Optimizing Exposure Assessment for Policy Decisions

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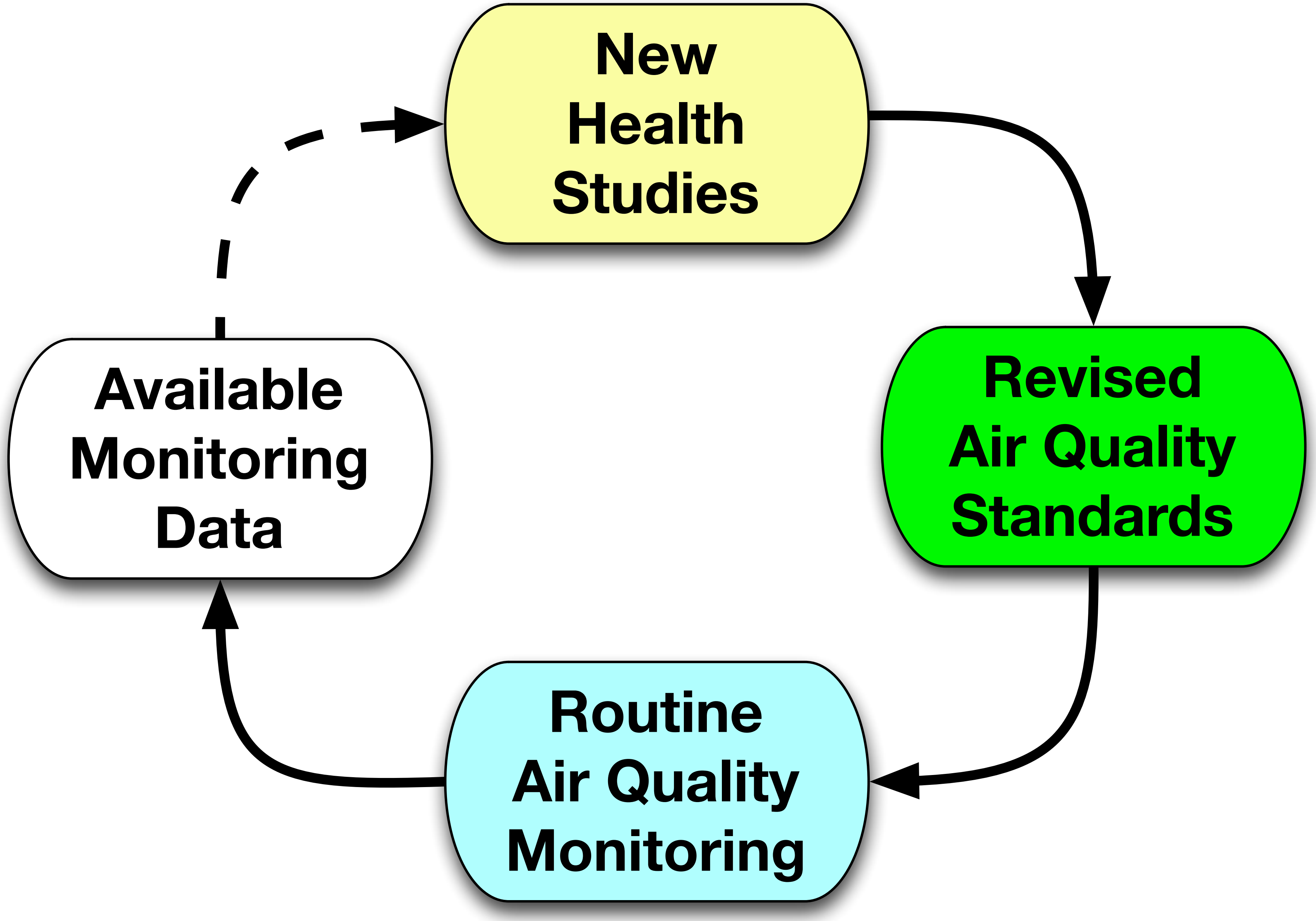
Chicken & egg: standards ↔ measurements

The pollutants we understand best are the ones we regulate.



Epidemiology drives policy. Health studies need exposure data.

Why? Not just for epidemiology

exposure assignment
in a health study

understanding processes
that influence exposure

why

identifying avenues
for intervention or
exposure reduction

understanding equity
and disparities

improving population health

Who, what, where, when?

who

individuals

populations

contrasts

what

pollutants mixtures

components

sources

where

spatial resolution and extent

population mobility

indoors vs. outdoors vs. personal

when

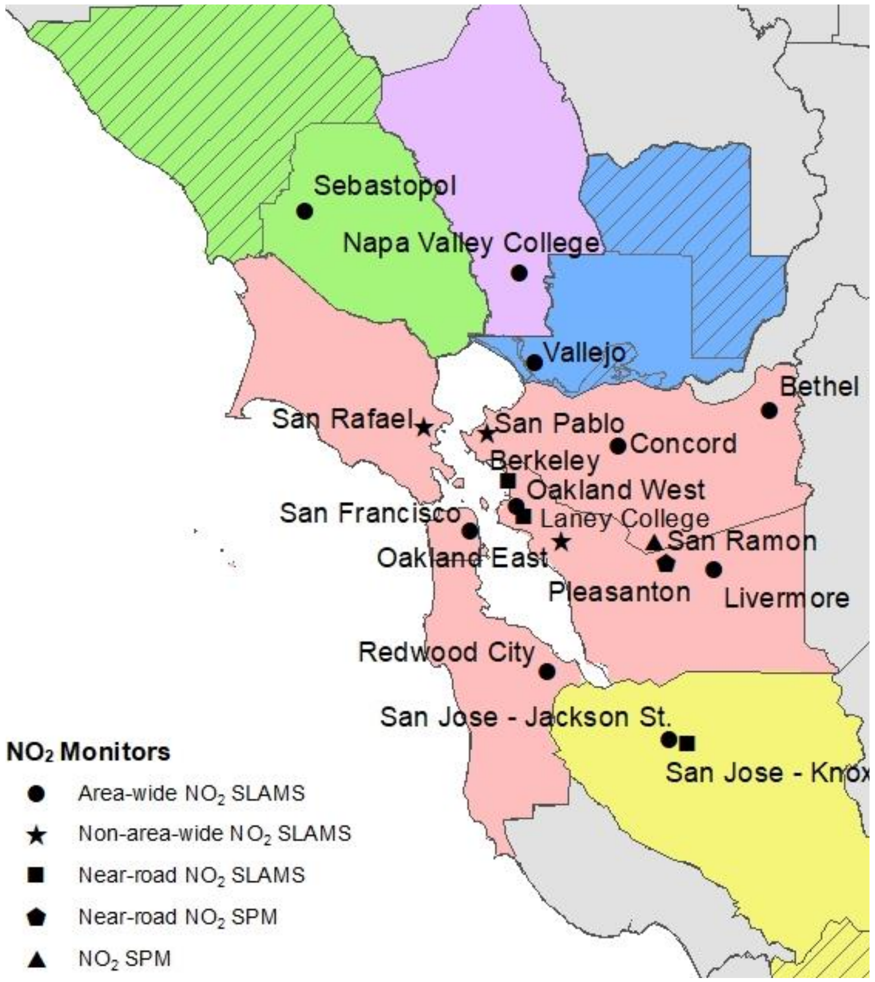
temporal resolution and extent

continuous vs. integrated measures

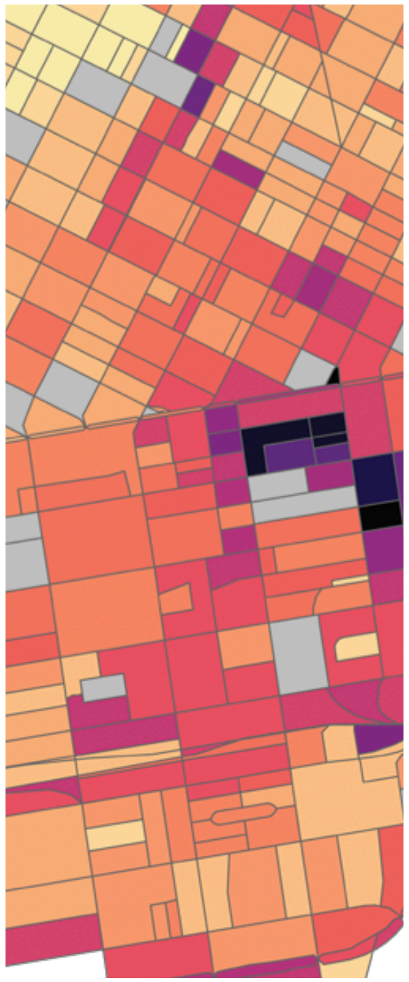
exposure window

Analytical challenges

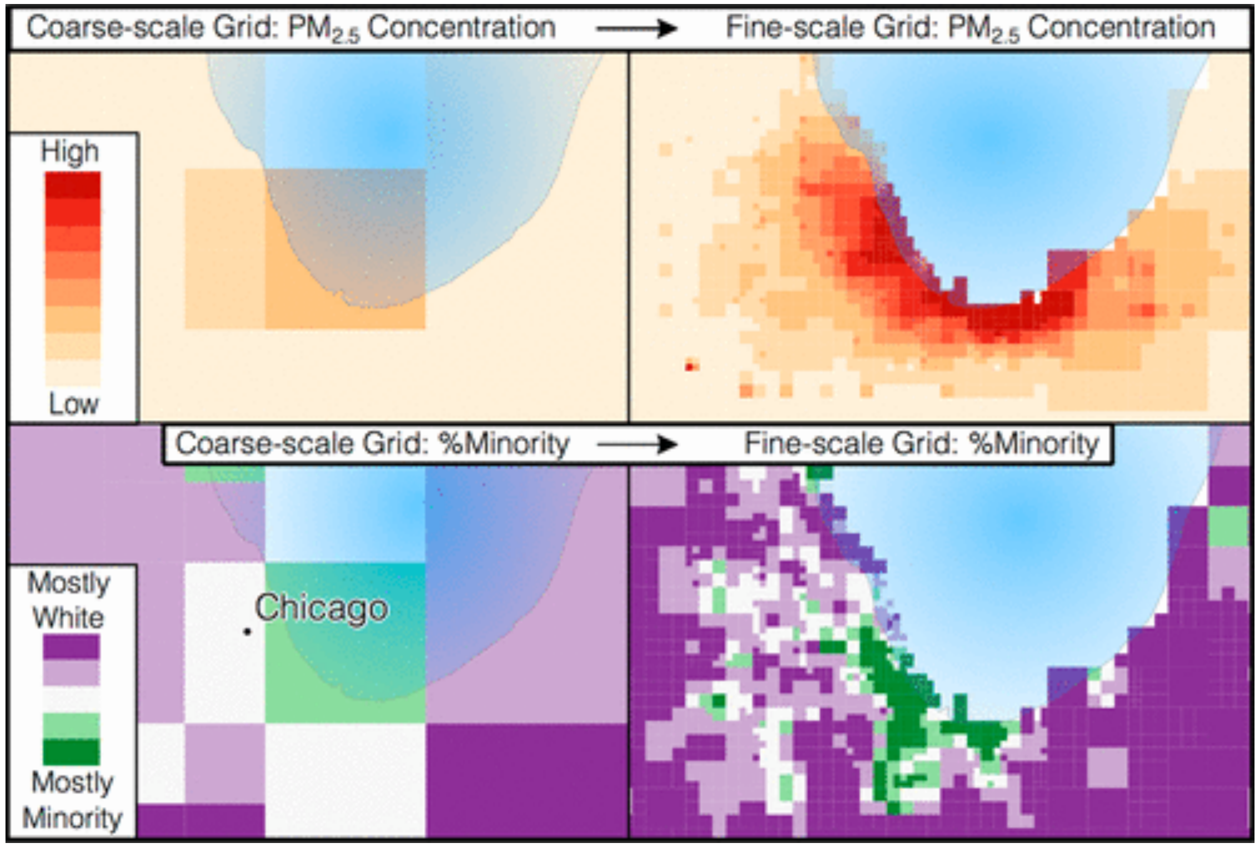
Sparse monitoring

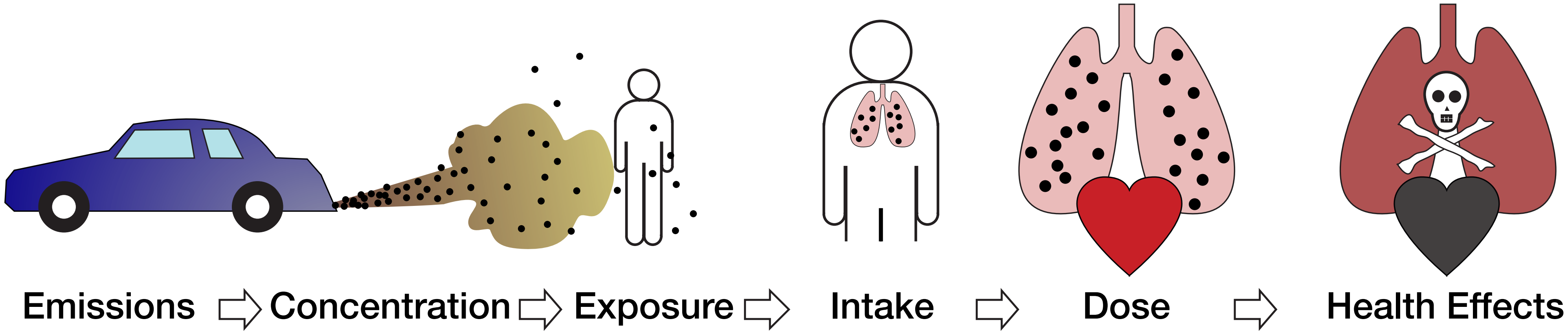


Sharp gradients



Spatial complexity: people and pollution





Causal chain is complex

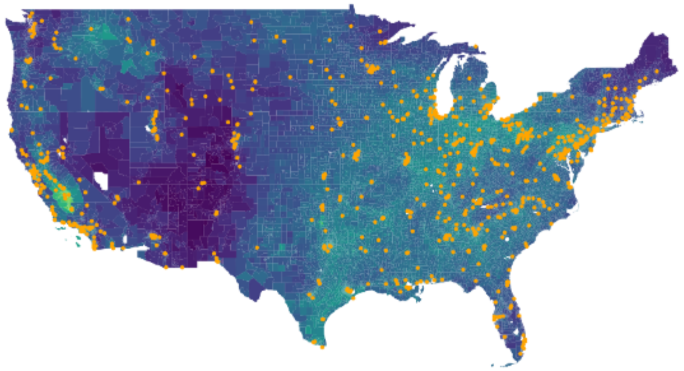
BAAQMD; Chambliss et al, *PNAS* 2021 ; Paolella et al 2018, *ES&T Letters*

Spatial and temporal scales


personal

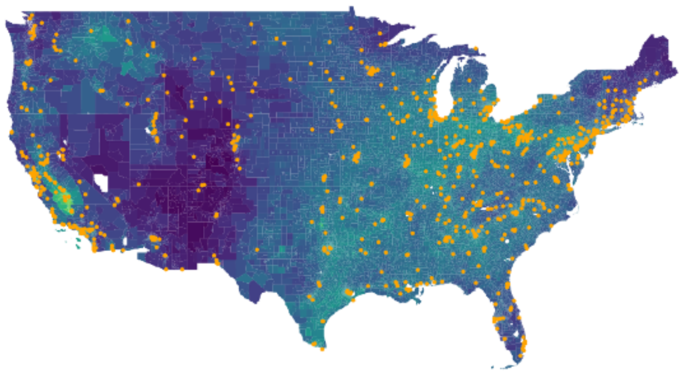

hyperlocal


urban/ambient

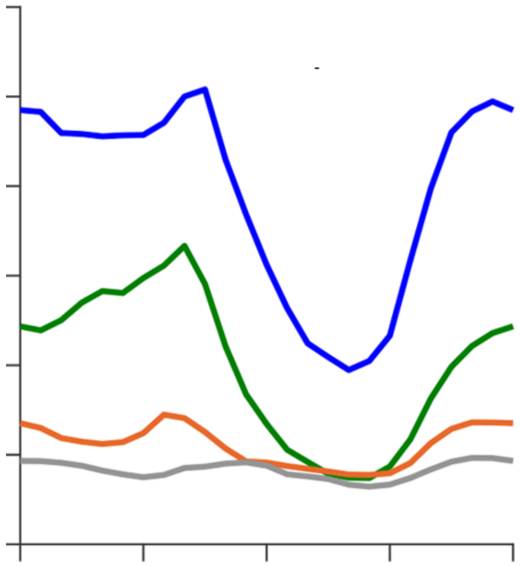

national

Spatial and temporal scales

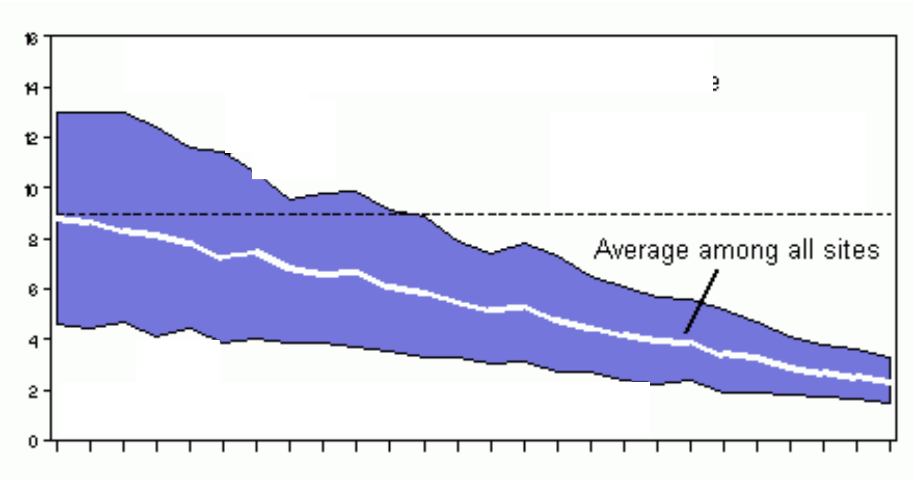


personal | **hyperlocal** | **urban/ambient** | **national**



hourly / daily



annual / long-term

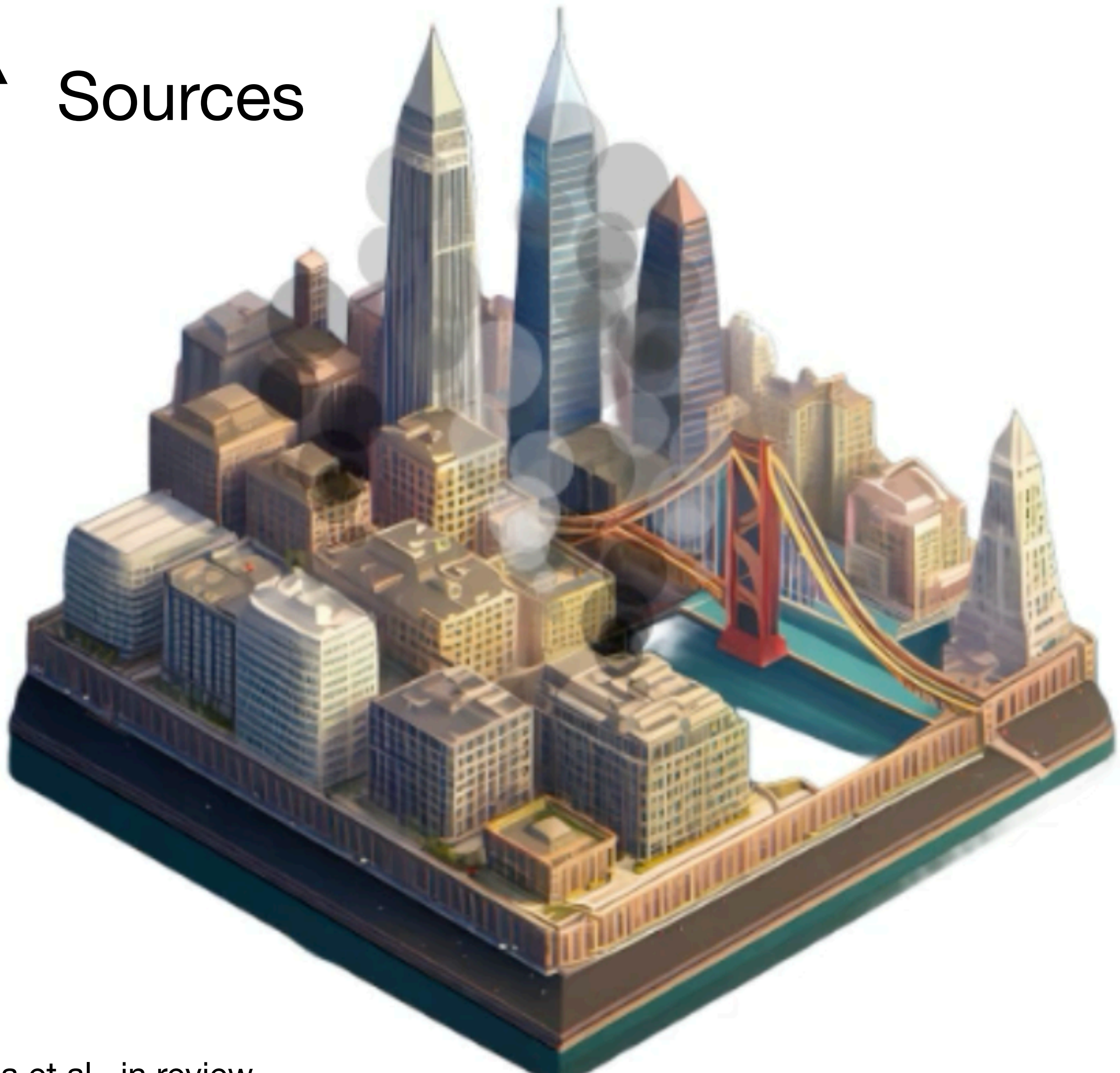
life course

Intraurban variation

Transformation

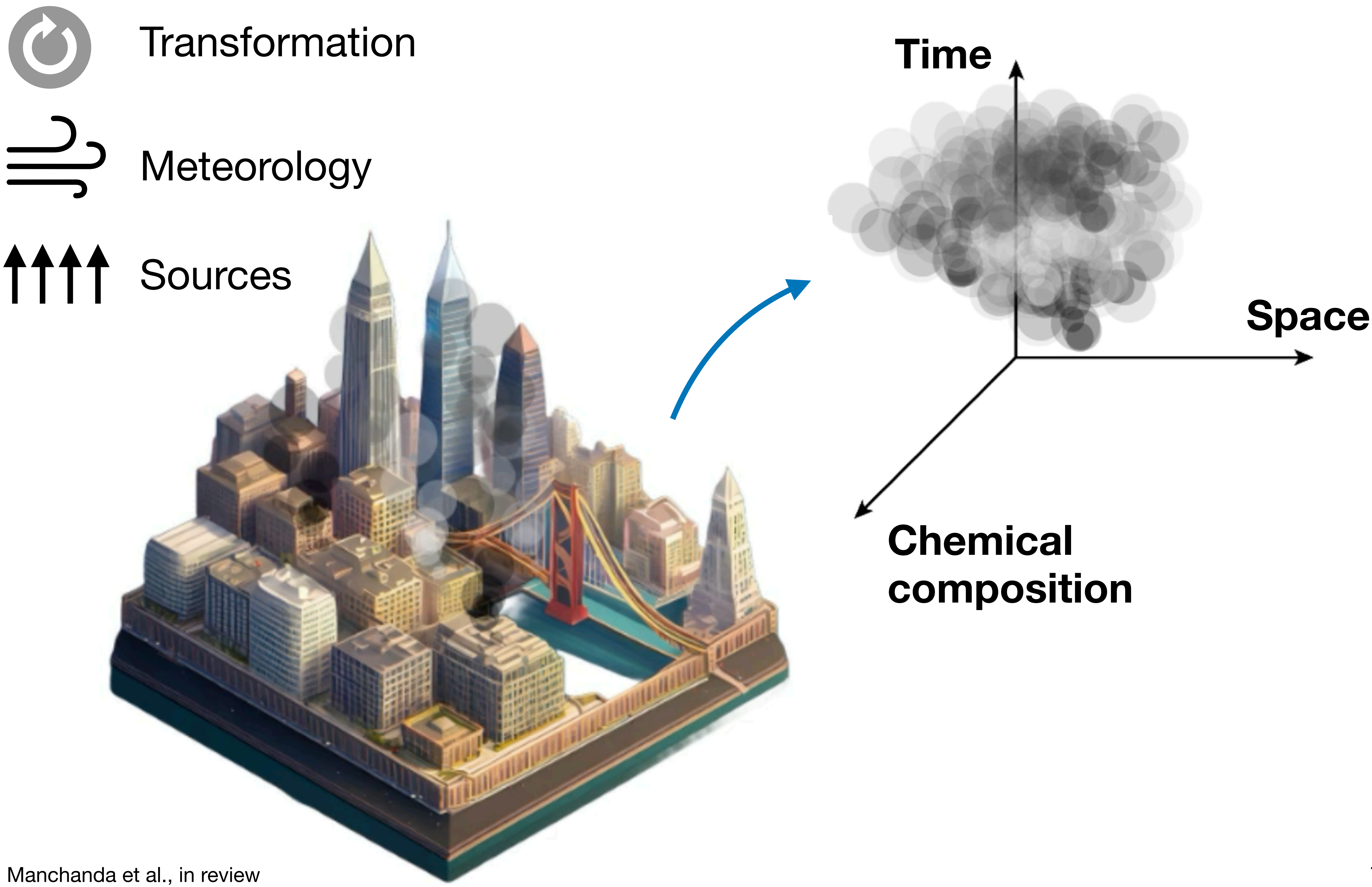
Meteorology

Sources



Manchanda et al., in review

Intraurban variation



Manchanda et al., in review

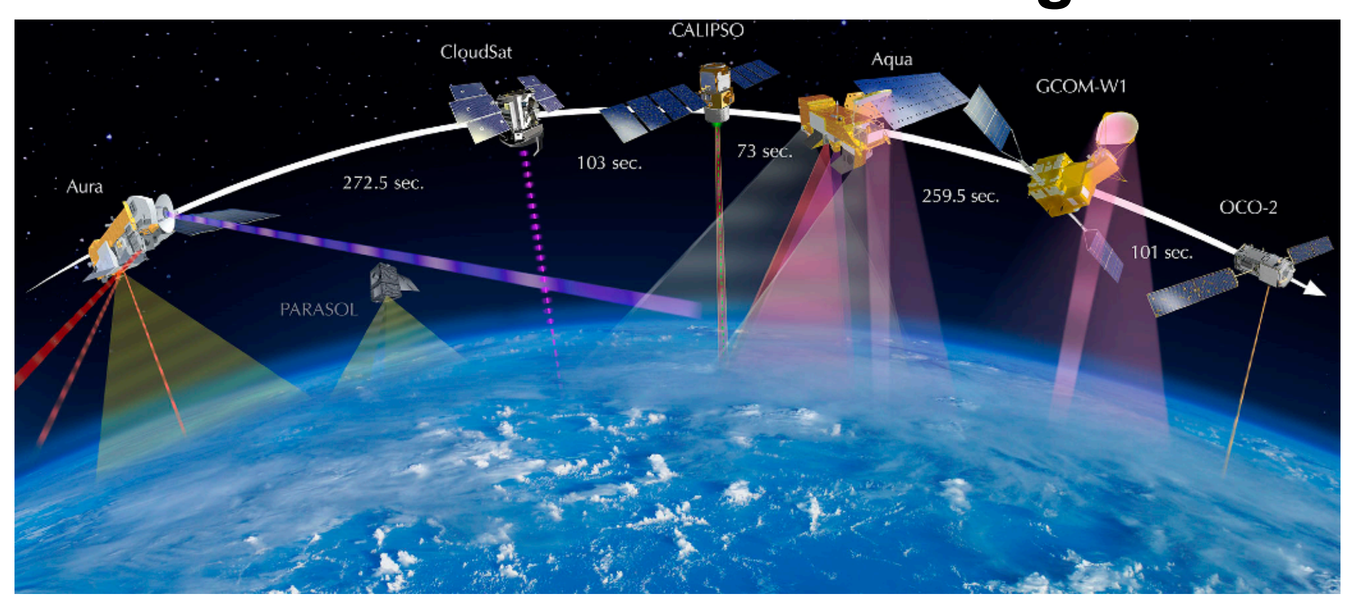
Newer measurement strategies

Low-cost sensor networks

Mobile monitoring

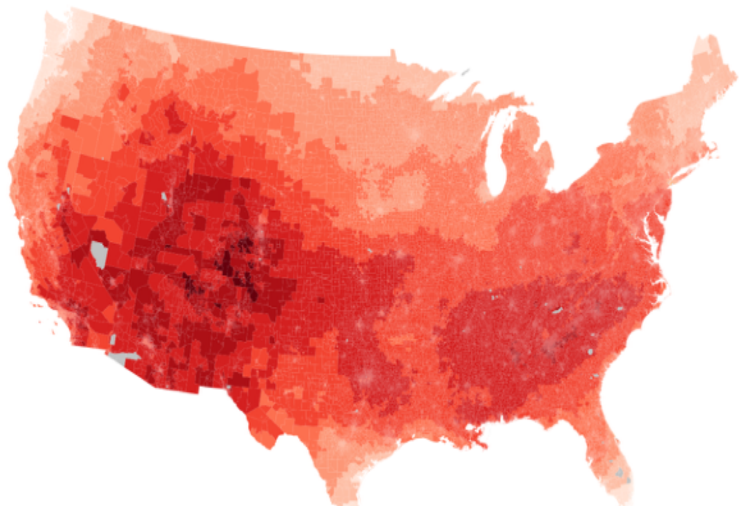
Personal measurements

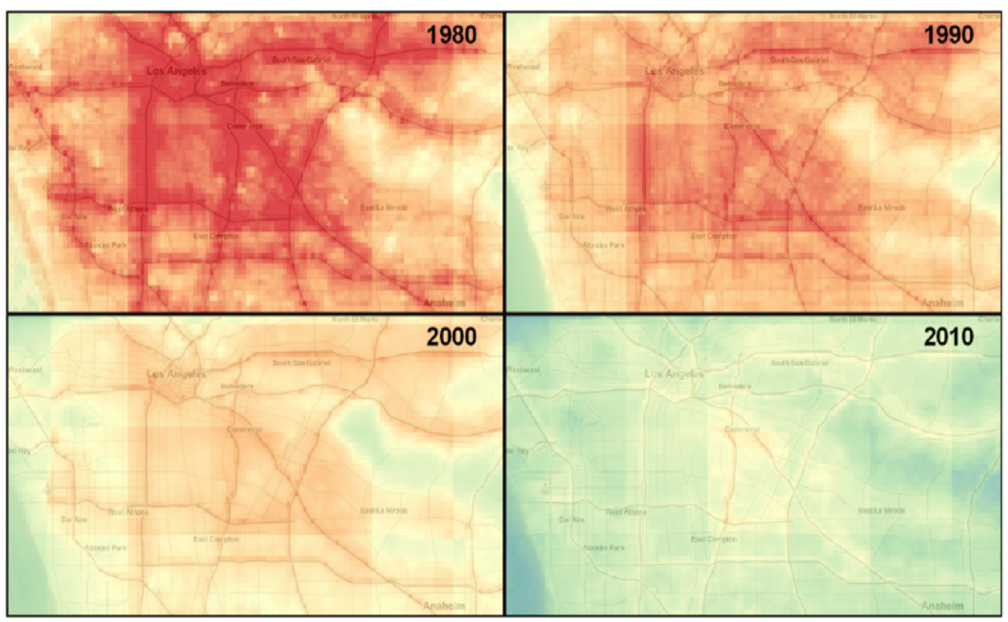
Satellite remote sensing



Exposure modeling approaches

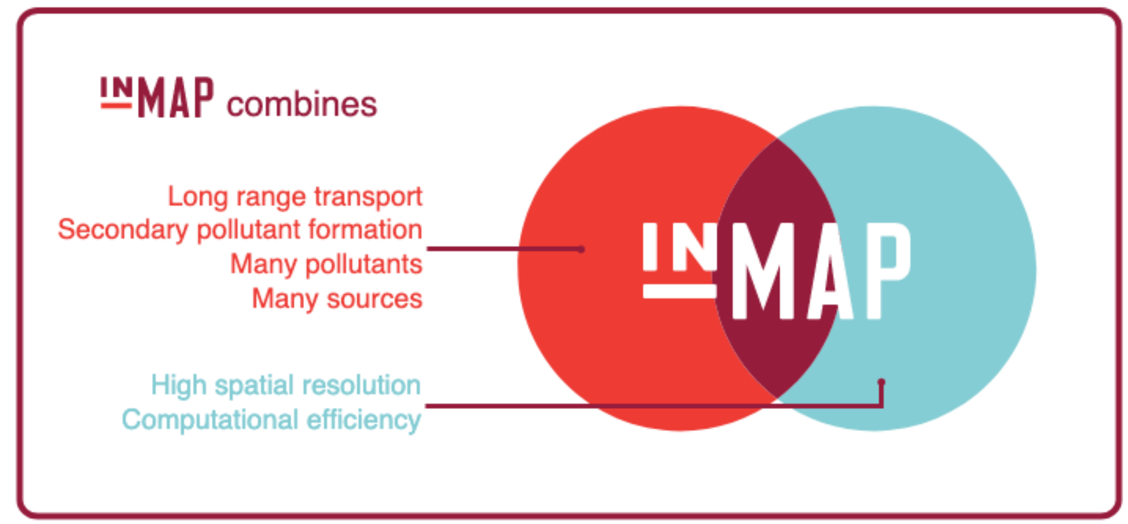
Empirical models (e.g., LUR)

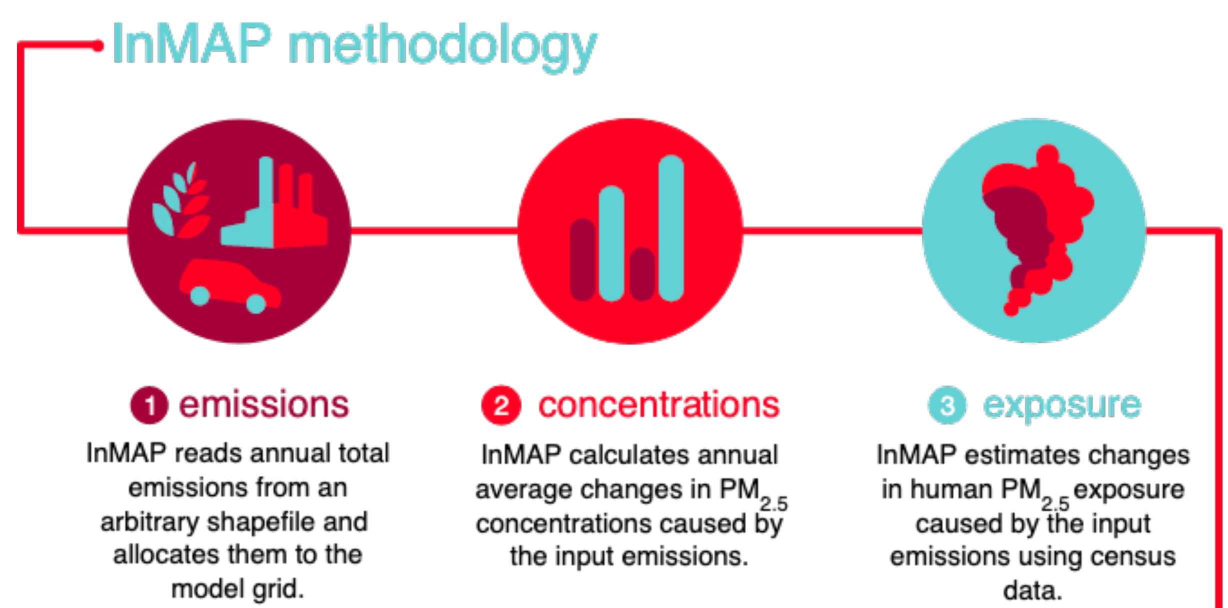




Broad spatial extent + high resolution
Capture very fine scale features
Empirical, not explanatory
Not suited to “what if” scenarios

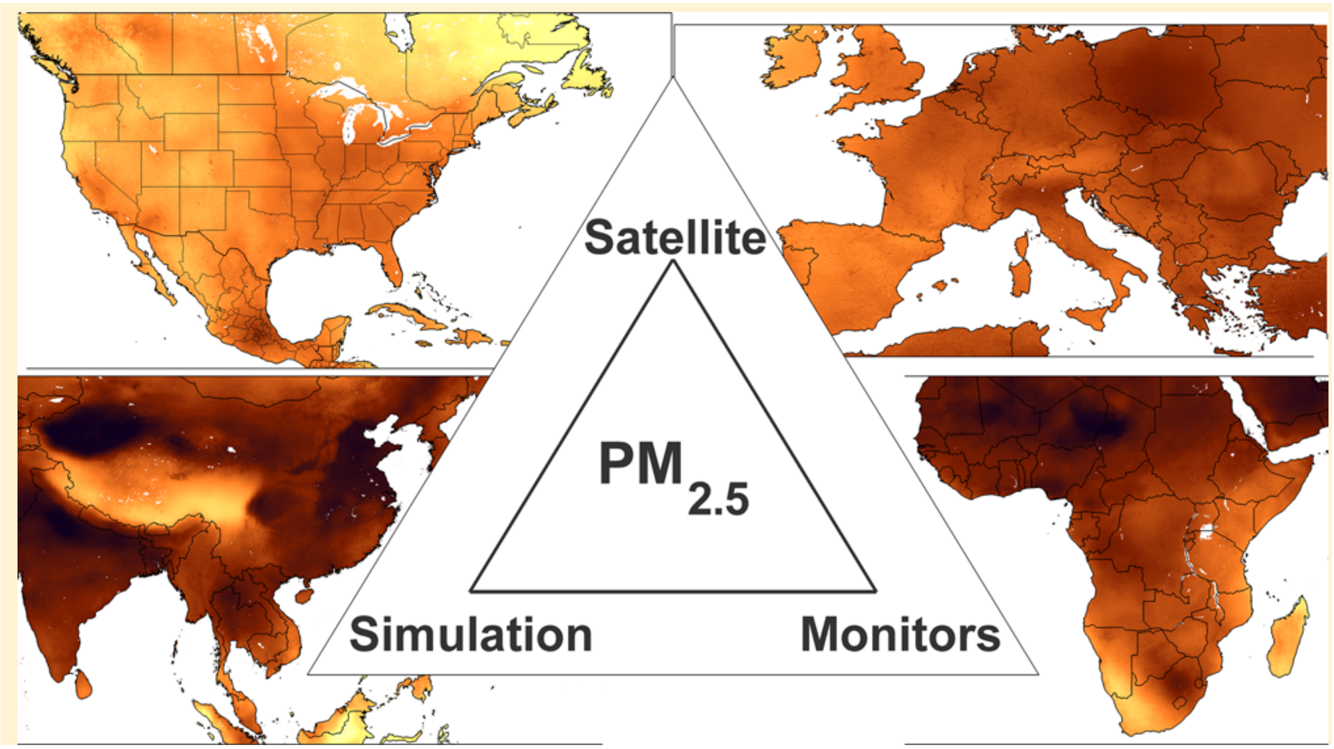
RCMs: Reduced-complexity models

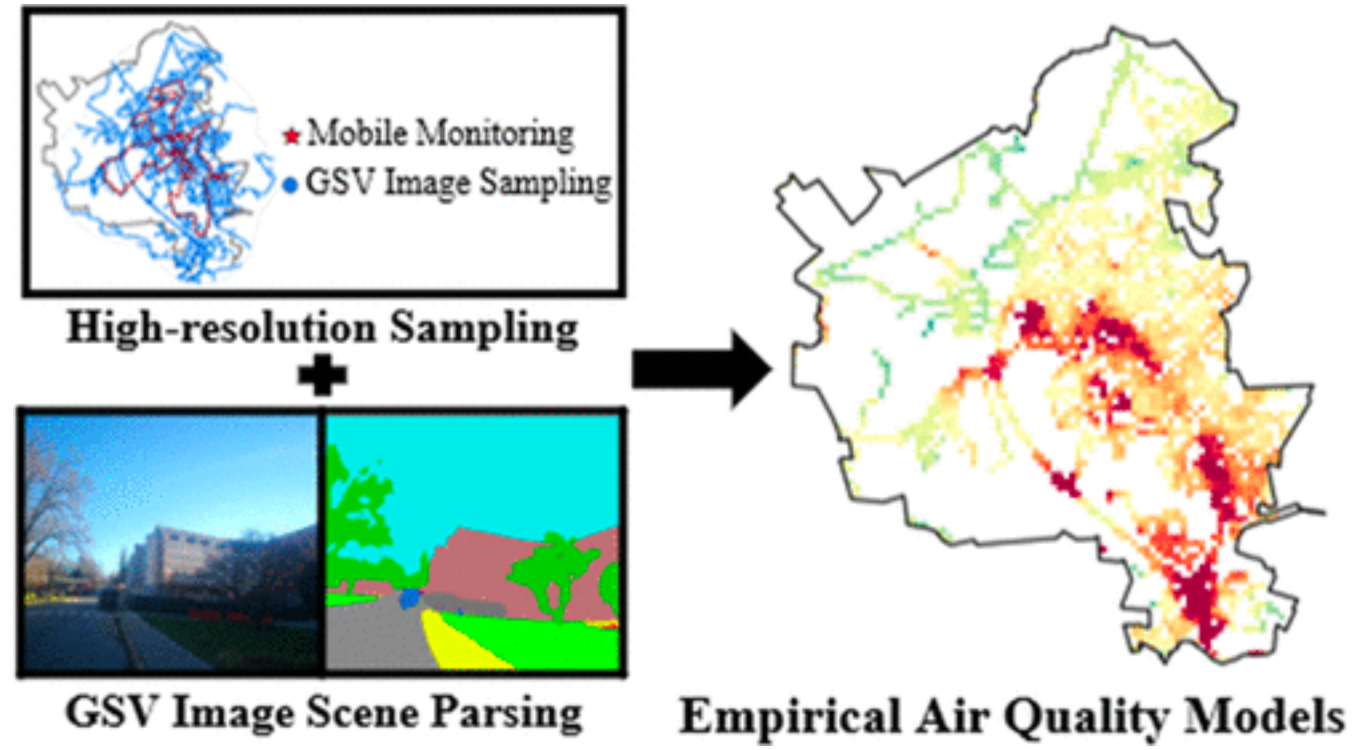


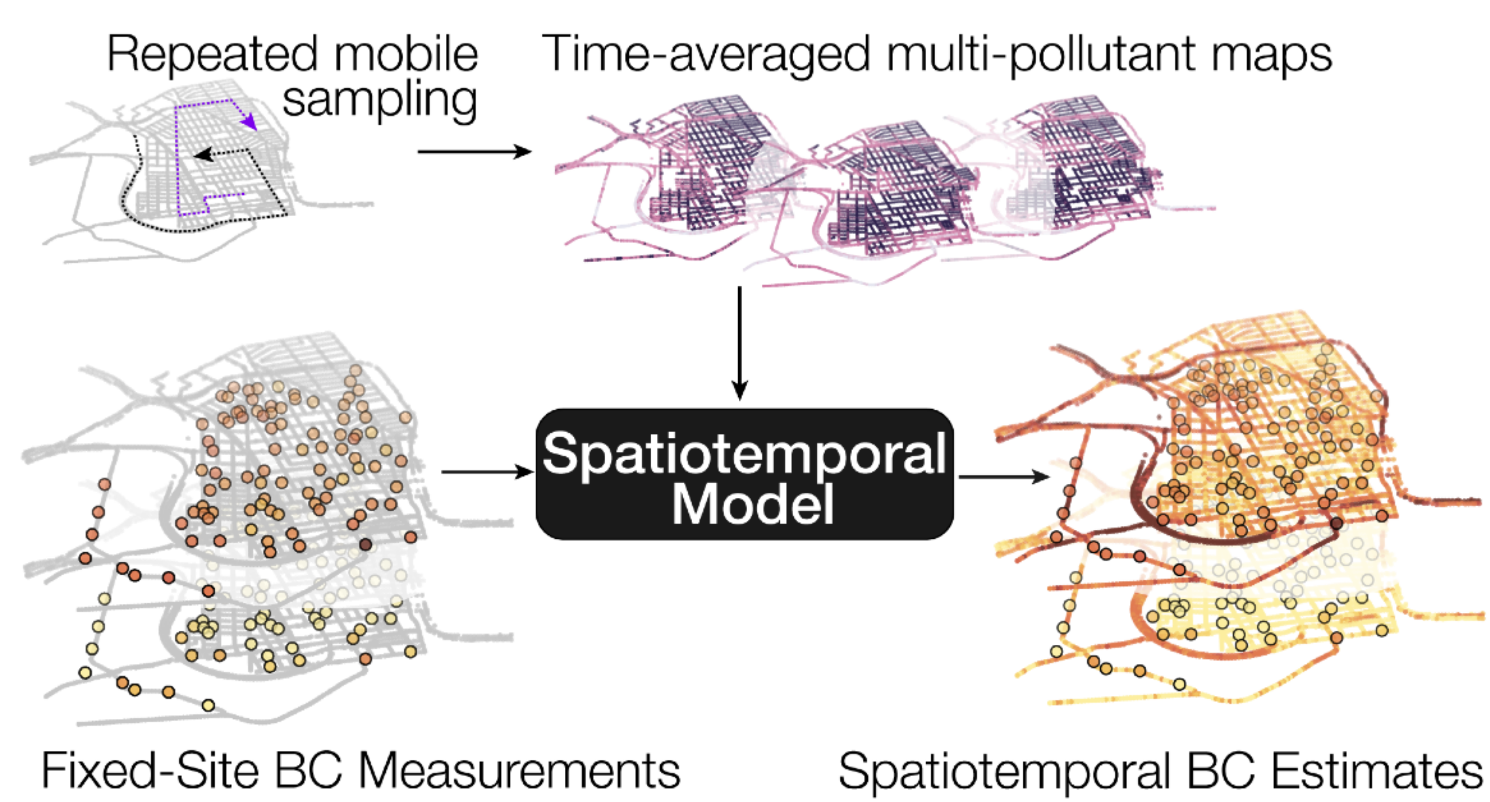


Can simulate alternate realities
Represent emissions→concentration relationship
Limited by available input data
Do not capture finest-scale spatial features

Data fusion and hybrid models







Van Donkelaar et al 2016

Qi and Hankey, *ES&T* 2021

Manchanda et al., in review

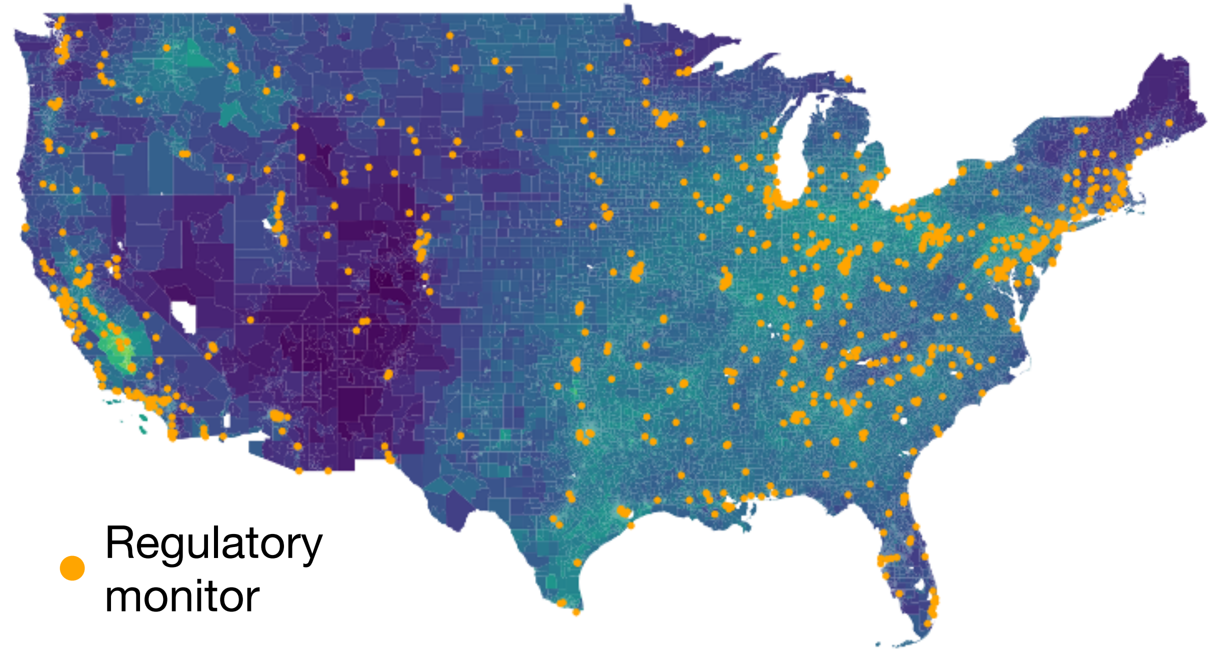
Match analysis method to scale of contrast

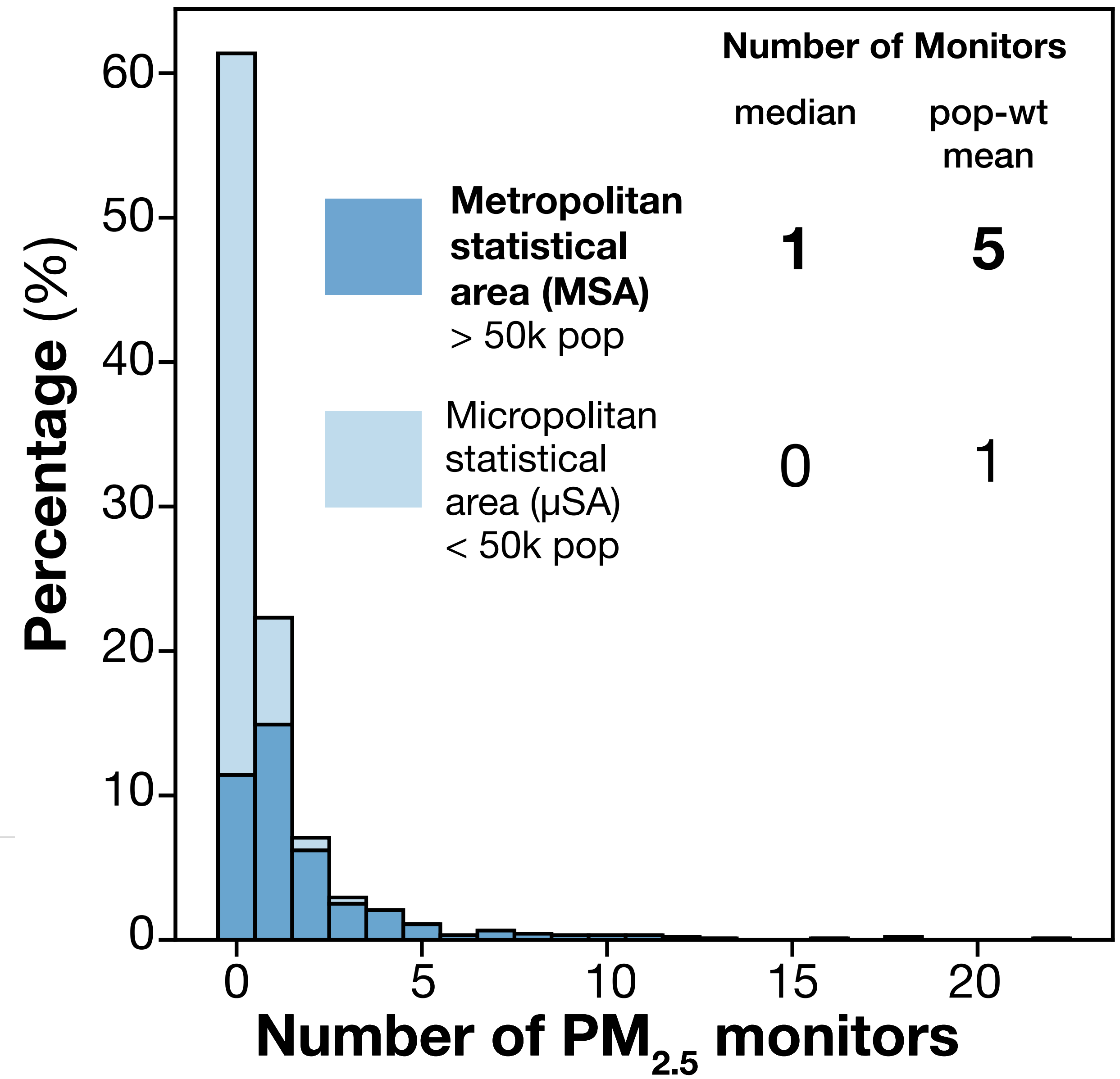
- **National scale**
  - Satellite
  - Empirical model (LUR, hybrid)
  - Mechanistic models (CTM, RCM)
- **Within-urban / hyperlocal**
  - Empirical models; satellite
  - Mobile monitoring
  - Low-cost sensors
- **Indoor or microenvironmental**
  - Personal monitoring
  - Low-cost sensors

Sparse regulatory monitoring

Most US urban areas have few monitors. How do we assess NAAQS?

$PM_{2.5}$ monitoring sites





CBSA: "core-based statistical area"

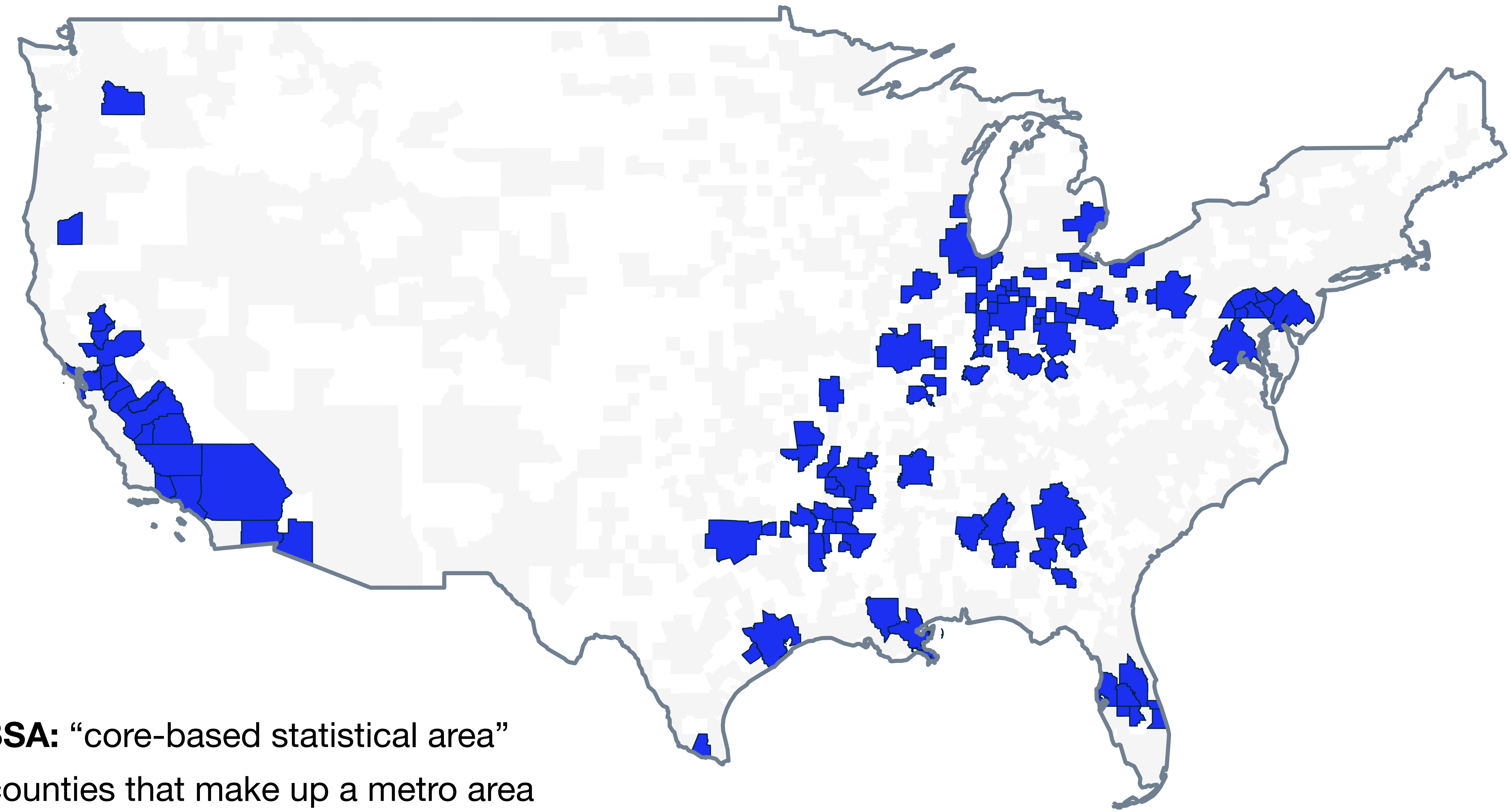
The counties that make up an urban area.

NAAQS attainment is often designated at CBSA scale.

Wang et al., *in prep*

If NAAQS exceedances were based on modeled PM…

All CBSAs with census tracts with $PM_{2.5}$ exceeding 9 µg m^{-3}



CBSA: "core-based statistical area"

~ counties that make up a metro area

NAAQS attainment is often designated at CBSA scale

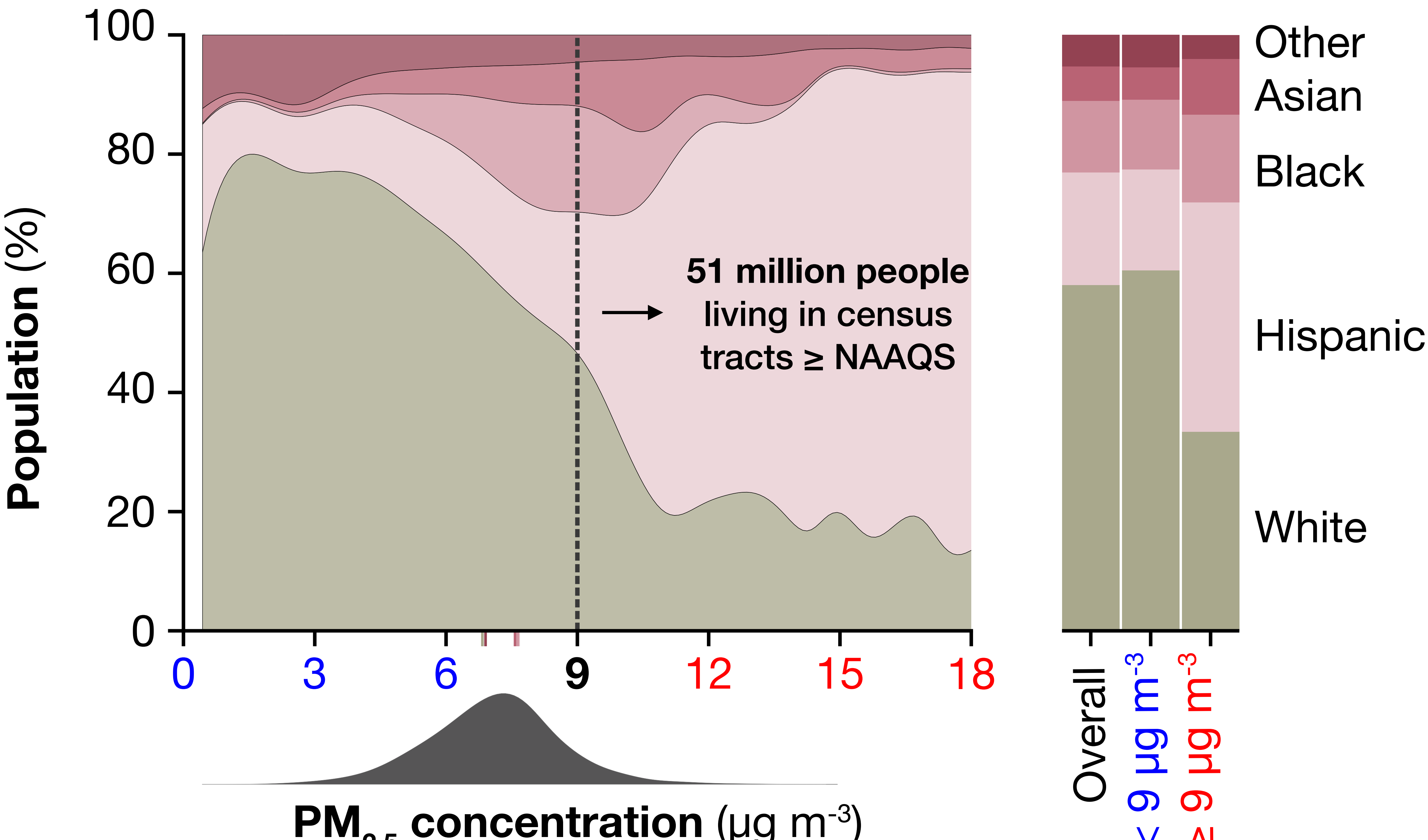
Dataset: CACES Empirical Model

Wang et al., *in prep*

data: www.caces.us

NAAQS and exposure disparities

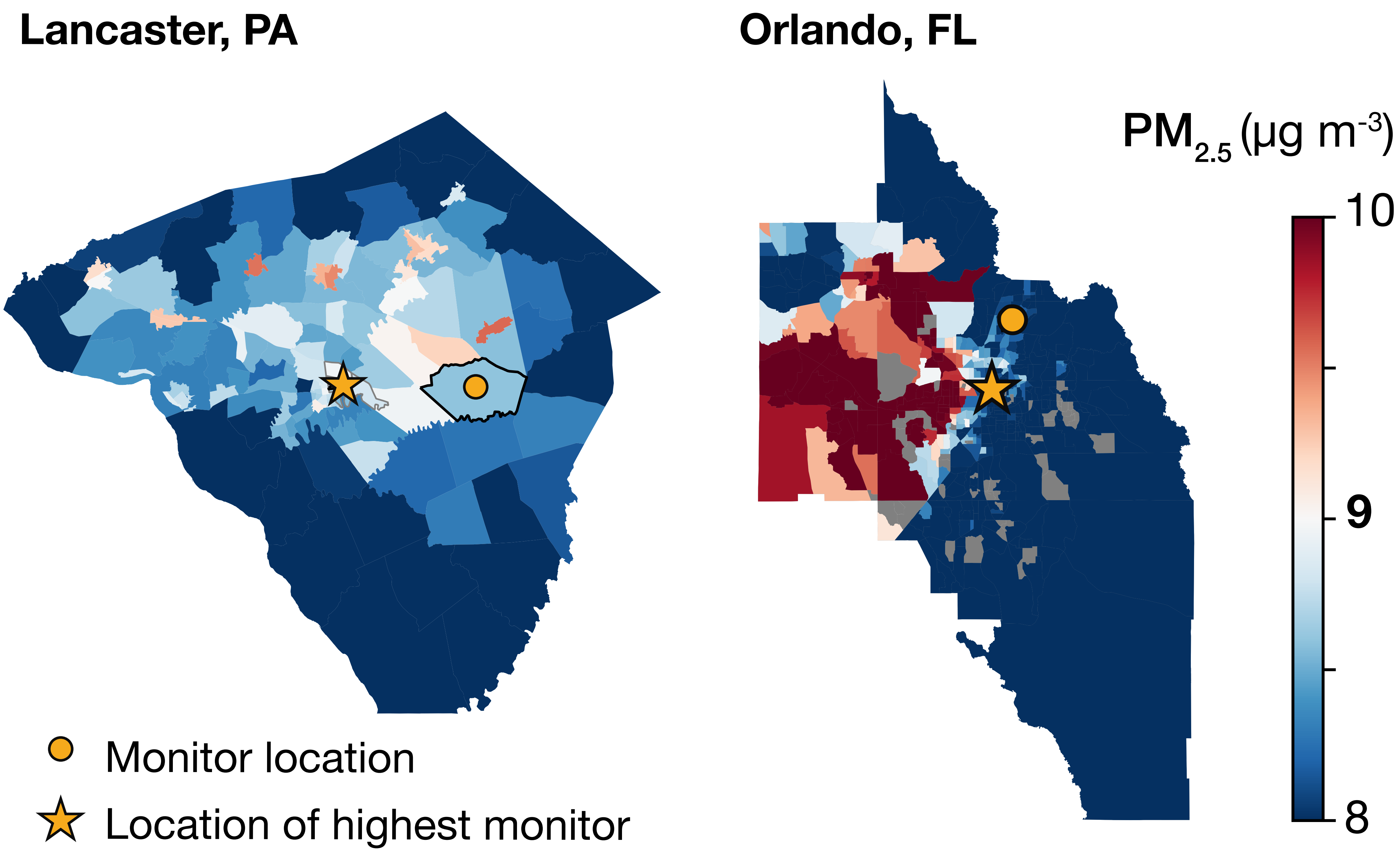
Attaining 9 µg $PM_{2.5}$ NAAQS would address large exposure disparities



Wang et al., *in prep*

Sparse monitoring networks may miss hotspots

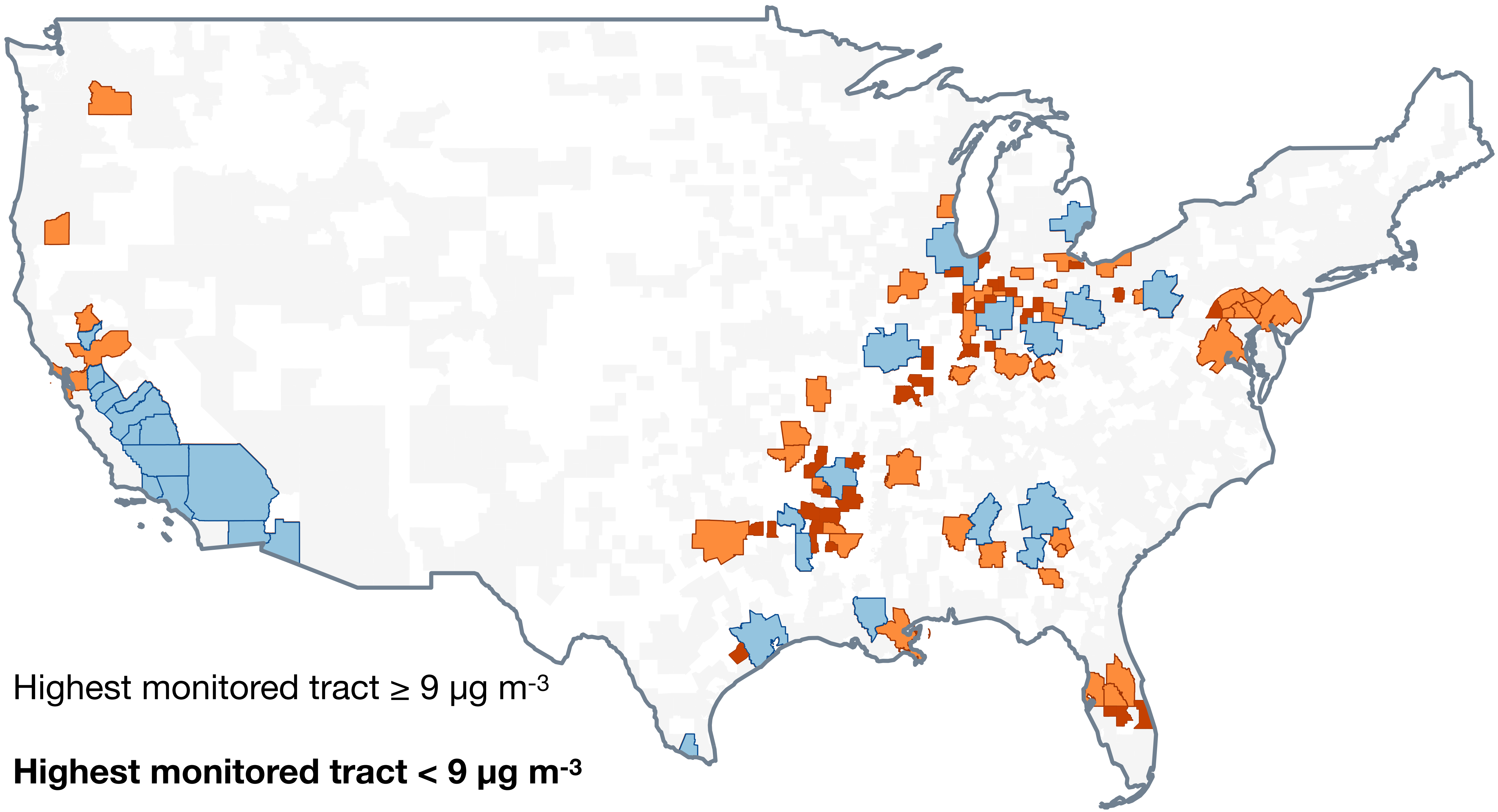
Concentrations at unmonitored hotspots can exceed NAAQS



Wang et al., *in prep*

Do monitors capture PM > NAAQS?

Dozens of CBSAs have unmonitored hotspots > 9 μg m^{-3}



Highest monitored tract ≥ 9 μg m^{-3}

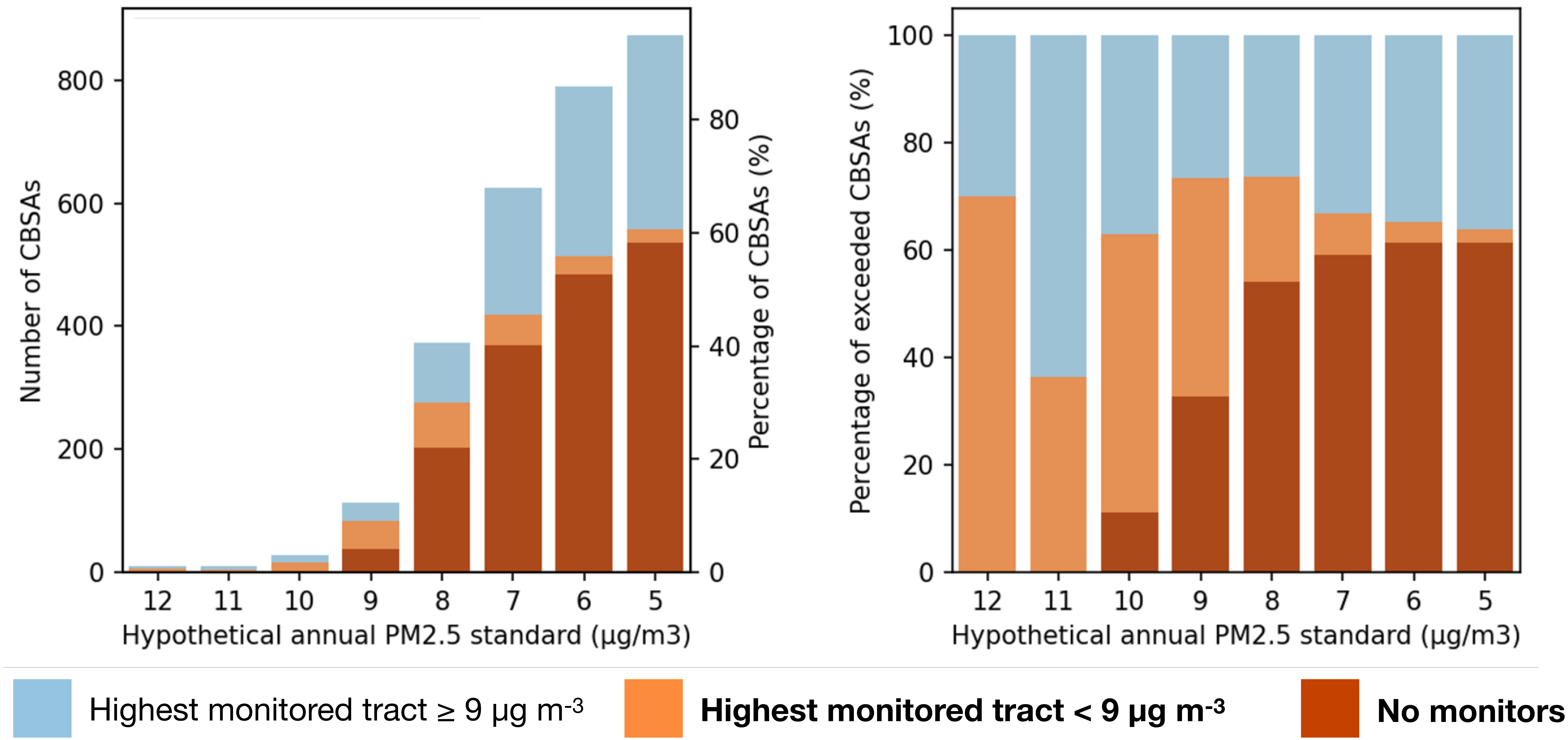
Highest monitored tract < 9 μg m^{-3}

No monitoring in CBSA

Wang et al., *in prep*

Existing monitoring misses high PM locations

51 million people in 113 CBSAs have hotspots with $PM_{2.5}$ > new NAAQS



How will we design monitoring infrastructure of the future under ever-tighter NAAQS?

Wang et al., *in prep*

Why make new measurements?

- Regulatory context: most **legally defensible** measure of exposure
- **Accountability** studies and trend analysis
- **Challenge our understanding** of relevant sources and processes
  - Identify or quantify “unknown unknowns”
- **Emerging priorities:** Assess exposure to non-criteria air pollutants
  - e.g., air toxics, source-specific indicators, UFP
- Personal, indoor, and microenvironmental exposures

Why *model* exposure?

Models and remote sensing are highly scalable.

- Study large populations.
- Simultaneously consider large range of spatial contrasts.
- Cost-effective relative to measurements.
- Use mechanistic models to understand “what-if” scenarios

Key take-homes

NAAQS science process relies on precisely defined exposure metrics

- Report *precise, detailed* information on exposure metrics to maximize value for EPA science and policy assessments.

- Traditional ambient monitoring is still essential.
- Emerging methods can add valuable detail and context.
- Models provide powerful scalability.

- Emerging needs:
  - Lots of new measurements and monitoring being funded. How do we capture these data?
  - How do we assimilate diverse datasets into standardized, validated products?
  - Systematic observations for EJ-focused accountability research.