Estimating Meteorological Inputs for Urban Dispersion Models

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Motivation

Can we use single level measurements of mean wind speed and temperature fluctuations made on towers located in urban areas to estimate inputs -***surface friction velocity an sensible heat flux*** - for dispersion models such as AERMOD?

$$WS,\ \sigma_T \xrightarrow{\ ?\ } u_*, Q_0$$

Heat Flux for Unstable Conditions

Formal expression for heat flux: $\overline{w'T'} = r_{wT}\sigma_w\sigma_T$

Measured

Using the standard deviation of the vertical velocity fluctuations,

$$\sigma_w = 1.3u_*\left(1 - \frac{z_r}{\kappa L}\right)^{1/3}$$

Heat flux becomes:

$$Q_0 = r_{wT}\sigma_w\sigma_T = r_{wT}\sigma_T 1.3u_*\left(1 - \frac{z_r}{\kappa L}\right)^{1/3}$$

The correlation coefficient r_{wT}

$$Q_0 = r_{wT}\sigma_w\sigma_T = r_{wT}\sigma_T 1.3u_*\left(1-\frac{z_r}{\kappa L}\right)^{1/3}$$

- Free convection: $$r_{wT} = \frac{(-z_r/L)^{1/3}}{1.3C_1(1-z_r/\kappa L)^{1/3}}$$

- Tillman's (1972) correction: $$r_{wT} = \frac{(C_2-z_r/L)^{1/3}}{1.3C_1(1-z_r/\kappa L)^{1/3}}$$

From field measurements

- Constant r_{wT}

Solving for u_* and Q_0

$$Q_0 = r_{wT}\sigma_w\sigma_T = r_{wT}\sigma_T 1.3u_*\left(1-\frac{z_r}{\kappa L}\right)^{1/3}$$

Solve iteratively for Q_0 and u_* using two equations:

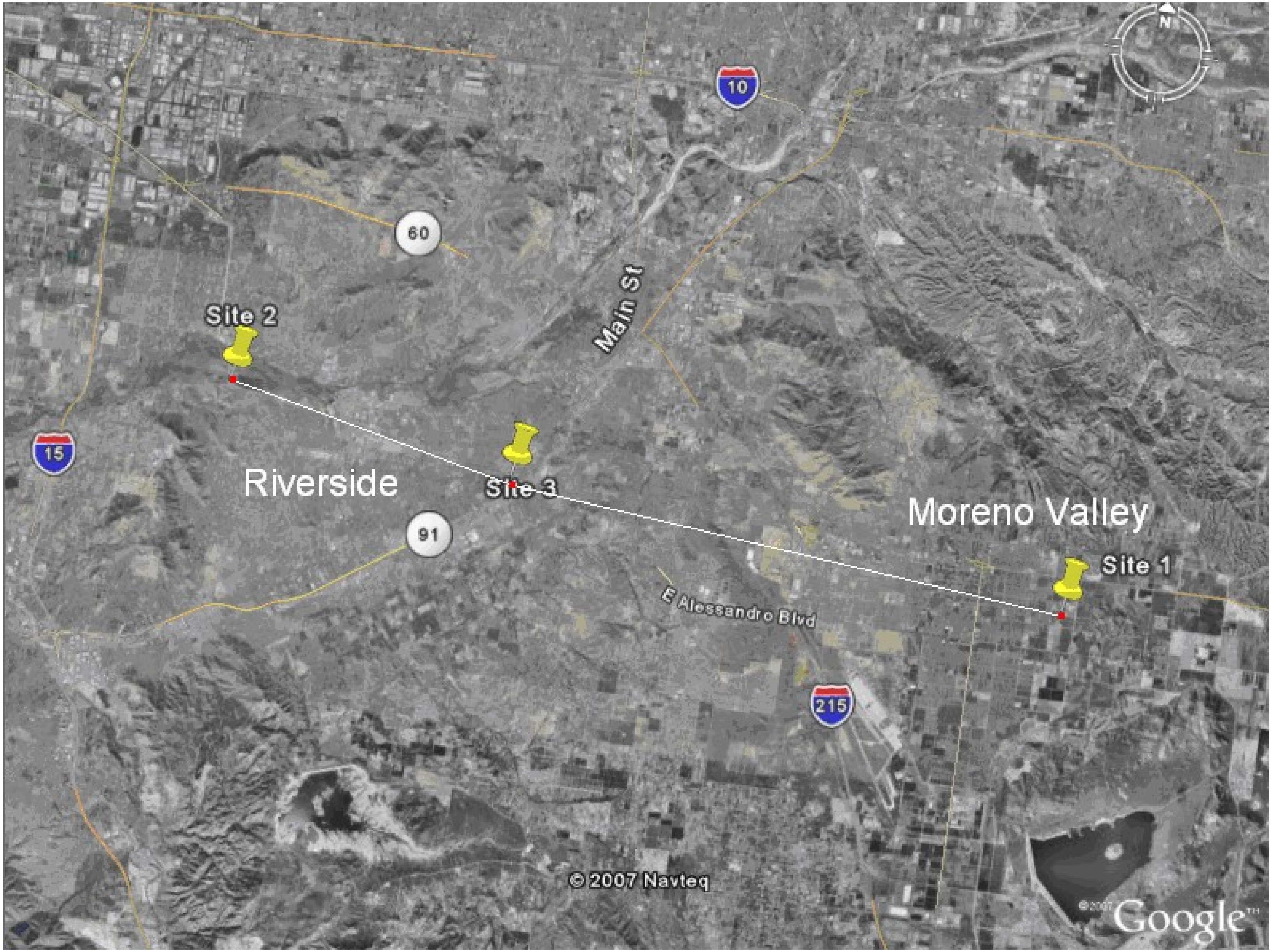
- u_* expressed in terms of u (measured) and Q_o - Wang and Chen (1980) approximation
- Q_o as expressed above

Field Study

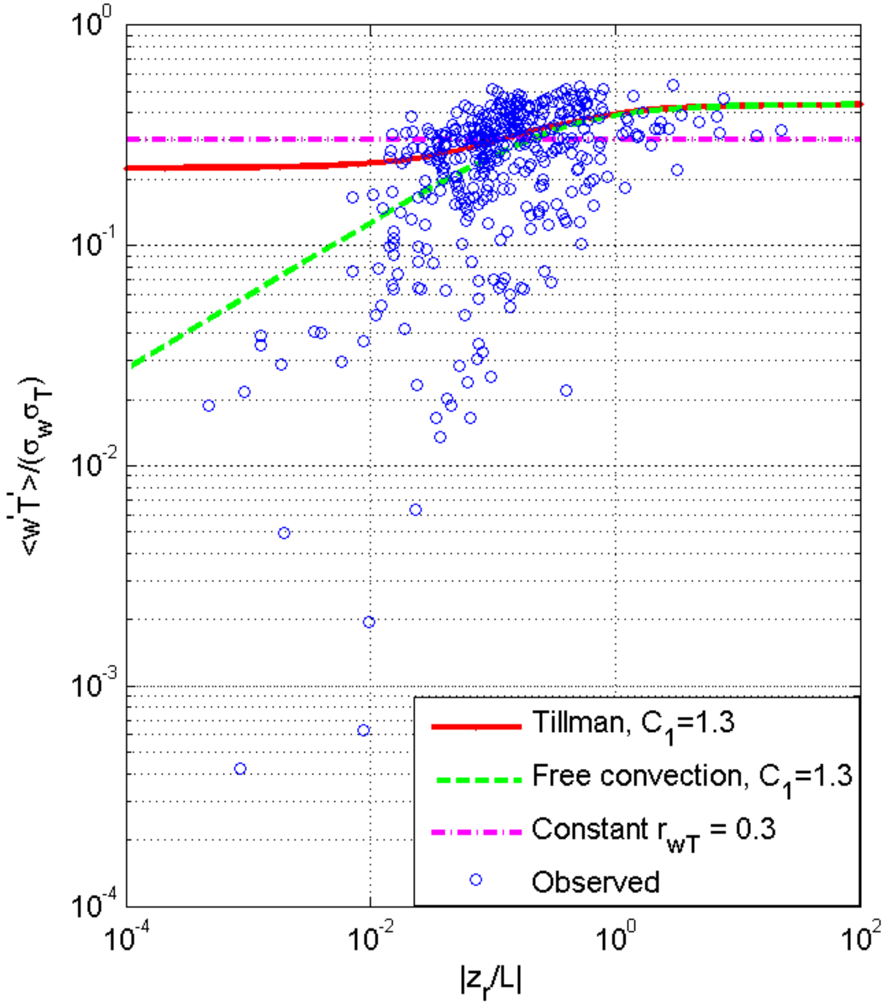
- The meteorological data measured at three sites in Riverside County, California, from early February through late April 2007
- The upwind suburban site is in desert plain in Moreno Valley, the downwind suburban site is on top of a bluff in suburban Riverside, and the center urban site is located on a street corner in downtown Riverside
- Each site was equipped with a 3 meter measurement tower.

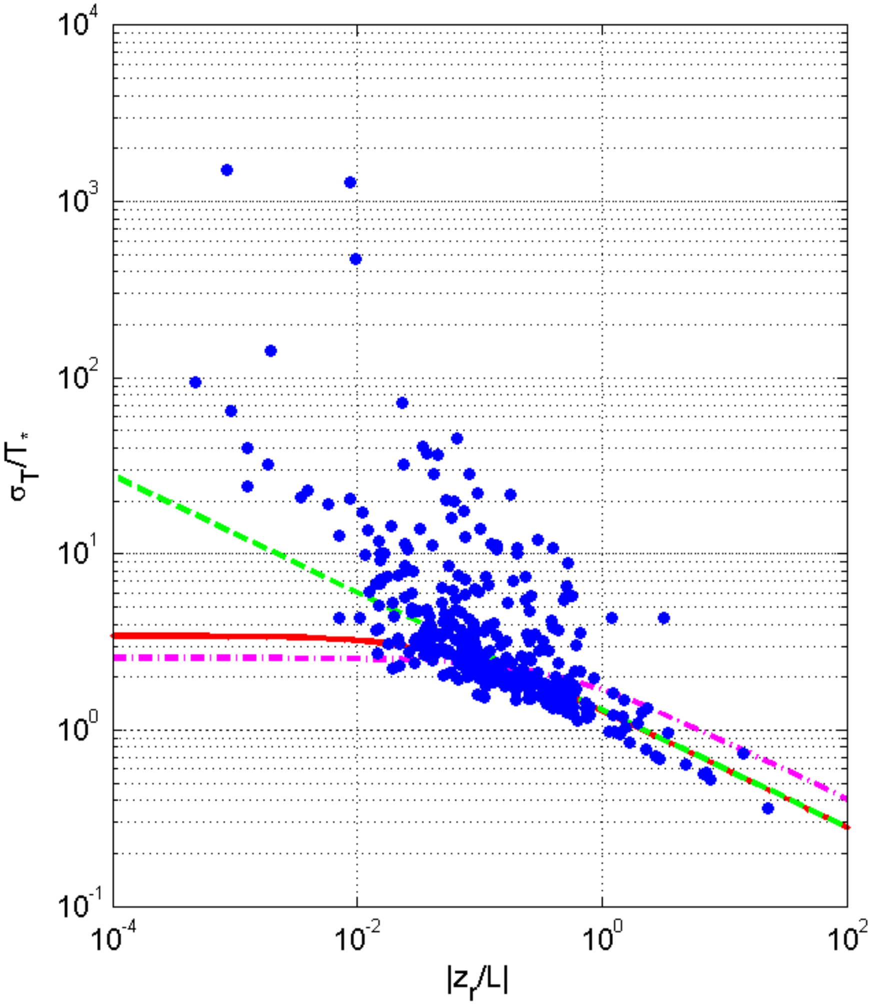


Overview of the site locations



Observed r_{wT} and σ_T/T_*





Model Performance Statistics

The performance of the models is quantified using

$$m_g = \exp(\langle \varepsilon_m \rangle)$$

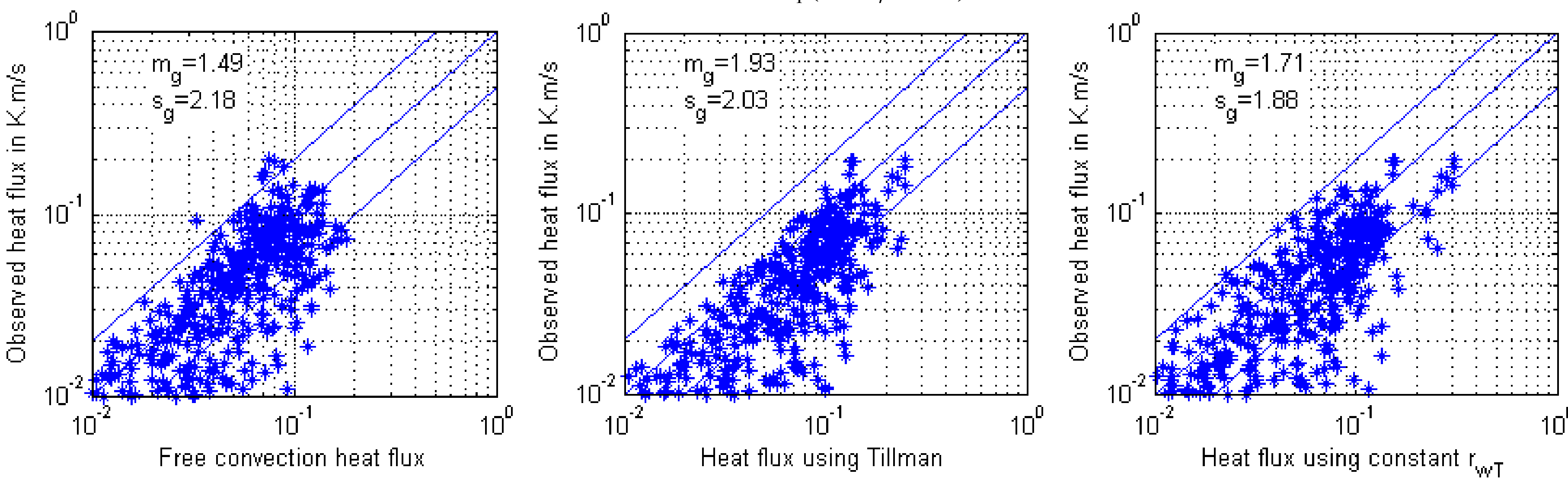
$$s_g = \exp(\text{standard deviation of } \varepsilon_m)$$

$$ln(C_o) = ln(C_p) + \varepsilon_m$$

Performance of Three Methods

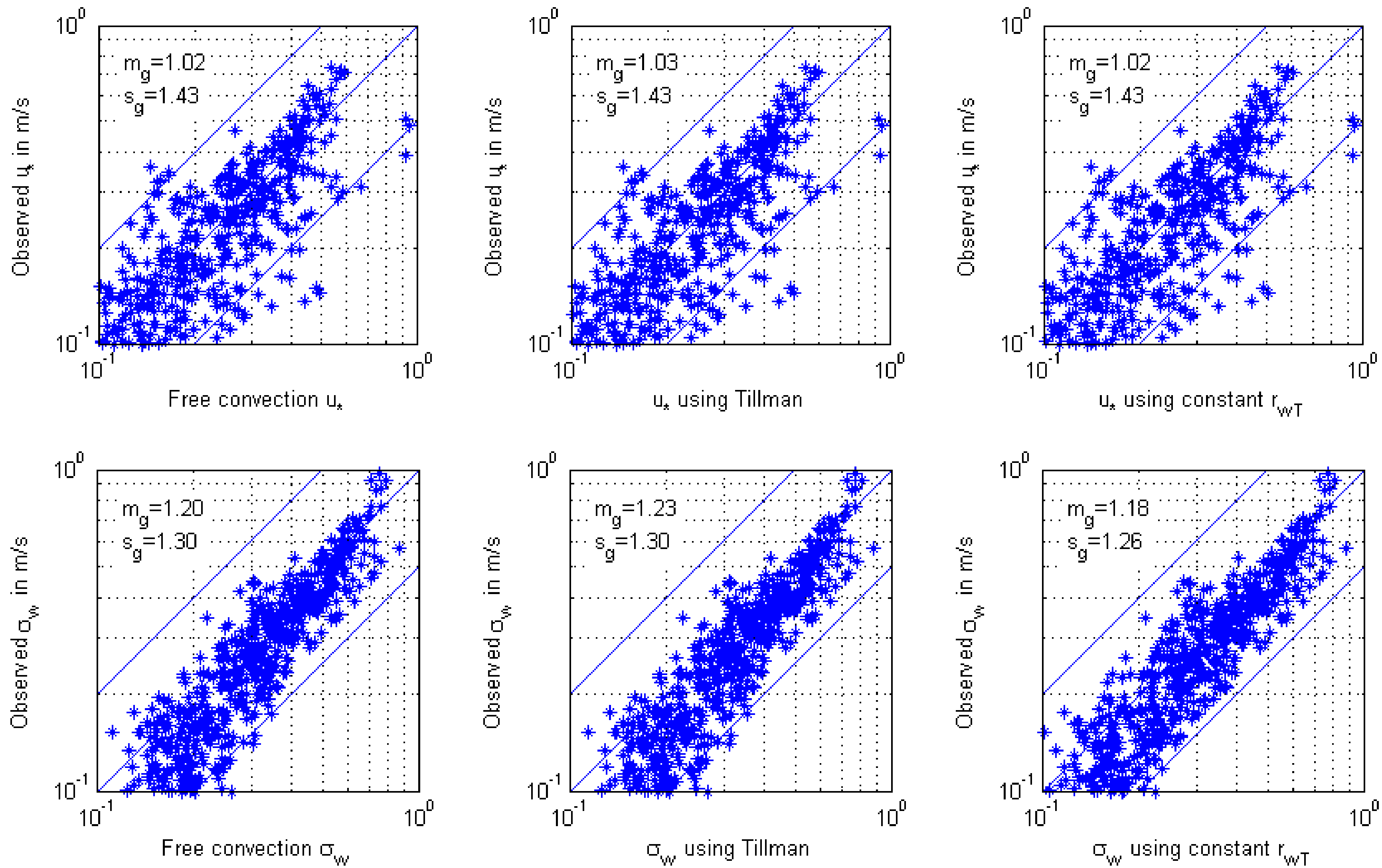
Observations were made at the urban Riverside site

$$r_{wT} = \frac{(-z_r/L)^{1/3}}{1.3C_1(1-z_r/\kappa L)^{1/3}} \qquad r_{wT} = \frac{(C_2-z_r/L)^{1/3}}{1.3C_1(1-z_r/\kappa L)^{1/3}} \qquad r_{wT} = const.$$



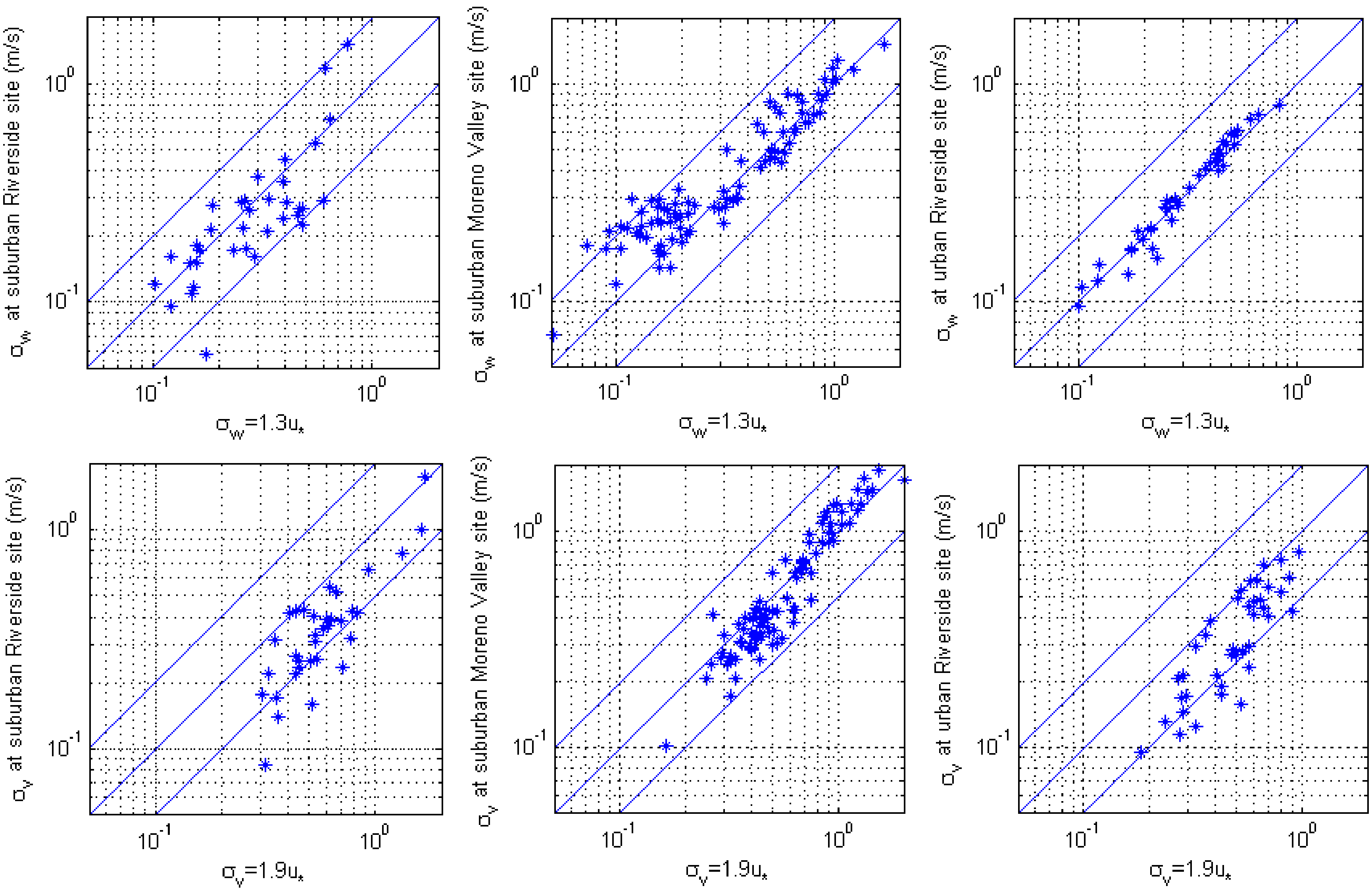
- Heat flux is overestimated at the urban Riverside site.
- The performance of the constant r_{wT} is similar to that of Tillman's method
- The simple free convection estimate (*C_1=1.3*) provides estimates of the heat flux that compare well with those from methods that account for wind shear

Estimation of u_*, σ_w using Estimated Heat Flux



- The overestimation of heat flux does not appear to affect estimates of u_*. However σ_w is overestimated by about 20% because the estimates depend explicitly on the surface heat flux, Q_0.

Can we estimate turbulent velocities in the **stable BL** using u_* ?



- The similarity relationships $\sigma_w=1.3u_*$ and $\sigma_v=1.9u_*$ provide adequate descriptions of the observations

Estimation of u_* for Stable Conditions

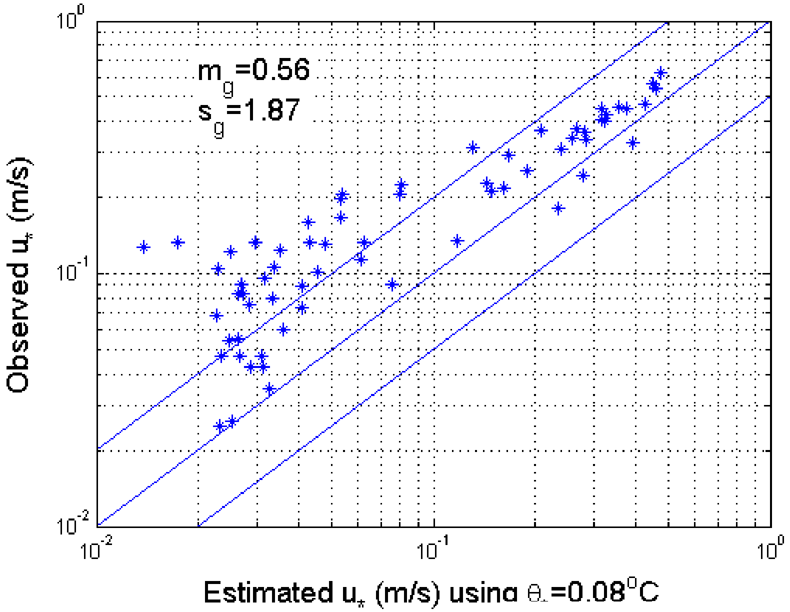
- Method based on the empirical observation (Venkatram, A. 1980)

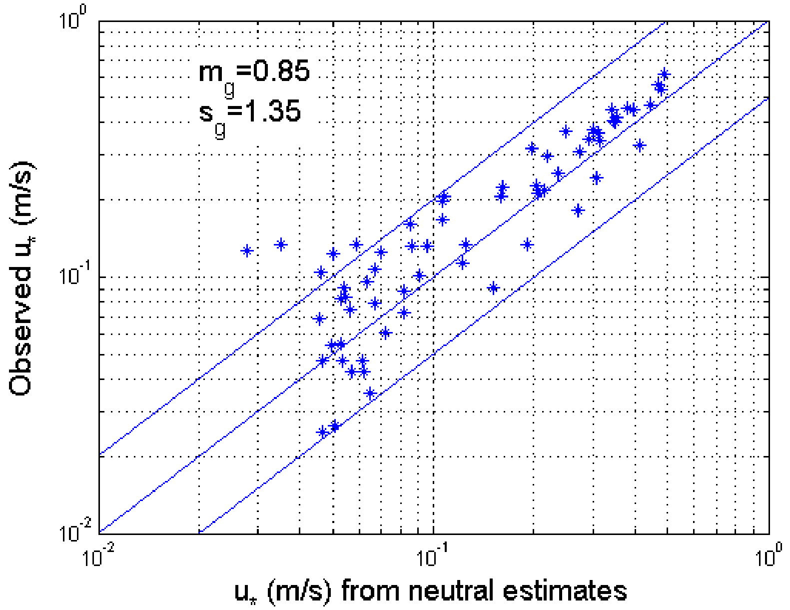
$$\theta_* = 0.08^o C$$

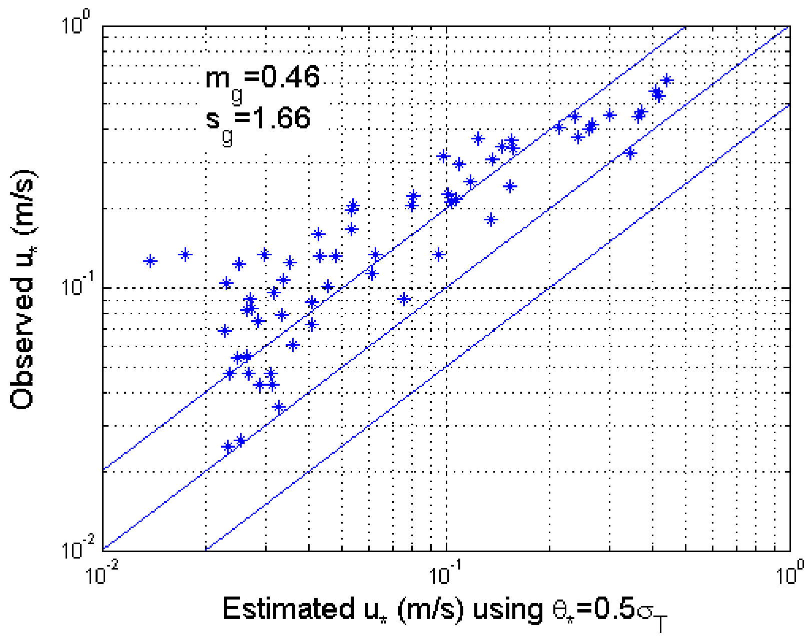
$$u_* = C_D u\left(z_r\right)\left\{\frac{1}{2} + \frac{1}{2}\left[1 - \left(\frac{2u_0}{C_D^{1/2} u}\right)^2\right]^{1/2}\right\}$$

- The second version of this method estimates θ_* from $\theta_*=0.5\sigma_T$ (Stull, R.B. 1988). In principle, this should yield better results than assuming a constant θ_*.

Performance of Methods to Estimate u_* for Stable Conditions







Conclusions

- During unstable conditions, the simple free convection estimate provides estimates of the heat flux that compare well with those from methods that account for stability effects through the M-O length
- The overestimation of heat flux does not appear to affect estimates of u_*, but results in overestimation of σ_w
- During stable conditions, σ_w *and* σ_v are related to u_* through similarity relationships derived in flat terrain
- u_* is underestimated at low values using constant θ_*. Estimates of u_* based on σ_T do not improve the results.
- Assuming neutral conditions provides estimates of u_* that compare better with observations than those from methods that account for stability.

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