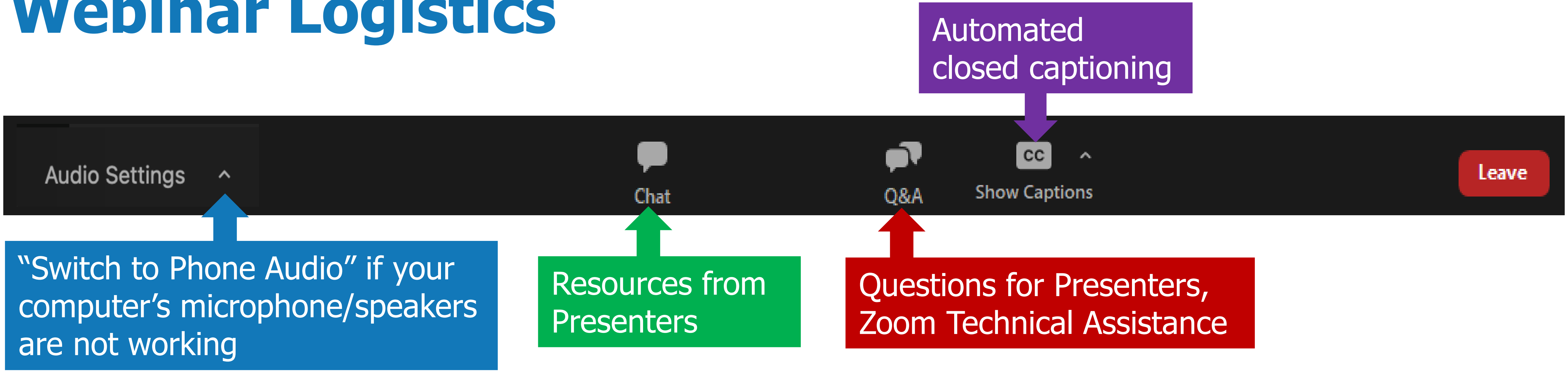
Community Air Monitoring Fundamentals

Webinar 5:
Building an Air Monitoring Network: Installation, Operation, Data Analysis, and Communication

TD Enviro
Eastern Research Group, Inc. (ERG)
US EPA Office of Air Quality Planning and Standards

Webinar Logistics



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Your Speakers

TD Enviro

Story Schwantes

TD Enviro

Tim Dye

TD Enviro

Helena Pliszka

Overview of Webinar Series

Fundamentals of Air Quality:

Webinar #1: Introduction to Air Quality Concepts and Regulations

Webinar #2: Introduction to Community Air Monitoring and Measurements

Building Community Air Monitoring Network:

Webinar #3: Objectives and Data Management

Webinar #4: Selecting Equipment, QAPPs, and Siting a Monitoring Device

Webinar #5: Installation, Operation, Data Analysis, and Communication

Agenda

1 Installation and Operation

2 Analyzing and Communicating data

3 Where To Go From Here

4 Recap

5 Thank You

6 Q&A

Recap of Webinar 4

- Selecting equipment
- Planning and QAPPs
- Determining air monitoring network sites

Installation & Operation

Review Where You’re At

Before installing monitoring equipment, you should have already figured out:

- Your monitoring objective
- What data management system you’re using
- How your data management system (DMS) is set up
- A QAPP and/or monitoring plan
- What devices you are using to meet your objective
- The sites you’re installing at and all the logistics operating a sensor at each location

Review Device Instructions!

Not the most exciting read, but it’s important

Test Devices

Make sure they:

- Turn on
- Show reasonable data
- Send data to your DMS

Note device information (serial number, pollutants and other parameters, which device is installed at each location, etc.)

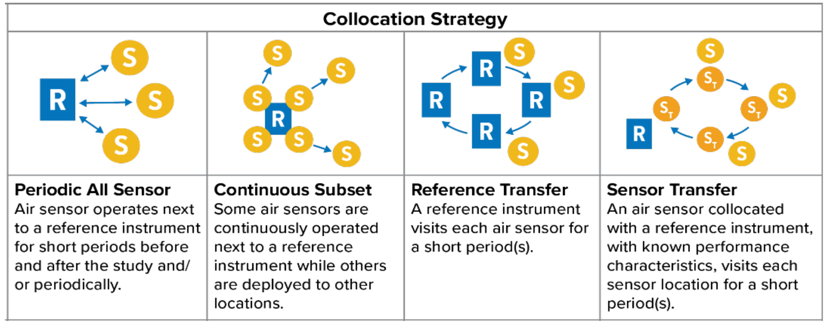
Collocate your Device(s)

Collocation is the process of checking the performance of a device (e.g., an air sensor) by installing and operating it near a reference instrument(s)

Raw data produced by devices may need to be adjusted to improve accuracy, called **correction**. Collocation allows you to see if a correction needs to occur and by how much

Collocation Shelter installed in Jacksonville, Florida

Collocate your Device(s) (cont.)

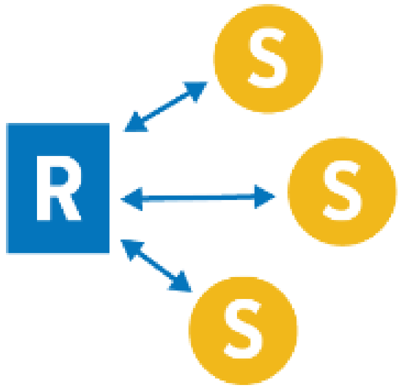
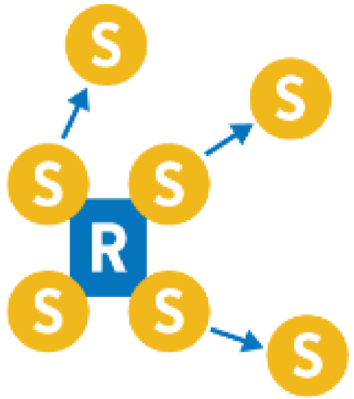
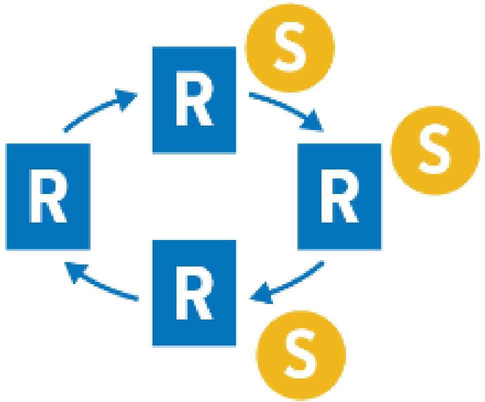
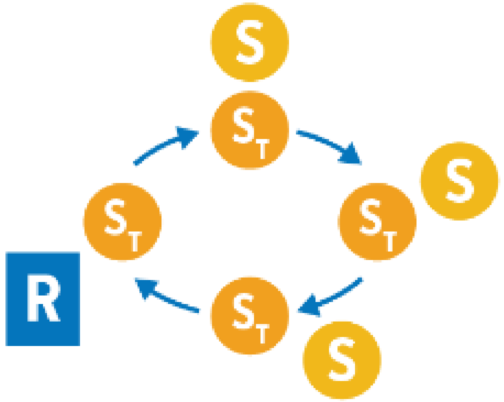


Tips for Collocation

- Collocate with a higher quality instrument (FRM, FEM, near-FEM)
  - If not available, collocate devices together to better understand how well their measurements compare
- Choose a collocation strategy that is both feasible and allows you to gain confidence in your data
  - Standard: Collocate all devices for at least 2 weeks (at beginning and end of study)
  - Bonus: Leave a device(s) at the reference instrument for full study period
  - Collect collocation data during a wide range of weather and pollution conditions
- Review data during collocation
- Compare device results to recommended EPA performance targets for air sensors (e.g., $PM_{2.5}$ and ozone)

Image source: EPA

Collocate your Device(s) (cont.)

Collocation Strategy			
			
Periodic All Sensor Air sensor operates next to a reference instrument for short periods before and after the study and/ or periodically.	**Continuous Subset** Some air sensors are continuously operated next to a reference instrument while others are deployed to other locations.	**Reference Transfer** A reference instrument visits each air sensor for a short period(s).	**Sensor Transfer** An air sensor collocated with a reference instrument, with known performance characteristics, visits each sensor location for a short period(s).

Install (Setup Checks from Webinar 3)

Make sure to record all metadata – (site address, device details, photos, nearby sources, etc.)

Ensure everything on the device and within the DMS is correctly set up and configured

Check for these common problems when a new device comes online:

- Data communication is unstable (e.g., WiFi, cellular signal is weak)
- Device is not receiving consistent power (e.g., solar panel not charging battery)
- Timestamp or time zone are incorrect
- GPS is off or information is incorrect
- Parameter names are inconsistent (e.g., PM2.5 vs. PM_2.5)
- Corrections/calibrations are not being applied to data

Operate Device (Operational Data Checks from Webinar 3)

Now that data are flowing from the device to the DMS, establish operational (i.e., day-to-day) procedures

- Review data to confirm all sites are reporting valid data
- Log any maintenance activities and document any changes
- Apply automatic and manual quality control checks
- Identify questionable data
- Correct or calibrate the data
- Visit site(s) on a routine basis to check on the device

Installation and Operation Guest Speaker

Karl Armstrong, Georgia Environmental Protection Division

Analyzing & Communicating Data

Revisit Your Objectives!

What did I want to learn from this data?

Who is the audience for the data and/or analysis?

Data Wrangling

Data Harmonization

Synchronize data across sites and parameters

- Format data files and types
- Align time zones and time standards
- Ensure units are uniform
- Harmonize parameter data with metadata (site locations, latitude, longitude)
- Ensure consistent averaging periods

Project Metadata				
Site Name	Site Desciption	Latitude	Longitude	Timezone
Site A	Citizen Science Air Monitor	40.7106	-74.1243	EST
Site B	Federal Monitor	40.711	-74.1213	EST

Site A PM2.5 Data	
Datetime (LST)	PM_2_5
4/7/2015 11:10:00	30.2
4/7/2015 11:15:00	27.38
4/7/2015 11:20:00	26.72
4/7/2015 11:25:00	25.61
4/7/2015 11:30:00	22.24
4/7/2015 11:35:00	22.13

Site B PM2.5 Data	
Datetime (UTC)	PM2.5
4/7/2015 16:10:00	23.8
4/7/2015 16:15:00	23.4
4/7/2015 16:20:00	23.8
4/7/2015 16:25:00	23.6
4/7/2015 16:30:00	23.2
4/7/2015 16:35:00	22.5

Harmonized data, metadata in local time zone

Datetime (EST)	Site Name	Site Description	Latitude	Longitude	PM2.5
4/7/2015 11:10:00	Site A	Citizen Science Air Monitor	40.7106	-74.1243	30.2
4/7/2015 11:15:00	Site A	Citizen Science Air Monitor	40.7106	-74.1243	27.38
4/7/2015 11:20:00	Site A	Citizen Science Air Monitor	40.7106	-74.1243	26.72
4/7/2015 11:25:00	Site A	Citizen Science Air Monitor	40.7106	-74.1243	25.61
4/7/2015 11:30:00	Site A	Citizen Science Air Monitor	40.7106	-74.1243	22.24
4/7/2015 11:35:00	Site A	Citizen Science Air Monitor	40.7106	-74.1243	22.13
4/7/2015 11:10:00	Site B	Federal Monitor	40.711	-74.1213	23.8
4/7/2015 11:15:00	Site B	Federal Monitor	40.711	-74.1213	23.4
4/7/2015 11:20:00	Site B	Federal Monitor	40.711	-74.1213	23.8
4/7/2015 11:25:00	Site B	Federal Monitor	40.711	-74.1213	23.6
4/7/2015 11:30:00	Site B	Federal Monitor	40.711	-74.1213	23.2
4/7/2015 11:35:00	Site B	Federal Monitor	40.711	-74.1213	22.5

QC Steps

Start early – it takes time to create quality data!

General Tips:

- Perform maintenance and repairs
- Review data every day – it's one of the best ways to spot problems
- Document problems, outcomes, and activities
- Use both automated (e.g., range) and manual (data review) checks
- Don't analyze data that hasn't been QC'd
- A DMS may have tools to do QC

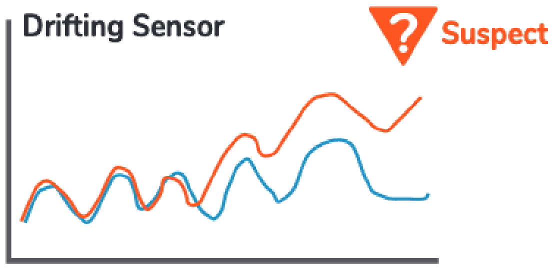
Enhanced Air Sensor Guidebook describes these in more detail!

QC Check	Description
Units	Check that the sensor reports data in the correct units of measure.
Time	Check that the sensor reports data at the correct time and in the right time zone. Check times after any seasonal time changes (e.g., daylight savings time).
Timestamp	Determine the timestamp, which is the time when data are stamped (i.e., tagged) by an instrument. Measurements and data averages will have times that either represent the beginning of the time period (time beginning) or the end of the period (time ending).
Matching Timestamps	Check the time zones and timestamps for each dataset to make sure they are similar when comparing measurements made by different instruments.
Data Review	Check data frequently (e.g., daily, weekly) to detect problems early, identify trends in the data, ensure that maintenance activities were completed, and become familiar with recurring patterns (see Section 3.7.1).
Data Completeness	Completeness measures the amount of data a sensor collects compared to the amount of data that was possible to collect if the sensor operated continuously, without data outages, during a period (e.g., 1-hour, 1-day). A 75% completeness level is a useful criterion to meet as the averaged data is generally representative of that time period. For example, at least 45, 1-minute measurements are needed to make a valid 1-hour average at 75% completeness.
Automatic Data Checks	Software can check data for problems and outliers. Check your data management system for these and other data checks. Note that some data checks may not catch subtle problems (e.g., a gas sensor degrading and slowly losing its response) or may flag an infrequent event or very high concentrations (e.g., high $PM_{2.5}$ concentrations from wildfire smoke) as bad data. Do not solely rely on automatic QC to check data quality; always do frequent manual data reviews. Common automatic checks include: • **Range**. Check the minimum and maximum concentrations expected and recognize some air sensors may report slightly negative values. • **Rate of Change**. Check the difference in data values from an air sensor between two consecutive time periods (e.g., hours). Flag the data if the difference, or rate of change, exceeds the value set by the user. For example, it is unusual for $PM_{2.5}$ concentrations to jump by more than 100 µg/m^3 from one hour to the next unless a significant source such as wildfire smoke or fireworks is present. Thus, if the value for the rate of change check is set to 100 µg/m^3, an increase from 70 µg/m^3 to 200 µg/m^3 between consecutive hours would exceed the rate-of-change check.

Image source: EPA

QA/QC Steps

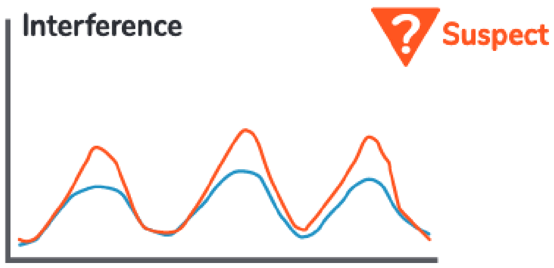
Check for common problems in the data:



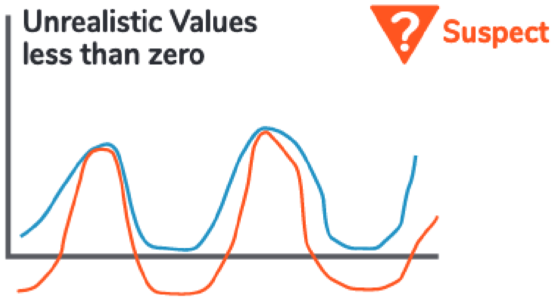
Bias
Gradual positive or negative change in a sensor's response over time (e.g., aging of the sensor component)

Unexpected downtime
Affects completeness of data

Missing parameter data
Some sensors may report more than one parameter important to check



Interferences
Other pollutants that interfere with the measurement of the target pollutant



Unexpected problems
e.g., large negative values, high values caused by sensor failure and outliers

Note: Time series are just one way to review data. Other forms (data summaries, AQI, and maps) can also be helpful for QC

Reference Instrument
Air Sensor

Image source: BAC

Averaging

Allows you to evaluate "big picture" signals in data
It also enables you to compare your data to other indicators (e.g., standards) like:

- Air Quality Index (AQI)
- National Ambient Air Quality Standards (NAAQS)

Typical averaging methods:

- Hourly
- 8-hour
- Daily (24 hours)
- Annual

Averaging best practices:

- Quality control data before averaging
- Make sure averages are representative
    - Use completeness criteria (>75% of the data required to make an average)

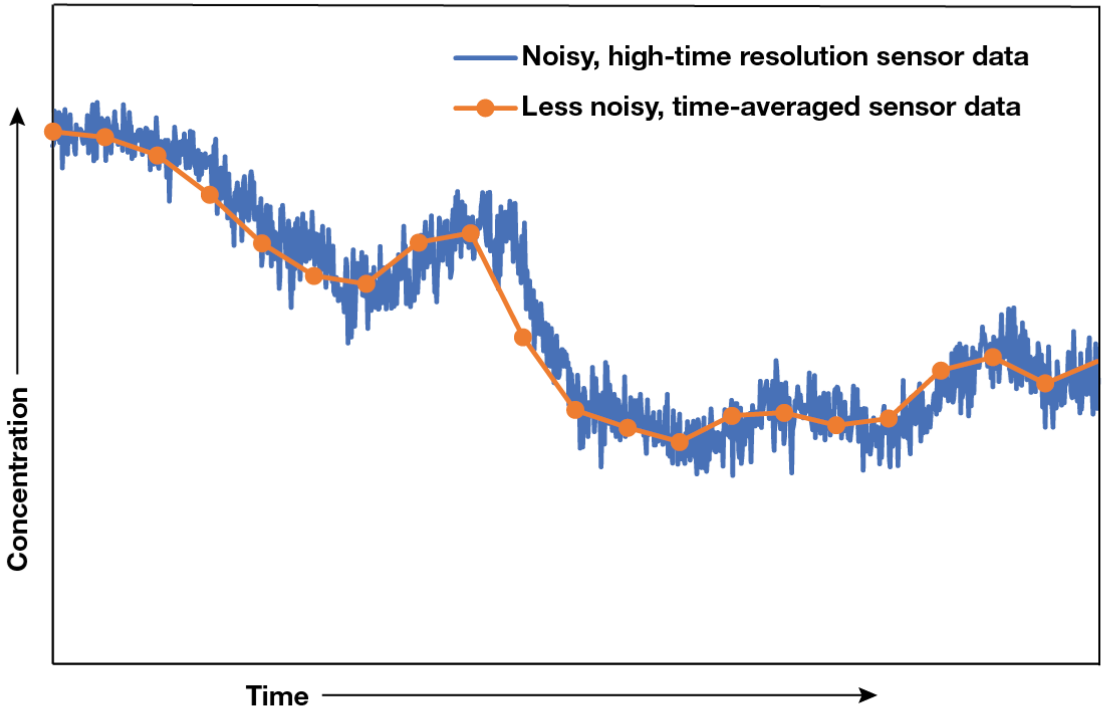


Image source: EPA

Data Analysis

Types of Data Analysis

1. **Comparing data across space and time**
2. **Comparing data to health-based standards**
3. **Exploring data and asking questions**
   e.g., Are there certain characteristics (weather conditions, emissions patterns, days of the week) that lead to high concentrations?

Which approach to use depends on project objective(s)

- Range from relatively simple to more complex
- The more complex, the more interpretation and the more challenging to communicate

Tip: Do not wait until data have been collected to determine how you will use the data. Evaluating the results may reveal unanswered questions that revise or update your questions or other steps in your plan

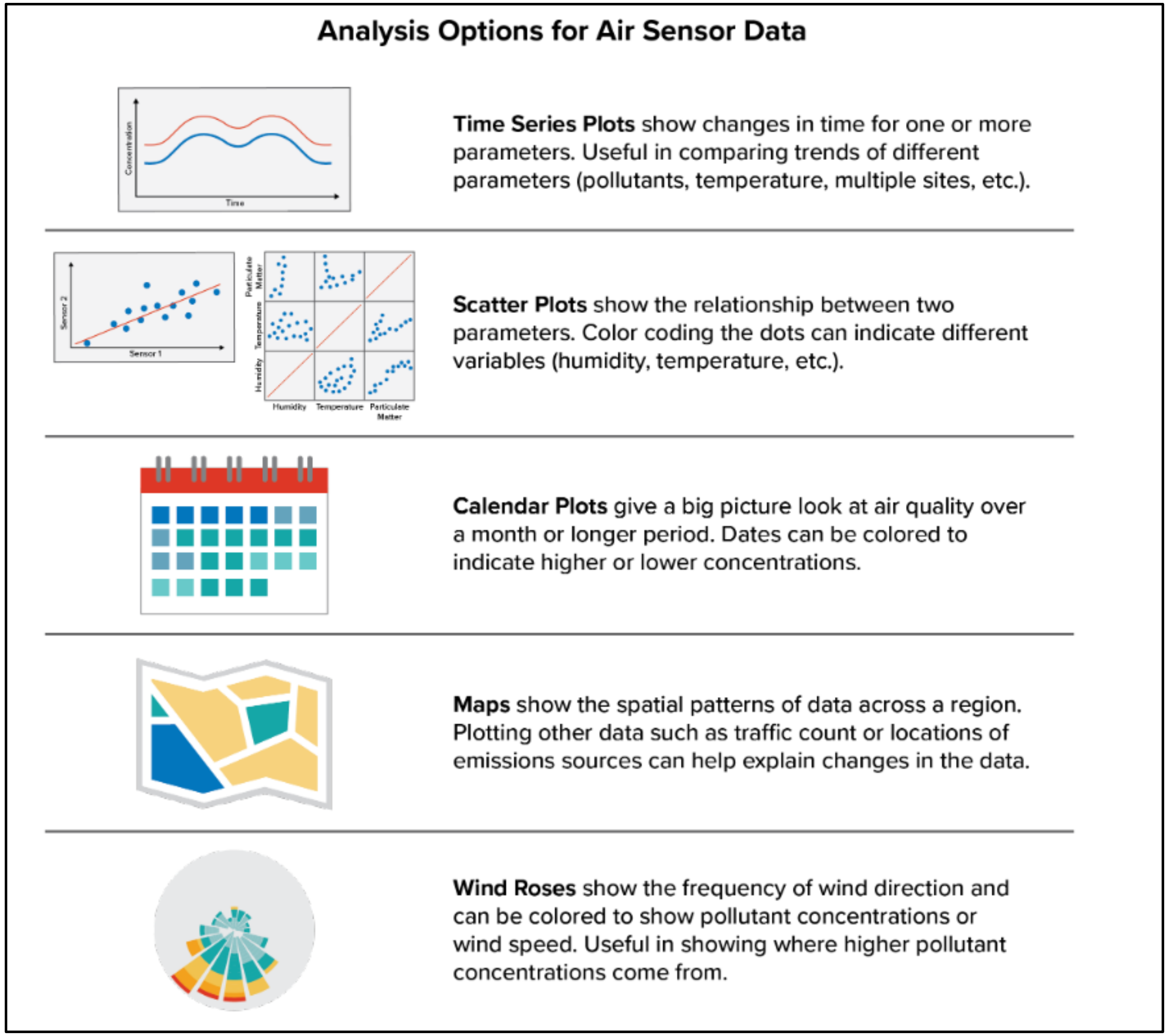


Image source: EPA

Time Series

Explore changes over time for one or more pollutants or parameters

- Useful for comparing trends across different parameters (pollutants, temperature, multiple sites, etc.)
- Averaged data can be compared to NAAQS or AQI

Possible Questions to Ask:

- How do measured concentrations compare to concentrations from nearby reference stations?
- How do measured concentrations compare to health indices like the AQI?

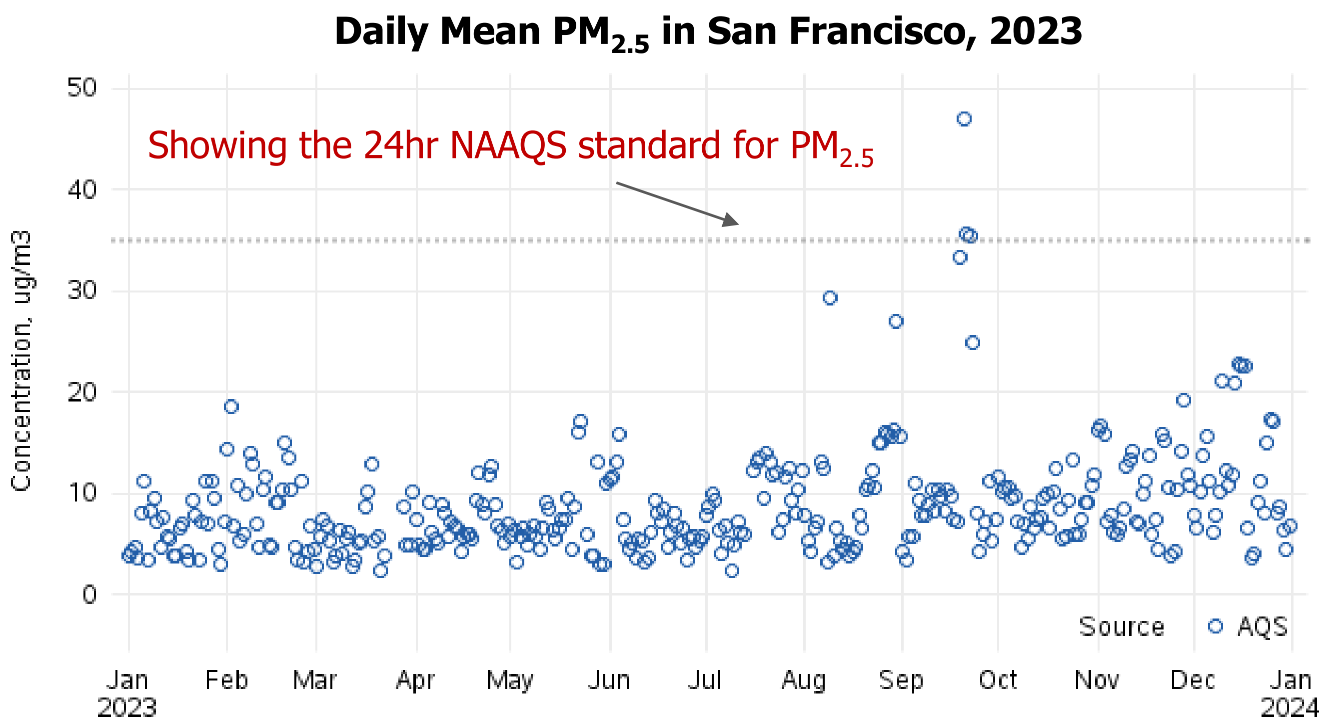


Image source: EPA

Diurnal and Weekly Trends

Group the data by time of day (diurnal) or day of the week to explore patterns across time

Possible questions to ask:

- Are pollutant levels higher on certain days of the week?
- How do pollutant concentrations change during the day?
- Is rush hour traffic or other activity (e.g., construction, fireworks) influencing diurnal levels?

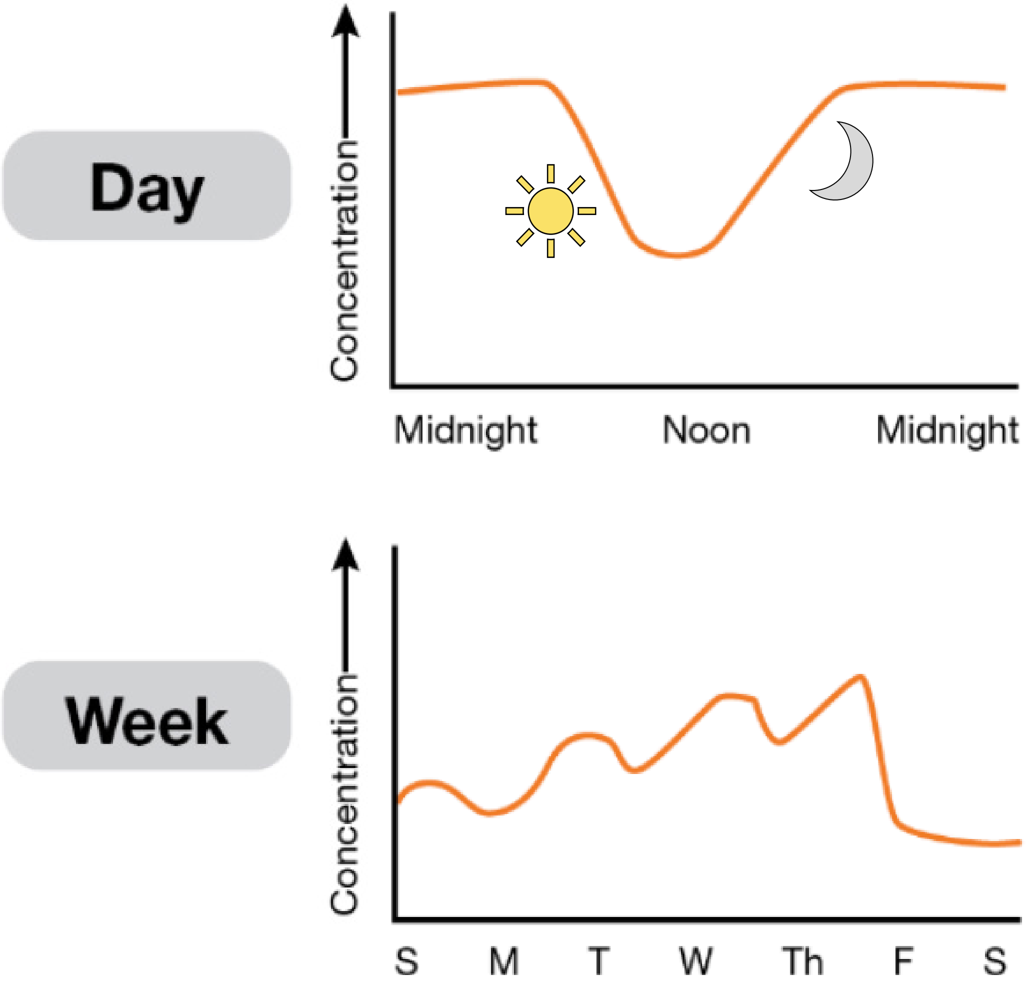
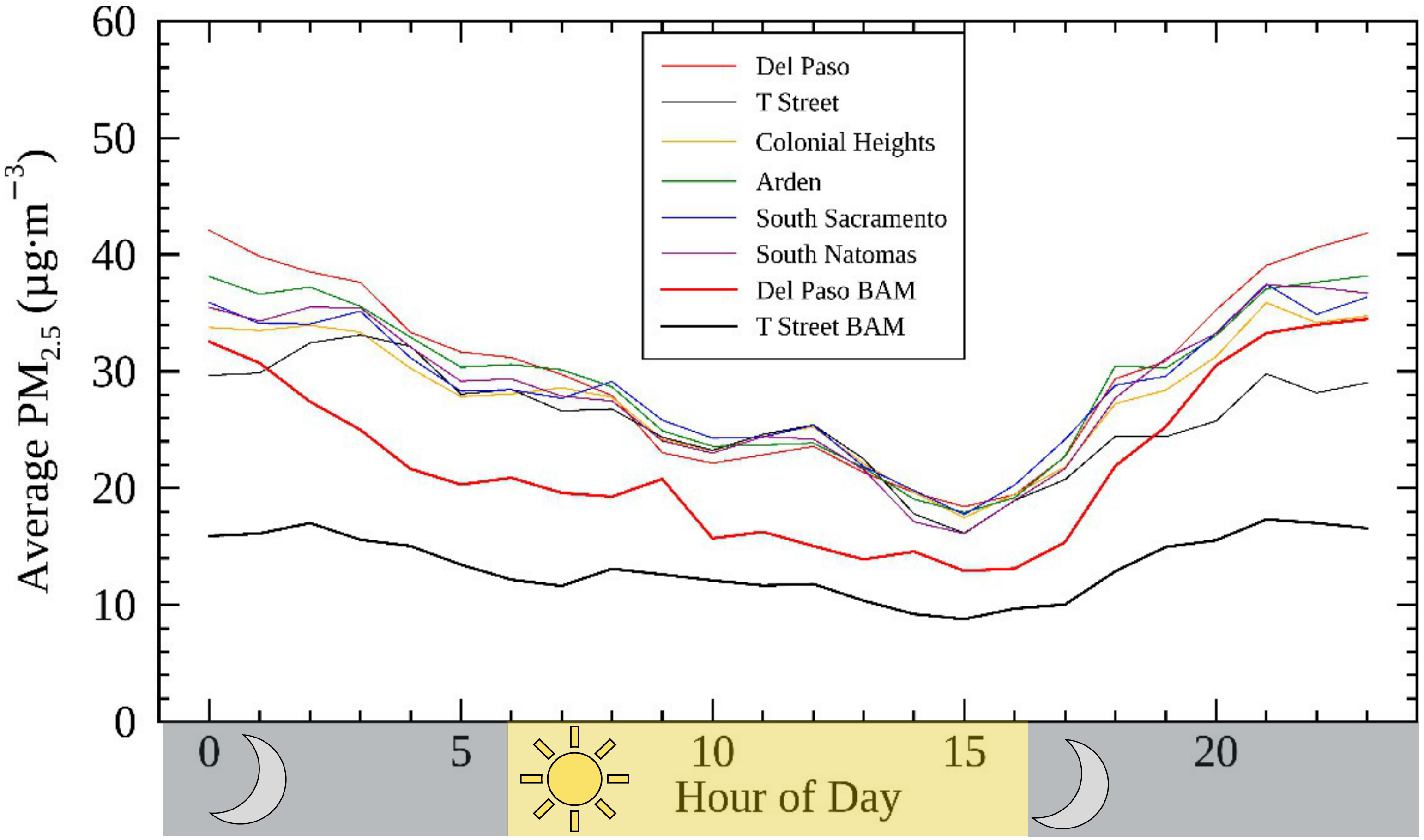


Image source: EPA

Example of Diurnal and Weekly Trends



Diurnal $PM_{2.5}$ sensor data from the six communities across Sacramento

Image source: Mukherjee et al. 2019

Calendar Plots

Provide a 'big picture' look at air quality over a month or longer period

- Dates can be colored to indicate a range of concentrations or AQI
- Helps illustrate trends across seasons

In this example, summer/fall months have more "Unhealthy" to "Hazardous" days from wildfires. Winter months have moderate days from residential woodsmoke

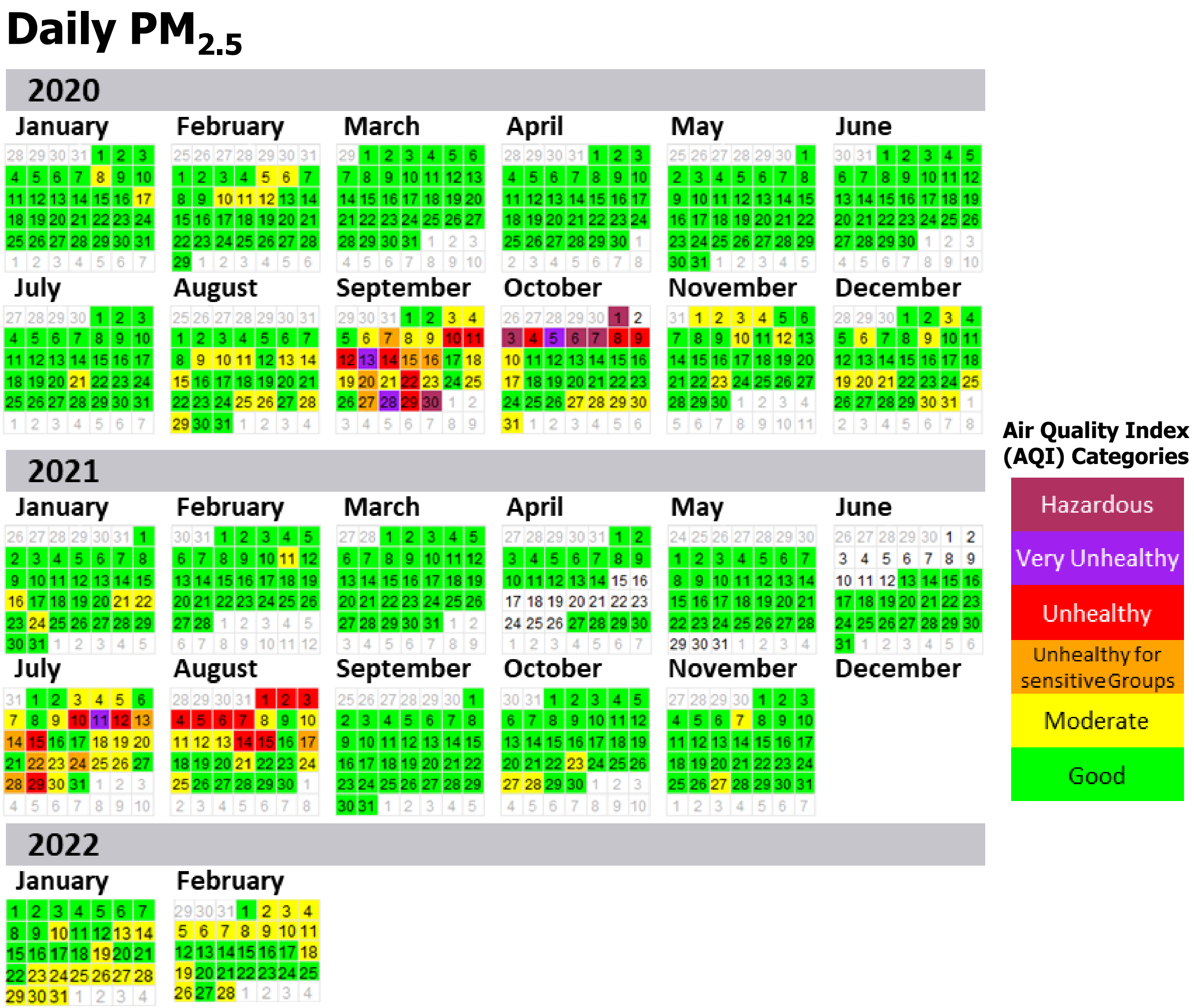


Image source: EPA

Maps

Show the spatial patterns of data across the project area

Tips for mapping:

- Label maps with date and time
- Add a key to show symbology
- Plotting other data such as traffic count, weather data, EJ data (EJScreen), or locations of emissions sources can help explain differences in the data
- Animations can show how a pollutant changes over space and time
- Resources: ArcGIS Online, Google Earth, device DMS

Possible Questions to Ask:
- Where do high (or low) concentrations occur? Are there patterns or clusters?
- Do certain conditions (weather, traffic patterns, etc.) occur when/where high concentrations are?

$PM_{2.5}$ sensor and reference data during wildfire season in the San Francisco, CA area

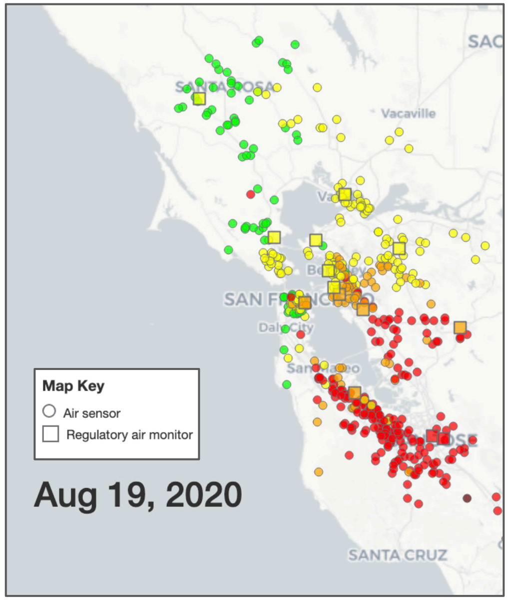


Image source: BAC

Mobile NO_2 in South Carolina

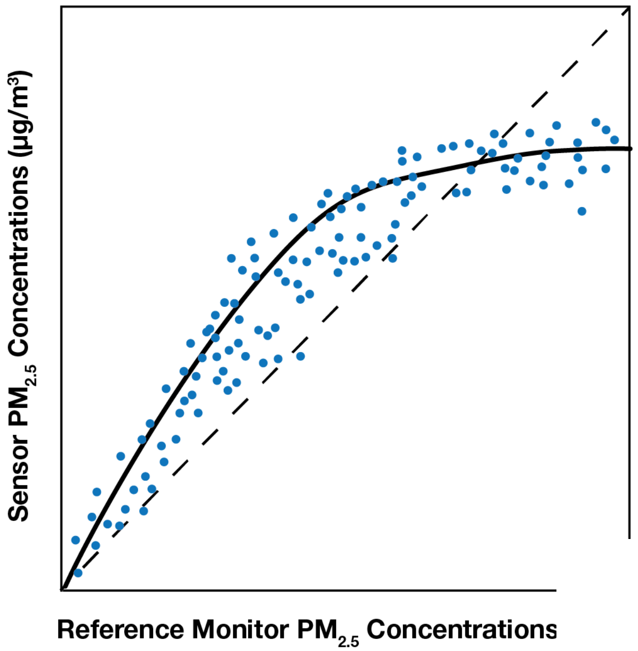
Image source: EPA

More Types of Analyses

Scatter Plots

Show the relationship between two parameters

- Helpful for evaluating collocation data and investigating relationships between different sites or parameters
- Color coding the dots can indicate different variables (humidity, temperature, etc.)

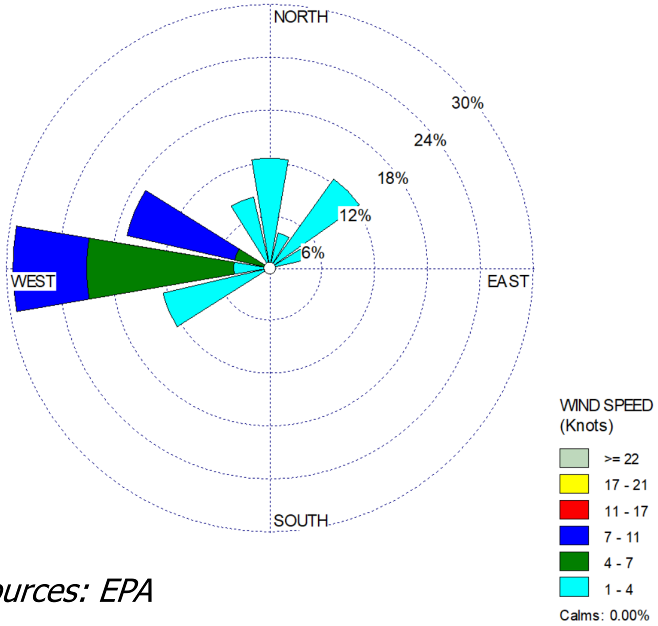


Scatter plot showing that an air sensor has a linear response at lower concentrations and a non-linear response at higher concentrations

Wind and Pollution Roses

Show the frequency of wind direction and can be colored to show pollutant concentrations or wind speed

- Useful in showing where higher pollutant concentrations come from
- Requires reliable local weather data



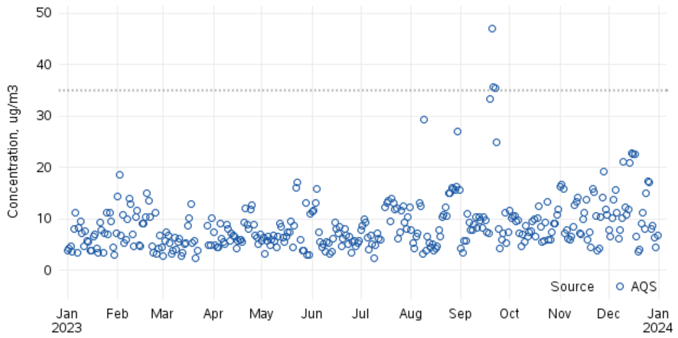
Wind rose showing majority of higher wind speeds coming from West and Northwest

Image sources: EPA

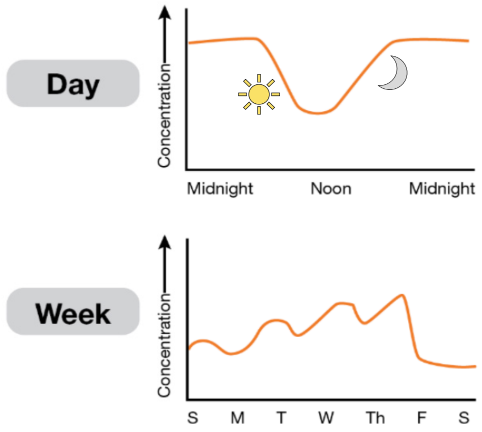
Poll:
Which of these plots do you find most useful?

Poll:
Which of these plots do you find most useful?

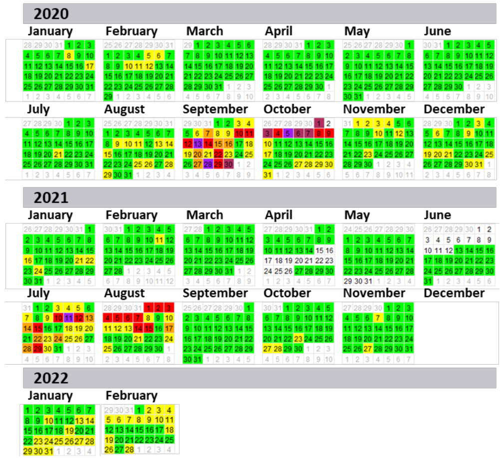
A. Time Series



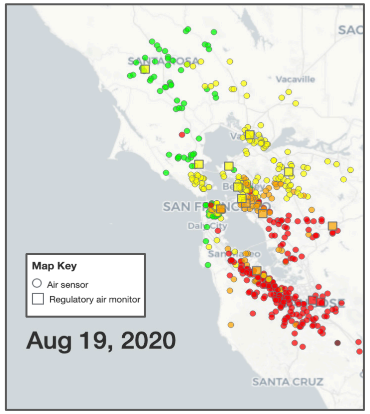
B. Diurnal and Weekly Trends



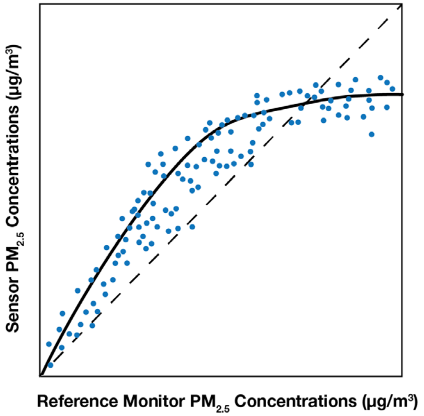
C. Calendar Plots



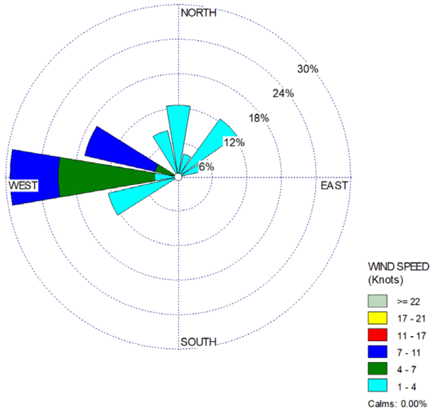
D. Maps



E. Scatter Plots



F. Wind/Pollution Rose



5 Minute Break

Resources for Analysis

Device Vendor Resources

Some air sensor companies may provide data visualization resources or a DMS with some analysis features

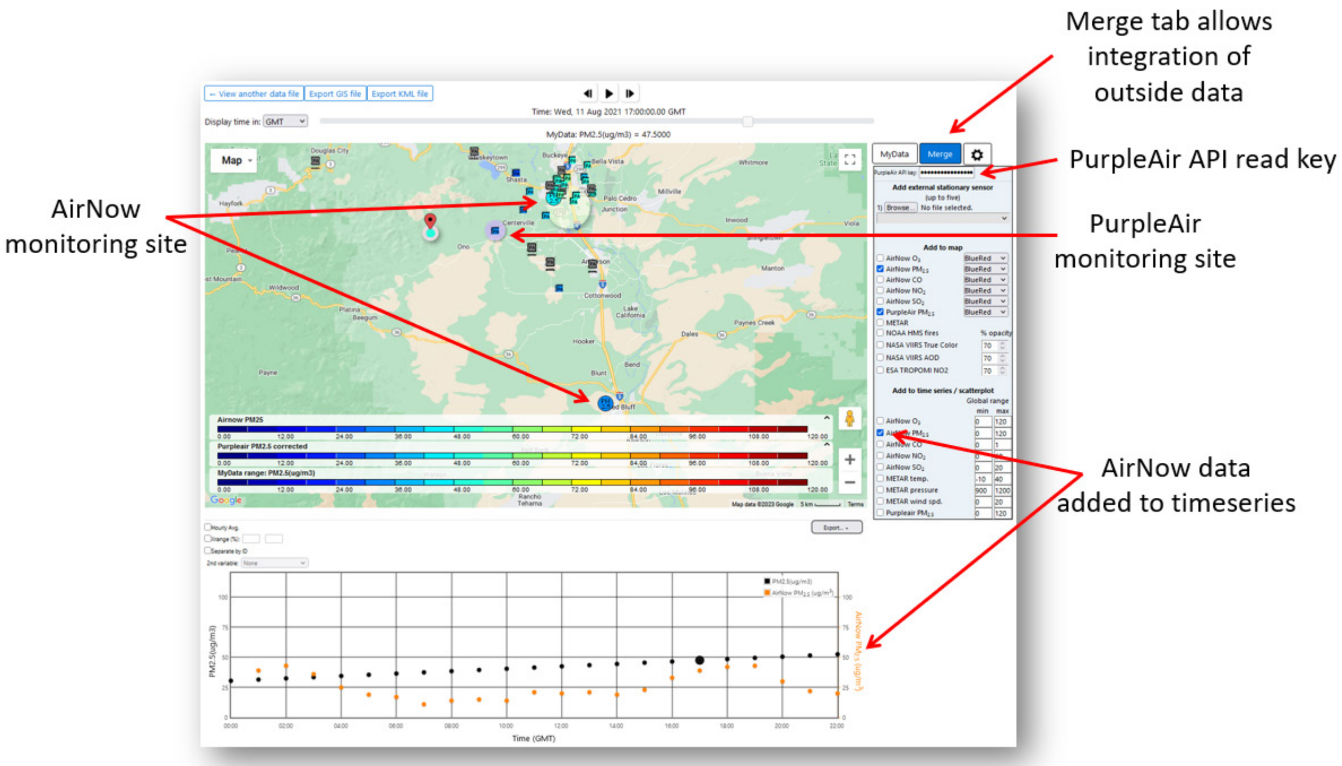
Assess the capabilities of the system:

- What visualizations are available? (time series, maps, data summaries)
- Is customization possible?
- Can visualization be saved or shared?
- Can additional data be ingested (e.g., weather stations or regulatory monitors)?
- Are there additional costs?

Project Partners

Other project partners (e.g., local air agencies, universities, etc.) can support data analysis

- Establish existing relationships with other groups early on
- What resources are available from these partnerships?
- Check with external project partners abou their programming experience and resourc



Example: EPA Real-Time Geospatial Data Viewer (RETIGO) – a free web-based tool that anyone can use to view data from their project and regulatory air quality or meteorological stations

Image source: EPA

Excel/Google Sheets

Spreadsheets are a great tool to support data analysis

- Simple analysis (time series, comparison plots, correlations)
- Can also serve as a DMS (simple data ingest and processing)
- Can handle smaller datasets (e.g., 1 – 2 sites)
- Widely available online help and tutorials

Make sure to evaluate project team experience with these tools beforehand!

Python and R

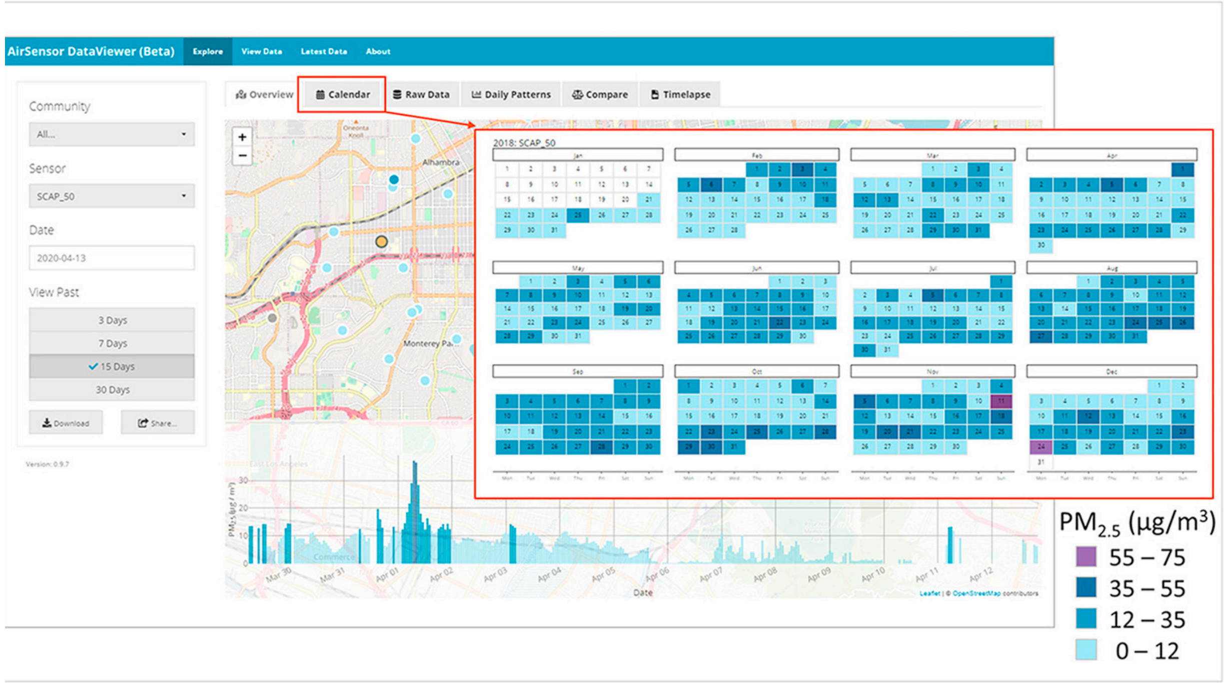
Free, open-source programming languages that support statistical computing and graphics

Things to consider:

- Python and R have large user communities with code-sharing practices
- Does your team have access to a computer and software?
- Does your team have programming experience? Keep in mind the steeper learning curve if training
- Will resources/expertise be available across the full project duration?

Some helpful resources:

- Openair - An R Package for Air Quality Data Analysis
- The AirSensor Open-source R-package and DataViewer
- EPA Sensortoolkit - Air Sensor Data Analysis Library (Python code library for evaluating air sensor data)



AirSensor and DataViewer. Image source: SCAQMD

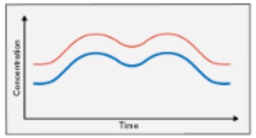
Poll:
Which of these resources do you or a member of your team have experience with?

Communicating Results

Communicating Results:

All these steps allow others to gain confidence in your data and results!

1. **State your Purpose/Objective** - Communicate why you conducted the study and why you made some of your decisions. Describe how your device data support meeting the project objective(s).
2. **Describe the Monitoring Setup and Data Collection** - Provide a description of where sensors were located and data collected. Make sure you include supporting information (e.g., device locations, site photographs, QC checks, time stamps, units).
3. **Describe the Data Processing and Analysis** - Share the methods used for data cleaning, corrections/adjustments, QC, data analysis and interpretation, and limitations of the data and your devices.
4. **Visualize Data and Share Results** - Be sure to include main take-aways and call to action or next steps for the project.



Tip: Know your audience before presenting your results!

- Who is in your audience? For example, a scientist may want technical details while others may want a big-picture summary
- How much information do they want?
- What type of visuals may work best for sharing results?

Project Narrative

+

Visuals

Sharing Project Story, Findings and Next Steps

Interactive End-of-Session Feedback

Where to go from here?

Accessing these resources

Video recordings will be available online

Encourage you to explore the EPA's website – lots of great resources:

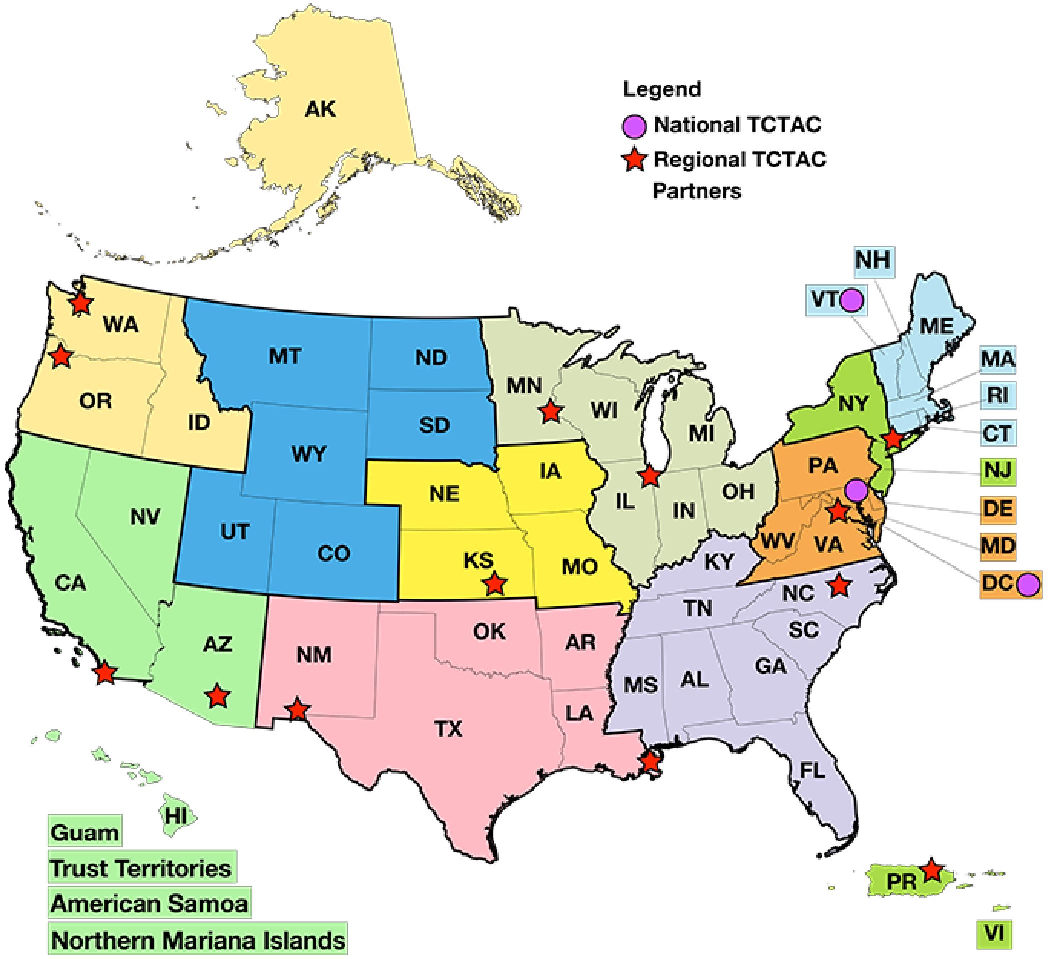
- Air Sensor Toolbox
- Enhanced Air Sensor Guidebook
- Quality Assurance Project Plan Development Tool
- Air Data

Resources for Assistance: EJ TCTACs

The Environmental Justice Thriving Communities Technical Assistance Centers (EJ TCTACs)

- 16 partners
- Training and assistance on federal grant application systems
- Assistance developing grant proposals and manage grant funding
- Provide guidance on community engagement, meeting facilitation, and translation and interpretation services

tinyurl.com/EJTCTACs



Other Suggestions & Resources

- Sign up for local air quality alerts
- Sign up for email listservs and/or social media posts from:
  - Local government air/environmental departments
  - Manufacturers and others in the air quality space
- Attend air quality conferences
- Connect with local university researchers doing air quality work

Reach out to others in your community working on air quality!

Recap

- Installing devices
- Operating devices
- Wrangling and analyzing data
- Communicating results

Recap of Webinar Series

Fundamentals of Air Quality:

Webinar #1: Introduction to Air Quality Concepts and Regulations

Webinar #2: Introduction to Air Monitoring and Measurements

Building an Air Monitoring Network:

Webinar #3: Objectives and Data Management

Webinar #4: Selecting Equipment, QAPPs, and Siting a Monitoring Device

Webinar #5: Installation, Operation, Data Analysis, and Communication

Thank You!

Q & A