Update on EPA & Air Sensors

Gayle Hagler, Ph.D.
EPA Office of Research and Development

August 16, 2016

EPA

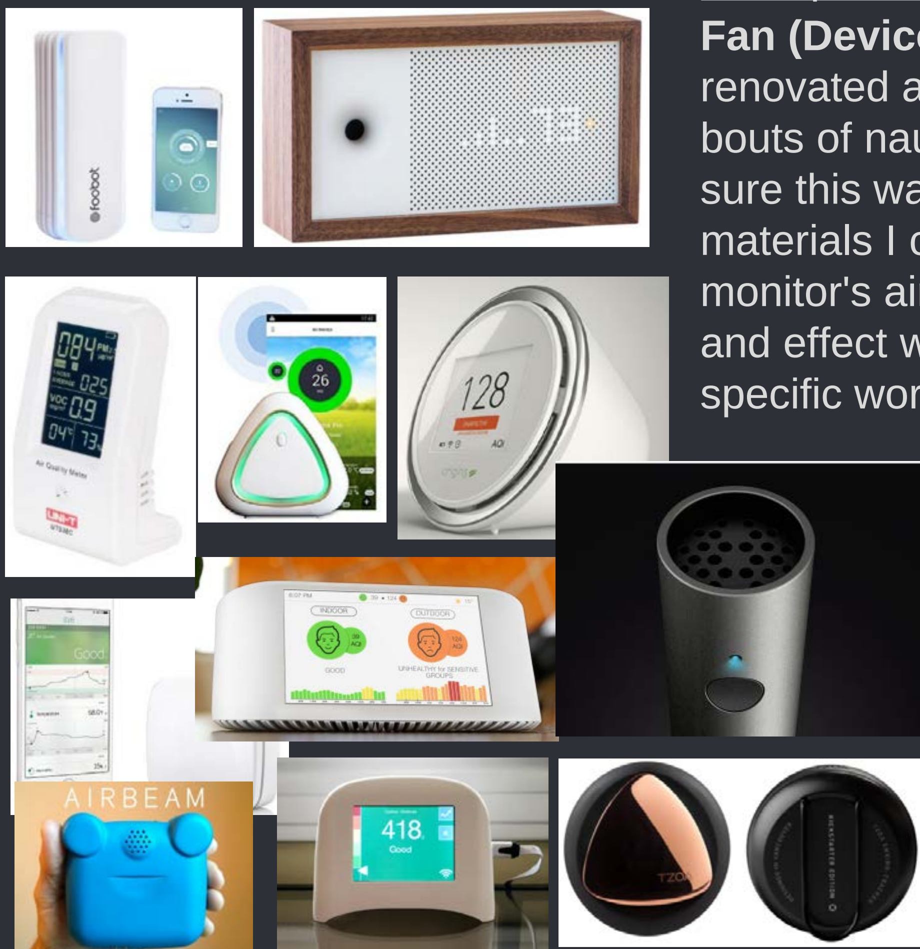
Air quality sensor characteristics…

- Small footprint or mobile, battery or solar power
- Direct-reading (w/out laboratory analysis)
- Variable in ease of use, turnkey or not
- Lower cost than traditional methods
- Variable users (e.g., universities, citizens, some air monitoring agencies experimenting)
- QA protocol gaps

Brief overview of air quality sensors

Still in the “early adopter” phase, but prevalence is quickly increasing everywhere

Consumer-oriented turnkey devices:



Example Amazon review comments

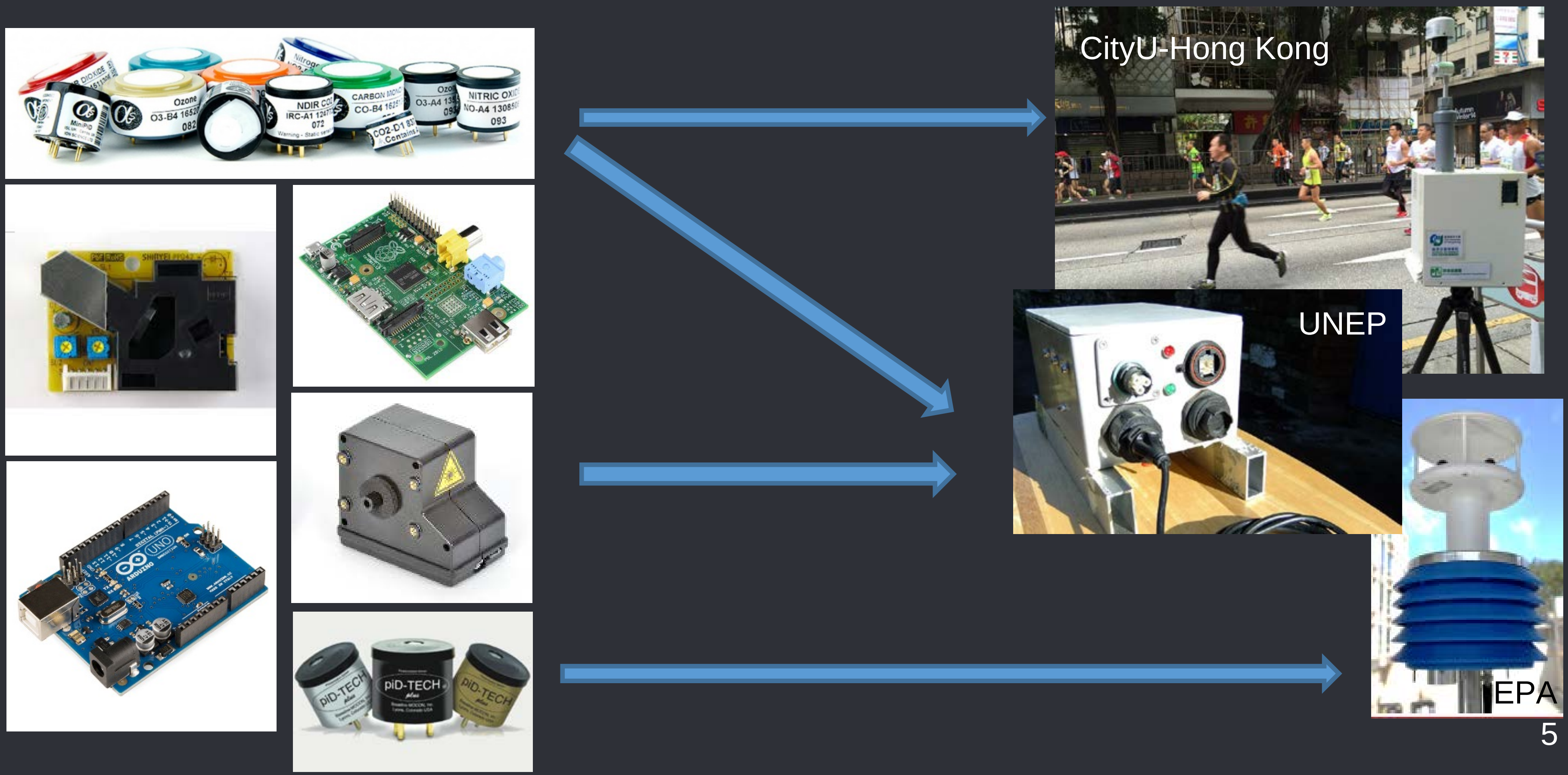
Fan (Device A): “…The apartment below us was being renovated and my children and I were suffered various bouts of nausea and headaches for few weeks. While I was sure this was directly attributable to the construction materials I couldn't prove it….I was able to show the monitor's air quality reports and…demonstrate a real cause and effect with graphs and time stamps correlating to their specific work. This changed everything for us…”

Fail (Device B): “The air quality levels indicated by this device fluctuate wildly. Particularly on even slightly humid days, the VOC levels…go haywire and begin showing very unhealthy air…if I unplug the device and plug it back in the VOC levels are back in line. So it is utterly unclear when the device is accurate and when it is not…In short, it is a heaping pile of manure...”

Still in the “early adopter” phase, but prevalence is quickly increasing everywhere

Researcher- or developer-oriented:

OEM sensors and supporting electronics for custom-built systems, with applications including stationary and mobile measurements

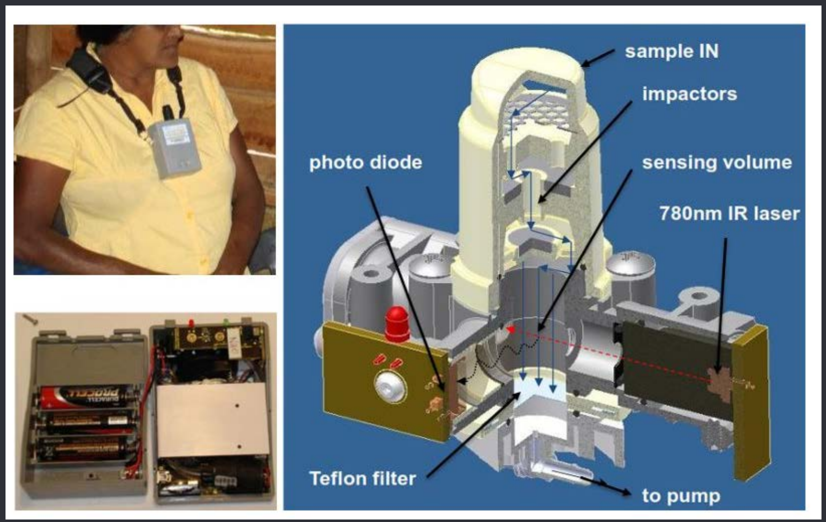


Still in the “early adopter” phase, but prevalence is quickly increasing everywhere

Research, advocacy, and screening application with turnkey devices:

Consumer-oriented products used in research applications

Research-oriented devices with additional features and capabilities



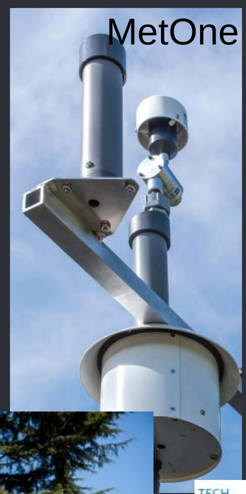
RTI MicroPEM, Source: Advances in Cookstove Field Monitoring Webinar

Star Tribune, June 25, 2016

”…local regulators experiment with cutting-edge, low-cost wearable devices that could illuminate how pollution varies across cities and neighborhoods.”

Still in the "early adopter" phase, but prevalence is quickly increasing everywhere

Designed for large-scale outdoor air monitoring:



AT&T to power Array of Things sensor network

Chicago Tribune, July 18, 2016

TECH

U.S. and Chinese Tech Firms Team Up on Sensor Networks for 'Smart Cities'

Sensity, CAS Smart City to work on technology that could monitor traffic and air quality, and provide video surveillance

Wall Street Journal, May 12, 2016

Unique application in London

https://www.theguardian.com/environment/2016/mar/14/pigeon-patrol-takes-flight-to-tackle-londons-air-pollution-crisis

A technical communications challenge

Sensor developer

The customers I serve want intuitive and actionable information, at the rate of the measurement (e.g., 10 seconds). There is no existing guidebook on how to do this. I'll take my best stab at it.

Citizen

I want to know if there is a problem, and how I can take action to reduce my air pollution exposure. I will prefer to purchase a sensor designed to fully meet this need.

Regulator

Using the EPA AQI as your reference point to communicate real-time sensor data is incorrect. Be careful how you communicate sensor data, especially given sensor performance uncertainty!

Why EPA is engaged

Sensors are bringing…

- **Opportunity**: New strategies for studying and improving air quality

- **Data Quality Questions**: Rapid influx of technologies to study the air, with unknown performance characteristics.

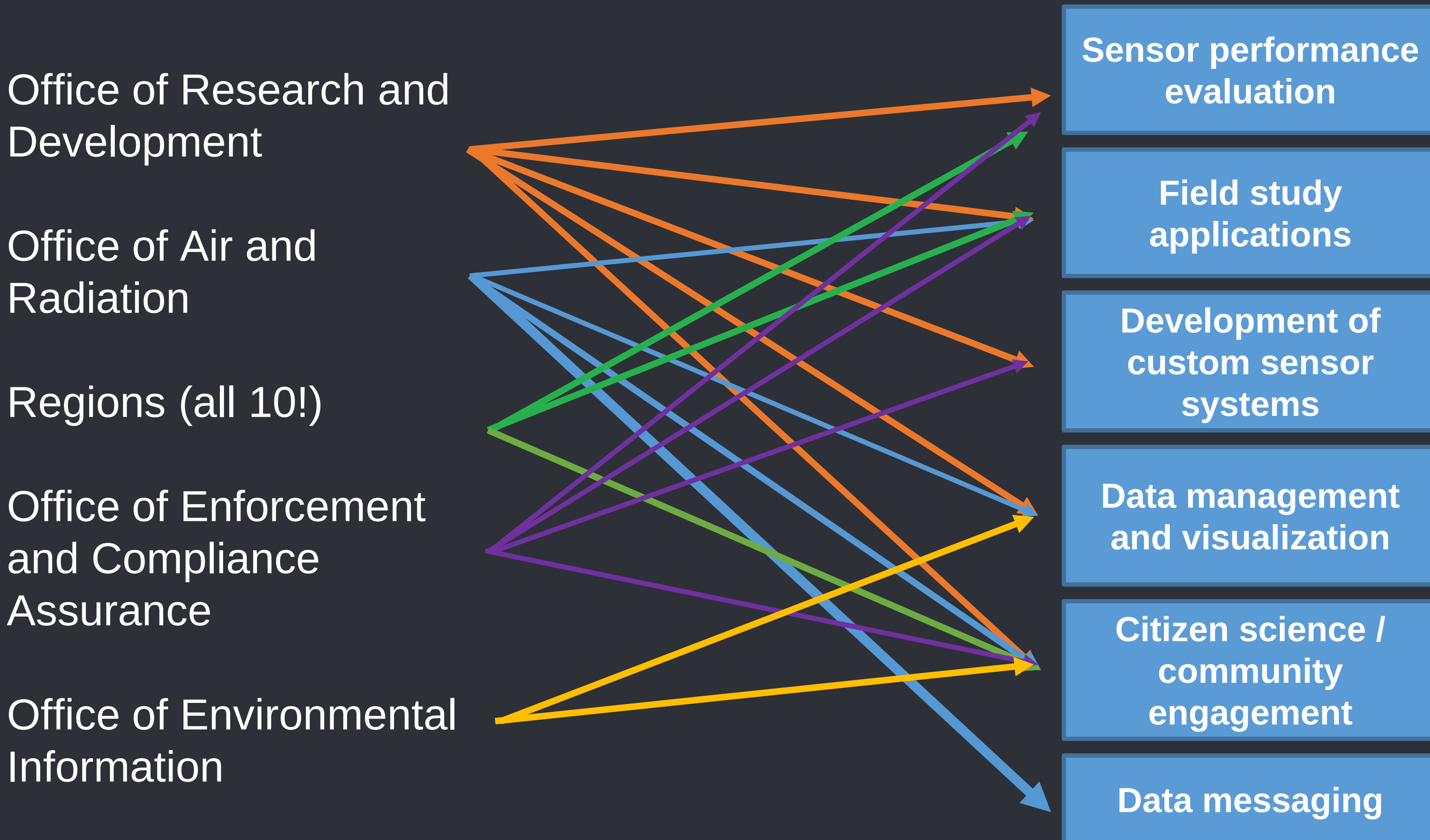
- **Participation**: Increase in the number of individuals and groups interested in monitoring their exposure.

- **New research questions:** What new information can be gained with sensors? What are defensible strategies to "fine tune" sensor data? What is the added-value of citizen science data? How will the use of sensors (and data communication) change individual behavior?

- **Requests for information**

Air quality sensors and EPA activities

A significant level of involvement and collaboration across the agency



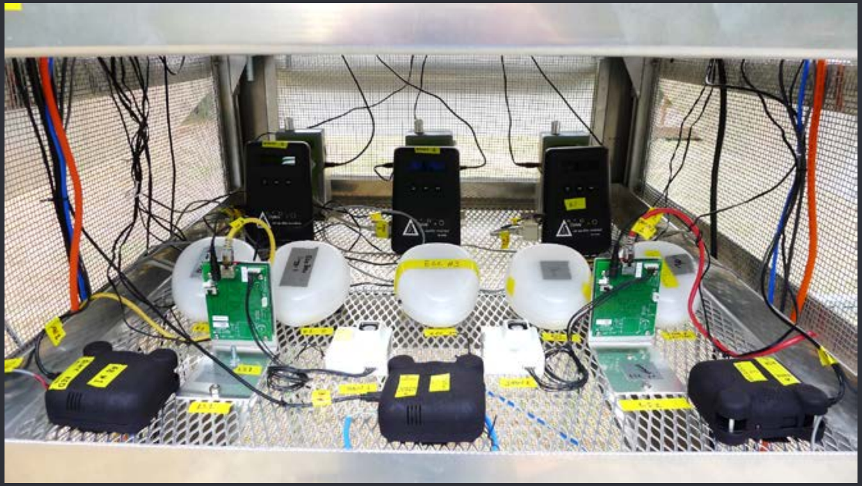
Plus, collaboration with state and local agencies, universities, sensor developers…

A significant level of involvement and collaboration across the agency

Sensor performance testing

Testing air sensor performance in laboratory and field settings

- Atlanta, GA (2014-2015)
- Denver, CO (2015-2016)
- Research Triangle Park, NC (2014 – 2016)



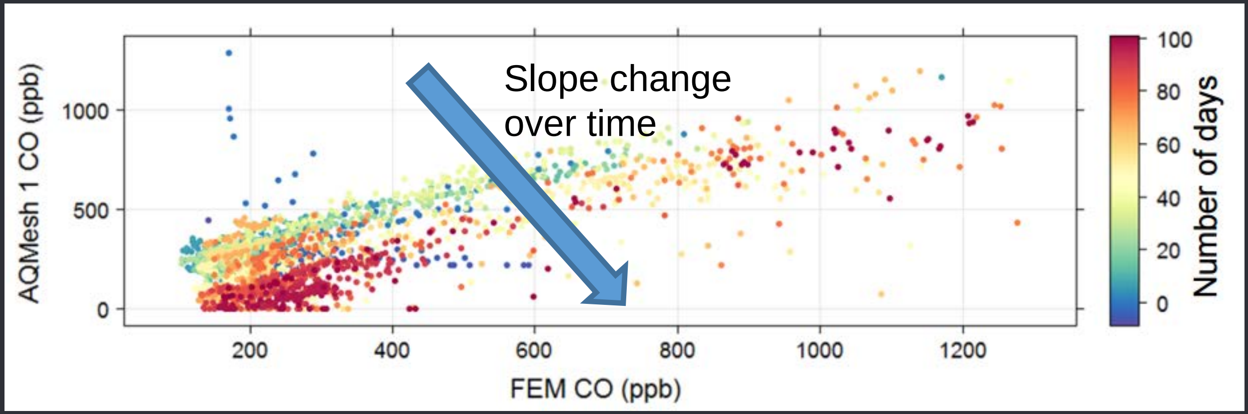
- Emphasis on turn-key devices that are commercially available, measure regulated air pollutants (e.g., ozone, particulate matter), and <2K
- Sensor performance has varied widely – from very strong (r>0.9) to very poor performance (r=0)

A significant level of involvement and collaboration across the agency

Sensor performance testing

Some important lesson learned:

- Laboratory evaluations are helpful in isolating artifacts, but cannot directly translate to predicted field performance.
- Identical sensors generally have strong precision, but this does not necessarily mean the sensor is accurate.
- Developing artifact adjustment algorithms (e.g., days of use, RH, temperature) can improve agreement with a reference for some select sensors.



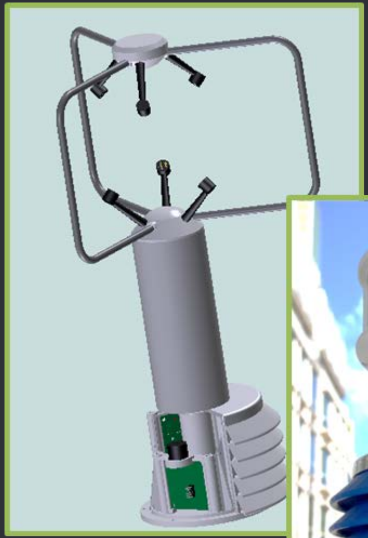
Jiao et al, AMTD, in review

Research and development activities

Development of custom sensor systems

Community stations

Emissions monitoring



SPOD: Fenceline VOC sensor system

Village Green Project (Kansas City station)

Research and development activities

Development of custom sensor systems

Citizen-science

CSAM, Region 2 Ironbound Community

AirMapper, Region 5 project; planned use in Region 10 in 2017

Research and development activities

Development of custom sensor systems

Wireless sensor networks: CitySpace project

ORD / Region 4 / Region 6 / Region 7:
~20 PM sensor node network implementation in Memphis area (starting in fall 2016)

Tough trade-offs:
How to optimize design for maximum measurements, minimizing cost/logistics to implement many nodes?

IT challenges:
How to transmit and store high time resolution data from many nodes? What are strategies to remotely monitor node performance?

Guidance and messaging

Citizen science / community engagement

- **Air Sensor Toolbox**: http://www.epa.gov/heasd/airsensortoolbox/
  - Test reports on sensor performance (field and laboratory)
  - Citizen science guidance
- Community Air Monitoring Training (summer 2015)

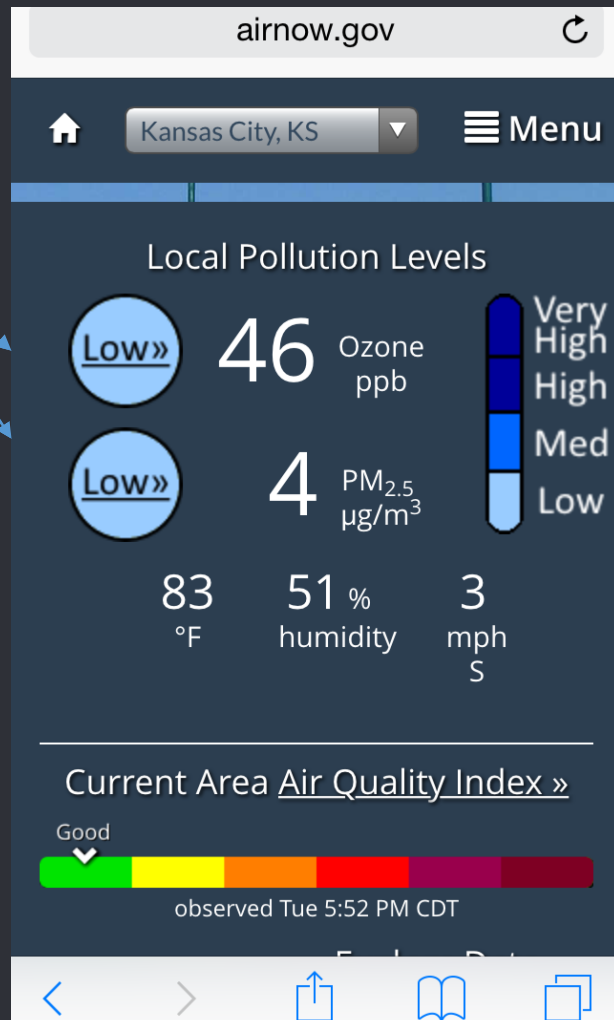
Guidance and messaging

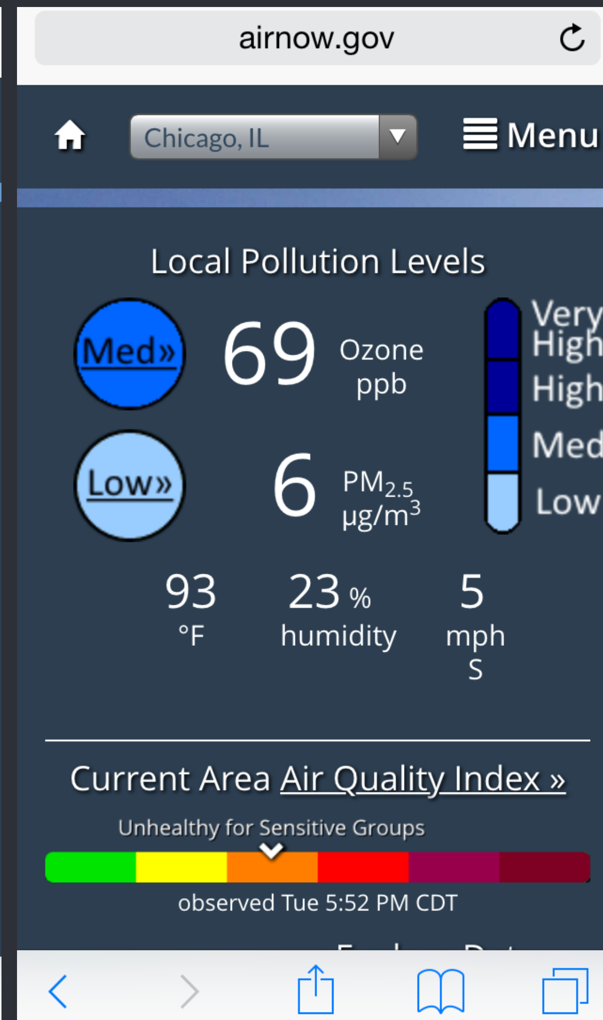
airnow.gov/villagegreen

Data messaging

A lot is behind these labels:

- Statistical analysis of high-time resolution data sets
- Mouse-over informational messages
- Focus-group testing of data display





Guidance and messaging

Data messaging

For more information:
https://www.epa.gov/air-research/communicating-instantaneous-air-quality-data-pilot-project

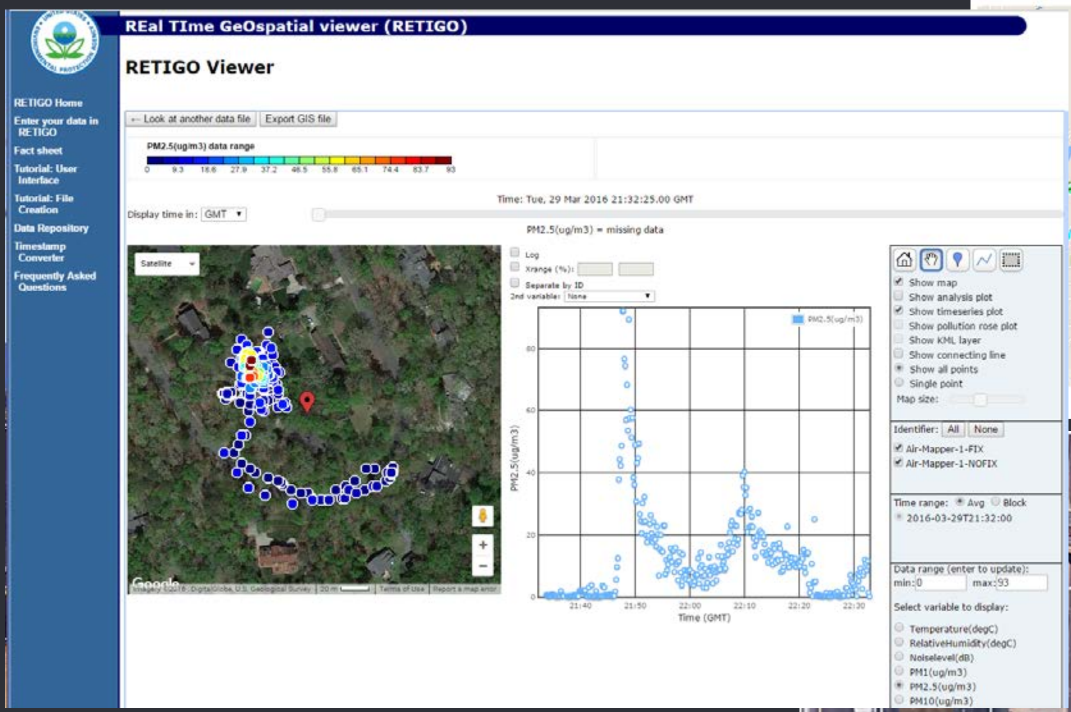
EPA contact (and go check out her presentation!)
Kristen Benedict (benedict.kristen@epa.gov)

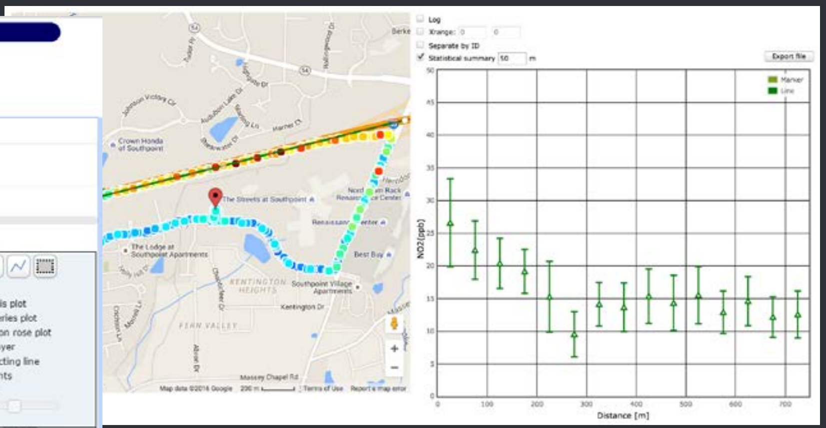
Research and development activities

Data visualization

Real-Time Geospatial Data Viewer (RETIGO)

Plug-and-play webtool to overcome technical barriers in sensor data exploration





Tool and information:
epa.gov/retigo

Announcement of new EPA grantee research: Air Pollution Monitoring for Communities

Grant: Research Questions (abbreviated)

How can low-cost portable air pollution sensors be used by communities to understand and reduce the pollutant concentrations to which they are exposed, in outdoor and/or indoor environments?

How do communities and individuals interact with low-cost portable air pollution sensors? What are effective distribution methodologies, training programs, design features, data products, etc., that maximize the value? How can such methods be evaluated for effectiveness in helping communities understand their exposure environment?

What are effective methods for understanding, quantifying, or managing data quality from these sensors? How well do sensors perform after sustained real-world use by communities?

What additional information about the spatiotemporal patterns of air pollution can be gained by the use of sensors, beyond that which can be known from existing monitoring networks?

New grant: Hawai'i Island Volcanic Smog Sensor Network (HI-Vog)

Principal Investigator: Jesse Kroll
Co-Investigator: Colette Heald
Institutions: MIT, The Kohala Center

- Set up network of low cost sensors (SO_2, PM) to observe air pollution related to emissions from Kilauea volcano

- Community engagement – Kohala Center, local schools, and community hubs in health centers

New grant: Monitoring the Air in Our Community: Engaging Citizens in Research

Principal Investigators:
Seung-Hyun Cho, Lisa Ciccutto
Institutions:
RTI International, National Jewish Health, Groundwork Denver

- Understand data presentation needs and preferences of users of air sensor data

- Evaluate how sensors and their data can be best used to support behavior modifications to minimize air pollution exposure

New grant: Shared Air/Shared Action (SA^2): Community Empowerment through Low-Cost Air Pollution Monitoring

<u>Principal Investigator:</u>
Wendy Griswold
<u>Institutions:</u>
Kansas State University
University of Memphis
Alliance for a Greener South Loop
Delta Institute
Little Village Environmental Justice Organization
People for Community Recovery
Respiratory Health Association
Southeast Environmental Task Force
University of Illinois-Chicago

- Use of portable air pollution sensors in four communities in Chicago
- Collect qualitative and quantitative data on how community members interact with sensors and understand their exposure

New grant: Engage, Educate, and Empower California Communities on the Use and Applications of Low-Cost Air Monitoring Sensors

Principal Investigators:
Andrea Polidori, Phil Fine, Laki Tisopulos, Yifang Zhu, Tim Dye

Institutions:
South Coast Air Quality Management District
University of California-Los Angeles
Sonoma Technology

- Development of toolkit on sensors and best practices for use
- Test performance of sensors
- Deploy sensors in six communities
- Public education and outreach events

New grant: Democratization of Measurement and Modeling Tools for Community Action on Air Quality, and Improved Spatial Resolution of Air Pollutant Concentrations

Principal Investigators:

R Subramanian, Albert Presto, Spyros Pandis, Julie Downs

Institutions:

Carnegie Mellon University

- Work with three community groups in Pittsburgh: Clean Water Action, Group Against Smog and Pollution, Clean Air Council
- Develop portable and stationary sensor units and test data quality
- Develop new Pittsburgh Air Quality Map with community input
- Measure exposure in EJ communities
- Utilize data in statistical and chemical transport models

New grant: Putting Next Generation Sensors and Scientists in practice to reduce wood smoke in a highly impacted, multicultural rural setting (NextGenSS)

Principal Investigator:

Catherine Karr

Institutions:

University of Washington-Seattle
Heritage University-Toppenish

- Deploy low cost particle sensors in student-directed studies related to wood smoke impacts in their community
- Engage with students representing community population including Yakima Nation and Latino immigrant families
- Goal of understanding variability of wood smoke impacts, association with cardiopulmonary health, impact of interventions

What else is coming up?

EPA’s Smart City Air Challenge

Challenge details:

- EPA goal: learn how communities deploy hundreds of air quality sensors and manage the data
- EPA offers up to $40,000 award for two communities to describe their plans to manage the sensors and make the data open
- Evaluate the projects after a year regarding partnerships with sensor developers and data management companies and collaboration with other communities

Timeframe: Planned for release in fall 2016

Challenge will be available at GSA challenge.gov website

Point of contact: Ethan McMahon (mcmahon.ethan@epa.gov)

What else is coming up?

Region 7 Kansas City Transportation and Air Quality Study (KC-TRAQS) - Planned use of low cost sensors in a distributed network, citizen science via portable sensors, plus higher end monitoring.

Region 2 study in Puerto Rico – PM, VOC sensors used in source impact investigations.

Region 6 Village Green Project station in Houston, TX – development work underway testing additional sensors for inclusion (e.g., black carbon, VOCs)

Region 9 study in southern California – working with AQ-SPEC program (SCAQMD), ozone and PM spatial variation assessment via sensors

Ongoing sensor testing and evaluation: Primarily in North Carolina (ambient, near-road settings)

E-Enterprise Advanced Monitoring Initiative

- **Leadership Council approved 5 recommendations**
  1. Conduct options and feasibility analysis for independent third-party certification
  2. Establish EPA/State technology screening and user support network
  3. Develop tools and guidance on interpretation of data from emerging sensors.
  4. Create data standards
  5. “Lean” technology evaluation process

- **Joint EPA/State workgroups are being set-up to address items 1-4. Contacts: George Wyeth (OECA) and Kelly Poole (ECOS)**

Summary thoughts

- Very high bar to reach for regulatory application
  - Must be officially certified as a method, siting criteria applied, etc.
  - e.g., a federal-equivalent monitor for ozone is used on the Village Project System, *however,* not operated according to regulations (siting criteria, QA, temperature range)

- However, other important applications are envisioned:
  - Research studies
  - Screening – siting a monitoring station
  - Community monitoring
  - Individual monitoring
  - Educational purposes

- A major concern for EPA – public data communication practices

To hear more…

- Check out the sensor presentations, posters, and breakout session!
- Stop by the EPA booth for information and demos

A few points of contact!
New Community Air Monitoring grants: Rich Callan (ORD), Sherri Hunt (ORD)
Sensor performance testing: Ron Williams (ORD)
Sensor messaging: Kristen Benedict (OAR)
CitySpace project (Memphis): Daniel Garver (R4), Ryan Brown (R4), Ron Williams (ORD)
CAIRSENSE: Daniel Garver (R4), Ryan Brown (R4), Ron Williams (ORD)
Ironbound: Marie O'Shea (R2), Ron Williams (ORD)
Village Green Project: Esteban Herrera (OECA), Gayle Hagler (ORD), Ron Williams (ORD)
Village Green Project website/database: John White (OAR), Phil Dickerson (OAR)
DISCOVER-AQ: Russell Long (ORD), Rachelle Duvall (ORD)
SPOD: Eben Thoma (ORD)
RETIGO: Gayle Hagler (ORD), Heidi Paulsen (OEI)
AirMapper: Marta Fuoco (R5), Gayle Hagler (ORD), Ron Williams (ORD)
KC-TRAQS: Sue Kimbrough (ORD)

Thank you to the many people involved in this work

EPA ORD: Ronald Williams, Vasu Kilaru, Amanda Kaufman, Rachelle Duvall, Amara Holder, Sue Kimbrough, Eben Thoma, Brian Gullett, Bill Mitchell, Paul Solomon, Neil Feinberg, Wan Jiao*, Teri Conner

EPA OAQPS: Kristen Benedict, Ron Evans, Lewis Weinstock, Elizabeth Mannshardt, Phil Dickerson, John White

EPA OECA: Esteban Herrera

EPA Regions: Ryan Brown (R4), Daniel Garver (R4), Marta Fuoco (R5), Marie O'Shea (R2), Brenda Groskinsky (R7), Mike Davis (R7), Michael Miller (R6), Michael Morton (R6), Bob Judge (R1), Motria Caudill (R5), Joshua Rickard (R8), Dena Vellano (R9), Matt Small (R9), Deldi Reyes (R9), Priyanka Pathak (R9), Sheryl Stohs (R10), Elizabeth Gaige (R3), Carl Ann Gross-Davis (R3), Adam Eisele (R8)

Plus university collaborators, CRADA/MCRADA partners, state and local agencies, and community groups!

*former EPA postdoc