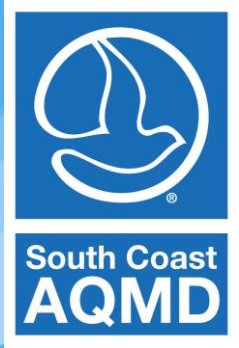


Community in Action: A Comprehensive Educational Toolkit on Air Quality Sensors

Vasileios Papapostolou, Sc.D. | Program Supervisor, AQ-SPEC



Background - The AQ-SPEC Program

- Availability, interest, and use of air quality sensors continues to increase
- **AQ-SPEC** (Air Quality Sensor Performance Evaluation Center), established in 2014
- Main Goals:
 - Evaluate the performance of commercially available "low-cost" air quality sensors in both field and laboratory settings
 - Catalyze the successful evolution, development, and use of sensor technology
 - Provide guidance and clarity for ever-evolving sensor technology and data interpretation

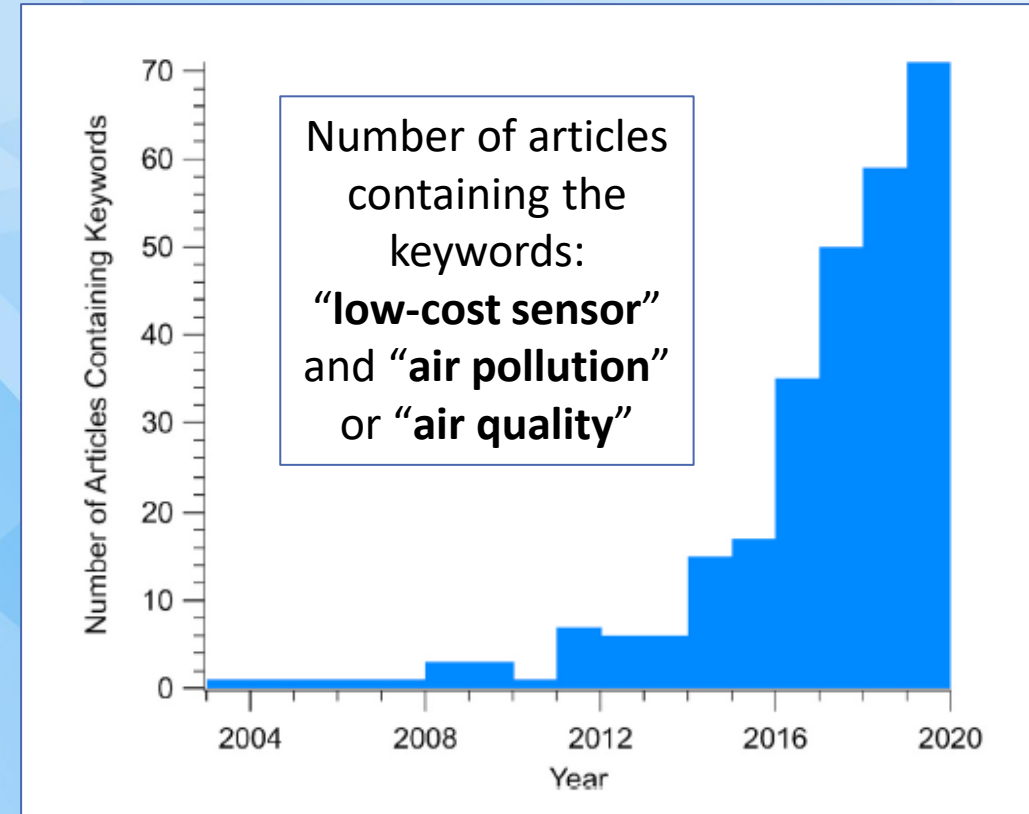
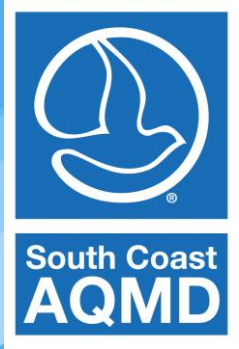


Figure from Giordano et al., 2021



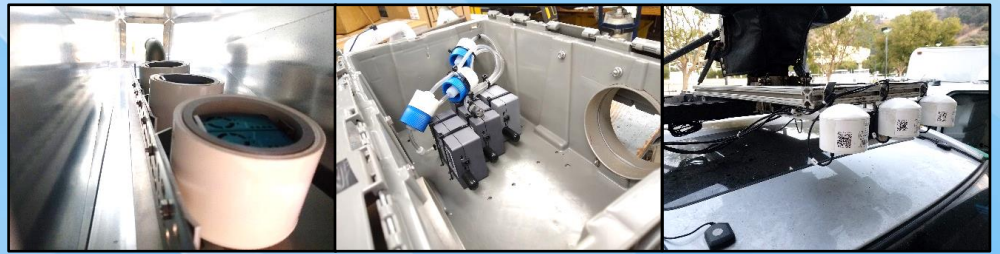
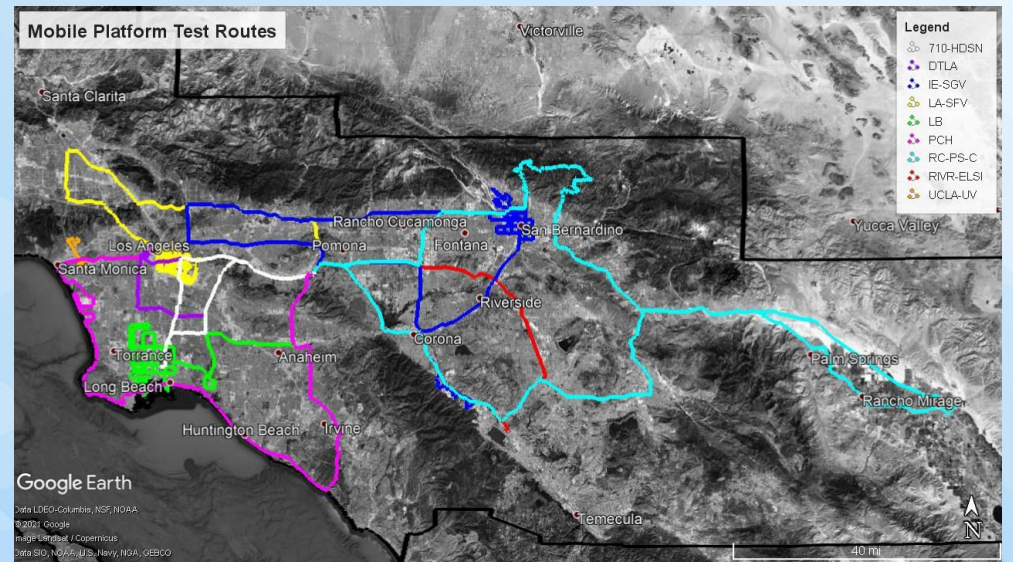
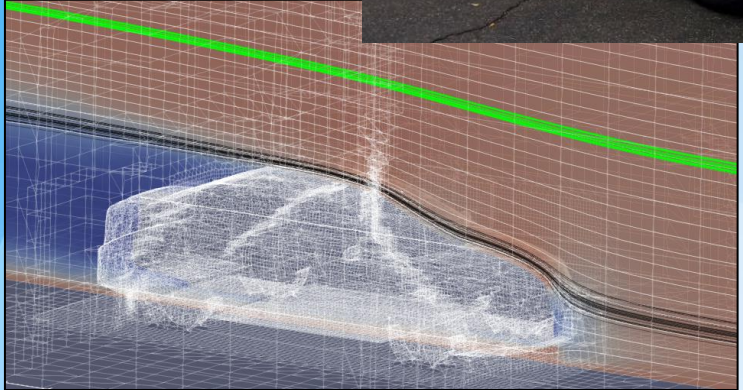
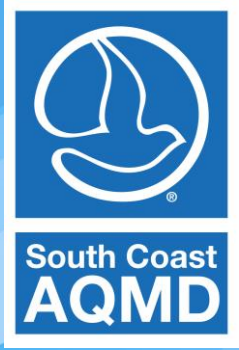


- ✓ **ASTM D8405-21 standard test method for IAQ PM_{2.5} sensors**
- ✓ Home Ventilating Institute (HVI) Certification
- ✓ ASTM DXXXX-XX standard test method for IAQ CO₂ sensors
- ✓ VOC sensor evaluations: 4-VOC blend/Benzene/CO/O₃

- ✓ 20+ Sensors testing
- ✓ Specialty Tests (wind, vibration, altitude)
- ✓ Simultaneous Pollutant testing
- ✓ U.S. EPA sensor testing protocols

www.aqmd.gov/aq-spec/evaluations/laboratory

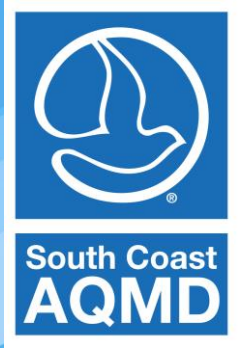
www.aqmd.gov/aq-spec/evaluations/astm-test-standards



- ✓ Chevy Volt mobile sensor testing platform
- ✓ Fully-equipped with FRM/FEM/BAT reference monitors
- ✓ Computational fluid dynamics and particle trajectory simulation inform design of sampling components
- ✓ Evaluate sensors that measure PM_{2.5}, PM₁₀, O₃, NO₂, or CO

- ✓ Three sensor testing scenarios: Controlled-flow duct; Rooftop box; Rooftop exposed
- ✓ Evaluation protocol published this year in *ES&T*
- ✓ Produce reports that help set user expectations of data quality from sensors used in mobile applications

www.aqmd.gov/aq-spec/special-projects/mobile-sensors



500 sensors and...deploying

Community Monitoring

- 350+ PurpleAir PA-II
- 60+ Aeroqual AQY

AB 617 Monitoring

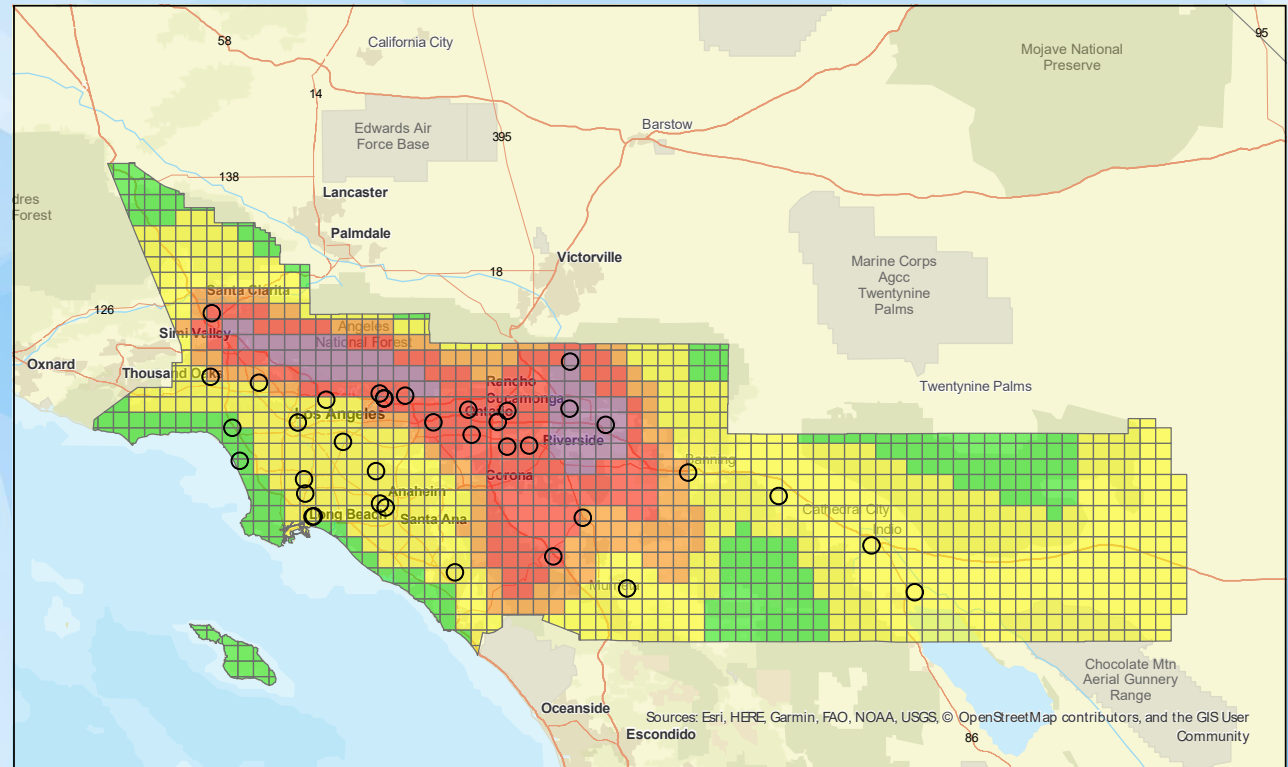
- San Bernardino
- Eastern Coachella Valley
- East LA

Wildfire Response

- fire.airnow.gov/

5 x 5 AQI Map

- www.aqmd.gov/aqimap



www.aqmd.gov/aq-spec/special-projects/aeroqual-aqy-deployments

www.aqmd.gov/aq-spec/special-projects/airsensor

14 Data Sources <-> Single-point of Access

- Analytics tools: High Charts and RStudio Team (Work Bench, Shiny apps, and Python)
- Compatible with: MatLab, JMP, Tableau, Power BI, and MS Excel

Internal Databases (data produced by South Coast AQMD)

- Sensor networks (non-regulatory)
 - Air monitoring stations (regulatory)
 - Laboratory samples
 - AB 617 Community Air Monitoring
 - Rule 1180 Refinery Emissions Monitoring
 - Air Quality Assessment (AQI data with associated health messaging)
 - Special projects (e.g., MATES V)
 - Air quality advisories
 - Facilities information
- (note, includes continuous/time integrated data as well as stationary/mobile data)*

External Databases

- Traffic count data
 - NOAA meteorological data
 - Fence line data collected by refineries
 - NASA satellite data (OMI, TROPOMI)
- (note, ability to add more in the future)*

Data Export

- Easier access to data
- Ability to customize downloaded data

Azure Cloud Infrastructure
(database for storage, organization, and processing)

External Dashboards (for the public and staff)

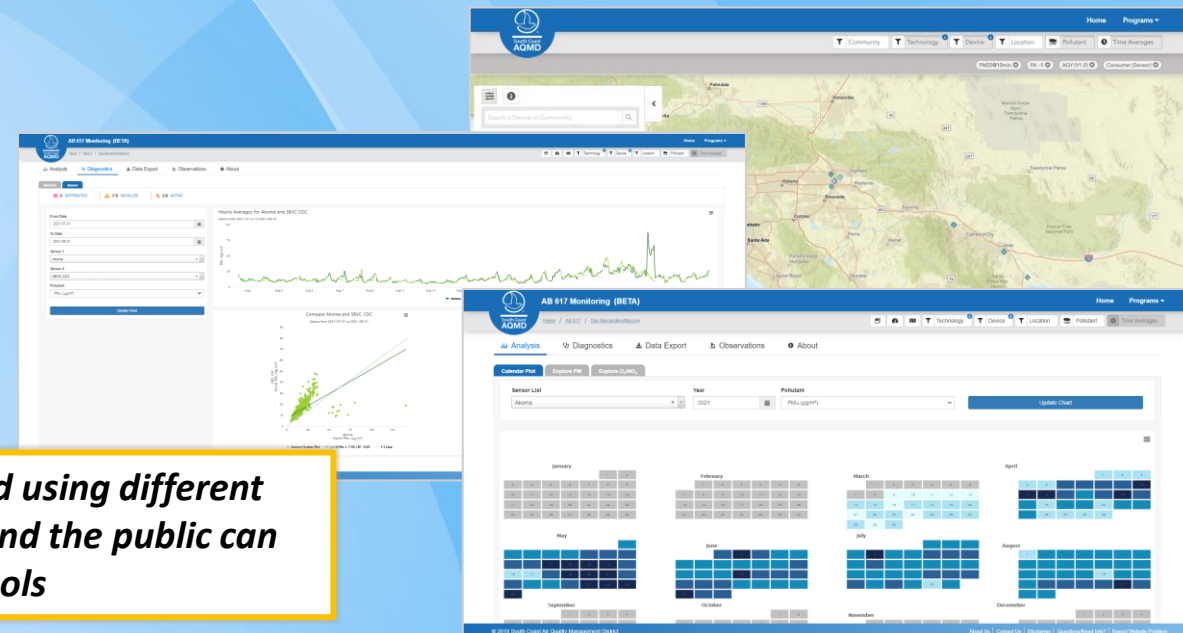
- Designed for intuitive use and engaging interaction with the data for all types of users
- Web-based
- For the public to better understand their local air quality AND explore special projects
- Wide range of visualization types
- Dashboards ranging from the “All Programs” or global/district level to the program-, project-, and even community-specific levels

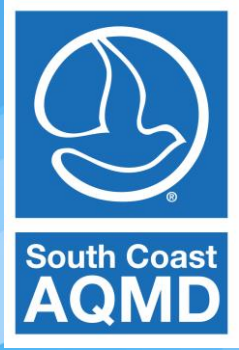
Internal Dashboards (for district staff)

- For diagnostics and more complex analysis

Air Quality Management District-level Solution

This solution harmonizes different types of air monitoring data, collected using different types of instrumentation, offering a single platform where district staff and the public can more easily access and analyze the data using advanced tools





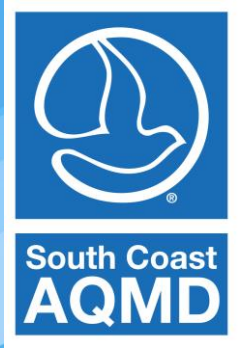
“Engage, Educate, and Empower California Communities on the Use and Applications of Low-Cost Air Monitoring Sensors”

- Main Objective: Provide communities across California with the knowledge necessary to appropriately select, use, and maintain “low-cost” sensors and to correctly interpret the collected data
- In 2015 the South Coast AQMD was awarded funding from the U.S. EPA under their “Science to Achieve Results” (STAR) Program (“Air Pollution Monitoring for Communities”)
- Collaboration:

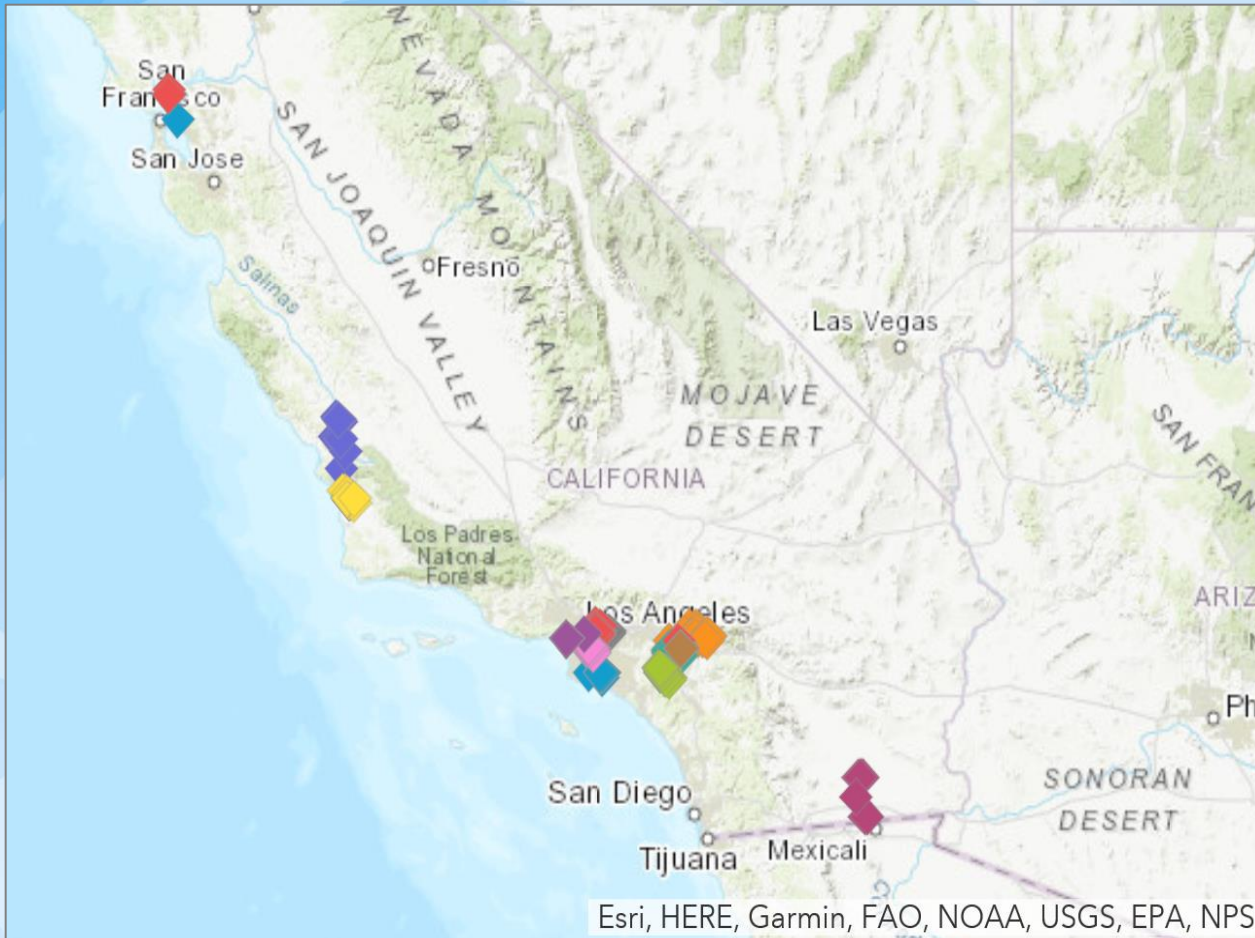


STi | Sonoma Technology

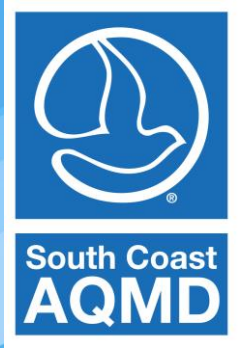
UCLA



Project Outcomes



- **14** California communities
- **300** PurpleAir PA-II sensors
- **100** Aeroqual AQY sensors
- **3** years of data
- **33** community workshops
- **86** installation surveys
- **113** surveys collected
- **3** Reports for/by STAR Grant communities
- **7** peer-reviewed publications
- **1** Master's Thesis
- **2** Conference Training Workshops
- **16** Conference Presentations



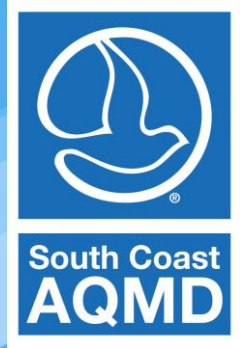
Educational Toolkit

All outcomes, products, and interaction with the communities informed and shaped the development of the Educational Toolkit

- Guidebook on Air Quality Sensors
- Training videos (3)
- Installation guides
- Surveys and project forms
- Data analysis/visualization tools
- Infographic examples
- Community reports & analysis



- ✓ Accessible to public
- ✓ Visually engaging
- ✓ One or more languages
- ✓ Decision-making to reduce exposure
- ✓ Data collection practices
- ✓ Resources for additional info

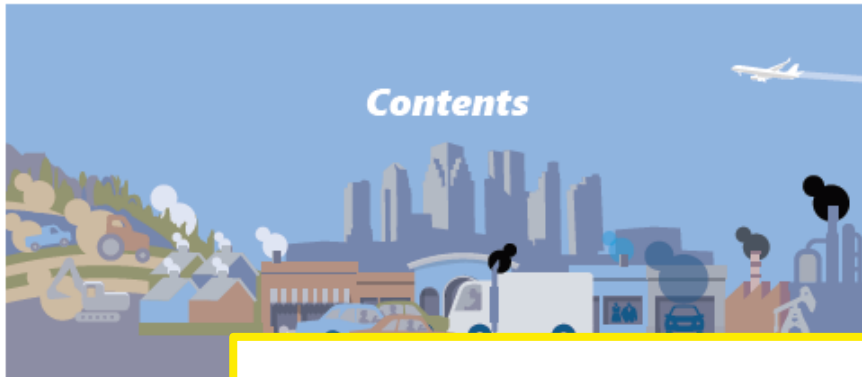
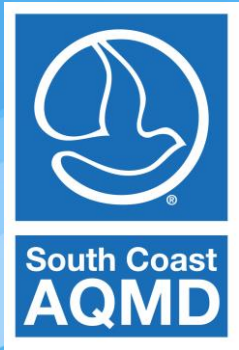


Versatile Product

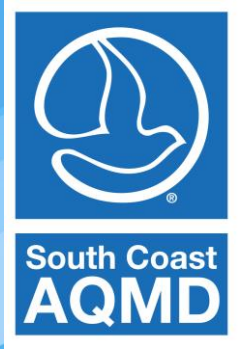
- Guidebook and other resources are designed to meet the needs of a broad range of users and projects
- For example, users could include:
 - An academic researcher new to community-based work
 - A community leader new to air quality and concerned about local sources
 - Staff from a government agency experienced in working with the public, but new to sensors
 - An individual interested in using sensors to better understand their own air quality

Table 1-1. A roadmap of the guidebook for users with different responsibilities and interests.

	Organizer	Participant	Individual	Partner	Academic	Industry	Government Agency
Chapters							
2 Learn Valuable information about air quality	•	•	•	•	•	•	•
3 Plan Plan a successful project	•		•	•	•	•	•
4 Deploy Deploy and maintain your sensors	•	•	•	•	•	•	•
5 Act Move from results to action	•	•	•	•	•	•	•
Appendices							
A Air Quality Index	•	•	•		•	•	•
B FAQs	•		•	•	•	•	•
C Purple Air Sensor	•	•	•	•	•	•	•
D Data Analysis	•		•	•	•	•	•
E Infographic	•						•
F Install Template				•			
G Project Template	•						•
H Log Notes	•	•	•		•	•	•
I Liability Form	•			•	•	•	•
J Agency Contacts	•						•
K Sensor Tests	•			•	•	•	•
L DataMewer	•	•		•	•	•	•
M Community Reports	•	•		•	•	•	•

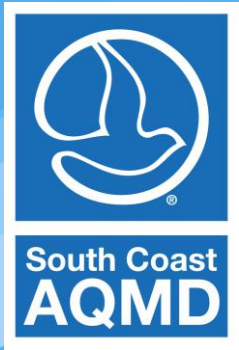


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03	Planning Your Project Planning Is a Process Why Does My Community Want to Take Air Quality Measurements? What Does My Community Want to Measure? Where and When Does My Community Want to Take Measurements? List Your Resources How to Select a Sensor System Sensor Project Tips References	3-1 3-2 3-3 3-8 3-13 3-18 3-20 3-28 3-29			
				04	Deploying Your Sensors Using and Troubleshooting Sensors Collecting Useful Data Understanding Your Data Maintaining Momentum on a Project References
				05	Taking Action Local Action Collecting More Data
					4-1 4-2 4-5 4-12 4-26 4-29 5-1 5-2 5-8 H-1 I-1 J-1 K-1 L-1 M-1



Understanding Air Quality and Monitoring:

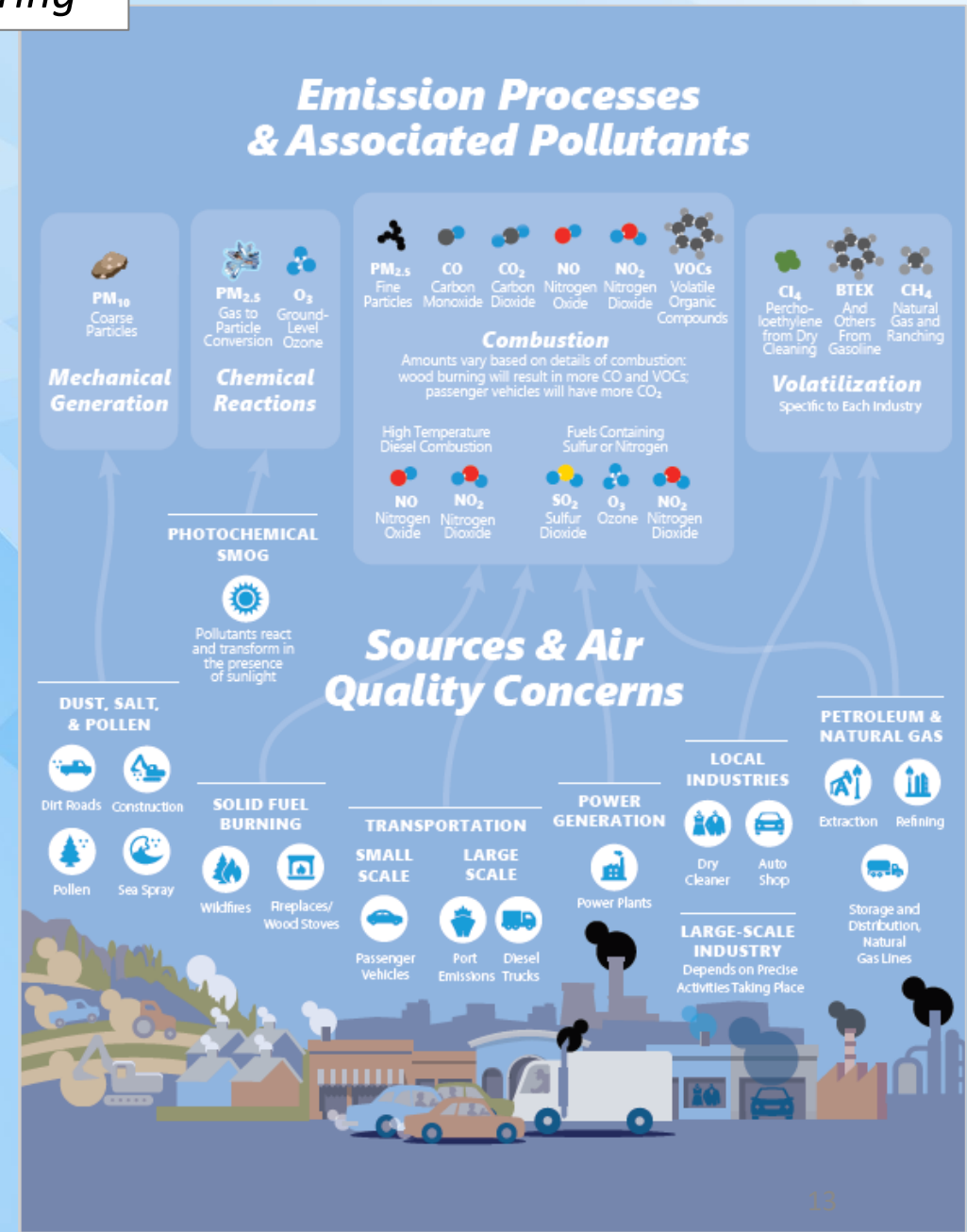


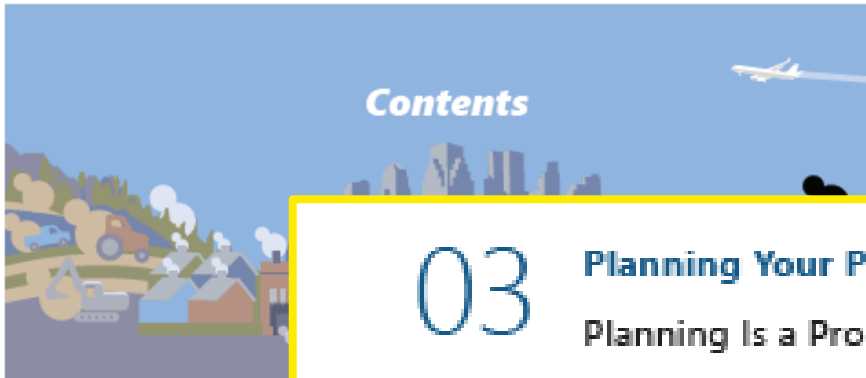
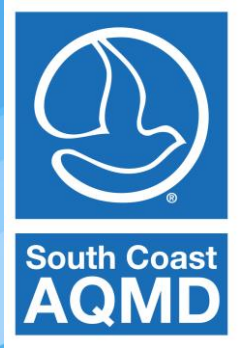


Chapter 2, "Understanding Air Quality and Monitoring"

Table 2-2. Summary of characteristics of fine and coarse particulate matter (adapted from Seinfeld and Pandis, 1998).¹¹

PM _{2.5} Fine Particles	PM ₁₀ Coarse Particles
Chemical Process <i>How the particles are formed</i>	
Reaction, nucleation, condensation, coagulation, cloud/fog processing	Suspension of dust or sea salt, mechanical process
Sources <i>Where the particles come from</i>	
<ul style="list-style-type: none"> Coal Combustion Gasoline Combustion Diesel Combustion Wood Combustion Motor Vehicles Industry Fires Gas to Particle Conversion 	<ul style="list-style-type: none"> Industrial Dust Farming Dust Mining Dust Unpaved Roads Biological Sources Construction/Demolition Ocean Spray Road Salt
Composition <i>What the particles are made of</i>	
<ul style="list-style-type: none"> Sulfates and Nitrates Elemental Carbon Other Organics Water Metals 	<ul style="list-style-type: none"> Crustal Elements Salt Pollen Mold Plant and Animal Debris
Formation <i>When the particles are formed</i>	
Primary (directly emitted) and Secondary (formed in the atmosphere)	Primary (directly emitted)
Atmospheric Lifetime <i>How long the particles stay in the air</i>	
Days to Weeks	Minutes to Days
Travel Distance <i>How far the particles travel</i>	
100 to 1000+ km (about 60 to over 600 miles)	Generally < 100 km (< about 60 miles)





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Background
Guidebook Purpose
References

02 Understanding Air Quality
Particle Pollution
Gas-Phase Pollution
What Is a Sensor?
References

03 Planning Your Project
Planning Is a Process
Why Does My Community Want to Take Air Quality Measurements?
What Does My Community Want to Measure?
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Thorough Planning Guidance

Figure 3-1. Project planning is a process that may need to be repeated to adjust for realities such as budget limitations.





Chapter 3, "How to Select a Sensor System"

HOW TO CHOOSE AN AIR QUALITY SENSOR

1 WHY? FRAME THE PROBLEM

What nearby pollution sources concern you?

DISTURBED SOIL	WOOD COMBUSTION	SMALL-SCALE TRANSPORT	LARGE-SCALE TRANSPORT	LIGHT INDUSTRY	HEAVY INDUSTRY
<ul style="list-style-type: none"> Dirt Roads Farming Construction Windblown Dust 	<ul style="list-style-type: none"> Fireplaces Restaurants Wildfires 	<ul style="list-style-type: none"> Passenger Vehicles Small Engines 	<ul style="list-style-type: none"> Diesel Trucks Shipping Airplanes Trains 	<ul style="list-style-type: none"> Dry Cleaner Auto Shop Fabrication 	<ul style="list-style-type: none"> Extraction Refining Factories Distribution

2 WHAT? IDENTIFY THE POLLUTANTS

What pollutants are being created by those sources?

PM₁₀ Coarse Particles	PM_{2.5} Fine Particles	VOCs Volatile Organic Compounds	CO₂ Carbon Dioxide	CO Carbon Monoxide	NO Nitrogen Oxide	NO₂ Nitrogen Dioxide	O₃ Ozone	SO₂ Sulfur Dioxide
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3 HOW? ASSESS YOUR RESOURCES

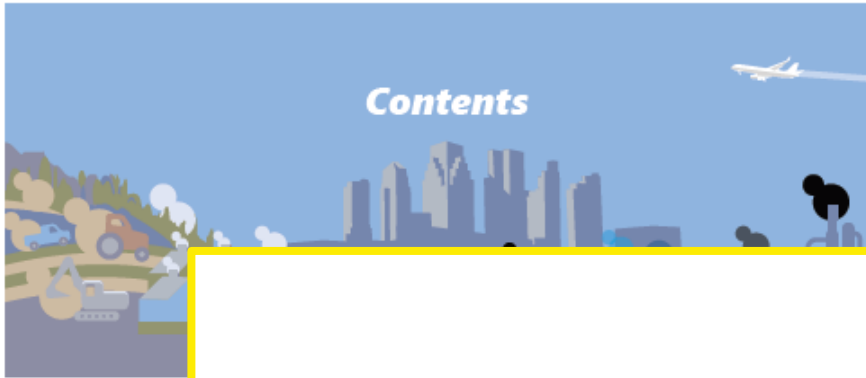
MONEY VOLUNTEERS TIME

4 WHERE AND WHEN?

What is your plan for taking measurements?

5 CHOOSE YOUR SENSORS

<p>What will you measure?</p> <p>PM_{2.5} CO O₃</p>	<p>How will you view the data?</p> <p>ON THE SENSOR WEB APP</p>
<p>Does it need to be Weatherproof?</p> <p>RAIN COLD HEAT</p>	<p>How many do you need?</p> <p>ONE SMALL NETWORK LARGE NETWORK</p>
<p>How will it be powered?</p> <p>PLUG BATTERY SOLAR</p>	<p>How will the data be stored and transmitted?</p> <p>WIFI CARD CLOUD</p>
<p>How much will it cost?</p> <p>TO BUY TO MAINTAIN</p>	



01
02
03

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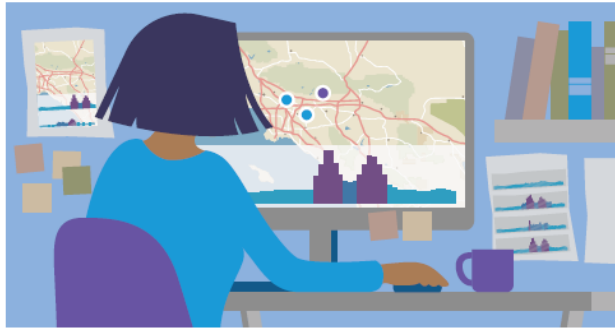
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Chapter 4, "Deploying Your Sensors"



Understanding Your Data
 Interacting with Your Data
 The first step to successful data analysis

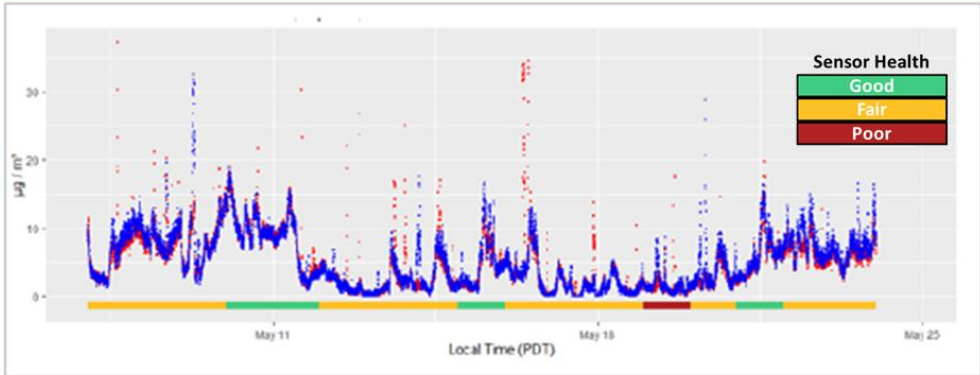
Visualizing your data is key. Visual data review is focused on patterns to verify that data are reasonable.

PurpleAir Sensor Data Processing Guides in Appendix C.

Spreadsheets (e.g., Excel): Microsoft Excel is fairly easy to use for basic data.



Using and Troubleshooting Sensors
 Sensor hosts will need training if they will be installing and



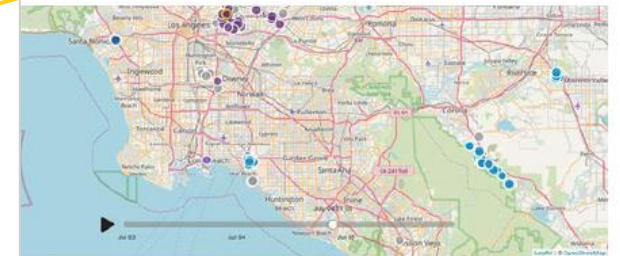
- Practical advice for siting, installing, and maintaining sensors
- Sensor co-location, correction, and calibration
- Introduction to different plot types, assessing accuracy, and useful quality control (QC) metrics/algorithms
- Ways to monitor the “State-of-Health” of deployed sensors
- Description of tools and resources available for data analysis
- Step-by-step example analysis of an air quality event (using the AirSensor DataViewer)



inspection. Defining and implementing a QA/QC procedure can help you to identify and remove questionable data

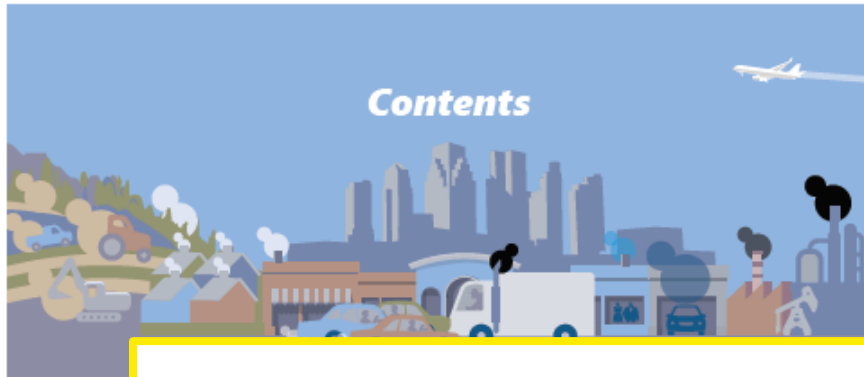
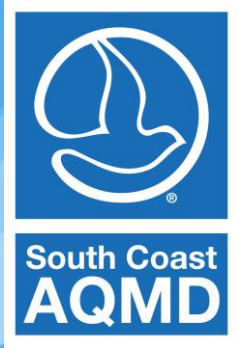
Calendar Plots

Calendar plots are useful for showing



Color Hex # (RGB)	PM _{2.5} Concentration (µg/m ³) 24-hour averages	PM _{2.5} Concentration (µg/m ³) 1-hour averages
#A8E3FA (171,227,246)	PM _{2.5} ≤ 8	PM _{2.5} ≤ 12
#F19C00 (17,140,084)	8 < PM _{2.5} ≤ 20	12 < PM _{2.5} ≤ 35
#E69A00 (16,95,100)	20 < PM _{2.5} ≤ 35	35 < PM _{2.5} ≤ 55
#8E5900 (14,92,0)	35 < PM _{2.5} ≤ 55	55 < PM _{2.5} ≤ 75

Figure 4-9. Map and time series from the AirSensor DataViewer tool¹⁸ showing high PM_{2.5} concentrations on July 4th. The time series at the bottom is for the site



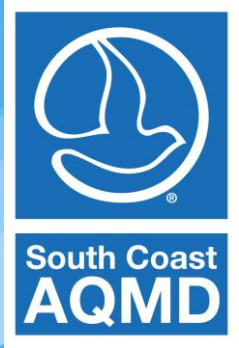
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Chapter 5, "Taking Action"



05 Taking Action

Now that you have data, what do you do with the results? Options include taking action locally



(Above) Create an anti-idling program to protect students from harmful vehicle emissions near schools.



(Left) Work with your local air quality agency to develop a no-burning policy for days with poor air quality.



Create a community awareness program that will help reduce emissions.



Other Mitigation Strategies

a flag that corresponds to the AQI: green, yellow, orange, red, and purple. EPA offers [guidance on school flag programs](#).¹⁵

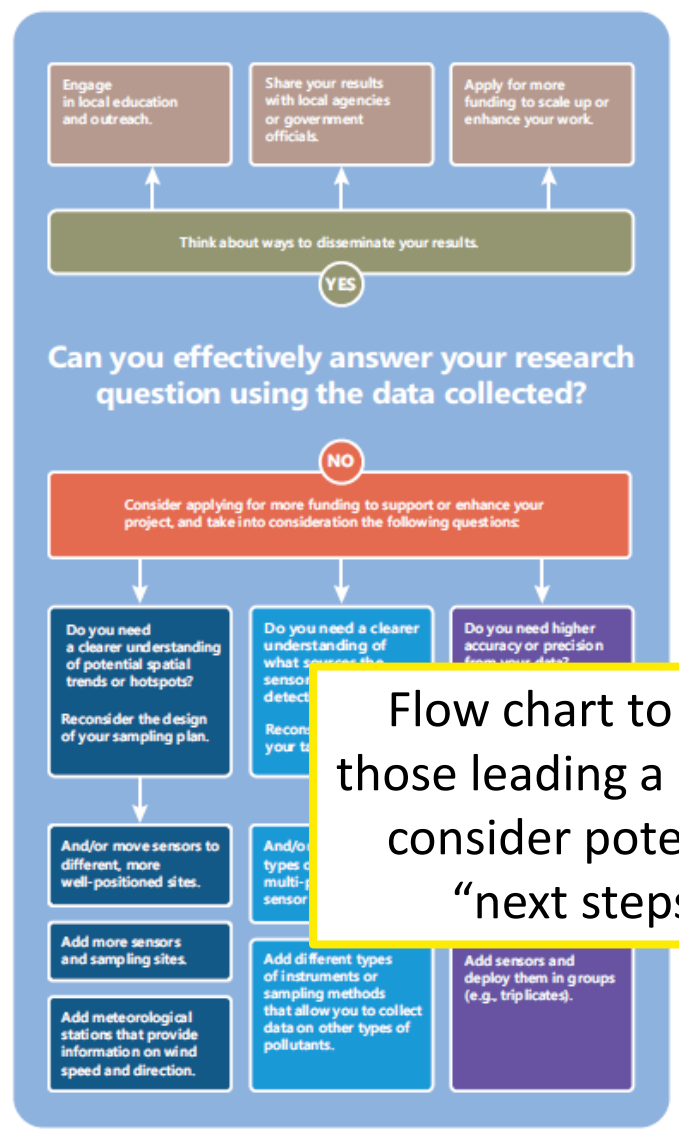
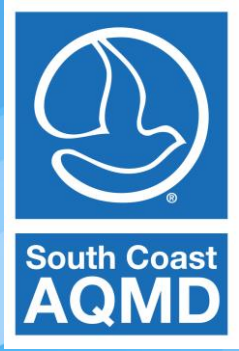


Figure 5-1. Use this decision tree to determine whether more measurements are needed to meet project objectives.

Flow chart to help those leading a project consider potential "next steps"

- Ideas for and examples of "local action"
- Advice to help determine whether additional data should be collected
- Strategies for communicating with local government agencies and/or the broader community (e.g., sharing results)

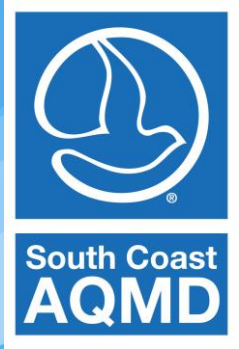


<http://www.aqmd.gov/aq-spec/special-projects/star-grant>

Conclusions & Future Work

- Next Steps -> ***Dissemination***
 - Disseminate to communities and via conferences
 - Publish products on the AQ-SPEC website
 - Future Work -> ***Sustainability***
 - Share with STAR Grant communities to help sustain and strengthen these partnerships
 - Conduct outreach to new communities and to support sensor projects locally and beyond
- ***Dissemination will bring more feedback and the opportunity to enhance and improve the Educational Toolkit***





Acknowledgements

*Thank you and for questions or comments:
vpapapostolou@aqmd.gov*

- Dr. Andrea Polidori **(PI)**
- Dr. Vasileios Papapostolou **(Project Lead)**
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- Dr. Yifang Zhu; University of California Los Angeles **(Co-PI)**
- Bay Area AQMD
- San Luis Obispo County APCD
- Santa Barbara County APCD
- Pioneer Valley High School, Santa Maria, CA
- Special Service for Groups - Asian Pacific Islander Forward Movement, Los Angeles, CA
- Leisure World Club, Seal Beach, CA
- Sycamore Heights Community Action Group, Riverside, CA
- California Environmental Health Action Team, South Gate, CA
- Temescal Valley Community, CA
- Asian Health Services, Oakland, CA
- Asian Pacific Environmental Network, Richmond, CA
- Comite Civico del Valle, Brawley, CA
- Other AQ-SPEC and South Coast AQMD Staff
- U.S. Environmental Protection Agency

