Near-Road Air Quality Monitoring Research

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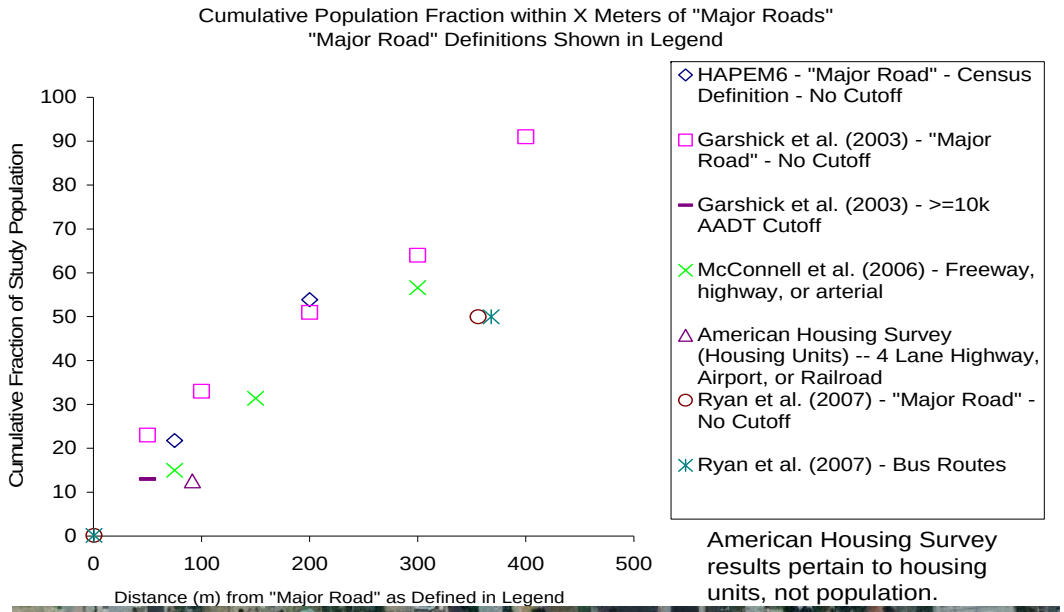
Why are we concerned? Adverse Health Effects

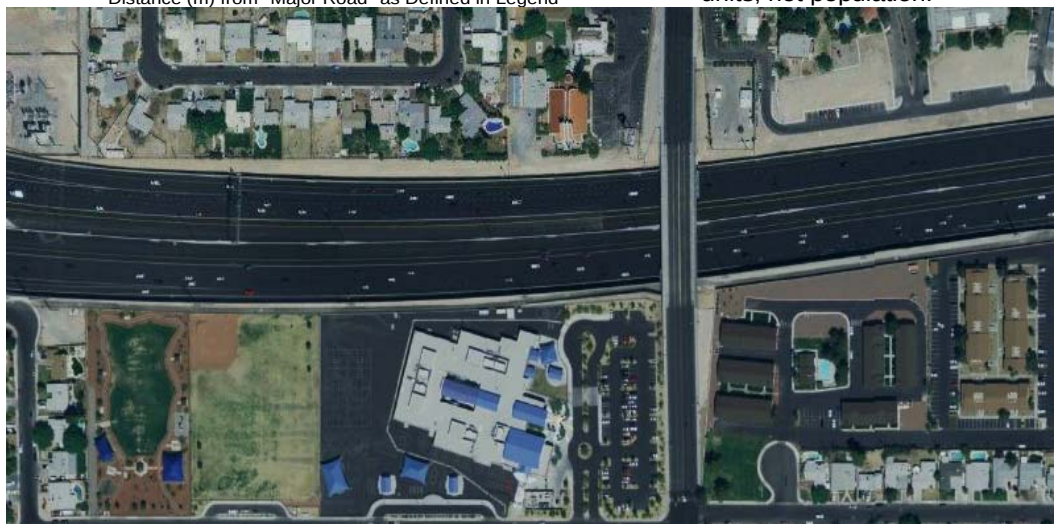
- Living, working, or going to school near major roadways has been associated with numerous adverse health endpoints
  - Respiratory effects (e.g., asthma, bronchitis)
  - Cardiovascular effects
  - Adverse birth outcomes/developmental effects
  - Premature mortality
  - Cancer
- Hundreds of studies published this decade
  - Account for varying fleets, engine technologies, etc.
  - Health Effects Institute (HEI) summarized these findings, concluding that exposures to traffic emissions near roads are a "public health concern." (http://pubs.healtheffects.org/)

Why are we concerned? Population Exposures

- Significant portion of U.S. population lives near large roads or transportation system
  - 2007 American Housing Survey estimates >45 million people
  - Additional portion of population works or goes to school near large roads
  - High density traffic residences and schools disproportionately lower income



American Housing Survey results pertain to housing units, not population.



Why are we concerned? Traffic Emissions

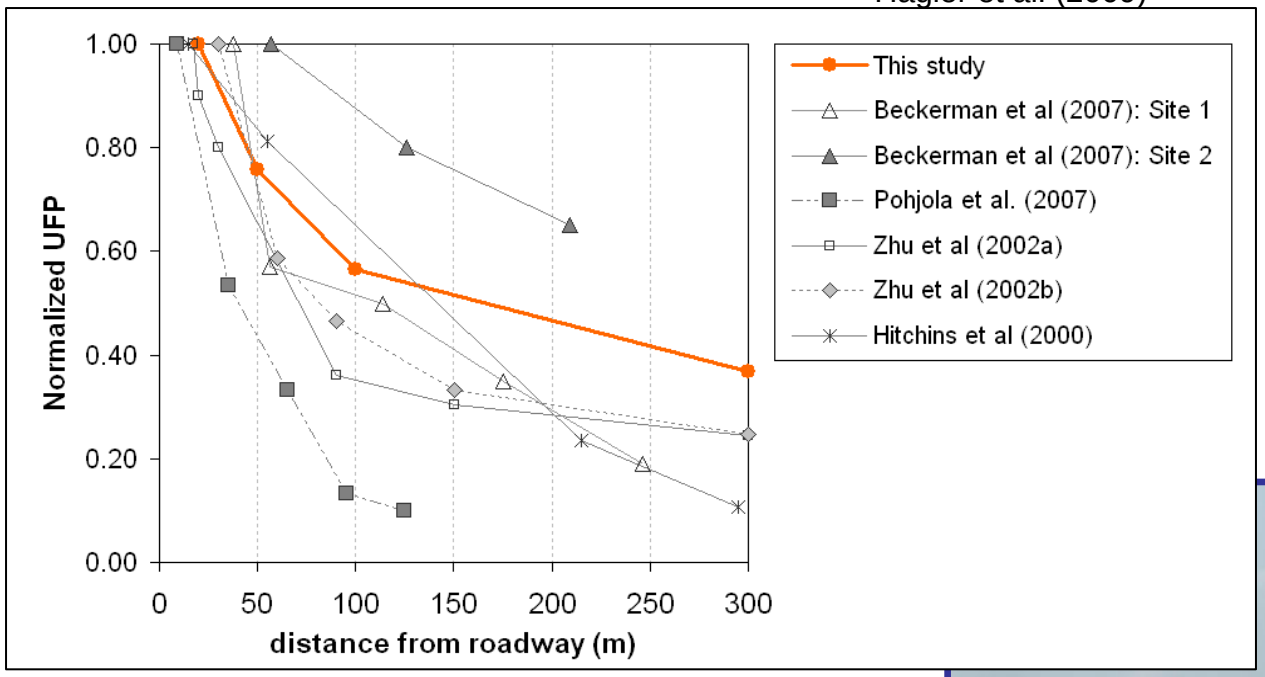
- More than 1,000 compounds have been identified in exhaust and evaporative emissions from mobile sources – many with known health implications
  - NAAQS Pollutants
  - Air Toxics
  - Particulate Matter
- Other air pollutant emissions from mobile sources
  - Tire wear
  - Brake wear
  - Resuspended road dust
  - Noise

What Have We Learned?

- Elevated concentrations of multiple pollutants present near roads
  - Pollutants often identified include:
    - NAAQS pollutants
      - Carbon monoxide
      - Nitrogen oxides (NO/NO2/NOx)
      - Particulate Matter Mass (PM10, PM2.5)
    - Air Toxics
      - Benzene
      - Metals
    - PM constituents
      - Number/count (reflects ultrafine particles from combustion)
      - Black carbon (elemental carbon, soot)

Concentration Gradients

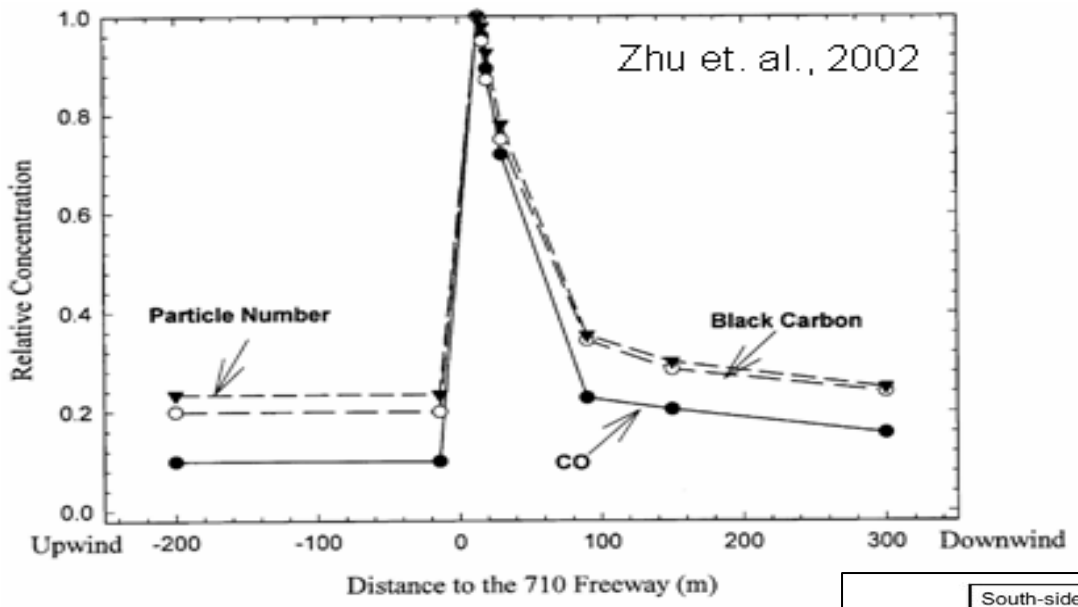
Hagler et al. (2009)



Studies in US and Canada show similar gradients for PM number concentrations

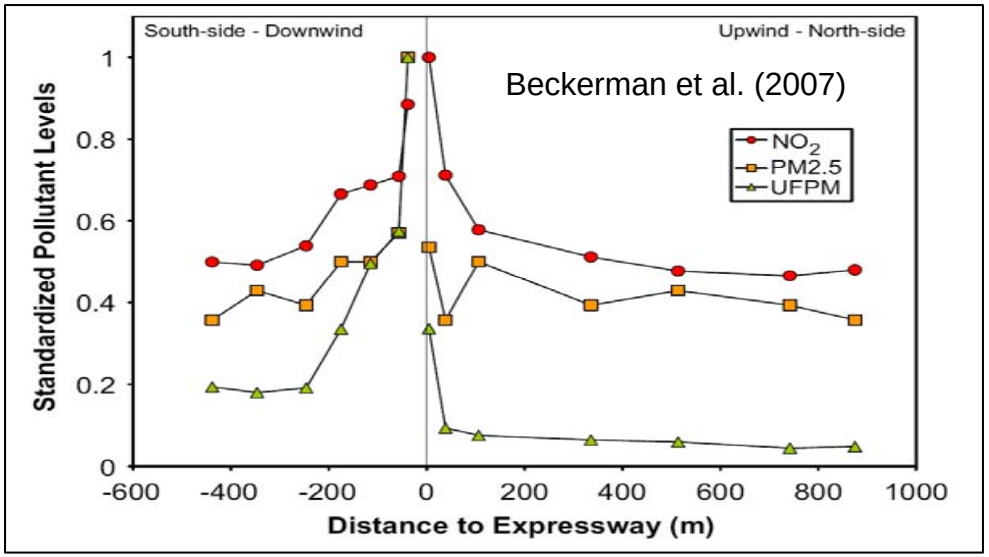
Studies conducted in mostly flat, open areas at-grade with the road measuring distance from the edge of the nearest travel lane

Concentration Gradients

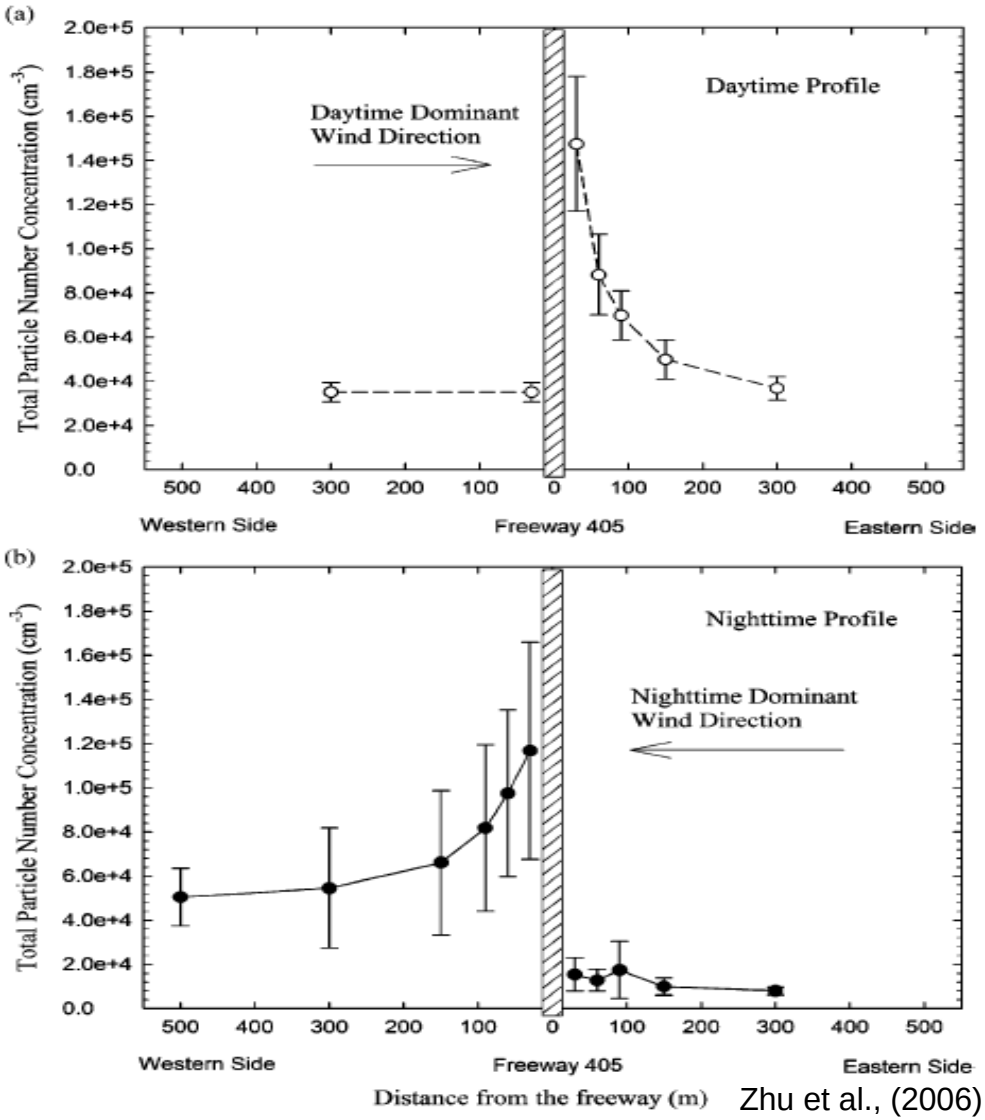


Similar gradients can exist for gaseous and PM pollutants

Gradients can exist over shorter (<1-hour) and longer (24+ hour) time averages



Concentration Gradients



Zhu et al., (2006)

Gradients and the zone of influence from the road will be influenced by environmental conditions (wind direction, wind speed, time of day, etc.)

What Have We Learned?

Interaction of traffic, meteorology and air quality create a complex mixture of pollutants near roads

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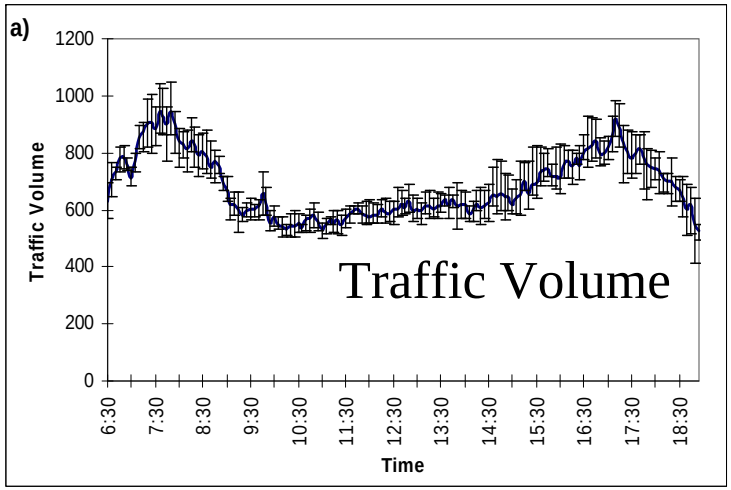
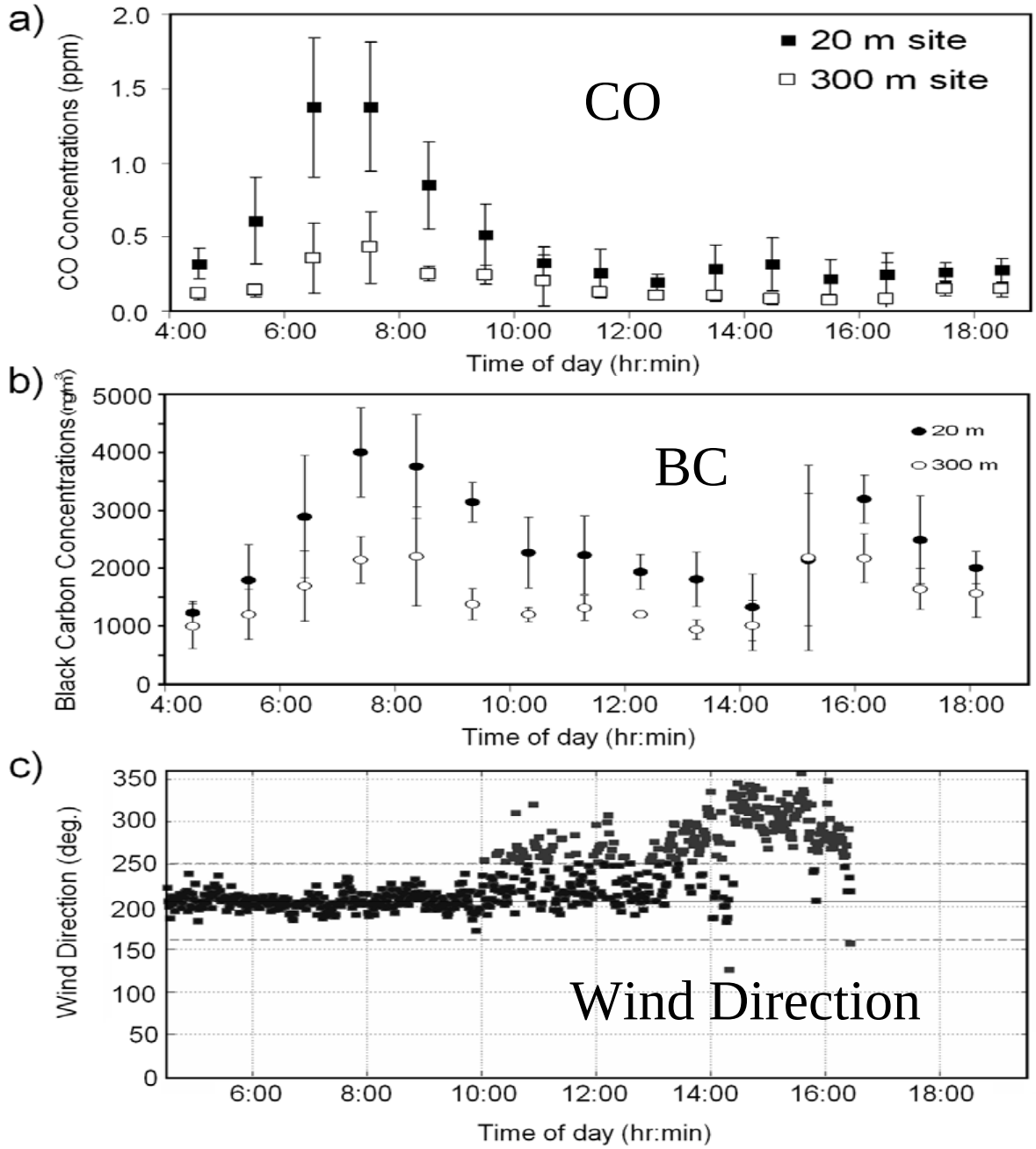
Gradients more pronounced during high traffic rush hours, especially when winds from the road (and lower mixing heights)



Baldauf et al. (2008)



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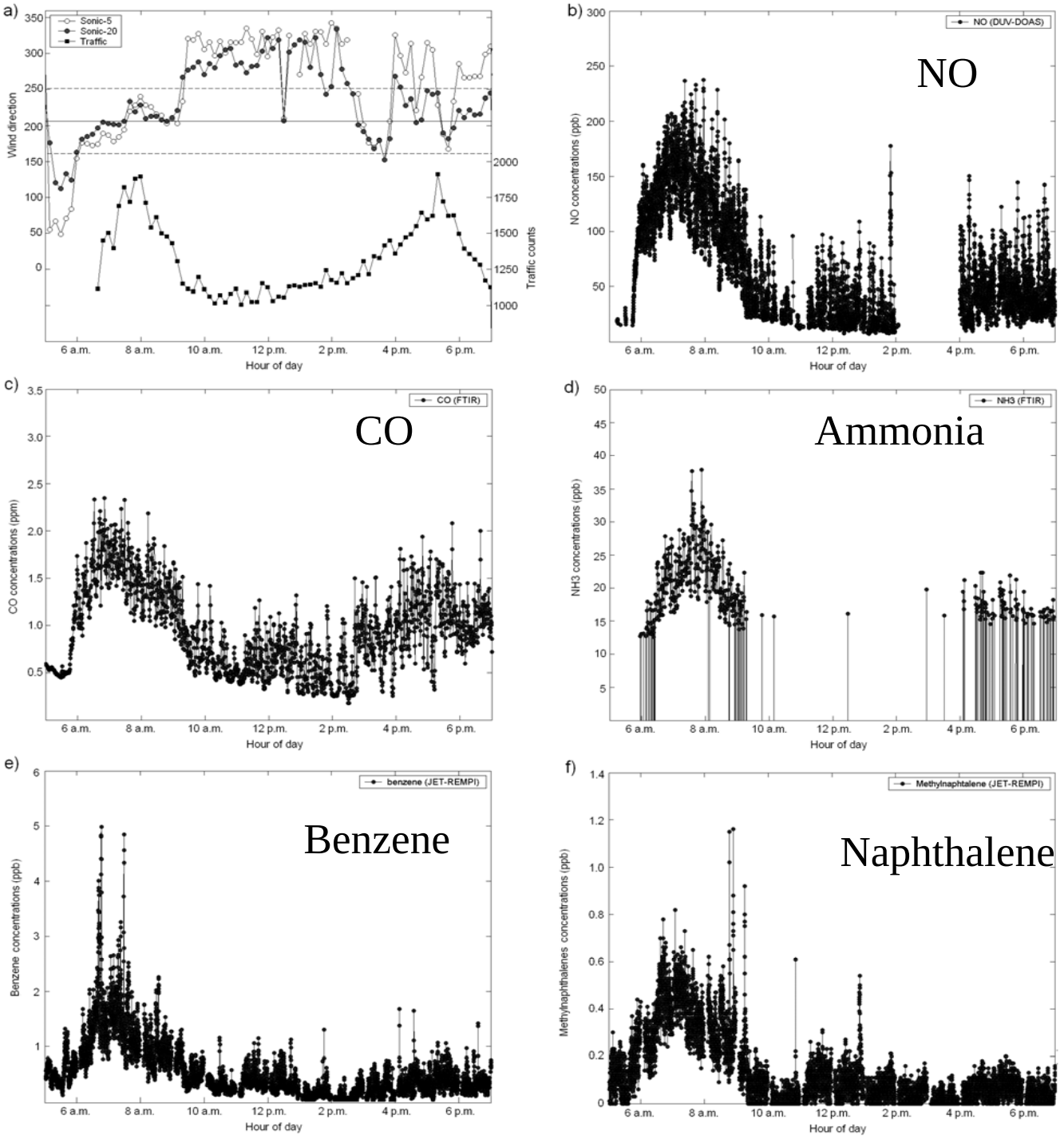
Complex mixture of pollutants includes NAAQS, toxics, and PM emitted from motor vehicles

Near road concentrations highest during morning rush hours with winds from the road

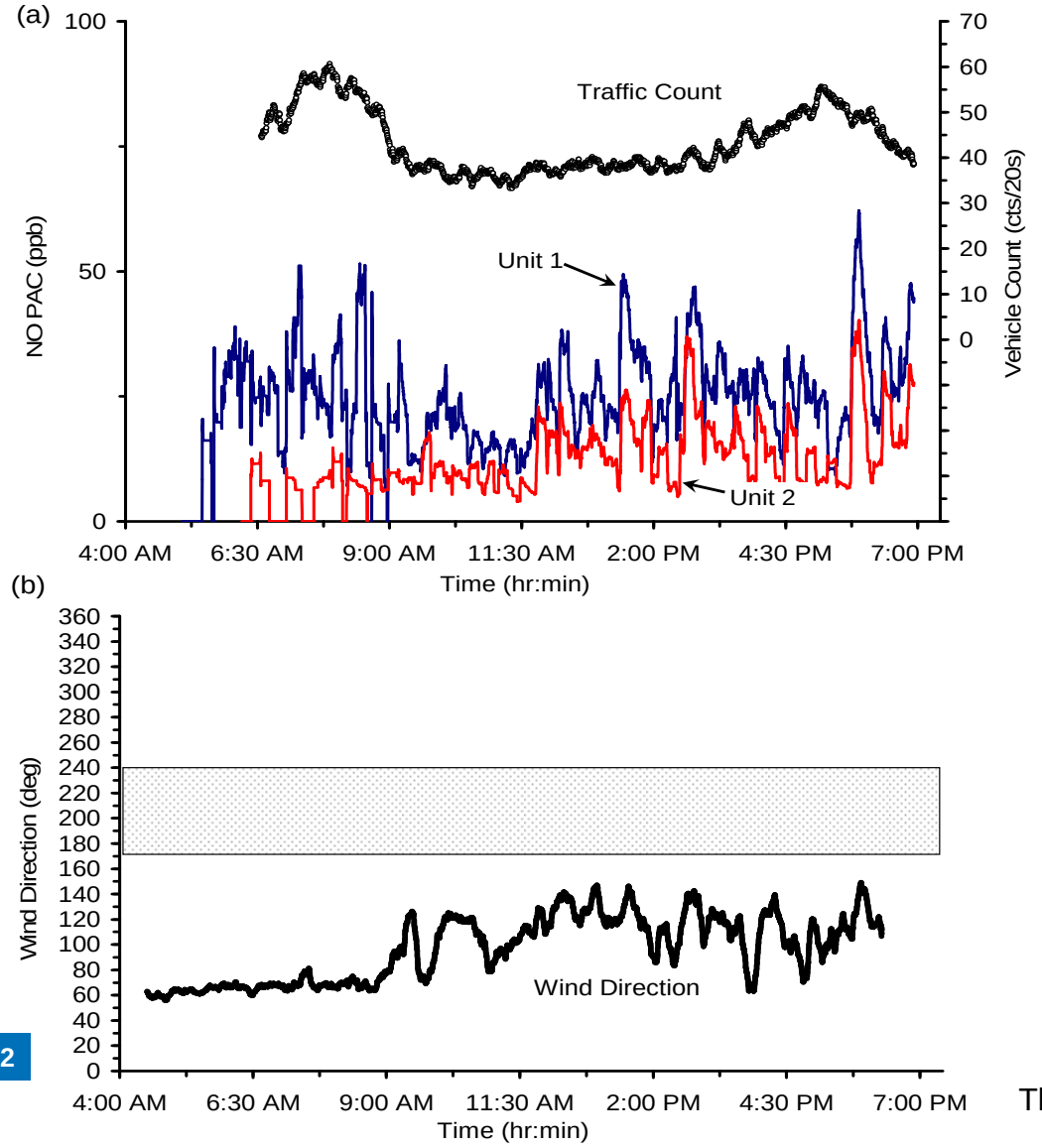


(Baldauf, et al.. 2008)

What Have We Learned?

Traffic-induced turbulence can impact pollutant concentrations upwind and downwind of the road

Upwind Meandering



Even when winds are blowing from the monitor to the road, elevated concentrations can occur upwind of the road due to vehicle induced turbulence.

3-D sonic anemometers are important in characterizing upwind and downwind pollutant transport due to roadway turbulence.

AERMOD model will use this information for new line source algorithm

Thoma et al. (2008); Venkatram et al (2009)

What Have We Learned?

Traffic activity influences emissions and near-road air quality

Traffic Activity and Emissions

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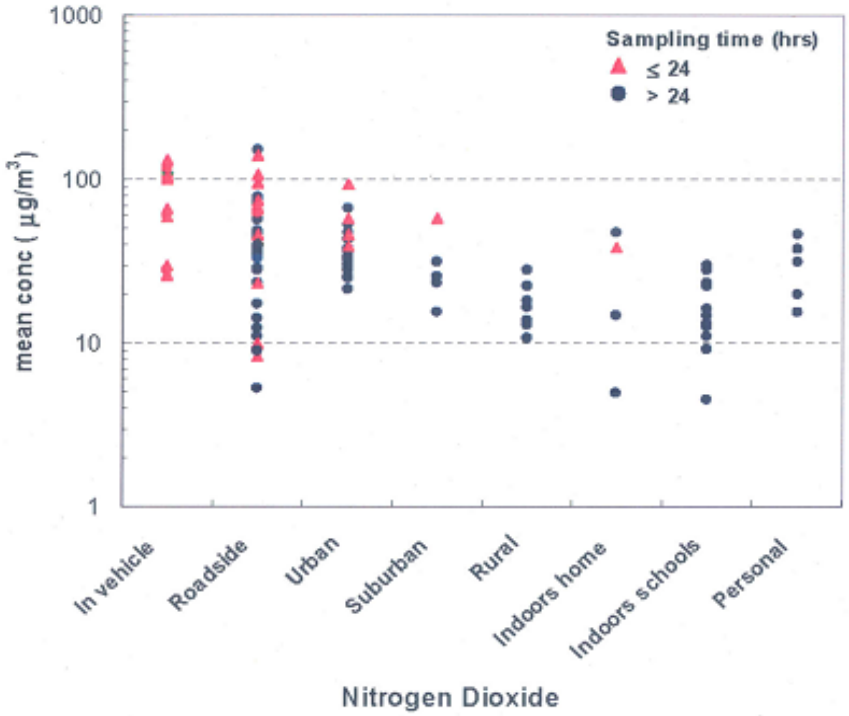
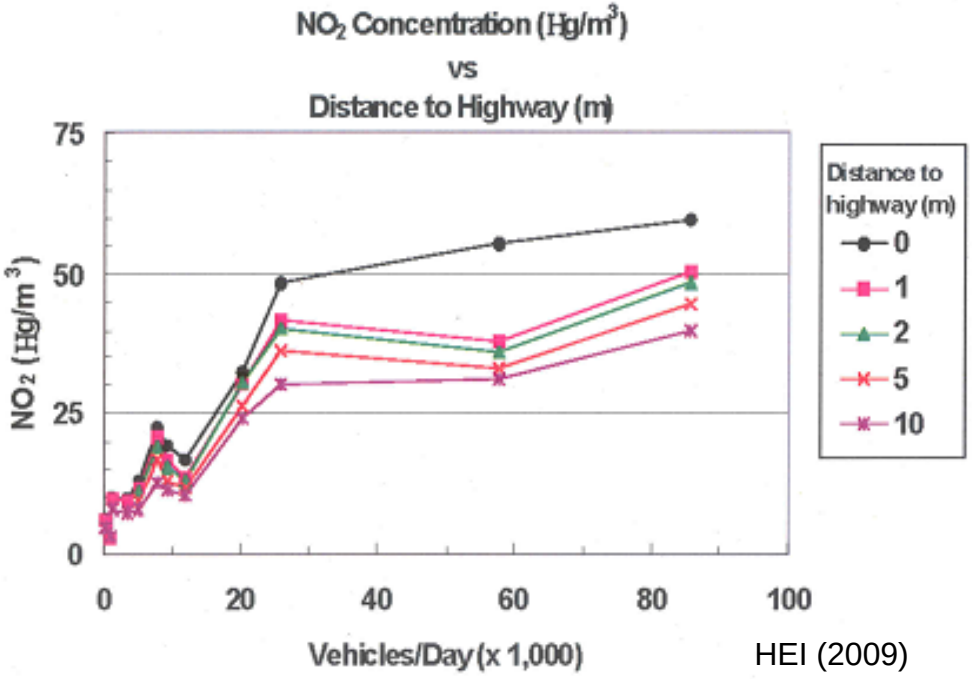


Roadside concentrations can vary significantly compared with urban and rural locations, showing the influence of local conditions



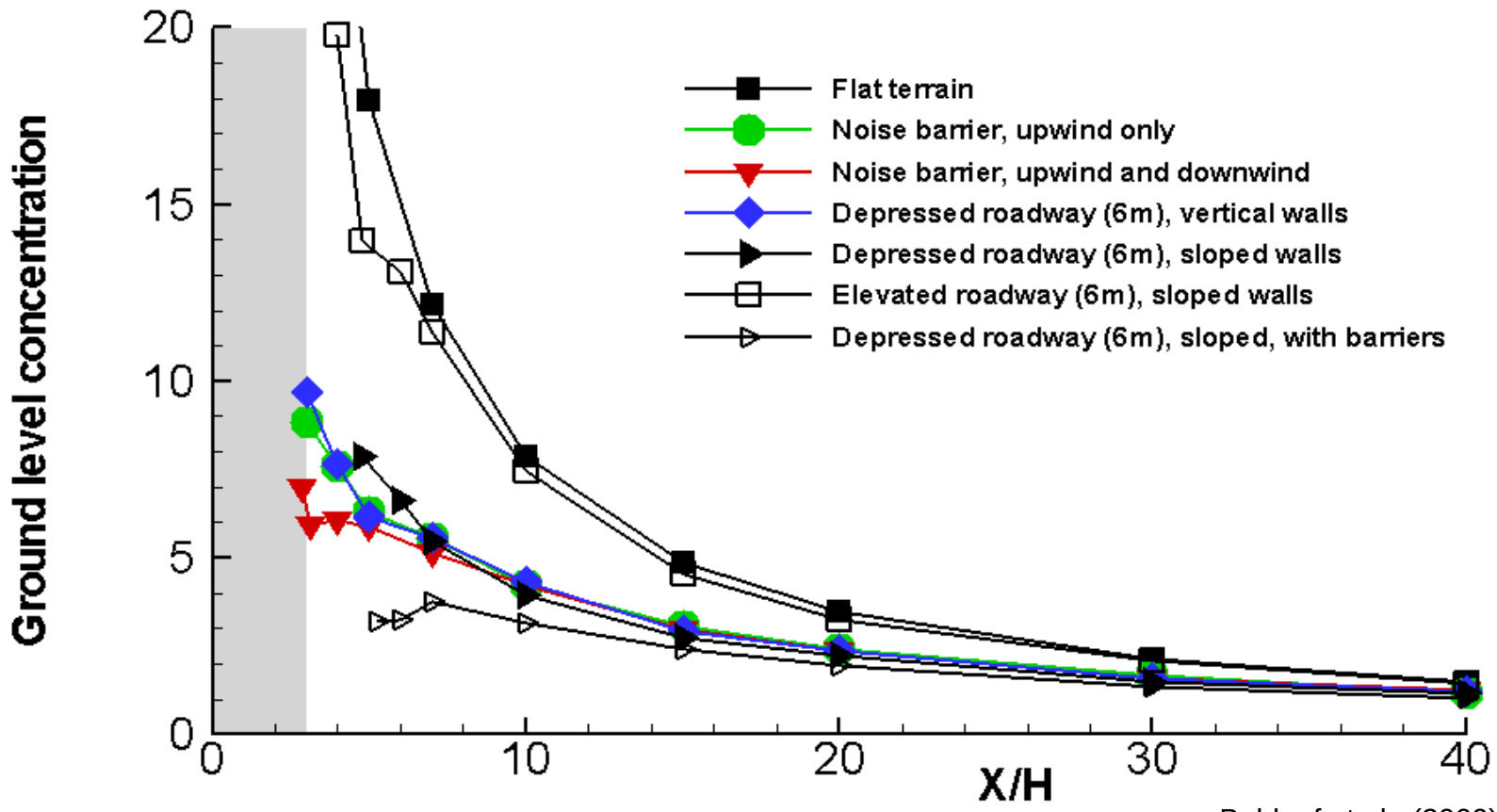
HEI (2009)

Total traffic volume (AADT) affects concentrations, although fleet mix (%heavy-duty diesels vs. %light-duty gasoline) and the roadway type can also influence

What Have We Learned?

Roadway design and roadside features influence concentrations and gradients

Roadway Design Influence: Wind Tunnel Results



Baldauf et al., (2009)

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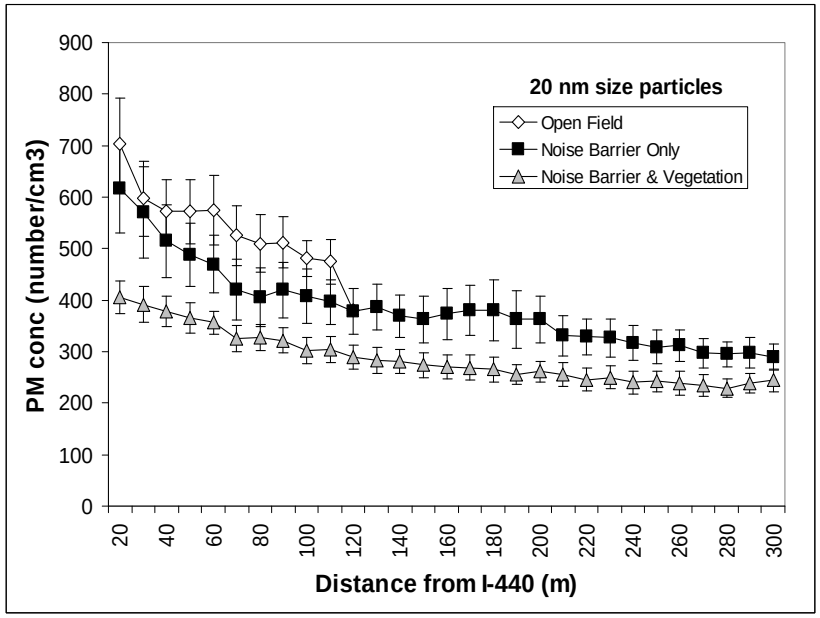
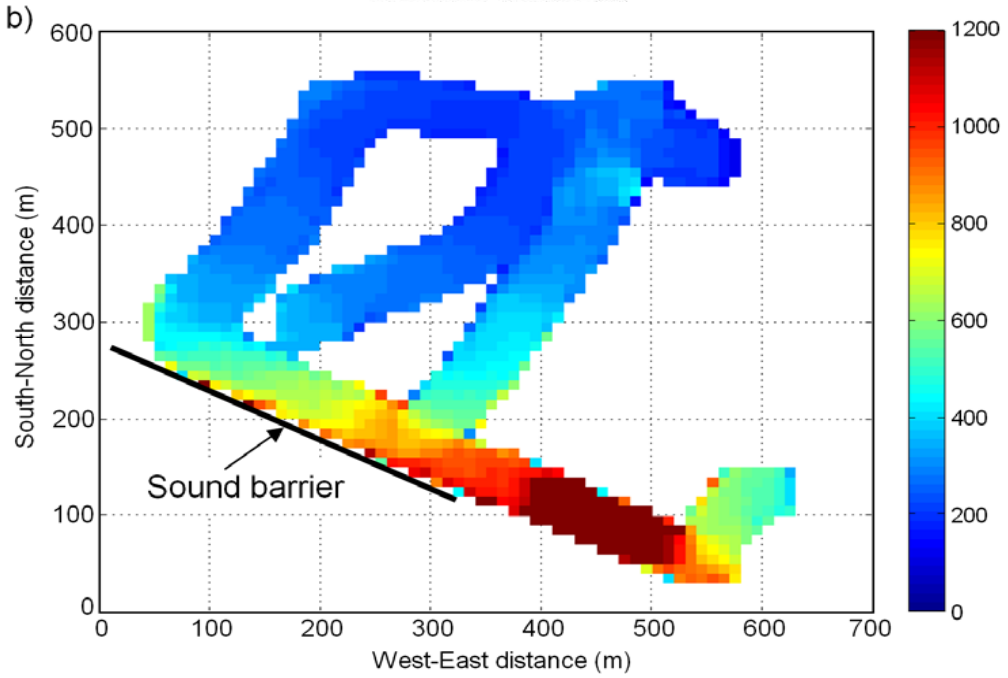
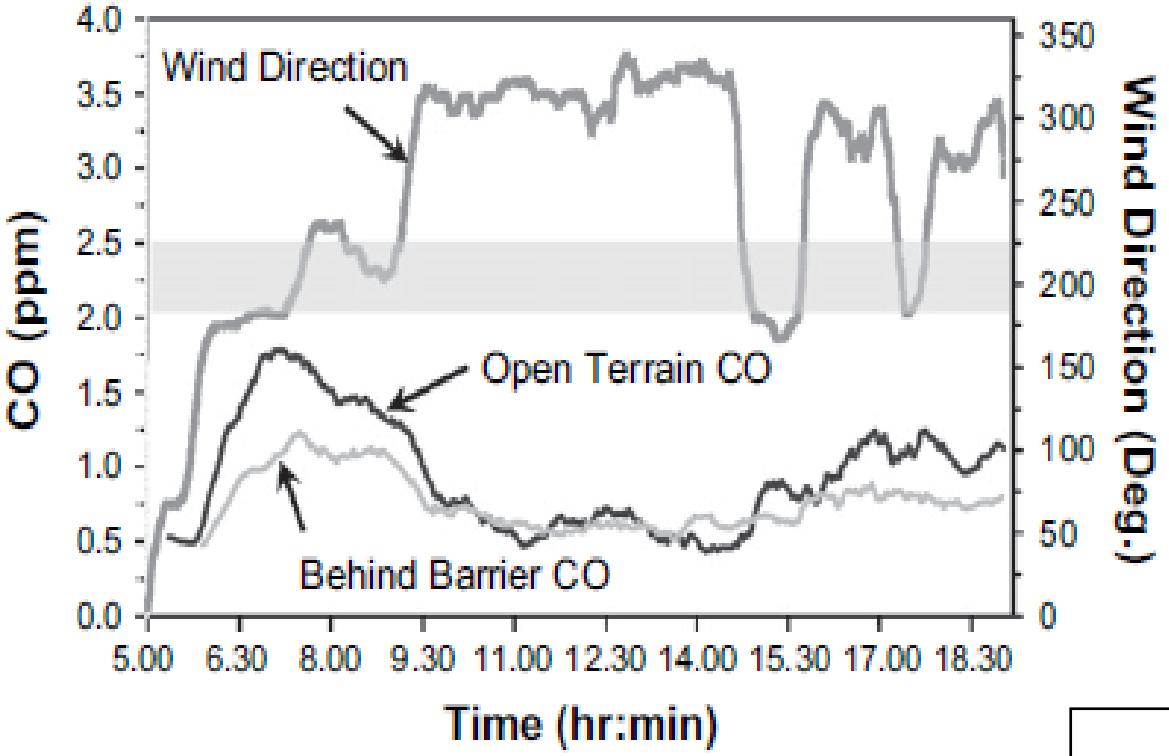
Field studies also show the influence of noise barriers and vegetation, affecting both pollutant concentrations and gradients





Baldauf et al., (2008)

Noise Barrier Effects



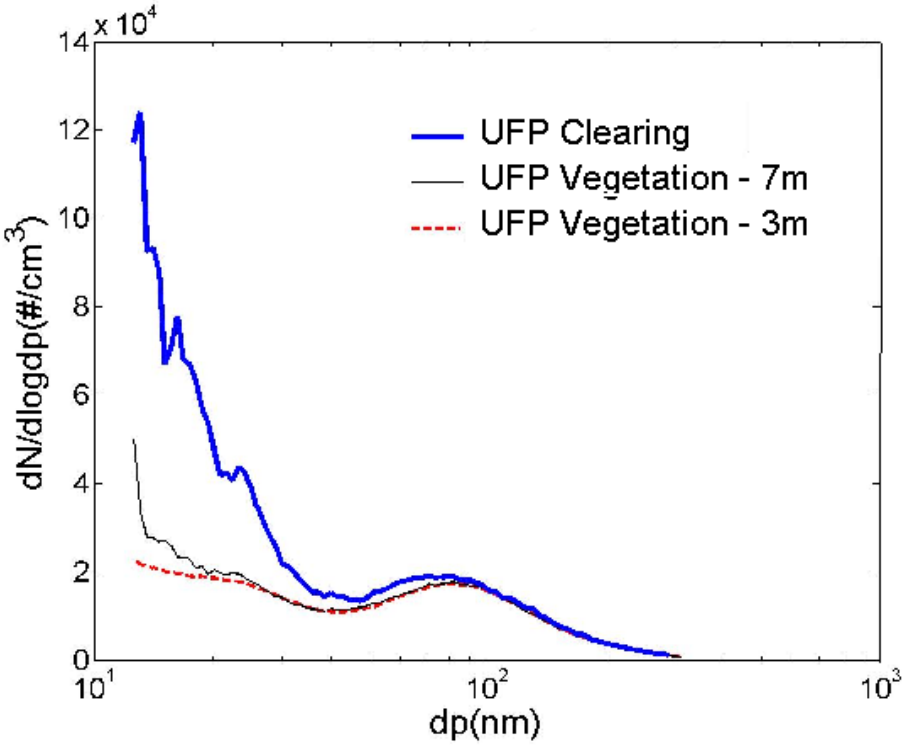
Noise barrier effects most pronounced when winds from the road and higher traffic volumes

Baldauf et al., (2008)

Barriers and roadside features may also trap pollutants behind the structure, leading to higher on-road concentrations

Vegetation Effects

Particle number/count concentrations reduced behind vegetation, especially at lower heights



Vegetation preferentially removes the smaller particles, having more of an influence on PM number/count than PM mass concentrations

Khlystov et al., (Preliminary Data – do not cite, quote, or reference)

What Have We Learned?

Roadway design and roadside features also influence plume heights of traffic emitted pollutants

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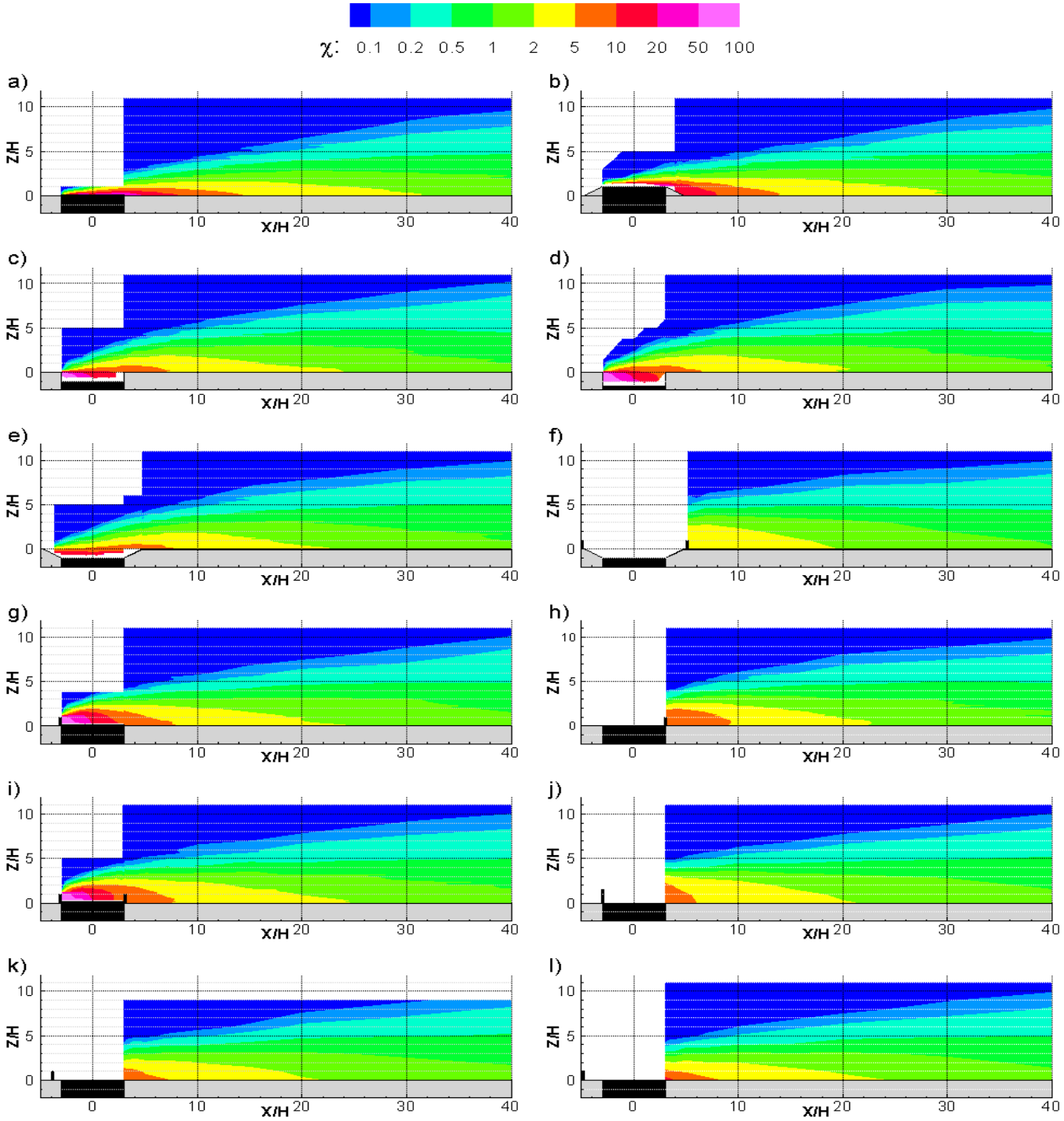
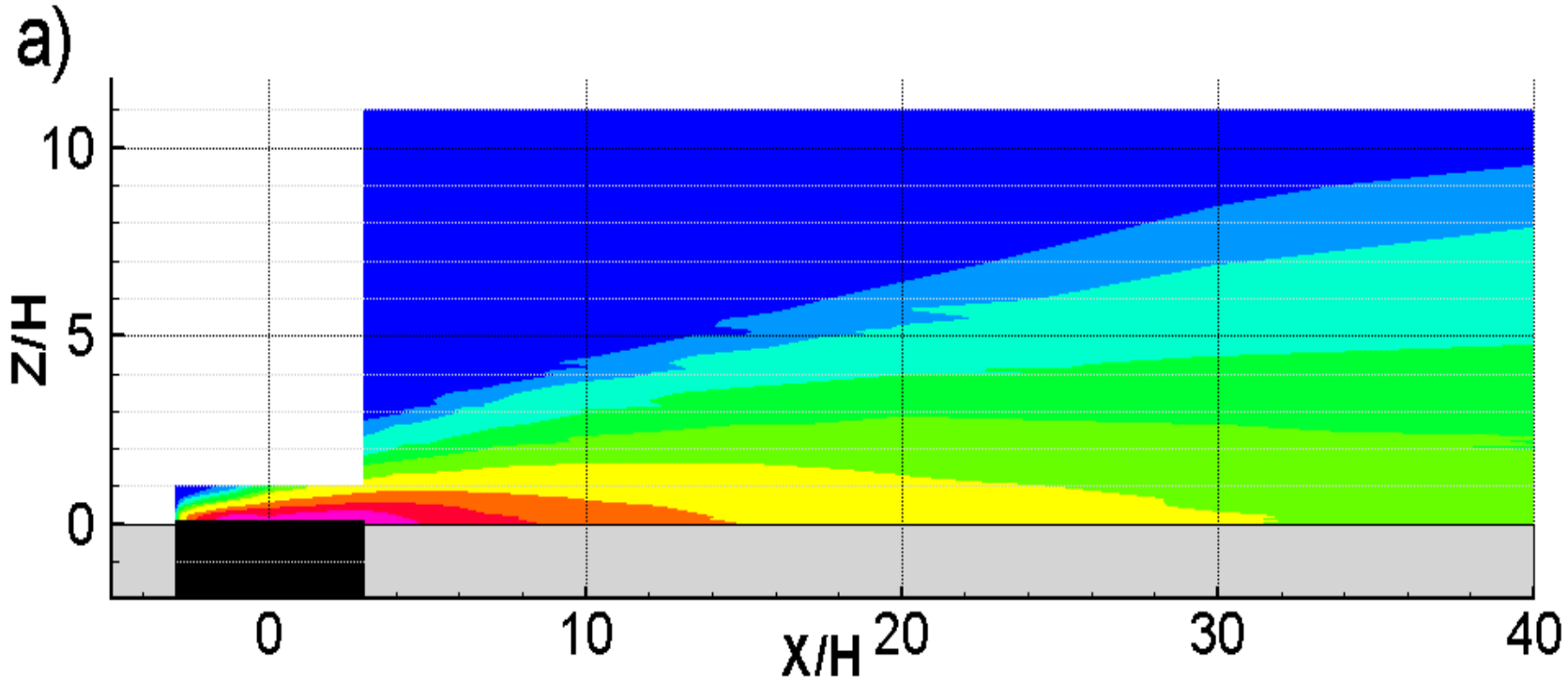
Profiles from wind tunnel studies show the differing impacts of traffic emissions with changing roadway designs (with winds from the road)

Profiles also show the changing plume heights with roadway design features



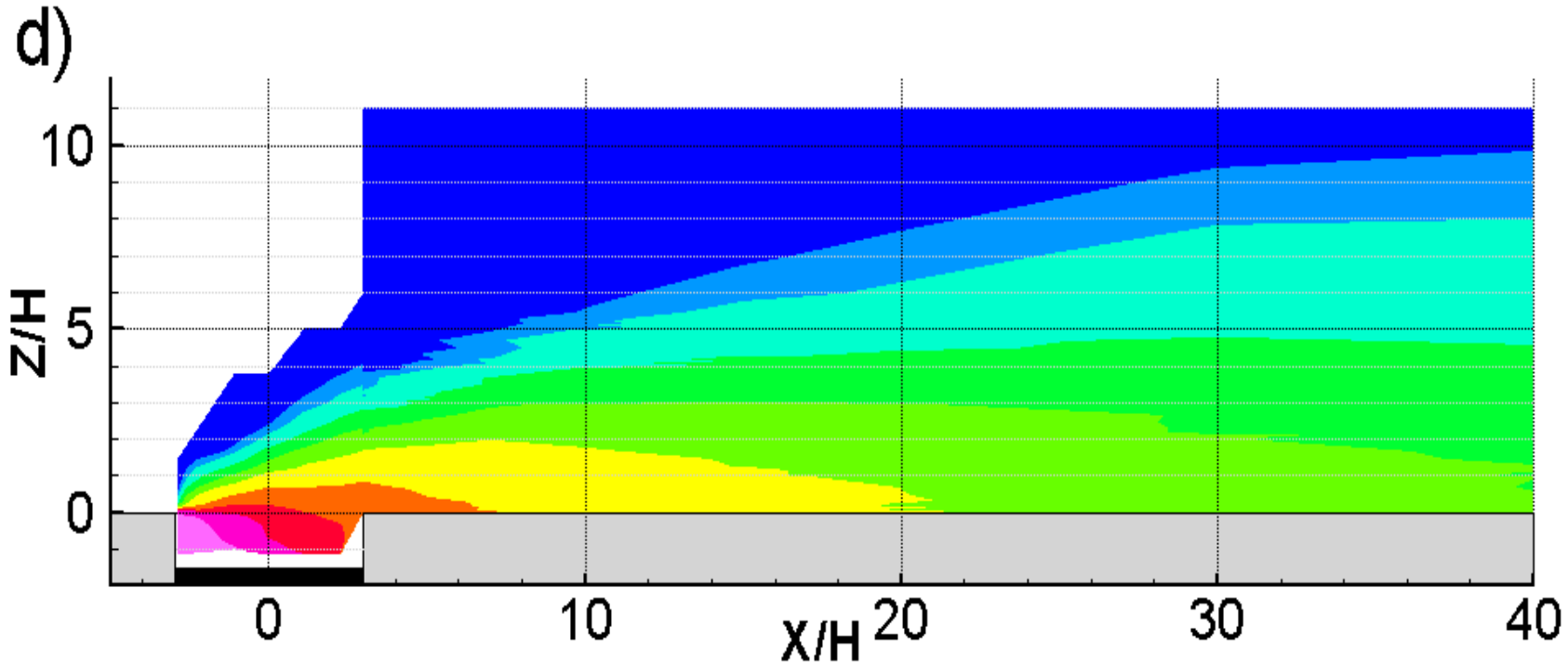
Heist et al., (2009)

Plume Height Considerations: At-Grade Road



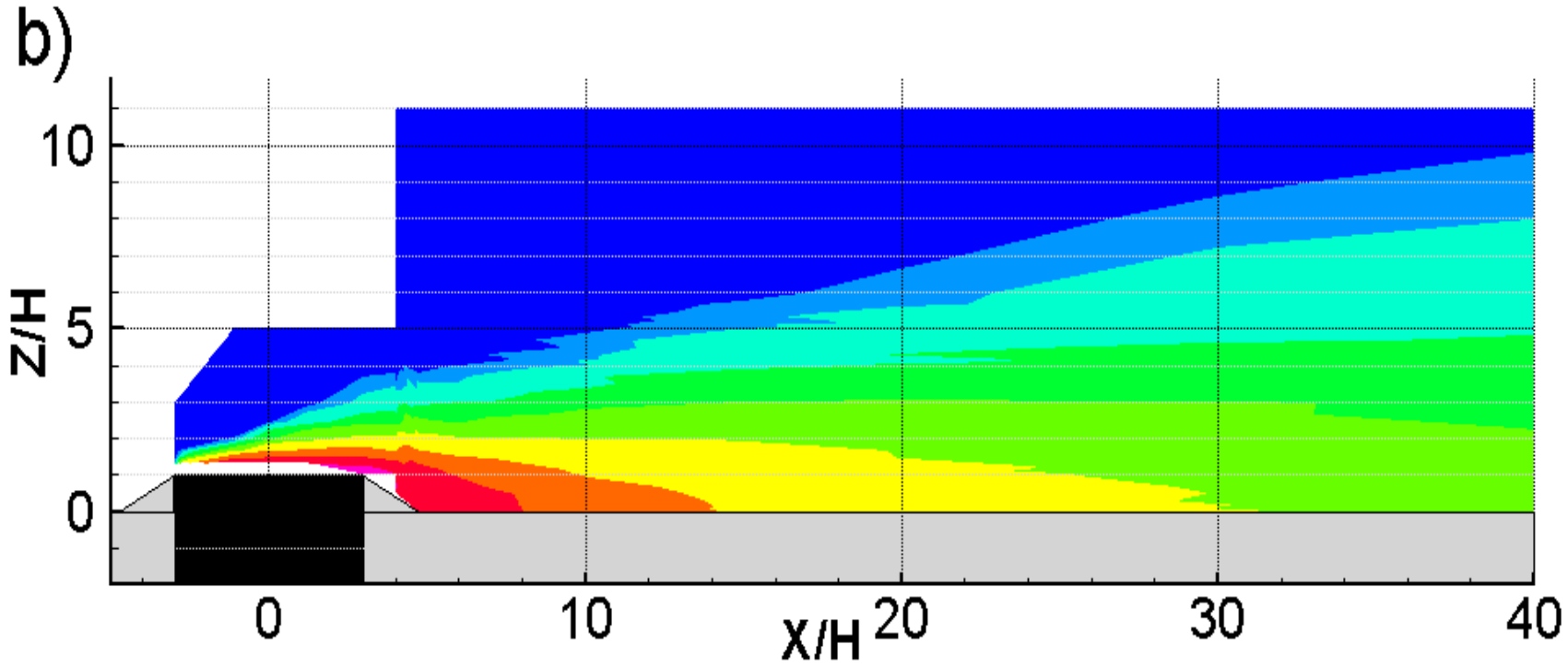
Plume remains generally intact, and maximum concentrations occur within ~3-4 meters of the road grade

Plume Height Considerations: Cut Section



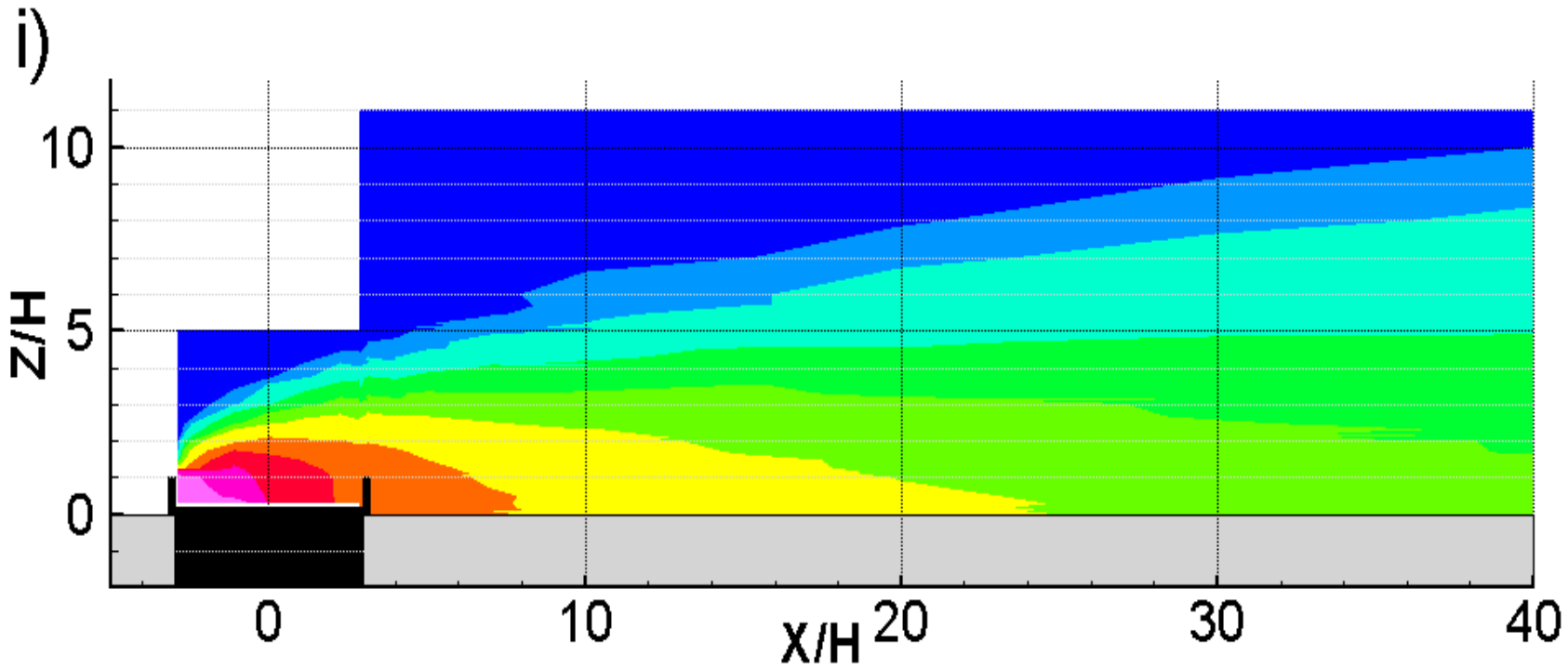
For a vertical cut section 6m in depth, more plume lift occurs, with maximum concentrations within a plume height of ~6-7 meters

Plume Height Considerations: Fill Section



For an elevated fill section with sloped walls 6m in height, the plume rise above the road grade is minimal, with maximum concentrations occurring within a plume height of ~10 meters

Plume Height Considerations: Noise Barriers



For an up and downwind noise barrier section with walls 6m in height, the plume rises above the barrier, with maximum concentrations occurring within a plume height of ~10 meters

Summary

- Growing interest in collecting near road air quality data due to public health and exposure concerns
- Recent research provides insights on near-road pollutant concentrations, gradients, and factors affecting plume rise, such as:
  - Traffic volumes and activities
  - Meteorological conditions
  - Topographical features
  - Roadway designs
  - Presence of roadside features
- This information can be useful for locating and designing near-road monitoring sites
- EPA and others continuing research on this issue

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Organizations:

U.S. Environmental Protection Agency

- Office of Research and Development, Research Triangle Park, North Carolina, USA
  - National Risk Management Research Laboratory
  - National Health and Environmental Effects Research Laboratory
  - National Exposure Research Laboratory
- Office of Air and Radiation
  - Office of Transportation and Air Quality
  - Office of Air Quality Planning and Standards
- Office of Civil Enforcement

National Oceanic & Atmospheric Admin, Atmospheric Sciences Modeling Division

Arcadis Inc., Research Triangle Park, North Carolina, USA

Alion, Research Triangle Park, North Carolina, USA

Duke University, Department of Civil and Environmental Engineering

North Carolina Central University, Department of Environmental Sciences

North Carolina State University, Department of Civil and Environmental Engineering

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