Cornell University

Roadside Vegetation Barrier Designs to Mitigate Near-Road Air Pollution Impacts

K. Max Zhang

Sibley School of Mechanical and Aerospace Engineering

Cornell University

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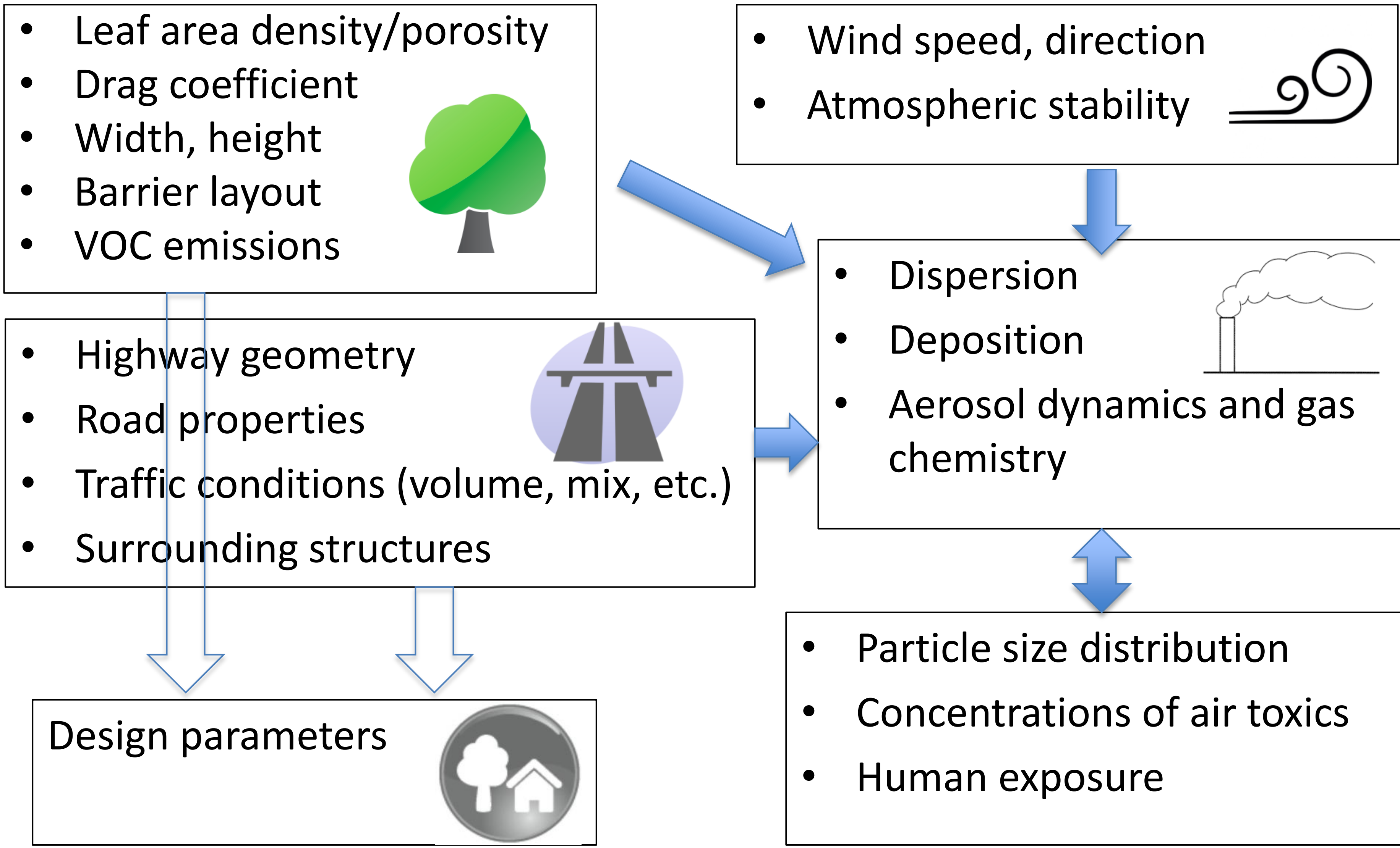
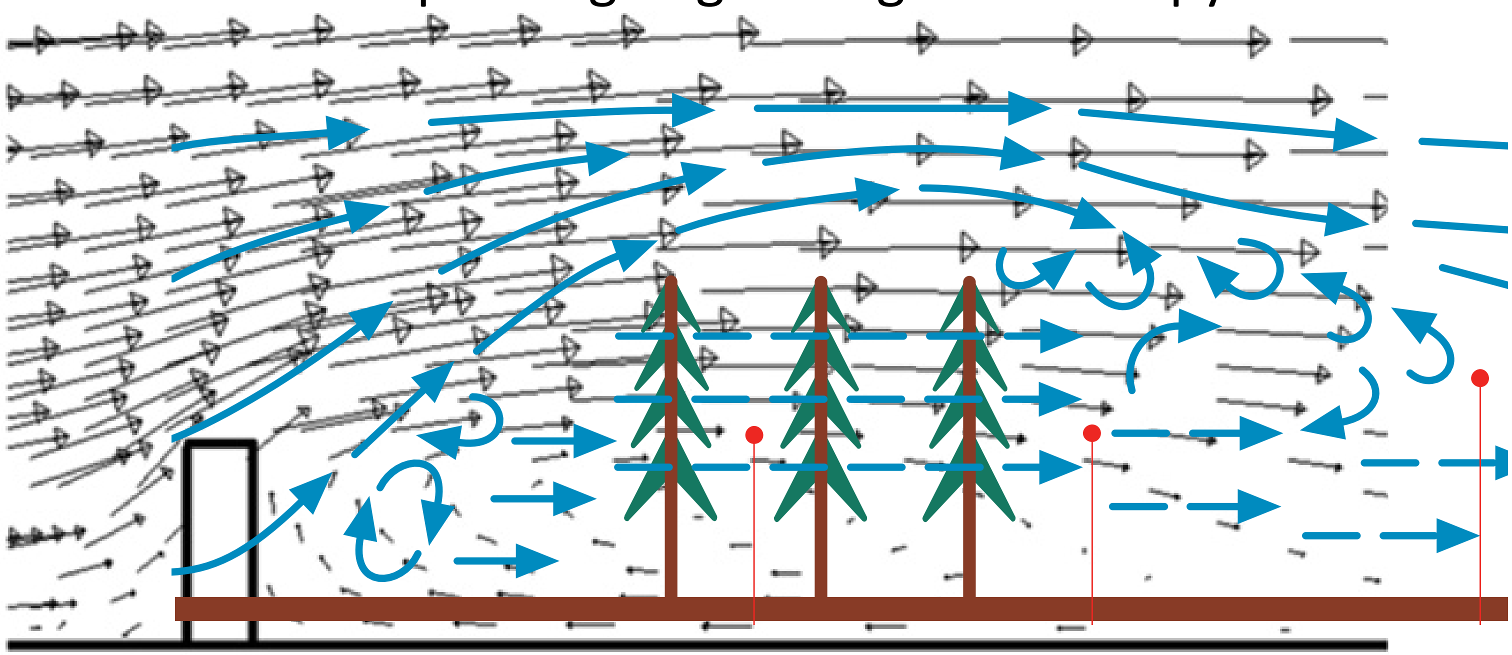
- Current and former PhD students working on this subject: Zheming Tong, Jon Steffens, and Bo Yang
- Valuable discussions with Drs. Rich Baldauf, Vlad Isakov and Parik Deshmukh at USEPA
- Experimental data from USEPA

Relevant Properties and Processes

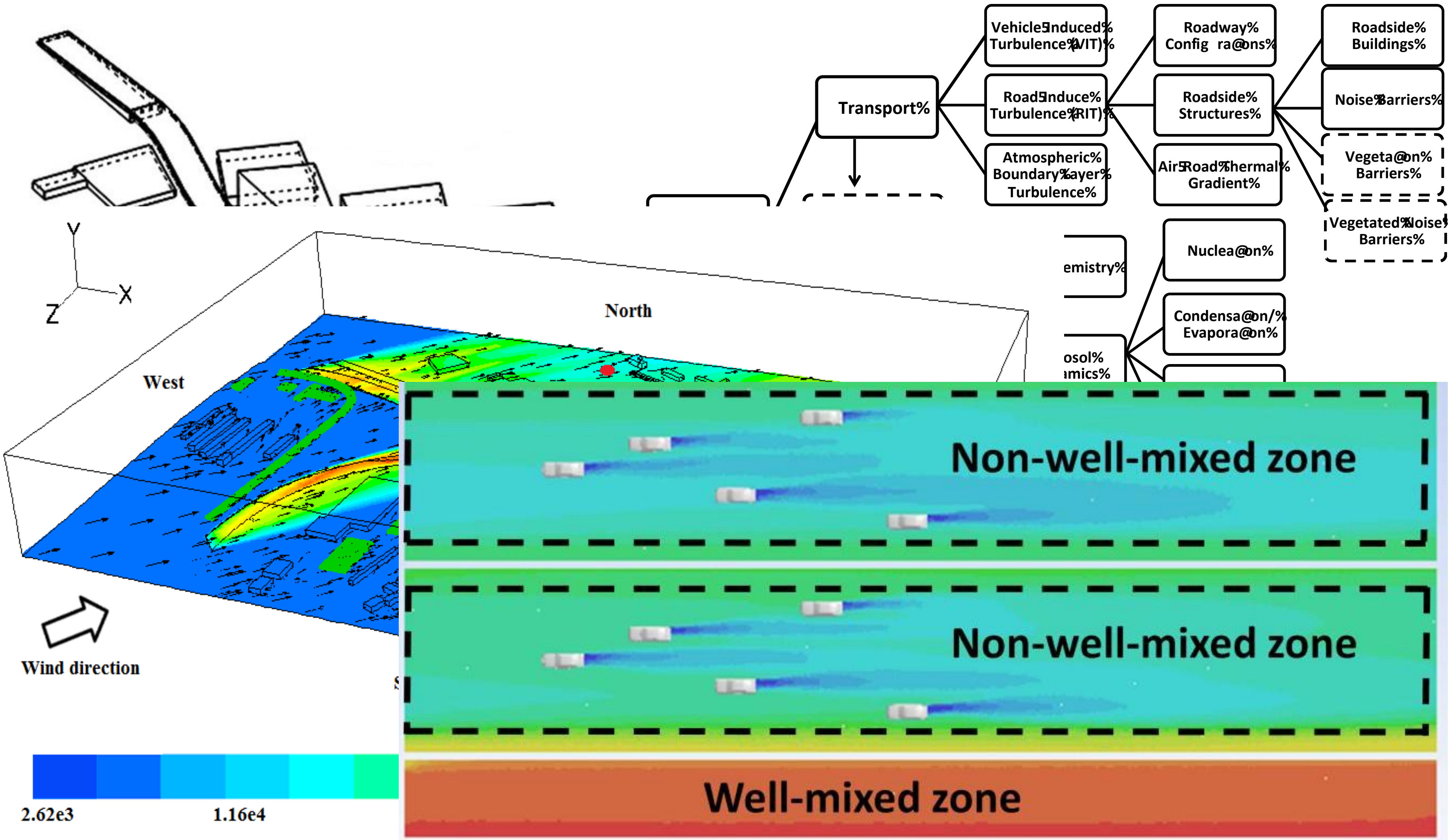


More on the Atmospheric Processes

- Dispersion
  - Solid barrier effect: creating upward momentum and enhancing plume dispersion -> lower ground level conc. behind the barrier
  - Windbreak effect: plume going through the canopy at slower s
  - C g
- Depo
  - S
  - T
  - R
- Aerosol dynamics and gas chemistry



Comprehensive Turbulent Aerosol and Gas Chemistry (CTAG)

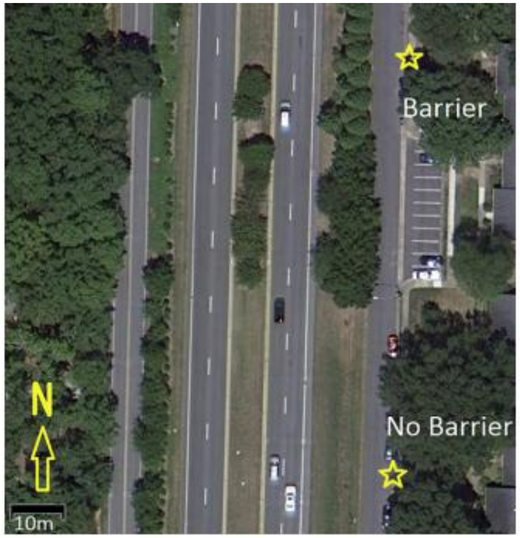


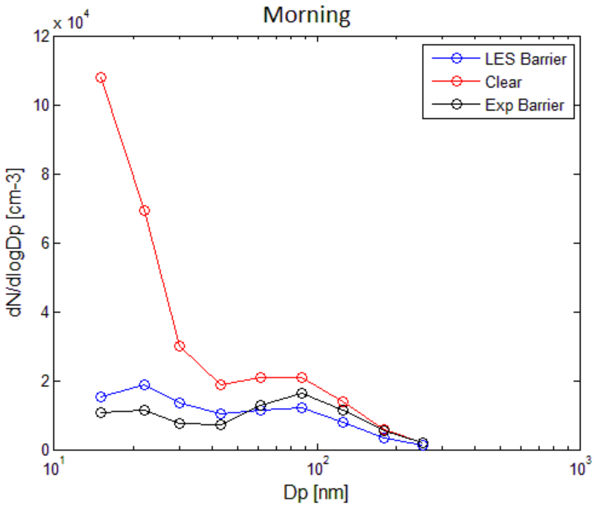
Past work on Transportation and Air Quality

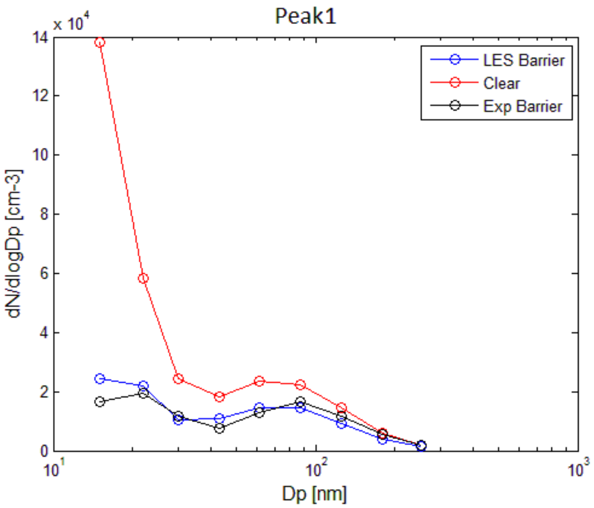
CTAG components	**Experimental datasets**	**Publications**
VIT	Turbulent flow filed measurements behind a moving van	Wang and Zhang (2009); Wang et al. (2012)
Road configurations	Horizontal and vertical CO profiles near an elevated highway and a ground-level highway in Los Angeles	Wang and Zhang (2009);
	Particle size distribution and CO measurements near a large highway intersection in Rochester, NY	Wang et al. (2013)
Roadside buildings	Spatial variations of black carbon in a highway-buildings environment in NYC	Tong et al., (2012)
Roadside solid barriers	Near-road tracer study 2008 in Idaho Falls, ND	Steffens et al. (2013)
	USEPA wind tunnel study of 12 road configuration	Steffens et al. (2014)
Roadside vegetation barriers	Field study in Chapel Hill, NC	Steffens et al. (2012)
Gas chemistry	NO and NO_2 horizontal gradients near two roadways near Austin, TX	Wang et al. (2011)
Aerosol dynamics	Particle size distribution measurements behind a diesel car	Wang et al. (2012)
	Particle size distribution and CO measurements near a large highway intersection in Rochester, NY	Wang et al. (2013)

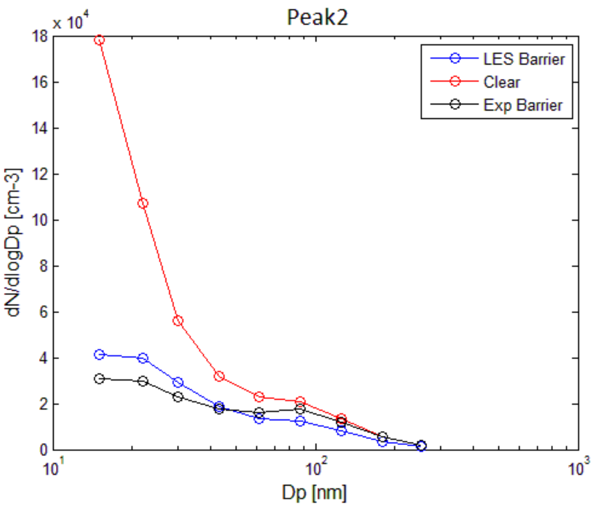
Revisiting Chapel Hill Experimental Dataset with Large Eddy Simulation (LES)

- The Chapel Hill (NC) dataset was collected by USEPA and Duke researchers (Hagler et al., 2011).
- Steffens et al. (2012) employed RANS turbulence model and two different particle deposition models to simulate the dataset.
- We recently applied the Large Eddy Simulation (LES) model to re-simulate the dataset.
- LES model shows generally good agreement.









Tong et al., manuscript in preparation

Design Configurations

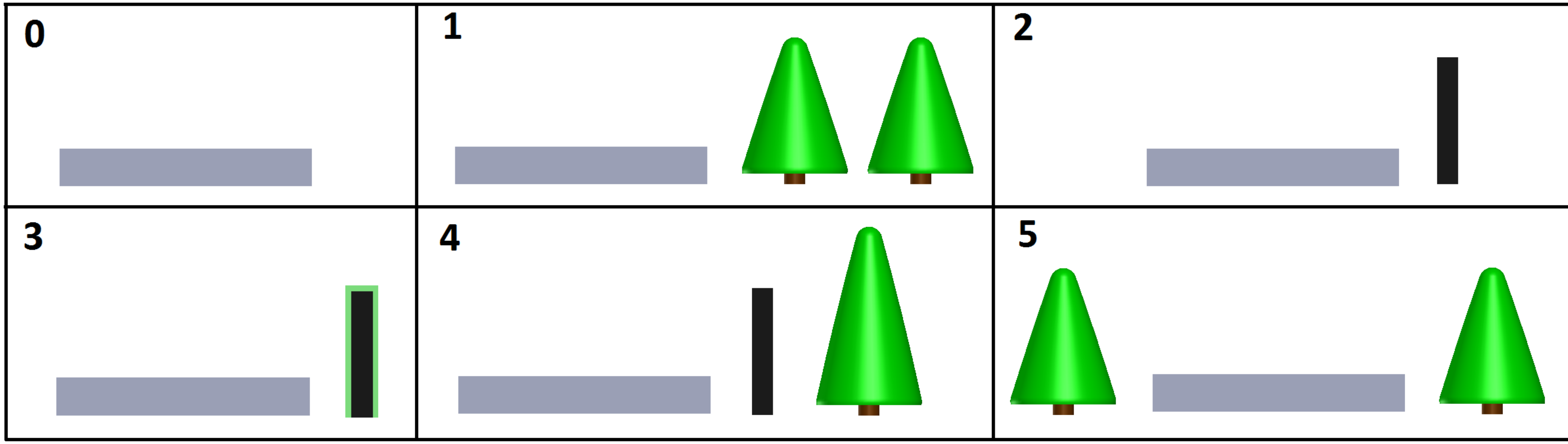


Table 1: Description of roadside barrier geometry for all configurations tested

Case #	0	1	2	3[a]	4		5	
					Solid barrier	Vegetation barrier	Upwind vegetation barrier	Downwind vegetation barrier
Height	N/A	6 m	6 m	6 m	6 m	10 m	6 m	6m
Width	N/A	6m,12 m,18m	1 m	1+0.25 m	1 m	6 m	6 m	12m
LAD[b]	1	1 ,1.5	1	0.33[c]	N/A	1, 0.25	1	1
U	2 m/s	1, 2, 4 m/s	2 m/s	2 m/s	2 m/s		2 m/s	
Stability	Unstable	Stable, Unstable, Neutral	Unstable	Unstable	Unstable		Unstable	
Direction[e]	90°	90°	90°	90°	30°, 45°, 90°		90°	

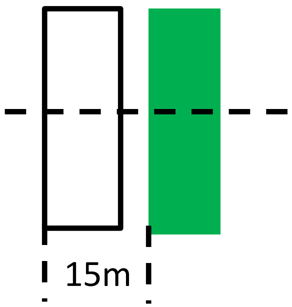
Tong et al., manuscript in preparation

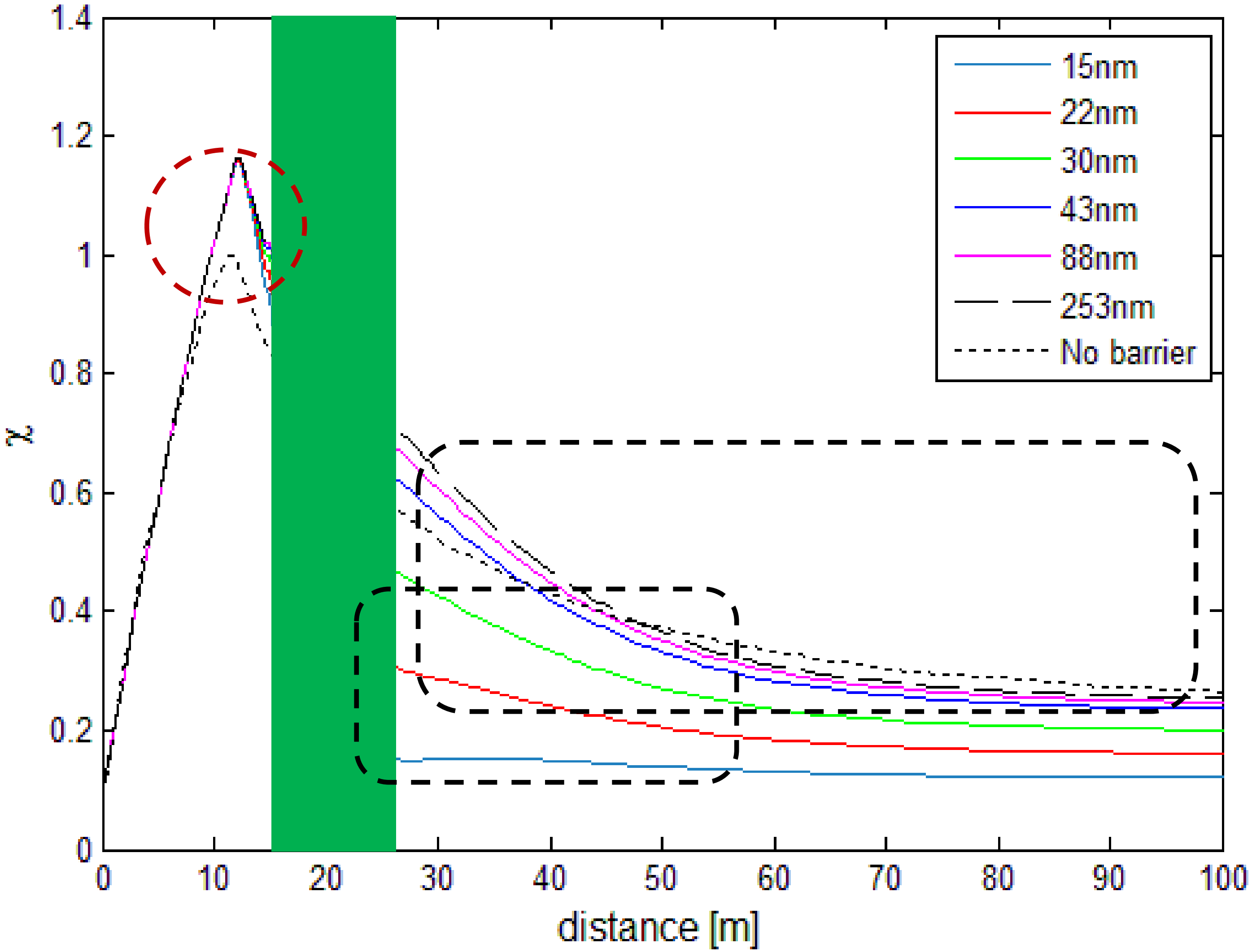
Main Assumptions

- Highway conditions are taken as the same as those in the Chapel Hill experiment
- Infinite long barrier
- Baseline case:
  - Leaf area density and drag coefficient taken from the Chapel Hill experiment (conifer)
  - Perpendicular wind direction

Case 1: Horizontal Gradient

Baseline Top View





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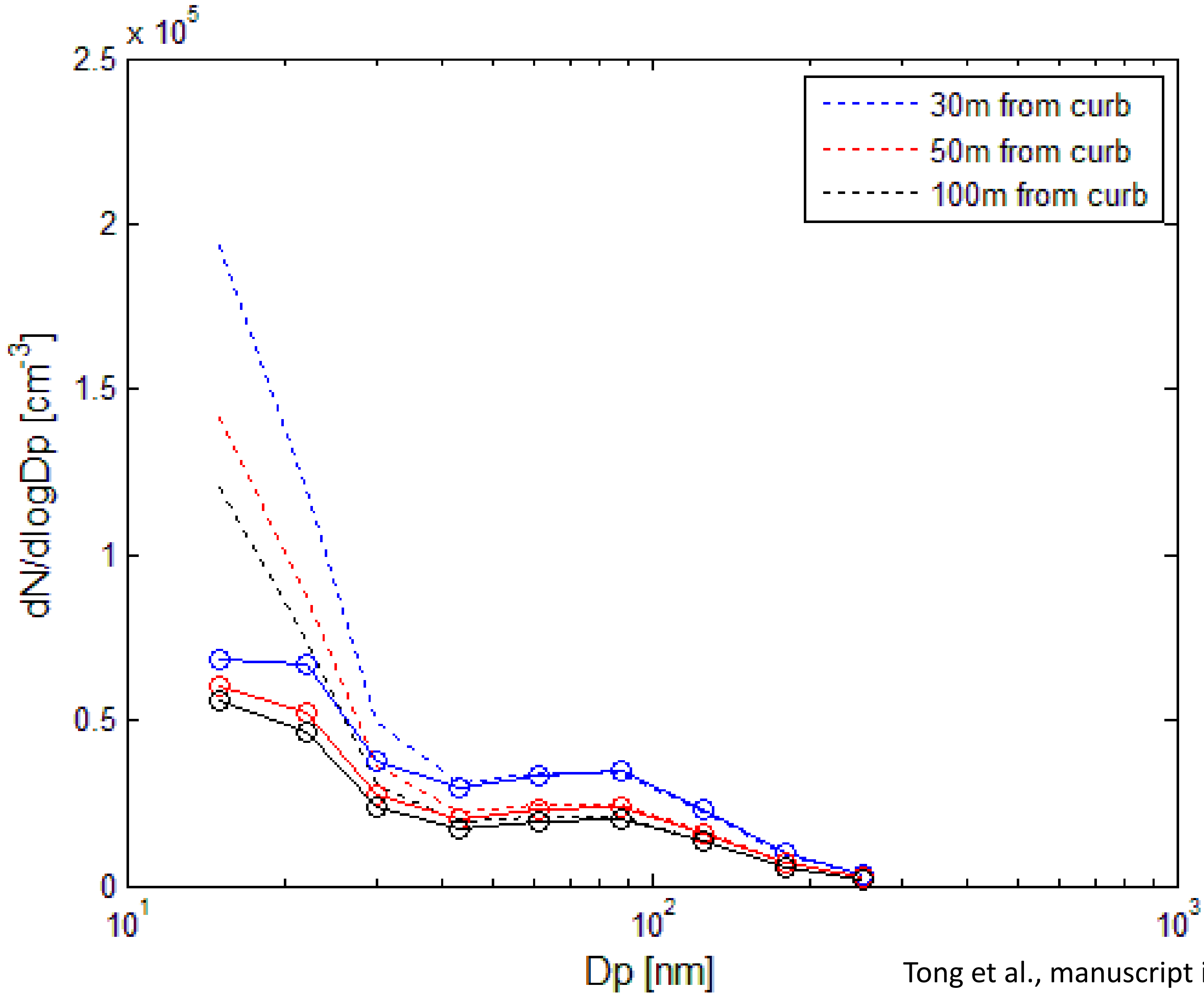
Case 1: Particle Size Distribution



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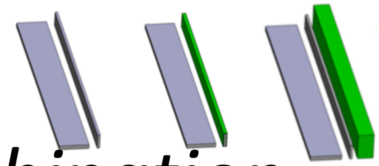
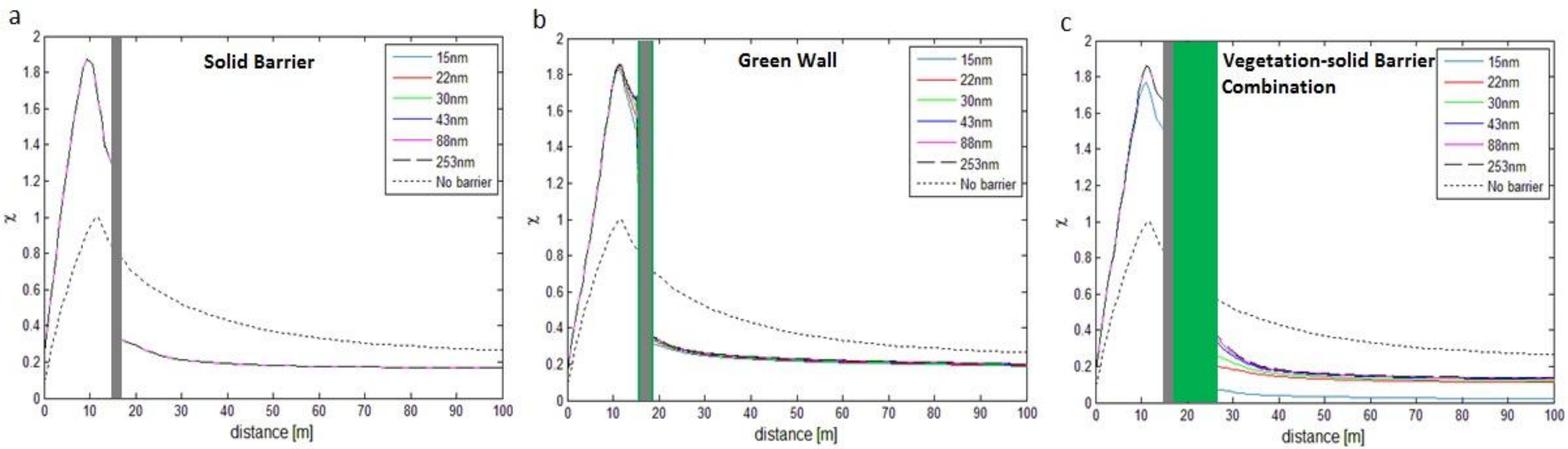


Cases 2, 3, 4: Solid, Green Wall and Combination

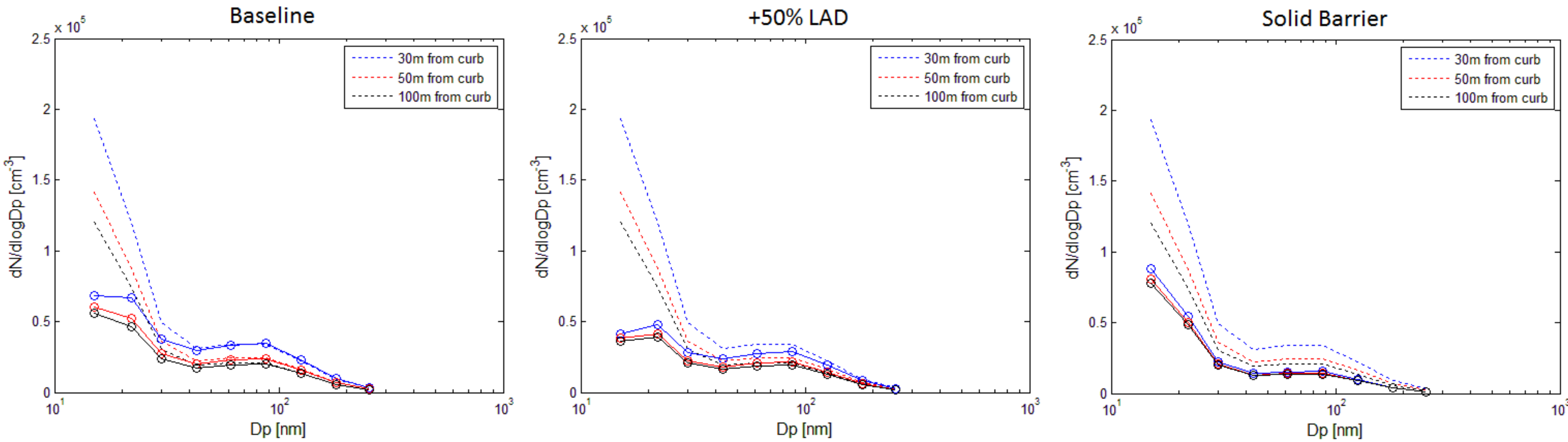


- Solid barrier: significant reduction in conc. behind the barrier with on-road accumulation
- Green Wall: Slight more reduction compared to the solid barrier case
- Vegetation-solid barrier combination: greatest reduction in conc. behind the barrier with on-road accumulation

Tong et al., manuscript in preparation

Sensitivity: Leaf Area Density (LAD)

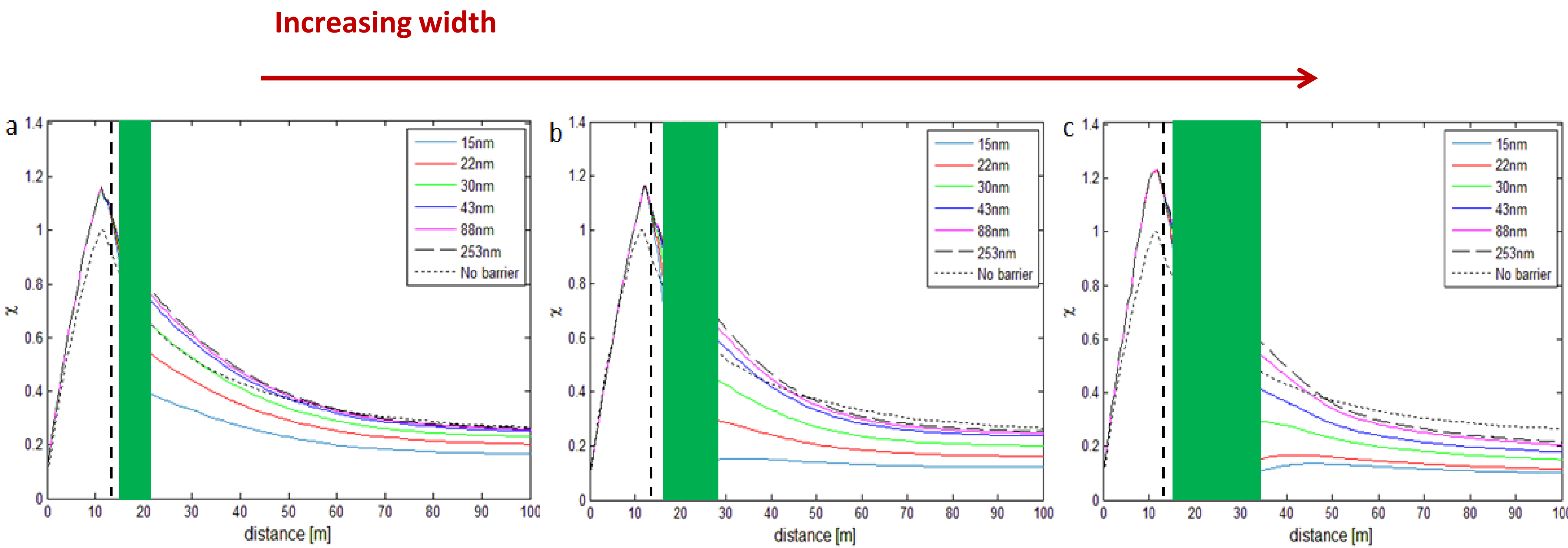
Increasing LAD



- Increasing LAD leads to more deposition and upward momentum
  - For smaller particles, greater reduction behind the barrier
  - For larger particles with relatively small deposition velocity, approaching the behaviors of a solid barrier

Tong et al., manuscript in preparation

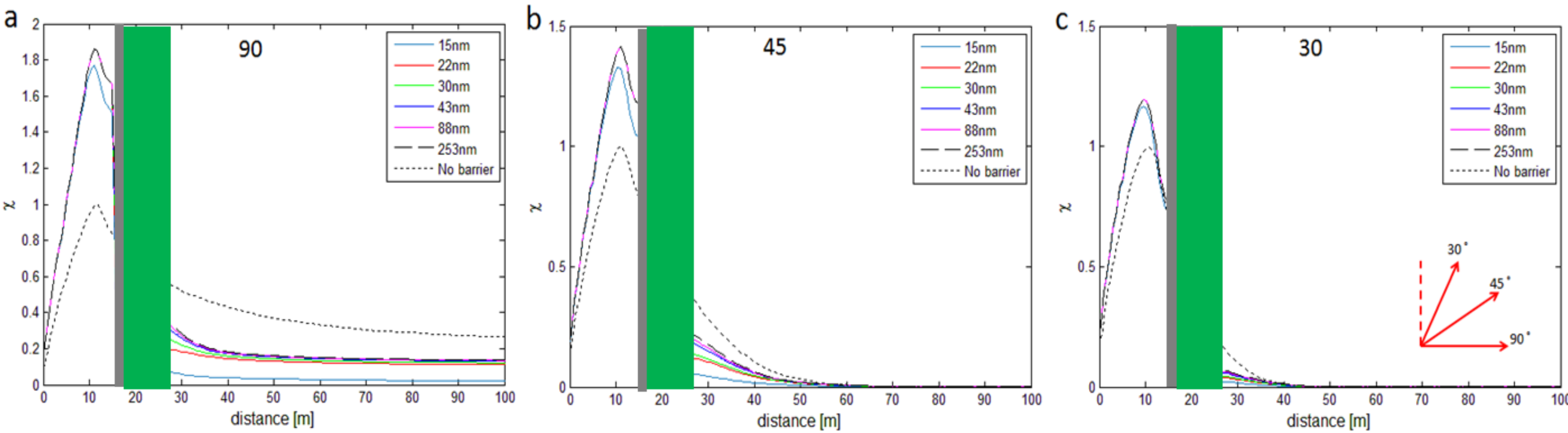
Sensitivity: Barrier Width



- Increasing width leads to more deposition
  - For smaller particles, greater reduction behind the barrier
  - For larger particles with relatively small deposition velocity, earlier transition to lower conc. compared to the no-barrier case
- On-road accumulation is modest compared to solid barrier

Tong et al., manuscript in preparation

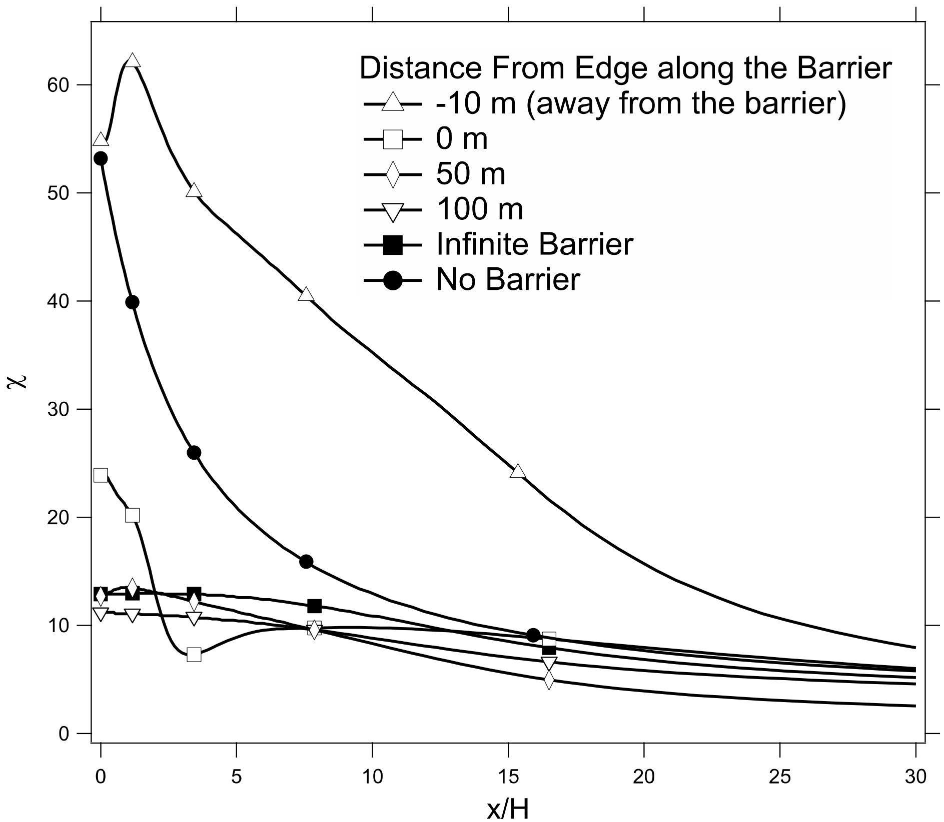
Sensitivity: Wind Direction



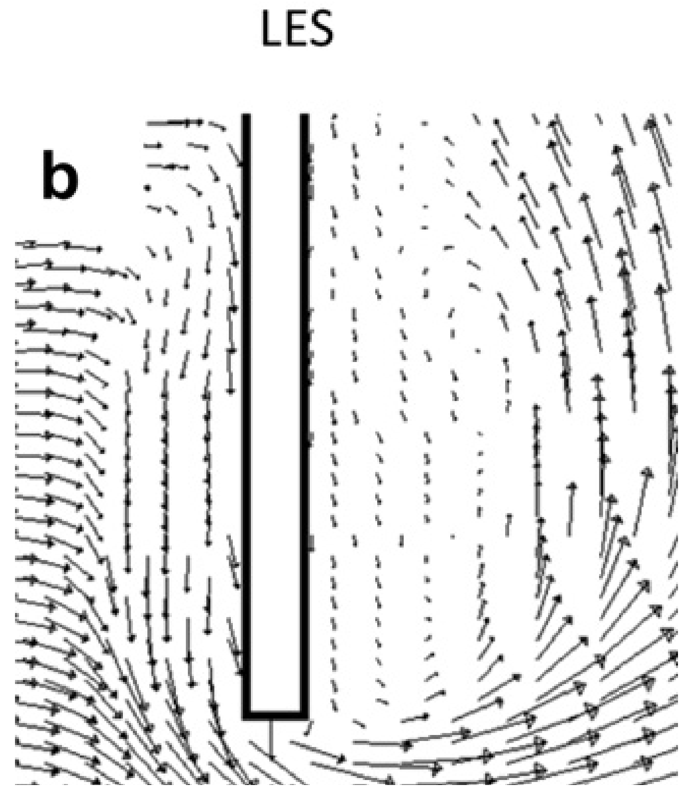
- The degree of on-road increase is contingent on oncoming wind direction.
- The on-road concentration decreases with more parallel wind to the road

Tong et al., manuscript in preparation

Edge Effects



Steffens et al. (2014)

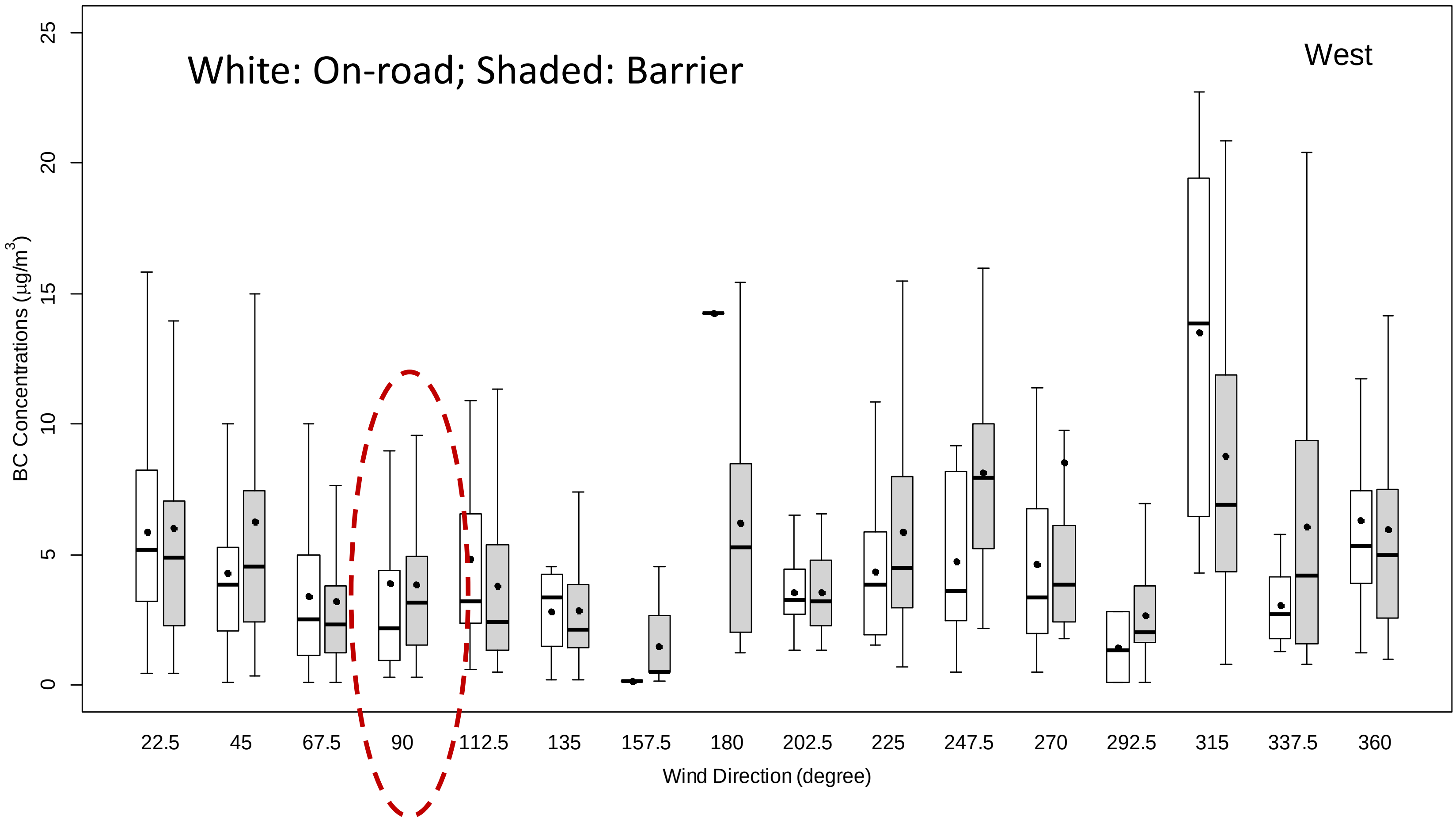


Steffens et al. (2013)

Report Card for Model Capability

- Modeling results capture the general phenomena very well
  - Vegetation-solid barriers show greatest reduction
  - Wider and denser trees lead to more reduction
  - Edge effects can be captured
  - …
- Research needs
  - More testing against different vegetation barrier configurations, meteorological and traffic conditions
  - Turbulence modeling: drag vs. wind speed
  - Deposition modeling
  - Effects of vegetation barriers on near-source chemistry and regional ozone chemistry
  - Parameterization
  - …

*The effect of wind direction on **on-road** concentrations*



Baldauf et al., manuscript under review