# Trends in Inter- and Intraurban Ultrafine Particle Levels in the U.S.: Exposure Implications

Albert Presto

Dept. of Mechanical Engineering

Center for Atmospheric Particle Studies

# Important questions about UFP exposures

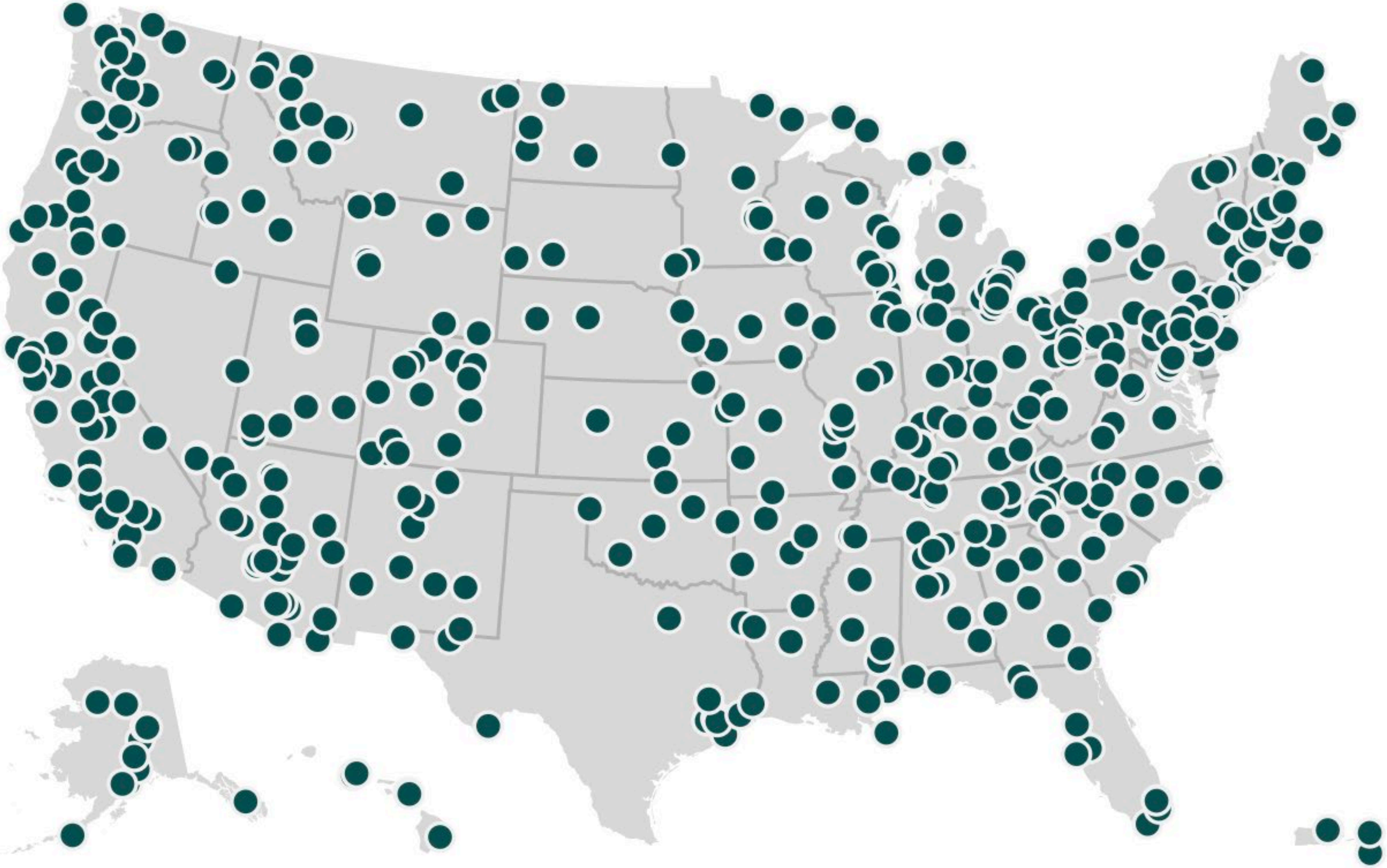
- Concentrations and spatial/temporal trends
  - What are typical concentrations?
  - What are the trends over time?
  - What are the inter- and intra-city spatial patterns?
- UFP sources
  - What are the major sources, and how do they drive temporal and spatial patterns?
  - What are contributions of primary and secondary particles?
- UFP exposures
  - What is the current ability to estimate exposures?
  - What would be needed to improve exposure estimates?

# Reminder 1: There is not a regulatory standard for UFP measurement or quantification

This presentation will use particle number count (PNC, # $cm^{-3}$) as a UFP surrogate

# Reminder 2: UFPs are a data-poor pollutant

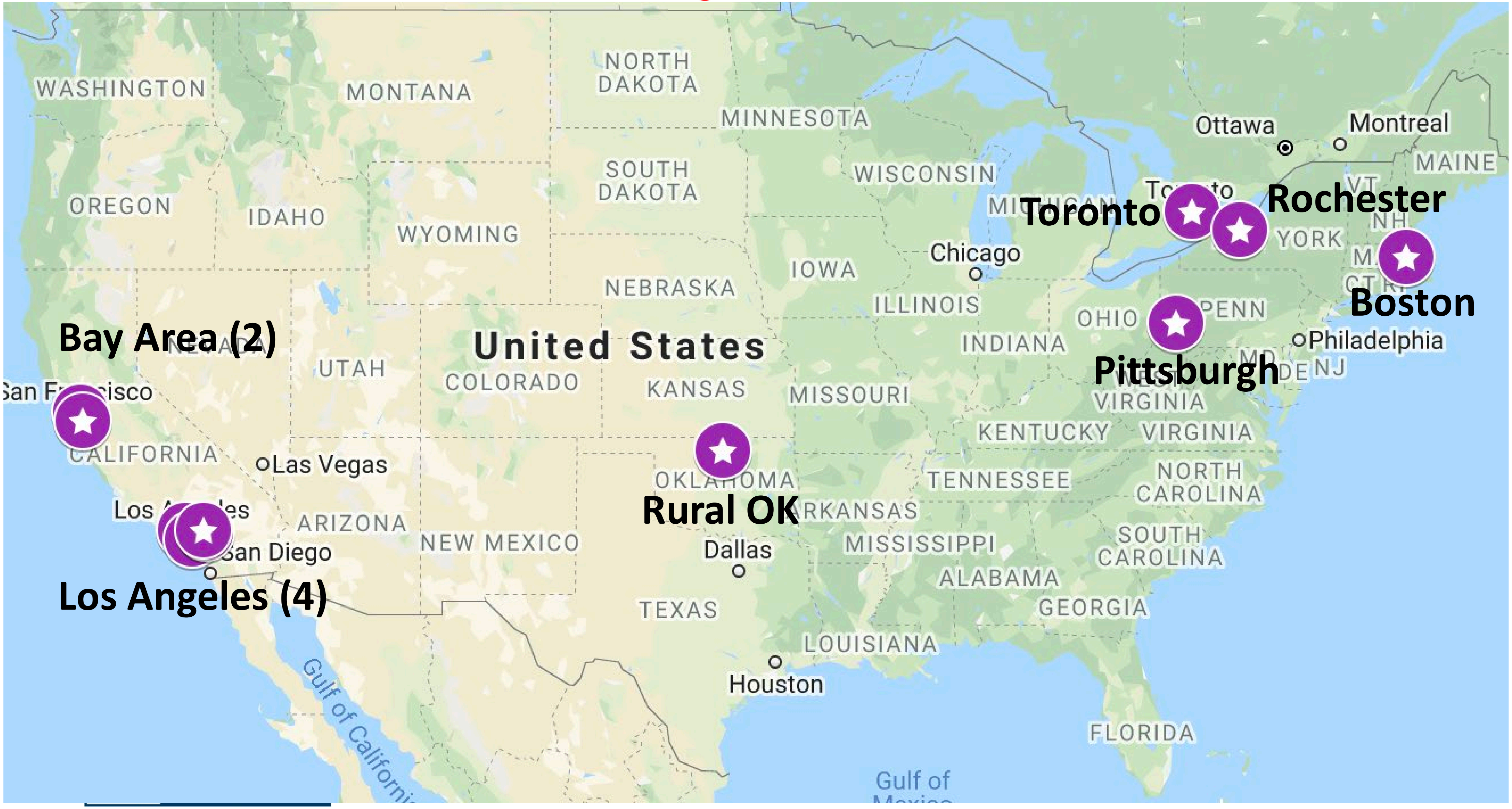
# This is the current EPA network for $PM_{2.5}$



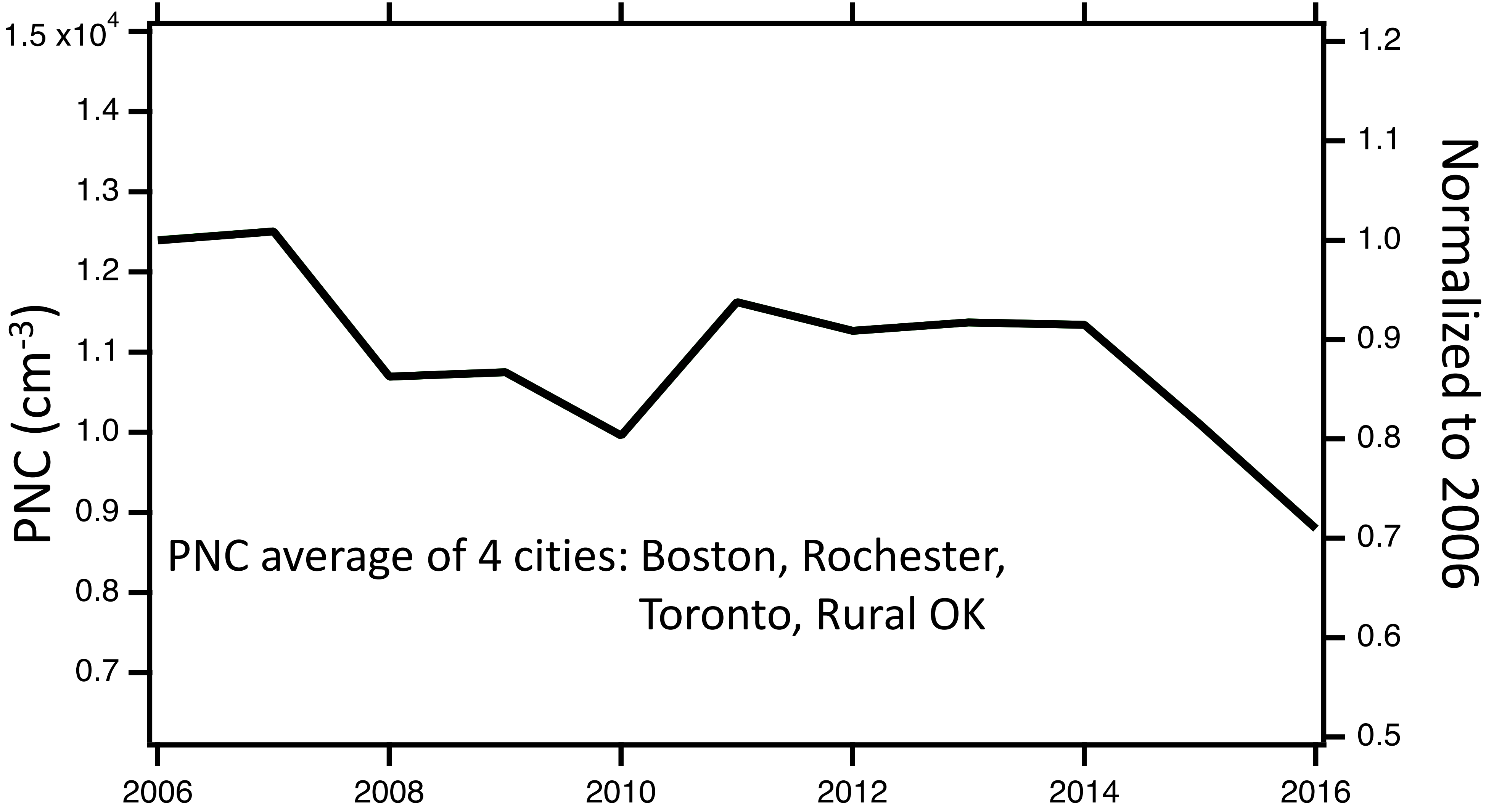
Source: US EPA

# This is the current EPA UFP network

# We will investigate trends with a small number of cities that have long(er) term measurements



# PNC concentrations have fallen ~30% since 2006

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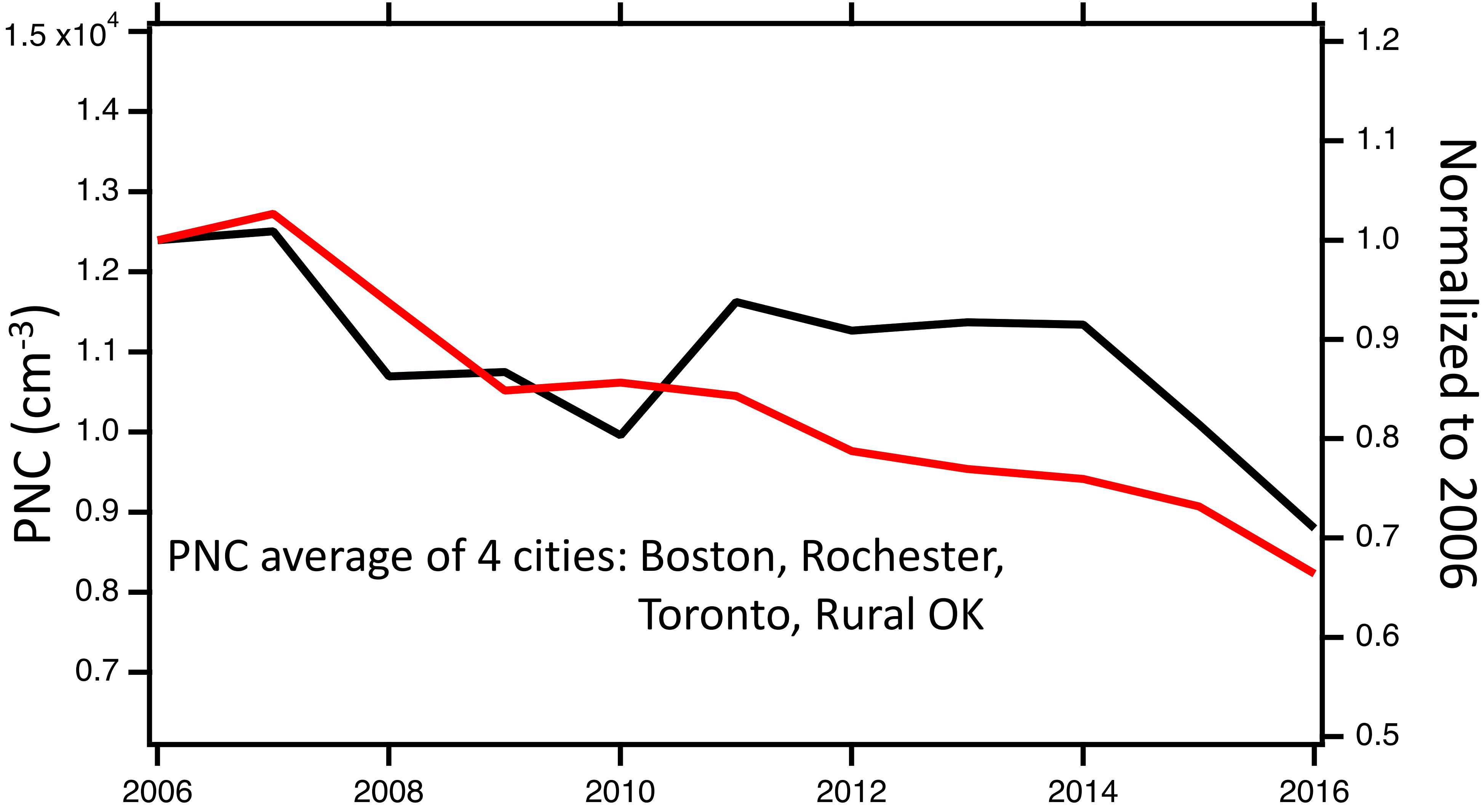
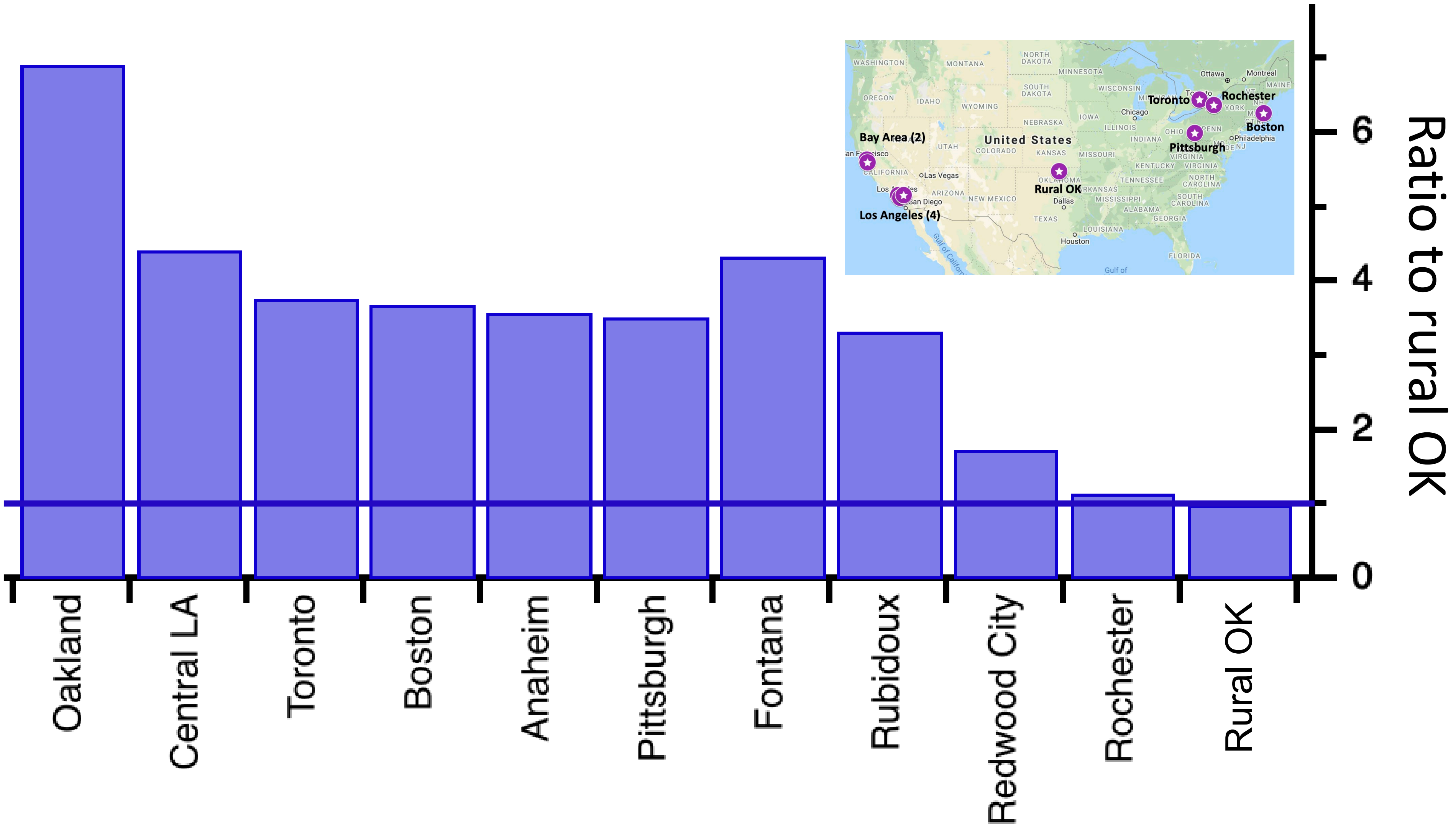
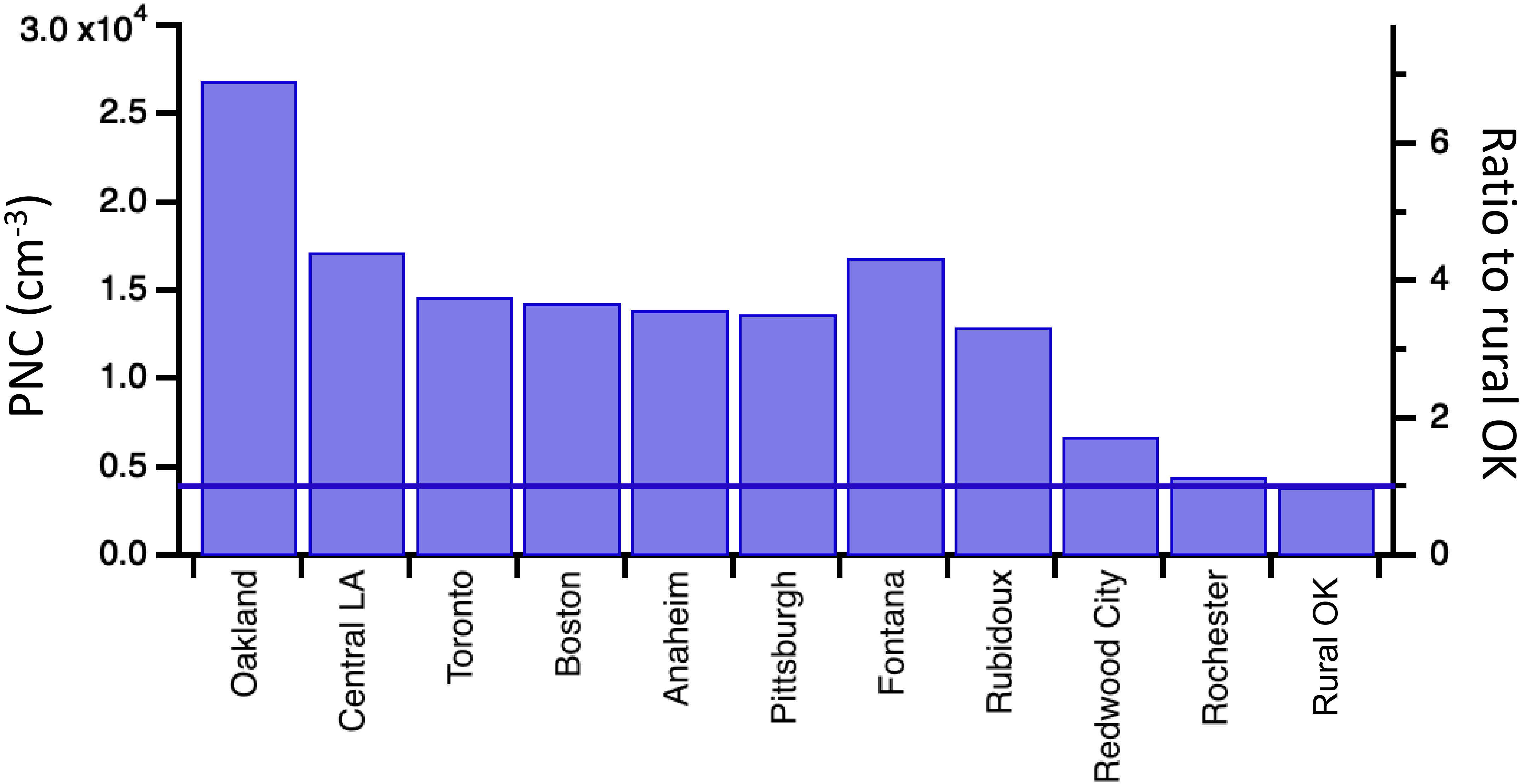



**National $PM_{2.5}$ reduction of 35% since 2006**

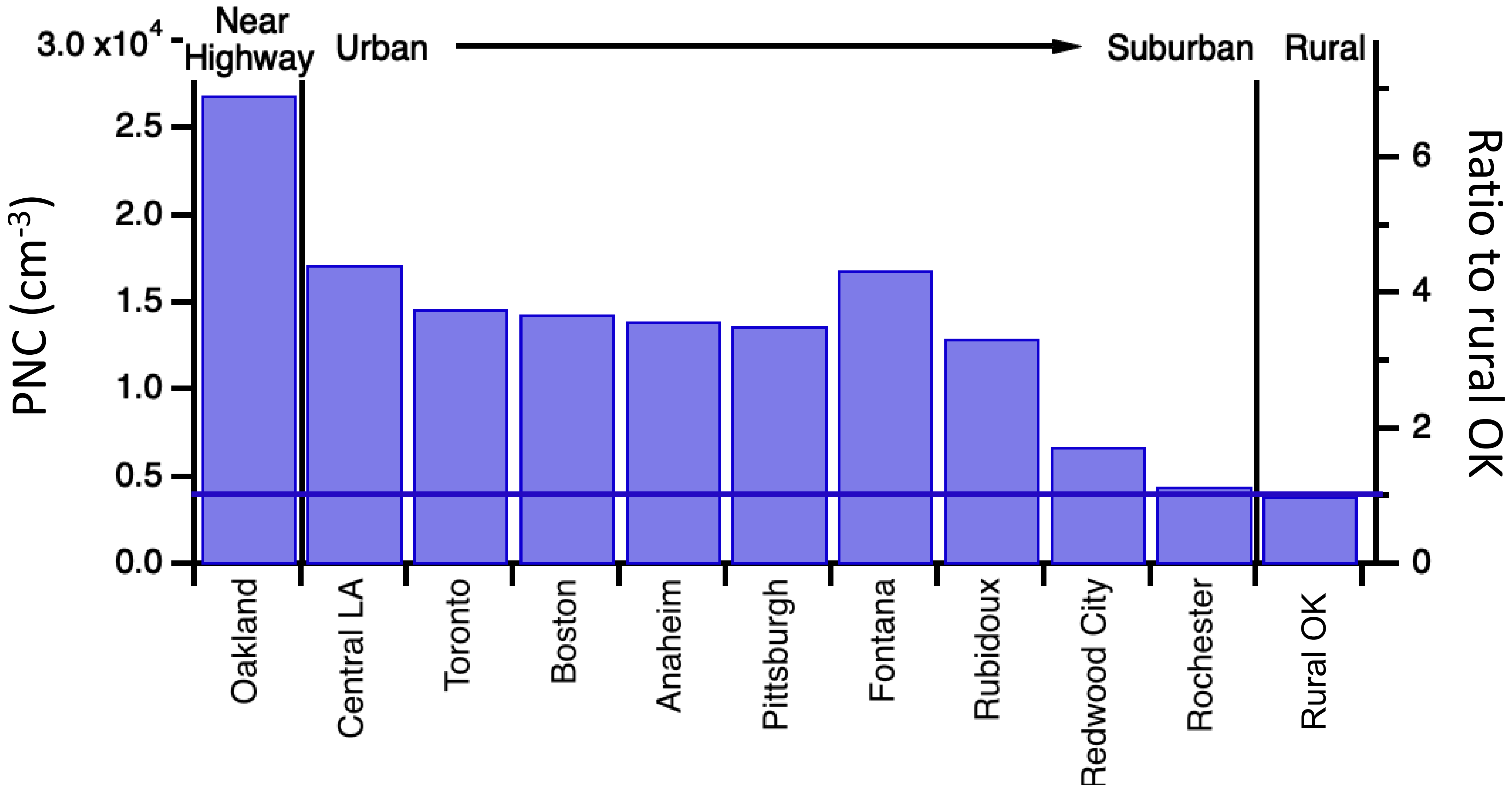
# PNC concentrations are highly variable



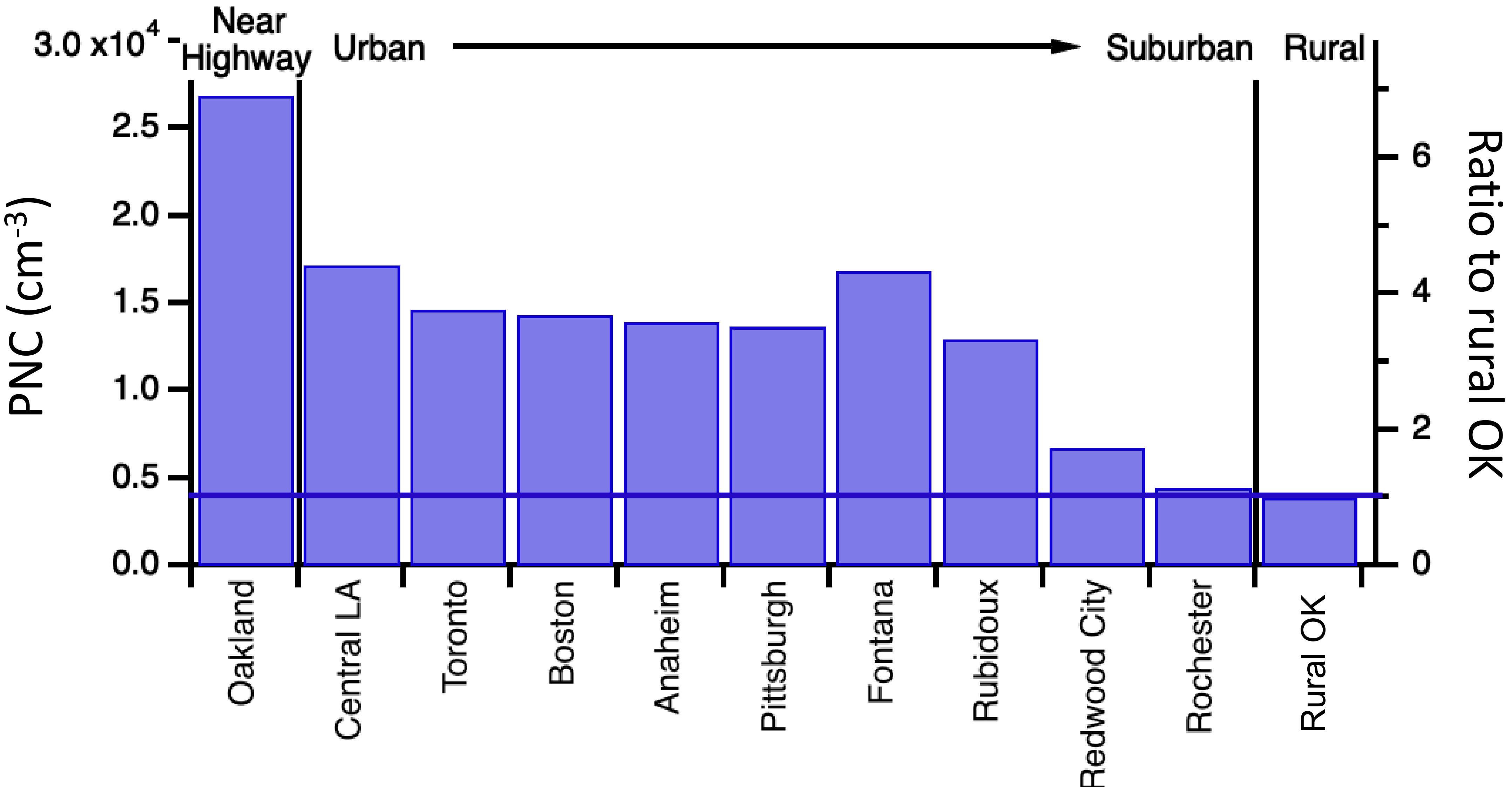
# PNC range from <5,000 to >20,000 $cm^{-3}$



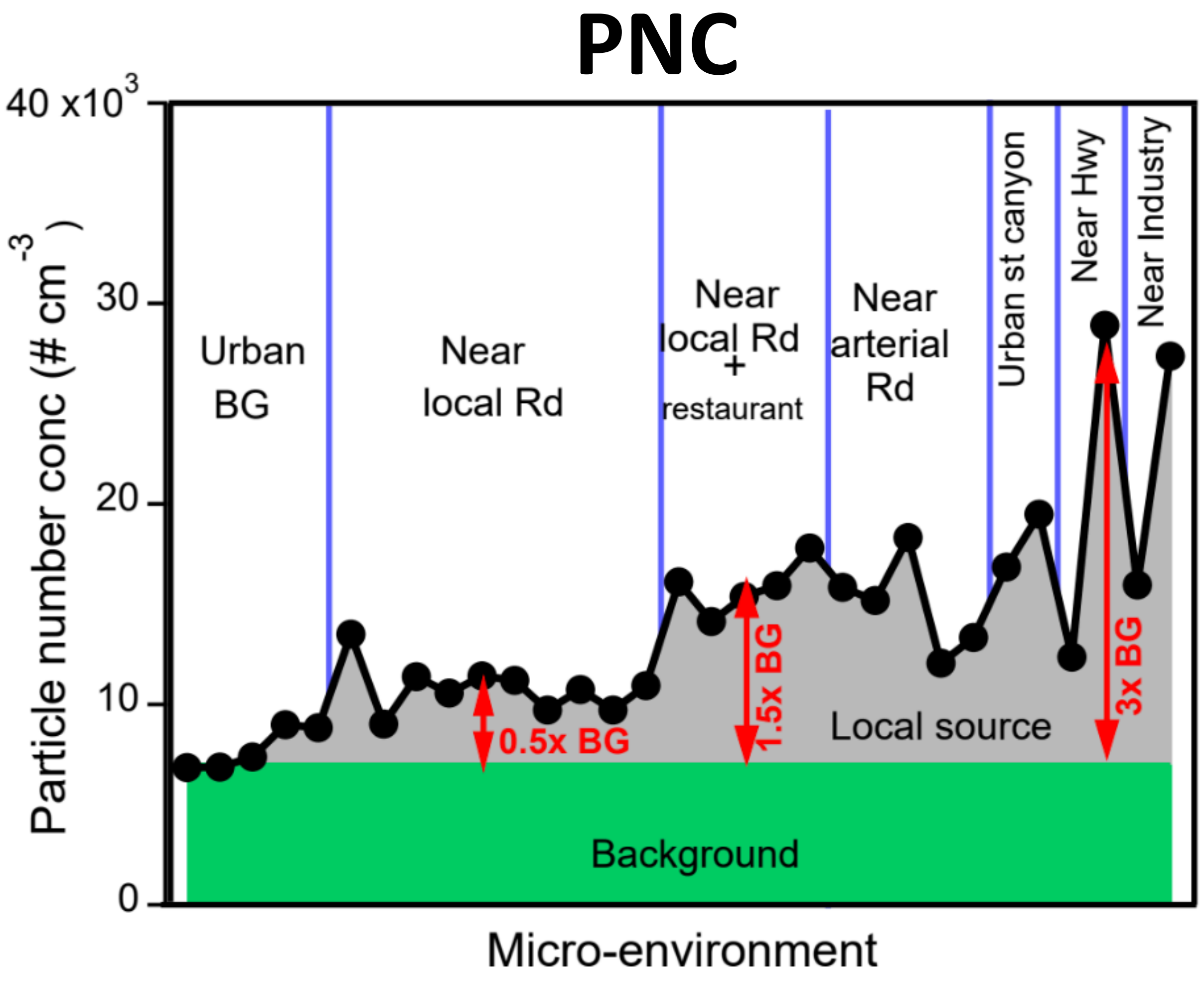
# PNC concentrations are highly variable and depend on sampling location



# How much of this inter-city variation is a result of the specifics of each sampling site?



# PNC varies by a factor of 2-3 at urban scales

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Saha et al, *STOTEN*, 2019

# We investigated inter- and intra-city PNC with mobile sampling

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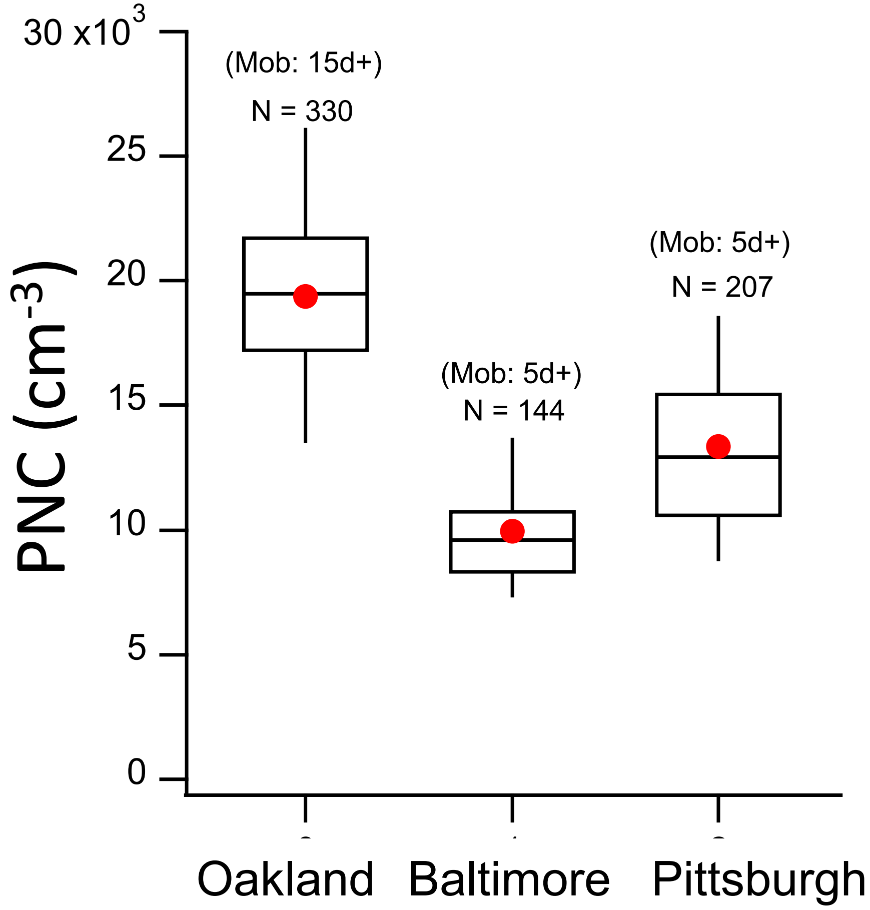


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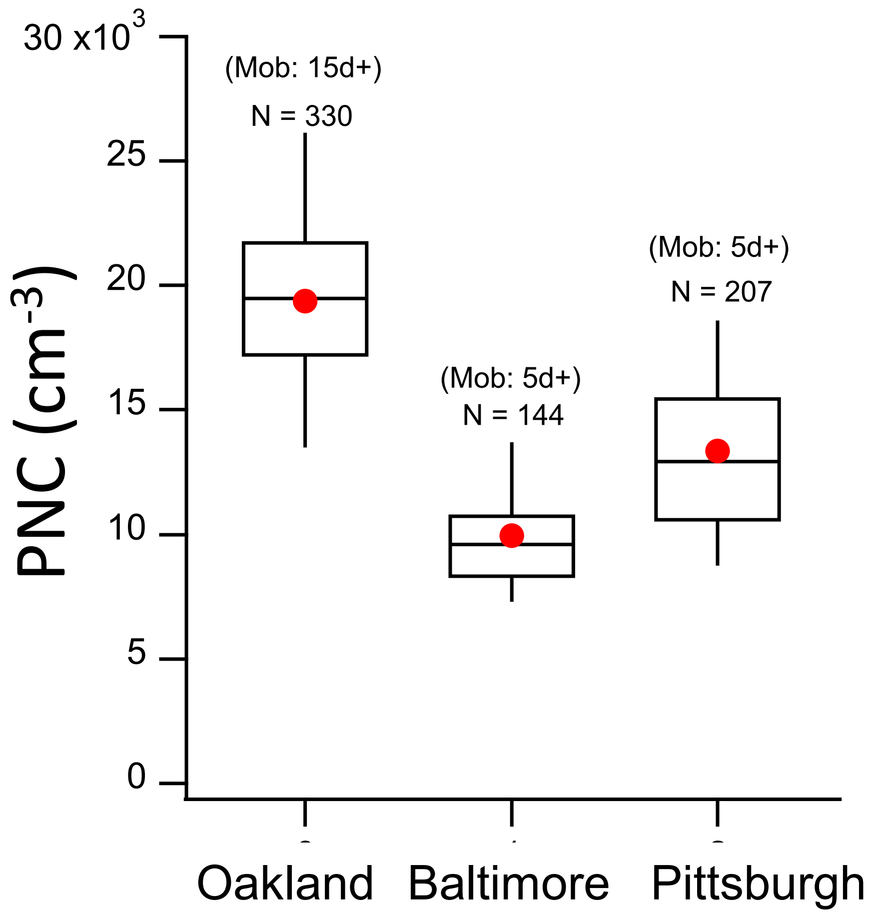
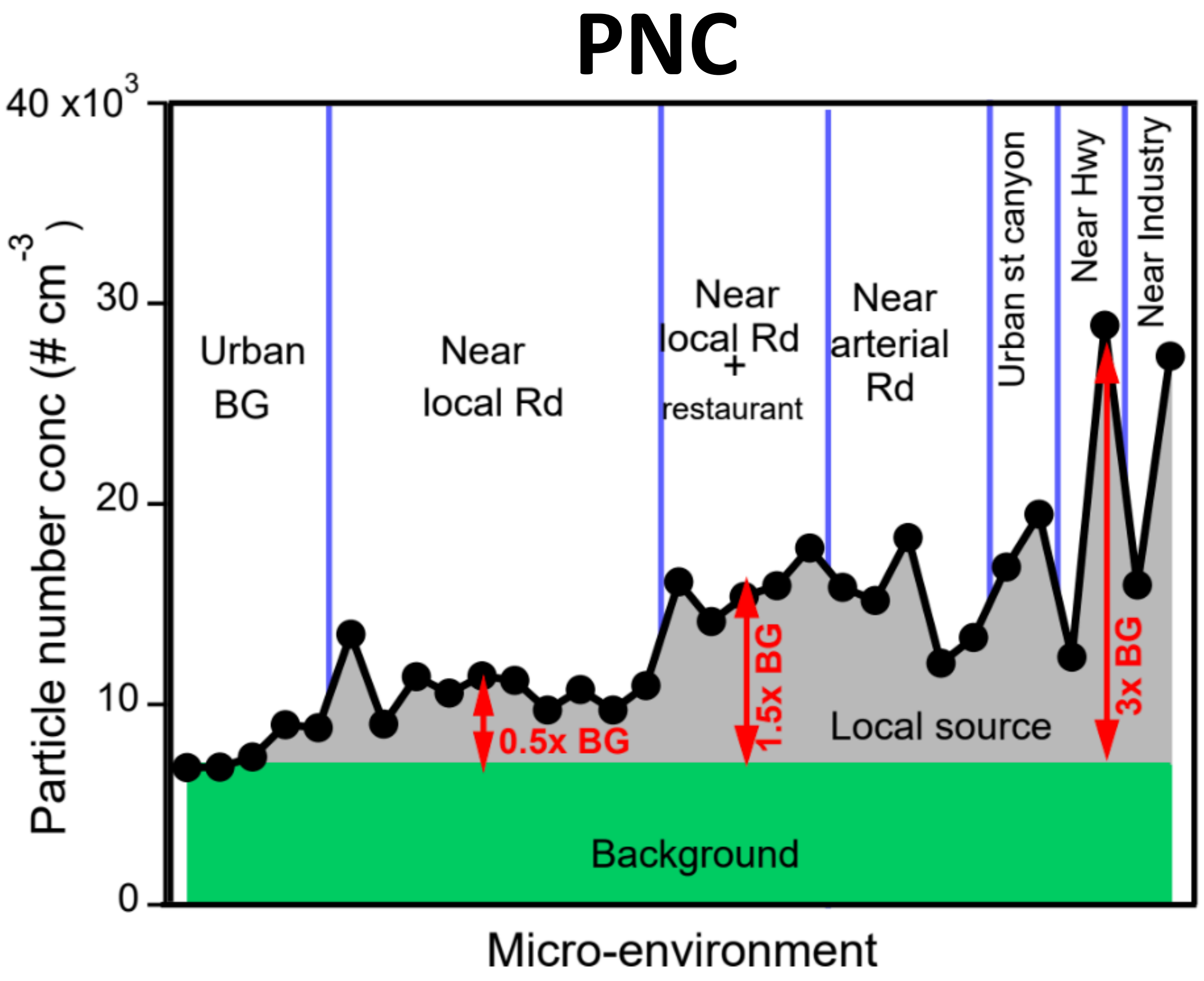
# We investigated inter- and intra-city PNC with mobile sampling

**Intra-city variations are a factor of 2-3**

**Inter-city variations are also a factor of ~2**



# Inter- and intra-city PNC variations are larger than for $PM_{2.5}$






Saha et al, *STOTEN*, 2019

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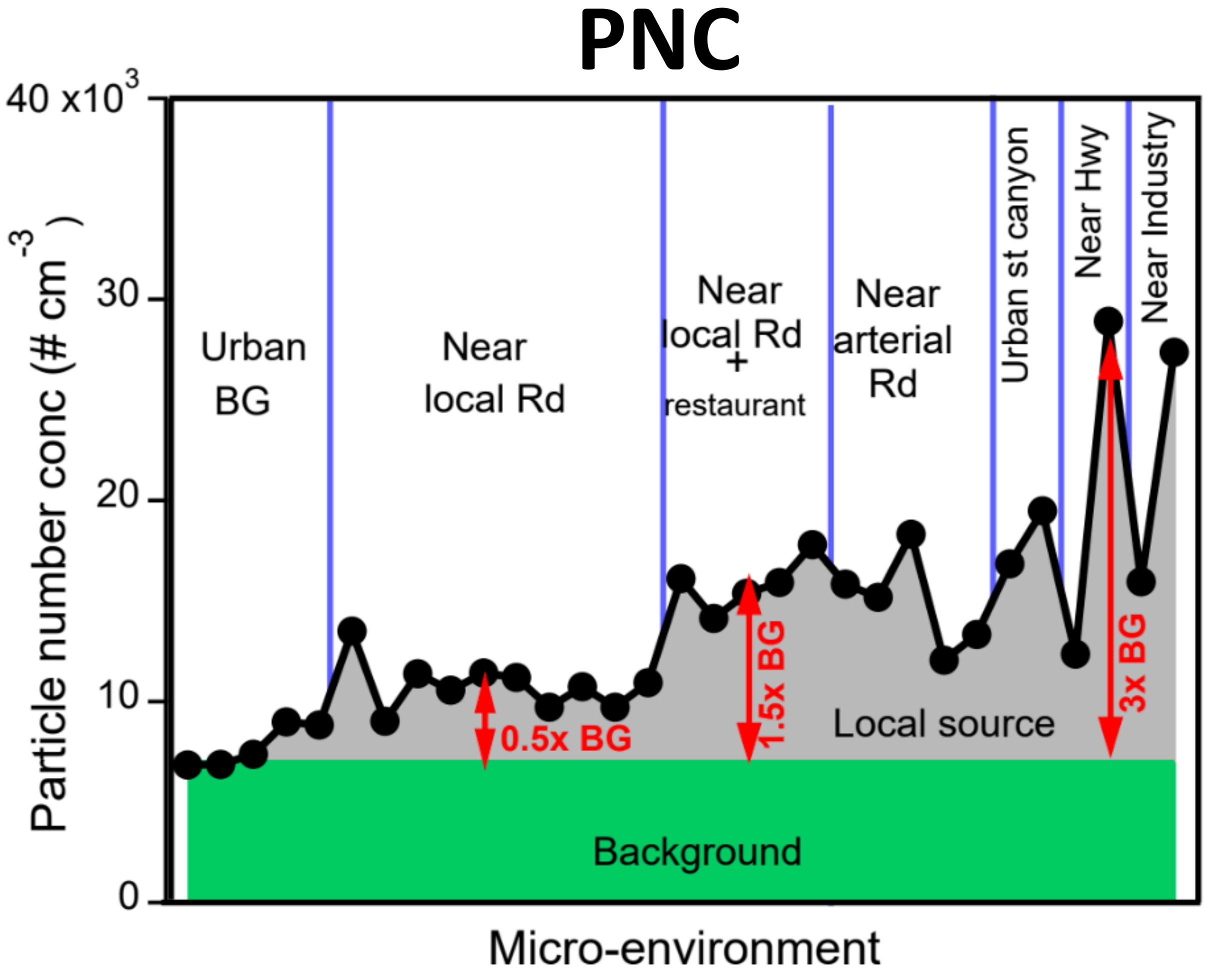


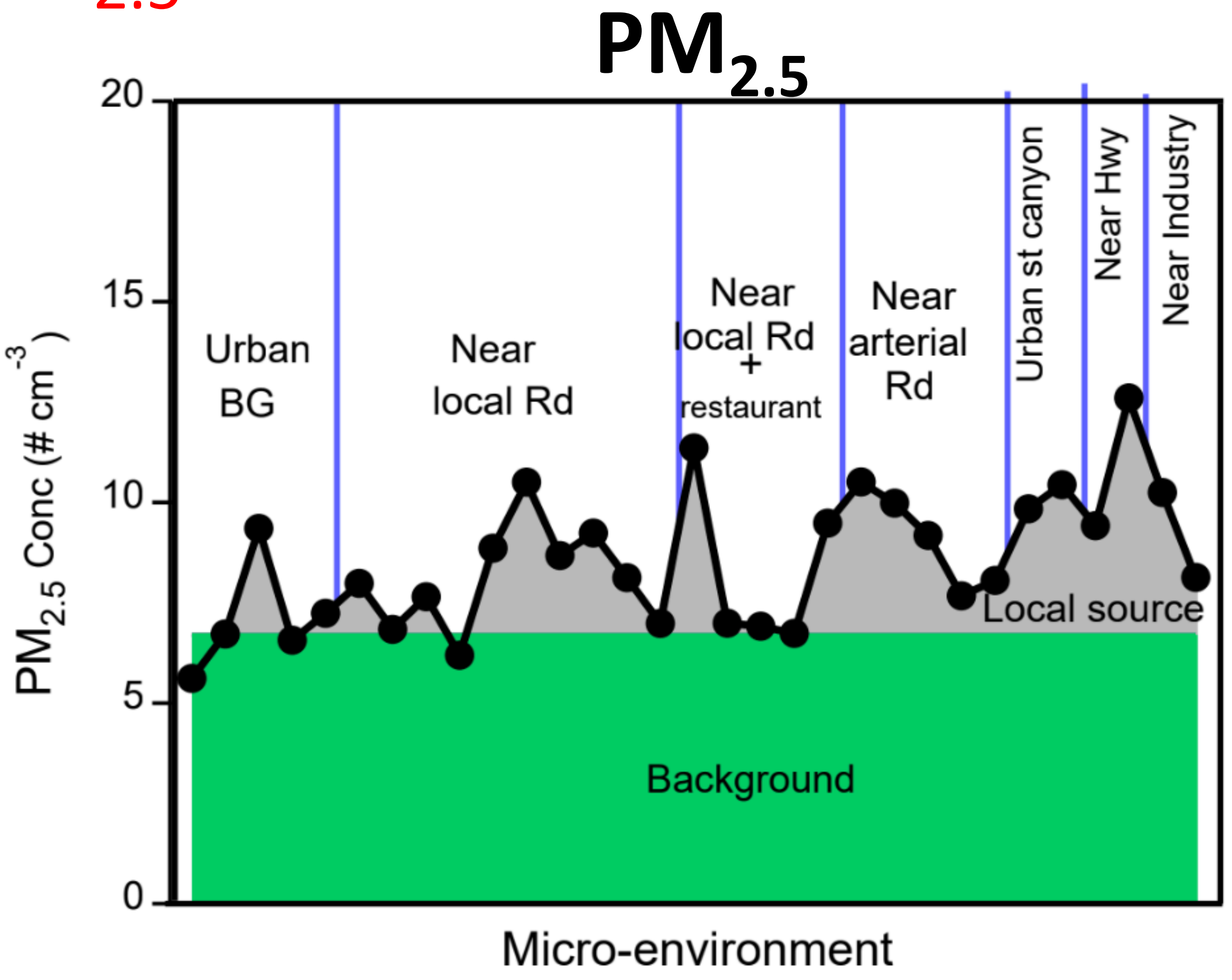


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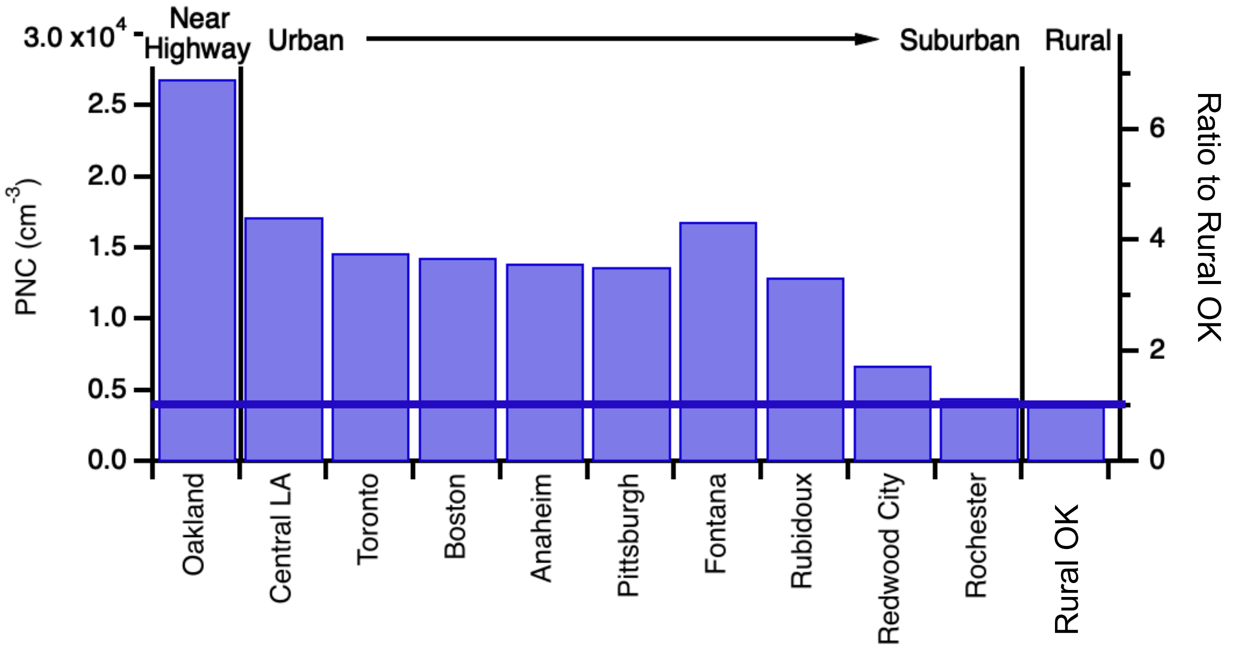
# $PM_{2.5}$ variability is much smaller and concentrations are less dependent on sampling site

## PNC

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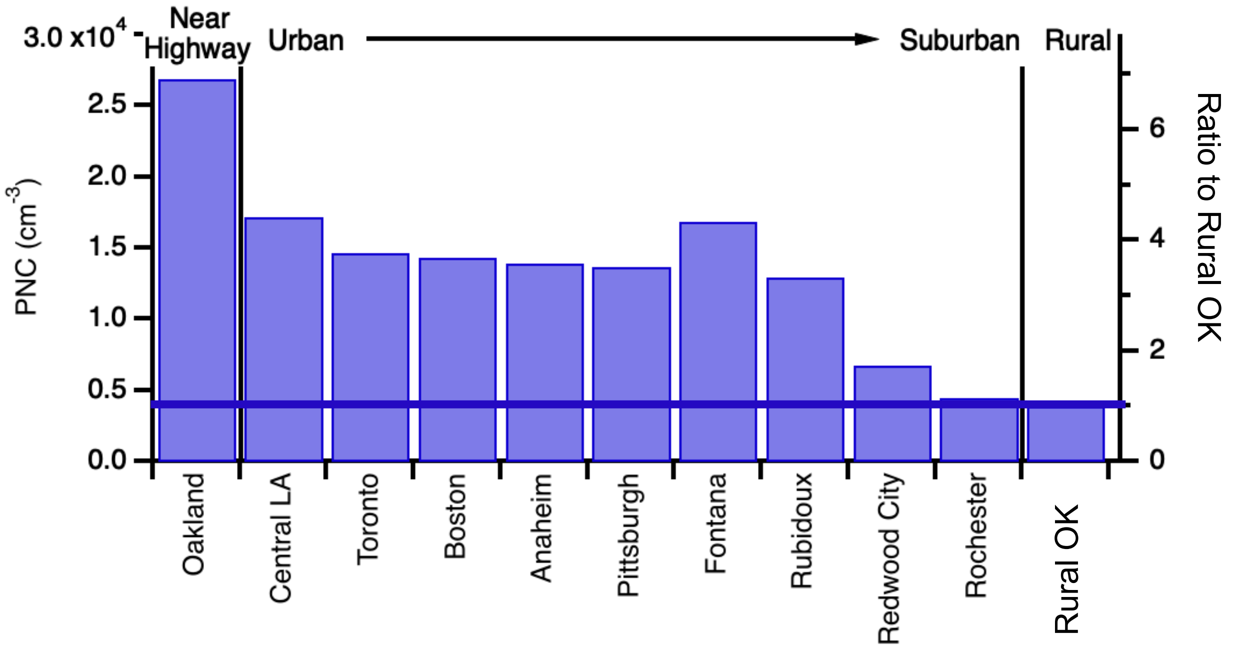
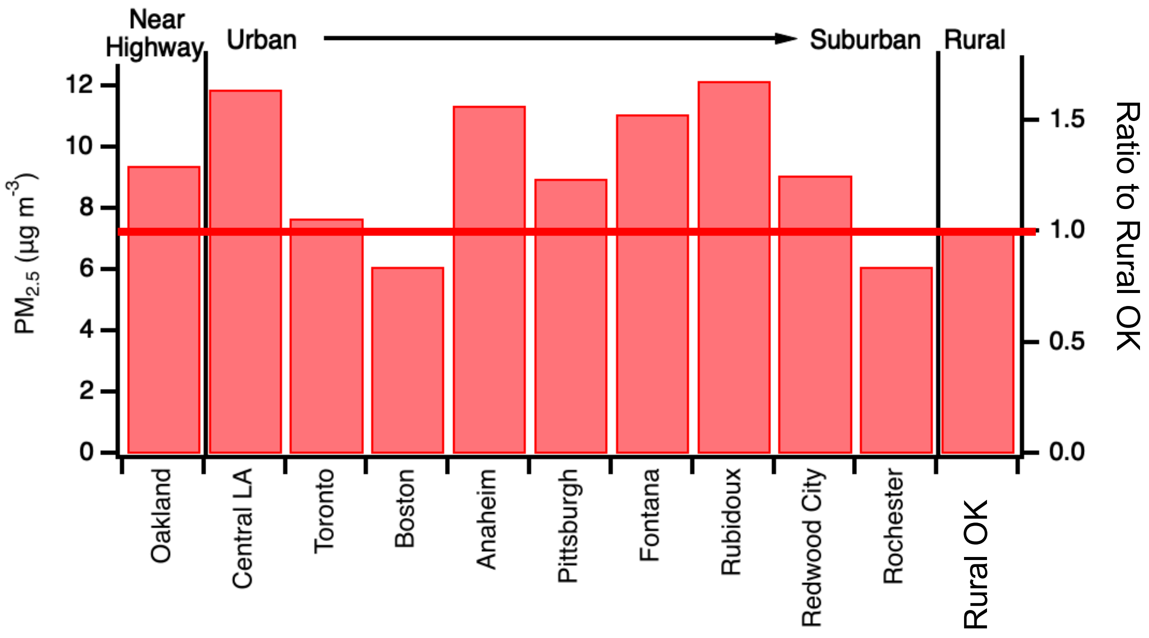
## PNC



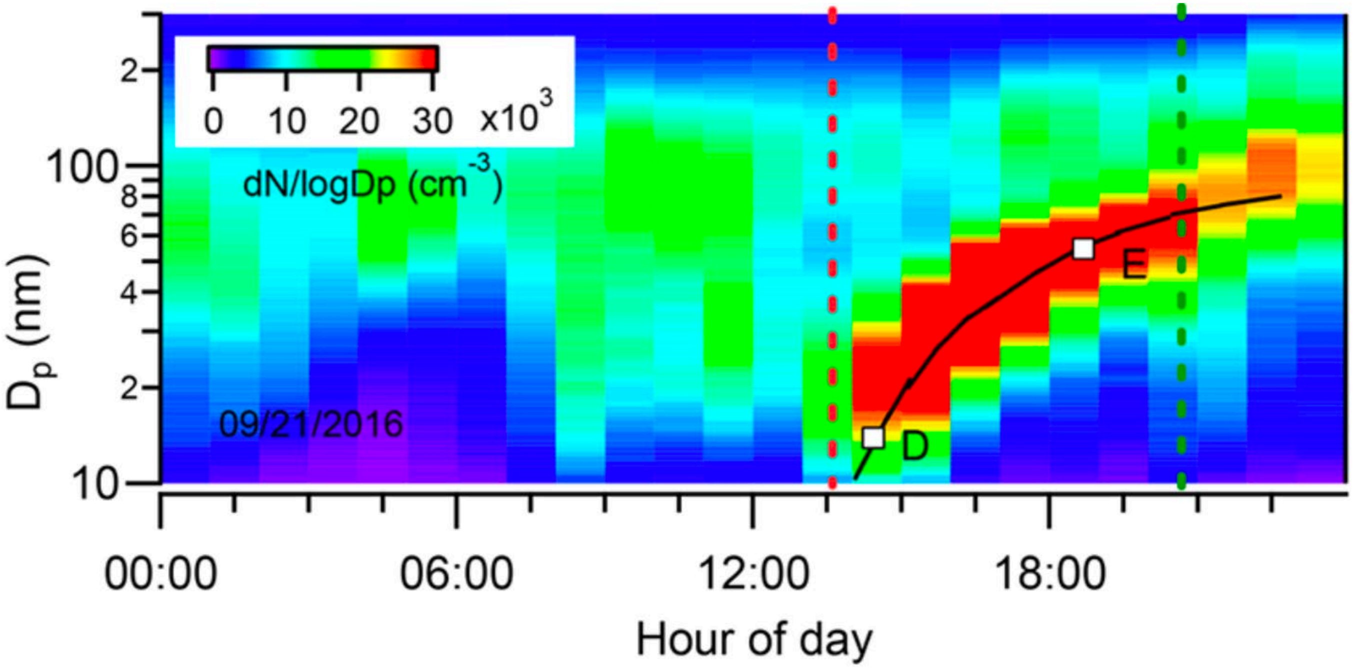

## $PM_{2.5}$



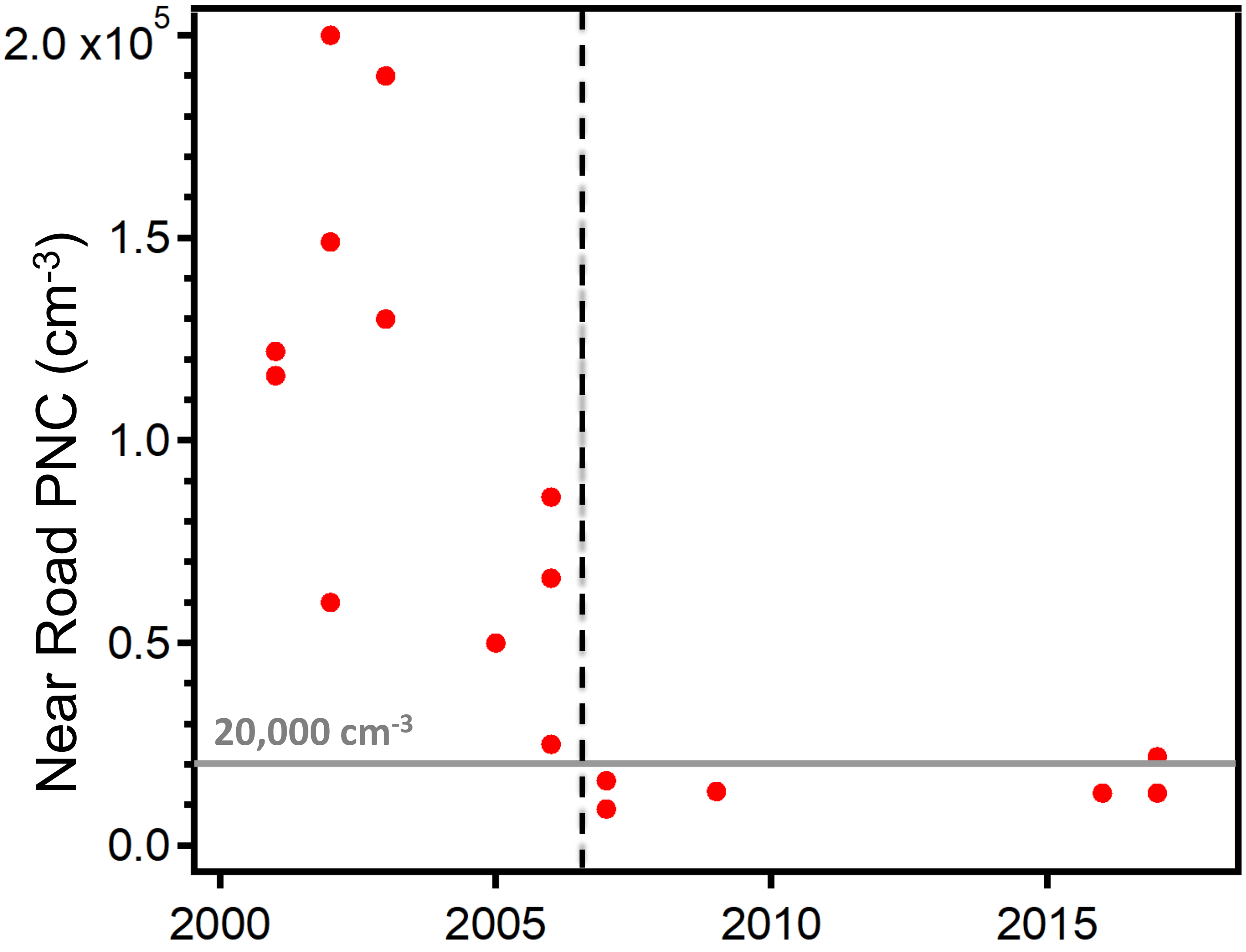
# Summary: Concentrations and trends

- Typical concentrations: <5k to >20k $cm^{-3}$. Urban ~10k $cm^{-3}$
- Trends over time: 30% decrease since 2006
- Inter- and intra-city spatial patterns: Factor of 2 within and between cities

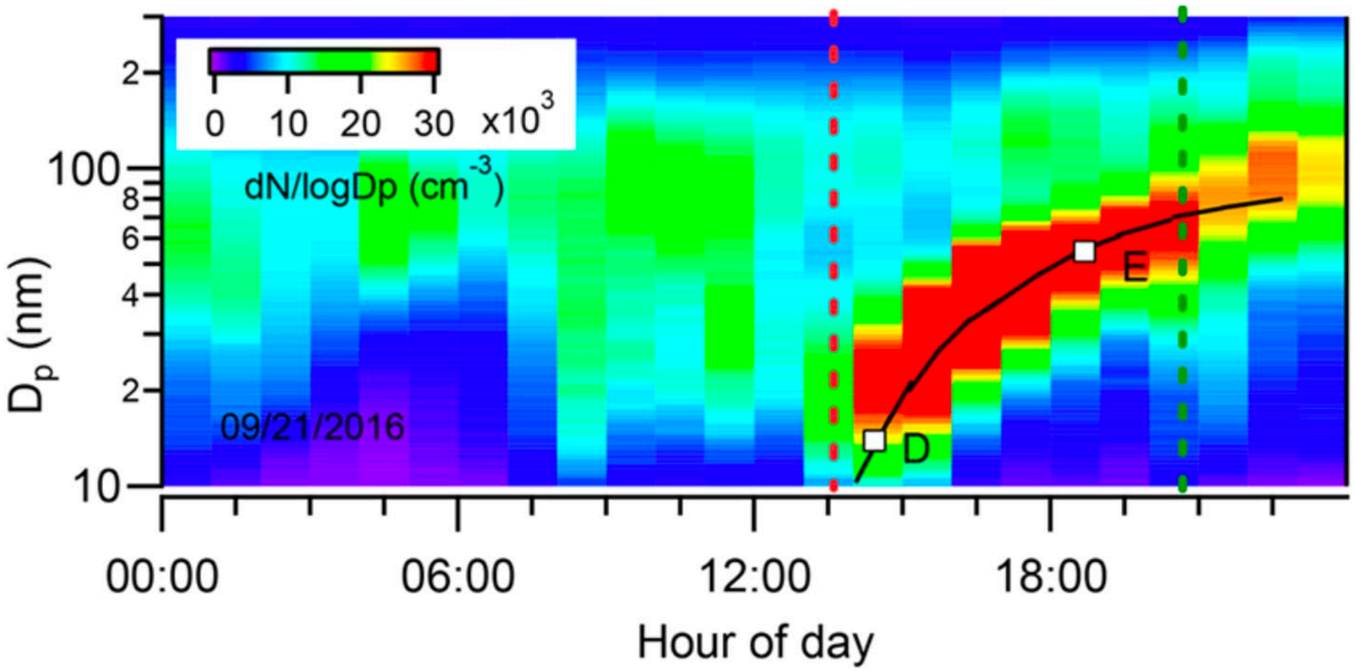
# Traffic and nucleation are two major sources



# Traffic: Large reductions in near-road PNC over time



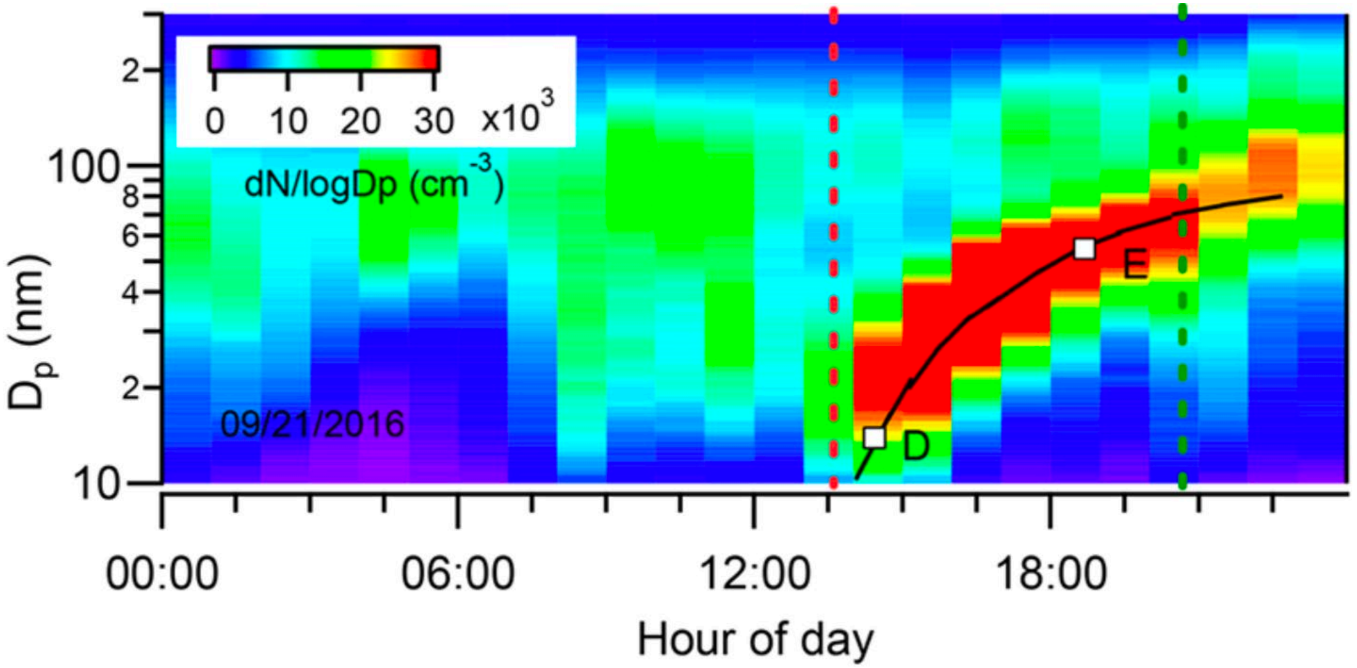
# Nucleation: Often driven by $SO_2$ chemistry

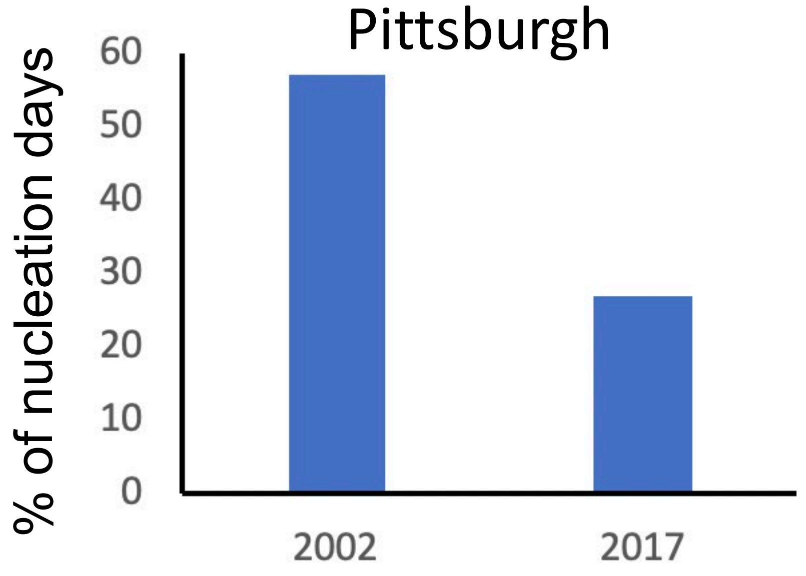





Saha et al, *ES&T*, 2018

# Nucleation: Fallen by half since 2002






Saha et al, *ES&T*, 2018

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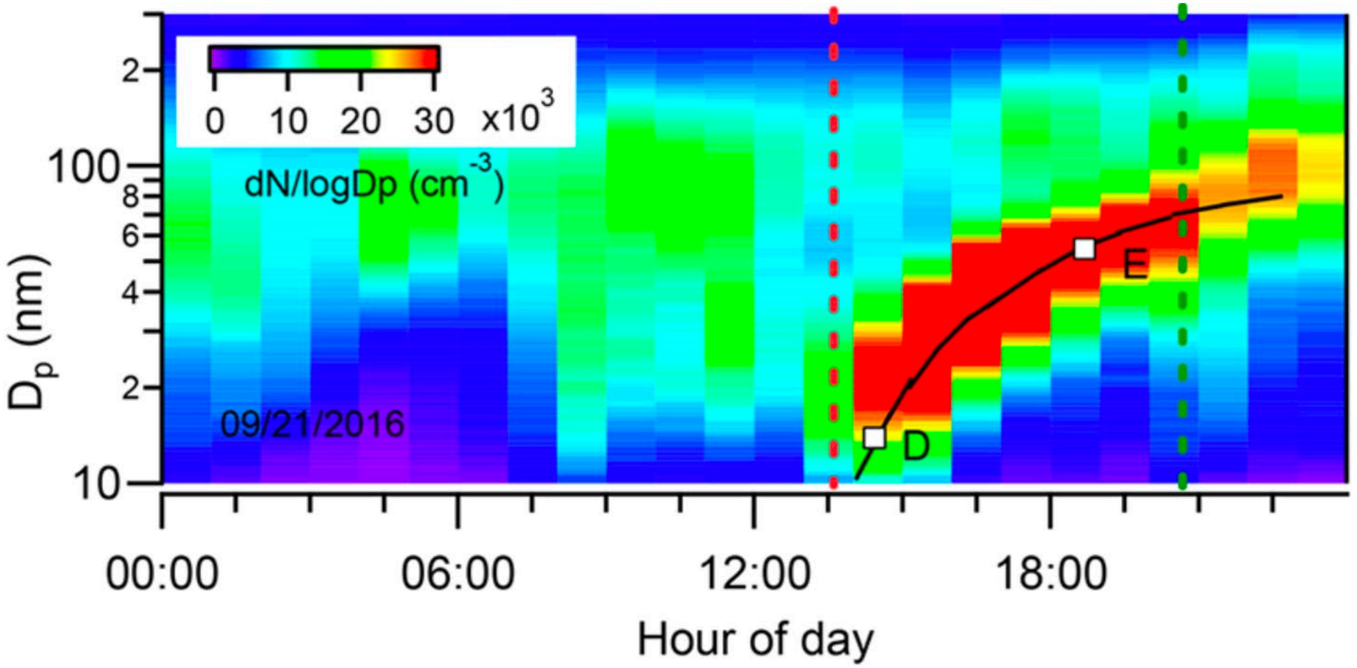


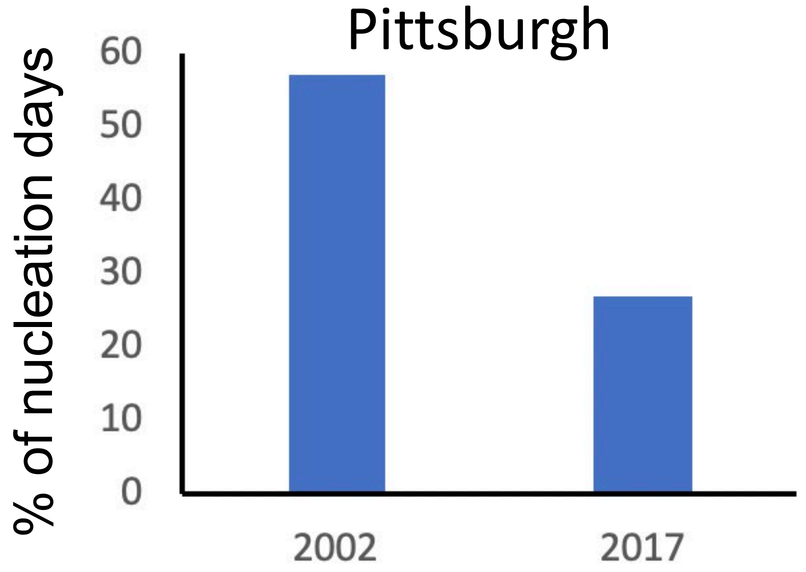


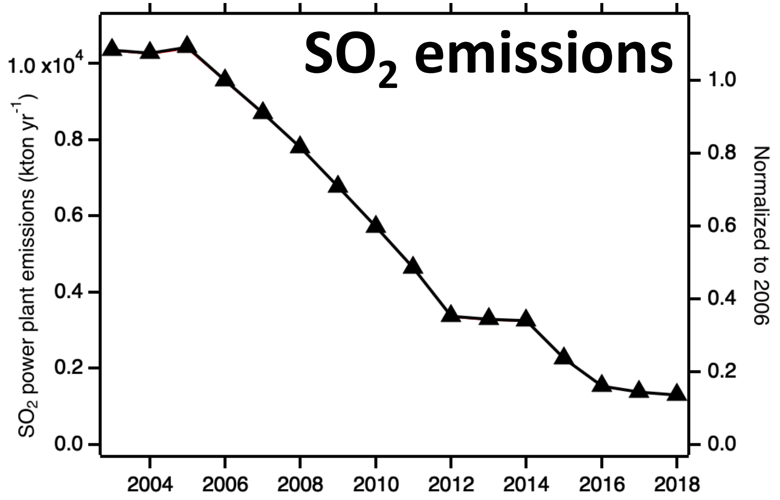


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Saha et al, *ES&T*, 2018

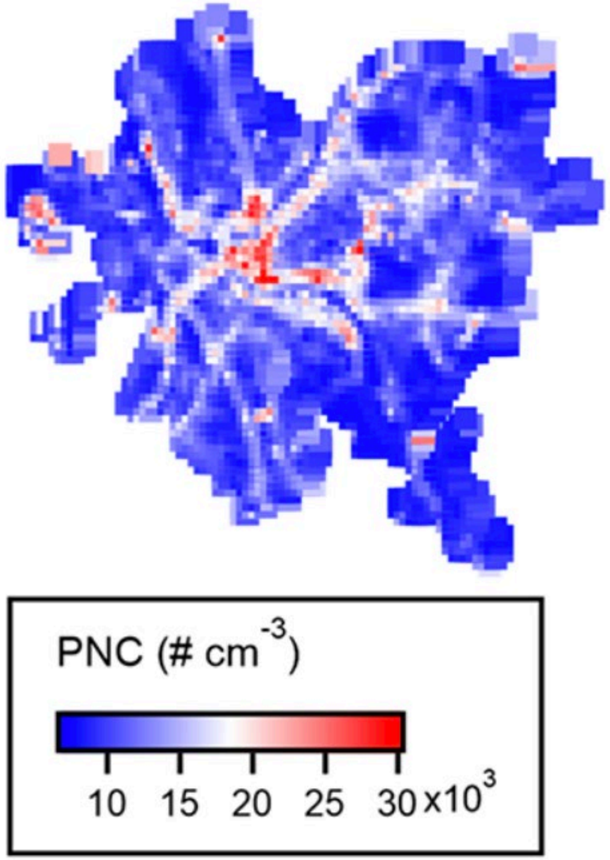
# Summary: Sources

- Major sources: **Traffic** and nucleation
- Contributions of primary and secondary particles: Much of the urban enhancement is primary.

# What is the status of exposure assessment for epidemiology?

# Recall: This is the current EPA UFP network

# Exposure assessment generally relies on single-city LURs built from mobile or distributed sampling



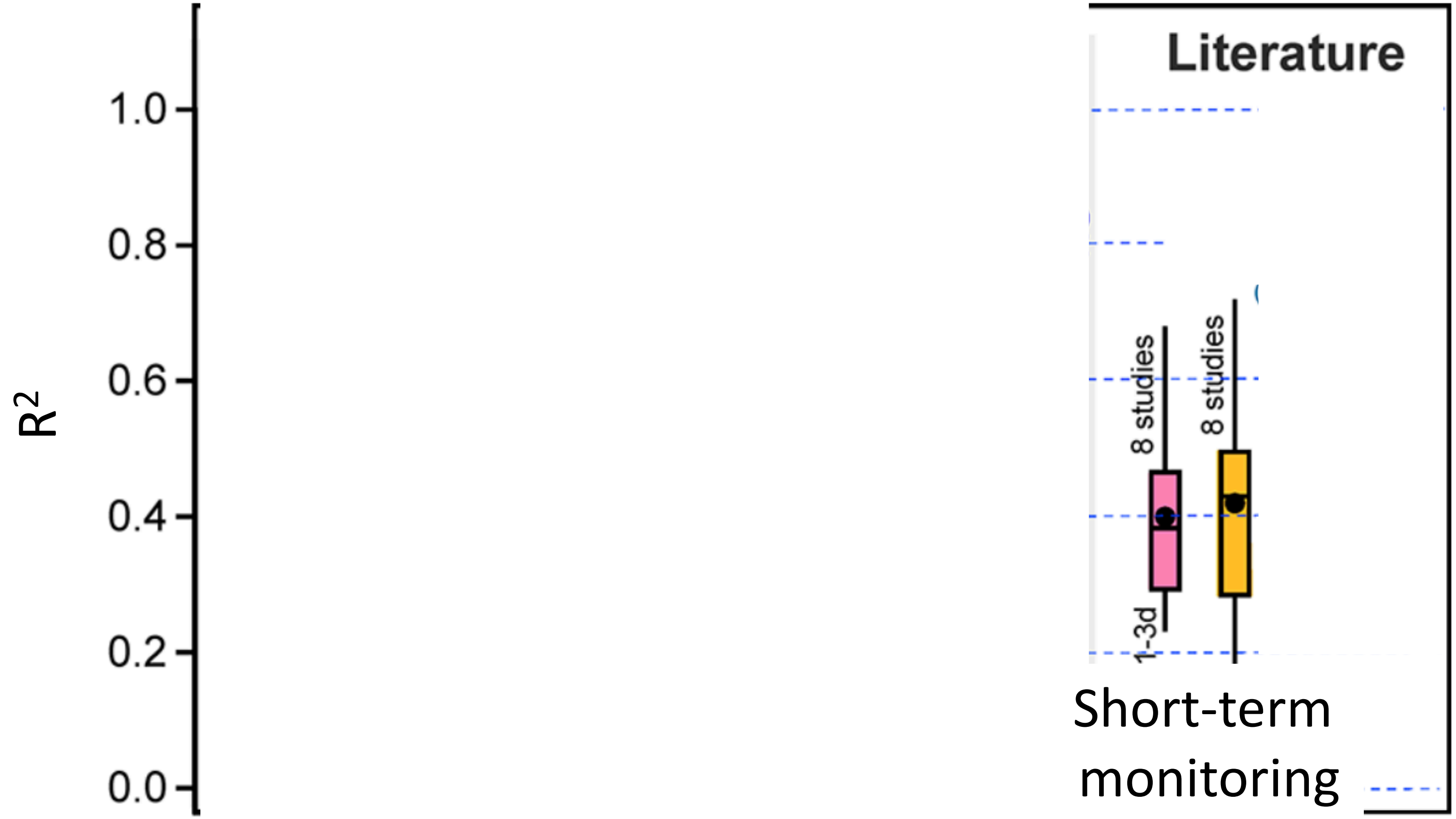



Saha et al, *ES&T*, 2019

Widescale UFP sampling can be expensive and time consuming

Many studies have used short-term or quasi-stationary sampling to fill data gaps

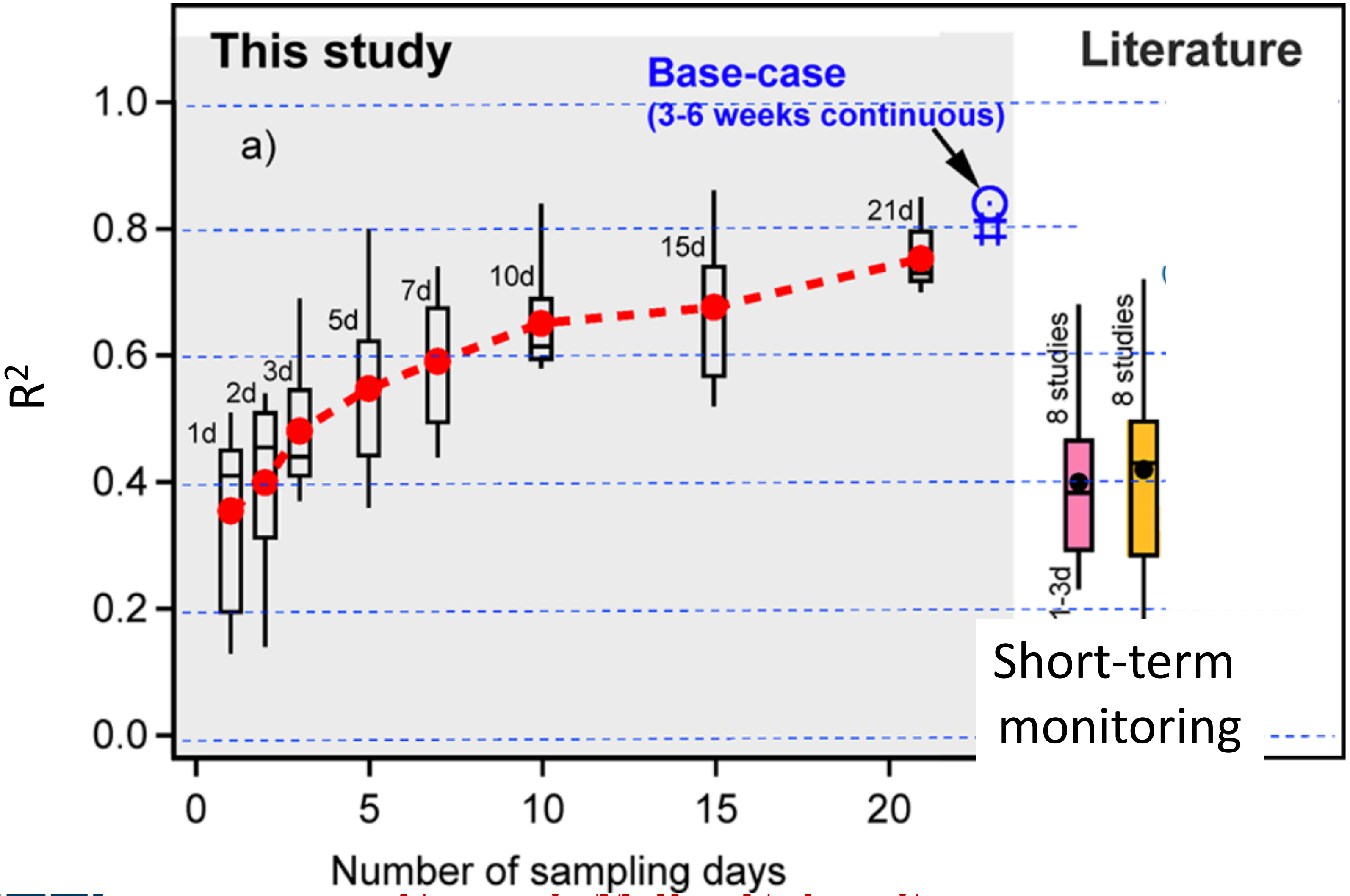
# Exposure estimates based on short-term monitoring can partially fill the data gap






Saha et al, *ES&T*, 2019

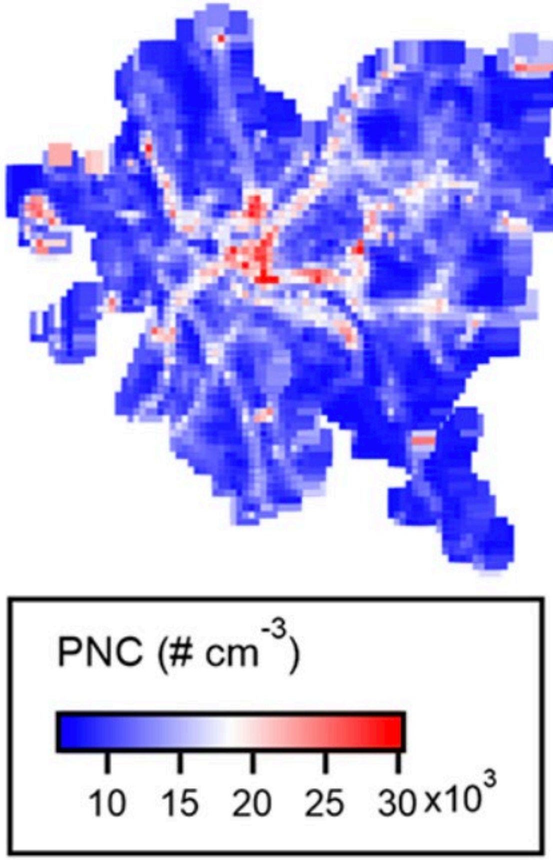
# There is large improvement with modest additional sampling



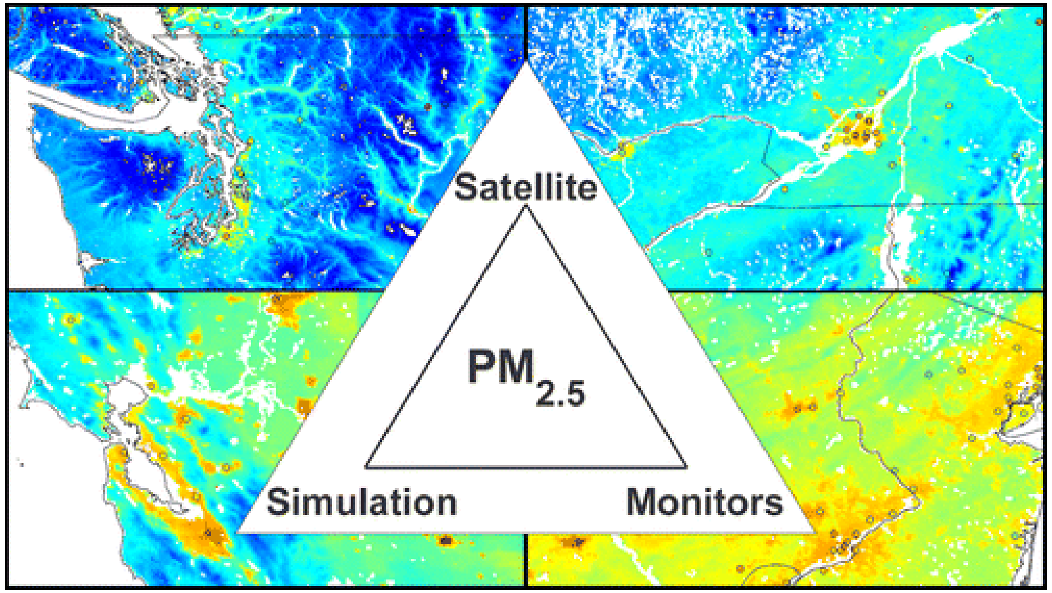



Saha et al, *ES&T*, 2019

# We are a long way off from national estimates




PM$_{2.5}$: continental-scale estimates that combine satellite and ground data

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Saha et al, *ES&T*, 2019
van Donkelaar et al, *EST*, 2015

# What is needed to improve UFP epidemiology?

- <u>More data is needed in more locations</u>
  - Systematically and continuously collected
  - 10s of sites per city in a mix of rural, suburban, and urban locations
- National-scale exposure estimates are not currently possible
  - Require either a large investment in monitoring or improvement in chemical transport models
- Improved UFP exposure and epidemiology data are likely necessary to help drive policy changes


# Acknowledgments

- Center for Air, Climate, and Energy Solutions (CACES)
  - U.S. Environmental Protection Agency, Assistance Agreement No. RD83587301
- Data access
  - Boston – Harvard (Petros Koutrakis; US EPA grants (RD-835872 and RD-834798))
  - Rochester – Phil Hopke
  - Toronto – Greg Evans
  - LA and Bay Area – Public records from SCAQMD and BAAQMD
  - Southern Great Plains – US DOE

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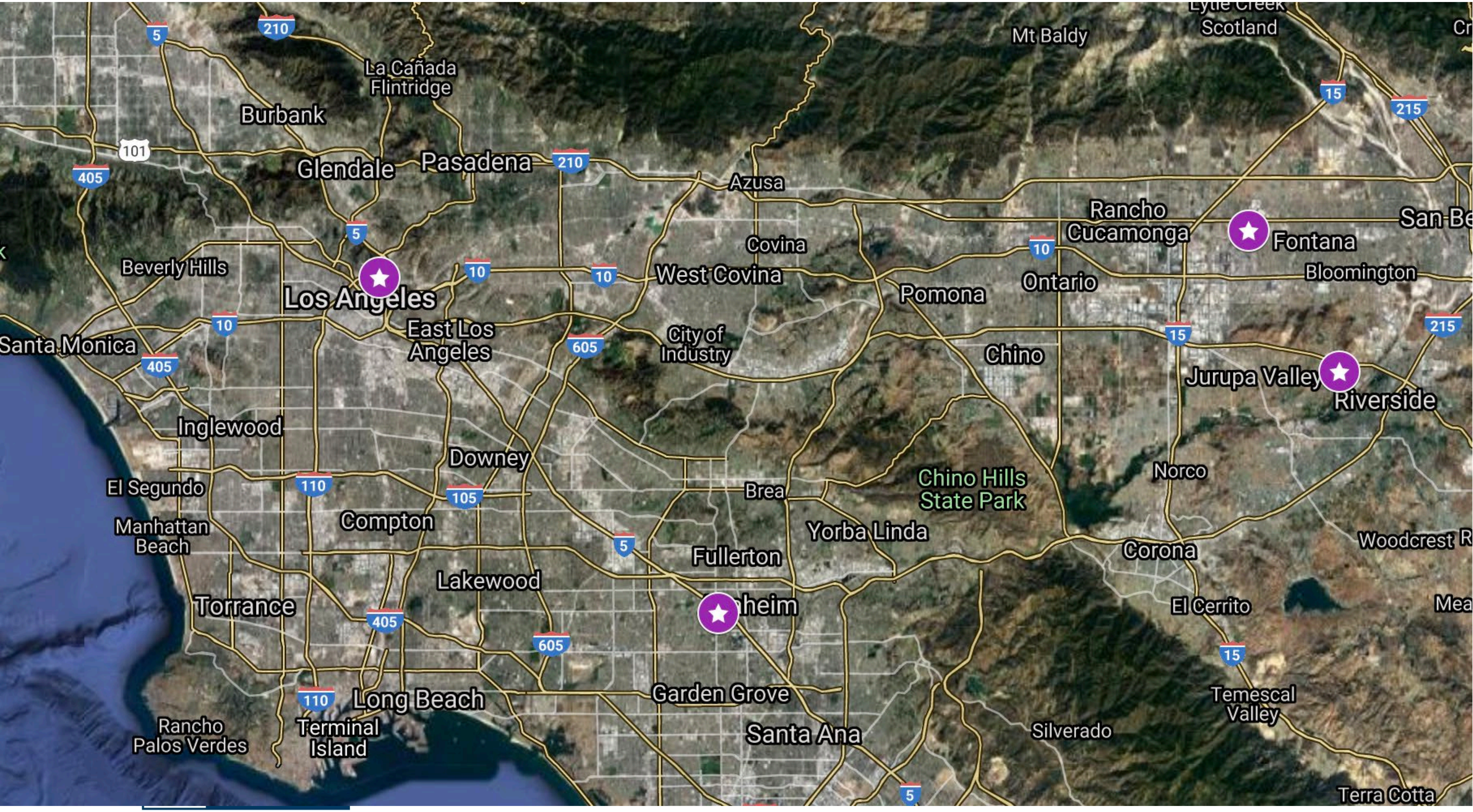
This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant #

**PNC concentrations at a given location depend strongly on site characteristics. This is less of an issue for $PM_{2.5}$.**

***Intra*-city variations are large for PNC**

**The large *intra*-city variations can mask *inter*-city variations**

**Robust exposure estimates require wide-scale distributed data collection**



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Scotland
Mt Baldy
La Cañada
Flintridge
Burbank
Glendale
Pasadena
Azusa
Rancho
Cucamonga
Fontana
San Be
Beverly Hills
Los Angeles
Covina
West Covina
Pomona
Ontario
Bloomington
Santa Monica
East Los
Angeles
City of
Industry
Chino
Jurupa Valley
Riverside
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Norco
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Manhattan
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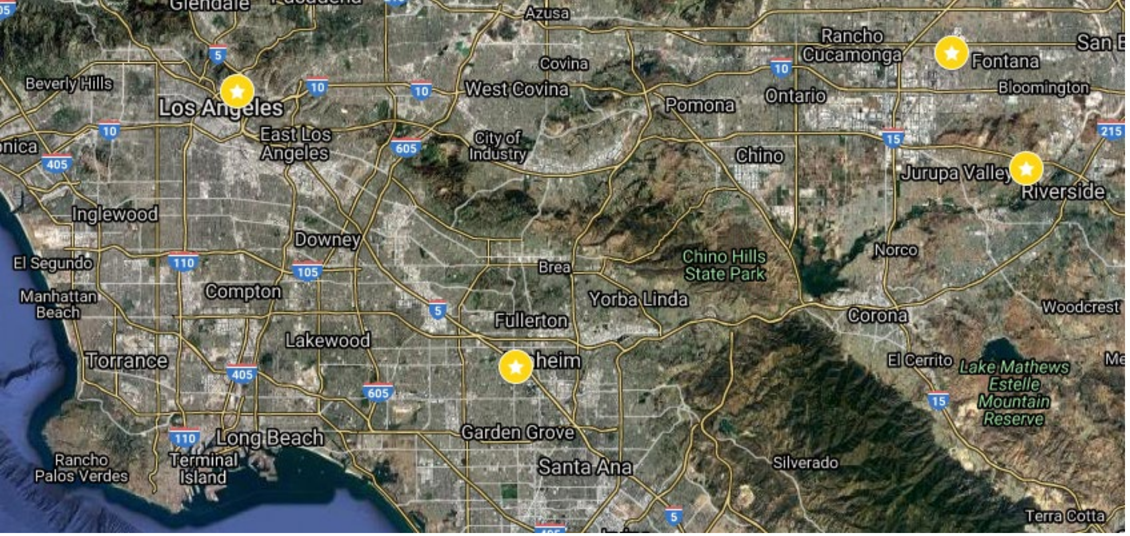


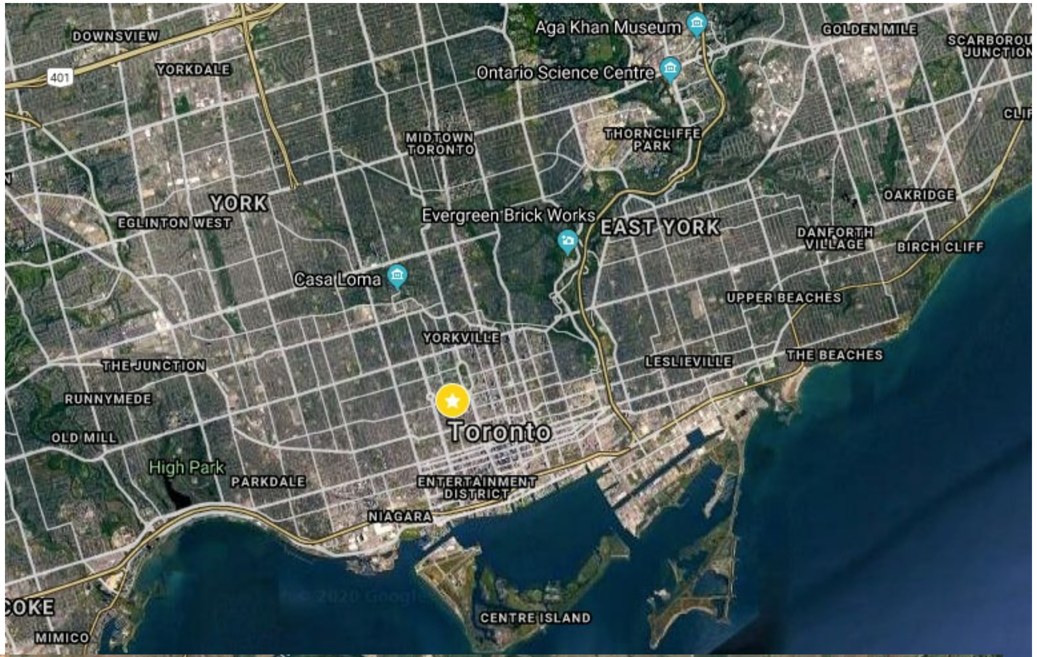


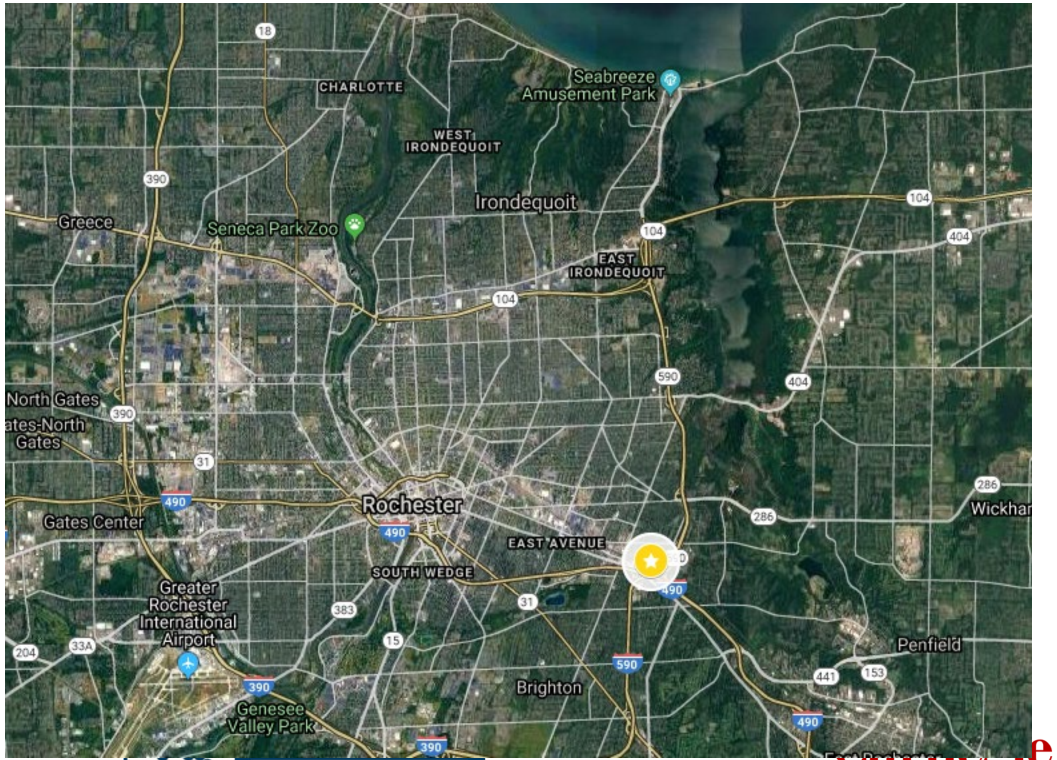


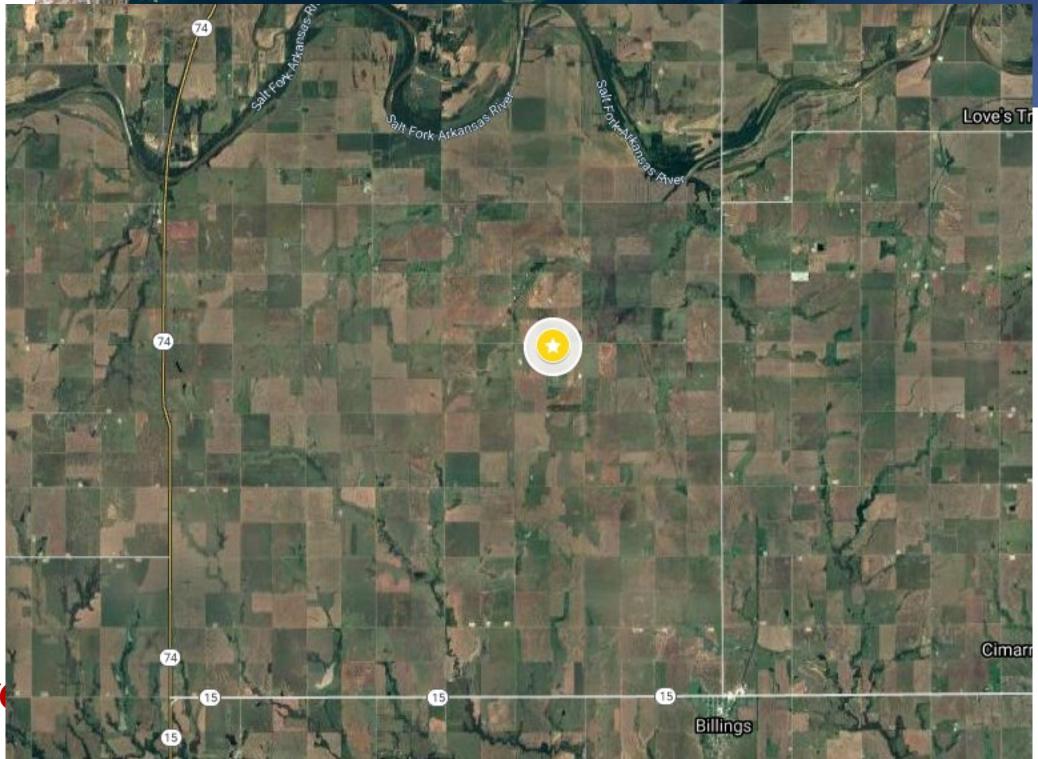


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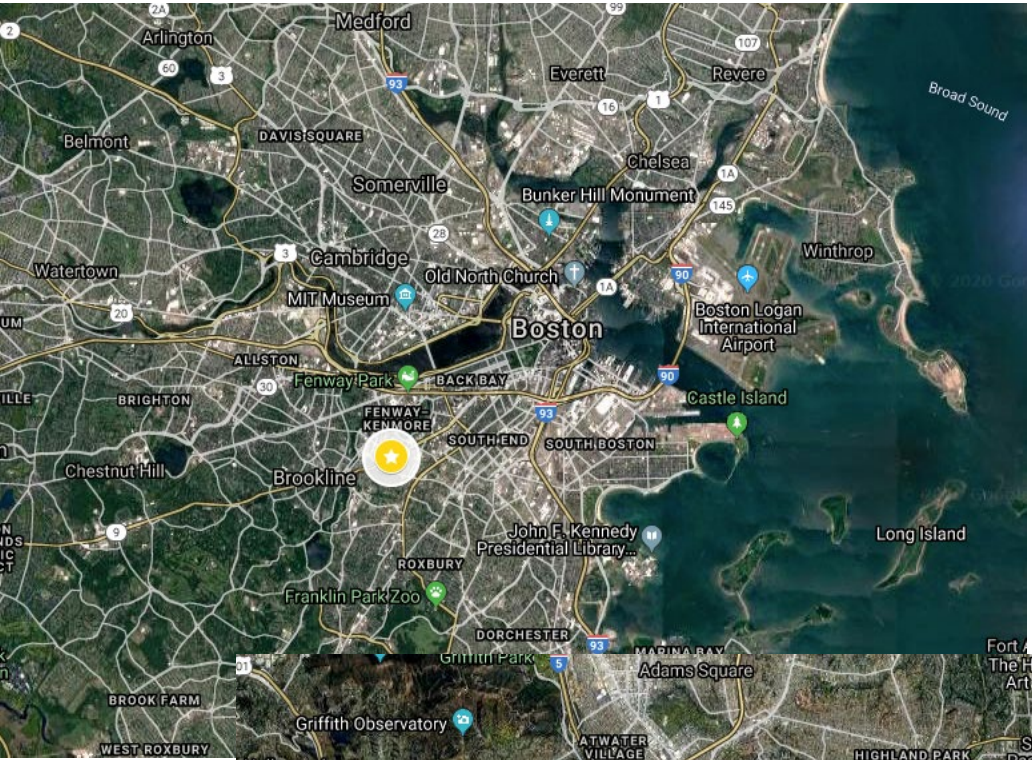
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Old North Church
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BRIGHTON
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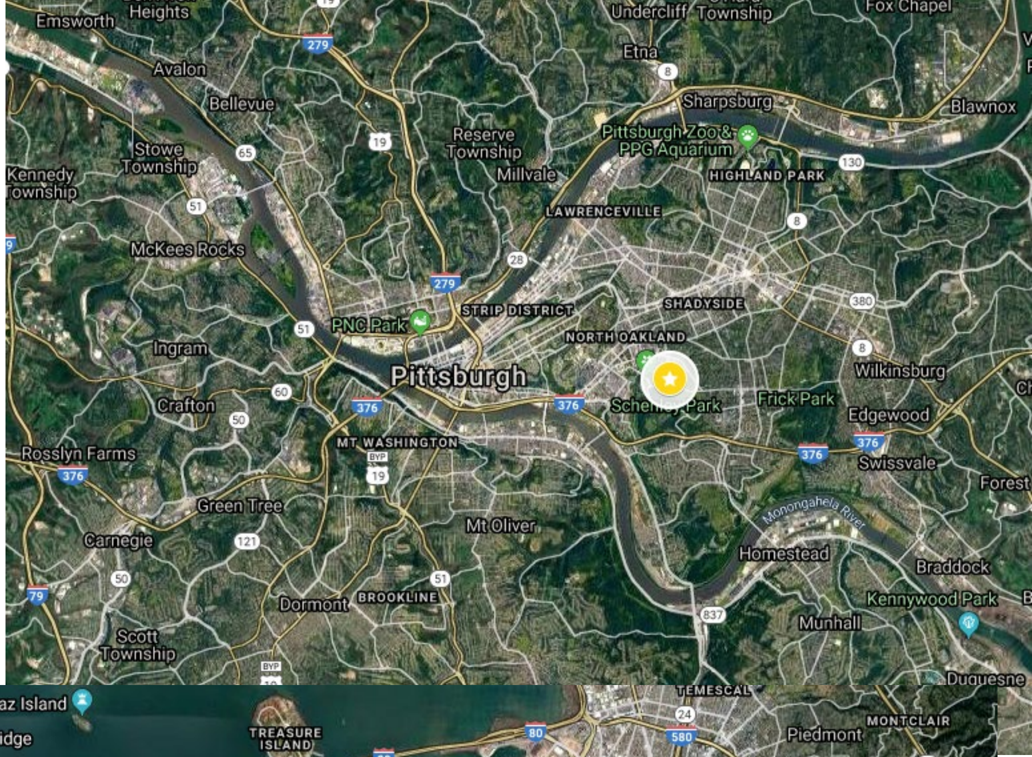
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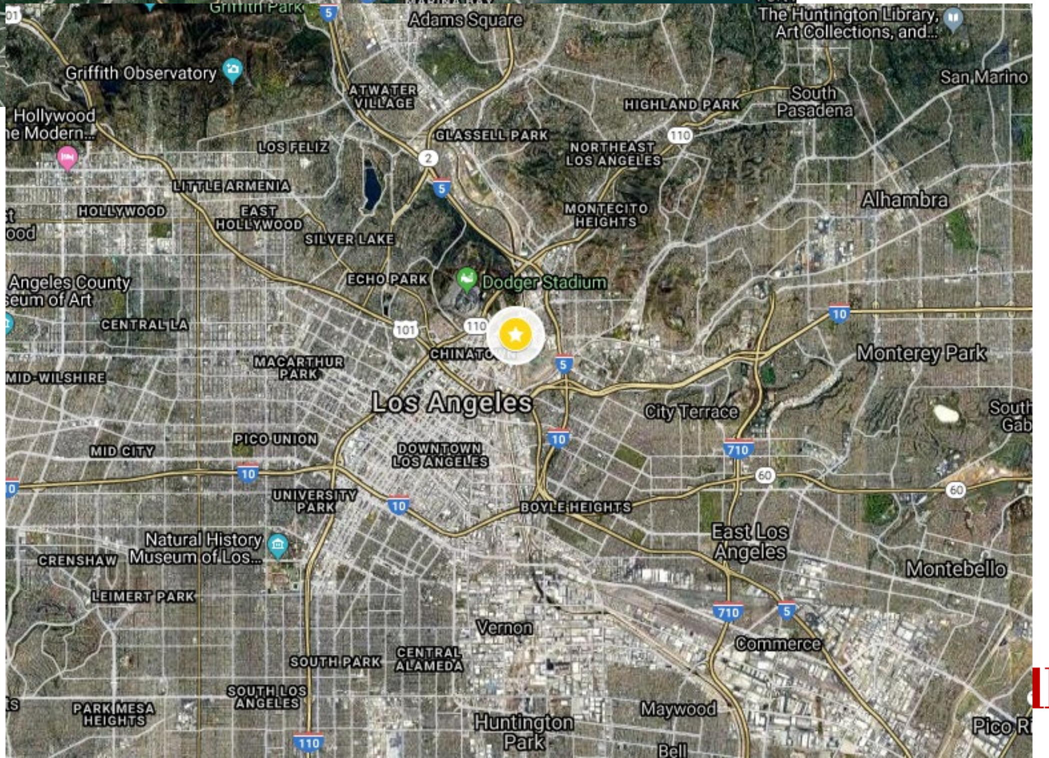
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Adams Square
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LITTLE ARMENIA
HOLLYWOOD
EAST HOLLYWOOD
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East Los Angeles
Natural History Museum of Los...
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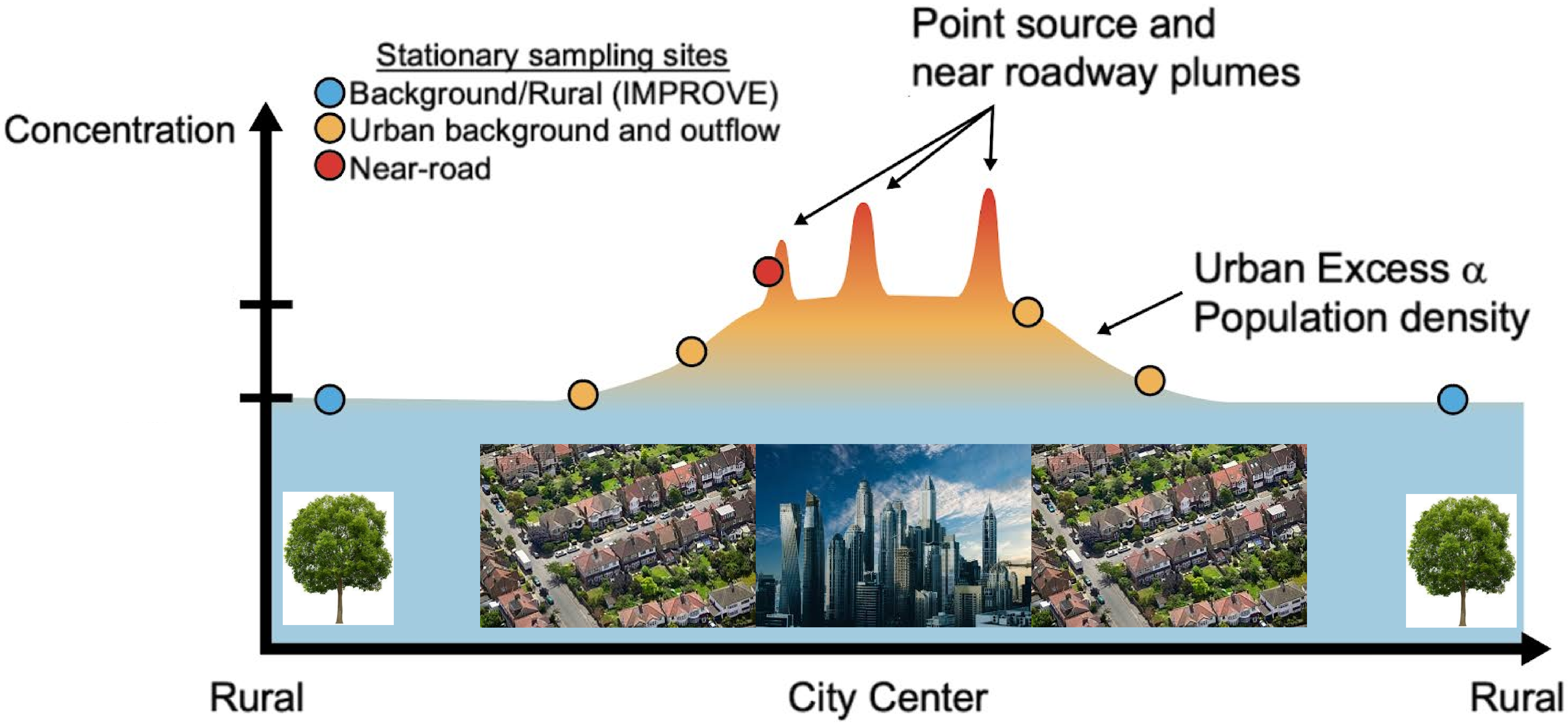


Adapted from Lenschow et al, 2001