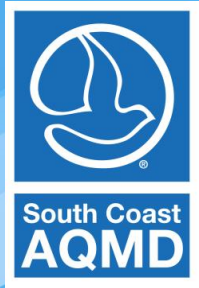


# Community in Action: A Comprehensive Educational Toolkit on Air Quality Sensors

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

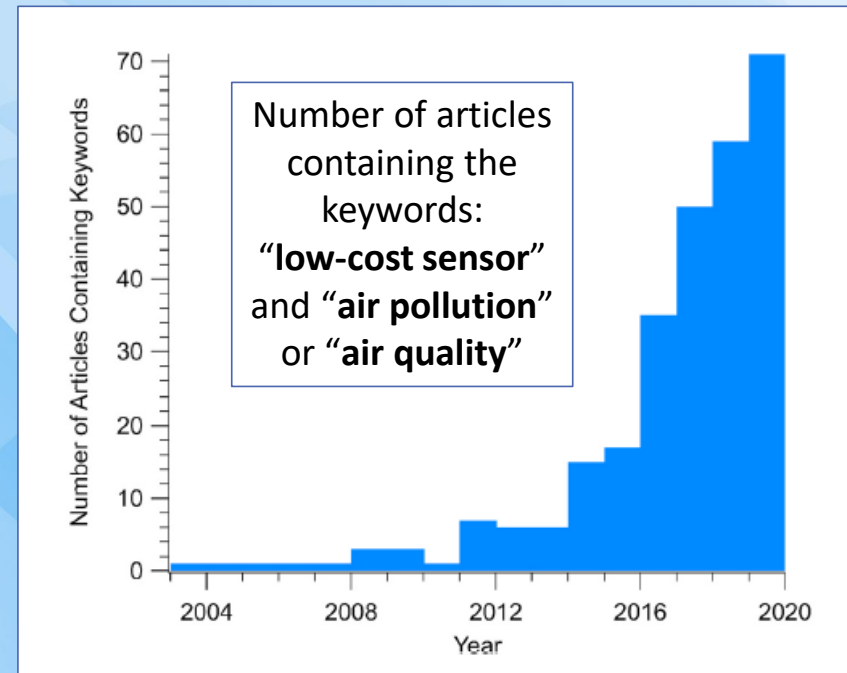
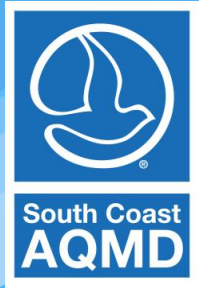


Figure from Giordano et al., 2021



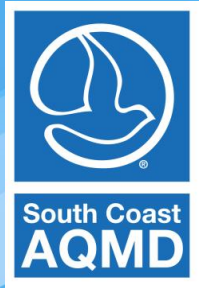


- ✓ **ASTM D8405-21 standard test method for IAQ PM<sub>2.5</sub> sensors**
- ✓ Home Ventilating Institute (HVI) Certification
- ✓ ASTM DXXXX-XX standard test method for IAQ CO<sub>2</sub> sensors
- ✓ VOC sensor evaluations: 4-VOC blend/Benzene/CO/O<sub>3</sub>

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

[www.aqmd.gov/aq-spec/evaluations/laboratory](http://www.aqmd.gov/aq-spec/evaluations/laboratory)





# 500 sensors and...deploying

## Community Monitoring

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

## AB 617 Monitoring

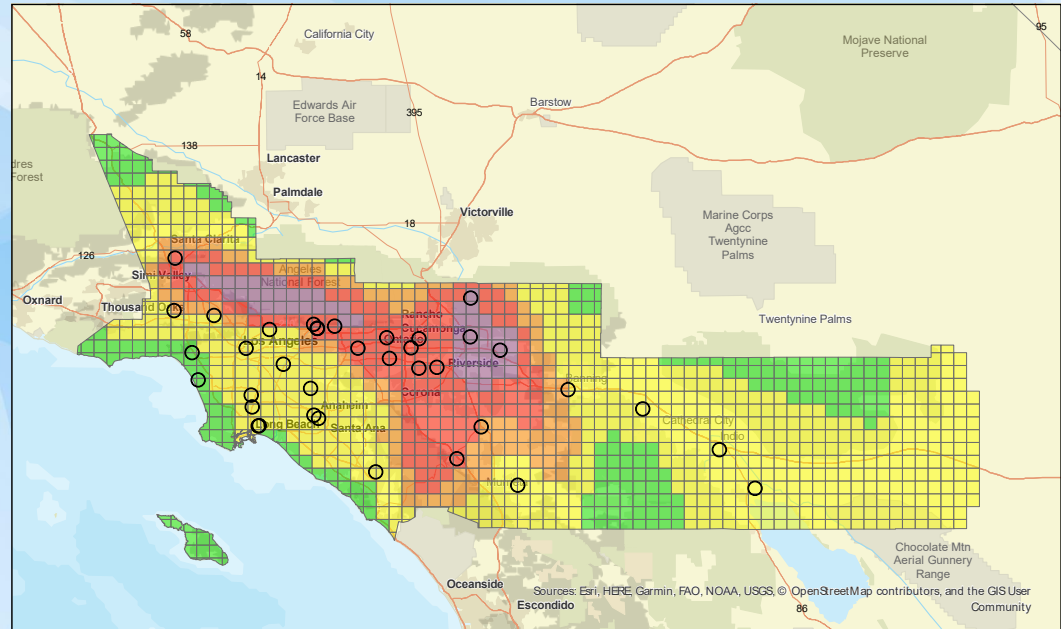
- San Bernardino
- Eastern Coachella Valley
- East LA

## Wildfire Response

- [fire.airnow.gov/](http://fire.airnow.gov/)

## 5 x 5 AQI Map

- [www.aqmd.gov/aqimap](http://www.aqmd.gov/aqimap)



[www.aqmd.gov/aq-spec/special-projects/aeroqual-aqy-deployments](http://www.aqmd.gov/aq-spec/special-projects/aeroqual-aqy-deployments)

[www.aqmd.gov/aq-spec/special-projects/airsensor](http://www.aqmd.gov/aq-spec/special-projects/airsensor)

# 14 Data Sources <-> Single-point of Access

## 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)*

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

**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)

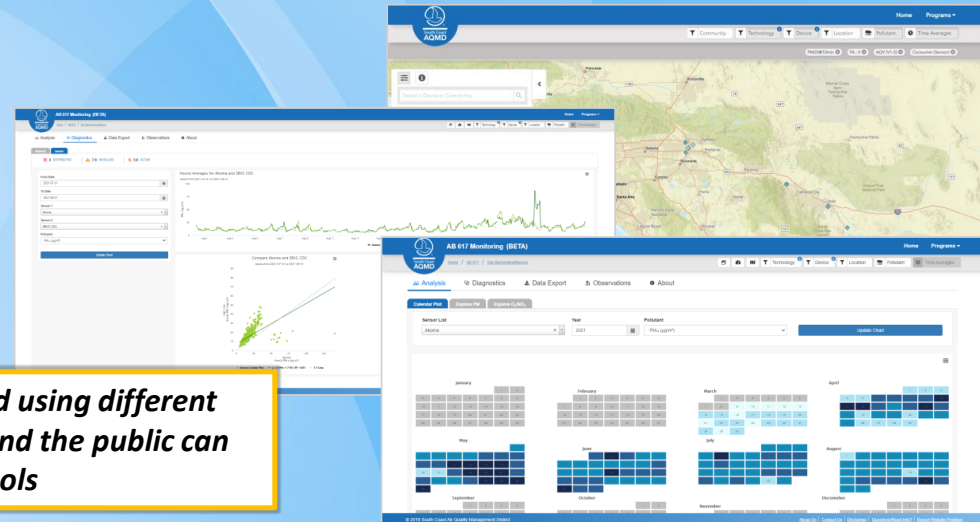
- For diagnostics and more complex analysis

## Data Export

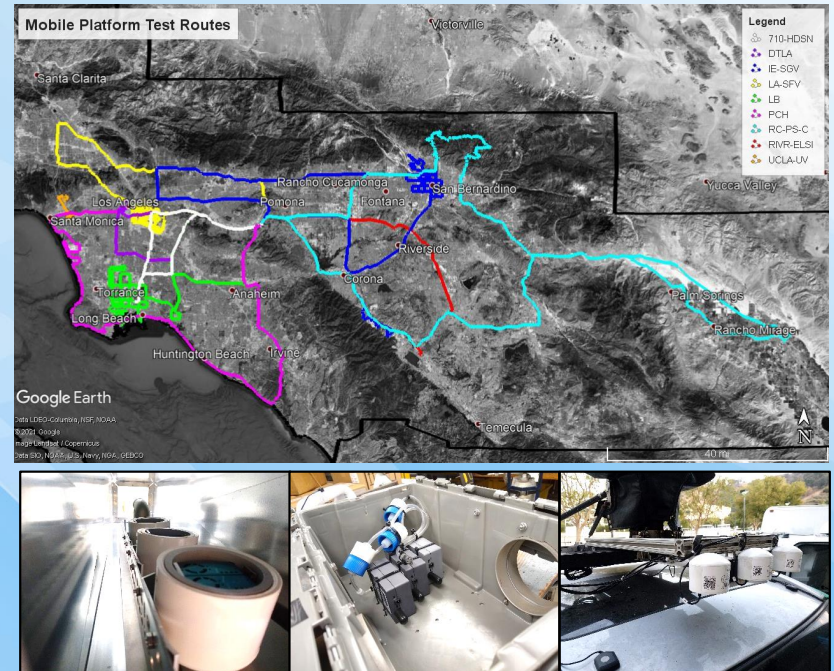
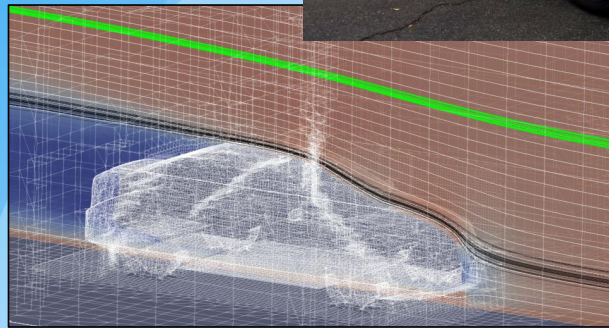
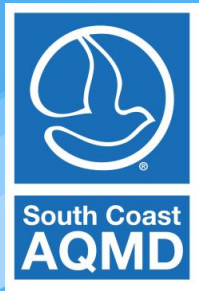
- Easier access to data
- Ability to customize downloaded data

## 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***



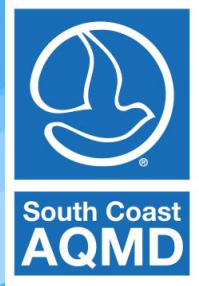




- ✓ Chevy Volt mobile sensor testing platform
- ✓ Fully-equipped with FRM/FEM/BAT reference monitors
- ✓ Computational fluid dynamics and particle trajectory simulation inform design of sampling components
- ✓ Evaluate sensors that measure  $PM_{2.5}$ ,  $PM_{10}$ ,  $O_3$ ,  $NO_2$ , or CO

- ✓ 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](http://www.aqmd.gov/aq-spec/special-projects/mobile-sensors)



*“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:



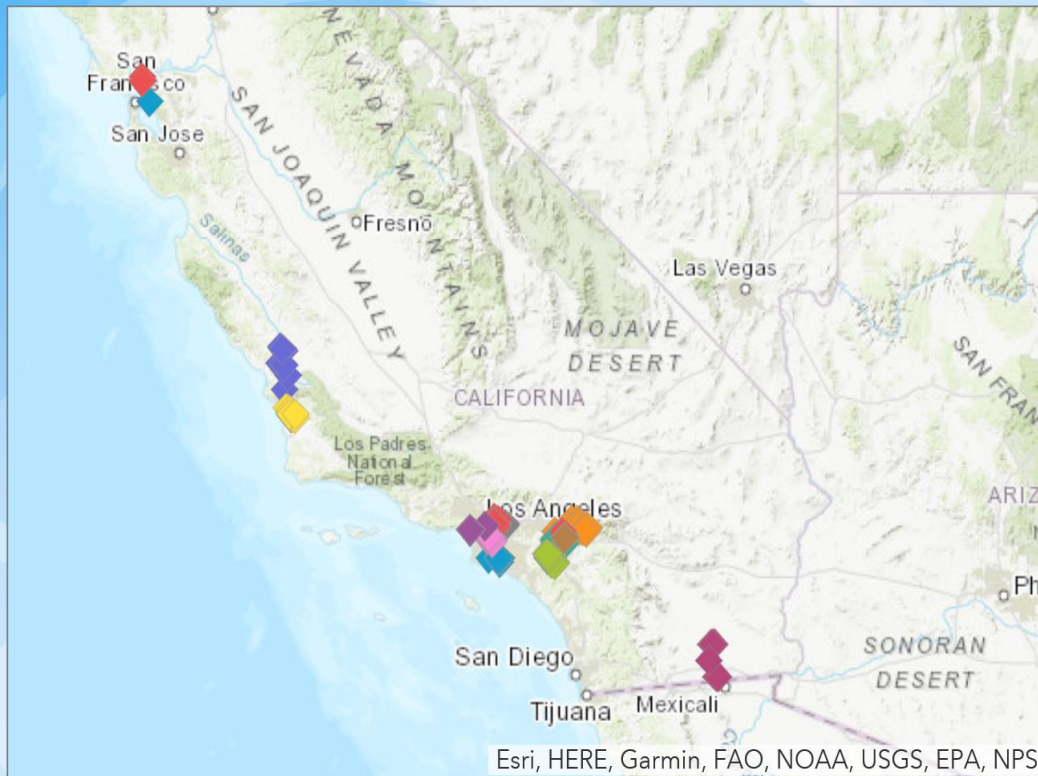
STI | Sonoma Technology

UCLA



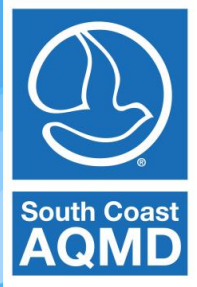


# Project Outcomes



- **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





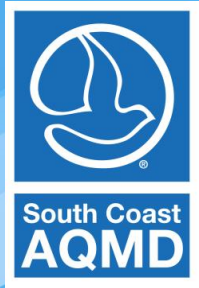
# Educational Toolkit

*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



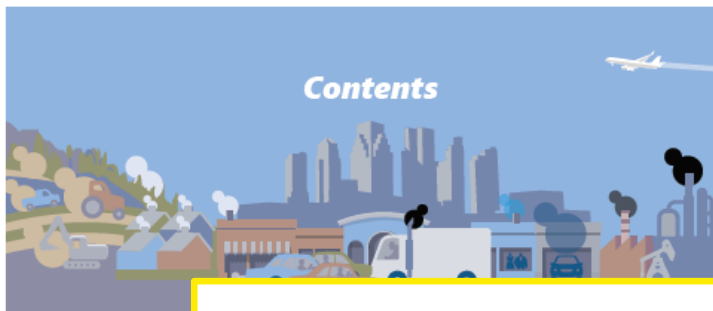
Chapter 1, "Introduction"

# 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<br>Community organizer or project lead for an air quality sensor project | Participant<br>Participant using a sensor in a community led project | Individual<br>Individual member of the public using a sensor | Partner<br>New to using sensors | Academic, Industry | Government Agency | Government Agency |
|--|--|--|--|---------------------------------|--------------------|-------------------|-------------------|
| Chapters   |  |  |  |                                 |                    |                   |                   |
| <b>2 Learn</b><br>Valuable information about air quality | •  | •  | •  | •                               | •                  |                   |                   |
| <b>3 Plan</b><br>Plan a successful project               | •  |  | •  | •                               | •                  |                   | •                 |
| <b>4 Deploy</b><br>Deploy and maintain your sensors      | •  | •  | •  | •                               | •                  | •                 | •                 |
| <b>5 Act</b><br>Move from results to action              | •  | •  | •  | •                               | •                  | •                 | •                 |
| Appendices   |  |  |  |                                 |                    |                   |                   |
| <b>A</b> Air Quality Index                               | •  | •  | •  |                                 |                    | •                 |                   |
| <b>B</b> FAQs  | •  |  | •  | •                               | •                  |                   | •                 |
| <b>C</b> Purple Air Sensor                               | •  | •  | •  | •                               | •                  |                   |                   |
| <b>D</b> Data Analysis                                   | •  |  | •  | •                               | •                  |                   |                   |
| <b>E</b> Infographic                                     | •  |  |  |                                 |                    |                   | •                 |
| <b>F</b> Install Template                                |  |  |  | •                               |                    |                   |                   |
| <b>G</b> Project Template                                | •  |  |  |                                 |                    |                   | •                 |
| <b>H</b> Log Notes                                       | •  | •  | •  |                                 | •                  |                   |                   |
| <b>I</b> Liability Form                                  |  |  |  | •                               | •                  |                   | •                 |
| <b>J</b> Agency Contacts                                 | •  |  |  |                                 |                    |                   | •                 |
| <b>K</b> Sensor Tests                                    | •  |  |  | •                               |                    |                   |                   |
| <b>L</b> DataViewer                                      | •  | •  |  | •                               | •                  |                   | •                 |
| <b>M</b> Community Reports                               | •  | •  |  | •                               |                    |                   | •                 |



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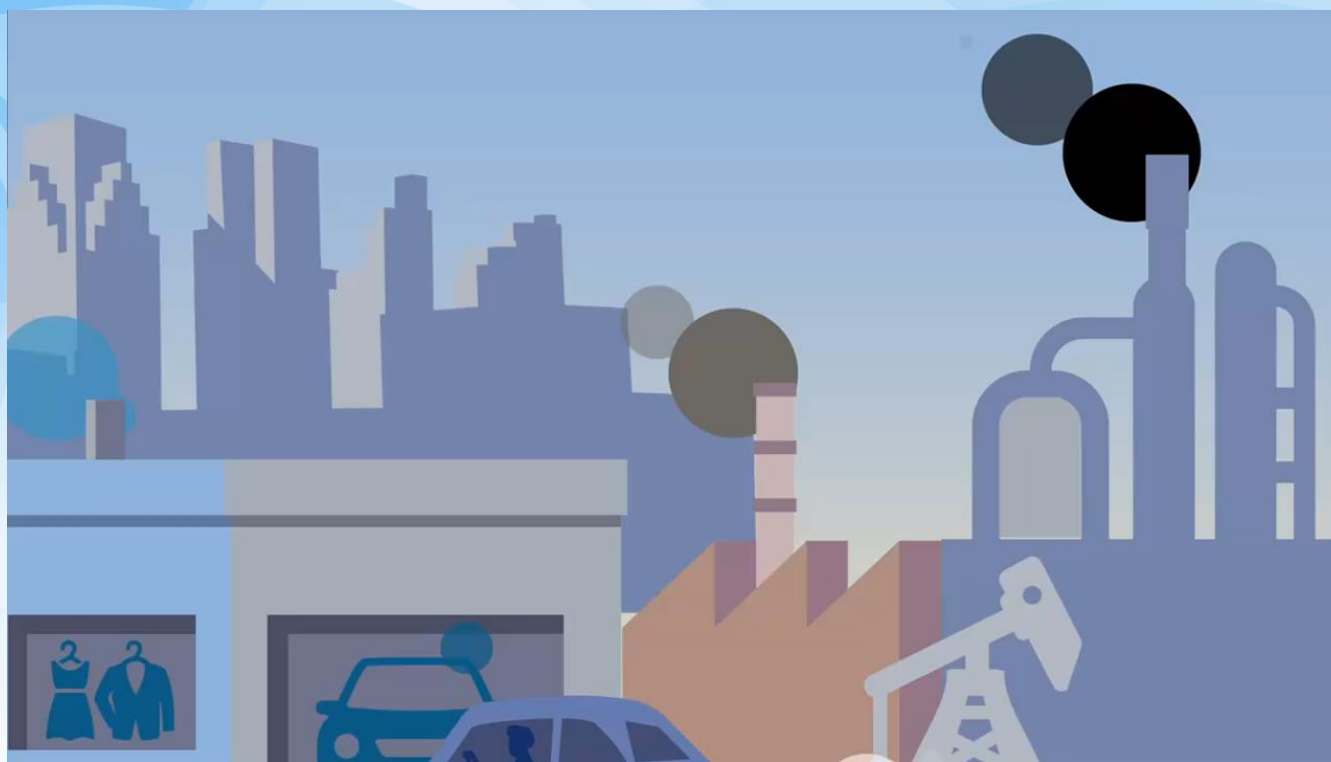
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# Understanding Air Quality and Monitoring:

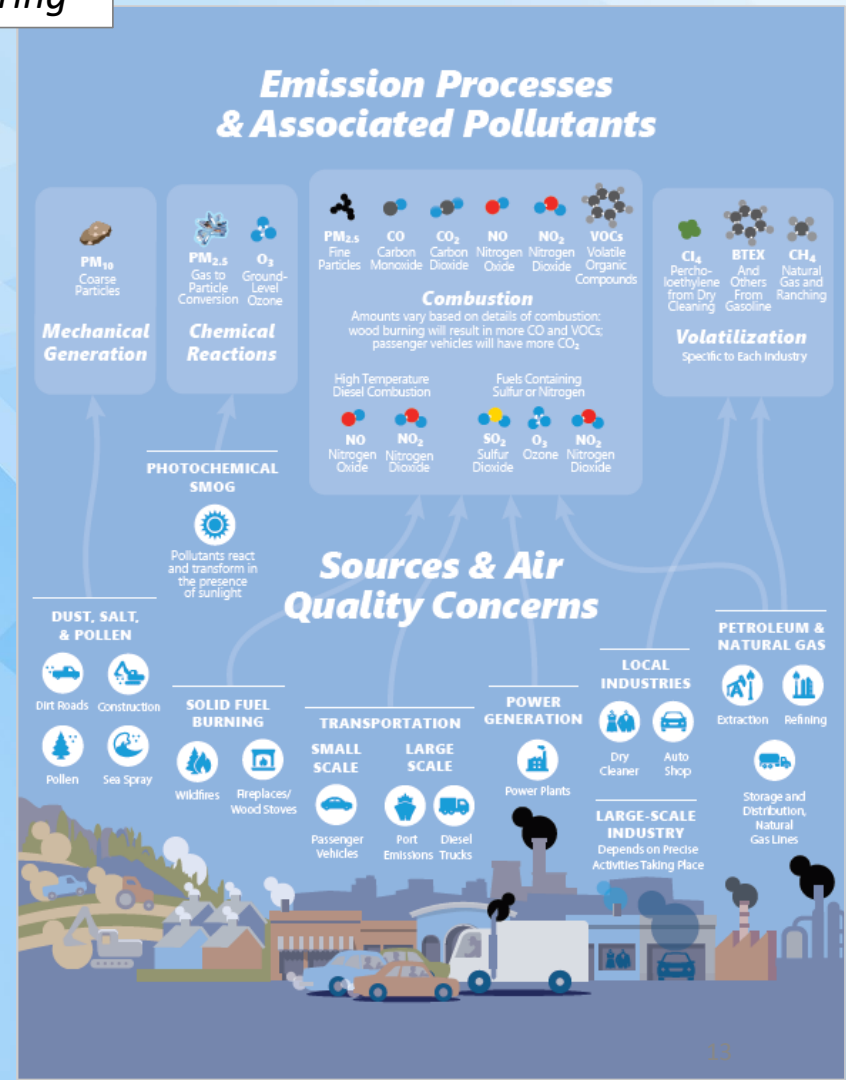


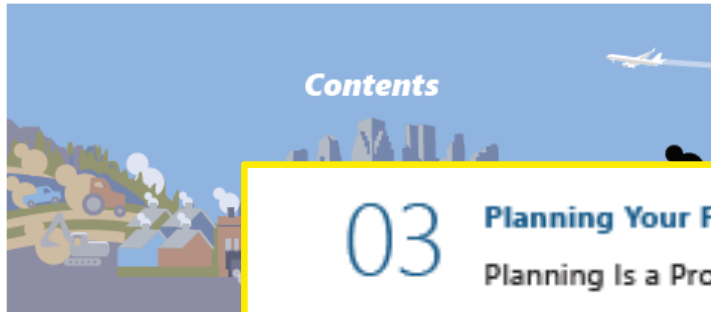


## Chapter 2, "Understanding Air Quality and Monitoring"

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

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



# 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"> <li>Dirt Roads</li> <li>Farming</li> <li>Construction</li> <li>Windblown Dust</li> </ul> | <ul style="list-style-type: none"> <li>Fireplaces</li> <li>Restaurants</li> <li>Wildfires</li> </ul> | <ul style="list-style-type: none"> <li>Passenger Vehicles</li> <li>Small Engines</li> </ul> | <ul style="list-style-type: none"> <li>Chesal Trucks</li> <li>Shipping</li> <li>Airplanes</li> <li>Trains</li> </ul> | <ul style="list-style-type: none"> <li>Dry Cleaner</li> <li>Auto Shop</li> <li>Fabrication</li> </ul> | <ul style="list-style-type: none"> <li>Extraction</li> <li>Refining</li> <li>Factories</li> <li>Distribution</li> </ul> |

### 2 WHAT? IDENTIFY THE POLLUTANTS

What pollutants are being created by those sources?

|  |   |   |   |                              |                             |   |                               |   |
|--|---|---|---|------------------------------|-----------------------------|---|-------------------------------|---|
| <b>PM<sub>10</sub></b><br>Coarse Particles | <b>PM<sub>2.5</sub></b><br>Fine Particles | <b>VOCs</b><br>Volatile Organic Compounds | <b>CO<sub>2</sub></b><br>Carbon Dioxide | <b>CO</b><br>Carbon Monoxide | <b>NO</b><br>Nitrogen Oxide | <b>NO<sub>2</sub></b><br>Nitrogen Dioxide | <b>O<sub>3</sub></b><br>Ozone | <b>SO<sub>2</sub></b><br>Sulfur Dioxide |
|--|---|---|---|------------------------------|-----------------------------|---|-------------------------------|---|

### 3 HOW? ASSESS YOUR RESOURCES

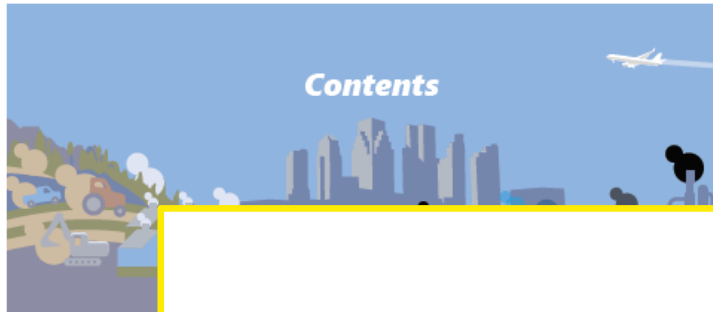
MONEY VOLUNTEERS TIME

### 4 WHERE AND WHEN?

What is your plan for taking measurements?

### 5 CHOOSE YOUR SENSORS

|  |  |  |
|--|--|--|
| <p>What will you measure?</p> <p>PM<sub>2.5</sub> CO O<sub>3</sub></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>                    |



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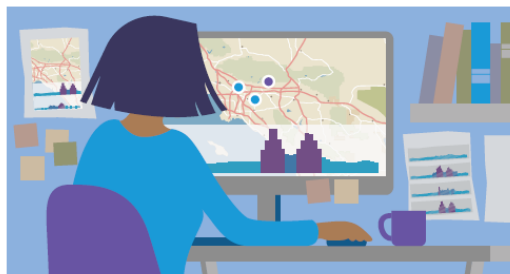
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## Chapter 4, "Deploying Your Sensors"



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

### Understanding Your Data

#### Interacting with Your Data

The first step to successful data analysis

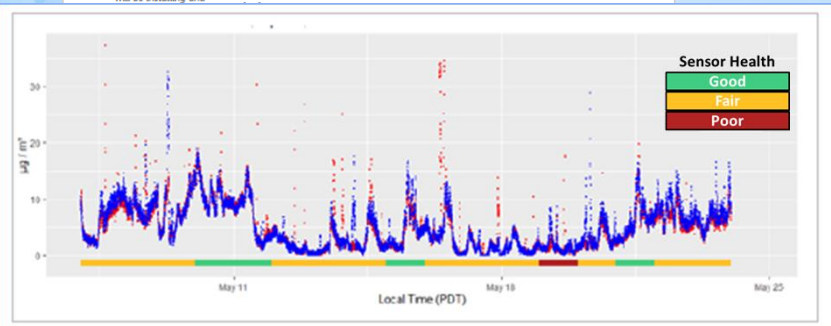
PurpleAir Sensor Data Processing Guides in Appendix C.

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



Sensor hosts will need training if they will be installing and

### Using and Troubleshooting Sensors



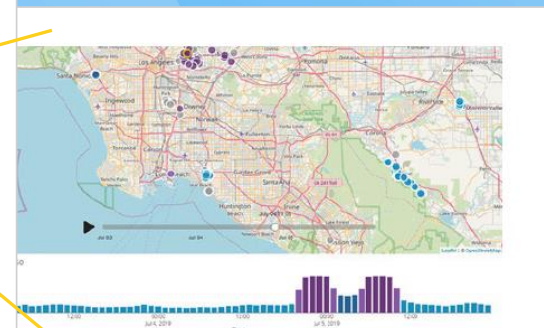
- Practical advice for siting, installing, and maintaining sensors
- Sensor co-location, correction, and calibration
- Introduction to different plot types, assessing accuracy, and useful quality control (QC) metrics/algorithms
- Ways to monitor the "State-of-Health" of deployed sensors
- Description 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

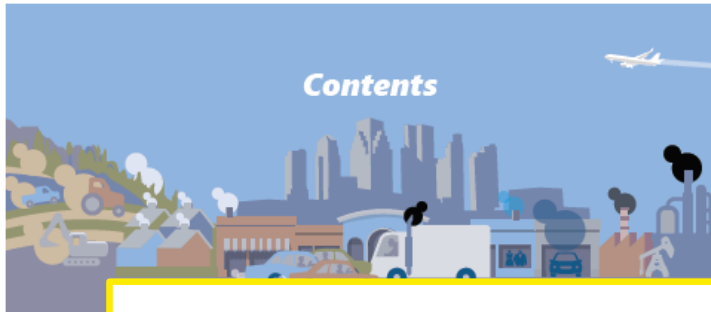
Calendar plots are useful for showing



4-8. elevated pollutant levels associated with the 4th of July are circled.

| Color Hex # (RGB) | PM <sub>2.5</sub> Concentration (µg/m <sup>3</sup> ) 24-hour averages | PM <sub>2.5</sub> Concentration (µg/m <sup>3</sup> ) 1-hour averages |
|-------------------|---|--|
| #A8D9E6           | PM <sub>2.5</sub> ≤ 8   | PM <sub>2.5</sub> ≤ 12   |
| #F3C865           | 8 < PM <sub>2.5</sub> ≤ 20  | 12 < PM <sub>2.5</sub> ≤ 35  |
| #E29E90           | 20 < PM <sub>2.5</sub> ≤ 35   | 35 < PM <sub>2.5</sub> ≤ 55  |
| #B65965           | 35 < PM <sub>2.5</sub> < 55   | 55 < PM <sub>2.5</sub> < 75  |

Figure 4-9. Map and time series from the AirSensor DataViewer tool showing high PM<sub>2.5</sub> 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.



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

#### Other Mitigation Strategies

At a higher level of funding and city...

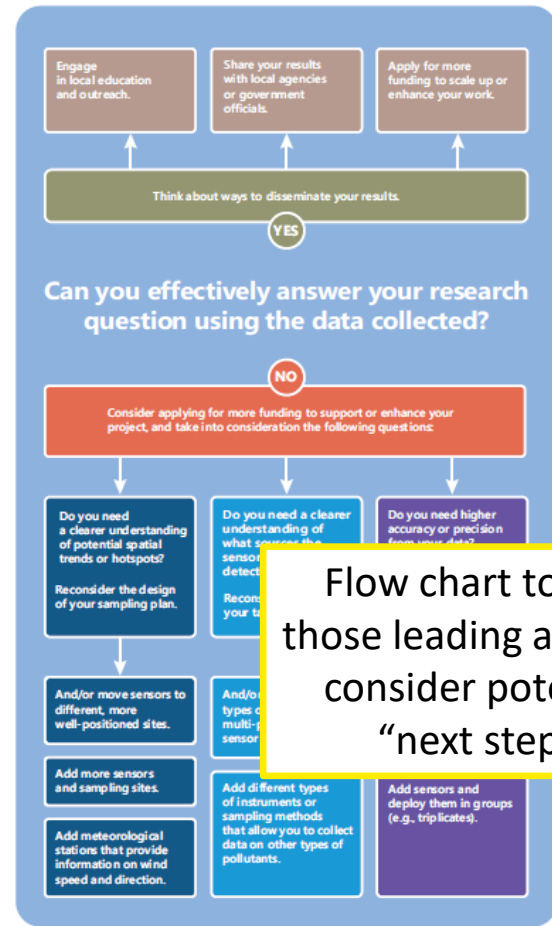
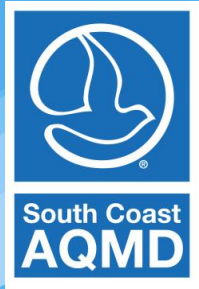


Figure 5-1. Use this decision tree to determine whether more measurements are needed to meet project objectives.

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**





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