MITIGATING ROADWAY POLLUTION IN URBAN AREAS: LOCATING TRANSIT STOPS

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***California Air Resources Board**

Aspects of the Built Environment that Influence Exposure

- The heights, size and layout of the buildings
- Where the people are relative to the traffic (land use)
- Barriers between the traffic and people
- Traffic Control Strategies
- Factors influencing transit user exposure

Minutes spent waiting for the bus/train each day (roundtrip)

- Boston, New York City, SF, LA: 36-41
- Brasil: 32 - 66; Colombia: 22 – 40;
- Germany, France: 20; UK: 26 - 32
- Spain: 16 - 20; Italy: 22-54

Crowdsourced data from Moovit Realtime

METHODS

Mobile measurements

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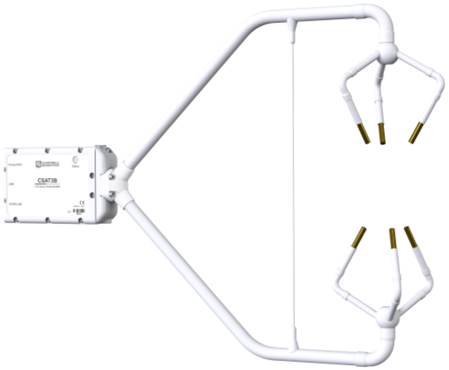
Mobile Monitoring Platform

Instrument	Measurement Parameter
CPC (TSI, Model 3007)	UFP number concentration (10 nm–1μm)
FMPS (TSI, Model 3091)	Particle size distribution (5.6–560 nm)
DisCMini (Testo)	UFP number and average size
DustTrak (TSI, Model 8520)	$PM_{2.5}$ and PM_{10} mass
EcoChem PAS 2000	Particle bound PAHs
LI-COR, Model LI-820	CO_2
Teledyne API Model 300E	CO
Teledyne API Model 200E	NO_X
Teledyne API Model 400A	O_3
3D-Sonic Anemometer (Campbell CSAT3)	Temperature, Relative humidity, Wind speed/direction, Turbulence Characteristics
Garmin GPSMAP 76CS	GPS
SmartTether™	Vertical profiles of temperature, *RH*, wind speed/direction
KciVacs video	Video record for traffic and fleet composition

California Air Resources Board Mobile Measurement platform (MMP)

Toyota RAV4 electric vehicle

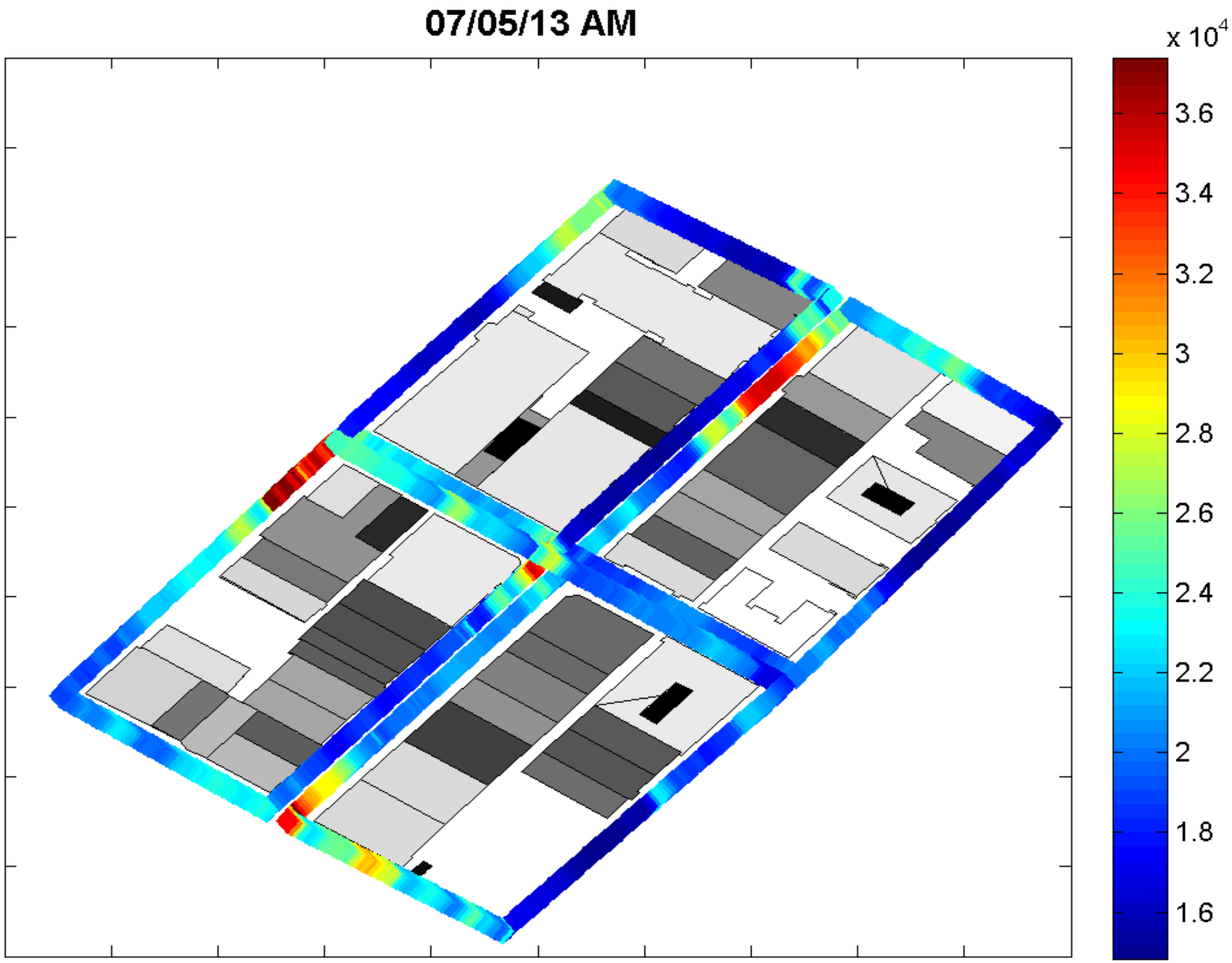


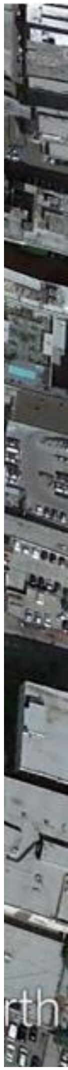
Processing Mobile Data

Ranasinghe, D., W.S. Choi, A.M. Winer and S.E. Paulson (2016) Developing High Spatial Resolution Concentration Maps Using Mobile Air Quality Measurements. *Aerosol and Air Qual. Res.* **16** (8), 1841-1853.

5 Meter Spatial Resolution Map for Downtown Los Angeles

Ranasinghe, D., W.S. Choi, A.M. Winer and S.E. Paulson (2016) Developing High Spatial Resolution Concentration Maps Using Mobile Air Quality Measurements. *Aerosol and Air Qual. Res.* 16 (8), 1841-1853.



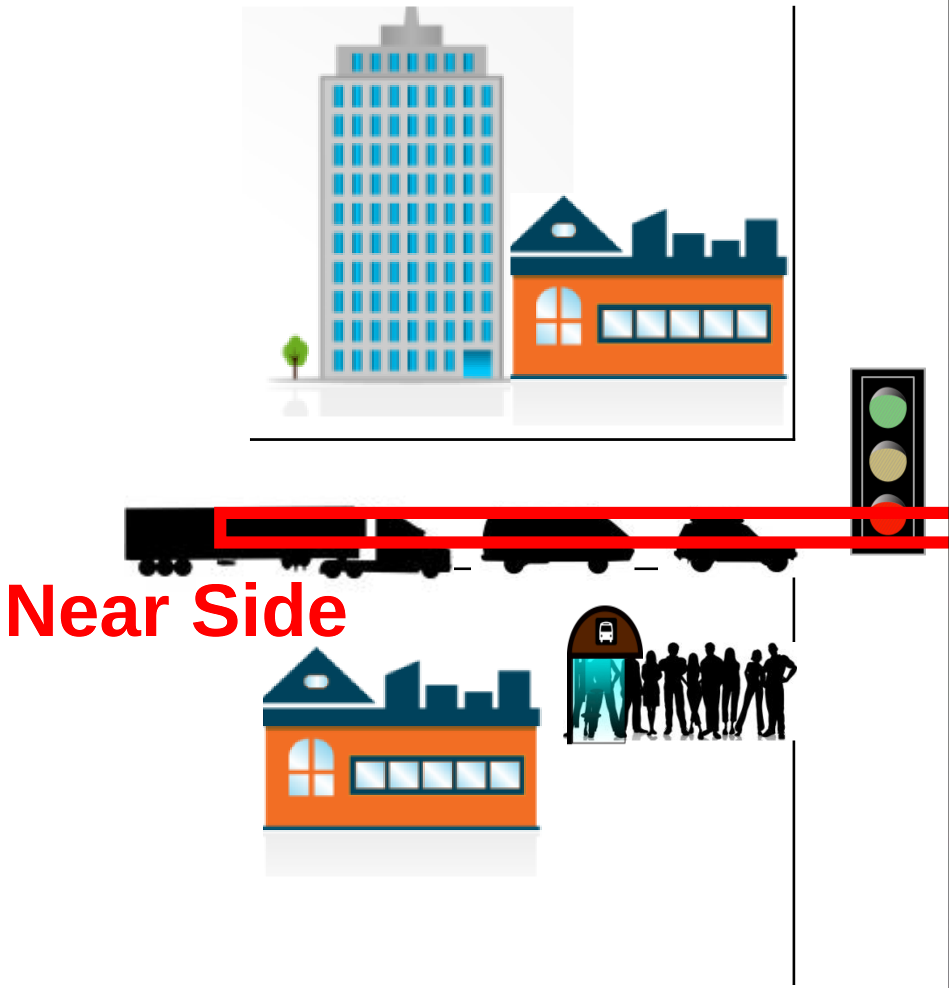


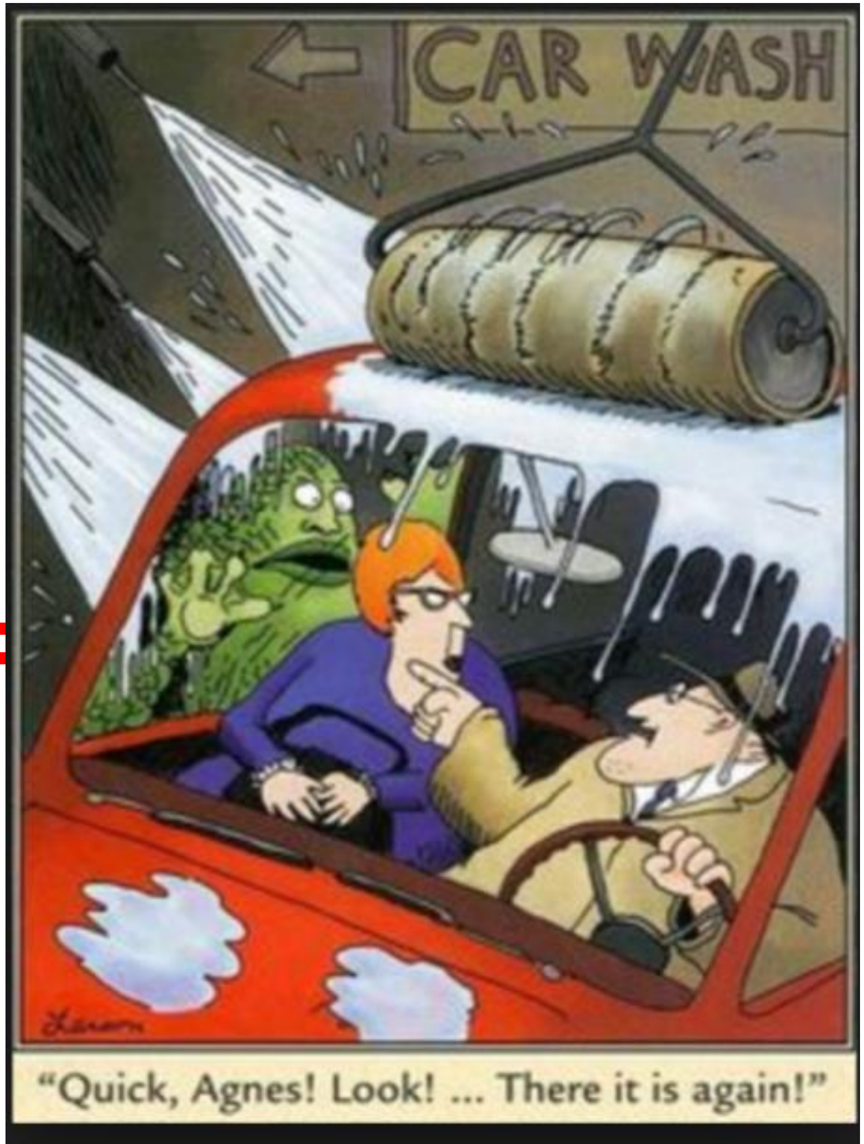
Decay of pollutants around the intersections: the best place for the bus stop?

Choi, W.S., D. Ranasinghe, J.R. DeShazo, J.J. Kim and S.E. Paulson (2017) *Cross-Intersection Profiles of Ultrafine Particles in Different Built Environments: Implications for Pedestrian Exposure and Bus Transit Stops*. Submitted.

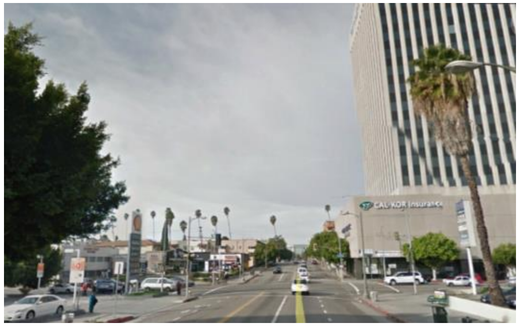
How Far Should the Bus Stop be from the Intersection?

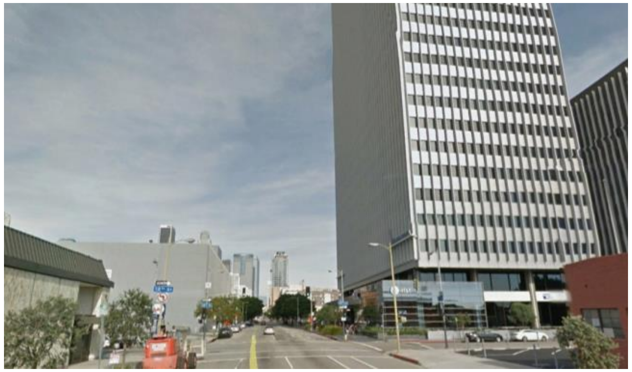
Gary Larson's Far Side Cartoons





Measurement Sites for Intersection Studies



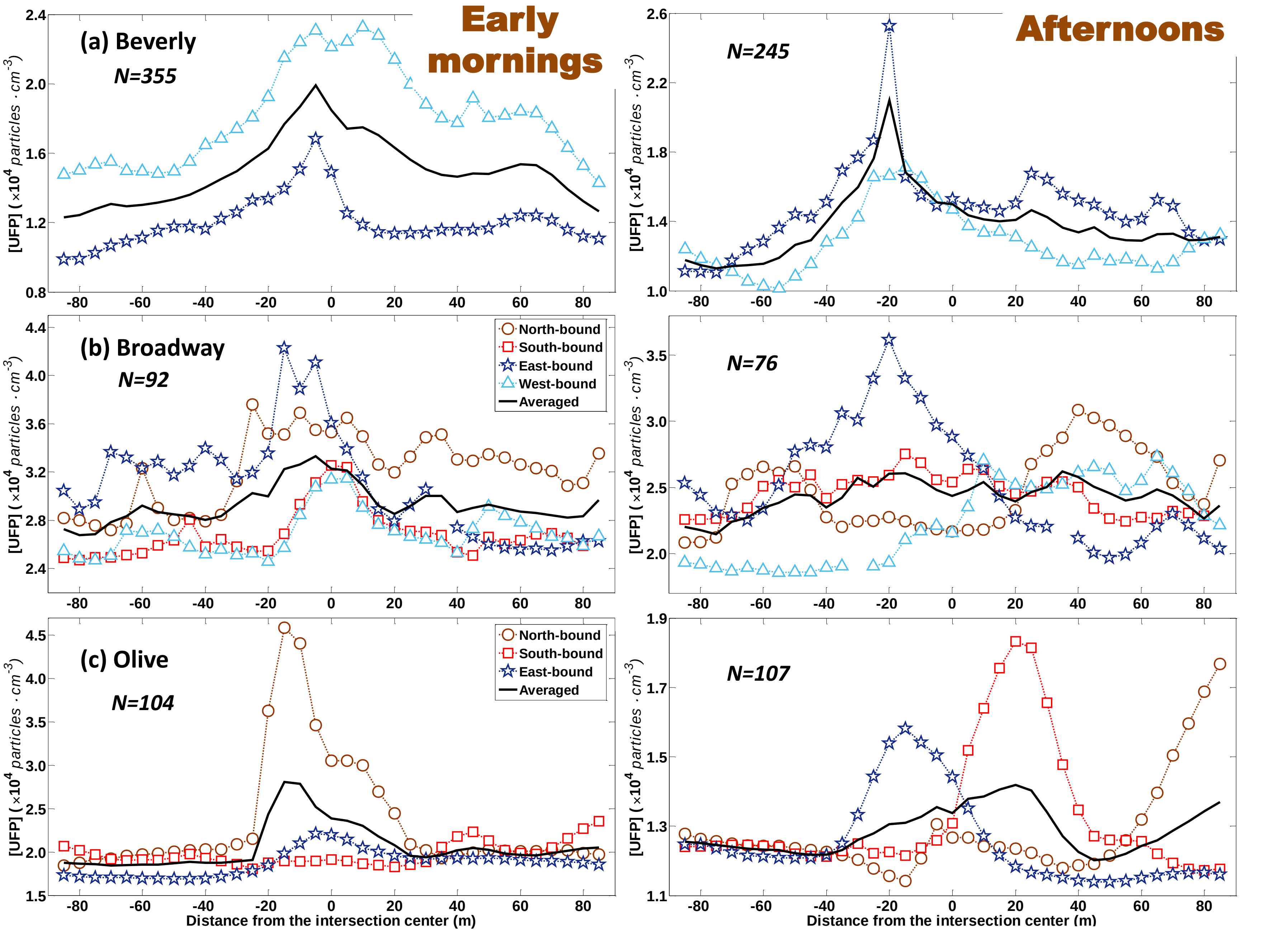


10 Intersections
1,744 Profiles

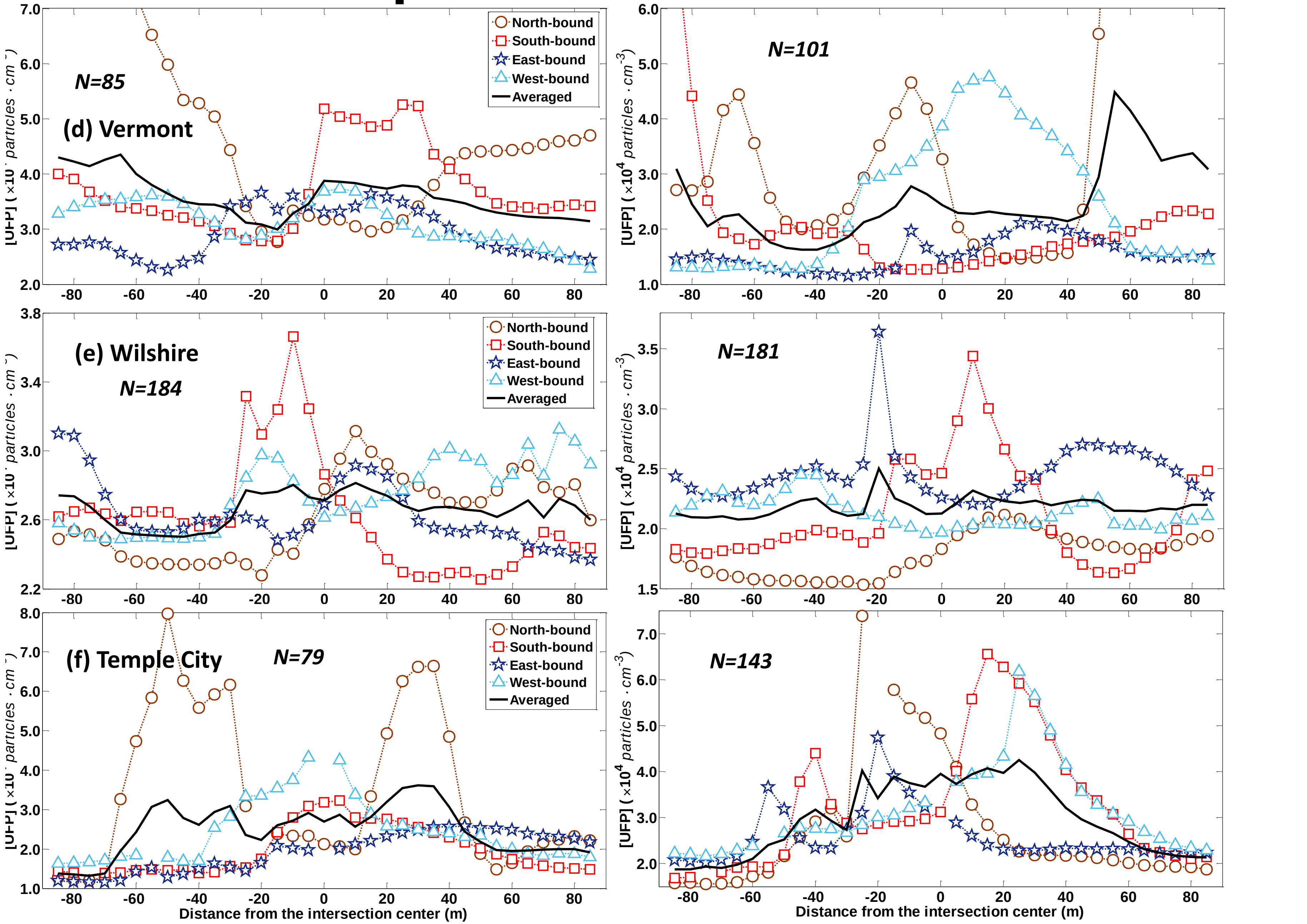
Variety of Intersections; 1,744 Profiles Total

	Wilshire in Beverly Hills (5 inter-sections)	Broadway & 7th Downtown Los Angeles	Olive & 12th Downtown Los Angeles	Vermont & 7th	Wilshire & Carondelet	Temple City & Las Tunas
Street width	30 - 38 m	22 & 26 m	17 & 28 m	25 & 30 m	17 & 37 m	24 & 30 m
Traffic flow rate (A.M.)	24	12 & 15	21 & 4	39 & 10	31 & 31	25 & 28
Traffic flow rate (P.M.)	47	20 &20	8 & 3	38 & 12	2 & 27	26 & 29
Traffic density	**Long queues, WB in A.M., EB in P.M.**	**Medium queues, slow vehicle speeds**	**Minimal queues**	**Long queues, often for entire block**	**Short queues**	**Long queues but queues dissipate rapidly**
Distance between traffic lights	330 m	125 - 200 m	(1) 180 m (2) 125 m	(1) 224 m (2) 174 m[c]	(1) 190 m (2) 100 m	(1) 200 m (2) 135 m

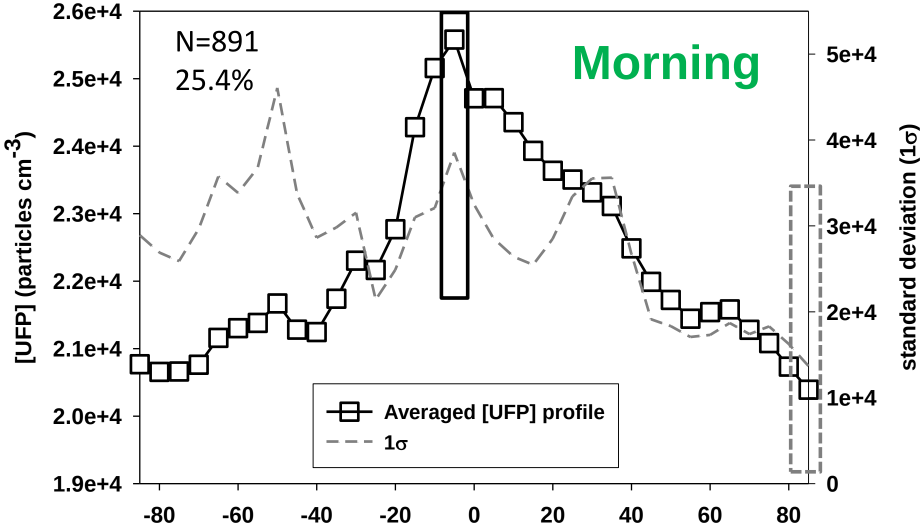
Cross-intersection profiles of UFPs for each traffic direction

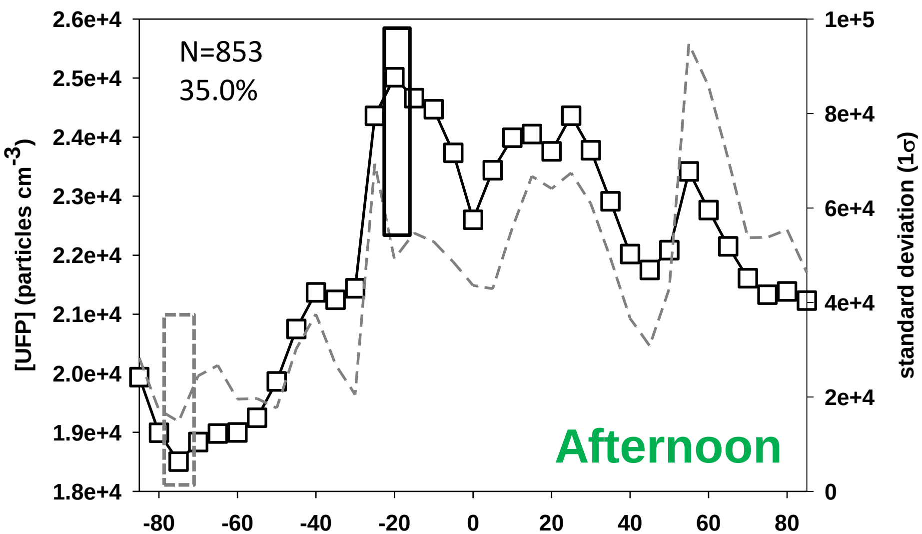


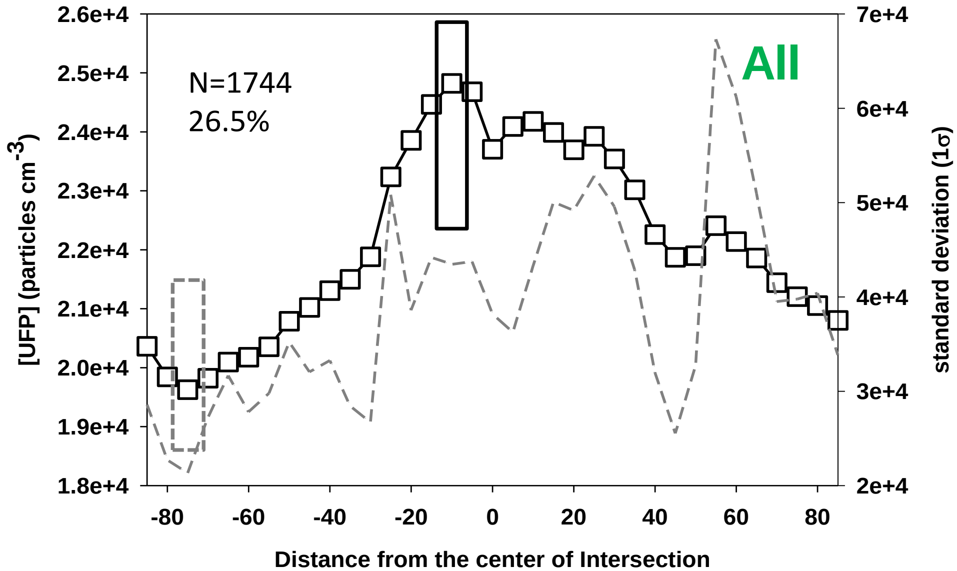
Cross-intersection profiles of UFPs for each traffic direction



Average Profiles







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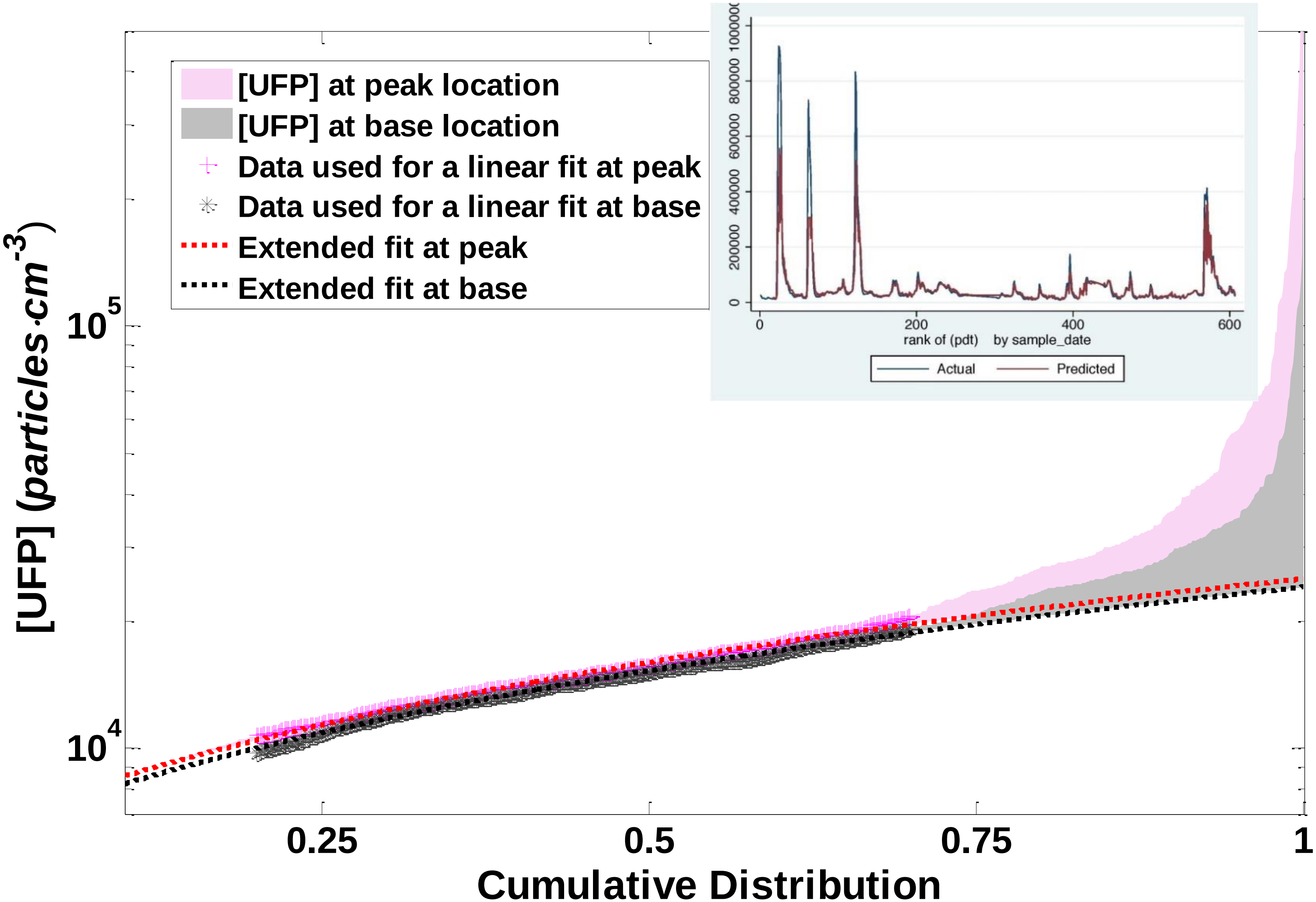
Cumulative distributions of UFPs at the peak and base locations of the profile



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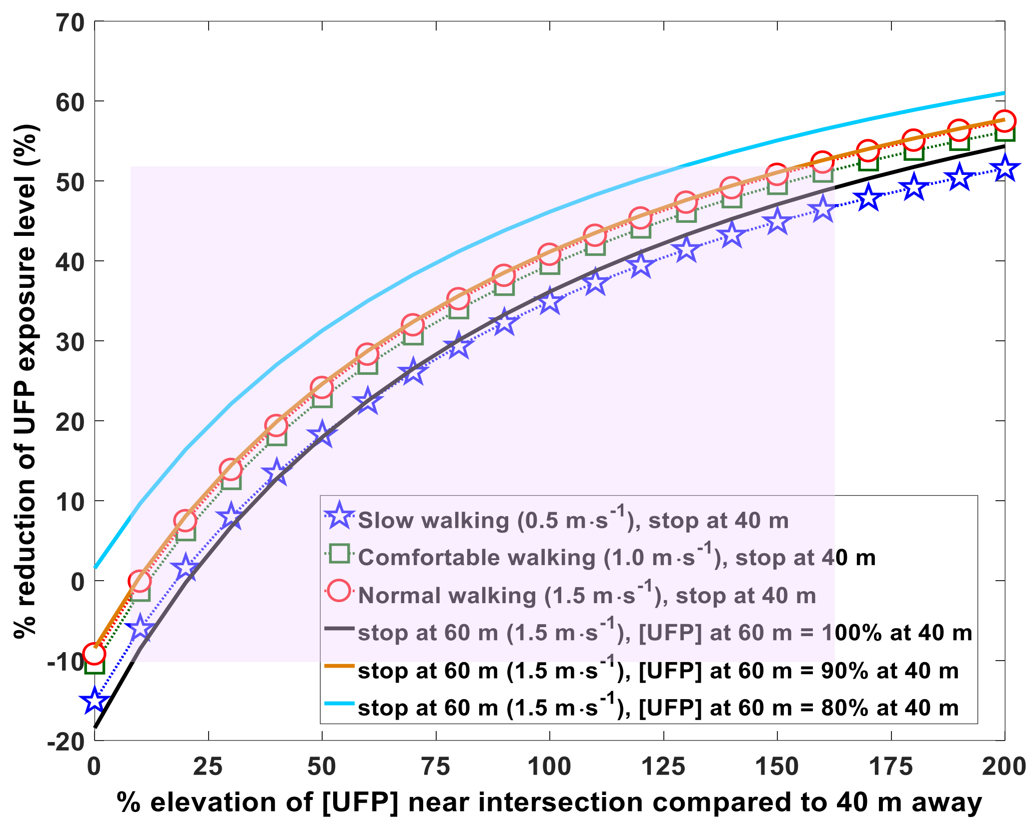
Exposure level of transit-users to UFP around intersections

Simple time-duration model to simulate **exposure reductions** when the **bus-stop is moved from 20 m to 40 m (or 60 m)** from the intersection:

Set two UFP zones: **within ± 20 m** of the intersection (high UFP) vs. **around (40 and 60 m)** (low UFP).

Transit-user's behavior includes disembarking, walking, crossing the intersection, waiting for a bus; assuming three pedestrian walk speeds: 0.5 (slow), 1.0 (comfortable), and 1.5 m/s (normal). Waits at the bus stop for only 10 minutes!



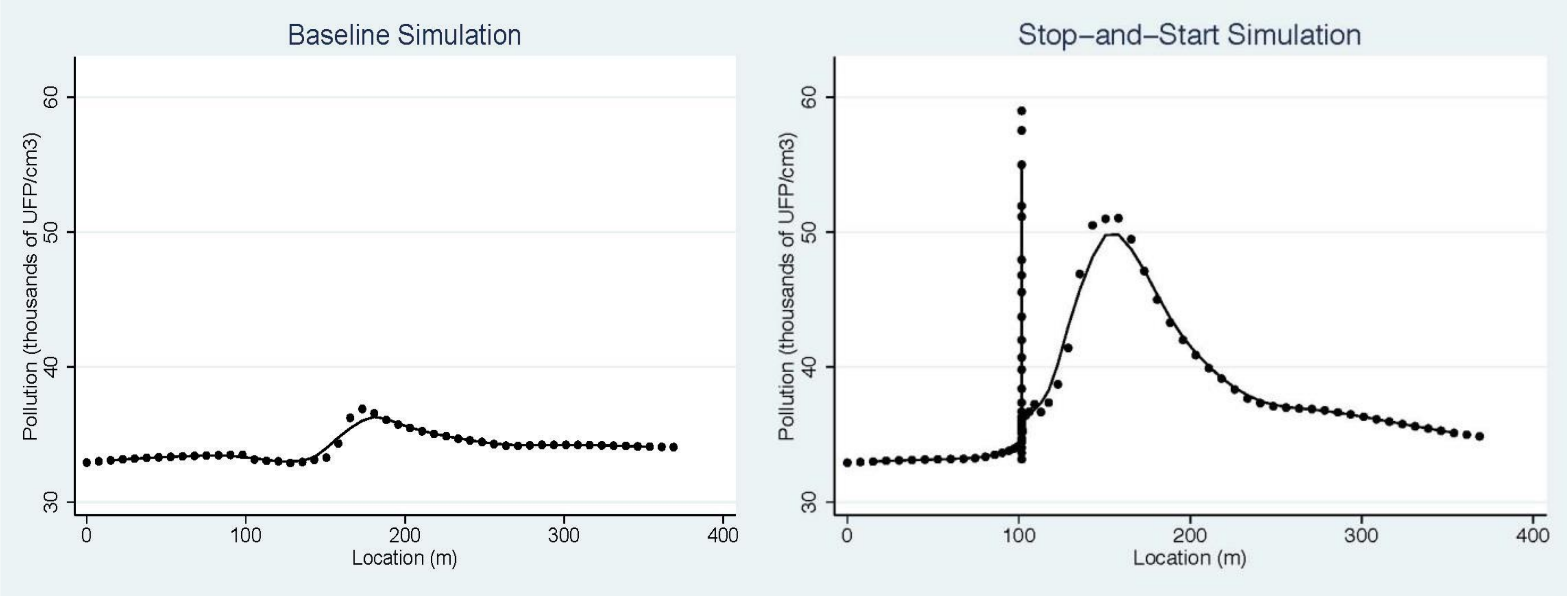
Summary

Management	Suggested Direction	Approx. Size of Effect
Bus/Transit Stop Siting	Further from the intersection is better, but improvements diminish within several tens of meters, depending on built environment (block length, queue lengths, etc.)	Up to approximately a factor of 3

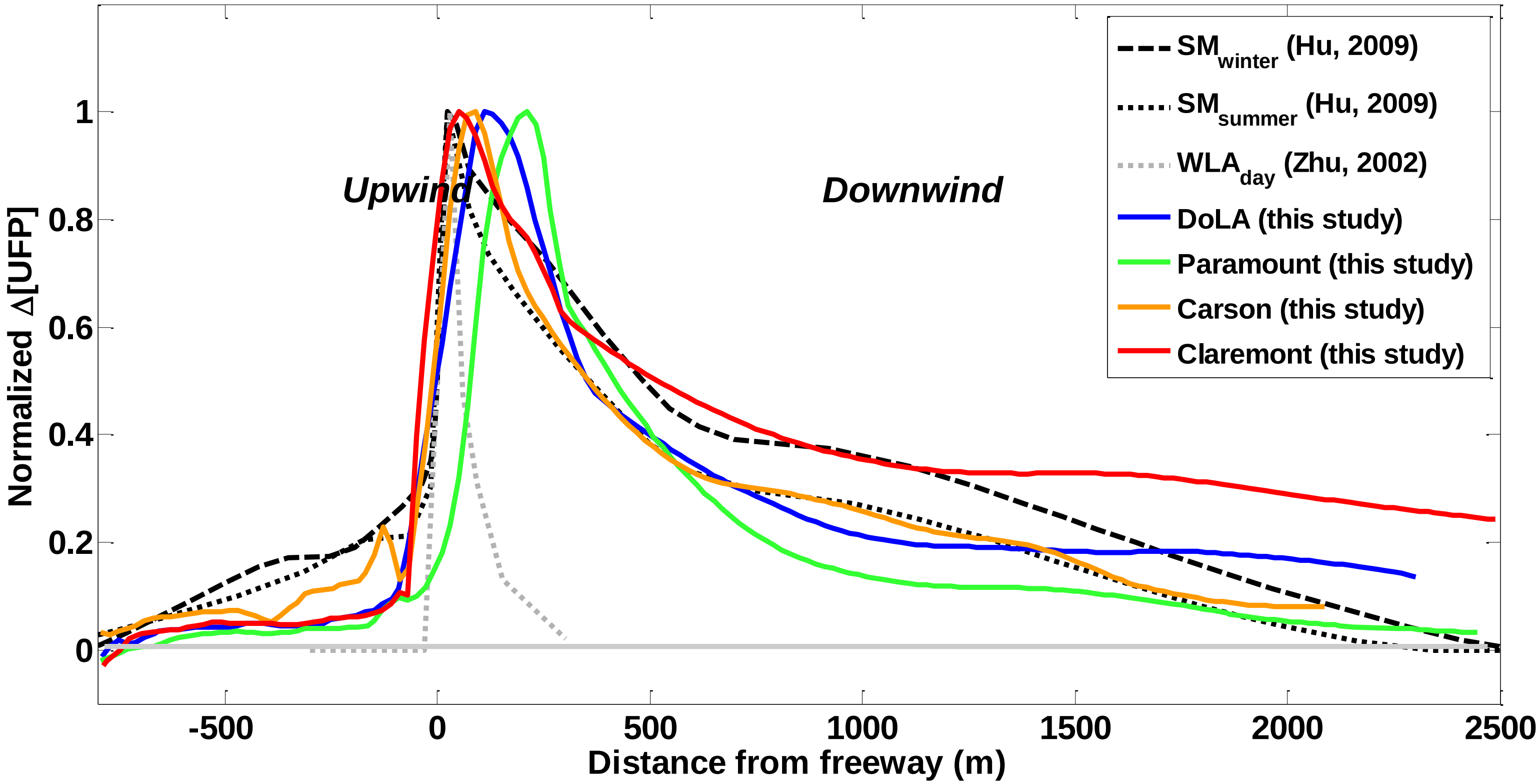
Some Other Options:

Traffic Management

Management	Suggested Direction	Approx. Size of Effect
Traffic Management	Fewer stops and smaller queues reduce emissions and elevated concentrations around intersections	Factor of 2 - 4



Plumes around Roadways: ~150 m during daytime, ~1500 m during Early Morning



$$\text{Normalized } \Delta[UFP(x)] = \frac{\Delta[UFP(x)]}{\Delta[UFP]_{peak}}$$

$$\Delta[UFP] = [UFP] - [UFP]_{bkgnd}$$

[Choi et al., Atmos. Environ., 62, 318-327, 2012]

Land Use Around Heavily Travelled Roadways

Management	Suggested Direction	Approx. Size of Effect
Sensitive uses near highways: Daytime downwind	Further is better, but under normal daytime conditions 150 meters is sufficient.	Up to a factor of four or more.
Sensitive uses near highways: Night/Morning downwind	1500 meters is desirable. Other mitigation strategies:	Up to a factor of four or more.

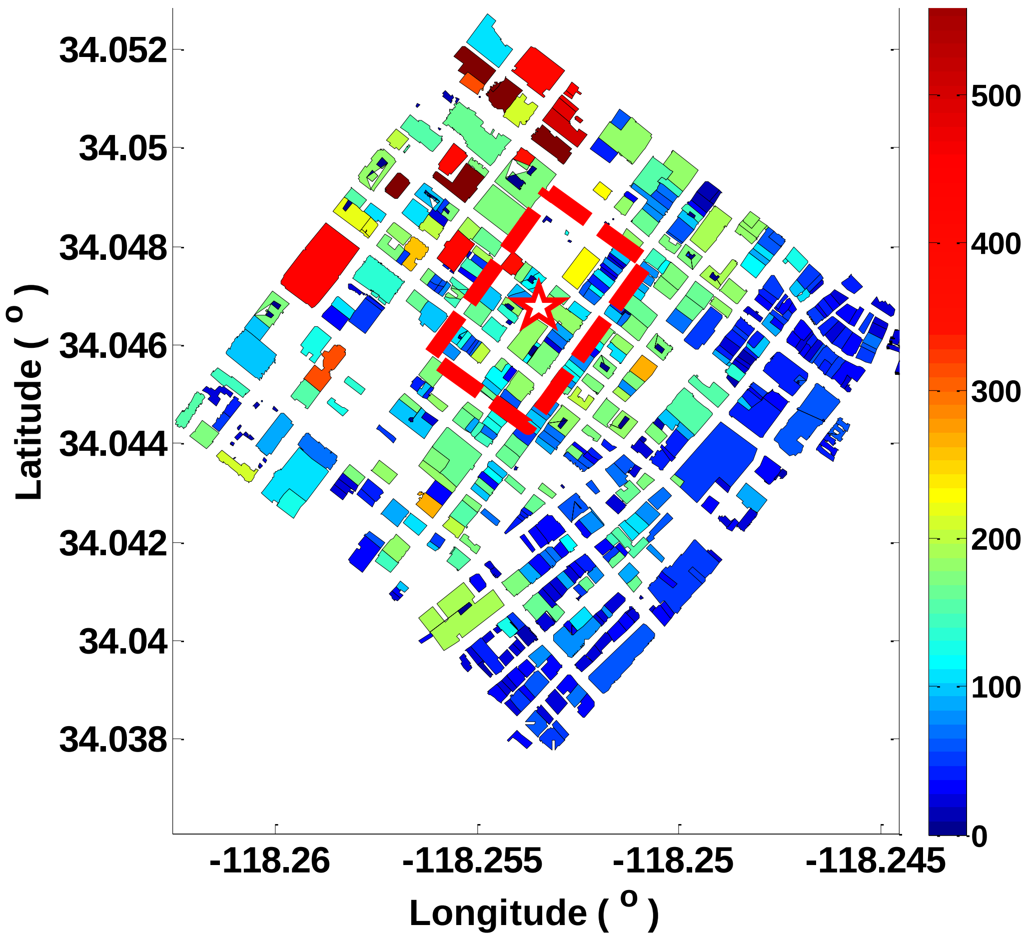
Other Mitigation Options: Build solid barriers (quite effective); Grow trees (less effective but worthwhile), move physical education classes later in the day; filter indoor spaces

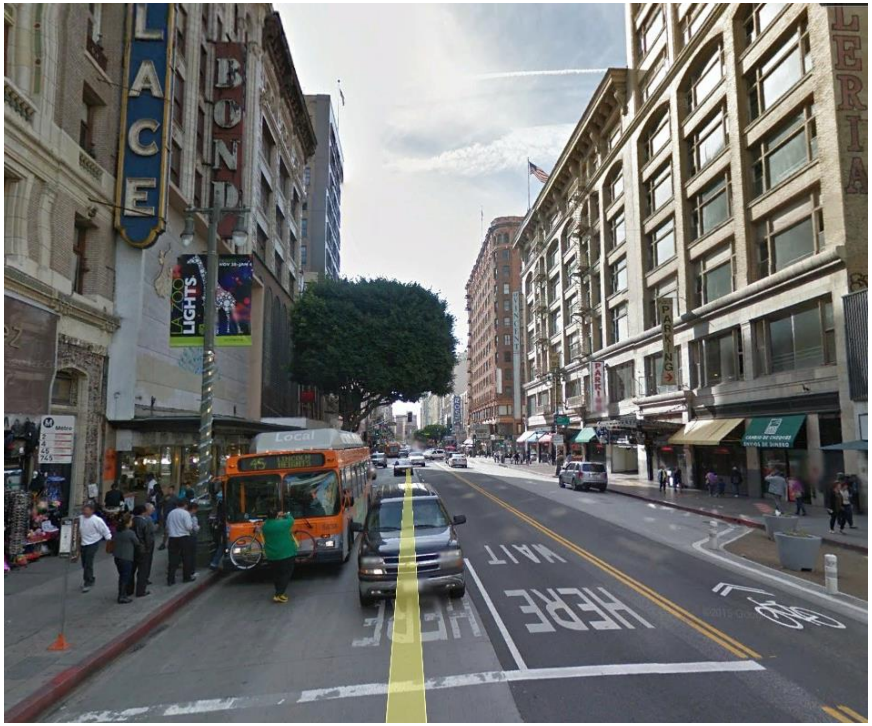
Beyond the street canyon: block scale characteristics influencing concentrations

Management	Suggested Direction	Approx. Size of Effect	Atmospheric Conditions & Notes
Areal aspect ratio (A_{area}); combines building area-weighted height, building footprint, and the amount of open space.	Lower building volumes and more open space lower pollutant concentrations.	Up to ~ a factor of 3.	Important under calm conditions.
Building Heterogeneity	Isolated tall buildings lower concentrations compared to homogeneous shorter or higher buildings with similar volume.	Up to ~ a factor of two.	Important under unstable conditions with moderate winds.

Site 1: Street Canyon

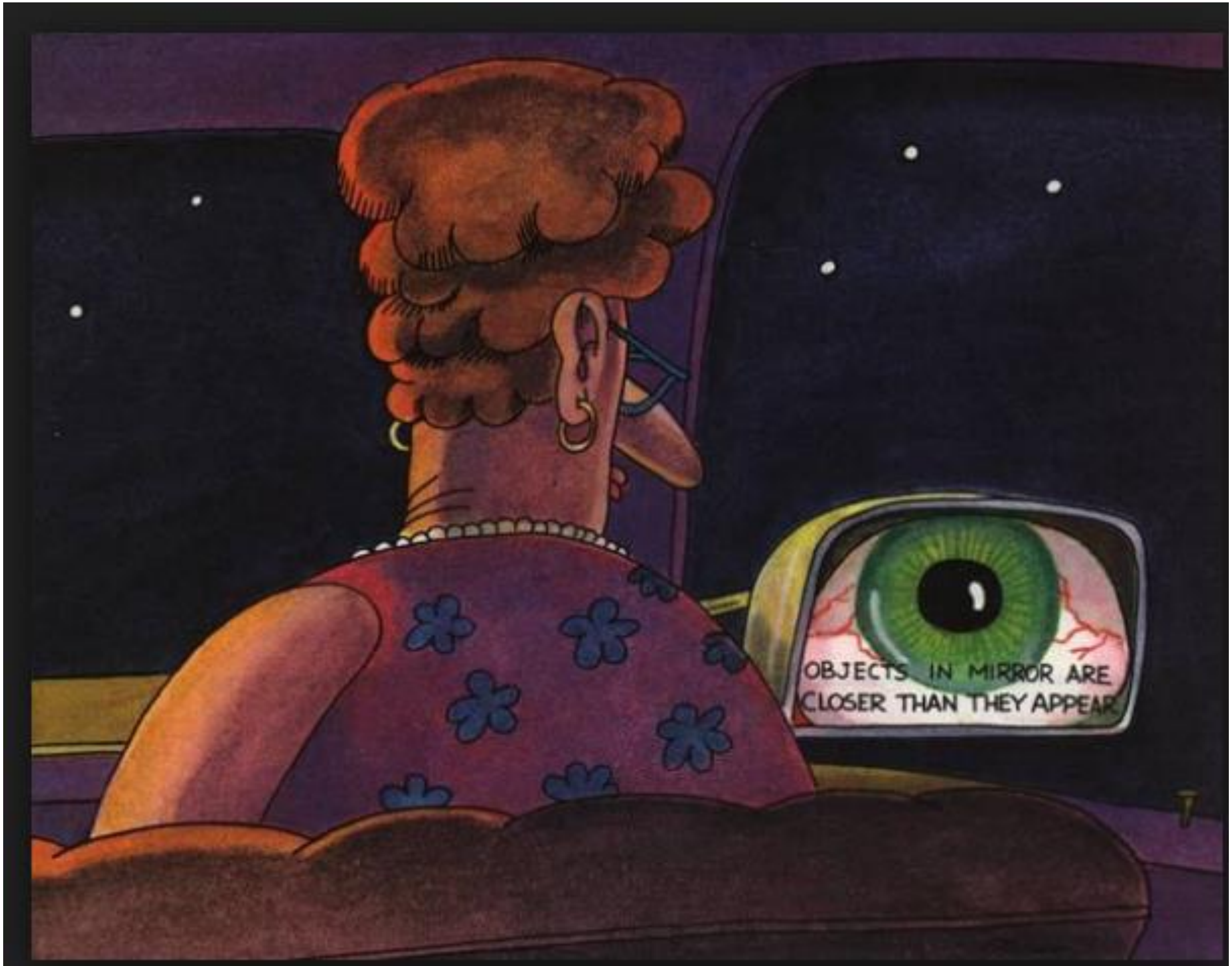
Building height (Ft.)





Broadway & 7th Site (Street view: heading South)

Thank you for your attention

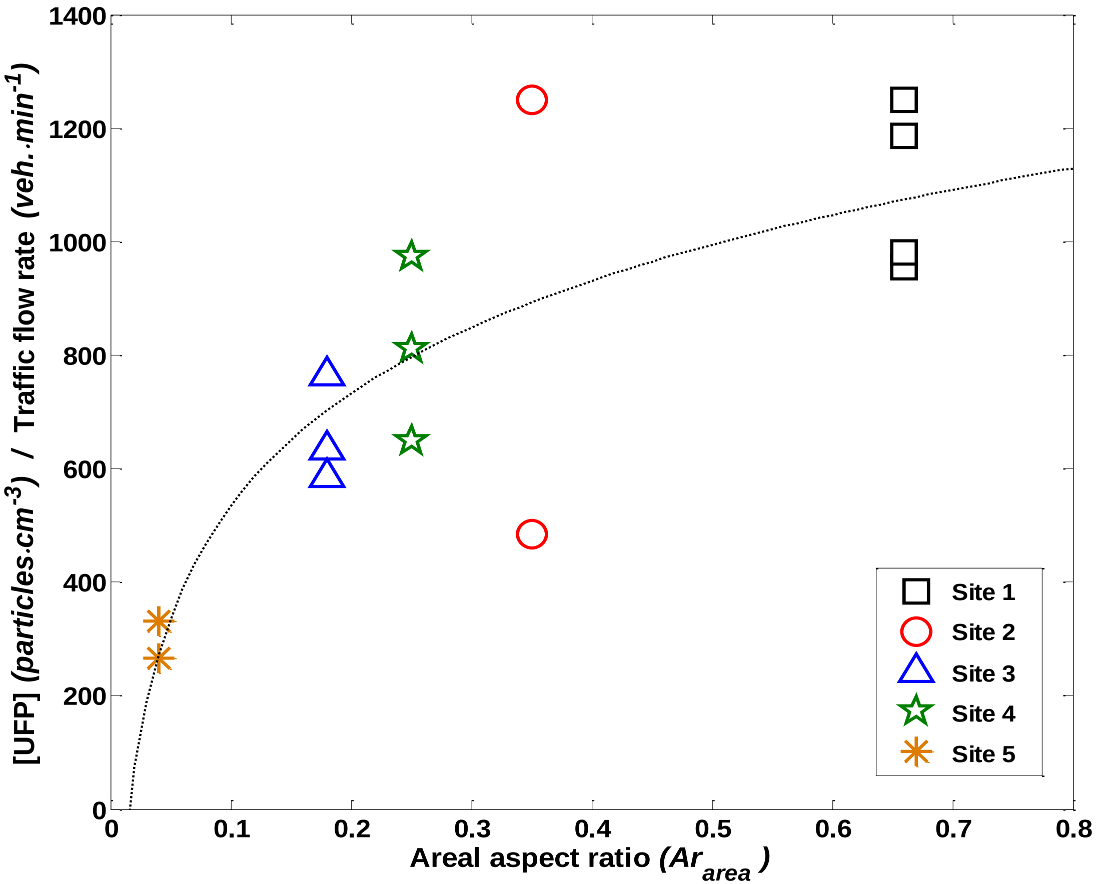


Best Explanatory Factor in the Morning:

The "Areal Aspect Ratio" =

Length scale of buildings over length scale of open space

$$Ar_{area} = \frac{H_{bldg}}{L_{diag} \times \left(1 - \sum S_{bldg} / A_{site}\right)} = \frac{H_{bldg}}{L_{diag} \times \left(A_{open} / A_{site}\right)} = \frac{H_{bldg}}{L_{open}}$$



H_{bldg}: Mean area-weighted building height

L_{diag}: Diagonal length of block

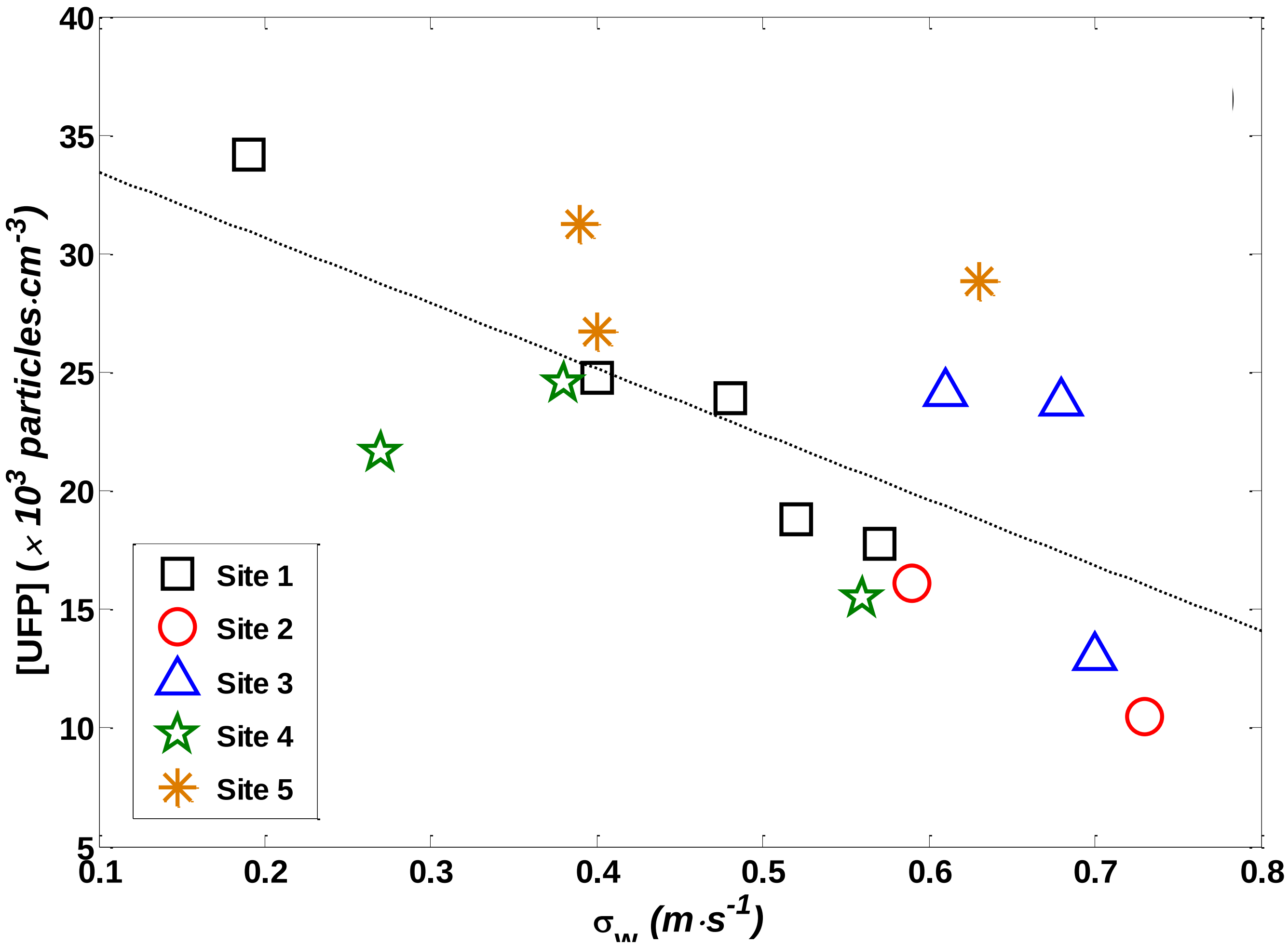
S_{bldg}: Building surface area

A_{site}: Area of the sampling site

A_{open}: Area of the open space in sampling site

Choi et al., 2016

Best Explanatory Factor in the Afternoon: Turbulence strength (vertical fluctuations of surface winds, σ_w)



Best Explanatory Factor in the Afternoon:

Turbulence strength (vertical fluctuations of surface winds, σ_w)

Appears to be from non-local emissions