APPENDIX VII

MATES V

FINAL REPORT

Ultrafine Particle Measurements at Fixed Sites

Appendix VII

Ultrafine Particle Measurements at Fixed Sites

VII.1. Background

A summary of the average concentrations of ultrafine particles (UFPs) measured during MATES V at each site and basin-wide trends (e.g., diurnal and seasonal profiles) is presented in Chapter 5. This appendix provides additional detail to quantify the differences in seasonal and diurnal trends across sites in greater depth, compares MATES V sites and South Coast AQMD near-road monitoring sites, and discusses the potential causes for the observed differences. Additional details on the validation of this data set are also included in this appendix.

UFPs are emitted from nearly all fuel combustion processes, including diesel, gasoline, and jet engines. UFP nucleation and growth mechanisms are not fully understood, but it is clear that vehicle exhaust is a major contributor to UFPs in urban areas (Guo et al., 2020). Consequently, people living nearby highly trafficked roadways and other sources of combustion-related pollutants (e.g., airports, refineries, and railyards) may be exposed to high levels of UFPs in addition to other air toxics. UFPs have a relatively short lifespan and their concentrations are strongly dependent on local sources and atmospheric conditions. Thus, their number concentrations can vary significantly on short temporal and spatial scales (Kozawa et al., 2009; Shirmohammadi et al., 2017; Zhu et al., 2002a, b).

Primary emissions of ultrafine particles formed in the engine or tailpipe are mostly sub-micrometer agglomerates of carbonaceous material. These particles may also contain metallic ash (from lubricating oil additives and engine wear), hydrocarbons, and sulfur-containing compounds (Morawska et al., 2008). Ultrafine particles can also be formed as hot exhaust gases are expelled from the tailpipe, which subsequently cool and condense on existing particles or nucleate to form new particles. In addition to primary UFP emissions, secondary formation of UFPs resulting from photochemical reactions also contributes to total particle number concentrations. Secondary formation of UFPs depends strongly on the intensity of solar radiation and presence of precursor gases and thus is more important during the summer. Once emitted or formed, UFPs undergo dilution with ambient air and are subject to chemical reactions and physical processes such as evaporation, condensation, and coagulation.

VII.2. Data validation

The particle number concentration (PNC) data was downloaded from the instruments using USB drives on a weekly basis. One-minute time resolution data for each site were validated and examined for anomalies. Hourly average particle number concentrations were calculated for each station from the corresponding one-minute data only when the data recovery was 75% or higher (i.e., when more than 45 one-minute data within the hour were valid). The hourly data recoveries for each sampling location are provided in Figure VII-1, with all sites having data recoveries above 85%. The overall hourly data recovery for the ten MATES V sites was 95%.

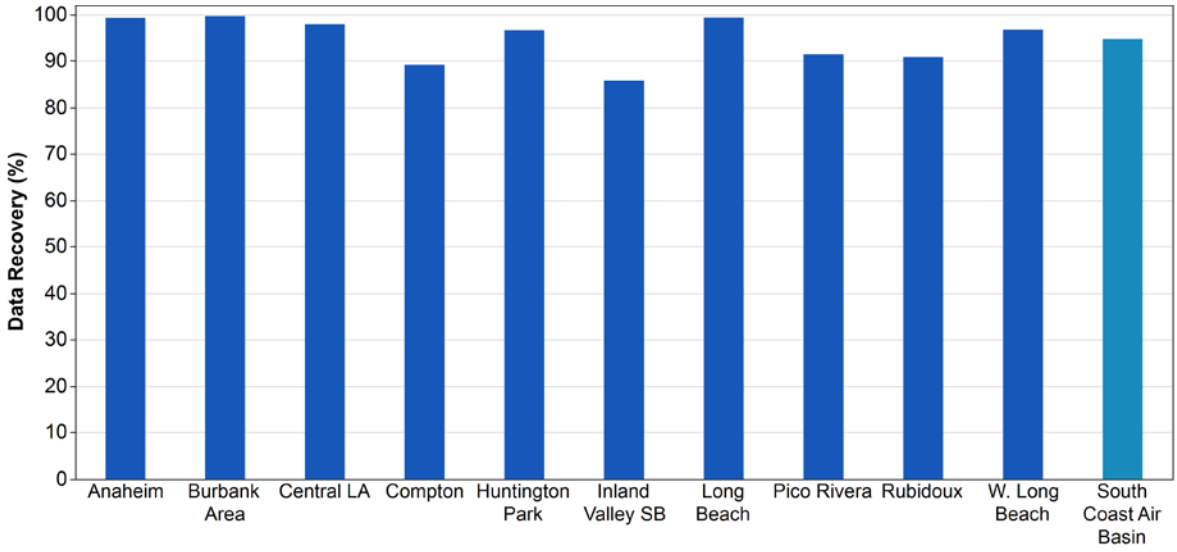

Figure VII-1: Data completeness for hourly ultrafine particle measurements during MATES V.

Three collocation studies were performed against a "Gold Standard" CPC (a reference instrument that was only used for collocation purposes) as a QA/QC check and to determine if correction factors should have been applied to the data to account for intra-model variations between CPC performances. These studies indicated that all ten site instruments were in good agreement with the "Gold Standard" CPC (i.e., high correlation coefficients with slopes close to one and small y-intercepts). Thus, no corrections were applied to the field data.

VII.3. Diurnal, day of week, and seasonal variations by site

Since UFP concentrations are highly spatially variable, it is important to consider the differences between sites. In MATES V, the highest average UFP levels observed for all seasons are in West Long Beach. In most instances, the highest average particle number concentrations at all sites are observed during the winter or summer months (see Chapter 5, Figure 5-5). In MATES IV, the highest UFP concentrations by season were consistently observed in the winter months. Average winter UFP concentrations have decreased for many sites with the exception of Anaheim, Inland Valley SB, and Rubidoux (Table VII-1 and Figure VII-2). Since UFP concentrations have mostly decreased during the winter from MATES IV to MATES V and summer concentrations have remained relatively constant, the summertime levels contributed more heavily to the annual average MATES V UFP concentrations compared to their contribution in MATES IV. This implies that secondary formation of UFPs may be playing a more prominent role in the overall UFP concentrations observed in the South Coast Air Basin.

Table VII-1. Average summer and winter UFP concentrations for MATES IV and MATES V for each site and overall MATES average.

	Average summer concentration (particles/cm^3)			Average winter concentration (particles/cm^3)		
Site	**MATES IV**	**MATES V**	**Change (%)**	**MATES IV**	**MATES V**	**Change (%)**
Anaheim	9877	11441	**15.8**	16768	17540	**4.6**
Burbank Area	16006	16353	**2.2**	17219	12024	**-30.2**
Central LA	16620	14097	**-15.2**	19676	16903	**-14.1**
Compton	13402	13816	**3.1**	17333	12408	**-28.4**
Huntington Park	22787	23055	**1.2**	28694	19387	**-32.4**
Inland Valley SB	16474	19964	**21.2**	12650	16085	**27.2**
Long Beach	15865	13333	**-16.0**	15968	14498	**-9.2**
Pico Rivera	15164	17634	**16.3**	20861	16635	**-20.3**
Rubidoux	8948	10859	**21.4**	13486	14615	**8.4**
W Long Beach	26303	25947	**-1.4**	27616	21923	**-20.6**
Overall	16145	16650	**3.1**	19027	16202	**-14.8**

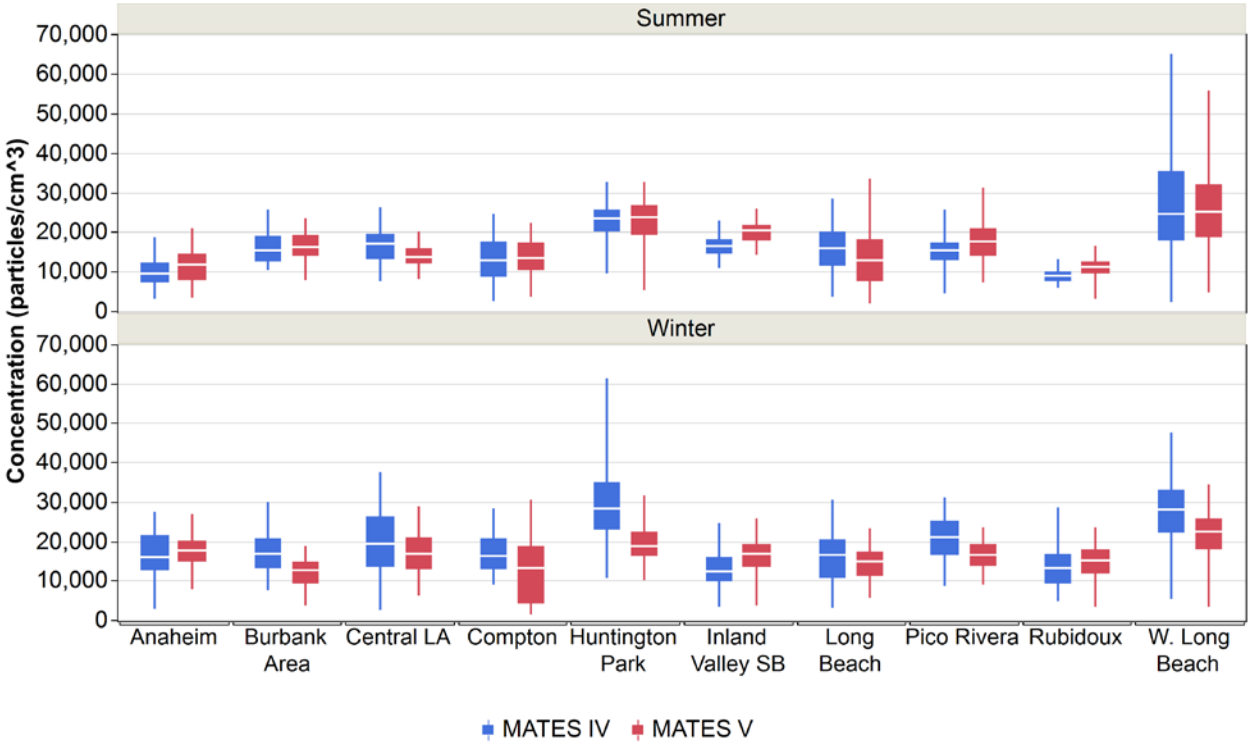

Figure VII-2. Daily average UFP concentrations for summer and winter seasons during MATES IV and V. Box plots show the daily average minimum, first quartile, median, third quartile, and maximum values.

Seasonal diurnal profiles show significant variation by site (Figures VII-3 and VII-4). For example, the summertime midday photochemical peak is more pronounced on the west side of the SCAB, with the exception of Burbank Area, and less distinct in the inland sites of Inland Valley San Bernardino and Rubidoux. Compton, Long Beach, West Long Beach, and Huntington Park show the largest midday peaks during the summer, exceeding the maximum hourly concentrations observed during the winter at these sites. The Inland Valley San Bernardino location did not reflect

the same seasonal trends as Rubidoux. At Inland Valley San Bernardino, a large broad peak begins in the early morning commute hours at 04:00, reaches a maximum at 14:00, and remains elevated during the evening. This is one of few sites where the summer evening particle number concentrations are higher than the winter evening concentrations. The photochemical peak was also in an earlier time frame compared to the other sampling locations. On the other hand, Rubidoux is the only site where the wintertime morning rush hour peak significantly exceeds the summertime midday peak. The UFP concentrations at Burbank show unique profiles where there is an increase in particle number in the early morning which persists throughout the day for all seasons. Generally, sites that show a prominent morning rush hour peak in the winter on the weekdays, do not show the same peak on the weekends (Figure VII-4). However, sites that show a large midday peak in the summer have equally large peaks on the weekdays and weekends. In fact, in Compton, the midday summer peak is larger on the weekends, further suggesting that secondary formation is important to particle number concentrations, especially during the summer when photochemical activity is the highest.

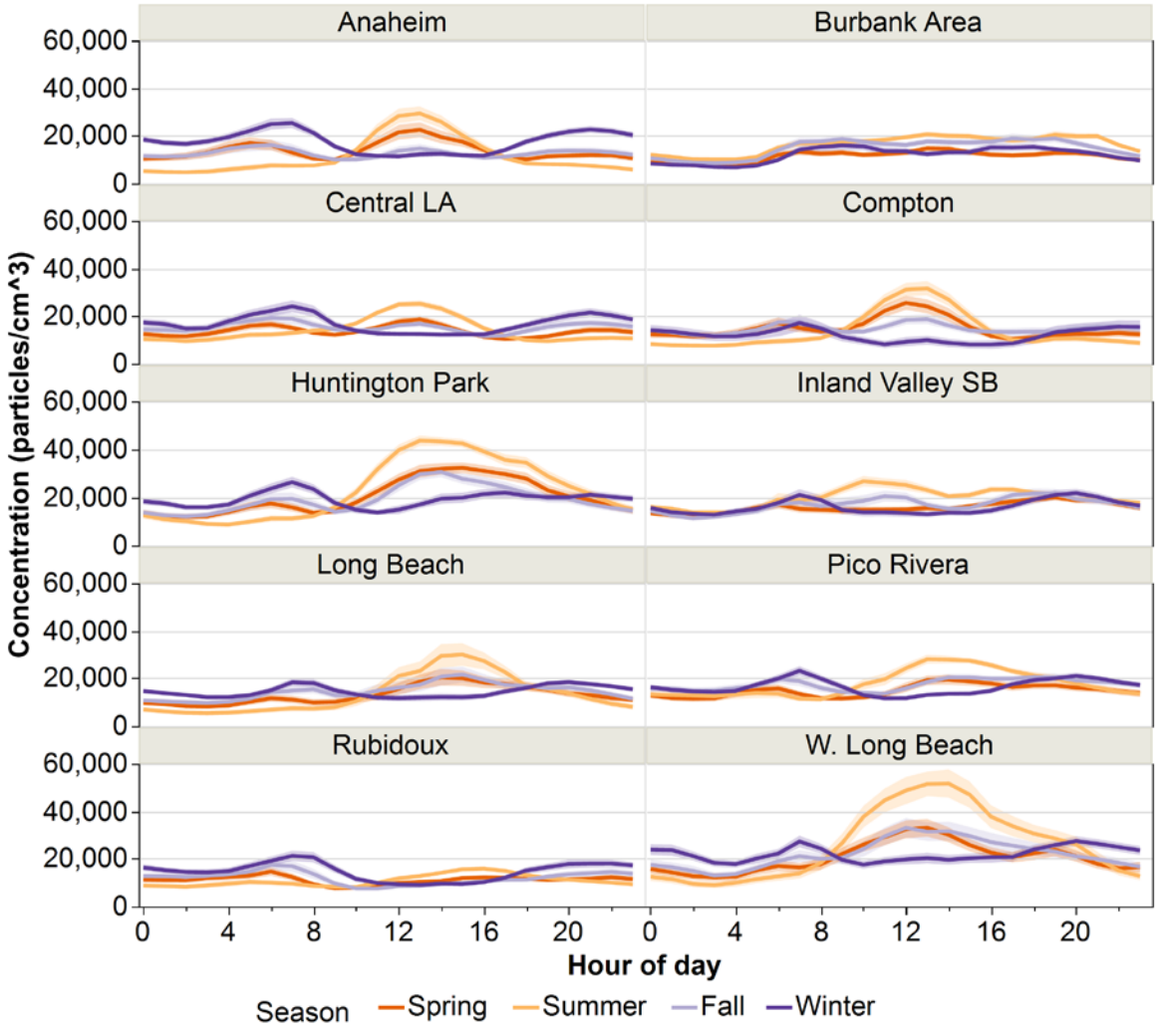

Figure VII-3 Seasonal diurnal profiles of ultrafine particle number concentration by site.

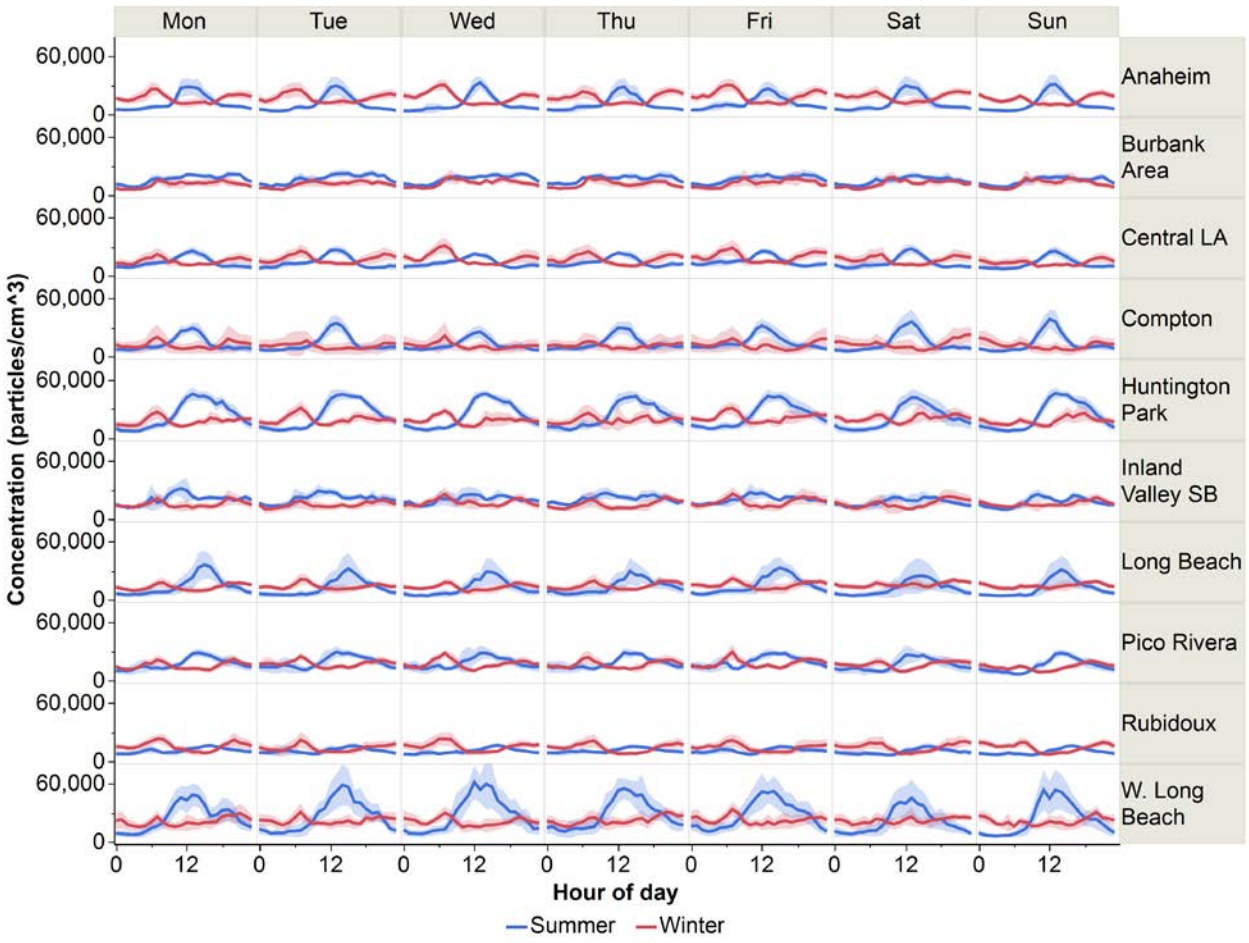

Figure VII-4. Summer and winter UFP diurnal profiles by day of week and site.

The seasonal polar time plots (Carslaw and Ropkins, 2012) in Figure VII-5 show the relative UFP concentration at each site organized by source direction and time of day. The polar angle of the data shows the direction from which that average concentration was observed and the distance from the center of each plot (0 – 23) indicates the hour of day. For example, the plots for Long Beach show that the highest average UFP concentrations during the MATES V period come from the northwest direction and usually occurs around midday for spring, summer, and fall. West Long Beach, despite the proximity of two major highways (Interstates 405 and 710) to the north and east, shows that the highest UFP concentrations in the summer come from the west around noon, with a consistent pattern during weekday and weekend, suggesting secondary particle formation when the predominant wind is westerly. Measurements of sulfur dioxide (SO_2), a potentially important precursor for new particle formation based on the available literature (Saha et al., 2018), also showed higher concentrations at this site during the summer around noon. The distribution of high concentrations seen at West Long Beach indicate the importance of wind direction and local sources to observed particle number concentrations. Some sites show that the direction (i.e., source) of highest UFP concentrations changes with season. For example, in Central Los Angeles, the highest concentrations in the summer come from the southwest direction around noon, suggesting a secondary source. However, the highest concentrations in the fall and winter come

from the northeast in the early morning and evening, suggesting a traffic-related source. Overall, variations in UFP concentrations based on season and time of day depend on site location, meteorology, and the proximity/location of UFP sources and their precursors.

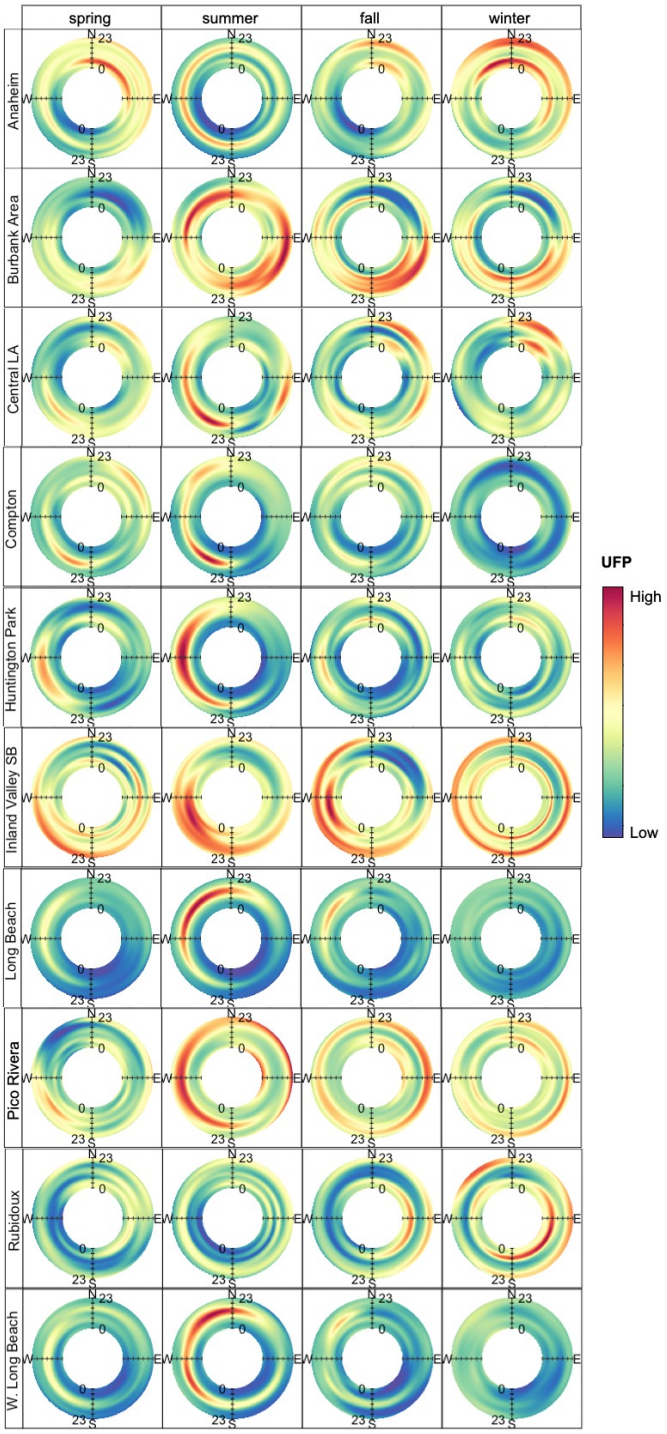

Figure VII-5. Polar time plots of relative UFP concentration by site and season.

VII.4. Comparison with near road sites

In addition to the MATES V sites, South Coast AQMD operates several near-road monitoring stations where ultrafine particles are measured. These sites include near-road stations in Ontario near CA-60 (60 NR), Anaheim near I-5 (Anaheim NR), Ontario near I-10 (Ontario NR), and Long Beach near I-710 (W710). UFP concentrations measured during the MATES V period for the near road monitoring stations are significantly elevated compared to the ten MATES V designated sites (Fig. VII-6). Average concentrations measured at these near-road stations are nearly twice that measured at the MATES V sites. The near-road sites also measured much higher maximum values compared to the MATES V sites, with hourly concentrations in some cases exceeding 100,000 particles per cubic centimeter (W710). These measurements provide further evidence that traffic emissions are major sources of UFPs (Sowlat et al., 2016; Zhu et al., 2002a, b).

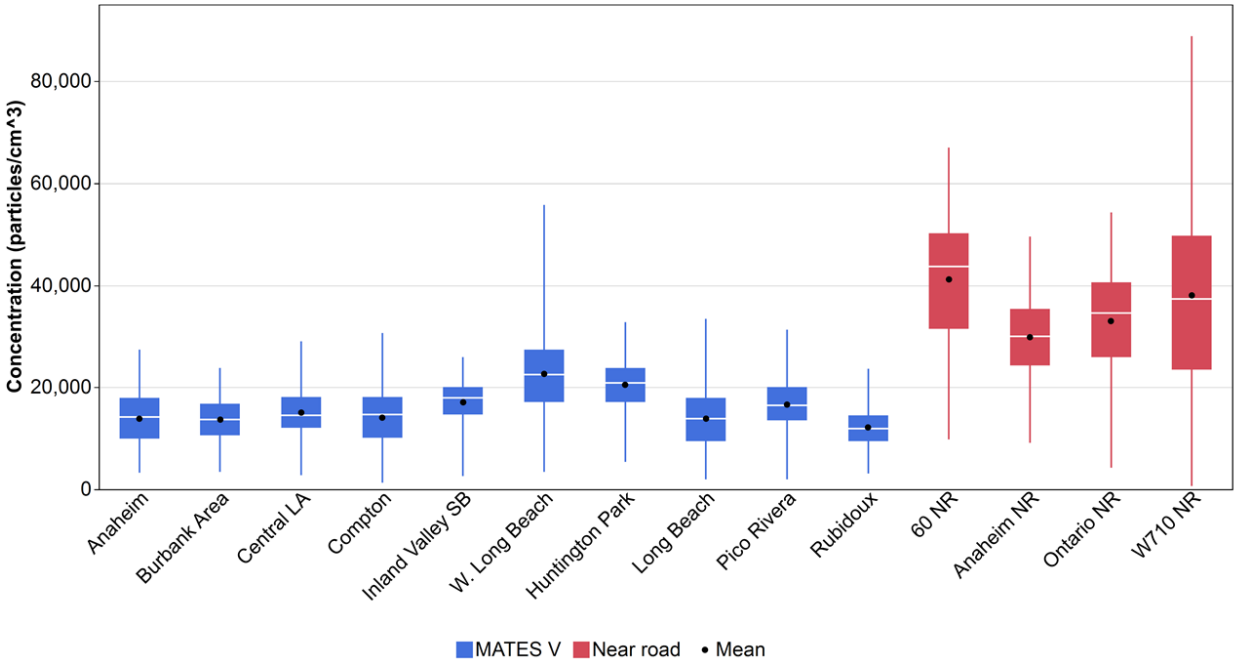

Figure VII-6. Comparison of UFP concentrations for MATES V sites (blue) and near-road sites (red). Box plots showing the minimum, first quartile, median, third quartile and maximum values observed at each site with outliers removed. Mean values for each site are marked with a black circle.

VII.5. Correlations between sites

Many factors contribute to ultrafine particle formation, including emissions, meteorology, and chemistry. Previous studies have also showed that UFP concentrations show high spatial variability, with very high levels near sources such as major highways, and decreasing steeply with distance from that source (Zhu et al., 2002 a, b). Therefore, it is not surprising that the ten sites studied for MATES V show significantly different UFP concentrations on a day-by-day basis. Figure VII-7 shows the coefficient of determination (r^2) matrix between the daily UFP concentrations at each site as a measure of their similarity. All r^2 values are 0.51 or below, with several sites showing little to no correlation with each other. The highest value observed is between West Long Beach and Long Beach, sites that are close in proximity to each other. In general,

Burbank Area, Compton, and Inland Valley San Bernardino show very low r^2 values with the other sites. Other sites typically show more intermediate r^2 values from 0.2 – 0.4.

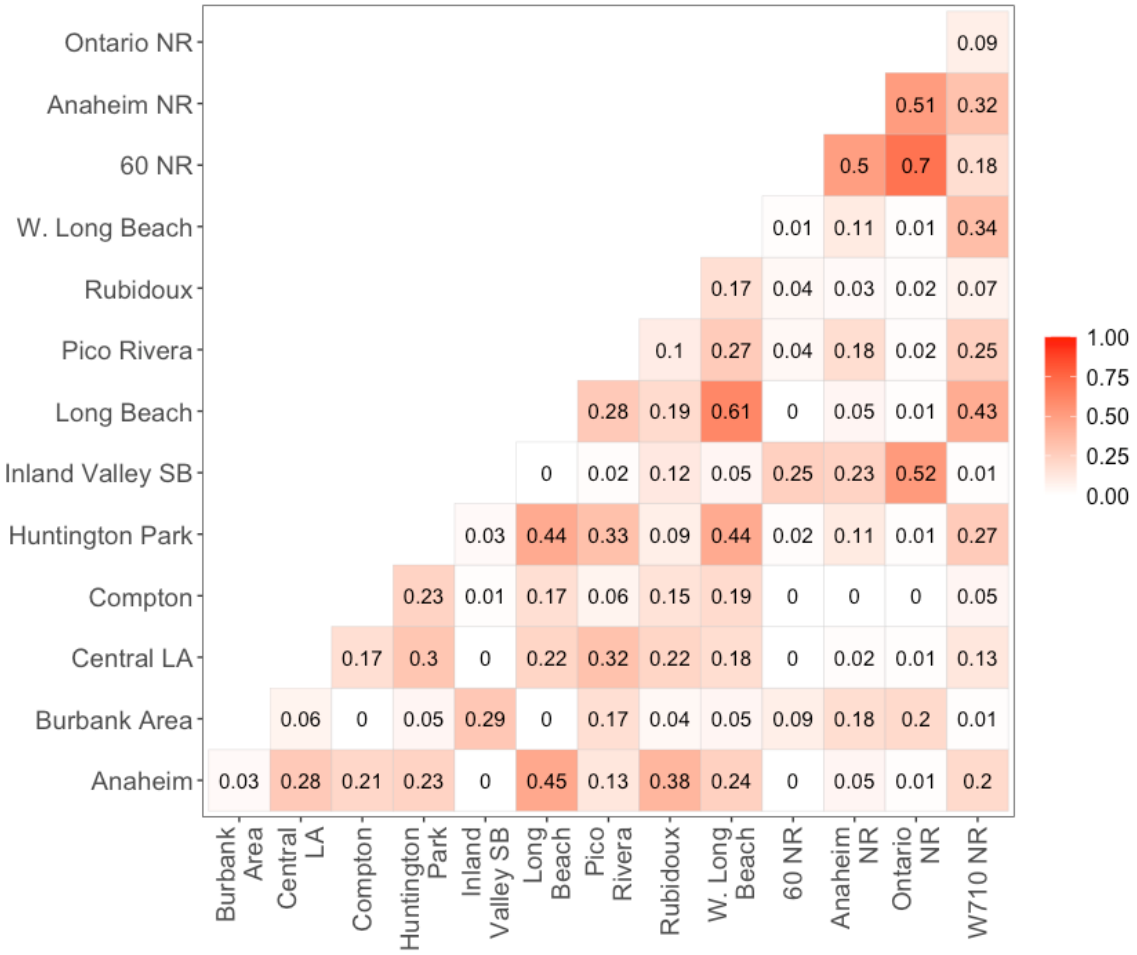

Figure VII-7. Coefficient of determination (r^2) matrix for MATES V and near-road sites.

The variability shown here at regionally representative sites emphasizes the heterogeneity of UFPs in the Basin and the impact of the proximity to nearby sources and precursors on measured UFP concentrations. As there is continued interest in studying the health effects of UFPs and continued research to develop improved modeling techniques to estimate long-term UFP exposures, the fixed-site monitoring data from the MATES program can help inform those efforts by providing year-long data in these locations, repeated over time.

In areas impacted by multiple sources of UFP emissions or its precursors, measurements with higher spatial resolution would be important to better quantify and characterize community UFP exposures. This can be achieved by conducting measurements at multiple sites or combining stationary and mobile monitoring to improve the characterization of UFPs.

VII.6. Summary

Continuous real-time UFP measurements collected at ten South Coast AQMD monitoring sites during MATES V show high temporal and spatial variability. Generally, wintertime concentrations

of UFPs have decreased (15% decrease in SCAB average) between the MATES IV (July 2012 – June 2013) and MATES V (May 2018 – April 2019) periods; however, summertime concentrations have either remained constant or increased (3% increase in SCAB average). This suggests the growing importance of secondary particle formation to UFP concentrations in the Basin. Diurnal and seasonal profiles vary significantly across sites. A variety of factors, such as the distance to the nearest emission source, type of emission source, traffic volume, wind speed, wind direction, relative humidity, and temperature (among other factors), can all influence the concentration, composition, and dispersion of UFPs. Furthermore, incorporating wind direction data shows that the sources that most impact UFP concentrations at a given site can change throughout the day and over the seasons. Measurements of UFPs at near-road sites are relatively new and show significantly higher UFP concentrations relative to the MATES sites, emphasizing that traffic is still a major source of UFPs. Continued measurements are needed to make robust conclusions on the long-term trends and spatial patterns of UFPs (Presto et al., 2021). Although our understanding of UFPs is increasing, additional information about UFP sources, precursors, and exposures would help improve the understanding of this type of pollution in the South Coast Air Basin.

VII.7. References

Carslaw, D.C., Ropkins, K. (2012) “openair – An R package for air quality data analysis”, Environmental Modeling & Software. Volume 27-28, 52-61.

Guo, S., Hu, M., Peng, J., Wu, Z., Zamora, M. L., Shang, D., Du, Z., Zheng, J., Fang, X., Tang, R., Wu, Y., Zeng, L., Shuai, S., Zhang, W., Wang, Y., Ji, Y., Li, Y., Zhang, A., Wang, W., Zhang, F., Zhao, J., Gong, X., Wang, C., Molina, M., Zhang, R. (2020) “Remarkable nucleation and growth of ultrafine particles from vehicular exhaust”, Proceedings of the National Academy of Sciences, 117(7), 3427–3432.

Kozawa, K. H., Fruin, S. A., & Winer, A. M. (2009) “Near-road air pollution impacts of goods movement in communities adjacent to the Ports of Los Angeles and Long Beach”, Atmospheric Environment, 43(18), 2960–2970.

Morawska, L., Ristovski, Z., Jayaratne, E.R., et al (2008) “Ambient nano and ultrafine particles from motor vehicle emissions: characteristics, ambient processing and implications on human exposure”, Atmospheric Environment, 42: 8113-8138.Presto, A.A., Saha, P.K., Robinson, A.L. (2021). Past, Present, and Future of Ultrafine Particle Exposures in North America. Atmospheric Environment: X, https://doi:org/10.1016/j.aeaoa.2021.100109.

Saha, P.K., Robinson, E.S., Shah, R.U., Zimmerman, N., Apte, J.S., Robinson, A.L., Presto, A.A. (2018). “Reduced Ultrafine Particle Concentration in Urban Air: Changes in Nucleation and Anthropogenic Emissions”, Environmental Science and Technology, 52 (12) 6798 – 6806.

Shirmohammadi, F., Sowlat, M. H., Hasheminassab, S., Saffari, A., Ban-Weiss, G., & Sioutas, C. (2017) “Emission rates of particle number, mass and black carbon by the Los Angeles

International Airport (LAX) and its impact on air quality in Los Angeles", Atmospheric Environment, 151, 82–93.

Sowlat, M. H., Hasheminassab, S., Sioutas, C. (2016) "Source Apportionment of Ambient Particle Number Concentrations in Central Los Angeles Using Positive Matrix Factorization (PMF)", Atmos. Chem. Phys. 16 (8), 4849–4866.

Zhu, Y., Hinds, H.C., Kim, S., et al. (2002a) "study of ultrafine particles near a major highway with heavy-duty diesel traffic", Atmospheric Environment, 36 (27): 4323-4335.

Zhu, Y., Hinds, H.C., Kim, S., et al (2002b) "Concentration and size distribution of ultrafine particles near a major highway", Journal of Air and Waste Management Association, 52: 1032-10.