Data-driven placement of $PM_{2.5}$ air quality sensors in the United States: An approach to target urban environmental injustice

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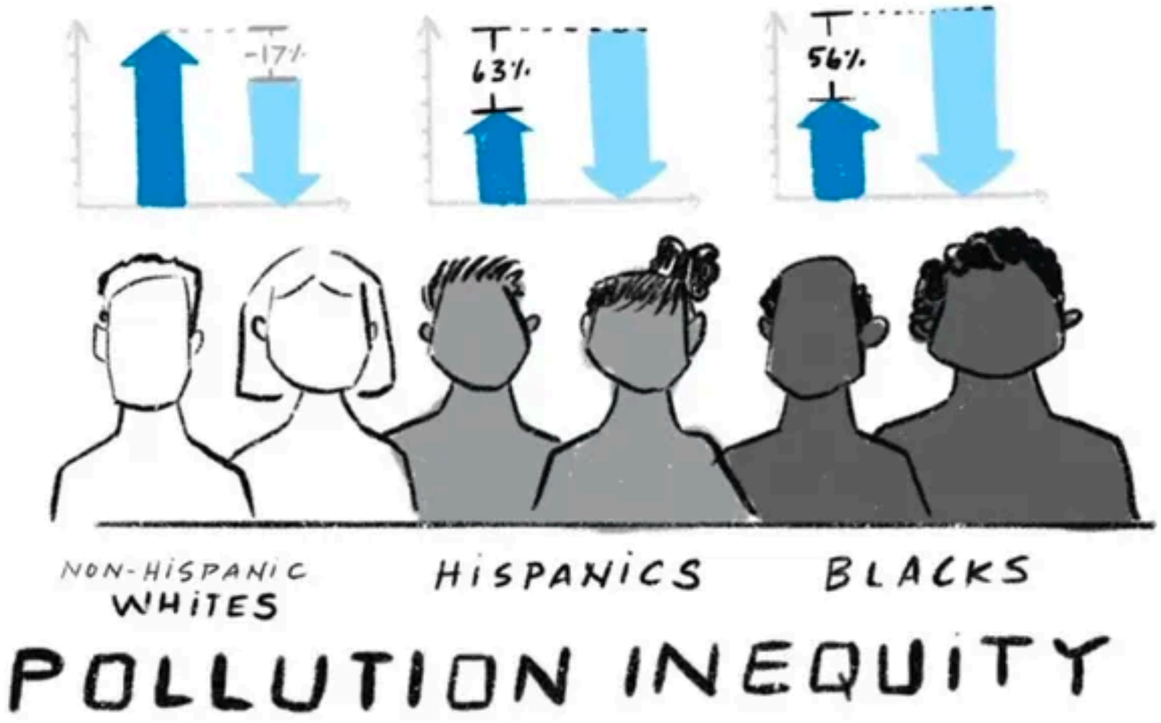
Timothy Fargiano, Samuel Lin, Tina Liu, Nathan Kutz, and Loretta Mickley
AGU Fall Meeting 20221212

The current generation of low-cost, citizen science networks contain racial and income biases



USA Today, “Study finds a race gap in air pollution — whites largely cause it; blacks and Hispanics breathe it”

Article | Published: 06 May 2021

On the distribution of low-cost $PM_{2.5}$ sensors in the US: demographic and air quality associations

Priyanka deSouza & Patrick L. Kinney

Journal of Exposure Science & Environmental Epidemiology **31**, 514–524 (2021) | Cite this article

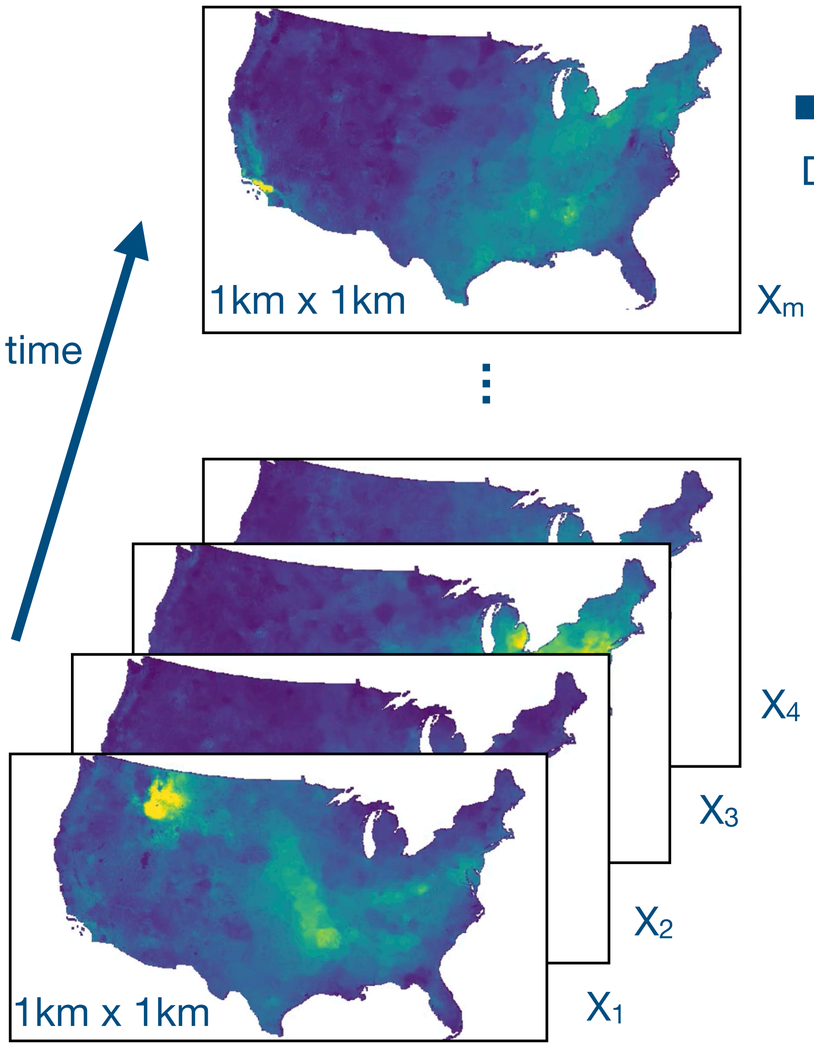
Purple Air sensors are …

1) “in significantly Whiter, higher income census tracts relative to the national average”
2) “in locations with lower annual-average $PM_{2.5}$ concentrations than [EPA] monitors [except California].”

Multi resolution Dynamic Mode Decomposition (mrDMD): A data-driven optimization for intentional sensor network design

1) Collect Data

$PM_{2.5}$ concentration fields: 2006-2016



Data

Lat, Lon x Time

$$X = [x_{t1} \quad x_{t2} \quad \cdots \quad x_{t-1}]$$

$$X' = [x_{t2} \quad x_{t3} \quad \cdots \quad x_{t}]$$

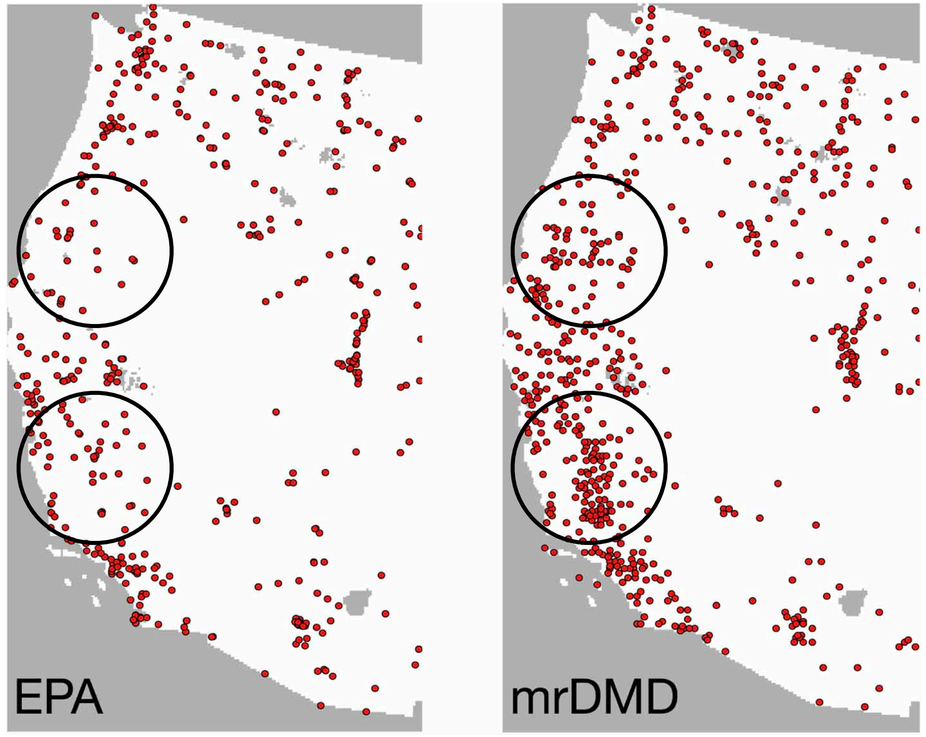
$$X' \approx AX$$

Regression

2) mrDMD algorithm

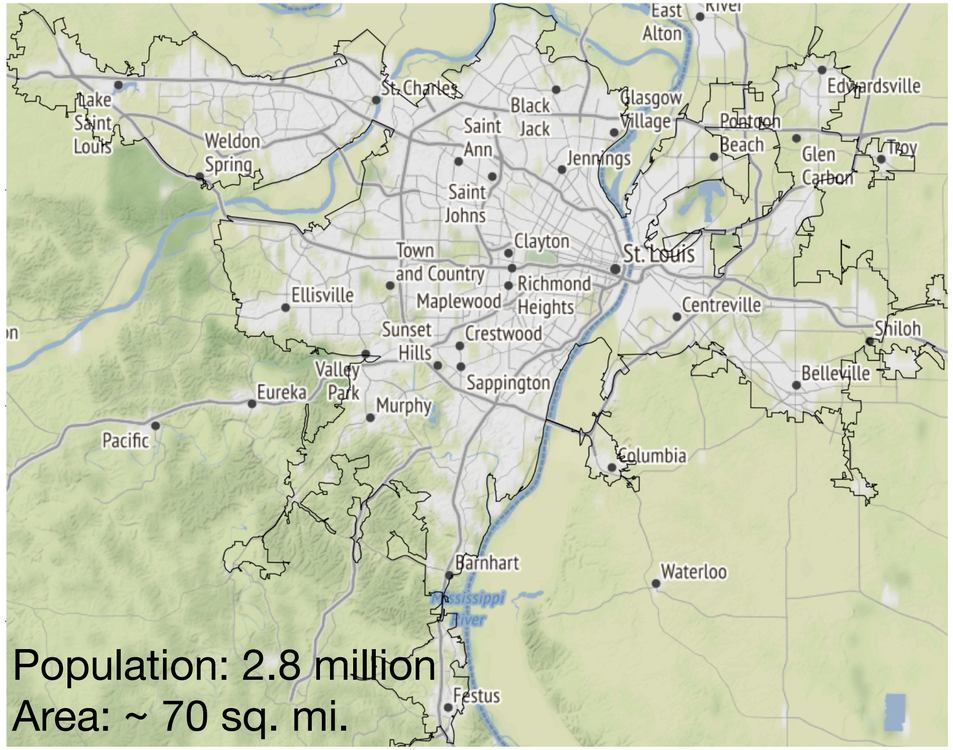
QR Pivots +
Environmental Justice Cost function

3) Data-driven sensor network

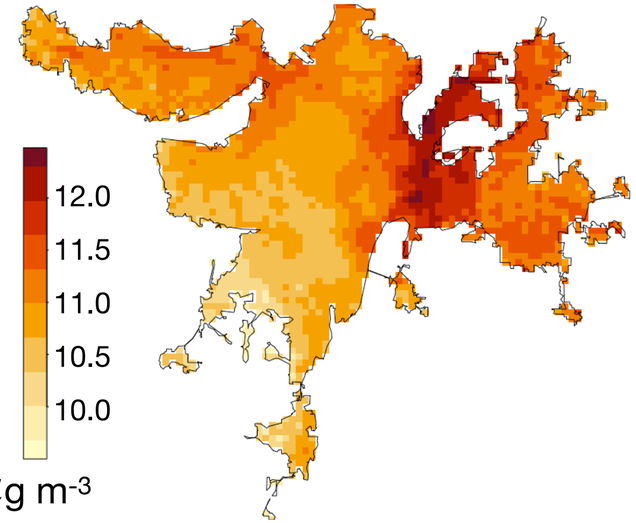


Kelp et al., (2022) ERL

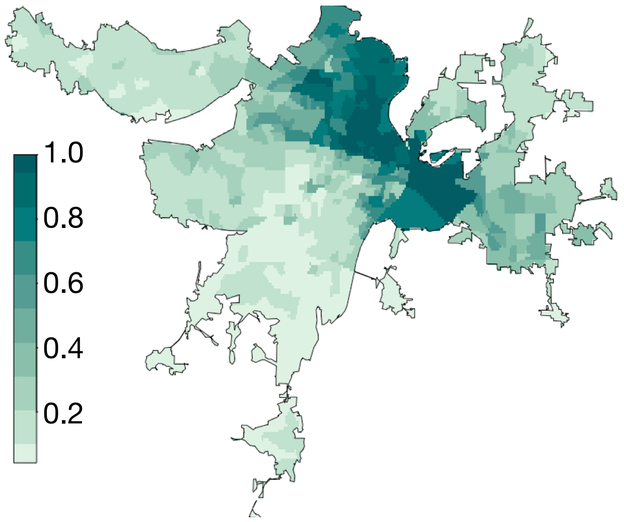
St. Louis, MO is a racially segregated city with a long history of env. racism



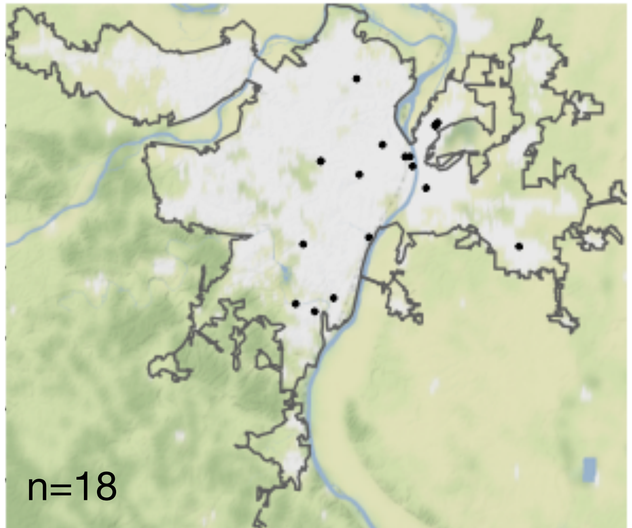
Average $PM_{2.5}$ Concentration (2006-2016)



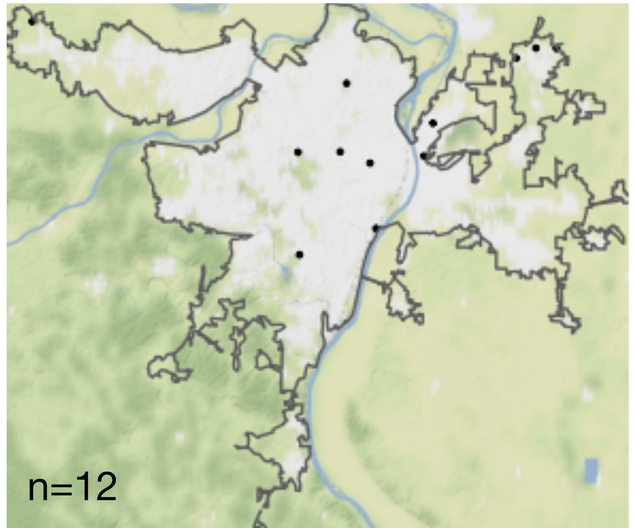
Proportion Nonwhite



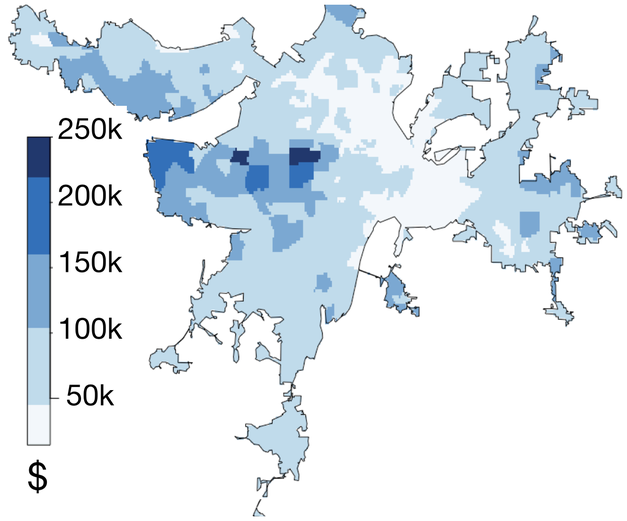
EPA sensors



Purple Air sensors

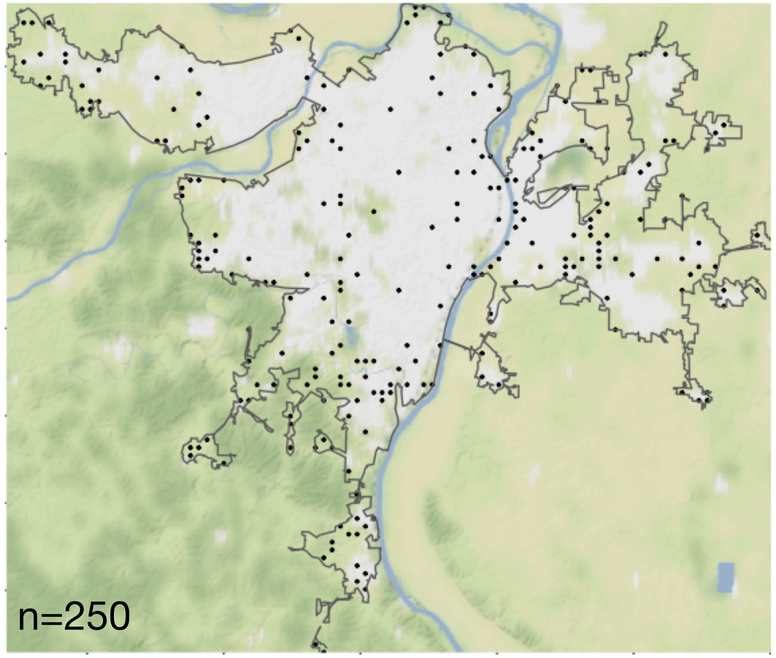


Median Annual Household Income



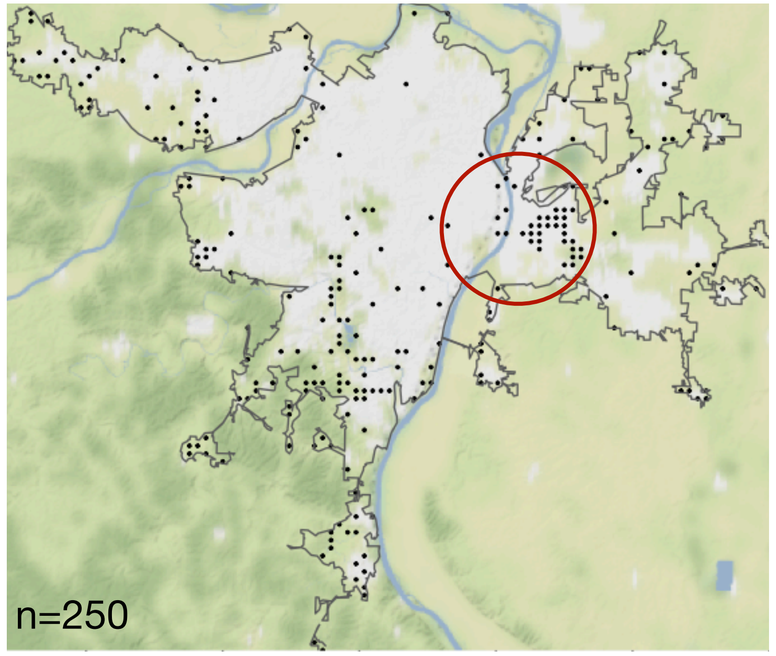
Incorporating race and income into sensor network optimization highlights historic, polluted nonwhite neighborhoods

mrDMD



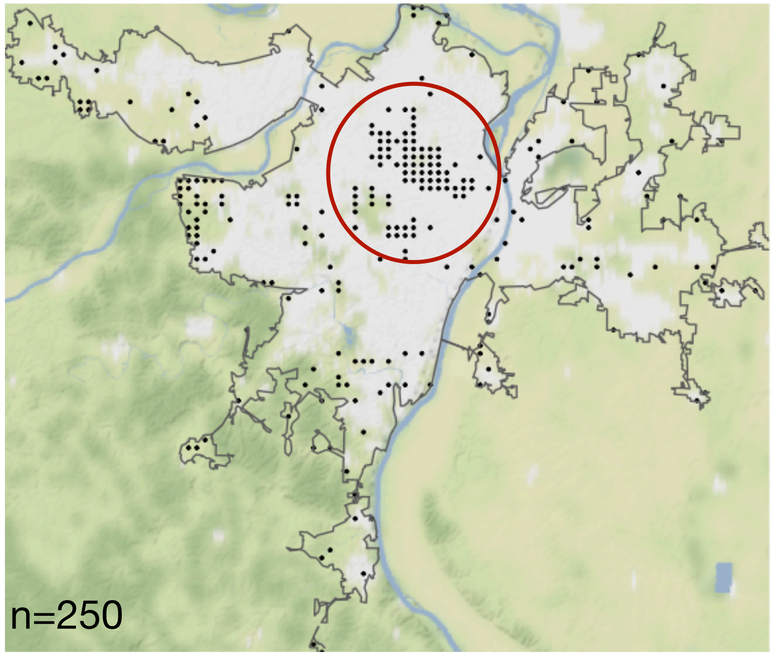
mrDMD - nonwhite

More sensors in Granite Falls steel mills in E. STL



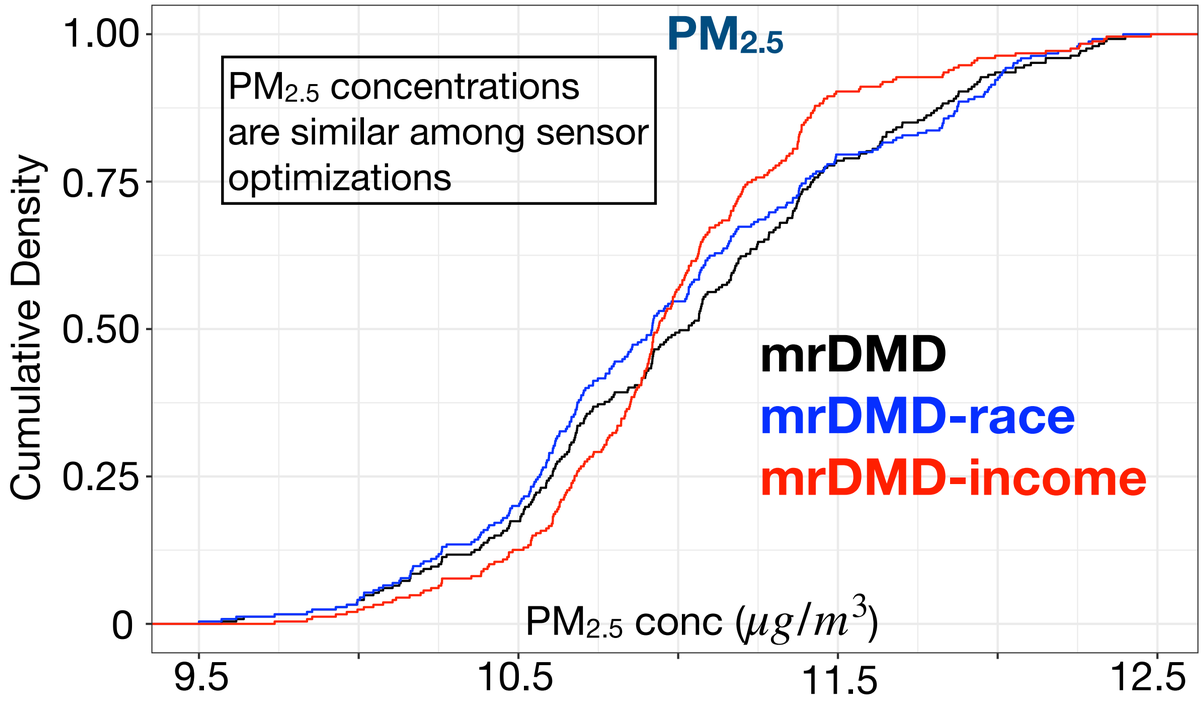
mrDMD - income

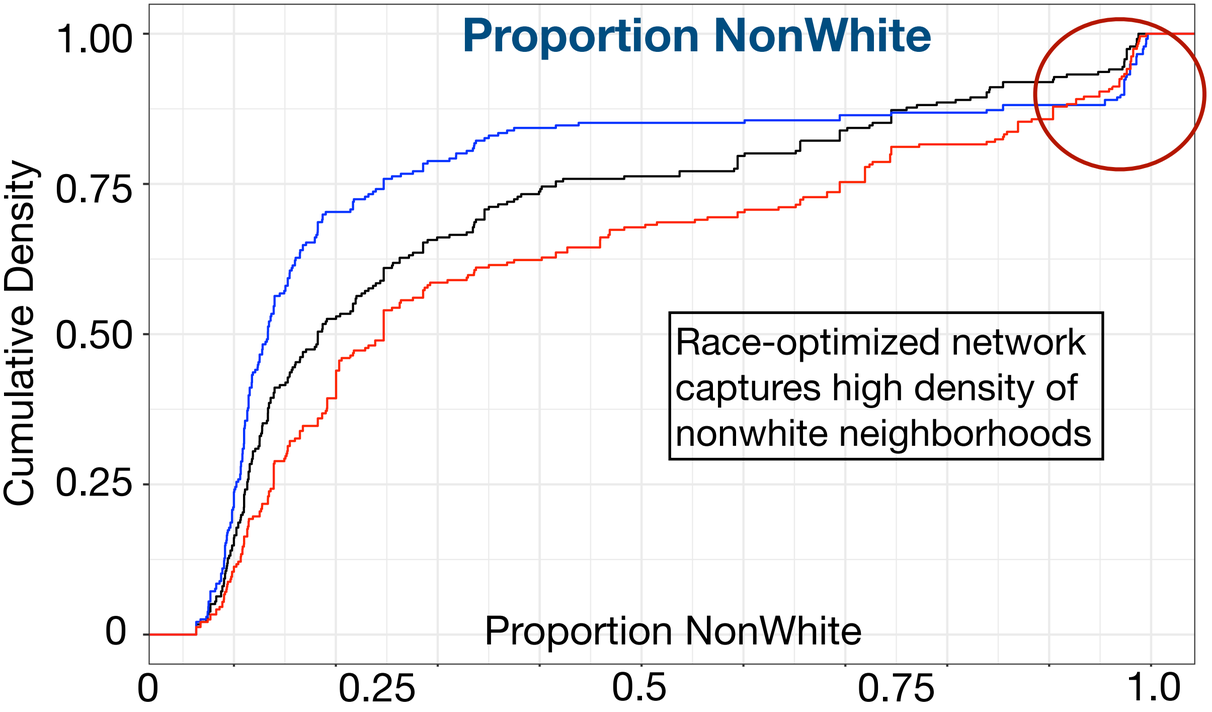
More sensors in Jennings and Ferguson

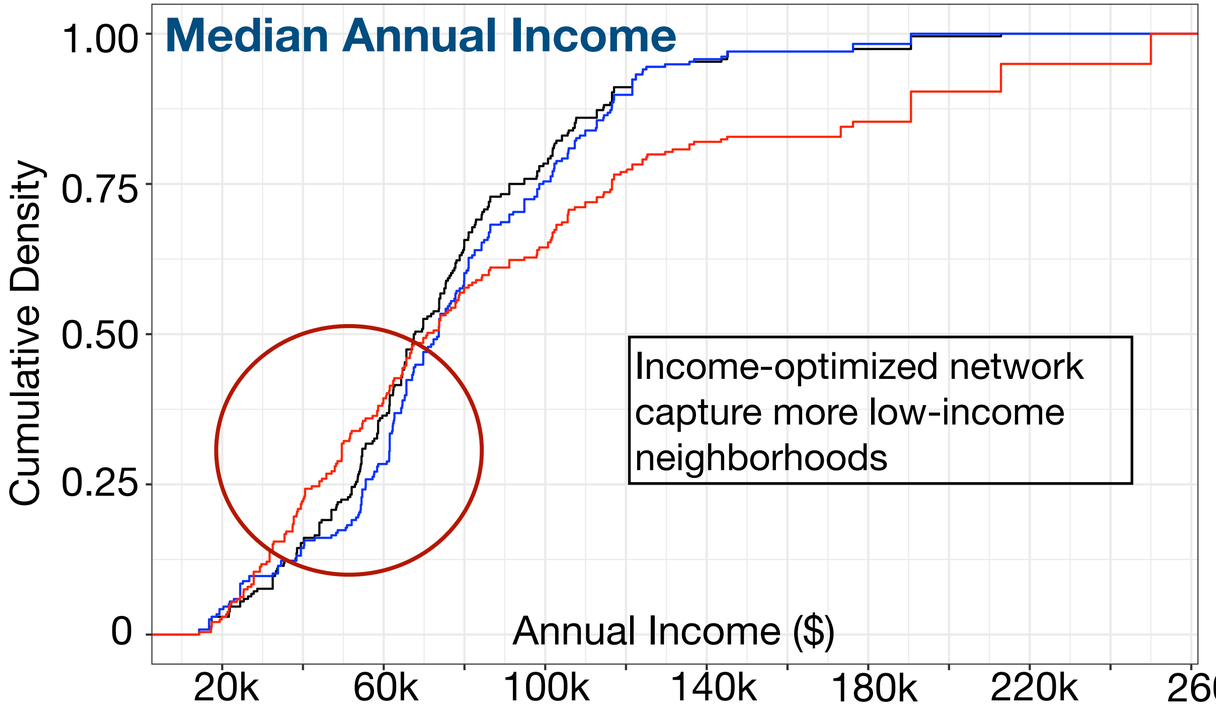


- Sensor location median PM2.5 exposure and median income do not significantly differ among the sensor networks, although the standard deviations are high.

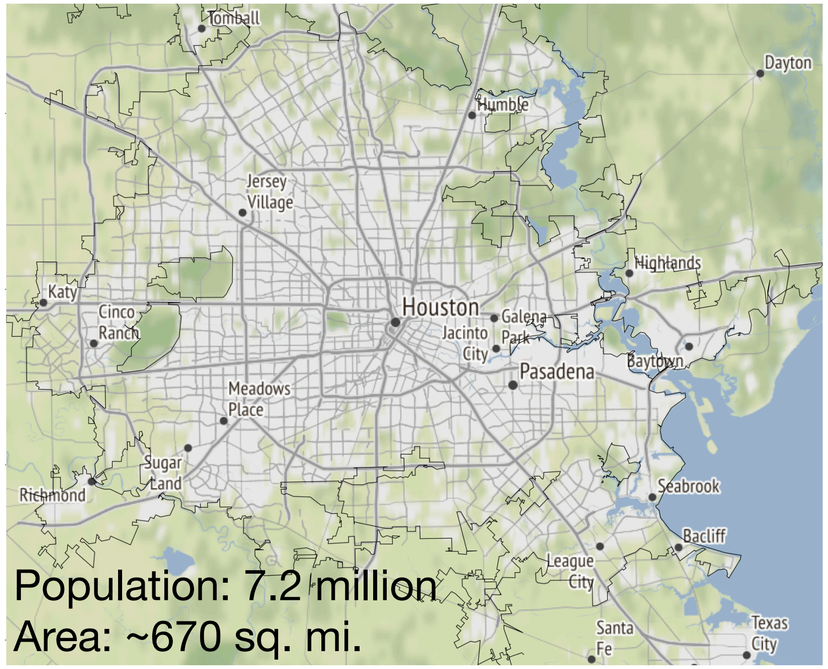
Cumulative distributions of sensors show that EJ optimizations capture more nonwhite and low-income neighborhoods







Houston, TX has poor air quality and a high nonwhite population



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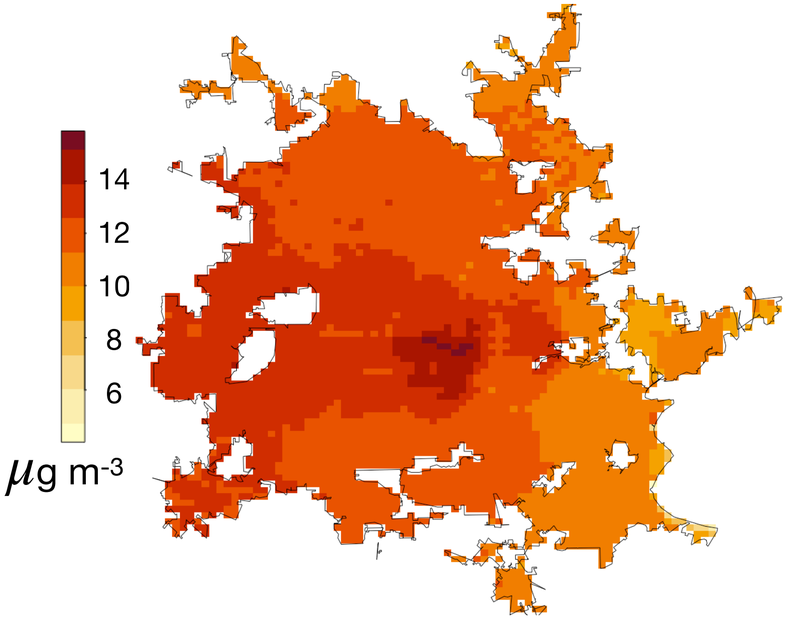

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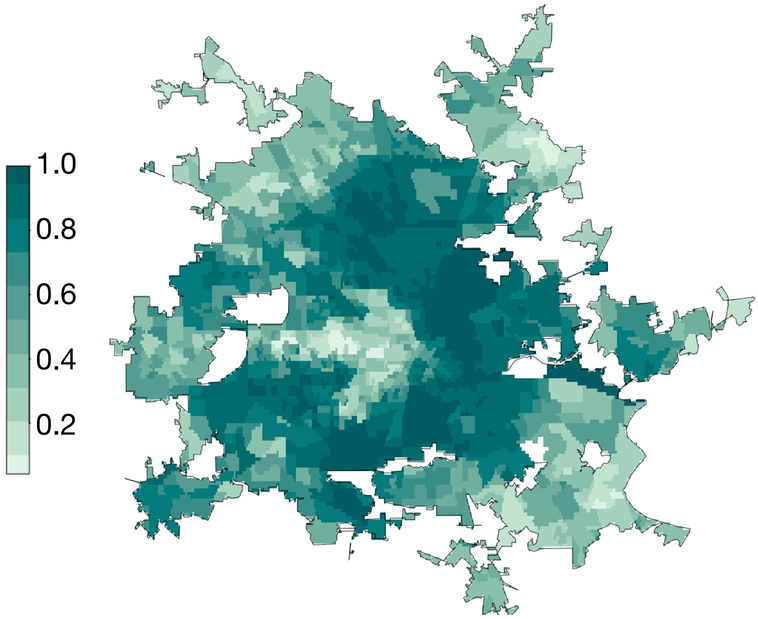
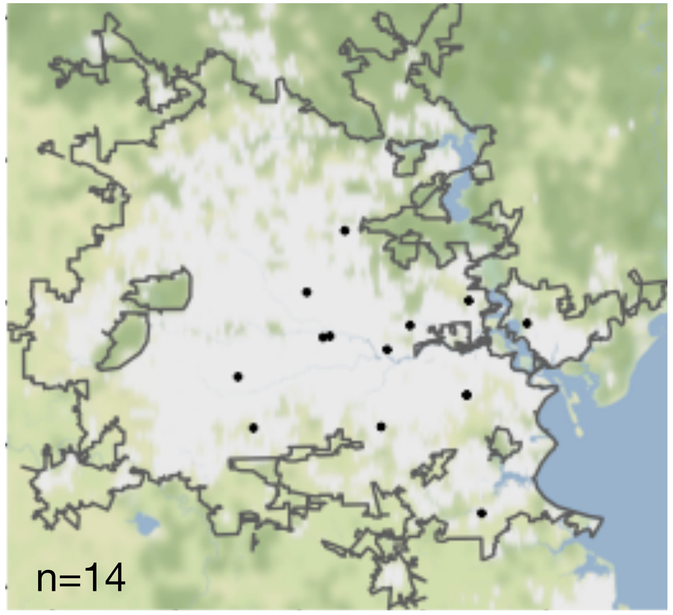
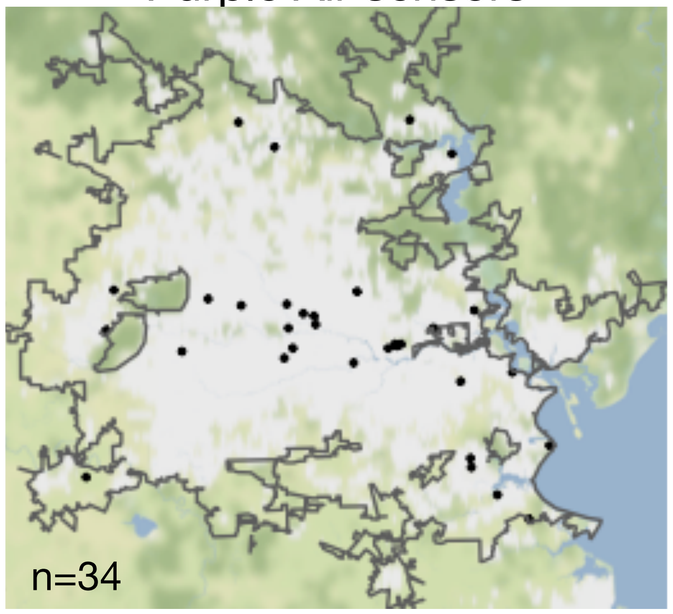


EPA sensors



Purple Air sensors



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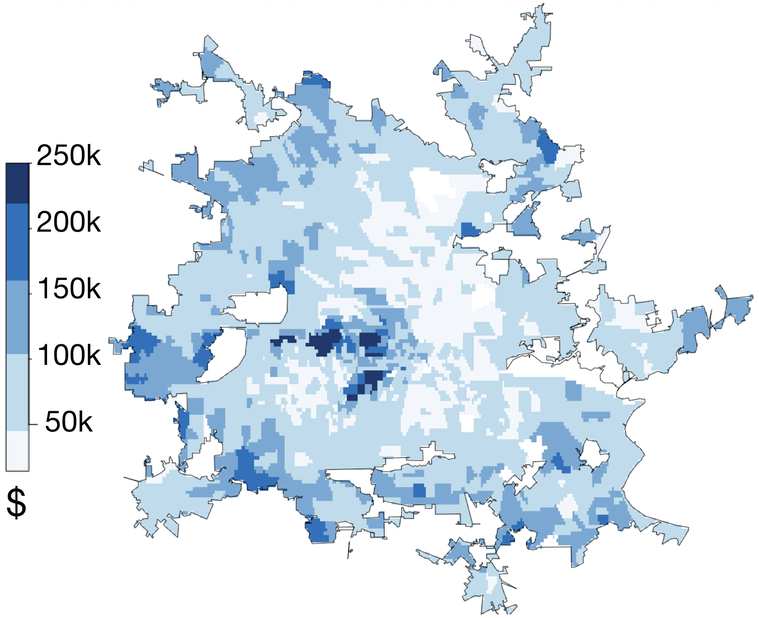
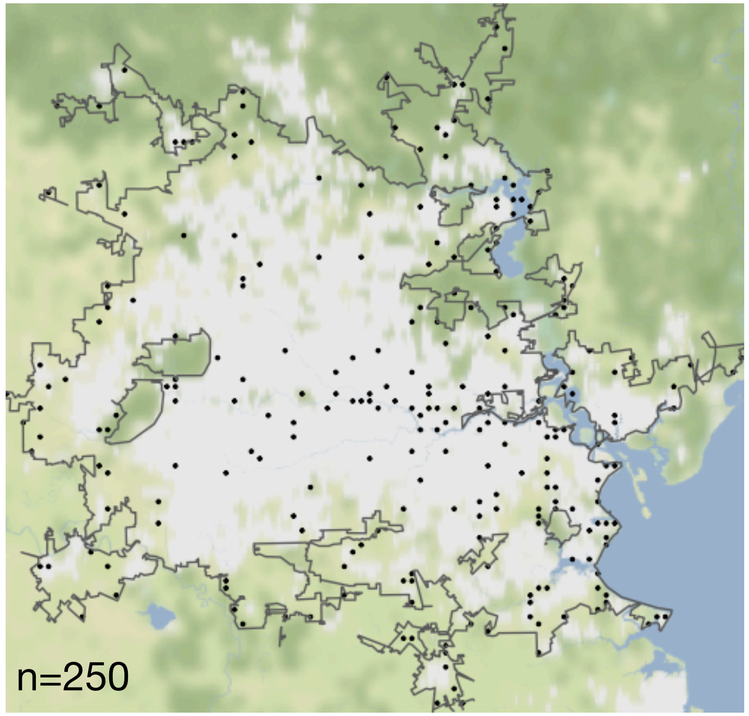


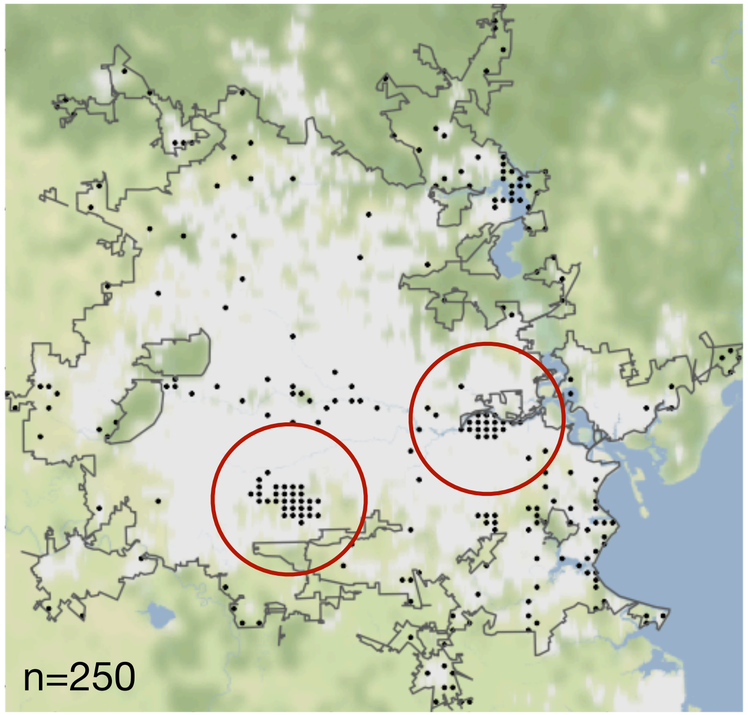
Incorporating race and income into sensor network optimization highlights Ship Canal region and polluted nonwhite neighborhoods

mrDMD



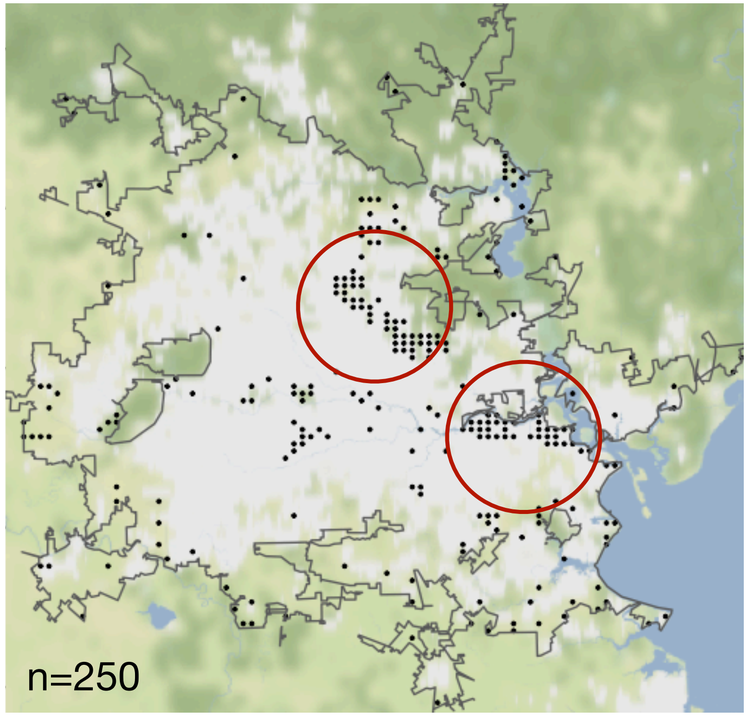
mrDMD - nonwhite

More sensors in Ship Canal region where oil refineries dominate + Southwest Houston (majority black neighborhood)



mrDMD - income

More sensors in Ship Canal region where oil refineries dominate + Trinity/Houston Gardens (majority black neighborhood)



- Sensor location median PM2.5 exposure and median income do not differ among the sensor networks, although the standard deviations are high.

Takeaways

-First data-driven study that diagnoses the optimal and equitable placement of $PM_{2.5}$ sensors based on air pollution modal information

-Optimizations incorporating racial and income disparities shift sensor distribution to more nonwhite and low-income neighborhoods

-Provide a roadmap for urban areas to create intentional low-cost sensor networks that are conscious of America's lineage of environmental racism

Makoto Kelp

18:00

**Wednesday December 14: If you are interested in the interplay between:
wildfire smoke, prescribed burns, and rural environmental justice in the western United States**

GH36A-08

Sensitivity of population-weighted smoke exposure to wildfires in the western United States: implications for prescribed burning at the state level and in rural environmental justice communities

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