Dispersion of Buoyant Emissions from a Low Level Urban Source

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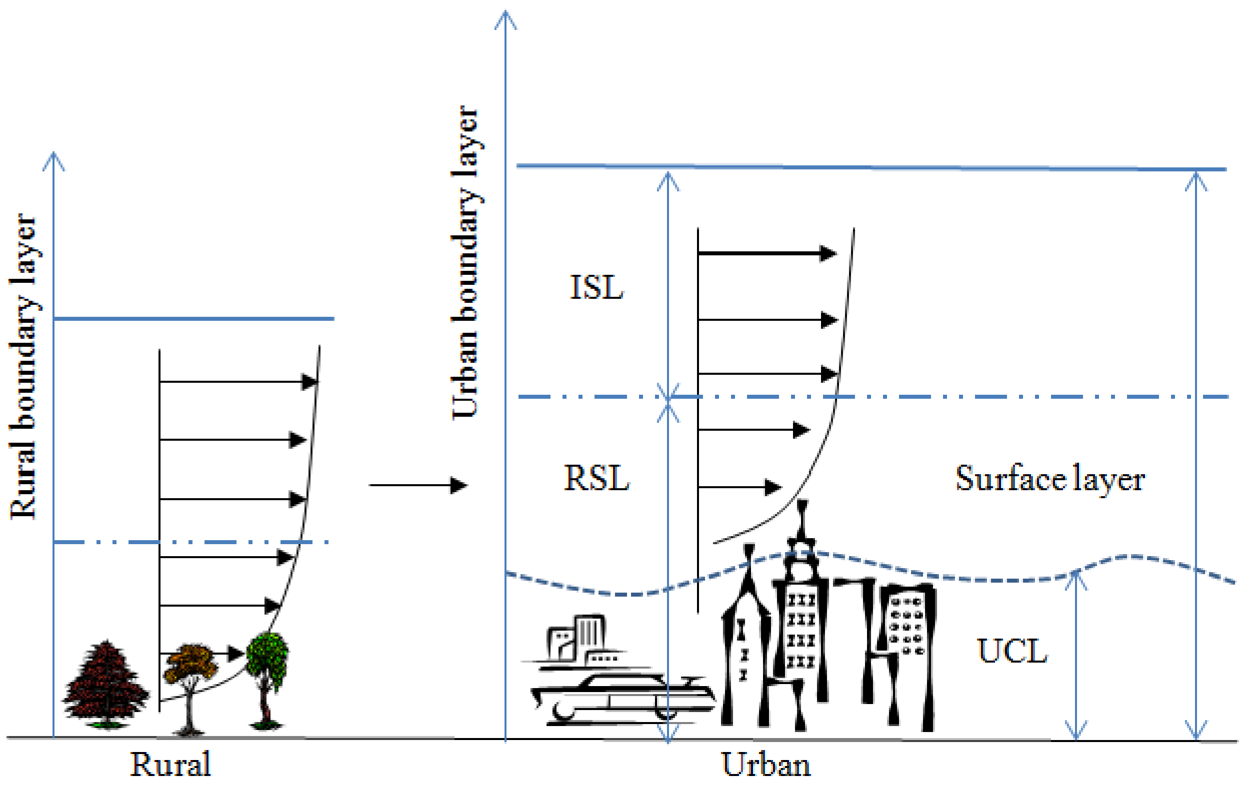
What are needed to know?

- Emissions
- Source characteristics
- Building geometry
- Urban meteorology

What is the significance of urban boundary layer?



Presence of buildings. Decreased mean wind. Increased turbulence.

Tracer Study

Conducted in Palm Springs, CA to obtain data on dispersion from low level and buoyant releases in an urban area

Release Site

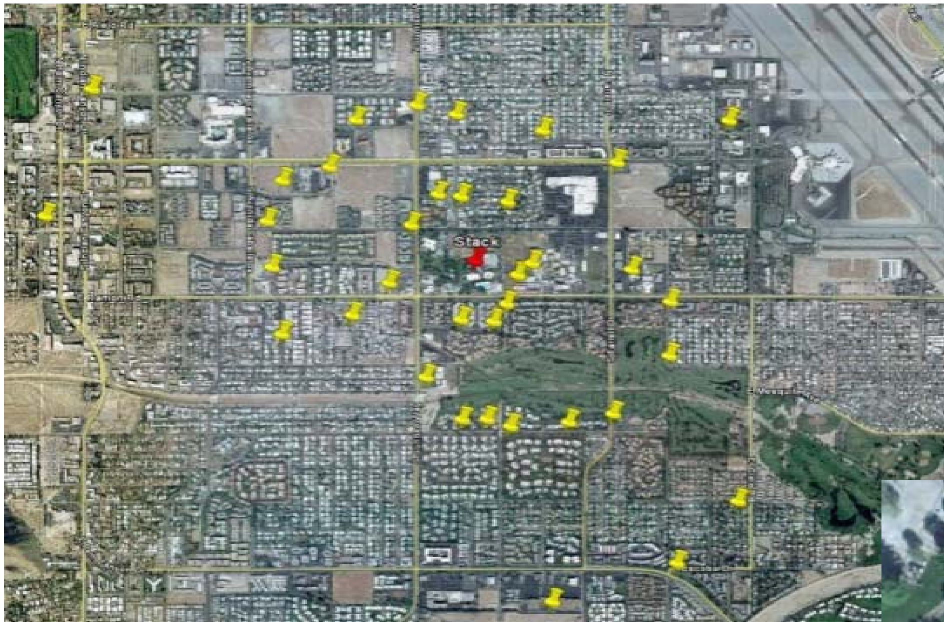
Stack height: 9.3 m

Exit temperature: 460 k

Exit velocity: 11 m/s

Emission rate: 3.3 kg/hr

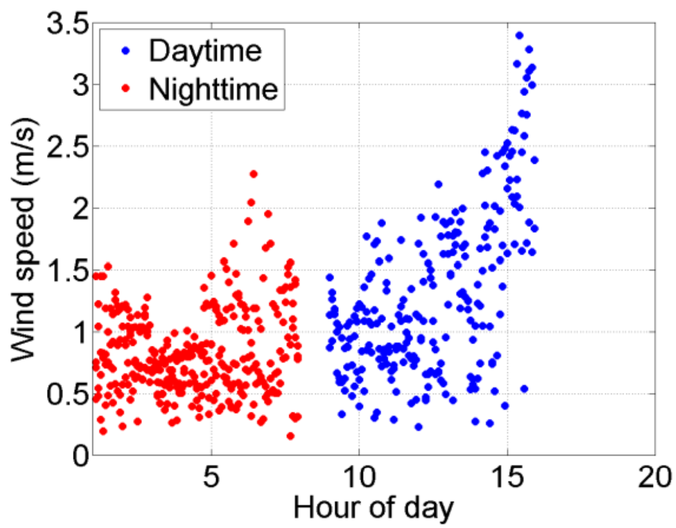
Sampling Sites

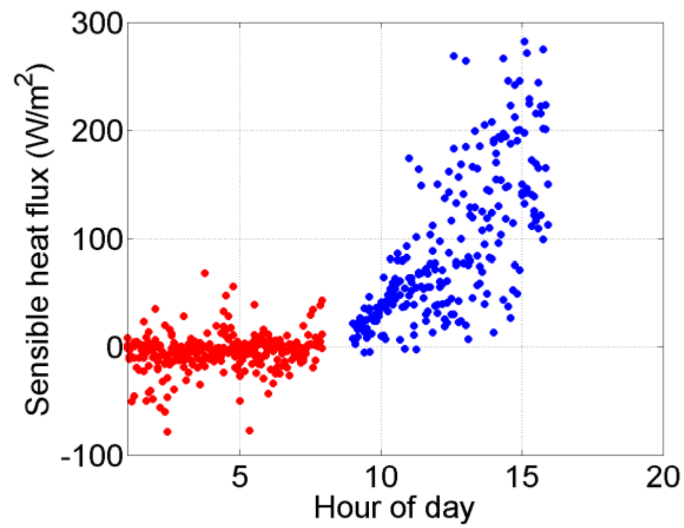


Flagpole: 1 m

48 samplers arranged in arcs at distances from 60 to 2000 m from the source;
Three daytime and four nighttime releases.

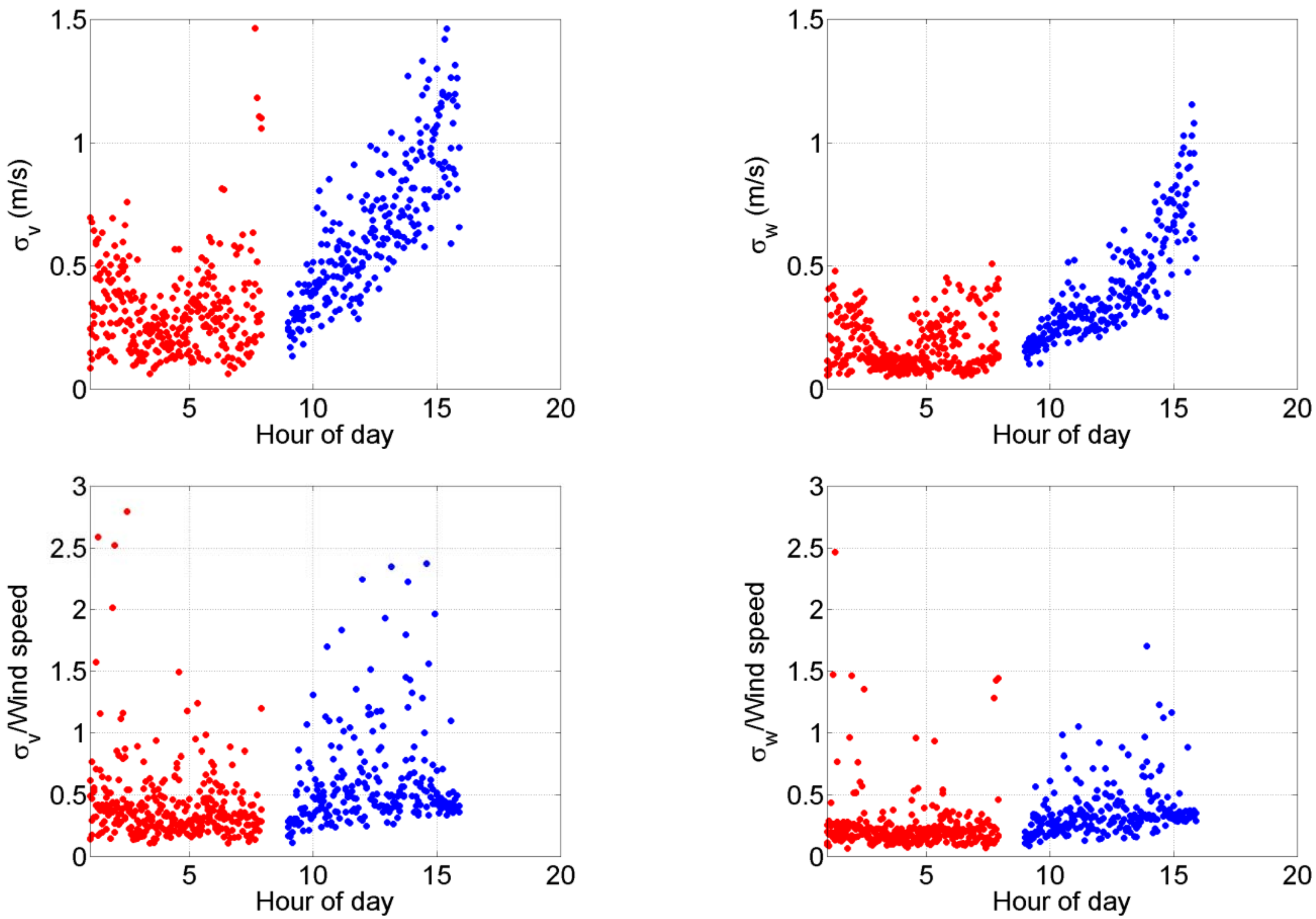
Meteorology during releasing periods





	U (m/s)			*Hs* (W/m^2)
	The percentile		Mean	Mean
	Median	95^{th}		
Daytime	1.1	2.6	1.3	95
Nighttime	0.8	1.4	0.8	-16

Turbulent levels

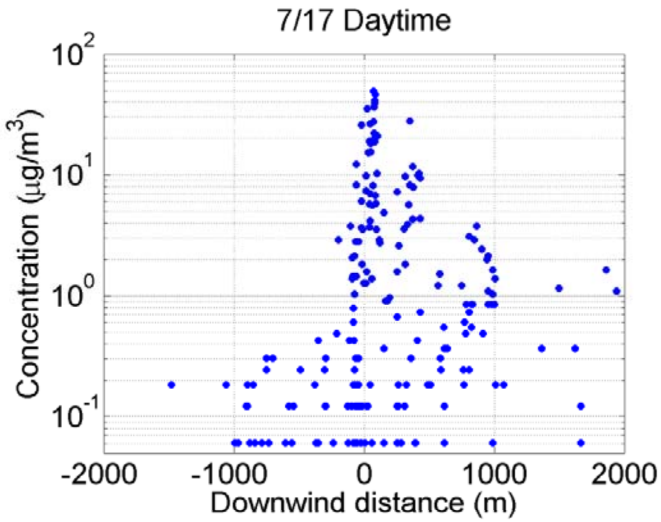


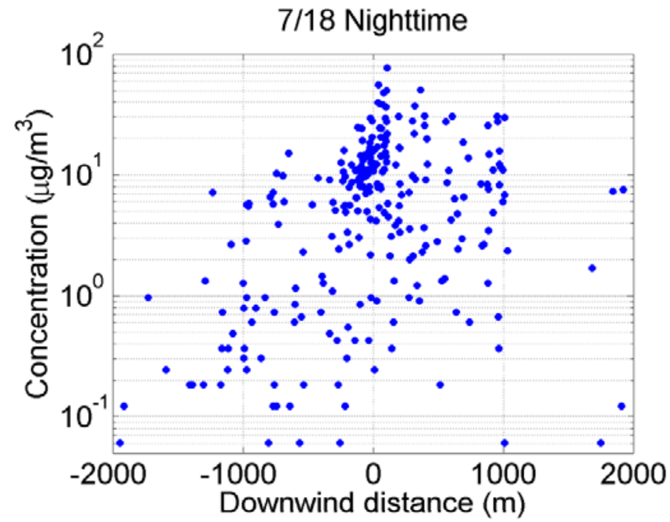
Turbulent levels

	$\sigma\text{-}^{-}_{w}$ (m/s)			$\sigma\text{-}^{-}_{v}$ (m/s)			$\sigma\text{-}^{-}_{w}/U$			$\sigma\text{-}^{-}_{v}/U$		
	The percentile		Mean	The percentile		Mean	The percentile		Mean	The percentile		Mean
	5^{th}	50^{th}		5^{th}	50^{th}		5^{th}	50^{th}		5^{th}	50^{th}	
Daytime	0.2	0.3	0.4	0.3	0.6	0.7	0.2	0.3	0.4	0.3	0.4	0.6
Nighttime	0.06	0.1	0.2	0.1	0.3	0.3	0.1	0.2	0.3	0.2	0.3	0.5

Meandering is important.

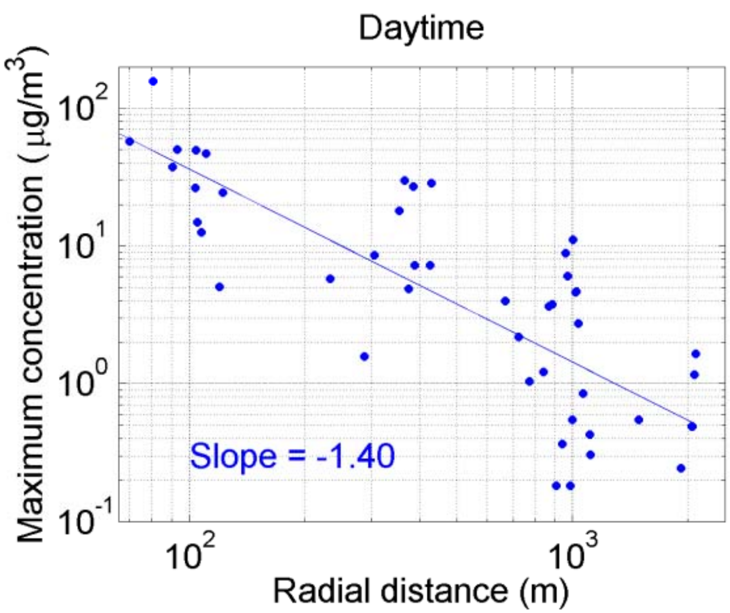
Spatial variation of Observed Concentrations

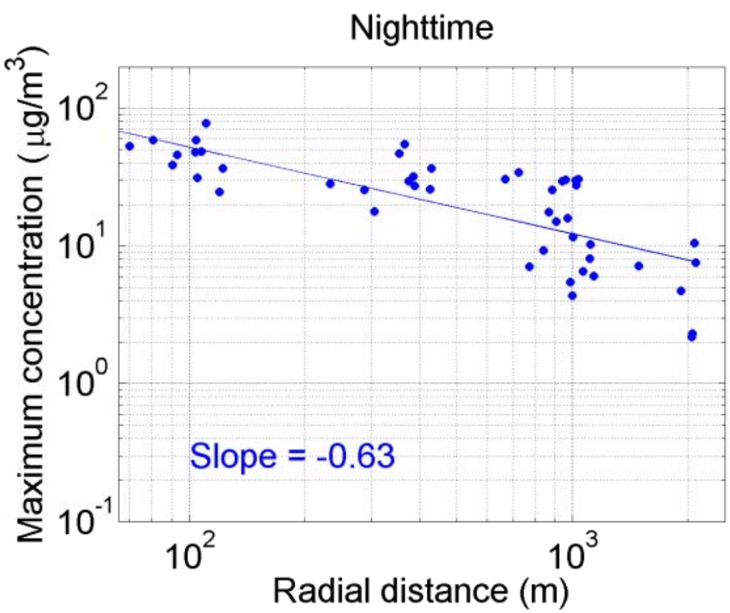




	Upwind concentration (μg/m^3)				Downwind concentration (μg/m^3)			
	The percentile			Maximum	The percentile			Maximum
	30th	50th	95th		30th	50th	95th	
Nighttime	1	5	18	29	4	8	39	77
Daytime	0	0.06	3	26	0.2	1	36	50

Spatial variation of Observed Concentrations



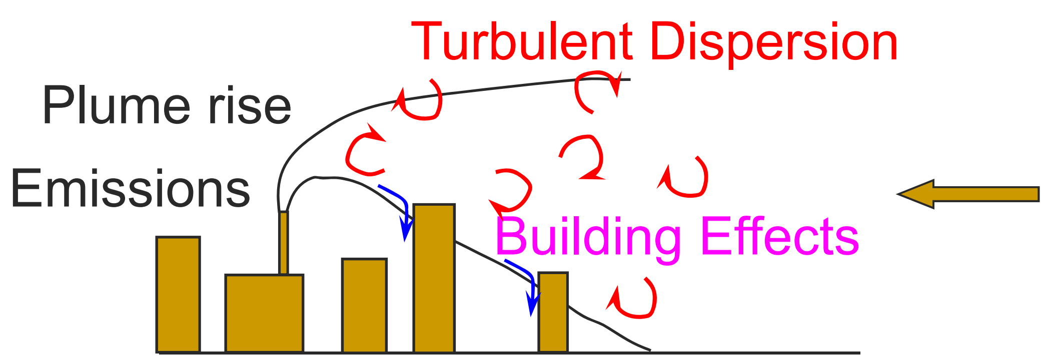


AERMOD

$$C(x,y,z) = \frac{1}{\sqrt{2\pi}\sigma_z U} H(x,y)\left[exp\left(-\frac{(z-h_{eff})^2}{2\sigma_z^2}\right) + exp\left(-\frac{(z+h_{eff})^2}{2\sigma_z^2}\right)\right]$$

$$H(x,y) = f_p H_p(x,y) + \left(1 - f_p\right) H_r(x,y)$$

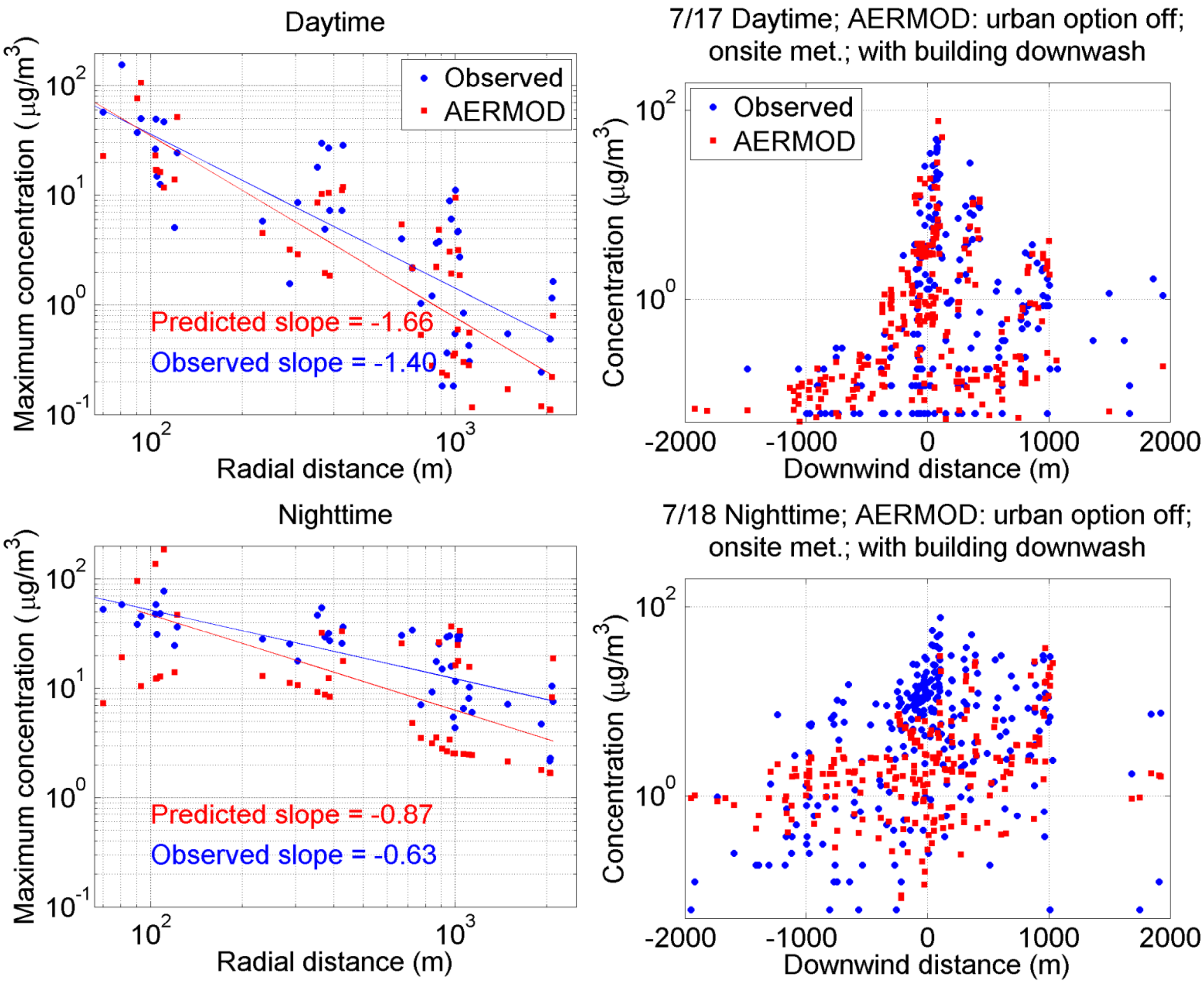
$$H_p = \frac{1}{\sqrt{2\pi}\sigma_y} exp\left(-\frac{y^2}{2\sigma_y^2}\right), \quad H_r = \frac{1}{2\pi r}.$$



Governing Processes

Venkatram (2008,CEC)

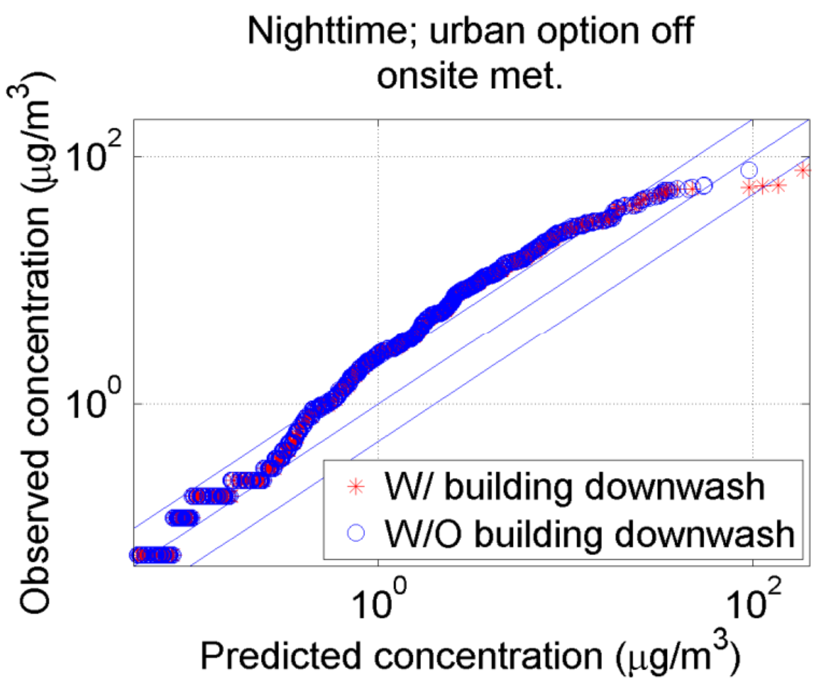
AERMOD Performance



Including meandering

High plume rise, mixing height, vertical spread?

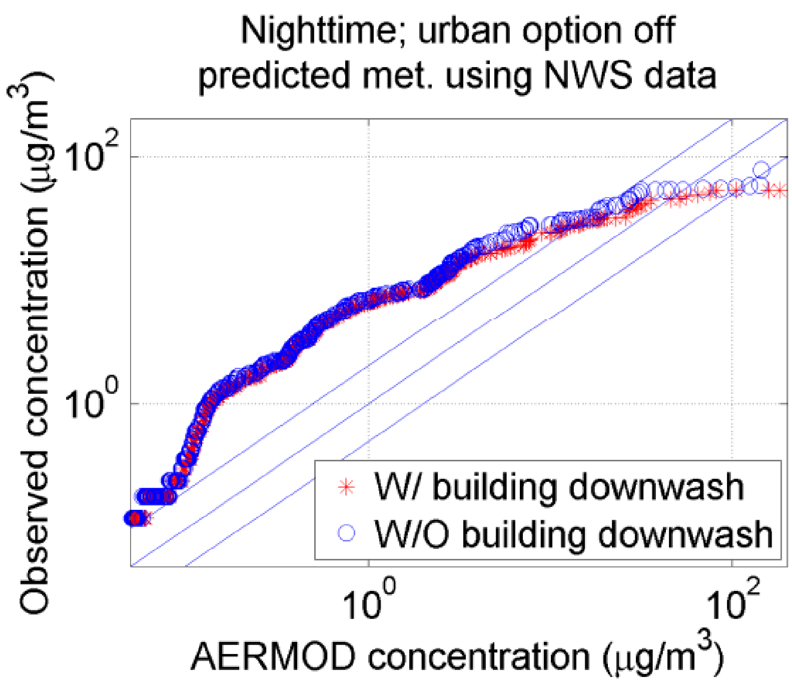
Sensitivity Studies on Nighttime Prediction



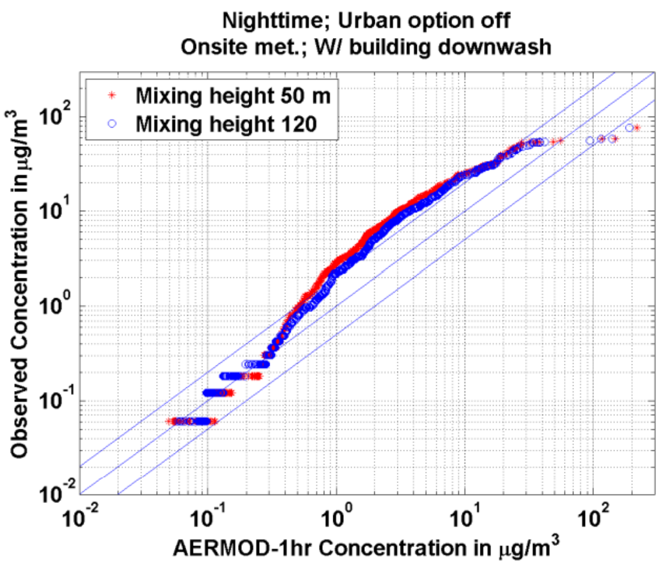
Q-Q plots compare distributions to minimize the scatter associated with inherent uncertainty

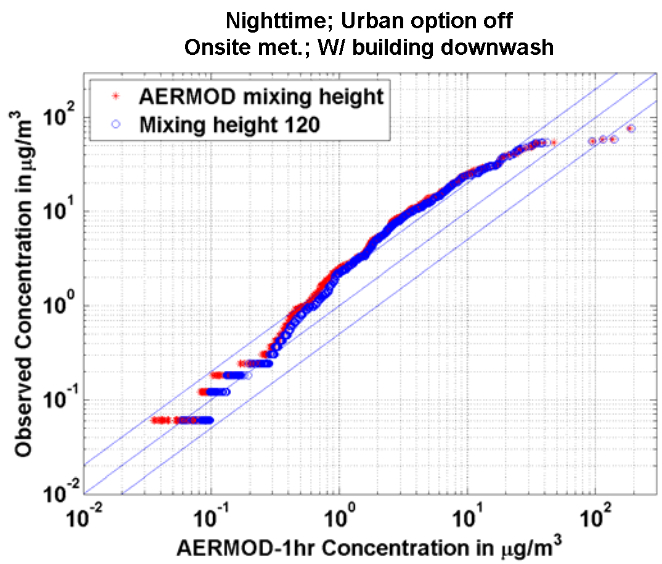
Average plume rise: 35 m

Sensitivity Studies on Nighttime Prediction



Sensitivity Studies on Nighttime Prediction





Fixed mixing height does not improve the performance. Right panel indicates the mixing heights estimated by AERMET are equivalent to fixed mixed layer height of 120 m.

Vertical spread is too high? Pollutants are trapped?

Modification to AERMOD

Model to estimate dispersion of elevated releases into a shear-dominated boundary layer

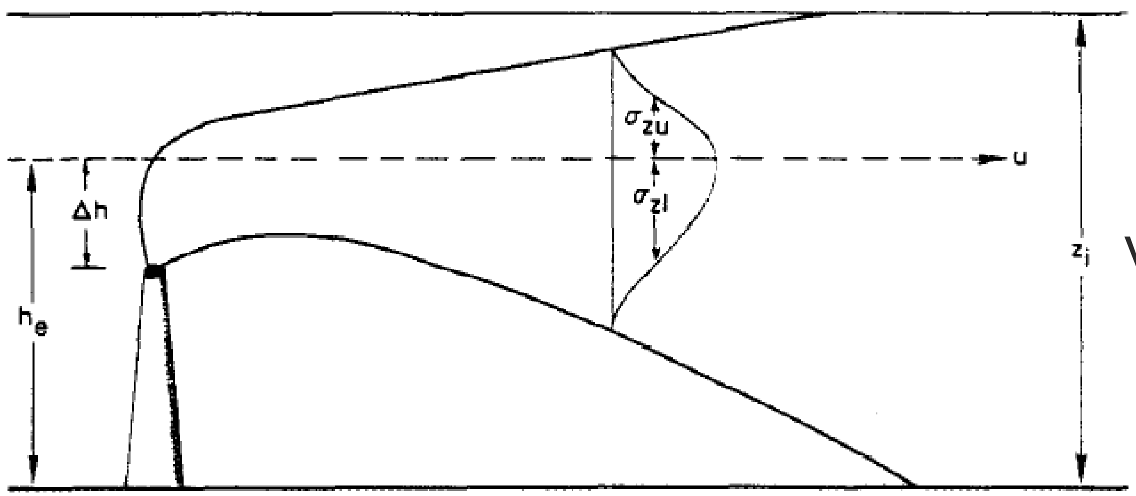


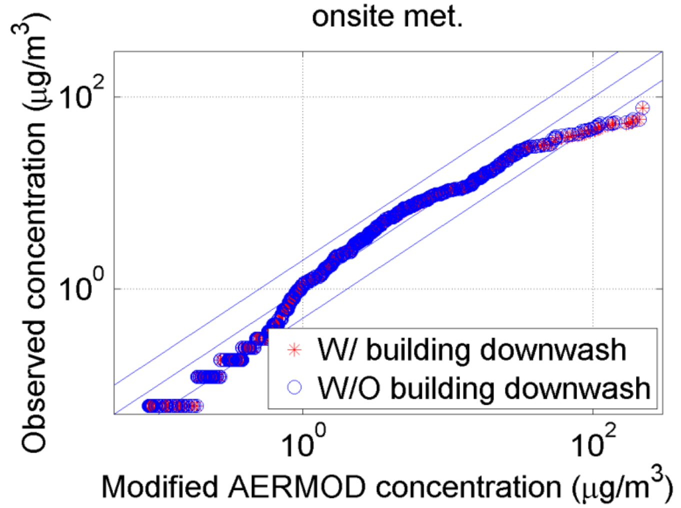
Fig. 1. Simplified picture of vertical dispersion in the neutral boundary layer.

Venkatram and Paine (1985)

$$\sigma_{zu} = min(\sigma_{zu}, z_i - H_e)$$

$$\sigma_{zl} = min(\sigma_{zl}, H_e)$$

$$\sigma_z = min\left((\sigma_{zu} + \sigma_{ul})/2\,, \sqrt{2/\pi}\, z_i\right)$$



Conclusions

- AERMOD provides an adequate description of concentrations associated with a buoyant release from the low level source during the daytime.
- AERMOD underestimates concentrations during the night when turbulence is generated by wind shear. A simple modification and onsite meteorology can improve its performance.

Thanks!

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