

Technical Support Document for the East Oakland Air Monitoring Project

October 2026



Bay Area Air District
CLEAN AIR FOR ALL

Contents

Contents.....	2
1. Executive Summary	3
2. Project Background	4
2.1. Objectives and Scope	4
2.2. Project Area	5
2.3. Target Pollutants.....	6
3. Data Collection	8
3.1. Instrumentation	9
3.2. Mobile Air Monitoring Van Operation.....	11
3.3. Data Review and Quality Assurance/Quality Control	12
3.4. Final Dataset	14
4. Data Analysis	15
4.1. Overall Approach	15
4.2. Method for Background and Enhancement	16
4.3. Methods for Identifying Air Quality Issues	17
4.4. Findings	24
5. Conclusion and Next Steps.....	28
6. Acknowledgements	29
7. Appendix.....	30

1. Executive Summary

The Bay Area Air District (Air District) partnered with Communities for a Better Environment (CBE) to conduct an air monitoring project in East Oakland using its air monitoring van. The project was designed to improve our understanding of air pollution within East Oakland, help identify local sources of air pollution, and inform the development of effective strategies to reduce emissions and limit people's exposure to pollution.

East Oakland community members and organizations have long advocated for health equity, cleaner air, and investments to promote a green and regenerative economy. A majority Black and Brown community, East Oakland contains large tracts of industrially zoned land with a complex mix of pollution sources. East Oakland is also a major transportation corridor with goods moving via air, ship, rail, freeways, and truck routes. These air pollution sources are often near residences, schools, and other locations where people live, work, or spend time.

This project resulted in a public-facing dataset of 120 hours of mobile monitoring van measurements that were collected during more than 1000 miles driven across 36 days in East Oakland. A high-level summary of initial findings was provided in a public StoryMap in [English](#) and [Spanish](#). The StoryMap and other project documents are posted on the [Air District's Community Air Monitoring in East Oakland web page](#). Some key accomplishments and insights from this project highlighted in the StoryMap include:

- The Air District used its air monitoring van to measure multiple air pollutants, including several volatile organic compounds (VOCs) and particulate matter (PM) of different sizes, on multiple drive days around key community-identified facilities and community assets.
- The air monitoring van detected higher than typical levels of different air pollutants on many occasions throughout the area. Some of the air pollutants are air toxics associated with significant health effects depending on level of exposure.
- Some of the occurrences of relatively high levels of different air pollutants were found near specific facilities and operations in the East Oakland area. These pointed to air quality issues, including previously unknown or potentially under-controlled sources of air pollution, and the Air District conducted follow-up investigations.

This document describes the technical work conducted by the Air District's Meteorology and Measurement division. The Air Monitoring Projects and Technology (AMPT) and Ambient Air Quality Analysis (AAQA) sections led and implemented the project.

2. Project Background

2.1. Objectives and Scope

The primary objective of this project was to characterize local-scale air quality impacts in East Oakland using the Air District's state-of-the-art air monitoring van. The monitoring van collected measurements of volatile organic compounds (VOCs), particulate matter (PM), and other air pollutants around sources of community interest or other areas and community assets where more vulnerable populations spend time.

Measurements from the Air District's air monitoring van will provide snapshots in time of pollutant concentrations and are expected to aid in:

- Evaluating VOC and PM levels around specific facilities and air quality concerns identified and prioritized by East Oakland community members;
- Identifying areas and times where VOC and PM levels are unusually high; and
- Informing efforts to reduce air pollutant emissions and exposure.

This project focused on measurements of VOCs and PM, given their associated health impacts and the numerous sources of these air pollutants in East Oakland. Measurements were conducted using the Air District's state-of-the-art air monitoring van. Equipped with a proton transfer reaction time-of-flight mass spectrometer (PTR-ToF-MS), the air monitoring van measures low-level concentrations of many VOCs at 1-second intervals. The air monitoring van is also equipped with particle sizers that accurately measure various sizes of PM and PM characteristics.

The air monitoring van drove in the vicinity of prioritized facilities multiple times and in other areas of interest to the community. Monitoring was planned for different times of day during work hours and on different days of the work week for added representativeness. However, given the short duration of measurements in any one location, changes in air quality or intermittent air pollution events that occur outside the time and location of active monitoring will not be reflected in the data. In addition, since these mobile measurements are short snapshots in many locations, they do not provide enough information to estimate health risks. When plumes or notable peaks in pollutant concentrations were detected, additional monitoring was conducted to investigate the extent of the detected issue. Data were reviewed and evaluated at regular intervals throughout the project to determine whether sufficiently representative data were collected around prioritized facilities and community assets.

In addition to helping identify opportunities for emissions and exposure reductions, the Air District anticipates that some of the findings will highlight the need for additional information to further characterize air pollution sources or other concerns. Throughout the

process, CBE actively engaged with community members to gather insights on local air quality concerns, provide feedback on the collected data, and identify potential data gaps.

2.2. Project Area

Air monitoring was conducted around facilities, key corridors, and community assets identified by the East Oakland community, as shown in Figure 1. CBE led community engagement efforts to identify these key air pollution sources of concern and community assets, like schools, parks, and other places where the community spends time. This input was used to develop a list of prioritized facilities and community assets. Community air

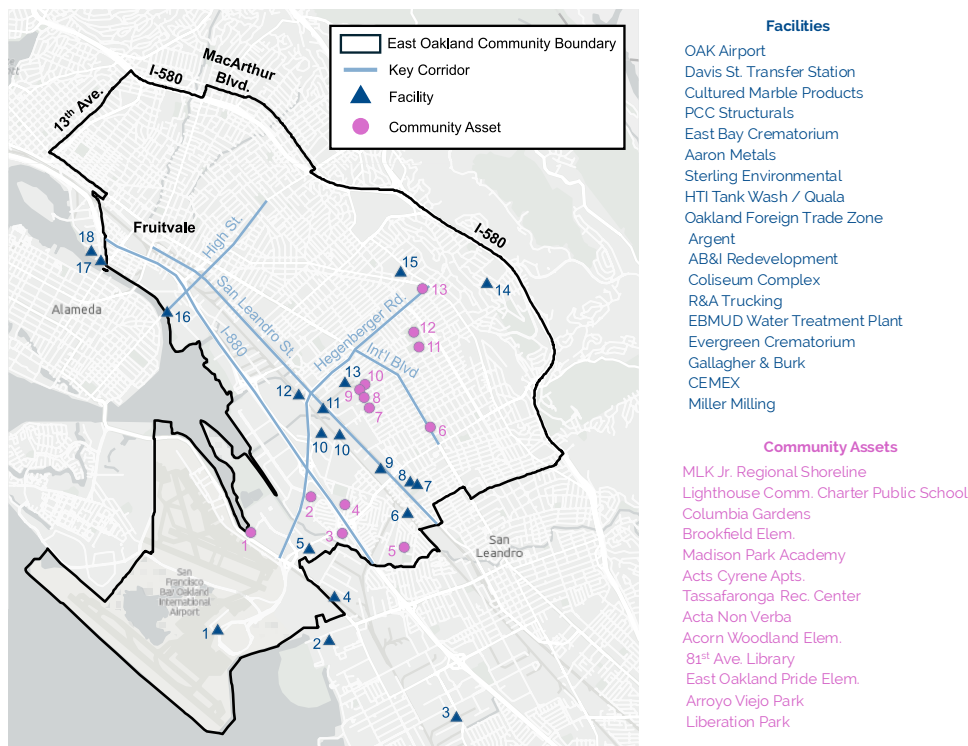


Figure 1. East Oakland Air Monitoring Project community boundary, facilities, and community assets

quality concerns that were identified through the AB 617 Community Emissions Reduction Plan (CERP) process in East Oakland were also included. Figure 2 shows the routes the mobile monitoring van drove in the community across all 36 drive days, including at least five passes by each of the prioritized facilities and community assets.

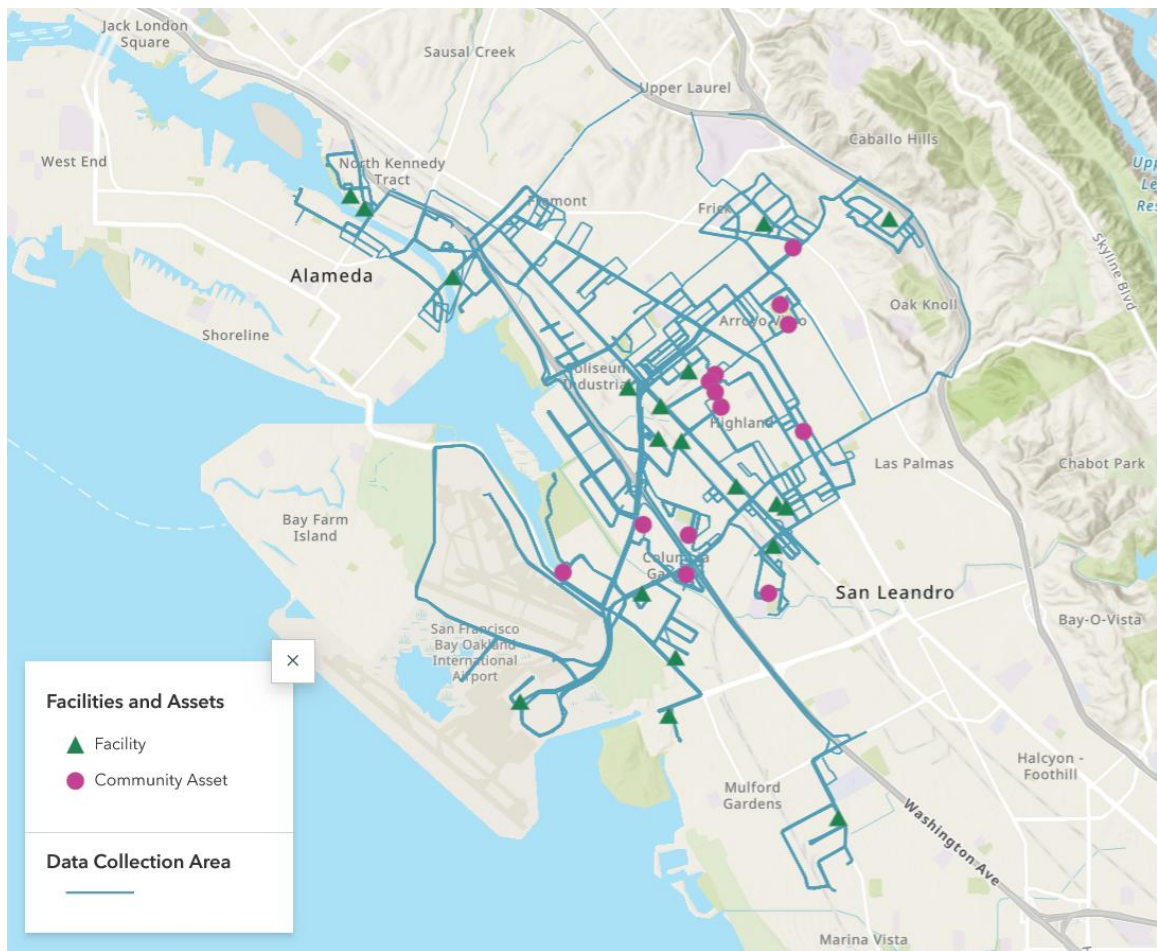


Figure 2. East Oakland prioritized facilities, assets, and drive routes where data were collected

2.3. Target Pollutants

Air monitoring was focused on identifying sources of VOCs and PM because those pollutants have serious health effects. VOCs include a wide range of compounds, some of which are classified as air toxics. PM is categorized by physical size (for example, PM₁₀ and PM_{2.5}, particles with diameters smaller than 10 or 2.5 micrometers, respectively) or by chemical composition (for example, black carbon [BC], a component of PM_{2.5}). The community also identified PM₁₀ from sources of fugitive dust as a key air pollution source of concern. Other pollutants, including Carbon Monoxide (CO) and Nitrogen Oxides (NO_x), are included to help identify sources of air pollution. Often, the relative amounts of air pollutants measured can tell us a lot about the source of the pollutant, for example, by distinguishing vehicle exhaust (i.e., fuel combustion) from evaporation of solvents from a manufacturing facility. Measurements of NO_x and CO were made to support data analysis and can be used to help identify combustion versus non-combustion related emissions. Many measured air pollutants have both health effects and are useful for the careful identification of specific sources.

Many air pollutants were measured during this project, chosen because several of them are emitted by sources that are common in urban areas, and others may be emitted by certain facilities and operations in the project area. In addition, these air pollutants can be measured by the instrumentation on board the air monitoring van. Multiple air pollutants can be emitted by the same source, and measurements of different combinations of pollutants can provide clues about possible emissions sources. The complete list of air pollutants measured and included in the public dataset include:

VOCs

- 1,3-Butadiene
- 1,3-Dichloropropene
- Acetaldehyde*
- Acetone
- Acrolein
- Acrylonitrile
- Benzene
- Carbon Tetrachloride
- Dichlorobenzene
- Ethylbenzene*
- Ethylene oxide*
- Formaldehyde
- Methyl ethyl ketone (MEK)
- Methylene Chloride
- Naphthalene
- p-Chlorobenzotrifluoride (PCBTF)
- Styrene
- Tertiary-Butyl Acetate (TBAC)
- Toluene
- Trimethylbenzene

- Xylene*

* Acetaldehyde and ethylene oxide have the same molecular weights and cannot be differentiated by the air monitoring method used. The same is true for ethylbenzene and xylene. The data listed is a combination of the pollutants that are measured at the same molecular weight.

Particulate Matter (PM)

- Ultrafine PM (UFP; <0.1 micrometers in diameter)
- PM₁ (particles <1 micrometers in diameter)
- PM_{2.5} (particles <2.5 micrometers in diameter)
- Black carbon (BC) (elemental carbon components of PM_{2.5})
- Brown carbon (BrC) (organic carbon components of PM_{2.5})
- PM₁₀ (particles <10 micrometers in diameter)

Other pollutants

- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Methane (CH₄)

3. Data Collection

The East Oakland air monitoring project used a targeted, source-oriented air monitoring approach focused on the areas around the list of prioritized facilities and community assets developed for this project. Prioritized facilities and community assets were mapped and the best possible route that circumnavigated them was determined. These routes were driven twice per drive-day and contextualized by a ten-minute stationary meteorological measurement period to aid in source identification, as shown in the example in Figure 3. The overall project area was split into several monitoring areas, each a route able to be driven twice in a single day. Every monitoring area was driven at least five times between July 15, 2025, and March 25, 2026, resulting in 36 total drives over 120 hours covering more than 1000 miles of roadway in East Oakland. Air monitoring was conducted on weekdays and typically began between 9:00 and 11:00 AM and ended between 3:00 and 5:00 PM. Some days were not suitable for driving due to rain, which can damage the instruments and bias measurements if water enters the sample line.



Figure 3. Circumnavigation route around Argent (in yellow) with associated meteorological measurements (in green).

3.1. Instrumentation

The air monitoring van was developed for fast, in-motion measurements of air pollution to develop a more spatially resolved understanding of air quality at the community scale in the Bay Area. The air monitoring van can measure its GPS position and a range of air pollutants at 1-second time resolution to directly associate measurements with the precise location they were observed. Pollutant measurements were made using several instruments, which are listed below with the relevant compounds measured:

- Proton Transfer Reaction-Time-of-Flight-Mass Spectrometer (Ionicon 6000X PTR-ToF-MS) for select speciated Volatile Organic Compounds (VOCs),
- Cavity Ring Down Spectrometer (Picarro G2401) for carbon monoxide (CO) and methane (CH₄),
- Optical Particle Sizer (TSI OPS 3330) for PM₁, PM_{2.5}, and PM₁₀,
- Aethalometer (Aerosol Magee Scientific AE33) for black carbon (BC) and brown carbon (BrC),
- Condensation Particle Counter (TSI CPC 3789) for ultrafine particulate matter, and
- Chemiluminescence Spectrometer (Thermo Scientific 42iQ in NO_x mode to achieve 1-second measurements) for NO_x (NO₂ + NO).

All pollution data were timestamp-aligned based on individual instrument response times. Timestamp alignment ensures accurate association of individual pollutant signals with a specific GPS location.

Additional on-board sensors were installed to detect when the van was backing up and if the engine was on or off. A metric called Global Operational Code (GOC) was determined using these sensors' signals along with vehicle speed and user-entered meteorological flags to determine if the van's operational state was:

- In motion (GOC 0),
- Stationary with engine off (GOC 1),
- Stationary meteorological measurement period with engine off (GOC 4),
- Stationary with engine on (GOC 5), or
- Backing up (GOC 7).

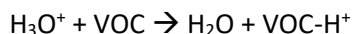
GOC helps contextualize what the van was doing, aiding analysis by excluding periods of possible self-sampling of the air monitoring van's exhaust and to indicate properly sited meteorological measurements. More information on self-sampling and GOC can be found in the EOAK_Mobile_Data_Readme.xlsx file provided with the publicly available dataset.

Additional supporting data, such as wind speed, wind direction, vehicle speed, and vehicle location, were collected by a roof-mounted weather and GPS sensor (Airmar 200WX). In-motion wind speed and direction data were not valid because these measurements are heavily impacted by vehicle motion. As discussed in Section 3.2, to gather valid wind speed and direction data, stops were made at predetermined and properly sited locations in the study area (e.g., green pin in Figure 3). Wind speed and direction data collected during these stationary measurement periods are identified with GOC 4.

Data were collected on a networked server with an onboard data acquisition system and visualized via a custom R Shiny app. This setup allowed the operator in the van's passenger seat to view and quality control (QC) instrument data and key operational parameters in real-time while monitoring. Data were also reviewed and quality controlled *post-hoc* using a separate custom-built R Shiny web app, called Plotster, described in more detail below.

VOC Measurements with the PTR-ToF-MS

The PTR-ToF-MS was a key instrument during the East Oakland air monitoring project. It uses a real-time analytical method that relies on an ion source containing water (H₂O) to produce hydronium, or protonated water (H₃O⁺). Hydronium then reacts with incoming VOCs which, if the VOC has suitable chemical properties (e.g., greater proton affinity than water), will accept the proton (H⁺) from the hydronium in a "proton transfer reaction (PTR)", as shown by the reaction below.



The protonated VOC-H⁺ then enters the "time-of-flight (ToF)" mass analyzer, where the time it takes the charged VOC-H⁺ to accelerate through an electric field is directly related to the molecular mass. The ability to detect and identify a specific VOC depends on the physical

characteristics of the VOC. For example, proton affinity, a characteristic that defines how easily the proton transfer reaction occurs, dictates the detectability of a compound by PTR-ToF-MS. VOCs with proton affinity greater than H₂O will gain protons from hydronium and be detected, while those with proton affinity lower than H₂O will not be protonated and will therefore not be detected. Several VOCs of interest were not detected during this project likely due to a low proton affinity, including acetylene, benzo(a)pyrene, ethylene, p-chlorobenzotrifluoride (PCBTF), tetrachloroethylene, and trichloroethylene. PCBTF fragment ions were used to identify the presence of PCBTF, listed as PCBTF (Frag). A VOC's molecular mass is also critical for being able to differentiate one compound from another. Though this is an identifying characteristic of a VOC, compounds with the same molecular mass will move through the ToF chamber at the same rate and appear identical to the detector. Of the target VOCs in this project, the molecular mass of acetaldehyde is the same as that of ethylene oxide, and the molecular mass of ethylbenzene is the same as xylene, therefore the PTR-ToF-MS could not differentiate between those compounds and results were reported as combined concentration measurements.

In addition, compounds with similar molecular masses may interfere with compounds of interest making the measurement of that compound less reliable. The more interferences present, the less reliable that measurement is. The measurement confidence of each VOC is defined as high, medium, and low based on interferences and other measurement sensitivities. Measurement confidence for VOCs is listed in Table A-1 in the Appendix.

3.2. Mobile Air Monitoring Van Operation

Each day prior to data collection, staff performed daily instrument checks upon system start-up to verify that all instruments were operating as intended, the air monitoring van was safe to drive, and data collection was of high quality.

Start-up included:

- Following a checklist of approximately 100 tasks, taking 90 minutes for two operators to complete collaboratively,
- Physical inspection of equipment and van,
- Instrument initiation and warm up,
- Flow and zero quality control checks on instrumentation,
- Initiating data logging, and
- Reviewing metadata, such as manifold pressure, instrument temperatures, and sample line flow, which are indicators of instrument and system health.

Shut-down at the end of the day also required a set of standardized procedures including:

- Approximately 50 steps taking 60 minutes for two operators to complete collaboratively,
- Switching the air monitoring van from battery to shore power,

- Flow and zero quality control checks on instruments,
- Terminating data logging,
- Shutting down instruments or putting them into standby mode, and
- Transferring and processing data.

The air monitoring van required two people to operate safely: a Mission Control Operator and a Driver. The Mission Control Operator was responsible for watching data in real-time; monitoring instruments for proper function; making log comments of observations of the environment such as construction, odors, or visible smoke; and spotting the Driver during lane changes, backups, and turns. The Driver was responsible for safely navigating the project routes using a navigation app that maps the routes while logging the GPS coordinates of the drive.

Every monitoring area had one to three intentionally sited meteorological measurement locations that were each used for ten-minute stationary samples on every drive day. Meteorological siting included open, 360° unobstructed areas, when possible, where the van had safe and easy access to stop and turn the engine off to prevent self-sampling of the van exhaust.

3.3. Data Review and Quality Assurance/Quality Control

Data collection was conducted in accordance with a Quality Assurance Project Plan (QAPP). To ensure all instruments were operating correctly, one week per month was designated for QC and maintenance of all air monitoring van instrumentation and supporting infrastructure. Routine monthly QC was assigned by instrument to staff who were responsible for following QC/maintenance schedules and procedures in the associated Standard Operating Procedures (SOPs). All QC checks are documented using a QC template that logs to a QC database. QC checks and maintenance vary per instrument but generally include replacing filters, performing calibration verifications, cleaning components, and conducting flow, pressure, and temperature verifications. The QAPP and relevant SOPs for instrumentation operated during this project can be requested via an online [public records request](#), with attention to Meteorology and Measurement division's AMPT section.

After the day's drive and shut-down procedures were completed, *post-hoc* data review was performed, which can take up to a full day per reviewer, per drive. A custom R Shiny app called Plotster was used for all *post-hoc* data QC. Plotster is an interactive app that is used for data visualization, auto-QC, data processing and organizing, pollution calculations, timestamp alignment, and final data packaging. Plotster has many features but several of the most critical ones are:

- Auto-QC checks to flag instrument metadata that fall outside of an expected range,

- Assigns GOC to the data using engine on/off and backup signals, vehicle speed, and met flags,
- Checks timestamp alignment by visualizing concurrent peaks of multiple pollutants across all instruments in the “Timestamp Alignment” tab,
- Custom and hard-coded interactive plots of all data and metadata for data review,
- Displays log comments created during drives that can be edited for clarity,
- QC editor for changes to QC codes and GOCs with a required log comment and initials for chain of custody tracking,
- Mapping pollution data that can be filtered for spatial observations, and
- Calculates data completeness and other statistics.

Both the Mission Control Operator and the Driver used Plotster to independently review all auto-QC and GOC values, as well as review all air pollutant and instrument metadata in detail. Operators were trained to identify unexpected or concerning data trends such as sharp jumps or drops, consistent baseline drifting, periodic cycling, repeated values, or self-sampling signals, any of which could indicate a problem with the measurement. All data review observations were documented in a notes template and after independent reviews were completed the reviewers compared and discussed their notes, consulting with senior AMPT staff regarding any opposing observations. Following reviewer consultation, if concentration or supporting data were determined to be erroneous by identifying an instrument issue, the data were invalidated and instrument repair procedures were initiated. Data were not invalidated unless there was a clear issue with the associated instrument or data itself. After all data were appropriately quality controlled, valid data were investigated spatially and via time series; measurements of pollutant concentrations that were unexpectedly high were documented in a dedicated air pollution observation log and escalated to the relevant internal Air District division.

Data that were below an instrument’s Method Detection Limit (MDL) were flagged with an associated data qualifier code. According to the EPA, the MDL is defined as the minimum measured concentration of a substance that can be reported as distinguishable from method blank results with 99% confidence.¹ The Reportable Detection Limit (RDL) is defined as the limit which can *reliably* be measured.² Unlike the MDL, the RDL is not defined in federal regulations and is particular to each laboratory.

Pollutant MDLs were determined using an average of pre- and post-project drives while sampling pollutant-free air. The gas instruments sampled air directly from a zero-air generator and particulate matter instruments sampled air that passed through a HEPA filter

¹ 40 CFR Appendix B to Part 136 - Definition and Procedure for the Determination of the Method Detection Limit, Revision 2: <https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-136#Appendix-B-to-Part-136>

² EPA, Office of Air Quality Planning and Standards, More Ado About Next to Nothing: Bringing Minimum Detection Levels into Focus. <https://www3.epa.gov/ttnemc01/meetnw/2015/moreado.pdf>

to remove any particulate matter in the sample. Concentration data were analyzed for each of the compounds during the pollutant-free air periods. The data were filtered to remove instances when vehicle speed was less than 0.5 mph. Filtering based on speed harmonized the calculated MDLs with mobile data characterized as GOC 0 (air monitoring van in-motion). The filtered data set was then used to calculate the MDL by determining the 1-second standard deviation, σ_i , of each species over the drive according to Eqn. 1 below:

$$\sigma_i = \sqrt{\sum |x_i - \mu_i| / 2N_i} \quad \text{Eqn. 1}$$

Where x_i is each individual 1-second concentration data point for compound i , μ_i is the average concentration of data for compound i over the course of drive, and N_i is the total number of data points of compound i .

The MDL for compound i was then determined using the Student's t -value appropriate for a single-tailed 99th percentile t statistic ($t_{(n-1, 1-\alpha=0.99)}$), a standard deviation estimate with $n-1$ degrees of freedom (σ_i), and the average concentration for compound i (μ_i) (Eqn. 2). The value for the Student's t -value metric (2.327 for this dataset) was determined from commonly available statistical tables.

$$MDL_i = \mu_i + t_{(n-1, 1-\alpha=0.99)} \sigma_i \quad \text{Eqn. 2}$$

The Reportable Detection Limit (RDL) for compound i was then determined according to equation 3 below. The factor of 3 was determined to be the lowest multiplier that allows all compounds to be reliably quantified.

$$RDL_i = MDL_i * 3 \quad \text{Eqn. 3}$$

Measurements with values below the MDL for a given compound have higher uncertainty and are not statistically distinguishable from method blank results. Measurements with values above the MDL but below the RDL confirm the presence of the compound in question but its concentration may not be reliably quantified and analysts should exercise caution when including these measurements in their analysis. Measurements above the RDL can be considered quantified with expected levels of measurement uncertainty.

MDLs and RDLs for each compound measured are provided in Table A-1 in the Appendix.

3.4. Final Dataset

Following the project QAPP, final quality assured datasets containing speciated VOCs, NO_x, CO, CH₄, BC, BrC, PM₁, PM_{2.5}, PM₁₀, UFP, ambient temperature and pressure, wind speed, wind direction and GPS data were made available for internal analysis and interpretation as soon as data review was complete. Only quality assured data that were valid, collected above the monitoring van speed threshold of 0.5 mph, and not collected during vehicle backups were used in the internal analysis by the Air District. Data collected while the vehicle was operating at low speeds (less than 0.5 miles per hour) or while backing up were

excluded from analysis to limit potential measurement contamination by self-sampling exhaust plumes produced by the air monitoring van, as flagged by the GOC procedures. Excluding these data results in gaps in the final pollution data. Final datasets containing the valid data that were used for internal analyses are available to the public on the Air District's website. A README file, containing descriptions of all data parameters, data quality control procedures, and other details necessary to interpret the data, is included with the final public datasets.

4. Data Analysis

4.1. Overall Approach

Measurements from the air monitoring van were analyzed continuously throughout the data collection period and after completion of the project period primarily using interactive web visualization tools developed using R Shiny and Observable Framework open source software packages. Data were analyzed on individual days and across the entire project period using various data visualizations including boxplots, histograms, scatterplots, time-series graphs, and maps. Each of these visualizations provides a different snapshot view of this high-resolution and highly dimensional air quality dataset and these examples were used in combination together to identify air quality issues. AMPT and AAQA staff used a collaborative SharePoint List database of air pollutant observations to prioritize findings for referral internally within the Air District and in public-facing materials, including the initial findings highlighted in the StoryMap.

To visualize and compare measurements at different times and on different days with varying meteorological conditions and changing ambient air pollutant concentrations throughout the project area, a method was developed to calculate a “background” pollutant concentration, and data were analyzed using either a concentration “enhancement” above the background concentration, or a ratio to the background concentration. Such an approach is particularly useful for mobile air monitoring data since background levels of some air pollutants can drift substantially over minutes to hours and from place to place, even over a relatively small area, due to changes in meteorological conditions, distance from local pollution sources, and other factors. This approach was developed to support the prioritization of identifying pollution sources for Air District follow-up and help isolate pollution plumes emitted by nearby sources from ambient concentrations when visualizing large quantities of monitoring data. The enhancement was used to visualize measurements in the initial findings highlighted in the public StoryMap summarizing this work. Detailed methods for calculating the background pollutant level, enhancement, and ratio to background, as well as example visualizations used to identify air quality issues, are described in the following sections.

Additionally, wind speed and direction data collected by the air monitoring van were used, when possible, to help contextualize and identify possible sources of higher measured air pollutant levels. Wind speed and direction data from the monitoring van were only considered when the van was not in motion. As an additional check, data from the mobile air monitoring van were compared with data from nearby fixed-site meteorological monitors, such as from the Oakland San Francisco Bay Airport.

Several factors were considered to identify air quality issues for follow-up by the Air District and to highlight in the StoryMap:

- Occurrences of higher levels of air pollutants near known sources or locations identified by the community
- Locations where higher levels of air pollutants occurred on multiple drive passes or drive days
- Air quality issues that were observed and noted by the Mission Control Operator or Driver while in the van, such as smoke or odors
- Highest levels of an air pollutant that were measured during a single drive day or the highest concentration of all drive days combined

4.2. Method for Background and Enhancement

The background concentration, defined as the 10th percentile of 1-second concentrations measured within a 30-minute rolling window centered on each observation, was calculated for each pollutant and used to aid in comparing air pollutant measurements across different times of day, separate days of the project period, and across different locations within the community.³ The background concentration was calculated for 30-minute rolling windows with at least 10% valid observations to ensure that the sample is reasonably representative of ambient conditions. This data completeness requirement is designed to account for missing periods of data occurring during normal van operation that include periods of time during which the van is not collecting valid data, including when stopped at intersections or while stopped to perform planned meteorological measurements. The following metrics were used to analyze and describe air pollutant measurements from the air monitoring van:

- enhancement: the absolute difference between the measured concentration and the calculated background concentration

³ The method for calculating background and enhancement concentrations was adapted from similar methods used in other mobile air monitoring studies, such as those summarized in Table 1 in Actkinson, B., Ensor, K., & Griffin, R. J. (2021). SiBaR: a new method for background quantification and removal from mobile air pollution measurements. *Atmospheric Measurement Techniques*, 14(8), 5809–5821. <https://doi.org/10.5194/amt-14-5809-2021>

- ratio to background: the measured concentration divided by the calculated background concentration.

Public-facing visualizations included in the StoryMap show air pollutant enhancements. Exploratory visualizations used by Air District staff to identify air quality issues used both enhancements and the ratio to background, with thresholds such as >10x or >25x background used to identify peak air pollutant concentrations across multiple drive days. Examples of these visualizations are shown in the following section.

4.3. Methods for Identifying Air Quality Issues

Numerous interactive data visualizations were used to inform the identification of air quality issues for referral to Air District inspectors or other staff for follow up. Distributions of concentration data (Figures 4-6) were viewed in combination with maps of air pollutant measurements (Figures 7 and 8) to identify extreme concentrations or patterns of repeated high pollutant concentrations. Figure 4 shows the distribution of an individual pollutant across all days of the project period, and Figure 5 shows time-series line plots of all pollutants observed on a specific day of the project period. Used together, these figures show how an individual observation compares to the full distribution from the project period. They also allow for the identification of co-occurring pollutants measured at the same time, which can help in source attribution. Figure 7 is a screenshot of an interactive dashboard that allows for visualization of concentrations, enhancements, and ratio to background for individual pollutants on individual days on a map. Figure 8 is a screenshot of an interactive dashboard that plots observations with pollutant concentrations exceeding a minimum ratio to background across all days of the monitoring project to aid in identifying areas with repeated observations of a selected air pollutant. Figure 9 shows wind roses using meteorological measurements taken at designated stops on each data collection day.

Figure 4: Interactive Boxplot

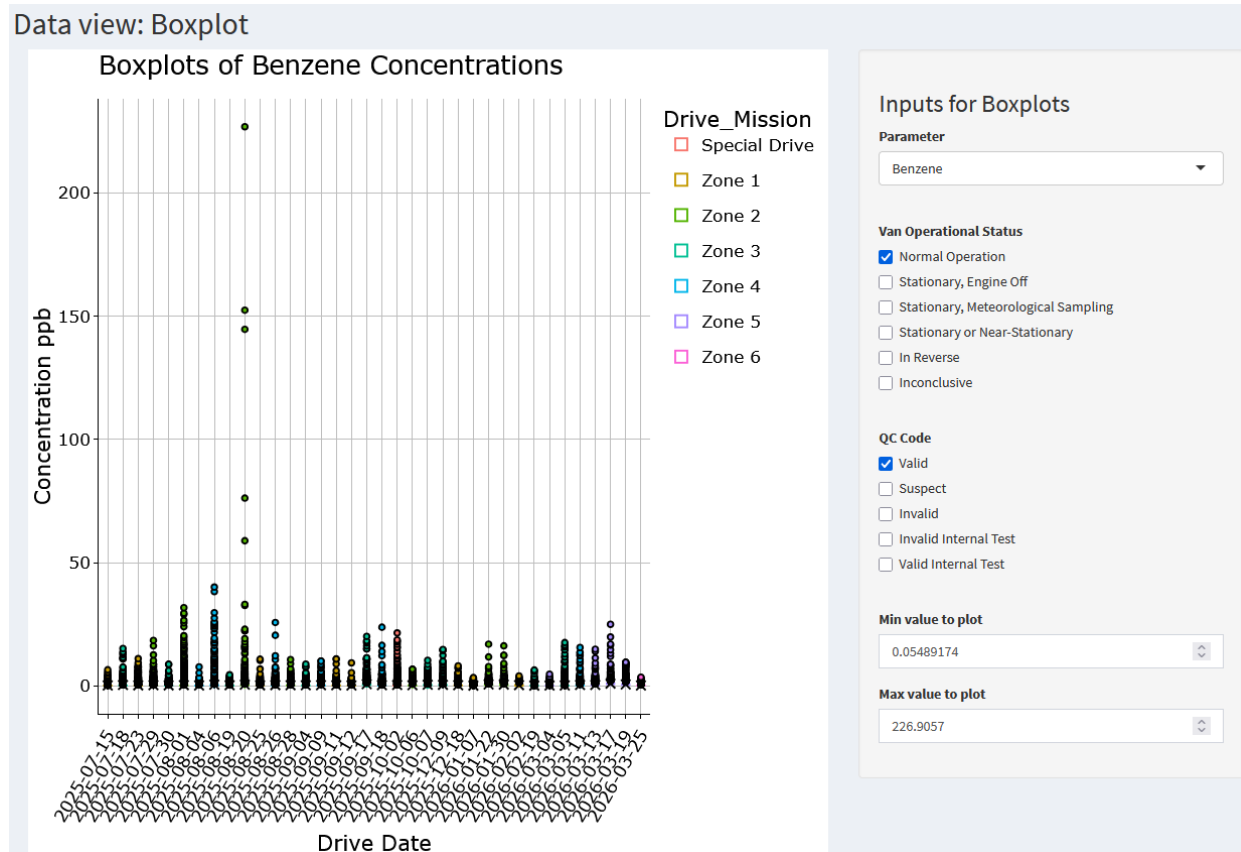


Figure 4. Interactive R Shiny visualization displaying distributions of concentrations of a single pollutant (Benzene in this example) across all drive days.

Figure 5: Interactive Time-Series Plot

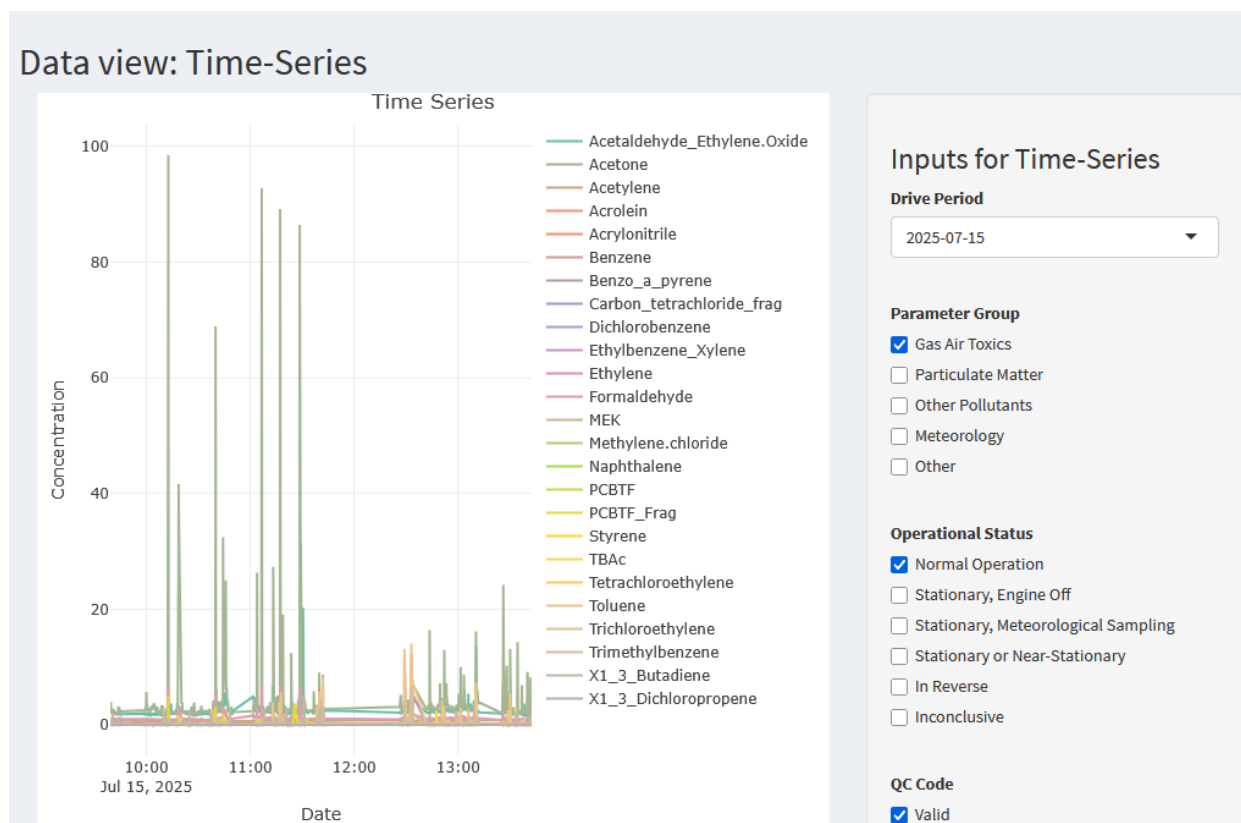


Figure 5. Interactive R Shiny visualization displaying time-series of concentrations of all gas air toxics on a single drive day (July 15, 2025 in this example).

Figure 6: Interactive Scatterplot

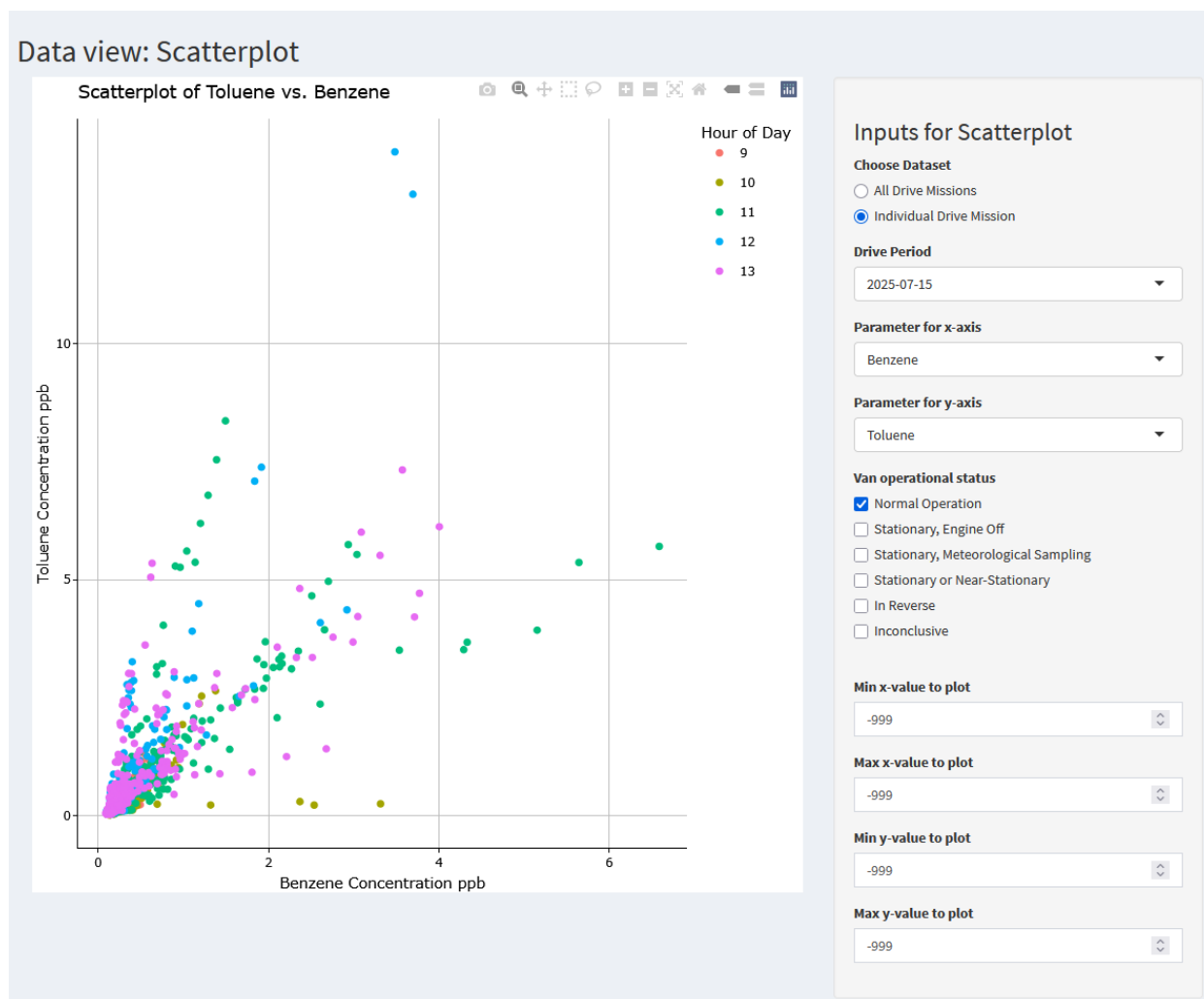


Figure 6. Interactive R Shiny visualization displaying relationships between pollutants on a scatter plot (benzene and toluene in this example), colored by hour of day.

Figure 7: Interactive Concentration Map



Figure 7. Interactive Observable Framework/Plotly web map used to plot concentrations, enhancements, and ratio to background for individual pollutants on individual days. Tooltips on mouse hover show the plotted parameter, time of measurement, drive mission zone, concentration value, and comment from van operators (if any). Although not shown in this example, point locations of known facilities or community assets are plotted on the map.

Figure 8: Interactive Map of High Pollutant Concentrations Across All Drive Days

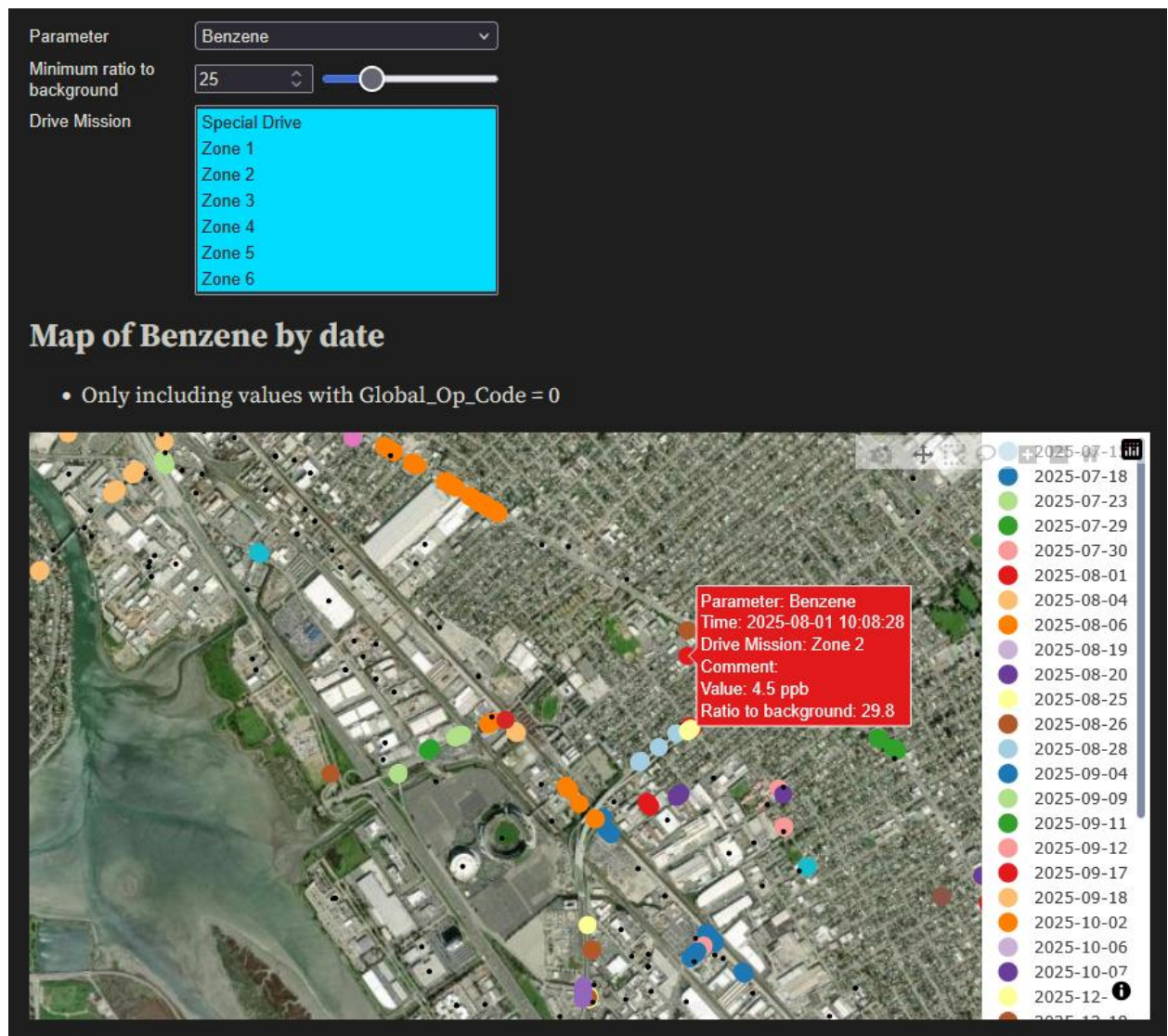


Figure 8. Interactive visualization displaying pollutant concentrations exceeding a minimum ratio to background (in this example, benzene concentrations $>25\times$ the background concentration) across all drive days. Tooltips on mouse hover show the time, drive mission zone, comment from van operators (if any), concentration value, and ratio to background. The qualifier of “Only including values with Global_Op_Code = 0” indicates that the data are filtered to only measurements collected while the van is in motion.

Figure 9: Interactive Wind Rose Map

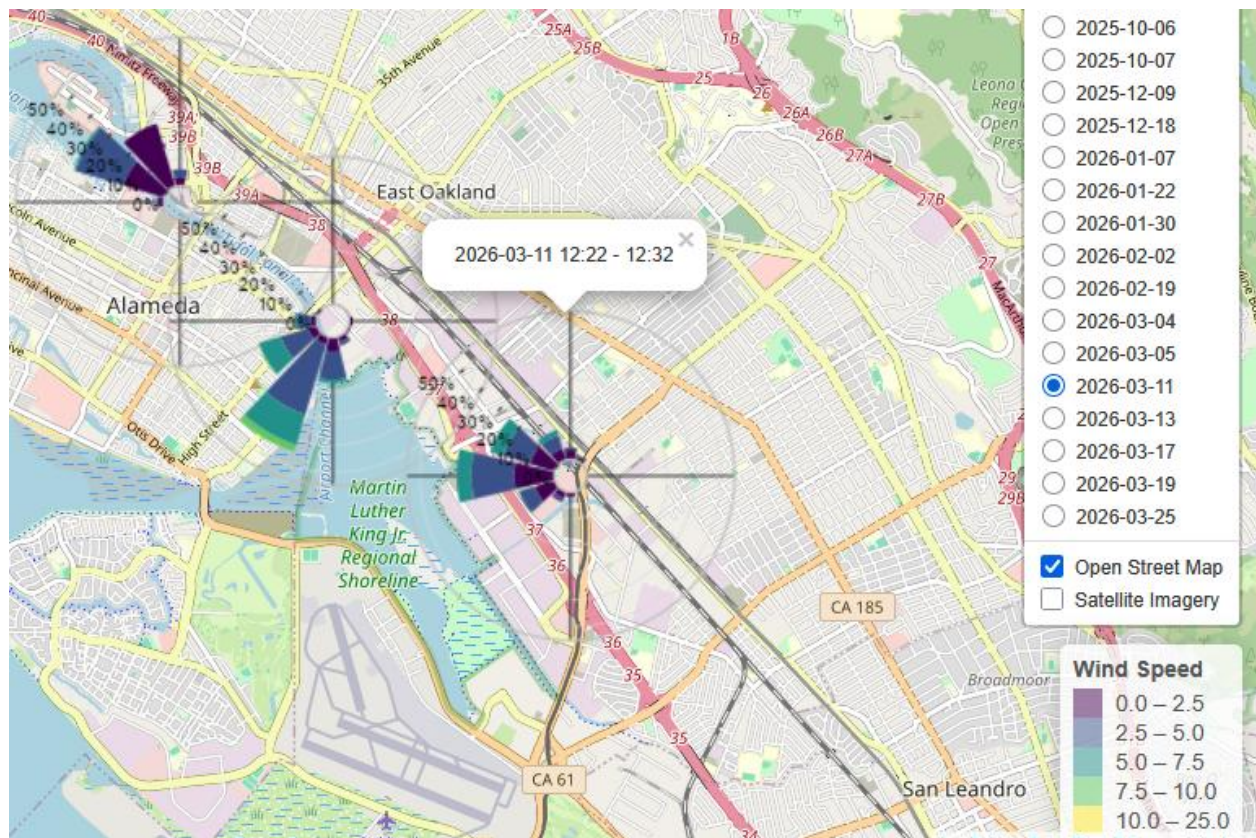


Figure 9. Example interactive wind rose visualizing meteorological data collected by the air monitoring van for each drive day. Tooltips show the time duration of the meteorological data collection (with the van stationary) for each individual stop on each day.

Other screening methods for identifying patterns of air pollutant measurements were used for screening observations near the prioritized facilities and community assets identified in this project or from the Air District’s emissions inventory. In this approach, pollutant measurements within a buffer distance (e.g., 25 or 50 meters) of a known point location above a threshold ratio to background (e.g., 25x background) were counted for each drive day and visualized on a heatmap. This method was used as a high-level screening approach to identify potential patterns of elevated concentrations across all measured pollutants near a previously identified location. Figure A-1 shows observations >25x background within a 50-meter buffer of a gas station in East Oakland. In general, this approach is appropriate for well-defined point locations that the van can drive close to, such as a gas station, but is less applicable to other more complex and larger sources of air pollution in East Oakland, like the Oakland San Francisco Bay Airport, that cover a large area and have many individual sources of air pollution but are represented by a single point location. The Air District is routinely evaluating new approaches for identifying air quality issues from mobile air monitoring data.

4.4. Findings

Numerous occurrences of relatively high levels of different air pollutants were found during this project. In many of these cases, higher levels of different pollutants were detected near and downwind of different industrial facilities and commercial operations. Some of these occurrences were highlighted in the public facing StoryMap along with additional context and information about the Air District's follow-up work. Air pollution measurements in the StoryMap are shown as pollutant enhancements, or absolute concentration differences from the background concentration calculated within a 30-minute rolling window.

Highlighted observations include:

- acetone and formaldehyde along Alameda Ave.
- methyl ethyl ketone (MEK) and other VOCs near the Davis Street Transfer Station
- styrene observed near the Cultured Marble Products business on Merced St.
- PM₁₀ concentrations near Gallagher & Burk and Martin Marietta aggregate materials facilities
- acetone and formaldehyde observed near the intersection of San Leandro St. and 49th Ave.
- PCBTF and other VOCs near Baldwin St. and 85th Ave.
- PM₁₀ concentrations near Argent Materials
- NO_x and UFP near the Oakland San Francisco Bay Airport (OAK)
- NO_x and VOCs observed near an OAK Bay Area Rapid Transit facility.

These observations were flagged internally at the Air District for further investigation. Inspections and area patrols were prioritized at these sites to review emission sources and operations for regulatory compliance. In one instance, the follow-up investigation resulted in the issuance of a Notice of Violation. Other actions taken in response to Air District follow-up include increased street sweeping to reduce the air quality impacts of vehicle track out near sources of PM₁₀ and raising general awareness of potential compliance issues that impact community air quality. The Air District also assisted facilities with permitting questions and provided businesses with a compliance advisory to clarify permit requirements for cannabis extraction facilities.

Several factors were considered during data analysis to locate, highlight, and contextualize the examples shown in the StoryMap, including areas near the prioritized facilities and community assets; locations where pollutant levels were notably higher compared to surrounding locations, especially if measured on multiple drive days; wind speed and wind direction data from nearby stationary meteorological sites and from the air monitoring van; and observations noted by the Mission Control Operator and Driver, such as odors, or visible smoke or dust from nearby sources. More details on these initial findings are available in the StoryMap. These findings are not comprehensive, and the dataset published as part of this project is intended to ensure the data is available to the public for review and additional analysis.

Summary statistics of valid 1-second air pollutant measurements collected while the van was in motion across all drive days are provided in Table 1, and MDLs and RDLs for each pollutant are reported in Table A-1. Of the VOCs measured in this project, acetone has the highest mean and median concentration of 4.97 and 3.26 ppb, respectively, as well as the highest valid maximum concentration observed of >2370 ppb. The sum of acetaldehyde and ethylene oxide (which cannot be separately measured using the PTR-ToF-MS method; the majority of this signal is expected to be driven by acetaldehyde concentrations) has the second highest mean concentration of 3.52 ppb, followed by formaldehyde, with a mean of 1.42 ppb. Many of the VOCs have median concentrations near zero because they are typically nearly absent in ambient air or are at concentrations below the MDL, except when the van drives near sources of those pollutants (e.g., PCBTF and styrene). Mean concentrations of PM_{2.5} are 5.13 µg/m³ and mean concentrations of PM₁₀ are 20.95 µg/m³. The statistics presented in Table 1 summarize data collected by the mobile monitoring van across 36 drive days conducted during the project. In some cases, problems with instrumentation led to the exclusion of a group of pollutants for an entire drive, leading to slightly different sampling periods for different pollutants. For example, all VOC data from the PTR-ToF-MS are flagged as suspect and excluded on September 17 and 18, 2025 (Figure A-2), but other pollutants measured during this time period were unaffected by the issue and included in the calculations for Table 1. Data collection occurred during typical business hours with varying start and end times between 9:00 AM and 5:00 PM on weekdays.

Table 1. Summary statistics of 1-second air pollutant concentrations measured by the air monitoring van across all drive days in East Oakland.

Pollutant	Units	25 th %	Median	Mean	75 th %	95 th %	98 th %	Max
Acetaldehyde/ Ethylene Oxide*	ppb	2.02	2.72	3.52	4.06	7.40	9.36	302.65
Acetone	ppb	2.34	3.26	4.97	5.57	11.88	17.10	2373.36
Acrolein	ppb	0.11	0.15	0.19	0.23	0.43	0.57	10.33
Acrylonitrile	ppb	0.01	0.01	0.01	0.02	0.03	0.04	1.19
Benzene	ppb	0.17	0.24	0.37	0.41	0.89	1.28	226.91
Carbon tetrachloride	ppb	0.05	0.05	0.05	0.06	0.07	0.08	0.91
Dichlorobenzene	ppb	0.00	0.00	0.01	0.01	0.02	0.03	0.44
Ethylbenzene/Xylene*	ppb	0.08	0.16	0.39	0.35	1.01	2.00	380.26
Formaldehyde	ppb	0.97	1.20	1.42	1.65	2.62	3.07	373.37
MEK	ppb	0.11	0.17	0.32	0.39	0.89	1.28	101.52
Methylene chloride	ppb	0.01	0.01	0.02	0.02	0.03	0.03	15.32
Naphthalene	ppb	0.02	0.03	0.03	0.04	0.08	0.11	1.09
PCBTF	ppb	0.02	0.04	0.12	0.09	0.28	0.50	103.92
Styrene	ppb	0.02	0.03	0.06	0.06	0.23	0.30	35.28
TBAc	ppb	0.00	0.01	0.01	0.01	0.03	0.04	6.78

Toluene	ppb	0.10	0.20	0.46	0.43	1.23	2.16	426.42
Trimethylbenzene	ppb	0.04	0.08	0.18	0.17	0.46	0.93	137.61
1,3-Butadiene	ppb	0.00	0.02	0.59	1.06	2.30	2.75	141.89
1,3-Dichloropropene	ppb	0.01	0.01	0.01	0.01	0.03	0.04	15.21
BC	µg/m ³	0.06	0.43	0.56	0.89	1.87	2.52	56.50
PM ₁	µg/m ³	0.55	1.33	1.76	2.02	5.93	7.92	195.37
PM ₁₀	µg/m ³	6.25	12.96	20.95	23.73	54.26	85.13	24929.52
PM _{2.5}	µg/m ³	2.07	4.59	5.13	7.10	11.52	15.05	641.01
UFP	#/cm ³	17000	26700	3175 4	39400	70100	88600	330000
BrC	µg/m ³	0.18	0.45	0.72	0.98	2.21	3.07	87.42
CH ₄	ppm	2.00	2.04	2.13	2.14	2.60	2.94	20.27
CO	ppm	0.13	0.17	0.27	0.30	0.64	0.98	26.03
NO _x	ppb	3.36	7.52	14.75	18.76	48.11	76.13	453.61

**These pollutants have the same molecular weights and cannot be differentiated by the air monitoring method used. The data listed is a combination of the pollutants that are measured at the same molecular weight.*

Data summarized in this table include valid measurements collected while the van was in motion.

The distribution of the 1-second air pollutant observations is right skewed for nearly all measured air pollutants, with outlying maximum concentrations observed near pollutant sources causing the mean to be equal to or higher than the median for all pollutants. For example, concentrations of PCBTF (Frag) (fragment ions of PCBTF that are more readily detected by the PTR-ToF-MS; PCBTF is often associated with auto body shop operations), were typically near 0 (median: 0.04 ppb) but with higher observed peaks (max: 103.92 ppb) in East Oakland. PCBTF (Frag) concentrations are shown as an example in Figure 10, and the distributions of each of the measured pollutants for every drive day are shown in Figures A-2 to A-4 in the Appendix. Many of the individual occurrences of higher, or peaks in, concentrations of some air pollutants coincide with high levels of other pollutants, and some of the VOCs are highly correlated with each other across the entire dataset (Figure 11). Benzene, toluene, and ethylbenzene/xylene (BTEX) are traffic-related pollutants that are highly correlated. The observed correlations across pollutants are often due to similar sources but can also be due to other factors like meteorological conditions that cause higher or lower concentrations of air pollutants in general.

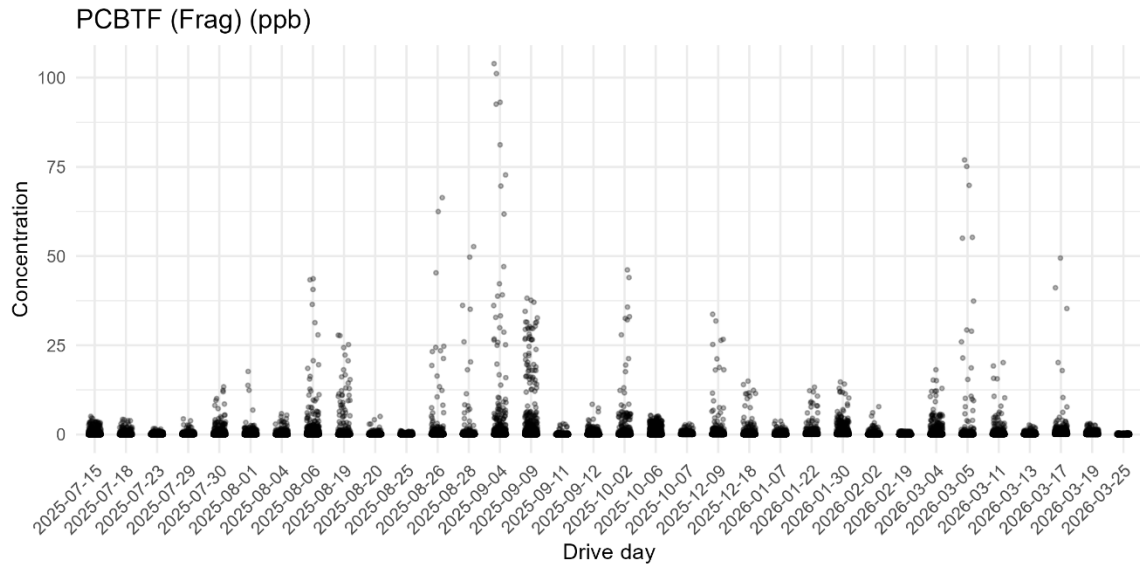


Figure 10. Distribution of PCBTF (Frag) concentrations by drive day in ppb. Each point represents a valid single 1-second measurement from the air monitoring van while in motion.

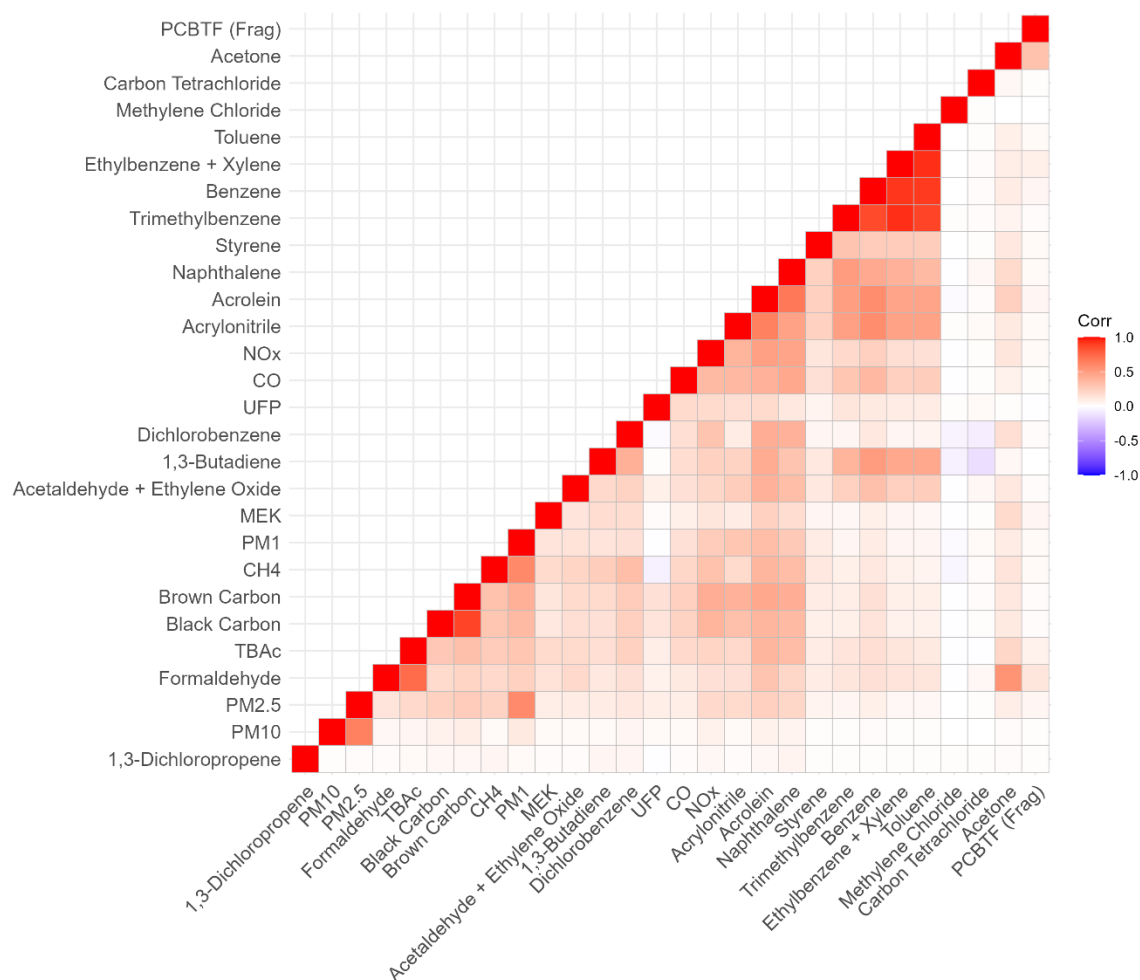


Figure 11. Pairwise Pearson's r correlation matrix for each included pollutant measured by the air monitoring van across all East Oakland drive days at 1-second resolution (including only valid measurements taken while in motion). Highly correlated pollutants are grouped closer together. Darker red shading indicates stronger positive correlation and darker blue shading indicates stronger negative correlation.

5. Conclusion and Next Steps

This project resulted in 120 hours of mobile monitoring measurements of VOCs, PM, and other pollutants from 1000 miles driven in East Oakland across 36 days between July 2025 and March 2026. This project and a summary of initial findings highlighted in the StoryMap were shared at a community event in East Oakland on June 25, 2026. This project improved the Air District's understanding of local-scale air quality issues in East Oakland and created a novel public dataset that is a resource for future work by the Air District and other investigators. Findings from this project can inform the development of effective strategies to reduce emissions and limit people's exposure to air pollution. Furthermore, these data

can highlight potential gaps in the Air District’s regulatory programs and inform future efforts, such as rule development, to better address such issues. Further analysis of the data by the Air District, community members, researchers, or other stakeholders may identify other air quality issues for investigation.

The dataset from this project is available for download on the [Air District's Community Air Monitoring in East Oakland webpage](#). A high-level overview of the project and a summary of initial findings is provided in an [ArcGIS StoryMap](#), also linked on the project website.

Thank you for your attention to and interest in this work. If you have questions, comments, or feedback on this report, please email analysis@baaqmd.gov.

To learn more about East Oakland air quality advocacy efforts and about the work that CBE does, please visit [CBE's website](#).

6. Acknowledgements

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7. Appendix

Table A-1. Method Detection Limit (MDL), Reportable Detection Limit (RDL), and quantification confidence for pollutants of interest in ppb unless otherwise noted

Target compound	MDL (ppb)	RDL (ppb)	Confidence
1_3_Butadiene	0.1	0.3	Low
1_3_Dichloropropene	0.01	0.03	Medium
Acetaldehyde_Ethylene.Oxide	0.6	2	High
Acetone	0.4	1	High
Acrolein	0.1	0.3	Medium
Acrylonitrile	0.01	0.03	Medium
Benzene	0.02	0.1	High
Carbon_tetrachloride_frag**	0.004	0.01	High
Dichlorobenzene	0.003	0.01	Medium
Ethylbenzene_Xylene	0.01	0.03	Medium
Formaldehyde	1	3	Medium
MEK	0.03	0.1	Low
Methylene.chloride	0.03	0.1	Medium
Naphthalene	0.01	0.03	Medium
PCBTF_Frag**	0.003	0.01	High
Styrene	0.005	0.02	Medium
TBAc	0.01	0.03	Low
Toluene	0.01	0.03	High
Trimethylbenzene	0.004	0.01	Medium
BrC (ng/m3)*	390*	1170*	High
BC (ng/m3)*	940*	2820*	High
UFP_Counts (#/cm3)*	0.03*	0.1*	High
PM1 (µg/m3)	0.001*	0.003*	High
PM2.5 (µg/m3)	0.001*	0.003*	High
PM10 (µg/m3)*	0.001*	0.003*	High
CO (ppm)*	0.04*	0.1*	High
CH4 (ppm)*	0.01*	0.03*	High
NOx	0.1	0.3	High

*CO, CH₄, UVPM, BC, UFP_Counts, PM₁, PM_{2.5}, and PM₁₀ MDL and RDL values are listed in their respective units to match concentrations in data file.

** In some cases where a specific compound cannot be detected by the PTR-MS, a fragment (frag) of that compound can be detected.

- To determine pollutant concentrations of parent pollutants from measured fragments, the reader must know branching ratios for parent and fragment ions (e.g., for Carbon Tetrachloride, the branching ratio for fragment measured here is 0.43) (Notø and Holzinger, Int. J. Mass Spec. 2024)

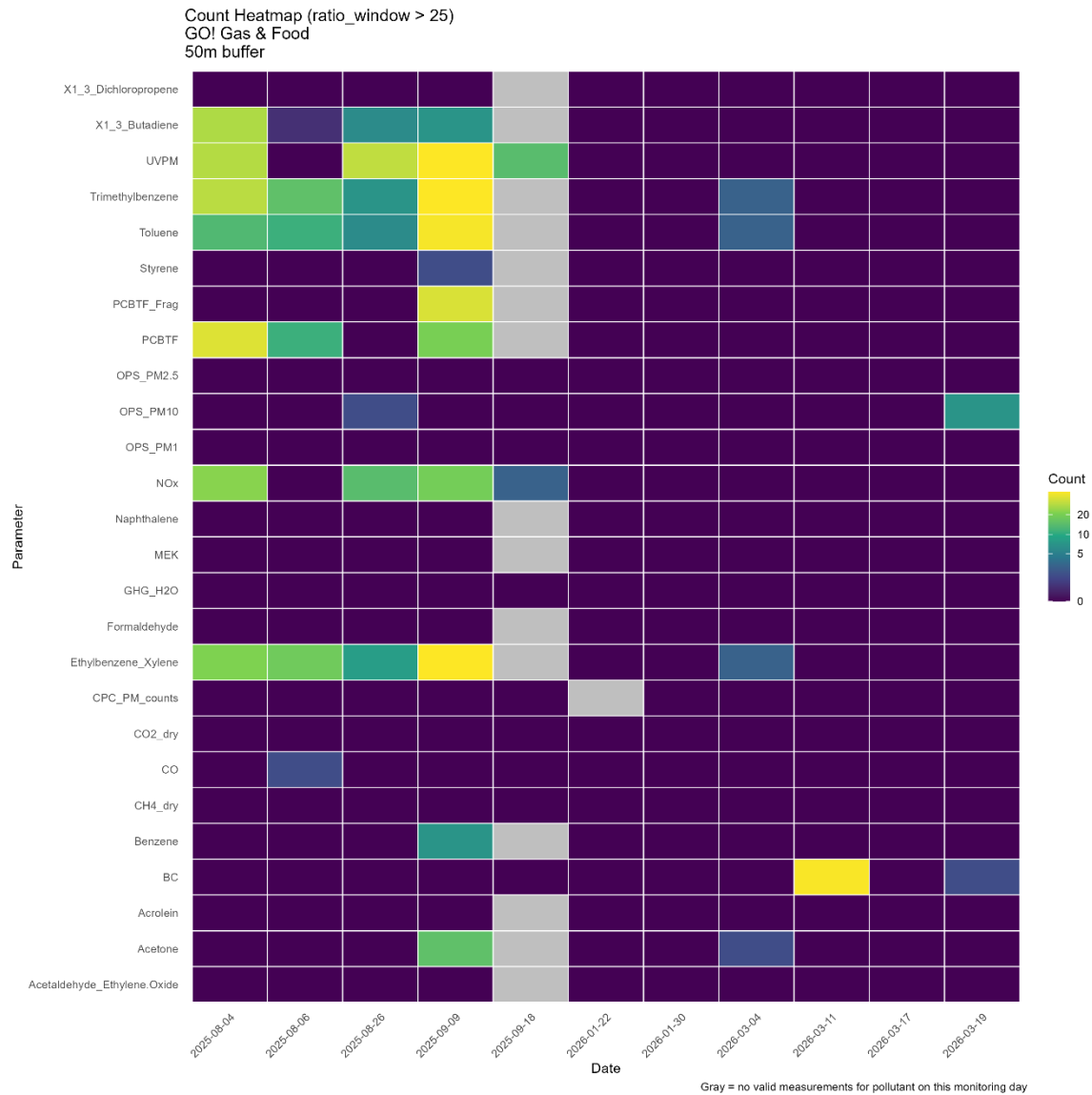


Figure A-1. Example of heatmap displaying the count of valid measurements taken while the van was in motion within 50m of the point location of a potential pollution source, Go! Gas & Food gas station, exceeding 25x the background concentration for each pollutant. Gray tiles represent pollutants with no valid measurements from the monitoring van on the selected drive date.

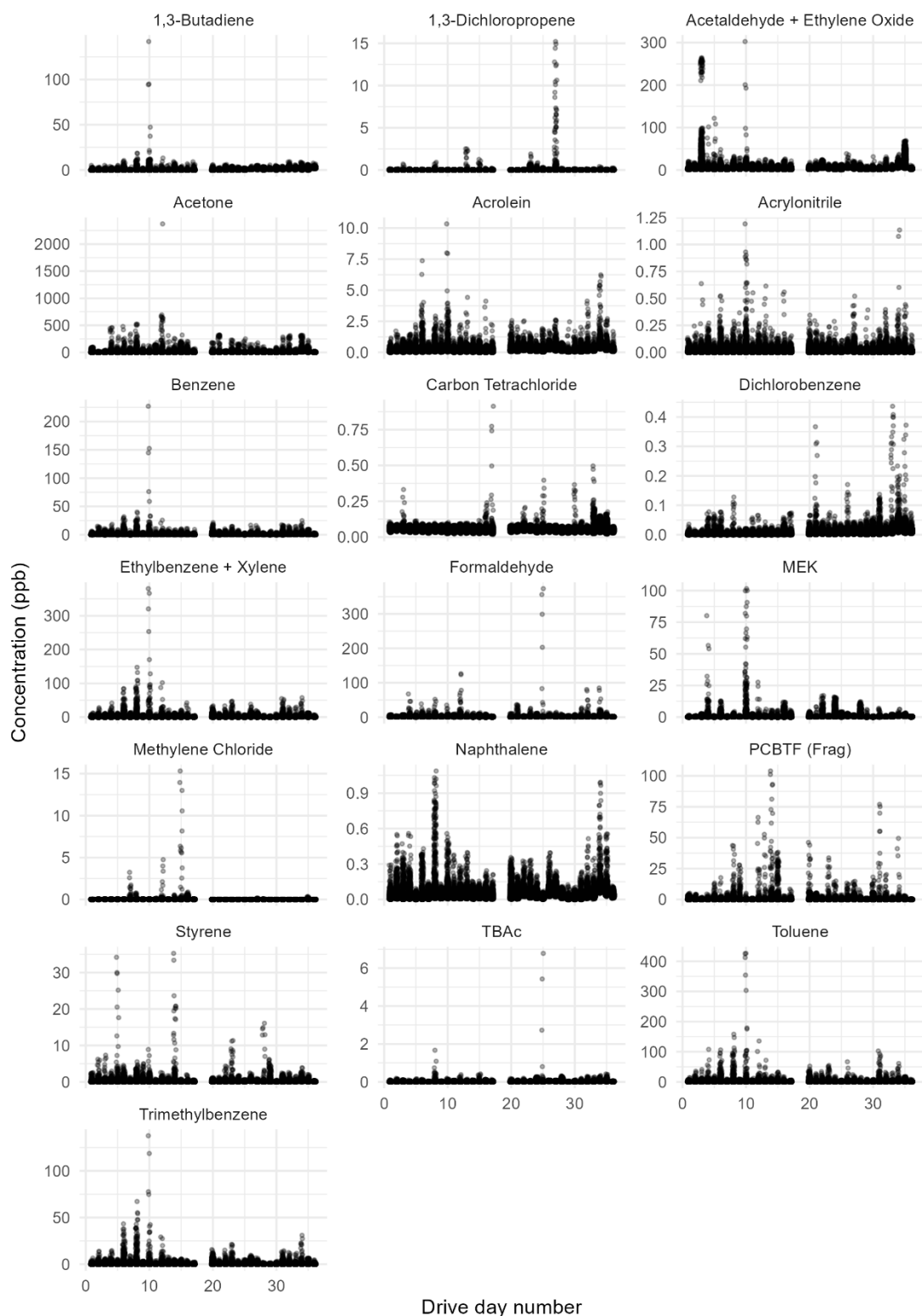


Figure A-2. Distribution of gas air toxic pollutant concentrations by drive day in ppb. Each point represents a valid single 1-second measurement from the air monitoring van while in motion. Drive days are numbered 1-36 consecutively by date to allow for more compact labels. Gaps in these plots indicate days without valid PTR-ToF-MS data (on September 17 and September 18, 2025).

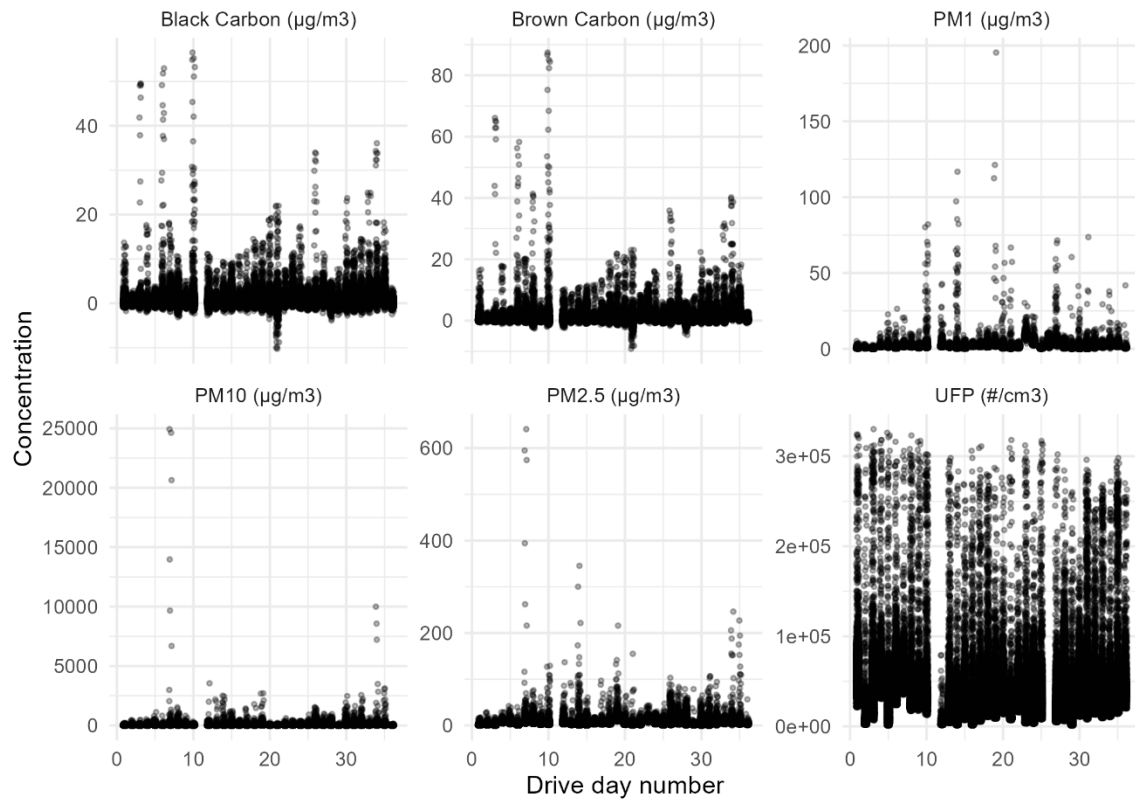


Figure A-3. Distribution of particulate matter pollutant concentrations by drive day. Each point represents a valid single 1-second measurement from the air monitoring van while in motion. Drive days are numbered 1-36 consecutively by date to allow for more compact labels. Negative values are due to noise and low signal-to-noise ratios when pollutant concentrations are very near zero.

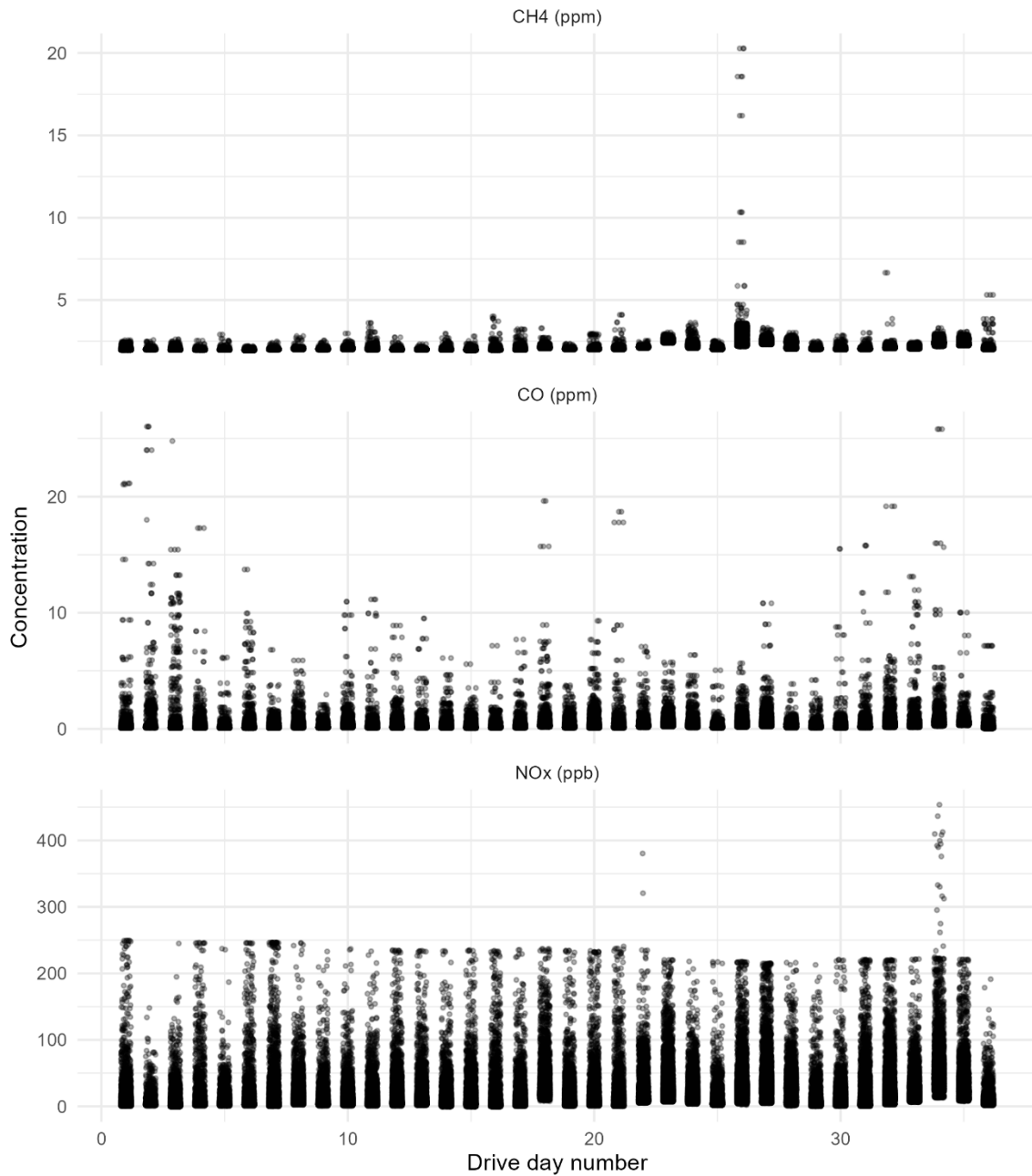


Figure A-4. Distribution of other air pollutant concentrations by drive day. Each point represents a valid single 1-second measurement from the air monitoring van while in motion. Drive days are numbered 1-36 consecutively by date to allow for more compact labels. NOx values between 200 and 300 ppb plateau temporarily due to limitations of the measurement method described in the documentation of the public dataset (in *EOAK_Mobile_Data_Readme.xlsx*). If NOx stays elevated for longer than 2-3 seconds, concentrations are again measured accurately or flagged accordingly.