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RAQM-5 Hong Kong Forum

Opportunities in the Greater Bay Area – Regional Collaboration & Exposure Management Breakthrough

RAQM5 Hong Kong Forum
November 20, 2017

US EPA perspective and research on emerging air sensor technology

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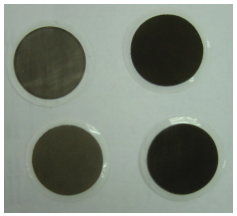
What we are used to

Regulatory monitoring networks are commonly:

- Limited in geographic coverage
- Well-maintained equipment, quality assured data
- Temporally limited for some parameters (PM species)
- Highly accurate – "the truth"

FRM

$PM_{2.5}$: integrated filters



24 hr average mass concentration

FEM

$PM_{2.5}$: continuous monitoring

Continuous measurements: hourly averages

Measurement challenges

Measuring in areas with limited infrastructure

Measuring fugitive emissions over large areas

Measuring at a neighborhood or microenvironment scale

Personal exposure & Indoors

Measurement challenges

Air sensor technology is here, and quickly increasing in use.

- Significant new players to the field
- Emerging diversity of approaches (mobile monitoring, sensor networks, crowd-sourcing)
- Exponential increase in data
- Data quality is uncertain

Received on 8/23/2017

MINNESOTA POLLUTION CONTROL AGENCY

MPCA to place new air quality sensors in every Mpls/St. Paul ZIP code - Open houses scheduled for residents to provide input on locations

WEATHER UNDERGROUND | PurpleAir.org

We Need Your Help to Fight Air Pollution

eds your help to gather air pollution data. When you install an air pollution monitor, you protect yourself and others in your community from dirty air.

Buy the Best Air Pollution Monitor

Learn More

Why We Recommend PurpleAir

Air pollution experts affiliated with Weather Underground have evaluated several air pollution monitoring devices and have determined that the PurpleAir PA-II is the best device for most people to track the deadliest type of air pollution.

Buy a PurpleAir Sensor

Emerging technologies

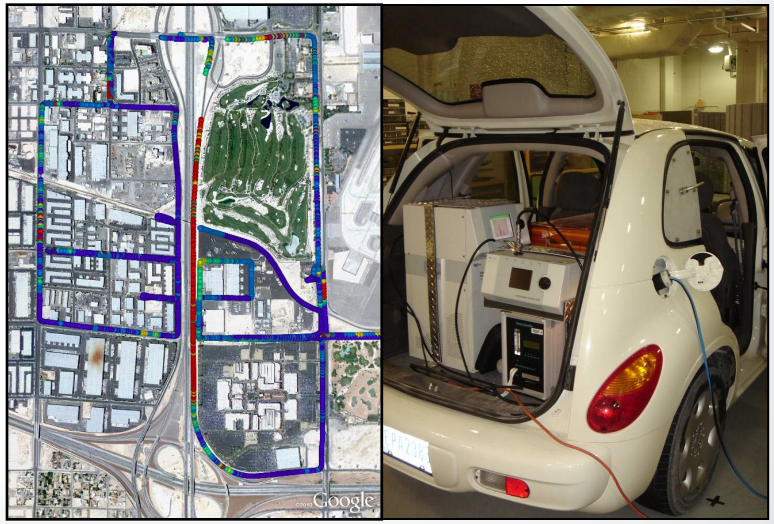
Emerging monitoring data includes:

Higher-end <u>mobile</u> platforms

http://apte.caee.utexas.edu/google-air-mapping/

Spatial coverage down to 10s of meters

"Snap shot" monitoring – any given location may only be sampled for seconds to minutes



Traditionally been conducted by professional researchers – expanding now to include commercial applications

Emerging technologies

Now, in larger number with higher measurement uncertainty:

Mid-cost to low-cost mobile sensor packages

Sensor systems added to: trams, buses, postal delivery vehicles, bicyclists, pedestrians, aerial systems

MINNEAPOLIS

Bicyclists strap on monitors to measure Twin Cities air quality

Emerging technologies

Emerging monitoring data includes:

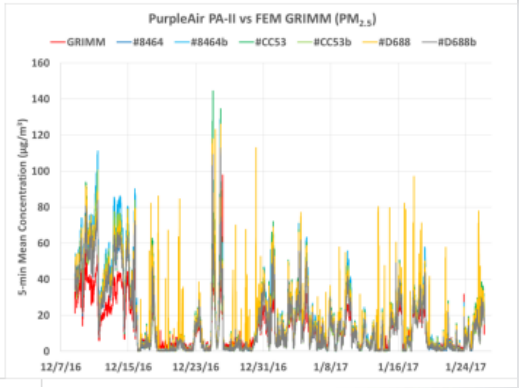
Low cost sensor networks

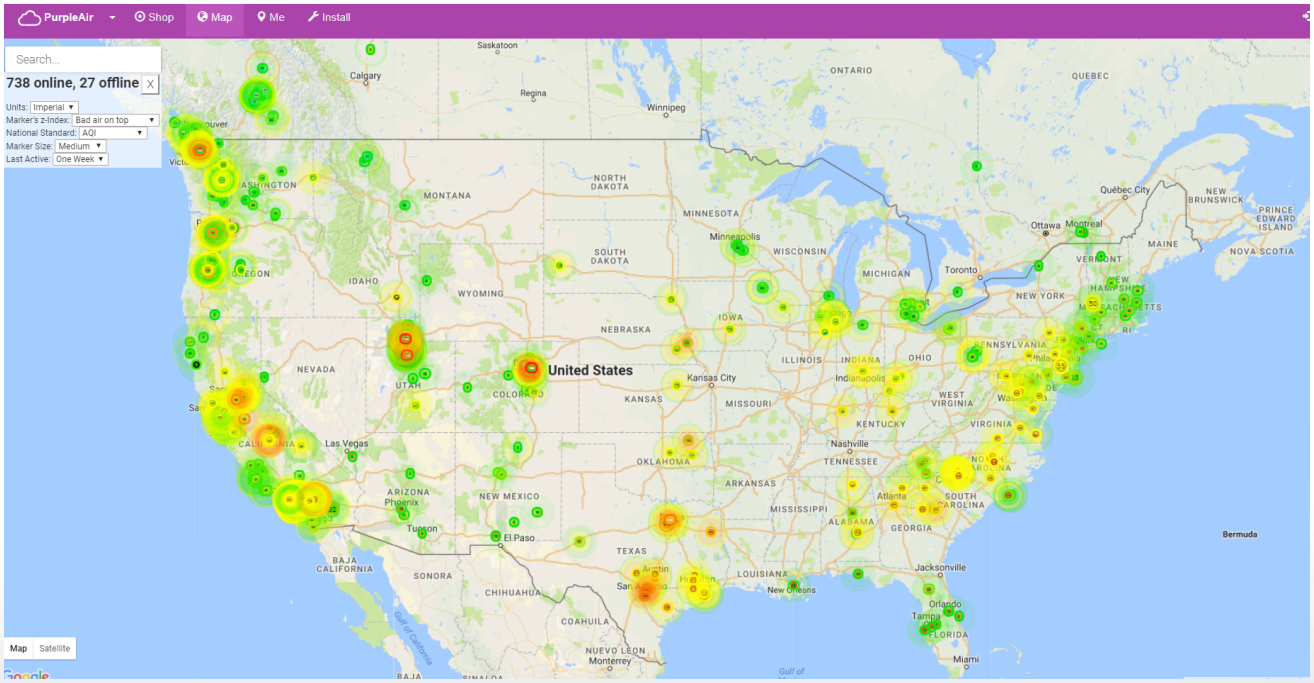
~$200 $PM_{2.5}$ sensor
- AQ-SPEC evaluation (www.aqmd.gov/aq-spec)

$PM_{1.0}$ R^2 ~ 0.96 to 0.98

$PM_{2.5}$ R^2 ~ 0.93 to 0.97

PM_{10} R^2 ~ 0.66 to 0.70





purpleair.com – on 11/3/2017

Emerging technologies

Quickly-moving technology: Sensors as consumer products

Designed to give real-time feedback (seconds)

May include measurements not usually incorporated into health-based standards(e.g., total VOCs)

Some developers are creating their own air quality indices.

ORD activities

- EPA activities involve:
  - Air sensor market research and technology evaluation
  - Development and application of custom sensor systems for specific research studies
  - Development of sensor data analytics, visualization, and real-time quality assurance measures
  - Communications / interpretation of sensor data

Technology evaluation

- Air sensor market research and technology evaluation

Example: Community Air Sensor Network (CAIRSENSE) project: Atlanta, GA and Denver, CO

Atmos. Meas. Tech., 9, 5281–5292, 2016
www.atmos-meas-tech.net/9/5281/2016/
doi:10.5194/amt-9-5281-2016

Atmospheric Measurement Techniques
Open Access
EGU

Community Air Sensor Network (CAIRSENSE) project: evaluation of low-cost sensor performance in a suburban environment in the southeastern United States

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Revised: 26 September 2016 – Accepted: 8 October 2016 – Published: 1 November 2016

Co-location of low-cost sensors at a the South Dekalb NCore site; pilot four-node sensor network

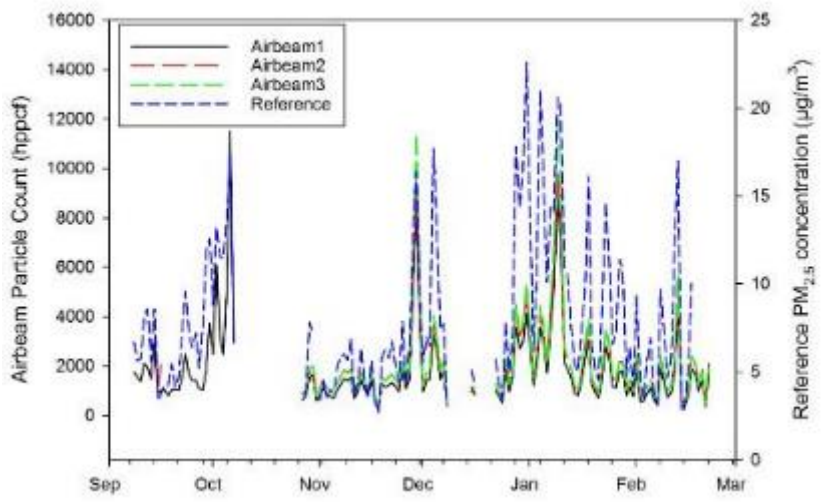
Figure 1. CAIRSENSE field equipment, including **(a)** SAFT instrument enclosure, (**b** and **c**) solar-powered WSN node, **(d)** interior of SAFT instrument shelter, and **(e)** WSN node utilizing 120 V (nominal) AC electricity.

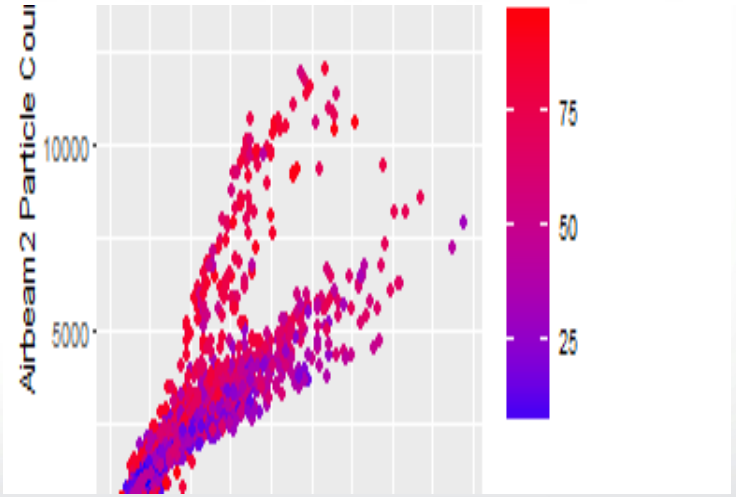
Ongoing testing of sensors at EPA-RTP campus – laboratory and field tests

Technology evaluation

- Sensor co-location test example: AirBeam

Image: aircasting.org





Feinberg et al., in preparation

Custom technology development

Village Green Project

Most common measures:
$PM_{2.5}$
Ozone
NO_2
VOCs
Black carbon

Drop-in-place sensor pods

Aerial systems

Mobile sensors

Fenceline monitoring

Wildland Fire Sensors Challenge

Grants to universities – air sensors and communities

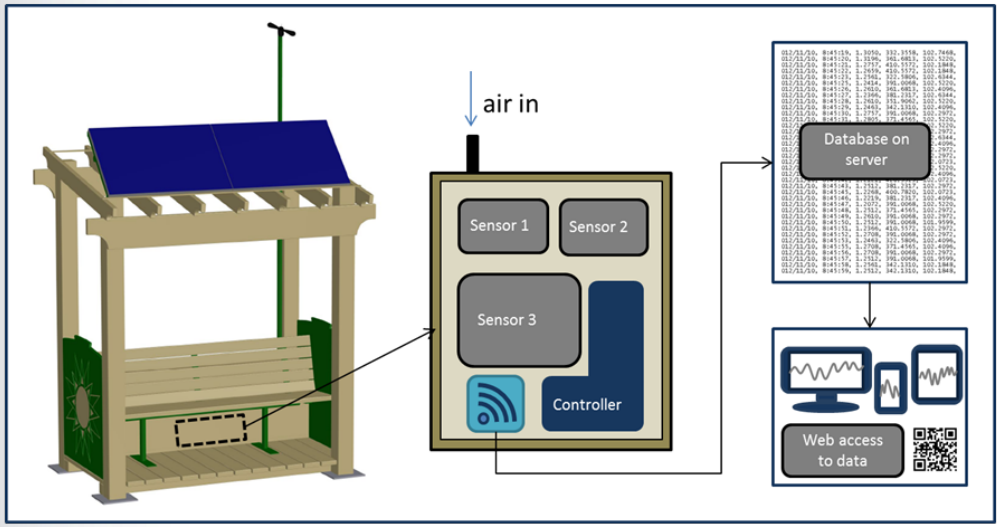
Six funded grants:

1. Putting Next Generation Sensors and Scientists in practice to reduce wood smoke in a highly impacted, multicultural rural setting (NextGenSS)
2. Monitoring the Air in Our Community: Engaging Citizens in Research
3. Shared Air/Shared Action (SA^2): Community Empowerment through Low-Cost Air Pollution Monitoring
4. Hawai'i Island Volcanic Smog Sensor Network (HI-Vog)
5. Engage, Educate, and Empower California Communities on the Use and Applications of Low-Cost Air Monitoring Sensors
6. Democratization of Measurement and Modeling Tools for Community Action on Air Quality, and Improved Spatial Resolution of Air Pollutant Concentrations

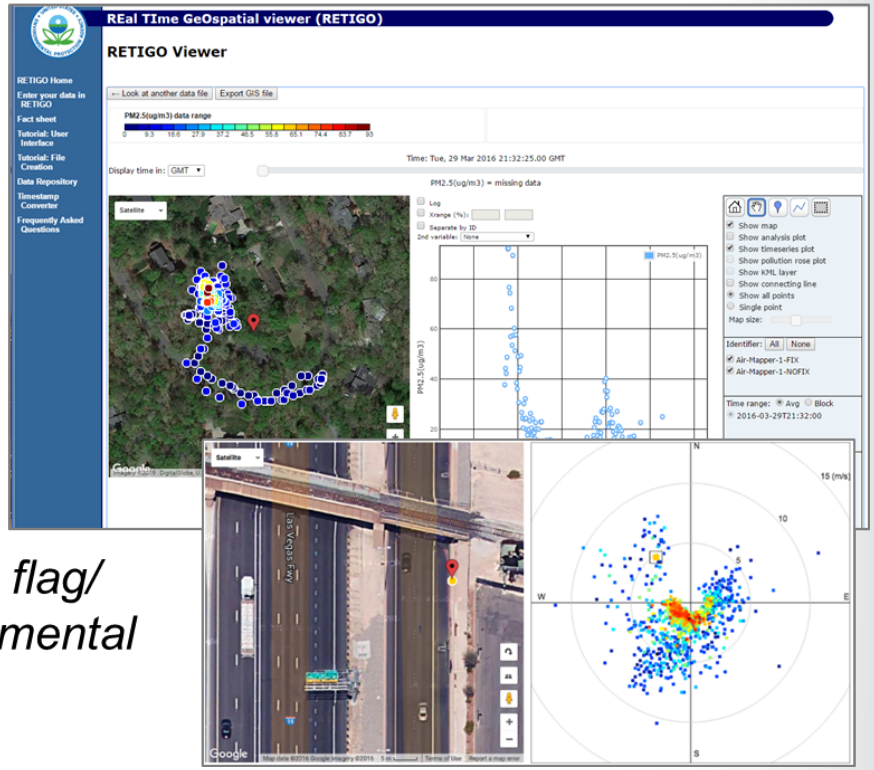
https://www.epa.gov/air-research/air-pollution-monitoring-communities-grants

Data analytics, visualization, QA

Quality checks in real-time, posted at airnow.gov/villagegreen



RETIGO: data visualization tool (epa.gov/retigo)



Multiple projects: Development of algorithms to flag/ correct for measurement artifacts (drift, environmental conditions, interferences)

Data analytics, visualization, QA

- Sensor data analytics, visualization, and real-time QA

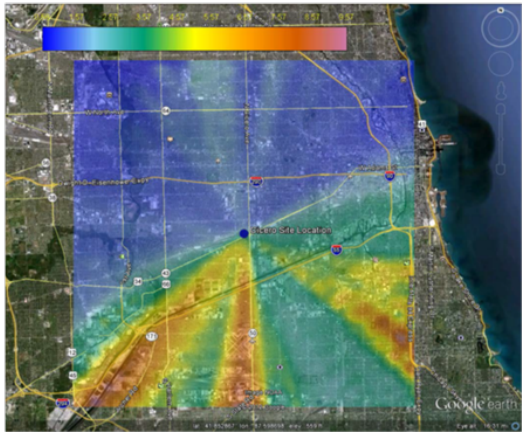
Coupling wind data and sensors to understand source location and type:

High time resolution (e.g., 1 min) observations of wind speed/direction and concentration

↓

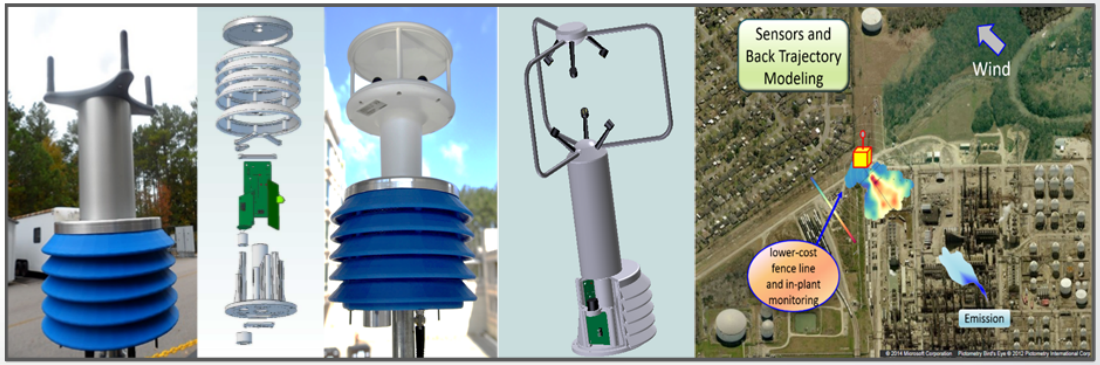
Inverse, local-scale modeling to estimate source locations and strength

→



Example: application to a regulatory-grade monitoring site in center of graphic, separating SO_2 contributions from rail yard, air port, and power plant.
Reference: Cicero Rail Yard Study, EPA /600/R/12/621 February 2014

Example: Fenceline systems plus inverse modeling to estimate locations of leaks in a major industrial facility



Emerging issues in sensor data sets

Mobile monitoring – how do you combine data collected **over different times and locations**?

Sensor networks – what are defensible strategies to adjust data or screen failing sensors?

- Nonlinear agreement with reference monitors?
- Machine learning? What is appropriate to include?
- "Virtual calibration" – adjusting sensor data at one location compared to comparison between sites?

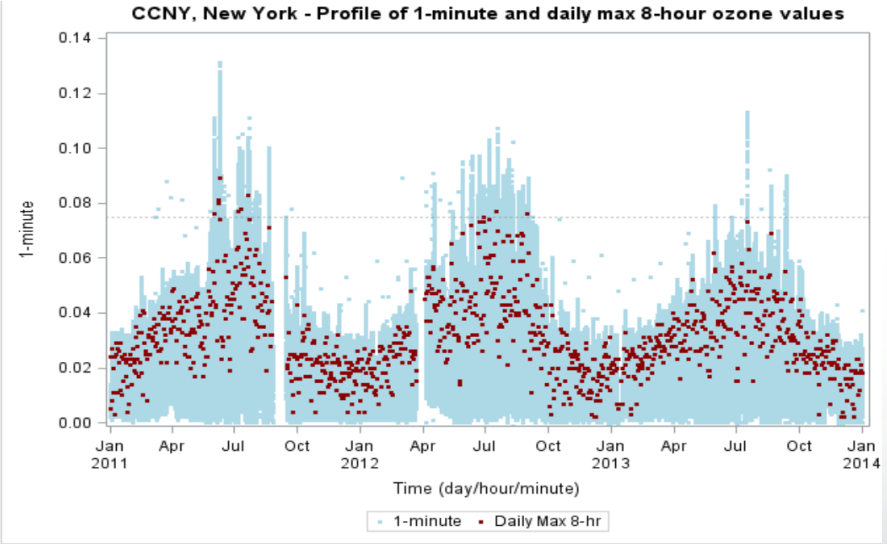
Data assimilation

- What are appropriate ways to combine data of different quality levels, different time bases, different vertical resolution?
- A new effort at EPA ORD – **"Big data on Microenvironmental Air Pollution (BigMAP)"** – undertaking exploratory work on assimilation of a diversity of observational data and models

Sensor data communications

The big question: How do we effectively communicate air quality conditions for sensor data?

Issues:
Timescale of measurement
Data quality
Geographic representativeness
Individual pollutant concentration vs. AQI



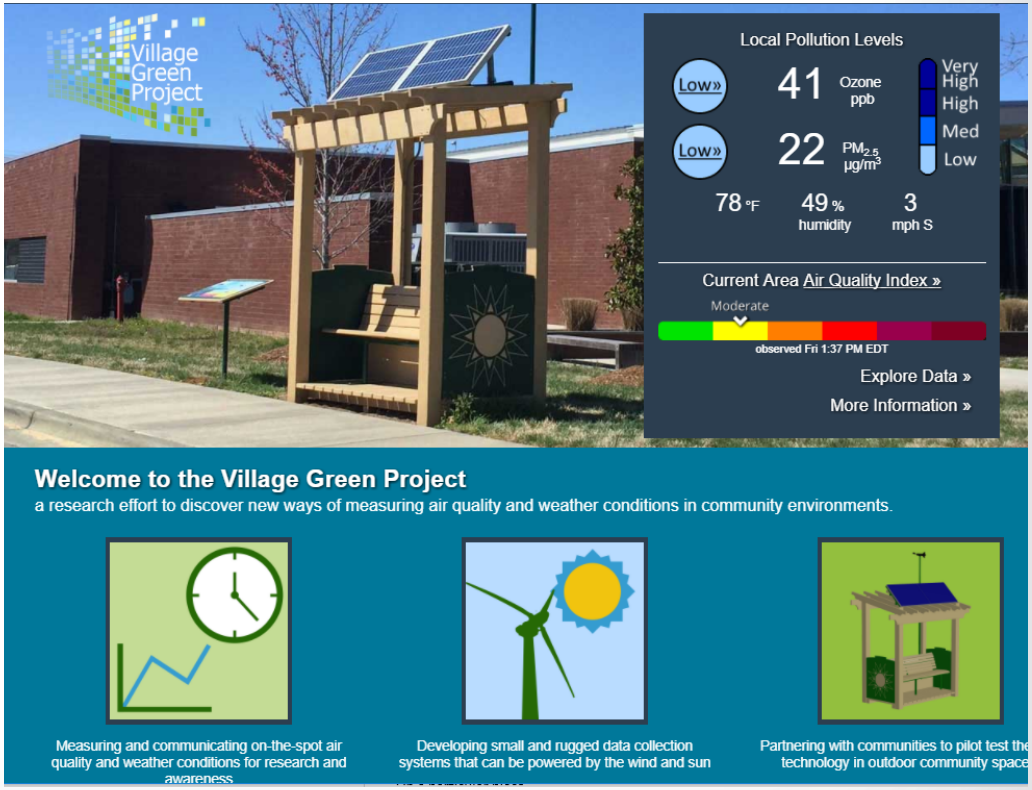
e.g., 1 minute versus daily max 8-hour ozone

Sensor data communications

Pilot version **1-Minute Ozone Readings** ***Not for regulatory purposes***	
Low **0-59 ppb**	Enjoy your outdoor activities.
Medium **60-89 ppb**	If medium readings continue, use the Air Quality Index to plan outdoor activities
High **90-149 ppb**	If high readings continue, consider adjusting outdoor activities, especially if you are sensitive to ozone. Check the Air Quality Index to find out.
Very High **≥150 ppb**	If high readings continue, consider adjusting outdoor activities. Check the Air Quality Index to find out. Very high readings may mean the sensor is not working properly.
🔧	Sensor may be offline. Check the Air Quality Index.

Pilot version **1-minute particle pollution ($PM_{2.5}$) readings** ***Not for regulatory purposes***	
Low **0-29 µg/m3**	Enjoy your outdoor activities.
Medium **30-69 µg/m3**	If medium readings continue (for an hour or more), use the Air Quality Index to plan outdoor activities.
High **70 - 499 µg/m3**	You may be near a source of particle pollution like dust, smoke or exhaust. Check the Air Quality Index to plan outdoor activities.
Very High **≥500 µg/m3**	You may be near a source of particle pollution like dust, smoke or exhaust. Check the Air Quality Index to find out if you should adjust outdoor activities. Very high readings may mean the sensor is not working properly.
🔧	Sensor may be offline. Check the Air Quality Index.

Sensor Scale: messaging of short-term air quality readings



Recent events in the USA

Federal and state government:

Currently referred to the Subcommittee on Environment:
H.R.1355 - Crowd Sourcing of Environmental Data Act of 2017: "To amend the Clean Air Act to give States the option of monitoring covered criteria air pollutants in designated areas by greatly increasing the number of air quality sensors in exchange for greater regulatory flexibility in the methods of monitoring, and for other purposes."

Law Passed In California
AB 617: "The bill would require the state board to select, based on the monitoring plan, the highest priority locations in the state for the deployment of community air monitoring systems. The bill would require an air district containing a selected location, by July 1, 2019, to deploy a system in the selected location."

Impact

Ultimately, air sensor technology has promise to result in reduced pollution exposure and improved public health through:

- Identification and mitigation of unintended source emissions
- More extensive data supporting public health communication
- Improved knowledge on exposure to air pollution at a community and individual level.

Questions?

- Some useful websites:
  - EPA Air Sensor Toolbox (sensor testing results, citizen science guidance, etc.): https://www.epa.gov/air-research/air-sensor-toolbox-citizen-scientists
  - AQ-SPEC site: http://www.aqmd.gov/aq-spec

Contacts for specific projects

EPA research projects:

- Sensor data messaging: Kristen Benedict
- Fenceline monitoring systems: Eben Thoma
- Black carbon sensor: Amara Holder
- Spod Sensor: Eben Thoma
- Village Green Project: Ron Williams, Sue Kimbrough
- RETIGO: Gayle Hagler
- Inverse modeling: Gayle Hagler, Eben Thoma, Neil Feinberg
- Sensor evaluation testing: Ron Williams, Teri Conner, Andrea Clements
- BigMAP: Tim Barzyk

Custom technology development

- Custom technology development

Through a competitive contract, worked with manufacturer to develop a low maintenance, low power, rugged BC option for outdoor monitoring:

Small size (7.9"x 4"x2.75") weatherized case