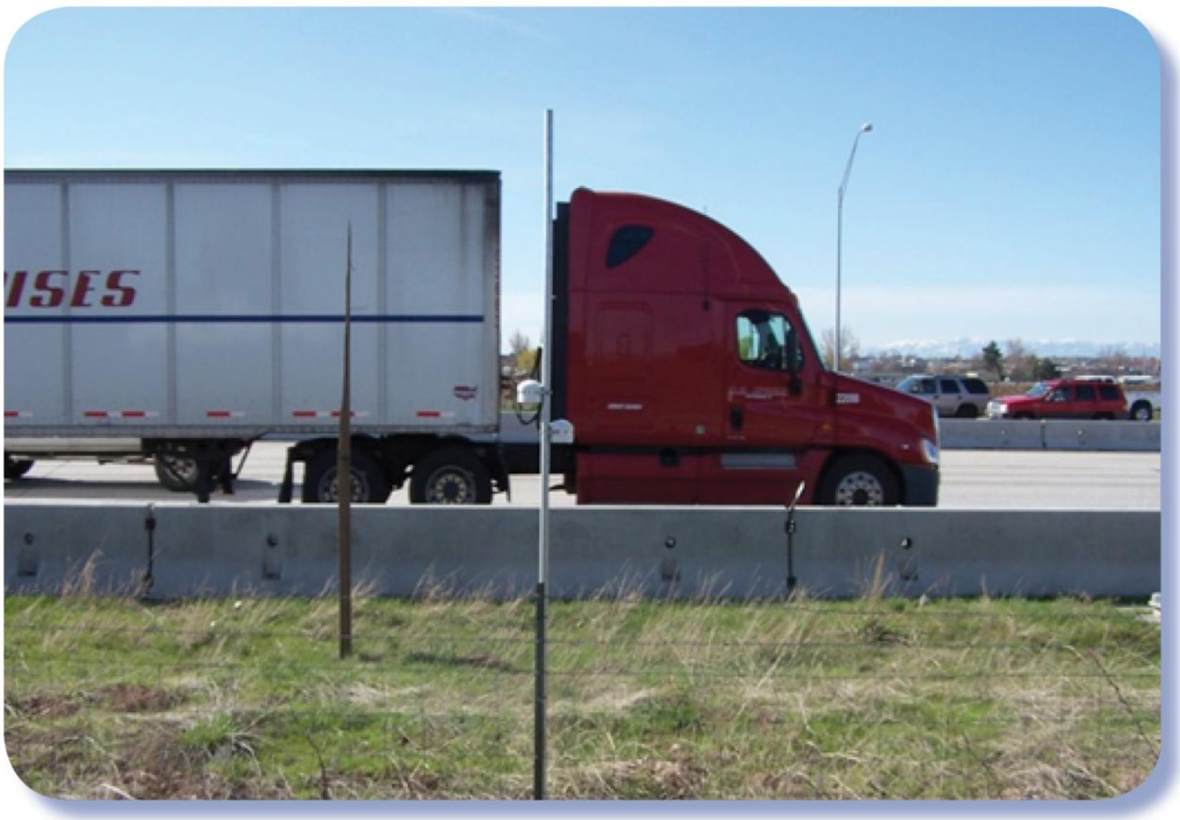
Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

Summary of Results from Near-Road NO_2 Monitoring Pilot Study



Final Report Prepared for

U.S. Environmental Protection Agency
Research Triangle Park, NC

December 2011

This document contains blank pages to accommodate two-sided printing.

Summary of Results from Near-Road NO_2 Monitoring Pilot Study

Final Report
STI-910308-4211-FR

Prepared by

Adam N. Pasch
Hilary R. Hafner
David L. Vaughn
Theresa E. O'Brien
Sonoma Technology, Inc.
1455 N. McDowell Blvd., Suite D
Petaluma, CA 94954-6503
Ph 707.665.9900 | F 707.665.9800
sonomatech.com

Prepared for

Nealson Watkins
U.S. Environmental Protection Agency
109 T.W. Alexander Drive
Mail Code C304-06
Research Triangle Park, NC 27709

December 19, 2011

Cover photo is the Boise St. Luke's site (source: Idaho Department of Environmental Quality, 2011).

Acknowledgments

The authors would like to acknowledge the hard work by the air monitoring agency staff, U.S. Environmental Protection Agency (EPA) national and regional staff, and laboratories who participated in this study. Their efforts made this pilot study a success.

- Ambient Air Section, Air Management Division, Environmental Protection Commission of Hillsborough County, Florida (Tom Tamanini, Manager)
- Ambient Air Monitoring Program, Environmental Protection and Growth Management, Broward County, Florida (Monica Pognon, Natural Resource Specialist III)
- Maryland Department of the Environment (Jennifer Hains, Research Statistician; Chris Smith, Technical Support Lead)
- Air Quality Division, City of Albuquerque, New Mexico (Ken Lienemann, Air Monitoring Supervisor)
- Idaho Department of Environmental Quality (Bruce Louks, Manager)
- Research Triangle Institute (RTI, Eva Hardison, Manager, Environmental Chemistry Department; Dorothy Pickett)
- EPA Region 6 Houston Laboratory (Johnson Mathew, Senior Scientist/Chemist; Mark Sather, Environmental Scientist; Christy Warren)
- EPA Office of Air Quality Planning and Standards (OAQPS) (Nealson Watkins)
- EPA Office of Research and Development (ORD) (Richard Baldauf)

We also appreciate Sonoma Technology, Inc.'s Publications team for helping produce this document.

Table of Contents

Section **Page**

List of Figures

Figure... Page

Figure ... Page

List of Tables

Table **Page**

1. Introduction

1.1 Background

In February 2010, the U.S. Environmental Protection Agency (EPA) promulgated new minimum requirements for the nitrogen dioxide (NO_2) monitoring network in support of a newly revised 1-hour NO_2 National Ambient Air Quality Standard (NAAQS), along with the retention of the existing annual NAAQS. In the new monitoring requirements, state and local air monitoring agencies are required to install NO_2 monitoring stations at locations where peak hourly NO_2 concentrations are expected to occur within the near-road environment. State and local agencies are required to submit their choices for near-road NO_2 sites in their annual monitoring plans, which are due July 1, 2012. To assist the air agencies in this process, EPA has developed a near-road NO_2 Technical Assistance Document (TAD) (U.S. Environmental Protection Agency, 2011). To better understand real-world issues in selecting potential monitoring sites and to support preparation of the TAD, the EPA worked with volunteer state and local agencies to conduct a near-road NO_2 pilot study. This report summarizes the NO_2 data collected during the pilot study.

1.2 Pilot Study

Air agencies are required to consider traffic volumes, fleet mix, roadway design, traffic congestion patterns, local terrain or topography, and meteorology in determining the placement of a required near-road NO_2 monitor.

State and local air agencies collected NO_2 and oxides of nitrogen (NO_x) data during a pilot study through the use of passive sampling devices (PSDs) near heavily trafficked roads within five Core Based Statistical Areas (CBSAs): Albuquerque, New Mexico; Baltimore, Maryland; Boise, Idaho; and Miami–Broward County and Tampa-Hillsborough County in Florida. The PSDs were exposed at locations that were selected by the state or local air agencies on the basis of traffic data analysis (considering traffic volumes, fleet mix, and congestion patterns) resulting in a prioritized list of road segments where peak NO_2 concentrations are expected to occur. The air agencies then selected target road segments from the prioritized list on the basis of additional factors, including roadway design, terrain, and meteorology; and logistical considerations, such as access and safety. Those target road segments were surveyed to identify the location or locations adjacent to those segments where PSDs could be deployed. The data collected from the PSDs were then to be used to supplement existing traffic data analyses in the identification of suitable locations for permanent near-road NO_2 monitoring stations.

PSD samples were collected at a CBSA-specific number of sites during the spring and summer of 2011. The PSDs were exposed for at least five consecutive weeks in week-long durations at each sampling location. PSDs were in place for both NO_2 and NO_x (with the exception of Albuquerque, where only NO_2 was sampled). Sampling for both NO_2 and NO_x ensured better quality data because it made it possible to determine whether NO_2 concentrations are less than or equal to NO_x concentrations for the same sampling period. PSDs were also placed at each location in pairs (duplicates) to increase precision and provide high data completeness. In addition, one PSD was co-located with an established continuous

NO_X monitor, representing areawide concentrations (e.g., neighborhood or larger spatial scales) in each CBSA to provide another measure of accuracy. Finally, 64 field and trip blanks, representing 12% of the samples, were deployed study-wide for quality control. Additional details regarding study design and quality assurance are provided in the Quality Assurance Project Plan (QAPP)[1] (Hafner et al., 2011).

The intent of the study design was to collect PSD data from a number of near-road locations within a CBSA that have the potential to be permanent near-road air quality measurement stations or near-road monitoring sites. By collecting PSD data, correlative comparisons between candidate site locations within the same CBSA can be performed. It is believed that combining knowledge of roadway characteristics and logistics with information gathered through exploratory studies using PSDs will improve state and local agencies' ability to select suitable near-roadway monitoring sites. Furthermore, the EPA has used the experiences of the participating state and local air agencies to inform the development of the TAD, providing some degree of confidence and additional ground-truth to the concepts presented and recommended therein.

1.3 Study Limitations

Two key limitations to interpreting the pilot study data should be considered when interpreting these study results. The pilot study was conducted in spring and summer and therefore does not account for expected seasonal variations in NO_2 concentrations. However, the relative differences observed between sampling locations are expected to be similar during other seasons over long-term averaging times. The NO_2 concentrations discussed in this study are 1-week averages and therefore should not be directly compared to the NAAQS.

1.4 Guide to This Report

The remainder of this report summarizes our assessment of the pilot study data and their usefulness in verifying and validating the near-road site selection process conducted by each state agency (which is also recommended in the TAD). We have compiled a comprehensive set of appendices, one for each pilot study CBSA, to accompany this report. Each appendix contains

- Detailed site information, including site name, coordinates, sampler distance to roadway, sampler height, road segment name, annual average daily traffic (AADT), heavy-duty truck AADT, road segment rank, terrain, roadway design, roadside structures, surrounding land use, safety features, whether there is an interchange or not, site photographs, and Google map images.
- Summary statistics by site and week and between-site and between-week variability in NO_2 concentrations.
- Graphics showing NO_2 concentrations compared to distance to roadway, sampling height, and traffic volume.
- Quality assurance and data completeness summaries, including tables and graphics.

[1] Available here: http://www.epa.gov/ttn/amtic/nearroad.html

These appendices should be useful to monitoring agencies during their own near-road monitoring site selection process.

1.5 Expectations

A conceptual model—i.e., what results to expect based on understanding the study design, pollutants, meteorology, measurement method, etc.—aids in interpreting the study findings. For near-road NO_2 measurements relative to flat, at-grade roads, the following findings were/are expected:

- The highest NO_2 concentrations along an individual road segment are expected to typically occur for the samples collected closest to the road, either vertically (from the roadbed) or horizontally (distance from the road).
- For samples mounted at two heights above ground, the highest NO_2 concentrations are expected for the samples collected from the PSD mounted closest to the ground.
- The highest NO_2 (and NO_x) concentrations are expected for samples collected at near-road sites with the highest AADT and/or roads with high traffic and a large number of heavy-duty vehicles.
- The highest NO_2 concentrations are expected to be influenced by certain roadway configurations, such as sampling near on-ramps or idling trucks.
- The highest NO_2 concentrations are expected to be affected by local winds. In general, it was expected that near-road monitoring sites that are predominantly downwind would have higher concentrations than upwind sites over long averaging times. However, it was also anticipated that short-term peak NO_2 concentrations will occur during low and calm wind speed conditions in which wind direction would be less of a factor.

1.6 Key Findings

In general, the near-road NO_2 concentrations measured during this study met the conceptual model, and deviations from expectations were explainable. NO_2 concentrations tended to be highest at locations nearest the roadway and near those roads with the highest daily traffic adjusted for heavy-duty traffic (i.e., Fleet-Equivalent AADT [FE-AADT]). Specific findings included

- **Distance to roadway.** Results from transect monitoring confirmed that NO_2 concentrations are highest at the sites closest to the roadway. The measurements were mostly within 7 to 45 meters of the edge of the roadway. The concentration gradients were relatively shallow. Any deviations from expectations were explained by roadway configuration or other considerations (e.g., higher NO_2 observed because of accelerating truck traffic on an on-ramp).
- **Sampling height.** Measurements at different heights demonstrated that concentrations were highest at the sampling height closest to the roadway (i.e., typically closest to ground level). Concentration differences were relatively small.

- **Traffic volumes and fleet mix.** NO_2 concentrations were typically highest near the road segments with the highest AADT and FE-AADT. Exceptions were explained by road configuration and potential impacts on NO_2 concentrations from nearby sources (e.g., a tollbooth site near a port, tunnel entrance/exit, and rail activities).
- **Roadway configuration.** Impacts on NO_2 concentrations were identified due to site placement relative to on-ramps (with accelerating traffic) and truck-only lanes, along with impacts due to site placement relative to an elevated roadway. Both of these sites were in Tampa.
- **Meteorology.** In the Miami CBSA (Broward County), winds attributable to daytime sea breeze had a profound effect on measured concentrations, where data collected downwind of the road showed much higher relative concentrations than data collected upwind. We note that over a longer period of time than this pilot study, wind direction can vary depending on the larger-scale meteorological conditions, so a site may not always be downwind. In addition, the relatively long averaging times of this study did not allow an evaluation of short-term peak NO_2 concentrations during calm wind conditions.

Overall, data quality was good. The monitoring staff in each CBSA experienced a range of siting issues—from relatively easy access to near-road sites to a lengthy permitting process—which helped inform the TAD.

1.7 Lessons Learned

This study provides an opportunity for the monitoring agencies to evaluate and work through physical and bureaucratic hurdles that many other air agencies might expect to meet when identifying and installing near-road monitoring stations. Lessons learned include

- Transect measurements and samples collected at different heights are likely not needed in future similar measurement efforts. As stated in 40 CFR Part 58, Appendix D, Section 4.3, and the TAD, states should attempt to place their permanent monitoring site as “near as practicable” to the road edge of highly trafficked roads; for NO_2 monitoring, the recommended distance is 10–20 m.
- PSD sampling was relatively straightforward and low cost. The pilot study seemed to help the monitoring agencies gain confidence in their site selection process and choices.
- While NO_2 concentrations varied from week to week at a given site, the spatial pattern of concentrations remained the same. Additional weeks of sampling conducted in the Boise, Idaho CBSA (nine weeks versus five weeks) did not provide additional insight or change any conclusions.
- The pilot study illustrated that the site selection process documented in the TAD typically results in a pool of candidate site locations from which an appropriate monitoring location can be selected.
- The pilot study illustrates the need to engage and cooperate with respective transportation agencies to safely and legally enter right-of-way properties when necessary.

2. Pilot Study Data

2.1 CBSA-Specific Information

Sampling was conducted in five CBSAs in April through June 2011. Sampling campaigns lasted five weeks, except at Boise, where sampling continued for an additional four weeks. **Table 2-1** summarizes the number of road segments, range of AADT counts, range of FE-AADT, range of sampler distance to roadway edge, and exact sampling periods. FE-AADT was derived using the equation from the TAD (U.S. Environmental Protection Agency, 2011), which requires the heavy-duty traffic estimates and a ratio of the heavy-duty to light-duty emissions. For this ratio, the default value of 10 was used for each CBSA.

Table 2-1. Summary of sampling dates and locations for the pilot study.

CBSA	Number of Road Segments	Range AADT	Range FE-AADT	Distance to Roadway (Meters)	Weeks	Sampling Periods (2011)
Albuquerque	3	29,300 – 164,500	Unavailable	5–45	5	04/04 – 04/11 04/11 – 04/18 04/18 – 04/25 04/25 – 05/02 05/02 – 05/09
Baltimore	5	121,017 – 210,790	209,928 – 452,309	8–38	5	04/11 – 04/18 04/18 – 04/25 04/25 – 05/02 05/02 – 05/09 05/09 – 05/16
Boise	4	61,000 – 104,728	114,100 – 162,838	12–42	9	04/03 – 04/10 04/10 – 04/17 04/17 – 04/24 04/24 – 05/01 05/01 – 05/08 05/15 – 05/22 05/22 – 05/29 05/29 – 06/05 06/05 – 06/12
Miami	2	224,000 – 306,000	384,875 – 622,161	15.2–24.4	5	05/16 – 05/23 05/23 – 05/30 05/30 – 06/06 06/06 – 06/13 06/13 – 06/20
Tampa	5	30,000 – 192,000	42,960 – 268,203	7–130	5	05/09 – 05/16 05/16 – 05/23 05/23 – 05/30 05/30 – 06/06 06/06 – 06/13

In addition to the PSD-derived NO_2 and NO_x data, NO_2 and NO_x data were obtained from a neighborhood or urban scale (areawide) background site in each CBSA for comparison to the collocated PSD sample concentrations. Ozone data were also obtained from an areawide site near the sampling locations in each CBSA. The air quality data were obtained from EPA's air quality system (AQS), AIRNow-Tech, or directly from the state agencies. Wind speed, wind direction, temperature (T), and relative humidity (RH) were obtained from Automated Surface Observing Systems (ASOS)[2] sites for each CBSA for use in computing NO_2 and NO_x concentrations from the filter analysis results (T, RH) and for data interpretation (winds).

Table 2-2 lists the ASOS sites used, including the distances from these sites to the areawide site for each pilot study CBSA. The ASOS data were used because not all areawide sites had meteorological data available.

Table 2-2. ASOS site names, locations, and distance to the areawide sites for each of the five pilot study CBSAs.

CBSA	ASOS ID	Airport	Latitude (°)	Longitude (°)	Distance from Areawide Site (Miles @ °)
Albuquerque	KABQ	Albuquerque International Sunport	35.0500	-106.6167	6.01 @ 199
Baltimore	KFME	Tipton	39.0833	-76.7667	6.28 @ 72
Boise	KBOI	Boise Air Terminal (Gowen Field)	43.5667	-116.2333	6.43 @ 116
Miami	KHWO	North Perry	26.0000	-80.2333	3.99 @ 159
Tampa	KVDF	Tampa (formerly Vandenberg) Executive	28.0167	-82.3500	8.03 @ 296

Appendices A–E provide detailed information for the pilot study sampling conducted in each CBSA, including site information, site photos and Google map images, summary statistics of the data collected, site-specific results (e.g., graphic of NO_2 concentrations as a function of AADT), and quality assurance and data completeness results.

2.2 Data Processing, Handling, and Validation

STI created a database with the NO_2 and NO_x data, including supporting information (e.g., sample identification information, site coordinates, date range of sample, and important monitoring log notes). We checked for missing information, computed concentrations (data

[2] The ASOS program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). ASOS supports weather forecast activities and aviation operations and supports the needs of the meteorological, hydrological, and climatological research communities (http://www.srh.noaa.gov/jetstream/remote/asos.htm)

were provided in ng/filter), assessed data completeness, compared sample concentrations to method detection limits (MDLs), compared duplicate samples, compared trip and field blanks to samples, and compared NO_2 and NO_x concentrations (i.e., collocated NO_2 concentrations should be equal to or less than NO_x concentrations). Details on data handling, validation, computations, and chemical analysis are provided in the QAPP and accompanying standard operating procedures (SOPs).

2.3 Laboratory Intercomparison

Since two laboratories were used during this study, we conducted laboratory intercomparisons of known samples. The two laboratories exchanged extra liquid extracts during Weeks 1 and 5 of the study, and also conducted one filter exchange during Week 3. The results of each laboratory for the same sample material were compared to assess relative precision between the two laboratories.

Precision between all exchanged samples was calculated as percent difference, and averaged 8%, with a range of 0 to 18% (**Table 2-3**).

Table 2-3. Results of the laboratory intercomparison for sample extracts and filters provided by the EPA Region 6 Houston Laboratory**.**

Sample Origin	Week # and Sample Type	Region 6	RTI	Precision (% Difference)
		NO_2 (ppb)		
Albuquerque	Week 1 Extract	10	12	18%
	Week 3 Filter	14	14	0%
	Week 5 Extract	19	18	5%
Boise[a]	Week 4 Extract	12	11	9%
	Week 5 Extract	13	11	17%

[a] The Boise concentrations for the Region 6 analyses were computed without blank-correcting the data using the lab blank (the lab blank is the average of the two trip blanks). Region 6 did not have the trip blank values for the Boise data and thus the reported NO_2 concentrations may be slightly high.

2.4 Data Quality Summary

2.4.1 Data Quality Objectives

The data quality objectives (DQOs) for precision, accuracy, and completeness are presented in **Table 2-4.** NO_2 and NO_x data were evaluated for completeness to determine whether sufficient experimental data were collected. The data completeness objective of 90%, where data completeness is the number of valid data points compared to the total number of measurements, was achieved (94% to 100%), as shown in **Table 2-5**. Very few samples were flagged as suspect (0% to 5%) or invalid (0% to 4%). For some of the suspect samples, reanalysis was requested of the laboratory. The reanalysis for suspect samples was requested in those cases for which (a) the reported NO_2 concentration was greater than the reported NO_x

concentration (two samples), or (b) the reported NO_2 and/or NO_x was an extreme outlier compared to the typical range of reported concentrations (four samples). Other samples, deemed suspect due to field handling discrepancies (e.g., “dropped PSD”), did not receive re-analysis if the analytical data appeared reasonable and within the expected range of concentrations. Invalidated samples were primarily attributed to field sampling irregularities. For example, four of the six invalidated samples for Boise were damaged during a storm.

Table 2-4. Data quality objectives.

Parameter (Method: PSD)	Precision (%)	Accuracy (%)	Completeness (%)
NO_2 concentration	20	15	90
NO_x concentration	20	15	90

Table 2-5. Data capture and valid, suspect, and invalid samples by CBSA.

CBSA	Target Sample Number[a]	% Data Capture[b]	% Data Valid[c]	% Data Suspect[c]	% Data Invalid[c]
Baltimore	90	100%	96.7%	3.3%	0.0%
Boise	180	100%	95.0%	1.1%	3.3%
Miami	80	99%	98.7%	0.0%	1.3%
Tampa	110	100%	94.5%	4.5%	0.9%
Albuquerque	80	100%	97.5%	1.3%	1.3%

[a] Target Sample Number is the number of PSD mounts, with two sample duplicates per mount, multiplied by the number of sample weeks.
[b] Percent Data Capture is the percentage of collected data values divided by the total number of target sample data values.
[c] Percent Data Valid, Suspect, or Invalid is the percentage of data values that are valid, suspect, or invalid divided by the number of captured data values.

2.4.2 Blanks

Another objective set for this study was collection and analysis of 10% quality control (QC) samples (field blanks [FB] and trip blanks [TB]). As shown in **Table 2-6**, this objective was met for all participants except Tampa (where trip and field blanks were not collected).

Table 2-6. Summary of field and trip blanks collected.

CBSA	Target QC Number (@ 10%)	Number of FB	Number of TB	% Actual QC[a]
Albuquerque	8	0	10	13%
Baltimore	9	8	8	18%
Boise	18	8	10	10%
Miami	8	10	10	25%
Tampa	11	0	0	0%

[a] The total number of QC samples (FB plus TB) divided by the number of captured sample data values, expressed as a percentage. All QC samples were valid. Tampa did not collect QC samples.

We compared the trip (unexposed PSD filter), field (PSD filter briefly deployed into clips and shelters), and sample values. Trip blanks document sample integrity associated with the shipment, collection, and storage of environmental samples. Field blanks document sample integrity associated with the shipment, collection, storage, and field mounting of environmental samples. The expectation for NO_2 concentrations is that trip blanks ≤ field blanks < samples. Trip and field blank concentrations were substantially lower than sample concentrations. However, there was no statistically significant difference in concentrations between the trip blanks and field blanks. An F-test of equality of variances between trip blanks and field blanks suggested that the variances between them were not equal ($p = 0.01$). Based on that finding, a two-sample T-test assuming unequal variances was performed. The high p-value (0.40) suggests that the average NO_2 parts per billion (ppb) values reported for field blanks and trip blanks were the same. **Figure 2-1** depicts the average NO_2 concentration and associated standard error, by CBSA, for the trip blanks and field blanks. **Figure 2-2** shows the frequency distribution of the collected NO_2 blanks. The majority of the blank NO_2 concentrations were between 0.5 and 1.0 ppb.

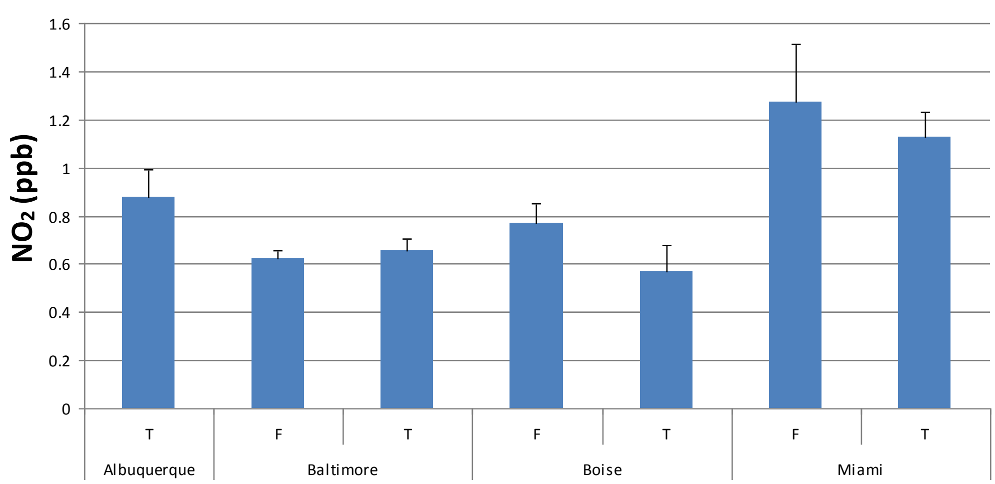


Figure 2-1. Summary by CBSA of field and trip blank averages, where standard error is the standard deviation of the blank mean divided by the square root of the blank count.

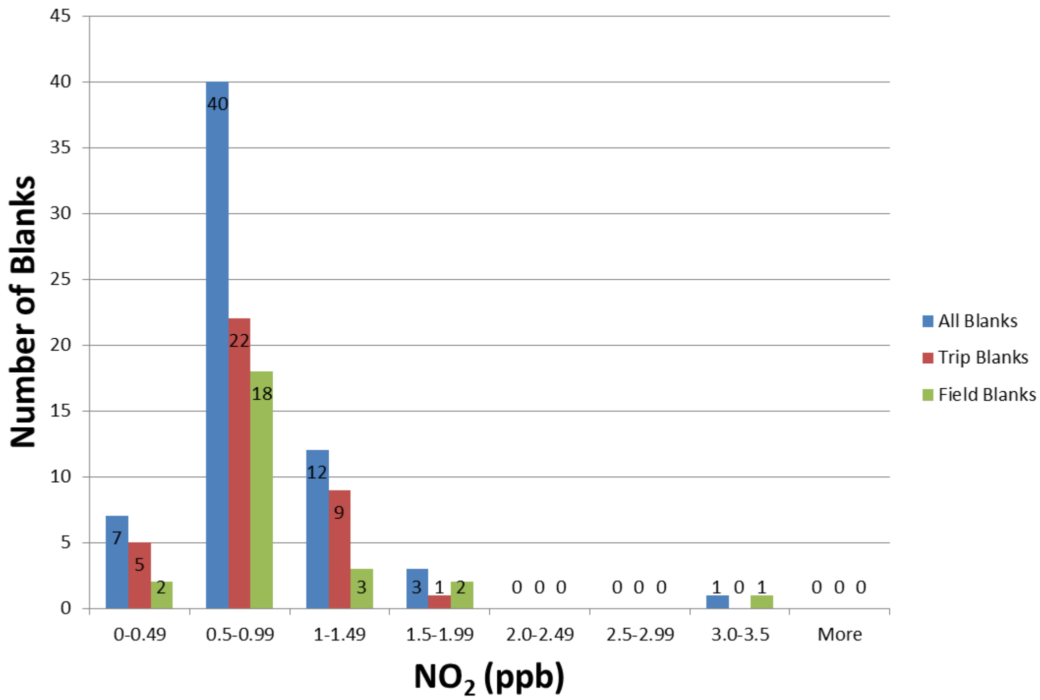


Figure 2-2. A histogram showing the distribution of NO_2 concentrations among field blanks and trip blanks. The majority of blank NO_2 concentrations were less than 1 ppb.

2.4.3 Duplicate Precision

For each sample time and location in this study, duplicate PSD samplers were deployed, to both allow determination of accuracy and ensure high data completeness. Precision estimates for the duplicate samples were determined as percent difference, as defined in **Equation 2-1**:

$$\frac{|x1 - x2|}{\left(\frac{x1 + x2}{2}\right)} \times 100 \qquad \textbf{(2-1)}$$

where $x1$ and $x2$ correspond to the analytical results (ng or ppb) of the duplicate PSDs.

The DQO for precision of 20% was met for 93% of the collocated NO_2 ppb concentrations and for 95% of the collocated NO_x ppb concentrations (**Figure 2-3**). A scatter plot of the collocated samples for Boise is shown in **Figure 2-4** and is illustrative of the precision achieved in other pilot cities.

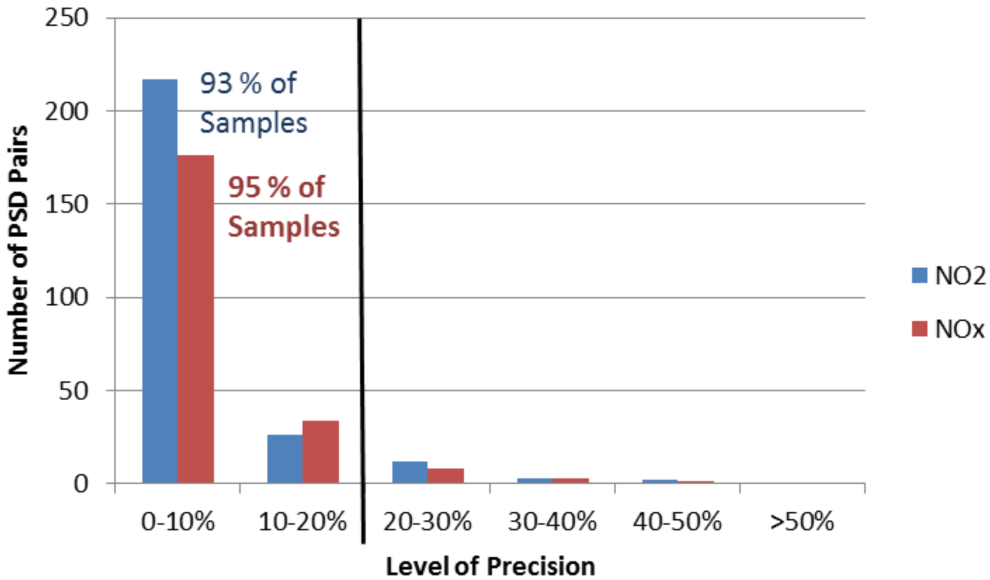


Figure 2-3. A histogram illustrating that 93% and 95% of the NO_2 and NO_x samples (respectively) met the DQO for precision of 20% or better.

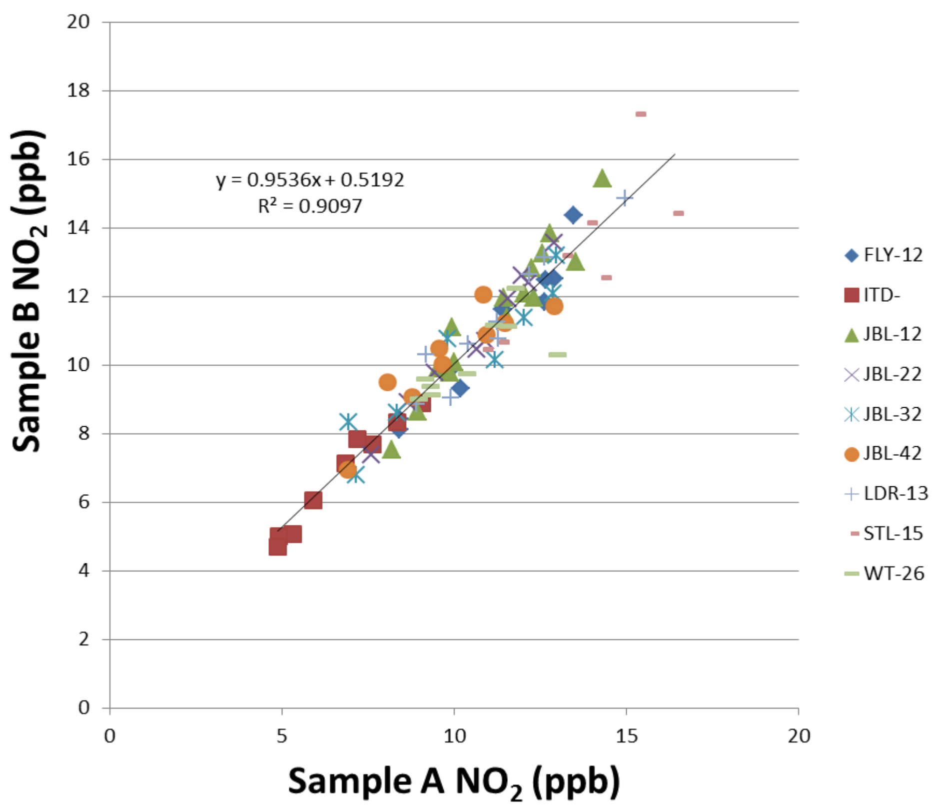


Figure 2-4. A scatter plot of collocated NO_2 samples collected in Boise which illustrates typical precision achieved throughout the NO_2 near-road pilot study. The legend indicates the different sites in Boise and their distance from the roadway in meters.

2.4.4 Accuracy

A comparison was made between the continuous NO_2 and NO_x monitors and the PSDs that were collocated at the background/areawide site. **Figure 2-5** is a histogram depicting the accuracy achieved when the PSD NO_2 concentrations are compared directly to the collocated reference (continuous) NO_2 instrument on a sample-by-sample basis (average weekly PSD NO_2 concentration versus the averaged NO_2 concentration from the continuous instrument). The direct comparison used the same percent difference calculation as employed for the precision estimates presented above. Only 14 of the 29 calculated comparisons met the 15% DQO objective for accuracy. However, it should be noted that PSD NO_2 concentrations were consistently higher than the reference NO_2 concentrations, suggesting that the method itself has a systematic bias.

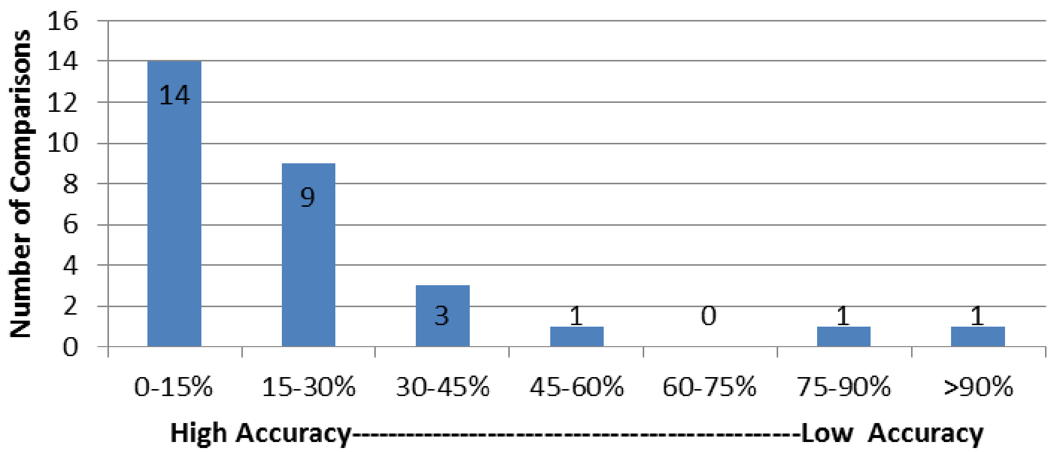


Figure 2-5. Accuracy (based on calculations of percentage difference) of the PSD NO_2 concentrations compared with the reference (continuous) monitors' NO_2 concentrations.

Additionally, measured average NO_2 concentrations were low (reference range 0.8–20.9 ppb and PSD range 1.9–22.9 ppb) so that small differences in concentration could yield large percent differences. The accuracy is best judged by viewing the percent difference calculations (**Table 2-7**) in addition to the scatter plot and regression analyses (**Figure 2-6**). For Albuquerque, the R^2, for example, is lower than the R^2 observed for the other site results. The lower R^2 resulted from the presence of at least one set of duplicates that differed substantially in quantity of NO_2 detected (by as much as an order of magnitude) nearly every week. There was no information in the chain of custody forms that implied one or the other of the duplicate samples should have been invalidated.

Table 2-7. Weekly averages of the differences between background PSD concentrations and the weekly averages for the continuous NO_2 monitor at the background site in ppb.

CBSA	Pollutant	Average Difference	Standard Deviation	R^2	Slope	Intercept
Albuquerque	NO_2	-0.10	1.94	0.53	0.46	5.40
	NO_x	Albuquerque did not sample for NO_x.				
Baltimore	NO_2	1.02	0.79	0.97	0.82	1.96
	NO_x	2.86	3.50	0.86	0.69	6.13
Boise	NO_2	1.32	0.77	0.82	0.58	1.51
	NO_x	5.28	0.87	0.91	0.64	-0.86
Miami	NO_2	1.62	0.37	0.99	0.94	-1.28
	NO_x	1.58	0.97	0.99	1.22	-3.22
Tampa	NO_2	0.71	0.33	0.83	0.94	-0.43
	NO_x	2.28	0.69	0.70	0.71	-0.14

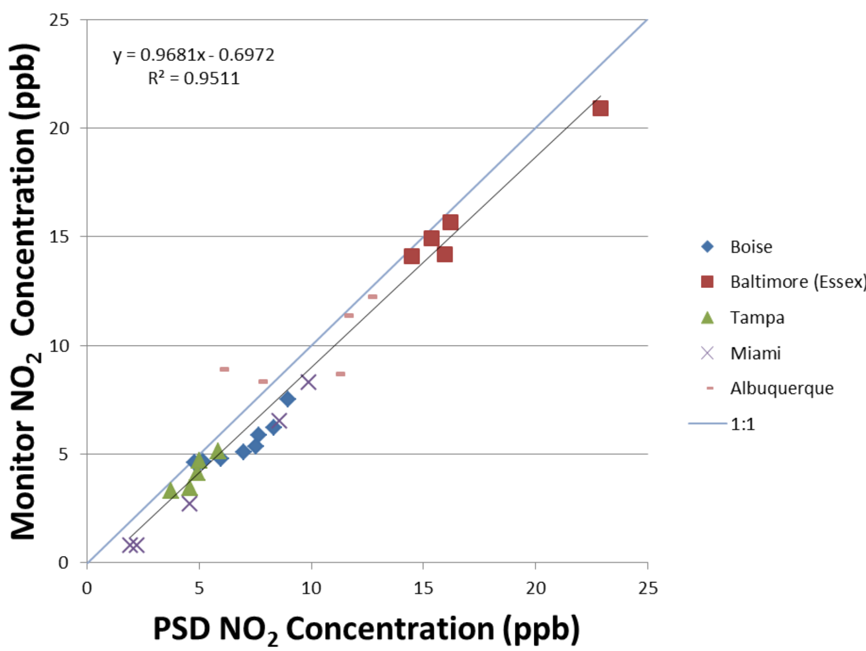


Figure 2-6. Weekly average NO_2 concentrations for the continuous NO_2 monitor compared to the PSD NO_2 concentrations from the collocated samplers in Boise, Baltimore, Tampa, Miami, and Albuquerque.

In summary,

- The data quality objective for data completeness (90%) was met and exceeded in the NO_2 near-road pilot study.
- The DQO for precision (20%) was met for more than 93% of all samples.

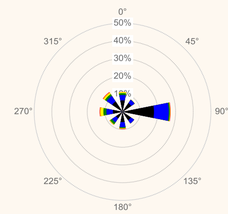
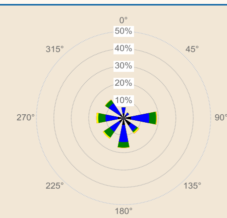
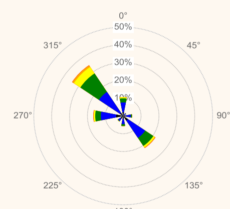
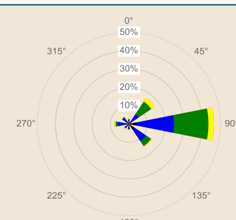
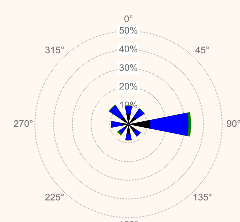
- The weekly PSD samples met the DQO for accuracy of 15% in 14 of 29 weekly comparisons. This accuracy statistic must be tempered by consideration of the effect of low data values on the percent difference calculation.
- Scatter plots and associated regression statistics show that over the course of the study, the PSDs systematically yielded higher NO_2 concentrations than collocated reference monitors, but the slope of 0.97 and the high R^2 (0.95) support a high level of confidence in the collected PSD data.

3. Results

3.1 Overview

Table 3-1 provides an overview by CBSA of average temperatures, RH, winds, and the range of NO_2 concentrations observed during the pilot study. Maximum 1-week average NO_2 concentrations ranged from 17 ppb in Boise to 30 ppb in Albuquerque and Baltimore.

Table 3-1. Weeklong average temperature, RH, and winds, and minimum and maximum NO_2 concentrations by CBSA. The legend for wind rose colors is provided in Figure 3-1 immediately following the table.

CBSA	Average Temperature (Degrees C)	Average RH (%)	Wind Rose	NO_2 Min (ppb)	NO_2 Max (ppb)
Albuquerque	15	20		6.0	30.1
Baltimore	15	73		12.5	29.7
Boise	11	55		4.8	16.3
Miami	28	66		1.8	24.6
Tampa	26	67		3.7	23.6

Wind roses illustrate how the wind speed and direction are distributed at a particular location over time. The wind roses in Table 3-1 include all hours of sampling during the pilot study for each CBSA. The direction of the rose petal with the longest spoke shows the wind direction with the greatest frequency. However, these wind roses do not provide any information about the diurnal or even weekly distribution of the winds. For example, the longest spoke in Miami is from the east, meaning that easterly winds occur with the greatest frequency. **Figure 3-1**, a larger version of the Miami wind rose in Table 3-1, shows that the wind speed and direction was distributed through many different directions during the pilot study. It is therefore important not to overanalyze these wind roses. Wind roses simply provide information about the distribution of wind speed and direction during the pilot study.

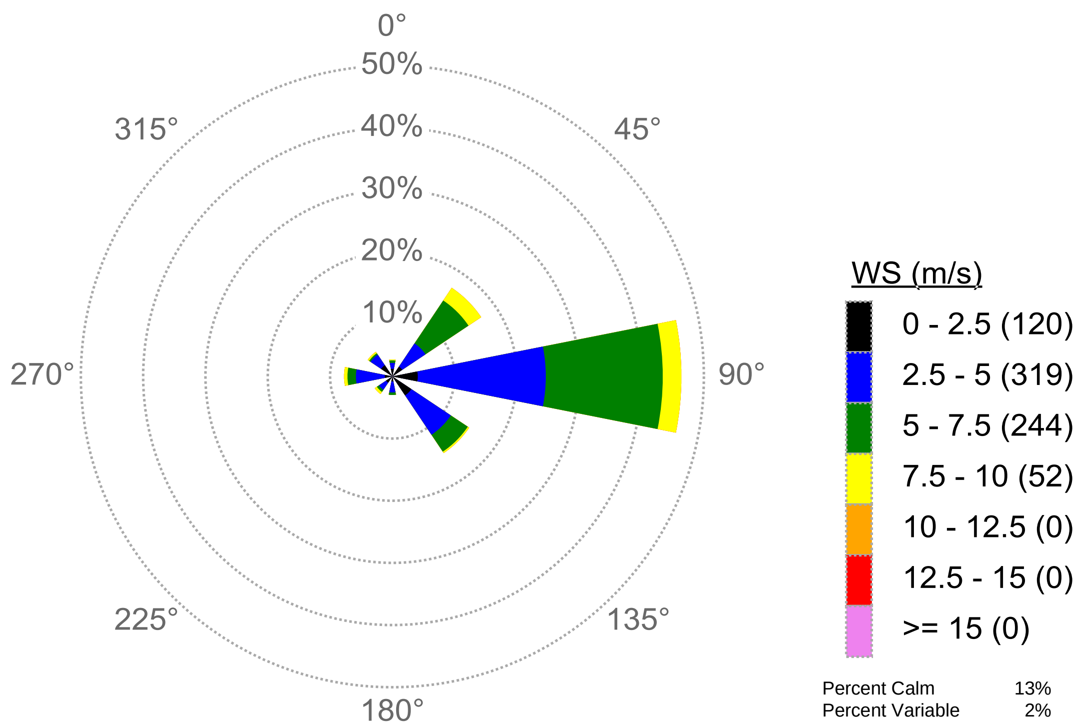


Figure 3-1. Wind rose for Miami for all hours during the five weeks of the pilot study, including the legend for the wind roses shown in Table 3-1.

3.2 Distance to Roadway and Sampling Height

One aspect of this pilot study was to place PSDs at three distances from a road at one of the sampling locations in each CBSA, creating a sampling transect. The goal was to collect data to understand the concentration gradient. Based on previous research, expectations were that concentrations from the sample closest to the roadway would be highest, with concentrations declining with distance from the road. **Figure 3-2** provides a summary of the study transect data, averaged across all weeks for each site. Albuquerque, Boise, Baltimore, and Miami transect concentration gradients met the expected pattern. Tampa data did not meet the expected pattern; however, characteristics of the sampling location nearest to the road, which are described below, likely contributed to this outcome.

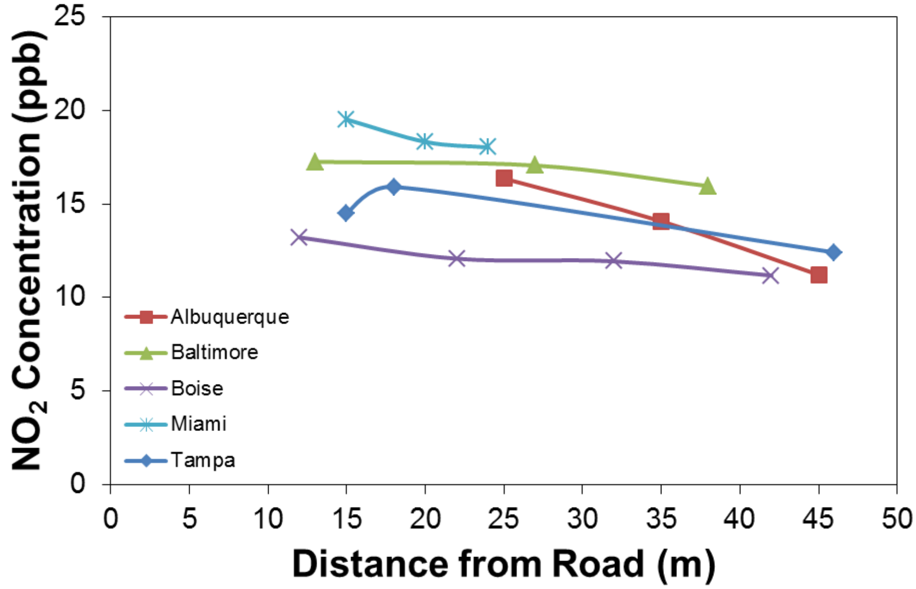


Figure 3-2. Weekly NO_2averages by CBSA for the transect sites.

In Tampa, the transect site was located at a weigh station (**Figure 3-3**) and the sampling locations were subject to very different traffic impacts. EPC04 (the closest site to the road) was next to the bypass lane for the weigh station and the I-4 travel lane; EPC06 (the site second-closest to the road) was located next to the I-4 travel lane, the bypass lane, and the on-ramp from the weigh station. The on-ramp from the weigh station services only heavy-duty (diesel) vehicles. These vehicles accelerate along the on-ramp to merge onto I-4. It is therefore likely that higher concentrations would be observed at this sampling location (EPC06) compared to the site closest to the road but further from the on-ramp. The discrepancy between the two sites is especially apparent when the winds were westerly; when that happened, the closest site to the road was upwind of the on-ramp (see Table E-3 in Appendix E).

Figure 3-3. Tampa EPC04, EPC05, and EPC06 site photo (top) and Google Earth image (bottom). This was the transect location. In the top photo, the lanes from left to right are the weigh station exit, the bypass lane, and the I-4 travel lane.

Samples were also to be collected at two heights at one sampling location to observe possible differences. The expectation was that the sampler closest to the roadway—vertically and horizontally—would record the highest concentration. **Figure 3-4** compares weekly average NO_2 concentrations at two heights by CBSA for each week. Typically, concentrations were higher at the sampling position closest to the road (the site closest to ground level).

In Tampa, one sampling location was positioned below an elevated highway (elevated on earthen and concrete fill, having no open space underneath). Elevated roads with vertical or sharply sloped walls can cause the traffic plume to loft above the ground immediately adjacent to the vertical or sharply sloped wall. The lofting pollutant plume creates a cavity that lacks roadway pollutants (due to eddy formation) immediately downwind of the roadbed, while the core of the emission plume affects the ground further downwind from the vertical or sharply sloped wall (U.S. Environmental Protection Agency, 2011).

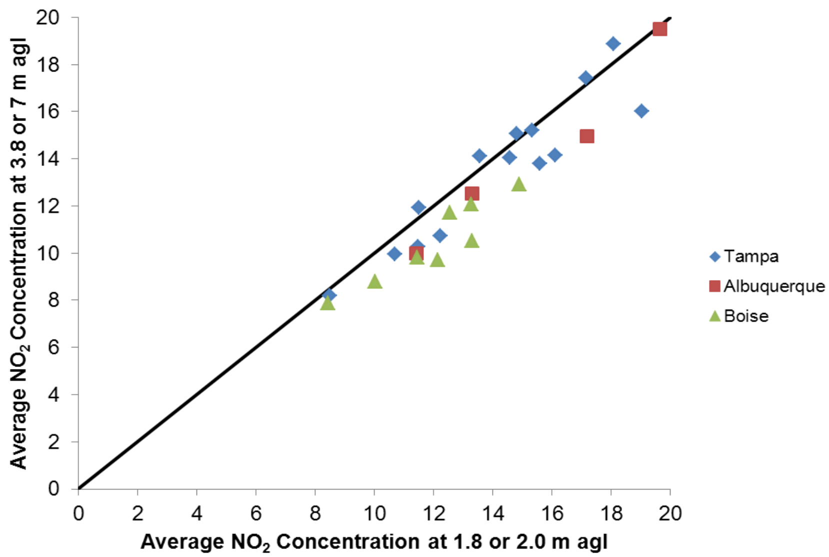


Figure 3-4. Average NO_2 concentrations at two heights by CBSA for each week.

The elevated site in Tampa consisted of a wall 7.6 m above the ground, the roadbed was located at 4.9 m above the ground, and sampling occurred at 1.8 m and 3.8 m above the ground. **Figure 3-5** shows that the sampling location measuring the highest concentrations was actually closest to the road. The other Tampa data that appear above the 1:1 line in Figure 3-4 are within 1 ppb of each other.

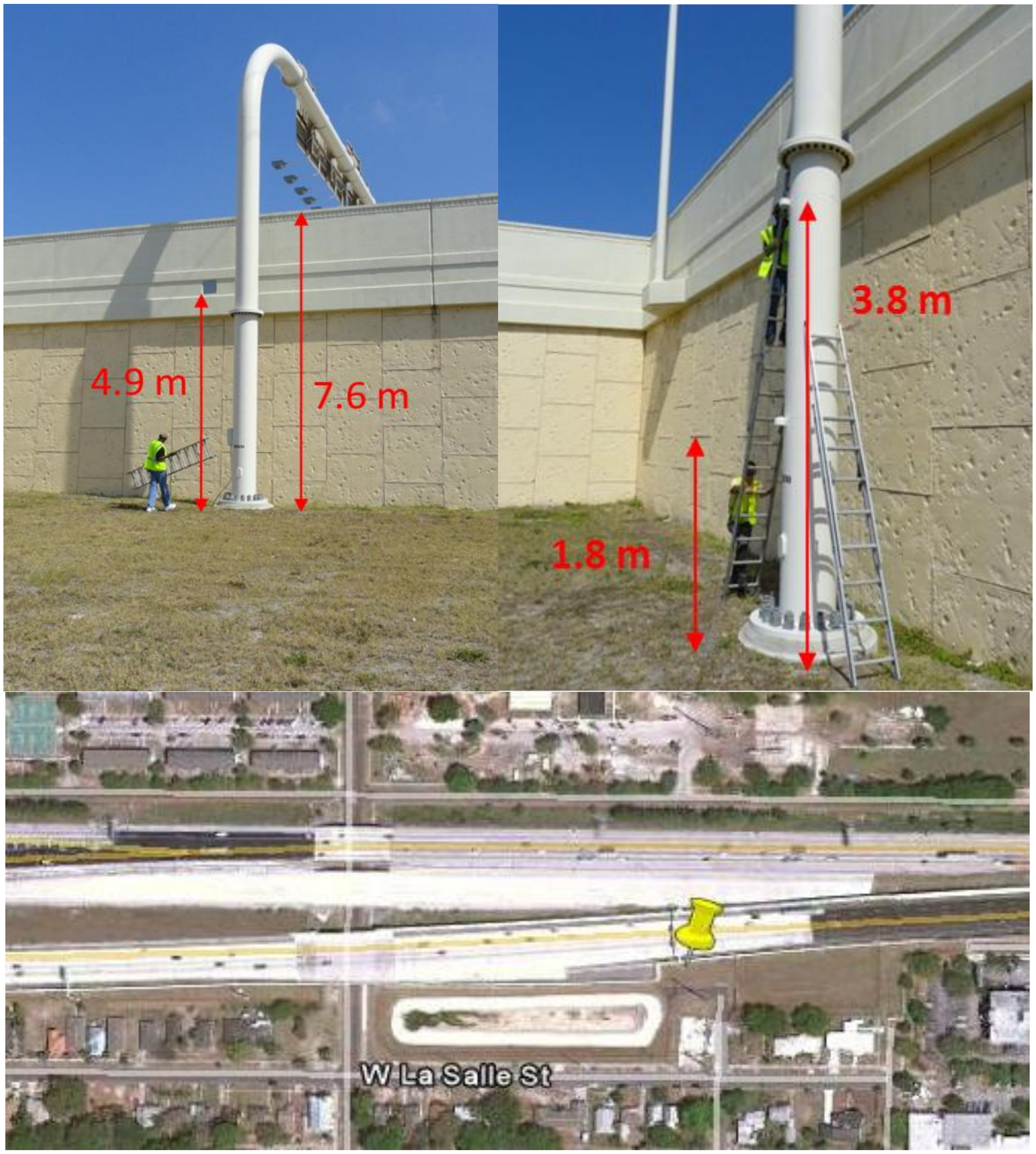


Figure 3-5. Tampa EPC03 site photos (top) and Google Earth image (bottom). Site is an elevated road (4.9 m agl) with a safety barrier (2.7 m). The top of the wall is 7.6 m above grade level. The PSD mounts were 7 m from the travel lane in the horizontal and 3.8 m and 5.8 m below the wall (3.8 m and 1.8 m above grade level, respectively).

3.3 Traffic Volume: AADT

In the first step to identify candidate road segments by which to conduct sampling, the total traffic volume, presented as AADT, were used to rank road segments. **Figure 3-6** provides a summary of average NO_2 concentration at all sites from all CBSAs and **Figure 3-7** provides a summary of average NO_2 concentrations at all sites by CBSA. The data show that, on average and with a few exceptions (discussed in Sections 3.5 and 3.6), the sampler placed along the road with the highest AADT in each CBSA had the highest NO_2 concentrations.

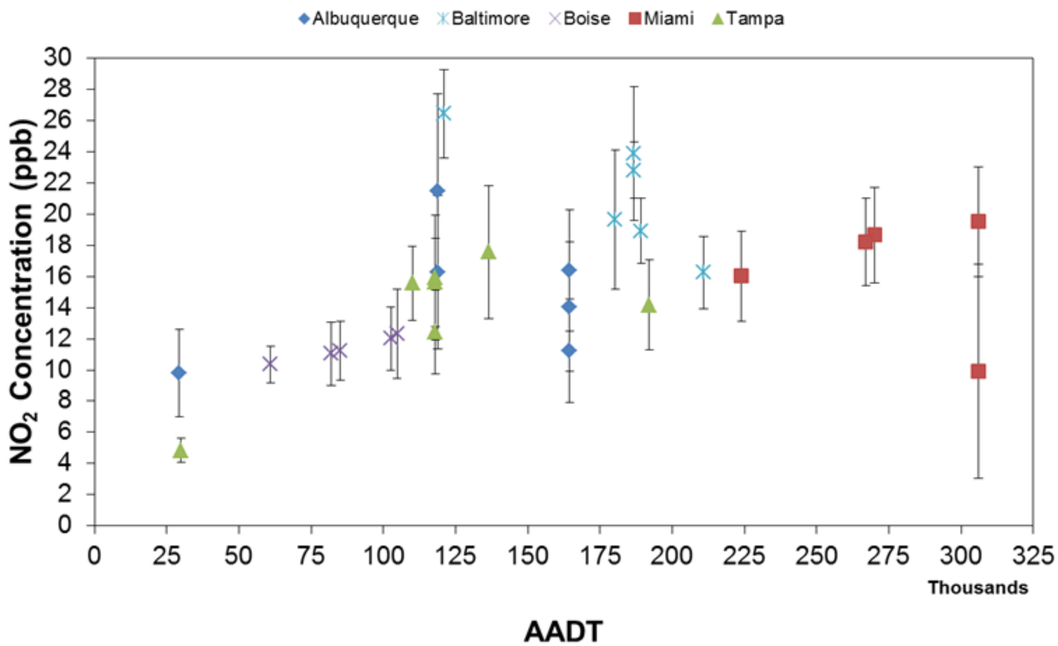


Figure 3-6. Average NO_2 concentrations (ppb) by site across all weeks of sampling at all sites compared to AADT. Bars indicate standard deviation of weekly averages.

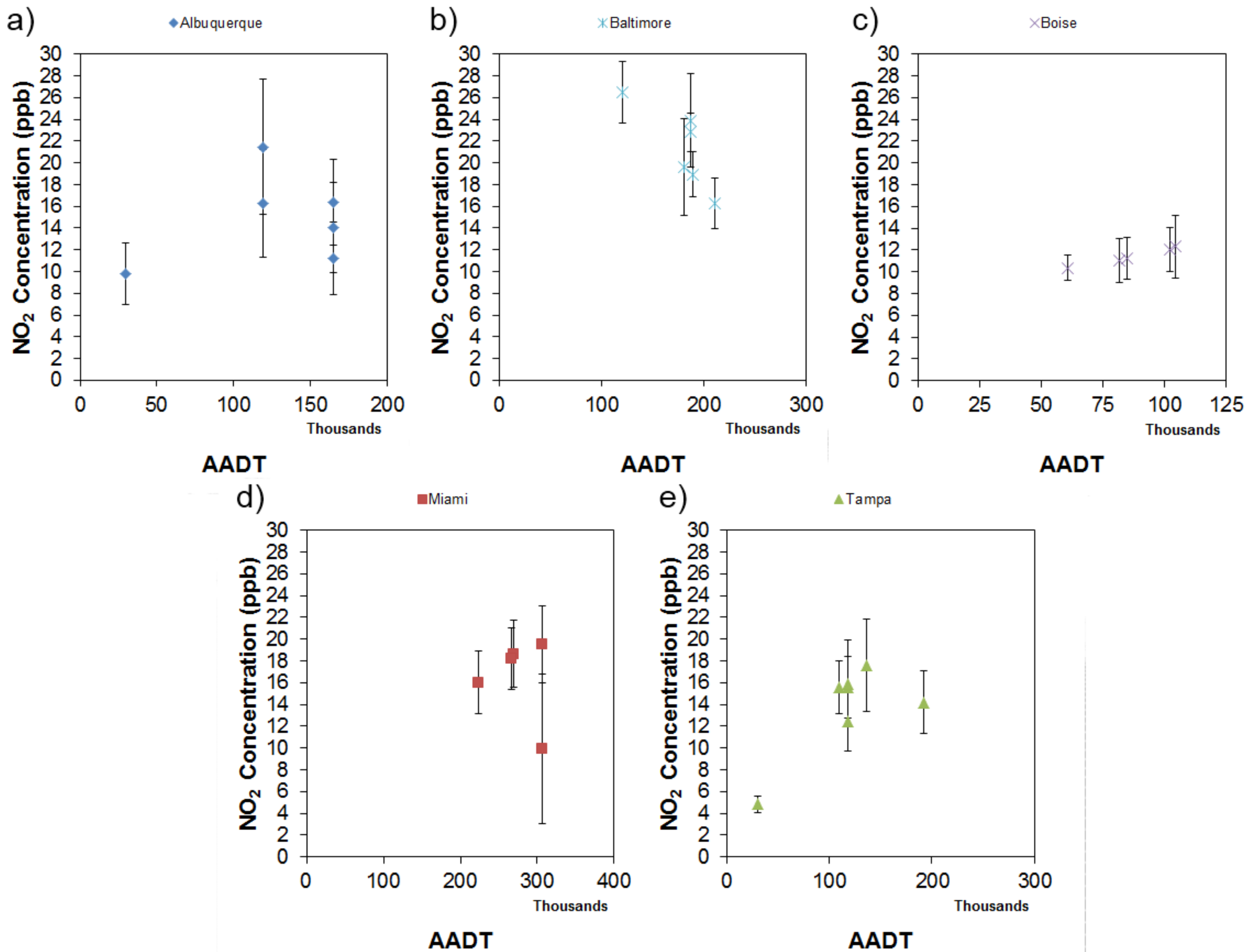


Figure 3-7. Average NO_2 concentrations (ppb) for Albuquerque (a), Baltimore (b), Boise (c), Miami (d), and Tampa (e) across all weeks of sampling at all sites compared to AADT. Bars indicate standard deviation of weekly averages.

3.4 Fleet-Equivalent AADT

The EPA's TAD (U.S. Environmental Protection Agency, 2011) provides a method with which to obtain a fleet-equivalent AADT (FE-AADT) metric that takes into account the fact that NO_x emissions are higher from heavy-duty (HD) vehicles than from light-duty (LD) vehicles. Determination of FE-AADT per segment depends on three variables: (1) total traffic volume, presented as AADT counts; (2) fleet mix, presented as HD vehicle number counts; and (3) the heavy-duty to light-duty vehicle NO_X emission ratio. **Equation 3-1** can be used to determine an FE-AADT value for each road segment:

$$\text{FE-AADT} = (\text{AADT} - HD_c) + (HD_m * HD_c) \qquad \textbf{(3-1)}$$

where AADT is the total traffic volume count for a particular road segment, the HD_c variable is the total number of heavy-duty vehicles for a particular road segment, and the HD_m variable is a multiplier that represents the heavy-duty to light-duty NO_x emission ratio for a particular road segment.

The TAD notes a national default value for HD_m of 10 (i.e., the NO_x emissions from one heavy-duty vehicle are approximately equivalent to the NO_x emissions from 10 light-duty vehicles operating on the same road segment and under the same environmental and relative operating conditions). Actual emission rates vary depending on a number of factors, including the vehicle technology, fuel burned, vehicle speed, vehicle load, and ambient temperature. The default HD_m value represents a ratio of average heavy-duty to light-duty vehicle emissions experienced across the U.S. for typical highway driving conditions.

Figure 3-8 shows average NO_2 concentration at all sites from all CBSAs versus FE-AADT. **Figure 3-9** shows average NO_2 concentration at all sites by CBSA versus FE-AADT.

Two parts of Figure 3-8 have been highlighted. In the green box in this figure, the large NO_2 concentration difference between the two points (Fort Lauderdale East and Fort Lauderdale West) is due to the location of the sampling site. These two sites have the same FE-AADT (Figure 3-8) and AADT (Figure 3-7) values because they are located along the same road segment. The site with lower average concentrations was on the eastern side of the road, and the site with higher average concentrations was on the western side of the road. In this case (Miami CBSA), meteorology likely caused the concentration differences between the sites; see Section 3.6 for a more detailed discussion. The blue circle in Figure 3-8 calls attention to a site with the highest average NO_2 concentration in the pilot study—a tollbooth in Baltimore. Several factors were identified for that site that may account for the higher NO_2 concentrations; see Section 3.5 for a more detailed discussion.

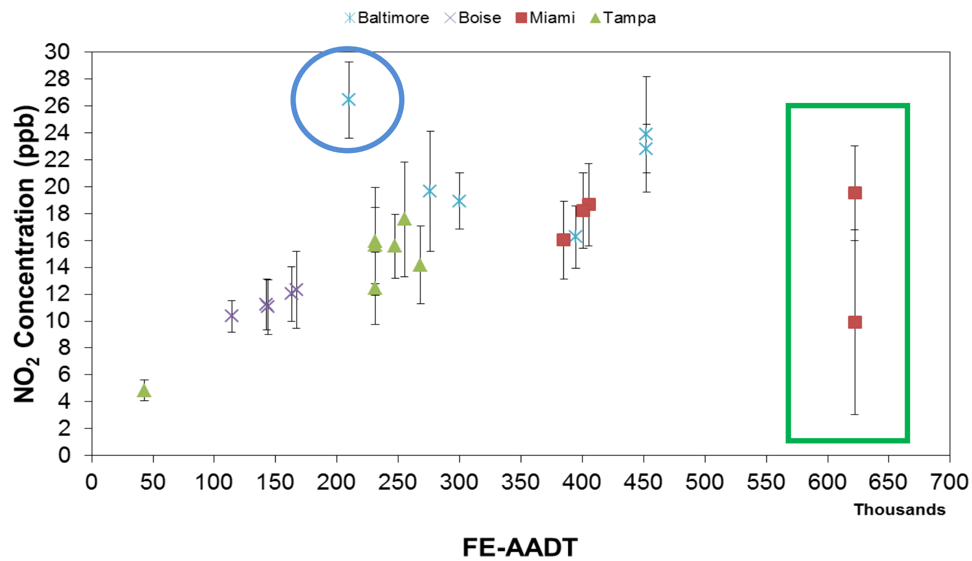


Figure 3-8. Average NO_2 concentrations shown by site across all weeks of sampling at all sites compared to FE-AADT. Bars indicate standard deviation of weekly averages.

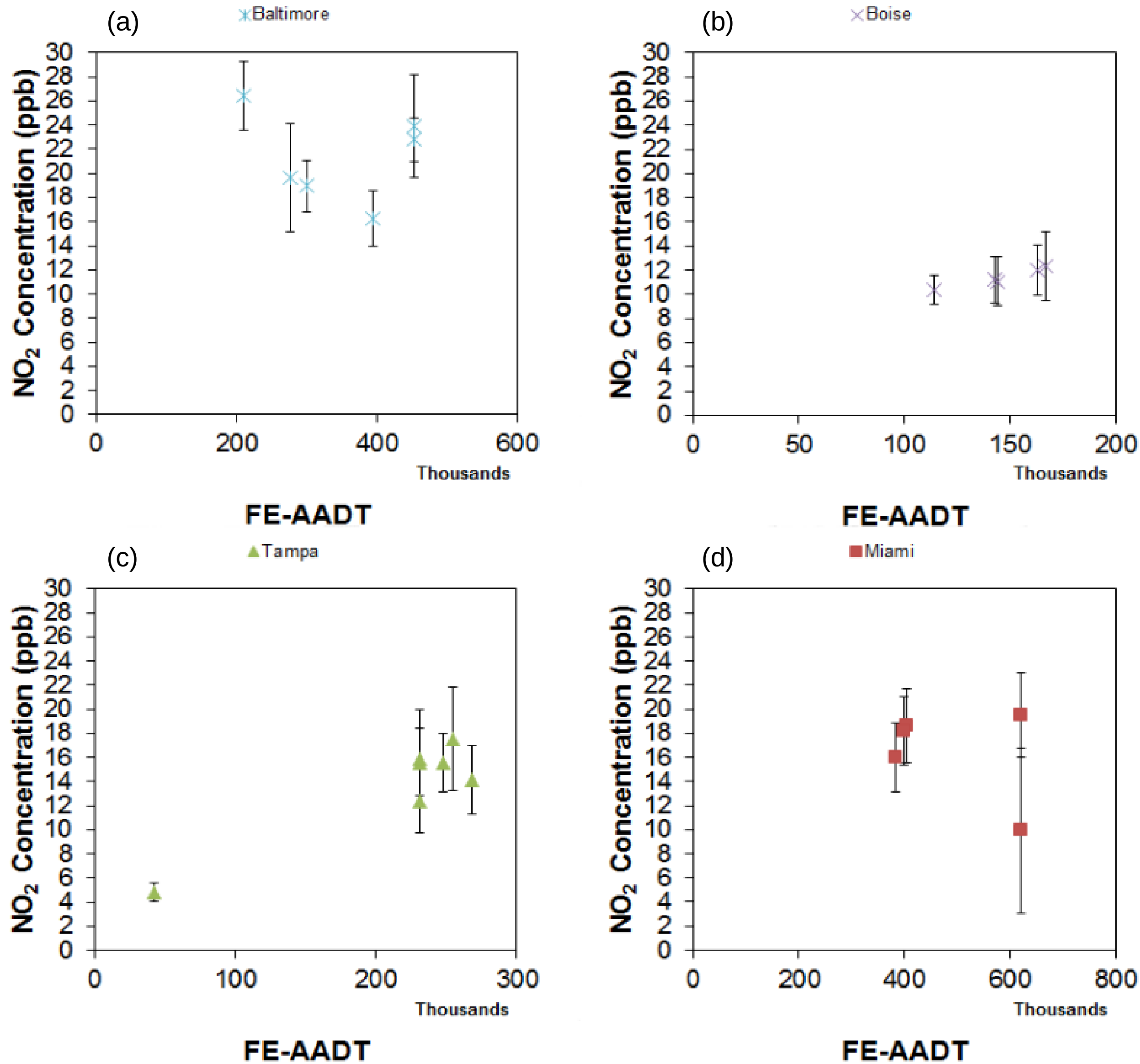


Figure 3-9. Average NO_2 concentrations for Baltimore (a), Boise (b), Tampa (c), and Miami (d) across all weeks of sampling at all sites compared to FE-AADT. Bars indicate standard deviation of weekly averages. Note: Albuquerque did not provide heavy duty counts; thus, the FE-AADT could not be calculated.

3.5 Background Sources, Congestion Pattern Indicators, and Terrain/Road Configuration

NO_2 concentrations at several sites in the pilot CBSAs were different from what was expected; however, these discrepancies can be explained. The following sites “did not fit” expectations:

- Baltimore: the tollbooth
- Baltimore: the northbound rest area (RAN)
- Baltimore: the southbound rest area (RAS)
- Tampa: the transect
- Tampa: the elevated roadway sites

3.5.1 Background Sources and Congestion Pattern Indicators

The Baltimore tollbooth site had much higher NO_2 concentrations than would be expected based on FE-AADT data alone. We and the Maryland Department of Environment monitoring staff believe these high concentrations were likely due to traffic and other influences, such as exhaust from the nearby Fort McHenry and the Harbor Tunnel Throughway entrance/exits, traffic accelerating and decelerating at the toll booth, and emissions from nearby operations of the Port of Baltimore and an associated rail yard (**Figure 3-10**). It is suggested that near-road NO_2 monitors not be placed in locations that may be highly unique within a CBSA (for example, like the Baltimore tollbooth site), because these sites are potentially affected by sources other than on-road emissions and are therefore not as representative of the emissions of other similarly trafficked roads in the area.

Figure 3-10. Tollbooth site in Baltimore (from Google Earth) showing the tunnel exit (A, 600 m away from the sampling location), the nearby rail facilities (B, 250 m away from sampling location), and port facilities (located south [C] and west [D] approximately 800 m away from the sampling location).

3.5.2 Terrain/Roadway Configuration

In Baltimore, the RAN and RAS sites were located on opposite sides of a roadway (**Figure 3-11**). NO_2 concentrations were higher at the RAS (south of highway) site than at the RAN (north of highway) site, even though the sites were on the same road segment (i.e., same AADT and FE-AADT). Absolute differences in NO_2 concentrations ranged from 0.1 to 6.2 ppb, with an average absolute difference of 3.4 ppb. These concentration differences could be related to meteorology and sampler location, but it is difficult to determine the cause from weekly averages. It is also possible that emissions from accelerating traffic affected the RAS sampler more strongly than the RAN sampler, especially during weeks when winds were conducive to transporting emissions toward the RAS sampler (specifically, Weeks 2 and 5); however, no specific data on the number of vehicles in transit was collected.

Figure 3-11. Google Earth view of RAS and RAN sites in Maryland. Note that the RAN site is closer to on-ramp traffic than the RAS site.

At the site in Tampa with the elevated roadway (see Figure 3-5), NO_2 concentration patterns can be explained by PSD placement relative to an elevated (over fill) roadway. The sampler placed higher on the traffic camera pole relative to the ground collected the highest concentration data. However, as noted earlier, this "higher" sampler was actually closer to the elevated road bed, while the "lower" sampler was actually below the roadbed and possibly in an eddy cavity. Also in Tampa, at the transect site, the highest NO_2 concentrations were observed at the second-farthest-placed sampler of the transect. Inspection of the site photos shows that this sampler was located between the on-ramp from the weigh station and the by-pass and travel lanes (see Figure 3-3). The on-ramp traffic consisted entirely of heavy-duty vehicles that were accelerating back onto the highway, causing higher emissions that would be expected to result in higher concentrations.

3.6 Meteorology

EPA's TAD suggests that an evaluation "of historical meteorological data could be useful in determining whether certain candidate locations may experience a higher proportion of direct traffic emission impacts from a given target road segment due to the local winds."

Understanding predominant winds may indicate which side of an individual road segment would be downwind of the road more often. Most studies showing high pollutant concentrations near roads have focused on measurements taken when winds flowed from the road to the downwind monitor or receptor (typically along a line normal to the roadbed).

In the TAD, EPA encourages downwind monitoring, but it is not required by rule. EPA notes that some evidence suggests that wind direction may not always be a major factor in leading to peak concentrations close to a major roadway. For example, peak NO_2 concentrations were found to sometimes occur during stable, low wind speed or otherwise stagnant conditions, or when winds are blowing roughly parallel to the target road. EPA notes in the TAD that "monitor placement on the climatologically down-wind side of a road segment is preferred; however, … this should not preclude consideration of sites located in the predominant climatologically upwind direction in light of applicable site access, safety, and other logistical issues."

The pilot study NO_2 results were reviewed with respect to average winds over the sampling periods to investigate the effect of wind direction on the concentrations observed. The frequency of low wind speeds or inversions during the sampling periods and climatological data were not investigated. In general, data indicate that the sampling locations where the average wind direction was most often downwind (or along or across the road) produced samples with higher concentrations than sites located on the upwind side of the road for these long-term averaging periods. CBSA-specific findings include

- **Albuquerque.** Winds were generally out of the west. Winds were measured as calm 8% of the time and the winds measured as variable 5% of the time. Sites S2 and S3 were on different sides of the same road segment; when winds were westerly, higher NO_2 concentrations were measured at the downwind S3 site than the upwind S2 site.

- **Baltimore.** Wind speeds and directions were variable week to week. Winds were measured as calm 30% of the time and variable winds were not measured. Concentration differences among sites did not seem to be a function of meteorology but of other siting factors.
- **Boise.** Winds were generally out of the northwest. Winds were measured as calm 11% of the time and as variable 2% of the time. NO_x and NO_2 concentrations were similar for all near-road sites. Meteorology did not seem to be a significant influence on concentrations at the different sites and was not as important in Boise as it was in other pilot CBSAs.
- **Miami.** Winds were generally easterly. Winds were measured as calm 13% of the time and as variable 2% of the time. Sites on the eastern side of the road (upwind) had lower concentrations than sites on the western side of the road (downwind). For example, during Week 2, concentrations measured at the Fort Lauderdale East (FLE) site (east side of the road) were nearly 5 times lower than concentrations measured at the Fort Lauderdale West (FLW) site (west side of the road).
- **Tampa.** Winds were westerly during Weeks 1 and 2 and out of the east during Weeks 3 through 5. Winds were measured as calm 47% of the time and variable winds were not measured. The site EPC02, located south of the road oriented east-northeast to west-southwest, had samples with the highest concentrations. Winds were generally along the road.

3.7 Areawide Versus Near-Road Sites

In addition to analyses performed evaluating metrics discussed in the TAD, other data depictions were investigated. For example, the average NO_2 concentrations observed at the sites closest to the roadway were compared with areawide (or background) NO_2 concentrations from the same CBSA as shown in **Figure 3-12**. As expected, NO_2 concentrations near the roadway were significantly higher than NO_2 concentrations at the background sites.

The biggest differences between background and near-road NO_2 concentrations were observed in Albuquerque, Miami, and Tampa (**Table 3-2**). The maximum FE-AADT in Boise (for the road segments studied) is the lowest of the pilot CBSAs; this fact may account for the smaller difference between the background site and the near-road site. In contrast, the background NO_2 concentrations in Baltimore are higher than background NO_2 concentrations in the other CBSAs. The urban background site may be influenced by nearby sources, or the regional background concentrations may be higher in general than in the other CBSAs.

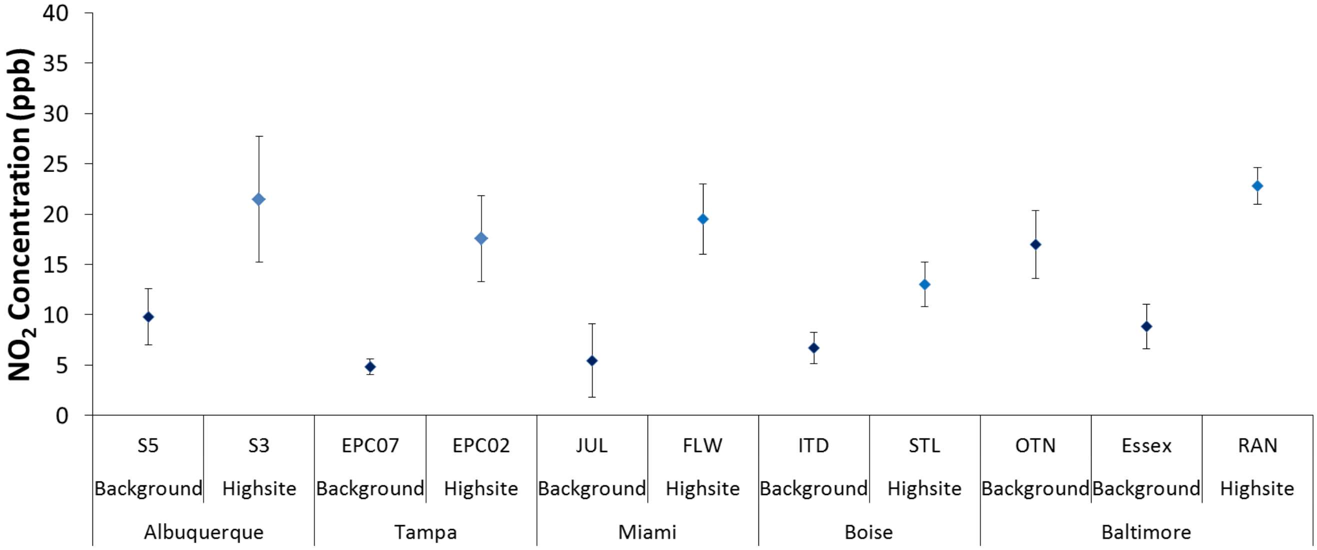


Figure 3-12. Average NO_2 concentrations at the background and highest-concentration sites by CBSA. In Baltimore, two background sites were included: Oldtown (OTN), located in an urban downtown environment, and Essex, located outside the urban area and more likely representative of the "areawide" background NO_2 concentrations. See Tables A-1, B-1, C-1, D-1, and E-1 in the appendices for sampler distance from road and height above ground level.

Table 3-2. Weekly averages of the differences between the site with the highest NO_2 concentrations and the background NO_2 concentrations for each of the pilot study CBSAs.

CBSA	High Site NO_2 (ppb) – Background NO_2 (ppb)			
	Minimum	Maximum	Average	Standard Deviation
Albuquerque	2.1	18.6	11.7	6.3
Baltimore	1.8	7.6	5.8	2.4
Boise	2.8	8.7	5.6	1.9
Miami	9.9	22.4	14.1	5.3
Tampa	7.5	17.3	12.7	3.8

3.8 Investigation of Surprising Results: NO_2/NO_x Ratios

We also noted significant differences in the NO_2/NO_x ratios observed in the pilot CBSAs (**Table 3-3**). The average ratios in Miami and Tampa were consistently higher than the NO_2/NO_x ratios observed in either Boise or Baltimore. We hypothesize that the ratios could be a function of the available ozone, with the thought that nitrogen oxide (NO) could more rapidly and completely be converted to NO_2 if ozone concentrations were sufficiently high. However, as shown in **Figure 3-13**, the plot of average ratios by site and CBSA with respect to ozone concentrations (from an urban background site) generally indicates clustering by CBSA, suggesting other factors like wind direction, stability/wind speed, and solar radiation affecting these results.

Table 3-3. CBSA-average near-road NO_2/NO_x ratios for the study period.

CBSA	Minimum	Maximum	Average	Standard Deviation
Baltimore	0.39	0.65	0.54	0.12
Boise	0.33	0.74	0.42	0.13
Miami	0.66	0.87	0.77	0.08
Tampa	0.64	0.85	0.72	0.09

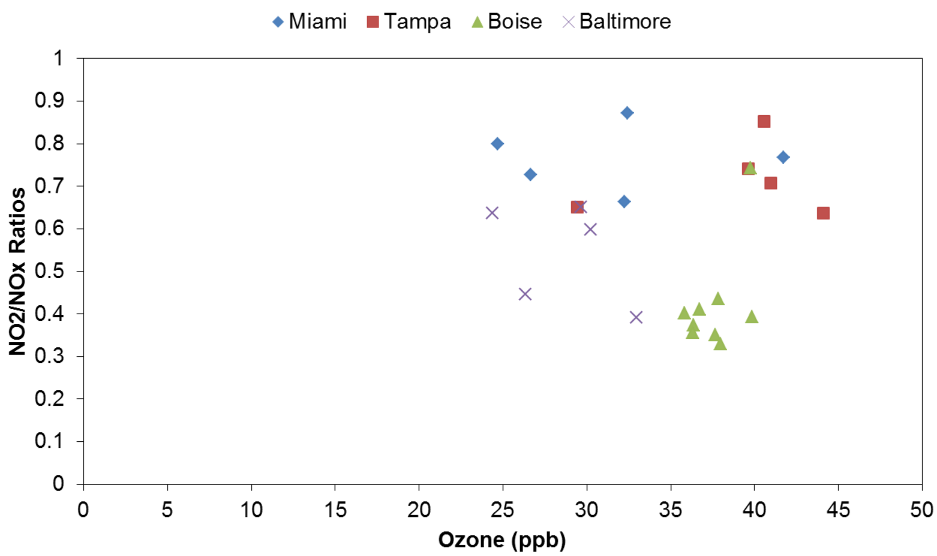


Figure 3-13. Average NO_2/NO_x ratios by site and CBSA compared to average ozone concentrations.

4. References

Hafner H., Vaughn D.L., and Pasch A.N. (2011) Quality assurance project plan: use of passive sampling devices (PSDs) in a near-road monitoring environment. Quality assurance project plan prepared for the Ambient Air Monitoring Group, Air Quality Assessment Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, by Sonoma Technology, Inc., Petaluma, CA, STI-910214-4060-QAPP, April. Available on the Internet at http://www.epa.gov/ttn/amtic/files/nearroad/20110428qapp.pdf.

U.S. Environmental Protection Agency (2011) Near-road NO_2 monitoring: technical assistance document. Draft document, August 11. Available on the Internet at http://www.epa.gov/ttn/amtic/files/nearroad/20110811tad.pdf.

Appendix A. Albuquerque

A.1 Site Information

Table A-1. Albuquerque sampling locations, traffic counts, rankings, distance from road, and sampling height.

<table>
<tr><th>Site Code</th><th>Site Name</th><th>Road Segment</th><th>AADT</th><th>AADT[b] Rank</th><th>FE-AADT[c]</th><th>Heavy Duty</th><th>FE-AADT Rank</th><th>Distance from Road (m)</th><th>Height (m)</th></tr>
<tr><td>S1</td><td>Site #1</td><td>Interstate 25 & access rd.</td><td>164,500</td><td rowspan="8" colspan="4">Not Available</td><td>25</td><td>2</td></tr>
<tr><td>S1</td><td>Site #1</td><td>Interstate 25 & access rd.</td><td>164,500</td><td>35</td><td>2</td></tr>
<tr><td>S1</td><td>Site #1</td><td>Interstate 25 & access rd.</td><td>164,500</td><td>45</td><td>2</td></tr>
<tr><td>S2</td><td>Site #2</td><td>Interstate 40 & Lomas</td><td>118,800</td><td>25</td><td>2</td></tr>
<tr><td>S3</td><td>Site #3</td><td>Interstate 40 & Lomas</td><td>118,800</td><td>25</td><td>2</td></tr>
<tr><td>S1</td><td>Site #1</td><td>Interstate 25 & access rd.</td><td>164,500</td><td>25</td><td>4</td></tr>
<tr><td>S4</td><td>Site #4</td><td>Interstate 40 & San Pedro</td><td>154,900</td><td>5</td><td>4</td></tr>
<tr><td>S5[a]</td><td>Site #5</td><td>San Mateo (NCore reference site)</td><td>29,300</td><td>5</td><td>4</td></tr>
</table>

[a] Urban background site.
[b] AADT is annual average daily traffic.
[c] FE-AADT is fleet-equivalent annual average daily traffic

Figure A-1. Albuquerque S1 site photo (left) and Google Earth image (right). This was the transect location.

Figure A-2. Albuquerque S2 site photo (left) and Google Earth image (right).

Figure A-3. Albuquerque S5 site photo (left) and Google Earth image (right). This is the area-wide/background monitoring location.

Figure A-4. Albuquerque S3 site photo (left) and Google Earth image (right).

Figure A-5. Albuquerque S4 site photos (top) and Google Earth image (bottom).

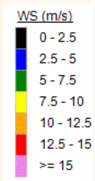
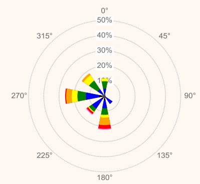
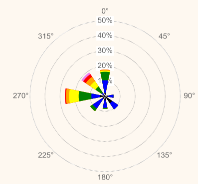
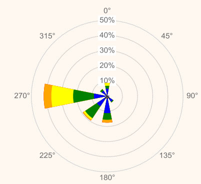
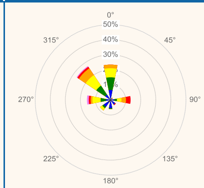
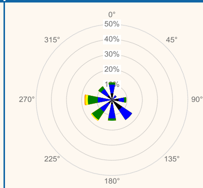
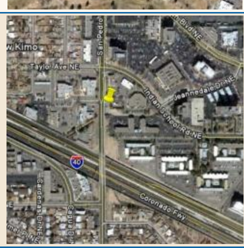
Table A-2. Albuquerque site metadata table.

Site Abbreviation ➔	S1	S1	S1	S2	S3	S4	S5
Site Name	Site #1	Site #1	Site #1	Site #2	Site #3	Site #4	Site #5 Reference Site
Latitude	35.136306°	35.136306°	35.136306°	35.086684°	35.087242°	35.102652°	35.134300°
Longitude	-106.604806°	-106.604806°	-106.604806°	-106.542765°	-106.541328°	-106.577438°	-106.585200°
Sampler Distance from Roadway (m)	25	35	45	25	25	5	5
Sampler Height (m)	2, 4	2	2	2	2	4	4
Road Segment Name	Interstate 25 & access rd.	Interstate 25 & access rd.	Interstate 25 & access rd.	Interstate 40 & Lomas	Interstate 40 & Lomas	Interstate 40 & San Pedro	San Mateo (NCore reference site)
AADT	164,500	164,500	164,500	118,800	118,800	154,900	29,300
HD[a] Counts							
FE-AADT	164,500	164,500	164,500	118,800	118,800	154,900	29,300
AADT Rank							
FE-AADT Rank							
Transect	Yes	Yes	Yes	No	No	No	No
Area-wide Location	No	No	No	No	No	No	Yes
Terrain	On grade	On grade	On grade	On grade	On grade	On grade	On grade
Roadway Design	Flat	Flat	Flat	Flat	NA	NA	No
Roadside Structures	No	No	No	No	No	No	No
Safety Features	Guardrail	Guardrail	Guardrail	Guardrail	Guardrail	Guardrail	Not next to street
Surrounding Land Use	Flat	Flat	Flat	Flat	Flat	Flat	Flat, small berm to East
Interchanges	No	No	No	Yes	Overpass	No	No

[a] Acronyms used in this table: heavy duty (HD), fleet-equivalent AADT (FE-AADT).

A.2 Summary Statistics

Table A-3. Albuquerque: summary of weekly average wind roses, temperature, relative humidity, and nitrogen dioxide (NO_2) concentrations by site.

Albuquerque		Week 1	Week 2	Week 3	Week 4	Week 5
Wind Rose[a]						
Average Temperature[a] (°C)		13	15	19	12	17
Average RH[a] (%)		24	14	21	27	15
Sites	Site Images	NO_2 (ppb)				
S1[b] 25 m		13.3	17.2	20.3	11.4	19.6
S1[b] 35 m		11.8	15.1	12.6	10.1	20.8
S1[b] 45 m		11.3	7.0	11.4	10.1	16.3
S2		10.0	20.4	12.0	18.4	20.6
S3		18.4	22.4	23.2	13.2	30.1
S4		10.4	16	14.3	13.1	19.3
S5		6.0	12.1	7.7	11.2	11.5

[a] Meteorological data were obtained from the Albuquerque International Sunport Airport Automated Surface Observing Systems (ASOS) site (KABQ). RH is relative humidity.
[b] Transect site in order of distance from the road.

Table A-4. Albuquerque: summary statistics of weekly average NO_2 concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
S5	5	4	6.0	12.1	9.8	2.8
S2	25	2	10.0	20.6	16.3	4.9
S3	25	2	13.2	30.1	21.5	6.3
S1	25	2	11.4	20.3	16.4	3.9
S1	35	2	10.1	20.8	14.1	4.2
S1	45	2	7.0	16.3	11.2	3.3
S1	25	4	10.0	19.5	14.0	3.6
S4	5	4	10.4	19.3	14.7	3.3

No NO_x concentrations were calculated for the Albuquerque sites.

Table A-5. Albuquerque: between-site and between-week variability, including the average and standard deviation of all weeks by site and all sites by week.

Site	S2	S3	S1	Average NO_2 (ppb)	STDEV NO_2 (ppb)
Distance	25	25	25		
Height	2	2	2		
Week 1 NO_2 (ppb)	10.0	18.4	13.3	13.9	4.2
Week 2 NO_2 (ppb)	20.4	22.4	17.2	20.0	2.6
Week 3 NO_2 (ppb)	12.0	23.2	20.3	18.5	5.8
Week 4 NO_2 (ppb)	18.4	13.2	11.4	14.4	3.7
Week 5 NO_2 (ppb)	20.6	30.1	19.6	23.4	5.8
Average NO_2 (ppb)	16.3	21.5	16.4		
STDEV NO_2 (ppb)	4.9	6.3	3.9		

A.3 Concentrations Compared to Distance to Roadway, Sampling Height, and Traffic

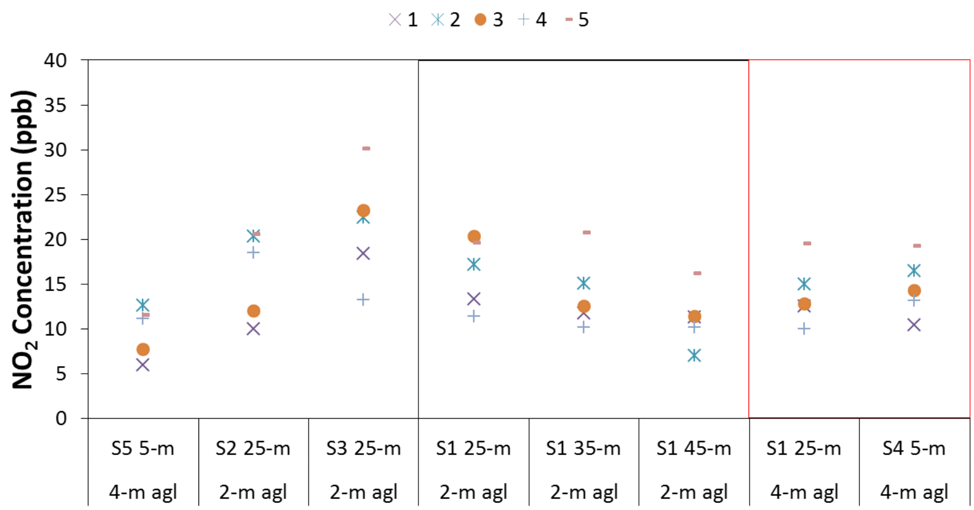


Figure A-6. Albuquerque: weekly average concentrations of NO_2 (ppb) at all monitoring sites, including the transect location (middle) and sites with height gradients (right). The x-axis labels are the site code, distance to the roadway (m), and sampler height above ground level (m).

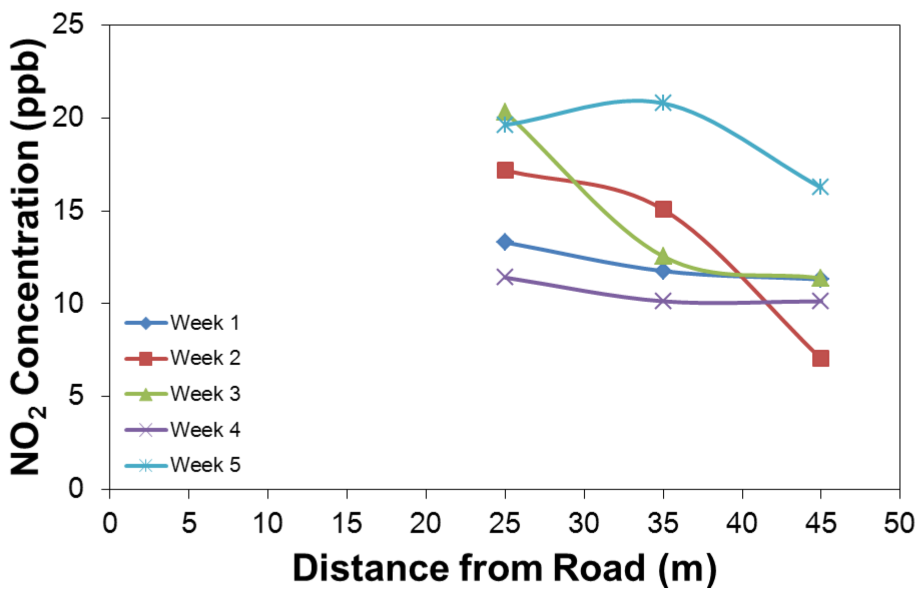


Figure A-7. Albuquerque: transect data NO_2 concentrations.

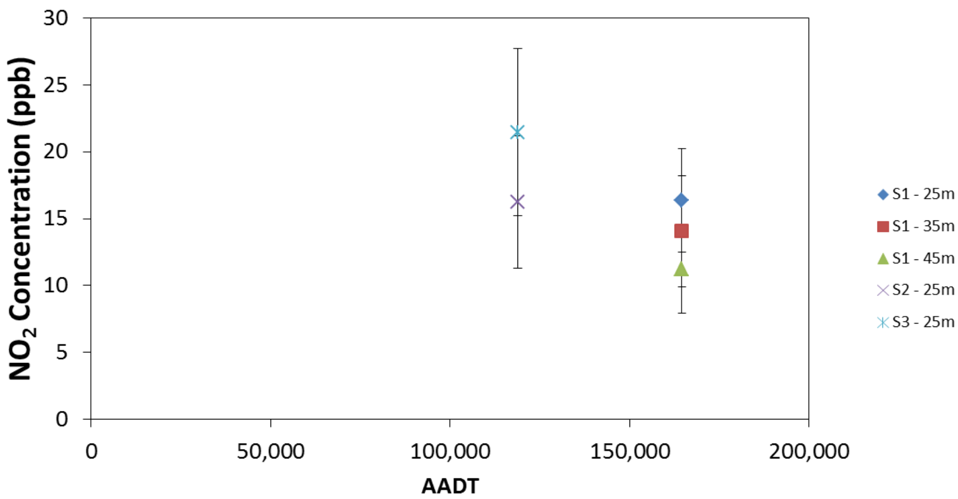


Figure A-8. Albuquerque: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to annual average daily traffic (AADT). Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

No heavy-duty counts were available for Albuquerque.

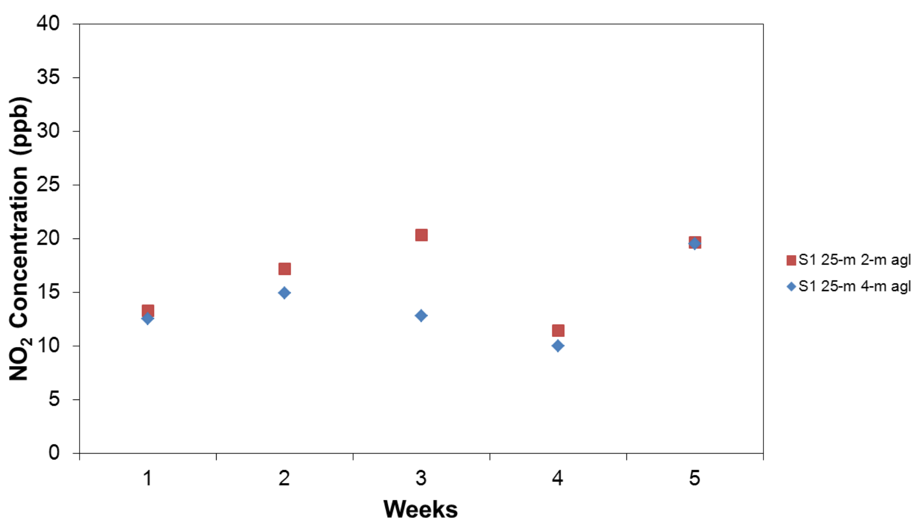


Figure A-9. Albuquerque: weekly average concentrations of NO_2 (ppb) at monitoring sites with two heights. Concentrations measured in Week 5 at the two heights are within 0.1 ppb of each other.

A.4 Albuquerque Quality Assurance and Data Completeness

Table A-6. Albuquerque: summary of data completeness statistics for Albuquerque samples, and field blanks and trip blanks for quality control**.**

Statistic	Value
Target Sample Number[a]	80
% Data Capture[b]	100%
% Data Valid[c]	97.50%
% Data Suspect[c]	1.30%
% Data Invalid[c]	1.30%
Target Quality Control (QC) Number (at 10%)	8
Number of Field Blanks (FB)	0
Number of Trip Blanks (TB)	10
% Actual Quality Control[d]	13%

[a] Target Sample Number is the number of passive sampling device (PSD) mounts, with two sample duplicates per mount, multiplied by the number of sample weeks.

[b] Percent Data Capture is the percentage of collected data values divided by the total number of target sample data values.

[c] Percent Data Valid, Suspect, or Invalid is the percentage of data values that are either valid, suspect, or invalid divided by the number of captured data values.

[d] The total number of QC samples (FB plus TB) divided by the number of captured sample data values, expressed as a percentage. All QC samples were valid.

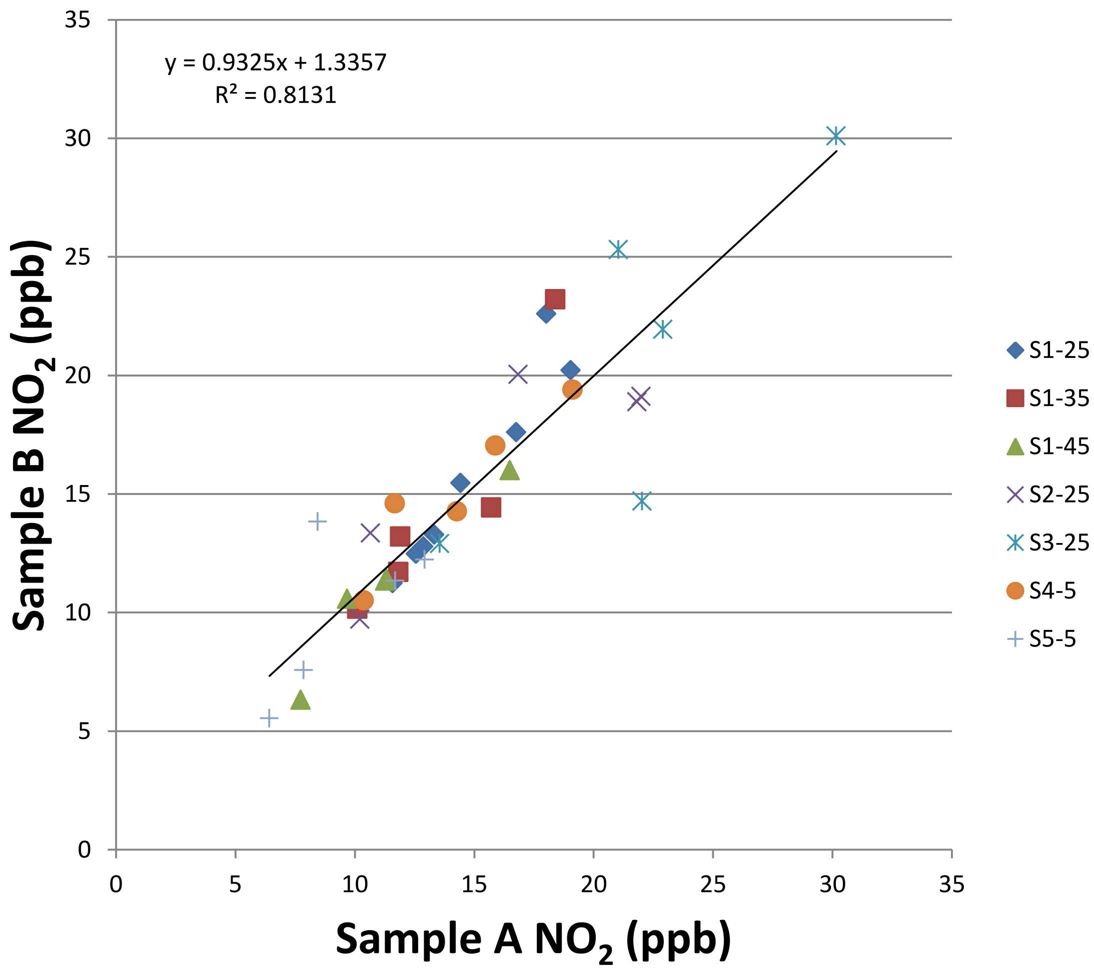


Figure A-10. Scatter plot and normal least square regression for duplicate NO_2 samples in Albuquerque. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_2 concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

Only trip blanks, no field blanks, were submitted from Albuquerque. The trip blanks averaged 0.9 ppb NO_2, with a standard error of 0.12 ppb, where standard error is the standard deviation of the blank mean divided by the square root of the blank count (n = 9).

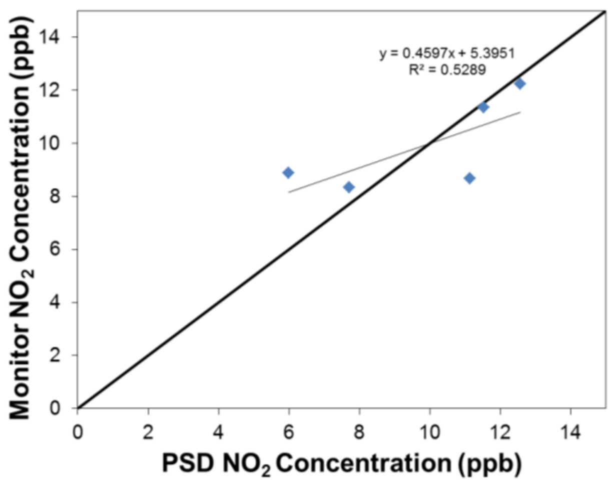


Figure A-11. Assessment of accuracy of PSDs deployed in Albuquerque by comparison with weekly averaged NO_2 concentrations from a collocated continuous monitor.

Appendix B. Baltimore

B.1 Site Information

Table B-1. Baltimore sampling locations, traffic counts, rankings, distance from road, and sampling height.

Site Code	Site Name	Road Segment	AADT	AADT Rank	FE-AADT[b]	Heavy Duty	FE-AADT Rank	Distance from Road (m)	Height (m)
CHH	Church	I-83/695 Ramp 7 to I-695 Ramps	210,790	2	394,810	20,447	9	18	2
MTA	Maryland Transit Authority	I695 and I795 P0078	189,237	9	299,941	12,300	29	13	2
MTA	Maryland Transit Authority	I695 and I795 P0078	189,237	9	299,941	12,300	29	27	2
MTA	Maryland Transit Authority	I695 and I795 P0078	189,237	9	299,941	12,300	29	38	2
OTN[a]	Oldtown	Corner of Hillen St. and Monument St.							
RAD	Radio Tower	I695 and 40	180,306	18	276,048	10,638	38	13	2
RAN	Northbound rest area	MD 216 to MD 32 NB	186,750	13	452,309	29,507	1	12	2
RAS	Southbound rest area	MD 216 to MD 32 SB	186,750	13	452,309	29,507	1	17	2
TLB	Tollbooth	I95 and Ft. McHenry Tollbooth T0007	121,017	57	209,928	9,879	53	8	2

[a] Urban background site.
[b] Fleet-equivalent annual average daily traffic (FE-AADT) is calculated using the formula in the EPA's technical assistance document (U.S. Environmental Protection Agency, 2011).

Figure B-1. Baltimore CHH site photo (left) and Google Earth image (right).

Figure B-2. Baltimore MTA site photo (left) and Google Earth image (right). This was the transect location.

Figure B-3. Baltimore OTN site photo (left) and Google Earth image (right). This is the areawide/background monitoring location.

Figure B-4. Baltimore RAD site photo (left) and Google Earth image (right).

Figure B-5. Baltimore RAN and RAS site photos (top left and right) and Google Earth image of both sites (bottom).

Figure B-6. Baltimore TLB site photo (left) and Google Earth image (right).

Table B-2. Baltimore site metadata table.

Page 1 of 2

Site Abbreviation ➔	CHH	MTA	MTA	MTA
Site Name	Church	Maryland Transit Authority	Maryland Transit Authority	Maryland Transit Authority
Latitude	39.41485	39.3716	39.37155	39.37155
Longitude	-76.6594	-76.7471	-76.7468	-76.74667
Sampler Distance from Roadway (m)	18	13	27	38
Sampler Height (m)	2	2	2	2
Road Segment Name	I-83/695 Ramp 7 to I-695	I-695 and I-795 P0078	I-695 and I-795 P0078	I-695 and I-795 P0078
AADT	210,790	189,237	189,237	189,237
Heavy Duty (HD) Counts	20,447	12,300	12,300	12,300
FE-AADT	394,813	299,937	299,937	299,937
AADT Rank	2	9	9	9
FE-AADT Rank	9	29	29	29
Transect	No	Yes	Yes	Yes
Areawide Location	No	No	No	No
Terrain	Flat grass land	Located on a grass hill at or slightly above grade; also a parking lot is adjacent for the MTA	Located on a grass hill at or slightly above grade; also a parking lot is adjacent for the MTA	Located on a grass hill at or slightly above grade; also a parking lot is adjacent for the MTA
Roadway Design	At grade	At/slightly below grade	At/slightly below grade	At/slightly below grade
Roadside Structures	No	No	No	No
Safety Features	Chain link fence	Jersey barriers and a chain link fence	Jersey barriers and a chain link fence	Jersey barriers and a chain link fence
Surrounding Land Use	Day school sensitive population	Located between the highway and an interchange ramp	Located between the highway and an interchange ramp	Located between the highway and an interchange ramp
Interchanges	No	Yes	Yes	Yes

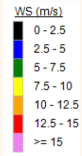
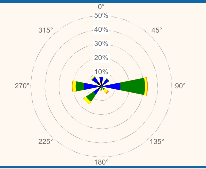
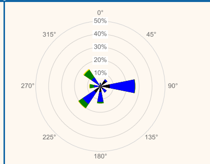
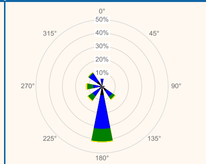
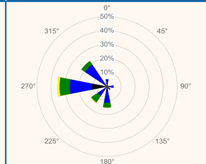
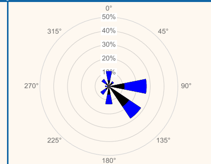
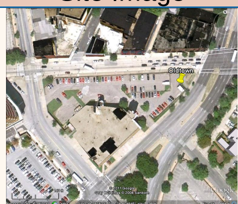
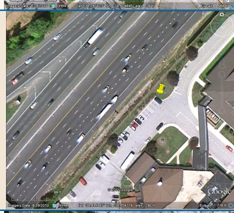
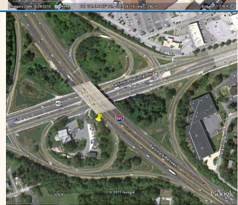
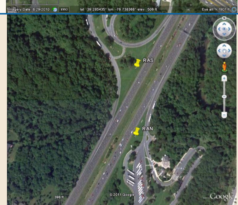
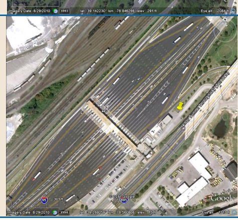
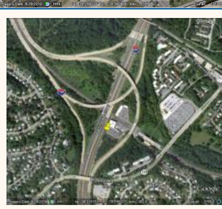
Table B-2. Baltimore site metadata table.

Page 2 of 2

Site Abbreviation →	RAD	RAN	RAS	TLB	OTN
Site Name	Radio Tower	Rest Area North	Rest Area South	Tollbooth	Oldtown
Latitude	39.28565	39.14165	39.14333	39.2667	39.2977
Longitude	-76.73838	-76.845867	-76.84585	-76.5608	-76.6046
Sampler Distance from Roadway (m)	13	12	17	8	
Sampler Height (m)	2	2	2	2	Roof of trailer
Road Segment Name	I-695 and 40	MD 216 to MD 32 NB	MD 216 to MD 32 SB	I-95 and Ft. McHenry Tollbooth T0007	Corner of Hillen St. and Monument St.
AADT	180,306	186,750	186,750	121,017	
HD Counts	10,638	29,507	29,507	9,879	
FE-AADT	276,048	452,313	452,313	209,928	0
AADT Rank	18	13	13	57	
FE-AADT Rank	38	1	1	53	
Transect	No	No	No	No	No
Areawide Location	No	No	No	No	Yes
Terrain	Sampler located below grade on a grass hill	Sampler located below grade in a grass ditch between the on ramp for the rest area and the main road	Sampler located below grade in a grass ditch between the on ramp for the rest area and the main road	No	No
Roadway Design	Road is above grade	Road is at or slightly above grade	Road is at or slightly above grade	At grade	At grade
Roadside Structures	No	No	No	No	No
Safety Features	None	None	None	None	Chain link fence on top of a sampling trailer
Surrounding Land Use	Located between ramps, depressed from roadway, near an overpass and an on ramp also near two busy streets	Nearby idling trucks, vehicles accelerating, road at slight incline	Nearby idling trucks, vehicles accelerating, road at slight incline	Near railroad, port operations, and the exit of a tunnel; accelerating vehicles and congestion; located between the toll plaza and an auxiliary road	Near-road inner city
Interchanges	Yes	No	No	No	No

B.2 Summary Statistics

Table B-3. Weekly average wind roses, temperature, relative humidity, and NO_2 concentrations by site.

Baltimore		Week 1	Week 2	Week 3	Week 4	Week 5
Wind Rose[a]						
Average Temperature[a] (°C)		13	15	18	14	16
Average RH[a] (%)		73	69	73	72	77
Site	Site Image	NO_2 (ppb)				
OTN		15.4	22.9	16.0	16.2	14.5
CHH		18.7	17.7	14.0	17.4	13.6
RAD		20.4	23.5	12.5	18.6	23.1
RAS		18.5	29.7	23.7	21.4	26.2
RAN		22.1	24.7	23.6	23.6	20.0
TLB		27.5	29.2	25.5	28.1	22.0
MTA[b] 13 m		16.2	21.2	15.4	17.9	15.6
MTA[b] 27 m		16.3	21.4	15.1	17.7	14.8
MTA[b] 38 m		15.4	20.2	14.1	15.8	14.3

[a] Meteorological data were obtained from the Tipton Airport Automated Surface Observing Systems (ASOS) site (KFME). RH is relative humidity.

[b] Transect sites in order of distance from the road.

Table B-4. Baltimore: summary statistics of weekly average NO_2 concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
OTN			14.5	22.9	17.0	3.4
CHH	18	2	13.6	18.7	16.3	2.3
RAD	13	2	12.5	23.5	19.6	4.5
RAN	12	2	20.0	24.7	22.8	1.8
RAS	17	2	18.5	29.7	23.9	4.3
TLB	8	2	22.0	29.2	26.4	2.8
MTA	13	2	15.4	21.2	17.3	2.4
MTA	27	2	14.8	21.4	17.1	2.7
MTA	38	2	14.1	20.2	16.0	2.5

Table B-5. Baltimore: summary statistics of weekly average NO_x concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
OTN			22.6	42.9	28.8	8.4
CHH	18	2	22.3	47.2	33.7	12.1
RAD	13	2	21.9	55.6	40.2	14.8
RAN	12	2	30.7	56.5	43.8	11.5
RAS	17	2	36.4	80.3	53.5	17.7
TLB	8	2	33.8	80.8	57.6	19.8
MTA	13	2	23.1	46.6	32.7	9.5
MTA	27	2	22.0	46.2	31.9	9.7
MTA	38	2	21.3	41.5	29.1	8.3

Table B-6. Baltimore: summary statistics of weekly average NO_2/NO_x ratios at each site.

Site	Distance (m)	Height (m)	Min	Max	Average	STDEV
OTN			0.51	0.68	0.60	0.07
CHH	18	2	0.38	0.68	0.52	0.13
RAD	13	2	0.38	0.65	0.52	0.11
RAN	12	2	0.39	0.65	0.54	0.12
RAS	17	2	0.37	0.65	0.47	0.14
TLB	8	2	0.34	0.65	0.49	0.13
MTA	13	2	0.38	0.67	0.53	0.12
MTA	27	2	0.44	0.67	0.56	0.10
MTA	38	2	0.46	0.67	0.57	0.09

Table B-7. Baltimore: between-site and between-week variability, including the average and standard deviation of all weeks by site and all sites by week.

Site	CHH	MTA	RAD	RAN	RAS	TLB	Average NO_2 (ppb)	STDEV NO_2 (ppb)
Distance	18	13	13	12	17	8		
Height	2	2	2	2	2	2		
Week 1 NO_2 (ppb)	18.7	17.8	20.4	22.1	18.5	27.5	20.8	3.6
Week 2 NO_2 (ppb)	17.7	22.0	23.5	24.7	29.7	29.2	24.5	4.5
Week 3 NO_2 (ppb)	14.0	17.1	12.5	23.6	23.7	25.5	19.4	5.6
Week 4 NO_2 (ppb)	17.4	20.1	18.6	23.6	21.4	28.1	21.5	3.9
Week 5 NO_2 (ppb)	13.6	17.5	23.1	20.0	26.2	22.0	20.4	4.4
Average NO_2 (ppb)	16.3	18.9	19.6	22.8	23.9	26.4		
STDEV NO_2 (ppb)	2.3	2.1	4.5	1.8	4.3	2.8		

B.3 Concentrations Compared to Distance to Roadway, Sampling Height, and Traffic

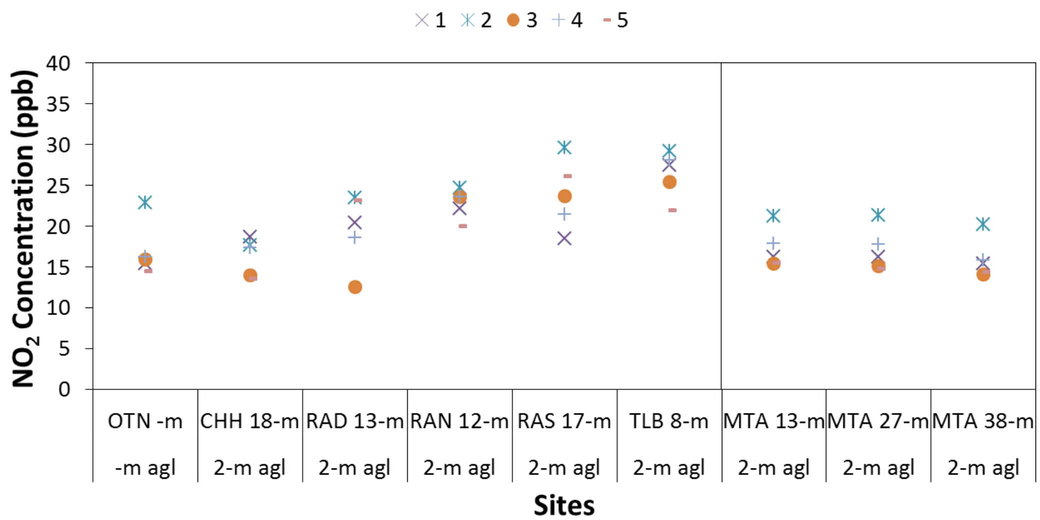


Figure B-7. Baltimore: weekly average concentrations of NO_2 (ppb) at all monitoring sites including the transect location (right hand side of the figure). The x-axis labels are the site code, distance to the roadway (m), and sampler height above ground level (m).

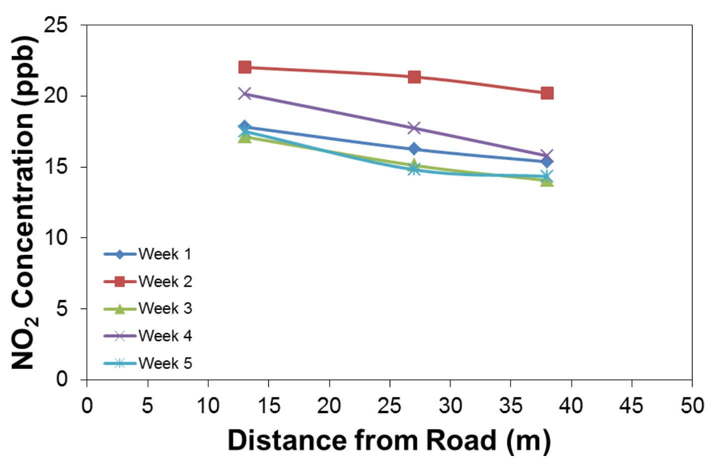


Figure B-8. Baltimore transect NO_2 concentration for all weeks.

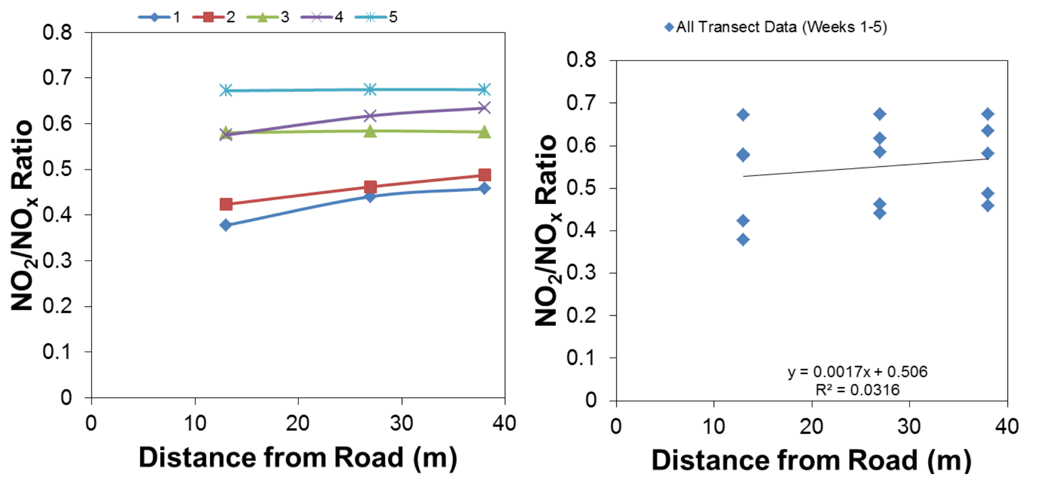


Figure B-9. Baltimore transect NO_2/NO_x ratios by week (left) and for all weeks (right).

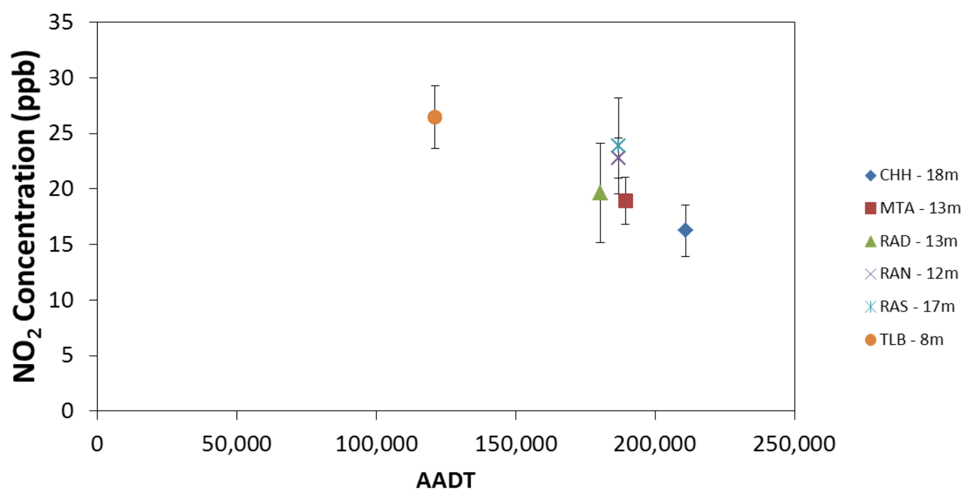


Figure B-10. Baltimore: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to annual average daily traffic (AADT). Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

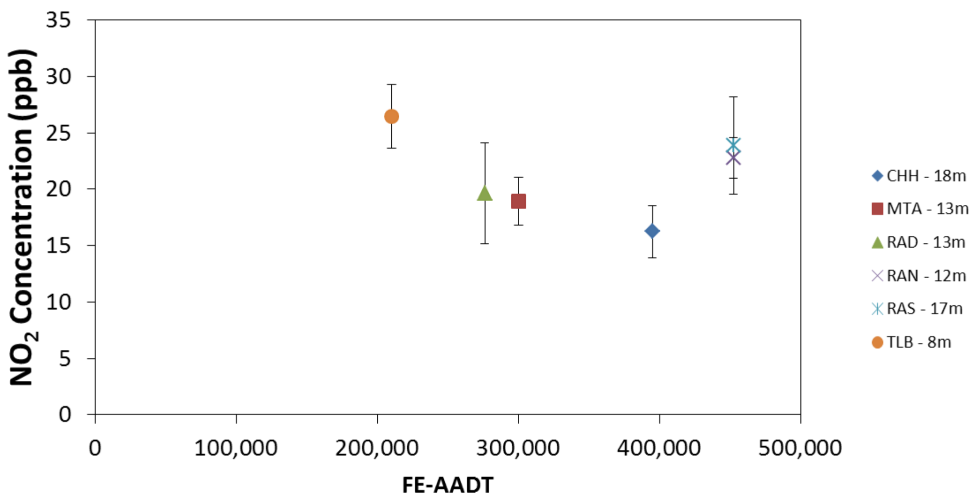


Figure B-11. Baltimore: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to fleet equivalent annual average daily traffic (FE-AADT). Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

None of the sites in Baltimore sampled at two heights.

B.4 Baltimore Quality Assurance and Data Completeness

Table B-8. Summary of data completeness statistics for Baltimore samples, and field blanks (FB) and trip blanks (TB) for quality control (QC)**.**

Statistic	Value
Target Sample Number[a]	90
% Data Capture[b]	100%
% Data Valid[c]	96.70%
% Data Suspect[c]	3.30%
% Data Invalid[c]	0.00%
Target Quality Control (QC) Number (at 10%)	9
Number of Field Blanks (FB)	8
Number of Trip Blanks (TB)	8
% Actual Quality Control[d]	18%

[a] Target Sample Number is the number of passive sampling device (PSD) mounts, with two sample duplicates per mount, multiplied by the number of sample weeks.
[b] Percent Data Capture is the percentage of collected data values divided by the total number of target sample data values.
[c] Percent Data Valid, Suspect, or Invalid is the percentage of data values that are either valid, suspect, or invalid divided by the number of captured data values.
[d] The total number of QC samples (FB plus TB) divided by the number of captured sample data values, expressed as a percentage. All QC samples were valid.

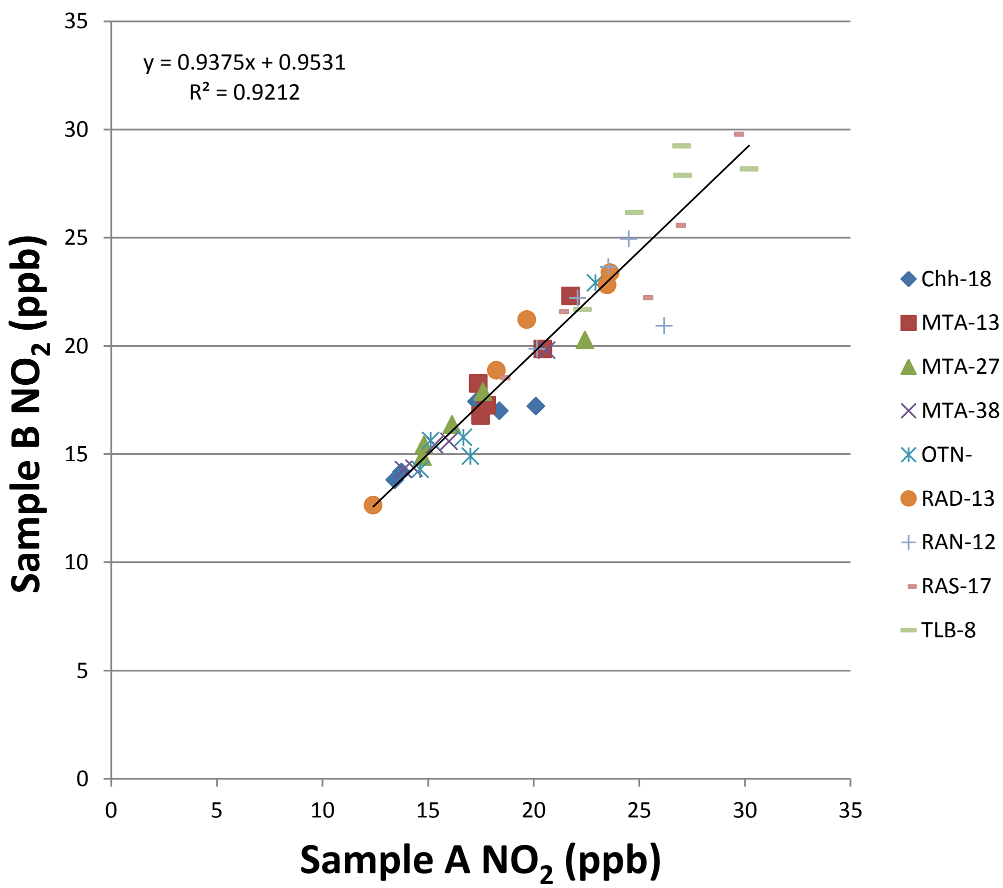


Figure B-12. Scatter plot and normal least square regression for duplicate NO_2 samples in Baltimore. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_2 concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

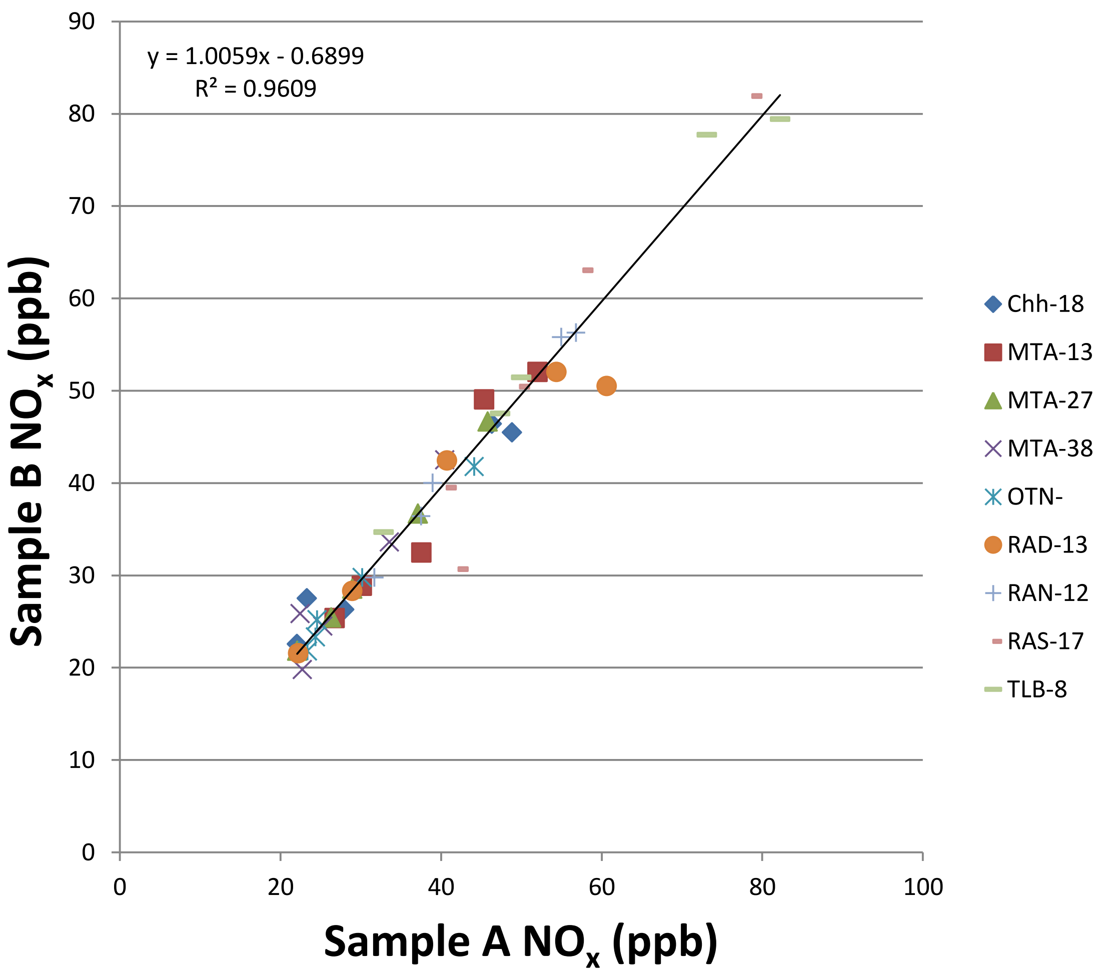


Figure B-13. Scatter plot and normal least square regression for duplicate NO_x samples in Baltimore. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_x concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

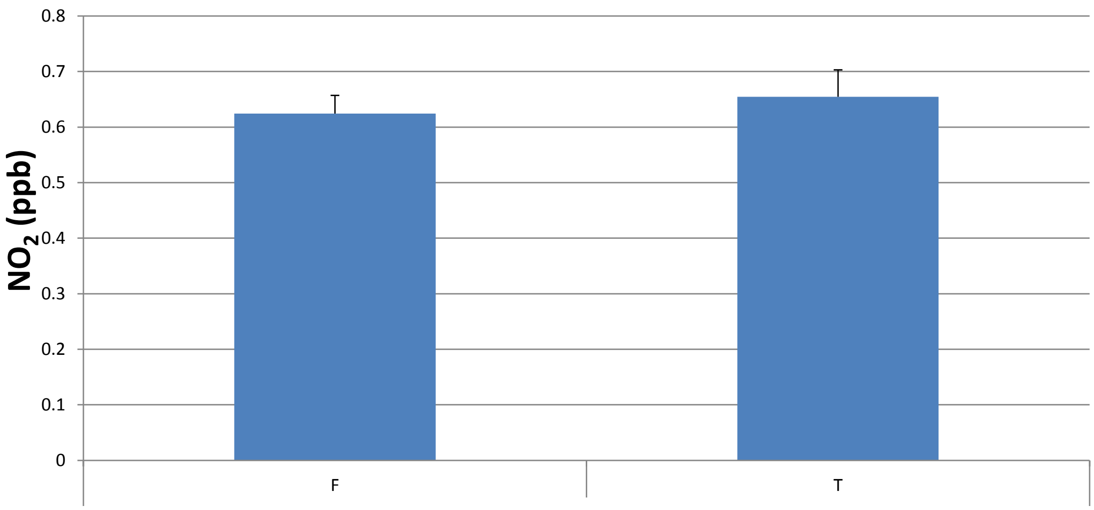


Figure B-14. Baltimore field (F) and trip (T) blank averages and standard errors, where standard error is the standard deviation of the blank mean divided by the square root of the blank count (*n* = 8 for both blank types). The Baltimore field and trip blanks were not statistically significantly different.

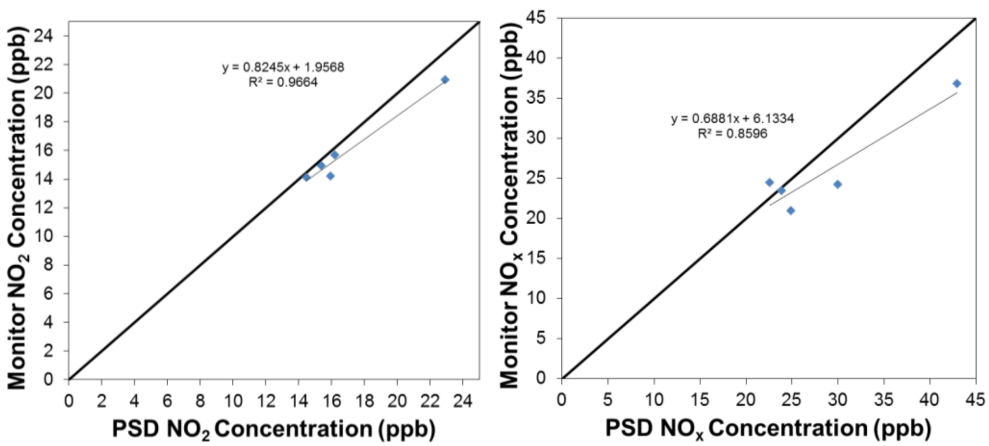


Figure B-15. Assessment of accuracy of PSDs deployed in Baltimore by comparison with weekly averaged NO_2 (left panel) and NO_x (right panel) concentrations from a co-located continuous monitor.

B.5 Reference

U.S. Environmental Protection Agency (2011) Near-road NO_2 monitoring: technical assistance document. Draft document, August 11. Available on the Internet at http://www.epa.gov/ttn/amtic/files/nearroad/20110811tad.pdf.

Appendix C. Boise

C.1 Site Information

Table C-1. Boise sampling locations, traffic counts, rankings, distance from road, and sampling height.

Site Code	Site Name	Road Segment	AADT	AADT Rank	FE-ADDT[b]	Heavy Duty	FE-AADT Rank	Distance from road (m)	Height (m)
FLY	Flying Wye	I-84 Y to east of Five Mile	81,902	6	144,002	6,900	1	12	2
ITD[a]	Idaho Transportation Dept.								3
JBL	Old Jabil Property	I-84 Eagle Road to east Meridian Road	102,538	2	162,838	6,700	2	12	2
JBL	Old Jabil Property	I-84 Eagle Road to east Meridian Road	102,538	2	162,838	6,700	2	12	7
JBL	Old Jabil Property	I-84 Eagle Road to east Meridian Road	102,538	2	162,838	6,700	2	22	2
JBL	Old Jabil Property	I-84 Eagle Road to east Meridian Road	102,538	2	162,838	6,700	2	32	2
JBL	Old Jabil Property	I-84 Eagle Road to east Meridian Road	102,538	2	162,838	6,700	2	42	2
LDR	Linder Road	I-84 Meridian Road to Linder	85,096	5	142,696	6,400	4	13	2
STL	St. Luke's	I-84 east of Five Mile to Eagle Road	104,728	1	166,828	6,900	1	15	2
WT	Western Truss		61,000		114,100	5,900		26	2

[a] Urban background site.
[b] Fleet-equivalent annual average daily traffic (FE-AADT) is calculated using the formula in the EPA's technical assistance document (U.S. Environmental Protection Agency, 2011).

Figure C-1. Boise FLY site photo (left) and Google Earth image (right).

Figure C-2. Boise JBL site photo (left) and Google Earth image (right). This was the transect location. The permanent site will be located here.

Figure C-3. Boise ITD site photo (left) and Google Earth image (right). This is the areawide/background monitoring location.

Figure C-4. Boise STL site photo (left) and Google Earth image (right).

Figure C-5. Boise LDR site photo (left) and Google Earth image (right).

Figure C-6. Boise WT site photo (left) and Google Earth image (right).

Table C-2. Boise site metadata table.

Page 1 of 2

Site Abbreviation →	FLY	JBL	JBL
Site Name	Flying Wye	Old Jabil Property	Old Jabil Property
Latitude	43.59792	43.59375	43.59384, 43.59393, 43.59405
Longitude	-116.28966	-116.38111	-116.381
Sampler Distance from Roadway (m)	12	12	22, 32, 42
Sampler Height (m)	2	2, 7	2
Road Segment Name	I-84 Y to east of Five Mile	I-84 Eagle Road to east Meridian Road	I-84 Eagle Road to east Meridian Road
AADT	81,902	102,538	102,538
Heavy Duty (HD) Counts	6,900	6,700	6,700
FE-AADT	144,002	162,838	162,838
AADT Rank	6	2	2
FE-AADT Rank	1	2	2
Transect	No	Yes	Yes
Areawide Location	No	No	No
Terrain	Flat grassland	The samplers are located in a flat grass field located at the bottom of sloping hill	The samplers are located in a flat grass field located at the bottom of sloping hill
Roadway Design	At grade	Above grade	Above grade
Roadside Structures	No	No	No
Safety Features	Concrete barriers	None	None
Surrounding Land Use	Highway elevated interchange sampler located below interchange; potentially heavy traffic area requiring departure from roadway at undeveloped location; low-speed road departure/re-entry required with other vehicles accessing I-84 west at freeway speed	Large parking lot to the northeast with a large grass lot to the northwest	Large parking lot to the northeast with a large grass lot to the northwest
Interchanges	Yes	No	No

Table C-3. Boise site metadata table.

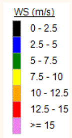
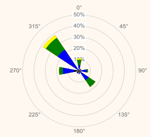
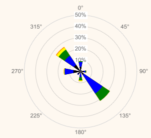
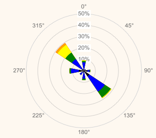
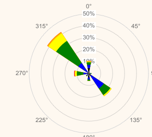
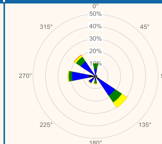
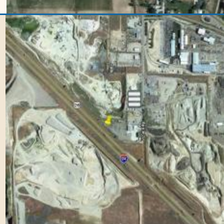
Page 2 of 2

Site Abbreviation →	LDR	STL	WT	ITD
Site Name	Linder Road	St. Lukes	Western Truss	Idaho Transportation Dept.
Latitude	43.59792	43.59375	43.59384	43.59405
Longitude	-116.41321	-116.34584	-116.17628	-116.23388
Sampler Distance from Roadway (m)	12	12	22	42
Sampler Height (m)	2	2, 7	2	2
Road Segment Name	I-84 Y to east of Five Mile	I-84 Eagle Road to east Meridian Road	I-84 Eagle Road to east Meridian Road	I-84 Eagle Road to east Meridian Road
AADT	81,902	102,538	102,538	102,538
Heavy Duty (HD) Counts	6,900	6,700	6,700	6,700
FE-AADT	144,002	162,838	162,838	162,838
AADT Rank	6	2	2	2
FE-AADT Rank	1	2	2	2
Transect	No	Yes	Yes	Yes
Areawide Location	No	No	No	No
Terrain	Flat grassland	The samplers are located in a flat grass field located at the bottom of sloping hill	The samplers are located in a flat grass field located at the bottom of sloping hill	The samplers are located in a flat grass field located at the bottom of sloping hill
Roadway Design	At grade	Above grade	Above grade	Above grade
Roadside Structures	No	No	No	No
Safety Features	Concrete barriers	None	None	None
Surrounding Land Use	Highway elevated interchange sampler located below interchange; potentially heavy traffic area requiring departure from roadway at undeveloped location; low-speed road departure/re-entry required with other vehicles accessing I-84 west at freeway speed	Large parking lot to the northeast with a large grass lot to the northwest	Large parking lot to the northeast with a large grass lot to the northwest	Large parking lot to the northeast with a large grass lot to the northwest
Interchanges	Yes	No	No	No

C.2 Summary Statistics

Table C-3. Weekly average wind roses, temperature, relative humidity, and NO_2 concentrations by site.

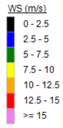
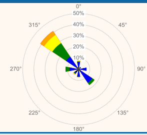
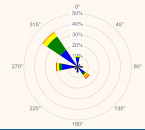
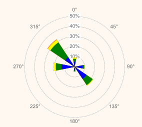
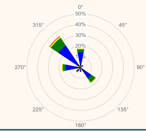
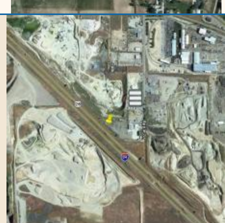
Page 1 of 2

Boise		Week 1	Week 2	Week 3	Week 4	Week 5
Wind Rose[a]						
Average Temperature[a] (°C)		6	10	7	8	12
Average RH[a] (%)		62	54	54	59	50
Site	Site Image	NO_2 (ppb)				
FLY		12.7	13.9	12.2	12.6	11.5
JBL[b] 12 m		12.5	14.9	13.3	13.3	12.1
JBL[b] 22 m		11.7	13.4	12.4	12.1	10.8
JBL[b] 32 m		11.7	13.1	12.5	11.7	10.7
JBL[b] 42 m		10.9	12.3	11.4	11.4	9.9
LDR		11.0	14.9	12.9	12.4	10.5
STL		13.2	16.3	15.4	14.0	13.4
WT		12.0	11.3	10.1	11.2	9.2
ITD		9.0	7.6	8.3	7.0	7.5

[a] Meteorology data were obtained from the Boise Air Terminal (Gowen Field) Automated Surface Observing Systems (ASOS) site (KBOI). RH is relative humidity.

[b] Transect sites in order of distance from the road.

Table C-3. Weekly average wind roses, temperature, relative humidity, and NO_2 concentrations by site.
Page 2 of 2

Boise		Week 6	Week 7	Week 8	Week 9
Wind Rose[a]					
Average Temperature[a] (°C)		13	15	18	14
Average RH[a] (%)		73	69	73	72
Sites	Site Images	NO_2 (ppb)			
FLY		8.3	9.9	9.8	8.4
JBL[b] 12 m		10.0	[c]	11.5	8.4
JBL[b] 22 m		9.0	8.7	10.6	7.5
JBL[b] 32 m		8.5	7.6	10.3	7.0
JBL[b] 42 m		8.8	8.9	10.0	6.9
LDR		9.5	9.8	11.2	8.9
STL		10.7	11.0	9.4	9.6
WT		11.7	9.0	9.4	9.4
ITD		5.2	5.0	6.0	4.8

[a] Meteorology data were obtained from the Boise Air Terminal (Gowen Field) ASOS site (KBOI). RH is relative humidity.
[b] Transect sites in order of distance from the road.
[c] Sample was invalidated because a severe wind storm blew over the PSD sampler pole and the samples were exposed to rain water.

Table C-4. Boise: summary statistics of weekly average NO_2 concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
ITD	0	0	4.8	9.0	6.7	1.5
FLY	12	2	8.3	13.9	11.0	2.0
LDR	13	2	8.9	14.9	11.2	1.9
STL	15	2	9.6	16.3	13.0	2.2
WT	26	2	9.0	12.0	10.4	1.2
JBL	12	2	8.4	14.9	12.0	2.0
JBL	22	2	7.5	13.4	10.7	2.0
JBL	32	2	7.0	13.1	10.3	2.2
JBL	42	2	6.9	12.3	10.1	1.7
JBL	12	7	7.9	12.9	10.4	1.7

Table C-5. Boise: summary statistics of weekly average NO_x concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
ITD	0	0	9.6	15.8	12.1	2.1
FLY	12	2	16.8	26.2	21.4	3.3
LDR	13	2	23.1	40.1	29.7	5.0
STL	15	2	18.2	45.9	32.3	7.9
WT	26	2	18.8	27.1	23.8	2.8
JBL	12	2	22.2	43.1	32.9	6.5
JBL	22	2	19.3	33.6	27.2	4.3
JBL	32	2	13.9	31.5	23.7	5.9
JBL	42	2	15.7	27.4	22.6	3.8
JBL	12	7	19.5	32.8	26.7	4.4

Table C-6. Boise: summary statistics of weekly average NO_2/NO_x ratios at each site.

Site	Distance (m)	Height (m)	Min	Max	Average	STDEV
ITD			0.45	0.62	0.55	0.06
FLY	12	2	0.46	0.56	0.52	0.03
LDR	13	2	0.34	0.42	0.38	0.02
STL	15	2	0.37	0.74	0.47	0.13
WT	26	2	0.38	0.50	0.44	0.04
JBL	12	2	0.35	0.41	0.37	0.02
JBL	22	2	0.35	0.43	0.39	0.02
JBL	32	2	0.40	0.55	0.44	0.05
JBL	42	2	0.42	0.47	0.45	0.02
JBL	12	7	0.37	0.41	0.39	0.01

Table C-7. Boise: between-site and between-week variability, including the average and standard deviation of all weeks by site and all sites by week.

Site	FLY	JBL	LDR	STL	WT	Average NO_2 (ppb)	STDEV NO_2 (ppb)
Distance	12	12	13	15	26		
Height	2	2	2	2	2		
Week 1 NO_2 (ppb)	12.7	12.5	11.0	13.2	12.0	12.3	0.8
Week 2 NO_2 (ppb)	13.9	14.9	14.9	16.3	11.3	14.3	1.9
Week 3 NO_2 (ppb)	12.2	13.3	12.9	15.4	10.1	12.8	1.9
Week 4 NO_2 (ppb)	12.6	13.3	12.4	14.0	11.2	12.7	1.1
Week 5 NO_2 (ppb)	11.5	12.1	10.5	13.4	9.2	11.4	1.6
Week 6 NO_2 (ppb)	8.3	10.0	9.5	10.7	11.7	10.0	1.3
Week 7 NO_2 (ppb)	9.9	*	9.8	11.0	9.0	9.9	0.8
Week 8 NO_2 (ppb)	9.8	11.5	11.2	13.5	9.4	11.1	1.6
Week 9 NO_2 (ppb)	8.4	8.4	8.9	9.6	9.4	8.9	0.5
Average NO_2 (ppb)	11.0	12.0	11.2	13.3	10.4		
STDEV NO_2 (ppb)	2.0	2.0	1.9	229	1.2		

* Sample was invalidated because a severe wind storm blew over the PSD sampler pole and the samples were exposed to rain water.

C.3 Concentrations Compared to Distance to Roadway, Sampling Height, and Traffic

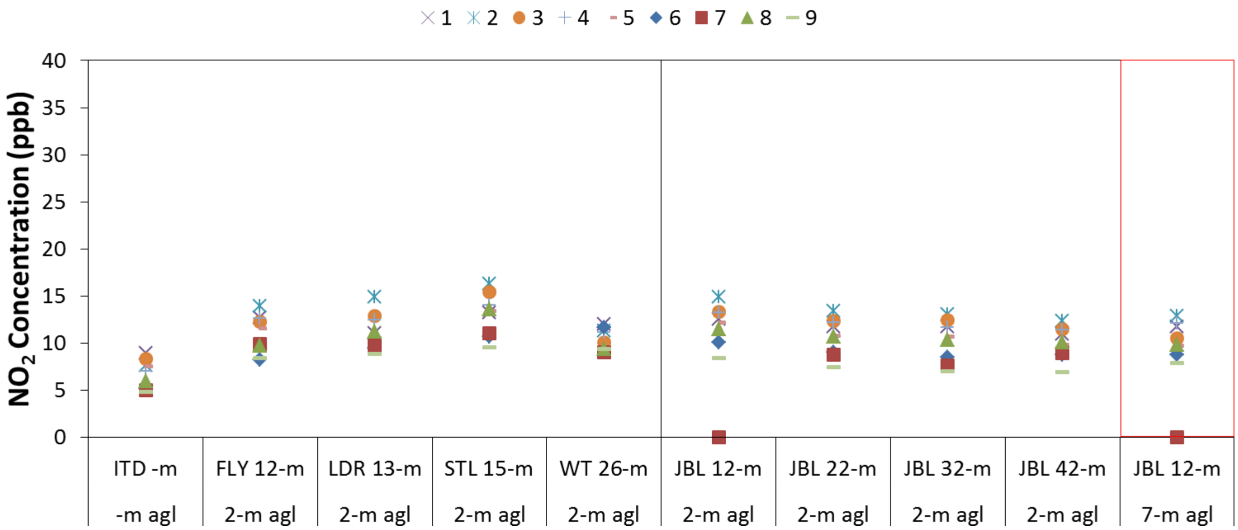


Figure C-7. Boise: weekly average concentrations of NO_2 (ppb) at all monitoring sites including the transect location (black box) and the site with a height gradient (red box). The x-axis labels are the site code, distance to the roadway (m), and sampler height above ground level (m).

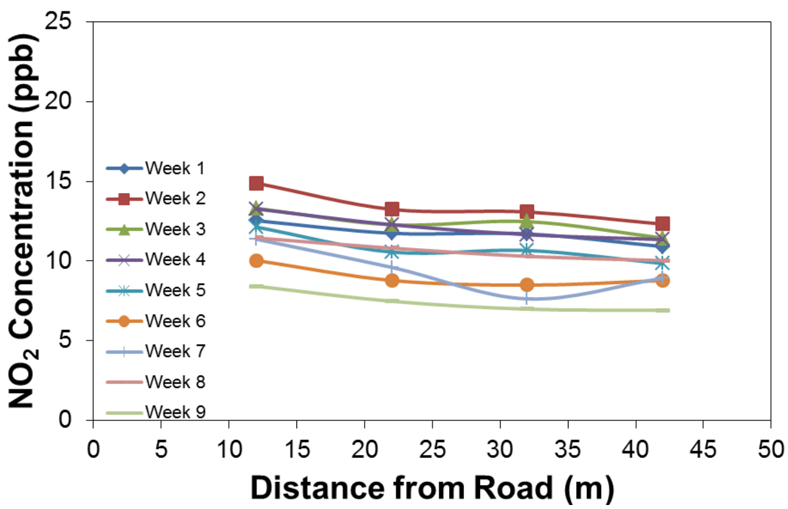


Figure C-8. Boise transect NO_2 data all weeks.

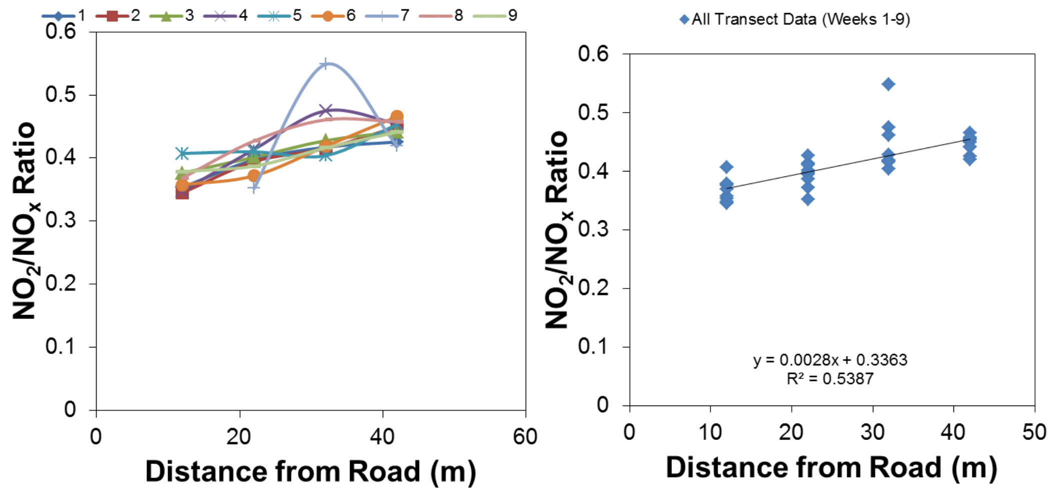


Figure C-9. Boise transect NO_2/NO_x ratio plots by week (left) and for all weeks (right).

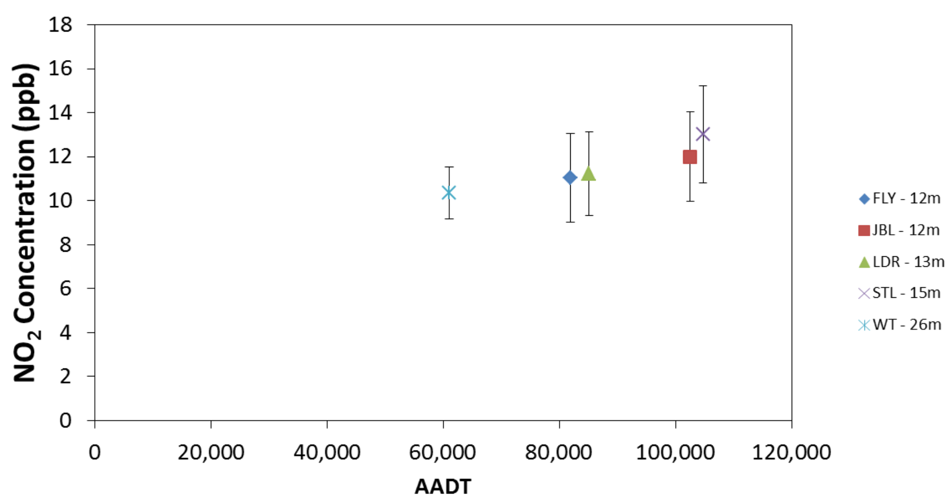


Figure C-10. Boise: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to annual average daily traffic (AADT). Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

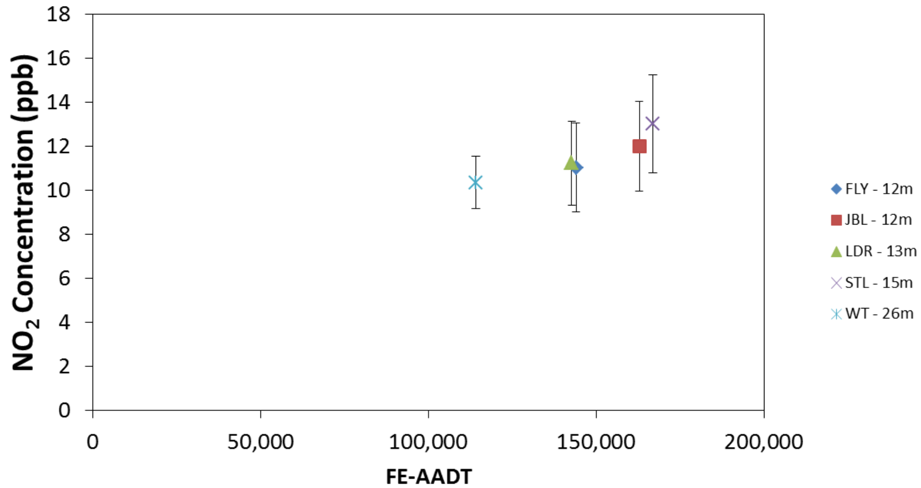


Figure C-11. Boise: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to fleet equivalent annual average daily traffic (FE-AADT). Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

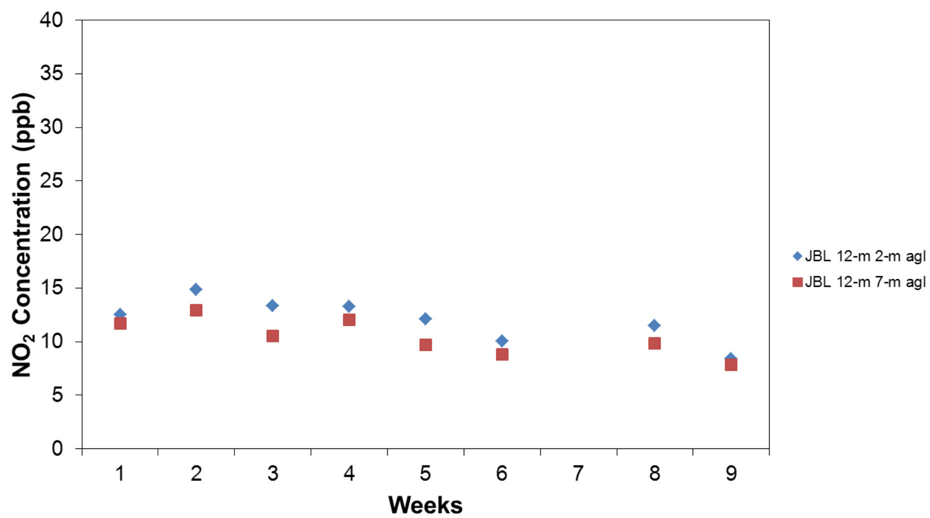


Figure C-12. Boise: weekly average concentrations of NO_2 (ppb) at monitoring sites with two heights.

C.4 Boise Quality Assurance and Data Completeness

Table C-8. Summary of data completeness statistics for Boise samples, and field blanks and trip blanks for quality control.

Statistic	Value
Target Sample Number[a]	180
% Data Capture[b]	100%
% Data Valid[c]	95%
% Data Suspect[c]	1.10%
% Data Invalid[c]	3.30%
Target Quality Control (QC) Number (at 10%)	18
Number of Field Blanks (FB)	8
Number of Trip Blanks (TB)	10
% Actual Quality Control[d]	10%

[a] Target Sample Number is the number of passive sampling device (PSD) mounts, with two sample duplicates per mount, multiplied by the number of sample weeks.

[b] Percent Data Capture is the percentage of collected data values divided by the total number of target sample data values.

[c] Percent Data Valid, Suspect, or Invalid is the percentage of data values that are either valid, suspect, or invalid divided by the number of captured data values.

[d] The total number of QC samples (FB plus TB) divided by the number of captured sample data values, expressed as a percentage. All QC samples were valid.

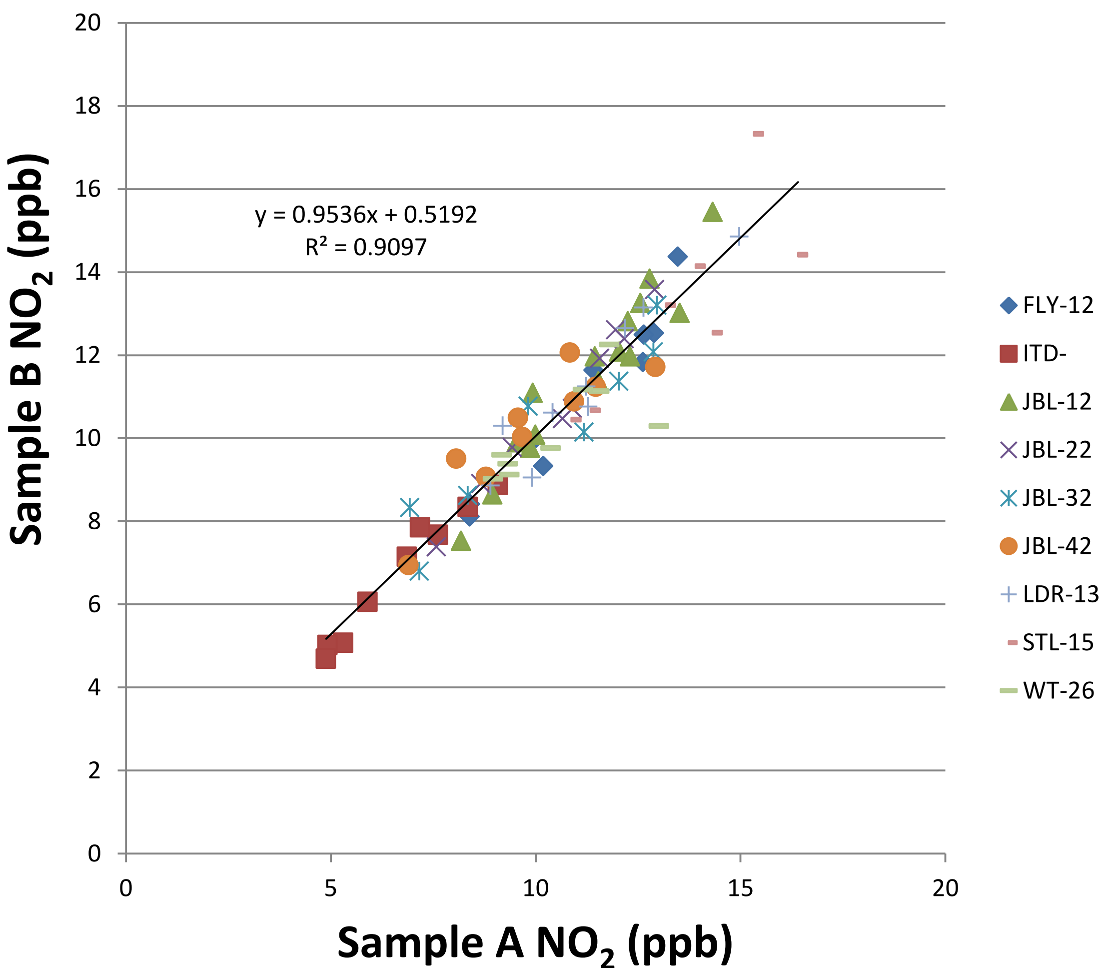


Figure C-13. Scatter plot and normal least square regression for duplicate NO_2 samples in Boise. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_2 concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

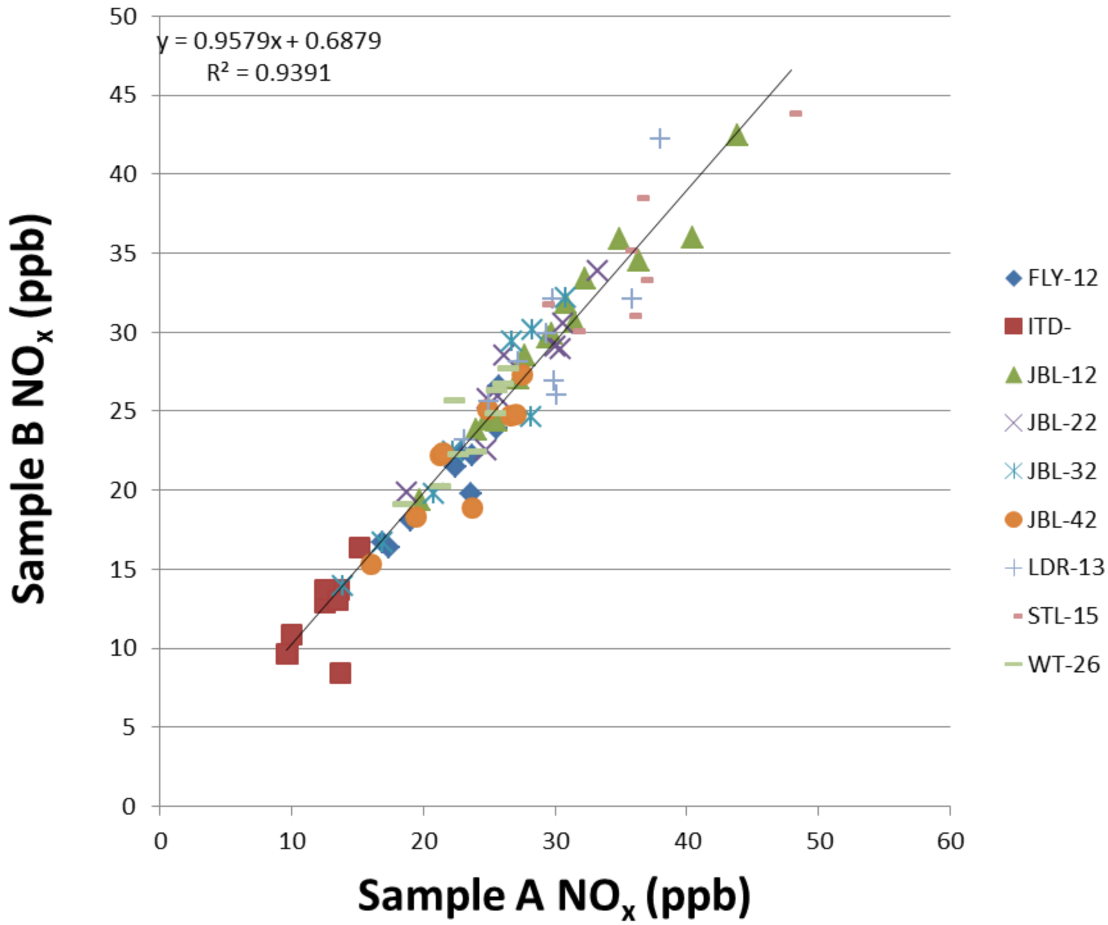


Figure C-14. Scatter plot and normal least square regression for duplicate NO_x samples in Boise. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_x concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

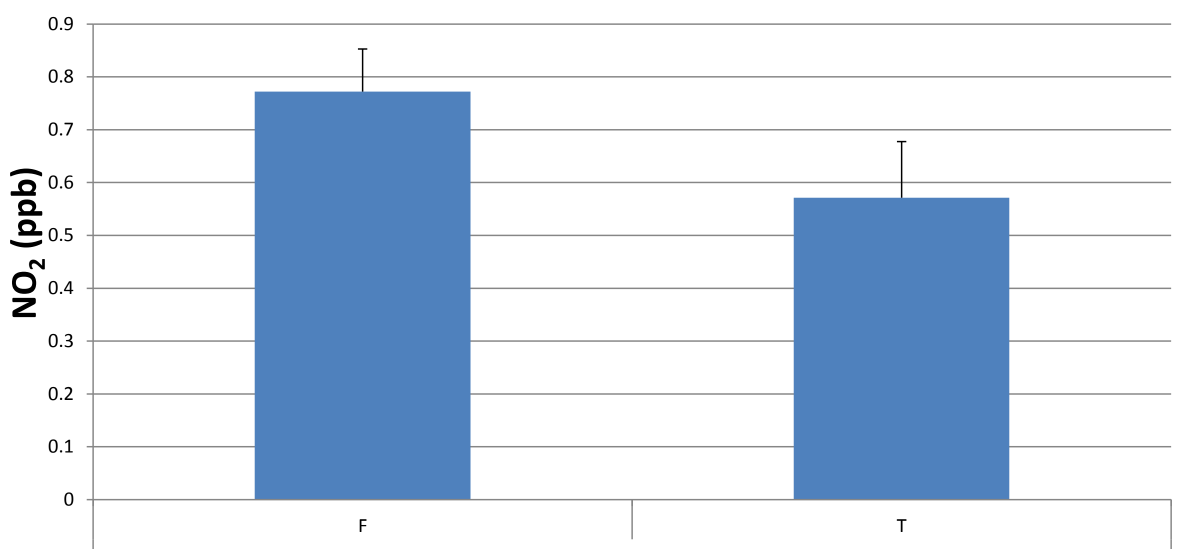


Figure C-15. Boise field (F; *n* = 8) and trip (T; *n* = 10) blank averages and standard errors, where standard error is the standard deviation of the blank mean divided by the square root of the blank count. The Boise field and trip blanks were not statistically significantly different.

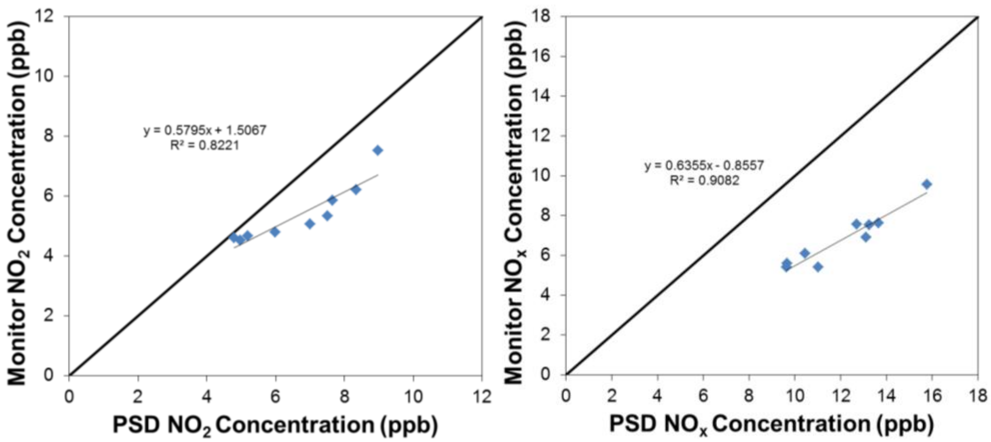


Figure C-16. Assessment of accuracy of PSDs deployed in Boise by comparison with weekly averaged NO_2 (left panel) and NO_x (right panel) concentrations from a co-located continuous monitor.

C.5 Reference

U.S. Environmental Protection Agency (2011) Near-road NO_2 monitoring: technical assistance document. Draft document, August 11. Available on the Internet at http://www.epa.gov/ttn/amtic/files/nearroad/20110811tad.pdf.

Appendix D. Miami

D.1 Site Information

Table D-1. Miami sampling locations, traffic counts, rankings, distance from road, and sampling height.

Site Code	Site Name	Road Segment	AADT	AADT Rank	FE-AADT[b]	Heavy Duty	FE-AADT Rank	Distance from road (m)	Height (m)
DBH	Dania Beach	I-95 & Stirling Road	270,000	6	405,108	15,012	7	15	2
FLE	Fort Lauderdale East	I-95 & Sunrise Blvd.	306,000	1	622,161	35,129	1	15	2
FLW	Fort Lauderdale West	I-95 & Sunrise Blvd.	306,000	1	622,161	35,129	1	15	2
FLW	Fort Lauderdale West	I-95 & Sunrise Blvd.	306,000	1	622,161	35,129	1	20	2
FLW	Fort Lauderdale West	I-95 & Sunrise Blvd.	306,000	1	622,161	35,129	1	24	2
HOL	Hollywood	I-95 & Pembroke Road	267,000	7	400,065	14,845	8	15	2
JUL[a]	John U Lloyd								2
PMB	Pompano Beach	I-95 & Atlantic Blvd.	224,000	16	384,875	17,875	10	15	2

[a] Urban background site.
[b] Fleet-equivalent annual average daily traffic (FE-AADT) is calculated using the formula in the EPA's technical assistance document (U.S. Environmental Protection Agency, 2011).

Figure D-1. Miami DBH site photo (left) and Google Earth image (right).

Figure D-2. Miami FLW site photo (left) and Google Earth image (right). This was the transect location.

Figure D-3. Miami JUL site photo (left) and Google Earth image (right). This is the areawide/background monitoring location.

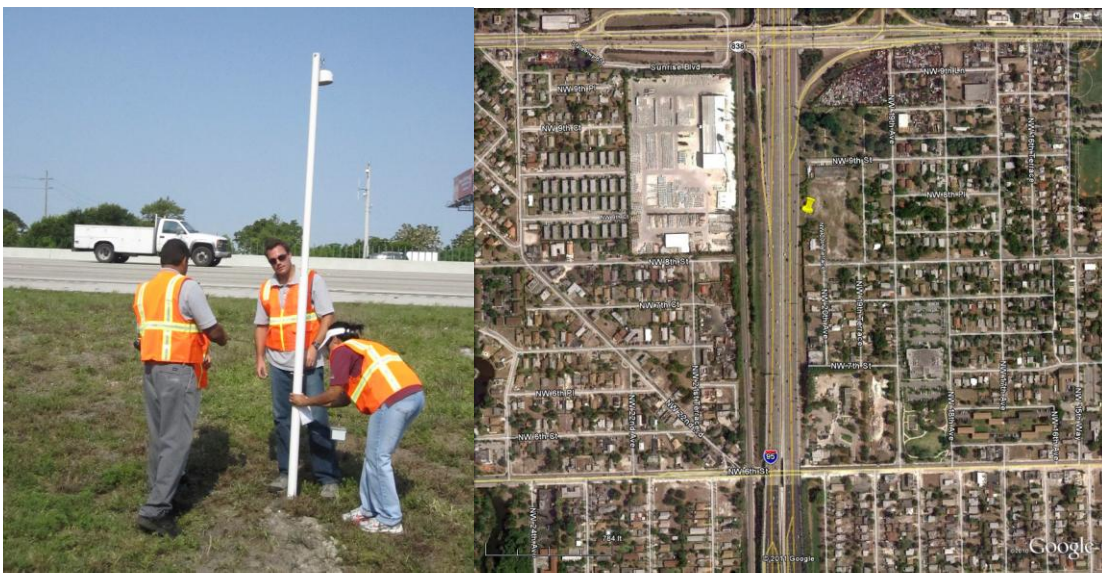


Figure D-4. Miami FLE site photo (left) and Google Earth image (right).

Figure D-5. Miami HOL site photo (left) and Google Earth image (right).

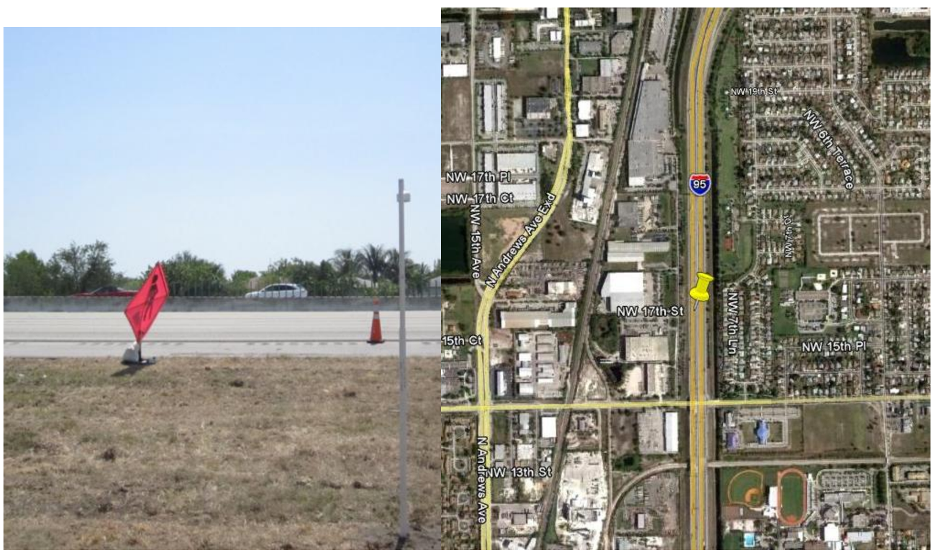


Figure D-6. Miami PMB site photo (left) and Google Earth image (right).

Table D-2. Miami site metadata table.

Page 1 of 2

Site Abbreviation ➔	FLE	FLW	FLW	FLW
Site Name	Fort Lauderdale East	Fort Lauderdale West	Fort Lauderdale West	Fort Lauderdale West
Latitude	26.133472	26.133194	26.132389	26.13322
Longitude	-80.168917	-80.16975	-80.169806	-80.169861
Sampler Distance from Roadway (m)	15.24	15.24	19.8	24.38
Sampler Height (m)	2	2	2	2
Road Segment Name	I-95 & Sunrise Blvd.	I-95 & Sunrise Blvd.	I-95 & Sunrise Blvd.	I-95 & Sunrise Blvd.
AADT	306,000	306,000	306,000	306,000
Heavy Duty (HD) Counts	35,129	35,129	35,129	35,129
FE-AADT	622,161	622,161	622,161	622,161
AADT Rank	1	1	1	1
FE-AADT Rank	1	1	1	1
Transect	No	Yes	Yes	Yes
Areawide Location	No	No	No	No
Terrain	Slight hill between sampler and road	Slight hill between sampler and road	Slight hill between sampler and road	Slight hill between sampler and road
Roadway Design	At or slightly above	At or slightly above	At or slightly above	At or slightly above
Roadside Structures	No	No	No	No
Safety Features	None	None	None	None
Surrounding Land Use	Largely residential sampler is located in an open grass lot, between two intersections one north 838 ~0.20 miles and one south ~0.30 miles	Largely residential sampler is located in an open grass lot, between two intersections one north 838 ~0.22 miles and one south ~0.28 miles	Largely residential sampler is located in an open grass lot, between two intersections one north 838 ~0.22 miles and one south ~0.28 miles	Largely residential sampler is located in an open grass lot, between two intersections one north 838 ~0.22 miles and one south ~0.28 miles
Interchanges	Yes north and south	Yes north and south	Yes north and south	Yes north and south

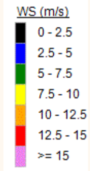
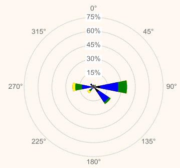
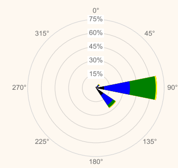
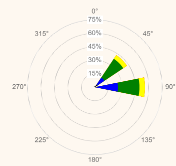
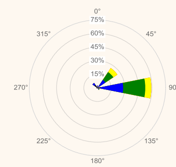
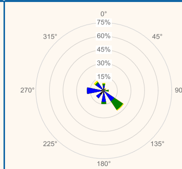
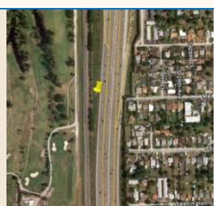
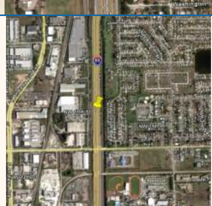
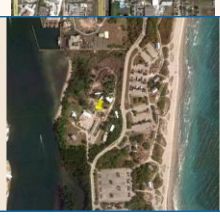
Table D-2. Miami site metadata table.

Page 2 of 2

Site Abbreviation →	PMB	DBH	HOL	JUL
Site Name	Pompano Beach	Dania Beach	Hollywood	John U Lloyd
Latitude	26.248333	26.056639	26.006	26.087194
Longitude	-80.136667	-80.162861	-80.167306	-80.111472
Sampler Distance from Roadway (m)	15.24	15.24	15.24	n/a
Sampler Height (m)	2	2	2	2.3
Road Segment Name	I-95 & Atlantic Blvd.	I-95 & Stirling Road	I-95 & Pembroke Road	John U Lloyd Sate Park Air Monitoring Station #25
AADT	224,000	270,000	267,000	n/a
HD Counts	17,875	15,012	14,845	n/a
FE-AADT	384,875	405,108	400,605	n/a
AADT Rank	2	6	7	n/a
FE-AADT Rank	10	7	8	n/a
Transect	No	No	No	No
Areawide Location	No	No	No	Yes
Terrain	Slight hill between sampler and road	Slight hill between sampler and road	Slight hill between sampler and road	n/a
Roadway Design	Slightly above	Slightly above	At or slightly above	n/a
Roadside Structures	No	No	No	No
Safety Features	None	None	None	n/a
Surrounding Land Use.	Residential to the east and more industrial on the west side of the highway, interchange northeast ~.81 miles	Bass pro shop to the northwest, shopping center, amusement park located to the southeast	Residential to the east of the highway and a golf course west of the highway and sampling	In John U. Lloyd beach state park, to the east is the Atlantic Ocean, background site
Interchanges	Yes north	No	No	No

D.2 Summary Statistics

Table D-3. Weekly average wind roses, temperature, relative humidity, and NO_2 concentrations by site.

Miami		Week 1	Week 2	Week 3	Week 4	Week 5
Wind Rose[a]						
Average Temperature[a] (°C)		27	27	28	28	29
Average RH[a] (%)		63	65	64	69	69
Site	Site Image	NO_2 (ppb)				
DBH		17.1	21.8	14.2	20.9	19.3
FLE		15.4	5.1	3.1	7.2	18.9
FLW[b] 15.24 m		18.4	24.4	14.6	20.3	19.8
FLW[b] 19.8 m		17.4	22.1	14.4	18.4	19.2
FLW[b] 24.38 m		17.2	21.6	14.6	18.7	18.1
HOL		16.0	22.1	15.0	19.4	18.5
PMB		14.8	18.3	11.7	16.4	18.8
JUL		8.6	1.9	2.2	4.6	9.9

[a] Meteorology data were obtained from the North Perry Airport Automated Surface Observing Systems (ASOS) site (KHWO). RH is relative humidity.
[b] Transect sites in order of distance from the road.

Table D-4. Miami: summary statistics of weekly average NO_2 concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
JUL			1.9	9.9	5.4	3.6
DBH	15	2	14.2	21.8	18.7	3.1
FLE	15	2	3.1	18.9	9.9	6.9
HOL	15	2	15.0	22.1	18.2	2.8
PMB	15	2	11.7	18.8	16.0	2.9
FLW	15	2	14.6	24.4	19.5	3.5
FLW	20	2	14.4	22.1	18.3	2.8
FLW	24	2	14.6	21.6	18.0	2.6

Table D-5. Miami: summary statistics of weekly average NO_x concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
JUL			3.6	12.2	7.5	4.0
DBH	15	2	19.5	27.0	23.9	2.8
FLE	15	2	5.3	24.3	13.8	9.0
HOL	15	2	17.7	26.7	22.1	3.3
PMB	15	2	15.6	26.3	21.8	4.2
FLW	15	2	18.3	31.8	25.7	5.1
FLW	20	2	18.4	32.3	24.2	5.1
FLW	24	2	19.7	29.4	23.1	3.7

Table D-6. Miami: summary statistics of weekly average NO_2/NO_x ratios at each site.

Site	Distance m	Height m	Min	Max	Average	STDEV
JUL			0.54	0.81	0.68	0.12
DBH	15	2	0.68	0.86	0.78	0.07
FLE	15	2	0.59	0.88	0.71	0.14
HOL	15	2	0.69	0.92	0.83	0.08
PMB	15	2	0.56	0.85	0.74	0.11
FLW	15	2	0.66	0.87	0.77	0.08
FLW	20	2	0.69	0.84	0.77	0.07
FLW	24	2	0.74	0.83	0.78	0.05

Table D-7. Miami: between-site and between-week variability, including the average and standard deviation of all weeks by site and all sites by week.

Site	DBH	FLE	FLW	HOL	PMB	Average NO_2 (ppb)	STDEV NO_2 (ppb)
Distance	15	15	15	15	15		
Height	2	2	2	2	2		
Week 1 NO_2 (ppb)	17.1	15.4	18.4	16.0	14.8	16.4	1.4
Week 2 NO_2 (ppb)	21.8	5.1	24.4	22.1	18.3	18.3	7.7
Week 3 NO_2 (ppb)	14.2	3.1	14.6	15.0	11.7	11.7	5.0
Week 4 NO_2 (ppb)	20.9	7.2	20.3	19.4	16.4	16.8	5.7
Week 5 NO_2 (ppb)	19.3	18.9	19.8	18.5	18.8	19.1	0.5
Average NO_2 (ppb)	18.7	9.9	19.5	18.2	16.0		
STDEV NO_2 (ppb)	3.1	6.9	3.5	2.8	2.9		

D.3 Concentrations Compared to Distance to Roadway, Sampling Height, and Traffic

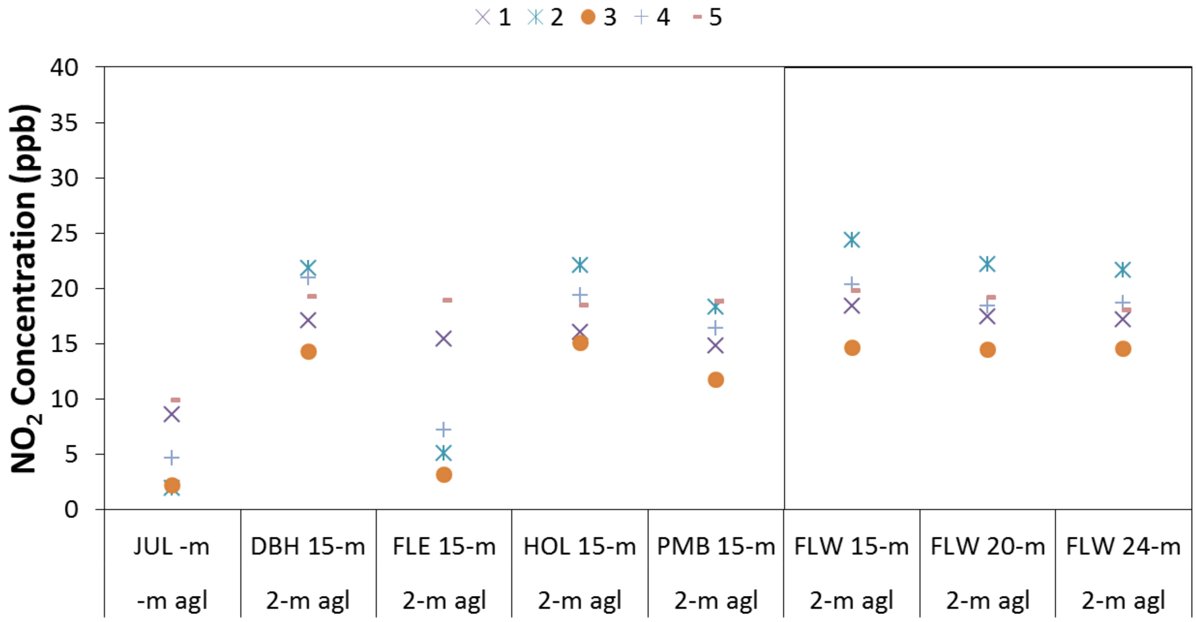


Figure D-7. Miami: weekly average concentrations of NO_2 (ppb) at all monitoring sites including the transect location (right hand side of the figure). Only 2-m height data are shown. The x-axis labels are the site code, distance to the roadway (m), and sampler height above ground level (m).

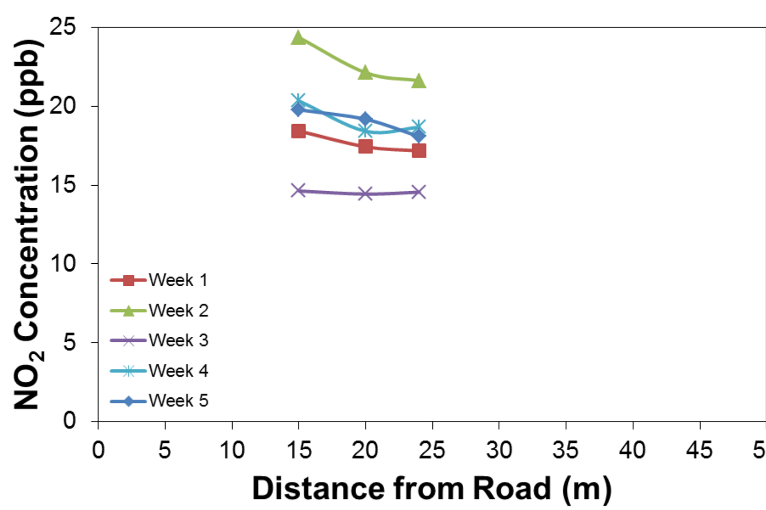


Figure D-8. Miami transect data NO_2 concentrations.

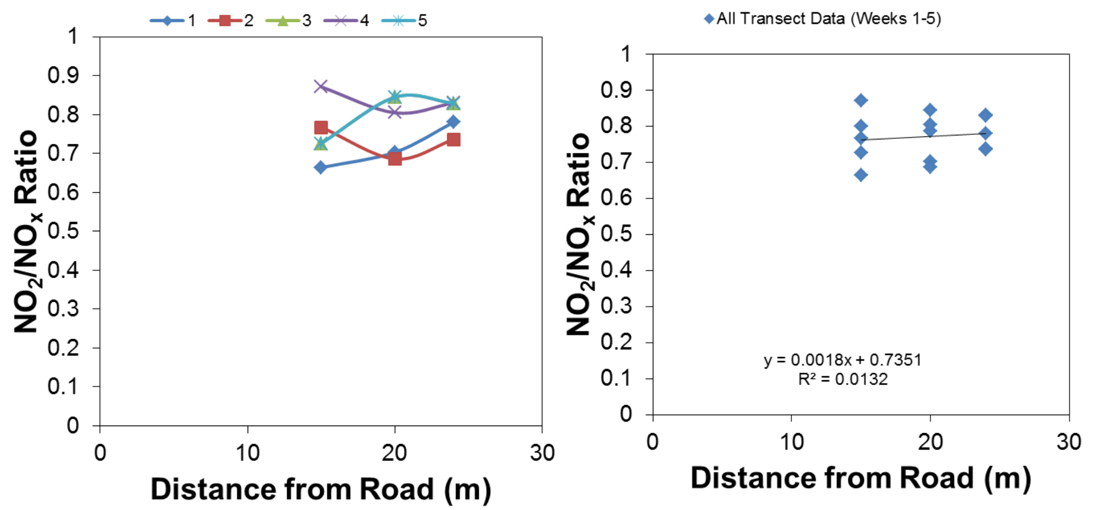


Figure D-9. Miami transect NO_2/NO_x ratio plots by week (left) and for all weeks (right).

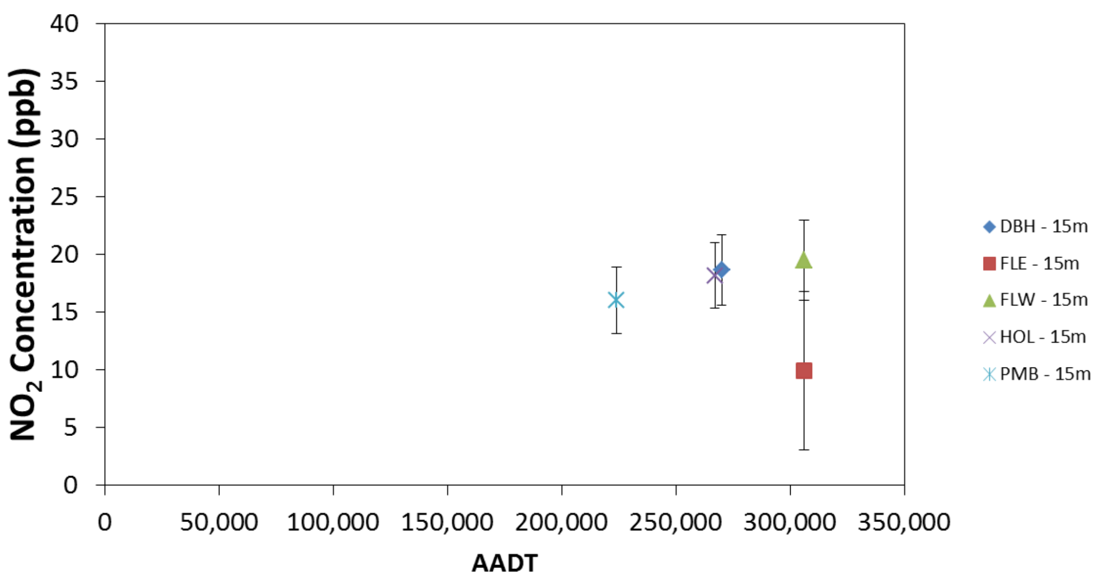


Figure D-10. Miami: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to AADT. Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

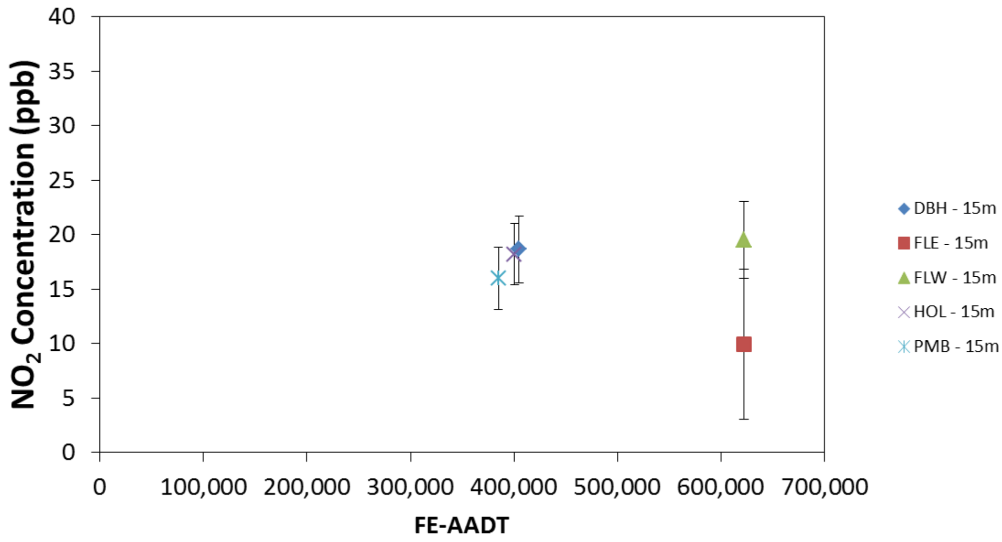


Figure D-11. Miami: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to FE-AADT. Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

D.4 Miami Quality Assurance and Data Completeness

Table D-8. Summary of data completeness statistics for Miami samples, and field blanks (FB) and trip blanks (TB) for quality control (QC).

Statistic	Value
Target Sample Number[a]	80
% Data Capture[b]	99%
% Data Valid[c]	98.70%
% Data Suspect[c]	0.00%
% Data Invalid[c]	1.30%
Target Quality Control (QC) Number (at 10%)	8
Number of Field Blanks (FB)	10
Number of Trip Blanks (TB)	10
% Actual Quality Control[d]	25%

[a] Target Sample Number is the number of passive sampling device (PSD) mounts, with two sample duplicates per mount, multiplied by the number of sample weeks.

[b] Percent Data Capture is the percentage of collected data values divided by the total number of target sample data values.

[c] Percent Data Valid, Suspect, or Invalid is the percentage of data values that are either valid, suspect, or invalid divided by the number of captured data values.

[d] The total number of QC samples (FB plus TB) divided by the number of captured sample data values, expressed as a percentage. All QC samples were valid.

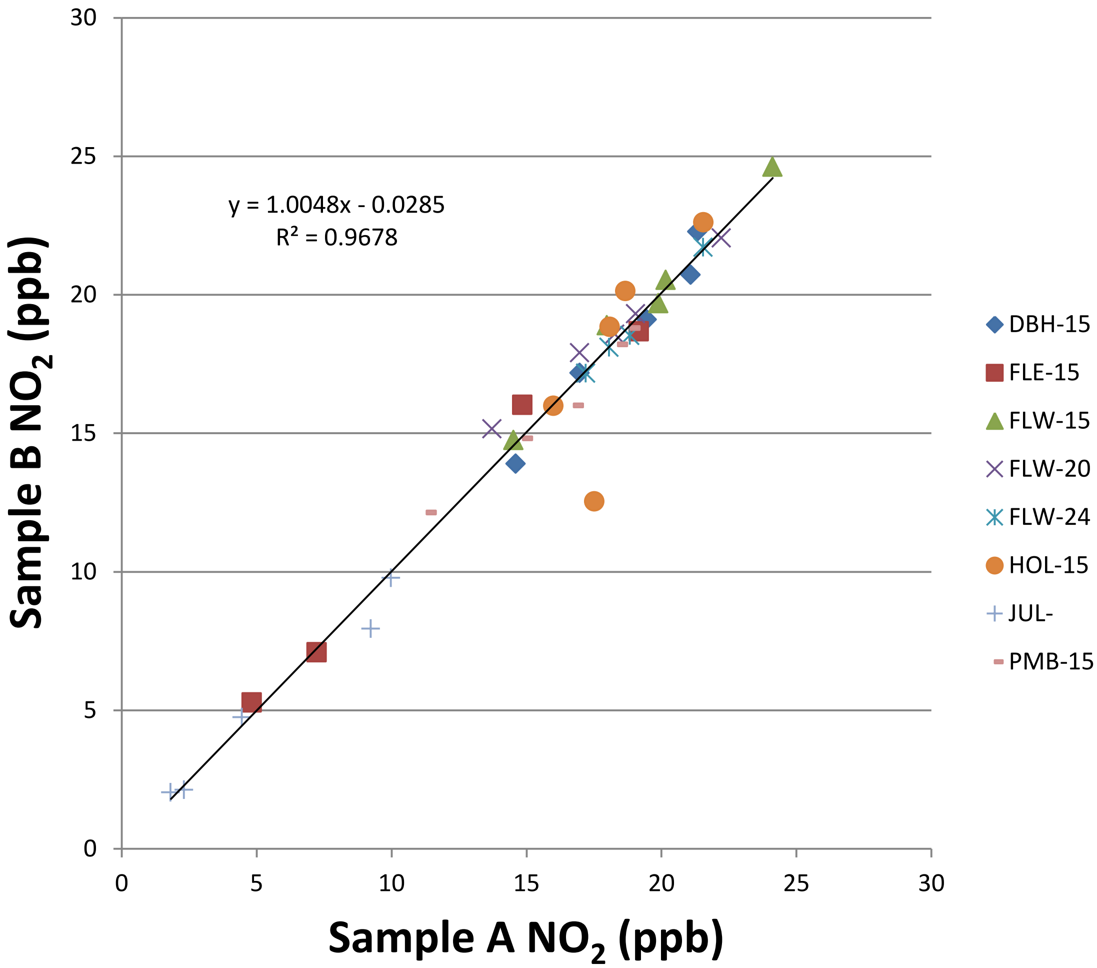


Figure D-12. Scatter plot and normal least square regression for duplicate NO_2 samples in Miami. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_2 concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

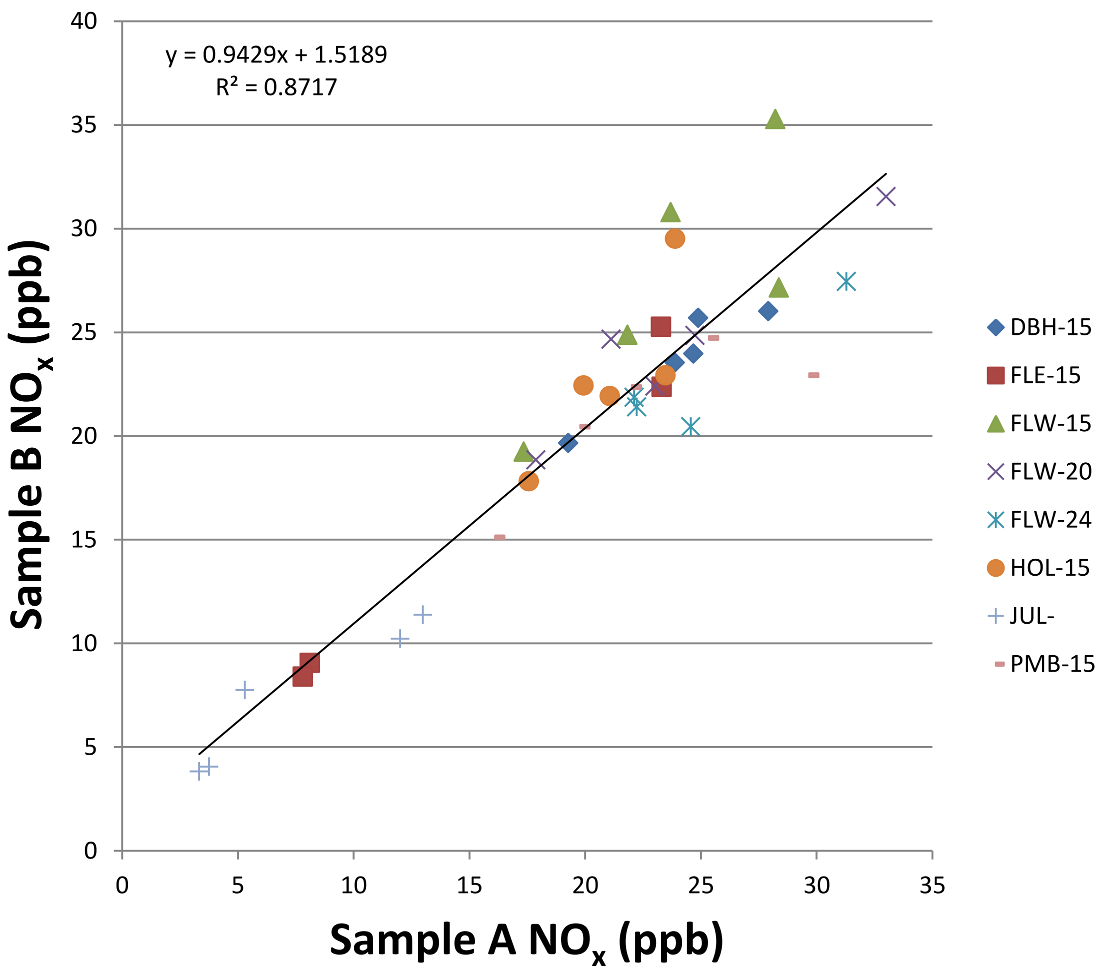


Figure D-13. Scatter plot and normal least square regression for duplicate NO_x samples in Miami. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_x concentrations of the paired samples were not significantly different at $p = 0.01$. Legends denote site identifiers and distance from roadway in meters.

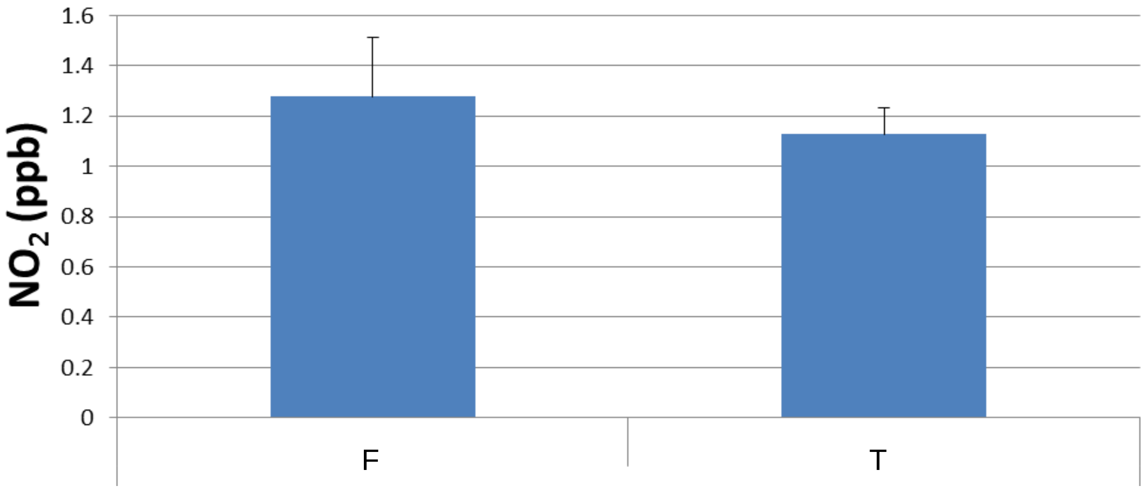


Figure D-14. Miami field (F) and trip (T) blank averages and standard errors, where standard error is the standard deviation of the blank mean divided by the square root of the blank count (*n* = 10 for both blank types). Although one high FB (3.1 ppb) contributed to unequal variances between the blank types, and to a higher FB mean, the Miami field and trip blanks were not statistically significantly different.

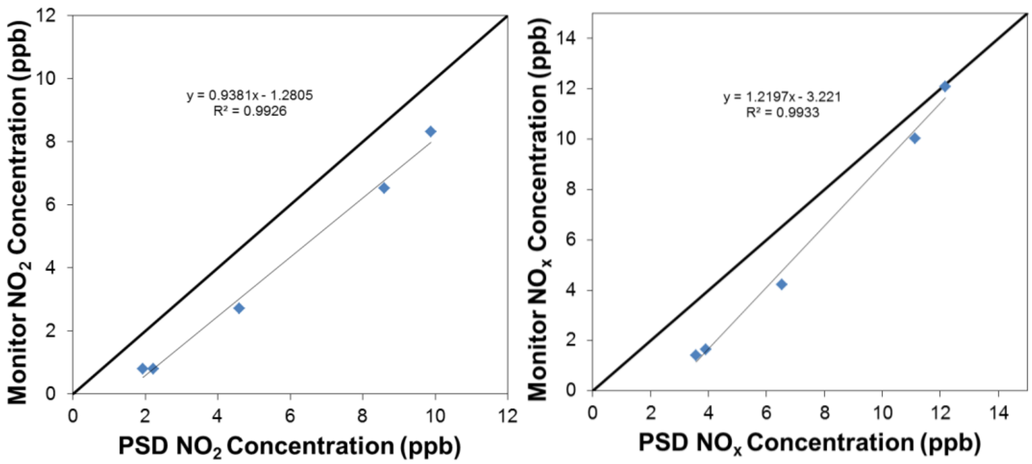


Figure D-15. Assessment of accuracy of passive sampling devices (PSDs) deployed in Miami by comparison with weekly averaged NO_2 (left panel) and NO_x (right panel) concentrations from a co-located continuous monitor.

D.5 Reference

U.S. Environmental Protection Agency (2011) Near-road NO_2 monitoring: technical assistance document. Draft document, August 11. Available on the Internet at http://www.epa.gov/ttn/amtic/files/nearroad/20110811tad.pdf.

Appendix E. Tampa

Site Information

Table E-1. Tampa sampling locations, traffic counts, rankings, distance from road, and sampling height.

Site Code	Road Segment	AADT	AADT Rank	FE-AADT[b]	Heavy Duty	FE-AADT Rank	Distance from Road (m)	Height (m)
EPC01	I-4 Sign Post 105070	110,000	25	247,511	15,279	7	13	1.8
EPC02	I-4 Camera Pole No. IOC017	136,500	15	255,048	13,172	5	12	1.8
EPC03	I-275 Sign Pole No. 105598	192,000	1	268,203	8,467	2	7	1.8
EPC03	I-275 Sign Pole No. 105598	192,000	1	268,203	8,467	2	7	3.81
EPC04	I-4 Weigh Station Light Pole No. 8-4-26	117,932	22	231,287	12,585	15	15	1.8
EPC04	I-4 Weigh Station Light Pole No. 8-4-26	117,932	22	231,287	12,585	15	15	3.81
EPC05	I-4 Weigh Station Light Pole No. 8-4-27	117,932	22	231,287	12,585	15	46	1.8
EPC05	I-4 Weigh Station Light Pole No. 8-4-27	117,932	22	231,287	12,585	15	46	3.81
EPC06	I-4 Weigh Station Light Pole No. 8-4-31	117,932	22	231,287	12,585	15	18	1.8
EPC06	I-4 Weigh Station Light Pole No. 8-4-31	117,932	22	231,287	12,585	15	18	3.81
EPC07[a]	Gandy Site Crank-up Wind Tower	30,000	-	42,960	1,440	-	130	1.8

[a] Urban background site.
[b] Fleet-equivalent annual average daily traffic (FE-AADT) is calculated using the formula in the EPA's technical assistance document (U.S. Environmental Protection Agency, 2011).

Figure E-1. Tampa EPC01 site photo (left) and Google Earth image (right).

Figure E-2. Tampa EPC04, EPC05, and EPC06 site photo (left) and Google Earth image (right). This was the transect location. From left to right, the lanes are the weigh station exit, the bypass lane, and the I-4 travel lane.

Figure E-3. Tampa EPC07 site photo (left) and Google Earth image (right). This is the area-wide/background monitoring location.

Figure E-4. Tampa EPC02 site photo (left) and Google Earth image (right).

Figure E-5. Tampa EPC03 site photos (left and middle) and Google Earth image (right). Site is an elevated road (4.9 m agl) with a safety barrier (2.7 m). The top of the wall is 7.6 m above grade level. The PSD mounts are 7 m from the travel lane in the horizontal and 3.8 m and 5.8 m below the wall.

Table E-2. Tampa site metadata table.

Page 1 of 2

Site Abbreviation →	EPC01	EPC02	EPC03	EPC04
Site Name				
Latitude	28.02674	28.00236	27.955466	28.01555
Longitude	-82.167716	-82.322551	-82.470676	-82.268219
Sampler Distance from Roadway (m)	13	12	7	15
Sampler Height (m)	1.8	1.8, 3.81	1.8, 3.81	1.8, 3.81
Road Segment Name	I-4 East of Tampa	I-4 East of Tampa	I-275 in City of Tampa	I-4 East of Tampa
AADT	110,000	136,500	192,000	117,932
Heavy Duty (HD) Counts	15,279	13,172	8,467	12,585
FE-AADT	247,511	255,048	268,203	231,287
AADT Rank	25	15	1	22
FE-AADT Rank	7	5	2	15
Transect	No	No	No	Yes
Areawide Location	No	No	No	No
Terrain	Flat grass land between the exit ramp and sampler and highway and sampler	Flat grass land between the exit ramp and sampler and highway and sampler	Samplers are located 3.0 and 5.5 meters below the elevated roadway	Samplers are located on light poles; there is a slight hill from the road and to and from the on-ramp
Roadway Design	At grade	At grade	Above grade	At or slightly above
Roadside Structures	None	No	Soundwall	Concrete jersey barriers
Safety Features	None	None	Soundwall	Jersey barriers
Surrounding Land Use		Samplers are located east of major interchange between the roadway and an exit ramp	Residential; elevated roadway	Residential and forested land; samplers located at a weigh station with heavy truck traffic
Interchanges	No	Yes	No	No

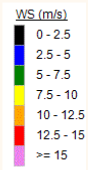
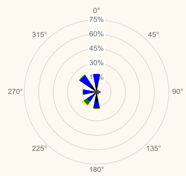
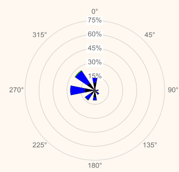
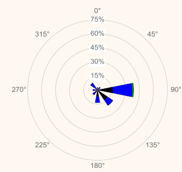
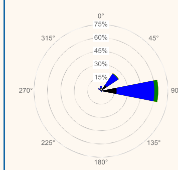
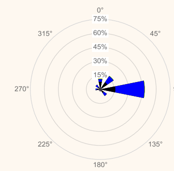
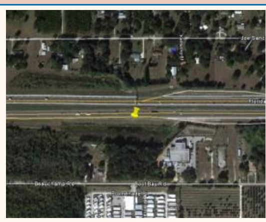
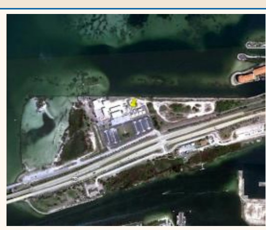
Table E-2. Tampa site metadata table.

Page 2 of 2

Site Abbreviation ➔	EPC05	EPC06	EPC07
Site Name			Marine Reserve Center Gandy Blvd.
Latitude	28.015252	28.015689	27.89325
Longitude	-82.268228	-82.267782	-82.538243
Sampler Distance from Roadway (m)	46	18	130
Sampler Height (m)	1.8, 3.81	1.8, 3.81	1.8
Road Segment Name	I-4 East of Tampa	I-4 East of Tampa	Gandy Blvd
AADT	117,932	117,932	30,000
Heavy Duty (HD) Counts	12,595	12,595	1,440
FE-AADT	231,287	231,287	42,960
AADT Rank	22	22	
FE-AADT Rank	15	15	
Transect	Yes	Yes	No
Areawide Location	No	No	Yes
Terrain	Samplers are located on light poles, there is a slight hill from the road and to and from the on ramp	Samplers are located on light poles, there is a slight hill from the road and to and from the on ramp	Flat
Roadway Design	At grade	At grade	At grade
Roadside Structures	No	No	None
Safety Features	None	None	None
Surrounding Land Use	Residential and forested land, samplers located at a weigh station with heavy truck traffic	Residential and forested land, samplers located at a weigh station with heavy truck traffic	Urban coast area by Tampa Bay
Interchanges	No	No	No

Summary Statistics

Table E-3. Tampa: summary of weekly average wind roses, temperature, relative humidity, and NO_2 concentrations by site.

Tampa		Week 1	Week 2	Week 3	Week 4	Week 5
Wind Rose[a]						
Average Temperature[a] (°C)		25	23	27	26	27
Average RH[a] (%)		71	67	64	68	64
Site	Site Image	NO_2 (ppb)				
EPC01		17.1	18.5	12.3	15.3	14.7
EPC02		19.9	23.2	14.4	12.5	17.9
EPC03		12.5	17.9	10.1	12.9	14.0
EPC04[b] 15 m		16.0	17.4	10.3	13.8	15.1
EPC06[b] 18 m		18.1	21.1	10.7	13.6	16.1
EPC05[b] 46 m		15.3	14.6	8.5	11.5	12.2
EPC07		4.9	5.9	3.8	5.0	4.6

[a] Wind data were obtained from the Tampa Executive (formerly Vandenberg) Airport Automated Surface Observing Systems (ASOS) site (KVDF). RH is relative humidity.
[b] Transect site in order by distance from the road.

Table E-4. Tampa: summary statistics of weekly average NO_2 concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
EPC07	130	1.8	3.8	5.9	4.8	0.8
EPC01	13	1.8	12.3	18.5	15.6	2.4
EPC02	12	1.8	12.5	23.2	17.9	4.3
EPC03	7	1.8	10.1	17.9	13.5	2.9
EPC04	15	1.8	11.5	19.0	15.6	2.8
EPC06	18	1.8	10.7	21.1	15.9	4.0
EPC05	46	1.8	8.5	15.3	12.4	2.7
EPC03	7	3.8	10.6	18.7	14.2	2.9
EPC04	15	3.8	10.3	17.4	14.5	2.7
EPC05	46	3.8	8.2	15.2	12.0	2.8
EPC06	18	3.8	10.0	20.8	15.6	4.3

Table E-5. Tampa: summary statistics of weekly average NO_x concentrations (ppb) at each site.

Site	Distance (m)	Height (m)	Min (ppb)	Max (ppb)	Average (ppb)	STDEV (ppb)
EPC07	130	1.8	5.4	8.8	7.5	1.2
EPC01	13	1.8	15.8	27.3	21.6	5.2
EPC02	12	1.8	19.3	32.7	24.7	6.7
EPC03	7	1.8	12.5	22.4	16.4	3.6
EPC04	15	1.8	17.9	29.8	23.0	5.7
EPC06	18	1.8	14.6	37.2	23.8	9.4
EPC05	46	1.8	12.5	24.1	17.5	4.8
EPC03	7	3.8	13.4	22.9	17.8	3.8
EPC04	15	3.8	14.4	26.5	20.5	5.3
EPC05	46	3.8	12.0	23.0	17.2	4.8
EPC06	18	3.8	15.5	29.5	22.0	6.6

Table E-6. Tampa: summary statistics of weekly average NO_2/NO_x ratios at each site.

Site	Distance (m)	Height (m)	Min	Max	Average	STDEV
EPC07	130	1.8	0.60	0.69	0.65	0.03
EPC01	13	1.8	0.64	0.83	0.73	0.07
EPC02	12	1.8	0.64	0.85	0.72	0.09
EPC03	7	1.8	0.78	0.92	0.83	0.06
EPC04	15	1.8	0.60	0.81	0.69	0.09
EPC06	18	1.8	0.49	0.79	0.70	0.13
EPC05	46	1.8	0.64	0.85	0.72	0.08
EPC03	7	3.8	0.70	0.93	0.80	0.08
EPC04	15	3.8	0.63	0.85	0.72	0.09
EPC05	46	4	0.65	0.84	0.71	0.08
EPC06	18	3.8	0.64	0.81	0.71	0.07

Table E-7. Tampa: between-site and between-week variability, including the average and standard deviation of all weeks by site and all sites by week.

Site	EPC01	EPC02	EPC03	EPC04	Average NO_2 (ppb)	STDEV NO_2 (ppb)
Distance	13	12	7	15		
Height	1.8	1.8	1.8	1.8		
Week 1 NO_2 (ppb)	17.1	19.9	14.1	19.0	17.5	2.6
Week 2 NO_2 (ppb)	18.5	23.2	18.7	17.2	19.4	2.6
Week 3 NO_2 (ppb)	12.3	14.4	10.6	11.5	12.2	1.6
Week 4 NO_2 (ppb)	15.3	12.5	13.5	15.6	14.2	1.5
Week 5 NO_2 (ppb)	14.7	17.9	14.0	14.8	15.3	1.7
Average NO_2 (ppb)	15.6	17.6	14.2	15.6		
STDEV NO_2 (ppb)	2.4	4.3	2.9	2.8		

Concentrations Compared to Distance to Roadway, Sampling Height, and Traffic

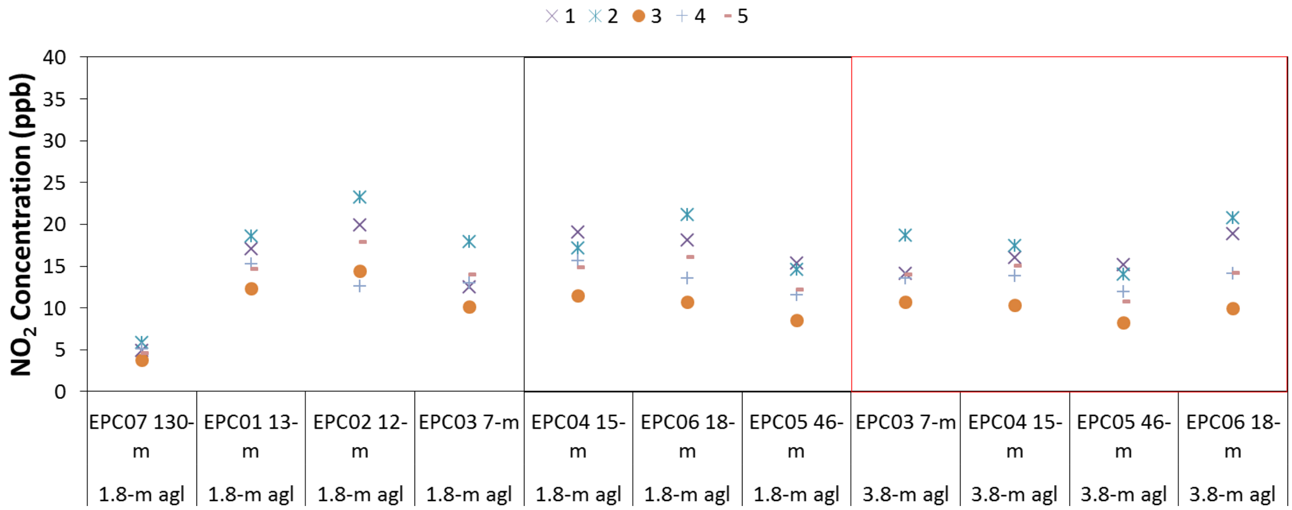


Figure E-6. Tampa: weekly average concentrations of NO_2 (ppb) at all monitoring sites including the transect location (middle) and sites with height gradients (right). The x-axis labels are the site code, distance to the roadway (m), and sampler height above ground level (m).

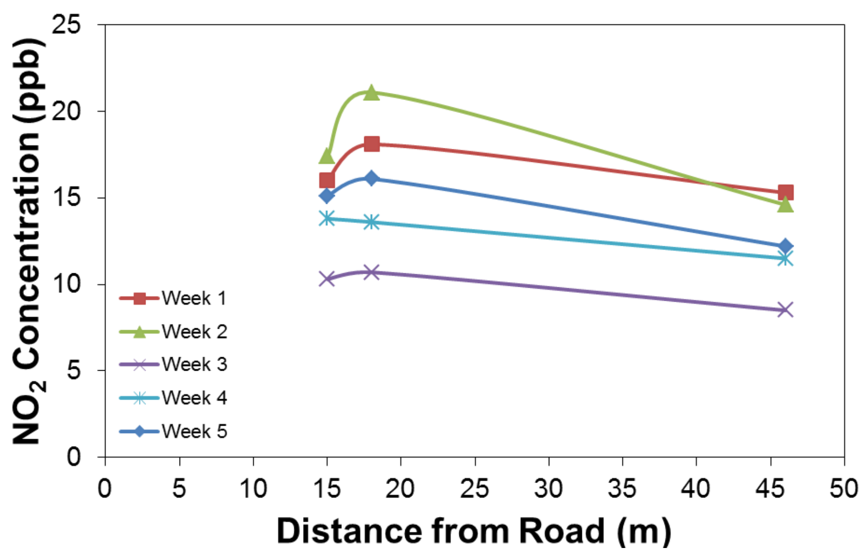


Figure E-7. Tampa transect data NO_2 concentrations.

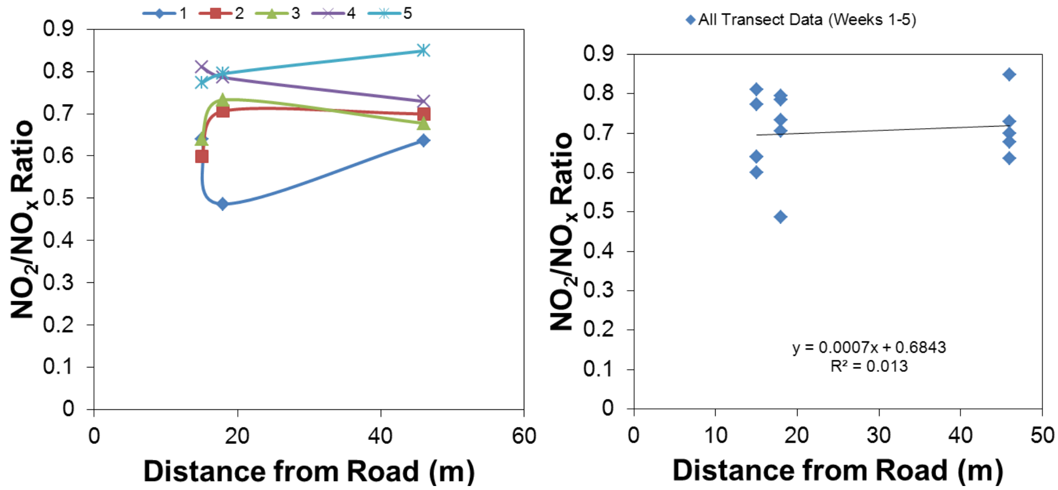


Figure E-8. Tampa transect NO_2/NO_x ratio plots by week (left) and for all weeks (right).

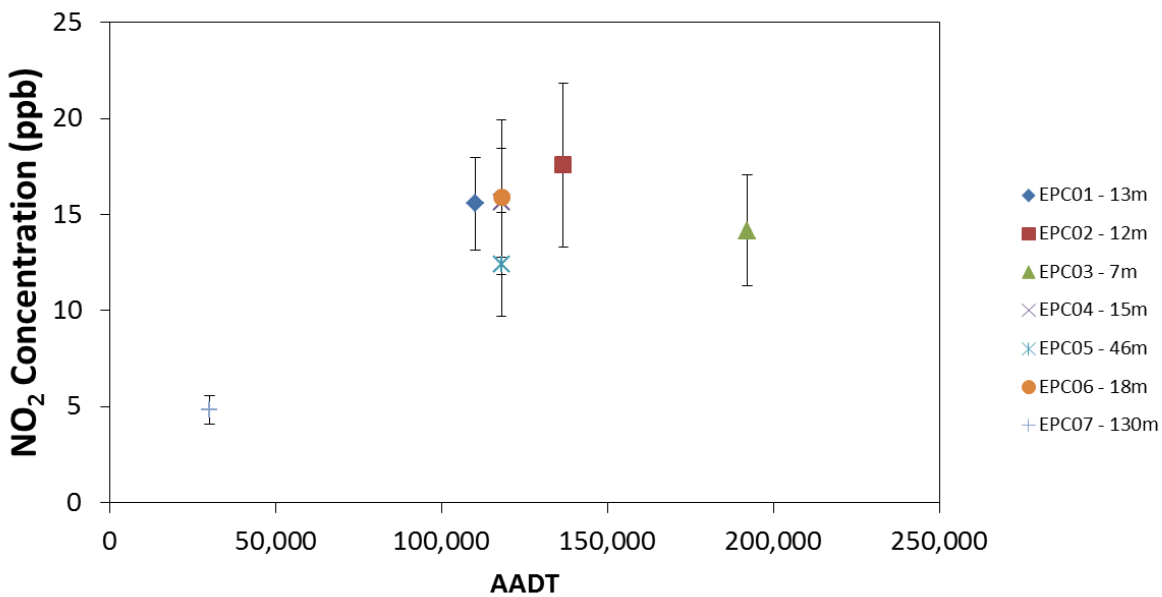


Figure E-9. Tampa: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to AADT. Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

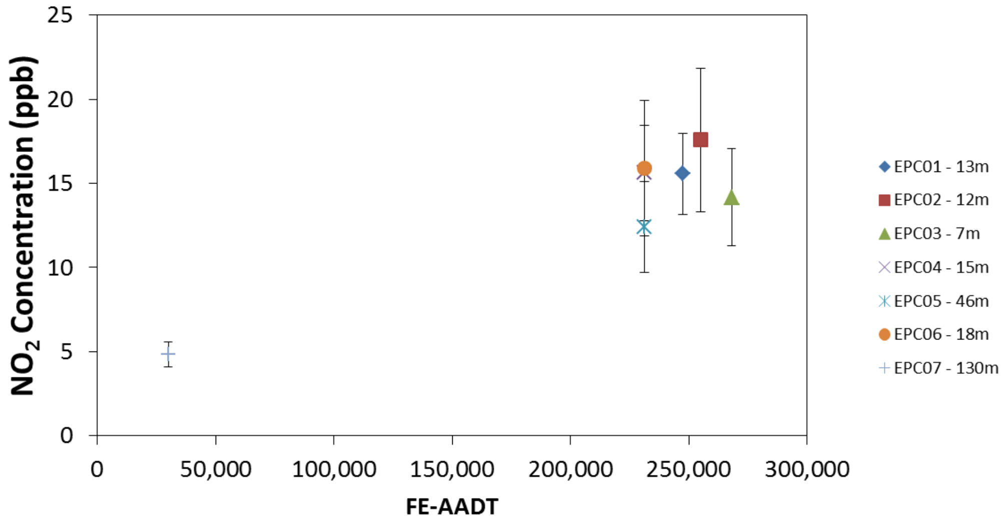


Figure E-10. Tampa: average NO_2 concentrations (ppb) by site across all weeks of sampling compared to FE-AADT. Bars indicate standard deviation of weekly averages. Only 2 m height data are shown.

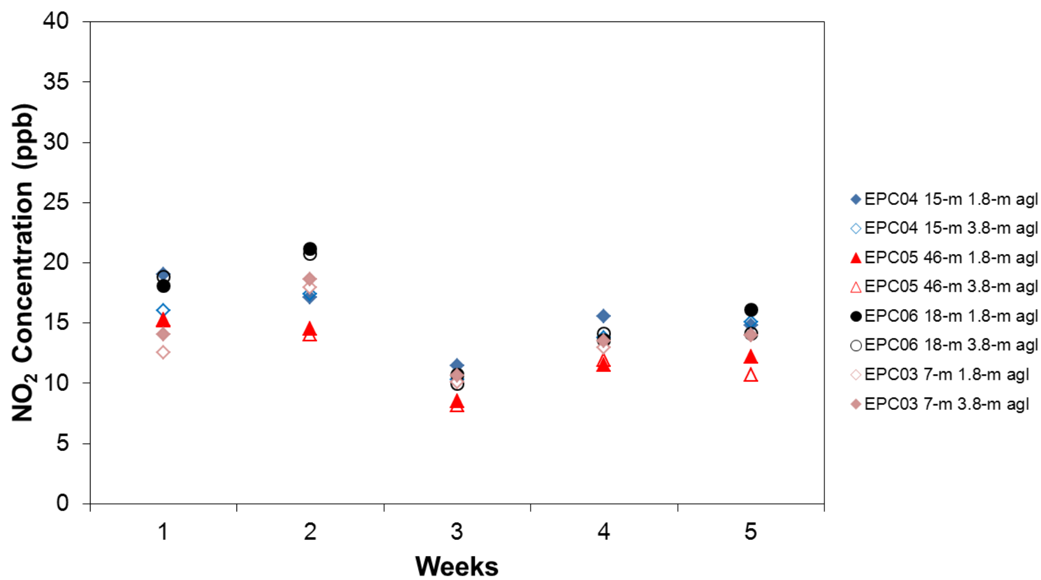


Figure E-11. Tampa: weekly average concentrations of NO_2 (ppb) at monitoring sites with two heights. The filled-in symbols represent the sites that were closest to the road.

Tampa Quality Assurance and Data Completeness

Table E-8. Summary of data completeness statistics for Tampa samples. Tampa did not submit field blanks (FB) and trip blanks (TB) for quality control (QC).

Statistic	Value
Target Sample Number[a]	110
% Data Capture[b]	100%
% Data Valid[c]	94.50%
% Data Suspect[c]	4.50%
% Data Invalid[c]	0.90%
Target Quality Control (QC) Number (at 10%)	11
Number of Field Blanks (FB)	0
Number of Trip Blanks (TB)	0
% Actual Quality Control[d]	0%

[a] Target Sample Number is the number of passive sampling device (PSD) mounts, with two sample duplicates per mount, multiplied by the number of sample weeks.
[b] Percent Data Capture is the percentage of collected data values divided by the total number of target sample data values.
[c] Percent Data Valid, Suspect, or Invalid is the percentage of data values that are either valid, suspect, or invalid divided by the number of captured data values.
[d] The total number of QC samples (FB plus TB) divided by the number of captured sample data values, expressed as a percentage. All QC samples were valid.

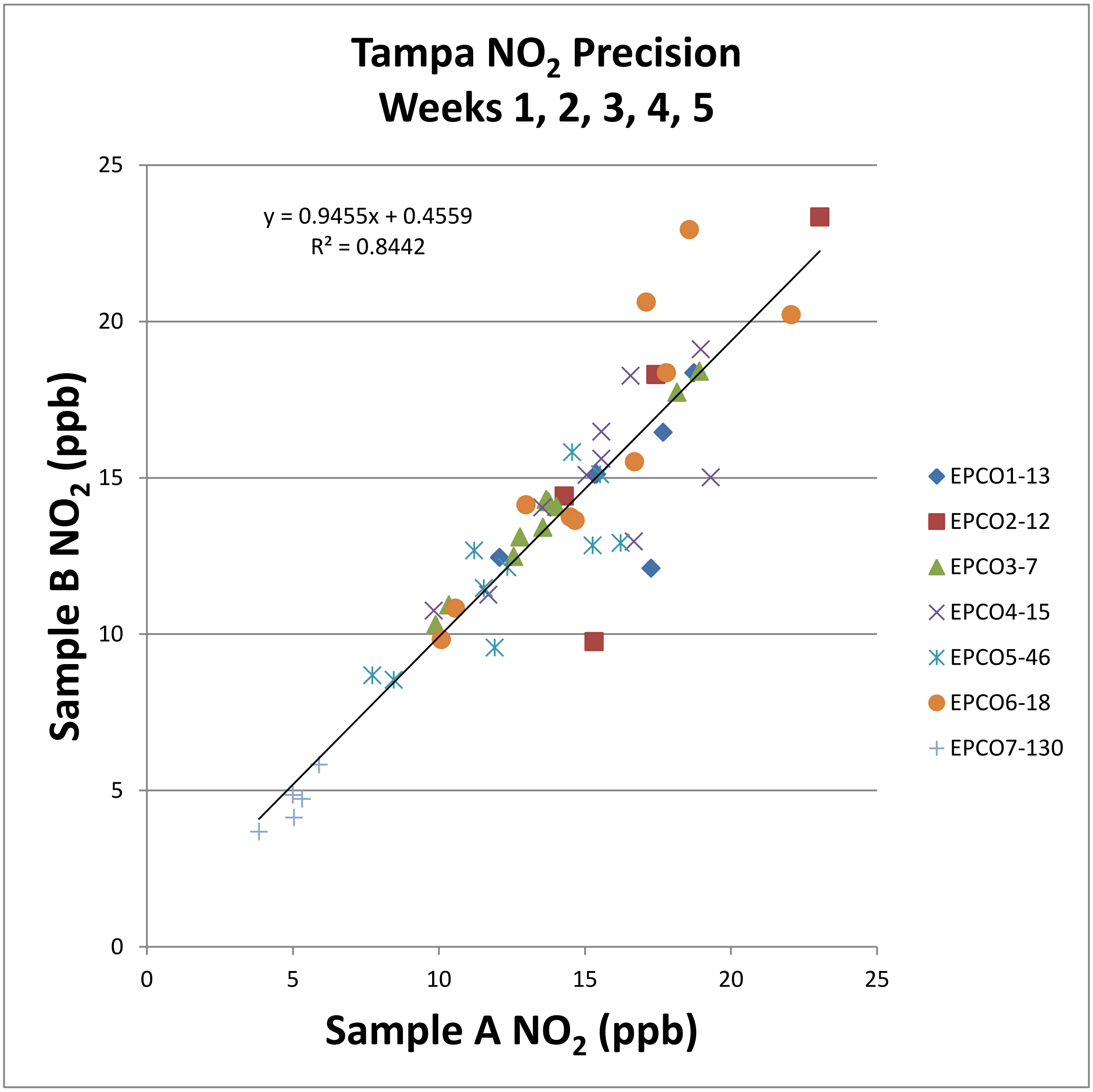


Figure E-12. Scatter plot and normal least square regression for duplicate NO_2 samples in Tampa. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_2 concentrations of the paired samples were not significantly different at p = 0.01. Legends denote site identifiers and distance from roadway in meters.

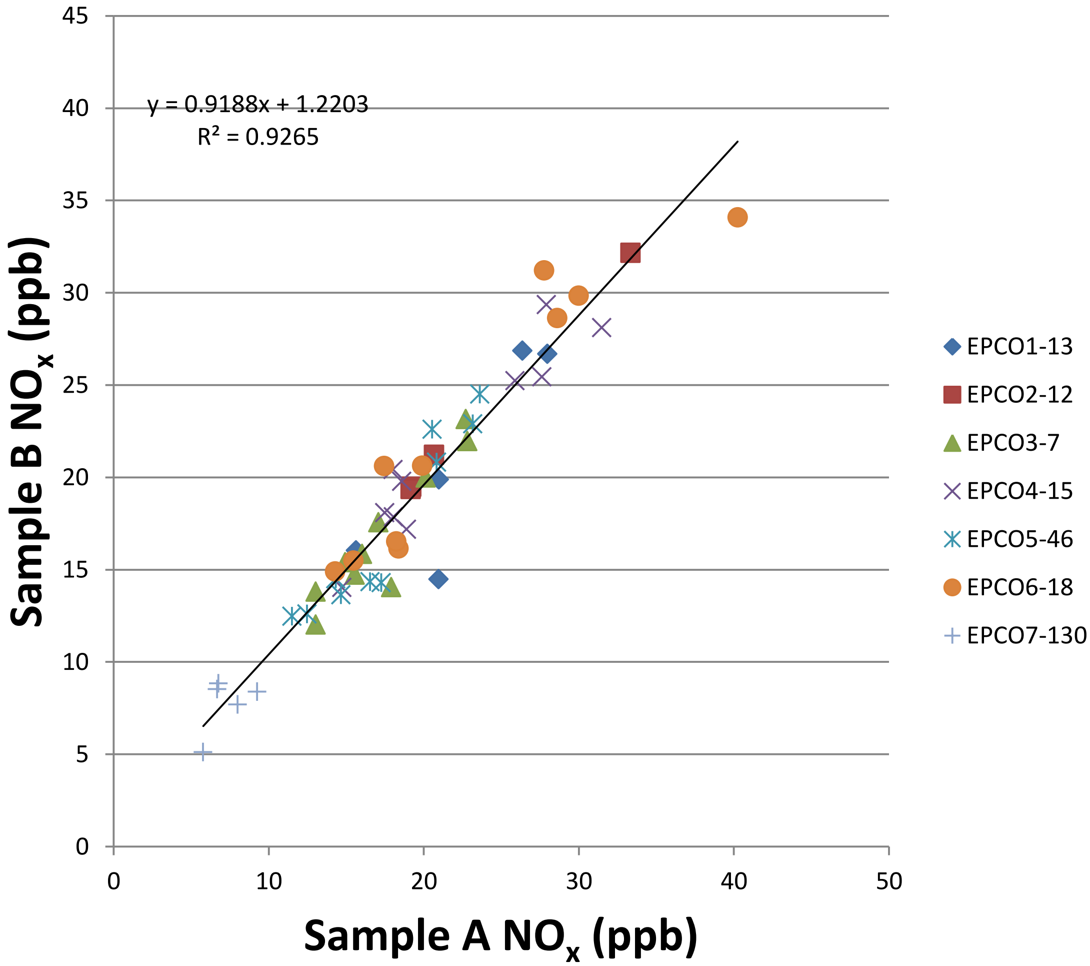


Figure E-13. Scatter plot and normal least square regression for duplicate NO_x samples in Tampa. A T-test for the mean of paired differences and a test of significance for paired samples indicate that the NO_x concentrations of the paired samples were not significantly different at p = 0.01. Legends denote site identifiers and distance from roadway in meters.

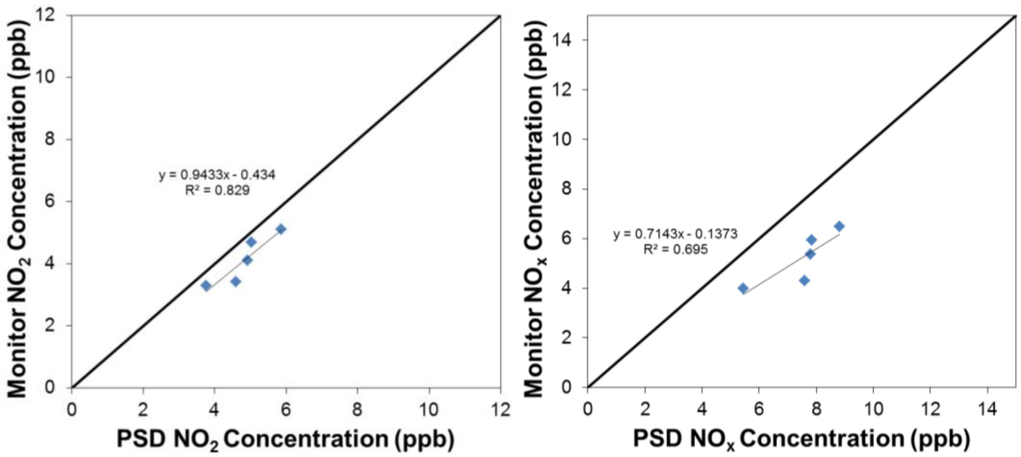


Figure E-14. Assessment of accuracy of passive sampling devices (PSDs) deployed in Tampa by comparison with weekly averaged NO_2 (left panel) and NO_x (right panel) concentrations from a collocated continuous monitor.

Reference

U.S. Environmental Protection Agency (2011) Near-road NO_2 monitoring: technical assistance document. Draft document, August 11. Available on the Internet at http://www.epa.gov/ttn/amtic/files/nearroad/20110811tad.pdf.