



Next Generation Air Monitoring: Sensors

Environmental Measurement Symposium

“The future of Environmental Measurement and Monitoring”

Washington, D.C.

August 4-8, 2014

Chet Wayland

Office of Air Quality Planning and Standards

U.S. Environmental Protection Agency



The Administrator's Message

Fiscal Year 2014-2018 EPA Strategic Plan (April 10, 2014)

"I will advance a rigorous research and development agenda that informs and supports the EPA's policy and decision making with **timely and innovative technology** and sustainable solutions. We also are **mobilizing citizen science** efforts to complement those of the EPA, which, combined with greater access to environmental data, **enhanced community engagement**, environmental education, **new tools and increased analysis**, will better support state and local decision making."



EPA Strategic Goals

Goal 1: Addressing climate change and improving air quality

Goal 2: Protecting America's waters

Goal 3: Cleaning up communities and advancing sustainable development

Goal 4: Ensuring the safety of chemicals and preventing pollution

Goal 5: Protecting human health and the environment by enforcing laws and assuring compliance





The Changing Paradigm of Air Monitoring

The image shows the cover of the journal "Environmental Science & Technology". The background is an aerial view of a city. Overlaid on this are several circular callouts connected by green lines, illustrating different air monitoring methods: a solar-powered ground station, a hand holding a smartphone displaying an "Air Quality Index" of 67 (Moderate), a vehicle-mounted sensor, and a hand holding a small green canister labeled "O3/NO2".

Environmental Science & Technology

October 15, 2013
Volume 47
Number 20
pubs.acs.org/est

The Changing Paradigm of Air Monitoring

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The Role of Sensor Technology in the Changing Paradigm



How data is collected?



Sensor Technology



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

Convergence of Technologies and Cultural Change

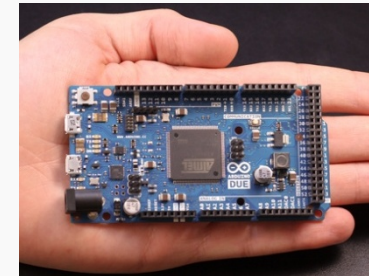


Miniaturized environmental sensors



e.g., CairClip

Introduction of low cost controls and communications



e.g., Arduino microprocessor

Emerging data-viewing/communication apps



AirCasting App

Smartphone / Tablet generation

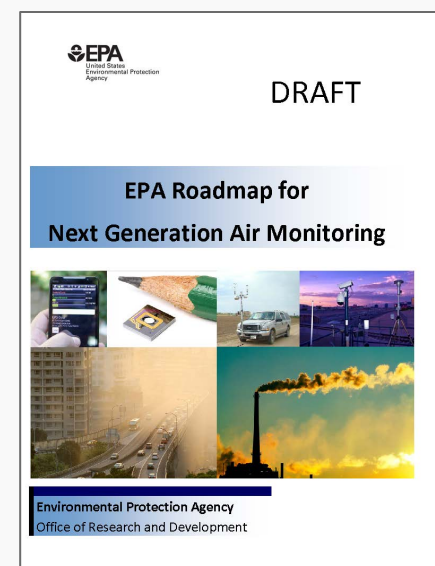
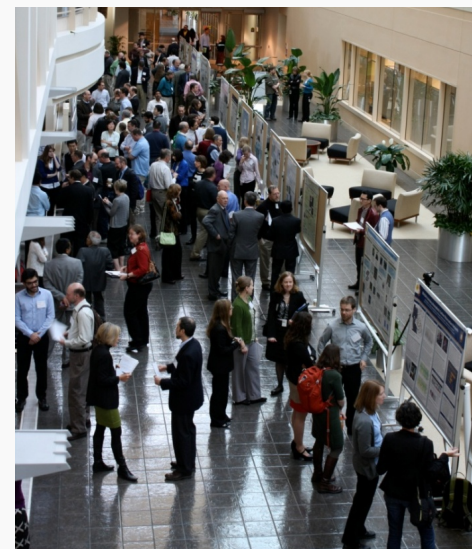
e.g., fitbit activity tracker



What is EPA doing?



- Stimulating collaboration and conversation
 - 4 NGAM Workshops since 2012
 - Government, Academia, International, DIY'ers
- Assessing emerging technology
 - Literature review of sensor technology
 - Sensor evaluation through laboratory and field analyses
- Thinking big picture about these developments and implications



<http://www.epa.gov/research/airscience/docs/roadmap-20130308.pdf>

EPA Technology Review



- Scope
 - Real time/continuous monitoring technologies of gases and particulates
 - Only lower-cost (<10 K) systems
 - Gas sensors: electrochemical, metal oxide, spectroscopic sensing principles
 - PM sensors: light scattering or light absorption sensing principles
- Pollutants
 - Criteria Air Pollutants - CO, SO₂, NO₂, PM, O₃, Pb
 - HAPs - formaldehyde, acetaldehyde, benzene, 1,3-butadiene, acrolein
 - Other Pollutants - ammonia, total VOCs, hydrogen sulfide, and methane
- Gaps
 - Many sensors that were reviewed do not have the detection limits required to measure ambient levels of these pollutants
 - Many of the sensors suffer from selectivity issues and/or impacts of high RH
 - There are no direct mass PM sensors and the light scattering sensors do not measure ultrafine PM
 - Very few of these systems have been rigorously tested

Ongoing EPA Sensor Evaluation Activities



- Ozone, NO₂, PM and VOC Sensor Evaluations
 - Ozone and NO₂ sensors evaluated in 2012/2013*
 - A host of low cost (<\$2500) PM_{2.5} and VOC sensors purchased or acquired for laboratory and/or field evaluation in 2013/2014
- Discussing potential sensor related projects in EPA Regions 2 and 4
- Publications
 - Air Sensors Guidebook
 - Citizen Science Fact Sheet
 - Mobile Air Sensors & Applications for Air Pollutants
 - Sensor Evaluation Report*
- Village Green Project
- Short Term Sensor Field Projects
 - Discover AQ
 - AIRS
 - Roadside, wildfire, fenceline



<http://www.epa.gov/research/airscience/next-generation-air-measuring.htm>

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.

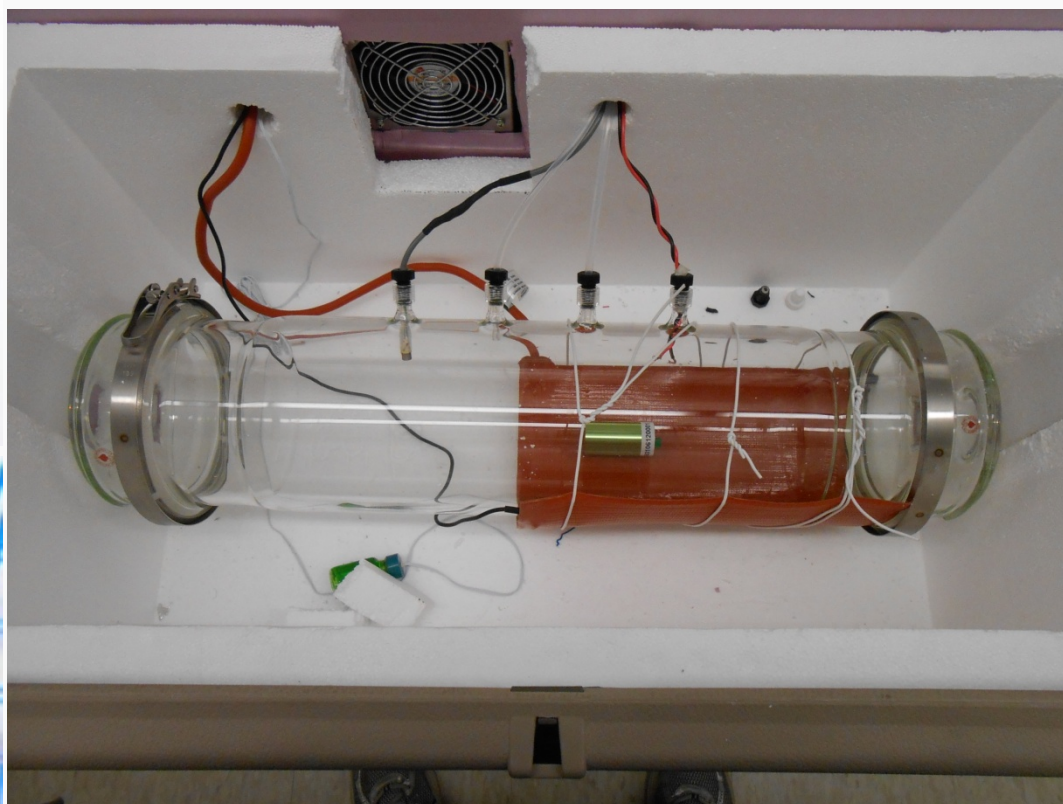
Description:

- 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:

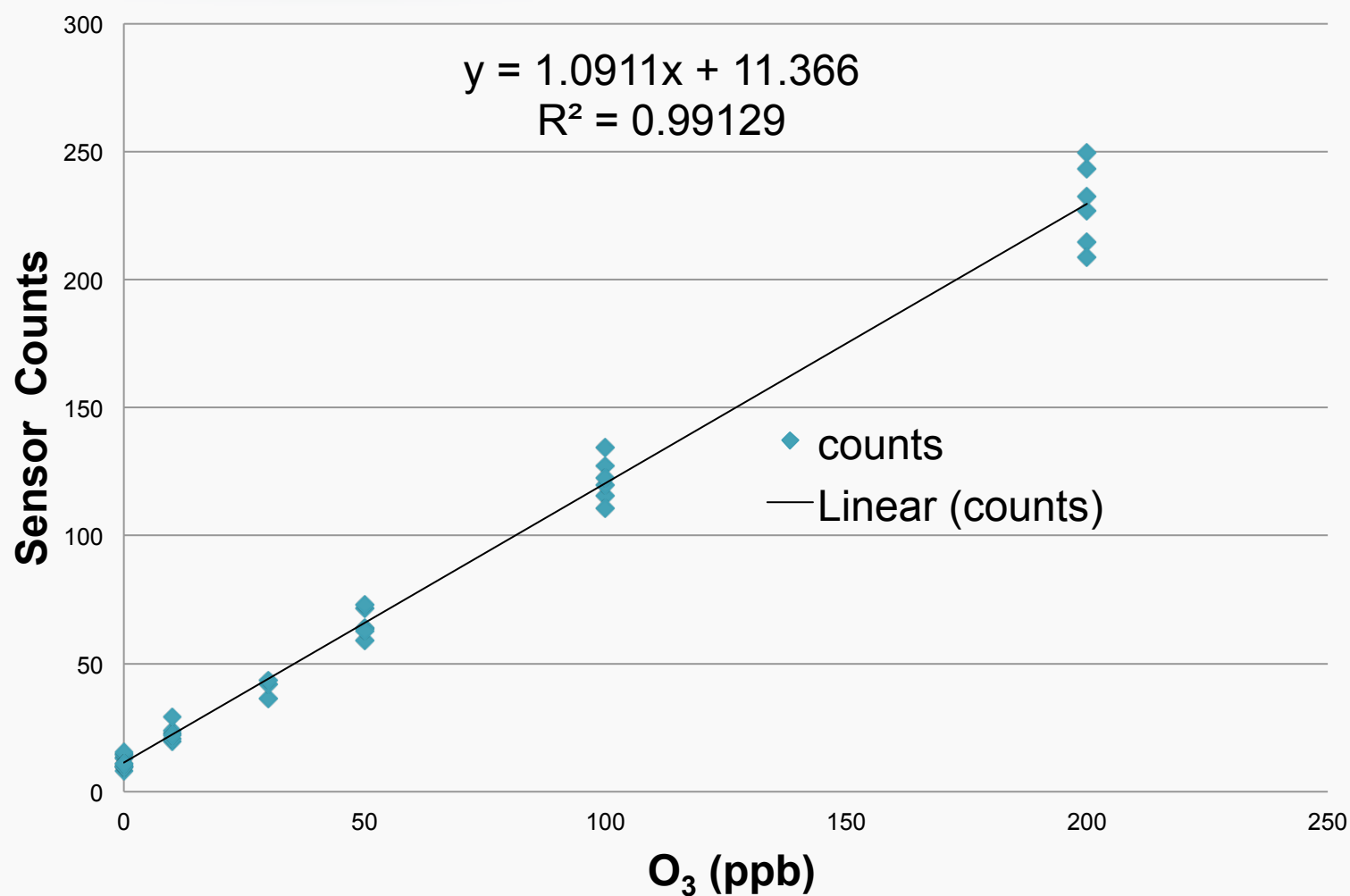
- General performance of the device
- Observations on operation
- Validated non-summarized data
- EPA's intent was not to compare one specific device with another
- EPA recognized the confidential nature of the technologies being evaluated

Evaluating Personal Sensors



CairClip electrochemical
sensor evaluated under the
Air Sensors Project

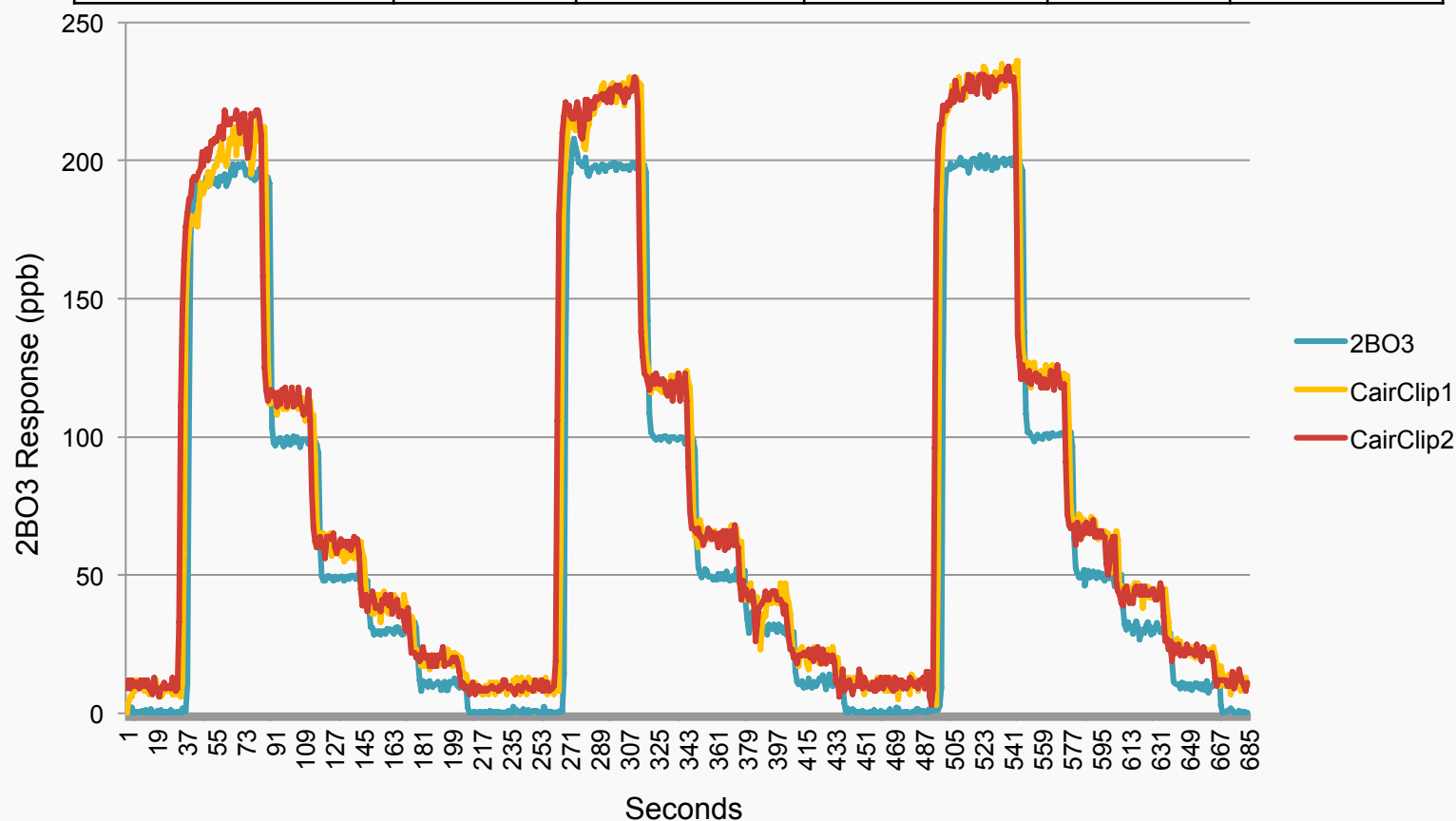
Cairclip performance against reference analyzer



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



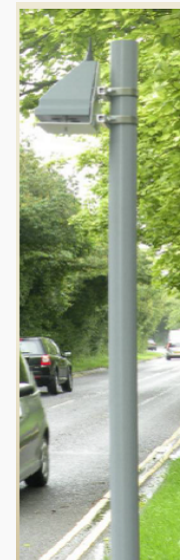
Sensor Evaluation in Collaboration with NASA (Houston, TX Sept 2013)



- 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

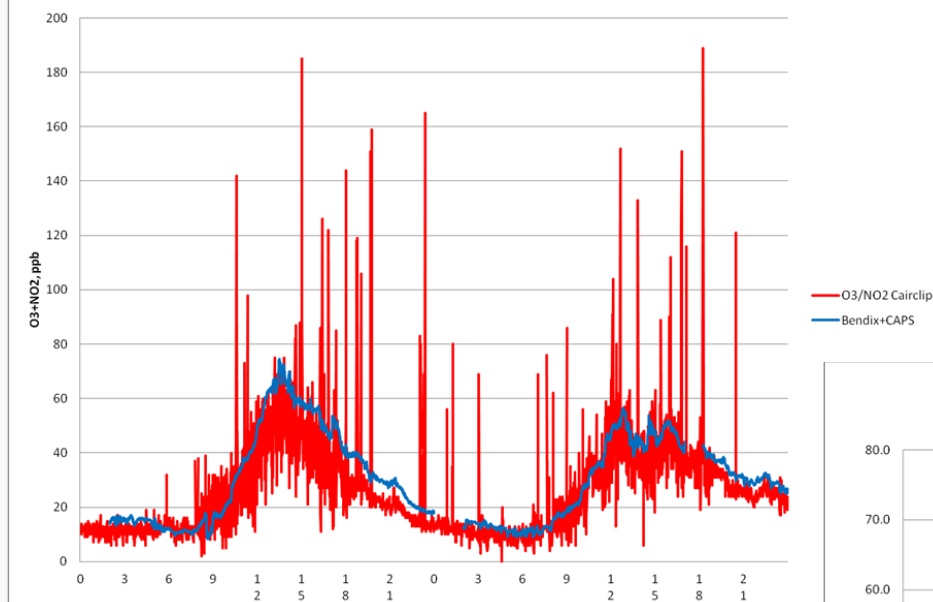


Geotech AQMesh-5

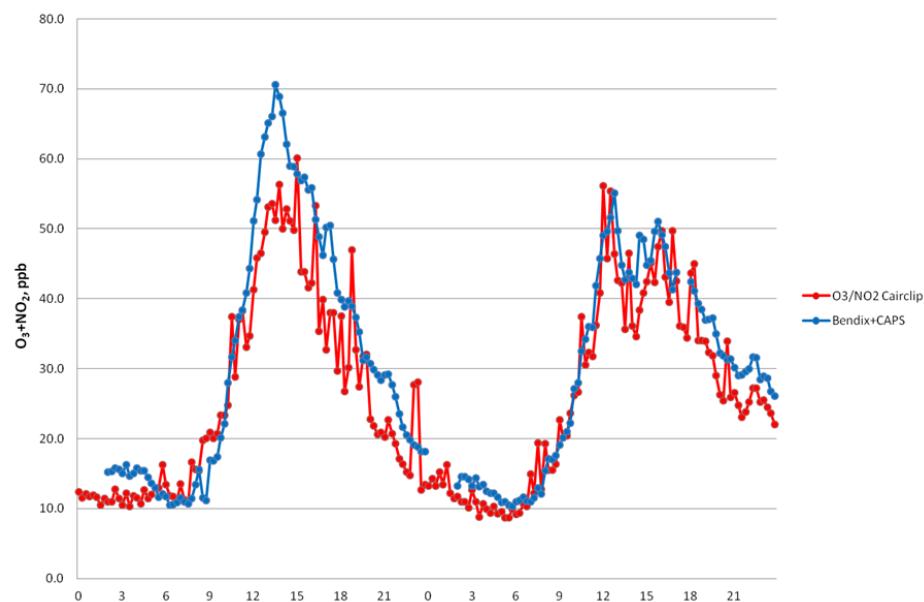
Preliminary Results from Houston: Integrated O_3 and NO_2



La Port Airport Sept. 3-4, 2013
1 min Average



September 3-4, 2013
15 min ave



What Does New Sensor Technology Bring?



Benefits

- Enhanced capability to monitor at local levels
- Enhanced ability to understand people's exposure to air pollution as they actually experience it
- Combined with other technologies (e.g. satellites and models), improved understanding of air quality
- Improved ability for individuals to take specific actions to protect their health
- Over time, ability to improve compliance with air regulations

Challenges (Opportunities)

- Data quality & levels of detection
- Interpretation & communication of the data
- Big data

Next Generation Air Monitoring Research at EPA

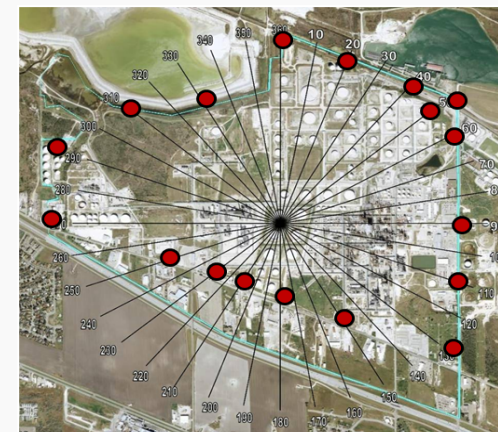
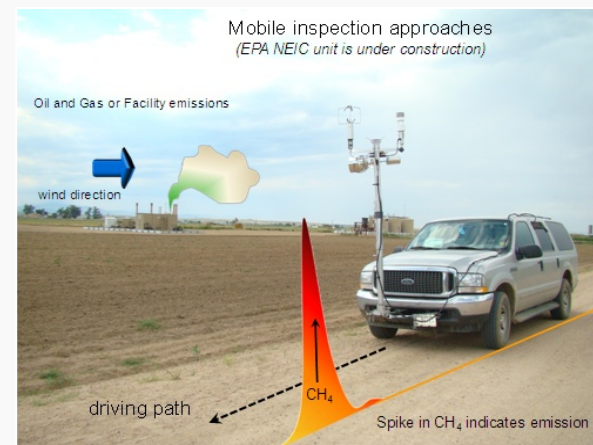


- **Lower Cost Sensors**

- Exploring applications of sensor data
- Developing sensor messaging
- Discussing data collection, fusion, and storage
- Village Green Project II
- Citizen Science Toolkit
- Development of Sensor Seal Program

- **Higher End Technology Scale**

- Facility Fenceline and Sensor Networks
- Geospatial Monitoring for Air Pollution (GMAP)*
- Data Visualization Support (RETIGO)*
- Sensor Network Intelligent Emissions Locator Tool (SENTINEL)





**“There are many ways of
going forward, but only
one way of standing still.”**

- Franklin D. Roosevelt