Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform

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Cover graphic shows the mobile monitoring platform that conducted air quality measurements around Sacramento.

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Terms

Term	Definition
AB 617	California Assembly Bill 617
BAM	Beta-attenuated mass
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CDF	Cumulative distribution function
CHHSL	California Human Health Screening Levels
CMB	Chemical mass balance
CO	Carbon monoxide
CO_2	Carbon dioxide
EJ	Environmental justice
EPA	U.S. Environmental Protection Agency
HAPs	Hazardous air pollutants
K-S test	Kolmogorov-Smirnov test
m	Meter
MDL	Method detection limit
NAAQS	National Ambient Air Quality Standards
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
OEHHA	Office of Environmental Health Hazard Assessment
PM	Particulate matter
PM_{10}	Particles less than 10 microns (10 µm)
$PM_{2.5}$	Particles less than 2.5 microns (2.5 µm)
PMF	Positive matrix factorization
ppbv	Parts per billion by volume
ppmv	Parts per million by volume
PFZs	Pollution Focus Zones
REL	Reference Exposure Level
RMP	Risk Management Plan
TCE	Trichloroethylene
VOCs	Volatile organic compounds

Executive Summary

Urban air pollution is complex and poses risks to human health. Mobile air monitoring is an emerging research tool that can help build understanding of the spatial patterns and variability of urban air pollution at resolutions that are not practical with traditional stationary monitoring. Mobile monitoring provides a broad spatial view of air pollution with highly granular detail. It can also be used to identify highly-localized areas of elevated pollution concentrations within communities.

This project, funded by the Sacramento Metropolitan Air Quality Management District (District) and the City of Sacramento, was designed to conduct an innovative mobile air monitoring study to obtain high spatial and temporal resolution maps of criteria air pollutants, air toxics, and climate forcers on a neighborhood scale. The project team deployed a mobile monitoring platform equipped with research- and regulatory-grade instrumentation to monitor air quality in disproportionately impacted communities in Sacramento, CA.

The campaign culminated in multiple days of observations from February-April 2023, and measured concentrations of (1) **criteria air pollutants**, including fine particulate matter ($PM_{2.5}$), inhalable particulate matter (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO); (2) **climate forcers**, including methane (CH_4), carbon dioxide (CO_2), and black carbon (BC); and (3) **air toxics**, including aromatics, dienes, and alkanes.

The resulting data were corrected for regional influences (i.e., background concentrations) and mapped onto 30- and 60-meter (m) resolution grid cells to generate concentration enhancements for each pollutant. Table 1 summarizes the general statistics of the monitoring campaign. Overall, the project team conducted 21 days of mobile monitoring and 10 days of stationary monitoring. Depending on the pollutant, this resulted in 81.4-112.5 hours of mobile monitoring data and 49-97 hours of stationary measurement data across the Sacramento area. There was a total of 193 road miles covered during the mobile campaign, with 179 of these occurring in communities.

The mobile measurement system calibrations were periodically evaluated and compared against regulatory-grade analyzers at a near-road monitoring site (Bercut) to verify that systems were operating normally. During the campaign, there were instrument issues with the CO analyzer. Based on data quality reviews, the CO measurements were determined to not meet applicable quality assurance standards throughout the entire campaign. As a result, these CO measurements are not included in the report. Furthermore, there were issues with the analyzer collecting NO_2 measurements strictly during stationary measurements. The instrument was later confirmed to be operating erroneously by the manufacturer. As a result, stationary NO_2 measurements are also not included in the report.

Table 1. Summary statistics for the mobile and stationary measurement campaigns from February-April 2023.

Measurement Campaign	Days	Hours	Miles Covered
Mobile	21	81.4-112.5	193
Stationary	10	49-97	N/A

Mobile Monitoring Results:

All mobile measurement data were aggregated to produce community-scale air quality maps for each measured pollutant. For the mobile monitoring campaign, regional background concentrations were calculated and subtracted from the measurements to estimate local air pollution enhancements above background. These enhancements were then averaged across time to understand whether an area was consistently above background. Therefore, all of the spatial air quality maps from the mobile monitoring campaign display mean concentration enhancements per grid cell.

Based on the mobile monitoring analyses, the following spatial patterns were observed:

- North Sacramento communities had greater levels of PM, alkanes, and aromatics, while dienes and CO_2 levels were higher in the South Sacramento communities.
- Methane levels on North Sacramento arterial roadways were higher than South Sacramento arterial roadways. However, methane levels within the communities themselves were generally similar in both regions of the city.
- Ozone, NO_2, and BC levels in communities were generally similar in both regions.

We also determined whether areas that had consistently higher concentrations were significantly different than other monitored locations in the Sacramento metropolitan area using an integrated approach for identifying local Pollution Focus Zones (PFZs) for each pollutant with low, medium, and high confidence scores. PFZ determination used a statistical analysis approach to identify localized air pollution hotspots and discern which areas were being disproportionately impacted by air quality burdens. PFZ maps were then used to prioritize community zones for subsequent stationary measurements to provide a more thorough characterization of localized pollution.

Figure 1 shows the percentage of identified PFZs in each north and south Sacramento community. Most northern communities had PFZ percentages ranging from 0-10% across the community. Some higher percentages were observed in Hagginwood (alkanes, aromatics, and methane), Northgate-Gardenland ($PM_{2.5}$), and Noralto-Old North Sacramento (alkanes, methane). Enhancements of alkanes, aromatics, CO_2, dienes, methane, and NO_2 were notably higher along most of the Marysville Boulevard-Del Paso Boulevard corridor. PM_{10} enhancements were also higher along this roadway, but enhancements were much higher in the southern portion of Marysville Boulevard-Del Paso Boulevard.

In southern Sacramento communities, higher PFZ percentages were also found in Little Pocket-Riverside-Freeport Manor (NO_2, CO_2, and dienes), Hollywood Park-Mangan Park (CO_2, methane, and dienes), Brentwood-Golf Course Terrace-Florin Gardens (CO_2), and Meadowview-Z'berg Park (dienes). The Fruitridge Road corridor had higher concentration enhancements of alkanes, aromatics, and dienes. Conversely, the Interstate-5 highway had the highest mean enhancements for other mobile emission source pollutants (i.e., BC and NO_2). There was an insufficient amount of VOC measurement data collected along Interstate-5 for mean enhancements to be statistically significantly higher than other areas in south Sacramento communities. While routes were not initially planned along the Interstate-5 highway, monitoring took place along this highway during the commute between the northern and southern Sacramento communities.

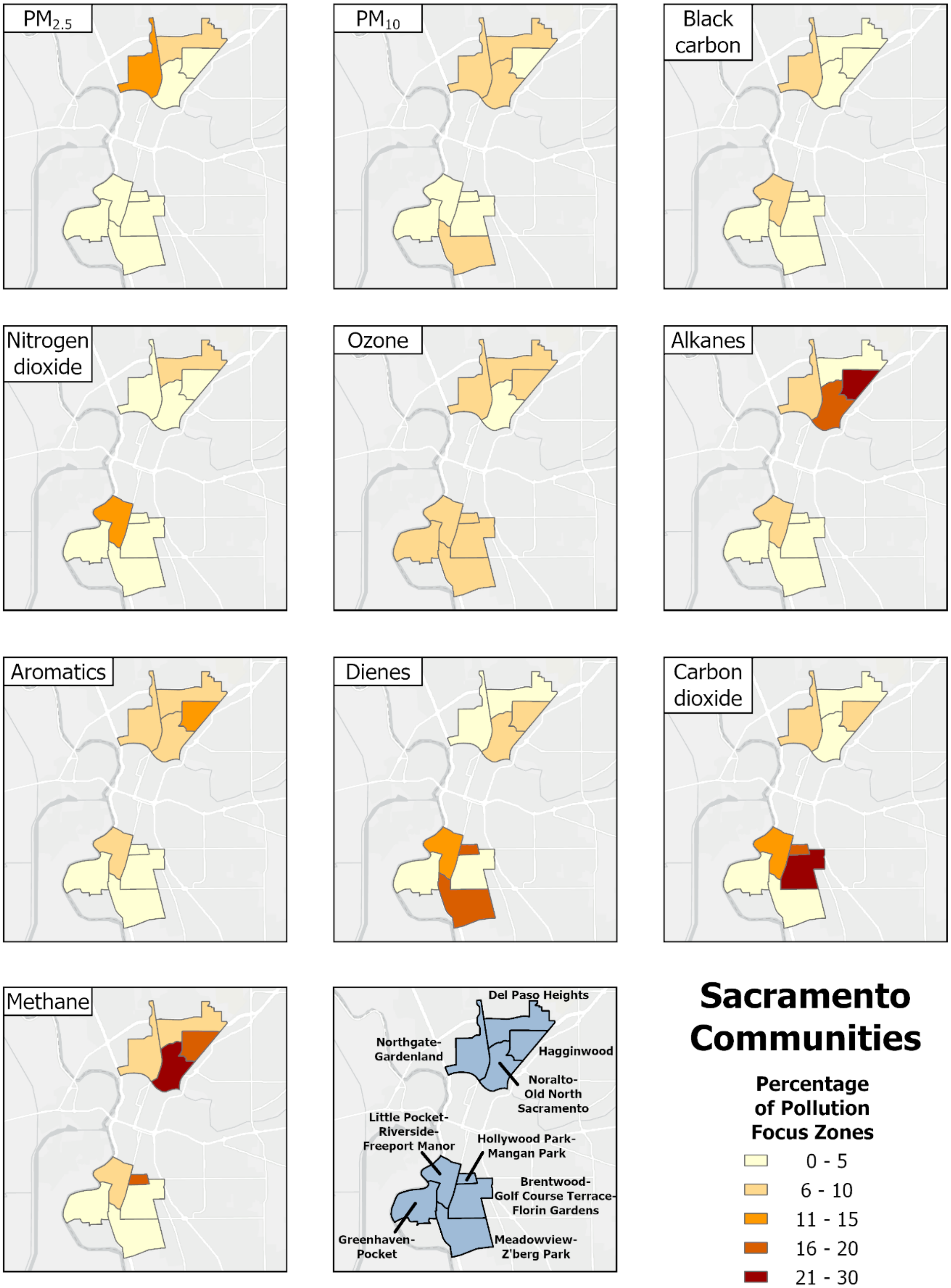

Figure 1. The percentage of pollution focus zones, including low, medium, and high confidence levels, across the grouped Sacramento communities.

Stationary Monitoring Results:

We also measured $PM_{2.5}$, O_3, BC, and speciated VOCs at stationary monitoring sites around the Sacramento metropolitan area. Since these measurements were only collected across one day at each location, these results represent a snapshot in time and may not be indicative of long-term trends or conditions.

- **Particulate Matter:** Concentrations of $PM_{2.5}$ are typically driven by regional influences. Many of the stationary $PM_{2.5}$ concentrations were not significantly different from one another, but two sites did have slightly higher concentrations.

  To disentangle regional influences, we compared stationary monitoring data against the near-road Bercut site using ratios of the stationary site concentrations to the Bercut site concentrations. A ratio above 1.0 means the stationary site had $PM_{2.5}$ concentrations higher than measurements from Bercut, and ratios below 1.0 had measurements lower than those taken at Bercut. The Erickson Industrial Park and Freeport Manor sites had the greatest number of observations with a ratio greater than 1.2 (50% of hourly averages), while the Del Paso Heights and Meadowview sites had the greatest number of observations with a ratio lower than 0.8 (44%). These findings suggest that additional monitoring campaigns in the Erickson Industrial Park and Freeport Manor may be useful to evaluate if these local-scale pollution events are common.

- **Ozone:** O_3 concentrations followed typical diurnal patterns at the stationary monitoring sites. Increases were observed following morning rush hour and concentrations peaked in the early afternoon. O_3 concentrations were consistent across different locations, and one site (Del Paso Heights) had slightly higher (>60 ppb) afternoon concentrations.
- **Black Carbon:** BC concentrations were not significantly different from one site to another during the stationary measurement campaign.
- **Speciated VOCs:** For stationary VOC measurements, site observations were consistent with typical urban background levels. Many of the sites had VOC concentrations that were similar to or below typical concentrations at the near-road Bercut site. However, the Freeport Manor site experienced higher average VOC concentrations than other sites. Further investigation at this location may be warranted to determine whether these higher concentrations are typical.

The study demonstrates that mobile monitoring is an effective tool to identify localized PFZs within a community. Future analyses may build upon this work and can shed more light on the sources and impacts of the pollution, including (1) deployment of monitoring resources and networks for longer-term measurements at PFZs, (2) source-apportionment analysis to identify regional sources and their contributions to air pollution for different wind sectors, and (3) high-level comparison of emissions in underserved communities versus other communities.

Project Highlights

- The study demonstrated that mobile monitoring is an effective tool for hyperlocal spatial mapping of air pollutants at neighborhood levels.
- The study also showcases the utility of regulatory-grade analyzers and advanced research monitoring systems for conducting mobile mapping and stationary monitoring over low-cost sensing approaches. These advanced systems allowed simultaneous high-quality measurements of a variety of criteria air pollutants, climate forcers, and air toxics.

Mobile Monitoring Results:

- This study primarily focused on conducting mobile surveys to study the spatial variability of air pollution in Sacramento communities. In this application, the mobile platform is driven around a community to collect short-term snapshots every day. However, by conducting advanced statistical analysis on daily patterns, the project was able to identify the typical spatial patterns of air pollution in each community.
- This project maximized the spatial coverage of measurements within each community, and the survey route was planned such that the entire route could be monitored every day.
- This study presents the local air pollution enhancements (local pollution above regional background) in each community where measurements were taken. By focusing on enhancements, the study results were able to pinpoint areas with a disproportionately higher air pollution impact from local sources.
- Given the limited length of measurement at any location, the data are not representative of longer-term exposures and cannot be directly compared against air quality standards.

Stationary Monitoring Results:

- Stationary measurements were collected over 6-12 hours on select locations during daytime hours. As such, these snapshots were aimed to provide screening assessments of longer-term measurements on one day at some of the selected hotspot locations.
- The presence or absence of high concentrations does not automatically suggest that typical concentrations would be higher or lower than air quality standards. Therefore, comparing against air quality and health standards is not advisable. Such comparisons require much longer-term measurements over multiple years.
- Furthermore, since measurements occurred on different days (one day per site), any comparison between sites is also not advisable given the expected day-to-day variability. However, the measurements can illuminate where additional investigations could be warranted, as exceptionally higher air pollution levels can help prioritize sites for follow-up monitoring.
- The measurements show the utility of mobile monitoring laboratories – which can be deployed at different locations for quick screening measurements at single locations.

1. Introduction

Urban air pollution is highly variable across metropolitan communities and can greatly vary even within communities. Air pollution exposure experienced by individuals may differ due to variable distributions and pollution source strengths, local meteorological conditions, land-use characteristics, proximity to pollution sources, and other factors. Longitudinal studies have shown minority groups tend to be disproportionately impacted by urban air pollution from sources such as major urban highways, warehouses, and hazardous waste facilities (Mohai, et al. 2015; Yuan, 2018). Characterizing air pollution hotspots affecting these communities can be scientifically challenging due to atmospheric chemistry, inconsistent emissions patterns, and other conditions (Zhang et al., 2021).

Traditional air quality monitoring solutions, such as regulatory monitoring networks, are very effective for measuring and tracking regional or urban air quality levels, evaluating attainment with the National Ambient Air Quality Standards (NAAQS), and understanding temporal patterns to characterize long-term trends. Due to this ability to measure ambient air concentrations with high degrees of accuracy and precision, continuous or near-continuous monitoring approaches are typically implemented for compliance with the Clean Air Act and local air quality standards.

Although these networks are frequently relied on in health research, they can have limited spatial coverage in most areas, and are sometimes specifically designed for an urban background emphasis without a focus on near-road environments where people are exposed to high levels of pollution (Cromar, et al., 2019). Therefore, while regulatory monitoring networks provide a generally effective measure of pollution levels for urban areas, they do not capture air pollution variability across communities. Understanding local spatial variability is even more complicated for pollutants such as air toxics, where current networks may not even provide adequate regional coverage, temporal coverage, or pollutant measurement capabilities to study public exposure. Moreover, regulatory monitoring systems are expensive to purchase and operate, so these instruments are not densely deployed across communities. A report by the American Thoracic Society highlights that limitations for increased spatial resolution of regulatory-quality monitors is economical, not technological (Cromar, et al, 2019). Therefore, there is a need for complementary air monitoring solutions to augment regional networks operating across the country, notably in urban areas.

Distributed passive samplers, air sensor networks, and mobile monitoring are all complementary efforts. Passive samplers have been used to gather measurements at increased spatial resolutions in urban locations for oxides of nitrogen (NO_x) (Sather et al., 2007), ozone (O_3) (Yli-Pelkonen et al., 2017) and air toxics such as benzene (Mukerjee et al., 2016; Mukerjee et al., 2020). However, since these methods are time-integrated, they do not provide sufficiently granular temporal resolution to understand variable emissions patterns. More recently, air sensor networks have been used because they are less expensive than regulatory monitors and can help increase spatial coverage and maintain higher temporal resolutions (Cromar, et al, 2019). Sensor networks in urban areas have found higher criteria air pollutant concentrations near industrial sites than other urban or suburban regions. These studies have found varying degrees of correlation with socioeconomic factors (Tanzer et al., 2019; Masri et al., 2022). Additionally, sensors are easy to use and have shown promise for increasing community participation in research (Ekman and Weilenmann, 2021; Masri et al., 2022). There are issues with sensor quality control and assurance though. While particulate measurements from sensors have better comparisons against regulatory monitors with some correction factors (Barkjohn et al., 2021; Feenstra et al., 2019), gaseous pollutants have been shown to be less reliable (Han et al., 2021). Furthermore, sensor networks tend to be in predominantly higher-income, white neighborhoods where disproportionate air quality impacts may not be occurring (Kelp et al., 2023).

Mobile monitoring is an efficient solution for capturing high-quality, high temporal frequency air quality measurements in communities. Short-term mobile monitoring campaigns are even being used to assess long-term air pollution exposure in epidemiology (Blanco, et al., 2023). Mobile monitoring studies can increase spatial understanding of air pollution for large regions, and fast-response measurements on roads are well-suited to sample recent and local emissions, especially from transportation sources, which may be beneficial for emissions analyses (Padilla, et al, 2022). As such, mobile measurements can provide information on fine-scale spatial variation to inform exposure assessment and mitigation efforts. However, the temporal sparsity of these measurements presents a challenge for estimating representative long-term concentrations (Chambliss, et al., 2020). A suitable number of repeat visits to each location is required to obtain reliable and representative estimates at desired spatial and temporal resolution (Padilla, et al., 2022). Moreover, such systems require robust data management and synchronization techniques, data analysis and visualization protocols, and trained experts to operate systems and analyze data.

Recent papers by Apte et al. (2017) and Chen et al. (2022) documented approaches used to study general spatial patterns of air pollution. Chen et al. (2022) developed an approach to identify localized high pollution zones, or pollution focus zones (PFZs), to estimate local and regional source contributions by breaking down background and local emissions to the community level. These studies suggest that 15–30 repeated mobile measurement campaigns provide useful data to map general air pollution patterns within a community. Chen et al. (2022) also presented a three-element geo-spatial statistical analysis approach to identify air pollution hotspots that experience consistently, persistently, and statistically higher air pollution levels than the rest of the community.

To understand where disproportional air quality impacts may be occurring in Sacramento, Sonoma Technology investigated intraurban variability in concentrations of criteria and hazardous air pollutants (HAP) from February to April 2023 using mobile monitoring. This project was funded by the Sacramento Metropolitan Air Quality Management District (District) and the City of Sacramento to obtain high spatial and temporal resolution maps of air pollutants and climate forcers on a neighborhood scale. To meet project objectives, Sonoma Technology deployed a high-quality and high-fidelity air quality measurement system capable of conducting regulatory- and research-grade air monitoring. Sonoma Technology partnered with Entanglement Technologies and the University of California (UC) Davis to offer a project team that could comprehensively deploy, monitor, and analyze complex air quality data from mobile and stationary sensor deployments.

2. Project Overview

2.1 Objectives

This project was designed to study the spatial and temporal patterns of ambient air pollution concentrations at a neighborhood scale, identify PFZs, evaluate pollution in underserved communities versus other communities (in conjunction with previous and on-going District projects), and help the City of Sacramento make informed decisions regarding land use and the implementation of strategies to reduce emissions in high pollution burden areas.

The specific goals of this project were to:

1. perform neighborhood mobile air monitoring in the city of Sacramento to collect ambient air pollutant concentration data at fine spatial and temporal resolutions for a comprehensive understanding of pollutants at a neighborhood-scale, and
2. use innovative air monitoring strategies to focus on areas of interest in Sacramento to determine disparities between underserved communities and other areas that supplement previous and current monitoring by the District.

2.2 Approach

The project team deployed a state-of-the-art mobile air monitoring system comprised of several research/regulatory-grade analyzers for measuring: (1) criteria air pollutants, including $PM_{2.5}$, PM_{10}, NO_2 via NO_x, O_3, and CO; and (2) climate forcers, including methane, CO_2, and BC. The selected instruments are built by industry-leading air quality analyzer manufacturers. The project also measured gaseous air toxics (i.e., VOCs) using the Entanglement Technologies AROMA analyzer.

The combination of these instruments provided high-quality, regulatory- or research-grade measurement capabilities for desired pollutants at temporal resolutions necessary to evaluate community-scale pollution levels. The system also provided the concurrent capability to measure a variety of VOC compounds in a stationary format, including benzene, toluene, 1,3-butadiene, alkenes, and chlorinated species, which augments ongoing air toxics measurements collected by the District.

The project team applied a 3-phase measurement and analysis approach:

- Phase 1: Mobile monitoring in nine Sacramento communities across 21 days, including weekdays and weekends.

- **Phase 2**: Advanced statistical analysis to identify PFZs in each community.
- **Phase 3**: Continuous stationary measurements at priority hotspots for up to 12 hours, with at least one site selected in each community to measure diurnal trends. The continuous stationary measurements setup operated the AROMA instrument in a speciation mode, which allowed the project team to characterize individual VOCs and better understand toxicity implications of air toxics in each community.

The application of this research-grade analyzer in dual modes, with initial mobile mapping of entire selected communities followed up by single day stationary deployment in the VOC speciation mode, allowed maximum spatial coverage and temporal and composition observations at key locations. The use of the system in both modes allowed for the assessment of important VOCs in the communities; these measurements often have important implications for communities and regulatory agencies due to their associated toxicity.

2.2.1 Community Selection

Overview

The project focused on community-scale air monitoring in two regions: north and south Sacramento. Initial community zones were identified by the District, and each represented an underserved community consisting of multiple census tracts with high cumulative, environmental burden, and population characteristic scores.

Census Tracts

Communities were grouped together by census tract to evaluate summary statistics. The census tracts used to develop the groupings are shown in **Table 2**. Additionally, a map showing the geographic representation of the community groupings is also shown in **Figure 2**.

Table 2. Community groupings and associated census tracts.

Community	Census Tracts[a]	North/South Sacramento
Brentwood-Golf Course Terrace-Florin Gardens	38, 41, 45.01	South
Del Paso Heights	64, 65.01, 67.05, 67.06	North
Greenhaven-Pocket	40.05, 40.06, 40.14, 40.15, 40.16, 40.18	South
Hagginwood	63, 66	North
Hollywood Park-Mangan Park	35.02	South
Little Pocket-Riverside-Freeport Manor	33, 34, 39	South
Meadowview-Z'berg Park	40.13, 42.01, 42.02, 42.03, 43.01, 43.02	South
Noralto-Old North Sacramento	68.01, 68.02, 68.03, 69.01, 69.02	North
Northgate-Gardenland	70.01, 70.07, 70.13, 70.23, 70.24	North

[a] Census tracts from the U.S. Census Bureau were used to group tracts into communities.

There was an average of 8.5 hours of data collection across all communities and parameters. The longest duration of measurements took place in Noralto-Old North Sacramento (14.4 hours) and Meadowview-Z'berg Park (16.7 hours). The shortest duration of measurements took place in Hagginwood (1.9 hours) and Hollywood Park-Mangan Park (3.8 hours). These shorter durations were a function of the strategic routing and the size of these grouped census tracts.

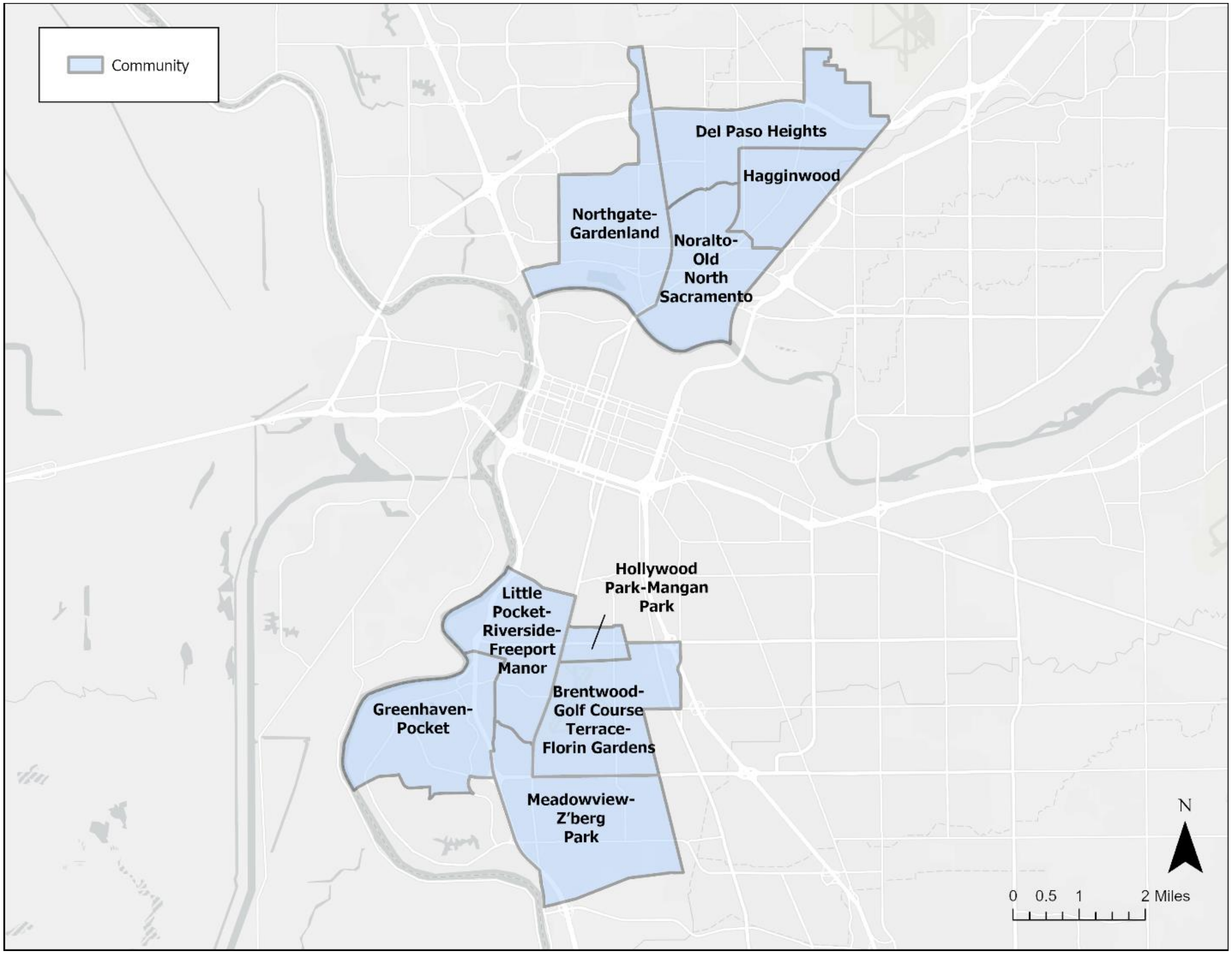

Figure 2. Community groupings in Sacramento from the census tracts (also detailed in Table 2).

Environmental Justice Characteristics

The U.S. Environmental Protection Agency (EPA) has developed the EJScreen application[1] and database, which is an environmental justice (EJ) tool that combines environmental and socio-economic indicators to compare different census tracts and block groups. U.S. EPA defines EJ as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies."[2] Notably, EPA defines six environmental indicators for air pollution, including exposure to particulate matter of the 2.5 μm size fraction (i.e., $PM_{2.5}$), ozone, diesel particulate matter, air toxics cancer risk, air toxics respiratory hazard index, and traffic proximity. **Table 3** shows these indices for communities of interest to this project. Additionally, other environmental indicators include lead paint exposure, Superfund site proximity, risk management plan (RMP) facility proximity, hazardous waste proximity, underground storage tank proximity, and wastewater discharge. **Table 4** shows these indices for communities of interest to this project. EPA develops two comparisons: one ranking all census tracts, or block groups, against the rest of the U.S., and another that ranks tracts or groups against all other boundaries within a given state. These rankings are described as percentiles. For example, if a percentile is 75, then that census tract or block group is at a higher risk than 75% of the other census tracts or block groups. EPA defines the 80th percentile as being the threshold at which a census tract or block group can be considered a potential community candidate for further review.

In the Sacramento communities of interest, we grouped census tracts as shown in **Table 2**. We evaluated the percentiles for EJ indices and tallied the number of EJ indices above the 80th percentile. Six out of the nine census tract-grouped communities had at least one EJ Index percentile that was above the 80th percentile. These included Del Paso Heights (7 EJ indices above the 80th percentile; subsequent numbers reflect the same metric), Brentwood-Golf Course Terrace-Florin Gardens (5), Hagginwood (5), Meadowview-Z'berg Park (5), Noralto-Old North Sacramento (5), and Northgate-Gardenland (5). All other communities had no environmental EJ indices above the 80th percentile. Notably, some of the communities were above the 90th percentile for $PM_{2.5}$, air toxics cancer risk, and air toxics respiratory hazard index. These included Del Paso Heights, Brentwood-Golf Course Terrace-Florin Gardens, and Meadowview-Z'berg Park. The air pollution EJ Index percentiles are shown in **Figure 3** for North Sacramento communities of interest and **Figure 4** for South Sacramento communities of interest. Communities that did not fall above the 80th percentile were also included in this study to allow for comparisons of measurements between communities with greater environmental burden to other areas.

[1] EJScreen state percentiles for air pollution indices are similar to metrics found in the CalEnviroScreen tool.
[2] https://www.epa.gov/environmentaljustice/learn-about-environmental-justice

Additionally, the California Assembly Bill 617 (AB 617) is state-sponsored legislation that was enacted in 2017[3] and is aimed at addressing air pollution impacts in disadvantaged communities. In 2018, the District conducted an assessment for proposed locations and identified ten communities of interest using comprehensive and technical analyses that evaluated air pollution exposure burdens on the census tract level. The California Air Resources Board (CARB) ultimately selected one of those ten communities in the Sacramento region to participate in the AB 617 Community Air Protection Program; however, the District is committed to enhancing community air quality monitoring and community engagement in all communities identified in the analysis. The District also engaged with communities to identify specific issues such as emissions sources of concern and the importance of indicators such as health risks, socioeconomic factors, location of sensitive receptors, etc. Based on the survey results, the community responses indicated that mobile sources and associated pollution were of the greatest concern.[4] The District's efforts to implement enhanced community air quality monitoring and engage with communities are ongoing. Of the ten identified communities in the District's 2018 assessment, we collected measurements in eight overlapping areas within this study.

[3] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB617
[4] Final Assessment of Proposed Monitoring Locations for AB 617 Community Air Protection Plan

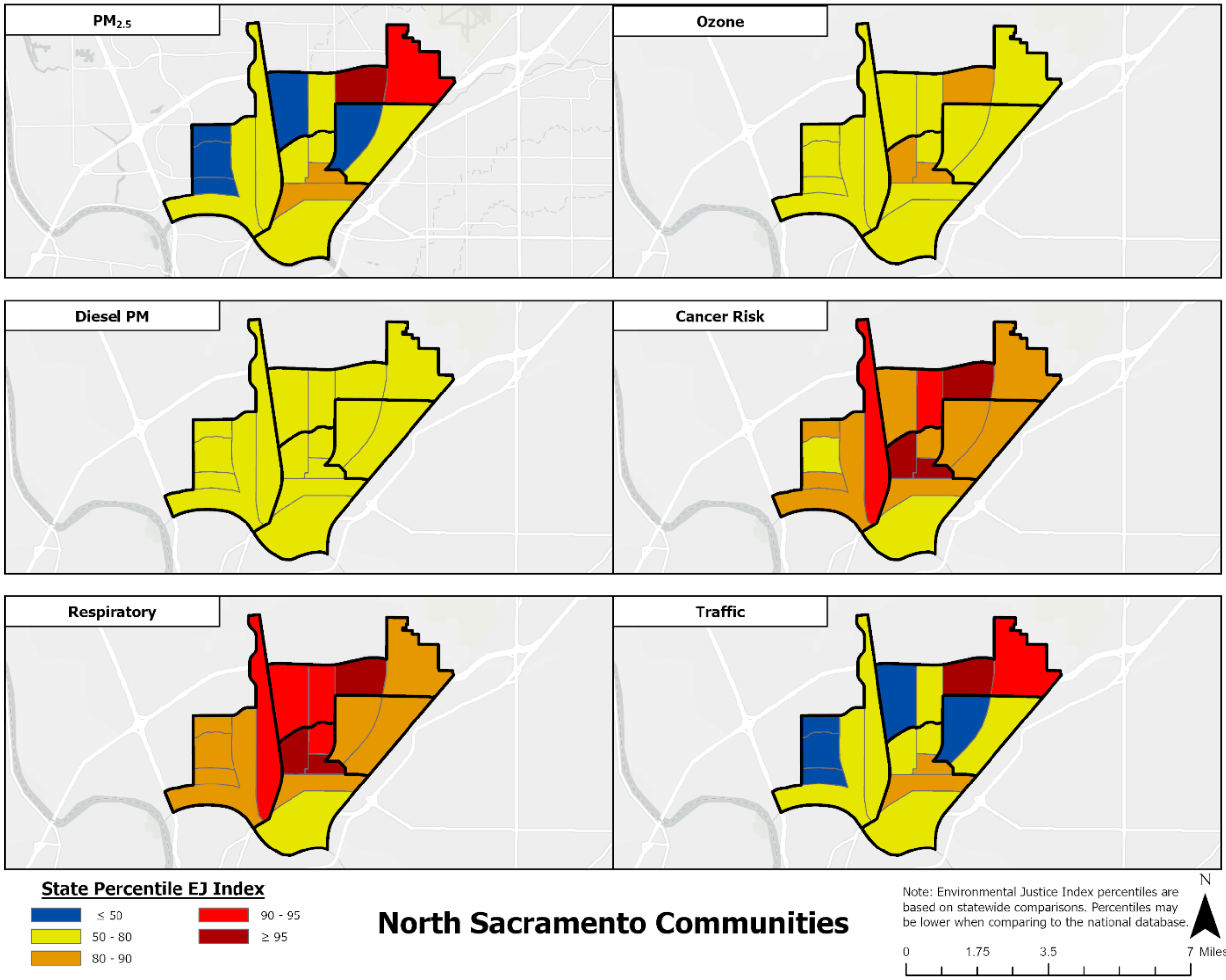

Figure 3. Census tract state EJ index percentiles for north Sacramento communities. State percentiles compare all other EJ indices in the state and rank them to develop the percentile. Only air pollutant EJ indices are shown. Each census tract of interest is included.

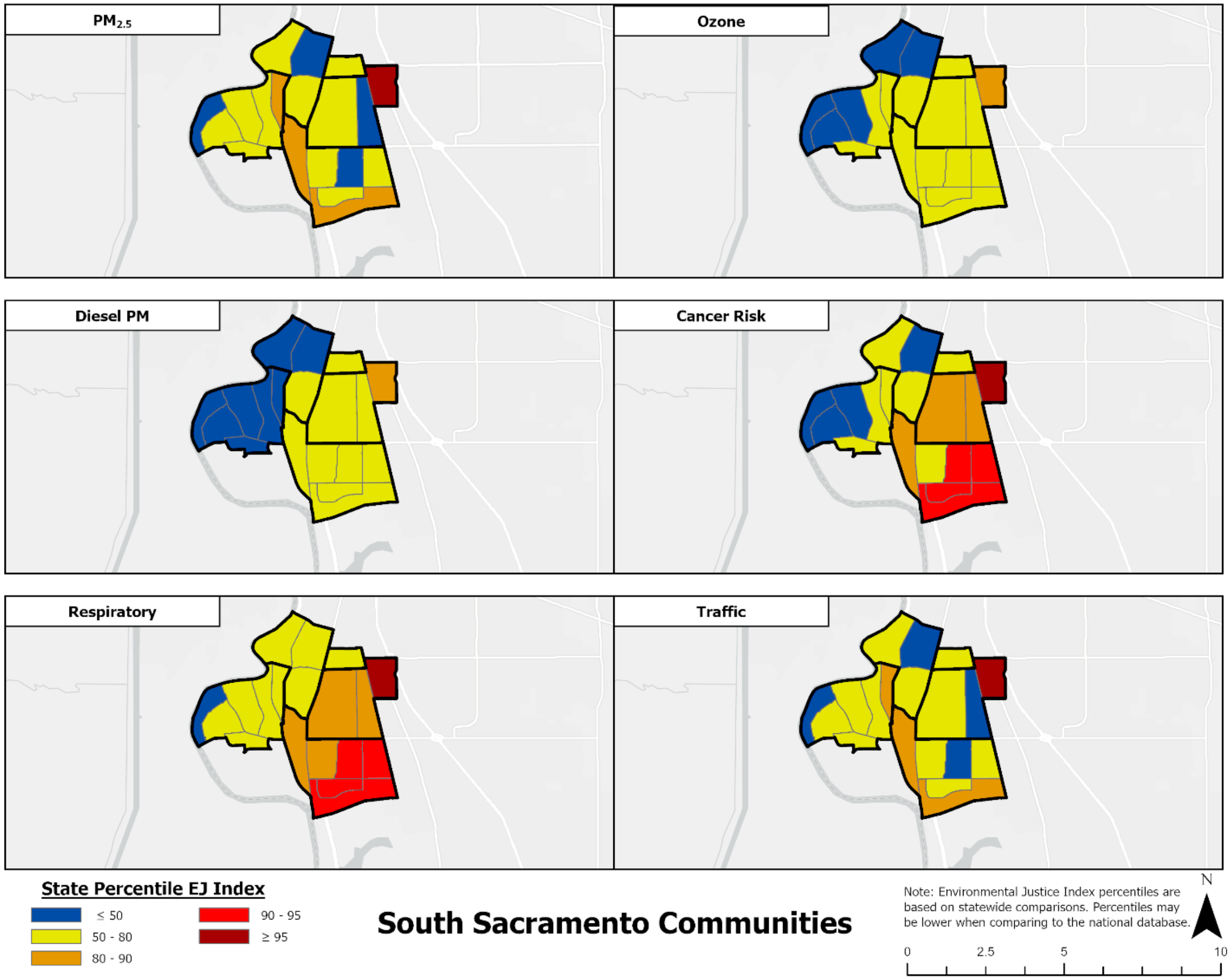

Figure 4. Census tract state EJ index percentiles for south Sacramento communities. State percentiles compare all other EJ indices in the state and rank them to develop the percentile. Only air pollutant EJ indices are shown. Each census tract of interest is included.

Table 3. Air pollution EJ indices for each community in the Sacramento metropolitan area. Percentiles are calculated against the rest of the state's census tracts. Community-level percentiles are summarized by taking the average across all census tracts within the given community.

Community	Air Pollution Indices						
	Average EJ Index Percentile for $PM_{2.5}$	Average EJ Index Percentile for Ozone	Average EJ Index Percentile for Diesel PM	Average EJ Index Percentile for Air Toxics Cancer Risk	Average EJ Index Percentile for Air Toxics Respiratory Hazard Index	Average EJ Index Percentile for Traffic Proximity	Number of Census Tracts
Brentwood-Golf Course Terrace-Florin Gardens	92	71	68	89	91	58	3
Del Paso Heights	92	80	67	91	92	78	4
Greenhaven-Pocket	71	49	35	51	63	60	6
Hagginwood	88	74	64	86	88	47	2
Hollywood Park-Mangan Park	72	52	53	62	68	55	1
Little Pocket-Riverside-Freeport Manor	69	48	46	57	60	51	3
Meadowview-Z'berg Park	93	72	62	87	90	67	6
Noralto-Old North Sacramento	84	70	64	80	83	72	5
Northgate-Gardenland	89	73	64	87	89	58	5

Table 4. Other environmental justice (EJ) indices for each community in the Sacramento metropolitan area. Percentiles are calculated against the rest of the state's census tracts. Community-level percentiles are summarized by taking the average across all census tracts within the given community.

Community	Other Indices						
	Average EJ Index Percentile for Lead Paint	Average EJ Index Percentile for Superfund Proximity	Average EJ Index Percentile for RMP Facility Proximity	Average EJ Index Percentile for Hazardous Waste Proximity	Average EJ Index Percentile for Underground Storage Tanks	Average EJ Index Percentile for Wastewater Discharge	Number of Census Tracts
Brentwood-Golf Course Terrace-Florin Gardens	82	80	86	49	86	45	3
Del Paso Heights	80	91	77	63	72	90	4
Greenhaven-Pocket	24	49	28	27	25	51	6
Hagginwood	85	86	83	54	86	78	2
Hollywood Park-Mangan Park	77	60	60	38	0	43	1
Little Pocket-Riverside-Freeport Manor	67	52	51	31	24	46	3
Meadowview-Z'berg Park	57	76	81	45	89	65	6
Noralto-Old North Sacramento	82	75	85	54	77	83	5
Northgate-Gardenland	66	75	89	64	62	85	5

Survey Routes

The project team developed driving routes that were based on initial routes and inputs provided by the District. The project routes considered some additional factors when routes were being established, including prioritization of:

- Side roads to reduce on-road emissions impacts
- Routes that included sampling near schools
- Routes that maximized the coverage within communities
- Routes that could fit within a single business day

The finalized routes included more detailed driving paths within communities compared to the initial routes and were ultimately designed to acquire enhanced spatial coverage and increased measurement time in each community. The District approved the final community routes before the field campaign commenced. Community routes were grouped together into classifications to ensure measurements were collected along consistent routes. Furthermore, classifications allowed for modular routing so that measurements were collected at different times of the day across the duration of the field campaign. In total, the initially proposed routes covered 112.6 unique road miles. When the campaign took place, additional unique road miles were covered for a total of 193 unique road miles due to driving that occurred between communities.

Additionally, the finalized routes included measurements in 8 census tracts in north Sacramento and 10 census tracts in south Sacramento. Communities and routes were grouped together through an alphanumeric structure where the letter corresponds to a community group and the number corresponds to the number in the route. The breakdown of final routes with the accompanying census tract, community classification (A-F), and accompanying routes are shown in **Table 5**. This system also allowed routes to directly feed into one another, except when traversing between north and south Sacramento. The expected time to survey the north and south Sacramento communities was roughly 3 hours each. The proposed routes prior to the field campaign are shown in **Figure 5** for north Sacramento and **Figure 6** for south Sacramento. Generally, the project's field team would begin field operations at a different route each morning to rotate the order. This rotation allowed for a better temporal analysis, so that an evaluation of each community's air quality could occur daily without being limited to certain times of the day. In theory, the maximum number of hours that could be collected across the entire field campaign was ~126 hours, when transit time and data validation were not considered.

Table 5. Project routes with accompanying community information, community classification, census tracts, routes, driving distance, and estimated driving time.

Community/ Neighborhood	Classification	Census Tract	Route	Driving Distance (miles)	Estimated Driving Time (minutes)
Del Paso Heights	A	64, 65	A1	5	25
Del Paso Heights/ Strawberry Manor	A	67.02	A2	5	24
Del Paso Heights/ Strawberry Manor/ Gardenland	A	67.02, 70.01	A3	7	27
Gardenland/Northgate	A	70.01, 70.07	A4	4	16
Northgate/River Gardens	B	70.07, 70.14	B1	5	23
Noralto	B	68	B2	6	23
Noralto/ South Hagginwood	B	68, 66	B3	6	23
Old North Sacramento	B	69	B4	4	21
Hollywood Park	C	35.02	C1	4	19
Brentwood/ Golf Course Terrace	C	41, 38	C2	4	20
Woodbine/Meadowview	C	41, 42.03	C3	4	18
Meadowview	D	42.03, 43	D1	5	20
Meadowview	D	42.01, 43	D2	3	12
Meadowview	D	42.01, 42.02,	D3	4	16
Meadowview/ Freeport Manor	E	40.01, 42.01	E1	3	16
Riverside	E	34	E2	3	15
Riverside/Greenhaven	F	34, 40.05	F1	4	14
Greenhaven	F	40.05	F2	5	17
Greenhaven	F	40.05	F3	4	15

Overall, the proposed routes covered a substantial amount of the roadways within each census tract-grouped community, and allowed for air quality surveys around 36 elementary, middle, high, and special education schools throughout the Sacramento metropolitan area. Beyond the proposed routes, measurements were also collected when traveling between communities and between routes.

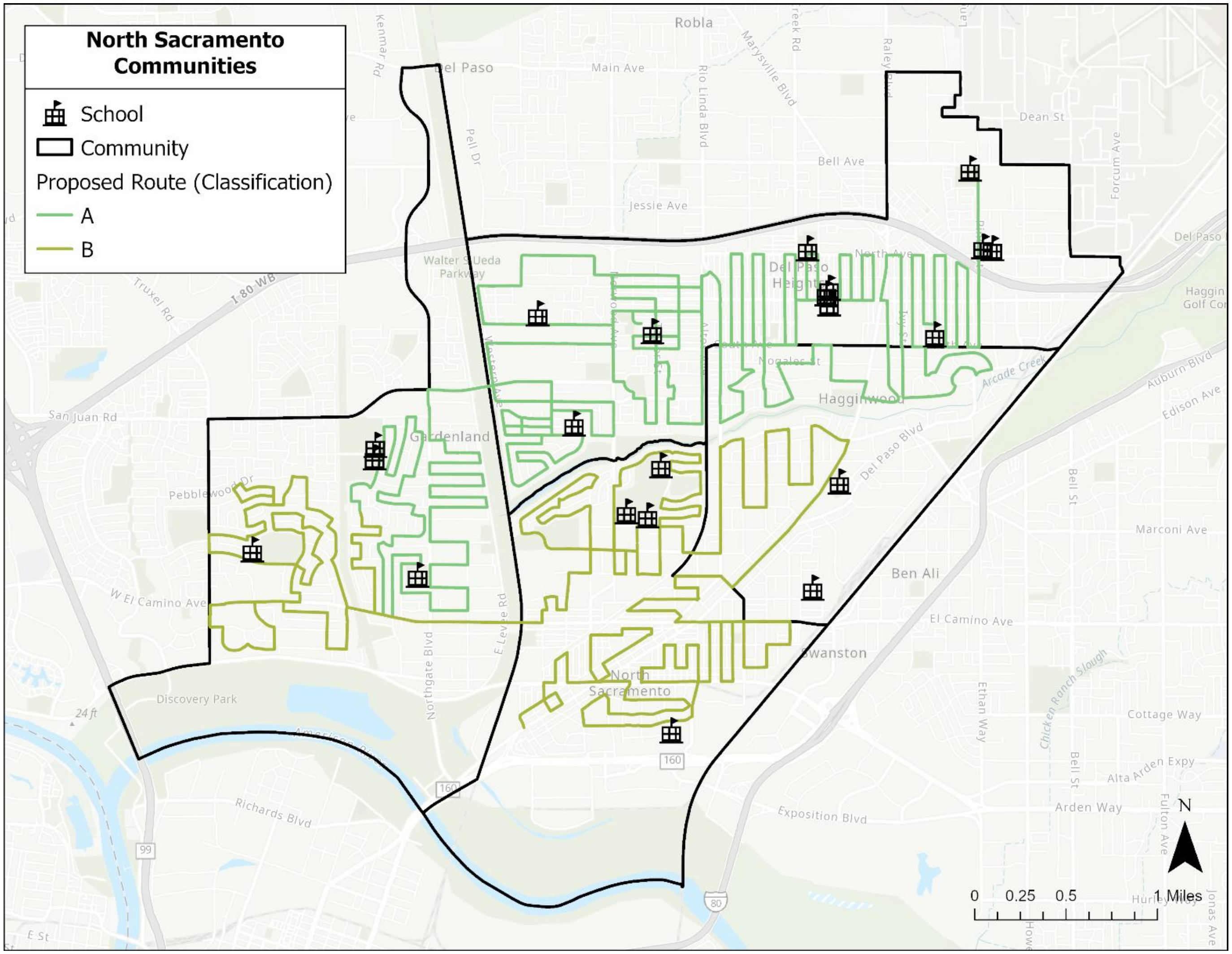

Figure 5. The proposed routes prior to the field campaign for north Sacramento communities. The route classification described in Table 5 are visualized by different colors. Schools and communities of interest are also shown.

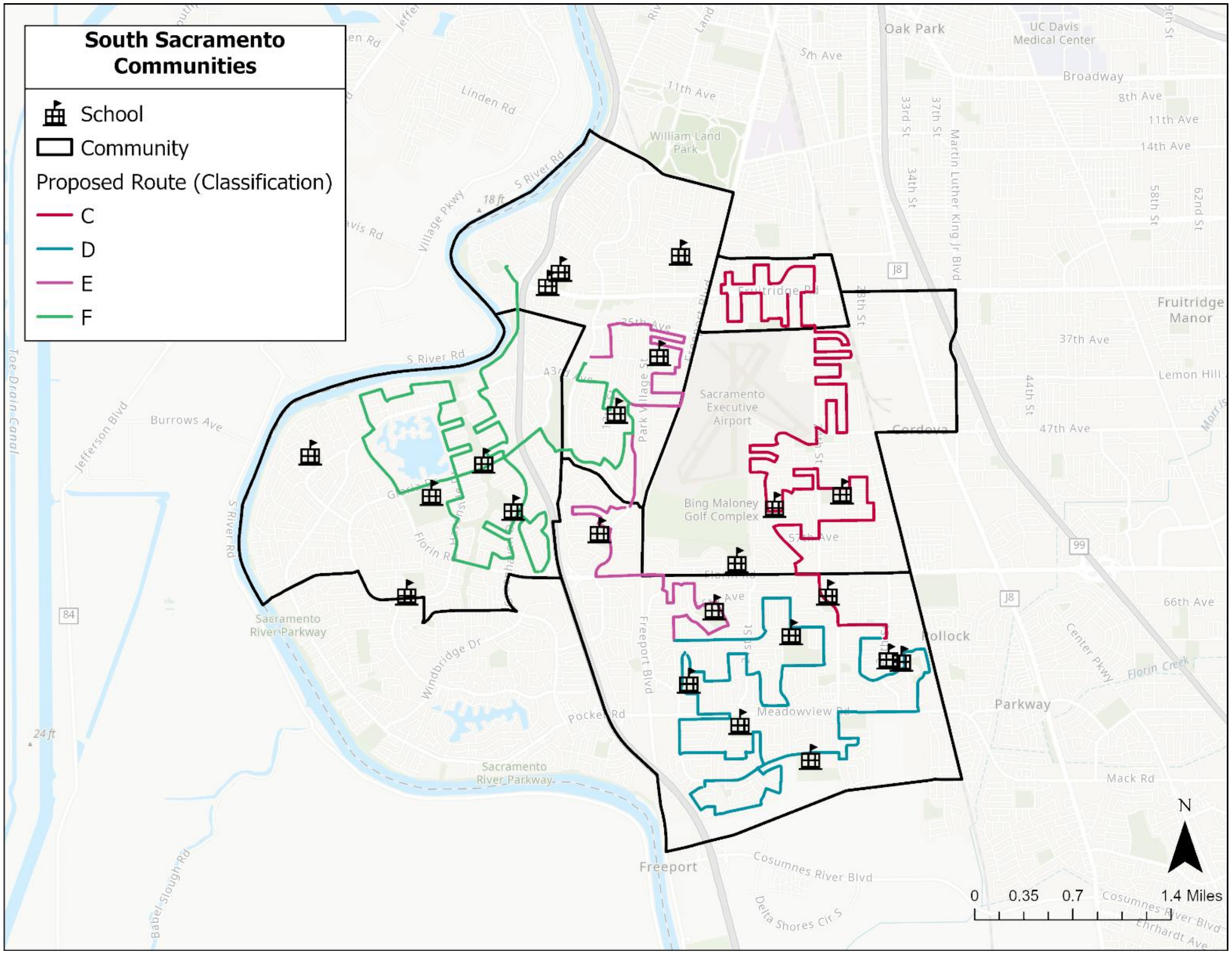

Figure 6. The proposed routes prior to the field campaign for south Sacramento communities. The route classification described in Table 5 visualized by different colors. Schools and communities of interest are also shown.

2.2.2 Measurements

Mobile Platform

The project used a mobile platform developed and configured by Entanglement Technologies and Sonoma Technology. It was built upon a customized Ford Transit Connect van platform to facilitate driving on difficult terrain and incorporated a battery system for stationary monitoring. With sufficient interior vertical height for full instrument racks with instruments, and adequate length for required power and sampling infrastructure, this vehicle provided a sturdy platform for continuous mobile measurements and a robust system for continuous stationary operations as a mobile lab.

Instrumentation and Pollutants

In order to obtain the highest quality measurements of desired air pollutants, the project team installed state-of-the-art air monitoring instruments, including several high-precision and high-sensitivity instruments for criteria and climate forcer measurements and an Entanglement Technologies AROMA analyzer. This combination provided the flexibility to measure a range of air pollutants on a high sensitivity and high frequency basis. The project used a customized AROMA single-laser system without preconcentration, which was used with two different modes: Rapid Scan mode (used to collect grouped measurements of target analytes [e.g., aromatics]), and Lab Scan mode (used to collected specific target analyte concentrations [e.g., benzene]). All instruments, corresponding detection limits, and measurement frequencies are summarized in Table 6.

Table 6. Summary of instrument specifications.

Pollutant Type	Target Compounds	Analyzer	Detection Limit	Measurement Frequency
Criteria Air Pollutants	$PM_{2.5}$ and PM_{10}	Teledyne T640	<0.1 µg m^{-3}	10 sec
	Nitrogen Dioxide	Teledyne T200	<0.4 ppbv	1 sec
	Ozone	Teledyne T400	<0.4 ppbv	1 sec
	Carbon Monoxide	Thermo 48i	<0.04 ppbv	2-5 sec
Climate Forcers	Methane	Entanglement AROMA (Rapid Scan mode)	<0.002 ppmv	2-5 sec
	Carbon Dioxide		<0.001 ppmv	2-5 sec
	Black Carbon	Magee AE33	10 ng/m3	1 sec
Air Toxics (Mobile Monitoring)	Aromatics	Entanglement AROMA (Rapid Scan mode)	<1 ppbv	1-5 sec
	Dienes		<1 ppbv	
	Alkanes		<1 ppbv	

Pollutant Type	Target Compounds	Analyzer	Detection Limit	Measurement Frequency
Air Toxics (Stationary Monitoring)	Benzene	Entanglement AROMA (Lab Scan mode)	<10 pptv	11 min
	Toluene		<50 pptv	
	Ethylbenzene		<100 pptv	
	Xylenes		<100 pptv	
	Trichloroethylene		<50 pptv	
	Cis-1,2-Dichloroethylene		<100 pptv	
	Isoprene		<100 pptv	
	1,3-butadiene		<200 pptv	
	Acrolein		<200 pptv	
	Styrene		<500 pptv	

Details for specific measurements are discussed below:

- **Criteria Pollutant and Climate Forcer Measurements**: The project used advanced regulatory- or research-grade analyzers with proven applications in a variety of field studies by regulatory and research organizations. In addition to their robust measurement capabilities, these also represented some of the fastest instruments available in the market for each pollutant, which was a key requirement to conduct high-spatial resolution mobile monitoring.

  Two different NO_x analyzers were used during the field campaign. The District's NO_x analyzer was primarily used during mobile measurements and Sonoma Technology's analyzer was used during stationary measurements. After the field campaign, it was determined by the instrument manufacturer that Sonoma Technology's NO_x analyzer was operating erroneously, and therefore, the stationary NO_2 measurement data are not reported.

  No other instruments were removed or swapped during the entirety of the monitoring campaign.

- **VOCs and Air Toxics Measurements**: Entanglement Technologies' state-of-the-art AROMA analyzer was used for VOC measurements. This analyzer measures a wide range of pollutants on a highly time-resolved basis, with high sensitivity and high-spatial resolution. This system also provided dual operational capabilities for the different phases of the project:
  - Mobile mapping in Rapid Scan mode (1-5 sec response rate)
  - Stationary measurements in Lab Scan speciation mode (11-min response cycle)

Measurement System

Sampling Probe: The mobile platform had a three-inlet system: (1) a particulate inlet, (2) an inlet for gaseous criteria pollutants, climate forcers, and VOCs, and (3) a size-selective (e.g., $PM_{2.5}$) cyclone inlet for BC.

The criteria and VOC pollutant sampling inlets used a 3′ 1/2″ Teflon line that was UV-protected by an over-wrap and rain-protected by an inverted funnel. A coarse inlet filter was also used. The inlet was connected to a multi-port glass manifold that allowed all instruments to be sampled. The combined flow from all instruments provided approximately 10 liters per minute total flow, thus providing a minimal residence time for the sampled targets.

GPS Sensor: The vehicle used two GPS sensors to record location with necessary redundancy to capture geolocation data and provide time-syncing between the two instrument platforms. The first GPS unit was incorporated in the AROMA instrument, and data were recorded at the instrument frequency (1-5 sec in Rapid Scan mode). A second GPS unit was connected to the criteria air quality and gaseous climate forcer analyzer setup.

Data Logging and Data Acquisition Systems: The AROMA system has a built-in data logger that records the measured concentrations and GPS data at 2-5 sec frequency. The criteria air pollutant and climate forcer analyzers were connected to a secondary data logging system, which used a CR1000X Campbell Scientific Data Logger, and recorded data at the fastest native data rate through the serial or analog connection (1 sec for most Teledyne analyzers and 2-5 sec for the AROMA analyzer) with time-synchronization via GPS signal. The UC Davis field team downloaded and transferred data to the Sonoma Technology data analysis team daily through a cloud data management system.

The continuous analyzer suite was connected to an on-board industrial computer that automatically downloaded data from the data logger, thus providing a continuous readout of analyzer data, a redundant data archive, and remote access via an on-board cellular modem. Both the continuous analyzers and AROMA had a small secondary monitor that was continuously surveilled by the vehicle co-pilot for any anomalies or interesting data.

Power System: Power for the measurement systems was provided by the extended battery system available in the Entanglement Mobile Platform. This included a built-in battery bank (3,000 wH), an additional Li battery to run devices on a separate circuit (3,000 wH), and a vehicle alternator (with 100A excess capacity). This provided approximately 8 hours of continuous operations for all instruments installed on the platform. In some instances, some analyzers were removed during stationary monitoring, which allowed for a longer duration of continuous monitoring (> 8 hours).

Operations

The District allowed the project team to temporarily store the mobile monitoring vehicle and support equipment at the Bercut Air Monitoring Station (Bercut station) located at 100 Bercut Drive, Sacramento, CA. This location was central to the targeted monitoring areas, but also allowed for collocation of the instruments with the District's regulatory monitors to assess ambient monitoring performance.

Operational activities included using EPA Protocol calibration gas cylinders and a dilution system to perform periodic calibration checks of gaseous analyzers, daily checks of vehicle operation (engine operation such as oil and fuel), general power, and inlet systems, and a daily safety briefing for the driving crew. The driving crew for mobile monitoring consisted of a driver and a co-pilot to guide the route, watch analyzer outputs, and provide general safety. Pre-determined routes were uploaded to a cell phone mounted on the dashboard that provided audible directions, which were augmented by the co-pilot.

Quality Control

The instruments were pre-calibrated using certified standards and instrument-specific protocols (concentration for the gas analyzers, flow for the particulate analyzers). During the study period, EPA protocol gases and gas dilution systems were used for periodic analyzer span checks. In addition, a qualitative check against the District's Bercut station instruments was used as a simple cross-check and a post-study calibration check was performed.

The AROMA instrument received a full calibration on October 10, 2022, against a certified standard onsite in the European Commission's Joint Research Center. Prior to deployment, the instrument passed Continuing Calibration Verification using a certified standard (December 22, 2022). The AROMA calibration verification was performed in-field using a mixed-gas cylinder standard of benzene, toluene, ethylbenzene, and xylenes (BTEX). During the mobile field campaign, the calibration standard was found to be expired but stable.

After the mobile deployment, a new 5% certified standard was used for the final calibration check. Although no Continuing Calibration Verification measurements were performed during the field deployment, the instrument was re-validated against the new 5% certified standard upon completion of the field campaign. The new 5% certified standard was measured against the in-field standard, showing that concentrations for the in-field standard were 12-44% lower than the certified standard, with the heaviest molecules showing the greatest discrepancy. This would have led to slightly inflated concentrations in mobile measurements. However, despite the discrepancy between the standards, post field campaign QC checks using both the newly certified and expired standard verified that the AROMA analyzer was operating appropriately during mobile and stationary field measurements. These calibration reports are detailed in full in **Appendix 1**: Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform: Quality Assurance Report. Lastly, the stationary speciated VOC data were corrected to the new certified standard as opposed to the expired standard.

Data Validation

The project team quality assured the air monitoring data using the EPA's Quality Assurance Handbook Volume II Appendix D: Measurement Quality Objectives and Validation Templates as guidance, standard operating procedures, and/or instrument specifications, where applicable. A summary of qualifiers and nullifiers used to quality assure data are shown in **Table 7**. Method detection limits (MDL) were assimilated from manufacturer specifications for each instrument (**Table 8**). If a measurement was between the negative and positive MDL, the value was replaced with half the MDL.

Table 7. A summary of the quality assurance codes for the mobile monitoring data.

Qualifier Code	Qualifier Description	Qualifier Type
IJ	Vehicle speed >30 knots (34.5 mph)	Informational Only
MD	Below method detection limit	Quality Assurance Qualifier
AH	Sample flow rate out of limits	Null Data Qualifier
AM	Miscellaneous void (sample relative humidity or box temperature out of limits for T640)	Null Data Qualifier
AN	Instrument malfunction	Null Data Qualifier

For PM_{10} and $PM_{2.5}$, additional quality assurance flagging was used to invalidate data that did not meet critical criteria, such as average sample flow rate (±5%), box temperature (<60 °C), or sample relative humidity (<35%). In these instances, data were invalidated with an AH or AM qualifier code.

Stationary VOC data were reviewed by Entanglement Technologies personnel, and flagged data were reviewed and removed from analysis, as required. Furthermore, VOC data were compared against chronic (>15 days) reference exposure levels (RELs) to understand the potential need for further long-term VOC measurements. All chronic RELs were above the AROMA MDL for the respective VOC.

Table 8. A summary of the reference exposure level (REL) and method detection limit (MDL) for the VOCs measured by the AROMA during speciated mode.

Compound	Chronic REL (µg/m^3)	AROMA MDL (µg/m^3)
Benzene	3	0.1
Toluene	430	0.3
Butadiene	2	0.9
Ethylbenzene	2,000	0.85
Xylenes (Combined)	700	3.1
Cis-1,2-Dichloroethylene	70	0.5
Trichloroethylene	600 (*CHHSL = 0.48)	0.04
Styrene	900	2.0
Isoprene	N/A	0.25

2.2.3 Community Monitoring

Mobile Mapping

The team followed general optimization strategies and good operational tactics for route selection and mobile monitoring, including selecting routes with maximum right turns, attempting to maintain vehicle speeds <25 mph, maintaining 2-3 car-length distance for safety, and avoiding direct tailpipe influences from other vehicles. These strategies were implemented so that there was minimal influence on the measurements from wind eddying or direct source emissions impacts, and so measurements could be more easily compared against one another. While these strategies were attempted, they were not always feasibly able to be followed to ensure safe vehicle operation on the routes. Moreover, the community measurement schedule was designed to attain staggered deployment to ensure that all measurements in a community did not happen at the same time every day (**Table 9**). For each community, there were five measurement campaigns each in the early morning, late morning, early afternoon, and late afternoon timeframes.

Table 9. The breakdown of which routes were completed at the corresponding time of the day (e.g., early a.m.) across all the mobile measurement days.

Weekday/Weekend	Day	Early a.m.		Late a.m.		Early p.m.		Late p.m.	
Weekday 1	Thu	A	-	B	-	C	D	E	F
Weekday 2	Fri	C	D	E	F	A	-	B	-
Weekday 3	Mon	B	-	A	-	E	F	C	D
Weekday 4	Tue	E	F	C	D	B	-	A	-
Weekday 5	Wed	A	-	B	-	C	D	E	F
Weekday 6	Fri	C	D	E	F	A	-	B	-
Weekday 7	Mon	B	-	A	-	E	F	C	D
Weekday 8	Tue	E	F	C	D	B	-	A	-
Weekday 9	Wed	A	-	B	-	C	D	E	F
Weekday 10	Thu	C	D	E	F	A	-	B	-
Weekday 11	Fri	B	-	A	-	E	F	C	D
Weekday 12	Mon	E	F	C	D	B	-	A	-
Weekday 13	Tue	A	-	B	-	C	D	E	F
Weekday 14	Wed	C	D	E	F	A	-	B	-
Weekday 15	Thu	B	-	A	-	E	F	C	D
Weekday 16	Fri	E	F	C	D	B	-	A	-
Weekend Day 1	Sat	A	-	B	-	C	D	E	F
Weekend Day 2	Sun	C	D	E	F	A	-	B	-
Weekend Day 3	Sat	B	-	A	-	E	F	C	D
Weekend Day 4	Sun	E	F	C	D	B	-	A	-

Stationary Monitoring

The project team conducted stationary monitoring at selected locations in the communities that were identified after discussion of potential areas with the District. The stationary monitoring activities began on April 2, 2023, and lasted until April 16, 2023, for a total of 10 days with stationary monitoring data collection. At least one location was selected in each community to provide an anchor measurement. Stationary deployments were conducted at the noted sites by first selecting an appropriate location from a list of PFZs in respective community areas. Schools and other publicly-accessible areas were prioritized. Following the standard pre-deployment checks at the Bercut station, the van was driven to the selected location and parked away from other vehicles or potential interferences. Since the van was stationary, the on-board battery systems provided power.

The instruments operated continuously at each site for 6-12 hours during daytime hours, depending on logistical limitations. This allowed measurement of general temporal diurnal patterns in each community. For this phase, all the criteria pollutant and gaseous climate forcer instruments were operated according to manufacturer-recommended specifications. The AROMA measurement system was operated in Lab Scan speciation mode, which allowed for more sensitive and broader assessment of toxic VOCs. In more detail, the AROMA analyzer was operated in speciated mode with 200 mL samples collected and analyzed on a 11-minute duty cycle.

2.2.4 Spatial Analysis

Background Correction

Consistent with the method described in Chen et al., 2022, we applied a time-series-based background correction method for mobile monitoring data. The method first calculates background concentrations using a low percentile of observation data over a set period, then calculates the concentration over background for each observation time. We refer to this concentration above background as a concentration enhancement. Figure 7 shows an example of how concentration enhancements are calculated.

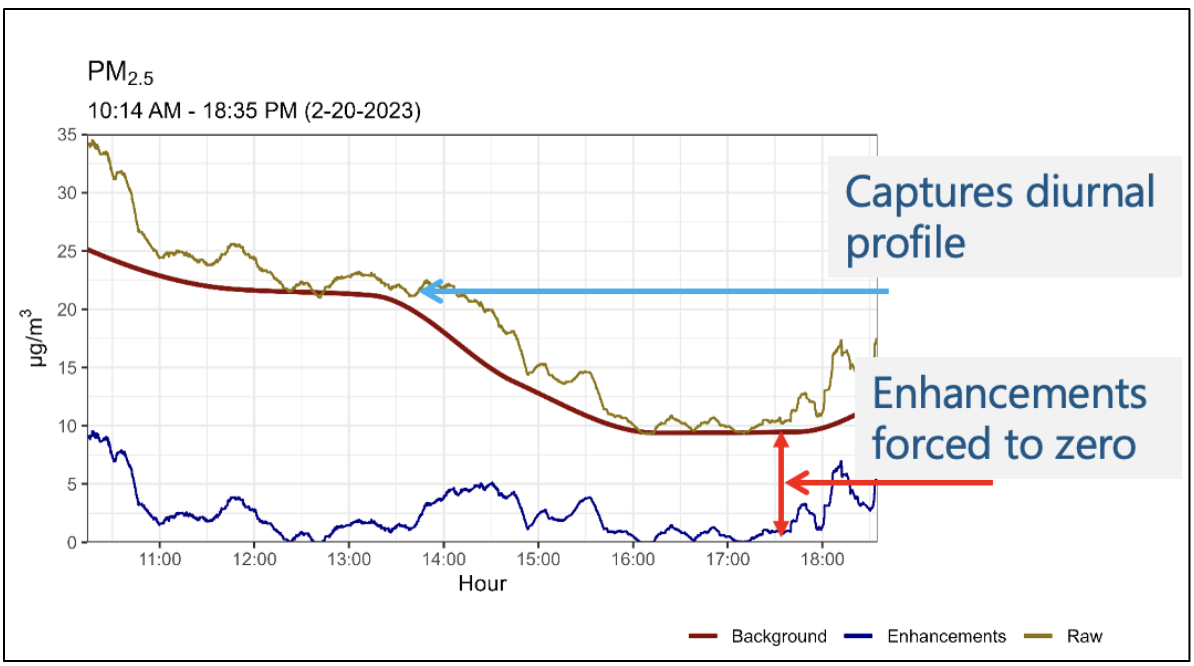

Figure 7. An example of how concentration enhancements were calculated using a rolling background concentration window.

To calculate background concentrations, we first calculated the bottom 5th percentile of the time-series data collected during stationary and mobile monitoring using a 90-min, center-aligned window. We chose a 90-min window because the mobile monitoring platform usually took approximately 3 hours to travel through all communities in north Sacramento or all communities in south Sacramento. Therefore, a 90-min window results in approximately two 5th percentiles for each community. The 90-min window also ensures that the resultant background concentration curve was smooth and more resistant to local emissions spikes. At least 75% of the data in the 90-min window must be present to calculate the 5th percentile. We included both stationary and mobile data to ensure the 5th percentile calculations had enough data at the beginning and end of the daily mobile monitoring periods, therefore inhibiting overfitting or underfitting the interpolated background concentrations at the start and end of mobile monitoring. Next, we fitted a smooth curve to the discrete 5th percentile points from the previous step using the “pchip” function in the “signal” package in the R programming language (Signal Developers, 2014). The interpolated 5th percentile of this 90-min, center-aligned window represents the background concentration of a given parameter for that time period.

The enhanced concentration was calculated as the difference between the stationary and mobile monitoring time-series data and the background concentration. Data points less than the background concentration were set to zero (i.e., no concentration enhancement). Data during the stationary monitoring period were filtered from the concentration enhancement data to create a purely mobile monitoring data set. Unless stated otherwise, data in subsequent sections are considered enhancements above the background concentration.

Data Aggregation

Concentration enhancements collected during mobile monitoring were aggregated into pre-defined 30-, 60-, and 90-m grids using a “pass-mean” method (Chen et al., 2022). Data collected at a 1-sec temporal resolution (BC, NO_2, O_3, $PM_{2.5}$, and PM_{10}) were aggregated into all three resolution grids, while data collected at a 5-sec temporal resolution (aromatics, alkanes, CO_2, methane, and dienes) were aggregated into 60- and 90-m grids. The grid sizes were chosen to ensure that there would be a sufficient number of data points (approximately 15-30) in a single grid cell over the entire mobile monitoring period (Chen et al., 2022). One “pass” is defined as the mobile monitoring instruments traveling through a given grid cell. We calculated the mean of all data points in each grid cell per day (i.e., pass-mean). A given grid cell must have at least one data point on a given day to derive a “pass-mean” concentration, and some grid cells had multiple observations per day depending on the grid cell resolution and on-road environment (e.g., stopped at a traffic light). We retained grid cells where the median number of daily pass-means was at least 50% of the overall median number of daily pass-means on a pollutant and grid cell resolution basis to ensure that only locations with representative data were used in subsequent analyses. The resultant data are daily gridded enhanced concentrations of pass-means. We calculated grid-cell level statistics, such as the mean, median, count of total data points, and count of total days (i.e., count of pass-means). Here, we used 30- and 60-m grid cells to present data, depending on the pollutant.

Pollution Focus Zone Identification

The three-method PFZ identification process detailed in Chen et al. (2022) was adopted to identify PFZs in each community. Each of the three methods was applied to the concentration enhancements, and PFZ indicators were assigned a confidence level based on the number of methods that identify each PFZ.

The three PFZ methods identify PFZ indicators based on distinct statistical characteristics. The first two methods calculated the top 5th percentile of the gridded (1) mean and (2) median concentration enhancements generated in the data aggregation step. For each statistic, grid cells in the top 5th percentile of the mean or median are designated as PFZ. In the third method, the Kolmogorov-Smirnov test (K-S test), a nonparametric statistical test to compare the cumulative distribution function (CDF) of two samples was applied to identify grid cells with statistically significantly different distributions of the pass-mean enhancements. The K-S test compares the CDFs of the pass-mean enhancements between a given grid cell and all other pass-mean enhancements, and provides p-values for each grid cell comparison. A small p-value indicates that the concentration of one grid cell is more likely to differ than the other (Chen et al., 2022). We used a p-value of 0.1 as a cutoff to determine grid cells that were statistically different from other grid cells. On a cell-by-cell basis, we calculated the proportion of p-values below 0.1 to the total p-value count. The proportion indicated the likelihood that a given grid cell would be statistically different from all other grid cells. Grid cells where the proportion was at least 50% were designated as PFZ based on the K-S test.

The top 5th percentile of pass-means mean and the pass-means median, as well as the K-S test indicator described above, define the confidence of the PFZ. Grid cells that meet one, two, or all three of these standards are defined as having a PFZ with low, medium, or high confidence, respectively. We identified an area as a PFZ when three high confidence PFZ indicators were located within 10 grid cells. For 30-m analyses, this would be within 300 meters. For 60-m analyses, this would be within 600 meters.

2.2.5 Temporal Analysis

Mobile

Temporal trends were evaluated for each community and parameter, where communities were comprised of multiple census tracts (Table 2). For each parameter and community, temporal trends were evaluated on a 1- or 5-sec resolution, where average and 95%-confidence interval of concentration enhancements were evaluated. Mobile temporal trends were limited to times of day when the mobile monitoring platform was in one of the communities. Concentration enhancements outside of the identified communities (Table 2) were not evaluated temporally. Furthermore, each data point collected within a community was aggregated to a community-wide mean, median, and max concentration enhancement. The total number of data points and number of measurement hours, by community and parameter, were also determined.

Stationary

Research experts from UC Davis Air Quality Research Center analyzed the stationary criteria pollutant results and Entanglement Technologies experts analyzed stationary VOC results to complement the mobile monitoring campaign in Sacramento, CA. For criteria pollutants, raw 1-sec data were retrieved from the Campbell datalogger system and evaluated by calculating hourly averages. The stationary data quality assurance followed the same procedures as the mobile monitoring data. The VOC data were extracted from the Entanglement Technologies AROMA instrument in the Lab Scan mode and analyzed for stationary measurement periods for each measured air toxic.

3. Quality Assurance

A comprehensive report detailing the overall quality assurance process is contained in Appendix 1: Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform: Quality Assurance Report, along with certification and calibration reports. In brief, a weight-of-evidence and compelling evidence approach was used to verify and validate all air quality data. Due to instrument issues resulting in poor-performing quality assurance, measurements from the CO instrument are not reported here. Furthermore, the NO_x analyzer used during stationary monitoring was operating erroneously, so stationary NO_2 measurements are not reported here.

3.1 Instrument Quality Assurance

As noted above, the analyzers were calibrated and evaluated prior to deployment. During the field campaign, periodic span, zero, and background (CO only) checks were performed, with the acceptance criterion of +/-20% of the target concentration and +/-10% of the span for zero. If any parameter was out of specification during the periodic span check, the instrument was re-spanned using calibration gases. If the zero check was out of specification, it was re-zeroed.

The need to re-span and re-zero each occurred a few times over the course of the study, because variable temperatures and vibrations from the vehicle affected instrument stability. However, for the periodic checks, only a few instances of out-of-specification results were noted, except for CO. The Thermo 48i CO analyzer was found to have significant drift and background concentration problems, resulting in a lower-than-expected quality. Ultimately, the analyzer ceased to perform effectively and was removed from operation. Here, CO concentrations are not reported due to the erroneous data collection.

Additionally, two different NO_x analyzers were used during the field campaign. The District's NO_x analyzer was used during mobile measurements and Sonoma Technology's analyzer was used during stationary measurements. After the field campaign, it was determined by the instrument manufacturer that Sonoma Technology's NO_x analyzer was operating erroneously, and therefore, the stationary NO_2 measurement data are not reported.

As previously mentioned, a post-calibration check was performed by Entanglement on the AROMA instrument using a different calibration gas cylinder. Stationary data were adjusted accordingly, and details on the adjustment are described in Appendix 1: Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform: Quality Assurance Report.

In addition to the periodic span and zero checks, the mobile system analyzer suite was compared to the output of the Bercut station analyzers. A quality assurance report detailing the periodic checks and other quality assurance results is contained in Appendix 1: Air Quality Mapping in Sacramento

Communities Using a Research-Grade Mobile Platform: Quality Assurance Report. These results are also briefly discussed below.

3.2 Data Completeness

Table 10 details overall data completeness for each parameter during mobile monitoring. Data completeness for the mobile and stationary monitoring measurements were evaluated separately. In general, data completeness was satisfactory, and all but one parameter achieved a valid data percentage greater than 85%. Alkanes had the highest percentage of valid data (98.9%), and dienes had the lowest percentage of valid data (65.6%). Because the "IJ" QC flag was determined based on driving speed, the percentage of data flagged as "IJ" was mostly consistent across all parameters.

Notable issues encountered throughout data collection that affected overall data completeness are outlined below.

- BC has a higher total data count because all other data collected at a 1-sec temporal resolution (NO_2, ozone, $PM_{2.5}$, and PM_{10}) were aggregated to a 1-min and 1-hr temporal resolution by the datalogger on 2/16 and 2/17, and thus were unusable for subsequent analysis. The 1-sec BC data collected during these days were manually extracted from the Magee AE33 aethalometer.
- Many diene data points were flagged as "AN" throughout mobile monitoring due to a high number of negative values below the negative MDL (Figure 8).

Table 10. Data completeness during the mobile monitoring data collection period.

Parameter	Total Count[a]	Missing Count (%)[b]	AN Count (%)[c]	MD Count (%)[c]	IJ Count (%)[c]	AM Count (%)[c]	Valid Count (%)[d]
Nitrogen Dioxide	407,119	55,843 (13.72%)	8 (0.00%)	16,056 (3.94%)	11,490 (2.82%)	0 (0.00%)	351,268 (86.28%)
Ozone	407,119	55,843 (13.72%)	321 (0.08%)	332 (0.08%)	11,737 (2.88%)	0 (0.00%)	350,955 (86.20%)
$PM_{2.5}$	407,119	55,843 (13.72%)	0 (0.00%)	0 (0.00%)	11,789 (2.90%	40 (0.01%)	351,236 (86.27%)
PM_{10}	407,119	55,843 (13.72%)	0 (0.00%)	0 (0.00%)	11,789 (2.90%	40 (0.01%)	351,236 (86.27%)
Alkanes	71,676	432 (0.60%)	345 (0.48%)	0 (0.00%)	1,956 (2.73%)	0 (0.00%)	70,899 (98.92%)
Aromatics	71,676	911 (1.27%)	2,293 (3.20%)	8 (0.01%)	1,908 (2.66%)	0 (0.00%)	68,472 (95.53%)
Black Carbon	447,801	0 (0.00%)	66,577 (14.87%)	0 (0.00%)	11,789 (2.63%)	0 (0.00%)	381,224 (85.13%)
Dienes	71,676	353 (0.49%)	21,465 (29.95%)	2,941 (4.10%)	1,198 (1.67%)	0 (0.00%)	49,858 (69.56%)
Carbon Dioxide	71,676	6,002 (8.37%)	0 (0.00%)	0 (0.00%)	1,834 (2.56%	0 (0.00%)	65,674 (91.63%)
Methane	71,676	8,214 (11.46%)	0 (0.00%)	0 (0.00%)	1,671 (2.33%)	0 (0.00%)	63,462 (88.54%)

[a] Total data count was calculated by counting the number of data points collected during the daily mobile monitoring period.
[b] Missing data count was calculated by counting the number of data points collected during the daily mobile monitoring period in which the concentration was missing (I.e., null).
[c] Flagged data counts were calculated by counting the number of data points collected during the daily mobile monitoring period that were flagged as "AN", "MD", "IJ", or "AM".
[d] Valid data counts were calculated by subtracting the number of data points flagged as "AN" or "AM" and the number of missing data points from the total data count.

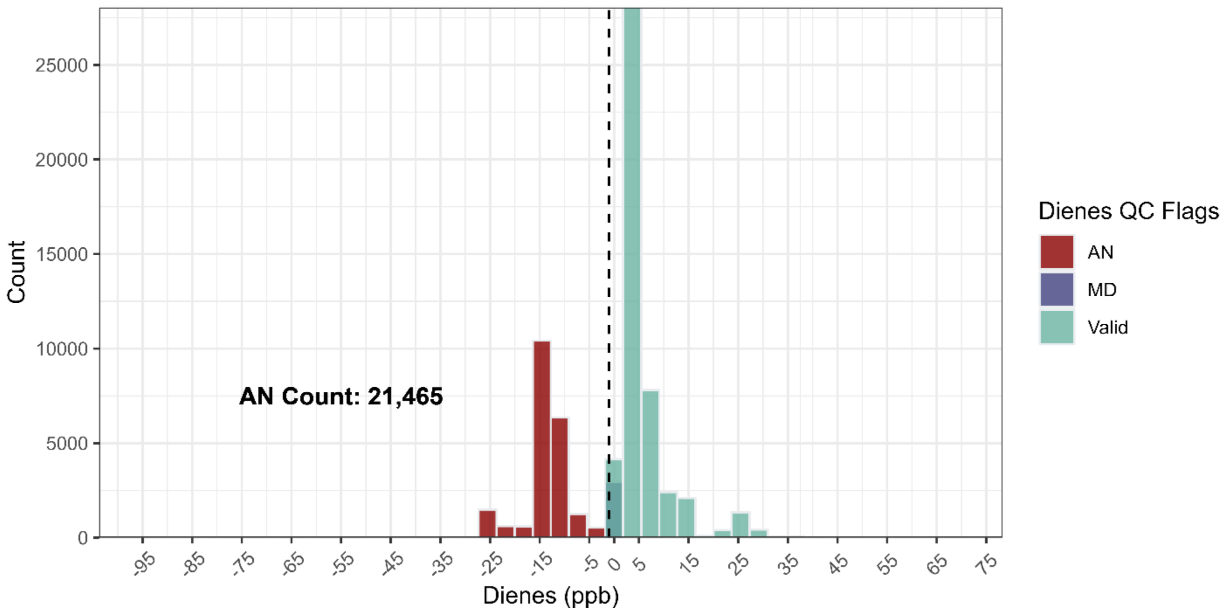

Figure 8. Raw diene concentrations collected during the mobile monitoring data collection period color coded by QC flags. Note: data flagged as "Valid" include data not flagged or flagged as "IJ."

Table 11 details the data completeness for each parameter during stationary monitoring at each monitoring location. For all parameters, data completeness was above the targeted 75% threshold, with an overall average of 87% across all parameters and locations. Notable issues were encountered for stationary CO and NO_2 measurements, as previously discussed. Data recording issues occurred at the Hagginwood stationary site for $PM_{2.5}$ measurements resulting in 0% completeness at that site.

Table 11. Data completeness during the stationary monitoring data collection period.

Location	Data Completeness (%)			
	BC	O_3	$PM_{2.5}$	VOCs
2005 Evergreen Street	85.5	85.6	85.7	100
Pocket	85.7	85.7	85.7	100
Del Paso Heights	85.4	85.4	85.4	100
Florin Gardens	85.4	85.4	85.4	100
Hagginwood	83.2	83.2	0	100
Meadowview	87.6	87.6	87.6	100
Old North Sacramento	86.3	86.3	86.3	100
Freeport Manor	86.2	86.2	86.2	100
Northgate	85.9	85.9	85.9	100
Total Average	**85.7**	**85.7**	**76.5**	**100.0**

3.3 Comparisons to Bercut Station

The project team evaluated the performance of NO_2, $PM_{2.5}$, and BC instruments in the mobile monitoring platform by comparing hourly-aggregated measurements against measurements from the District's Bercut station (AQS ID: 06-067-0015). These evaluations were conducted for all timeframes outside of normal mobile monitoring operations (i.e., 18:00-8:00). In the analysis, outliers outside of the 99th percent confidence interval of the van measurements were removed.

In the stationary measurement comparisons to Bercut site measurements, slopes ranged from 0.6-1.9. NO_2 concentrations (**Figure 9**) had the best comparison (slope = 1.1, r^2 = 0.75, $p < 0.01$). $PM_{2.5}$ concentration measurement comparisons (**Figure 10**) were statistically significant and strongly correlated (slope = 1.0, r^2 = 0.76, $p < 0.01$). BC measurements (**Figure 11**) in the van measured higher than the stationary monitoring instrument (slope = 1.9, r^2 = 0.73, $p < 0.01$), but this high slope was primarily driven by hourly measurements from February 19-20, 2023, and when BC measurements in the van were high (> 3 μg m^{-3}). When these measurements are removed (not shown), the BC measurements compared very well against the SLAMS monitor (slope = 1.1, r^2 = 0.65, $p < 0.01$).

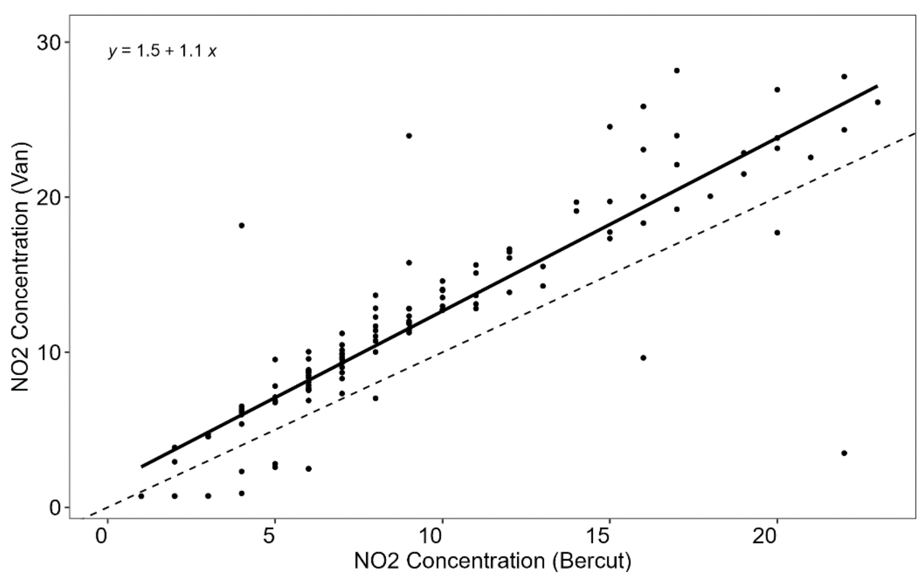

Figure 9. Overnight comparisons of hourly NO_2 concentrations (ppbv) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

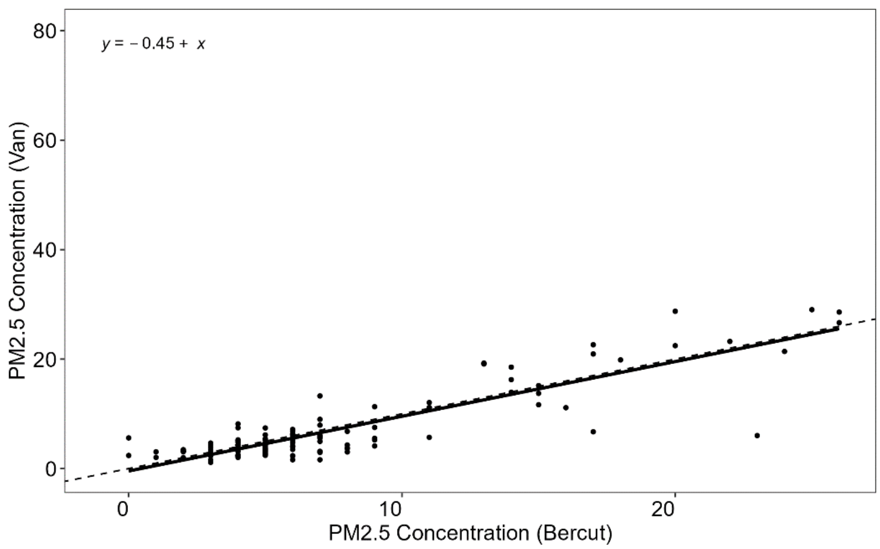

Figure 10. Overnight comparisons of hourly $PM_{2.5}$ concentrations (µg m^{-3}) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

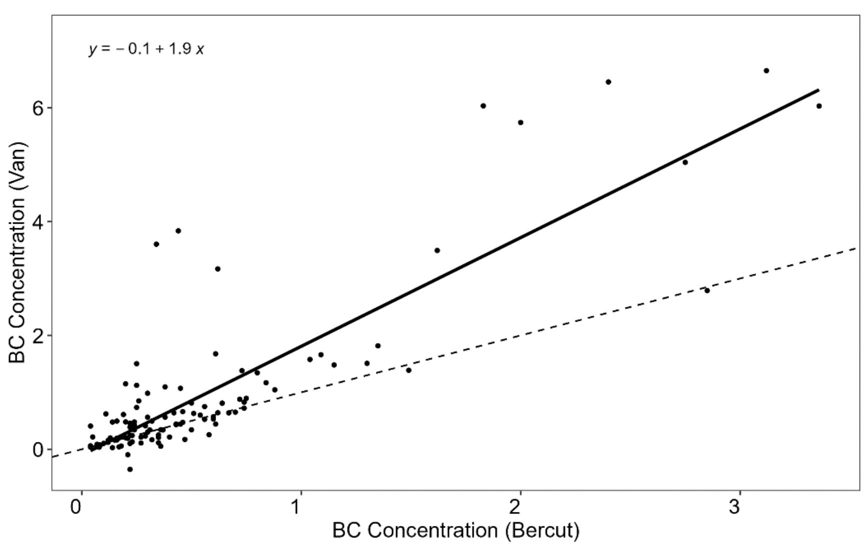

Figure 11. Overnight comparisons of hourly BC concentrations (µg m^{-3}) between the Bercut monitoring station (x-axis) and mobile monitoring platform (y-axis). The regression equation is shown in the top left. The regression line (solid black line) and the 1:1 line (dashed black line) are also shown.

Measurement comparisons to the Bercut station were not used as a quality assurance check, but were used to verify that measurements were similar between the Bercut site and the mobile monitoring platform. The quality assurance procedures (e.g., calibrations, quality control checks) used during field operations were considered the principal data quality indicator of valid measurements.

4. Results

4.1 Measurement Statistics

Mobile Mapping

Overall, the project team conducted mobile monitoring over 21 days. In total, the project team conducted 112.5 hours of mobile monitoring across the Sacramento metropolitan area, though the total hours of collected data per pollutant ranged from the smallest total of 81.4 hours for dienes to the highest total of 112.5 hours for O_3, $PM_{2.5}$, and PM_{10}. Table 12 details the total measurement time, in hours, for each parameter during the mobile monitoring field campaign. Some parameters had a lower amount of measurement hours due to instrument issues (e.g., dienes).

Table 12. The total valid measurement time across all 21 days within the Sacramento metropolitan area by parameter.

Parameter	Total Measurement Time (Hours)
Alkanes	111.1
Aromatics	107.1
Black Carbon	115.0
Carbon Dioxide	111.3
Dienes[a]	81.4
Methane	108.6
Nitrogen Dioxide	112.5
Ozone	112.5
PM_{10}	112.5
$PM_{2.5}$	112.5

[a]Dienes experienced a high percentage of invalid measurements that were below the MDL. Only valid measurements are included in this table.

Driving at the posted speed limits along roadways, the project team collected data across 179 miles of unique roads on a typical day if measurements were collected in all target communities. Including roadways outside of the selected communities, a total of 193 unique road miles were evaluated during the field campaign.

Stationary Monitoring

The project team conducted stationary monitoring at selected locations in the communities over 10 days (Table 13). These sites were selected based on the results from the mobile monitoring after discussion of potential areas with the District. The project prioritized at least one location in each community to provide anchor measurements.

Table 13. The stationary monitoring locations and dates when monitoring took place.

Region	Location	Date	Start Time (a.m.)	End Time (p.m.)
North Sacramento	Hagginwood	Mar 24 (Fri)	11:08	4:58
	Northgate	Apr 9 (Sun)	11:09	6:37
	Del Paso Heights	Apr 10 (Mon)	11:41	7:06
	Old North Sacramento	Apr 12 (Wed)	9:27	7:36
	2005 Evergreen St, Sacramento, CA 95815	Apr 14 (Fri)	9:59	10:05
	925 Del Paso Blvd, Sacramento, CA 95815	Apr 16 (Sun)	9:24	6:44
South Sacramento	Meadowview	Apr 2 (Sun)	10:01	6:20
	Freeport Manor	Apr 8 (Sat)	9:20	6:11
	Florin Gardens	Apr 11 (Tue)	8:51	5:03
	Pocket	April 13 (Thu)	10:30	6:51
	24th and Fruitridge Rd, Sacramento, CA 95822	April 15 (Sat)	10:40	6:44

The instruments were operated continuously for 6-12 hours during the day which allowed measurement of general temporal diurnal patterns in each community. Since day-to-day pollution patterns are expected to vary, this may not be representative of a typical day for each community; however, it provided a high-quality level of screening data to study temporal patterns in each community. In total, the team collected approximately 97 hours of data during the stationary measurements.

4.2 Overall Air Pollution Statistics and Spatial Patterns

Highlights

Overview:

- The mobile monitoring campaign aimed at quantifying the local concentration enhancements and identifying localized PFZs in communities that could benefit from additional stationary monitoring. Across different pollutants, multiple PFZs were identified.
- Different spatial resolutions were used for pollutants (30- and 60-m) depending on their measurement frequency. These fine spatial resolutions allowed for close examination of where additional monitoring could be warranted.
- Major roadways (highway and arterial) were found to have a larger number of PFZs than areas within communities that were investigated.

Pollutant:

- North Sacramento communities had greater levels of PM, alkanes, and aromatics, while dienes and CO_2 were greater in south Sacramento communities
- Methane levels along north Sacramento arterial roadways were higher than along south Sacramento arterial roadways. However, methane levels in communities were generally similar in both regions.
- Ozone, NO_2, and BC levels in communities were generally similar in both regions
- Major highway roads were found to have PFZs for several pollutants that are typically indicative of mobile emissions sources. These included NO_2, $PM_{2.5}$, and BC. BC had many higher concentration enhancements throughout communities as well.
- Major arterial roads were also found to have PFZs for a number of pollutants, including aromatics, alkanes, dienes, CO_2, and methane.

As described in previous sections, all mobile measurement data were aggregated to produce community-scale air pollution maps for each measured pollutant. The following sections show measurement summaries and spatial air pollution maps for the mean enhancements of each pollutant in the pre-defined grid cells. Data collected at a 1-sec temporal resolution (NO_2, $PM_{2.5}$, PM_{10}, BC, and O_3) are displayed at a 30-m grid cell resolution, and data collected at a 5-sec temporal resolution (alkanes, aromatics, CO_2, dienes, and methane) are displayed at a 60-m grid cell resolution. In Figures 12 through 19 and Figures 21-22, the maps display concentration enhancements using slightly modified natural breaks that have been rounded to the nearest whole number or half digit (i.e., 0.5). The Jenks natural breaks classification method is a data clustering method designed to determine the best arrangement of values into different bins within a distribution of values. For data visualization purposes, these were slightly modified to allow for easier comprehension. Values on the map bins were not modified beyond 0.25 increments.

Criteria Air Pollutants

In **Figures 12 through 22**, areas that are displayed with a dashed red line represent locations where three or more high confidence PFZs are found within a 10-grid cell radius. Depending on the pollutant spatial resolution, there are at least three 30-m or 60-m grid cells that have a high confidence PFZ in these areas.

NO_2 enhancements were variable across communities (**Figure 12**), with the lowest mean enhancements occurring in Greenhaven-Pocket (1.3 ppbv) and the highest occurring in Hagginwood (3.2 ppbv). The largest max NO_2 enhancements occurred in Northgate-Gardenland (181.1 ppbv) and Del Paso Heights (169.6 ppbv). While north Sacramento communities had higher max enhancements, Meadowview-Z'berg Park and Brentwood-Golf Course Terrace-Florin Gardens also had large max NO_2 enhancements (81.1-96 ppbv).

Ozone enhancements were similar across communities (**Figure 13**), and mean enhancements ranged from 9.0 (Noralto-Old North Sacramento) to 10.6 ppbv (Brentwood-Golf Course Terrace-Florin Gardens). The highest max ozone enhancement (48.8 ppbv) occurred in Brentwood-Golf Course Terrace-Florin Gardens.

The largest mean enhancements for $PM_{2.5}$ were measured in Northgate-Gardenland (1.1 µg m^{-3}), Del Paso Heights (1.0 µg m^{-3}), and Meadowview-Z'berg Park (1.0 µg m^{-3}). Brentwood-Golf Course Terrace-Florin Gardens (0.5 µg m^{-3}) and Greenhaven-Pocket (0.5 µg m^{-3}) had the lowest mean concentration enhancements. The largest max enhancement was observed in Northgate-Gardenland (9.4 µg m^{-3}). The largest $PM_{2.5}$ concentration enhancements were observed along El Camino Avenue. in Northgate-Gardenland. Mean $PM_{2.5}$ concentration enhancements are shown in **Figure 14**.

The larger mean enhancements for PM_{10} were observed in Noralto-Old North Sacramento (3.7 µg m^{-3}), Del Paso Heights (3.4 µg m^{-3}), and Meadowview-Z'berg Park (3.0 µg m^{-3}). Noralto-Old North Sacramento also had the largest max concentration enhancements of PM_{10} (97.1 µg m^{-3}). Other than Meadowview-Z'berg Park, south Sacramento communities had much lower mean and max PM_{10} concentration enhancements. Mean PM_{10} concentration enhancements are shown in **Figure 15**.

Volatile Organic Compounds and Hazardous Air Pollutants

Alkane enhancements were the largest along arterial roadways across north Sacramento communities (**Figure 16**). Hagginwood (9.6 ppmv), Noralto-Old North Sacramento (7.9 ppmv), and Del Paso Heights (6.5 ppmv) had the highest mean alkane concentration enhancements. Furthermore, the max alkane concentration enhancements were observed in Noralto-Old North Sacramento (415.8 ppmv) and Northgate-Gardenland (339.6 ppmv). These large enhancements tended to occur along Marysville Boulevard-Del Paso Boulevard.

Aromatic VOC enhancements were also the largest in north Sacramento communities (**Figure 17**), with mean concentration enhancements ranging from 1.9-2.8 ppbv. Hagginwood and Del Paso Heights had the largest mean aromatic concentration enhancements. The largest aromatic concentration enhancement was measured in Northgate-Gardenland (100.8 ppbv), followed by Meadowview-Z'berg Park (42.8 ppbv) and Del Paso Heights (41.6 ppbv).

Conversely, the largest mean diene enhancements were measured in south Sacramento communities – Hollywood Park-Mangan Park (2.7 ppbv), Meadowview-Z'berg Park (2.6 ppbv), and Brentwood-Golf Course Terrace-Florin Gardens (2.3 ppbv) (**Figure 18**).

Climate Forcers

Mean BC enhancements ranged from 0.5 (Hollywood-Mangan Park) to 0.9 µg m^{-3} (Little Pocket-Riverside-Freeport Manor) (**Figure 19**). Similar to other mobile source pollutants (e.g., NO_2), the largest enhancements were measured along major roadways in Sacramento. It should be noted that BC smoothing algorithms were not applied in this study so 1-sec data could reflect large spikes that would have been smoothed out if these algorithms had been applied. We evaluated the concentration enhancements using two methods – one using a custom visualization (Figure 19) and one using natural breaks in the data (**Figure 20**). Because we did not apply the smoothing algorithm, the maps using natural breaks may not be the best reflection of true concentration enhancements, so that is why both maps have been included here. Additionally, we report 95th percentiles for BC in **Table 14** to best reflect realistic conditions due to the lack of applying the smoothing algorithm. 95th percentile concentration enhancements for BC were relatively similar across most communities (~1.2-1.4 µg m^{-3}).

CO_2 enhancements (**Figure 21**) were largest in the Brentwood-Golf Course Terrace-Florin Gardens community, with mean enhancements of 242.3 ppmv. Meadowview-Z'berg Park (190.8 ppmv) and Northgate-Gardenland (169.9 ppmv) also had larger mean CO_2 enhancements. The Northgate-Gardenland community had the largest max concentration enhancement (21,639 ppmv), followed by Greenhaven-Pocket (18,868 ppmv).

Methane enhancements (**Figure 22**) were fairly consistent across communities, ranging from 0.0-0.2 ppmv for mean concentration enhancements. The largest max concentration enhancements for methane were observed in Northgate-Gardenland (3.5 ppmv), followed by the other three north Sacramento communities, which all had a max methane concentration enhancement of 2.0 ppmv.

Concentration Enhancement Summary

The spatial mapping analysis observed the following trends:

- PM_{10} and $PM_{2.5}$ levels in north Sacramento communities and arterials were larger than south Sacramento communities

- Ozone and NO_2 levels were generally similar between north and south Sacramento communities
- BC levels were also generally similar between north and south Sacramento communities
- Methane levels along north Sacramento arterial roadways were significantly greater than south Sacramento arterial roadways; however, methane levels in both communities were generally similar
- On the other hand, south Sacramento communities had higher CO_2 levels than north communities
- Alkanes and aromatics were considerably greater in north Sacramento communities and arterials, while diene levels were considerably greater in south Sacramento communities and arterials

Summary statistics of enhanced concentrations are shown in Table 14. Overall, concentration enhancements of many pollutants tended to be along traffic corridors in both north and south Sacramento communities. Enhancements of alkanes, aromatics, CO_2, dienes, methane, and NO_2 were notably higher along most of the Marysville Boulevard-Del Paso Boulevard corridor. PM_{10} enhancements were also higher along this roadway but were much higher in the southern portion.

In the south Sacramento communities, the Fruitridge Road corridor had higher concentration enhancements of alkanes, aromatics, and dienes. Conversely, the Interstate-5 highway had the highest mean enhancements for other mobile emission source pollutants (i.e., BC and NO_2). There was an insufficient amount of data collection by the AROMA analyzer along the Interstate-5 highway for mean enhancements to be observed as consistently higher than other areas in south Sacramento communities.

Table 14. Summary statistics of enhanced concentrations including mean, median, 95th percentile, and maximum enhancement. Pollutant type, pollutant measurement time, by community, and total measurement count, by community, are also included. Depending on the pollutant, concentration enhancements may reflect a 1- to 10-second resolution temporally and a 30- or 90-m resolution spatially. These details are outlined in Table 6. Subheadings include the pollutant[a] and criteria.[b] Communities are grouped by multiple census tracts.

Community	Mean Concentration Enhancement	Median Concentration Enhancement	95th Percentile Enhancement	Max Concentration Enhancement	Measurement Time (Hours)	Total Measurement Count (n)[c]
Nitrogen Dioxide (Criteria Pollutant)						
Brentwood-Golf Course Terrace-Florin Gardens	1.9	0.7	7.3	81.1	7.9	28,273
Del Paso Heights	2.8	1.3	7.5	169.6	13.6	49,026
Greenhaven-Pocket	1.3	0.4	4.5	25.9	6.4	22,894
Hagginwood	3.2	1.2	11.3	73.0	3.4	12,341
Hollywood Park-Mangan Park	2.1	1.1	8.6	45.7	3.5	12,467
Little Pocket-Riverside-Freeport Manor	1.9	0.6	8.1	44.1	6.1	22,075
Meadowview-Z'berg Park	3.0	0.8	14.2	96.0	15.1	54,199
Noralto-Old North Sacramento	3.1	1.4	11.0	113.2	15.2	54,653
Northgate-Gardenland	2.6	1.0	9.1	181.1	10.4	37,607
Ozone (Criteria Pollutant)						
Brentwood-Golf Course Terrace-Florin Gardens	10.6	9.5	27.5	48.8	7.9	28,273
Del Paso Heights	9.9	9.7	18.7	32.1	13.6	49,013
Greenhaven-Pocket	10.1	9.7	19.6	33.3	6.4	22,894
Hagginwood	9.5	8.9	19.7	30.3	3.4	12,296
Hollywood Park-Mangan Park	10.3	9.9	20.9	38.8	3.5	12,467
Little Pocket-Riverside-Freeport Manor	10.1	9.5	21.4	36.0	6.1	22,072
Meadowview-Z'berg Park	10.2	9.6	21.5	46.5	15.1	54,198
Noralto-Old North Sacramento	9.0	8.6	18.6	45.4	15.1	54,497
Northgate-Gardenland	9.9	9.6	18.3	33.0	10.4	37,535

Community	Mean Concentration Enhancement	Median Concentration Enhancement	95th Percentile Enhancement	Max Concentration Enhancement	Measurement Time (Hours)	Total Measurement Count (n)[c]
PM_{10} (Criteria Pollutant)						
Brentwood-Golf Course Terrace-Florin Gardens	2.3	1.9	6.5	10.1	7.9	28,273
Del Paso Heights	3.4	2.7	9.4	16.7	13.6	49,026
Greenhaven-Pocket	1.7	1.3	4.6	9.3	6.4	22,894
Hagginwood	2.7	2.3	6.7	10.7	3.4	12,341
Hollywood Park-Mangan Park	2.5	2.0	7.5	10.2	3.5	12,427
Little Pocket-Riverside-Freeport Manor	2.2	1.6	7.2	10.7	6.1	22,075
Meadowview-Z'berg Park	3.0	1.8	9.4	44.2	15.1	54,204
Noralto-Old North Sacramento	3.7	2.5	7.1	97.1	15.2	54,654
Northgate-Gardenland	2.5	2.1	7.5	12.3	10.4	37,607
$PM_{2.5}$ (Criteria Pollutant)						
Brentwood-Golf Course Terrace-Florin Gardens	0.5	0.4	1.4	4.3	7.9	28,273
Del Paso Heights	1.0	0.8	3.6	6.0	13.6	49,026
Greenhaven-Pocket	0.5	0.4	1.5	3.9	6.4	22,894
Hagginwood	0.8	0.6	2.3	5.1	3.4	12,341
Hollywood Park-Mangan Park	0.7	0.6	2.2	2.8	3.5	12,427
Little Pocket-Riverside-Freeport Manor	0.7	0.4	2.4	4.0	6.1	22,075
Meadowview-Z'berg Park	1.0	0.5	3.9	7.0	15.1	54,204
Noralto-Old North Sacramento	0.9	0.6	3.1	4.5	15.2	54,654
Northgate-Gardenland	1.1	0.4	4.8	9.4	10.4	37,607

Community	Mean Concentration Enhancement	Median Concentration Enhancement	95th Percentile Enhancement	Max Concentration Enhancement	Measurement Time (Hours)	Total Measurement Count (n)[c]
Alkanes (VOC/HAP)						
Brentwood-Golf Course Terrace-Florin Gardens	3.6	1.9	11.6	66.6	7.9	5,706
Del Paso Heights	6.5	3.6	28.4	58.2	13.7	9,878
Greenhaven-Pocket	3.9	2.2	12.5	77.4	7.8	5,619
Hagginwood	9.6	4.6	36.4	59.7	3.8	2,765
Hollywood Park-Mangan Park	4.5	1.9	14.3	76.5	3.6	2,617
Little Pocket-Riverside-Freeport Manor	4.7	3.3	14.0	82.7	6.7	4,817
Meadowview-Z'berg Park	5.5	3.1	22.0	133.1	16.1	11,603
Noralto-Old North Sacramento	7.9	2.9	27.6	415.8	16.7	12,026
Northgate-Gardenland	6.1	2.4	20.1	339.6	11.7	8,416
Aromatics (VOC/HAP)						
Brentwood-Golf Course Terrace-Florin Gardens	1.4	0.3	6.0	13.6	7.7	5,570
Del Paso Heights	2.6	0.6	19.6	41.6	12.7	9,176
Greenhaven-Pocket	1.2	0.3	7.0	17.6	7.7	5,525
Hagginwood	2.8	0.7	14.8	22.7	3.7	2,648
Hollywood Park-Mangan Park	1.8	0.4	6.4	16.8	3.6	2,617
Little Pocket-Riverside-Freeport Manor	1.6	0.8	7.0	17.4	6.6	4,761
Meadowview-Z'berg Park	1.5	0.6	8.2	42.8	16.2	11,650
Noralto-Old North Sacramento	1.9	0.6	8.1	37.3	16.0	11,501
Northgate-Gardenland	1.9	0.6	7.2	100.8	10.8	7,788

Community	Mean Concentration Enhancement	Median Concentration Enhancement	95th Percentile Enhancement	Max Concentration Enhancement	Measurement Time (Hours)	Total Measurement Count (n)[c]
Black Carbon (CF/HAP)						
Brentwood-Golf Course Terrace-Florin Gardens	0.6	0.2	1.2	931.2	7.6	27,478
Del Paso Heights	0.6	0.2	1.3	913.0	13.2	47,393
Greenhaven-Pocket	0.6	0.2	1.2	930.3	6.3	22,751
Hagginwood	0.6	0.2	1.4	681.3	3.3	11,968
Hollywood Park-Mangan Park	0.5	0.2	1.2	936.9	3.3	12,054
Little Pocket-Riverside-Freeport Manor	0.9	0.2	1.3	936.8	6.0	21,735
Meadowview-Z'berg Park	0.6	0.2	1.3	917.1	14.9	53,499
Noralto-Old North Sacramento	0.6	0.1	1.2	932.7	14.7	52,812
Northgate-Gardenland	0.7	0.1	1.3	949.0	10.1	36,413
Dienes (VOC/HAP)						
Brentwood-Golf Course Terrace-Florin Gardens	2.3	0.9	8.7	22.5	5.2	3,723
Del Paso Heights	1.6	0.8	5.3	19.7	10.0	7,207
Greenhaven-Pocket	1.7	0.6	7.7	28.4	5.5	3,926
Hagginwood	2.1	0.9	9.0	13.3	3.0	2,188
Hollywood Park-Mangan Park	2.7	1.0	8.1	26.6	2.5	1,773
Little Pocket-Riverside-Freeport Manor	1.8	0.8	6.3	27.6	4.6	3,312
Meadowview-Z'berg Park	2.6	1.3	10.3	25.8	11.1	7,970
Noralto-Old North Sacramento	1.7	0.8	7.3	33.2	10.8	7,799
Northgate-Gardenland	1.5	0.7	5.1	62.8	8.7	6,234

Community	Mean Concentration Enhancement	Median Concentration Enhancement	95th Percentile Enhancement	Max Concentration Enhancement	Measurement Time (Hours)	Total Measurement Count (n)[c]
Carbon Dioxide (CF)						
Brentwood-Golf Course Terrace-Florin Gardens	242.3	95.8	1557.6	1,761.3	7.7	5,513
Del Paso Heights	85.8	31.3	264.4	1,596.3	13.0	9,344
Greenhaven-Pocket	146.6	62.2	386.2	18,868.6	6.6	4,745
Hagginwood	120.9	35.1	352.2	1,500.7	3.6	2,561
Hollywood Park-Mangan Park	165.5	57.0	652.2	1,325.0	3.5	2,554
Little Pocket-Riverside-Freeport Manor	133.1	60.6	406.3	794.5	5.7	4,072
Meadowview-Z'berg Park	190.8	42.2	1403.3	1,750.9	15.4	11,068
Noralto-Old North Sacramento	113.0	50.0	368.9	1,398.3	15.4	11,088
Northgate-Gardenland	169.9	51.5	359.3	21,639.3	11.2	8,084
Methane (CF)						
Brentwood-Golf Course Terrace-Florin Gardens	0.1	0.0	0.4	0.7	7.2	5,171
Del Paso Heights	0.1	0.0	0.6	2.0	12.4	8,946
Greenhaven-Pocket	0.0	0.0	0.1	0.3	7.3	5,290
Hagginwood	0.2	0.1	1.2	2.0	3.3	2,350
Hollywood Park-Mangan Park	0.1	0.1	0.3	0.3	3.2	2,300
Little Pocket-Riverside-Freeport Manor	0.1	0.0	0.2	0.5	5.9	4,253
Meadowview-Z'berg Park	0.1	0.0	0.3	0.8	14.4	10,357
Noralto-Old North Sacramento	0.1	0.0	0.4	2.0	14.7	10,592
Northgate-Gardenland	0.1	0.0	0.2	3.5	10.2	7,349

[a] Alkanes, CO_2, and methane are in parts per million by volume (ppmv). Aromatics, dienes, NO_2, and ozone are in parts per billion by volume (ppbv). BC, PM_{10}, and $PM_{2.5}$ are in micrograms per cubic meter ($\mu g\ m^{-3}$).

[b] Criteria include criteria air pollutants, VOC/HAP (volatile organic compounds and hazardous air pollutants), and CF (climate forcer).

[c] Total measurement counts for AROMA analyzer parameters (alkanes, aromatics, CO_2, dienes, and methane) were collected at a 5-sec resolution (0.2 Hz) so these parameters will have lower counts than other parameters which were collected at a 1-sec resolution (1 Hz).

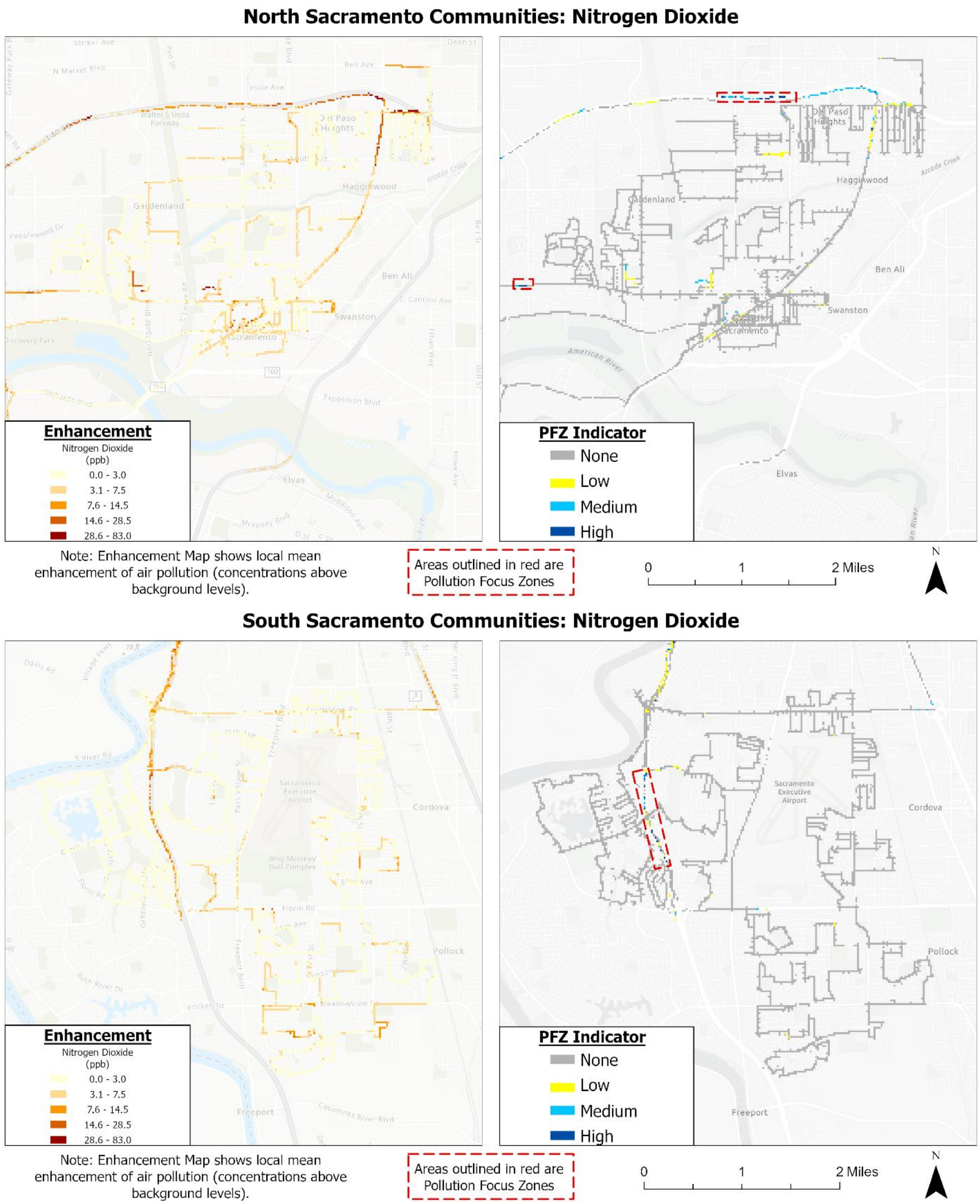

Figure 12. Mobile monitoring measurements in north and south Sacramento communities for NO_2. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

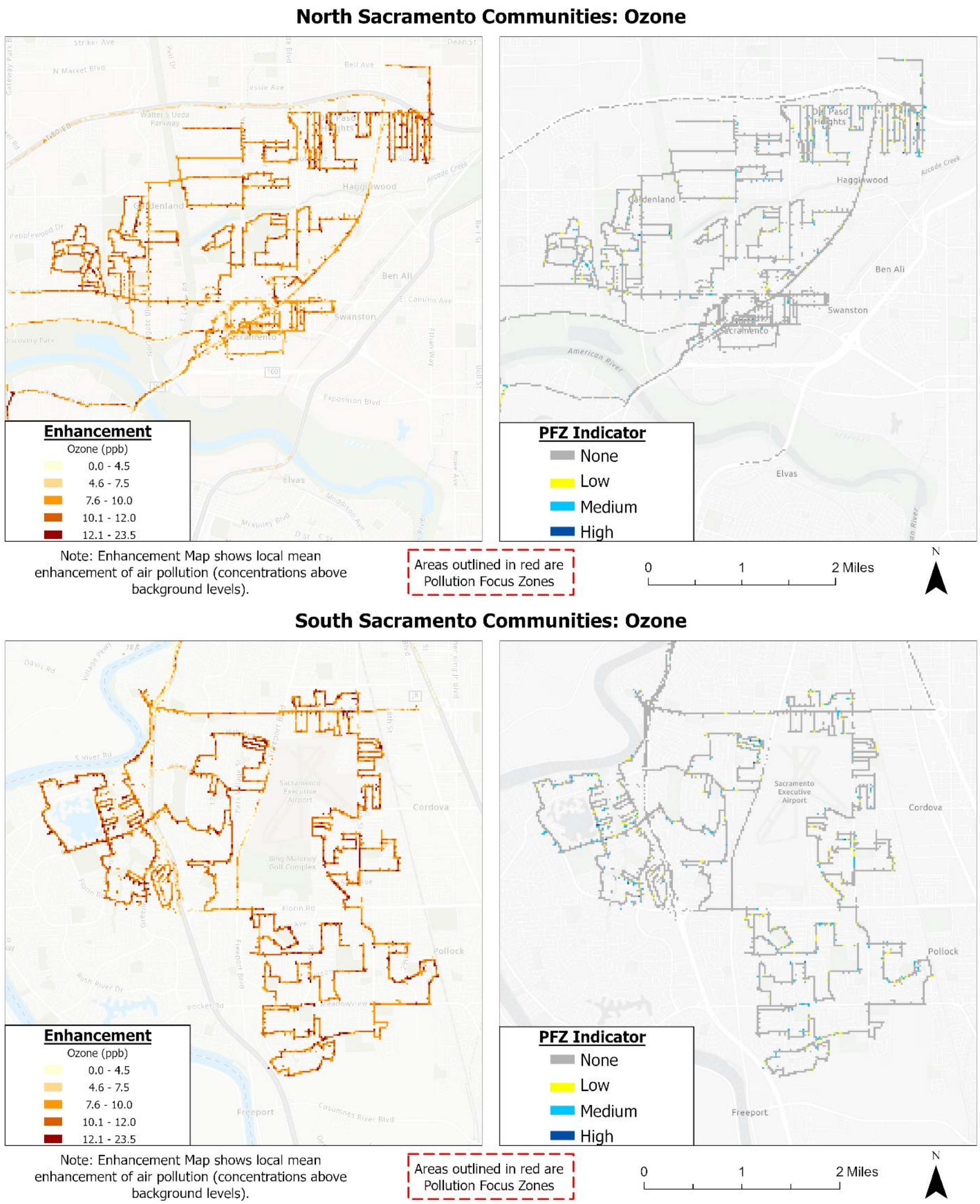

Figure 13. Mobile monitoring measurements in north and south Sacramento communities for O_3. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

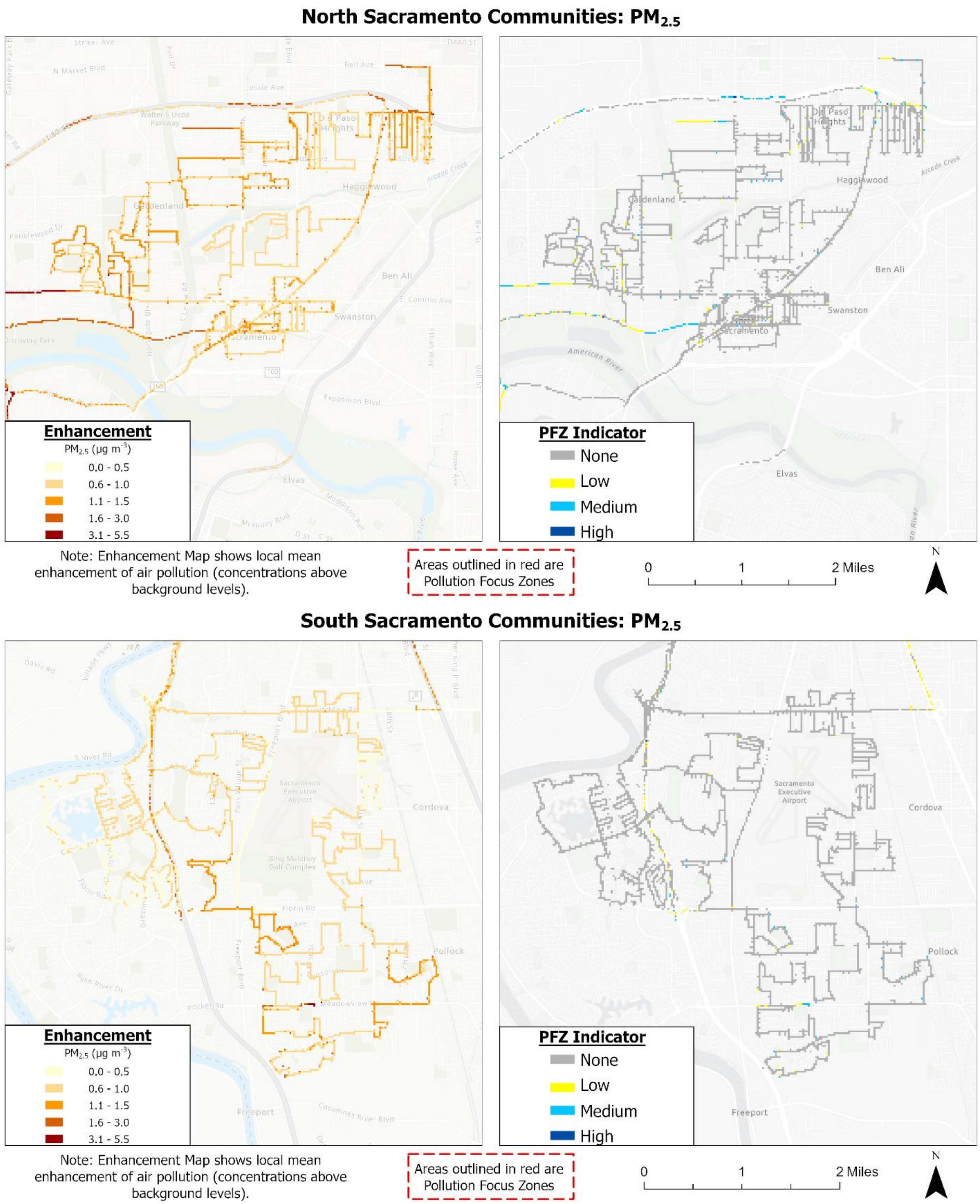

Figure 14. Mobile monitoring measurements in north and south Sacramento communities for $PM_{2.5}$. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

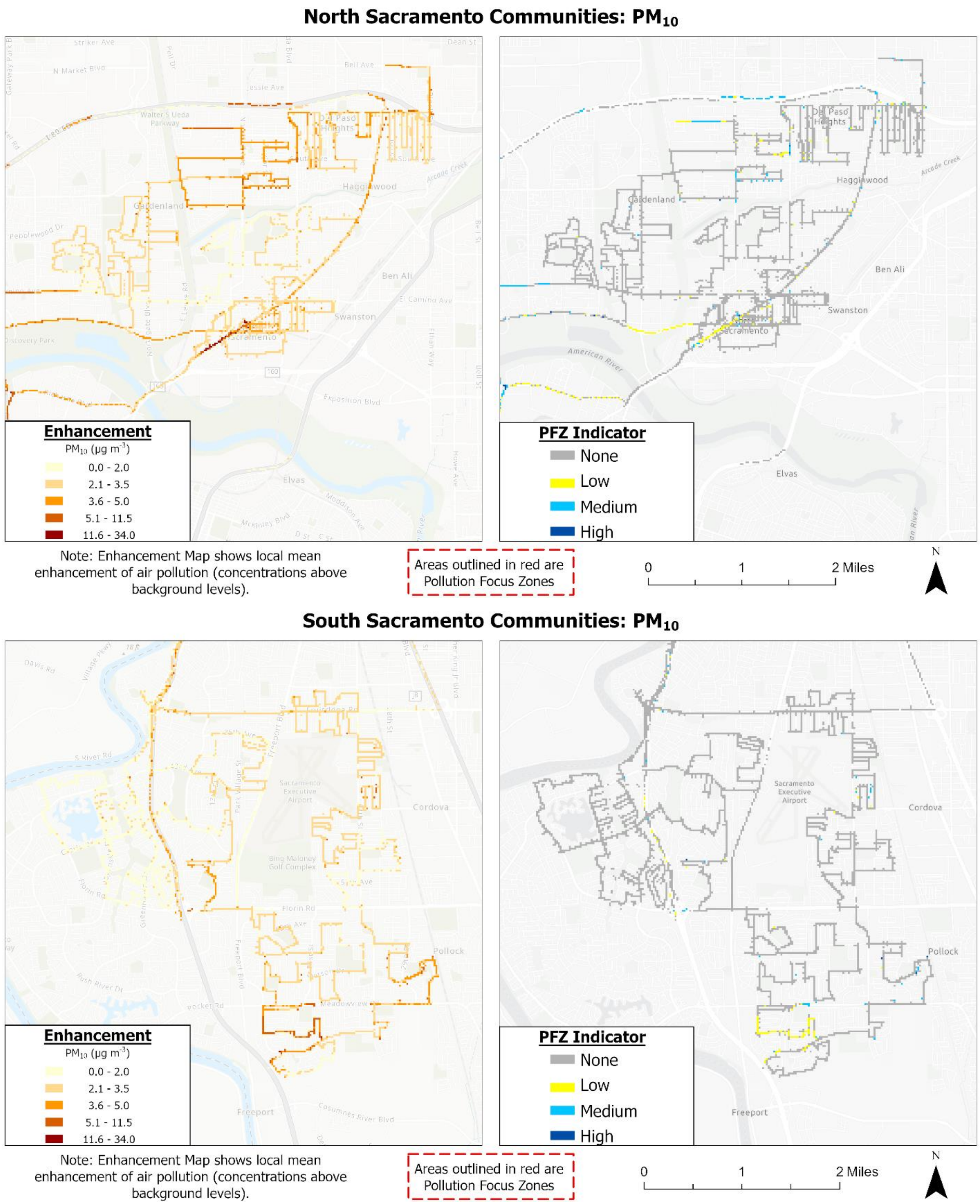

Figure 15. Mobile monitoring measurements in north and south Sacramento communities for PM_{10}. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

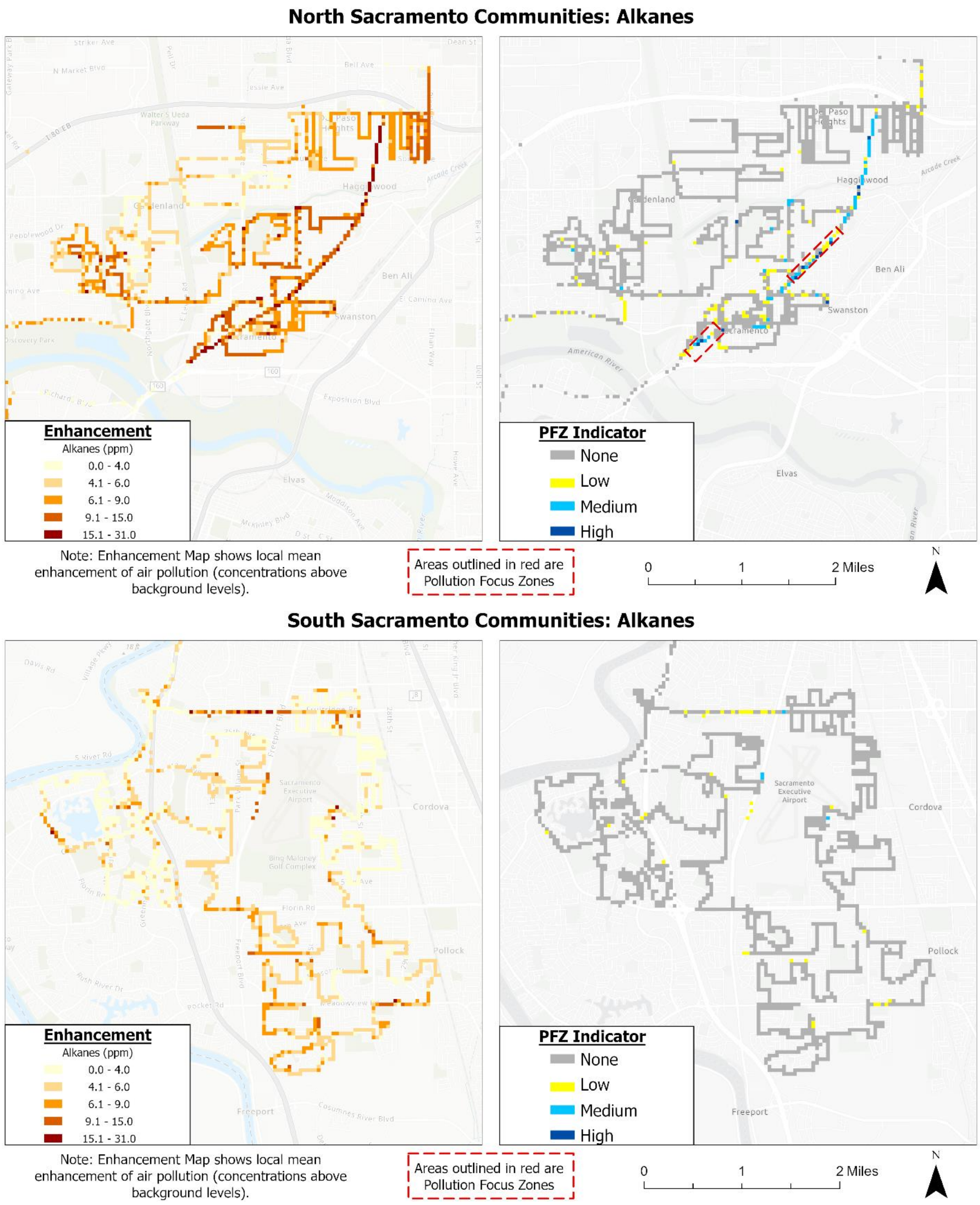

Figure 16. Mobile monitoring measurements in north and south Sacramento communities for alkanes. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

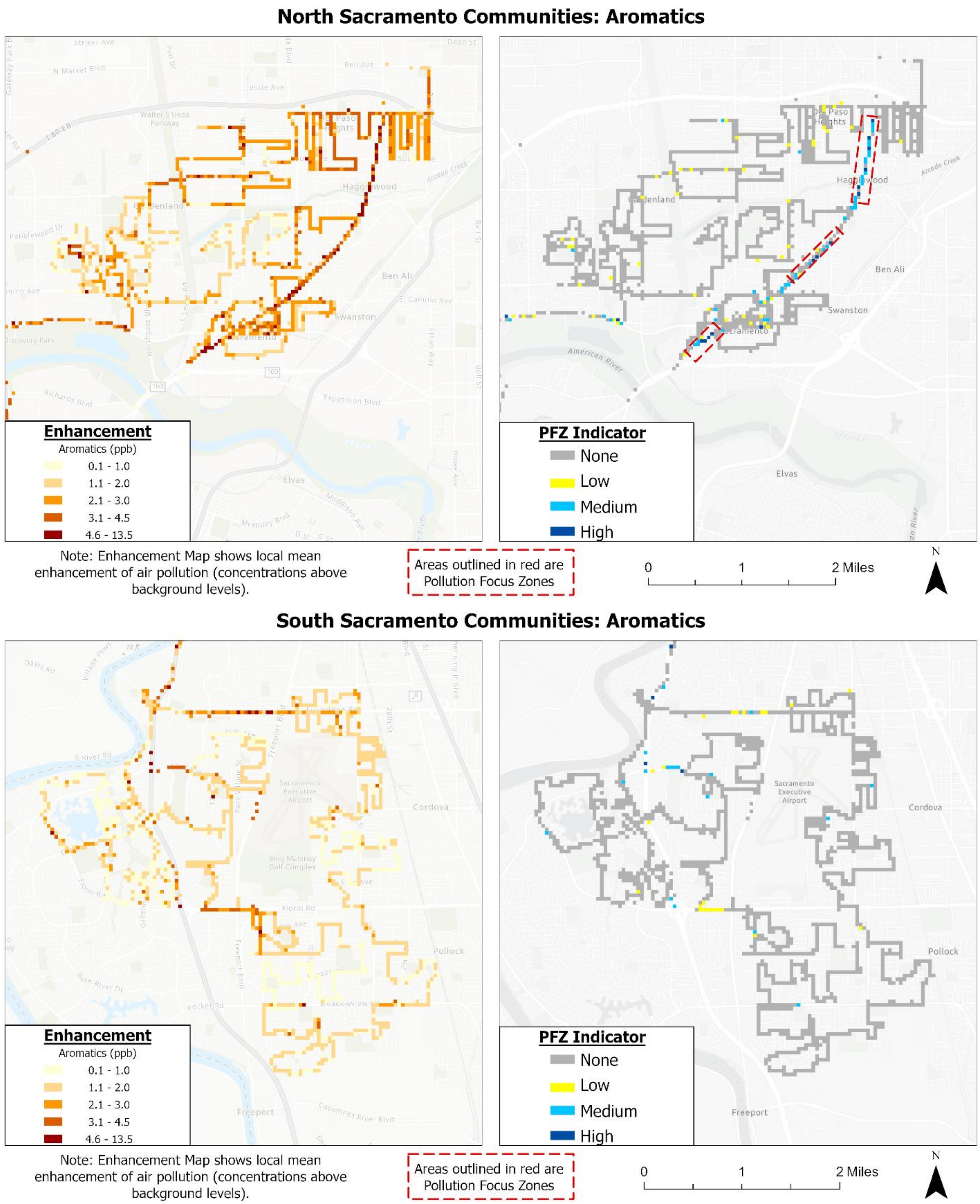

Figure 17. Mobile monitoring measurements in north and south Sacramento communities for aromatic VOCs. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

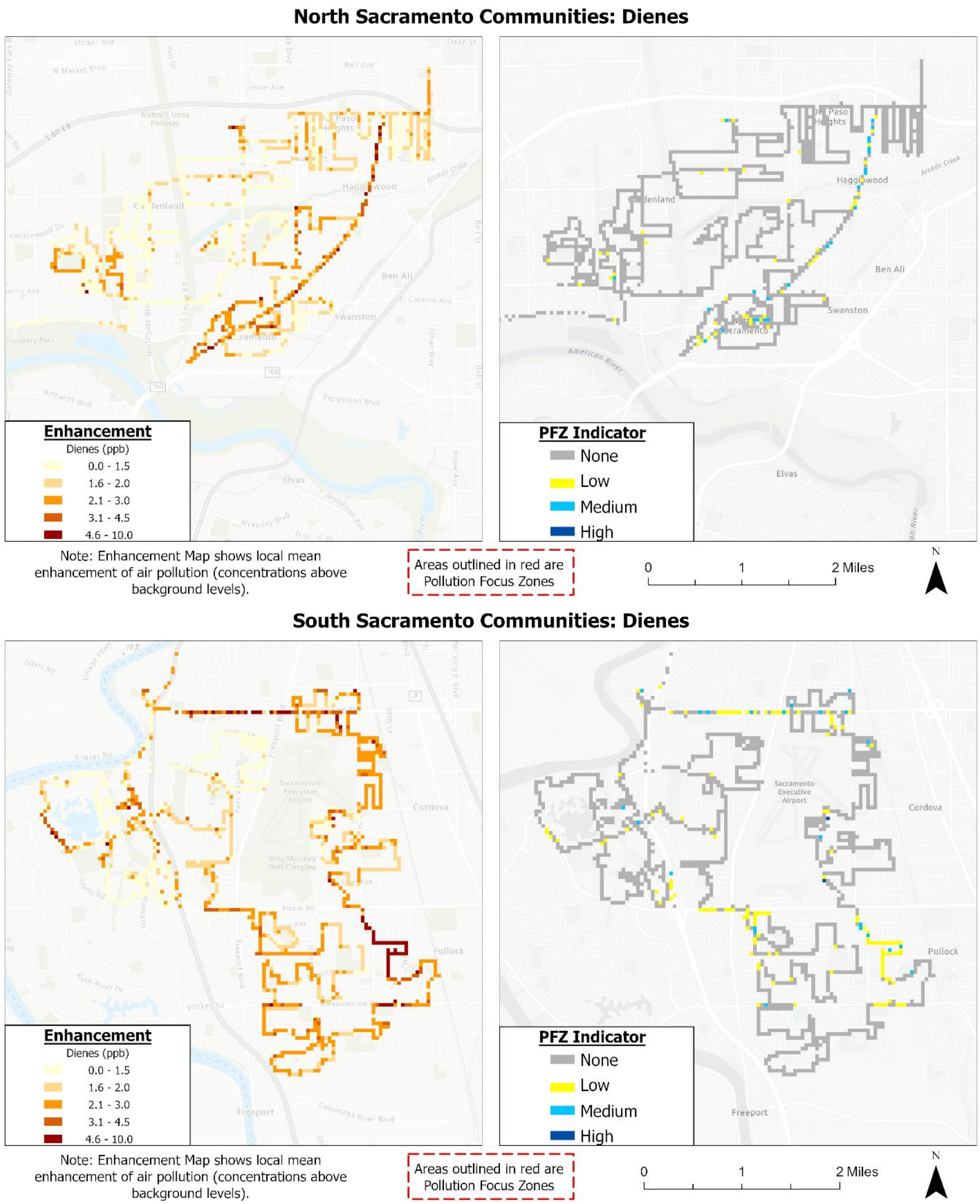

Figure 18. Mobile monitoring measurements in north and south Sacramento communities for dienes. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

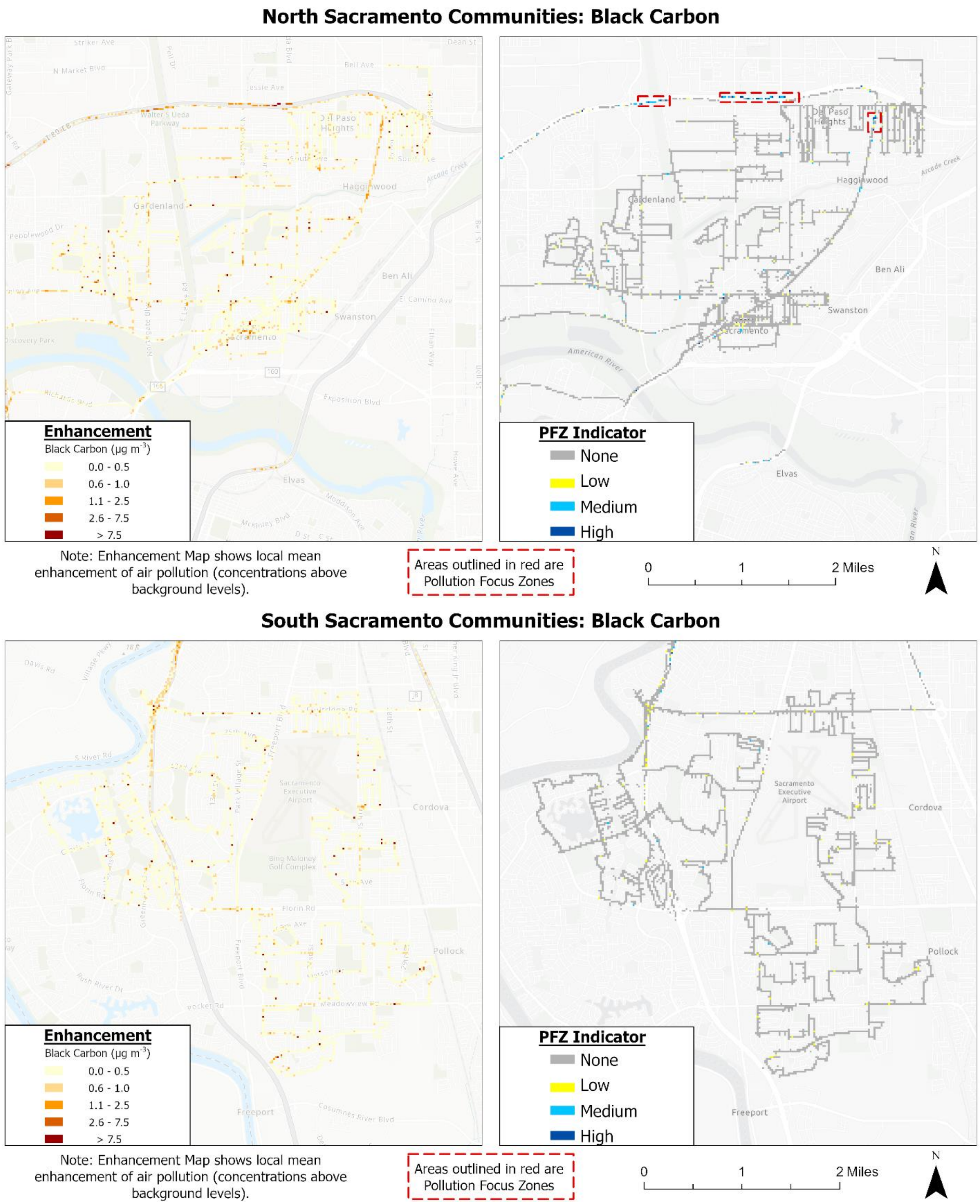

Figure 19. Mobile monitoring measurements in north and south Sacramento communities for BC. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels, with adjustments to the natural breaks, and PFZ Indicators are shown in the right panels.

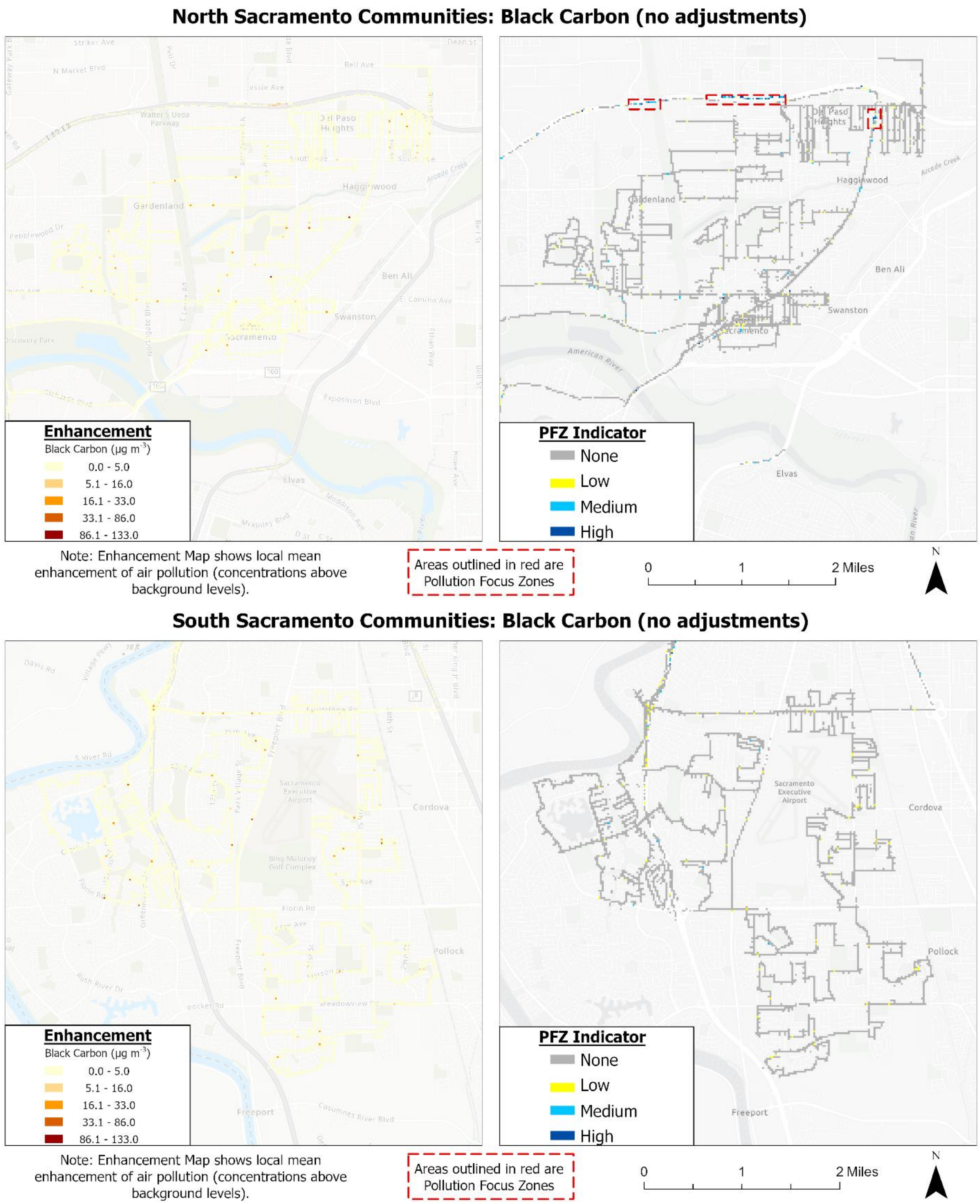

Figure 20. Mobile monitoring measurements in north and south Sacramento communities for BC. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels, without adjustments to the natural breaks, and PFZ Indicators are shown in the right panels.

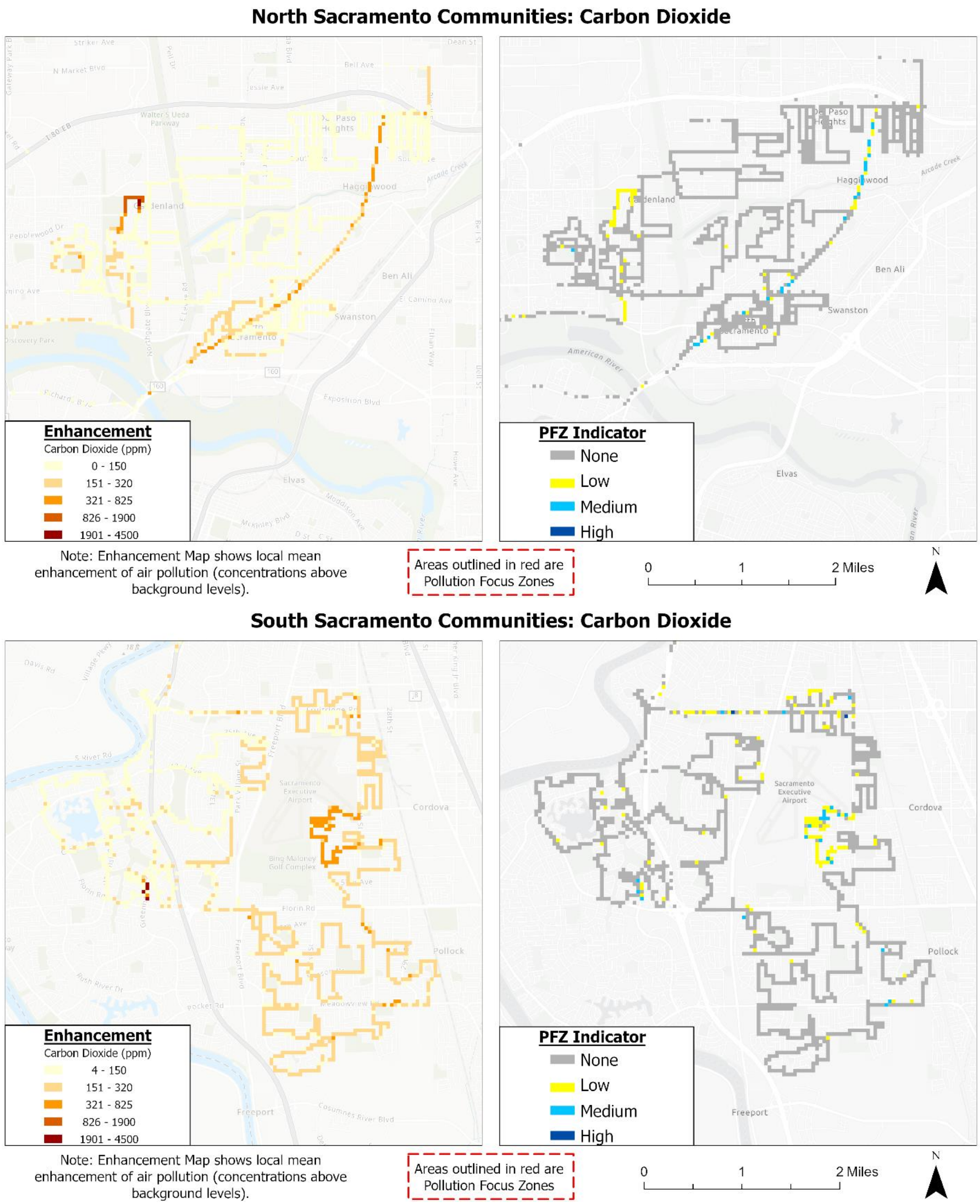

Figure 21. Mobile monitoring measurements in north and south Sacramento communities for CO_2. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

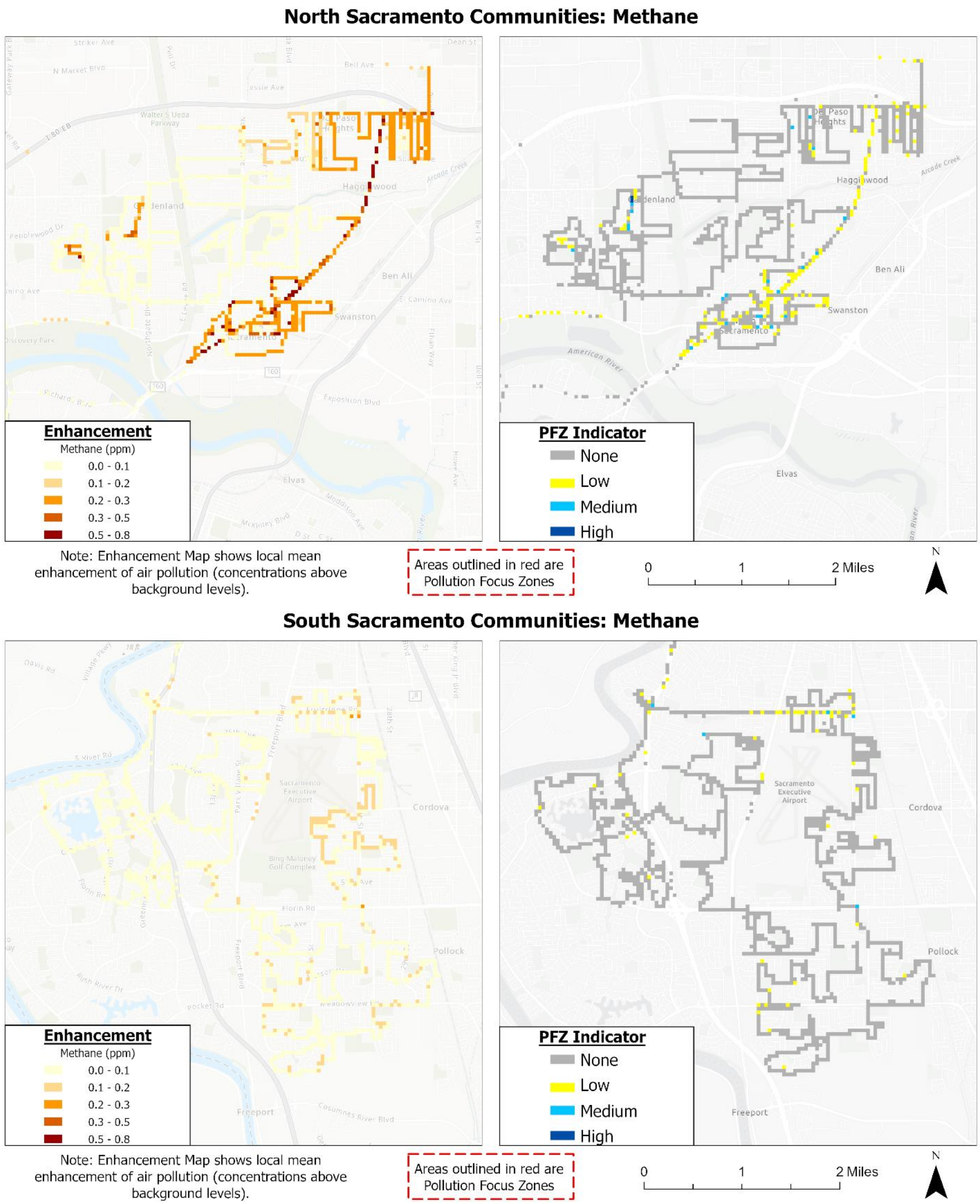

Figure 22. Mobile monitoring measurements in north and south Sacramento communities for methane. Concentration enhancements (concentration above 90-min rolling backgrounds) are shown in the left panels and PFZ Indicators are shown in the right panels.

4.3 Pollution Focus Zone Statistics

Localized PFZs were identified using a statistical analysis approach to identify areas disproportionately impacted by air quality burdens. The approach was consistent with the three-method high pollution zone, or PFZ here, identification process detailed in Chen et al. (2022) and relied on the analysis of concentration enhancements from each day of the monitoring campaign. Grid cells that meet one, two, or all three of these standards are defined PFZ with low, medium, or high confidence, respectively. The results from this analysis are presented below in Table 15.

Table 15. The total count of no (none), low, medium, and high PFZ indicator grid cells by pollutant and community. Subheadings include the pollutant and criteria,[b] Communities are grouped by multiple census tracts.

Community	None	Low	Medium	High
Nitrogen Dioxide (Criteria Pollutant)				
Brentwood-Golf Course Terrace-Florin Gardens	719	1	3	0
Del Paso Heights	1,187	58	53	14
Greenhaven-Pocket	968	21	6	13
Hagginwood	424	7	1	0
Hollywood Park-Mangan Park	280	1	0	0
Little Pocket-Riverside-Freeport Manor	651	62	10	18
Meadowview-Z'berg Park	1,194	6	3	0
Noralto-Old North Sacramento	1,137	28	12	0
Northgate-Gardenland	1,039	36	8	2
Ozone (Criteria Pollutant)				
Brentwood-Golf Course Terrace-Florin Gardens	665	33	24	1
Del Paso Heights	1,210	43	56	3
Greenhaven-Pocket	908	44	51	5
Hagginwood	405	12	14	1
Hollywood Park-Mangan Park	256	12	13	0
Little Pocket-Riverside-Freeport Manor	693	24	20	3
Meadowview-Z'berg Park	1,095	54	53	1
Noralto-Old North Sacramento	1,142	17	18	0
Northgate-Gardenland	1,017	39	26	2

Community	None	Low	Medium	High
PM_{10} (Criteria Pollutant)				
Brentwood-Golf Course Terrace-Florin Gardens	711	4	8	0
Del Paso Heights	1,187	47	75	3
Greenhaven-Pocket	991	13	4	0
Hagginwood	410	15	6	1
Hollywood Park-Mangan Park	280	0	1	0
Little Pocket-Riverside-Freeport Manor	728	5	8	0
Meadowview-Z'berg Park	1,099	78	22	4
Noralto-Old North Sacramento	1,110	53	13	1
Northgate-Gardenland	1,018	44	20	3
$PM_{2.5}$ (Criteria Pollutant)				
Brentwood-Golf Course Terrace-Florin Gardens	716	6	1	0
Del Paso Heights	1,187	68	54	3
Greenhaven-Pocket	983	21	3	1
Hagginwood	427	4	1	0
Hollywood Park-Mangan Park	280	1	0	0
Little Pocket-Riverside-Freeport Manor	728	11	2	0
Meadowview-Z'berg Park	1,157	26	20	0
Noralto-Old North Sacramento	1,144	17	16	0
Northgate-Gardenland	934	105	45	1
Alkanes (VOC/HAP)				
Brentwood-Golf Course Terrace-Florin Gardens	267	4	3	0
Del Paso Heights	450	13	10	1
Greenhaven-Pocket	346	6	0	0
Hagginwood	130	28	27	7
Hollywood Park-Mangan Park	111	0	1	0
Little Pocket-Riverside-Freeport Manor	243	17	2	0
Meadowview-Z'berg Park	504	11	0	0
Noralto-Old North Sacramento	355	48	20	6
Northgate-Gardenland	384	25	2	0

Community	None	Low	Medium	High
Aromatics (VOC/HAP)				
Brentwood-Golf Course Terrace-Florin Gardens	271	0	2	0
Del Paso Heights	443	19	8	3
Greenhaven-Pocket	333	4	10	1
Hagginwood	159	5	20	6
Hollywood Park-Mangan Park	110	2	0	0
Little Pocket-Riverside-Freeport Manor	236	8	6	6
Meadowview-Z'berg Park	497	11	4	0
Noralto-Old North Sacramento	382	13	17	6
Northgate-Gardenland	372	20	7	2
Black Carbon (CF/HAP)				
Brentwood-Golf Course Terrace-Florin Gardens	701	21	0	0
Del Paso Heights	1,247	29	20	14
Greenhaven-Pocket	986	17	4	0
Hagginwood	415	12	5	0
Hollywood Park-Mangan Park	279	2	0	0
Little Pocket-Riverside-Freeport Manor	687	32	14	6
Meadowview-Z'berg Park	1,182	22	2	0
Noralto-Old North Sacramento	1,135	33	6	3
Northgate-Gardenland	1,002	41	27	14
Dienes (VOC/HAP)				
Brentwood-Golf Course Terrace-Florin Gardens	237	7	2	2
Del Paso Heights	424	9	7	0
Greenhaven-Pocket	297	16	3	0
Hagginwood	158	13	7	0
Hollywood Park-Mangan Park	86	12	5	0
Little Pocket-Riverside-Freeport Manor	197	21	4	0
Meadowview-Z'berg Park	395	80	10	0
Noralto-Old North Sacramento	357	17	10	0
Northgate-Gardenland	375	9	1	0

Community	None	Low	Medium	High
Carbon Dioxide (CF)				
Brentwood-Golf Course Terrace-Florin Gardens	200	56	13	0
Del Paso Heights	455	7	4	0
Greenhaven-Pocket	326	11	3	0
Hagginwood	166	10	10	0
Hollywood Park-Mangan Park	90	19	2	1
Little Pocket-Riverside-Freeport Manor	207	24	1	1
Meadowview-Z'berg Park	495	12	4	0
Noralto-Old North Sacramento	397	12	10	0
Northgate-Gardenland	364	45	1	0
Methane (CF)				
Brentwood-Golf Course Terrace-Florin Gardens	263	6	1	0
Del Paso Heights	437	31	3	0
Greenhaven-Pocket	330	8	0	0
Hagginwood	146	37	3	0
Hollywood Park-Mangan Park	88	18	2	0
Little Pocket-Riverside-Freeport Manor	235	15	2	0
Meadowview-Z'berg Park	495	11	1	0
Noralto-Old North Sacramento	324	79	11	0
Northgate-Gardenland	348	25	5	2

Criteria Air Pollutants

Three communities had >5 PFZs with high confidence for NO_2 – Little Pocket-Riverside-Freeport Manor (18), Del Paso Heights (14), and Greenhaven-Pocket (13). Additionally, Northgate-Gardenland also had two NO_2 PFZs with high confidence. The NO_2 PFZs with high confidence tended to be along major arterial roadways within communities. Only one community (Greenhaven-Pocket) had >5 ozone PFZs with high confidence. Several other communities had one to three O_3 PFZs with high confidence, including Del Paso Heights (3), Little Pocket-Riverside-Freeport Manor (3), Northgate-Gardenland (2), Brentwood-Golf Course Terrace-Florin Gardens (1), Hagginwood (1), and Meadowview-Z'berg Park (1).

No community had >5 PFZs with high confidence for PM_{10}. A number of communities did have elevated medium-confidence PFZs for PM_{10}, including Del Paso Heights (75), Meadowview-Z'berg Park (22), Noralto-Old North Sacramento (13), Northgate-Gardenland (20), Hagginwood (6), and Greenhaven-Pocket (4). Few communities had any high-confidence PFZs for $PM_{2.5}$, although Del Paso Heights (3), Greenhaven-Pocket (1), and Northgate-Gardenland (1) had a few. Similar to PM_{10}, some communities had medium-confidence PFZs for $PM_{2.5}$, including Northgate-Gardenland (45), Del Paso

Heights (54), Meadowview-Z'berg Park (20), Noralto-Old North Sacramento (16), Greenhaven-Pocket (3), and Little Pocket-Riverside-Freeport Manor (2).

Volatile Organic Compounds and Hazardous Air Pollutants

Hagginwood (7) and Noralto-Old North Sacramento (6) had a handful of high-confidence PFZs for alkanes. Noralto-Old North Sacramento, Hagginwood, Northgate-Gardenland, and Del Paso Heights also had increased alkane PFZs at medium-confidence levels. Three communities had 6 high confidence PFZs for aromatics – Hagginwood, Little Pocket-Riverside-Freeport Manor, and Noralto-Old North Sacramento. A number of communities also had medium-confidence aromatic PFZs, including Northgate-Gardenland, Del Paso Heights, Noralto-Old North Sacramento, Hagginwood, Greenhaven-Pocket, and Meadowview-Z'berg Park. Alkane and aromatic PFZs tended to occur along arterial roadways with a handful of PFZs near industrial or commercially zoned areas, such as in Noralto-Old North Sacramento. No communities had >5 high-confidence diene PFZs. In fact, the only community with a nonzero number of high-confidence diene PFZs was Brentwood-Golf Course Terrace-Florin Gardens (2). By far, Meadowview-Z'berg Park had the largest number of diene PFZs when evaluating low and medium-confidence levels.

Climate Forcers

For BC, Del Paso Heights (14), Northgate-Gardenland (14), and Little Pocket-Riverside-Freeport Manor (6) had a larger number of high-confidence PFZs. Every community other than Hollywood Park-Mangan Park had >10 low confidence BC PFZs, and Northgate-Gardenland had the highest (41).

Low- and medium-confidence CO_2 PFZs were higher in two communities – Brentwood-Golf Course Terrace-Florin Gardens and Northgate-Gardenland - no high-confidence PFZs were present in these communities. Additionally, Hollywood Park-Mangan Park (3) and Little Pocket-Riverside-Freeport Manor (2) also had a couple of medium-high CO_2 PFZs. Only Northgate-Gardenland (2) had high-confidence PFZs for methane. Noralto-Old North Sacramento had the largest number of overall methane PFZs across all confidence levels. Hagginwood, Del Paso Heights, and Northgate-Gardenland also had a higher total number of methane PFZs.

4.4 Temporal Patterns

Temporal patterns for mobile monitoring data were analyzed within each community. Pollutants were separated into criteria pollutants (i.e., O_3, NO_2, $PM_{2.5}$, and PM_{10}), gaseous climate forcers (i.e., CO_2, methane, and BC), and VOCs and HAPs (i.e., alkanes, aromatics, and dienes). Since the project team rotated mobile monitoring routes during the field campaign, data could be evaluated between 8:00 and 19:00 across communities. Figure 23 shows the number of measurements by hour. The counts in the 8:00-9:00 and 18:00-19:00 bins are lower because these were start and end times for most measurement days.

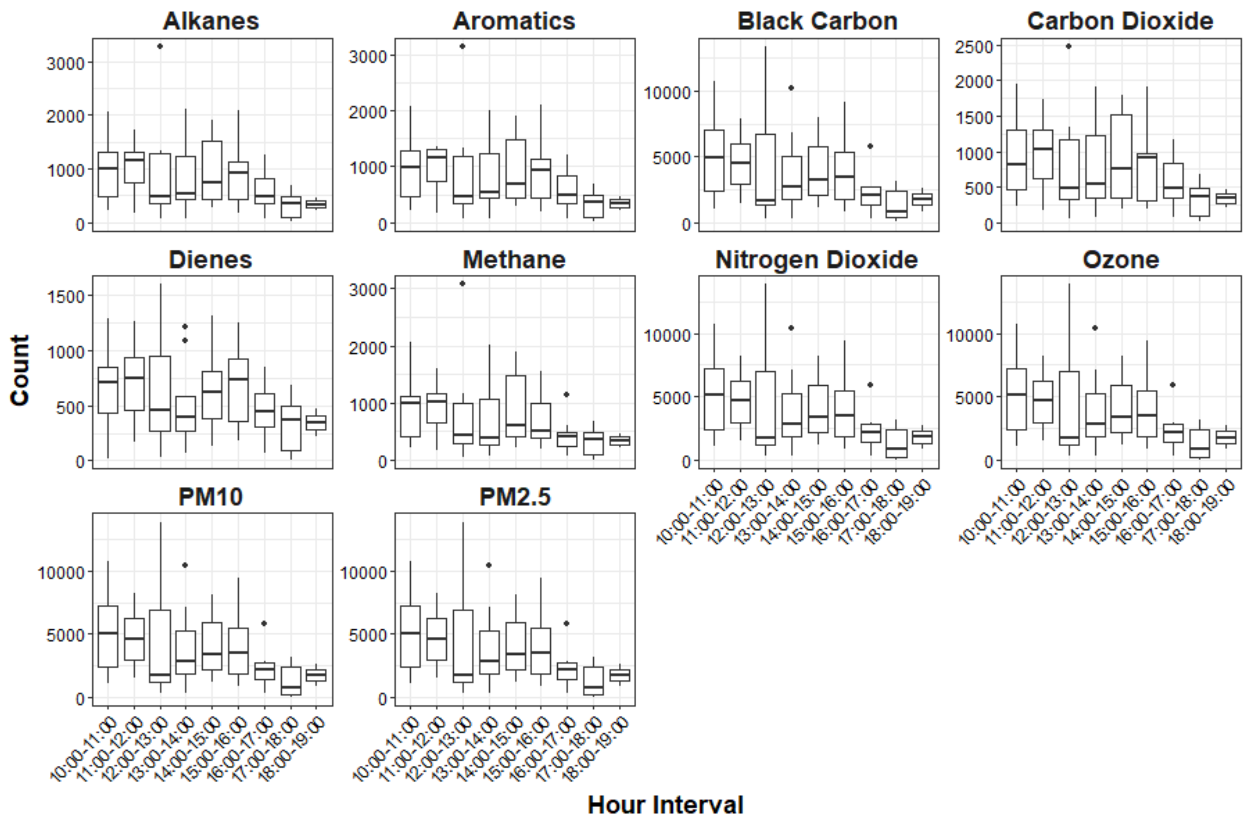

Figure 23. Box plot distributions of the count of data points by parameter for different communities across the duration of the mobile monitoring campaign. Total measurement counts for AROMA analyzer parameters (alkanes, aromatics, CO_2, dienes, and methane) were collected at a 5-sec resolution (0.2 Hz), so these parameters have lower counts than other parameters which were collected at a 1-sec resolution (1 Hz).

Criteria Air Pollutants

The concentrations of several criteria air pollutants tended to follow diurnal traffic patterns with mobile source pollutants (e.g., NO_2 and $PM_{2.5}$), showing higher mean enhancements in the morning (~8:30), decreasing during the late morning and early afternoon, then elevating again during peak afternoon rush hour (~16:00). Patterns of criteria pollutant concentrations were consistent across communities – notably for ozone and NO_2 – which is indicative of the NO_x-ozone cycling pattern with mobile vehicle emissions. Figure 24 shows all average criteria air pollutant enhancements by hour and community.

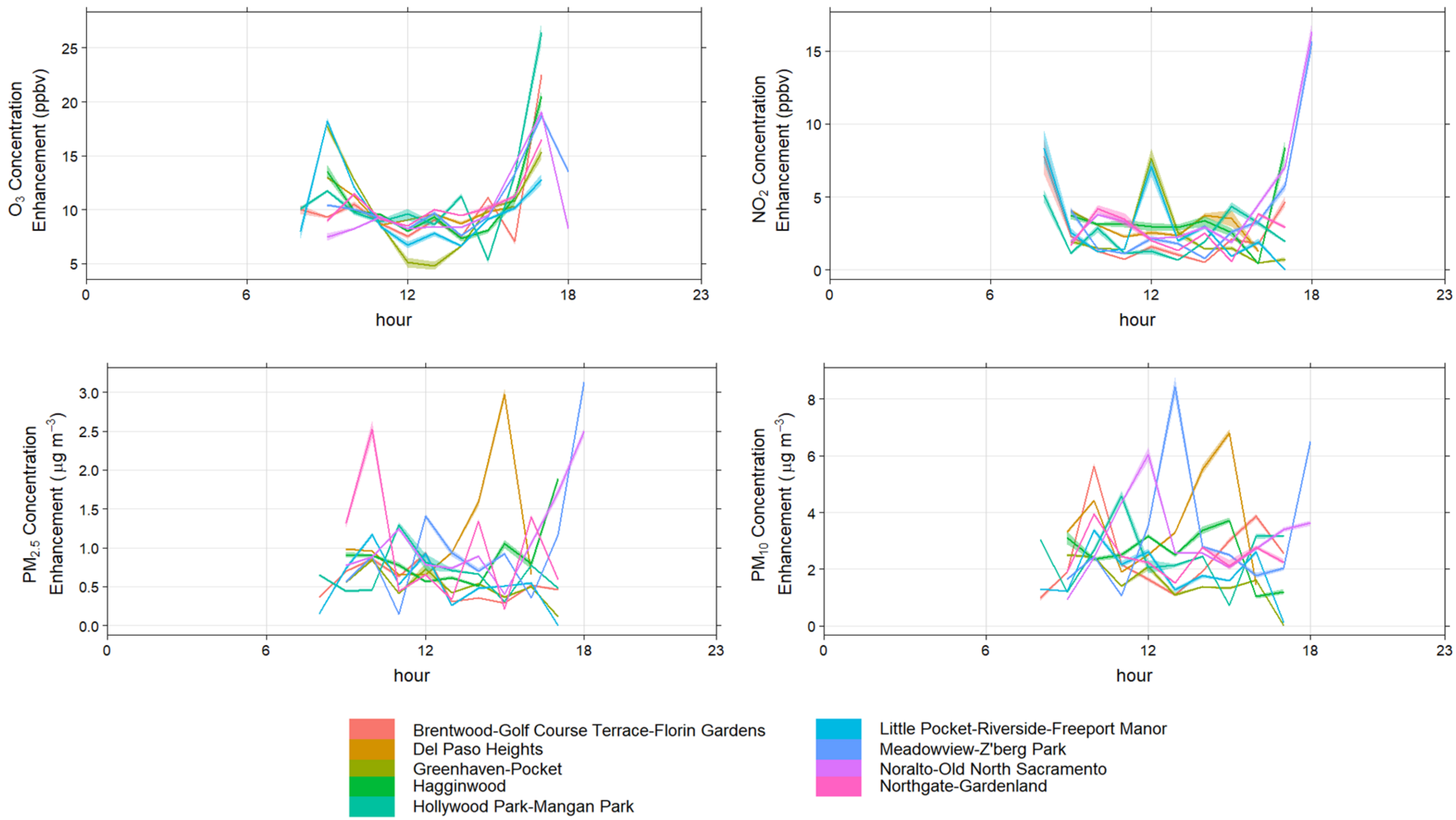

Figure 24. Temporal patterns of mobile monitoring data for criteria pollutants. Mean concentration enhancements and the 95% confidence interval (shading) are shown for each community. Communities are differentiated by color. Temporal patterns were limited to times of the day when mobile monitoring occurred. The hour of the day along the x-axis is for the hour interval for the successive hour (e.g., 12 is 12:00-13:00).

Noralto-Old North Sacramento and Meadowview-Z'berg Park had the highest average NO_2 enhancements between 18:00-19:00, ranging from 15.7-16.3 ppbv. All other average NO_2 enhancements were <9 ppbv for every community and hour of the day.

The five highest average ozone enhancements directly followed afternoon rush hour (17:00-18:00) and ranged from 18.7-26.4 ppbv. These communities included Hollywood Park-Mangan Park, Brentwood-Golf Course Terrace-Florin Gardens, Hagginwood, Noralto-Old North Sacramento, and Meadowview-Z'berg Park. Little Pocket-Riverside-Freeport Manor and Greenhaven-Pocket also experienced higher average ozone enhancements directly after morning rush hour (9:00-10:00), ranging from 17.7-18.2 ppbv. These ozone enhancement patterns typically coincided with periods of decreased NO_2 concentrations caused by atmospheric cycling resulting in ozone formation following periods of high NO_2 concentrations.

Higher average $PM_{2.5}$ concentration enhancements were observed in Meadowview-Z'berg Park (18:00-19:00, 3.1 $\mu g\ m^{-3}$), Del Paso Heights (15:00-16:00, 3.0 $\mu g\ m^{-3}$), Hagginwood (17:00-18:00, 1.9 $\mu g\ m^{-3}$), and Noralto-Old North Sacramento (17:00-18:00, 1.7 $\mu g\ m^{-3}$) during the afternoon, while Northgate-Gardenland experienced higher $PM_{2.5}$ concentration enhancements in the morning (10:00-11:00, 2.5 $\mu g\ m^{-3}$). Other than Meadowview-Z'berg Park, other south Sacramento communities tended to have mean $PM_{2.5}$ enhancements <1 $\mu g\ m^{-3}$.

PM_{10} concentration enhancements were the most temporally variable across communities where Meadowview-Z'berg Park experienced large enhancements during mid-afternoon (13:00-14:00, 8.4 $\mu g\ m^{-3}$). Other communities also experienced PM_{10} concentration enhancements in the afternoon, notably Noralto-Old North Sacramento (12:00-13:00, 6.0 $\mu g\ m^{-3}$) and Del Paso Heights (14:00-16:00, 5.5-6.8 $\mu g\ m^{-3}$).

Volatile Organic Compounds and Hazardous Air Pollutants

Figure 25 shows all average VOC and HAP enhancements from mobile monitoring by hour and community.

Alkane concentration enhancements were temporally variable across most communities with higher average enhancements that occurred in the early afternoon (12:00-14:00). Some higher enhancements also occurred in communities in the late afternoon (after 16:00). Hollywood Park-Mangan Park (12:00-13:00) and Hagginwood (13:00-14:00) had the highest average alkane concentration enhancements (17.5-18.2 ppmv) across all communities. Noralto-Old North Sacramento had higher average alkane concentration enhancements (~15 ppmv) in the afternoon as well (13:00-14:00 and 18:00-19:00). Meadowview-Z'berg Park also had higher ppmv alkane concentration enhancements (13.2-14.0 ppmv) in late afternoon following rush hour (17:00-19:00).

Average aromatic concentration enhancements were between 0.1-6.3 ppbv for most communities across all hours of the day. Del Paso Heights had the highest average aromatic concentration enhancement between 15:00-16:00 (10.2 ppbv).

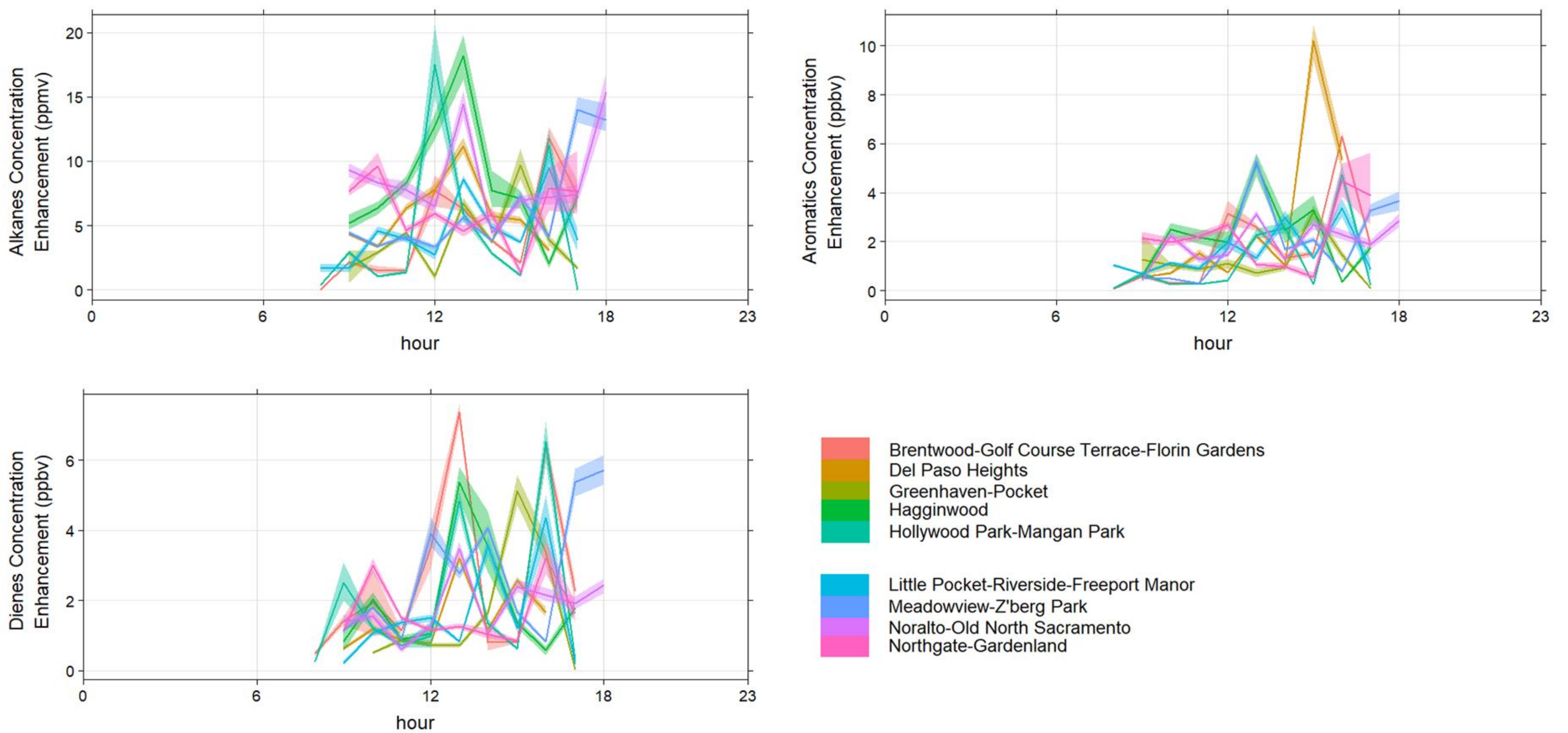

Figure 25. Temporal patterns of mobile monitoring data for volatile organic compounds and hazardous air pollutants. Mean concentration enhancements and the 95% confidence interval (shading) are shown for each community. Communities are differentiated by color. Temporal patterns were limited to times of the day when mobile monitoring occurred. The hour of the day along the x-axis is for the hour interval for the successive hour (e.g., 12 is 12:00-13:00).

Additionally, Little Pocket-Riverside-Freeport Manor and Hagginwood both had hourly mean aromatic concentration enhancements of ~5 ppbv between 13:00-14:00. Some communities also experienced higher aromatic enhancements (3.4-6.3 ppbv) in late afternoon (after 16:00), including Brentwood-Golf Course Terrace-Florin Gardens, Northgate-Gardenland, Little Pocket-Riverside-Freeport Manor, and Hagginwood.

Hourly diene concentration enhancements were also temporally variable, with most communities experiencing larger enhancements (~3-7 ppbv) in the afternoon between 13:00-18:00. Brentwood-Golf Course Terrace-Florin Gardens had the largest mean enhancements (7.4 ppbv) across all communities between 13:00-14:00. Overall, every community experienced at least one hourly average diene concentration enhancement >2 ppbv in the afternoon.

Climate Forcers

Figure 26 shows all average greenhouse gas enhancements by hour and community.

Hourly BC mean enhancements were highly variable for some communities. For example, Little Pocket-Riverside-Freeport Manor had a 95% confidence interval for enhancements that spanned ~20 µg m^{-3} between 8:00-9:00, but there were fewer data points for this community-parameter-hour pairing (n = 167). Generally, all other mean BC enhancements were <3.7 µg m^{-3}. Little Pocket-Riverside-Freeport Manor typically had higher mean BC enhancements than other communities with wide ranges, notably around morning (8:00-9:00) and afternoon (12:00-13:00) rush hour (1.5-9.8 µg m^{-3}) and lunch hours (1.5-2.9 µg m^{-3}). Hollywood Park-Mangan Park (12:00-13:00, 3.7 µg m^{-3}), Brentwood-Golf Course Terrace (8:00-9:00, 3.5 µg m^{-3}), and Hagginwood (14:00-15:00, 2.0 µg m^{-3}) also experienced higher mean BC enhancements around these times. Lastly, Northgate-Gardenland experienced mean BC enhancements ~1 µg m^{-3} between 10:00-15:00.

Average CO_2 enhancements were very large in early morning for some communities, ranging from 347.5-1,383.4 ppmv between 8:00-10:00. These communities included Brentwood-Golf Course Terrace-Florin Gardens, Hollywood Park-Mangan Park, Meadowview-Z'berg Park, Northgate-Gardenland, and Greenhaven-Pocket. Brentwood-Golf Course Terrace-Florin Gardens had four of the eight highest hourly mean CO_2 enhancements. Afternoon enhancements tended to be lower, and hours between 12:00-17:00 all had average CO_2 enhancements <300 ppmv.

Average methane enhancements were also found to be higher in the morning for a handful of communities, including Noralto-Old North Sacramento, Del Paso Heights, and Hagginwood, ranging from 0.33-0.68 ppmv between 10:00-12:00. Some other south Sacramento communities (Brentwood-Golf Course Terrace-Florin Gardens and Hollywood Park-Mangan Park) also had higher average methane concentration enhancements (>0.2 ppmv) at variable times during the day. Northgate-Gardenland had an increasing methane concentration enhancement as the day progressed after 13:00.

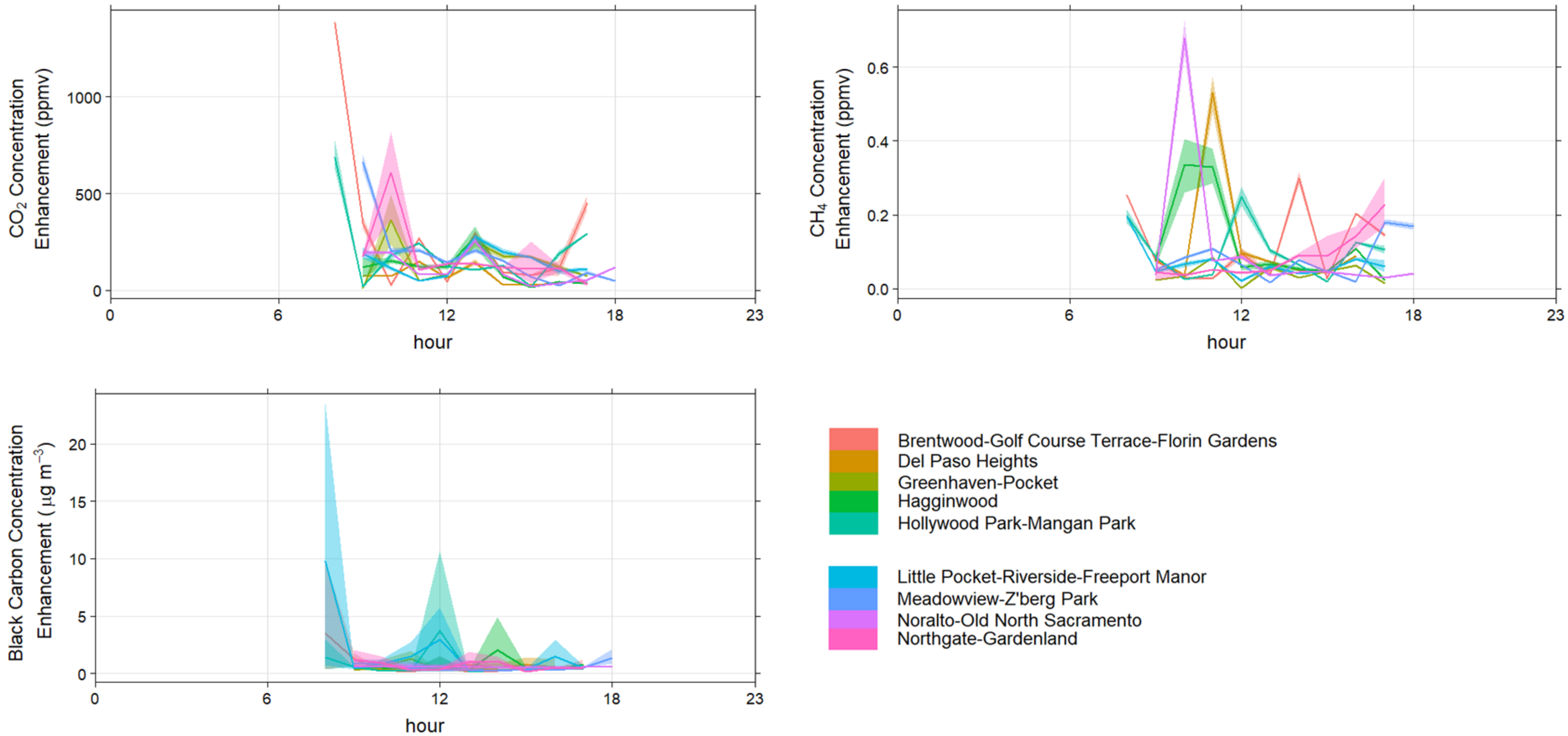

Figure 26. Temporal patterns of mobile monitoring data for climate forcers. Mean concentration enhancements and the 95% confidence interval (shading) are shown for each community. Communities are differentiated by color. Temporal patterns were limited to times of the day when mobile monitoring occurred. The hour of the day along the x-axis is for the hour interval for the successive hour (e.g., 12 is 12:00-13:00.

4.5 Stationary Measurements

Overview:

- Stationary measurements were conducted over 6-12 hours at select locations during daytime hours. As such, these snapshots were aimed to provide a screening assessment of longer-term measurements on one day at some of the selected hotspot locations.
- An absence of high concentrations does not automatically suggest or disprove that typical concentrations would be higher or lower than the standards. Therefore, comparing against air quality and health standards is not advisable. Such comparisons require multiple days of measurement for a total of 24 hours or more each.
- Furthermore, since the measurements each occurred on different days (one day per site), any comparison between sites is not advisable given expected day-to-day variability. However, the measurements can point to big picture issues, as sites with exceptionally higher air pollution levels can help prioritize follow-up monitoring.
- The measurements show the utility of mobile labs, which can be deployed at different locations for quick screening measurements.
- The study also shows the utility of regulatory grade analyzers and advanced research monitoring systems (like AROMA) for mobile mapping and stationary deployment to measure a variety of criteria air pollutants, climate forcers, and air toxics.

Stationary measurements were collected for 6-12 hour measurement periods at ten different locations, not including Bercut station, as shown in Figure 27.

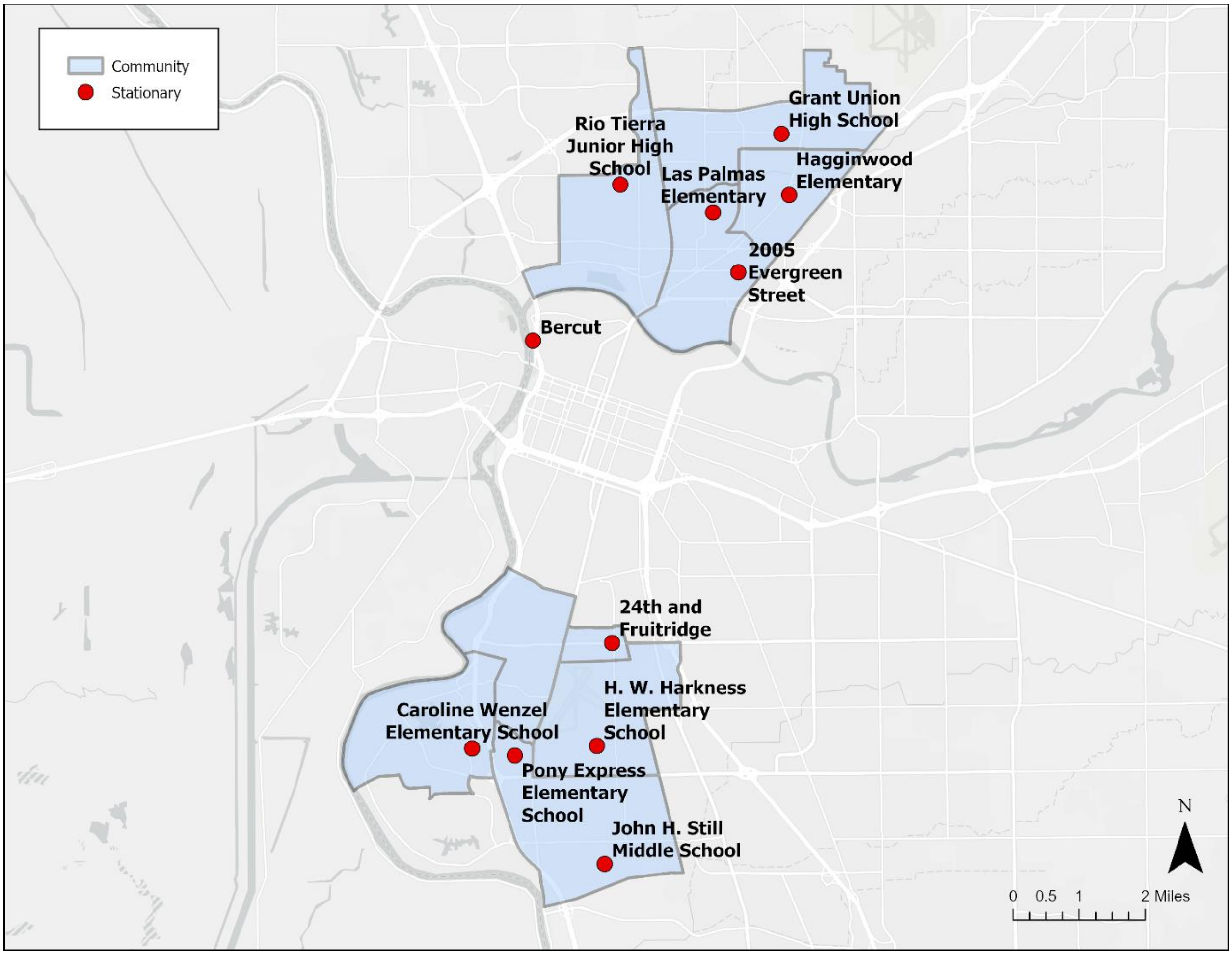

Figure 27. A map of the ten stationary community monitoring locations with the community overlays.

A summary of stationary pollutant measurements by hour of the day are shown in Figure 28 for BC, O_3, and $PM_{2.5}$. These data summaries present concentrations as absolute concentrations, rather than enhancements. Enhancements were not used during stationary monitoring because we were not attempting to remove regional background influences on measurements, but focused on how concentrations compare to air quality standards and/or reference exposure levels.

All hourly pollutant concentration averages were below the respective NAAQS (O_3 and $PM_{2.5}$). Monitoring results are merely an observation of the results in comparison to NAAQS levels, and are not presented in the context of risk assessments. Temporally, O_3 concentrations increased following morning rush hour (~10:00-11:00) and peak in early afternoon. For $PM_{2.5}$ and BC, many averages were not statistically significantly different from one another across locations, and temporal trends were not necessarily apparent, except for $PM_{2.5}$ at Old North Sacramento and Del Paso Heights, which experienced elevated concentrations in early afternoon. Due to the short timeline of this study, a thorough statistical analysis of the dataset was not performed, nor was data placed within the context of the available regulatory monitoring network data, including longitudinal analysis.

Normality testing of each pollutant using the Levene's test and the Shapiro-Wilks test indicated that data cannot be considered normal, therefore non-parametric testing should be used.

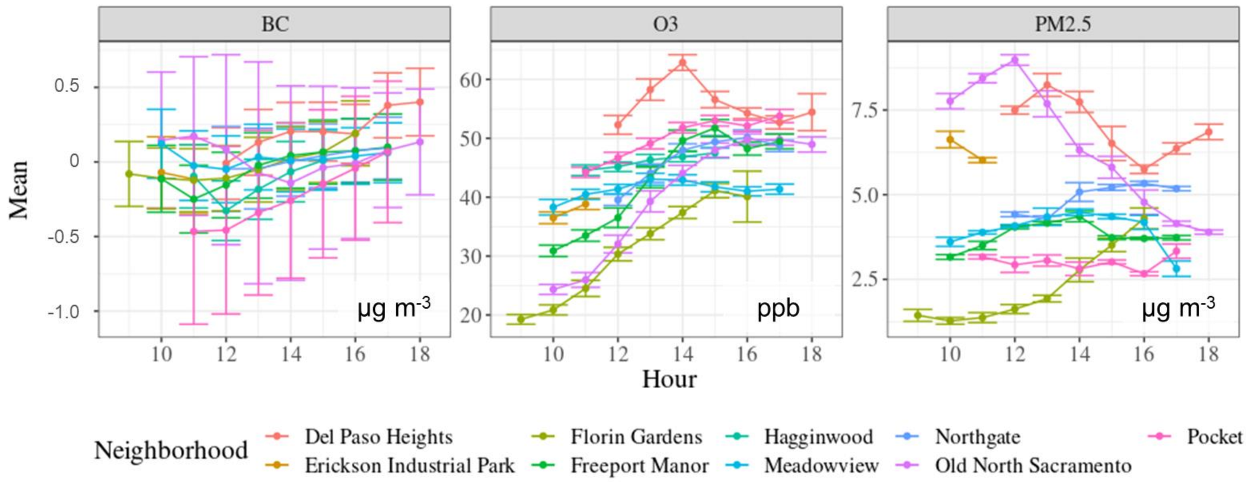

Figure 28. Hourly pollutant concentrations for each monitoring location for BC, O_3, and $PM_{2.5}$. Average concentrations are shown by the dot and error bars (e.g., one standard deviation) are shown by the horizontal lines extending from the average concentration. Units for each pollutant are shown in the bottom right of the panel.

The CO monitor was not functioning properly during the stationary monitoring campaign. This could possibly be due to the zero offset or elevated temperatures in the mobile platform. Observations showed concentrations clustered around 0.1 ppm in Hagginwood and 0 ppm in Meadowview. The zero offset was changed in between these two stationary monitoring periods, so the Meadowview measurements were likely impacted. The rest of the observations were tightly clustered around -0.5 ppm. Therefore, CO will not be considered further in this analysis.

Similarly, and as described before, there were issues with the stationary NO_2 measurements due to analyzer malfunctions. The analyzer that was used during mobile monitoring was removed and replaced with Sonoma Technology's analyzer after maintenance was performed. It was later determined by the instrument manufacturer that major maintenance was required, and thus, the data collected during the stationary measurements were invalid. Therefore, NO_2 is also not considered in this analysis.

Criteria Gaseous Pollutants

O_3 concentrations were compared across locations using observation frequency distributions. Concentrations of O_3 were relativized to the average concentration across all community sites. This translates to showing whether concentrations at a given community site were higher than the other community sites. These results are summarized by violin plots shown in Figure 29.

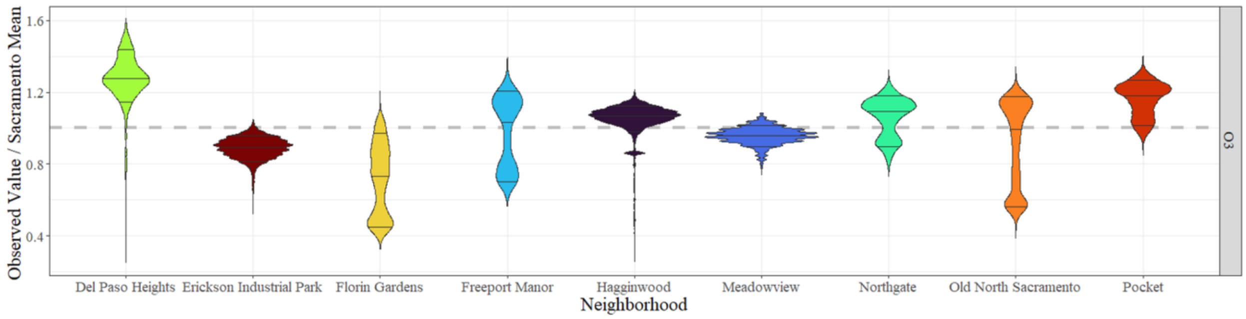

Figure 29. Relativized violin plots of O_3 (bottom) observed in Sacramento neighborhoods. Concentrations of O_3 were relativized to the average concentration across all community sites for comparison. Generally, violin plots show the frequency of observations (shape width) at each y-axis value (i.e., concentration relative to the average). Horizontal lines within each violin show the 10th, 50th, and 90th percentiles in each distribution. The dashed line in the shows the average relativized concentration of NO_2 and O_3 across all community sites (i.e., equal to 1.0).

There were some differences across community sites when comparing relativized O_3 concentrations. The variability between sites may be due to real differences in anthropogenically-driven O_3 concentrations or due to monitoring under different atmospheric conditions and/or times of day. In general, the Del Paso Heights O_3 concentrations were highest, and Florin Gardens and Old North Sacramento were lowest. Elongated violins observed at Florin Gardens, Freeport Manor, and Old North Sacramento correspond to steeper diurnal gradients (i.e., a greater change in O_3 concentration between the morning and evening hours). Erickson Industrial Park, Hagginwood, and Meadowview presented relatively little change in O_3 concentrations throughout the monitoring period.

Particulate Pollutants

A comparison of stationary $PM_{2.5}$ concentrations in communities with measurements from Bercut station showed that $PM_{2.5}$ concentrations were consistent at a regional level. Figure 30 shows a time-series plot of hourly-averaged $PM_{2.5}$ concentrations observed at each neighborhood location superimposed on the Bercut station beta-attenuated mass (BAM) measurements. This comparison underscores the importance of temporal context in regional and local $PM_{2.5}$ evaluations. In other words, direct comparisons of absolute differences could be misleading when comparing measurements across different days. For example, Northgate $PM_{2.5}$ concentrations on April 9 are demonstrably lower than the subsequent observations in Del Paso Heights on April 10, but measurement periods were consistent with $PM_{2.5}$ measurements at Bercut station. Overall, both neighborhoods present similar concentrations of $PM_{2.5}$ when compared to Bercut station, although levels at Del Paso Heights were slightly lower (~1-2.5 µg m^{-3}) than Bercut station on that particular measurement day. Similarly, Meadowview also showed lower levels than Bercut station on April 2. In total, $PM_{2.5}$ concentrations were much lower than the daily $PM_{2.5}$ NAAQS of 35 µg m^{-3}.

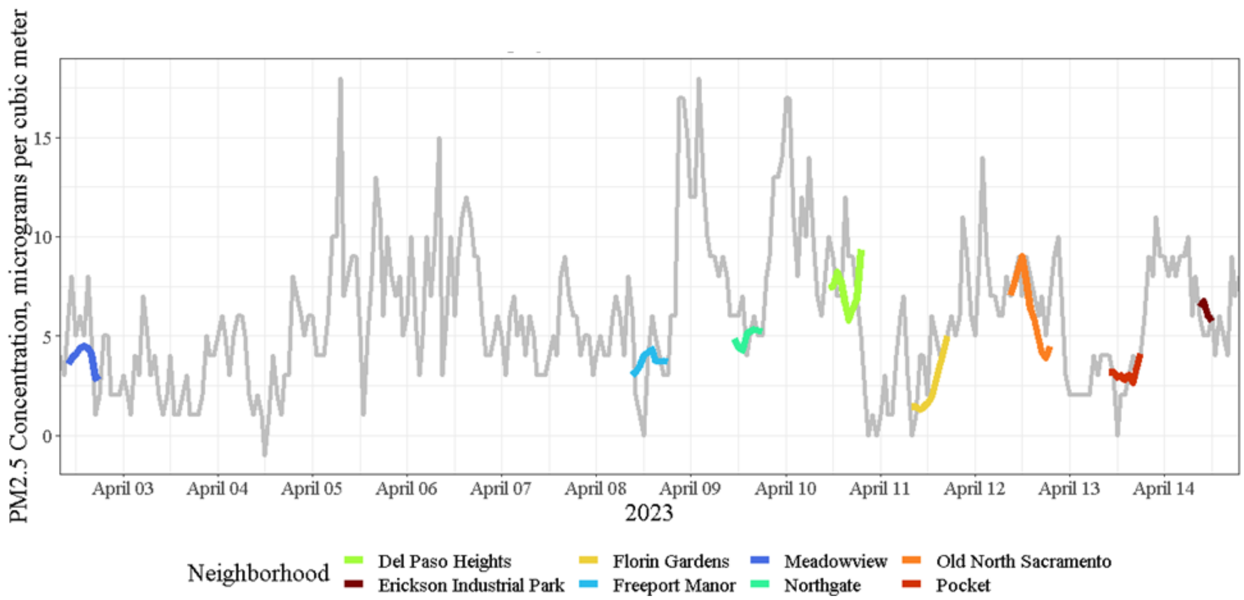

Figure 30. Time-series plot of $PM_{2.5}$ concentrations at Bercut station (grey) and the different hotspot locations (varied colors).

An alternative comparison normalizes neighborhood observations by a common reference, the Bercut station $PM_{2.5}$ measurements (**Figure 31**). In this analysis, each hourly average $PM_{2.5}$ value measured at the hotspots was divided by the corresponding Bercut station $PM_{2.5}$ hourly average concentrations reported to AirNow. A ratio of unity indicates no discernible difference. The region of ±20% (grey region) highlights measurements were relatively similar in the Sacramento region, suggesting that $PM_{2.5}$ concentrations may have lower intra-urban variability, which is expected given regional and local $PM_{2.5}$ sources. Approximately half of all $PM_{2.5}$ observations during the stationary community monitoring were within ±20% of the Bercut station measurements. Erickson Industrial Park and Freeport Manor had the greatest number of observations with a ratio >1.2 (50% of hourly averages), while Del Paso Heights and Meadowview had the greatest number of observations with a ratio <0.8 (44%).

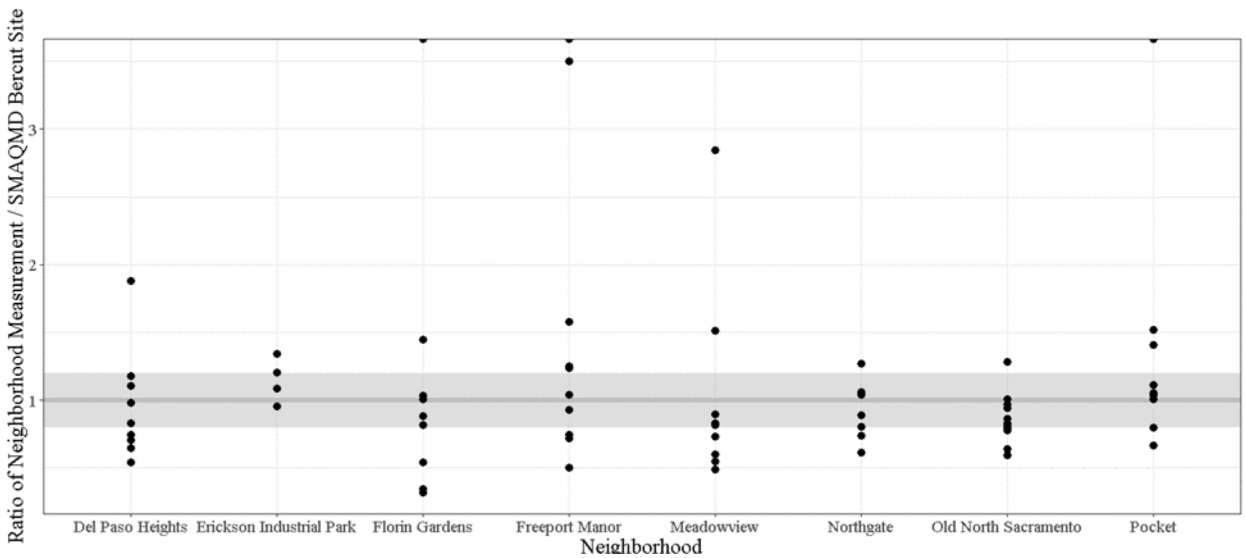

Figure 31. Stationary $PM_{2.5}$ observations normalized by Bercut station BAM $PM_{2.5}$. The horizontal grey-shaded area is the ±20% measurement band in comparison to Bercut station.

Volatile Organic Compounds and Hazardous Air Pollutants

Speciated air toxics measurements were collected for 49 hours across the 10 stationary sites and the Bercut station (Figures 32 through 42). An aggregate statistical summary of speciated VOC analysis across all sites is shown in Figure 43. In addition, background data was collected at the Bercut station overnight. Toxics concentrations were compared against California's chronic Office of Environmental Health Hazard Assessment (OEHHA) Reference Exposure Levels (REL)[5] or the California Human Health Screening Levels (CHHSLs), as appropriate for each compound.

OEHHA is a department within the California Environmental Protection Agency that evaluates health risks associated with different chemical contaminants, including airborne pollutants. OEHHA's RELs are determined using research studies that evaluate health conditions other than cancer. RELs are time-averaged estimates of the level of a pollutant or chemical that a person can breathe without detectable risk to health. Exposure to a concentration level above an REL does not necessarily mean that adverse health effects occur, but rather, it indicates the need to investigate the situation more closely. OEHHA establishes three types of Reference Exposure Levels based on different time intervals:

- Short-term (acute) exposure: Exposure for 1 hour or less
- Long-term (chronic) exposure: Exposure from 1 year to a lifetime
- Offsite Worker Exposure (8-hour): Exposure for 8 hours per day, repeated over the course of a year

[5] OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary

No exceedances of relevant acute or chronic RELs were observed at any of the stationary sites within communities. At the Bercut station, three measurements out of 660 exceeded the 3 μg m^{-3} chronic OEHHA REL for benzene. The chronic and 8-hour benzene REL set by OEHHA are both 3 μg m^{-3}. The acute (1-hour or less) OEHHA REL for benzene is set at 27 μg m^{-3}. The chronic OEHHA REL for benzene is used here because it is the most protective REL (i.e., lowest concentration) and is set at the same concentration level as the 8-hour OEHHA REL. It should be noted that the stationary measurements are not directly comparable to chronic RELs though. Chronic RELs are typically evaluated on annual scales while our measurements were much shorter in duration (i.e., <1 day).

BTEX compounds are commonly encountered toxic chemicals. Benzene, the most toxic BTEX compound, is most commonly encountered when emitted by combustion sources, like vehicle exhaust and biomass burning, chemical manufacturers, or evaporated from common fuel sources. Benzene is found in gasoline (<0.62% average and <1.3% max by federal regulation), and elevated concentrations can typically be observed at gas stations and in locations where vehicles are stored indoors. Other BTEX compounds are also used as solvents and thinners, although a transition to lower VOC-containing paints and building materials has reduced exposures to these compounds.

The chlorinated solvent trichloroethylene (TCE) is a highly toxic compound formerly used as a degreasing and cleaning agent, including in dry cleaning, but has recently been largely phased out. Primary threats from this compound are contaminated sites. Elevated concentrations are not anticipated in ambient air. Cis-1,2-Dichloroethylene is a decomposition product of TCE, 1,3-butadiene is a combustion biproduct and is used to manufacture a number of rubber and plastic compounds, and styrene emissions are primarily driven by plastic, latex, and polystyrene manufacturing operations. Styrene is also present in combustion emissions.

Observations at all sites are consistent with typical urban background levels. Occasional spikes in concentrations are likely due to the presence of specific emitters near particular sampling locations. The only sites that displayed consistently higher VOC concentrations were Freeport Manor and Meadowview. Although these concentrations were higher than other locations, these measurements reflect a snapshot in time and did not exceed any applicable health standards for the compounds that were measured. Additional studies would be needed to identify whether these concentrations were due to isolated conditions on the study days or if the patterns are truly representative of a nearby source.

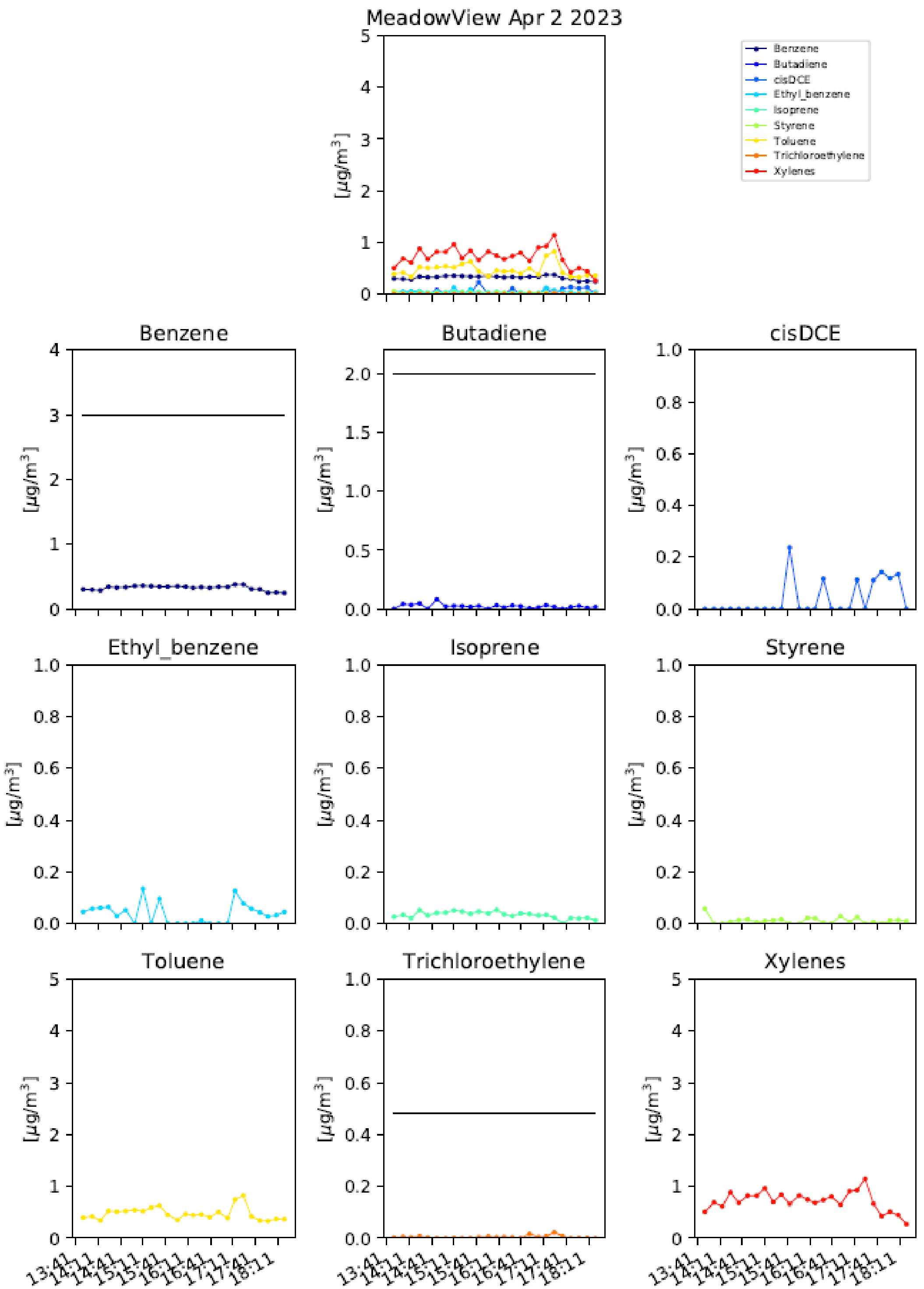

Figure 32. Time-series (April 2, 2023) of speciated VOC measurements at the Meadowview site.

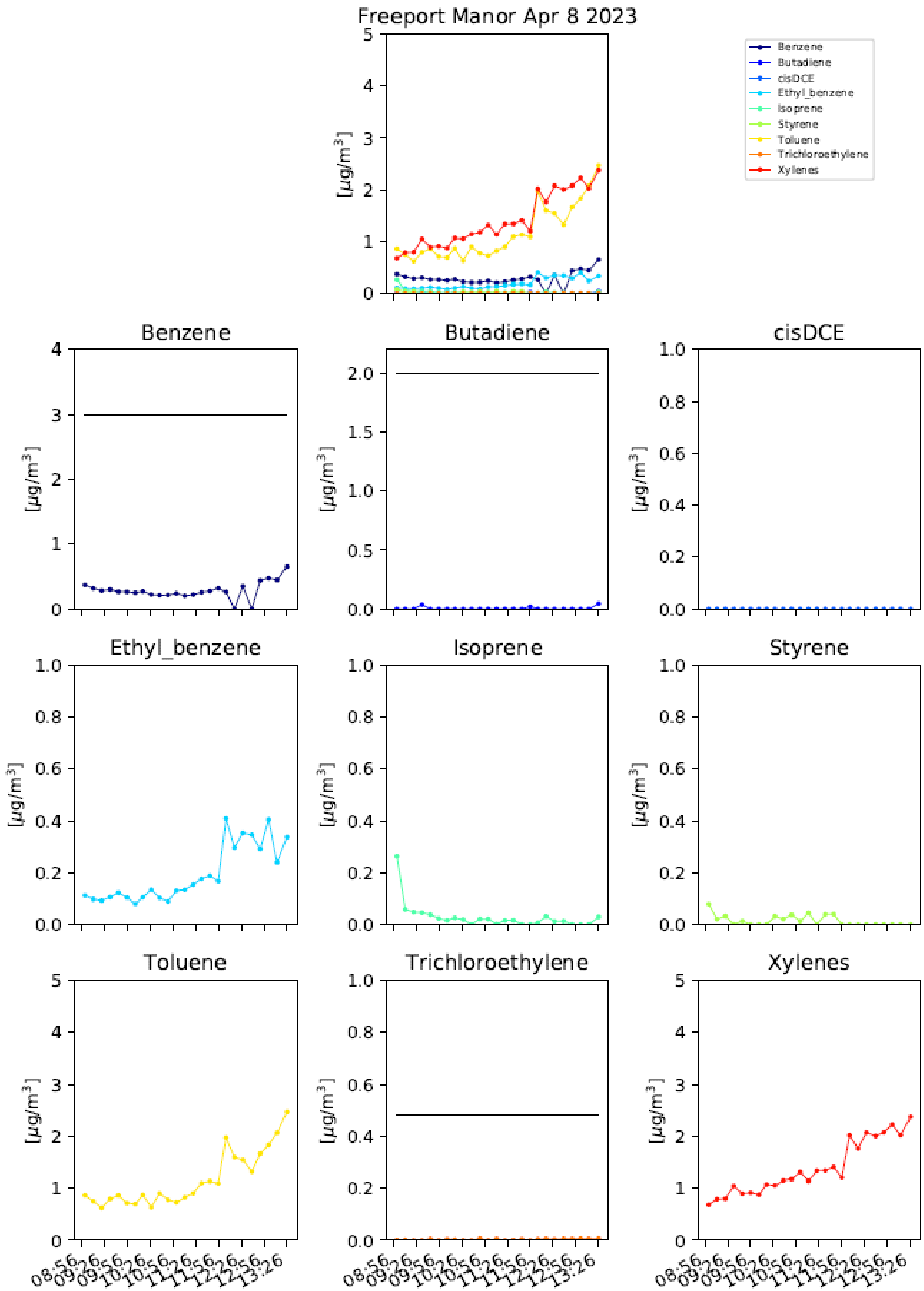

Figure 33. Time-series (April 8, 2023) of speciated VOC measurements at Freeport Manor site.

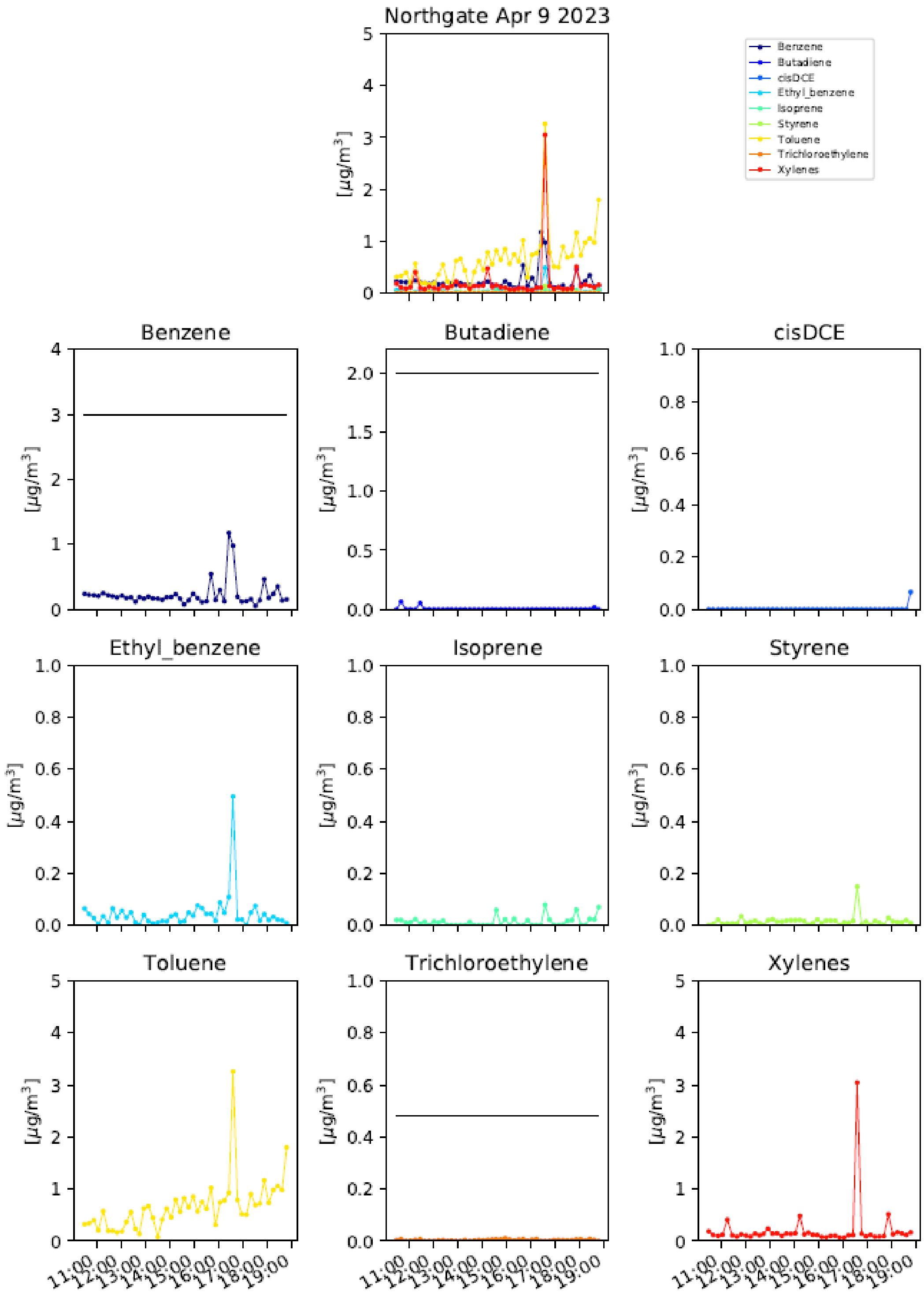

Figure 34. Time-series (April 9, 2023) of speciated VOC measurements at the Northgate site.

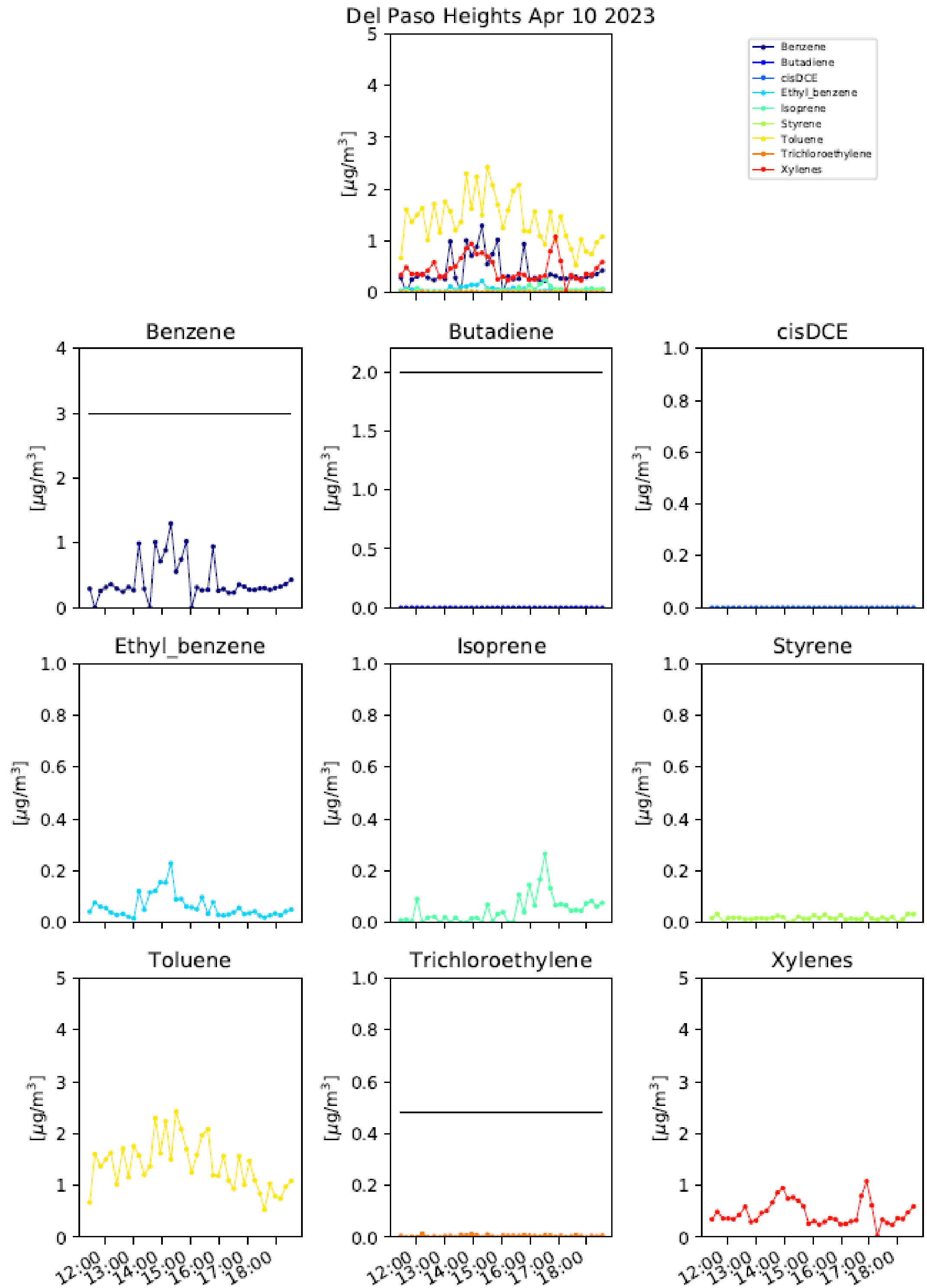

Figure 35. Time-series (April 10, 2023) of speciated VOC measurements at the Del Paso Heights site.

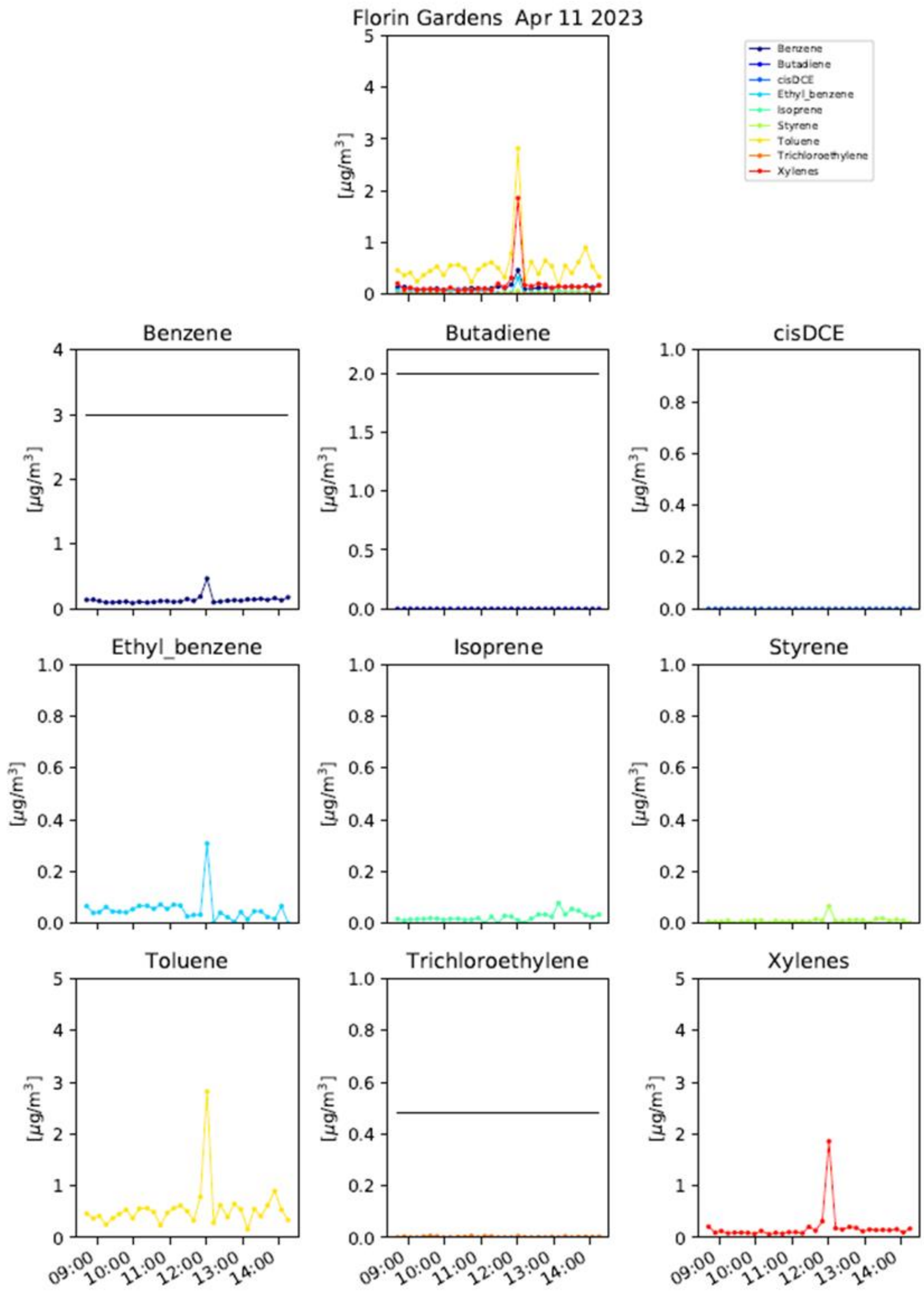

Figure 36. Time-series (April 11, 2023) of speciated VOC measurements at the Florin Gardens site.

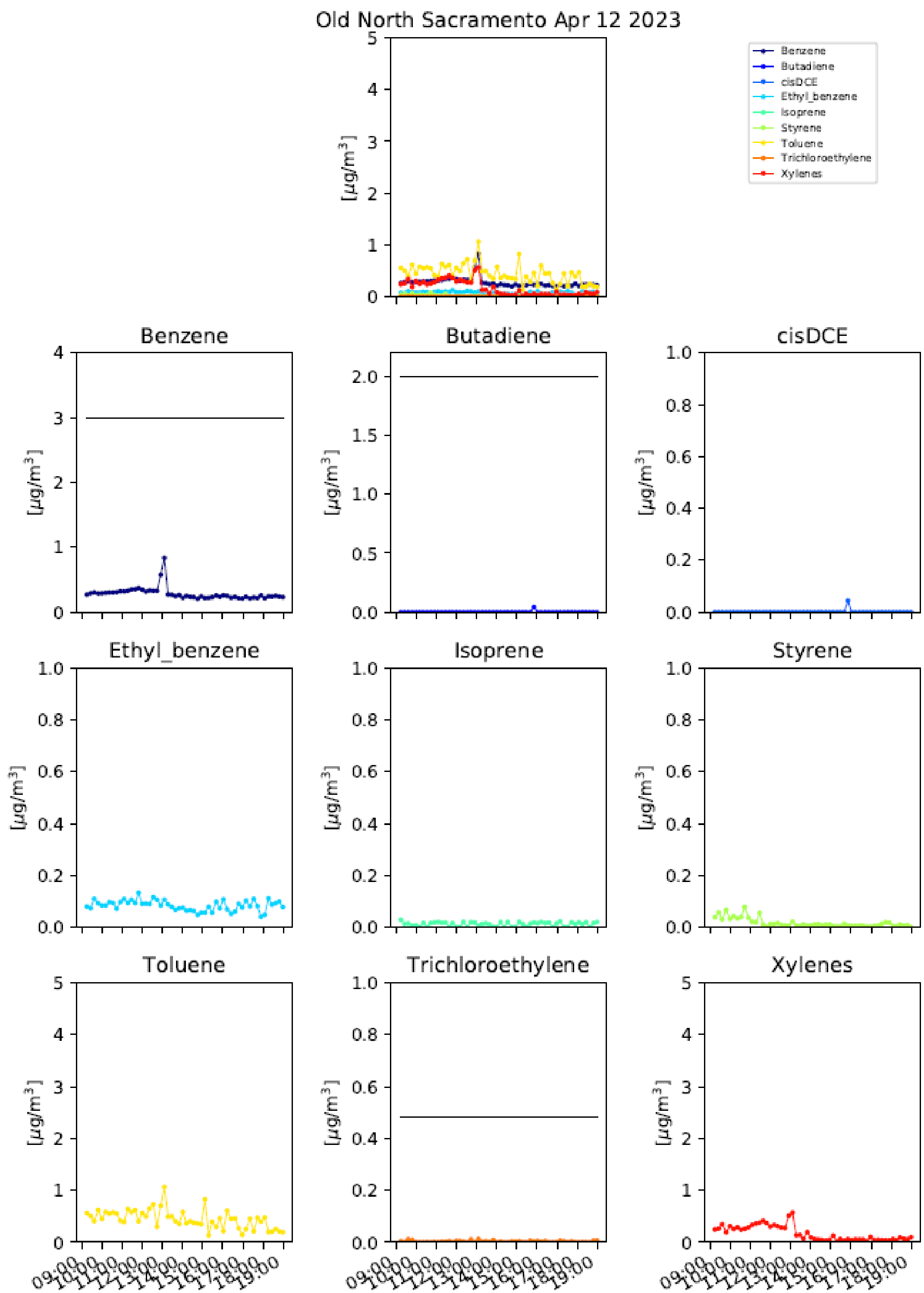

Figure 37. Time-series (April 12, 2023) of speciated VOC measurements at the Old North Sacramento site.

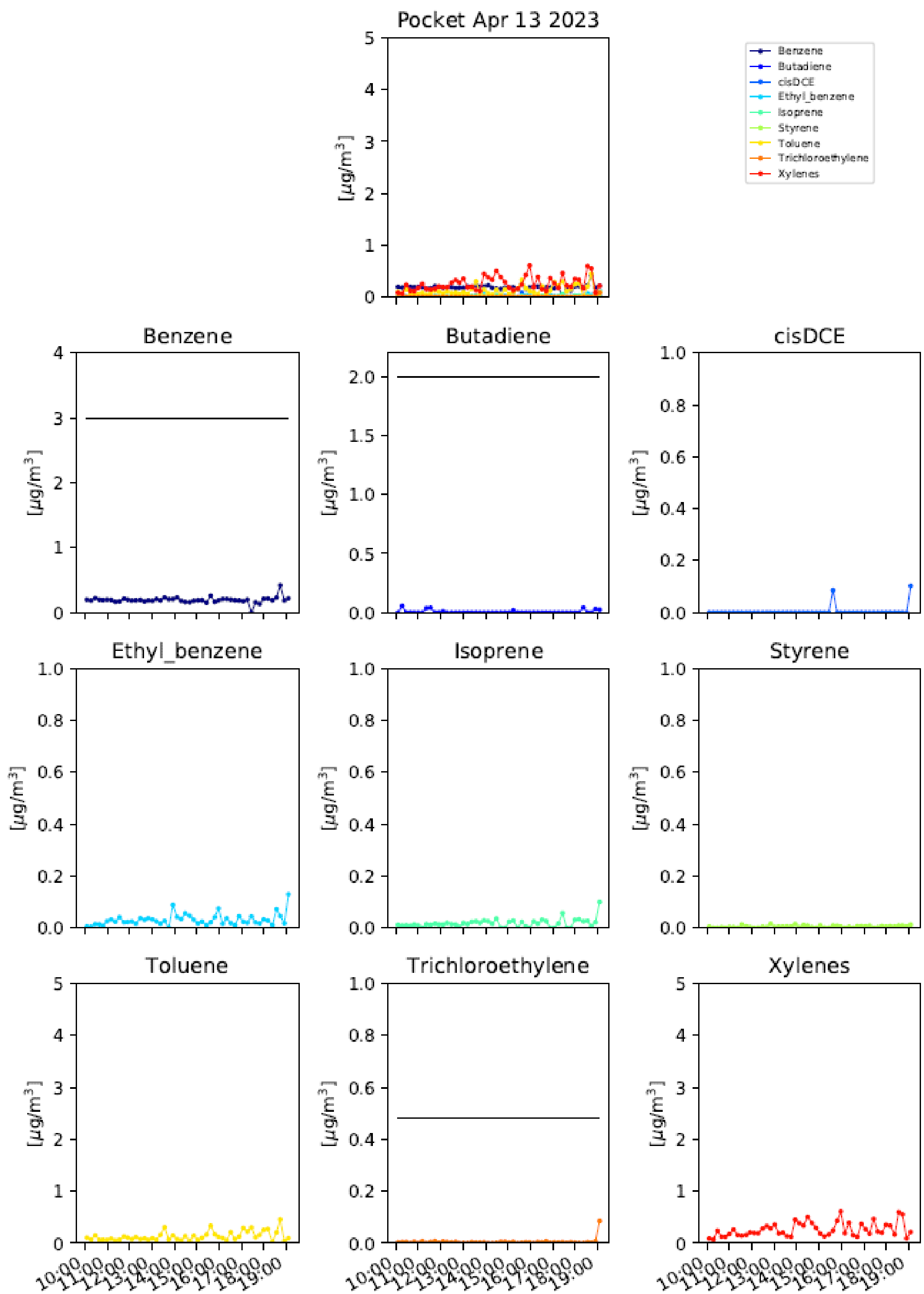

Figure 38. Time-series (April 13, 2023) of speciated VOC measurements at the Pocket site.

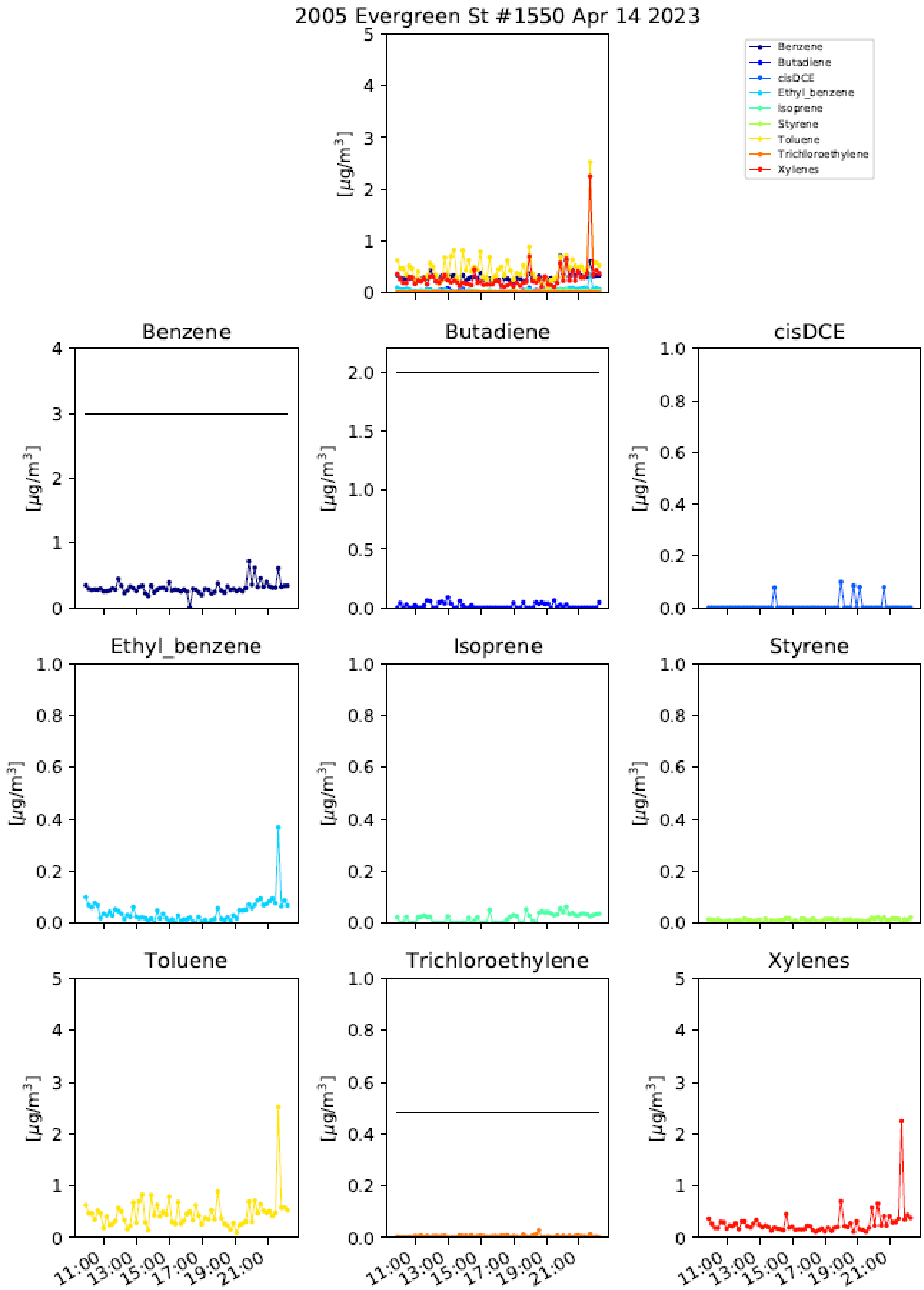

Figure 39. Time-series (April 14, 2023) of speciated VOC measurements at 2005 Evergreen St.

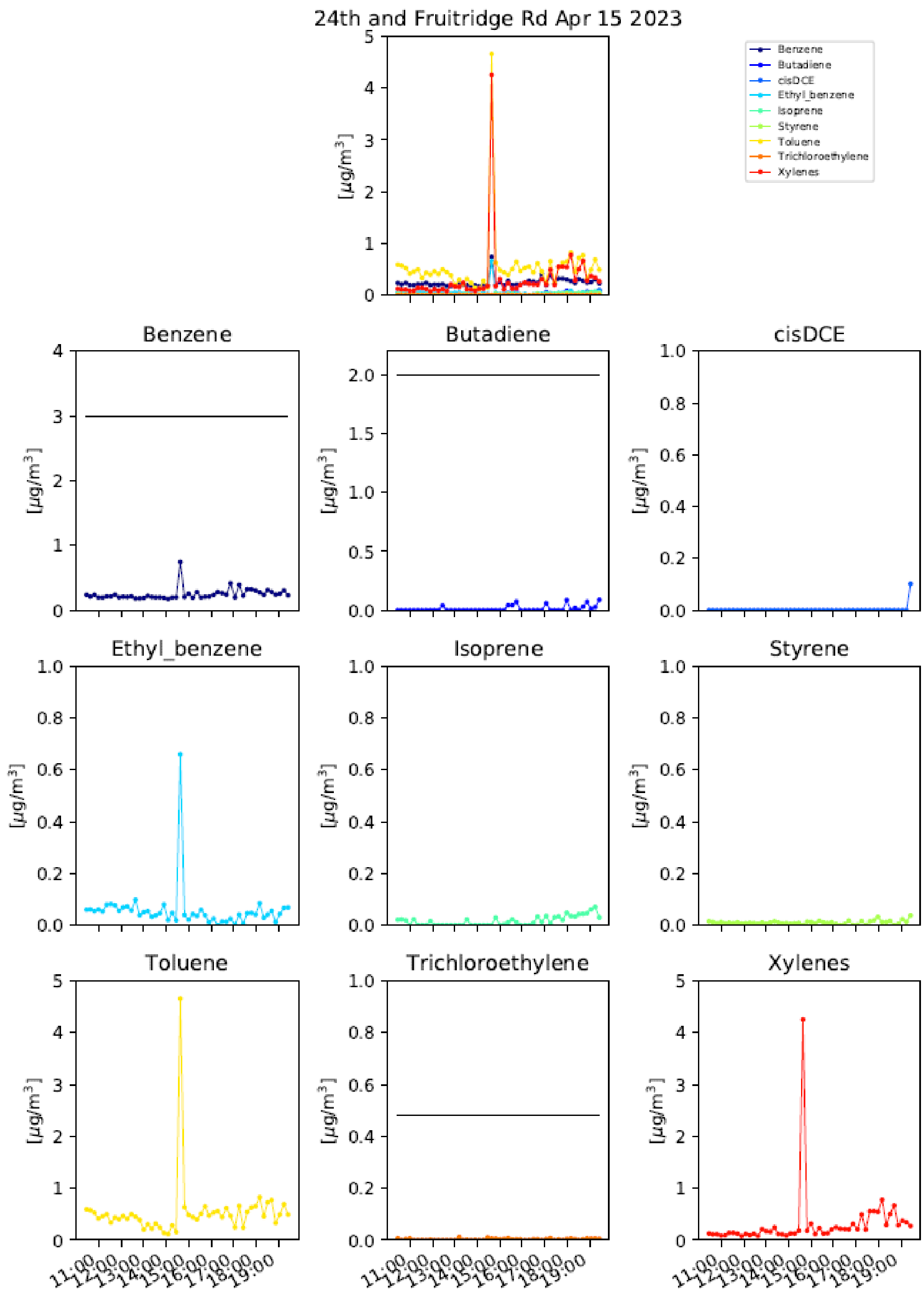

Figure 40. Time-series (April 15, 2023) of speciated VOC measurements at 24th and Fruitridge Rd.

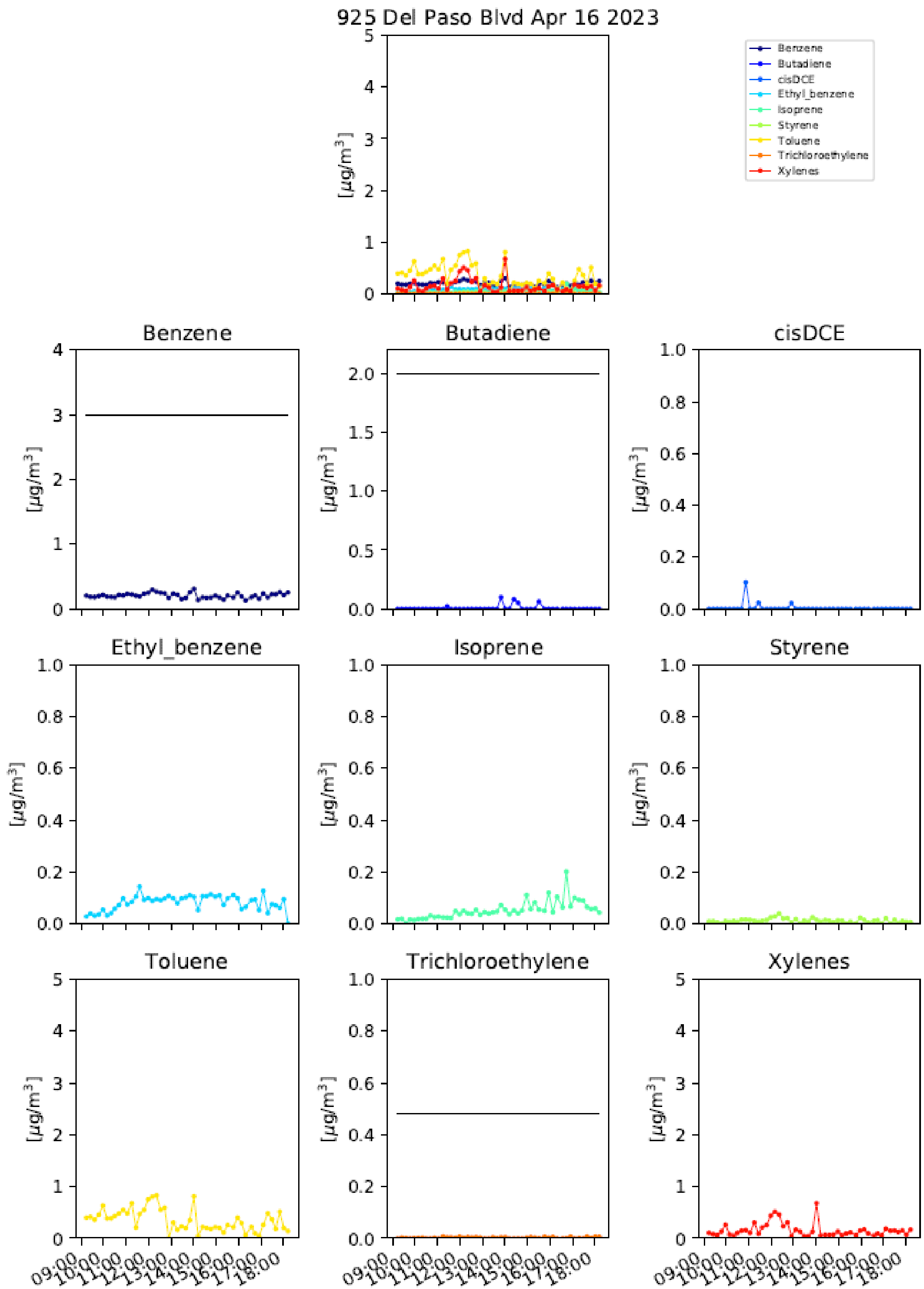

Figure 41. Time-series (April 16, 2023) of speciated VOC measurements at 925 Del Paso Blvd.

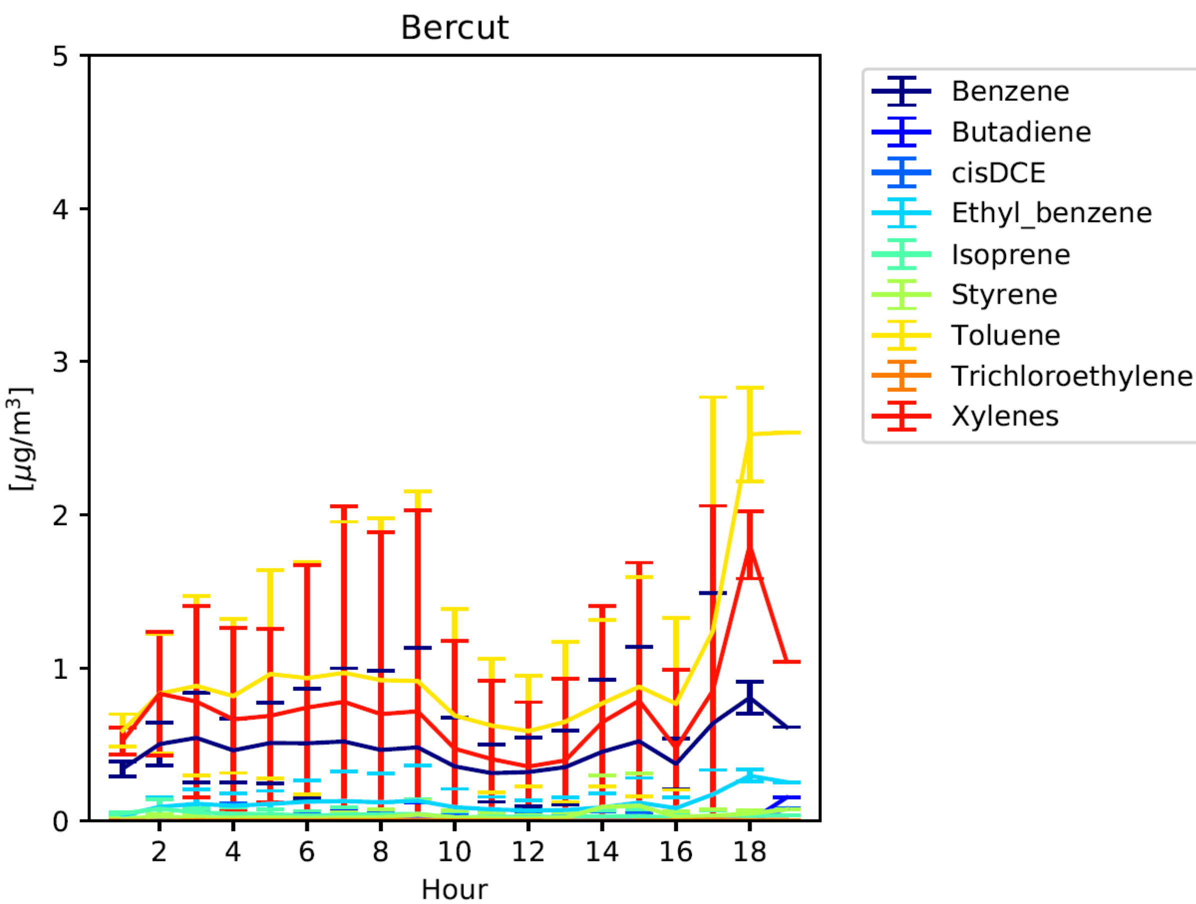

Figure 42. Time-series of speciated VOC measurements at the Bercut station during April 2023 by hour of the day.

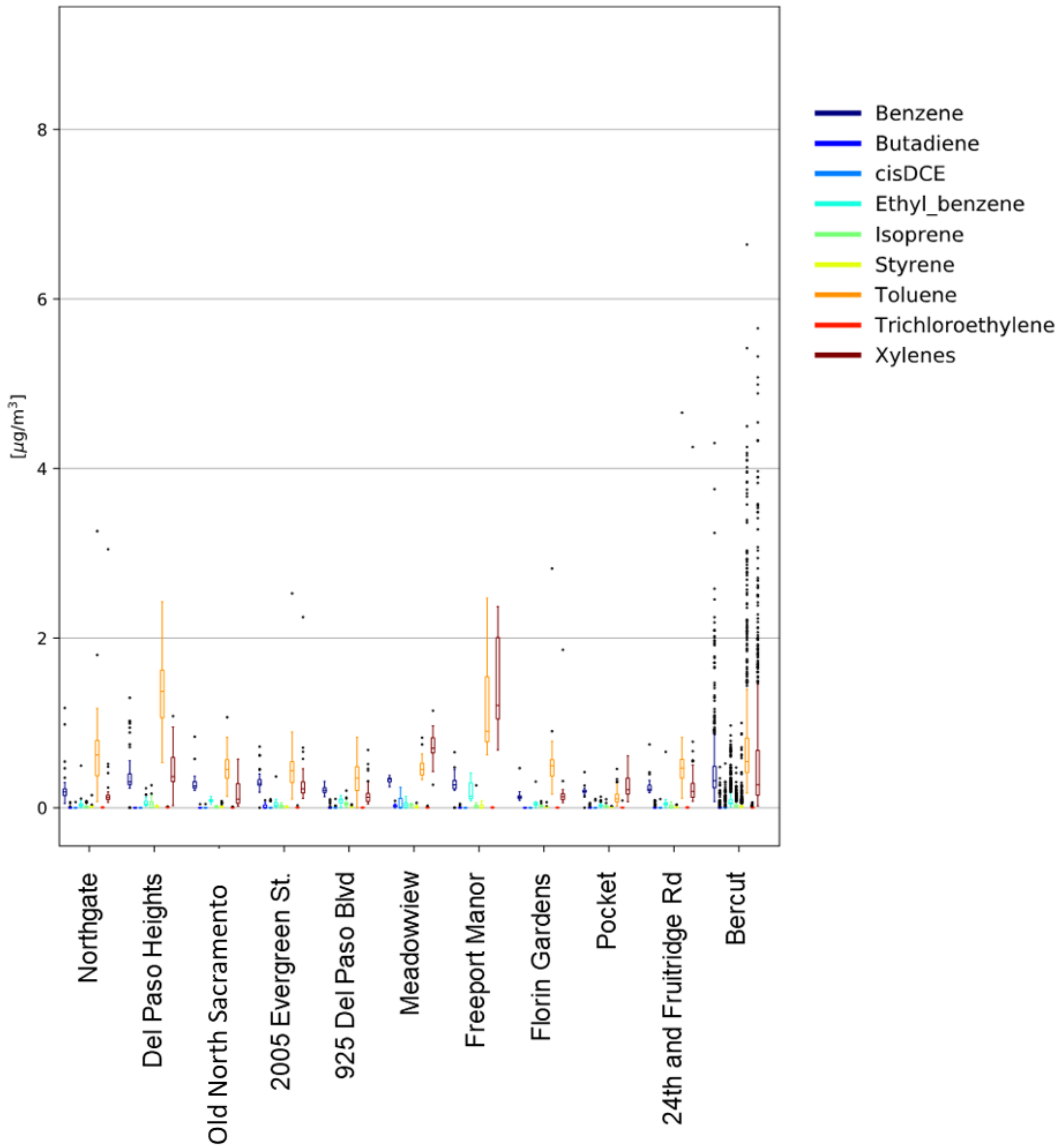

Figure 43. Aggregate statistical summary of speciated VOC analysis across all sites. Boxplots show the distribution of VOC measurements at a given site. VOCs are differentiated by color.

5. Conclusions

This extensive study of spatial pollutant concentration mapping and PFZ analysis in nine communities was conducted in Sacramento from February to April 2023. Over these three months of measurements, the project team conducted mobile mapping in each community, which included daytime measurements on weekdays and weekends. During the campaign, heavier precipitation periods (e.g., atmospheric rivers) occurred, which led to a longer duration campaign than originally planned. In addition, the project team conducted dedicated stationary measurements at select hotspots to characterize constituents, distribution, and toxicity implications of air toxics in each community. These measurements also allowed study of temporal daytime patterns of air pollution.

Spatial Trends

Overall, concentration enhancements of many pollutants tended to be along traffic corridors in both north and south Sacramento communities. Enhancements of alkanes, aromatics, CO_2, dienes, methane, and NO_2 were notably higher along most of the Marysville Boulevard-Del Paso Boulevard corridor. PM_{10} enhancements were also higher along this roadway, but were much higher in the southern portion.

In the south Sacramento communities, the Fruitridge Road corridor had higher concentration enhancements of alkanes, aromatics, and dienes, likely due to higher volumes of traffic along this arterial roadway. Conversely, the Interstate-5 freeway had the highest mean enhancements for other mobile emission source pollutants (i.e., BC and NO_2). There was insufficient data collected by the AROMA analyzer along Interstate-5 to observe statistically significantly higher mean enhancement spatial patterns when compared to other areas in south Sacramento communities.

Greenhaven-Pocket and Little Pocket-Riverside-Freeport Manor had the largest number of PFZs with high confidence for NO_2, and O_3, although these regions had very few PFZs with high confidence for all other pollutants. Del Paso Heights had the highest number of PFZs with high confidence for PM, BC, NO_2, and O_3. Hagginwood and Noralto-Old North Sacramento had the largest number of high-confidence PFZs for alkanes and aromatics. Generally, hotspots were able to be identified and located during mobile monitoring. Notably, Del Paso Heights stationary monitoring confirmed elevated NO_2 and O_3 concentrations.

When normalizing neighborhood-level $PM_{2.5}$ observations collected during the limited stationary measurement campaigns in each community against concurrent $PM_{2.5}$ measurements at Bercut station, approximately half of all observations were within ±20% of those from Bercut station. However, Erickson Industrial Park and Freeport Manor had the greatest number of observations with a ratio >1.2 (50% of hourly averages), while Del Paso Heights and Meadowview had the greatest number of observations with a ratio <0.8 (44%). This suggests that additional monitoring campaigns in Erickson Industrial Park and Freeport Manor may be useful to evaluate if these local-scale pollution events are common, and if so, prioritize these communities for additional monitoring.

Temporal Trends

Mobile measurements showed expected temporal trends for gaseous criteria pollutants, including NO_2 and O_3. NO_2 concentrations rose during morning and afternoon rush hours, with O_3 concentration increases directly following these times. This is a well-documented atmospheric chemistry cycling process due to vehicle traffic. Similarly, temporal trends for some of the measured VOC groupings (i.e., aromatics, alkanes, dienes) also experienced elevated concentrations during rush hours. Mobile temporal trends were variable across communities, with some neighborhoods experiencing higher concentrations than others.

Stationary observations were conducted at ten unique neighborhood locations throughout the Sacramento area, not including Bercut station. More than one million data points were retrieved and evaluated. Of the pollutants included in this analysis, two pollutants were determined to be invalid (CO and NO_2). Of the remaining three pollutants (BC, O_3, and $PM_{2.5}$), relatively small differences were observed when comparing concentrations across different communities, except for Del Paso Heights O_3 measurements. For stationary VOC measurements, site observations were consistent with typical urban backgrounds. Some occasional increases in VOC concentrations are likely due to the presence of nearby emission sources (e.g., gas stations). Notably, there were increasing concentrations of BTEX compounds measured at the Freeport Manor stationary site over the course of the day. Further investigation at this location may help determine if these higher concentrations were anomalous.

Potential Future Efforts

These results demonstrate mobile monitoring is an effective tool to identify community PFZs. Future efforts can build upon this work and shed light on the sources and impacts of pollution, including:

- Deploy additional monitoring resources for longer-term measurements at PFZs.
- Perform source apportionment analysis to identify regional sources and their contributions to air pollution for the different wind sectors. Factor analytic tools, such as positive matrix factorization (PMF) and/or chemical mass balance (CMB), may be used to further interpret VOC data. VOC samples coupled with published source profiles relevant to the airshed are available, and CMB can help understand VOC sources and aim to differentiate among mobile source exhaust, regional emissions, and potential emissions from local industrial sources.
- Perform a high-level comparison of emissions in underserved communities versus other communities. This could be based on the general approach documented in Chen et al. (2022), which uses the breakdown of background and local contribution of each city/community to compare general air pollution contributions of local and regional sources.

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Appendices

Appendix 1: Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform: Quality Assurance Report

Appendix 1 is attached a separate document titled “Appendix 1. Air Quality Mapping in Sacramento Communities Using a Research-Grade Mobile Platform - Quality Assurance Report.”

Appendix 2: Detailed Summary Statistics

Table A-1 details the overall summary statistics for different pollutants across community groupings, as observed during the mobile monitoring campaign. See the Excel spreadsheet titled "Appendix 2. Table A-2.xlsx" for additional statistics summarized by hour.

Table A-1. Summary statistics for each pollutant in each community grouping showing the mean, median, and max concentration enhancements during the mobile monitoring campaign. Depending on the pollutant, concentration enhancements may reflect a 1- to 10-sec resolution temporally, and a 30- or 90-m resolution spatially. These details are outlined in Table 6. The measurement time and total measurement count are also shown.

Parameter	Mean Concentration Enhancement[1]	Median Concentration Enhancement[1]	Max Concentration Enhancement[1]	Measurement Time (Hours)	Total Measurement Count (n)
Brentwood-Golf Course Terrace-Florin Gardens					
Alkanes	3.6	1.9	66.6	7.9	5,706
Aromatics	1.4	0.3	13.6	7.7	5,570
Black Carbon	0.6	0.2	931.2	7.6	27,478
Carbon Dioxide	242.3	95.8	1761.3	7.7	5,513
Dienes	2.3	0.9	22.5	5.2	3,723
Methane	0.1	0.0	0.7	7.2	5,171
Nitrogen Dioxide	1.9	0.7	81.1	7.9	28,273
Ozone	10.6	9.5	48.8	7.9	28,273
PM_{10}	2.3	1.9	10.1	7.9	28,273
$PM_{2.5}$	0.5	0.4	4.3	7.9	28,273
Del Paso Heights					
Alkanes	6.5	3.6	58.2	13.7	9,878
Aromatics	2.6	0.6	41.6	12.7	9,176
Black Carbon	0.6	0.2	913.0	13.2	47,393
Carbon Dioxide	85.8	31.3	1596.3	13.0	9,344
Dienes	1.6	0.8	19.7	10.0	7,207
Methane	0.1	0.0	2.0	12.4	8,946
Nitrogen Dioxide	2.8	1.3	169.6	13.6	49,026
Ozone	9.9	9.7	32.1	13.6	49,013
PM_{10}	3.4	2.7	16.7	13.6	49,026
$PM_{2.5}$	1.0	0.8	6.0	13.6	49,026

Parameter	Mean Concentration Enhancement[1]	Median Concentration Enhancement[1]	Max Concentration Enhancement[1]	Measurement Time (Hours)	Total Measurement Count (n)
Greenhaven-Pocket					
Alkanes	3.9	2.2	77.4	7.8	5,619
Aromatics	1.2	0.3	17.6	7.7	5,525
Black Carbon	0.6	0.2	930.3	6.3	22,751
Carbon Dioxide	146.6	62.2	18868.6	6.6	4,745
Dienes	1.7	0.6	28.4	5.5	3,926
Methane	0.0	0.0	0.3	7.3	5,290
Nitrogen Dioxide	1.3	0.4	25.9	6.4	22,894
Ozone	10.1	9.7	33.3	6.4	22,894
PM_{10}	1.7	1.3	9.3	6.4	22,894
$PM_{2.5}$	0.5	0.4	3.9	6.4	22,894
Hagginwood					
Alkanes	9.6	4.6	59.7	3.8	2,765
Aromatics	2.8	0.7	22.7	3.7	2,648
Black Carbon	0.6	0.2	681.3	3.3	11,968
Carbon Dioxide	120.9	35.1	1500.7	3.6	2,561
Dienes	2.1	0.9	13.3	3.0	2,188
Methane	0.2	0.1	2.0	3.3	2,350
Nitrogen Dioxide	3.2	1.2	73.0	3.4	12,341
Ozone	9.5	8.9	30.3	3.4	12,296
PM_{10}	2.7	2.3	10.7	3.4	12,341
$PM_{2.5}$	0.8	0.6	5.1	3.4	12,341
Hollywood Park-Mangan Park					
Alkanes	4.5	1.9	76.5	3.6	2,617
Aromatics	1.8	0.4	16.8	3.6	2,617
Black Carbon	0.5	0.2	936.9	3.3	12,054
Carbon Dioxide	165.5	57.0	1325.0	3.5	2,554
Dienes	2.7	1.0	26.6	2.5	1,773
Methane	0.1	0.1	0.3	3.2	2,300
Nitrogen Dioxide	2.1	1.1	45.7	3.5	12,467
Ozone	10.3	9.9	38.8	3.5	12,467
PM_{10}	2.5	2.0	10.2	3.5	12,427
$PM_{2.5}$	0.7	0.6	2.8	3.5	12,427

Parameter	Mean Concentration Enhancement[1]	Median Concentration Enhancement[1]	Max Concentration Enhancement[1]	Measurement Time (Hours)	Total Measurement Count (n)
Little Pocket-Riverside-Freeport Manor					
Alkanes	4.7	3.3	82.7	6.7	4,817
Aromatics	1.6	0.8	17.4	6.6	4,761
Black Carbon	0.9	0.2	936.8	6.0	21,735
Carbon Dioxide	133.1	60.6	794.5	5.7	4,072
Dienes	1.8	0.8	27.6	4.6	3,312
Methane	0.1	0.0	0.5	5.9	4,253
Nitrogen Dioxide	1.9	0.6	44.1	6.1	22,075
Ozone	10.1	9.5	36.0	6.1	22,072
PM_{10}	2.2	1.6	10.7	6.1	22,075
$PM_{2.5}$	0.7	0.4	4.0	6.1	22,075
Meadowview-Z'berg Park					
Alkanes	5.5	3.1	133.1	16.1	11,603
Aromatics	1.5	0.6	42.8	16.2	11,650
Black Carbon	0.6	0.2	917.1	14.9	53,499
Carbon Dioxide	190.8	42.2	1750.9	15.4	11,068
Dienes	2.6	1.3	25.8	11.1	7,970
Methane	0.1	0.0	0.8	14.4	10,357
Nitrogen Dioxide	3.0	0.8	96.0	15.1	54,199
Ozone	10.2	9.6	46.5	15.1	54,198
PM_{10}	3.0	1.8	44.2	15.1	54,204
$PM_{2.5}$	1.0	0.5	7.0	15.1	54,204
Noralto-Old North Sacramento					
Alkanes	7.9	2.9	415.8	16.7	12,026
Aromatics	1.9	0.6	37.3	16.0	11,501
Black Carbon	0.6	0.1	932.7	14.7	52,812
Carbon Dioxide	113.0	50.0	1398.3	15.4	11,088
Dienes	1.7	0.8	33.2	10.8	7,799
Methane	0.1	0.0	2.0	14.7	10,592
Nitrogen Dioxide	3.1	1.4	113.2	15.2	54,653
Ozone	9.0	8.6	45.4	15.1	54,497
PM_{10}	3.7	2.5	97.1	15.2	54,654
$PM_{2.5}$	0.9	0.6	4.5	15.2	54,654

Parameter	Mean Concentration Enhancement[1]	Median Concentration Enhancement[1]	Max Concentration Enhancement[1]	Measurement Time (Hours)	Total Measurement Count (n)
Northgate-Gardenland					
Alkanes	6.1	2.4	339.6	11.7	8,416
Aromatics	1.9	0.6	100.8	10.8	7,788
Black Carbon	0.7	0.1	949.0	10.1	36,413
Carbon Dioxide	169.9	51.5	21639.3	11.2	8,084
Dienes	1.5	0.7	62.8	8.7	6,234
Methane	0.1	0.0	3.5	10.2	7,349
Nitrogen Dioxide	2.6	1.0	181.1	10.4	37,607
Ozone	9.9	9.6	33.0	10.4	37,535
PM_{10}	2.5	2.1	12.3	10.4	37,607
$PM_{2.5}$	1.1	0.4	9.4	10.4	37,607

[1] Alkanes, CO_2, and methane are in parts per million by volume (ppmv). Aromatics, dienes, nitrogen dioxide, and ozone are in parts per billion by volume (ppbv). BC, PM_{10}, and $PM_{2.5}$ are in micrograms per cubic meter (μg m^{-3}).