

Next Generation Air Monitoring: An Overview of US EPA Activities

**COST Action TD1105
Second Scientific Meeting
Queens' College
Cambridge, UK
December 18-20, 2013**

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Air Climate and Energy Research
US EPA/Office of Research and Development**



Current Air Monitoring



Why



Personal Exposure and Health Monitoring



Near or within Sources for Regulatory Compliance



In Communities to Assess Exposure



In the Ambient Air for Regulatory Compliance, to Track Trends, and for Public Information

How



Expensive instruments
Specialized training required
Large physical footprint
Large power draw

Convergence of Technologies and Cultural Change



Miniaturized environmental sensors



e.g., CairClip

Introduction of low cost controls and communications



e.g., Arduino microprocessor

Emerging data-viewing/communication apps

OzoneMap App!
Mobile App



OzoneMap - Air Alliance Houston, in collaboration with University of Houston and the American Lung Association have developed a new mobile phone app with real-time ozone data for the Houston area. Check it out here!

airalliancehouston.org



AirCasting App

Smartphone / Tablet generation

e.g., fitbit activity tracker



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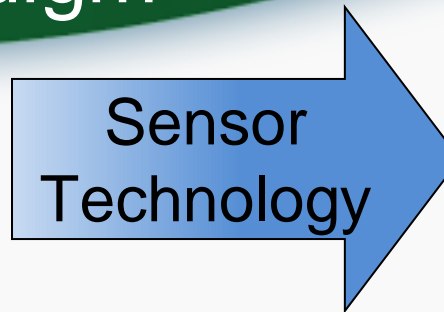
The Changing Paradigm of Air Monitoring



The Changing Paradigm of Air Monitoring

Snyder et al, ES&T, 2013
Accepted

The Role of Sensor Technology in the Changing Paradigm



How data is collected?

Who Collects the data?

Why data is collected?

How data is accessed?

Limited Mostly to Governments, Industry, and Researchers

Compliance Monitoring, Enforcement, Trends, Research

Government Websites, Permit Records, Research Databases

Expanded Use by Communities and Individuals

New Applications and Enhancement of Existing Applications

Increased Data Availability and Access

Next Generation Air Monitoring (NGAM): A Challenge and an Opportunity

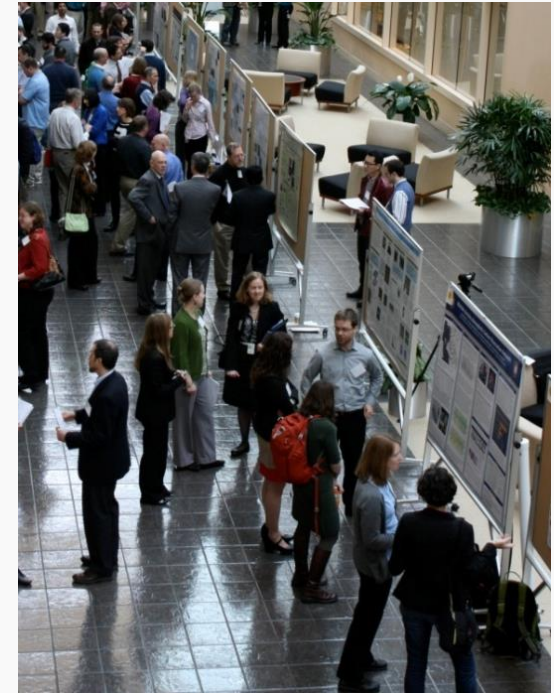


- Government organizations need to prepare for data deluge and responses to concerned citizens
 - What's the quality of the data?
 - How to interpret data from sensors' short term measurements from a public health perspective?
- Government organizations will also have new sources of data to better manage air quality and protect public health
- The EPA is engaging with the early adopters and developers of these sensors to help ensure this technology is used in a fashion that is appropriate and most useful to us as regulators and to communities and the public.

How can EPA help?



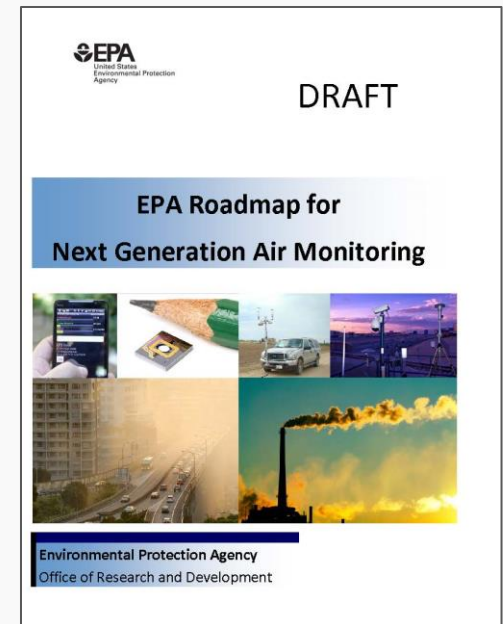
- Stimulating collaboration and conversation
- Assessing emerging technology
- Supporting new technology development in areas of need
- Providing education and Outreach
 - Sensor users and developers
 - Data Quality
 - Public health context and messaging
- Thinking big picture about these developments and implications



EPA Roadmap for Next Generation Air Monitoring



- **Goals**
 - Affordable near source, fence line monitoring technologies and sensor network-based leak detection systems
 - Supplement air quality monitoring networks through development of low cost, reliable air quality sensor technology
 - Support environmental justice (EJ) communities and citizen science efforts to measure air pollution in local areas
- **Cross Cutting Areas of Focus**
 - Technology Development, Testing, and Integration
 - Technology Demonstration, Outreach and Communication
 - IT infrastructure and New Data Streams
- **For Each Area of Focus**
 - Major Findings/Conclusions
 - Recommendations/Gaps
 - Short and Long Term Priorities
 - Implementation Strategy
- **Draft version available:**
<http://www.epa.gov/research/airscience/docs/roadmap-20130308.pdf>



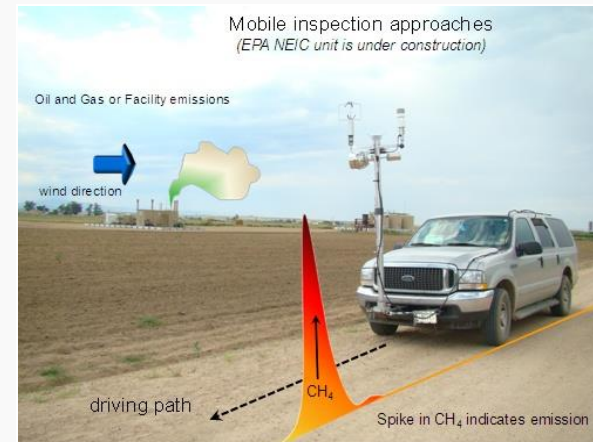
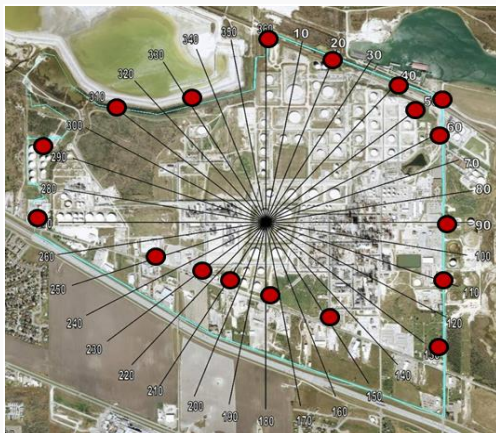
Next Generation Air Monitoring Research at EPA



- Evaluating Sensor Technology
 - Ozone, NO₂, PM, and VOCs
- Community Monitoring Applications
- Source Monitoring Applications
 - Facility Fence Line and Sensor Networks
 - Geospatial Mapping of Air Pollution (GMAP)



CairClip
(O₃ & NO₂)



Evaluating Sensor Technology



Sensor Evaluation Open House



www.epa.gov/airsience



AIR CLIMATE & ENERGY RESEARCH PROGRAM
BUILDING A SCIENTIFIC FOUNDATION FOR SOUND ENVIRONMENTAL DECISIONS

Sensor and Apps Evaluation Opportunity

WHAT: EPA offers technology developers the opportunity to send in your sensor for evaluation in a controlled laboratory setting.

WHEN: Nominate your device by June 30, 2012
Testing to occur July – September, 2012

HOW: Device developers should submit a statement of interest to EPA by June 30, 2012 providing basic information about their device. Due to capacity constraints, EPA will accept a limited number (~10) devices for evaluation over a range of pollutant concentrations and environmental conditions (e.g. humidity and potential interferences). Participants will be invited to visit the EPA lab in early July to discuss their instruments, the evaluation protocol, and receive a tour of the facility. Following the completion of the evaluation each participant will receive information on the performance of their device under known environmental conditions.

QUESTIONS or Point of Contact: Ron Williams, 919-541-2957,
williams.ronald@epa.gov

SELECTION CRITERIA: Devices receiving the highest consideration:

- have the technical feasibility to measure NO₂ and/or O₃ at environmentally relevant concentrations,
- have some preliminary data on expected performance characteristics,
- have not previously undergone standardized evaluations under known challenge test conditions by any party, and
- represent highly portable sensor and smart phone type applications featuring continuous measurement capabilities.

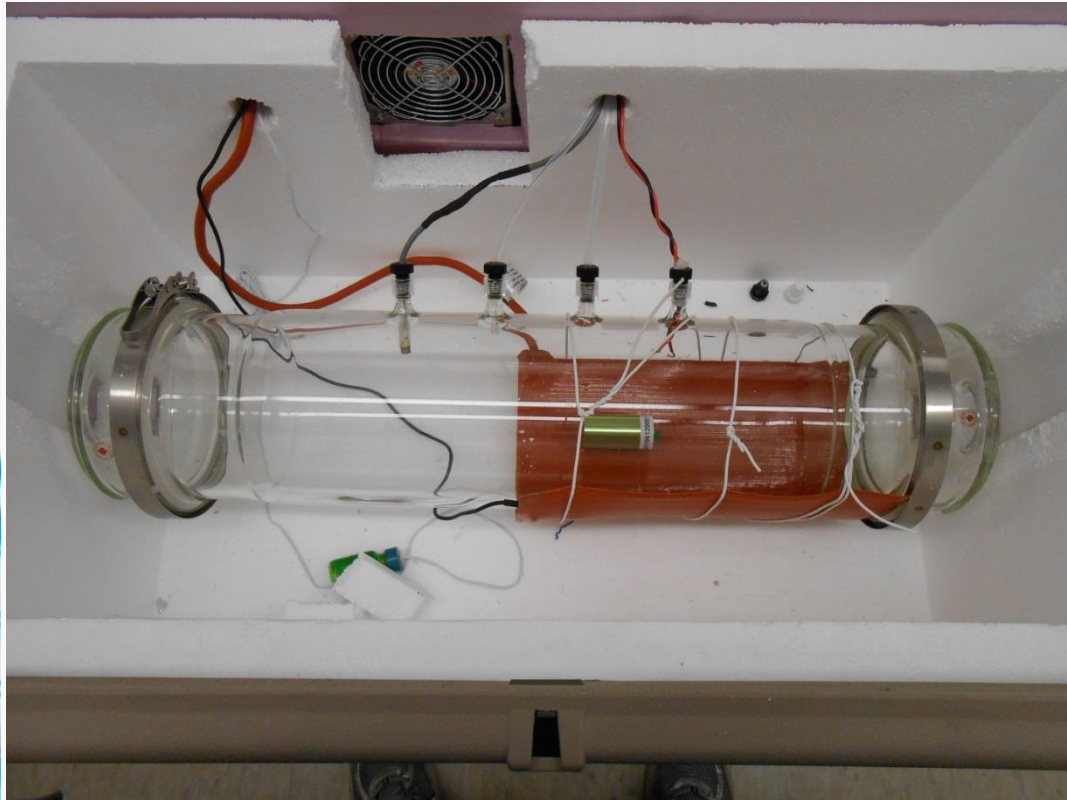
Description:

- Open call for potential collaboration
- O₃ and NO₂ focus
- A total of 9 research groups nominated devices for evaluation
- Variety of devices
- Formal cooperative agreements established
- Not FRM/FEM Evaluations

Feedback Provided to Sensor Developers:

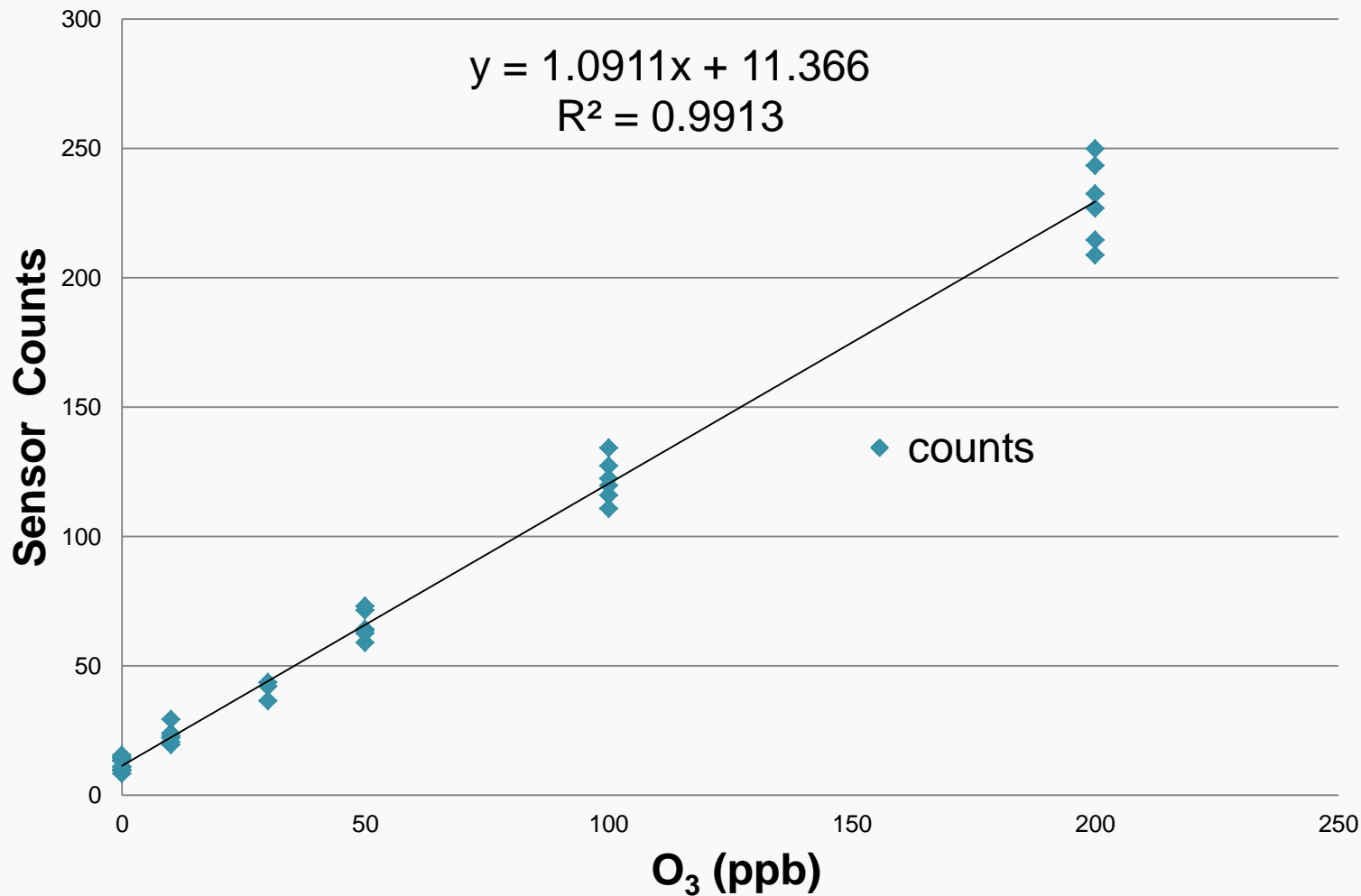
- General performance of the device
- Observations on operation
- Validated non-summarized data
- EPA's intent was not to compare one specific device with another
- EPA recognized the confidential nature of the technologies being evaluated

Evaluating Personal Sensors



CairClip electrochemical sensor evaluated under the Air Sensors Project

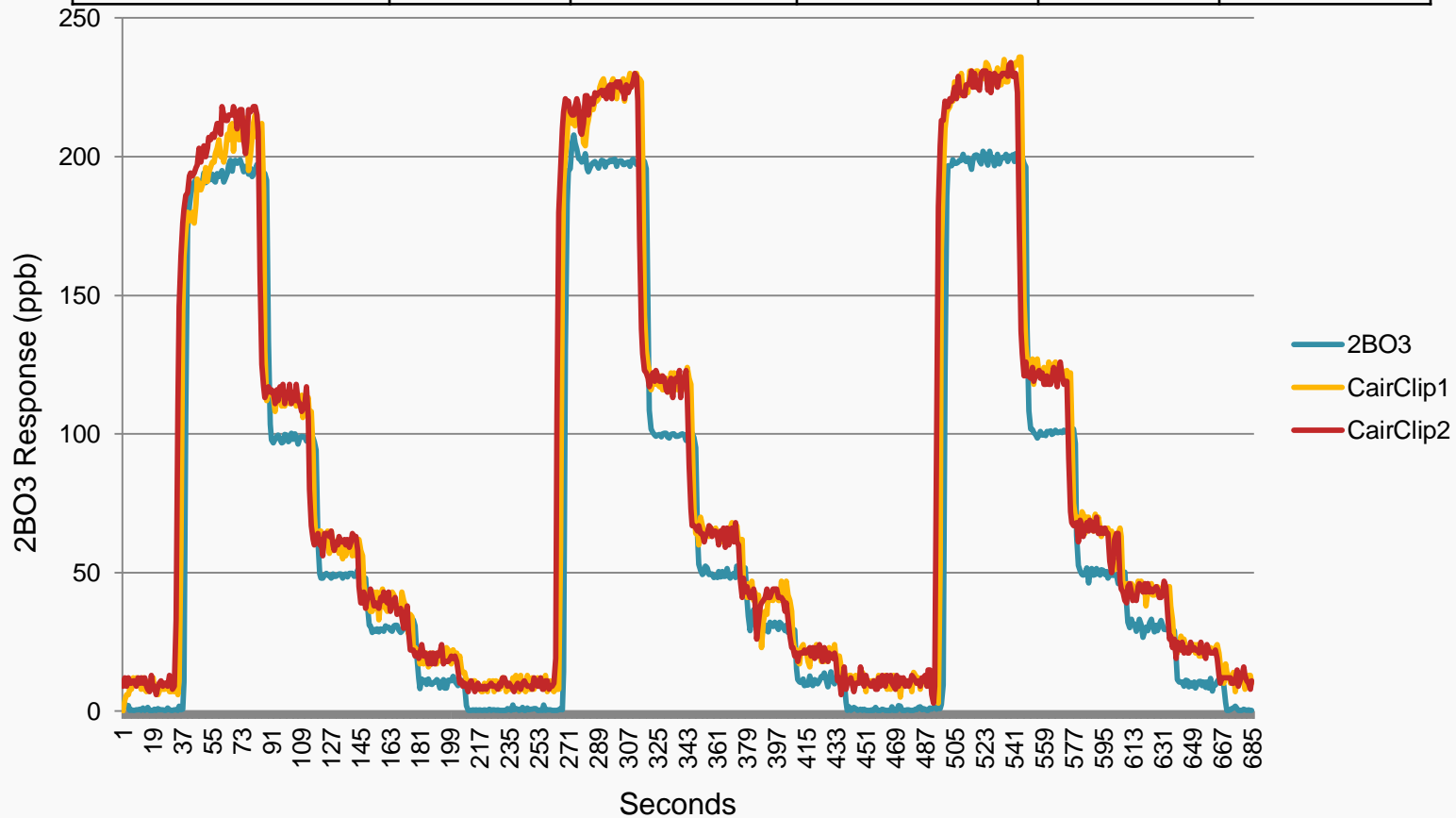
Cairclip performance against reference analyzer



Example of Basic Performance Characteristics



Calibration #	2BO3 (minutes rise time)	CairClip 1 (minutes rise time)	CairClip 2 (minutes rise time)	CairClip 1 (final rise time)	CairClip 2 (final rise time)
1	5	19	17	14	12
2	3	5	5	2	2
3	4	4	5	<1	1



Sensor Evaluation in Collaboration with NASA (Houston, TX Sept 2013)



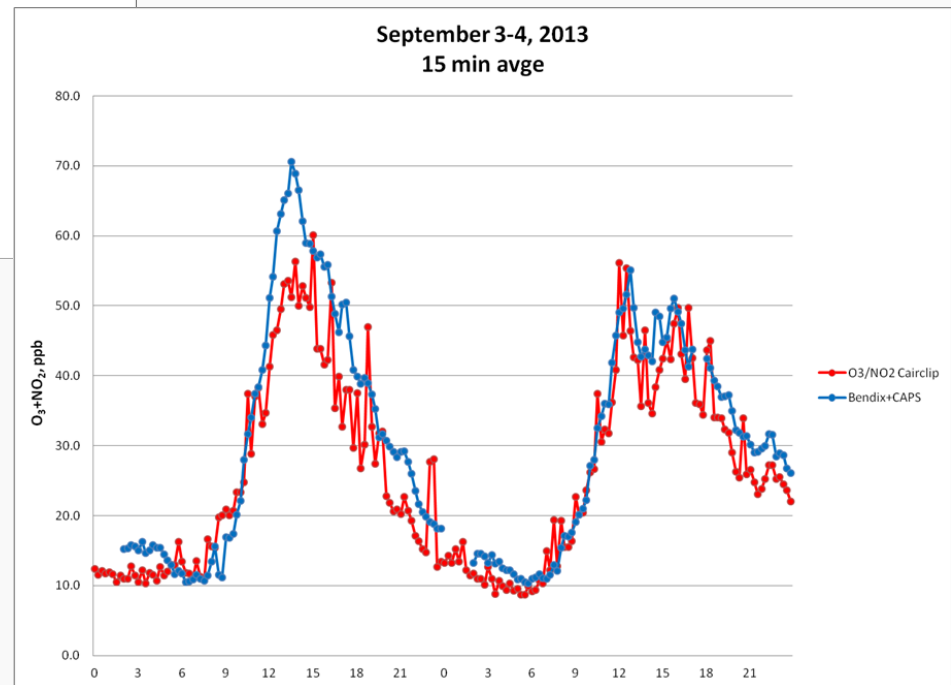
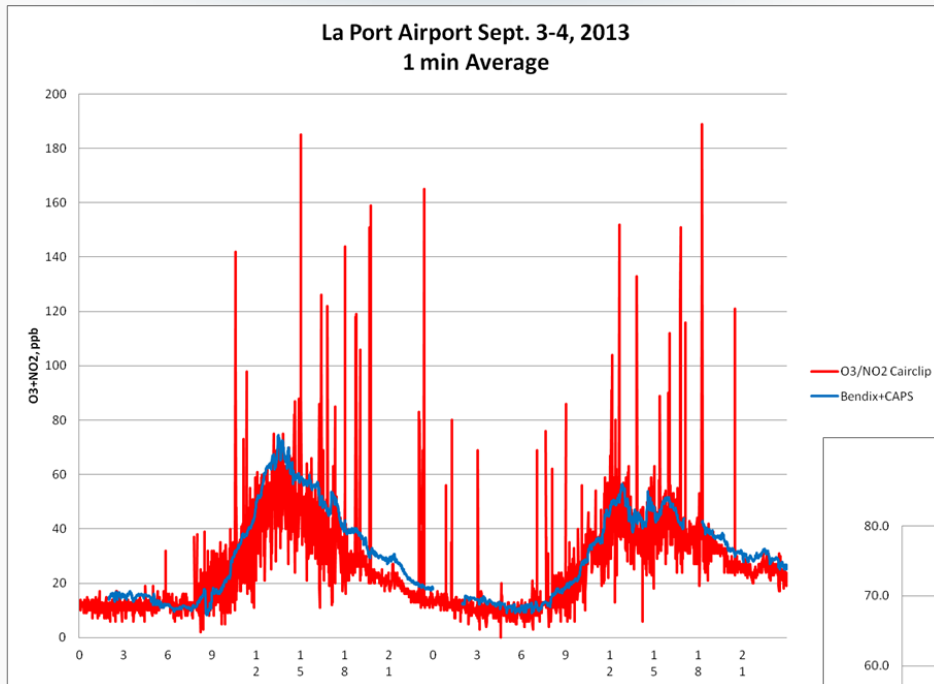
- EPA deploying sensor technology (CairClip) for NO₂ and O₃ that performed well during the EPA Sensor Evaluation Open House.
- NASA deploying sensor technology (Geotech AQMesh-5) to measure O₃, NO, NO₂, CO, SO₂.
- Sampling with sensors will be used to evaluate air craft and remote measurements as well as air quality models.
- Provides EPA with additional insights and experience with the use of sensor technologies in the field for future applications.



CairClip



Preliminary Results from Houston: Integrated O₃ and NO₂



Ongoing and Future EPA Sensor Evaluation Activities

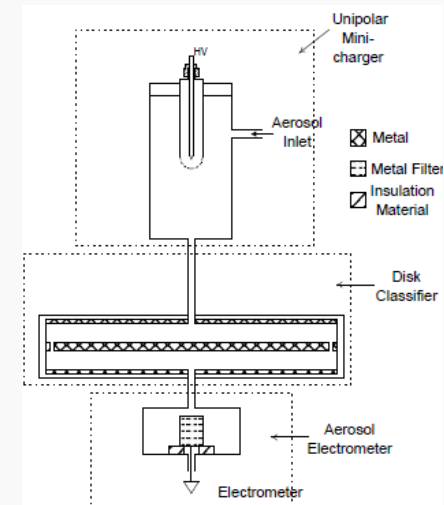


- PM and VOC Sensor Evaluations
 - A host of low cost (<\$2500) PM_{2.5} and VOC sensors purchased or acquired for laboratory and/or field evaluation
 - Field work to be completed in CY 2013
 - Results available in CY 2014



Micro Personal Exposure Monitor (PEM)
Research Triangle Institute

- Recent EPA Grant
 - Da-Ren Chen (Virginia Commonwealth University) “Development of Cost-effective, Compact Electrical Ultrafine Particle (eUFP) Sizers and Wireless eUFP Sensor Network”

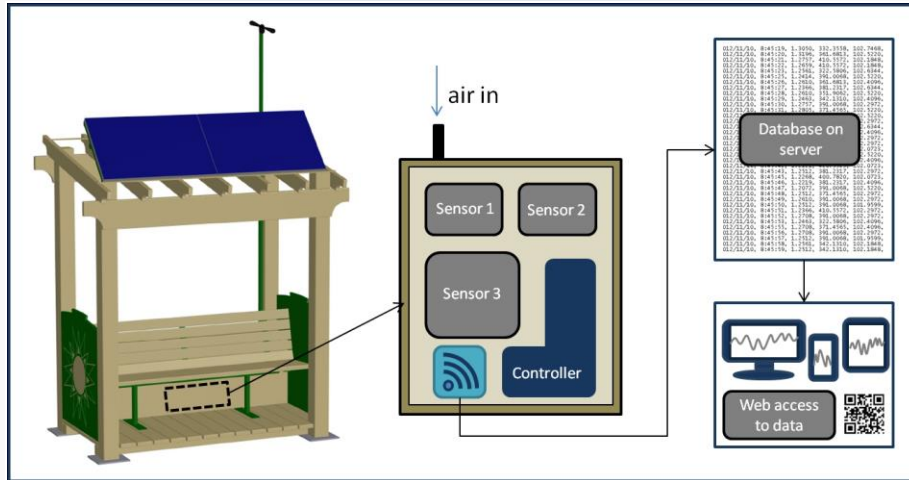


(Chen et al., 2013)

Community Monitoring Applications



Village Green Project



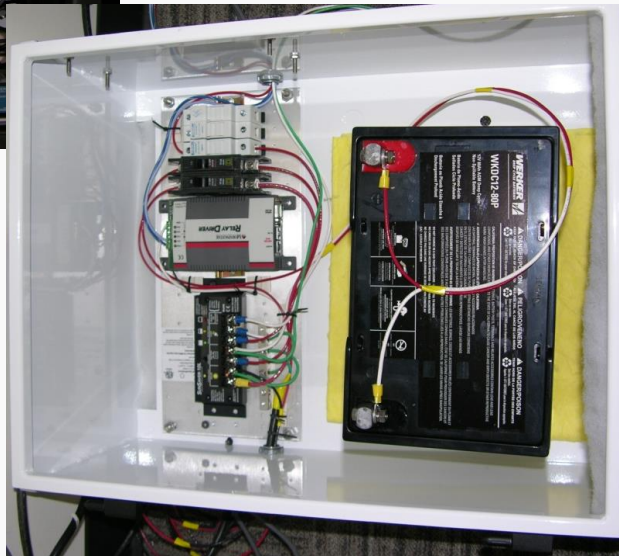
- Self-powered air and meteorological sampler
- Lower cost, real-time instruments - proven capability at ambient levels (wind, black carbon, PM_{2.5}, ozone)
- Wireless data communication to publically-accessible website
- Designed to add value to and be secure in public environments



Components



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



Village Green Website



Village Green Project Contact Us Share

About
Welcome to the Village Green Project! The goals of this research and development project are to increase air pollution monitoring capabilities in communities and provide real-time air pollution measurements at lower cost and maintenance.

Air Data
This website shows data arriving minute-by-minute from our prototype, a solar-powered air pollution and meteorological monitoring station located outside of the Durham County Library South Regional Branch in Durham, North Carolina. We also show the official Air Quality Index estimated for the same region. Please note that the live data being reported are intended only for research and educational use.

System

Blog

Resources

- Fact Sheet (PDF) (2 pp, 3.7MB)
- Air Research
- Next Generation Air Monitoring
- Teacher Air Quality Materials
- School Flag Program
- Air Quality Index

Current Readings: Durham

Regional Air Quality Index: Today is a **GREEN** day, which means regional air quality conditions are "good".

observed at 7:00 EDT

Current meteorological readings from the Village Green Project station:

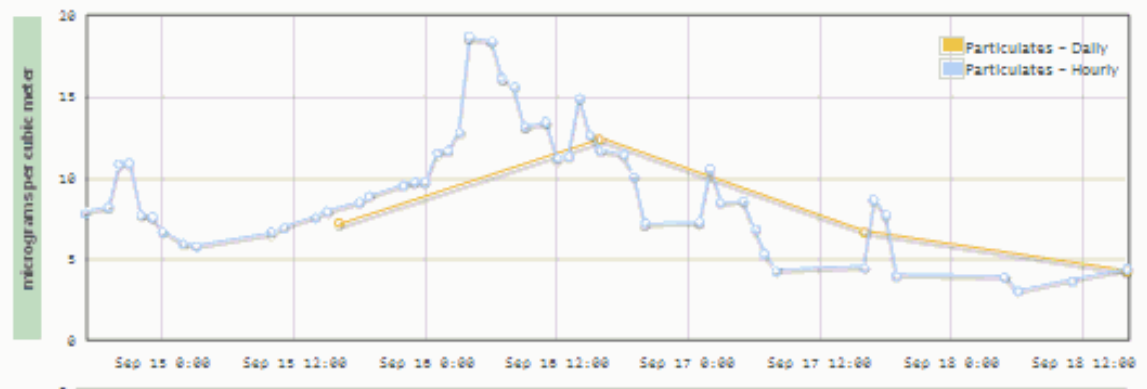
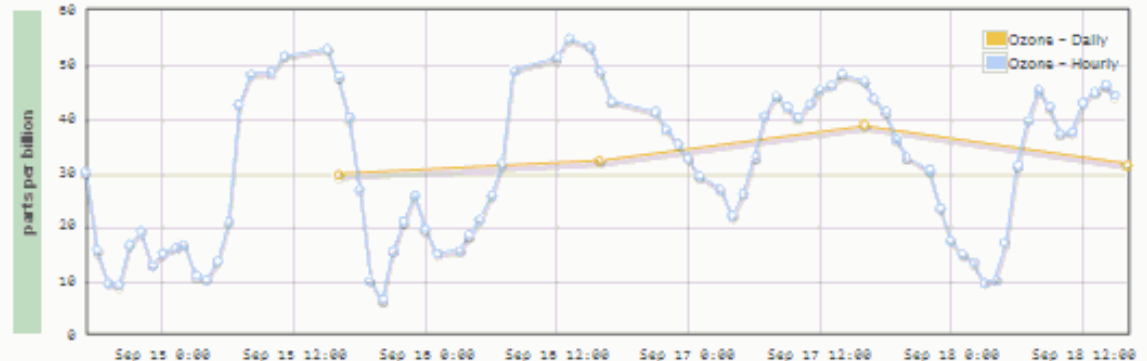
120
100
80
60
40
20
0
-20

75.6 F
07:38 AM
07/09/2013

5 mph

<http://villagegreen.epa.gov/>

Educational and community outreach opportunity



It All Starts with Science
AN EPA BLOG ABOUT SCIENCE MATTERS

Home About Comment Policy Other Greenversations

303 people like this.

SUBSCRIBE TO THIS BLOG

Posts from the 'Village Green Project' Category

Sensor Technology is Enabling Citizen Science



How to Build an AirCasting Air Monitor







Funding for the AirCasting Air Monitor was provided by the New York Hall of Science, the New York State Dept. of Environmental Conservation Environmental Justice Community Impact Grant Program, and the National Science Foundation (NSF ATE No 1003712). The Monitor was created at the Mechatronics Technology Center (MTC) of the New York City College of Technology (City Tech). The electronics were designed and programmed by Dr. Iam Heng and Raymond Yip and the casing was designed by Dr. Jinyi Zhang. AirCasting is a collaborative project lead by HabitatMap in partnership with City Tech's MTC and the New York Hall of Science.

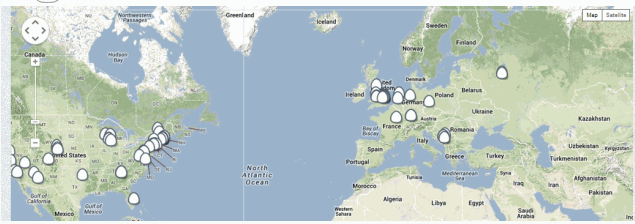



AirCasting App AirCasting Air Monitor

Citizen Science for a variety of interests:

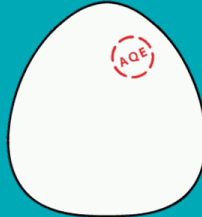
- Individual Health
- Community Exposures
- Research
- Education
- Technology

Air Quality Egg community led sensing network



Home Updates **20** Backers **327** Comments **187** New York, NY Hardware

Funded! This project successfully raised its funding goal on April 26, 2012.



AIR QUALITY EGG

927 backers
\$144,592
 pledged of \$39,000 goal
0 seconds to go

Funding period
 Mar 27, 2012 - Apr 26, 2012 (30 days)

Project by
#Sensemakers
 New York, NY
[Contact me](#)

First created - 9 backed
 Has not connected Facebook
 Website: sensemake.rs
[See full bio](#)

Share Tweet Embed

A community-led air quality sensing network that gives people a way to participate in the conversation about air quality.



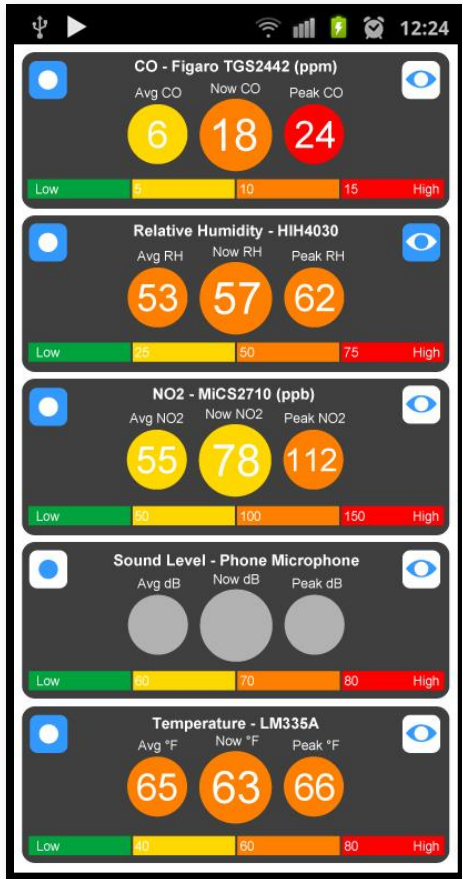
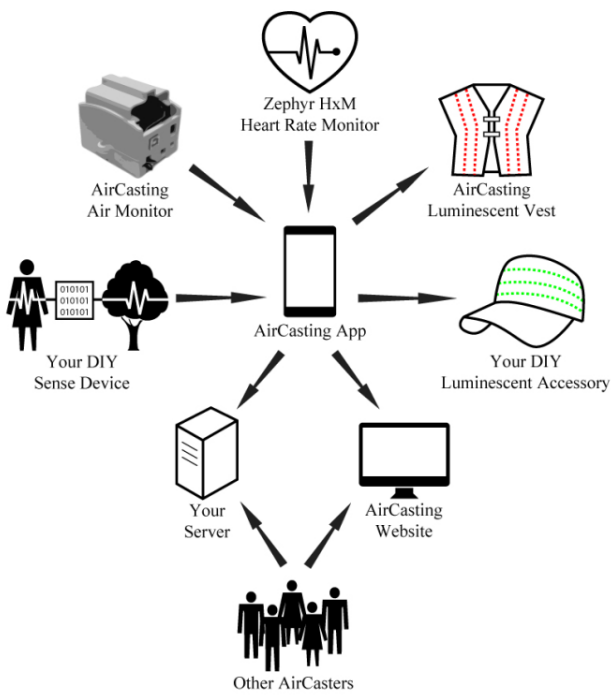
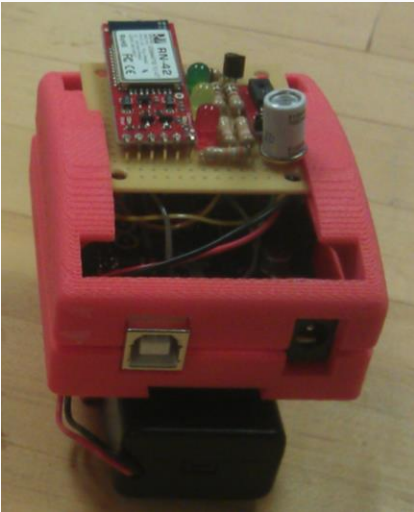
**My Air
My Health**

U.S. Department of Health and Human Services
 U.S. Environmental Protection Agency

Example: Air Casting



Share Your Air!



Courtesy of Michael Heimbinder, Habitat Map, Brooklyn NY

Wearable Monitors



My Air
My Health

U.S. Department of Health and Human Services
U.S. Environmental Protection Agency



Conscious Clothing:
measuring breathing
rates/volume and heart rates



Wear Air (CMU):
VOC sensor

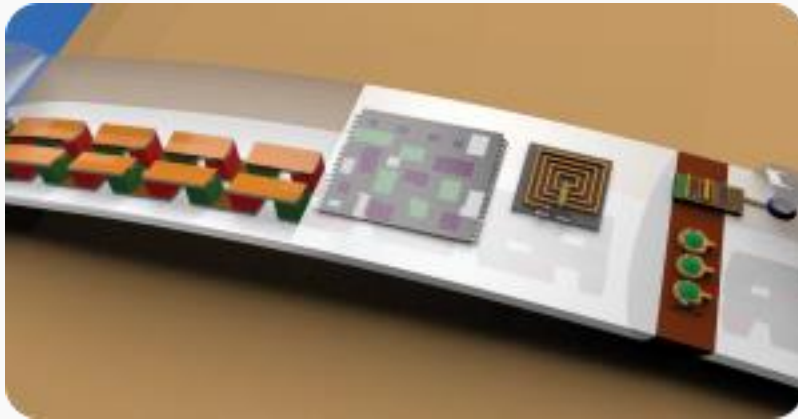
<http://www.youtube.com/watch?v=XPvylXdkc4g>

More on Integrating Environmental and Health Sensors



Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)

(Veena Misra - North Carolina State University)



NC State ASSIST Vision: a paradigm shift in health informatics enabled by wearable nanotechnologies that monitor individual health parameters and environmental exposures.

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

Source Monitoring Applications

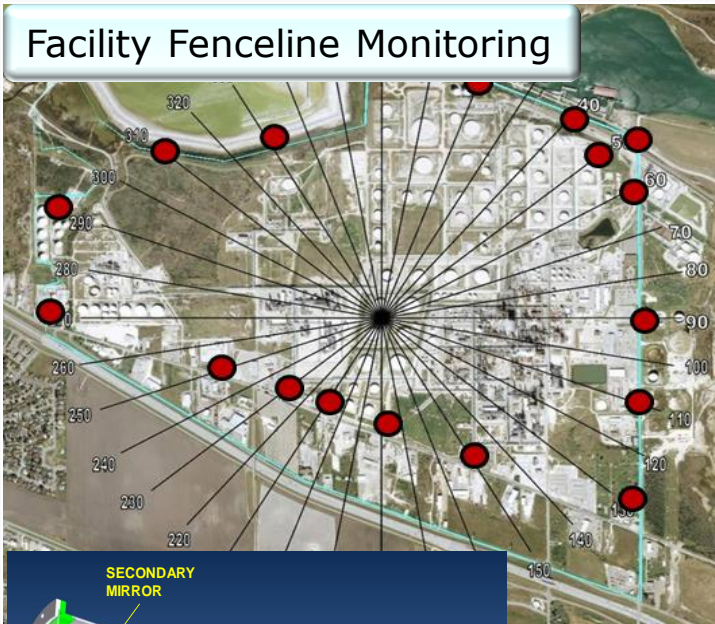


New Opportunities for Source Oriented Monitoring



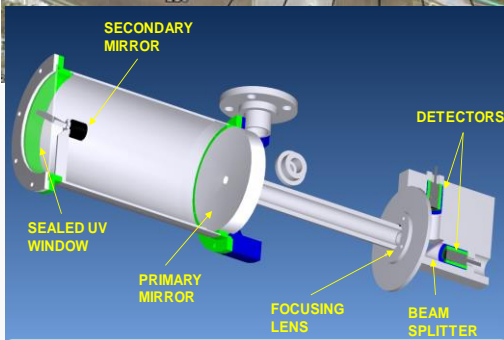
Mid-range Sensors and Remote Measurements

Facility Fenceline Monitoring



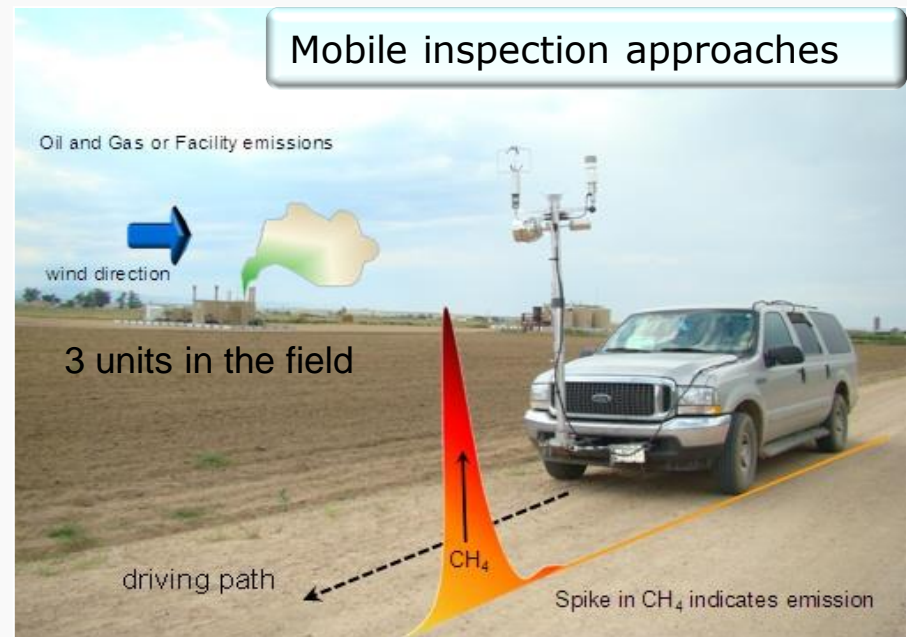
Advanced LDAR and fugitive strategies

- In-plant sensor networks
- IR camera protocols
- Passive samplers

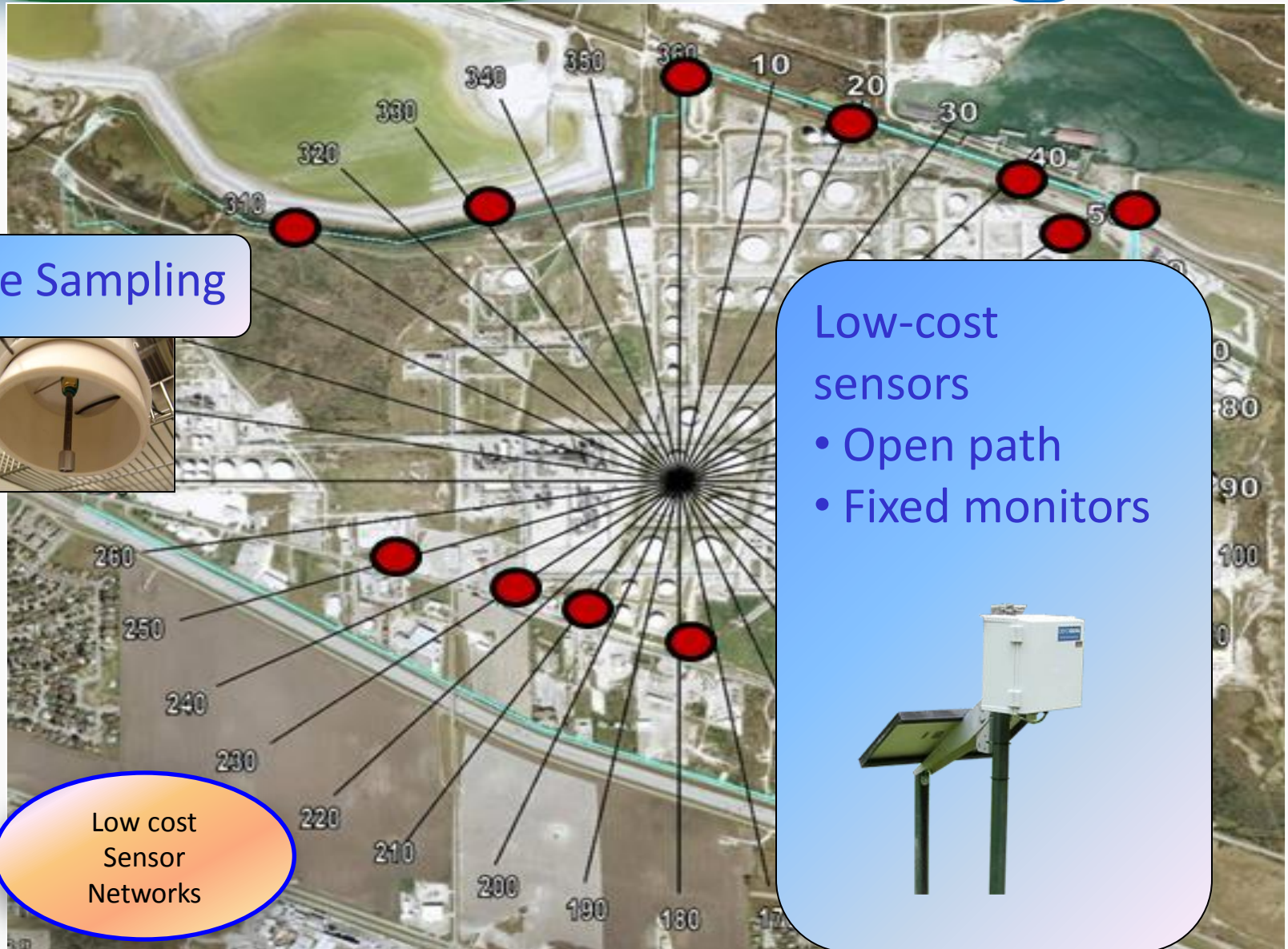


Low cost remote sensing

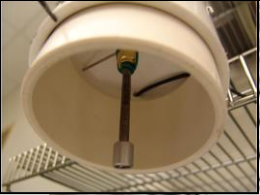
Mobile inspection approaches



Sensor Networks In-plant and Along Facility Fence Line



Passive Sampling



Low-cost sensors

- Open path
- Fixed monitors

Low cost Sensor Networks

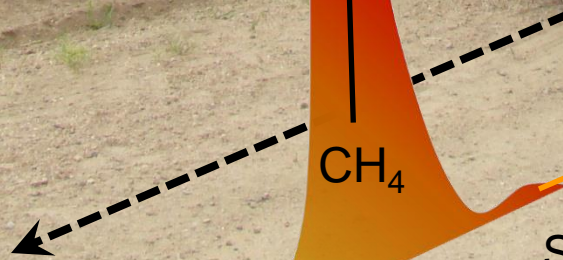
Off-site assessment with *GMAP-REQ*

(Geospatial Measurement of Air Pollution – Remote Emissions Quantification)

wind direction



driving path



CH₄

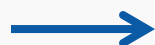
Mobile
Inspection
systems

Spike in CH₄ indicates emission

The Future of Air Monitoring?



Data from Multiple Tiers



Tier1: Regulatory or regulatory-equivalent air monitoring stations
Cost: \$\$\$\$, Data reliability = A+

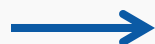
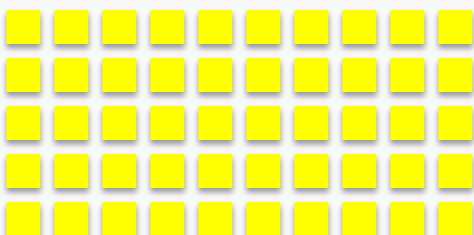
existing



emerging



Tier 2: Smaller-footprint monitoring systems for community screening and research studies
Cost: \$\$, Data reliability = B+ (target)

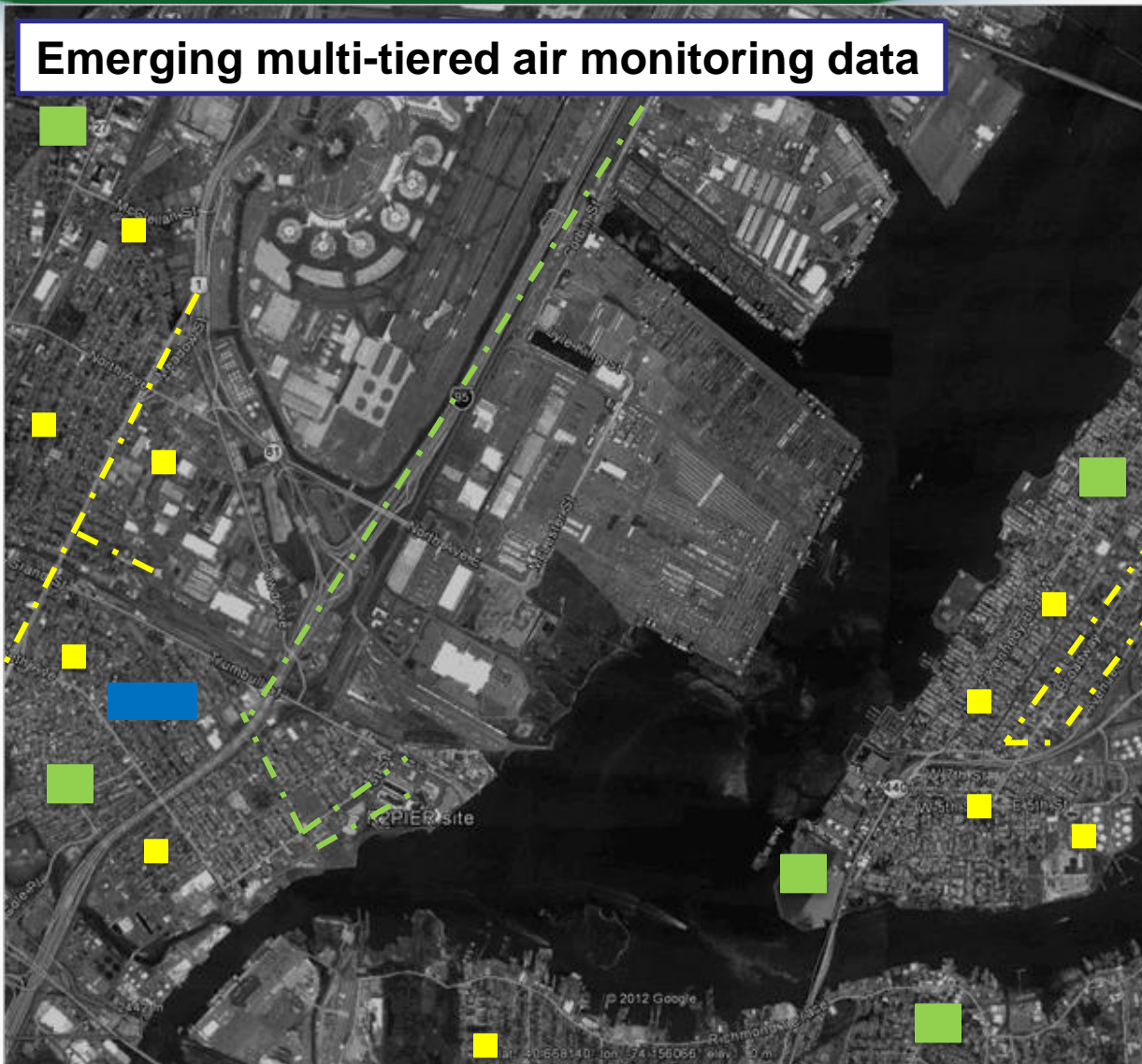


Tier 3: Very small, very low cost systems enabling dense sensor networks, citizen science
Cost: \$, Data reliability = ?

Challenges and opportunities



Emerging multi-tiered air monitoring data



Opportunities:

- Lower cost strategies to achieve air monitoring goals
- Engagement with communities, schools, industry
- Improved public health

Challenges:

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

Next Steps for EPA Next Generation Monitoring



- Sensor Evaluations
 - Evaluation of PM and VOC sensors
 - Publish results
- Community Applications
 - Request for Applications for grants for community sensor applications
 - Participate in next DISCOVER-AQ field study (summer of 2014)
 - Possible expansion of Village Green sites
- Source Monitoring Applications
 - Possible deployment in near source studies (oil and gas production or ports)
- Guidance
 - Guidebook for sensor users and developers
 - Public health messages

EPA Next Generation Air Monitoring Site



For More Information:

The screenshot shows the EPA website's "Next Generation Air Monitoring" page. At the top, there is the EPA logo and navigation tabs for "LEARN THE ISSUES", "SCIENCE & TECHNOLOGY", "LAWS & REGULATIONS", and "ABOUT EPA". A search bar and "Advanced Search" link are also present. The main heading is "Next Generation Air Monitoring" with a breadcrumb trail: "You are here: EPA Home » Research » Air Research » Next Generation Air Monitoring". Below the heading is a "Background" section with text explaining the need for enhanced air quality monitoring. To the right of the text is an image of a blue and white air monitoring station. Further down, there is a section about a solar-powered bench system, accompanied by an image of a hand holding a smartphone displaying air quality data and an image of the bench itself. On the right side of the page, there are two green-bordered boxes: "Related Links" containing links to "Background", "Air Sensor Studies", and "Moving Forward with Collaboration"; and "Resources" containing links to "Roadmap for Next Generation Air Monitoring", "Air Sensor Evaluation and Collaboration", "My Air, My Health", "EPA Exposure Research", "Village Green Project Blogs", "Air Sensor Blogs", "March 2013: Air Sensors 2013: Data Quality and Applications", and "Next Generation Air Monitoring presentation (PDF) (21 pp, 2.8MB)".

EPA United States Environmental Protection Agency

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Next Generation Air Monitoring


Background

Traditionally, air pollution is measured by expensive, stationary and complex air-monitoring instrumentation. Only a few organizations, like Federal, State and some industries, typically collect data of such high quality. Even so, this limits the amount of environmental monitoring data that is often available for exposure and health assessments. As air quality management problems become more complex, there is a need for enhanced air quality and exposure monitoring capabilities.



Related Links

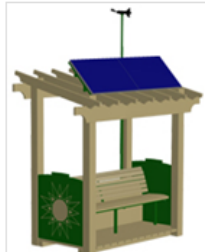
- Background
- Air Sensor Studies
- Moving Forward with Collaboration



To meet this growing technological need, EPA, the commercial sensor industry, academic institutions, and others, are developing, evaluating and applying a variety of innovative technologies. Currently, EPA is investigating the means to monitor personal air quality in community settings, and other areas of interest.

These air sensors range anywhere from an application on a cell phone to a device that gives by-the-minute, real-time data while interacting with the public, like the [Village Green Project](#).

This project developed a solar-powered air monitoring system in the shape of a bench, and encourages the public to interact and learn more about their local air quality. People can interact with the bench system with their Smartphones and see current local air quality and meteorological conditions. The air pollutants being measured include ozone, black carbon and particulate matter where the system automatically sends collected data to an online, open-sourced website. This system is charged by two solar panels and will automatically turn off in dark, cloudy conditions and re-start once the sun again comes out.



Resources

- Roadmap for Next Generation Air Monitoring
- Air Sensor Evaluation and Collaboration
- My Air, My Health
- EPA Exposure Research
- Village Green Project Blogs
- Air Sensor Blogs
- March 2013: Air Sensors 2013: Data Quality and Applications
- Next Generation Air Monitoring presentation (PDF) (21 pp, 2.8MB)

Acknowledgements



US EPA: Ron Williams, Russell Long, Emily Snyder, Eben Thoma, Bill Mitchell, Brian Gullett, David Shelow, Stacey Katz, Gail Robarge, Rachel Duvall

Habitat Map: Michael Heimbinder

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