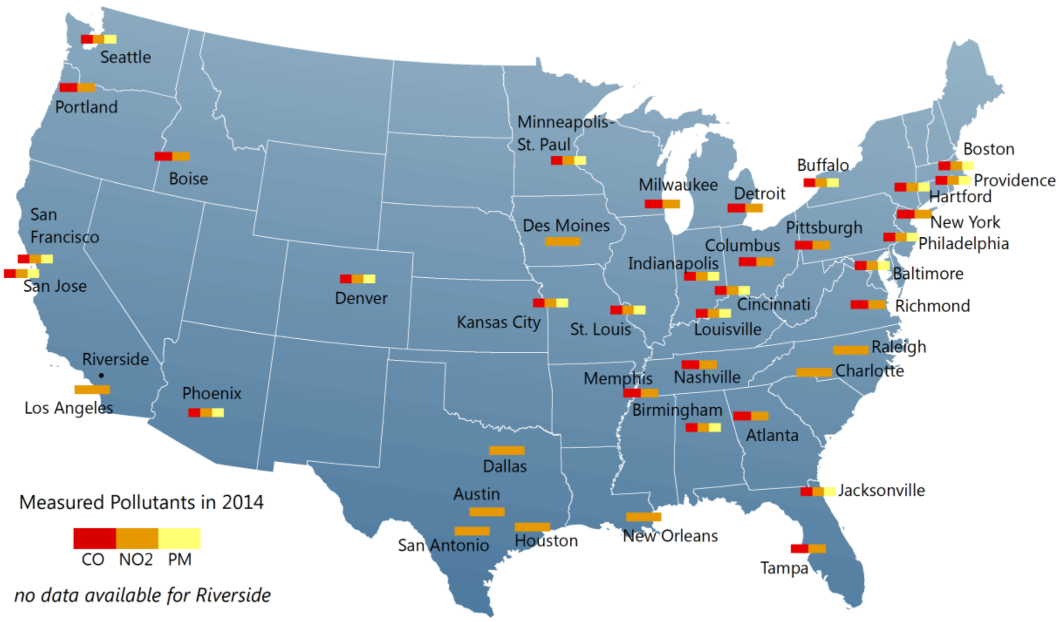
National Near-Road Data Assessment: Report No. 1



Interim Final Report Prepared for

Washington State Department of Transportation
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Lead Agency for the Near-Road Air Quality Research Transportation Pooled Fund, TPF-5(284)

May 2015

Sonoma Technology, Inc.
Environmental Science and Innovative Solutions

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Interim Final Report

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Cover graphic illustrates data available from the U.S. Environmental Protection Agency's (EPA's) Air Quality System (AQS) database from near-road monitoring sites at the time of this report. See Section 2 for details.

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Acknowledgments

The authors would like to acknowledge the assistance of Nealson Watkins with the U.S. Environmental Protection Agency (EPA) for supplying summary information on official near-road monitoring sites.

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Abstract

The work presented here was completed as part of the Near-Road Air Quality Research Pooled Fund, TPF-5(284), under the U.S. Federal Highway Administration (FHWA) Transportation Pooled Fund Program. The lead agency for TPF-5(284) is the Washington State Department of Transportation. Other participants include the FHWA and the Arizona, California, Texas, and Virginia Departments of Transportation. Sonoma Technology, Inc. (STI) provides TPF-5(284) participants with technical, planning, facilitation, and website support.

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Background: The U.S. Environmental Protection Agency (EPA) has mandated air quality monitoring next to selected major roadways throughout the United States; monitoring began in phases during 2012–2015 and included nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter (PM). The objective of this study was to obtain, summarize, and interpret data from the national near-road monitoring program. This report is the first in a series that will provide a digest of findings from around the United States and (in subsequent work phases) highlight and examine situations where relatively high near-road pollutant concentrations have been observed.

Methods: Routine near-road air quality data were collected by monitoring agencies in 2014 and stored in the EPA's Air Quality System (AQS) database. STI gathered and processed the 2014 data, and conducted a national-scale review of near-road air pollutant concentrations. The data collected included NO_2, CO, and $PM_{2.5}$ from official near-road monitoring sites. These data were quality controlled by the air monitoring agency, and in May 2015, they were certified by the states as final. STI gathered state-reported annual average daily traffic (AADT) and fleet mix characteristics of the major roads associated with each of the official near-road monitoring sites. We then evaluated if and where high concentrations of NO_2, $PM_{2.5}$, and CO occurred, and how concentrations varied by factors such as location, distance to roadway, and traffic volume. We also obtained and assessed NO_2 and $PM_{2.5}$ data from other state- or locally-operated routine monitoring sites that, though not officially in the EPA-mandated near-road measurement program, are within 50 m of major roads.

Results: As of May 2015, sites in 40 of the 41 urban areas covered by the first phase of the EPA's mandate reported NO_2 data to AQS; only Riverside, California, data had yet to be reported. Of the 40 areas reporting 2014 data, 29 reported at least three full quarters of NO_2 data; 13 of the 40 areas also reported at least three quarters of $PM_{2.5}$ data; six other areas reported limited $PM_{2.5}$ data. There were two 1-hr daily maximum NO_2 concentrations, and five hourly observations total, above 100 ppb; these values were measured at the George Washington Bridge (GWB) in New York/New Jersey during August 2014. Sites in Cincinnati and Indianapolis recorded $PM_{2.5}$ annual averages greater than 12 µg/m^3, and sites in Baltimore and Louisville recorded $PM_{2.5}$ annual averages equal to 12 µg/m^3. There were 15 days in 2014 when near-road sites measured 24-hr $PM_{2.5}$ concentrations above 35 µg/m^3. However, none of the sites had a 98th percentile of 24-hr $PM_{2.5}$ concentrations greater than 35 µg/m^3.

1. Introduction

1.1 Overview

The U.S. Environmental Protection Agency (EPA) has mandated air quality monitoring next to major roadways throughout the United States; monitoring began in phases during 2012–2015 (U.S. Environmental Protection Agency, 2010; 2012). Monitoring includes nitrogen dioxide (NO_2) and at some sites also includes carbon monoxide (CO), particulate matter (PM), air toxics, and ultrafine particles (UFP). These data will be used by the EPA to verify that the National Ambient Air Quality Standards (NAAQS) are being met in areas where peak pollutant concentrations are expected to occur within the near-road environment. The EPA and others will also use these data for research purposes to evaluate the relationship between near-road pollutant concentrations and traffic volumes, fleet mix, and travel speeds. In addition to the EPA-mandated near-road monitoring, several near-road research studies have been completed in recent years in various U.S. cities; during these studies, near-road air quality data have been collected that represent different geographic locations, vehicle fleets, time periods, and other variables. Data from monitors collecting routine air quality measurements within a few hundred meters from a major road offer the opportunity to investigate the relationship between near-road pollutant concentrations and traffic.

The objective of this study is to obtain, summarize, and interpret data from the national near-road monitoring program, from other air quality sites next to major roadways, and from selected special-purpose near-road studies. This report is the first in a series that will provide a digest of findings from the study for monitoring sites around the United States and (in the next work phase) highlight and explain situations where relatively high near-road pollutant concentrations have been observed. The results generated in this work will help Transportation Pooled Fund (TPF) partners understand measured near-road concentrations, trends, and conditions that lead to high-concentration events. This report is for research purposes and should not be used for determining attainment status. Although the report includes comparisons of ambient data to NAAQS, these comparisons are included to provide context for the data collected to date; findings are not appropriate for use as a measure of attainment status of particular sites. Note also that states are at varying stages of near-road monitoring implementation and, in many cases, sites have not collected sufficient data to support NAAQS attainment calculations by the EPA or the states.

In this initial study, we gathered routine near-road air quality data collected in 2014 and conducted a national-scale review of near-road air pollutant concentrations. Specific steps included the following:

- Assembled air quality data from official near-road monitoring sites. These data are quality controlled by the air monitoring agency and were certified in May 2015 as being final for 2014.
- Collected state-reported annual average daily traffic (AADT) and fleet mix characteristics of official near-road monitoring sites.

- Identified and obtained data from other state- or locally operated routine monitoring sites that, though not officially in the EPA-mandated near-road measurement program, are within 50 m of major roads and are generating readily available near-road air quality measurements.
- Performed a national-scale analysis of official near-road monitoring network data to determine if/where high concentrations of NO_2, $PM_{2.5}$, and CO occurred and how concentrations varied by location, distance to roadway, weekday/weekend, and traffic volume.
- Documented findings.

In addition, we were able to complete initial work on a portion of the effort planned for Phase 2 of the overall project. We identified and began to assemble data sets from special near-roadway studies. This work includes the following studies: (1) STI-NDOT US 95 study, with black carbon (BC), NO_2, and air toxics data from Las Vegas, Nevada; (2) EPA/ Federal Highway Administration (FHWA) I-15 study, with BC, PM, NO_2, and air toxics data from Las Vegas; (3) South Coast Air Quality Management District (SCAQMD) Highway I-710 study, with NO_2 data from southern California. These data may be further evaluated as part of Phase 2 or Phase 3 of the overall project.

1.2 Background

The EPA promulgated near-road air quality monitoring requirements in 2010 at the same time that the agency revised the NAAQS[1] for NO_2 (U.S. Environmental Protection Agency, 2010). Monitoring requirements were revised in 2013 to extend deadlines for initiating near-road NO_2 monitoring (U.S. Environmental Protection Agency, 2013b). Monitoring near major roadways in cities across the U.S. initially focused on NO_2 but additional CO and $PM_{2.5}$ requirements were added during NAAQS rulemakings (U.S. Environmental Protection Agency, 2011; 2013a). The EPA adopted a phased implementation plan with the first set of sites to be operational by January 1, 2014; subsequent sites are to be added by early 2015 and 2017. A small subset of the sites also measure air toxics, BC, and UFP (see **Table A-1**); however, there are no requirements to monitor these compounds. This report refers to EPA-required near-road monitoring sites as “official” near-road sites to distinguish them from sites established outside the near-road monitoring requirements.

As shown in near-road monitoring studies conducted in Las Vegas, Los Angeles, and elsewhere, air pollutants such as BC, CO, and PM are measurably greater near roadways than elsewhere in the urban environment [see Roberts et al. (2010), Karner et al. (2010), and Zhu et al. (2002), for example]. Studies have shown that pollutant concentrations can be many times greater within 150 m (approximately 500 feet) of a major roadway, decreasing rapidly with increasing distance from the roadway, and that the concentrations of certain pollutants (such as BC) in the near-road setting are

[1] With its 2010 NO_2 NAAQS revision, the EPA augmented the existing annual standard of 53 ppb, calculated as the annual arithmetic mean, with a 1-hr NAAQS of 100 ppb. Compliance with the 1-hr NO_2 NAAQS is determined by calculating the 98^{th} percentile of all the daily maximum 1-hr concentrations in a year, and then averaging three consecutive years of these 98^{th} percentile values with the averaged value not to exceed 100 ppb.

heavily influenced by truck emissions (see Figure 1). The literature also shows that at night during calm wind conditions, roadway-related pollutants can be detected at distances as great as 1,100 m (3,600 feet) from a major road (Hu et al., 2009).

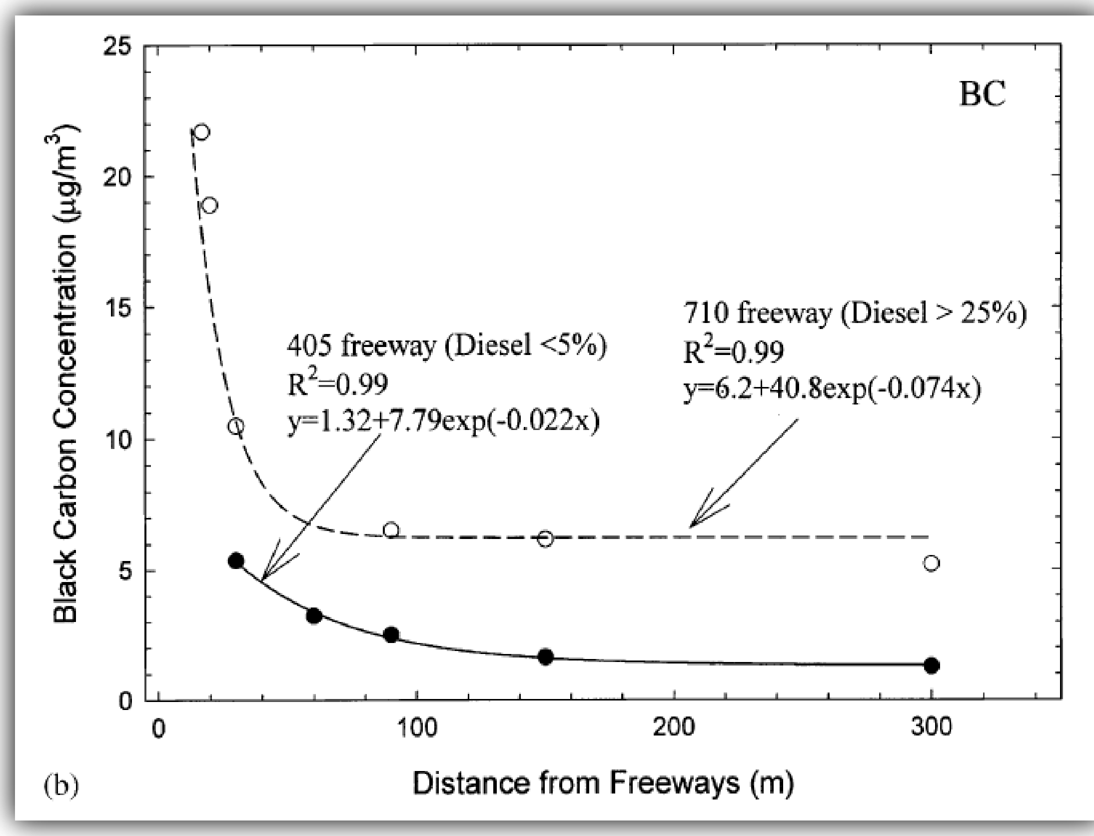


Figure 1. Decrease in BC concentrations at increasing distances from the I-405 and 710 freeways in Los Angeles [reproduced from Zhu et al. (2002)].

State and local air monitoring agencies are required to install near-road NO_2 monitoring stations at locations where peak hourly NO_2 concentrations are expected to occur. Agencies must consider traffic volumes, fleet mix, roadway design, traffic congestion patterns, local terrain or topography, and meteorology in determining placement of a required near-road NO_2 monitor. Additional factors to consider in locating a near-road monitoring station include site logistics (such as access and safety) and population exposure. The EPA provided extensive guidance on site selection and implementation (U.S. Environmental Protection Agency, 2012), including information on optional multi-pollutant monitoring. The guidance suggested

> *...the monitor probe shall be as near as practicable to the outside nearest edge of the traffic lanes of the target road segment; but shall not be located at a distance greater than 50 meters, in the horizontal, from the outside*

nearest edge of the traffic lanes of the target road segment... [The EPA] recommends that the target distance for near-road NO_2 monitor probes be within 20 meters of the target road whenever possible.

The EPA established a near-road monitoring implementation phase-in schedule based on the populations of the Core Based Statistical Area (CBSA) for each city, as well as the AADT on road segments. **Table 1** summarizes the implementation phases for the near-road monitoring, and **Figure 2** shows where each phase of monitoring was proposed. More than 50 NO_2 sites and 30 sites with CO and $PM_{2.5}$ were required to be operating by the end of 2014. Most Phase 1 and 2 sites became operational sometime in 2014. Data are required to be uploaded to the EPA's Air Quality System (AQS—the national data repository for air quality monitoring) within three months of the end of each quarter. As of May 2015, when data to complete this report were accessed, all sites except the Riverside, California monitor were reporting NO_2, although some had missing or incomplete data for parts of 2014. Data availability is described in further detail in Section 2.

Table 1. Summary of EPA-required implementation phases for near-road monitors (Watkins, 2015).

Phase	CBSA Population and/or AADT	NO_2	CO and $PM_{2.5}$
Phase 1	>= 1M	Jan. 1, 2014	Jan. 1, 2015 (CBSA >= 2.5M) or Jan. 1, 2017 (CBSA >= 1M)
Phase 2	>= 2.5M, or AADT >= 250k	Jan. 1, 2015	
Phase 3	500k – 1M	Jan. 1, 2017	

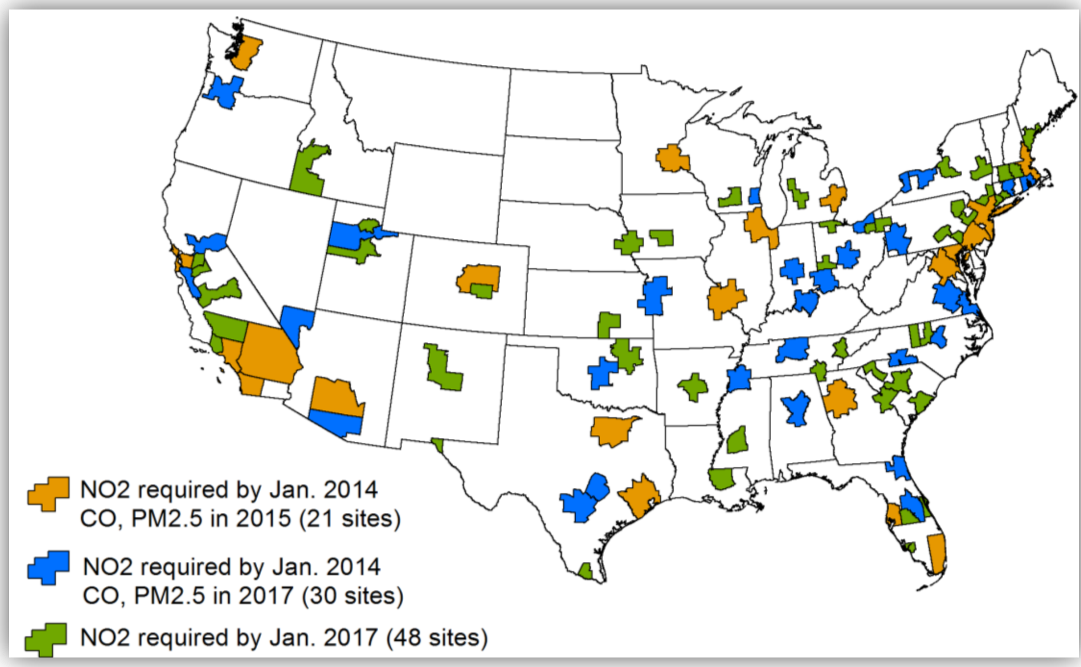


Figure 2. Expected locations (CBSA) for near-road NO_2 monitors in 2014–2017, with collocated CO and $PM_{2.5}$ monitors in 2015 (orange) and 2017 (blue). Note that the locations are not yet finalized. Figure based on Watkins (2015).

In addition to air quality measurements collected at EPA-required near-road monitoring stations, near-road measurements have been collected during several research studies to represent different geographic locations, vehicle fleets, time periods, and other variables. In addition, some agencies operate monitoring stations that routinely collect air quality data within a few hundred meters of a major road. We obtained and evaluated data from routine monitoring and research efforts.

Pollutant concentrations measured at near-roadway monitors consist of background pollution plus an incremental contribution from the adjacent roadway. Analysis of near-road data alone is insufficient to estimate roadway contributions; analysis must also estimate the regional background concentration and subtract that concentration from the near-road measurement. Therefore, we plan to examine case studies and quantify roadway increments for selected high-concentration events in a future work phase.

1.3 Highlights

Highlights from the study include:

- As of May 2015, NO_2 data for sites in 40 CBSAs were reported in the EPA's AQS; only the Riverside, California data have not yet been reported. About half of these sites did not report data for the first half of 2014, yielding an inconsistent data record for 2014 across all sites. We expect to have a more consistent and robust data record for 2015.

- As of May 2015, of the 40 CBSAs with sites reporting NO_2 data to AQS, 15 CBSAs had reported a full year of NO_2 data, and another 14 had reported three full quarters of data for 2014. For $PM_{2.5}$ data, 10 of the 40 CBSAs reported a full year of data for 2014; three additional CBSAs reported at least three full quarters of data. Six other CBSAs had $PM_{2.5}$ data for fewer than three full quarters in 2014.

- As of May 2015, two 1-hr daily maximum NO_2 concentrations, and five hourly observations total, were above 100 ppb; these values were measured at George Washington Bridge (GWB) in New York/New Jersey during August 2014. Only two quarters of NO_2 data were available at the GWB site at the time of this report.

- Sites in Cincinnati (two monitors) and Indianapolis recorded $PM_{2.5}$ annual averages greater than 12 µg/m^3; in addition the Baltimore and Louisville sites recorded $PM_{2.5}$ annual averages equal to 12 µg/m^3. The Baltimore site had incomplete data for 2014. In 2014 across all sites reporting $PM_{2.5}$ data, there were 15 days when 24-hr $PM_{2.5}$ concentrations were above 35 µg/m^3. For example, in Denver, 24-hour $PM_{2.5}$ concentrations greater than 35 µg/m^3 were observed at the I-25 near-road site on February 7 (35.4 µg/m^3), 9 (44.4 µg/m^3) and 10 (57.0 µg/m^3) of 2014. However, none of the sites recorded a 98th percentile of 24-hr $PM_{2.5}$ concentrations greater than 35 µg/m^3.

- CO concentrations were typically 1 ppm or less.

1.4 Guide to This Report

Section 2 of this report provides an overview of the technical approach used to identify, acquire, process, and analyze air pollutant concentration data and traffic information. Analysis results are described in Section 3 of this report, followed by conclusions in Section 4. Appendix A details data available by site, and Appendix B shows time series plots of $PM_{2.5}$ at each site for data available during 2014.

2. Technical Approach

2.1 Overview

We assembled air quality data for the near-road monitoring locations, and we put concentrations in a national context by developing high-level summary statistics of the national data set. These data were acquired from the EPA's Air Quality System (AQS), and have been quality assured (QA'd) by each air monitoring and reporting agency; data for 2014 were certified by the states as final on May 1, 2015, and data were acquired on May 14. We also obtained supplemental information to further highlight high-concentration occasions at two locations. High NO_2 concentrations were observed near the George Washington Bridge (GWB) in the New York/New Jersey CBSA; the site is at the toll plaza on the New Jersey side, but in this report we use the CBSA designation of "New York." High $PM_{2.5}$ concentrations were observed adjacent to Highway I-25 in Denver, Colorado.

2.2 Data Acquisition

We assembled the following data sets:

- **Data collected at official near-road monitoring sites since the EPA near-road measurement requirement took effect**. Air quality and meteorological data from official EPA-designated near-road monitoring sites, as documented in epa.gov/ttnamti1/nearroad.html, were acquired via the EPA's AQS and assembled into a database. We acquired data reported to AQS through May 2015. Data will be updated quarterly in subsequent work phases.
- **Routinely measured air quality data within 50 m of a major roadway**. These data were used to supplement the official near-road monitoring results; they were obtained through AQS by completing the following steps:
    1. Identify sites with $PM_{2.5}$, PM_{10}, NO_2, CO, NATTS, NCORE, BC, UFP, benzene.
    2. Cross-reference site locations with proximity to the edge of the closest freeway lane, identifying those within 50 m.
    3. Confirm that each site identified in Step 2 had sufficient data to be useful (i.e., it is active now, or has multiple years of data available).
    4. Visually inspect maps of each site that passed Steps 2 and 3 to confirm location and distance from the edge of the roadway.
    5. For each site, pull air quality and meteorology data (temperature, wind speed, wind direction) starting in 2009. Air quality data were pulled for $PM_{2.5}$, PM_{10}, NO_2, NO, NOx, NO_y, CO_2, CO, EC, OC, BC, UFP, benzene, formaldehyde, acetaldehyde, acrolein, 1,3-butadiene, toluene, and ozone (O_3).

In addition, we were able to advance to some of the work planned for Phase 2 of the project. We began assembly of

- **Readily available special-purpose near-road measurements collected under the sponsorship of public agencies.** These data were obtained from
  - STI-NDOT US 95 study, with BC, NO_2, and air toxics data from Las Vegas, Nevada
  - EPA/FHWA I-15 study, with BC, PM, NO_2, and air toxics data from Las Vegas
  - South Coast Air Quality Management District (SCAQMD) I-405 and I-710 studies, with BC, PM, and NO_2

We will complete the task of assembling special study data during Phase 2. We plan to also obtain data from an EPA I-40 study in Raleigh, North Carolina (BC, PM, and NO_2) and an EPA/FHWA I-96 study in Detroit, Michigan (PM, BC, NO_2, air toxics, and UFP).

This report focuses on data available within AQS that were collected at official near-road sites; these sites are listed in Table 2. The monitoring locations encompass major urban areas across the United States. Populations are between 500,000 and 10 million people at most locations, 15 million at Los Angeles, and 20 million at New York. The monitors are between 2 m and 50 m from a major roadway, with traffic counts (Fleet Equivalent Annual Average Daily Traffic, or FE-AADT)[2] that range from approximately 130,000 to 700,000 vehicles.

Figure 3 details the number of sites by distance from the roadway; most are within 20 m of the edge of the roadway. Figure 4 shows the distribution of FE-AADT by site; more than half the sites have an FE-AADT above 300,000 vehicles/day, and four sites have an FE-AADT greater than 600,000 vehicles/day. Figure 5 shows the intersection of distance to roadway, FE-AADT, and population for each site. This figure shows that most sites with high FE-AADT are close to the roadway (with the exception of Riverside, California, nearly 50 m from the roadway, likely due to siting constraints). Two sites, Phoenix and Los Angeles, stand out on this plot for having high FE-AADT and being very close to the roadway, and they may provide insightful case studies. The range of distances from the roadway and the range of FE-AADT on the roadways are considerable. As additional data become available, future work can focus on understanding how concentrations vary by roadway characteristics.

[2] FE-AADT is a metric that weights trucks and light-duty vehicles to come up with a single emissions-weighted traffic volume measure. EPA guidance suggests weighting heavy-duty trucks by a factor of 10 and calculates FE-AADT with the following equation: $FE\text{-}AADT=(AADT-HD_c)+(10\times HD_c)$ where HD_c is the total number of heavy-duty vehicles on a road segment. See the EPA's 2012 Near-Road NO_2 Monitoring TAD.

Table 2. Locations of official near-road monitors in operation as of May 2015. *Although the Riverside monitor started operation in August, data were not yet publicly available at the time of this report.

Urban Area	Population 2012	Road	AADT	FE-AADT	Distance to Road (meters)	Start Date (NO_2)	Start Date ($PM_{2.5}$)	Start Date (CO)
Atlanta-Sandy Springs-Roswell, GA	5,457,831	I-85	284,920	406,256	2	6/15/14	1/1/15	6/15/14
Austin-Round Rock, TX	1,834,303	I-35	188,150	350,712	27	4/16/14		
Baltimore-Columbia-Towson, MD	2,753,149	I-95	186,750	452,309	16.15	4/1/14	4/7/14	4/1/14
Birmingham-Hoover, AL	1,136,650	I-20	141,190	215,527	23.2	1/1/14	1/5/14	1/1/14
Boise, ID	637,896	I-84	103,000	162,000	32	4/1/12		1/11/12
Boston-Cambridge-Newton, MA-NH	4,640,802	I-93	193,000		10	6/13/13	10/1/13	7/7/13
Buffalo-Cheektowaga-Niagara Falls, NY	1,134,210	I-90	131,019		20	4/1/14	7/10/14	8/1/14
Charlotte-Concord-Gastonia, NC-SC	2,296,569	I-77	153,000	260,830	30	7/17/14		
Cincinnati, OH-KY-IN	2,128,603	I-75	163,000	386,380	8	1/1/14	1/2/14	8/1/14
Columbus, OH	1,944,002	I-270	142,361	286,050	32	1/1/14		1/6/14
Dallas-Fort Worth-Arlington, TX	6,700,991	I-635	235,790	431,027	24	4/2/14		
Denver-Aurora-Lakewood, CO	2,645,209	I-25	249,000	263,118	8.7	6/1/13	1/1/14	6/1/13
Des Moines-West Des Moines, IA	588,999	I-235	110,000	150,140	13	1/1/13		
Detroit-Warren-Dearborn, MI	4,292,060	I-96	140,500	188,200	8.5	10/1/11		10/1/11
Hartford-West Hartford-East Hartford, CT	1,214,400	I-84	159,900	231,855	17.7	4/1/13	3/6/14	4/1/13
Houston-The Woodlands-Sugar Land, TX	6,177,035	I-69/US 59	324,119	496,226	24	1/22/14		
Indianapolis-Carmel-Anderson, IN	1,928,982	I-70	189,760	362,110	24.5	2/7/14	2/1/14	5/2/14
Jacksonville, FL	1,377,850	I-95	139,000	304,062	20	4/1/14	4/1/14	4/1/14

Urban Area	Population 2012	Road	AADT	FE-AADT	Distance to Road (meters)	Start Date (NO_2)	Start Date ($PM_{2.5}$)	Start Date (CO)
Kansas City, MO-KS	2,038,724	I-70	114,495	347,582	20	7/1/13	7/1/13	7/1/13
Los Angeles-Long Beach-Anaheim, CA	13,052,921	I-5	272,000	695,776	9	1/1/14		
Louisville/Jefferson County, KY-IN	1,251,351	I-264	163,000	247,600	32	2/19/14	1/2/14	1/15/14
Memphis, TN-MS-AR	1,341,690	I-40	140,850	292,968	23.75	7/1/14		7/15/14
Milwaukee-Waukesha-West Allis, WI	1,566,981	I-94	133,000	133,000	14	1/1/14		1/1/14
Minneapolis-St. Paul-Bloomington, MN-WI	3,422,264	I-94/I-35W	277,000	387,250	32.5	4/1/13	10/1/13	1/17/13
Nashville-Davidson-Murfreesboro-Franklin, TN	1,726,693	I-40/I-24	144,204	338,879	30	7/1/14		7/1/14
New Orleans-Metairie, LA	1,227,096	I-610	68,015	129,229	28.5	3/19/14		1/1/15
New York-Newark-Jersey City, NY-NJ-PA	19,831,858	I-95/US 1	311,234	612,212	20	7/1/14		4/1/14
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	6,018,800	I-95	124,610	257,460	12	1/1/14	1/5/14	1/7/14
Phoenix-Mesa-Scottsdale, AZ	4,329,534	I-10	320,138	624,315	12	2/13/14	5/1/14	2/21/14
Pittsburgh, PA	2,360,733	I-376	87,534	148,248	18	9/1/14		9/1/14
Portland-Vancouver-Hillsboro, OR-WA	2,289,800	I-5	156,000	289,052	25	5/8/14		5/8/14
Providence-Warwick, RI-MA	1,601,374	I-95	186,300	416,790	5	4/1/14	4/1/14	4/1/14
Raleigh, NC	1,188,564	I-40	141,000	203,280	20	1/8/14		
Richmond, VA	1,231,980	I-95	151,000	259,720	20	10/1/13		10/1/13
Riverside-San Bernardino-Ontario, CA	4,350,096	I-10	245,300	646,804	50	*8/1/14		
San Antonio-New Braunfels, TX	2,234,003	I-35	201,840	405,295	20	1/8/14		
San Francisco-Oakland-Hayward, CA	4,455,560	I-880	216,000	424,008	20	2/1/14	2/1/14	2/1/14

Urban Area	Population 2012	Road	AADT	FE-AADT	Distance to Road (meters)	Start Date (NO_2)	Start Date ($PM_{2.5}$)	Start Date (CO)
San Jose-Sunnyvale-Santa Clara, CA	1,894,388	US 101	191,000	294,140	32	9/1/14	9/1/14	9/1/14
Seattle-Tacoma-Bellevue, WA	3,552,157	I-5	237,000	471,630	4.5	4/1/14	5/21/14	4/1/14
St. Louis, MO-IL	2,795,794	I-64	159,326	360,077	25	1/1/13	1/3/13	1/1/13
Tampa-St. Petersburg-Clearwater, FL	2,842,878	I-275	190,500	327,660	20	4/1/14		4/1/14

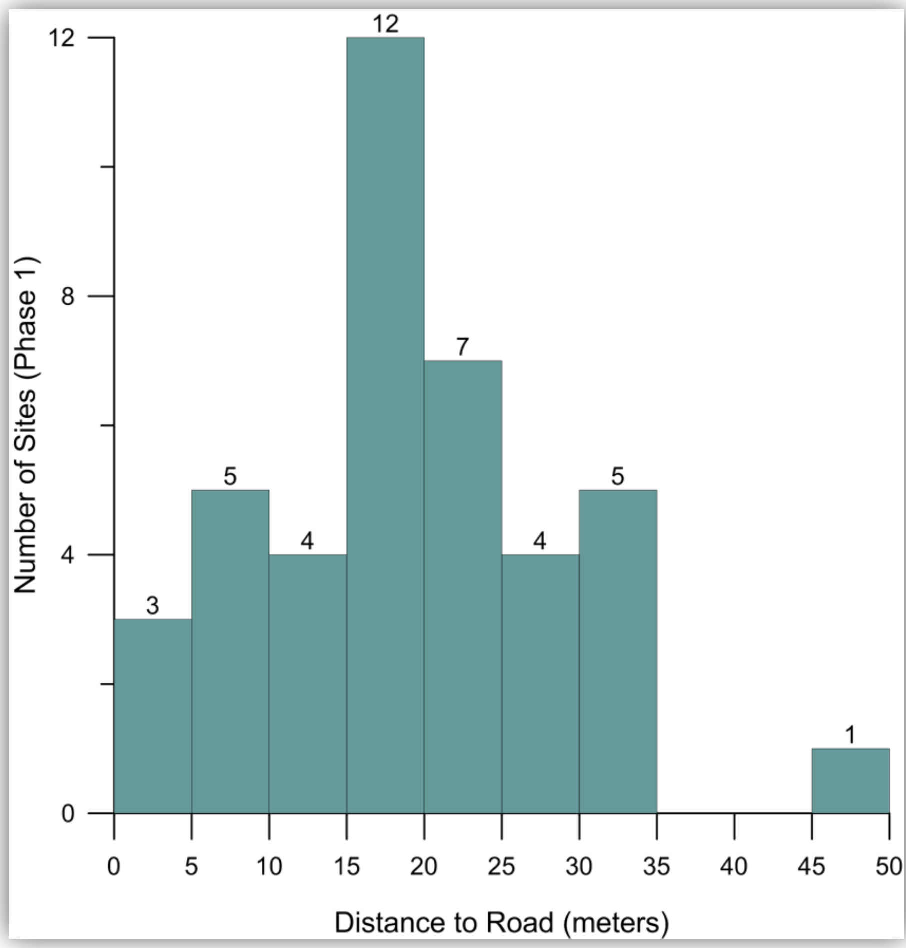


Figure 3. Histogram of number of official near-road sites by distance to roadway.

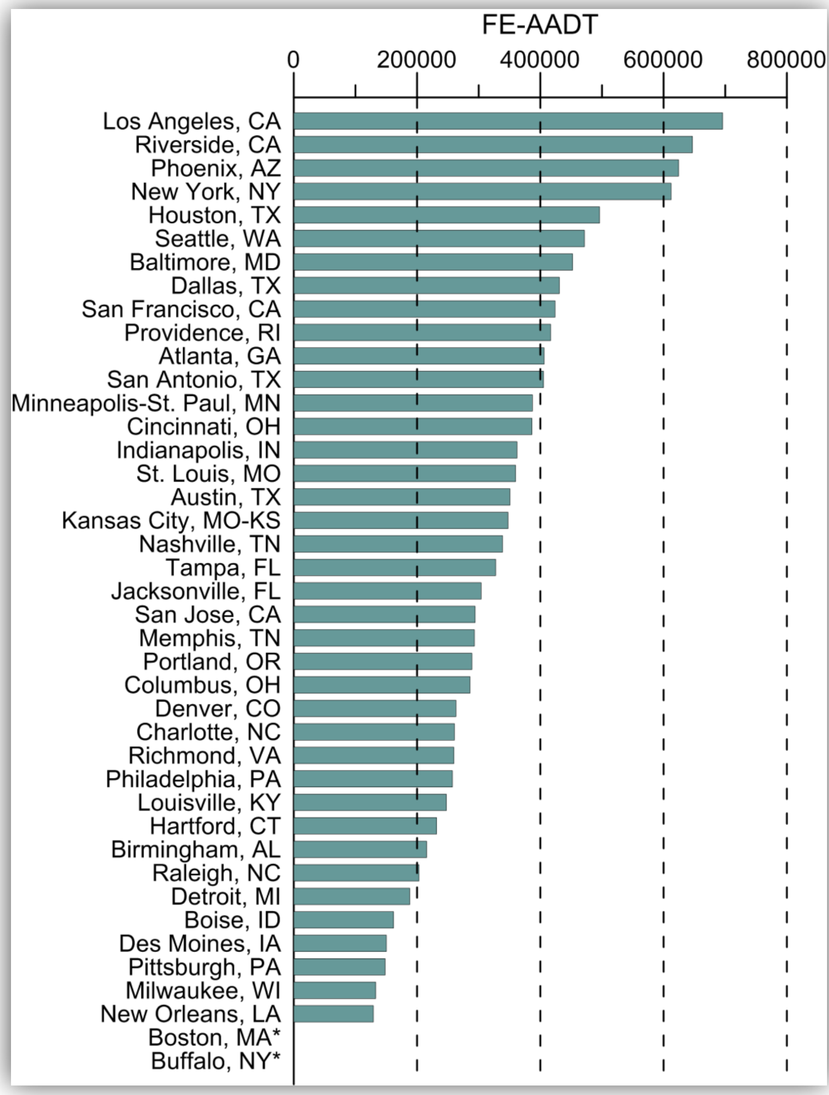


Figure 4. Histogram of FE-AADT of roadways for official near-road sites. FE-AADT data are not available for the sites in Boston and Buffalo.

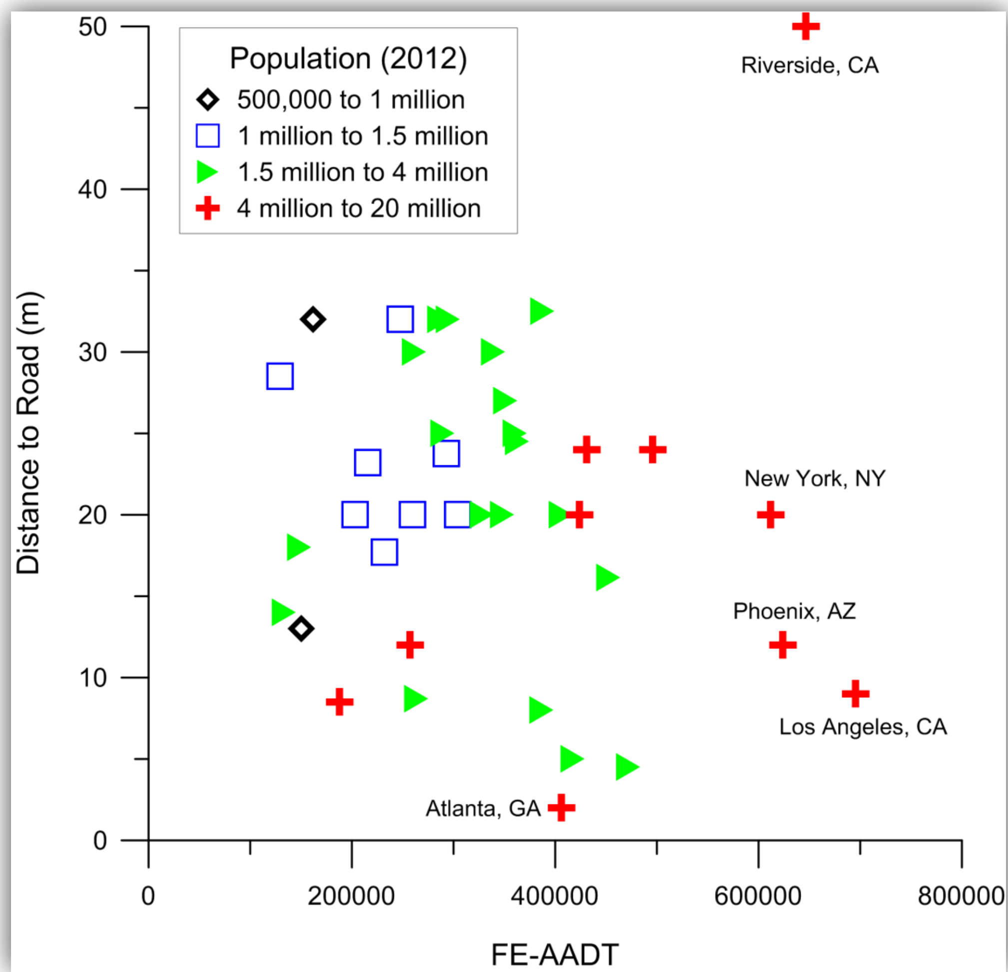


Figure 5. FE-AADT versus distance to roadways for official near-road sites, with symbols showing population.

2.3 Official Near-Road Site Data Availability

Data from official near-road sites in 40 CBSAs were available in AQS as of May 2015 (Tables 3 and 4); some sites had collocated monitors, meaning two measurements of a given pollutant. Data were unavailable in AQS for one location that was expected to have a near-road monitor in 2014; as shown in Figure 6, only Riverside has no data reported yet. Of the sites with data in AQS, all are reporting NO_2 data, and many sites are already reporting PM and/or CO. Some of the sites are also reporting additional pollutants [BC, O_3, volatile organic compounds (VOC), PM speciation, and/or meteorology; see Table A-1]. Tables 3 and 4 show the data availability and data completeness for PM and NO_2 data in AQS for 2014, as of May 2015. The EPA typically requires data for 75% of the time periods measured in a year, plus 75% completeness by quarter or month, for a site to meet minimum data completeness. $PM_{2.5}$ data were also measured in 2013 at four sites: Boston, Kansas City, Minneapolis, and St. Louis. A full table of data availability is provided in Appendix A.

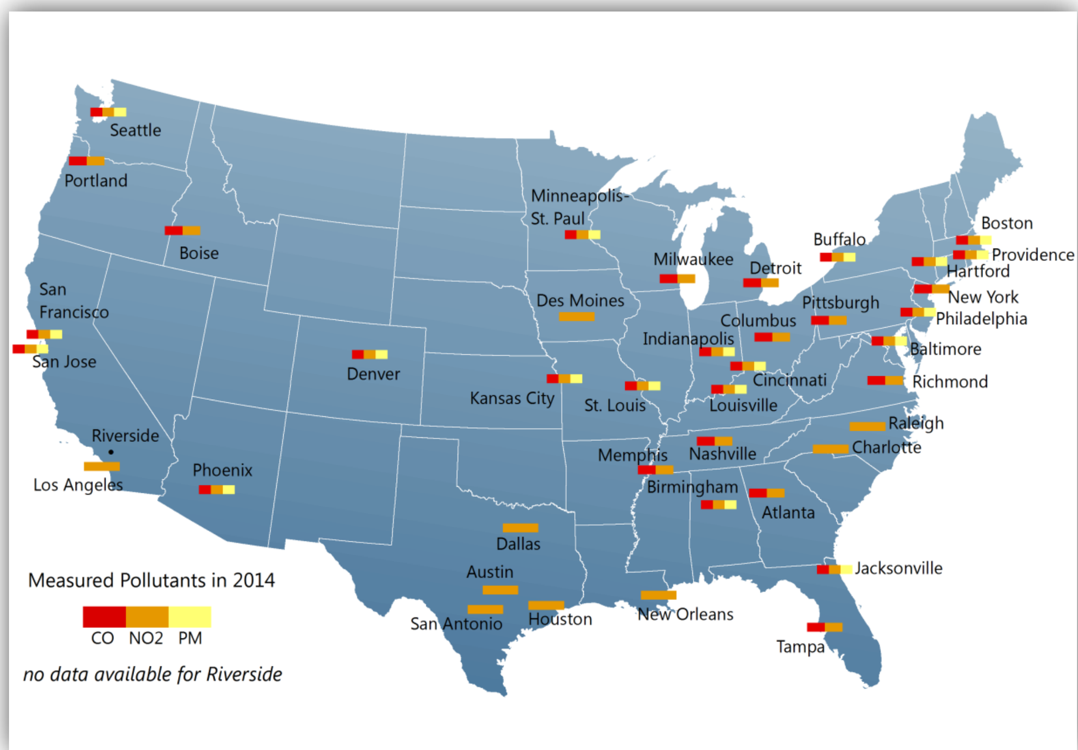


Figure 6. Map of official near-road monitoring stations reporting CO, NO_2, and/or PM to the EPA's AQS database in 2014 as of May 2015. Some locations also reported BC, O_3, VOC, chemical speciation, and/or meteorology.

Table 3. $PM_{2.5}$ data completeness for 2014 at the time of data acquisition (May 2015). Colored cells indicate data completeness: green more than 75%, orange 50-75%, and pink less than 50%. All sites are measuring data hourly, unless specified otherwise. Numbers in parentheses indicate that a site parameter occurrence code (POC) other than 1 was used; in most cases, this is to indicate collocated monitors. Empty gray cells indicate that no data were available.

	2014			
Location	Qtr. 1	Qtr. 2	Qtr. 3	Qtr. 4
Atlanta-Sandy Springs-Roswell, GA				
Austin-Round Rock, TX				
Baltimore-Columbia-Towson, MD (3)		92	99	95
Birmingham-Hoover, AL[B]	100	100	100	100
Boise, ID				
Boston-Cambridge-Newton, MA-NH[A]	100	93	100	93
Buffalo-Cheektowaga-Niagara Falls, NY[A]			87	97
Charlotte-Concord-Gastonia, NC-SC				
Cincinnati, OH-KY-IN[B]	100	100	100	93
Cincinnati, OH-KY-IN (4)[B]	93	100	100	100
Columbus, OH				
Dallas-Fort Worth-Arlington, TX				
Denver-Aurora-Lakewood, CO[A]	100	100	100	100
Denver-Aurora-Lakewood, CO (3)	99	86	93	99
Des Moines-West Des Moines, IA				
Detroit-Warren-Dearborn, MI				
Hartford-West Hartford-East Hartford, CT[A]	23	80	70	100
Houston-The Woodlands-Sugar Land, TX				
Indianapolis-Carmel-Anderson, IN[A]	100	97	100	100
Jacksonville, FL (3)		87	46	99
Kansas City, MO-KS (4)	99	98	97	97
Los Angeles-Long Beach-Anaheim, CA				
Louisville/Jefferson County, KY-IN[A]	87	100	100	100
Memphis, TN-MS-AR				
Milwaukee-Waukesha-West Allis, WI				
Minneapolis-St. Paul-Bloomington, MN-WI (3)	95	100	95	94
Nashville-Davidson--Murfreesboro--Franklin, TN				
New Orleans-Metairie, LA				
New York-Newark-Jersey City, NY-NJ-PA				
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	83	77	94	100

Location	2014 Qtr. 1	Qtr. 2	Qtr. 3	Qtr. 4
Phoenix-Mesa-Scottsdale, AZ (3)		61	97	98
Pittsburgh, PA				
Portland-Vancouver-Hillsboro, OR-WA				
Providence-Warwick, RI-MA		96	87	96
Raleigh, NC				
Richmond, VA				
Riverside-San Bernardino-Ontario, CA				
San Antonio-New Braunfels, TX				
San Francisco-Oakland-Hayward, CA (3)	65	100	99	100
San Jose-Sunnyvale-Santa Clara, CA (3)			32	97
Seattle-Tacoma-Bellevue, WA (3)		43	98	92
St. Louis, MO-IL (4)	93	77	94	91
Tampa-St. Petersburg-Clearwater, FL				

[A] *24-hr $PM_{2.5}$ samples on a 1-in-3 day sampling frequency*
[B] *24-hr $PM_{2.5}$ samples on a 1-in-6 day sampling frequency.*

Table 4. Hourly NO_2 and CO 2014 data completeness at the time of data acquisition (May 2015). Colored cells indicate data completeness: green (more than 75%), orange (50-75%), and pink (less than 50%). Empty gray cells indicate that no data were available. Some sites also measured hourly NO_2 and CO data in 2011–2013 (Boise, Boston, Denver, Des Moines, Detroit, Hartford, Kansas City, Minneapolis, Richmond, and St. Louis); NO_2 data only are also available in Des Moines in 2013. Numbers in parentheses indicate that a site POC other than 1 was used; in most cases, this is to indicate collocated monitors.

Location	2014 NO_2 Qtr. 1	2014 NO_2 Qtr. 2	2014 NO_2 Qtr. 3	2014 NO_2 Qtr. 4	2014 CO Qtr. 1	2014 CO Qtr. 2	2014 CO Qtr. 3	2014 CO Qtr. 4
Atlanta-Sandy Springs-Roswell, GA		17	97	97		17	99	98
Austin-Round Rock, TX		81	88	97				
Baltimore-Columbia-Towson, MD		99	99	99		92	93	99
Birmingham-Hoover, AL	90	93	94	94	90	93	93	94
Boise, ID		60	98	98	98	98	98	98
Boise, ID (2)	97	64						
Boston-Cambridge-Newton, MA-NH	95	95	94	95	89	94	69	60
Buffalo-Cheektowaga-Niagara Falls, NY		93	98	99			62	86
Charlotte-Concord-Gastonia, NC-SC			64	78				
Cincinnati, OH-KY-IN	99	96	99	97			66	100
Columbus, OH	96	95	95	95	93	99	99	96
Dallas-Fort Worth-Arlington, TX		97	98	97				
Denver-Aurora-Lakewood, CO	95	92	89	94	99	99	99	99
Des Moines-West Des Moines, IA	99	89	98	94				
Detroit-Warren-Dearborn, MI	100	96	98	99	96	93	95	82
Hartford-West Hartford-East Hartford, CT	97	96	96	97	95	88	95	95
Houston-The Woodlands-Sugar Land, TX	73	95	97	97				
Indianapolis-Carmel-Anderson, IN	55	97	97	96		64	82	92
Jacksonville, FL		90	89	88		93	94	94
Kansas City, MO-KS	91	100	99	99	98	95	97	95
Los Angeles-Long Beach-Anaheim, CA	93	98	96	95				
Louisville/Jefferson County, KY-IN	42	94	96	96	78	98	97	99

Location	2014 NO_2				2014 CO			
	Qtr. 1	Qtr. 2	Qtr. 3	Qtr. 4	Qtr. 1	Qtr. 2	Qtr. 3	Qtr. 4
Memphis, TN-MS-AR			90	90			73	89
Milwaukee-Waukesha-West Allis, WI	94	94	94	95	99	99	99	100
Minneapolis-St. Paul-Bloomington, MN-WI	99	98	98	99	99	96	99	99
Nashville-Davidson--Murfreesboro--Franklin, TN			88	90			88	97
New Orleans-Metairie, LA	14	97	96	97				
New York-Newark-Jersey City, NY-NJ-PA			98	94		99	99	96
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	96	91	94	95	92	93	98	95
Phoenix-Mesa-Scottsdale, AZ	51	98	98	98	42	99	98	99
Pittsburgh, PA			31	94			31	95
Portland-Vancouver-Hillsboro, OR-WA		57	91	99		57	89	100
Providence-Warwick, RI-MA		95	96	96		95	96	96
Raleigh, NC	86	70	88	94				
Richmond, VA	52	53	98	84	56	99	98	98
Riverside-San Bernardino-Ontario, CA								
San Antonio-New Braunfels, TX	85	91	98	98				
San Francisco-Oakland-Hayward, CA	61	94	94	95	61	95	95	95
San Jose-Sunnyvale-Santa Clara, CA			31	95			31	95
Seattle-Tacoma-Bellevue, WA		67	91	95		71	62	93
St. Louis, MO-IL	98	89	98	99	96	93	98	98
St. Louis, MO-IL (2)	95	98	99	99				
Tampa-St. Petersburg-Clearwater, FL		99	99	87		66	36	71

3. Analysis

3.1 Overview of Concentrations at Near-Road Sites

For research purposes, this discussion includes comparisons of measured data to NAAQS levels; the NAAQS are shown in Table 5. These comparisons are provided for context and are not meant to assess attainment status; attainment and nonattainment areas are designated by the EPA. Note also that most near-road sites do not have sufficient data to determine whether a site recorded a NAAQS violation for hourly NO_2, 24-hr $PM_{2.5}$, or annual $PM_{2.5}$, because these calculations require at least three years of valid monitoring data. The CO requirement is based on a single year of data; however, only a portion of 2014 data was available for analysis at the time of the data retrieval. The following results are based on the data available in 2014. Summary statistics for CO, NO_2, and PM at each site are provided in Appendix A. We are reporting values directly from AQS, as verified by the states and made available by EPA, some values are negative.

Table 5. Primary NAAQS levels for CO, NO_2, and $PM_{2.5}$. (Source: epa.gov/air/criteria.html.)

Pollutant	Averaging Time	Level	Form
CO	8-hr	9 ppm	Not to be exceeded more than once per year
	1-hr	35 ppm	Not to be exceeded
NO_2	1-hr	100 ppb	98th percentile of 1-hr daily maximum concentrations, averaged over 3 years
	Annual	53 ppb	Annual mean
$PM_{2.5}$	24-hr	35 µg/m^3	98th percentile, averaged over 3 years
	Annual	12 µg/m^3	Annual mean, averaged over 3 years

Concentration changes throughout the day are linked to typical travel activity patterns. The temporal patterns of CO and NO_2 concentrations are typical for urban monitoring locations. The diurnal concentration profiles include morning and evening peaks that are consistent with commute hours (Figure 7). Peak travel periods can be characterized by higher traffic volumes, lower vehicle speeds, higher per-vehicle emission rates, and (especially in the morning) low wind speeds and/or limited atmospheric mixing. Typical daily traffic patterns overlap more closely with NO_2 concentrations than with $PM_{2.5}$ concentrations. $PM_{2.5}$ concentrations are heavily influenced by regional emissions and atmospheric $PM_{2.5}$ formation that occurs throughout the day. Weekly patterns vary by pollutant: NO_2 concentrations are higher on weekdays than on weekends across all sites (Figure 7), but $PM_{2.5}$ concentrations are higher on weekdays than on weekends at some sites but not all.

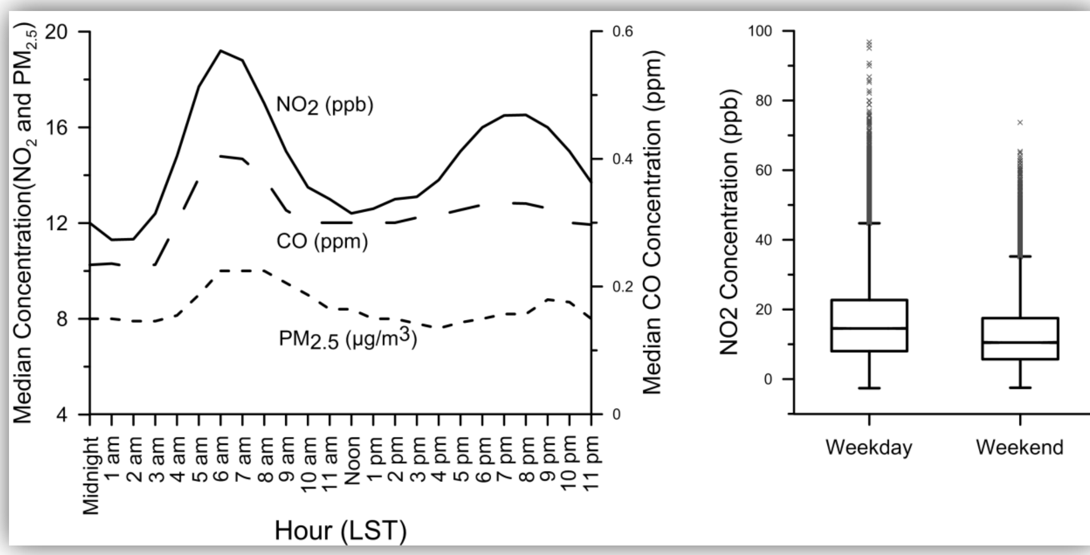


Figure 7. Diurnal patterns in hourly median NO_2, CO, and $PM_{2.5}$ on weekdays in 2014 (left), and NO_2 concentrations on weekdays and weekends in 2014 (right). Both figures include hourly data from 2014 at all near-road sites. In the box plot on the right, the horizontal line indicates the median, the box indicates the interquartile range (IQR), the whiskers indicate 1.5*IQR, and individual points are beyond 1.5*IQR. Five outliers with concentrations above 100 ppb are not shown in the weekday box plot.

3.1.1 CO Concentrations

The hourly CO concentrations measured at the official near-road monitors ranged from a minimum value near zero to a maximum value of 4.8 ppm, while most hourly CO concentrations were in the 0-1 ppm range (Figure 8).

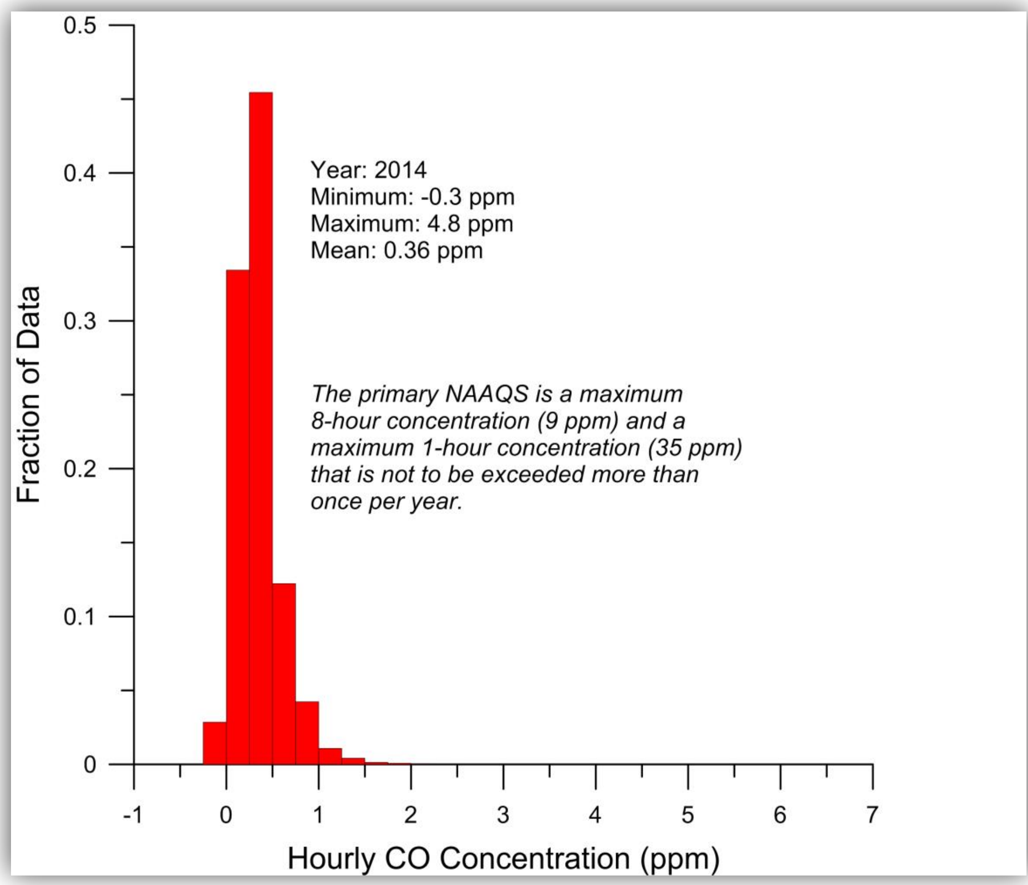


Figure 8. Distribution of all hourly CO concentrations at the official near-road monitors for 2014.

3.1.2 NO_2 Concentrations

Five hourly NO_2 concentrations over two days (August 1 and 14, 2014) were above 100 ppb, including a maximum value of 258 ppb. All of these high values were observed at the New York/New Jersey George Washington Bridge site (see **Table 6**). **Figure 9** shows the distribution of all hourly NO_2 concentrations across all sites for 2014. **Figure 10** shows box plots of hourly NO_2 concentrations by site for 2014, and **Figure 11** shows box plots of daily 1-hour maximum concentrations by site for 2014. Concentrations at Denver approached 100 ppb in February 2014 (maximum of 96.8 ppb), and concentrations at Seattle also exceeded 90 ppb. The 98th percentile at all sites was below 100 ppb. At New York, the 98th percentile of the daily 1-hr maximum concentration was 91.8 ppb, but only two quarters of data were reported. The highest annual average from the data available in 2014 was at the Los Angeles (Anaheim) location, where a value of 27.1 ppb was observed.

Table 6. NO_2 1-hr maximum, 1-hr average, and 98^{th} percentile of daily 1-hr maximum (ppb) by site during 2014, plus the number and date range of 2014 1-hr samples reported as of May 2015. One complete year of hourly data comprises 8,760 observations.

Urban Area	Start Date (2014)	Last Reported Date (2014)	No. of Reported Samples	1-Hr. Max. (ppb)	1-Hr. Avg. (ppb)	98^{th} Percentile of Daily Maximum (ppb)
Atlanta, GA	15-Jun	31-Dec	4,658	57.9	19.8	50.3
Austin, TX	16-Apr	31-Dec	5,840	56.8	14.0	48.2
Baltimore, MD	01-Apr	31-Dec	6,538	56.0	17.8	50.8
Birmingham, AL	01-Jan	31-Dec	8,107	67.4	14.0	51.5
Boise, ID	06-May	31-Dec	5,654	48.4	10.6	43.1
Boise, ID (2)	01-Jan	31-May	3,497	48.1	11.5	43.6
Boston, MA-NH	01-Jan	31-Dec	8,288	64.0	17.5	53.7
Buffalo, NY	01-Apr	31-Dec	6,366	49.5	9.9	40.1
Charlotte, NC	17-Jul	31-Dec	3,126	43.6	11.4	39.5
Cincinnati, OH	01-Jan	31-Dec	8,546	68.0	23.4	59.7
Columbus, OH	01-Jan	31-Dec	8,343	53.0	12.4	47.7
Dallas, TX	02-Apr	31-Dec	6,414	58.2	9.6	40.9
Denver, CO	01-Jan	31-Dec	8,083	96.8	25.4	70.7
Des Moines, IA	01-Jan	31-Dec	8,310	41.1	8.7	34.9
Detroit, MI	01-Jan	31-Dec	8,584	62.0	16.3	51.7
Hartford, CT	01-Jan	31-Dec	8,470	80.0	14.5	51.7
Houston, TX	22-Jan	31-Dec	7,918	55.1	12.5	48.8
Indianapolis, IN	07-Feb	31-Dec	7,582	64.4	16.7	58.6
Jacksonville, FL	01-Apr	31-Dec	5,846	70.0	12.4	46.1
Kansas City, MO-KS	08-Jan	31-Dec	8,519	52.1	12.4	46.7
Los Angeles, CA	01-Jan	31-Dec	8,376	78.8	27.1	66.5
Louisville, KY	19-Feb	31-Dec	7,226	69.8	13.7	49.0
Memphis, TN	01-Jul	31-Dec	3,978	48.5	12.1	44.7
Milwaukee, WI	01-Jan	31-Dec	8,247	61.7	15.7	53.6

Urban Area	Start Date (2014)	Last Reported Date (2014)	No. of Reported Samples	1-Hr. Max. (ppb)	1-Hr. Avg. (ppb)	98th Percentile of Daily Maximum (ppb)
Minneapolis-St. Paul, MN	01-Jan	31-Dec	8,610	53.0	15.9	48.0
Nashville, TN	01-Jul	31-Dec	3,939	63.0	14.6	53.6
New Orleans, LA	19-Mar	31-Dec	6,663	64.0	11.7	48.2
New York, NY	01-Jul	31-Dec	4,224	258.0	18.5	91.8
Philadelphia, PA	01-Jan	31-Dec	8,230	65.0	15.5	51.6
Phoenix, AZ	13-Feb	31-Dec	7,583	62.0	20.8	59.0
Pittsburgh, PA	01-Sep	31-Dec	2,769	42.1	12.5	40.3
Portland, OR	08-May	31-Dec	5,439	48.6	12.2	38.1
Providence, RI	01-Apr	31-Dec	6,328	55.9	20.2	51.7
Raleigh, NC	08-Jan	31-Dec	7,412	41.2	10.5	36.7
Richmond, VA	01-Jan	31-Dec	6,273	54.1	14.1	46.6
San Antonio, TX	08-Jan	31-Dec	8,135	51.0	10.7	45.5
San Francisco, CA	01-Feb	31-Dec	7,558	64.6	17.2	52.5
San Jose, CA	01-Sep	31-Dec	2,781	64.9	19.7	52.4
Seattle, WA	01-Apr	31-Dec	5,560	90.7	23.9	69.1
St. Louis, MO	01-Jan	31-Dec	8,404	71.7	13.7	50.4
St. Louis, MO (2)	01-Jan	31-Dec	8,560	78.9	14.0	60.5
Tampa, FL	01-Apr	31-Dec	6,252	59.0	12.1	45.6

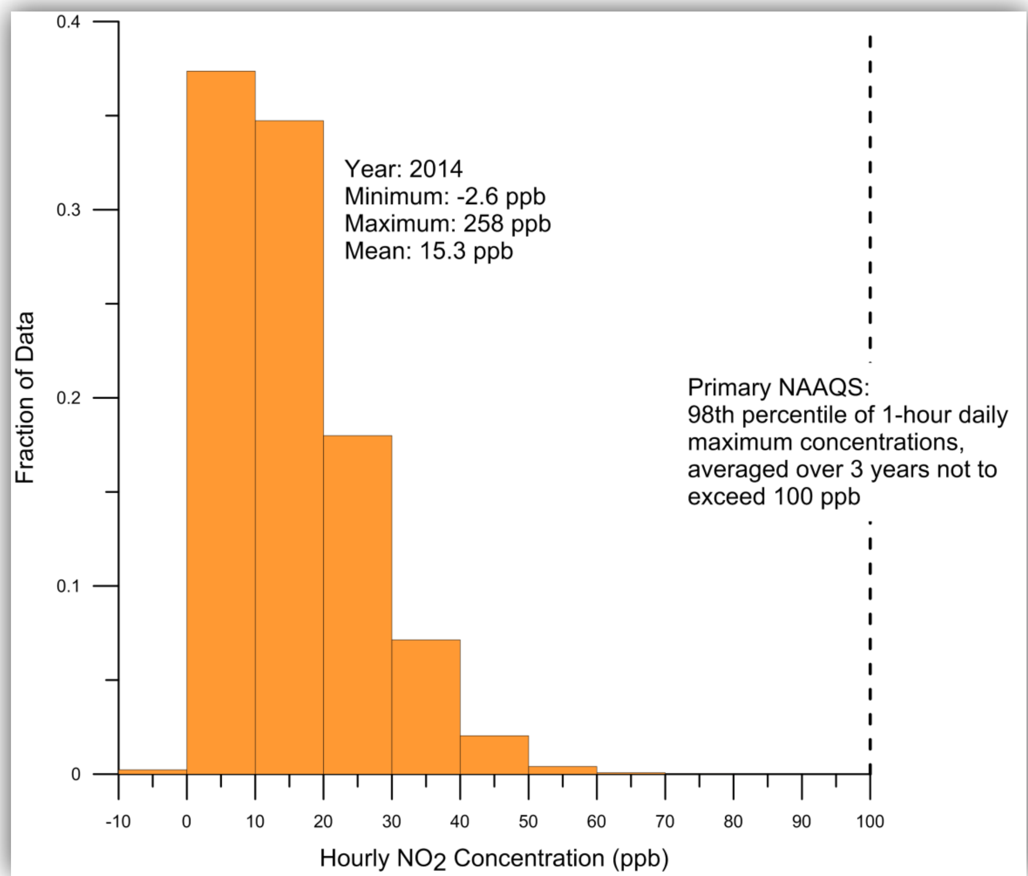


Figure 9. Distribution of all hourly NO_2 concentrations at the official near-road monitors for 2014. The NO_2 NAAQS threshold is also indicated.

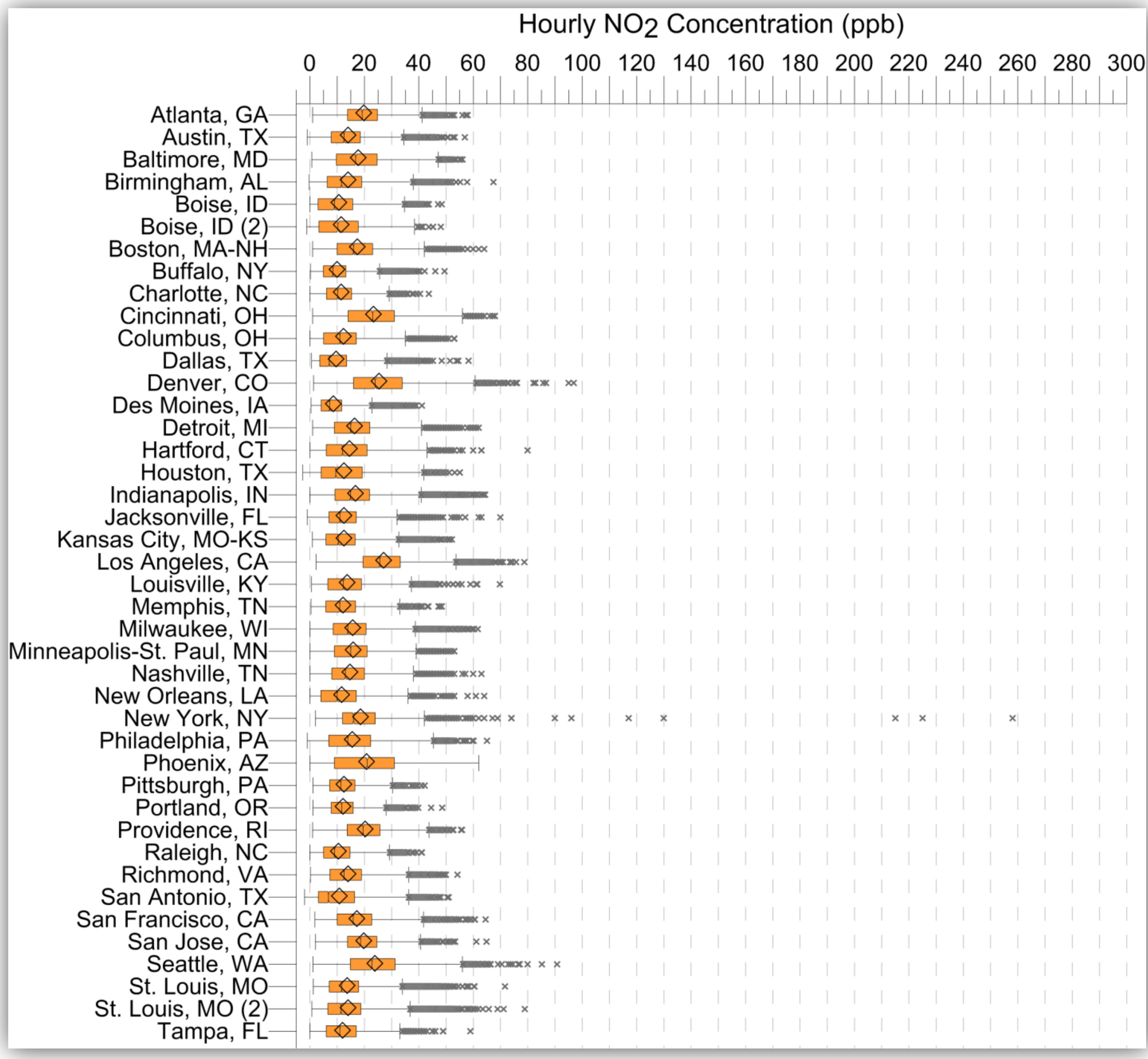


Figure 10. Box plot of all hourly NO_2 concentrations at the official near-road monitors for 2014. The vertical line indicates the median; the diamond indicates the mean; the box indicates the interquartile range (IQR); the whiskers indicate 1.5*IQR; and individual points are beyond 1.5*IQR.

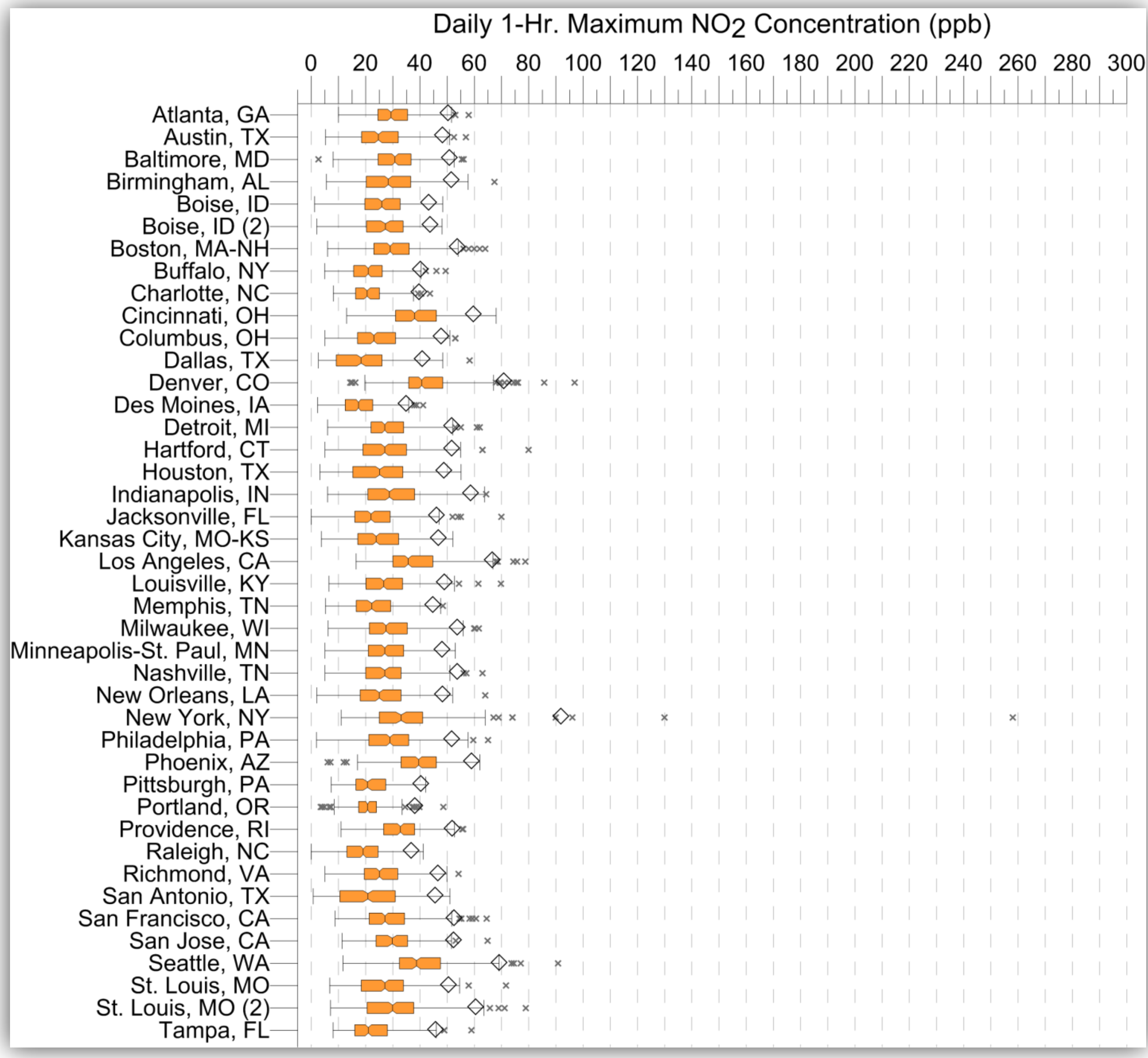


Figure 11. Box plot of daily 1-hour maximum NO_2 concentrations at the official near-road monitors for 2014. The vertical line indicates the median; the diamond indicates the 98th percentile; the box indicates the interquartile range (IQR); the whiskers indicate 1.5*IQR; and individual points are beyond 1.5*IQR.

3.1.3 PM Concentrations

As of May 2015, 19 CBSAs had $PM_{2.5}$ data reported in AQS. Thirteen CBSAs had three full quarters of data, of which 10 had a full year; six CBSAs had less than three full quarters of data. Twelve CBSAs reported hourly $PM_{2.5}$ data for their near-road sites to AQS, and eight CBSAs reported 24-hr data (sampling on 1-in-3 or 1-in-6 day cycles). Cincinnati and Denver both had collocated monitors at their sites. Denver had both hourly and 24-hr data, while Cincinnati had two 24-hr monitors.

Figure 12 shows the 98th percentile of 24-hr $PM_{2.5}$ and annual average $PM_{2.5}$ for 2014 at official near-road monitoring sites, along with the associated nonattainment and maintenance areas designated by the EPA.[3] Several near-road monitoring sites are located in $PM_{2.5}$ nonattainment or maintenance areas.

This preliminary comparison shows that five sites in four cities were at or exceeded the $PM_{2.5}$ thresholds. Figure 13 shows the distribution of the 24-hr and annual average concentrations. Data available in May 2015 show annual averages greater than 12 μg/m^3 at Cincinnati (two monitors) and Indianapolis, while the Baltimore and Louisville sites show annual averages equal to 12 μg/m^3. Data records for Baltimore are incomplete for 2014.

Also, as shown in Figure 14, across all sites there were 15 days in 2014 when 24-hr $PM_{2.5}$ concentrations were greater than 35 μg/m^3. This occurred in Cincinnati, Denver, Indianapolis, Kansas City, Louisville, Philadelphia, and St. Louis during either February 2–19, March 6–8, or July 4 (Louisville only). However, the 98th percentile of 24-hr $PM_{2.5}$ concentrations did not exceed 35 μg/m^3 at any site. Table 7 lists where and when high concentrations occurred. The high concentrations in Denver are further examined in Section 3.3.

[3] See epa.gov/pmdesignations/.

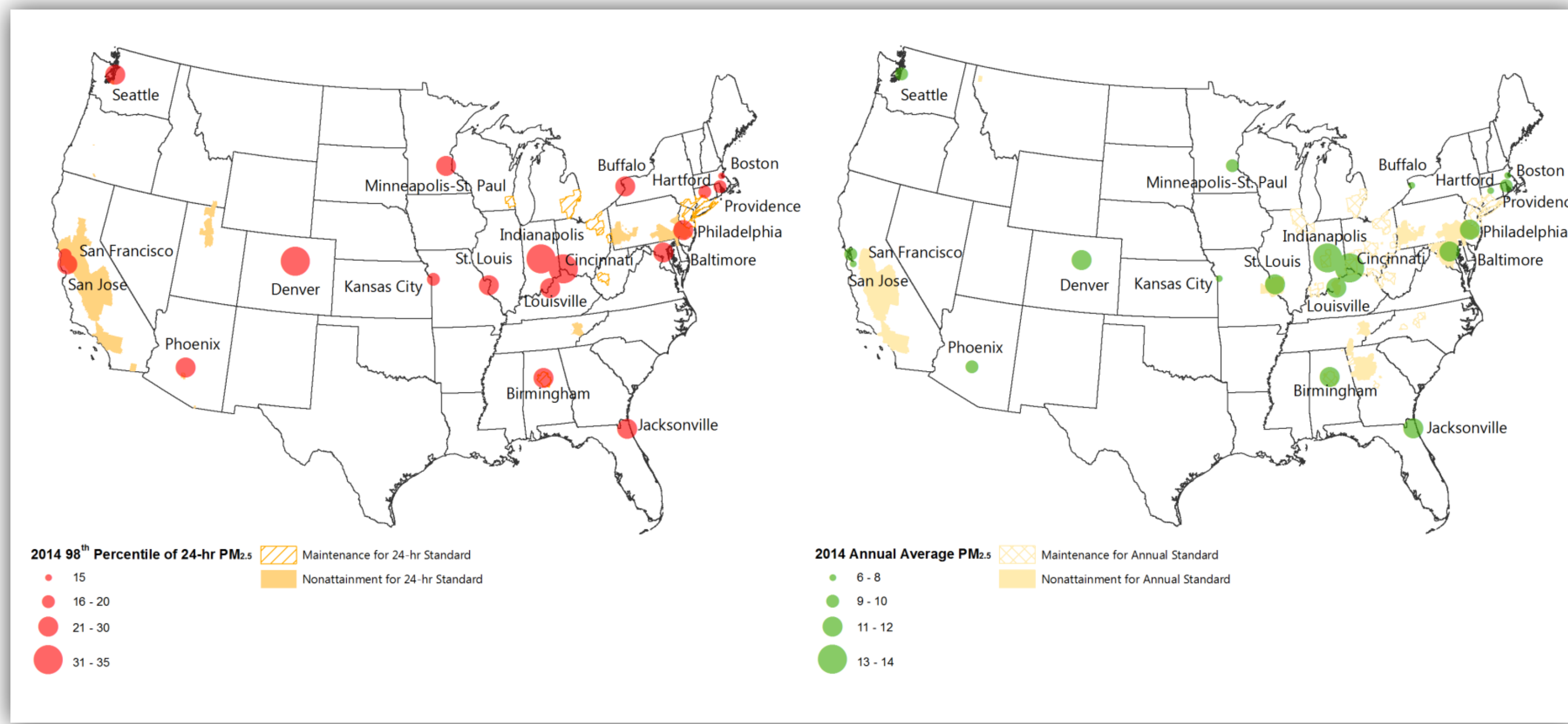


Figure 12. Maps showing 2014 $PM_{2.5}$ concentrations ($\mu g/m^3$) at official near-road monitoring sites plus nonattainment and maintenance areas for (left) the 98th percentile of 24-hr $PM_{2.5}$ concentrations and (right) annual average $PM_{2.5}$ concentrations. More sites are expected to report data in 2015.

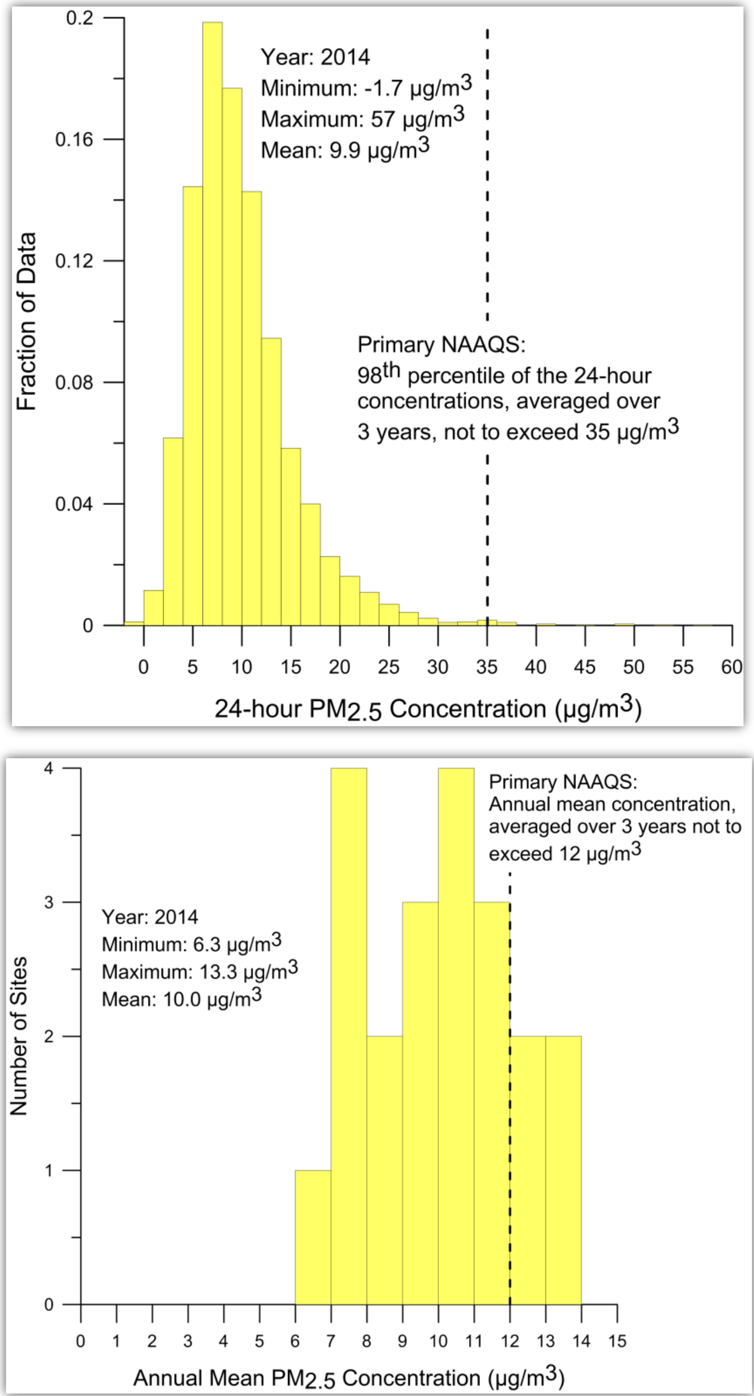


Figure 13. Distribution of 24-hr (top) and annual average (bottom) $PM_{2.5}$ concentrations at the official near-road monitors for 2014. NAAQS thresholds are also indicated. Note that of the five sites with averages at or above 12 µg/m^3—Cincinnati (two monitors), Indianapolis, Baltimore, and Louisville—the Baltimore site has an incomplete data record for 2014, while the Cincinnati, Indianapolis, and Baltimore sites have a complete year of data for 2014.

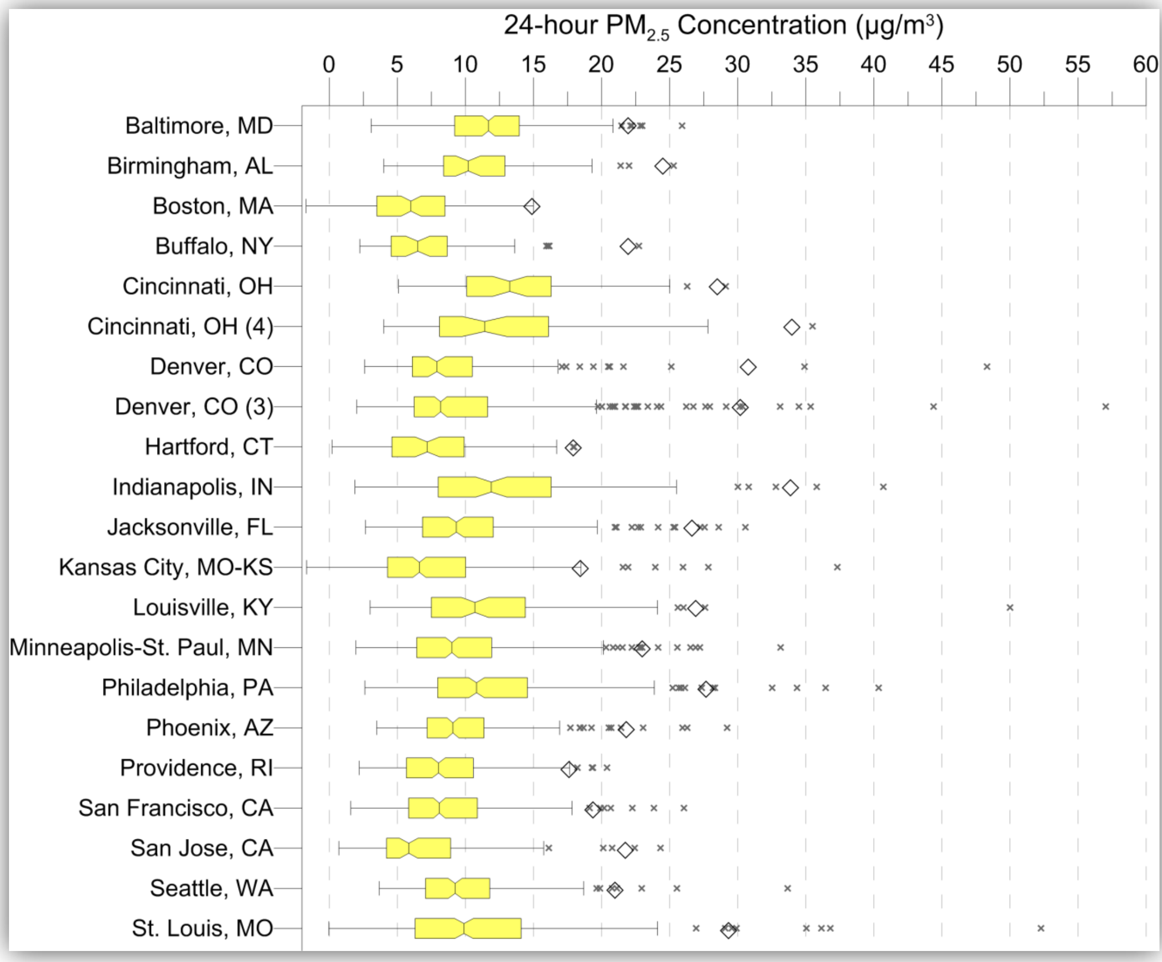


Figure 14. 24-hr $PM_{2.5}$ concentrations at the official near-road monitoring locations in 2014. The vertical line indicates the median; the notch around the vertical line indicates the 95^{th} confidence interval in the median; the box indicates the interquartile range (IQR); the whiskers indicate 1.5*IQR; and individual points are beyond 1.5*IQR. The 98^{th} percentile value, based on the available data as of May 2015, is also shown (diamond). Numbers in parentheses indicate collocated monitors that may be of different sampling durations (see Table 3). The NAAQS is exceeded when the 98^{th} percentile, averaged over three years, is greater than 35 µg/m^3. Note that six of the sites (Buffalo, Hartford, Jacksonville, Phoenix, San Jose, and Seattle) have fewer than three quarters of data available for 2014.

Table 7. Locations and dates with 24-hr $PM_{2.5}$ concentrations above 35 µg/m^3 or 2014 average concentrations at or above 12 µg/m^3 at the official near-road sites. Baltimore had limited data for calculating the annual average; see Table 3 for data completeness.

Urban Area	Sample Duration	Date (2014)	End Date (Annual, 2014)	Concentration (µg/m3)	NAAQS Attainment Status[a]
24-Hour					
Denver-Aurora-Lakewood, CO (3)	1-hr	10-Feb		57.0	A
St. Louis, MO-IL (4)	1-hr	8-Mar		52.3	A
Louisville/Jefferson County, KY-IN	24-hr	4-Jul		50.0	A
Denver-Aurora-Lakewood, CO	24-hr	10-Feb		48.3	A
Denver-Aurora-Lakewood, CO (3)	1-hr	9-Feb		44.4	A
Indianapolis-Carmel-Anderson, IN	24-hr	8-Mar		40.7	A
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	1-hr	2-Feb		40.4	N
Kansas City, MO-KS (4)	1-hr	6-Mar		37.3	A
St. Louis, MO-IL (4)	1-hr	6-Mar		36.8	A
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	1-hr	19-Feb		36.5	N
St. Louis, MO-IL (4)	1-hr	7-Mar		36.1	A
Indianapolis-Carmel-Anderson, IN	24-hr	4-Feb		35.8	A
Cincinnati, OH-KY-IN (4)	24-hr	10-Feb		35.5	A
Denver-Aurora-Lakewood, CO (3)	1-hr	7-Feb		35.4	A
St. Louis, MO-IL (4)	1-hr	12-Feb		35.1	A
Annual					
Cincinnati, OH-KY-IN	24-hr	2-Jan	28-Dec	13.3	M
Indianapolis-Carmel-Anderson, IN	24-hr	1-Feb	31-Dec	13.1	M
Cincinnati, OH-KY-IN (4)	24-hr	11-Jan	25-Dec	12.6	M
Louisville/Jefferson County, KY-IN	24-hr	2-Jan	31-Dec	12.0	N
Baltimore-Columbia-Towson, MD (3)	1-hr	8-Apr	31-Dec	12.0	M

[a] NAAQS attainment statuses are for the 35 µg/m^3 24-hr and 15 µg/m^3 annual $PM_{2.5}$ standards, as per http://www.epa.gov/pmdesignations/. As of May 1, 2015, attainment designations had not yet been assigned for the 12 µg/m^3 annual $PM_{2.5}$ standard.

3.2 Concentrations Relative to Roadway Characteristics

We examined how NO_2 and PM concentrations at the near-road sites varied by monitor distance from the roadway and by FE-AADT. These analyses will be updated in future work phases as additional data become available.

Of the 40 CBSAs that reported data for 2014 (as of May 2015), eight sites were within 10 m, 16 within 10-20 m, and 16 within 20-50 m of the target roadway. Comparisons of NO_2 concentrations to distance from roadway and to FE-AADT are shown in **Figure 15**. Average NO_2 concentrations are typically higher at sites within 10 m of the roadway, but there is a wide distribution of average concentrations at all distances from the roadway. There is a wide range of concentrations even at high FE-AADT sites; future case studies may further investigate the relationship between FE-AADT, concentrations, and other factors such as meteorology.

Average 2014 $PM_{2.5}$ concentrations at each site are compared to distance from roadway and FE-AADT in **Figure 16**. Average $PM_{2.5}$ concentrations did not exhibit a trend with distance from the roadway or with FE-AADT, possibly because of high background $PM_{2.5}$ at most sites. Previous work has documented that near-road $PM_{2.5}$ exhibits less of a gradient than other pollutants such as CO (Karner et al., 2010). As of May 2015, insufficient data had been reported from the national near-road measurement network to provide a robust characterization of near-road $PM_{2.5}$ and its relationship to FE-AADT.

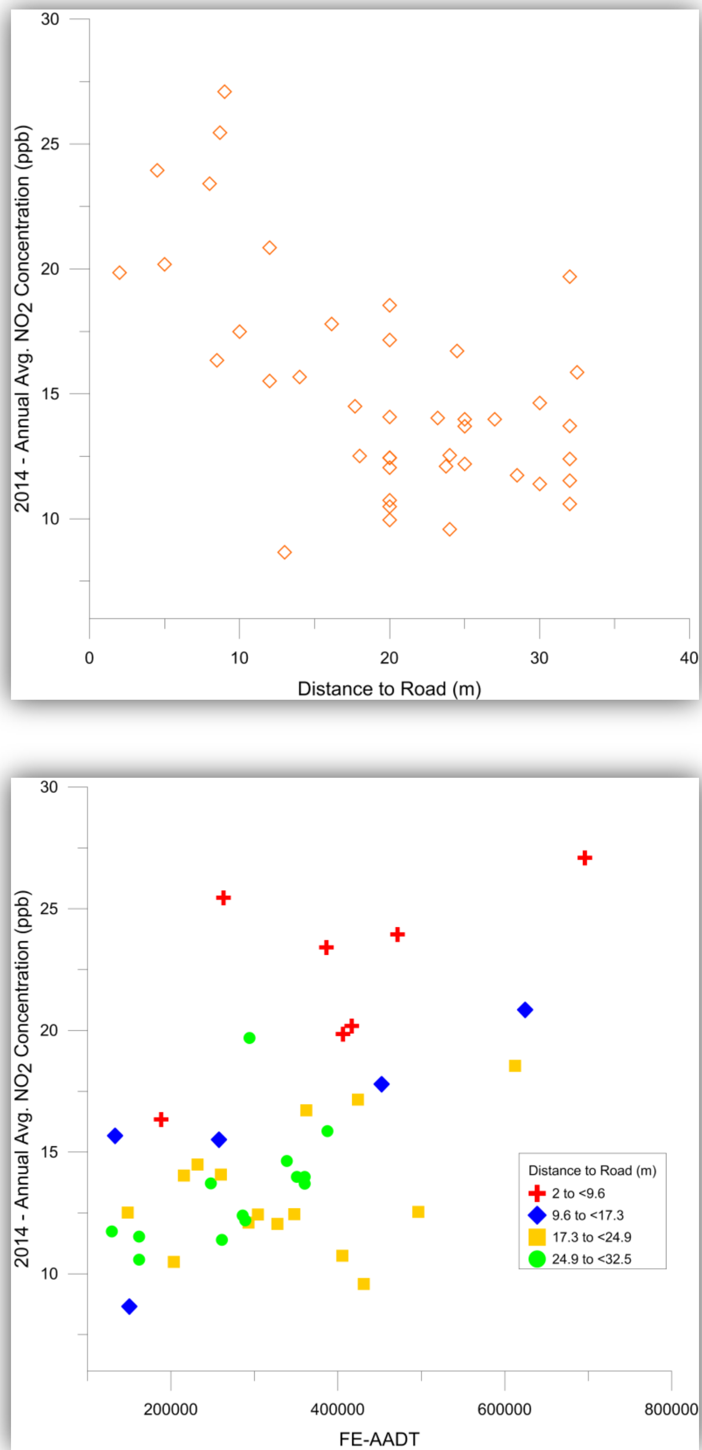
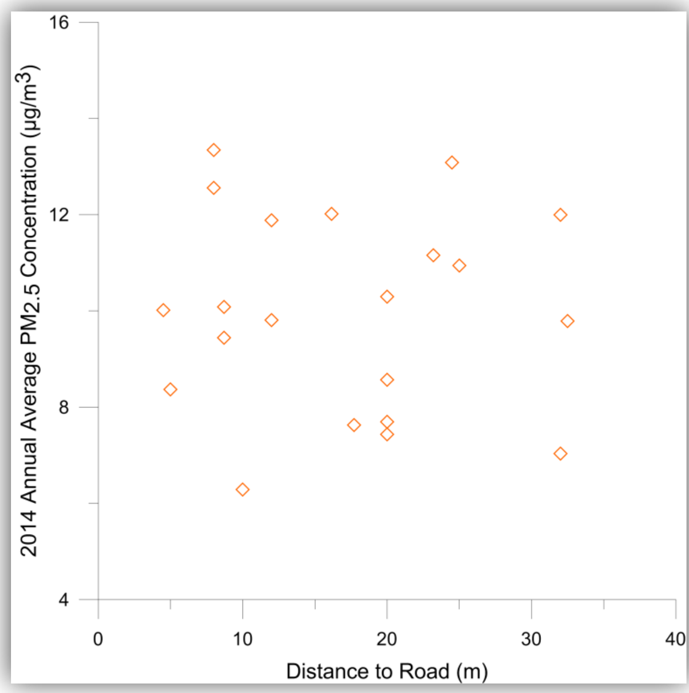


Figure 15. 2014 average NO_2 concentrations relative to distance to the roadway (top) and FE-AADT (bottom).



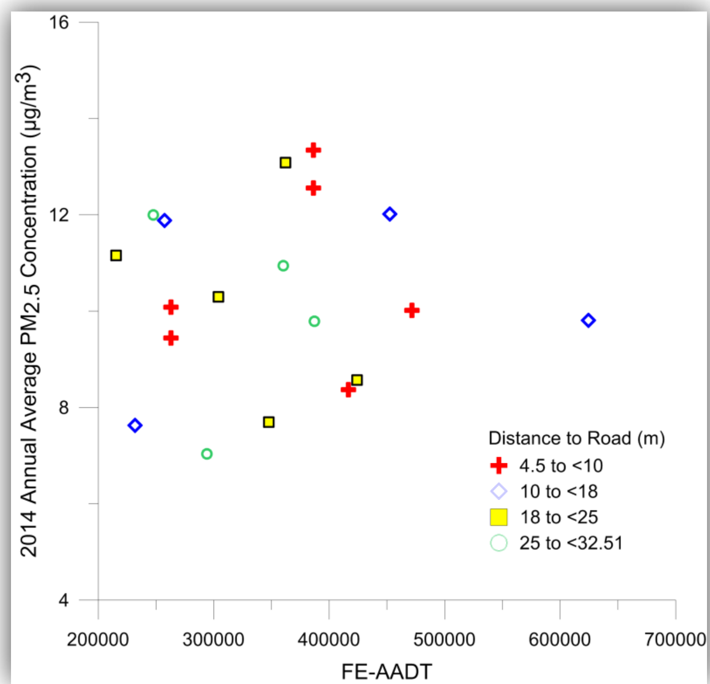


Figure 16. 2014 average $PM_{2.5}$ data at near-road sites compared to distance of monitoring site to roadway (top) and compared to both FE-AADT and distance from roadway (bottom).

3.3 Example High-Concentration Values

This section compares high near-road concentrations to readily available regional data collected at nearby sites. It does not attempt to determine the cause of the high concentrations. Phase 2 of this project will include more in-depth analysis of high-concentration episodes.

3.3.1 High NO_2 Concentrations: George Washington Bridge, New York/New Jersey CBSA

The near-road air quality monitoring site for the New York-New Jersey CBSA is next to the GWB toll booth on Interstate 95 in New Jersey. Hourly NO_2 concentrations were greater than 100 ppb on August 1 and 14, 2014. The location of the site is shown in **Figure 17**. The peak hourly NO_2 concentrations at the near-road site were 130 ppb on August 1 and 258 ppb on August 14 (**Figure 18**), at 20:00 on both days. The hourly NO_2 data and the daily maximum of hourly data at the near-road GWB site were compared to data from regional NO_2 monitors within 20 km of the GWB site. Three nearby sites in New York had NO_2 data for August 2014 (**Figure 19**). The NO_2 concentrations measured at the GWB site were significantly higher than the concentrations at the nearby sites (**Figure 20**) at 20:00 on August 1 and August 14.

Wind data were not available at the near-road site. However, the data at two of the nearby sites indicated that wind speed and direction were within a normal range during the hours that high concentrations were measured. Wind speed was low (1–4 mph), meaning that emissions from the roadway could potentially accumulate at the GWB monitoring site.

The hourly data during this time period were submitted to AQS with a qualifier code ("RR") indicating a "unique traffic disturbance" occurred near the monitor. Preliminary information provided by the EPA suggests that construction equipment was idling near the monitor and potentially contributing to the high concentrations.

Further investigation is needed to identify the cause of the high NO_2 concentrations measured on August 1 and 14, 2014. In Task Order Phase 2, we will attempt to acquire local traffic data for a more in-depth case study. Traffic count and/or traffic camera data at the GWB toll booth could be used to identify unusual activities (e.g., traffic accidents, truck activity, or construction work) that may have contributed to the high NO_2 concentrations. We plan to also determine whether surface meteorological data for the near-road site are available but not reported; such data can be used to better understand whether local-scale meteorology may have led to the high NO_2 concentrations.

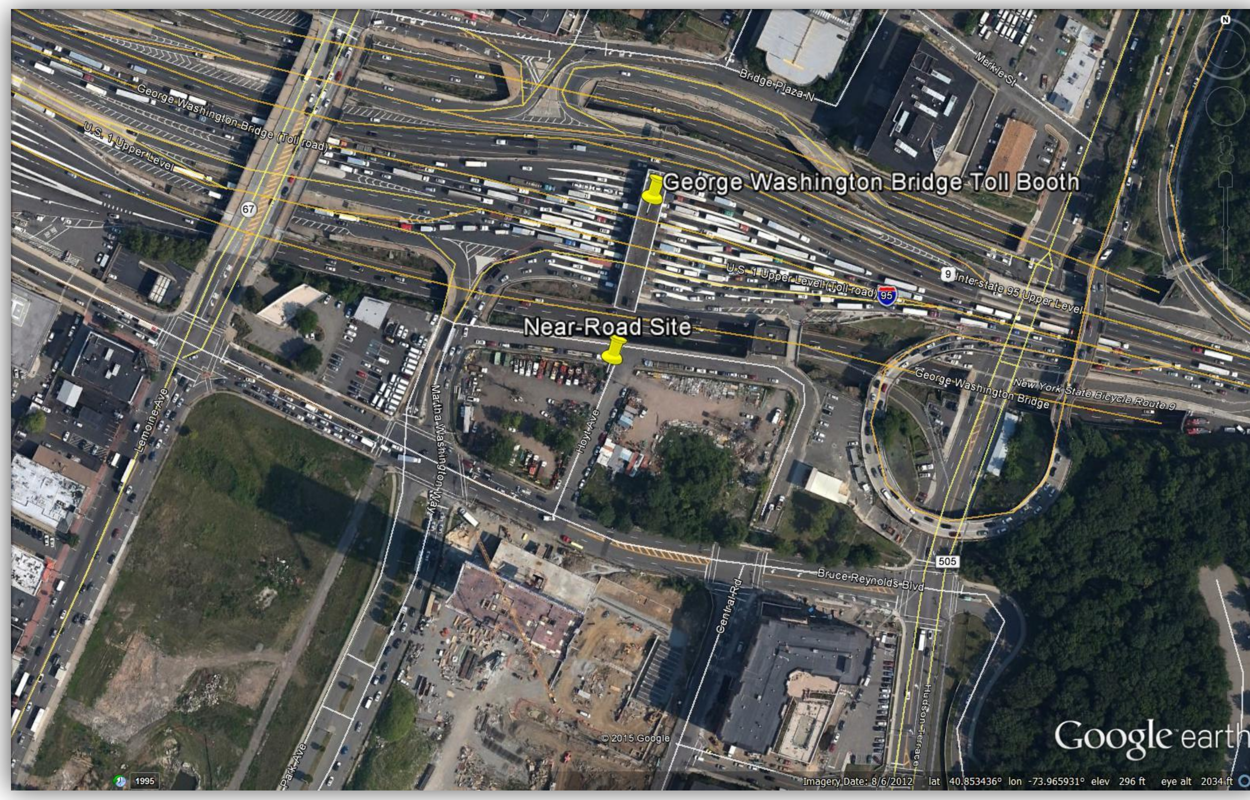


Figure 17. The location of the New York-New Jersey CBSA near-road air qaulity monitoring site on the New Jersey side of the George Washington Bridge toll booth on Interstate 95.

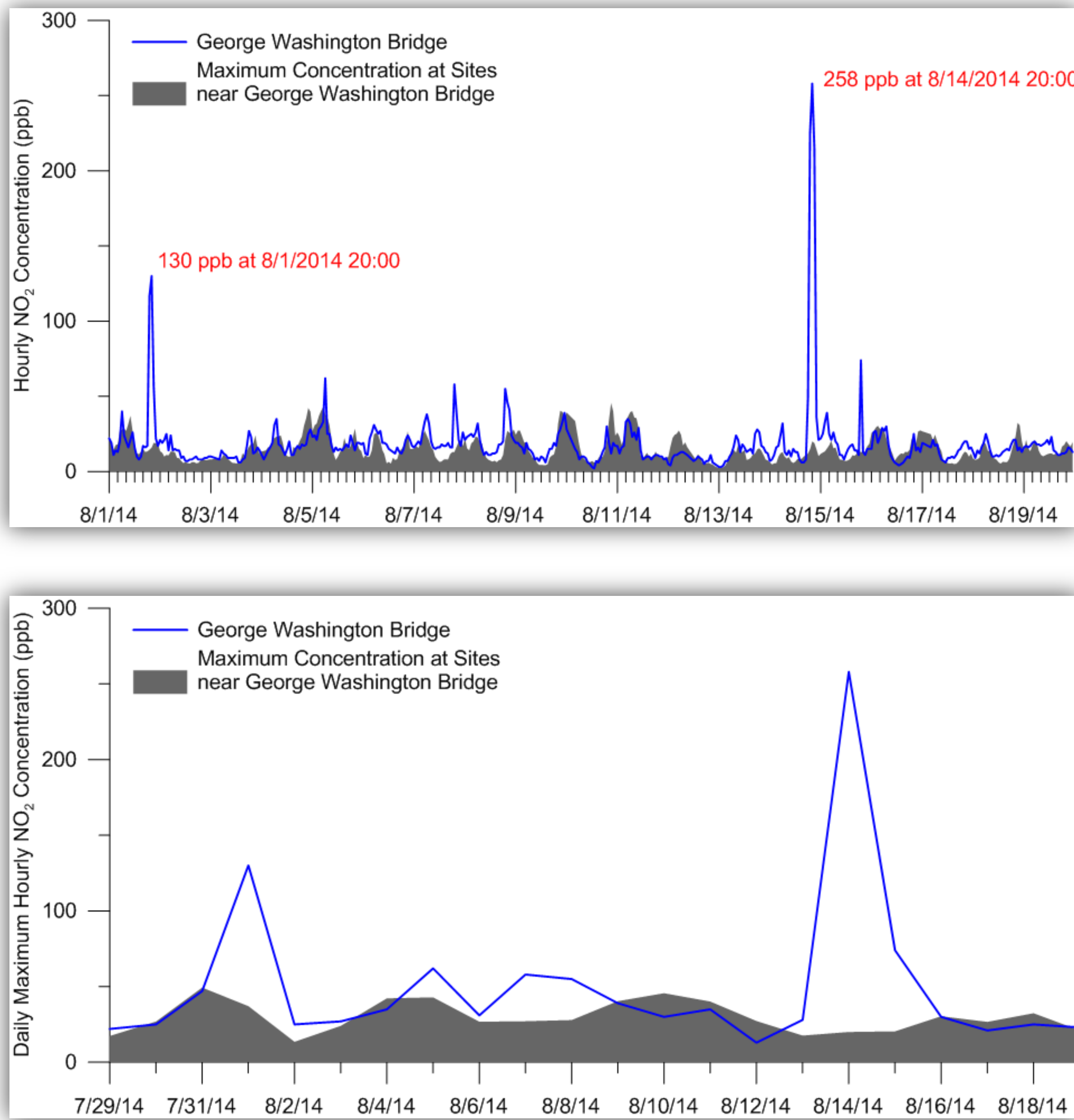


Figure 18. Hourly NO_2 concentrations (top) and daily maximum 1-hr NO_2 concentrations (bottom) at the near-road site (blue lines) vs. peak values among three nearby NO_2 monitoring sites (gray areas).

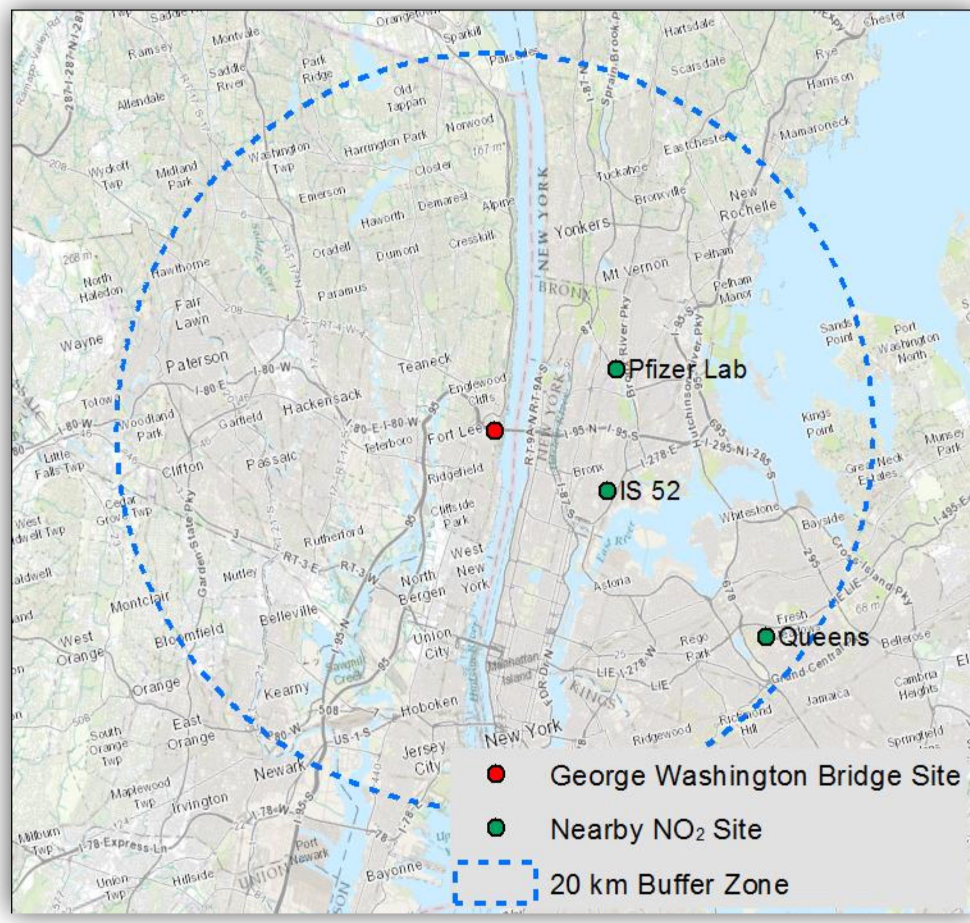


Figure 19. The locations of the three nearby sites where NO_2 was measured (green dots) within 20 km of the GWB near-road site (red dot).

3.3.2 High $PM_{2.5}$ Concentrations: Denver, Colorado

$PM_{2.5}$ concentrations greater than 35 µg/m^3 were observed at the Denver I-25 near-road site on February 7 (35.4 µg/m^3), 9 (44.4 µg/m^3), and 10 (57.0 µg/m^3) of 2014. We examined the meteorology and the $PM_{2.5}$ concentrations at nearby sites on these days, to better understand whether there may have been a regional $PM_{2.5}$ episode and/or whether $PM_{2.5}$ concentrations were higher near the roadway than at other nearby monitors. Six $PM_{2.5}$ monitoring sites within 20 km of the near-road site were found; Figure 20 shows a map of the Denver area with these monitoring sites, and Figure 21 shows a close-up view of the near-road site.

Figure 22 shows the daily $PM_{2.5}$ concentrations at the near-road site and the maximum $PM_{2.5}$ concentrations across the six nearby sites. On February 7, the 24-hr average $PM_{2.5}$ concentrations at the near-road site were slightly lower than the maximum concentrations at the other six nearby sites.

On February 9 and 10, however, concentrations at the near-road site were 7-12 μg/m^3 higher than at other nearby sites.

We examined hourly near-road $PM_{2.5}$, wind speed, wind direction, and temperature in February. February 7 was a cold day with inversions and low wind speed; there were multiple hours where $PM_{2.5}$ was greater than 40 μg/m^3. On February 9 and 10, wind speeds were modest (below 5 mph); $PM_{2.5}$ rose quickly in the morning of the 9th and stayed high for nearly two days. Winds were mostly from the north; the near-road site was downwind of the central Denver area and also immediately downwind of a section of the I-25 freeway.

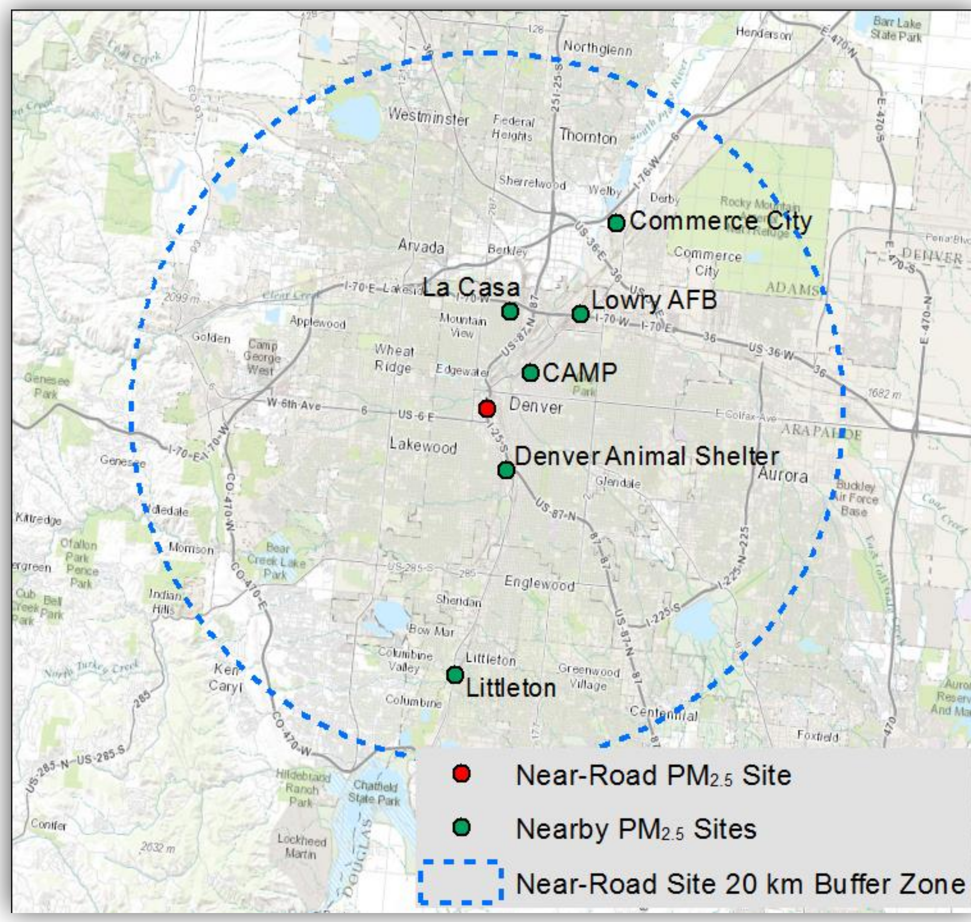


Figure 20. The locations of the six nearby sites where $PM_{2.5}$ was measured (green dots) within 20 km of the Denver I-25 near-road site (red dot).

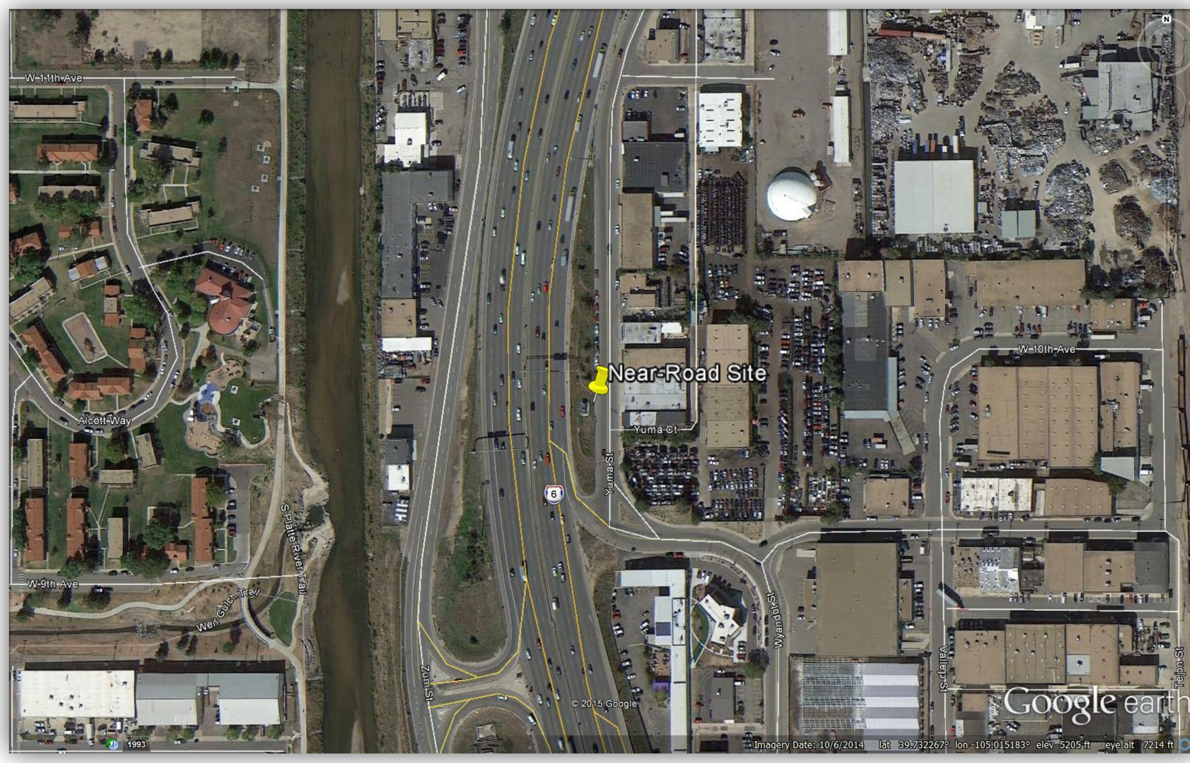


Figure 21. Close-up view of Denver near-road monitor next to I-25.

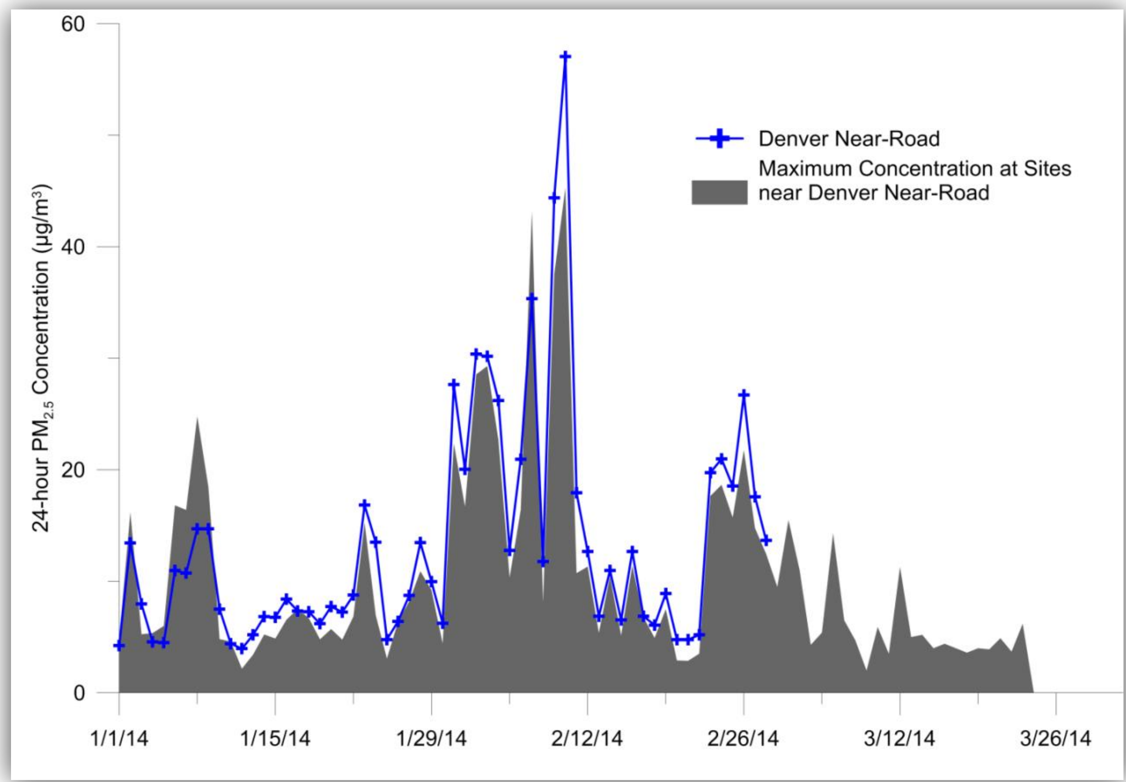


Figure 22. Daily $PM_{2.5}$ concentrations ($\mu g/m^3$) at the near-road site in Denver (blue lines) and the maximum $PM_{2.5}$ concentrations among six sites within 20 km of the near-road site (gray) during January–March 2014.

3.4 Other Sites Near Major Roads

Using the spatial analysis described in Section 2.3, we identified 33 CBSAs with air quality monitoring sites, in addition to the official near-road sites, that met the following criteria: (1) the monitor was active in 2014; (2) the monitor is within 50 m of a major roadway;[4] and (3) the monitor measures $PM_{2.5}$ and/or NO_2. Of the identified monitors, some use Federal Reference Method (FRM) or Federal Equivalent Method (FEM) sampling methodologies, while some use other sampling methodologies that may not be of equal quality. Ten sites measured NO_2; none of these sites measured concentrations greater than 100 ppb in 2014. This result is consistent with results from the official near-road sites. Annual averages at all sites were between 2 ppb and 23 ppb. As shown in Figure 23, the median hourly concentration was typically between 10 ppb and 20 ppb, and the overall mean hourly NO_2 was 14 ppb for the five-year period from 2009 to 2014 (Figure 24). Hourly concentrations at two sites, in Philadelphia and Schiller Park, were greater than 100 ppb. However the three-year

[4] We used GIS search tools combined with U.S. Census Bureau Feature Class Codes A10–A16 (primary road with limited access, or interstate highway) and A20–A28 (primary highways) to identify major roads.

average (2012–2014) 98th percentile values were below 100 ppb in both Philadelphia (53.5 ppb) and Schiller Park (62.3 ppb).

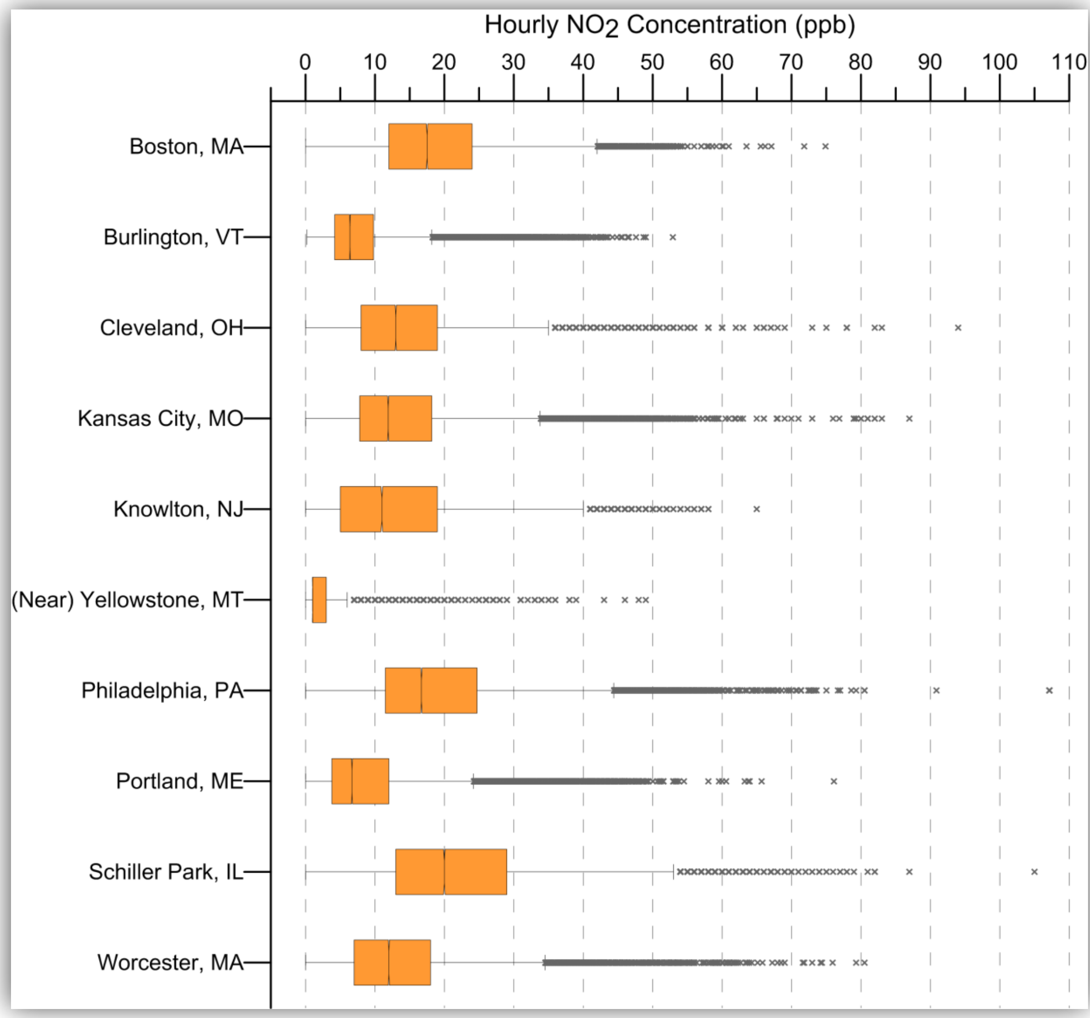


Figure 23. Hourly NO_2 concentrations near major roadways in 2009–2014, measured at routinely operating monitoring sites separate from the national near-road monitoring network.

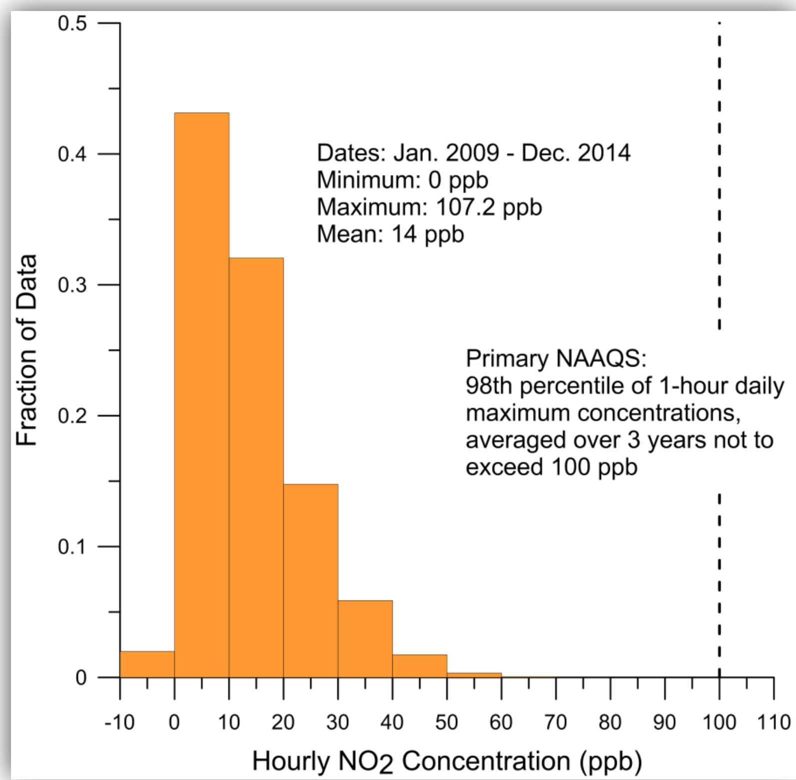


Figure 24. Distribution of hourly NO_2 concentrations at monitors near major roads for 2009–2014, measured at routinely operating monitors separate from the national near-road monitoring network. The NO_2 NAAQS threshold is also indicated.

We identified 33 CBSAs with $PM_{2.5}$ monitoring sites that are near roadways but are outside of the official near-road network. The annual means at three sites (Cleveland, Schiller Park, and near Atlanta) were greater than 12.0 µg/m^3 during some years in the 2009–2014 time period (Figure 25). However, only the Cleveland site exceeded (12.6 µg/m^3) the annual standard based on the three-year mean (2012–2014). In addition, 19 sites measured 24-hr concentrations that were greater than 35 µg/m^3 (shown in Figures 26 and 27). None of the sites recorded a three-year average 98th percentile greater than 35 µg/m^3 during 2012–2014.

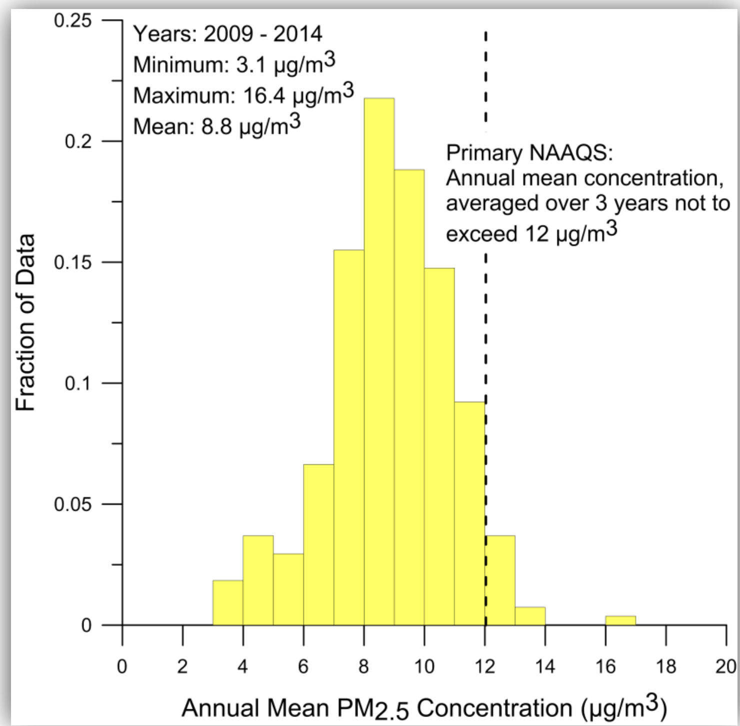


Figure 25. Distribution of annual average $PM_{2.5}$ concentrations in 2009–2014 at routinely operating monitors near roadways but separate from the national near-road monitoring network. The NAAQS threshold is also indicated.

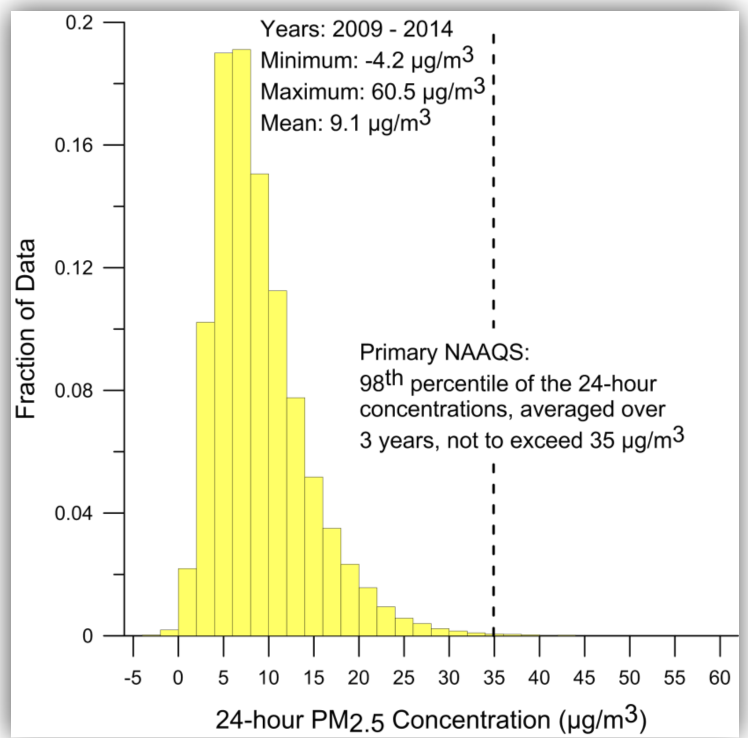


Figure 26. Distribution of 24-hr $PM_{2.5}$ concentrations in 2009–2014 at routinely operating monitors near roadways but separate from the national near-road monitoring network. The NAAQS threshold is also indicated.

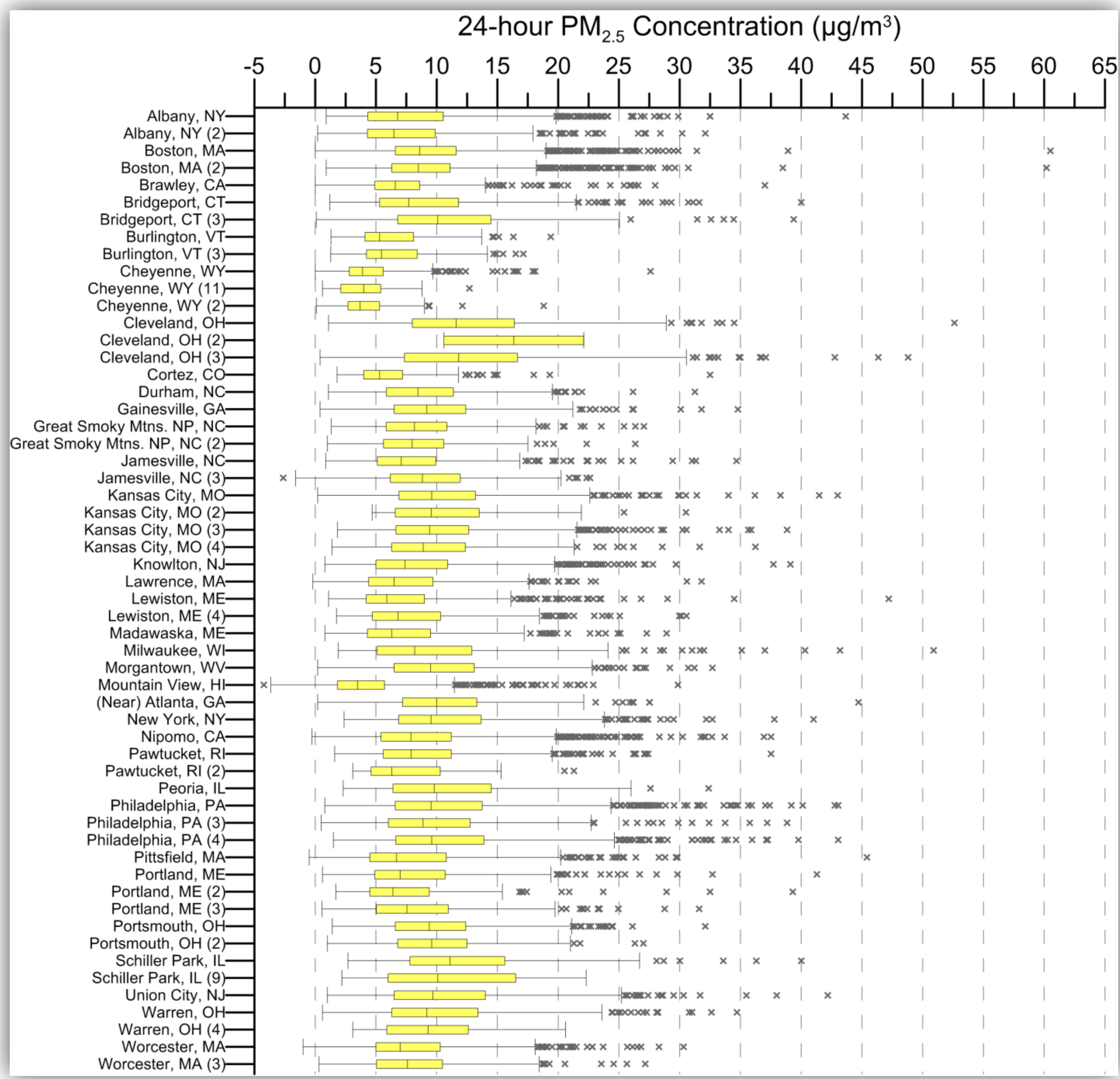


Figure 27. 24-hr $PM_{2.5}$ concentrations in 2009–2014 at routinely operating monitors near roadways but separate from the national near-road monitoring network. Numbers in parentheses indicate collocated monitors for a city.

4. Summary

An understanding of air pollutant concentrations next to national near-road monitoring sites is emerging, but additional data are needed to assess the variability in pollutant concentrations. We anticipate that by summer or fall 2015, virtually all of the required near-road sites will be operational, and a full year of data will be available from nearly all operational sites. With the data available as of May 2015, we found:

- Official near-road NO_2 data were reported for 40 (of 41 expected) CBSAs. About half of these sites did not report data for the first half of 2014, yielding an inconsistent 2014 data record across sites. In 2015, a more consistent and full data record will likely be available.
- Of the 40 CBSAs with sites reporting NO_2 data to AQS, 15 CBSAs had reported a full year of NO_2 data, and an additional 14 reported at least three full quarters of data; 11 more reported less than three full quarters. Of the 40 CBSAs, 13 CBSAs reported at least three full quarters of $PM_{2.5}$ data for 2014, of which 10 CBSAs had a full year. Six other CBSAs had $PM_{2.5}$ data for fewer than three full quarters in 2014.
- Sites in four CBSAs recorded $PM_{2.5}$ annual averages greater than or equal to 12 $\mu g/m^3$; however, one of these sites (Baltimore) had an incomplete data record for 2014. Incomplete data were due to missing data over one or more entire quarters. In 2014 across all sites reporting $PM_{2.5}$ data, there were 15 days where 24-hr $PM_{2.5}$ concentrations were greater than 35 $\mu g/m^3$. However, none of the sites recorded a 98th percentile of 24-hr $PM_{2.5}$ concentrations greater than 35 $\mu g/m^3$.
- There were two reported 1-hr daily maximum concentrations of NO_2, and five hourly values total, above 100 ppb.
- CO concentrations were typically 1 ppm or less.

In future work, we will assess high-concentration events by examining traffic and meteorology, and by distinguishing roadway increments from background concentrations. Overall, we anticipate that a much larger data set will become available later in 2015; we will use those data to better understand when and under what conditions high near-road $PM_{2.5}$ or NO_2 events occur.

5. References

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Appendix A: Details of Data Availability and Ambient $PM_{2.5}$ Concentrations

Table A-1. Species monitored at near-road monitoring sites.

Site	BC	CO	NO	NO_2	NO_x	O_3	VOC	Met	$PM_{2.5}$ Speciation	$PM_{2.5}$
Atlanta		✓	✓	✓	✓					
Austin			✓	✓	✓					
Baltimore		✓	✓	✓	✓			✓		✓
Birmingham		✓	✓	✓	✓			✓	✓	✓
Boise		✓	✓	✓	✓					
Boston	✓	✓	✓	✓	✓			✓	✓	✓
Buffalo		✓	✓	✓	✓					✓
Charlotte				✓						
Cincinnati		✓	✓	✓	✓			✓	✓	✓
Columbus		✓		✓				✓	✓	
Dallas			✓	✓	✓			✓	✓	
Denver		✓	✓	✓	✓			✓	✓	✓
Des Moines			✓	✓	✓					
Detroit		✓	✓	✓	✓			✓	✓	
Hartford		✓	✓	✓	✓			✓		✓
Houston			✓	✓	✓			✓	✓	
Indianapolis		✓	✓	✓	✓	✓		✓	✓	✓
Jacksonville		✓	✓	✓	✓					✓
Kansas City	✓	✓	✓	✓	✓			✓	✓	✓
Los Angeles			✓	✓	✓					
Louisville		✓	✓	✓	✓			✓	✓	✓
Memphis		✓		✓						
Milwaukee		✓	✓	✓	✓		✓	✓		
Minneapolis-St. Paul		✓	✓	✓	✓	✓	✓	✓	✓	✓
Nashville										

Site	BC	CO	NO	NO_2	NO_x	O_3	VOC	Met	$PM_{2.5}$ Speciation	$PM_{2.5}$
New Orleans			✓	✓	✓					
New York		✓	✓	✓						
Philadelphia		✓	✓	✓	✓			✓		✓
Phoenix		✓		✓				✓		✓
Pittsburgh		✓		✓						
Portland		✓	✓	✓	✓	✓		✓	✓	
Providence	✓	✓	✓	✓	✓					✓
Raleigh			✓	✓	✓					
Richmond		✓	✓	✓	✓					
Riverside										
San Antonio			✓	✓	✓		✓	✓	✓	
San Francisco	✓	✓	✓	✓	✓		✓	✓	✓	✓
San Jose		✓		✓						✓
Seattle		✓	✓	✓	✓			✓		✓
St. Louis	✓	✓	✓	✓	✓			✓	✓	✓
Tampa		✓	✓	✓	✓					

Table A-2. CO 1-hr maximum and 1-hr average (ppm) by site during 2014, plus the number and date range of 2014 1-hr samples reported as of May 2015. One complete year of hourly data comprises 8,760 observations.

Site	Start Date (2014)	Last Reported Date (2014)	No. of Reported Samples	1-Hr. Max. (ppm)	1-Hr. Avg. (ppm)
Atlanta, GA	15-Jun	31-Dec	4,714	2.2	0.64
Baltimore, MD	1-Apr	31-Dec	6,248	1.125	0.26
Birmingham, AL	1-Jan	31-Dec	8,106	2.14	0.43
Boise, ID	1-Jan	31-Dec	8,602	1.38601	0.24
Boston, MA-NH	1-Jan	31-Dec	6,806	1.88991	0.33
Buffalo, NY	1-Aug	31-Dec	3,249	0.7868	0.29
Cincinnati, OH	1-Aug	31-Dec	3,659	1.51	0.40
Columbus, OH	6-Jan	31-Dec	8,459	1.5	0.20
Denver, CO	1-Jan	31-Dec	8,673	3.27	0.53
Detroit, MI	1-Jan	31-Dec	8,019	2.2	0.48
Hartford, CT	1-Jan	31-Dec	8,148	1.88	0.34
Indianapolis, IN	2-May	31-Dec	5,249	1.4	0.26
Jacksonville, FL	1-Apr	31-Dec	6,181	4.8	0.42
Kansas City, MO-KS	1-Jan	31-Dec	8,440	1.599	0.28
Louisville, KY	15-Jan	31-Dec	8,153	2.11	0.39
Memphis, TN	15-Jul	31-Dec	3,572	1.124	0.28
Milwaukee, WI	1-Jan	31-Dec	8,690	1.405	0.22
Minneapolis-St. Paul, MN	1-Jan	31-Dec	8,607	2	0.17
Nashville, TN	1-Jul	31-Dec	4,078	1.435	0.39
New York, NY	1-Apr	31-Dec	6,475	1.9	0.26
Philadelphia, PA	7-Jan	31-Dec	8,278	2.03	0.40
Phoenix, AZ	21-Feb	31-Dec	7,415	1.5	0.38
Pittsburgh, PA	1-Sep	31-Dec	2,790	3.1307	0.40
Portland, OR	8-May	31-Dec	5,403	1.2885	0.36
Providence, RI	1-Apr	31-Dec	6,331	2.92	0.57
Richmond, VA	1-Jan	31-Dec	7,710	1.8	0.27

Site	Start Date (2014)	Last Reported Date (2014)	No. of Reported Samples	1-Hr. Max. (ppm)	1-Hr. Avg. (ppm)
San Francisco, CA	1-Feb	31-Dec	7,577	2.02	0.45
San Jose, CA	1-Sep	31-Dec	2,781	2.24	0.70
Seattle, WA	1-Apr	31-Dec	4,977	3.3091	0.57
St. Louis, MO	1-Jan	31-Dec	8,412	1.655	0.28
Tampa, FL	1-Apr	31-Dec	3,793	1.727	0.32

Table A-3. $PM_{2.5}$ 1-hr maximum and 1-hr average (µg/m^3) at sites measuring continuous hourly $PM_{2.5}$, plus the number and date range of 2014 1-hr samples reported as of May 2015. One complete year of hourly data comprises 8,760 observations.

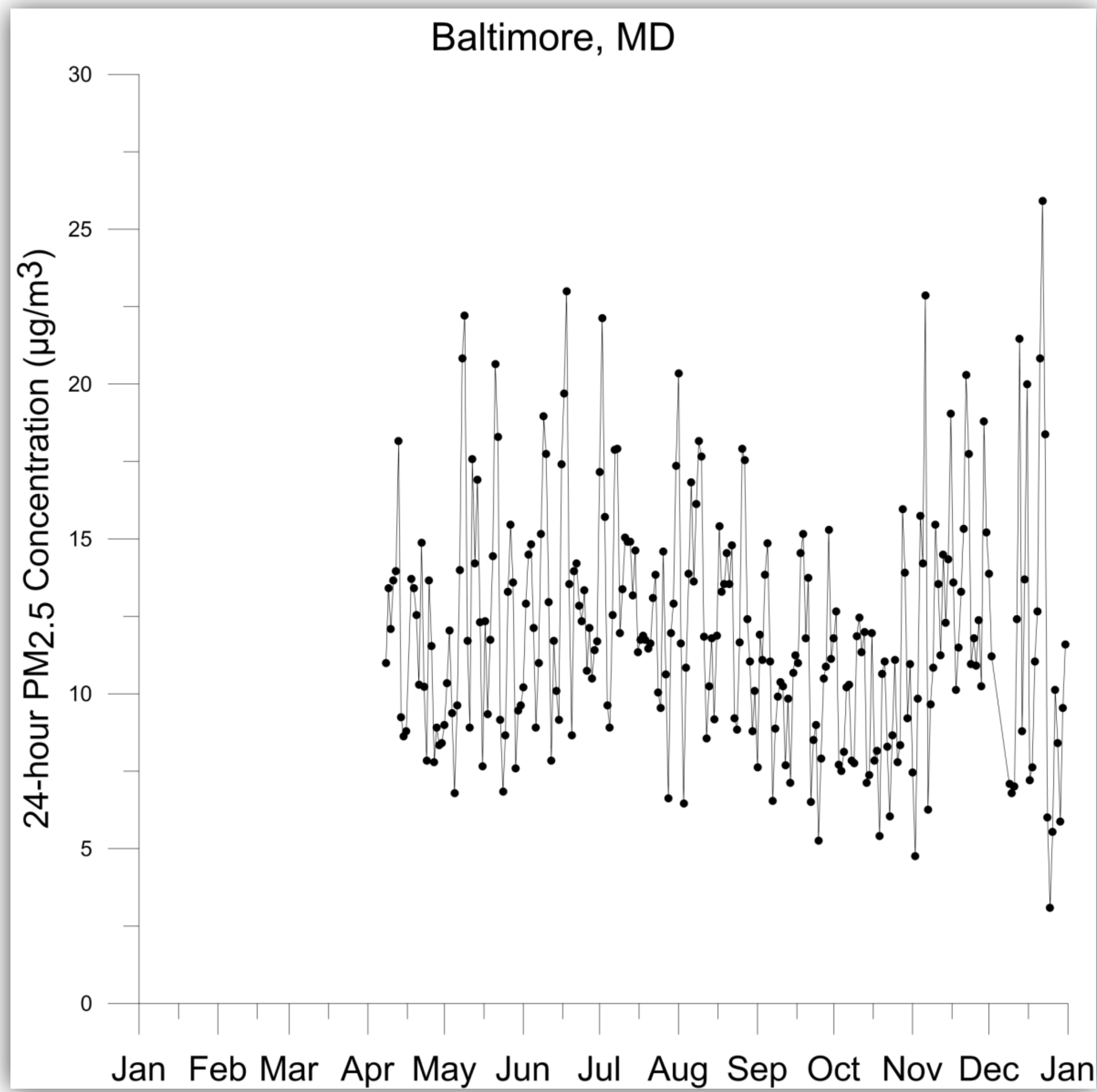
Urban Area	Duration	Start Date (2014)	Last Reported Date (2014)	No. of Reported Samples	1-Hr. Max. (µg/m^3)	1-Hr. Avg. (µg/m^3)
Baltimore-Columbia-Towson, MD (3)	Hourly	7-Apr	31-Dec	6,291	72.0	12.0
Denver-Aurora-Lakewood, CO (3)	Hourly	1-Jan	31-Dec	8,254	87.0	10.1
Jacksonville, FL (3)	Hourly	1-Apr	31-Dec	5,120	99.1	10.3
Kansas City, MO-KS (4)	Hourly	1-Jan	31-Dec	8,568	64.3	7.7
Minneapolis-St. Paul-Bloomington, MN-WI (3)	Hourly	1-Jan	31-Dec	8,406	61.0	9.8
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	Hourly	5-Jan	31-Dec	7,752	69.4	11.8
Phoenix-Mesa-Scottsdale, AZ (3)	Hourly	1-May	31-Dec	5,629	116.0	9.8
Providence-Warwick, RI-MA	Hourly	1-Apr	31-Dec	6,125	40.0	8.4
San Francisco-Oakland-Hayward, CA (3)	Hourly	1-Feb	31-Dec	7,977	132.0	8.6
San Jose-Sunnyvale-Santa Clara, CA (3)	Hourly	1-Sep	31-Dec	2,867	41.0	7.0
Seattle-Tacoma-Bellevue, WA (3)	Hourly	21-May	31-Dec	5,153	49.6	10.0
St. Louis, MO-IL (4)	Hourly	1-Jan	31-Dec	7,774	91.5	10.9

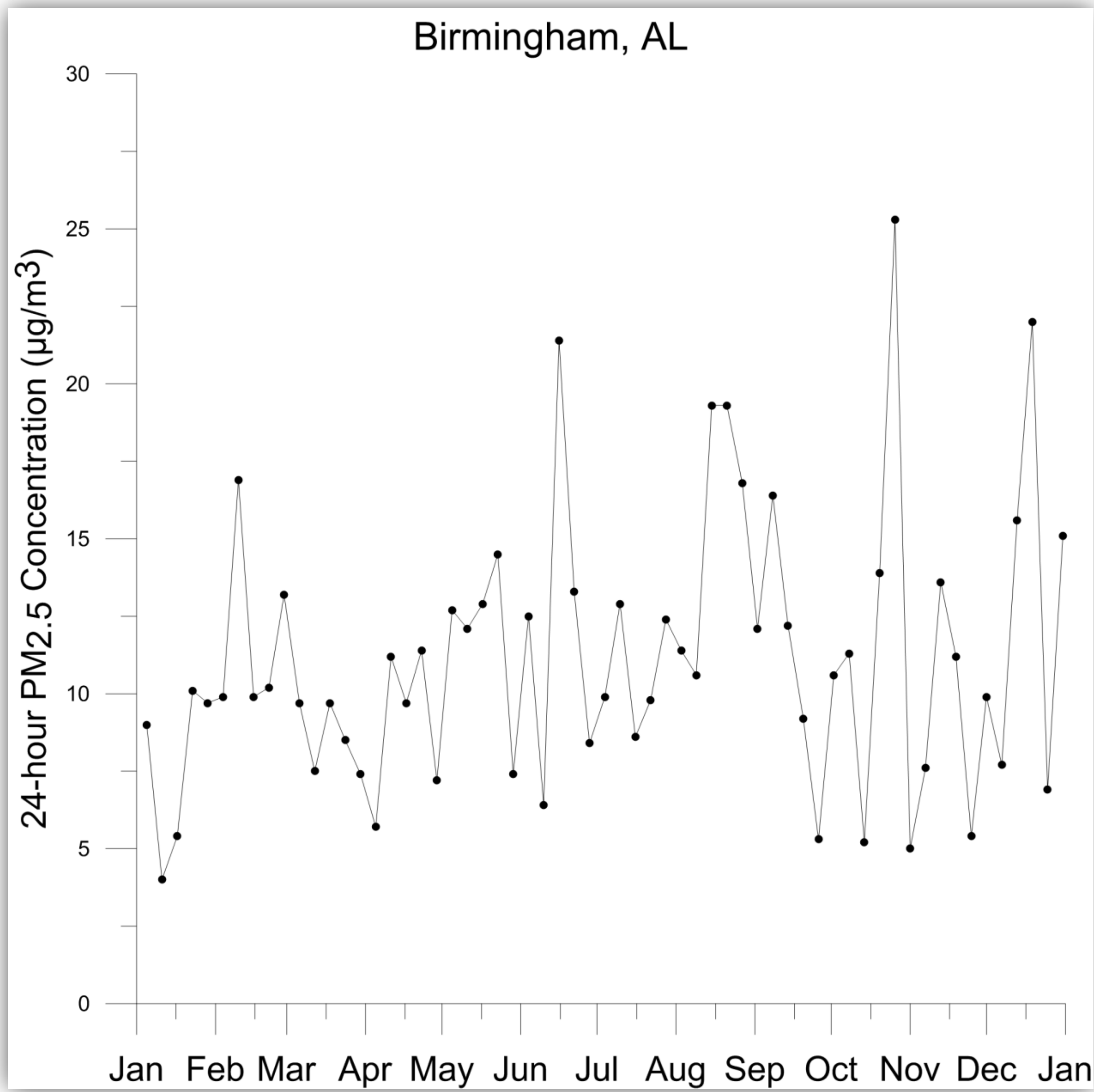
Table A-4. $PM_{2.5}$ 24-hr maximum, 98th percentile of 24-hr values, and annual average (µg/m^3) by site during 2014, plus the number and date range of 2014 24-hr values reported as of May 2015. One complete year of hourly duration data comprises 365 averages; one complete year of 24-hour samples comprises approximately 122 observations (1-in-3 day frequency) and 61 observations (1-in-6 day frequency).

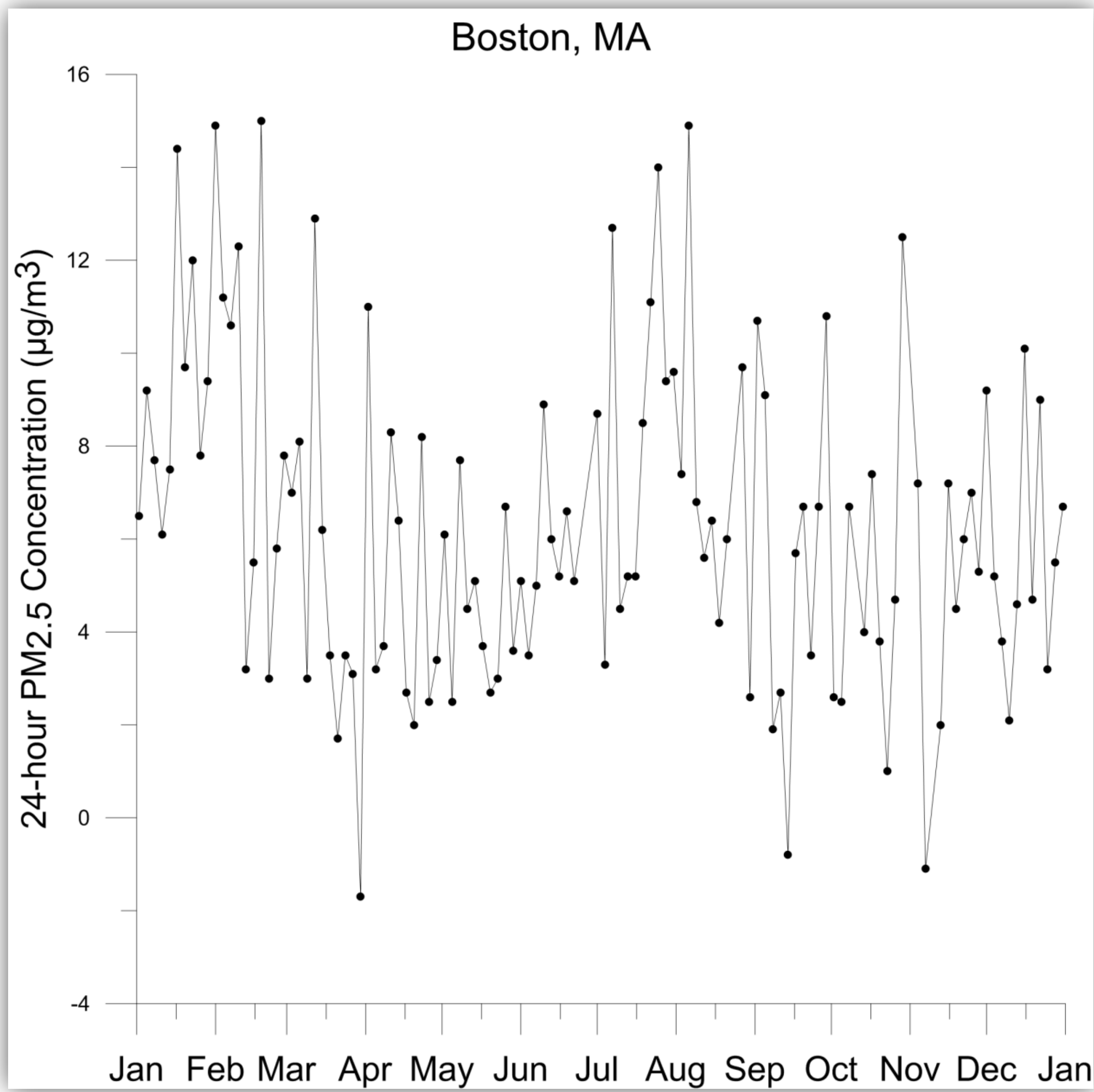
Urban Area	Sample Duration	Frequency	Start Date (2014)	Last Reported Date (2014)	No. of Samples or Averages	24-Hr Maximum (µg/m^3)	98th Percentile of 24-Hr Values (µg/m^3)	Annual Average (µg/m^3)
Baltimore-Columbia-Towson, MD (3)	Hourly	Every Day	08-Apr-14	31-Dec-14	261	25.9	22.0	12.0
Birmingham-Hoover, AL	24-hour	1-in-6	05-Jan-14	31-Dec-14	61	25.3	24.5	11.2
Boston-Cambridge-Newton, MA-NH	24-hour	1-in-3	02-Jan-14	31-Dec-14	116	15.0	14.9	6.3
Buffalo-Cheektowaga-Niagara Falls, NY	24-hour	1-in-3	10-Jul-14	31-Dec-14	55	22.7	21.9	7.4
Cincinnati, OH-KY-IN	24-hour	1-in-6	02-Jan-14	28-Dec-14	60	29.1	28.5	13.3
Cincinnati, OH-KY-IN (4)	24-hour	1-in-6	11-Jan-14	25-Dec-14	59	35.5	34.0	12.6
Denver-Aurora-Lakewood, CO	24-hour	1-in-3	08-Jan-14	28-Dec-14	120	48.3	30.8	9.4
Denver-Aurora-Lakewood, CO (3)	Hourly	Every Day	01-Jan-14	31-Dec-14	345	57.0	30.2	10.1
Hartford-West Hartford-East Hartford, CT	24-hour		06-Mar-14	31-Dec-14	83	18.0	17.9	7.6
Indianapolis-Carmel-Anderson, IN	24-hour	1-in-3	01-Feb-14	31-Dec-14	131	40.7	33.9	13.1
Jacksonville, FL (3)	Hourly	Every Day	01-Apr-14	31-Dec-14	216	30.6	26.6	10.3
Kansas City, MO-KS (4)	Hourly	Every Day	01-Jan-14	31-Dec-14	359	37.3	18.4	7.7
Louisville/Jefferson County, KY-IN	24-hour	1-in-3	02-Jan-14	31-Dec-14	120	50.0	26.9	12.0
Minneapolis-St. Paul-Bloomington, MN-WI (3)	Hourly	Every Day	01-Jan-14	31-Dec-14	349	33.2	23.0	9.8

Urban Area	Sample Duration	Frequency	Start Date (2014)	Last Reported Date (2014)	No. of Samples or Averages	24-Hr Maximum (µg/m^3)	98th Percentile of 24-Hr Values (µg/m^3)	Annual Average (µg/m^3)
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	Hourly	Every Day	05-Jan-14	31-Dec-14	331	40.4	27.7	11.9
Phoenix-Mesa-Scottsdale, AZ (3)	Hourly	Every Day	01-May-14	31-Dec-14	238	29.2	21.8	9.8
Providence-Warwick, RI-MA	Hourly	Every Day	05-Apr-14	31-Dec-14	250	20.4	17.6	8.4
San Francisco-Oakland-Hayward, CA (3)	Hourly	Every Day	01-Feb-14	31-Dec-14	334	26.0	19.4	8.6
San Jose-Sunnyvale-Santa Clara, CA (3)	Hourly	Every Day	01-Sep-14	31-Dec-14	120	24.3	21.7	7.0
Seattle-Tacoma-Bellevue, WA (3)	Hourly	Every Day	22-May-14	31-Dec-14	216	33.7	21.0	10.0
St. Louis, MO-IL (4)	Hourly	Every Day	01-Jan-14	31-Dec-14	322	52.3	29.3	10.9

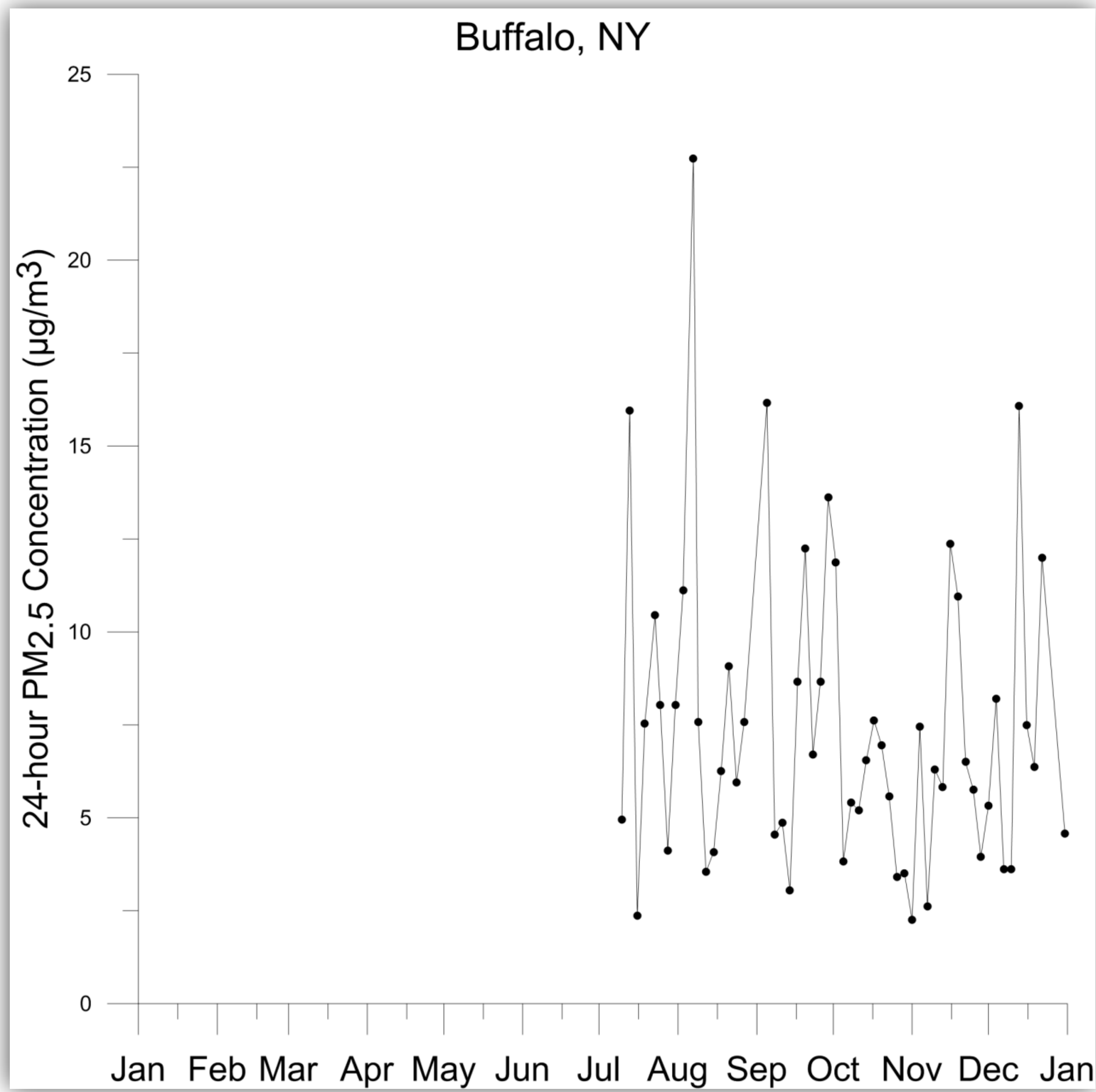
Appendix B: 2014 24-Hour $PM_{2.5}$ Near-Road Data Time Series

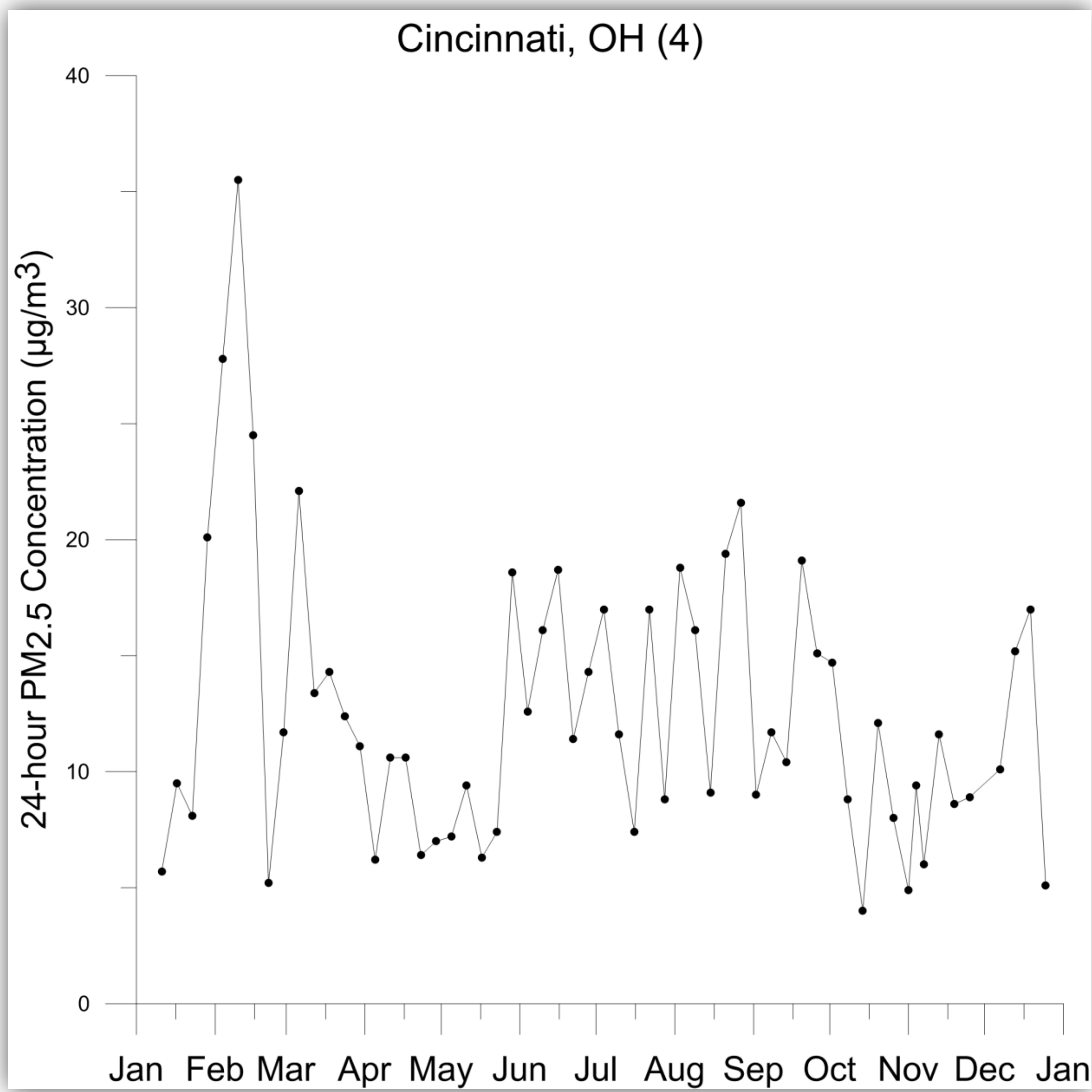


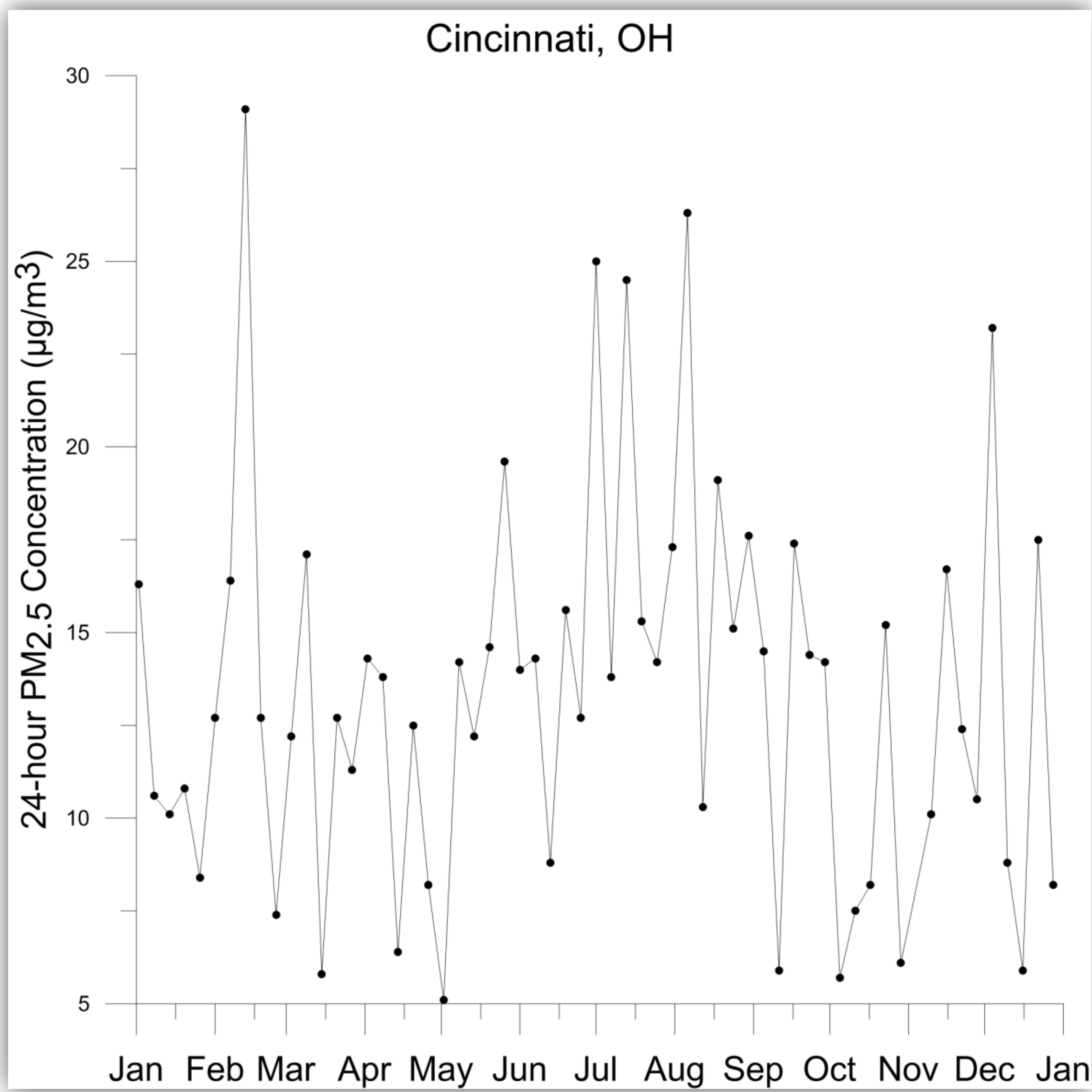

Birmingham, AL
24-hour PM2.5 Concentration (µg/m3)
30
25
20
15
10
5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan



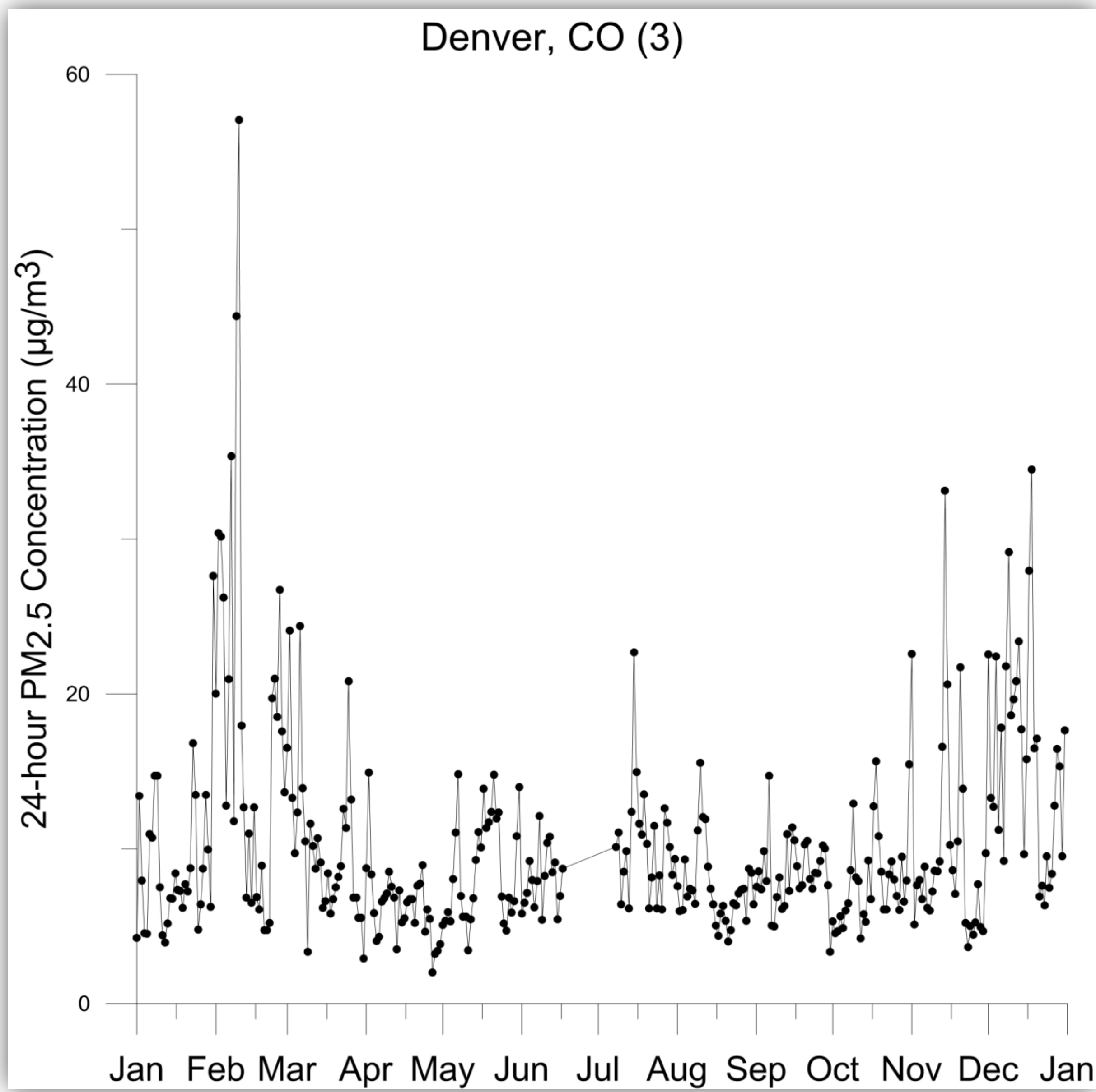
Boston, MA
24-hour PM2.5 Concentration (µg/m3)
16
12
8
4
0
-4
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

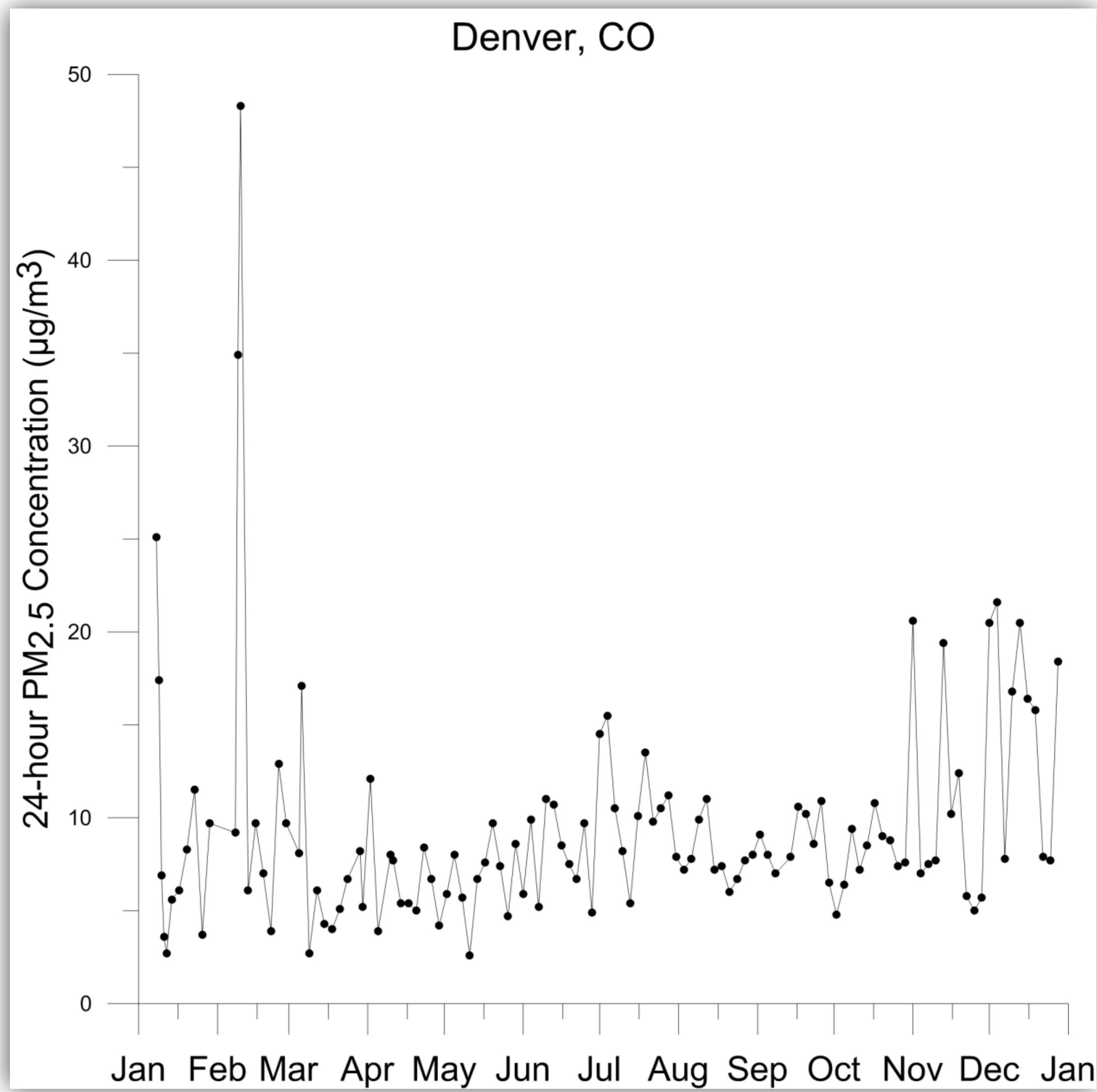

Buffalo, NY
24-hour PM2.5 Concentration (µg/m3)
25
20
15
10
5
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

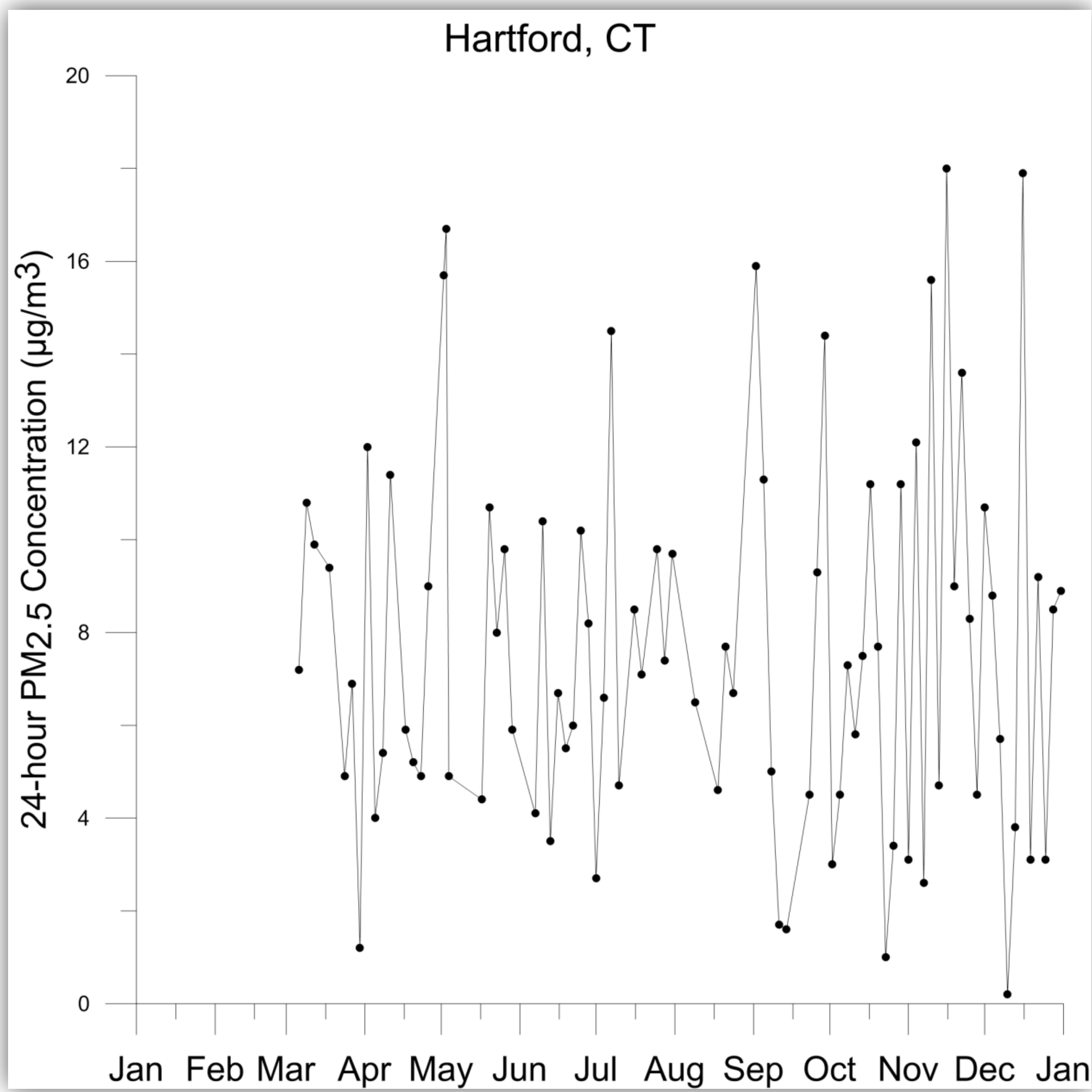

Cincinnati, OH (4)
24-hour PM2.5 Concentration (µg/m3)
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

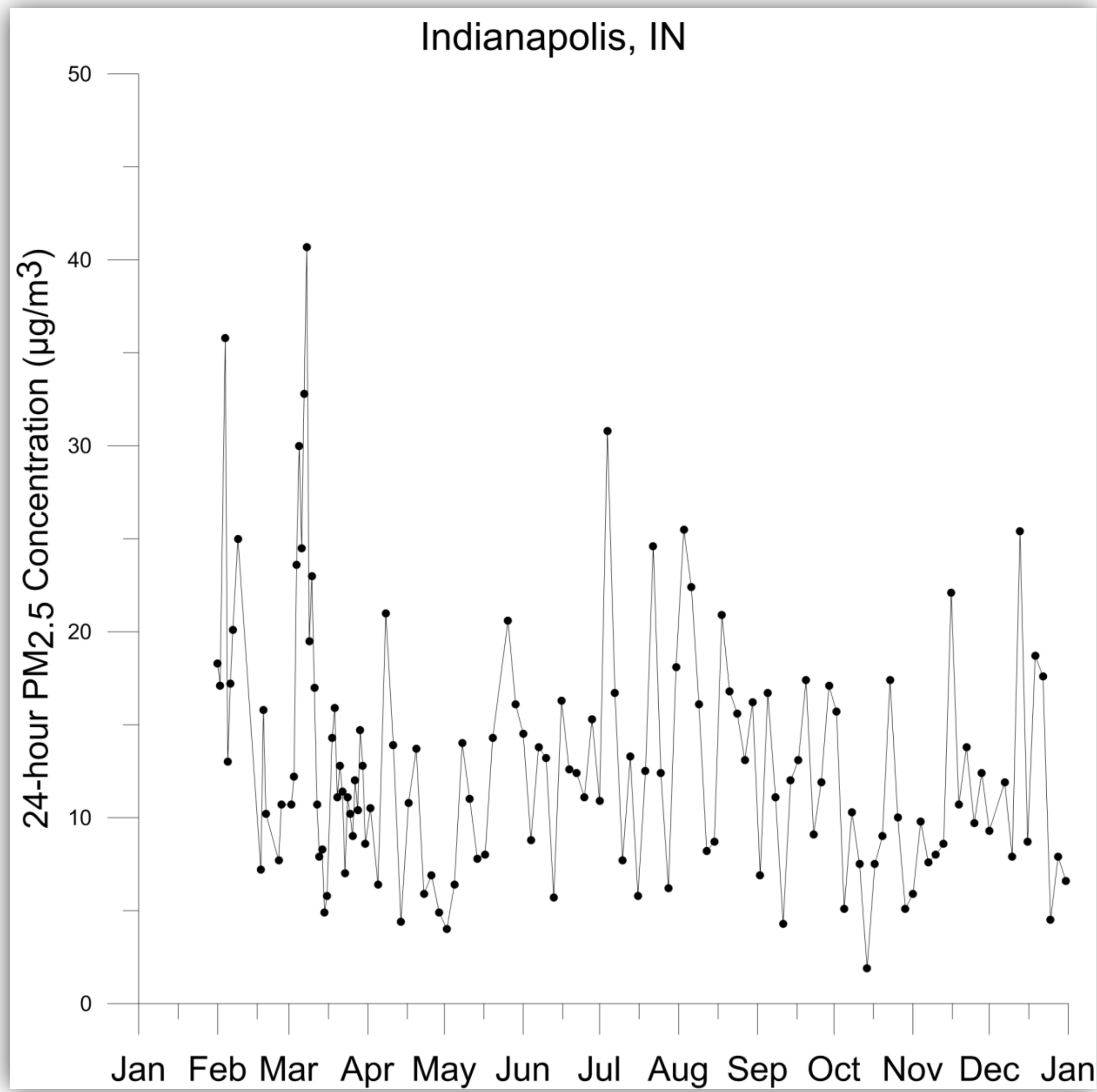


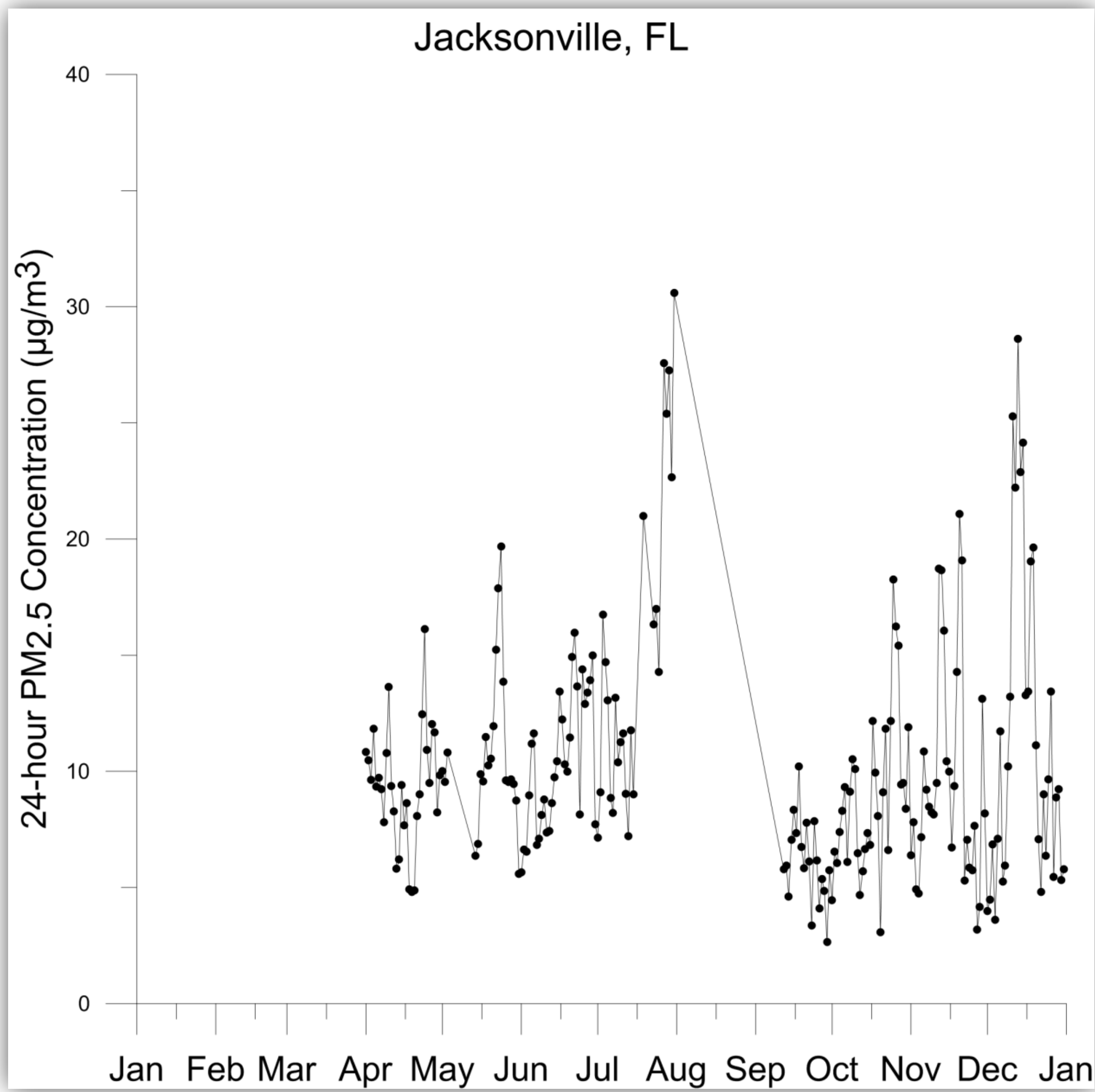
Cincinnati, OH
24-hour PM2.5 Concentration (µg/m3)
30
25
20
15
10
5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

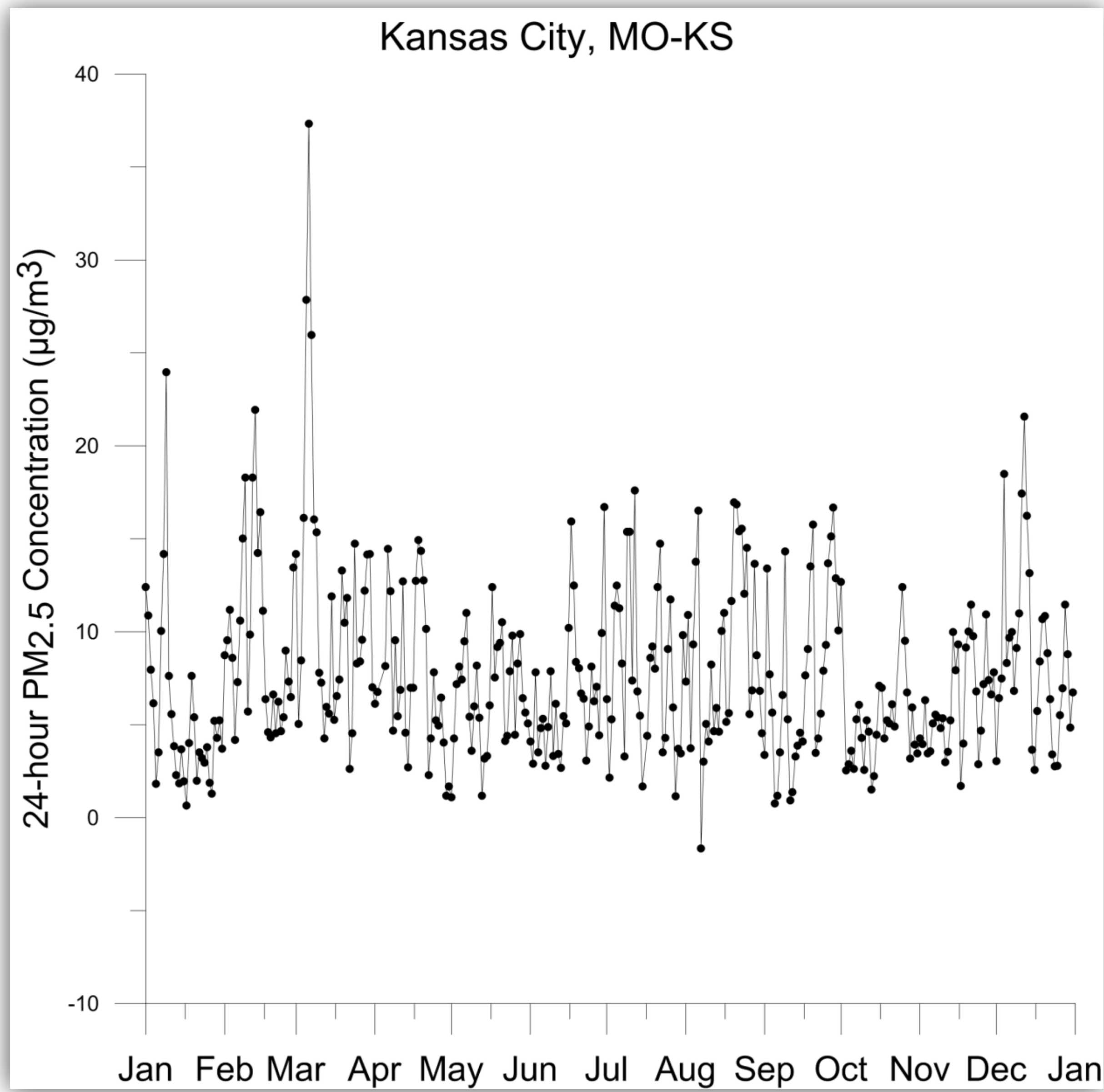

Denver, CO (3)
24-hour PM2.5 Concentration (µg/m3)
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

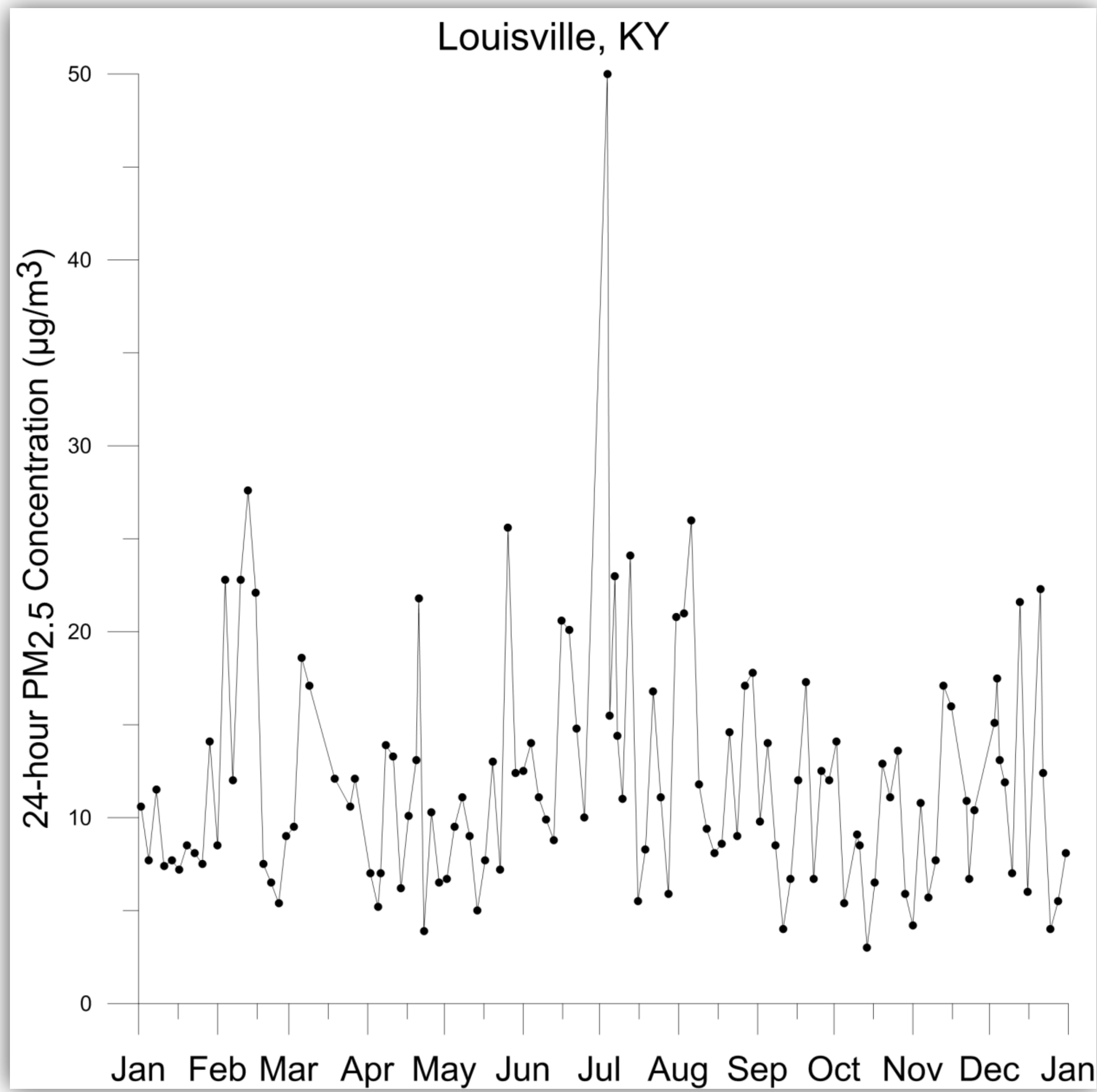

Denver, CO
24-hour PM2.5 Concentration (µg/m3)
50
40
30
20
10
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

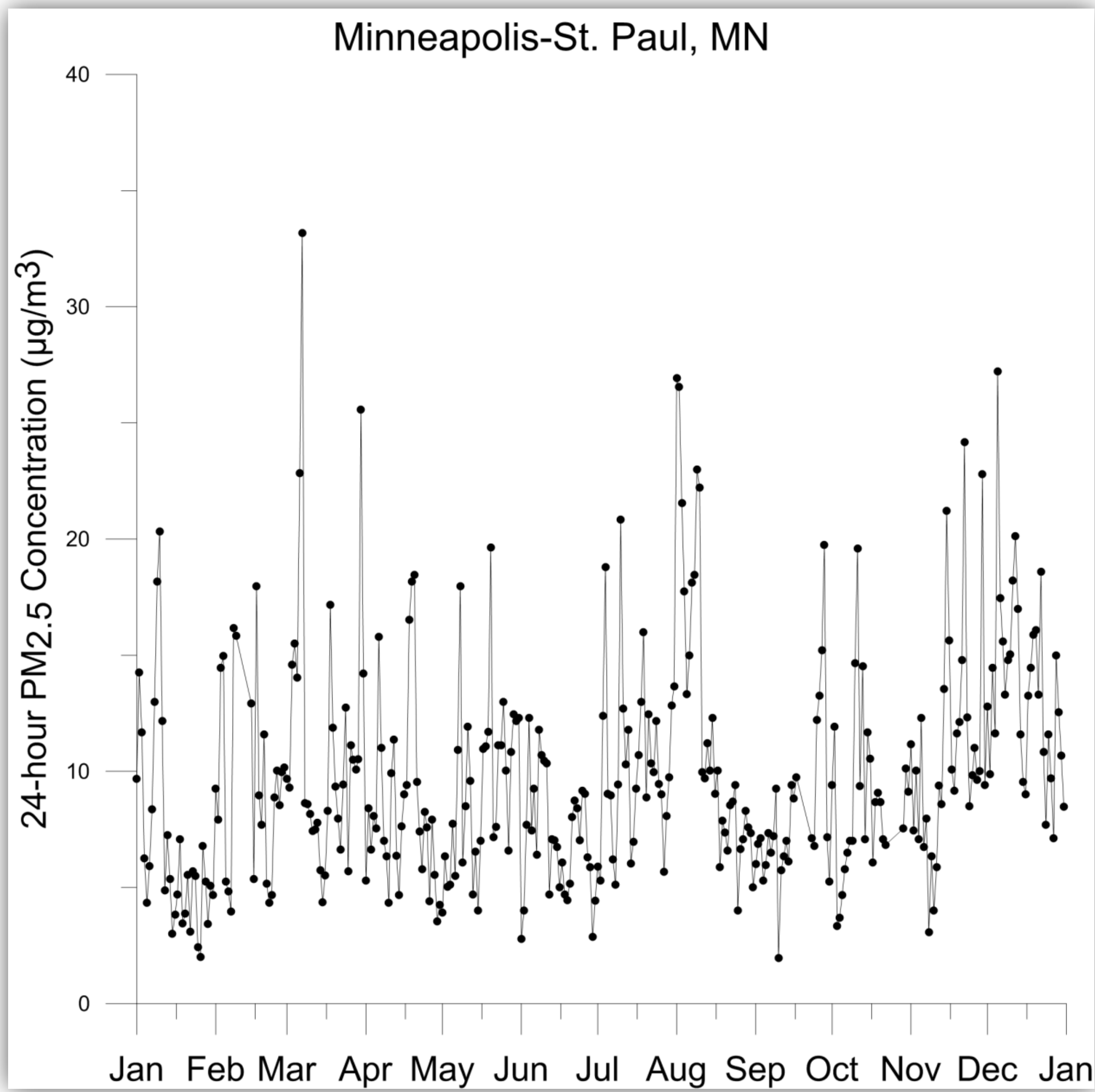

Hartford, CT
24-hour PM2.5 Concentration (µg/m3)
20
16
12
8
4
0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

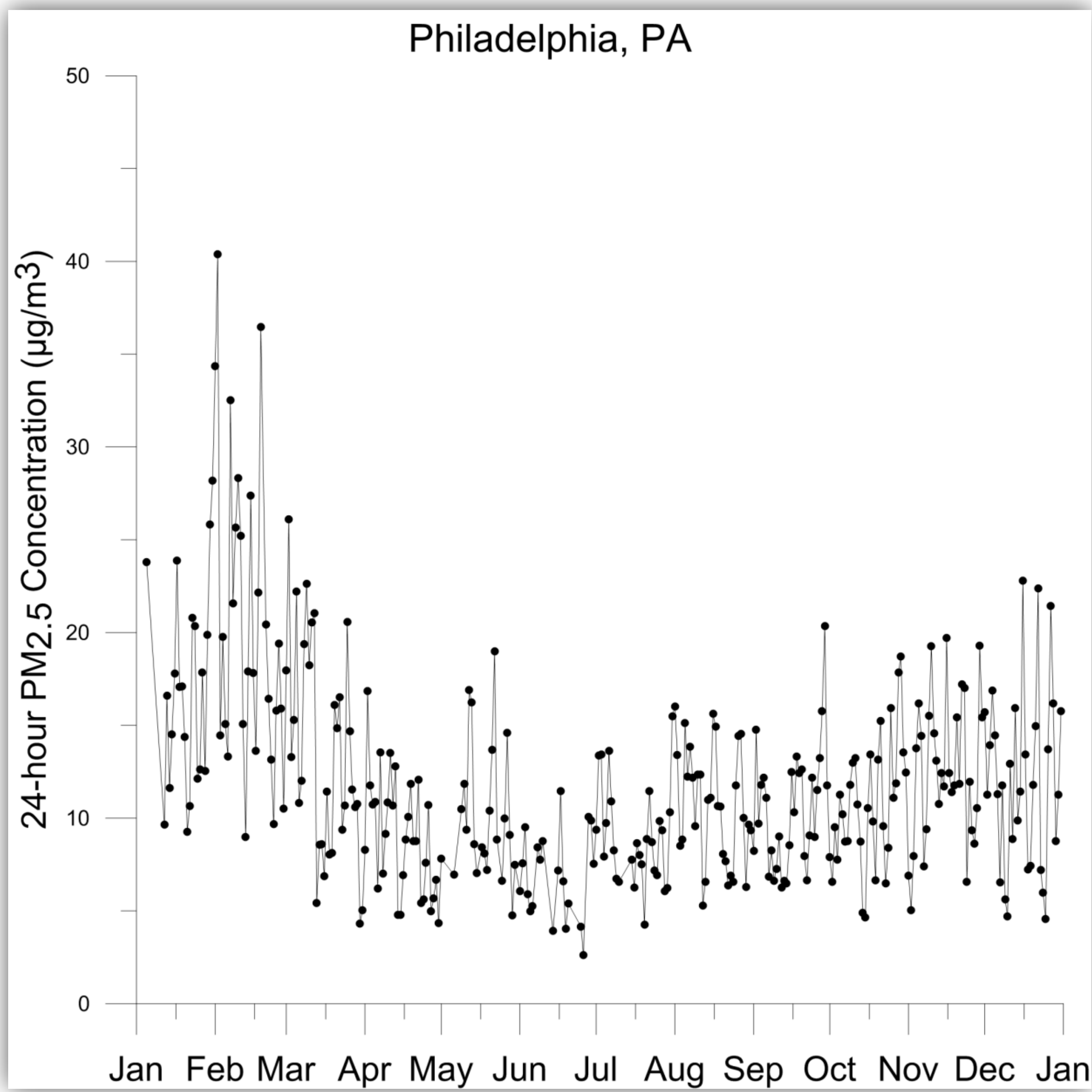

Indianapolis, IN
24-hour PM2.5 Concentration (µg/m3)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

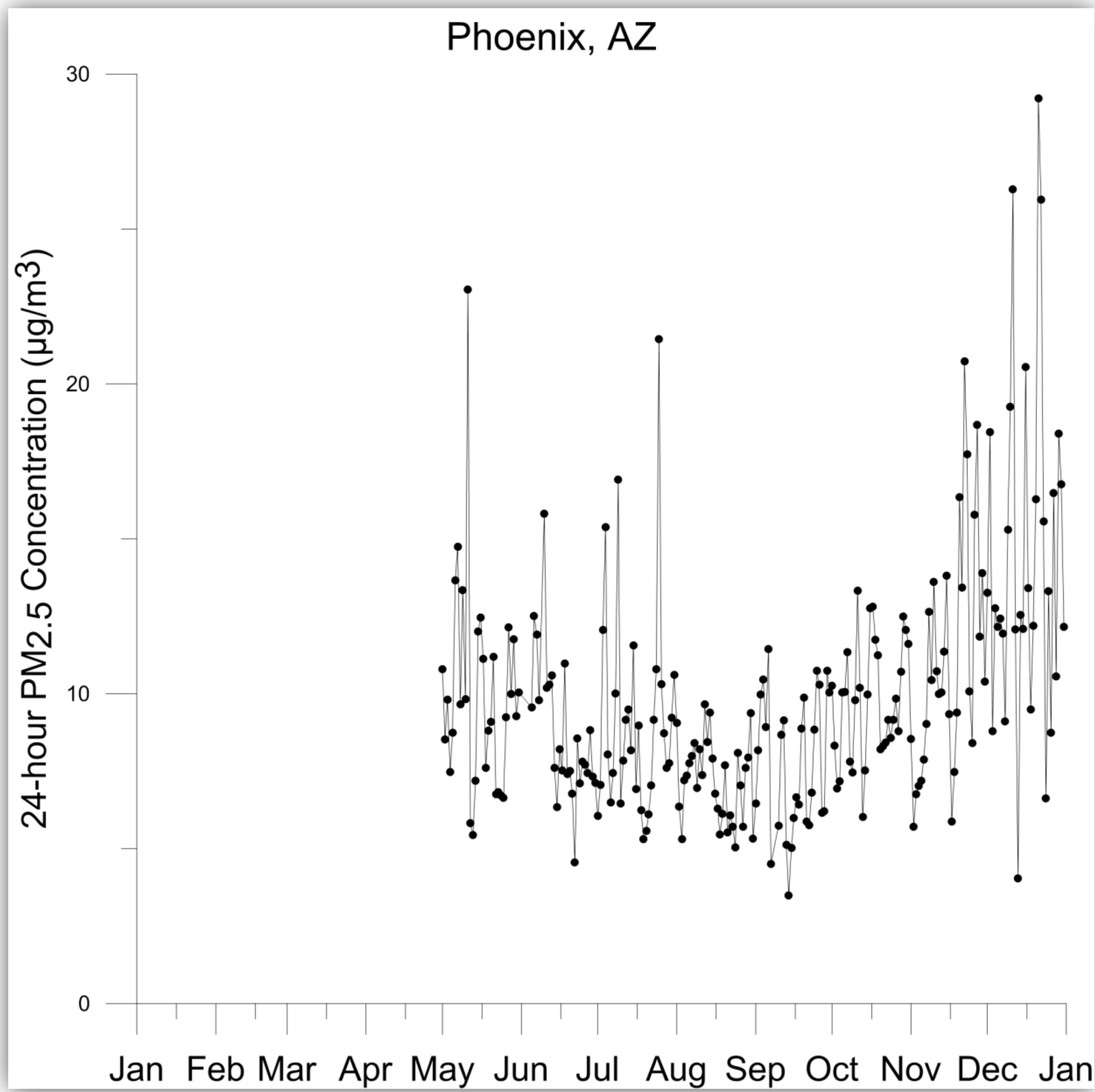

Jacksonville, FL
24-hour PM2.5 Concentration (µg/m3)
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

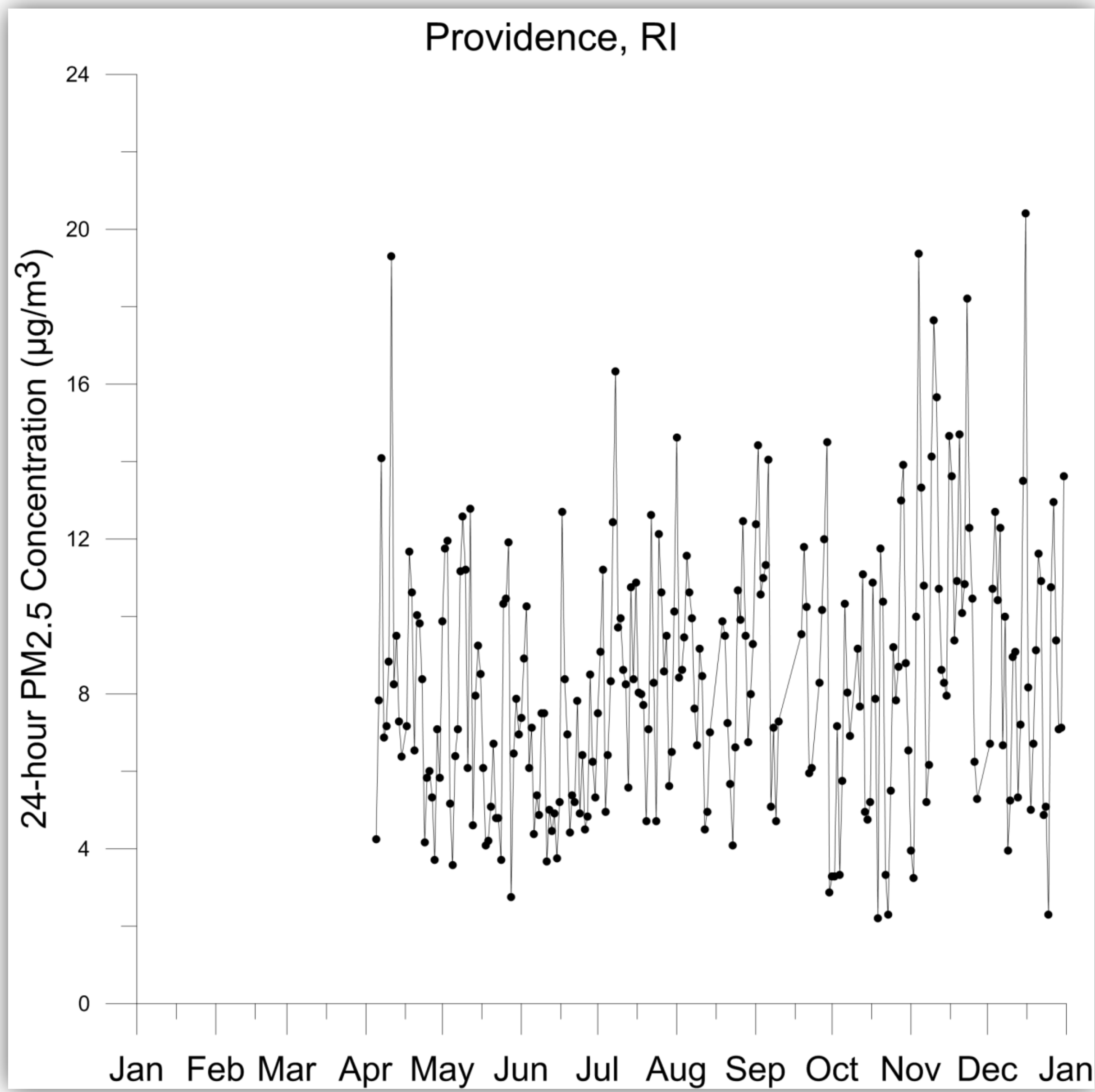

Kansas City, MO-KS
24-hour PM2.5 Concentration (µg/m3)
40
30
20
10
0
-10
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan

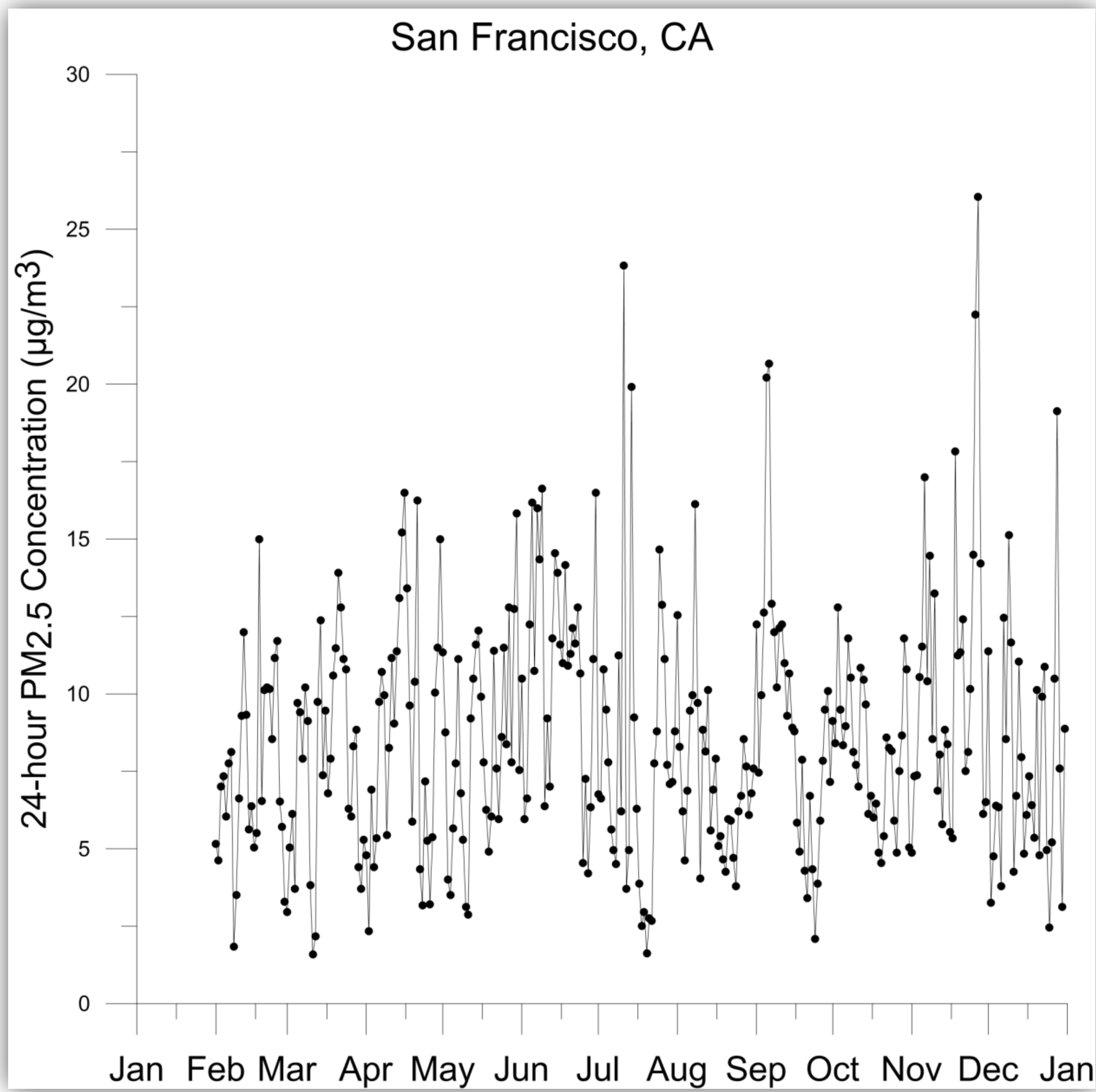

Louisville, KY
24-hour PM2.5 Concentration (µg/m3)
0
10
20
30
40
50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

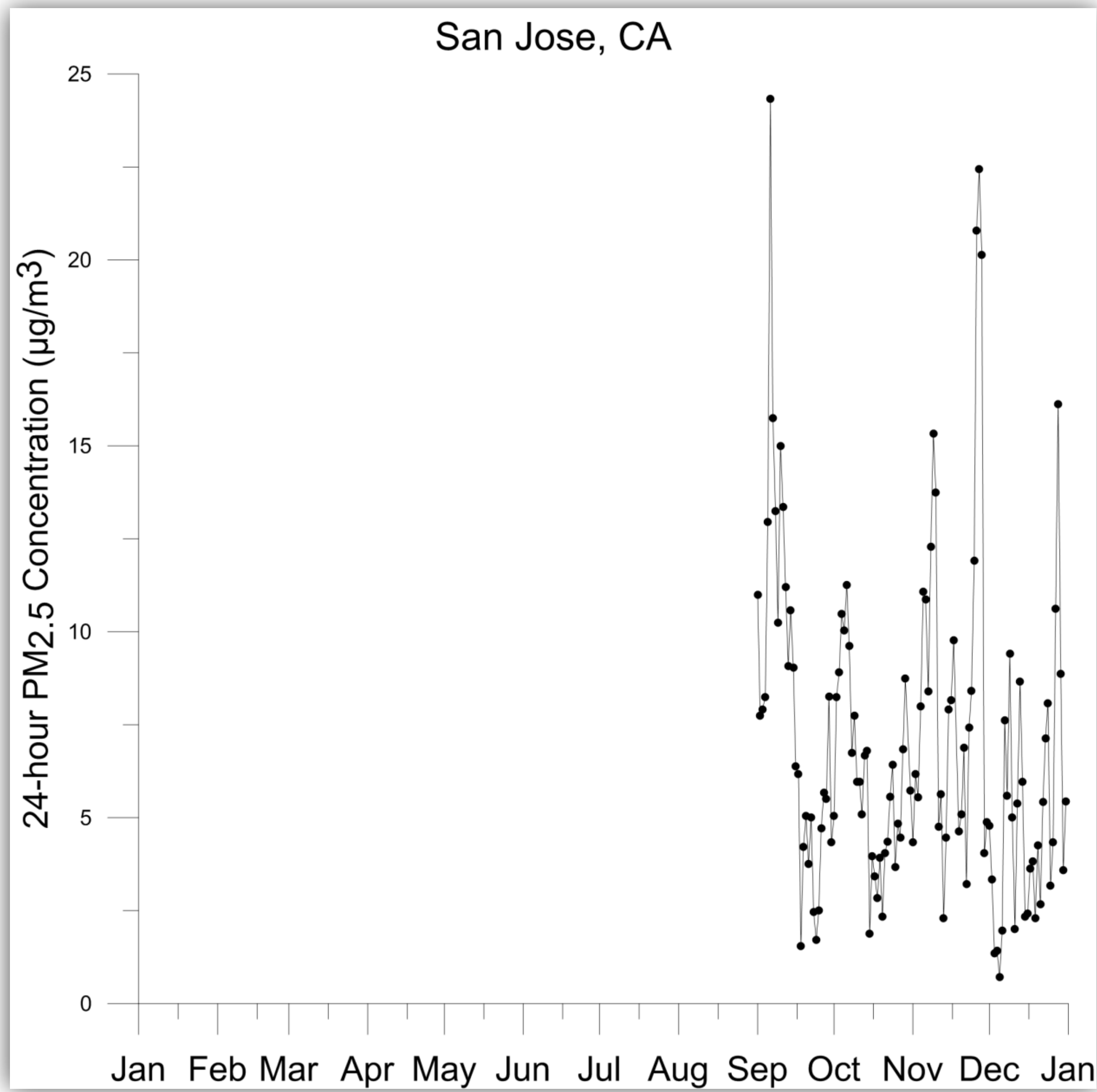

Minneapolis-St. Paul, MN
24-hour PM2.5 Concentration (µg/m3)
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

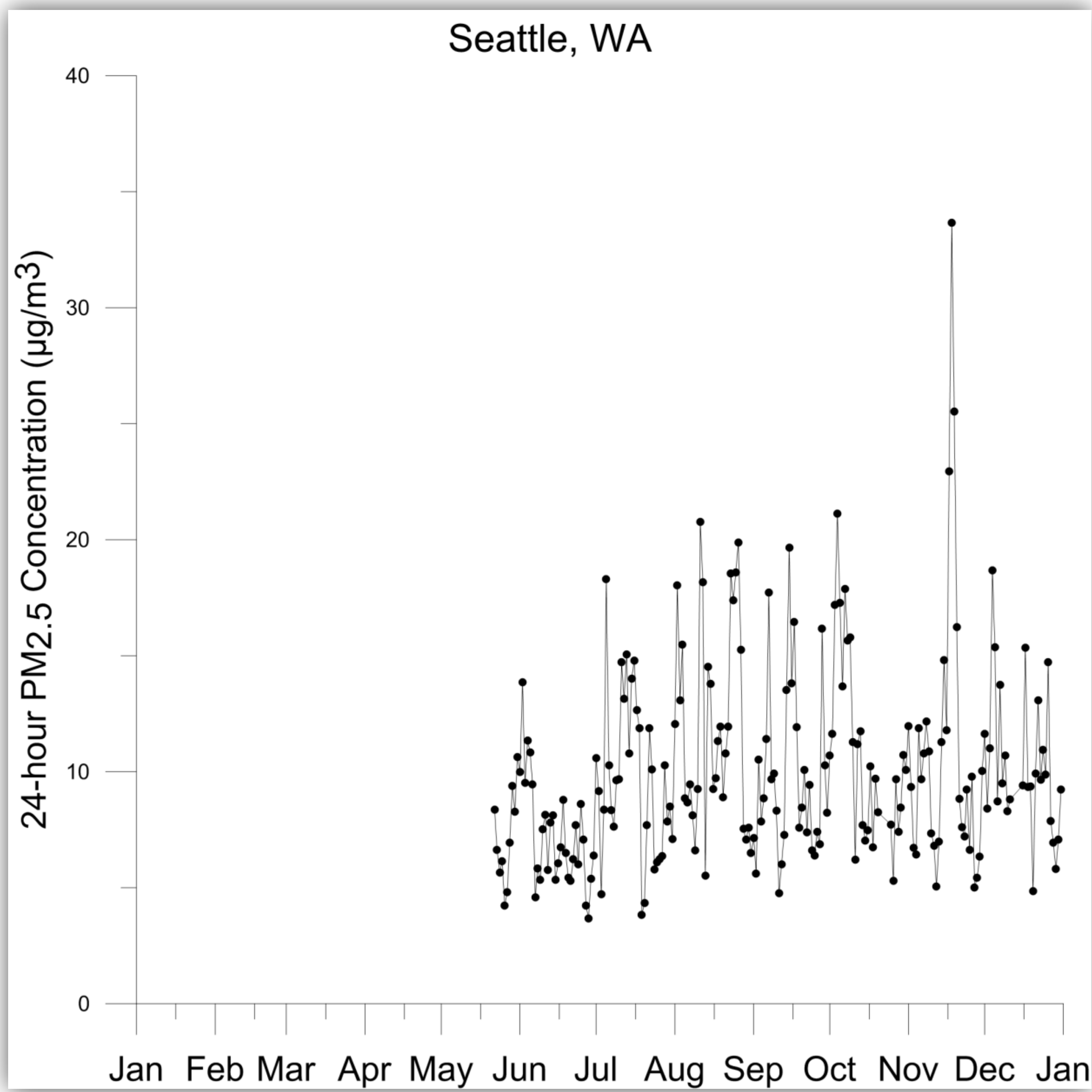

Philadelphia, PA
24-hour PM2.5 Concentration (µg/m3)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan

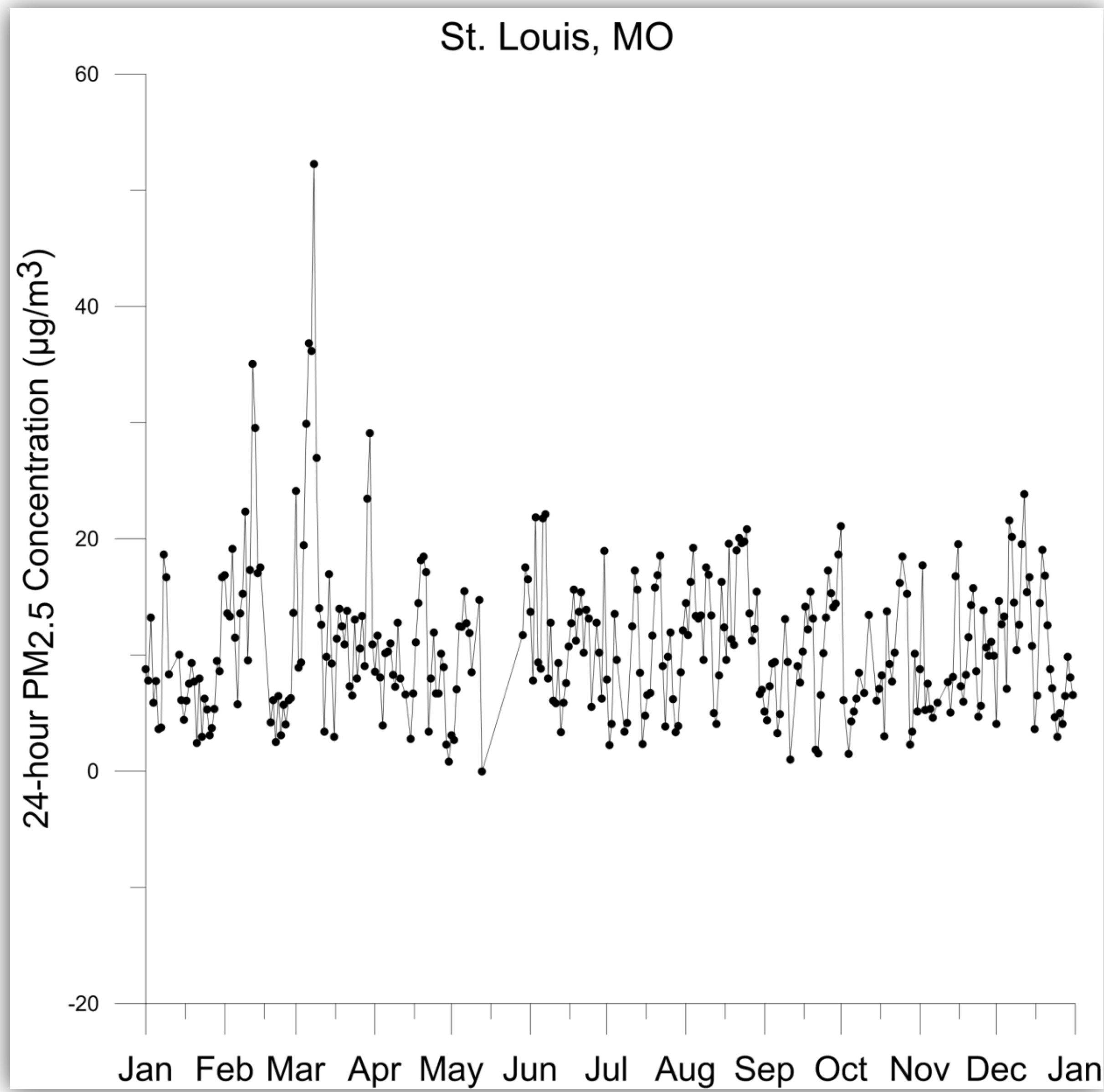

Phoenix, AZ
24-hour PM2.5 Concentration (µg/m3)
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Providence, RI
24-hour PM2.5 Concentration (µg/m3)
0
4
8
12
16
20
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


San Francisco, CA
24-hour PM2.5 Concentration (μg/m3)
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


San Jose, CA
24-hour PM2.5 Concentration (µg/m3)
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


Seattle, WA
24-hour PM2.5 Concentration (µg/m3)
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan


St. Louis, MO
24-hour PM2.5 Concentration (µg/m3)
60
40
20
0
-20
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan