Summary of Noise Barrier and Other Roadside Feature Impacts on Near-Road Air Quality

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Office of Research and Development
National Risk Management Research Laboratory/Air Pollution Prevention and Control Division

Background

- Evidence of increased health risks for populations living, working and going to school near large roads
- Elevated concentrations of air pollutants near large roads
- Large population exposed, including children at school
- Interest in methods to understand and mitigate these traffic emission exposures and health effects
- Transportation and land use planning mitigation options :
  - Vehicle emission standards and voluntary programs
  - Reducing vehicle activity/Vehicle Miles Travelled (VMT)
  - Buffer/exclusion zones
  - Use of roadway design and urban planning
    - Road location and configuration
    - ***Roadside noise barriers and vegetation***

Why study roadside barriers?

- Roadside barriers alter air pollution transport and dispersion
- Roadside barriers may already be present and affecting exposures
- Roadside barriers often have other positive benefits
- Few other “short-term” mitigation options
  - Emission reductions take long to implement (fleet turnover required)
  - Planning and zoning involved in rerouting/VMT reduction programs
  - Buffer/exclusion zones may not be feasible

Summary of Research Results

- Noise Barriers can reduce downwind air pollutant concentrations
  - Design characteristics affect levels of reductions
  - Meteorology impacts pollutant transport and dispersion
- Air pollution can be trapped on the upwind side of the structure
- Air pollution can meander around the edges and through gaps in barriers
- Combination of noise barriers and vegetation may maximize pollutant reductions, especially for particulate matter

Roadway Configuration Effects

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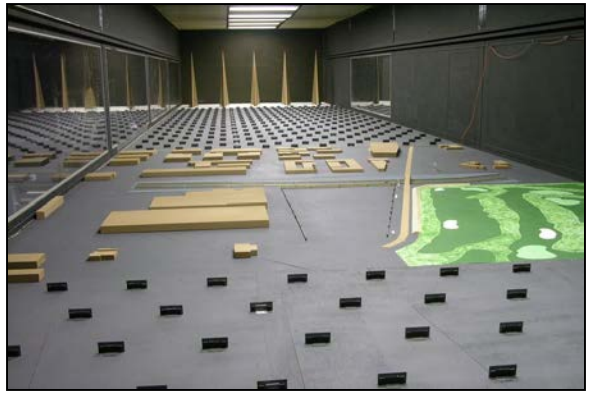
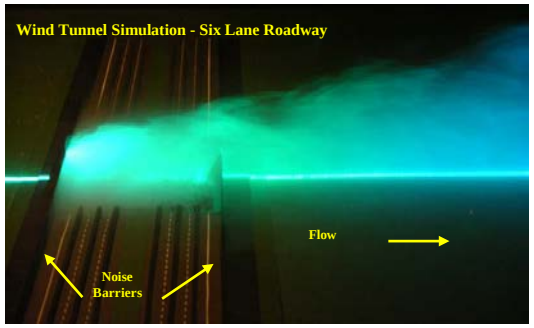
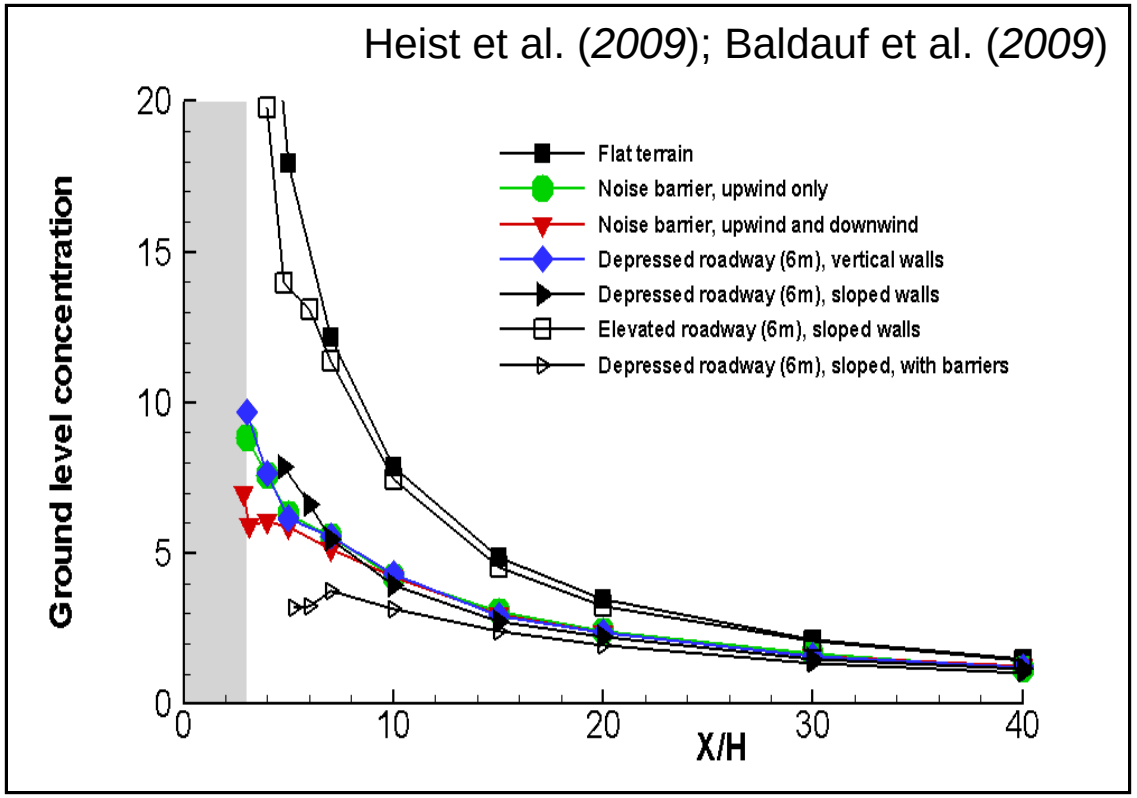






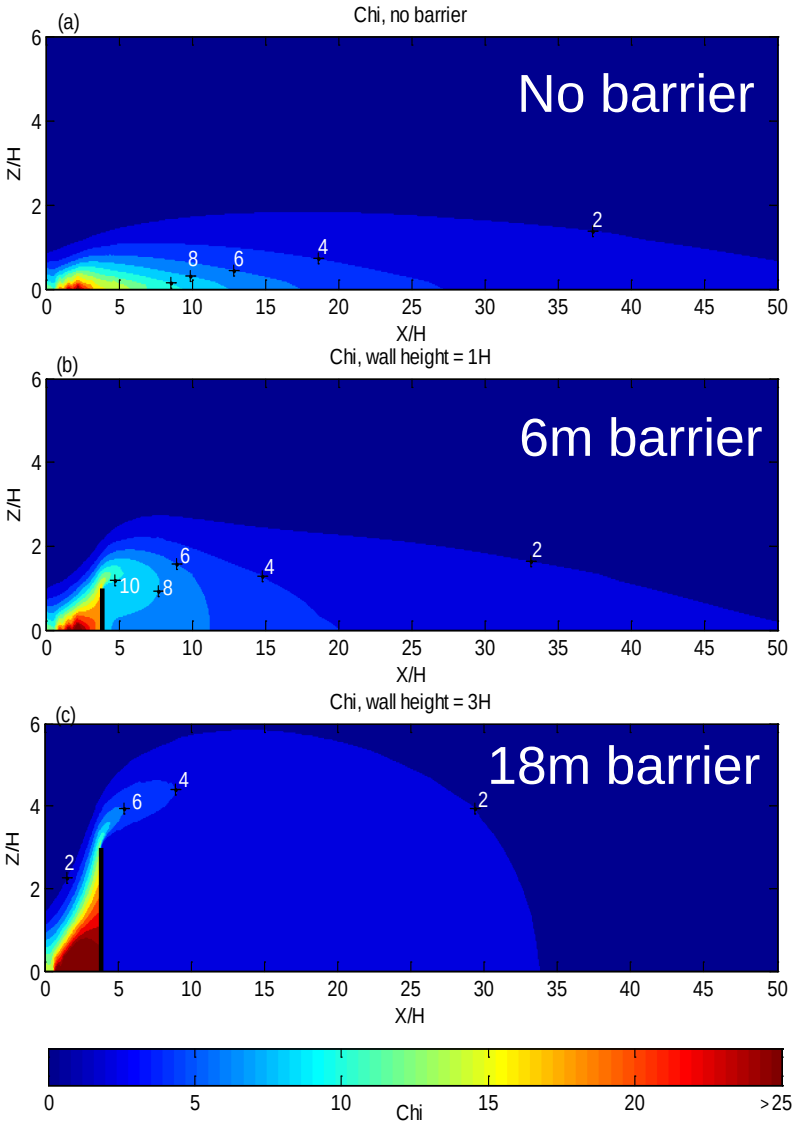
Wind tunnel simulations show roadway design effects on pollutant transport and dispersion. Highest levels occur with at-grade and elevated fill roads. Lowest levels occur with cut sections and noise barriers

Noise Barriers & Air Quality

United States Environmental Protection Agency

CFD modeling suggests:

- Decreased concentrations downwind of barrier
- Increased concentrations on-road due to upwind trapping
- The higher the barrier, the greater the downwind reduction and on-road increase

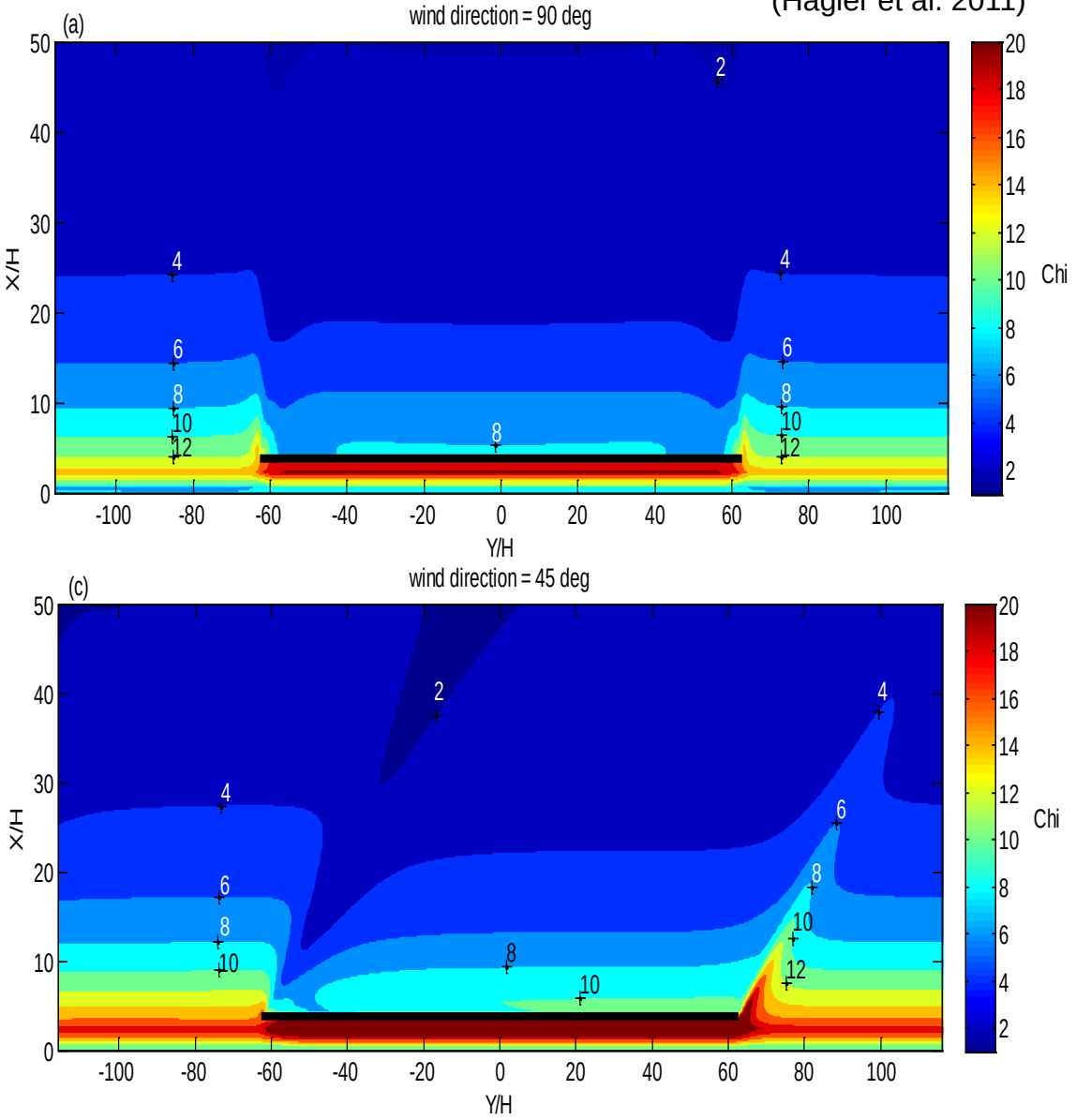


(Hagler et al. 2011)

Impact of wind direction

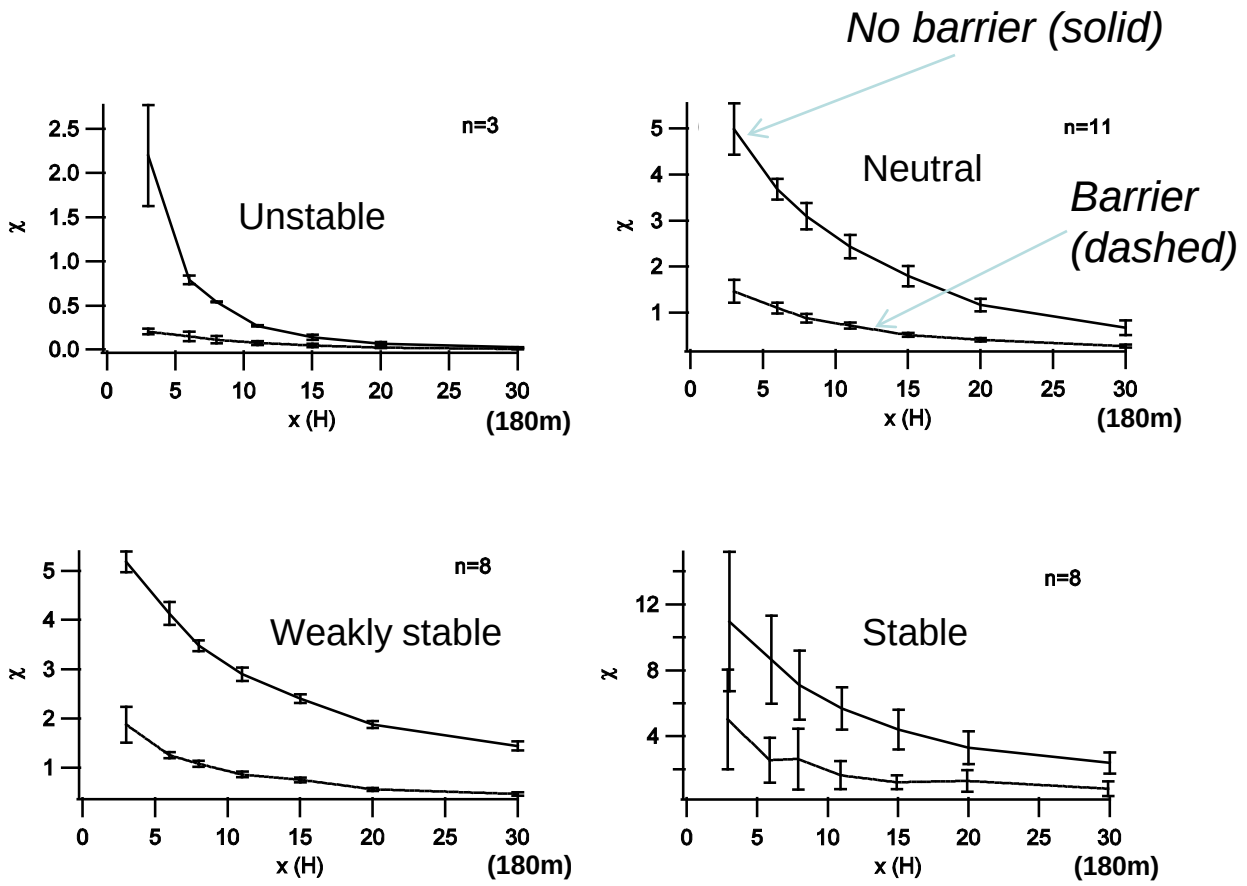
- Pollutant wrap around can occur at barrier edges
- Modeling estimates effect is less than 50m from edge
- Higher open area concentrations can occur within ~20m

(Hagler et al. 2011)



Noise Barriers & Air Quality

(Finn et al., 2010)



Tracer gas experiments show downwind pollutant reductions under all stability classes; more variability with stable, calm wind conditions

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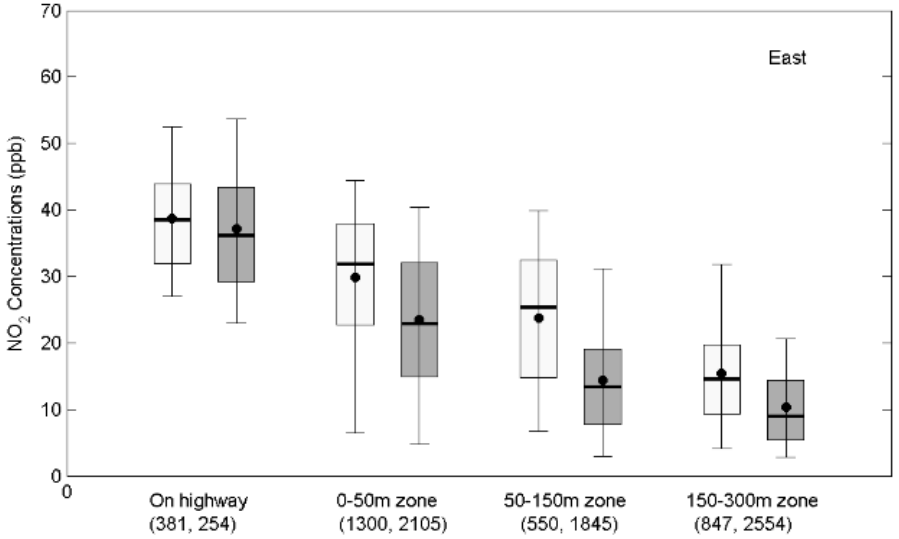
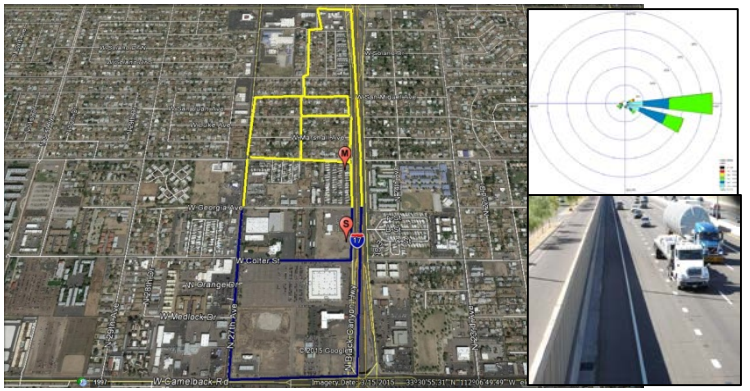
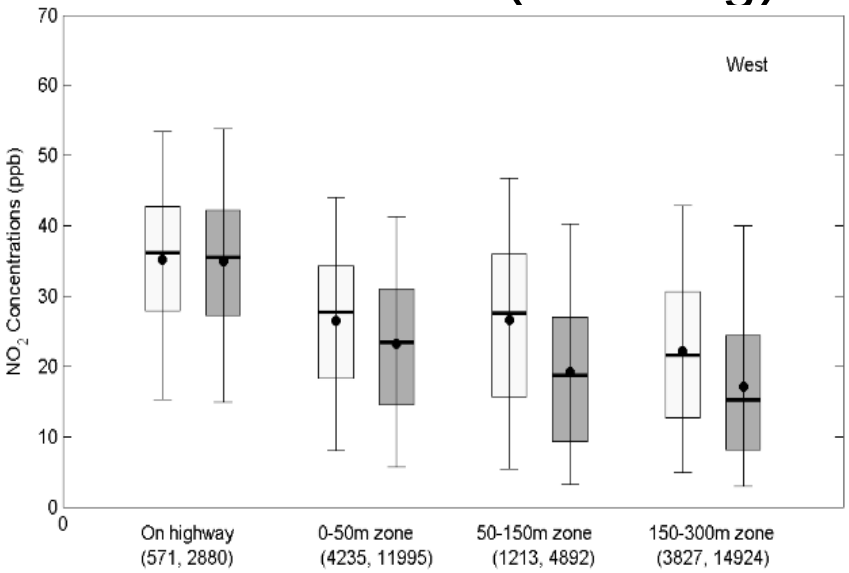
NO_2 concentrations





West Section (Morning)

East Section (Afternoon)



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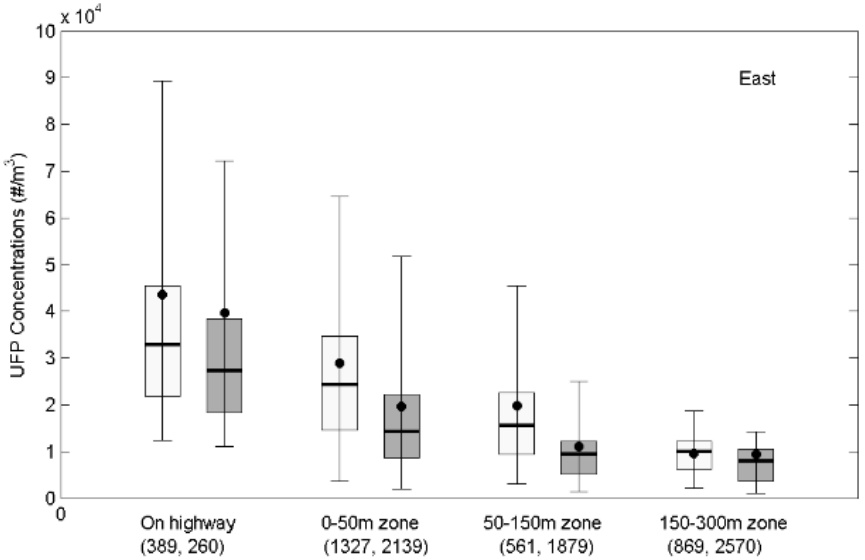
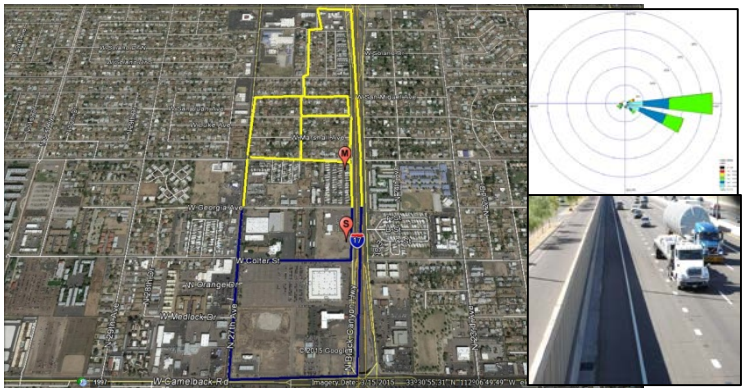
UFP concentrations





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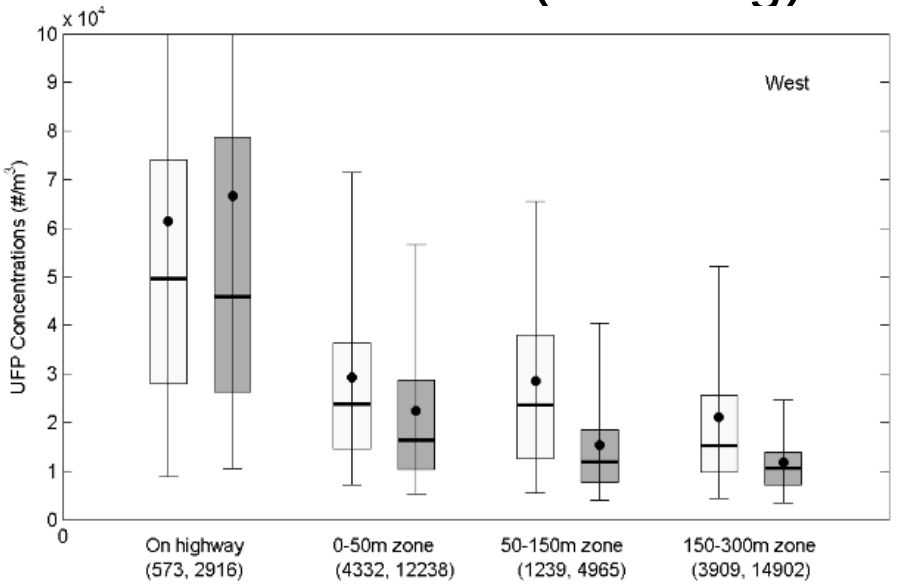

Noise Barriers & Air Quality

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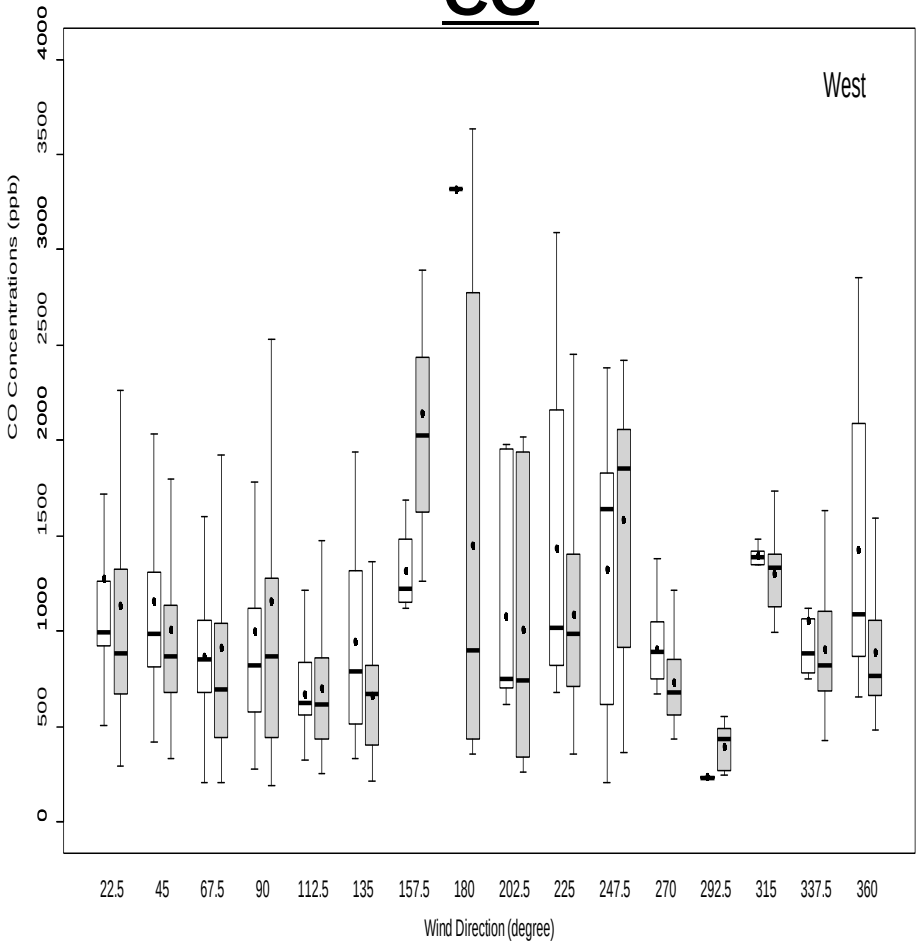
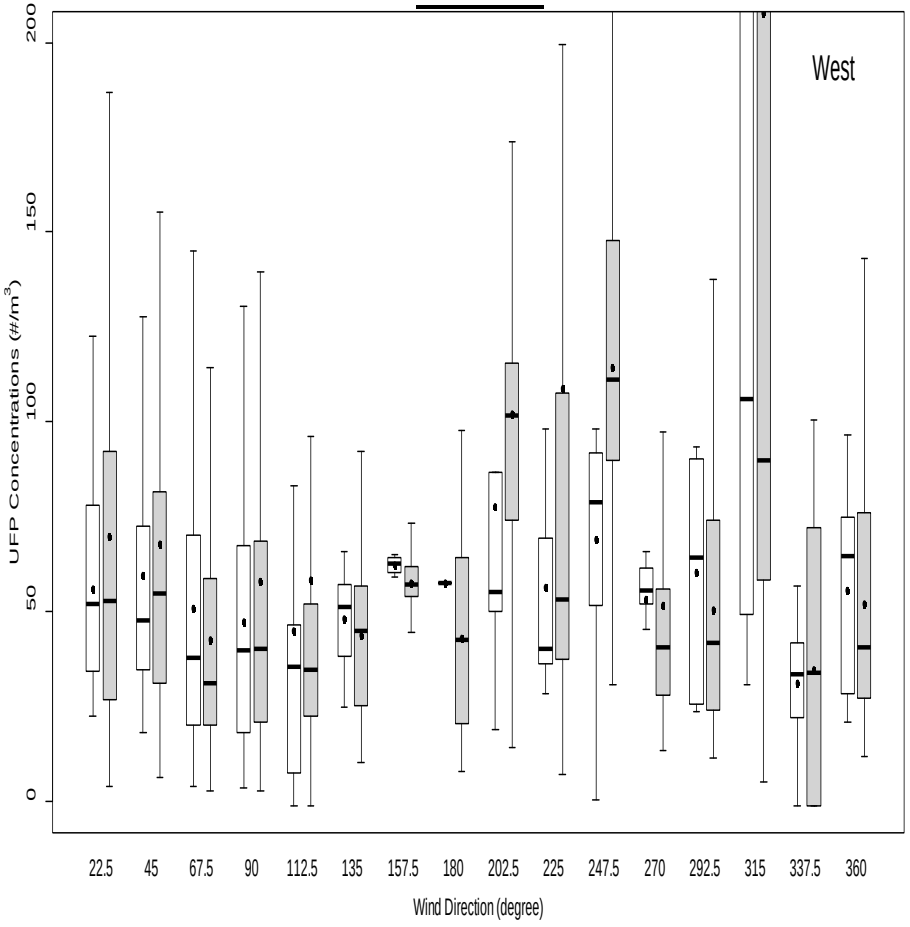


UFP



On-road pollutant concentrations generally similar in front of the noise barrier (gray) and in front of the open section (white)

Noise Barriers with Vegetation

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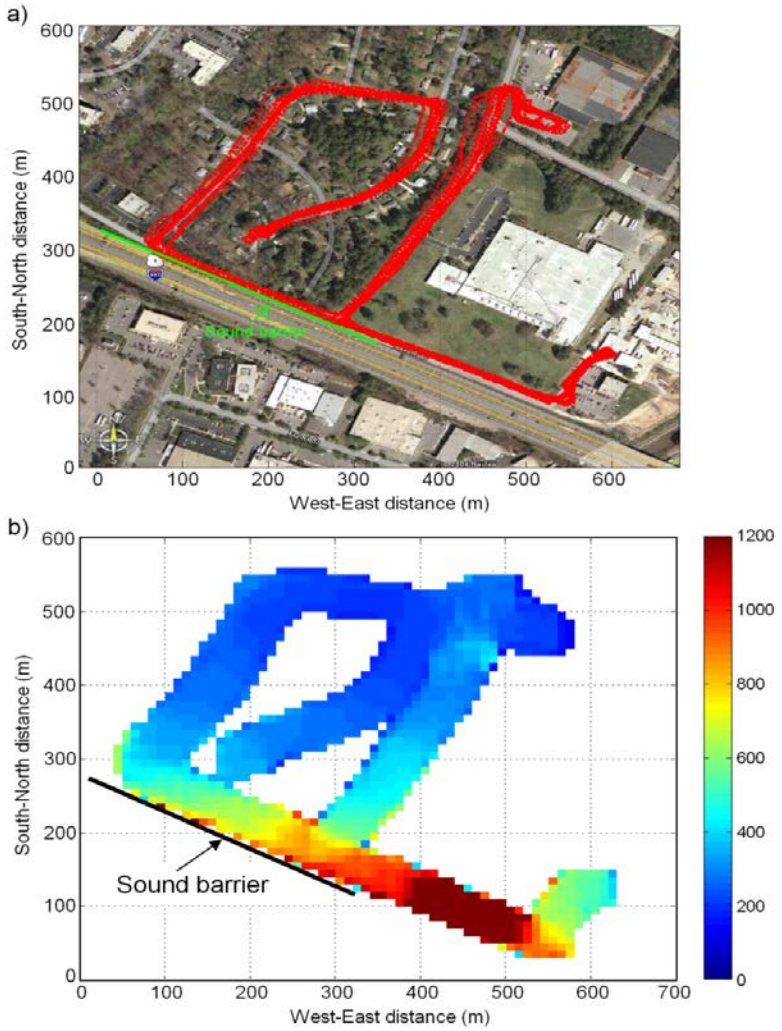
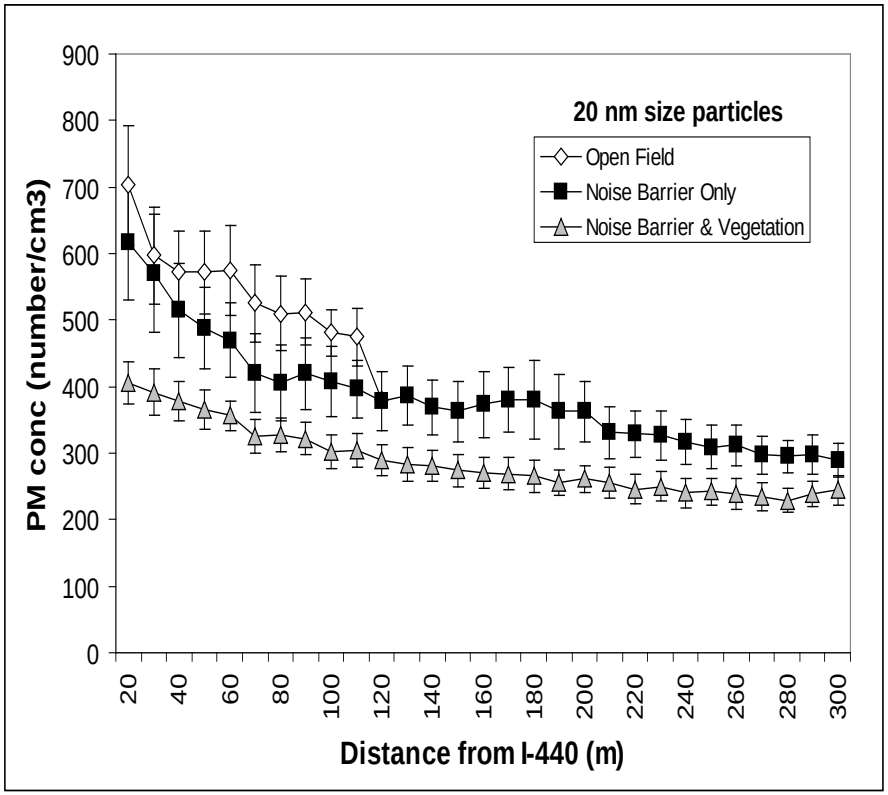


- Noise barriers reduced PM levels compared with a clearing
- Vegetation with noise barriers provided further PM reductions



(Baldauf et al., 2008a; 2008b)

Vegetation Effects

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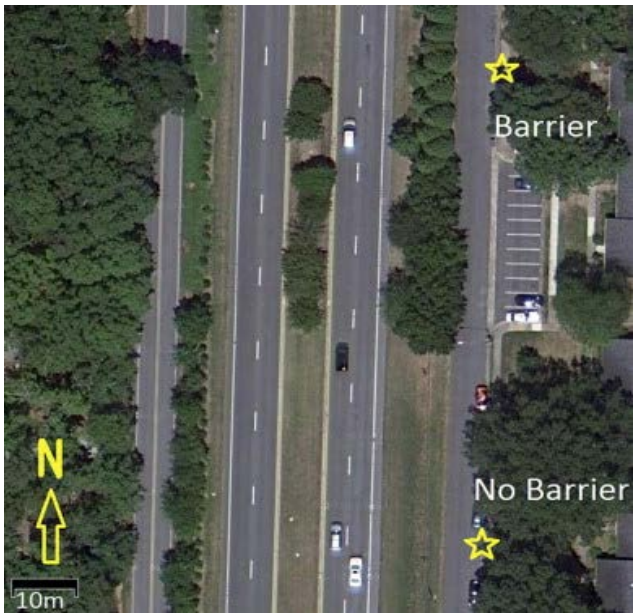
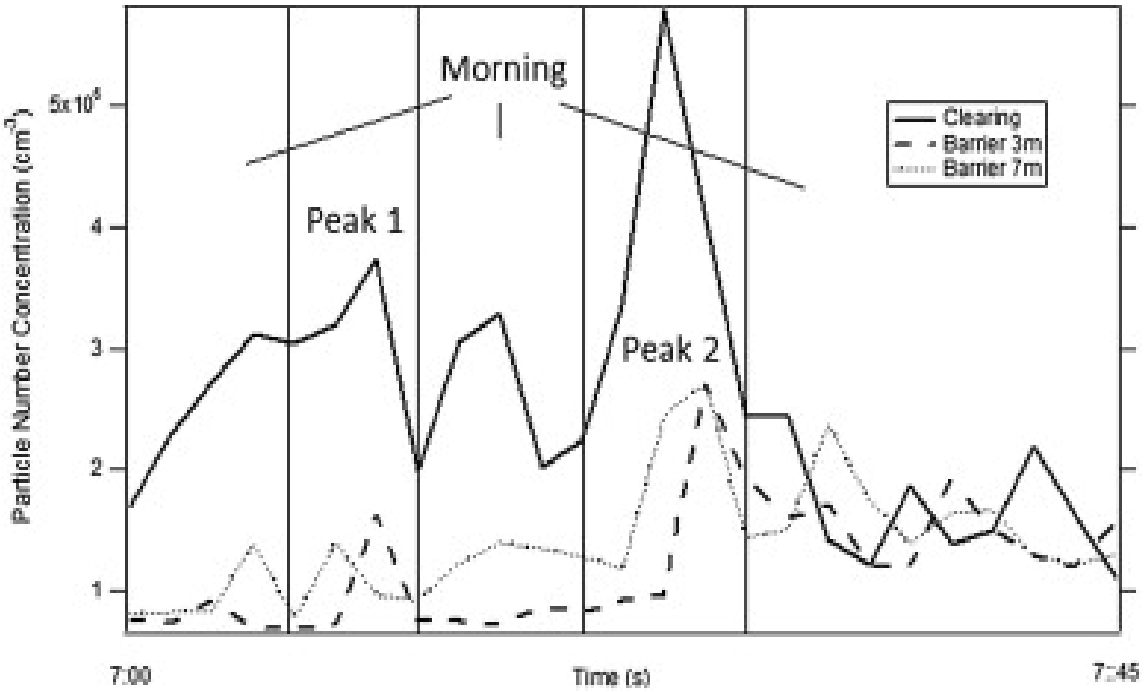


Steffens et al. (2012)

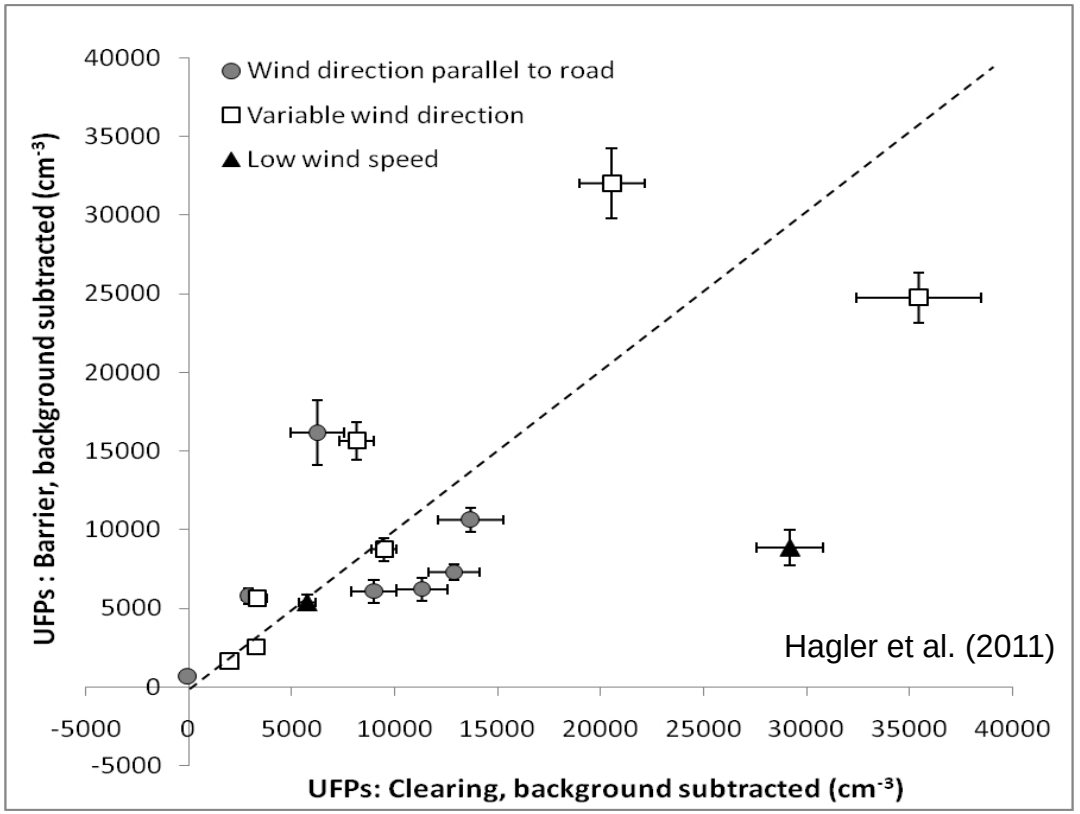


- Ultrafine PM number count generally reduced downwind of a vegetation stand
- Higher reductions most often occurred closer to ground-level
- Variable winds caused variable effects

Vegetation Effects

United States Environmental Protection Agency

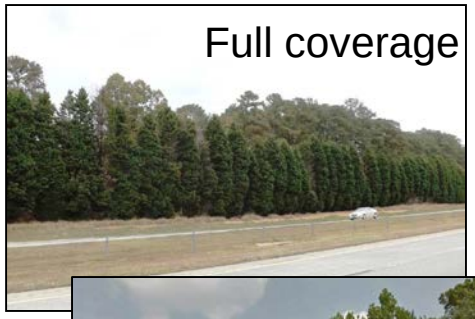
- For thin tree stands, variable results seen under changing wind conditions (e.g. parallel to road, low winds)
- Gaps/dead trees may have led to higher concentrations
- Future research looking into effects of lower porosity/wider tree stands

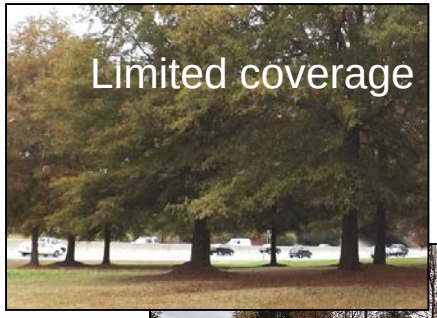


Summary – Noise Barriers

- Research shows noise barrier design characteristics that can reduce downwind pollutant levels
  - The higher the barrier, the higher the pollution reduction
    - Most studies conducted with barriers ≥ 6m
  - Pollutants can meander around edges
    - Sensitive areas should be ≥ 50m from edges
    - Sensitive areas should be below barrier top
  - Pollutants can be trapped on the upwind side of the barrier
    - "Upwind" sources need to be considered
    - May lead to increased levels on the road
  - Barrier should be close to the road
    - Most studies had barriers within 5m of road

Summary - Vegetation





- Research shows roadside vegetation characteristics that can reduce downwind pollutant levels
  - Generally, the higher and thicker the vegetation, the higher the reduction
  - Pollutants can meander around edges or through gaps and increase concentrations, so sensitive areas should avoid edge effects
  - Vegetation should be appropriate for area:
    - Native plants and trees preferred
    - Mature vegetation – trees take time to grow
    - Reasonable water use; water runoff control
    - Limited seasonal effects for year-round benefits
    - Low pollution emitters
    - Falling debris will not impact roadway

Summary – Combination Barriers

- Noise barriers with vegetation may provide the highest reductions
  - Increase potential for pollutant dispersion and removal
  - May be solid barrier with vegetation behind and/or in front
  - Use of climbing vegetation and hedges with solid barrier may also provide additional benefits
    - Field study results mixed
    - Vegetation on solid wall should extend enough to allow air to flow through

Research Needs

- Quantify the relationship of varying barrier heights to:
  - downwind pollutant reductions
  - trapping of upwind pollutants
- Quantify pollutant meander around barrier edges and through gaps:
  - under varying meteorological conditions
  - under varying design characteristics
- Sensitivity of the barrier distance from the source
- Effectiveness of different barrier designs
  - Noise barrier shape, material, surface coating
  - Vegetation species, porosity, thickness
- Evaluation of models quantifying noise/vegetation barriers
- Conduct “proof of concept” studies for air quality mitigation

Conclusions

- With the increase in near-road public health concerns, comprehensive mitigation strategies are needed
- Noise barriers and roadside vegetation can affect local pollutant transport and dispersion, providing an opportunity for air pollution mitigation
  - Design conditions have been identified that lead to downwind pollutant reductions and potential pollutant increases
  - Model algorithms have been developed to quantify barrier impacts under certain design conditions
- Research still needed to understand the range of options and reductions available from roadside barriers
- Models still need to be developed to quantify reduction benefits and identify potential unintended consequences under range of designs

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Kirk Clawson

For More Information

- Websites:
  - http://www.epa.gov/nrmrl/appcd/nearroadway/workshop.html
  - http://www.epa.gov/ord/ca/quick-finder/roadway.htm
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