Mitigating Roadway Pollution in Urban Areas: Locating Transit Stops

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Several people at this conference will discuss how to clean up emissions.

Other people at this conference will (hopefully) convince you roadway pollution isn't good for you.

I'd like to discuss how the built environment design influences how much you breathe.

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

- **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

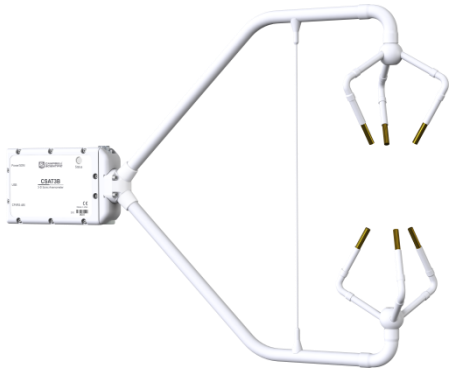
METHODS

Mobile measurements

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) DustTrak (TSI, Model 8520)	UFP number and average size $PM_{2.5}$ 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

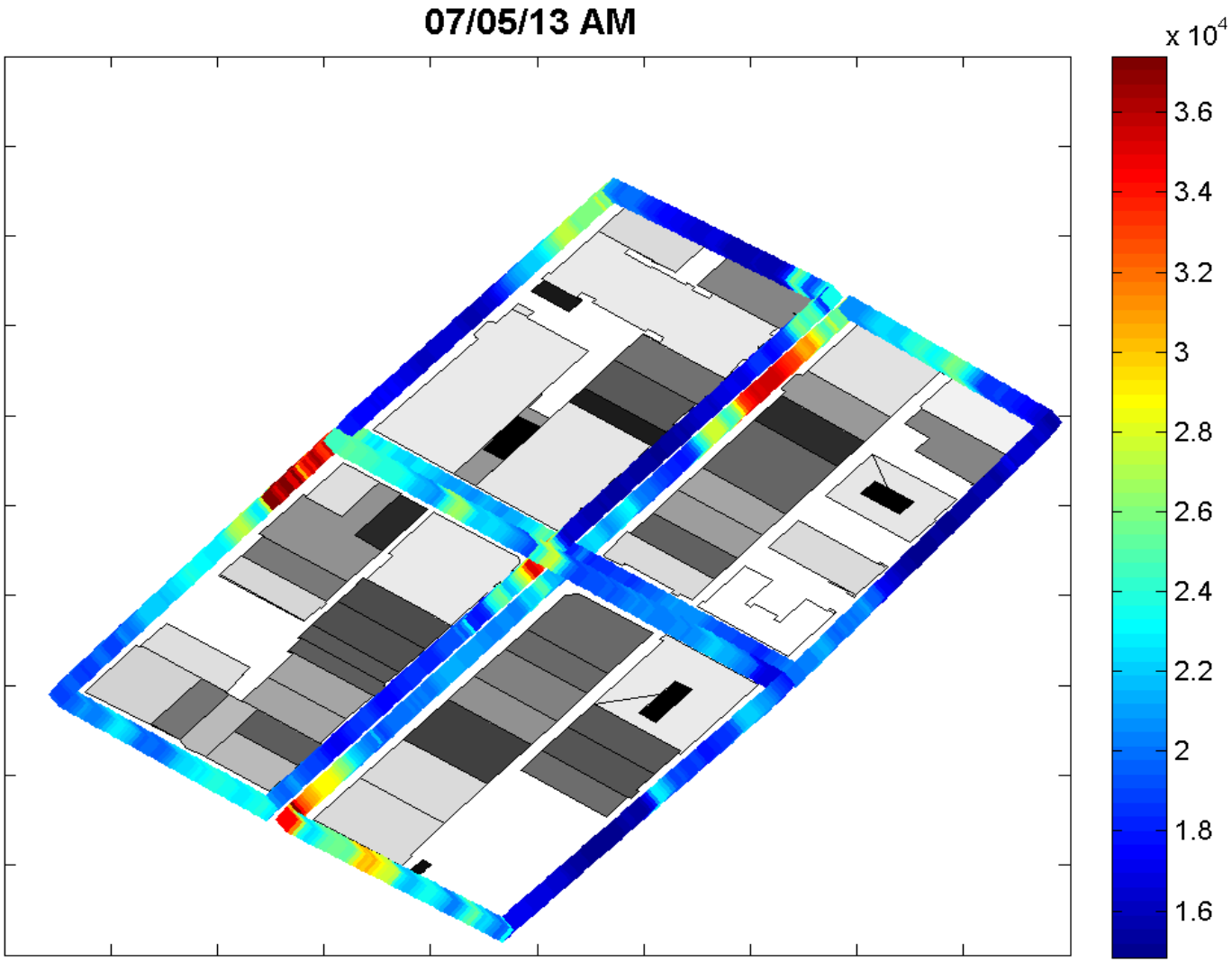
California Air Resources Board Mobile Measurement platform (MMP)
Toyota RAV4 electric vehicle



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.

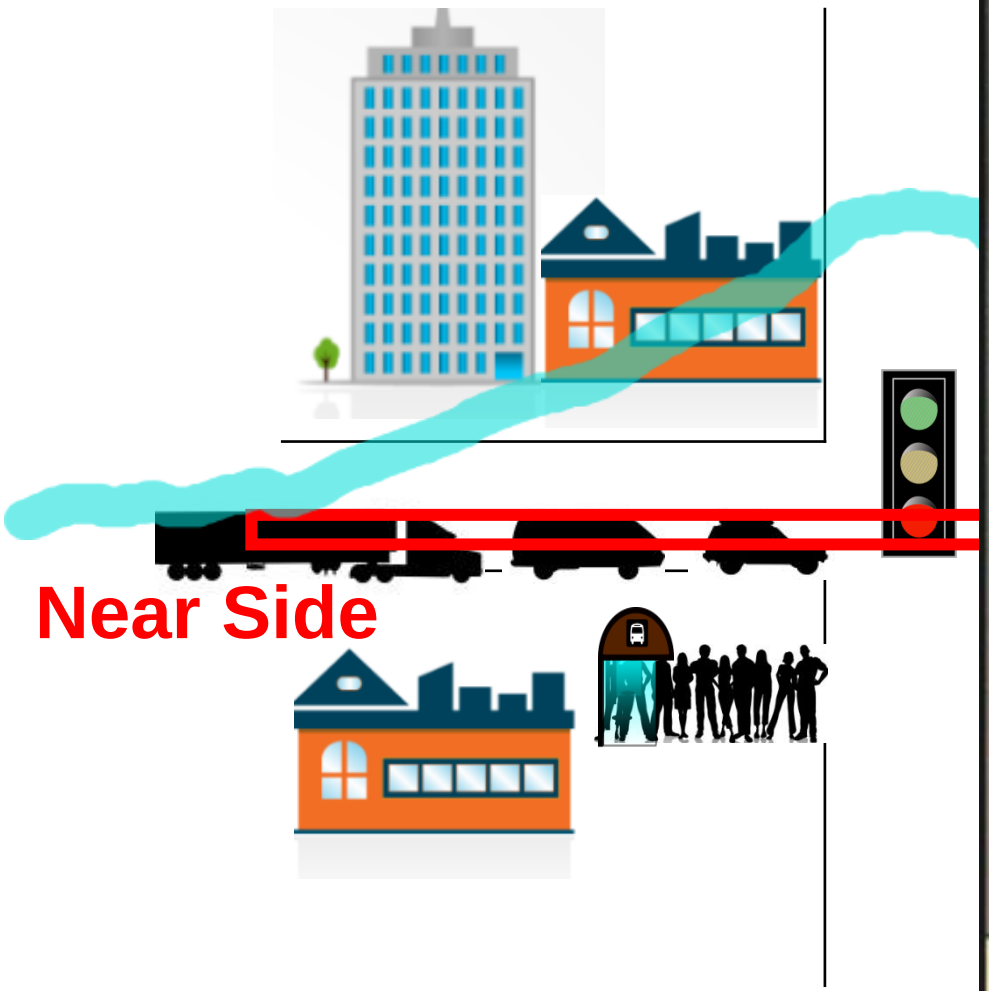
5 Meter Spatial Resolution Map for Downtown Los Angeles



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

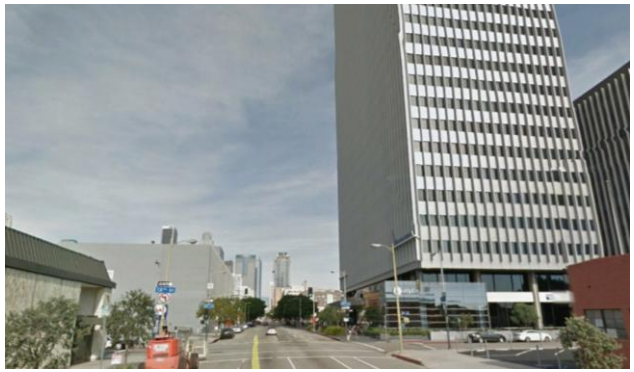
Choi, W.S., D. Ranasinghe, J.R. DeShazo, J.J. Kim and S.E. Paulson (2017) *Cross-Intersection Profiles of Ultrafine Particles in Different Built Environments: Implications for Pedestrian Exposure and Bus Transit Stops*. Submitted.

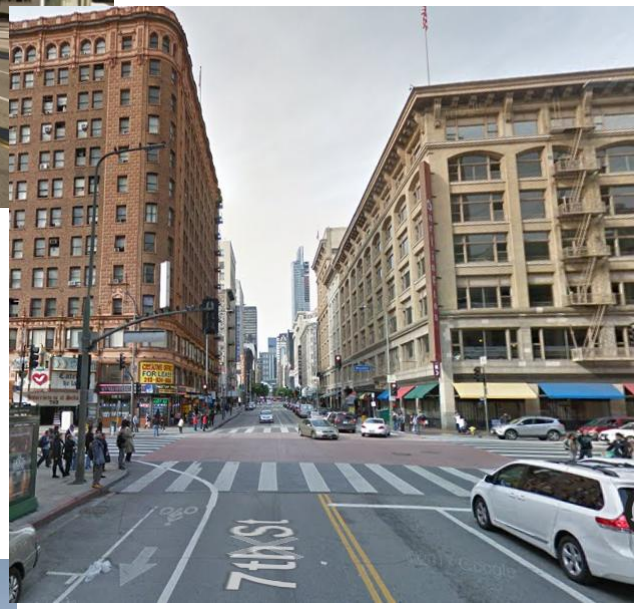
How Far Should the Bus Stop be from the Intersection?



Gary Larson's Far Side Cartoons

Measurement Sites for Intersection Studies



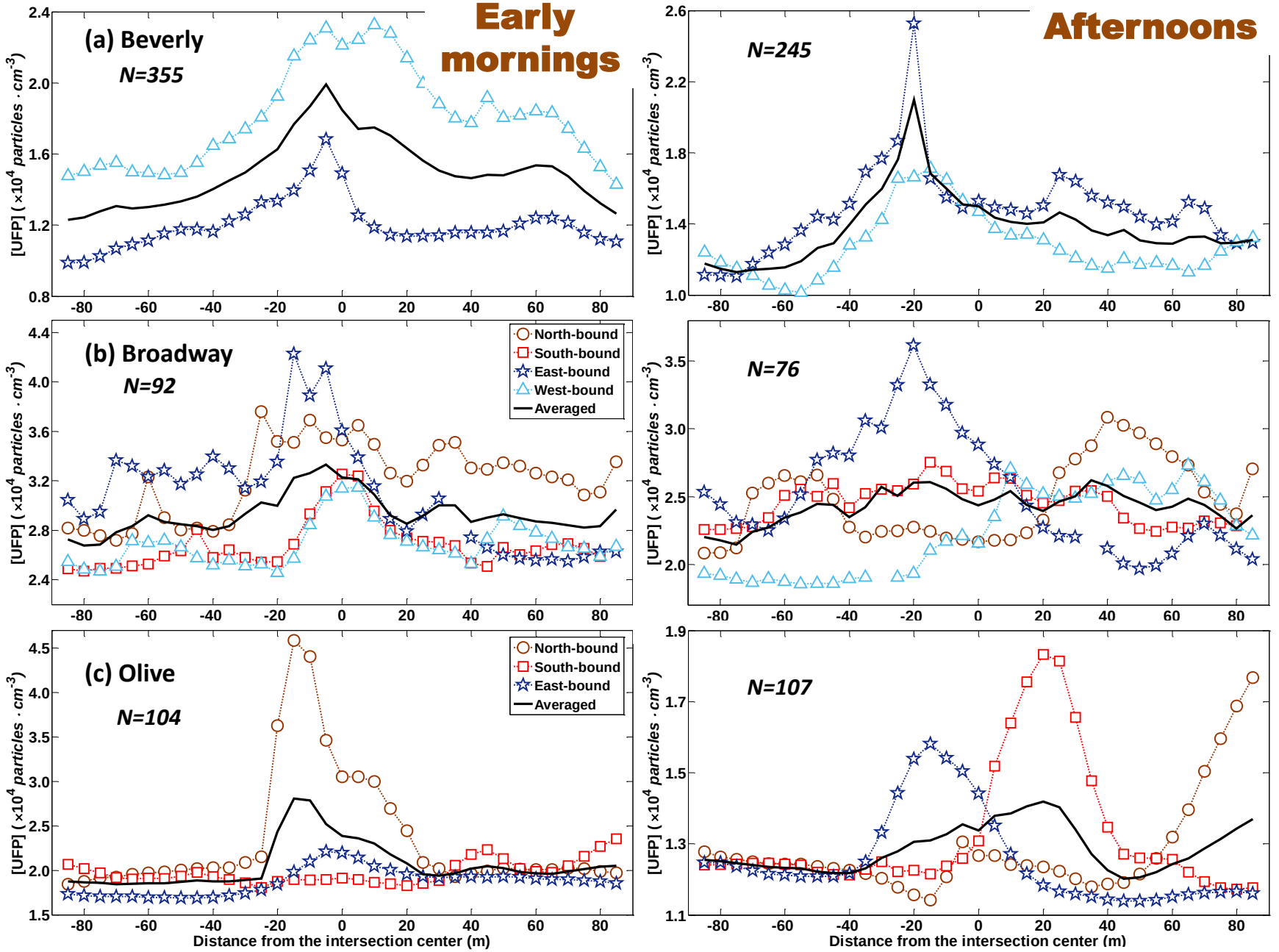


10 Intersections
1,744 Profiles

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



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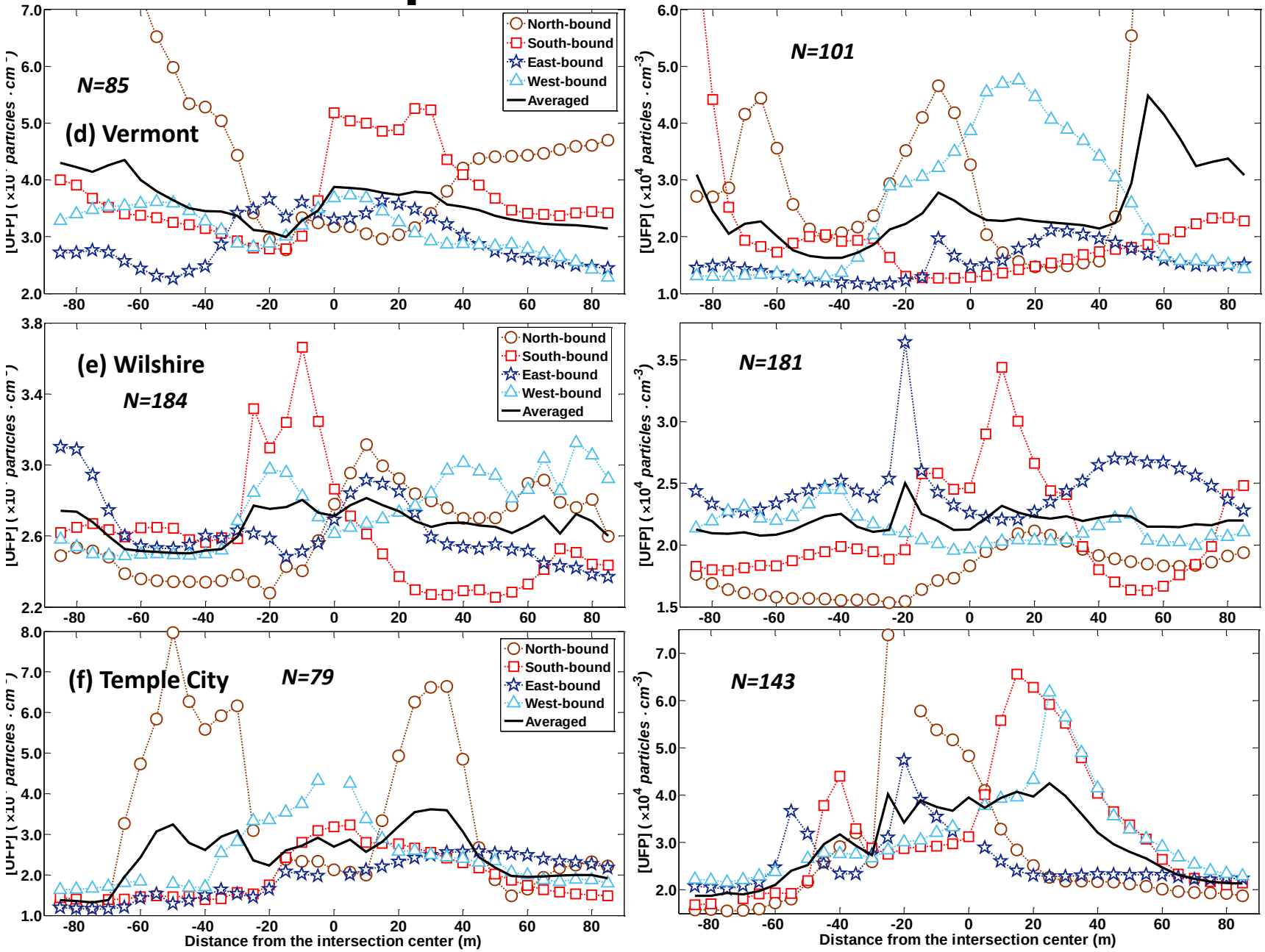
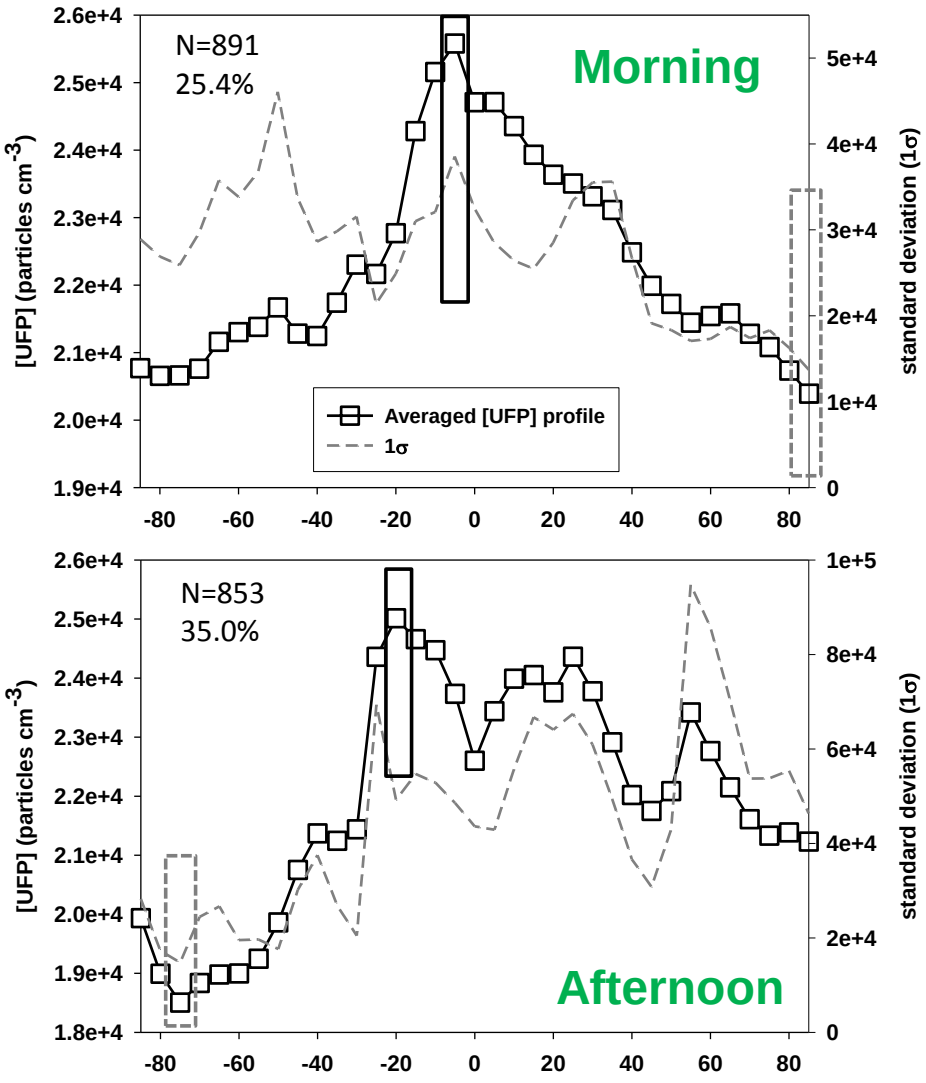
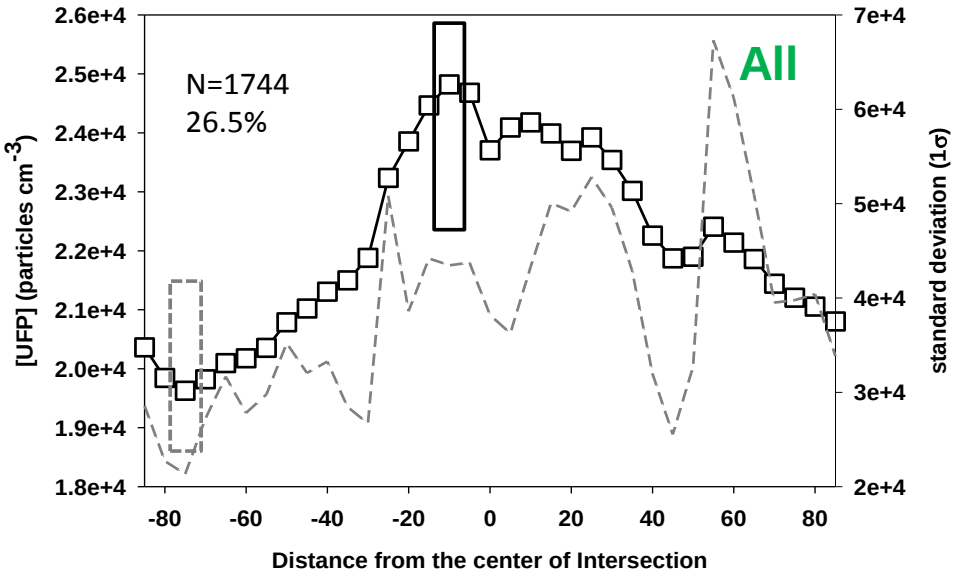
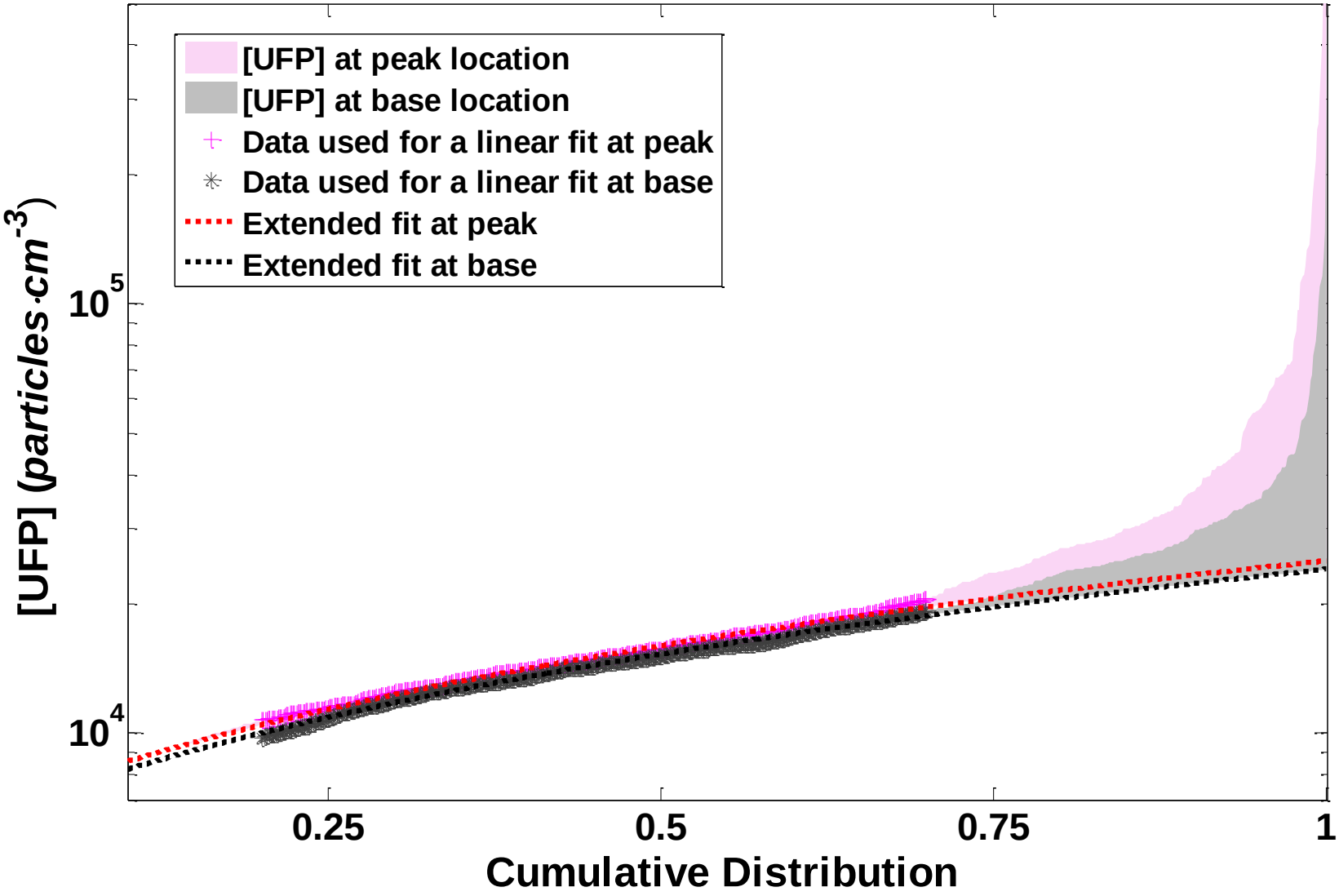


Average Profiles





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

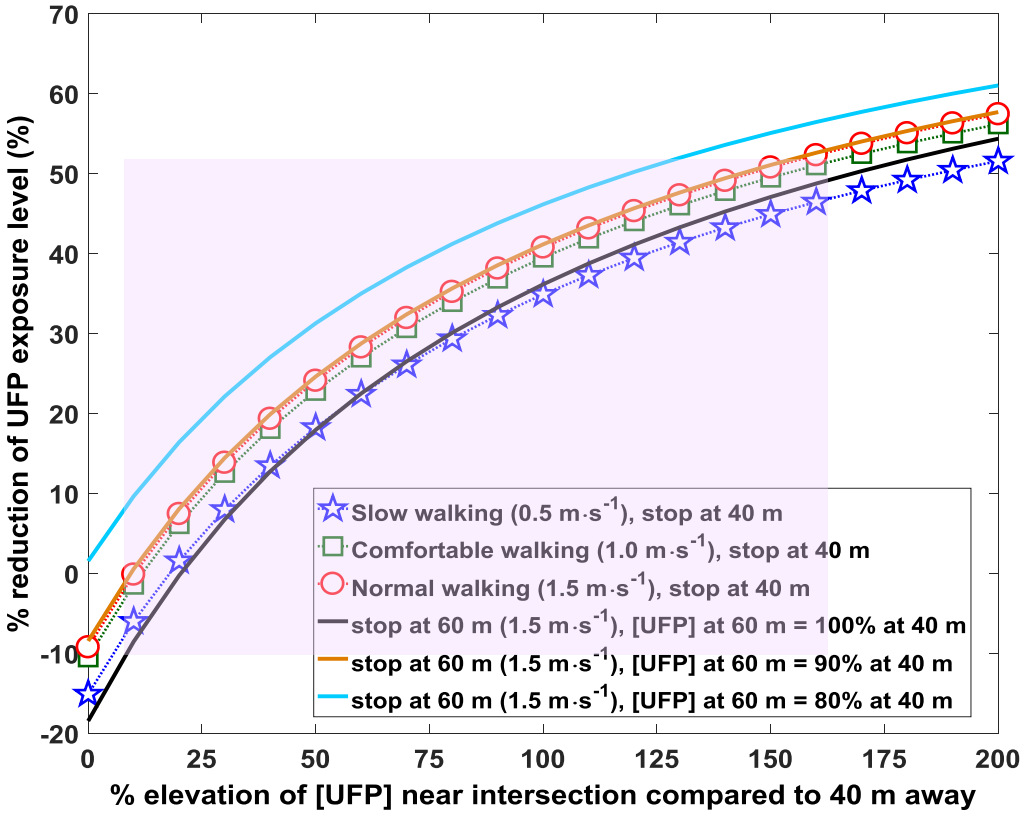


Exposure level of transit-users to UFP around intersections

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!



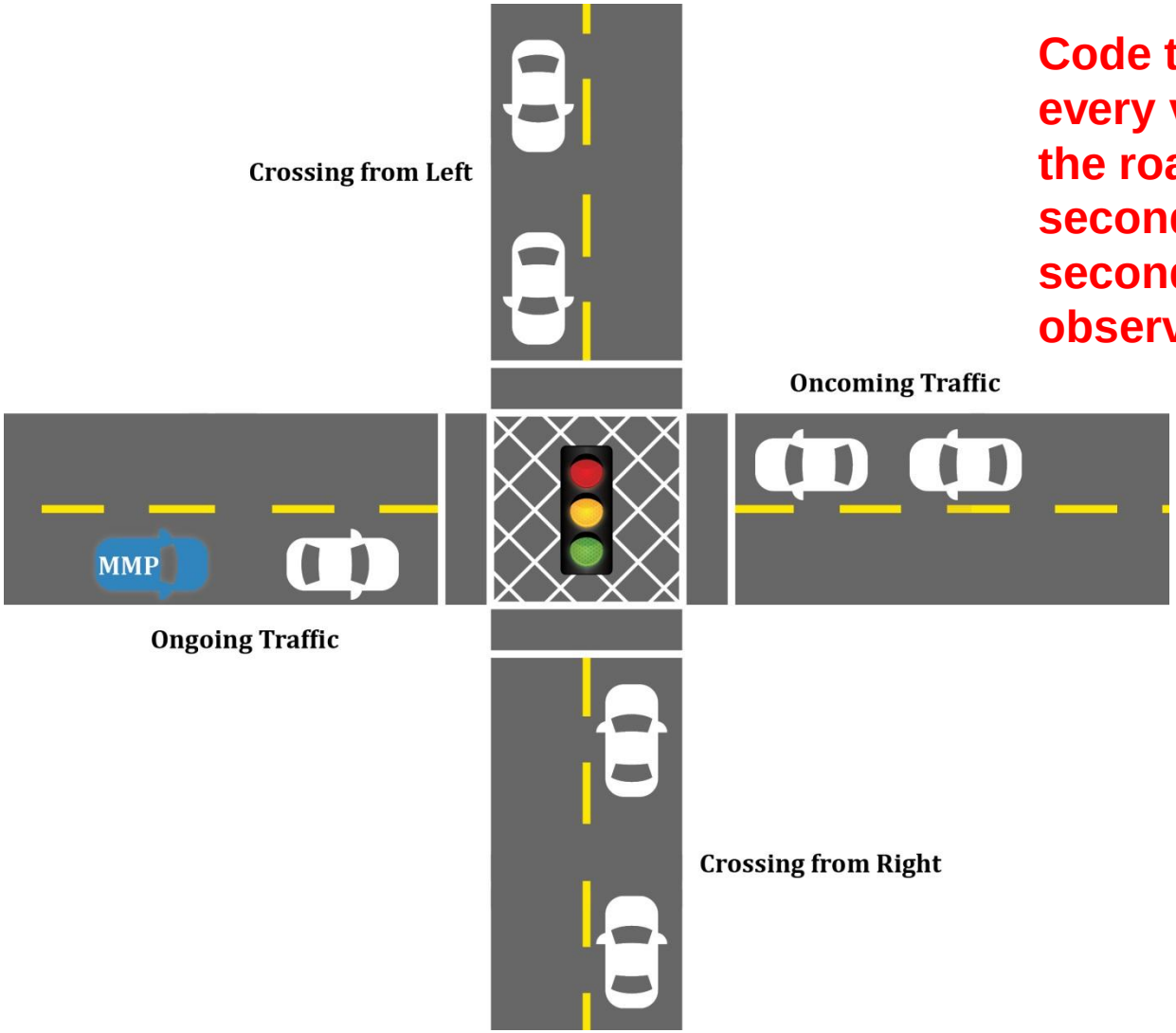
Modeling the Determinants of Highly-localized UFP Concentrations

J.R. DeShazo, Suzanne Paulson, Lisa Wu, Owen Hearey, and others

Broadway Transect in Downtown Los Angeles

- April-July 2008
- ~5 km long
- 12 MMP runs
- ~7000 observations

Intersection Diagram with Mobile Monitoring Platform (MMP)



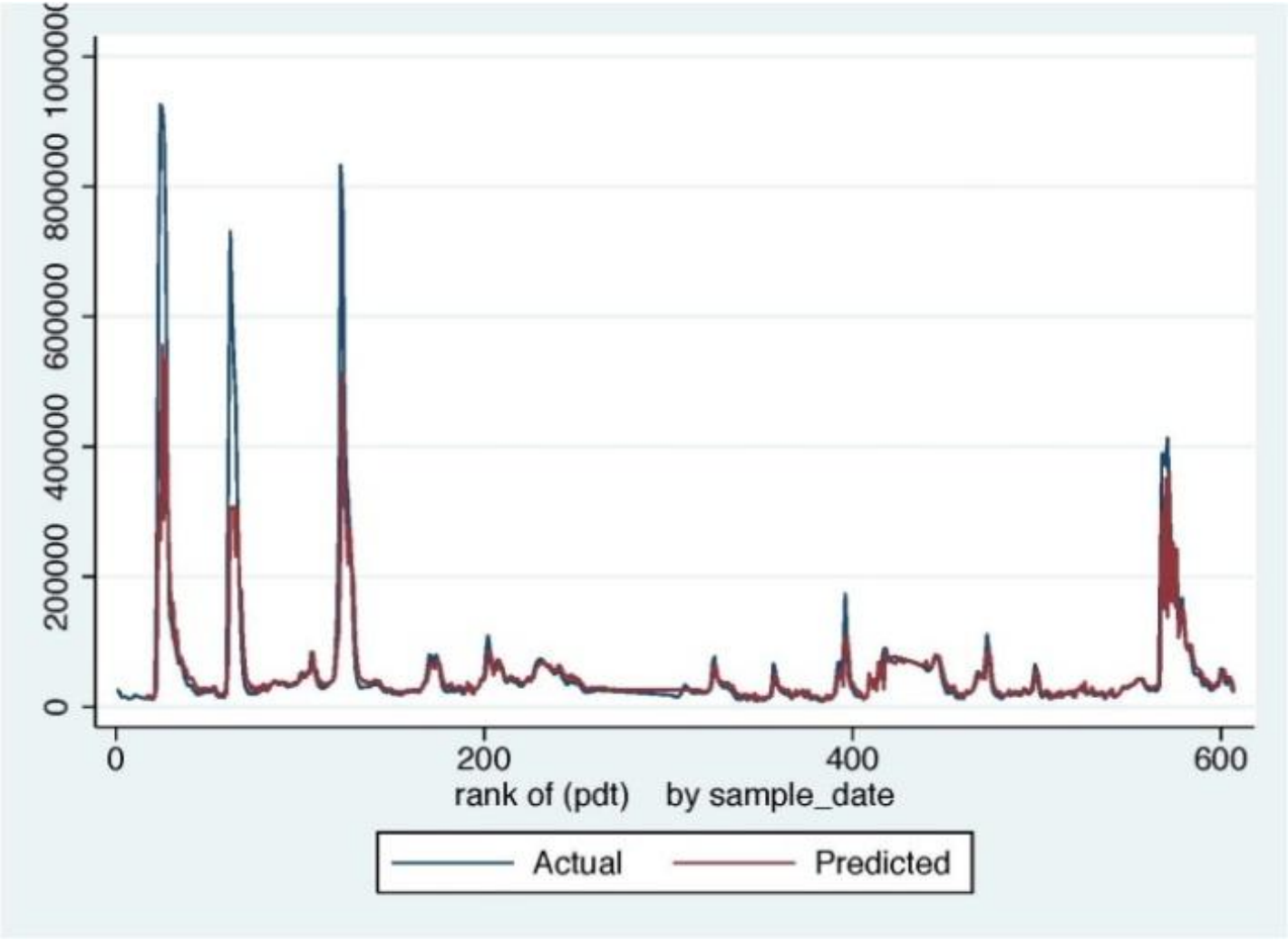
Code the location of every vehicle visible in the roadway every second, for 7000 seconds of observations!!

Modeling the effects of highly-localized factors

UFP = f(emission sources,
sources of mixing
atmospheric conditions,
built environment,
position of the mobile monitoring platform,
constant background concentration)

Regression model will seek to explain the concentration of UPF measure as function of a these explanatory variables.

Validating the model's predictive power: Actual v. Predicted UPF Concentrations



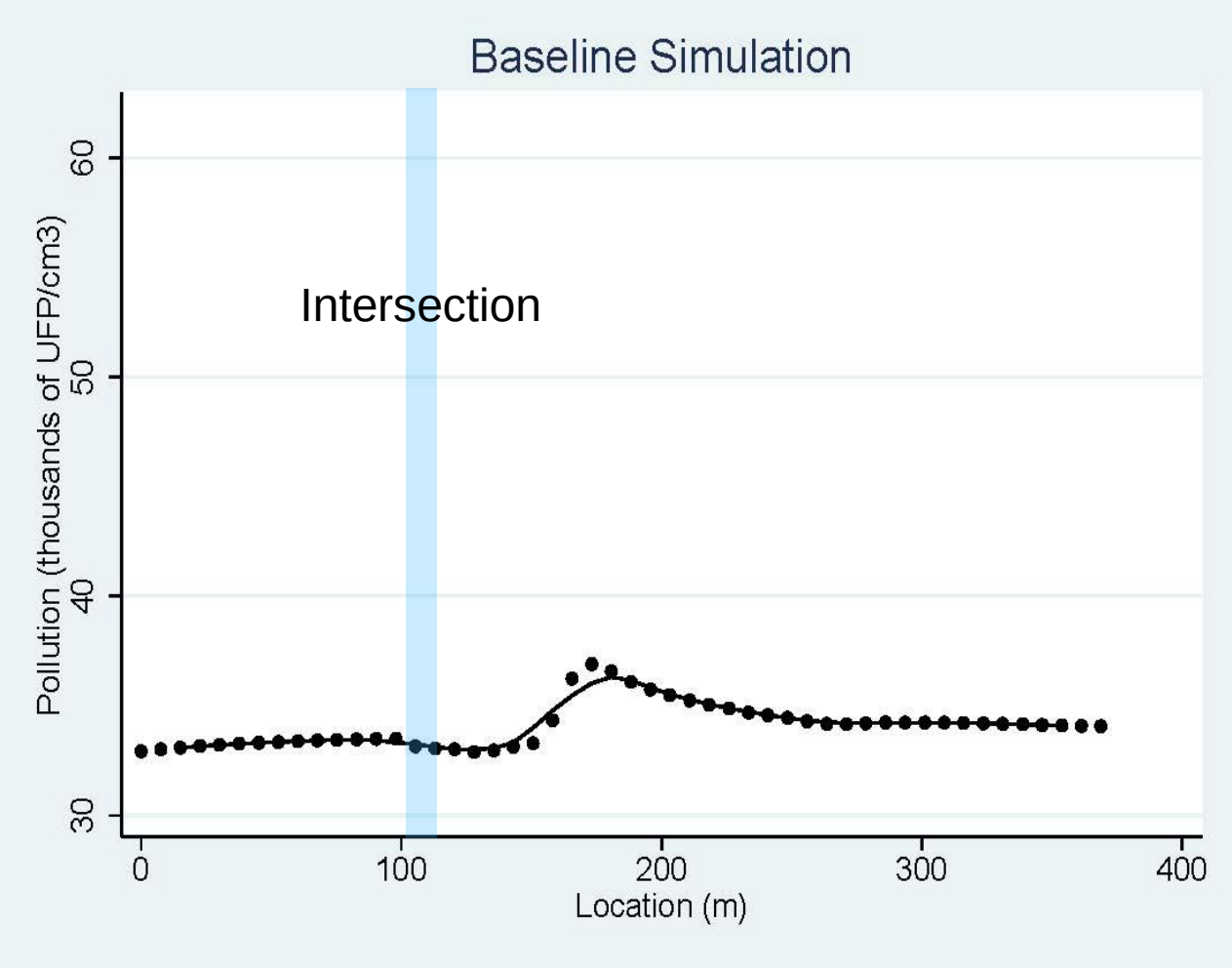
Cumulative impacts of factors on street level UFP

- Top five factors:
  - Medium/Heavy Duty Vehicle in On-going traffic
  - Medium/Heavy Duty Vehicle crossing from the left
  - Bus crossing from the left
  - Being in an intersection
  - Difference in building heights between the two sides of the street.

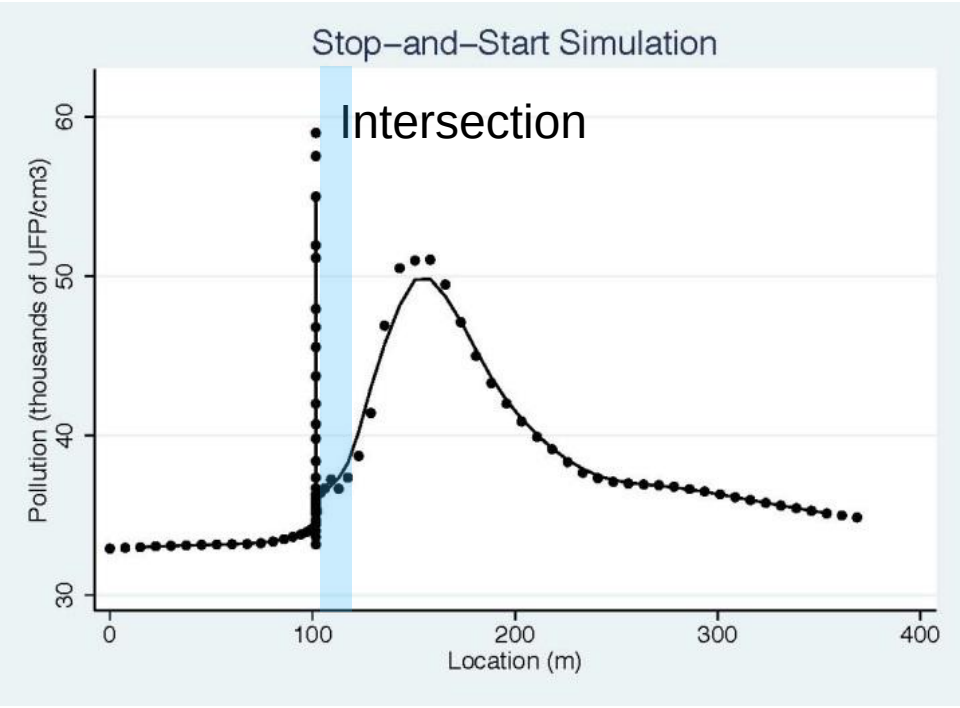
Cumulative Impacts of Traffic Events (in thousands of particles/cm^3)

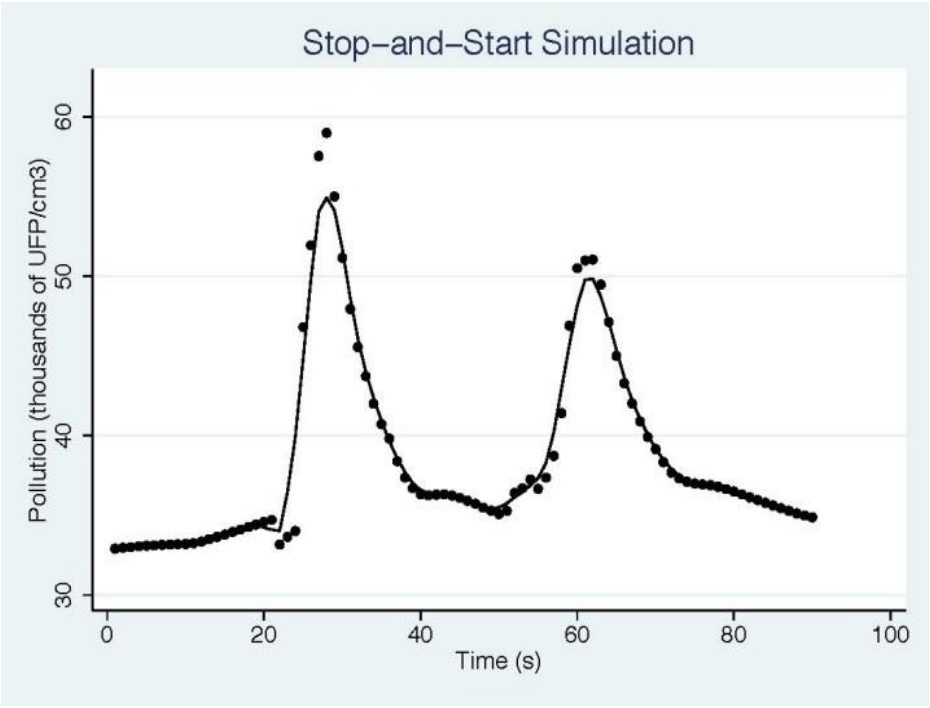
	Impact	Std. Error	95% Conf. Interval	
MMP State of Motion and Speed				
Idle-to-moving	-28.65	(-11.4)	-50.99	-6.31
Speed (m/s)	-15.32	(-5.74)	-26.56	-4.07
Lane number	15.73	(-4.47)	6.97	24.49
On-going Traffic				
Light-duty	9.78	(-14.01)	-17.69	37.24
Medium & Heavy-duty	142.76	(-90.31)	-34.26	319.78
Buses	-25.66	(-155.91)	-331.25	279.92
Acceleration event	-58.7	(-122.98)	-299.74	182.34
On-Coming Traffic				
Light-duty	-0.99	(-16.77)	-33.85	31.87
Medium & heavy-duty	-18.8	(-57.18)	-130.88	93.28
Buses	-21.31	(-71.44)	-161.34	118.72
Acceleration event	-158.72	(-127.01)	-407.66	90.22
Crossing from the Left Traffic				
Light-duty	30.05	(-34.74)	-38.04	98.15
Medium & heavy-duty	80.79	(-76.07)	-68.31	229.89
Buses	92.64	(-111.96)	-126.8	312.08
Acceleration event	26.96	(-98.47)	-166.05	219.97
Crossing from the Right Traffic				
Light-duty	-10.94	(-58.6)	-125.8	103.92
Medium & heavy-duty	-30.58	(-162.81)	-349.68	288.53
Buses	54.04	(-59.01)	-61.61	169.69
Acceleration event	52.59	(-50.29)	-45.98	151.17
Built Environment				
Intersection	320.15	(-120.69)	83.6	556.7
Average building height (m)	1.7	(-4.5)	-7.13	10.52
Building height differential (m)[a]	233.06	(-270.62)	-297.36	763.48

“Free-flow” Simulation Results



“Stop-Start” Simulation Results





Summary for Planners

Management	Suggested Direction	Approx. Size of Effect	Atmospheric Conditions & Notes
Traffic Management	Fewer stops and smaller queues reduce emissions and elevated concentrations around intersections	Factor of 2 - 4	Concentrations depend on emissions, micro-scale turbulence, dispersion, transport from nearby streets, and other factors
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 length, etc.	Up to approximately a factor of 3	Measurements are available for calm to moderate winds, when the effect is likely to be strongest.

Summary for Planners

Management	Suggested Direction	Approx. Size of Effect	Atmospheric Conditions & Notes
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.	More important when windspeeds are lower.
Sensitive uses near highways: Night/Morning downwind	1500 meters is desirable. Other mitigation strategies:	Up to a factor of four or more.	Concentrations are typically highest in the morning, so this is a period of greatest concern.

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

Thank you for your attention