Atmospheric Flow Decoupling in an Urban Environment and its Effects on Plume Dispersion

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What Is Flow Decoupling?

- Occurs when the interaction of the atmospheric layer at the surface with the layers above is severely limited
- Wind direction at the surface diverges from the wind direction aloft

What Can Cause Flow Decoupling?

- Low wind speeds
  - Results in lower turbulence
- Reduced bouyant production of turbulence at night
- Flow obstructions (e.g. deep street canyons)

How Might Flow Decoupling Be Expressed?

- Plume dispersion pattern diverging from overall wind field
  - Apparent “upwind dispersion” of plume
- Surface vs. rooftop wind speeds
- Plume concentration fluctuations
- Reduced vertical mixing
- Slow plume arrival times
- Slow plume decay times

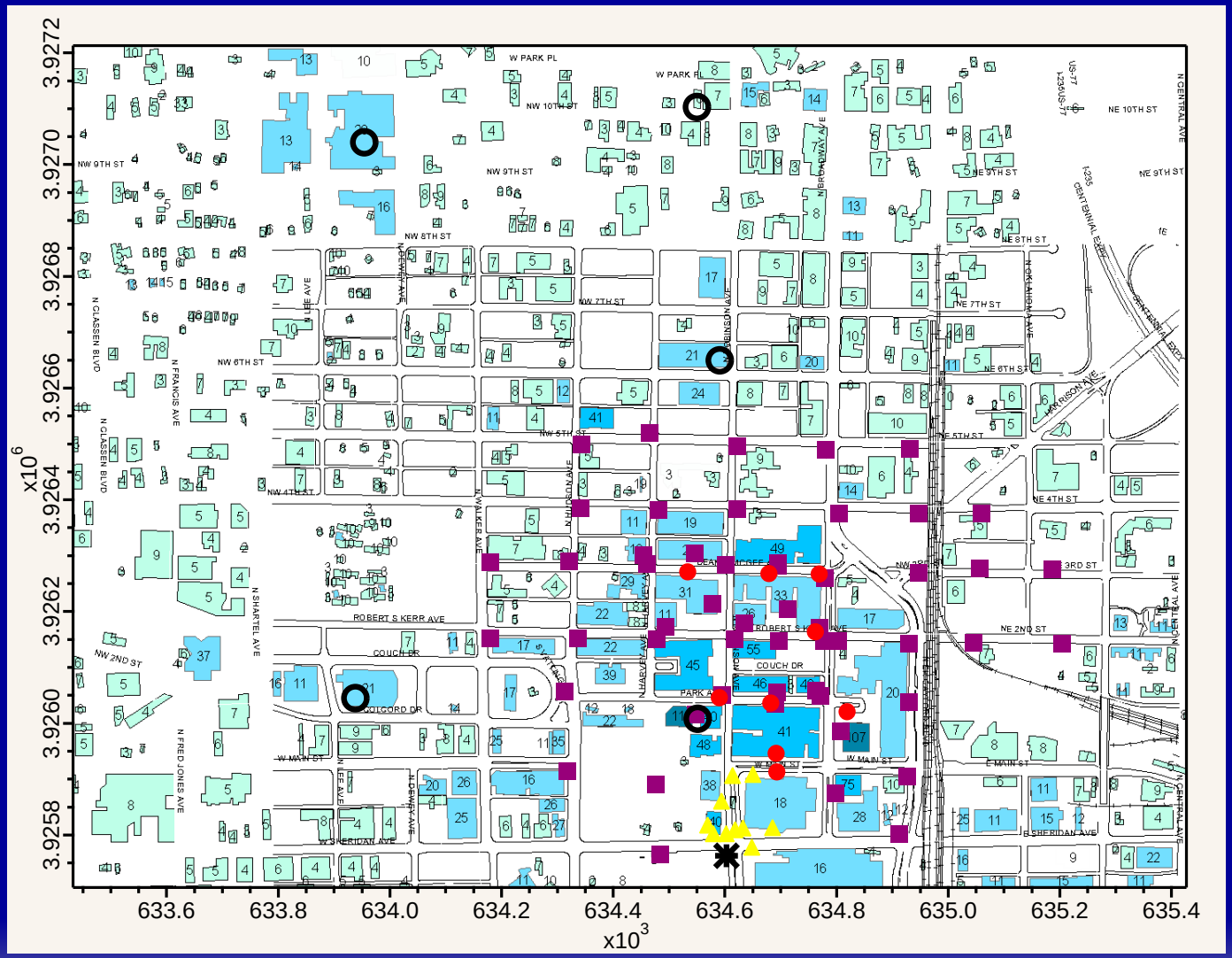
Joint Urban 2003 (JU03) SF_6 Atmospheric Tracer Field Study

- Dispersion experiment conducted in Oklahoma City, July, 2003
- 6 daytime and 4 nighttime experiments
  - Multiple puff and continuous ½ hr releases
- Multiple collaborators and measurements
  - Approximately 150 stationary bag samplers
  - Ten real-time tracer analyzers
  - Over 100 3-D sonic anemometers
  - Surface, rooftops, and street corners

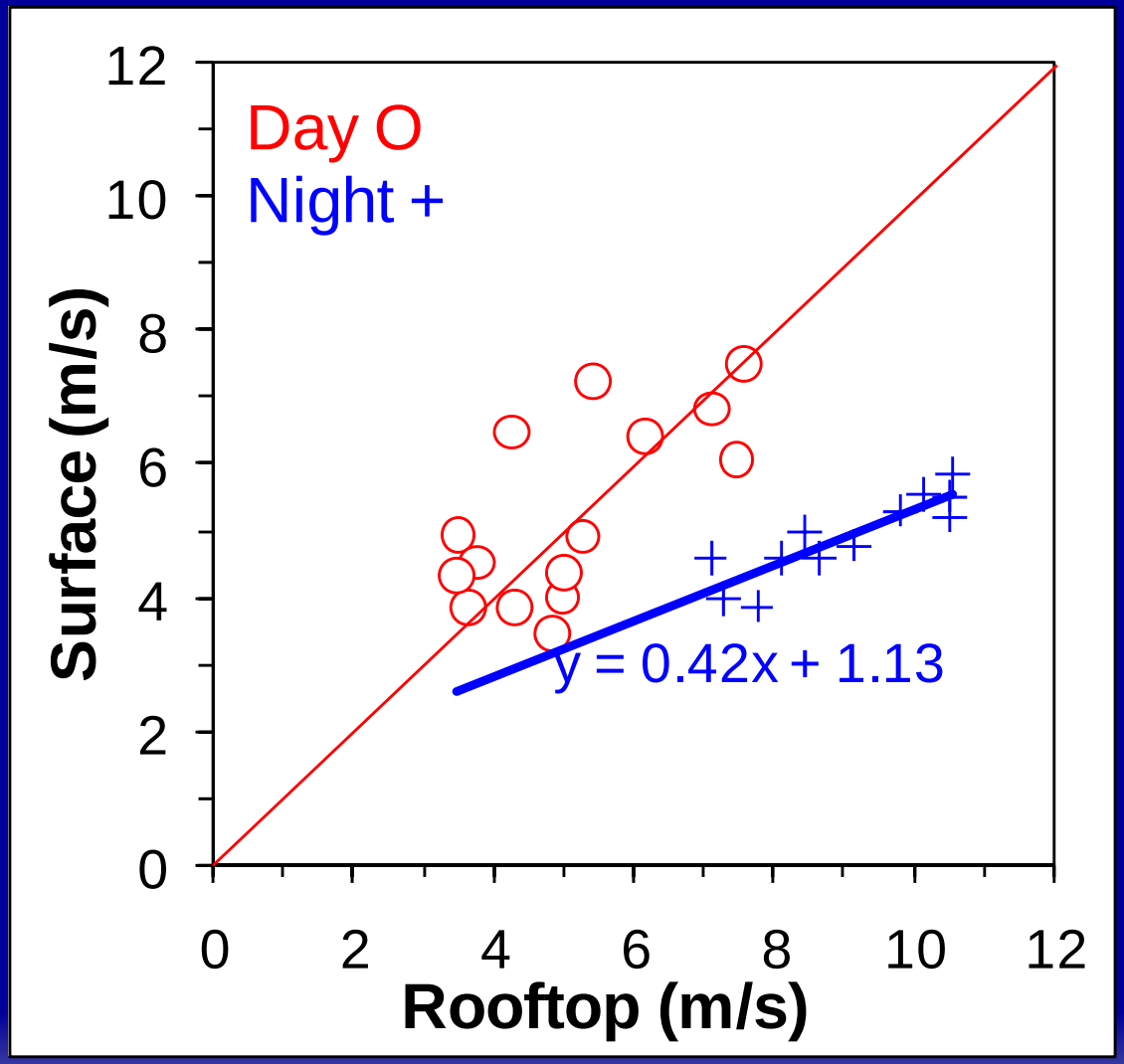
Continuous Real-Time Analyzers

Time-Integrated Bag Sampler

JU03 Field Study Configuration



Wind Speed Comparison



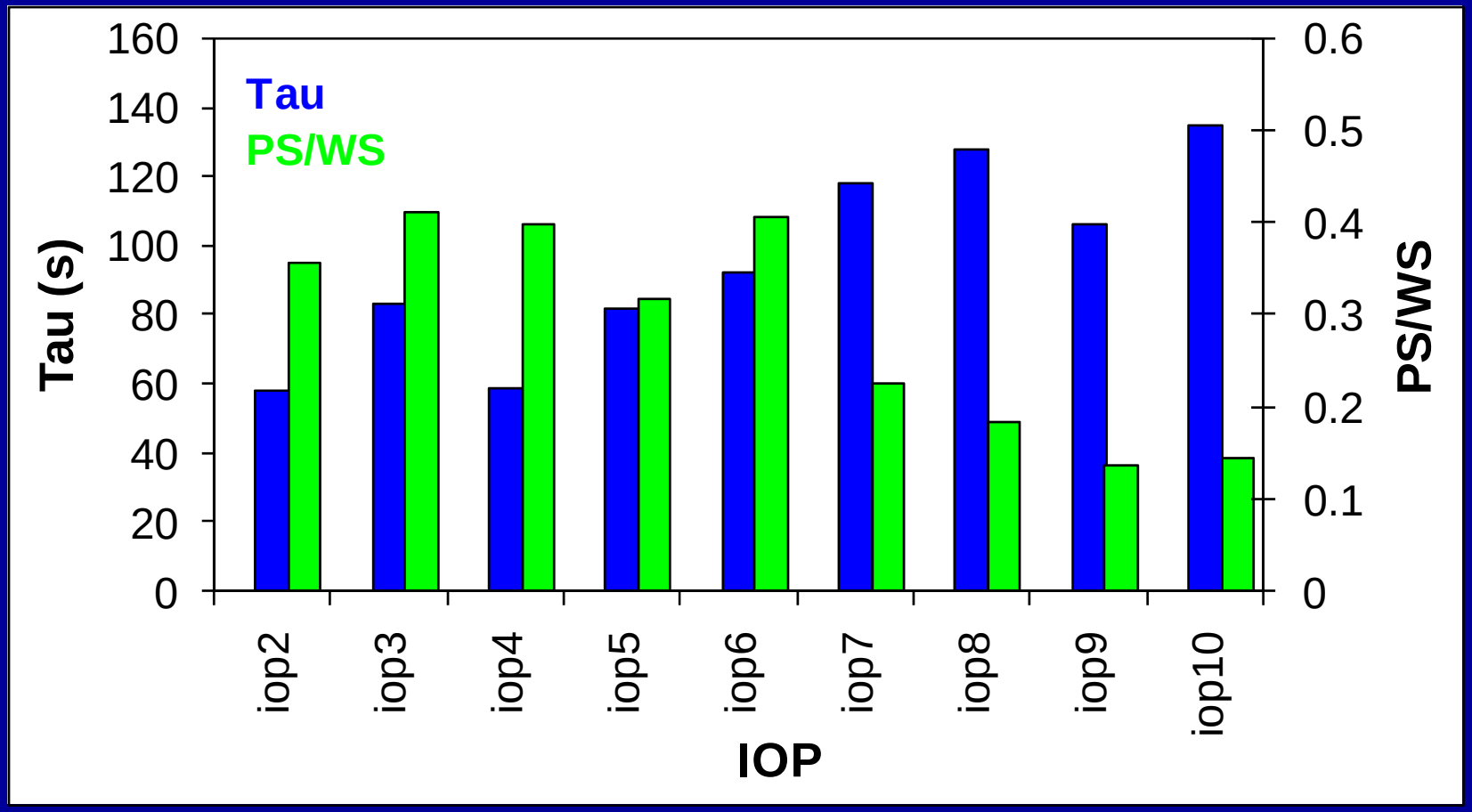
Plume Concentration Decay Time & Plume Speed to Wind Speed Ratio

- Exponential plume concentration decay time (τ)

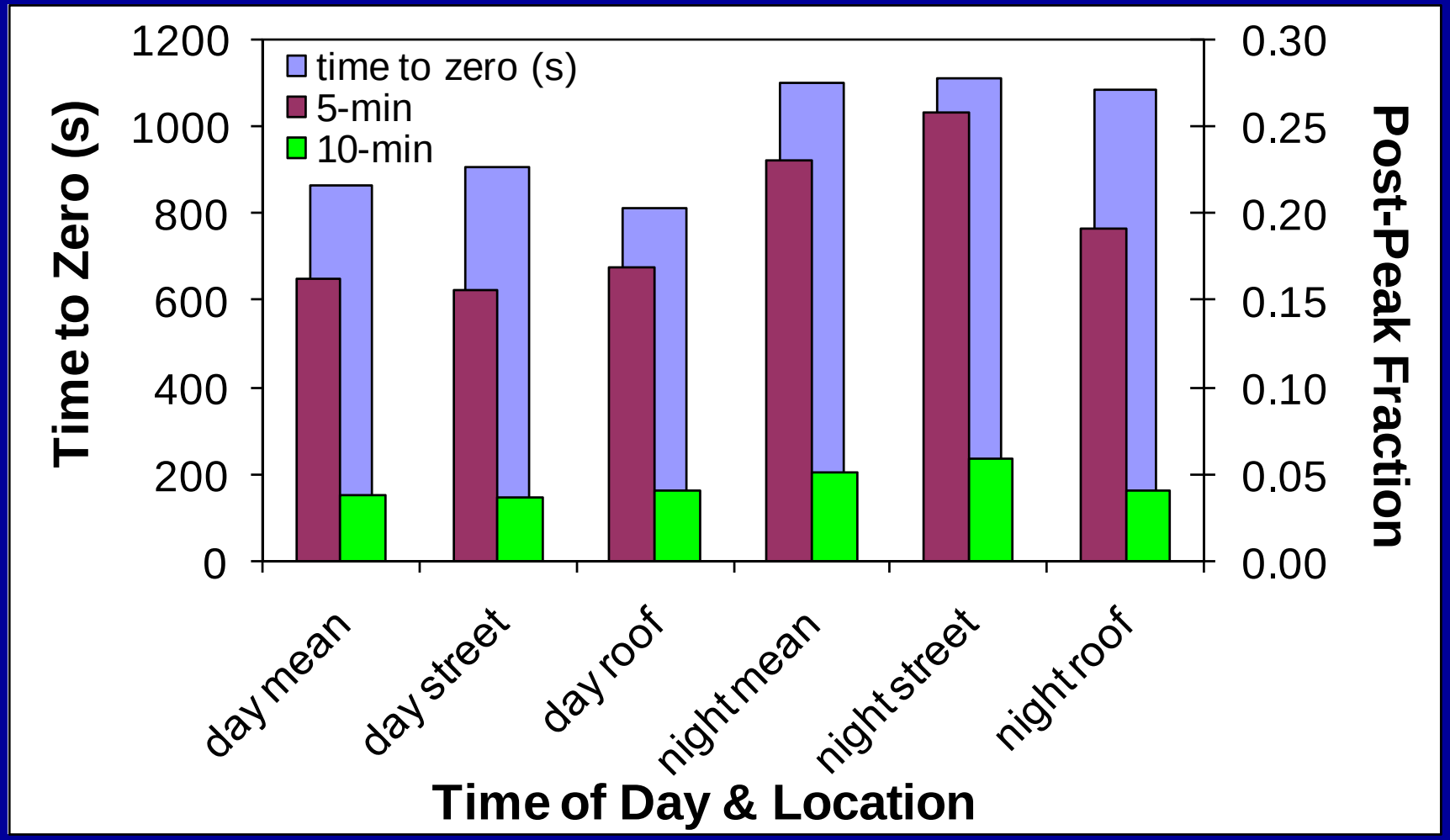
  $C = C_0 e^{-t/\tau}$

- Ratio of plume speed within the urban canopy to wind speed above the canopy: PS/WS
  - Value <1 indicates the plume is moving slower than the wind

Decay Time and PS/WS

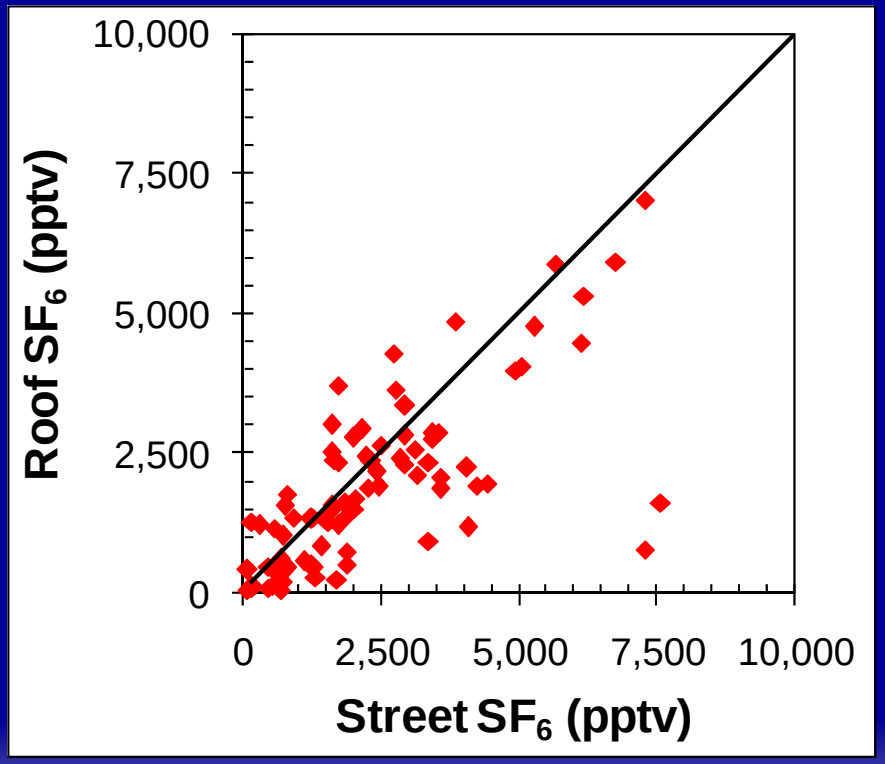


PIGS Tracer Decay Summary

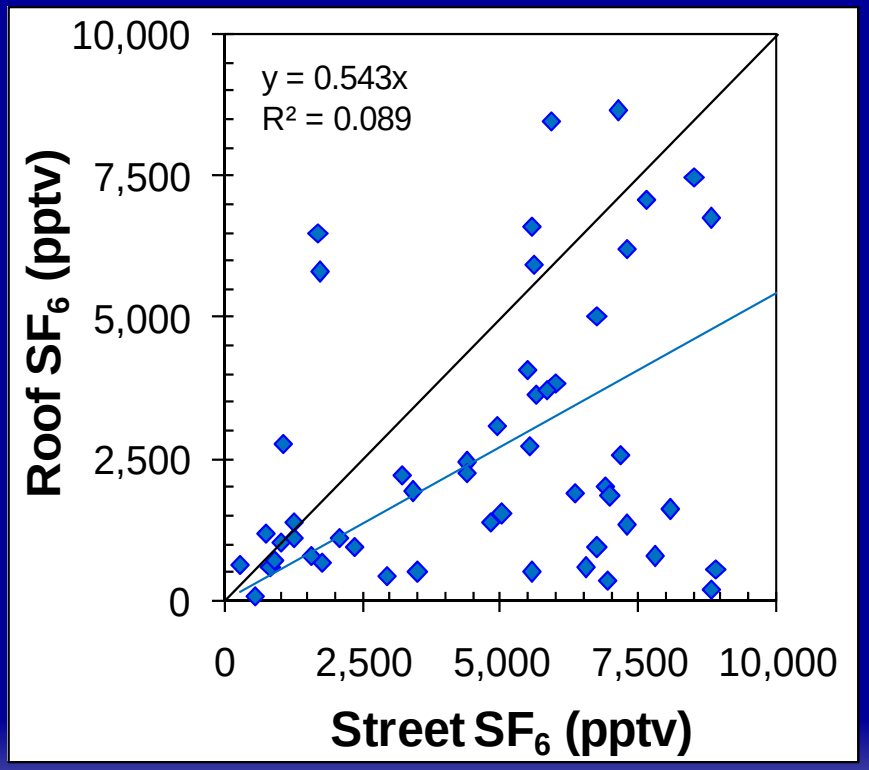


Vertically Collocated Rooftop Versus Street Level Concentrations

Day

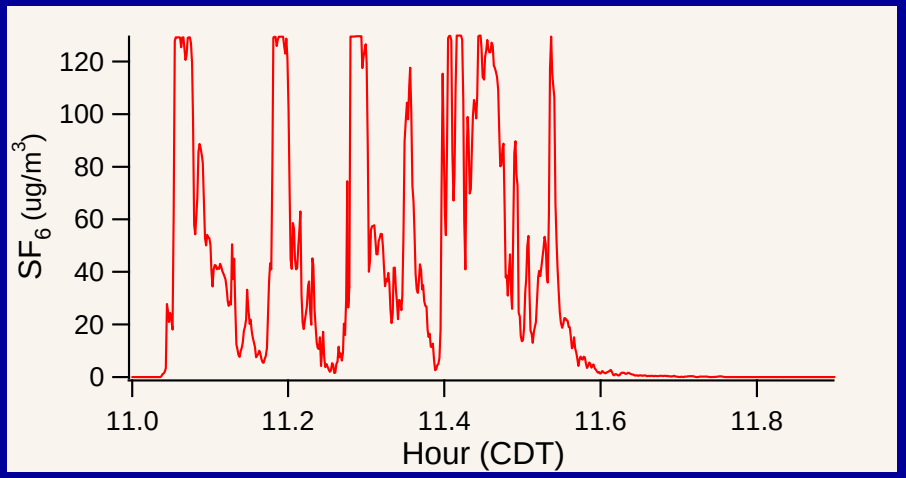


Night

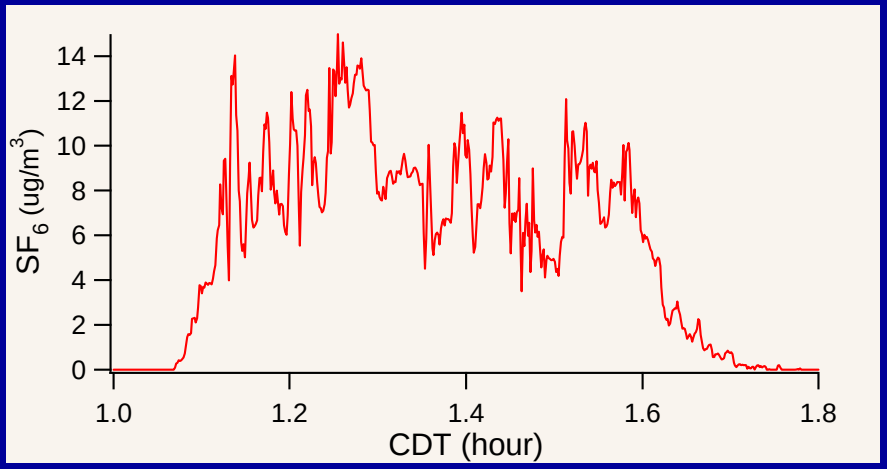


Typical Tracer Time Series

Day (Coupled)



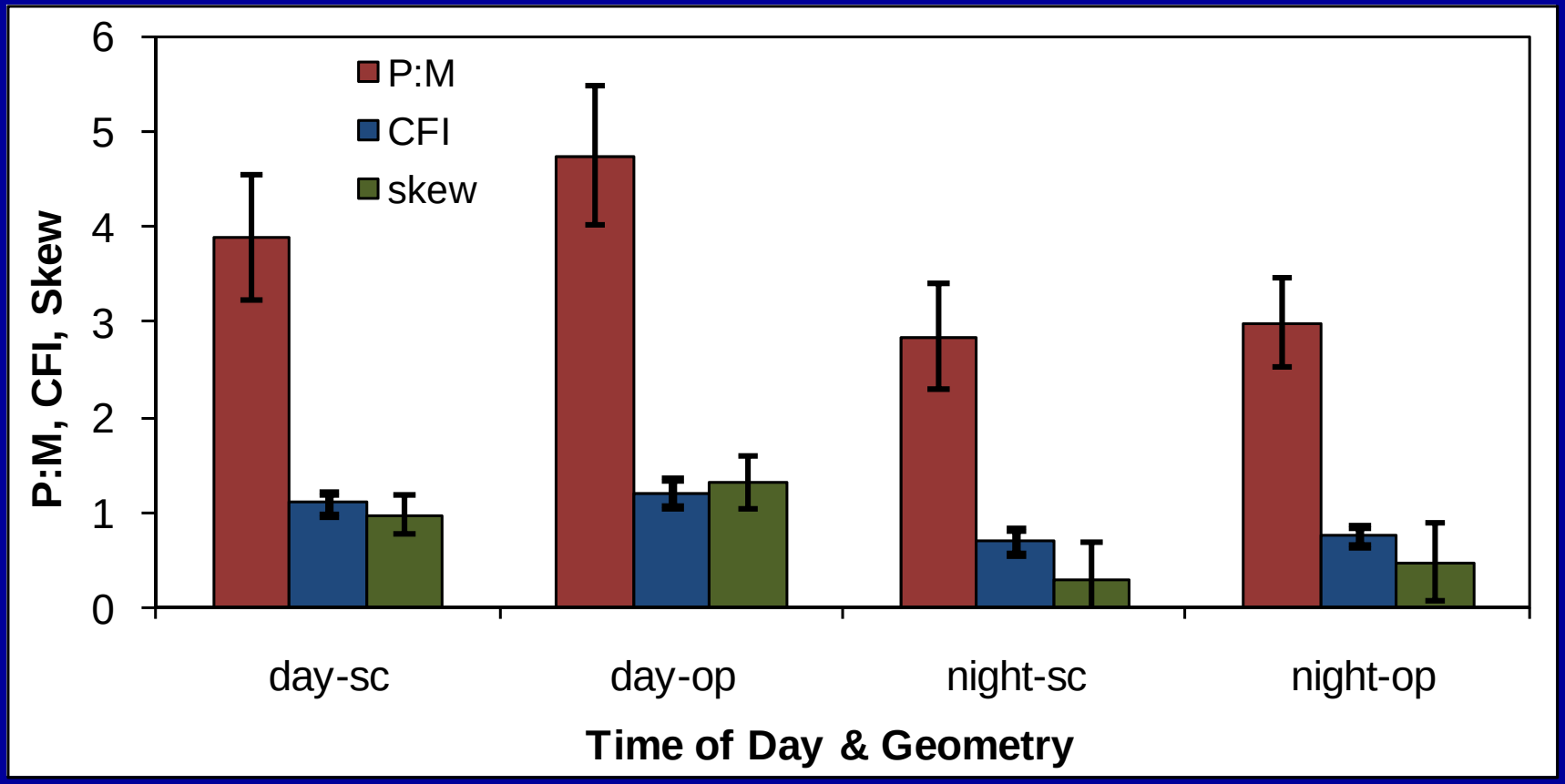
Night (Decoupled)



Plume Fluctuation Intensity

- P:M – Peak to Mean Ratio
- CFI – Concentration Fluctuation Intensity (Std. Deviation/Mean)
- Skewness

Plume Fluctuation Intensity



Flow Decoupling Summary

- Wind speeds are attenuated in the canopy
- Inhibited mixing and plume dilution
  - Reduced penetration of winds aloft into urban canopy
- Slower plume travel speeds
- Slower plume decay times
- Weaker plume fluctuations
- Possible divergence between overall wind field and direction of plume dispersion
- Dense urban mesonet or empirical adaptation based on atmospheric tracers is needed for dispersion characterization