The wind, the traffic and the buildings: the role of the built environment in determining air pollution exposures

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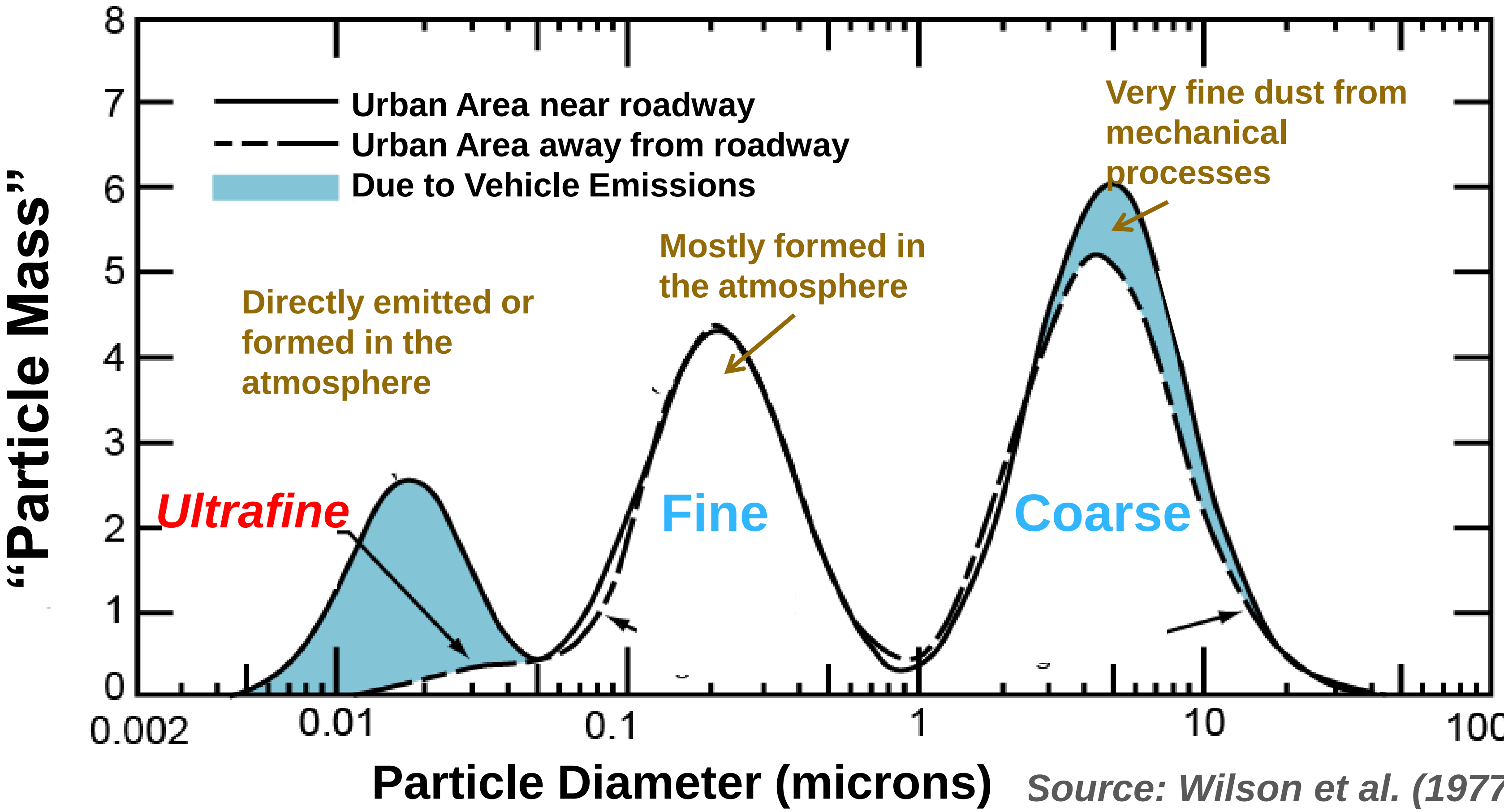
Very Small Particles: lots of spatial heterogeneity

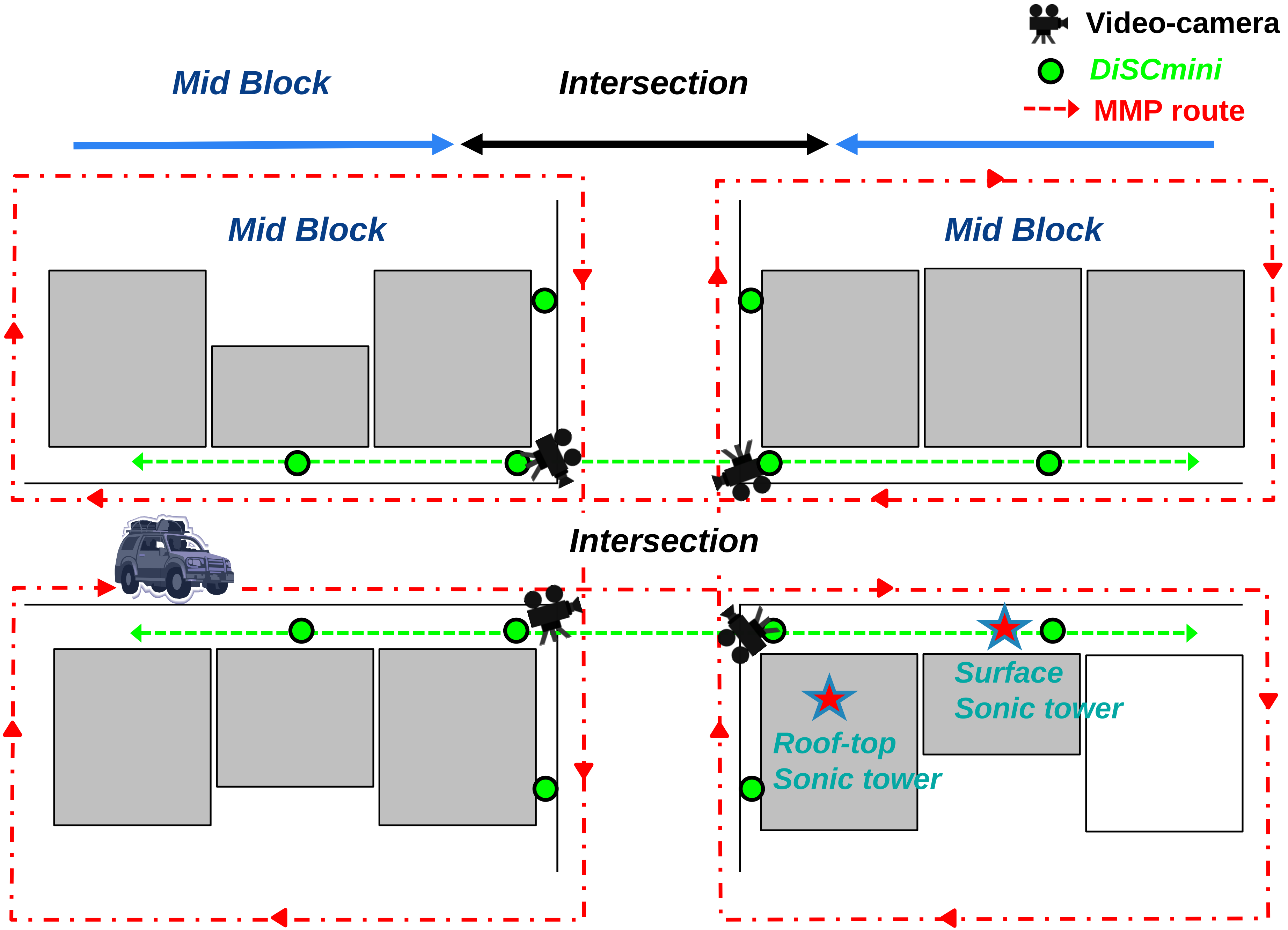


Source: Wilson et al. (1977)

Ultrafine particles are mostly from vehicular emissions. They disappear In around a half an hour: rather than magically going away, they collide and stick to fine particles. As a result, they are highly elevated around roadways compared to everywhere else.

Hotspots in urban areas

Measurement Design

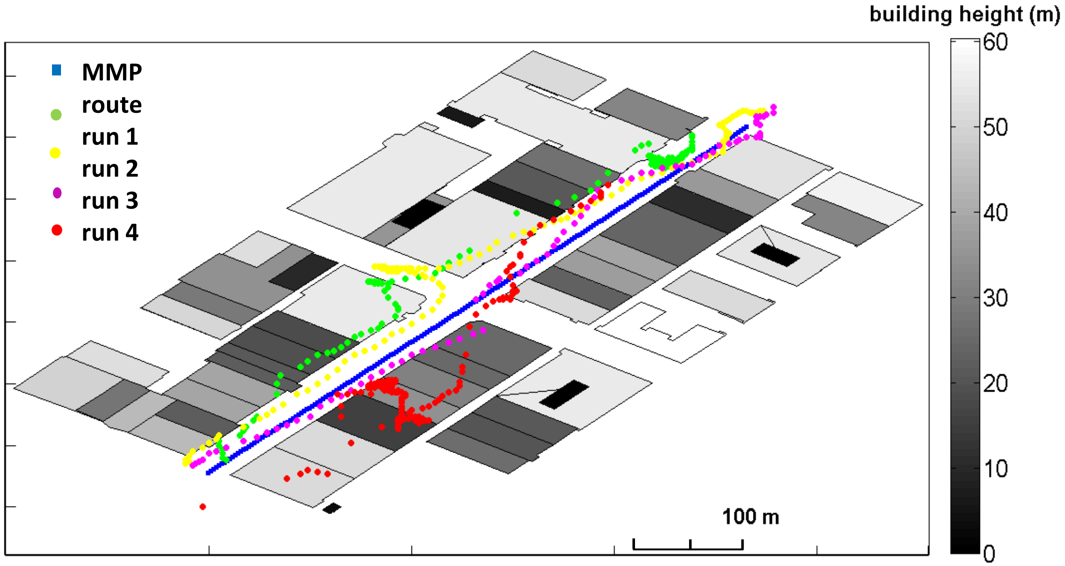


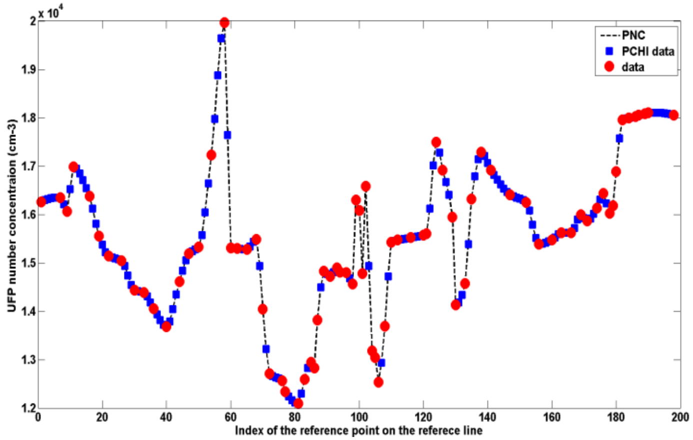
Dealing with the mobile data

- Mobile data gives spatially heterogeneous measurements; sometimes you get 30 in one spot, and sometimes one every 20 m.
- Simple averaging of mobile data (after correction for the wandering GPS signal) ends up looking like a trail of confetti after a parade route.

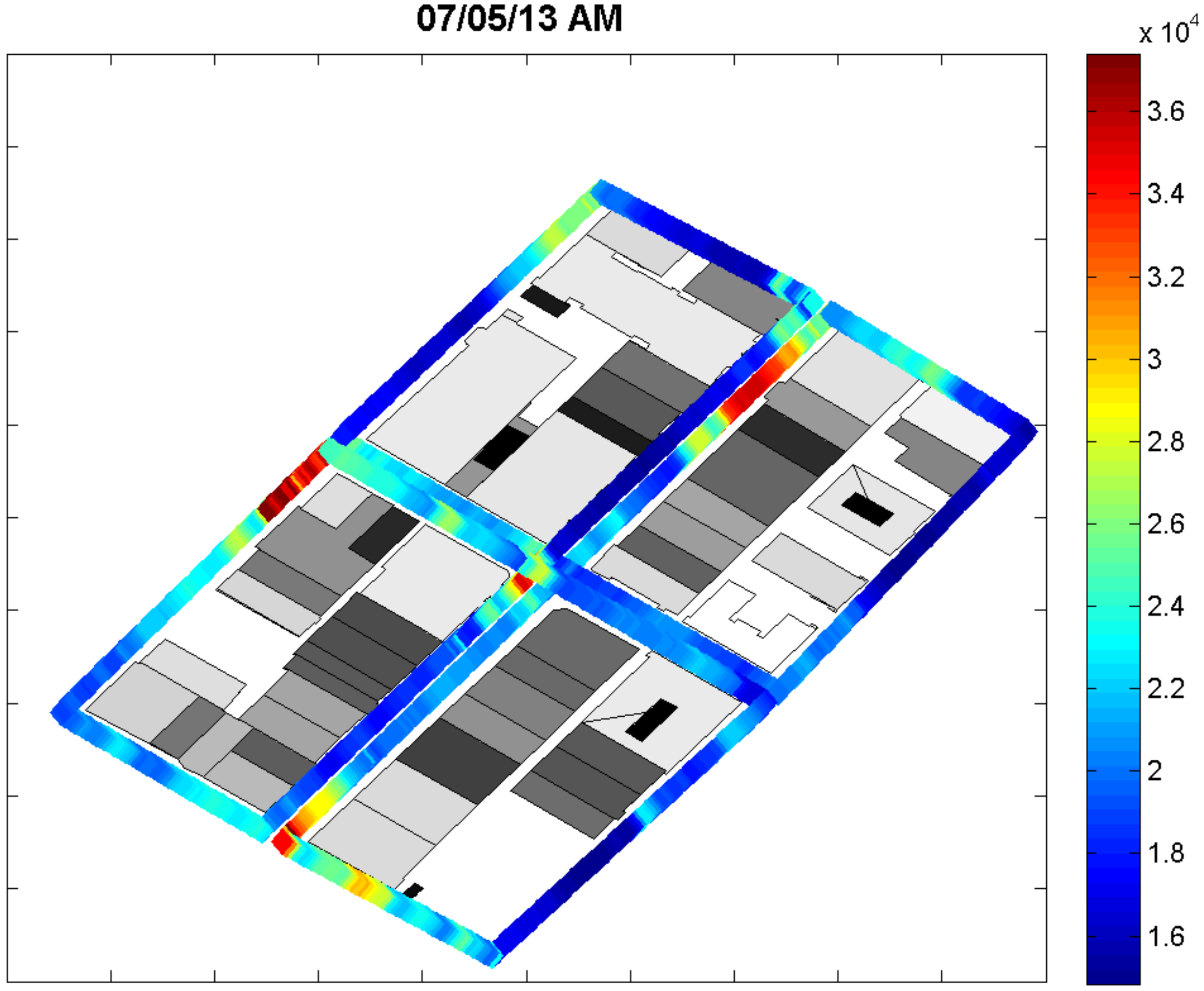
Using a line-reference system

- Divide the street into a grid with reference points every *x* meters.
  - Each reference point gets 1 value per run. If there are 30 data points, they are averaged. If there are no data points, we interpolate one.
  - This avoids under/overweighting individual “runs” on the route.

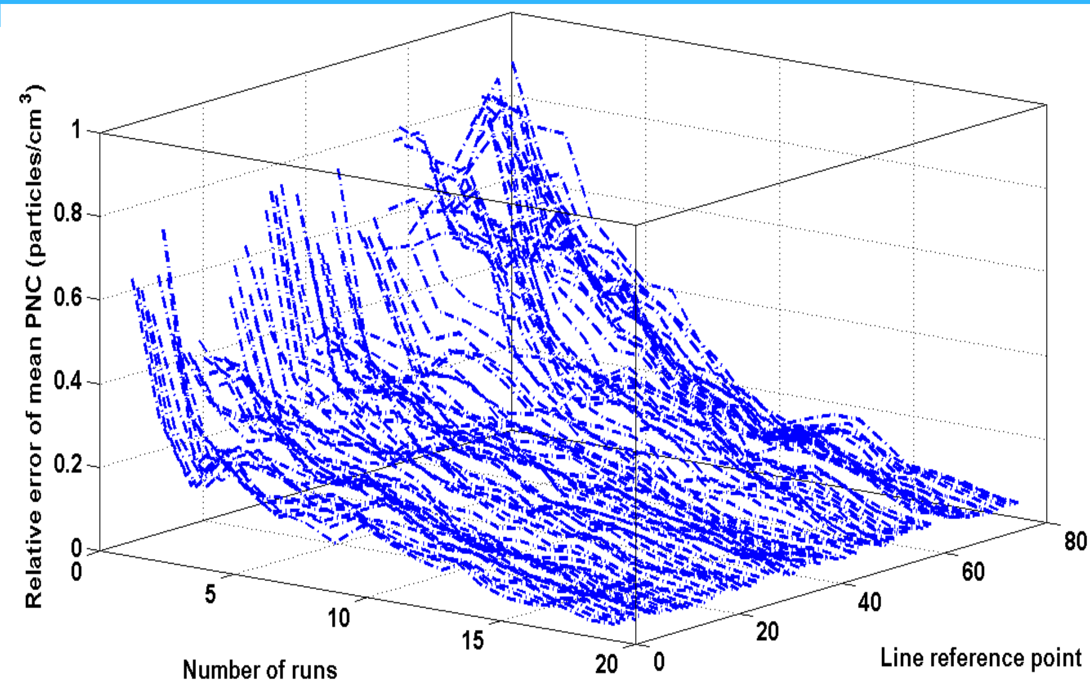


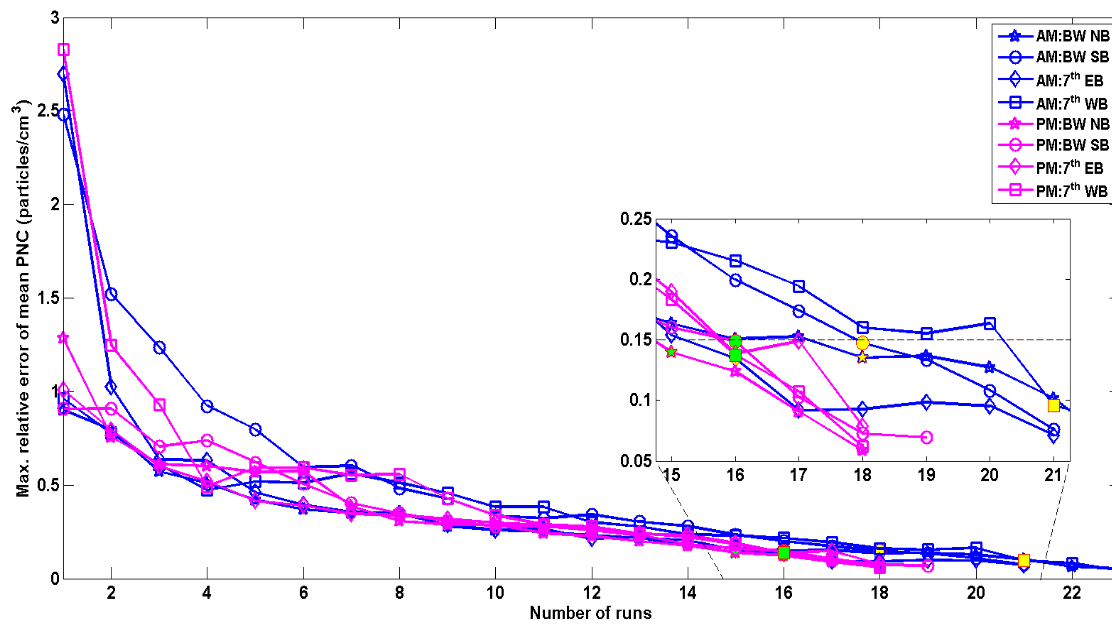


At high spatial resolution, mostly see the effects of accelerations around traffic stops.



Need ~20 repeats under similar met conditions to get a reasonable average



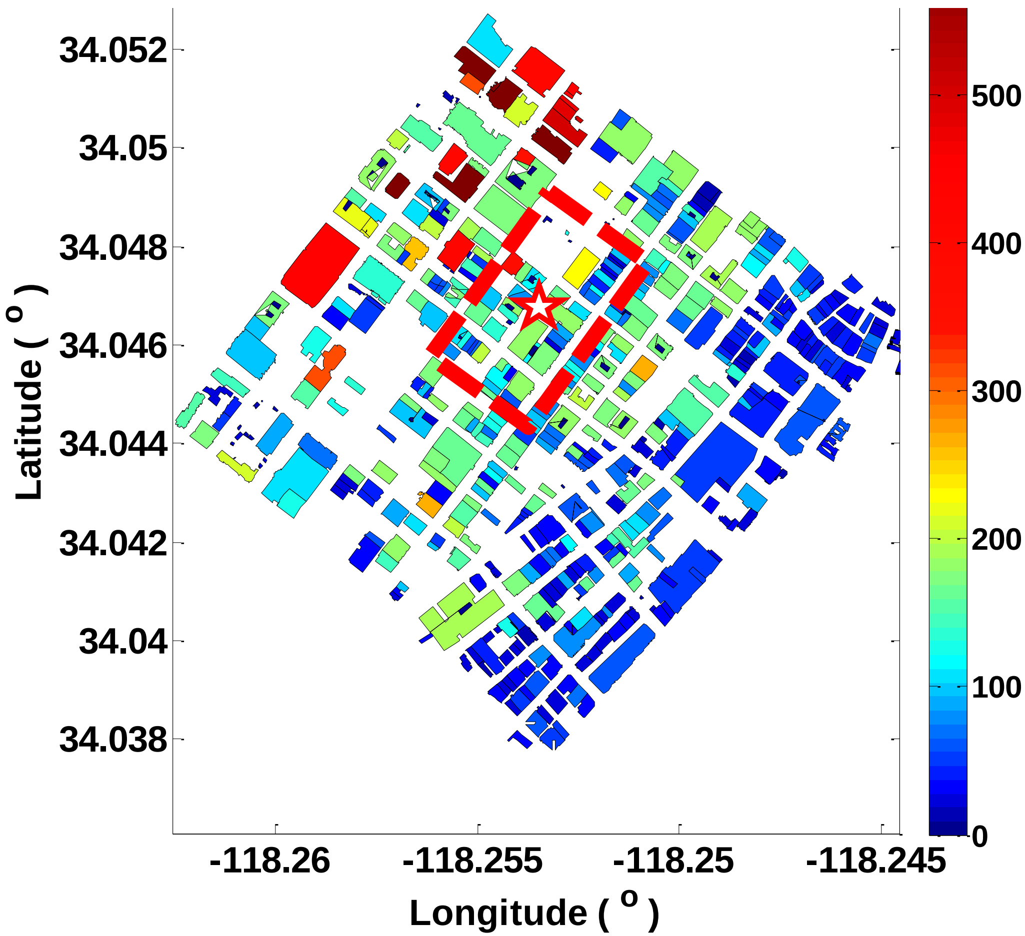


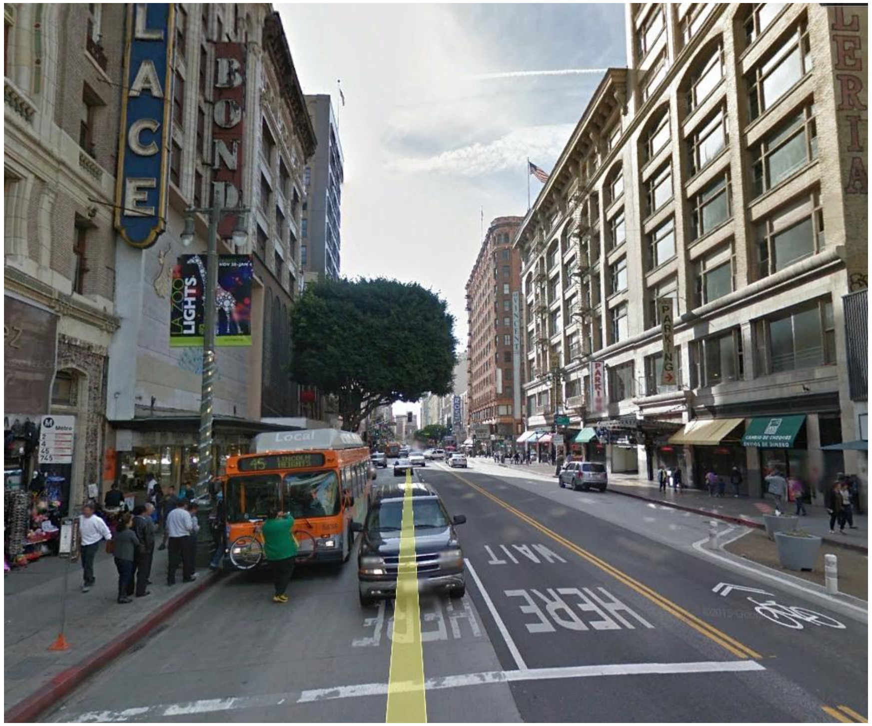
Ranasinghe et al. AAQR (2016)

What is the effect of the built environment at the block/neighborhood scale on pollutant concentrations at the street?

Site 1: Street canyon

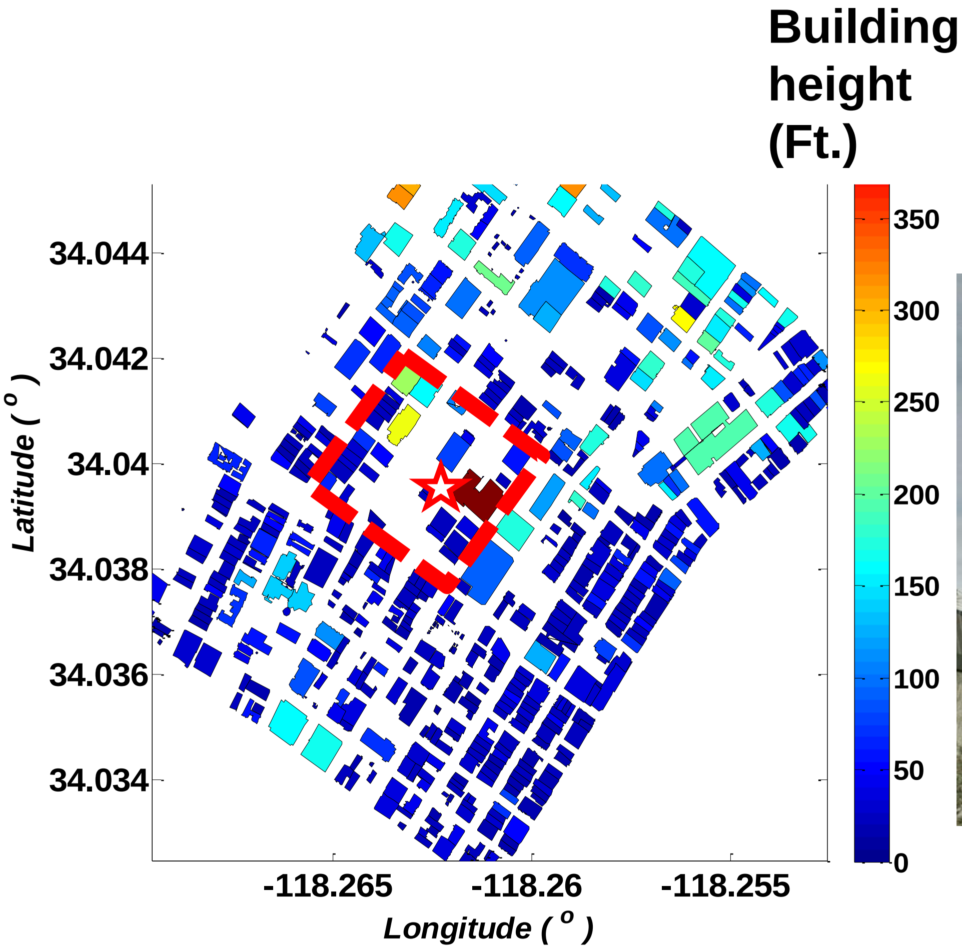
Building height (Ft.)

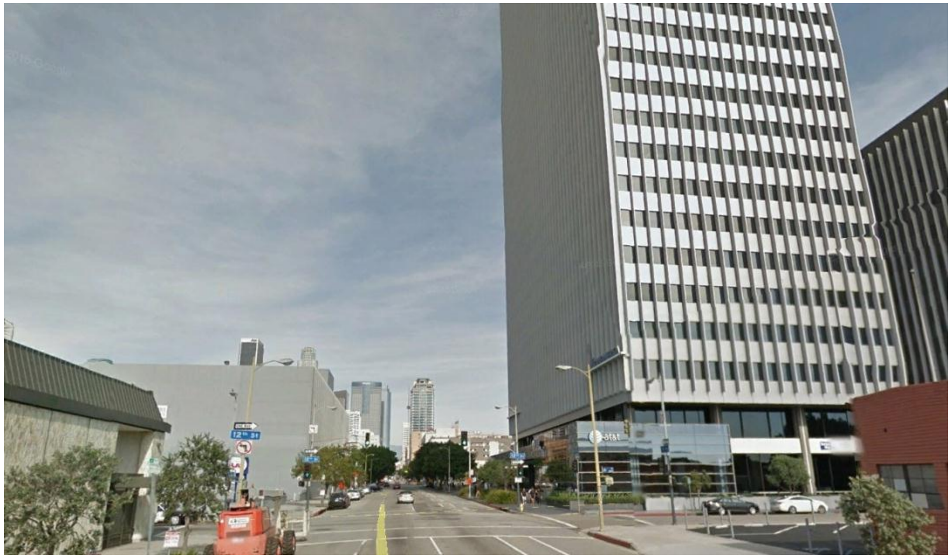




Olive & 12th Site (Street view: heading to South)

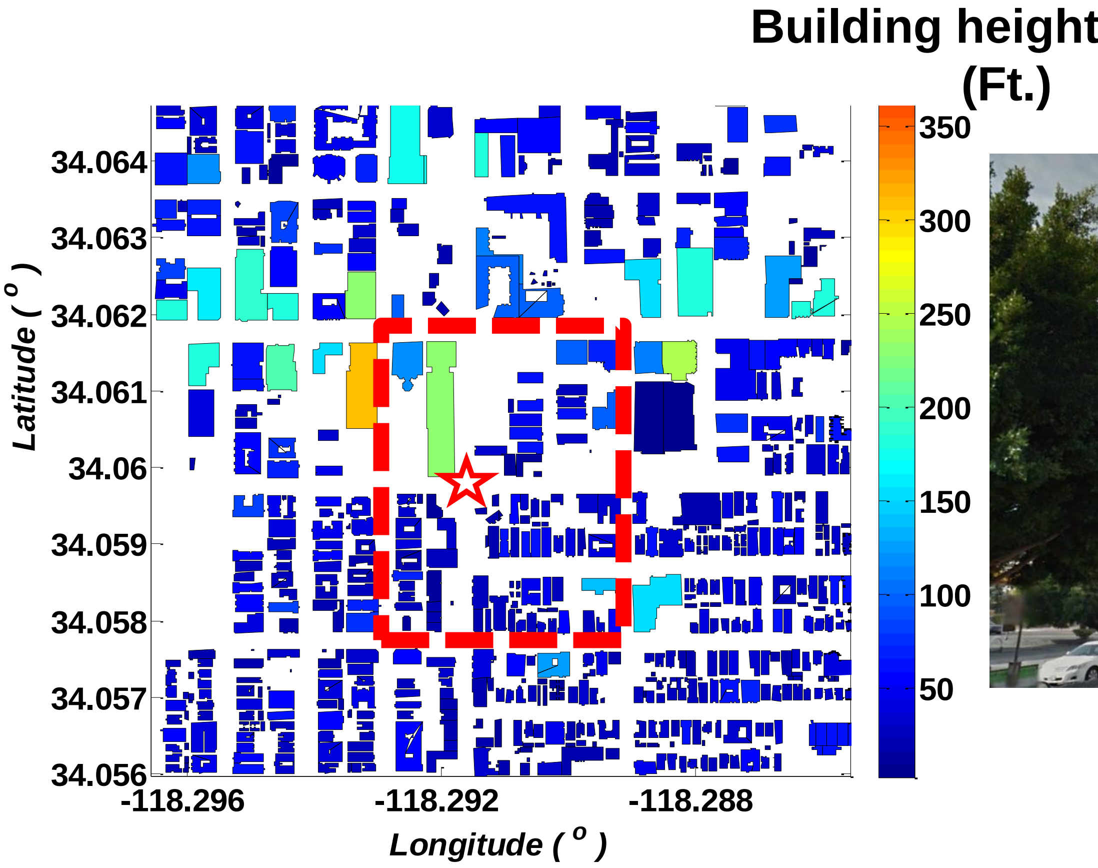
Site 2: One isolated tall building with low traffic





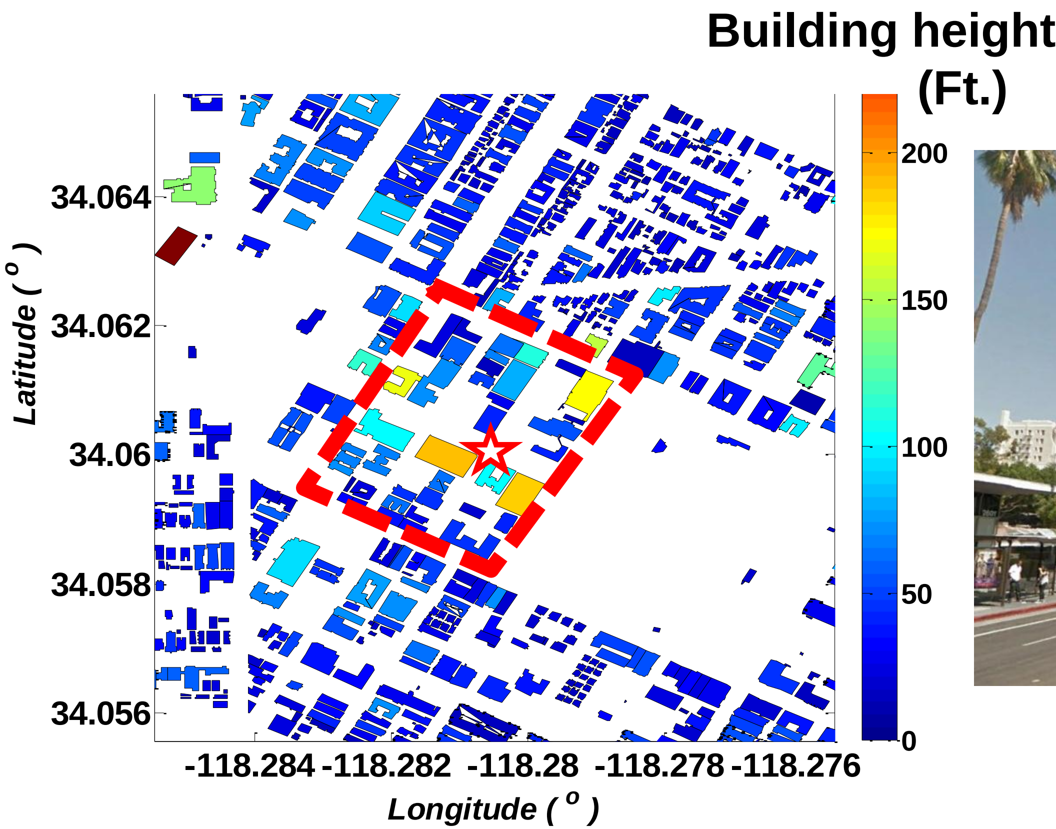
Olive & 12th Site (Street view: heading to North)

Site 3: One isolated tall building with high traffic



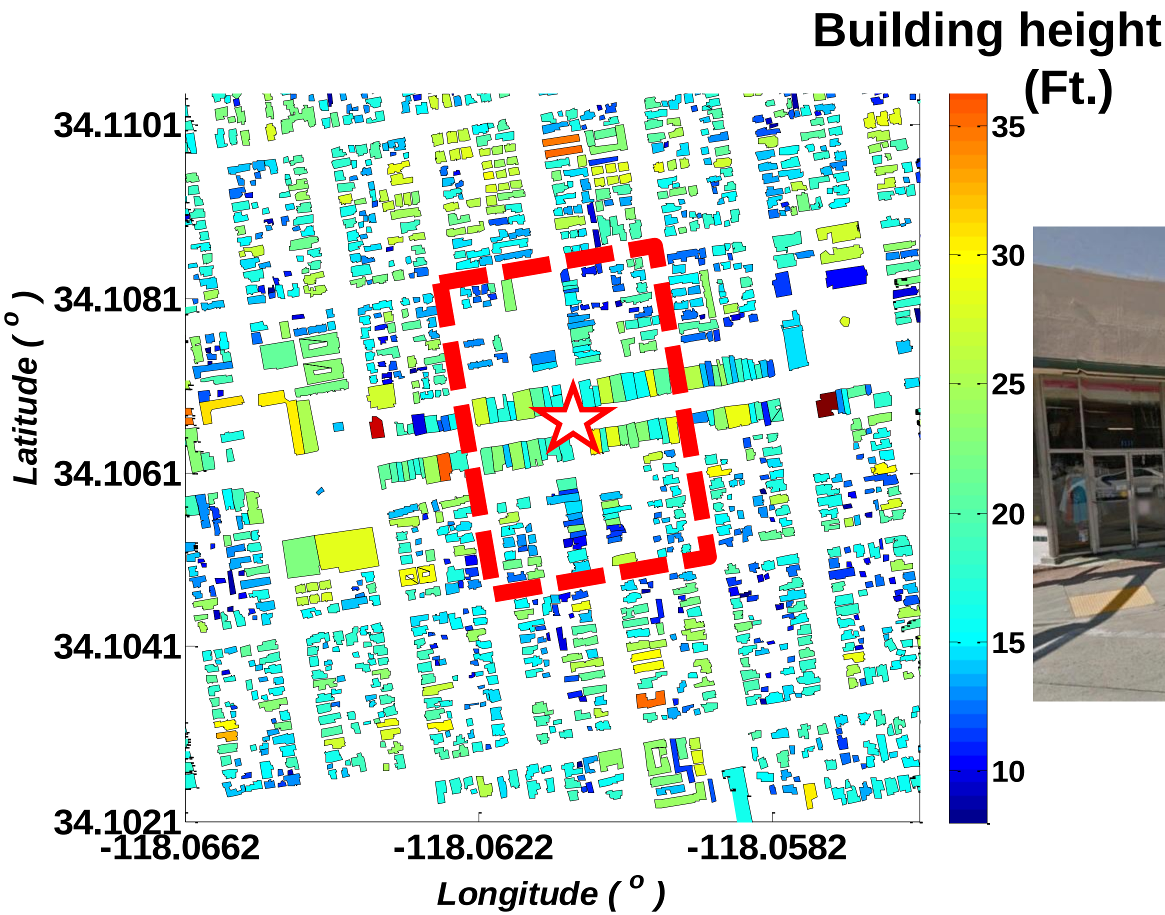
Vermont & 7th Site (Street view: heading to West)

Site 4: Intermediate buildings in one side and low buildings in the other side of the street



Wilshire & Carondelet Site (Street view: heading to East)

Site 5: All single story buildings

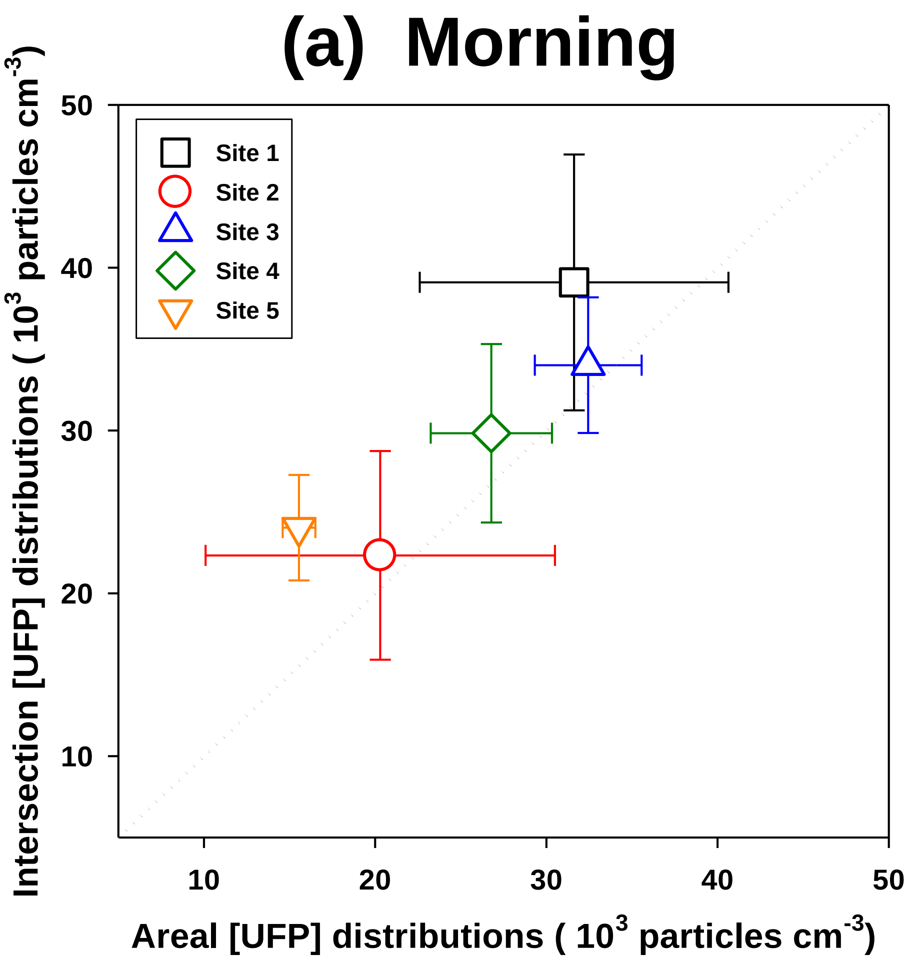


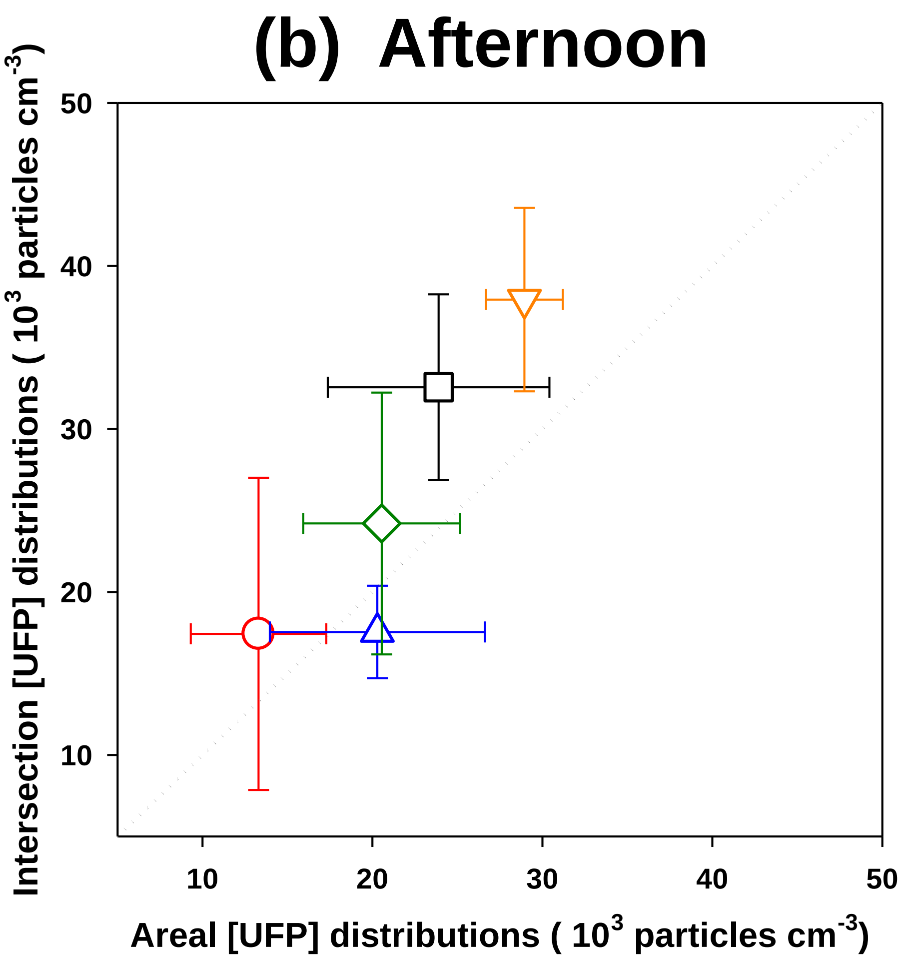
Temple City & Las Tunas Site (Street view: heading to North)

Built environment quantitative descriptors

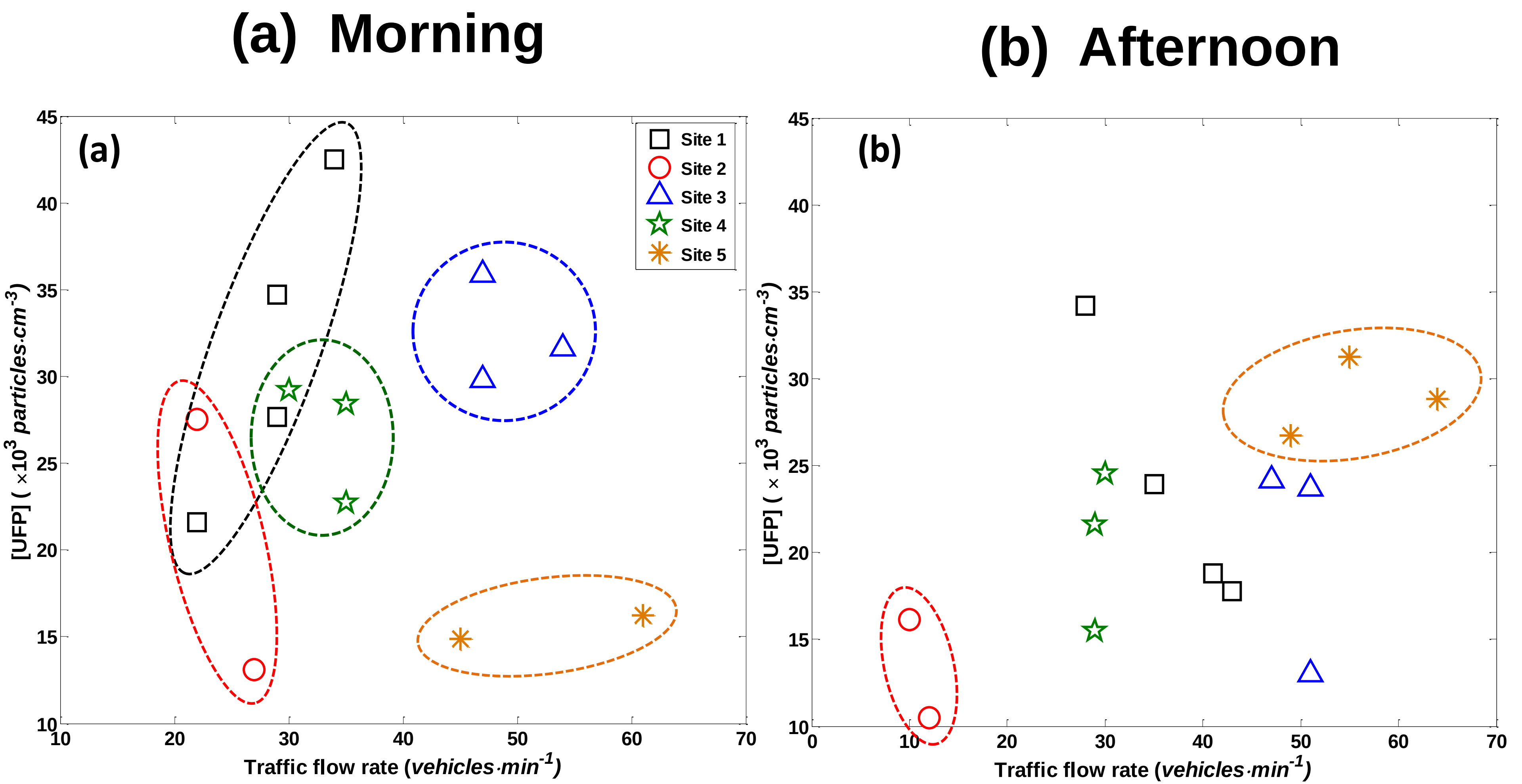
	Broadway & 7th *(Site1)*	Olive St. & 12th St. *(Site2)*	Vermont & 7th St. *(Site3)*	Wilshire & Carondelet *(Site4)*	Temple City & Las Tunas *(Site5)*
# of buildings	59	34	90	44	143
Max. building height (m)	58	129	80	57	8
Mean building height, H_{bldg} (m)	34	21	11	18	5
Bldg area weighted height, H_{area} (m)	40	42	25	24	6
Bldg. homogeneity, H_{area}/H_{bldg} (dimensionless) (1=perfectly homogeneous)	1.16	2.01	2.21	1.39	1.09
Mean building ground area (m^2)	1,030	1,395	585	992	225
Street width (m)	26 (BW) / 22 (7th)	28 (Olive) / 17 (12th)	30 (Ver) / 25 (7th)	17 (Car) / 37 (Wil)	24 (TC) / 30 (LT)
Simple Aspect ratio (H_{area}/W_{street})	1.7	1.9	0.9	0.9	0.2
Block length (m)	190 (BW) / 100 (7th)	180 (Olive)/ 95 (12th)	190 (Ver) / 95 (7th)	160 (Car) / 75 (Wil)	175 (TC) / 115 (LT)
Ratio occupied by bldg.	*0.72*	*0.42*	*0.33*	*0.46*	*0.30*

Intersection PNC (Stationary) vs. Over the site average PNC (Mobile)





Higher traffic → higher UFP, except at the two sites with extreme built-environments, homogeneous & high or low: the street canyon (*Site1*) and the low, flat bldg. canopy (*Site5*).

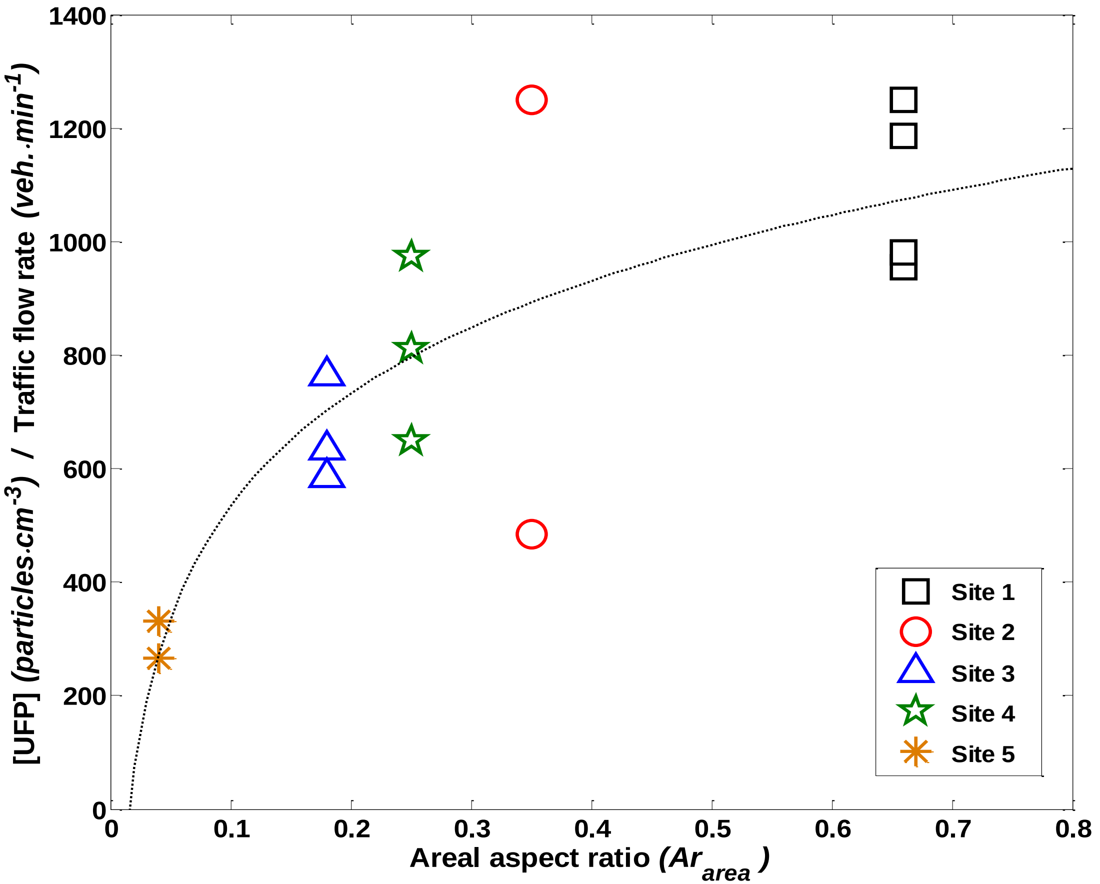


Best Explanatory Factor in the Morning:

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

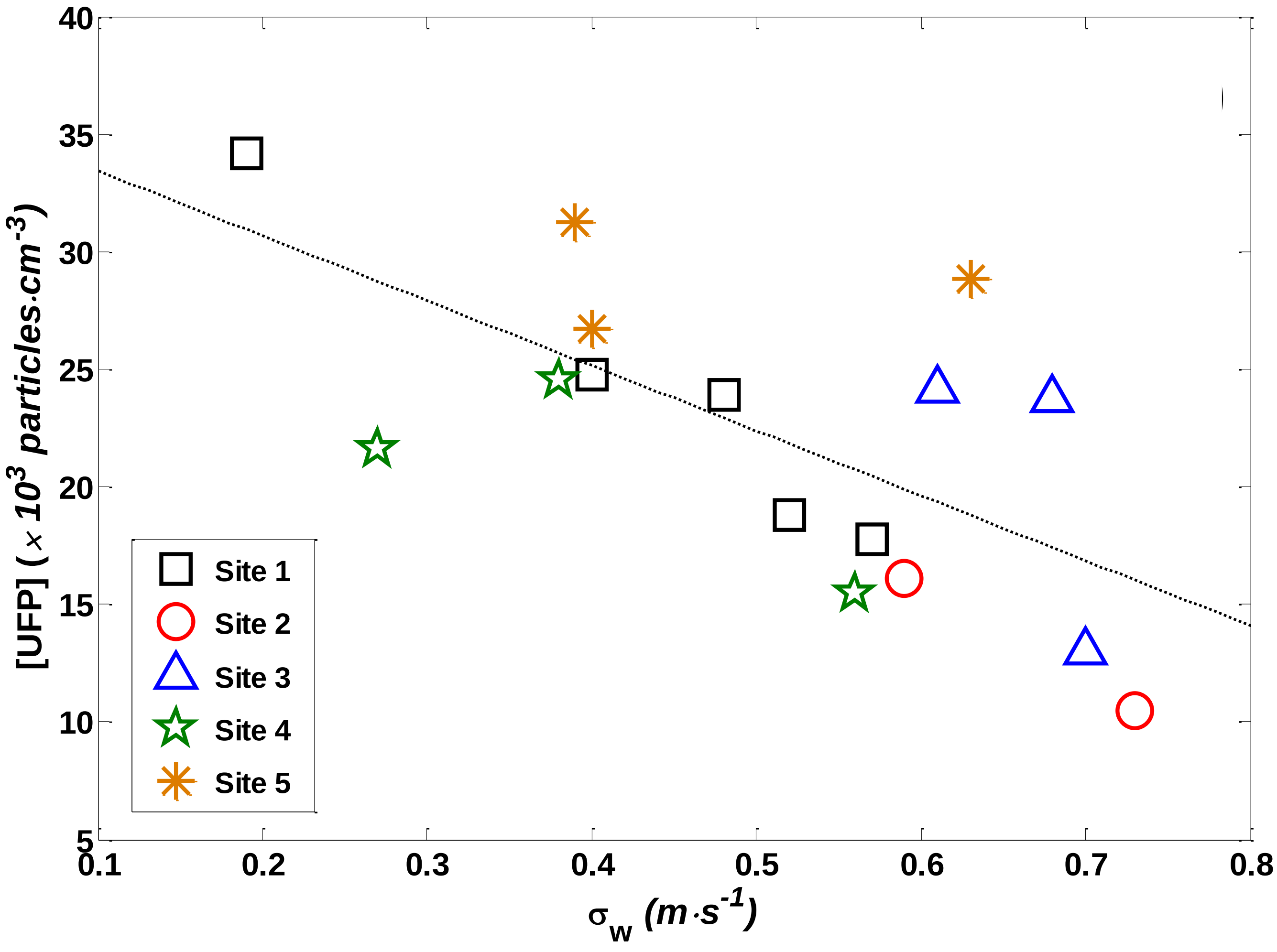
S_{bldg}: Building surface area

A_{site}: Area of the sampling site

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

Choi et al., 2016

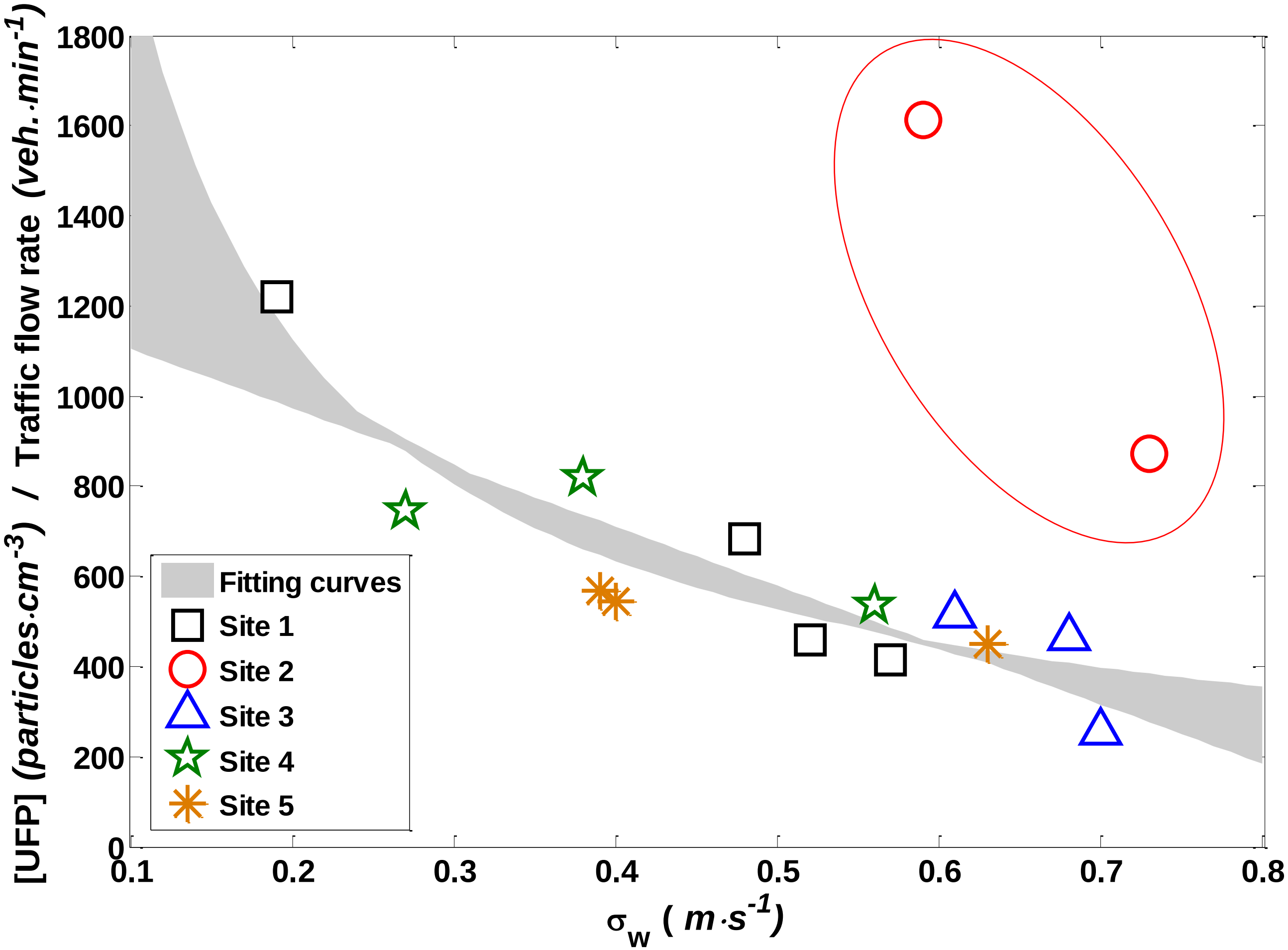
Best Explanatory Factor in the Afternoon: Turbulence strength (vertical fluctuations of surface winds, σ_w)



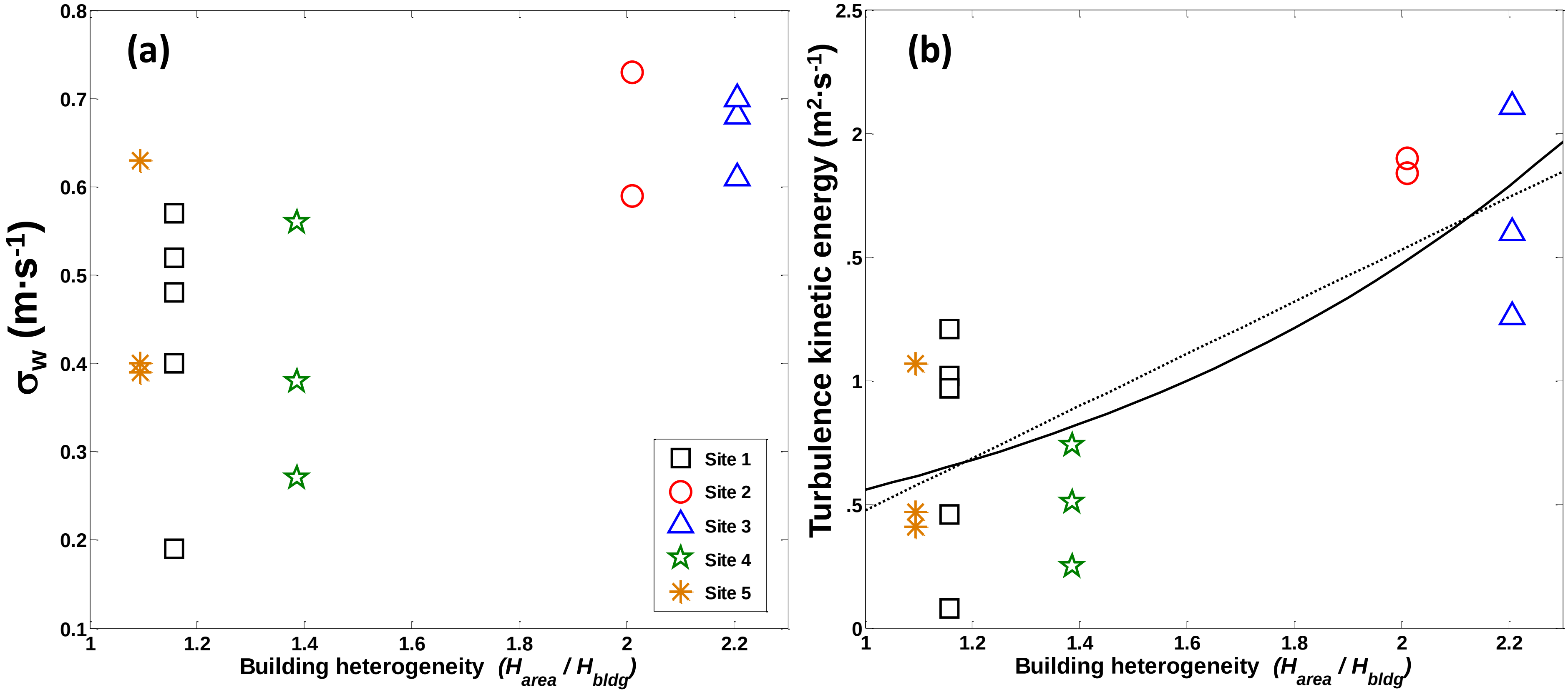
Best Explanatory Factor in the Afternoon:

Turbulence strength (vertical fluctuations of surface winds, σ_w)

Appears to be from non-local emissions



The effects of building heterogeneity on turbulence in the afternoon:



Higher building heterogeneity appears to enhance surface turbulence, under conditions with moderate winds and an unstable atmosphere

Summary for Planners:

Built environment and traffic management design characteristics that influence near-roadway exposures to vehicular pollution

Management	Suggested Direction	Approx. Size of Effect	Atmospheric Conditions & Notes
Areal aspect ratio (A_{area}) A_{area} combines building area-weighted height, building footprint, and the amount of open space.	Lower building volumes and more open space result in lower pollutant concentrations.	Up to approximately a factor of three.	Important under calm conditions (in the mornings at our sites). Not critical when the atmosphere is unstable.
Building Heterogeneity	Isolated tall buildings result in lower concentrations than homogeneous shorter or higher buildings with similar volume.	Up to approximately a factor of two.	Important under unstable conditions with moderate winds (afternoons at our sites). Not critical when the atmosphere is stable.
Traffic flow	Lower traffic flow is better, controlling for fleet mix.	At a given location, concentrations are roughly proportional to traffic flow.	

Summary for Planners:

Built environment and traffic management design characteristics that influence near-roadway exposures to vehicular pollution

Management	Suggested Direction	Approx. Size of Effect	Atmospheric Conditions & Notes
Traffic Management	Fewer stops and smaller queues reduce emissions and elevated concentrations around intersections	Cannot estimate from our data	Concentrations depend on emissions, micro-scale turbulence, dispersion, transport from nearby streets, and other factors
Sensitive uses near highways	Further is better, but under normal daytime conditions 500 feet is sufficient. If there are consistent nocturnal surface inversions, much longer distances are recommended.	Up to a factor of four or more.	Much more important during surface inversions, which usually occur during night and can persist through mid-morning.
Airports	Site residential and other sensitive uses far from airports.	Up to a factor of four or more	

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Thank you for your attention