# Spatial and Temporal $PM_{2.5}$ Trends in Alhambra and Monterey Park: Application of Purple Air Sensor Network for Asian Pacific Islander Forward Movement (APIFM)

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## ABSTRACT

Temporal and spatial air quality (i.e., $PM_{2.5}$) trends within Alhambra and Monterey Park, CA were examined using data from low-cost PurpleAir sensors. $PM_{2.5}$ data recorded from January 2019 to July 2020 by 27 PurpleAir sensors (24 outdoors and 3 indoors) were analyzed to understand hourly, daily, and seasonal trends of $PM_{2.5}$ concentrations as well as the variations across space. Over 70% of days in 2019 showed 24-hr average $PM_{2.5}$ levels above the "moderate" air quality index (AQI) limit established by the U.S. Environmental Protection Agency. Temporal variation in $PM_{2.5}$ concentrations was substantially larger than its spatial variation in the study area. The COVID-19 lockdown in 2020 led to 42% lower outdoor $PM_{2.5}$ concentrations in comparison to that of the pre-lockdown period in 2020. Further, during the lockdown in 2020, 28% lower outdoor $PM_{2.5}$ levels were observed compared to that of the same period in 2019. Results also showed 2-3 fold higher $PM_{2.5}$ concentrations on the 4$^{th}$ and 5$^{th}$ of July in 2020 relative to the concentrations before and after the firework episode, suggesting the important contribution of city-wide household/personal firework activity to $PM_{2.5}$ pollution. During the study period, most major wildfire events coincided with Santa Ana winds, which transported particles toward the ocean and therefore minimized their influence on community $PM_{2.5}$ levels. Three census tracts were identified where high $PM_{2.5}$ exposure and potential high impact of $PM_{2.5}$ co-exist. Further analyses of factors correlated with air quality trends near sensitive communities and the deployment of more air quality sensors in such areas are suggested for inclusion in local regulation.



**Keywords:** Air pollution, Air quality, Alhambra, Clean Air SGV, Community Based Participatory Research (CBPR), COVID-19, Particulate Matter 2.5 (PM 2.5), Purpleair sensors, Monterey Park, San Gabriel Valley (SGV)

## PARTICIPATING ORGANIZATIONS/LEAD RESEARCHERS

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Professor Jun Wu and Dr. Amirhosein Mousavi are affiliated with the Department of Environmental and Occupational Health, Program in Public Health, University of California, Irvine (UCI). Professor Wu's primary research focuses on environmental exposure assessment, environmental epidemiology, and environmental health disparities, specifically the impact of air pollution, climate change, and the built environment on exposure and human health. Amirhosein Mousavi is currently a postdoctoral research scholar focusing on air pollution exposure assessment and analysis using field measurements and low-cost sensor network data. For more information please visit: https://www.coeh.uci.edu/.

*Special Service for Groups, Inc. (SSG)/Asian Pacific Islander Forward Movement (APIFM)*

Special Service for Groups, Inc. (SSG) is a non-profit organization dedicated to providing community-based solutions to the social and economic issues facing those in greatest need. SSG has evolved into a model organization which is designed to provide service to diverse groups with maximum efficiency and impact. This is achieved by developing and managing programs which serve our many communities by encouraging their involvement and self-sufficiency. SSG believes that the needs of groups and individuals cross traditional ethnic, racial, and other cultural boundaries. SSG serves as a bridge between people with common needs to identify ways to pool resources for the greatest good of all. For more information please visit: www.ssg.org.

Asian Pacific Islander Forward Movement (APIFM) is a unique division of SSG which operates with a mission to cultivate healthy, long-lasting, and vibrant Asian and Pacific Islander communities through grassroots organizing. APIFM works to ensure that API communities have access to green space, safe environments, and opportunities to engage with nature. Since 2013, APIFM has been at the forefront of advocating for cleaner air in the San Gabriel Valley. APIFM's Clean Air SGV program aims to educate, engage, and empower local Alhambra and Monterey Park residents about air quality issues impacting the communities' health. There are three key objectives of the program: (1) Inform and raise awareness of air quality issues specific to San Gabriel Valley communities, (2) provide community members with the tools necessary to measure local air quality in their neighborhoods, and (3) engage local communities in conversation to develop tangible, actionable policy solutions that will improve air quality for all residents. For more information about the Clean Air SGV program please visit: www.apifm.org/cleanairsgv/.

Our research partnership with UCI follows a community-based participatory research approach, which equitably involves community members, organizational representatives, and academic researchers. Environmental justice advocacy, while engaging youth participation, is one of APIFM's primary goals. For more information please visit: www.apifm.org.

# 1. INTRODUCTION

## 1.1. Particulate matter (PM) and air pollution sources

Long term exposure to air pollution has been consistently associated with serious adverse health effects such as asthma, respiratory disease, and cancer, and is estimated to cause 6.4 million premature deaths per year globally[1]. Particulate matter (PM), the main contributor to urban air pollution, is a product of tailpipe and non-tailpipe urban emissions[2], as well as industry-related emissions in different urban settings. PM with an aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) is of greatest concern due to its abilities to penetrate deep into the lungs and because of its high surface-to-volume ratio that enables large amounts of toxic contaminants such as metals and organic matters being absorbed on its surface and further transported to lung tissue. Exposure to $PM_{2.5}$ is associated with a variety of respiratory and cardiovascular health effects[3].

More than 80% of people living in urban cities are exposed to air pollution that exceeds World Health Organization (WHO) guidelines[1]. While all regions of the world are affected, populations in low-income areas are disproportionately impacted[3]. Specifically, in metropolitan areas such as Los Angeles, $PM_{2.5}$ concentrations reported by the U.S. Environmental Protection Agency (EPA) often exceed the WHO Air Quality Guideline of annual or 24-hr mean levels[2]. For instance, based on California Air Resources Board (CARB) data[4], between 2010 and 2019, annual average $PM_{2.5}$ concentrations for Los Angeles County ranged between 11.9-17.4 $\mu g.m^{-3}$, exceeding the 10 $\mu g.m^{-3}$ annual average threshold established by WHO. Further, daily $PM_{2.5}$ trends reported by the U.S. EPA[2] in 2019 show that only 92 days with 24-hr average $PM_{2.5}$ concentrations below 25 $\mu g.m^{-3}$ (24-hr mean guideline by WHO) were recorded in Los Angeles County. Further, California is the most polluted state in the country in terms of emissions from motor vehicles[5]. Multiple mobile and stationary emission sources, including international airports (e.g. Los Angeles International Airport, Ports of Los Angeles, and Long Beach), locomotives and railways in the Alameda corridor and interstate freeways have made Los Angeles County one of the most polluted regions around the globe[6].

## 1.2. Community-based air monitoring

Regulatory air quality monitoring sites tend to be sparsely located among disadvantaged communities. Such communities, as defined by California Senate Bill (SB) 535, include census tracts within the top 25% of CalEnviroScreen scores. The lack of spatial and temporal air monitoring by regulatory agencies leads to significant disparities as it relates to our understanding of air pollution within such communities and other densely populated areas. Low-cost air pollution sensors, however, allow for a spatially resolved community air pollution monitoring network that can be operated by various stakeholders, including concerned residents, organizations, academics, and/or government agencies[7-9]. Such networks therefore have the potential to fill spatial and temporal gaps between existing government-operated monitoring sites. One potential benefit of finer scale monitoring is the ability to identify elevated air pollution episodes in locations and time periods that have not been previously identified by government-operated monitoring sites (e.g. local industrial and other sources, impacts from wildfires and firework emissions), which has the potential to improve public health warning systems and ensure the safety of those who may be particularly sensitive to high levels of air pollution.

### 1.3. Alhambra and Monterey Park

Alhambra and Monterey Park are cities located in the western region of Los Angeles County's San Gabriel Valley, approximately eight miles from Downtown Los Angeles. According to the 2018 American Community Survey, these cities had populations totaling about 158,000 combined. The Alhambra and Monterey Park neighborhoods are in the 6$^{th}$ and 4$^{th}$ percentiles, respectively, in terms of pollution burden as defined by the California Healthy Places Index Clean Environment Score, a composite measure of pollution that was developed by the Public Health Alliance of Southern California[10]. Several neighborhoods within Alhambra are also designated as low income, under California Assembly Bill 1550, or disadvantaged, under California Senate Bill 535. Recently, studies have shown that exposure to $PM_{2.5}$ from cars, trucks, and buses is not equally distributed across the state of California[5], and that people living in Los Angeles County are exposed to 60% more vehicle-related air pollution than the state average. Emission sources in the southern part of Los Angeles County, including the Los Angeles International Airport and Ports of Los Angeles and Long Beach, are disproportionately influencing the PM air pollution across the county (**Appendix Figure 1**). Further, several major freeways/highways (e.g. I-10, I-710, and I-60) surrounding the Alhambra and Monterey Park neighborhoods carry a high volume of heavy-duty diesel vehicles originating from the ports, which exacerbate the air pollution problem in the neighboring communities.

### 1.4. APIFM sampling campaign using PurpleAir sensors

APIFM has deployed PurpleAir sensors that have been continuously measuring air pollution levels within the cities of Alhambra and Monterey Park, California, since 2017. PurpleAir sensors are relatively inexpensive compared to other air quality instruments and sensors while still exhibiting reasonable correlation with more expensive reference instruments[11], thus making them ideal for large-scale community-based data collection.

### 1.5. Research-oriented approach

The goal of this project is to analyze air quality trends across time and space in Alhambra and Monterey Park using time-resolved $PM_{2.5}$ and meteorology data from established community-based PurpleAir sensors. The goal of this report is to quantitatively characterize ambient $PM_{2.5}$ concentrations based on high spatiotemporal resolution data collected from 27 PurpleAir sensors operating from January 2019 to July 2020. In addition, we aim to understand the impact of meteorological conditions and local sources on $PM_{2.5}$ concentrations. Further, daily $PM_{2.5}$ levels were assessed and compared to the air quality guidelines outlined by the U.S. EPA. Changes in air quality were explored for the COVID-19 lockdown as well as specific emissions events such as wildfires and firework activity related to the 4$^{th}$ of July.

Further, spatial trends in $PM_{2.5}$ levels were examined based on population characteristics within different census tracts. The information contained in this report has been synthesized for distribution to members of the community of Alhambra and Monterey Park. This analysis aims to serve city officials, policy making agencies and community members as it relates to administrative and mitigation strategies concerning community-level air quality.

## 2. METHODOLOGY

PurpleAir sensors are low-cost air quality monitors that have started to become widely deployed in the U.S. and worldwide as of 2017. The latest model (PA- II-SD) contains two PMS5003 sensors (Plantower, Beijing, China), which estimate particle mass concentrations by measuring the amount of light scattered at ~680 nanometers. Greater details regarding the lab evaluation by South Coast Air Quality Management District (AQ-SPEC team) can be found elsewhere[11]. Although PurpleAir sensors report PM mass concentrations of three size fractions, i.e. PM less than 1 µm, less than 2.5 µm ($PM_{2.5}$), and less than 10 µm, we focused on $PM_{2.5}$ in this study mainly due to three reasons: 1) among the three size fractions $PM_{2.5}$ has been mostly associated with adverse health outcomes; 2) $PM_{2.5}$ is regulated and routinely monitored by the U.S. EPA; and 3) PM concentrations from the three size fractions are highly correlated with one another in the PurpleAir data (more than 0.9 correlation coefficient between different size fractions). In addition to PM, PurpleAir sensors measure humidity and temperature. PurpleAir measurements are recorded through two separate channels and are automatically uploaded to purpleair.com, which become open source data that are publically available.

Ten-minute interval PurpleAir $PM_{2.5}$ data (channel A) from all the sensors in the study region were downloaded between January 2019 and July 2020 as .csv files using the ThingSpeak's API provided by the PurpleAir company. From roughly 40 sensors deployed in the study area, 27 met our 75% completion criterion: the data was available for ≥ 75% of time within a given day, month, and year. Data availability during the study period is depicted in **Appendix Figure 2**. **Figure 1** shows the Google map locations of the 27 PurpleAir sensors used in this study. Among the 27 sensors, 24 were located outdoors and 3 were located indoors. For the 24 outdoor sites, 18 of which were considered urban background sites and 6 were considered near-traffic sites (within 50 meters of the freeway/highway and major arterial streets). Further, $PM_{2.5}$ data during July 4$^{th}$ firework episodes (July 1$^{st}$ to 7$^{th}$) were downloaded for 10 PurpleAir sensors that had continuous measurements from 2018 to 2020. PurpleAir data time stamps were changed from Coordinated Universal Time (UTC) to the appropriate local time, Pacific Standard Time (PST). Temperature and relative humidity data measured by PurpleAir sensors were extracted from each of the 24 outdoor sensors in 2019 (N=6,280 hourly data points). Daily wind direction and wind speed data were extracted from a meteorology/air quality monitoring station operated by California Air Resources Board (CARB) in central Los Angeles near Alhambra and Monterey Park communities. Daily total precipitation data in 2019 were extracted from the closest National Oceanic and Atmospheric Administration (NOAA) weather station, Lindaraxa Park station (latitude: 34.10 °N, longitude: 118.12 °W, elevation: 500 ft). Hourly and daily averages were calculated for $PM_{2.5}$ concentrations. Daily averages were calculated for temperature and relatively humidity.

We examined temporal variations of $PM_{2.5}$ concentrations at hourly, daily, and seasonal levels, as well as the influence of meteorological factors (temperature, relatively humidity, precipitation, and wind) on $PM_{2.5}$ concentrations. Spatial variations of $PM_{2.5}$ across different sensors/sites were also investigated. Further, we examined the impact of important events (i.e. COVID-19 lockdown, July 4$^{th}$ firework emissions, and wildfires) on community-level $PM_{2.5}$ concentrations. For COVID-19 impact, we compared $PM_{2.5}$ concentrations at various time periods: pre-lockdown (January 1$^{st}$ – March 16, 2020), during lockdown (March 17 – May 5, 2020), post-lockdown (May 6$^{th}$ – July 30$^{th}$, 2020), and the normal periods in 2019 that cover the same days of the year as those for pre-, during-, and post-lockdown in 2020. For the fireworks impact, we compared daily $PM_{2.5}$ levels from July 1st to 7th in 2018 through 2020. For the wildfire impact, we identified the time periods and locations of major wildfires (i.e., over 1,000 acres burned area) occurring in 2019 (January-December) and 2020 (January-July) and examined their impact on $PM_{2.5}$ concentrations.

The CalEnviroScreen (CES) 3.0 dataset (2018 update) was obtained from the California Communities Environmental Health Screening Tool[12] CalEnviroScreen was created and designed by the California Environmental Protection Agency to address the issue of environmental justice and screening of disadvantaged communities in California. This tool integrates both pollution burden indicators and population characteristics indicators that reflect sensitive population and socioeconomic status (e.g., asthma rate, educational attainment, and poverty). The overall CES score was calculated by combining both the pollution burden and the population characteristics[12]. We selected total population per census tract, the overall CES score, asthma rate, and total pollution burden in this analysis.

All data analyses were performed using RStudio. ArcGIS software was also used to analyze the spatial trends in $PM_{2.5}$ as well as population characteristics at the community level.

# 3. RESULTS AND DISCUSSION

## 3.1. Temporal variation of $PM_{2.5}$ concentrations and influence of meteorological parameters

**Figure 2** shows the temporal variation in $PM_{2.5}$ concentrations across 24 outdoor sensors with daily $PM_{2.5}$ concentrations. Among these 24 sensors, one sensor (SCAP_10; urban background site) showed extremely high daily $PM_{2.5}$ concentrations (> 120 $\mu g.m^{3}$) continuously from June to December in 2019, indicating the malfunction of the sensor for at least half of the year in 2019. Thus, this sensor was removed from all the subsequent analysis, leaving 23 sensors for outdoor $PM_{2.5}$ measurements. Black shading in the plot shows daily average sensor data. Red and yellow dashed lines indicate the threshold of 24-hr average $PM_{2.5}$ concentrations considered "moderate" and "unhealthy for sensitive group" according to the air quality index (AQI) categories, respectively[13]. Lower $PM_{2.5}$ levels during the lockdown period (March 17 to May 7, 2020) relative to 2019 is evident. We also observed a sharp peak during the 4th of July firework episode both in 2019 and 2020, with drastically higher values in 2020. The peak value in 2020 was almost 4-times higher than the 2019 daily average in the Alhambra-Monterey community. Daily $PM_{2.5}$ levels recorded by sensors ranged between 21.3±2.3 $\mu g.m^{-3}$ during 2019. By comparison, the WHO Air Quality Guideline for a 24-hr average is 25 $\mu g.m^{-3}$. Further, the annual $PM_{2.5}$ mean across all the sensors was 13.3±3.2 $\mu g.m^{-3}$, higher than the 10 $\mu g.m^{-3}$ annual average $PM_{2.5}$ Air Quality Guideline of WHO.

**Table 1** shows the Pearson correlation between meteorological parameters and $PM_{2.5}$ concentrations during different seasons in 2019. Summer months included May through September, while winter months included January through March as well as November and December. April and October were selected as transition months. Overall, $PM_{2.5}$ levels were negatively correlated with temperature in winter but positively correlated with temperature in summer. Lower temperature and more stable atmosphere (reduced air mixing) in the wintertime are expected to result in higher $PM_{2.5}$ concentrations[14]. Warmer temperature and strong sunlight in the summertime facilitate photochemical reactions, which increases secondarily-formed particulate matter[15]. $PM_{2.5}$ levels were negatively correlated with precipitation in both summer and winter, which is expected as precipitation can wash out or remove PM from the atmosphere.

For monthly average concentrations in 2020 vs. 2019, **Figure 3** shows slightly higher $PM_{2.5}$ levels in January and February in 2020 compared to 2019, but a clear sharp decrease in $PM_{2.5}$ levels from March to June of 2020, likely reflecting the impact of the COVID-19 lockdown due to substantially reduced traffic activities and other emissions. **Figure 3** also showcases a sharp peak in July concentrations in 2020 relative to 2019 (more than 2-fold difference in July compared to June in 2020). Overall, the air quality was worst in winter and summer seasons; better air quality was observed in transition months (i.e. April and October). **Figure 4a** further shows that on average $PM_{2.5}$ levels in 2019 were higher (statistically insignificant with P value = 0.12) in the winter season due to more stable atmospheric conditions[14]. Seasonal trends recorded by the PurpleAir sensor network agrees with the California statewide trend reported previously[14,15].

**Figure 4b** illustrates average diurnal $PM_{2.5}$ concentrations by season in 2019.  In the winter time, $PM_{2.5}$ concentrations were the highest during nighttime but also peaked during morning traffic hours in the day (~7-8 AM PST). This is likely caused by 1) stable atmosphere in the winter night time that prevents the mixing of the air and leads to pollutant accumulation; and 2) emissions from morning rush hour traffic. In the summer time, $PM_{2.5}$ concentrations were the highest at around 6 AM PST (7 AM Pacific daylight saving time), reflecting the impact of morning traffic emissions. The traffic impact is further demonstrated by the diurnal plot of summary data from outdoor traffic sites within 50 m of the San Bernardino Freeway and Mission Road (N= 6 sites) vs. urban background sites (N=18 sites). These results are consistent with previous studies in the area[14-16].

**Figure 5** shows rose plots depicting the directionality of wind and $PM_{2.5}$ concentrations in the area. **Figure 5(a)** suggests that the south-westerly direction is the main and most frequent wind direction during the study period, carrying PM emissions from the City of Los Angles to the Alhambra area. **Figure 5(b)** also confirms that the highest PM pollution episodes during the year occurred when south westerly wind was blowing in the area.

### 3.2. Spatial variation of $PM_{2.5}$ concentrations

**Figure 6** describes 2019 daily boxplot data for each of the 23 outdoor sensors. The spatial variation across different sites (both non-traffic urban background and traffic sites) was smaller than the temporal variation (i.e. the differences of median concentrations across the sites were much smaller than the ranges of daily $PM_{2.5}$ concentrations in each box plot). This is likely due to the relatively small study area and that $PM_{2.5}$ is more homogeneous distributed spatially than other traffic-related pollutants[17,18]. Sensor SCAP_49 had the lowest median $PM_{2.5}$ levels within the community. Further investigation shows that the SCAP 49 site is located at a relatively high elevation in the hills and is surrounded by dense greenspace in the absence of immediate urban emission sources. In 2019, more than 70% of days in the Alhambra and Monterey area showed 24-hr average $PM_{2.5}$ levels above the U.S. EPA's "moderate" $PM_{2.5}$ AQI threshold (yellow dash line). For approximately 30% of the year, $PM_{2.5}$ levels were "unhealthy for sensitive groups" in the Alhambra and Monterey communities.

### 3.3. Influence of COVID-19 lockdown on $PM_{2.5}$ concentrations

**Figure 7** shows the effect of COVID-19 lockdown on $PM_{2.5}$ levels in the study area based on both indoor sensors (N=3 sensors) and outdoor sensors (N=23 sensors). On average, 42% lower outdoor $PM_{2.5}$ concentration was observed during the COVID-19 lockdown in comparison to that of the pre-lockdown period in 2020. Similarly, 28% lower $PM_{2.5}$ concentration was observed during the COVID-19 lockdown in comparison to that of the normal period in 2019. The average $PM_{2.5}$ concentration post lockdown in 2020 was comparable to that before the lockdown although with larger daily fluctuations.

### 3.4. Influence of 4$^{th}$ of July fireworks on $PM_{2.5}$ concentrations

**Figure 8** shows daily $PM_{2.5}$ variations across all 10 outdoor sensors that had continuous monitoring data from 2018 to 2020 during the first week of July. In 2018 and 2019, the $PM_{2.5}$ levels were comparable, albeit the increases and decreases around the peak value on July 4$^{th}$ and 5$^{th}$ were smoother in 2018 and 2019 than those in 2020. $PM_{2.5}$ peaks on July 4$^{th}$ and 5$^{th}$ in 2020 were roughly 2- to 3-times higher than the background concentration before and after the firework episode. The highest daily average $PM_{2.5}$ level for the firework episode in 2020 was recorded by the SCAP_26 sensor (located in an urban background area with dense houses and near the intersection of I-710 and I-10 freeways). This may suggest that the degradation in air quality on the 4$^{th}$ of July in 2020 may be due to more than just household-level firework emissions, but also to barbeque-related use of charcoal and vehicle emissions[19,20].

### 3.5. Potential influence of nearby wildfires on $PM_{2.5}$ concentrations

**Figure 9** shows the five wildfire (> 1,000 burn acres) locations in Los Angeles County from late October to early November of 2019. No major wildfires were identified in January-July of 2020. Most of these wildfires coincided with Santa Ana winds, which transported particles toward the ocean, minimizing the effect on $PM_{2.5}$ levels in the cities of Los Angeles County. Thus, no apparent wildfire impact was observed for $PM_{2.5}$ concentrations in 2019 and 2020 in the study area.

### 3.6. Population characteristics and $PM_{2.5}$ spatial distribution

We examined the distribution of $PM_{2.5}$ concentrations in the context of different population characteristics (**Figure 10**). Red dots in the figures show census tracts where annual average $PM_{2.5}$ concentrations were above the community average in 2019. Blue squares show the census tracts with potentially higher $PM_{2.5}$ impact (above the average for the number of population, CES score, asthma rate, and total pollution burden). Green lines indicate boundaries of three census tracts with both high $PM_{2.5}$ concentrations and potentially high $PM_{2.5}$ impacts (2 in Alhambra and 1 in Monterey Park). It should be mentioned that not all of the census tracts evaluated in this study had a deployed and operating air sensor, which limited the ability of our analysis to fully characterize the relationship between population characteristics and $PM_{2.5}$. More specifically, no PurpleAir sensor was deployed in roughly 20 census tracts in the study area, including two out of the four SB535 census tracts; one sensor was located at the very south edge of the third SB535 census tract (**Figure 1b**).

# 4. LIMITATIONS

Four major limitations of this study include: 1) non-uniform coverage and non-random geographic distribution of PurpleAir sensors in the community, 2) missing and/or lost data due to issues related to internet connection and maintenance for the deployed sensors, 3) no calibration of the sensor against filter-based $PM_{2.5}$ mass concentrations, and 4) only $PM_{2.5}$ was measured. Only two sensors were deployed in two out of the four SB 535 census tracts in the study region. These communities need to be considered as priority for future sensor deployment. Missing and incomplete data were not trivial in the data we retrieved; this problem needs to be addressed in future studies (e.g. ensuring good WIFI connection, regular maintenance/check). Due to the lack of a reference air quality station operated by the South Coast Air Management District in the area, measurements were only calibrated by the PurpleAir sensor algorithm; no co-located measurements and further adjustment based on federal reference/equivalent methods have been performed. Due to the limited scope of work, only $PM_{2.5}$ was measured in this study, which prevented us from identifying local non-traffic sources that may generate sharper spatial gradients for other pollutants, e.g. volatile organic compounds from gas stations, metals from industrial facilities.

# 5. CONCLUSION

This project aimed to understand temporal and spatial variation of $PM_{2.5}$ concentrations and influential factors at a local scale using low-cost PurpleAir sensors in the Alhambra-Monterey Park area where no routine EPA monitoring is available. In general, 2019 showed "moderate" air quality in the area for more than 70% of the days and "unhealthy for sensitive groups" air quality for 30% of the days throughout the year. Seasonal and diurnal variations in $PM_{2.5}$ were observed and may be explained by meteorological parameters and traffic emission patterns. Temporal variation in $PM_{2.5}$ concentrations was substantially larger than its spatial variation in the study area. The COVID-19 lockdown in 2020 led to 42% lower $PM_{2.5}$ concentrations in comparison to the pre-lockdown period in 2020. Further, during the lockdown in 2020, 28% lower outdoor $PM_{2.5}$ levels were observed compared to the same period in 2019. The 4$^{th}$ of July firework episode generated nearly 3-times higher daily averaged $PM_{2.5}$ concentrations in 2020 compared to the time before and after the episode. Three census tracts were identified where high $PM_{2.5}$ exposure and potential high impact of $PM_{2.5}$ co-existed. Finally, while the density of the PurpleAir sensors was relatively high, it failed to cover two SB 535 disadvantaged communities; new sensor deployment needs to focus in these areas.

# 6. RECOMMENDATIONS FOR FUTURE WORK

- Overall, air pollution remains a leading concern in the greater Los Angeles area. While recent efforts from APIFM and funding from public/private entities have been a good first step in understanding local air quality data, future targeted deployment of air monitors will help the community to gain a better understanding of air quality in the region.
- There are many potential benefits of engaging community stakeholders to collect richer and more relevant environmental monitoring data such as $PM_{2.5}$ concentrations to inform environmental policy and planning. Community-engaged research projects like the current

study may improve collective knowledge and build consensus towards an understanding of the hazards that exist within a community.

- Results of the current study are not valid for the SB 535 communities located in the north eastern parts of the area given the lack of air monitoring sensors in such regions. Such areas should be a priority in terms of the future deployment of air sensors and air monitoring given the lack of continuous air quality measurement in areas with the lowest CES scores in the community.
- Additionally, creating a centralized database of air quality data, including archive reports of the air quality trends in the community, could help enable residents to educate themselves regarding the major sources of air pollution and important influential factors. Such efforts will enhance personal air quality monitoring and social and environmental justice awareness across the community.
- Finally, future air sensor deployments near vulnerable communities such as those with many elderly, schools, and disadvantage residents living close to emission sources (e.g. major freeways) could lead to more targeted and engineered policy/restrictions to reduce acute and chronic air pollution exposure.

**a)**

Low temperature — High temperature

| | Average Temperature (°C) | Minimum Temperature (°C) | Maximum Temperature (°C) |
|---|---|---|---|
| January | 13.1 | 6.4 | 19.9 |
| February | 14.2 | 7.6 | 20.9 |
| March | 14.7 | 8.4 | 21.1 |
| April | 16.6 | 10 | 23.2 |
| May | 18.4 | 12.3 | 24.5 |
| June | 20.8 | 14.4 | 27.3 |
| July | 23.6 | 16.5 | 30.8 |
| August | 24.2 | 17.1 | 31.3 |
| September | 22.9 | 15.9 | 30 |
| October | 20.2 | 13.1 | 27.3 |
| November | 16 | 9.1 | 23 |
| December | 13.3 | 6.4 | 20.2 |

**b)**

| Parameter | Pearson Correlation Coefficient (R) | | |
|---|---|---|---|
| | Summer | Transition | Winter |
| Temperature | **0.31** | -0.23 | **-0.41** |
| Relative Humidity | 0.12 | 0.03 | 0.02 |
| Precipitation | **-0.12** | -0.02 | **-0.20** |

***Table 1.*** *(a) Monthly average, minimum and maximum temperature in 2019. (b) Pearson correlation coefficients between $PM_{2.5}$ and meteorological parameters. Pearson's coefficients in bold are statistically significant (P value < 0.05).*

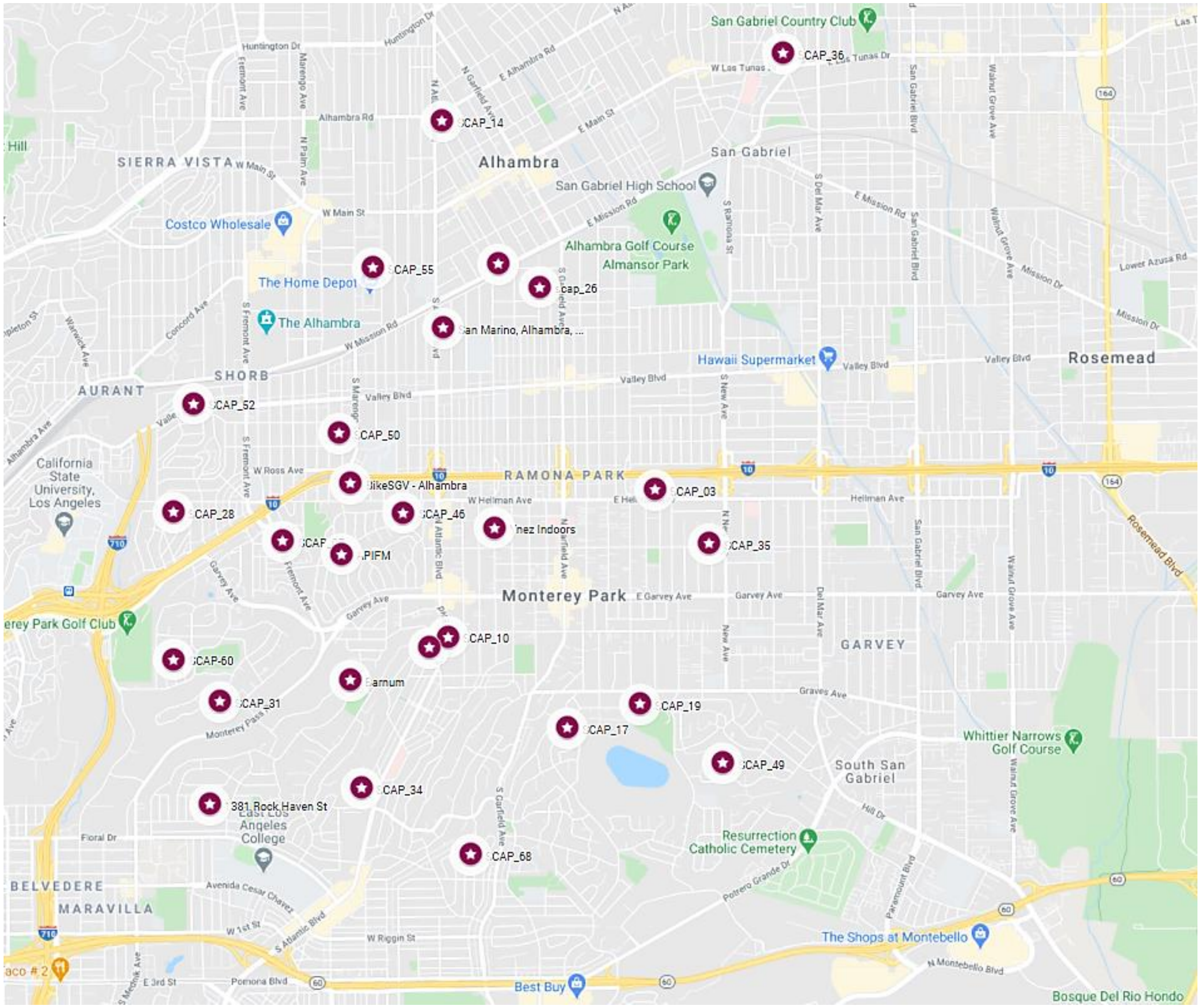


***Figure 1(a).*** *Map of PurpleAir sensors in Alhambra and Monterey park.*

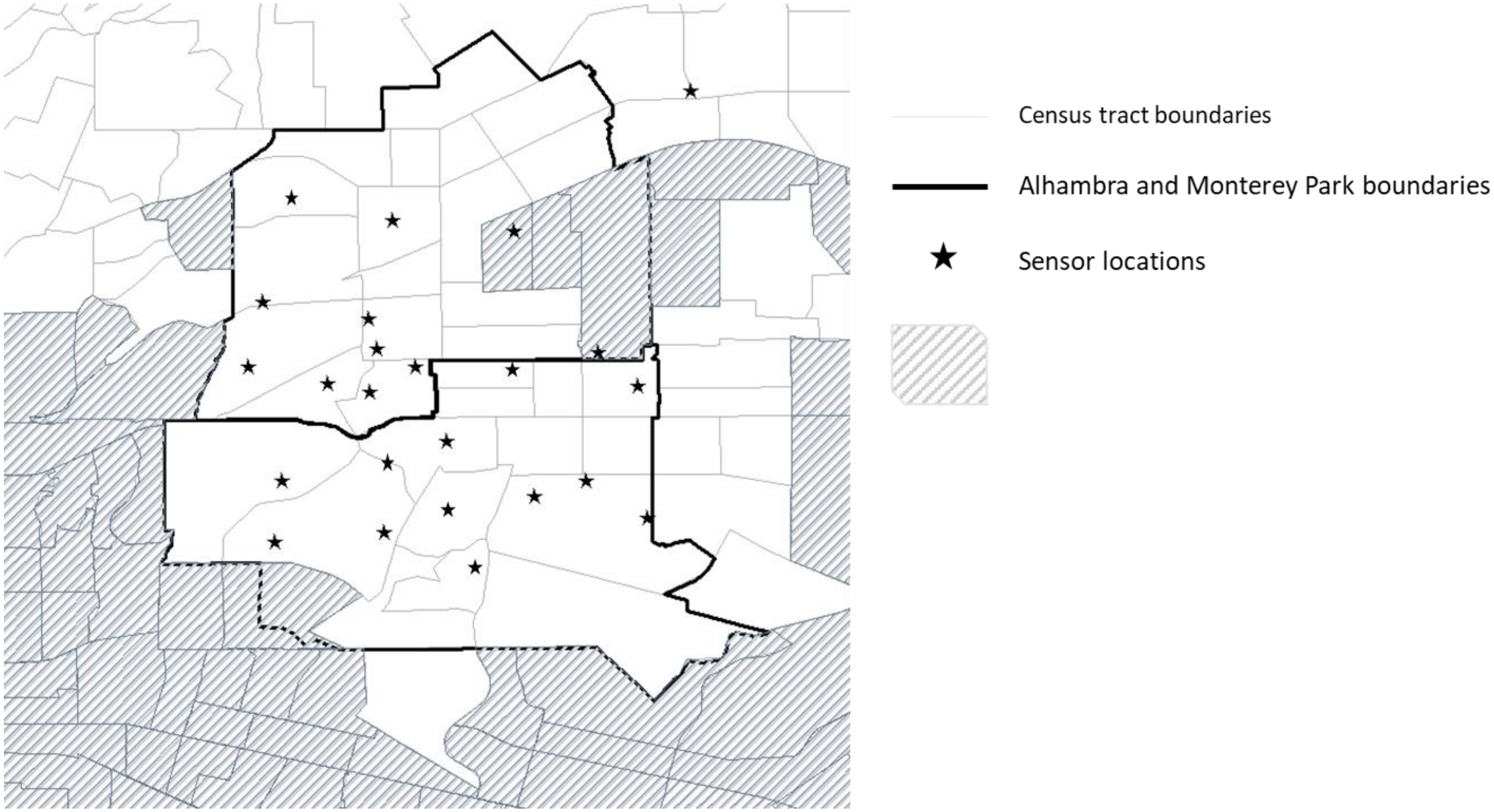


***Figure 1(b)*** *Distribution of Outdoor PurpleAir sensors in SB535 communities at Alhambra and Monterey Park.*

***Figure 1.*** *(a) Map of PurpleAir sensors in Alhambra and Monterey park. (b) Distribution of outdoor PurpleAir sensors in SB535 communities at Alhambra and Monterey Park.*

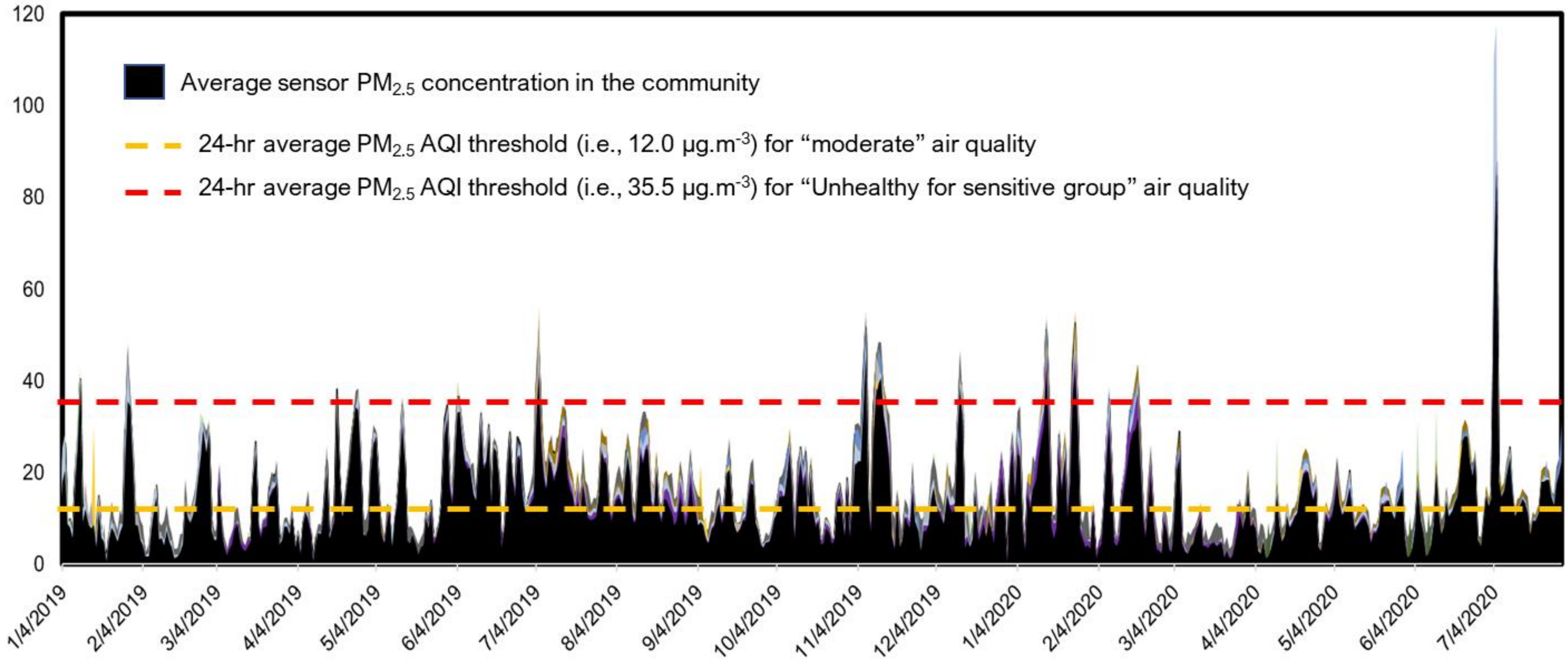


***Figure 2**. Temporal variation of $PM_{2.5}$ in Alhambra and Monterey Park in 2019 - 2020*

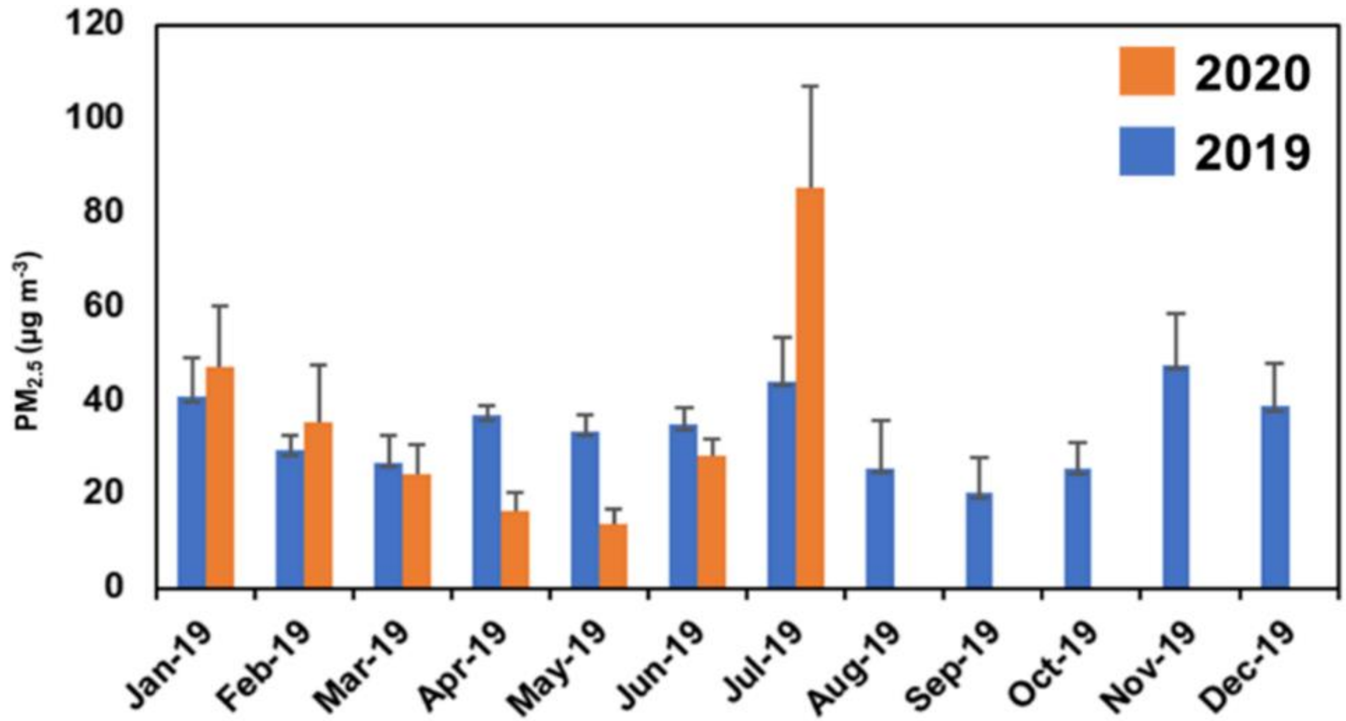


***Figure 3.*** *Monthly variations of $PM_{2.5}$ in Alhambra and Monterey Park in 2019 - 2020*

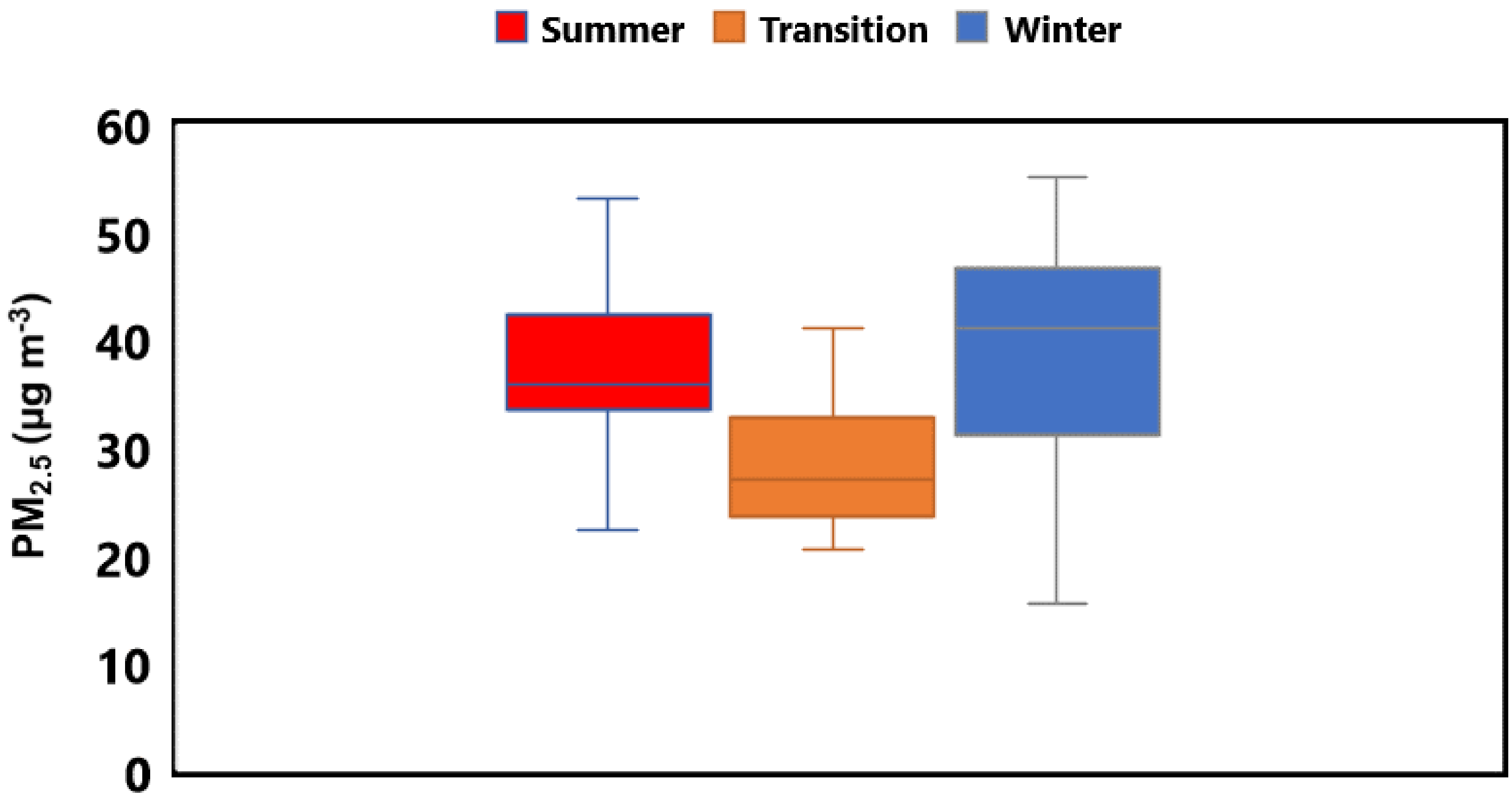


***Figure 4(a).*** *Seasonal variation of $PM_{2.5}$ concentrations in 2019 in Alhambra and Monterey Park*

**b)**

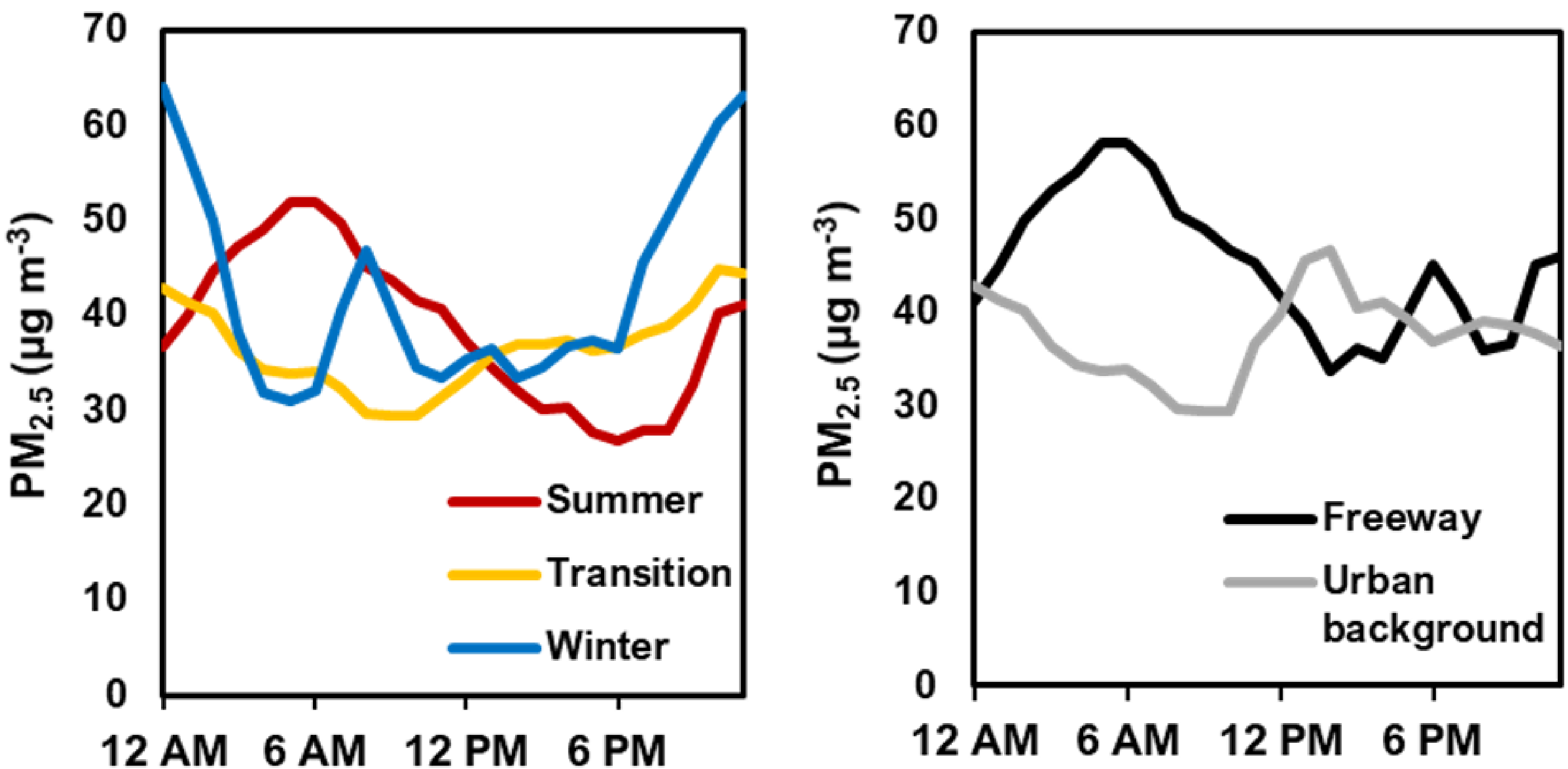


***Figure 5(b).*** *Diurnal variation of $PM_{2.5}$ concentrations in 2019 in Alhambra and Monterey Park.*

***Figure 6.*** *(a) Seasonal and (b) diurnal variation of $PM_{2.5}$ concentrations in 2019 in Alhambra and Monterey Park. Diurnal variation of $PM_{2.5}$ concentrations are presented by season and site type (i.e., freeway vs urban background)*

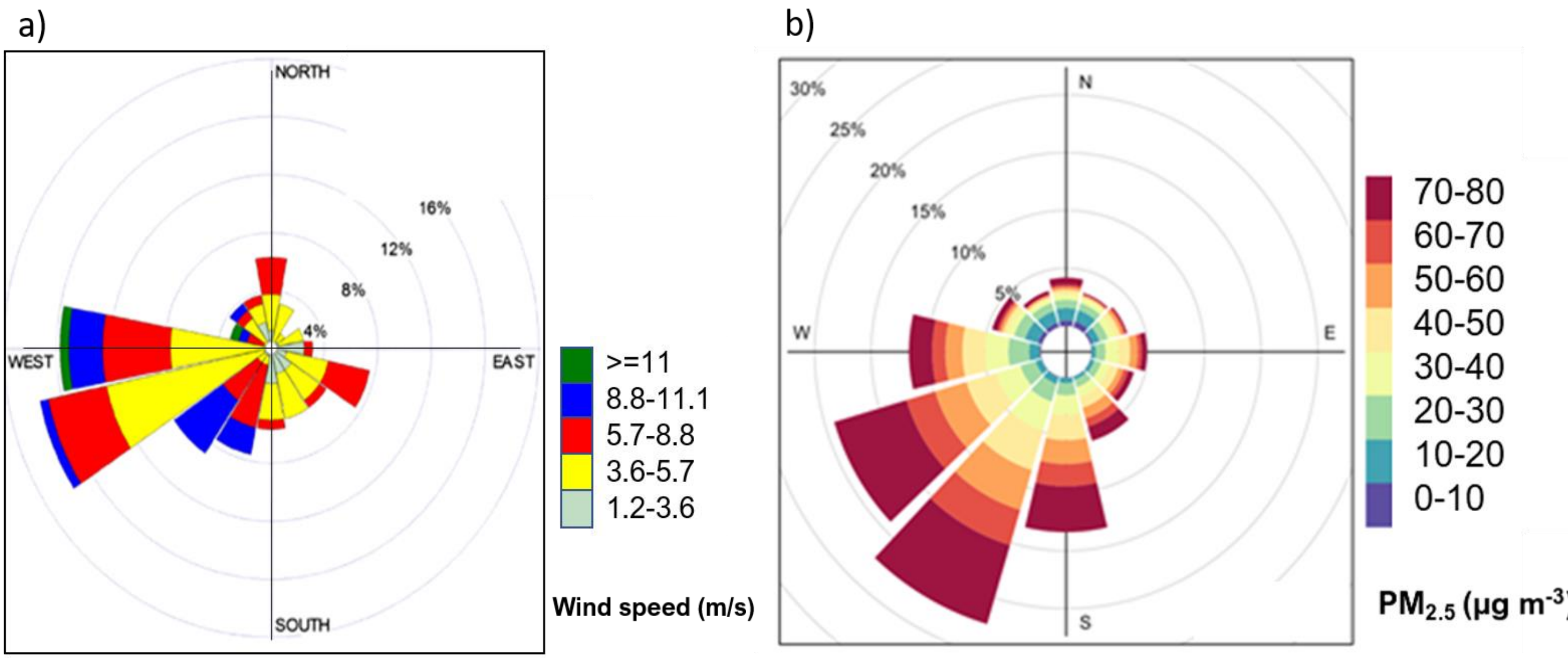


***Figure 7.*** *a) Wind rose and b)* $PM_{2.5}$ *concentration rose plots of the Alhambra-Monterey Park area in 2019*

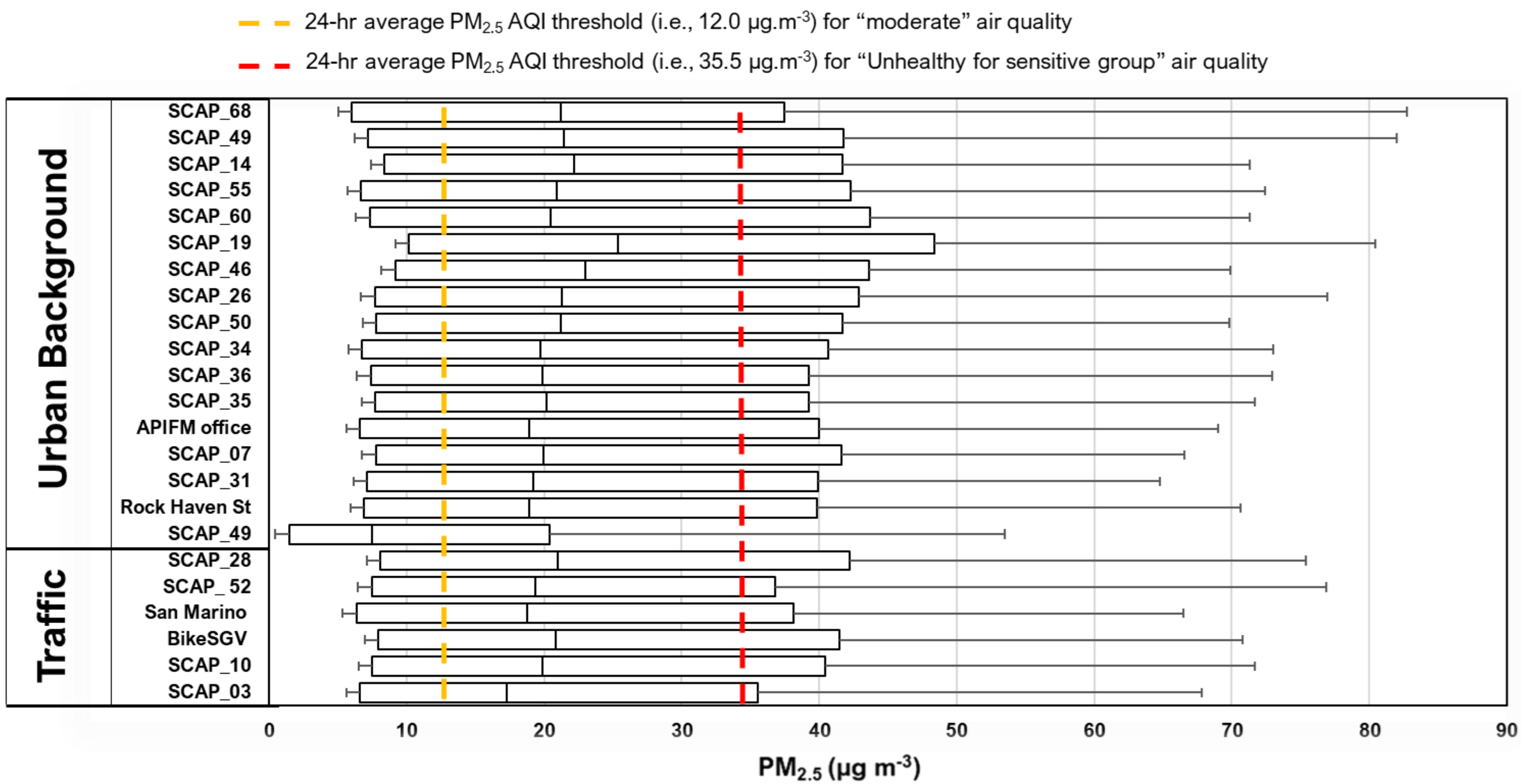


***Figure 8.*** *$PM_{2.5}$ concentrations across different sites in 2019.*

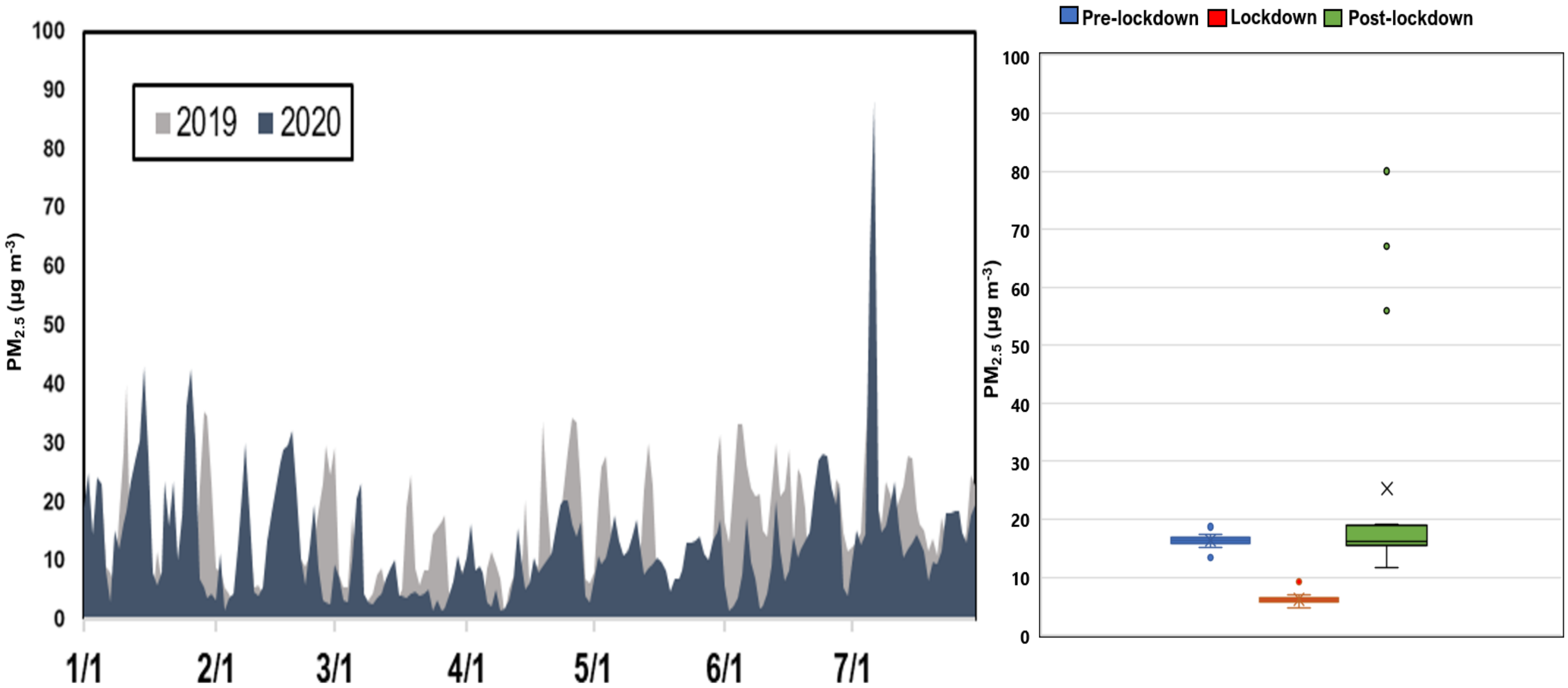


***Figure 9(a).*** *Outdoor $PM_{2.5}$ concentrations pre- and post-COVID-19 lockdown*

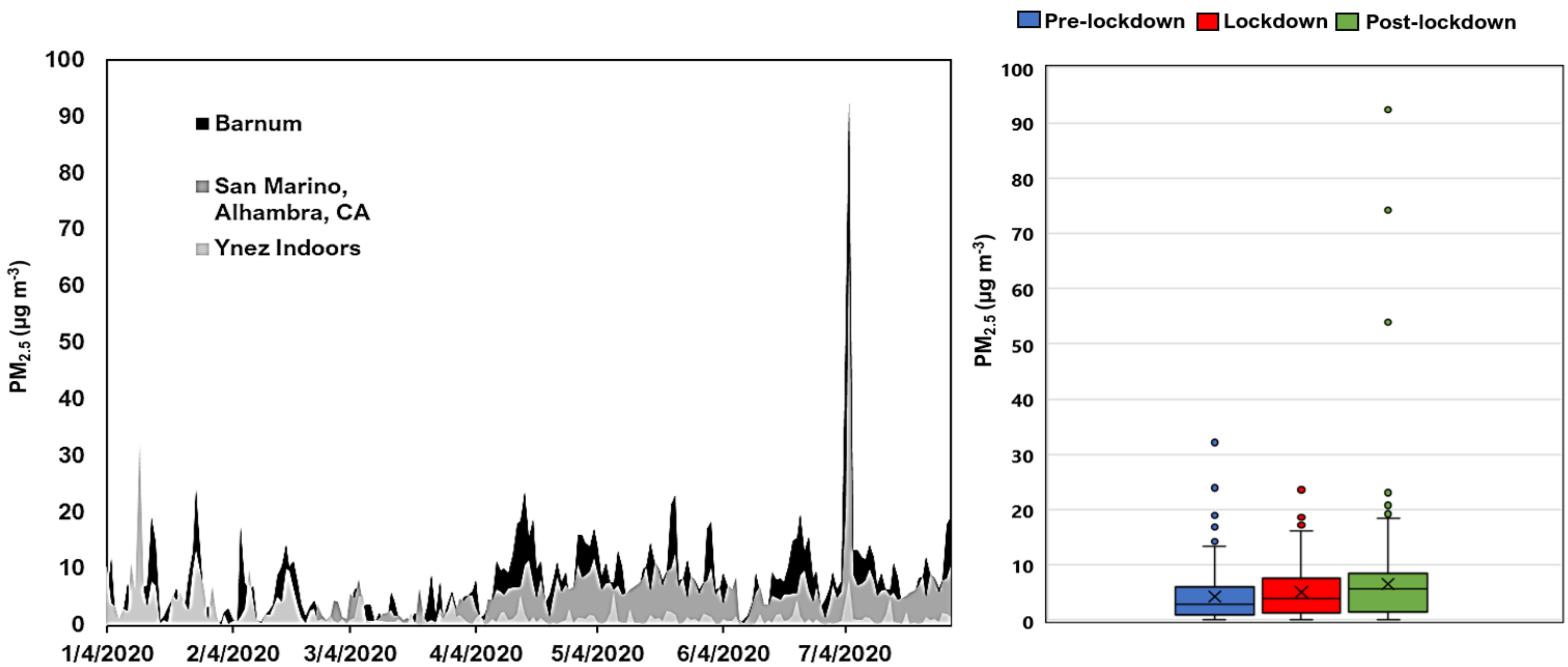


***Figure 10(b).*** *Indoor $PM_{2.5}$ concentrations pre- and post-COVID-19 lockdown*

| Period in 2020 | Average outdoor $PM_{2.5}$ ($\mu g.m^{-3}$) | Percent change to 2019 values |
|---|---|---|
| Pe- lockdown | 14.1 | 26.9% |
| During lockdown | 8.1 | -28.3% |
| Post- lockdown | 14.0 | 14.1% |

***Figure 7(c).*** *Percent change of outdoor $PM_{2.5}$ concentrations during different stages of COVID-19 lockdown in comparison to normal periods in 2019.*

***Figure 11.*** *(a) Outdoor and (b) indoor $PM_{2.5}$ concentrations pre- and post-COVID-19 lockdown. Percent change of outdoor $PM_{2.5}$ concentrations during different stages of COVID-19 lockdown in comparison to normal periods in 2019 are shown in (c) panel.*

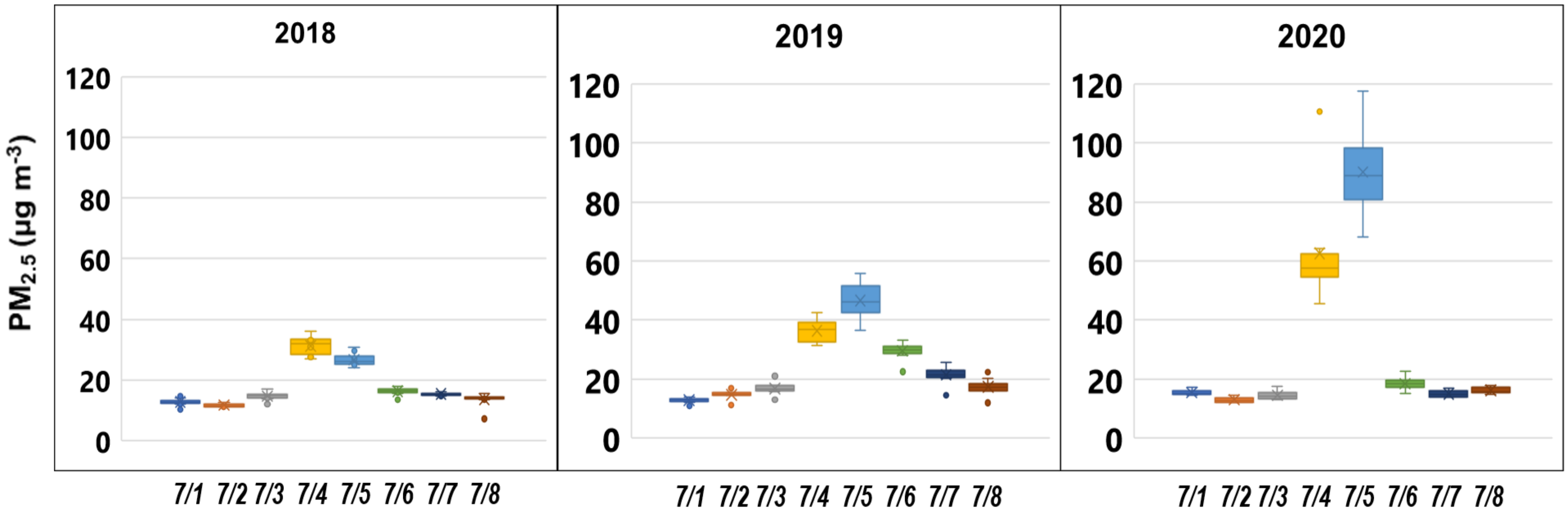


***Figure 12.*** *$PM_{2.5}$ concentrations during the 4th of July episodes in 2018 - 2020*

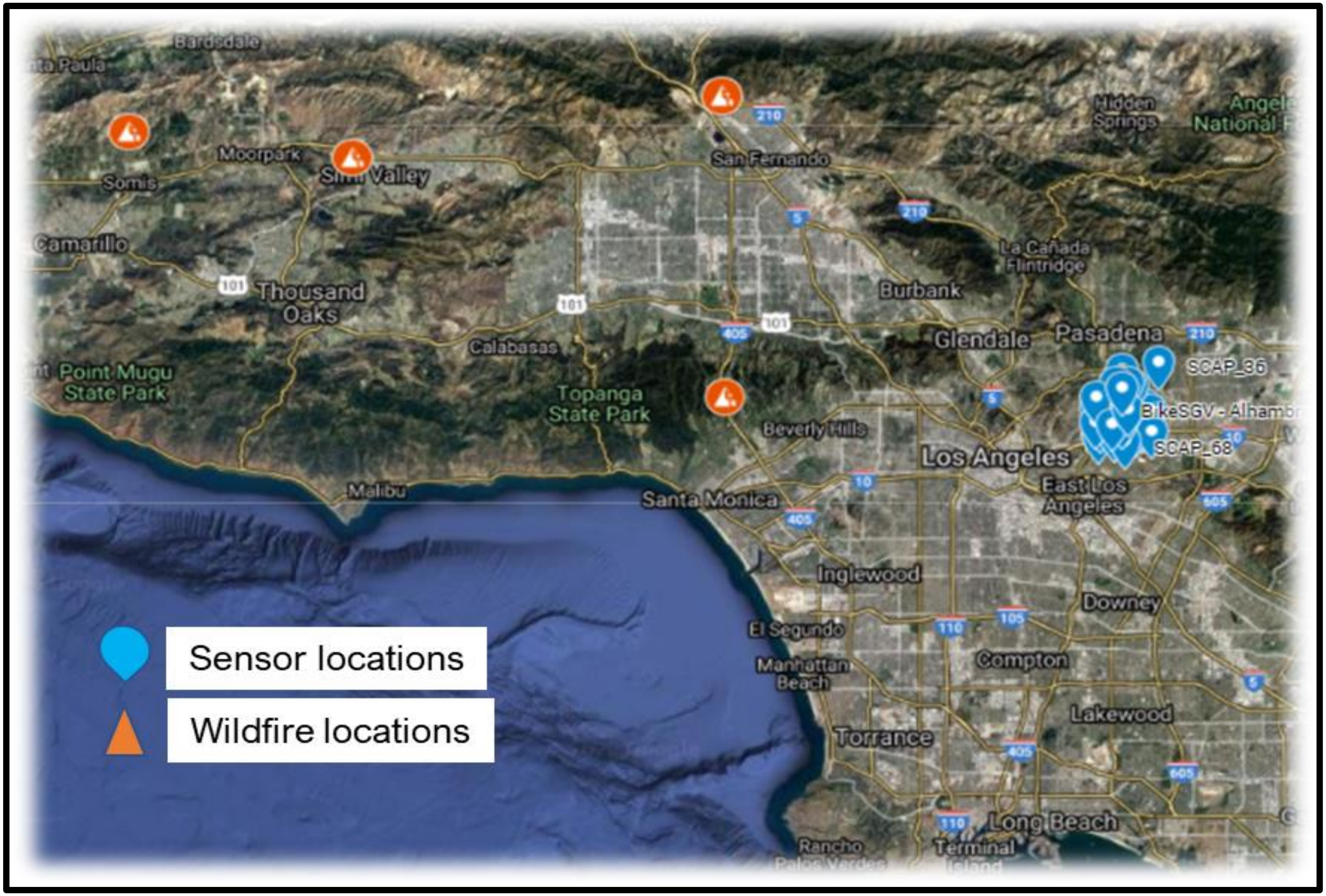


***Figure 13.*** *Wildfires locations during the study period in 2019 and 2020*

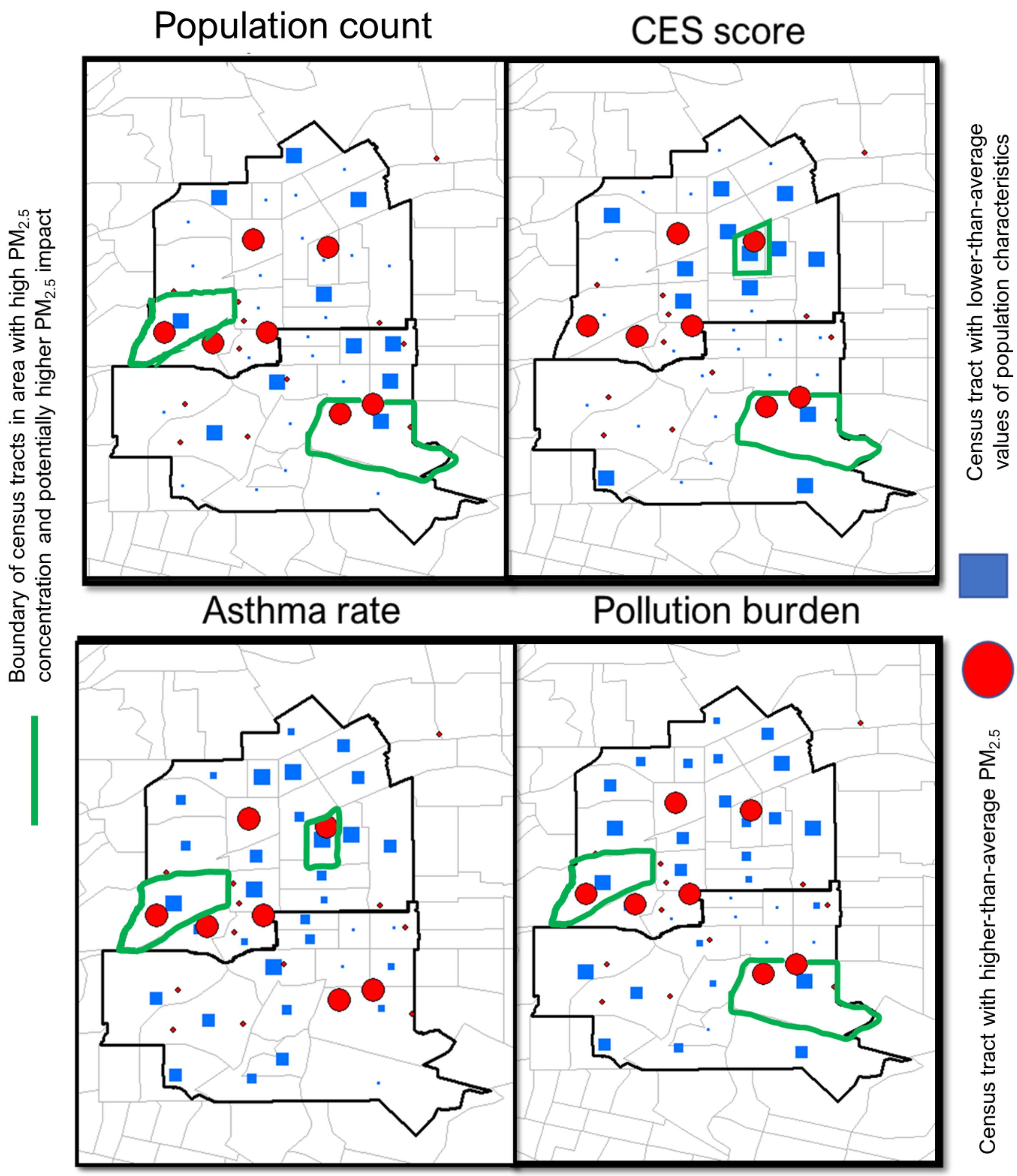


***Figure 14.*** *Population characteristics and $PM_{2.5}$ spatial distribution*

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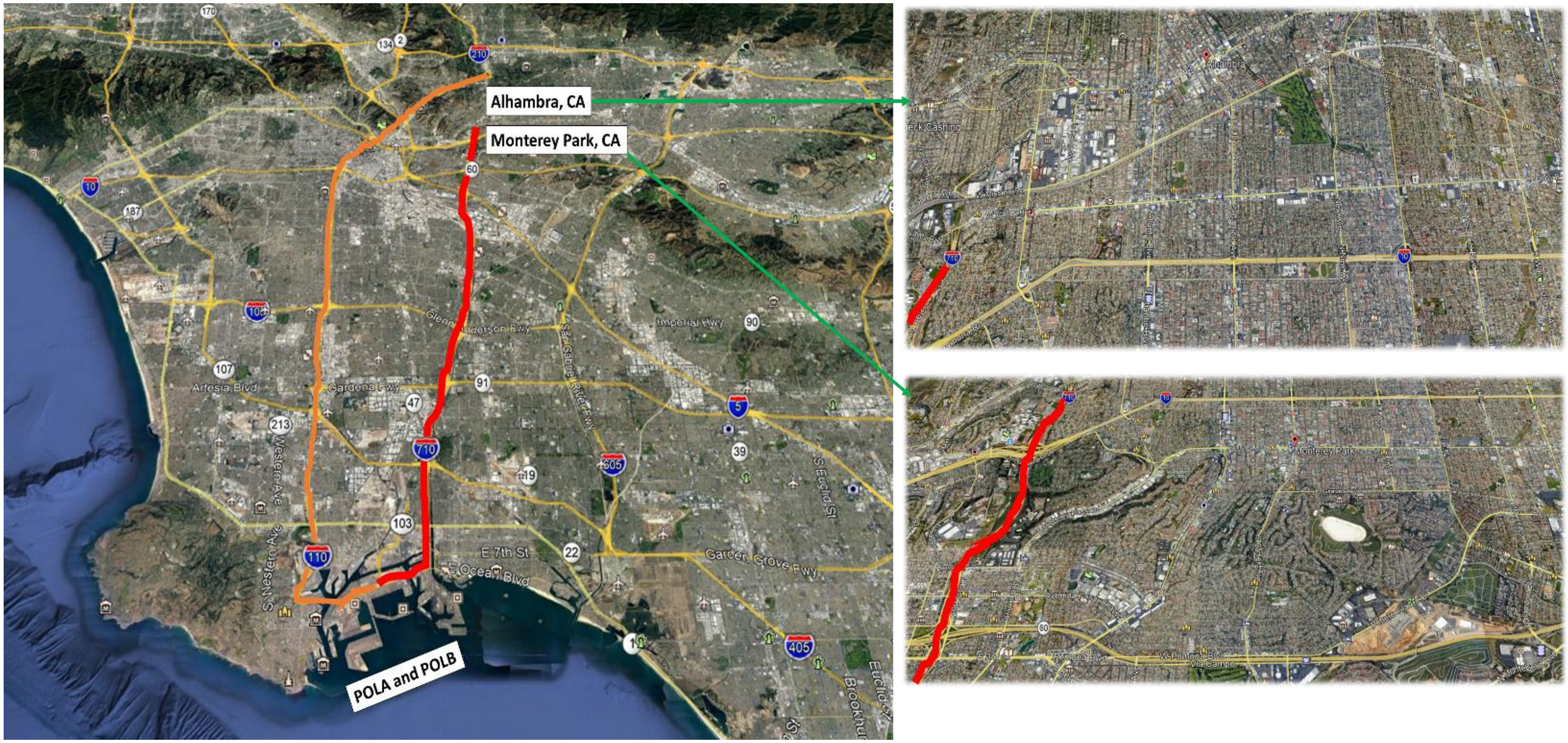
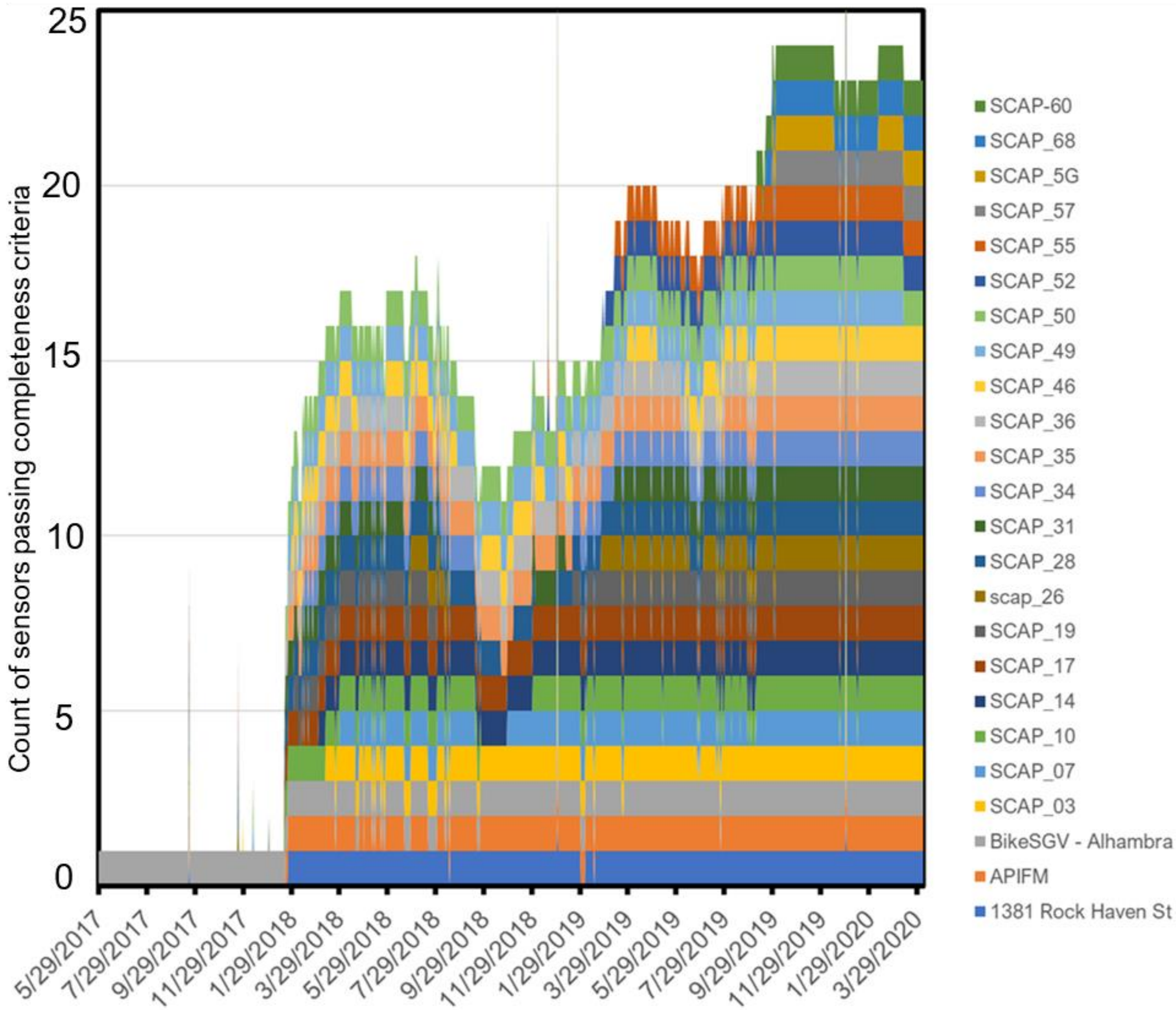
# APPENDIX




***Appendix Figure 1.*** *Locations Alhambra and Monterey Park in relation to Los Angeles County and major sources (POLA, POLB, and 110 and 710 freeways)*




***Appendix Figure 2.*** *Completeness of the outdoor sensor data during the study period.*