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EPA Tools and Resources Webinar:
The Enhanced Air Sensor Guidebook

Andrea Clements and Rachelle Duvall
Center for Environmental Measurement and Modeling
US EPA Office of Research and Development (ORD)

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Presentation Outline

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- Problem
- Approach
- Results
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- Next Steps
- Anticipated Outcomes
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- Take Home Messages
- Resources
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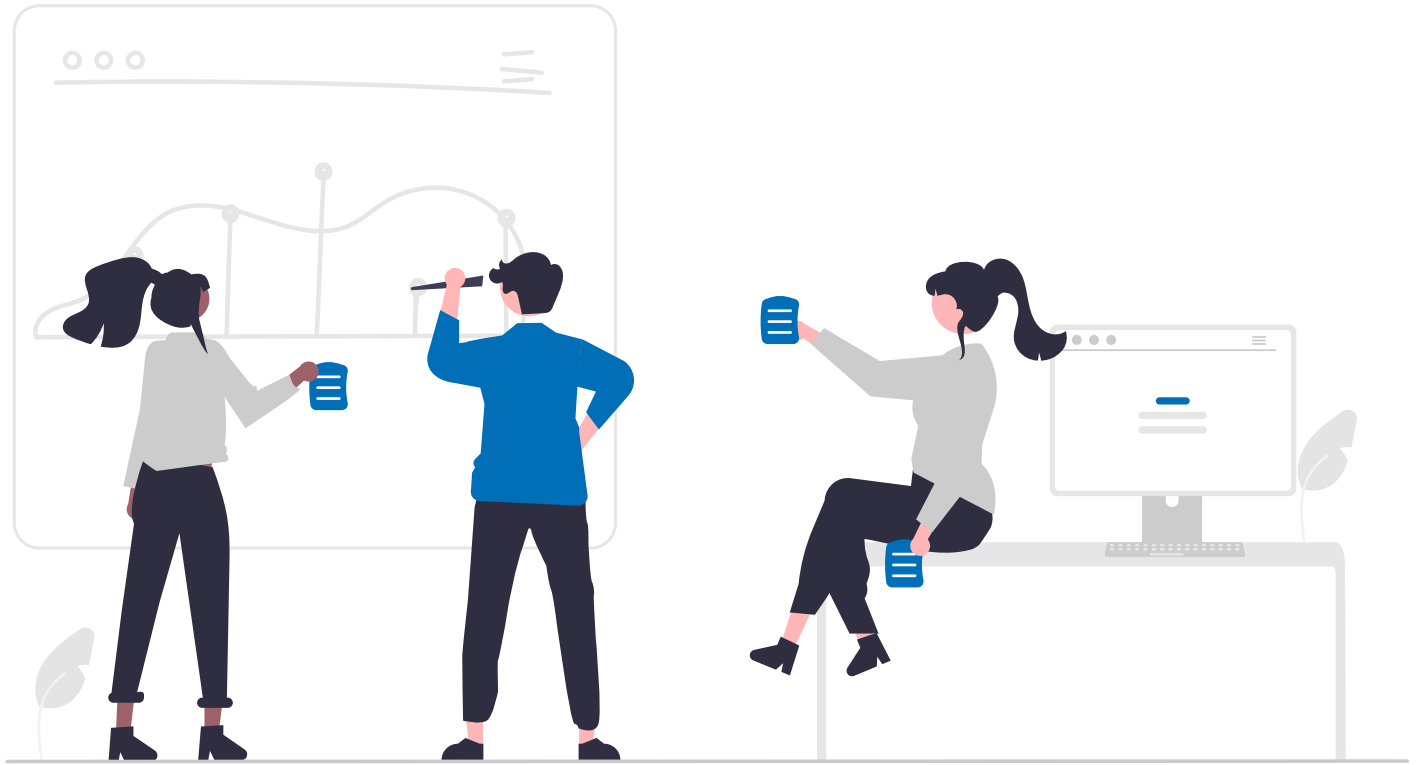


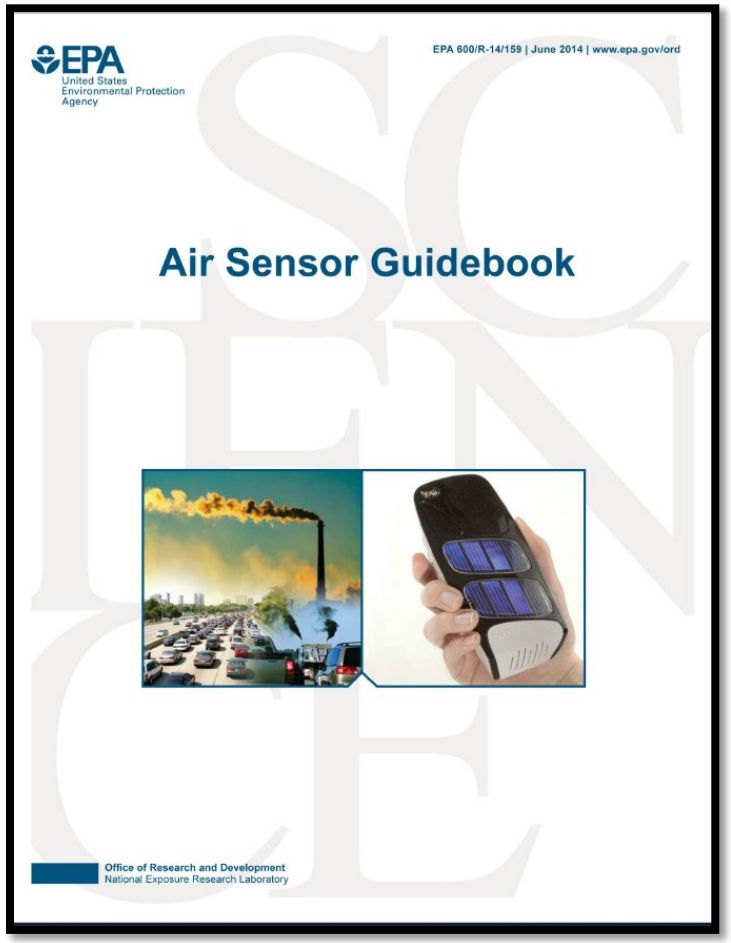
Background: Why Update the Guidebook?

- **Interest in and concern about local air quality** continues to grow
- **Availability of air sensors has increased** over the years, encouraging:
  - Increase in the number of air monitoring projects
  - Dramatic increase in the user base
- New and seasoned sensor **users can benefit from guidance and support** to effectively use air sensors
- Tribal, state, and local agencies need **easy-to-use resources** that can be shared with different audiences

EPA sought to update the Air Sensor Guidebook to provide effective support and resources to help the public conduct air quality monitoring projects using air sensors

Background: Air Sensor Guidebook

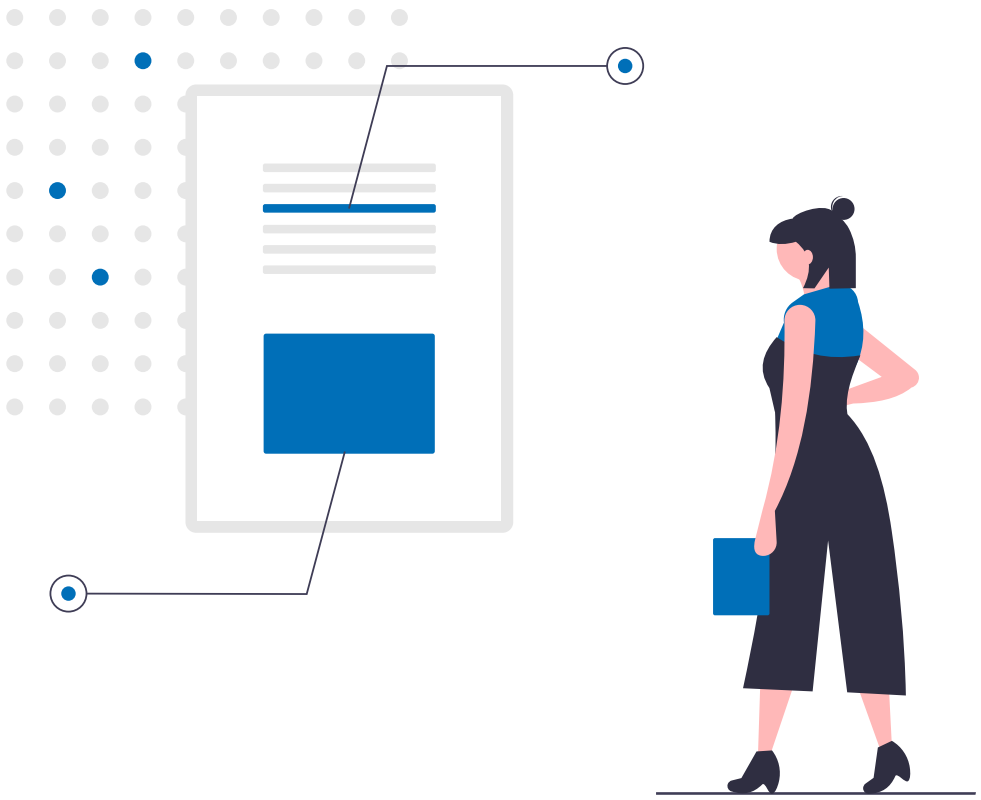
- **The original Air Sensor Guidebook was published in 2014** with the goal of helping air sensor users collect air quality measurements and interpret sensor data
- **The Guidebook is one of the most popular resources** on US EPA's Air Sensor Toolbox website averaging > 6,500 views per year
- This resource has largely been considered a **good starting point for new users**



Air Sensor Toolbox:
https://www.epa.gov/air-sensor-toolbox

Problem: Outdated Information

- **Review of the 2014 Guidebook found several issues**
  - Broken weblinks
  - Example projects were out-of-date
  - EPA shifted approach on some topics (e.g., sensor performance targets) and the information is no longer accurate
  - Some best practices have evolved and additional information could be provided to enable successful projects



Approach: Big Picture

Updated the Guidebook to reflect the state of the science and to include more evergreen content

Approach: Goals

- **Maintain this document as an one-stop-shop, easy-to-access reference** connecting users with the tools and information they need to use air sensors and appropriately interpret sensor data
- **Update the content** to incorporate best practices, current knowledge, and recommendations on the use of air sensors
- **Focus on lessons learned** using example projects, rather than actual projects, to keep content more evergreen

Approach: Getting Started

- **Reviewed 2014 guidebook**
  - What information needs to be updated?
  - What information is missing and where can we provide additional guidance?
  - Should the document structure be changed?
  - What new resources are available now?
- **Solicited feedback**
  - Met with EPA Regions and Program Offices
    - Included voices that may have been missing in 2014 (e.g., indoor air, environmental justice)
  - Gathered feedback about common questions, frustrations, and needs
  - Shared plans for updating the guidebook at meetings/conferences

Approach: Improving Content and Layout

- **Increased use of infographics** to convey important information
- **Included links to additional resources** in each section to enable users to dive deeper
- **Increased accessibility**
  - Included a full glossary to standardize definitions
  - Added hyperlinks to jump to related content
  - Considered Spanish translation, if feasible
- **Added "callout" boxes**
  - Green tip boxes highlight important information
  - Blue boxes answer common questions or provide additional information

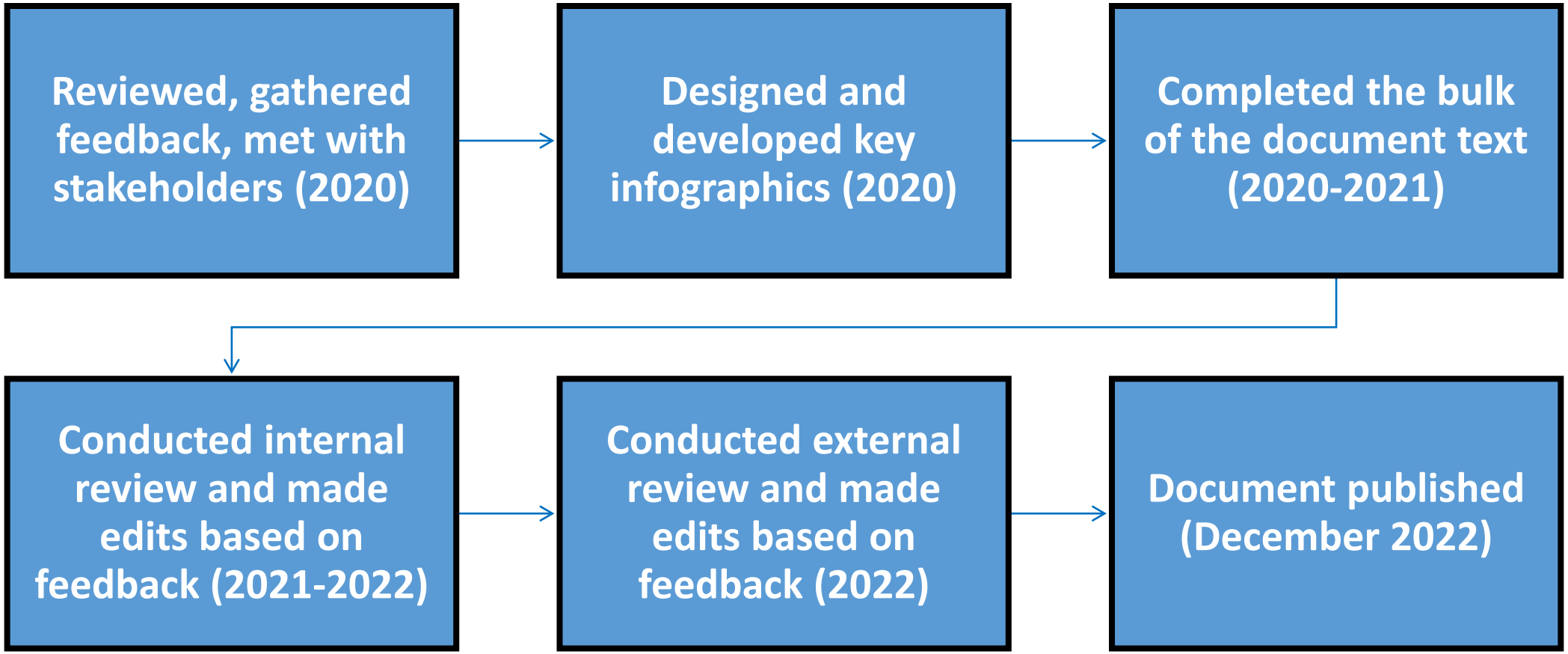
Tip: Carefully consider where to locate air sensors when conducting an air monitoring study

Carefully locating an air sensor will play a significant role in determining whether the data collected represent the location and are useful. Section 3.5 provides further discussion regarding where and how to properly place air sensor devices.

What are the Benefits of Frequent Data Review?

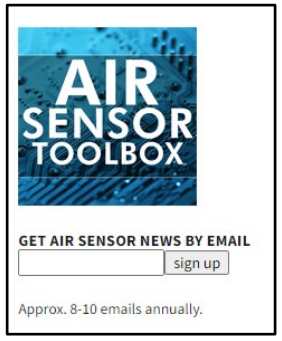
- Identify and resolve problems quickly
- Minimize data loss
- Learn what normal patterns look like
  - Detect real, high-pollution events early
  - Understand how air quality changes:
  - During the day
  - Weekend vs. weekday

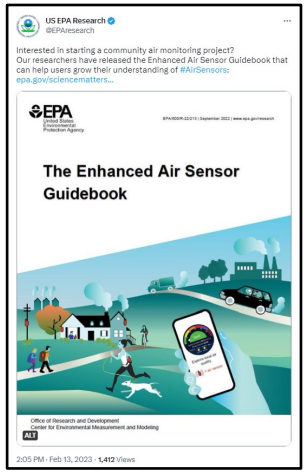
Approach: Timeline

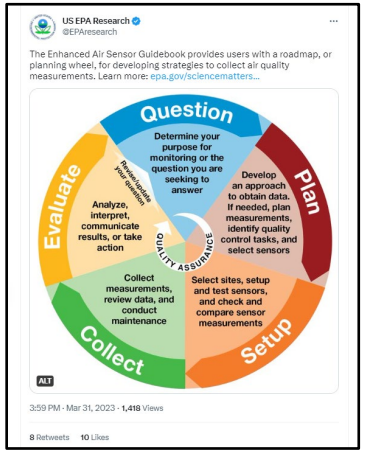


Results

- The **Enhanced Air Sensor Guidebook** was released in December 2022
- **A lot of interest!**
  - Guidebook accessed > 3,000 times (as of 4/5/2023)
- **Public notifications were shared**
  - Listservs (e.g., Air Sensor Toolbox , Air Monitoring)
  - Targeted emails
  - Social media







Available at: https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook

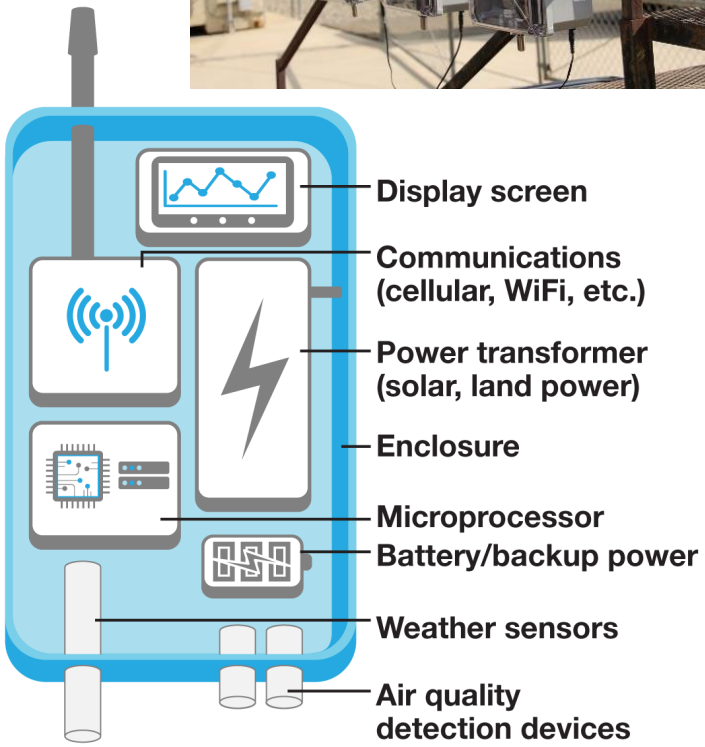
Guidebook Outline

- **Chapter 1**: Introduction to Air Sensors and the Guidebook
- **Chapter 2**: Air Quality 101
- **Chapter 3**: Monitoring Using Air Sensors
- **Chapter 4**: Air Sensor Performance Guidance
- **Appendices**
  - Appendix A: Resources
  - Appendix B: Questions to Consider When Planning for and Collecting Air Sensor Data, and Sharing Your Results
  - Appendix C: Checklists
  - Appendix D: Data Handling and Air Quality Index (AQI) Calculations
  - Appendix E: Interpreting Sensor Performance Evaluation Results
  - Appendix F: Glossary

Let's Take a Look Inside →

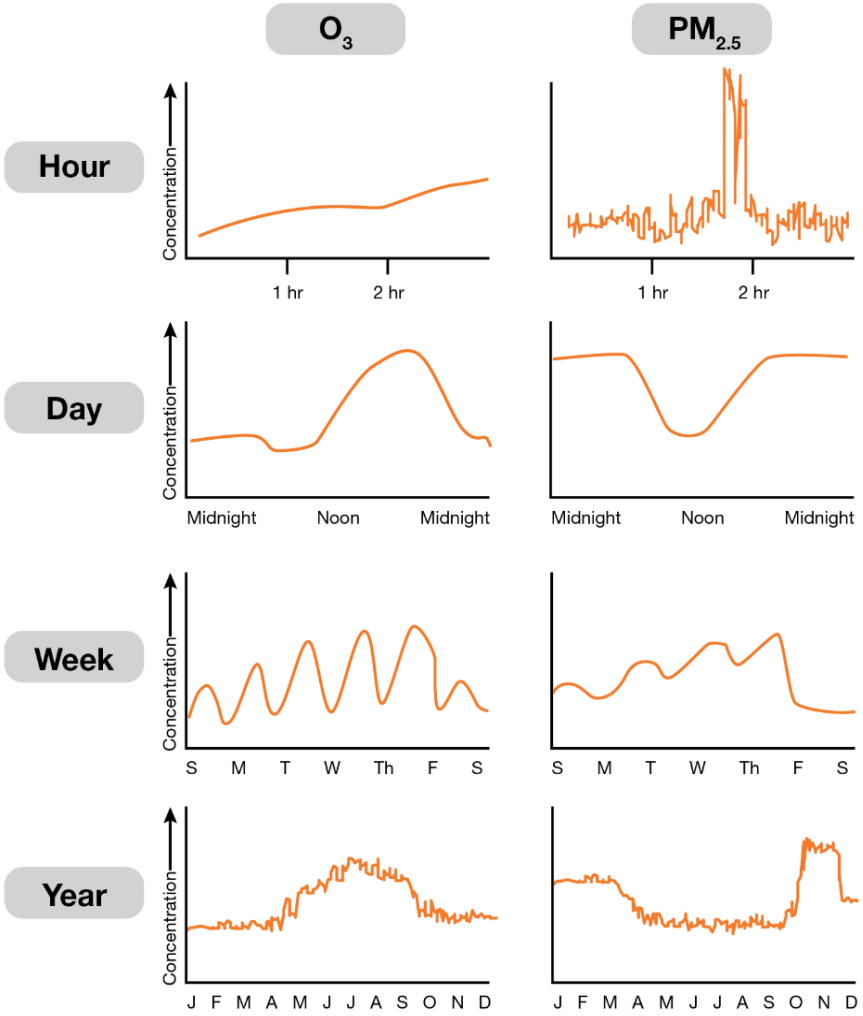
What's Inside: Chapter 1

- **Introduction to Air Sensors and the Guidebook**
  - Background information about air sensors
    - Common components
    - Common applications
    - Deployment examples
  - Purpose of the Enhanced Air Sensor Guidebook
  - Key differences between the 2014 Guidebook and this enhanced version
  - Intended audience of the Enhanced Guidebook
    - Participatory scientists, environmental agency officials, researchers, health professionals, emergency responders, technology developers, educators, and the public



What's Inside: Chapter 2

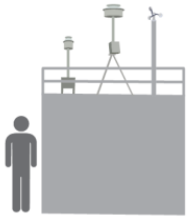
- **Air Quality 101**
  - Overview of outdoor air quality and air pollution
    - Types of pollutants, sources, and typical concentrations
    - Pollutant lifecycle
    - Pollutant concentrations vary with time
  - Pollutant effects on health and the environment
  - Outdoor air pollution monitoring approaches
  - Air quality standards and indices
  - Information on the Air Quality Index (AQI)



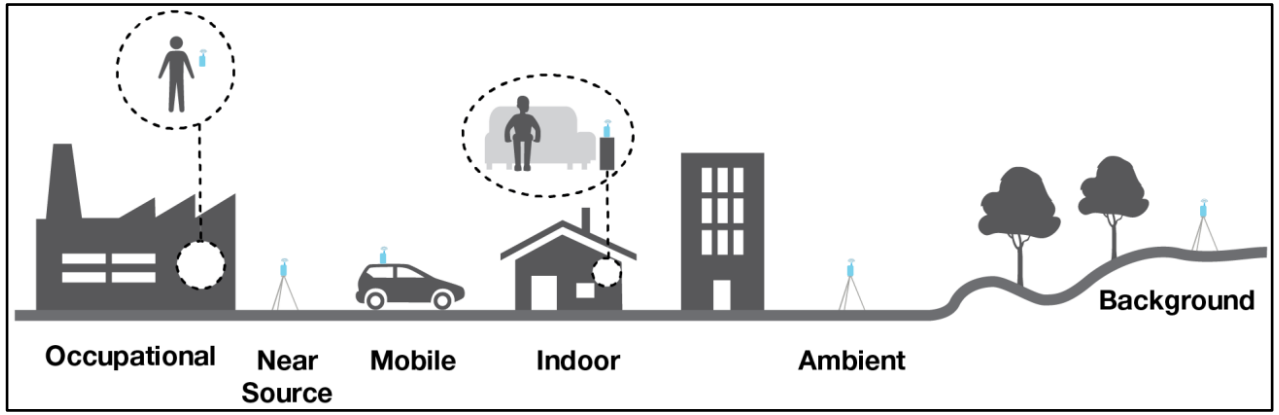
What's Inside: Chapter 2

Examples of infographics and callout boxes

Common Air Monitoring Approaches

	Reference (Certified)		Remote Sensing		Air Sensor
	Sampler	Continuous	Ground-based	Space-based	
					
Accuracy	High	High	High	Varies	Varies
Complexity	High	High	High	High	Low
Measurement Frequency	Daily	Sub hourly to hourly	Sub hourly	Hourly to Daily	Sub hourly
Relative Cost	**$$**	**$$$**	**$$$$**	**$$$**	**$**

Different Air Monitoring Locations



How Can I Compare Air Sensor Measurements to the NAAQS or AQI for Informational Purposes?

When comparing measurements from an air sensor to the NAAQS or AQI, it is important to remember that air sensors may over- or under-estimate pollutant concentrations (see *Section 3.6*). Therefore, sensor data must be cleaned and corrected and then averaged to match the time average specified for the pollutant and air quality standard or index. For example, to compare O_3 air sensor measurements provided every minute to the 8-hour NAAQS for O_3 of 70 ppb, you would need to clean and correct the O_3 sensor data and then calculate an 8-hour average from the 1-minute sensor measurements before comparing.

What Happens if an Air Pollutant Measurement is Above the NAAQS Concentration Level for the Specified Averaging Period?

Each NAAQS has a 'form' (see Table 2-4) which is a criterion for how many times the standard may be exceeded in a certain timeframe. Even though a measured concentration may exceed the NAAQS (called an **exceedance**), it does not constitute a NAAQS violation. So, what is a NAAQS **exceedance** vs. a NAAQS **violation**?

A NAAQS **exceedance** occurs when a measured concentration exceeds the concentration level for the averaging period specified by the NAAQS. For example, an exceedance of the short-term (24-hour) $PM_{2.5}$ NAAQS occurs when the $PM_{2.5}$ concentration measured at a regulatory air monitoring location is greater than 35 $\mu g/m^3$.

Air monitoring agencies must report NAAQS exceedances to the public.

A NAAQS **violation** occurs when a measured concentration level exceeds the concentration level for the specified NAAQS averaging period for specific criteria over a specified timeframe. For example:

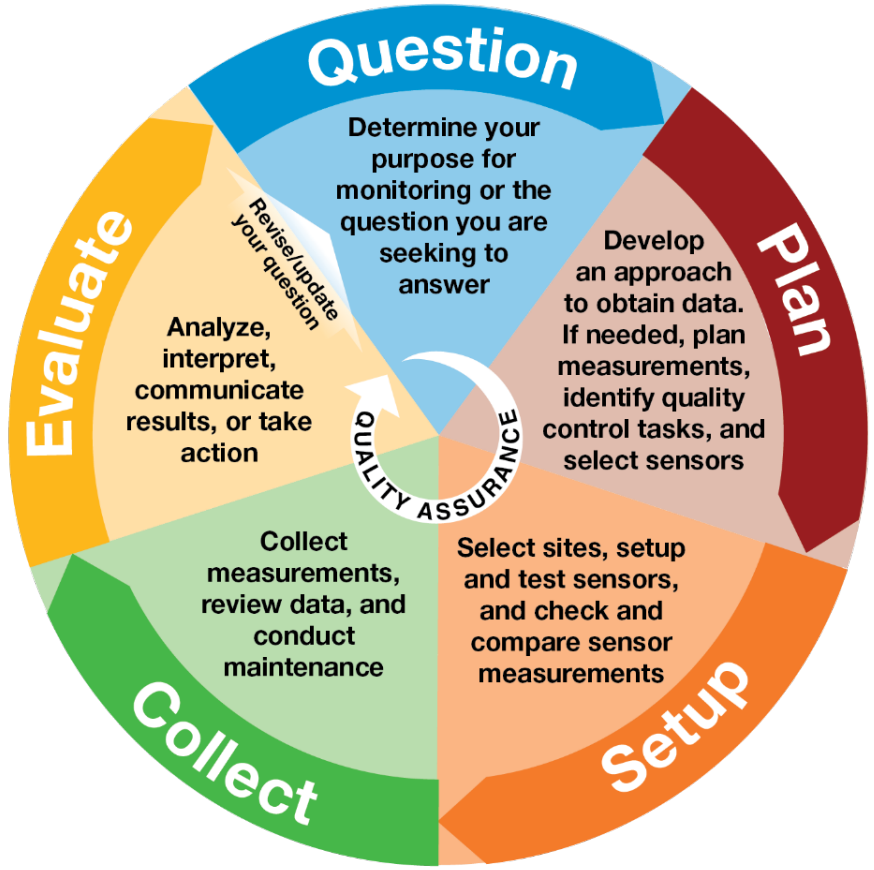
A **violation** of the 24-hour $PM_{2.5}$ NAAQS occurs when the 3-year average of the annual 98th percentile 24-hour concentration is greater than 35 $\mu g/m^3$

A **violation** of the 1-year $PM_{2.5}$ NAAQS occurs when the annual mean averaged over 3 years is greater than 12 $\mu g/m^3$

An area that has a NAAQS **violation** for any given criteria air pollutant, can potentially be designated as **nonattainment** (not meeting the NAAQS) for that pollutant and may need to address in State Implementation Plans (SIPs) how they will reach attainment.

What's Inside: Chapter 3

- **Monitoring Using Air Sensors**
  - **Question:** determining a purpose for monitoring
  - **Plan:** developing a monitoring plan including guidance for selecting a sensor
  - **Setup:** locating a monitoring site(s), install a sensor(s), designing a sensor network(s), and planning and conducting a collocation
  - **Collect:** reviewing data collection activities, common quality control and assurance checks, and the role of data management systems
  - **Evaluate:** analyzing, interpreting, communicating, and acting on the results



Project Planning Wheel

What's Inside: Chapter 3 – Question

- Air monitoring using sensors requires planning **before** you begin a study or select a sensor
- **The best question** seeks to understand, addresses a concern or suspicion, and can be answered using available resources
- **Consider:**
  - What is the concern and desired outcomes?
  - What data is already available?
  - What resources are available (e.g., people, time, funding, skills)?

Good

"What is the air pollution in my neighborhood?"

Better

"What time of day is $PM_{2.5}$ higher in my neighborhood?

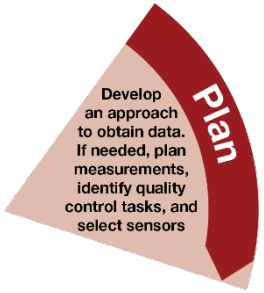
Does that vary by day of the week?"

Best

"When does $PM_{2.5}$ in my neighborhood reach unhealthy levels and from what direction is the wind blowing. What are the potential causes of the higher $PM_{2.5}$?"

Some questions can be answered without collecting additional data or may not be answerable using air sensors!

What's Inside: Chapter 3 – Plan



- Developing a plan helps you **ensure useful data are collected** and **identify potential problems early**
- Chapter 3 has many tables and link to help create a project plan

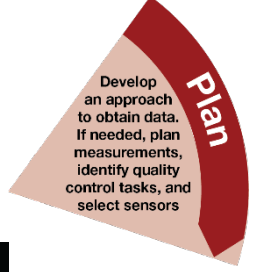
Info Box on QAPPs

What is a Quality Assurance Project Plan (QAPP)?
A QAPP is a written document that explains how organizations ensure, using quality assurance (QA) and quality Control activities, that the data collected can be used for its intended purpose. A QAPP gives more confidence that the data collected will meet the project objective and help others understand the data quality.

Common Topics & Information in an Air Monitoring Plan (Excerpt)

Topic	Information to Include
Purpose and Organizational Topics	
Purpose for monitoring	State the specific environmental topic/problem that is to be investigated, the decision to be made, or the outcome to be achieved using the sensor data. *(See Section 3.2)*
Project/task organization	Determine the roles and responsibilities of all key players in the project.
Engagement with local partners	Solicit insights from tribal/state/local/ air quality or health agencies, universities, research organizations, or others. Engage them early and discuss the project and desired outcomes. *(See Appendix B)*
Project/task description	Summarize the work, objectives, schedule (timeline), and expected outcomes.
Data quality objectives and criteria	Define: 1) Why data are needed? 2) Does this data already exist? 3) What measurements are needed and what do they need to represent? 4) Is there a certain level of accuracy needed? *(See Section 3.2)*

What's Inside: Chapter 3 – Plan



- **Selecting a sensor** is an important part of the planning process
- Considerations provided to help in **choosing sensors that fit the intended application or purpose** for monitoring

Six Questions to Consider Before Purchasing Air Sensor Technology

What are your goals?
- Environmental education
- General air quality monitoring
- Pollutant emissions detection
- Understanding personal exposure

What measurements are needed to meet my goals?
- Air pollutant type(s) (e.g., particulate matter, ozone)
- Meteorology (e.g., temperature, humidity)
- Other (e.g., GPS location, sound)

What design features do I need?
- Portability and size
- Power source (e.g., battery, solar)
- Outdoor or indoor use
- Data display, storage, and transmission
- Maintenance needs

What are some factors that can influence the cost of buying and operating a sensor?
- Loan, lease, or purchase of a sensor device
- Maintenance and/or replacement cost
- Data transmission and storage on a server
- Data ownership
- Data analysis and visualization tools

How do I know if the air sensor is accurate?
- Seek information from the manufacturer and independent evaluations (e.g., Air Quality Sensor Performance Evaluation Center)
- Check if conditions (e.g., weather, pollutant levels) in which the sensor was evaluated are similar to your intended use
- Seek information on appropriate data quality checks from the manufacturer or other source

What details should I look for in a user manual?
- Measurements collected by a device
- Capabilities of a sensor device (e.g., specifications)
- General installation, operating, and maintenance instructions
- Data transmission (e.g., WiFi, cellular)
- Data storage (e.g., local, remote server)
- Instructions on obtaining data
- Customer service support

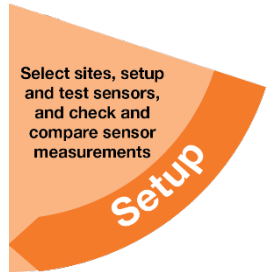
Learn more about how to select and use an air sensor technology:

Air Sensor Toolbox --
https://www.epa.gov/air-sensor-toolbox

Air Sensor Guidebook --
https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook

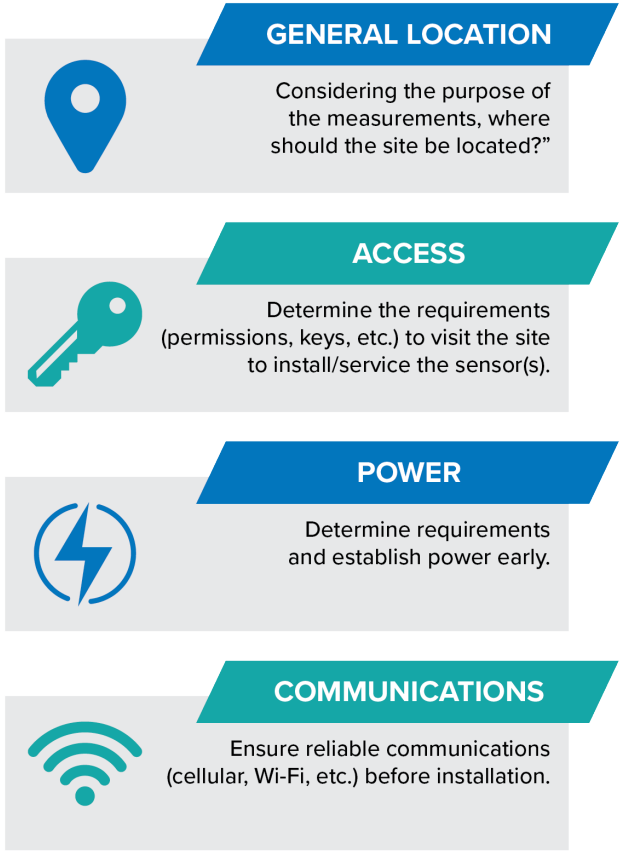
EPA United States Environmental Protection Agency

What's Inside: Chapter 3 – Setup

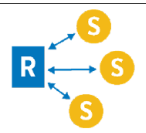
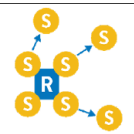
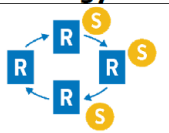
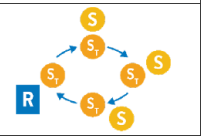


- **Careful placement** and **collocation** are key to collecting useful, accurate data

Considerations and Tips for Installing Air Sensors (excerpt)



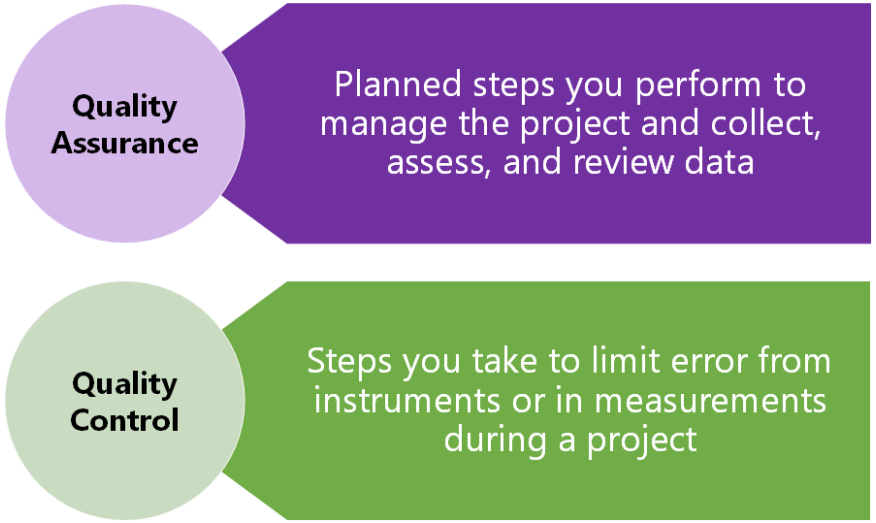
Types of Air Sensor Collocation Strategies (Excerpt)

Key S sensor R reference instrument S_T sensor transfer ✓ yes ~ somewhat X no $ cost maintenance	**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).
Continually check sensor performance	X	~	X	X

Learn more at: **https://www.epa.gov/air-sensor-toolbox**

What's Inside: Chapter 3 – Collect

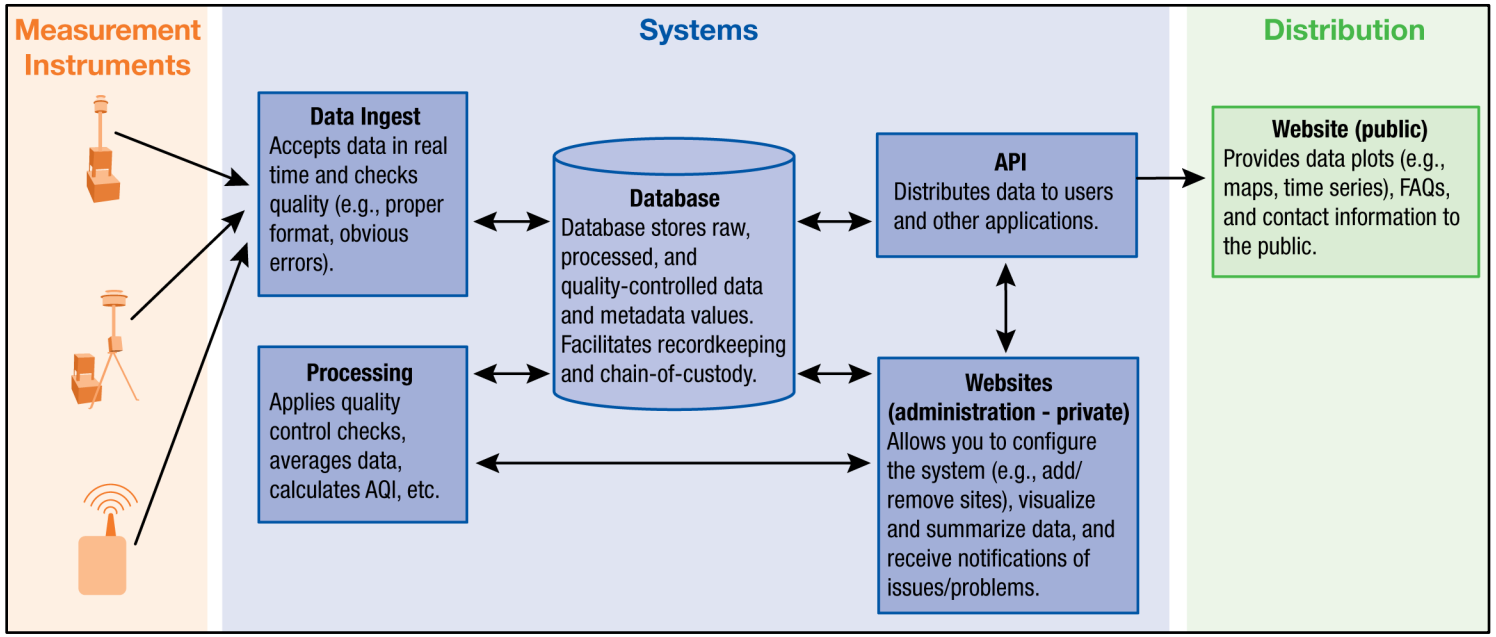
- **Frequent data review** can help identify and resolve problems quickly minimizing data loss
- **Regular maintenance** ensures sensors are operating properly and collecting reliable data
- **Troubleshooting** can identify and resolve problems as they arise
- Performing **quality control checks** on the data can identify problems early
- **Periodic collocation** can ensure sensor performance is not changing or that data correction methods can account for them



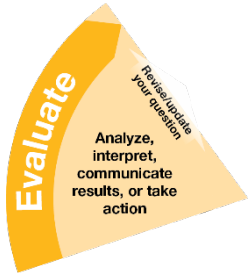
What's Inside: Chapter 3 – Collect

- **Overview of Data Management Systems (DMS)**
  - Basic functions (e.g., ingesting data, storing data, processing data, monitoring network health, data distribution)
  - Recommended features to look for (e.g., data security, backups, ability to access data anywhere, visualization tools, notifications of data issues)

Major Components and Functions of a DMS

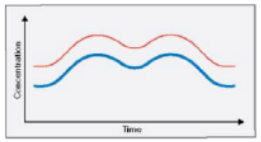


What's Inside: Chapter 3 – Evaluate

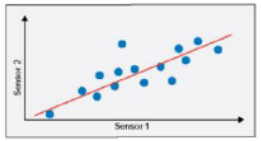


- **Data processing** can include data cleaning, documentation, averaging, grouping, and comparing
- **Data visualizations** can help summarize results and put them into context
- Effective **communication** may require tailored visualizations for each audience
- Information can **empower action**
- Evaluate data early and frequently; results may reveal unanswered questions that **revise or update your plan**

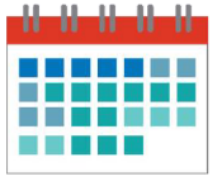
Common Data Visualizations Methods



Time Series Plots show changes in one or more parameters with time. Useful in comparing trends (pollutants, temperature, multiple sites, etc.).

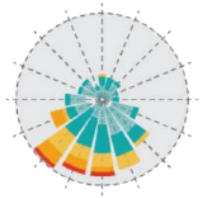


Scatter Plots show the relationship between two parameters. Color coding the dots can indicate a different variable (humidity, temperature, etc.).



Calendar Plots give a big picture look at quality over a month or longer period. Dates can be colored to indicate higher or lower concentrations.

Maps show the spatial patterns of data across a region. Plotting other data such as traffic count or locations of emissions sources can help explain changes in the data.



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.

What's Inside: Chapter 4

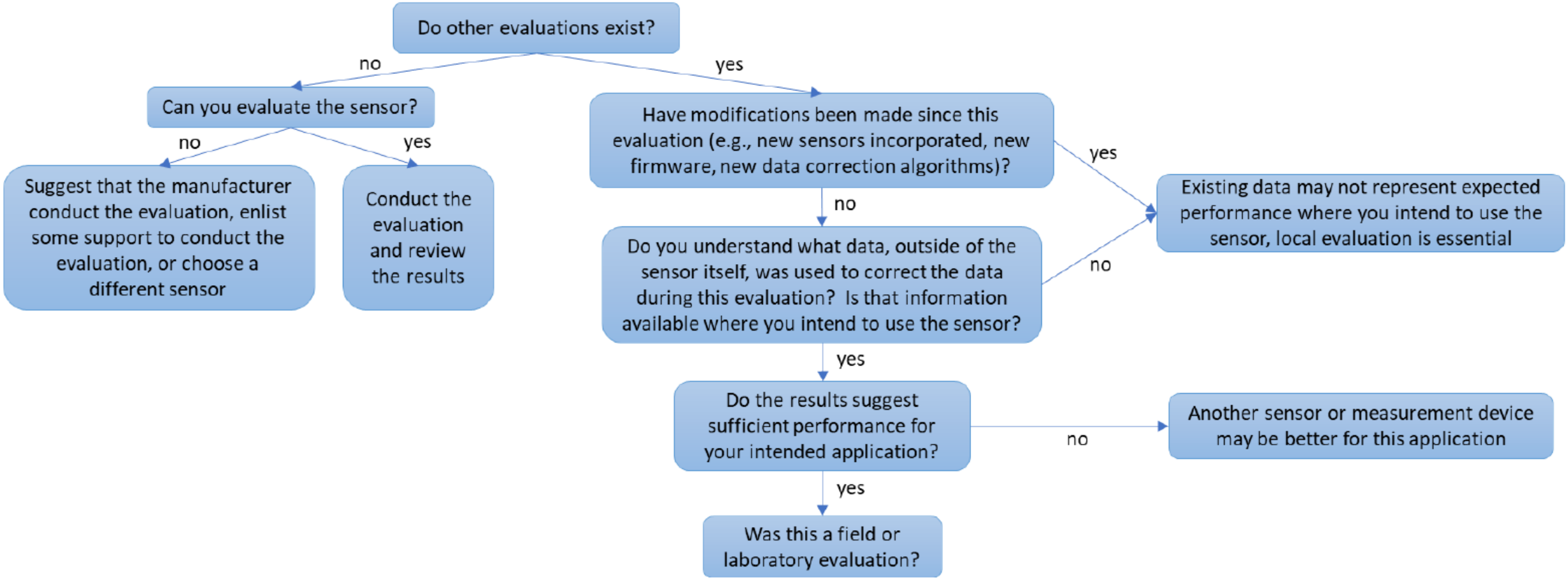
- **Sensor Performance Guidance**
  - An overview of sensor performance guidance
  - Information about sensor performance evaluations
  - Approaches used to evaluate sensor performance
  - Information about how to select sensors based on evaluation reports and other information

Common Approaches for Evaluating Sensor Performance

Evaluation Approach	Description	Purpose
Field	Sensors evaluated in the field at an ambient (outdoor) fixed site	• Gives information on how a sensor performs in real-world, outdoor conditions • Gives users information on how they might expect a sensor to perform in similar outdoor conditions
Laboratory	Sensors evaluated in a controlled laboratory setting	• Allows us to study a range of conditions that may be more difficult to come across outdoors • Allows us to better understand certain performance parameters that are difficult to test outdoors

What's Inside: Chapter 4

Flow chart for how to select sensors based on their performance (*excerpt*)



What's Inside: Appendices A and B

- Resources related to air sensors and air quality (**Appendix A**)
- Questions to consider when planning a study, collected data, and sharing results (**Appendix B)**

Excerpts from Appendix A and B

Appendix A: Resources

A.1 Introduction to Air Sensors

- **U.S. EPA's Air Sensor Toolbox**
  - Information and resources for topics related to air sensors; includes links to other organizations and resources that sensor users may find helpful
  - https://www.epa.gov/air-sensor-toolbox

A.2 Air Quality 101

Appendix B: Questions to Consider When Planning for and Collecting Air Sensor Data, and Sharing Your Results

Getting input from others before you start collecting measurements will help you better plan and collect data to meet your purpose. Below we provide a list of the types of questions to consider. While this list is by no means exhaustive, answering these questions helps you plan and ensures credibility in your data and results. These questions can also help you respond to inquiries from others if you decide to share your plans, data, and results.

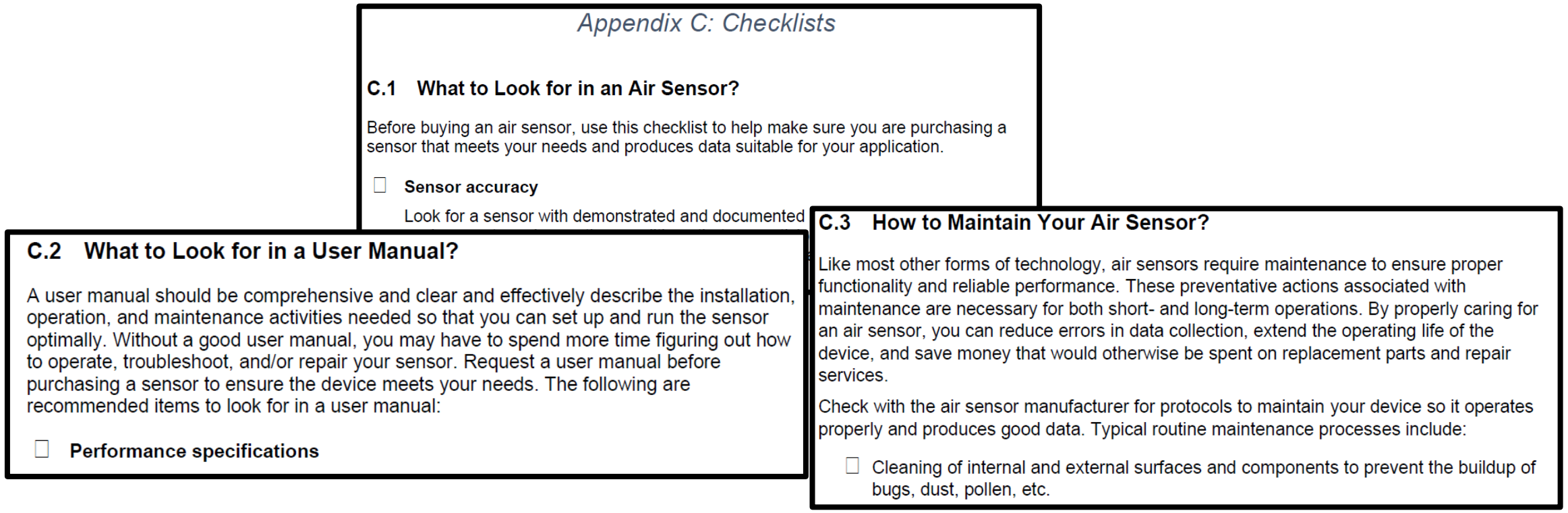
B.1 Planning (see Section 3.3)

- What is the purpose of the project and the question you want to answer?
- What existing research and data are available to help answer your question?
- What actions might you take depending on the research, data, or air monitoring results?
- What pollutants will you measure? If you are interested in a particular source of air pollution, have you checked that your selected pollutant is relevant to that source (see *Table 2-1*)?

What's Inside: Appendix C

- Checklists providing **guidance on choosing sensors, things to look for in a user manual**, and **maintaining an air sensor**

Excerpts from Appendix C



Appendix C: Checklists

C.1 What to Look for in an Air Sensor?

Before buying an air sensor, use this checklist to help make sure you are purchasing a sensor that meets your needs and produces data suitable for your application.

☐ **Sensor accuracy**

Look for a sensor with demonstrated and documented

C.2 What to Look for in a User Manual?

A user manual should be comprehensive and clear and effectively describe the installation, operation, and maintenance activities needed so that you can set up and run the sensor optimally. Without a good user manual, you may have to spend more time figuring out how to operate, troubleshoot, and/or repair your sensor. Request a user manual before purchasing a sensor to ensure the device meets your needs. The following are recommended items to look for in a user manual:

☐ **Performance specifications**

C.3 How to Maintain Your Air Sensor?

Like most other forms of technology, air sensors require maintenance to ensure proper functionality and reliable performance. These preventative actions associated with maintenance are necessary for both short- and long-term operations. By properly caring for an air sensor, you can reduce errors in data collection, extend the operating life of the device, and save money that would otherwise be spent on replacement parts and repair services.

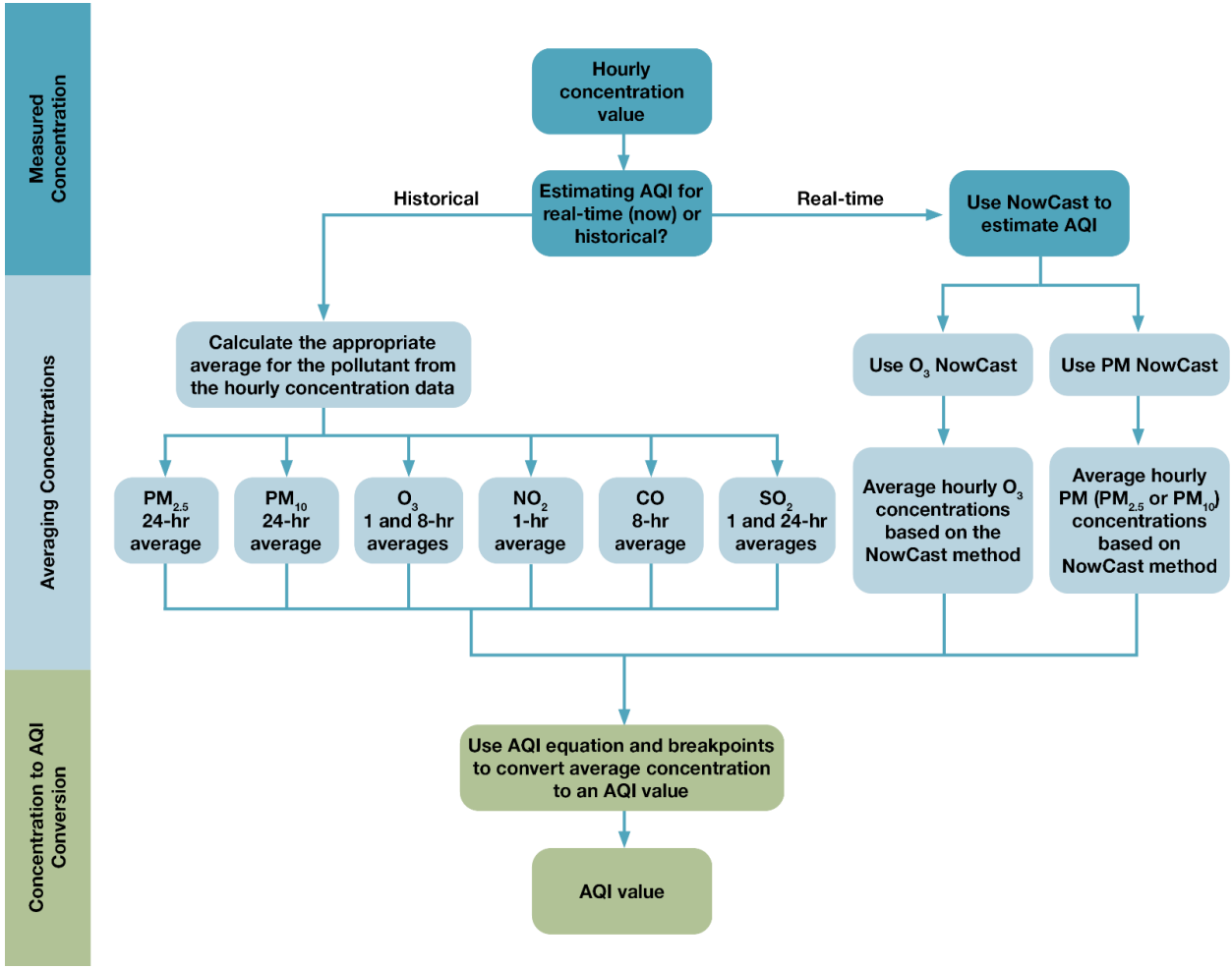
Check with the air sensor manufacturer for protocols to maintain your device so it operates properly and produces good data. Typical routine maintenance processes include:

☐ Cleaning of internal and external surfaces and components to prevent the buildup of bugs, dust, pollen, etc.

What's Inside: Appendix D

- **Data Handling and Air Quality Index (AQI) Calculations**
  - Data processing
  - Common data quality assurance checks
  - Data averaging methods
  - AQI and NowCast AQI
    - Background
    - AQI colors and exploration of color accessible options
    - Computing AQI

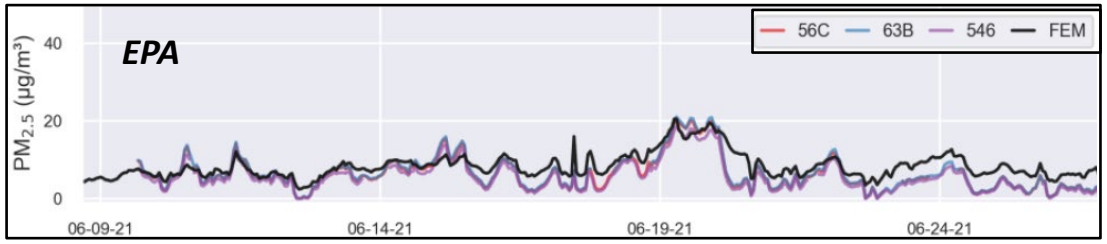
Flow Chart Showing how to Compute the AQI

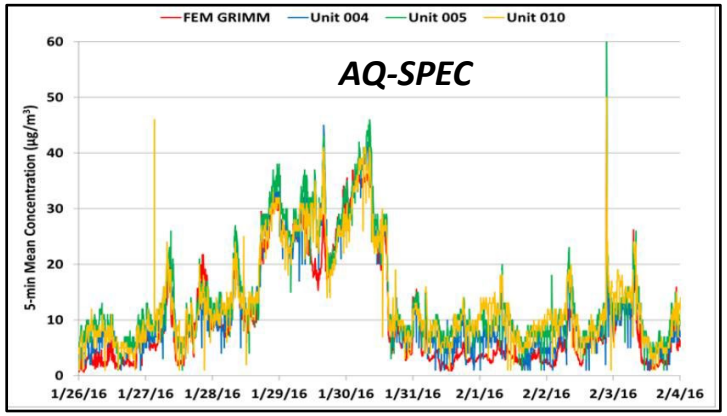


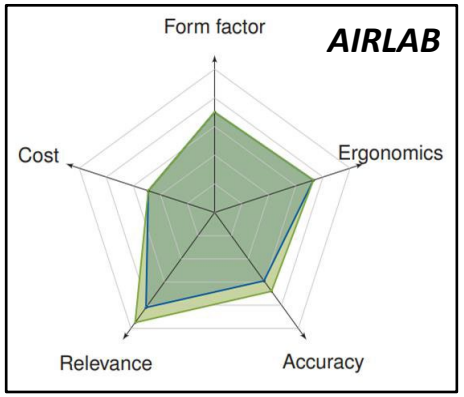
What's Inside: Appendix E

- **Interpreting Sensor Performance Evaluation Results**
  - Provides an overview of EPA's sensor performance evaluation report template
  - Discusses the information users will find in each section of the template
  - Gives examples of how similar information is presented in other evaluation reports (e.g., AQ-SPEC and AIRLAB)

Performance Evaluation Reports (excerpts)







AQ-SPEC = Air Quality Sensor Performance Evaluation Center (South Coast Air Quality Management District)
AIRLAB = Sensor performance challenge organized by Airparif (Paris, France)

What's Inside: Appendix F

- **Glossary**
  - Provides consistent definitions for commonly used terms
  - Uses an alphabet navigation pane to help users quickly locate the terms
  - Includes links to Sections of the Guidebook where the concepts are discussed
  - Provides a link to the source of information, if applicable

Excerpt from Appendix F

Appendix F: Glossary

A – B – C – D – E – F – G – H – I – J – K – L – M – N – O – P – Q – R – S – T – U – V – W – X – Y – Z

-A-

accuracy:

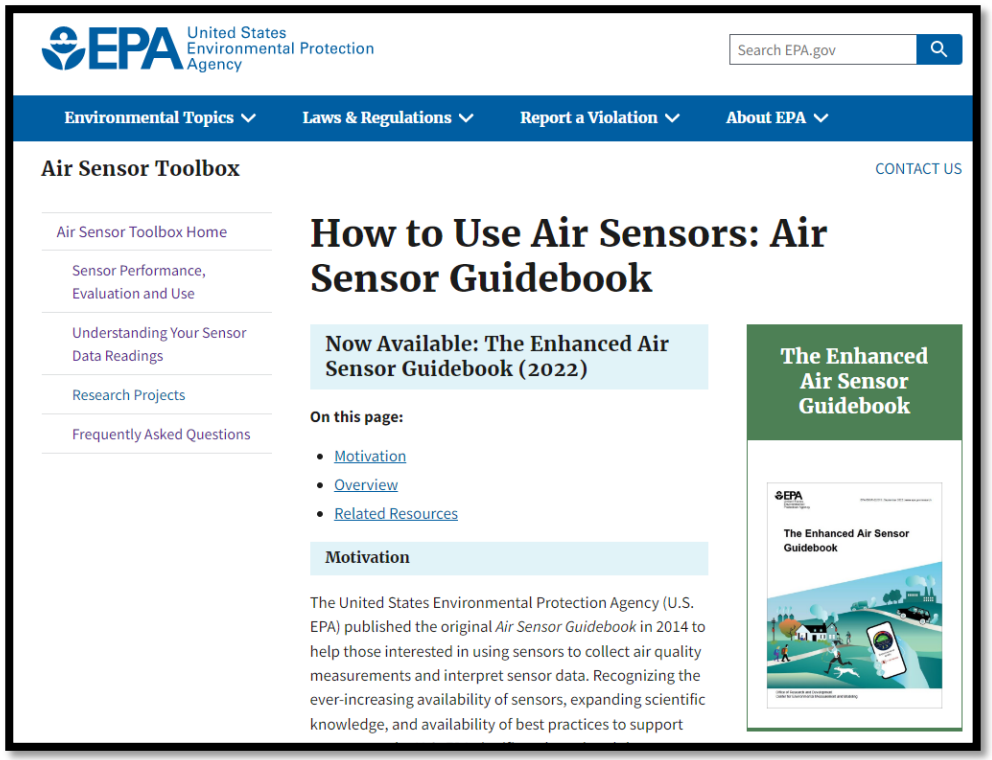
A measure of the agreement between the pollutant concentrations reported by the sensor and the reference instrument. This includes a combination of random error (precision) and systematic error (bias) components which are due to sampling and analytical operations. One way to measure this agreement is by calculating the root mean square error. See *Section 3.4.1*.

Source: https://www.epa.gov/air-sensor-toolbox/air-sensor-performance-targets-and-testing-protocols

Next Steps

- **Spanish Translation**
  - Add the Enhanced Air Sensor Guidebook to the Spanish language resources already available
- **Guidebook Website Development**
  - Add high level summary information on webpages so that it is available quickly
- **Expand the Resource Guide (Appendix A)**
  - Keep content up-to-date
  - Add new resources as they become available

Spanish Air Sensor Toolbox: https://espanol.epa.gov/espanol/caja-de-herramientas-de-sensores-de-aire



Anticipated Outcomes

- New and experienced air sensor users can benefit from a **comprehensive summary of current best practices and considerations** for using air sensors
- New air monitoring efforts are emerging from various grant programs and will have **more guidance to plan and execute effective projects**
- Air monitoring **projects can be better equipped to collect higher quality data** that may enable action, reduce air pollution exposures, and provide other community benefits
- **Sensor users will be more prepared** to have conversations with state/local/federal agencies, researchers, or others, thereby building positive relationships or potential collaborations

Impact

Thanks so much for sharing, and congratulations on the culmination of your team's extensive work in this area; we and our collaborators really appreciate it. – *Madeleine Daepp, Microsoft Research*

Wow! Great to see this. We are doing a bunch of training courses and capacity-building for community groups. This guidebook will be a great resource! Thanks! – *Tim Dye, TD Environmental Services*

I am really excited about all of the new/updated information which we can share with our stakeholders. – *Sheila Batka, EPA Region 5*

Within my group, we all...mentioned how comprehensive and detailed it was, and its use as a good go-to resource. – *Edmund Seto, University of Washington*

It's comprehensive (I feel like it is a great reference even for folks like us!) – *Chris Zuidema, University of Washington*

Take Home Messages

- Guidebook is updated and ready for use
- Share it!
  - Give it to your community members, grantees, educators, or others
  - Feel free to post to social media, websites, or other venues
- These types of resources often take a long time to develop – feel free to build from here, no need to re-invent the wheel
- **Feedback and stories are welcome**
  - Tell us about items we should add to the resources list (*Appendix A*)
  - Share how you are using the guidebook
  - Give us other comments or feedback

Available at: https://www.epa.gov/air-sensor-toolbox/how-use-air-sensors-air-sensor-guidebook

Resources

Air Sensor Toolbox

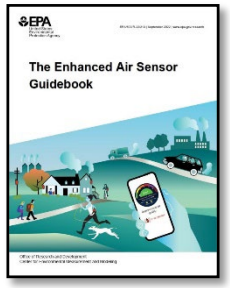
Provides the latest science on the performance, operation, and use of air sensors; select resources are now available in Spanish

Guide to Siting and Installing Air Sensors

Discusses logistical considerations for finding places to locate air sensors and makes recommendations for how to setup sensors at outdoor and indoor locations

Enhanced Air Sensor Guidebook

Comprehensive resource providing guidance on the effective use of air sensors for conducting air quality monitoring



US EPA Sensor Performance Targets and Testing Protocols

Reports, reporting templates, presentations, FAQs, and a Python code library supporting the implementation of EPA's sensor targets and testing protocols

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Authors of the Original 2014 Air Sensor Guidebook: Ron Williams (*retired*), Vasu Kilaru, Emily Snyder, and Amanda Kaufman (EPA); Tim Dye, Andrew Rutter (*deceased*), Ashley Russell, and Hilary Hafner (Sonoma Tech)

Contacts

Andrea Clements, PhD
Center for Environmental Measurement & Modeling
US EPA Office of Research and Development
clements.andrea@epa.gov
919-541-1363

Rachelle Duvall, PhD
Center for Environmental Measurement & Modeling
US EPA Office of Research and Development
duvall.rachelle@epa.gov
919-541-4462