Sensor Technologies: EPA's Ongoing Efforts in Discovery and Application

US EPA's Emerging Technologies Research Program

Ron Williams

AAPCA Annual Meeting

EPA Collaborators and Contacts

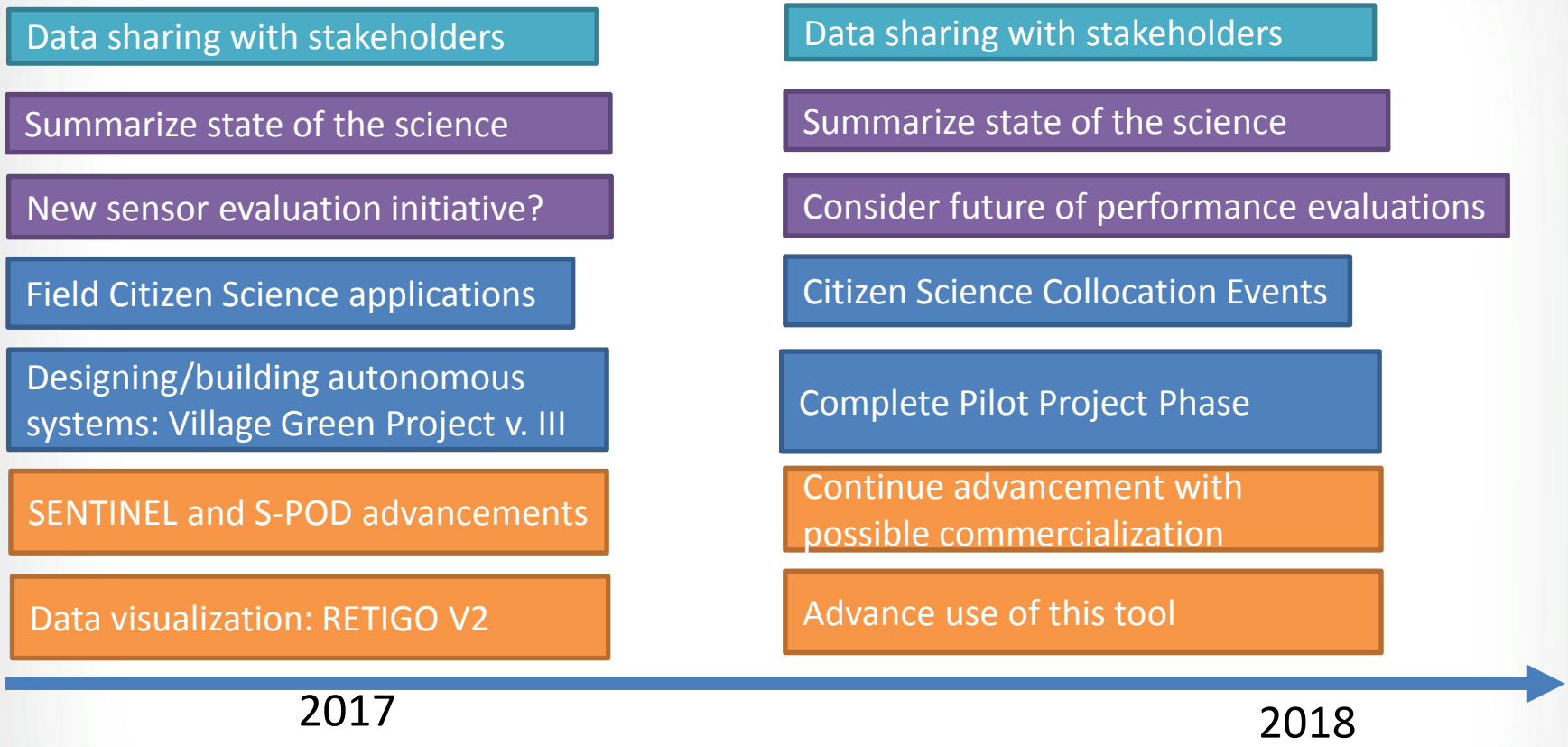
- Amanda Kaufman- Air Sensors Toolbox
- Village Green-Sue Kimbrough
- RETIGO-Gayle Hagler

Emerging Technologies Research Agenda

1. Investigate emerging technologies and potential to meet future air quality monitoring needs
2. Establish market surveys of commercially-available air quality sensors
3. Conduct extensive literature survey on the state of sensor technologies
4. Develop sensor user guides
5. Educate sensor developers and users on the state of low cost censors
6. Facilitate knowledge transfer to wide range of stakeholders
7. Work with sensor developers to speed up development
8. Support ORD's Sensor Roadmap by focusing on high priority issues (NAAQS, Air Toxics, Citizen Science)
9. Establish highly integrated research efforts across EPA
10. Apply knowledge gained in hands-on sensor deployment activities

*These areas will be highlighted in our discussion

Ongoing/Planned Activities



Example- Gas Sensors

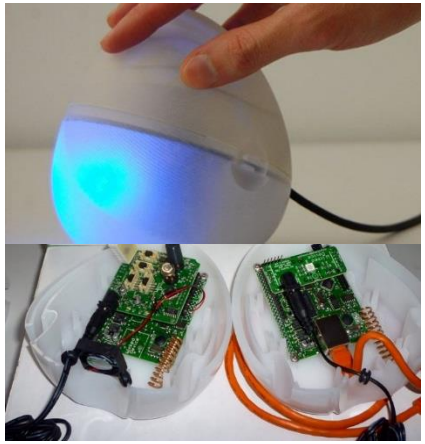
SENSARIS

AIR CASTING

CAIRCLIP

AEROQUAL

AQ EGG



NODE

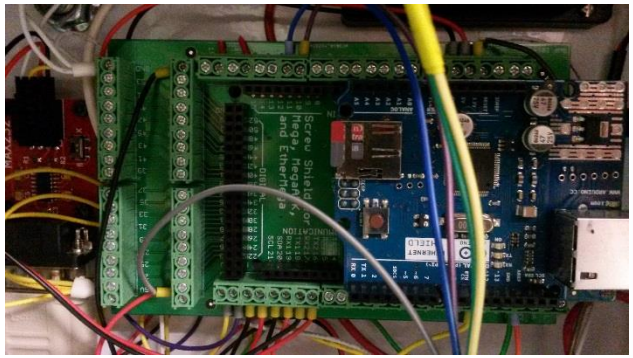
Direct Collocation with FEMs

CAMP Denver-CAIRSENSE Deployment

Repeat of Atlanta Design

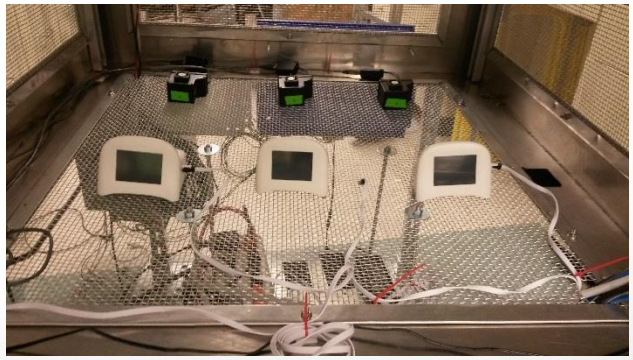
Multiple shelving options

Interior view



Arduino MicroProcessing

New TSI sensors



New Speck and OPC N2 sensors

Ad-Hoc Testing

AQMesh: NO_2, NO, O_3, SO_2, CO

MetOne 831 particle sensor

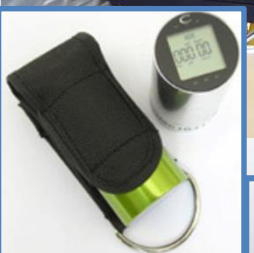
Dylos particle sensor

Air Quality Egg (CO, NO2, PM, VOCs)

Aeroqual SM50 O_3 sensor

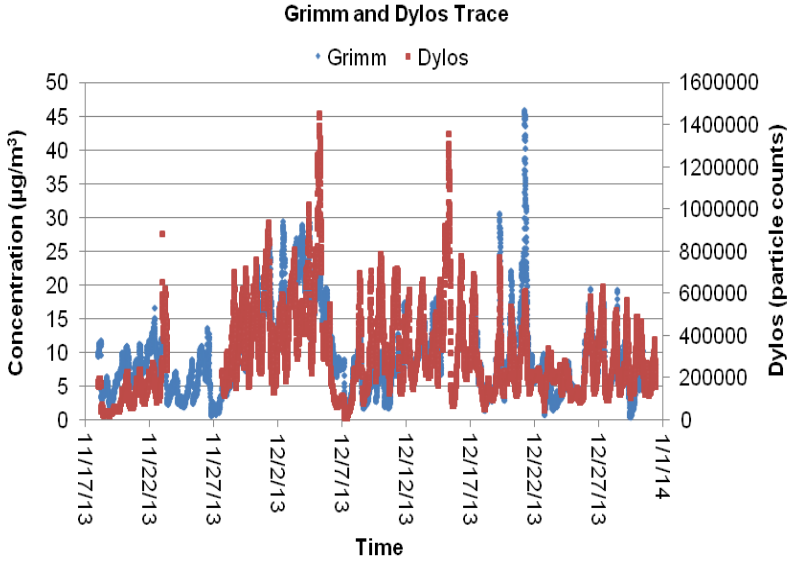
Airbeam particle sensor

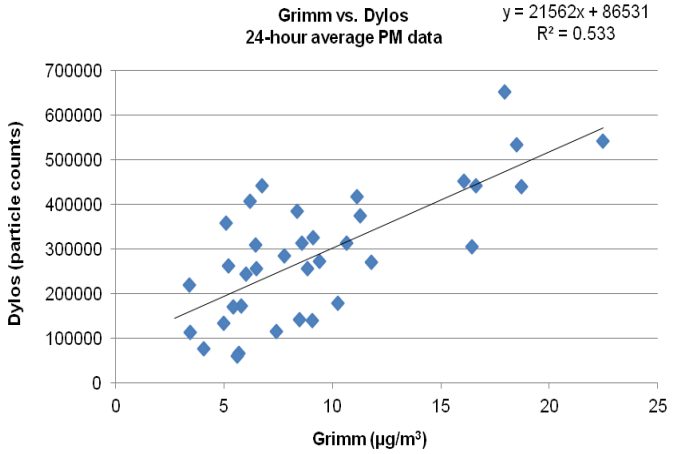
Shinyei particle sensor

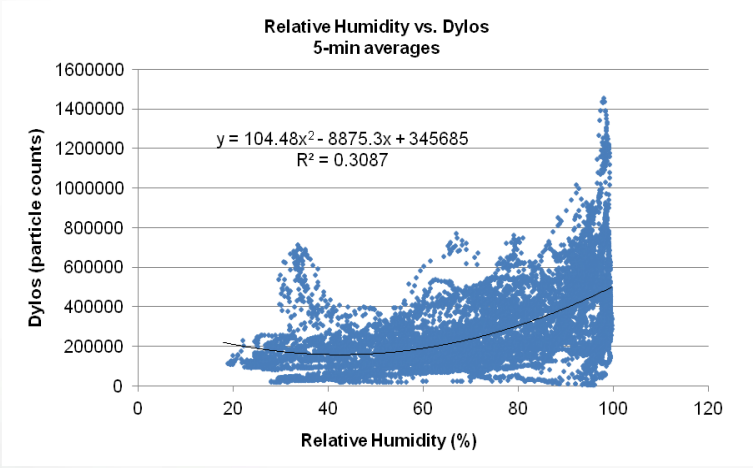


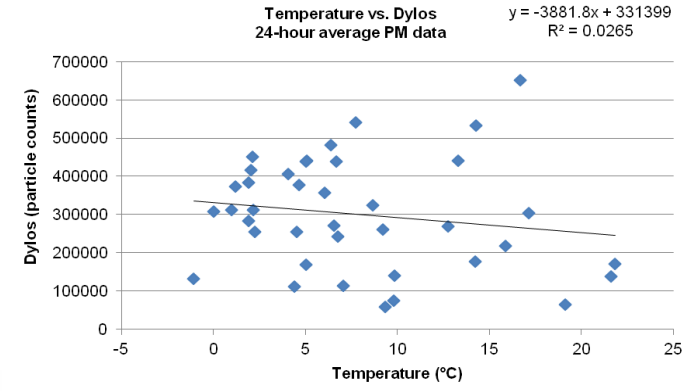
Not shown: Cairpol NO_2/O_3 sensor

An Example of In-Depth PM Sensor Evaluation

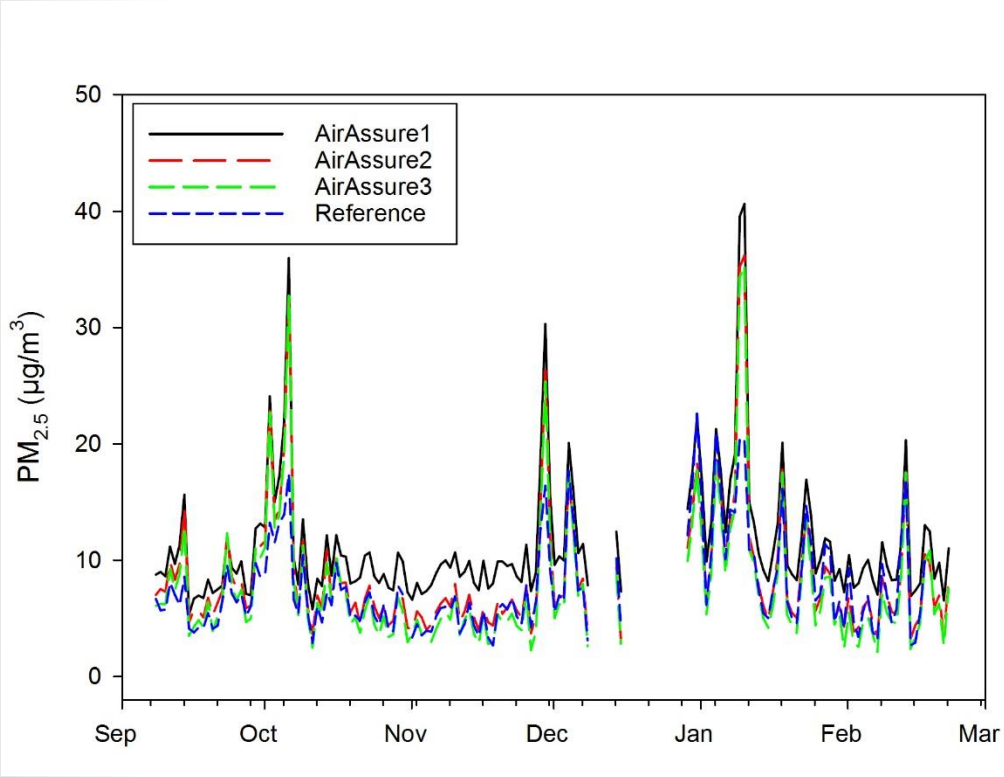


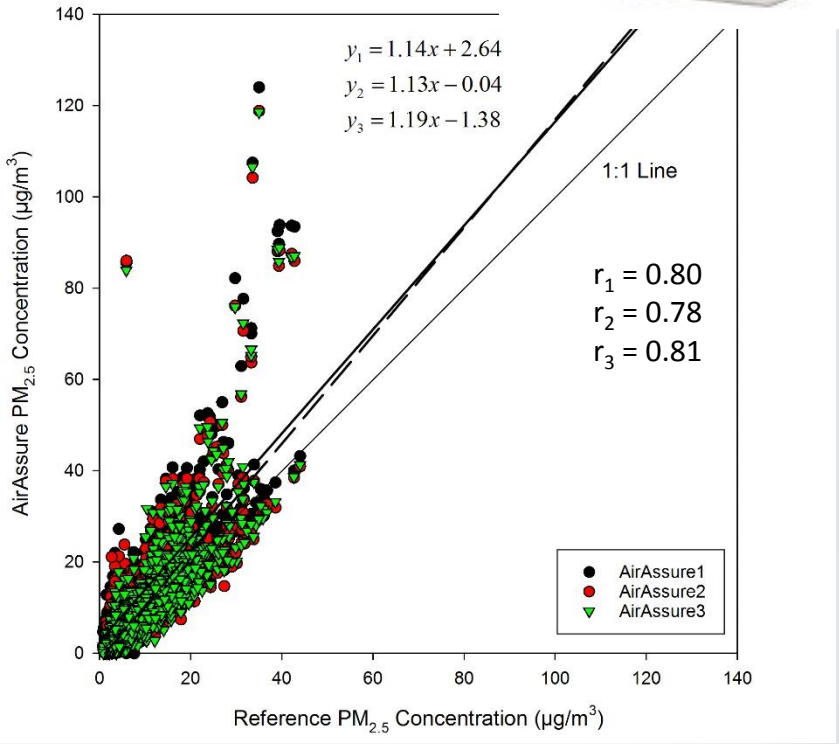






AirAssure – $PM_{2.5}$

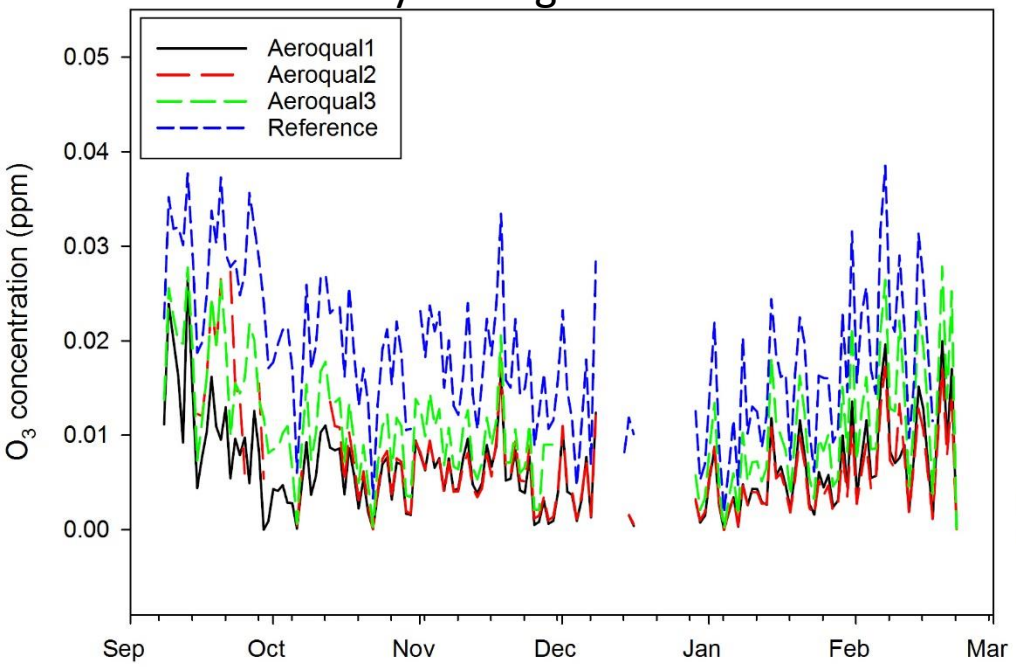




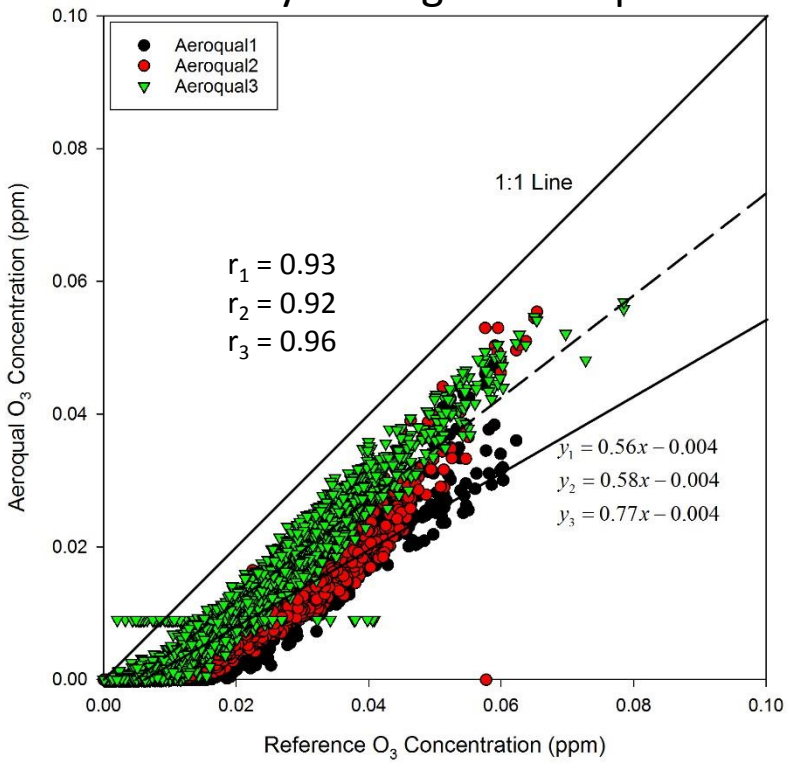
- Few over-responding events
- Strong agreement between units 2 and 3
- Strong correlation with monitor

Aeroqual – O_3

Daily Average Time Series

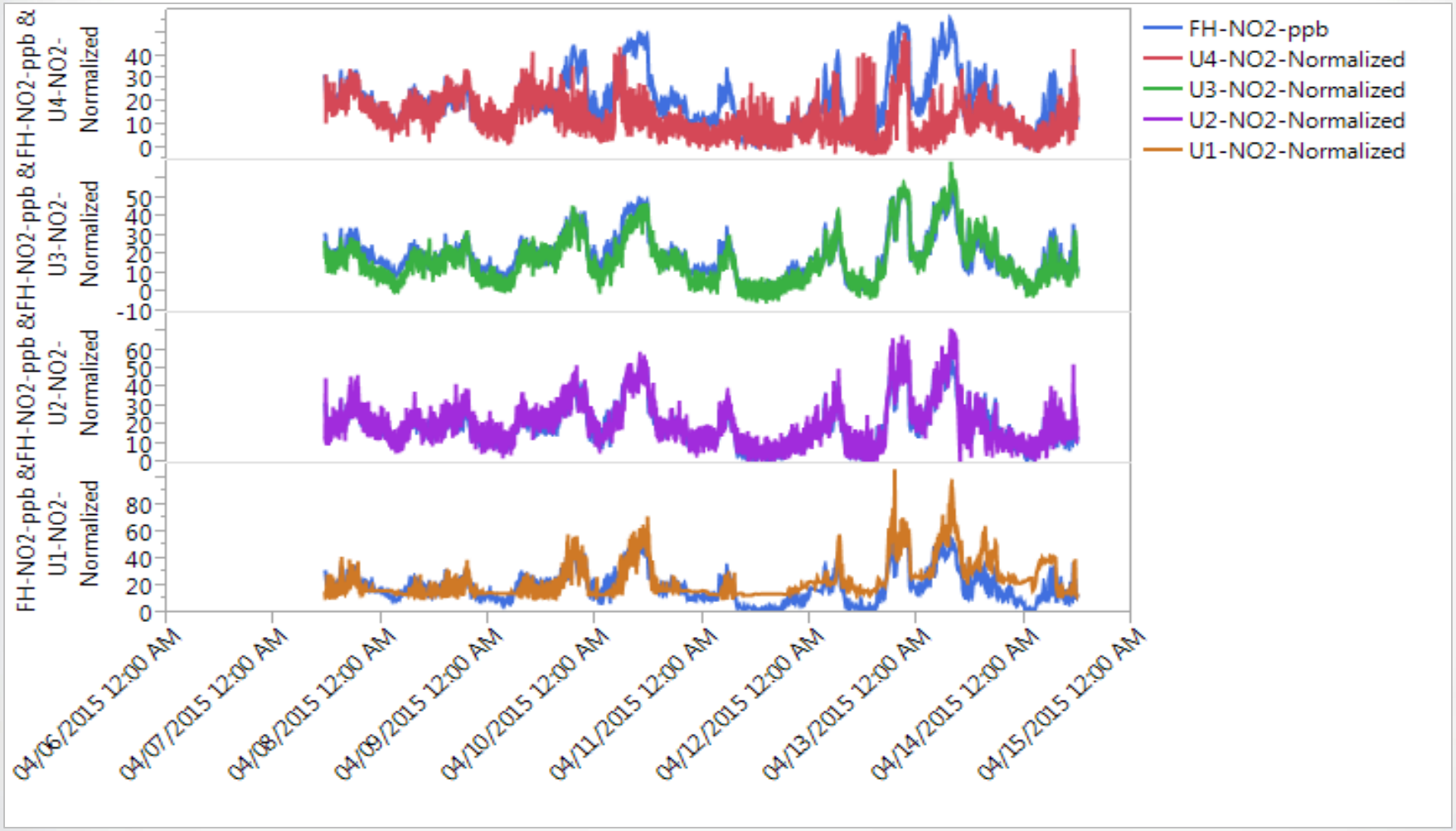


Hourly Average Scatterplot

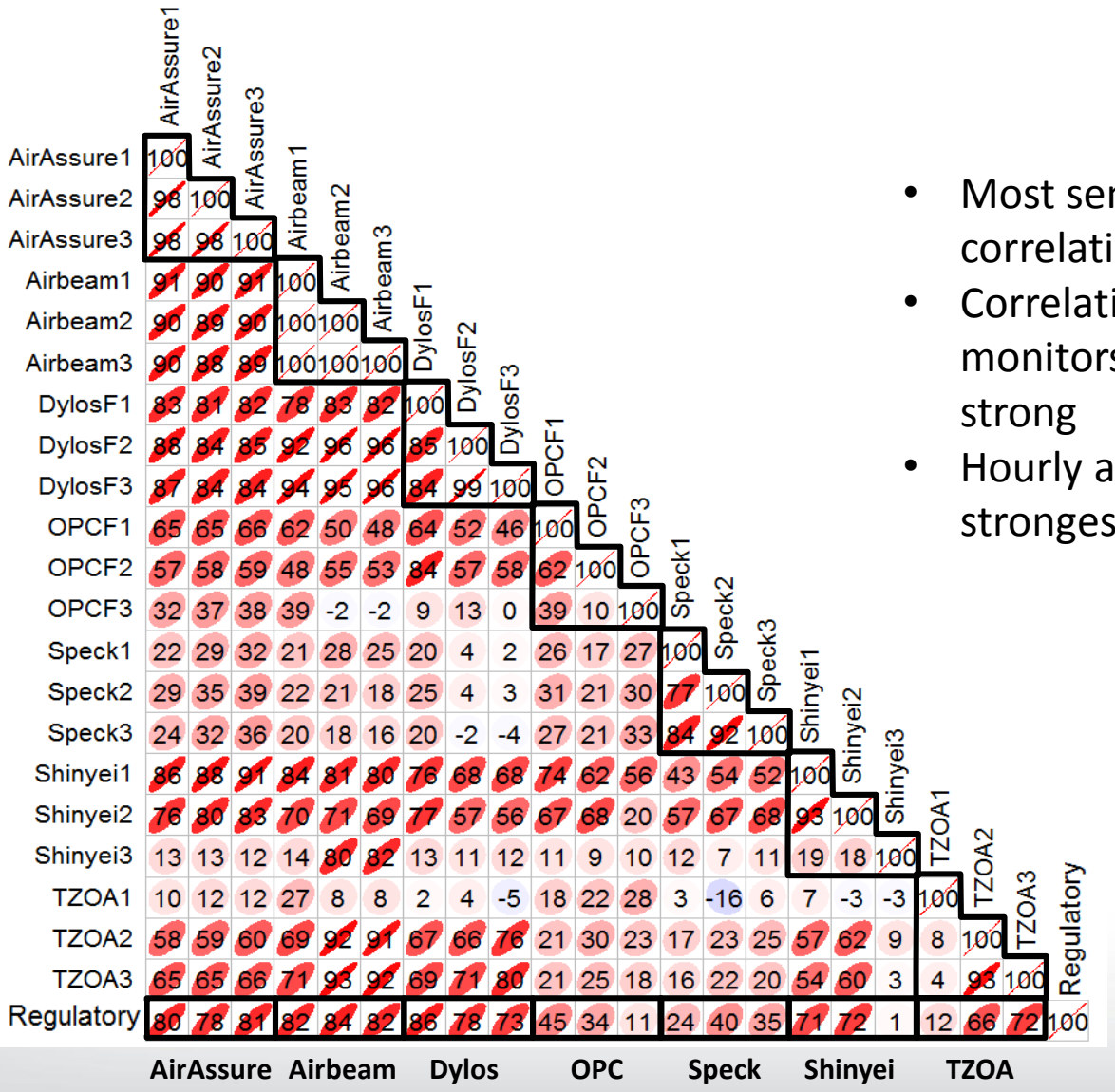


- Initial lab audit had 1:1 ratio
- Underreports regulatory monitor O_3
- Consistent across seasons
- Strong correlation to regulatory monitor

Sensor Response Normalization (NO_2) CSAM vs FEM

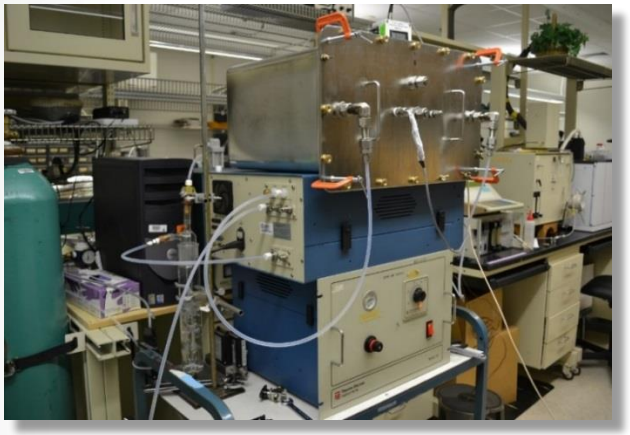


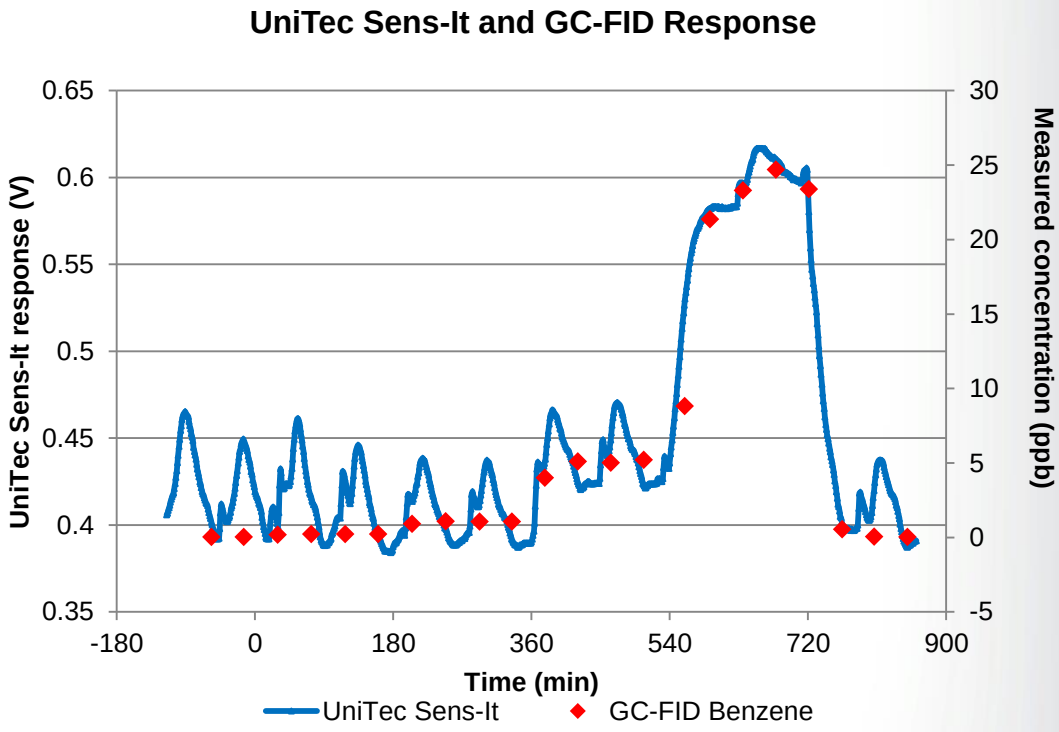
Hourly Average PM Correlations



- Most sensors exhibit strong correlation within model types
- Correlations with regulatory monitors range from weak to very strong
- Hourly average values had strongest correlations

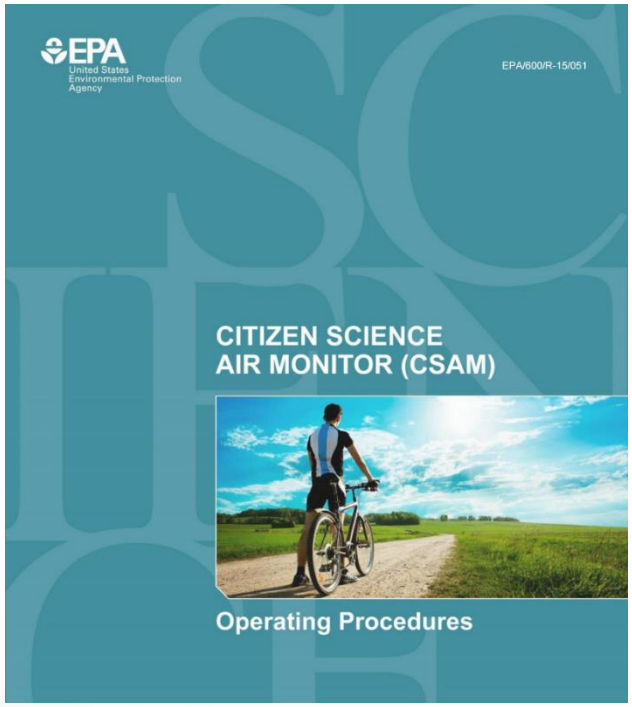
Laboratory VOC Sensor Evaluation

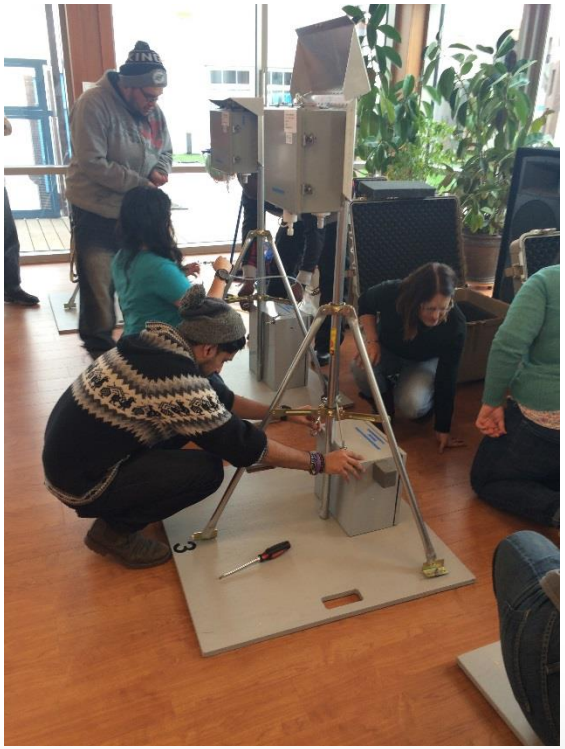




How can EPA facilitate citizen science?

- What tools are needed?
- What types of interactions best accomplish tool transfer?
- What technologies might be applied in pilot efforts?

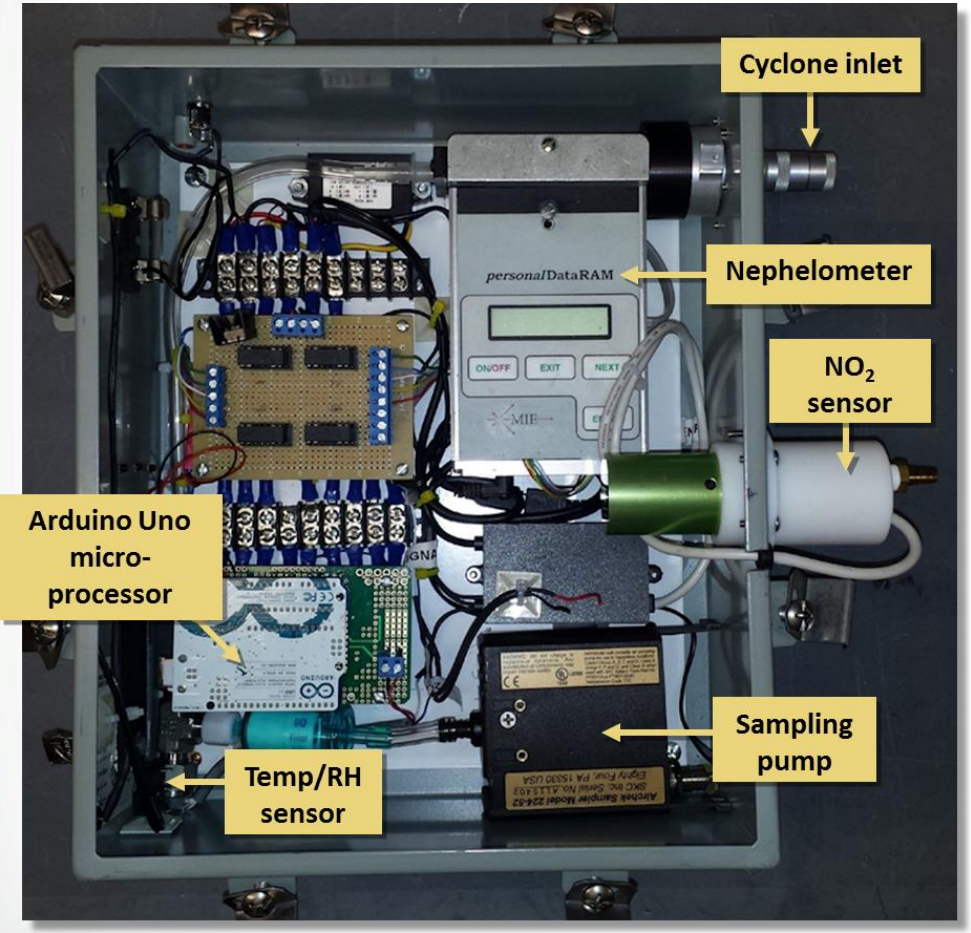




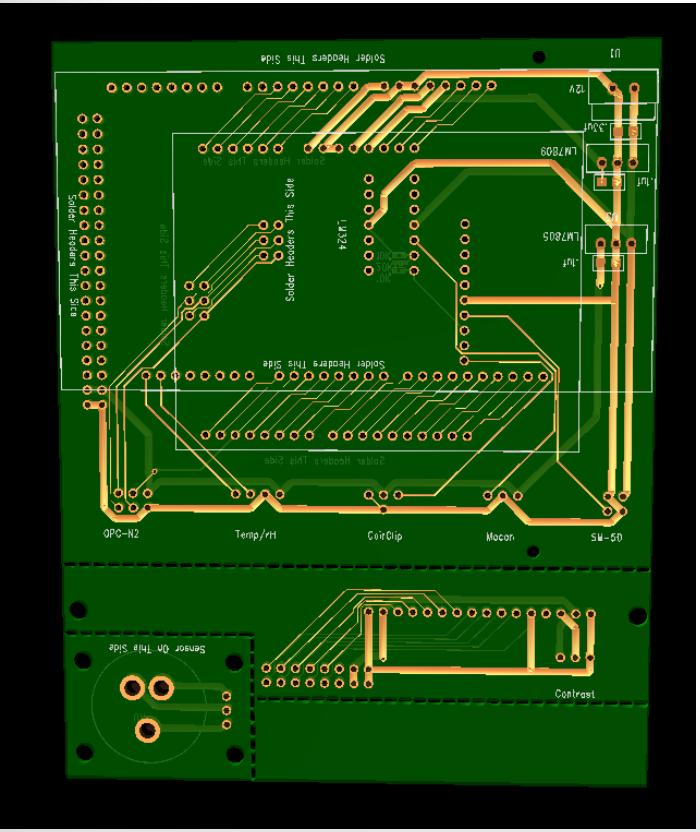
EPA's Recent Community Air Monitoring Training Event

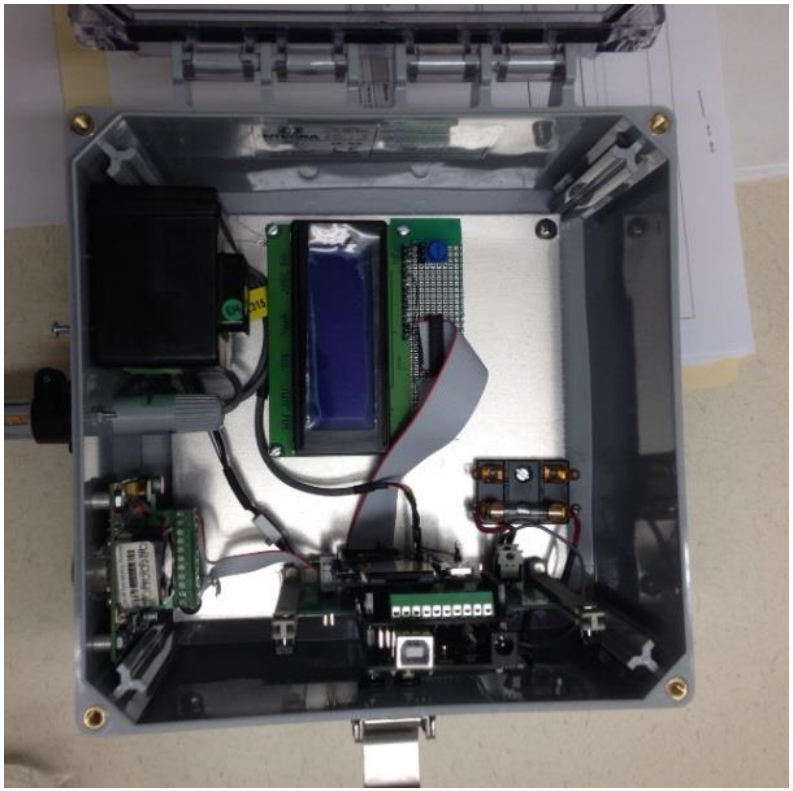
- Goals:
  - To share tools, best practices, and resources from EPA's Air Sensor Toolbox for Citizen Scientists
  - To educate interested groups and individuals on how to conduct successful air monitoring projects
- 30 in-person attendees, 800+ via webinar
- Training videos now available on Air Sensor Toolbox website
- Ongoing follow-up with Regions/State/Tribal interests

The Sensor Pod - CSAM



Measurement	Reporting Unit
NO_2 concentration	Parts per billion (ppb)
PM concentration	Micrograms per cubic meter ($\mu g/m^3$)
Temperature	Degrees Celsius (°C)
Relative humidity (RH)	Percent (%) at °C


Solder Headers This Side
U1
12V
LM7809
LM7805
LM324
Solder Headers This Side
Solder Headers This Side
OPC-N2
Temp/rH
CairClip
Macon
SW-GO
Sensor On This Side
Contrast



ORD-Region research projects using sensors (FY16-17)

Project / Year	Regional Partner(s)	Measurements	Location
CAIRSENSE (Being summarized)	Region 1,4,5,7,8	PM, ozone, nitrogen dioxide, CO – four sensor nodes	Atlanta/Denver
CSAM (Being summarized)	Region 2	PM, NO_2, temperature, humidity – portable stations	Ironbound community, NJ
CitySpace	*Region 4* *Region 6* *Region 7*	*PM – up to 20 stationary nodes*	*Memphis, TN*
AirMapper	*Region 5* *Region 10*	*PM, noise, temperature, humidity – portable units*	*Chicago, IL* *Portland, OR*
Puerto Rico EJ	*Region 2*	*PM, VOCs, NO_2 – 10 portable units*	*Puerto Rico*
Southern California	*Region 9*	*PM, ozone temperature, humidity – portable units- 10 portable units*	*200 mile swath of southern California*
AIRS platform	*OAQPS*	*UN sensor pod, Array of Things, Air Quality Egg, TZOA, CSAM v2, Aeroquals*	*RTP FEM platform*

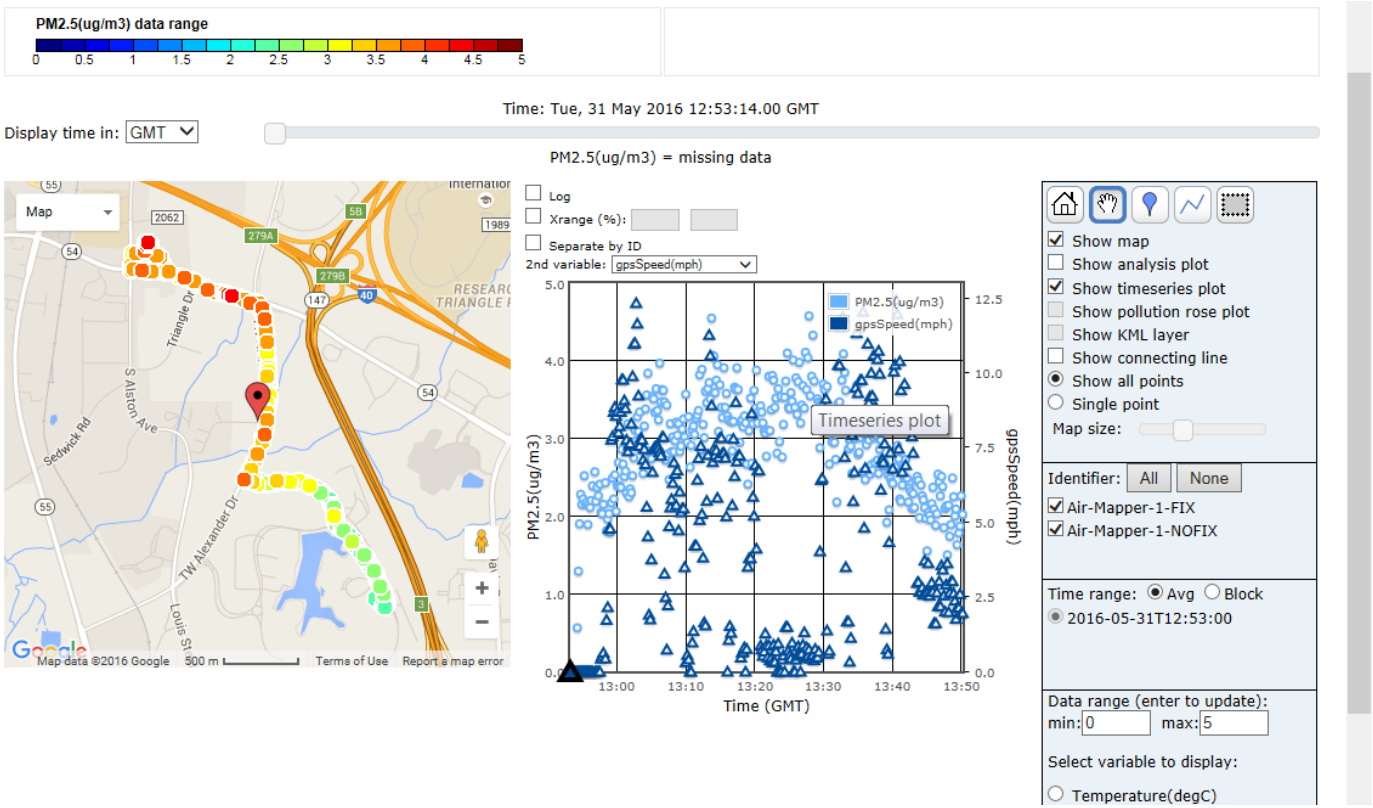
ORD-Region example research projects using sensors

Goal: Support community group in using low-cost sensors to explore their air quality

AirMapper

- Designed for use by citizens/students
- Local (on-board) data storage
- Designed for ease of use by non-professionals
- Lessons learned from ORD evaluations integrated into design function (e.g., technology selected /data visualization tools employed)

AIRMAPPER – UNIT I



Recorded data for ~1hour. We were stationary for ~5 minutes then biked, stopped at library, biked back and walked final 5 min. Highest PM values near highway 54 and library. RETIGO contact is Dr. Gayle Hagler-US EPA

The Take Home Message

- We have examined and are continuing to examine sensors as they become available.
- We are integrating these technologies (either as is or following further development) into a variety of research projects
- Both lower cost (< $2500) as well as mid-tier ($3000-$10000) sensors are being investigated
- A wide range in capabilities are being observed. Cost is not necessarily the driver in how well any given device might function.
- Generally speaking, Ozone>PM> CO> NO2>SO2 relative to performance in low cost sector.
- Fewer options available for air toxics. VOCs, ammonia, hydrogen sulfide, methane, etc limited in the low cost category.
- Most citizens unable to handle the large volume of data created by real time sensor devices
- Demand to understand this technology sector is only increasing in intensity

Sensor Related Resources

Air Sensor
Measure · Learn · Share

Contacts:

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Amanda Kaufman
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Online Resources Available at:
www2.epa.gov/air-research/air-sensor-toolbox-citizen-scientists

Air Sensor Guidebook

CSAM Operating Procedures

Mobile Sensors & Applications for Air Pollutants

Citizen Science Air Monitor (CSAM): Quality Assurance Guidelines

Evaluation of Field-deployed Low Cost PM Sensors