



# Air Quality Monitoring with Low-cost Sensors in Pioneer Valley of Western Massachusetts

DONG GAO, Jiarong Qi, Mahea Heimuli, Anna Woodroof, David Bloniarz, Alexander Sherman, Samantha Hamilton, Yoni Glogower, Sarita Hudson, Krystal Pollitt

Yale University

ASIC 2022

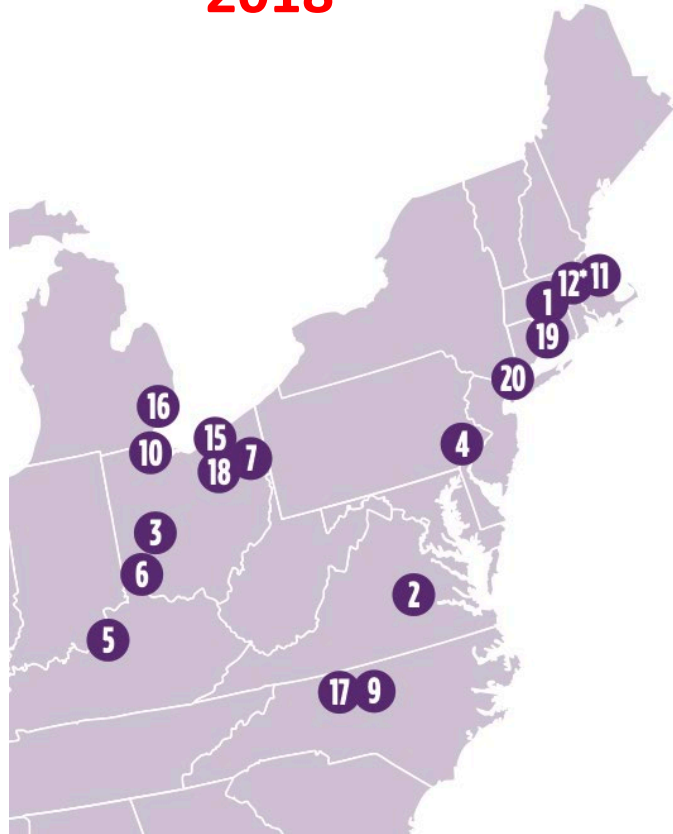


# Introduction

- **The Top 20 Most Challenging Places to Live with Asthma**

*[Asthma Capitals Report by AAFA (Asthma and Allergy Foundation of America)]*

**2018**



**2019**

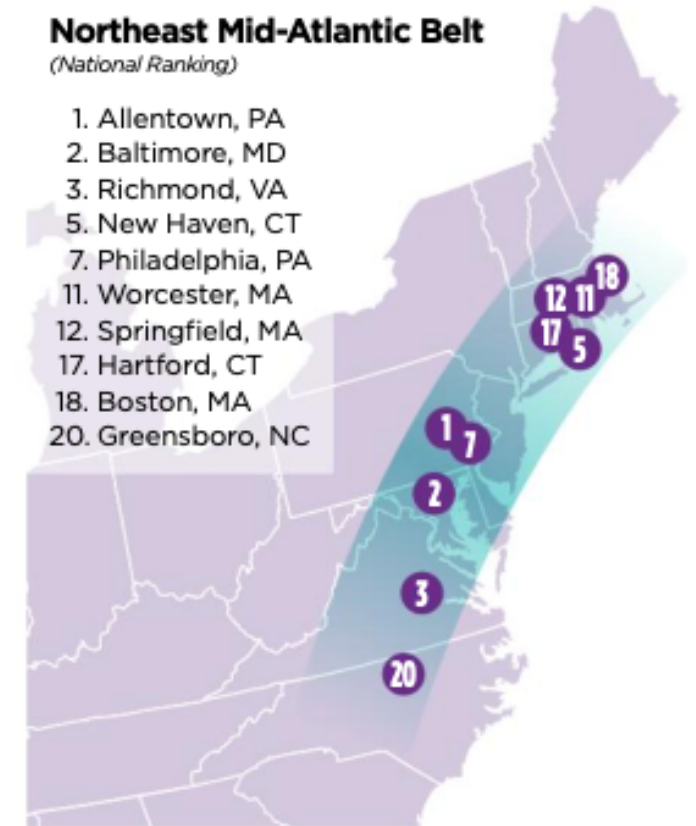


**2021**

## **Northeast Mid-Atlantic Belt**

*(National Ranking)*

1. Allentown, PA
2. Baltimore, MD
3. Richmond, VA
5. New Haven, CT
7. Philadelphia, PA
11. Worcester, MA
12. Springfield, MA
17. Hartford, CT
18. Boston, MA
20. Greensboro, NC



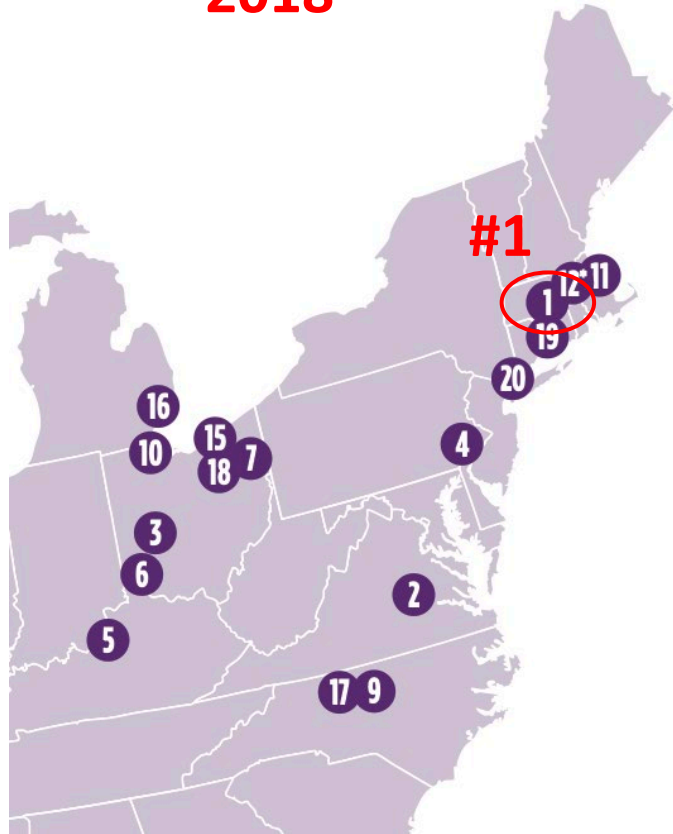
Pioneer Valley – high number of asthma-related ER visits  
– high rate of asthma prevalence, esp. among children.

# Introduction

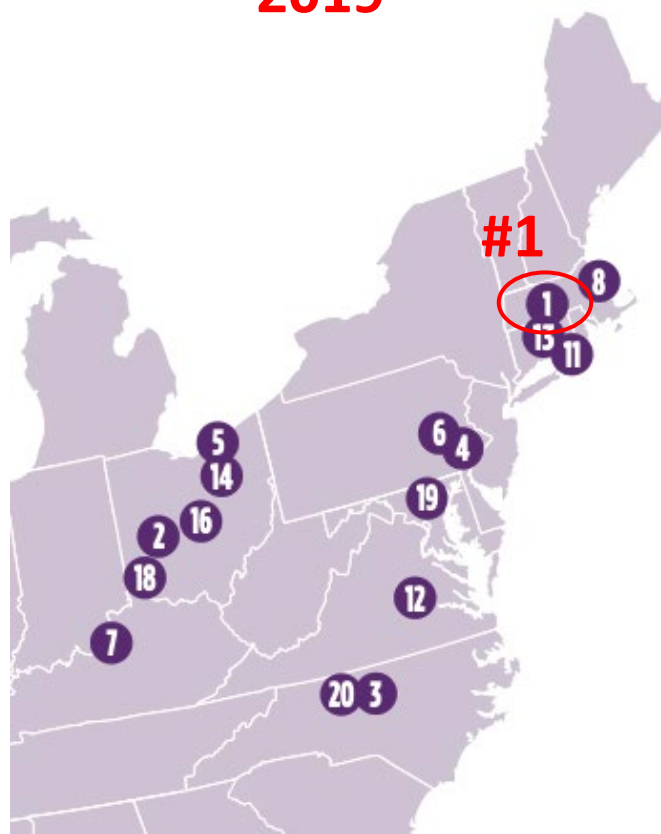
- **The Top 20 Most Challenging Places to Live with Asthma**

*[Asthma Capitals Report by AAFA (Asthma and Allergy Foundation of America)]*

**2018**



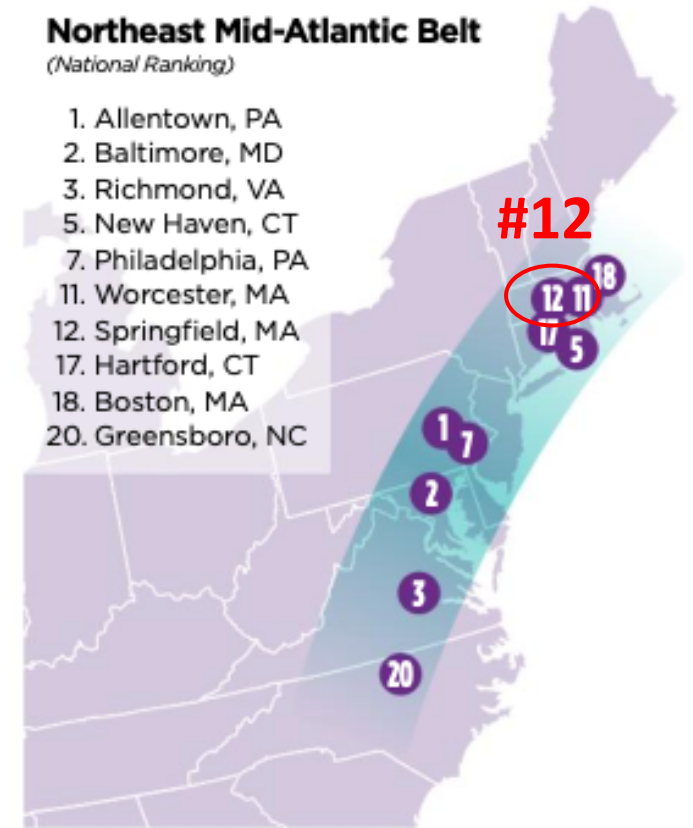
**2019**



**2021**

**Northeast Mid-Atlantic Belt**  
*(National Ranking)*

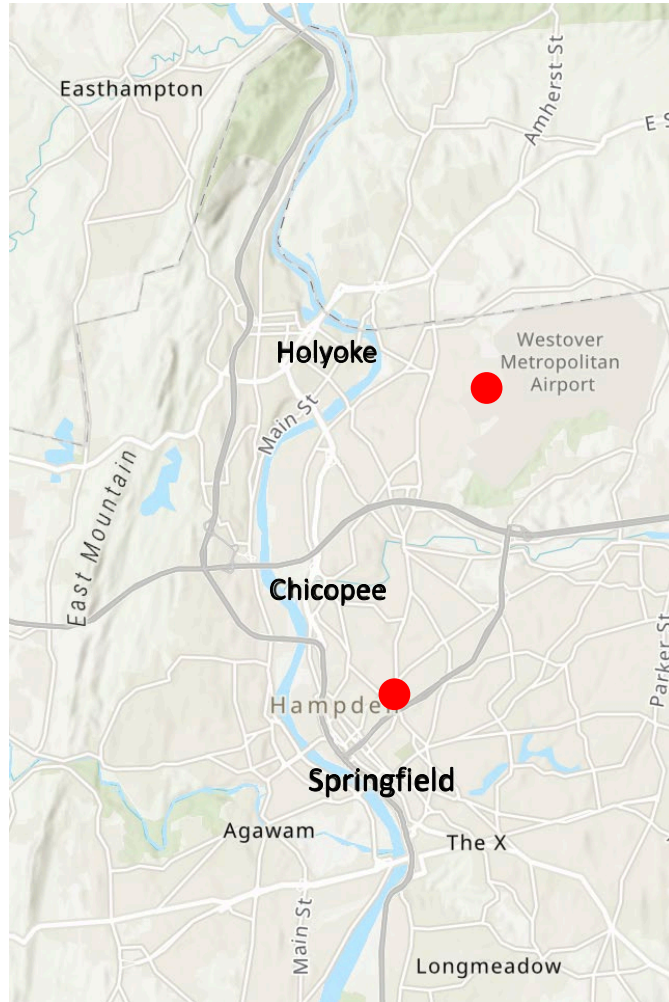
1. Allentown, PA
2. Baltimore, MD
3. Richmond, VA
5. New Haven, CT
7. Philadelphia, PA
11. Worcester, MA
12. Springfield, MA
17. Hartford, CT
18. Boston, MA
20. Greensboro, NC



Pioneer Valley – high number of asthma-related ER visits  
– high rate of asthma prevalence, esp. among children.

# Introduction

- Air pollution is one of the key risk factors in the region affecting asthma outcomes
- Sparse coverage of air quality monitoring



## PurpleAir Sensor

PM mass concentration

*Real-time estimates*



## AirU Sensor

PM mass concentration, reducing and oxidizing gases

*Real-time estimates*



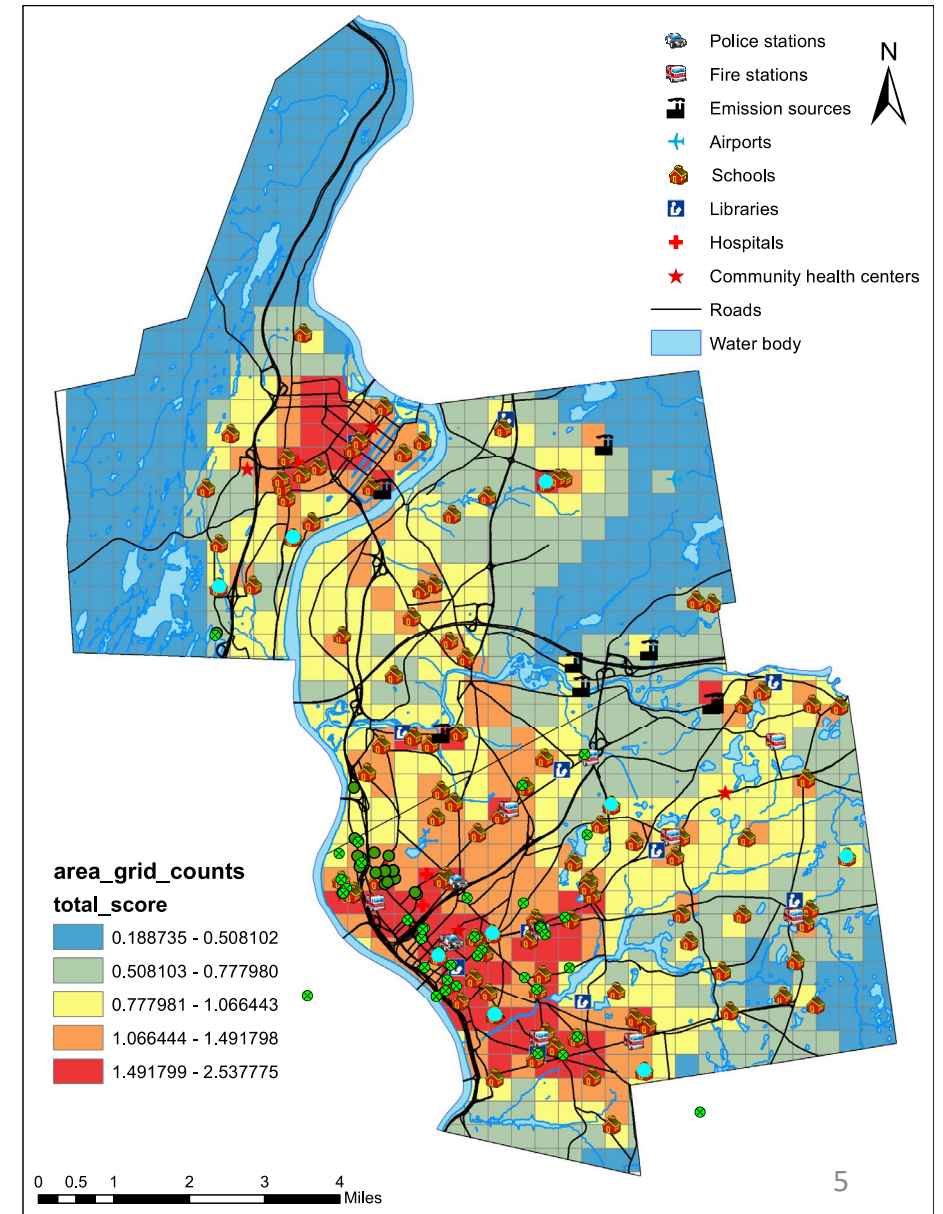
## FreshAir Clip

Air Toxics (VOCs, PAHs, other organic gases)

*2-week integrated averages*

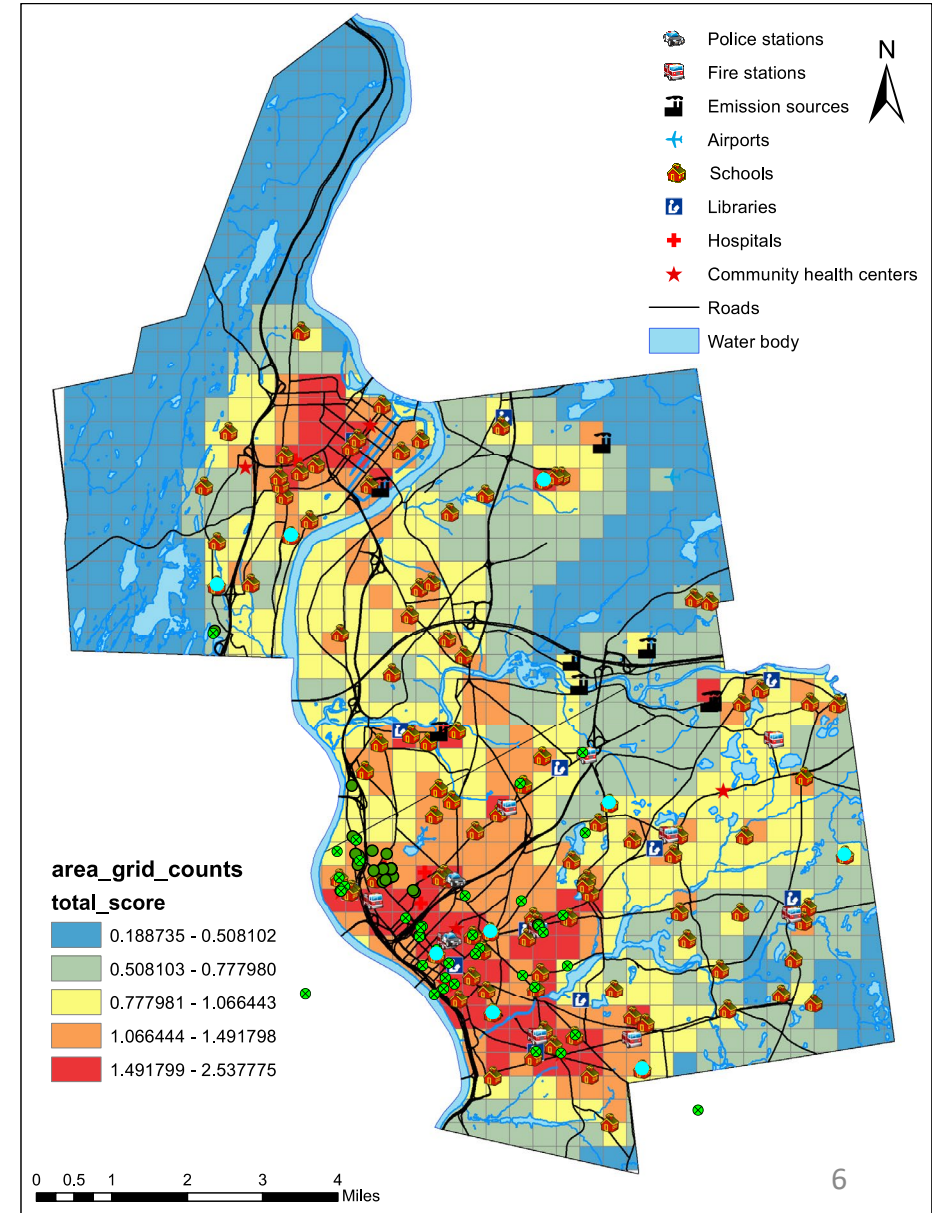
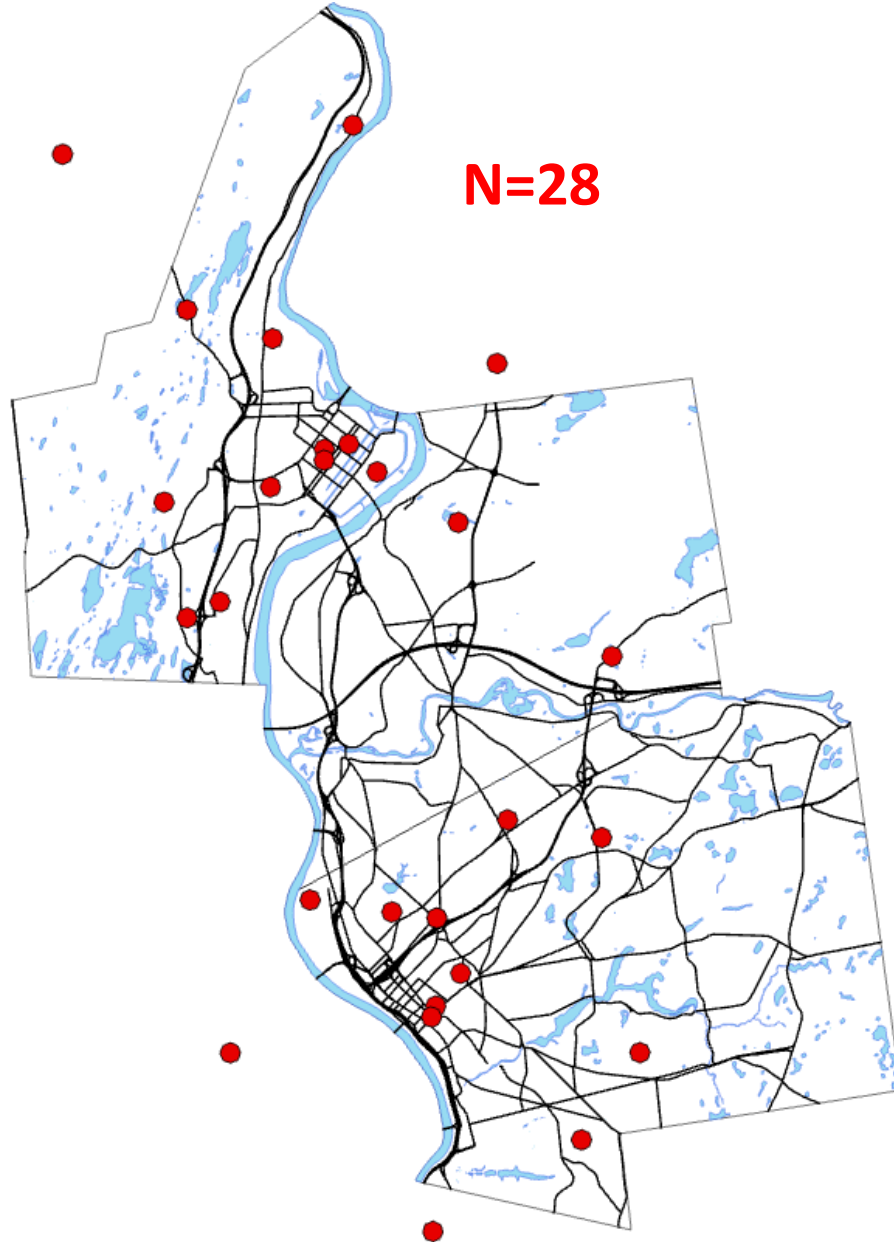
# Sensor Deployment

- **Suitability Analysis – weighted site selection**
- **Criteria**
  - Traffic
  - Emission sources – e.g., airports, identified sources from EPA emission inventory
  - Population characteristics  
population density, sensitive population
  - Convenience for install – city-owned facilities
- **65 monitoring locations in the cities of Holyoke, Chicopee and Springfield**



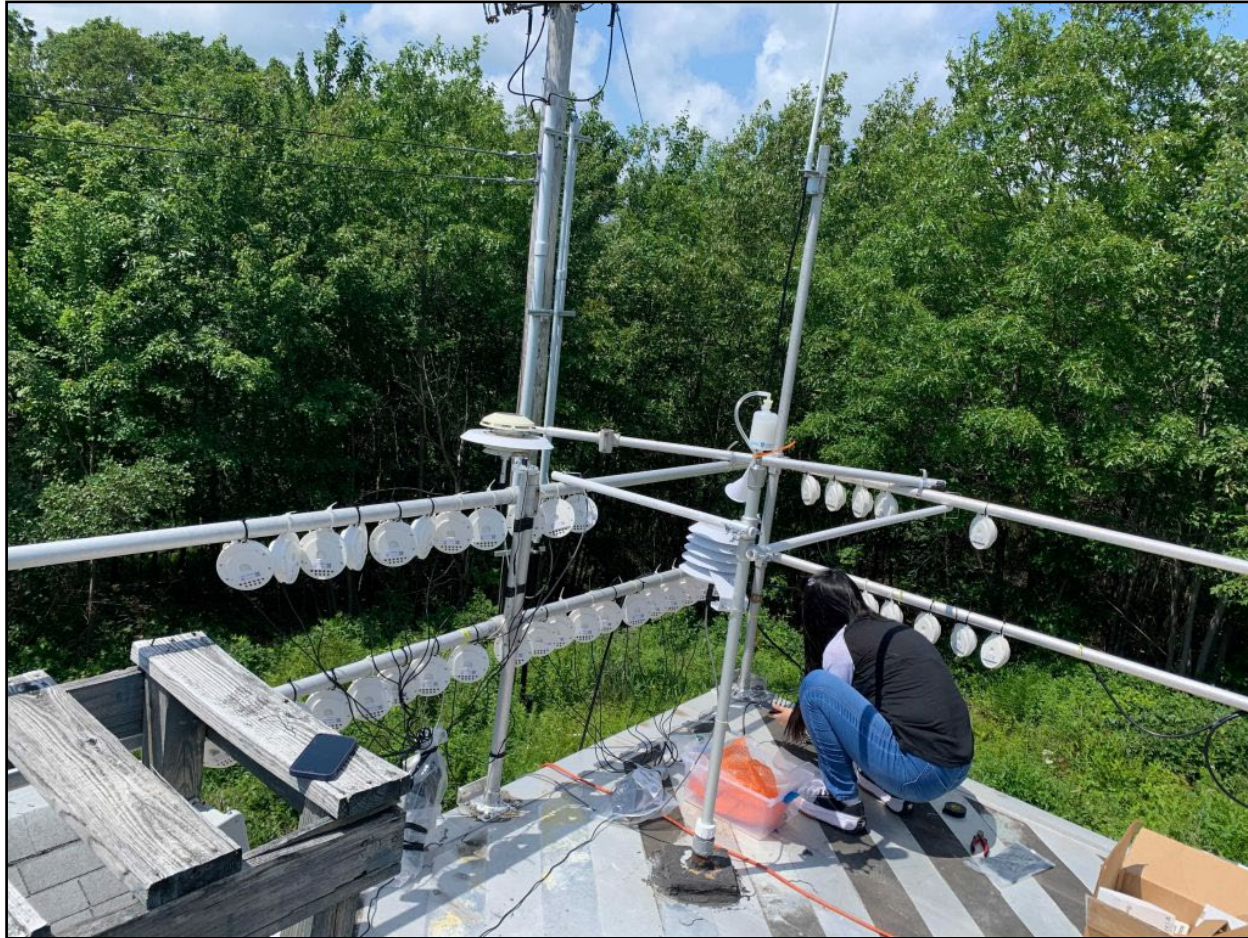
# Sensor Deployment

- Suitability Ar
- Criteria
  - Traffic
  - Emission sources fr
  - Populatio populatio
  - Convenie
- 65 monitorin
- Chicopee anc



# Sensor Calibration

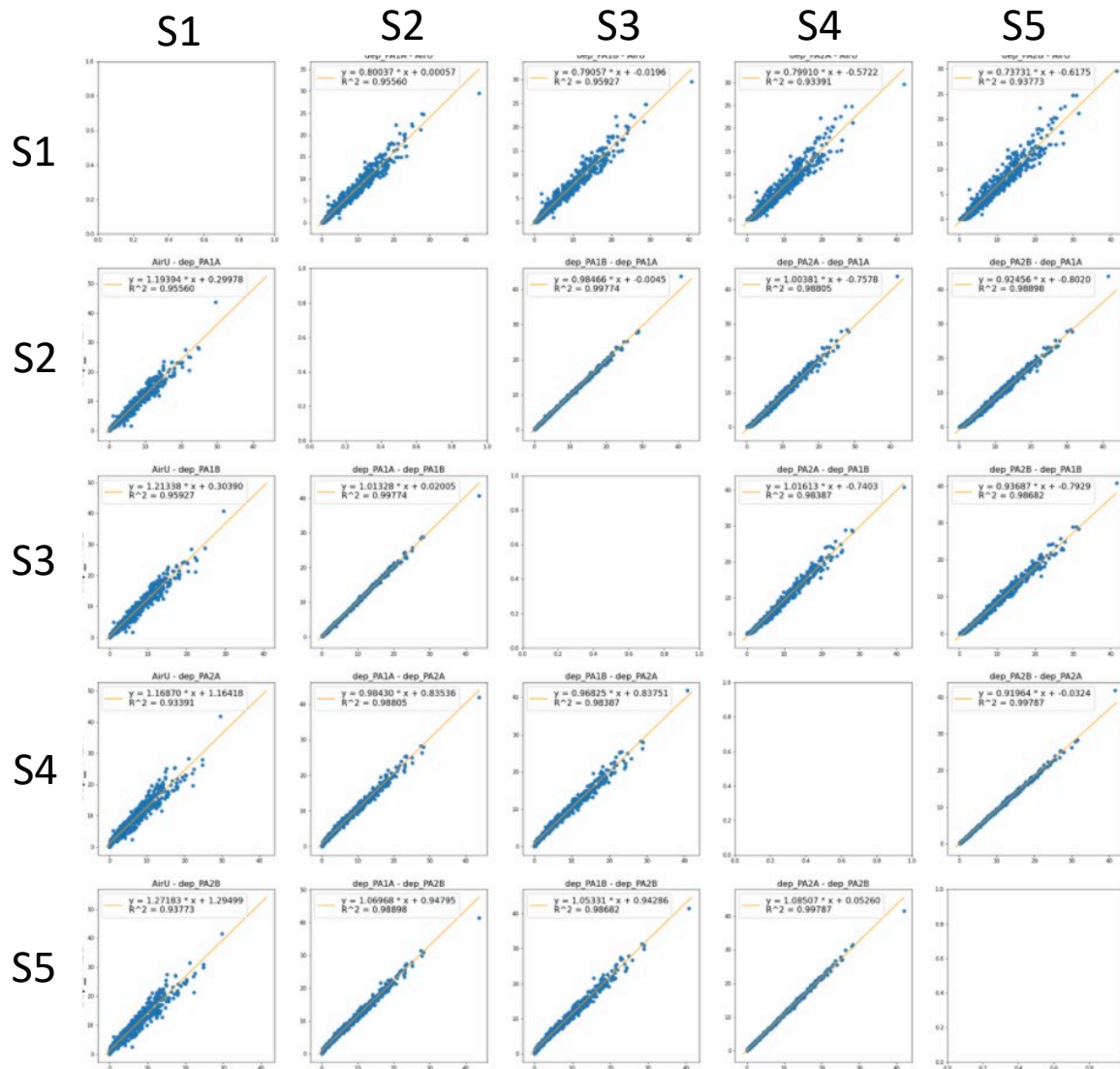
- Pre-deployment Calibration



- The sensors were collocated with regulatory grade reference monitors in field for 2~3 weeks.
- The sensors are exposed to realistic environmental conditions and realistic pollution concentrations.

# Sensor Calibration

- Pre-deployment Calibration



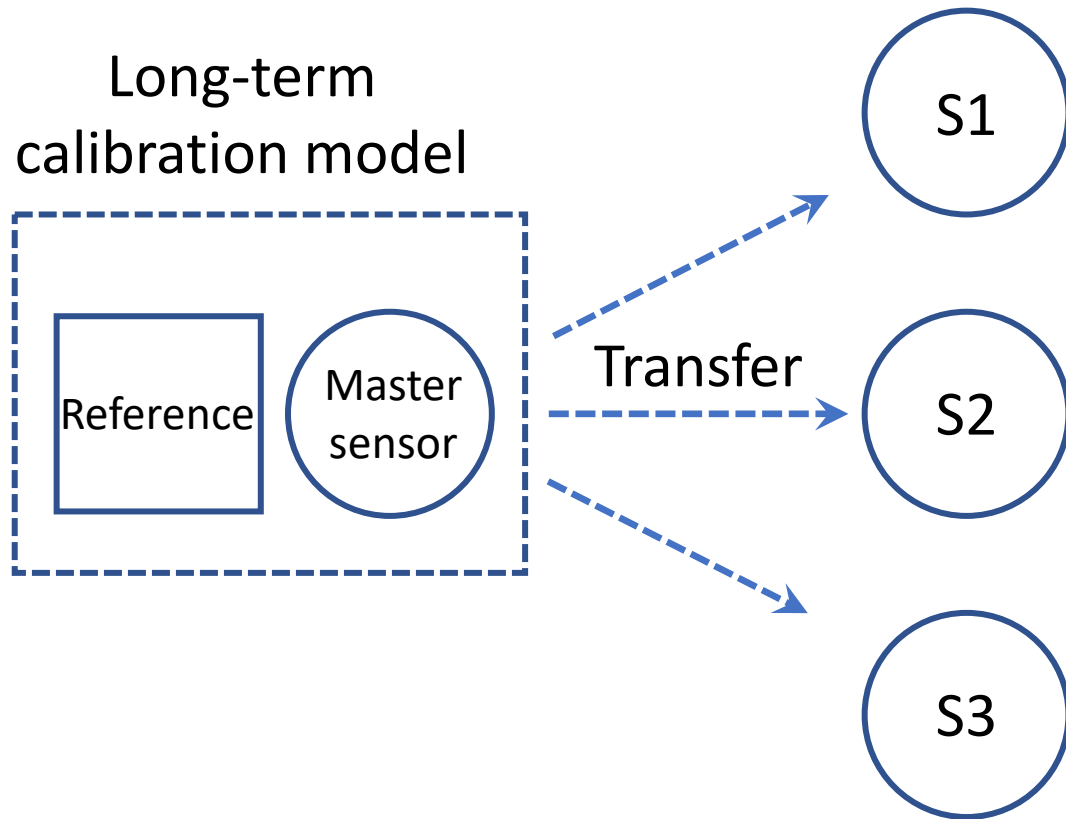
- Capture sensor behavior within expected concentration ranges
- Identify baseline shift, invalid readings (esp. readings in low PM range).

➔ **Master sensor** ➔ All the other sensors standardize their raw data individually to the master sensor readings based on inter-sensor relationships.



# Sensor Calibration

- Post-deployment Calibration



Calibration models:

- Simple linear regression

$$PM_{2.5} = a * sensor + b$$

- Multivariate regression

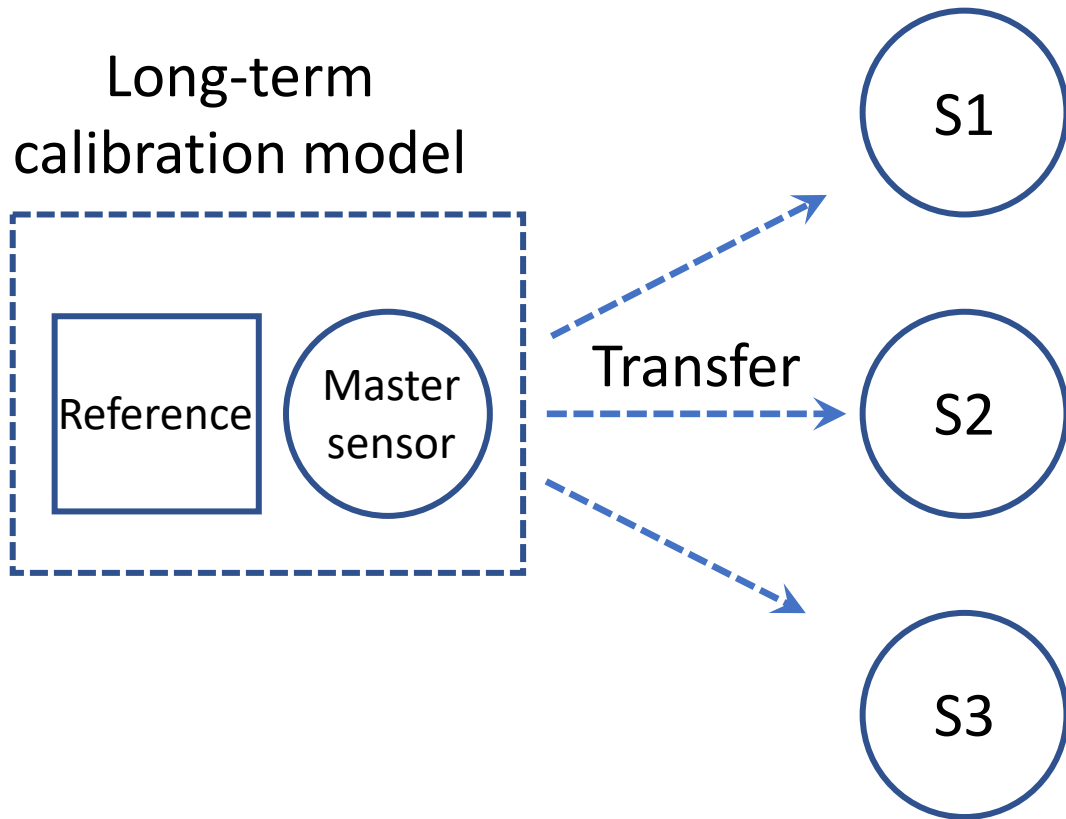
$$PM_{2.5} = a_1 * sensor + a_2 * RH + b$$

$$PM_{2.5} = a_1 * sensor + a_2 * \frac{RH^2}{1 - RH} + b$$

$$PM_{2.5} = a_1 * sensor + a_2 * Temp + a_3 RH + b$$

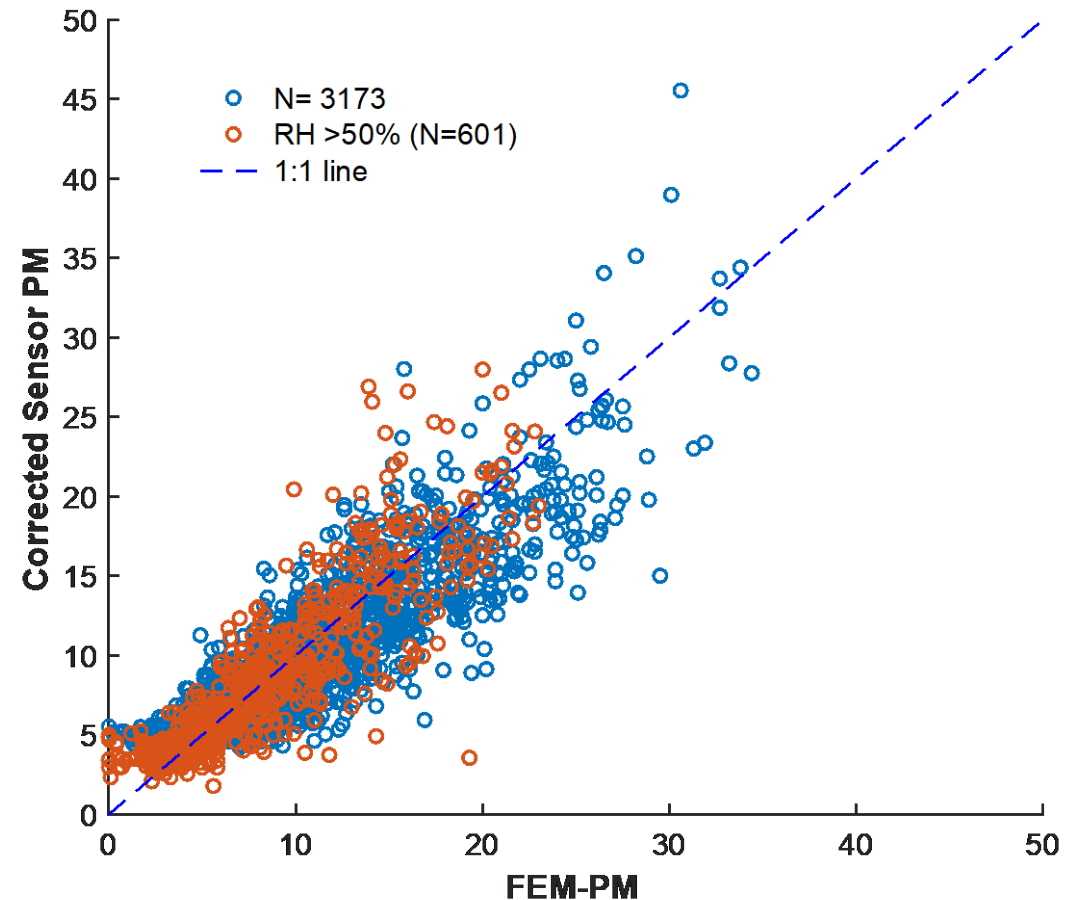
# Sensor Calibration

- Post-deployment Calibration

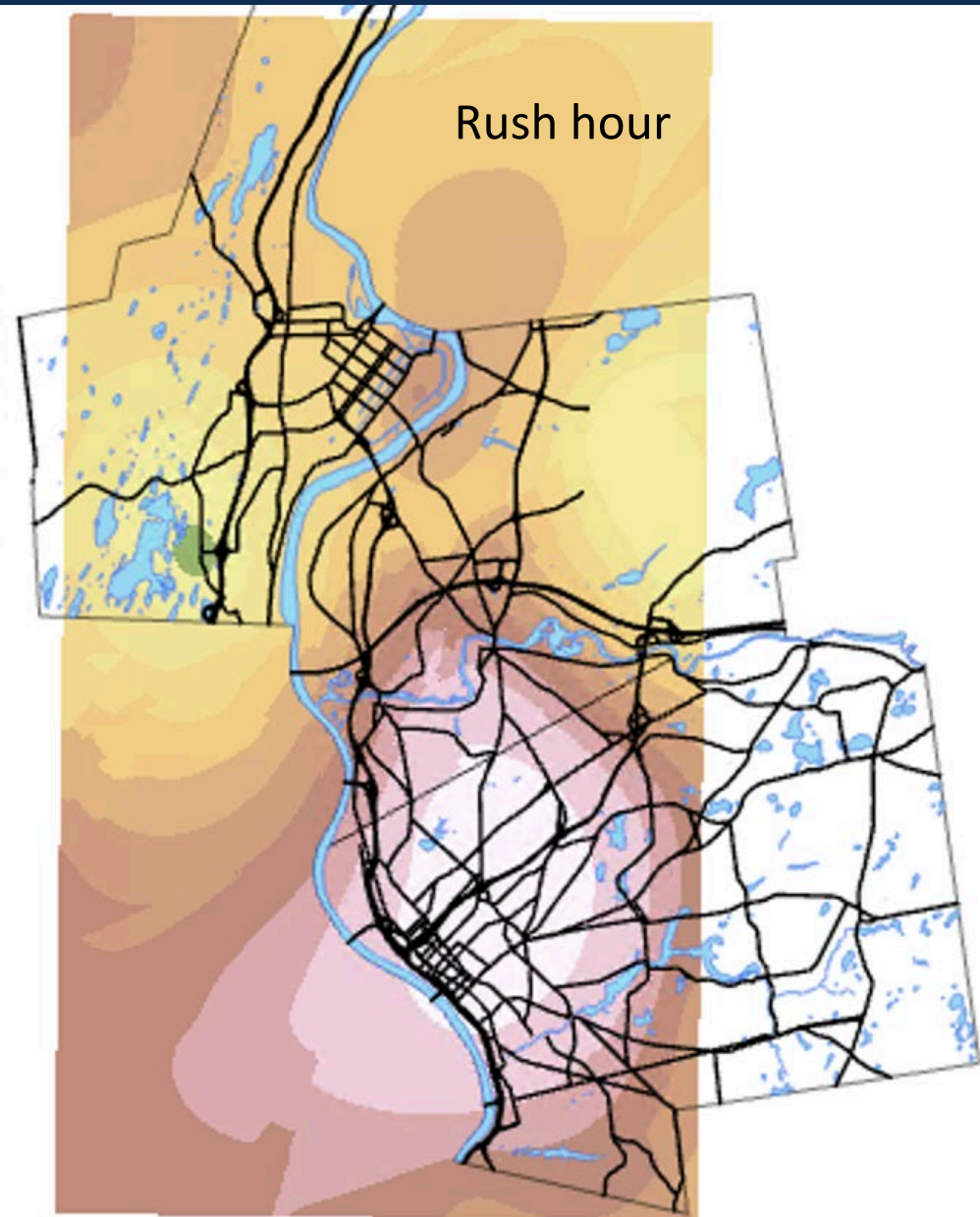
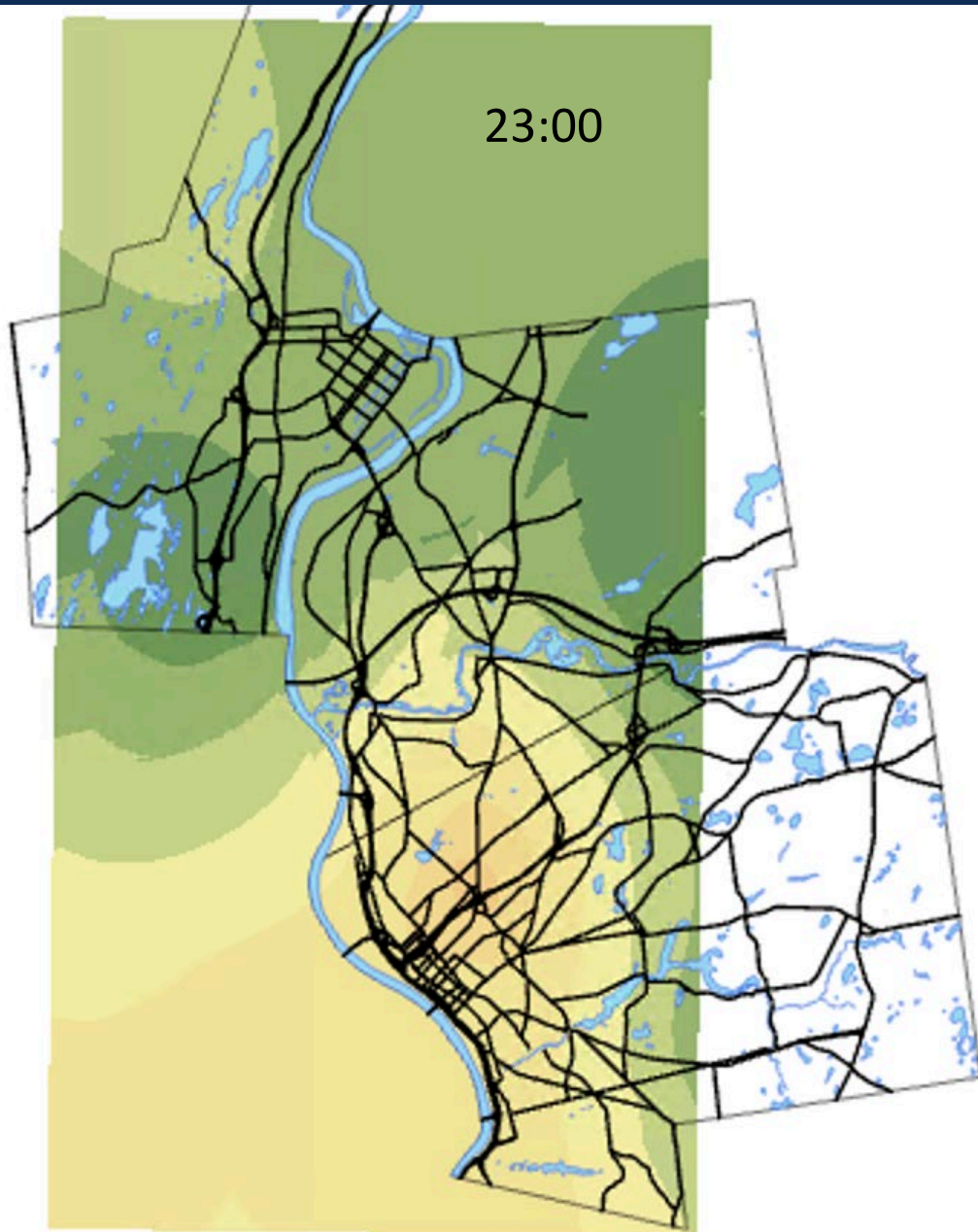


$$PM_{2.5} = 0.443 * sensor - 2.12 * \frac{RH^2}{1 - RH} + 5.14$$

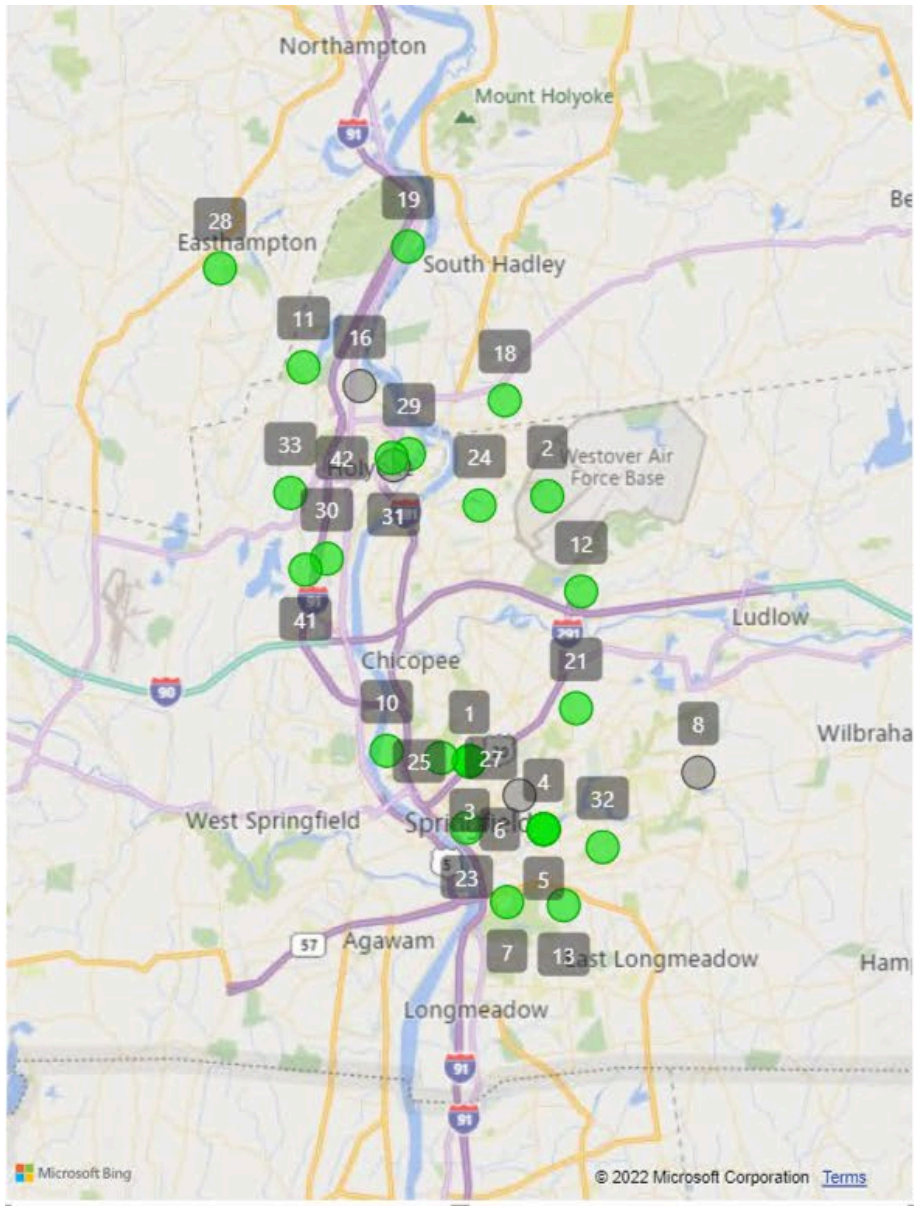
$$R^2 = 0.775 \quad RMSE = 2.49$$



# Sensor Calibration



# Sensor Health Dashboard



## Map Coloring

- air quality
- problem

## Calibration

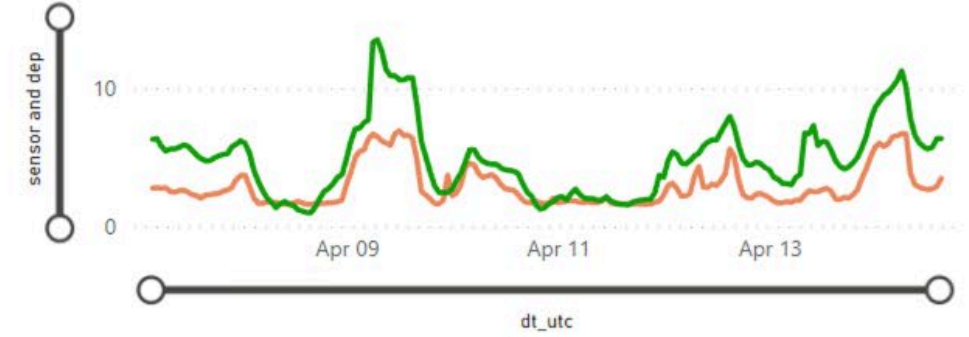
- calibrated
- raw

## Sensor Type

- Select all
- PurpleAir
- Tetrad

## PM 2.5

sensor dep

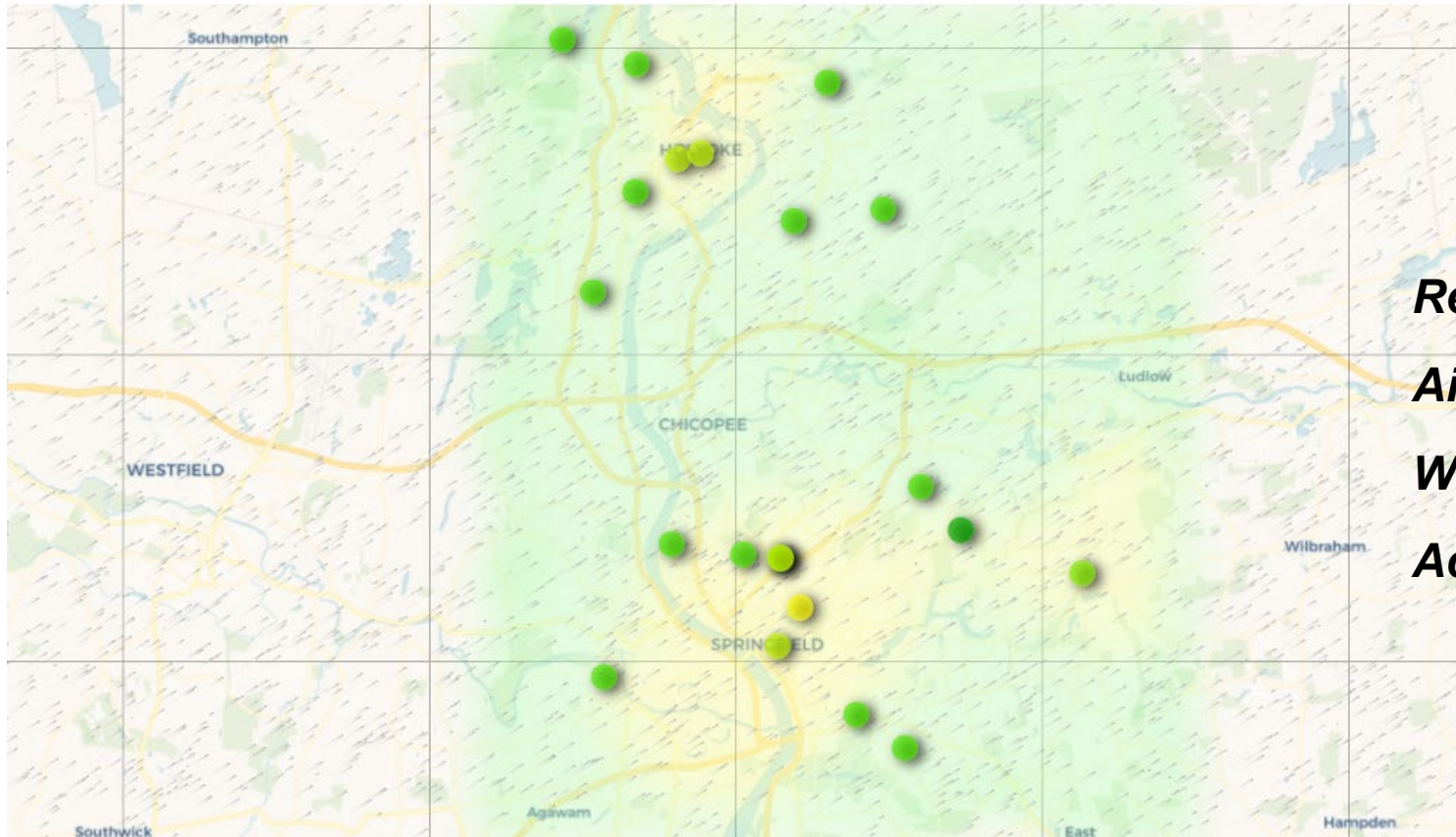


#	Sensor Info	PM (last 7 hrs)	Valid Data (last 7 days)	Hardware (PA only)	Problem Summary (PA only)
3	104290		71.53%		
4	Springfield College Main Campus 2	9.2 $\mu\text{g}/\text{m}^3$	4773 reads in last 7 days	unstable: -84db	WIFI unstable
5	Springfield College Main Campus 3	0.2 $\mu\text{g}/\text{m}^3$	4949 reads in last 7 days	unstable: -82db	WIFI unstable; Channel A downgraded; Low confidence between two channels: 2%
6	Springfield College Main Campus	7.6 $\mu\text{g}/\text{m}^3$	5028 reads in last 7 days	weak: -76db	WIFI weak
7	PVHealthyAir_ResidentHome_EW	5.5 $\mu\text{g}/\text{m}^3$	4236 reads in last 7 days	unstable: -82db	WIFI unstable



## Explore Air Quality in the Pioneer Valley

Each circle on the map shows an air monitor in the Pioneer Valley Healthy Air Network. The color will change based on measured air quality. You can click on each circle for more information about the monitoring site. The grey moving lines show the current wind conditions.



***Real time PM2.5 and AQI***

***Air quality contour map***

***Wind information***

***Activity recommendations***

# Acknowledgement



**Krystal Pollitt**

Assistant Professor  
Yale School of Public Health



**Jiarong Qi**

Research Assistant  
Yale School of Public Health



**Mahea Heimuli**

Undergraduate Student  
Yale School of Engineering and Applied Science



**Sarita Hudson**

Director of Programs and Development  
Public Health Institute of Western Massachusetts



**Samantha Hamilton**

Live Well Springfield Manager  
Public Health Institute of Western Massachusetts



**Kayla Fennell**

Undergraduate Student  
Mt. Holyoke College



**Anna Woodroof**

Senior Program Manager  
Earthwatch Institute



**David Bloniarz**

President  
Regreen Springfield



**Yoni Glogower**

Conservation & Sustainability Director  
City of Holyoke



**Alexander Sherman**

City Forester  
City of Springfield

- Funded by the Massachusetts Attorney General's Office's Environmental Protection Division and the Massachusetts Municipal Vulnerability Program.