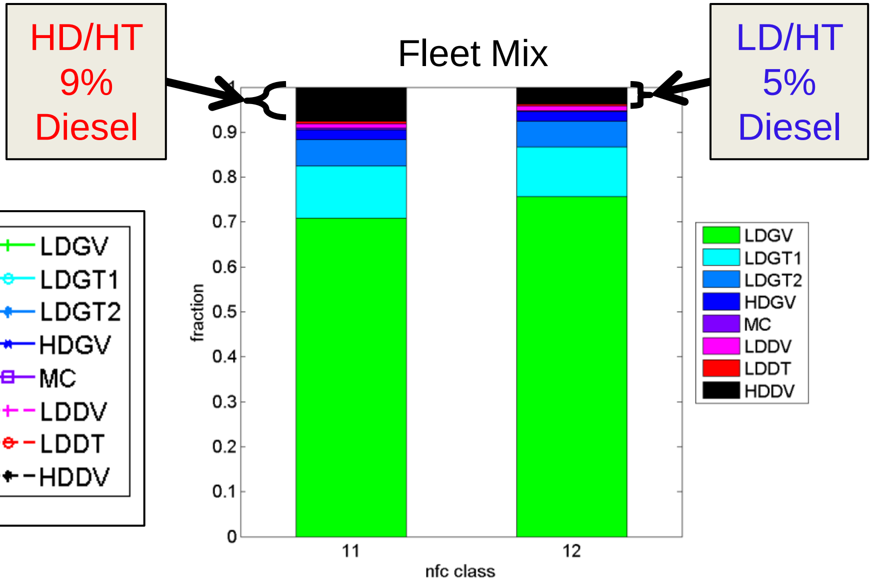
Estimating Mobile Source Emissions

- Meteorology (hr of day, temp) –Detroit Airport
- Link-based network(AADT, speed) –SEMCOG
- TAFs (vehicle type, month, day of week, hr of day) - SMOKE
- Emission Factors (temp, speed, vehicle type, month) – MOVES 2010
- Fleet Mix (nfc class, vehicle type) - FHWA









Office of Research and Development
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Sensitivity Analysis of Mobile Source Modeling

1. Meteorological conditions change daily, weekly, and seasonally. How big of a role does meteorology play in the dispersion of traffic-related pollutants?

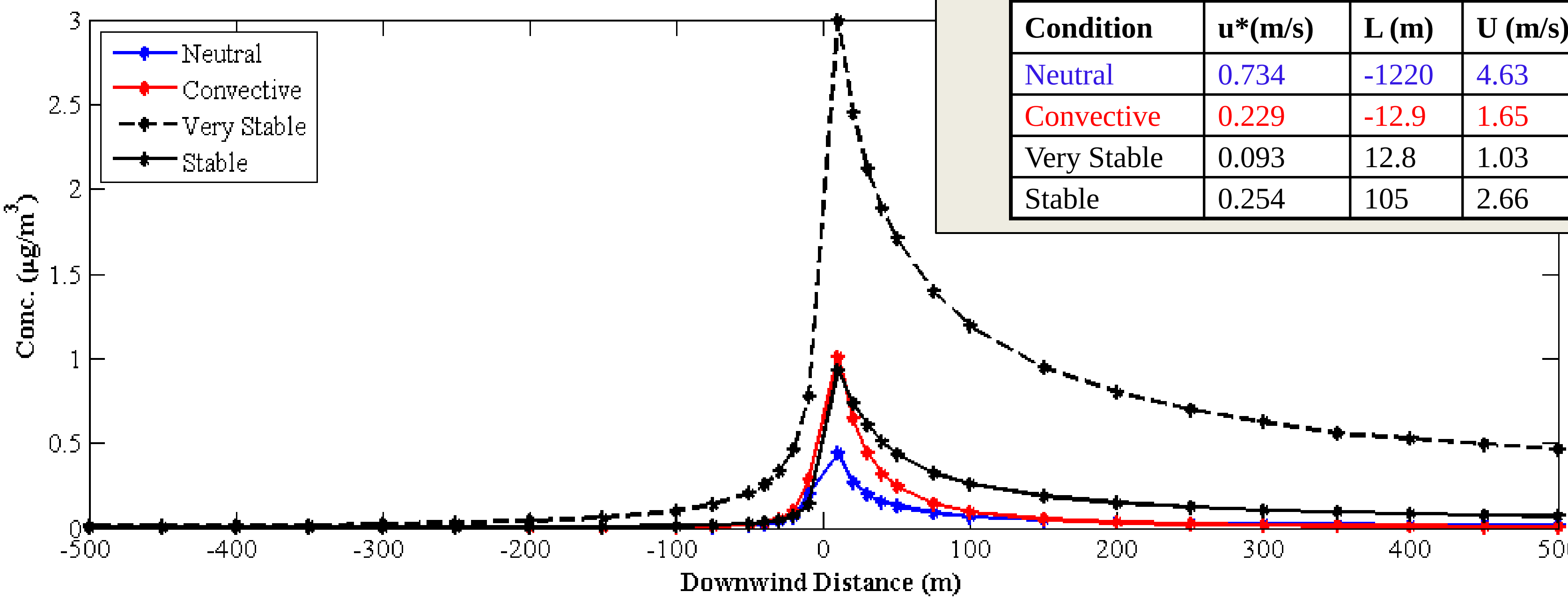
2. Traffic volumes change hourly and by day of week. How well does our modeling estimate these variations?

3. Roadways have different characteristics. Can modeling distinguish between roadways with high and low diesel traffic volumes?

4. Do all roadways with the same classification have the same fleet mix?

1. Meteorological conditions change daily, weekly, and seasonally. How big of a role does meteorology play in the dispersion of traffic-related pollutants?

RLINE was run with unit-emissions for one line source and the wind direction perpendicular to the source.

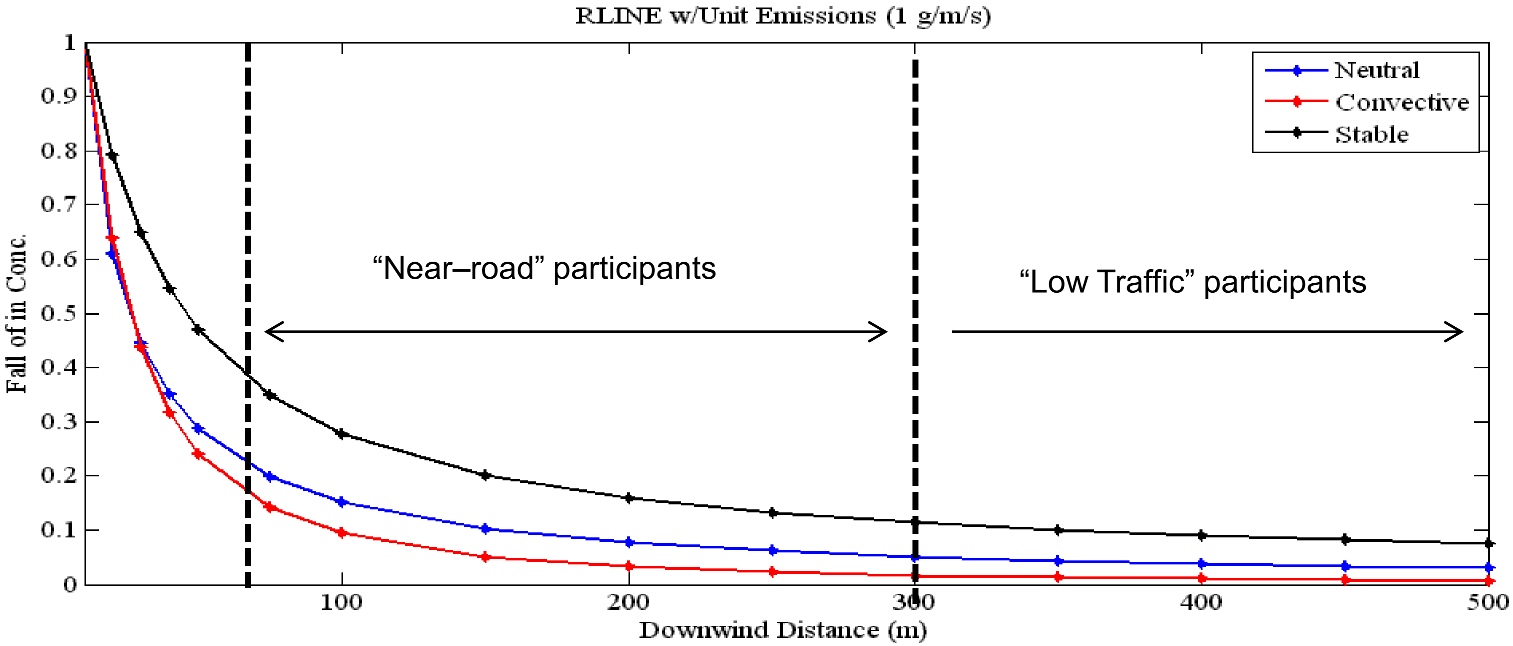


Representative Met. Parameters from Fall 2010 in Detroit, MI.

Condition	u*(m/s)	L (m)	U (m/s)
Neutral	0.734	-1220	4.63
Convective	0.229	-12.9	1.65
Very Stable	0.093	12.8	1.03
Stable	0.254	105	2.66

- All conditions fall off as you get away from the roadway, some fast than others.
- Notice that stable, convective, and neutral met hours are all under $1x10^5$.
- Very Stable hours can produce extremely low dispersion rates, and high concentrations.

1. Meteorological conditions change daily, weekly, and seasonally. How big of a role does meteorology play in the dispersion of traffic-related pollutants? (con't)



Representative Met. Parameters from Fall 2010

Condition	u*(m/s)	L (m)	U (m/s)
Neutral	0.734	-1220	4.63
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Stable	0.254	105	2.66

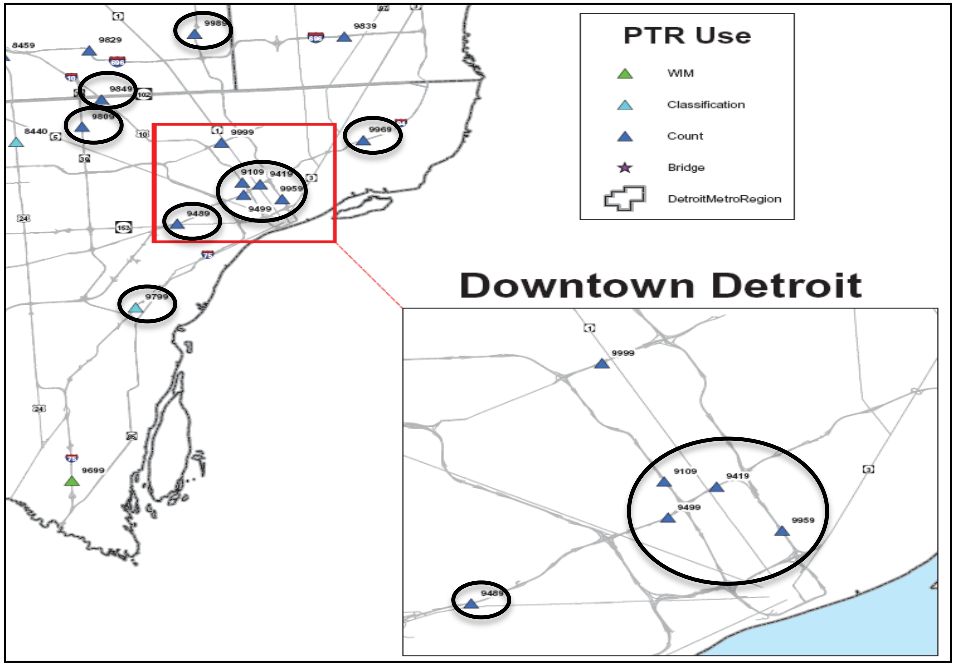
Convective and Neutral conditions show similar fall off in concentration.

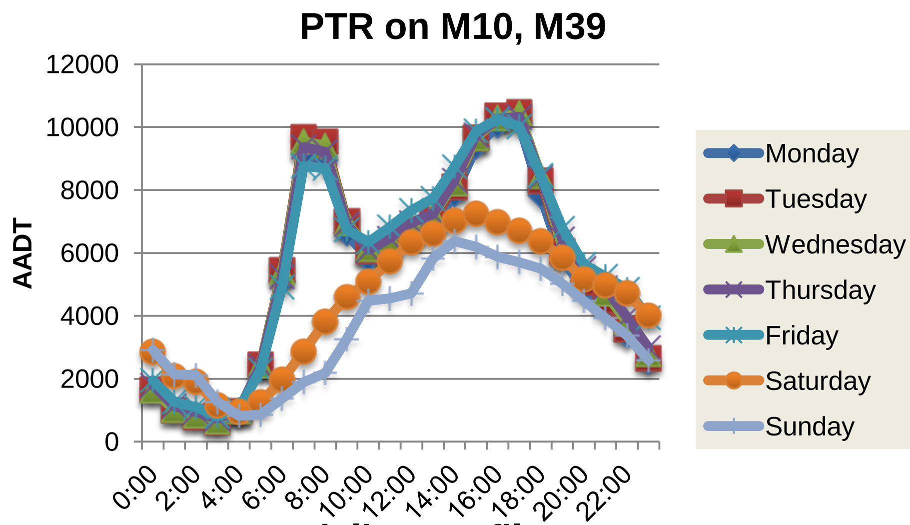
Stable conditions seem to have nearly twice the concentrations and slow fall off.

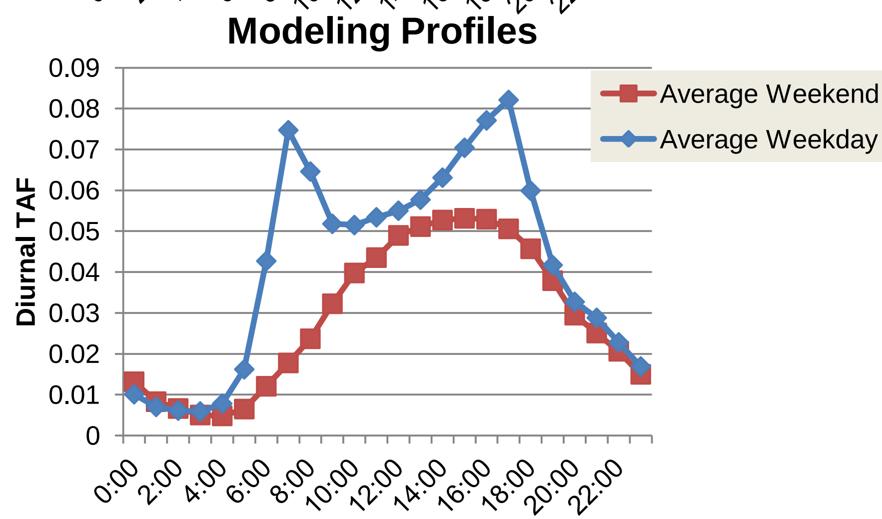
Stability conditions are very important in model results because of high concentrations and slower decrease in concentration as distance from the roadway increases.

2. Traffic volumes change hourly and by day of week. How well does our modeling estimate these variations?

Permanent Traffic Recorders (PTR)





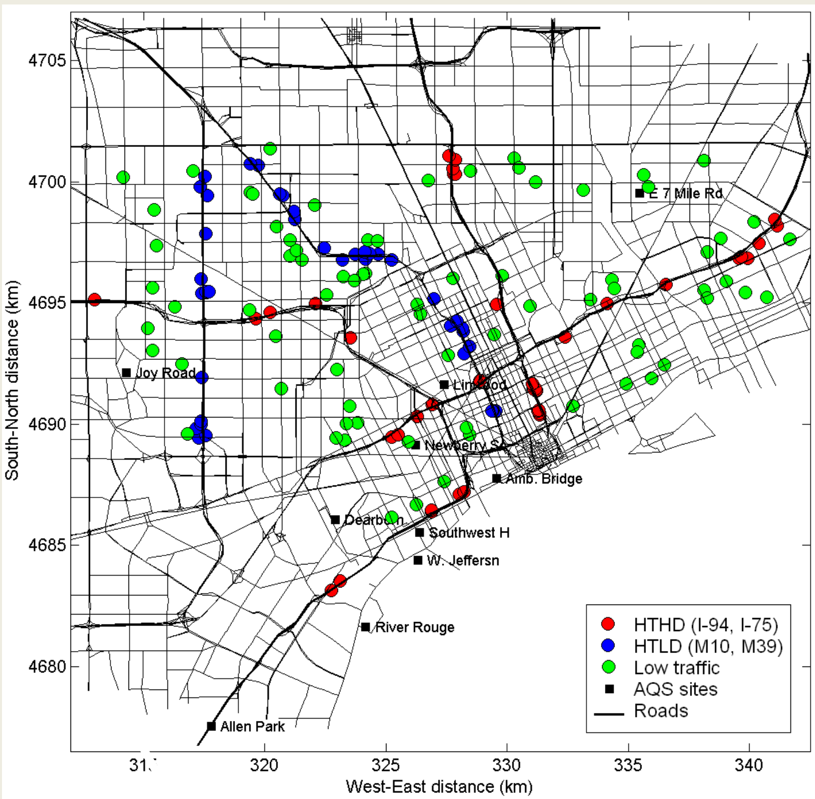


Temporal Allocation Factor (TAF) contain the traffic pattern. These vary by time of day, day of week, and month of year.

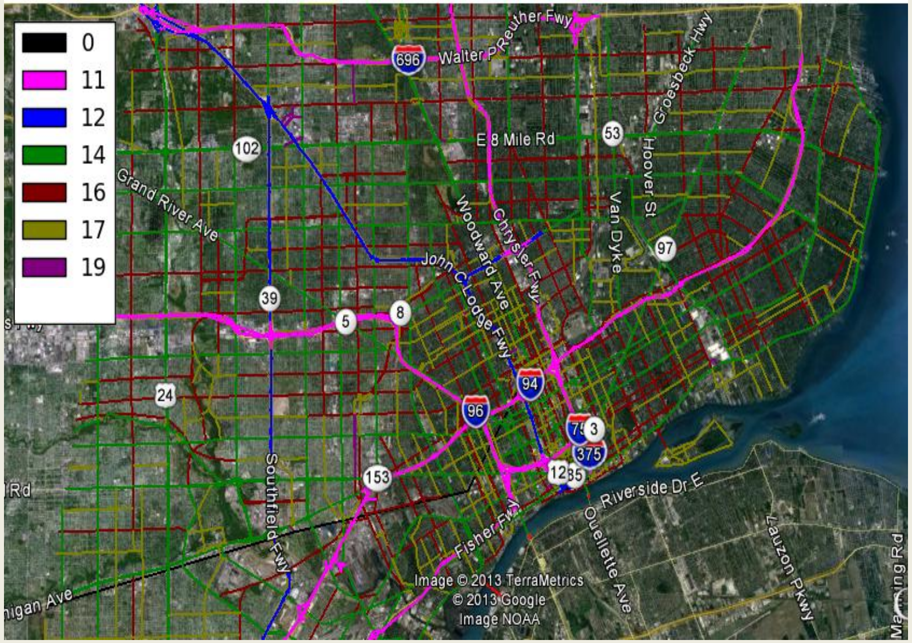
Traffic patterns and meteorology have temporal variation, thus capturing this correctly is essential to estimating air quality.

3. Roadways have different characteristics, can modeling distinguish between roadways with high and low diesel traffic volumes?

NEXUS Participant Locations



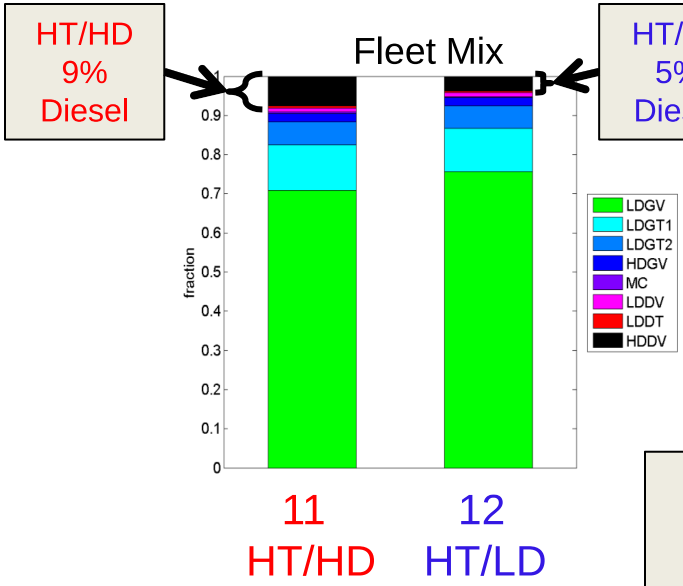
Modeled Roadways



NFC = 11 are High Traffic/High Diesel (Interstates)
NFC = 12 are High Traffic/Low Diesel (Highways)
All others are Low Traffic roadways

Meteorological conditions are the same for all participants, so the only hourly variability between participants is EMISSIONS.

3. Roadways have different characteristics, can modeling distinguish between roadways with high and low diesel traffic volumes? (con't)



Roadlink characteristics for average NFC 11 and 12 roadlinks in Detroit domain.

NFC	11	12
Avg AADT	30900	32900
Avg Speed	46	48
Max. Speed	65	65
Min. Speed	20	27

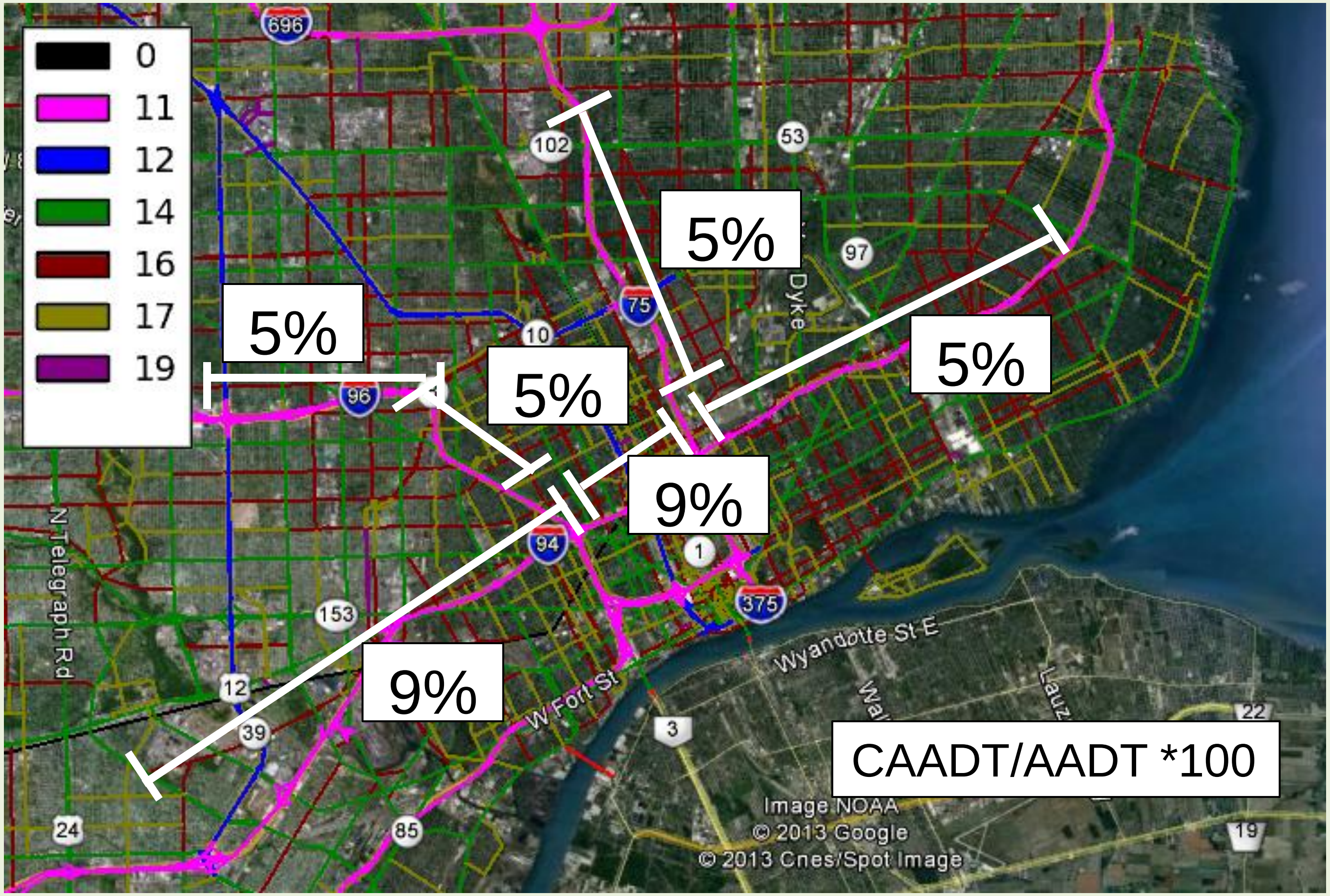
Ratio of emissions for NFC 11 and 12 roadways, dispersion is NOT considered (based on average values for August 2010).

Pollutant	Ratio of Emissions: NFC 12/11		
	Min. Speed	Avg. Speed	Max. Speed
$PM_{2.5}$	0.639	0.655	0.663
$EC_{2.5}$	0.558	0.567	0.574
CO	1.06	1.06	1.06

Emissions contain the distinction between high diesel (11) and low diesel (12) roadways, therefore modeling results should contain a distinction between these roadways. (This puts added pressure on the roadway classifications.)

4. Do all roadways with the same classification have the same fleet mix?

Michigan DOT - Measurements



FLEET MIX

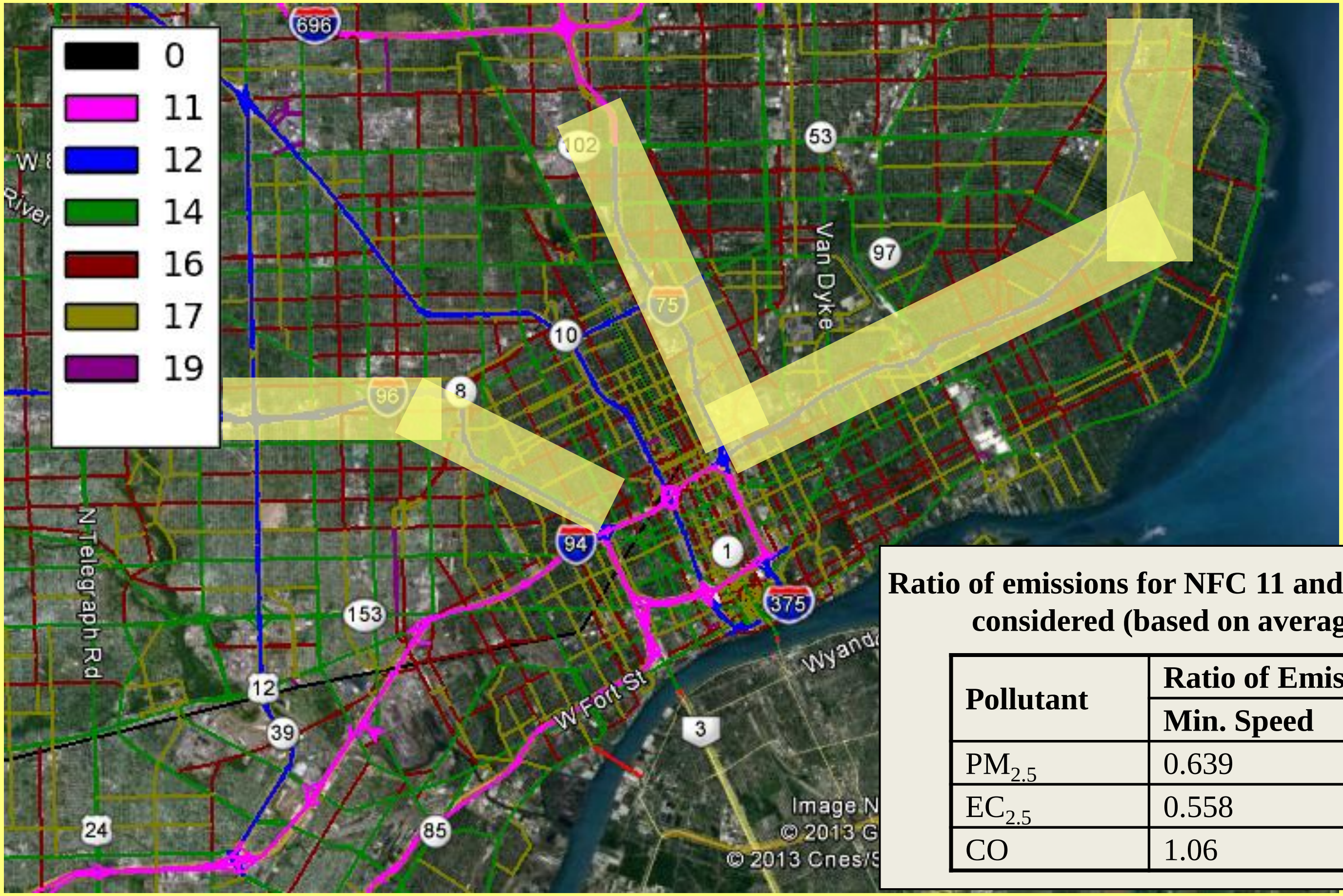
Interstates
nfc 11 – 9% diesel

Highways
nfc 12 – 5% diesel

In the Detroit domain interstates are all classified the same, thus the same fleet mix, however local traffic measurements suggest there is a large discrepancy in commercial traffic between roadways.

4. Do all roadways with the same classification have the same fleet mix? (con't)

Revised Roadway Designations



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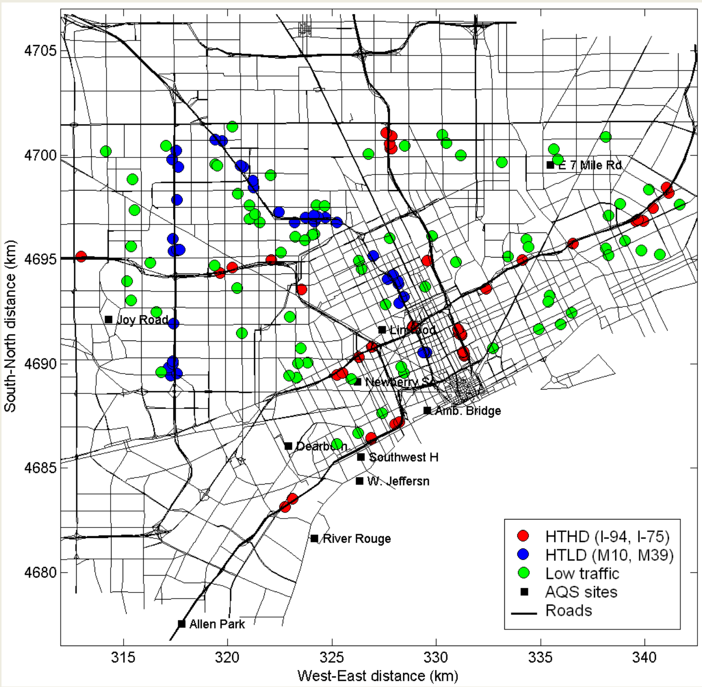
Misclassifying roadways can lead to an overprediciton in exposure by ~40% for some traffic-related pollutants . Local measurements of traffic, especially fleet mix, can help reduce this overprediction.

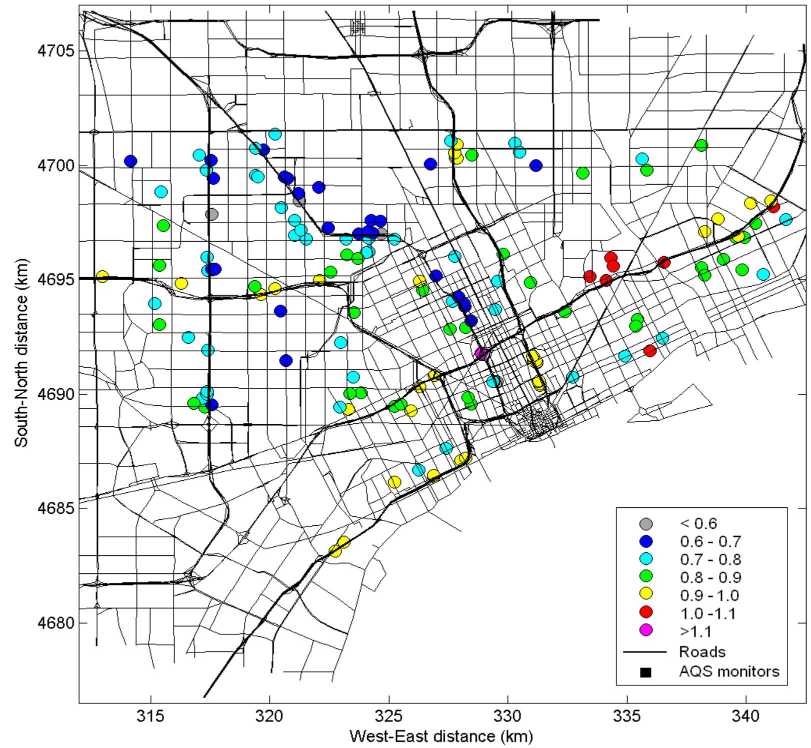
United States Environmental Protection Agency

Preliminary Modeling Results: Spatial Variability

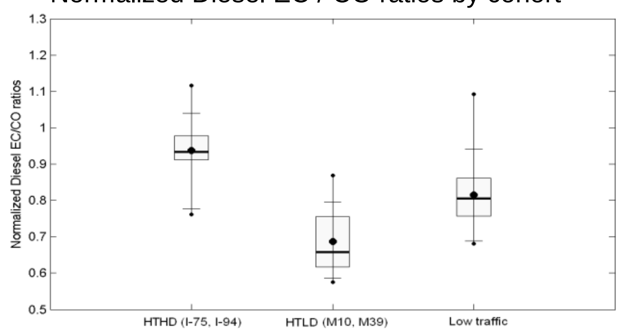
NEXUS Participant Locations



Normalized Diesel EC / CO ratios



Normalized Diesel EC / CO ratios by cohort

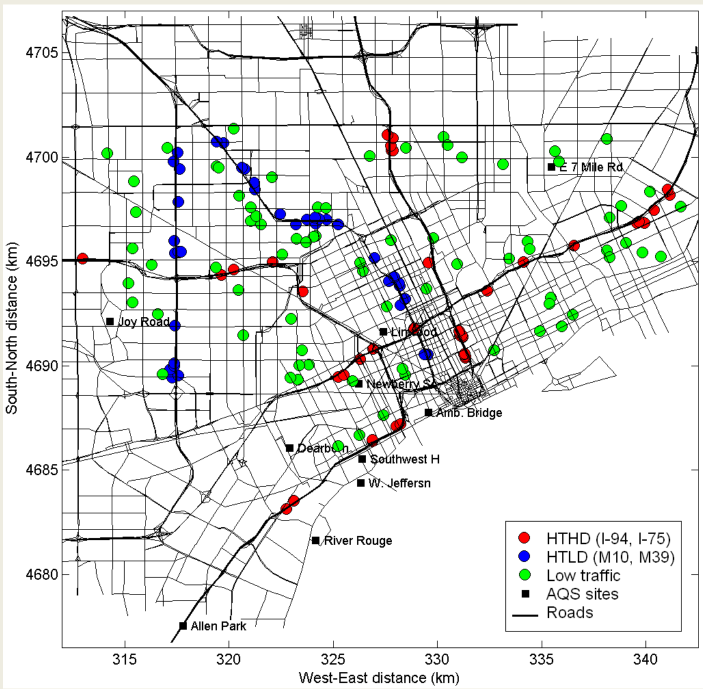


** Results shown are for ONE day of Fall 2010 period.

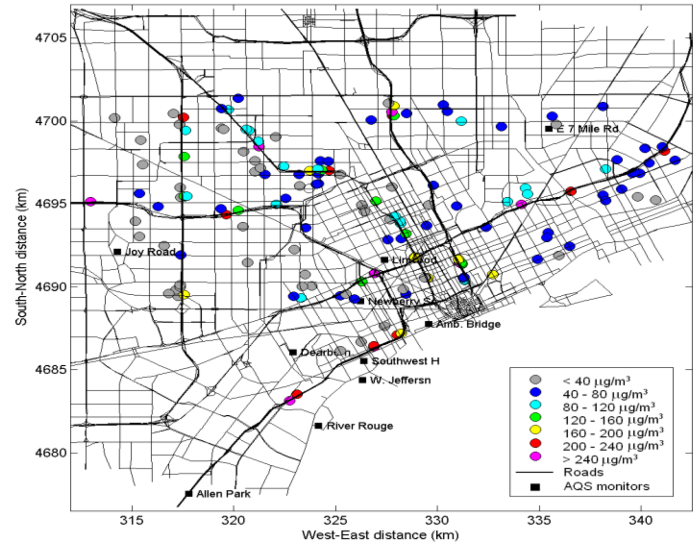
United States Environmental Protection Agency

Preliminary Modeling Results: Temporal Variability

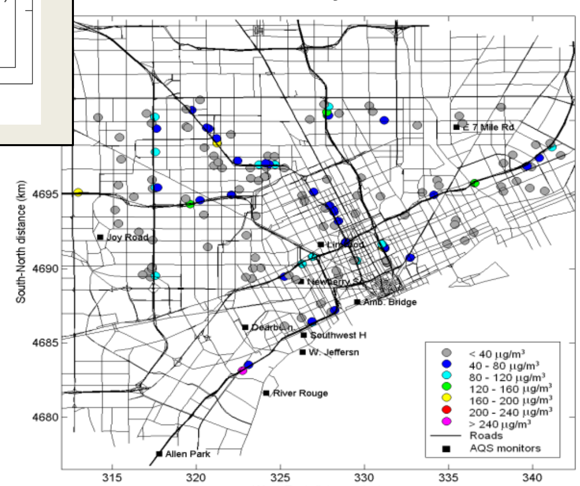
NEXUS Participant Locations



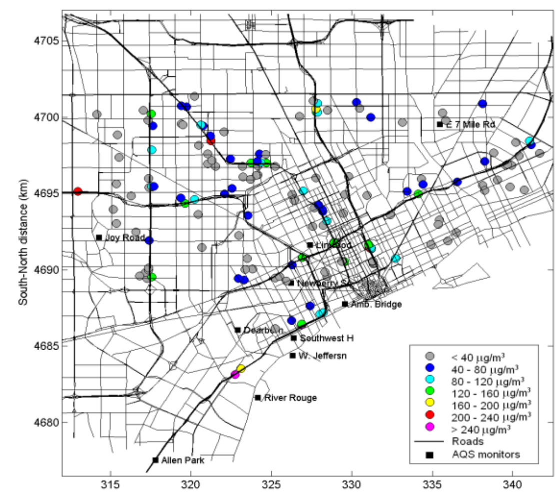
AM Peak



Mid-Day



PM Peak



** Results shown are for ONE day of Fall 2010 period.

Conclusions

The key factors in modeling exposure from mobile sources are

1. Roadway classification (including fleet mix)
2. Meteorological conditions (especially stability)
3. Traffic volume

In general….

- Road-link networks are hard to generate.
- Meteorological conditions are applied to a large spatial range, where boundary layer characteristics may vary.
- Local measurements are needed to verify general characteristics in traffic patterns and volumes.
- Air quality modeling is computationally resource intensive, but capture temporal and spatial variability with accurate emissions and meteorological inputs.

United States Environmental Protection Agency

Special thanks to the NEXUS team

Source Apportionment and Field Study

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Air Quality Modeling

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Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.