United States
Environmental Protection
Agency

How does vegetation affect pollutant transport and dispersion?

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Critical Questions

- Does vegetation in the roadside environment reduce near-road air pollution concentrations...?
  - …For all vertical heights?
  - …Under all meteorology conditions?
  - …For all vegetation types?
  - …For all vegetative barrier heights/depths?
  - …For distributed vegetation?
  - …For all building densities?
  - …With additional emissions sources, such as behind-barrier access roads?
- Do trade-offs exist for on-road?

Historical Context

Vegetative barriers, a.k.a.…

- Shelterbelts
- Wind breaks
- Buffer strips
- Forest strips
- Riparian strips
- Hedge rows

…have been studied for many years, but for different objectives

Photo by: G. Tom Tabler, University of Arkansas

Field windbreaks in North Dakota: Photo by Erwin Cole, USDA Natural Resources Conservation Service.

For example:

→ Mid-1400s: Scottish Parliament promotes tree planting for agriculture

→ 1930s: Roosevelt initiates Prairie States Forestry Project, in response to Dust Bowl. From 1935-1942: US Forest Service, with Works Progress Administration and Civilian Conservation Corps planted 18,600 miles on windbreaks on 30,000 farms.

Historical Context

Shelterbelts and Windbreaks

Defined: One or more rows of trees/shrubs planted to reduce wind

Goal: reduce wind speed to protect crops, livestock, homes, habitat; reduce pesticide spray drift; odor mitigation; manage snow

e.g., Snow management

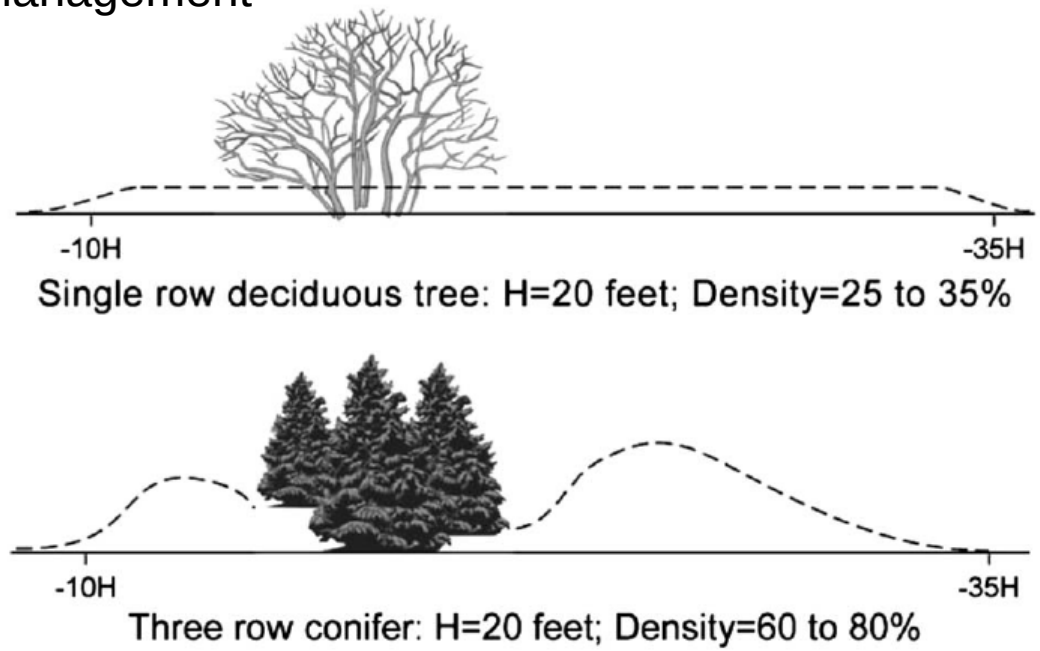


Figure 3. Snow distribution as influenced by a very porous windbreak and a very dense windbreak. The porous windbreak is used to distribute snow across a field while a dense windbreak is used to collect snow in a relatively narrow deep drift.

Brandle (2004)

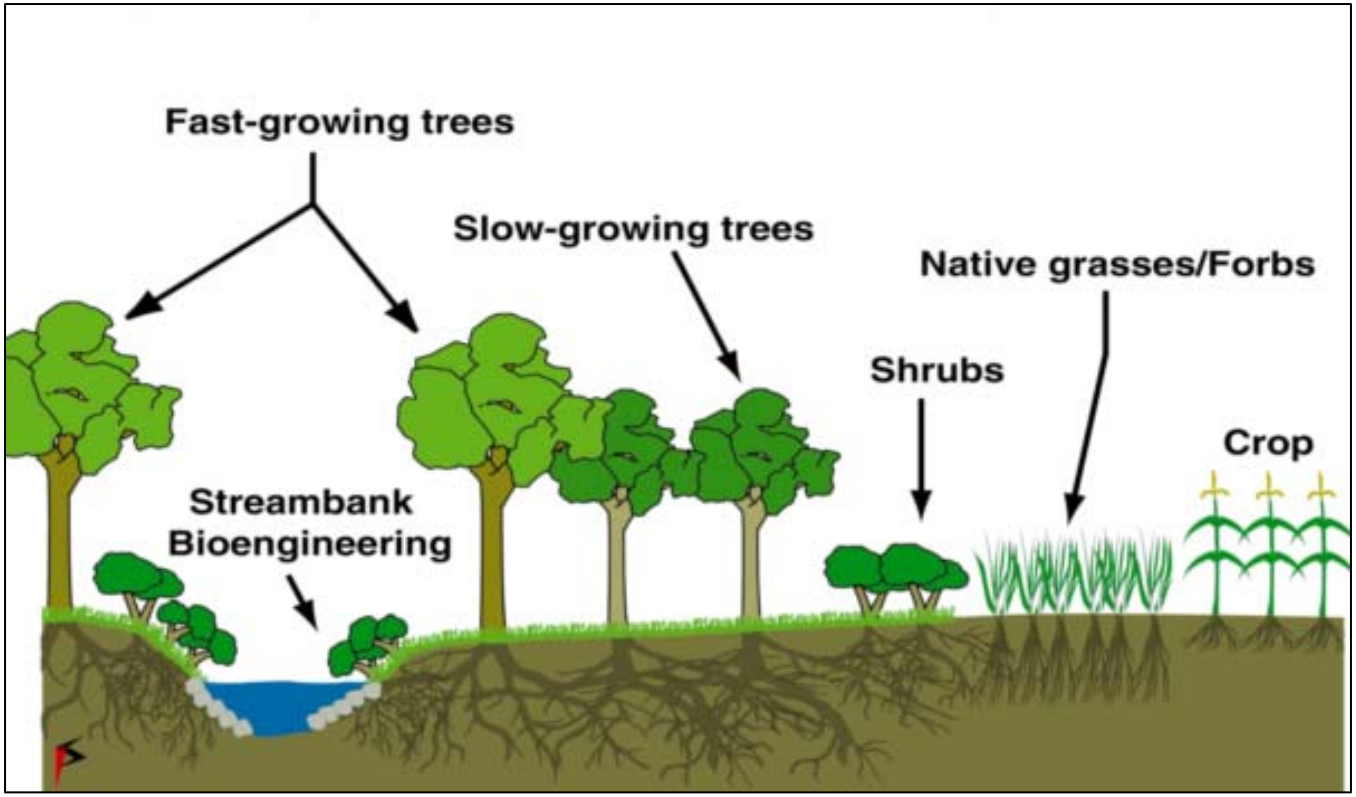
Historical Context

United States Environmental Protection Agency

Buffer strips, forest strips, riparian strips:

Defined: Preserved or engineered section of land surrounding developed land – may be grass, shrubs, trees, or combination

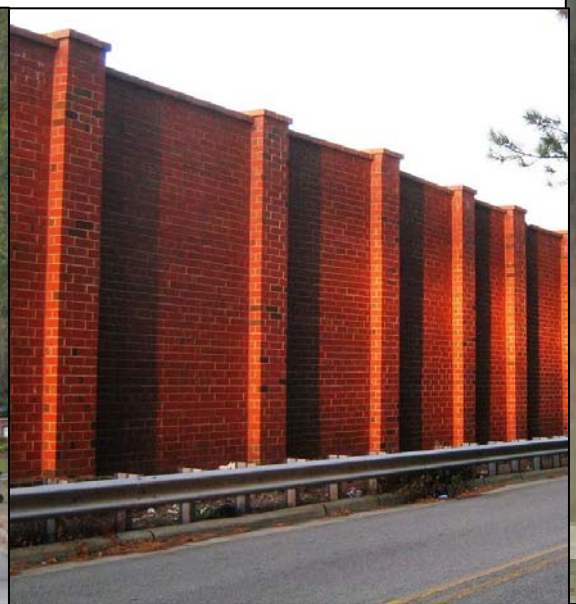
Goal: Protect watershed, biodiversity, soil conservation



Iowa State: http://www.buffer.forestry.iastate.edu

Road + Vegetation = ?

- Highways frequently bordered by barriers to wind flow
  - Vegetation
  - Noise walls
  - Buildings
  - Combination of elements



Road + Vegetation = ?

Questions:

- → Do we have evidence that vegetation would improve near-road air quality?
- → What are the critical factors affecting transport of traffic emissions to the near-road environment?
- → What are areas of needed research?

Field Data Suggest…

Raleigh Near-Road Study:

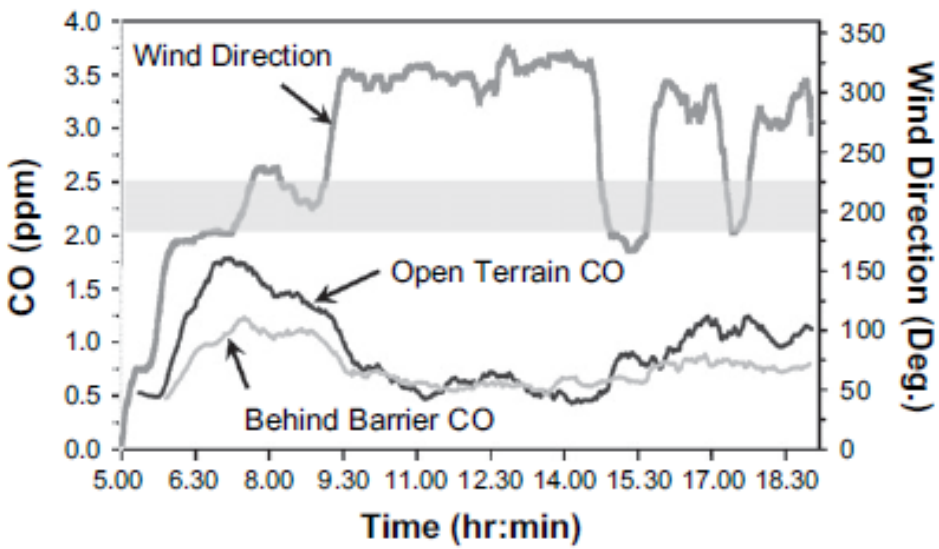
Extensive sampling during summer 2006:
-Air toxics
-Gases: CO, NOx
-Particulate matter

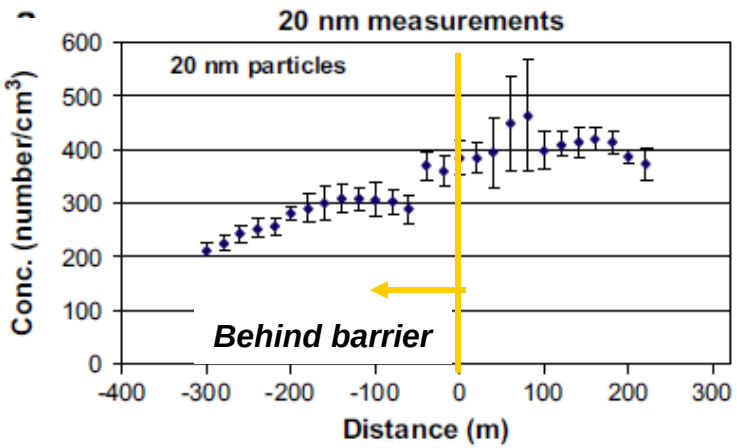
Areas of unobstructed flow and areas obstructed by **6 m noise barrier and vegetation**

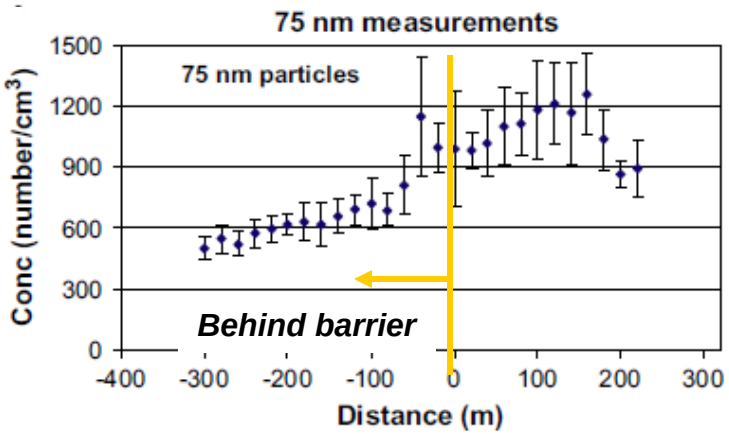
Field Data Suggest…

Raleigh Near-Road Study:

- EPA/Duke field measurements found lower concentrations of carbon monoxide and particle counts downwind of barrier







Baldauf et al. (2008)

Field Data Suggest…

Near Roadway Tracer Study:

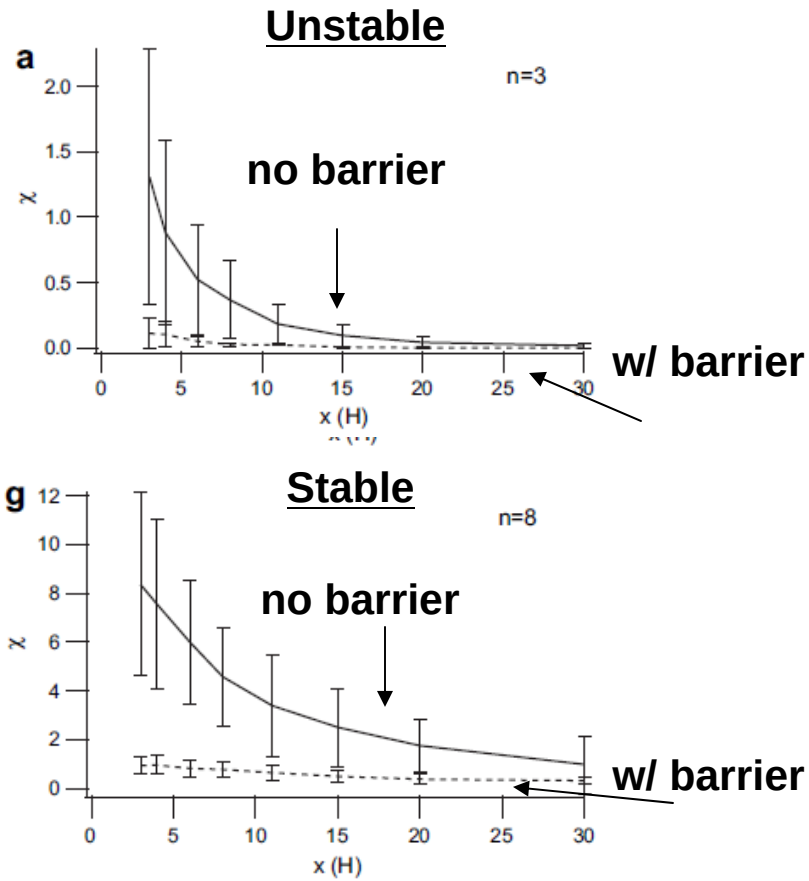


Fig. 1. Mock straw bale sound barrier, 6 m high and 90 m long.

Finn et al. (2010)

Field Data Suggest…

Near Roadway Tracer Study:

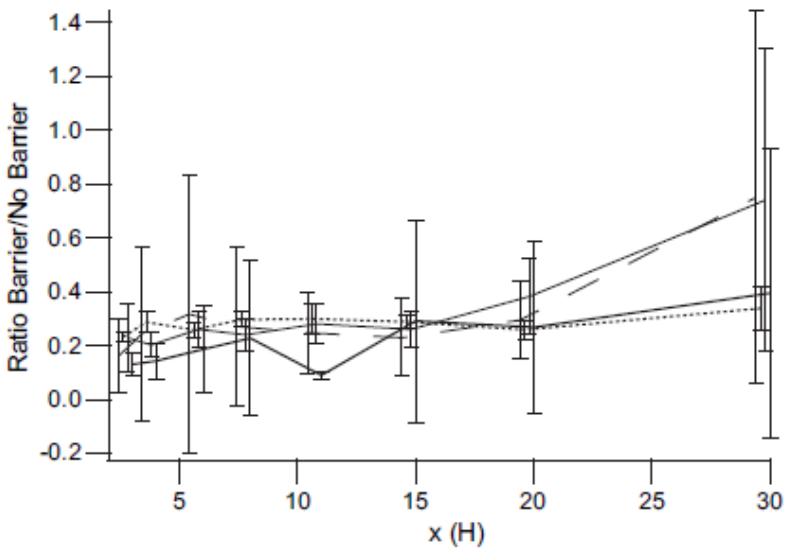


Fig. 9. Mean barrier/non-barrier normalized centerline concentration ratios for qualifying periods: unstable, bold; neutral, solid; weakly stable, dotted; stable, dashed. Error bars are standard deviations.

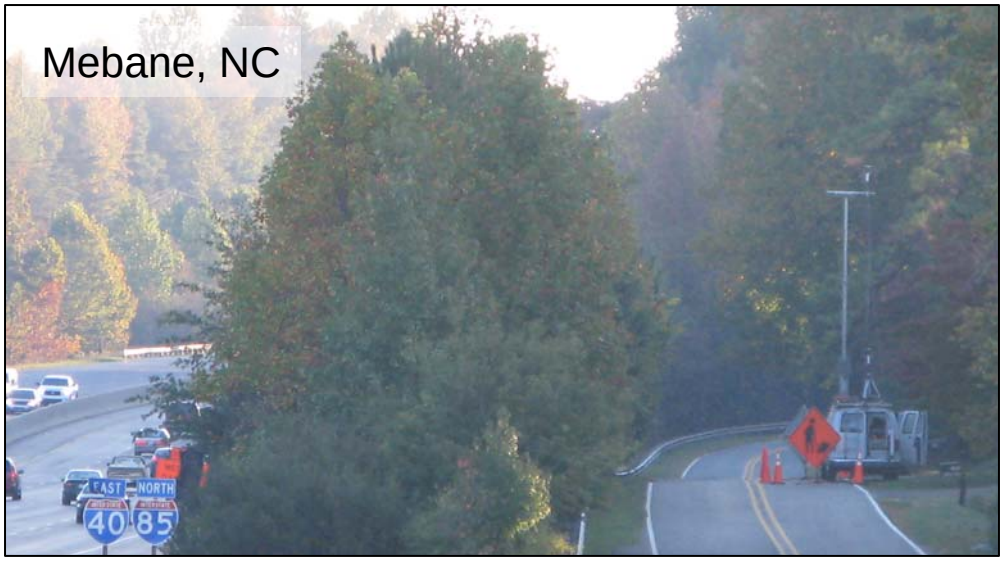
Fig. 1. Mock straw bale sound barrier, 6 m high and 90 m long.

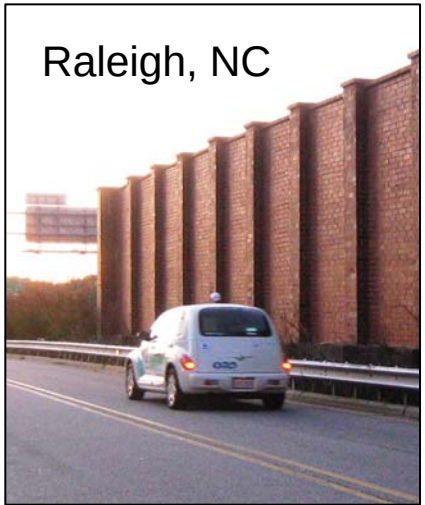
Finn et al. (2010)

Field Data Suggest…

Triangle-Area Barriers Study (2008)

- 2 vegetative barrier sites
- 1 solid barrier site
- Mobile monitoring data collection

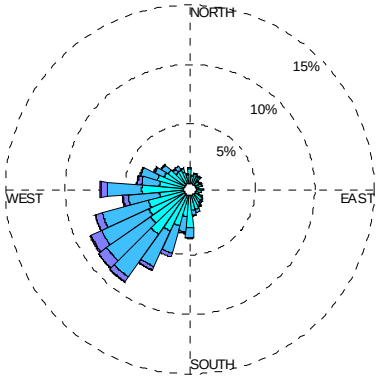


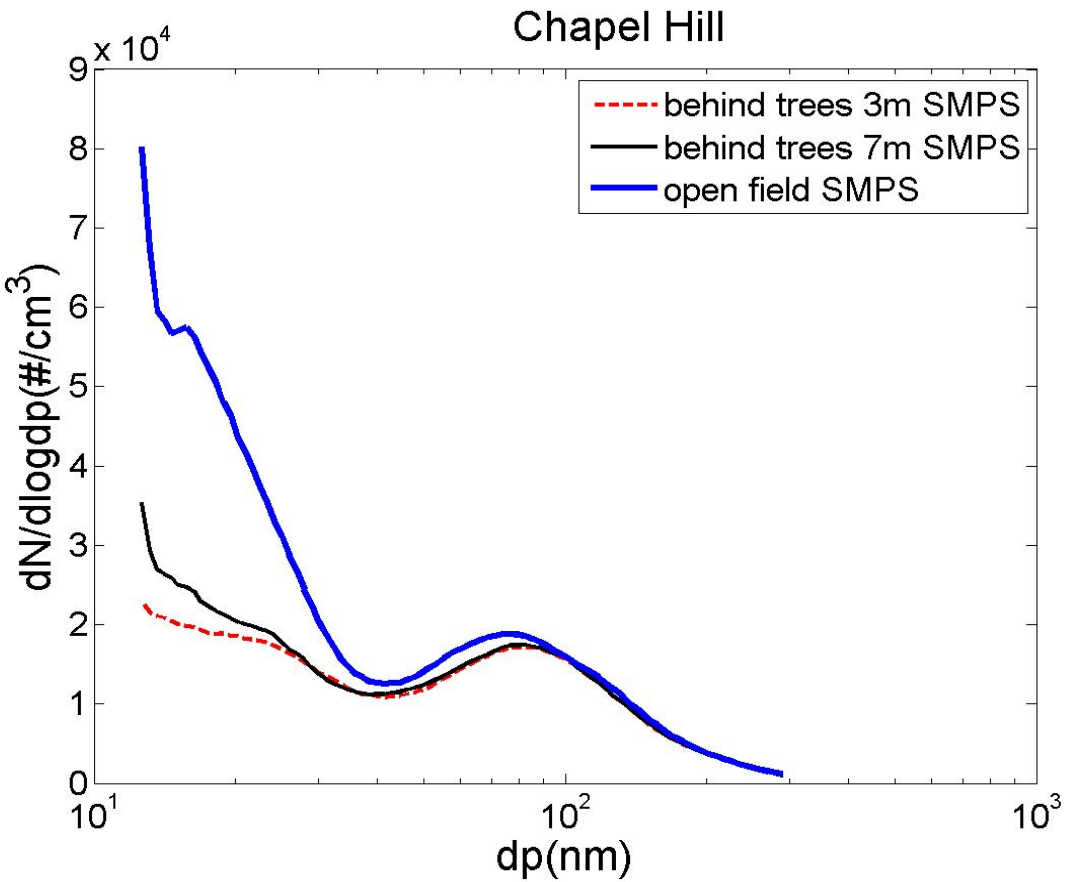


Hagler et al.

Field Data Suggest…

Triangle-Area Barriers Study (2008) – example 2 hour period of sampling downwind of road + evergreen barrier





Lin et al.

Draft – do not cite or distribute

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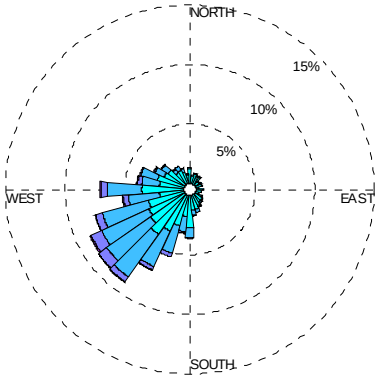

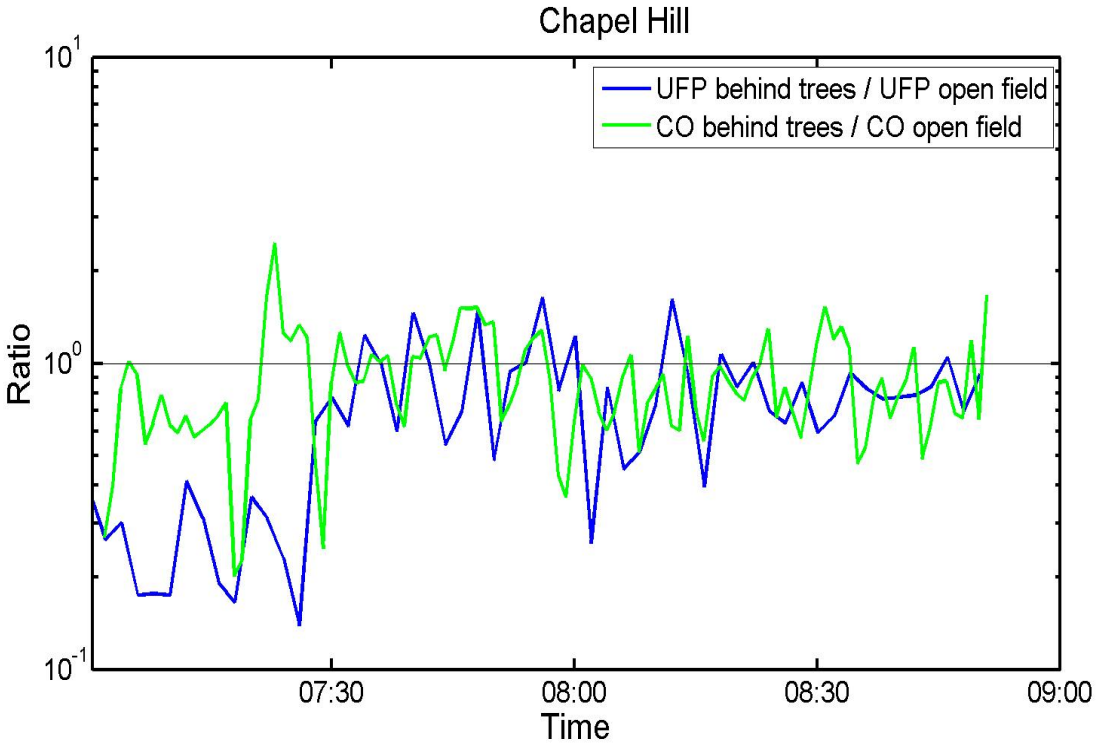

Lin et al.

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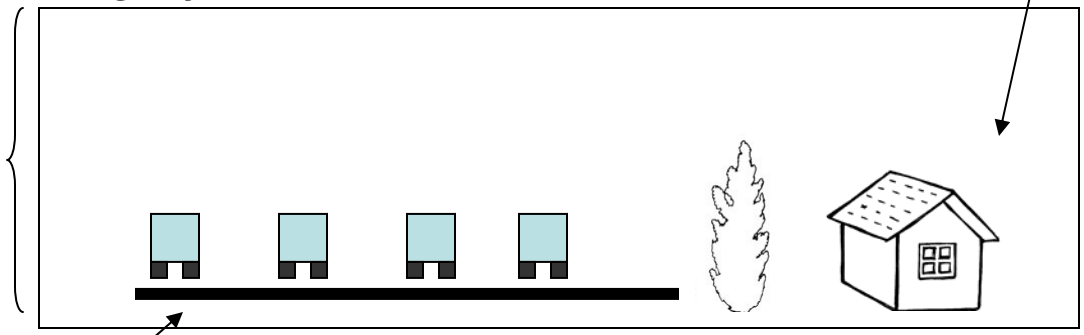
Highway + Vegetation = ?

Start with "Simple Scenario": Even this is challenging…

Meteorology factors:
-Wind direction and speed
-Stability category

Behind barrier factors
- Building height/location
- Any other pollution sources?



On-road factors:
- Traffic-induced turbulence (vehicle speed, traffic volume)
-Surface temperature of the road
-Emissions characteristics

Vegetation factors:
- Dimensions
- Porosity
- Location

Highway + Vegetation = ?

Can we isolate the impact of specific factors?

Meteorology factors:
-Wind direction and speed
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Behind barrier factors
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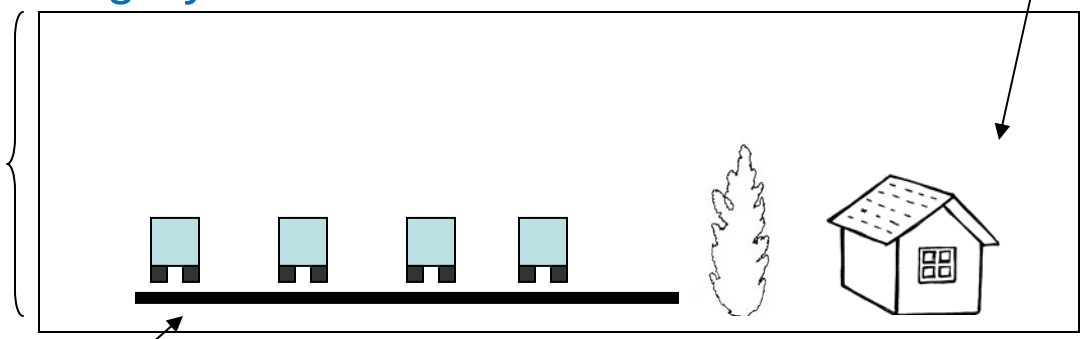

On-road factors:
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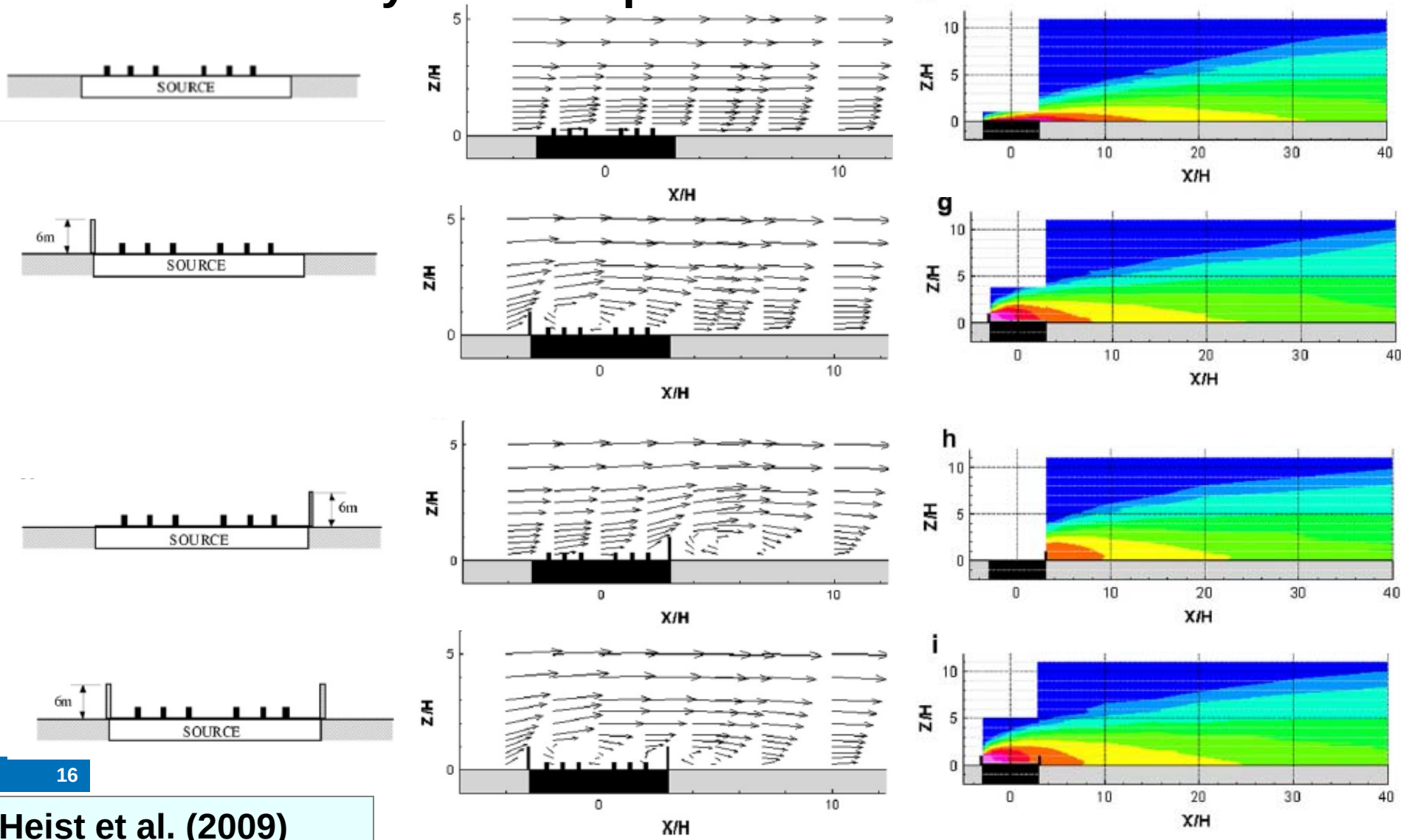
Barrier Location Effect

Wind tunnel study – barrier placement effect



Heist et al. (2009)

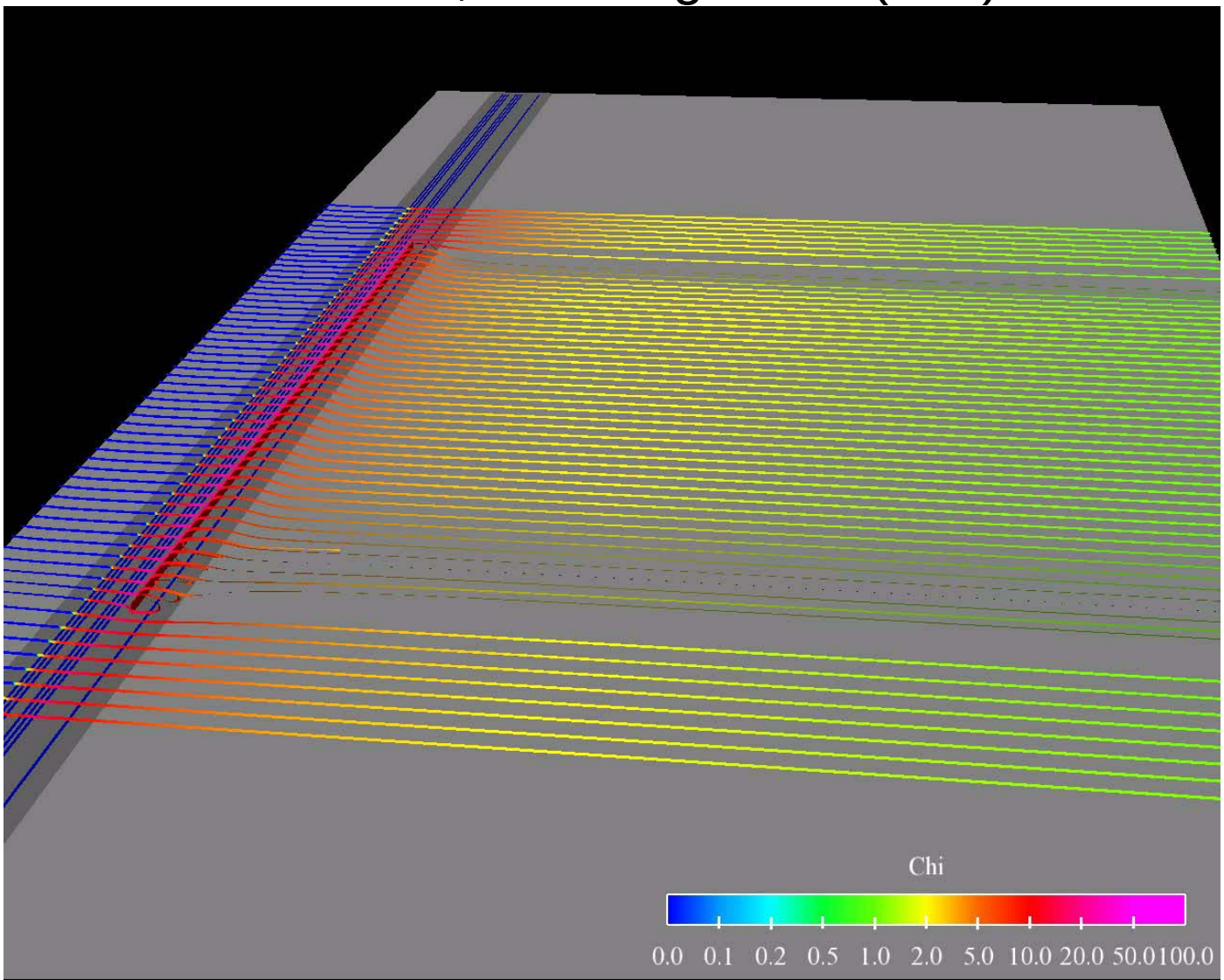
Barrier Height Effect

Base case: winds normal to road, wall height = H (6 m):

Model domain:
2000 x 900 m

Cell size:
0.25 m near barrier
1 m at ground

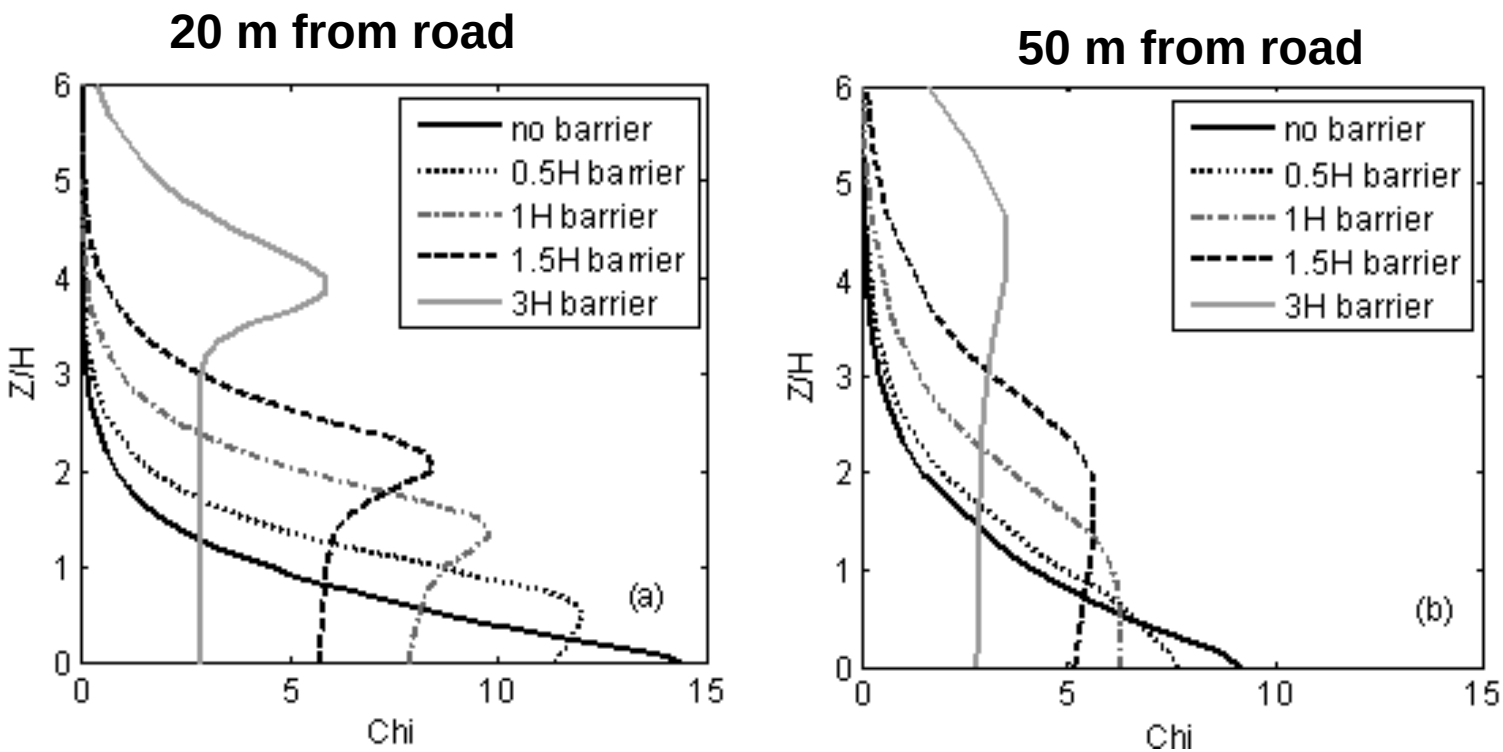
Total cells:
25 million



Hagler et al.

Barrier Height Effect

CFD study – barrier height effect (H = 6 m): Vertical distribution of tracer concentrations



Hagler et al. (in preparation)

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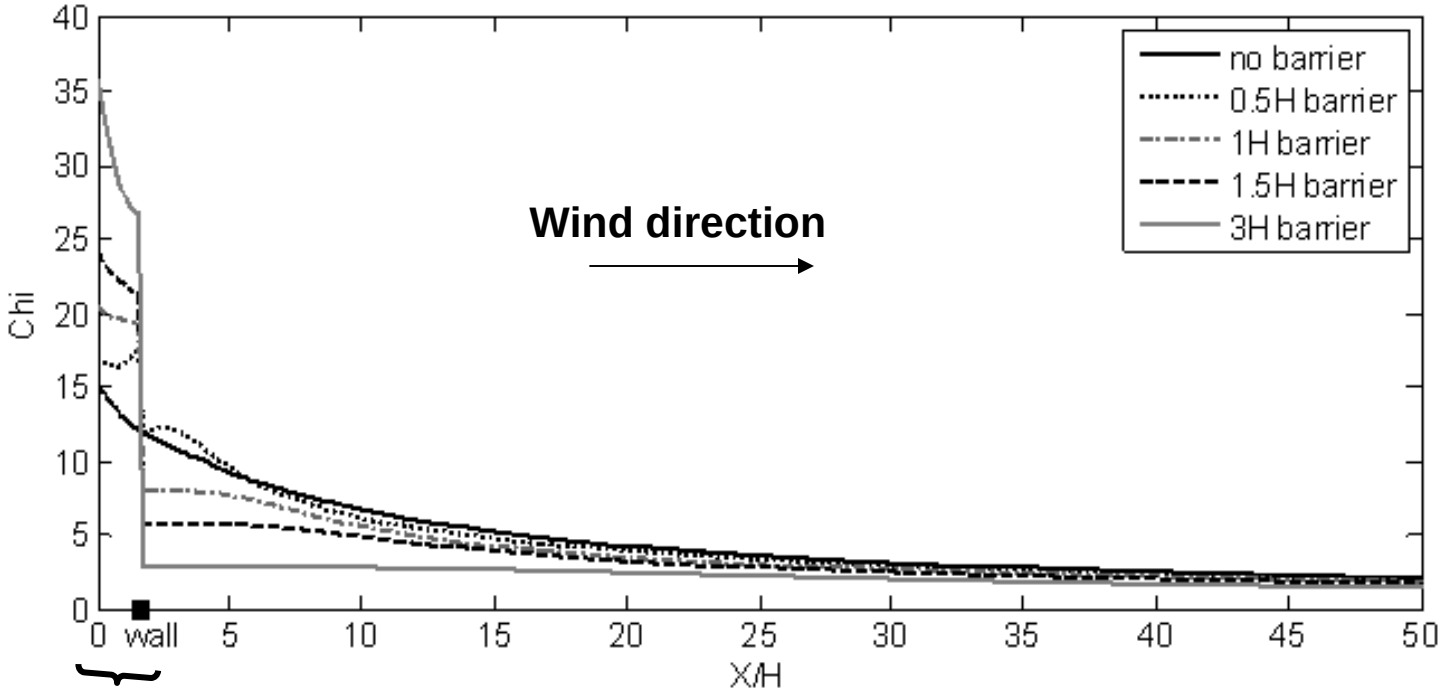
Barrier Height Effect

CFD study – barrier height effect (H = 6 m): Trade-off between near-road and on-road concentration levels…



Between highway and wall…concentrations predicted to increase with wall height

Hagler et al. (in preparation)

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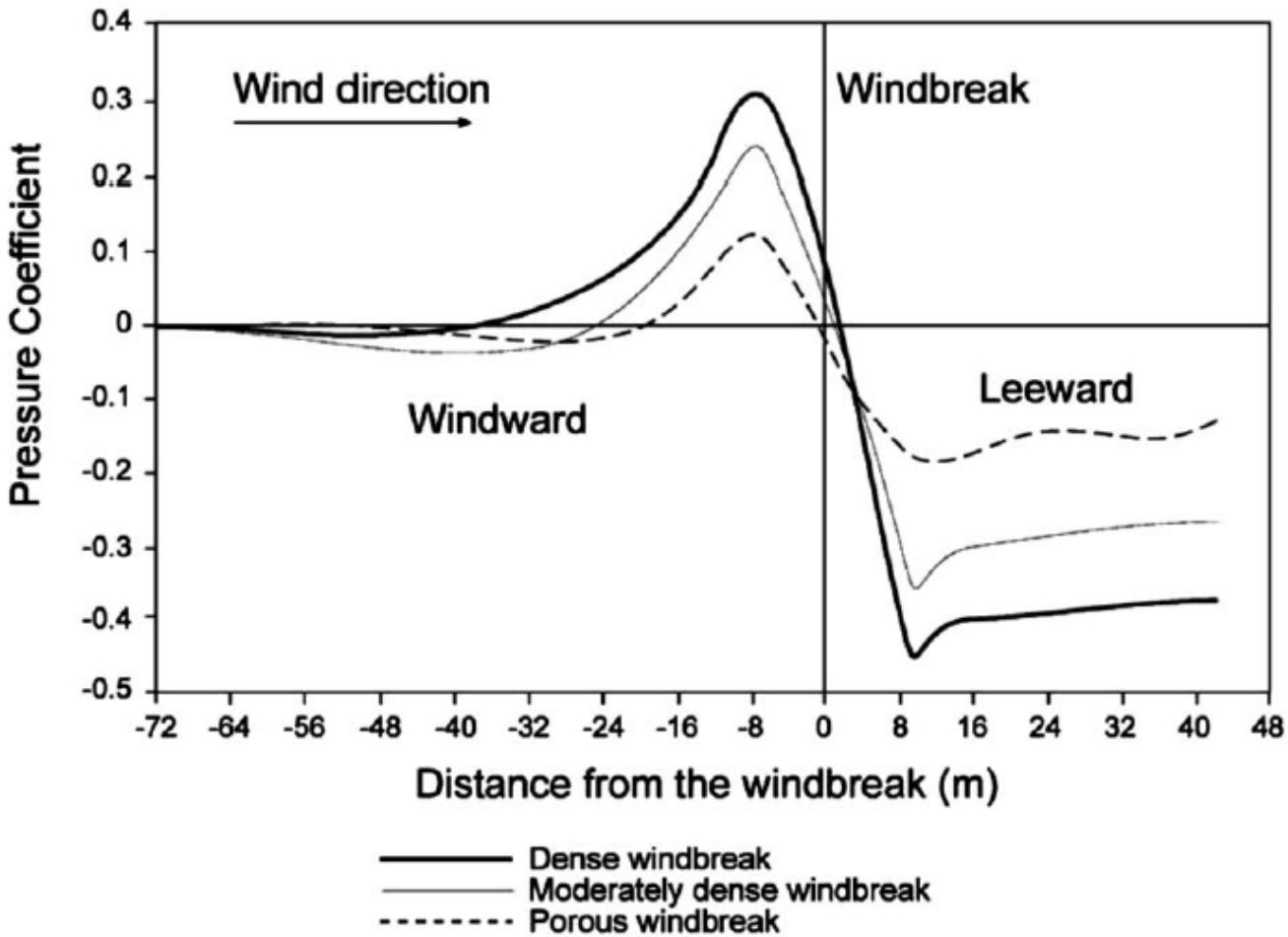
Porosity Effect

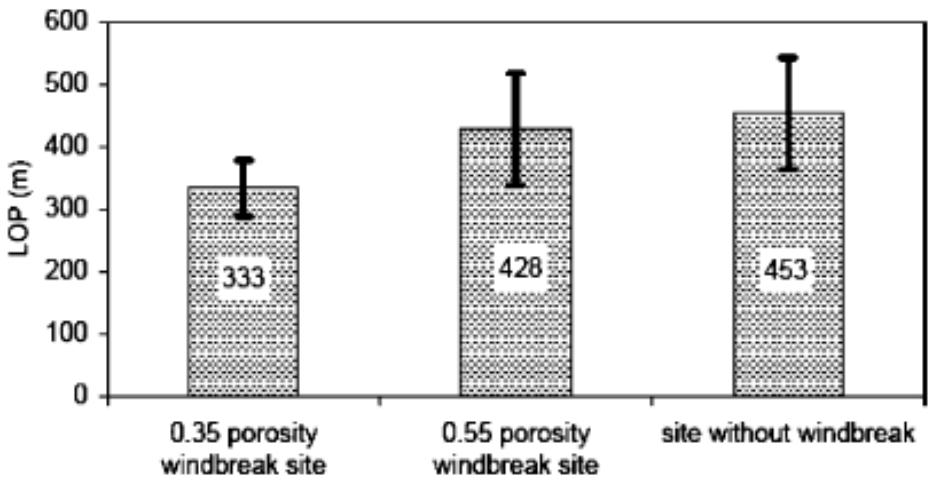
Evidence from windbreak research – porosity significantly changes flow

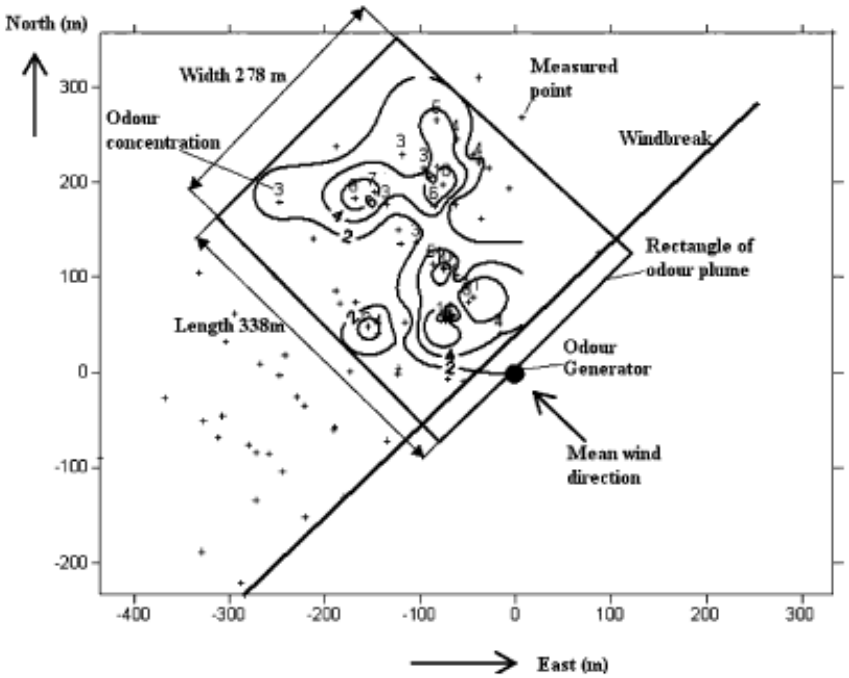


Brandle (2004)

Porosity Effect

Evidence from windbreak research – porosity changes spatial extent of livestock odor plume detection





Lin (2007)

Highway + Vegetation = ?

Can we isolate the impact of specific factors?

Meteorology factors:
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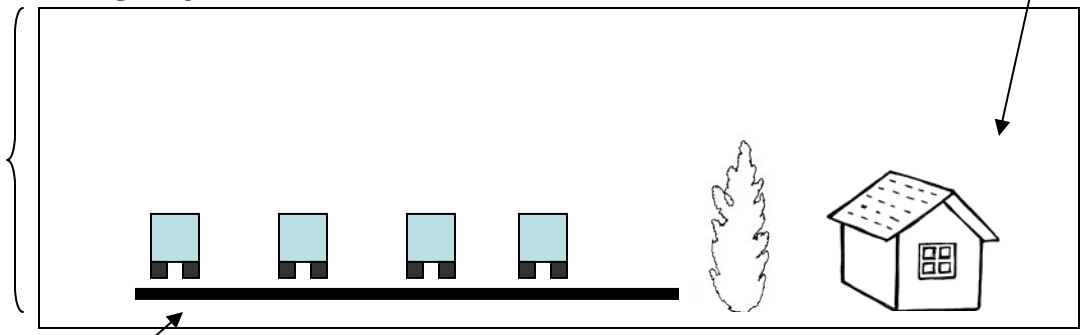
-Stability category

Behind barrier factors
- Building height/location
- Any other pollution sources?



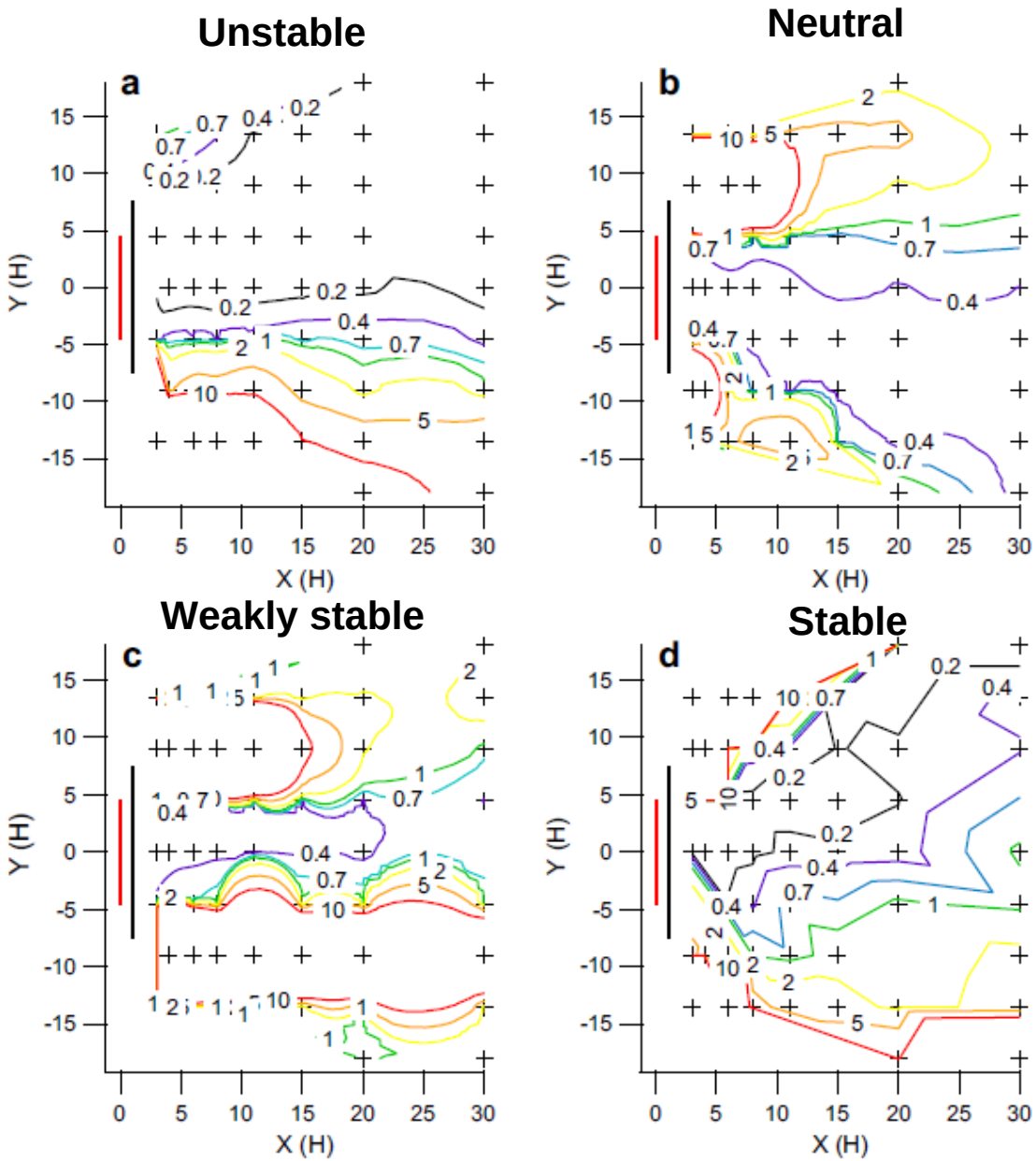
On-road factors:
- Traffic-induced turbulence (vehicle speed, traffic volume)
-Surface temperature of the road
-Emissions characteristics

Vegetation factors:
- Dimensions
- Porosity – assume “solid”
- Location

Highway + Vegetation = ?

Stability effect:

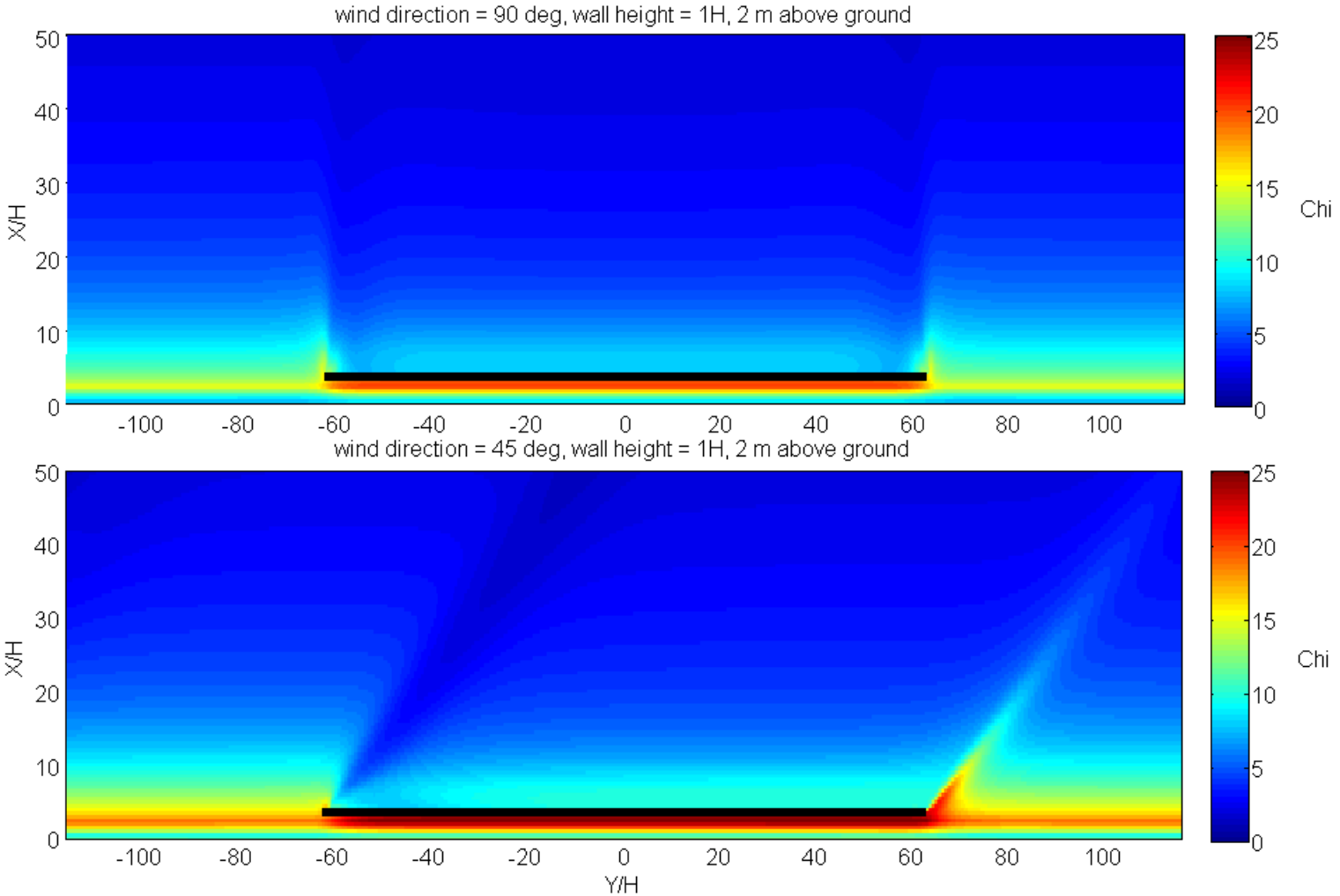
Fig. 1. Mock straw bale sound barrier, 6 m high and 90 m long.



Finn et al. (2010)

Highway + Vegetation = ?

Wind direction effect:



Hagler et al.

Draft – do not cite or distribute

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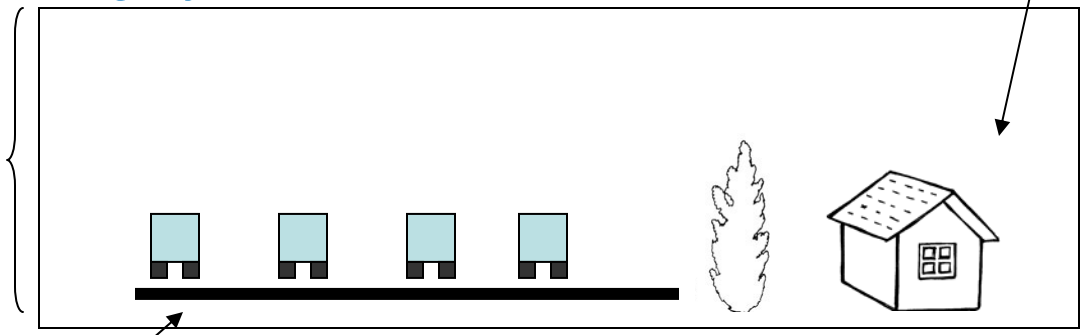

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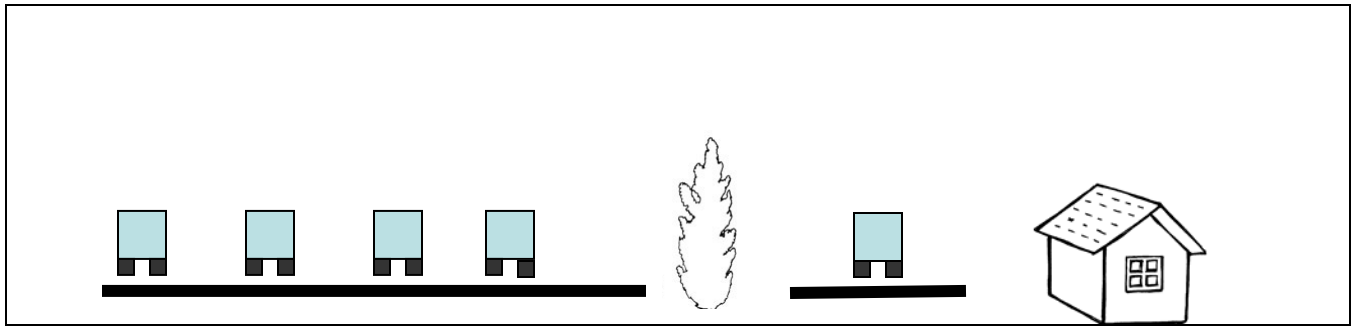
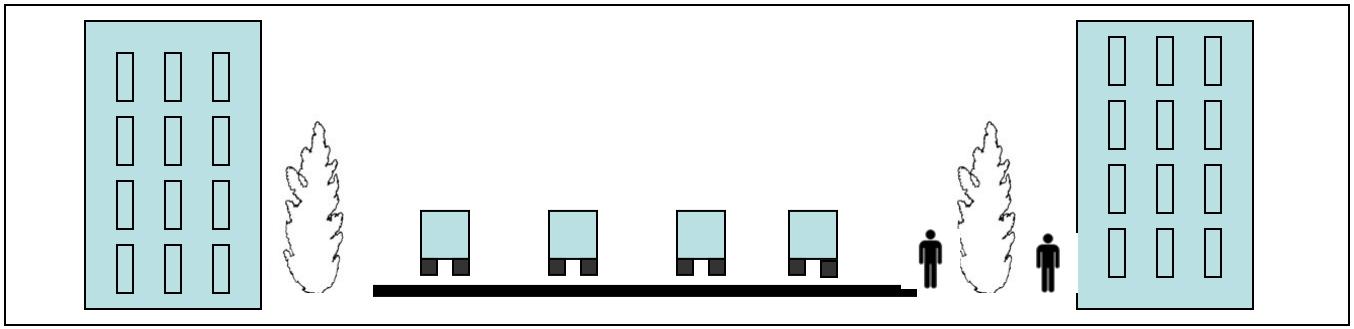
Highway + Vegetation = ?

More complex situations…

Arterial roads



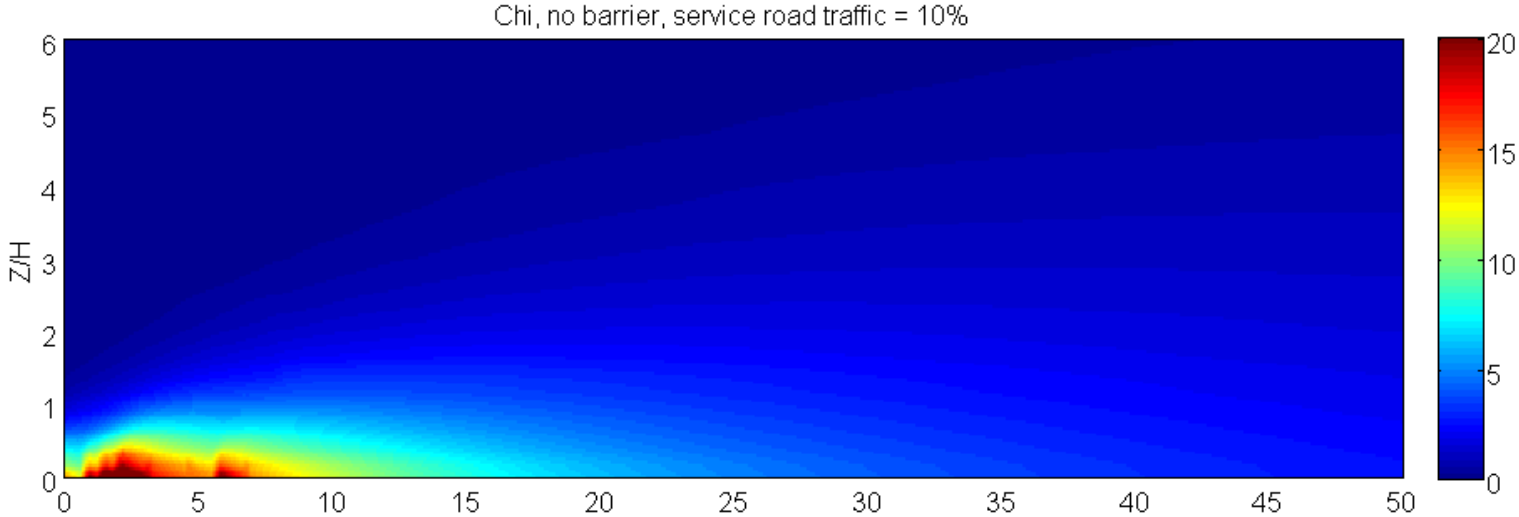
Street Canyons



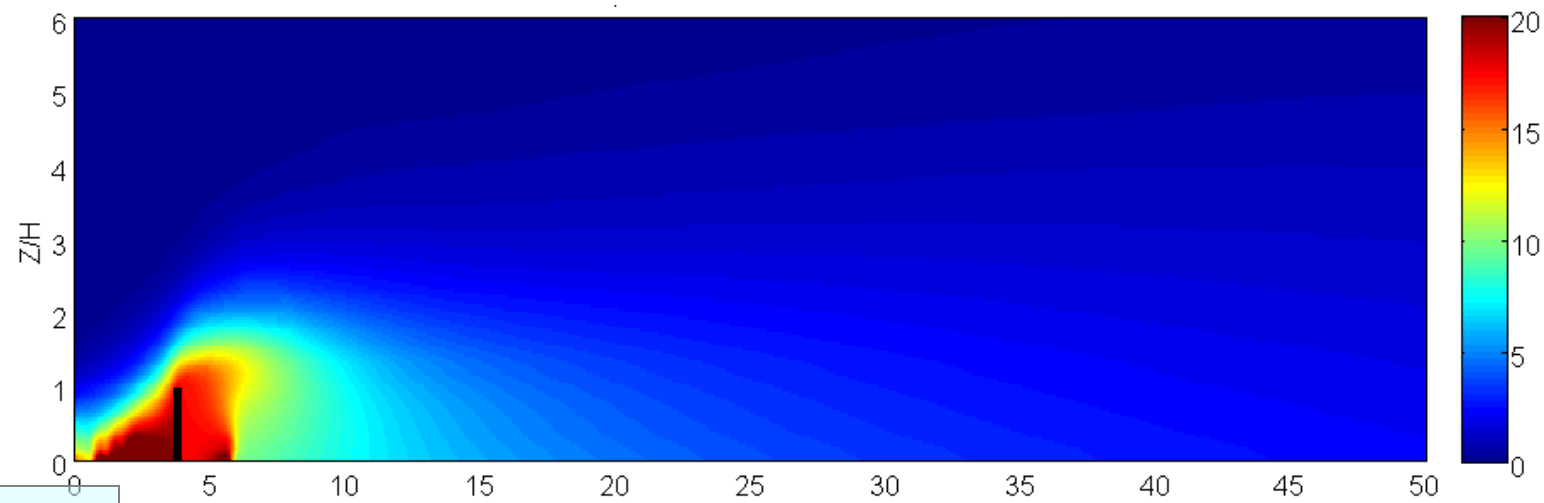
Highway + Vegetation = ?

Behind barrier sources: Important!

Wind direction



Wind direction



Hagler et al.

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Highway + Vegetation = ?

Street Canyon Situations

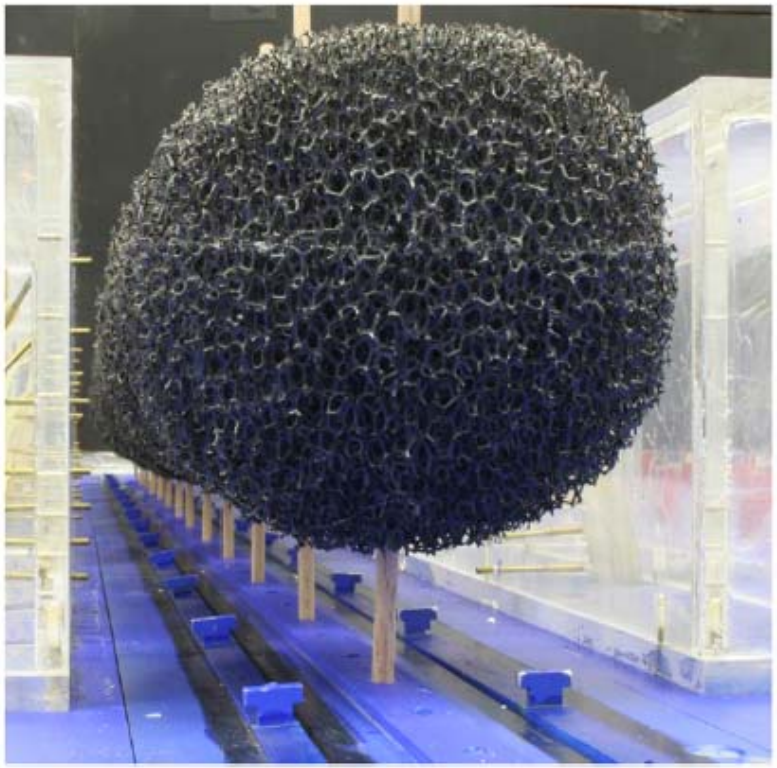


Fig. 20. Photograph of a tree crown made out of foam 10 ppi.

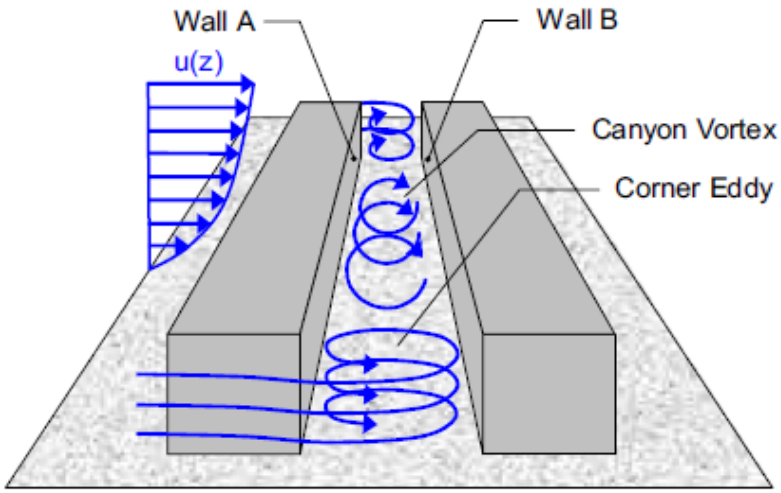


Fig. 2. Flow field in and around an urban street canyon.

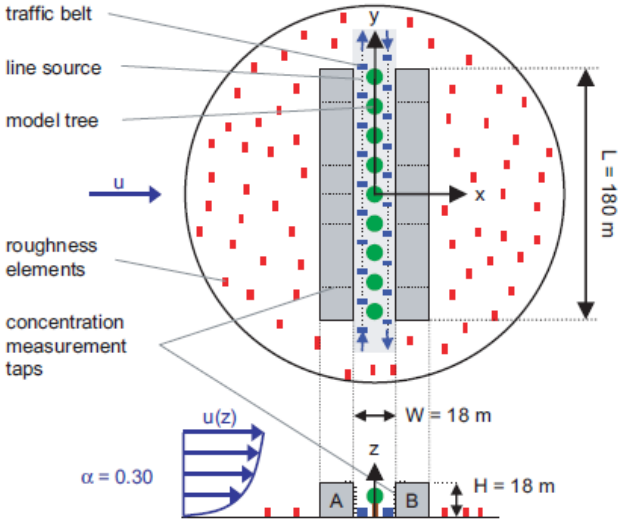


Fig. 1. Wind tunnel model of the urban street canyon (scale 1:150).

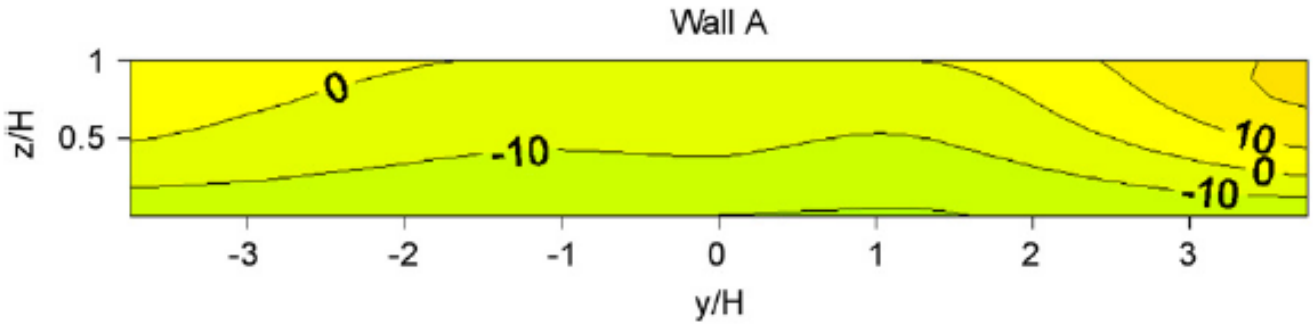
Gromke (2007)

Highway + Vegetation = ?

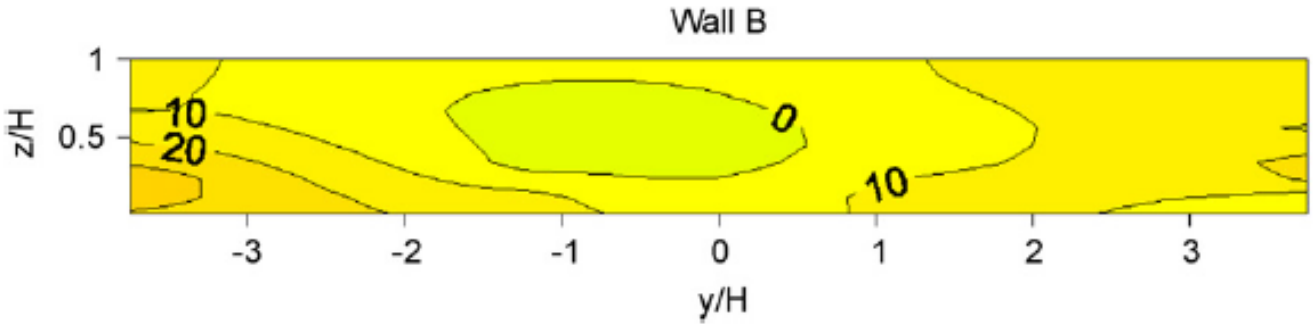
Street Canyon Situations

Comparison of w/vegetation to no-barrier case – moving traffic

Upwind wall – concentrations generally lower/same →



Downwind wall – concentrations generally increase (!) →

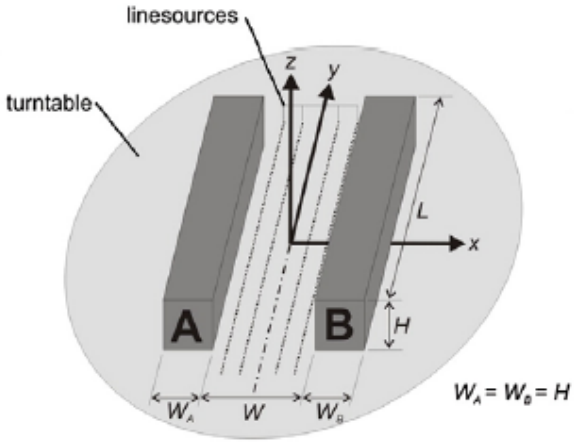


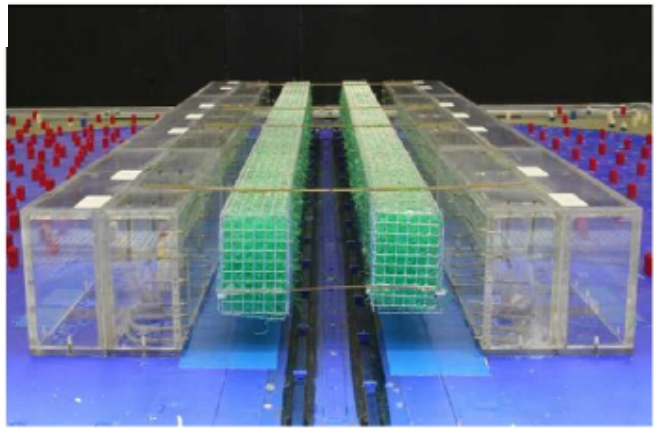
Gromke (2007)

Highway + Vegetation = ?

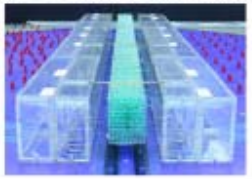
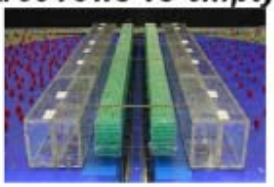
Street Canyon Situations

Comparison of two rows of vegetation:





General finding: Presence of vegetation appears to have a net increase for in-canyon concentrations

	W/H=1 – single tree row vs empty 	W/H=2 – two tree rows vs empty 
leeward	+71%	+42%
windward	-35%	-32%

Buccolieri (2009)

Take-Away Thoughts

- Impact of vegetation on near-road air quality is site-specific, key factors are:
  - -Local meteorology
  - -Building density/height/distance from road
  - -Placement of pedestrian/bike paths

- Trade-off may exist between on-road air quality and near-road air quality

-Areas of needed research:
  - -Quantifying on-road impacts
  - -Field data assessing long-term concentration difference for behind-vegetation vs. unobstructed air flow
  - -Assessing importance of “breaks” in vegetative barrier
  - -Assessing effect of distributed vegetation vs. wall