Comparison of Results from Three Urban Tracer Experiments

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- Objectives and Motivation
- Field Studies
- Results
- Comparison of Results
- Conclusions and implications

Objectives

- Examine field studies conducted to understand dispersion in urban areas
- Compare results from these studies
- Draw general conclusions on urban dispersion

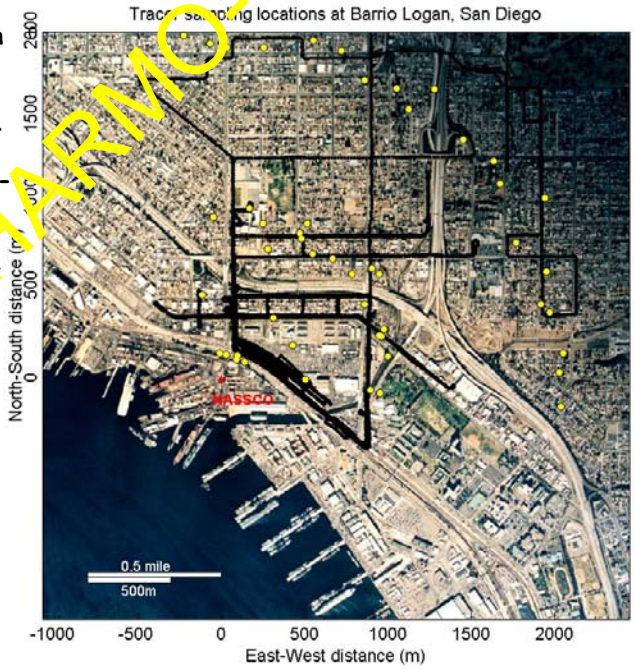
Field Experiments

Tracer studies designed to study dispersion at scales of kilometers in urban areas.

- St. Louis study conducted in 1963-1965
- Barrio Logan field study in August 2001
- Urban 2000 conducted in Salt Lake City in September-October 2000

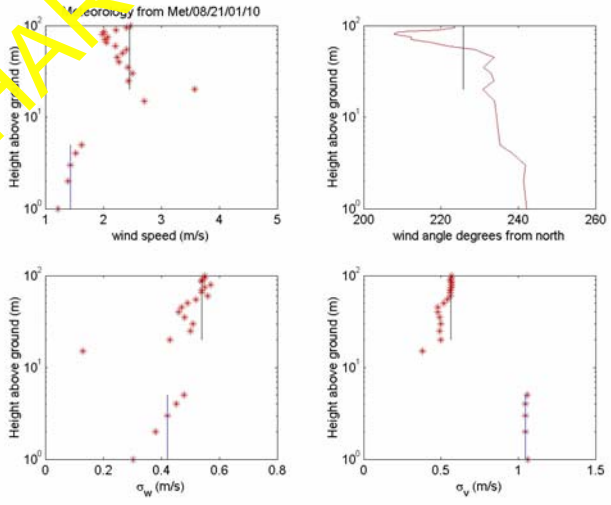
Barrio Logan tracer experiment August 2001

yellow dots - stationary samplers
black lines - mobile van locations

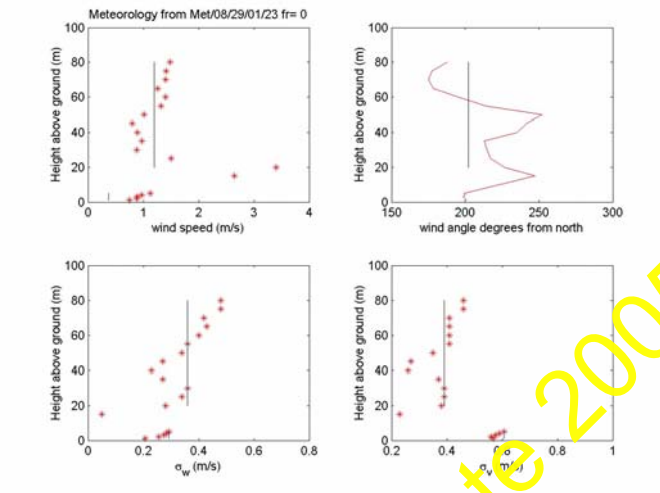


Sampling System

Meteorology



Meteorology



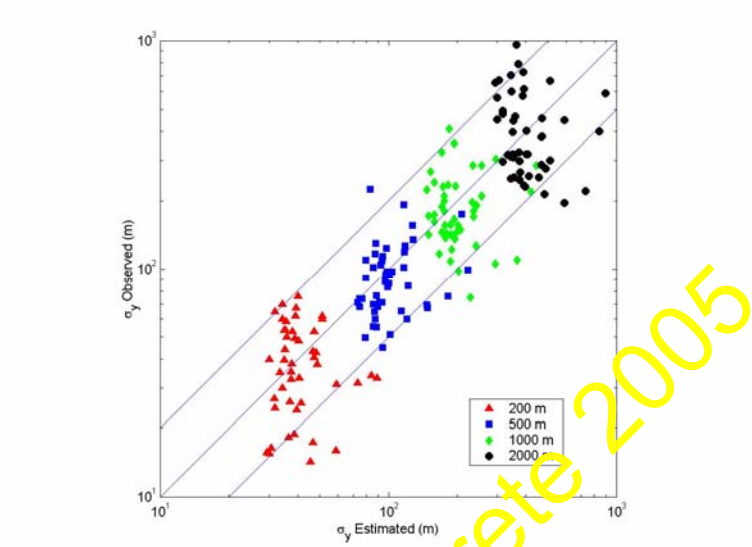
Barrio Logan Model

$$C(x,y,0) = \frac{Q}{\pi U \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)$$

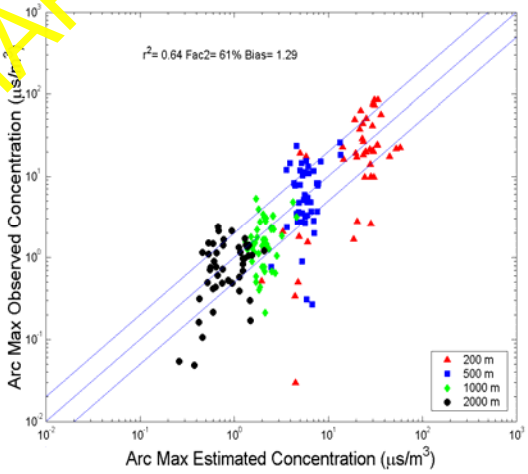
$$\sigma_y = \sigma_{yo} + \frac{\sigma_v x}{U}$$

$$\sigma_z = \frac{\sigma_w x}{U}\left(1 + \frac{x}{50|L|}\right)^{1/2}$$

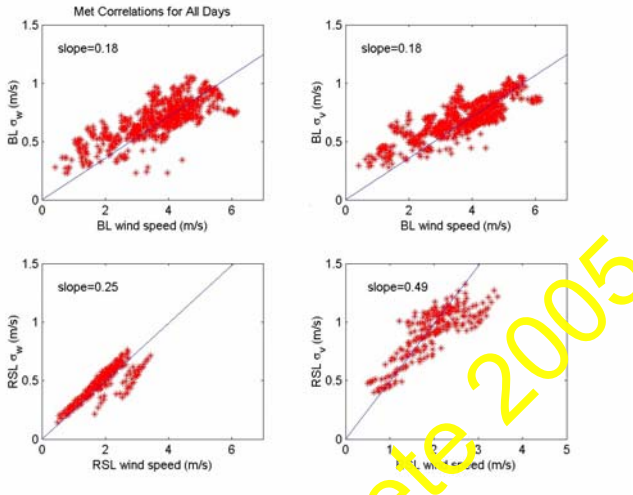
Horizontal Plume Spread



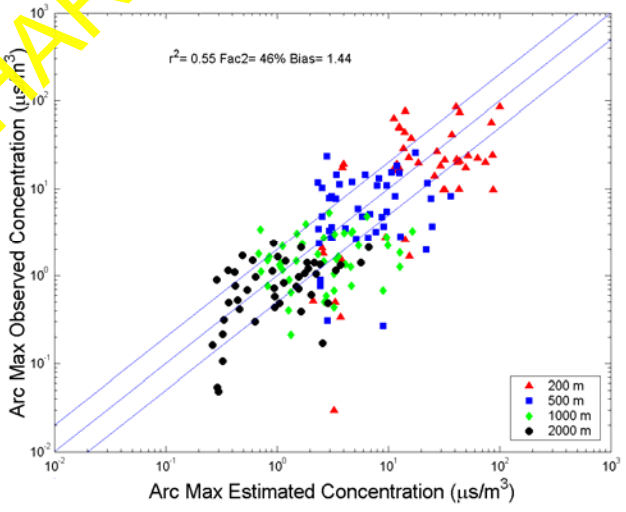
Model Results using Boundary Layer Information and Initial Spread



Meteorological Correlations in Barrio Logan



Model Results Using Briggs Curves



Briggs Dispersion Curves

$$\sigma_y = i_y x \left(1 + a_y x\right)^{b_y}$$

$$\sigma_z = i_z x \left(1 + a_z x\right)^{b_z}$$

Stability Class	i_y	$a_y(m^{-1})$	b_y	i_z	$a_z(m^{-1})$	b_z
A	0.32	0.0004	-1/2	0.24	0.001	1/2
B	0.32	0.0004	-1/2	0.24	0.001	1/2
C	0.22	0.0004	-1/2	0.20	0	0
D	0.16	0.0004	-1/2	0.14	0.0003	1/2
E	0.11	0.0004	-1/2	0.08	0.0015	-1/2
F	0.11	0.0004	-1/2	0.08	0.0015	-1/2

Conclusions

- Turbulence above the urban canopy controls dispersion once the plume spread exceeds canopy height
- Simple models for dispersion provide adequate concentration estimates
- Surface based meteorology might allow us to infer boundary layer properties
- Upwind rural meteorology can be used to estimate urban dispersion –Briggs curves

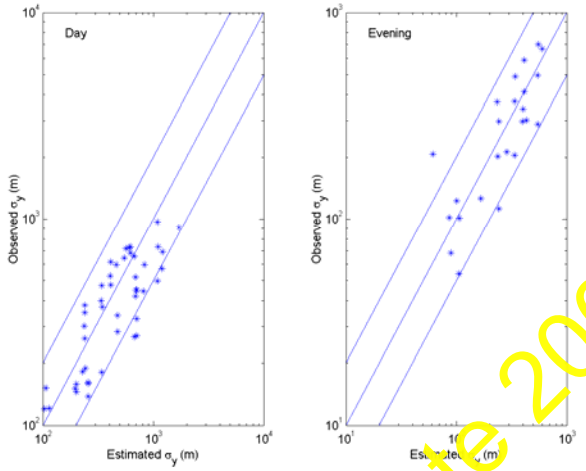
St Louis Experiment

- Conducted in 1963-65
- Zinc Cadmium Sulfide particles released close to the surface
- Doses sampled at 30-50 locations on arcs ranging from 800 m to 16 km from the source along the estimated plume centerline
- Meteorology measured at three surface stations and an instrumented TV tower in the middle of the city
- Resulted in 26 daytime and 16 evening hour-long experiments

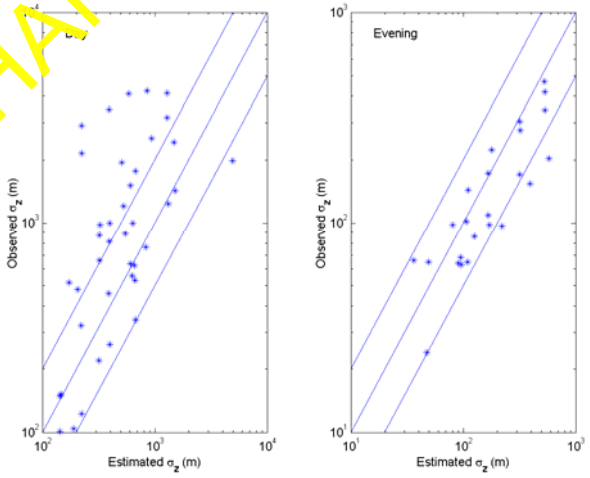
Analysis of Data

- McElroy and Pooler derived horizontal spreads from arc doses, and vertical spreads from maximum ground-level concentrations
- They presented these spreads as functions of stability parameters
- Briggs (1973) presented analytical forms that fit the data
- Used in ISC model as urban dispersion curves

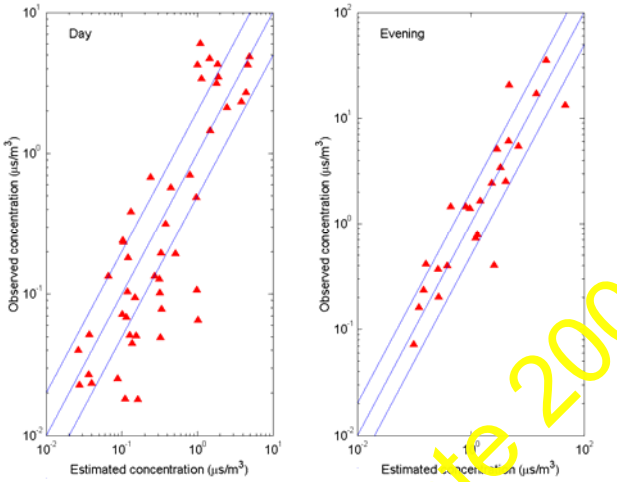
Horizontal Spread Comparison
St Louis



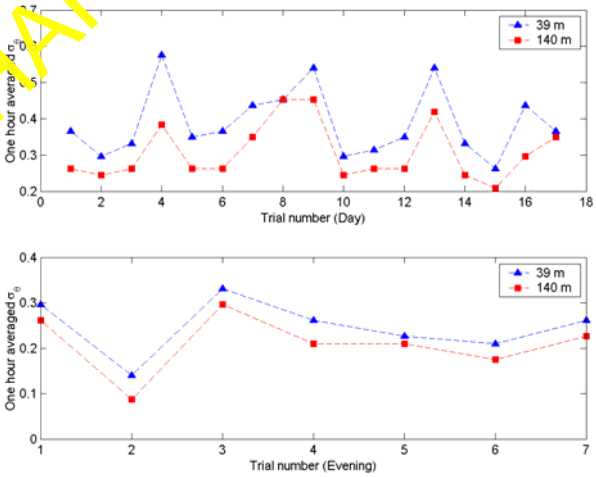
Vertical Spread Comparison
St Louis



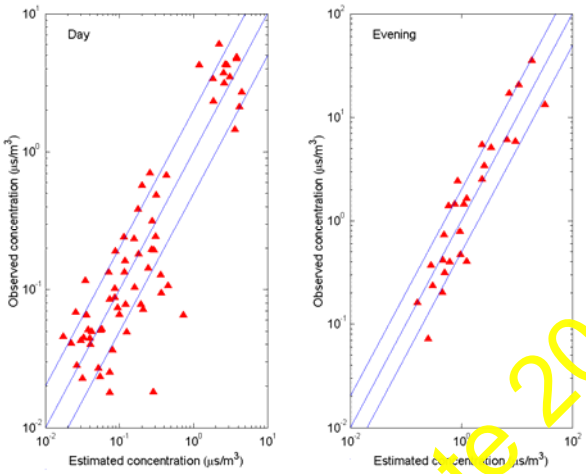
St Louis Model Performance
Briggs Curves



Horizontal Velocity Fluctuations



St Louis Model Performance Onsite Meteorology



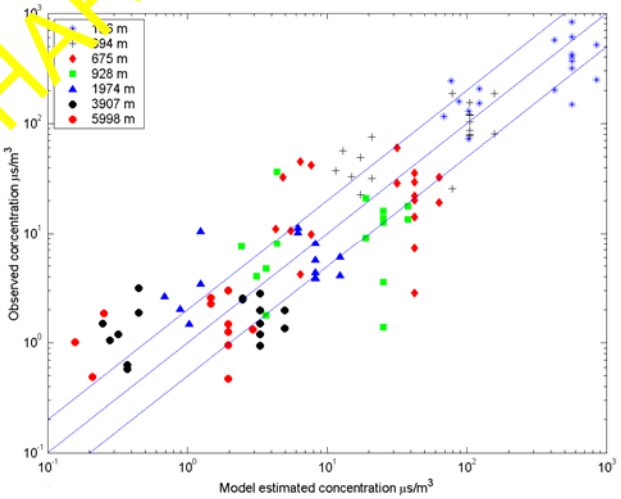
Model Performance Statistics

Model	m_g	s_g	r^2	95% confidence interval of the ratio C_p/C_o
Briggs-Day	1.17	2.85	0.67	0.15-9.1
Briggs-Evening	0.92	2.02	0.82	0.23-3.7
Barrio Logan-Day	1.06	2.22	0.78	0.2-5.0
Barrio Logan-Evening	0.97	1.87	0.85	0.28-3.3

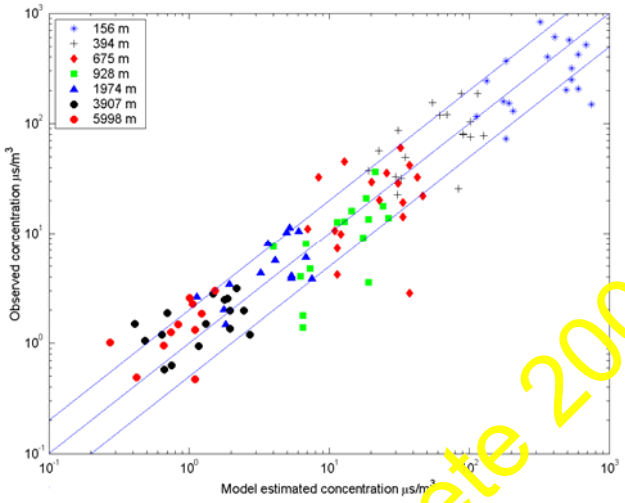
URBAN 2000

- Conducted in Salt Lake City in September-October 2000
- SF_6 released during 8 nights resulting in 18 hours of data
- Concentrations sampled on arcs ranging from 0.15 km to 6 km
- Meteorology measured with sonic anemometers and sodars

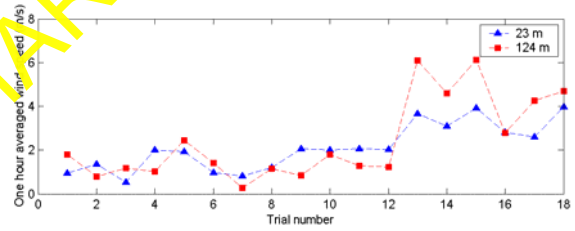
Model Performance
Briggs Curves, SLC Airport

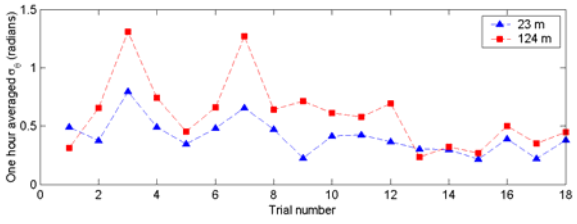


Model Performance
Briggs Neutral Curves, Suburban site, Hanna et al (2003)

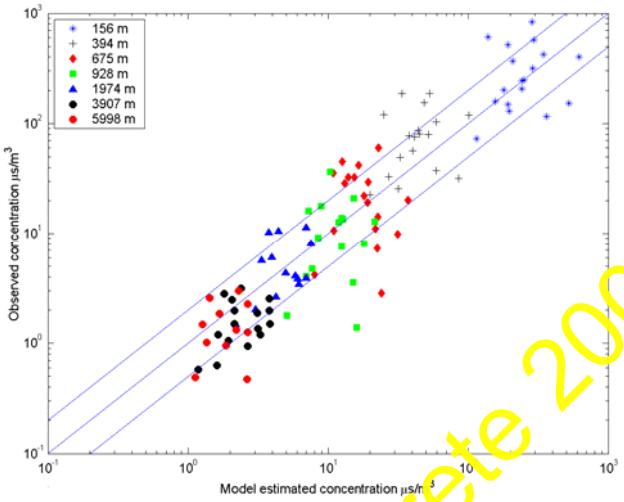


Meteorology





Model Performance
Onsite Meteorology at 23 m, Mixed layer height=150m

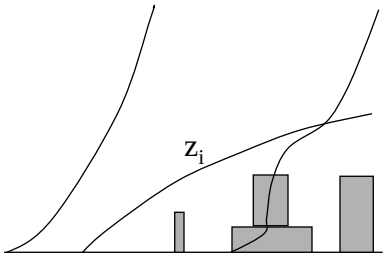


Conclusions

- Ground-level concentrations in urban areas can be estimated using simple models that use plume spreads based on urban boundary layer information
- The relative success of Briggs curves suggests that upwind rural information can be used to estimate urban dispersion
- Need models to estimate urban boundary layer parameters from rural values

Urban Parameters in AERMOD

Internal boundary layer model



$$\Delta T_{u-r} = \Delta T_{max}\left(0.1\ln\left(\frac{P}{P_o}\right)+1\right)$$

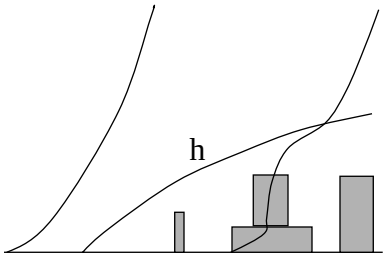
$$H = a\Delta T_{u-r}u_*$$

$$z_i = z_{io}\left(\frac{P}{P_o}\right)^{1/4}$$

$$w_* = \left(\frac{g}{T_o}Hz_i\right)^{1/3}$$

Urban Parameters

Internal boundary layer model



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

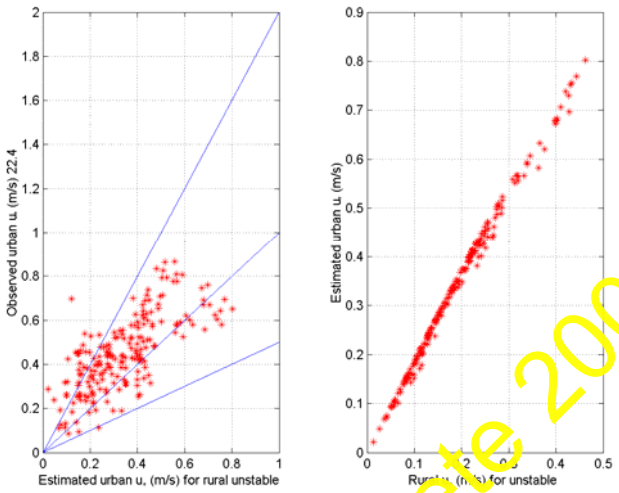
$L_u = \infty$ when $L_r > 0$

$L_u = L_r$ when $L_r < 0$

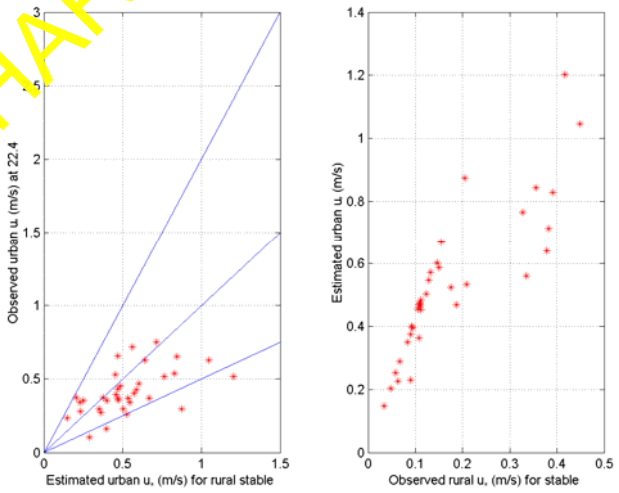
$$U_u(h) = U_r(h)$$

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

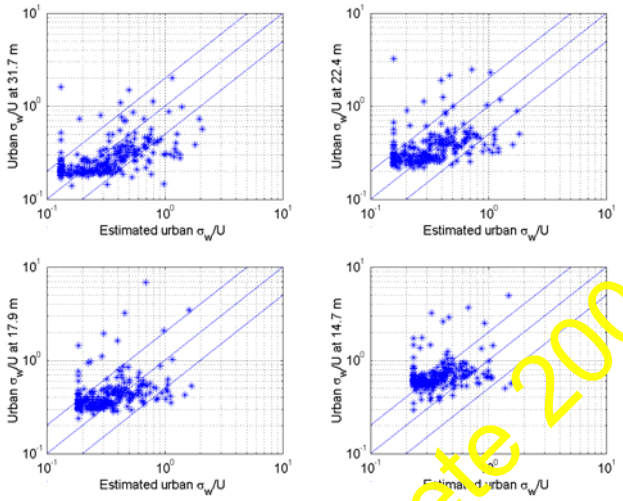
U* predictions for BUBBLE



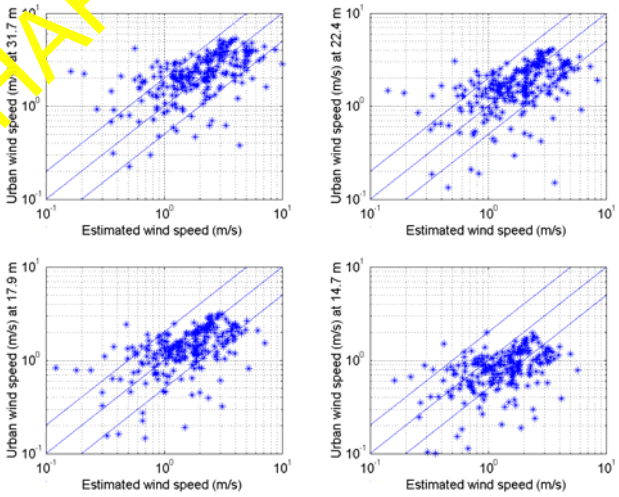
U* predictions for BUBBLE



Turbulent intensity predictions for BUBBLE



Wind speed predictions for BUBBLE



Conclusions

Can formulate simple models to estimate urban boundary layer parameters from rural meteorology