Clean air in cities: impact of the layout of buildings in urban areas on pedestrian exposure to traffic-related pollutants

Suzanne Paulson*

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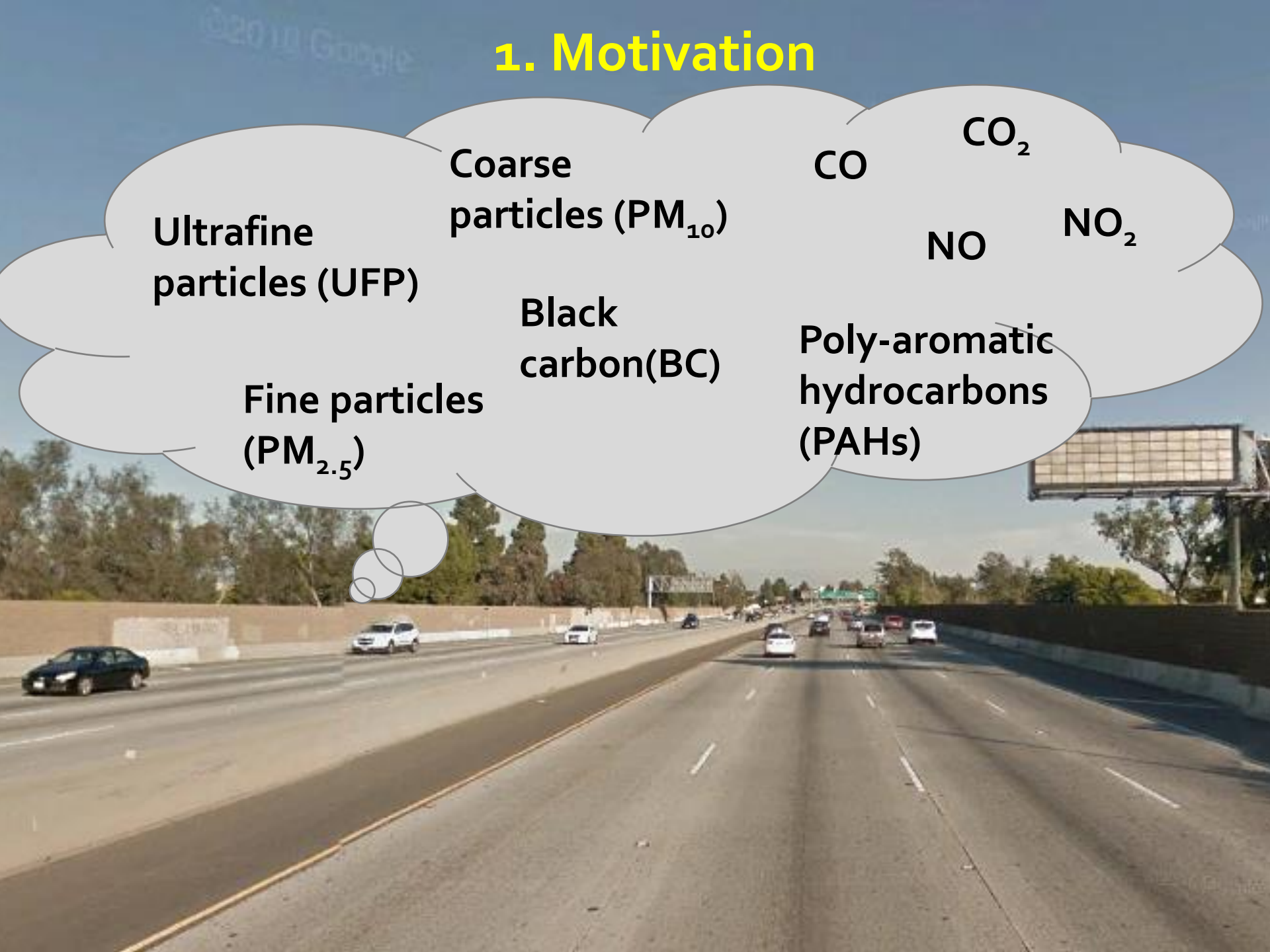
***Los Alamos National Laboratory**

1. Motivation



Motivation

" More than 45 million people in the United States live, work, or attend school within 300 feet of a major road…" (source: US EPA) And lots of people in other countries…

Pollution elevation near heavily trafficked roads linked to numerous health impacts

Pediatric Pulmonology 50:252–259 (2015)

Exposure to Traffic and Early Life Respiratory Infection: A Cohort Study

Mary B. Rice, MD,[1,2*] Sheryl L. Rifas-Shiman, MPH,[3] Emily Oken, MD,[3] Matthew W. Gillman, MD, SM,[3] Petter L. Ljungman, MD, PhD,[2] Augusto A. Litonjua, MD, MPH,[4] Joel Schwartz, PhD,[5]

Residential Traffic Exposure and Childhood Leukemia

A Systematic Review and Meta-analysis

Vickie L. Boothe, MPH, Tegan K. Boehmer, PhD, MPH, Arthur M. Wendel, MD, MPH, Fuyuen Y. Yip, PhD, MPH

Context: Exposure to elevated concentrations of traffic-related air pollutants in the near-road environment is associated with numerous adverse human health effects, including childhood cancer, which has been increasing since 1975. Results of individual epidemiologic studies have been inconsistent. Therefore, a meta-analysis was performed to examine the association between residential traffic exposure and childhood cancer.

Evidence acquisition: Studies published between January 1980 and July 2011 were retrieved from a systematic search of 18 bibliographic databases. Nine studies meeting the inclusion criteria were identified. Weighted summary ORs were calculated using a random effects model for outcomes with

Atmospheric Environment 79 (2013) 198–208

Contents lists available at SciVerse ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005

Fabio Caiazzo, Akshay Ashok, Ian A. Waitz, Steve H.L. Yim, Steven R.H. Barrett*

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to individuals with disabilities. A fully accessible (Section 508–compliant) is available at http://dx.doi.org/10.1289/ehp.1307289.

posure to Criteria Air Pollutants and Congenital Heart Defects Results from the National Birth Defects Prevention Study

one,[1] Thomas J. Luben,[2] Julie L. Daniels,[1] Montserrat Fuentes,[3] David B. Richardson,[1] th,[4,5] Amy H. Herring,[6] Marlene Anderka,[7] Lorenzo Botto,[8] Adolfo Correa,[9] Suzanne M. Gilboa,[10] [11] Bridget Mosley,[12] Gary M. Shaw,[13] Csaba Siffel,[10] Andrew F. Olshan,[1] and the National vention Study

miology, UNC Gillings School of Global Public Health, Chapel Hill, North Carolina, USA; [2]National Center for ment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North tment of Statistics, North Carolina State University, Raleigh, North Carolina, USA; [4]Department of Pediatrics, ediatrics Genetics, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA; [5]Department tistics, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, USA; husetts Center for Birth Defects Research and Prevention, Massachusetts Department of Public Health, Boston, Massachusetts, epartment of Genetics and Pediatrics, University of Utah, Salt Lake City, Utah, USA; [9]Department of Pediatrics, University of ppi Medical Center, Jackson, Mississippi, USA; [10]National Center on Birth Defects and Developmental Disabilities, Centers for

UCLA

Science of the Total Environment 553 (2016) 474–485

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

The effects of the built environment, traffic patterns, and micrometeorology on street level ultrafine particle concentrations at a block scale: Results from multiple urban sites

Wonsik Choi [a,b,*], Dilhara Ranasinghe [a], Karen Bunavage [a], J.R. DeShazo [c], Lisa Wu [c], Rodrigo Seguel [a,d], Arthur M. Winer [e], Suzanne E. Paulson [a,b]

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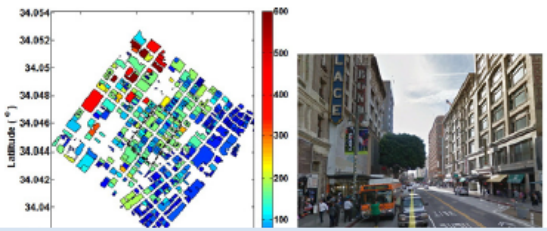
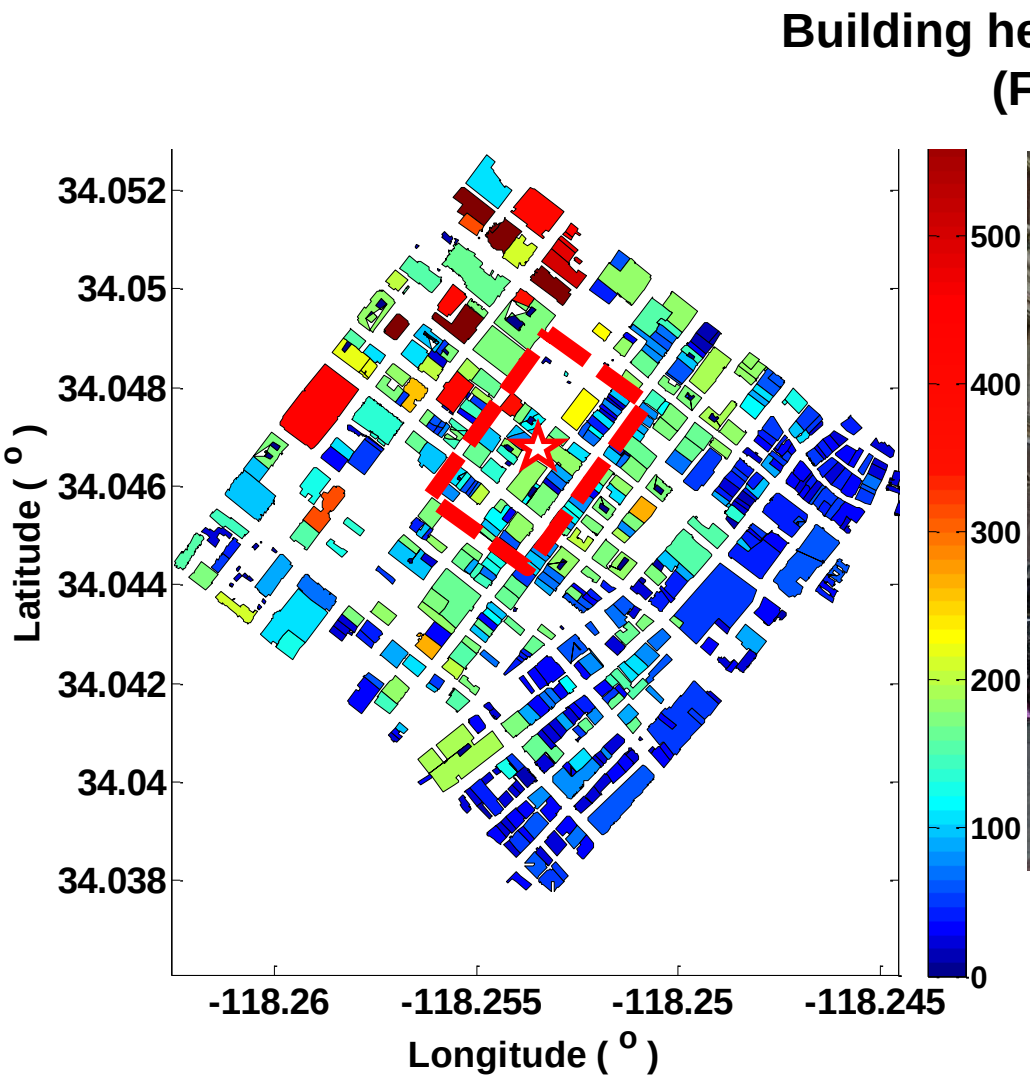
HIGHLIGHTS

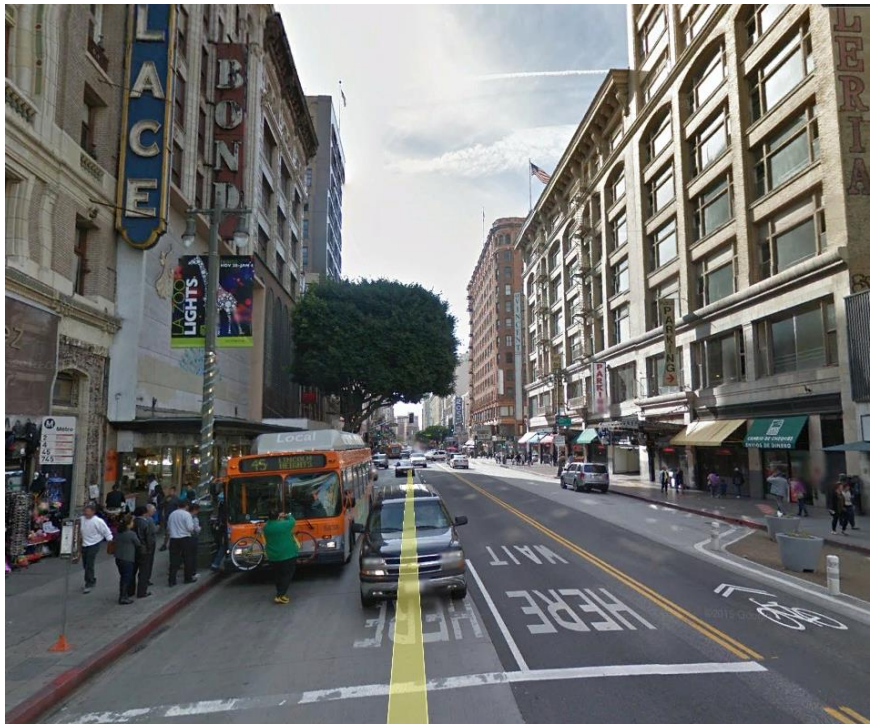
- This study quantitatively examined built-environment effects on near-road UFP level.
- Block-scaled UFP conc. strongly depend on built environment and surface turbulence.
- Areal aspect ratio was a major contributor to UFP variations in the morning

GRAPHICAL ABSTRACT



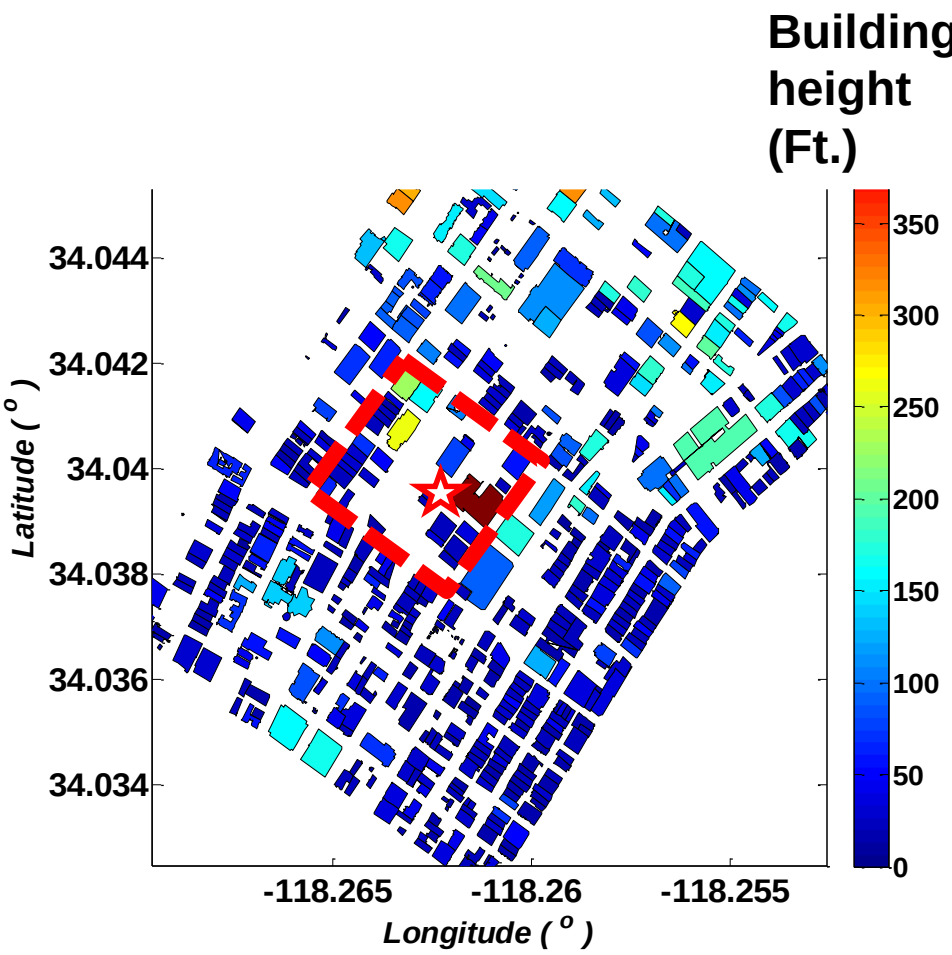
Site 1: Street canyon

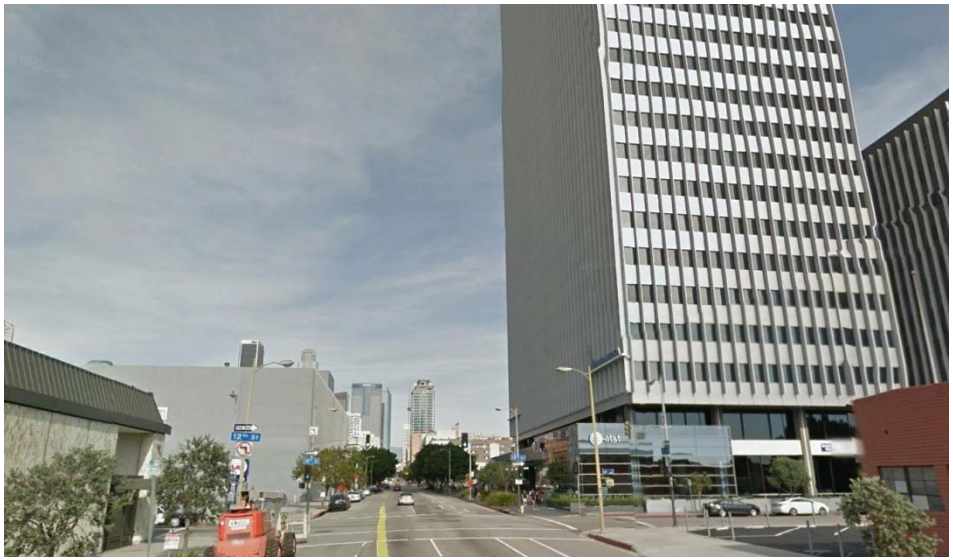




Olive & 12th Site (Street view: heading to South)

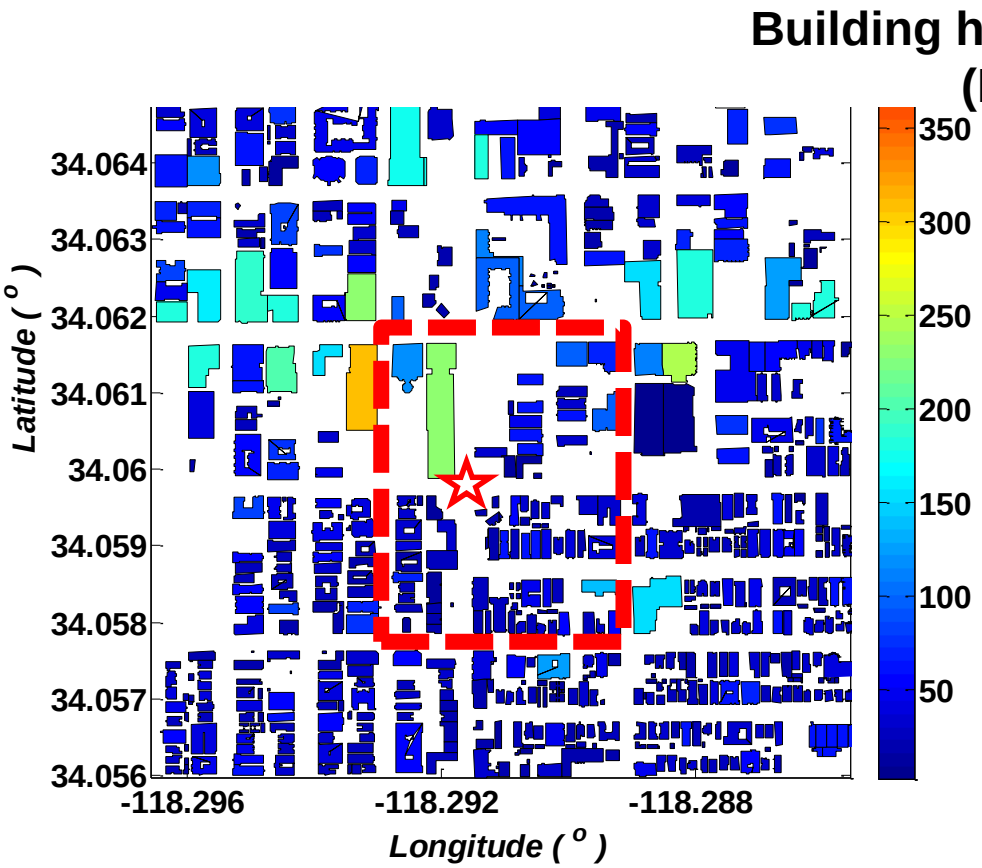
Site 2: One isolated tall building with low traffic





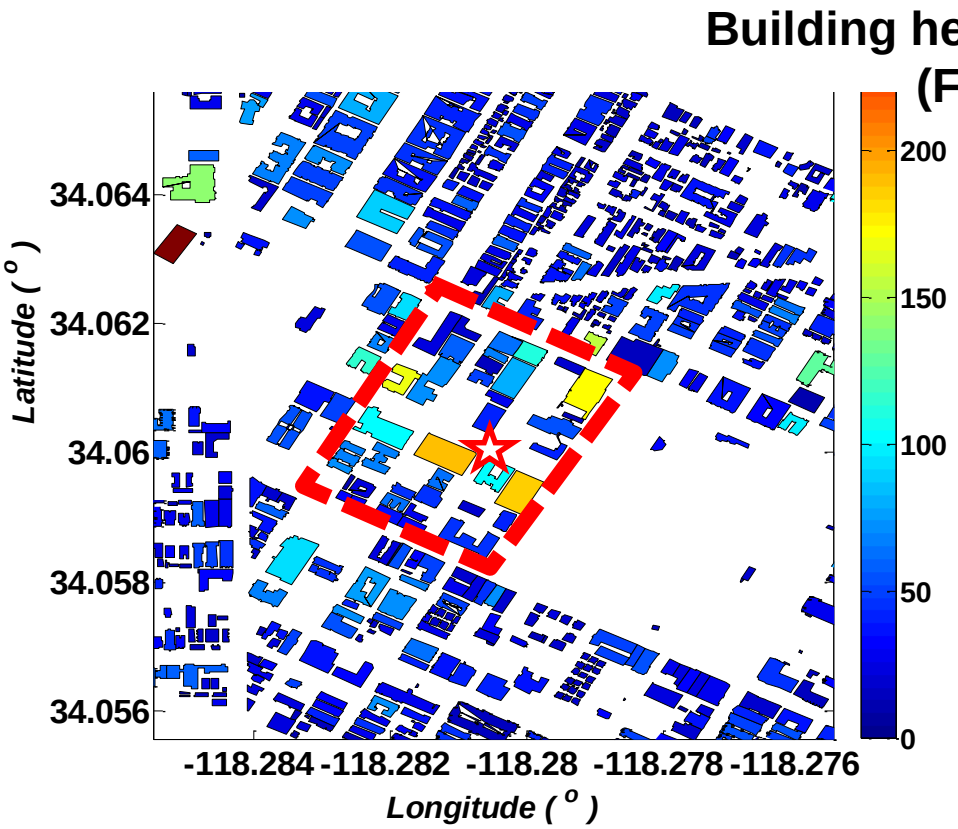
Olive & 12th Site (Street view: heading to North)

Site 3: One isolated tall building with high traffic



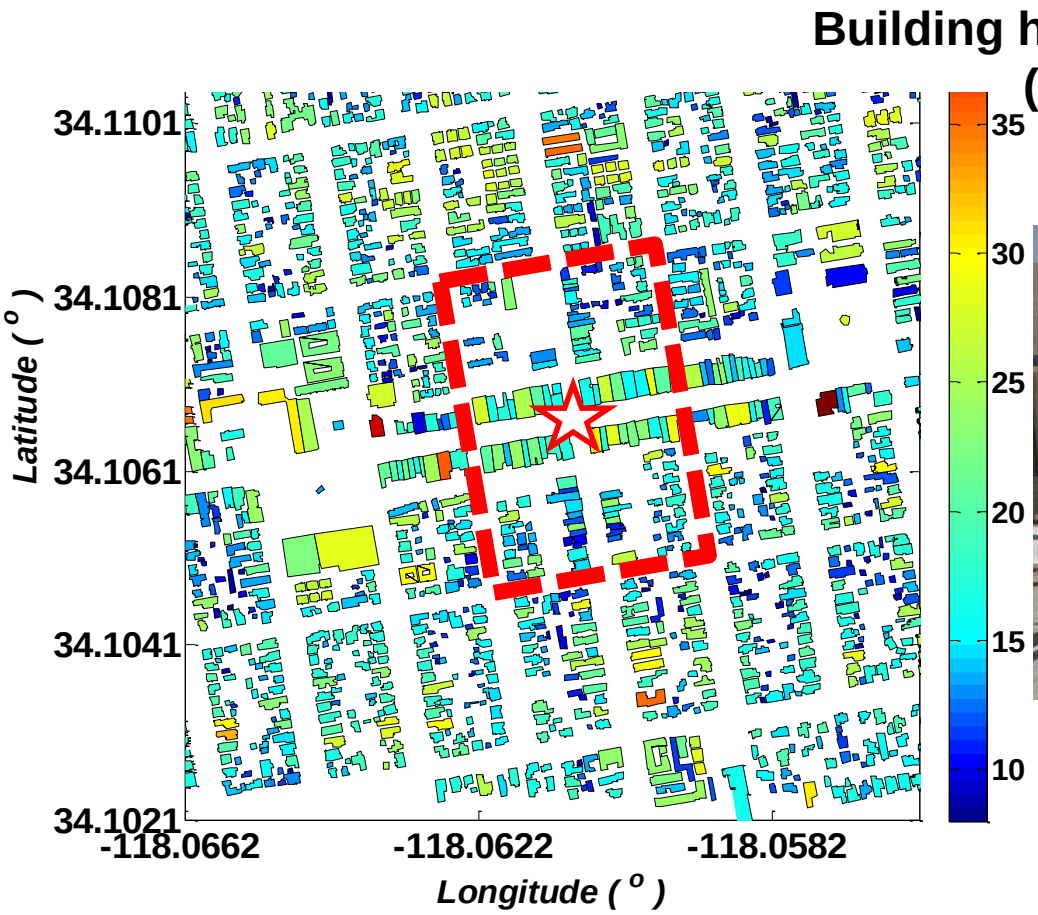
Vermont & 7th Site (Street view: heading to West)

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)

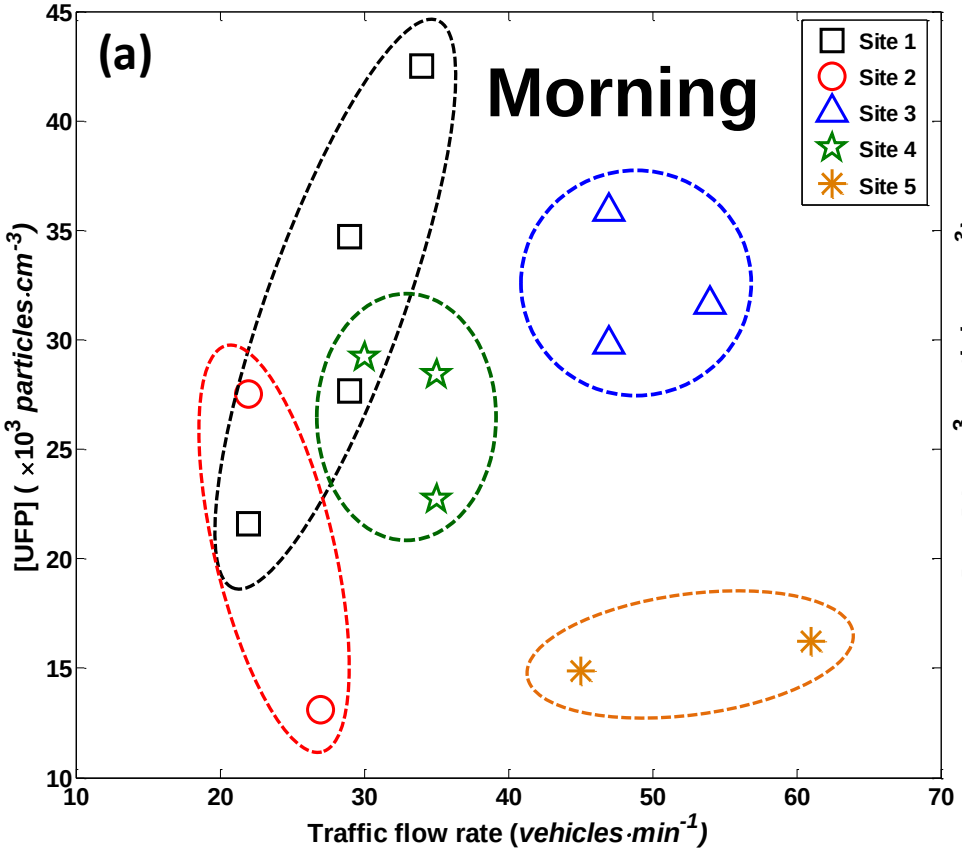
Site 5: All single story buildings

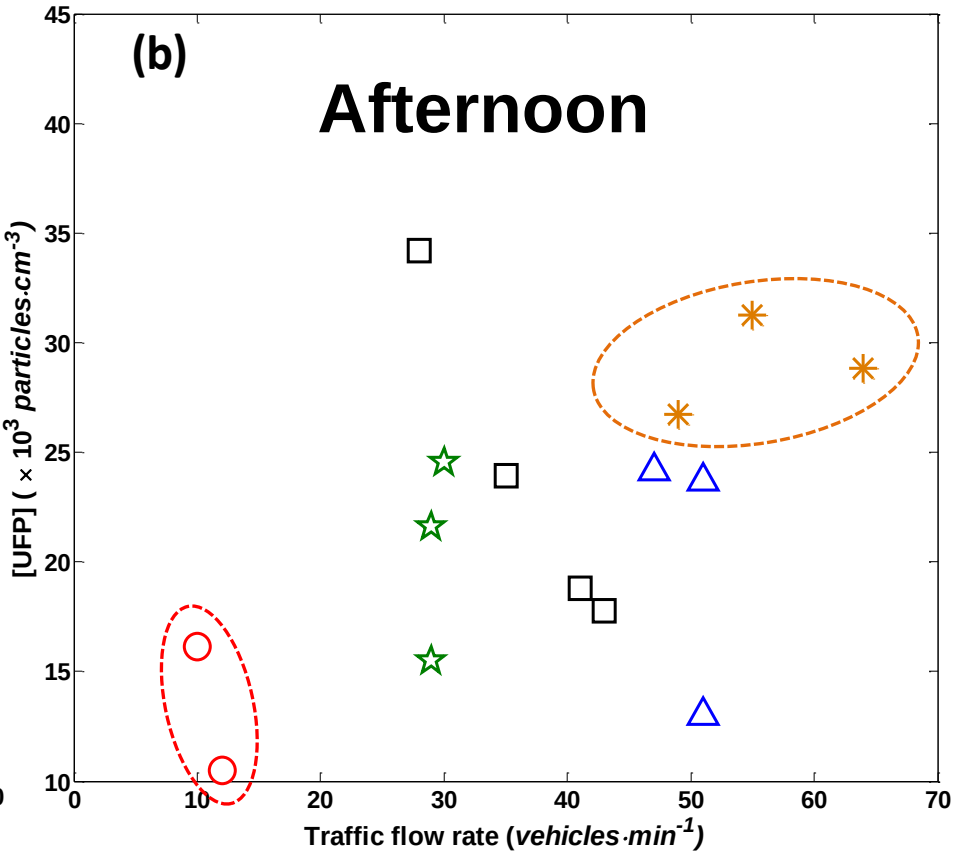


Temple City & Las Tunas Site (Street view: heading to North)

UFP vs. Traffic

Higher traffic → higher UFP, but other things appear to be going on.



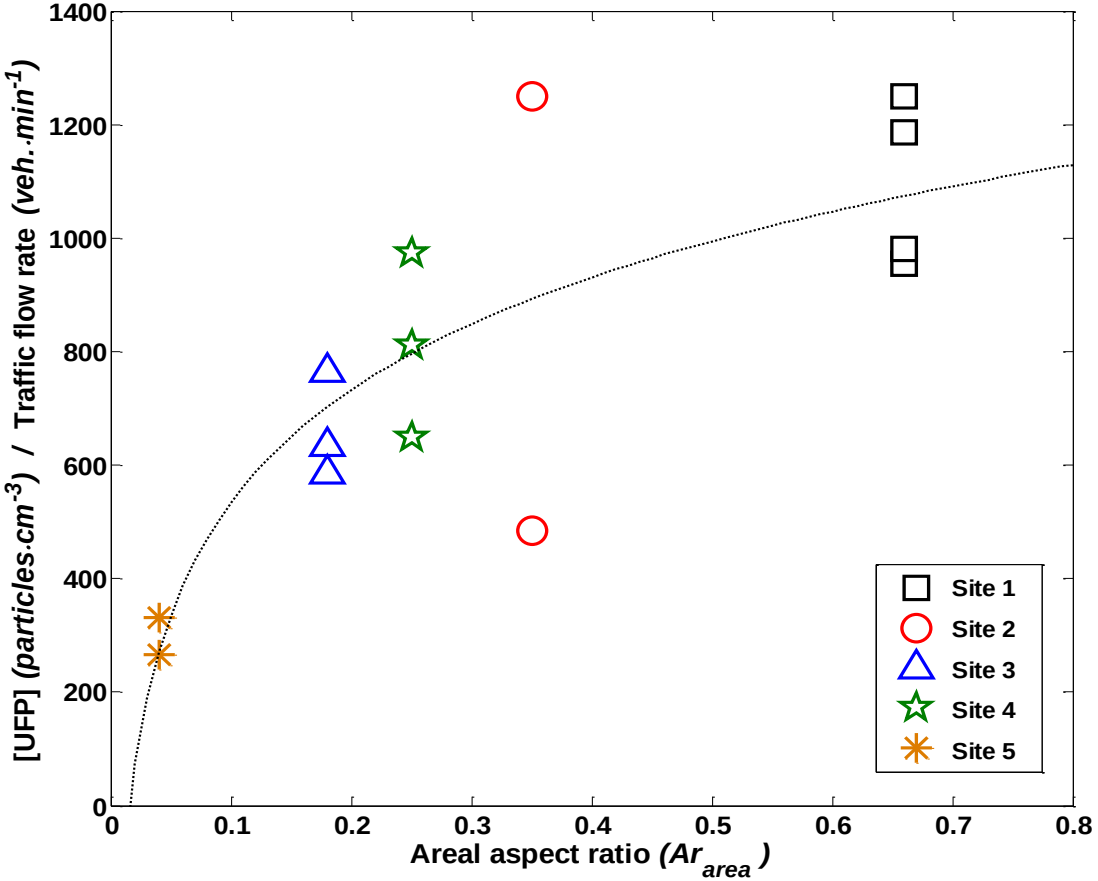


Best Explanatory Factor in the Morning:

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

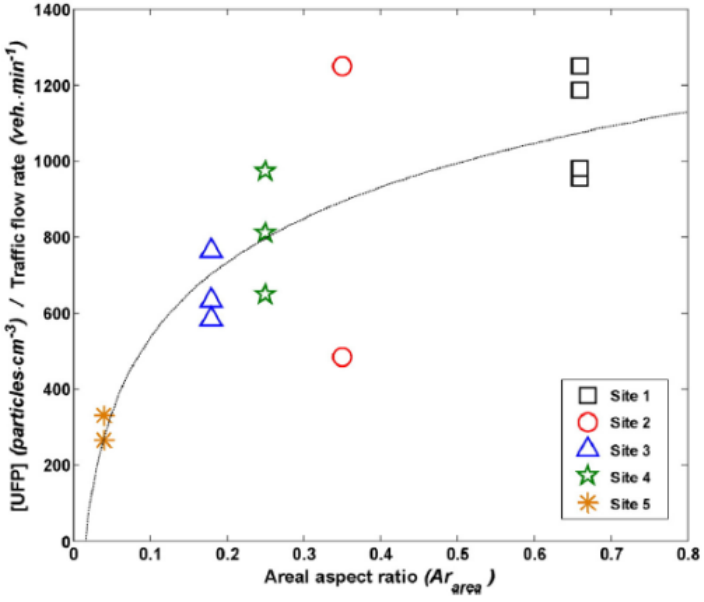
A_{open}: Area of the open space in sampling site

Choi et al., 2016

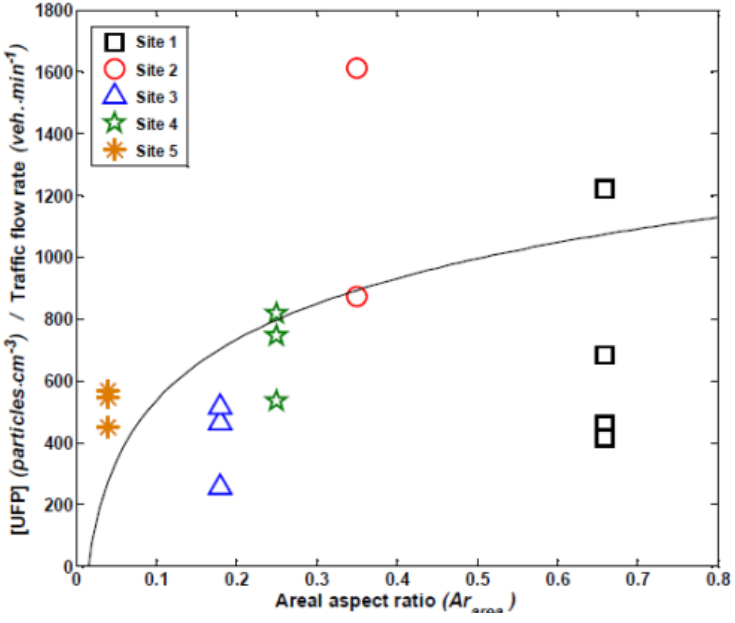
Traffic – normalized FP have a strong relationship with "areal aspect ratio" in AM, less so in afternoons.

Choi et al. (2016)

AM



PM



Ar_{area}: based on the building area-weighted building height, the amount of open space, and the building footprint.

But we have limited observational data and cannot probe the influence of different built environment configurations in a systematic way.

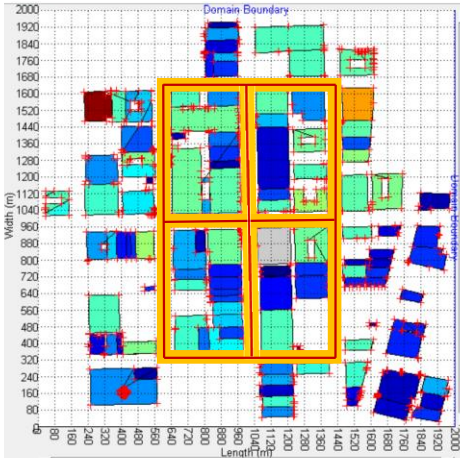
Modeling Dispersion in Complex Urban Areas: Tricky

- **CFD is too computationally intensive; Large Eddy Simulations have too low spatial resolution.**
- **Quick Urban & Industrial Complex (QUIC) from Los Alamos National Lab.**
- **Runs in minutes on a laptop.**
- **Two main model components:**
  - **Wind solver (QUIC-URB) → Solves for flows around built environment** using empirical algorithms and mass conservation to estimate the wind velocities around buildings (Röckle, 1990). Although not as accurate as computational fluid dynamics modeling, it captures the major flow features.
  - **Dispersion model (QUIC-PLUME)**

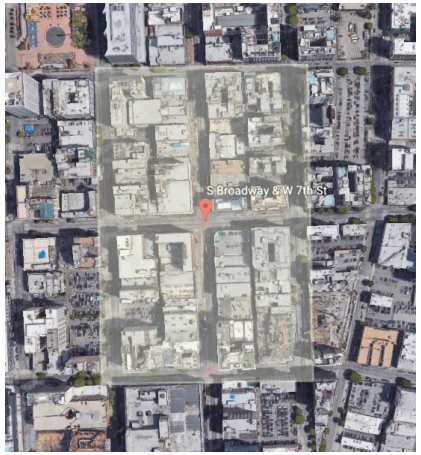
Model configurations

The Quick Urban and Industrial Complex model - QUIC (Brown et al., 2010)

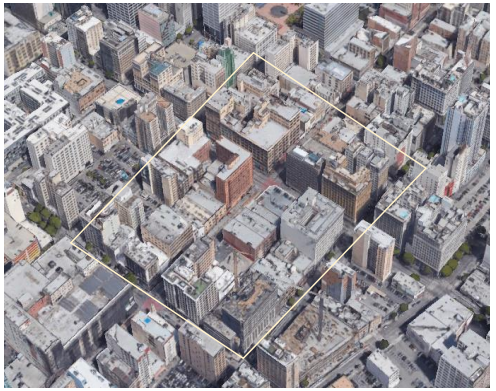
Broadway & 7th in QUIC



2D in Google Earth



3D in Google Earth



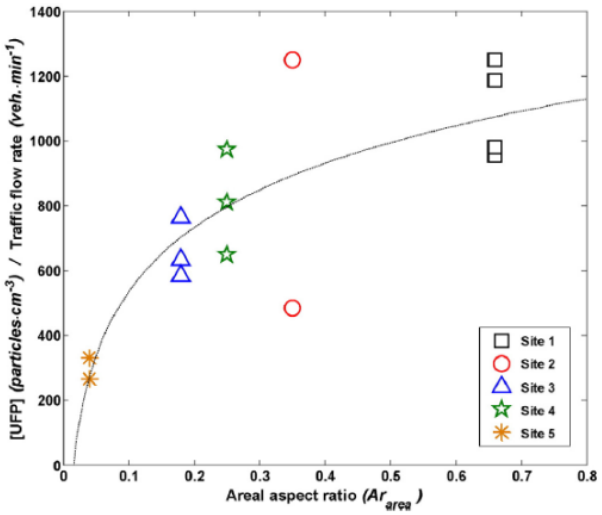
- **Measured wind speed, direction and Monin-Obukhov length (a measure of turbulence from buoyancy vs. wind shear)**
- **Horizontal resolution 5 x 5 m.**
- **Vertical resolution: first 10 levels 0.4 m levels, then parabolic dz to the top of the domain; domain 20 m above tallest bldg.**
- **Emissions: assume continuous line sources at 0.5 m (red lines);**
- **Average particle concentrations 0.4-2 m above the ground on main and sub-main streets (yellow belts)**

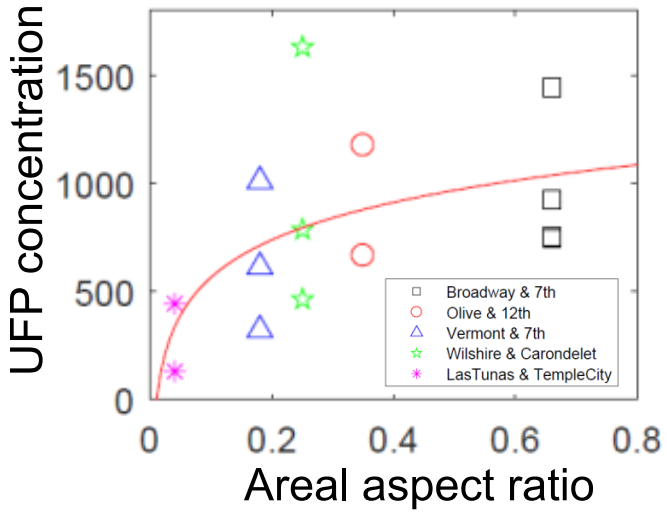
QUIC can Qualitatively Reproduce the Field Data.

(a) Choi et al. (2016)

(b) This Study

AM





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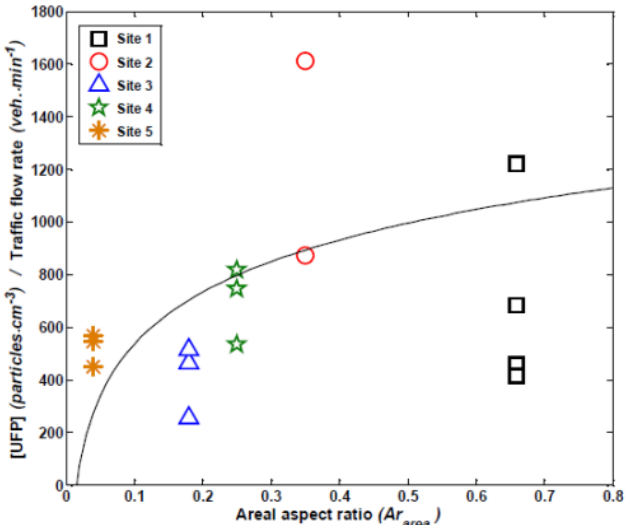
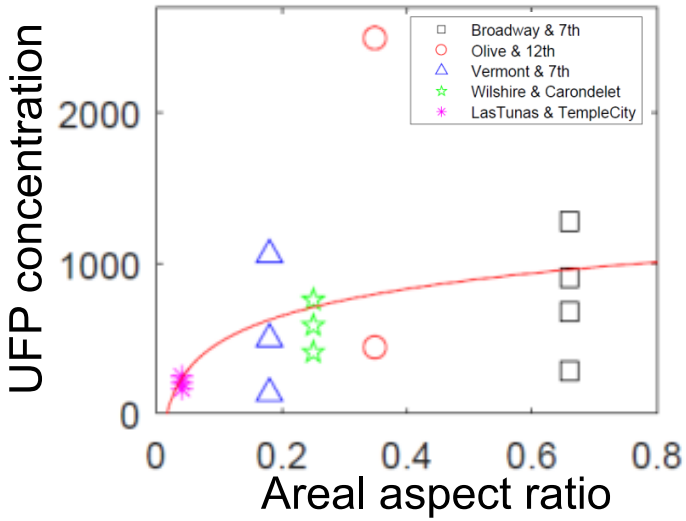
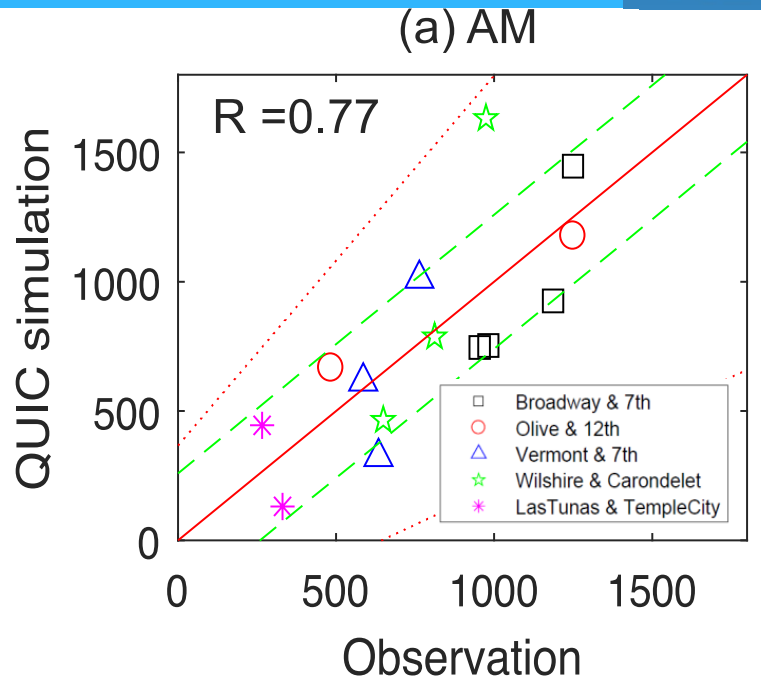
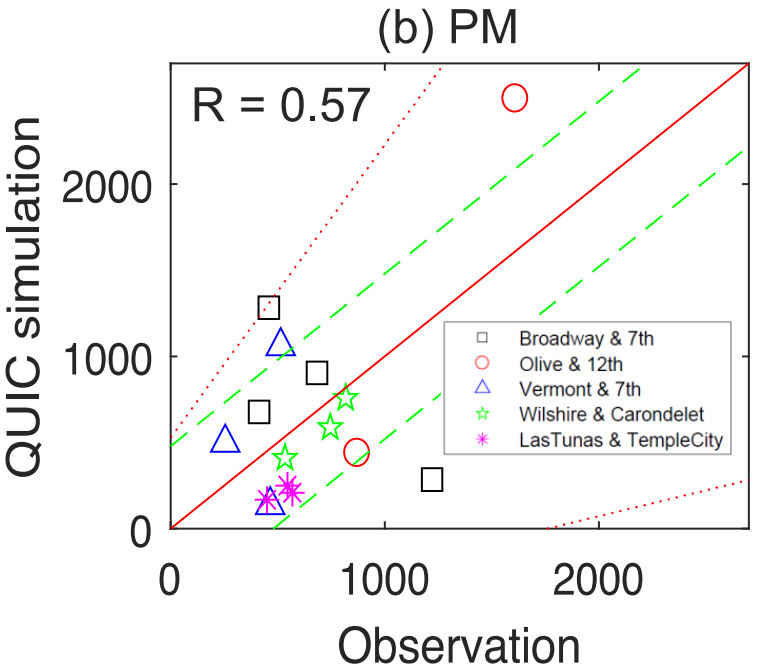




QUIC simulations are able to reproduce the observational patterns.



Red line: regression line
Green line: ± RMSE
Red dot lines: prediction band (90% confidence level)



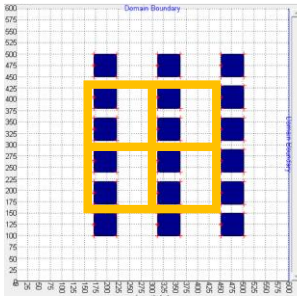
- **All the markers are within the 90% confidence red band;**
- **Most of them are within the green RMSE band.**

Build a New Development?
(hold volume/m² constant)

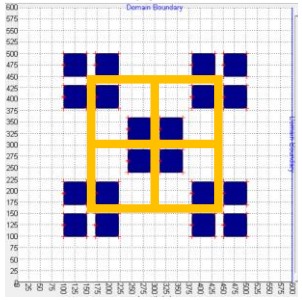
Types 1 – 3 have 45 m buildings with open space

Types 4 – 6 have 15 m (blue) and 30 m (red) buildings and much less open space

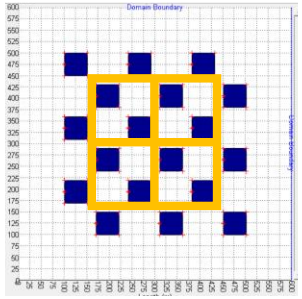
Type 1

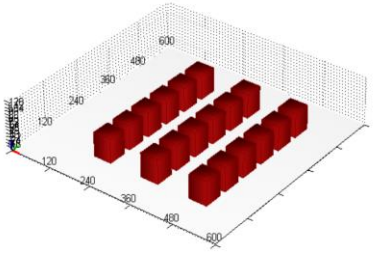


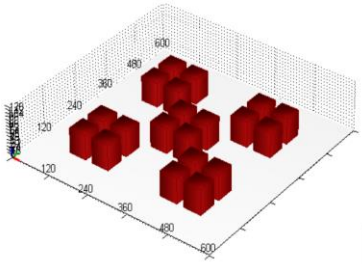
Type 2

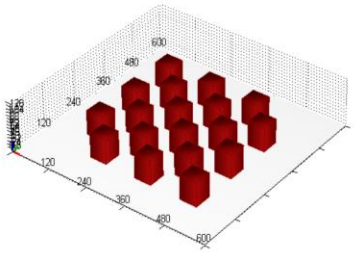


Type 3

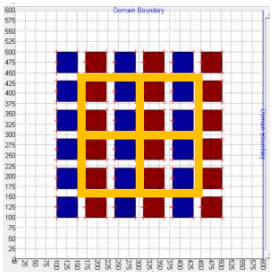




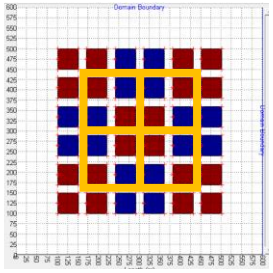




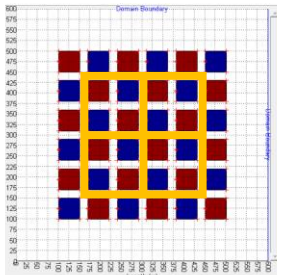
Type 4

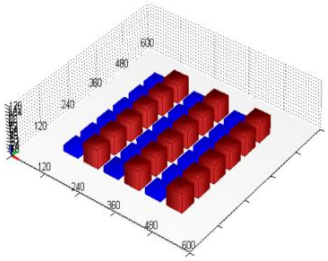


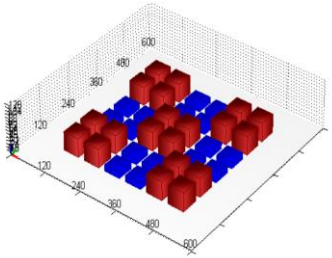
Type 5

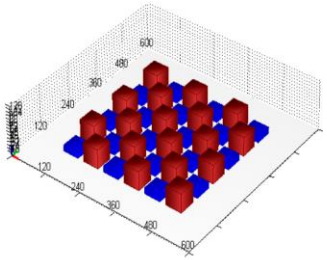


Type 6

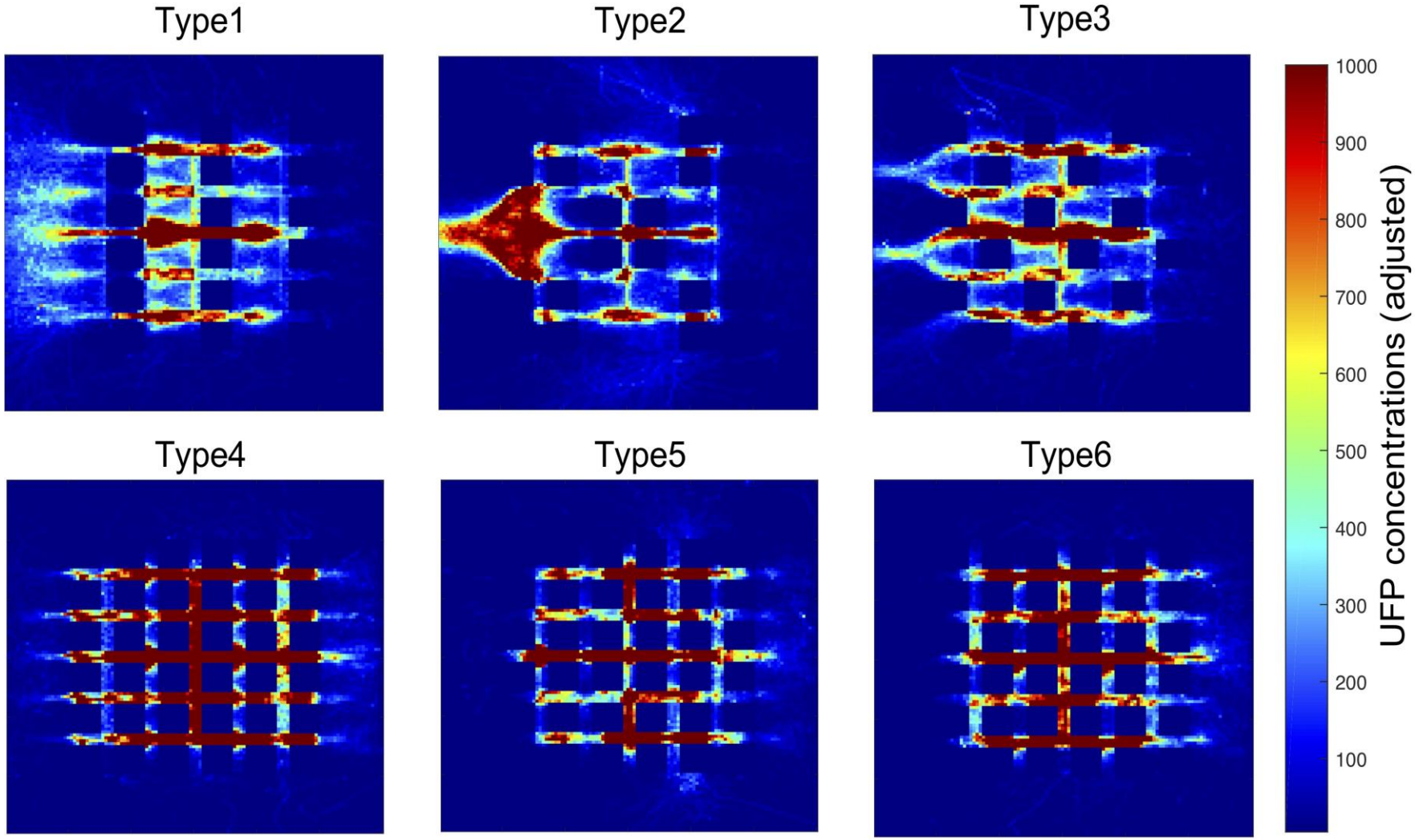






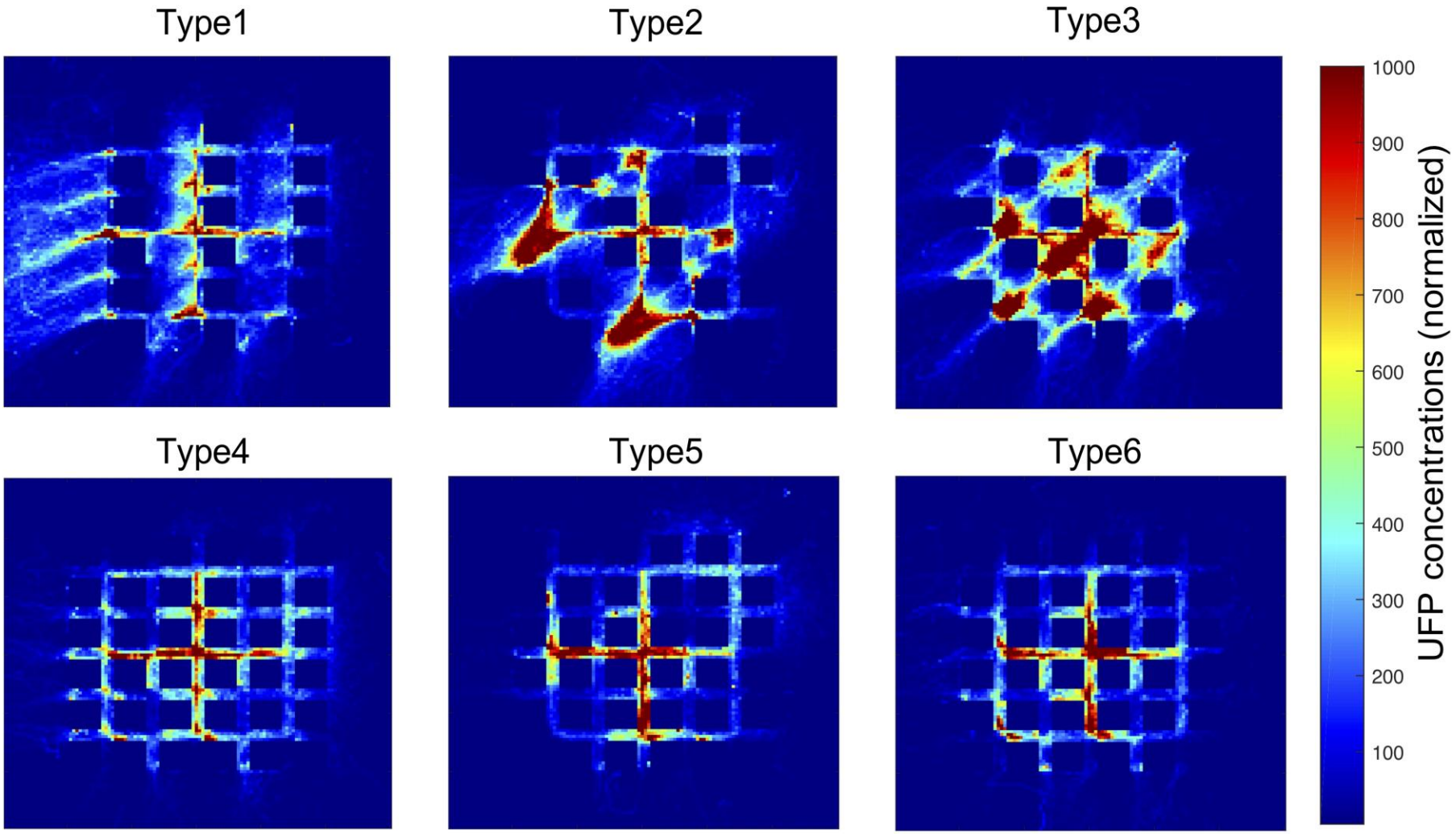


Pollutant Concentrations @ Breathing Level: Winds from the West



UFP concentrations at street levels. Wind direction: West

Pollutant Concentrations @ Breathing Level, Winds from the South West: Lower Concentrations



UFP concentrations at street levels. Wind direction: Southwest

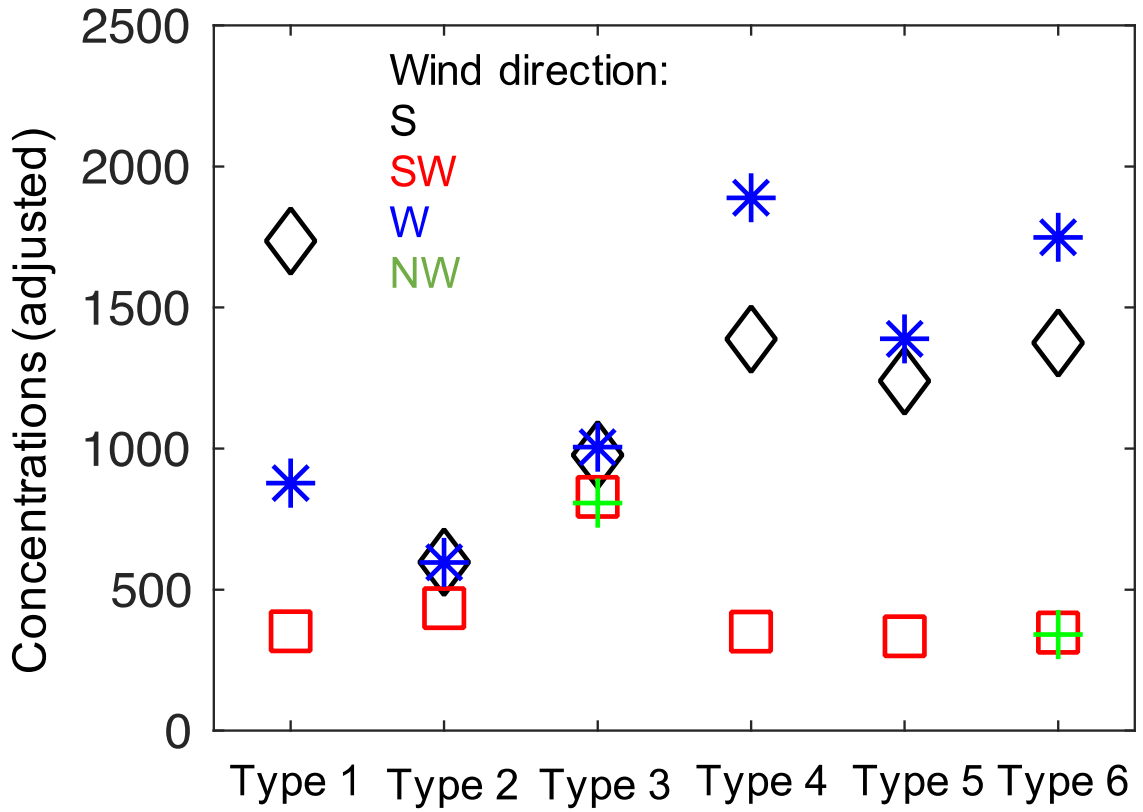
Average Concentrations at Ground Level

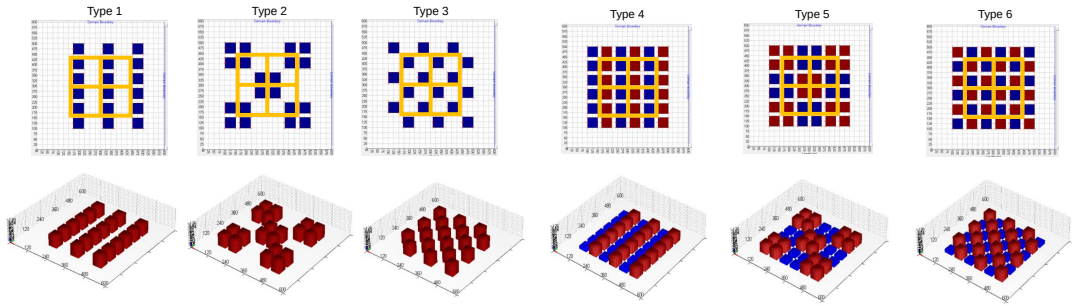
Good:

- open space between buildings
- Clusters
- Grids
- Winds at 45°

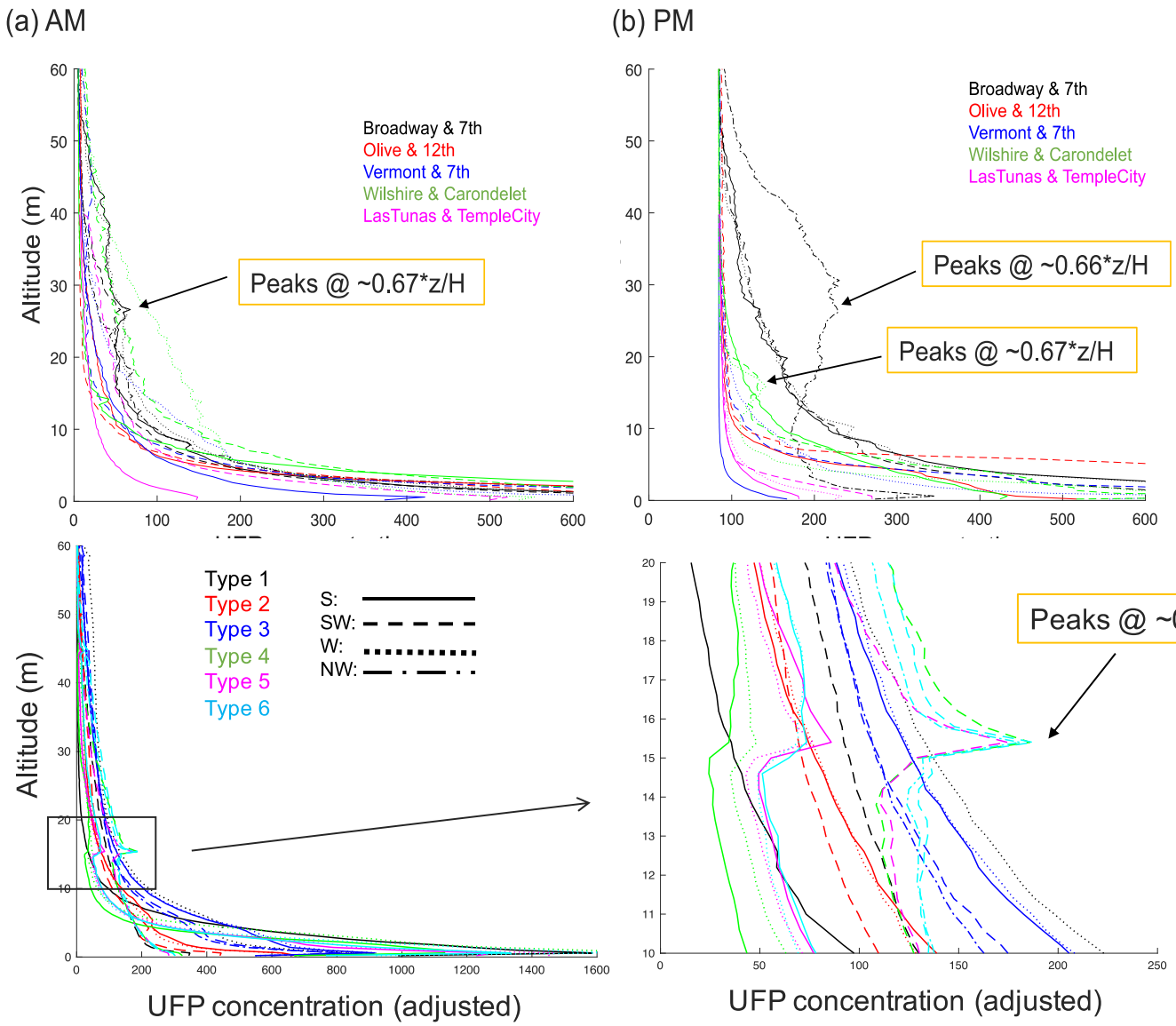
Bad:

- Rows ☹
- Buildings covering most space.





Vertical Concentration Profiles

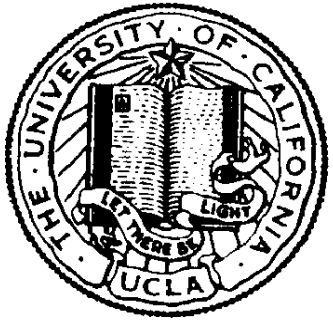


Upper Floors are Much Cleaner.

But there is a Peak @ 0.5 – 0.67

Coming to a (non Elsevier) Journal Soon…

Thank you!



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