Exposure Beyond Mass:
High-Spatial Resolution Exposure to Source-Resolved Atmospheric Particle Number and Chemical Mixing State

Qing Ye, Hugh Z. Li, Peishi Gu, Ellis S. Robinson, Joshua S. Apte, Ryan C. Sullivan, Allen L. Robinson, Neil M. Donahue, and Albert A. Presto

CACES

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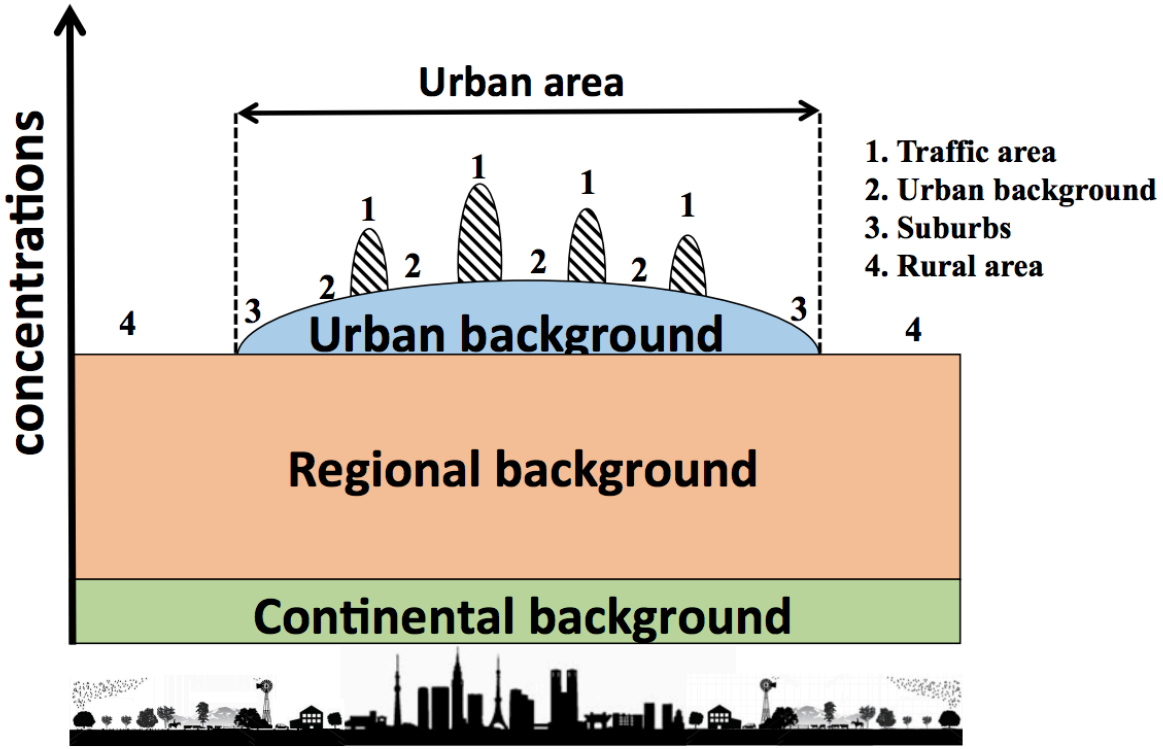
Carnegie Mellon University

Concentrations of air pollutants in urban areas have strong spatial heterogeneities



Fuzzi *et al*., 2015

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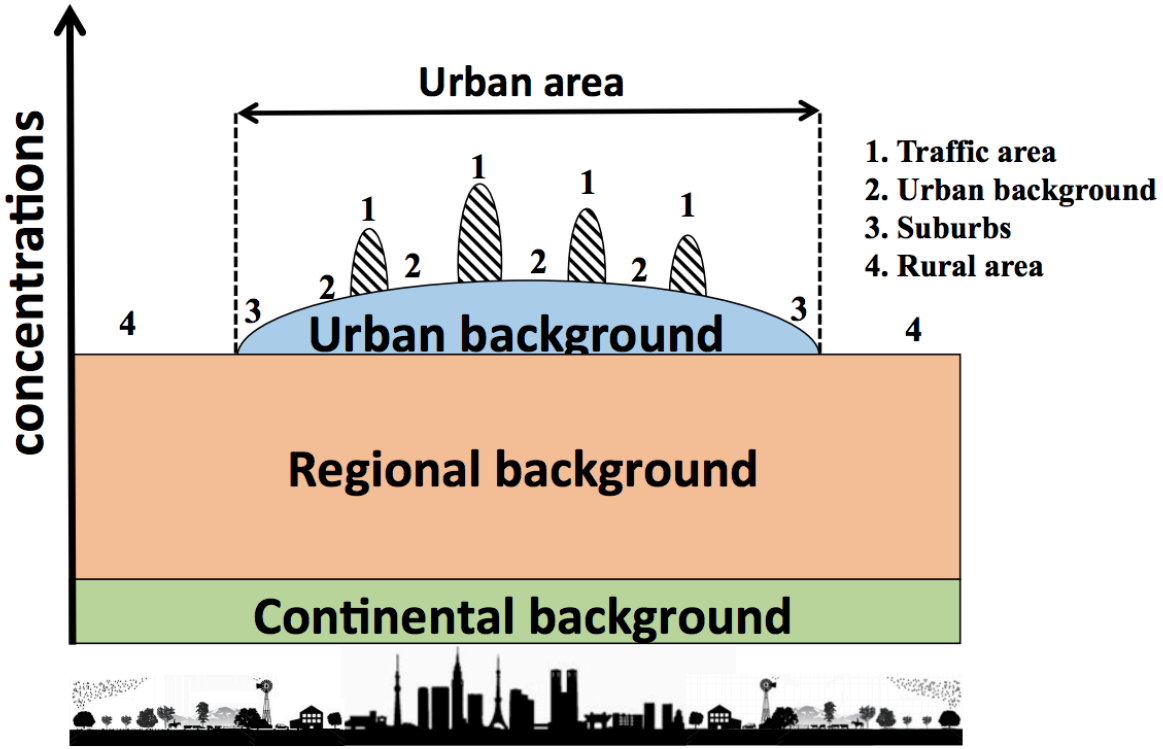

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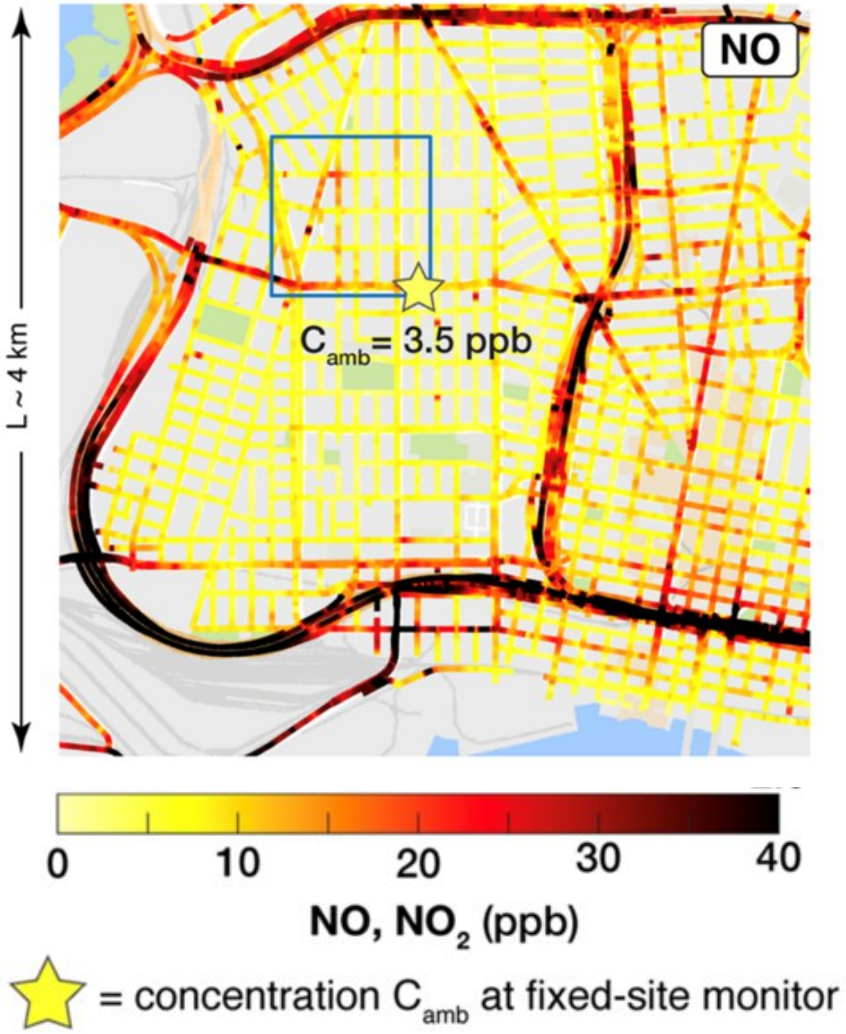
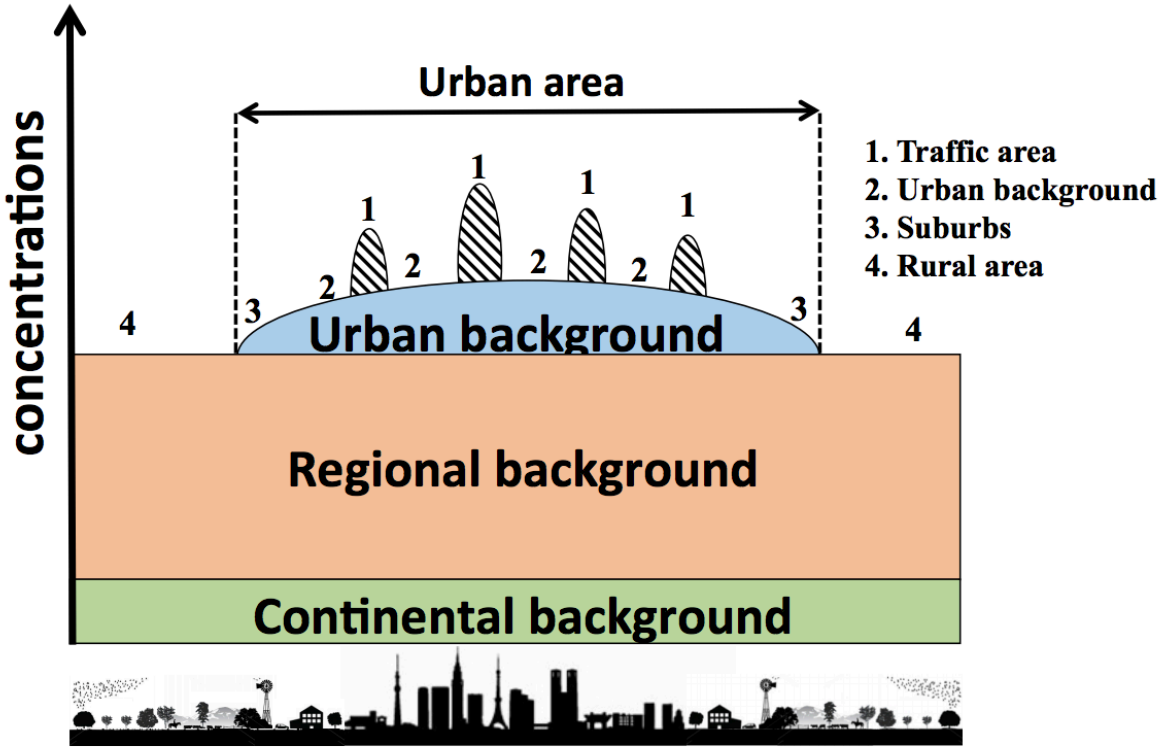


Apte *et al*., 2017

Particulate matter pollution has more complexities in physiochemical properties



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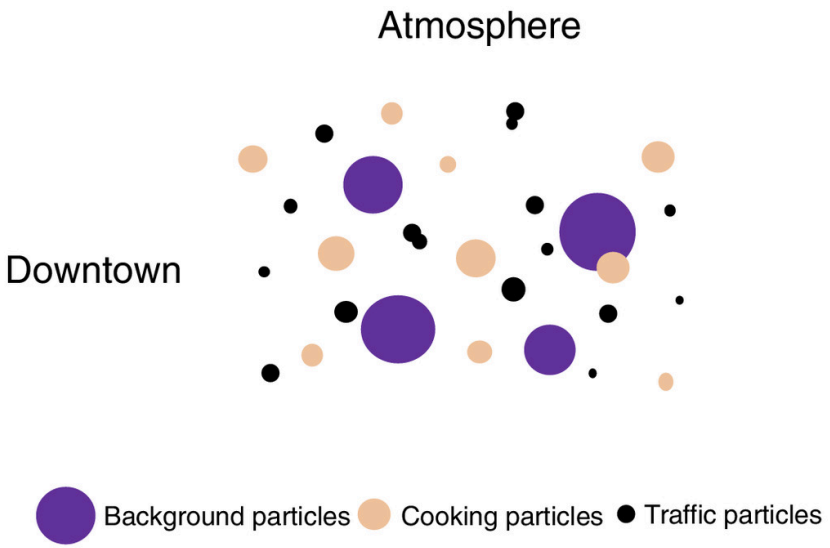

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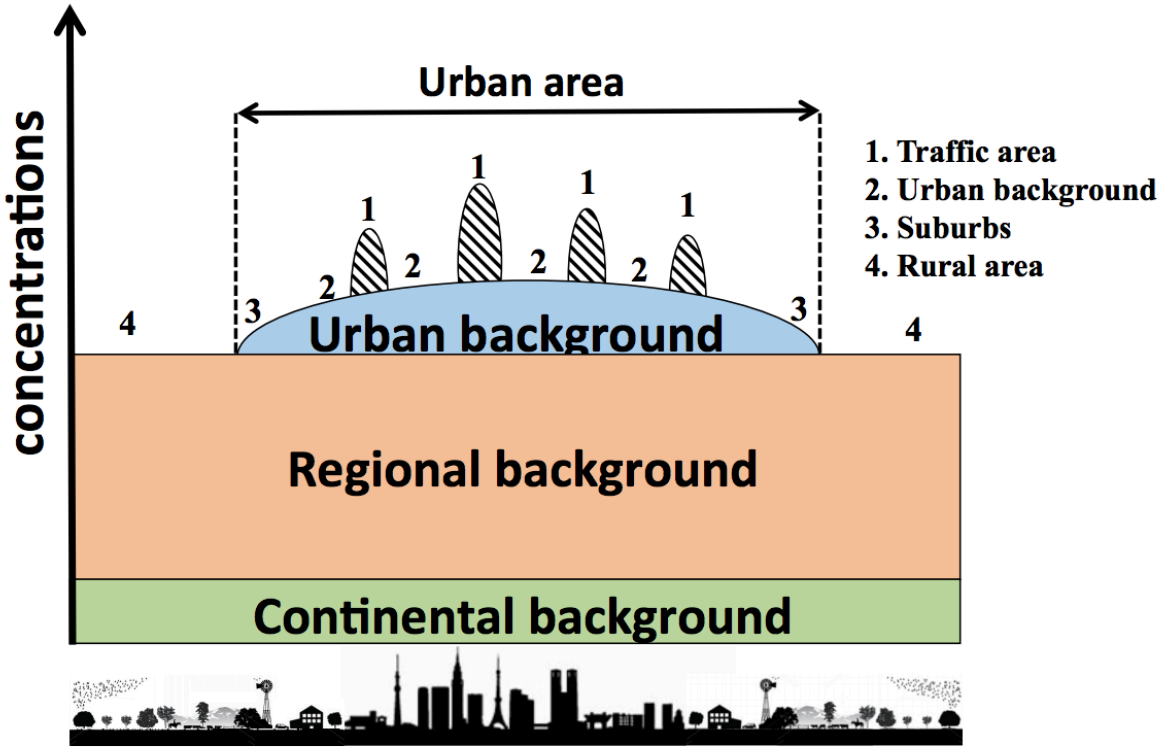

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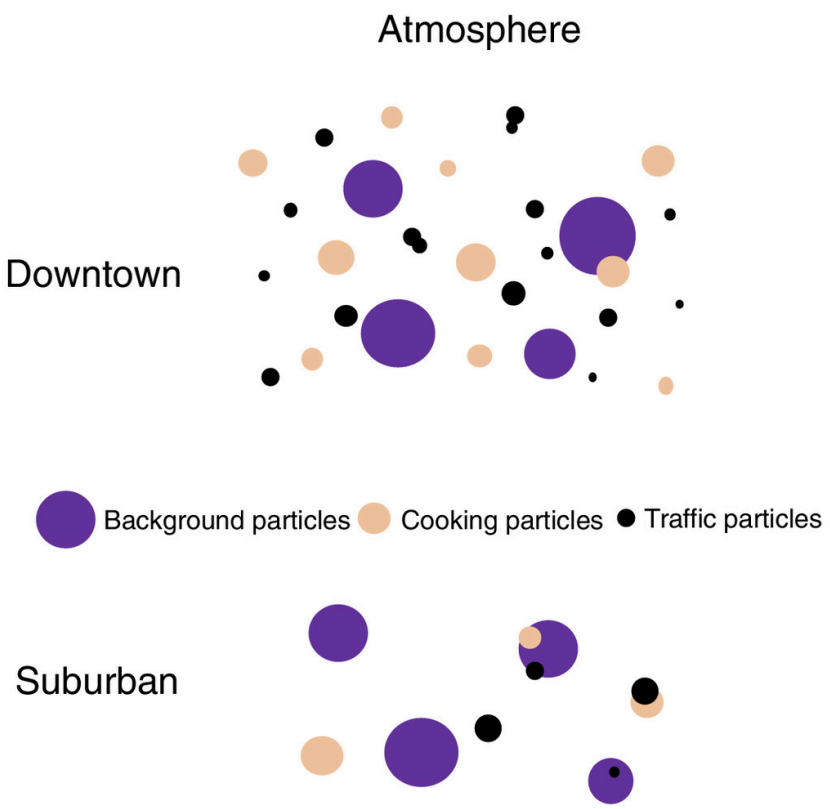
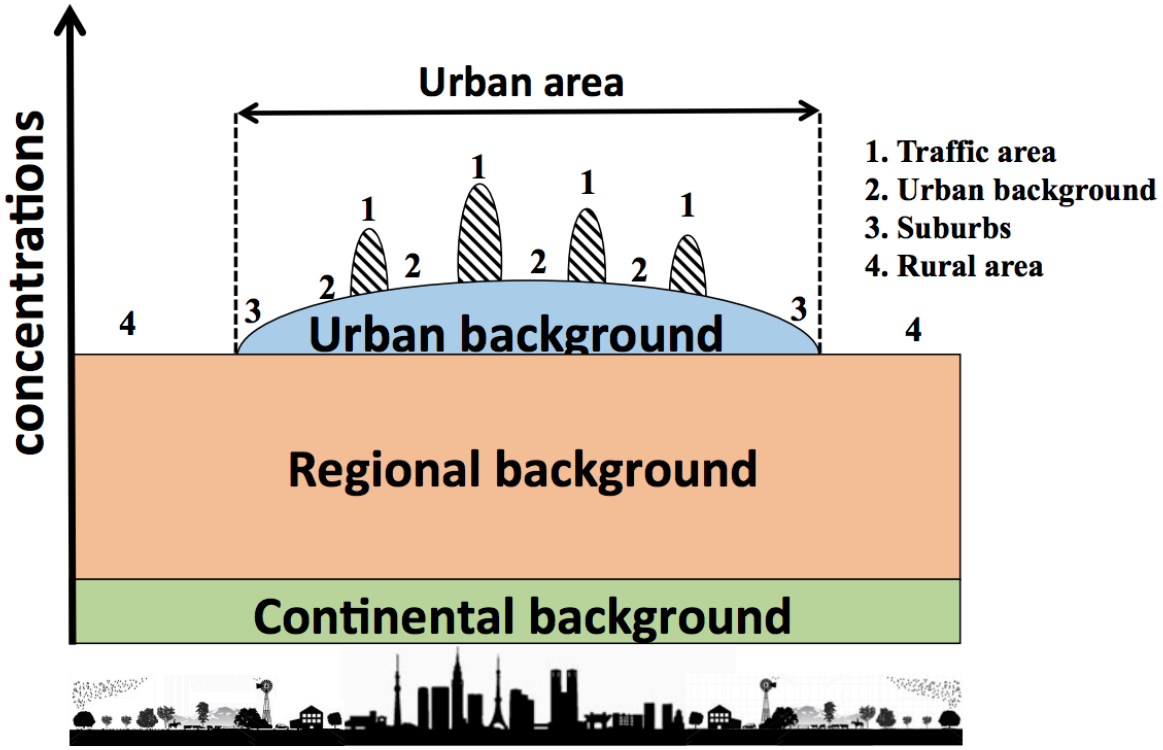
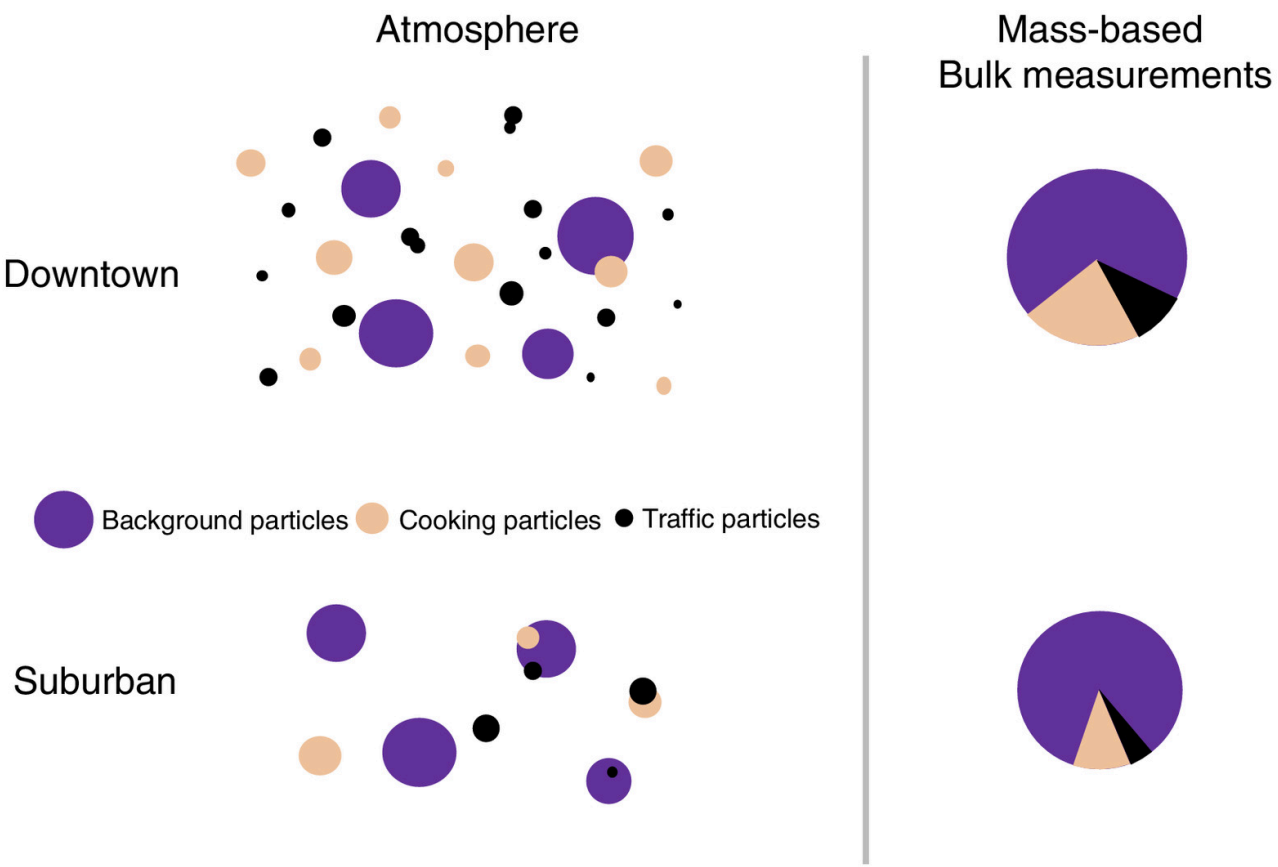


Bulk mass-based filter measurements may not be sufficient to capture complexities



Fuzzi *et al*., 2015



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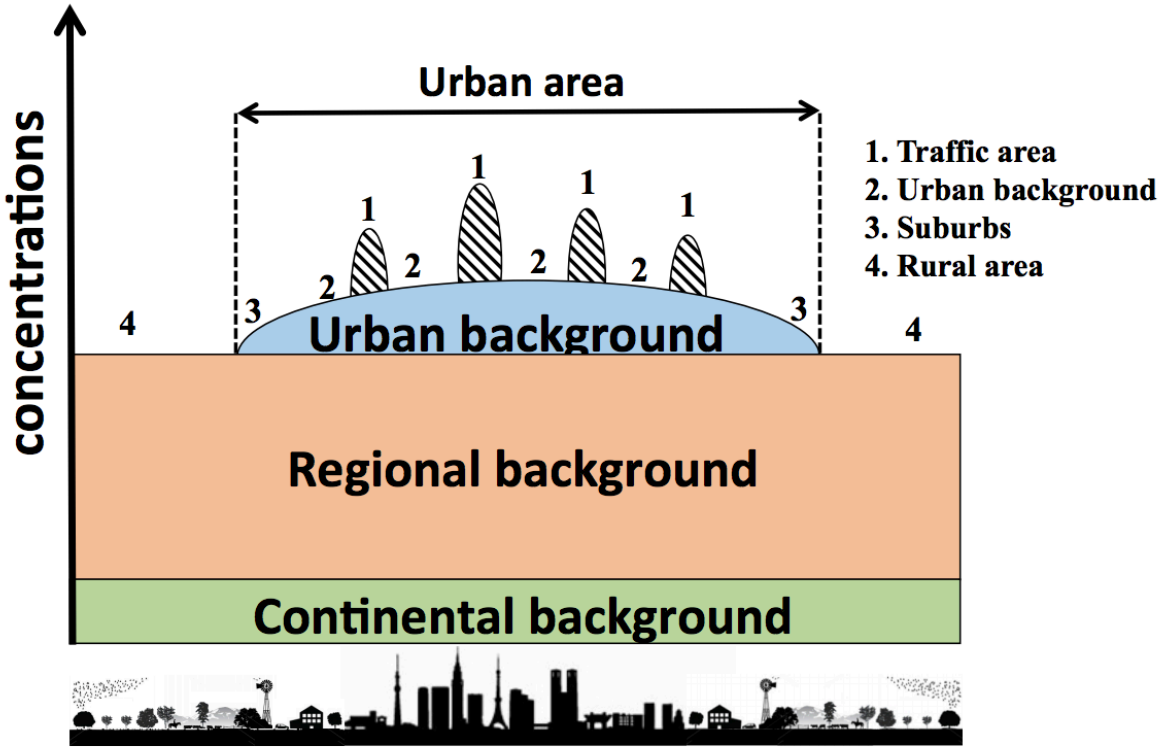

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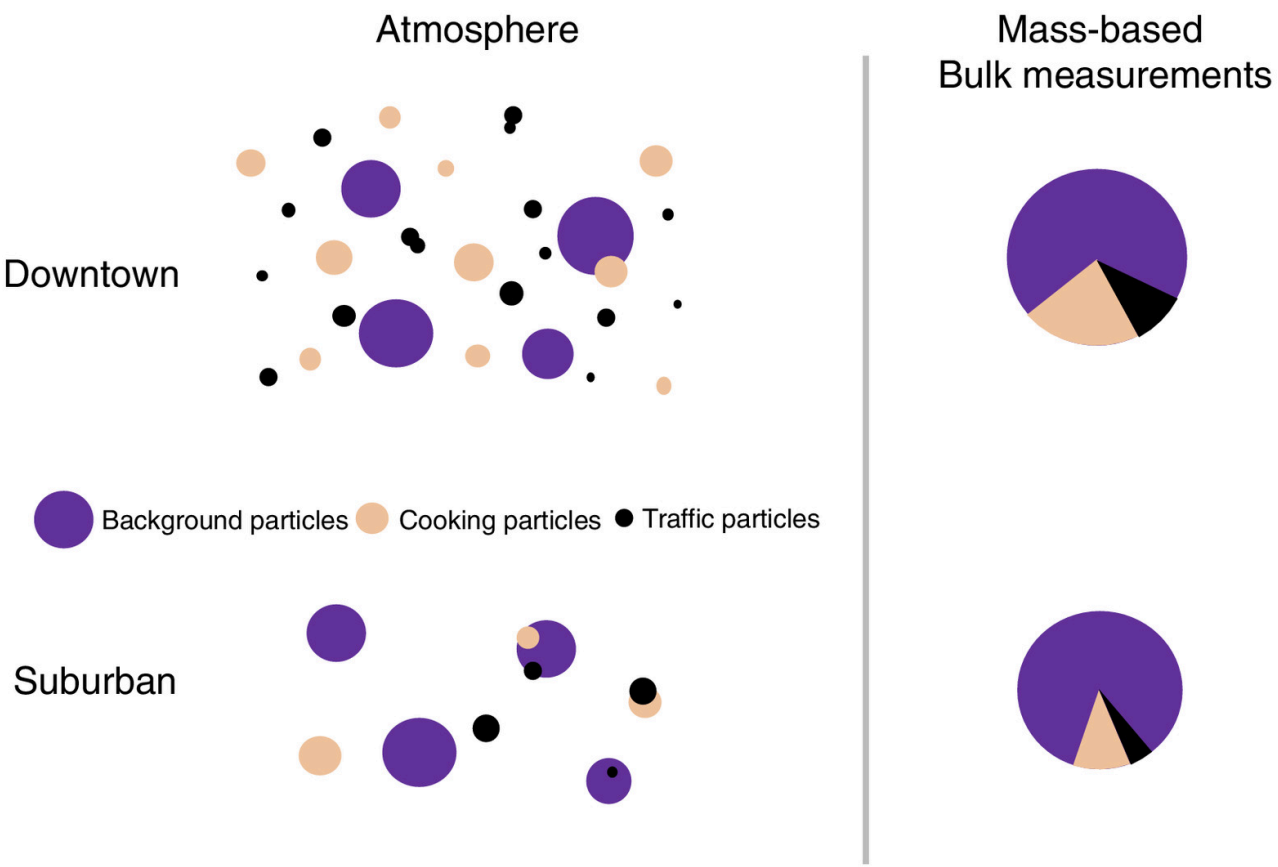
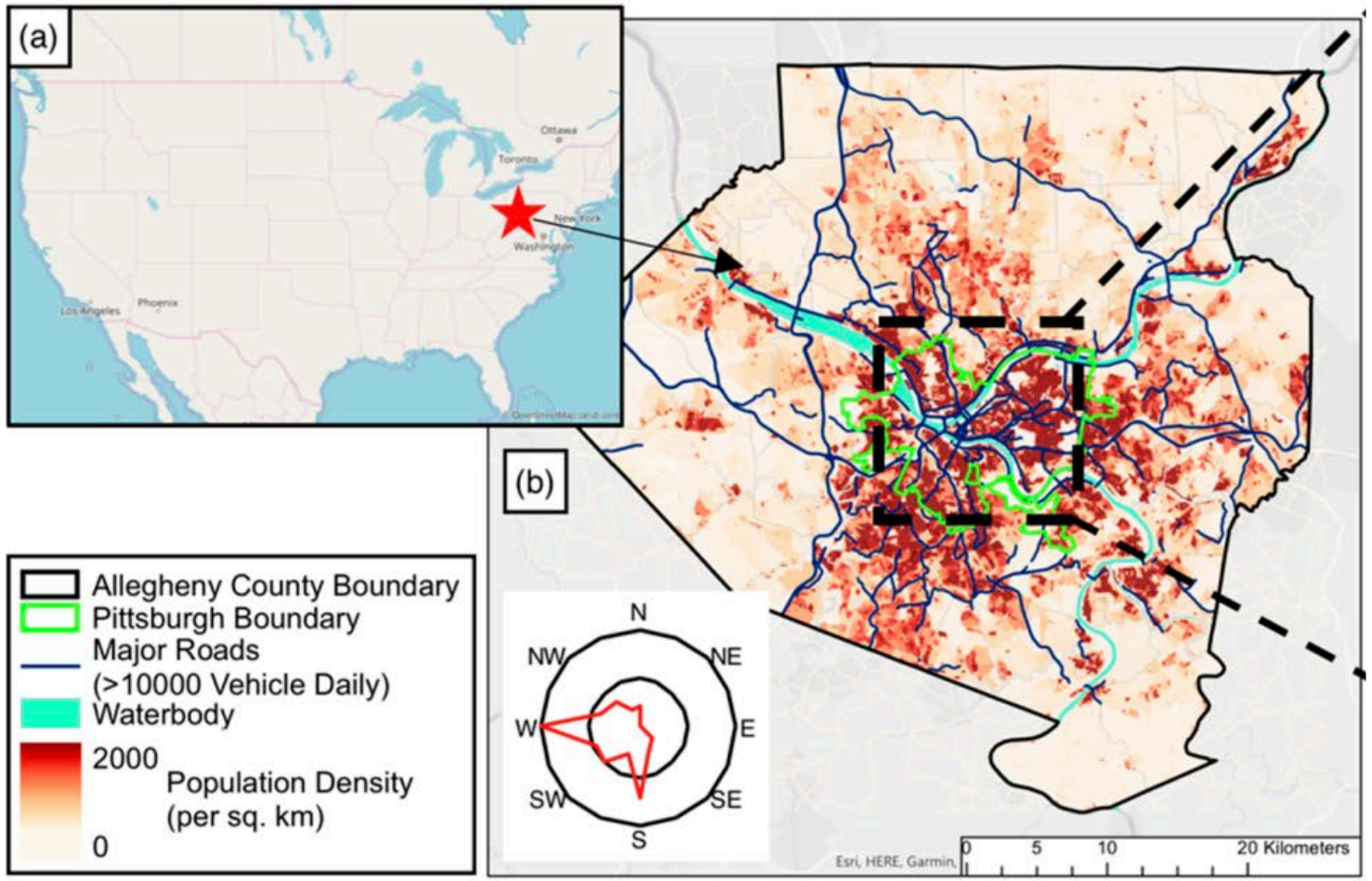


What are the spatial patterns of PM exposure in different particle metrics?

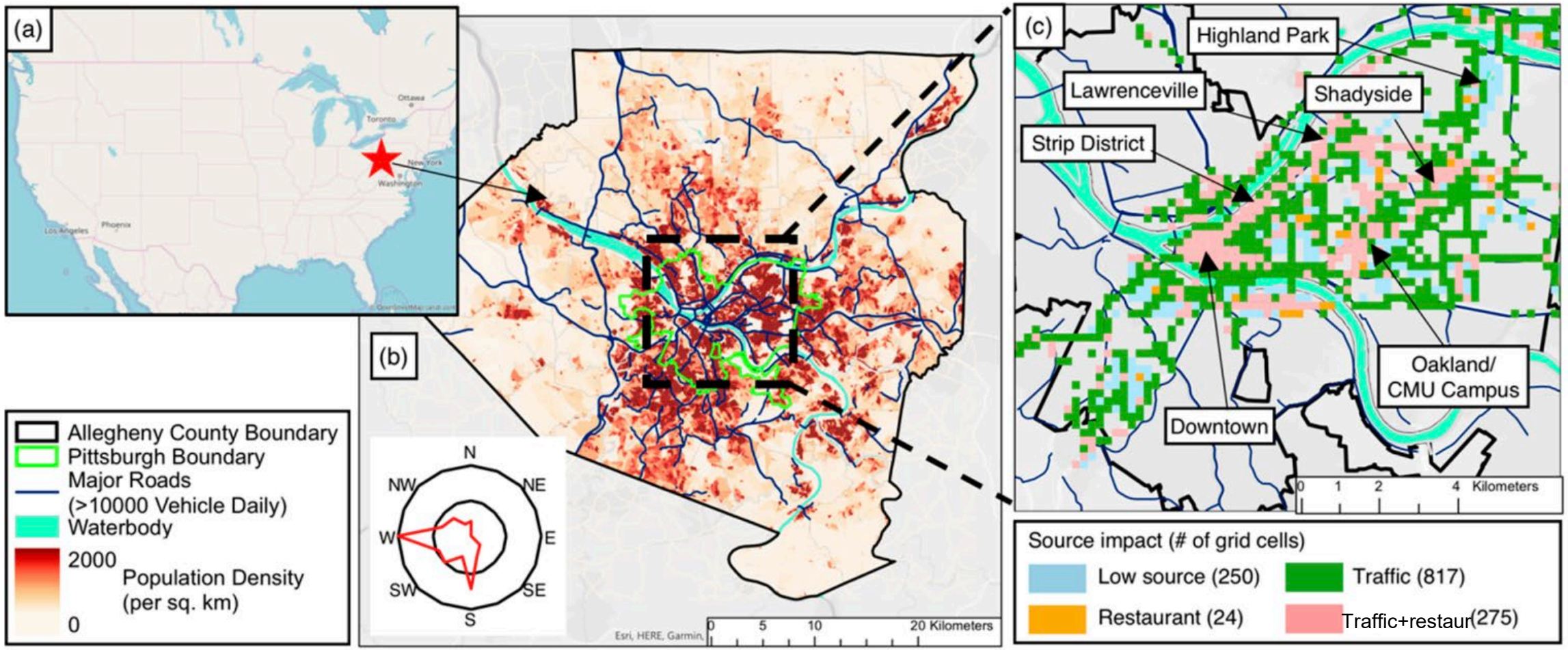
Overview of the sampling location---Pittsburgh PA



Gu *et al*., 2019

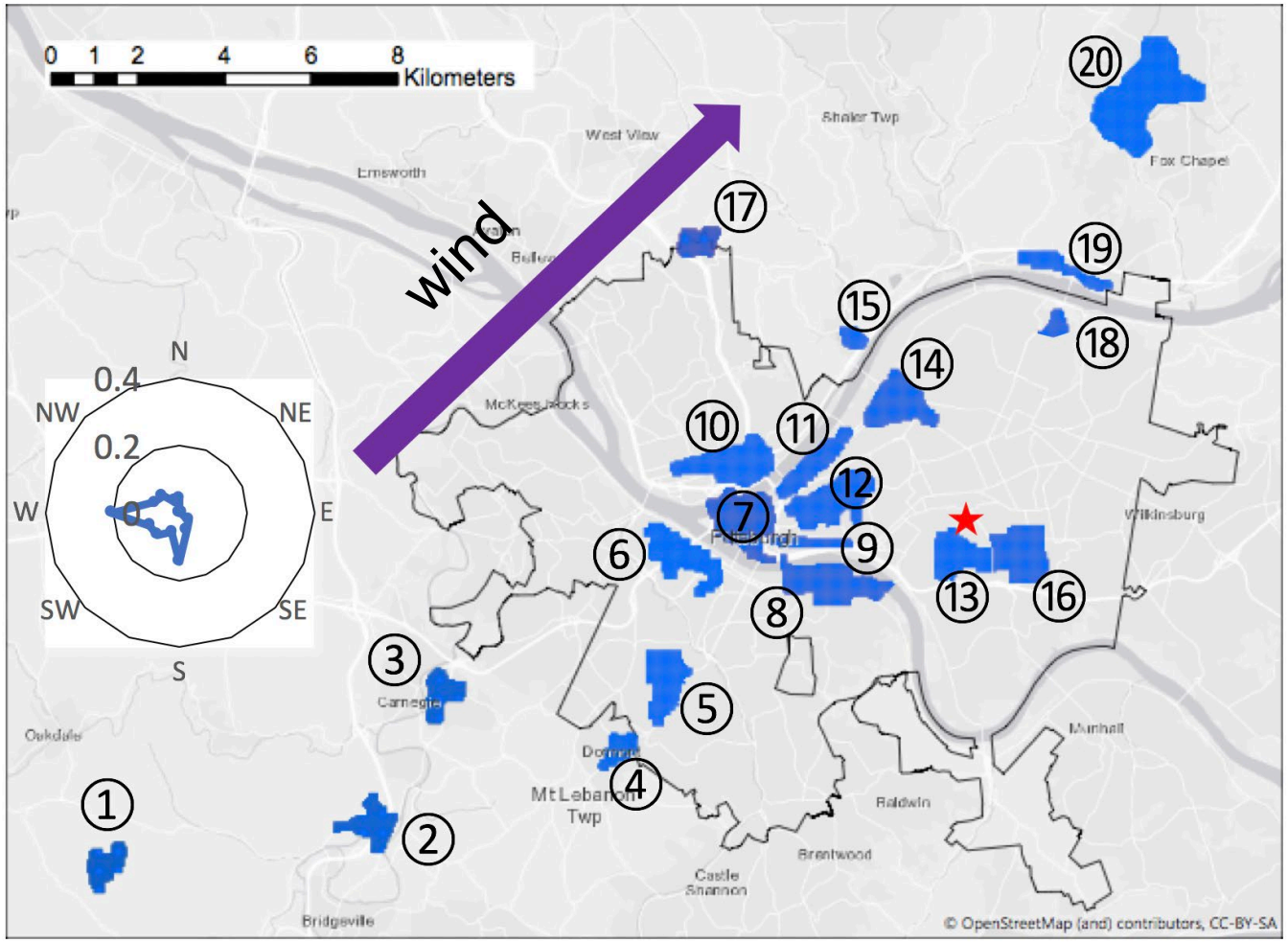
Overview of the sampling location---Pittsburgh PA

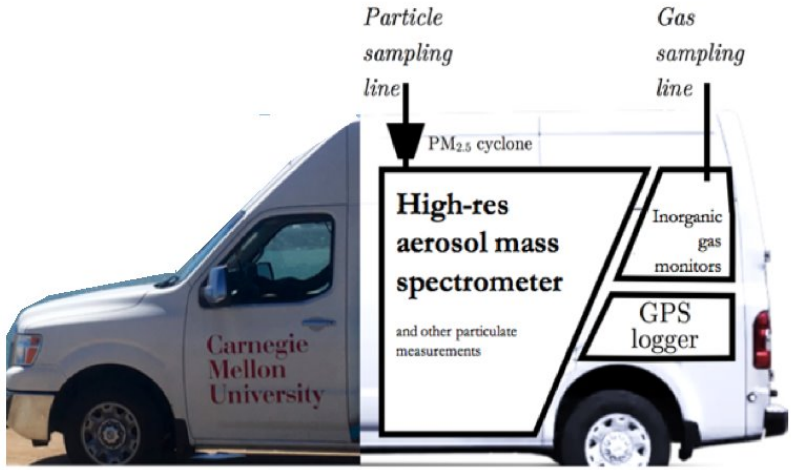
Spatially variable emission sources



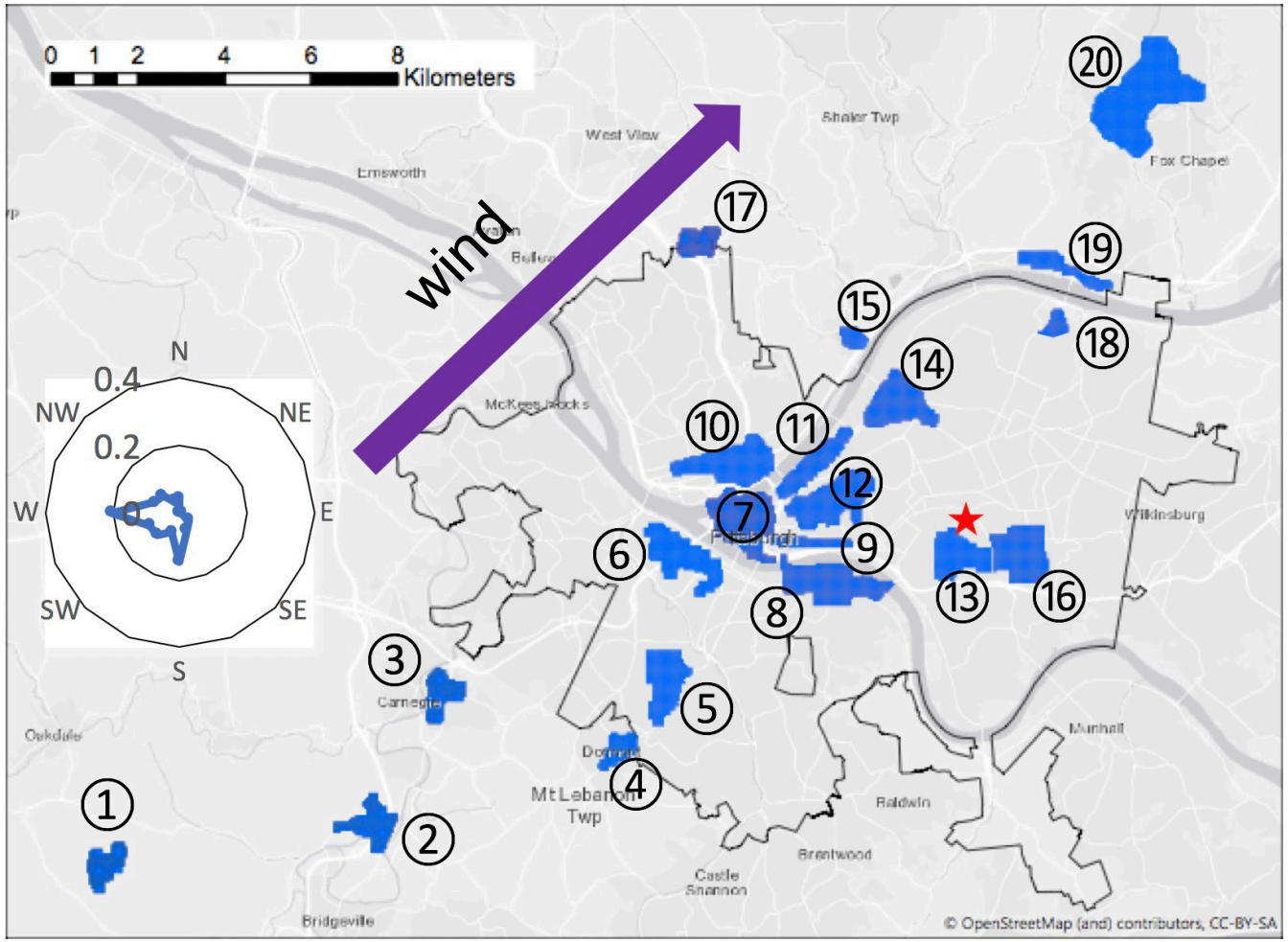
Gu *et al*., 2019

Conduct repeated mobile sampling in Pittsburgh to map PM pollution





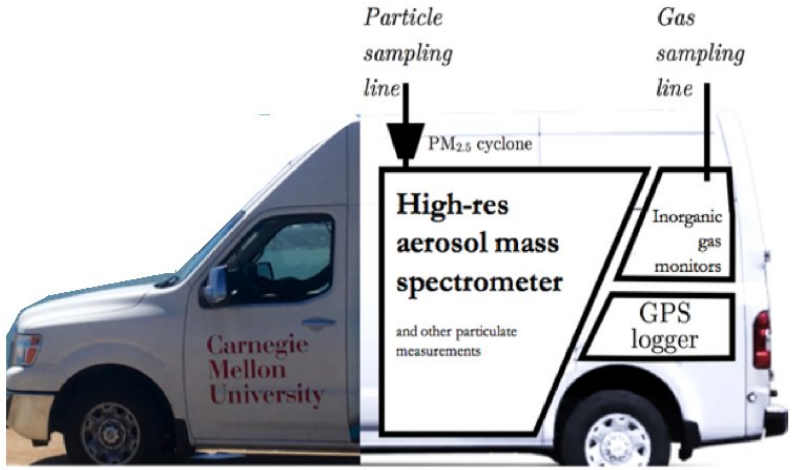
Single-particle mass spectrometry resolves individual particle's composition and source



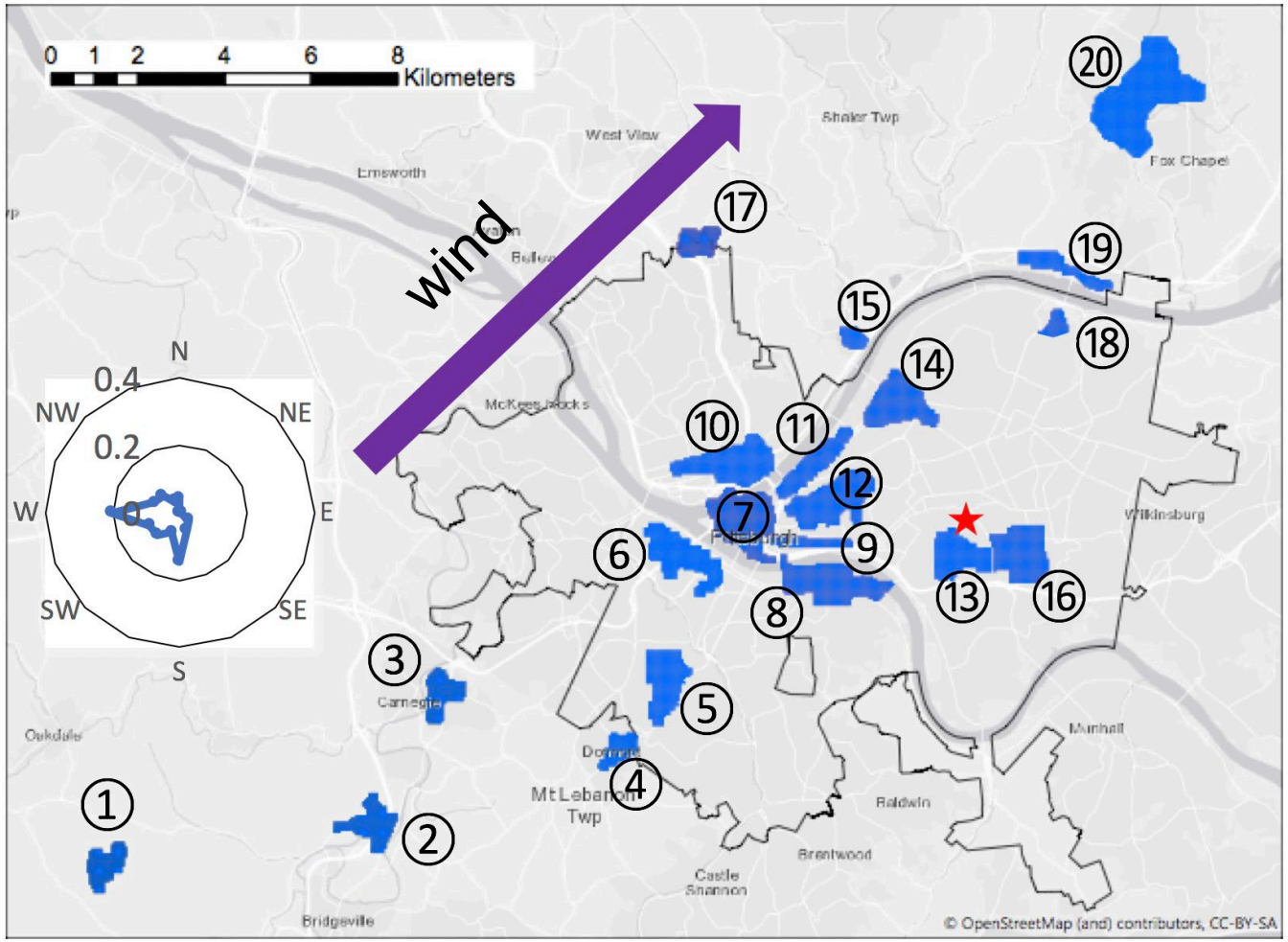
Single-particle mass spectrometer

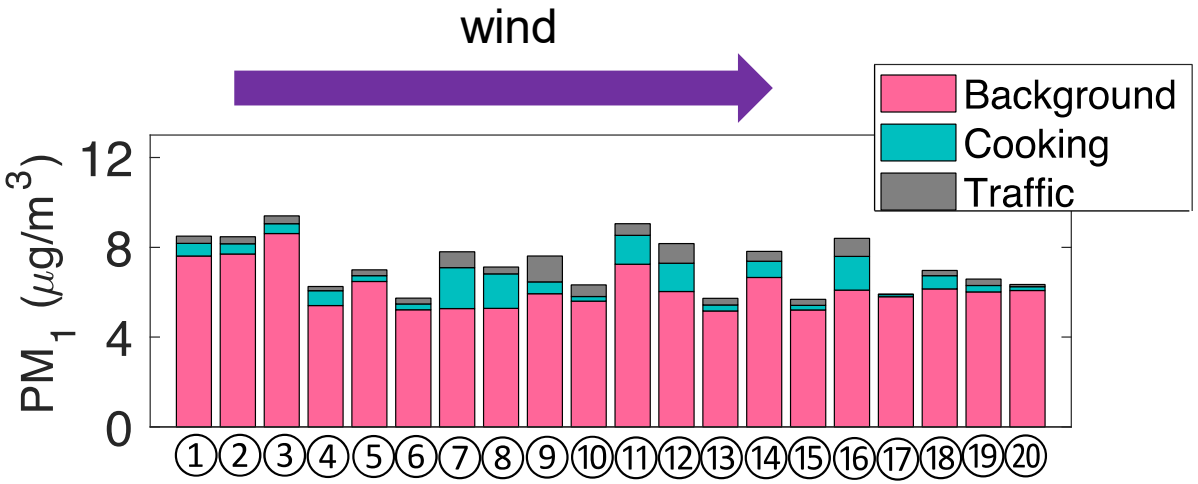
- Bulk PM_1 mass and composition
- Individual particle's size and composition
- Count individual particles (50-1000nm)

ion fragments of particles → source
- Background
- Traffic
- Cooking

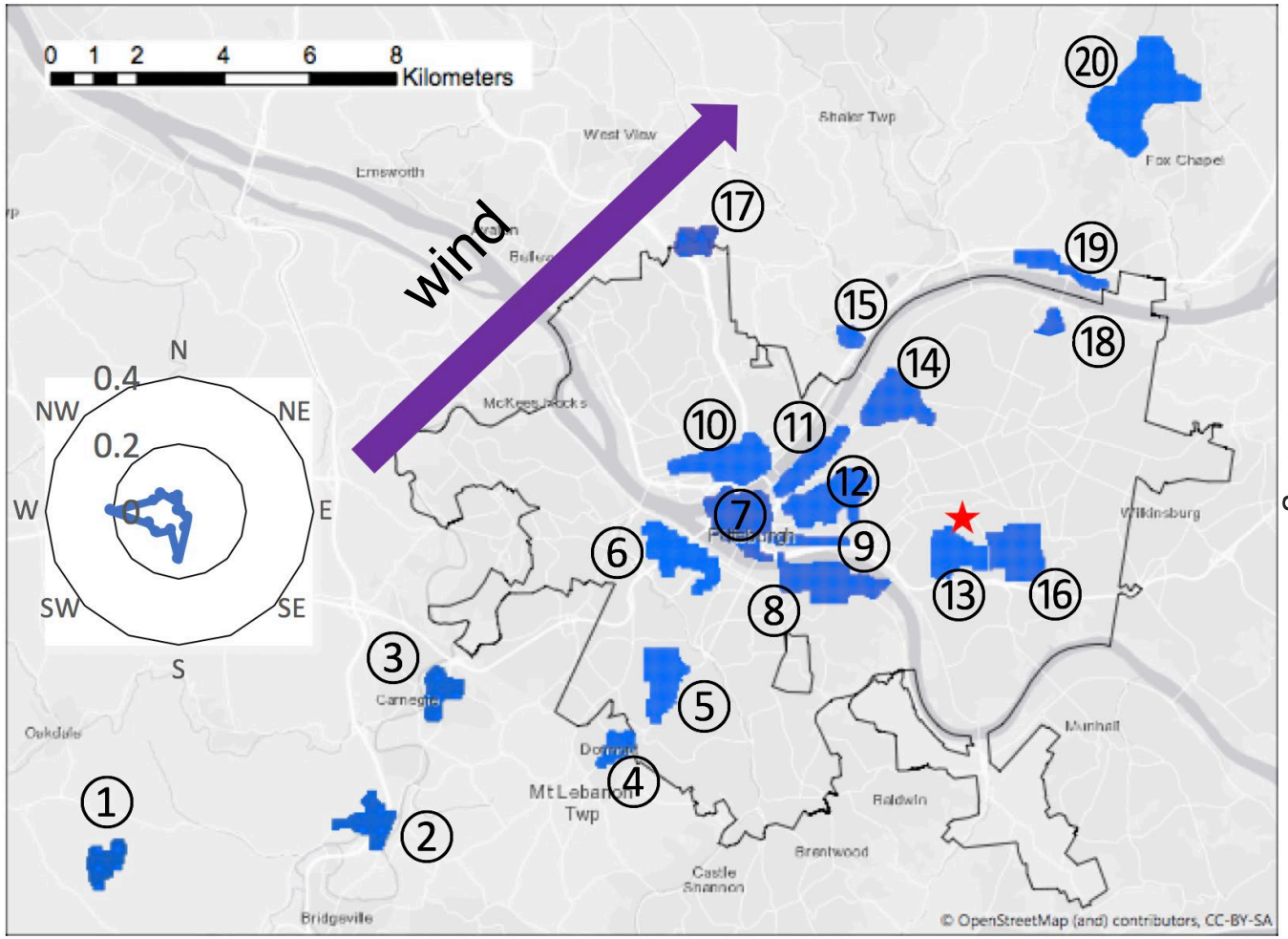


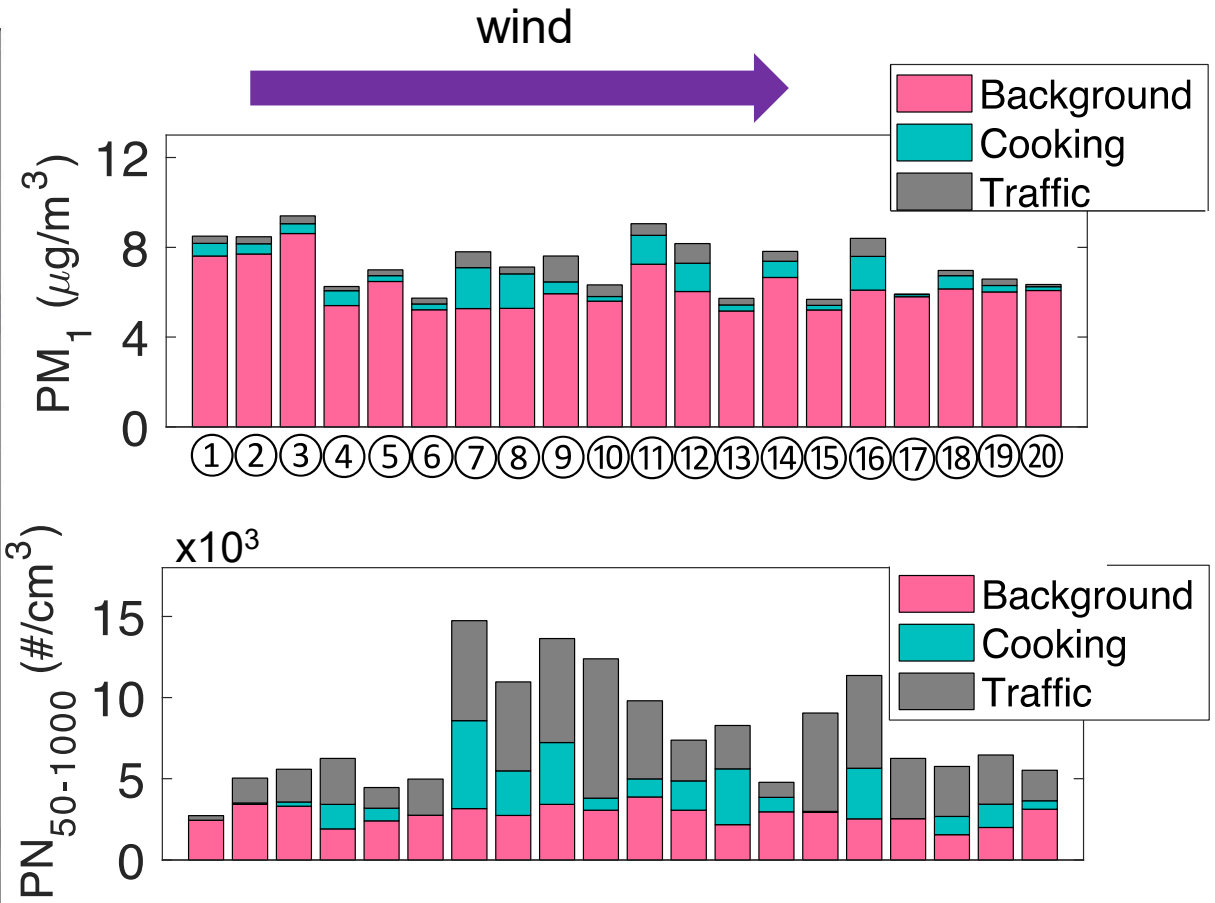
Total mass concentration is relatively uniform





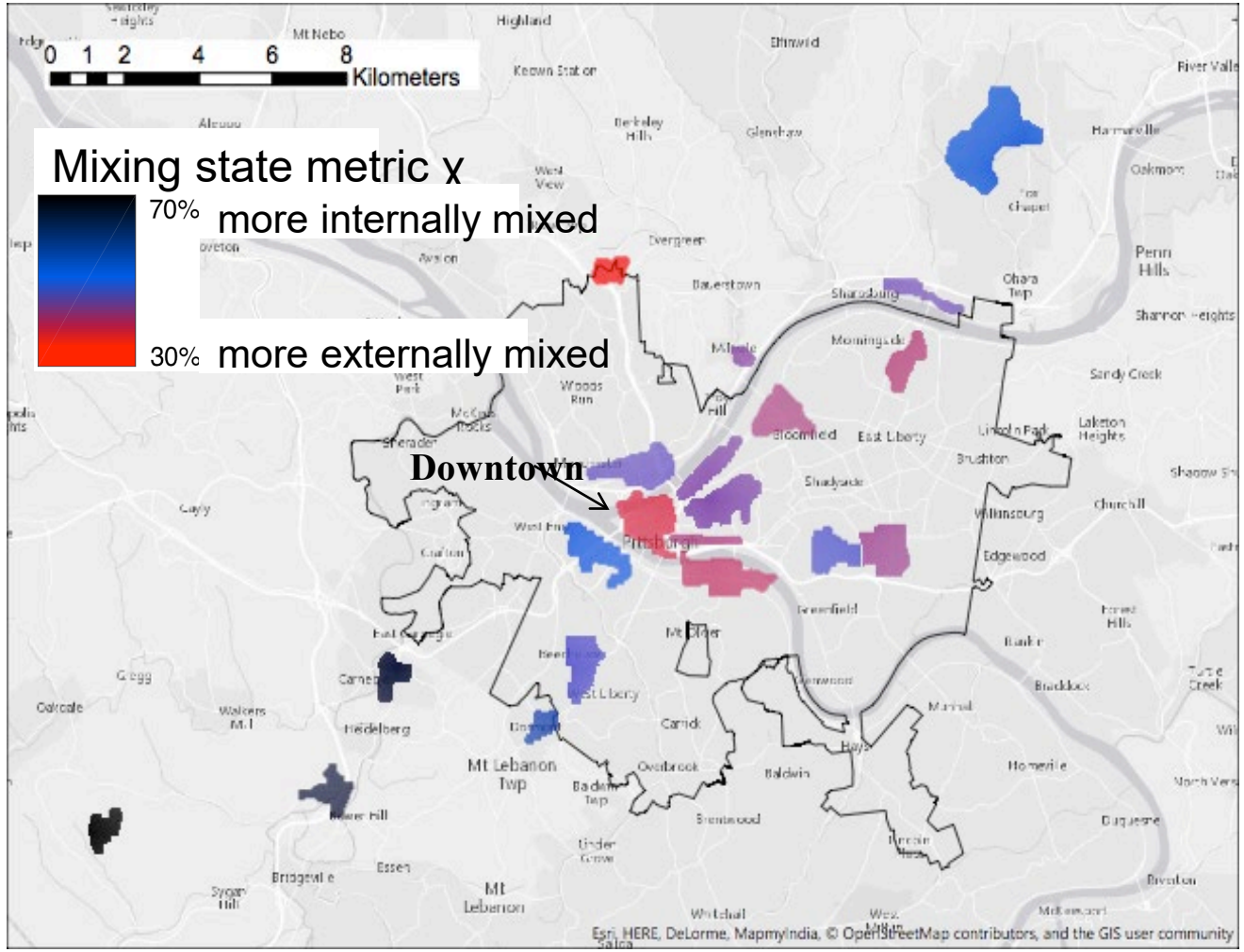
Total mass concentration is relatively uniform, but number concentration varies drastically

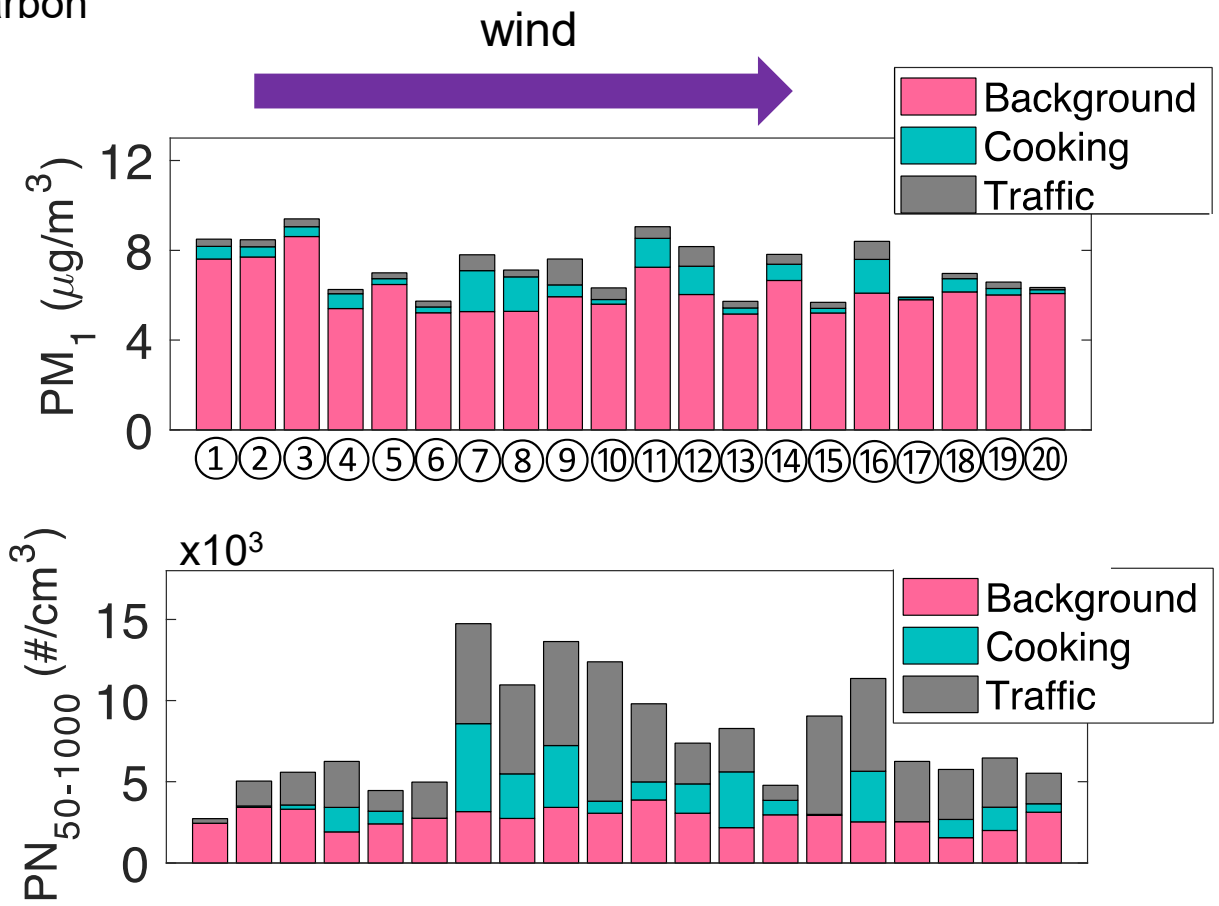




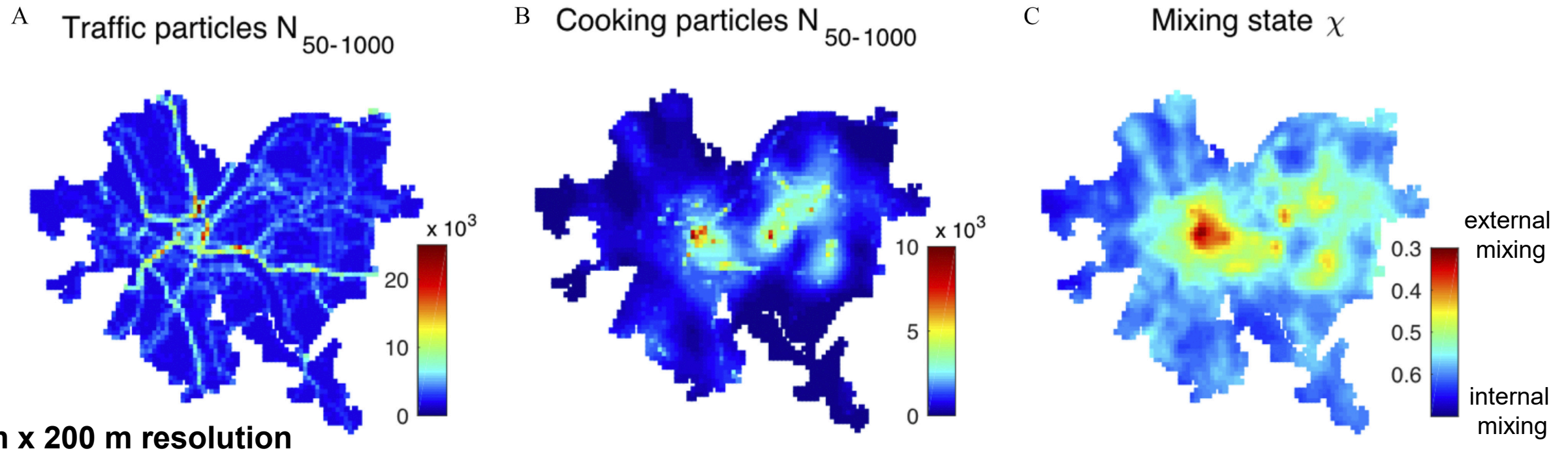
Urban emissions also affect particle mixing state (i.e. distribution of chemical species within a particle population)

Chemical species include organics, nitrate, sulfate, chloride, black carbon





Land-use regression modeling to predict source-resolved particle number concentration and mixing state



200 m x 200 m resolution

Covariates selected[a]	Coefficient	Partial R^2
Traffic	—	—
Vehicle density in all roads (100 m)	21.48	0.37
Diesel annual average daily travel × squared inverse distance to the nearest road (100 m)	321.5	0.21
Intercept	1,577	—

total R^2: 0.58

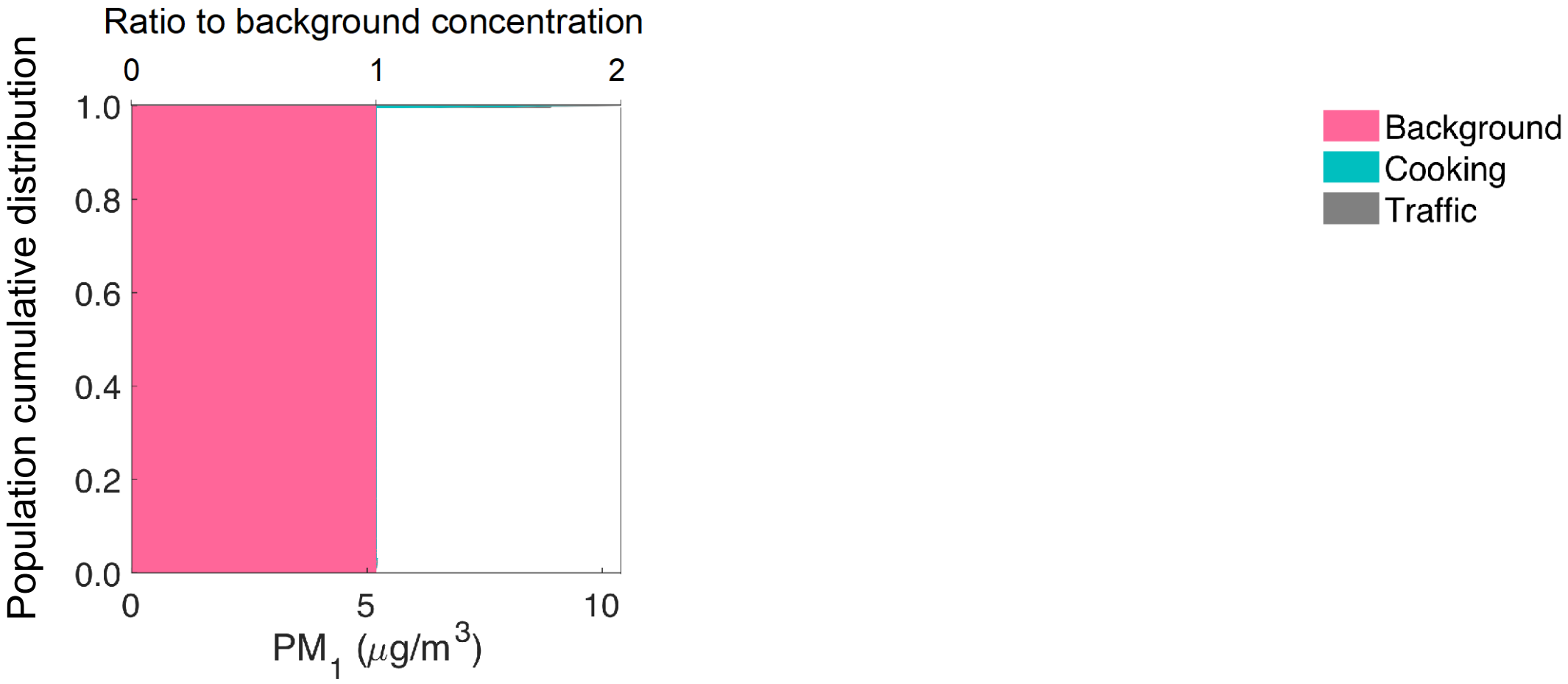
Covariates selected[a]	Coefficient	Partial R^2
Cooking	—	—
Restaurant counts (100 m)	12.87	0.37
Major road length (1,000 m)	0.0505	0.24
Population density (1,000 m)	0.1633	0.06
Intercept	−717.8	—

total R^2: 0.67

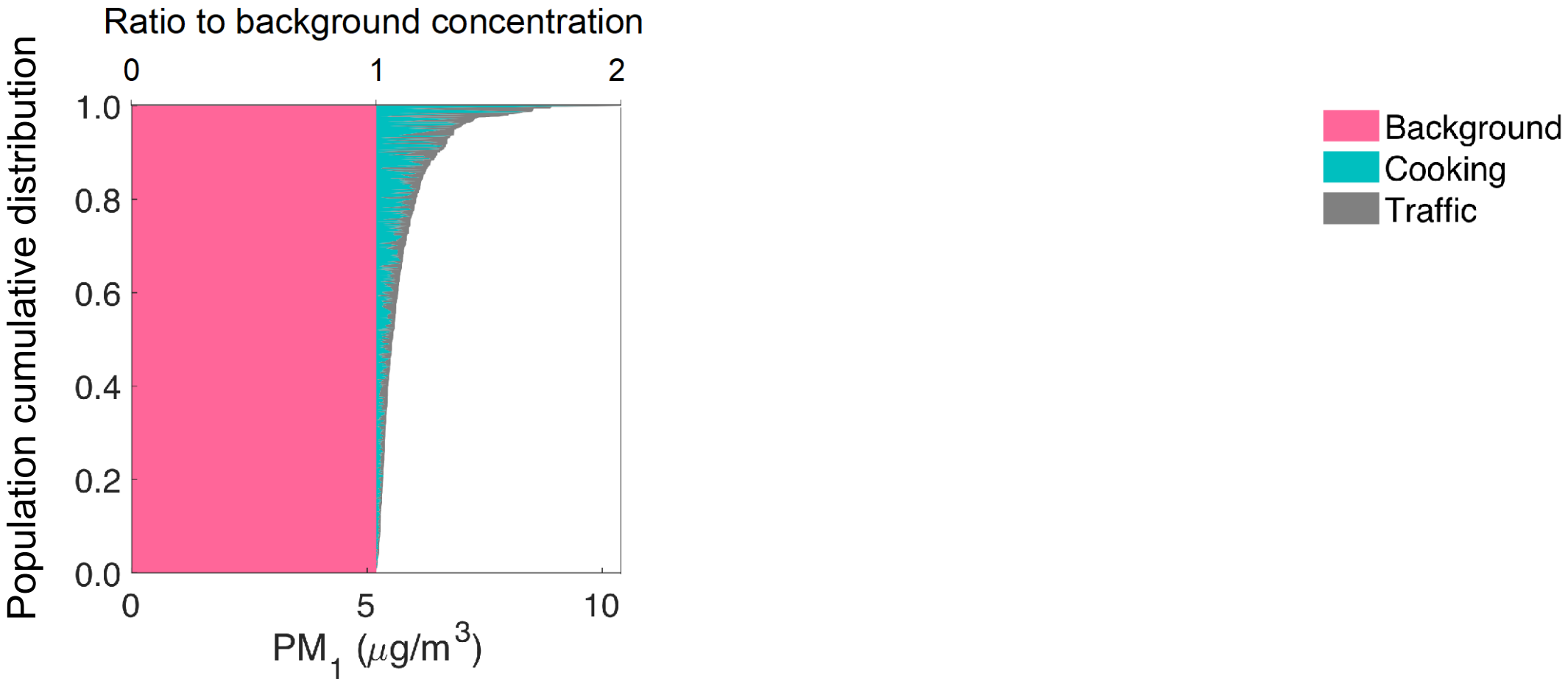
Covariates selected[a]	Coefficient	Partial R^2
Mixing State $(1-\chi)$, unitless	—	—
Major road length (1,000 m)	5.77×10^{-6}	0.54
House density (300 m)	7.59×10^{-5}	0.06
NEI point source density (30 km)	9.44	0.03
Intercept	−0.304	—

total R^2: 0.63

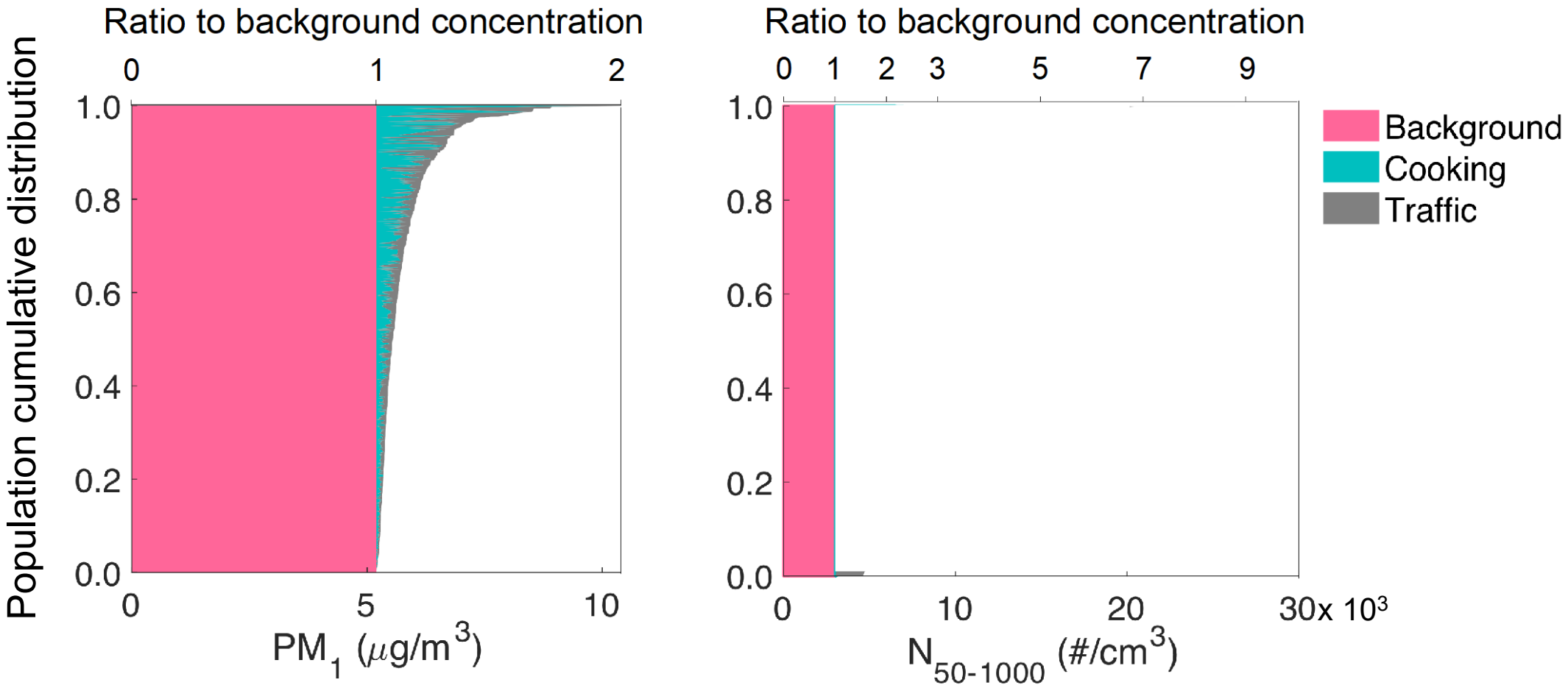
Mass exposure includes uniform background particles



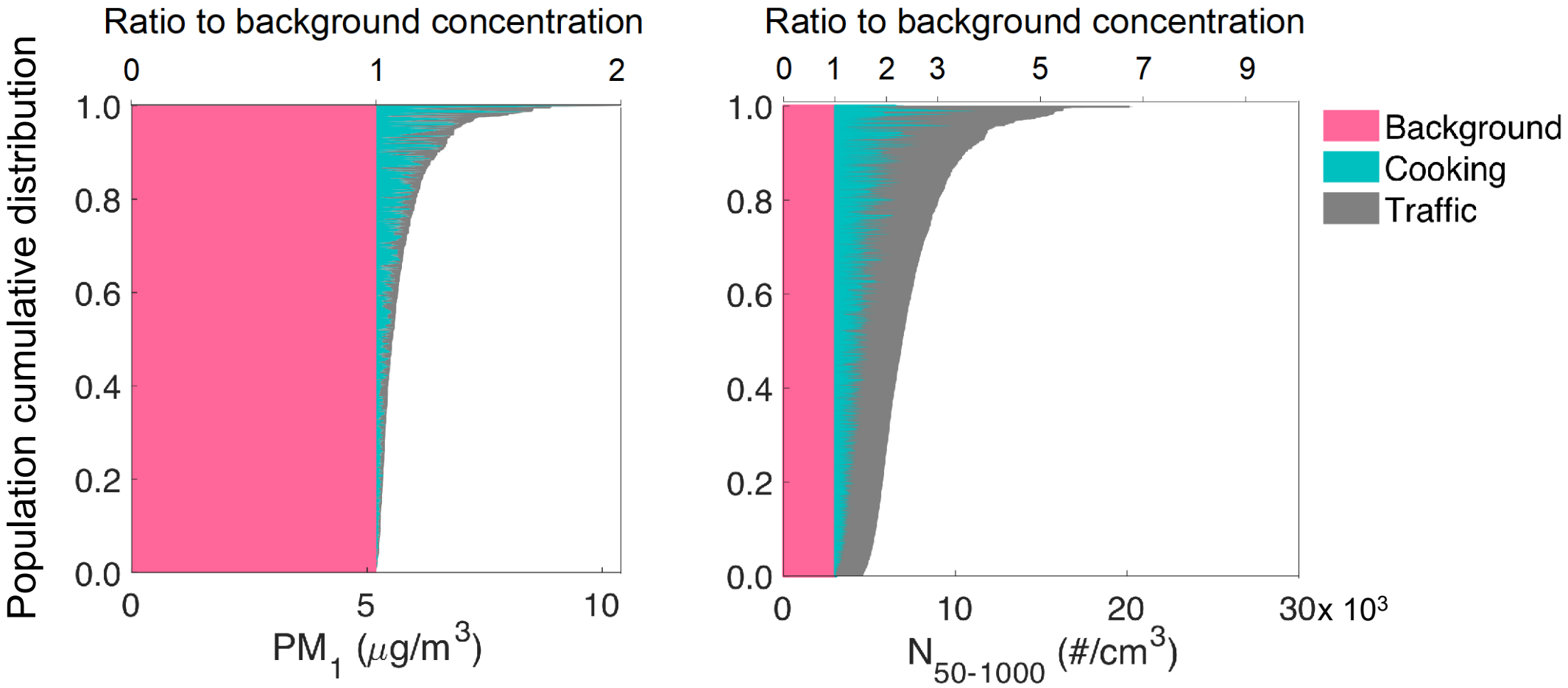
Mass exposure is dominated by background particles



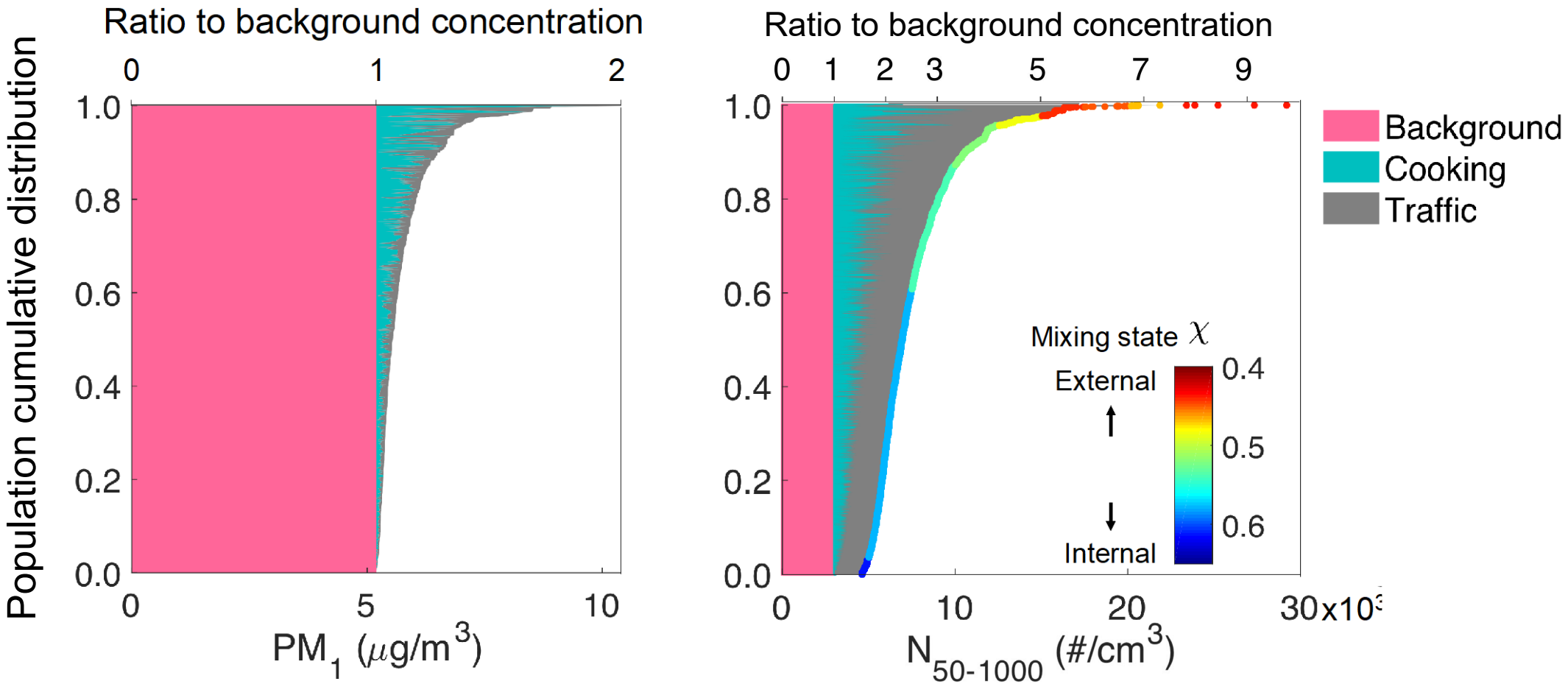
Number exposure also includes relatively uniform background particles



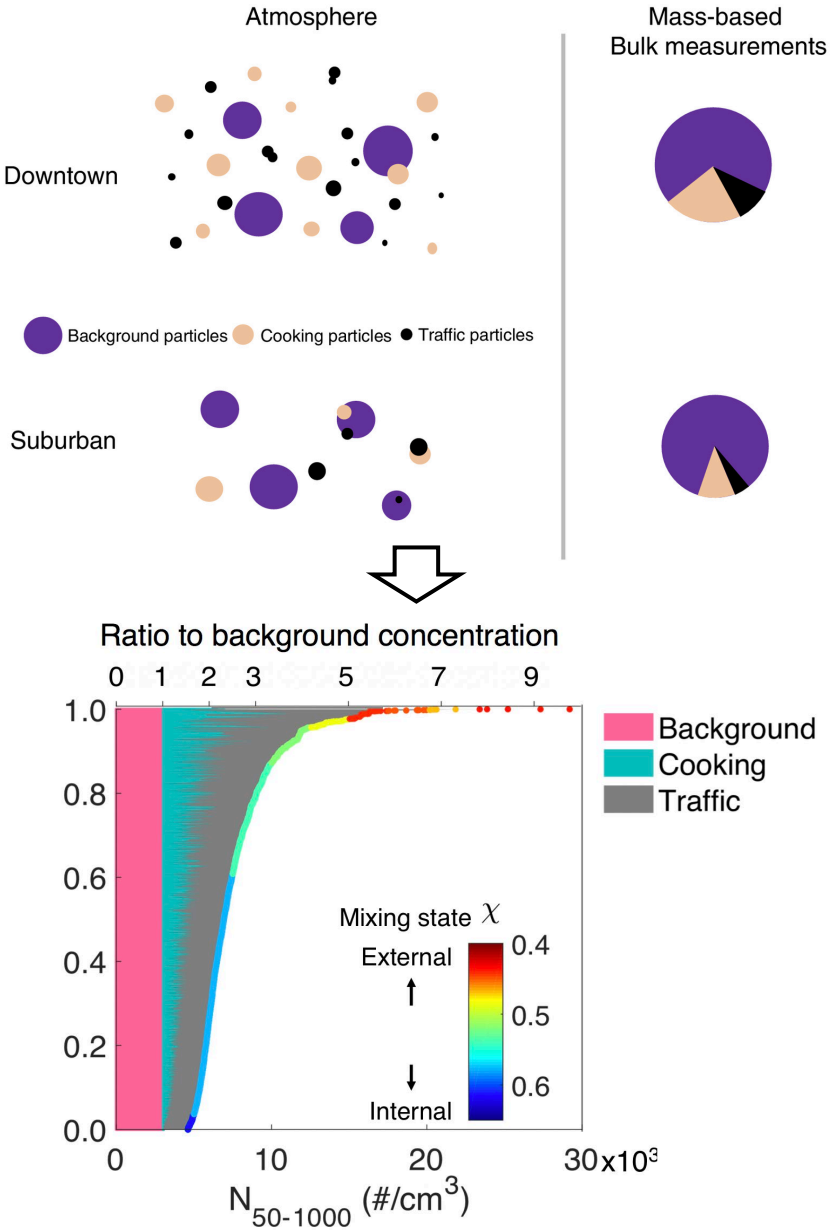
Number exposure is dominated by primary particles with high variability



High concentration exposure also correlates with external mixing



Conclusions



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Spatial Variability of Sources and Mixing State of Atmospheric Particles in a Metropolitan Area

Qing Ye,[†] Peishi Gu,[†,‡] Hugh Z. Li,[†,‡] Ellis S. Robinson,[†,‡] Eric Lipsky,[§] Christos Kaltsonoudis,[†] Alex K.Y. Lee,[∥] Joshua S. Apte,[⊥] Allen L. Robinson,[†,‡] Ryan C. Sullivan,[†,‡] Albert A. Presto,[†,‡] and Neil M. Donahue*[,†]

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