High Resolution Particulate Matter Exposure Data for Health Applications

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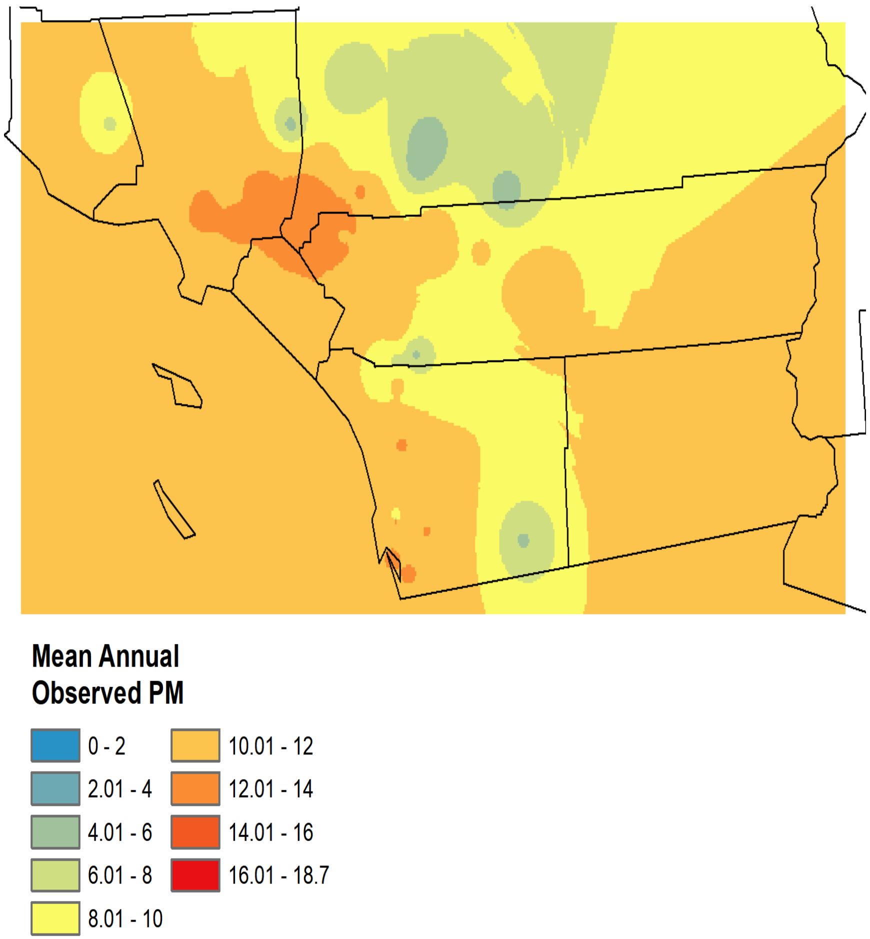
NASA

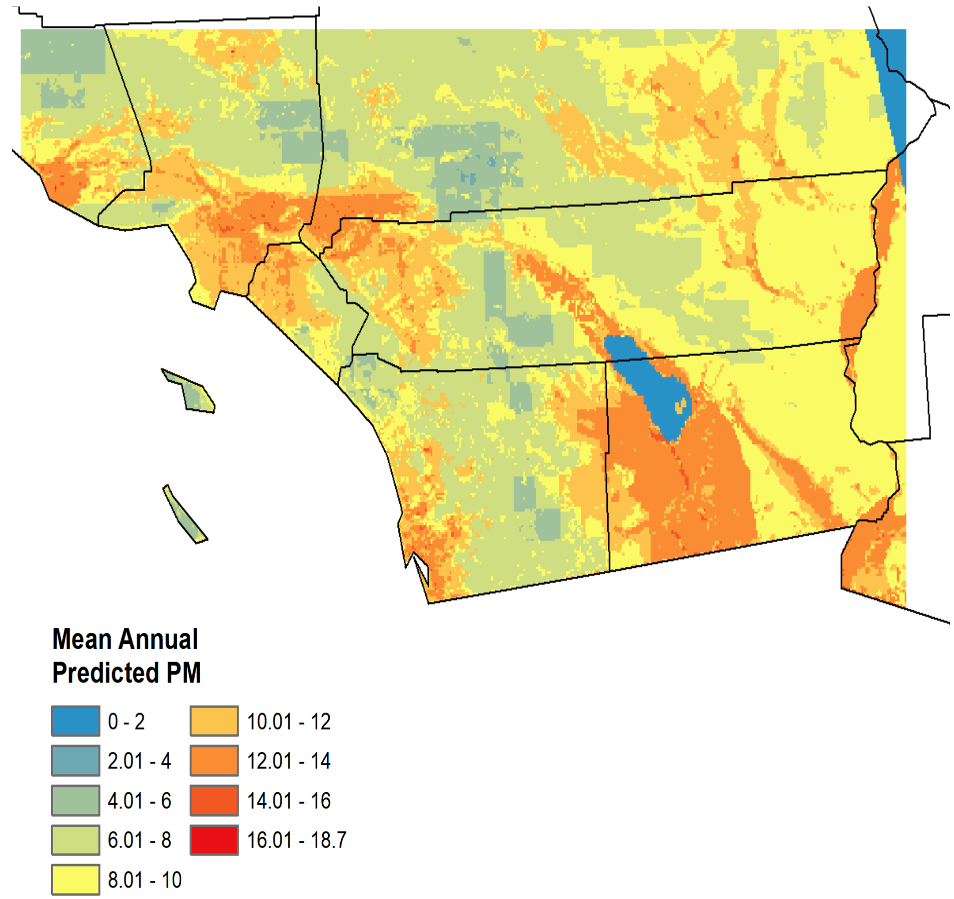
Annual Average PM2.5 in California South Coast Region

Source: Yang Liu

Interpolation from regulatory monitors



Satellite-based estimate



Potential Value of High Resolution Exposure Data for Improved Health

- To support fine scale urban epidemologic studies
- To assess current health burdens at the neighborhood scale using health impact assessment methods
- To identify pollution hot spots at the intra-urban scale, and target needed source reductions
- To track progress in achieving air quality-related health improvement goals
- To quantify health co-benefits of carbon mitigation strategies, helping to prioritize climate solutions being driven by cities

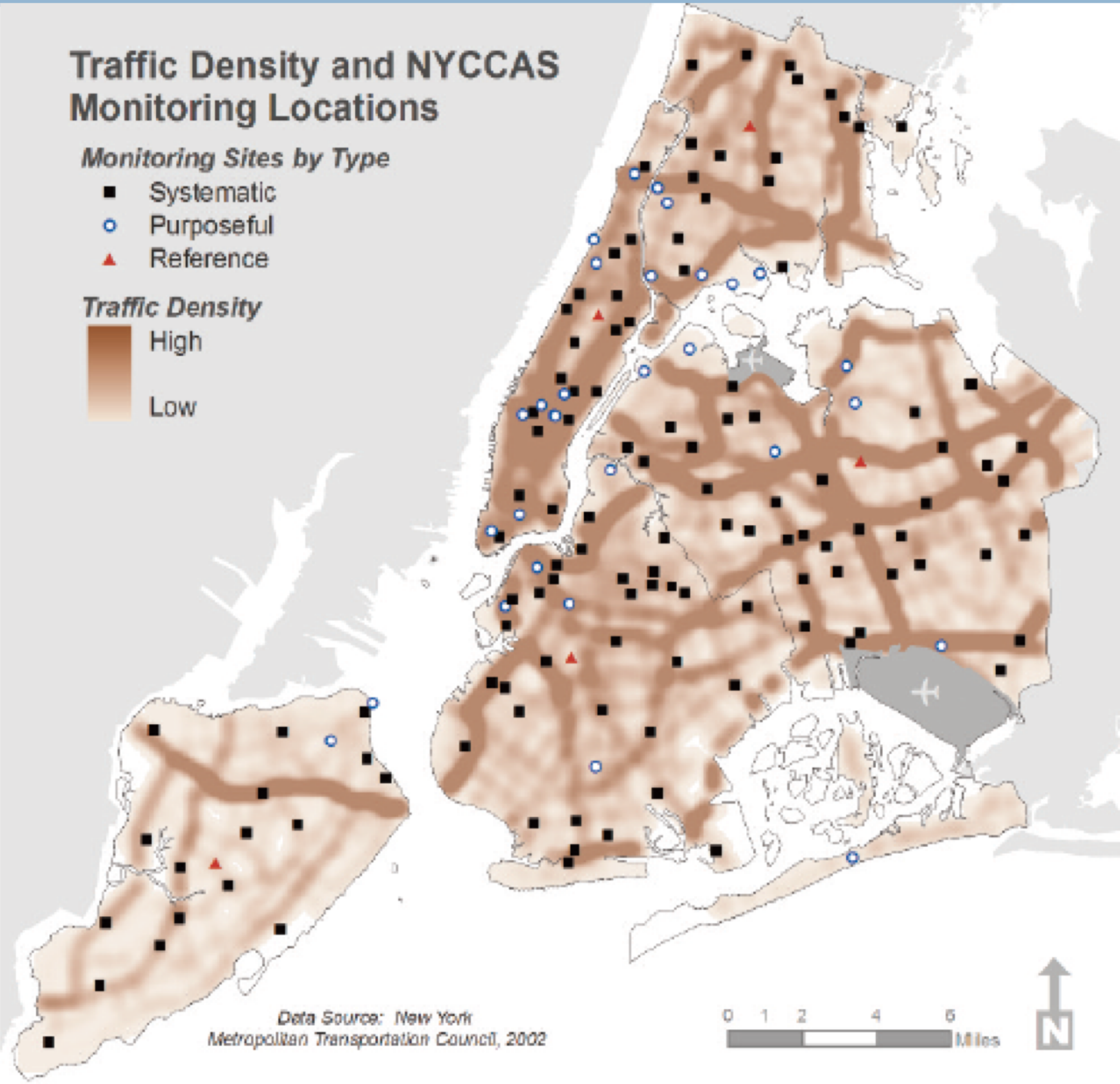
How to Get High Resolution?

- Put out lots of sensors
- Use satellite remote sensing – e.g., MODIS MAIAC retrievals at 1x1 km
- Carry out air quality modeling at fine spatial scales
- Combine several of these

Sensor Example:
New York City Community Air Survey

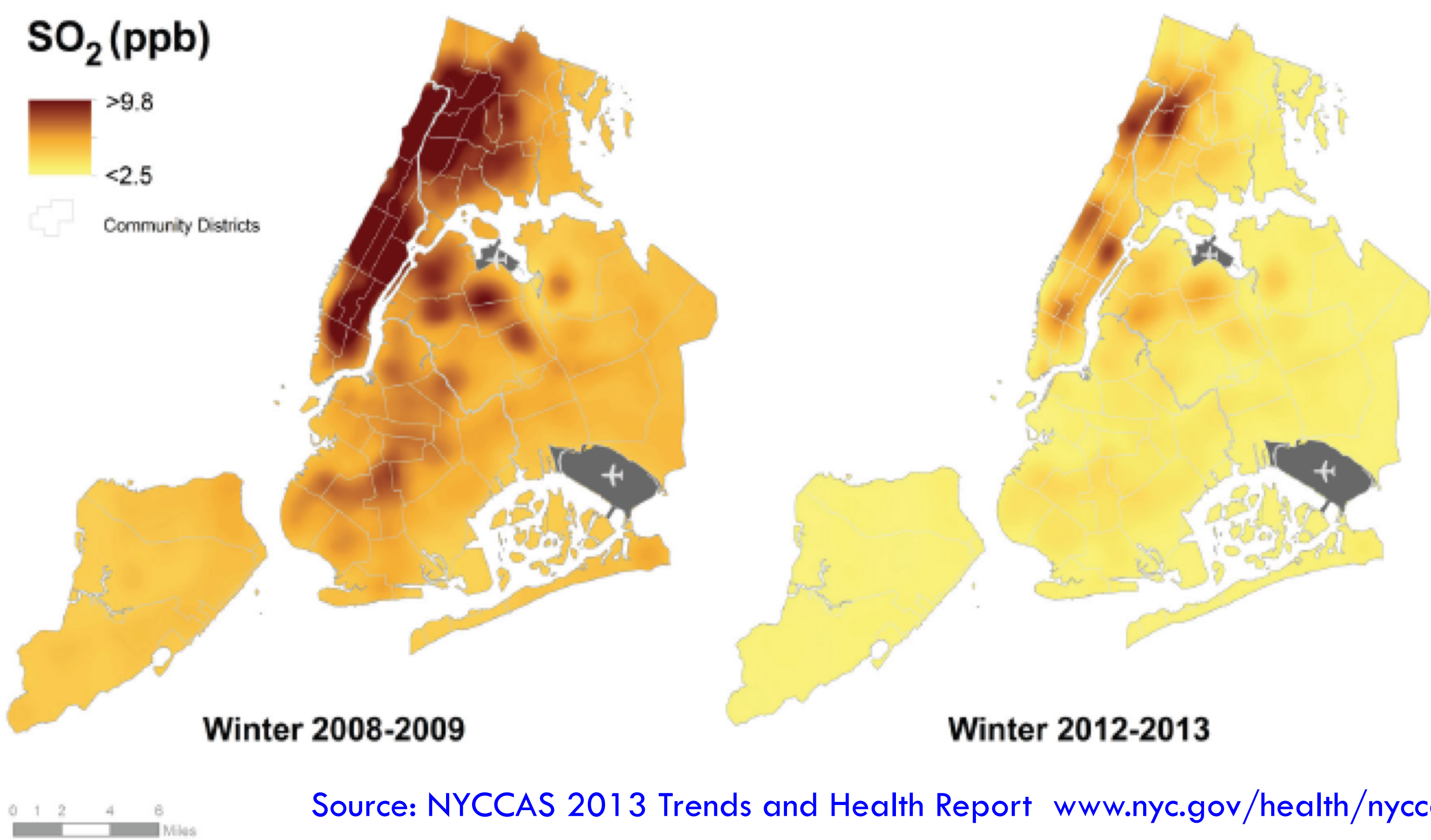
NYCCAS Air Sampling Unit

NYCCAS Winter 08/09 Report
www.nyc.gov/health/nyccas



Initial hi-res exposure data (left) revealed local air impacts of residual oil burning; Clean fuel intervention led to a striking decreases in winter SO_2 concentrations (right)

Figure 3: Estimated SO_2 Concentrations, winter 2008-2009 and winter 2012-2013



Source: NYCCAS 2013 Trends and Health Report www.nyc.gov/health/nyccas

“Hi-Res” Tiger Team Objectives
(abbreviated)

1. Pilot test and evaluate a novel low-cost passive sampler for long-term monitoring of $PM_{2.5}$, including elemental composition.

   Applied in: Boston, NYC, San Francisco Bay Area, Seattle

2. Generate high-resolution $PM_{2.5}$ concentration maps using 1 km MAIAC MODIS/AOD retrievals, surface measurements, land use data, and air dispersion modeling

   Being applied in: NYC, Los Angeles, Imperial Valley CA, Wash. DC

3. Estimate health impacts of $PM_{2.5}$ using outputs from (2)

   See talk by Susan Anenberg later at this meeting

Objective 1. Low-Cost PM Sensors

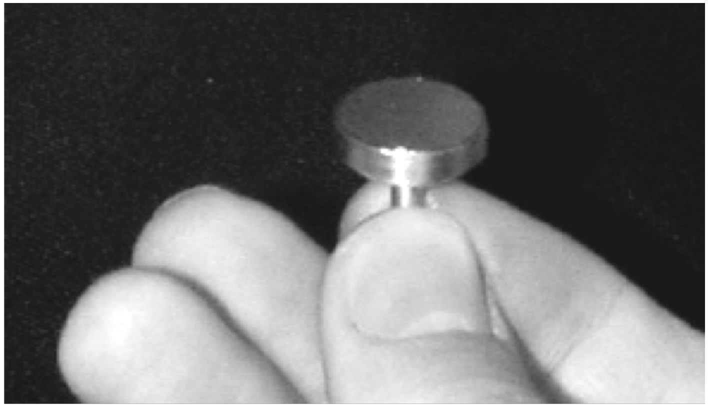
Characteristics:

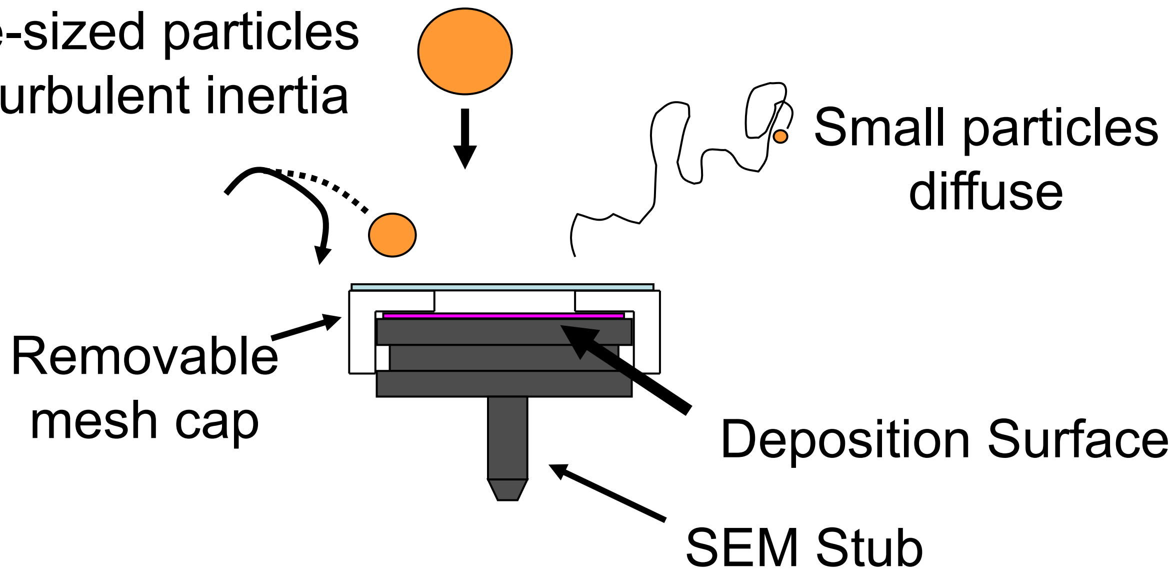
- ***Use light scattering to infer PM mass***
- ***Ideal for short-term sampling on order of seconds-weeks***
- ***Sensitive to humidity variations***
- ***Calibration drift due to soiling of optics***
- ***Require power***
- ***Don't measure PM composition***
- ***No archived sample***

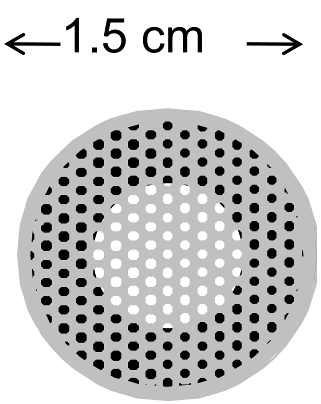
An Interesting Alternative: the UNC Passive Aerosol Sampler

- Innovative sampling technology developed to provide medium to long-term average ambient concentrations of particulate matter (PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$)
- Collects PM in a passive manner, through gravitationally settling and diffusion
- Has been demonstrated to provide coarse PM data that correlate well with FRM samplers

UNC Passive Sampler



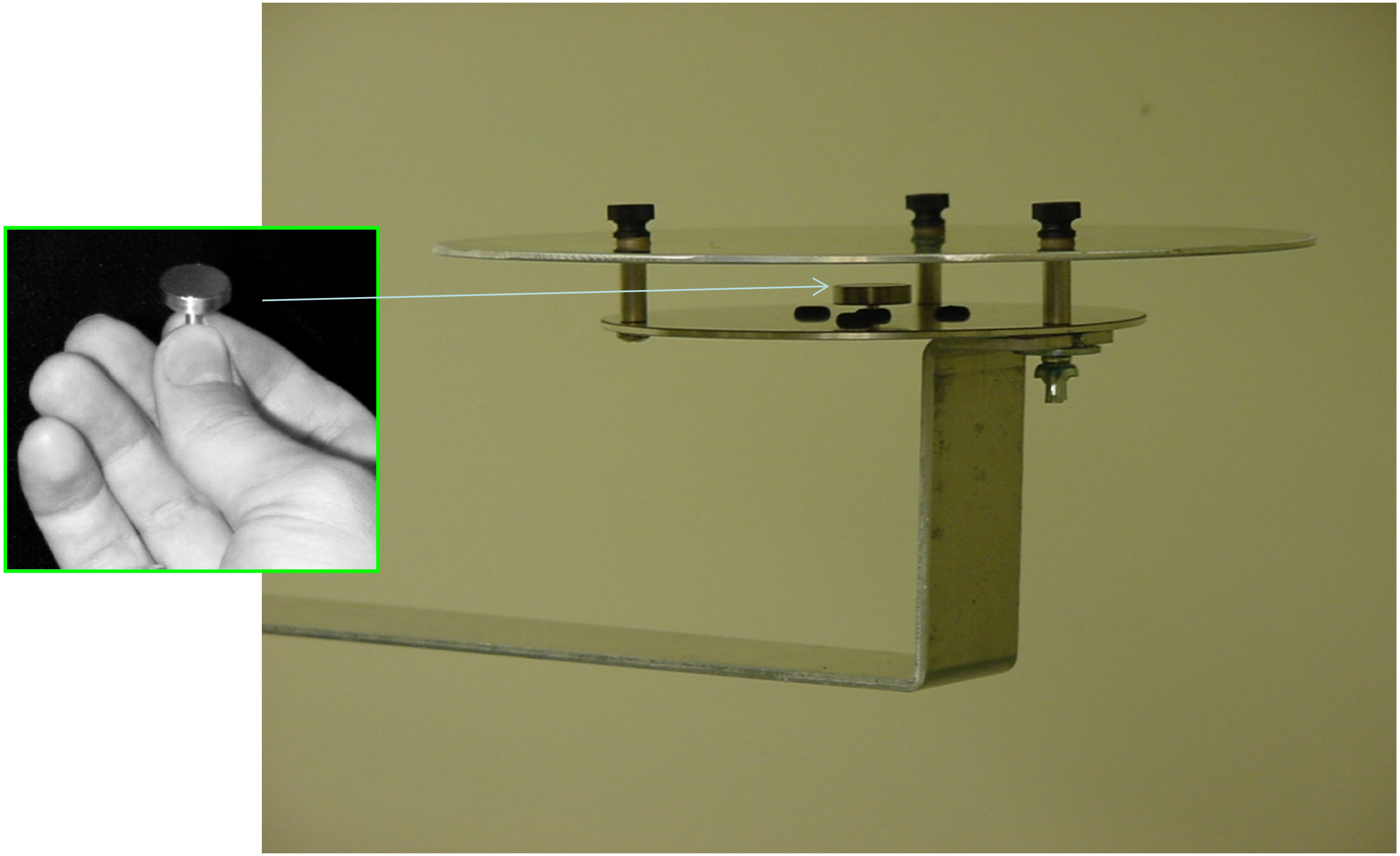




Top View

Wagner and Leith (2001) Aerosol Sci. Technol. 34:186-192

Samplers are placed between aluminum plates to protect from weather and turbulence

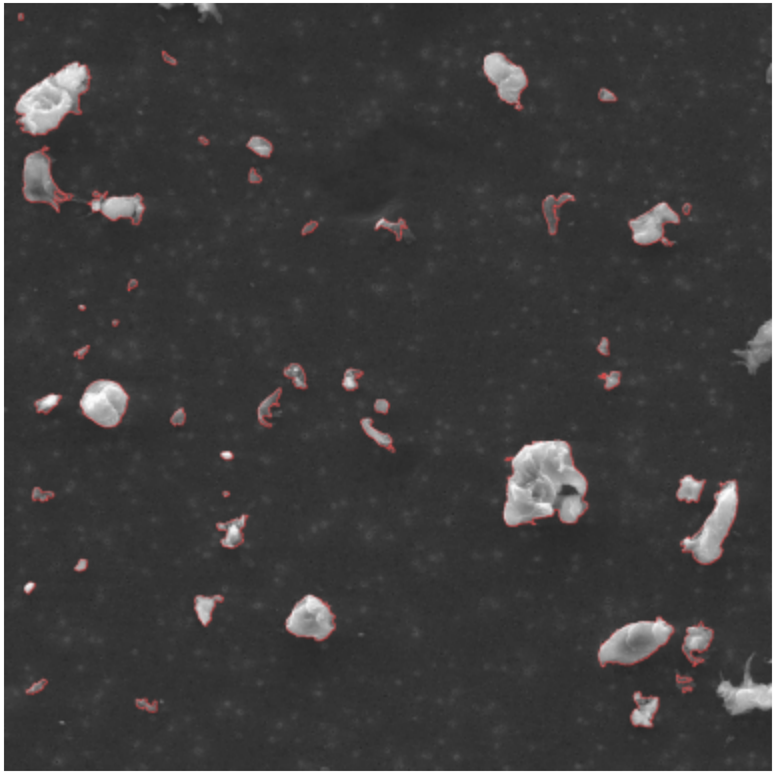


Ott, D. and T. Peters. *Aerosol Science and Technology.* 2008, 42(4), 299-309

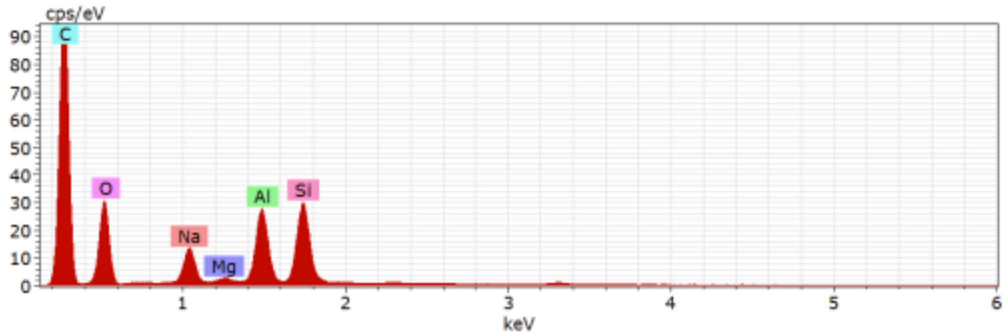
Source: RJLee Group

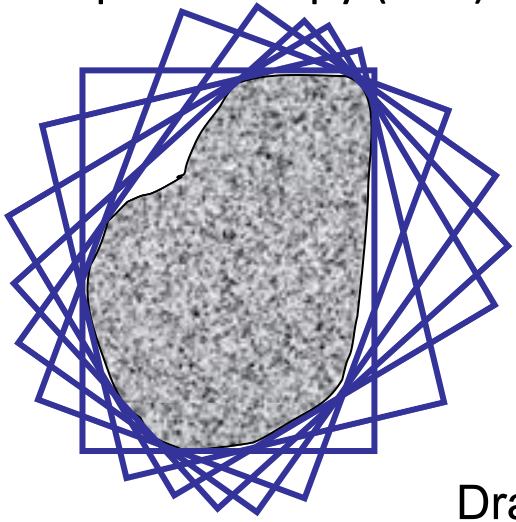

Samplers deployed at Von Hillern MA DEP site adjacent to Rt 93 in Boston
Shelter 094
Shelter 153

Automated PM sizing and elemental analysis



- Graphical representation of grayscales in the SEM image is used for particle detection
- Individual particle images are acquired for each individual particle
- 45 Rotating Feret boxes are used to measure each particle (90 diameters)
- Elemental composition is obtained using Energy Dispersive Spectroscopy (EDS)





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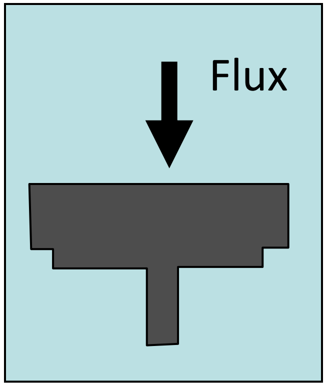
Estimating Airborne Concentration

Flux

Airborne concentration

$$C = \frac{F}{V_{dep}} = \left(\frac{\#}{cm^2\ s}\right)\left(\frac{s}{cm}\right) = \frac{\#}{cm^3}$$

Deposition Velocity = f(diameter)

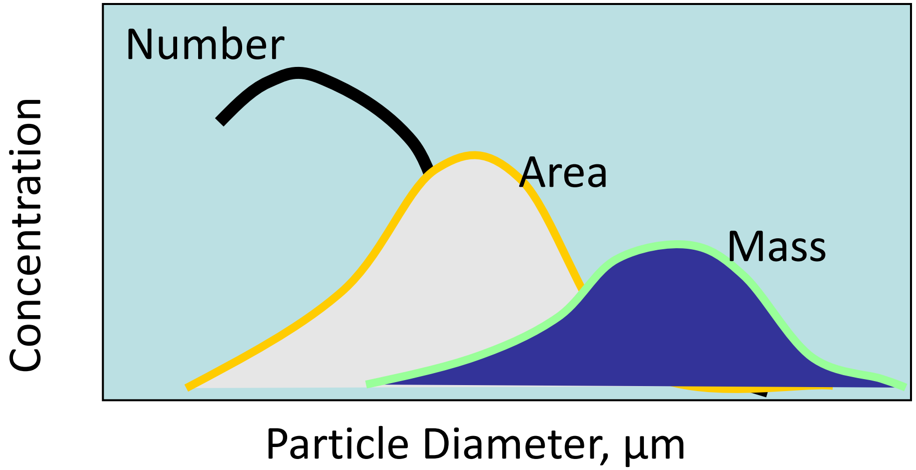


Surface loading from microscope

Flux

$$F = \frac{SL}{t} = \left(\frac{\#}{cm^2}\right)\left(\frac{\ }{s}\right)$$

Sampling time



Progress to Date

Partnerships established in 2017 to co-locate samplers at regulatory monitoring stations

3 sites in Boston have been running since August 2017

2 sites in NYC have been running since October 2017

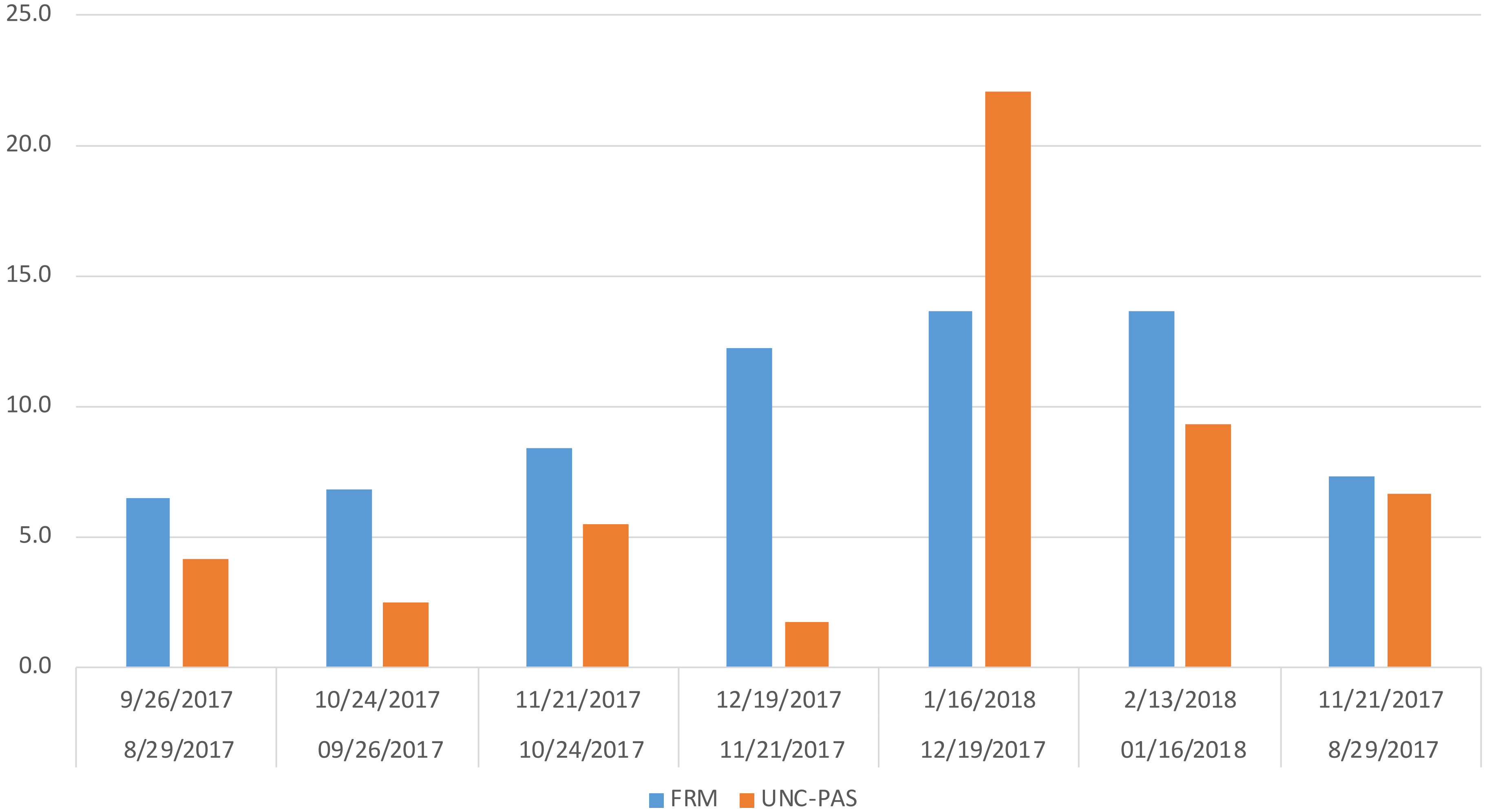
3 sites in SF Bay area have been running since Nov, 2017

At each site: Sequential 1 and 3 month samples; duplicates; field blanks

Particle loadings are light for 1 month samples; good for 3-month samples

Analyses underway to evaluate data in relation to FRM PM2.5

Boston Von Hillern Comparison of FRM and UNC-PAS ($PM_{2.5}$)



Objective 2. Spatial-temporal $PM_{2.5}$ prediction model at 100-meter resolution in NYC using MAIAC AOD +

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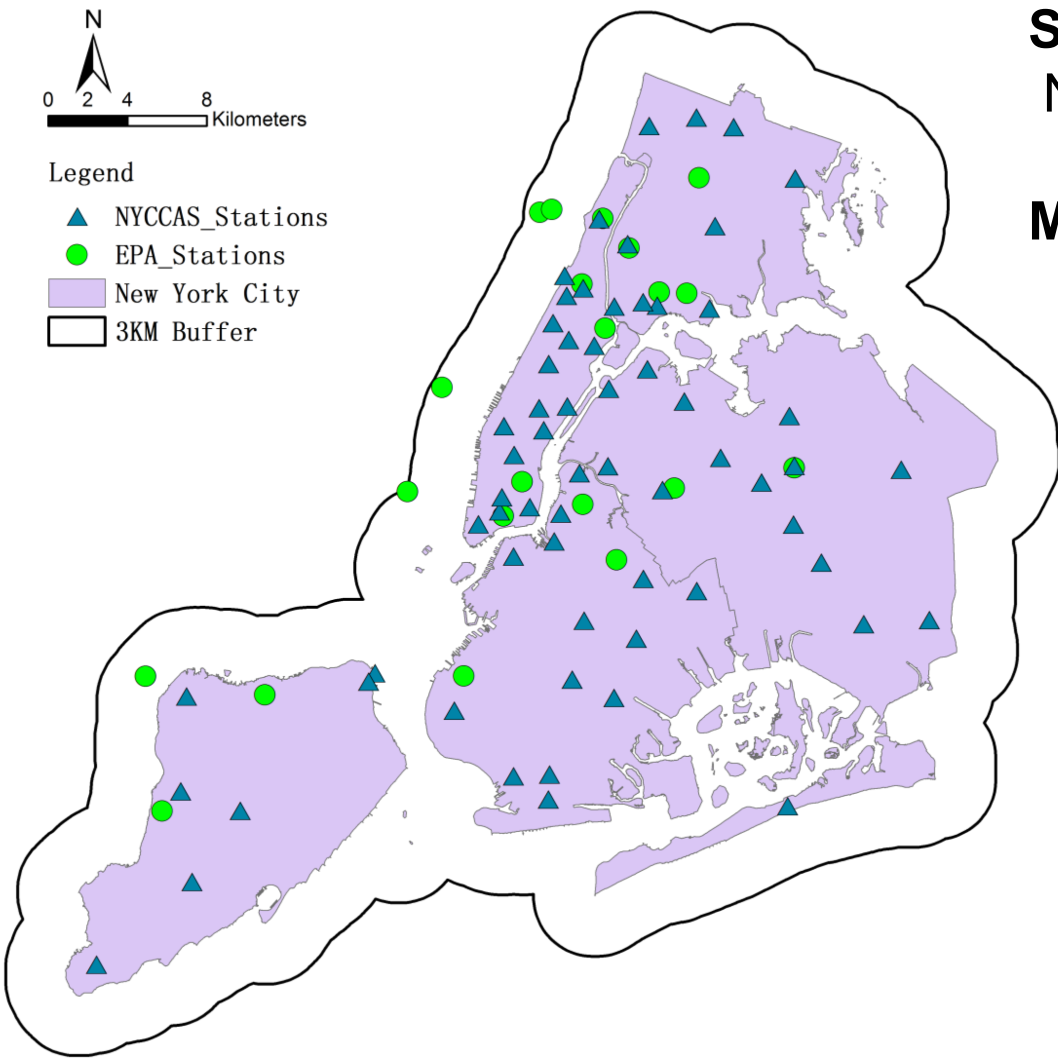
- Objectives
  - To develop a 100-meter resolution spatial-temporal prediction model in NYC, using MAIAC AOD, meteorology, land use and traffic volume data as predictors.
- Methods
  - Machine learning algorithm-random forest
- AOD gap filling
  - Using MODIS snow cover, cloud fraction, meteorology and land use to impute the missing AOD

Study domain and datasets



Study domain:

NYC (789 KM^2) + 3km buffer

Modeling datasets:

- ❑ Regulatory "EPA" $PM_{2.5}$ monitoring data
- ❑ NYCCAS $PM_{2.5}$ monitoring data
- ❑ MAIAC AOD data
- ❑ NLDAS meteorology
- ❑ Weather Underground meteorology
- ❑ NYC traffic volume
- ❑ NLCD land use
- ❑ MODIS NDVI
- ❑ US Census

Annual average $PM_{2.5}$ estimates using just regulatory sites (left) and regulatory+NYCCAS sites (right)

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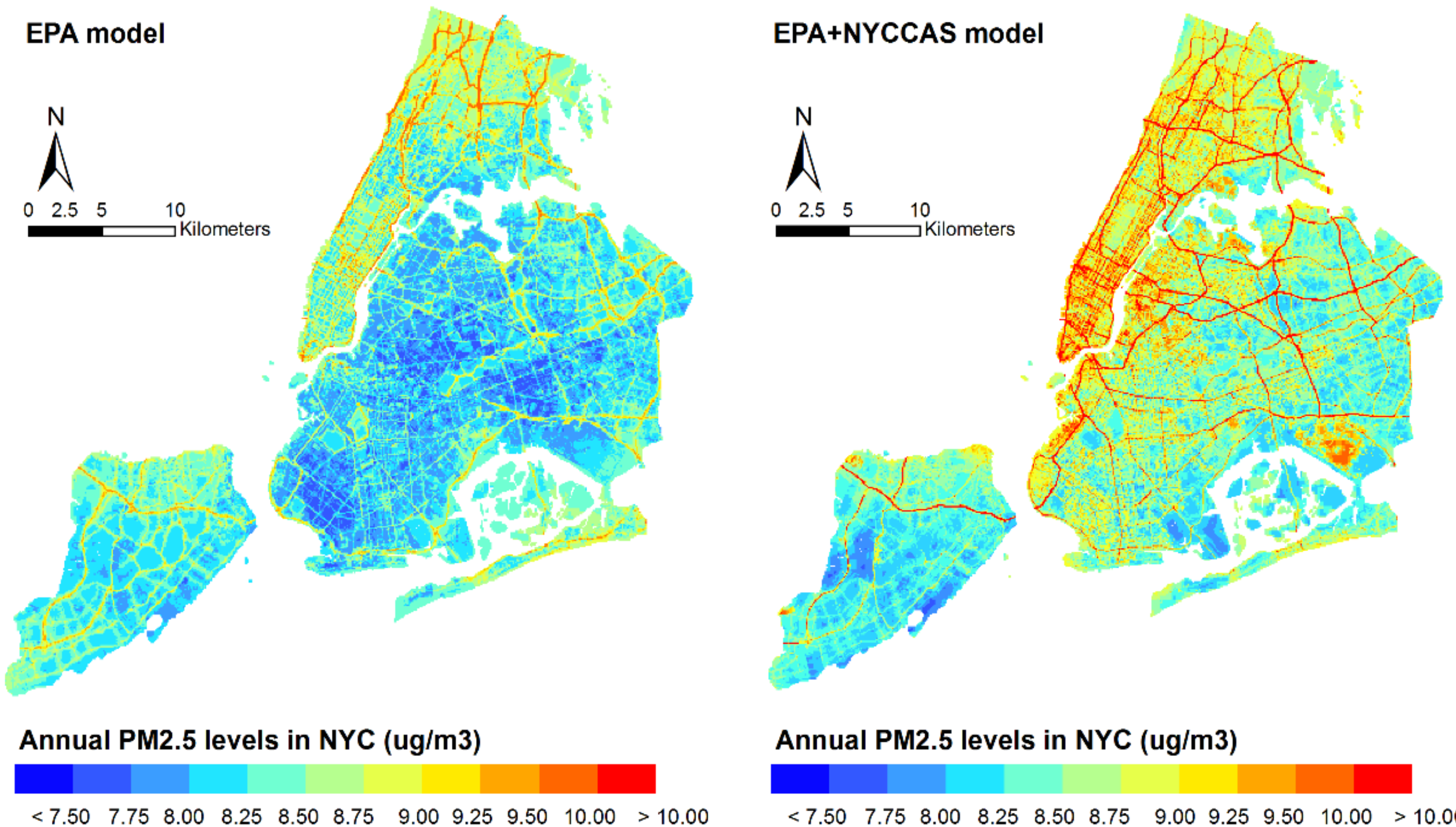

HAQAST Participants

- Pat Kinney (Boston University) and Frank Freedman (San Jose State Univ) – Co-Leads
- Mohammad Al-Hamden (NASA)
- Susan Anenberg (George Washington Univ.)
- Arlene Fiore (Columbia Univ.)
- Daven Henze (Univ. of Colorado – Boulder)
- Jeremy Hess (Univ. of Washington)
- Yang Liu (Emory Univ.)
- Susan O'Neill (US Forest Service)
- Daniel Tong (George Mason Univ.)
- Akula Venkatram (UC Riverside)
- Mark Zondlo (Princeton Univ.)

External Partners

- **Massachusetts Department of Environmental Protection**
  - Thomas McGrath, Chief, MassDEP Air Assessment Branch
- **Boston Department of the Environment**
  - Carl Spector, Director
- **Harvard School of Public Health**
  - Petros Koutrakis, Professor
- **New York City Department of Health and Mental Hygiene**
  - Iyad Kheirbek, Director, Air Quality Program
- **Queens College**
  - Holger Eisl, Barry Commoner Center for Health and the Environment
- **South Coast Air Quality Management District**
  - Sang-Mi Lee (Planning, Rule Development & Area Sources)
- **California Department of Public Health**
  - Paul English (California Environmental Health Tracking Program)
  - Jeff Wagner (Environmental Health Laboratory Branch)
- **California Air Resources Board**
  - Cynthia Garcia (Research Division)
- **Wildland Fire Air Quality Response Program**
  - USFS and NPS Leadership