Projects with Portable Air Sensors

Board of Directors

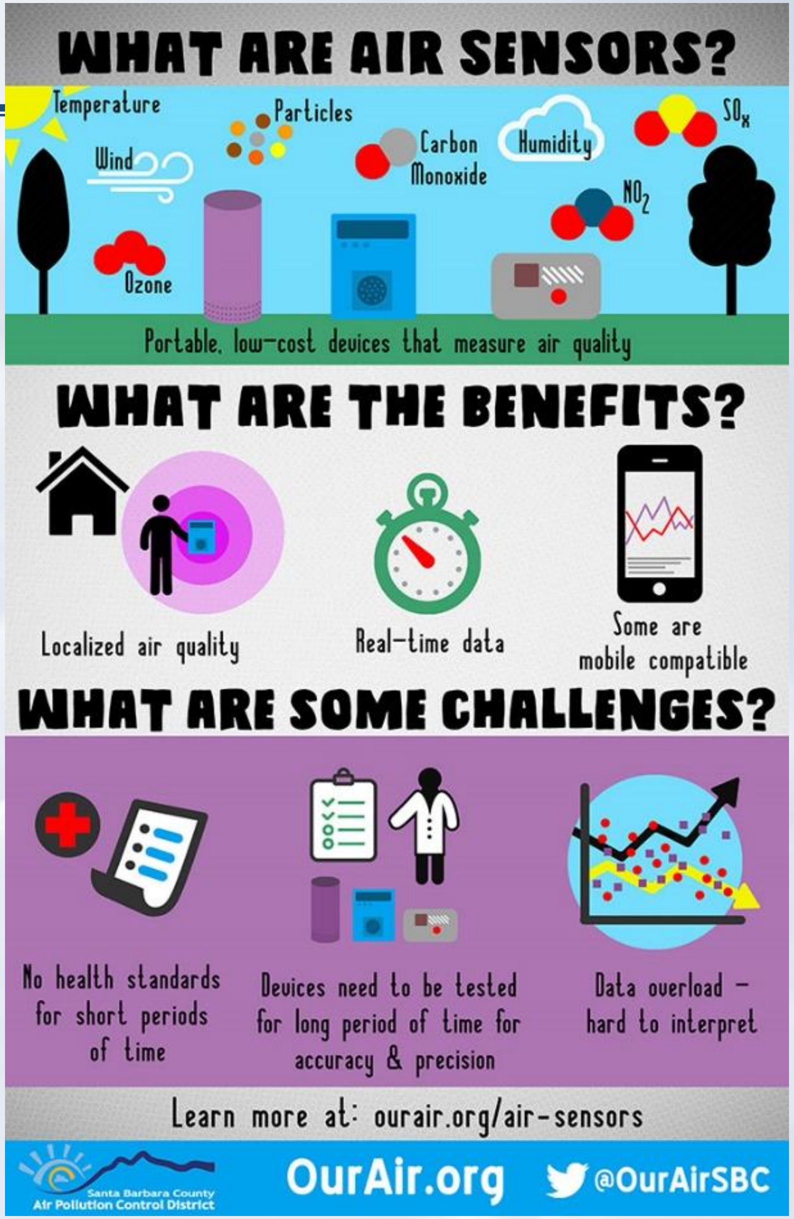
Santa Barbara County

Air Pollution Control District

Our Mission: To protect the people and the environment
of Santa Barbara County from the effects of air pollution.

Aeron Arlin Genet
Director / APCO

Mary Byrd, Community Programs Supervisor
With Co-Presenters
January 18, 2018

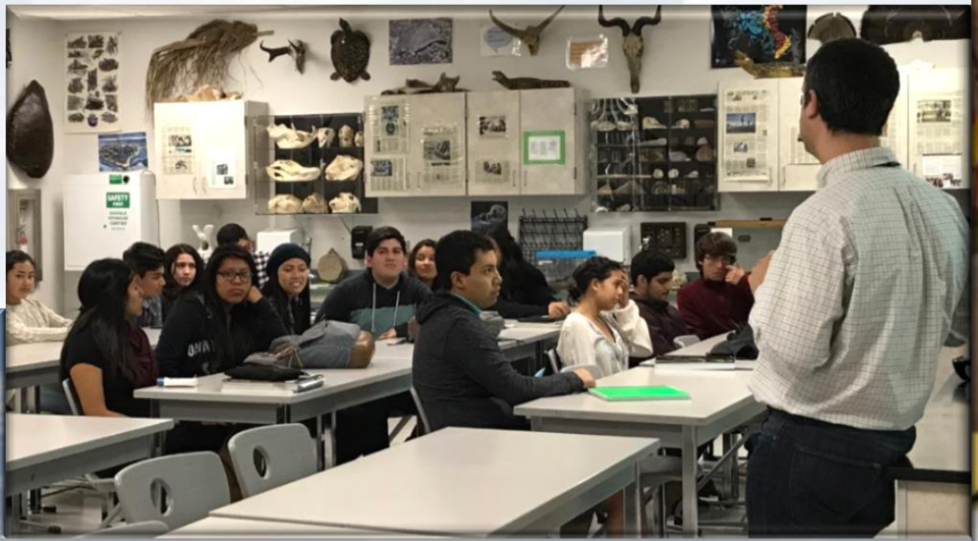


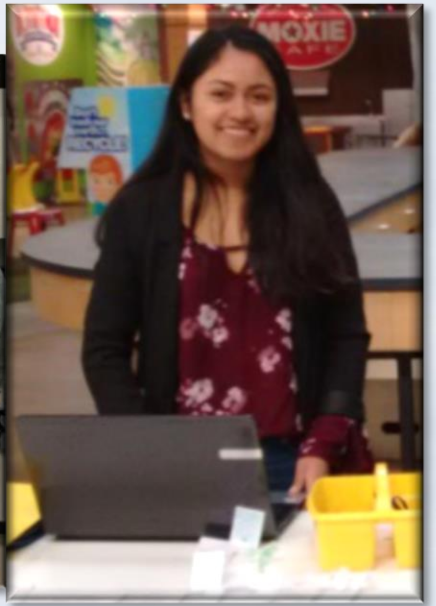
Santa Barbara County
Air Pollution Control District

Overview

- District's experience
- Jennifer Hernandez-Mora: Comparing 2 particle sensors
- Riccardo Magni: Sensors in the classroom
- Dr. Polidori: South Coast Air Quality Management District's sensors programs

AQ-SPEC





District Approach

- Gain experience with sensors data
  - Consult with experts
  - Compare against federal reference method equipment
  - Identify optimal uses
- Explore educational opportunities

Santa Barbara County
Air Pollution Control District

Cuyama Valley High School Study

- District coordinated study by Sonoma Technology
  - AirBeam ($250) and Alphasense ($500) particle sensors
  - Compared against federal reference method equipment
  - Classroom presentation

AirBeam

Alphasense

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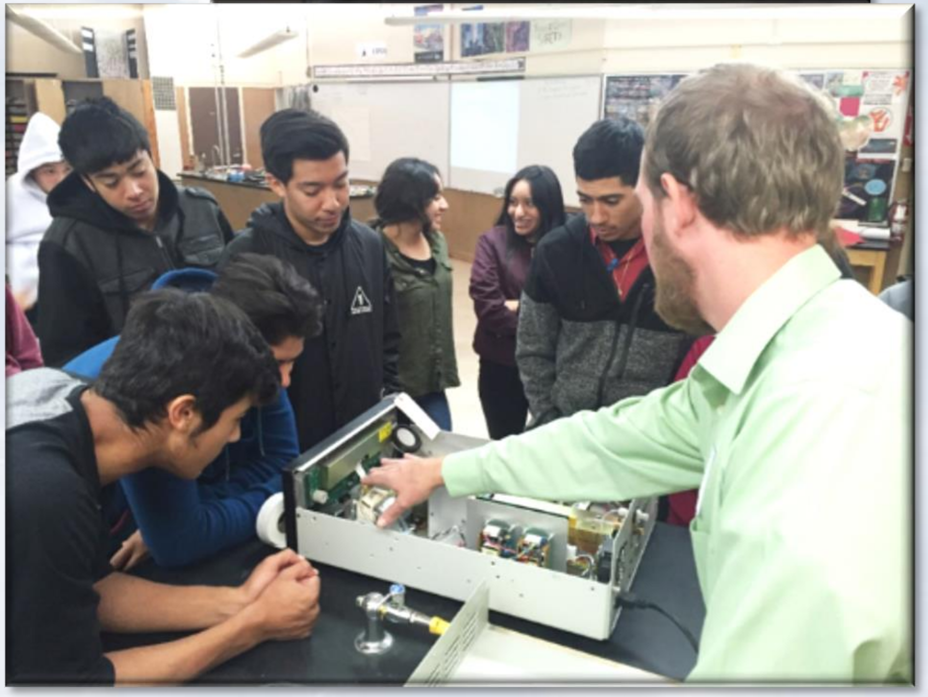
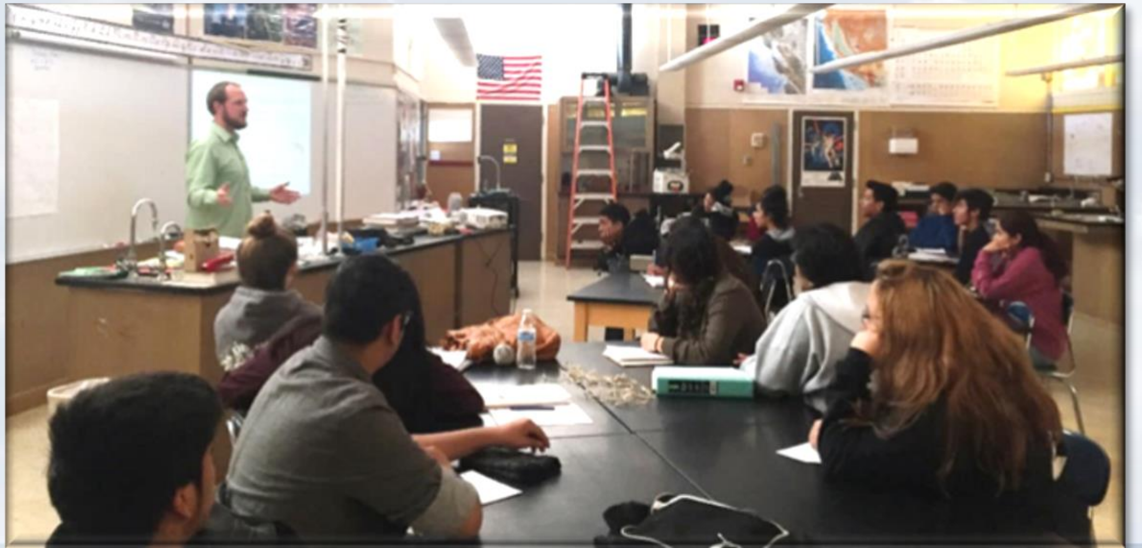
District Experience

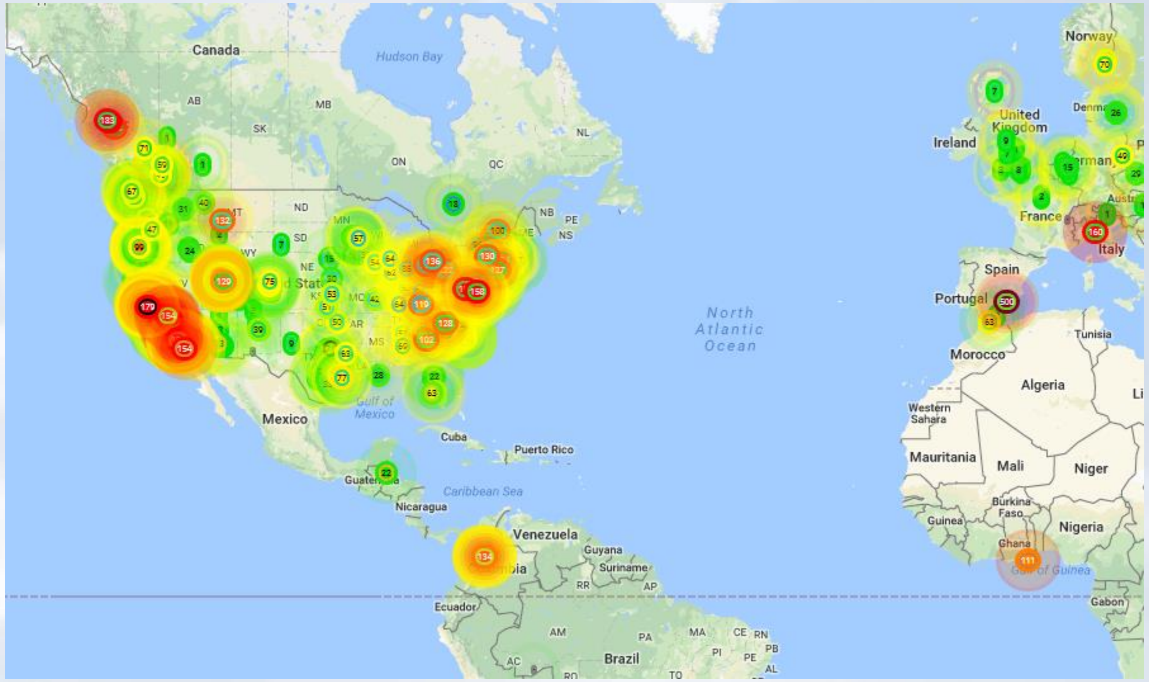
- Results from New Cuyama
  - Sensors can detect high PM episodes
  - Useful as educational tool
  - More experience needed





PurpleAir Sensors

- Low-cost sensor ($230)
- Uses a fan to draw air past a laser, causing reflections from any particles in the air
- Measures fine particles (PM2.5), also PM1.0 and PM10



- Reports data to public website along with Air Quality Index rating

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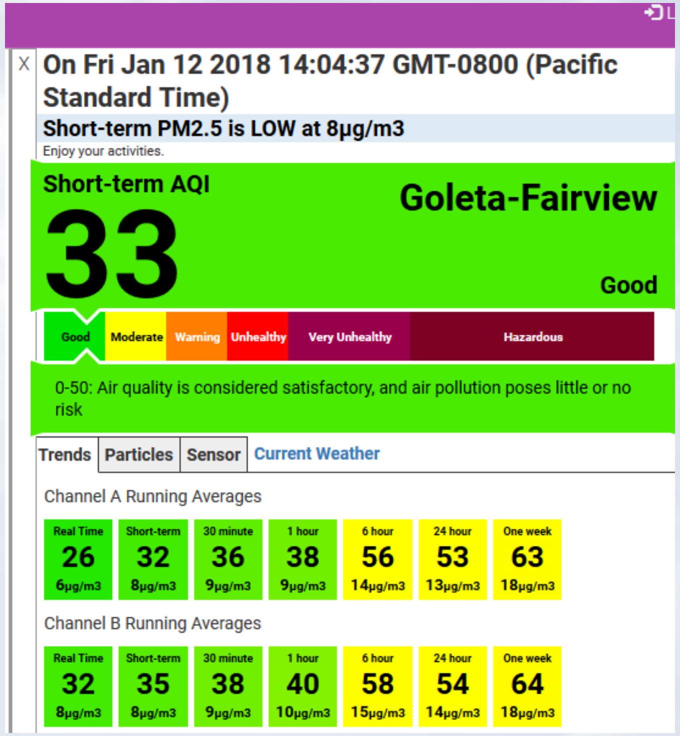
PurpleAir Sensors

- Evaluating data
  - Sensor at Goleta monitoring station compared against federal reference method equipment
    - Followed trend, BUT sensor had much higher readings during Thomas Fire
    - Readings closer during non-fire conditions
  - More evaluations ongoing
- Educational projects



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Early Takeaways

- Variable accuracy individually
- Many sensors taken together can offer higher accuracy
- Useful in detecting trends
- Need to provide public with tools for understanding levels that don't match the official monitoring results
- Need to continue to get experience, consult with experts
- Educational tool

Contact Information

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Next: Jennifer Hernandez-Mora

Santa Barbara County
Air Pollution Control District

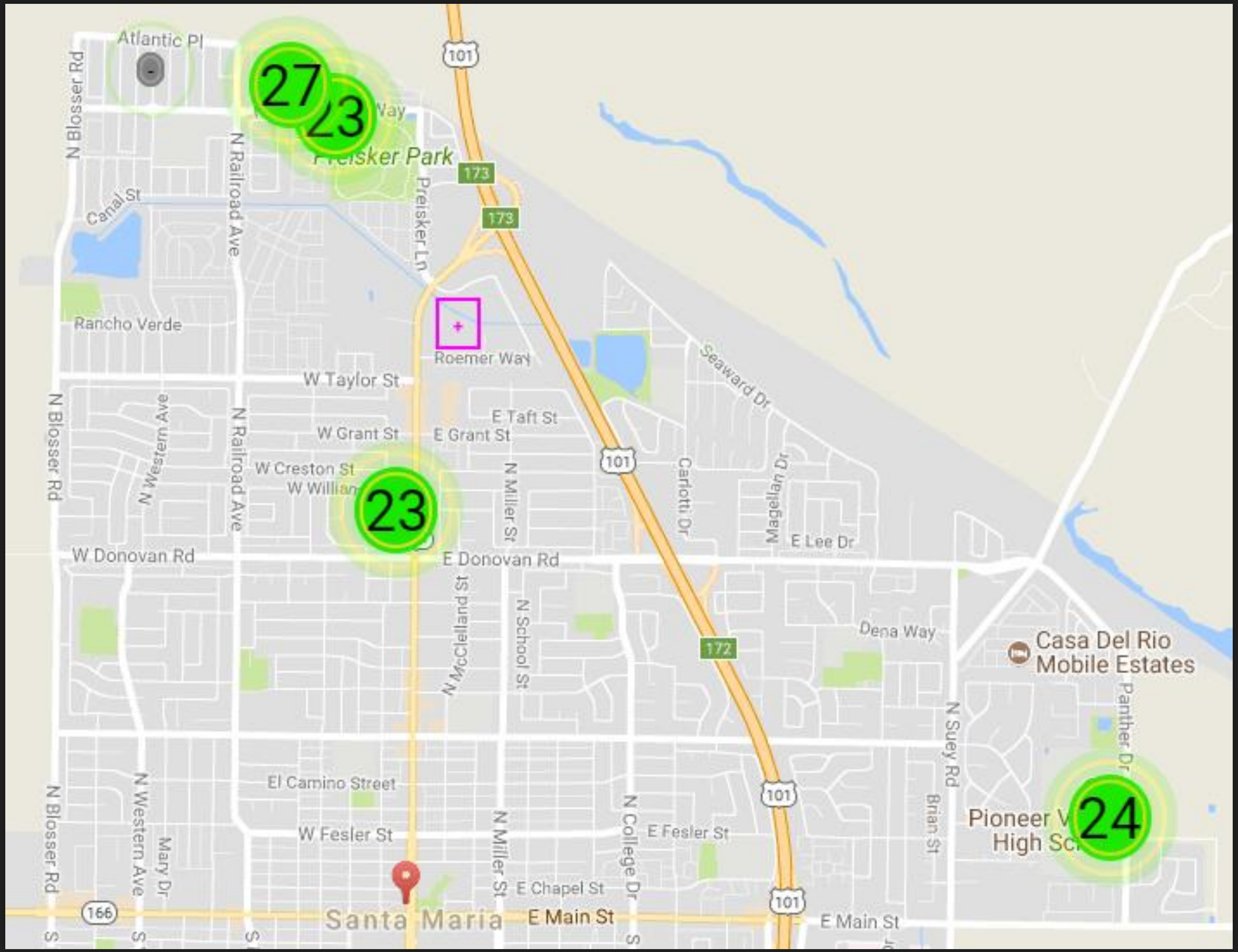
A Quantitative Analysis of PM 2.5 Microns in Santa Maria, CA

- Question: What time during the day would the air quality be classified as the worst?
- Hypothesis: The worst time would be the evening time.
- Device utilized: Dylos DC 1700
- Procedure: Tested 4 times throughout the day for 30 minute trials.
- Duration: 22 days
- Conclusion: The earliest time proved to have the highest levels of particulates.

Continuing the Research...

- Purpose: To determine if the air in my neighborhood met air quality standards throughout the testing period.
- Duration: From the month of June to December.
- New monitor: Purple Air monitor
  - Detects sizes of 0.3, 0.5, 1.0, 2.5, 5.0 and 10um suspended in the air.
  - Uses PMS1003 laser particle counters
  - Records per minute and will give 1440 data points per day
  - Data is downloadable on purpleair.com
- Conclusion is yet to be determined

PURPLE AIR AT PVHS!



PROS AND CONS

- **PROS:**
  - REAL TIME DATA
  - STUDENTS CAN SEE LOCAL DATA
  - STUDENTS CAN LEARN MORE ABOUT INTERNATIONAL OR FAR AWAY AREAS
  - STUDENTS GET MORE PRACTICE WITH NUMBERS
- **CONS:**
  - TECHNICAL DIFFICULTIES
  - RELIANCE ON SENSOR NOT GETTING DAMAGED
  - NEEDS CONTINUAL POWER AND WIFI

SBCEO COACHING PROJECT

- THE NEXT PHASE IN PURPLE AIR EDUCATION!
- I am going to educate 4 high school teachers about how to use Purple Air sensors in their classrooms with their students.
- Schools represented in the study include Santa Ynez High School, Santa Maria High School, and Pioneer Valley High School.
- Each participating teacher will get a Purple Air sensor to use for the remainder of the school year.

Santa Barbara County APCD
Board of Directors Meeting; January *18, 2018*

Evaluation of "Low-cost" Sensors for Measuring Gaseous and Particle Air Pollutants: Results from Three Years of Field and Laboratory Testing

Andrea Polidori, Ph.D.
Atmospheric Measurements Manager
South Coast Air Quality Management District
Diamond Bar, CA

South Coast AQMD

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

- Established in July 2014
- Over $600,000 investment
- Main Goals & Objectives
  - Provide guidance & clarity
  - Promote successful evolution and use of sensor technology
  - Minimize confusion
- Sensor Selection Criteria
  - Commercially available
    - *Optical*
    - *Electrochemical*
    - *Metal oxide*
  - Real- or near-real time
  - Criteria pollutants & air toxics

South Coast AQMD

AQ-SPEC

Air Quality Sensor Performance Evaluation Center

Field Testing

- Started in September, 2014
  - 30+ sensors evaluated
- Process
  - Sensor tested in triplicates
  - Collocation with FRMs/FEMs
  - Two month deployment
  - < ~ $2,000: purchase
  - > ~ $2,000: lease or borrow
- Locations:
  - Rubidoux station (main)
    - Inland site
    - Fully instrumented

Laboratory Testing

T and RH controlled: T (0-50 ^{0}C); RH (5-95%)

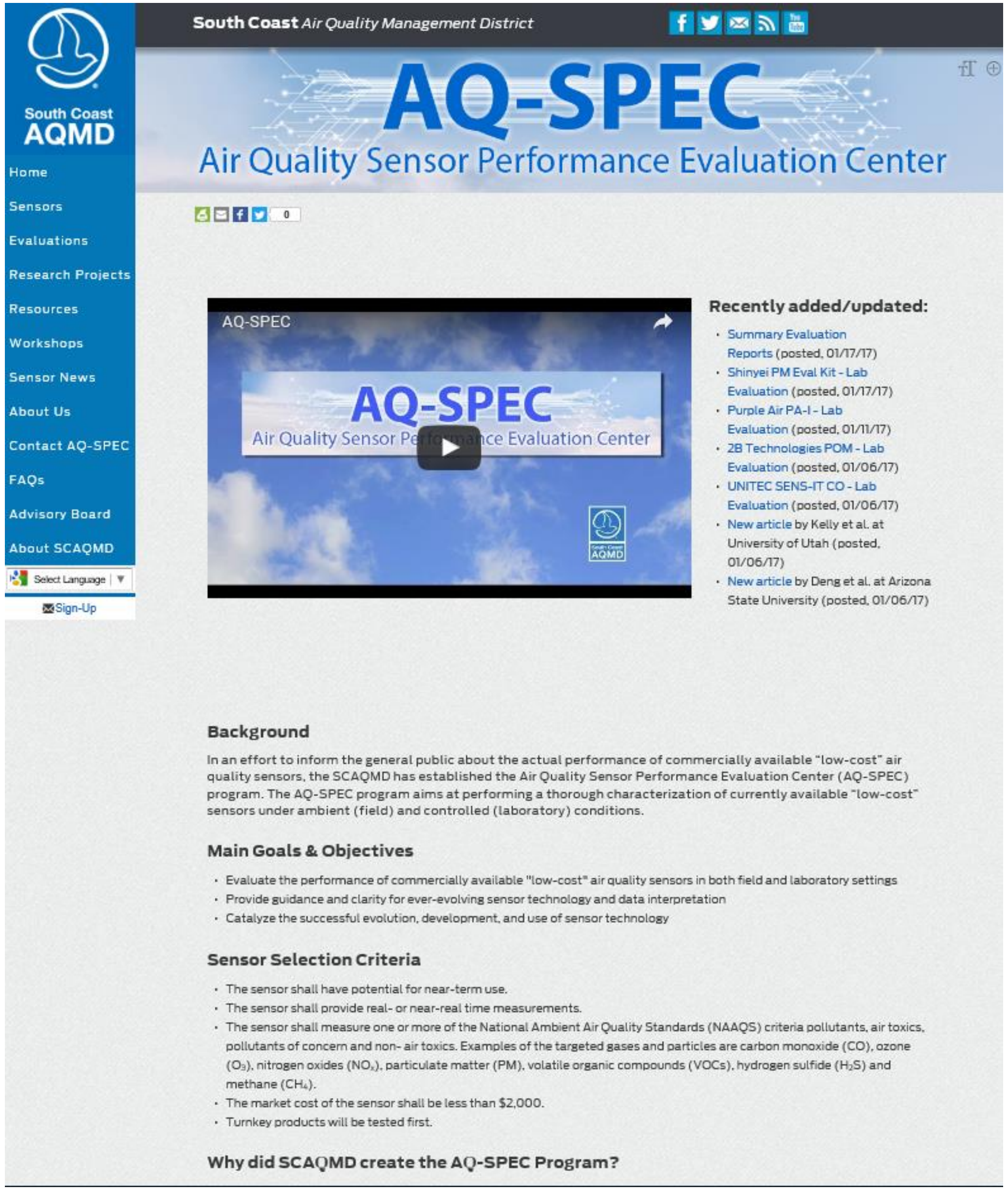
Particle testing

- Particle generation systems
- Particle monitors: mass concentration and size distribution

Gas testing

- Gas generation / dilution system
- Gas monitors: CO, NO_X, O_3, SO_2, H_2S, CH_4/NMHC

www.aqmd.gov/aq-spec



South Coast *Air Quality Management District*

South Coast AQMD

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- Sensors
- Evaluations
- Research Projects
- Resources
- Workshops
- Sensor News
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- Contact AQ-SPEC
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- Advisory Board
- About SCAQMD

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AQ-SPEC

Air Quality Sensor Performance Evaluation Center

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Air Quality Sensor Performance Evaluation Center

Recently added/updated:

- Summary Evaluation Reports (posted, 01/17/17)
- Shinyei PM Eval Kit - Lab Evaluation (posted, 01/17/17)
- Purple Air PA-I - Lab Evaluation (posted, 01/11/17)
- 2B Technologies POM - Lab Evaluation (posted, 01/06/17)
- UNITEC SENS-IT CO - Lab Evaluation (posted, 01/06/17)
- New article by Kelly et al. at University of Utah (posted, 01/06/17)
- New article by Deng et al. at Arizona State University (posted, 01/06/17)

Background

In an effort to inform the general public about the actual performance of commercially available "low-cost" air quality sensors, the SCAQMD has established the Air Quality Sensor Performance Evaluation Center (AQ-SPEC) program. The AQ-SPEC program aims at performing a thorough characterization of currently available "low-cost" sensors under ambient (field) and controlled (laboratory) conditions.

Main Goals & Objectives

- Evaluate the performance of commercially available "low-cost" air quality sensors in both field and laboratory settings
- Provide guidance and clarity for ever-evolving sensor technology and data interpretation
- Catalyze the successful evolution, development, and use of sensor technology

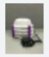
Sensor Selection Criteria

- The sensor shall have potential for near-term use.
- The sensor shall provide real- or near-real time measurements.
- The sensor shall measure one or more of the National Ambient Air Quality Standards (NAAQS) criteria pollutants, air toxics, pollutants of concern and non- air toxics. Examples of the targeted gases and particles are carbon monoxide (CO), ozone (O_3), nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOCs), hydrogen sulfide (H_2S) and methane (CH_4).
- The market cost of the sensor shall be less than $2,000.
- Turnkey products will be tested first.

Why did SCAQMD create the AQ-SPEC Program?

www.aqmd.gov/aq-spec

PM Sensors

Sensor Image	Manufacturer (Model)	Type	Pollutant(s)	Approx. Cost (USD)	*Field R^2	*Lab R^2	Summary Report
	**AethLabs** (microAeth)	Optical	BC (Black Carbon)	~$6,500	R^2 ~ 0.79 to 0.94		
	**Air Quality Egg** (Version 1)	Optical	PM	~$200	R^2 ~ 0.0		
	**Air Quality Egg** (Version 2)	Optical	PM	~$240	$PM_{2.5}$: R^2 ~ 0.79 to 0.85 PM_{10}: R^2 ~ 0.31 to 0.40		
	**Alphasense** (OPC-N2)	Optical	$PM_{1.0}$, $PM_{2.5}$ & PM_{10}	~$450	$PM_{1.0}$: R^2 ~ 0.63 to 0.82 $PM_{2.5}$: R^2 ~ 0.38 to 0.80 PM_{10}: R^2 ~ 0.41 to 0.60	R^2 ~ 0.99	PDF (1,291 KB)
	**Dylos** (DC1100)	Optical	$PM_{(0.5-2.5)}$	~$300	R^2 ~ 0.65 to 0.85	R^2 ~ 0.89	PDF (1,384 KB)
	**Foobot**	Optical	$PM_{2.5}$	~$200	R^2 ~ 0.55		
	**HabitatMap** (AirBeam)	Optical	$PM_{2.5}$	~$200	R^2 ~ 0.65 to 0.70	R^2 ~ 0.87	PDF (1,144 KB)
	**Hanvon** (Hanvon N1)	Optical	$PM_{2.5}$	~$200	R^2 ~ 0.52 to 0.79		
	**MetOne** (Neighborhood Monitor)	Optical	$PM_{2.5}$	~$1,900	R^2 ~ 0.53 to 0.67		
	**Moji China** (Airnut)	Optical	$PM_{2.5}$	~$150	R^2 ~ 0.81 to 0.88		
	**Naneos** (Partector)	Electrical	PM (LDSA: Lung-Deposited Surface Area)	~$7,000	$PM_{1.0}$: R^2 ~ 0.1 $PM_{2.5}$: R^2 ~ 0.2		
	**Origins** (Laser Egg)	Optical	$PM_{2.5}$ & PM_{10}	~$200	$PM_{2.5}$: R^2 ~ 0.58 PM_{10}: R^2 ~ 0.0		
	**Perkin Elmer** (ELM)	Optical	PM	~$5,200	R^2 ~ 0.0		
	**PurpleAir (PA-I)**	Optical	$PM_{1.0}$, $PM_{2.5}$ & PM_{10}	~$150	$PM_{1.0}$: R^2 ~ 0.93 to 0.95 $PM_{2.5}$: R^2 ~ 0.77 to 0.92 PM_{10}: R^2 ~ 0.32 to 0.44	$PM_{1.0}$: R^2 ~ 0.95 $PM_{2.5}$: R^2 ~ 0.99 PM_{10}: R^2 ~ 0.97	PDF (1,072 KB)
	**PurpleAir (PA-II)**	Optical	$PM_{1.0}$, $PM_{2.5}$ & PM_{10}	~$200	$PM_{1.0}$: 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	$PM_{1.0}$: R^2 ~ 0.99 $PM_{2.5}$: R^2 ~ 0.99 PM_{10}: R^2 ~ 0.95	PDF (1,328 KB)
	**RTI** (MicroPEM)	Optical	$PM_{2.5}$	~$2,000	R^2 ~ 0.65 to 0.90	R^2 ~ 0.99	PDF (1,087 KB)
	**Shinyei** (PM Evaluation Kit)	Optical	$PM_{2.5}$	~$1,000	R^2 ~ 0.80 to 0.90	R^2 ~ 0.93	PDF (1,156 KB)
	**Speck**	Optical	$PM_{2.5}$	~$150	R^2 ~ 0.32		
	TSI (AirAssure)	Optical	$PM_{2.5}$	~$1,500	R^2 ~ 0.82		

Results

Most PM sensors showed:
- Minimal down time
- Moderate intra-model variability
- Strong correlation (R^2) with EPA "approved" instruments (e.g., FEM)

However…
- Sensor "calibration" is needed in most cases
- Very small particles (e.g. < 0.5 µm) are not detected
- Bias in algorithms used to convert particle counts to particle mass

Gaseous Sensors

Sensor Image	Manufacturer (Model)	Type	Pollutant(s)	Approx. Cost (USD)	*Field R^2	*Lab R^2	Summary Report
	**2B Technologies** (POM)	UV absorption (FEM Method)	O_3	~$4,500	R^2 ~ 1.00	R^2 ~ 0.99	PDF (1,295 KB)
	**Aeroqual** (S-500)	Metal Oxide	O_3	~$500	R^2 ~ 0.85	R^2 ~ 0.99	PDF (1,197 KB)
	**Air Quality Egg** (Version 1)	Metal Oxide	CO, NO_2 & O_3	~$200	CO: R^2 ~ 0.0 NO_2: R^2 ~ 0.40 O_3: R^2 ~ 0.85		
	**Air Quality Egg** (Version 2)	Electrochem	CO & NO_2	~$240	CO: R^2 ~ 0.0 NO_2: R^2 ~ 0.0		
	**Air Quality Egg** (Version 2)	Electrochem	O_3 & SO_2	~$240	O_3: R^2 ~ 0.0 to 0.20 SO_2: R^2 n/a		
	**AQMesh** (v.4.0) (Discontinued)	Electrochem	CO, NO, NO_2 & O_3	~$10,000	CO: R^2 ~ 0.42 to 0.80 NO: R^2 ~ 0.0 to 0.44 NO_2: R^2 ~ 0.0 to 0.46 O_3: R^2 ~ 0.46 to 0.83		
	**Perkin Elmer** (ELM)	Metal Oxide	NO, NO_2 & O_3	~$5,200	NO: R^2 n/a NO_2: R^2 ~ 0.0 O_3: R^2 ~ 0.89 to 0.96		
	**Smart Citizen Kit**	Metal Oxide	CO, NO_2	~$200	CO: R^2 ~ 0.50 to 0.85 NO_2: R^2 ~0.0		
	**Spec Sensors**	Electrochem	CO, NO_2 & O_3	~$500	CO: R^2 ~ 0.84 to 0.90 NO_2: R^2 ~ 0.0 to 0.16 O_3: R^2 ~ 0.0 to 0.24		
	**UNITEC** (SENS-IT)	Metal Oxide	CO, NO_2 & O_3	~$2,200	CO: R^2 ~ 0.33 to 0.43 NO_2: R^2 ~ 0.60 to 0.65 O_3: R^2 ~ 0.72 to 0.83	CO: R^2 ~ 0.99 O_3: R^2 ~ 0.82 to 0.90	CO: PDF (1,283 KB) O_3: PDF (1,177 KB)

Results

Most gaseous sensors showed:

- Acceptable data recovery
- Wide intra-model variability range
- CO; NO; O_3 (when measured alone): good correlation with FRMs
- O_3 + NO_2: low correlation with FRM (potential O_3/NO_2 interference)
- SO_2; H_2S; VOC: difficult to measure with available sensors

AQ-SPEC - What's Next?
Sensor Certification Program?



- Which pollutant(s) / sensor type(s)?
  - Are PM (e.g., particle counters) and Ozone (e.g., electrochemical) sensors good candidates?

- "Certified" for which use?
  - Regulatory?
  - Fenceline?
  - Improve network design?
  - Permitting?
  - Other?

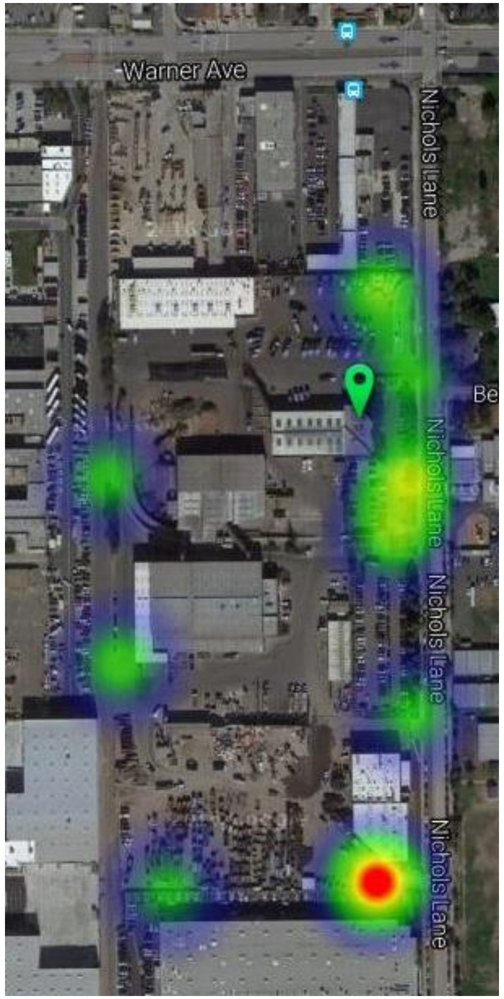
…….for what?

- Very expensive to implement correctly
  - Multiple field testing locations across the Nation
  - Multiple laboratory testing facilities
  - Extended testing time

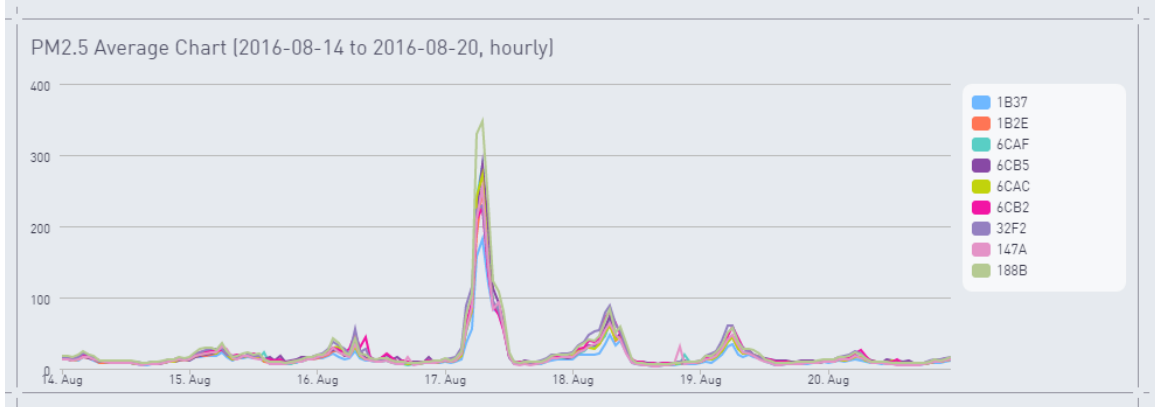
AQ-SPEC – Current Activities
Fenceline Monitoring: Waste Disposal Facility

- Monitor fugitive emissions from a Waste Disposal facility in Southern California
- 9 sensor nodes deployed at facility fenceline on June 2016
- Wireless network / remote server
- Real-time PM_1, $PM_{2.5}$ and PM_{10} monitoring

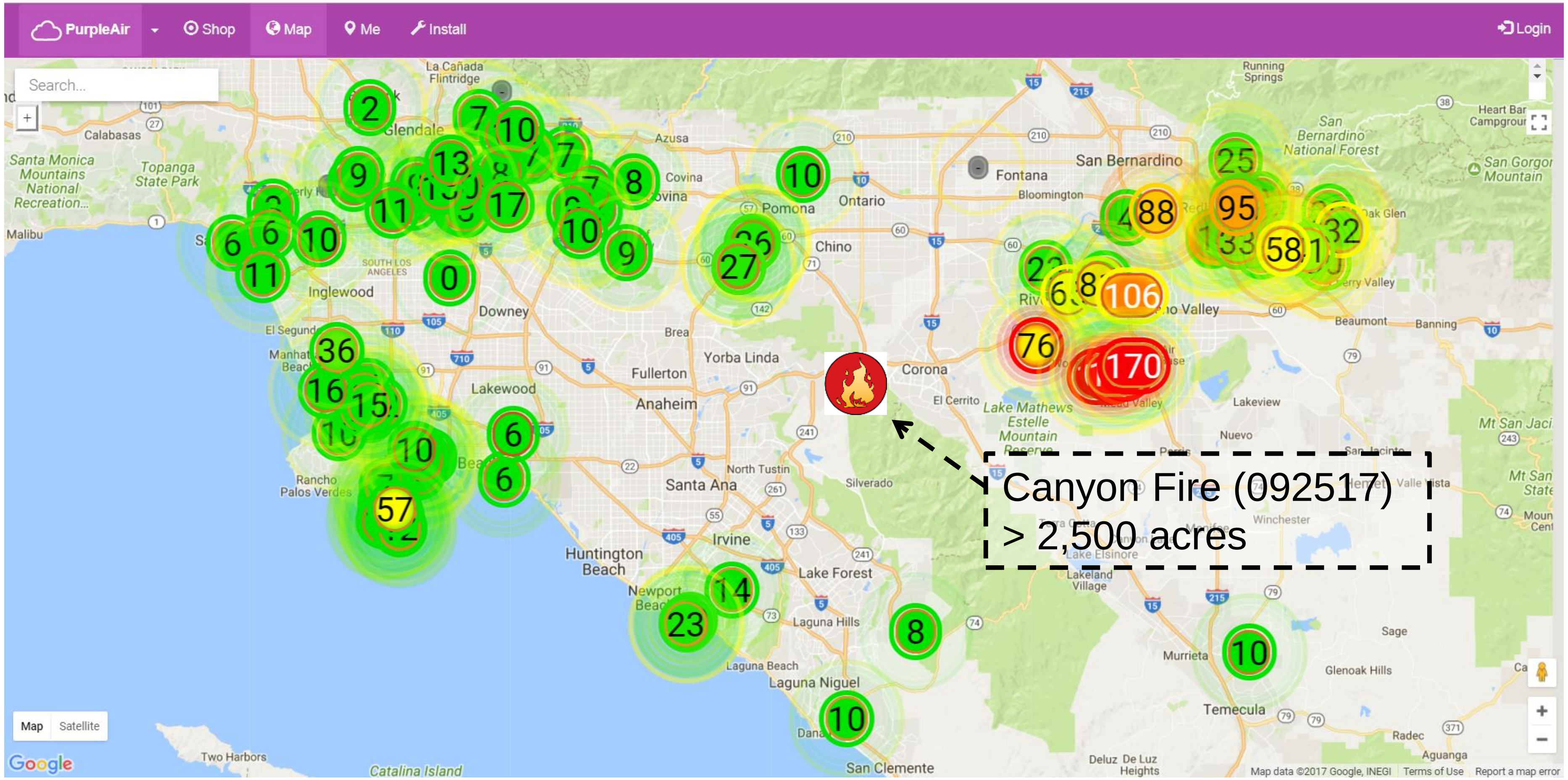
AQ-SPEC – Current Activities
Fenceline Monitoring: Waste Disposal Facility



- Dedicated website
  - *www.aqmd.meshify.com*
  - *Real-time data logging, display, and mapping*
  - *Data analytics*
  - *Email and/or text alerts*
- Project benefits
  - *Correlate PM measurements w/ on-site activities*
  - *Measure PM levels before and after facility upgrades*



AQ-SPEC – Current Activities
PM Sensor Network



Note: Values are reported as AQI units

AQ-SPEC – Current Activities

U.S. EPA Science To Achieve Results (STAR) project

Engage, educate, and empower California communities
on the use and applications of "low-cost"
air monitoring sensors

- Provide communities with the knowledge necessary to select, use and maintain low-cost sensors and to correctly interpret the collected data
- Three year study:
  - SCAQMD (PI)
  - University of California Los Angeles (UCLA; Co-PI)
  - Sonoma Technology Inc. (STI; Co-PI)
  - BAAQMD
  - Other CAPCOA agencies
  - Community Groups
  - Leisure World (Seal Beach, CA)
  - Weather Underground
  - University of Auckland (New Zealand)

South Coast AQMD

UCLA

STi Sonoma Technology, Inc.

AQ-SPEC – Current Activities

U.S. EPA Science To Achieve Results (STAR) project

Engage, educate, and empower California communities on the use and applications of "low-cost" air monitoring sensors

- Four specific aims:
  1. Develop educational material for communities
  2. Evaluate / identify candidate sensors for deployment
  3. Deploy selected sensors in California communities
  4. Communicate the lessons learned to the public

- On-going activities:
  - Wide Spread Sensor Deployment across California
    - Over 450 PM sensors
    - 100 Aeroqual nodes (i.e., PM, O_3, NOx)
  - Cloud Based Platform Development
    - Data ingestion and storage
    - Data visualization and mapping
    - Data dissemination

South Coast AQMD

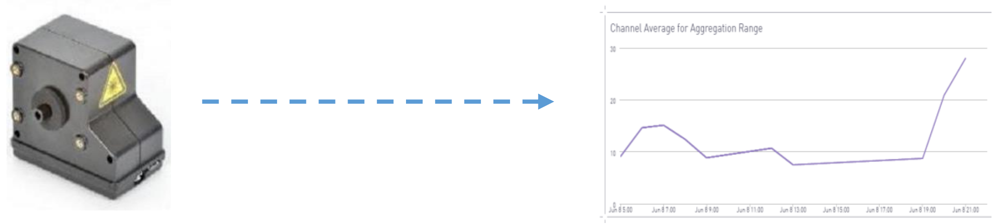
UCLA

STi Sonoma Technology, Inc.

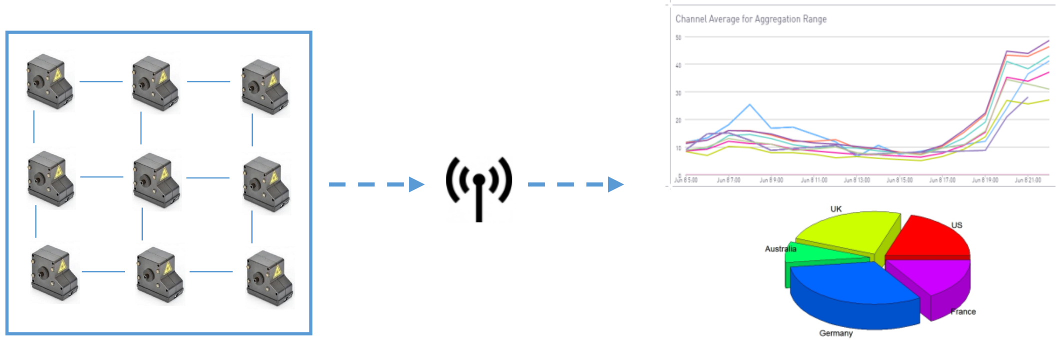
- 6 selected CA communities
- EJ areas
- 200+ subjects
- > 150 sensors

Low-cost Sensors / High-cost Networks

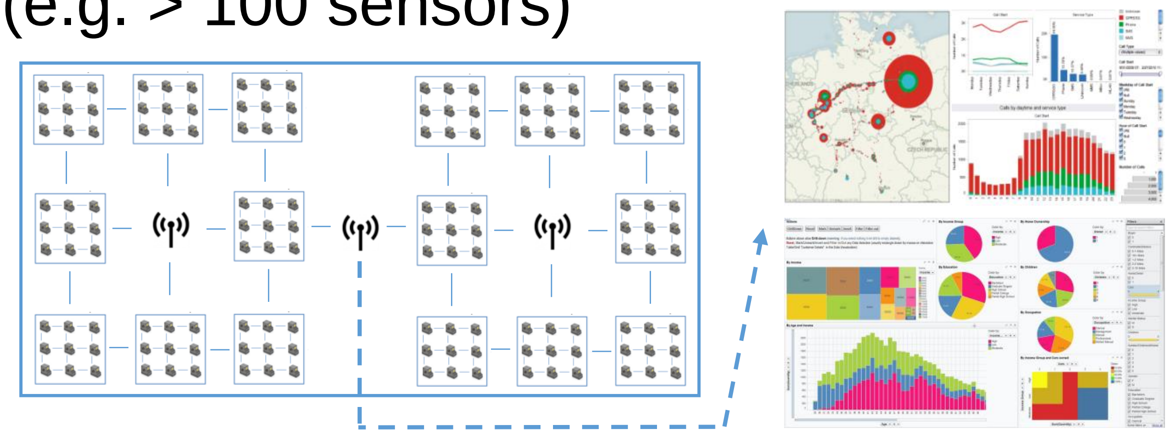
- Single user (e.g. 1 sensor)
  - Cost: $
    - Hardware
    - Minimal maintenance



- Small sensor network (e.g. 9 sensors)
  - Cost: $$
    - Hardware
    - Maintenance & calibration
    - Sensor connectivity
    - Data logging and management
    - Data validation and analysis
    - Visualization and reporting



- Large sensor network (e.g. > 100 sensors)
  - Cost: $$$$
    - Hardware
    - Maintenance & calibration
    - Sensor connectivity
    - Data logging and management
    - Data validation and analysis
    - Visualization and reporting



Thanks!

The AQ-SPEC Team

- *Dr. Andrea Polidori*
- *Dr. Vasileios Papapostolou*
- *Brandon Feenstra*
- *Dr. Hang Zhang*
- *Berj Der Boghossian*
- *Dr. Olga Pikelnaya*