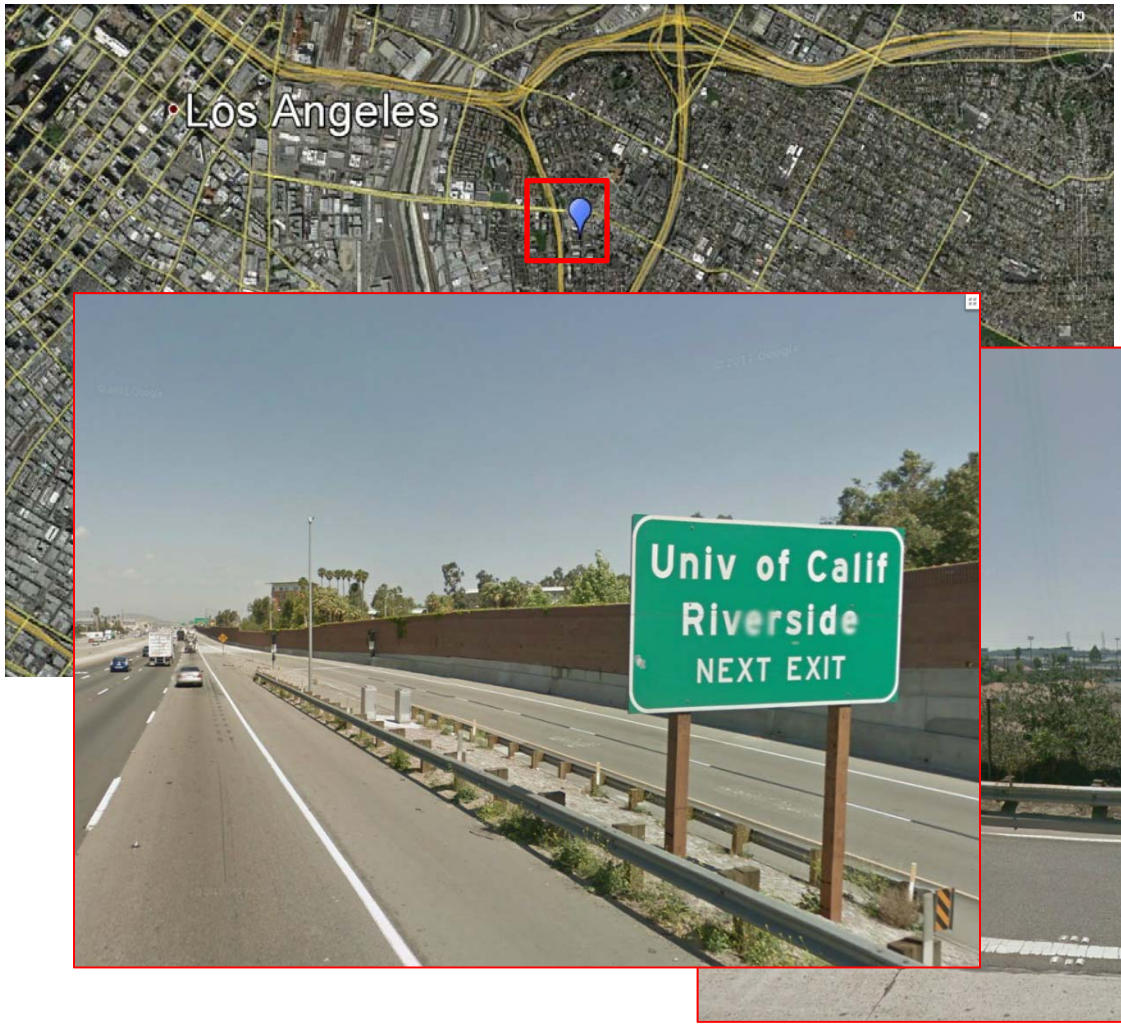
UNIVERSITY OF CALIFORNIA
UC RIVERSIDE

THE IMPACT OF ROADSIDE BARRIERS ON NEAR-ROAD CONCENTRATIONS OF TRAFFIC RELATED POLLUTANTS

Nico Schulte (nschu003@ucr.edu)
Akula Venkatram

Overview



Map data ©2013 Google

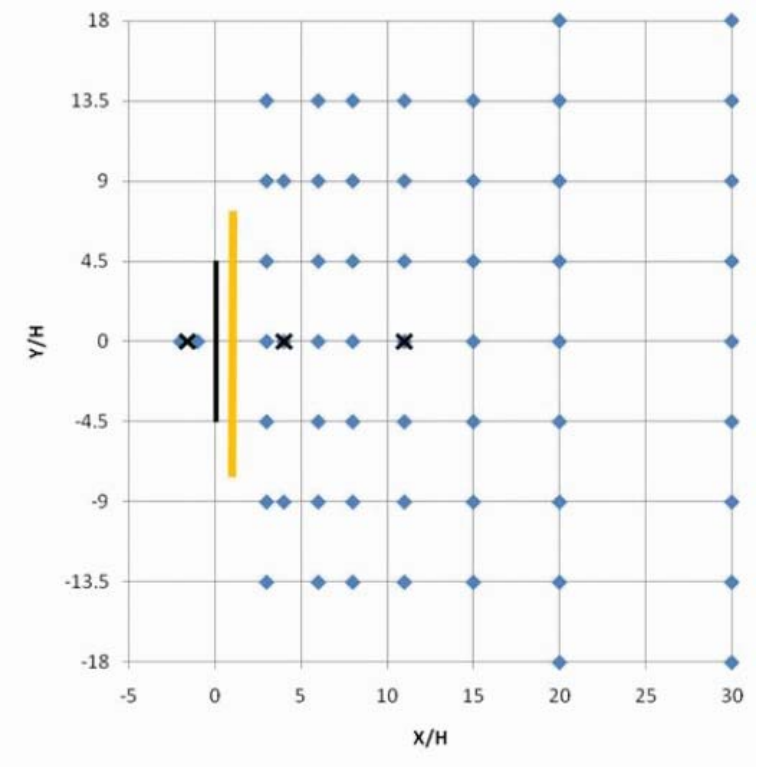
Overview

- Goal
  - Determine if barriers can be used to reduce near-road concentrations
  - Give guidelines for the use of barriers
- Results
  - A model that can explain the effect of barriers
- Main Conclusions
  - Barriers reduce concentrations
  - Reduction persists farthest during stable atmospheric conditions, when concentrations are normally largest

Outline

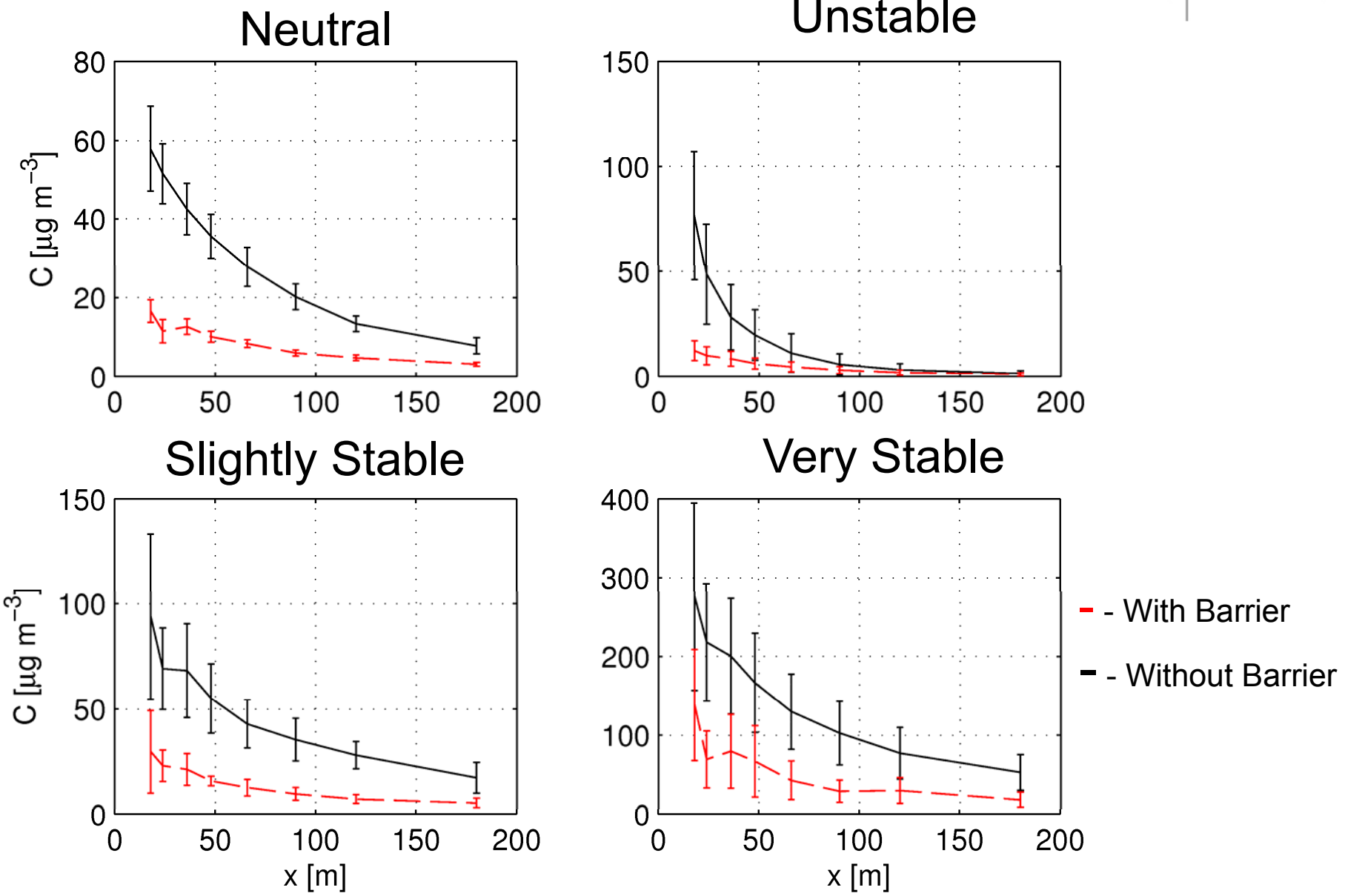
- Effects of barriers
  - Measurements
  - Two barrier models
- Comparison with measurements
- Sensitivity of model predictions to changes in barrier height

Idaho Falls (Finn et al. 2010)

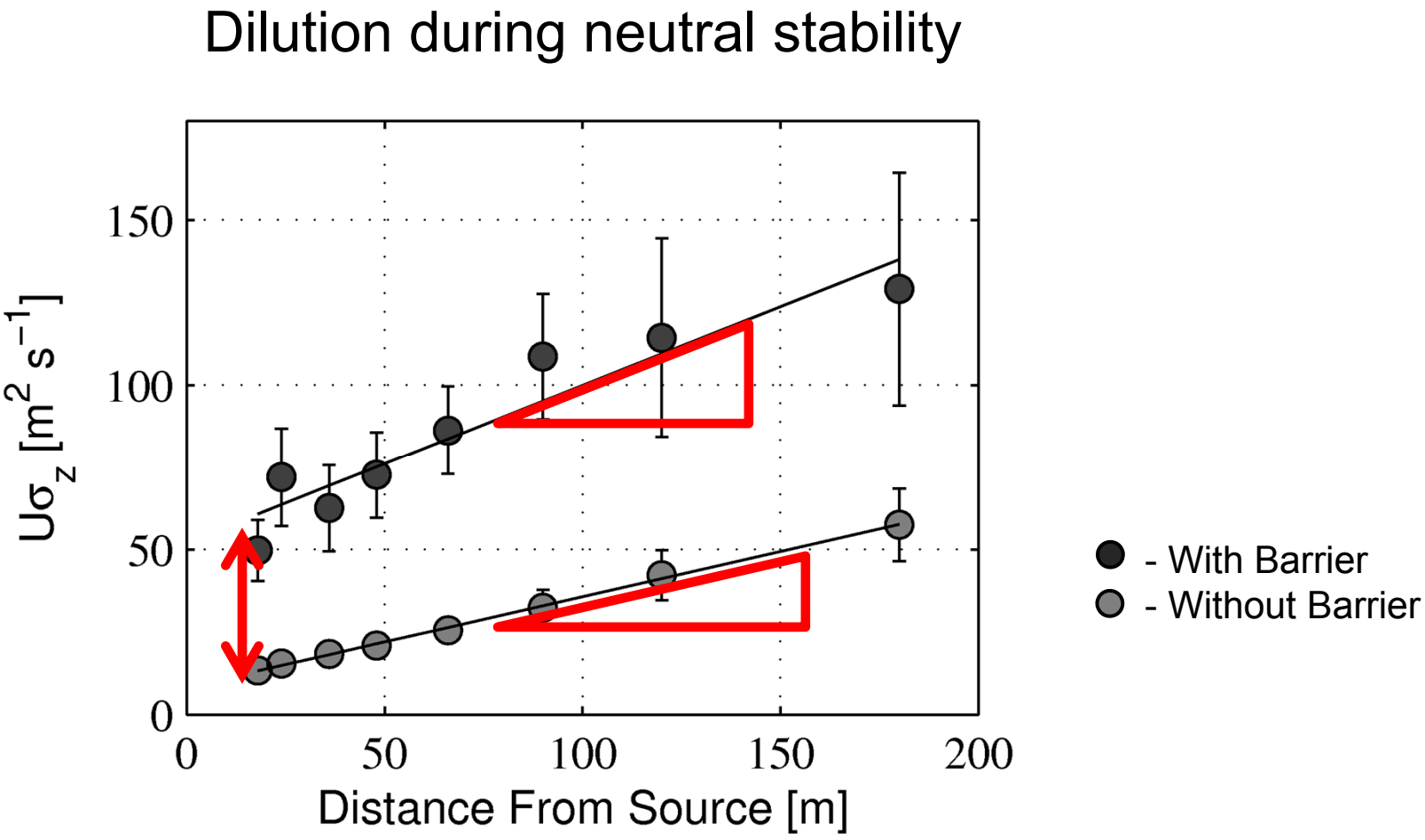


- SF_6 released from two sources simultaneously
- Concentrations measured at 56 receptors
- Spanned neutral, unstable, and stable conditions

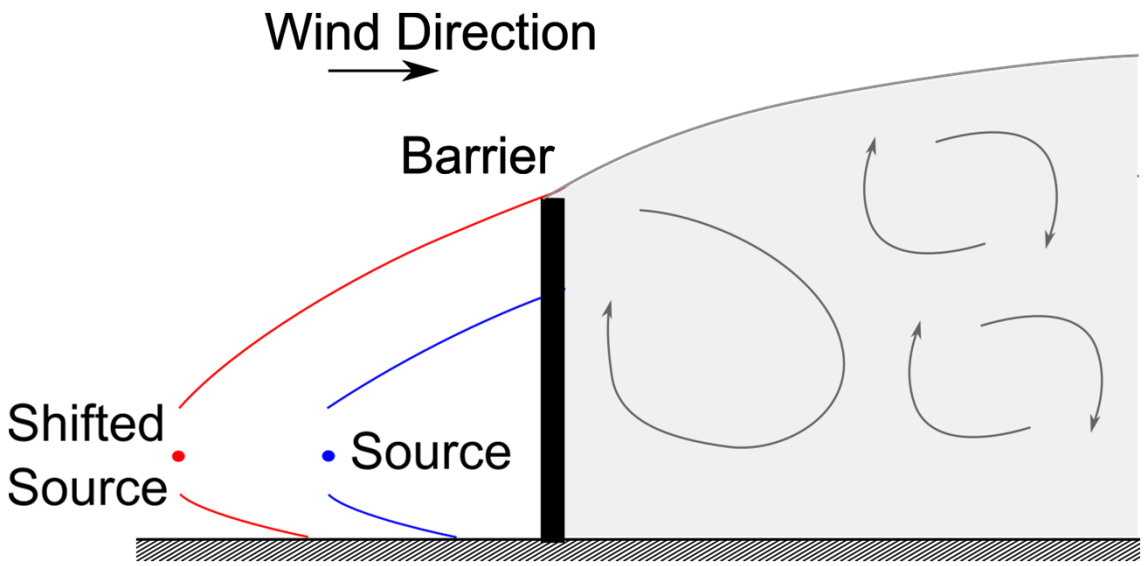
Idaho Falls (Finn et al. 2010)



Idaho Falls


Dilution during neutral stability
$U\sigma_z$ [m^2 s^{-1}]
150
100
50
0
0
50
100
150
200
Distance From Source [m]
- With Barrier
- Without Barrier

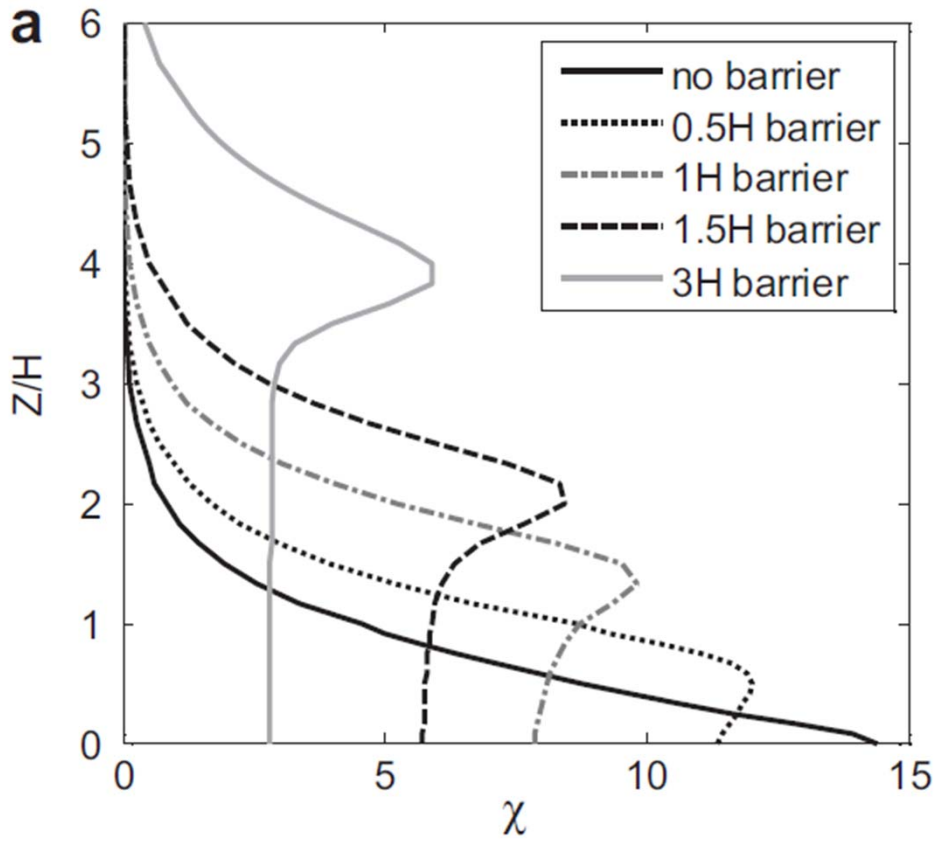
Source Shift Model (Heist et al. 2009)



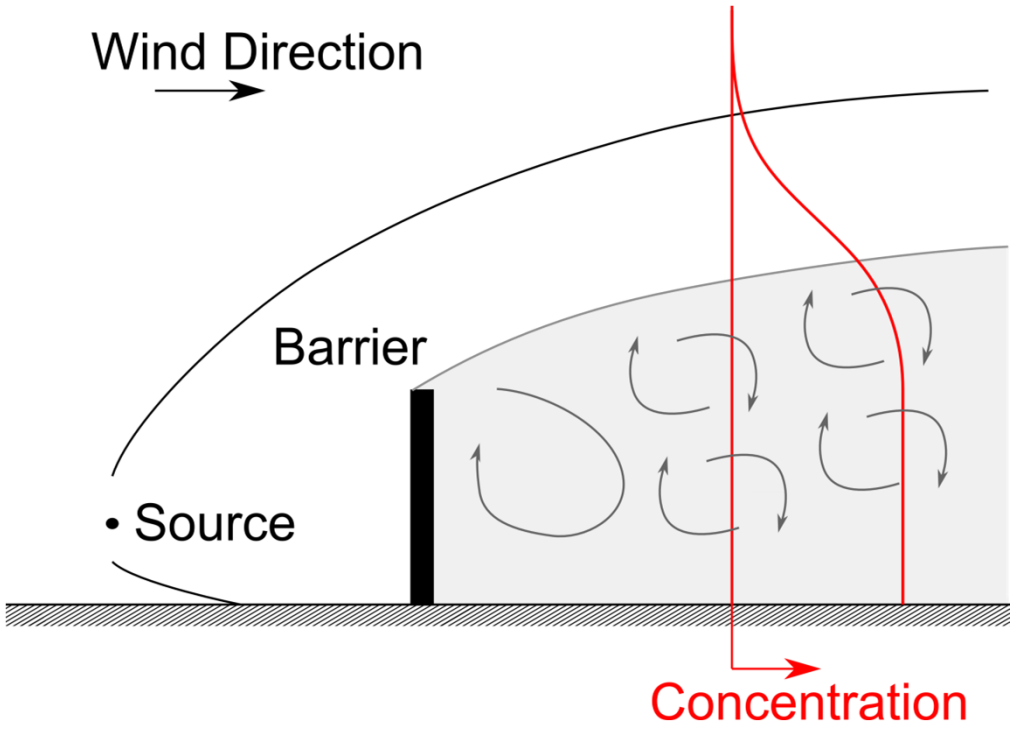
- Source shifted upwind by a distance, *s*
- Vertical plume spread increased by a factor *α*

□□(□) = □□□E□ + □F

CFD Simulation (Hagler et al. 2011)



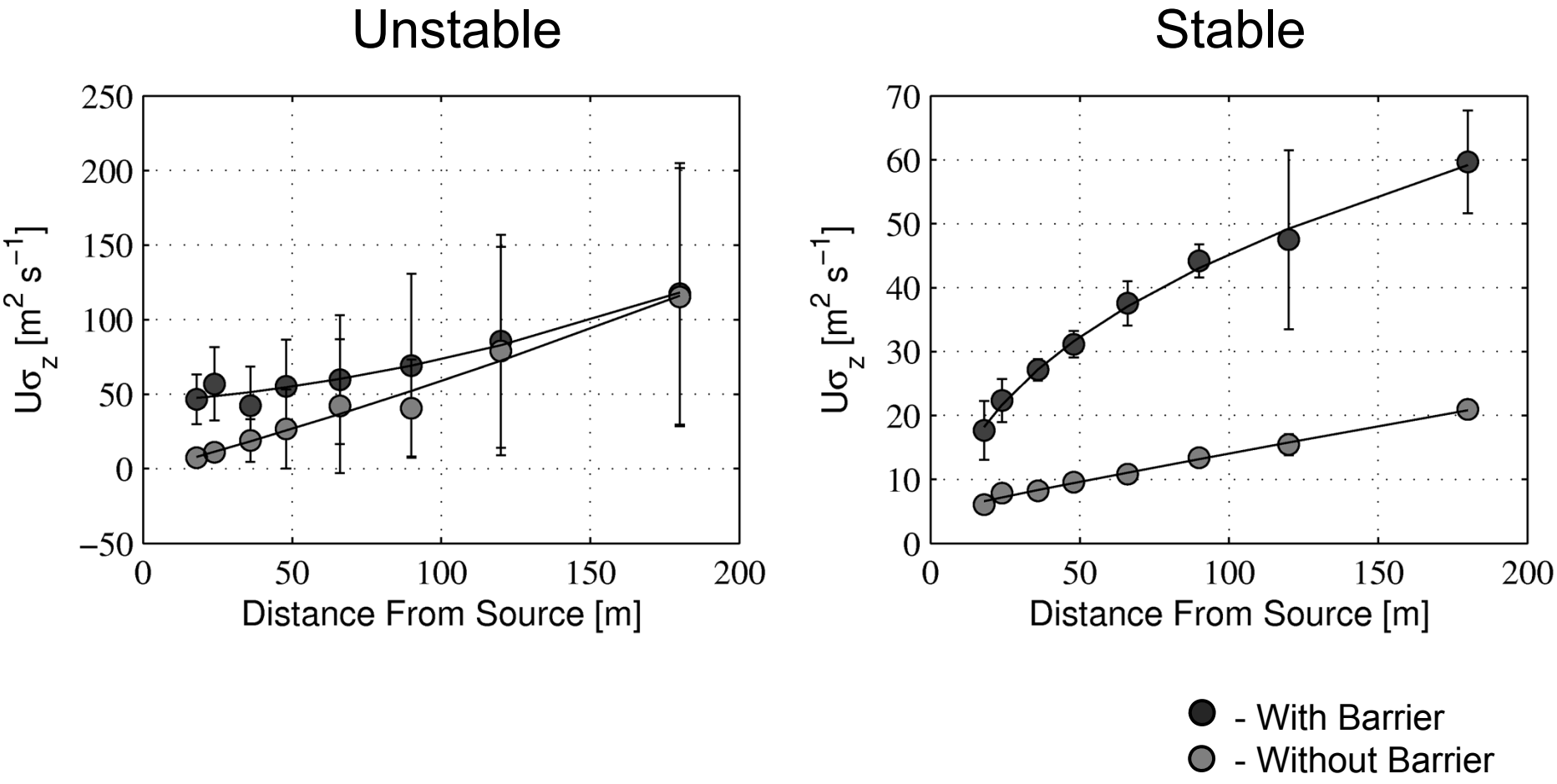
Mixed Wake Model



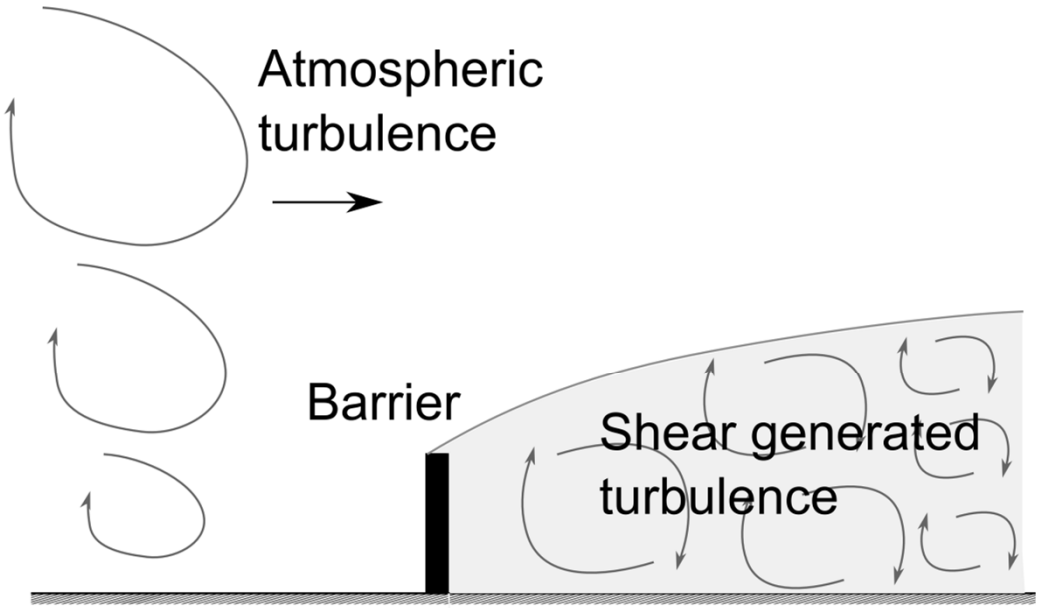
- Concentration is <u>well mixed</u> over the height of the barrier, *H*
- <u>Vertical plume spread increased</u> by a factor α

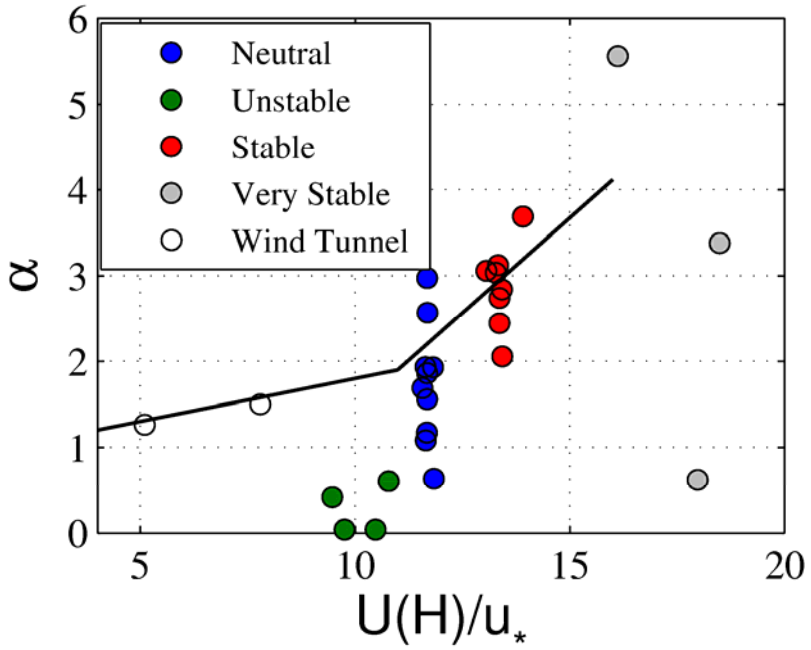
$$\square\,\square(\square) = \square\, E\square F \;\square\,\square\, E\square F + \square\, E_{2}F\;\square\ddot{u}_{2}\;\square$$

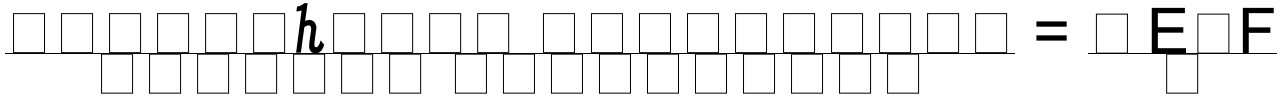
Idaho Falls


Unstable
Stable
$U\sigma_z$ [m^2 s^{-1}]
Distance From Source [m]
250
200
150
100
50
0
−50
70
60
50
40
30
20
10
0
0
50
100
150
200
- With Barrier
- Without Barrier

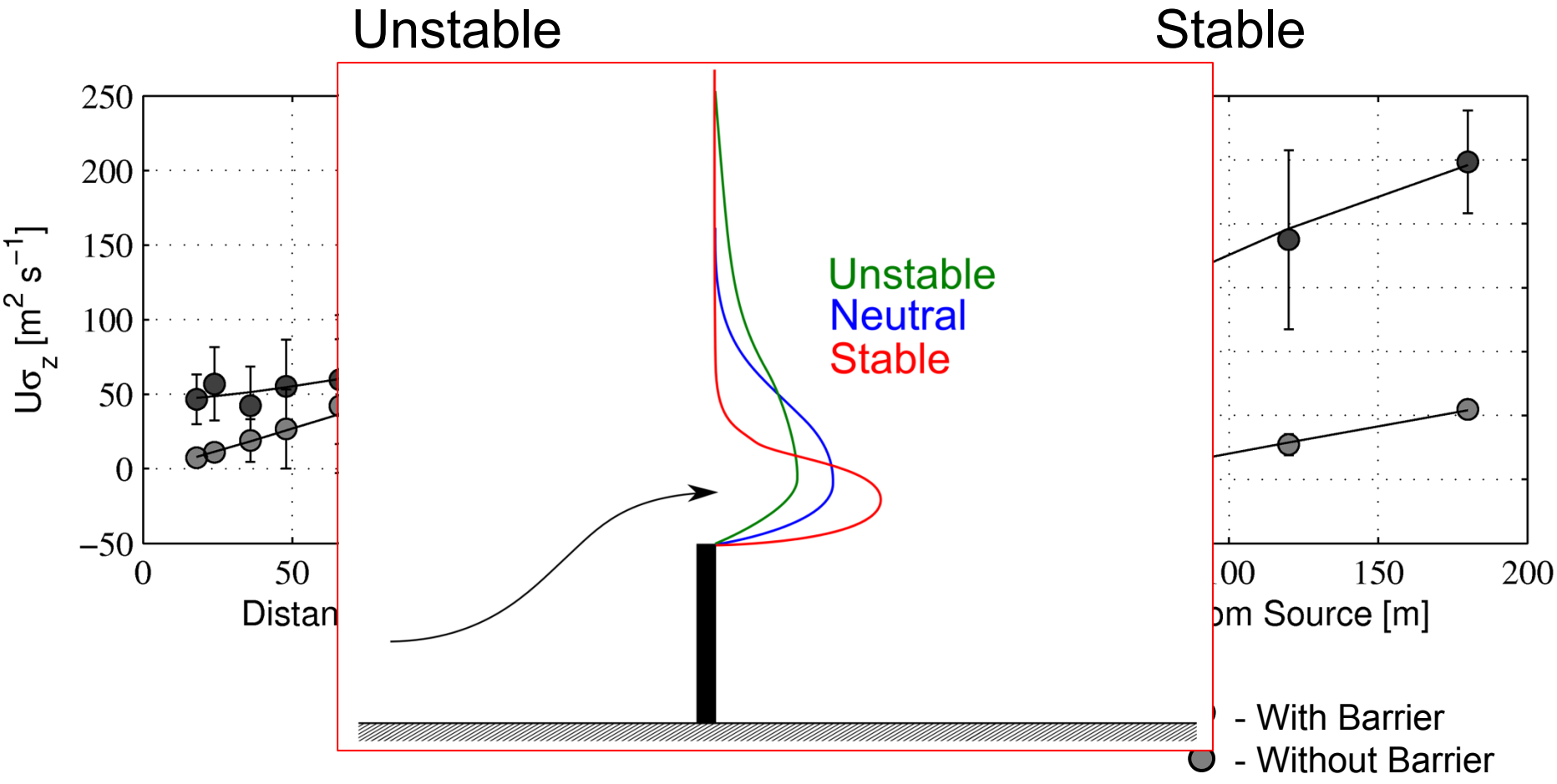
Idaho Falls


Atmospheric
turbulence
Barrier
Shear generated
turbulence


Neutral
Unstable
Stable
Very Stable
Wind Tunnel
α
U(H)/u*
0
1
2
3
4
5
6
5
10
15
20

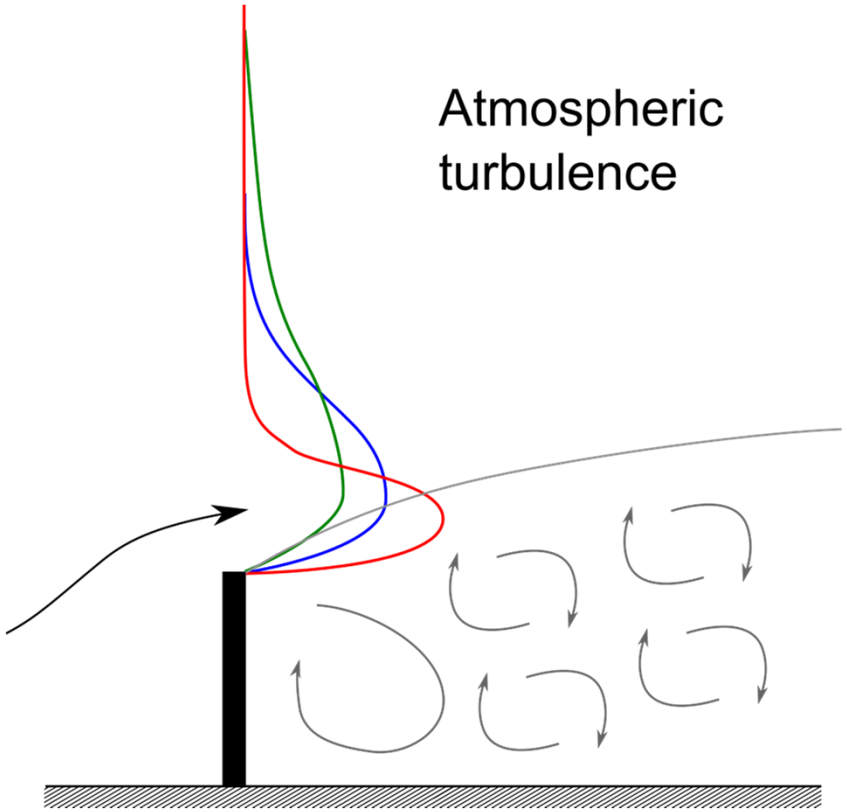


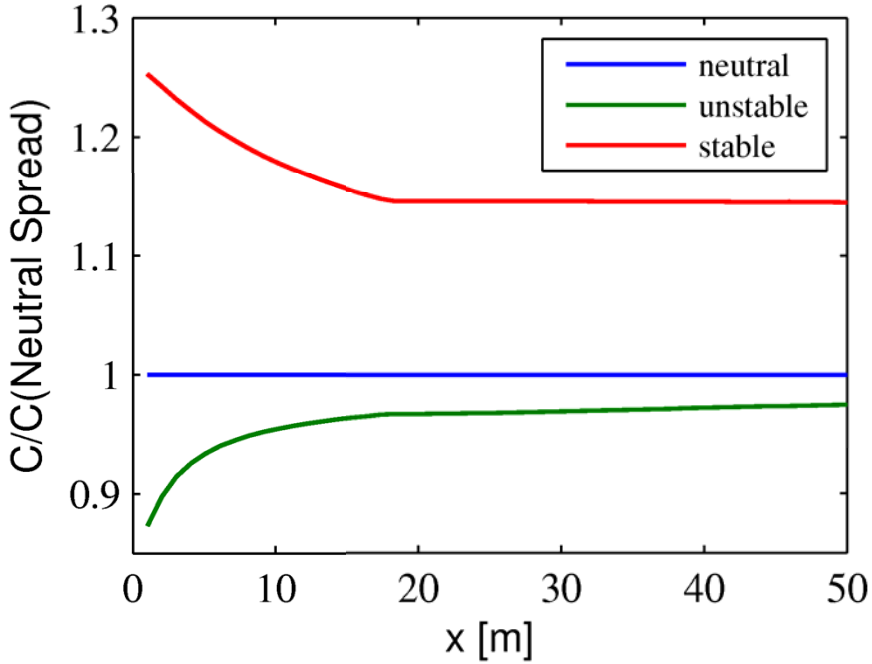
Idaho Falls


Unstable
Stable
250
200
150
100
50
0
−50
$U\sigma_z$ [m^2 s^{-1}]
0
50
Distan
Unstable
Neutral
Stable
00
150
200
om Source [m]
- With Barrier
- Without Barrier

Models

- We used a numerical model to check this idea



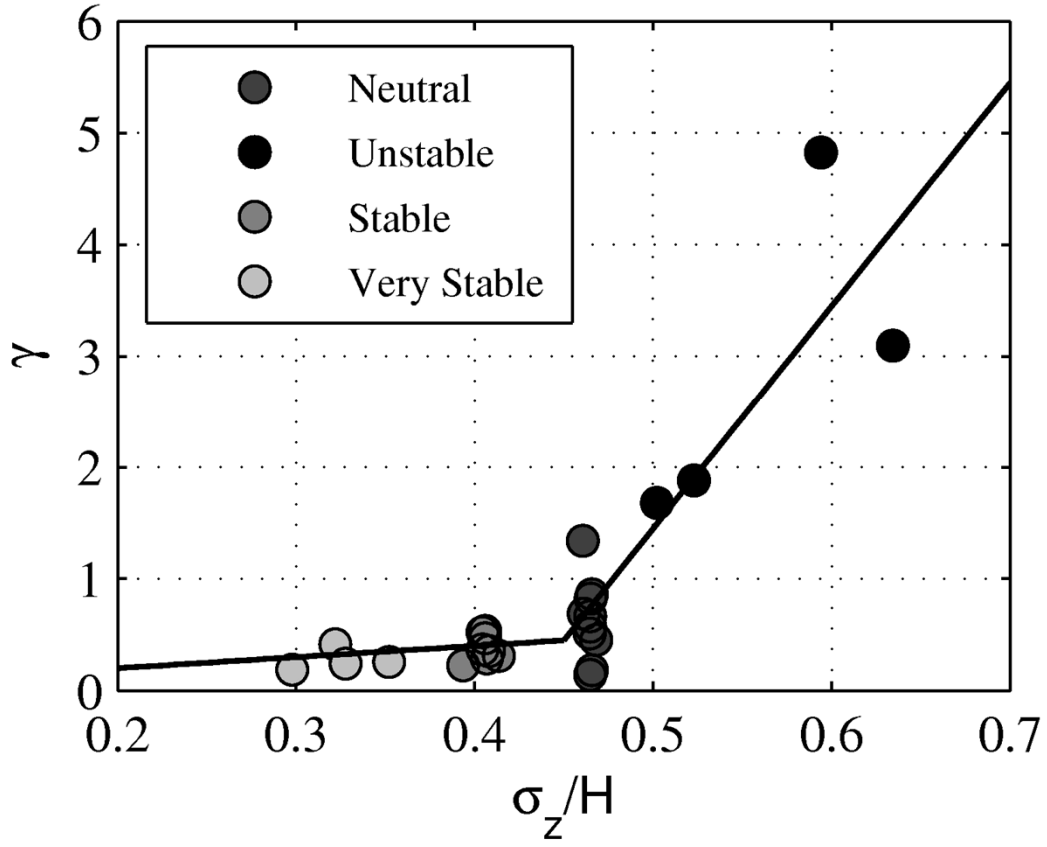


Shear generated
turbulence

$$K = UH$$

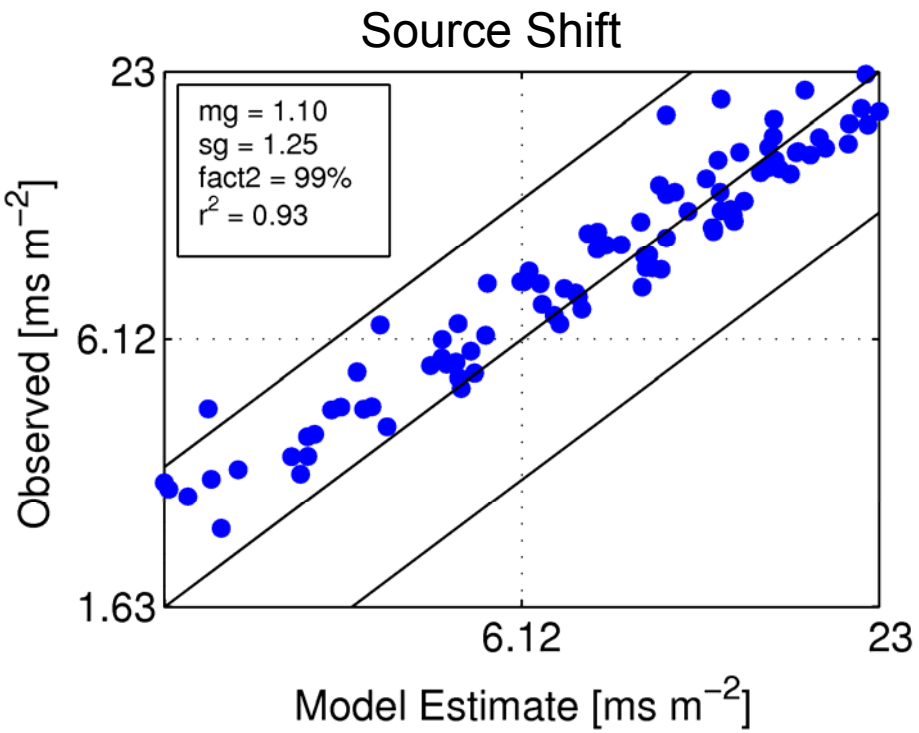
Models

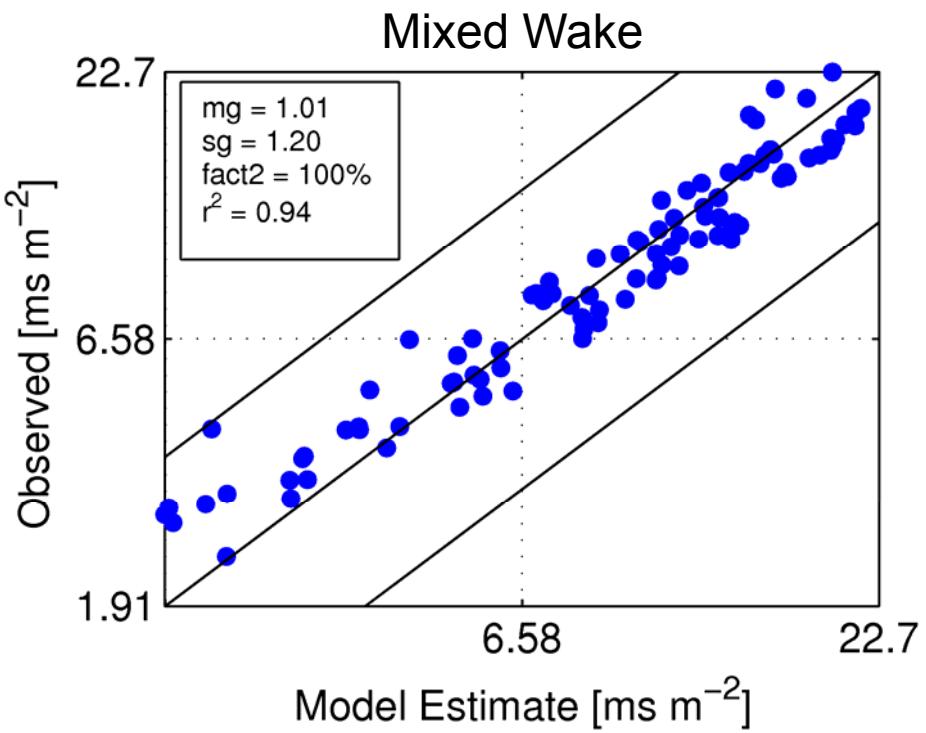
Increase in Initial Vertical Plume Spread



Comparison with Idaho Falls

Neutral Conditions

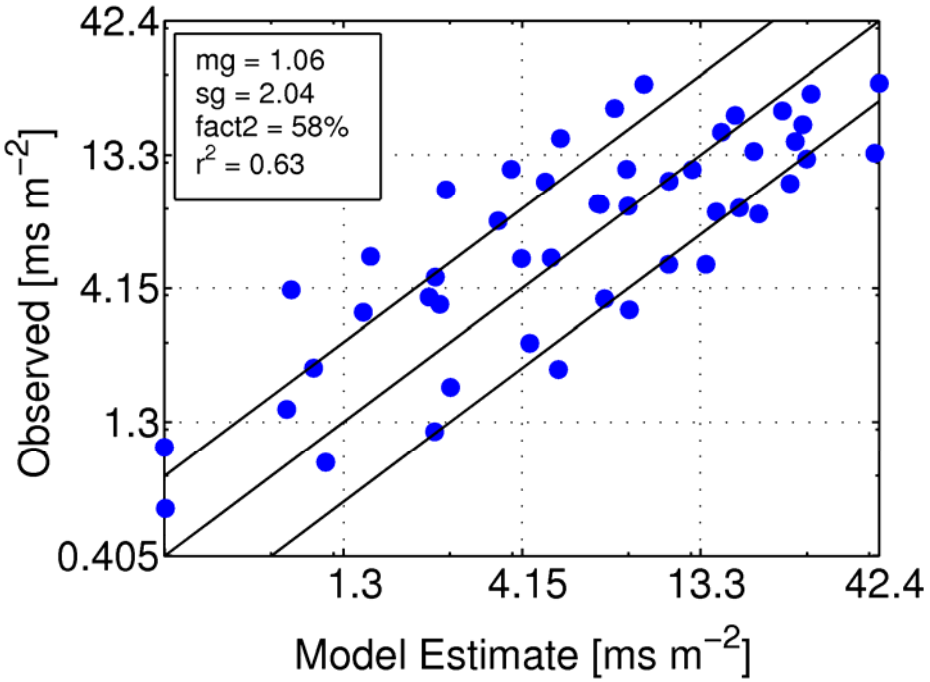




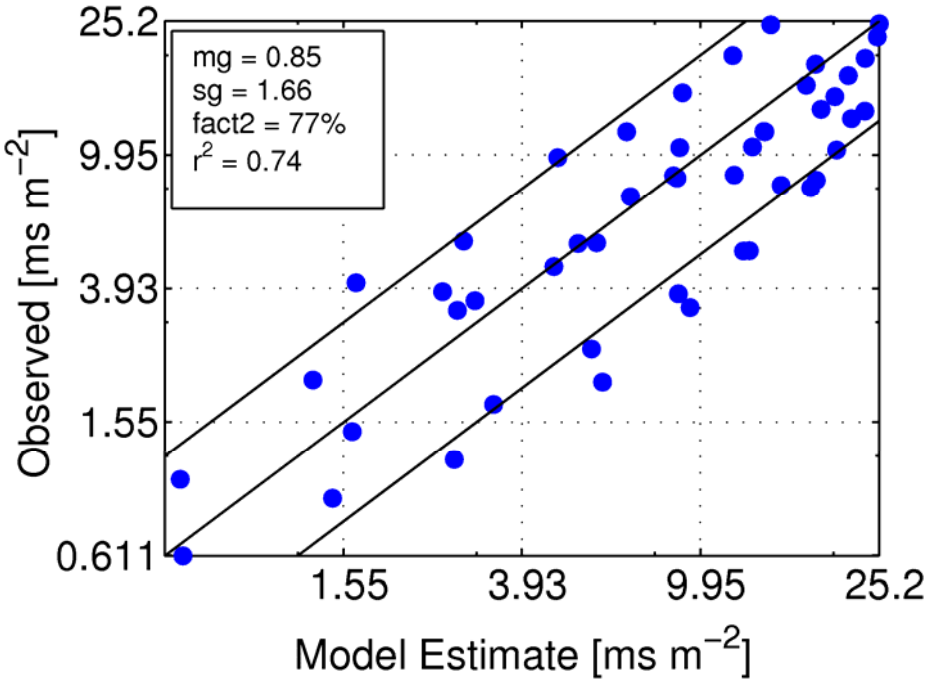
Comparison with Idaho Falls

Unstable Conditions

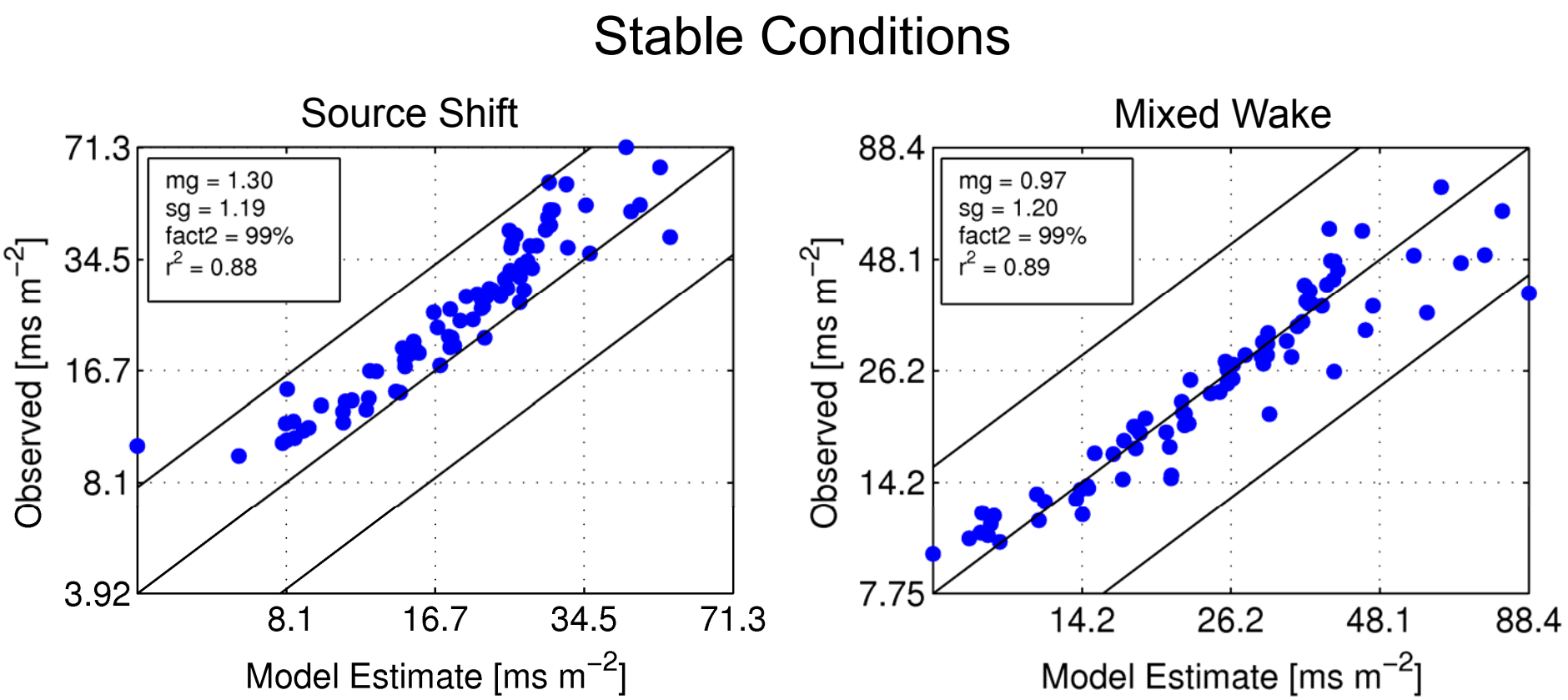
Source Shift



Mixed Wake

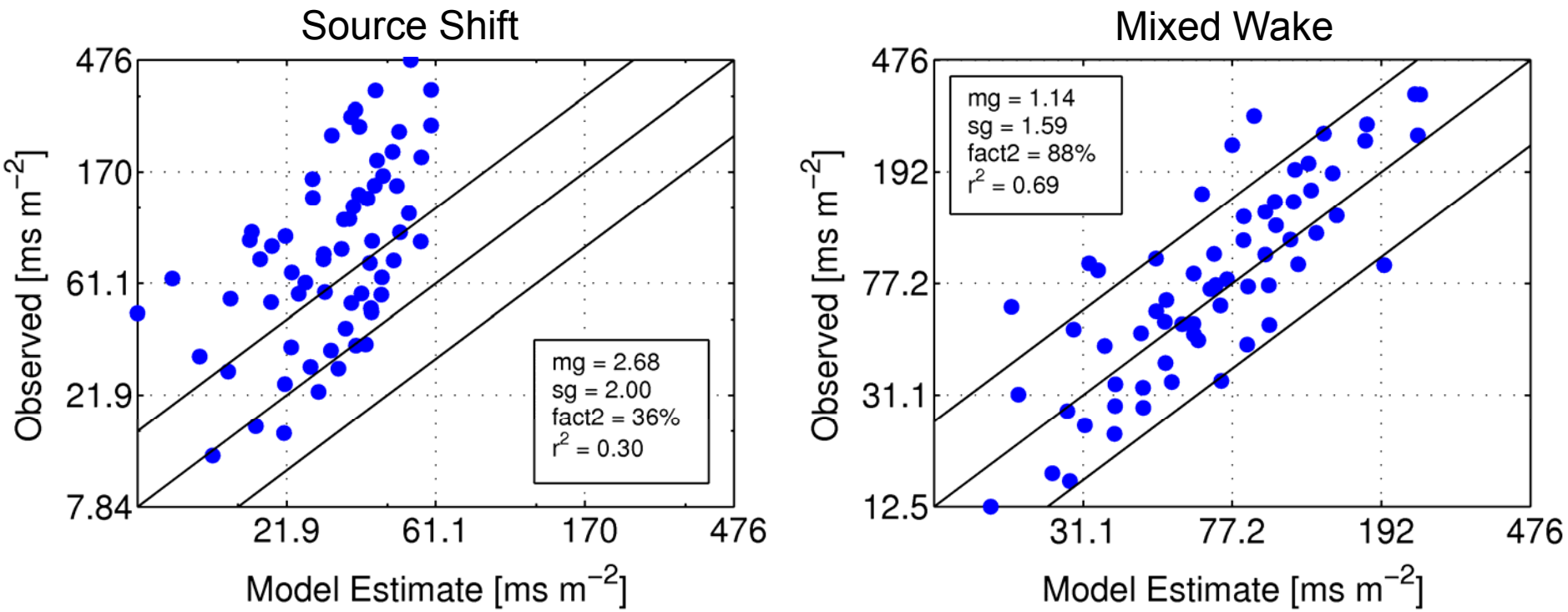


Comparison with Idaho Falls

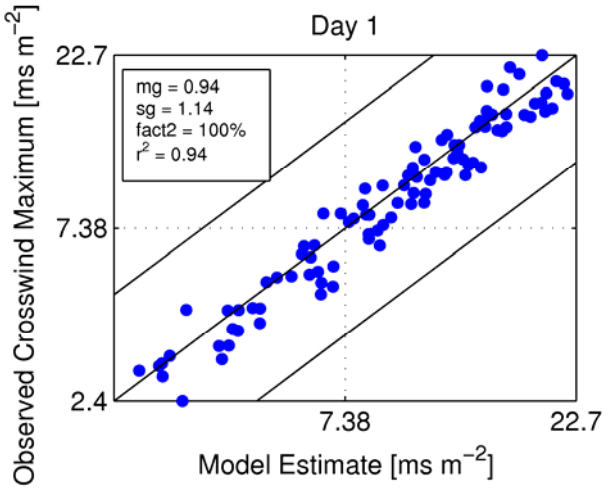


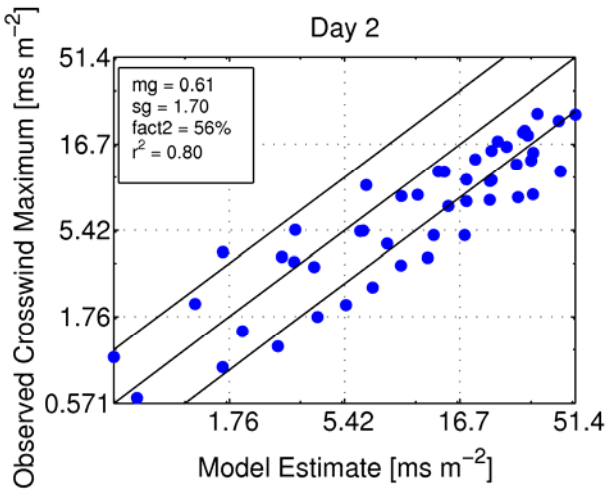
Comparison with Idaho Falls

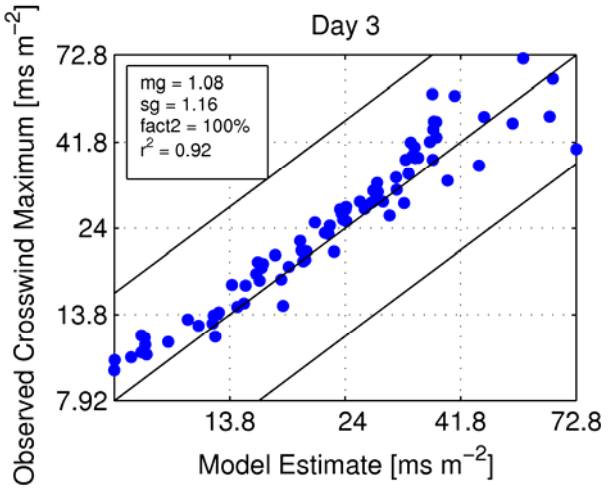
Very Stable Conditions

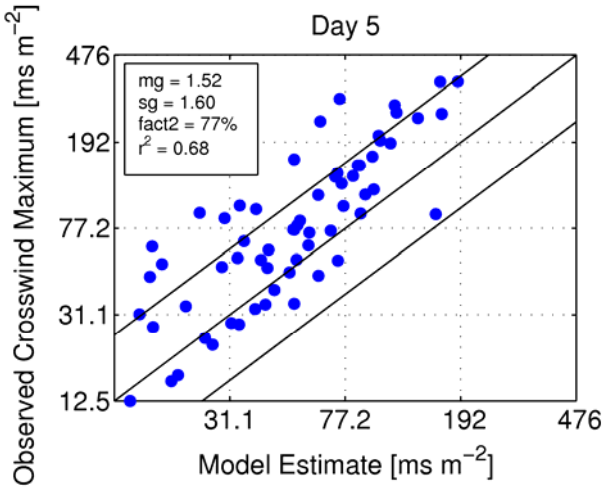


Without γ model





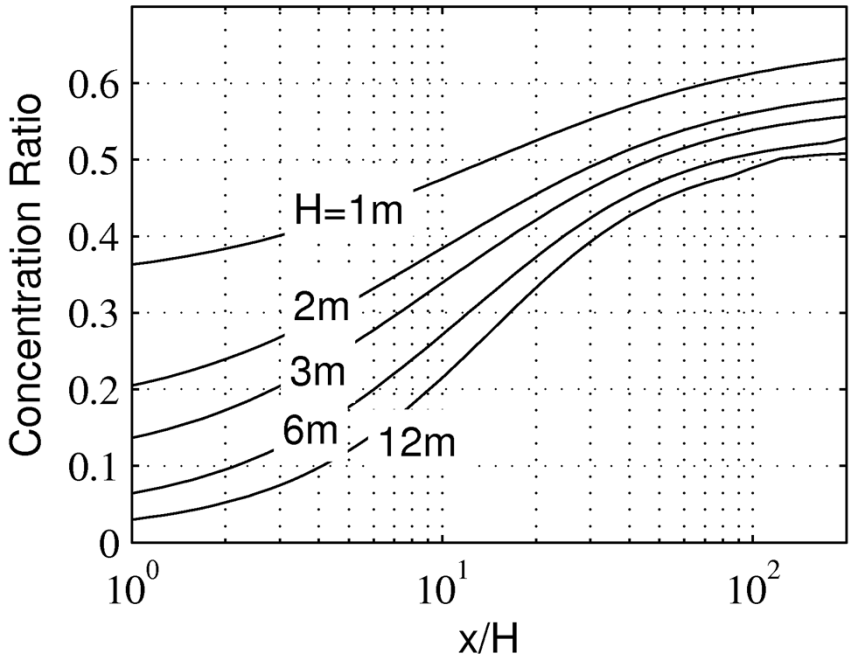




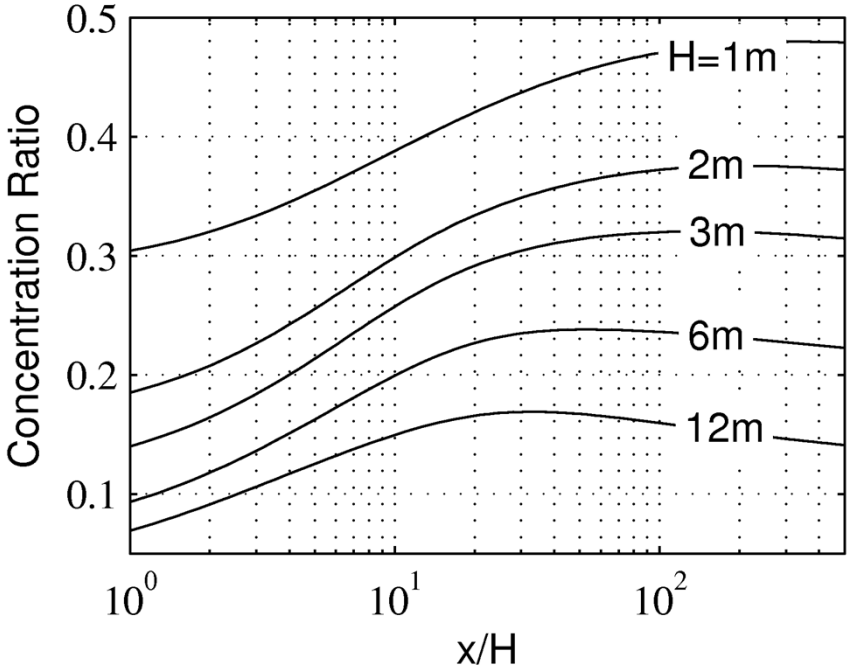
Comparison with Data

Sensitivity to Barrier Height

Unstable

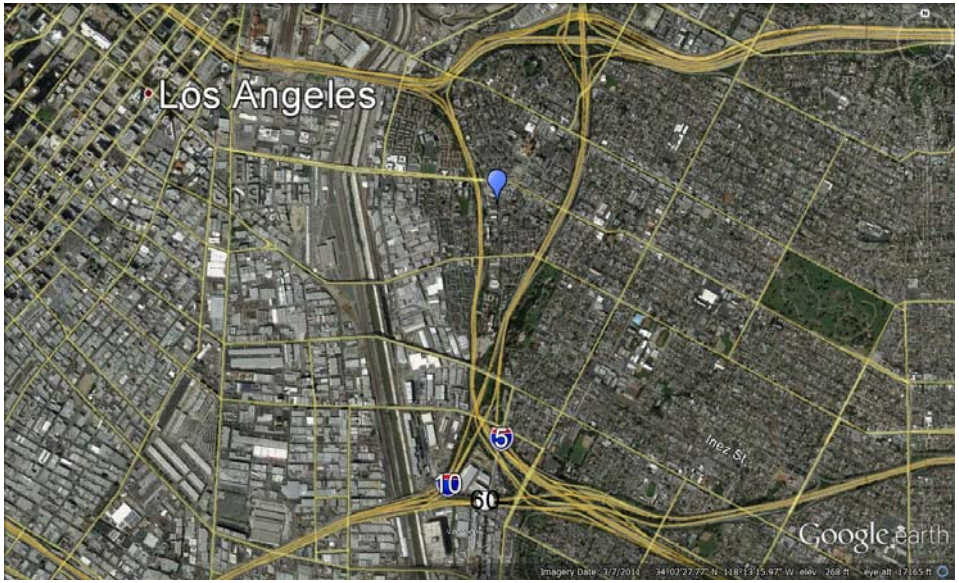


Stable



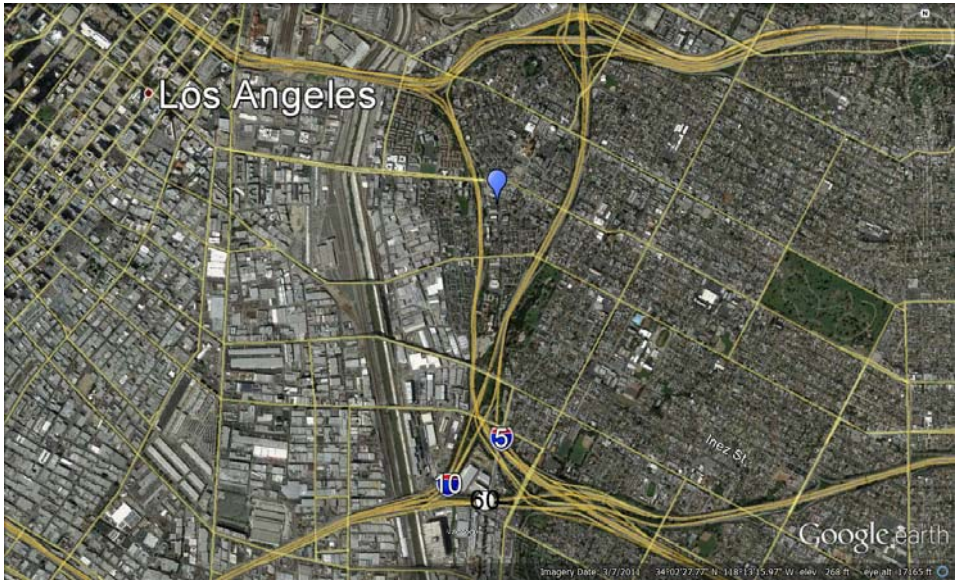
Example

- Receptor 40 m from road
- Meteorology from 2006 – 2007
- PM2.5 emissions
  - 0.03 g km^{-1}
  - 86000 vehicles day^{-1}



Example

	Without Barrier	With Barrier
Maximum (μg m^{-3})	120	28
Annual Average (μg m^{-3})	15	4.5
Background (μg m^{-3})	15	15

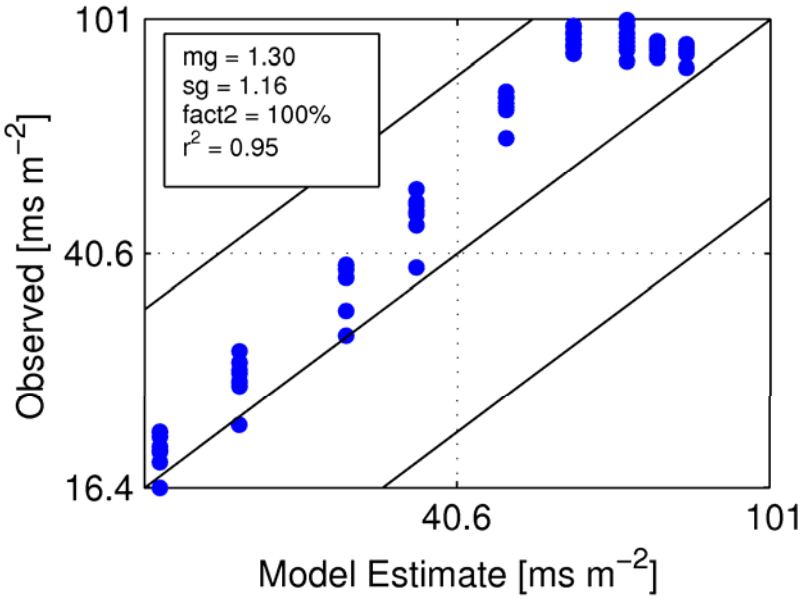


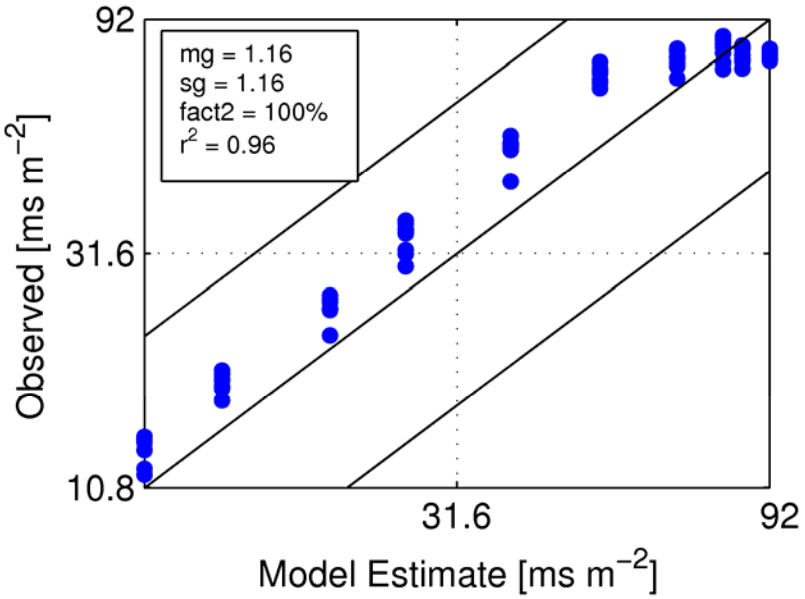
Conclusion

- Barrier causes:
  - Larger initial vertical plume spread
  - More rapid increase in the plume spread with distance from the source
- Barrier effect persists farthest during stable conditions

Conclusion

- Mixed wake model:
  - Compares well with observations
  - Gives useful estimates of concentrations





Thank You
Questions?

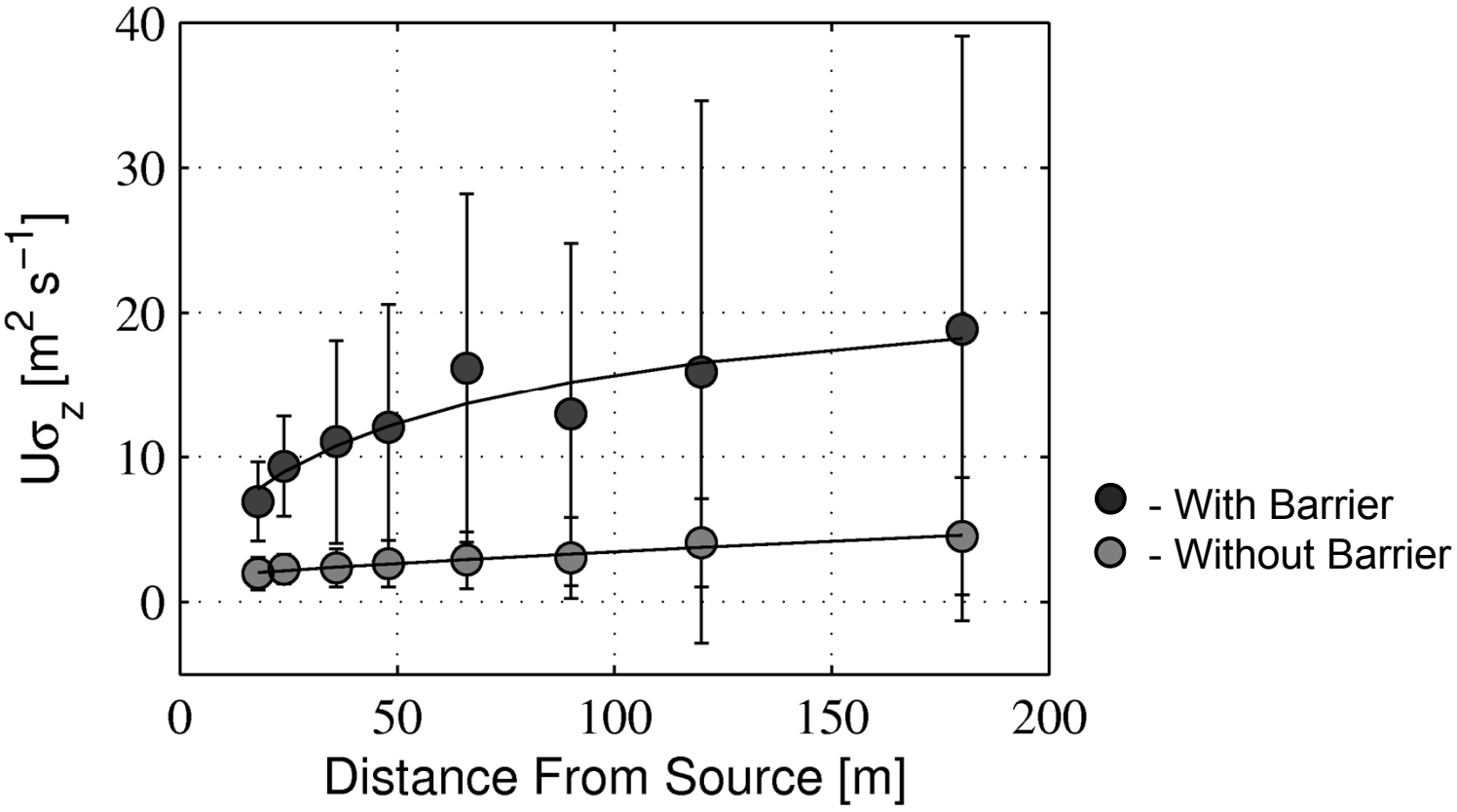
- Heist, D. K., S. G. Perry, and L. A. Brixey. 2009. “A wind tunnel study of the effect of roadway configurations on the dispersion of traffic-related pollution.” *Atmospheric Environment* 43 (32) (October): 5101-5111. doi:10.1016/j.atmosenv.2009.06.034.
- Hagler, Gayle S.W., Wei Tang, Matthew J. Freeman, David K. Heist, Steven G. Perry, and Alan F. Vette. 2011. “Model evaluation of roadside barrier impact on near-road air pollution.” *Atmospheric Environment* 45 (15) (May): 2522-2530. doi:10.1016/j.atmosenv.2011.02.030.
- Finn, Dennis, Kirk L Clawson, Roger G Carter, Jason D Rich, Richard M Eckman, Steven G Perry, Vlad Isakov, and David K Heist. 2010. “Tracer studies to characterize the effects of roadside noise barriers on near-road pollutant dispersion under varying atmospheric stability conditions.” *Atmospheric Environment* 44 (2): 204-214. doi:10.1016/j.atmosenv.2009.10.012.

Overview

- Living near major roads is linked to
  - Development of asthma
  - Impaired lung function
  - Total and cardiovascular mortality
  - Birth and developmental effects
  - Cancer

Idaho Falls

Plume spread during very stable stability



Source Shift Model

- We formulate a model of the shift distance, *s*, in terms of barrier height, *H*

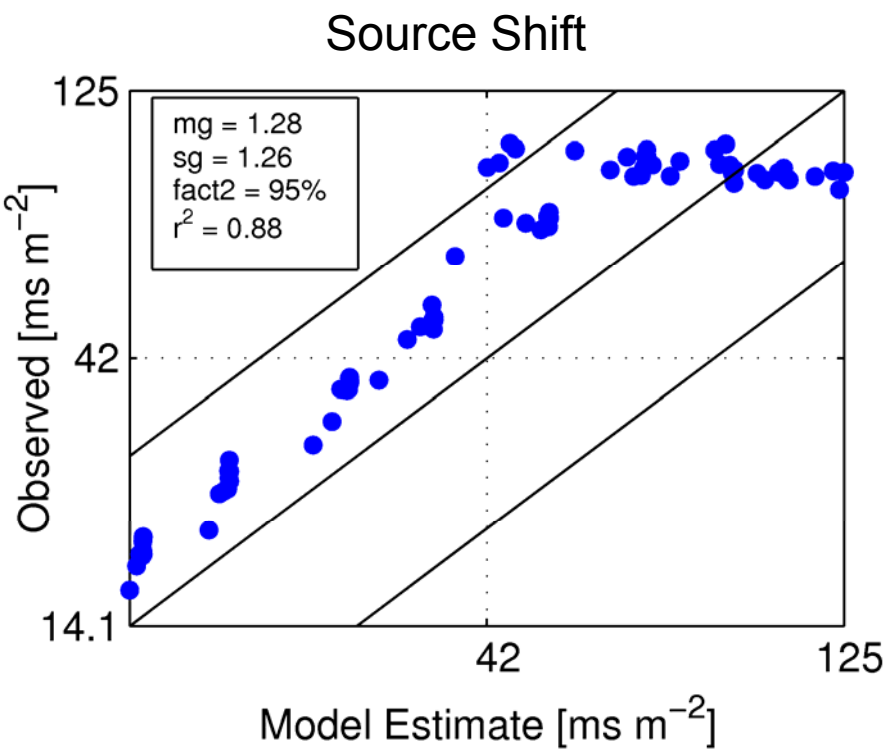
$$\square_{E}\square - E\square - \square F_{F} = \ddot{u}2\square$$

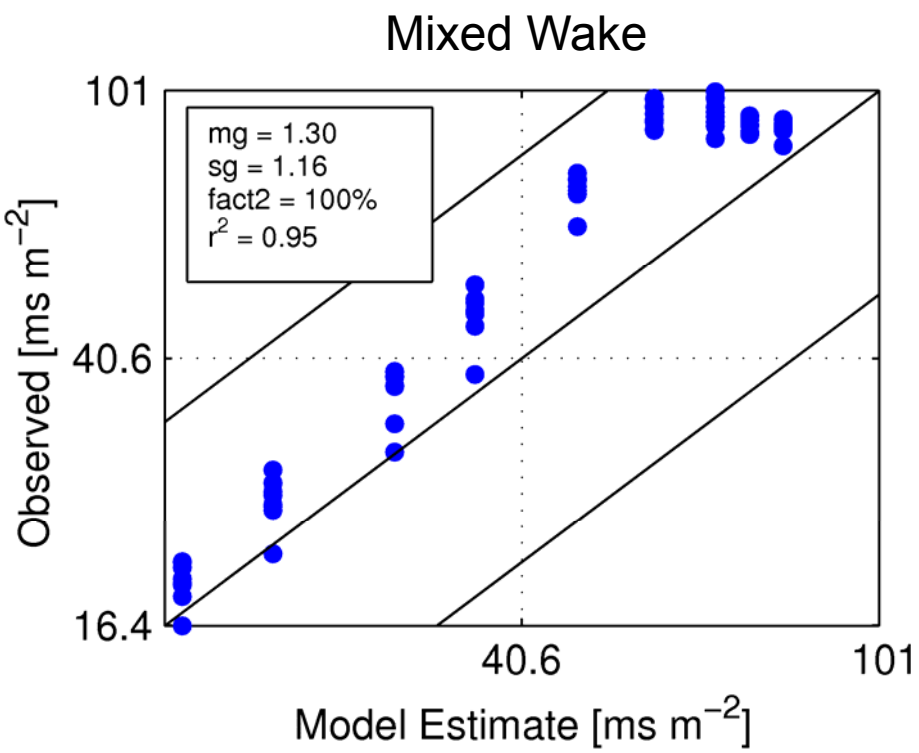
$\square$ - Location of barrier

$\square$ - Location of source

β – Empirical correction factor

Comparison with Wind Tunnel





Comparison with Wind Tunnel