EPA's Air Sensors/Advanced Monitoring Update

The Association of Air Pollution Control Agencies

2022 Spring Meeting

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Office of Research and Development (ORD)

Topics Covered

1. Sensor Performance Testing Protocols, Metrics, and Target Values
2. Sensor Evaluation Efforts
3. Sensor Data for the Fire and Smoke Map
4. Smoke Monitoring and Exposure Reduction Efforts
5. Next Generation Emissions and Fenceline Measurements
6. Expanding Resources to Support Sensor Use and Education
   - Deployment of Collocation Shelters
   - Educational Resources
   - Lessons Learned from Sensor Loan Programs
   - Enhanced Air Sensor Guidebook

Category: Ambient

Sensor Testing Protocols and Performance Targets

Project Leads: **Rachelle Duvall and Andrea Clements**

- **Issue**
  - Challenging to understand sensor performance and how technologies compare
  - Difficult to confidently respond to a data with unknown quality
  - Hard to inform decisions based on data with unknown quality
- **Approach**
  - EPA developed two reports that outline recommended performance testing protocols, metrics, and target values for air sensors
  - Pollutants of focus are ozone (O_3) and fine particulate matter ($PM_{2.5}$) due to widespread use, understanding of technologies, and data availability
  - Work is ongoing to develop similar protocols and targets for other pollutants, namely PM_{10}, carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2)
- **Outcomes/Findings**
  - Goal is to provide a consistent approach for performance testing and the reporting of results to help users identify sensors that meet their needs
  - Performance testing recommendations are beginning to be adopted by testing facilities, manufacturers, and users

Sensor Test Protocols and Targets: https://www.epa.gov/air-sensor-toolbox/air-sensor-performance-targets-and-testing-protocols

PM_{10} = inhalable particles, with diameters that are generally 10 micrometers and smaller

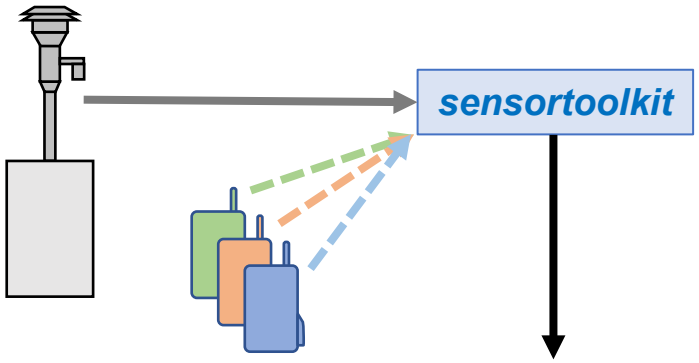
Category: Ambient

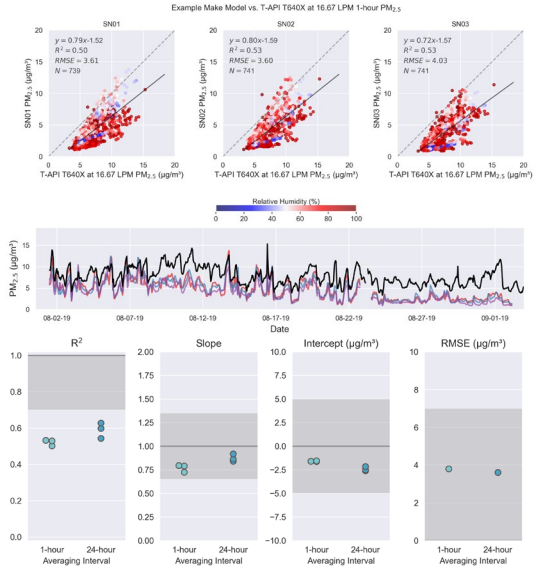
sensortoolkit – Air Sensor Data Analysis Library

Project Leads: **Andrea Clements and Sam Frederick (NSSC)**

NSSC = National Student Services Contractor

- **Issue**
  - Data formatting varies by sensor make/model
  - Most sensor data analysis tools are sensor-specific
  - Users need to write their own code to evaluate data
- **Approach**
  - EPA released an open-source Python code library called sensortoolkit, available on GitHub and PyPI, in February 2022
  - Both sensor and reference data are imported using an interactive ingestion module which reformats and aligns the data streams
  - Performance evaluation and reporting modules calculate metrics and generate the evaluation report as recommended in the testing reports
- **Outcomes/Findings**
  - The library ensures performance metrics are calculated similarly and makes it easier for users to generate an evaluation report
  - EPA's ongoing evaluations will be summarized using this code



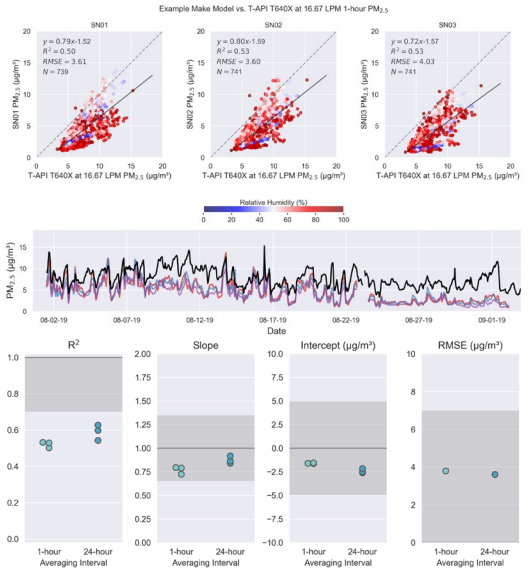


GitHub – sensortoolkit USEPA repository: https://github.com/USEPA/sensortoolkit
PyPI – sensortoolkit: https://pypi.org/project/sensortoolkit/

In-House Air Sensor Evaluations

Project Lead: **Andrea Clements**

- **Issue**
  - Performance remains variable and hands-on experience is needed to better understand the operation and appropriate applications space for new sensors
- **Approach**
  - EPA continues to evaluate sensors focusing on criteria pollutants, products likely to be widely adopted, and sensors useful for ongoing research efforts
  - Continue to monitor the market for new measurement or data processing approaches and meet with vendors to learn about new products
  - To the extent possible, evaluation efforts conform to EPA's guidance in EPA's performance testing protocols, metrics, and target value reports
- **Outcomes/Findings**
  - New evaluation reports will be posted to the Air Sensor Toolbox this summer
  - Efforts help inform other work on performance targets, data quality, etc.
  - Efforts enable ORD to provide guidance to others as they start using sensors including selection, deployment, troubleshooting, data processing, quality assurance, and the purposeful use of air sensor data for other applications

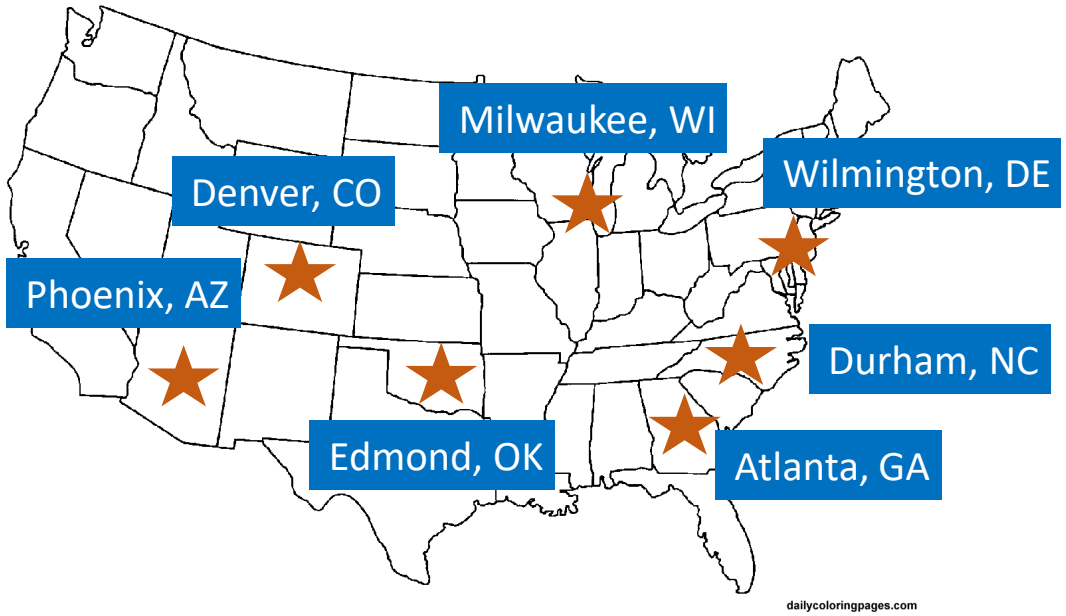


Sensor Evaluation: https://www.epa.gov/air-sensor-toolbox/evaluation-emerging-air-sensor-performance

Long-Term Performance Project

Project Leads: **Andrea Clements and Karoline Barkjohn**

- **Issue**
  - Sensor performance remains highly variable even among sensors measuring the same pollutant
  - Meteorology and pollutant properties/mixtures are known to impact sensor performance
  - Changes in performance over longer time scales is still uncertain
- **Approach**
  - Collocate 6 popular sensor types at 7 climatologically different regulatory air monitoring sites for at least 1 year
- **Outcomes/Findings**
  - Frequent checks of the sensors and data and troubleshoot ensure good data capture
  - $PM_{2.5}$ sensors are typically well correlated with monitors
  - Performance varies by site and season



Collocation sites

Project Summary: https://www.epa.gov/air-sensor-toolbox/epa-air-sensor-research-overview

Field Deployment of Collocation Shelters

Project Leads: **Karoline Barkjohn and Andrea Clements**

- **Issue**
  - Sensor precision and accuracy remains highly variable resulting in a need to collocate sensors with regulatory grade reference monitors to better understand comparability
  - State/Local/Tribal air agencies (SLTs) are increasingly asked to support collocation efforts
  - Sites may be space and access limited making requests time and labor intensive
- **Approach**
  - Design and build 18 collocation shelters to be deployed at volunteer, community-engaging air monitoring sites across the country measuring at least continuous $PM_{2.5}$ and O_3
  - Shelters provide secure, potentially autonomous infrastructure to enable collocations
- **Outcomes/Findings**
  - Enable more sensor collocations thereby increasing our understanding of sensor data quality
  - Help build relationships between SLTs and sensor users thereby increasing knowledge sharing
  - Provide schematics and best practices for other agencies wanting to add collocation shelters

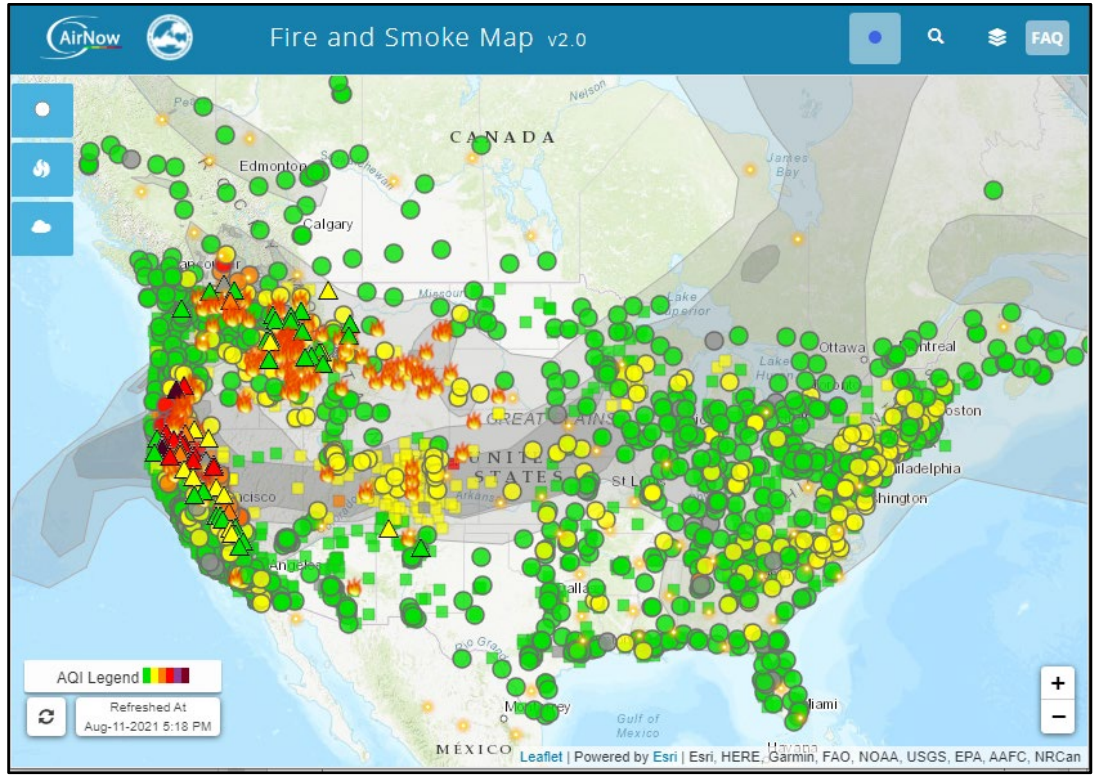
Example collocation shelter

Learn More: https://www.epa.gov/air-sensor-toolbox/air-sensor-collocation-instruction-guide

AirNow Fire and Smoke Map

Project Leads: **Karoline Barkjohn, Andrea Clements, and Amara Holder**

- **Issue**
  - Actionable $PM_{2.5}$ measurements are needed to protect human health during smoke events
  - $PM_{2.5}$ is highly spatially/temporally variable making local scale measurements vitally important
- **Approach**
  - In 2020, air sensor data was added to AirNow Fire and Smoke map to provide more local information about $PM_{2.5}$ concentrations
  - A quality assurance and correction approach was developed to enhance the quality and comparability of the sensor data
  - The correction has been evaluated and updated over time as new data becomes available
- **Outcomes/Findings**
  - Sensor data continues to help fill in measurement gaps
  - Correction provides reasonable accuracy across AQI categories
  - Sensor limitations result in poor accuracy during dust events



Fire.AirNow.gov

Link to the Map: Fire.AirNow.gov
Link to Technical Information: https://www.epa.gov/air-sensor-toolbox/technical-approaches-sensor-data-airnow-fire-and-smoke-map

Wildfire Smoke Air Monitoring Response Technology Pilot

Project Lead: **Amara Holder**

- **Issue**
  - During wildfires, pollution levels can change dramatically with wind, topography, and fire behavior
  - Increasing ground level observations can help inform air quality response and communications about fire impacts
- **Approach**
  - Initiated in 2021, loan of supplemental monitoring technology continues:
    - On-request by state, local, and tribal air organizations
    - On-request by Air Resource Advisors (ARAs) deployed to wildfires under the federal Interagency Wildland Fire Air Quality Response program
  - Technology types: 1) compact air sensor systems; and 2) vehicle add-on mobile monitoring system (VAMMS) with interactive data visualization using the EPA RETIGO platform
- **Outcomes/Findings**
  - 2021: Technologies utilized by ARAs at 7 major wildfires – quick start guides and remote coaching helpful to support integration into time-sensitive workflows
  - 2022: Continued technology development based upon user feedback, including building an extended mobile monitoring system (VAMMS-X) that will add carbon monoxide measurement capability

WSMART: https://www.epa.gov/air-sensor-toolbox/wildfire-smoke-air-monitoring-response-technology-wsmart-pilot
RETIGO: https://www.epa.gov/hesc/real-time-geospatial-data-viewer-retigo
Image credits: Visibility conditions near Monument Fire (Ali Kamal, EPA); VAMMS system (Amara Holder, EPA)

Category: Smoke/Indoor

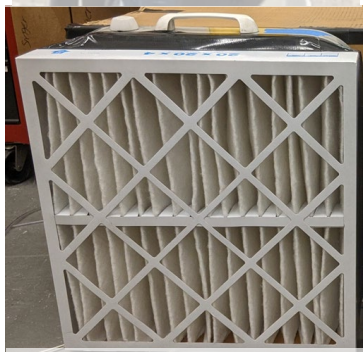
Wildfire ASPIRE Study

Project Leads: **Beth Hassett-Sipple, Amara Holder, and Ann Chelminski**

- **Issues**
  - Often, people are not aware of potential health impacts associated with wildland fire smoke exposures nor what actions they can take to protect themselves
  - Public health guidance advises closing windows and doors to reduce smoke infiltration
- **Approach**
  - Collaborate with two communities routinely impacted by wildfire smoke, Missoula, MT & Hoopa, CA
  - Use lower-cost PM sensors to:
    - Improve understanding of smoke infiltration into indoor environment
    - Evaluate effectiveness of commercial and DIY air cleaners to improve indoor air quality and related health impacts
- **Outcomes/Findings**
  - Knowledge of real-world variation of indoor air quality under typical ambient conditions and opportunistically during smoke events
  - Building factors that influence indoor air concentrations in commercial/public buildings
  - Development of guidelines for commercial buildings including the use of PM sensors with ASHRAE; interim planning framework issued in Feb 2021

Indoor sensor

Outdoor sensor

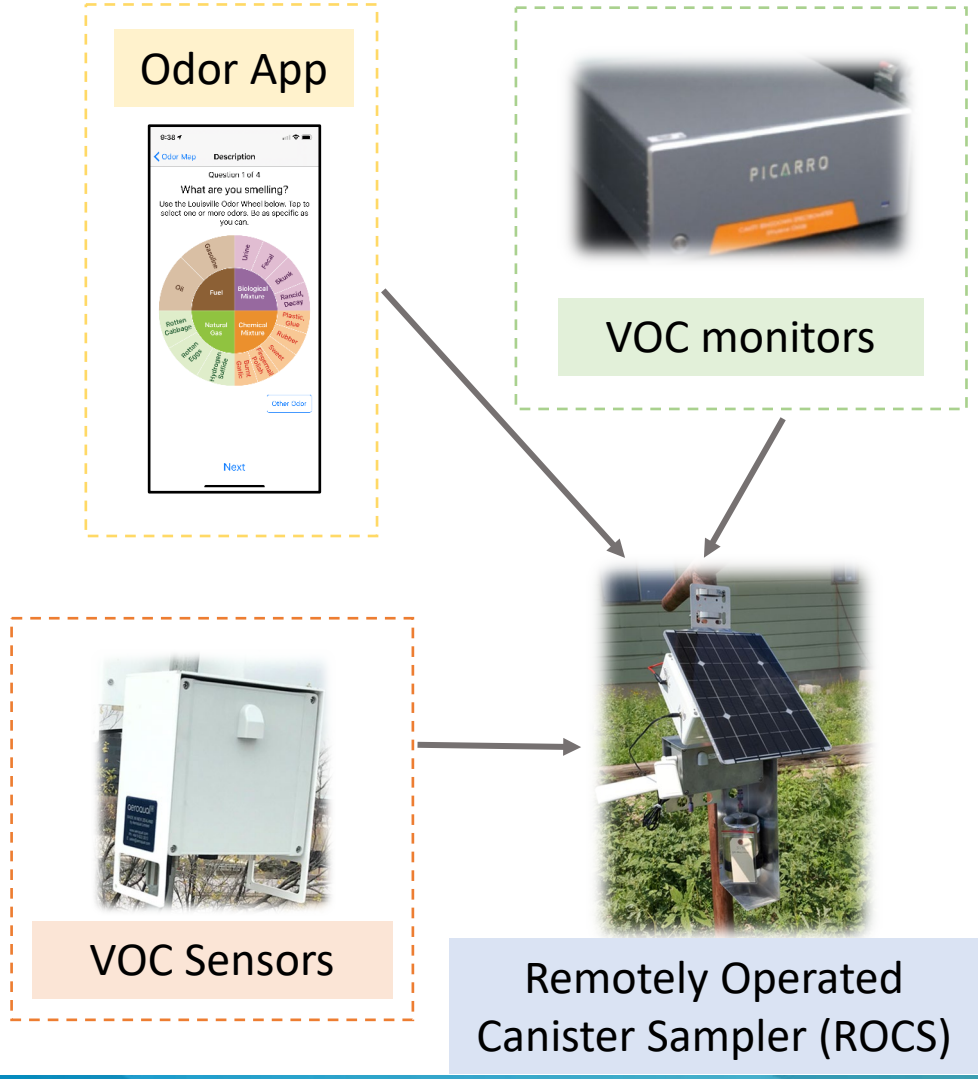


DIY air cleaner

Next Generation Emissions Measurement (NGEM): Triggered Canister Sampling

Project Leads: **Ingrid George, Eben Thoma, and Rachelle Duvall**

- **Issue**
  - Numerous communities are affected by air toxic and odorous volatile organic compound (VOC) emissions from nearby facilities contributing to serious air quality and odor issues
- **Approach**
  - Remotely operated canister samplers (ROCS) are in development that will optimally collect canister samples for source identification
  - ROCS are low-cost, versatile sampling systems that can be operated as stand alone by text or could be automatically triggered by other approaches (e.g., sensors, apps) during emissions events
- **Outcomes/Findings**
  - ROCS were field tested in Carlsbad, NM to evaluate ozone precursor levels impacting air quality in the Permian Basin
  - Current efforts involves coupling ROCS systems with EPA's Odor Explore app to characterize odors based on community-generated odor reports

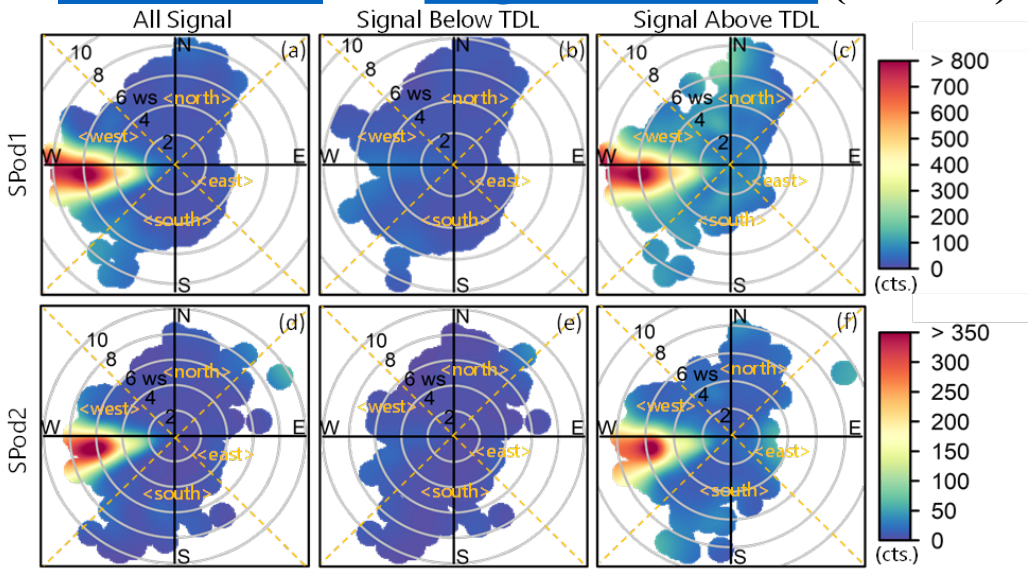


Science Matters article on ROCS testing in Carlsbad, NM: https://www.epa.gov/sciencematters/remotely-operated-air-samplers-offer-innovative-method-locating-fugitive-emissions
Odor Explore App: https://www.epa.gov/air-research/odor-explore-citizen-science-project-using-mobile-app-and-new-measurement-approaches

Fenceline Sensors and Grab Sampling near Facilities in Louisville

Project Leads: **Eben Thoma and Megan MacDonald (ORISE)**

- **Issue**
  - Chemical facilities emit volatile organic compounds (VOCs)
  - Emissions impact communities with environmental justice concerns who need cost effective methods to help monitor the impacts
- **Approach**
  - EPA developed SPods – a low-cost prototype VOC sensor for fenceline monitoring applications
  - EPA SPods were collocated in Louisville, KY for 2 years
- **Outcomes/Findings**
  - ~ 60 valid manually/automatically acquired canister samples were collected
  - ~ 50% of SPod readings were above the Theoretical Detection Limit when winds were from the West (20% of the time)
  - Elevated 1,3-Butadiene and Cyclohexane were associated with winds from the West in the direction of a nearby facility

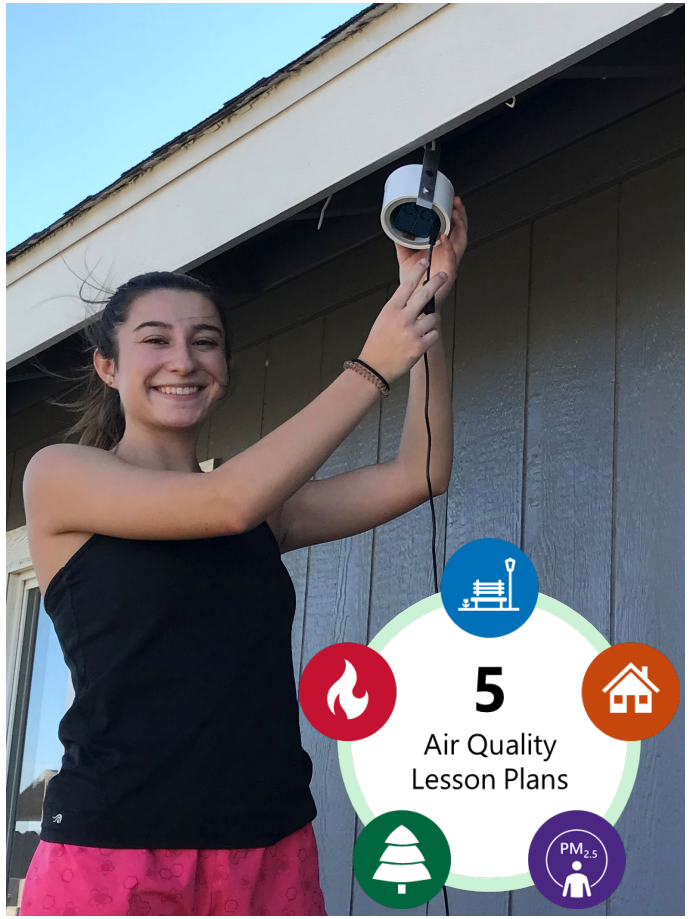


Fenceline Monitoring Video: https://www.youtube.com/watch?v=ACFm8-WhMRU
Previous Paper (2022 paper coming soon): https://www.mdpi.com/1660-4601/16/11/2041

Educational Resources and Lessons Learned from Pilot Air Sensor Loan Programs

Project Leads: **Andrea Clements and Rachelle Duvall**

- **Issue**
  - Air sensors are a powerful tool for public education and enable people to make informed decisions to protect their health
  - Resource constrained communities and individuals often lack access to air sensors
- **Approach**
  - Support air sensor loan programs in urban, rural, and tribal communities
  - Develop resources that educators can use to conduct lessons about air pollution, air sensors, and how they can reduce their air pollution exposure
  - Develop a lessons learned guide to assist new air sensor loan programs
- **Outcomes/Findings**
  - Students and educators engage with and enjoy the air quality lesson plans
  - Loaning through local partners can decrease administrative burden and increase community involvement
  - Partners creatively adapt programs and materials to fit their local contexts



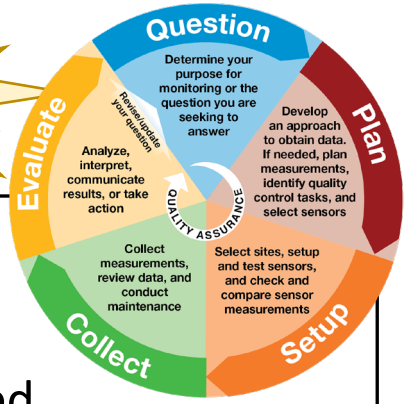
Sensor Loan Programs: www.epa.gov/air-sensor-toolbox/air-sensor-loan-programs
Educational Resources: www.epa.gov/air-sensor-toolbox/educational-resources-related-air-sensor-technology

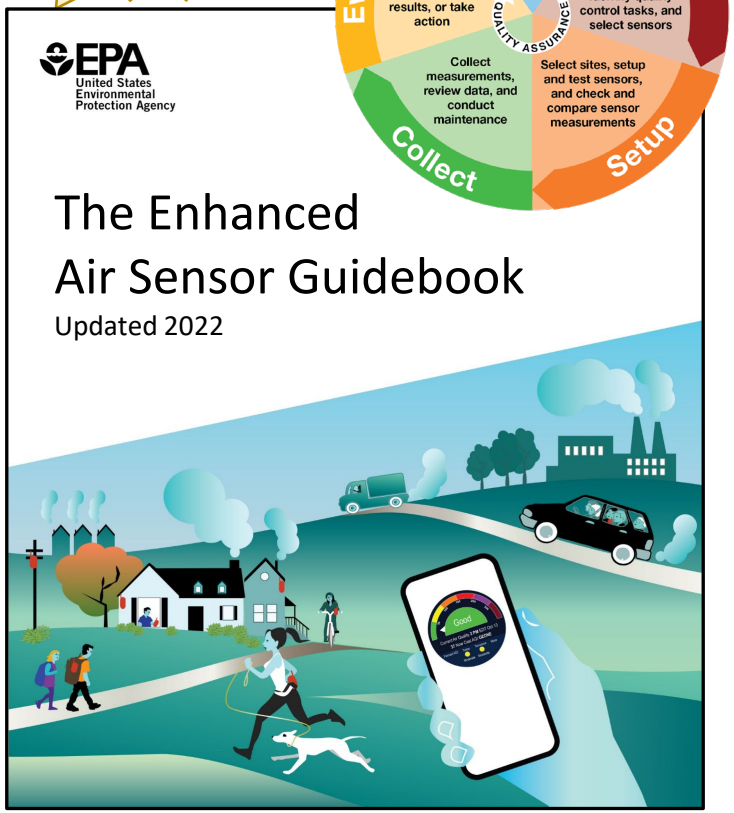
Enhanced Air Sensor Guidebook

Project Leads: **Andrea Clements and Rachelle Duvall**

- **Issue**
  - Air sensors are accessible tools which engage a wide array of users
  - Some users need basic information about air quality, pollution sources, sensor capabilities and limitations, and sensor selection
  - Users also need guidance on how to properly plan and execute an air monitoring study involving air sensors
  - The air sensor guidebook is a highly cited resource which has become outdated
- **Approach**
  - EPA is updating the Air Sensor Guidebook to reflect changes in technology and guidance available today; planned release is summer of 2022
  - The guidebook will provide a robust roadmap to assist users in planning projects
- **Outcomes/Findings**
  - The updated guidebook will provide better guidance and enable thoughtful air monitoring projects
  - The guidebook will include links to additional publicly available resources
  - A future website will assist users on the go and allow for easy updates

Coming Summer 2022





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