A Reduced-Form Model to Estimate Near-Road Air Toxics for Communities: The Community Line Source Modeling System (C-LINE)

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What is C-Line?

The Community Line Source (C-Line) modeling system estimates toxic air pollutant (air toxics) concentration gradients within 500 meters of busy roadways for community-sized areas on the order of 100 km^2. It currently does not include any other pollution sources except roadway vehicles. C-Line accesses publicly available datasets with national coverage for model inputs; therefore, users are not required to supply input data, but user-supplied datasets can be uploaded and used if available. A user-friendly interface facilitates analysis of what-if scenarios. Users can modify traffic attributes on different road segments or area-wide meteorological conditions to evaluate respective changes in resulting air quality; for example, from an increase in the number of diesel vehicles on a given road segment.

C-Line is described as a modeling system, because it includes inputs, analytics, and visualization in a single package. It is currently housed in ArcGIS as a standalone application, which requires users to download C-Line and have the appropriate software to run it; however, future work is geared toward making it an online application. C-Line cannot be used for regulatory applications, but lends itself to community-based assessments related to an overall characterization of conditions or to relative changes in air toxics concentrations based on changes in traffic or meteorological conditions.

Community Applications

Community groups are becoming increasingly active in local initiatives that seek to ameliorate potentially harmful environmental conditions. These are independent, locally-based, solution-oriented studies, and as such, can utilize different types of information than required for regulatory procedures. For example, qualitative or semi-quantitative (e.g., relative conditions as opposed to absolute conditions) data can be sufficiently robust to make informed decisions. In these instances, reduced-form models can provide valuable insights to assist with the decision-making process.

Reduced-Form Model

Reduced-form models provide an opportunity to examine how changes in input parameters, such as vehicle counts or speed, can affect results. The structure of reduced-form models can vary depending on the developers or application; typically, they maintain the same major, core components as their more detailed counterparts, but are accurate for a prescribed set of conditions defined by the user, as opposed to predicting conditions based on a wide range of highly detailed input parameters.

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

Modeling System

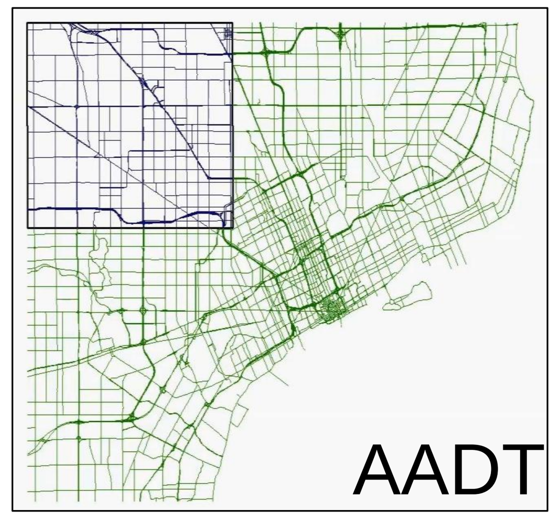
Current

- ArcGIS Standalone
- National datasets
- Traffic sources only

Future Work

- Exposure and ports
- Web-based
- Full automation

Road Network
Traffic Activity
Emission Factors
→ **1. Emissions**

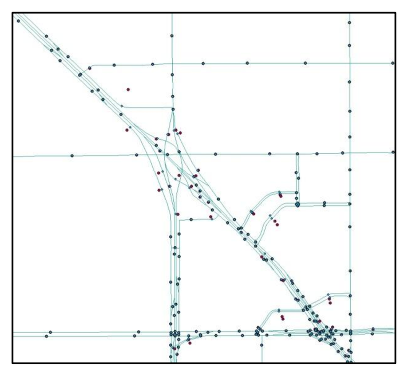


	Rural Interstate	Rural Other Arterials	Rural Other	Urban Interstate	Urban Other Arterials	Urban Other
MC	0.90%	1.10%	1.60%	0.40%	0.20%	2.10%
LDGV	65.99%	65.00%	70.72%	70.82%	75.66%	50.50%
LDGT1	12.04%	14.94%	15.45%	11.59%	11.08%	24.98%
LDGT2	6.13%	7.61%	7.87%	5.90%	5.64%	12.72%
LDDT	0.53%	0.65%	0.68%	0.51%	0.49%	1.09%
LDDV	0.91%	0.90%	0.98%	0.98%	1.04%	0.70%
HDGV	2.40%	2.41%	1.24%	2.21%	2.20%	1.15%
HDDV	11.1%	7.39%	1.46%	7.69%	3.70%	6.75%

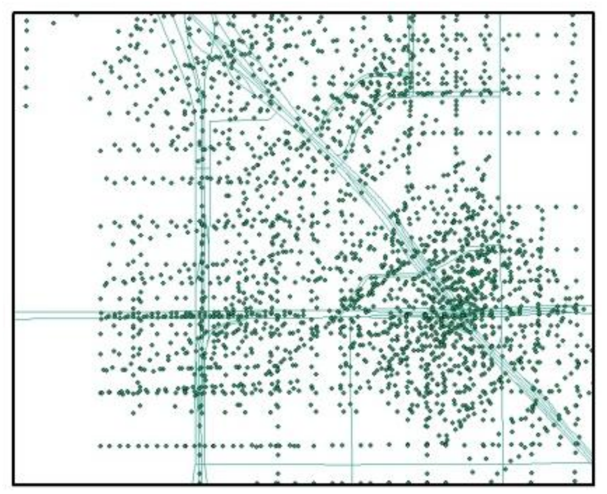
Table G-1: Calculation of Exhaust HC Emission Factor* For LDGVs

Model Year(i)	BER	OMTCF	OMTTAM	SALHCF	TF	BEF**
1995	0.246	1.549	0.001	0.742	0.0237	0.0067
1994	0.330	1.458	0.007	0.742	0.1130	0.0409
1993	0.456	1.366	0.017	0.742	0.1123	0.0533
1992	0.558	1.310	0.026	0.742	0.1049	0.0589
1991	0.649	1.268	0.035	0.742	0.1017	0.0647
1990	1.009	1.178	0.046	0.748	0.0928	0.0857
1989	1.328	1.131	0.056	0.763	0.0835	0.0993
1988	1.583	1.102	0.066	0.777	0.0574	0.0807
1987	1.891	1.086	0.075	0.792	0.0484	0.0816
1986	2.239	1.076	0.089	0.801	0.0467	0.0934
1985	2.555	1.070	0.110	0.809	0.0430	0.0989
1984	2.771	1.060	0.120	0.797	0.0436	0.1062
1983	3.036	1.061	0.470	0.806	0.0357	0.1062
1982	3.363	1.108	0.515	0.798	0.0259	0.0877
1981	3.694	1.101	0.530	0.786	0.0157	0.0567
1980	3.738	1.378	1.445	0.684	0.0119	0.0537

Line Segments
Point Receptors
Meteorology
→ **2. Dispersion**

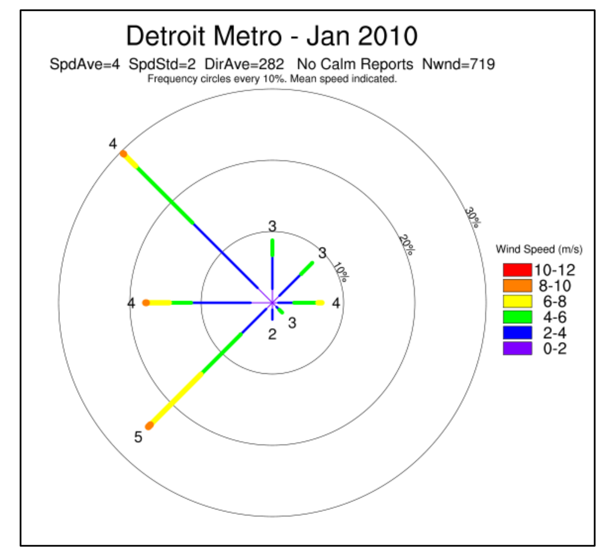


Midpoints

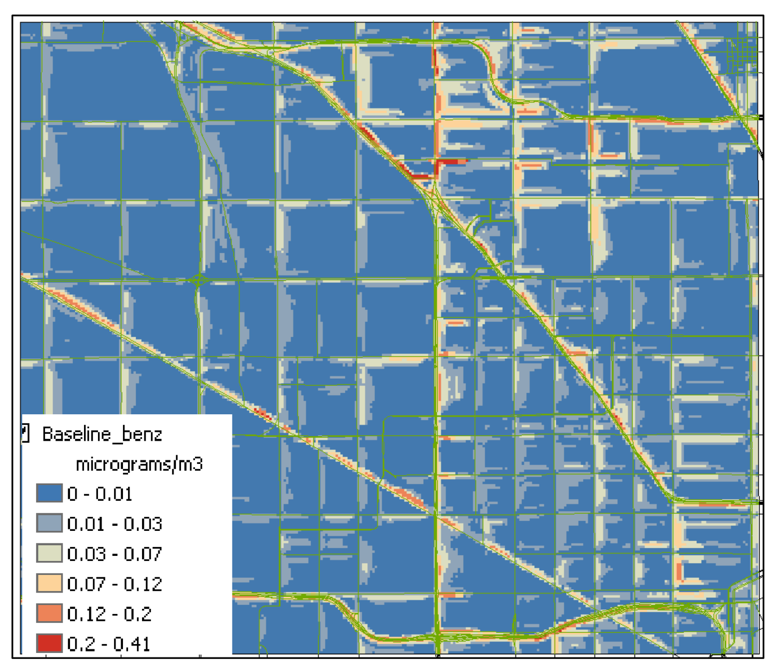


Receptors at 50, 100, 200, 300, 400, 500m

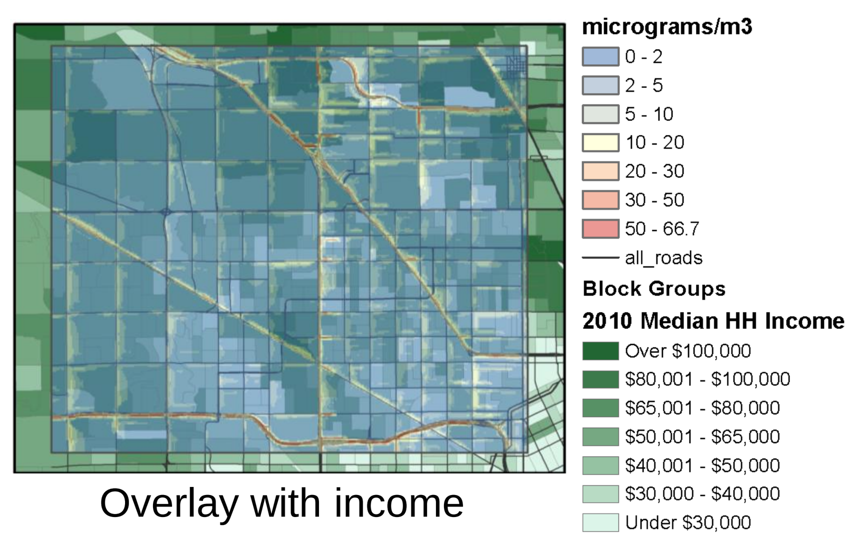
	Season	Wind Speed (m/sec)	U-Star	Monin-Obhukhov Length, (m)
Typical	Winter	3.7	0.58	-3846
Unfavorable	Winter	1.3	0.23	11
Favorable	Winter	7.2	1.03	-2482
Typical	Summer	3.1	0.46	-343
Unfavorable	Summer	1.3	0.15	5
Favorable	Summer	5.5	0.58	-66



Interpolation
GIS Mapping
Overlays
→ **3. Visualization**



Concentrations, ug/m^3



Overlay with income

Buildings & indoor air

Port area sources

Future Work:

- Indoor Air
- Ports

Dispersion Algorithm

Steady-state Gaussian-based plume model

The dispersion algorithm treats each lane of a highway as a line source located along the center of the lane. The contribution of the elemental point source, *dC*, located at *(0,Y$_s$)* to the concentration at *(X$_r$, Y$_r$, Z$_r$)* is given by the Gaussian plume formulation.

$$C(X_r,Y_r)=\int_{Y_1}^{Y_1+L} dC \quad \Rightarrow \quad C_p(X_r,Y_r)\approx \frac{qF(Z_r)}{\sqrt{2\pi}U\sigma_z\left(x_r^{eff}\right)\cos\theta}\left[erf(t_1)-erf(t_2)\right]$$

Meander

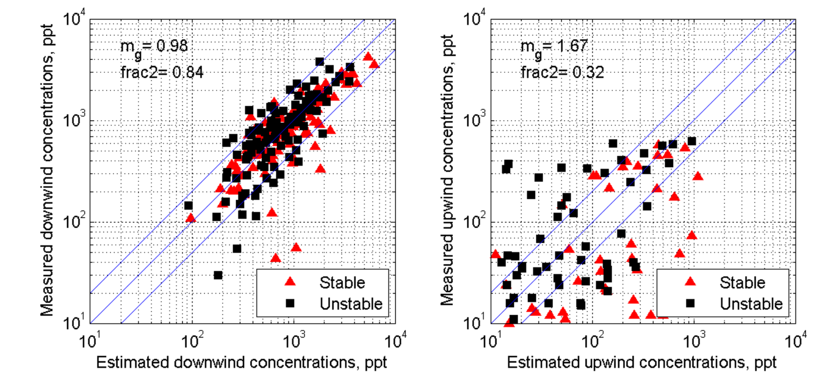
Under low wind speeds, horizontal meandering of the wind spreads the plume over large azimuth angles, which might lead to concentrations upwind relative to the vector-averaged wind direction.

$$C_m(X_r,Y_r)\approx\sqrt{\frac{2}{\pi}}\frac{qF(Z_r)}{U\sigma_z(X_r)}\frac{\theta_s}{2\pi}$$

References

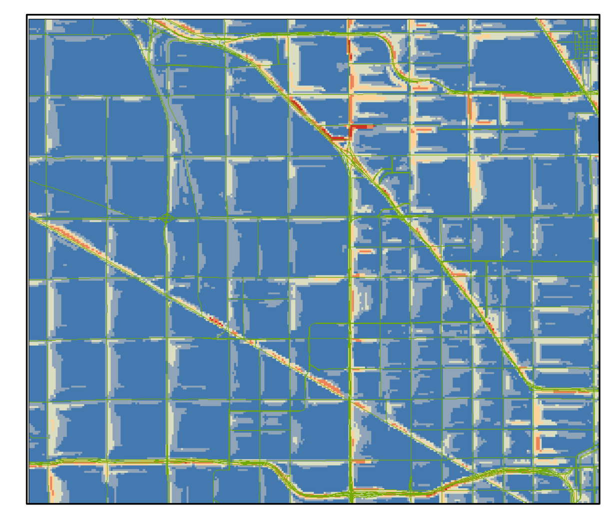
A. Venkatram, M. Snyder, V. Isakov, S. Kimbrough. Impact of Wind Direction on Near-Road Pollutant Concentrations. *Atmospheric Environment* 80, 248–258 (2013)

A. Venkatram, M. Snyder, V. Isakov. Modeling the impact of roadway emissions in light wind, stable and transition conditions. *Transportation Research Part D* 24: 110-119 (2013)

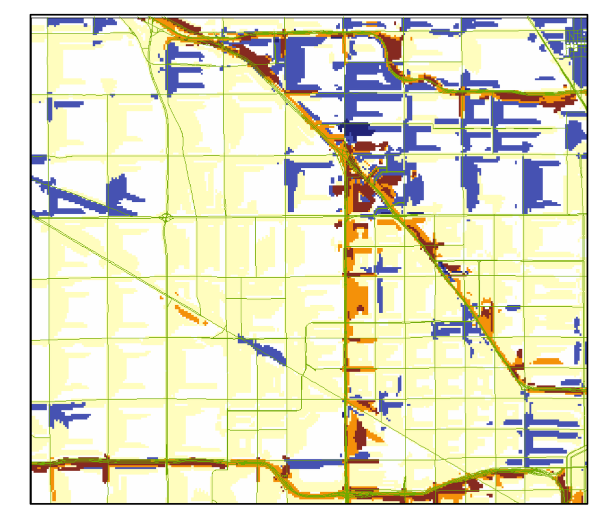


Model-Measurement Comparison
Downwind & Upwind
SF_6 Tracer

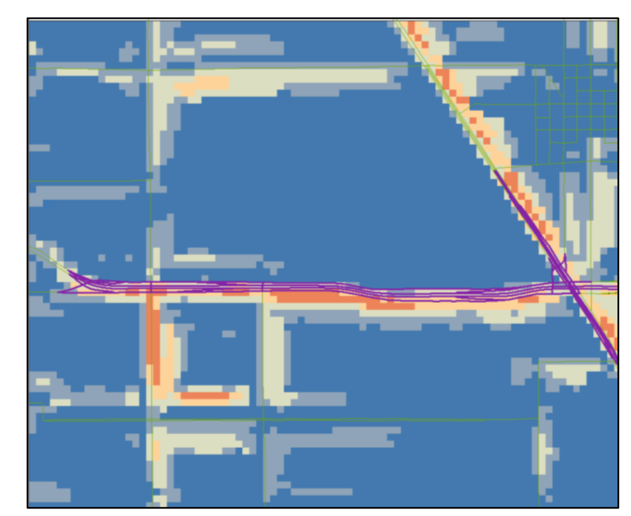
What-if Scenarios



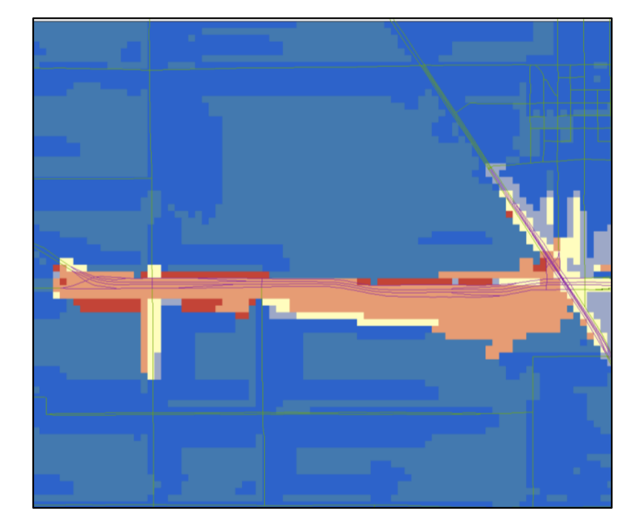
Example of C-LINE model results: benzene concentrations



Benzene concentration differences when VMT is increased by 20% and overall speed by 10%



Example of modeled benzene concentrations for selected roads



Benzene concentration differences when both gasoline and diesel trucks are increased by 20%