Next-generation air monitoring – an overview of EPA research to develop real-time instrumentation packages for stationary and mobile monitoring

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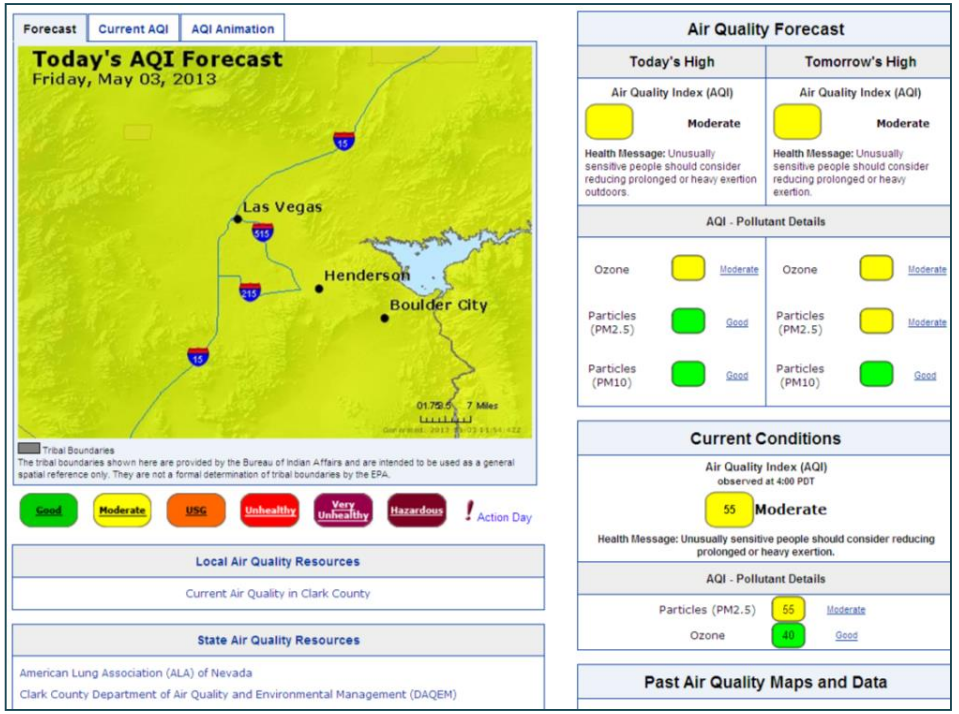
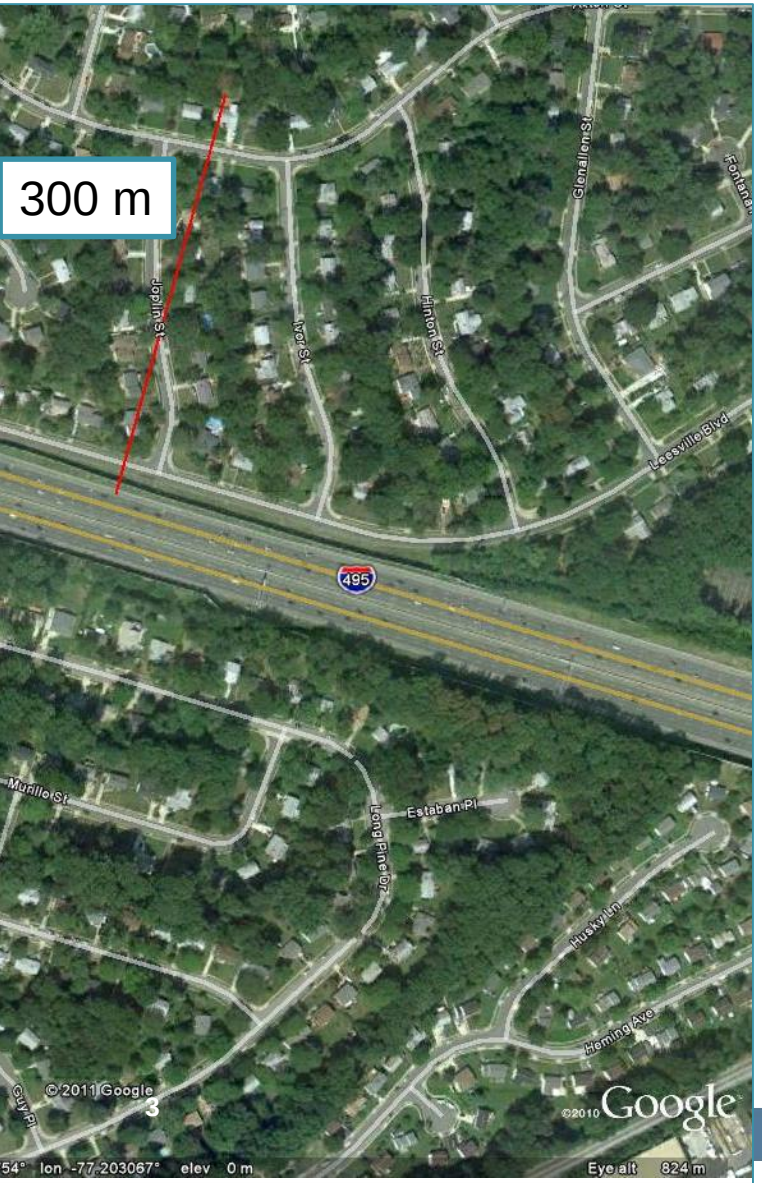
Traditional air monitoring paradigm

Government-provided data, Air Quality Index provided on broad time and spatial scales.

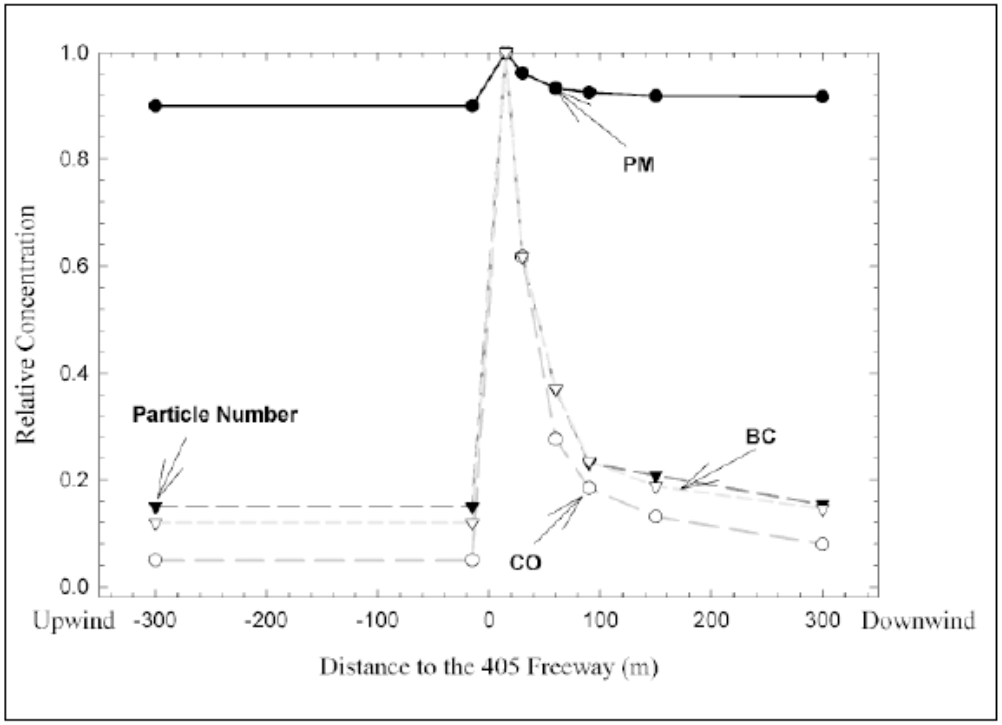
Expensive instruments
Specialized training required
Large physical footprint
Large power draw



However, research shows that air pollution can vary over small spatial increments



e.g., Over 45 million people in the United States live within 100 meters of a major transportation system.



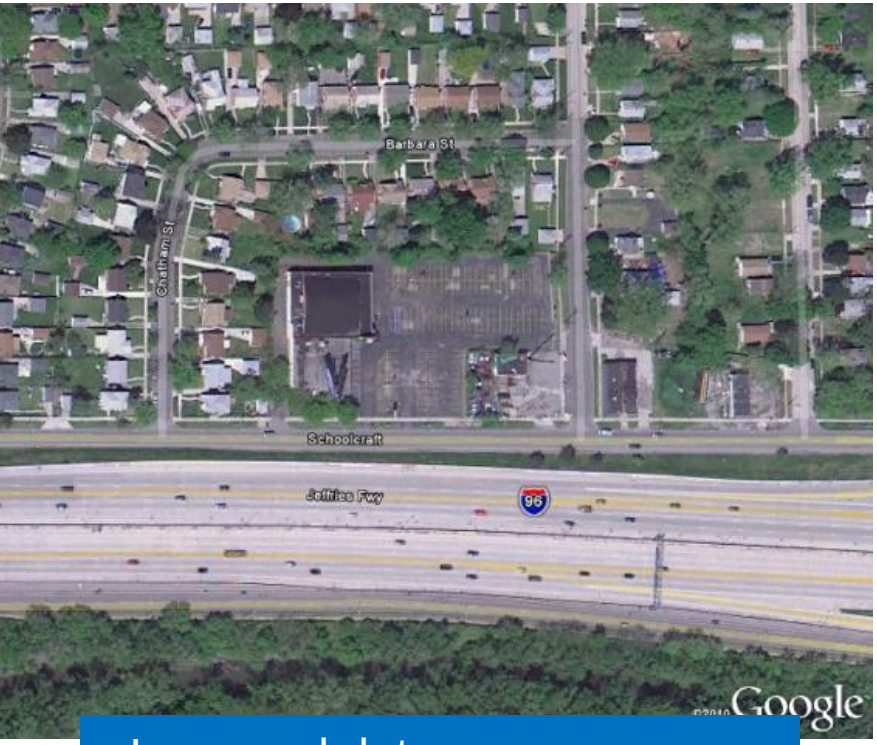
Zhu et al (2002)

High interest by public for more information

Public demand for more personalized information – what about *my* exposure, *my* neighborhood, *my* child??

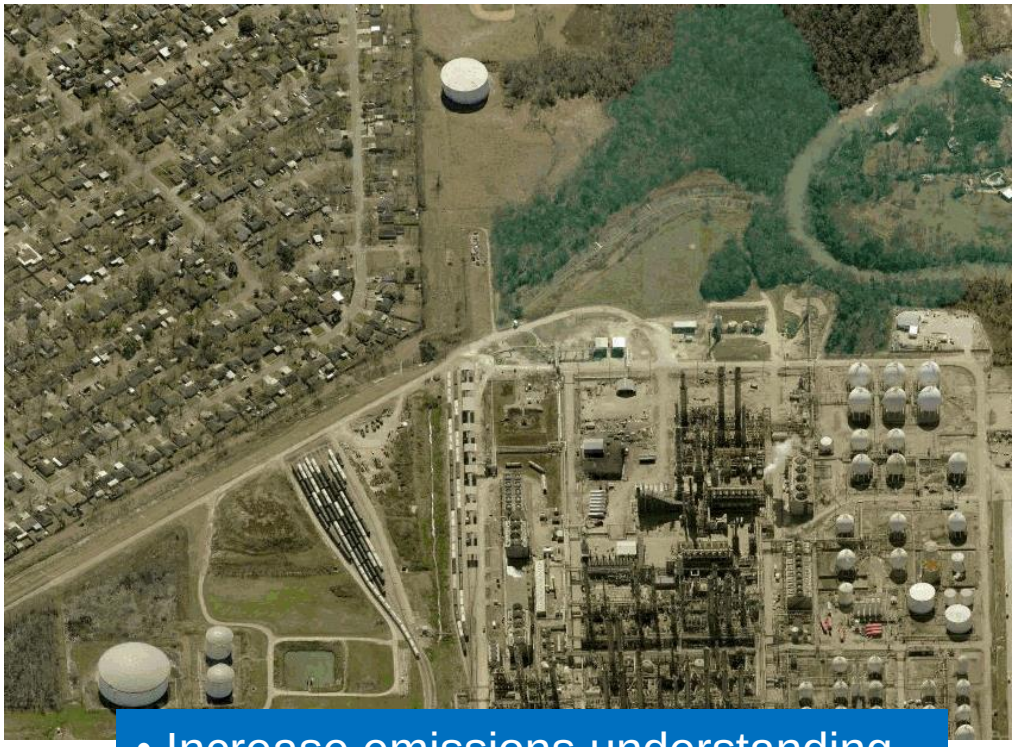
Example environments for NGAM application

Near-road assessment:



- Improved data on exposure
- Mitigation assessment
- Urban planning
- Personal health decisions

Industry fence line



- Increase emissions understanding
- Improve worker safety
- Reduced product loss
- Benefit local air quality
- Provide transparency
- Improve public relations

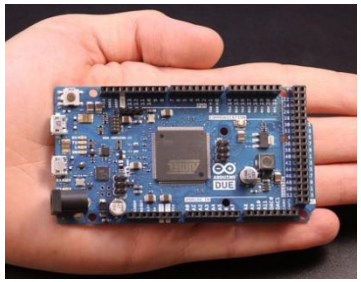
New technologies to meet the demand

Technology advances are supporting a shift towards new ways of measuring and communicating air quality information

Smartphones / Tablets in wide use

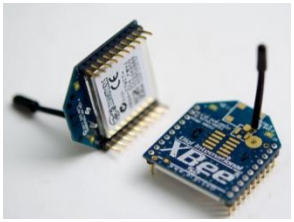
e.g., fitbit activity tracker

Miniaturization of sensors



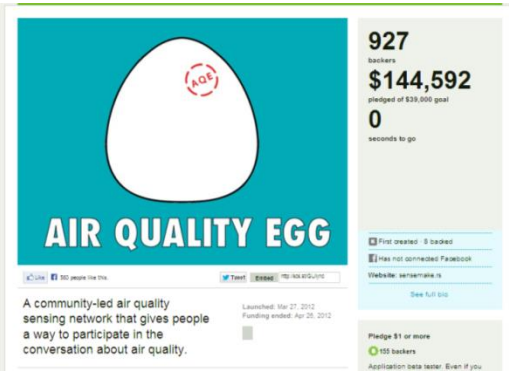
Introduction of low cost controls and communications

e.g., Arduino microprocessor



Crowd-funding supporting do-it-yourself (DIY) innovation

e.g., Kickstarter



A cultural and technology shift is underway

Emerging data-viewing/communication apps

airalliancehouston.org

londonair.org.uk/iphone

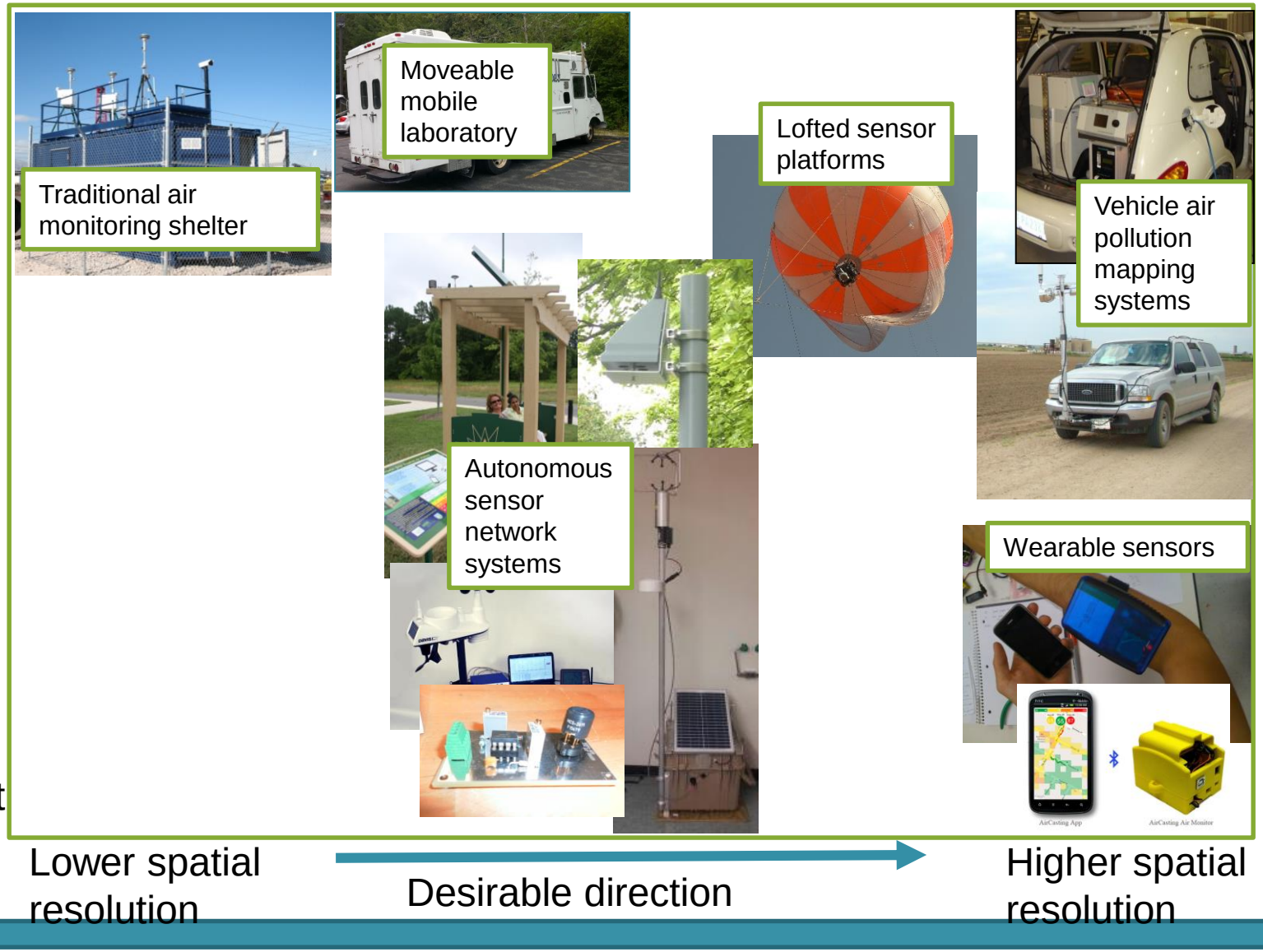
AirCasting App

aircasting.org

AirCasting Air Monitor

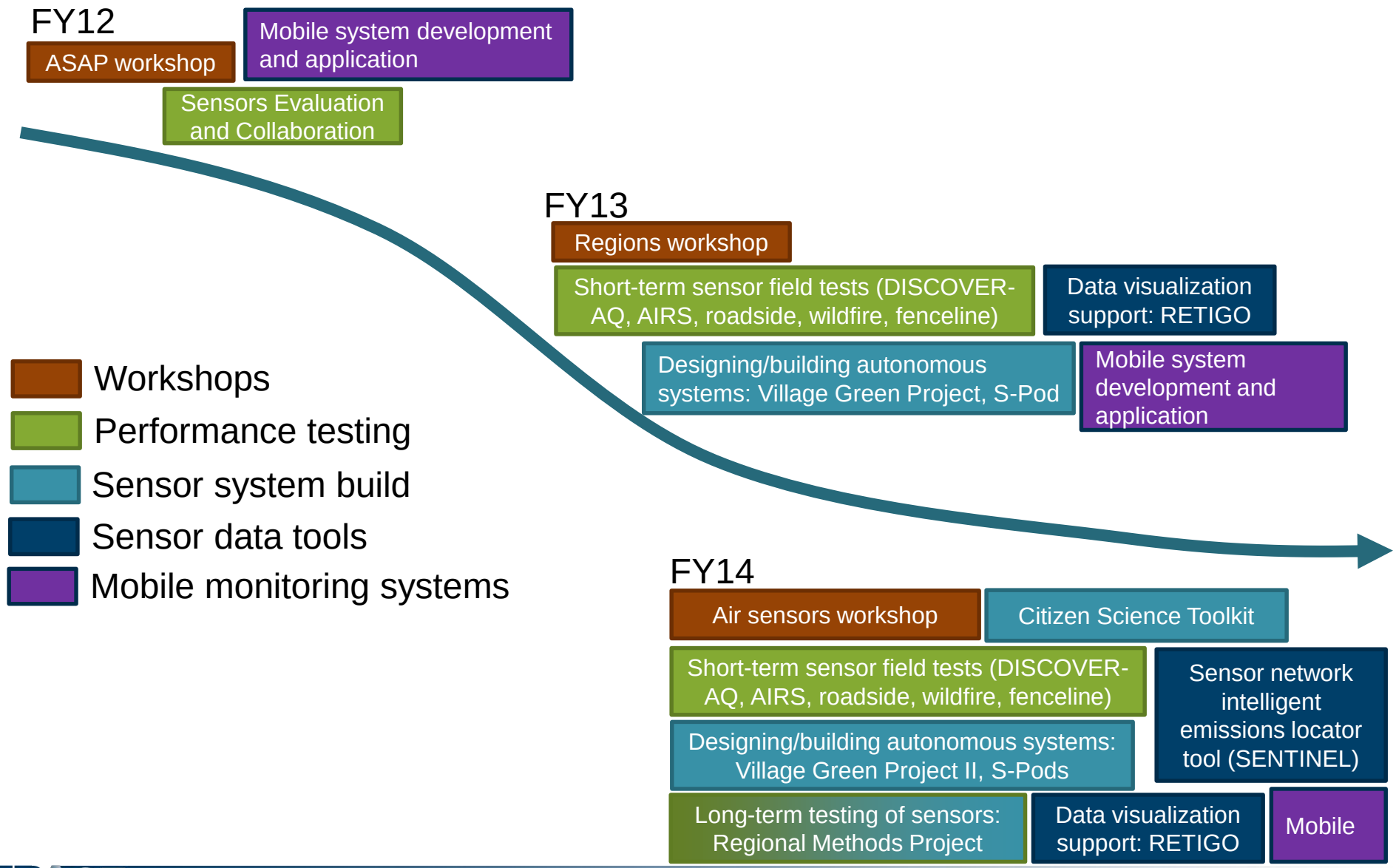
airqualityegg.com

Innovation in air monitoring

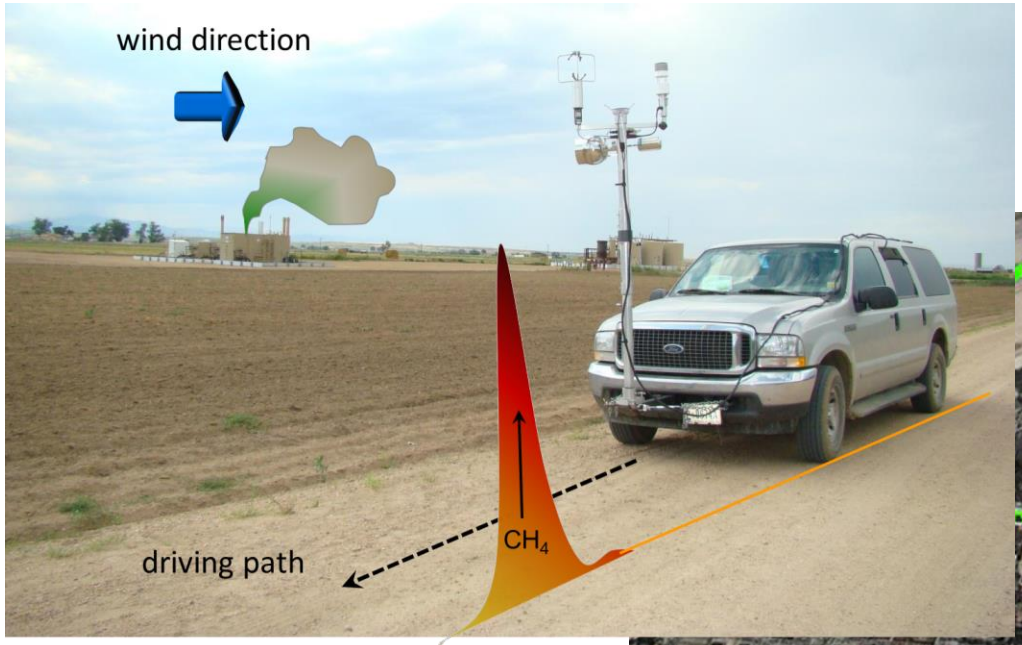


Other factors: sensor reliability, data quality, sampling rate

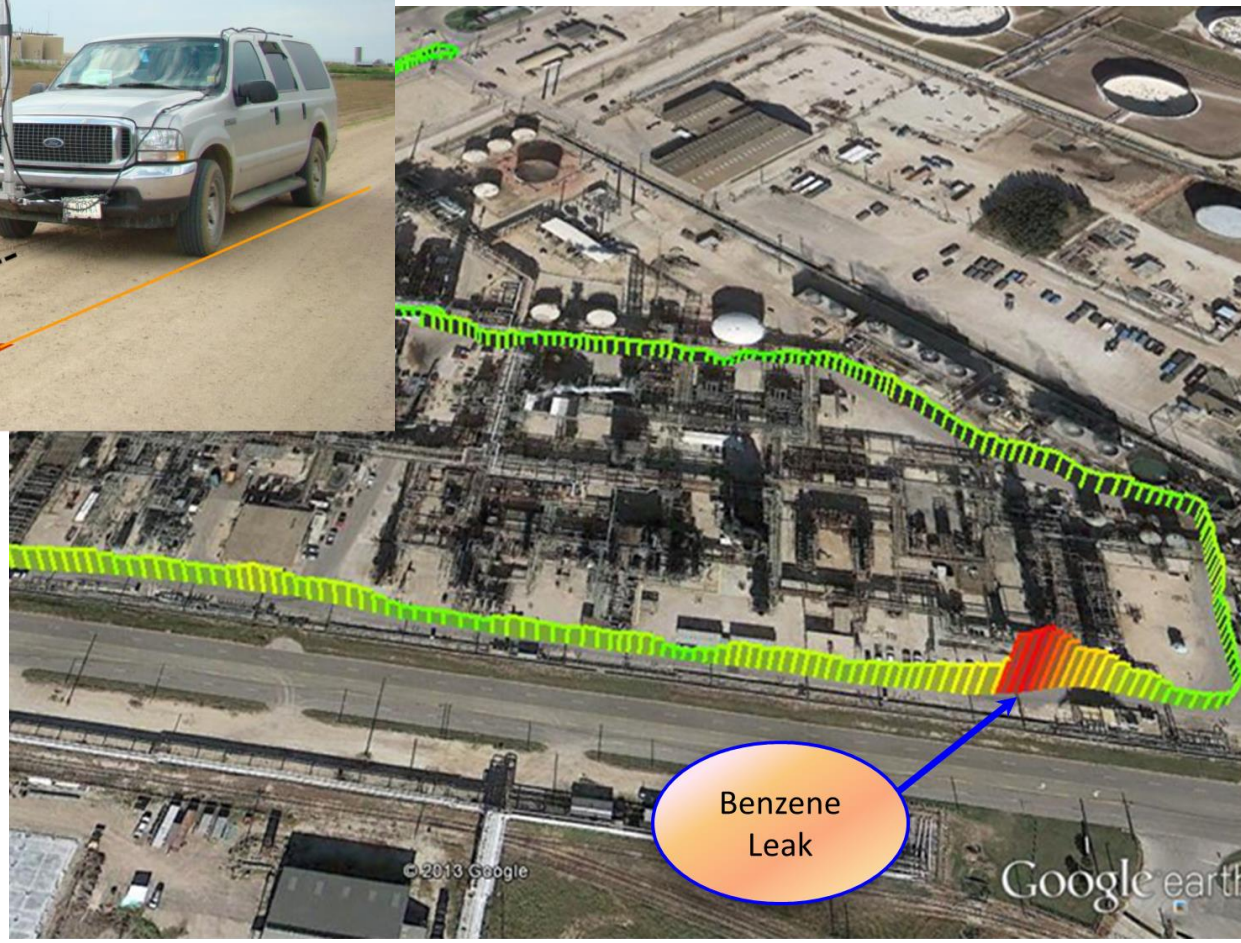
NGAM R&D has been a rapidly moving area



Mobile system development and application



Mobile monitoring to detect source emissions



Point of contact: Eben Thoma

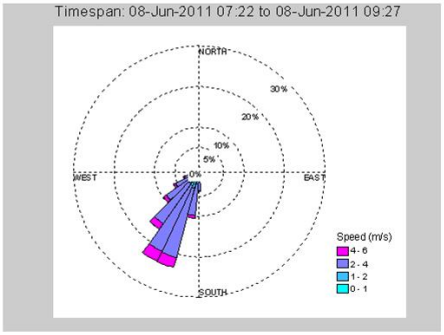
Mobile system development and application

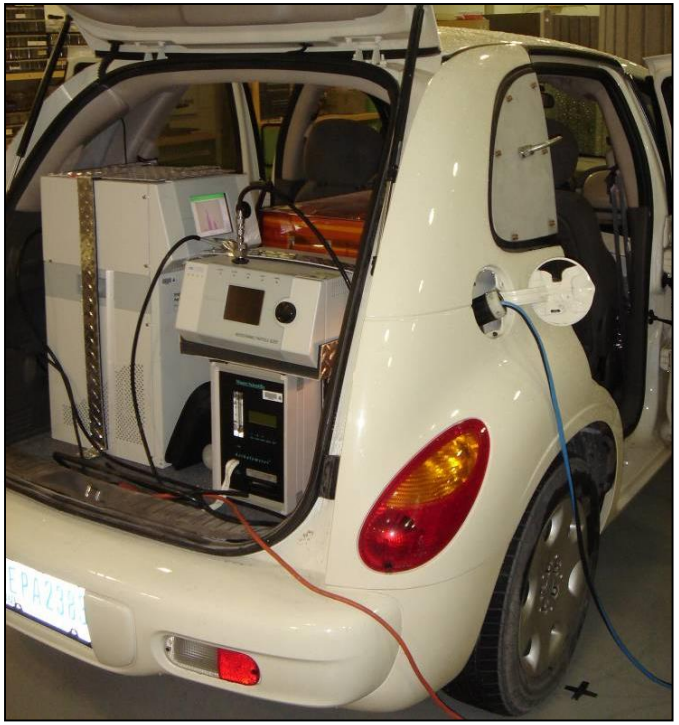
Mobile monitoring to map multipollutant air quality

Point of contact: Gayle Hagler

10m avg Excess Above Background

CO (ppb)	BC (ng/m^3)
background	background
0.001 - 19.9	0.0001- 260.5
20.0 - 53.6	260.6 - 721.2
53.7 - 140	721.3 - 1350
141 - 307	1351 - 2699
308 - 1550	2700 - 62860
UFPS (#/m^3)	**PM2 (ug/m^3)**
background	background
0.0001 - 2179	0.001 - 2.00
2180 - 4848	2.01 - 4.00
4849 - 9003	4.01 - 6.00
9004 - 19340	6.01 - 10.0
19350 - 452000	10.1 - 32.0





CO: carbon monoxide
BC: black carbon
UFPs: ultrafine particles
PM2: particles smaller than 2 micrometers

Sensor performance evaluation: lab and field

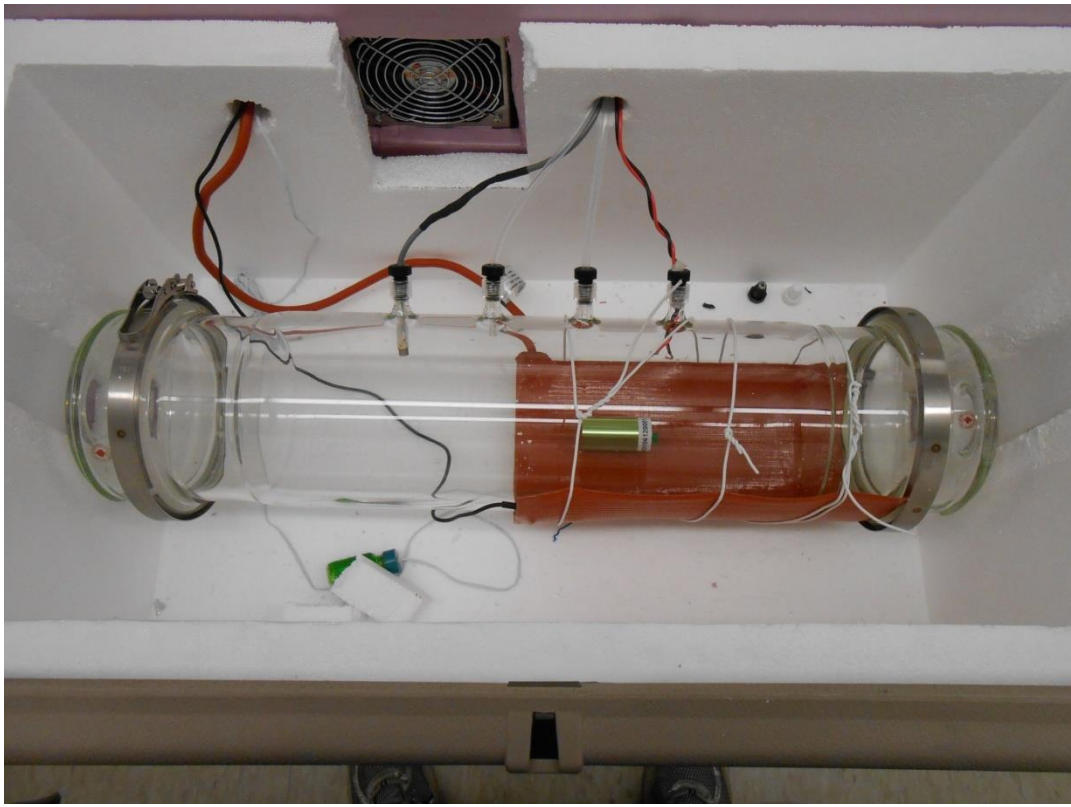
Pollutant	Laboratory controlled test	Short-term field test	Long-term field test
PM	n/a	Near-road, ambient (2013-2014)	Regional methods (2014-2016)
Ozone	Completed (2013)	DISCOVER-AQ (2013-2014)	Regional methods (2014-2015)
Nitrogen dioxide	Completed (2013)	DISCOVER-AQ (2013-2014)	Regional methods (2014-2015)
VOCs	Ongoing	Near-road, ambient (2013-2014)	Regional methods (2014-2015)
Carbon monoxide	Ongoing	DISCOVER-AQ (2014) Forest fire study (2014)	Regional methods (2014-2015)
Sulfur dioxide		DISCOVER-AQ (2014)	

- Report on laboratory evaluation of ozone and nitrogen dioxide sensors to be released in 2014

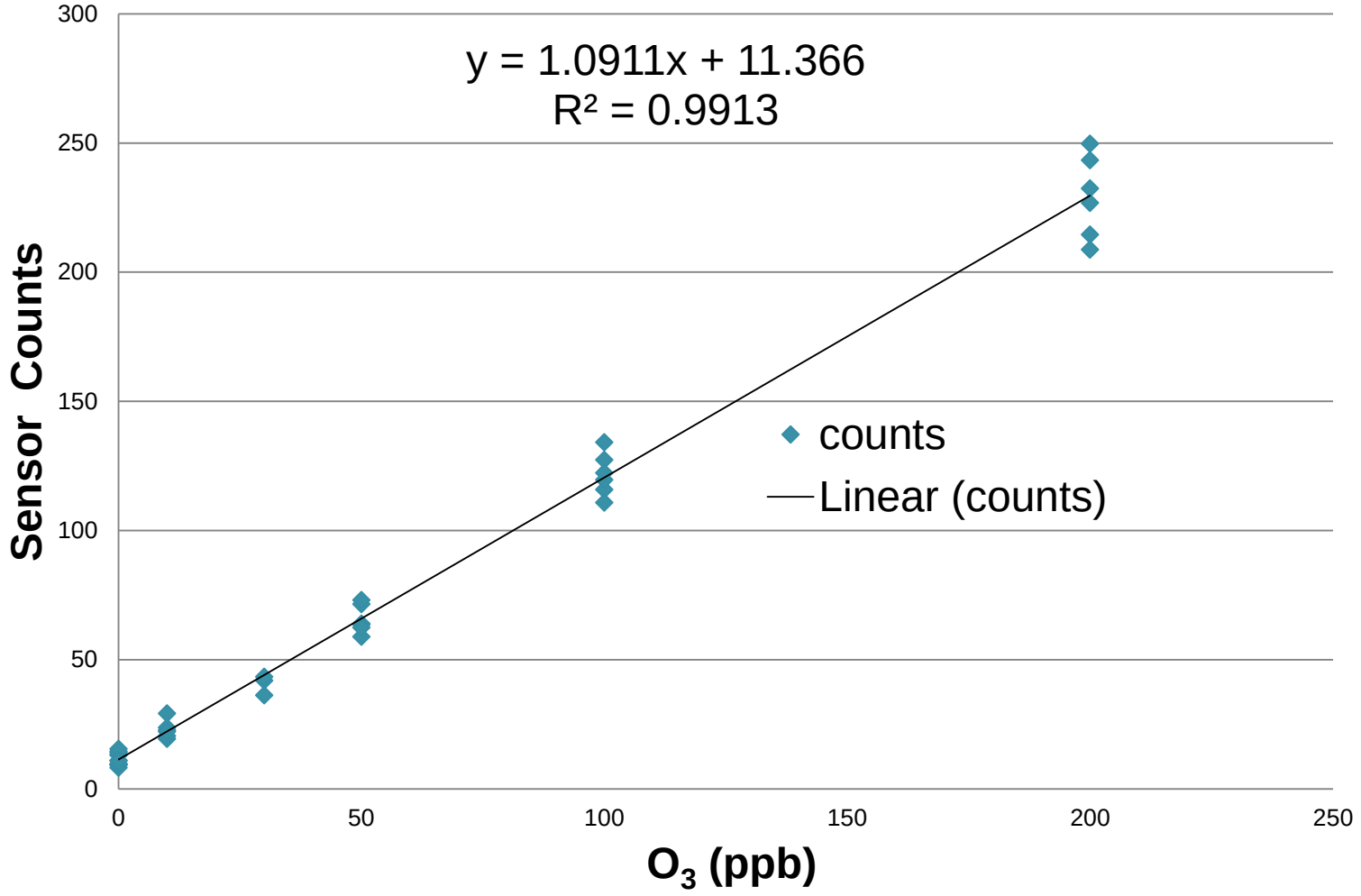
Points of contact: Ron Williams, Russell Long, Gayle Hagler

Sensor performance evaluation: lab and field

Example: Cairpol sensor for NO_2/O_3



Sensor performance evaluation: lab and field



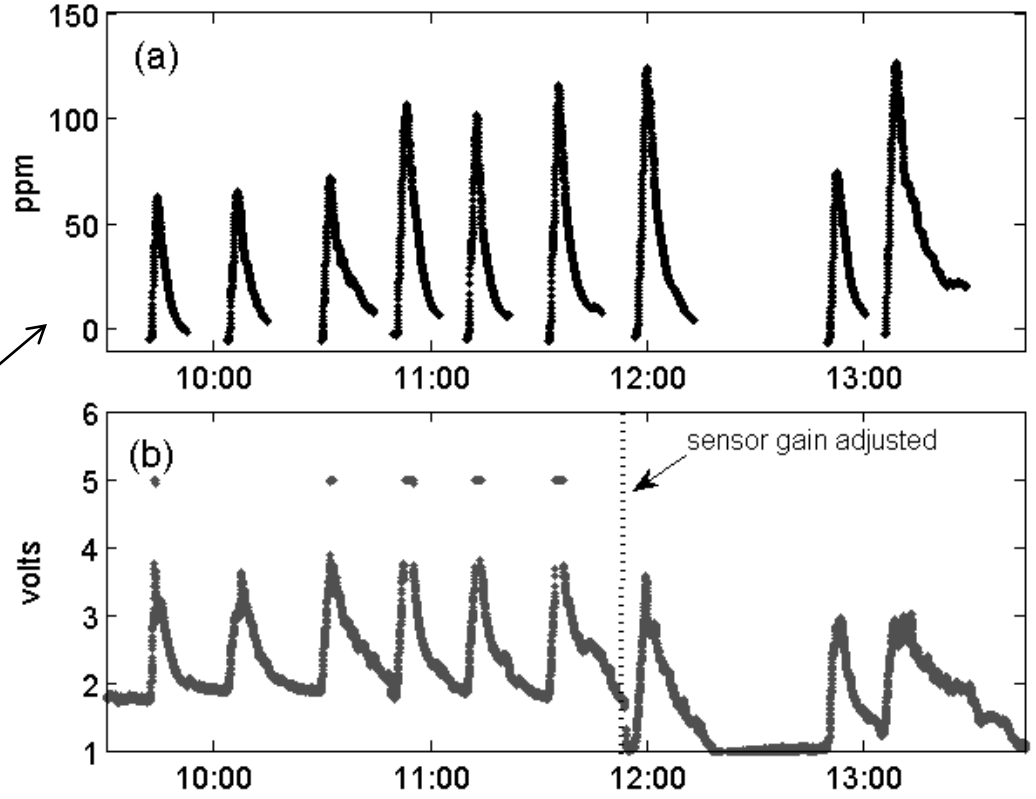
(slide courtesy of Ron Williams)

Sensor performance evaluation: lab and field

Source emissions test of CO metal oxide sensor

~$10K reference analyzer

$20 CO sensor



(Johnson et al., 2013)

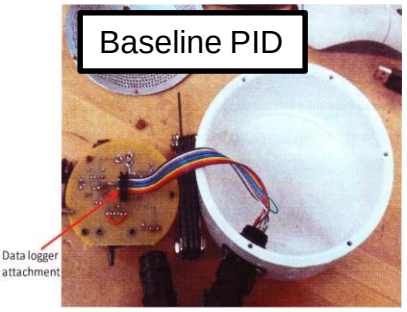
Sensor performance evaluation: lab and field

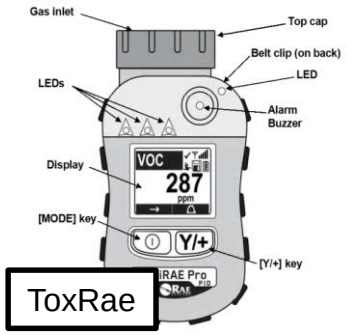
PM short-term tests – ambient, field conditions

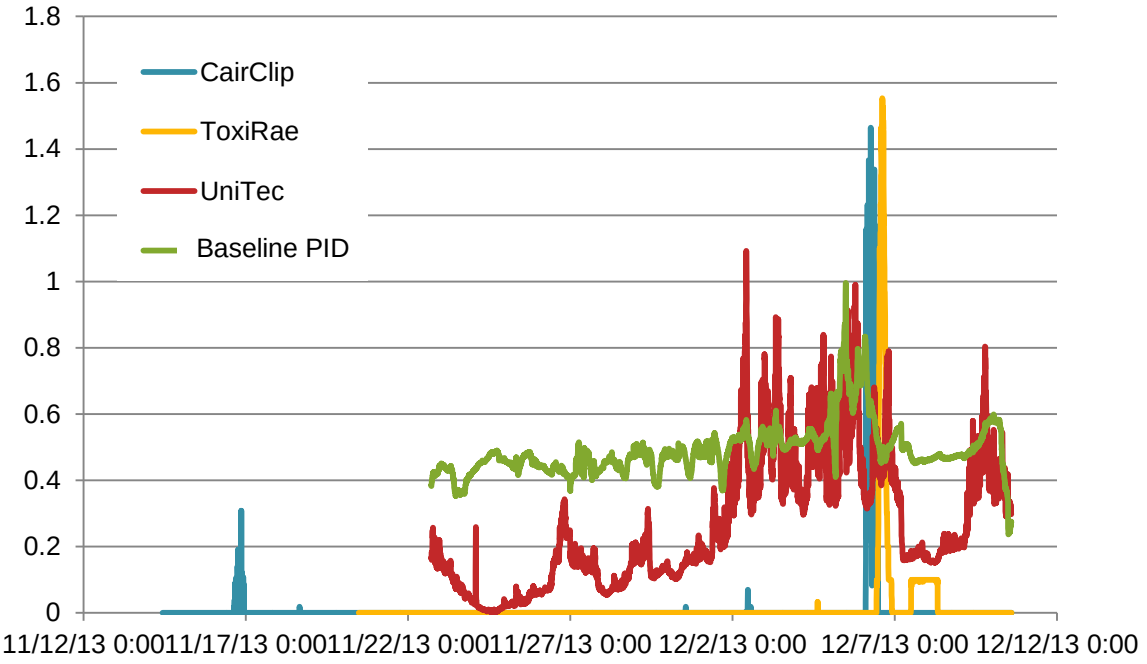
- Most low cost PM sensors provide **modest agreement with FEM** in direct collocation challenge (CODs between 0.1 to 0.5).
- **Temperature and RH being observed as influencing factors**. Some (Cairpol) suffering from very poor sensitivity. The Dylos appears to be one of the more agreeable units even though it only provides particle counts (not mass).
- We have no information on intra/inter-variability of these sensors.

VOC sensors

- It is obvious the occupational sensors (although well characterized by the manufacturer) sufferers from poor sensitivity (as expected)
- Significant disagreement between low cost sensor response







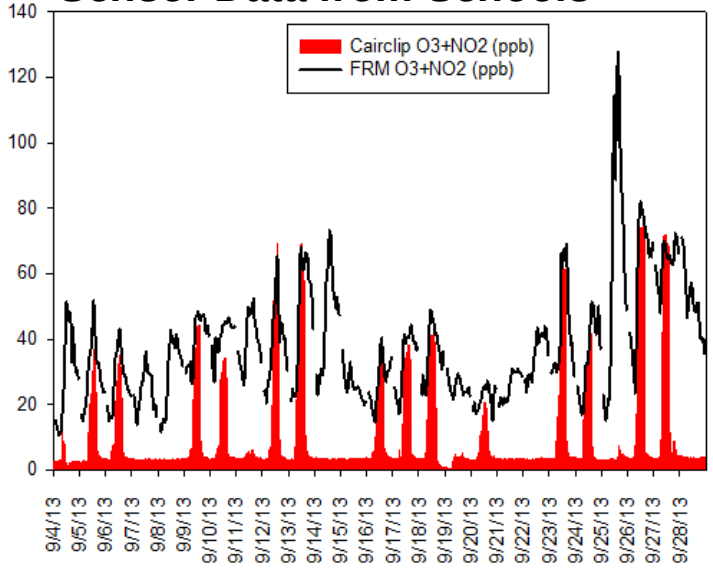
Sensor performance evaluation: lab and field

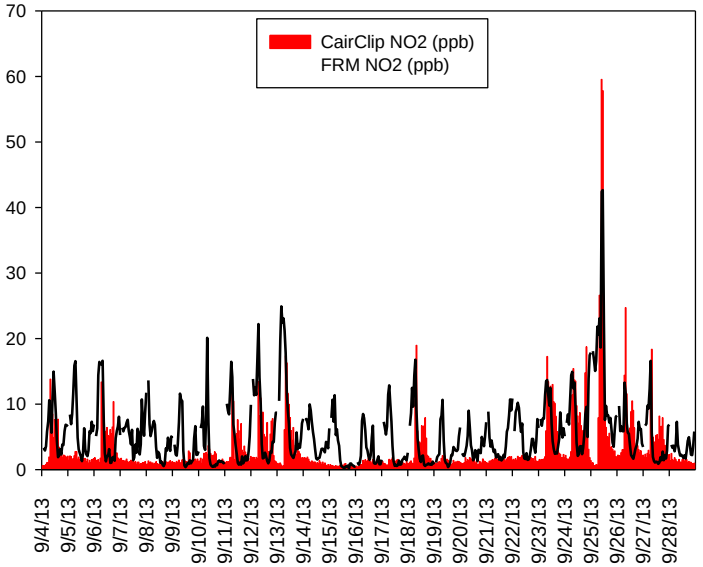
DISCOVER-AQ Study Houston, TX (Sept. 2013)

- Citizen science: small NO_2/O_3 and NO_2 sensors deployed at 7 schools
- Sensor data compared to reference analyzer data
- Low-cost sensors performed well

CairClip Sensor

Sensor Data from Schools

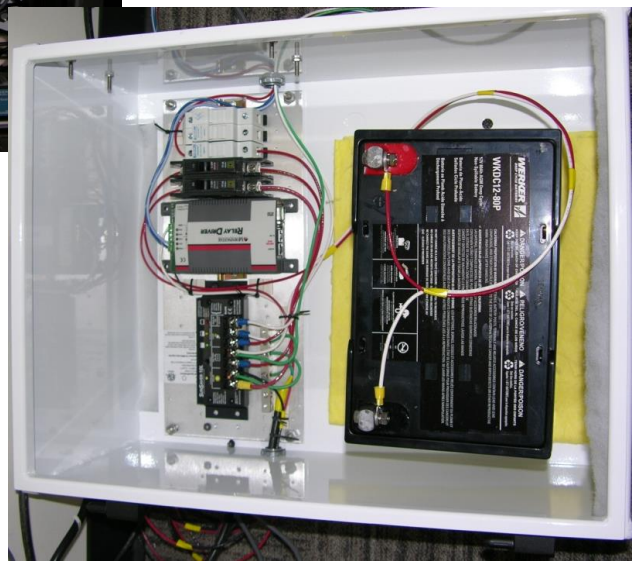




Point of Contact: Russell Long, Rachelle Duvall

Sensor system development

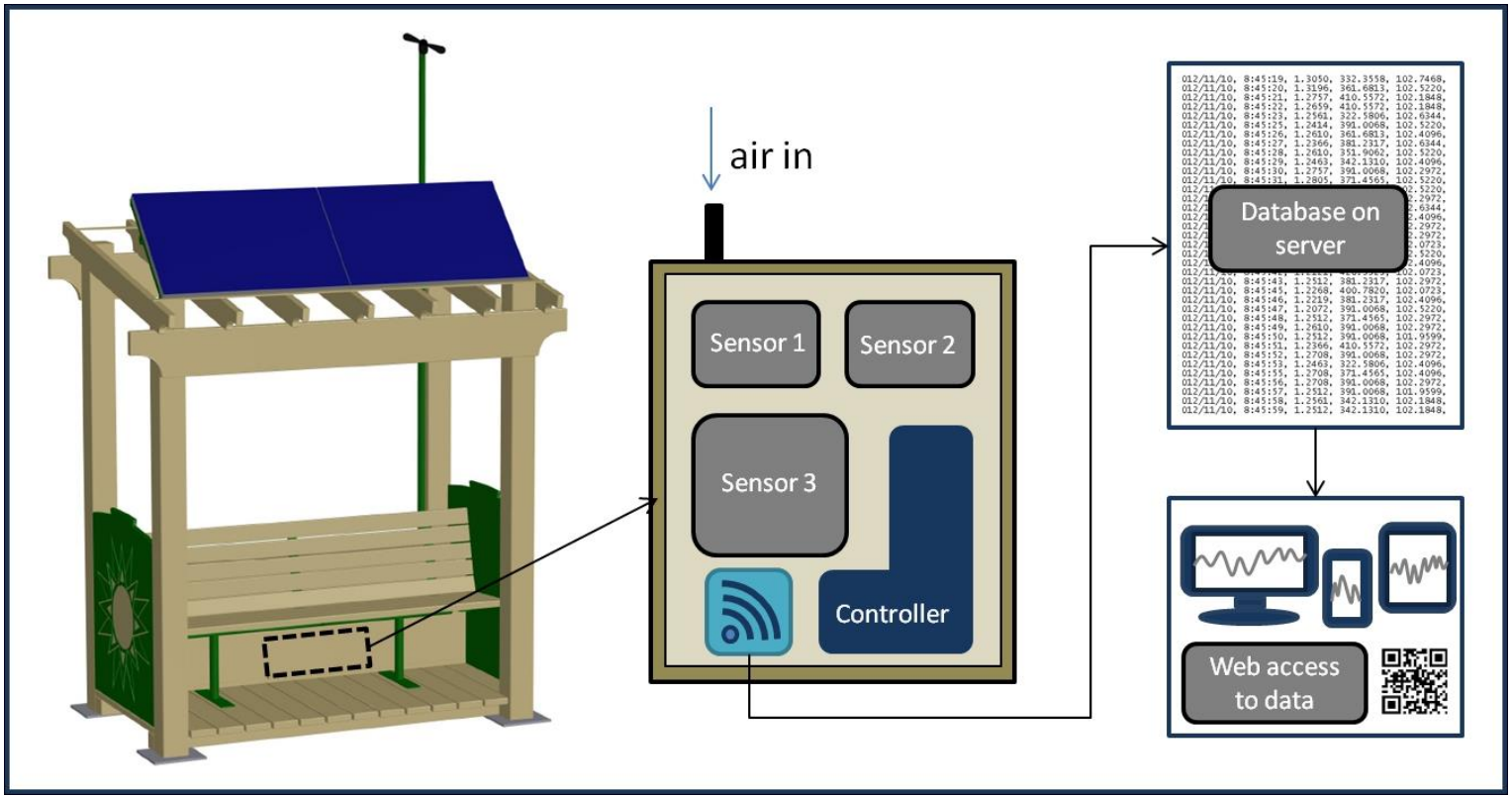
Points of contact: Gayle Hagler, Ron Williams



Air instruments (PM, ozone), power system and communications components stored securely behind bench

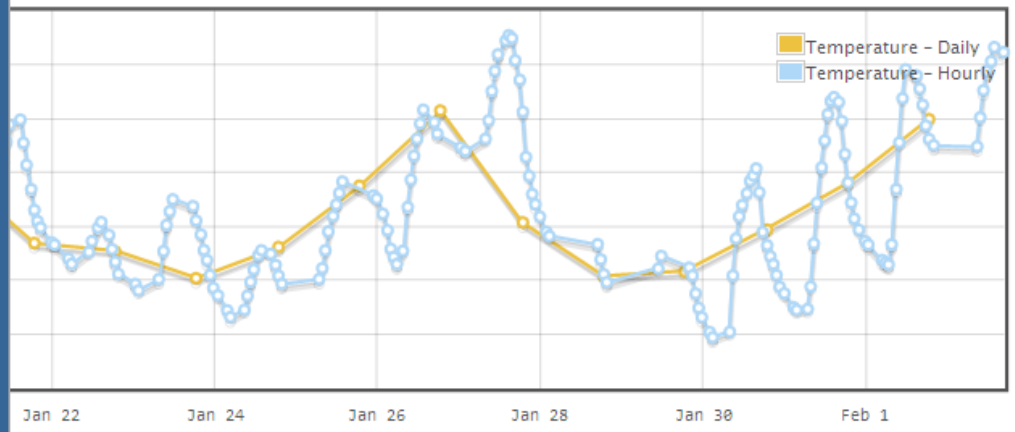
Data communication

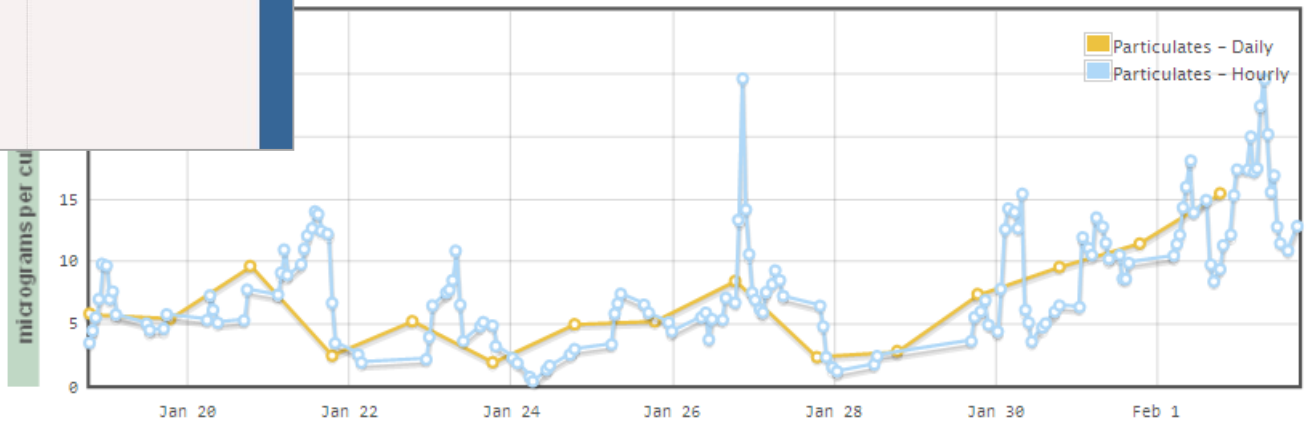
- Data transmitted via cellular modem to HTTP server
- Data screened on SQL server for various diagnostic indicators, averaged to desired interval (e.g., hourly, daily)
- Data available to web browser interface



Sensor system development

Public website updated minute-by-minute





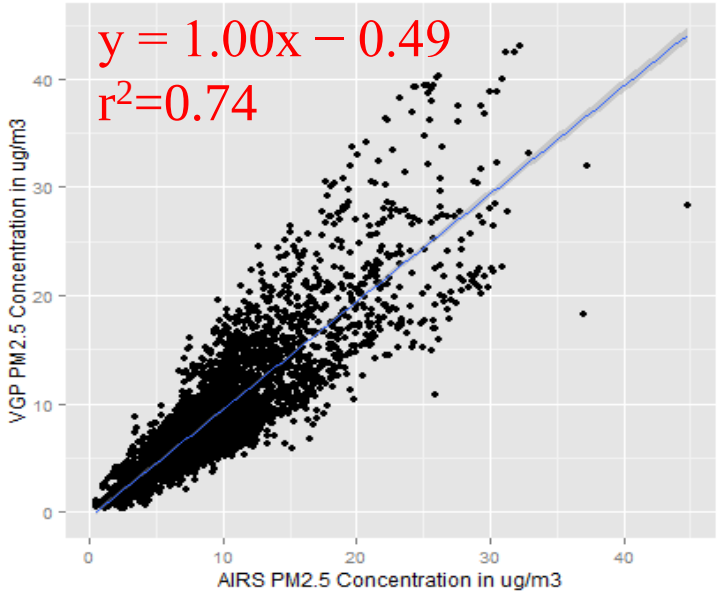
Sensor system development

MOU with Durham County supporting station placement and outreach

Sensor system development

System performance:
Solar power system has provided sufficient power 95% of the time over June 2013 to March 2014 (9 months) for instruments to collect data.

Data quality:
ORD and OAQPS collaborating to compare the Village Green station data with regulatory data. Initial comparisons are promising.

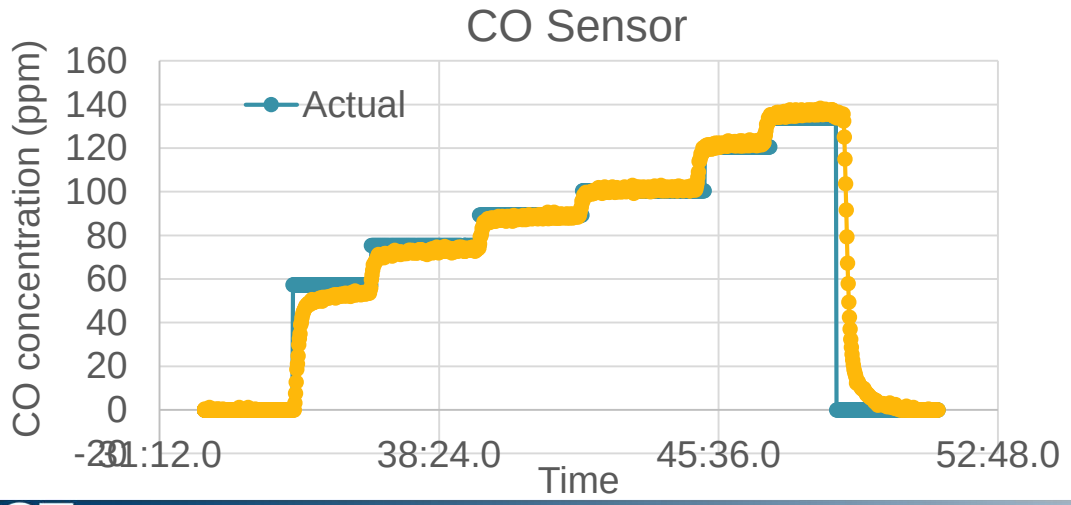


Example: comparison of 6 months of hourly $PM_{2.5}$ values from the Village Green particle instrument ("VGP") against a federal equivalent method instrument OAQPS runs on the RTP-campus ("AIRS")

Sensor system development

Point of contact: Brian Gullett

Air sensor system development to characterize emission plumes

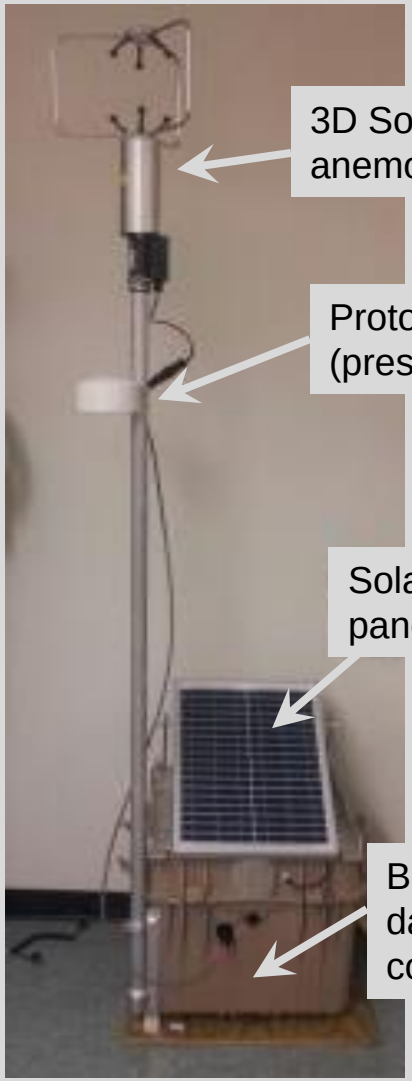


Very small sensors undergoing laboratory testing in advance of field tests of source emissions

Sensor system development

Point of contact: Eben Thoma

Drop-in-place Sensor Pod (SPod)



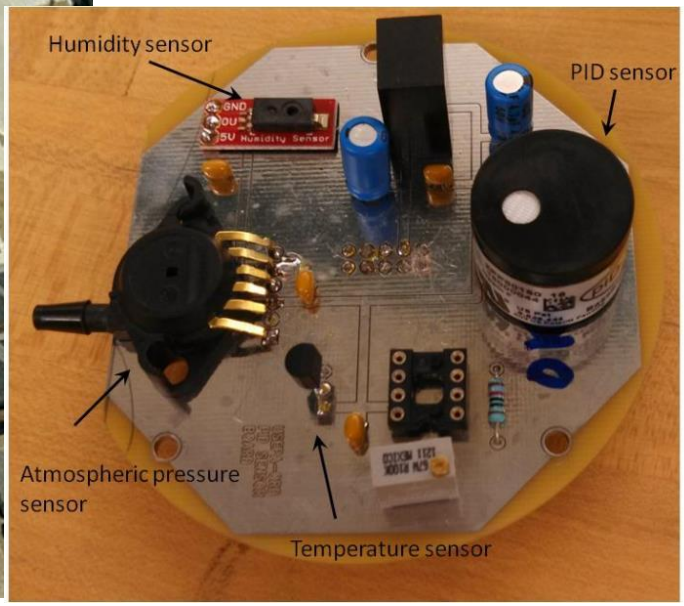
Inside of battery box

Sensor system development

Conceptual application

EPA PID sensor board

(PID from Baseline Mocon Inc.)



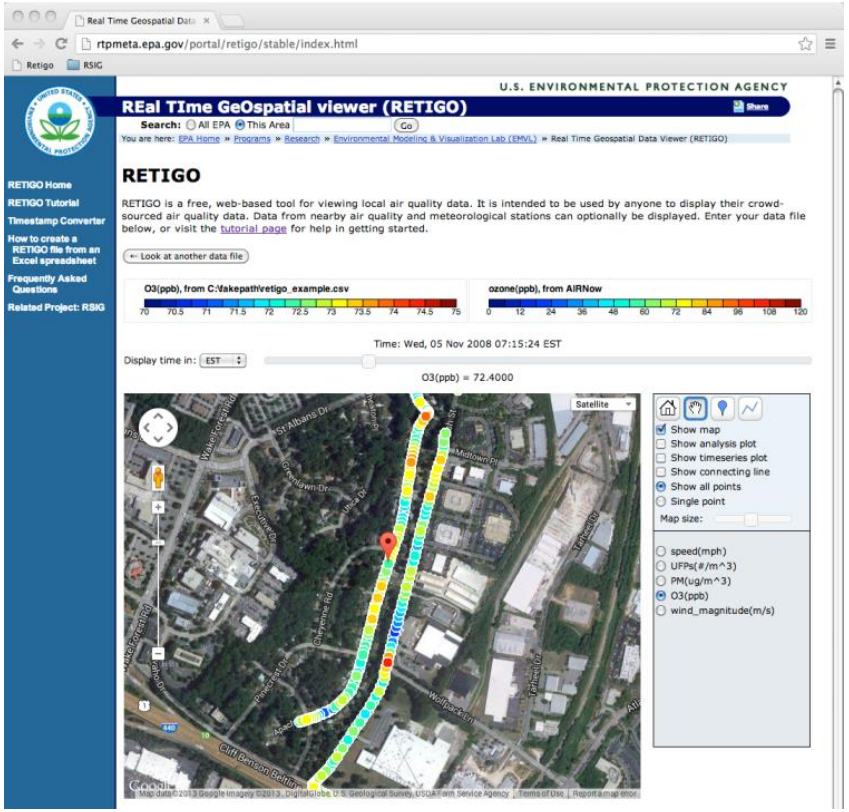
Data visualization support: RETIGO

Point of contact:
ORD: Gayle Hagler

Objective: reduce barriers to participating in mobile air monitoring data analysis

Mobile air monitoring data:
- A function of time, location, and pollutant
- Often collected at a high time resolution (large time series)
- Variable format, location, instruments

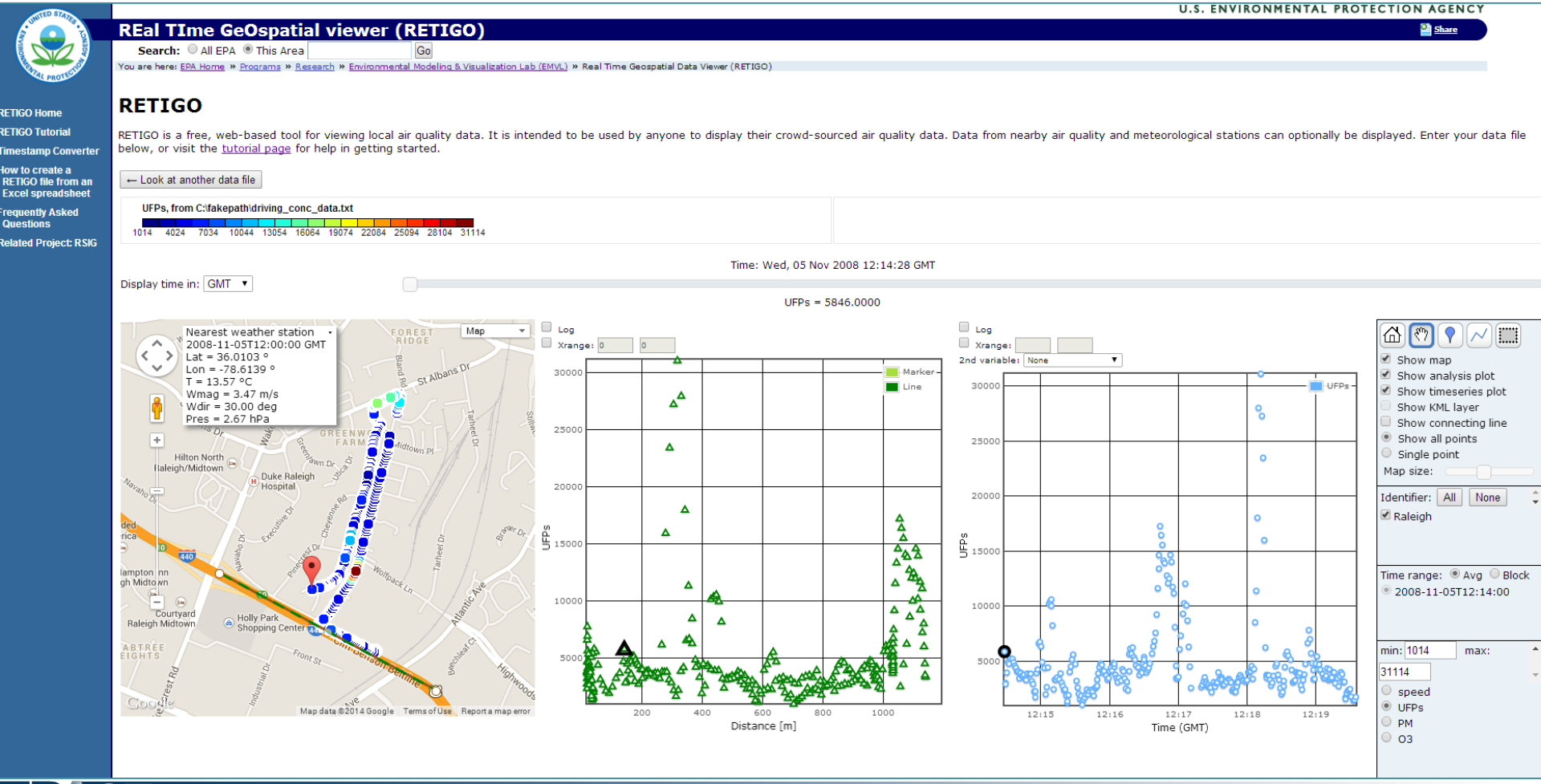
Mobile air monitoring data analysis and exploration:
- Analysis often limited to those individuals with advanced training and access to specific software tools (e.g., MATLAB, GIS, etc.)



We are building RETIGO to support mobile air monitoring individuals and teams, reducing the technical barriers to visualize the complex data and complement advanced data analysis techniques.

Data visualization support: RETIGO

- Allows exploration of data over time and space
- Supports plotting concentration as a function of distance from a hypothesized line or point source



What else is out there? : Adding biometric sensors

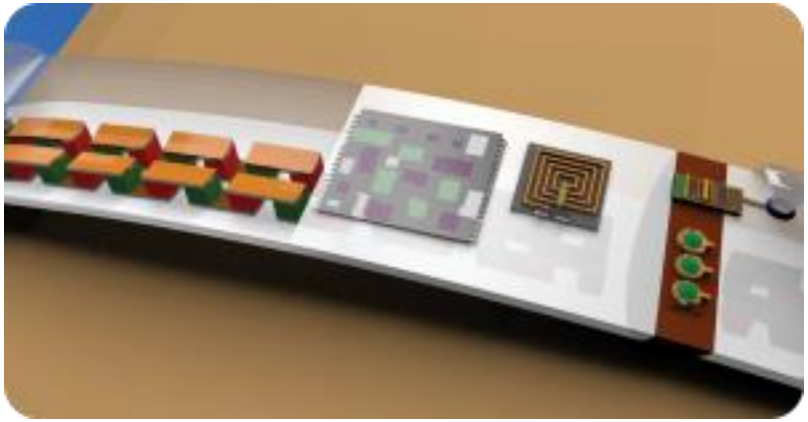
Conscious Clothing – measuring breathing rates/volume and heart rates

Winner of DHHS/EPA's My Health/My Air contest:
David Kuller, Gabrielle Dockterman, and Dot Kelly

- Lilly pad microcontroller (Arduino) designed for wearable applications
- Particle sensor
- Breath analyzer

http://www.youtube.com/watch?v=XPvyIXdkc4g

What else is out there? : Adding biometric sensors

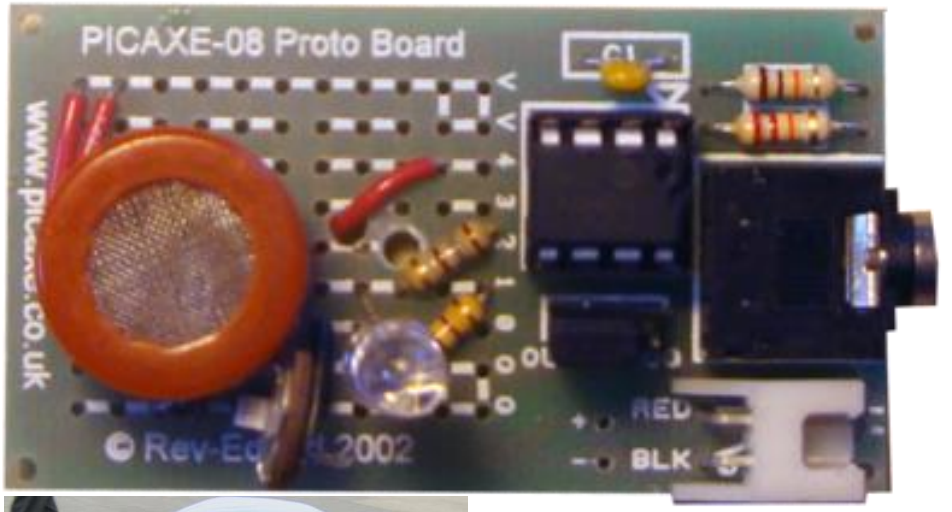


NC State ASSIST program: vision of innovation to support wearable sensors for health and the environment

- Aiming for very low power devices (micro-Watts), power supplied by the wearer (motion, heat)
- Pushing the boundaries for miniaturized air monitoring strategies

(assist.ncsu.edu)

What else is out there? : Art (and data) displays



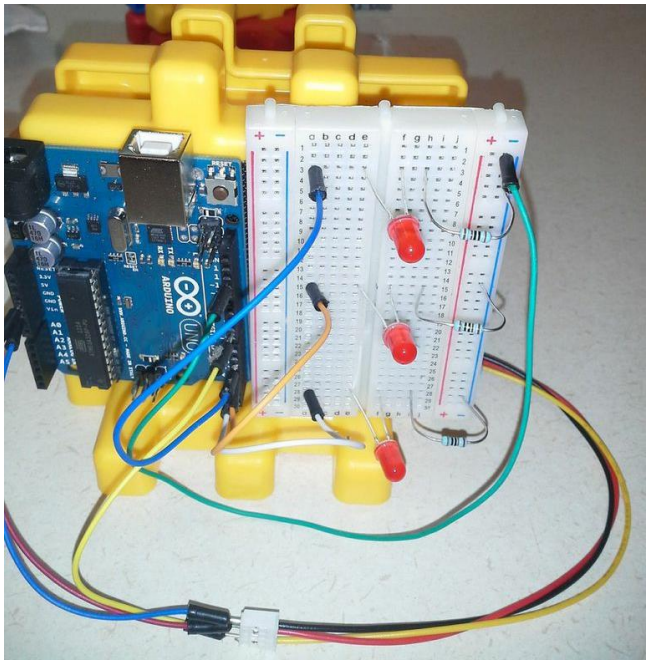
http://f-l-o-a-t.com/

What else is out there? : Education focus

- Supporting project-based learning and STEM (science, technology, engineering, and mathematics) education

Components

- Low cost particle sensor
- Arduino microprocessor
- Breadboard, LEDs, wires



What else is out there? : Education focus

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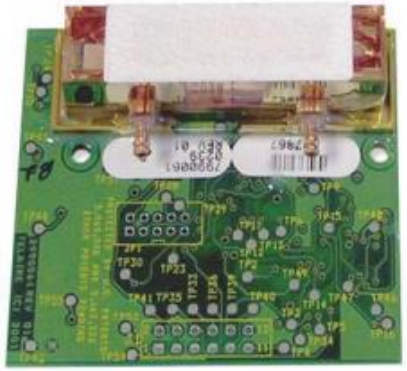
Hacking a fiber-optic flower centerpiece to change colors with CO_2 levels



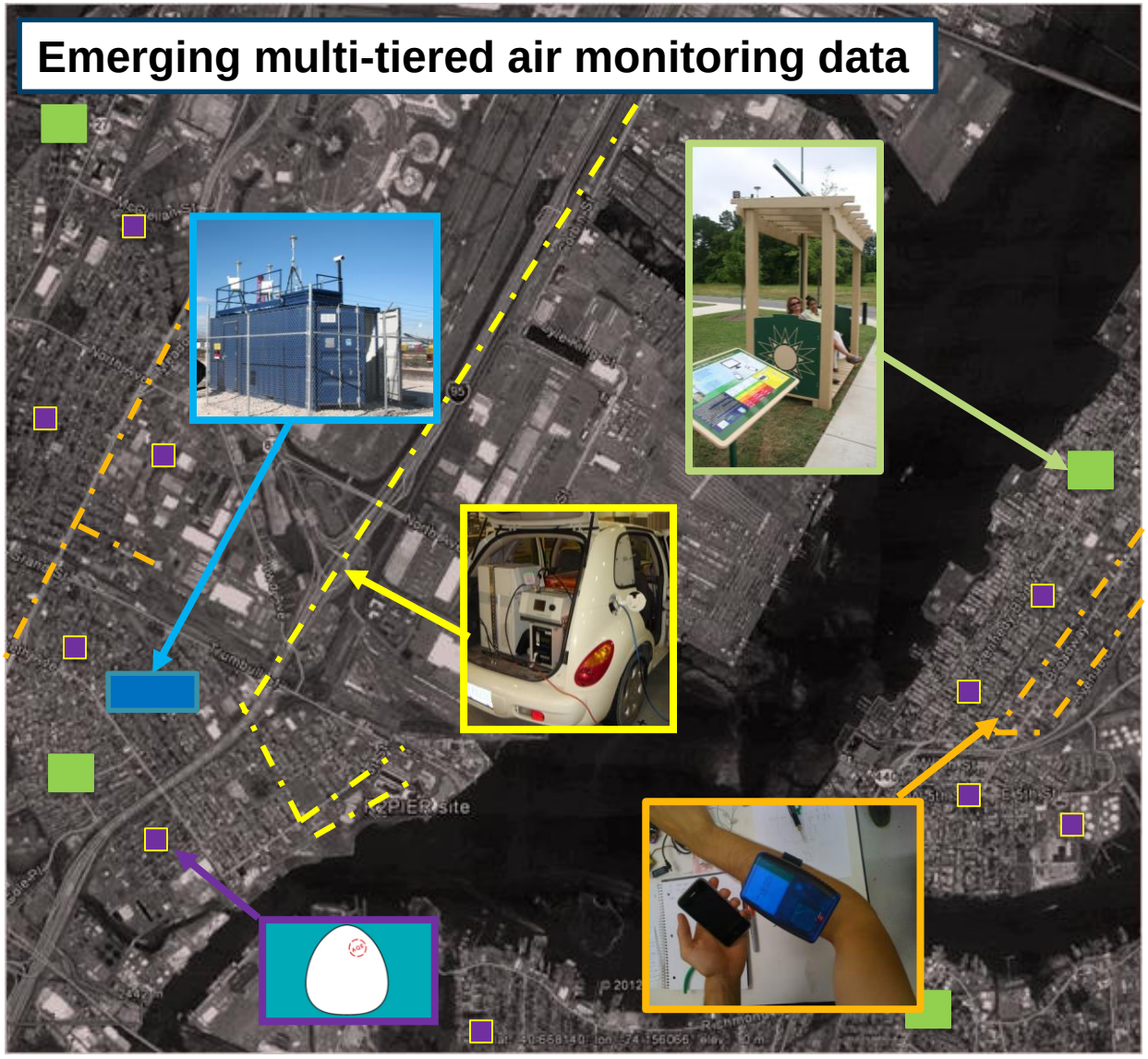
CO_2 NDIR sensor

Fiber optic flower demo

What does this all mean?

	Current Approach	New Paradigm
How data are collected?		Sensor Technology 
Who collects the data?	Limited Mostly to Governments, Industry, and Researchers	Expanded Use by Communities and Individuals
Why data are collected?	Compliance Monitoring, Enforcement, Trends, Research	New and Enhanced Applications
How data are accessed?	Government Websites, Permit Records, Research Databases	Increased Data Availability and Access

Challenges and opportunities



Opportunities:

- Unprecedented access to data on neighborhood-scale air quality
- Lower cost strategies to achieve air monitoring goals
- Engagement with communities, schools, industry

Challenges:

- Data interpretation and public messaging
- "Big data" analysis
- Support for do-it-yourself/citizen science

Ongoing work at EPA

- Field and laboratory research to characterize performance of new sensors

- Development of tools for managing and visualizing sensor data

- Ongoing dialogue on policy implications and public health messenging

Acknowledgements

WISeNET program and their very bright students!!

EPA ORD staff: Tim Watkins, Lindsay Stanek, Vasu Kilaru, Paul Solomon, Stacey Katz, Gail Robarge, Peter Preuss, Emily Snyder, Ann Brown, Kelly Leovic

Student services contractors and interns: Dana Buchbinder, Rachel Clark, Halley Brantley, Amanda Kaufman, Karoline Johnson (former), Tierney Foster-Wittig, Ashleigh Swingler