Update of Next Generation Air Monitoring Research at EPA

Clean Air Act Advisory Committee

October 29, 2014

The Changing Paradigm of Air Monitoring

Snyder et al., ES&T, August 2013
http://pubs.acs.org/doi/abs/10.1021/es4022602

The Role of Sensor Technology in the Changing Paradigm

How data is collected?

Limited Mostly to Governments, Industry, and Researchers

Who Collects the data?

Compliance Monitoring, Enforcement, Trends, Research

Why data is collected?

Government Websites, Permit Records, Research Databases

How data is accessed?

Sensor Technology

Expanded Use by Communities and Individuals

New Applications and Enhancement of Existing Applications

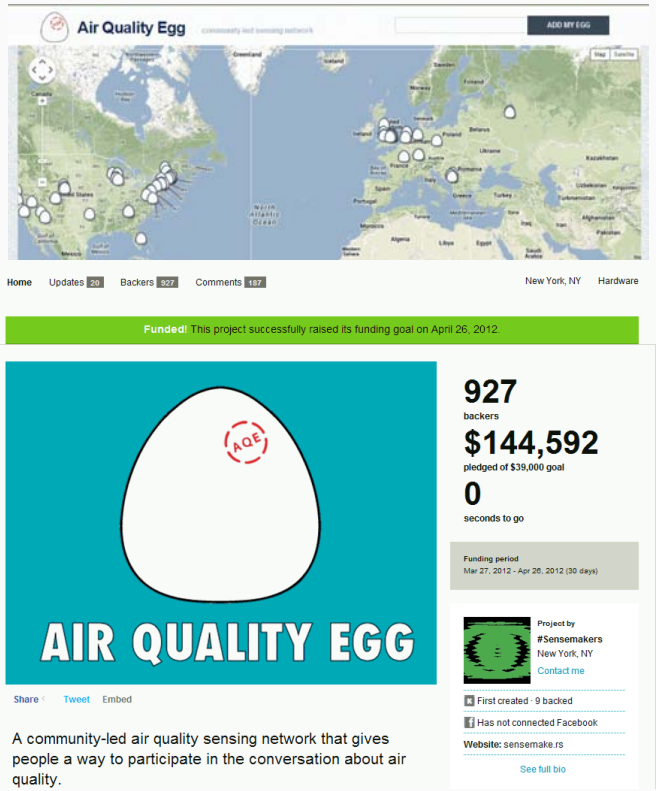
Increased Data Availability and Access

Snyder et al., 2013

Sensor Technology is Enabling Citizen Science

Citizen Science for a variety of interests:

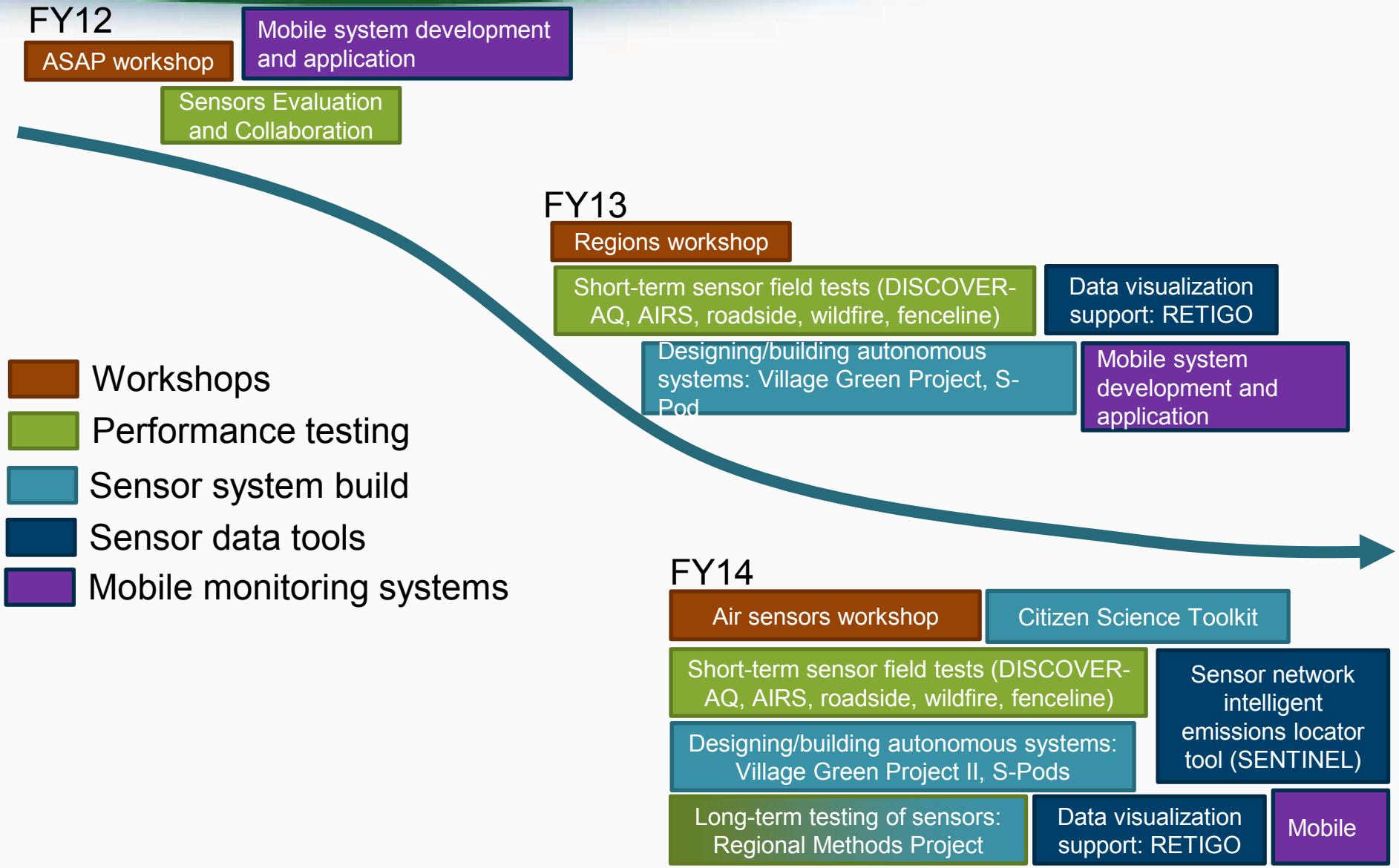
- Individual Health
- Community Exposures
- Research
- Education
- Technology



My Air My Health

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

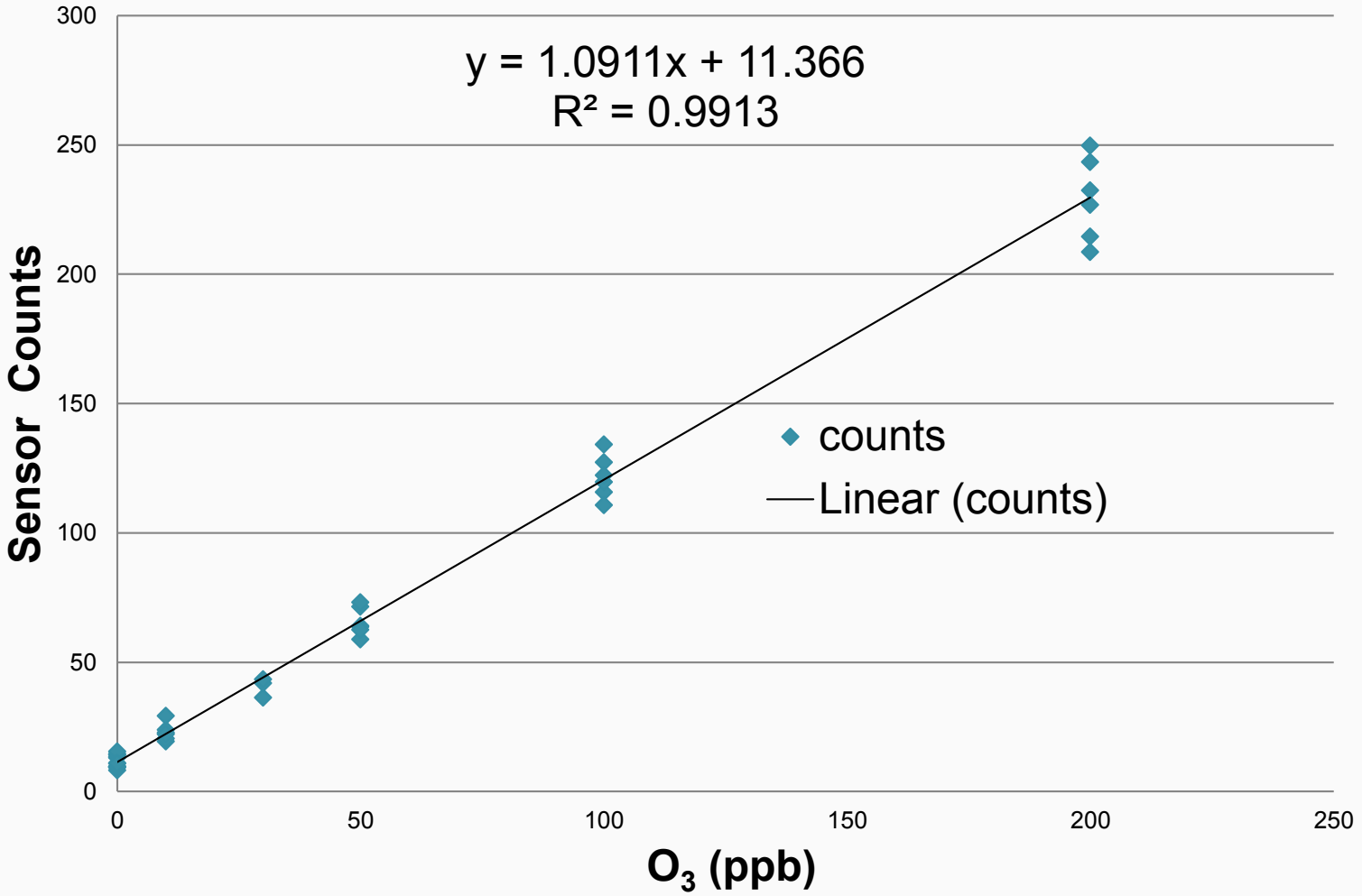
ORD NGAM R&D has been a rapidly moving area

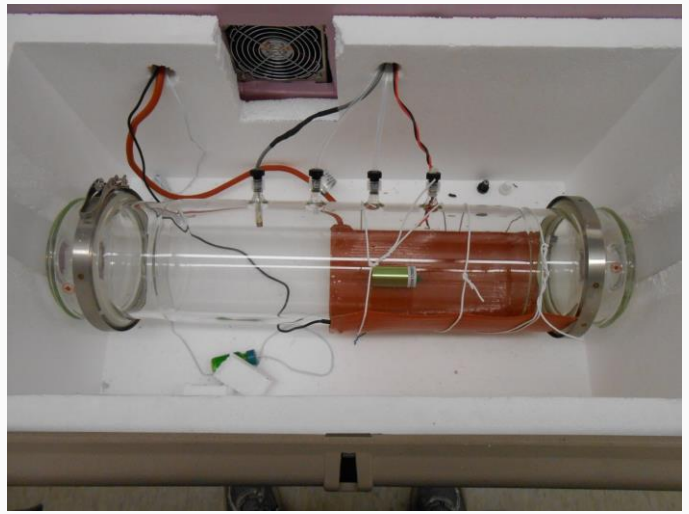


Sensor Performance Evaluation

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)	

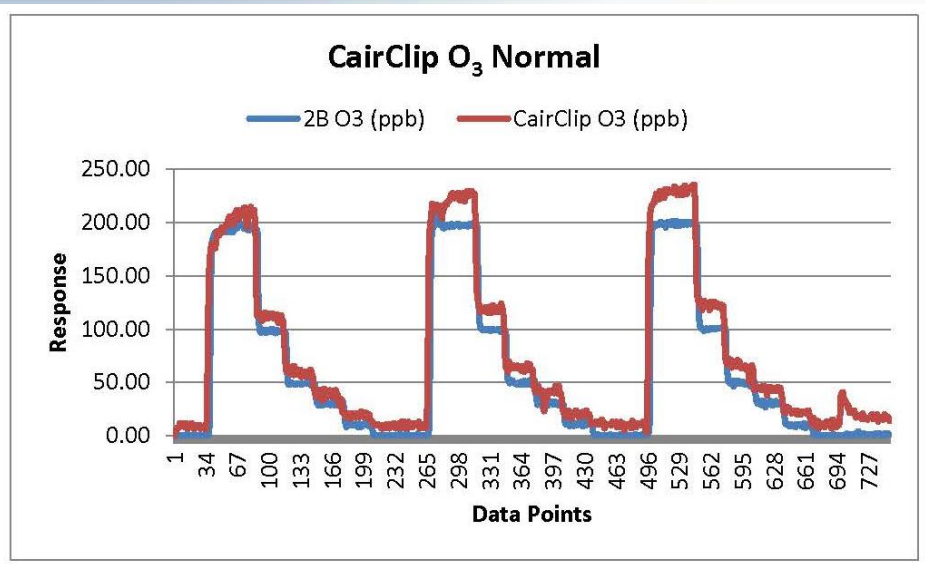
Example Results from Laboratory Evaluation



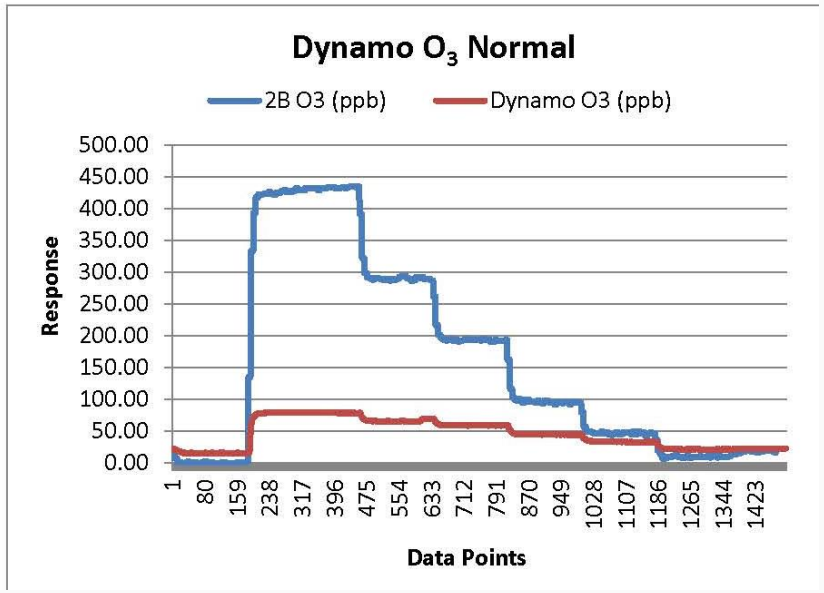


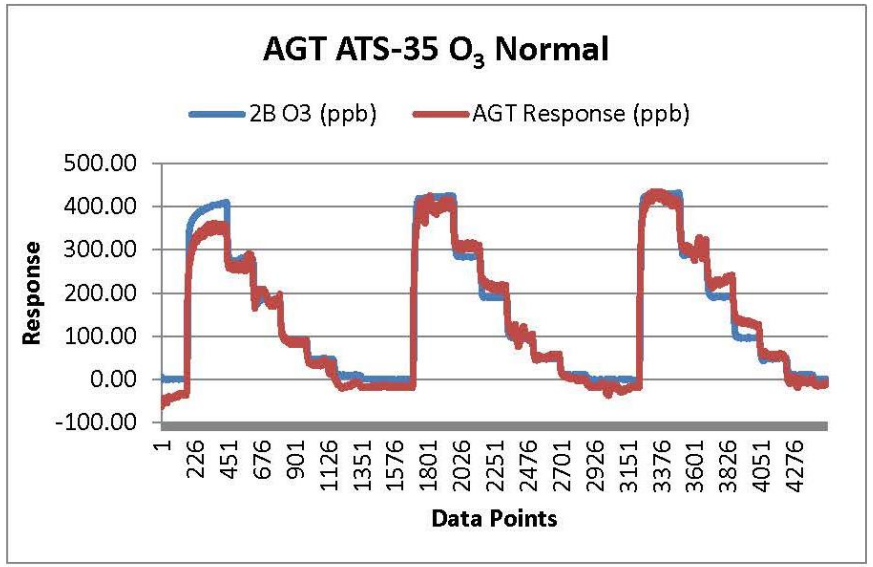
Example: Cairpol CairClip sensor

Example Results from Laboratory Evaluation: Ozone



Source: EPA Sensor Evaluation Report
EPA 600/R-14/143 | May 2014





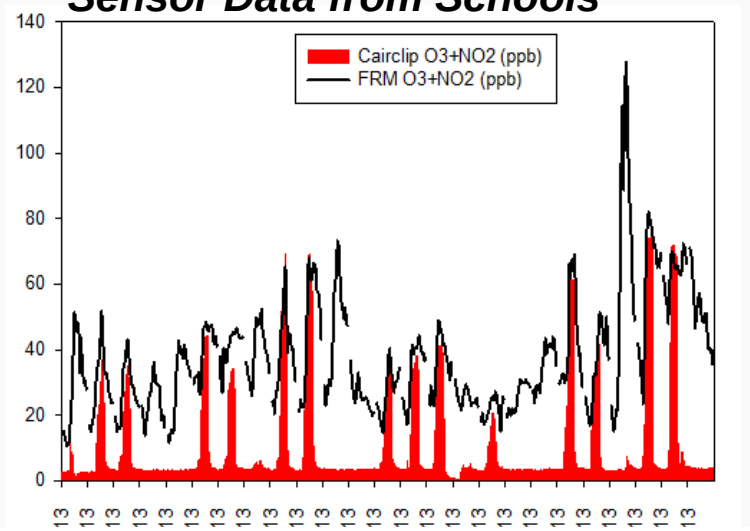
Example Field Test Results

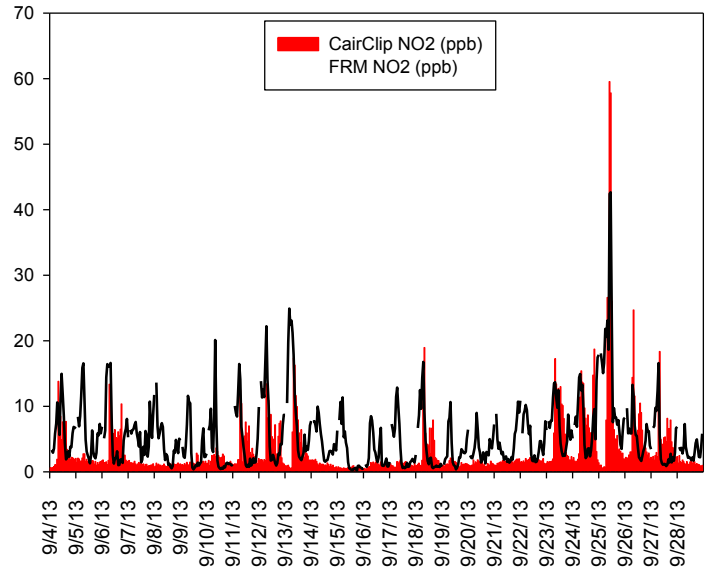
DISCOVER-AQ Study Houston, TX (Sept. 2013)

- 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





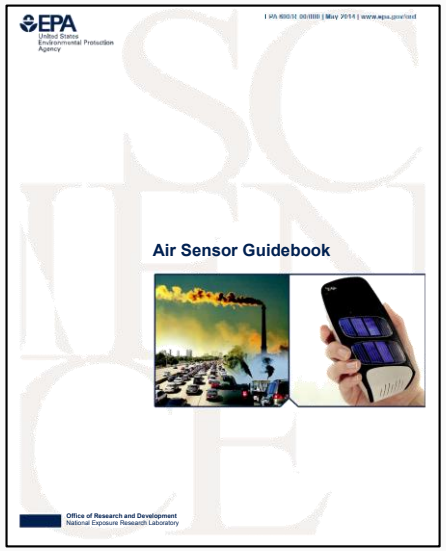
Air Sensor Citizen Science Toolbox

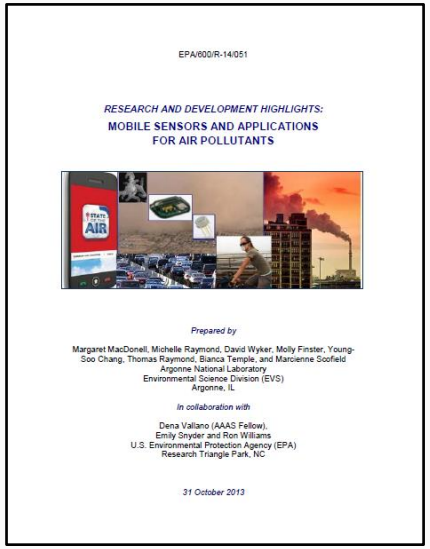
- The Toolbox provides information to help citizens more effectively and accurately collect air quality data in their community, including information on;
  - Sampling methodologies
  - Generalized calibration/validation approaches
  - Measurement methods options
  - Data interpretation guidelines
  - Education and outreach
  - Low cost sensor performance information

- Available Resources include
  - Air Sensor Guidebook
  - Sensor Evaluation Reports
  - EPA Presentation: Sensor Technology
  - Citizen Science Funding Resource Guide

Air Sensor Citizen Science Toolbox
EPA
Measure • Learn • Share

http://www.epa.gov/heasd/airsensortoolbox/

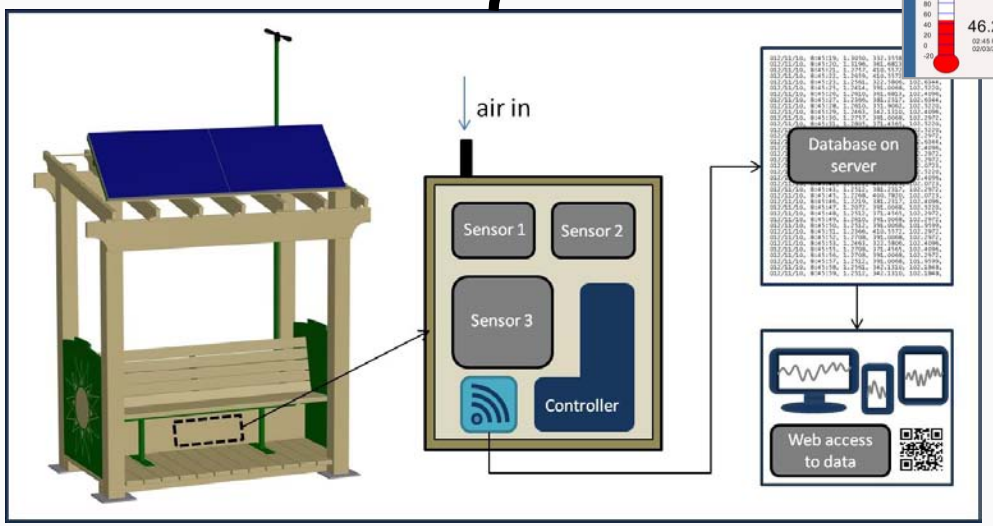




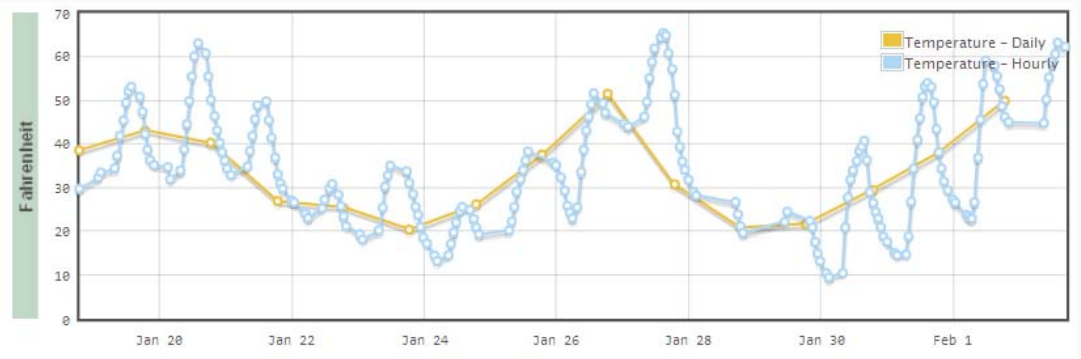
Village Green Project

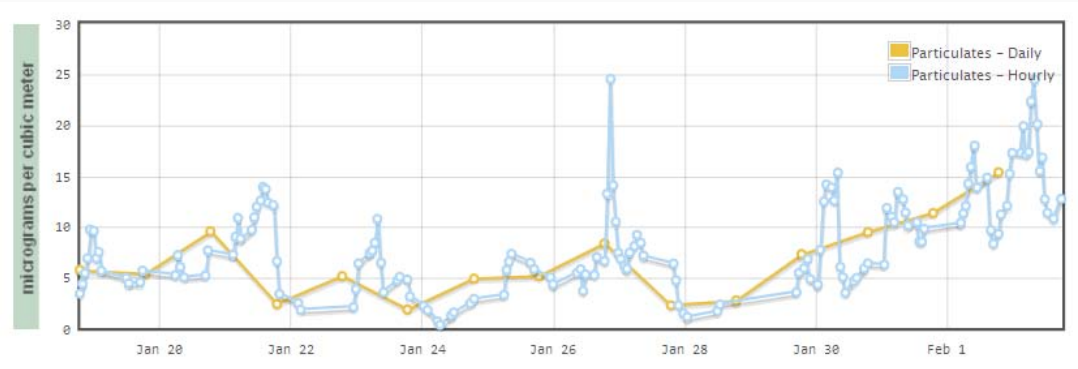
Air instruments (PM, ozone), power system and communications components stored securely behind bench

Village Green Communications/Website



Public website updated minute-by-minute

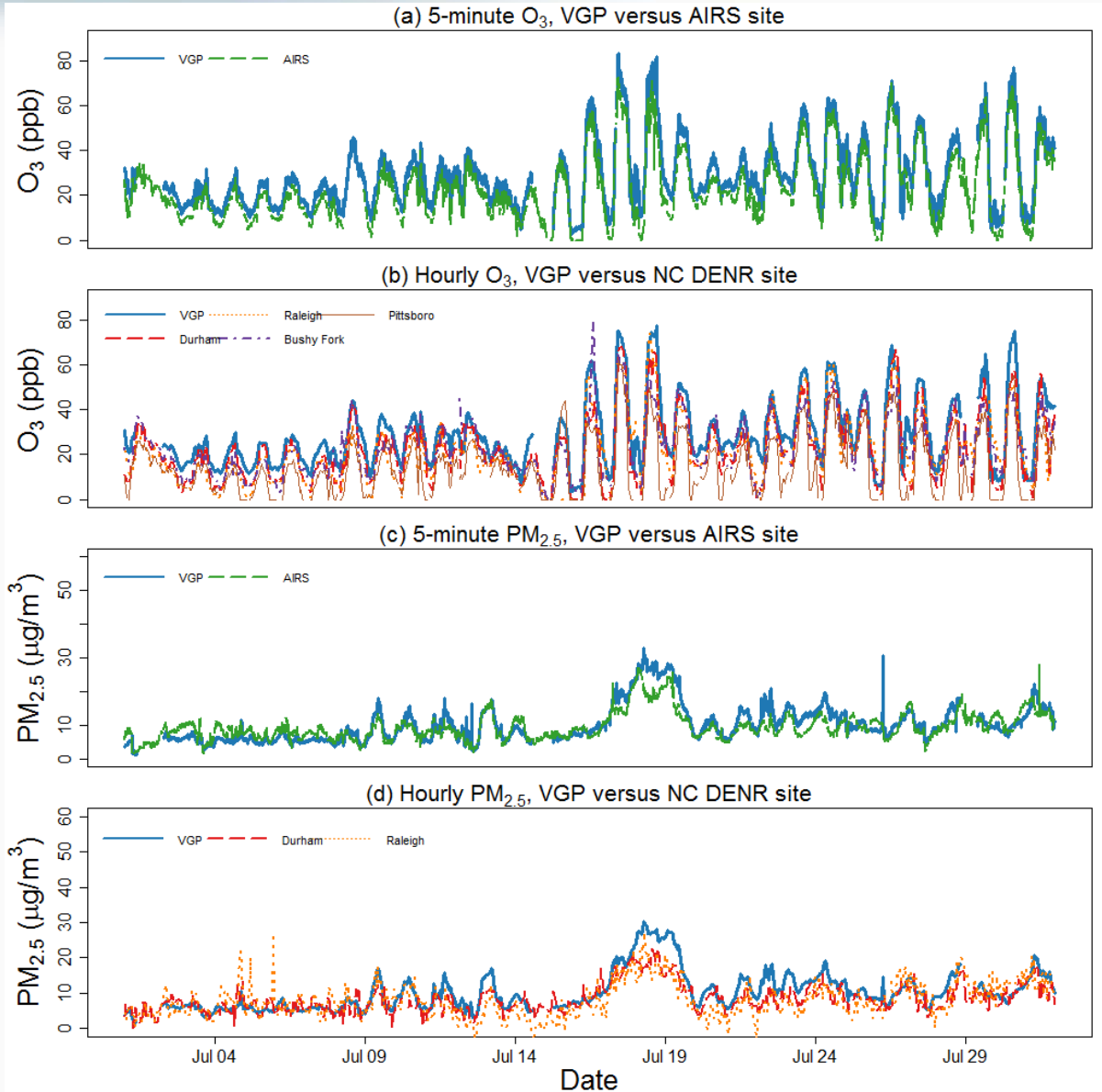




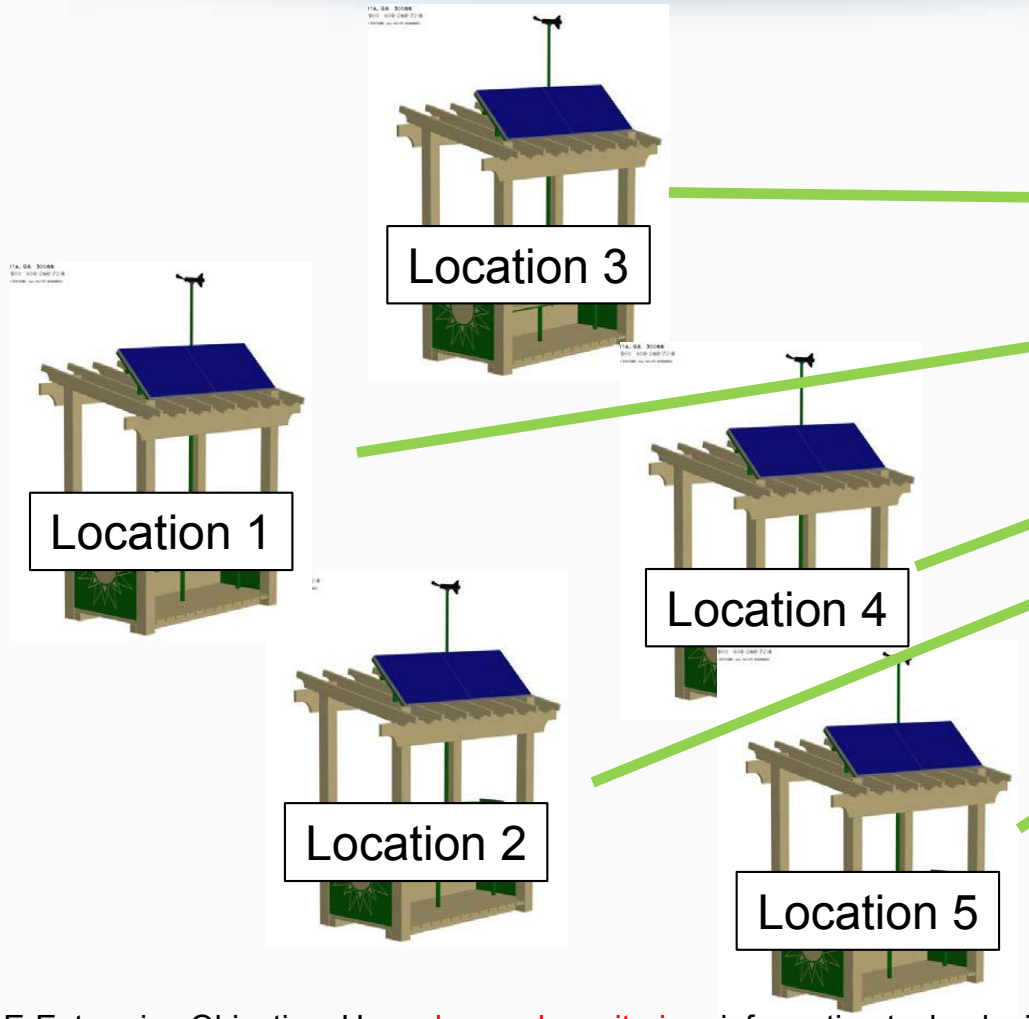
- Data transmitted via cellular modem to HTTP server
- Data screened on SQL server for various diagnostic indicators, averaged to desired interval (e.g., hourly, daily)
- Data available to web browser interface

http://villagegreen.epa.gov/

Village Green Evaluation



Village Green Expansion through the EPA E-Enterprise Program



New back-end support by AirNow, with development underway to support high time-resolution data.

Website re-design to support real-time data viewing for multiple locations

E-Enterprise Objective: Use advanced monitoring, information technologies, optimized business processes, and increased transparency to improve environmental outcomes and enhance service to the regulated community. By September 30, 2015, provide real-time environmental data to at least two communities.

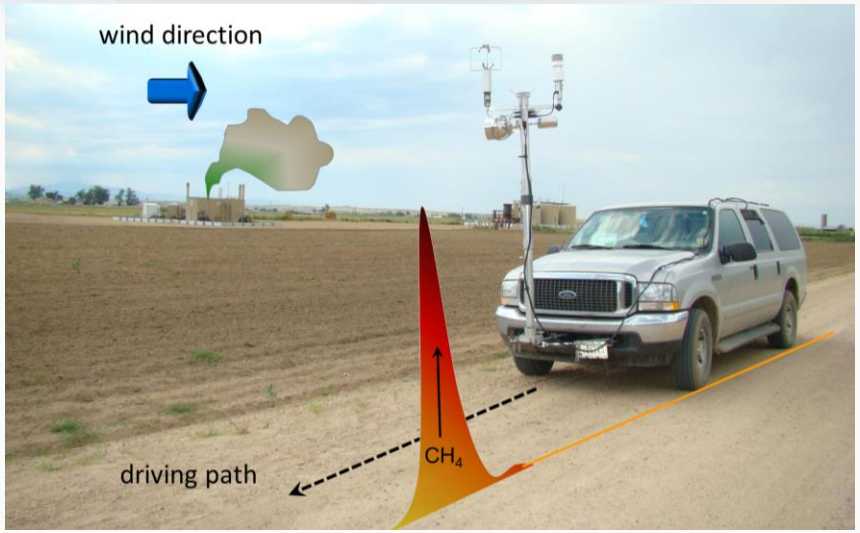
Village Green/E-Enterprise Timeline

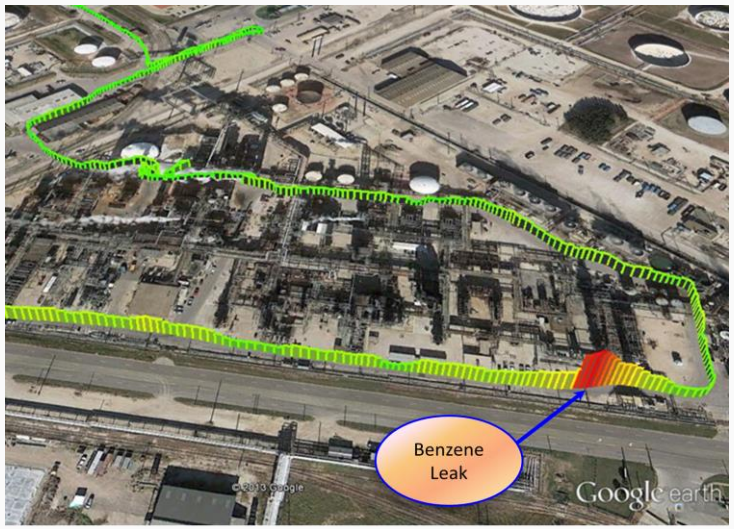
- Summer 2014:
  - Hardware development (ORD): develop new VGP system for northern climates (combined solar/wind)
  - Publish Village Green Project prototype design
  - Website development (OAQPS): develop data stream process for multiple VGP stations to transmit data to the AirNowserver; redesign website to show data for multiple stations (future URL may be airnow.gov/villagegreen)

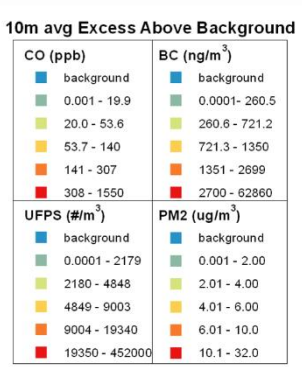
- Fall-Winter, 2014:
  - Determine state partners for new stations
  - Build and deploy approximately 4 VGP stations

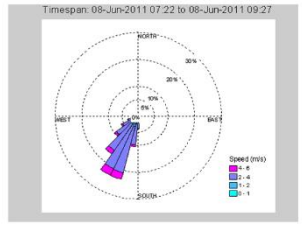
- E-Enterprise team is also connecting with others interest in self-funding to obtain stations and would allow the data stream to be hosted on the new website.

Mobile System Development and Application

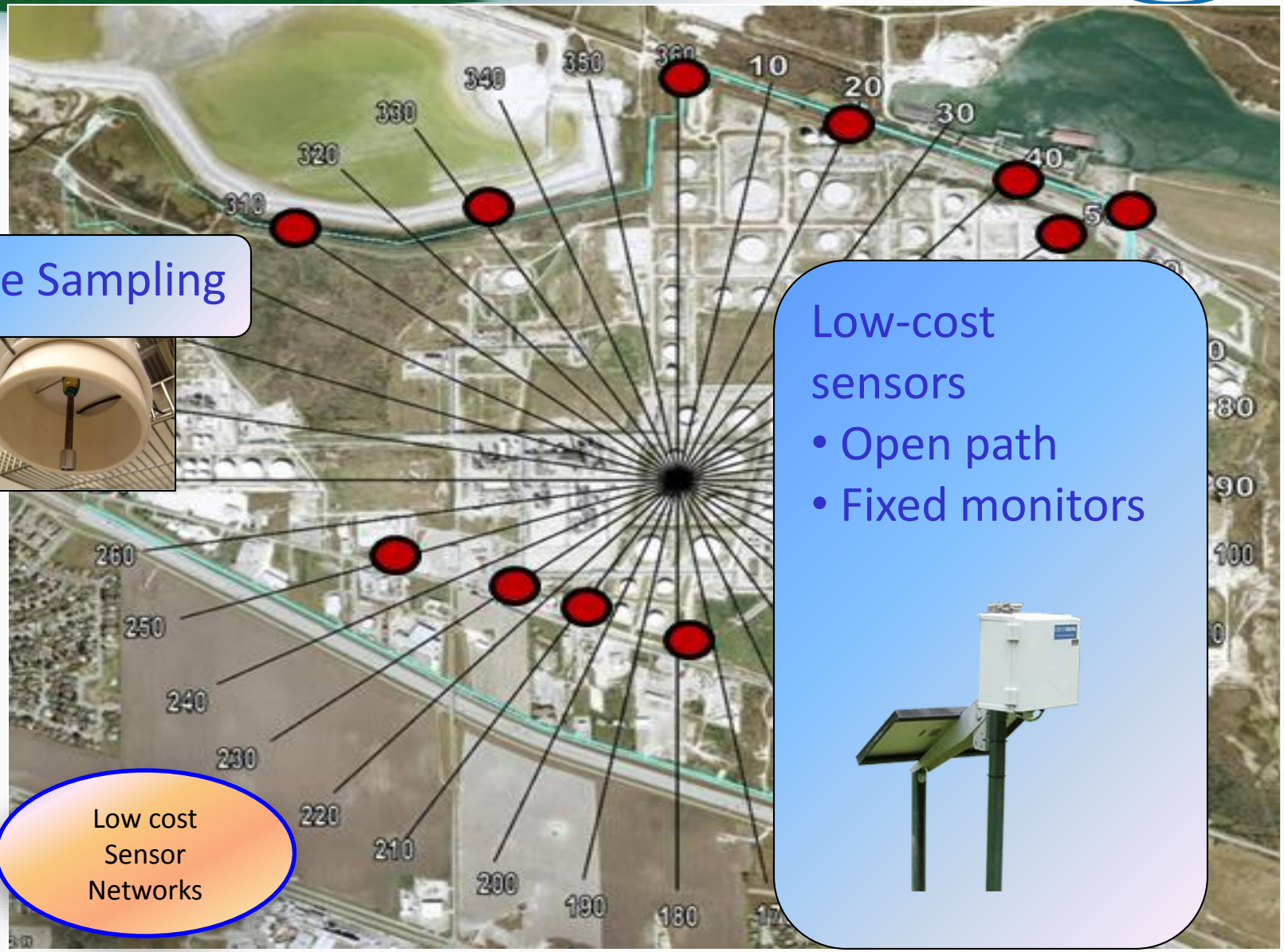




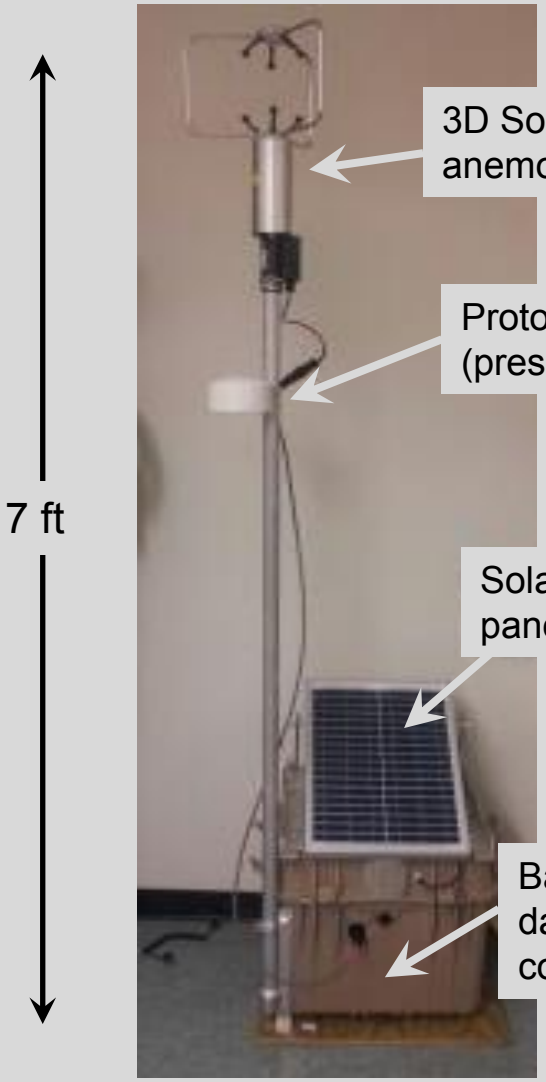




Sensor Networks In-plant and Along Facility Fence Line



Portable/Solar Powered System



Drop-in-place Sensor Pod (SPod)

Inside of battery box

EPA Regional Methods Projects

- Collaborative evaluation/validation of low-cost volatile organic compound passive sampling methods (FY13 Project)
  - Multi-Region Project (R8 lead, R3, R5, and R6)

- Field evaluation of lower cost, continuous measurement of air pollutants (FY 14 Project)
  - Multi-Region Project (R4 lead, R1, R5, and R8)
  - Community Air Sensor Network (CAIRSENSE) Project

DISCOVER-AQ

- How can ambient air quality be reliably informed using non-traditional approaches, such as satellite remote sensing?

- Collaboration with NASA to explore temporal and spatial relationships between column and surface measurements at locations with differing air quality.
  - *Maryland, July 2011*
  - *California, January 2013*
  - *Texas, September 2013*
  - *Colorado, July 2014*

- Unprecedented 3-dimensional characterization of pollutants and precursors.
  - Result is an expansive database of satellite, aircraft, ground-based measurements for gaseous air pollutants (i.e., NO_2, NO_y, O_3, …) and particulate matter over urban areas with persistent air quality problems – final data in publicly accessible archive within 6 months.

- EPA research is being use to Inform:
  - NAAQS compliance monitoring methods
    - Federal Reference (FRM) and Equivalent (FEM) methods
  - Value of new monitoring approaches (in-situ, small sensors, and remote sensing)
  - Evaluation and improvements for Community Multiscale Air Quality (CMAQ) fine-scale modeling

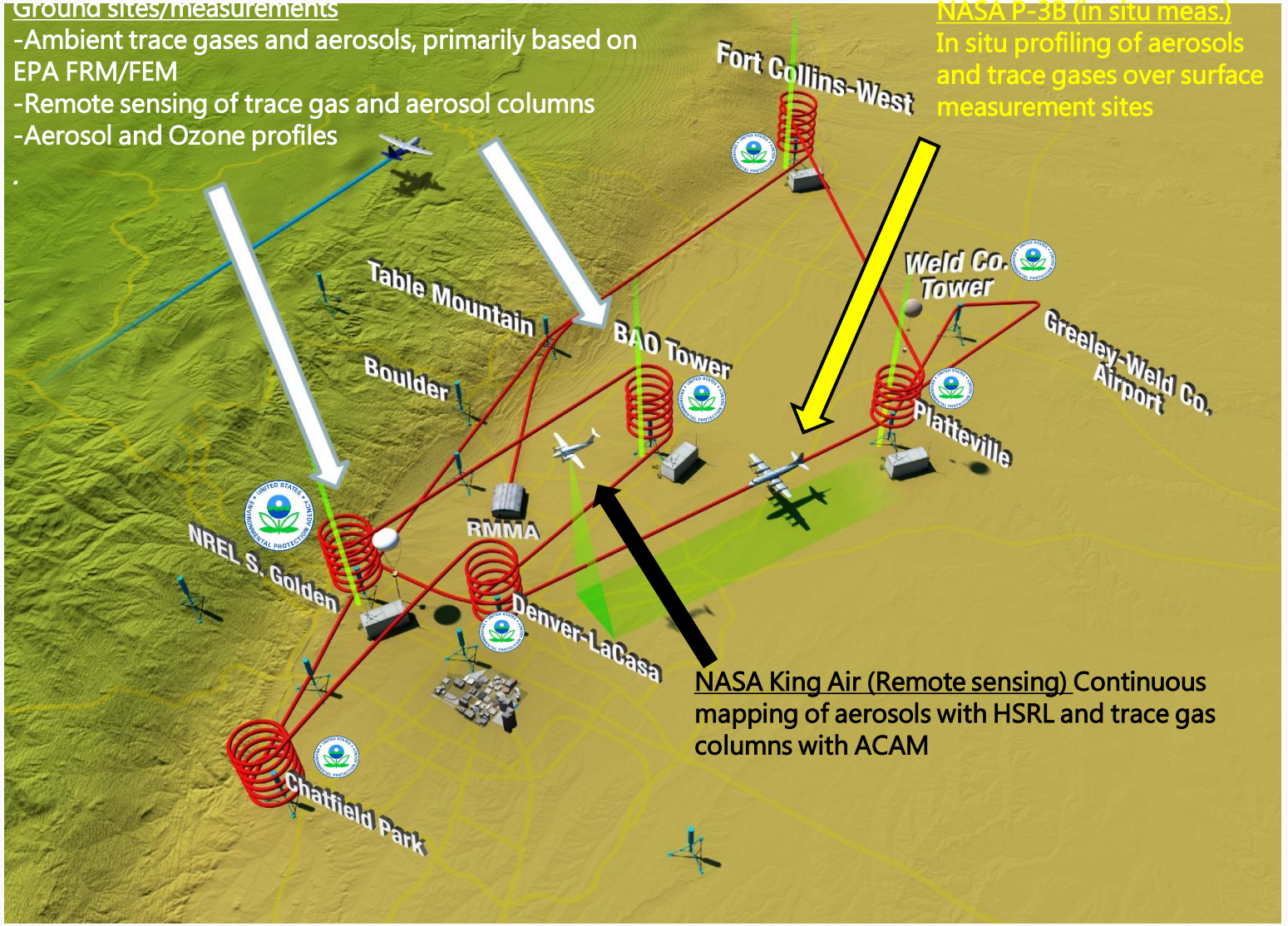
ORD's DISCOVER-AQ Field Campaign Objectives

	DISCOVER-AQ Field Mission Locations and Timeframes			
	Baltimore, MD July 2011	San Joaquin Valley, CA Jan-Feb, 2013	Houston, TX Sep 2013	Denver, CO Jul-Aug, 2014
Federal Reference Methods (FRM)/Federal Equivalent Methods (FEM)				
Ozone – ambient evaluation of new FRM for NAAQS	■		■	■
NO_2 – ambient evaluation of new direct measurement methods for FEM	■	■	■	■
NO_y – ambient evaluation of method compared to NOx for NO_x/SO_x secondary standard	■	■		■
Remote Sensing Methods				
Evaluation of column-to-surface measurements (NO_2, AOD/$PM_{2.5}$)	■	■	■	■
Evaluation of aerosol lidar (ceilometer) for continuous mixing heights in support of PAMS				■
Small Sensor Technology				
Evaluation with collocated FRM/FEM measurements			■	■
Understand vertical distribution of pollutants				■
Citizen science and educational outreach activities			■	■

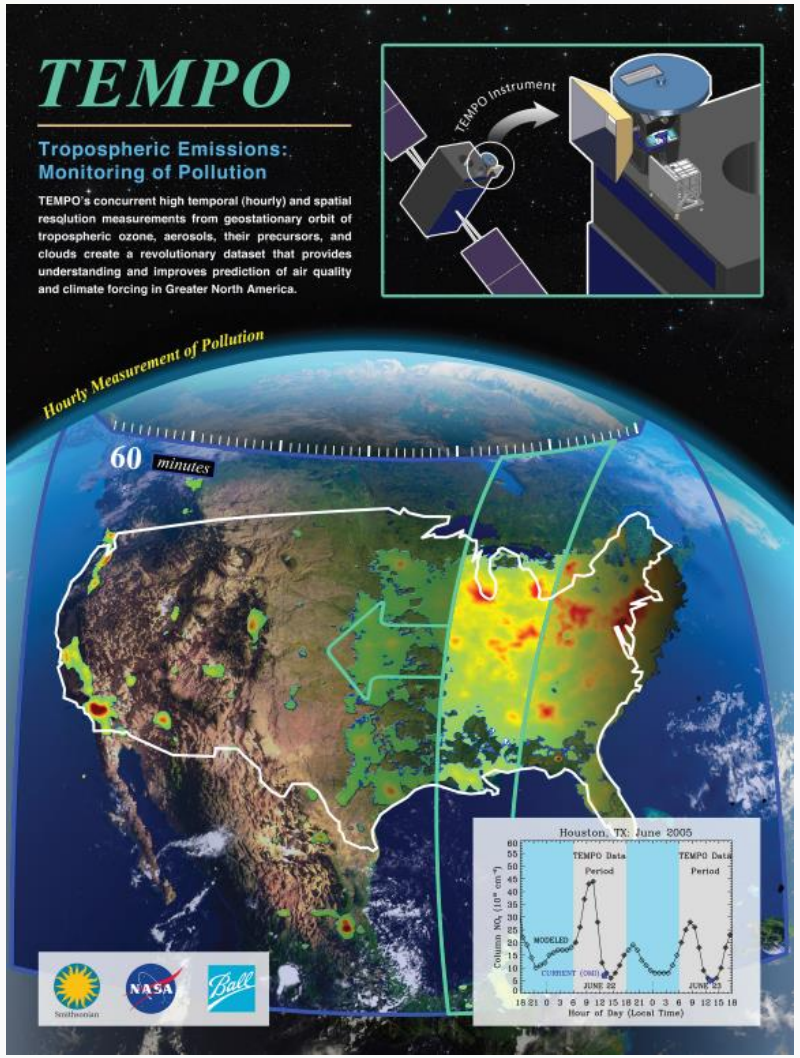
Denver, CO Observation Strategy (July-August 2014)

Systematic and concurrent observation of column-integrated, surface, and vertically-resolved distributions of aerosols and trace gases relevant to air quality as they evolve throughout the day.

Three major observational components:



From DISCOVER-AQ to TEMPO



Selected Nov. 2012 as NASA's first Earth Venture Instrument

- Instrument delivery September 2017, with expected ~2018 launch

Provides hourly daylight observations to capture rapidly varying emissions & chemistry important for air quality

- UV/visible grating spectrometer to measure key elements in tropospheric ozone and aerosol pollution
- North American component of a constellation for air quality observations

TEMPO data and potential application areas within EPA and the Air Quality Management Community

- Emissions Inventories (improve or develop new methods, including mobile sources and area sources such as soil NOx)
- Inform air quality model development and evaluation
- Evaluation of impact of short term climate forcers (ozone, chemically produced aerosols) and climate-chemistry connections
- Data on smaller spatial scales better supports AQ assessment and planning activities: Source attribution, Exceptional Event Evaluations (Wildfires and Strat. Intrusions) and Trends
- Intercontinental transport of air pollution (HTAP and other activities

Acknowledgements and Key Points of Contact

- Melinda Beaver (DISCOVER-AQ)
- Rachelle Duval (Community Sensor Applications, DISCOVER-AQ)
- Gayle Hagler (Village Green, Mobile Systems)
- Amanda Kaufman (Air Sensor Citizen Science Toolbox)
- Russell Long (DISCOVER-AQ)
- Eben Thoma (Fenceline Monitoring, SPod, Mobile Systems)
- Jim Szykman (DISCOVER-AQ, Remote Sensing)
- Ron Williams (Sensor Evaluation, Village Green, Air Sensor Citizen Science Toolbox)

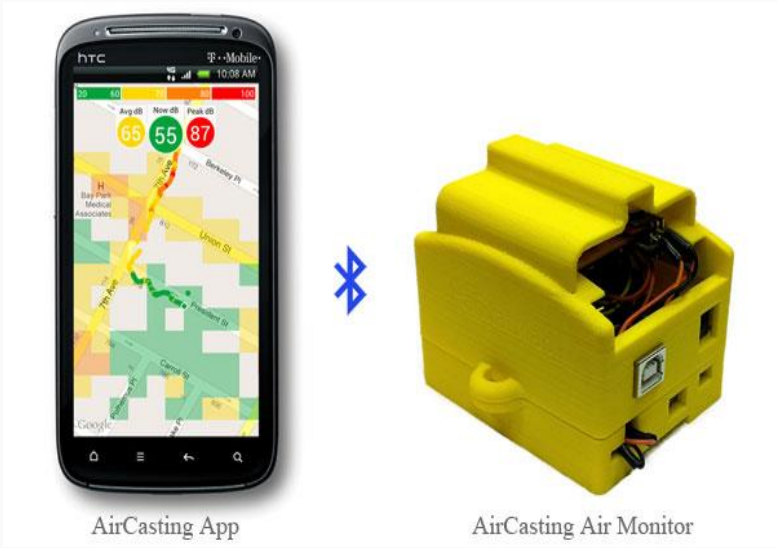
For additional information: Tim Watkins (watkins.tim@epa.gov)

Air Sensors and Potential Uses

Clean Air Act Advisory Committee
October 29, 2014

Defining “Sensor”

- Technologies that include small portable, low-cost, real time devices



Defining "Sensor"

Tier	Cost Range (instrument only)	Anticipated User
Tier V (most sophisticated)	$10 – 50 K	Regulators (supplement existing monitoring – ambient and source)
Tier IV	$5 – 10 K	Regulators (supplement existing monitoring – ambient and source)
Tier III	$2 – 5 K	Community groups and regulators (supplement existing monitoring- ambient and source)
Tier II	$100 – 2 K	Community groups
Tier I (more limited)	Less than $100	Citizens (education and personal health purposes)

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

State of the Science

- **FEM Applications**
  - AQMesh (measuring O_3, NO_2, SO_2, CO, and NO) applied for federal equivalent method (FEM) status in May 2014 ($10K)
  - 2B O_3 and Thermo 1500 PM expected to apply ($5K-$10K)
- **O_3 and NO_2 sensors**
  - Lab testing results in Sensor Evaluation Report (May 2014)
    - Good agreement between low cost ($500-$1000) sensors and FEM instruments
    - Issues with lifespan of sensor and interferents

    Electrochemical analyzers an alternative option to measure NO_x and CO in RICE rules ($5K-$15K)
- **Particulate Matter ($PM_{2.5}$ & PM_{10}) sensors**
  - Current lab and field performance evaluations in RTP, NC
  - Fair agreement between low cost ($300) sensors and FRM instruments
    - Temperature and relative humidity influencing factors




State of the Science

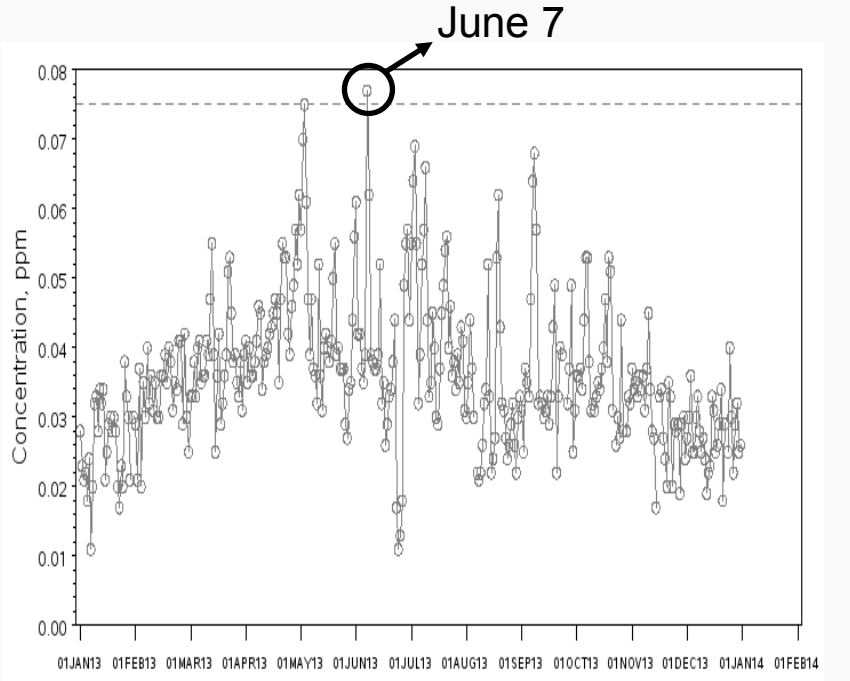
- **CO and SO_2**
  - NASA deployed AQMesh technology to measure O_3, NO, NO_2, **CO, and SO_2** in summer 2014
- **Lead**
  - No known advances for sensors to measure lead
- **VOC/Air Toxics**
  - Wide range of sensitivities/speciation challenges
  - ORD considering the purchase of a "FROG" - $25K GC instrument
- **NH_3 and Methane**
  - Not a lot of commercial movement in NH_3 sensors, better sensitivity needed
  - $30M DOE funding opportunity for methane observation networks with innovative technology to obtain reductions (closed June 2014)
  - Environmental Defense Fund – Methane Detectors Challenge for oil and gas industry

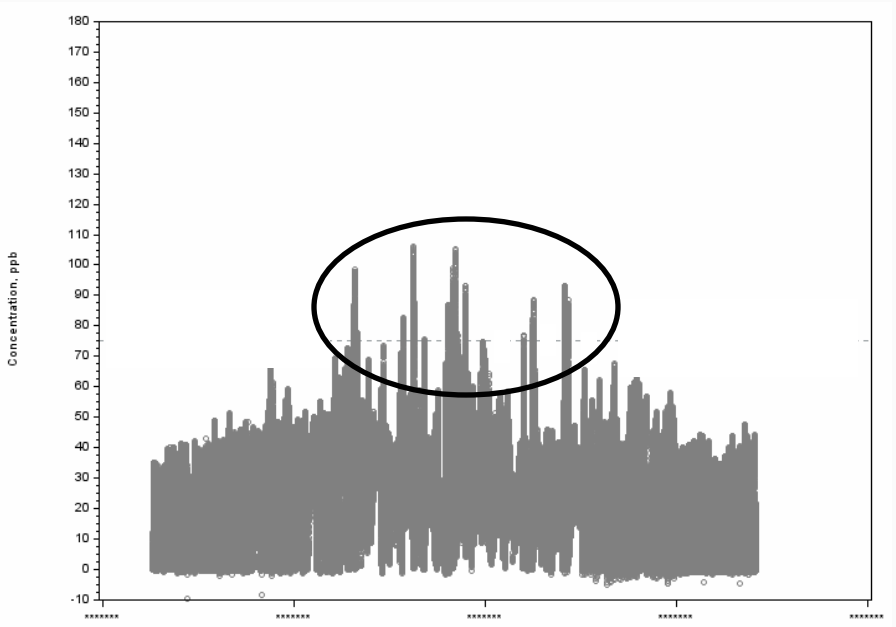
Data Application

- Informing Network Design
  - Locate monitor in high concentration areas
- Provide insight into near road concentrations (NO_2)
- Personal Exposure Monitoring
- Risk assessment
  - Characterization & Modeling
  - Fenceline/Community Monitoring
- Permitting
  - Help understand background pollutant concentrations

Brainstorming Sensor Messaging

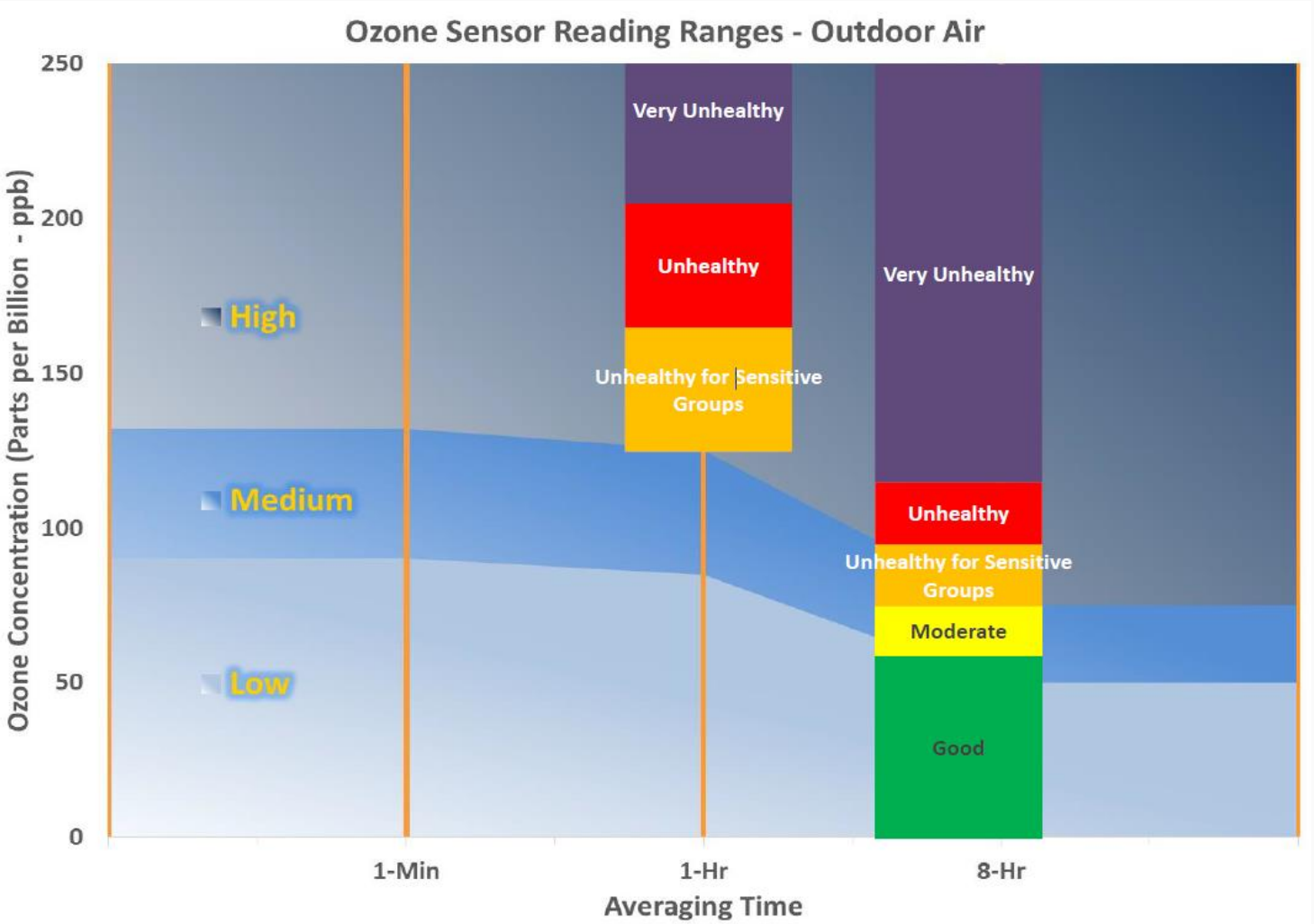
Profiles of Max 8-Hour and 1-Minute Ozone Concentrations
Livermore California (2013)





Brainstorming Sensor Messaging

NCEA, HEID, PACS and AQAD Collaborative Effort



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 traditional monitoring approaches

Challenges (Opportunities)

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