RLINE: A Line Source Dispersion Model for Near-Surface Releases

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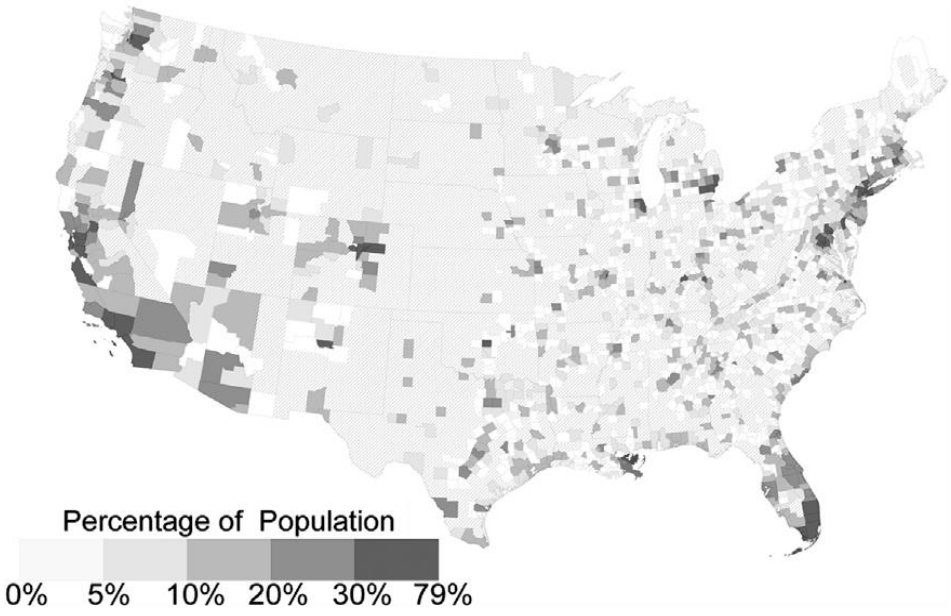
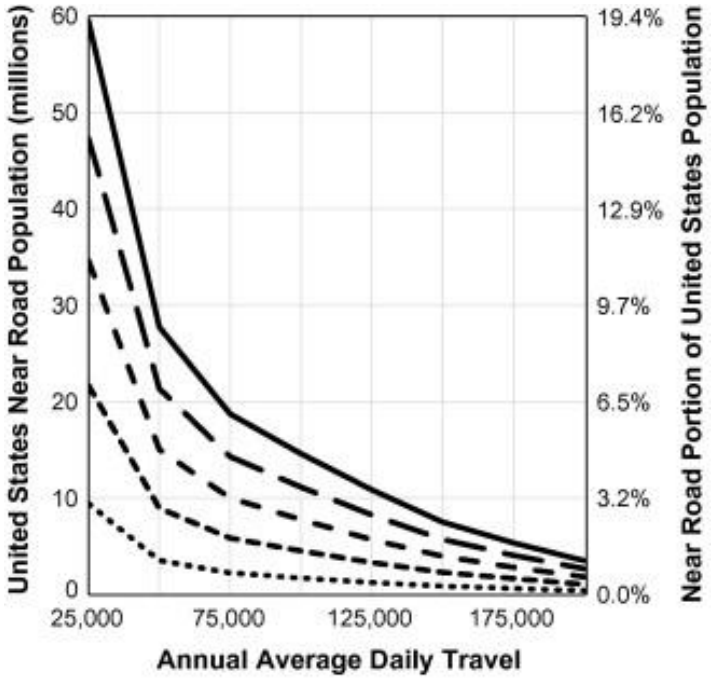
Background

- 59.5 million people live within 500m of roads with > 25,000 Annual Average Daily Traffic (AADT)





Source: Rowangould, *Transport Research Part D*, 2013

Why was RLINE Developed?

- Based on Science Advisory Board and the National Research Council recommendations, EPA-ORD initiated research on near-road air quality and health effects

- Field measurements indicated that exposures to traffic-emitted air pollutants near roads can be influenced by complexities of roadway configurations (noise walls, depressed sections, etc.)

- To improve exposure metrics for future health studies, ORD initiated model development project to account for these important parameters

What is RLINE?

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
- 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

EPA-ORD: Model Development Focus

- Account for near-road complexities and very near road concentrations (i.e. within a few meters of the road)
- Design and conduct wind tunnel and field studies for development and evaluation of improved line source algorithms
- RLINE is the initial modeling product of this development program
- It is a research tool that is designed primarily to support risk assessments and health studies related to near-road pollutants

What RLINE is NOT?

- RLINE is not designed for regulatory applications (e.g. NAAQS enforcement, New Source Review, PM Hot Spot Conformity, SIP analyses, etc).
- It is contained in a research platform and has not gone through the rigorous review and public comment required for inclusion in the list of recommended regulatory models

Model Algorithm

Steady-state, Gaussian based plume model

$$C_{line} = \int dC_{pt} \quad \text{where} \quad dC_{pt} = (1-f)dC_{plume} + f dC_{meander} \quad \text{and} \quad f = \frac{2\sigma_v^2}{U^2}$$

Concentration at a receptor is the integrated contributions from points along the line using a Romberg Iteration Scheme.

Plume

For each point source within the integration, a wind-direction following plume is simulated.

$$C_{plume} = \frac{Q}{U}\frac{1}{2\pi\sigma_z\sigma_y}\left[\exp\left(-\frac{1}{2}\left(\frac{z-z_s}{\sigma_z}\right)^2\right)+\exp\left(-\frac{1}{2}\left(\frac{z+z_s}{\sigma_z}\right)^2\right)\right]\exp\left(-\frac{1}{2}\left(\frac{y-y_s}{\sigma_y}\right)^2\right)$$

Meander

For each point source within the integration, meander is handled in the same way as AERMOD point source meander.

$$C_{meander} = \frac{Q}{U}\frac{1}{\sqrt{2\pi}\sigma_z}\left[\exp\left(-\frac{1}{2}\left(\frac{z-z_s}{\sigma_z}\right)^2\right)+\exp\left(-\frac{1}{2}\left(\frac{z+z_s}{\sigma_z}\right)^2\right)\right] \quad \frac{1}{2\pi R}$$

Model Algorithm

Mean Plume Height

Concentration is a function of mean plume height (similar in nature to the effective parameter concept used in AERMOD).

$$\bar{z} = \sigma_z \sqrt{2/\pi}\, \exp\left[-\frac{z_{source}^2}{2\sigma_z^2}\right] + z_{source}\, erf\left[\frac{z_{source}}{\sqrt{2}\sigma_z}\right]$$

Meteorological Inputs

RLINE uses the meteorological inputs from the AERMOD met. preprocessor (u_*, w_*, mixing height, L_{mo}, z_0, Wspd, Wdir, heat flux, T) then corrects u_* for light wind conditions.

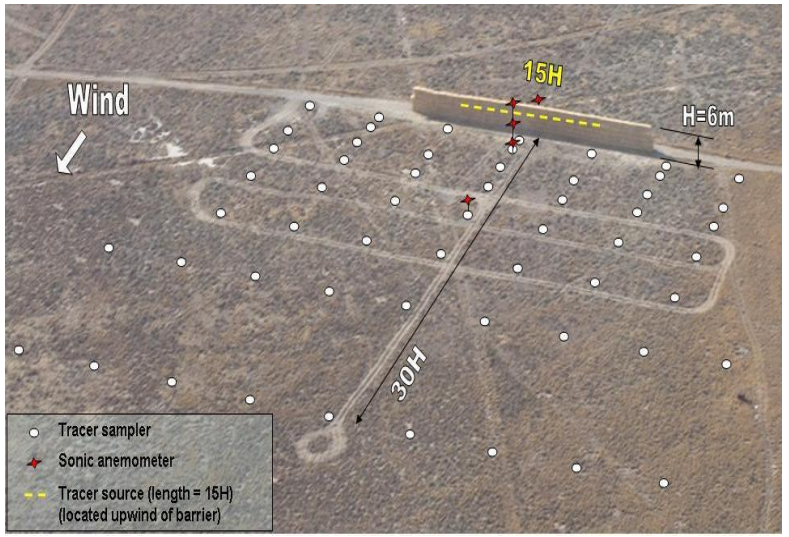
$$u_{*,corr} = \frac{u_*}{1 - \exp(2U_{crit}/U)}$$

Other surface parameters are then recalculated to be internally consistent with M-O theory.

This method was developed and evaluated by Qian and Venkatram (BLM 2011).

Model Development Databases

- Tracer Studies
  - Idaho Falls 2008
  - Prairie Grass
- Wind tunnel studies
- Field studies



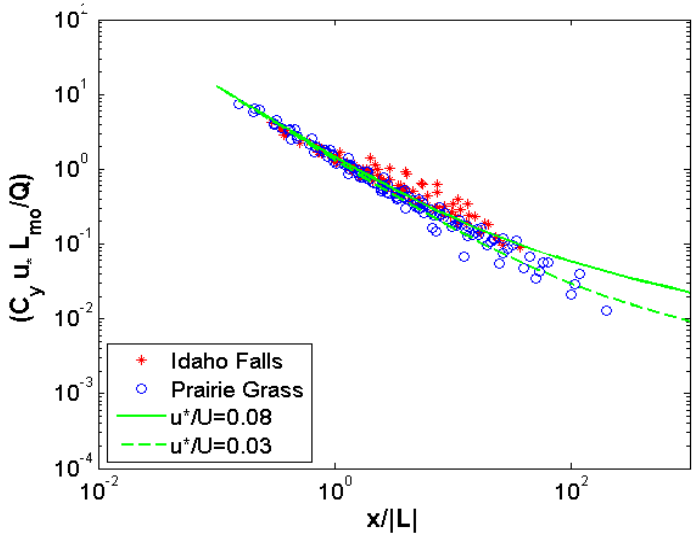
Model Algorithm
New Dispersion Formulations

Vertical Dispersion

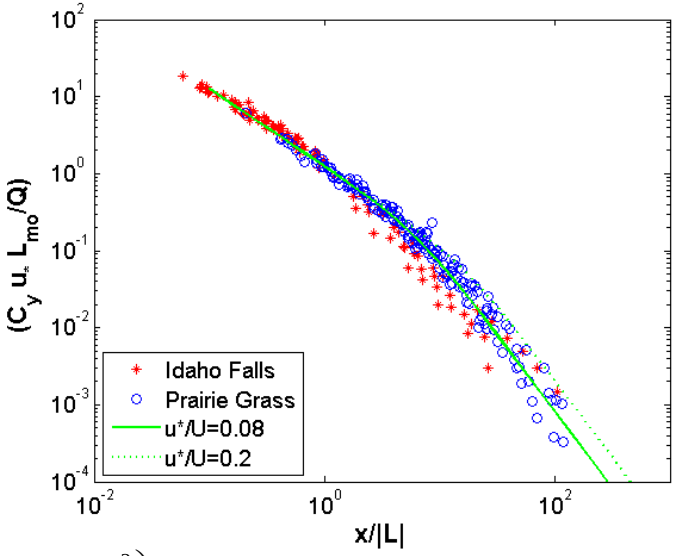
$$\sigma_{z,stable} = 0.57\frac{u_* x}{U}\left[1+3\left(\frac{u_*}{U}\right)\left(\frac{x}{L}\right)^{2/3}\right]^{-1}$$

$$\sigma_{z,conv} = 0.57\frac{u_* x}{U}\left[1+2\left(\frac{u_*}{U}\frac{x}{L}\right)\right]$$

Stable



Convective



$$C_{plume} = \frac{Q}{U}\frac{1}{2\pi\sigma_z\sigma_y}\left[\exp\left(-\frac{1}{2}\left(\frac{z-z_s}{\sigma_z}\right)^2\right)+\exp\left(-\frac{1}{2}\left(\frac{z+z_s}{\sigma_z}\right)^2\right)\right]\exp\left(-\frac{1}{2}\left(\frac{y-y_s}{\sigma_y}\right)^2\right)$$

$$C_{meander} = \frac{Q}{U}\frac{1}{\sqrt{2\pi}\sigma_z}\left[\exp\left(-\frac{1}{2}\left(\frac{z-z_s}{\sigma_z}\right)^2\right)+\exp\left(-\frac{1}{2}\left(\frac{z+z_s}{\sigma_z}\right)^2\right)\right]\frac{1}{2\pi R}$$

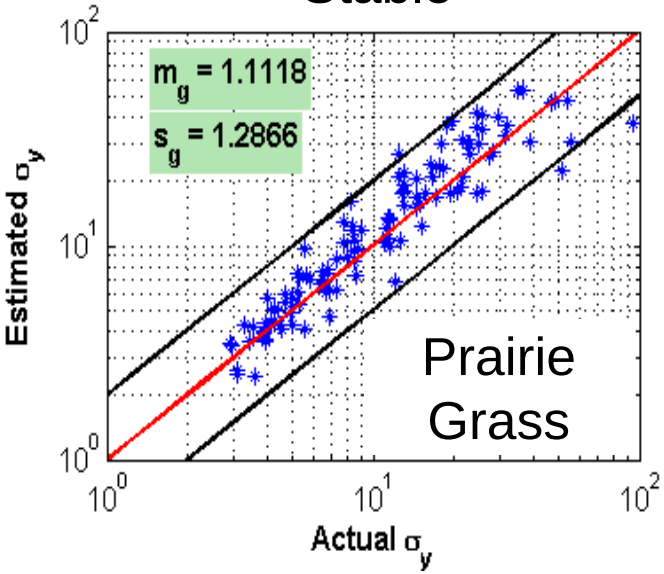
Model Algorithm
New Dispersion Formulations

Lateral Dispersion

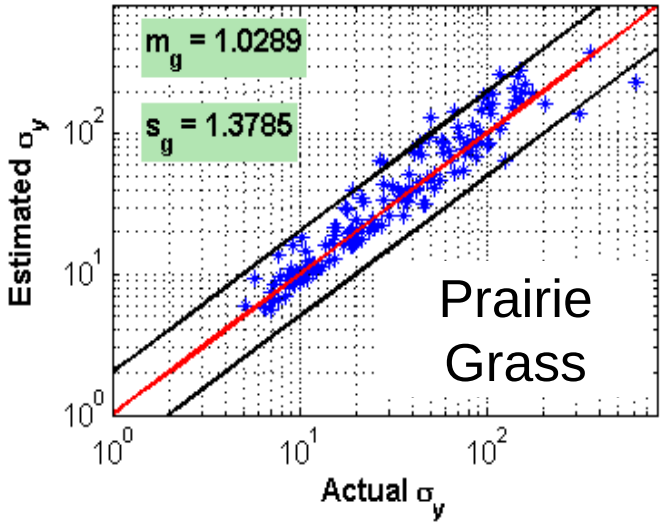
$$\sigma_{y,stable} = 1.6\frac{\sigma_v}{u_*}\sigma_z\left[1+2.5\frac{\sigma_z}{L}\right]$$

$$\sigma_{y,conv} = 1.6\frac{\sigma_v}{u_*}\sigma_z\left[1+\frac{\sigma_z}{|L|}\right]^{-1/2}$$

Stable



Convective



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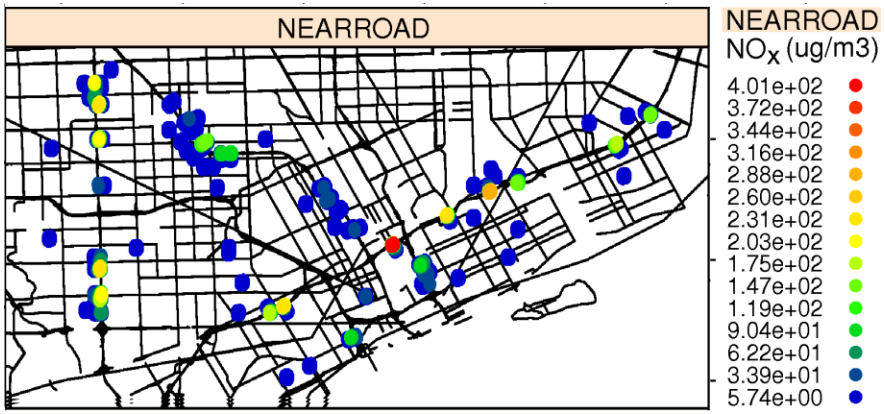
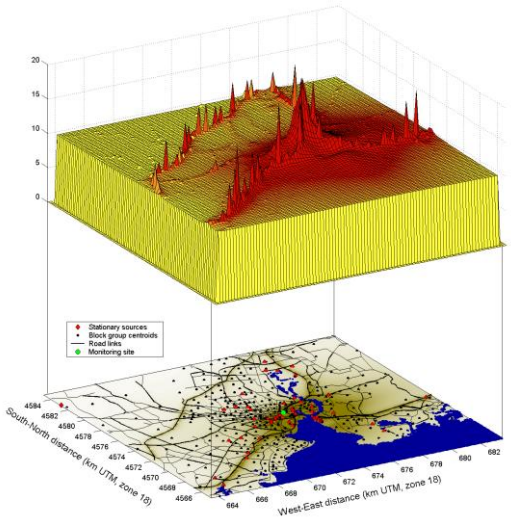
How is RLINE being used?

• The model can support health and risk assessments, epidemiology studies, and community based tools.

• RLINE is designed to handle urban situations with thousands of line sources and receptors.



RLINE is used in “Near-Road EXposures to Urban air pollutants Study” (NEXUS) in Detroit examining the role of near-road exposures on asthmatic children who live near major roadways.



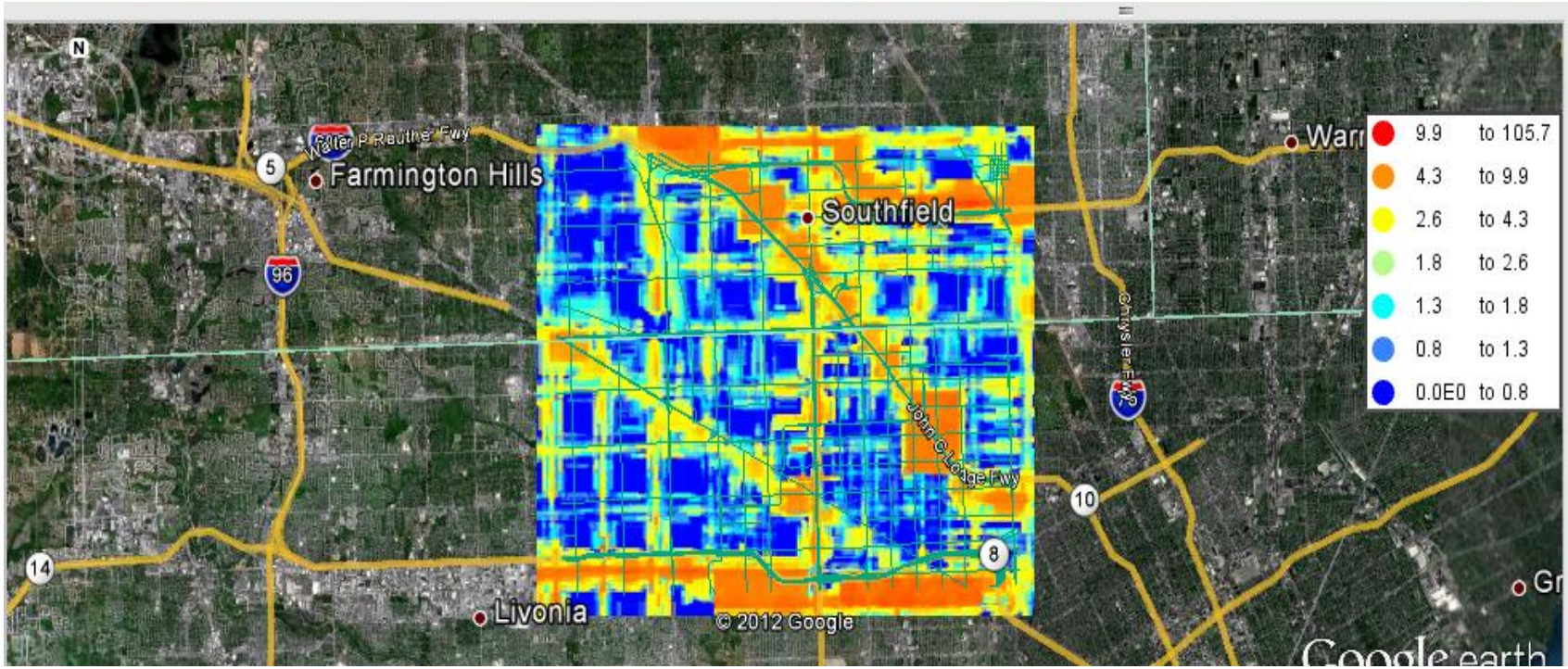
RLINE can be used to estimate spatial variability in urban areas with many roadways.

See: Talks by a) Snyder et al, (b) Chang et al, and Poster by (c) Isakov et al.

How does RLINE support community tools?

R-LINE algorithm is used in C-LINE, a decision support tool for evaluating effects of alternate transportation options on community health

EPA's C-LINE Tool



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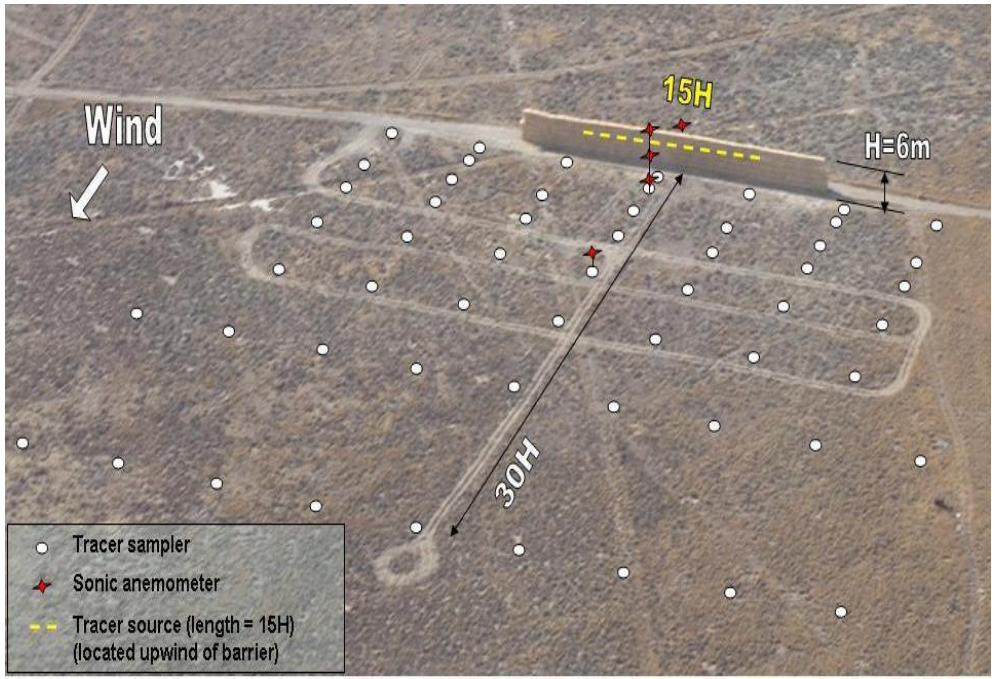
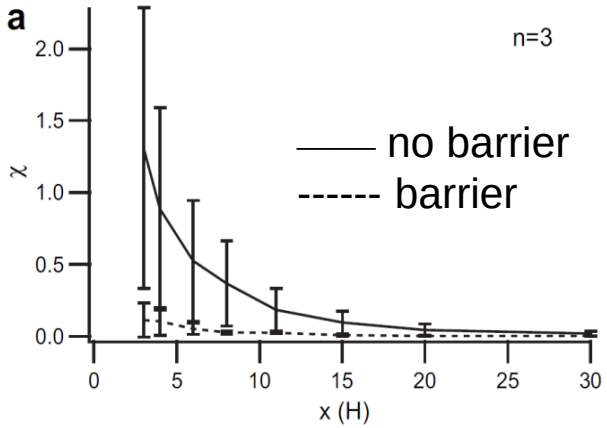
See: Poster by (d) Barzyk et al

Ongoing Development Work

- The model framework is designed to accommodate future algorithms for simulating the near-source effects of complex roadway configurations (noise barriers, depressed roadways, etc).
- These configurations could be used in mitigation, to reduce exposure near high emission roadways.

Idaho Falls 2008 tracer study



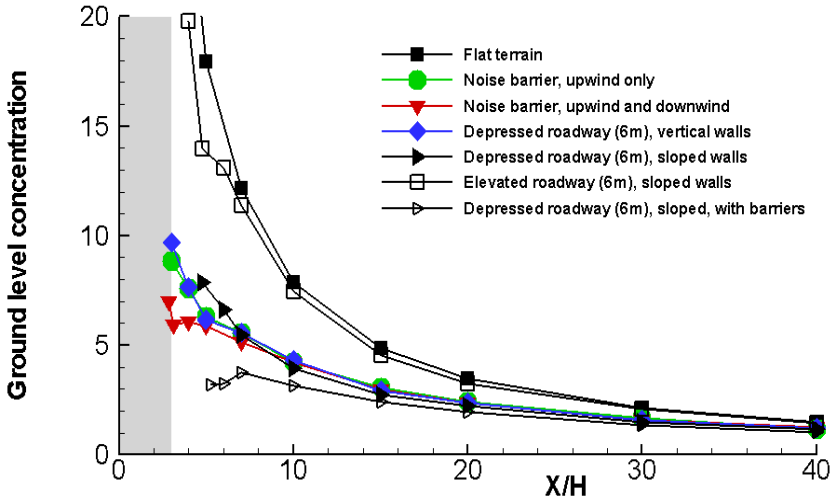


Finn et al., 2010

Ongoing Development Work

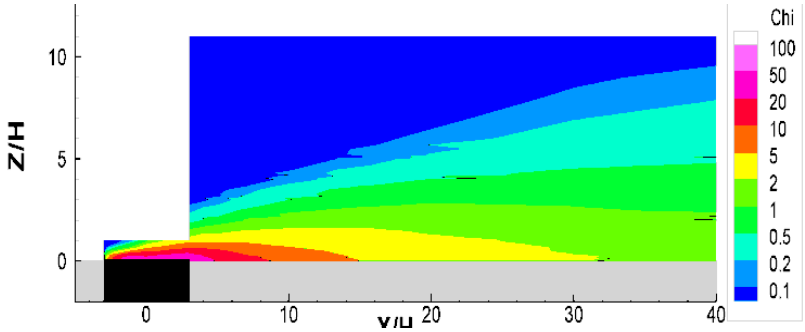
H = 6 m

Wind tunnel studies

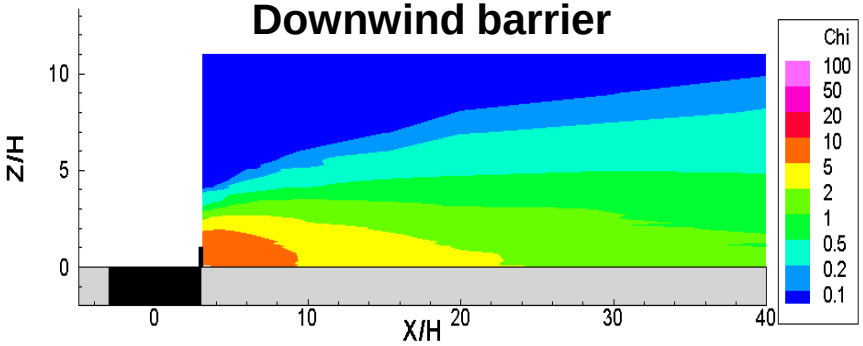


Baldauf et al, 2009

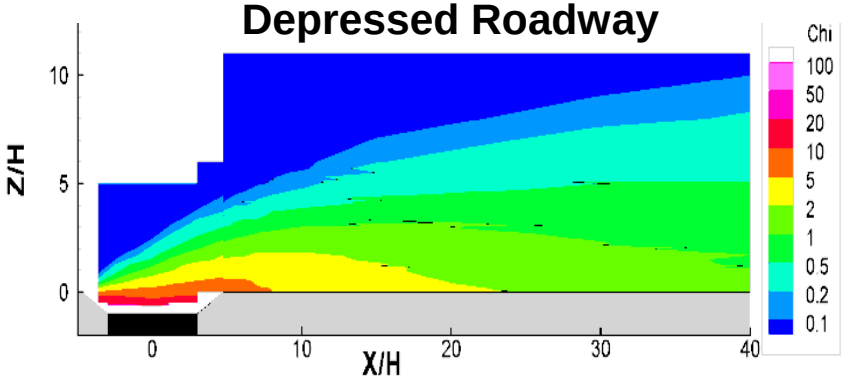
Flat terrain



Downwind barrier



Depressed Roadway



Heist et al, 2009

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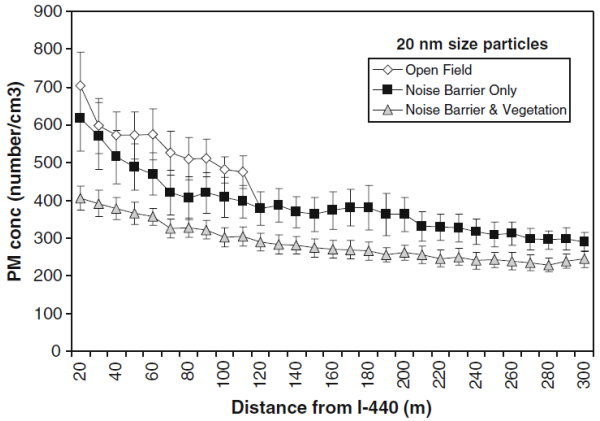
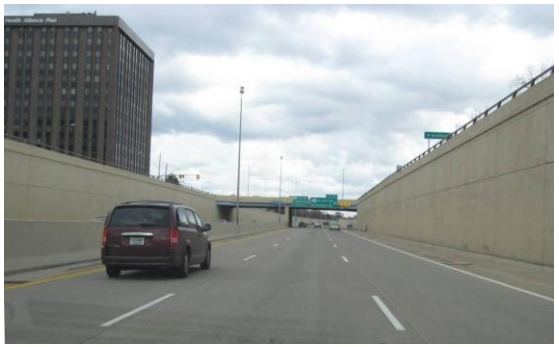
Ongoing Development Work

Field studies

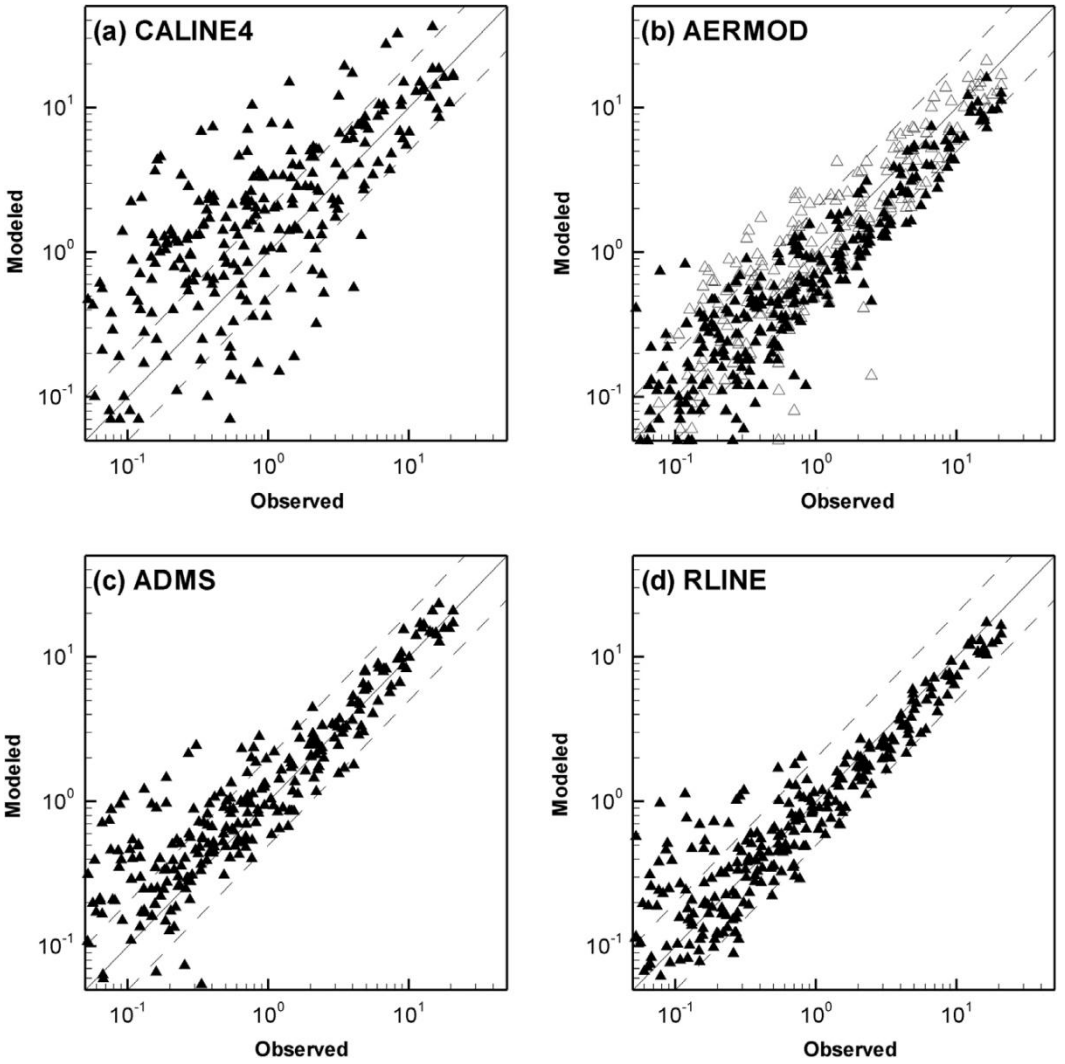




Field and wind tunnel studies show noise barriers and depressions reduce downwind concentrations under multiple stability conditions. These features will be added to the flat terrain RLINE model.

Inter-comparison against other models

- 4 models applied for 2 Tracer Studies
  - Idaho Falls 2008
  - CalTrans Highway 99
- All models showed ability to estimate majority of observations within a factor of 2
- Models performed best for near-neutral conditions in both tracer studies
  - Mixed results in convective and stable conditions



Heist et al, 2013

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Features in Release Version of RLINE

- Uses hourly meteorological data from AERMET v12345
  - Similar to AERMOD applications
- Contains updated σ_y and σ_z formulations
  - See Venkatram et al, 2013
- Can handle inputs in the form of activity (in AADT) or emissions (in g/m/s)
  - AADT outputs can be postprocessed with TAFs and species-specific emissions to obtain variable emissions
  - g/m/s is output in $\mu g/m^3$
- Produces grouped source outputs
  - Hourly (for entire period or monthly)
  - Daily average

Features Available as Beta Options

- Analytical solution for near-source receptors
  - Speeds up computation
- Input # lanes per roadway
  - Spreads emissions over the lanes of traffic
- Solid/noise barrier algorithm
- Depressed roadway algorithm

Where to get RLINE from?

- Summer 2013: Availability of pre-release version announced via Community Modeling & Analysis System (CMAS) website
- November 2013: Full public release expected via CMAS to include:
    - Explanation of model code, use, and inputs required
    - Documented evaluation and evaluation data
    - Qualifications on appropriate use
- Spring/Summer 2014: Planned repository of tools and utilities for pre- and post-processing to support user community

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