THE IMPACT OF ROAD STRUCTURES AND BUILDINGS ON URBAN AIR QUALITY

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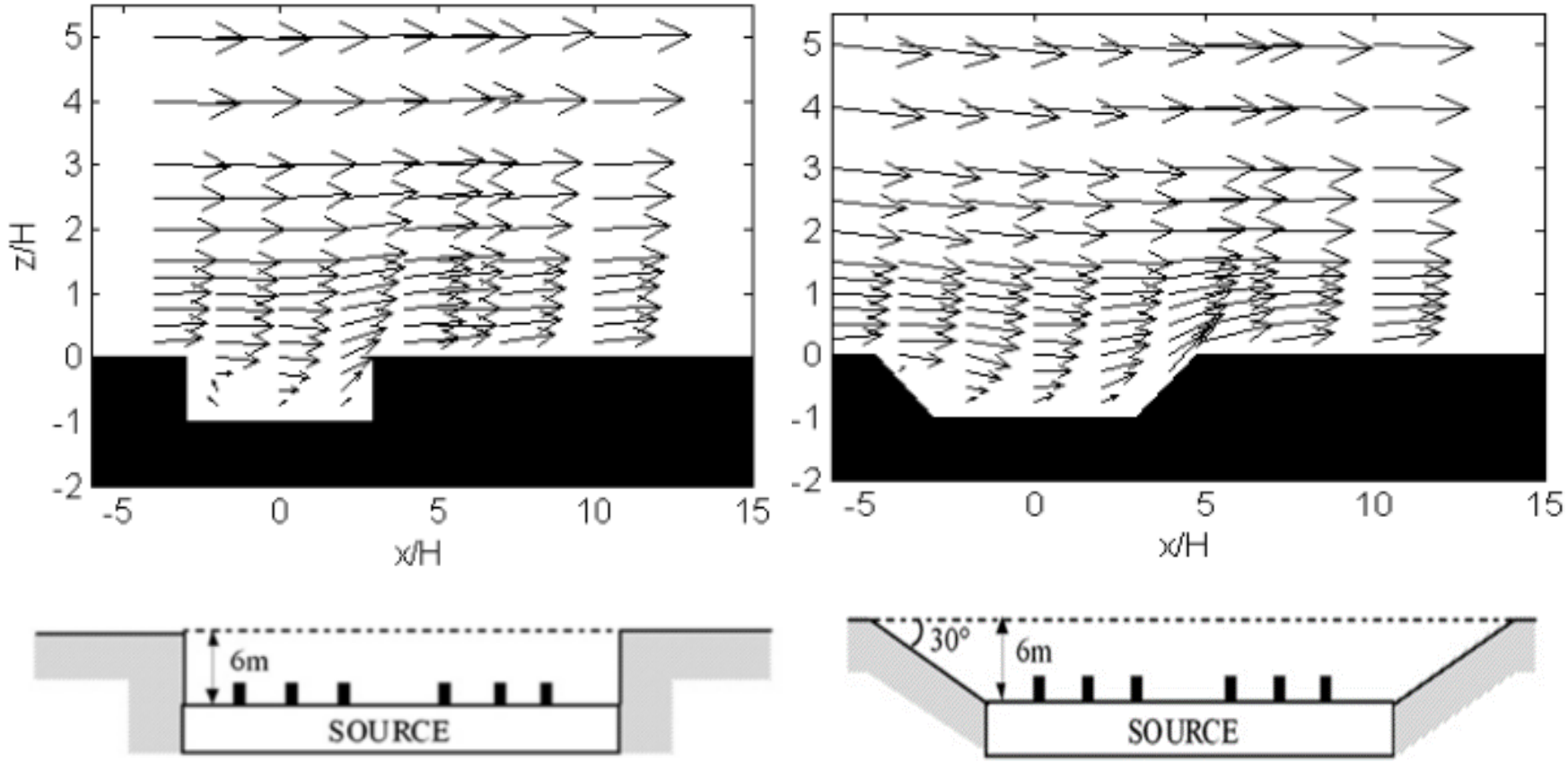
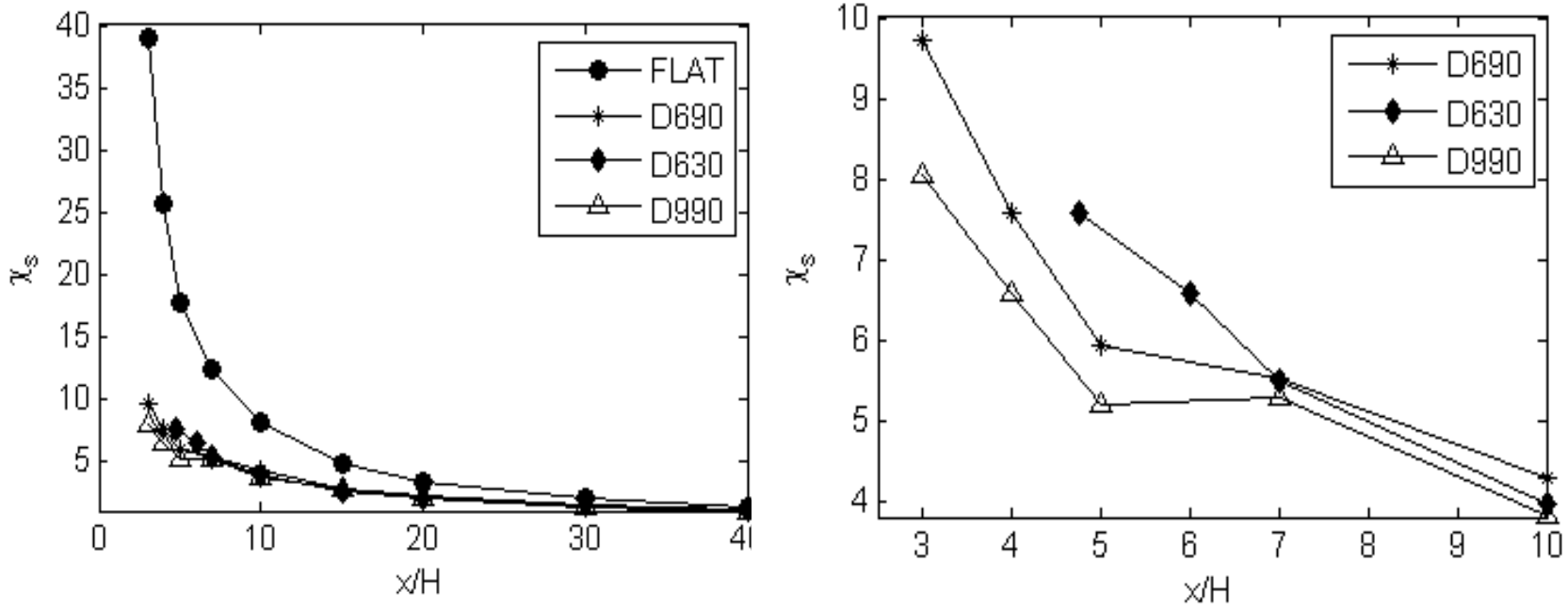
1. Street canyons
2. Highways with and without noise barriers
3. Depressed/elevated highways
4. Vegetative barriers
5. Urban meteorology

Depressed Road Effects



USEPA Wind Tunnel , Heist et al. (2009)

Depressed Road Effects



Near surface concentration (Heist et al., 2009)

Depressed Road Effects Modeling (van Ulden, 1978)

$$\frac{C(x,z)}{q} = \frac{A}{\bar{U}\bar{z}} \exp\left(-\left(\frac{Bz}{\bar{z}}\right)^{s}\right)$$

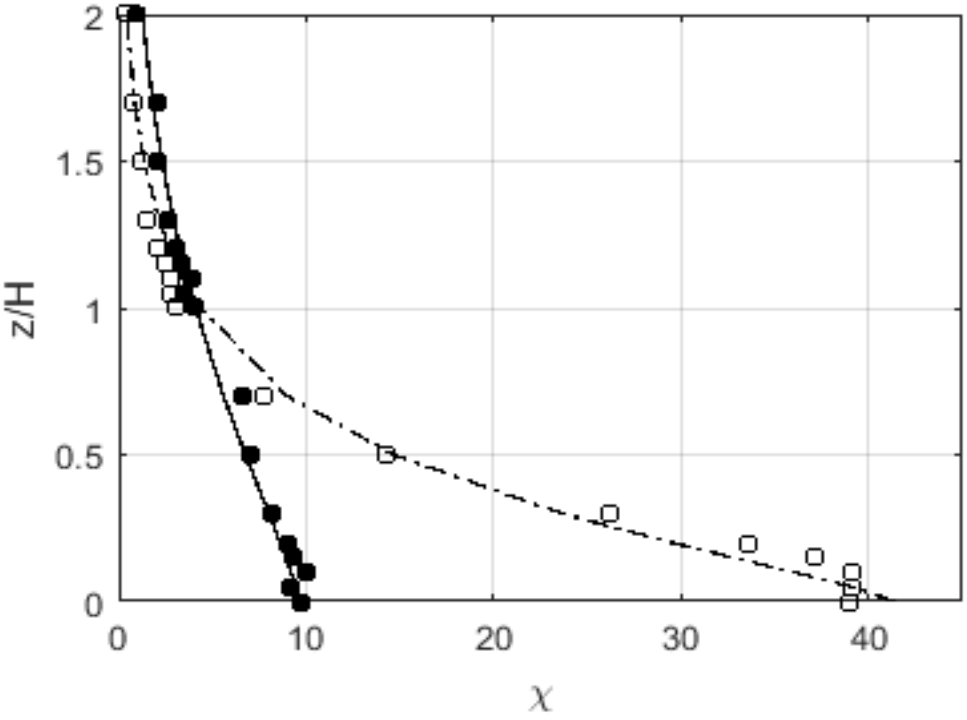
$$\bar{z} = \left(a\frac{\beta u_*}{U_r} z_r^p x + b h_0^{p+1}\right)^{\frac{1}{p+1}}$$

h_0 = *Initial mixing height*

β = *Turbulence enhancement factor*

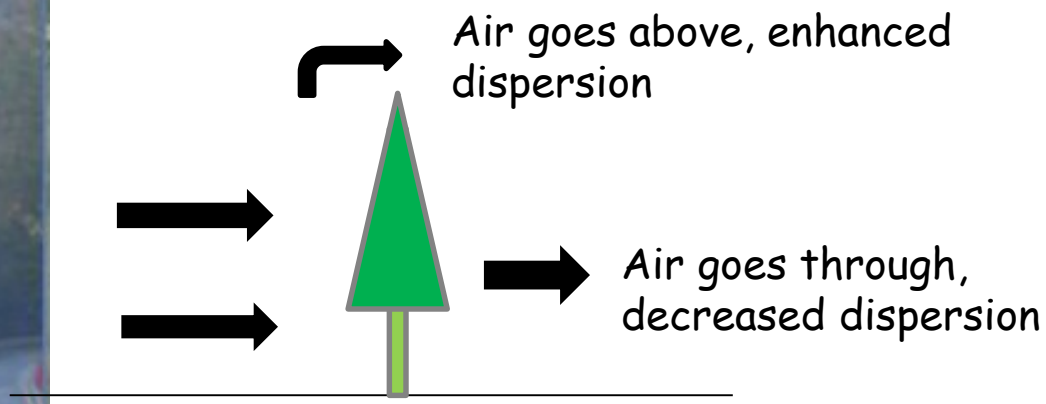
Depressed Road Effects Modeling

Model estimates for flat and 6 m depressed highway compared with measurements



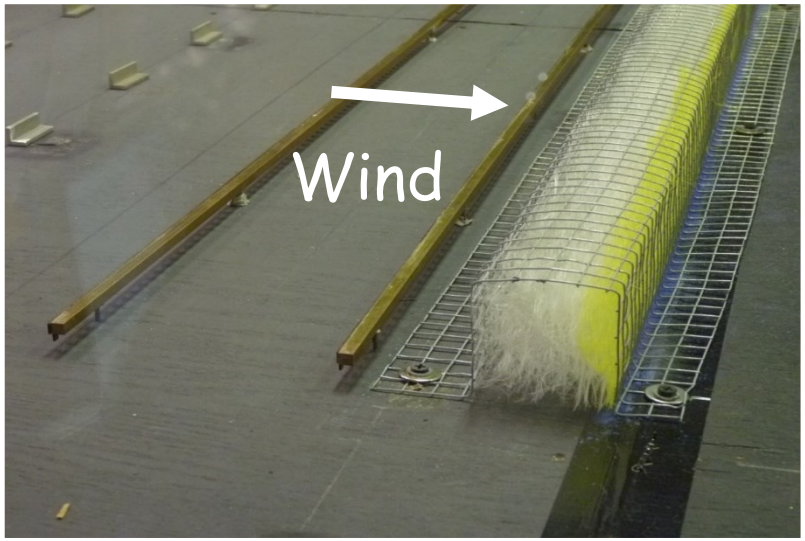
Case	$h_0(m)$	β
FLAT	1.2	1.00
D690	4.8	1.12
D630	3.6	1.37
D990	5.9	1.31

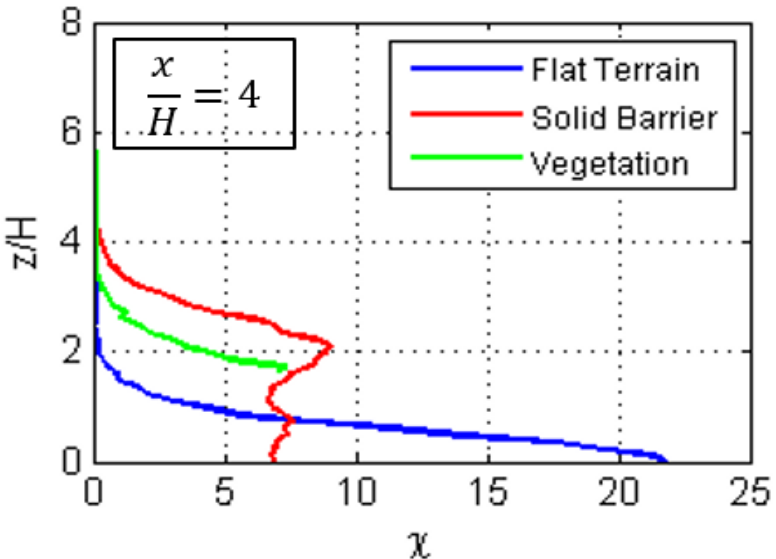
Vegetative Barriers

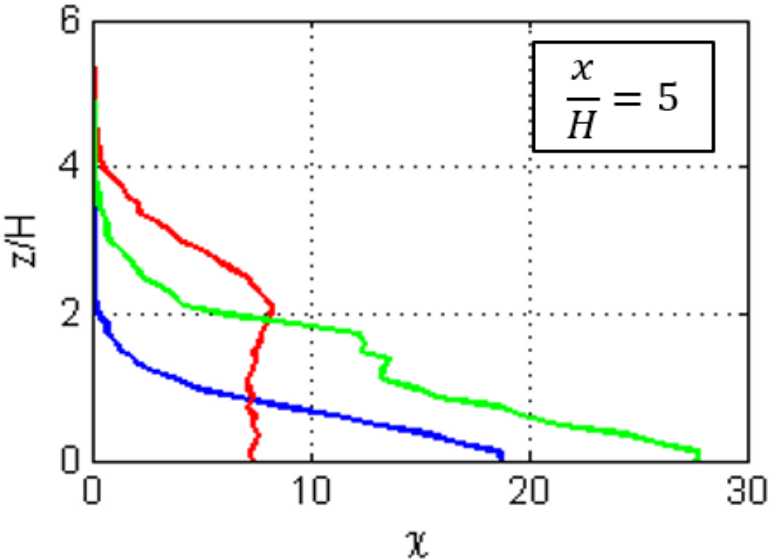


Downwind concentrations can increase or decrease depending on the relative magnitudes of "blocking" and "stabilizing" effects

Vegetative Barriers (Heist et al., 2016)



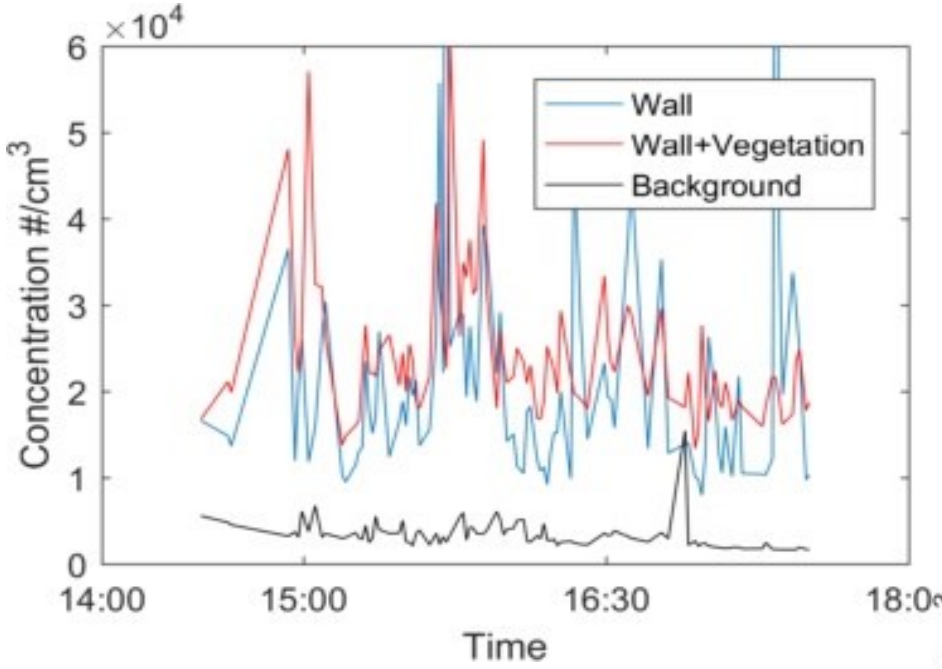


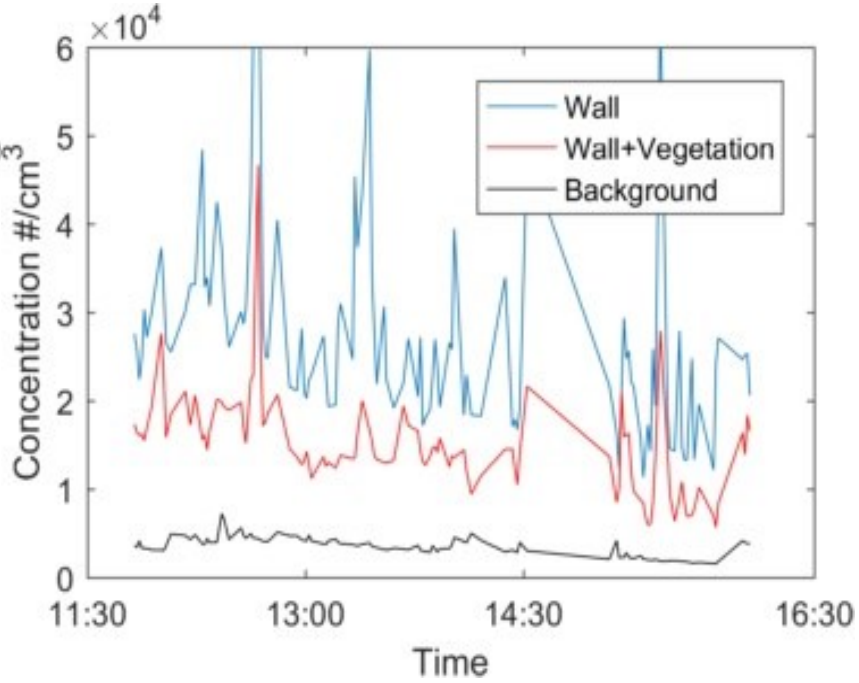


Sacramento Field Study

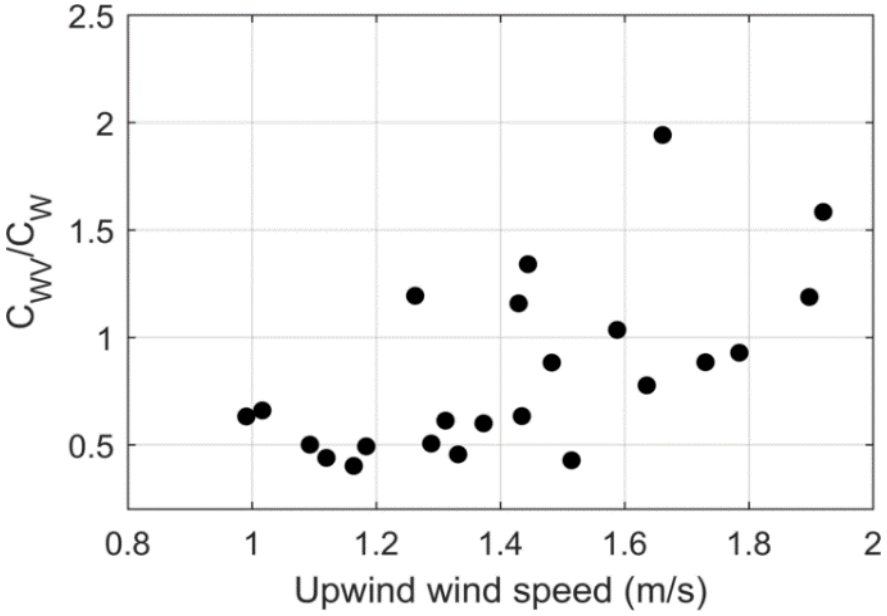
Two sites: 5 m barrier extending over 500 m on the east side of CA-99 highway, and a barrier of the same height with a row of 15-18 m high pine trees planted next to it extending over 200 m along the highway.

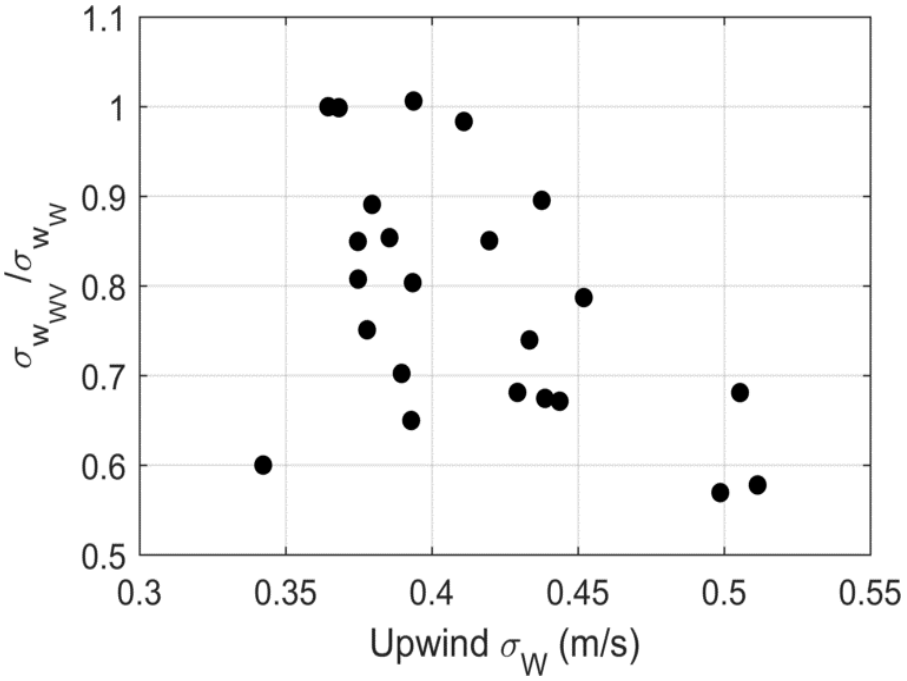
Sacramento Field Study-Results





Sacramento Field Study-Results

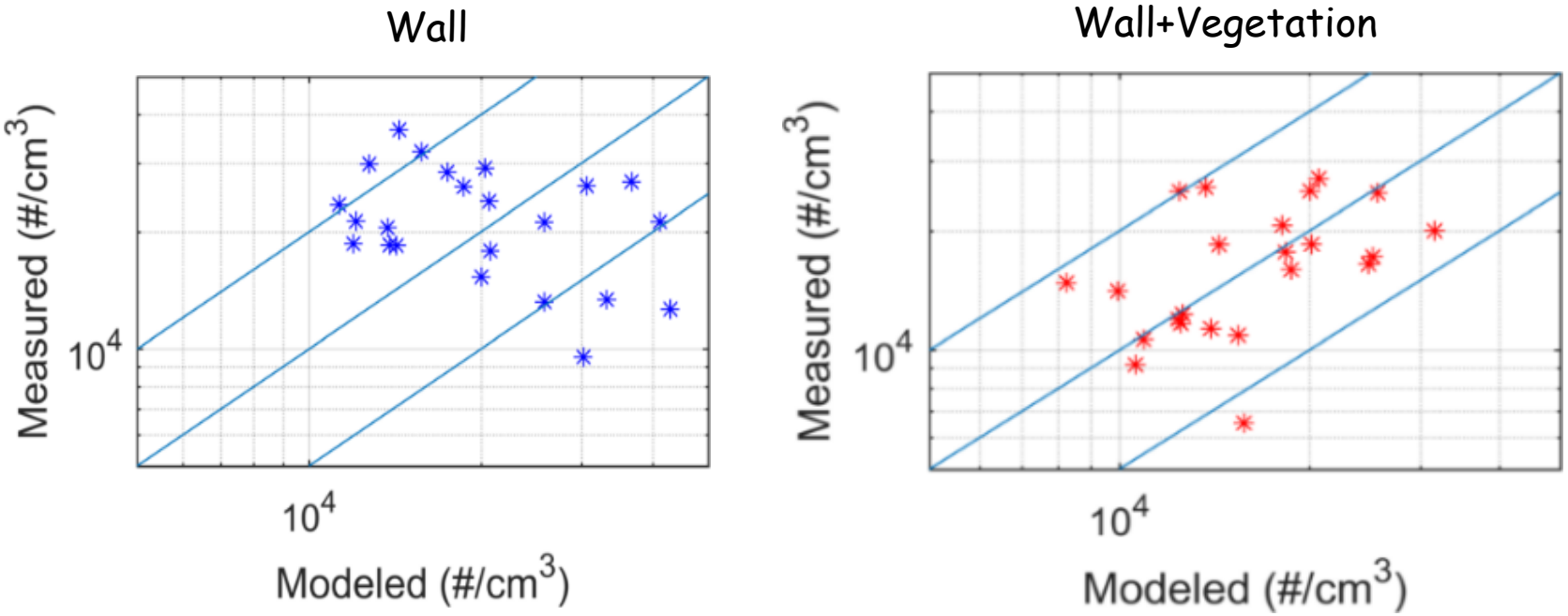




Sacramento Field Study-Modeling

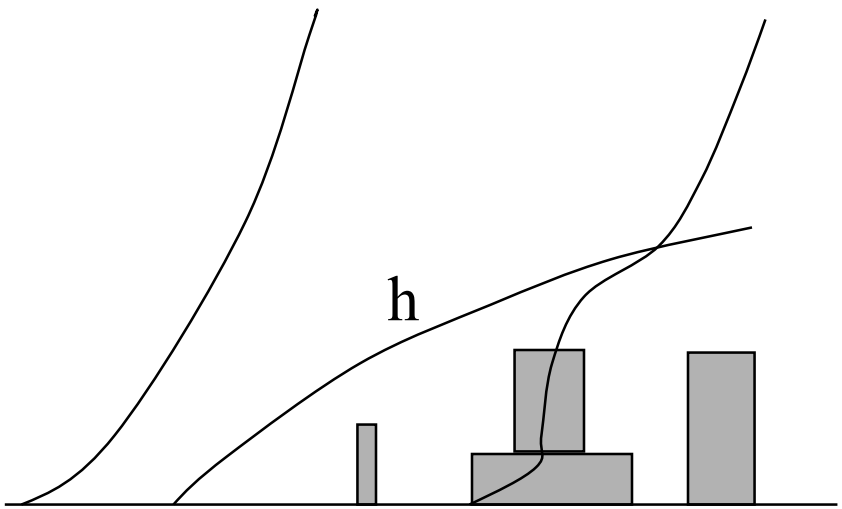
Adapted solid barrier model

1. Decreased entrainment into wake
2. Decreased dispersion above wall-*stabilization*
3. Increased effective height of barrier-*blocking*



Urban Micrometeorology (Luhar et al., 2006)

Internal boundary layer model



$$\frac{dh}{dx} = \frac{\sigma_w}{U}\varphi\left(\frac{h-d}{L_u}, z_{ou}\right)$$

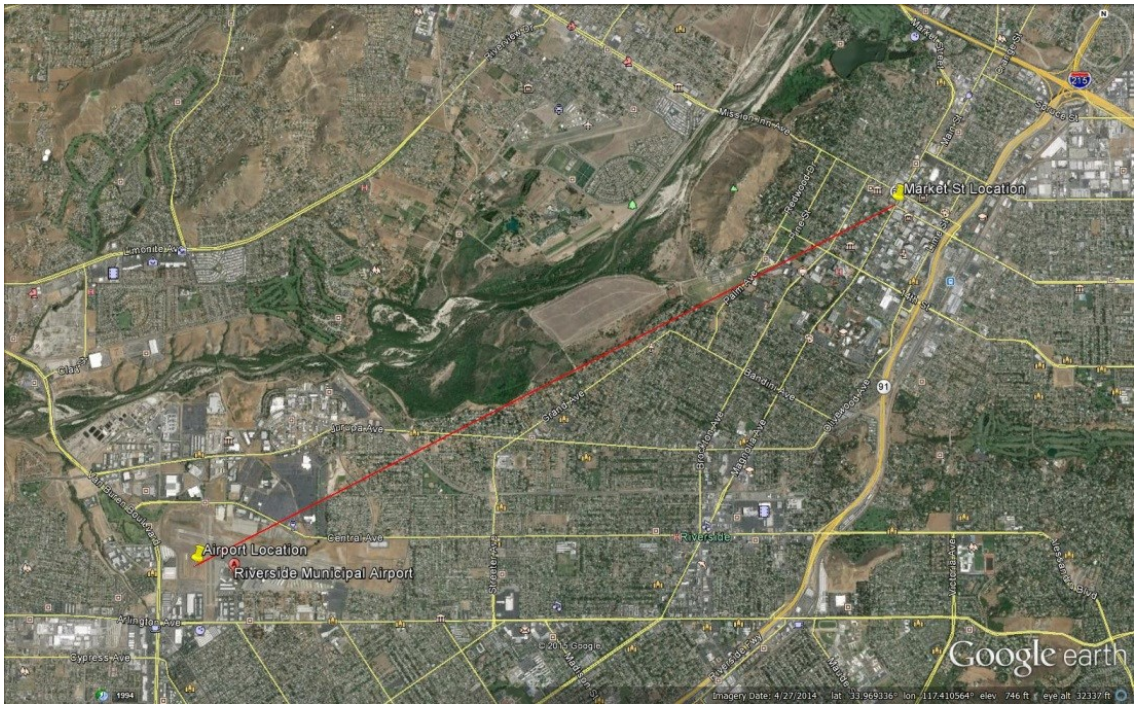
$L_u = \infty$ when $L_r > 0$

$L_u = L_r$ when $L_r < 0$

$$U_u(h) = U_r(h)$$

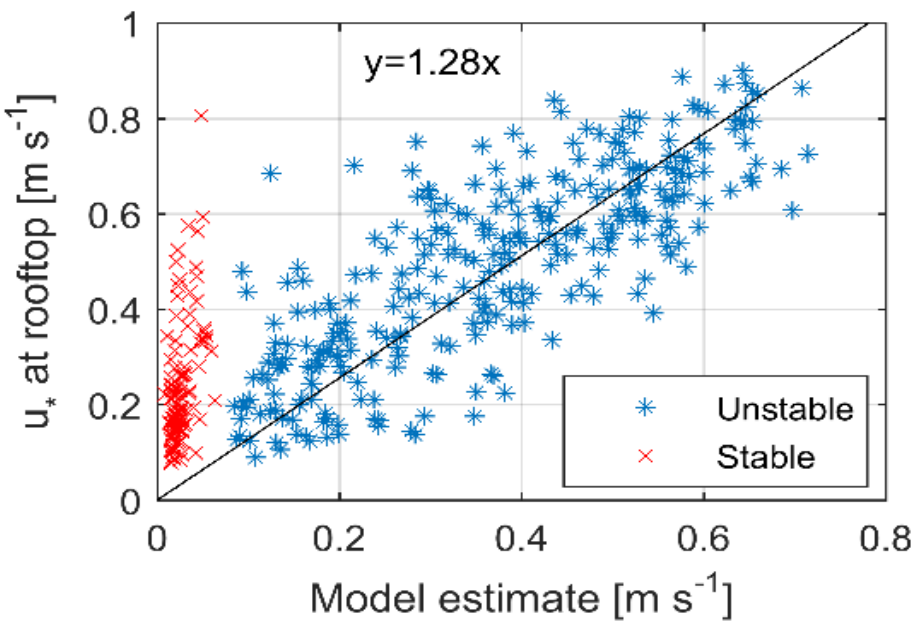
$$u_{*u} = \frac{kU_u(h)}{\ln\left(\frac{h-d}{z_{ou}}\right) + \varphi_m\left(\frac{h-d}{L}, z_{ou}\right)}$$

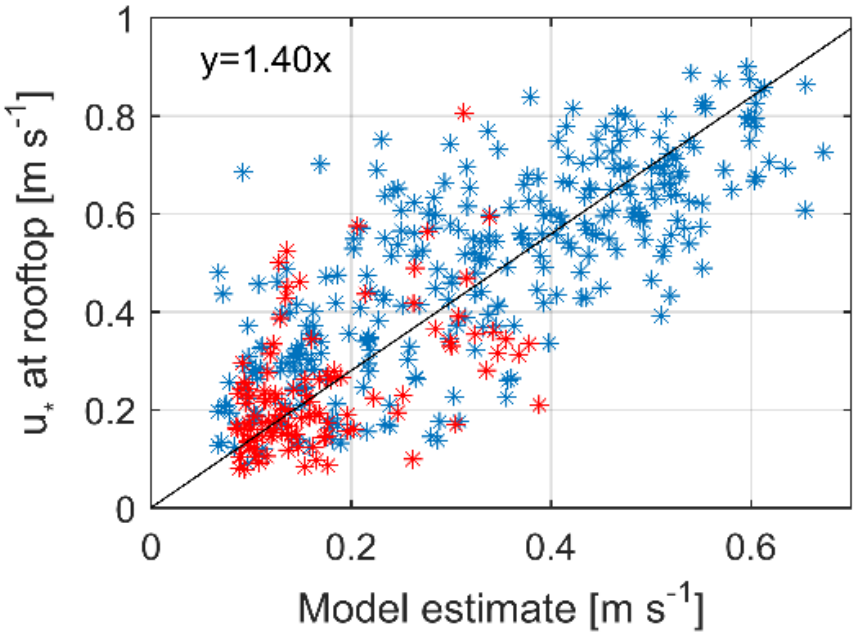
Urban Micrometeorology



A Campbell scientific CSAT3 sonic anemometer measured the three components of the wind speed vector and the sonic temperature at 10 Hz on the roof of city hall. Another sonic anemometer was placed at Riverside airport, about 7.8 km southwest from city hall, at 2.7 m above ground level. The micrometeorological measurements were made continuously between July 30 and September 9, 2015.

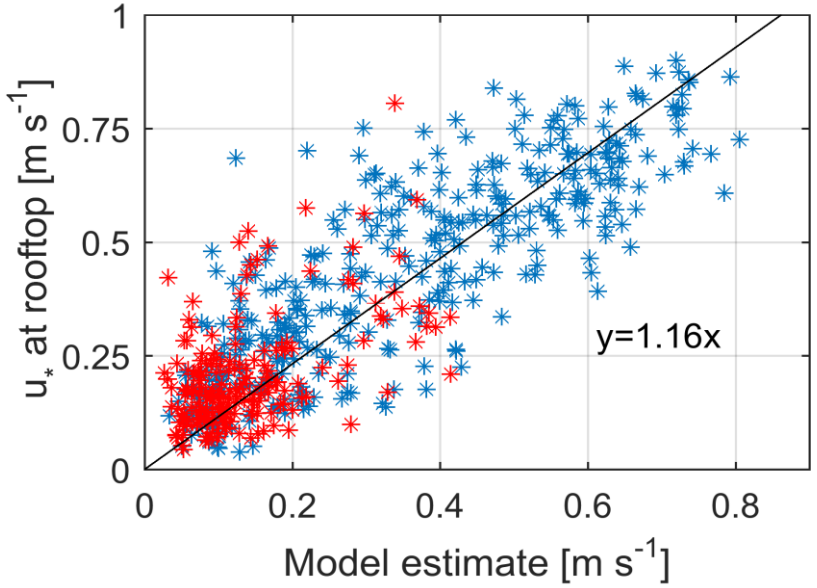
Urban Micrometeorology-Results

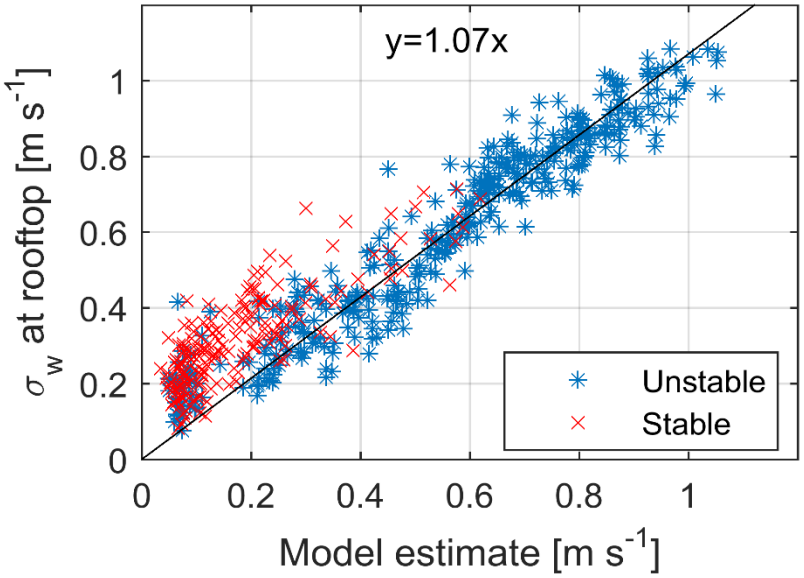




Model estimates of rooftop friction velocity compared with observations. Left panel: Accounts for stability. Right panel: Assumes neutral conditions at both locations.

Urban Micrometeorology-Simple Model





$$\frac{u_{*urban}}{u_{*rural}} = \left(\frac{z_{0urban}}{z_{0rural}} \right)^{\alpha}$$

$\alpha = 0.14$

$\sigma_w = 1.3 u_*$

Can be derived from the IBL model. Fisher et al. (2006) recommend $\alpha = 0.07$

Conclusions

1. Dispersion effects associated with depressed highway can be modeled through simple modifications of flat terrain model
2. Need more work on the effects of vegetative barriers-increased downwind concentrations need better explanation
3. Need better models to estimate urban micrometeorology –stability effects can be neglected?