Next Generation Air Monitoring: An Overview of US EPA Activities

COST Action TD1105

Second Scientific Meeting

Queens' College

Cambridge, UK

December 18-20, 2013

Tim Watkins

Deputy National Program Director

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

e.g., Arduino microprocessor

Introduction of low cost controls and communications

Emerging data-viewing/ communication apps

AirCasting App

Smartphone / Tablet generation

e.g., fitbit activity tracker

The Changing Paradigm of Air Monitoring

Snyder et al, ES&T, 2013
Accepted

The Role of Sensor Technology in the Changing Paradigm

Sensor Technology

How data is collected?		
Who Collects the data?	Limited Mostly to Governments, Industry, and Researchers	Expanded Use by Communities and Individuals
Why data is collected?	Compliance Monitoring, Enforcement, Trends, Research	New Applications and Enhancement of Existing Applications
How data is accessed?	Government Websites, Permit Records, Research Databases	Increased Data Availability and Access

Snyder et al., 2013

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

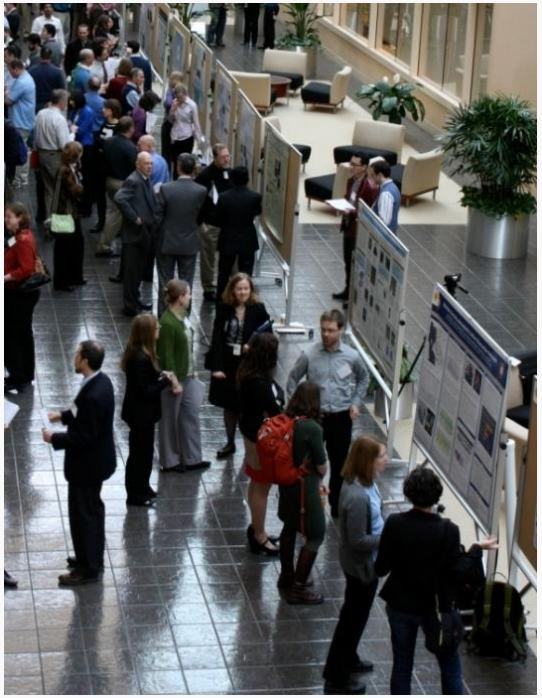
- Government organizations need to prepare for data deluge and responses to concerned citizens
  - What's the quality of the data?
  - How to interpret data from sensors' short term measurements from a public health perspective?

- 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

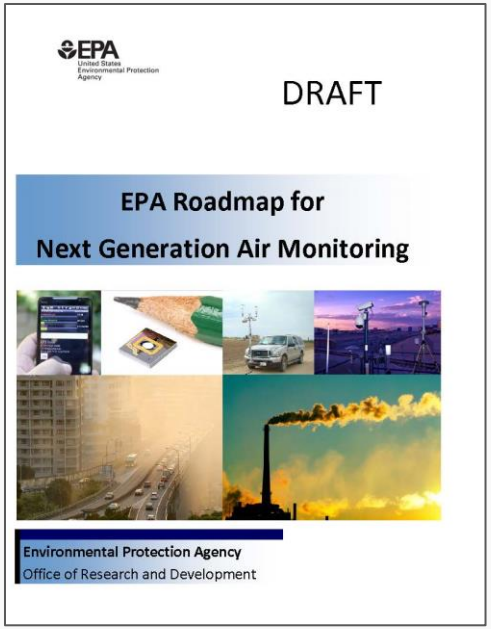


EPA Roadmap for Next Generation Air Monitoring

- 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



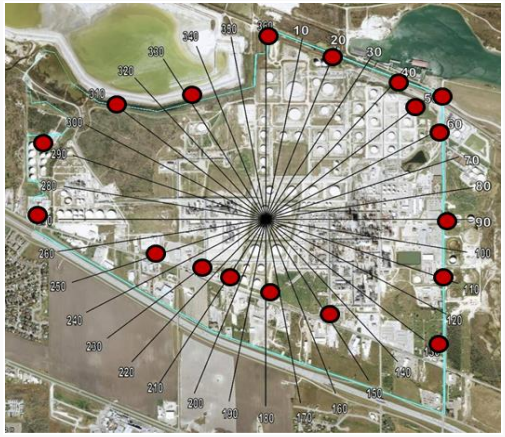
- Draft version available:
  http://www.epa.gov/research/airscience/docs/roadmap-20130308.pdf

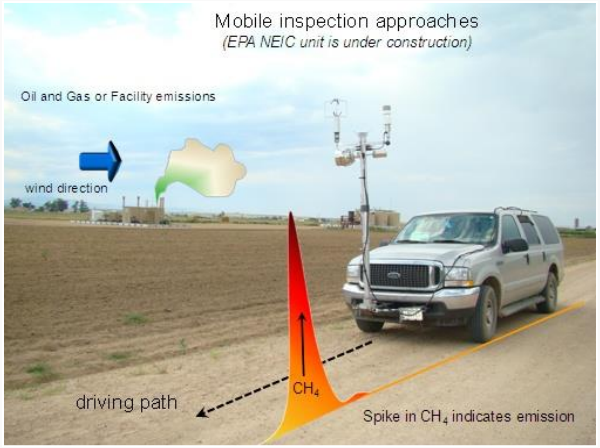
Next Generation Air Monitoring Research at EPA

- Evaluating Sensor Technology
  - Ozone, NO_2, PM, and VOCs
- Community Monitoring Applications
- Source Monitoring Applications
  - Facility Fence Line and Sensor Networks
  - Geospatial Mapping of Air Pollution (GMAP)

EPA Village Green Project

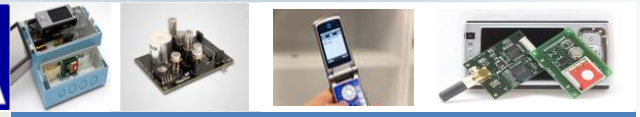
CairClip
(O3 & NO2)





Evaluating Sensor Technology

Sensor Evaluation Open House



www.epa.gov/airscience

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 NO_2 and/or O_3 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.

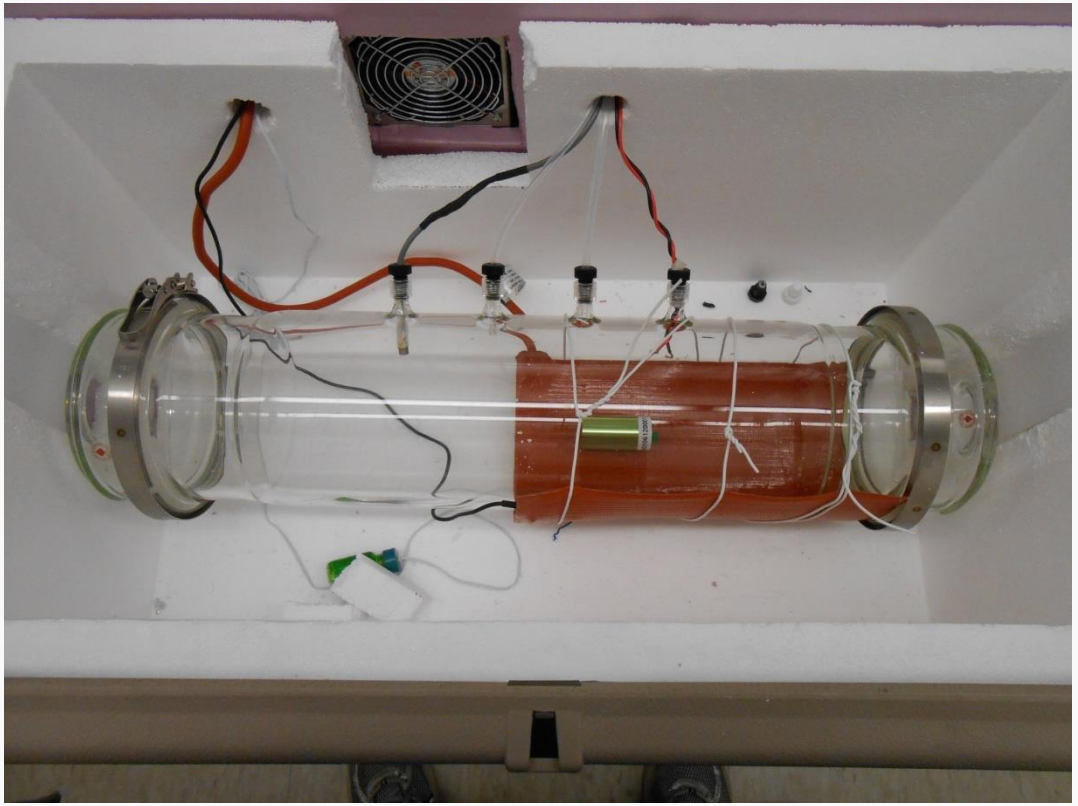
Description:

- Open call for potential collaboration
- O_3 and NO_2 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:

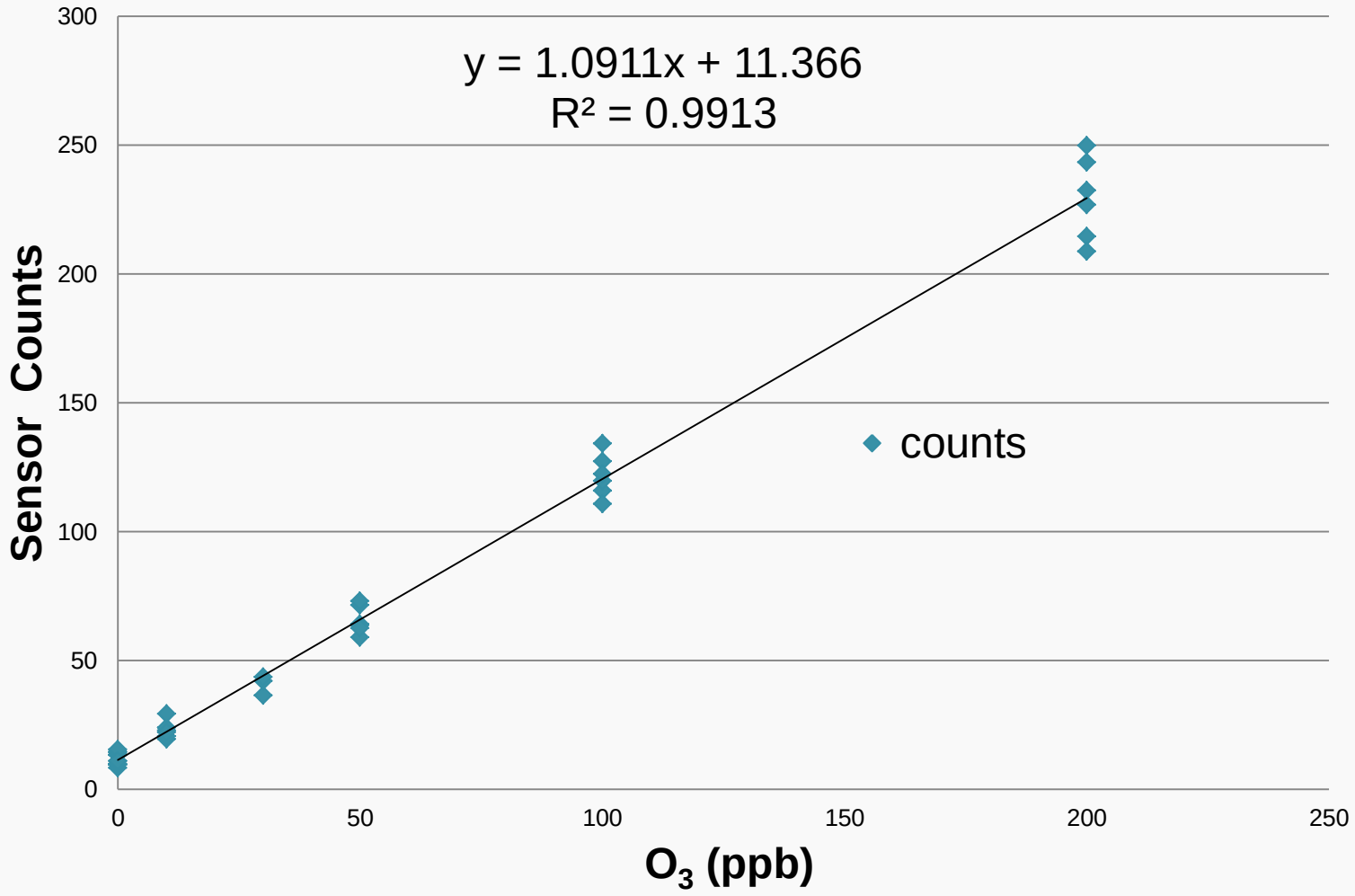
- General performance of the device
- Observations on operation
- Validated non-summarized data
- EPA's intent was not to compare one specific device with another
- EPA recognized the confidential nature of the technologies being evaluated

Evaluating Personal Sensors



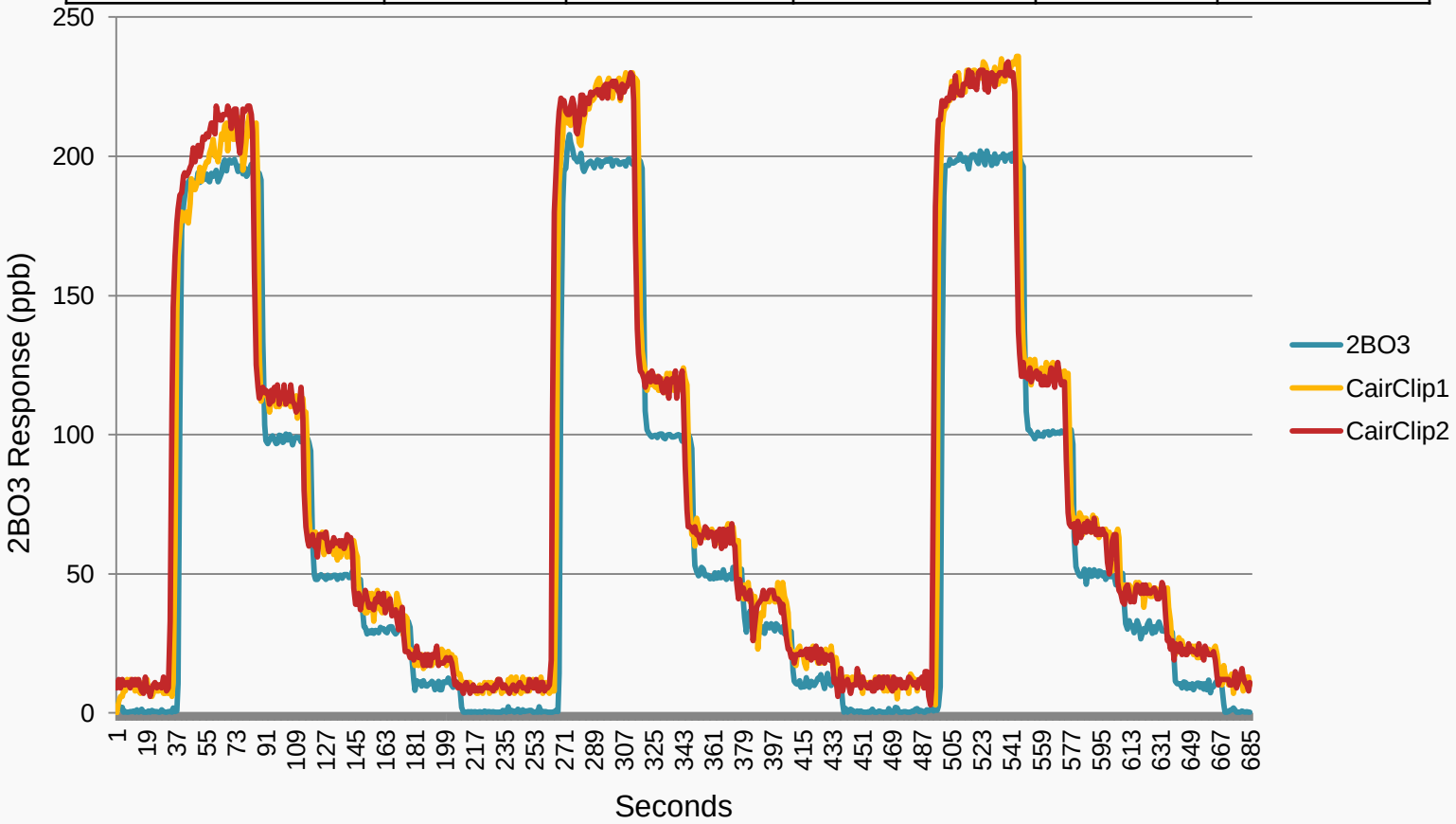
CairClip electrochemical sensor evaluated under the Air Sensors Project

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



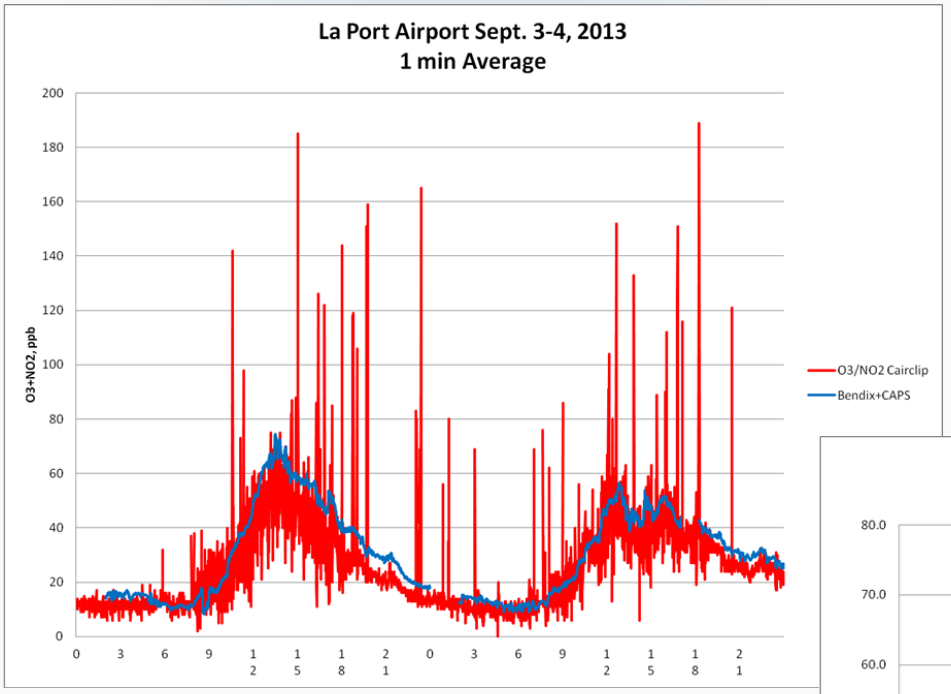
Sensor Evaluation in Collaboration with NASA (Houston, TX Sept 2013)

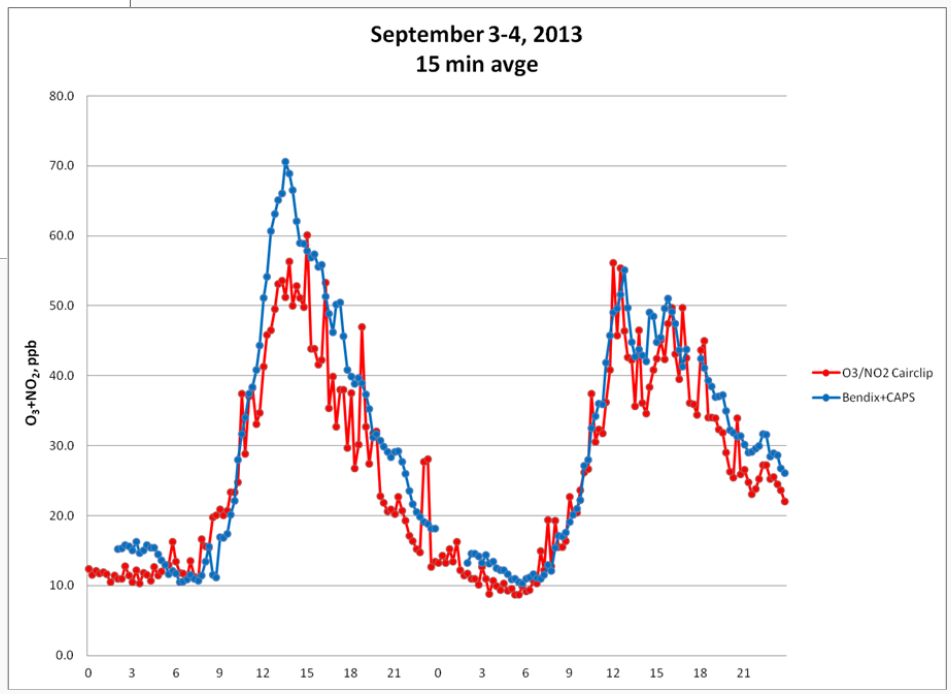
- EPA deploying sensor technology (CairClip) for NO2 and O3 that performed well during the EPA Sensor Evaluation Open House.
- NASA deploying sensor technology (Geotech AQMesh-5) to measure O3, NO, NO2, CO, SO2.
- Sampling with sensors will be used to evaluate air craft and remote measurements as well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

CairClip

Geotech AQMesh-5

Preliminary Results from Houston: Integrated O_3 and NO_2



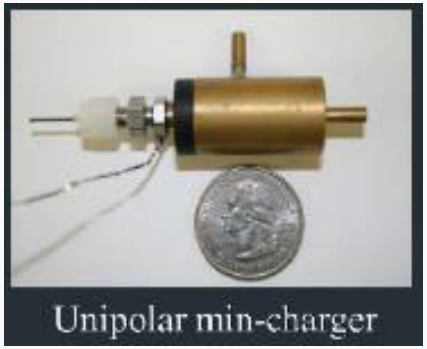


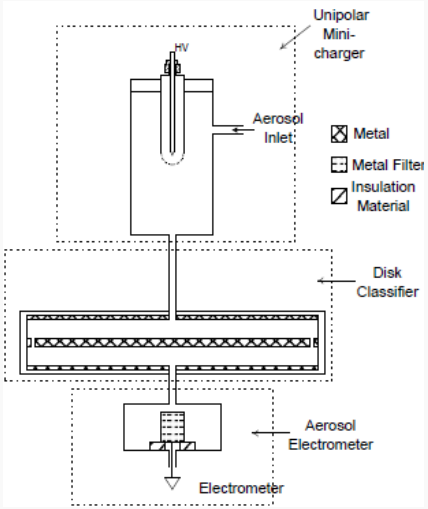
Ongoing and Future EPA Sensor Evaluation Activities

- PM and VOC Sensor Evaluations
  - A host of low cost (<$2500) PM2.5 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"

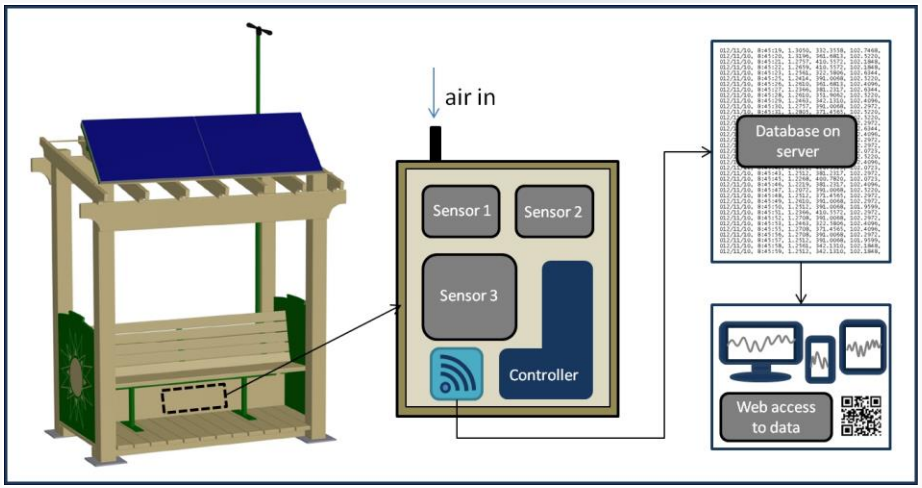




(Chen et al., 2013)

Community Monitoring Applications

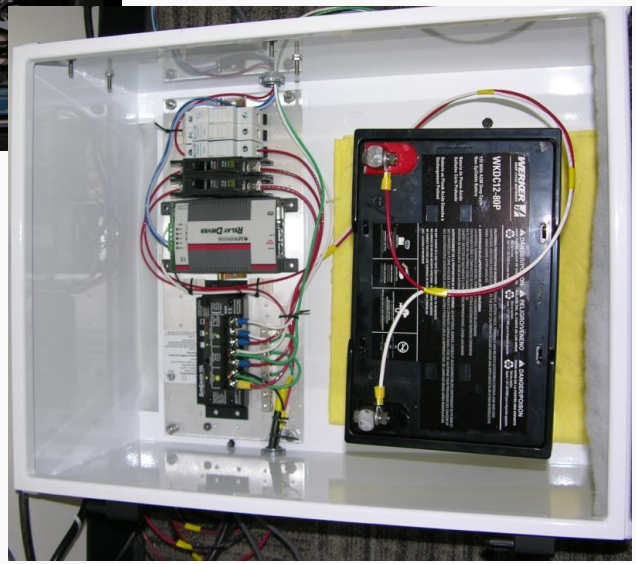
Village Green Project



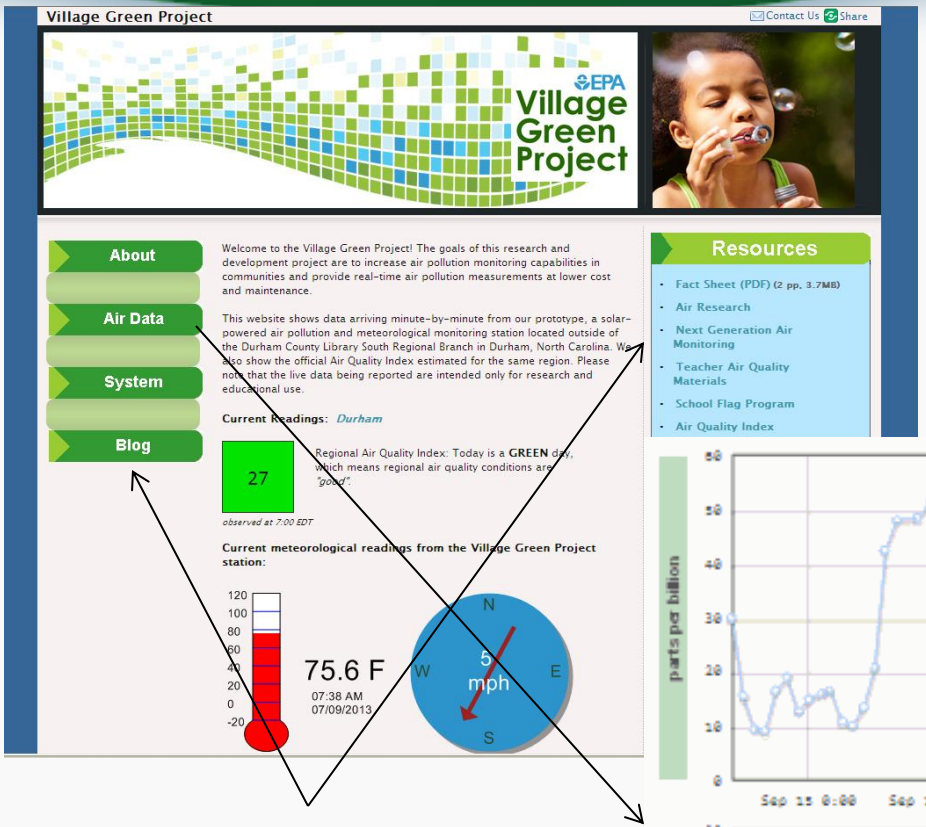
- Self-powered air and meteorological sampler
- Lower cost, real-time instruments - proven capability at ambient levels (wind, black carbon, $PM_{2.5}$, ozone)
- Wireless data communication to publically-accessible website
- Designed to add value to and be secure in public environments

Components

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

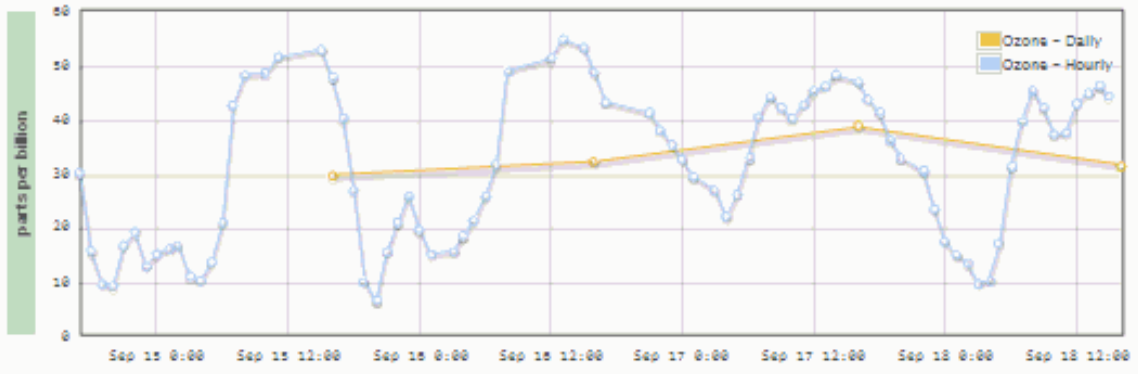


Village Green Website



http://villagegreen.epa.gov/

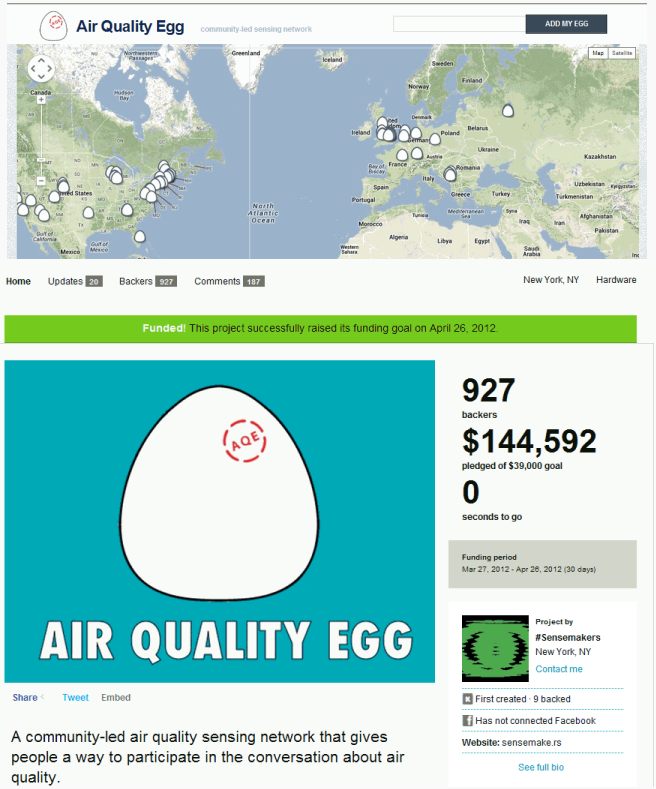
Educational and community outreach opportunity



Sensor Technology is Enabling Citizen Science

Citizen Science for a variety of interests:

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

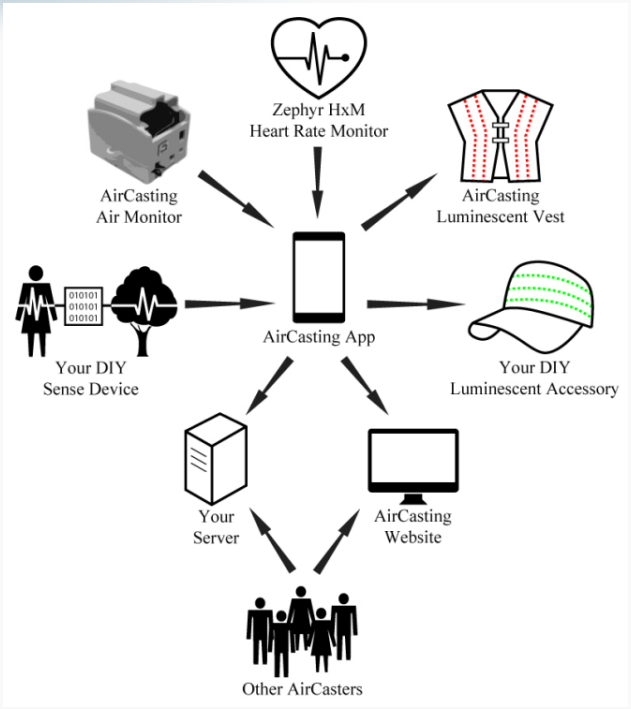


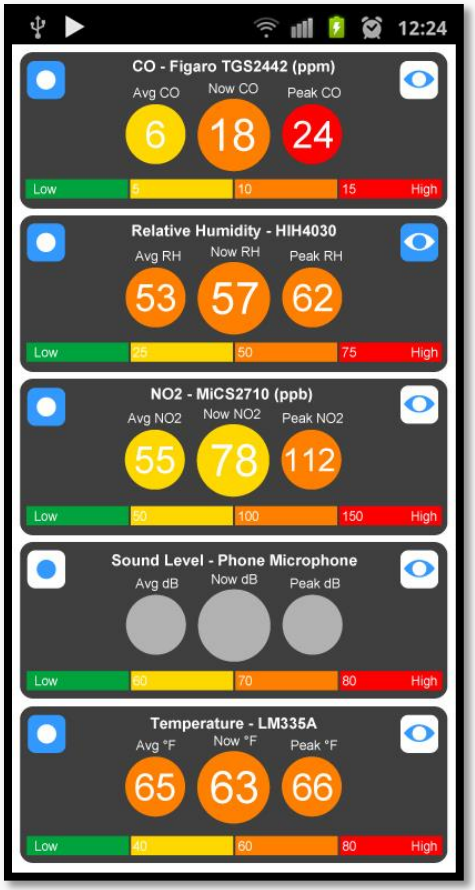
My Air My Health

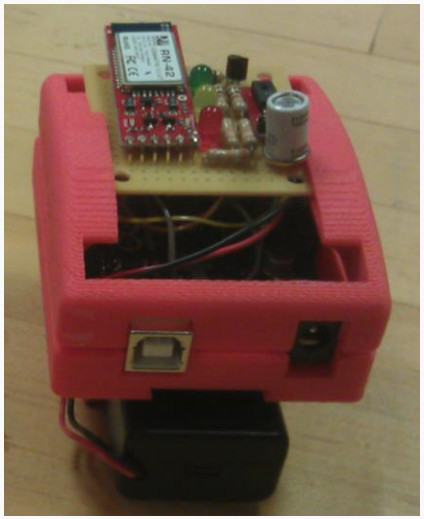
U.S. Department of Health and Human Services
U.S. Environmental Protection Agency

Example: Air Casting

Share Your Air!







habitat map

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

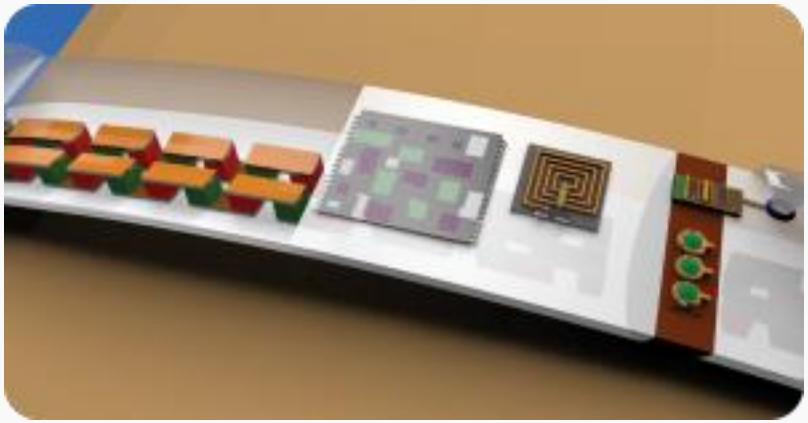
Wear Air *(CMU)*: VOC sensor

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

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

NC STATE UNIVERSITY

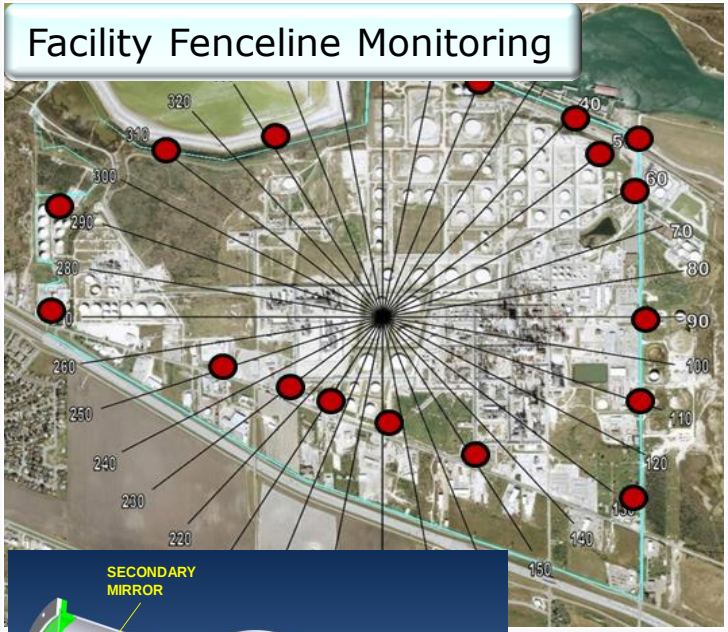
(assist.ncsu.edu)

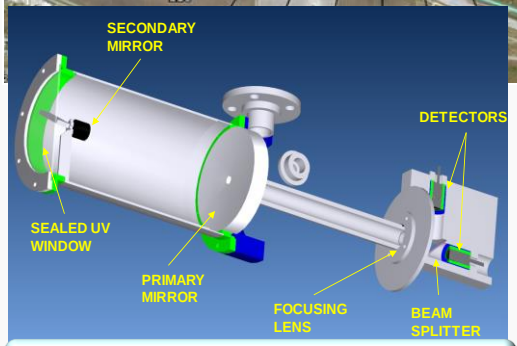
Source Monitoring Applications

New Opportunities for Source Oriented Monitoring

Mid-range Sensors and Remote Measurements

Facility Fenceline Monitoring

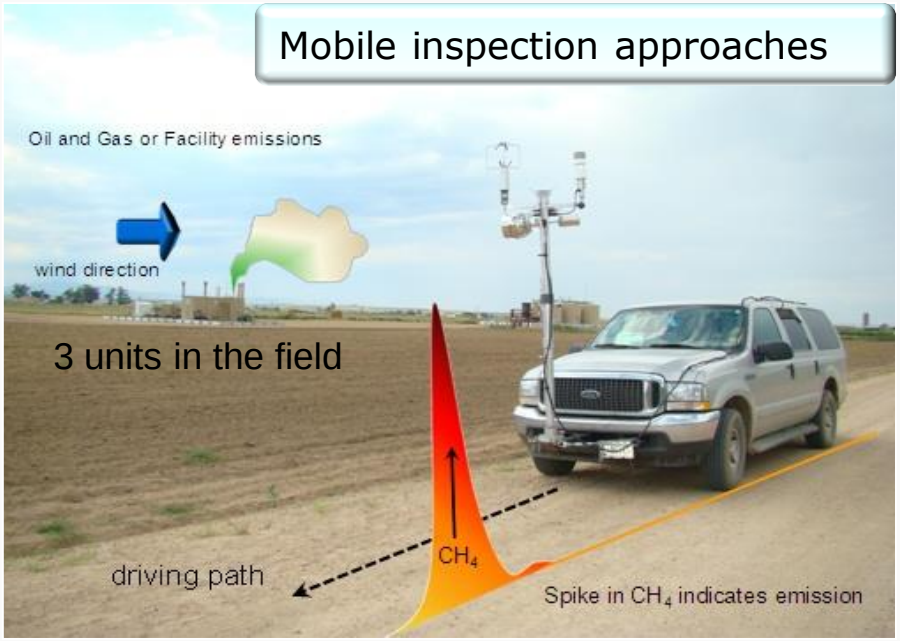




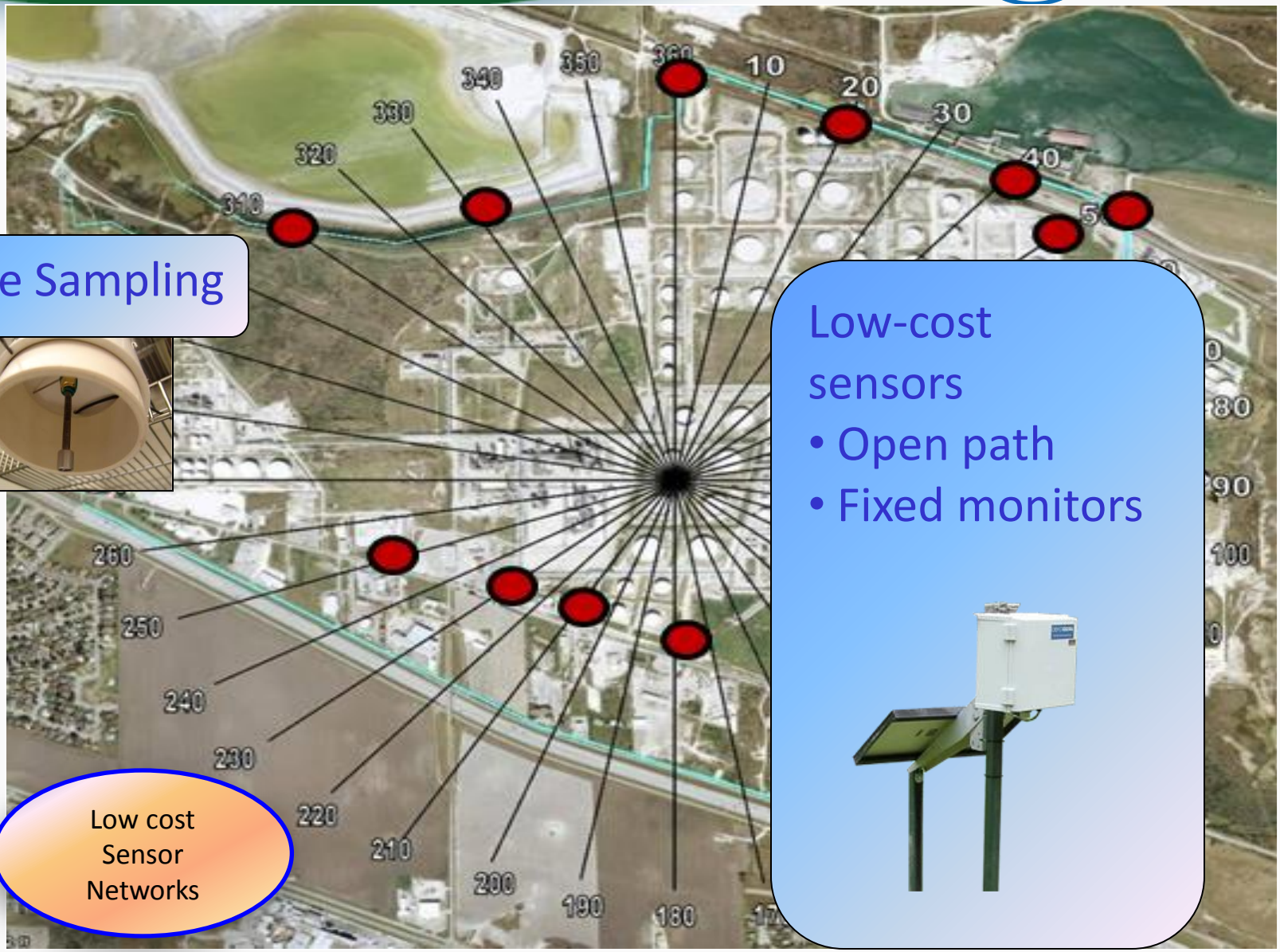
Low cost remote sensing

Advanced LDAR and fugitive strategies
- In-plant sensor networks
- IR camera protocols
- Passive samplers

Mobile inspection approaches

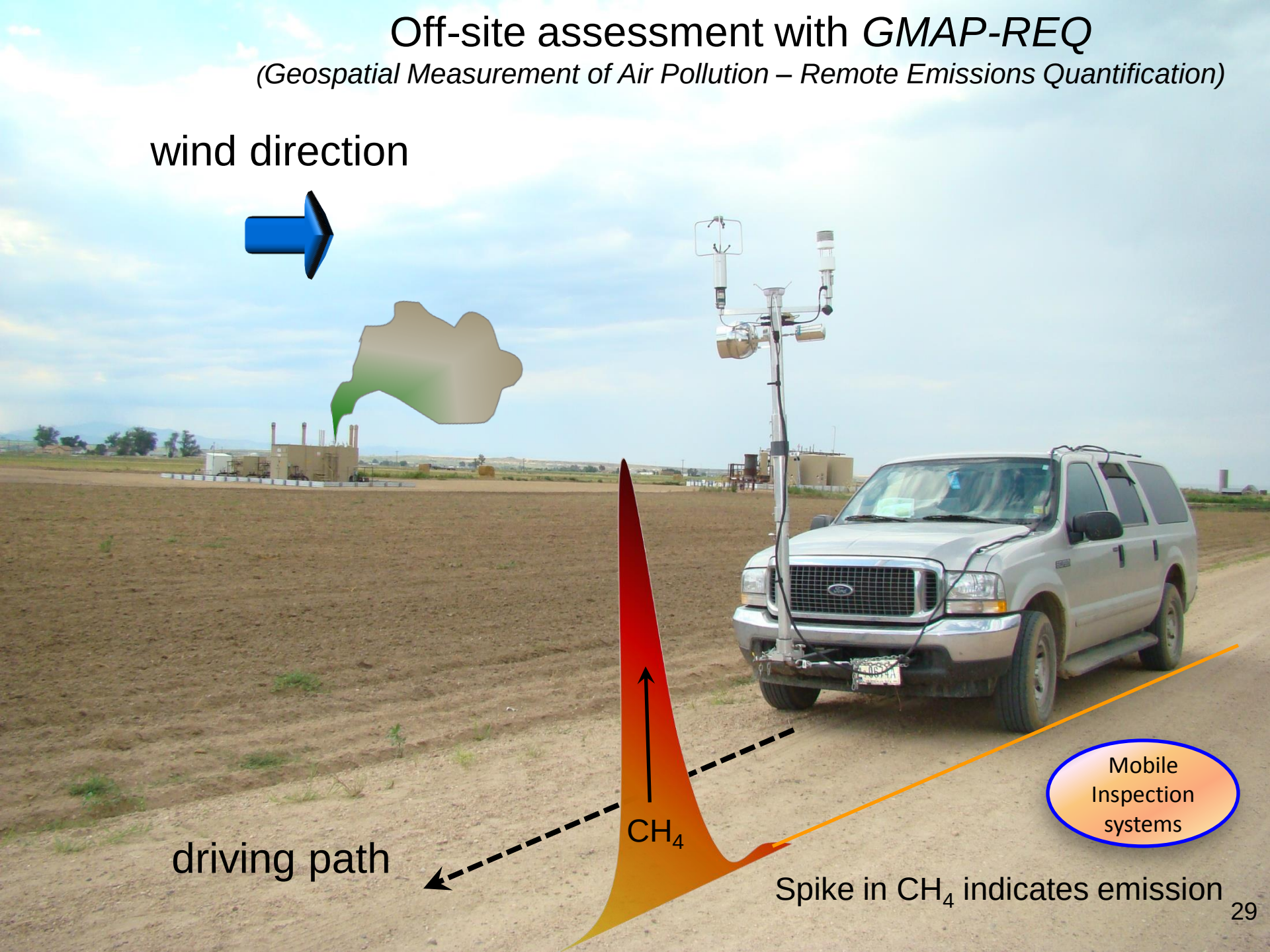


Sensor Networks In-plant and Along Facility Fence Line



Off-site assessment with *GMAP-REQ*

(Geospatial Measurement of Air Pollution – Remote Emissions Quantification)



The Future of Air Monitoring?

Data from Multiple Tiers

existing

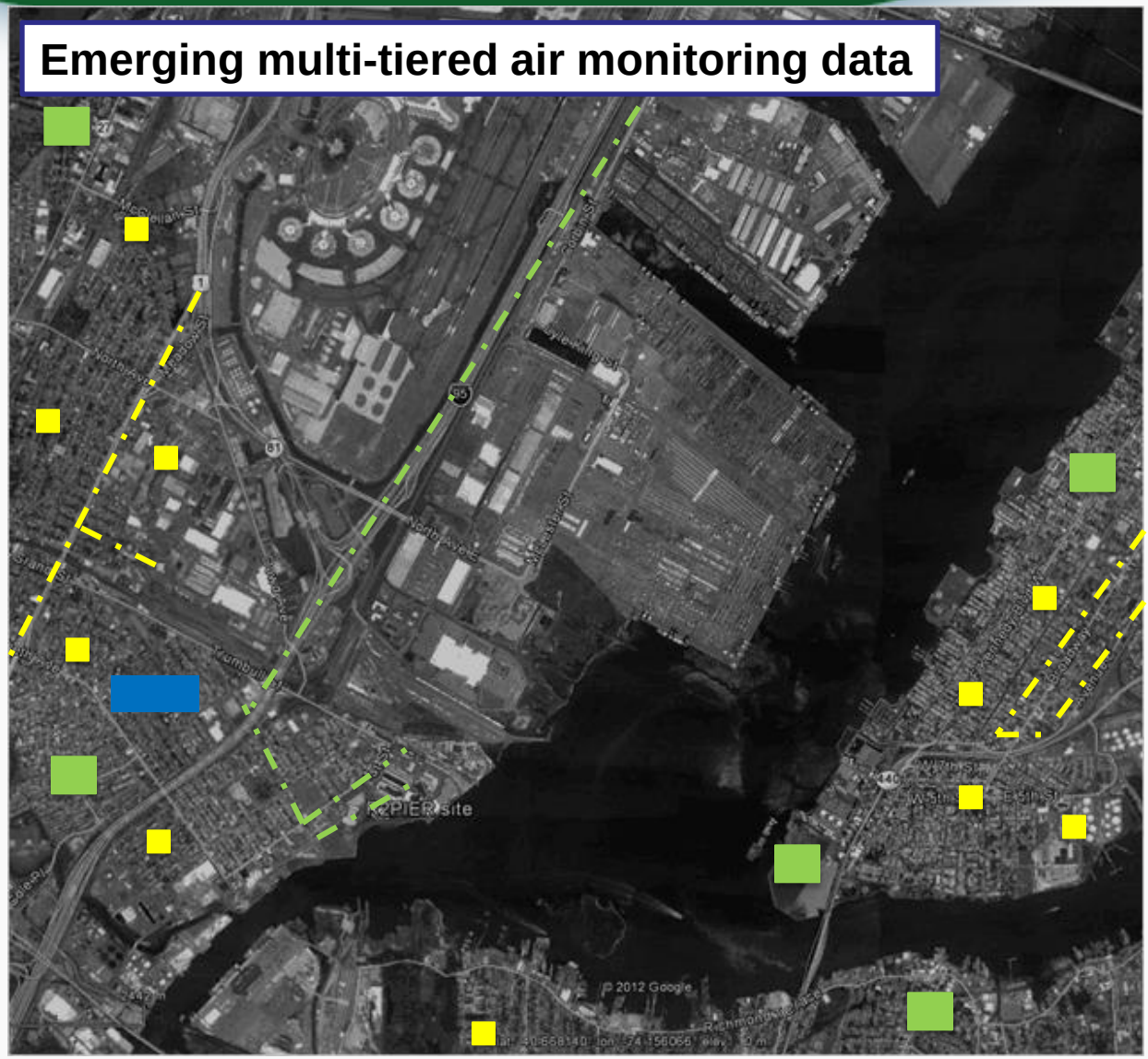
Tier1: Regulatory or regulatory-equivalent air monitoring stations
Cost: $$$$, Data reliability = A+

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



Opportunities:

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

Challenges:

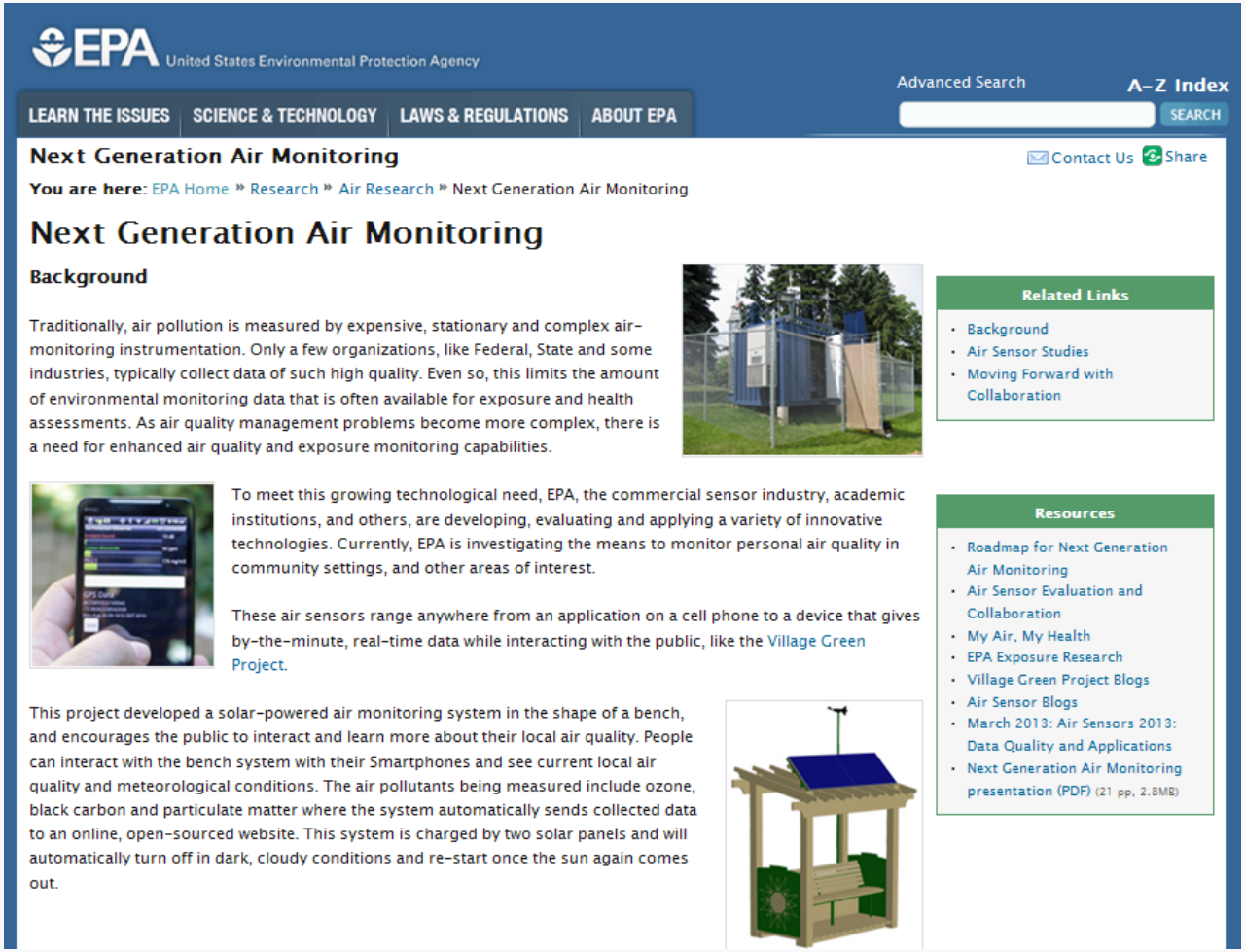
- Data interpretation and public messaging
- “Big data” analysis
- Support for do-it-yourself/citizen science

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:



http://www.epa.gov/research/airscience/air-sensor-research.htm

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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