Community Air Quality Sensing

What we've learned from calibration and crowdsourcing studies

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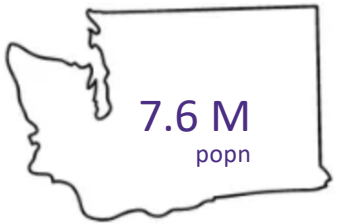
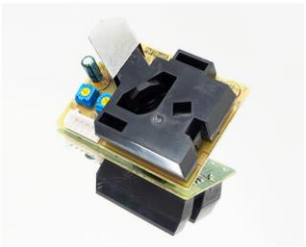
Early Days

California Air Resources Board
~$100 **M** /yr



WA Puget Sound Clean Air Agency
~$30 **M** /yr



Low-cost Particle Sensor
~$10 /ea

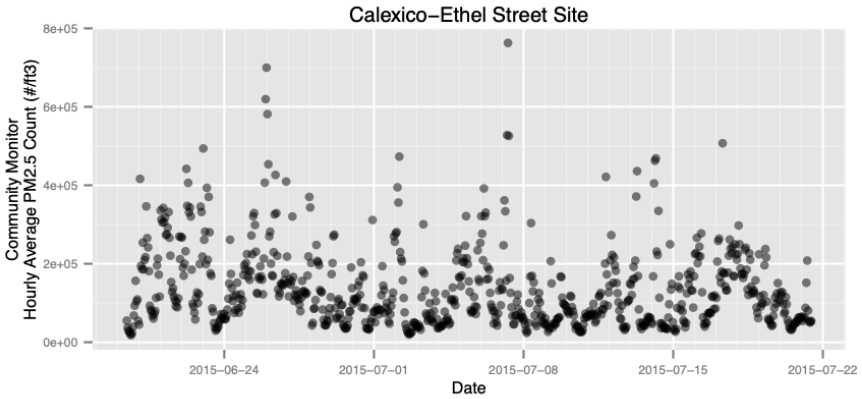
Too good to be true?

Colocation Studies

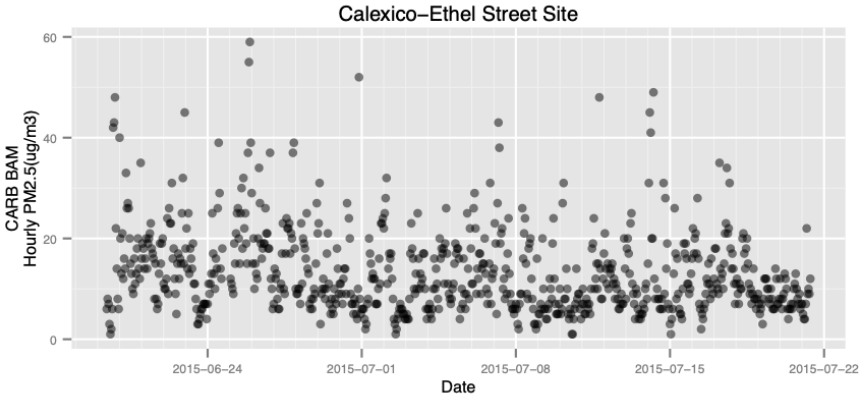
- How well do low-cost sensors perform?
- Colocations at government sites with Federal Reference Method or Federal Equivalent Method Instruments

First month of colocation data at government monitoring site

Community Air Monitor (4-bin Dylos)

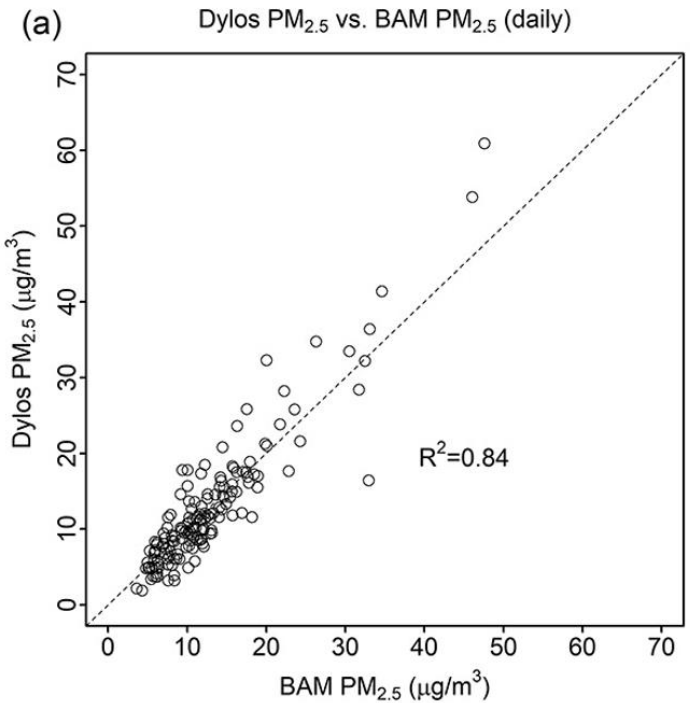


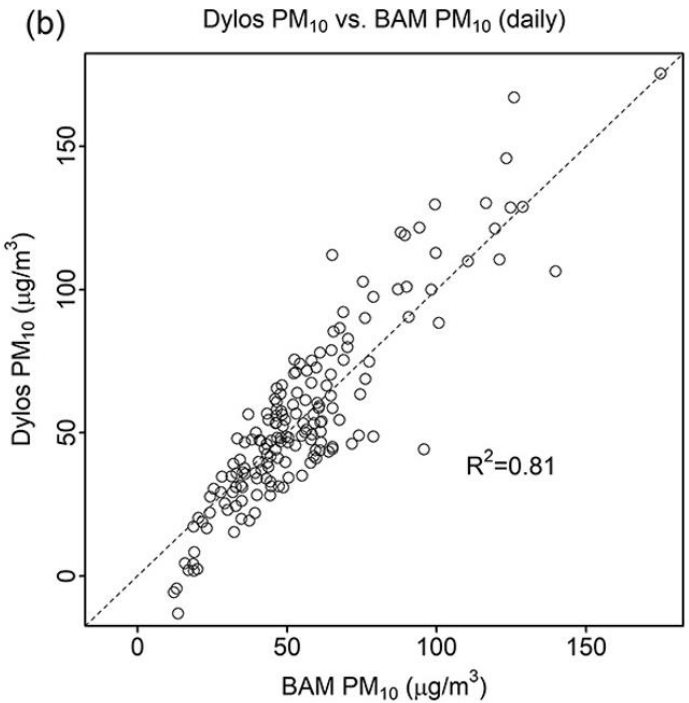
Government Air Monitor (BAM)



Comparisons to CARB FEM

Shared data with California Air Resources Board, and collaborated on the data analyses.

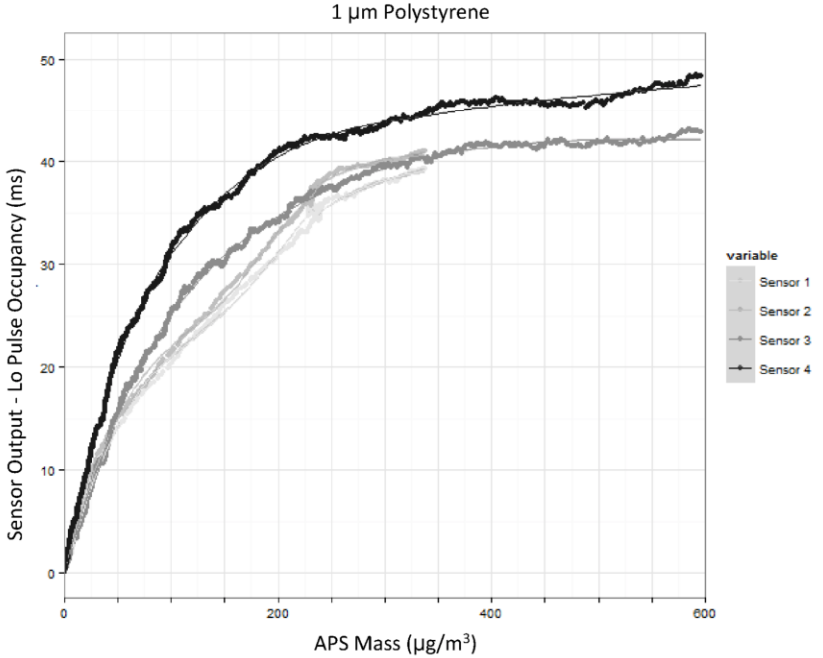




Carvlin, et al., 2017 JAWMA

Colocation – but for different purposes

> **Quality control issues with early sensors from manufacturers – large inter-sensor variations**



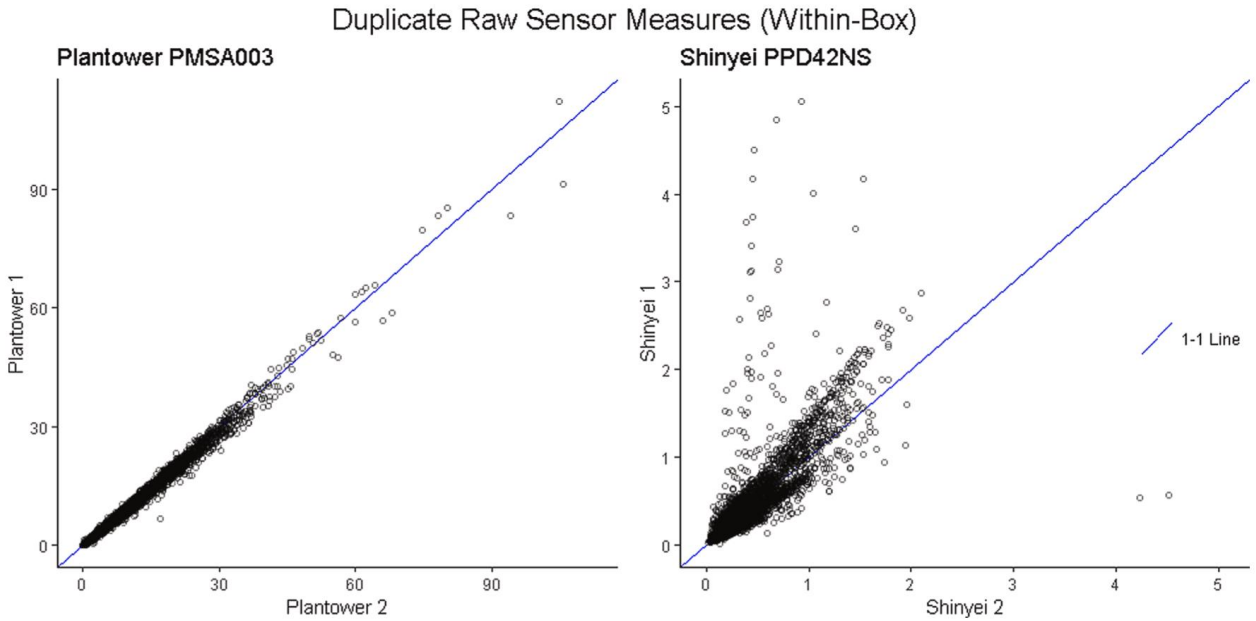
Lab chamber study with consistent synthetic particles

Observed variations in response from 4 “identical” sensors (same batch from manufacturer).

APS is reference particle instrument

Austin, et al., 2015

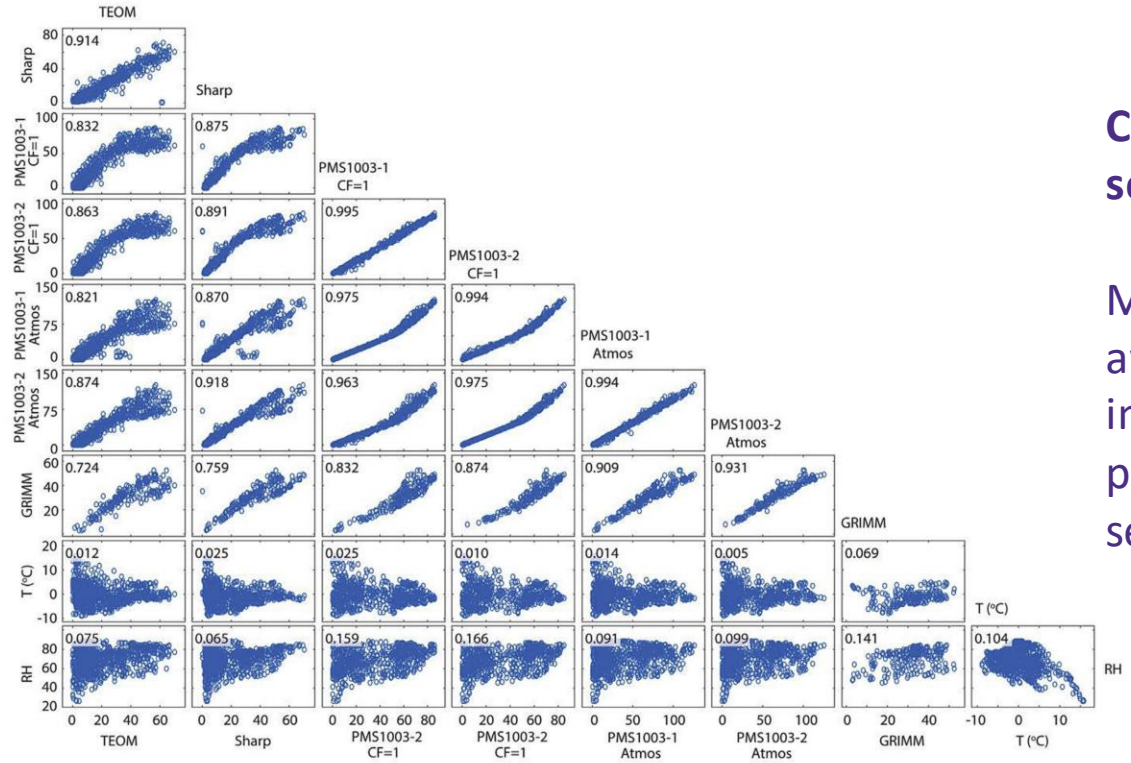
Particle Sensor Improvements



2 Plantower sensors
2 Shinyei sensors
in the same box in the field

Zusman, et al., (2020), Env Int 134

Colocation – More Sensors, More Problems



T

RH

Fig. 3. Scatter plots and correlation coefficients for $PM_{2.5}$ ($\mu g/m^3$) concentrations (PMS 1003-1/2) with FEMs (TEOM and Sharp), research-grade monitor (GRIMM), temperature and RH. No correlation was seen between $PM_{2.5}$ concentration measured between any of the devices and wind speed (R^2 of 0.03–0.04), results not shown.

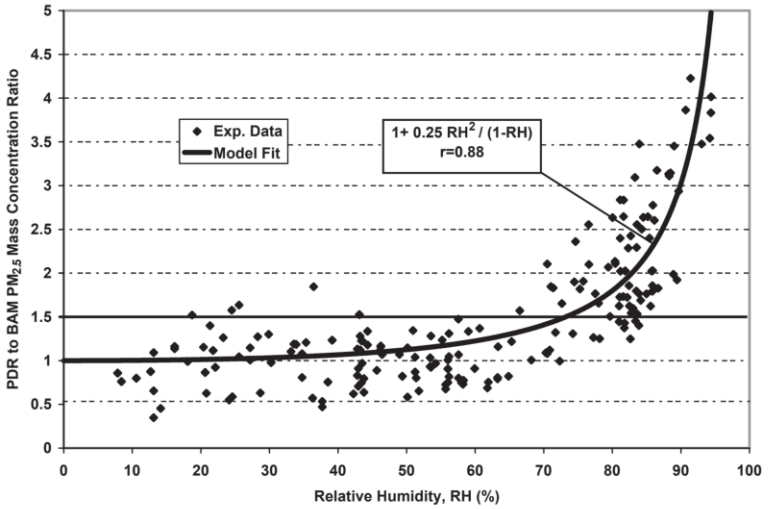
Comparison of 5 different sensors/models

Makers of commercially available particle monitors incorporate their own signal processing to the underlying sensor measurements.

Kelly, K et al., Env Poll 221 (2017) 491-500

Colocation – Environmental Interferences

- **US EPA FRM and FEM particulate matter methods generally measure "mass" concentrations. (µg/m^3)**
- **Low-cost PM sensors measure light scattering, not mass.**



Two-hour averaged pDR to BAM $PM_{2.5}$ concentration ratio as a function of relative humidity.

Environmental Interferences
Non-linear response of particle light-scattering measurements compared to FEM particle matter mass measurements at high levels of relative humidity.

B. Chakrabarti et al. / Atmospheric Environment 38 (2004) 3329–3340

Colocation – More Places, More Problems

> **Particle light scattering is affected particle particle composition (size, shape, refractive index)**

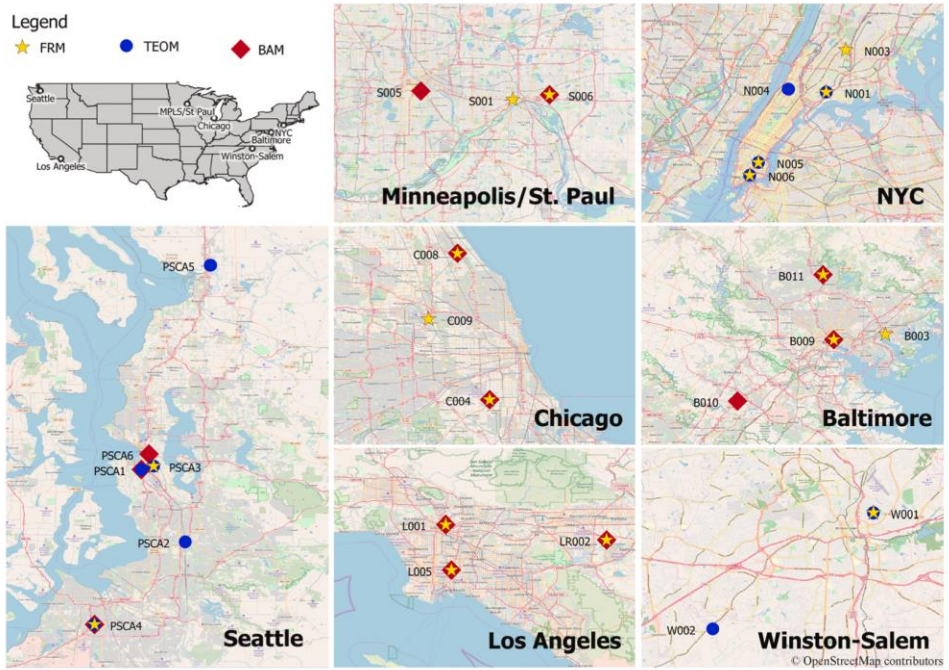


Fig. 1. Map of regions covered by the ACT-AP and MESA Air studies with the locations of $PM_{2.5}$ reference sites.

Colocations in multiple cities

Calibrations

Statistical regression models that relate particle mass concentrations to sensor measurements for specific regional contexts.

Zusman, et al., (2020), Env Int 134

Colocation – More Places, More Problems

Region-Specific Calibrations

$R^2 = 0.74 – 0.95$

correlation with regulatory measurements

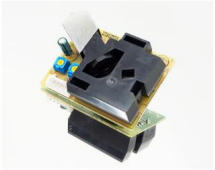
Take the Seattle Calibration and Apply it to Other Regions

$R^2 = 0.67 – 0.84$

correlation with regulatory measurements

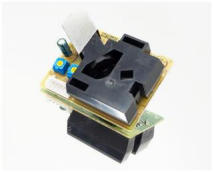
Zusman, et al., (2020), Env Int 134

Low-cost sensors are NOT low-cost



Low-cost Particle Sensor
~$10 /ea

But it's really…

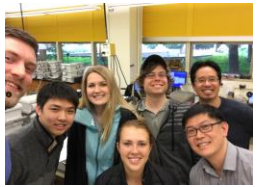


Sensors

Engineering

Training / Field Staff
Maintenance

Community Engagement



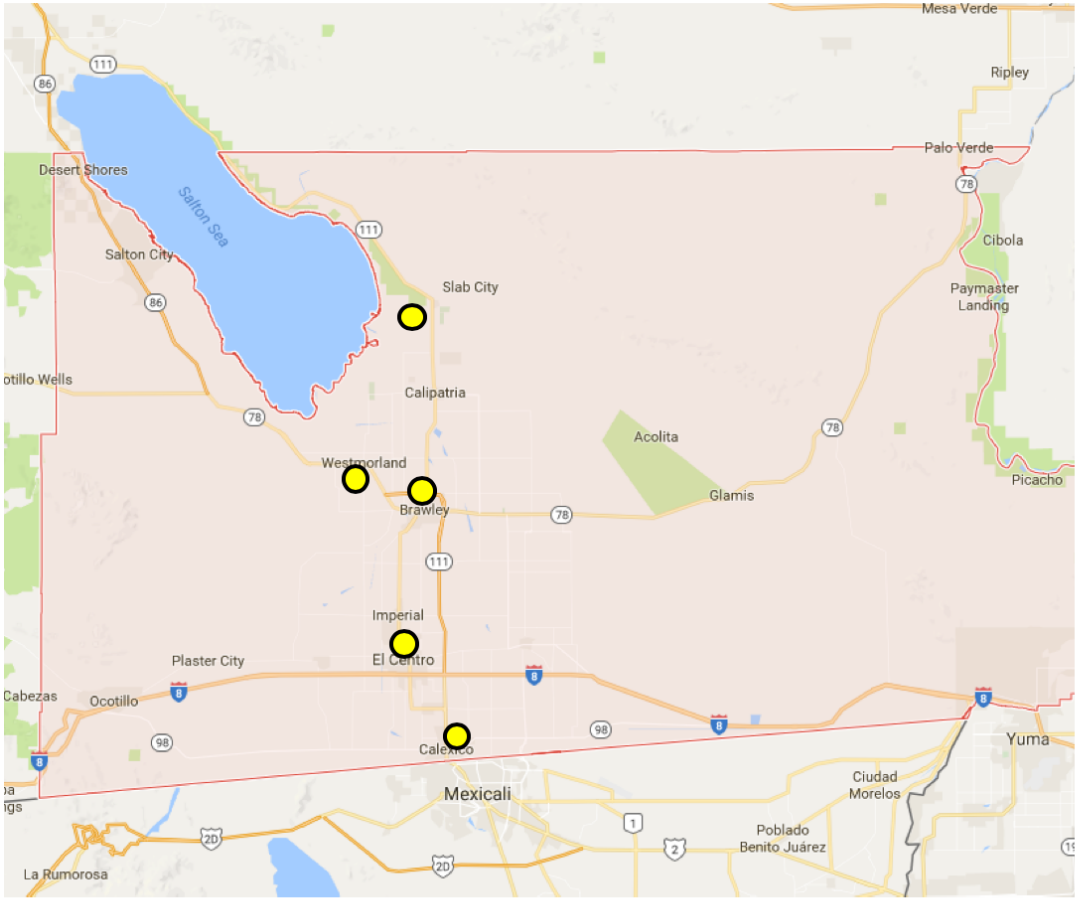
Researchers (*priceless*)

Imperial County Community Air Monitoring Project

Using low cost sensors to develop a community air monitoring network

Paul English & **Michelle Wong** | California Environmental Health Tracking Program
Humberto Lugo & **Luis Olmedo** | Comite Civico del Valle
Graeme Carvlin, Jeff Shirai, Edmund Seto | University of Washington

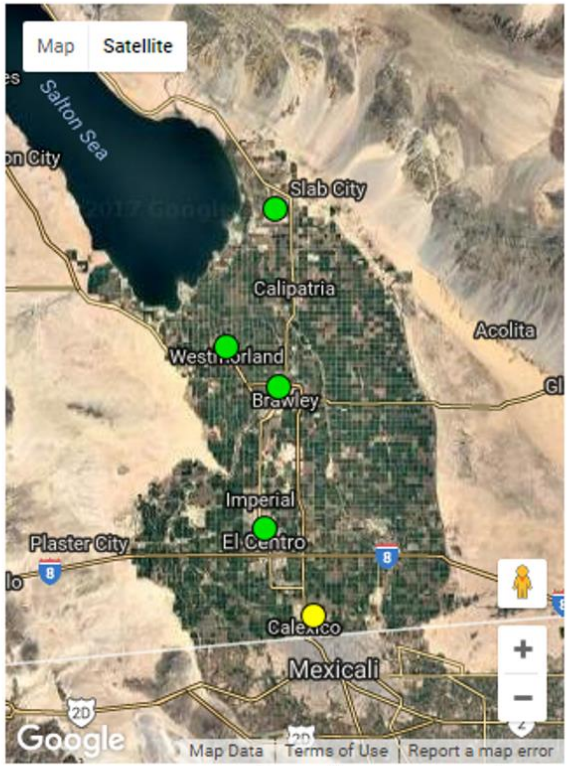
Air quality is a community priority



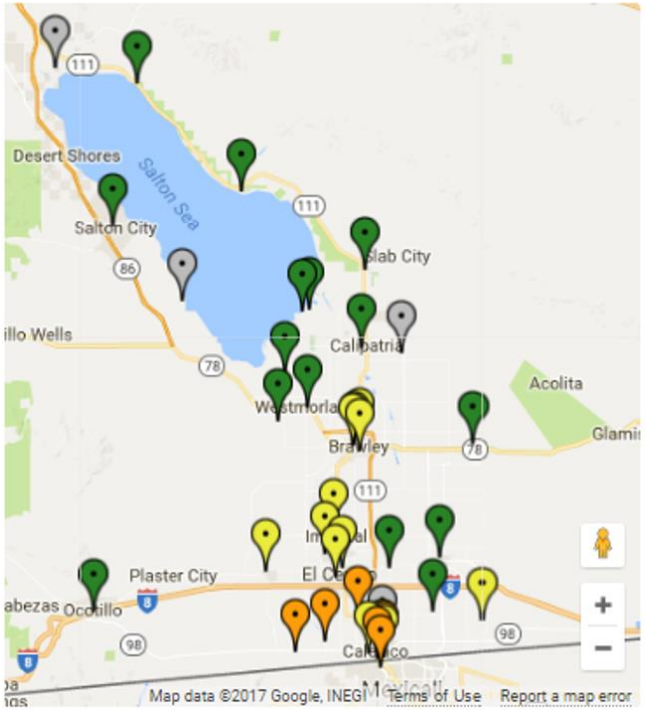
Locations of regulatory monitors in Imperial County

- PM10 standards unmet
- High rates of asthma
- Few regulatory monitors
- Need for more local air quality data

Better understanding of community air quality



Regulatory monitors

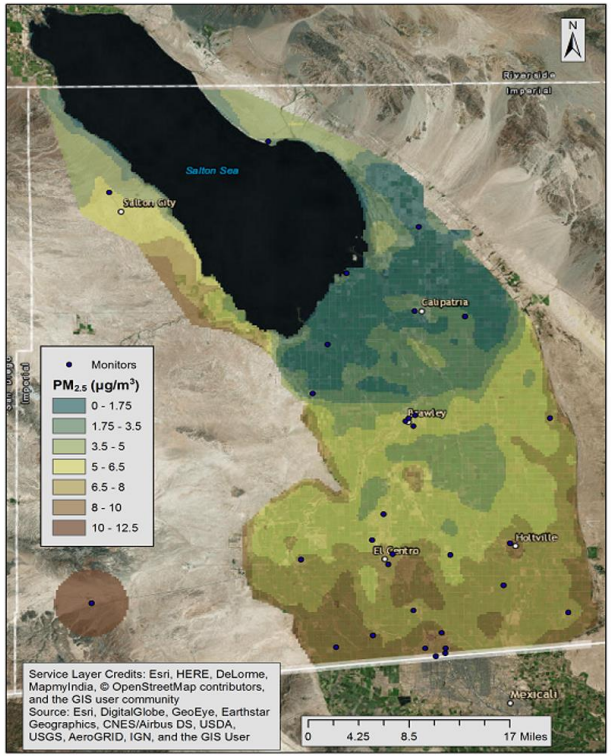


IVAN AIR monitors

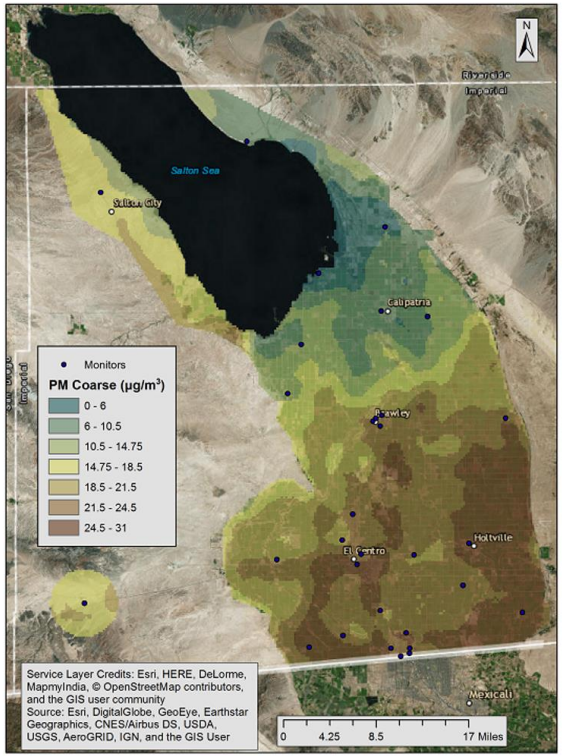
Modeled Air Pollution Concentrations

10/1/2016 – 10/1/2017

$PM_{2.5}$



PM Coarse (Particle sizes between PM_{10} and $PM_{2.5}$)

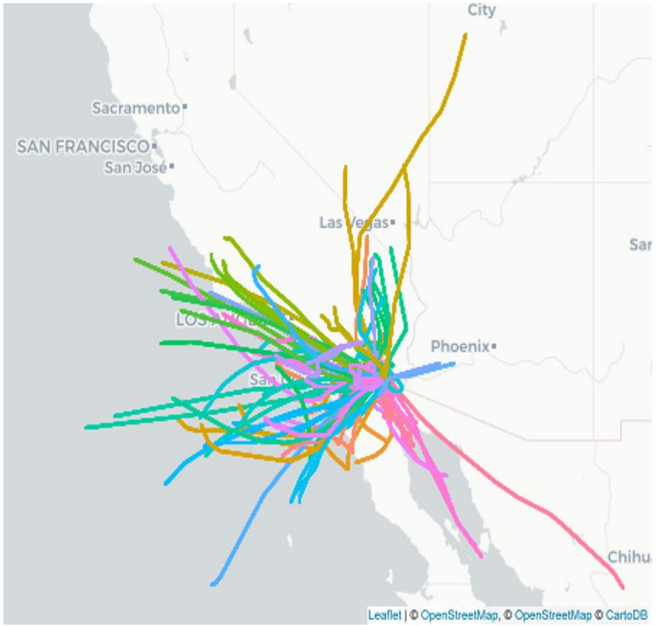


Carvlin, et al., 2019 Atmosphere

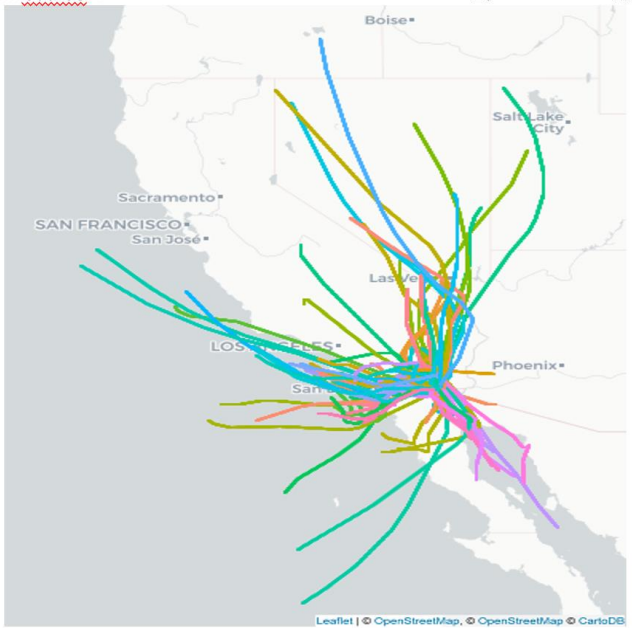
Which meteorological conditions contribute to high PM?

24-hour back-trajectory analyses for high concentrations observed during 10/1/2016 – 10/1/2017

$PM_{2.5}$

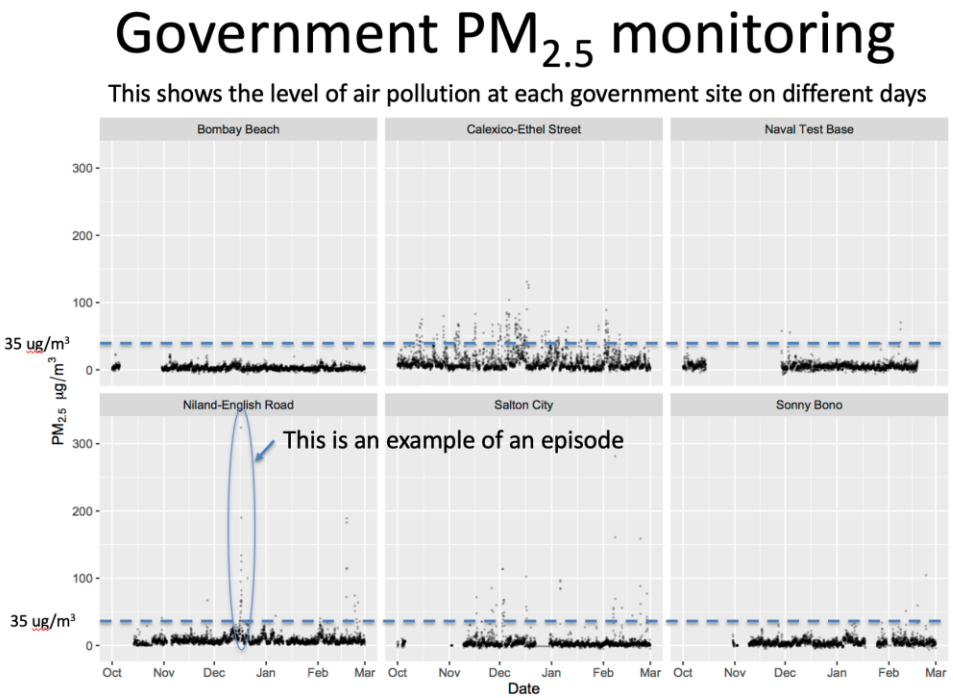


PM_{Coarse} (Particle sizes between PM_{10} and $PM_{2.5}$)



Government vs Community Air Monitoring

- Identifying air pollution "episodes", when hourly conc > 35 µg/m³
- One year: October 2016 – February 2017



Also, notice that the government monitoring data are incomplete.

Seto, et al., 2019, IJERPH 16(18) 3268

Government vs Community Air Monitoring

Community $PM_{2.5}$ Monitoring

Government Monitors:
116 episodes

Community Air Monitors:
1426 episodes

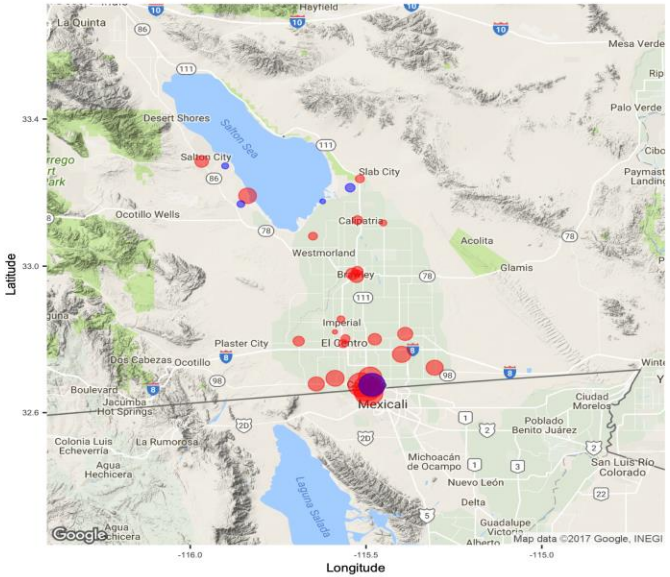
90% of the time, when a government monitor observes an episode, it is only observed by one government monitor.

For community air monitoring, 68% of the time, an episode is observed ***and confirmed*** by at least 5 community sites.

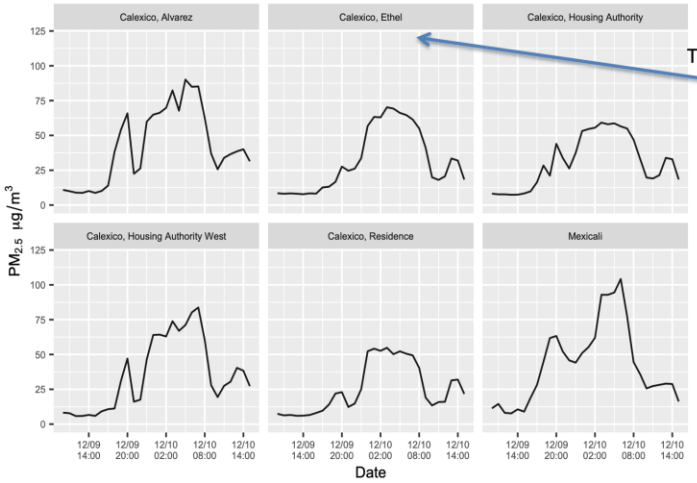
Seto, et al., 2019, IJERPH 16(18) 3268

Government vs Community Air Monitoring

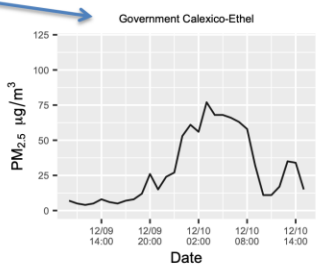
Example: Dec 10, 2016



Episode observed at 6 community sites.



These are colocated



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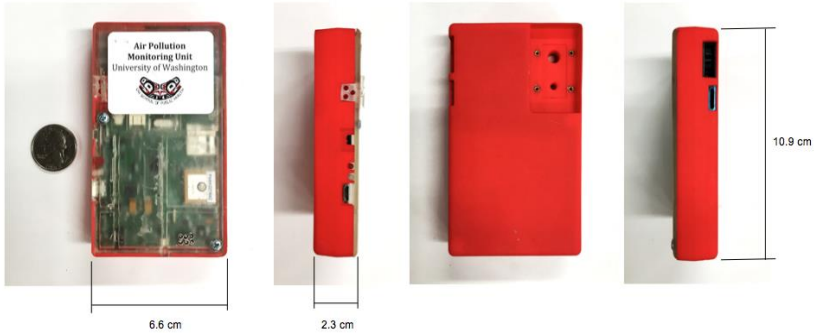
Personal Exposure Monitoring

Portable University of Washington Particle (PUWP) Monitor



About this size

- Low-cost particle sensor
- Temp, RH
- 3-axis accelerometer
- GPS
- Data-logger

- Collects particle sample in an injection-molded cartridge for later analysis.

2-weeks for 300-people
WA State Twin Registry

Example: Personal Exposures for one of the participants during the BC Wildfire 2017

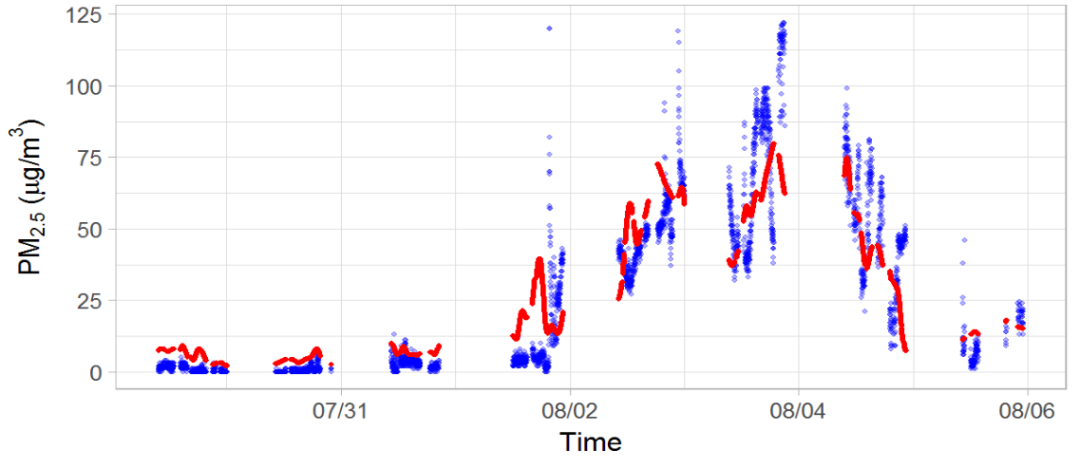
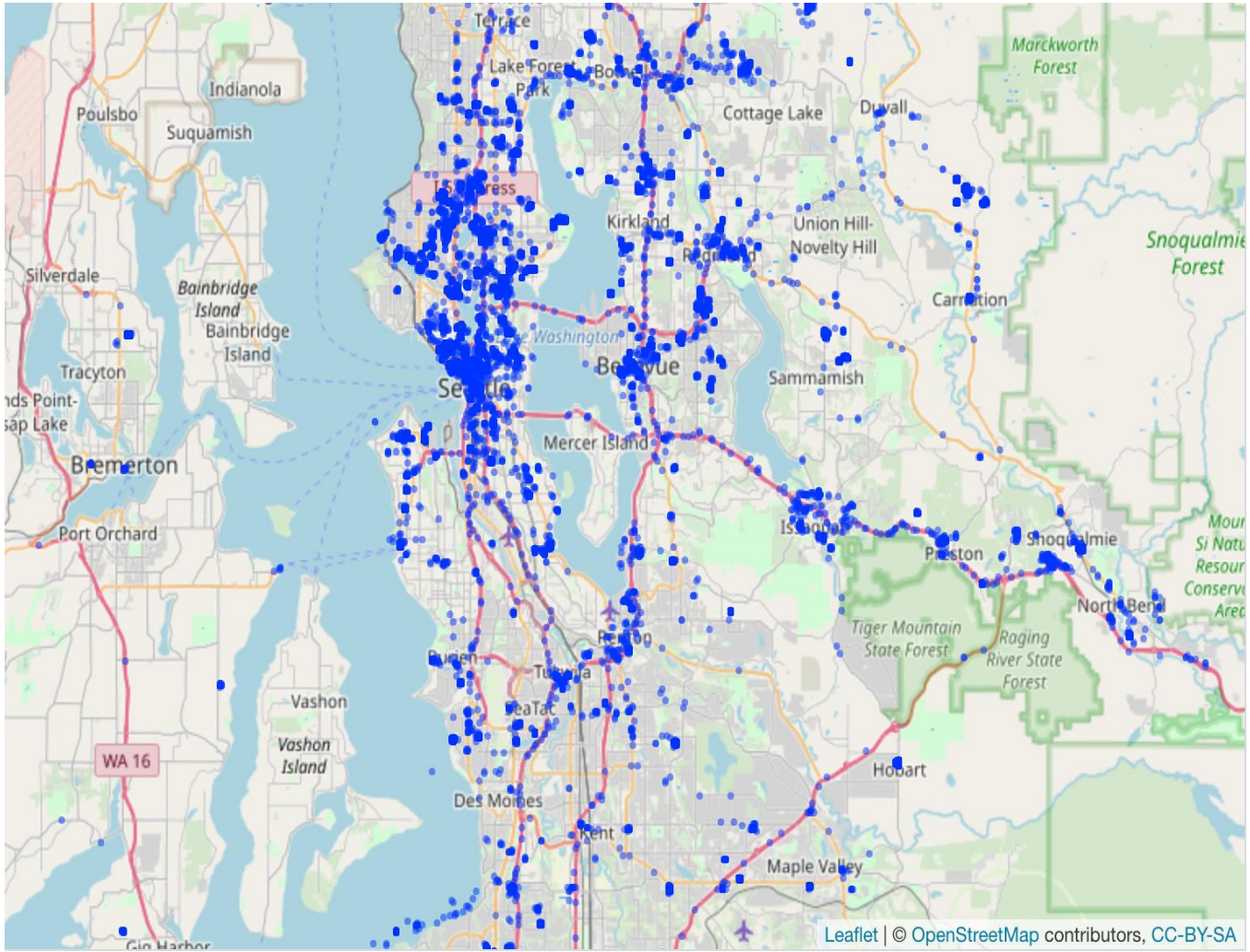


Figure 2. Personal exposure measures compared to outdoor ambient levels in Seattle.



Jittered sample of ~3 GB of personal exposure monitoring data, zoomed in on the Seatte, WA Region

Thanks

- Imperial Project: CA Tracking, Comite Civico del Valle, CARB
- MESA Air and ACT AP Study Teams and air quality agency collaborators
- Twin PUWP: WA State Twin Registry, Novosselov Lab

- Contact: Edmund Seto eseto@uw.edu