Spring evaluation and calibration of low-cost aerosol sensors

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Reference Instrument: ADR-1500

Low-Cost Sensors

PMS

OPC-N3

Low-Cost Monitors

Clarity

AirBeam

Background

- Environmental exposure to fine particulate matter ($PM_{2.5}$ - particles 2.5 in size and smaller) have been linked with serious respiratory health problems.
- Environmental Protection Agency (EPA)-regulated air quality monitoring sites are scarce due to the high operation and maintenance costs.
- One EPA air quality site cannot effectively be used as a standardized measure of air quality for a whole county because the site averages air quality and introduces exposure misclassification.

Objective

- Determine the accuracy and precision of a low-cost aerosol instruments (PMSA003, OPC-N3, BlueSky, AirBeam3, and Clarity) by comparing their data to a reference real-time high-cost filter-corrected aerosol monitor (ADR-1500).

Methods

Measurement Devices

- The ADR-1500 sampled every minute and reported time-weighted averages over an hour and reported real-time measurements. The data was gravimetrically corrected using 24-hour filter measurements.
- A weather station was deployed with temperature and humidity recording capabilities along with 3 replicate low-cost monitors (AirBeam, Clarity) .
- The low-cost sensors (OPC-N3, PMSA003) with 3 replicates were fitted into a custom box and sampled every 5 minutes and transmitted via a gateway.

Deployment

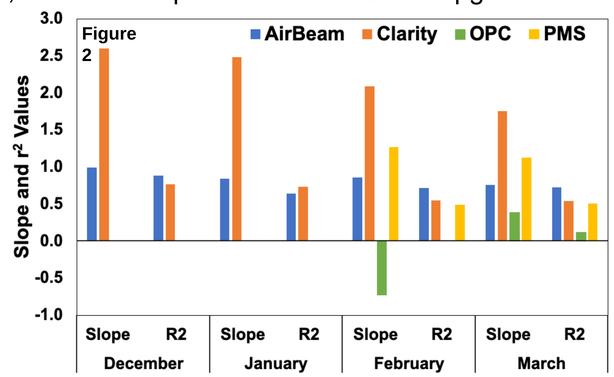
- All devices were deployed across 3 tripods at a busy intersection in Greenville, North Carolina at the intersection of Greenville Blvd and Charles Blvd.

Analysis

- $PM_{2.5}$ data were averaged and then time-paired and compared to the reference data collected from the ADR-1500 using MATLAB.
- Slope, intercept, correlation coefficient (r), coefficient of determination (R^2), bias, root square mean (RSME) and coefficient of variation (CV)

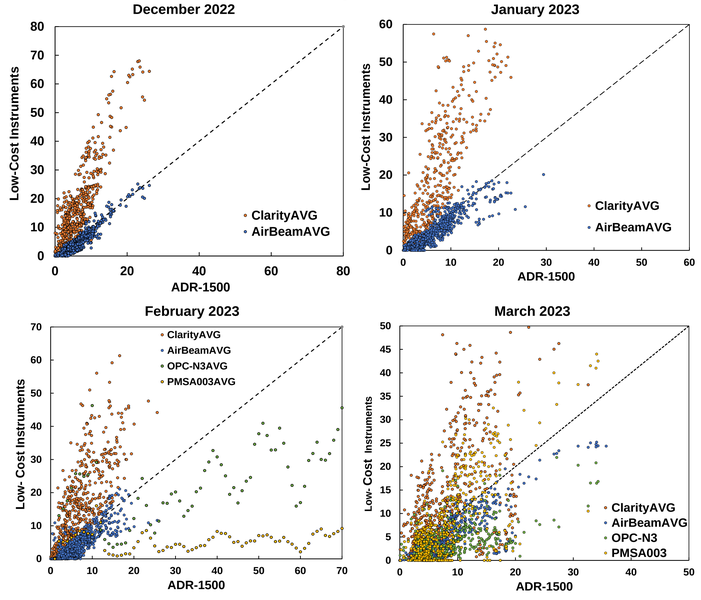
Results

- According to the EPA, the ideal linear regression requires a slope of 1.0 ± 0.35, an intercept of 0 ± 5 µg/m³, $r^2 \geq 0.70$, and a root square mean value of <7 µg/m³.



- The monthly values of slope for the AirBeam were between 0.76 - 0.99 which is within EPA standards.
- The OPC-N3 sensors had monthly slope value less than 0, making it far below EPA standards.
- The monthly values of intercept for the AirBeam monitor were between -1.55 - 0.85, which were closest to the standard.
- The PMSA003 generated an intercept value of -0.90 for the limited time the sensor was online due to a delay in deployment. This value would be considered relatively close to EPA standards.
- The AirBeam values for r^2 were between 0.64-0.88 and were within the range of the EPA standards.
- The OPC-N3 values for r^2 were less than 0.2 and were farthest from the EPA standard values.
- The AirBeam monitors and the PMSA003 sensors were both within the EPA guidelines for RSME.

Figure 3



- As shown in Figure 3, the one-to-one line indicates the accuracy of the low-cost instruments in relation to the ADR-1500 reference instrument.
- The Clarity monitor consistently overestimated PM2.5.
- The OPC-N3 and PMSA-003 instruments data fluctuated between overestimating and underestimating but typically underestimated.
- The AirBeam monitor best fits the the one-to-one line, despite slightly underestimating, indicating that it is the most accurate instrument deployed at the site.
- The AirBeam monitor data indicates that it is precise according to EPA standards. In contrast to the OPC-N3 data points that were more broadly distributed.
- The AirBeam monitor outperformed the other low-cost instruments in terms of accuracy, precision, and EPA standards when compared to the reference device.
- Of the low-cost sensors, the PMS performed within the EPA standards.
- It is important to note that the AirBeam uses a PMS sensor along with a built-in linear regression model that uses months of co-locating sensor data to correct raw data obtained from its sensor.

Conclusions

- The evaluation of these sensors has revealed that the average air quality in Greenville, NC is within EPA standards.
- There are spikes in aerosol concentration that are indicative of poor air quality, that are not reflected in the data from the EPA air quality site.
- It is important for those living with respiratory diseases to be able to monitor air quality. Low-cost sensors and monitors allow them to properly assess their risk.
- The novel use of a gateway allowed the low sensors to transmit data to the cloud, which could be downloaded and visualized on the Grafana website.
- In the future, the Grafana website will automatically create the plots and statistics, cutting down the time for data processing.
- Also deployed at the site were the BlueSky monitors and SEN-54 sensors, that will be evaluated in the coming months.
- Further evaluation of these sensors and monitors is required to create custom calibration models that account for fluctuation in seasonal changes.