

US EPA ARCHIVE DOCUMENT

How does vegetation affect pollutant transport and dispersion?

Gayle Hagler – EPA/ORD



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

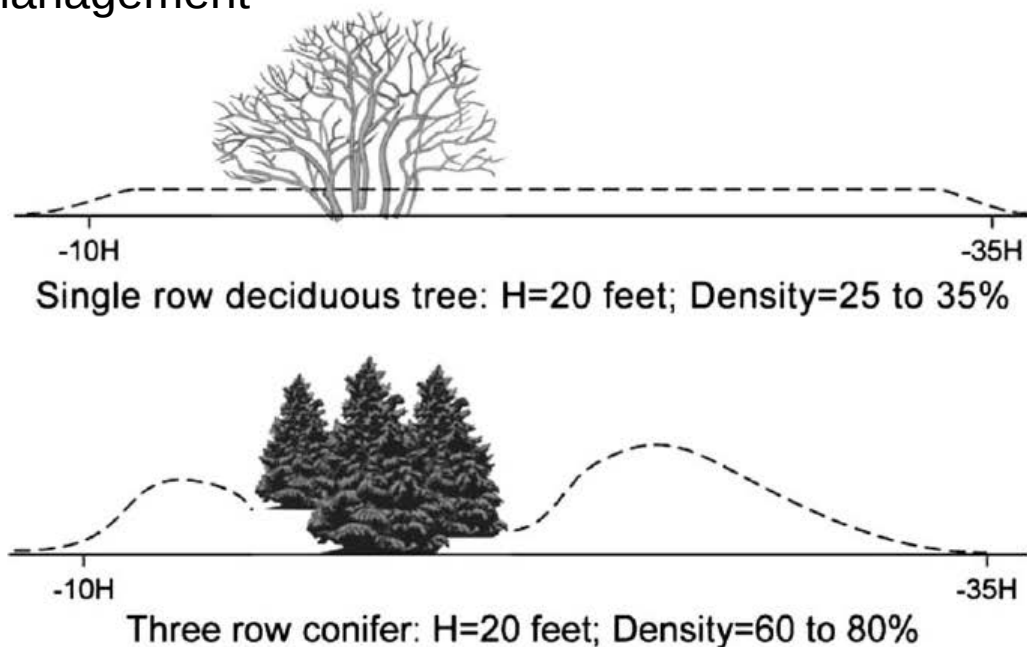


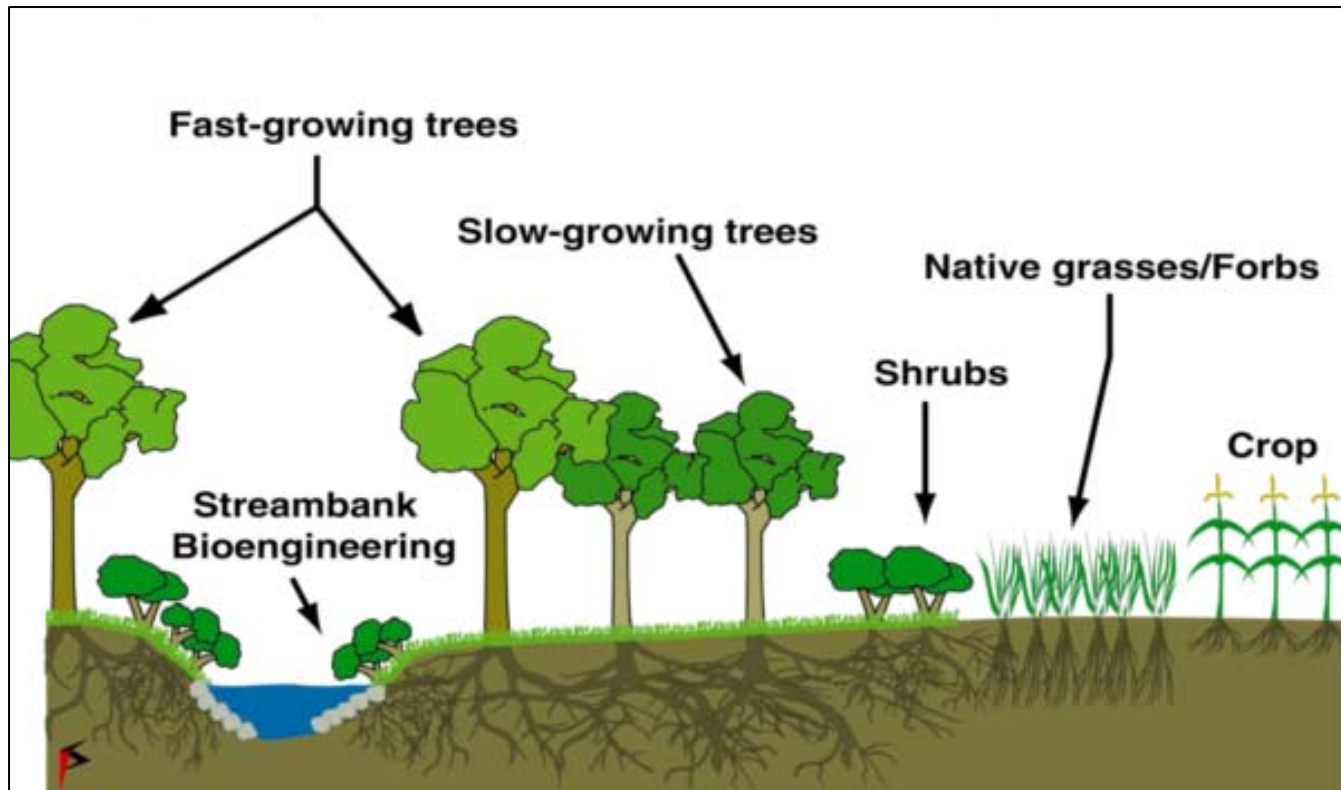
Figure 3. Snow distribution as influenced by a very porous windbreak and a very dense windbreak. The porous windbreak is used to distribute snow across a field while a dense windbreak is used to collect snow in a relatively narrow deep drift.

Historical Context

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



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, NO_x
- Particulate matter

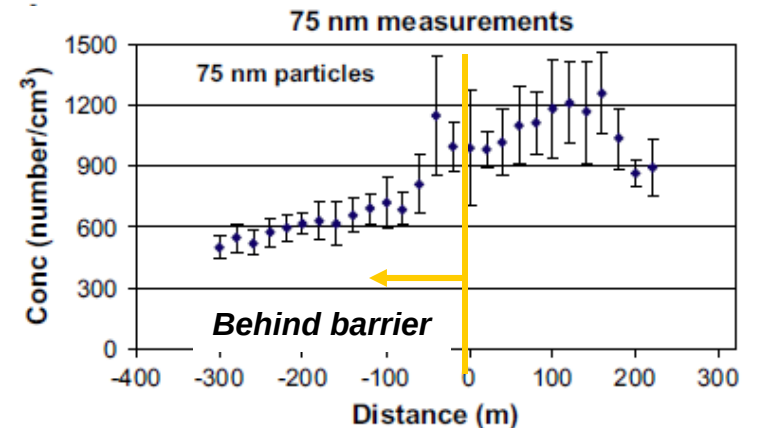
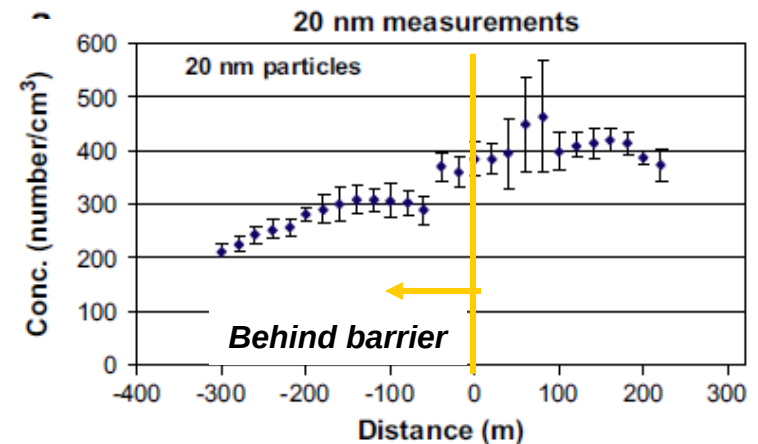
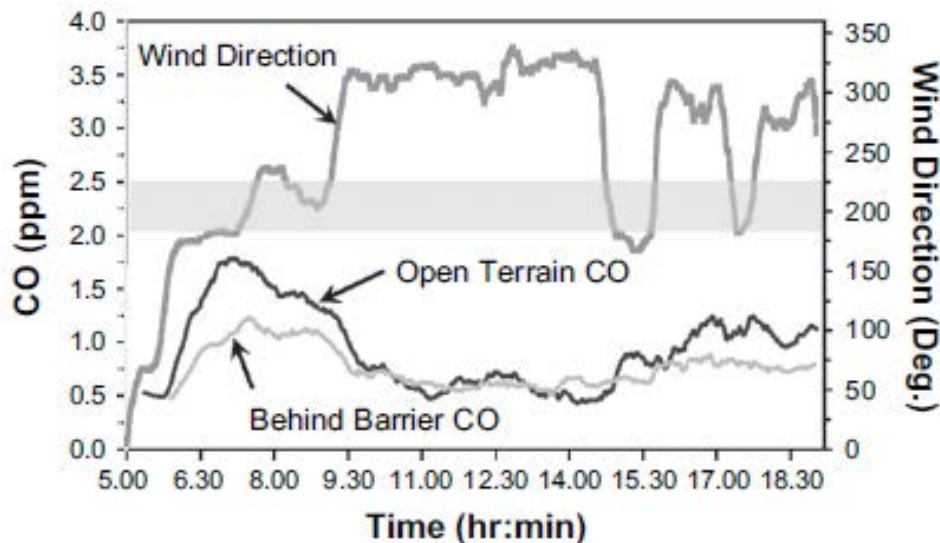
Areas of unobstructed
flow and areas
obstructed by **6 m noise
barrier and vegetation**



Field Data Suggest...

Raleigh Near-Road Study:

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



Field Data Suggest...

Near Roadway Tracer Study:

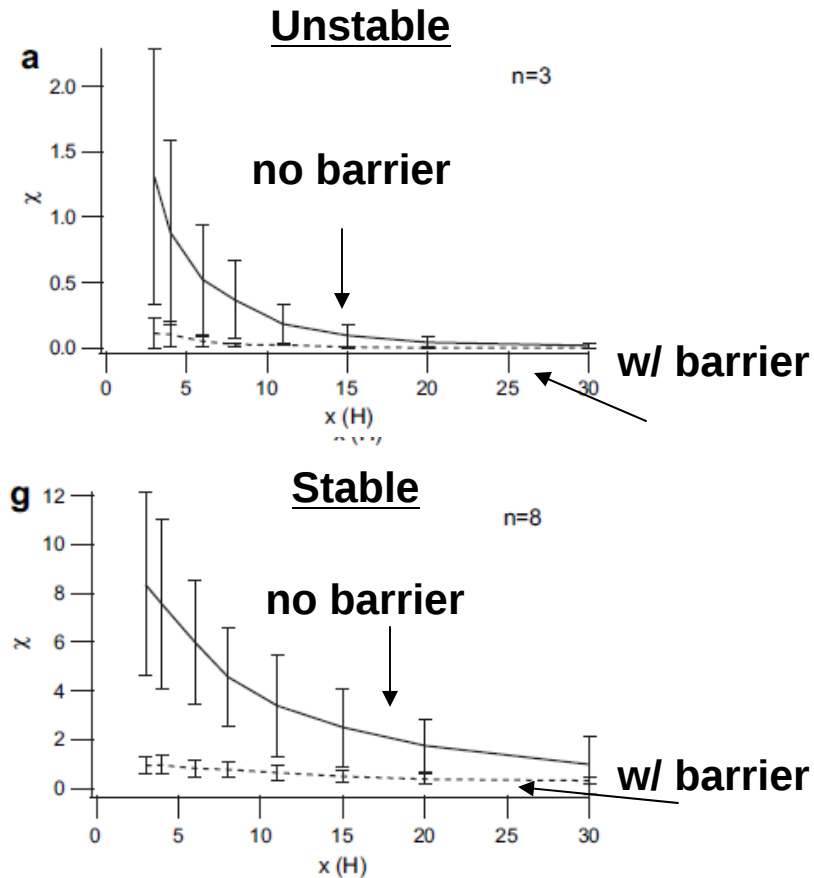


Fig. 1. Mock straw bale sound barrier, 6 m high and 90 m long.

Field Data Suggest...

Near Roadway Tracer Study:

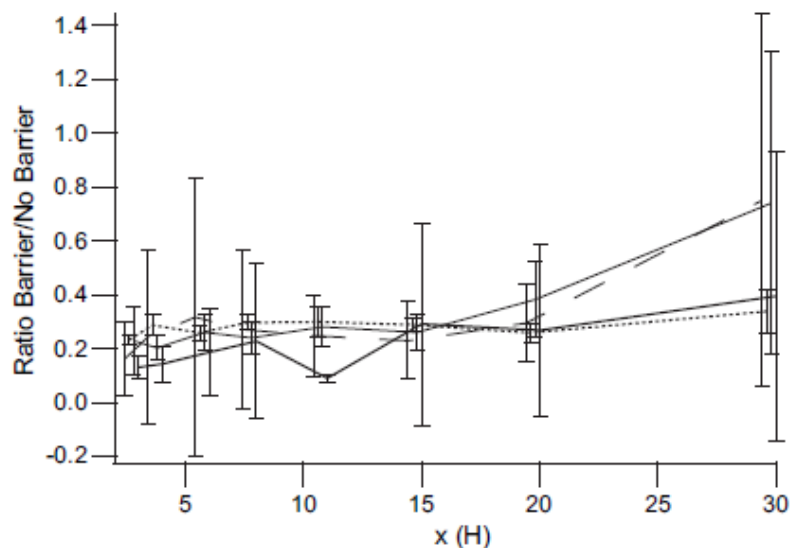


Fig. 9. Mean barrier/non-barrier normalized centerline concentration ratios for qualifying periods: unstable, bold; neutral, solid; weakly stable, dotted; stable, dashed. Error bars are standard deviations.



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

Field Data Suggest...

Triangle-Area Barriers Study (2008)

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

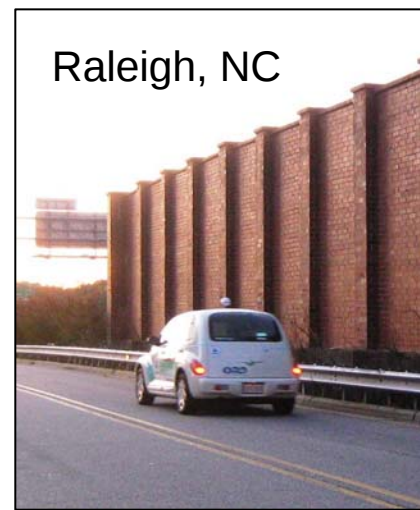
Mebane, NC



Chapel Hill, NC

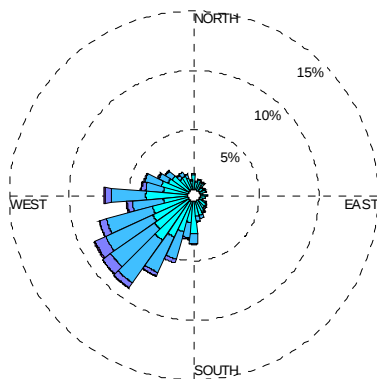


Raleigh, NC

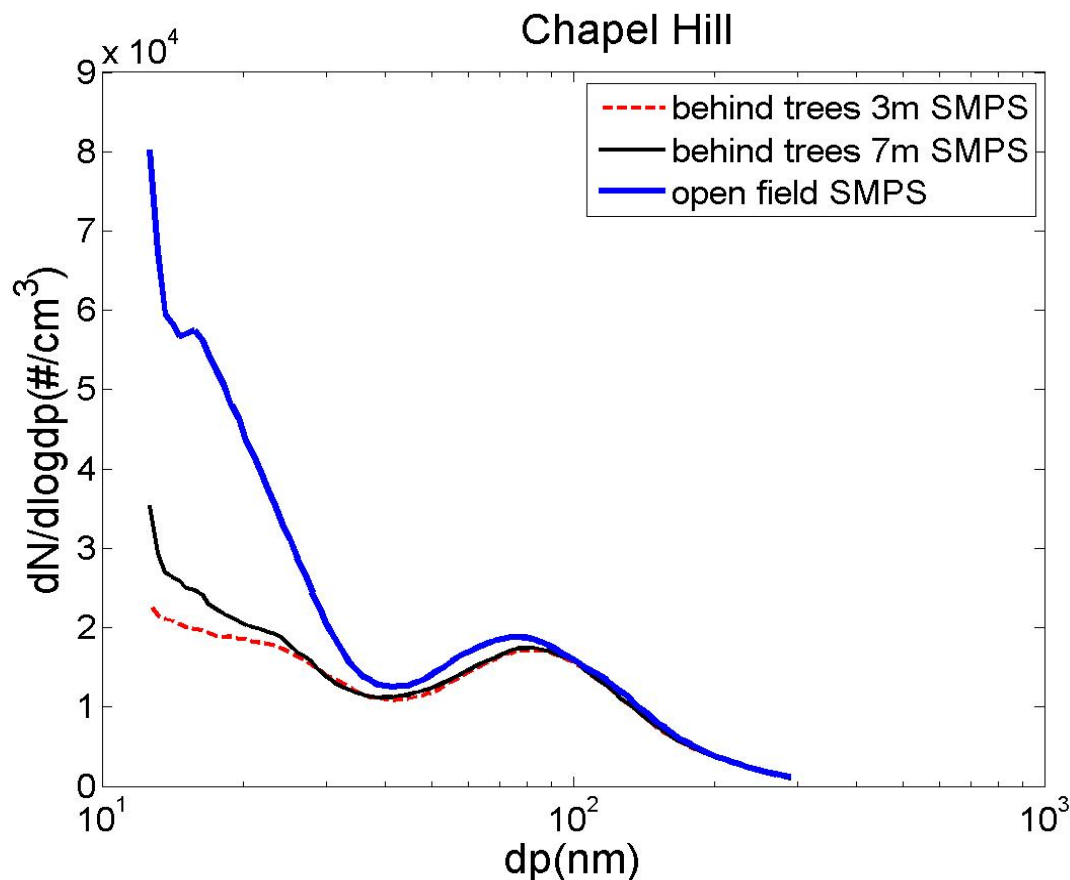


Field Data Suggest...

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

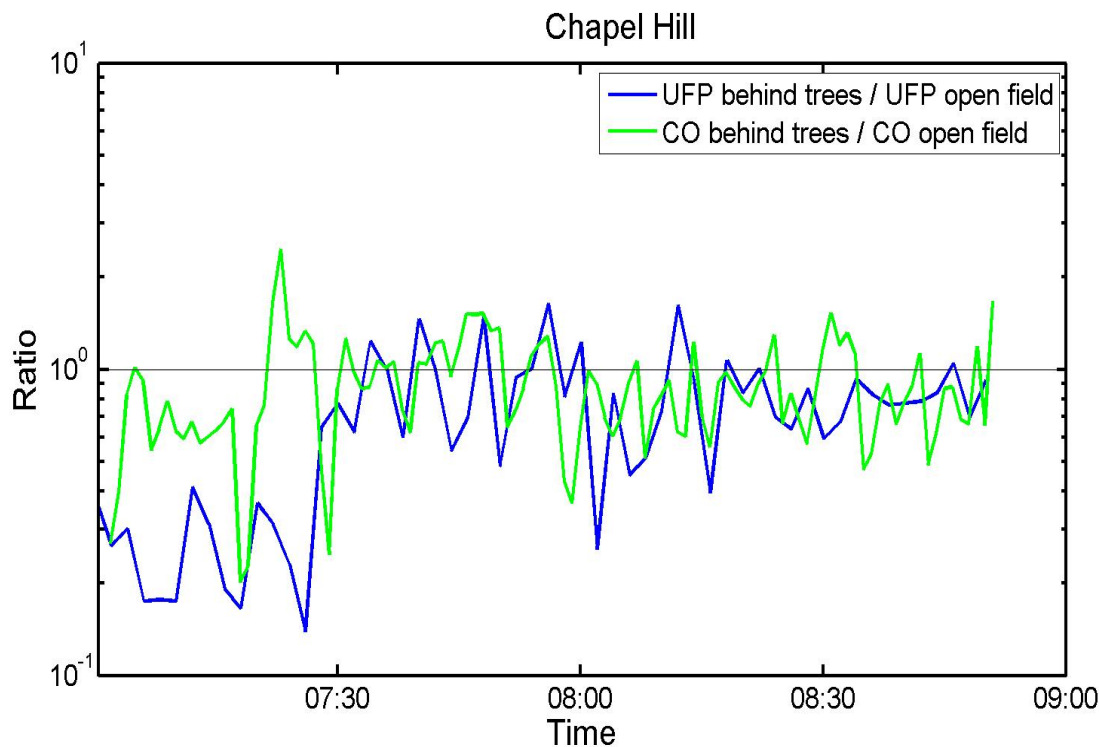
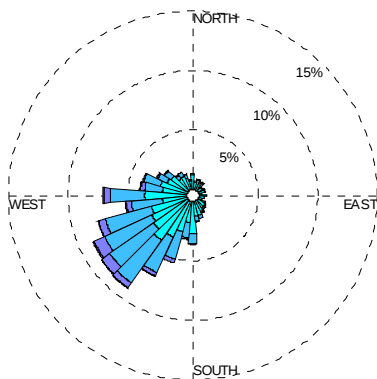


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Field Data Suggest...

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



Highway + Vegetation = ?

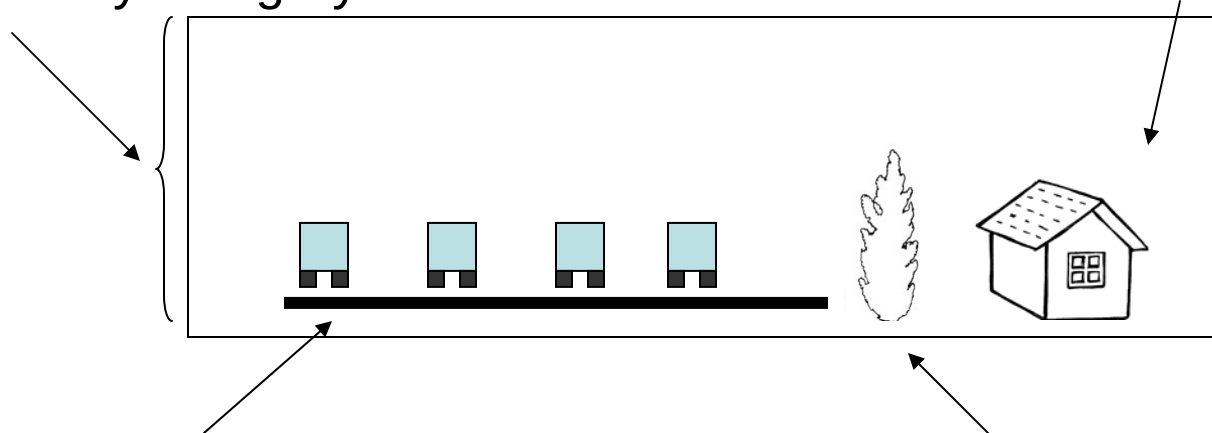
Start with “Simple Scenario”: Even this is challenging...

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 = ?

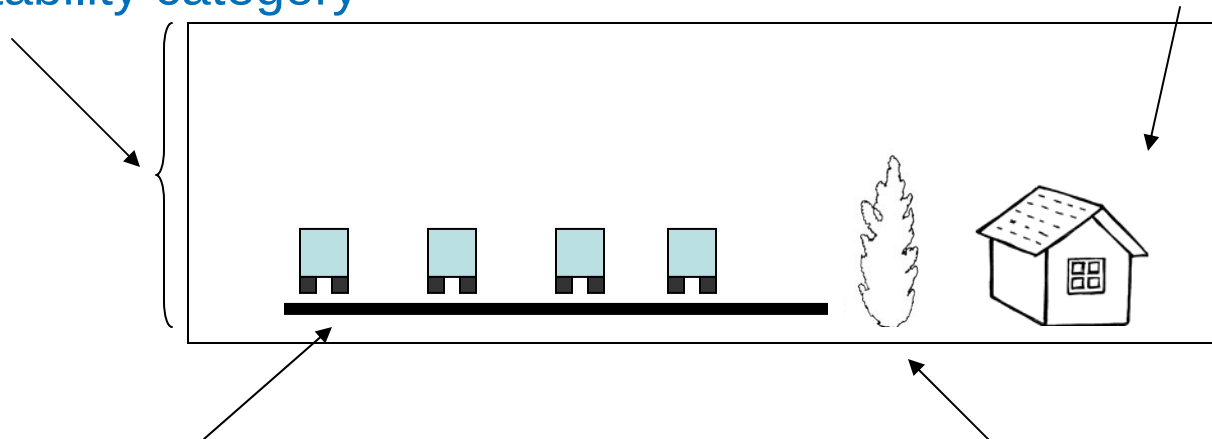
Can we isolate the impact of specific factors?

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On-road factors:

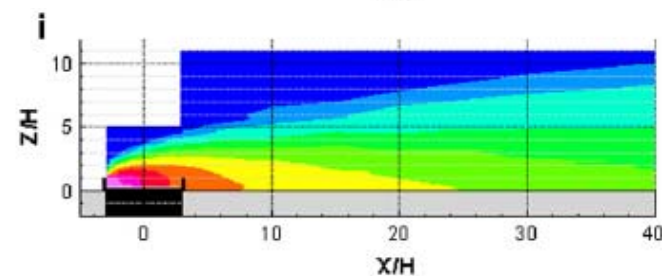
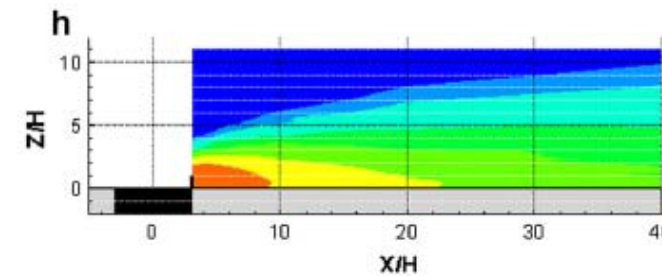
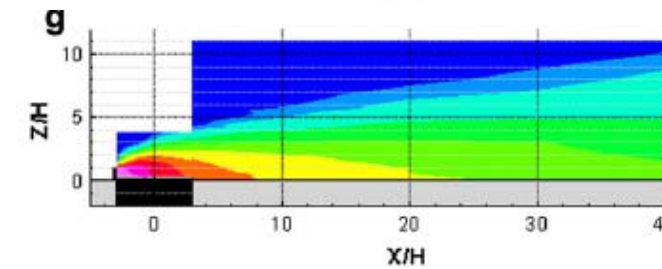
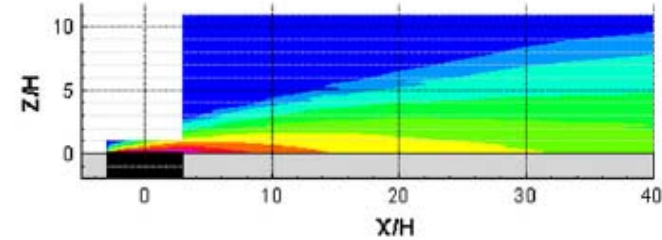
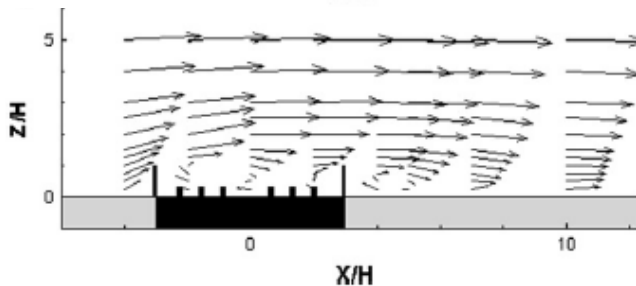
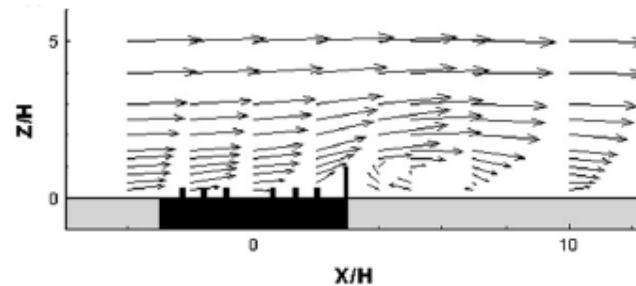
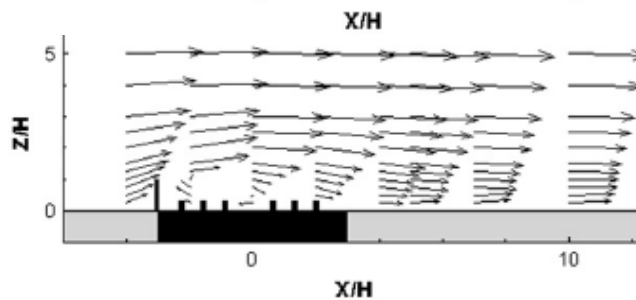
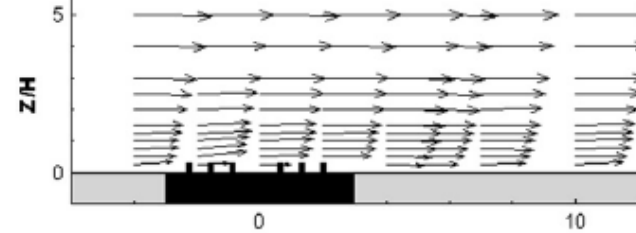
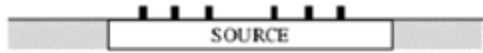
- Traffic-induced turbulence (vehicle speed, traffic volume)
- Surface temperature of the road
- Emissions characteristics

Vegetation factors:

- Dimensions
- Porosity
- Location

Barrier Location Effect

Wind tunnel study – barrier placement effect



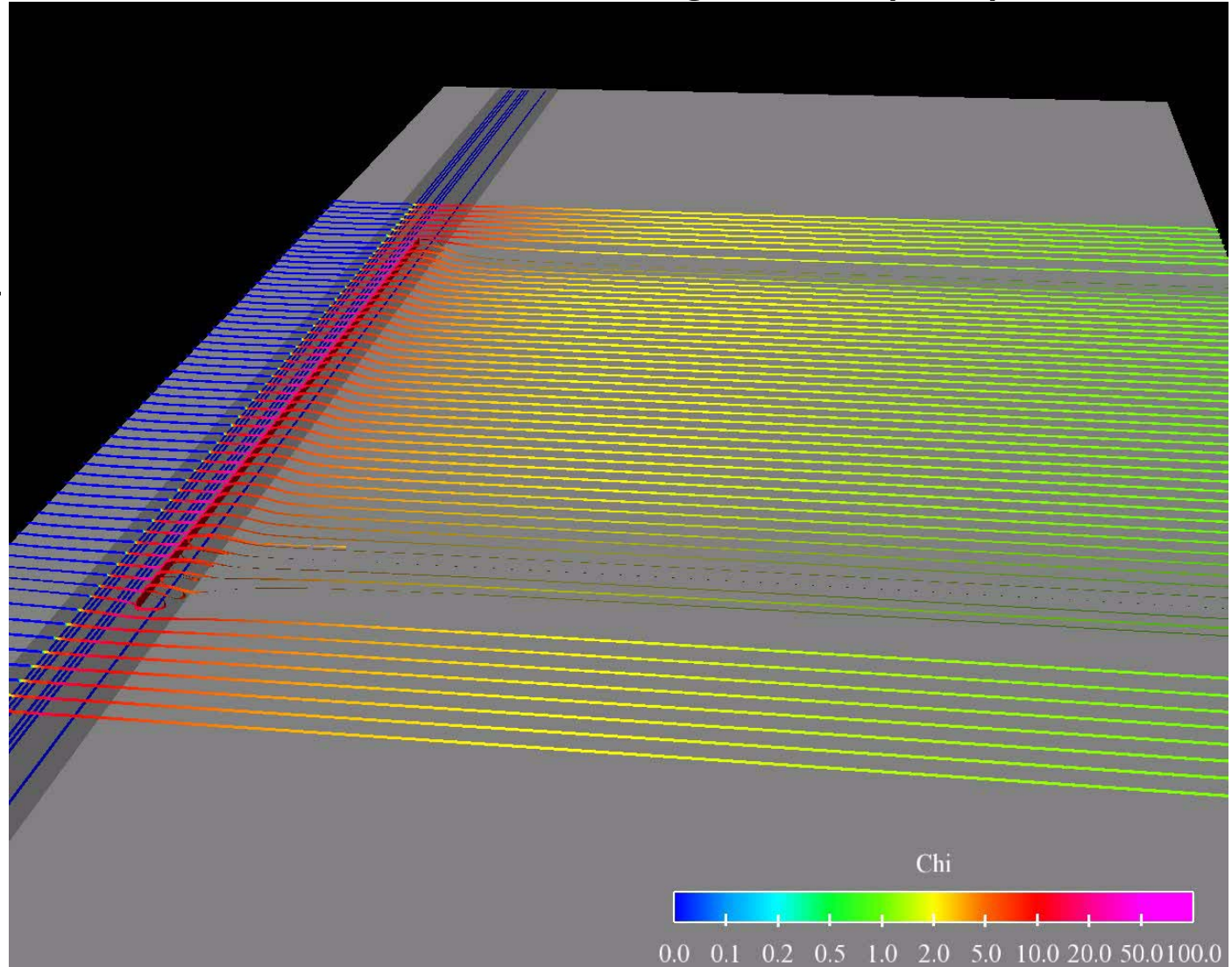
Barrier Height Effect

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

Model domain:
2000 x 900 m

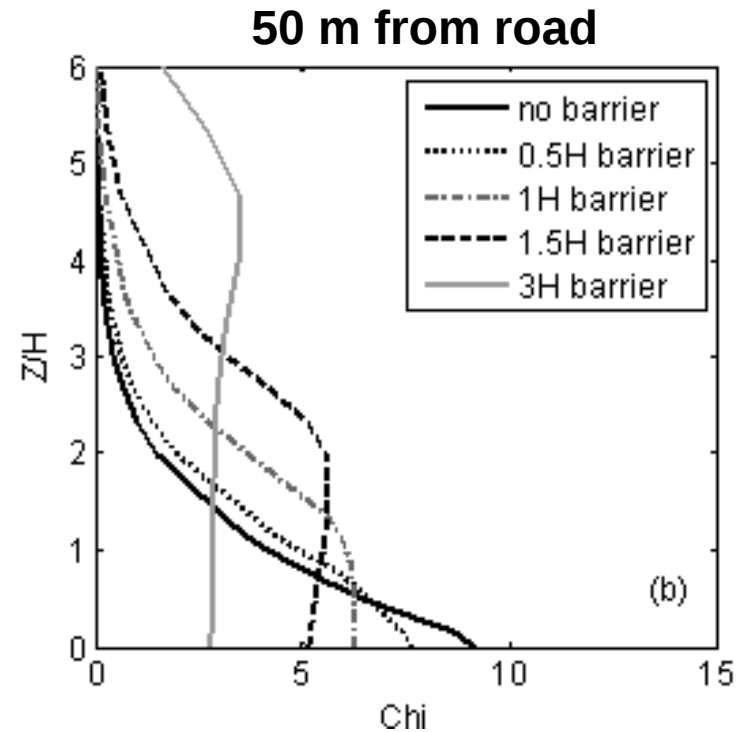
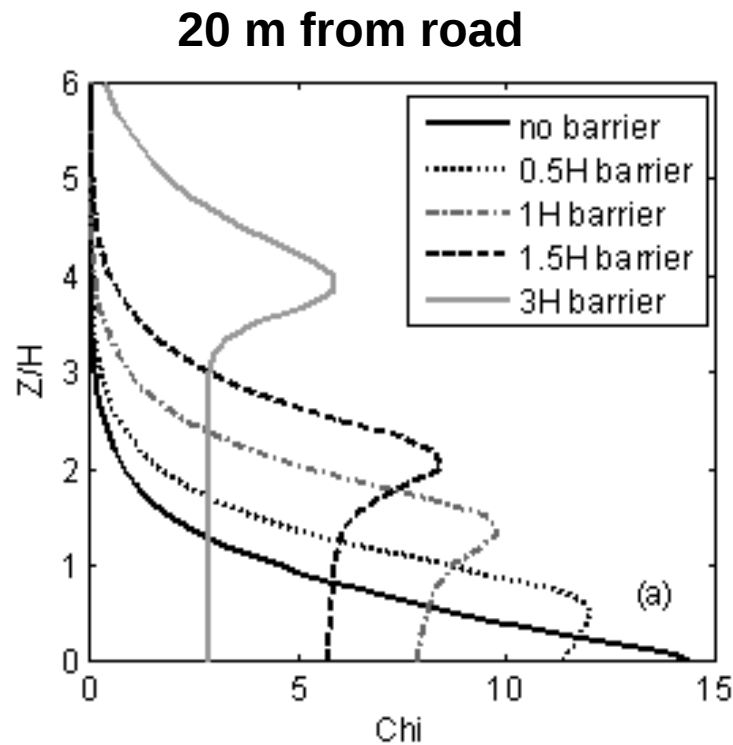
Cell size:
0.25 m near barrier
1 m at ground

Total cells:
25 million



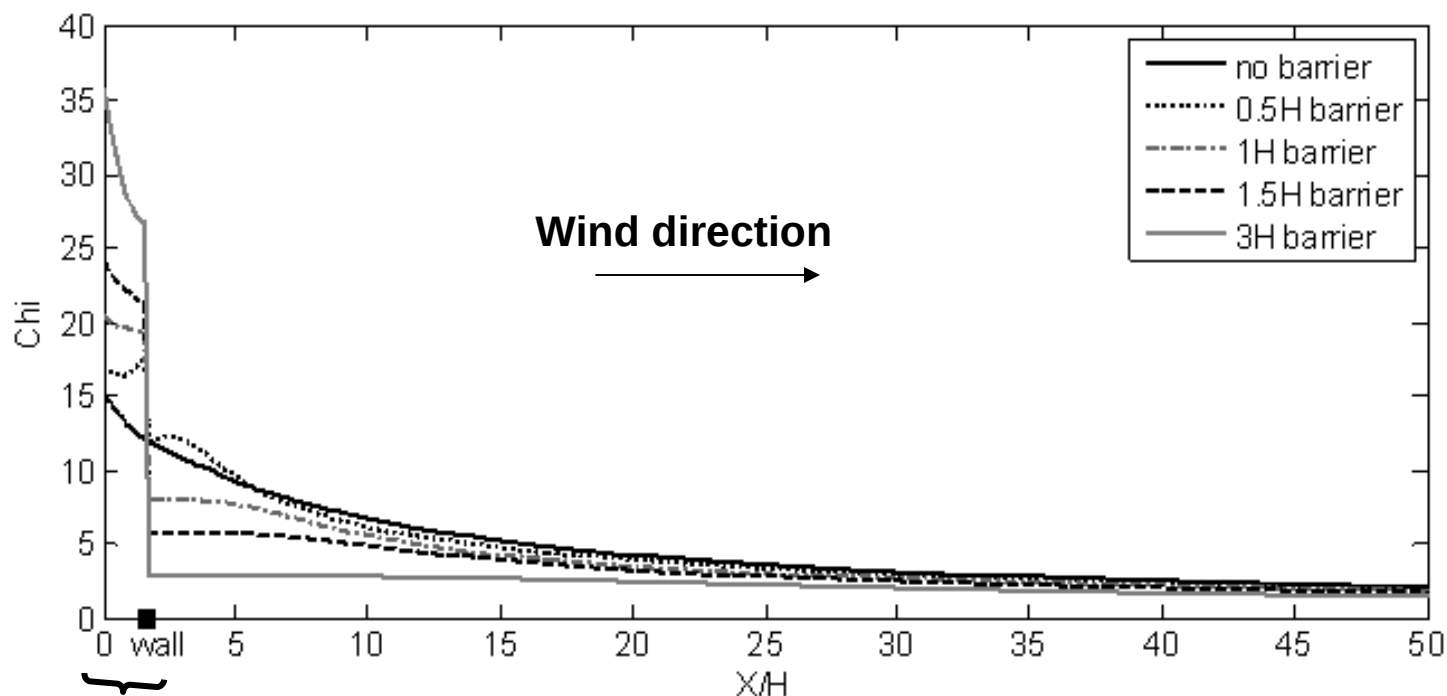
Barrier Height Effect

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



Barrier Height Effect

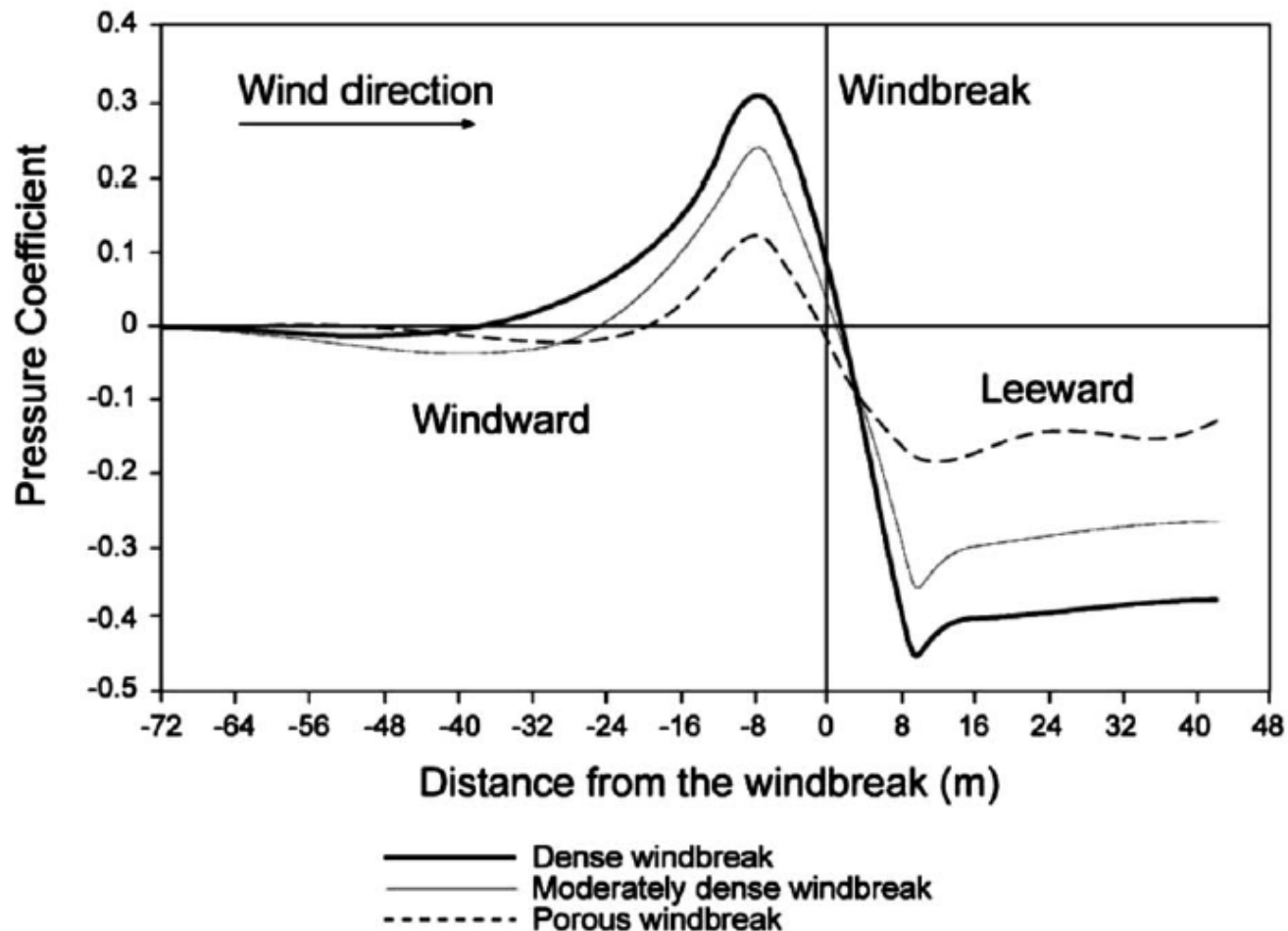
CFD study – barrier height effect ($H = 6$ m): Trade-off between near-road and on-road concentration levels...



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

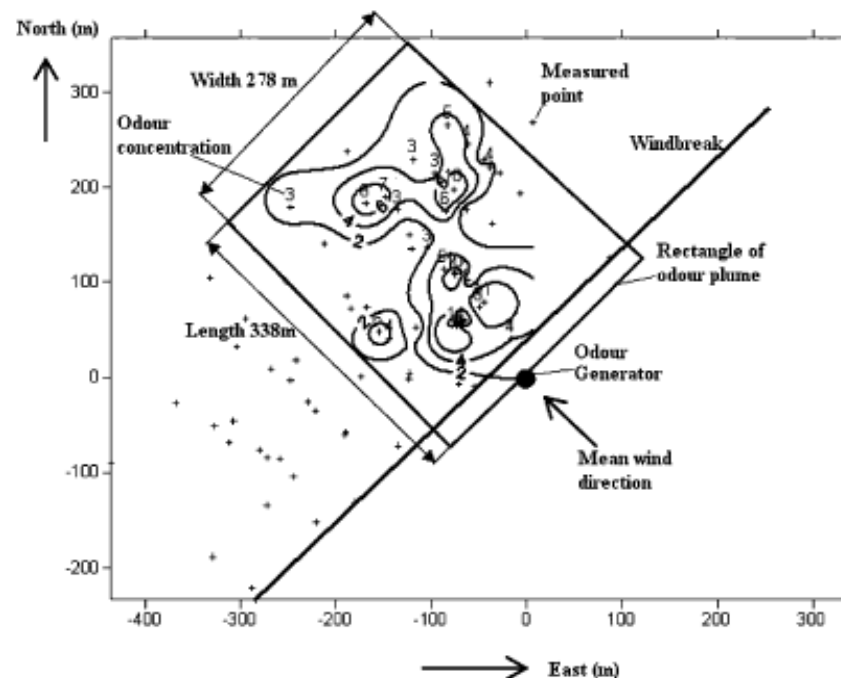
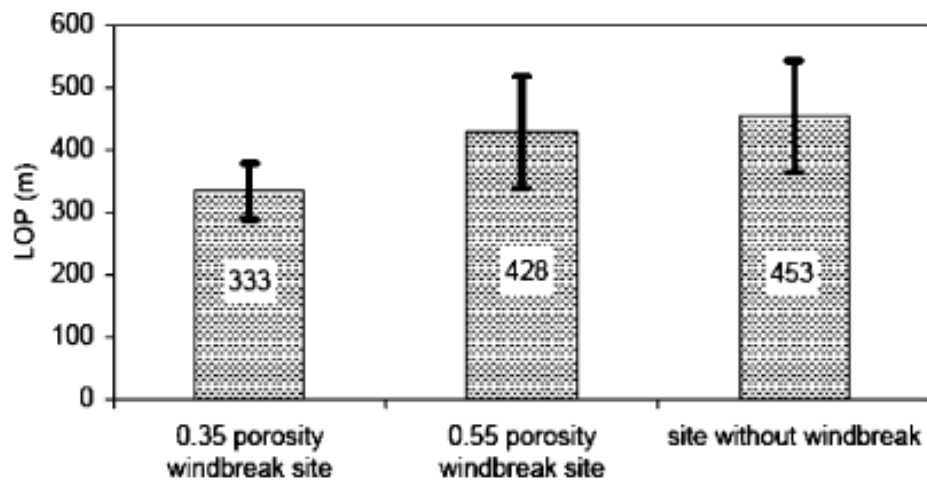
Porosity Effect

Evidence from windbreak research – porosity significantly changes flow



Porosity Effect

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



Highway + Vegetation = ?

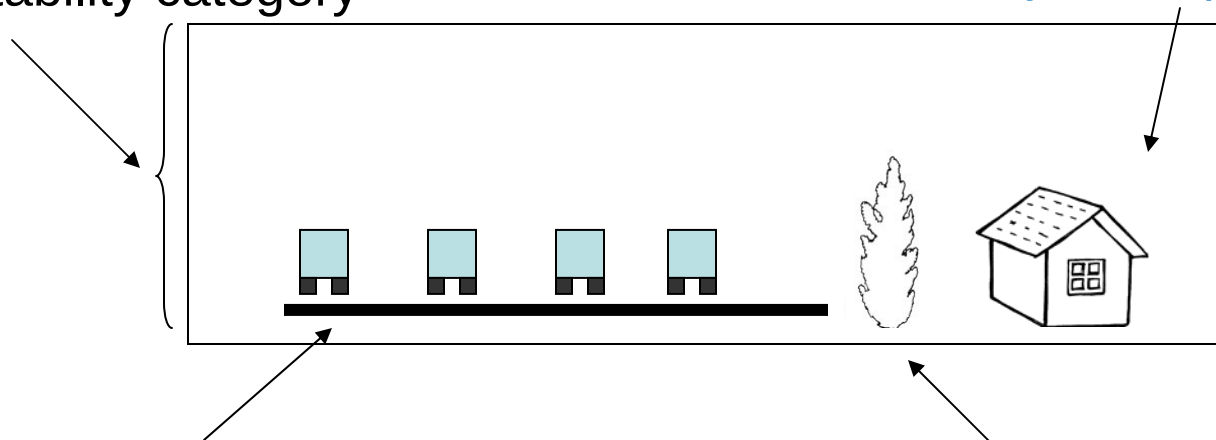
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- Stability category

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:

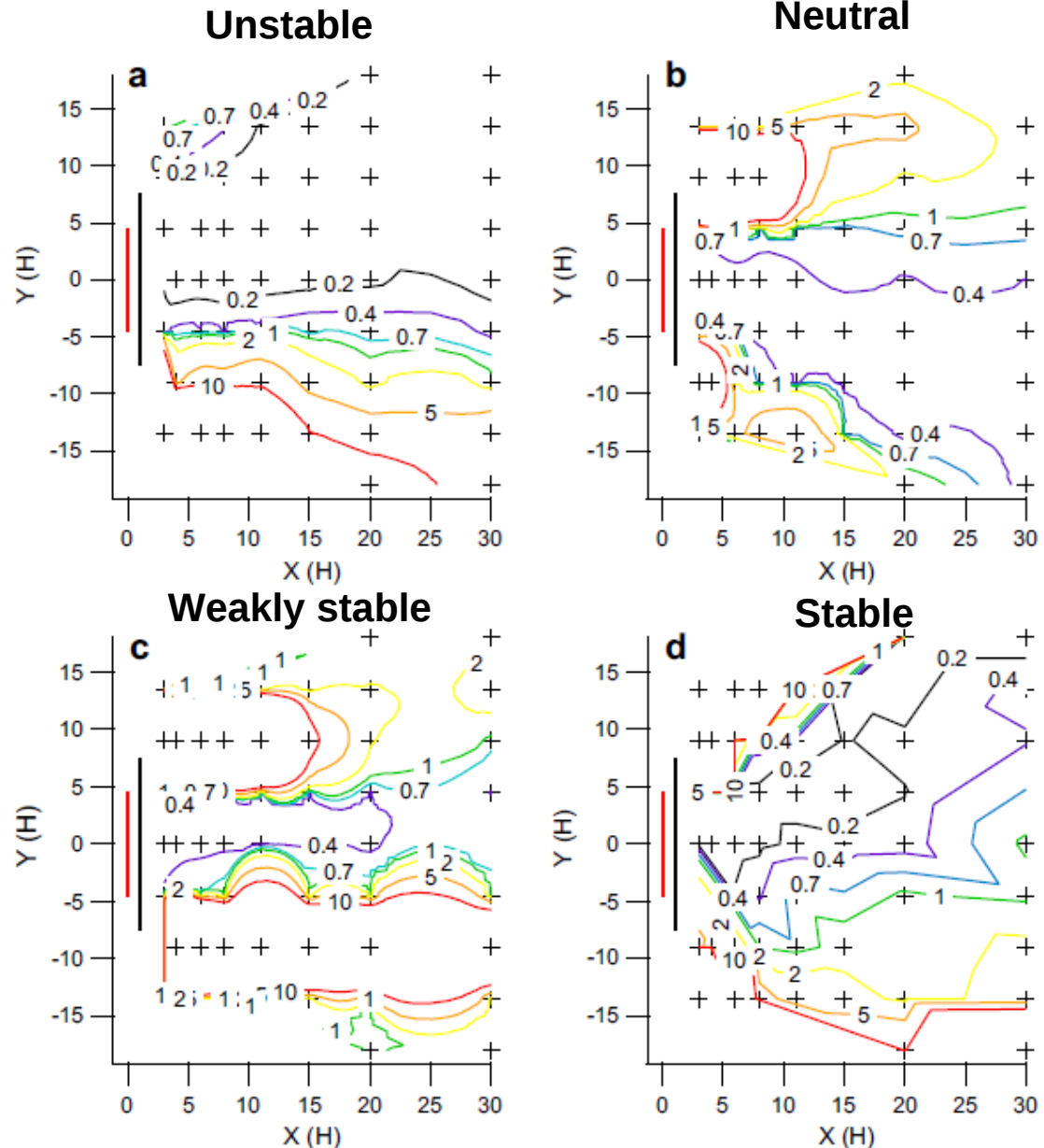
- Dimensions
- Porosity – assume “solid”
- Location

Highway + Vegetation = ?

Stability effect:

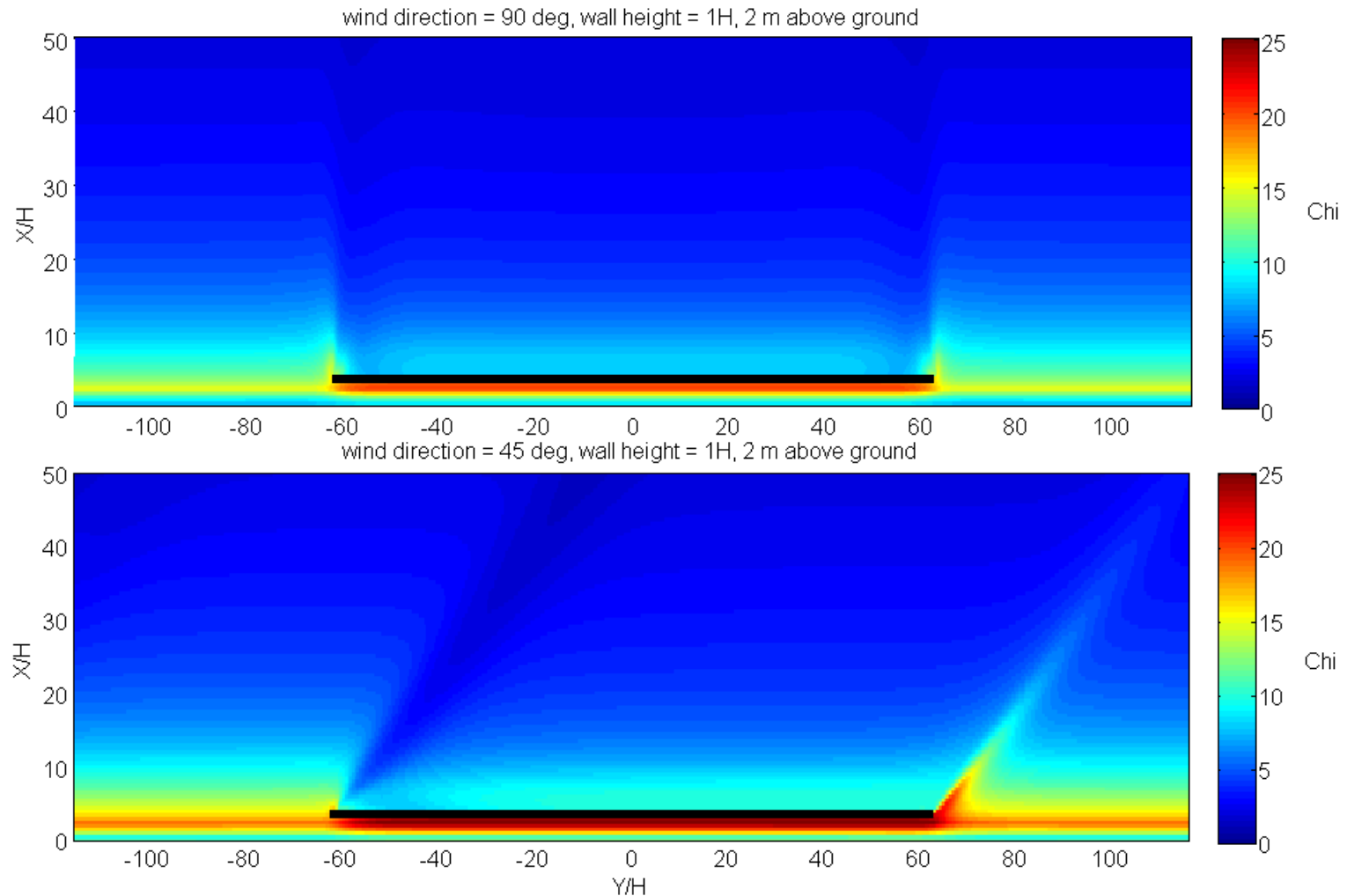


Fig. 1. Mock straw bale sound barrier, 6 m high and 90 m long.



Highway + Vegetation = ?

Wind direction effect:



Highway + Vegetation = ?

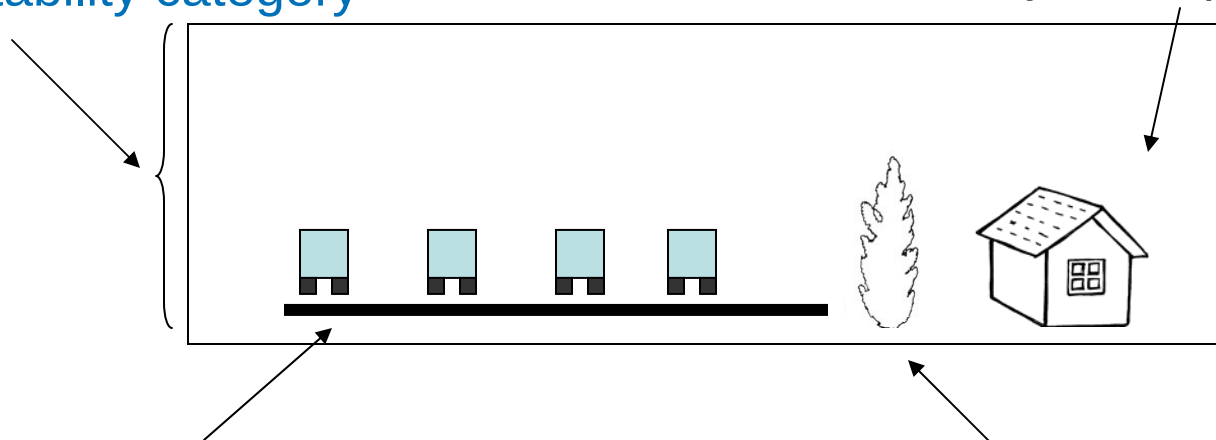
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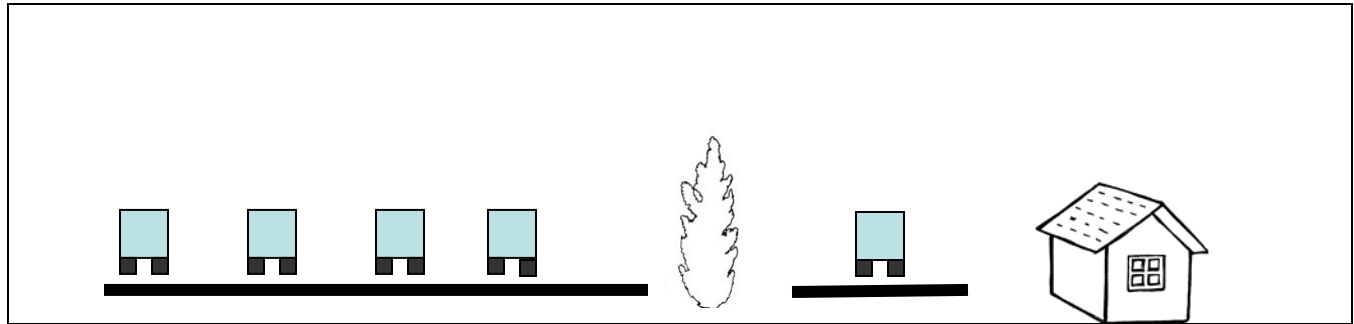
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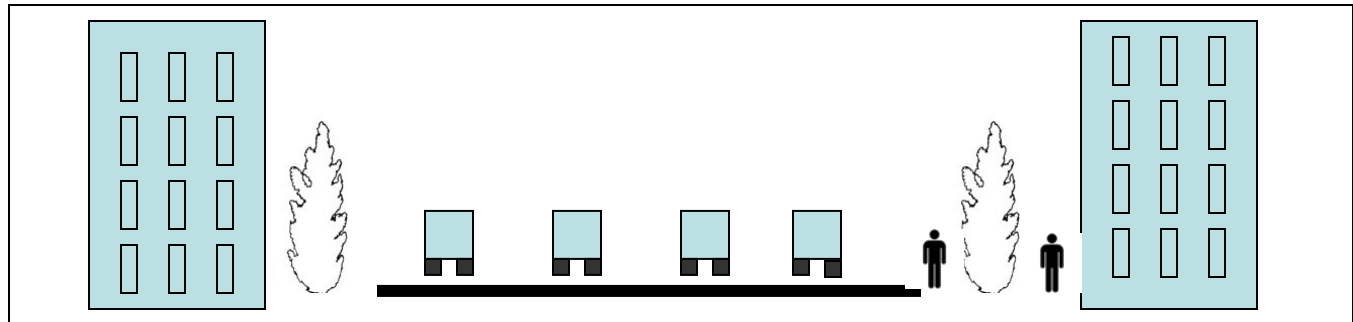
Highway + Vegetation = ?

More complex situations...

Arterial roads



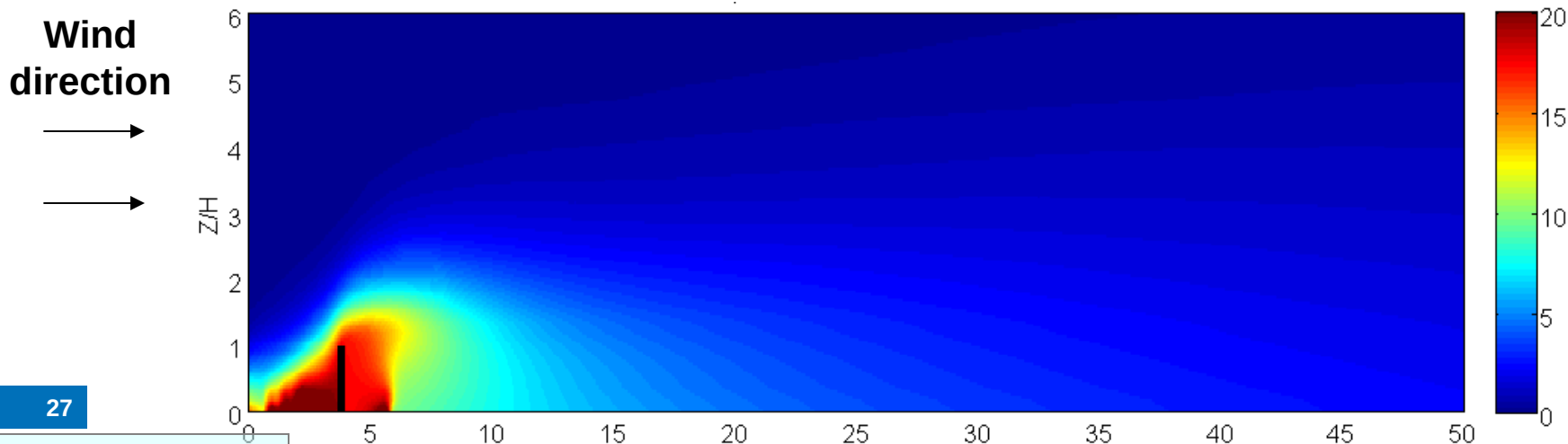
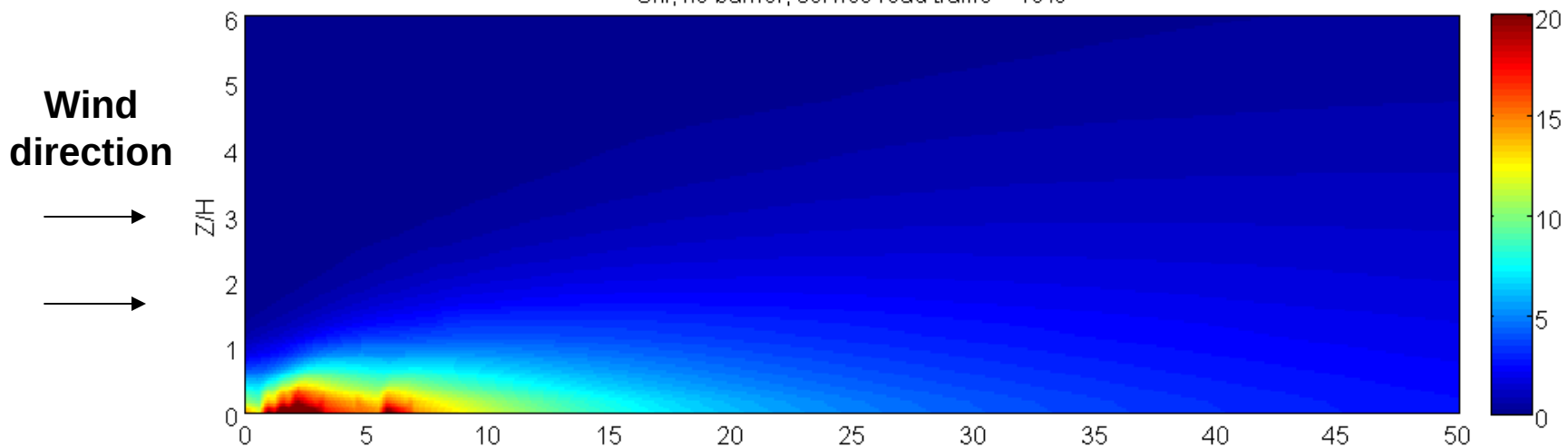
Street Canyons



Highway + Vegetation = ?

Behind barrier sources: Important!

Chi, no barrier, service road traffic = 10%



Highway + Vegetation = ?

Street Canyon Situations

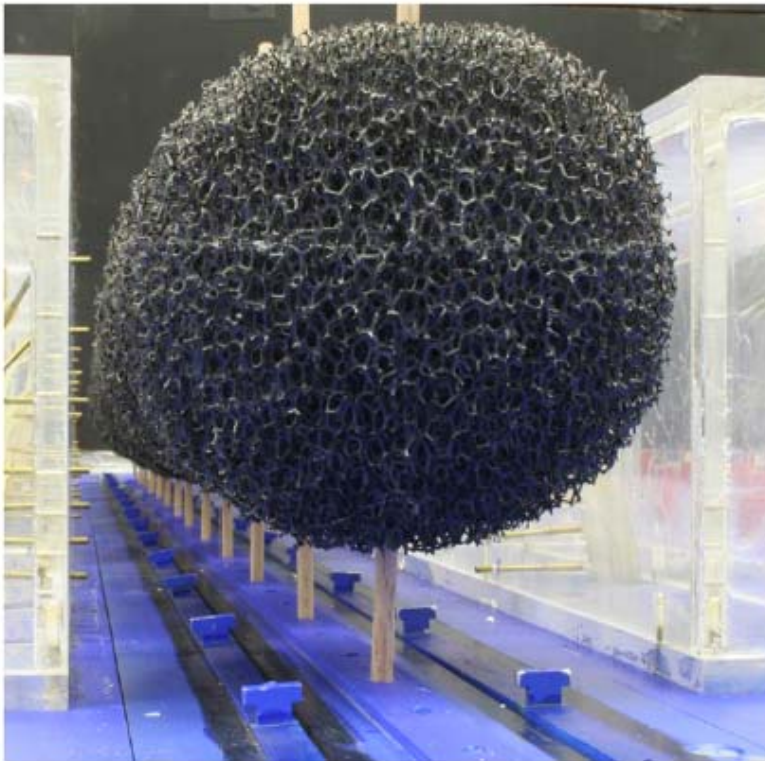


Fig. 20. Photograph of a tree crown made out of foam 10 ppi.

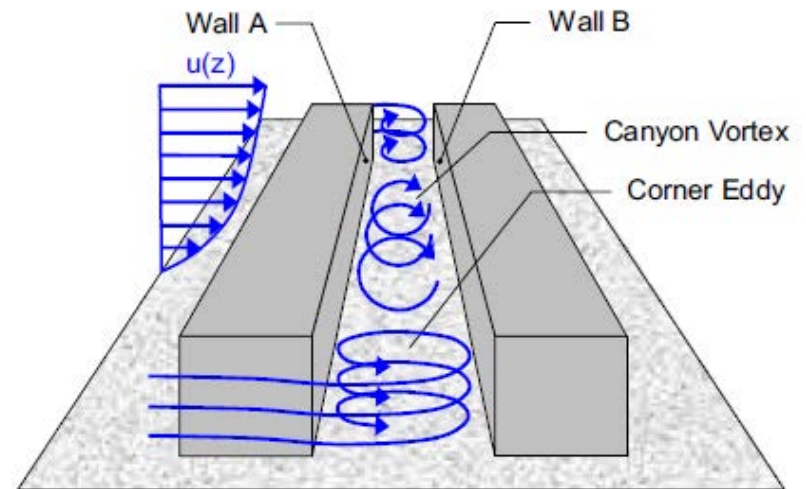


Fig. 2. Flow field in and around an urban street canyon.

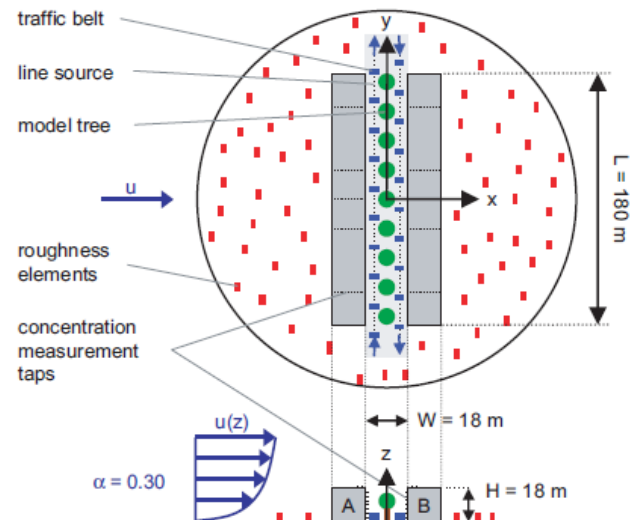


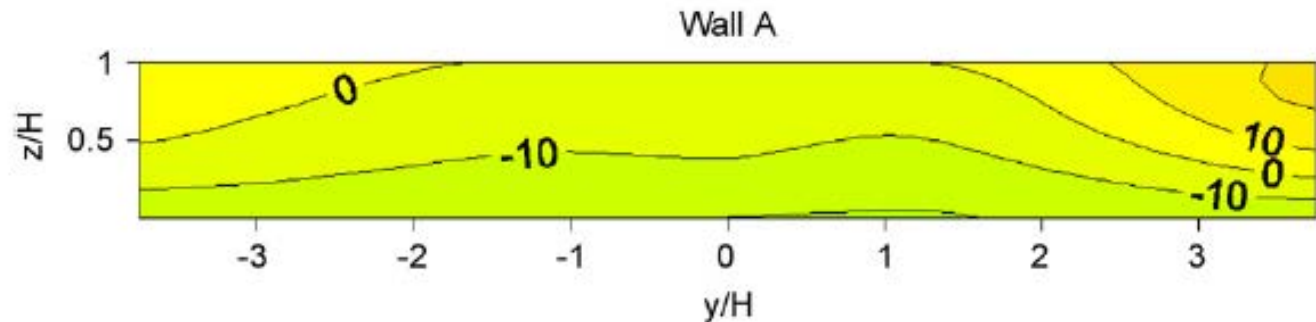
Fig. 1. Wind tunnel model of the urban street canyon (scale 1:150).

Highway + Vegetation = ?

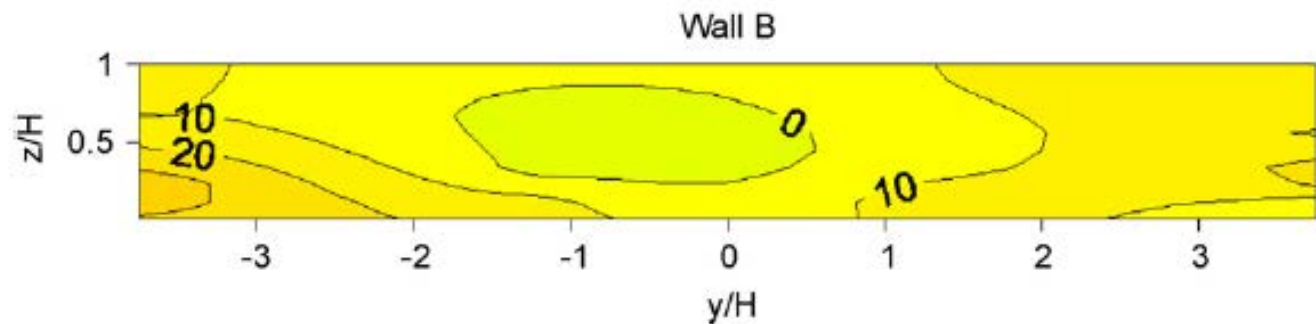
Street Canyon Situations

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

Upwind wall –
concentrations generally
lower/same →



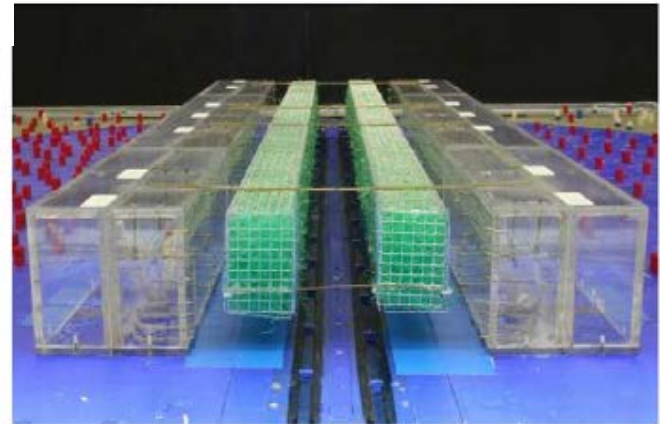
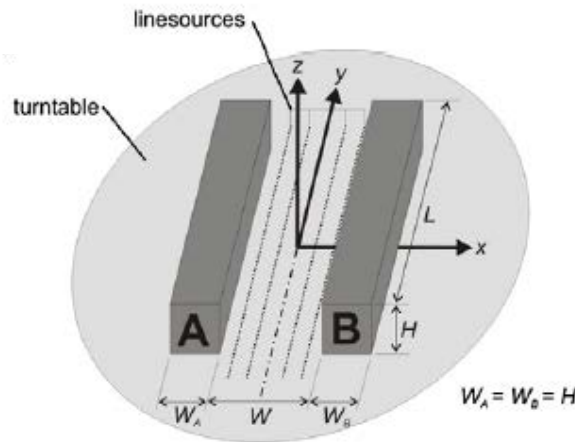
Downwind wall –
concentrations generally
increase (!) →



Highway + Vegetation = ?

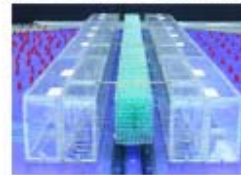
Street Canyon Situations

Comparison of two rows of vegetation:

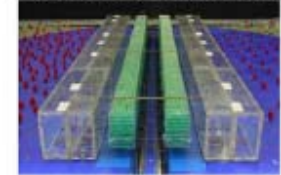


General finding: Presence of vegetation appears to have a net increase for in-canyon concentrations

***W/H=1 – single
tree row vs empty***



***W/H=2 – two
tree rows vs empty***



leeward

+71%

+42%

windward

-35%

-32%

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