High Resolution Particulate Matter Exposure Data for Health Applications

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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 epidemiologic 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 Winter 08/09 Report
www.nyc.gov/health/nyccas
Initial high-resolution exposure data (left) revealed local air impacts of residual oil burning; clean fuel intervention led to a striking decrease in winter SO$_2$ concentrations (right).

Figure 3: Estimated SO$_2$ Concentrations, winter 2008-2009 and winter 2012-2013

“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 ($\text{PM}_{10}$, $\text{PM}_{2.5}$ and $\text{PM}_{10\text{-}2.5}$)
- 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

Intermediate-sized particles affected by turbulent inertia

Large particles settle

Small particles diffuse

Removable mesh cap

Deposition Surface

SEM Stub


Source RJLee Group
Samplers are placed between aluminum plates to protect from weather and turbulence.


Source: RJLee Group
Samplers deployed at Von Hillern MA DEP site adjacent to Rt 93 in Boston
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)
Estimating Airborne Concentration

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

- **Airborne concentration**
- **Deposition Velocity** = \( f(\text{diameter}) \)

\[ F = \frac{SL}{t} = \left(\frac{\#}{\text{cm}^2}\right) \left(\frac{1}{\text{s}}\right) \]

**Sampling time**

**Surface loading from microscope**

**Flux**

**Number**

**Area**

**Mass**

**Particle Diameter, µm**

**Concentration**

**Flux**
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 +

- **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)
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