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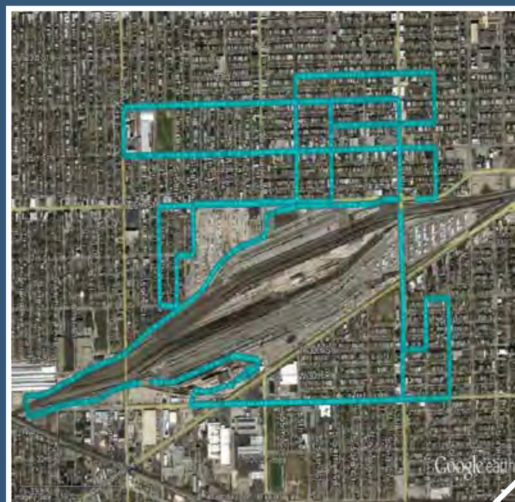
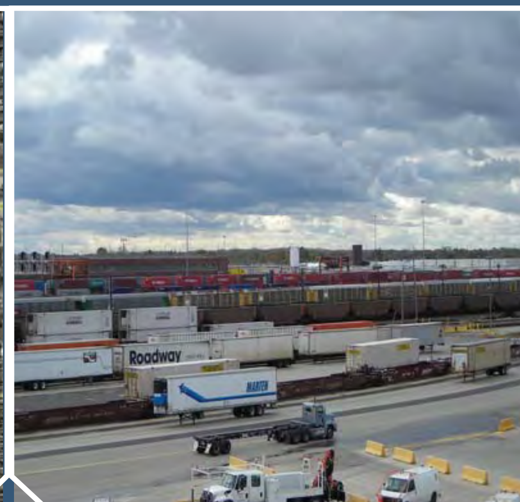
Cicero Rail Yard Study (CIRYS) Final Report





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Cicero Rail Yard Study (CIRYS)

Final Report

by

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List of Acronyms

Acronym	Description
APS	Aerodynamic Particle Sizer
BAM	Beta-Attenuation Mass monitor
BC	Black carbon
BGD	Background
CIRYS	Cicero Rail Yard Study
CO	Carbon monoxide
DQO	Data Quality Objective
EC	Elemental carbon
EEPS	Engine Exhaust Particle Sizer
FEM	Federal Equivalent Method
FRM	Federal Reference Method
GPS	Global Positioning System
HEPA	High-Efficiency Particulate Air (type of filter)
NAAQS	National Ambient Air Quality Standards
NAMS	National Air Monitoring Sites
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NDIR	Non-dispersive Infrared (type of detector)
NO	Nitrogen oxide
NO_2	Nitrogen dioxide
NT	Neighborhood Transect
NTA	Non-parametric Trajectory Analysis
OC	Organic carbon
ONA	Optimized Noise-reduction Algorithm
ORD	Office of Research and Development
$PM_{2.5}$	Particulate matter smaller than 2.5 microns
PM_{10}	Particulate matter smaller than 10 microns
QA	Quality assurance
QAPP	Quality assurance project plan
RARE	Regional Applied Research Effort
SLAMS	State and Local Air Monitoring Stations
UFP	Ultrafine particle
USEPA	United States Environmental Protection Agency

Executive Summary

The Cicero Rail Yard Study (CIRYS) was initiated as a second phase of an EPA Region 5 Regional Applied Research Effort (RARE), a program which facilitates the collaboration between a particular Region and EPA's Office of Research and Development (ORD) in an area of research where the Region needs scientific information to support implementation of a specific program or strategy. EPA Region 5 identified local scale air pollution impacts due to rail yard emissions as a poorly understood issue and the region's concern was solidified by a regulatory monitoring station measuring elevated readings for $PM_{2.5}$ at a location near a rail yard in Dearborn, MI. To better understand the local-scale air pollution impact of rail yard activities, the RARE effort covered two independent research studies – Phase I, the emissions inventory, modeling, and field measurements conducted at a rail yard in Dearborn, Michigan, and Phase II, a two-pronged field measurement campaign conducted near a rail yard in Cicero, Illinois. This report covers this Phase II effort in Cicero, IL.

Field measurements of local scale air pollution are an evolving field of research and require advances in air quality measurement. Previous near-road studies documented that air pollution concentrations within close proximity to a highway can vary significantly in both time and space, with local meteorology and the local terrain significantly affecting near-field concentrations of traffic-related pollutants (e.g., Baldauf et al. 2008a, Karner et al. 2010). The rail yard environment was considered likely to be even more complex in nature than a highway, given emissions from multiple sources that vary in time and location within the yard. Therefore, ideal field measurements would cover a wide spatial area as well as a long time horizon. To meet this goal, a combined strategy of short-term mobile and longer-term stationary monitoring was identified. A variety of rail yards in the Chicago area were surveyed to determine which rail yard environment would be compatible with this field measurement strategy as well as meeting several other study goals, including avoidance of potential confounding sources as well as location in an urban environment. The Cicero rail yard was selected for study, based upon these objectives.

The Cicero rail yard is an intermodal rail yard, with emissions including both truck and locomotive operations. Measuring rail yard activity by freight container lifts, the Cicero rail yard ranked 7th in the Chicago area in 2011 (out of 19 total) with 370,000 lifts. In addition to freight trains passing through the rail yard, a commuter train line also passes along the northern border of the Cicero rail yard. The surrounding environment is primarily residential with two-story single-family homes densely located in a grid fashion surrounding the yard. With prevailing winds from the southwest, a stationary monitoring site was located to the northeast of the rail yard at approximately 50 meters from the train tracks running along the northern border of the yard and provided continuous 5-minute measurements of sulfur dioxide, oxides of nitrogen, carbon monoxide, black carbon, fine particulate matter, and meteorology over nearly a year timeframe. The mobile monitoring driving route was designed to measure air pollutant concentrations along low-traffic residential roads north of the rail yard, as well as capturing urban background air pollution levels from areas upwind of the yard. Mobile monitoring was conducted over a one month period and utilized advanced real-time measurement instrumentation for carbon monoxide, black carbon, particle size distribution (ultrafine to coarse range), and location.

Key findings from the CIRYS study include the following:

- Stationary monitoring results
    - Analysis of an approximate 6 month period of continuous data collection (November 2010 to May 2011) determined elevated sulfur dioxide, black carbon, and oxides of nitrogen during conditions of wind from the southern sector.
    - Diurnal analyses of stationary monitoring results, isolated in weekday/weekend timeframes and North / South wind timeframes, indicate higher overall pollution levels on weekdays and with winds from the south.
    - Nonparametric trajectory analysis (NTA), an inverse modeling approach utilizing high time resolution monitoring and wind data, estimated multiple southern source areas contributing to the elevated concentrations under southerly winds, including the rail yard area, an airport located due south, and a nearby power plant.
- Mobile measurement results
    - Evaluation of mobile air monitoring sessions – with data sets including carbon monoxide, ultrafine particles, fine and coarse particle counts, and black carbon – indicate that residential areas north of the rail yard have elevated black carbon concentrations relative to a residential area south of the yard (estimated 30-104% increase over urban background) during early morning and evening time periods with southerly winds. Other pollutant measurements on the mobile platform either did not show statistically significant increases relative to the background or were less consistent.
    - Black carbon in the northern neighborhoods was elevated under both northerly and southerly winds during the mid-day period relative to a residential area south of the yard, indicating that other local sources had higher emissions activity during this time.
    - During the early morning and evening sessions with southerly wind, excess black carbon concentrations in northern neighborhoods are shown to decrease with increasing wind speed. In addition, elevated black carbon concentrations in these downwind neighborhoods do not appear to have a consistent trend associated with increasing downwind distance from the rail yard boundary, which is likely related to the complexity of rail yard and surrounding environment.

These results support the notion that local concentrated areas of higher diesel emissions activity adversely impact local-scale air quality and mitigation efforts may reduce local exposure to air pollution. It should be noted that uncertainty remains regarding source attribution, both within the rail yard and considering potential traffic on boundary roads, which may require modeling or controlled field experiments for further characterization.

1. Introduction

1.1. Background

Near-source air quality is currently a priority research area for the US EPA, with recent research studies focusing on transit sources such as major roads and rail yards. "Near-source" generally constitutes areas within several hundred meters of a major source, where excess local air pollution may be present in addition to regional background air pollution levels. The vast majority of past near-source research has focused on the near-road environment, with very limited information to date on rail-related environments.

Past near-road research has determined that certain air pollutants – particularly those produced directly from the tail pipe – can have significantly higher levels in close proximity to roadways and generally attenuate exponentially with distance from a road (Karner et al. 2010). For example, ultrafine particles (UFPs, particles smaller than 100 nanometers in diameter) have been observed in multiple locations to be significantly higher in close proximity to roadways and to decrease quickly with distance (Figure 1-1). For air pollutants that are composed of constituents formed post-emission through chemical reactions in the atmosphere and with a higher regional background, such as fine particulate matter, the near-source effect is usually smaller but may still be elevated relative to background concentrations. A review of health studies related to near-road exposure has determined a significant association between residing near roads and the exacerbation of asthma; other health outcomes (e.g., cardiovascular mortality, onset of childhood asthma) also have suggestive associations but more research is required (HEI Panel on the Health Effects of Traffic-Related Air Pollution 2010). Important factors that affect near-road air pollution include meteorology, road design and surrounding structures, traffic volume, fleet mix, and driving mode (e.g., Baldauf et al. 2008a, Hu et al. 2009).

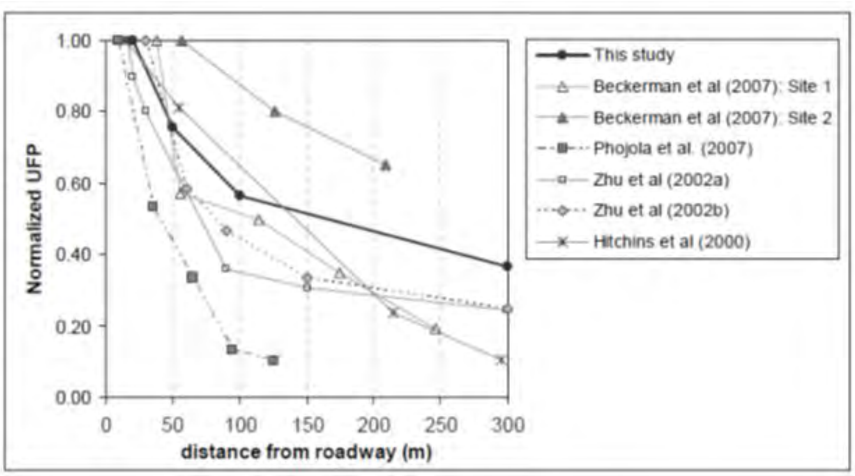

Figure 1-1. Ultrafine particles (UFP) as a function of downwind distance from the roadway, with concentrations normalized by the location nearest to the road. Originally published in Hagler et al., (2009).

Limited information is currently available on near-rail air pollution. The rail environment may be considered in two parts – the network of tracks connecting destinations and the "nodes" of the network (rail yards) where freight is organized and may be moved from one transportation system to another. Within the category of rail yards, a defining characteristic is whether they exclusively move freight containers from one train to another (classification) or whether the rail yard also serves as a location where freight may move to other modes of transportation such as trucks (intermodal). Emissions within a rail yard – particularly intermodal rail yards – are considerably more complex than highway environments. While the rail yard is a fixed area, emissions within an intermodal yard are of multiple types, including locomotives passing through the yard, switcher locomotives that route containers within the yard, trucks coming to and from the yard, hostler trucks moving containers within the yard, cranes moving containers, and other distributed emissions associated with servicing the rail yard equipment (Federal Highway Association 2010). These emissions can be considered as multiple point and line sources, which may shift both in location and emissions strength with time.

Two recent field studies have been conducted to estimate the local-scale air pollution impact attributed to emissions within a rail yard. One recent study in Detroit – the Midwest Rail Study – evaluated emissions and local-scale $PM_{2.5}$ trends related to the CSX Rougemere rail yard in Dearborn, MI (Turner 2009). An emissions inventory estimated significant improvements in rail yard $PM_{2.5}$ emissions over 2007-2008 related to replacing yard switcher locomotives with Gen Set locomotives as well as through the introduction of low sulfur fuel. Turner (2009) also reported that a dispersion modeling exercise estimated that the Rougemere rail yard contributed 0.2 $\mu g\ m^{-3}$ $PM_{2.5}$ on an annual average basis at an air monitoring station located within 150 m East of the rail yard boundary. The impacts were primarily attributed to locomotive emissions in the yard (switcher, arriving/departing, and through locomotives). Upwind and downwind point monitoring of carbonaceous particulate matter – elemental carbon (EC), black carbon (BC), and organic carbon (OC) – was also conducted for several months in 2008. The field data appeared to be significantly affected by other nearby sources which confounded the upwind/downwind local air quality analysis.

Another major field study took place over the timeframe of 2005-2008 to document local air pollution impacts related to emissions from the Union Pacific Rail Road J.R. Davis rail yard that is located in Roseville, CA. The Davis rail yard is unique in having primarily locomotive emissions, lacking the truck traffic associated with intermodal rail yards. In addition, the rail yard had somewhat steady and predictable winds that cross over the yard during summertime, supporting the application of time-integrated upwind/downwind measurements (Cahill et al. 2011). During nighttime summer conditions in 2005, it was reported that NO, NOx, BC, and $PM_{2.5}$ exhibited downwind concentrations that were enhanced by a factor of 21.9 (net difference: 77 ppb), 7.1 (net difference: 103 ppb), 2.4 (net difference: 0.7 $\mu g\ m^{-3}$), and 1.5 (net difference: 4.7 $\mu g\ m^{-3}$) in comparison to upwind measurements, respectively (Cahill et al. 2011). Over the course of the following three years, the pollution levels at the downwind site tapered down substantially due to emissions improvements at the Davis rail yard. By 2008, downwind-upwind concentration differences were reduced for NO, NOx, BC, and $PM_{2.5}$ by over 50% (Campbell 2009).

While the field results from Campbell (2009) and Cahill et al. (2011) support the notion that rail yards may significantly increase local-scale air pollution, it is uncertain to what degree these findings translate to rail yards with different emissions composition (e.g., intermodal yards with fewer trains, more trucks) that are located in other areas of the country with different local meteorology trends. As Turner (2009) experienced, certain rail yards are located in close proximity to other major sources – these multi-source environments are of significant interest in terms of local air pollution exposure but pose a significant challenge to isolate and assess individual source contributions to local excess air pollution.

1.2. Purpose and Scope of Study

The objective of this study was to evaluate the impact of an active rail yard on local air quality, within an urban area in EPA Region 5. This report describes the field measurements conducted through a month-long mobile monitoring campaign (October-November, 2010) as well as longer-term stationary monitoring (October 2010- October 2011) adjacent to a mid-sized rail yard in Chicago – the BNSF Cicero Rail Yard. Additional ancillary data utilized in the data analysis include a time series of truck counts at the BNSF gate ("gate count") and a count of freight containers lifted by the cranes within the yard ("lift count"), as recorded by BNSF employees at the Cicero yard.

Specific scientific goals of the study included:

- Measure the spatial extent of elevated local air pollution compared to the background, downwind of a major rail yard in Region 5.
- Measure the spatial and temporal variability of near-rail yard air pollution, under different meteorological conditions and source emission characteristics.
- Spatially attribute source area contributions to local excess air pollution.

2. Methods

2.1. Site Selection Process and Description

EPA Region 5 and EPA Office of Research and Development staff came to consensus on a number of siting criteria to support the project objectives outlined in Section 1.2. These criteria and the relative ranking applied to Chicago-area rail yards are provided in Table 2-1. The identified criteria were related to several goals. One goal was to employ a mobile air monitoring approach to measure spatial gradients of air pollution, an approach that was determined to be lower cost and more flexible in comparison to implementing multiple stationary monitoring sites. Part of the site objectives therefore included assessing the surrounding roadway network to determine if a mobile sampling vehicle could travel along relatively low traffic roads in close proximity to a rail yard. In addition, with Region 5 staff providing in-kind support to the study through implementing a stationary monitoring site, initial site selection was focused on the Chicago area where Region 5 headquarters are located.

Table 2-1. Site selection criteria

Criteria	Rank (H:high, M:mid, L:low)
Activity level of rail yard	H
Existence of historical monitoring data at the site	M
Ease of setting up a fixed sampling site and monitoring meteorology and air quality for several months.*	H
Few other nearby sources	H
Capability to drive in close proximity to rail yard on multiple sides, particularly along axis of prevailing wind	H
Access to low traffic roads surrounding rail yard, to avoid biases from single vehicle exhaust	H
Characteristics of surrounding environment (residential, commercial, etc.)	M

*To support collaborative monitoring effort by Region 5 staff.

A number of monitoring sites were considered throughout the Chicago-area, including the following rail yards – Corwith, Proviso, Cicero, 59th Street, The Belt, Ashland, and Elwood. The BNSF Cicero Rail Yard met the majority of the selection criteria in Table 3-1 when compared to the other candidates and was selected as the optimal site. Cicero is an intermodal rail yard, with both locomotive and truck traffic inside the rail yard boundary. A common metric for intermodal rail yard activity is the number of shipping container lifts per day – Cicero has approximately 1000-1200 lifts per day. To put the Cicero yard activity into perspective, Figure 2-1 shows the number of container lifts on an annual basis for a number of yards located in the Chicago area – in 2010, Cicero was reported to have approximately 370,000 lifts, with other rail yards in the Chicago area ranging from below 100,000 to above 800,000 lifts (Chicago Metropolitan Agency for Planning, 2011). In addition to emissions by diesel-powered cranes, other on-site emissions include 5-9 hostler trucks, 500 heavy-duty trucks traveling in/out of the yard, 8 daily intermodal trains, approximately 140 through trains (~120 passenger trains, 20 mixed freight trains), and 4-5 switcher locomotives. During the time period of this study, intermodal equipment (cranes, hostlers) used within the yard were operating on ultra low sulfur diesel fuel (maximum sulfur content of 15 ppm). Locomotives fueled in the area during the time of the study were using low sulfur diesel fuel (in the range of 125-400 ppm sulfur) (Michael Stanfill, BNSF – personal communication). The surrounding environment is primarily residential with two-story single-family homes densely located in a grid fashion surrounding the yard.

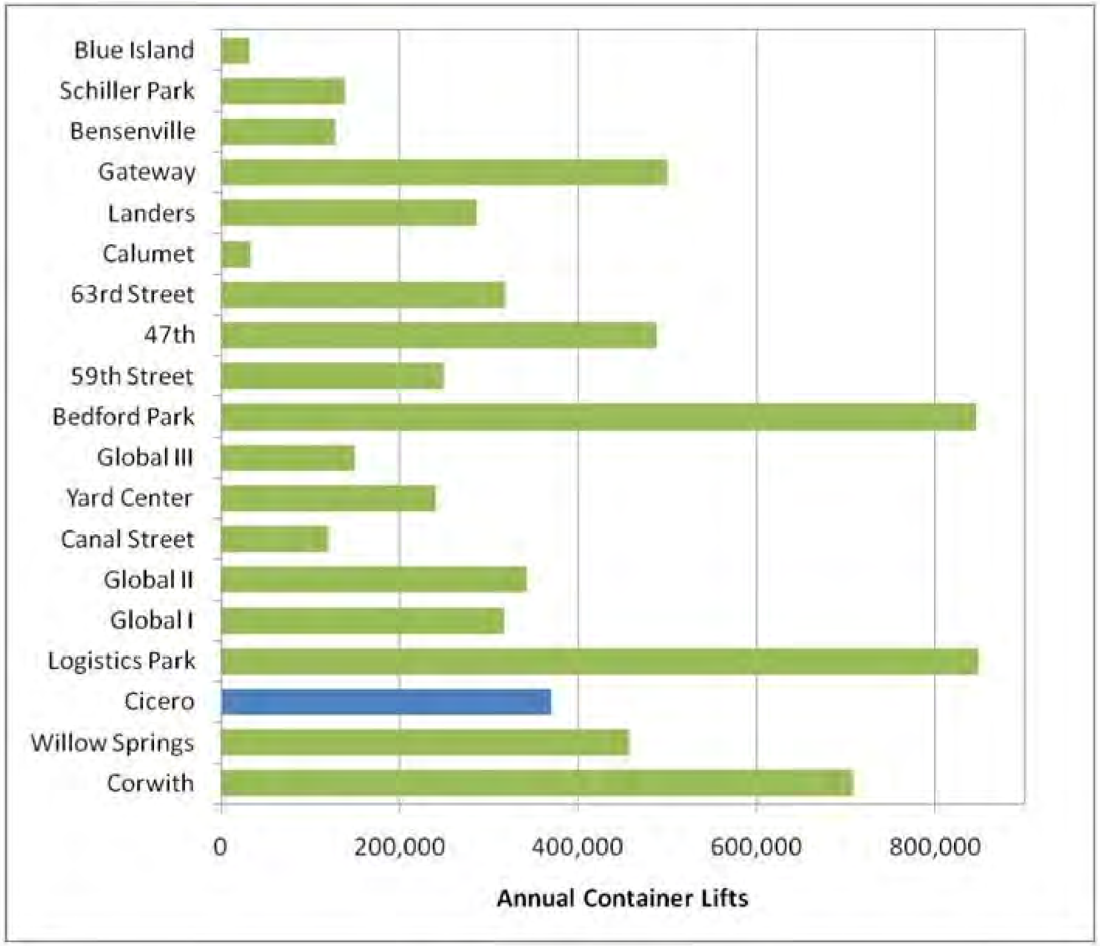

Figure 2-1. Annual number of container lifts per rail yard facility in the Chicago area. Data source: Chicago Metropolitan Agency for Planning (2011). The rail yard focused on for this research, Cicero, is shaded in blue.

2.2. Mobile and Stationary Sampling Approach and Schedule

With a goal of characterizing spatial gradients of air pollutant concentrations in neighborhoods located near the yard as well as observing long-term temporal variation, a combined mobile and stationary monitoring approach was implemented. EPA ORD staff led the mobile monitoring measurements and EPA Region 5 staff led the stationary monitoring measurements. These two approaches were complementary in nature. Mobile monitoring was conducted to drive a network of roadways surrounding the rail yard and provide data on the spatial variability of air pollutant concentrations. Meanwhile, the stationary monitoring was conducted at a single location over approximately one year, allowing longer-term temporal trends in near-rail yard concentrations to be understood. These two approaches required different air pollution measurement techniques. To collect high spatial resolution air pollution data while the mobile monitoring vehicle was in motion, air pollution measurement techniques were employed that were capable of measuring at a very fast rate (<10 seconds) while maintaining enough sensitivity to resolve ambient concentration levels. The instruments employed in the mobile monitoring vehicle were therefore on the leading edge of technology and are not commonly found in typical air monitoring networks. In contrast, a nominal 5-minute sampling time requirement was set for the stationary monitoring site to resolve air pollutant concentrations with changing wind direction. Therefore, instrumentation that is commonly used for regulatory air monitoring purposes and capable of data output on the order of minutes was applied. A general summary of these two sampling approaches and instrumentation are provided in Table 2-2.

Table 2-2. Measurement approaches

	Mobile Monitoring Vehicle	Stationary Monitoring Site
	Sampling times	
Time span	October-November, 2010	October, 2010 – October, 2011
Measurement rate	1-10 seconds, driving sessions of approximately 3 hours	5 minutes, continuous data
	Measurement techniques[a]	
Fine particulate matter	Aerodynamic sizing, light scattering detection, mass-estimation from size-resolved number counts	Beta-attenuation through particle-laden filter, with an inlet cut at 2.5 microns (FEM)
Ultrafine particles	Electrical mobility sizing, detection by electrometer	N/A
Black carbon	Light absorption (880 nm) through particle-laden filter	Light absorption (880 nm) through particle-laden filter
Carbon monoxide	Quantum cascade laser	Nondispersive infrared detector (FRM)
Sulfur dioxide	Quantum cascade laser	Pulsed fluorescence (FEM)
Oxides of nitrogen	N/A	Chemiluminescence (FRM)

[a]FEM means Federal Equivalent Method and FRM means Federal Reference Method.

2.3. Mobile Monitoring Methods

The mobile monitoring data set covers the time period of October 27, 2010 to November 21, 2010 and included 23 deployments in total. Air monitoring measurements were conducted using an electric vehicle outfitted with rapid-response air sampling instrumentation. The vehicle is powered by lithium ion batteries, which provide enough power for approximately 100 miles of driving. However, the actual driving time depends on the true operating conditions of the vehicle, with higher speed driving more quickly draining the power supply. Under the driving conditions in CIRYS, the vehicle was maintained generally at low driving speeds; therefore, approximately 3-4 hours of driving time and an additional 1 hour stationary sampling period was performed. The stationary sampling by the mobile vehicle was conducted primarily to compare side-by-side with the stationary monitoring site. In addition to electric power for driving, the vehicle also had built-in inverters providing up to 2 kW of power for on-board instrumentation.

The air monitoring instruments utilized for mobile monitoring were selected for a very fast response time and sensitivity at ambient levels, allowing accurate air quality readings and spatially resolved data while the vehicle is in motion. Details regarding the instrumentation, driving path, data processing, and quality assurance are provided below.

2.3.1. Mobile Monitoring Instrumentation

A list of the instrumentation used on-board the mobile sampling platform is provided in Table 2-3. Gaseous measurements included CO and SO_2, both measured in parallel using a quantum cascade laser instrument. This instrument is able to measure trace gas concentrations with high specificity and with manufacturer-reported sub-ppb sensitivity while measuring at one second time intervals.

As described in section 3.1.1.1, the SO_2 measurement ended up being unsuccessful due to poor performance of the on-board laser and was not able to meet the in-field quality checks. The CO laser had excellent performance throughout the mobile campaign.

Particle measurements were conducted using optical-based methodologies that provided the nominal sampling time resolution of 10 seconds or faster. Particle size-resolved number concentration was measured using two instruments with the detection method optimized in each instrument for the size regime being sampled. The very small particles – 5.6 to 560 nm in size or 0.0056-0.560 µm – were measured based on particle electrical mobility using an Engine Exhaust Particle Sizer (TSI, Inc.). Briefly, the particles are drawn into the instrument, charge-neutralized, then provided a surface charge. The particles then travel along a column of stacked charged rings, which attract and then count particles of specific sizes based upon how the charged particle moves in an electric field. In this way, the instrument is capable of isolating and simultaneously counting particles of different sizes. The larger particle range – 0.5 – 20 µm – was measured based upon inertial principles. The Aerodynamic Particle Sizer (TSI, Inc.) continuously draws in a sample and then accelerates the sample air flow. The particles accelerate based upon their size and are counted via light scattering. These two instruments together provide a size-resolved number concentration, with the size range of 0.0056-20 µm sampled in 84 discrete size intervals. This size-resolved particle number concentration can be used to approximate a mass concentration using the following assumptions – particles are spherical with a diameter at the mid-point of the size bin and particles have a density of a certain value.

Black carbon (BC) is another particle measurement that was conducted on-board the mobile platform. BC is the sole measurement that has nearly identical measurement methodology in the stationary monitoring site (Table 2-2). The instrument operates by drawing a sample air stream through a filter, with a red light beam (880 nm) passing through the filter and a detector continuously reading the change in light attenuation over time due to light-absorbing particles (lpm) (Hansen et al. 1984). The model used on-board the mobile platform (AE-42) was customized for higher time-resolution readings by using a relatively small particle deposition area ("spot size") and a high flow rate (4 lpm).

Table 2-3. Mobile monitoring instrumentation

Measurement	Rate	Instrument
Carbon monoxide (CO)	1 s	Quantum cascade laser (QCL, Aerodyne Research, Inc., Billerica, MA, USA)
Sulfur dioxide (SO_2)	1 s	Quantum cascade laser (QCL, Aerodyne Research, Inc., Billerica, MA, USA)
Particle number concentration (5.6-560 nm, 32 channels)	1 s	Engine Exhaust Particle Sizer (EEPS, Model 3090, TSI, Inc., Shoreview, MN, USA)
Particle number concentration (0.5-20 µm, 52 channels)	10 s	Aerodynamic Particle Sizer (APS, Model 3321, TSI, Inc., Shoreview, MN, USA)
Black carbon	1 s	Single-channel Aethalometer (Magee Scientific, AE-42, Berkeley, CA, USA)
Longitude and latitude	1 s	Global positioning system (Crescent R100, Hemisphere GPS, Calgary, Alberta, Canada)

Additional instrumentation on-board the electric vehicle included a high-resolution global positioning system, which has been tested to have a spatial resolution of <1 meter while sampling at 1 Hz. The global positioning system (GPS) requires overhead satellites to provide positioning information – lack of satellite detection due to blocked (e.g., dense buildings) or interfering signals can lead to areas where position data are not known. To understand if the GPS would have any troublesome areas, preliminary drives were conducted. The key areas of the route were detected correctly by the GPS; however, when the car was positioned near the stationary monitoring location the GPS signal dropped off for reasons unknown. Another on-board instrument was a forward-facing webcam that was used to continuously record the driver's view over the course of each sampling session.

Finally, during the window of time when mobile monitoring sessions occurred, an ultrasonic anemometer (RM Young, Model 81000) was positioned on the rooftop of the BNSF office building to measure 3-dimensional wind speed and direction. This building is located on the northern boundary of the rail yard (yellow star in Figure 2-2). These data were recorded at a very fast time-rate (4 Hz) and then were sub-sampled to be 10 s data in order to have more manageable file sizes.

2.3.2. Driving Route

The mobile sampling car driving route was designed to meet several key criteria – 1) ability to repeat the route at least three times within a given 2-3 hour driving session, allowing areas to be sampled repeatedly, 2) measuring air quality in low-traffic neighborhoods on the prevailing downwind side of the yard and areas representative of the urban background, 3) driving safety and minimal time on rough road surfaces which could give the vehicle hard jolts and affect instrument performance.

The final driving route was selected when staff arrived in the field and test drove possible roadways; the route is shown in Figure 2-2. For each lap of the route, the vehicle initiated at the southern side of the rail yard, traveled along the boundary roadway surrounding the yard (going West and then North), then exited to travel along areas to the North of the yard, followed by crossing over the rail yard to sample an area to the southeast of the yard, and finally returning to the starting location.

Some key areas to note for the route include low-traffic areas designated as urban background (BGD1 and BGD2), with the assumption that these areas would represent local air quality conditions without any major sources emitting in the immediate vicinity. BGD1, the northern background area, was estimated to receive winds from the surrounding area but not from the rail yard during winds from the west, north, and due east (195-360 degrees and 0-90 degrees). Meanwhile, BGD2, the southeastern background area, was estimated to receive winds from the surrounding area but not directly from the rail yard area under conditions of winds from the south and east (75-220 degrees). Also shown in Figure 2-2 are several neighborhood transects of interest (NT1-NT4), which were determined to be low traffic residential roadways that spanned from very near the northern side of the rail yard to several hundred meters in downwind distance.

Additional locations marked include the location of the temporary meteorological monitoring location during the mobile sampling (yellow star) and the location of the stationary monitoring site (orange star).   After the driving route was completed on any given session, the sampling vehicle was then parked at the stationary monitoring location which is directly NE of the rail yard.

Figure 2-2. Mobile sampling vehicle driving route surrounding the rail yard of interest. Background (BGD) and neighborhood transect (NT) areas are noted, as well as the location of the meteorological station put in place during the mobile sessions (yellow star) and the stationary monitoring site (orange star).

2.3.3. Mobile Data Processing

Analysis of mobile air monitoring data includes a series of data-processing steps that carefully time-align the location and measurement data, apply specific data filtering procedures depending on the analysis objectives, spatially reference the measurement locations against an area of interest, and then final analyses are initiated (Figure 2-3). For CIRYS, mobile monitoring data processing involved first logging the raw data to two onboard computers that were time-synchronized prior to each drive to the GPS timestamp. One computer logged the data from the EEPS, APS, Aethalometer, GPS, and webcam. The second computer was built into the quantum cascade laser system and logged CO and SO_2 data.

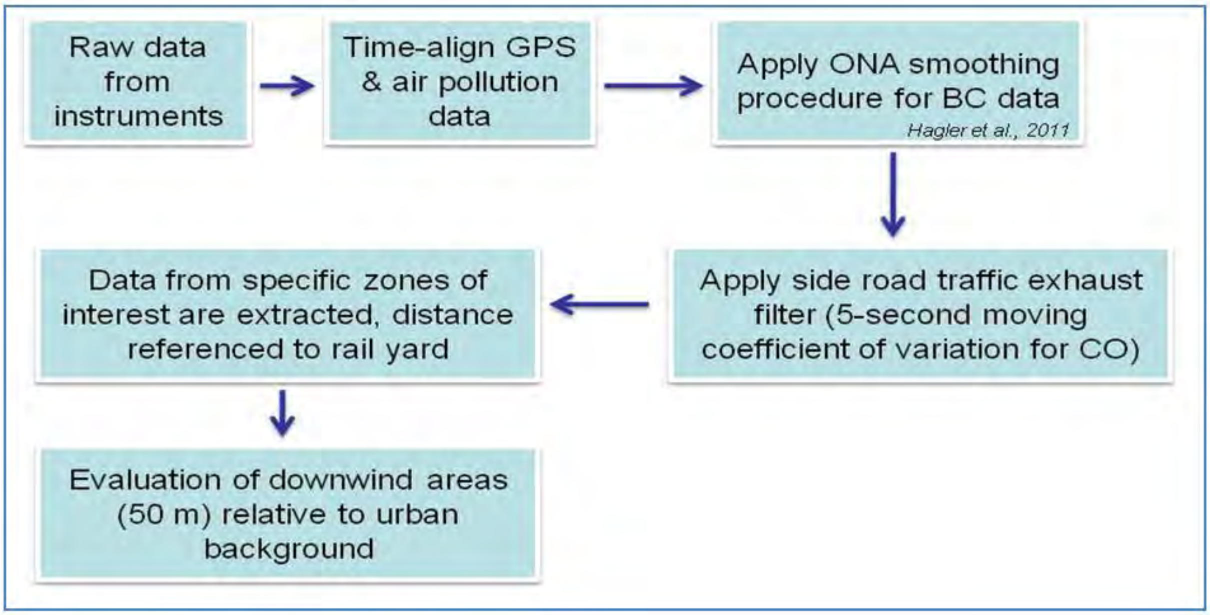

Figure 2-3. Mobile data processing steps.

After data collection, data processing included providing a time-adjustment of ~1-5 seconds to account for the time it took for a change in concentration at the sample inlet to be registered on a particular instrument, which is a function of the flow rate and response time of each instrument. A change in concentration was provided by applying a zero filter to the inlet for the particle measurement instruments and by providing a concentration change using a gas standard for the gas-phase measurement instruments. Following this time adjustment, the air monitoring data were synchronized with the GPS data, providing an air quality data series that is a function of time and location.

Aethalometer data required an additional data processing step – the application of the Optimized Noise-Reduction Algorithm (ONA), which has been shown to significantly reduce noise in real-time BC data while preserving significant trends (Hagler et al. 2011). This instrument operates by observing the attenuation of red light (880 nm) through a particle-laden filter at the start and end of each sampling period, translating the difference in light attenuation into a concentration. At low concentration periods, the addition of new light-absorbing particles to the filter may be insufficient to change the light attenuation enough to overcome the background noise, leading to a possible under-prediction of concentration in one instance followed by an over-prediction of concentration in the next instance (or vice versa). However, over time, the loading of light-absorbing particles leads to a meaningful decrease in the light signal and translates to an accurate BC concentration estimate. The ONA algorithm uses the light detection data ('ATN') that is logged by the instrument to guide the appropriate smoothing of the data. Other commercially available high-time resolution air monitoring instruments perform similar functions internally and output noise-reduced data – the Aethalometer is unique in having this necessary smoothing process deferred to the user.

Prior to mobile data analysis occurring regarding near-rail yard air pollution, a final data processing step is a screening algorithm seeking to detect and remove any instances of local vehicular exhaust that may provide a bias in the data. The mobile monitoring schedule and driving routes were designed to minimize the occurrence of local vehicular exhaust. However, unpredictable events may have occurred and an algorithm seeking short-term spikes in a pollutant indicative of local exhaust impacts is one objective data-screening approach (Hagler et al. 2010, Hagler et al. 2012). As this study was seeking to characterize local level impacts due to what was anticipated to be concentrated diesel emissions within the rail yard environment, CO was selected as the primary indicator to selectively remove impacts of side road gasoline vehicle exhaust within the time series. This algorithm performs a running calculation of a 5-point standard deviation in CO (logged in 1 second intervals) and divides this value by the ~2 hr session mean value, providing a modified running coefficient of variation. The algorithm then flags and removes from analysis all 5-second time periods where the standard deviation more than doubles the session mean. This procedure typically flags approximately 1-3% of the 1-second CO data collected. An example of the data flagging results for CO is provided in Figure 2-4. One should keep in mind that the full time series of data, as shown in Figure 2-4, also includes portions of the route that are known to have significant on-road traffic and were utilized to access lower traffic areas that are the primary areas for analysis.

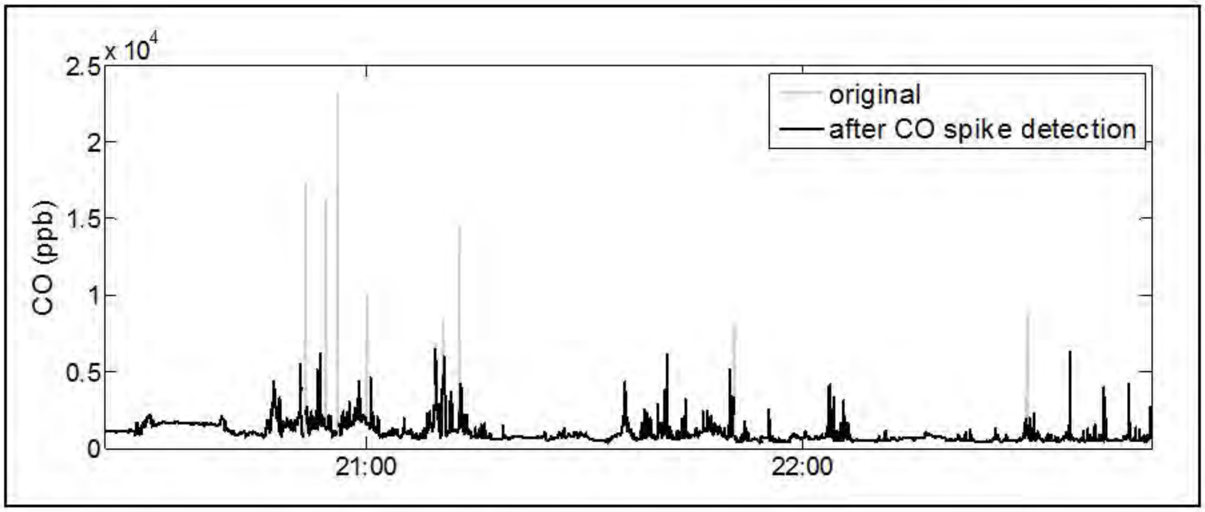

Figure 2-4. Example time series of carbon monoxide data, showing the original raw data (gray) and the data time series after detected significant short-term spikes were removed, which were presumably due to local gasoline vehicle exhaust impacting the measurements.

After these preliminary processing steps, the mobile data set for a particular 3-hour session were now prepared for data analysis and interpretation. For a particular session, data relevant to specific areas of interest (Figure 2-2) were extracted from the time series based upon the recorded longitude and latitude. For example, the mobile vehicle may have traveled slowly along the NT1 neighborhood area four or five times during a sampling session, collecting data continuously while driving the path. The data relevant to the NT1 area would be extracted and then the data could be grouped into specific distance ranges from the rail yard boundary, with the boundary being estimated as the northern route driven by the mobile vehicle surrounding the yard (Figure 2-2). For the analyses shown in this report, the distance between a transect location and the rail yard boundary was calculated as the shortest distance between the two, with the rail yard boundary estimated as shown in Figure 2-5. An example of a concentration versus distance from rail yard is provided in Figure 2-6. When the real-time data were grouped into 50 m intervals, each interval for neighborhoods NT2-4 generally had thirty 1-second data points per session and NT1 50 m interval typically had ninety 1-second data points per session; the higher number of points in NT1 is due to this area having a somewhat U-shaped transect with more measurement time spent per spatial increment.

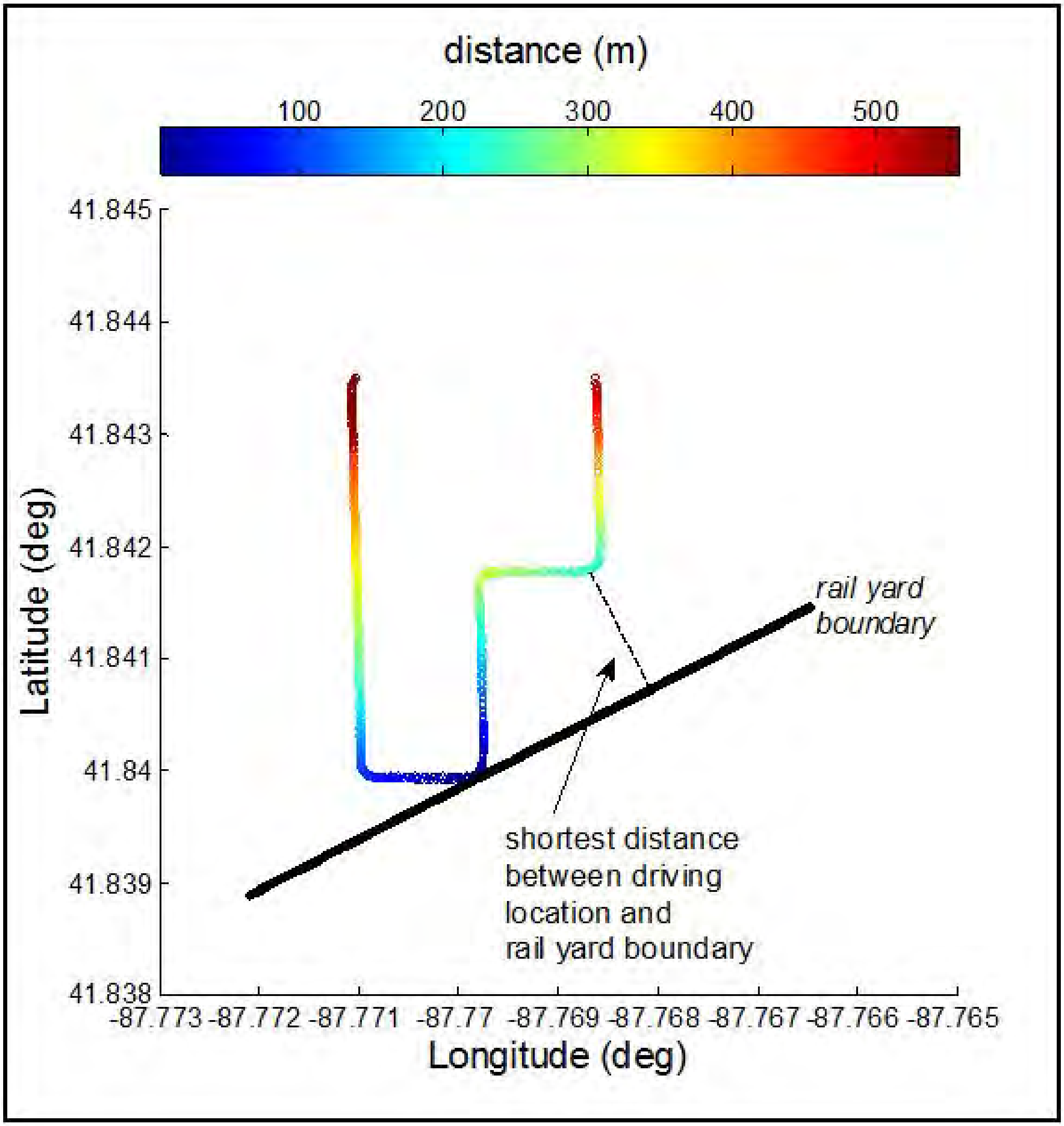

Figure 2-5. Example of distance estimated from the pathway driven in neighborhood NT1 relative to the rail yard edge. The dashed line demonstrates the shortest distance from an example location along the driving route to the estimated rail yard boundary line. The shortest distance from each location in neighborhood NT1 to the rail yard boundary is calculated and can be compared to the color bar at the top of the figure.

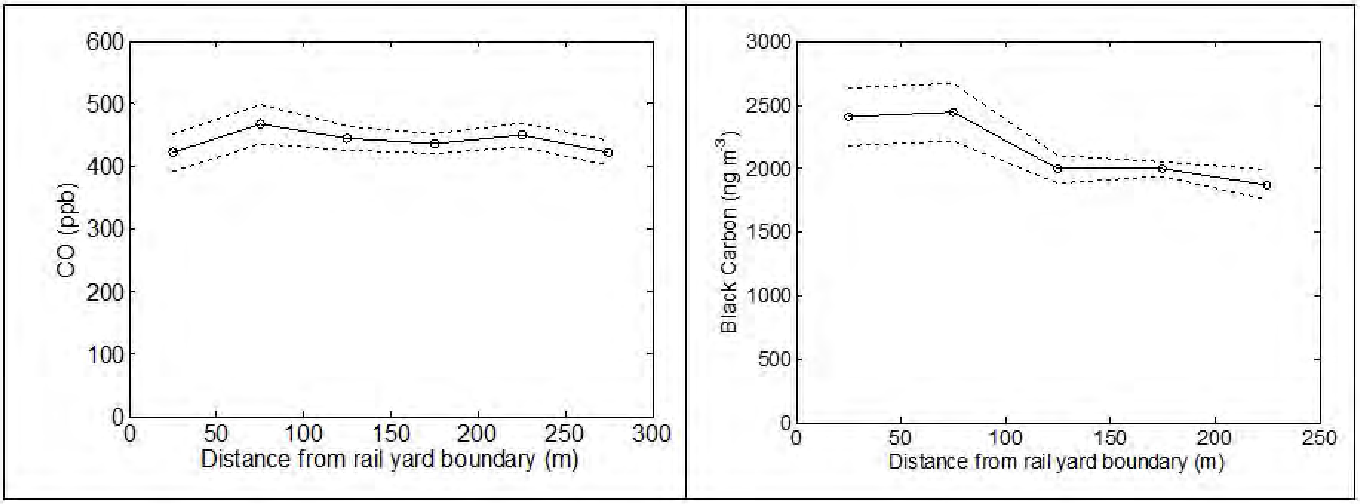

Figure 2-6. Example of a concentration versus distance from rail yard boundary figure for CO (left) and black carbon (right). The circle markers indicate the mean value measured and are centered at the midpoint of the distance range; the dashed line indicates the standard error of the measurement.

Another method to relate measurements spatially to a presumed source area is along the lines of a wind trajectory, what may be considered as the “effective distance” under a specific wind condition (Barzyk et al. 2009). This method was explored; however, perpendicular distance was used as the primary method of distance calculation for the analyses to follow in order to focus upon practical questions of actual distance of a residential area versus impact.

Finally, after data were organized into spatial increments with respect to the rail yard boundary, the concentrations were then evaluated with respect to measurements collected in an upwind region that is considered representative of urban background conditions – BGD1 or BGD2, depending upon the wind condition. In order to determine whether or not concentrations downwind of the rail yard were significantly elevated with respect to the background, a variation of the t-test was calculated – the Welch’s t-test, which does not assume that the two populations of data have equal variances (Welch 1947). If the t-test showed a significant difference and there was a positive difference in concentration (downwind minus background), then the data in the given downwind spatial increment were considered to be significantly elevated with respect to the background.

2.3.4. Quality Assurance

Quality assurance (QA) is an underlying principle of this research study, from the planning stages to implementation of the field research activities. For the case of the mobile monitoring data, a critical QA activity was the development of a Category III Quality Assurance Project Plan (QAPP) for Measurement Projects, which was reviewed by EPA’s Office of Research and Development (Appendix A). The QAPP spells out the objectives of the overall study and actions taken to provide quality data and analyses to meet those goals. After acceptance, the QAPP then guided the overall project pathway and daily QA activities in the field. Further information regarding a QA assessment of the mobile monitoring data is available in section 3.1.1.

2.4. Stationary Sampling Methods

The stationary data set covers the time period from October 2010 to October 2011. Air monitoring measurements were taken using monitors typically used for National Ambient Air Quality Standard (NAAQS) comparisons; these monitors were housed in an air monitoring station located in a lightly used parking lot to the northeast of the Cicero Rail Yard. The station provided power, heating/cooling, and a workspace for operators. The deck on the roof of the station provided space for the $PM_{2.5}$ and meteorological monitors and the inlets for the gaseous pollutants. The monitors were connected to a data logger, and the data were downloaded nightly or manually during an operator site visit.

The air monitoring instruments utilized for the stationary monitoring were borrowed from a number of agencies both from within and outside of Region 5. The Region attempted to use equipment similar to what is typically used at National Air Monitoring Stations (NAMS) or State or Local Air Monitoring Sites (SLAMS). Details regarding instrumentation, data processing, and quality assurance are provided below.

2.4.1. Instrumentation

A list of the instrumentation used in the station is provided in Table 2-4. Gaseous measurements included CO, NO, NO_2, NOx, and SO_2; particulates ($PM_{2.5}$) and black carbon were also measured. Meteorological parameters measured included wind speed and direction, relative humidity, temperature, and barometric pressure.

Data for the gas pollutants were stored in an ESC data logger, and collected nightly via a cell modem. The data for the Aetholometer were stored on an internal floppy disc; the disc was collected monthly during a site operator visit. The meteorological data were collected by a dedicated data logger; these data were downloaded manually each week during a site operator visit.

Table 2-4 Stationary monitoring instrumentation

Measurement	Rate	Instrument
Carbon monoxide (CO)	1 min	API 200E (Teledyne API, San Diego, CA, USA)
Sulfur dioxide (SO_2)	1 min	API 101E (Teledyne API, San Diego, CA, USA)
$PM_{2.5}$	5 min /1 hr	E-BAM Mass Monitor (Met One Instruments, Grants Pass, OR, USA)
Oxides of Nitrogen(NO, NO_2, NO_x)	1 min	TECO 42 (Thermo Scientific, Franklin, MA, USA)
Black carbon	5 min	AE 21 (Magee Scientific, Berkeley, CA, USA)
Ambient wind speed	5 min	Cup anemometer (Met One Instruments, Grants Pass, OR, USA)
Ambient wind direction	5 min	Wind vane (Met One Instruments, Grants Pass, OR, USA)
Ambient relative humidity	5 min	RH sensor (Met One Instruments, Grants Pass, OR, USA)

2.4.2. Stationary Monitoring Location

The site was located in the parking lot of the Cicero Public Works building, approximately 50 meters from the nearest train tracks bordering the upper northeast area of the rail yard (Figure 2-7). This site was selected after surveying a number of possible locations surrounding the rail yard, and met the desired attributes of being on the prevailing downwind side of the rail yard and being in close proximity to the rail yard. The southern end of this parking lot borders the BNSF rail yard. The northern end is bordered by a low volume road (W 26th Street). The area is mostly residential with some commercial buildings and several industrial sources.

The tracks located approximately 50 m from the station were in routine use throughout the monitoring study by both commuter and freight trains. This near-field emissions source was anticipated to contribute short-term concentrated plumes which would be captured in the monitoring data. However, it was uncertain prior to measurements whether or not the 5 minute data would be able to isolate time periods affected by train plumes or not. Part of the study design therefore included periods where the mobile monitoring vehicle would park adjacent to the stationary monitoring site and collect higher time-resolution measurements for comparison purposes (section 3.1.1.4).

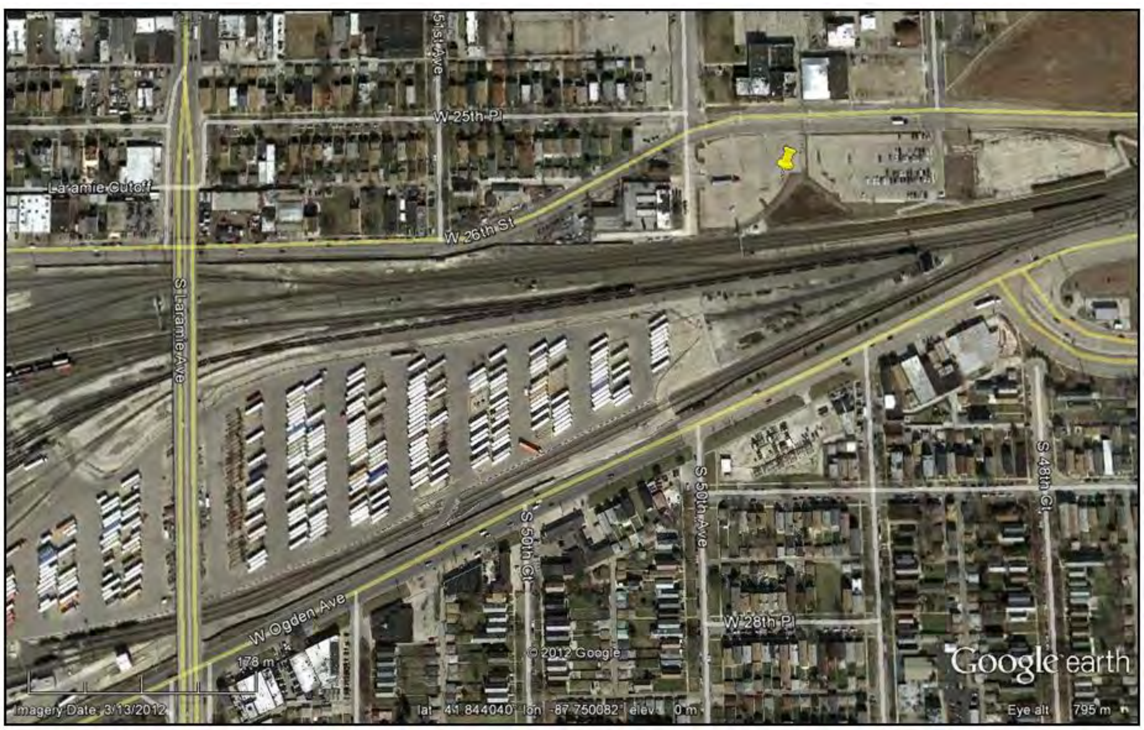

Figure 2-7. Sampling location, where the stationary monitoring site was located for approximately a year's time and the mobile vehicle would park for 1-2 hour intercomparison periods.

2.4.3. Data Processing

The stationary monitoring data set included several processing steps – data collection either internal to instruments or using external dataloggers, quality assurance review of the data, consolidation of the multiple measurements into a single multipollutant time series, and finally temporal and wind-directional analyses using several approaches. Data for the gas pollutants were stored in an ESC data logger, and collected nightly via a cell modem. The data from the Aetholometer were stored on an internal floppy disc; the disc was collected monthly during a site operator visit. The meteorological data were collected by a dedicated data logger; there data were manually downloaded each week during a site operator visit.

As discussed in section 3.1.1.4, the near-field effects of passing trains south of the monitoring site were unidentifiable to be flagged in the 5-minute data time series. Therefore, the stationary monitoring data set represents general ambient trends at this location, which would be affected by both the near-field passing trains under certain wind conditions as well as other sources in the area.

Data for the stationary site were reviewed for quality using the criteria listed in Table 2-5 by the Region's quality assurance coordinator. After the quality-assured data were consolidated into a single multipollutant time series, analyses were conducted using the R statistical package (R Development Core Team 2008). The R program, a common platform upon which several custom functions have been developed, is helpful for air monitoring research. One group of functions used in this analysis were developed by the OpenAir project (http://www.openair-project.org/), which provides algorithms to generate wind roses, concentration roses, and time series figures.

Further exploration of the stationary monitoring data trends was accomplished using the nonparametric trajectory analysis (NTA) model that has been recently developed by EPA's Office of Research and Development (Henry et al. 2011). NTA is a technique which utilizes highly time resolved data collected at five minute intervals to identify the possible location of sources in close proximity to a monitoring site. Backward wind trajectories from the monitoring site are constructed from the wind data and associated with a single measured concentration at the time when the air parcel arrives at the monitor. A spatially weighted average then aggregates the pollutant concentrations so that areas of high concentration are isolated for further study as well as quantifying possible contributions from potential local sources.

Usually, the five minute averaged wind data are used to create trajectories that go back one hour in time. The path taken by the trajectory shows the area where the air parcel passed over for the previous hour at a total of 12 endpoints. The pollutant concentration associated with the most recent 5 minute measurement is then assigned to each node along the trajectory's path (Figure 2-8).

Time	Wind Direction	Wind Speed
12/23/20100:55	305.8	2.6
12/23/20100:50	306.1	2.3
12/23/20100:45	308.1	1.8
12/23/20100:40	306.5	2
12/23/20100:35	303.8	2
12/23/20100:30	315.4	2.2
12/23/20100:25	305.5	2
12/23/20100:20	307.3	2.4
12/23/20100:15	316.9	2.7
12/23/20100:10	323.3	2.3
12/23/20100:05	319	2.1
12/23/20100:00	317.6	1.5

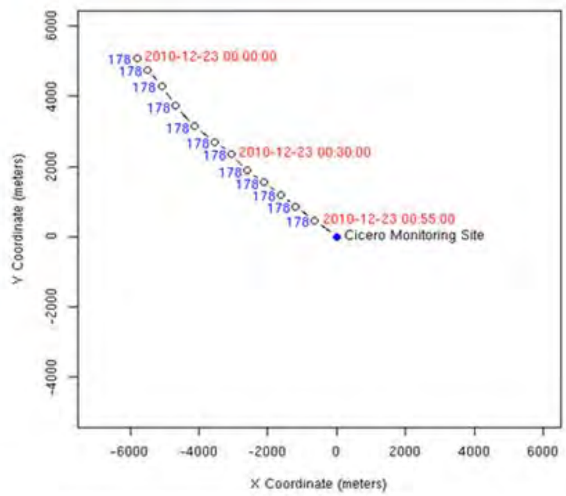

Figure 2-8. Example wind data showing how a typical backward trajectory is constructed for NTA. The twelve endpoints making up the hour long trajectory are listed in the table at the left and plotted in the graph. The value of 178 represents a concentration measured at time 2010-12-23 00:55:00.

Repeating the trajectory construction process for all 5 minute measurements yields a large cluster of trajectories along with their associated 5 minute pollutant concentrations (Figure 2-9). A spatial grid is laid over the trajectories and a weighted average is computed for each cell by using a kernel function. The purpose of the kernel function is to weigh the values associated with the nodes in proximity to the cell's center so that points further away from the center are weighted less than those closer to the center. The expected concentration at each cell's center is represented by the equation:

$$\frac{\sum_{i=1}^{m}\sum_{j=1}^{n} C_j W_{ij}}{\sum_{i=1}^{m}\sum_{j=1}^{n} W_{ij}} \qquad \text{(eq 1)}$$

where

$$W_{ij} = K\left(\frac{X-x_{ij}}{h}\right) K\left(\frac{Y-y_{ij}}{h}\right) \qquad \text{(eq 2)}$$

and

$$K(u) = 0.75(1-u^2) \quad \text{for } |u|<=1 \qquad \text{(eq 3)}$$

$$K(u) = 0 \quad \text{otherwise} \qquad \text{(eq 4)}$$

The function K shown above (equations 2-4) represents the Epinechikov kernel function where any points outside the boundary set by the smoothing parameter (h) have a zero weight and, therefore, are not used in calculating the average for the cell. The smoothing parameter represents the distance from the center of the cell of the endpoints to include in the weighted average. Varying this parameter controls the smoothness of the overall concentration field. A smaller value will make the field appear more "spiky" while a larger value will encompass more points and make the field appear more smoothed.

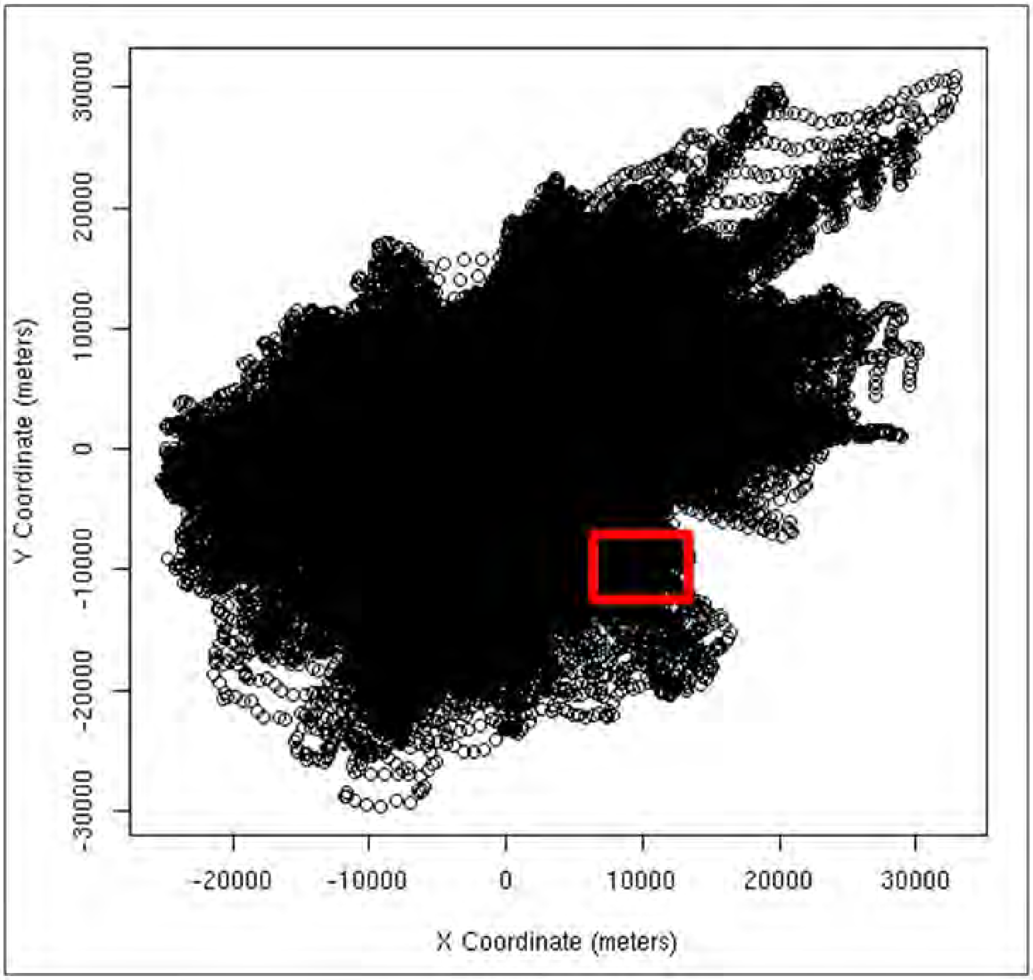

Figure 2-9. Example showing all of the backward trajectories for all 5 minute averaged data collected at the Cicero stationary monitor. The red box represents a grid cell for calculating the weighted average at the cell's center. The cell's expected concentration would be calculated based on the distance individual trajectory endpoints are from the grid cell's center.

The results of the pollutant spatial fields are displayed on Google Earth maps to determine possible local sources that could be contributing to the short term measured concentrations at the Cicero stationary monitoring site. The NTA expected concentrations were calculated for black carbon, SO_2 and NO for a period from November 2010 through May 2011 when all three pollutants were being measured concurrently. The time period encompasses the full measurement record for black carbon and includes, for comparability purposes, the corresponding SO_2 and NO measurements. Due to the diverse local source mix within the vicinity of the Cicero rail yard, a grid spanning 20 km in both the north-south and east-west directions was created and centered at the monitoring location just north of the rail yard boundary. The grid's extent included other possible source contributors such as the Crawford power plant, Midway Airport, the McCook industrial zone to the southwest as well as other rail yards within the general vicinity. These results are discussed in section 3.2.1.2.

2.4.4. Quality Assurance

Quality Assurance was an important consideration for the stationary monitoring effort. To that end, the Region wrote a Quality Assurance Project Plan, which outlined the process and targets to assure the data was of sufficient quality to meet the objectives of the study. Methods, frequencies, and criteria goals for the stationary monitoring are summarized in Table 2-5 below.

Table 2-5. Stationary monitoring site quality assurance procedures

Measurement Parameter	Assessment Method	Minimum Frequency	Criteria
$PM_{2.5}$	Flow Checks; flow check using independent standard	Monthly; every 6 months	±4%
Black Carbon	Flow checks	Monthly	±4%
NO, NO_2, NO_x	Single point QC check; Audit (consecutive levels at 80% of measured conc.)	Every 2 weeks; Every 6 months	<10% <15%
SO_2	Single point QC check; Audit (consecutive levels at 80% of measured conc.)	Every 2 weeks; Every 6 months	<10% <15%
CO	Single point QC check; Audit (consecutive levels at 80% of measured conc.)	Every 2 weeks; Every 6 months	<10% <15%
Ambient wind speed and direction	Certification, general inspection and maintenance	Pre-deployment; Every 6 months	See manual

2.5. Ancillary data

Aside from the measurements collected in stationary and mobile sampling modes, several additional data sources used in the interpretation of field measurements included rail yard activity information provided by the Cicero rail yard hub manager, meteorological data collected at the Midway Airport, and air measurement data from several nearby regulatory ambient monitoring stations that are implemented by the state of Illinois. The Cicero rail yard activity information included a minute-by-minute time series of freight container lifts by cranes in the rail yard (“Lifts”) and a second time series of trucks passing through the rail yard gate (“Gate”) during the course of the field study. These data were primarily used to understand the diurnal, weekly, and seasonal trends in rail yard operation and help put the field measurement time periods into context. The Midway Airport meteorological data were utilized as a quality assurance check to ensure the correct orientation of the temporary meteorological station put in place during the mobile monitoring study. These data were accessed through NOAA’s National Climatic Data Center (NCDC) Quality Controlled Local Climatological Data.

3. Data Analysis

3.1. Mobile Sampling

3.1.1. Mobile Data Overview

A total of 23 mobile sampling sessions were performed between October 27, 2010 and November 21, 2010 and are listed in Table 3-1. Each mapping period was conducted for approximately 3-4 hours, followed by parking the sampling vehicle next to the stationary air monitoring shelter for a period of 1-2 hours to allow for intercomparison between measurements. The total sampling duration was constrained by available power in the electric vehicle.

Table 3-1. Mobile Sampling Sessions

			Driving mode			Stationary mode		
Date (start)	Time category	Day of week	Start	End	Duration	Start	End	Duration
27-Oct-10	Mid-Day	Wednesday	9:16	13:05	3:49	13:05	13:25	0:20
28-Oct-10	Evening	Thursday	18:53	0:50	5:57	0:55	2:00	1:05
29-Oct-10	Evening	Friday	18:45	22:45	4:00	22:45	23:45	1:00
30-Oct-10	Mid-Day	Saturday	8:52	12:15	3:23	12:15	13:15	1:00
31-Oct-10	Early Morning	Sunday	3:52	7:23	3:31	7:25	8:25	1:00
1-Nov-10	Evening	Monday	19:18	23:22	4:04	23:22	0:10	0:48
3-Nov-10	Mid-Day	Wednesday	11:50	15:25	3:35	15:25	16:25	1:00
4-Nov-10	Early Morning	Thursday	4:10	7:45	3:35	7:45	8:42	0:57
5-Nov-10	Mid-Day	Friday	9:00	12:23	3:23	13:50	14:30	0:40
6-Nov-10	Early Morning	Saturday	3:52	7:15	3:23	7:15	8:15	1:00
7-Nov-10	Evening	Sunday	19:40	23:09	3:29	23:09	23:56	0:47
8-Nov-10	Evening	Monday	19:00	22:52	3:52	22:52	0:10	1:18
10-Nov-10	Mid-Day	Wednesday	9:10	12:30	3:20	12:30	14:00	1:30
11-Nov-10	Early Morning	Thursday	4:00	7:10	3:10	7:10	9:40	2:30
12-Nov-10	Mid-Day	Friday	10:00	13:41	3:41	13:41	15:05	1:24
13-Nov-10	Early Morning	Saturday	4:00	7:00	3:00	7:00	8:40	1:40
15-Nov-10	Evening	Monday	19:30	23:10	3:40	23:10	1:05	1:55
16-Nov-10	Evening	Tuesday	18:55	23:30	4:35	23:30	1:30	2:00
17-Nov-10	Mid-Day	Wednesday	9:45	12:52	3:07	12:52	14:37	1:45
18-Nov-10	Early Morning	Thursday	3:58	7:00	3:02	7:00	8:42	1:42
19-Nov-10	Early Morning	Friday	3:52	7:08	3:16	7:08	8:30	1:22
20-Nov-10	Early Morning	Saturday	3:57	8:06	4:09	8:06	9:49	1:43
21-Nov-10	Evening	Sunday	19:02	22:30	3:28	22:30	0:09	1:39

The sampling vehicle repeatedly followed a driving route that surrounded the rail yard (Figure 3-2), but emphasized capturing data in areas to the northwest of the rail yard – area downwind of prevailing wind. The vehicle traveled along roadways that immediately bordered the rail yard – Ogden Ave to the south, an interior roadway to the rail yard, and W 26th St to the North. The vehicle covered the path shown approximately four times per sampling session. The vehicle was driven as slowly as possible to optimize the spatial resolution of the data – the majority of the route was at rates of 5-25 mph (Figure 3-1). Images of the sampling vehicle taken during the field study are provided in Figure 3-2.

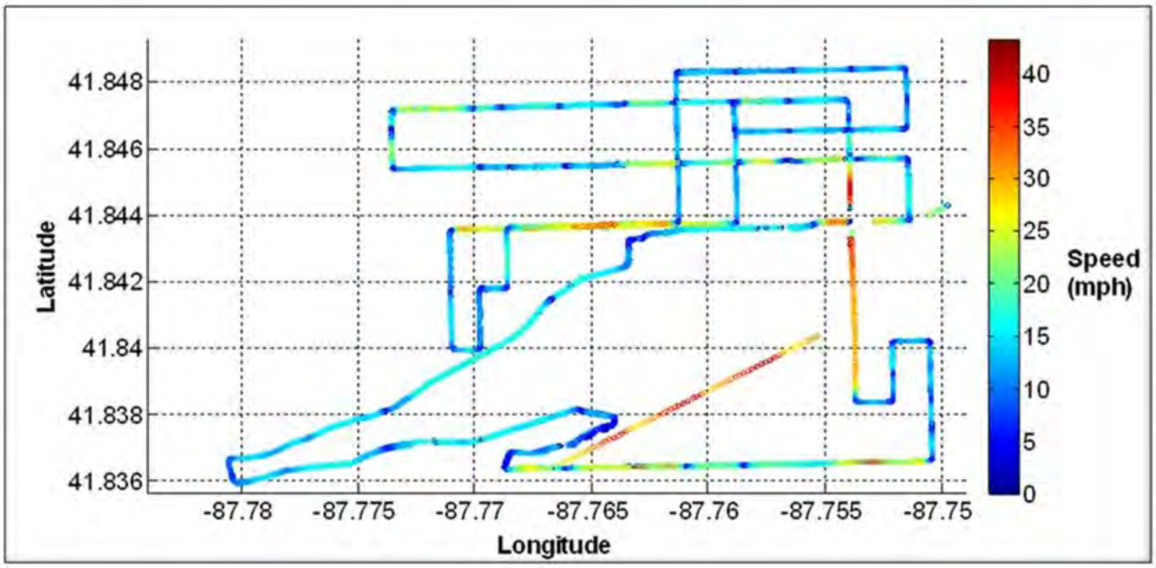

Figure 3-1. Driving speed recorded by the sampling vehicle's GPS

Figure 3-2. Picture of the instrumentation in the vehicle (left) and sampling vehicle in action (right) at the Cicero Rail Yard.

3.1.1.1. Quality assurance review and data completeness

As detailed in the Quality Assurance Project Plans (QAPP – Appendix A), pre-study checks and daily quality checks were conducted to verify the performance of air monitoring instruments. The pre-study checks included flow rate verification for all analyzers. The daily checks included:

- Gas-phase species (carbon monoxide, sulfur dioxide): within +/- 20% of a calibration gas
- Particulate matter measurements (black carbon, fine/coarse particulate matter, ultrafine particle counts): zero check by applying a high-efficiency particulate air (HEPA) capsule filter to the inlet and observing concentrations for several minutes.

QC checks were performed both before and after each sampling drive. An example analysis of QC check results is shown in Table 3-2 and the full set of QC checks is shown in Appendix B. As shown, CO checks were within 2% of the gas standard, whereas SO_2 failed to meet the quality objective of within 20%. While these two measurements were collected using the same instrument platform (dual quantum cascade laser), they were measured using independent lasers and the SO_2 laser performance appeared to have been affected by temperature control issues. The failure of the SO_2 laser was detected during the mobile monitoring field intensive and correspondence with the manufacturer occurred to diagnose the cause of the instrument failure. After several attempts to troubleshoot the laser during the study, it was determined that in-field repair of the SO_2 laser system was not possible and also could not remotely occur in a timely fashion. Considering the value of other pollutant measurements occurring and project budget/schedule constraints, the field study continued and due to failed quality checks, the SO_2 data were discarded for data analysis and will not be evaluated in this report. The CO data met data quality objectives and had 100% completeness (Table 3-3).

The daily zero checks on the particulate matter instruments served to determine whether or not the connections between the instrument and the inlet were airtight, as well as to indicate whether the instruments were responsive to a sudden and significant change in particulate concentrations. The HEPA filter is rated to remove 99.97% of particles above 0.3 µm in diameter. It is possible that smaller particles (<0.3 µm in diameter) have a higher penetration through the filter to the instrument. Therefore, the zero check was estimated by looking at particle counts for particles greater than 0.1 um in size for the EEPS. Black carbon particles, also often smaller than 0.3 µm, may have penetrated through the filter and caused non-zero readings during the zero check; however, the readings were still within the target of <20% of ambient (Table 3-2). The zero checks were calculated by averaging the time period of data collected when the filter was in place on the inlet and dividing this value by the ambient concentration measured over the 30 min either before or after the zero check, depending on whether the check occurred at the start or end of the daily sampling session. An example time series showing a zero check is provided in Figure 3-3. Overall, the particulate measurements had nearly 100% completeness, with only one instrument data flagged and removed for analysis (Aethalometer) for a single sampling session.

Table 3-2. Example QC metrics for the air monitoring instruments onboard the sampling vehicle

Sampling Date	Aeth-Zero (filtered/ ambient * 100%)	EEPS-Zero (filtered/ ambient * 100%)	APS-Zero (HEPA-filtered/ ambient * 100%)	CO (measured/cal* 100%)	SO_2 (measured/cal *100%)
11/3/2010	2%	1%	0%	99%	69%
11/4/2010	9%	0%	0%	98%	67%
11/5/2010	7%	0%	0%	98%	68%

Table 3-3. Data completeness

Measurement	Completeness (#/23 sessions)
Quantum Cascade Laser - Carbon monoxide	100%
Quantum Cascade Laser - Sulfur dioxide	0%
Aethalometer - Black carbon	96%
Aerodynamic Particle Sizer – Fine/coarse particle counts	100%
Engine Exhaust Particle Sizer – Ultrafine particle counts	100%
Global positioning system – Longitude and latitude	100%
Ultrasonic anemometer – Wind speed, wind direction, temperature	100%

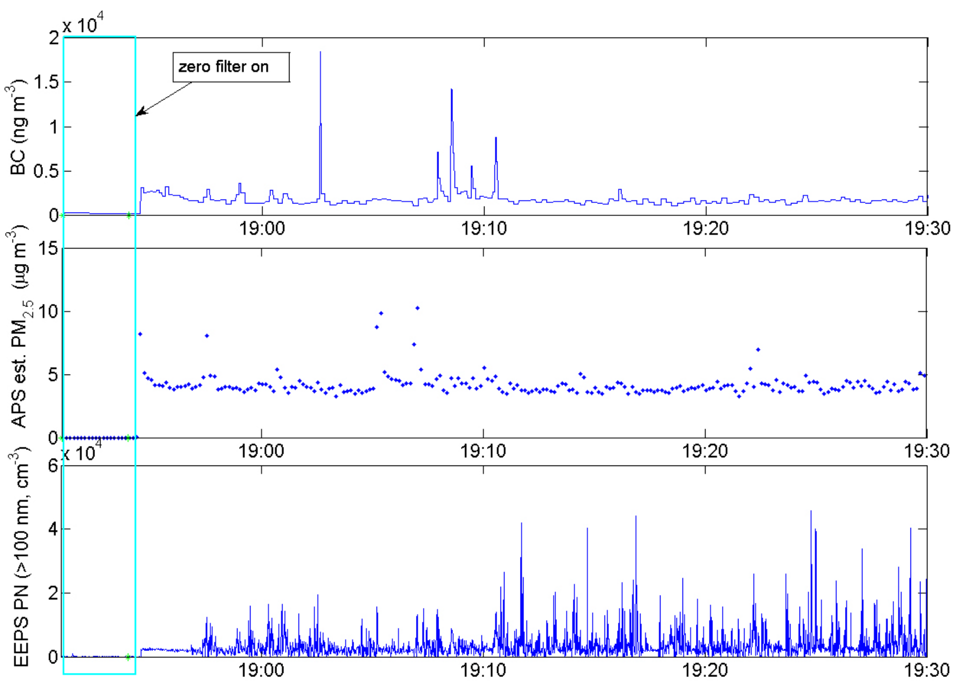

Figure 3-3. Example particulate time series during the addition of a zero filter and after the filter is removed. The filter-on period is marked with the light blue box.

Additional measurements used in the analysis include the global positioning system to determine real-time location as well as an ultrasonic anemometer to measure meteorological parameters. As discussed in the QAPP, the GPS data were verified against the driver's observations (e.g., start time and stop time from a particular location) and the planned driving route. The wind sensors were aligned properly and compared against operator observations (e.g., observation of strong winds from the South matching measurements).

A period of wind data collected on the rooftop (24 hr period from 10/26/2010 15:00-10/27/2010 15:00) was compared with a nearby meteorological station at Midway Airport, located approximately 4 miles south of the rail yard. The wind data at Midway Airport were collected at 1.5 m above ground at hourly intervals, while the study meteorological sensors collected data on top of a 3-story building (~12 m above ground). As shown in Figure 3-4, both sensors agreed with the general range of wind speed and orientation of wind direction. However, the much more rapid sampling of the sensor used in this study (10 s data), provided approximately 8600 data points versus 24 data points collected at Mid-way, which explains the better defined wind rose in Figure 3-4.

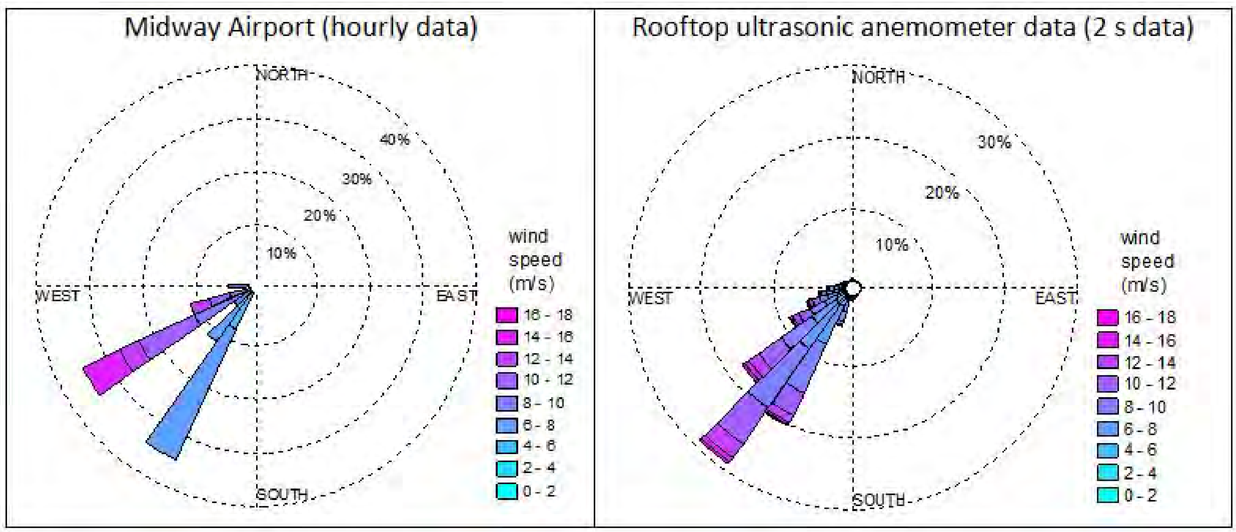

Figure 3-4. Comparison of wind measurements collected at Midway airport (left) with wind data collected on top of a BNSF building (right).

Another comparison was made between the ultrasonic anemometer data collected during this study and data from the Region 5 air monitoring station, situated near the northwest corner of the rail yard; the Region's sensors were placed 2 m above the ground. The Region 5 station collected wind speed and wind direction data at 5 min increments. Wind roses were generated for a 24 hour time period (11/17/2010 00:00 – 11/18/2010 00:00) using each station's data. As shown in Figure 3-5, it can be seen that the very high data rate collected using the ultrasonic anemometer yielded a broader distribution of observations. However, both sets of data are in agreement in terms of general wind direction and wind speed.

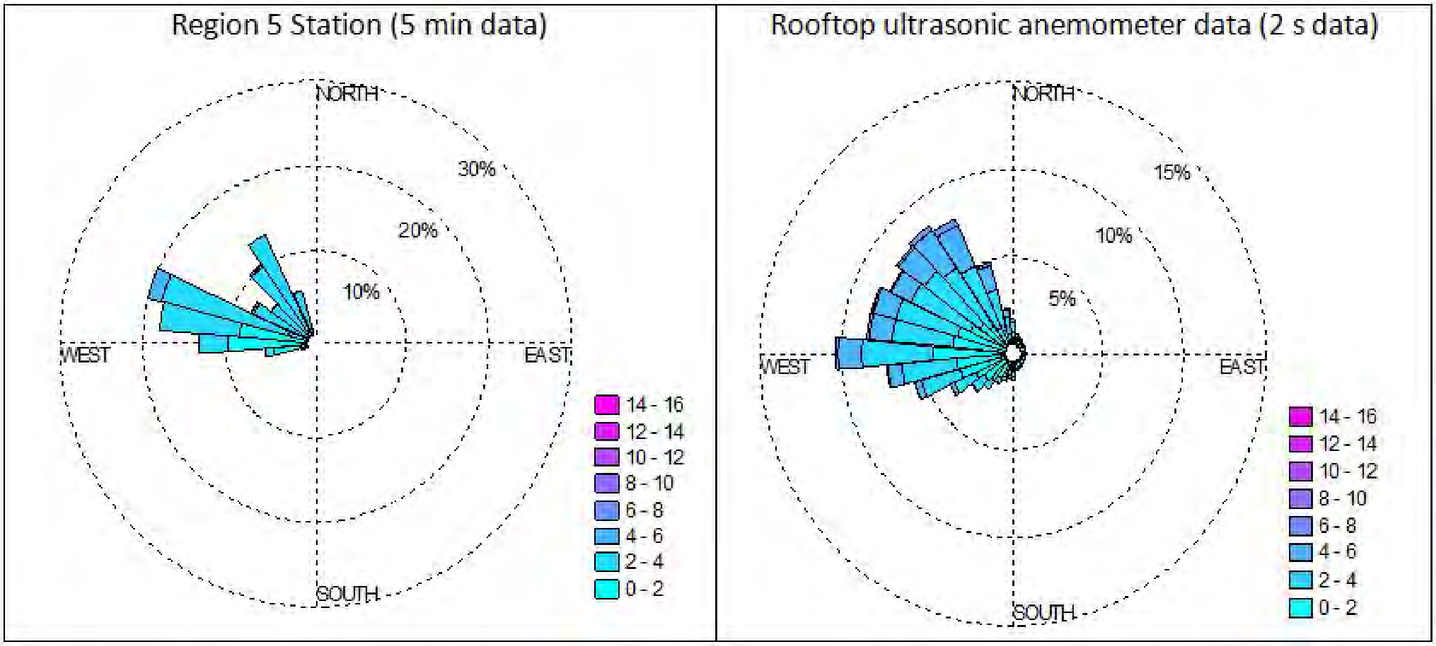

Figure 3-5. Comparison of wind measurements collected at the stationary monitoring location (left) with wind data collected on top of a BNSF building (right).

3.1.1.2. Sampling sessions in the context of meteorology

Local meteorology and rail yard emissions activity are anticipated to be critical factors driving the degree of local air quality impact associated with proximity to a rail yard. Average wind speed and wind direction were calculated for each mobile sampling session, from the point when the vehicle began driving to when stationary sampling was completed (Table 3-4). Wind roses were generated on 15 min intervals and for the entire session for each sampling time frame (Appendix C). Wind direction standard deviation was calculated using equations (5)-(6), below (Yamartino 1984).

$$\epsilon^2 = 1 - \left(\frac{1}{n}\sum_{\mathrm{i=0}}^{\mathrm{n}} \sin^2 \theta_{\mathrm{i}} + \frac{1}{n}\sum_{\mathrm{i=0}}^{\mathrm{n}} \cos^2 \theta_{\mathrm{i}}\right) \quad \text{(eq 5)}$$

$$\sigma_\theta = \sin^{-1}(\varepsilon)\,[1.0 + 0.1547\varepsilon^3] \quad \text{(eq 6)}$$

Table 3-4. Wind characteristics during mobile sampling sessions

Session	Start time	End time	U, scalar (m/s)	U, vector (m/s)	θ^a (deg)	$\sigma_\theta{}^b$ (deg)	Category
1	10/27/2010 9:16	10/27/2010 13:05	8.0	7.4	236	33	SW
2	10/28/2010 18:53	10/29/2010 2:00	3.1	2.5	294	41	NW
3	10/29/2010 18:45	10/29/2010 23:45	4.6	4.5	208	9	SW
4	10/30/2010 8:52	10/30/2010 13:15	6.4	5.7	232	32	SW
5	10/31/2010 3:52	10/31/2010 8:25	2.4	2.2	352	18	N
6	11/1/2010 19:18	11/2/2010 0:10	1.9	1.7	70	13	NE
7	11/3/2010 11:50	11/3/2010 16:25	4.0	3.6	230	29	SW
8	11/4/2010 4:10	11/4/2010 8:42	4.1	3.9	327	14	NW
9	11/5/2010 9:00	11/5/2010 14:30	5.1	4.7	338	22	NW
10	11/6/2010 3:52	11/6/2010 8:15	1.8	1.7	309	17	NW
11	11/7/2010 19:40	11/7/2010 23:56	1.9	1.7	184	11	S
12	11/8/2010 19:00	11/9/2010 0:10	2.1	2.0	175	16	S
13	11/10/2010 9:10	11/10/2010 14:00	3.6	3.3	164	25	SE
14	11/11/2010 4:00	11/11/2010 9:40	2.2	2.1	184	21	S
15	11/12/2010 10:00	11/12/2010 15:05	3.1	2.8	44	24	NE
16	11/13/2010 4:00	11/13/2010 8:40	2.8	2.6	137	21	SE
17	11/15/2010 19:30	11/16/2010 1:05	2.7	2.5	192	17	S
18	11/16/2010 18:55	11/17/2010 1:30	2.0	1.9	304	21	NW
19	11/17/2010 9:45	11/17/2010 14:37	2.9	2.3	280	48	W
20	11/18/2010 3:58	11/18/2010 8:42	2.7	2.6	321	16	NW
21	11/19/2010 3:52	11/19/2010 8:30	3.7	3.5	194	21	S
22	11/20/2010 3:57	11/20/2010 9:49	2.2	2.1	358	19	N
23	11/21/2010 19:02	11/22/2010 0:09	8.4	8.3	212	9	SW

[a]Vector mean wind direction
[b]Standard deviation of the wind direction, calculated according to eq. (5).

Mean wind speeds ranged from moderate (1-2 m/s) to high (5-8 m/s) throughout the course of sampling. No sessions were considered to have calm conditions, indicated by low mean wind speeds (<1 m/s). Wind direction standard deviation is a useful parameter to indicate the degree of change in wind direction over the course of sampling. Of the twenty-three sampling sessions, nineteen of the sessions had very low variability in wind direction (<30 deg) while the remaining four sessions had moderate variability (30-48 deg).

Visuals of mean wind speed and direction per session, organized by sampling time of day, are provided in Figures 3-6 (early morning sessions, Figure 3-7 (mid-day sessions), and Figure 3-8 (evening sessions). The sampling route had been set to cover the neighboring residential areas located to the North of the rail yard thoroughly, based on historical wind data indicating prevailing wind direction from the southwest. Of the cases sampled, approximately half of the sessions had winds from the SW/S/SE.

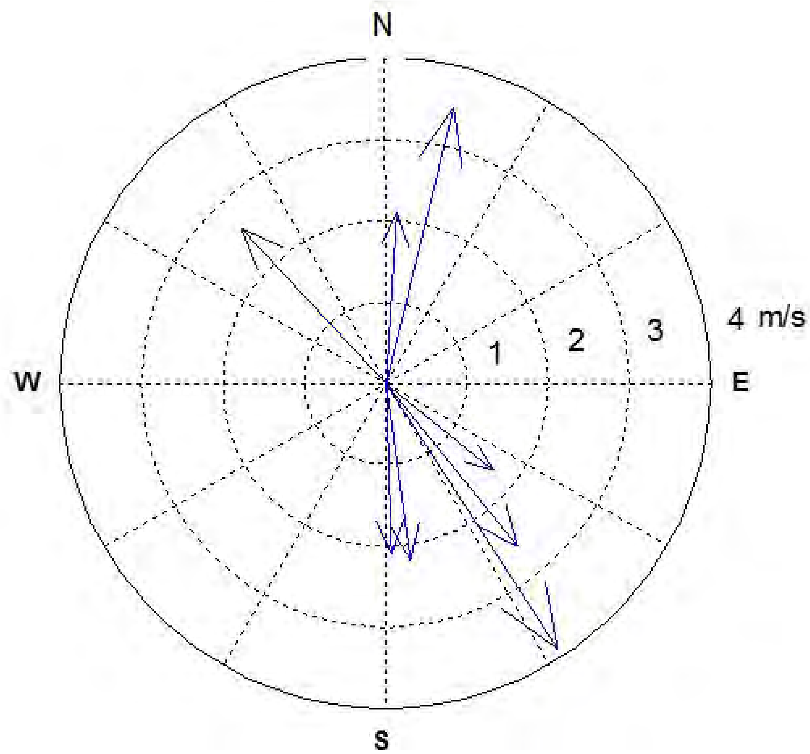

Figure 3-6. Morning session wind trends – arrow orientation indicates wind direction (e.g., pointing towards N means wind from the S) and extent indicates mean wind speed. Sessions shown are #5, 8, 10, 14, 16, 20, 21, and 22.

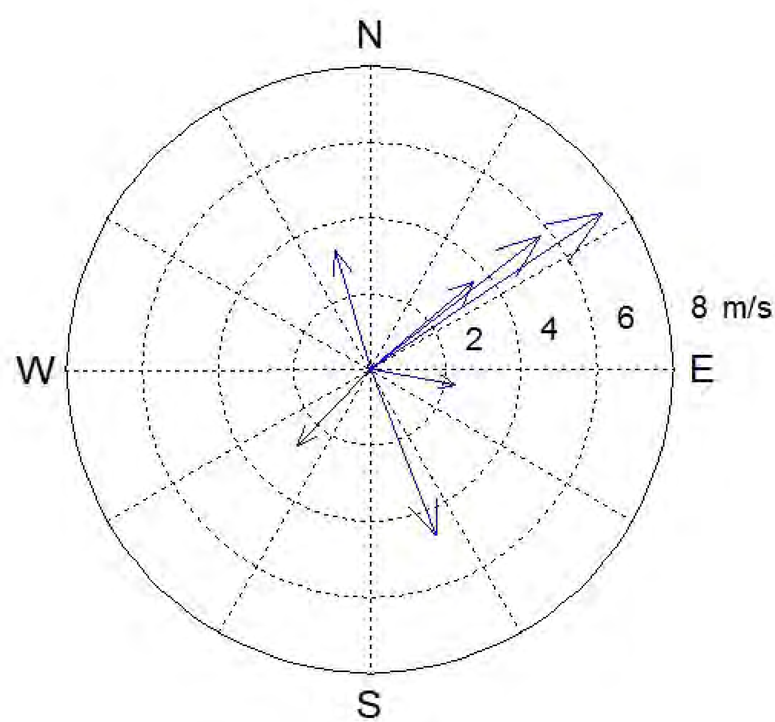

Figure 3-7. Mid-day session wind trends – arrow orientation indicates wind direction (e.g., pointing towards N means wind from the S) and extent indicates mean wind speed. Sessions shown are 1, 4, 7, 9, 13, 15, and 19.

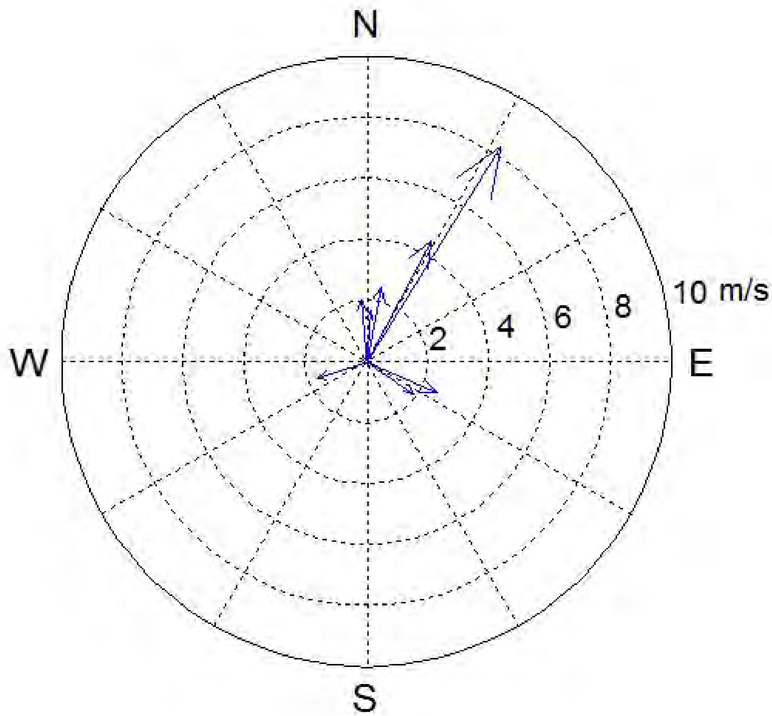

Figure 3-8. Evening session wind trends – arrow orientation indicates wind direction (e.g., pointing towards N means wind from the S) and extent indicates mean wind speed. Sessions shown are #2, 3, 6, 11, 12, 17, 18, and 23.

3.1.1.3. Sampling sessions in the context of rail yard activity

The BNSF staff at the Cicero Rail Yard arranged for automatic reports of the minute-by-minute container lifts ("Lift counts") and trucks passing through the gate ("Gate counts") to be sent daily by email to EPA Office of Research and Development. These daily data files were concatenated into a longer time series and used as the basis for calculating hourly and daily totals. Given that the mobile sampling sessions represented only a several hour window of time on any given day, it is of interest to understand the rail yard activity both by day of the week and time of day. Figure 3-9 shows the daily lift and gate counts associated with the sampling window (October 27, 2010 to November 22, 2010). In addition, Figure 3-10 shows the average diurnal rail yard activity trends for each day of the week over the course of the study period.

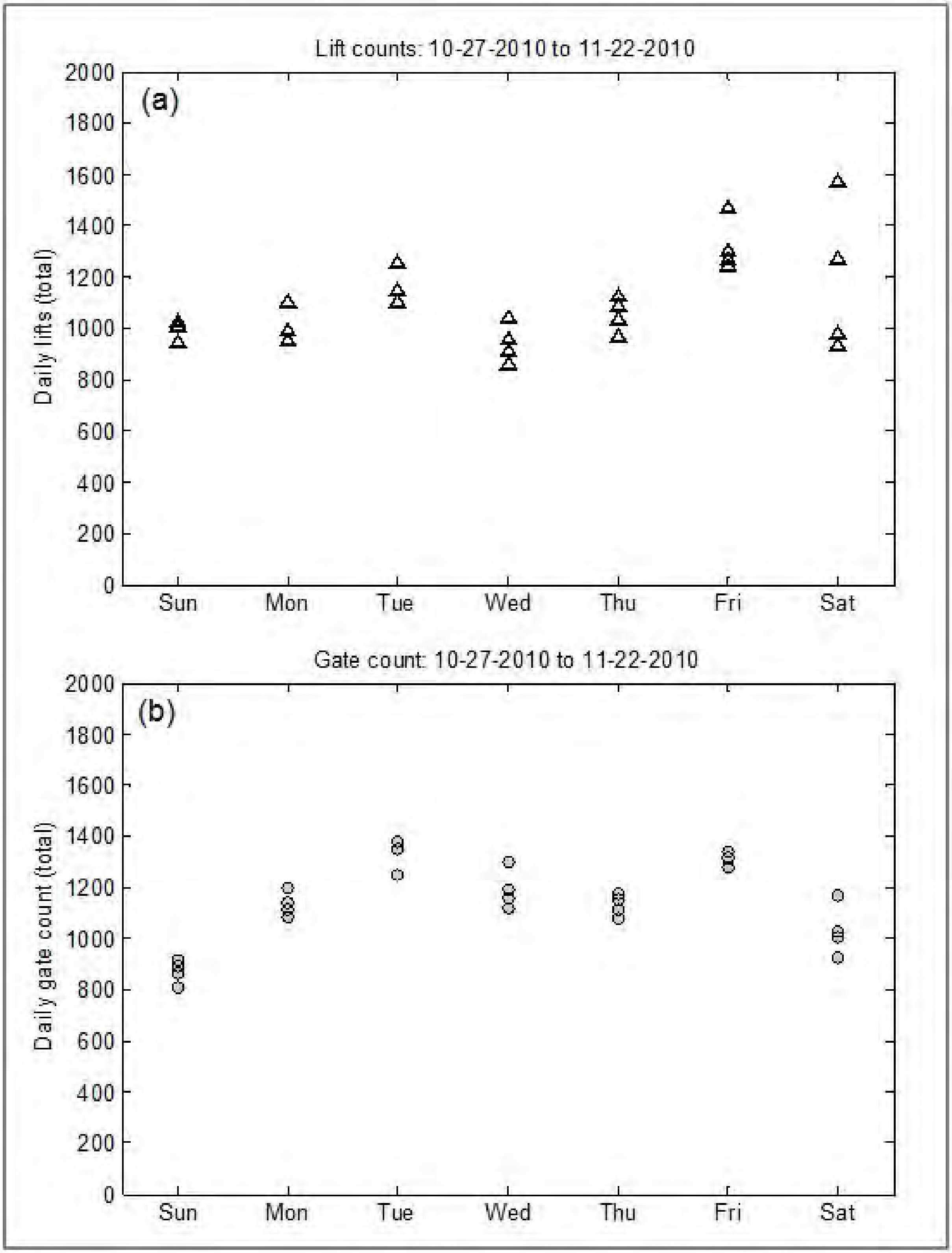

Figure 3-9. Daily total crane container lifts (a) and truck counts at the gate (b) during the mobile sampling period of October 27, 2010 through November, 22, 2010.

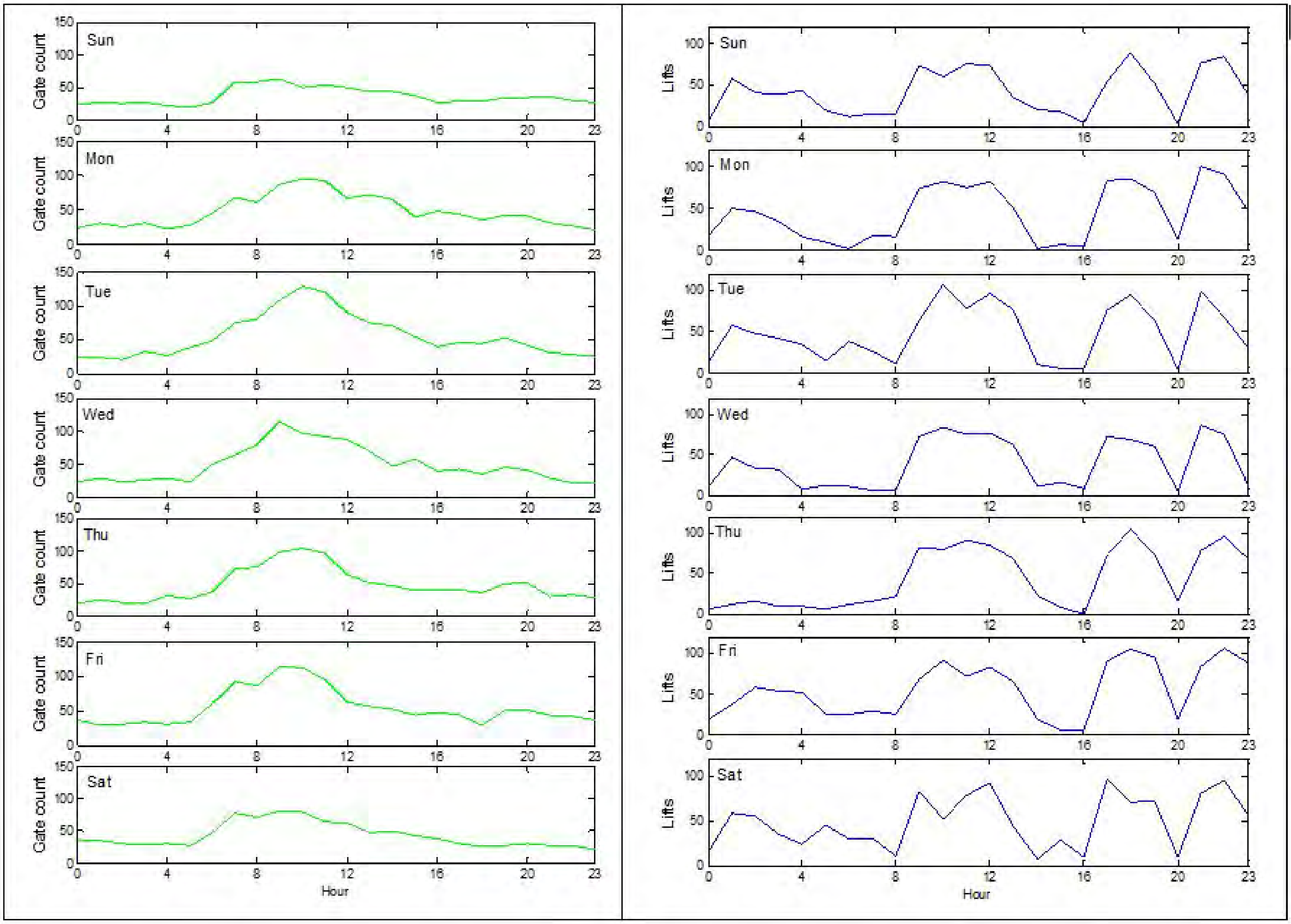

Figure 3-10. Average gate counts (left) and lift counts (right) by day of week and hour of day during the study period of October 27, 2010 through November, 22, 2010.

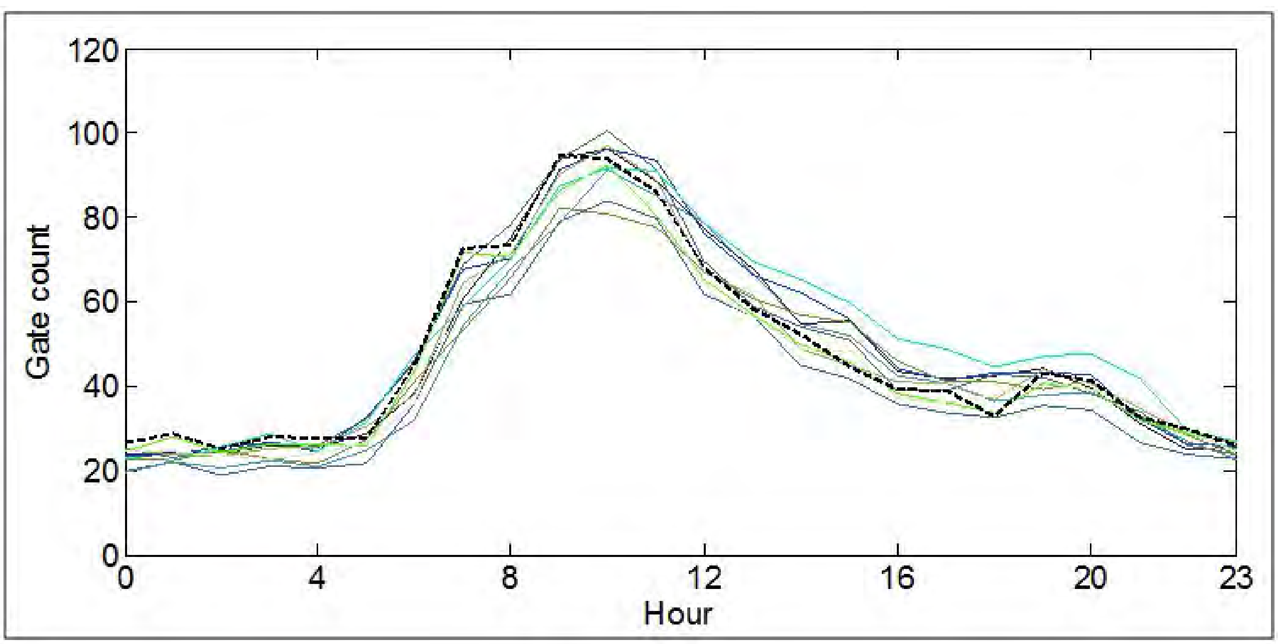

Figure 3-11. Comparison of mean diurnal gate activity during the study (heavier dashed black line) with monthly average diurnal trends from October 2010 to July 2011 (10 months) shown in thin colored lines.

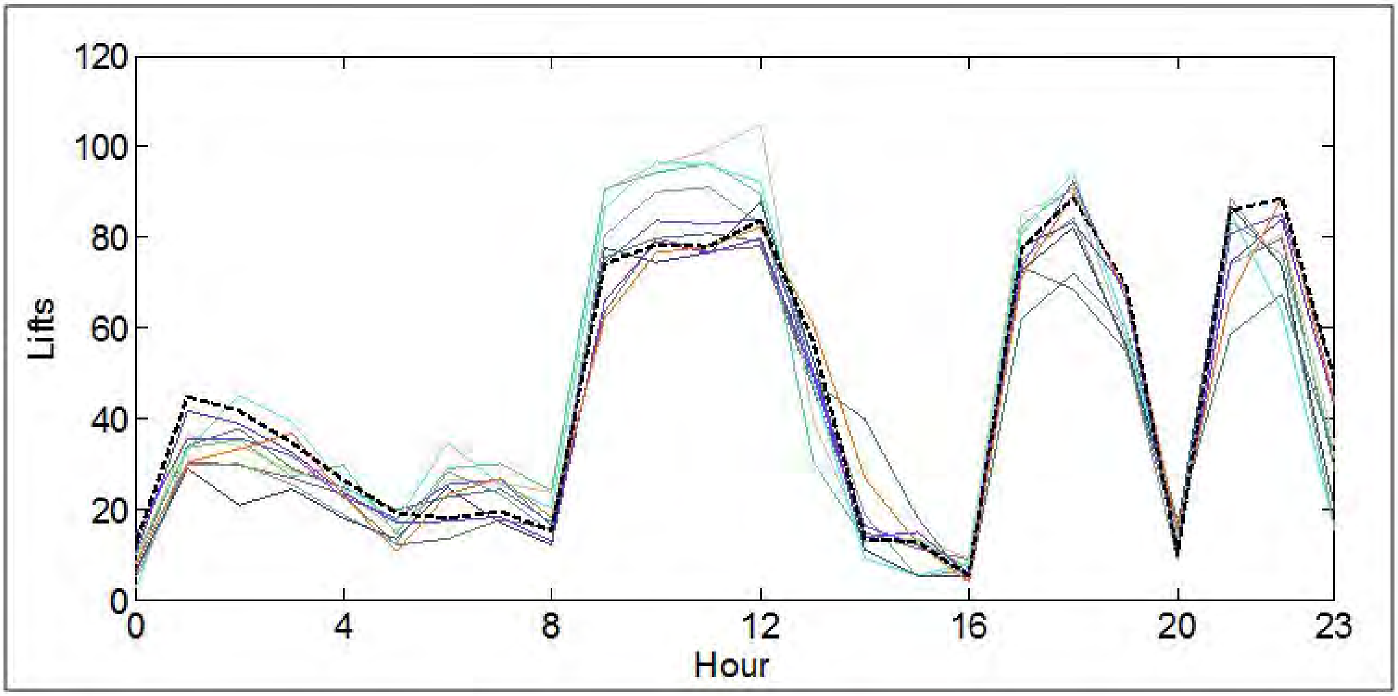

Figure 3-12. Comparison of mean diurnal lift activity during the study (heavier dashed black line) with monthly average diurnal trends from October 2010 to July 2011 (10 months) shown in thin colored lines.

3.1.1.4. Mobile / Stationary data comparison

During the course of the mobile sampling campaign, the mobile sampling vehicle would routinely park for an hour at the stationary monitoring location and continue sampling with all air monitoring instrumentation. With the stationary sampling shelter initiating data collection in mid-November, several sessions towards the end of the mobile sampling campaign are candidates for inter-comparison of the two data sets. The sampling location is shown in Figure 2-6 and is estimated at approximately 50 m from the nearest set of train tracks.

An important caveat of this comparison is that the mobile and stationary instruments pulled samples from different locations both horizontally and vertically and therefore may experience different concentrations for narrow plumes advected from the near-field. In addition, the measurements that overlap between the two data series – BC, CO, and $PM_{2.5}$ – were not sampled using identical sampling techniques. As the mobile vehicle requires high time-resolution sampling (1-10 second data) and portable instrumentation, BC was collected using a high-precision portable Aethalometer, CO was measured using a quantum cascade laser system, and $PM_{2.5}$ is *estimated* from particle count data collected using an Aerodynamic Particle Sizer. Meanwhile, the stationary site measured concentrations at slower timeframes (5 minutes) – BC was measured using a rackmount Aethalometer, CO was measured using an NDIR-type rackmount analyzer (FRM), and $PM_{2.5}$ was measured by beta attenuation (FEM) with a size-selective inlet. Despite these caveats, the comparison may still yield helpful information in addressing the questions below:

- Comparing the real-time data (seconds) collected onboard the mobile car with the 5-minute data resolution of the stationary monitoring station, are the 5-minute data of sufficient resolution to isolate periods affected by nearby train emissions?
- How do like-measurements generally compare?

To evaluate these questions, a 5-day series of sampling sessions where the mobile and stationary data sets overlapped were assessed (11/17 – 11/21/2012) for a general comparison between the measurements. Within this window of time, the sampling sessions with wind flow from the South – advecting air from the rail yard area – were studied to determine how near-field train emissions were captured in the high time-resolution versus 5-minute data series. The comparison of each sampling session is shown in Appendix B. Shown here is a case study of 11/19/2011 7:00-9:00 AM, selected due to being a period with winds advecting rail yard / passing train emissions northward towards the sampling station (Figure 3-13), as well as being a period of time with anticipated frequent train traffic. The parallel time series of data for BC, CO, and $PM_{2.5}$ is shown in Figure 3-14.

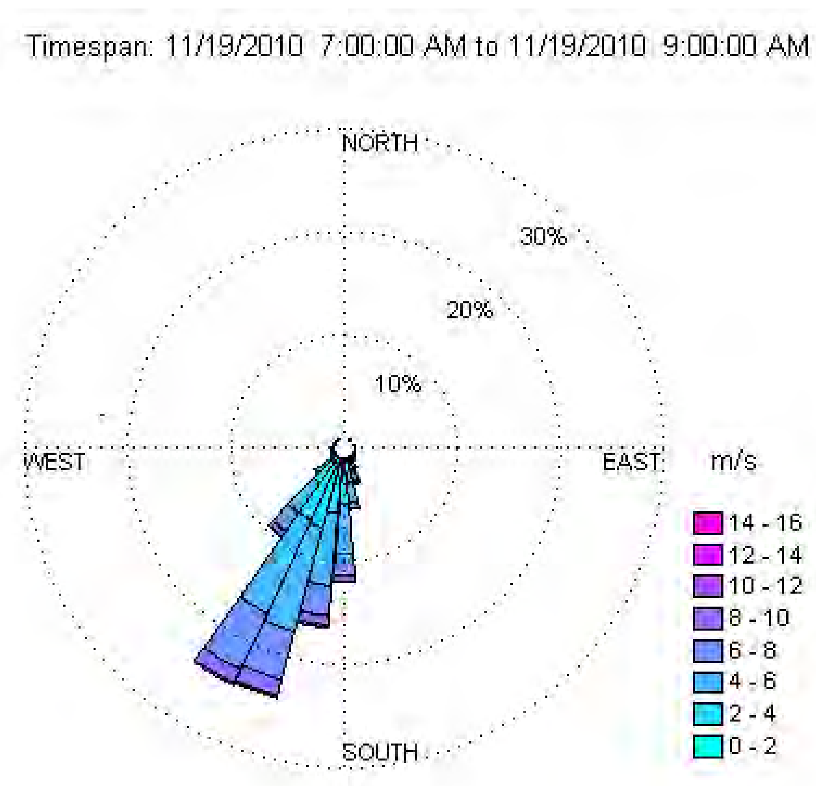

Figure 3-13. Wind rose during a period of mobile and stationary site side-by-side sampling.

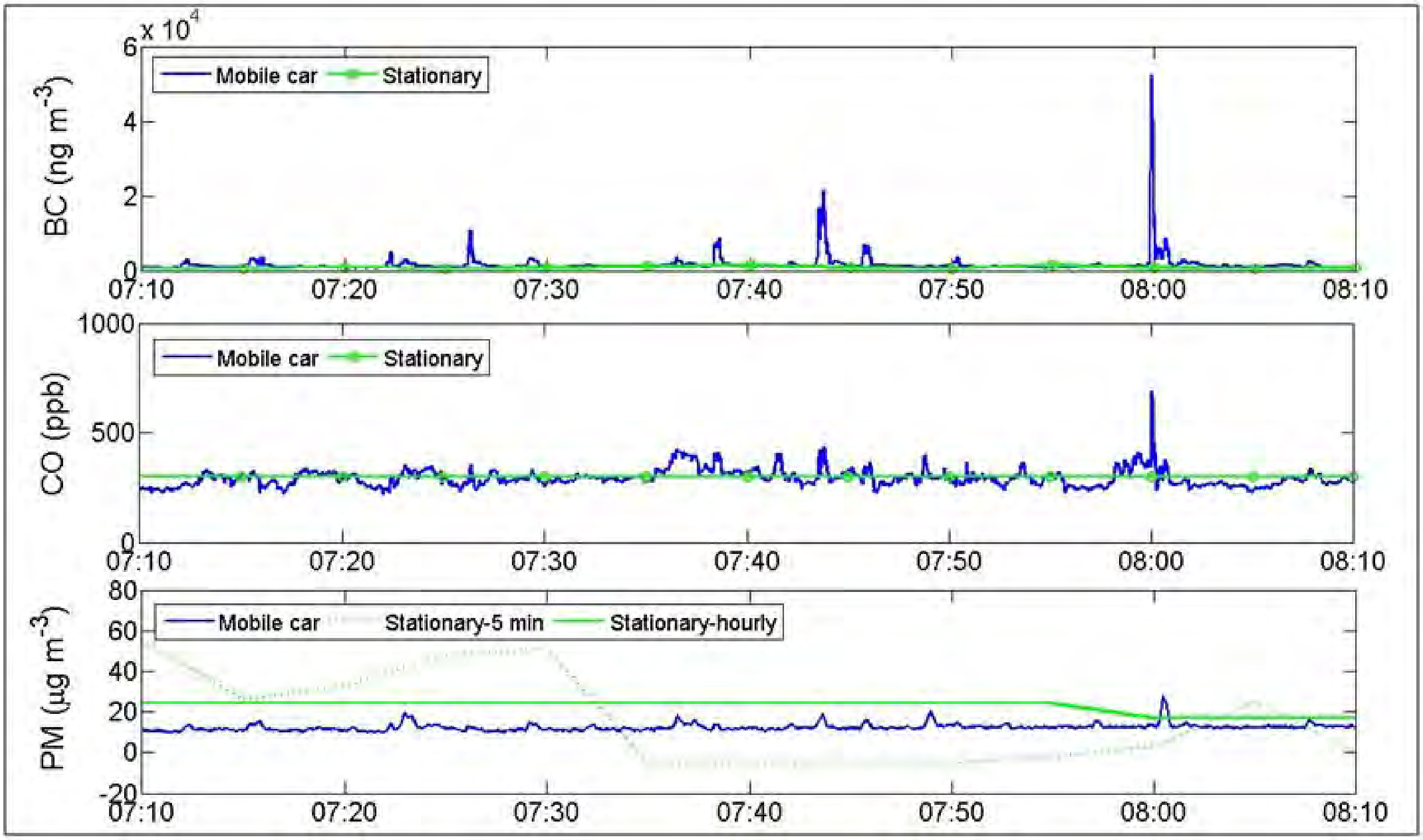

Figure 3-14. Parallel time series of concentrations for the stationary monitoring site (green) reporting raw data at 5- minute intervals and the real-time data collected onboard the mobile monitoring vehicle (blue). Note: Lower limit of detection for the stationary CO analyzer is 300 ppb.

Of the overlapping measurements for the mobile and stationary data sets (CO, PM, and BC), the real-time BC data appear to have the highest sensitivity to fresh exhaust impacts presumably related to the upwind rail / rail yard sources. For example, at approximately 0800 (Figure 3-14), BC increases by a factor of ~45. Meanwhile, for this same episode, CO and $PM_{2.5}$ increase by only a factor of ~2, which is related to the relative abundance of these species in fresh emissions as well as existing background levels. In addition, for this same spike, UFPs measured on the mobile platform increase by a factor of ~11. Therefore, of the suite of continuous measurements collected at the stationary site that overlap with the mobile vehicle measurements, BC has the highest likelihood of success as an indicator of train events. However, as shown in Figure 3-15, the very short duration of these spikes – approximately 10 seconds - translate into only a marginal change in concentration when the real-time data are averaged to five minutes.

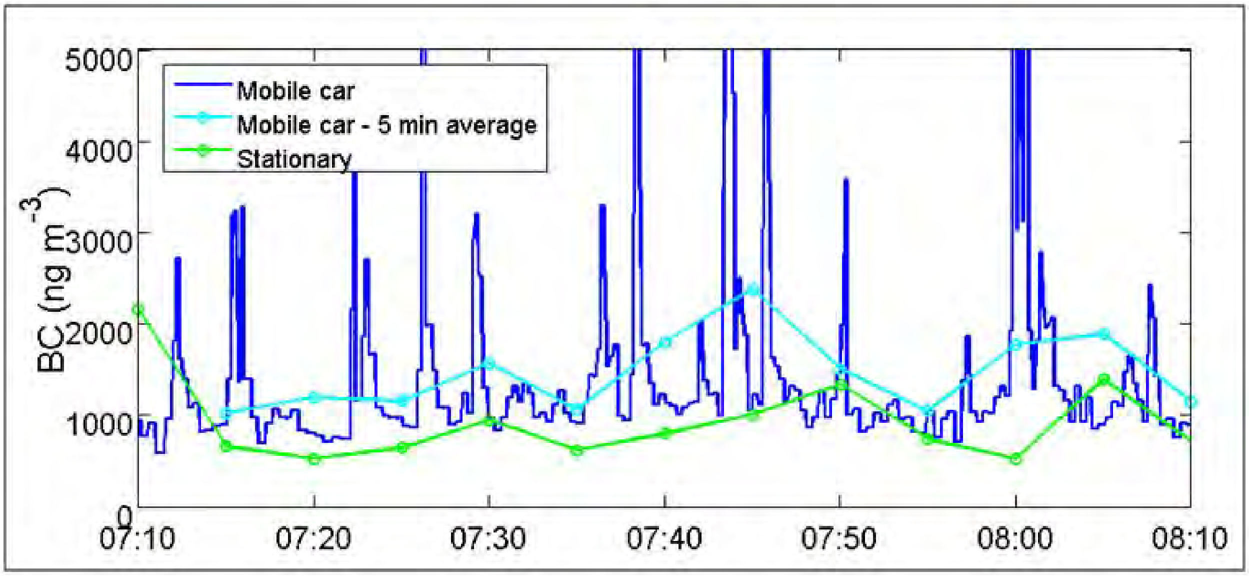

Figure 3-15. Black carbon time series for the mobile car (real-time in dark blue, 5-minute average in light blue) and 5-minute stationary data (green).

Regarding the comparison of the two sets of measurements for BC, $PM_{2.5}$, and CO, the time series shown in Figure 3-14 and Appendix B indicate that BC data generally track closely when averaged at the same time rate; however the comparison for the other two species is challenged by differences in instrumentation. In the example shown in Figure 3-15, BC concentrations for this particular hour were generally higher measured at the mobile vehicle location relative to the stationary site – one possible reason for this is the difference in vertical and horizontal sampling locations for the two monitors relative to a near-field emissions plume. For $PM_{2.5}$, the beta attenuation measurement approach used at the stationary site requires sufficient particle loading over time to reach a sufficient signal to noise ratio. As shown in Figure 3-14, at a 5-minute averaging rate the $PM_{2.5}$ BAM signal oscillates above and below zero, while at an hourly averaging period the signal appears to settle on a positive value. However, as shown in Appendix B, the hourly data still had negative values for one intercomparison period (11/20), indicating even longer averaging of those data is required at lower concentration periods. Given that the intercomparison period between the mobile vehicle and the stationary site were only in increments of 1-2 hours, the ability to compare the two PM data streams is limited. However the hourly data and the mobile vehicle Aerodynamic Particle Sizer data are within a similar general range of concentrations. For the comparison of the CO data, the CO analyzer onboard the electric car has a sub-ppb level detection limit, whereas the CO analyzer at the stationary site has a 300 ppb lower detection limit. For most of the comparisons, the CO stationary site analyzer was recording at or below the limit of detection, which generally agreed with the concentration range observed by the Quantum Cascade Laser onboard the mobile vehicle for these time periods.

3.1.2. Assessment of local air quality impact through mobile monitoring

For the purposes of this report, mobile monitoring data were analyzed to address several specific questions relating to near-source air quality – (1) Are air pollution levels in residential areas downwind of the rail yard area significantly higher than a similar environment that is upwind of the rail yard? (2) If so, how does this impact vary with wind speed, time of day, and distance from the rail yard?

For the mobile monitoring analyses to follow, the term "rail yard area" is defined as any emissions from within the rail yard boundary, which may include commuter and freight trains, switcher locomotives, truck emissions, and other emissions within the yard area, as well as potential boundary traffic on two roads immediately adjacent to the yard. One roadway passes immediately south of the yard (Ogden Rd., 22,000 vehicles, annual average daily traffic) and also lies between the urban background area to the south and the residential neighborhoods to the north. Another roadway (26th Street, 9600 vehicles, annual average daily traffic) passes on the immediate north side of the rail yard between the rail yard and three of the four neighborhoods of interest (NT2-NT4). These roadways are generally low in terms of traffic volume – 150,000 vehicles annual average daily traffic is the typical lower threshold for a major highway from the current perspective of local air pollution impact – however, traffic along these roadways may contribute to the measured upwind/downwind signals, particularly during higher traffic portions of the day. The fraction of traffic along these roads associated with the Cicero rail yard is unknown at this time.

3.1.2.1. Downwind and upwind comparison

With the four neighborhood transects (NT1, NT2, NT3, NT4) shown in Figure 2-2 located on the northern side of the rail yard, time periods of wind from the south would be considered as downwind of the rail yard for those areas and periods of wind from the north would be considered as upwind of the rail yard. The sampling sessions were first organized by time of day into the three deployment periods – early morning (~3-7 AM), late morning to afternoon (~10 AM – 1 PM), and evening (~7-10 PM) – followed by categorization by wind trends. This organization allows both diurnal and wind direction effects to be studied. One important diurnal trend that can affect local air quality includes the atmospheric mixing height, whereby the solar heating of the earth's surface during the daytime can enhance upward mixing of air and lower air pollution levels and the reverse is true during cooler late evening and early morning periods. A second important diurnal trend is source emissions activity – both sources internal to the rail yard as shown in Figures 3-10, 3-11, and 3-12, and sources external to the rail yard (e.g., street traffic).

Early Morning Periods

Three mobile sessions (#14, #16, #21) captured trends during winds from the south and five mobile sessions (#5, #8, #10, #20, and #22) captured trends during winds from the north during the very early morning time period (4-7 AM). An example of a downwind period is shown in Figure 3-16, below. The primary focus of this analysis is to determine whether there is a statistically significant exceedance in downwind air pollution levels relative to the general urban background. Therefore, Figure 3-16 shows specifically the net concentration difference between the downwind measured (in 50 m spatial increments) and background levels for areas where the comparison between downwind measurements and the background were determined to be significantly different (refer to section 2.3.3). Areas outside of these specific neighborhood transects, calculated at distances up to 300 m from the estimated rail yard boundary, and areas without statistically significant differences in downwind concentrations are left as black points along the mobile route.

The full series of mobile driving maps for each session is provided in Appendix D. Each map can be viewed to understand both the location and relative concentration difference for a particular pollutant. As shown in the example session (Figure 3-16), black carbon appears to be the most sensitive indicator of downwind impact and has exceedances over background levels along all four neighborhood transects, which is in-line with the observations of diesel emission plumes discussed in section 3.1.1.4. Meanwhile, carbon monoxide and $PM_{2.5}$ do not show any significant difference in comparison to the background for this specific case, and PM_{10} and UFPs show only several isolated areas with an exceedance.

To summarize the broad trends among the eight sampling sessions (three downwind, five upwind), the four neighborhood areas were considered as twenty-four 50 m segments (0-50, 50-100, 100-150, 150-200, 200-250, and 250-300 m) and for each species the fraction of segments with exceedances was calculated. This summary for the early morning period is provided in Figure 3-17.

During the very early morning period, BC appears to have the strongest upwind/downwind signal of the various pollutants measured, with nearly three-quarters of the downwind areas indicating statistically significant excess BC levels above the background. For the three sessions measured, this translated to an absolute excess concentration of 0.3-0.6 $\mu g\ m^{-3}$ BC. This excess translated to the downwind neighborhood areas having 30-40% higher total BC concentrations relative to the urban background (background ranged from 0.8-2.0 $\mu g\ m^{-3}$ BC). The other measurements shown – UFPs, CO, $PM_{2.5}$, and PM_{10} – do not show the same upwind/downwind trend of excess levels. It is important to emphasize that this analysis is requiring that the concentration difference meet the test of statistical significance – one limitation to point out regarding the $PM_{2.5}$ and PM_{10} data is that both were collected at slower time intervals (10 seconds) than the other measurements, therefore the lower number of data points per area weakens the spatial statistical strength of those two data sets. This limitation may be partially overcome by grouping the neighborhood transect PM data into one concentration versus distance evaluation, but these further analyses are not currently explored in this report.

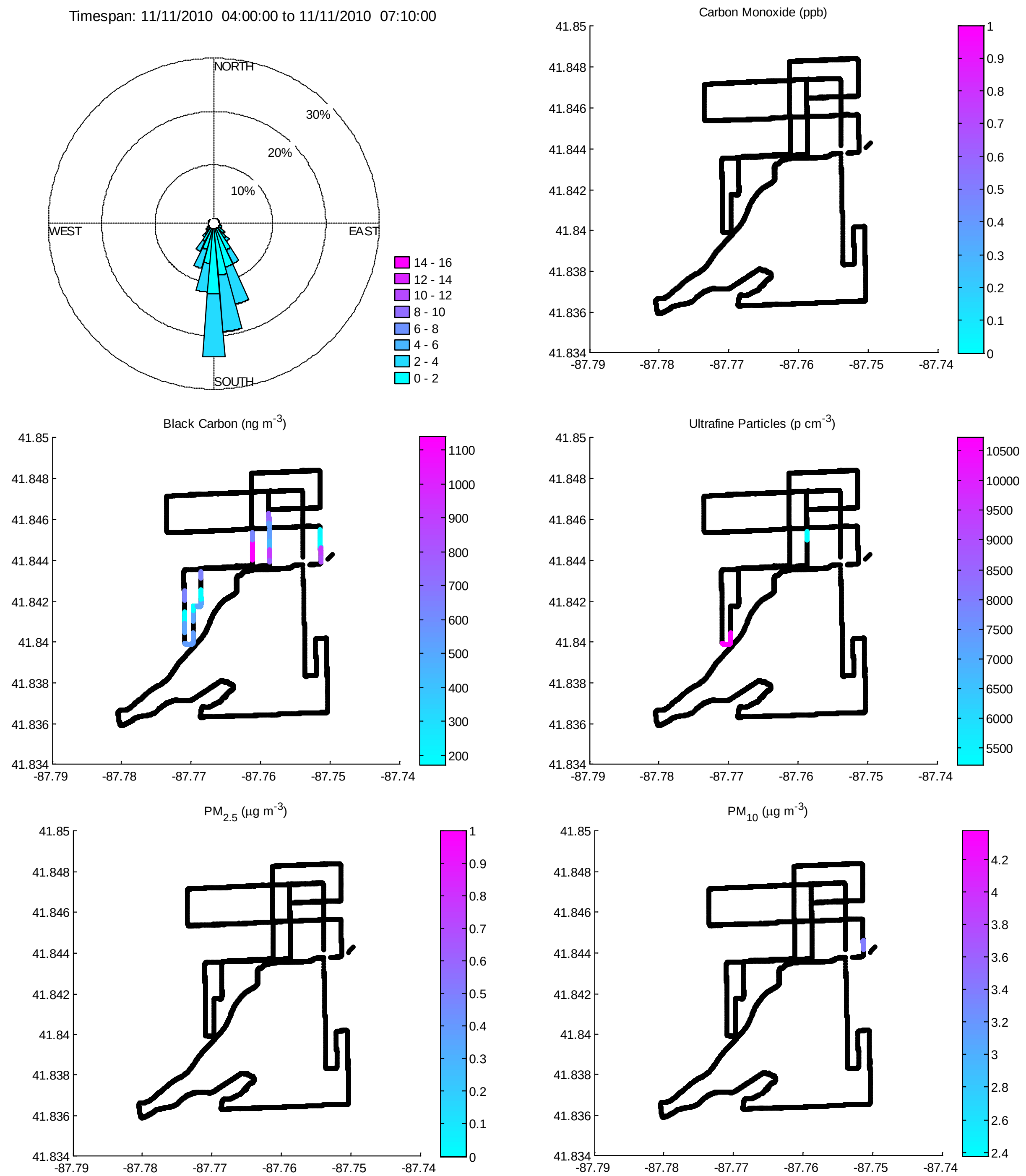

Figure 3-16. Statistically significant excess concentrations above the background for neighborhood transects NT1-NT4, calculated for areas up to 300 m from the rail yard.

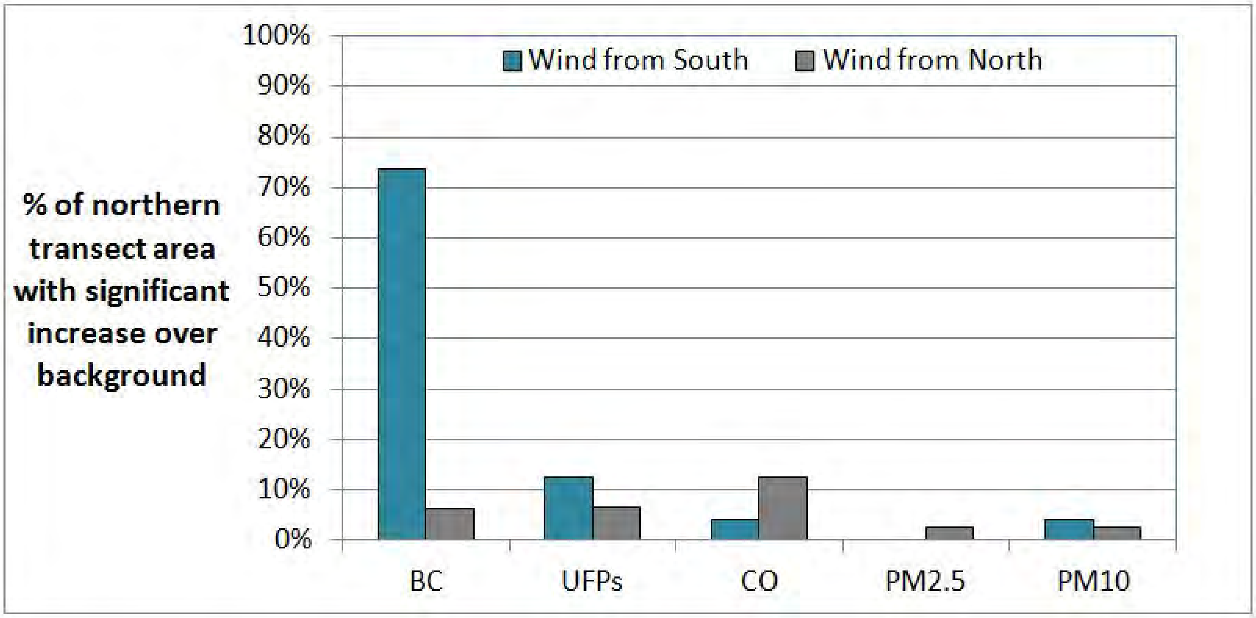

Figure 3-17. Fraction of neighborhood areas (NT1-NT4), in 50 m increments up to 300 m from the rail yard, with significant increase in pollutant levels above the background during early morning sessions (~4-7 AM).

Mid-day Periods

Five sampling sessions were conducted during the late morning to early afternoon and had a clear upwind (two sessions) or downwind (three sessions) meteorological trend. Of these five sessions, one upwind session was excluded from analysis as the operator was able to accomplish only two driving laps (instead of the usual four laps) due to instrumentation troubleshooting. During these sampling periods, the vehicle operator noted "very high" side road traffic including school buses during this time frame.

As observed in Figure 3-18, during periods of wind from the South, the northern neighborhoods experienced a broad (75% of the 50 m increments) increase in BC relative to background areas, however other pollutants measured had sporadic rather than consistent increases above the background. Excess BC levels ranged from 0.3-1.2 μg m^{-3}, equivalent to a 62-101% increase over the background (the background ranged from 0.3-2.0 μg m^{-3}). During this time period, it is anticipated that the rail yard would have higher emissions according to diurnal activity data (Figure 3-11 and Figure 3-12) but is also a timeframe of greater atmospheric mixing. In addition, what is unique to this mid-day time period is that under periods of wind from the North, these same neighborhoods to the north of the rail yard indicated elevated BC levels relative to the background for approximately 45% of the neighborhood areas. This indicates an emissions source located north of the neighborhoods, likely heavier side road traffic during this time of day. Given that one roadway passes south of NT2-NT4 (Figure 3-2), these results suggest that side road traffic may contribute to excess BC levels in addition to rail yard emissions during periods of wind from the South, and the contribution from the rail yard cannot be as distinctly isolated in the mid-day timeframe.

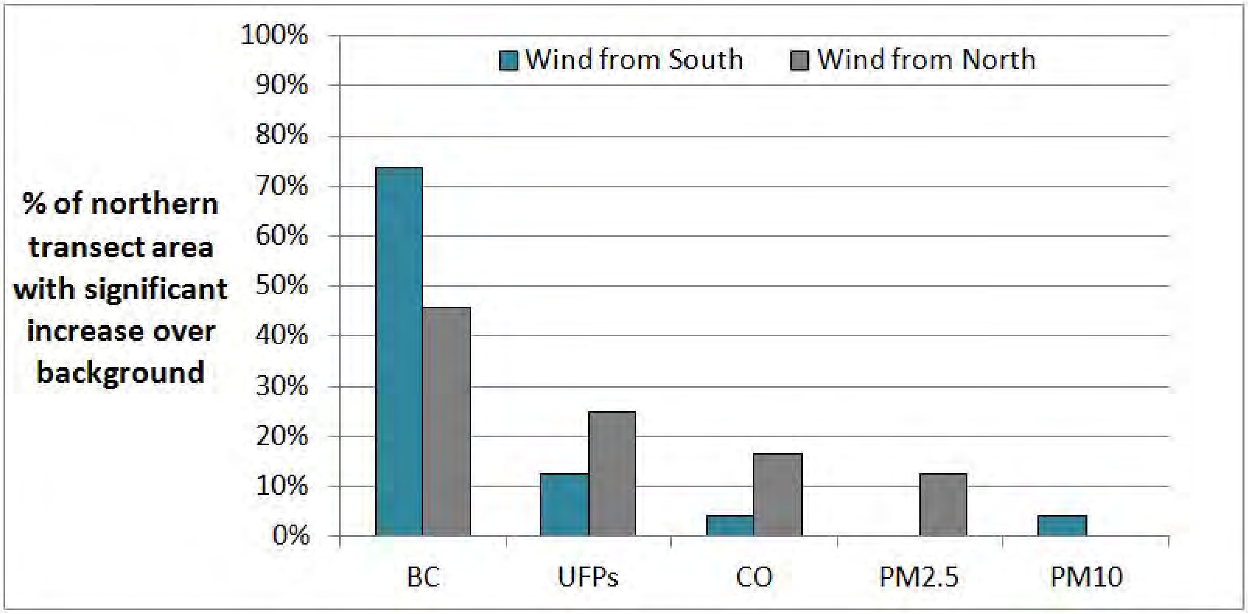

Figure 3-18. Fraction of neighborhood areas (NT1-NT4), in 50 m increments up to 300 m from the rail yard, with significant increase in pollutant levels above the background during mid-afternoon time periods (~10 AM-1 PM).

Evening Periods

Six evening (~7-10 PM) sampling sessions were conducted under conditions with either winds from the South (five sessions) or from the North (one session). Figure 3-19 shows nearly identical results as that observed during the early morning period – a clear upwind/downwind signal is observed for excess BC concentrations, whereas the other species show only sporadic concentration differences above the background. During the five sessions with wind from the South, 79-96% of the four downwind neighborhood areas (50 m increments covering 0-300 m from the rail yard) observed excess BC concentrations. The excess BC in these areas ranged from 0.3-1.3 µg m^{-3}, which translates to 39-104% increase above the background (background average BC ranged 0.6-3.2 µg m^{-3}).

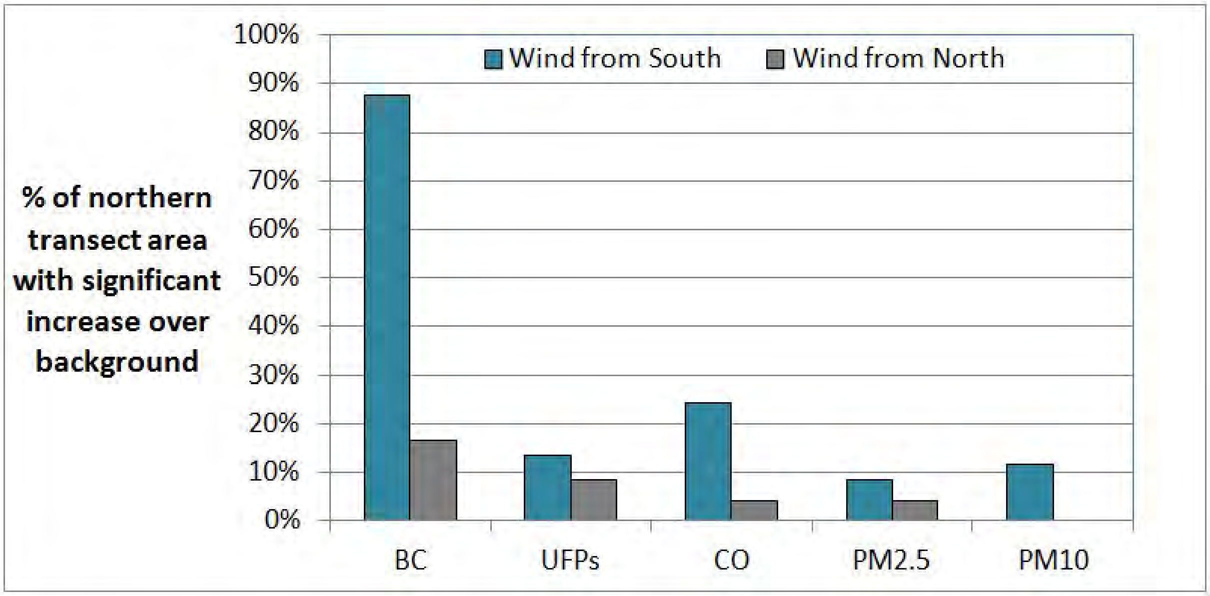

Figure 3-19. Fraction of neighborhood areas (NT1-NT4), in 50 m increments up to 300 m from the rail yard, with significant increase in pollutant levels above the background during evening time periods (7-10 PM).

3.1.2.2. Wind speed effect

The mobile monitoring sessions that were conducted during the early morning and evening periods – where a clear upwind/downwind trend was detectable for black carbon, were further analyzed to understand how downwind excess BC compares with local wind speed. For both the early morning and evening period, a negative relationship was observed between downwind excess BC and wind speed (Figure 3-20). This relationship indicates that higher wind speeds favor improved dispersion of local black carbon emissions from the rail yard area and lower the near-source air quality impact. This result is similar to that determined in near-road field studies for directly-emitted pollutants (Hitchins et al. 2000, Zhu et al. 2002).

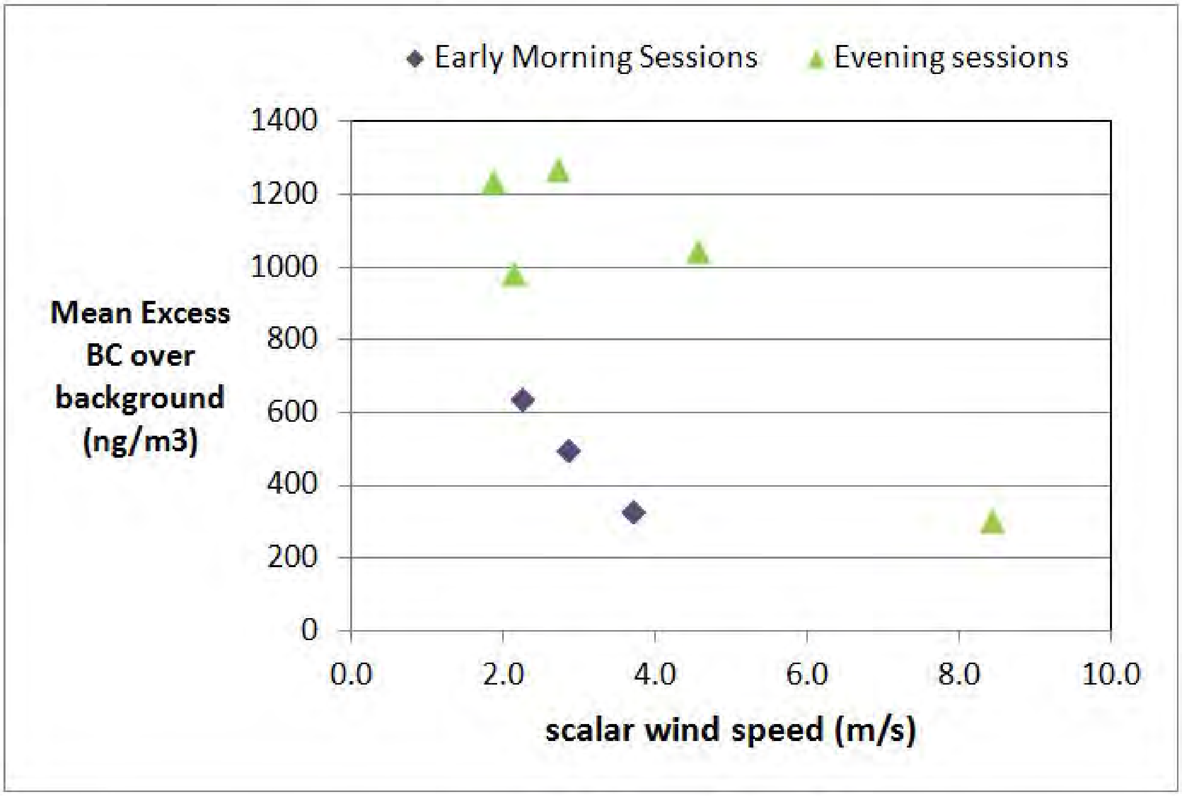

Figure 3-20. Mean downwind BC concentrations in neighborhood areas up to 300 m from the rail yard, as a function of local wind speed.

3.1.2.3. Impact as function of distance

For the early morning and evening sessions, downwind excess BC concentrations were plotted as a function of perpendicular distance from the estimated boundary of the rail yard, in 50 meter increments. In contrast to what has been observed in many near-road monitoring studies (summarized in Karner et al. 2010), the excess BC concentrations do not follow an exponential decrease in concentration with distance from the road (Figures 3-21 and 3-22).

These results imply that the spatial extent of downwind impact, in terms of excess black carbon, likely exceeds 300 m in distance. One influential factor affecting the spatial extent and variability of the excess BC levels is the densely built environment surrounding the rail yard, which likely affect the downwind dispersion of emissions. It has been observed in roadway modeling and measurement studies that even a thin roadside noise barrier can dramatically alter the vertical and horizontal concentration field in the near-road environment (e.g., Baldauf et al. 2008b).

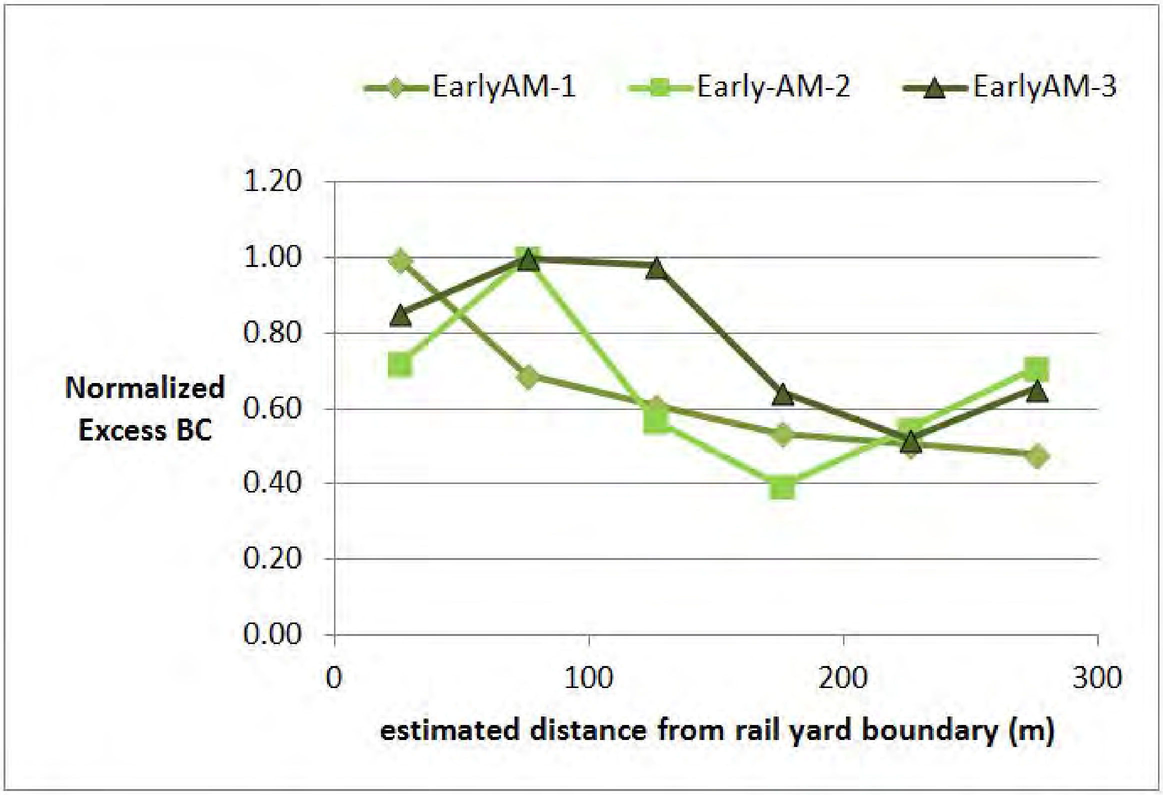

Figure 3-21. Normalized downwind excess BC during early morning sampling sessions in neighborhood areas up to 300 m from the rail yard, as a function of distance from the rail yard. Concentration markers are located at the midpoint of the distance range (e.g., 25 m for 0-50 m). Points for a given line are normalized by the highest excess BC value for that data series.

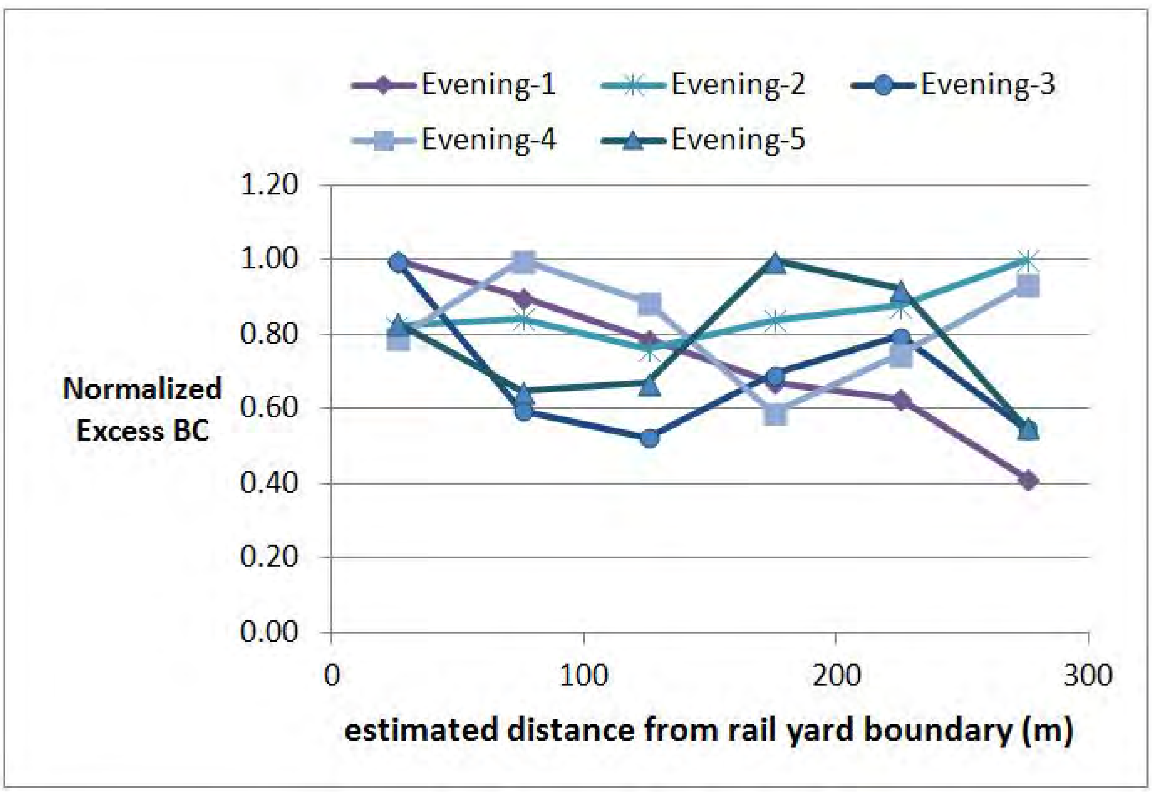

Figure 3-22. Normalized downwind excess BC during evening sampling sessions in neighborhood areas up to 300 m from the rail yard, as a function of distance from the rail yard. Concentration markers are located at the midpoint of the distance range (e.g., 25 m for 0-50 m). Points for a given line are normalized by the highest excess BC value for that data series.

3.2. Stationary Sampling

3.2.1. Stationary Data Overview

3.2.1.1. Quality assurance review and data completeness

As detailed in the Quality Assurance Project Plan (QAPP – Appendix A), 2-week QC checks and 6-month performance evaluations were performed to meet DQOs. These checks are listed in section 2.4.4. Data completeness for each instrument is provided on a monthly basis in Table 3-5 and a broad view of the data collected is provided in Figure 3-23. Despite the high completeness in data, the carbon monoxide values were below detection limits (300 ppb) for 89% of the measuring period (Figure 3-23). It should be noted that CO instrument detection limit is far below the regulatory limit for CO (9 ppm at an 8 hr average or 35 ppm at a one hr average) and is commonly used for ambient monitoring. At the time of the study, a CO instrument with a lower detection limit was not available as a substitute and the very sensitive quantum cascade laser CO instrument used on the mobile platform was isolated to the mobile sampling vehicle. Given the very low concentrations observed routinely below the detection limit, CO is not included in any of the analyses to follow. The air conditioning unit at the site began to fail in late May to early June of 2011, which caused a period of overall data loss and led to significant instrument performance issues for the particulate matter instruments. While monitoring utilizing all working instruments continued until October of 2011, this analysis is currently restricted to the period of time when all measurements were being collected simultaneously and the time span where operating conditions did not cause potential concern for data. Therefore, the analyses in this report include only values up to May 5. Future research involving these data may include data collected after that time, however the data will need to be carefully reviewed to ensure instrument performance was acceptable. In addition, $NO/NO_2/NO_x$ data were invalidated from March 1 to March 13 because the QC check on March 13 did not meet the requirements set forth in the QAPP. Finally, it should be noted that $PM_{2.5}$ measurements were collected but will not be presented, aside from brief discussion in the mobile and stationary intercomparison section. During the time of available data, the instrument performance met QA requirements, but the higher time resolution data appears to require post-averaging in order to resolve the signal to noise, related to the tape-based method. The PM data will require further analysis to determine the appropriate time-averaging interval.

An independent Technical System Audit and site evaluation were performed on February 8, 2011 by Basim Dihu of USEPA Region 5.

Table 3-5. Stationary monitoring data completeness by month

Year	Month	CO	NO	NO_2	NOX	SO_2	WS[a]	WD[a]	BC	$PM_{2.5}$
2010	November	99.6%	28.9%	28.9%	28.9%	99.7%	29%	29%	98.7%	90.2%
2011	January	99.9%	100%	100%	100%	99.9%	100%	100%	97.8%	88.4%
2011	February	99.5%	99.7%	99.7%	99.7%	99.8%	100%	100%	75.9%	66.2%
2011	March	99.8%	99.1%	99.1%	99.1%	99.8%	100%	100%	99.3%	80.9%
2011	April	99.4%	98.9%	98.9%	98.9%	99.2%	100%	100%	89.2%	100%
2011	May	87.3%	93.5%	70.8%	93.5%	93.6%	100%	100%	70.4%	89%
2011	June	26.9%	85.2%	49.3%	58.2%	58.4%	96.5%	96.5%	0%	54.7%
2011	July	95.4%	50.6%	50.6%	50.6%	94.7%	96.3%	96.4%	0%	0%
2011	August	99.2%	87.7%	87.7%	87.7%	89.6%	83.2%	83.2%	0%	0%
2011	September	92.4%	92.3%	92.3%	92.3%	92.4%	47.1%	47.1%	0%	0%
2011	October	94.2%	94.7%	94.7%	94.7%	94.6%	95.6%	95.6%	0%	0%

[a]Gaps in MetOne meteorology (WS and WD) were filled using the meteorology from the $PM_{2.5}$ E-BAM.

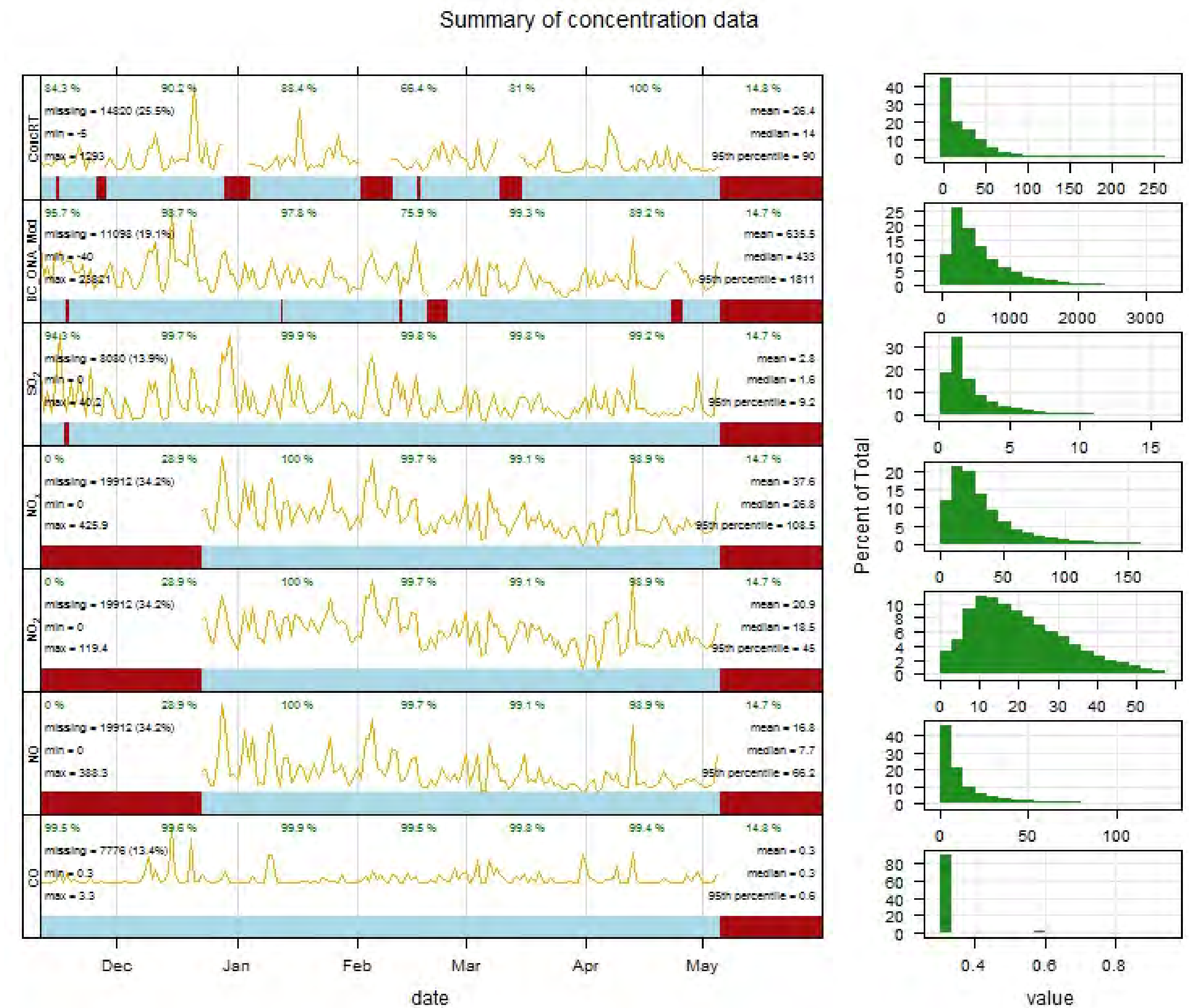

Figure 3-23. Time series and histogram summarizing stationary monitoring data collected during the time period isolated for analysis (November 2010 – May 2011).

Table 3-6. Summary statistics for 5-minute pollutant data (NOx and SO_2 in ppb, BC in ng m^{-3})

Case	Pollutant	N	Mean	Standard deviation	Lower 95th CI	Upper 95th CI	Percentiles 25th	50th	75th	90th	95th
All data	NO_2	38253	20.9	12.7	20.7	21.0	11.2	18.5	28.6	38.4	45.0
	NO	38253	16.8	25.5	16.5	17.0	3.0	7.7	18.6	43.8	66.2
	NO_x	38253	37.6	35.6	37.3	38.0	15.7	26.8	46.9	80.2	108.5
	SO_2	50085	2.8	3.3	2.7	2.8	1.0	1.6	3.2	6.2	9.2
	Black carbon	47067	635.5	690.5	629.3	641.7	235.4	433.0	796.0	1330.0	1811.0
Wind from SE (angles: 105 - 215)	NO_2	8274	24.6	12.7	24.3	24.9	15.2	23.2	32.7	42.5	47.4
	NO	8274	24.4	32.2	23.7	25.1	3.7	12.0	32.1	63.8	92.1
	NO_x	8274	48.9	41.5	48.0	49.8	21.2	36.8	63.8	104.2	134.2
	SO_2	8310	4.8	3.8	4.7	4.9	2.3	3.6	5.8	9.9	12.5
	Black carbon	7652	819.1	737.0	802.6	835.6	378.0	618.0	1011.0	1580.0	2079.5
Wind from SW (angles:215 - 266)	NO_2	7156	27.6	15.6	27.3	28.0	15.4	26.8	38.2	48.0	54.0
	NO	7156	30.8	34.7	30.0	31.6	6.4	18.8	43.4	74.8	101.1
	NO_x	7156	58.5	47.8	57.4	59.6	23.7	46.9	80.4	119.4	151.4
	SO_2	7176	3.5	3.7	3.4	3.6	1.3	2.1	4.3	8.2	10.9
	Black carbon	6791	815.9	726.6	798.6	833.1	359.0	630.0	1031.5	1610.0	2092.0
Wind from N (angles: 300 - 60)	NO_2	13212	16.8	9.7	16.6	16.9	9.6	14.7	22.5	31.1	35.1
	NO	13212	8.5	11.2	8.3	8.7	2.4	5.3	10.1	18.8	27.8
	NO_x	13212	25.3	19.1	24.9	25.6	13.2	20.5	32.0	48.2	59.8
	SO_2	13248	1.3	1.0	1.3	1.3	0.8	1.1	1.5	2.4	3.1
	Black carbon	12235	333.6	327.5	327.8	339.4	143.3	243.0	419.0	662.0	858.3

Summary statistics for different wind sectors show that values are generally low for all pollutants (Table 3-6). Confidence intervals for NO_x compounds do not overlap for any of the sub-sectors, with the highest values coming from the body of the rail yard (SW) and the lowest levels coming from upwind. SO_2 values from Midway airport (SE) might be significantly different from those of the rail yard and upwind, but the absolute differences are small. Black Carbon values are over double, on average, during winds from the South in comparison to wind from the North. CO was not included in the table given that the significant fraction of time measurements was below the detection limit.

3.2.1.2. Data collection in context of local meteorology

Local wind trends can significantly influence local air quality trends for monitoring stations in close proximity to emissions. The stationary monitoring site located to the northwest of the Cicero rail yard collected wind data at a 5-minute resolution throughout the course of the study. These data are compared against a similar timeframe at the Midway airport, located several miles south from the stationary monitoring site. As shown in Figure 3-24, both monitoring stations show a significant portion of the sampling year with winds from the West to South sector. Greater maximum and mean wind speeds were evident at Midway in comparison to the stationary site. In addition, the wind field at the Cicero site appears to have a greater SW-NE prevailing direction in comparison to the more broadly distributed flow at the Midway site. While no air flow obstructions were in the immediate proximity of the stationary site at Cicero, it is possible that nearby buildings may have influenced general local air flow.

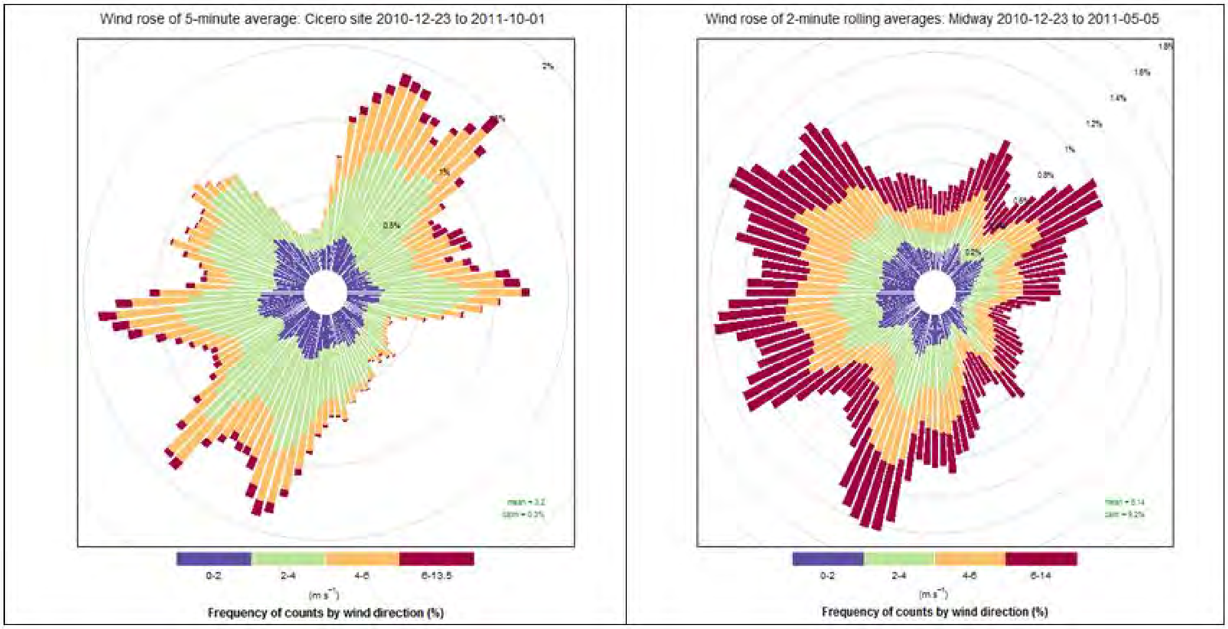

Figure 3-24. Wind trend comparison for the Cicero monitoring site compared with the Midway airport meteorological station.

Wind trends at the Cicero site were also analyzed as a function of time of day (Figure 3-25). Diurnal patterns at the Cicero site show a greater frequency of winds from the east, from Lake Michigan, during the day than at night. In addition, lower wind speeds (0-2 m/s) were more frequent during the night time hours.

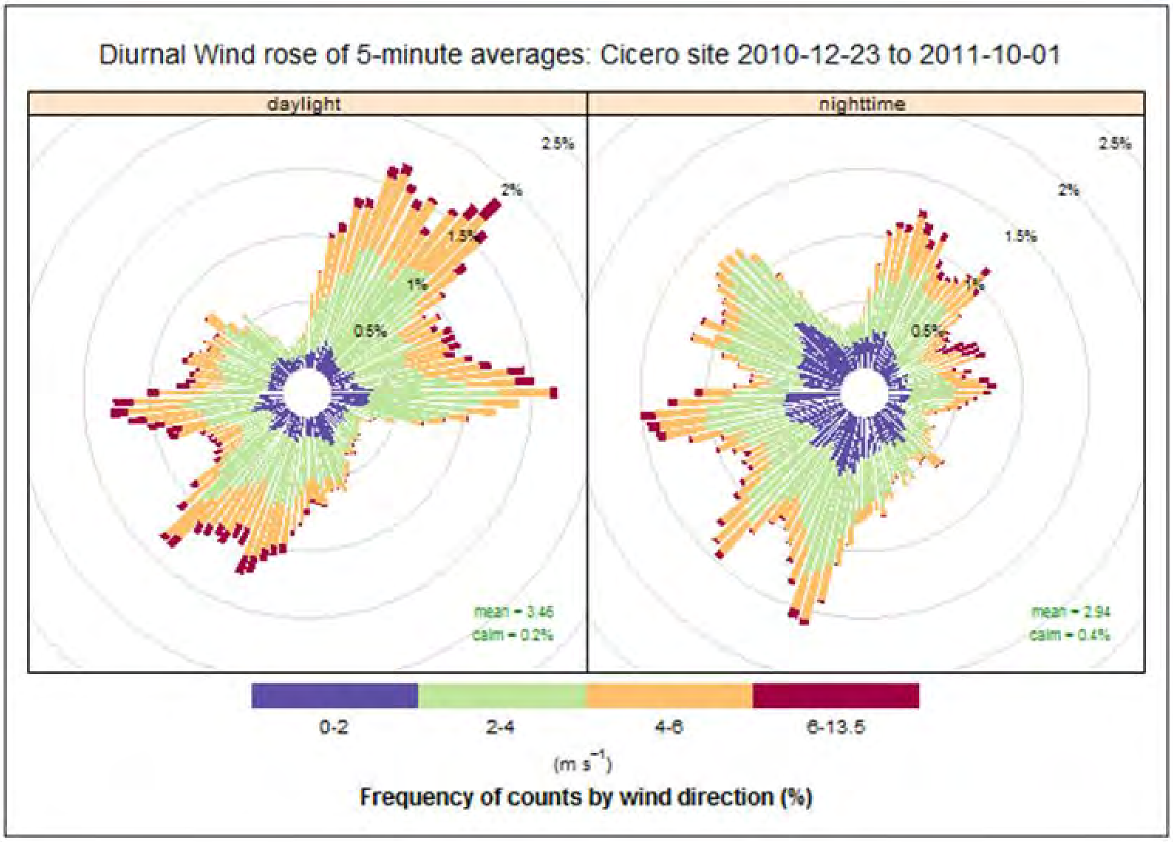

Figure 3-25. Cicero stationary monitoring site wind trends during the day (left figure) and night (right figure).

3.2.2. Assessment of rail yard impact

3.2.2.1. Impacts of meteorology and time of day on air quality measurements

Measured concentrations at the stationary site were evaluated as a function of wind direction, with both sets of variables measured at five minute intervals. Shown in Figure 3-26, concentration roses were created by binning the measured values according to wind direction, then magnitude (by 0-25th, 25-50th, 50-75th, 75-95th, and 95-100th percentiles) and displaying in a polar plot with the length of the ray relating to the frequency of that magnitude.

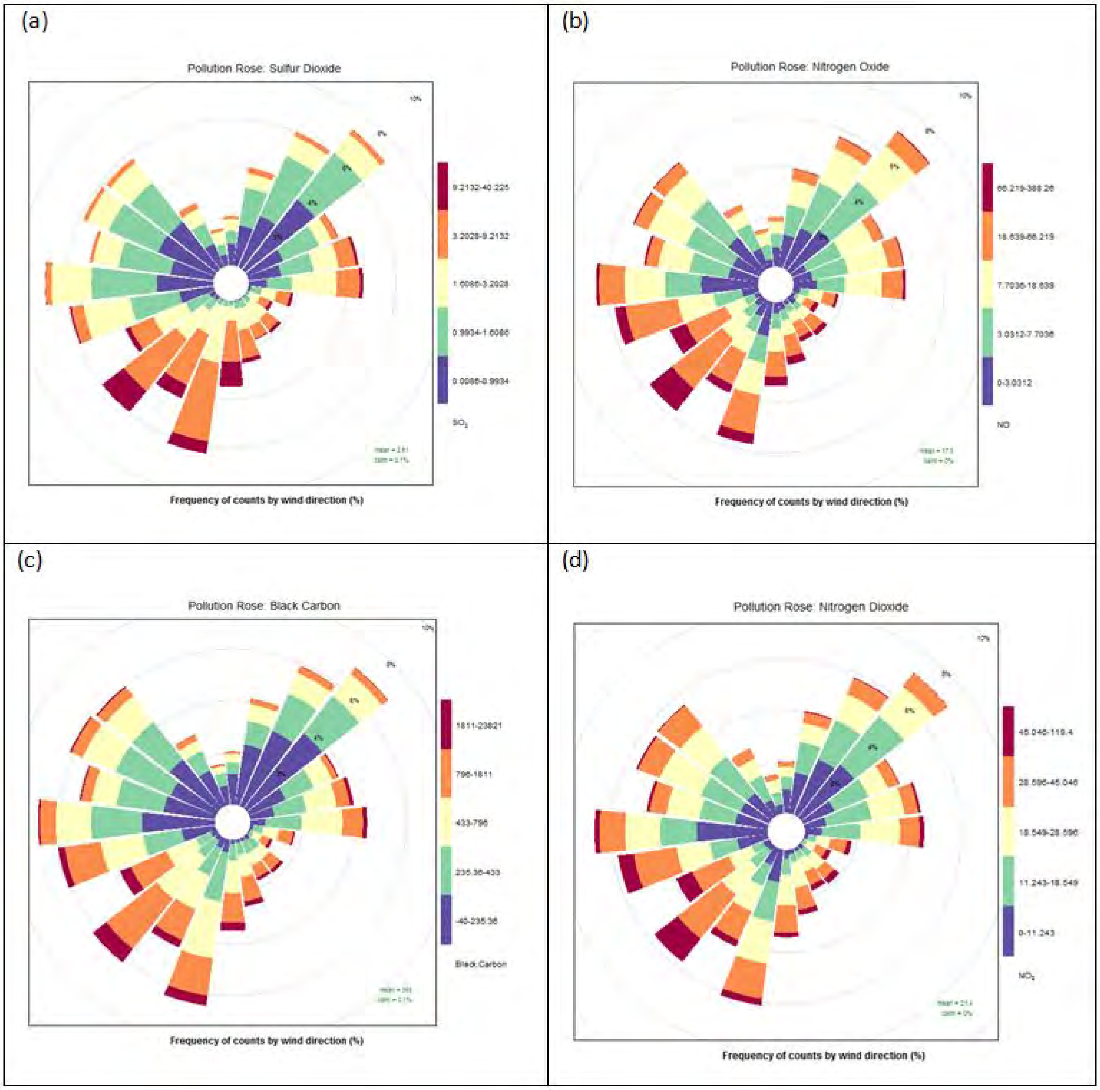

Figure 3-26. Concentration roses for sulfur dioxide (ppb) (a), nitrogen oxide (ppb) (b), black carbon (ng m^{-3}) (c), and nitrogen dioxide (ppb) (d). The extent of a given ray indicates the fraction of data associated with a certain wind direction and the rays are colored by concentration range measured from that particular wind sector (color bins are: 0-25th, 25-50th, 50-75th, 75-95th, 95-100th percentiles).

Observing the relationship of concentrations with wind direction, SO_2, NO, NO_2 and black carbon all appear to show strong directionality from the south and southwest with moderate levels also occurring from the east. While the rail yard is located immediately south of the site, with a rail line oriented West-East passing south of the site, additional industrial sources are present at a further distance to the south (e.g., airport, power plant).

Wind directional trends in measured pollutant concentrations were also assessed as a function of time of day (Figure 3-27). All pollutants show similar patterns for directionality and magnitude between day and night, and show higher values to the southwest, south and east. Despite the lower wind speed during the evening hours (Figure 3-25), there does not appear to be a significant increase in the general measured concentrations during evening hours. The lower advection by wind may be offset by also generally lower emissions activity during the evening hours.

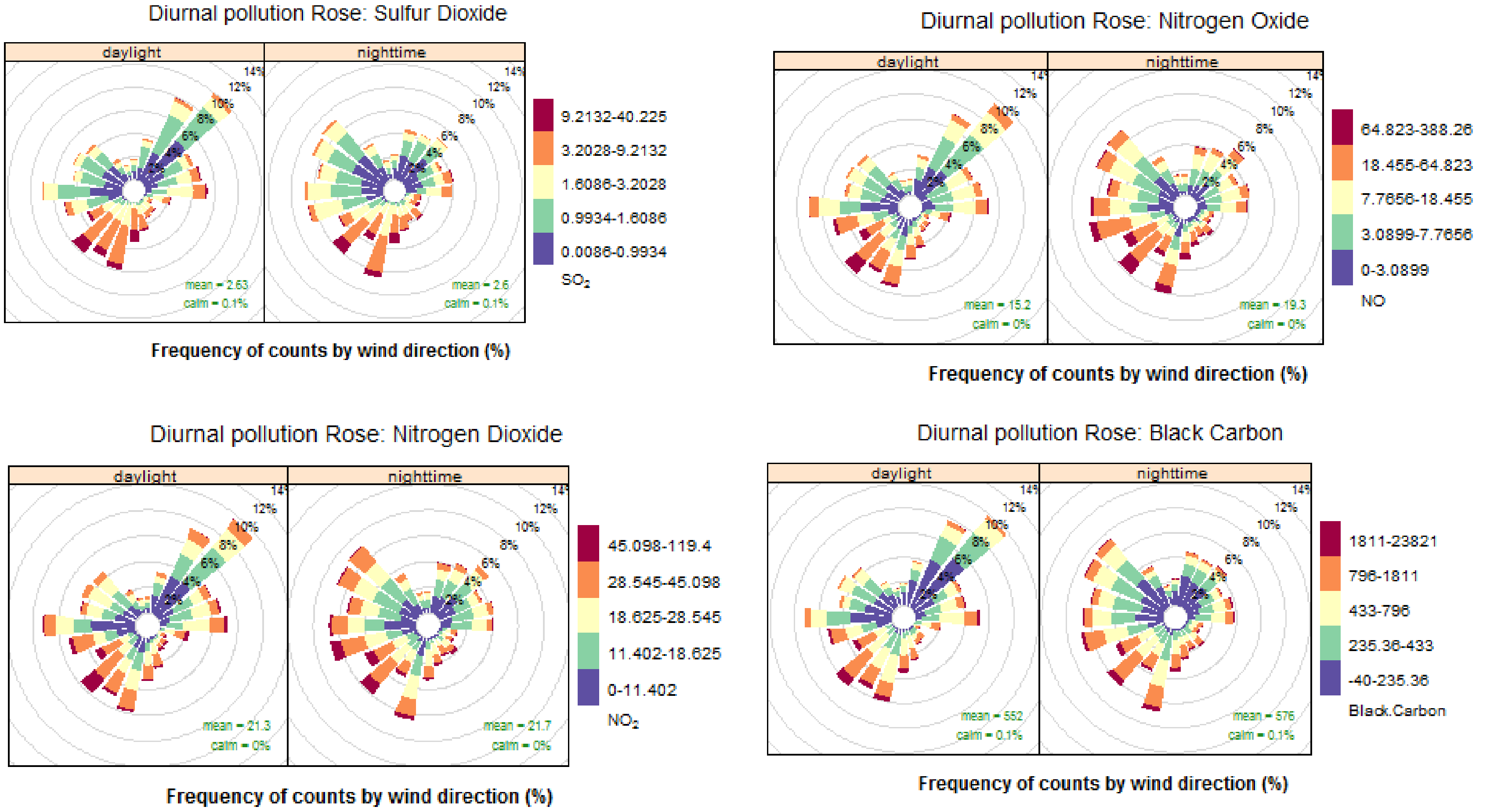

Figure 3-27. Diurnal concentration roses for sulfur dioxide (ppb), nitrogen oxide (ppb), nitrogen dioxide (ppb), and black carbon (ng m^{-3}). The extent of a given ray indicates the fraction of data associated with a certain wind direction and the rays are colored by concentration range measured from that particular wind sector (color bins are: 0-25th, 25-50th, 50-75th, 75-95th, 95-100th percentiles).

Daily patterns for pollutants were normalized by calculating the average value for each hour of the day and dividing values by the mean of the set to normalize them. Bootstrapped 95% confidence intervals were calculated for each hour. Shown in Figure 3-28, NO, NO_2 and BC follow similar trends with peaks in the morning and afternoon, indicating they are driven by commuter traffic. SO_2 values peak at noon, with the greatest mid-day means occurring from the east, southeast, south and southwest. This indicates that Midway Airport and the Crawford power station are the potential major contributors to mid-day SO_2.

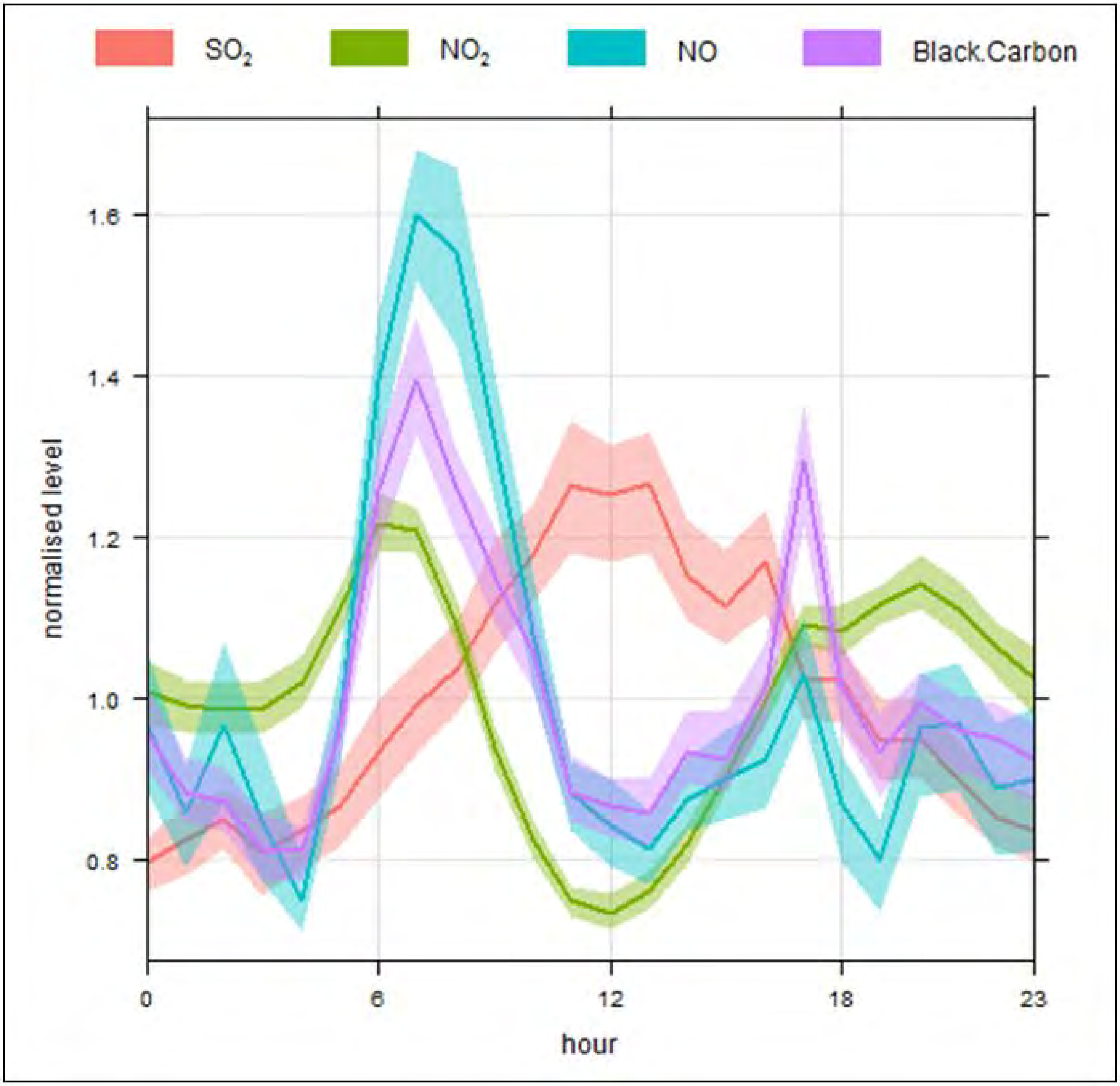

Figure 3-28. Normalized diurnal time series of measured concentrations at the stationary monitoring site, for all data collected during November, 2010 – May, 2011.

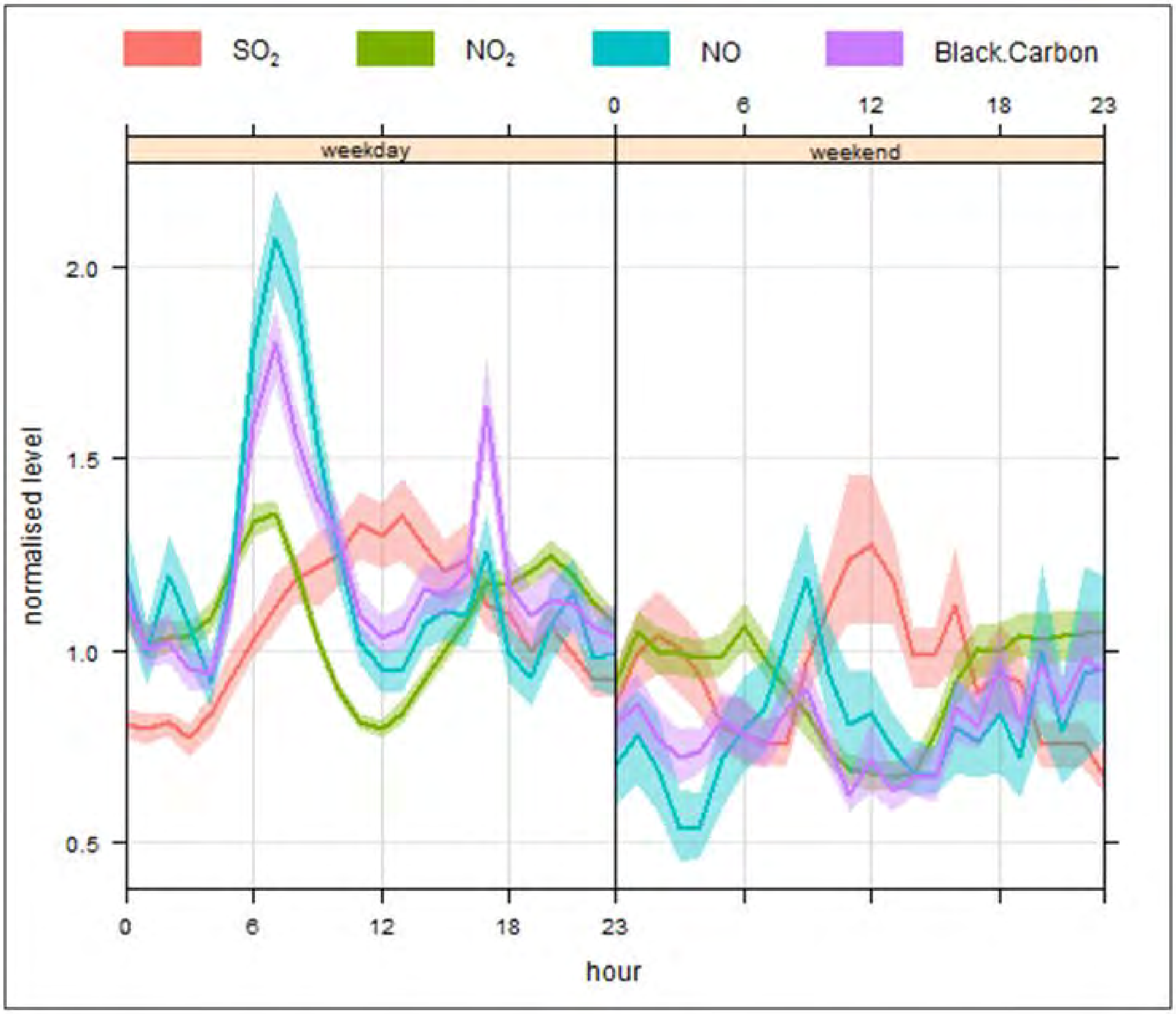

Figure 3-29. Normalized diurnal time series of measured concentrations at the stationary monitoring site, for weekday (left) and weekend periods (right) collected during November, 2010 – May, 2011.

Using the same method pollutants were separated into weekdays and weekends and hourly means were plotted, shown in Figure 3-29. SO_2 shows similar patterns on weekdays and weekends. Other pollutants show overall lower values and depressed peaks on weekends. The change in pattern for NO, NO_2 and BC is consistent with the differences in commuter traffic on weekends.

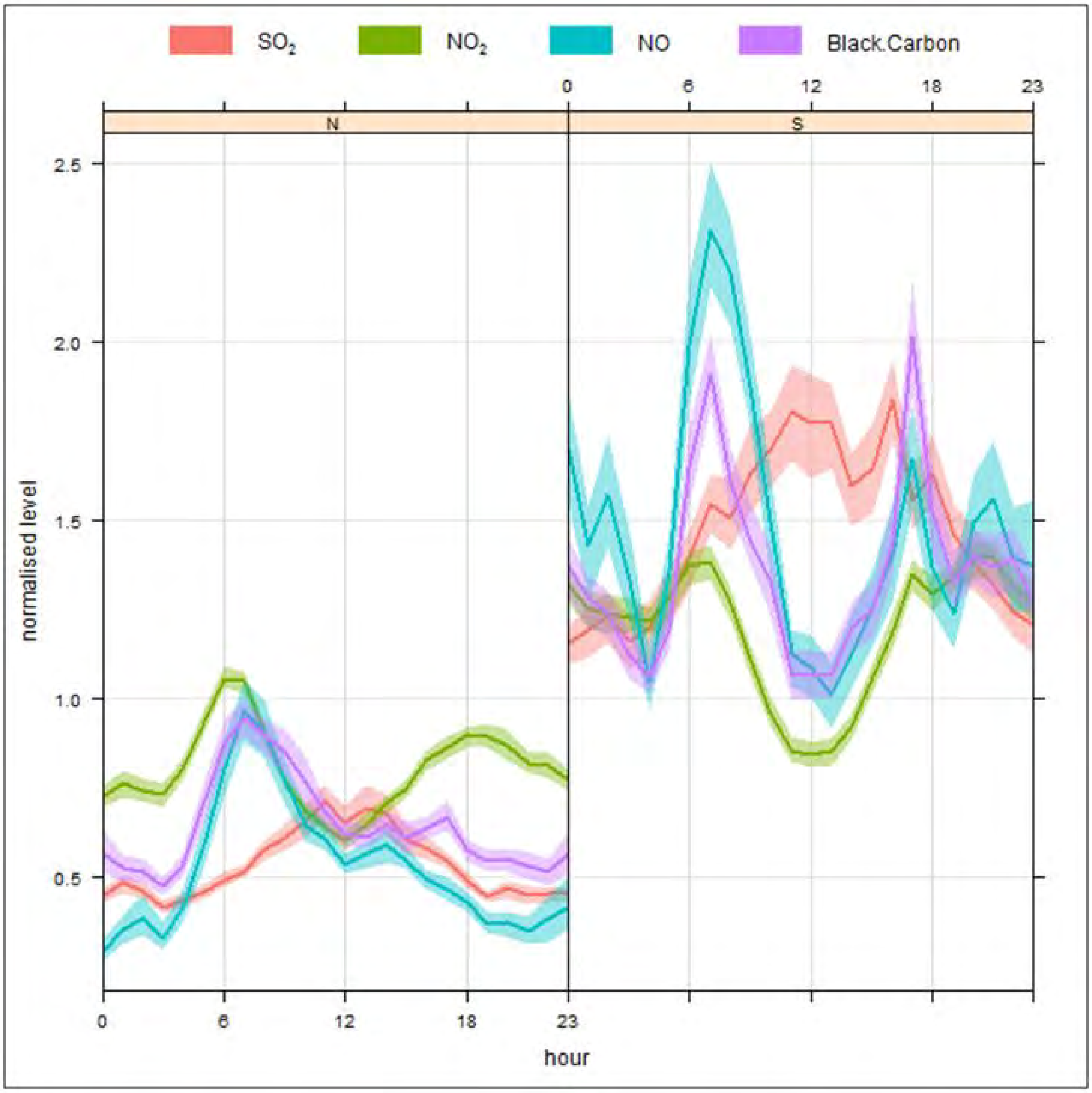

Figure 3-30. Normalized diurnal time series of measured concentrations at the stationary monitoring site, for periods of wind from the North (left) and wind from the South (right) collected during November, 2010 – May, 2011.

By the same method but binning concentrations by the northern sector (less than 90 degrees or greater than 270 degrees) and southern sector (greater than 90 degrees and less than 270 degrees) concentrations show similar patterns with significantly greater values when winds are from the south (Figure 3-30).

3.2.2.2. Nonparametric trajectory analysis of stationary monitoring data

The results for the black carbon analysis are shown in Figure 3-31. Black carbon is the directly emitted product of fossil fuel combustion, especially from diesel emissions which relates to the truck and locomotive operations at the rail yard. The concentration field shows that the higher black carbon concentrations are confined mostly to times when air parcels pass over land south of the monitor's location with notably higher concentrations occurring when winds are from the southwest and southeast. The highest concentrations (greater than 1 $\mu g/m^3$) occur when the winds pass over areas due south and adjacent to the rail yard but also from the area around the Crawford power plant and another large rail yard which is due south of Crawford on the other side of the Chicago Sanitary and Ship Canal. The area around the Cicero stationary monitor is heavily laden with fossil fuel burning industries. The NTA does an adequate job of isolating the majority of peak black carbon emissions to the southern half of the grid with isolating nearby local sources of fossil fuel combustion as possibly being the largest contributors to black carbon at the Cicero monitoring site. The NTA shows lower level expected black carbon concentrations north of the monitor site including areas along major roadways such as I-290. These expected concentrations are much more uniform over a large area suggesting more consistent emissions from dense urban mobile sources usually present in a large metropolitan area. The black carbon pollution rose in Figure 3-26 shows a consistent pattern with the highest concentrations south of the monitor and lower concentrations to the north. Such a gradient indicates that sources south of the site contribute more to the higher black carbon observations measured by the monitor than general urban mobile source emissions consistent across large metropolitan areas.

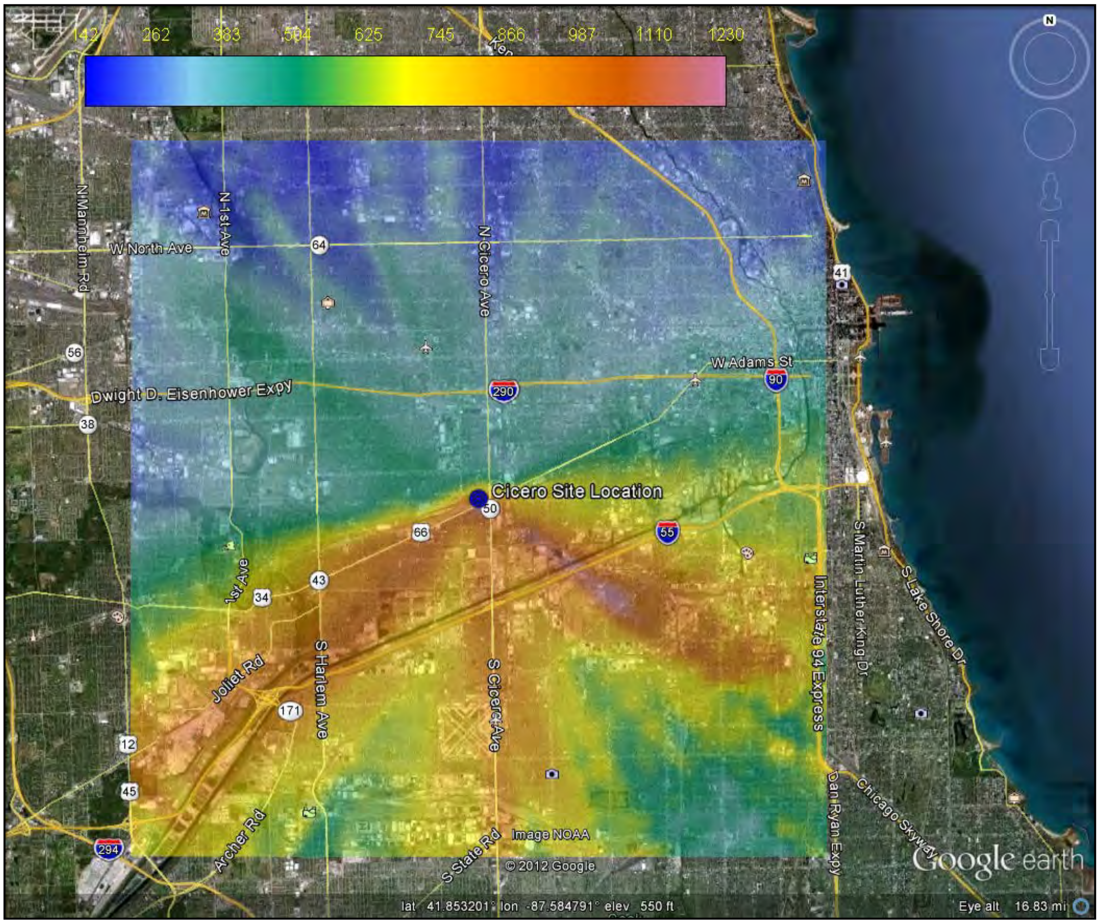

Figure 3-31. Black carbon expected concentration field from NTA in ng/m^3

The SO_2 expected concentrations show a pattern similar to black carbon in that the majority of SO_2 emissions appear to be coming from the southern half of the domain (Figure 3-32). The higher concentrations are isolated along heavily traveled transportation corridors and industrial zones within the area including Interstate 94 (Dan Ryan Expressway), south of the monitor with air parcels passing over Midway Airport and another large rail yard close to Midway, and the Interstate 55 corridor along the McCook industrial area by the Chicago Sanitary and Ship Canal. The SO_2 expected concentration field also shows “coning” to the south of the monitor as concentrations increase toward Midway Airport and suggests that persistent winds from the southerly direction could be representing emissions not only attributable to Midway but also nearby SO_2 emissions from the other local sources including the Cicero rail yard. The commingling of emissions from local sources in close proximity to one another makes it difficult to determine the extent of the Cicero rail yard impact on ambient SO_2 concentrations at the receptor. However, the amount of air traffic from Midway and the emissions associated with jet aircraft cannot be ignored as a major source of SO_2 for the area.

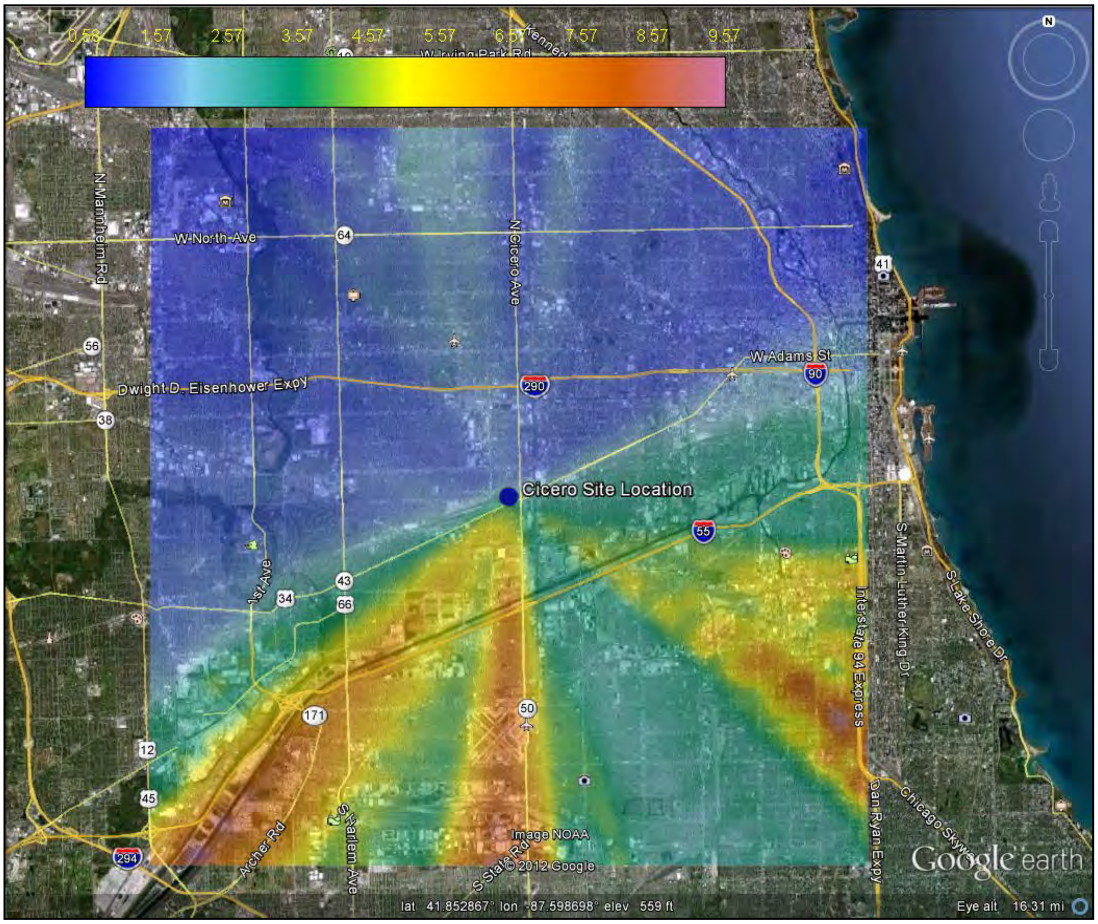

Figure 3-32. Sulfur dioxide expected concentration field from NTA.

The NO concentration field is more similar to that of black carbon suggesting that both NO and black carbon are more likely to be coming from similar sources within the area (Figure 3-33). The Pearson correlation coefficient shows that the black carbon and NO have the highest correlation to each other out of the three possible pairings between black carbon, NO and SO_2 (Table 3-7). While this correlation could suggest that the black carbon and NO come from the same source, there are multiple mobile sources within the area burning fossil fuels including various on-road diesel sources. The relatively low correlations between the three pollutants suggest that area around the monitoring site is dominated by a diverse variety of sources in close proximity to one another all contributing to ambient air quality by varying amounts thereby making it difficult to discern a distinct signal from any one particular source.

The difference in the spatial variability in NO concentrations versus SO_2 concentrations helps to validate that aircraft emissions from Midway Airport are contributing substantially to the area's SO_2 concentrations. The high NO concentrations in the vicinity of the Crawford power plant are also consistent with emissions expectations for a source of its size. With the Crawford power plant scheduled to be completely shut down by the end of 2014, the majority of black carbon, SO_2 and NO contributions to local air quality will further shift to transportation-oriented sources.

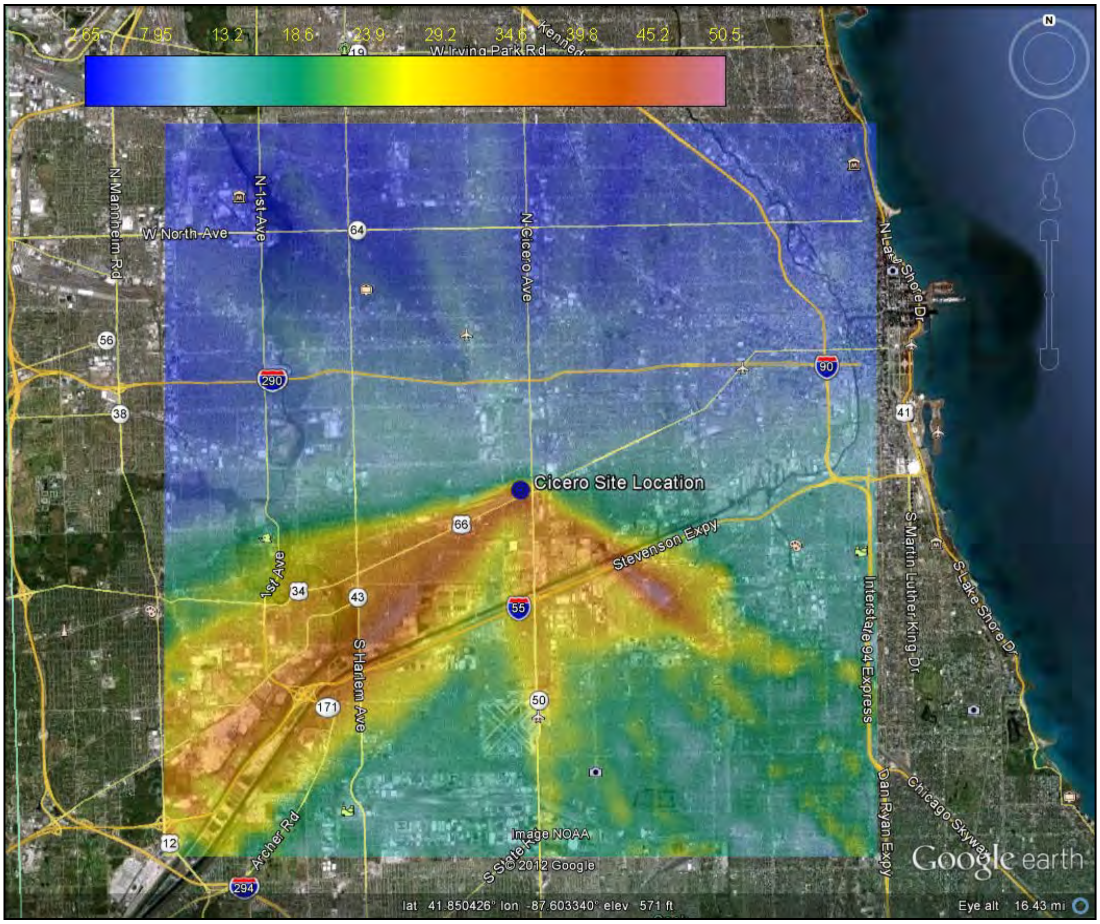

Figure 3-33. Nitric oxide expected concentration field from NTA.

Table 3-7. Pearson Correlation Coefficients (R) for Pollutant Pairs

	Nitric Oxide	Black Carbon
Sulfur Dioxide	0.19	0.31
Nitric Oxide		0.52

4. Summary and Conclusions

Elevated local air pollution levels within several hundred meters of a major transit source – also referred to as near-source air pollution – have been observed in numerous field studies measuring air quality alongside major roadways and motivates ongoing research to understand local air quality trends near other transit modes. Rail yards are important nodes in the rail network, serving to route trains and transfer containers from one mode of transportation to another. Emissions activities within typical intermodal rail yards – such as the Cicero rail yard studied in this report – include commercial trucks arriving and departing with containers, within-yard hostler trucks, switcher locomotives moving containers within the yard, freight and/or commuter trains transiting through the yard, and diesel-powered cranes. These emissions are heterogeneously distributed over a discrete large area and have both temporal and spatial variability.

Rail yards are commonly located in densely populated areas, as the customer and industry base of populated areas demands efficient transportation of goods. The Cicero rail yard is a good example of this situation, where dense residential communities are built right next to the rail yard boundary. In these environments, it is important to understand whether these communities are at a greater risk for air pollution due to local emissions. This research study evaluated local air pollution trends both spatially and temporally, utilizing a combined strategy of short-term mobile and longer-term stationary monitoring.

Mobile monitoring results indicate that the intermodal rail yard area – which for this data set analysis includes freight and commuter trains, trucks, cranes, and limited traffic on boundary public roads to the North and South of the yard – is associated with elevated black carbon concentrations in downwind residential neighborhoods up to and possibly exceeding 300 m in downwind distance from the rail yard boundary. The attribution of this impact to the rail yard environment is most clear during the early morning and evening time periods, when a clear difference in elevated BC exists between cases of winds from the North versus South. During the mid-day, residential neighborhoods experience elevated BC under multiple wind conditions, which suggests that other local sources of BC (e.g., street traffic) also contribute to elevated concentrations in these neighborhood areas. Other pollutants measured on the mobile platform – ultrafine particles, carbon monoxide, and particulate matter – either did not show statistically significant impact or had inconsistent trends, likely explained by the pollutant emissions and also affected by monitoring instrumentation limitations. Regarding pollutant emissions, abundant directly emitted pollutants associated with diesel emissions are anticipated to be the most sensitive tracers of local air pollution impact. As observed when sampling in stationary mode, BC spiked 45-fold when experiencing a near-field emissions plume; meanwhile, carbon monoxide and $PM_{2.5}$ only changed by a factor of 2 and UFPs by a factor of 11. This difference is likely due to variations in emission factors, whether the pollutant has significant background levels (e.g., $PM_{2.5}$ anticipated to have a significant regional component), as well as the sensitivity of the measurement instrumentation. Ultrafine particles (particles smaller than 100 nm) often track closely with BC signals for highway environments; however, emissions and field studies indicate that increased ultrafine particle emissions are related to higher driving speeds. The results of this study indicate that BC and UFPs may not track as closely in the rail yard environment, but more research is needed to further understand this relationship.

Stationary monitoring results also indicate a clear association of air pollution levels with wind direction, finding air pollution levels for multiple pollutants (BC, NO_2, NO, SO_2) elevated with winds from the south. Nonparametric trajectory analysis – an inverse modeling research tool that utilizes high time-resolution air monitoring and wind data – indicates that important source areas affecting stationary monitoring data include areas to the Southwest (including the rail yard area), due South (including Midway airport), and the Southeast (including a power plant). Diurnal analyses of stationary monitoring results, isolated in weekday/weekend timeframes and North / South wind timeframes, indicate higher overall pollution levels on weekdays and with winds from the south.

The study results overall indicate that residential areas in close proximity to the Cicero rail yard generally experience higher overall air pollution levels with winds from the South, which may be related to multiple significant emission sources including the rail yard environment. In addition, under southerly wind conditions, mobile monitoring data suggests an indicator of diesel emissions (black carbon) increased 30-104% over the urban background during early morning and evening periods and is more directly associated with emissions activity associated with the rail yard area. Uncertainty remains regarding source attribution, both within the rail yard and considering potential traffic on boundary roads, which may require modeling or controlled field experiments for further characterization. These results support the notion that local concentrated areas of higher diesel emissions activity adversely impact local-scale air quality and mitigation efforts may reduce local exposure to air pollution.

5. Acknowledgements

This research was conducted under EPA's Regional Applied Research Effort (RARE) program, which encourages collaborative research between the EPA Regions and the Office of Research and Development. Field measurement support for the mobile monitoring campaign was provided by ARCADIS through contract EP-C-09-027. BNSF staff provided in-kind support to this project through sharing rail yard activity data for the Cicero rail yard, providing logistical support for the mobile monitoring study, and providing insight throughout the project. EPA QA personnel in ORD and Region 5 supported this study through reviewing Quality Assurance Project Plans and report drafts. EPA researchers Ram Vedantham and Rich Baldauf are also appreciated for providing technical peer reviews of a draft version of the report.

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Cicero Rail Yard Study (CIRYS)

Appendix A: Quality Assurance Project Plans

Cicero Rail Yard Study (CIRYS) – High-Resolution Mobile Monitoring of Near-Rail Yard Air Pollution

Quality Assurance Project Plan - Revision 2
Category III / Measurement Project

NRMRL / APPCD / ECPB
EPA Technical Lead: Gayle Hagler

13 January 2011

Cicero Rail Yard Study (CIRYS) – High-Resolution Mobile Monitoring of Near-Rail Yard Air Pollution

Quality Assurance Project Plan

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1. Approvals

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3. Project Description and Objectives

3.1 Background

Air quality research has progressed over recent years from focusing on primarily regional level air pollution (10s of kilometers), monitored using a network of ambient monitoring sites that are removed from any major sources, to an emerging parallel focus on local air pollution (10s of meters). In the transportation sector, recent field studies have shown that air pollution levels can be significantly higher than background levels when immediately downwind of a highway (e.g., Zhu et al., 2002), airport (e.g, Westerdahl et al., 2008), or rail yard (e.g., Chang, 2007). While a large number of field studies have taken place to assess local air pollution effects from highway-related emissions, air monitoring data are sparse for many other sources, including distribution centers, airports, rail yards, refineries, powerplants, ports, etc. This study is seeking to begin to fill in the knowledge gaps by focusing on studying local impact due to rail yard emissions.

Near-road research, which is anticipated to have similarities for near-rail yard research, has quantified elevated concentrations on the downwind side of the source attenuating with increasing distance and eventually reaching background levels (e.g., Baldauf et al., 2008a). Near-road field studies have determined that the degree of air pollution concentration elevation over background concentrations and the rate of attenuation with distance from a road depends on the pollutant type, meteorology, and the surrounding terrain. For example, a near-road study in North Carolina revealed that certain air pollutants, such as black carbon, nitrogen oxide, and ultrafine particles (particles with diameters smaller than 100 nanometers), have a stronger response to traffic emissions in comparison to other air pollutants, such as fine particulate matter (particles with diameters smaller than 2.5 micrometers) or nitrogen dioxide (Hagler et al., 2009, Thoma et al., 2008). Another study in California demonstrated the significant effect local meteorology can have on the downwind dispersion of traffic-related air pollution, with an atmospheric inversion leading to elevated concentrations up to a mile and a half in distance from a major highway (Hu et al., 2009). Finally, near-source obstacles, such as buildings and walls, have been shown to alter the concentrations of near-road air pollution (Baldauf et al., 2008b, Heist et al., 2009). While these near-road studies have identified several important factors affecting emissions dispersion, it is an open question as to what degree the pollutant type, local meteorology, and surrounding terrain determine concentration gradients for other source types, including rail yards.

This study seeks to characterize local impacts from an intermodal rail yard in Cicero, IL, including magnitude of impact for specific pollutants, assessing the spatial variability of concentrations, and downwind extent of elevated concentrations over the upwind background levels. This research study was originated by an EPA Region 5 RARE proposal, which hypothesized that rail yard emissions may locally elevate air pollutant levels in their region and contribute to regional $PM_{2.5}$ nonattainment status. Phase I of the study focused on the CSX Rougemere Rail Yard in Dearborn, Michigan in a multi-component research effort that included a rail yard emissions inventory, dispersion modeling, and a several month monitoring campaign measuring carbonaceous particulate matter (black carbon, elemental carbon, and organic carbon) at two sites immediately adjacent to the rail yard and additional site located within a nearby residential area and representative of urban background concentrations. The results from the Phase I study have been published in a report (Turner et al., 2009). The emissions inventory component of this study identified a number of different emission types within the rail yard, as shown in Table 3-1 and Figure 3-1 (Heiken, 2009) and demonstrated a reduction in $PM_{2.5}$ emissions due to a switch to lower sulfur fuel in 2008. Analysis of ambient monitoring data collected upwind and downwind of the Dearborn rail yard did not successfully isolate the rail yard signal due to other large emitting sources immediately adjacent to the rail yard. The Phase I experience lead to the Phase II measurement campaign being located at another study site (Cicero, IL) that met site criteria including few confounding sources (Section 5).

Table 3-1. Emission Sources at the CSX Rougemere Rail Yard (Heiken, 2009)

Locomotives	Non-Locomotives
• Through Locomotives	• Worker Vehicle Exhaust
• Arrival/Departure Locomotives	• Worker Vehicle Evaporative
• Additional Idling from Arrival/Departure Locomotives	• HDDT Delivery
	• HDDT Delivery Idle
• Switcher Locomotive Operation	• Facility Truck Facility Truck Idle
• Switcher Refueling Idling	• Space Heating
	• Water Heating
	• LPG - Welders/Cutters
	• Diesel - Specialty Vehicle Carts
	• Diesel - Rubber Tire Loaders
	• Diesel - Forklifts
	• Diesel - Other General Industrial Equipment
	• Diesel - Snowblowers
	• Aerosol Paints

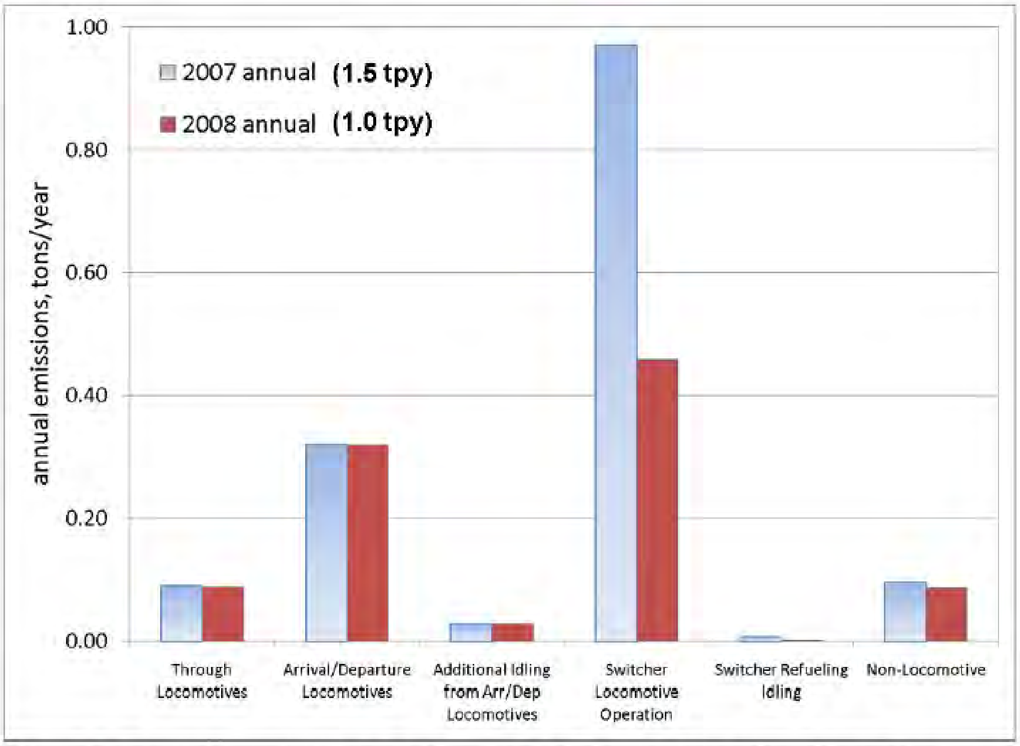

Figure 3-1. $PM_{2.5}$ emissions by source type at the CSX Rougemere Rail Yard in Dearborn, Michigan (Heiken, 2009).

Rail yard emissions are unevenly distributed over the source area, with certain zones with high activity (e.g., container moving by cranes, through locomotives) and other zones relatively inactive (e.g., container storage). This contrasts to the well-studied highway source, which is a generally homogenous spatially distributed line source that varies temporally. Rail yard emissions vary both temporally and spatially, although limited by known boundaries. This study seeks to add to the body of knowledge on rail yard impacts on local air pollutant levels in the Region 5 territory, and is focused on the BNSF Cicero Rail Yard in Cicero, IL, as a fairly representative example of an intermodal rail yard. This study will use a mobile monitoring approach, combined with local meteorology information, to collect data on air pollutant concentrations upwind and downwind of the rail yard. This method utilizes the flexibility of mobile monitoring to collect data surrounding the rail yard and at extended distances downwind of the rail yard, allowing upwind/downwind concentrations to be compared and the extent of downwind influence to be detected. Recognizing the diurnal variability in the atmospheric mixing height, local wind conditions, and rail yard emissions activity, mobile deployments will be conducted over several different time frames to observe the variability of near-rail yard air pollutant concentrations and spatial extent of any excess air pollution detected over the upwind background levels. The different time frames will also cover periods anticipated to range from low to moderate side road traffic, thus will allow the influence of this other local source on data to be detected.

3.2 Project Purpose and Objectives

The purpose of this study is to measure the spatial patterns of rail yard-related gas- and particle-phase pollutants at a rail yard site within Region 5.

The specific objectives of this research study are:

- Measure the spatial extent of local air pollution elevated over the background, downwind of a major rail yard in Region 5.
- Measure the spatial and temporal variability of near-rail yard air pollution, under different meteorology conditions and source emission characteristics.

4. Organization and Responsibilities

4.1 Project Personnel

This QAPP addresses the measurement of spatial patterns of ambient air pollution nearby major rail yard using air monitoring instruments onboard multiple mobile and fixed sampling units. The field measurements will be performed by ARCADIS personnel, with technical guidance from EPA/ORD/NRMRL personnel. Table 4-1 lists the personnel responsible for the oversight and QA review of this project. Additional team members that will be involved in this study are listed in Table 4-2.

Table 4-1. Key Points of Contact

Name	Organization Affiliation	Title	Responsibilities	Contact Information
Gayle Hagler	EPA / NRMRL	Technical Leader/Project Leader	Technical leadership for study, WAM for ARCADIS research support, data analysis for fixed and backpack monitoring	Phone: (919) 541-2827 Email: hagler.gayle@epa.gov
Eben Thoma	EPA / NRMRL	Project Scientist	Technical support for study, Alternate WAM for ARCADIS research support, data analysis for mobile monitoring	Phone: (919) 541-7969 Email: thoma.eben@epa.gov
Bob Wright	EPA/ NRMRL	QA Manager	Quality Assurance through review of QAPP and presentation of results	Phone: (919) 541-4502 Email: wright.bob@epa.gov
David Proffitt	ARCADIS	Work Assignment Leader	Coordination of ARCADIS research support activities	Phone: (919) 544-4535 Email: david.proffitt@arcadis-us.com
Libby Nessy	ARCADIS	ARCADIS QA Manager	ARCADIS QA activities oversight	Phone: (919) 541-2260 Email: lnessley@arcadis-us.com

Parik Deshmukh	ARCADIS	Field operator	Operation of air monitoring vehicle, instrumentation, and data management.	Phone: 919-541-2980 Email: Parikshit.Deshmukh@arcadis-us.com
Monica Paguia	EPA Region 5	Project team member	Region 5 project leadership.	Phone: 312-353-1166 Email: paguia.monica@epa.gov
Loretta Lehrman	EPA Region 5	Project team member	Region 5 project coordination.	Phone: 312-886-5482 Email: lehrman.loretta@epa.gov

Table 4-2. Additional Project Team Members

Name	Organization Affiliation	Title	Responsibilities	Contact Information
Bill Mitchell	EPA / NRMRL	Project Engineer	Data-logging set-up support	Phone: (919) 541-2515 Email: mitchell.bill@epa.gov
Bill Squier	EPA/NRMRL	Project Engineer	Shop support for instrumentation mounting.	Phone: (919) 541-2516 Email: squier.bill@epa.gov
James Faircloth	EPA / NRMRL	Project Technician	GMAP vehicle troubleshooting support	Phone: (919) 541-0157 Email: faircloth.james@epa.gov
Jerry Faircloth	ARCADIS	Project Technician	Field study support	Phone: (919) 541-0314 Email: faircloth.jerry@epa.gov
Michal Derlicki	ARCADIS	Project Technician	Field study support	Phone: (919) 544-4535 Email: Michal.derlicki@arcadis-us.com
Richard Snow	ARCADIS	Project Scientist	Field study support	Phone: (919) 541-3135 Email: snow.richard@epa.gov
Chad McEvoy	EPA Region 5	Project team member.	Field study support	Phone: (312) 886-6084 Email: Mcevoy.chad@epa.gov
Jaime Wagner	EPA Region 5	Project team member.	Field study communications	Phone: (312) 886-9402 Email: Wagner.jaime@epa.gov

4.2 Project Schedule

The target project schedule is as follows:

- September, 2010: Preparation activities for field campaign
- October-November, 2010: Field campaign at the Cicero Rail Yard.
- December, 2010-March, 2011: Preliminary data analysis, including data report.
- March, 2011-September, 2011: Ongoing data analysis and presentation of results.

5. Scientific Approach

5.1 Sampling Design

In order to meet project objectives (Section 3.2), the following field data will be collected:

1) High-resolution mobile monitoring campaign – EPA's Geospatial Monitoring of Air Pollution (GMAP) vehicle will be deployed to map air pollutants surrounding the rail yard boundary and in near-rail yard neighborhoods.

2) Local meteorology data will be collected using a portable meteorology station.

The field study will be conducted over a 1-month period in Cicero, Illinois. The length of the field campaign was chosen to allow for repetitive fixed and mobile monitoring under a variety of meteorology conditions.

5.1.1 Site Selection and Description

The monitoring sites are selected based on the following criteria, shown in Table 5-1.

Table 5-1. Site selection criteria

Criteria	Rank (H:high, M:mid, L:low)
Activity level of rail yard	H
Existence of historical monitoring data at the site	M
Ease of setting up a fixed sampling site and monitoring meteorology and air quality for several months.*	H
Few other nearby sources	H
Capability to drive in close proximity to rail yard on multiple sides, particularly along axis of prevailing wind.	H
Access to low traffic roads surrounding rail yard, to avoid biases from single vehicle exhaust.	H
Characteristics of surrounding environment (residential, commercial, etc.)	M

*To support collaborative monitoring effort by Region 5 staff.

A number of monitoring sites were considered throughout the Chicago-area in Region 5, including the following rail yards – Corwith, Proviso, Cicero, 59th Street, The Belt, Ashland, and Elwood. The BNSF Cicero Rail Yard was selected as the optimal site based upon the criteria laid out in Table 5-1 and is shown in Figure 5-1. Cicero is an intermodal rail yard, with both locomotive and truck traffic inside the rail yard boundary. A common metric for intermodal rail yard activity is in terms of shipping container lifts per day – Cicero has approximately 1000-1200 lifts per day. In addition to emissions by diesel-powered cranes, other on-site emissions include 5-9 hostler trucks, 500 in/out truck traffic, 8 daily intermodal trains, and approximately 140 through trains (~120 passenger trains, 20 mixed freight trains), and 4-5 switcher locomotives.

Figure 5-1. Satellite image of the Cicero Rail Yard.

The area surrounding the Cicero Rail Yard is primarily residential neighborhoods, which provides a dense network of low-traffic residential roads allowing for multiple transects to be driven upwind and downwind of the rail yard. The roads surrounding the rail yard and estimated Average Annual Daily Traffic (AADT) for 2009 by the Illinois DOT are shown in Table 5-2 and Figure 5-2.

Table 5-2. Daily traffic counts on nearby roadways

Street	**Truck only (Daily counts)**	**Total Traffic (Daily counts)**
Cicero Ave. (South of rail line)	9,100	43,200
Cicero Ave. (North of rail line)	2,200	34,300
Cicero Ave. (Further south near I-55)	5,050	41,300
26^{th} North of yard	N/A	9,900
Ogden (east of yard)	N/A	22,400
Ogden (west of yard)	N/A	18,500
Ogden to Cicero turn off	N/A	11,200
Austin (west end of yard)	N/A	13,700
I-55 (~2 mile south)	12,000	149,100

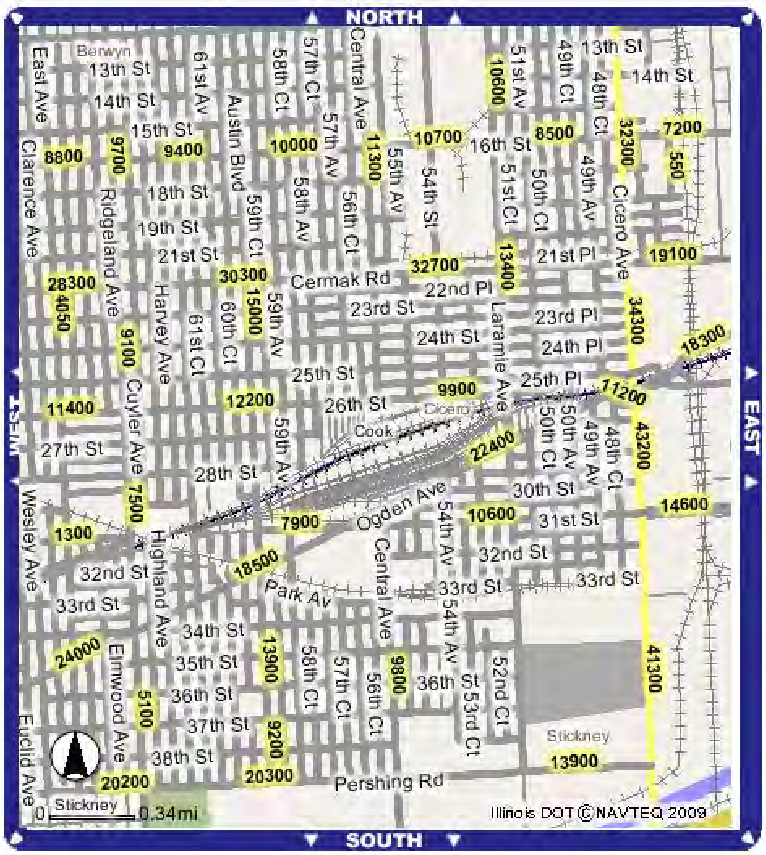

Figure 5-2. Average Annual Daily Traffic (AADT) along roads surrounding the Cicero Rail Yard.

The surrounding roads generally have low to moderate level traffic (150,000 AADT is the threshold usually considered as indicating a major highway) and the nearest major highway is over a mile away. In the interest of minimizing potential biases due to the roadways with moderate level traffic (e.g., Ogden Ave, Cicero Ave), the sampling will be conducted outside of typical commuter hours. However, it should be noted that up to 20% of traffic on some of the busier arterials can be due to truck traffic, which may not follow traditional commute hours. In addition to avoiding hopefully the worst case time periods, another preventative action to minimize bias due to local truck exhaust is the selection of specific residential side roads for monitoring without significant truck traffic. Finally, the electric vehicle will have a webcam recording the driver's view as well as real-time instruments that can detect sudden spikes in concentrations that would indicate a local exhaust event. The driving route is provided in more detail in section 5.1.3 and the monitoring actions to mitigate local exhaust bias are detailed in section 6.1.

5.1.2 Sampling Schedule

The mobile monitoring is conducted using an electric vehicle outfitted with fast-response air monitoring instruments. This vehicle has an on-board battery supply supporting driving and powering the air monitoring instruments. The daily sampling duration is limited by power availability, usually limited to approximately 2-3 hours of driving mode sampling, followed by 1-2 hours of stationary sampling. Several considerations are guiding the selected days of the week and time of day for sampling:

- Rail yard activity: BNSF reports that the lowest rail yard activity days are Tuesday and Wednesday, with Thursday, Friday, and Saturday having the highest traffic. During the day, highest traffic occurs during 10-11:30 AM and 8-9 PM. Lowest traffic occurs from midnight – 8 AM.
- Avoidance of commuter traffic: Commuter traffic windows (6:30-8:30 AM, 4:30-6:30 PM) are to be avoided in order to minimize the degree of local traffic influence.
- Meteorology: Atmospheric mixing height is lowest in the evening and pre-sunrise hours, which can reduce the dispersion of emissions and increase ground-level concentrations. During the day, the atmospheric mixing height increases as the sun heats the ground surface and dispersion of pollutants increases.

The following three periods of time are selected for sampling activity, all outside of the main commute periods:

A) 7 PM – 9:30 PM: Peak traffic at rail yard, mid-level atmospheric mixing height
B) 9 – 11:30 AM: Peak traffic at rail yard, high atmospheric mixing height
C) 4 AM – 6-30 AM: Low traffic at rail yard, low atmospheric mixing height

Sampling will occur over 6 days per week, and a tentative sampling schedule is laid out in Table 5-3. The schedule rotates the deployments as A, B, C, repeat, with a goal of having 8 of each time schedule and a variety of wind conditions for each time window. The rotation scheme is also considering the need for a vehicle recharge window between deployments, providing a minimum of 10 hours between deployments. An example sampling deployment timing is provided in Table 5-4.

Table 5-3 Tentative Sampling Schedule (blue = 7-9:30 PM [A] , orange = 9-11:30 AM [B], gray = 4-6:30 AM [C])

OCTOBER						
M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

NOVEMBER						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Table 5-4 Daily Sampling Schedule (e.g. for Schedule C)

Time	Action
0330	GMAP vehicle instrument QC checks
0400	Monitoring initiates – GMAP vehicle on route (4-6 repeats)
0630	GMAP driving ends, stationary sampling initiates
0800	GMAP stationary sampling ends, data downloaded

5.1.3 Driving Route

The electric car driving route outside of the rail yard boundaries is shown in Figure 5-3. This driving route was designed to have multiple transects extending at least 200 m away from the rail yard on each side of the yard. Several transects extend well over 300 m in distance, which is the threshold distance at which near-road field studies typically see elevated concentrations return to background levels. Data at distances downwind and data collected upwind of the rail yard will be compared to determine the distance at which concentrations downwind are similar to that upwind.

Figure 5-3. External rail yard mobile monitoring driving route (blue line) and location for stationary monitoring (yellow marker).

The draft driving route is approximately 11 miles and is anticipated to take 25 minutes to complete and allowing for the route to be repeated multiple times within the 2-3 hour driving period. This route may also be extended, or alternate with, a section of road that is within the rail yard boundaries, upon consultation with BNSF for access and vehicle safety. The driving route will be tested during a pre-deployment site visit for feasibility and may be altered, but will meet the goal having multiple transects on each side of the rail yard. The selection of the stationary monitoring location, to occur at the end of the driving route, is based upon Region 5's plan to initiate a stationary monitoring site there to collect data continuously during the field campaign. Thus, stationing the electric vehicle at that location for daily fixed point sampling will provide data inter-comparing the air monitoring instrument data onboard the vehicle with that of the Region 5 instruments. This is also the tentative location for local meteorology measurements to be conducted.

5.2 Process Measurements

All measurements that will be collected by the two monitoring methods are described in Table 5-5. In addition to the below measurements, forward-facing video of the route will also be collected during each deployment using an on-board webcam.

Table 5-5. Measurements to be conducted during the mobile monitoring campaign

Measurement	Rate	Instrument
Carbon monoxide (CO)	1 s	Quantum cascade laser (QCL, Aerodyne Research, Inc.)
Sulfur dioxide (SO_2)	1 s	Quantum cascade laser (QCL, Aerodyne Research, Inc.)
Particle number concentration (size range 5.6-560 nm, 32 channels)	1 s	Engine Exhaust Particle Sizer (EEPS, Model 3090, TSI, Inc.)
Particle number concentration (size range 0.5-20 µm, 52 channels)	1 s	Aerodynamic Particle Sizer (APS, Model 3321, TSI, Inc.)
Black carbon	1-5 s	Single-channel Aethalometer (Magee Scientific, AE-42)
Longitude and latitude	1 s	Global positioning system (Crescent R100, Hemisphere GPS)
3D wind speed and direction	1 s	Ultrasonic anemometer (RM Young, Model)

5.3 General Approach and Test Conditions for Each Experimental Phase

This is an ambient monitoring study that will not have experimental phases. The sampling details are described in Section 6.

6. Sampling Procedures

6.1 Site-Specific Considerations

The primary objective of this monitoring study is to measure *in situ* the dispersion of rail yard emissions to surrounding near-rail yard areas. The measurement results are understood to be site-specific in nature due to the unique building and vegetation topography, which are known to impact dispersion. Another site-specific feature is the Cicero rail yard emissions spatial distribution – the within-yard location and strength of multiple emission points (e.g., diesel-powered cranes, hostler trucks, and switcher locomotives) will affect the resulting spatial distribution and chemical composition of emissions. All of these factors will be considered in the interpretation of results.

The primary site-specific factors that will affect monitoring procedures are local meteorology, rail yard source activity, and side-road traffic. The researchers are in communication with BNSF employees, who have already provided information on general activity trends for the Cicero rail yard. This information was useful in selecting three different monitoring periods for sampling. The driving route is designed to provide useful data regardless of wind direction, with transects located on each side of the yard. In addition to the basic information provided by BNSF which was utilized in selecting the monitoring time periods, BNSF has also agreed to provide EPA with daily timestamped recordings of container lifts and trucks entering/exiting the facility. These data will be used to understand the daily activity trends of the rail yard.

Side-road traffic is an important consideration affecting both the monitoring procedures as well as the ensuing data analysis. Emissions from local traffic can lead to biases in the monitoring data and obscure the characterization of the rail yard emissions impact on surrounding areas. Several methods are used to minimize this potential bias in the data set. First, the site selection process included surrounding sources, including major roads, as a factor in selecting the Cicero rail yard site. Second, the sampling timeframes are selected outside of the commute period, with 0630-0830 and 1430-1830 avoided. Finally, an effort will be made to detect and flag data that may have a threat of bias due to an individual vehicle's exhaust, which is described in further detail below.

During sampling, webcams will be used onboard the GMAP to record local vehicle exhaust episodes. In addition, the operator will also write in the sampling notes (street name and time) potential exhaust events that were observed and potentially not captured on the webcam video. Also, the GMAP vehicle will be driven, with safety as the first priority, at a distance behind other vehicles on the road. Finally, post-processing will be completed of the electric vehicle data set - an algorithm will be applied that detects and flags time periods with apparent local exhaust impact, characterized by a sudden sharp spike in carbon monoxide concentrations. This algorithm will be applied equally to all data recorded by the GMAP vehicle. This algorithm was developed by Gayle Hagler based upon near-road field studies (Hagler et al., 2010) in the Triangle Region of North Carolina and found to successfully remove incidences of local exhaust, with a total loss of data around 2-3% for driving routes with relatively low side road traffic. The MATLAB code for this algorithm is provided in Appendix A. This algorithm will be tested again for the CIRYS field study by comparing the flagged time periods for one complete field sampling deployment with a webcam video record from the dashboard of the GMAP vehicle. If found to be insufficient in detecting biases, the algorithm will be modified and rationale for any changes documented. One possibility, specific to this site, is that using carbon monoxide as the main indicator may not be sufficient to detect truck exhaust. If evaluation with webcam data reveals that this is the case, black carbon or ultrafine particles would be tested to see if they are more sensitive indicators of vehicle exhaust.

6.2 Sampling Equipment and Procedures

The sampling equipment used in this study includes one mobile monitoring vehicle equipped with air monitoring analyzers, GPS, and a webcam, as well as a portable meteorology station.

Supporting equipment includes a truck equipped with a car-hauling trailer to transport the electric vehicle as needed.

The following general tasks will be completed as part of the daily instrument deployment process. Specific details regarding the operation of the GMAP vehicle are found in Appendix B.

1. GMAP electric vehicle will be fully charged (refer to Appendix B, Section 3, GMAP MOP #1) and equipped with a GPS, webcam, and high time resolution air monitoring instruments. Time of response will be tested for the various instruments to exactly time-align data.
2. QC checks on all GMAP analyzers will be performed daily during the study.. Prior to initiating a daily driving period, the multiple computers used for data logging will be time-aligned with the GPS-derived “true” timestamp.
3. The GMAP electric vehicle will be transported to the field site using a vehicle equipped with a car-hauling trailer unless a storage and charging area is found near the sampling site.
4. Ambient mobile monitoring sampling will take place for approximately 3 hours. The GMAP electric vehicle will be driven repeatedly around an assigned route. After approximately 3 hours, the GMAP vehicle will be parked at the location indicated in Figure 5-3 and sampling will ensue for approximately 1-2 hours, depending on the vehicle battery life.
5. The GMAP air monitoring instrumentation will be shut down and the vehicle will be relocated to a secure and temperature-controlled environment for recharging and overnight storage.

The manuals providing procedures for operating the electric vehicle, air monitoring instruments, and supporting instrumentation are provided in the Appendices B-H as follows:

- Appendix B: GMAP manual
- Appendix C: Hemisphere GPS manual
- Appendix D: EEPS manual
- Appendix E: APS manual
- Appendix F: Aethalometer manual
- Appendix G: QC Laser system technical information
- Appendix H: Ultrasonic anemometer manual

Log sheets will be kept to record the daily sampling events and QA checks – an example log sheet for the mobile monitoring is below.

Example:
GMAP Daily Log Sheet

Date: 11/1/09 Sampling Day: 1

Site: Cicero Rail Yard Operator: James

Sync computer clocks with GPS ☑

Fill QCL with liquid N_2 ☑

PM instrument zero checks:

	Time: 7:49 AM	Time: 11:30 AM
Aethalometer	BC:	BC:
EEPS	Total PN:	Total PN:
APS	Total PN:	Total PN:

QCL CO Check:

	Time: 8:05 AM	Time: 1:05 PM
CO	176 ppb	164 ppb
SO_2	110 ppb	115 ppb

QC checks acceptable?

Aethalometer ☑ EEPS ☑ APS ☑ CO ☑ SO2 ☑

	Start time:	End time:
Driving route	9:15 AM	11:13 AM
Webcam	9:13 AM	12:00 PM
Stationary	11:13 AM	12:00 PM

Total number of laps for the run: 5

Observed weather: Light winds from the SW

Comments:
For QCL CO and SO2 Check, using N_2 cylinder with 0.18 ppm CO and 0.1 ppm SO_2

6.3 Quality Control in Sample Analysis

No physical samples will be collected and analyzed – data will be collected using air monitoring instruments. The Quality Control procedures for the air monitoring and supporting measurements are described in Section 8.

6.4 Sample Preservation

No physical samples will be collected – data files labeling and storage are discussed in section 6.5.

6.5 Sample Numbering

Air monitoring data will be timestamped and will not have specific sample numbers assigned. For the GMAP samplers, the individual data files will be uniquely labeled by sampling vehicle, location, instrument, and date – Location_PlatformName_Instrument_YYYYMMDD. For example, UFPs measured using the EEPS on-board the GMAP electric vehicle on November 1, 2010 during the CIRYS Study would be labeled as – CIRYS_GMAP_EEPS_20101101. The raw data files will maintain this naming scheme in a master database stored by the EPA Project Leader. Any periods of missing data due to equipment malfunction, severe weather, or unacceptable quality of data will be documented in the project notebook or electronic files.

6.6 Sample Chain-of-Custody

The original data files will be collected and maintained by ARCADIS personnel. At the completion of the entire field campaign and data post-processing, final data files and site notes will be sent to the EPA Technical/Project Leader, Gayle Hagler, for final storage on an EPA server. An overview of the raw data collection and storage is provided in Figure 6-1. Prior to sampling with the GMAP vehicle, the on-board data logging computers are manually time-synchronized to the satellite-based time recorded by the on-board GPS. The instruments log data using either generic programs (e.g., WinWedge or HyperTerminal) or instrument-specific programs (e.g., Aerosol Instrument Manager for the EEPS). Prior experience using these instruments guides the number of external computers needed to simultaneously log all data streams or reliance upon internal memory for certain instruments. The GMAP instruments (GPS, EEPS, APS, AE42, QC laser, and webcam) will log to an external onboard computer and the meteorology station measurements will also log to a separate and time-synchonized computer.

After data is recorded and downloaded from the instruments or external data-logging computers, the data is transferred using a USB drive and a copy is retained by ARCADIS personnel. Along with field notes recorded electronically, the raw data is later transferred to the EPA network, with the exception of video files (each about 1 GB) that are stored to an external hard drive and maintained by the EPA Technical Leader. The raw data files are stored in a folder labeled "raw data" and remain unchanged, with copies of these files made for post-processing activities. Secondary processing of data, for purposes of aligning real-time concentrations and location data as well as analysis of trends, is described in detail in Section 9.

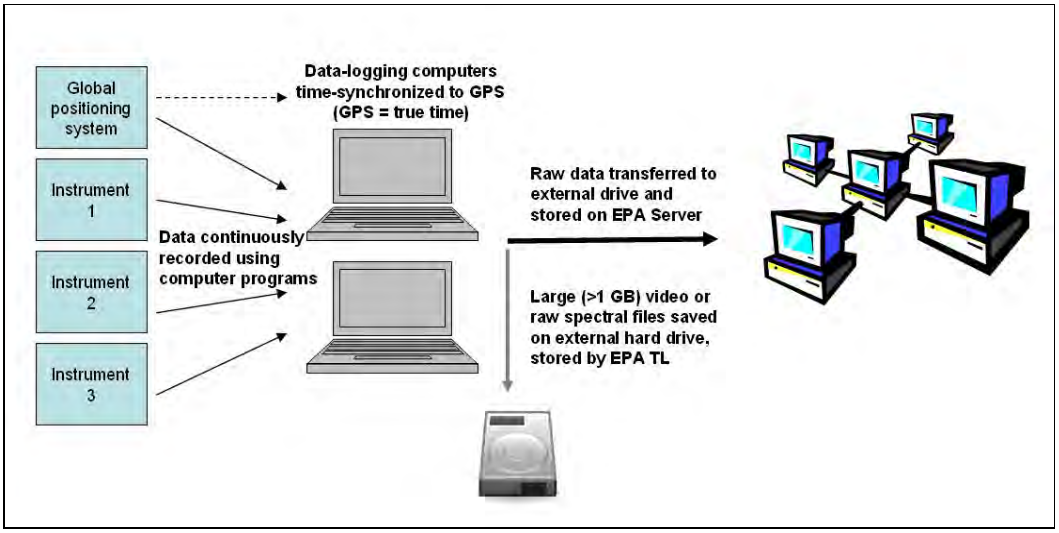

Figure 6-1. Data collection and storage process

7. Measurement Procedures

No analytical methods will be performed on this project, all data is acquired real-time. The critical measurements for the project were listed in Table 5-5.

7.1 GMAP monitoring

This study will utilize a mobile monitoring vehicle (GMAP) operating in driving-mode sampling. An image of the GMAP vehicle is provided in Figure 5-1.

Figure 7-1. Mobile monitoring vehicle planned for use in this study.

While most sampling approaches used in typical stationary fixed site sampling studies directly translate to this project, such as the use of electrically conductive tubing to minimize particle loss and careful time-alignment of data-logging laptops, some unique considerations need to be made for the GMAP vehicle which operates in driving mode. The two primary additional considerations made are the sampling inlet and the determination of lag time for sampling instruments.

The GMAP sampling inlet is designed to provide isokinetic conditions while the vehicle is in motion. Isokinetic conditions are most important for the larger particle sizes (e.g., PM_{10}) and are generally negligible for gases and ultrafine particles. Two air velocity parameters are taken into consideration in the design of the inlet – the combined inlet volume flow of the instruments on-board the electric car and the air flow rate as the vehicle is in motion. The inlet design assumes an air flow rate for a vehicle driving at approximately 30 mph. In order to determine whether speed-based correction will be needed for higher driving speeds, preliminary field tests will be conducted driving the GMAP vehicle over a range of speeds (0-45 mph) on roads with minimal traffic (refer to Appendix B for more information).

In order to precisely align position and air concentration data for the GMAP vehicle, another important factor is characterizing the amount of lag time associated with an air sample transporting through the sample line and measurement by a given air monitoring instrument. This lag time will be experimentally determined by inducing a sudden concentration change for the analyte of interest, such as using a HEPA filter for the particulate instruments, and observing the amount of time before the concentration is recorded by the monitoring instrument. Further details are provided in Appendix B.

7.2 Calibration Procedures

All equipment will be calibrated annually and/or cal-checked as part of standard operating procedures. Calibration records are kept on file. Maintenance records are kept for any equipment adjustments or repairs in project logbooks that include the date and description of maintenance performed. Details on the instrument-specific calibration and cal-check procedures are available in the Appendices and Section 8.1.

8. Quality Metrics

8.1 QC Checks

The QC checks used in the field to assess the QA Objectives (section 8.2) are provided in Table 8-1.

Table 8-1. Procedures Used to Assess QA Objectives

Measurement Parameter	Analysis Method	Assessment Method
Particulate size and number concentration	EEPS 3090	Single point flow check prior to field campaign and weekly during campaign; Daily zero check
Particulate size and number concentration	APS Model 3321	Single point flow check prior to field campaign and weekly during campaign; Daily zero check
Black carbon	Aethalometer	Single point flow check prior to field campaign and weekly during campaign; Daily zero check
SO_2	QC Laser, Aerodyne	Pre-deployment multi-point calibration check Daily zero/span check
CO	QC Laser, Aerodyne	Pre-deployment multi-point calibration check Daily zero/span check
Ambient wind speed and wind direction	RM Young Ultrasonic Anemometer Model 81000	Pre-deployment calibration by Metrology Lab
Location (longitude, latitude, elevation)	Hemisphere GPS	Pre-deployment comparison of measured GPS data with known reference location
Leaf area index	LAI2000	Comparison of LAI data with known range of historically observed values for similar vegetation types.

8.1.1 Particle Measurement Instrument Assessment

The EEPS, APS, and Aethalometer measure particulate components based on manufacturer calibration. For the instruments used in this study, the manufacturer calibration took place in 2009 for the EEPS and APS. The Aethalometer was calibrated in 2008. To test each instrument's performance prior to use in the field and periodically during the sampling campaign, single-point flow verification and a zero check should be conducted. The flow verification should be conducted using a calibrated flow meter and flows should be within 10% of the set point. The zero check is conducted by attaching a high efficiency particulate air (HEPA) filter to the sampling inlet, which removes >99% of particulates of diameter >0.3 μm. While the HEPA filter is in place, downstream particulate concentrations should read near zero for the instrument to be deemed acceptable. The zero check should be performed prior to each daily deployment to the field and a flow check should be performed weekly during the field campaign. Given a failure in meeting this data quality indicator, response actions include, but are not limited to, (1) performing cleaning maintenance, (2) changing sampling inlet, and (3) seeking technical support from the instrument manufacturer.

8.1.2 Quantum Cascade Laser assessment

The CO and SO_2 data from the QCL will be verified against gas standards which bracket the anticipated range of ambient concentrations. Given a failure to meet this data quality indicator, response actions will include, (1) verifying the data collection process is being performed correctly, (2) seeking technical support from the instrument manufacturer.

8.1.3 Global Positioning System Assessment

The GPS system will be verified by driving along a specific route and remaining stationary at a known location, then comparing reported longitude/latitude against mapping data. Several software or internet-based programs are available to determine whether reported data matches the actual route, including ArcGIS, MATLAB, and Google Earth Pro.

8.1.4 Ultrasonic Anemometer Assessment

The ultrasonic anemometer DQIs are checked annually as part of a routine calibration procedure. The specific ultrasonic anemometer used for this study has recently undergone repair and recalibration by the manufacturer (Summer 2010).

8.2 QA Objectives and Acceptance Criteria

The Data Quality Indicator goals for accuracy, precision, and completeness for this project are listed in Table 8-2. Any failure of the instrumentation to meet the DQI goals will be reported to the EPA TLP. Data collected during time periods in non-attainment with DQI goals will be flagged as questionable, but not necessarily considered invalid. Corrective action to be taken depends on the nature of the problem encountered. For example, given an error in sampling flow, careful cleaning of the inlet may be required.

Table 8-2. Data Quality Indicator Goals for the Project

Measurement Parameter	Analysis Method	Assessment	Criteria Accuracy	Complete-ness	Precision[b]	Corrective Actions Given Failure to meet Criteria
Carbon Monoxide	Quantum Cascade Laser	(1) Initial flow check (2) Zero/Span check in the field	Within +/- 20% of calibration gas	90%	+/-10%	(1) Inlet will be checked for flow obstructions (2) Instrument troubleshooting will take place.
Sulfur dioxide	Quantum Cascade Laser	(1) Initial flow check (2) Zero/Span check in the field	Within +/- 20% of calibration gas	90%	+/-10%	(1) Inlet will be checked for flow obstructions (2) Instrument troubleshooting will take place.
Black carbon	Aethalo-meter	(1) Initial single point flow check (2) Daily zero check	(1) +/- 10% of set-point (2) 5-min average at <20% of ambient[a]	90%	N/A	(1) Sampling inlet will be checked for obstructions. If flow errors continue, instrument troubleshooting and/or flow recalibration will take place. (2) Instrument connections will be checked and zero-check repeated. Data collection will continue given repeat failure, but data will be flagged.
Particulate size and number concentration	EEPS 3090	(1) Initial single point flow check (2) Daily zero check	(1) +/- 10% of set-point (2) 5-min average at <20% of ambient[a]	90%	N/A	(1) Sampling inlet will be checked for obstructions. If flow errors continue, instrument troubleshooting and/or flow recalibration will take place. (2) Instrument connections will be checked and zero-check repeated. Data collection will continue given repeat failure, but data will be flagged.
Particulate size and number concentration	APS Model 3321	(1) Initial single point flow check (2) Daily zero check	(1) +/- 10% of set-point (2) 5-min average at <20% of ambient[a]	90%	N/A	(1) Sampling inlet will be checked for obstructions. If flow errors continue, instrument troubleshooting and/or flow recalibration will take place. (2) Instrument connections will be checked and zero-check repeated. Data collection will continue given repeat failure, but data will be flagged.
Wind speed and direction	Ultrasonic anemometer	Data will be compared with field operator observations on log sheet.	General matching of wind direction and speed	90%	N/A	(1) Orientation of sonic anemometer will be checked and corrected if found to be out of alignment.
Location	Hemisphere GPS	(1) Status lights indicate collected signal (2) Review of mapped location with pre-designated route and stationary location.	+/- 10 m of a known location	95%	+/- 10 m of a known location	Sampling will discontinue until GPS is determined to be functioning properly.

[a]The HEPA filter removes >99% of particulates of diameter >0.3 μm, however the particle instruments also measure particles under 0.3 μm, which may have a higher penetration efficiency.
[b]Precision will be based upon comparison with a gas standard. GPS data precision will be compared by looking at the variability of the location data when the car remains parked at a single location.

9. Data Analysis, Interpretation, and Management

9.1 Data Reporting

Research results are intended for publication in scientific journals, thus no writing of internal EPA reports is expected. The EPA Technical Lead, Gayle Hagler, will be responsible for generating a data report for internal use among EPA scientists. This report will include information on the sampling collection times, field notes, and preliminary data review (completeness, QC checks).

9.2 Data Validation

Verification and validation of the procedures used to collect and analyze data are critical to achieving project objectives. Data validation for this study will be accomplished through a review of quality control checks conducted daily for the instrumentation as described in Table 8-2. This review will determine whether or not instrumentation had acceptable performance and the data useable in analysis. ARCADIS will be responsible for the operation all field instrumentation. The EPA Technical Lead, Gayle Hagler, will be responsible for reviewing the GMAP vehicle data.

9.3 Data Analysis

Following the collection of raw data, as described in Section 6, the GMAP data are processed using several standard algorithms developed in MATLAB, which is described in Figure 9-1 – (1) Adjustment for lag time, (2) Combining GPS location data and air monitoring data into a joint matrix that is now time and spatially-resolved concentration data, and (3) Spatially consolidating data from repeat drives into spatial increments of interest (user-defined) for purpose of calculating averages or other statistics. Data analysis can take place at various levels of post-processing. For example, inter-comparing data for the same variable (e.g., black carbon) may only require that the data be time-aligned (step 1). Observing concentration changes in both time and location would require steps 1 and 2 to be conducted. Finally, looking at 2-hour average concentration maps would require steps 1-3 to be completed. While the algorithms used to process steps 1-3 are customized based upon each specific instrument's data, the common algorithm elements are provided in Appendix H.

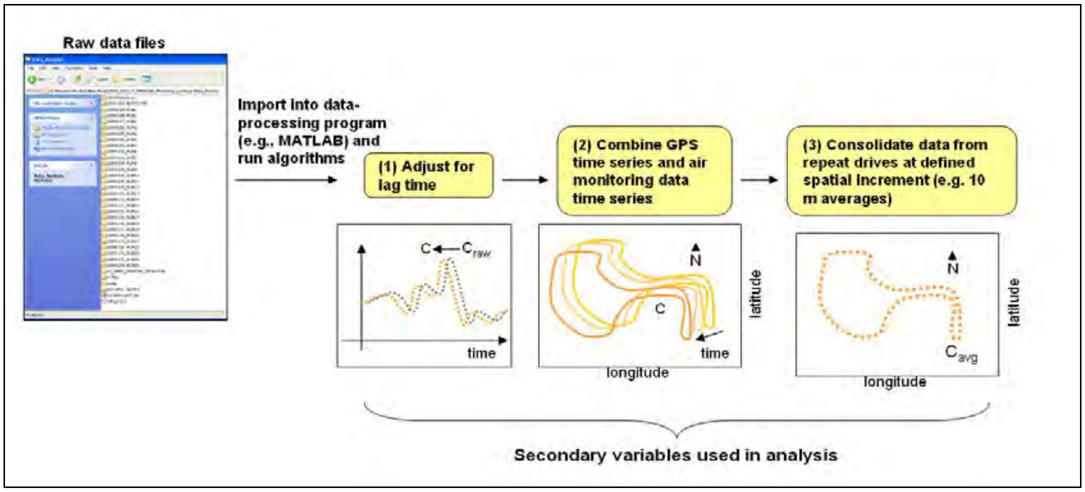

Figure 9-1. Post-processing of mobile monitoring raw data for use in analysis.

For this study, data analysis after the above processing steps will include parallel time series and correlation analysis of the air pollutant measurements (following step 1) as well as geospatial and temporal analysis (following step 2 and/or step 3) of the driving-mode mobile monitoring vehicle data. These and other analyses may lead to further post-processing of data, dependent on project needs. Additional data used for interpretation will include regional meteorology data and other air pollutants measured simultaneously on-board the electric vehicle. In addition, Region 5 is planning to set-up a fixed monitoring site adjacent to the rail yard and may have a number of continuous measurements that duplicate those in the electric car. This monitoring site will have a separate QA document processed by Region 5 QA staff. If this fixed monitoring data is available concurrent with the mobile monitoring study, this will be a second data set available for analysis and will provide context for the mobile monitoring data. Gayle Hagler will be the main individual responsible for the analysis of the GMAP data and any combined analysis of the GMAP and Region 5 fixed monitoring site data.

In order to meet project objectives of characterizing whether or not, and to what extent, rail yard-related air pollutants are elevated over background concentrations, it is important to define how "background" is defined for this case. The concept of "background" ranges in the scientific community to the natural ambient background, without any development; to a rural setting, removed from any major industry; to an "urban background", in a developed area but removed from any major source. For this study, the urban background concept will be applied and defined as upwind-of-rail-yard areas that are greater than 200 m from the road, with minimal traffic on roadways monitored. The lower wind threshold will be 1 m/s – if wind speeds are lower, the meteorology conditions will be considered low speed, mixed winds and an upwind area will not be defined. For days with winds > 1 m/s, the mobile monitoring data covering urban background areas meeting the aforementioned criteria will be averaged and the variability of the background will be quantified. These upwind data will be compared vis-à-vis data covering areas downwind of the rail yard, again on roadways with minimal traffic, to evaluate whether downwind concentrations are higher than urban background conditions.

9.4 Data Storage Requirements

No physical samples will be collected or require storage. Section 6.6 discusses the chain-of-custody and storage for the mobile monitoring data.

10. Reporting

10.1 Deliverables

Deliverables from this study include final quality-assured field data and manuscripts for publication in scientific journals.

10.2 Expected Final Products

Anticipated final products for this study are peer-reviewed, published research papers in science journals and presentations at scientific conferences.

11. References

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Quality Assurance Project Plan (QAPP)

US EPA Region 5

Regional Applied Research Effort (RARE) Project

Cicero Rail Yard Study (CIRYS)

Stationary Special Purpose Monitoring (SPM) of Near Rail Yard Air Quality

Version 1.0

Approval Date: OCT 2 1 2010

A. PROJECT MANAGEMENT

A1. Approval Sheet

Cicero Rail Yard Study (CIRYS) – Stationary Special Purpose Monitoring (SPM) of Near Rail Yard Air Quality

Monica Paguia 10/21/10

Monica Paguia Date
Region 5 Air & Radiation Division
U.S. Environmental Protection Agency
Project Leader/QA Coordinator

Chad McEvoy 10·21·2010

Chad McEvoy Date
Region 5 Air & Radiation Division
U.S. Environmental Protection Agency
Project Scientist

10-21-10

Loretta Lehrman Date
Region 5 Air & Radiation Division
U.S. Environmental Protection Agency
Quality Assurance Manager/Section Chief

A2. Table of Contents

A3. Distribution List

The QAPP will be distributed electronically. A hardcopy will be kept at the fixed site location.

<u>EPA Region 5</u>
Loretta Lehrman
Monica Paguia
Chad McEvoy
Michael Compher
Jaime Wagner
Basim Dihu
Anthony Ross
Jesse McGrath

<u>EPA ORD</u>
Gayle Hagler
Eben Thoma

<u>BNSF</u>
Paul Nowicki
David Seep
Michael Stanfill

A4. Project Organization

Table A-1: Key points of contact

Name	Organization Affiliation	Title	Responsibilities	Contact Information
Monica Paguia	EPA Region 5	Project Leader/QA Coordinator	Overall project leadership for study; data review, verification, and validation; and maintaining official QAPP	Phone: (312) 353-1166 Email: paguia.monica@epa.gov
Chad McEvoy	EPA Region 5	Project Scientist	Project coordination. Lead for fixed site technical activities and data generation.	Phone: (312) 886-6084 Email: mcevoy.chad@epa.gov
Loretta Lehrman	EPA Region 5	Supervisor/ QA Manager	Project oversight and Quality Assurance	Phone: (312) 886-5482 Email: lehrman.loretta@epa.gov
Gayle Hagler	EPA / NRMRL	Project team member	ORD technical leadership for mobile monitoring, data analysis.	Phone: (919) 541-2827 Email: hagler.gayle@epa.gov
Eben Thoma	EPA / NRMRL	Project team member	ORD technical support for mobile monitoring	Phone: (919) 541-7969 Email: thoma.eben@epa.gov

Table A-2: Additional Project Team Members

Name	Organization Affiliation	Title	Responsibilities	Contact Information
Michael Compher	EPA Region 5	Project team member	Project coordination	Phone: (312) 886-5745 Email: compher.michael@epa.gov
Jaime Wagner	EPA Region 5	Project team member	Field Study Communications	Phone: (312) 886-9402 Email: wagner.jaime@epa.gov
Basim Dihu	EPA Region 5	Project team member	Field study support	Phone: (312) 886-6242 Email: dihu.basim@epa.gov
Jesse McGrath	EPA Region 5	Project team member	Field study support	Phone: (312) 886-1532 Email: mcgrath.jesse@epa.gov
Anthony Ross	EPA Region 5	Project team member	Field study support	Phone: (312) 353-0826 Email: ross.anthony@epa.gov

A5. Problem Definition & Background

This research study was originated by an EPA Region 5 RARE proposal, which hypothesized that rail yard emissions may locally elevate air pollutant levels and contribute to regional $PM_{2.5}$ nonattainment status. The initial intent of this study was to better understand carbon emissions near rail yards in Region 5, determine how locomotive emissions contribute to local $PM_{2.5}$ concentrations, and to further the overall objective of better understanding rail yard emission impacts on $PM_{2.5}$ concentrations and other pollutants in the ambient air within Region 5.

Phase I of the RARE study focused on the CSX Rougemere Rail Yard in Dearborn, Michigan in a multi-component research effort that included a rail yard emissions inventory, dispersion modeling, and a several month monitoring campaign. This campaign measured carbonaceous particulate matter (black carbon, elemental carbon, and organic carbon) at two sites immediately adjacent to the rail yard and additional site located within a nearby residential area which represented urban background concentrations. A formal technical report on Phase I results has been completed. The results documented a reduction in annual $PM_{2.5}$ emissions due to locomotive replacements and fuel changes which occurred at the rail yard and it recommended that characterization of other nearby sources be performed. Because our research objective is to better our understanding of rail yard emission impacts within Region 5, the decision was made to continue Phase II at a larger rail yard within an urban, as opposed to an industrial setting.

This QAPP applies to the Phase II of this study; particularly the special purpose stationary monitoring site. The primary objective of Phase II, which is planned to occur near the BNSF Cicero Rail Yard in Cicero, IL is to characterize the spatial extent and variability of near-rail yard impact on air pollutant concentrations in an urban area.

Region 5 will support the stationary site. It is located near- downwind of the Cicero Rail Yard and along the mobile monitoring route. In addition to providing context for the mobile monitoring data, it will provide a continuous time series of meteorology and concentrations of fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), sulfur dioxide (SO_2), black carbon (BC), and nitrogen oxides (NOx).

A separate component of Phase II uses a mobile monitoring approach to measure concentrations of multiple species (CO, SO_2, BC, and size-resolved particle number concentration) in real-time while driving on multiple transects on upwind and downwind sides of the rail yard. This other component is addressed in a separate QAPP authored by EPA's Office of Research and Development (ORD).

A6. Project/Task Description

This QAPP addresses the special purpose stationary monitoring component of Phase II and involves three major tasks.

1. Special Purpose Monitoring: Install, operate, and maintain continuous measurements for $PM_{2.5}$, BC, SO_2, CO, NOx and meteorological data. This monitoring is planned to start from mid-October 2010 and continue for six months to a year.

   The site location is downwind (based on prevailing winds in the Cicero area), just northeast of the Cicero Rail Yard as shown in figure A-1 as indicated by the orange circle. It was chosen based on prevailing wind direction, openness (no obstructions to the site), ease of access, security, and electrical availability.

2. Data Analysis: Prepare a database with the measurements from the special purpose monitoring study, perform data validation, and conduct data analyses to characterize the spatial extent and variability of near-rail yard impact on air pollutant concentrations and to provide context for the data generated from the mobile monitoring vehicle. Data validation and preliminary analyses will occur as data is being collected and throughout the project period. Data analysis will include assessing concentrations as a function of wind direction, wind speed, time of day, and day of the week. In addition, the fixed site data trends will be compared with that of the mobile monitoring vehicle during the mobile monitoring time periods. Data analysis will continue for several months after sampling.

3. Reporting: Develop presentations and prepare an EPA internal technical memorandum summarizing the monitoring field study efforts and data analysis performed by Region 5. The data collected from this fixed site may be used by ORD for research purposes and published in scientific journals.

Figure A-1 Satellite view of Cicero Rail Yard and the fixed site location

A.7 Quality Objectives and Criteria

The primary objective of this research study is to characterize the spatial extent and variability of near-rail yard impact on air pollutant concentrations in an urban area. Because the special purpose monitoring data collected at the fixed site will be used together with the mobile monitoring data and possibly other nearby regulatory ambient air monitoring data, data quality objectives must meet similar or more rigorous requirements.

The location of the fixed monitoring site allows for samples to be representative of near- rail yard ambient air concentrations. The site is located to the northeast of the rail yard, which is in the prevailing wind direction and thus is frequently expected to be the receptor of transported rail yard emissions. For a given wind direction and wind speed, the measured concentrations will be a function of the emissions strength and emission location for a particular species throughout the rail yard. Thus, the concentrations measured adjacent to the rail yard may be more heavily impacted by emissions in the near-field zone. This would be true of any near-rail yard monitoring location, thus this site is considered to be generally representative of near-rail yard air quality.

- **Precision** is a measurement of mutual agreement between two measurements of the same property usually under prescribed similar conditions. At a minimum, bi-weekly QC checks will be conducted on the gaseous analyzers. The met equipment has recently been recertified.

- **Bias** (a combination of precision and bias) is defined as the systematic or persistent distortion of a measurement process which causes errors in one direction. Audits will be performed on the gaseous analyzers and flow checks conducted on the $PM_{2.5}$ sampler & aethalometer. The mobile (GMAP) monitoring data will be collected simultaneously with the special purpose monitoring data at the same location of the fixed site for each day the GMAP is deployed.

- **Completeness** refers to a measure of the amount of valid data obtained from a measurement system compared to the expected amount obtained under normal conditions. A data completeness goal of at least 75% is expected.

- **Sensitivity or Detect ability** refers to the low critical range value that a method could reliably discern.

Table A-3 Method Detection Limits (MDL)

Measurement Parameter	Analysis Method	MDL
$PM_{2.5}$	EBAM (beta attenuation method)	Dependant on time resolution
Black Carbon	Optical Transmission Method	Dependant on flow

		rate and time resolution
NOx	TECO 42	0.5 ppb
SO_2	TEI 450C, API 101A, & API 101E	0.5 ppb
CO	API 300E	40 ppb
Ambient wind speed	Met One	0.3 m/s

A8. Special Training/Certification

All personnel have the appropriate training and experience necessary to fulfill their role and responsibilities needed to implement this project and meet the required quality objectives.

A9. Documentation and Records

Bound logbooks will be maintained at the stationary monitoring site. Information documented in these logbooks will include at least the date, time, site operator initials, calibrations and audits conducted, preventative maintenance, and troubleshooting performed on any of the instruments, along with any other pertinent observations and information.

Additionally, a binder containing all QC documentation (audit sheets, calibration sheets and standards certification certificates) will be maintained by U.S. EPA.

B. DATA GENERATION & ACQUISITION

This project will rely on this QAPP, EPA Standard Operating Procedures (SOPs), and manufacturer's instrument manuals to acquire and generate data. Instrument manuals and SOPS can be found in the appendices.

B1. Sampling Process Design

The sampling process is designed to help better understand the local impact of rail yard emissions on ambient air pollutant concentrations, to characterize the air quality in this area over a longer period of time than the mobile monitoring campaign, and to provide supporting information for the mobile monitoring effort. The sampling approach consists of continuous monitoring of $PM_{2.5}$, BC, SO_2, CO, NOx, wind speed/wind direction and other meteorological data at a fixed location over a six month to one year time period.

B2. Sampling Methods

All data will be collected using automatic continuous air pollution measurement analyzers and meteorological sensors. Table A-3 lists the instrument methods used. Neither manual sampling nor analytical methods (sample analyses) are needed for this project.

B3. Sample Handling and Custody

Sample handling is not necessary for this project. The used tape from the continuous $PM_{2.5}$monitor and aethalometer will be properly labeled, transferred, and stored at the Region 5 Air Monitoring Laboratory. This will be appropriately documented; no formal chain of custody is necessary.

B4. Quality Assurance/Quality Control

The purpose of Quality Control (QC) is to establish confidence, demonstrate reliability, and ensure a sufficient level of data quality for its intended use. The appropriate quality control checks will be performed on all instruments prior to the start and at the end of the project and according to the schedule as shown in Table B-1. Independent audits and flow checks will be performed by an outside source.

See Tables B-1, B-2 and section B6 for detailed information regarding QC for this project.

Table B-1. Procedures Used to Assess QA Objectives

Measurement Parameter	Assessment Method	Minimum Frequency	Acceptance Criteria
$PM_{2.5}$	Flow Checks; flow check using independent standard	Monthly; every 6 months	≤4% of Standard; ±5% of Design Value
Black Carbon	Flow Checks	Monthly	≤10%
NOx	Single point QC Check (zero & span); Audit (3 consecutive levels at 80% of measured conc.)	Every 2 weeks; Every 6 months	≤10%; ≤15%
SO_2	Single point QC Check (zero & span); Audit (3 consecutive levels at 80% of measured conc.)	Every 2 weeks; Every 6 months	≤10%; ≤15%
CO	Single point QC Check (zero & span); Audit (3 consecutive levels at 80% of measured conc.)	Every 2 weeks; Every 6 months	≤10%; ≤15%
Ambient wind speed and wind direction	Certification; General inspection and maintenance	Pre-deployment; Every 6 months	See manual

B5. Instrument/Equipment Testing, Inspection, and Maintenance

All instruments will be inspected and tested prior to deployment and installment at the fixed site. General inspection of the instruments will be conducted during each visit to ensure proper performance. Preventative maintenance and troubleshooting will occur on an as needed basis and documented accordingly.

Quality control for the meteorological sensors is achieved by using certified MET sensors. The installation of sensors will follow the Quality Assurance Handbook Volume 4 and the instrument manual.

B6. Instrument Calibration and Frequency

Calibrations for the continuous gaseous analyzers use the following methods:

1. Multi-point calibration of the analyzers at the start-up of the project.
2. Audit or verification of the analyzers at the end of the project.
3. Multi-point calibration of the analyzers after any major repairs.
4. Multi-point calibration of the analyzers if a zero/span/precision (audit) check of the analyzer exceeds +/- 10% of the expected known value.

At a minimum, a calibration sequence will include at least a zero point, a span point of approximately 80% of the instrument range and at least 3 additional points equally spaced at intervals of 20% of the range and the span point.

> For example, for monitors ranging from 0 - 0.500 ppm the following concentrations could be generated and introduced into the reporting instrument:
>
> Zero air
> 0.030 ppm - 0.100 ppm
> 0.150 ppm - 0.200 ppm
> 0.250 ppm – 0.300 ppm
> 0.350 ppm - 0.450 ppm

If the lowest expected calibration point cannot be reached (because of calibration system limitations at low flows) then the lowest possible point will be used.

ALL CALIBRATION POINTS DURING THE CALIBRATION MUST BE WITHIN 3.0% OF THE EXPECTED VALUE.

Following a successful calibration the converter efficiency will be calculated according to the manufacturer's manual and should be > 90% and <105%. If not, the converter will be replaced as soon as possible. If a new converter is unavailable and the instrument has demonstrated acceptable audit checks then the monitoring location will continue and all data from the instrument will be flagged accordingly.

A slope and intercept will also be calculated using the standard concentration and the analyzer response. **The slope should be between 1.005 and 0.950 and the intercept should be between -5.0 and 5.0 ppb.**

At no time will monitoring data be reported as valid if any point in an audit is over 15% difference when comparing the standard concentration versus the analyzer response.

A one point calibration will be performed on the continuous $PM_{2.5}$ analyzer prior to the start of sampling.

Re-calibration of the aethalometer's flowmeter is only necessary if there is serious reason to believe that the flowmeter response is incorrect.

All calibration responses, all audit check responses, and any adjustments made will be documented in the worksheets, checklists, or logbooks.

B7. Inspection/Acceptance for Supplies and Consumables

All supplies and consumables are purchased from established vendors to maintain consistent quality. All calibration gases are NIST traceable and have been purchased from recognized, reputable suppliers.

An adequate amount of supplies, consumables, and gasses will be purchased prior to the start of sampling. They will be inspected at least every two months and re-ordered if necessary.

B8. Non-Direct Measurements

The calibration gases used for multi-point calibrations and audit checks will be of a certified mixture type as specified by the "EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards (Revised September 1993)". Gases for audits and gases for calibrations will be independent. These gases will be labeled clearly to indicate whether they are to be used for audits or for calibration.

A multi-gas dilution calibrator will be used for generating the calibration challenge points for audits and calibrations. Calibrators for audits and for calibrations will be independent. Both gas blenders will be labeled clearly to indicate whether they to be used for audits or calibrations. **The flow rates of the multi-gas dilution calibrators will be checked against a NIST traceable flow device at a frequency of every 6 months (due next in Jan. 2011).** If systematic problems are suspected during any QC activity it is recommended that the calibration system is recertified prior to the diagnosis of required repairs.

Quality control for the dataloggers used to capture and store the data will be achieved by **verifying that the analyzer readings match the dataloggers instantaneous reading responses to within 2.0 ppb.** Caution will also be necessary in ensuring and documenting that the analog output channels of the pollutant analyzers match the reading on the data logger. Adjustments will be made according to the manufacturer instrument manual to the analyzer analog output channels zero and span settings if this comparison does not show agreement. All adjustments made will be recorded in the site logbooks.

Cellular phone times may be used for comparing times on analyzers and data loggers as long as a brief comparison has been established between the cellular phone and the Official U.S. Time Clock that can be found online at http://www.time.gov/timezone.cgi?central/d/-6/java. A comparison of analyzer time versus data logger time versus standard time should be completed and documented at each site visit. **Times should be adjusted if found to be off by more than 60 seconds.** Any adjustments and the magnitude of any adjustments will be recorded in the site logbook. This site is in the central time zone. The time will be recorded in Central Standard Time (CST).

Table B-2. QA/QC Non-Direct Measurements

Parameter	Assessment Method	Minimum Frequency
Data Capture	download	monthly
Calibration Gases	Certification	NO_x – every 24 months CO – every 36 months SO_2 – every 24 months
Multi-Gas dilution calibrators	Checked against NIST traceable flow device	Every 6 months (due in Jan.2011)
Dataloggers	reading responses within 2.0 ppb	Every site visit
Times on analyzers	Official U.S. Time Clock http://www.time.gov/timezone.cgi?central/d/-6/java.	Every site visit

B9. Data Management

Data will be downloaded from the analyzers and samplers on an as needed basis or at least a monthly basis; whichever is more frequent. Raw data is archived on EPA Region 5 ARD share drive, G.

Data will be provided to ORD electronically for comparison to mobile monitoring data, which will be stored on EPA servers with the mobile monitoring data set.

All data, documentation and records associated with the special purpose monitoring at the fixed site, will be maintained by the USEPA Region 5 Air Monitoring and Analysis Section (AMAS) for at least 5 years from the end of the project. These will be stored electronically on the Air & Radiation (ARD) G drive and hardcopy in AMAS filing cabinet.

C. ASSESSMENT & OVERSIGHT

C1. Assessment and Response Actions

Precision and accuracy (zero and span checks) measurements are conducted on the gaseous analyzers every 2 weeks. The flow checks on the continuous PM2.5 sampler and aethalometer are conducted monthly. A site evaluation will be conducted prior to the start of data collection. A technical system audit may be conducted within a few weeks of the start of data collection to ensure all procedures are in place and to ensure the level of QA/QC is sufficient. All audit/check worksheets, checklists, and reports will be reviewed by the project QA Coordinator on a quarterly basis.

Any corrective actions needed for any part of the project will be properly verified, implemented and documented by the QA Coordinator.

C2. Reports to Management

An EPA internal technical memorandum summarizing the special purpose monitoring field study efforts and data analysis performed by Region 5 will be developed for management after the sampling and data analysis has been concluded. The data collected from this fixed site may be used by ORD for scientific research and published in scientific journals and in presentations.

D. DATA VALIDATION & USABILITY

D1. Data Review, Verification, and Validation

Data Review – General review of the data will be based on level of data capture or completeness and by using graphs of the data to determine any trends or anomalies.

Data Verification – Verification includes review of the QC checks meeting the criteria and comparing them and their implications to the data.

Data Validation – Validation of the data is determined by usability of the data. Any data outliers will be flagged and appropriately qualified.

D2. Verification and Validation Methods

Every site visit or at least each month, whichever is more frequent, the site operator will review the sampling logs and raw data. Any deviations from the QAPP will be documented and reported to the project QA Coordinator. Project QA status reports/checklists will be developed quarterly and submitted to the QA Coordinator for review.

The data generated during this project will be reviewed, verified, and validated by the project QA coordinator on a quarterly basis by comparison with analyzer and sensor performance parameters and quality control results.

	QC Check Results (red text = flagged) - Check 1					QC Check Results (red text = flagged) - Check 2					
Day	Aethal ometer	EEPS	APS	CO	SO_2	Aethal ometer	EEPS	APS	CO	SO_2	GPS check
DQI (Table 8-2 of QAPP)	*<20%*	*<20%*	*<20%*	*80-120%*	*80-120%*	*<20%*	*<20%*	*<20%*	*80-120%*	*80-120%*	*meets +/- 10 m criteria*
10/27/2010	n/a	1%	3%	97%	68%	n/a	n/a	n/a	n/a	n/a	OK
10/28/2010	14%	0%	0%	99%	67%	9%	8%	4%	99%	83%	OK
10/29/2010	5%	1%	0%	100%	69%	-7%	1%	0%	99%	70%	OK
10/30/2010	43%	1%	0%	101%	69%	9%	5%	5%	98%	80%	OK
10/31/2010	110%	1%	0.4%	99%	64%	56%	1%	0%	99%	65%	OK
11/1/2010	0%	1%	0%	100%	68%	2%	0%	0%	94%	65%	OK
11/3/2010	2%	1%	0%	99%	69%	0%	2%	0%	96%	68%	OK
11/4/2010	9%	0%	0%	98%	67%	5%	3%	0%	101%	65%	OK
11/5/2010	7%	0%	0%	98%	68%	13%	2%	1%	98%	66%	OK
11/6/2010	4%	1%	0%	98%	66%	2%	1%	0%	102%	63%	OK
11/7/2010	2%	1%	0%	99%	68%	7%	1%	0%	98%	71%	OK
11/8/2010	2%	2%	0%	98%	68%	2%	1%	0%	98%	78%	OK
11/10/2010	1%	1%	0%	97%	65%	1%	1%	5%	96%	77%	OK
11/11/2010	12%	1%	0%	101%	71%	5%	6%	0%	101%	79%	OK
11/12/2010	8%	3%	0%	100%	73%	8%	1%	0%	99%	65%	OK
11/13/2010	9%	2%	0%	100%	71%	3%	1%	0%	101%	69%	OK
11/15/2010	2%	3%	0%	102%	66%	3%	2%	0%	101%	72%	OK
11/16/2010	11%	0%	0%	101%	71%	20%	0%	N/A	101%	73%	OK
11/17/2010	20%	0%	0%	97%	68%	16%	0%	0%	98%	75%	OK
11/18/2010	10%	1%	0%	94%	69%	8%	2%	0%	95%	79%	OK
11/19/2010	3%	5%	0%	97%	69%	-2%	0%	0%	100%	66%	OK
11/20/2010	16%	1%	0%	98%	69%	10%	1%	0%	101%	70%	OK
11/21/2010	6%	2%	0%	96%	70%	13%	0%	0%	n/a	n/a	OK

[a]EEPS zero checks are evaluated for particles >100 nm

Cicero Rail Yard Study (CIRYS)

Appendix C: Mobile and Stationary Side-by-Side Sampling

This Appendix provides further information on the side-by-side sampling conducted between the mobile air monitoring vehicle and the air monitoring station located to the NE of the Cicero Rail Yard. The data shown are for five mobile monitoring sessions conducted on consecutive days, from November 17-21, 2010. For each day, the mobile air monitoring vehicle was parked for 1-2 hours adjacent to the sampling station. The vehicle sampling height was approximately 1.5 m, whereas the station sampling height was approximately 2 m. The location of the intercomparison sampling is shown in Figure C-1 and is approximately 50 m from the nearest set of train tracks.

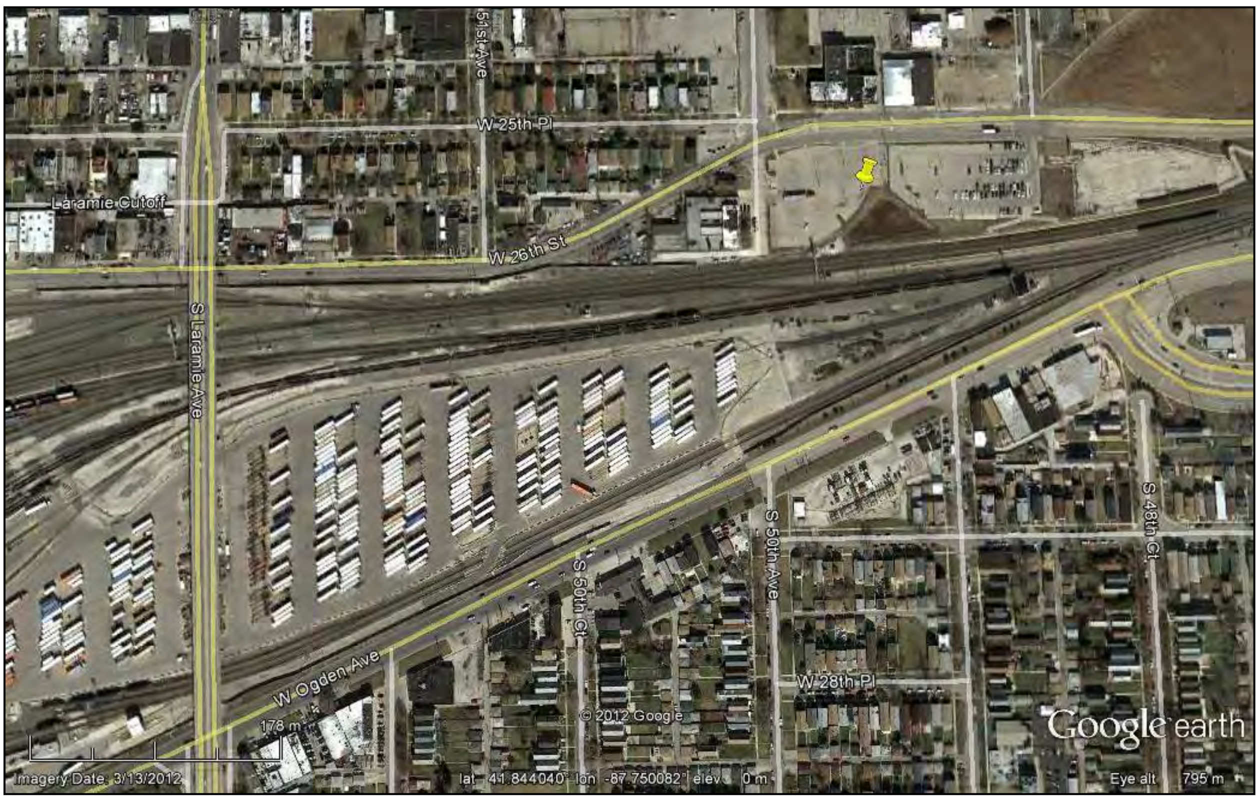


Figure C-1. Intercomparison sampling location.

Sampling date: November 17, 2010

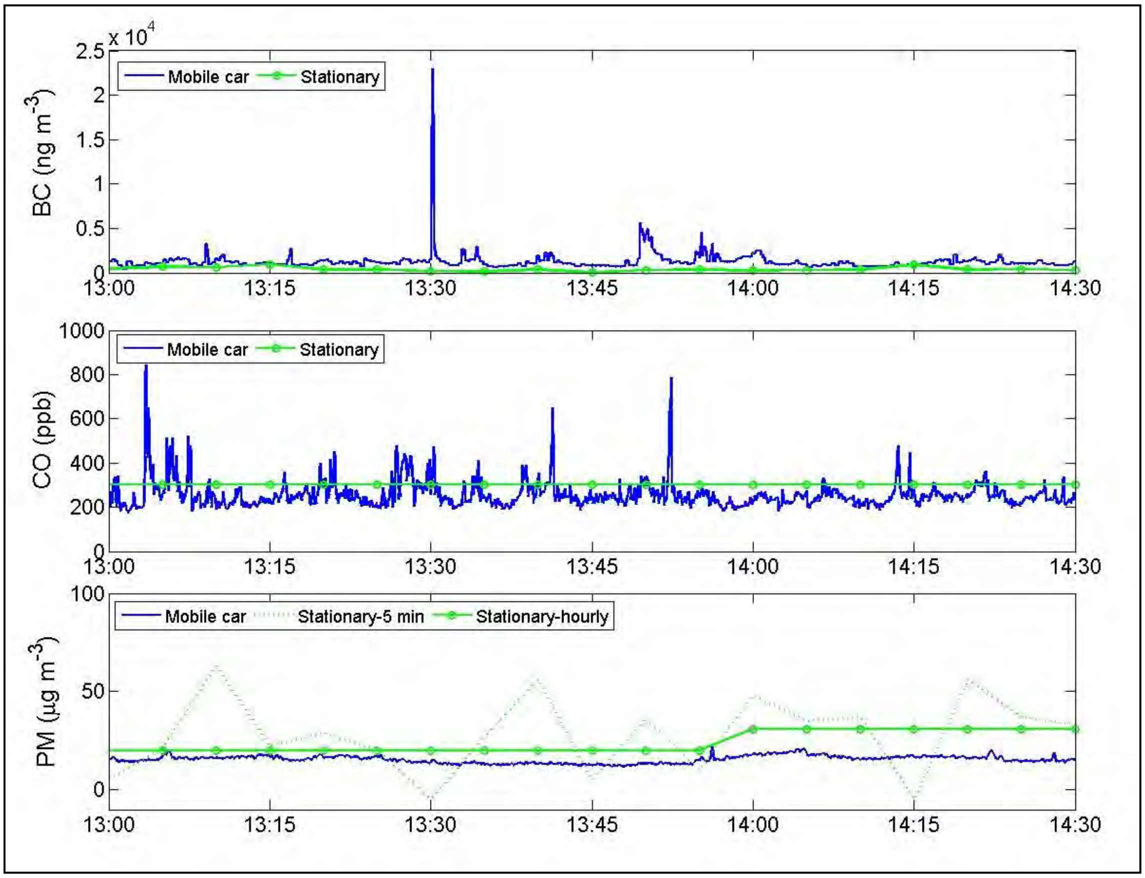


Figure C-2. Intercomparison time series for BC, CO, and $PM_{2.5}$ on November 17, 2010.

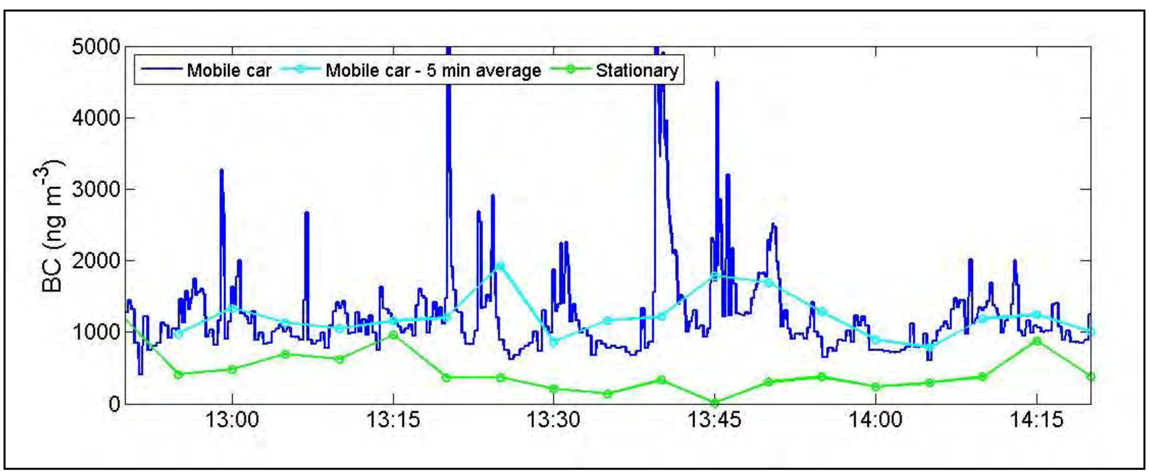


Figure C-3. Intercomparison time series for BC on November 17, 2010, with the y-axis decreased to 5000 ng m^{-3} (5 µg m^{-3}).

Sampling date: November 18, 2010

Note: No BC data was available at the stationary monitoring site for this period of time, therefore no second figure showing the mobile BC data averaged at a 5 minute rate for comparison with the stationary monitoring data set is provided on 11/18.

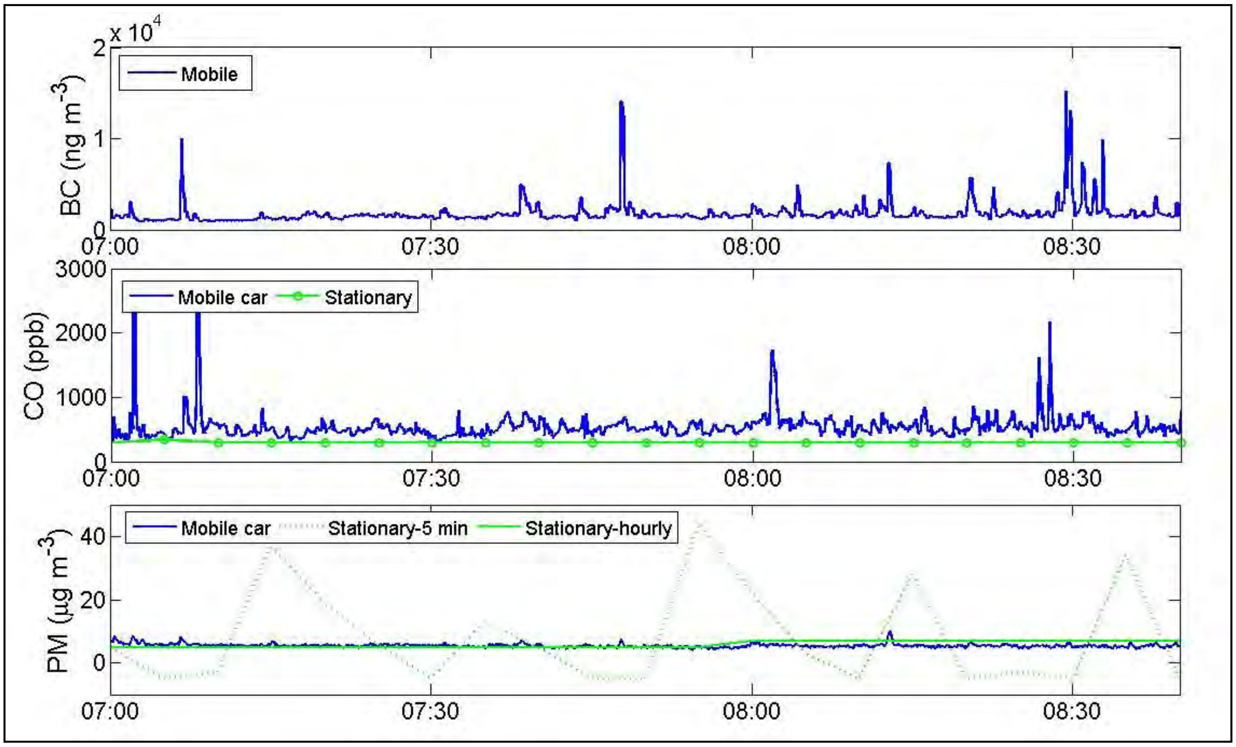


Figure C-4. Intercomparison time series for BC, CO, and $PM_{2.5}$ on November 18, 2010.

Sampling date: November 19, 2010

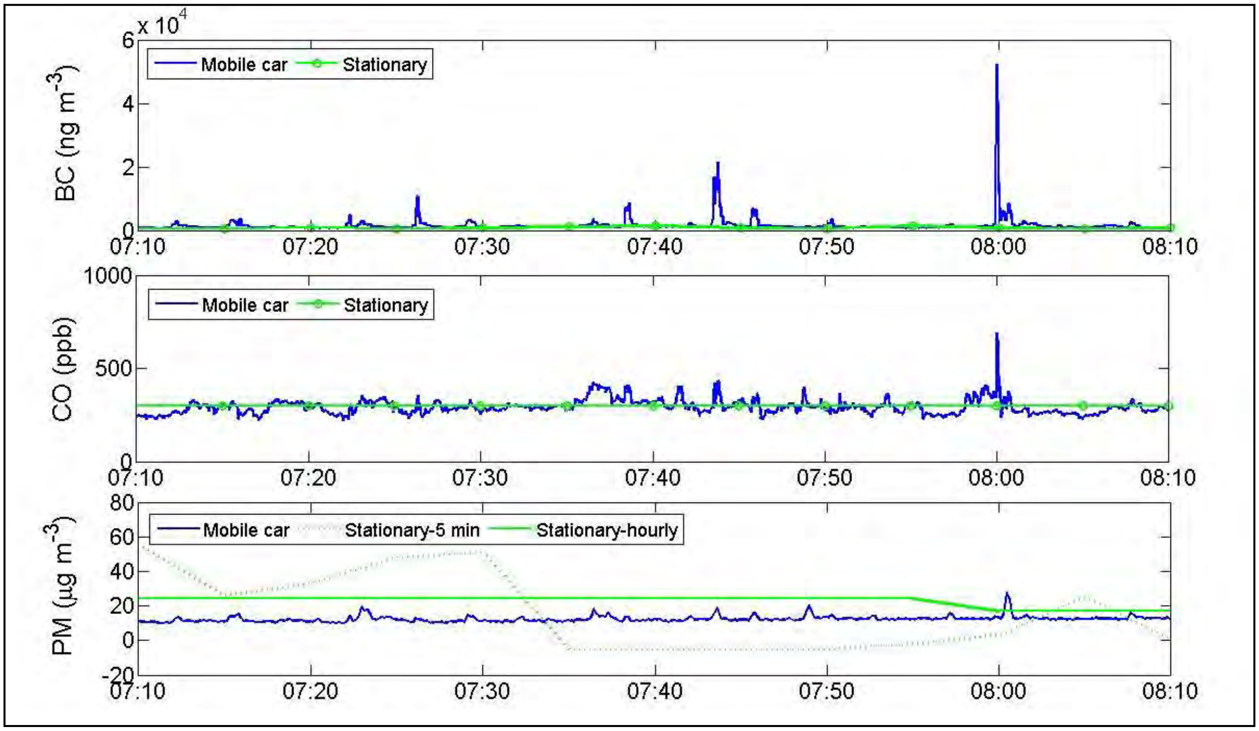


Figure C-5. Intercomparison time series for BC, CO, and $PM_{2.5}$ on November 19, 2010.

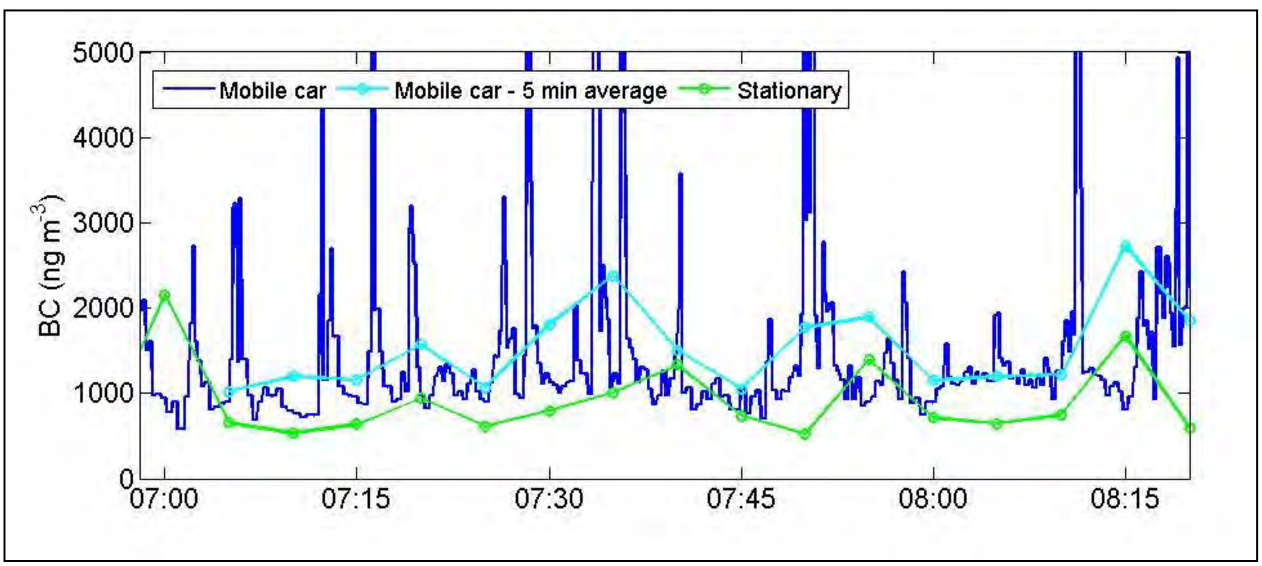


Figure C-6. Intercomparison time series for BC on November 19, 2010, with the y-axis decreased to 5000 ng m^{-3} (5 µg m^{-3}).

Sampling date: November, 20, 2010

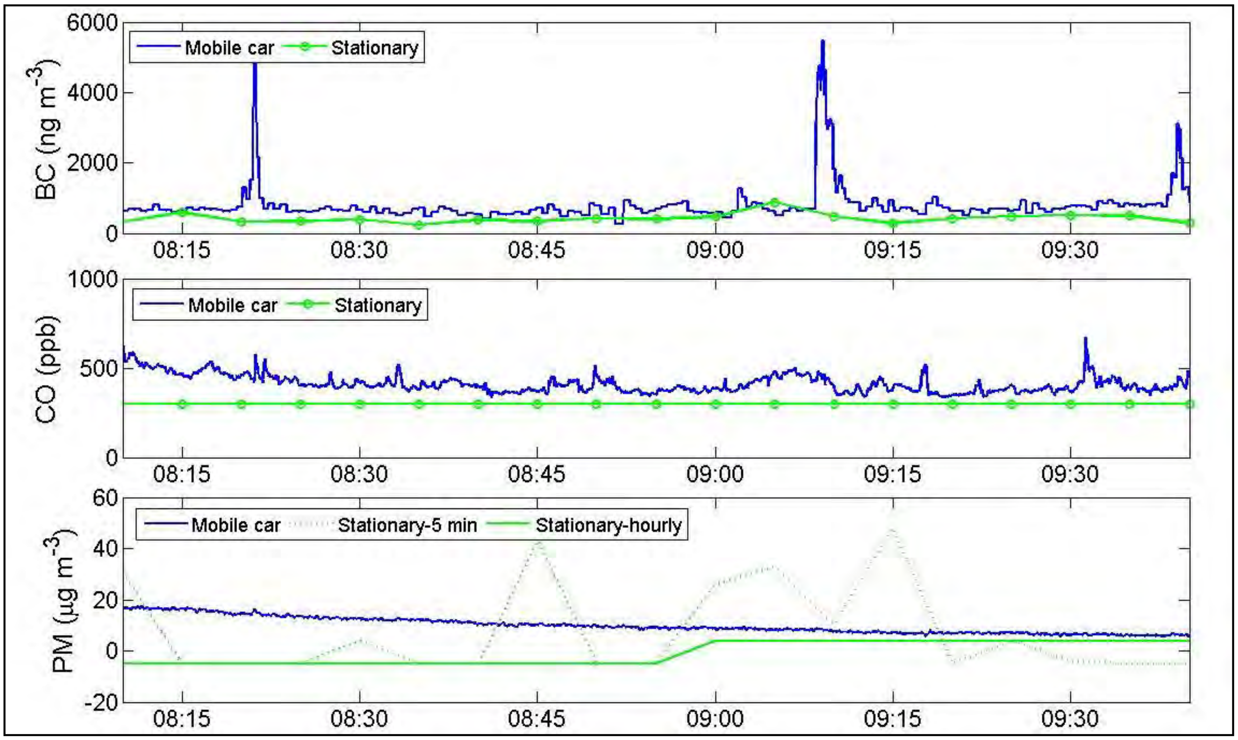


Figure C-7. Intercomparison time series for BC, CO, and $PM_{2.5}$ on November 20, 2010.

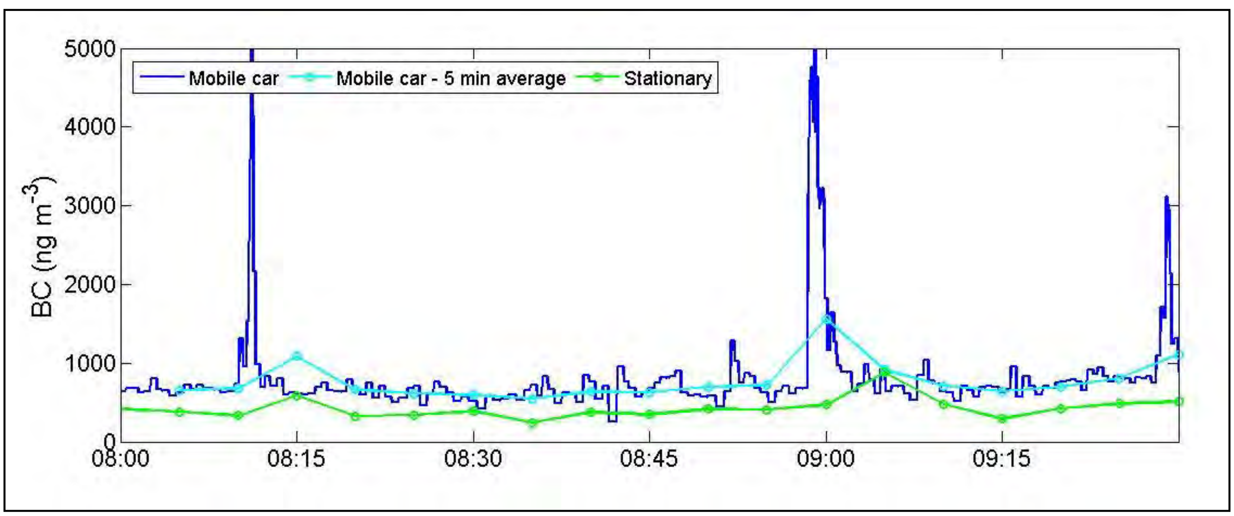


Figure C-8. Intercomparison time series for BC on November 20, 2010, with the y-axis decreased to 5000 ng m^{-3} (5 µg m^{-3}).

Sampling date: November, 21, 2010

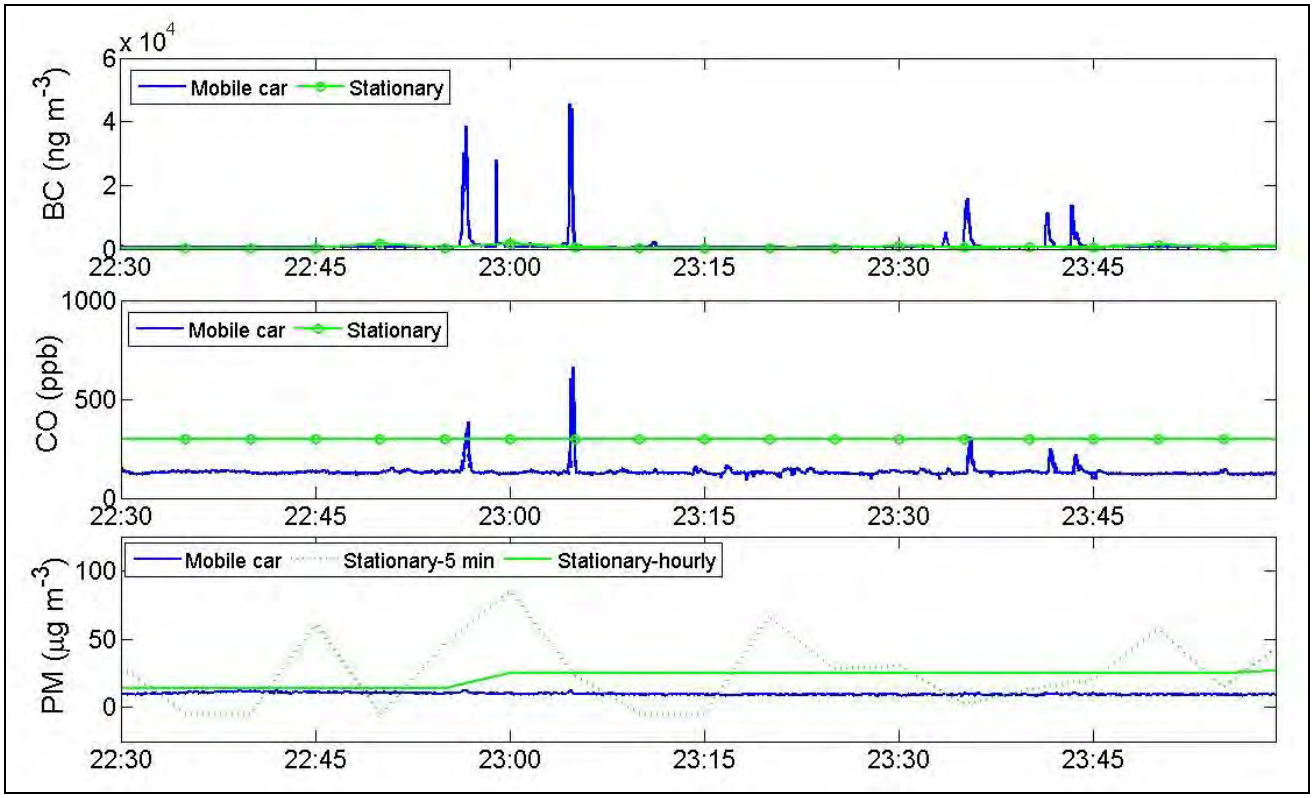


Figure C-9. Intercomparison time series for BC, CO, and $PM_{2.5}$ on November 21, 2010.

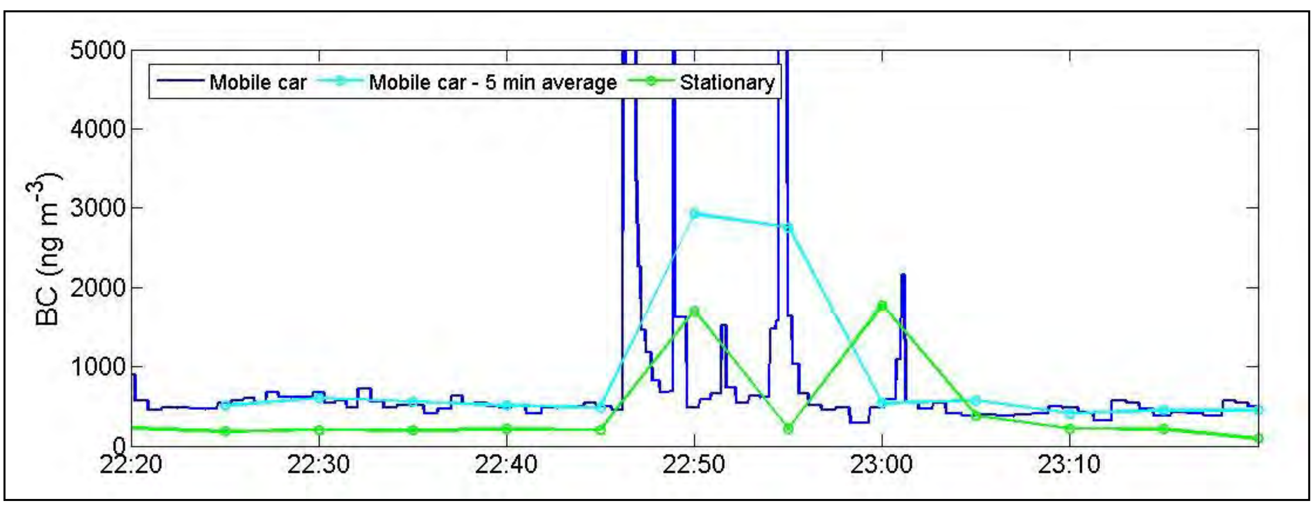
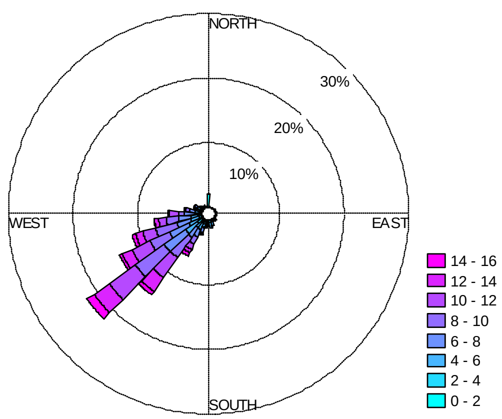
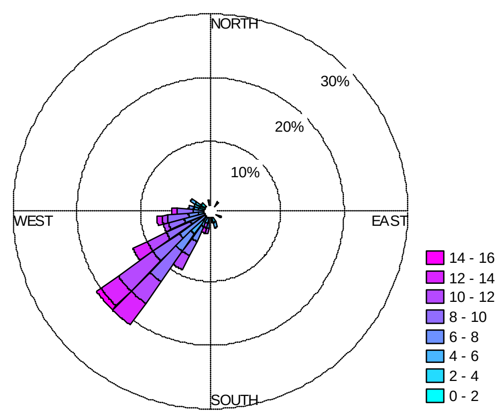
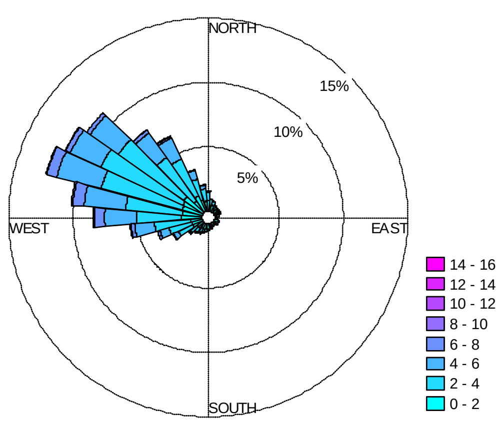
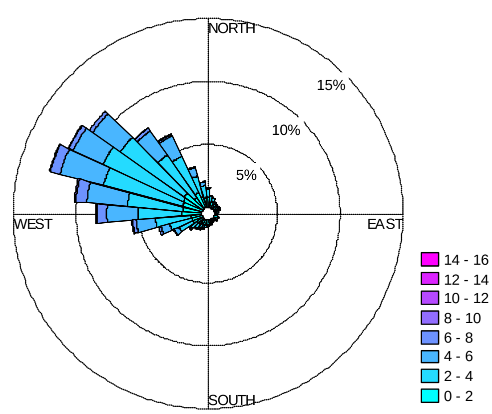


Figure C-8. Intercomparison time series for BC on November 21, 2010, with the y-axis decreased to 5000 ng m^{-3} (5 µg m^{-3}).

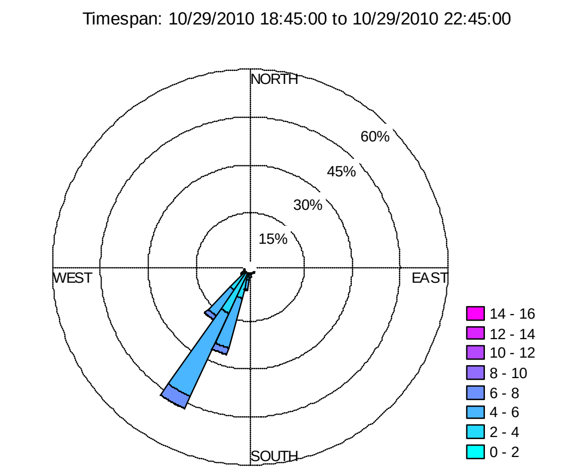
Cicero Rail Yard Study (CIRYS)

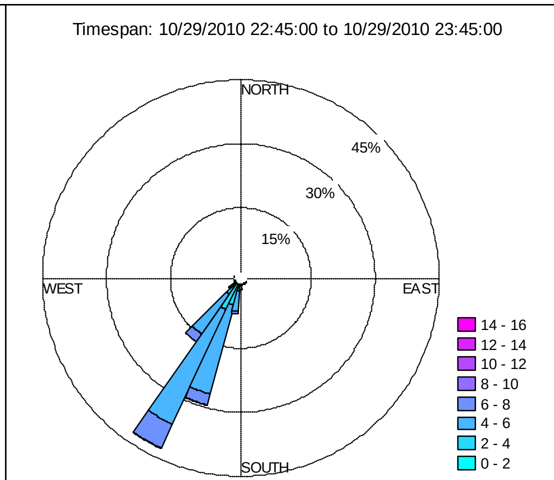
Appendix D: Mobile Monitoring Wind Roses and Driving Maps

Description: Wind roses are provided during each mobile sampling session – one rose for the period when the vehicle was in driving mode and a second wind rose for the period when the mobile vehicle was parked at the stationary monitoring location NE of the rail yard. Concentration maps represent statistically significant excess concentrations in neighborhoods NT1-NT4 in comparison to the urban background. Concentrations shown are net values - (average value in a specific 50 m increment minus background mean).

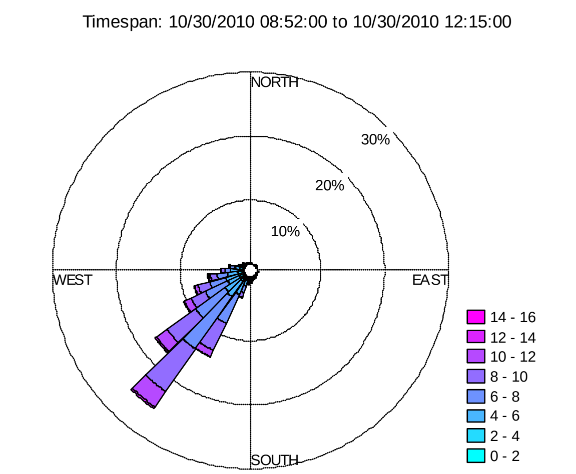
Mobile session date:	Wind rose during driving period	Wind rose during stationary period
10/27	Timespan: 10/27/2010 09:16:00 to 10/27/2010 13:05:00 	Timespan: 10/27/2010 13:05:00 to 10/27/2010 13:25:00 
10/28	Timespan: 10/28/2010 18:53:00 to 10/29/2010 00:50:00 	Timespan: 10/28/2010 18:53:00 to 10/29/2010 00:50:00 

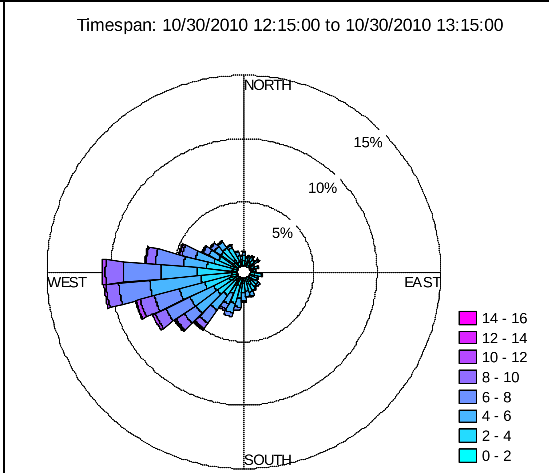
10/29



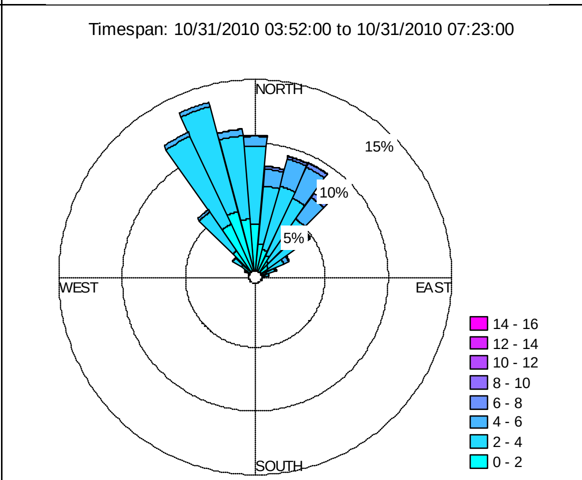


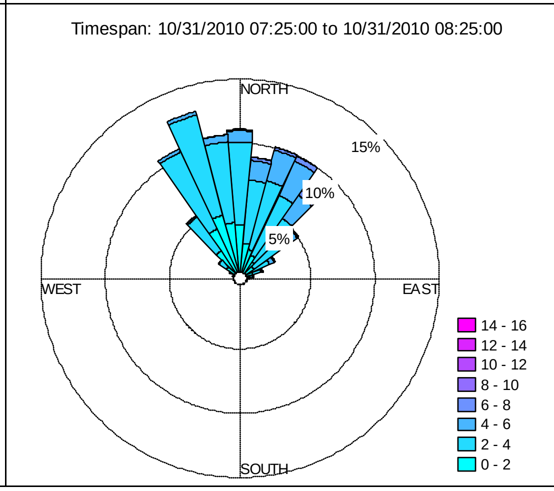
10/30



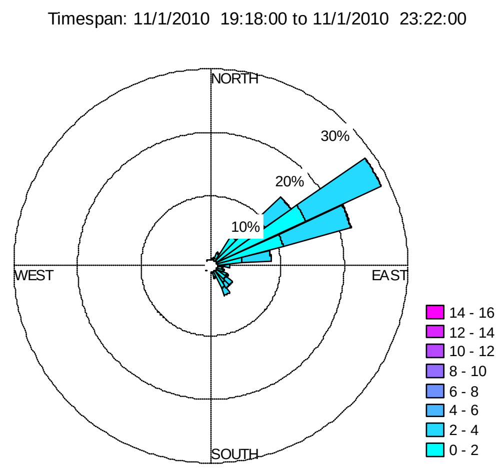


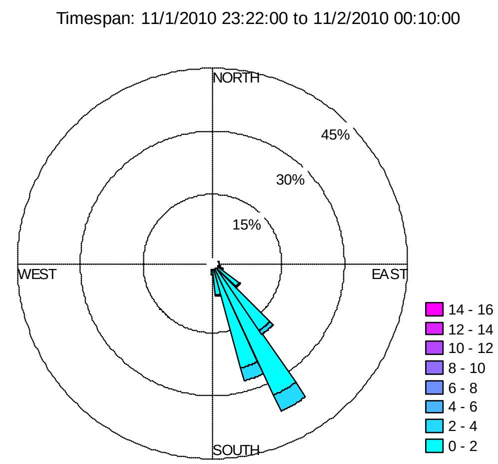
10/31



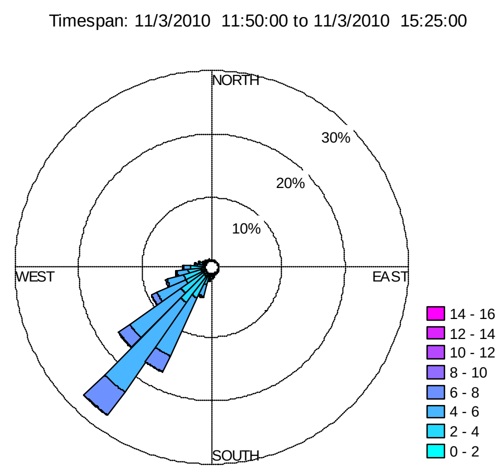


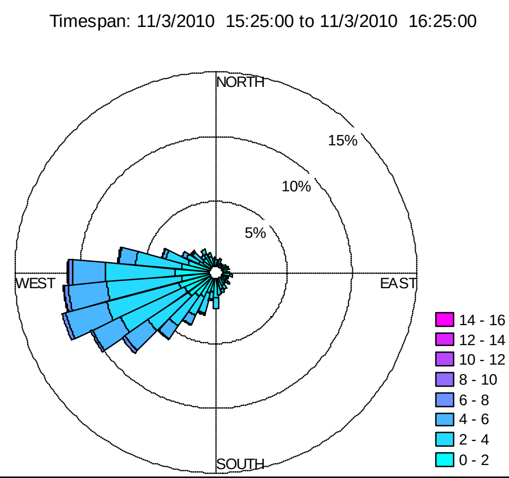
11/01



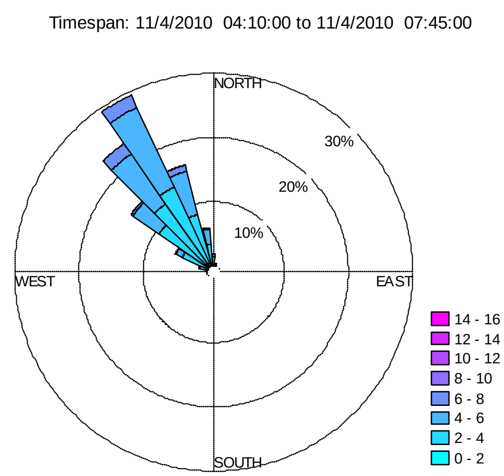


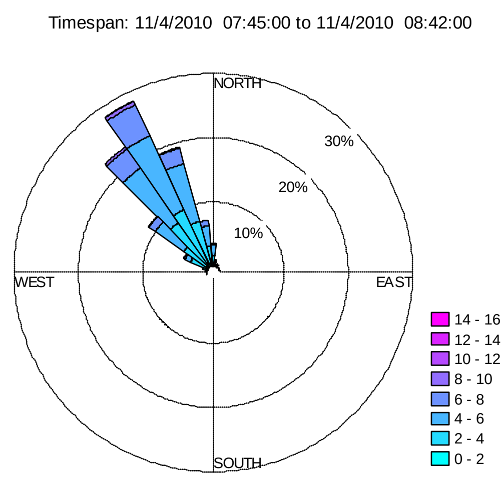
11/03



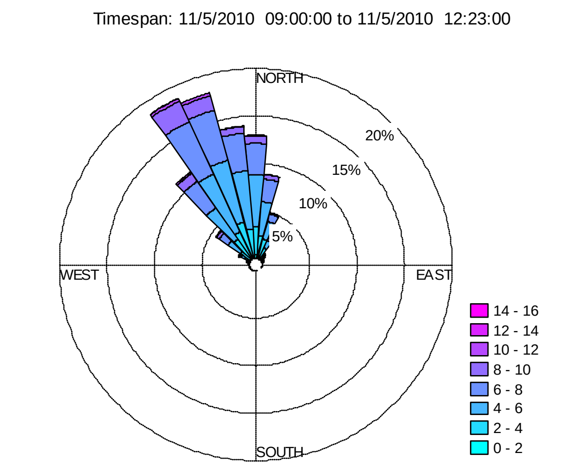


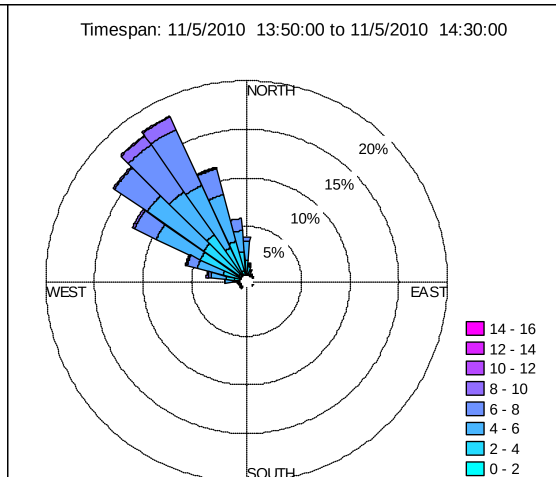
11/04



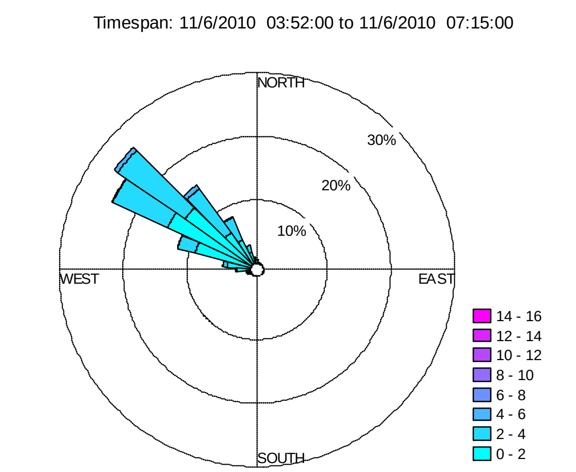


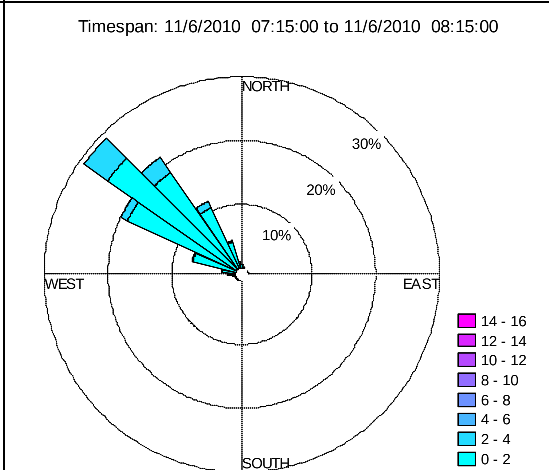
11/05



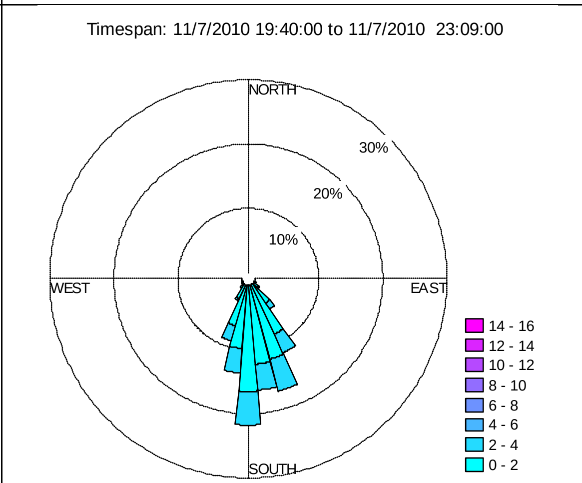


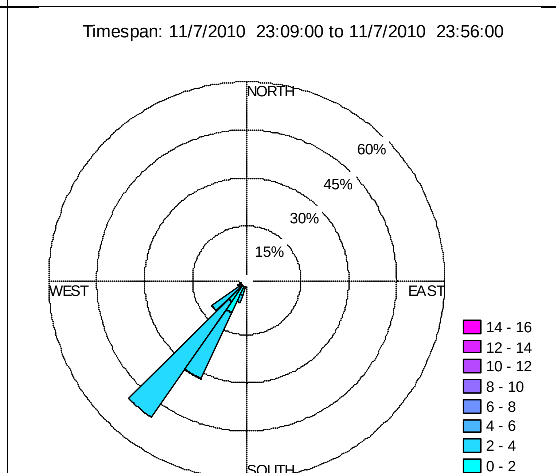
11/06



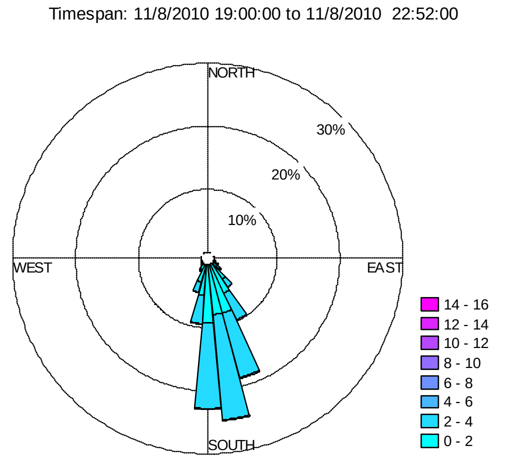


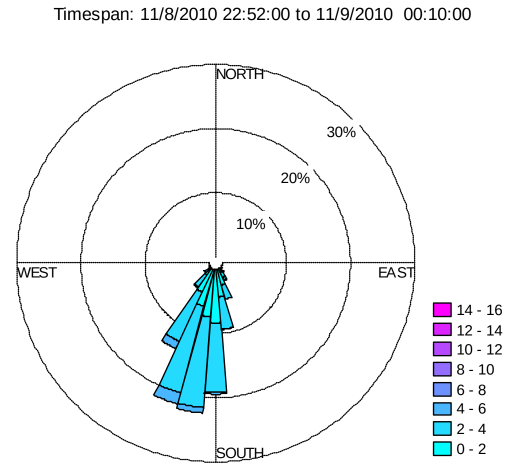
11/07



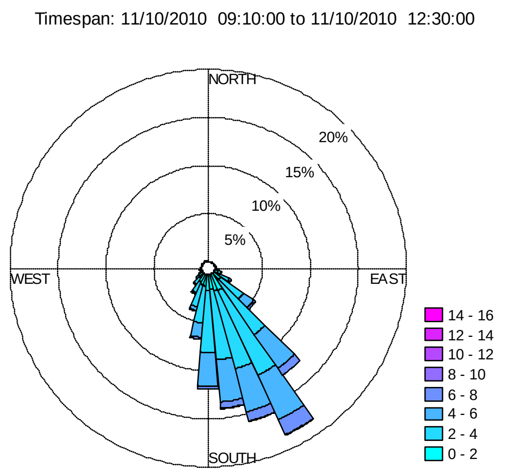


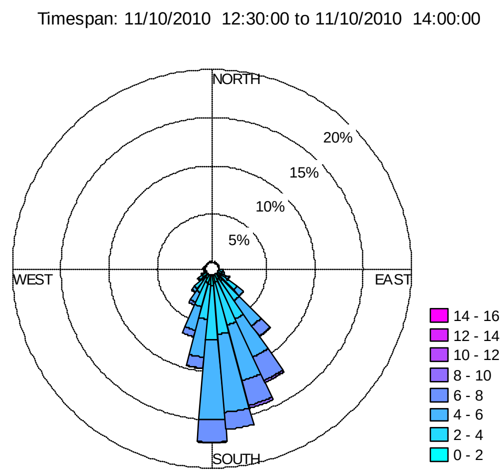
11/08



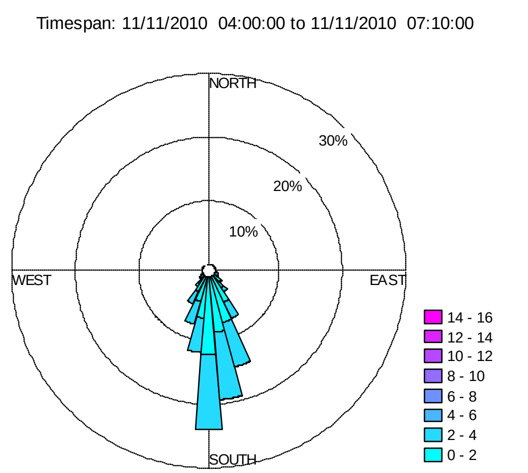


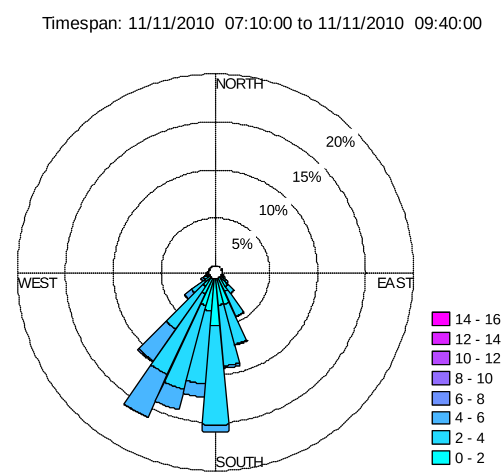
11/10





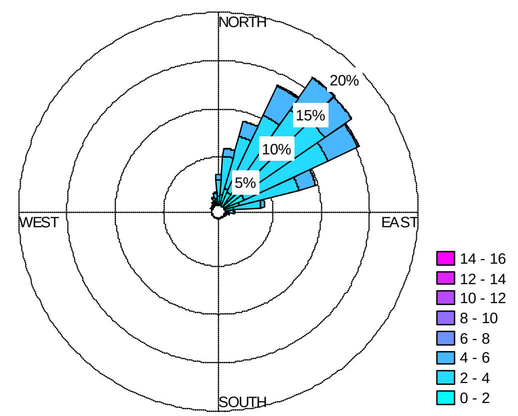
11/11



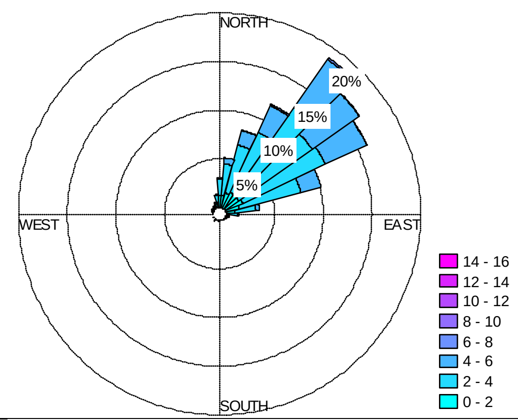


11/12

Timespan: 11/12/2010 10:00:00 to 11/12/2010 13:41:00

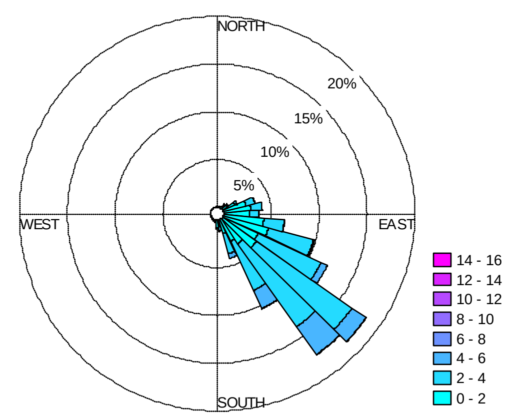


Timespan: 11/12/2010 13:41:00 to 11/12/2010 15:05:00

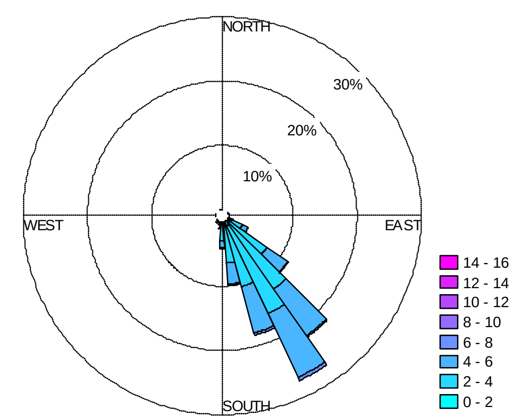


11/13

Timespan: 11/13/2010 04:00:00 to 11/13/2010 07:00:00

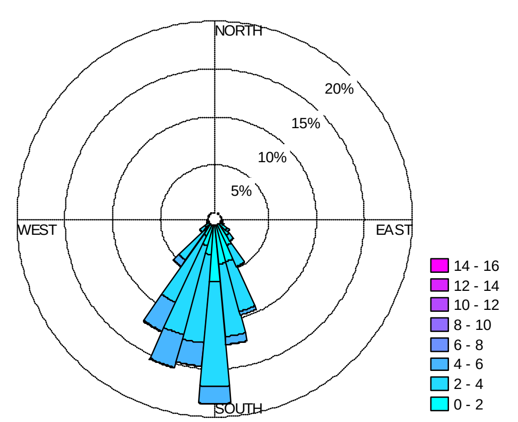


Timespan: 11/13/2010 07:00:00 to 11/13/2010 08:40:00

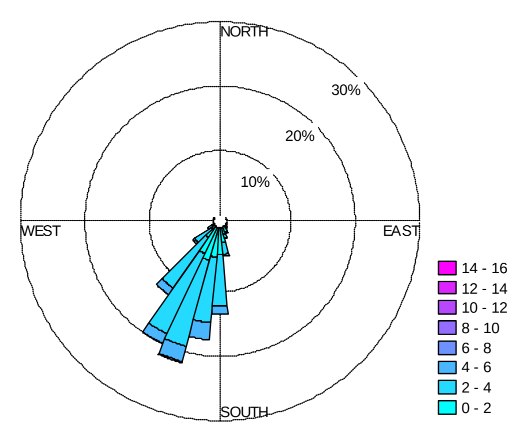


11/15

Timespan: 11/15/2010 19:30:00 to 11/15/2010 23:10:00

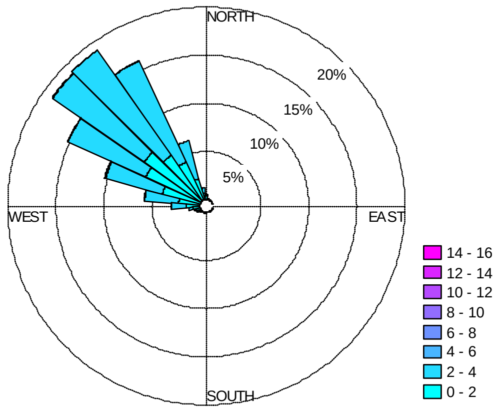


Timespan: 11/15/2010 23:10:00 to 11/16/2010 01:05:00

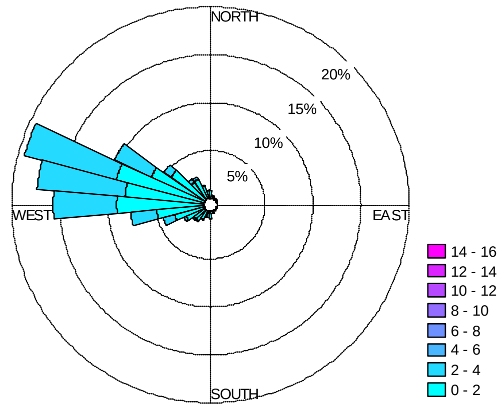


11/16

Timespan: 11/16/2010 18:55:00 to 11/16/2010 23:30:00

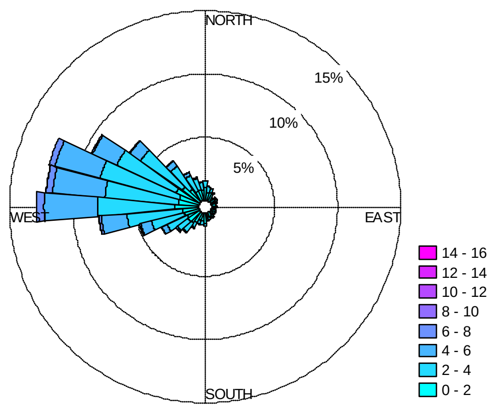


Timespan: 11/16/2010 23:30:00 to 11/17/2010 01:30:00

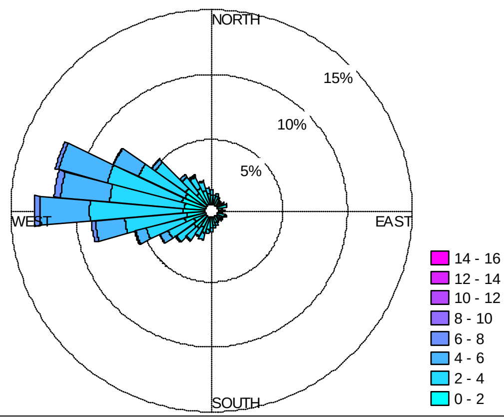


11/17

Timespan: 11/17/2010 09:45:00 to 11/17/2010 12:52:00

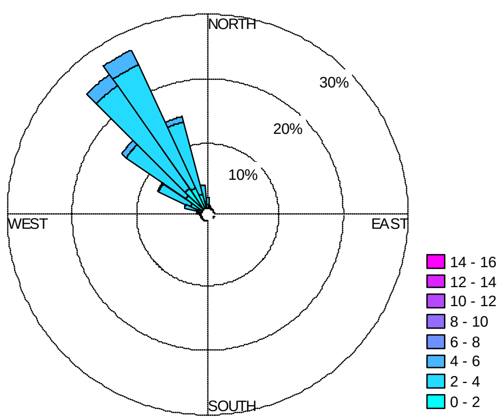


Timespan: 11/17/2010 12:52:00 to 11/17/2010 14:37:00

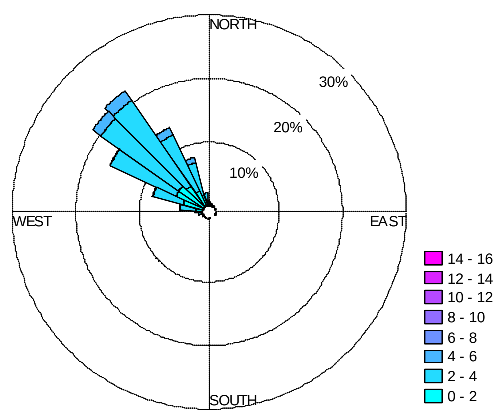


11/18

Timespan: 11/18/2010 03:58:00 to 11/18/2010 07:00:00

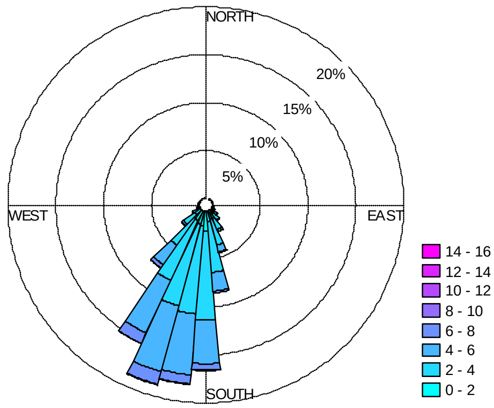


Timespan: 11/18/2010 07:00:00 to 11/18/2010 08:42:00

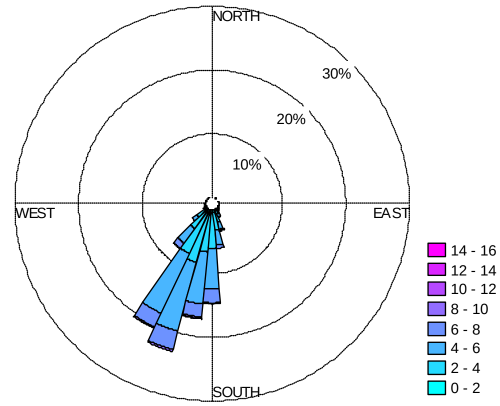


11/19

Timespan: 11/19/2010 03:52:00 to 11/19/2010 07:08:00

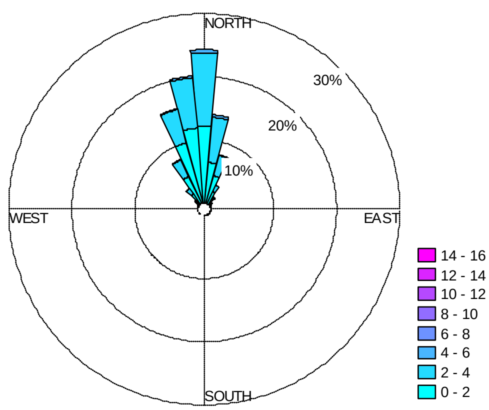


Timespan: 11/19/2010 07:08:00 to 11/19/2010 08:30:00

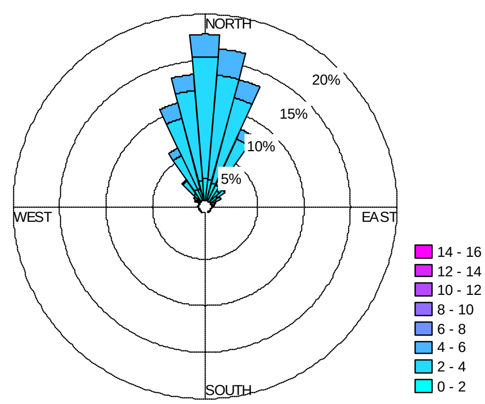


11/20

Timespan: 11/20/2010 03:57:00 to 11/20/2010 08:06:00

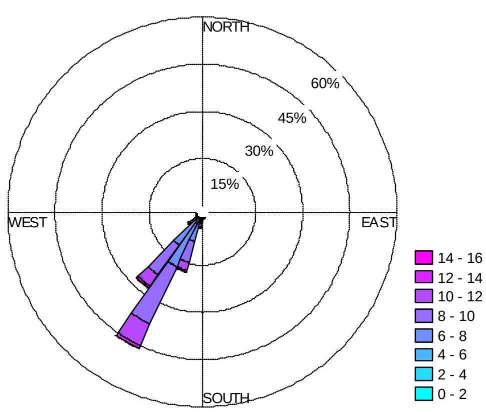


Timespan: 11/20/2010 08:06:00 to 11/20/2010 09:49:00

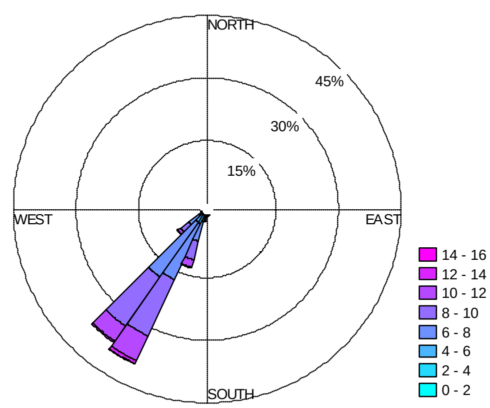


11/21

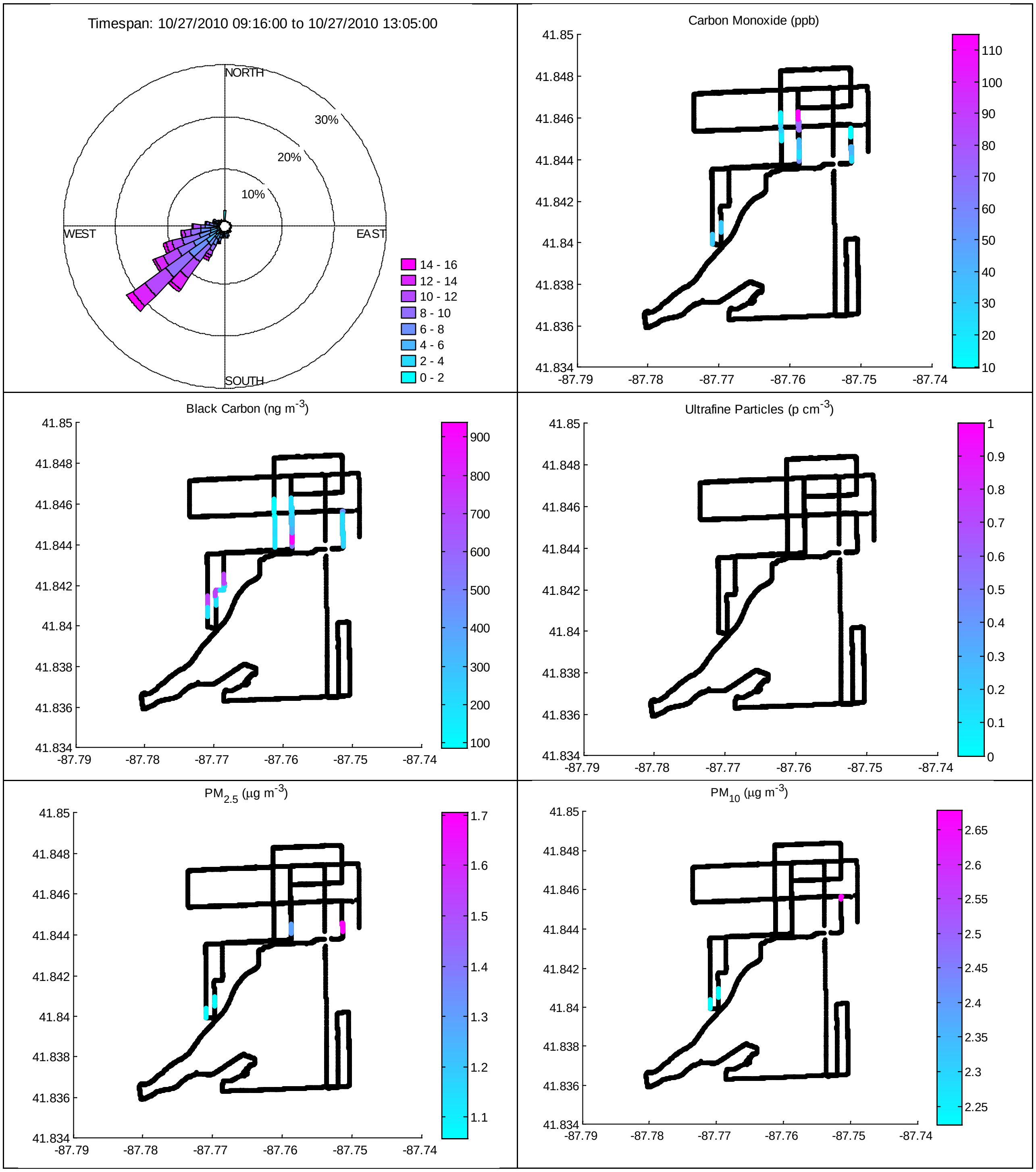
Timespan: 11/21/2010 19:02:00 to 11/21/2010 22:30:00



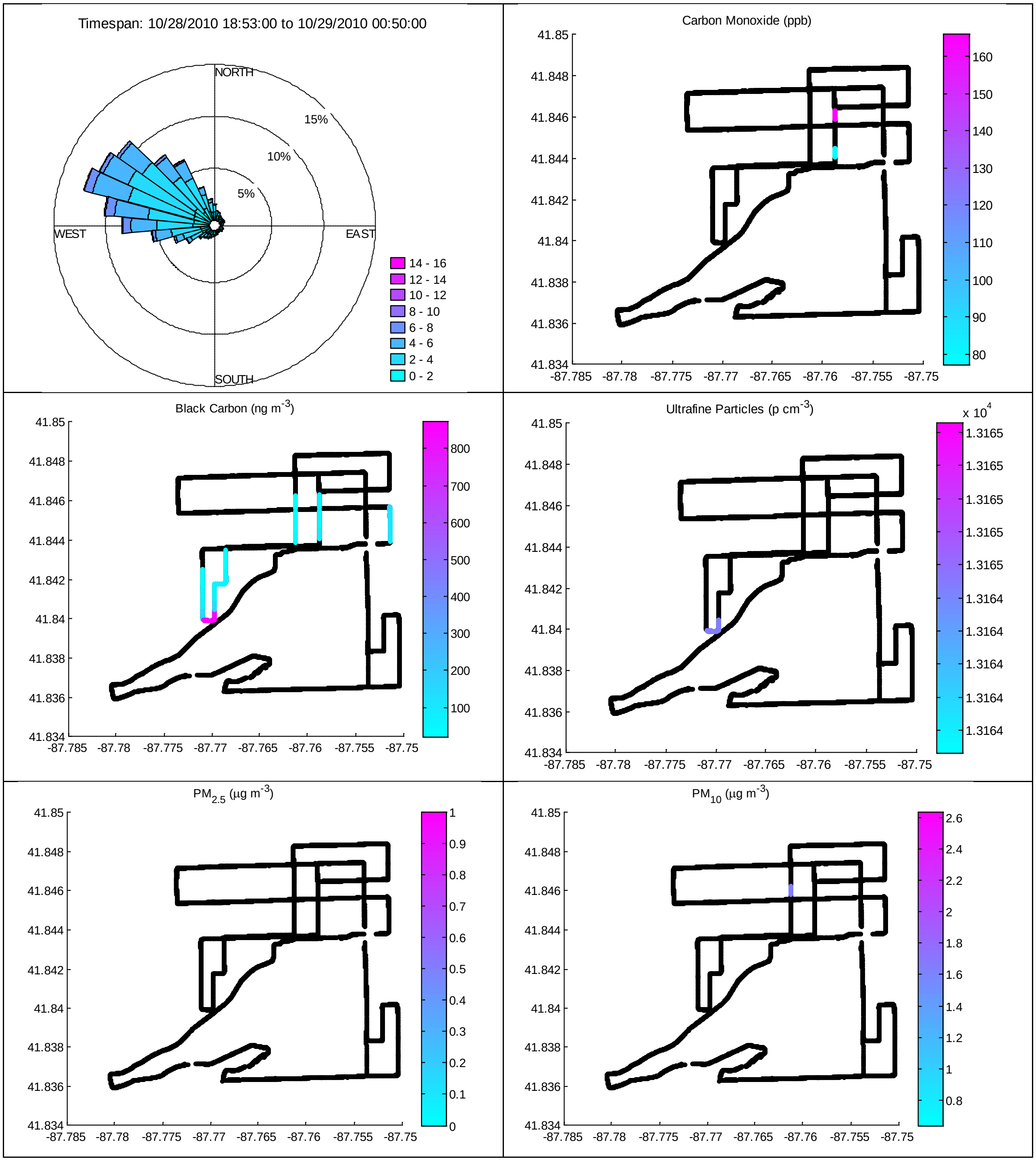
Timespan: 11/21/2010 22:30:00 to 11/22/2010 00:09:00



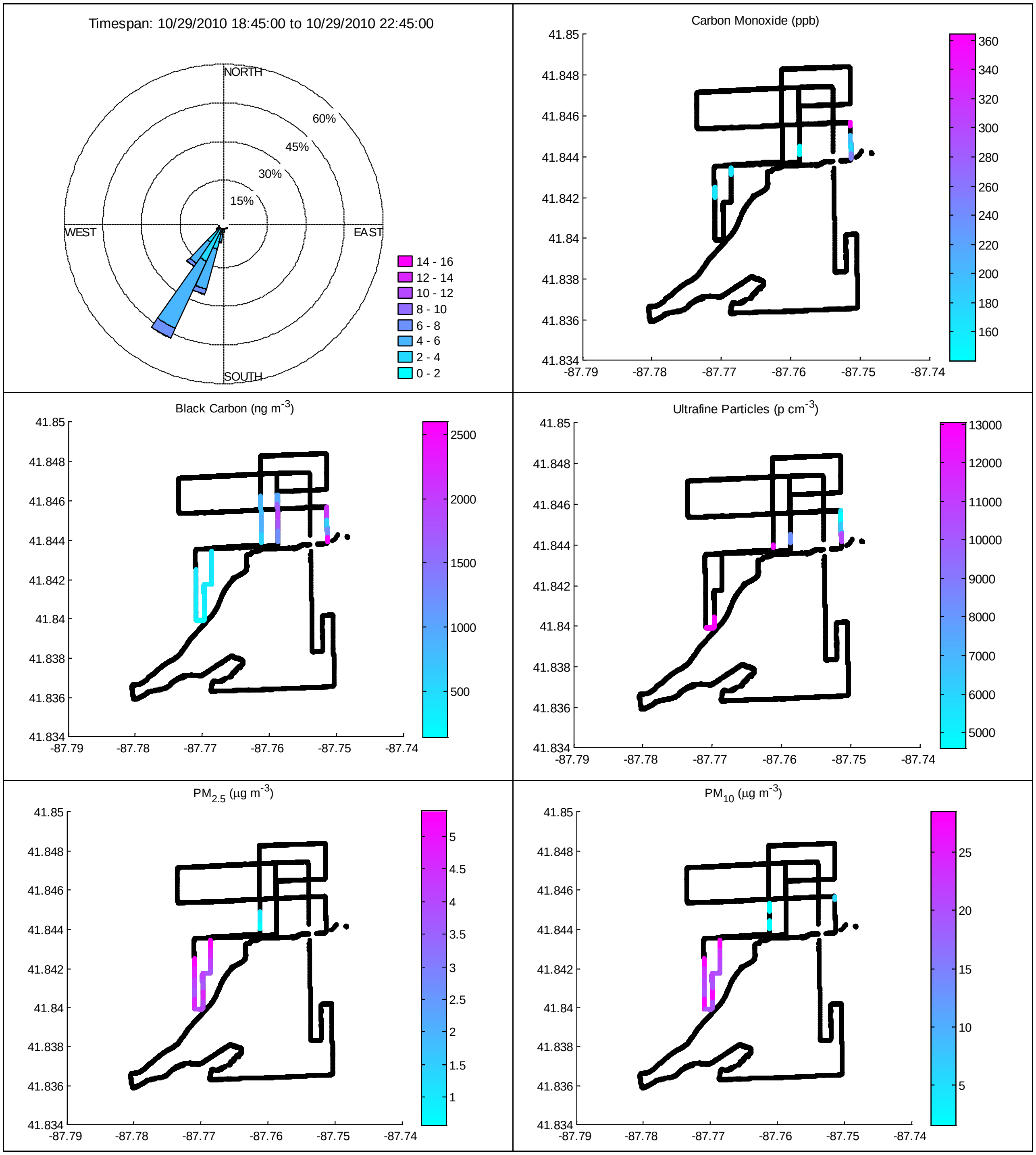
Sampling date: 10/27



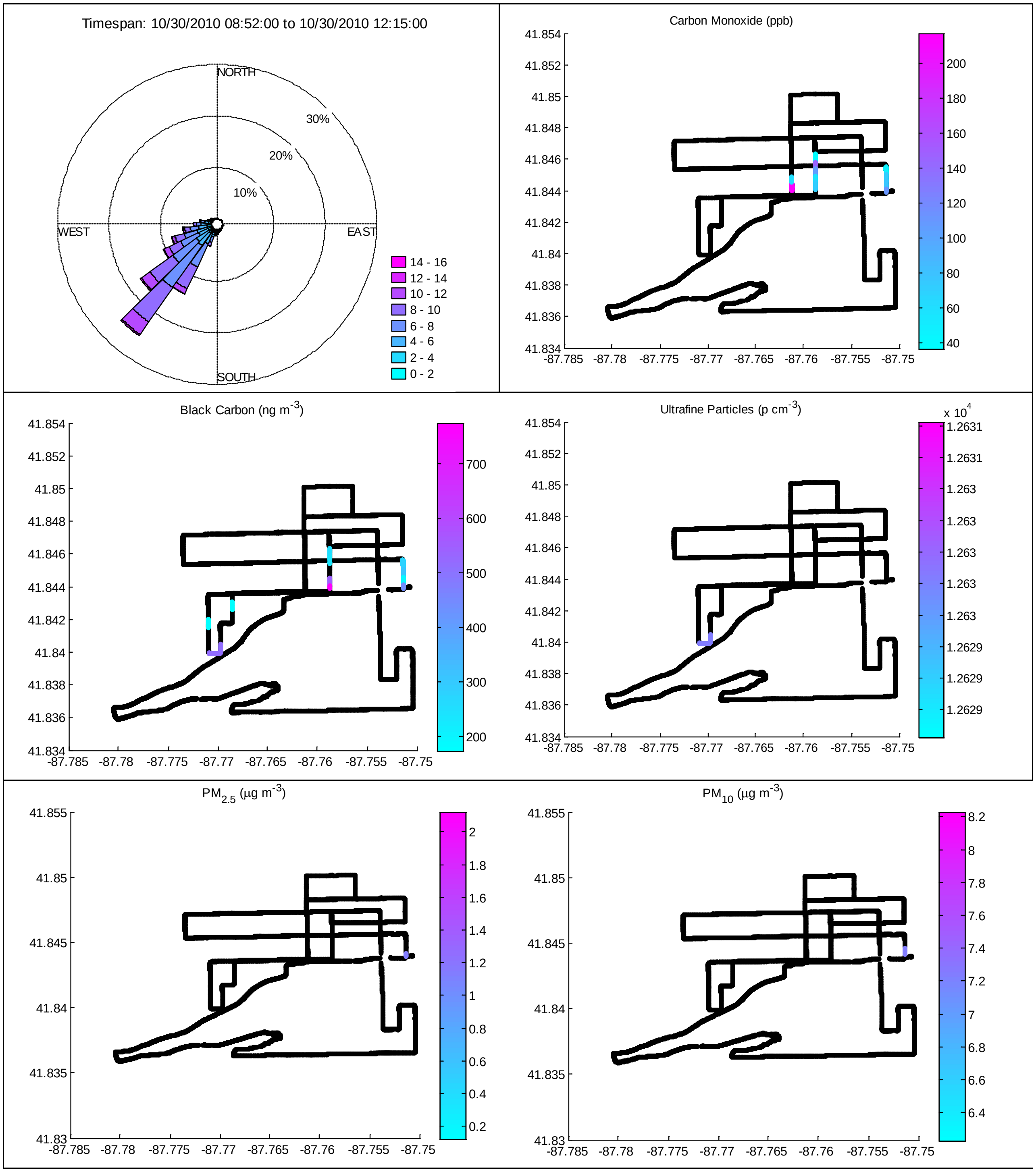
Sampling date: 10/28



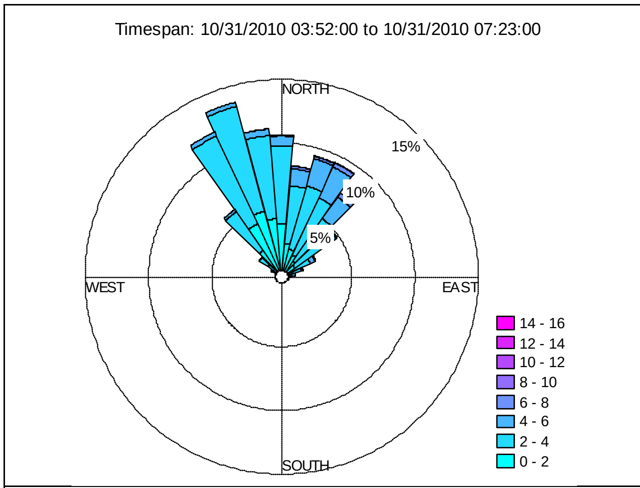
Sampling date: 10/29

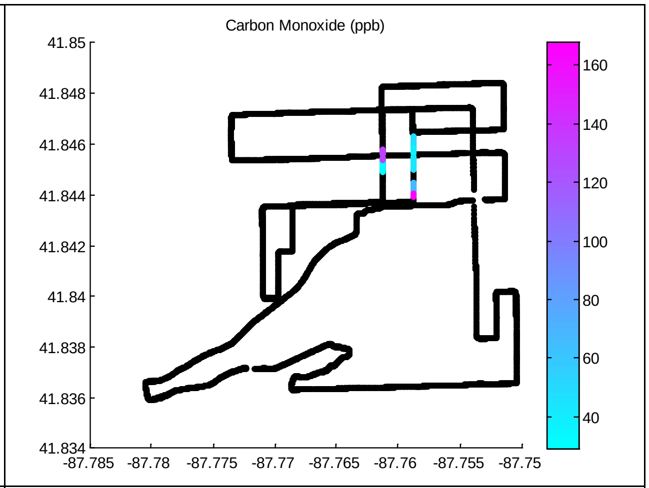


Sampling date: 10/30

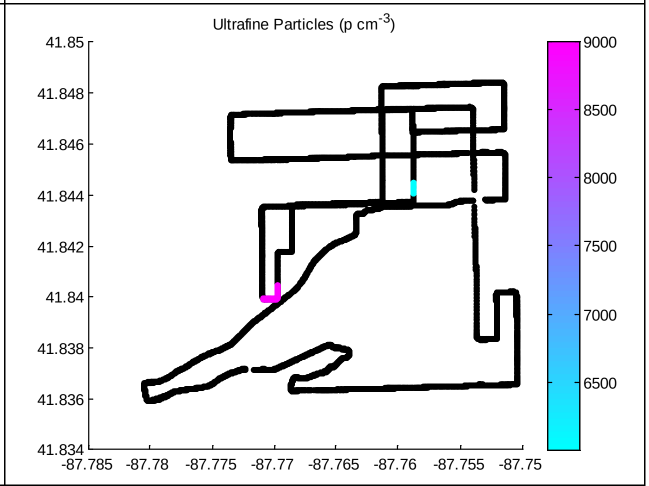


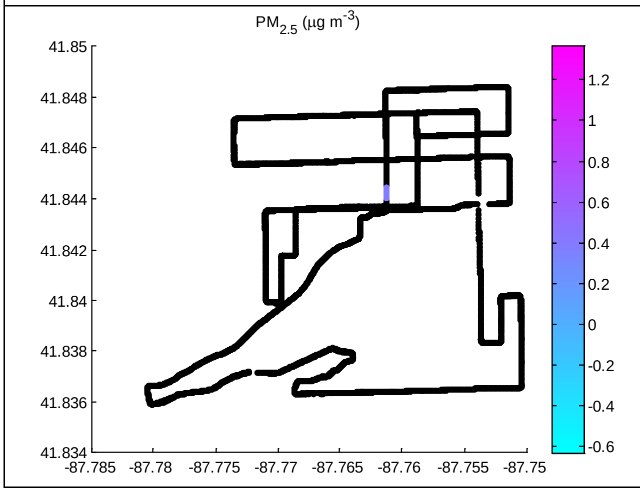
Sampling date: 10/31

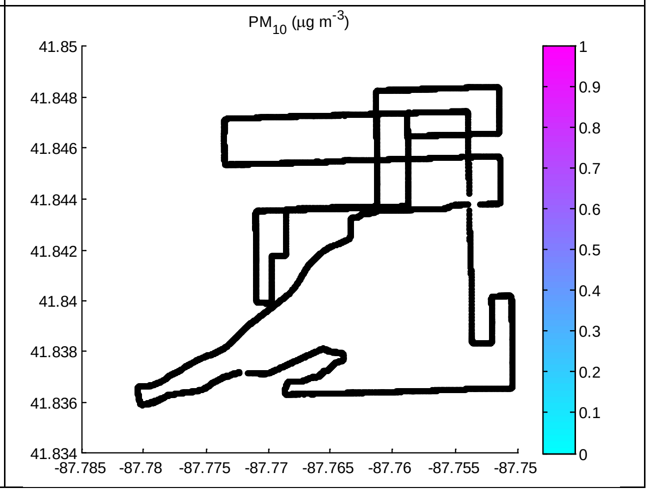




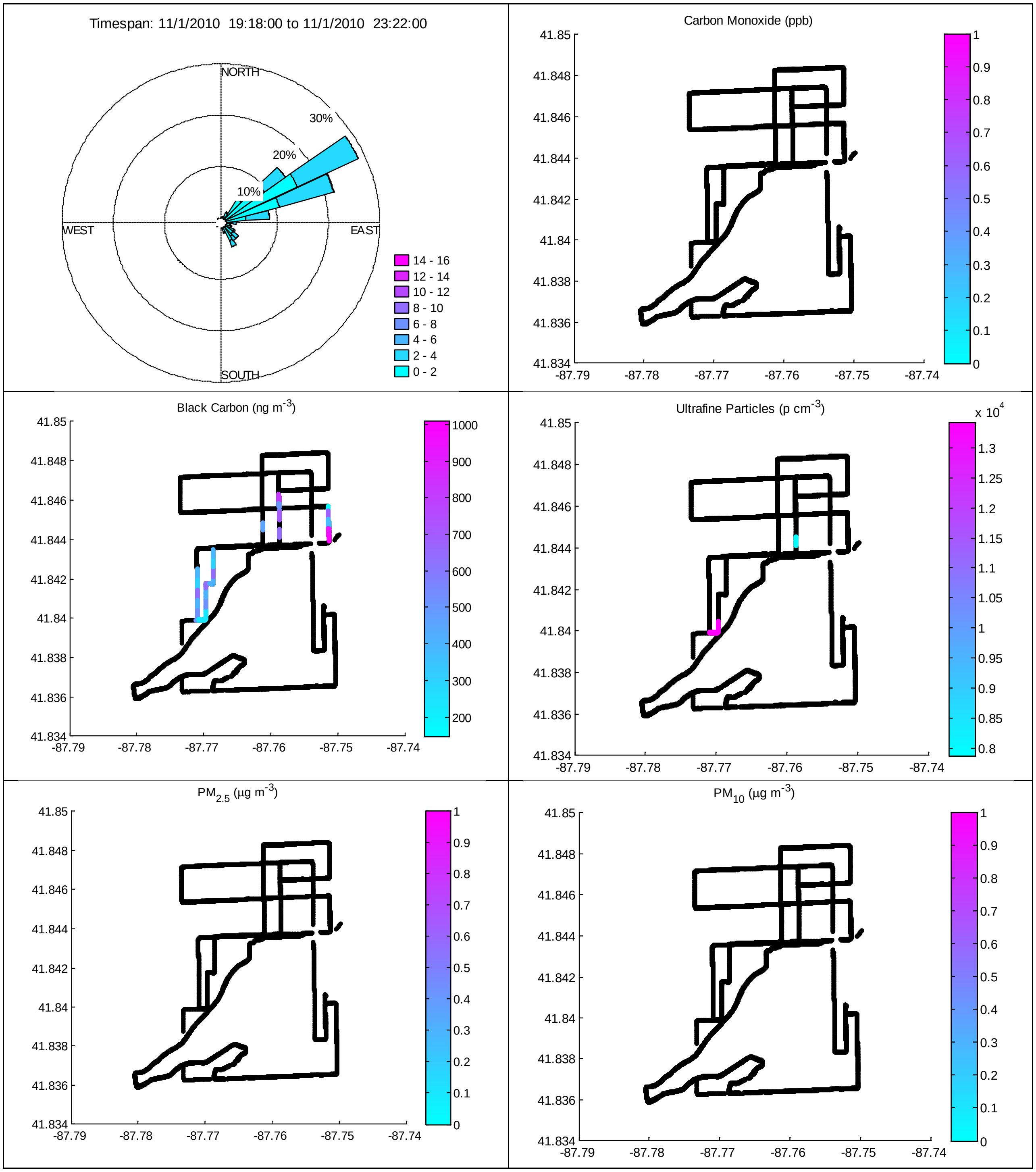
N/A – failed quality check



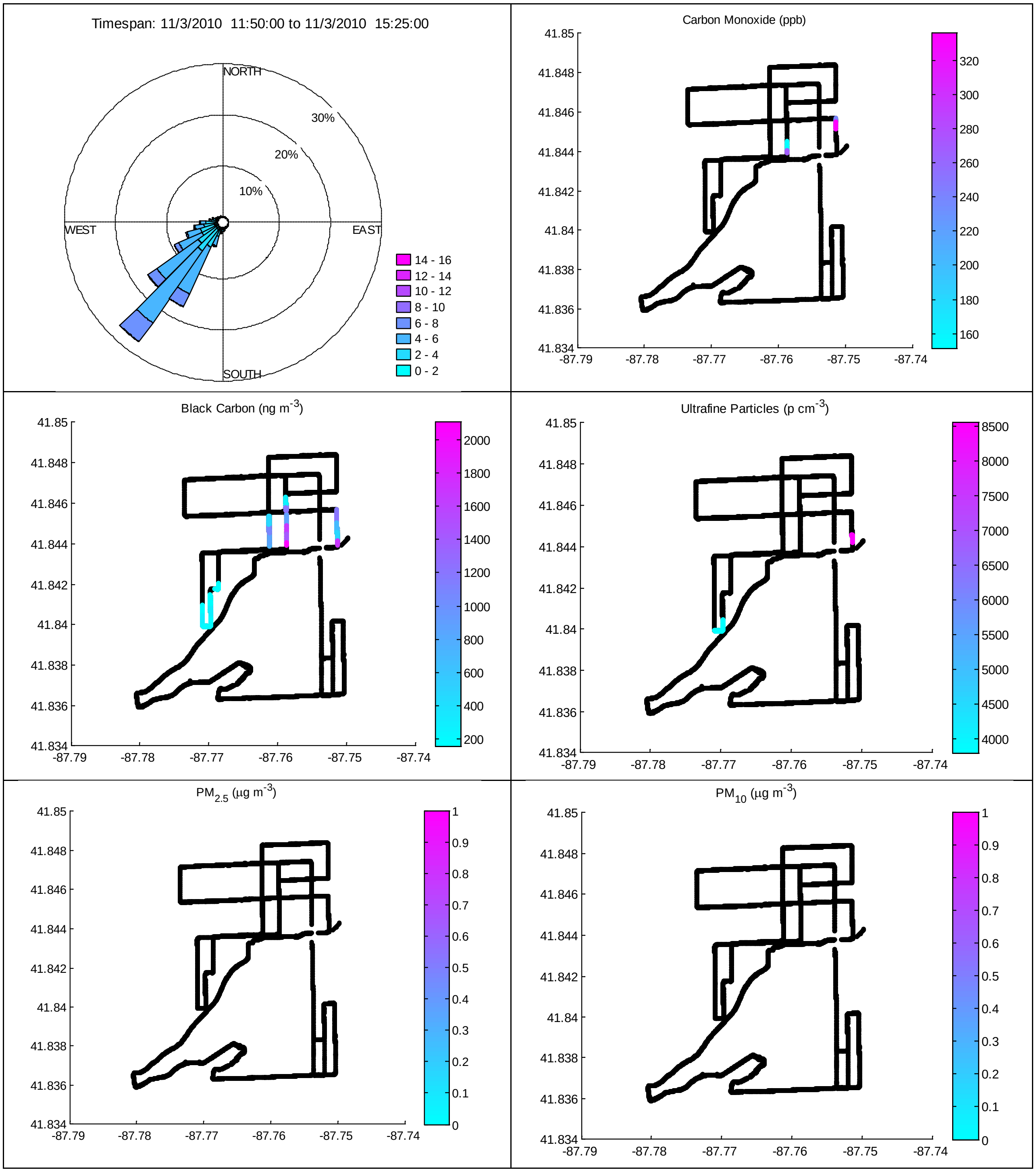




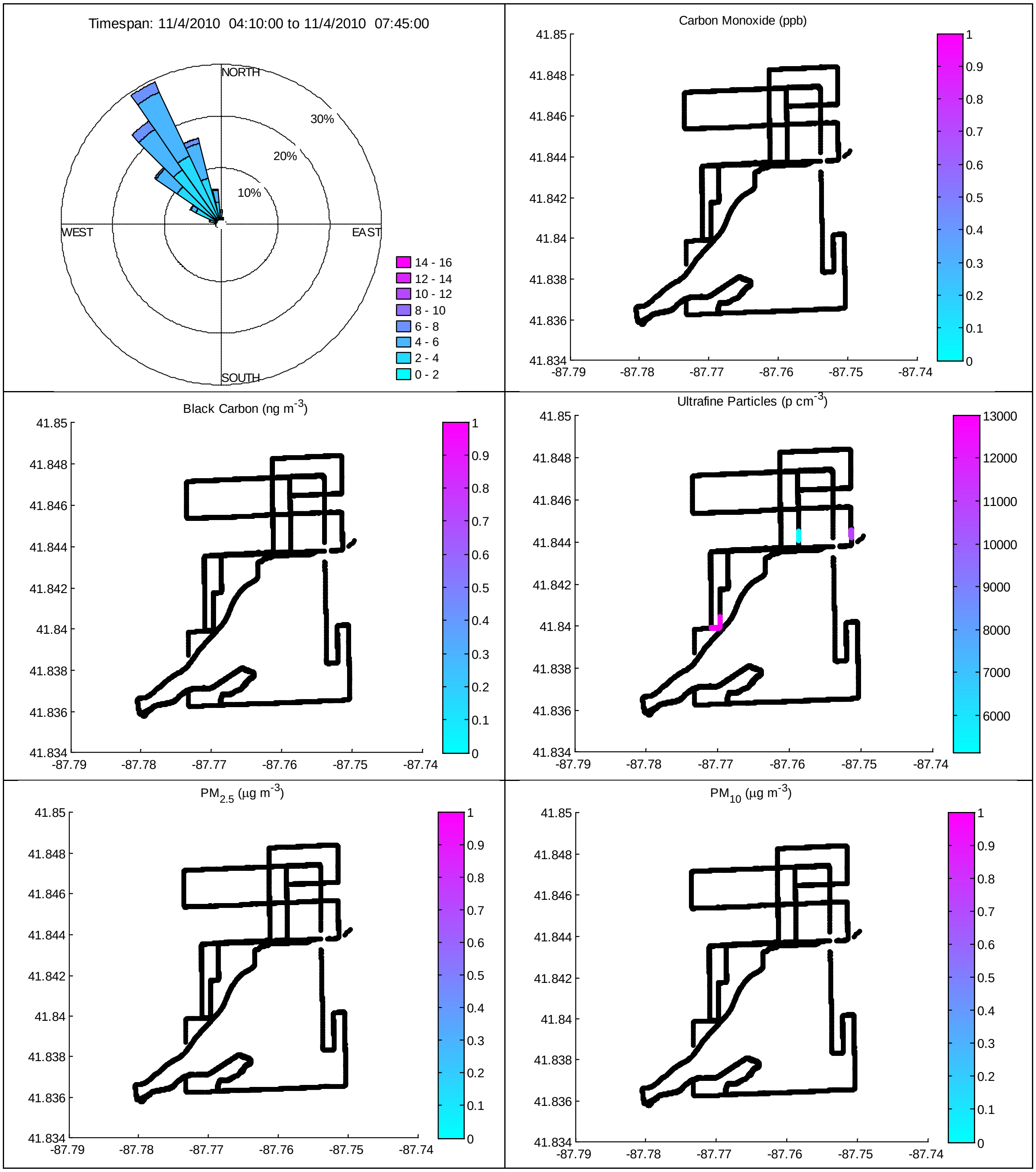
Sampling date: 11/01

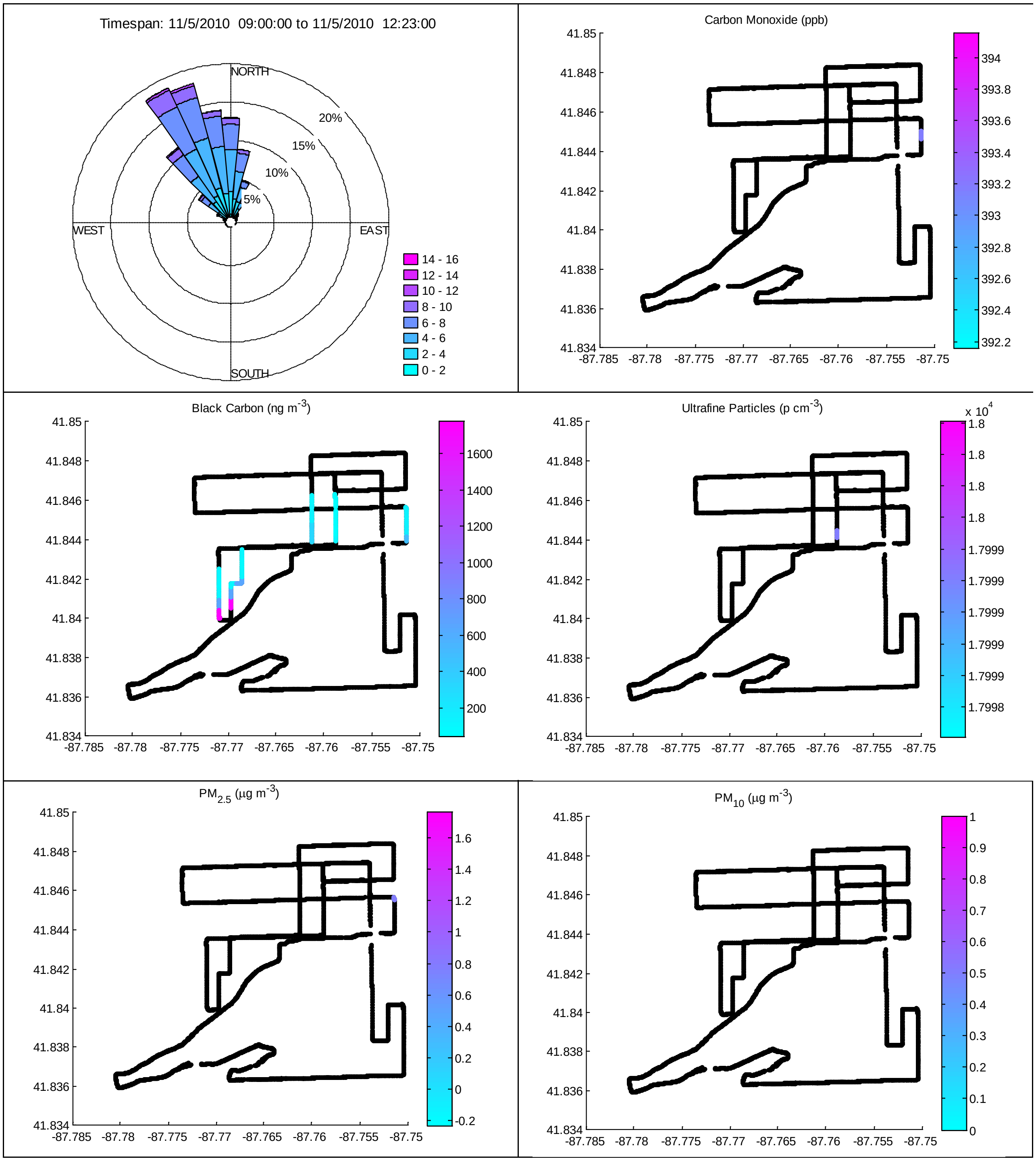


Sampling date: 11/03

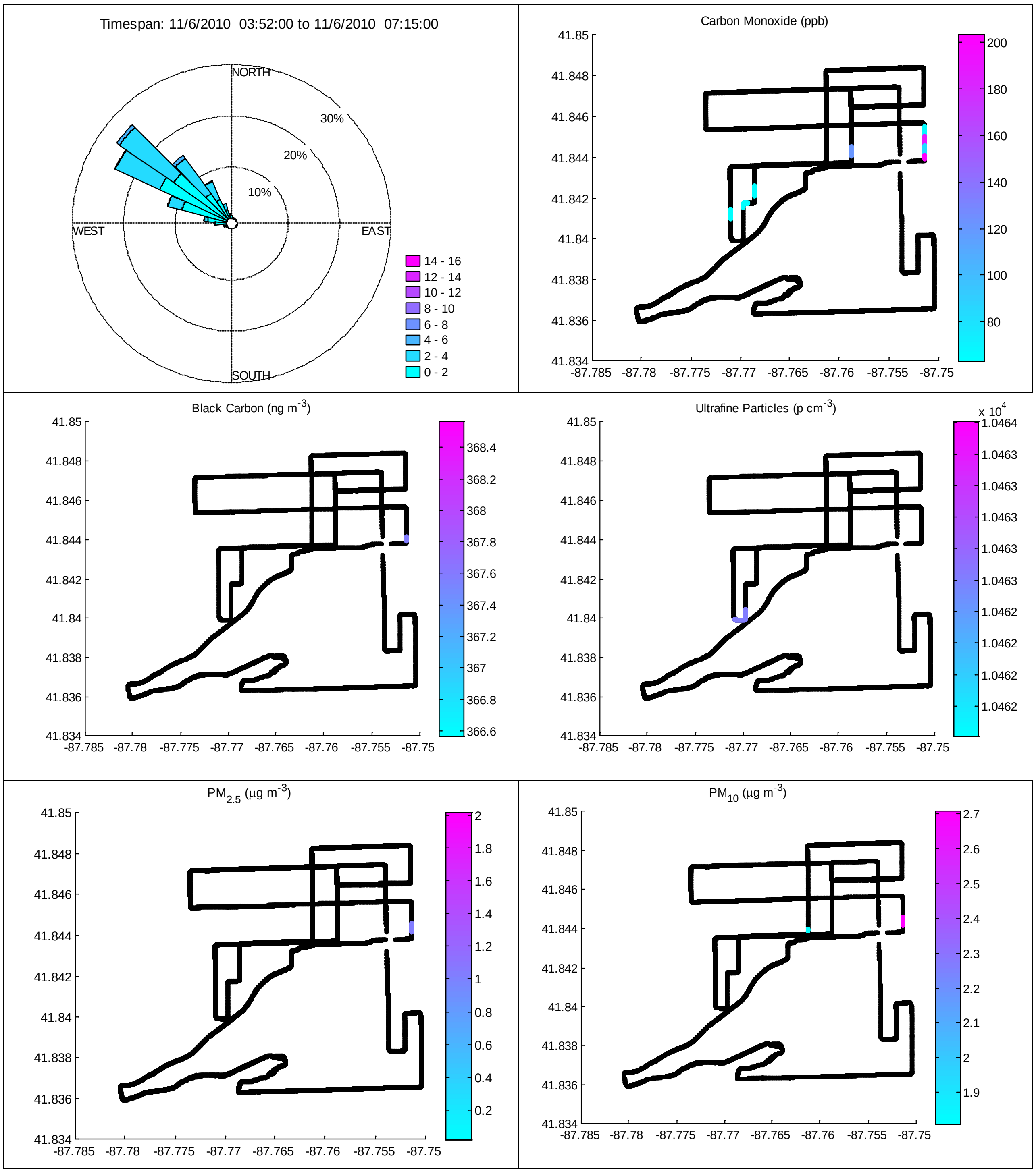


Sampling Date: 11/04

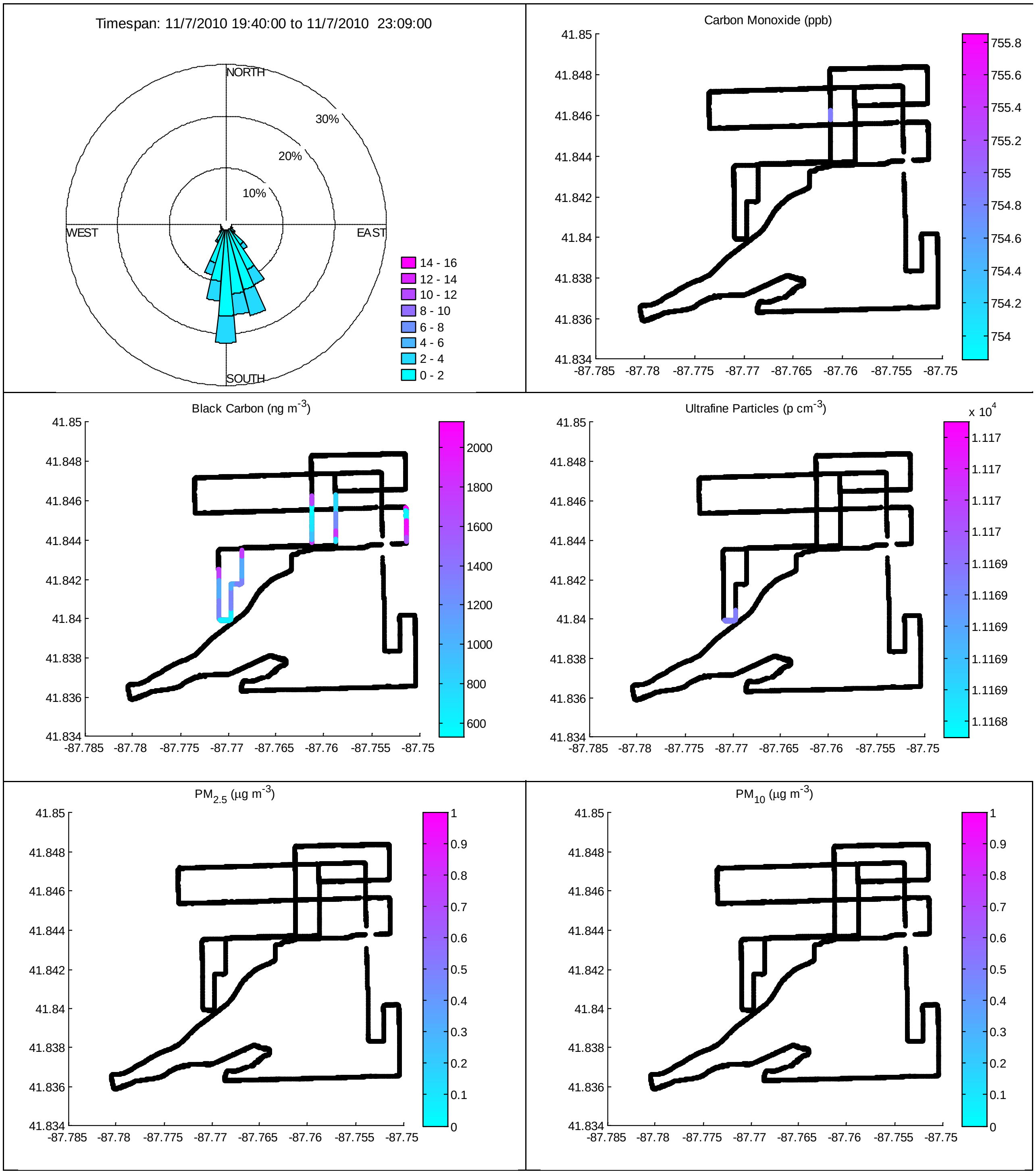



Timespan: 11/5/2010 09:00:00 to 11/5/2010 12:23:00
NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
Carbon Monoxide (ppb)
394
393.8
393.6
393.4
393.2
393
392.8
392.6
392.4
392.2
Black Carbon (ng m-3)
1600
1400
1200
1000
800
600
400
200
Ultrafine Particles (p cm-3)
x 10^4
1.8
1.7999
1.7998
PM2.5 (µg m-3)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
PM10 (µg m-3)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
41.85
41.848
41.846
41.844
41.842
41.84
41.838
41.836
41.834
-87.785
-87.78
-87.775
-87.77
-87.765
-87.76
-87.755
-87.75

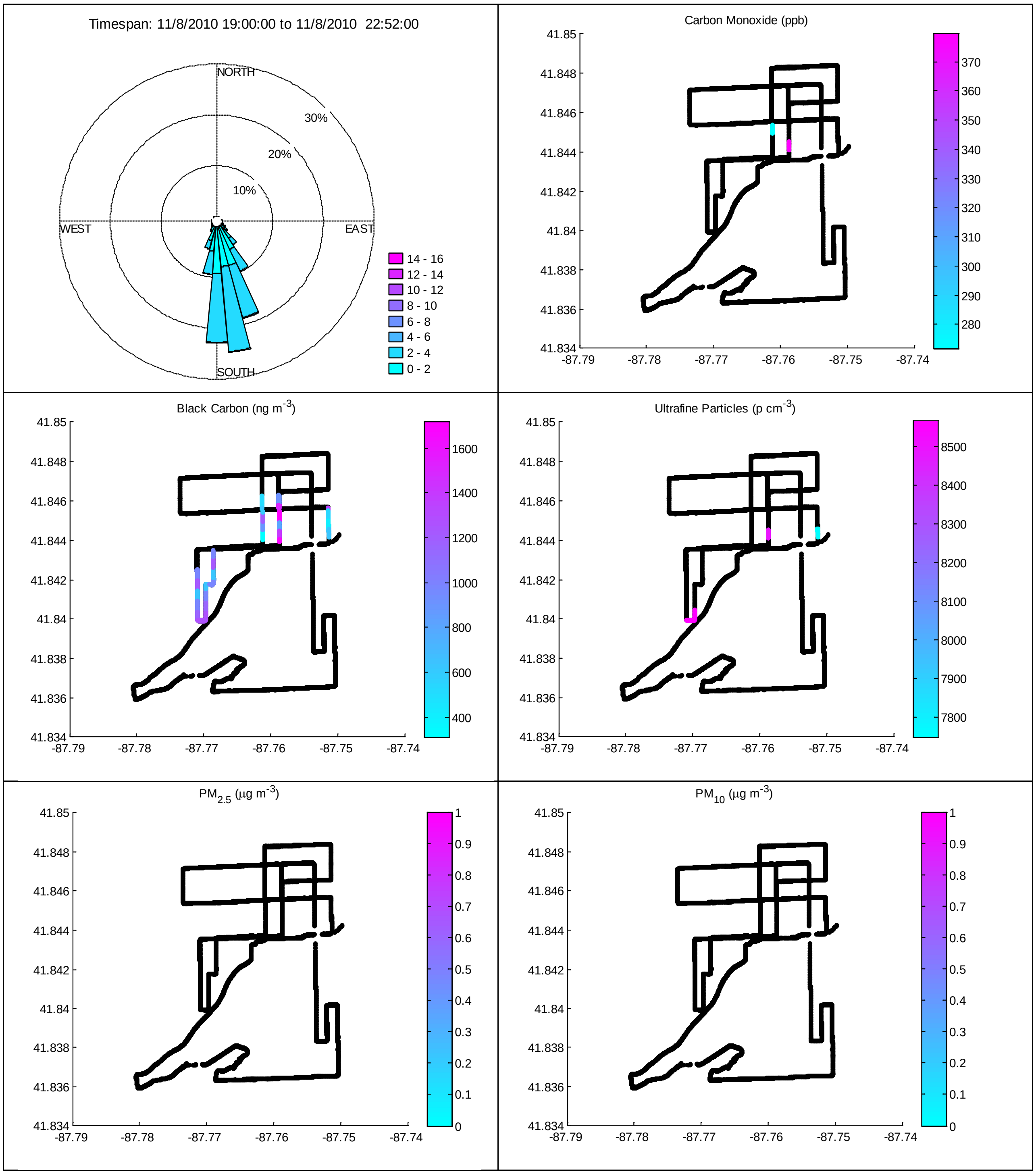
Sampling date: 11/06



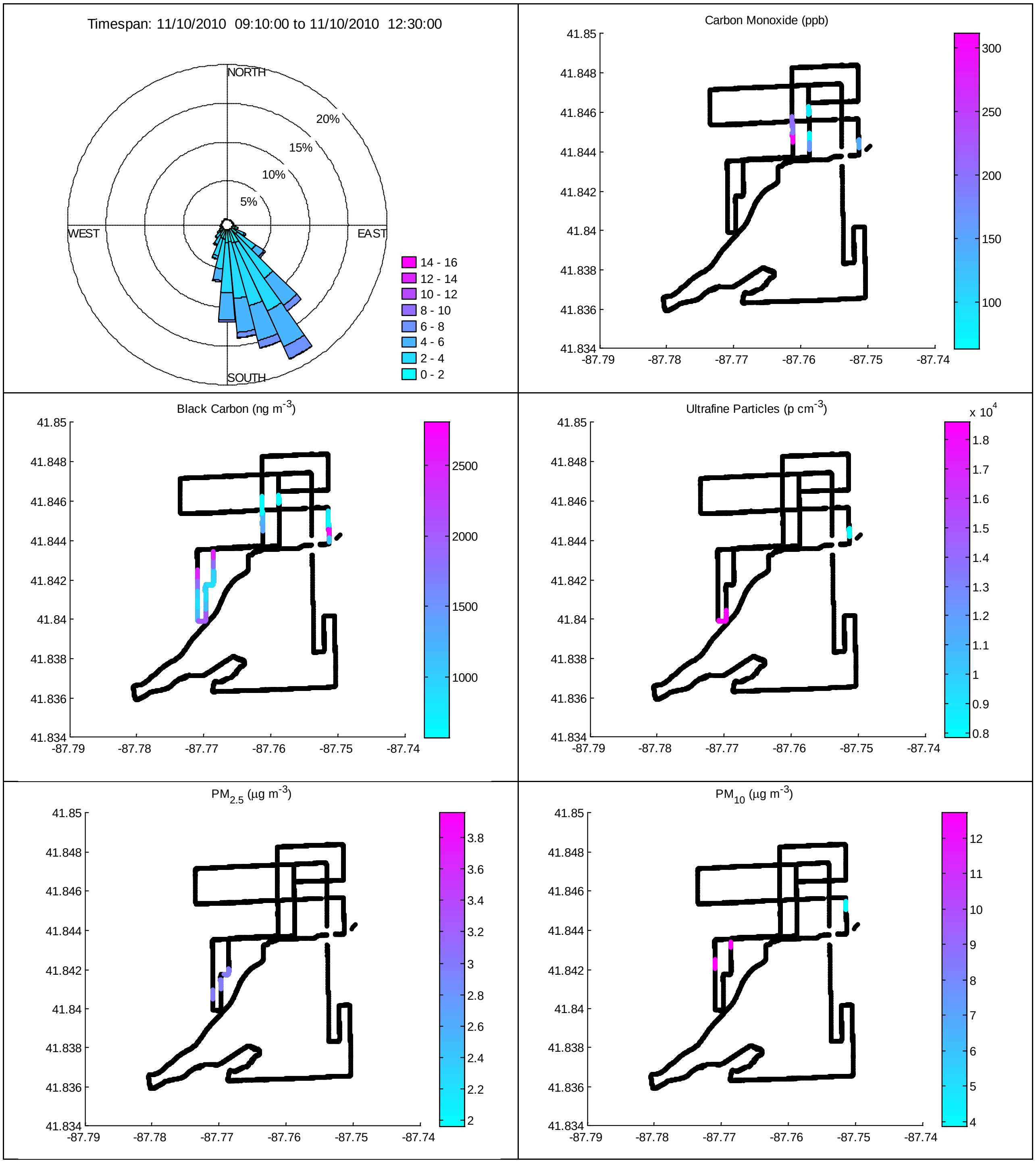
Sampling date: 11/07



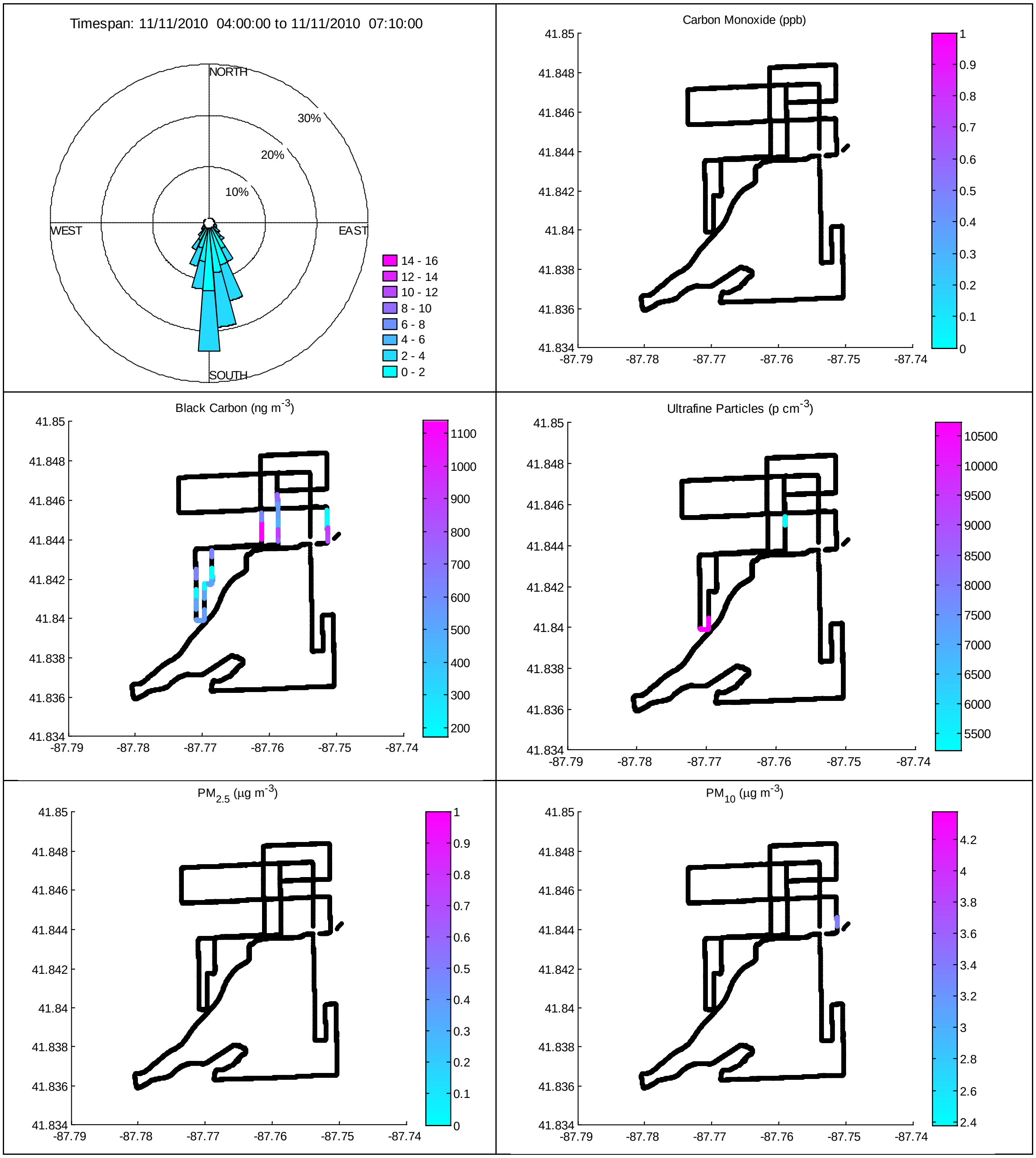
Sampling Date: 11/08



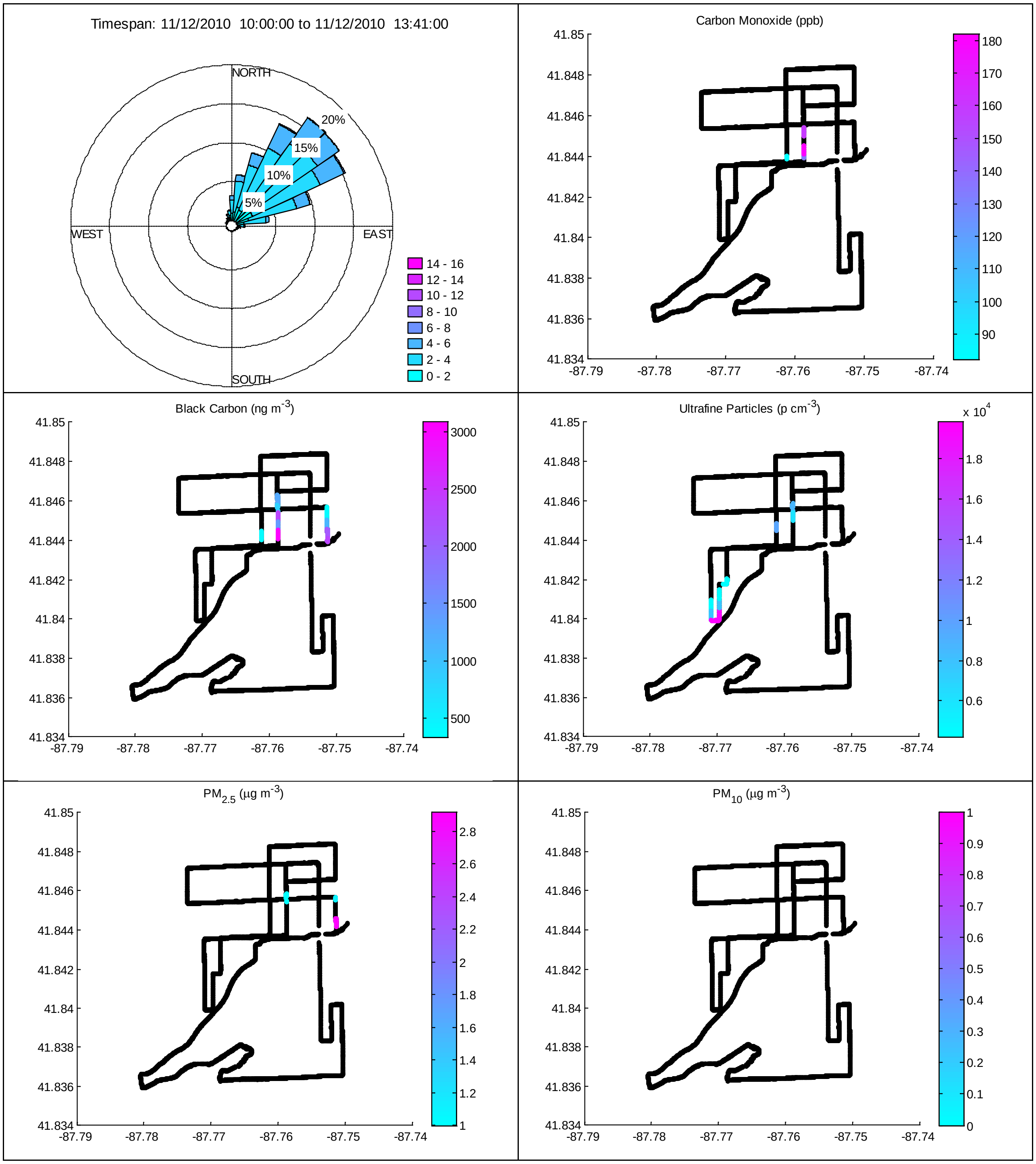
Sampling date: 11/10



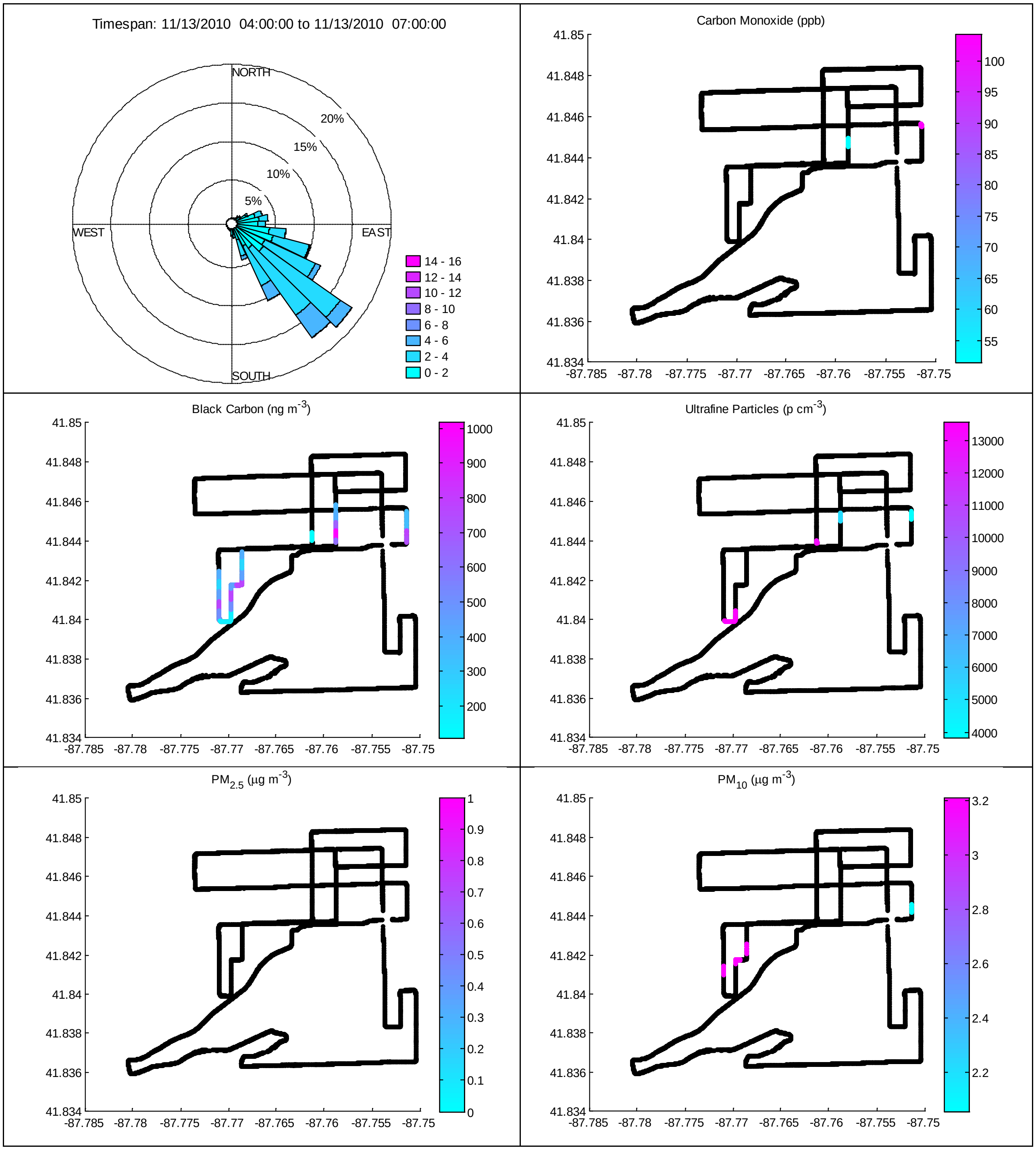
Sampling date: 11/11



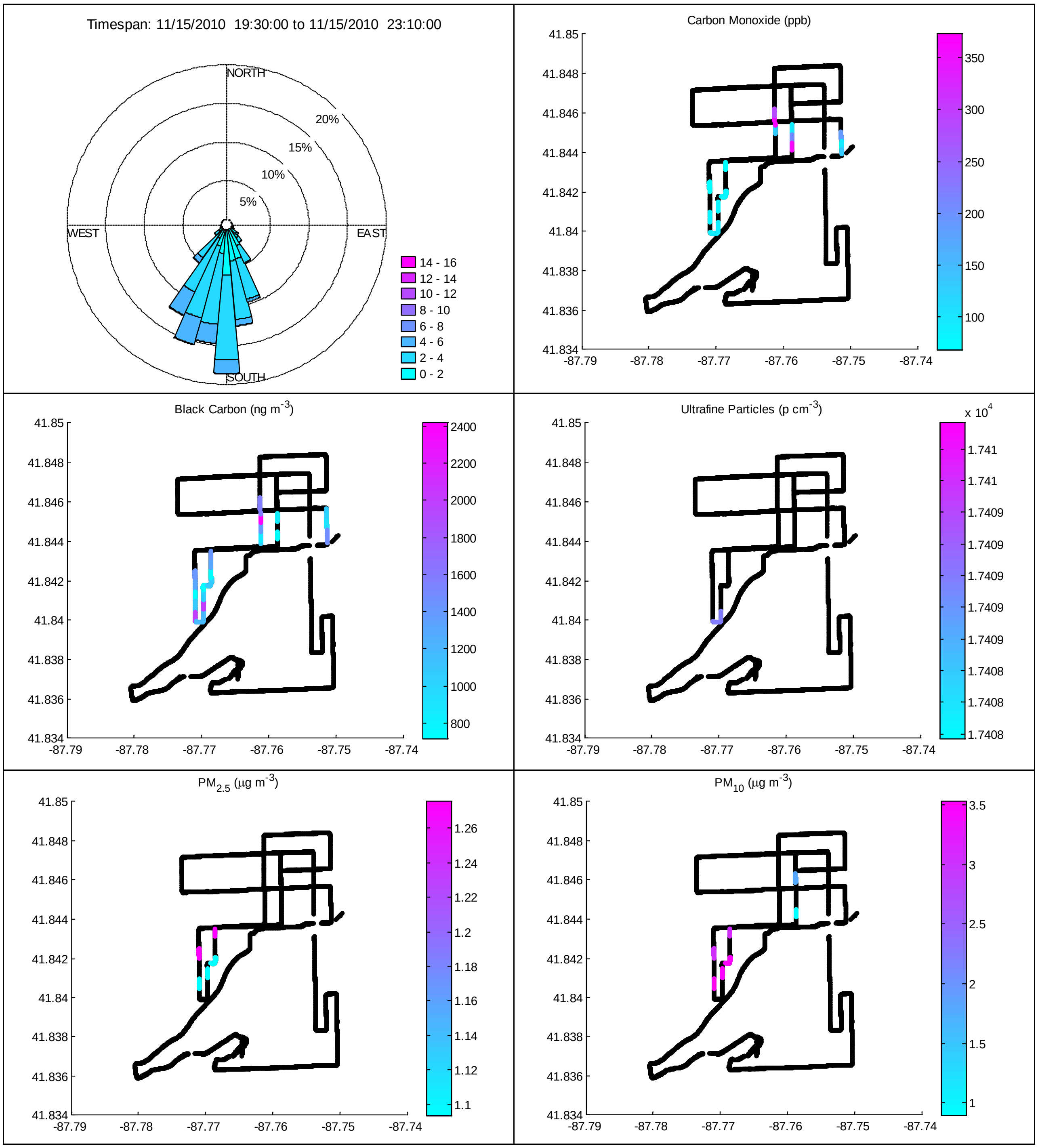
Sampling date: 11/12



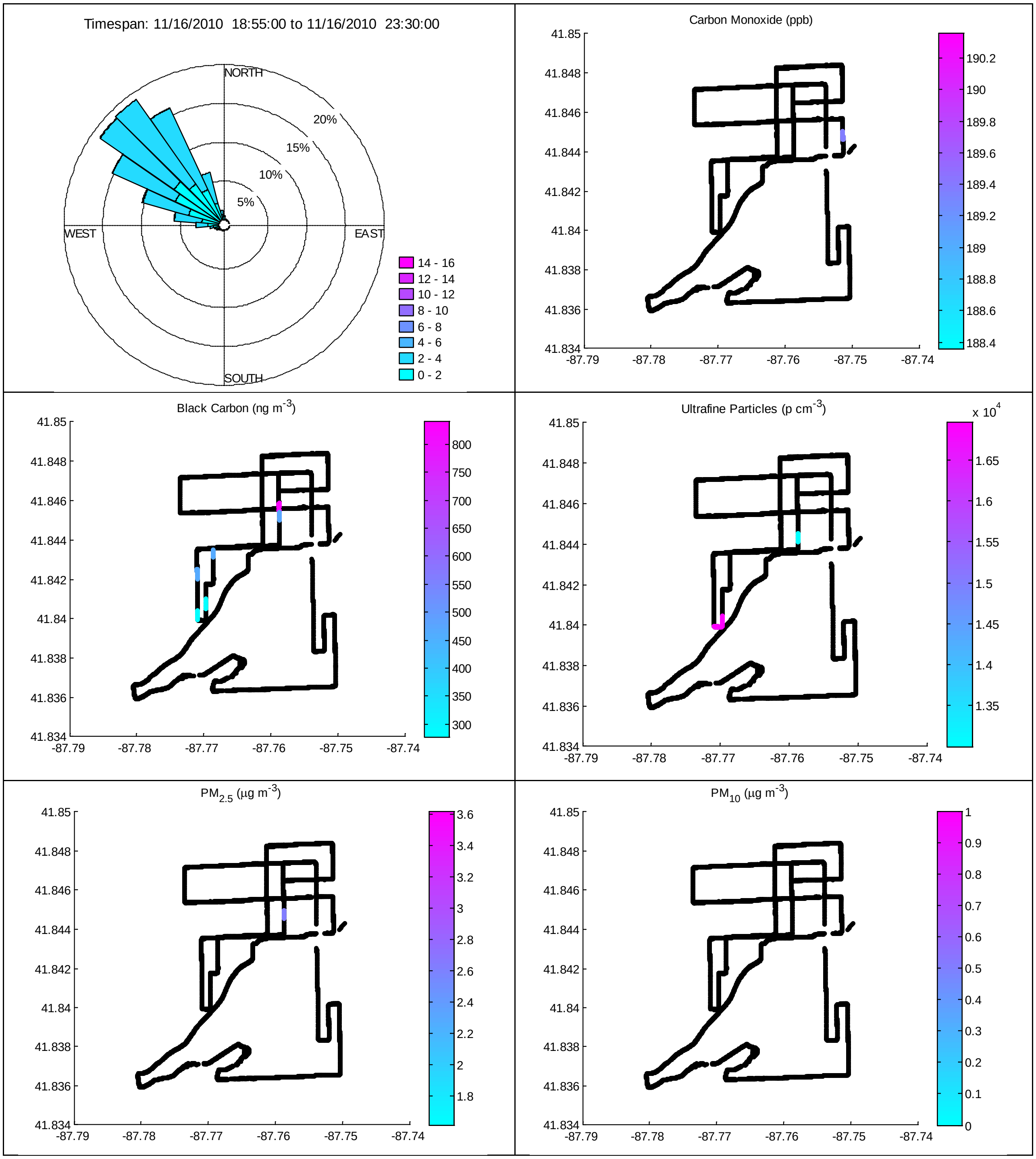
Sampling date: 11/13



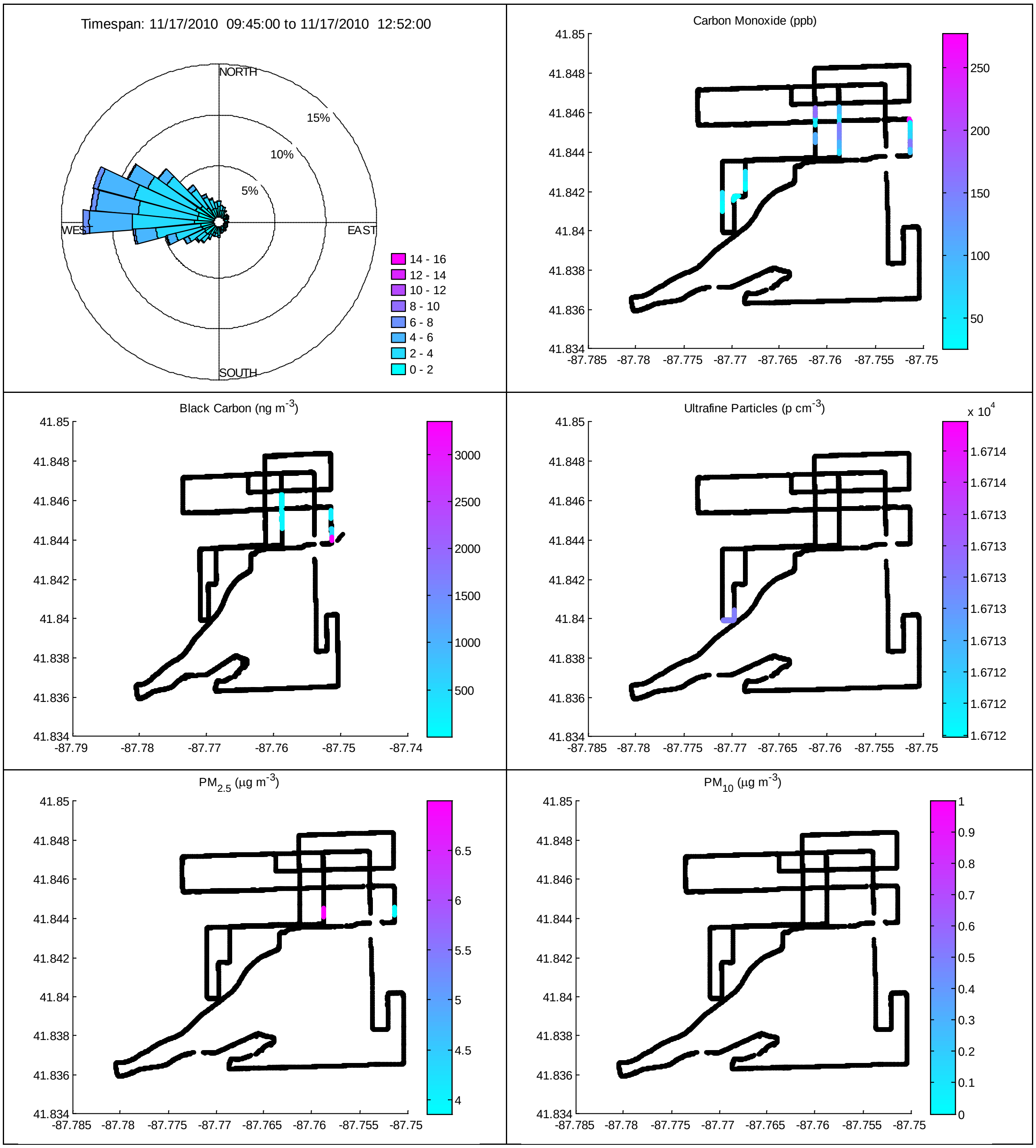
Sampling date: 11/15



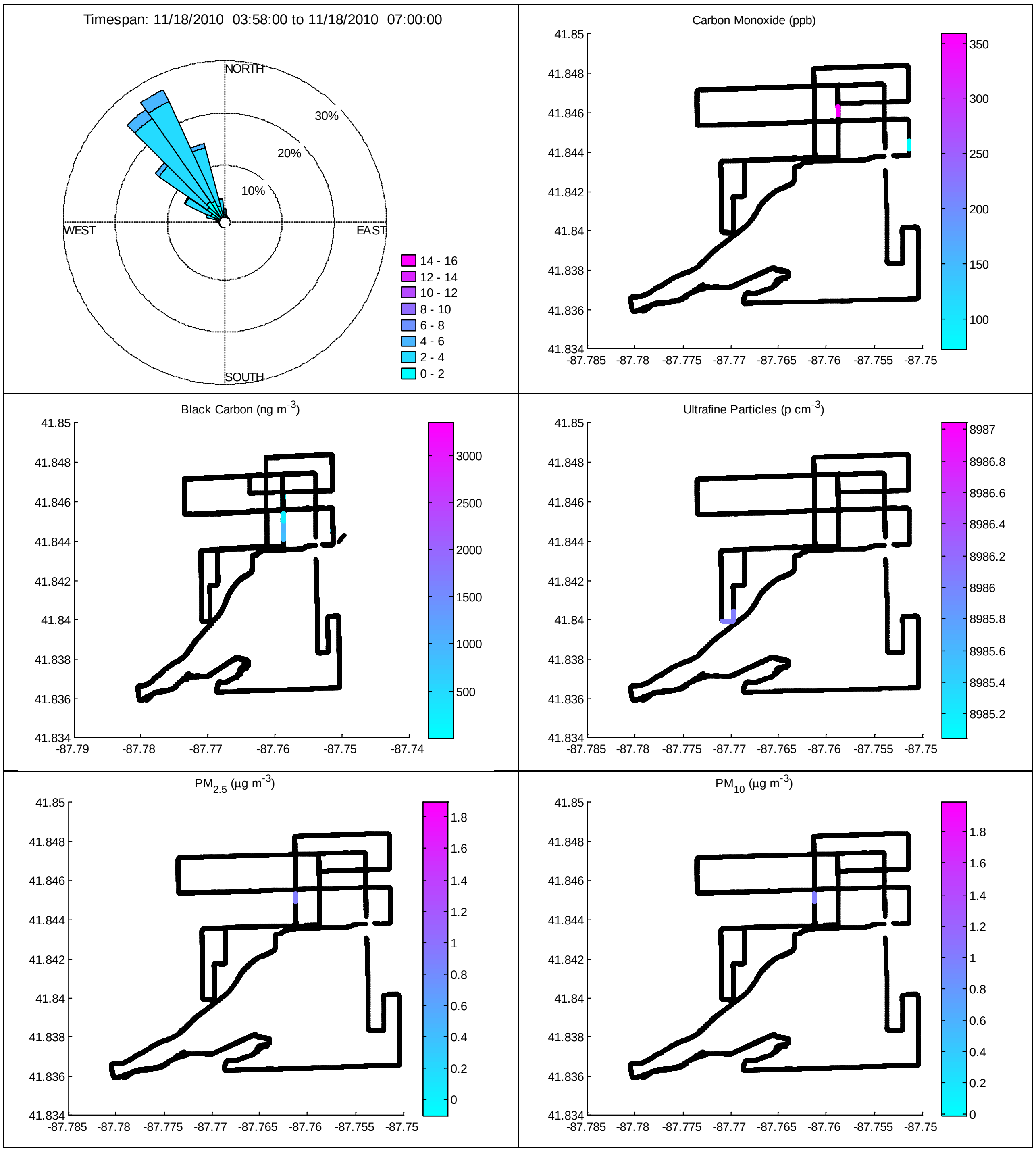
Sampling date: 11/16



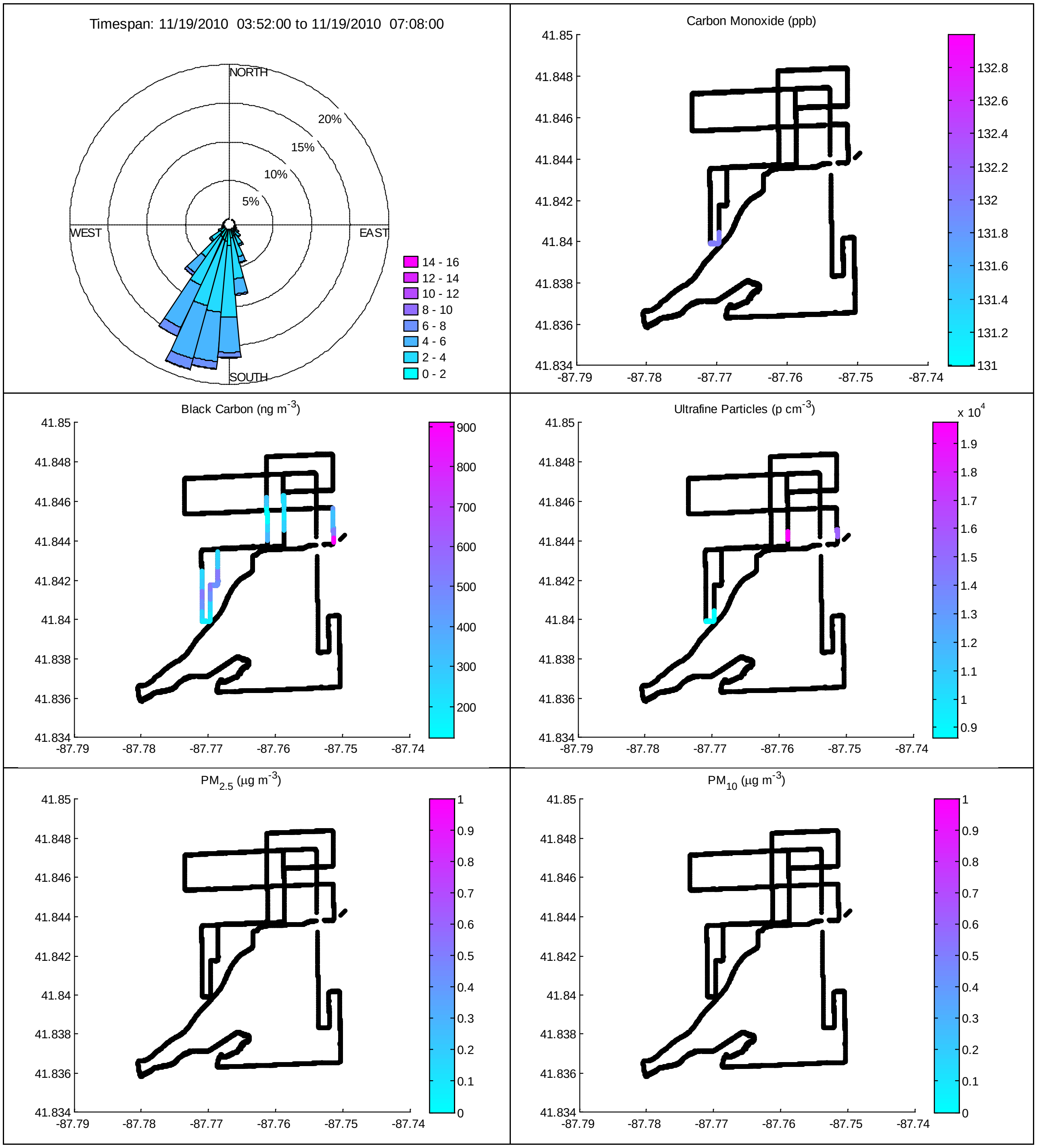
Sampling date: 11/17



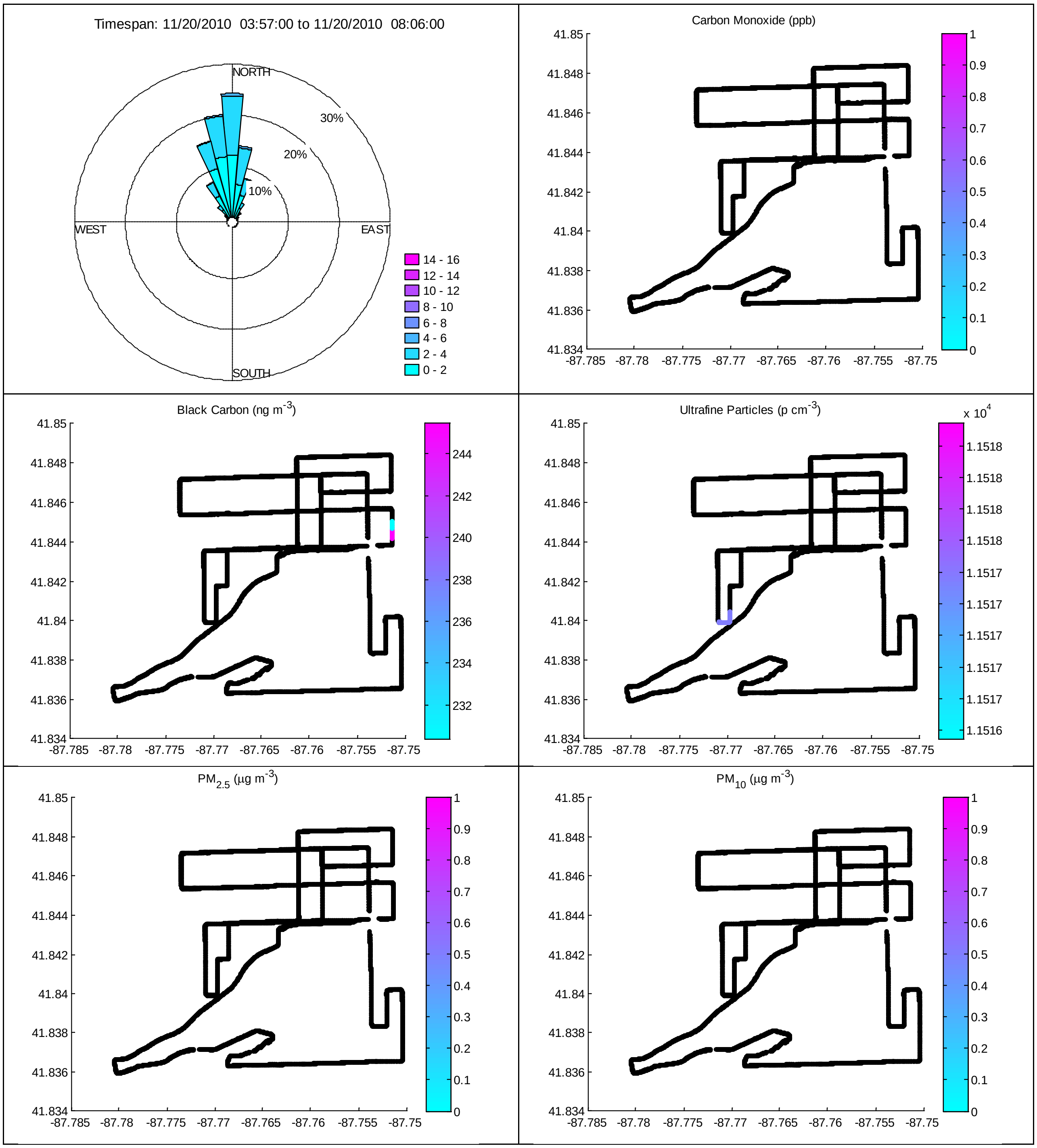
Sampling date: 11/18



Sampling date: 11/19



Sampling date: 11/20



Sampling date: 11/21