March 30, 2011

ORD presentation to Region 5 on Near-Road Research in Detroit

Introduction to EPA ORD Near-Road Research Program
Dan Costa, Sc.D., DABT, National Program Director for Air Research

FHWA/EPA Collaboration Project: National Near-Road MSAT Study
Sue Kimbrough, National Risk Management Research Laboratory (NRMRL)

Mitigation of Near-Road Air Pollution Impacts
Rich Baldauf, Ph.D., ORD/NRMRL and Office of Transportation and Air Quality (OTAQ)

Region 5 Overview of ORD's Detroit Area Near Road Research - Introduction

Dan Costa, Sc.D., DABT

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USEPA

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Motor Vehicles are “Life-Blood” in the U.S.

The current U.S. population is 310 million[1] and growing

There are over 250 million registered vehicles[2]

- Passenger vehicles, ~96%
- Trucks and buses, ~4%

Over 140 million people commute to work[2,3]

- Work, ~45 minutes
- School, ~35 minutes

Over 45 million people live within 300 ft of an airport, railroad or major highway[4]

[1]U.S. Census; [2]National Transportation Statistics; [3]American Time Use Survey; [4]American Housing Survey

Policy Considerations

- Mobile Source Regulations
- Transportation Conformity
- National Environmental Policy Act (NEPA)
- State and local planning
  - Transportation systems
  - School site requirements
  - Child/elderly care facilities
  - Urban planning

"Pressing" Uncertainty - Health

Several Health Outcomes Now Associated

- The PM story until recently has largely had focused on biologic plausibility and its attributes (components and size)
- "Source attribution" studies brought insight into the potential links to transportation – mobile sources.
- European science community has been focused on diesel, traffic, and "ultrafine" particles
- Some outcomes associated with "near road" included:
  - Mortality (apparently stemming from myocardial events)
  - Asthma exacerbation and maybe initiation
  - Cancers
  - Lung growth retardation in children
  - Birth defects
- Uncertain role of co-pollutants - MSATs

"Keystone" Uncertainty - Exposure

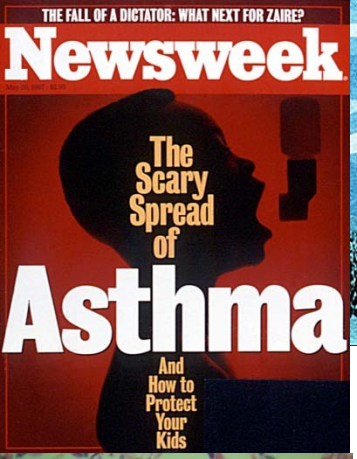
Lack of Good Metrics to Assess Exposure

- Distance from roadway (residence, school, etc.)
  - Linear distance
  - Effective Radius
  - Angular distance
- Cumulative traffic over some temporal period
- Numbers of vehicles per time (exposure rate)
- Vehicle type, speed, etc.
- Person hours within a varying distances or…
- Person hours (~TWA) at locations: e.g., activity diaries
- Any number of statistical models based on the metrics above or land-use estimations
- Emission data – part of the story but alone is not enough

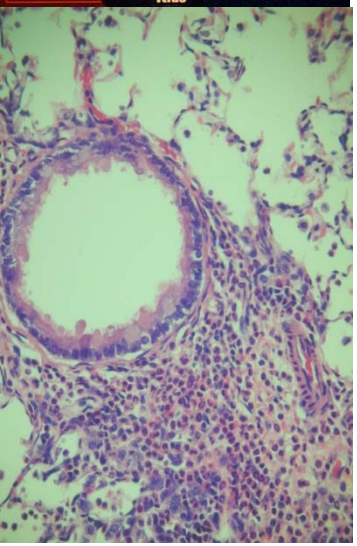
Near Road Uncertainties

Pressing Program & Regional Needs Seemingly Linked to MSAT and PM Exposures Associated with Mobile Sources

- **What do we really know about NR exposures?**
  - **Is this an issue of exhaust emission MSATs or PM?**
  - **What about dispersed roadway and mechanical materials?**
  - **Can we have establish reliable / transferable metrics?**
  - **What are the relevant temporal / spatial exposure profiles?**
- **Health Implications?**
  - **What in fact are the acute / chronic outcomes and risks?**
  - **Who is susceptible?**
  - **Is there biologic plausibility?**
- **Interventions may exist – what is their value?**



Many Ties to Asthma



- van Vliet et al. 1997 **Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways** *Environ Res* 74 (2):122-32
- Delfino et al., 2003. **Respiratory symptoms and peak expiratory flow in children with asthma in relation to volatile organic compounds in exhaled breath and ambient air.** *J Exposure Anal Environ Epidemiol* 13: 348-363.
- Gauderman et al., 2005. **Childhood asthma and exposure to traffic and nitrogen dioxide**. *Epidemiol* 16(6):737-743.
- Morgenstern et al., 2008 **Atopic diseases, allergic sensitization, and exposure to traffic-related air pollution in children**. *Am J Resp Crit Care Med* 177(12):1331-7.
- Singh et al. 2005 **Effects of diesel exhaust particles and carbon black on induction of dust mite allergy in brown norway rats**. J Immunotox 2(1):41-9.

Health Effects Institute
Comprehensive Review of Traffic Research (2010)

Traffic-related exposures are extensive and associated with adverse health outcomes

30-45% of people living in large North American cities live in traffic exposure areas

Conclusion: Traffic-related pollution may cause a range of health outcomes including cardiovascular and respiratory effects

Implementation of ORD's Near Road Action Plan

- **ORD FY06 Raleigh NR Pilot**
  - **Project & instrument 'shakedown'**
  - **Analysis, Tox samples, various modeling efforts**
- **IAG w/ Federal Highway Admin. (FHWA)**
  - **Las Vegas (2009-10)**
    - **Focus on near road emission profile**
  - **Detroit (2010-11) – FHWA & *NEXUS***
    - **NEXUS STAR project to assess health (asthma, indicators)**
    - **Coop allow coordination between ORD and awardee**
    - **Coordination with OAQPS, negotiations w/ NIEHS & others**
- **Intensive (targeted) ORD Study – Raleigh (~2013)**

Draft Near Roadway Action Plan

- **Source / Emissions –** characterization (combustion and mechanically generated); source apportionment; impact of traffic conditions (e.g., volume, speed, fleet mix)
- **Air Quality –** spatial and temporal variability; atmospheric processes; impact of environmental conditions (e.g., topography, meteorology)
- **Exposure Assessment –** gradients; source apportionment; dispersion / AQ-linked models
- **Health Effects –** source apportionment; tox and epi panel studies
- **Indoor Micro-environments –** source impacts; mitigation

ORD Near Road Research

NHEERL

Epidemiology

Clinical and Animal Toxicology Studies

Molecular

Intramural Program

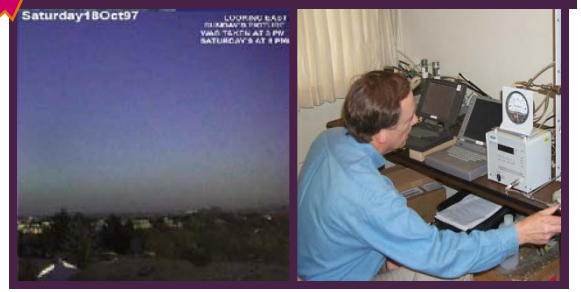
EPA STAR Program (PM Ctrs & RFAs)

EPA Partners:
- *Federal Agencies (FHWA)*
- *NIEHS*
- *Health Effects Institute*
- *Academia*
- *Industry*

NRMRL - Emission Source Characterization

OTAQ

NERL - Exposure, Atmos. Measurement and Models



PM Centers – Near-Road Studies

Harvard PM Center

TERESA tunnel study: Harvard's mobile facility transforms primary emissions from a large Boston tunnel to realistic atmospheric mixtures (with primary and secondary particles) for toxicological studies.

University of Rochester PM Center

- Epidemiological studies in Rochester and Germany – urban fine and ultrafine particles, gaseous pollutants, with source apportionment to identify traffic component
- Controlled human exposure studies in Rochester, to be conducted in the early morning to capture rush hour exposures
- Animal studies using on-highway exposures

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EPA/FHWA Near Road Collaboration Project:

Region 5 Briefing

National Near Road MSAT Study

Sue Kimbrough[1], Richard Shores[1], Donald Whitaker[1], Bill Mitchell[1], Gayle Hagler[1], Daniel Vallero[1], Alan Vette[1], Carry Croghan[1], Victoria Martinez[2], Michael Claggett[2].
[1]U.S. Environmental Protection Agency, Office of Research and Development
[2]Federal Highway Administration

Office of Research and Development

January 10, 2011

Who are the members of the EPA/FHWA Near Road team?

Project Team:

- Strategic Project/Science Management
  - Dan Costa
  - Carlos Nunez
  - Doug Mckinney
  - Richard Baldauf
  - David Kryak
  - Alan Vette
- NRMRL – Project Management
  - Sue Kimbrough
  - Richard Shores
- EPA/FHWA Technical Working Group (including above)
  - Victoria Martinez (FHWA) -- IAG Project Officer
  - Dan Vallero (EPA IAG Project Officer)
  - Bill Mitchell
  - Donald Whitaker
  - Richard Baldauf
  - Gayle Hagler
  - James Hirtz
  - Jason Herrington
  - Paul Solomon
  - Other EPA technical staff as needed……..

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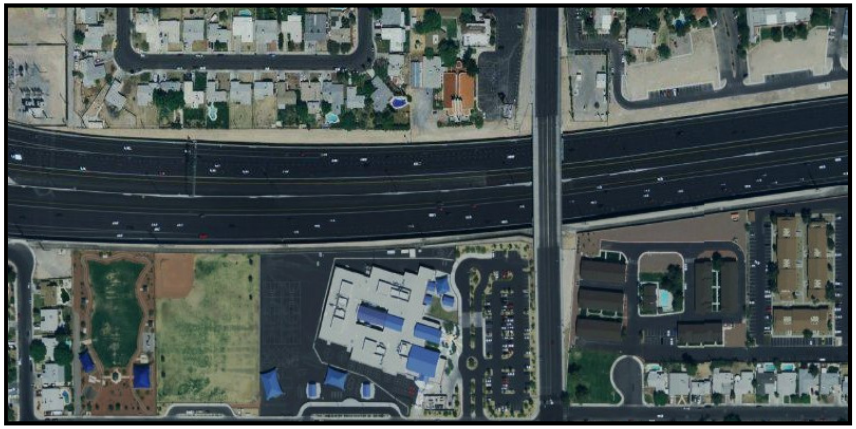
Near Road Air Quality Background

- Estimate over 45 million people live within 100 meters of a major transportation system including 4+ lane highways – many more work or attend school near roads
- More than 1,000 compounds have been identified in exhaust and evap emissions from mobile sources
  - Regulated Pollutants
  - Air Toxics
  - Particulate Matter
- Air quality measurements have indicated elevated pollutant concentrations near roads
- Near-road exposures have been associated with numerous adverse health endpoints, including:
  - Respiratory effects (e.g., asthma)
  - Cardiovascular effects
  - Adverse birth outcomes
  - Premature mortality
  - Cancer



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Why are we involved in this project? --- Key Science Questions ---

- What is the spatial and temporal variability of traffic-related pollutants near roadways?
- How do traffic (volumes, speeds, fleet mix, etc.) and environmental (meteorology, topography, etc.) conditions affect vehicle emissions and near road air quality?
- What marker(s)/metric(s) can be used to identify exposures to traffic-related emissions?
- What tools are available, or can be produced, to identify the relationship from traffic emissions to population exposures to adverse health effects for use in regulatory decision making and transportation planning?
- What are the concentration gradients at a fine(er) scale resolutions?
- How does urban topography and barriers impact these gradients?
- Are there mitigation techniques that can reduce exposures to susceptible populations?

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Site Selection Methodology

Step	Site Selection Steps	Method	Comment
1	Determine Site Selection Criteria	Monitoring Protocol	Developed by U.S. FHWA
2	Develop List of Candidate Sites	GIS Data; Site Visit(s)	Additional sites added as information is developed.
3	Apply Coarse Site Selection Filter	Team Discussions, Management Input	Eliminate sites below acceptable minimums.
4	Site Visit	Field Trip	Application of Fine Site Selection Filter
5	Select Candidate Site(s)	Team Discussions, Management Input	
6	Obtain Site Access Permissions	Contact Property Owners	If property owners do not grant permission, then the site is dropped from further consideration.
7	Site Logistics (i.e., physical access, utilities – electrical and communications)	Site Visit(s), Contact Utility Companies	

What do we hope to get out of this effort?

Outcomes	Clients
Provide FHWA with data necessary to comply with Settlement Agreement.	FHWA
Understanding the relationship between traffic, meteorology and near road air quality	FHWA, NRMRL/NERL
Identify metrics used to relate traffic emission impacts on air quality and adverse health effects for inclusion in risk and health assessments	FHWA, OTAQ, OAQPS, NHEERL, HEI, states
Provide improved air quality dispersion algorithms for near-road assessments and upgrade EPA's regulatory dispersion model AERMOD	OTAQ, OAQPS, NOAA, FHWA, DOE, states

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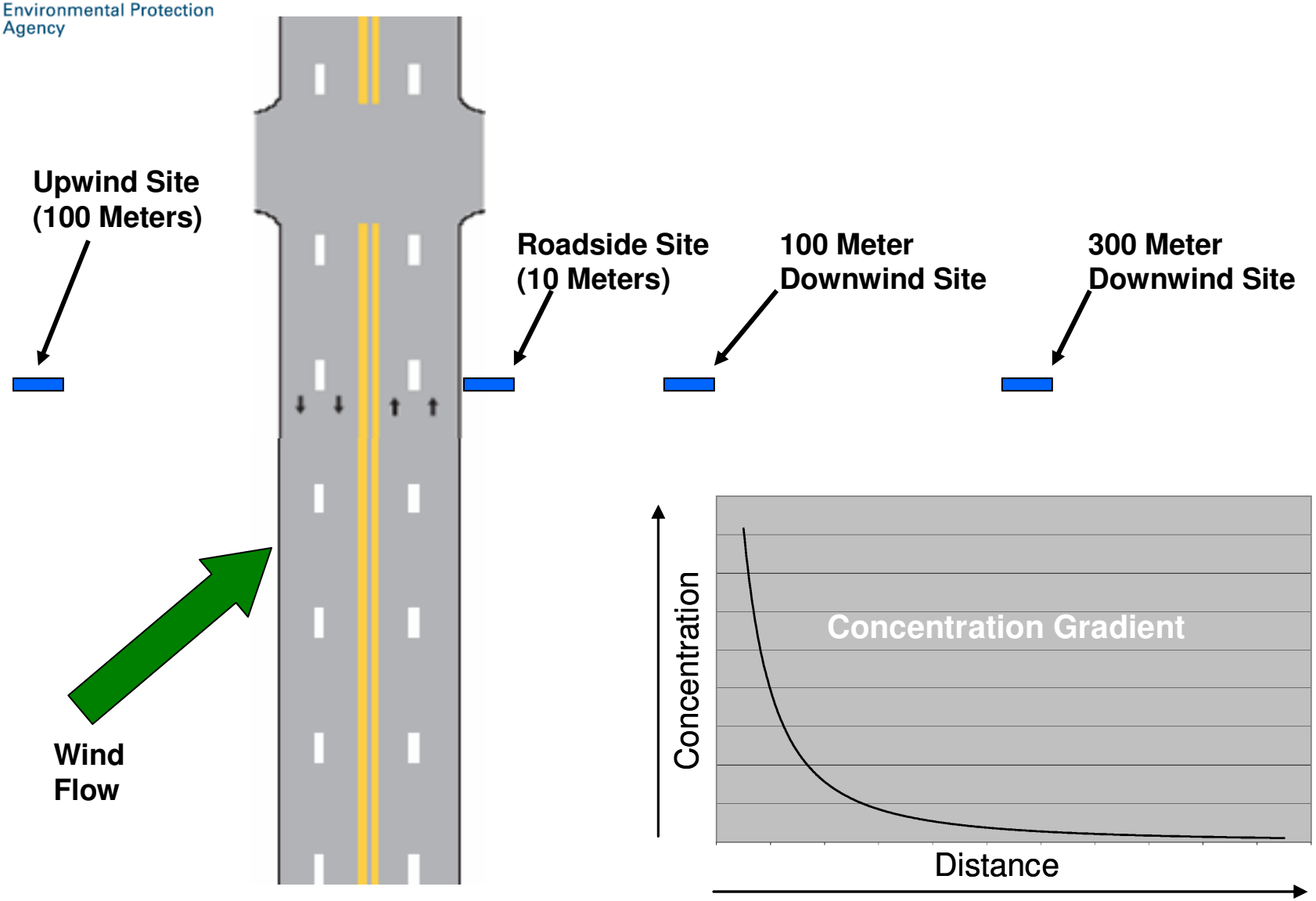

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Site Selection Criteria

Selection Considerations	Monitoring Protocol Criteria
AADT (> 150,000)	Only sites with more than 150,000 annual average daily traffic (AADT) are considered as candidates.
Geometric Design	The geometric design of the facility, including the layout of ramps, interchanges and similar facilities, will be taken into account. Where geometric design impedes effective data collection on MSATs and $PM_{2.5}$, those sites will be excluded from further consideration.
Topology (i.e., Sound Barriers, Road Elevation)	Sites located in terrain making measurement of MSAT concentrations difficult or that raise questions of interpretation of any results will not be considered. For example, sharply sloping terrain away from a roadway could result in under representation of pollutants.
Geographic Location	Criteria applicable to representing geographic diversity within the U.S. as opposed to within any given city.
Availability of Data (Traffic Volume Data)	Any location where data, including automated traffic monitoring data, meteorological or MSAT concentration data, is not readily available or instrumentation cannot be brought in to collect such data will not be considered for inclusion in the study.
Meteorology	Sites will be selected based on their local climates to assess the impact of climate on dispersion of emissions and atmospheric processes that affect chemical reactions and phase changes in the ambient air.
While not explicitly included in the Monitoring Protocol, the following selection criteria were deemed important to the selection process and were included.	
Downwind Sampling	Any location where proper siting of downwind sampling sites is restricted due to topology, existing structures, meteorology, etc., may exclude otherwise suitable sites for consideration and inclusion in this study.
Potentially confounding air pollutant sources	The presence of confounding emission sources may exclude otherwise suitable sites for consideration and inclusion in this study.
Site Access (Admin/Physical)	Any location where site access, is restricted or prohibited either due to administrative or physical issues, will not be considered for inclusion in the study.

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I-15 Monitoring Site:

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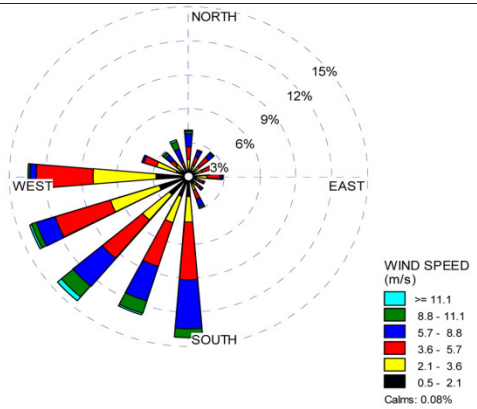
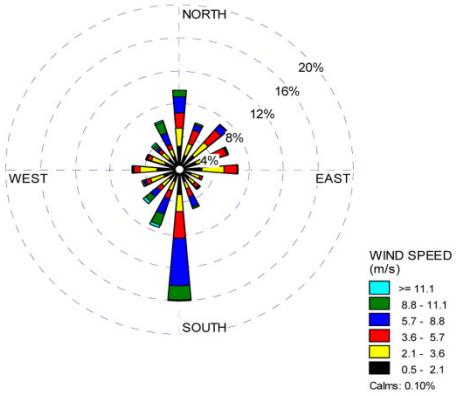
Meteorology

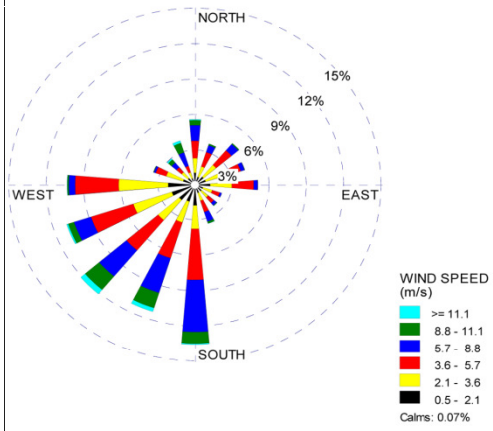
Winds generally from the SSW, although diurnal variations exist



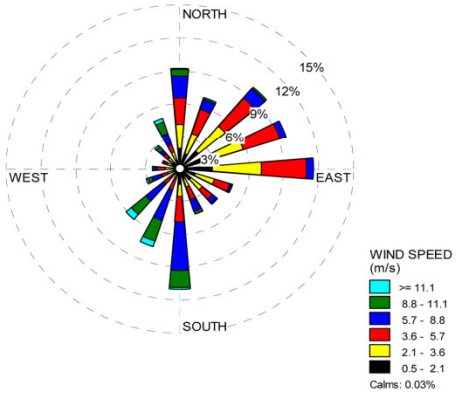
Hour 0 to Hour 15



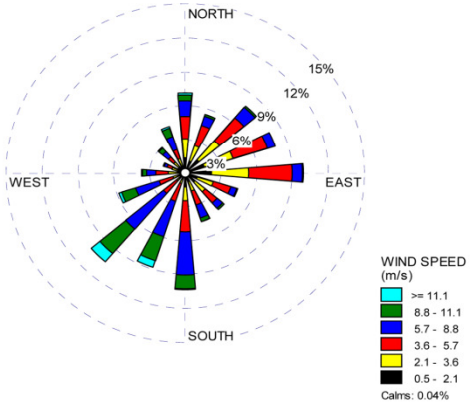
Hour 16 to Hour 17



24-Hour



Hour 18 to Hour 21



Hour 22 to Hour 23

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I-15 Site

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Instrument Deployment - Overview

Core Instruments	10 Meters @ I-96 Roadside	100 Meter Downwind	300 Meter Downwind	100 Meter Upwind
TO-11A Cartridge sampling	X	X	X	X
TO-15 Canister sampling	X	X	X	X
Continuous GC	X	X	X	X
Continuous gas monitoring (CO, NOx)	X	X	X	X
Continuous black carbon monitoring (Aethalometer)	X	X	X	X
Continuous fine particle (TEOM)	X	X	X	X
Integrated PM2.5 (FRM)	X	X	X	X
Wind speed/wind direction (sonic anemometer)	X	X	X	X
Meteorological monitoring (temp, RH, solar, etc.)		X		
Study Enhancements				
Continuous Ultrafines (20nm – 200+ nm)	X		X	
Water-based CPC	X		X	
Continuous gas monitoring (CO_2)	X	X	X	X
Michigan DOT -- Traffic Data				
Vehicle Count, Vehicle Speed, Vehicle Class				

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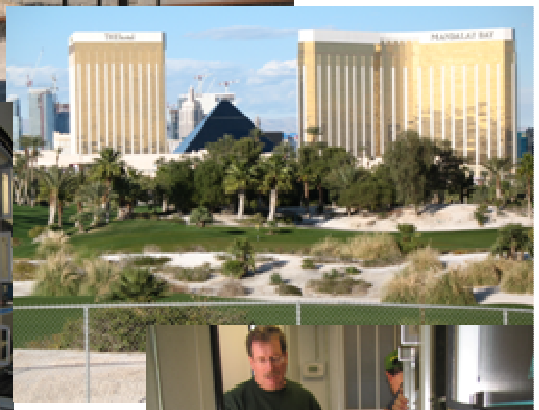

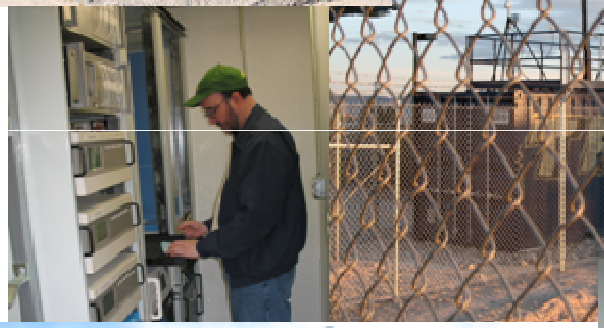





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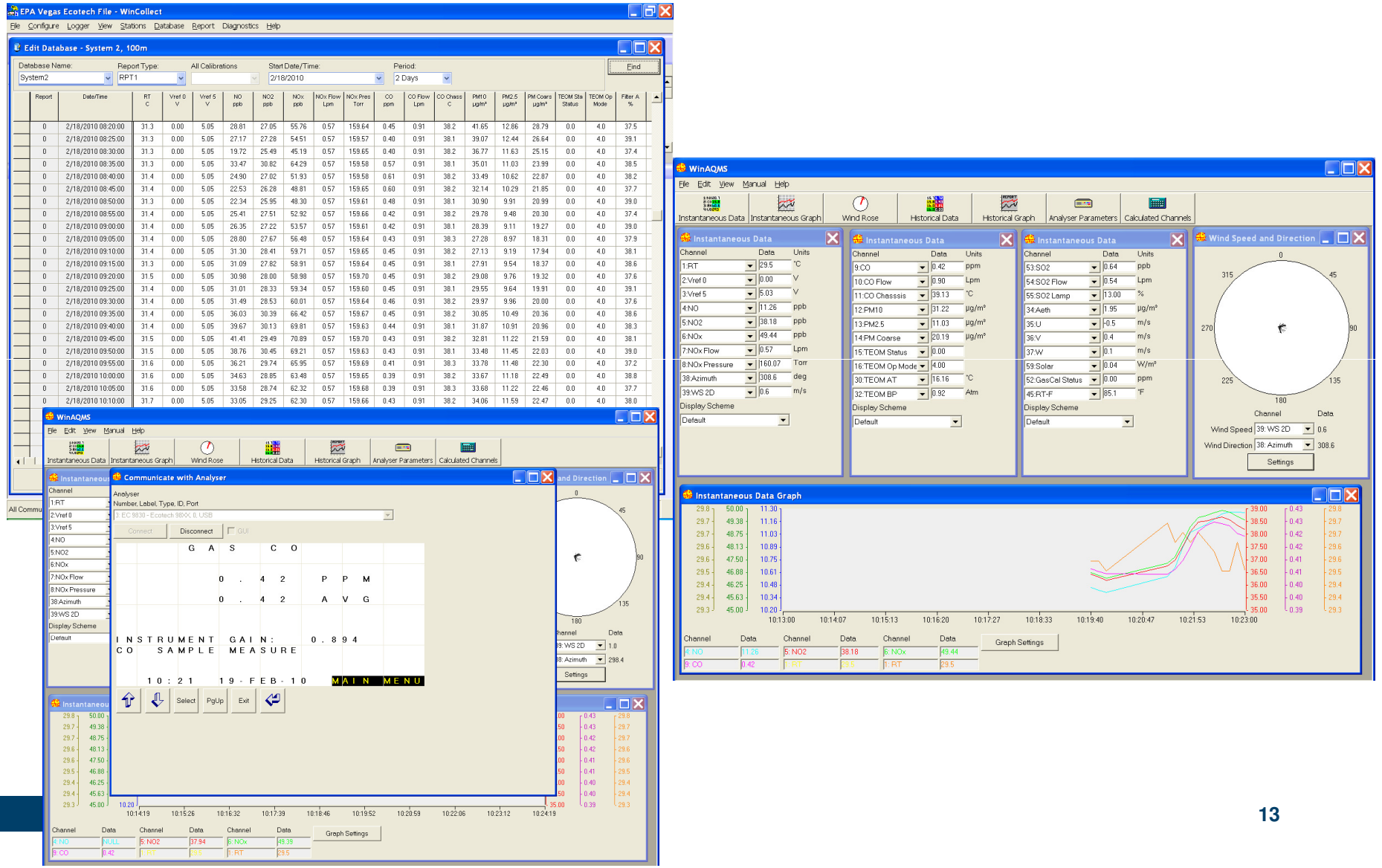
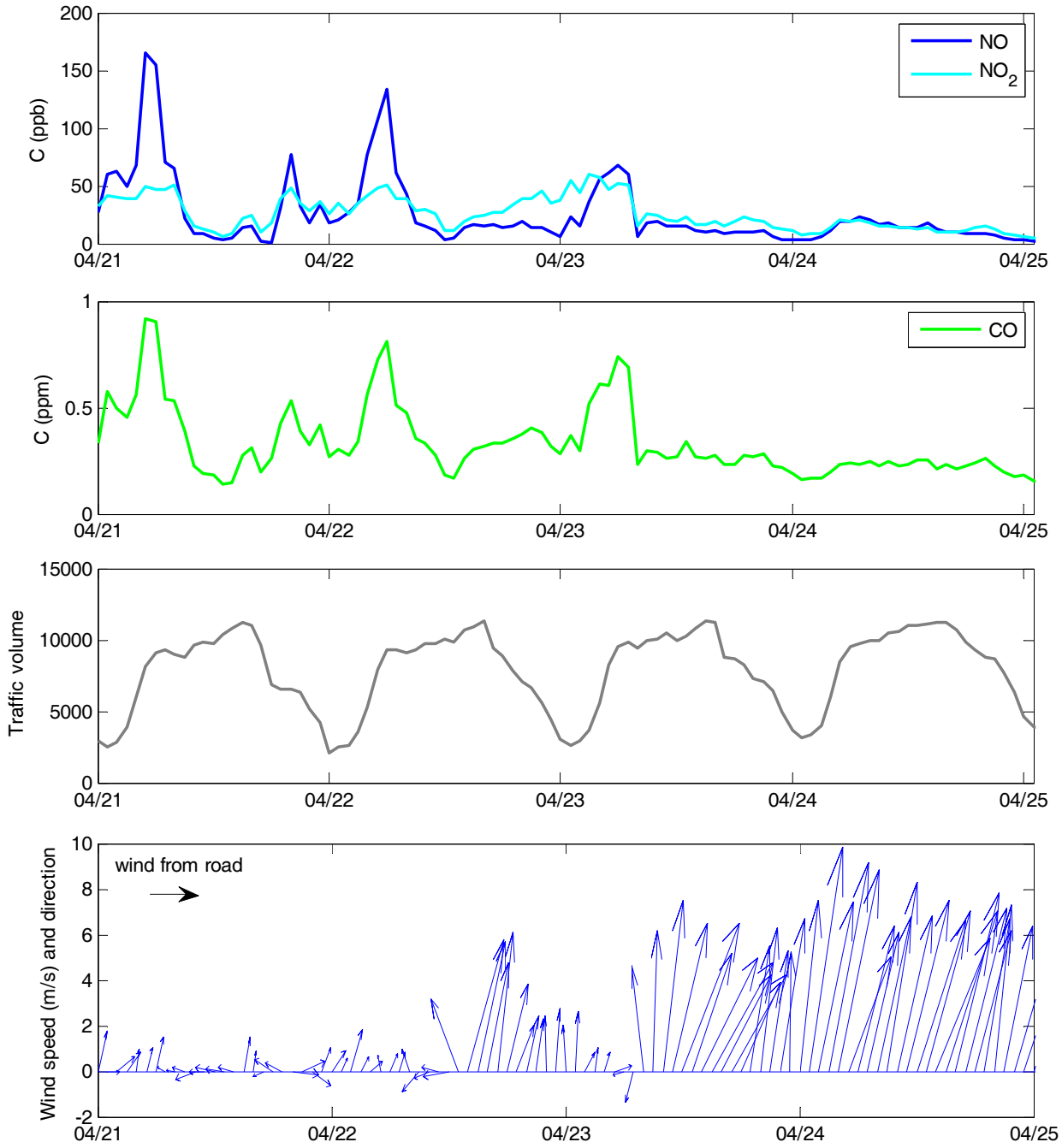
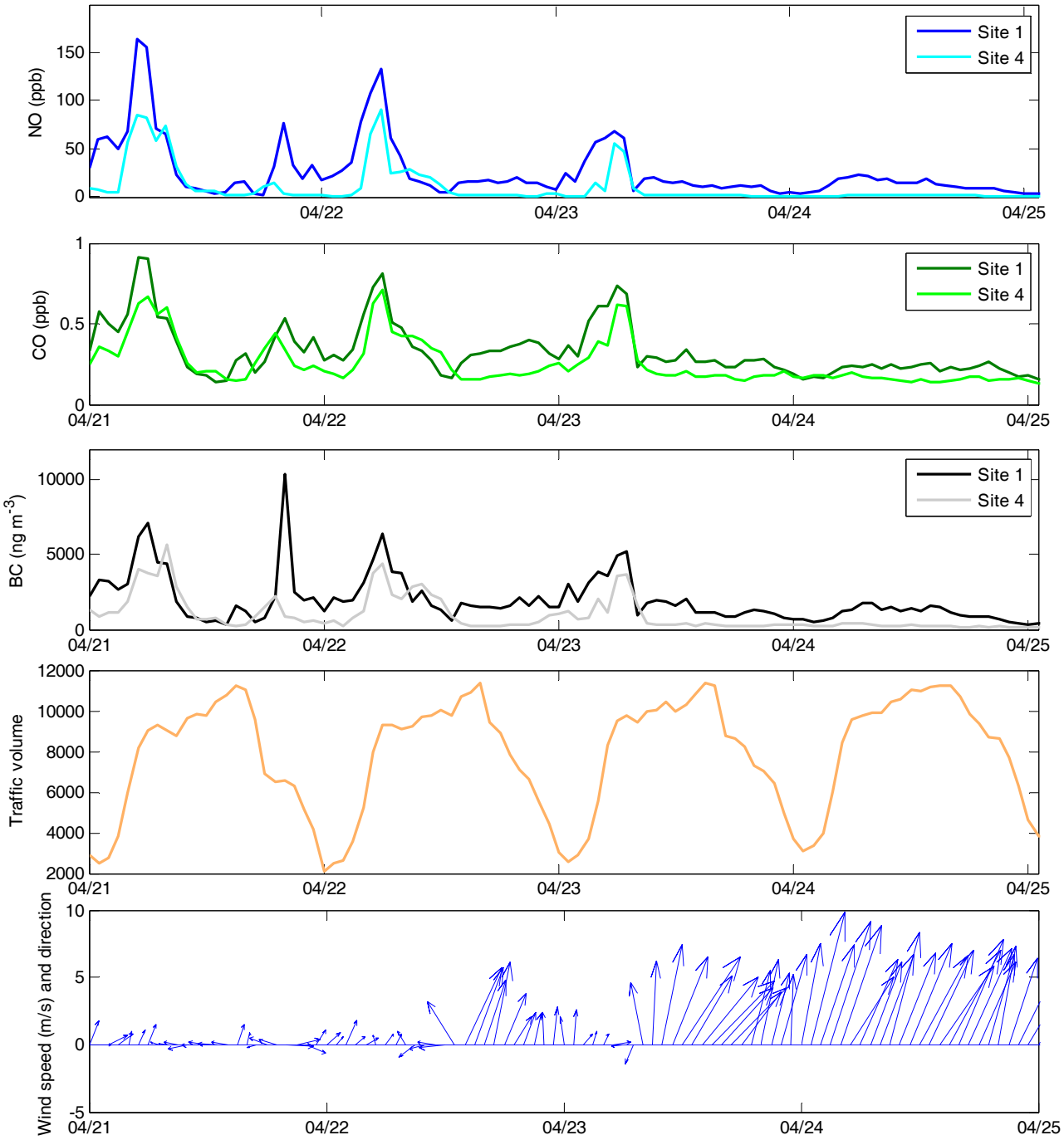
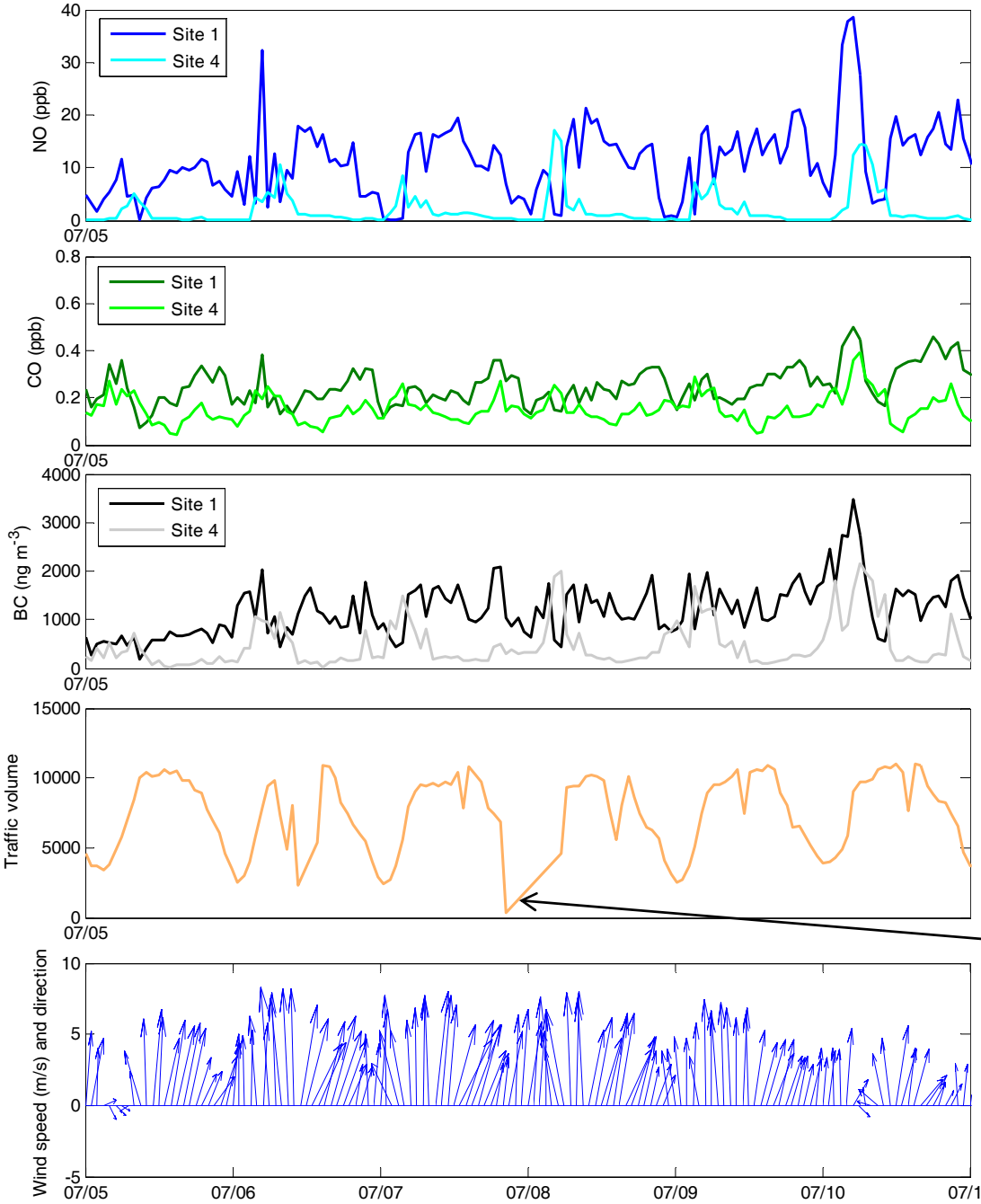
Remote Data Streaming – WinAQMS/WinCollect, RealVNC Software

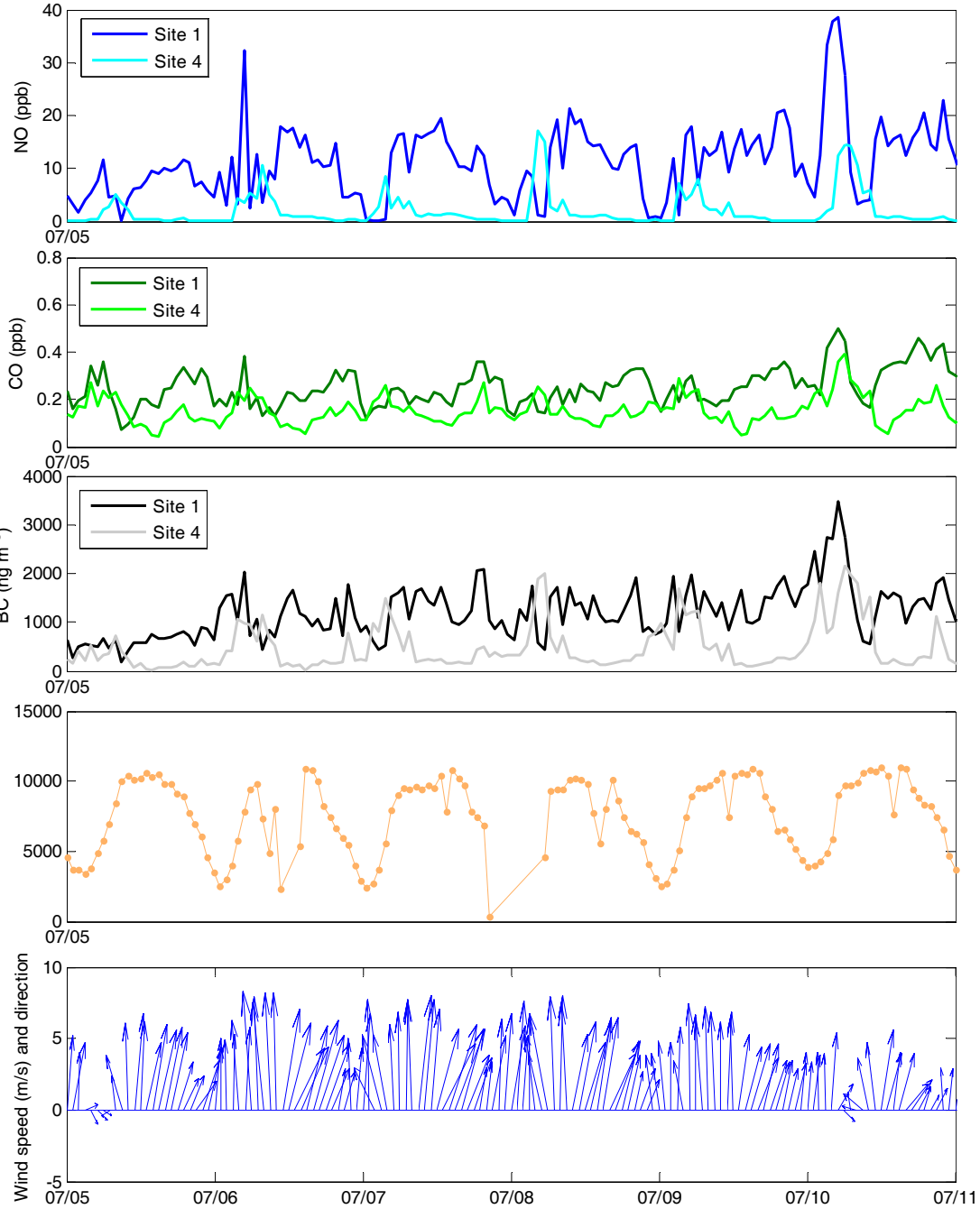




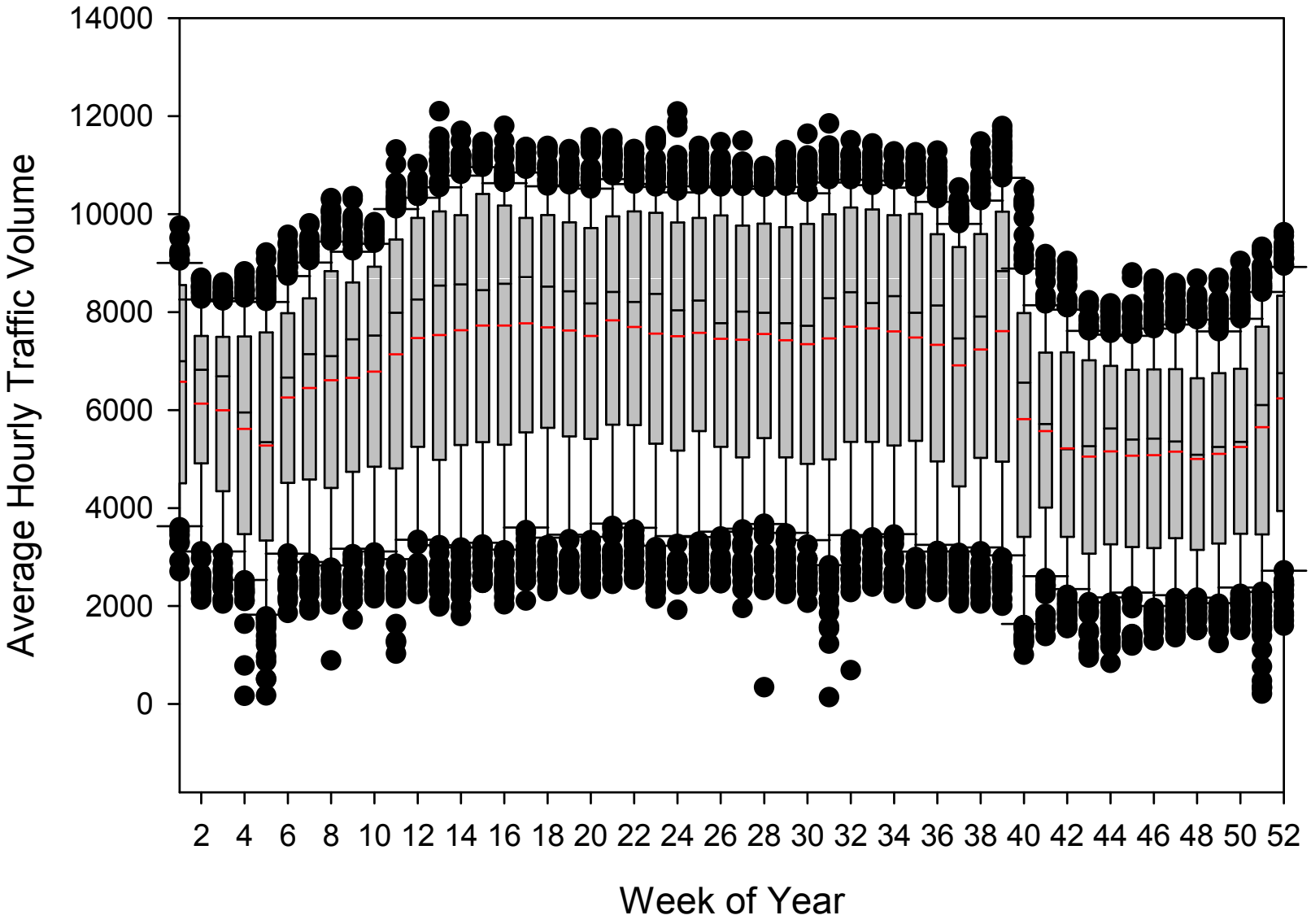




Radar – Instrument Issues



Average hourly traffic volume by week of year



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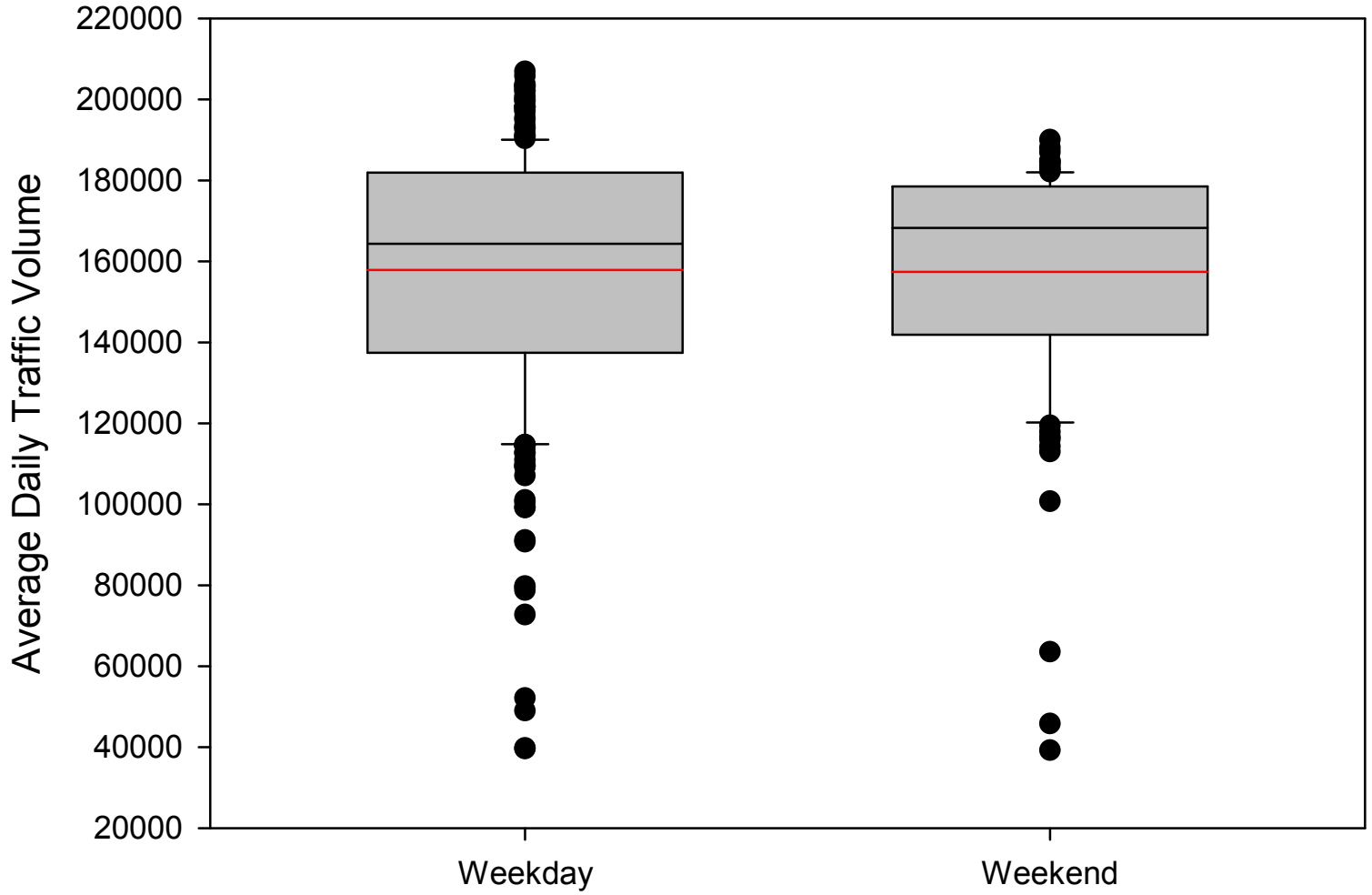
Average daily traffic volume by weekday and weekend



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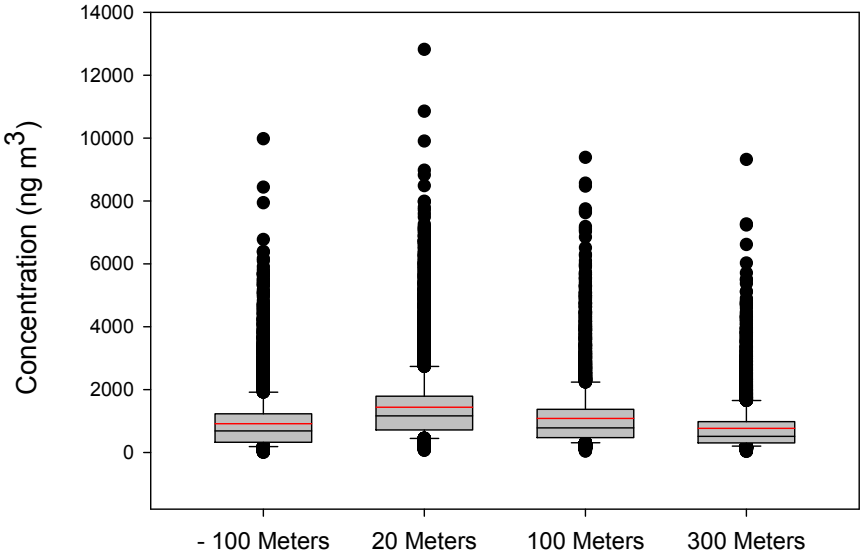
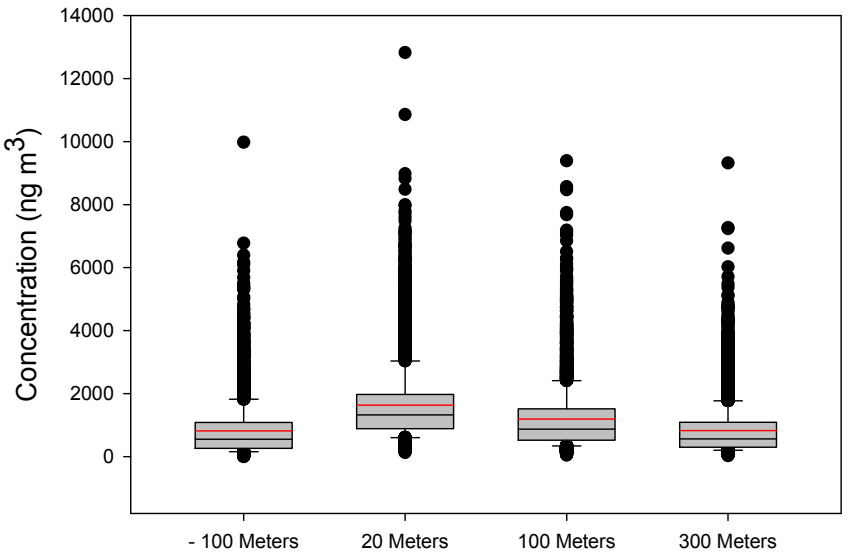
Black Carbon Concentration
(all wind directions)



Black Carbon
(winds from road)



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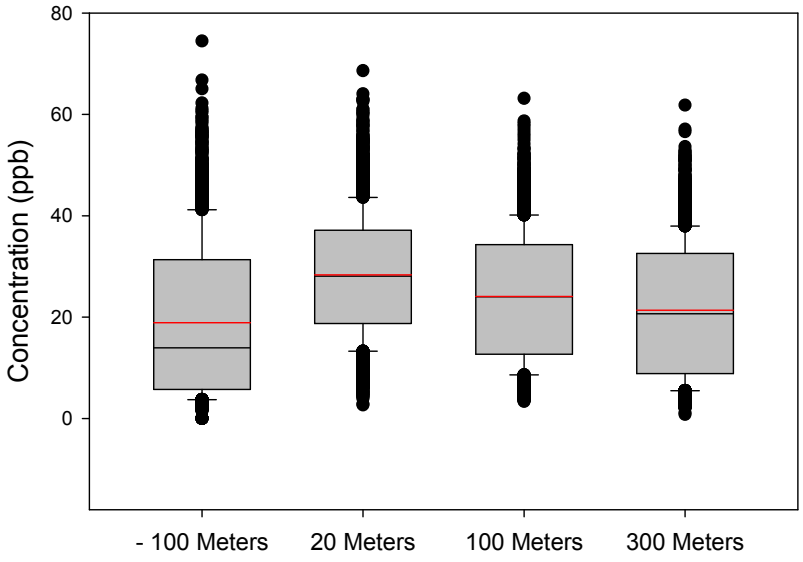
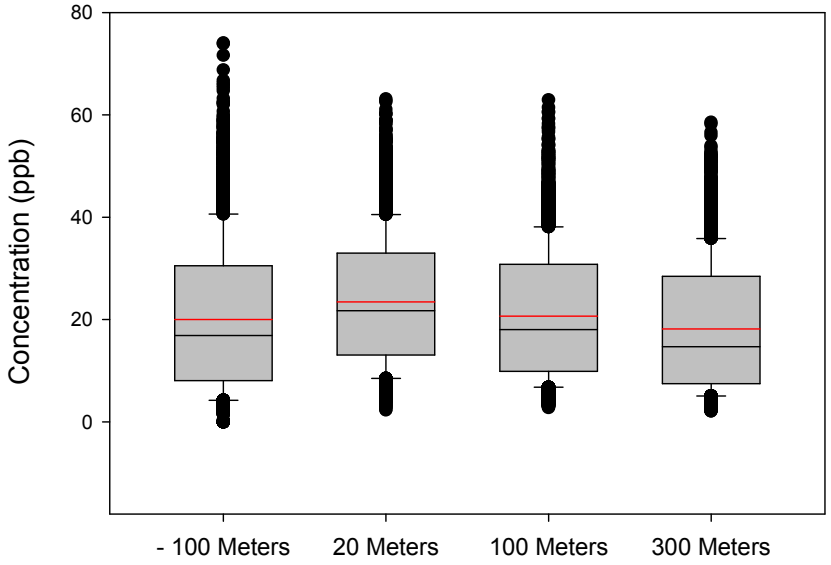
Hourly Average NO_2 Concentrations
(winds from road)



Mean NO_2 Concentations by Station
(all wind directions)



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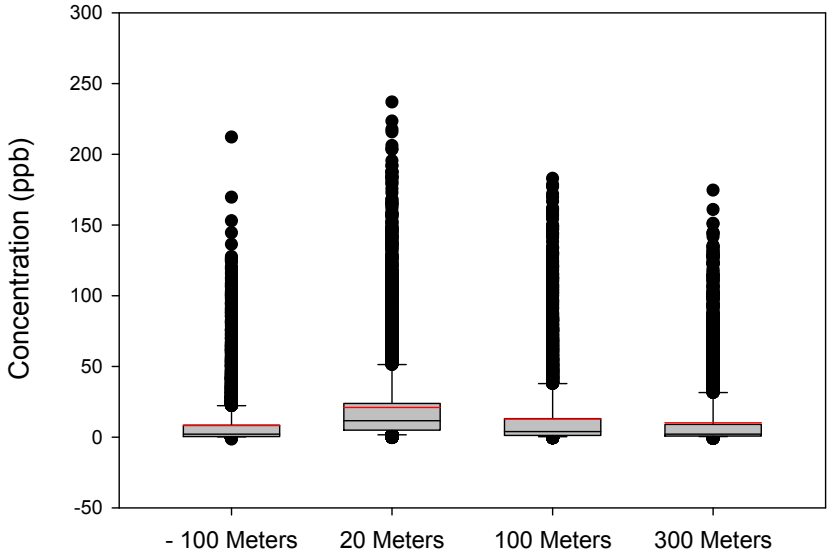
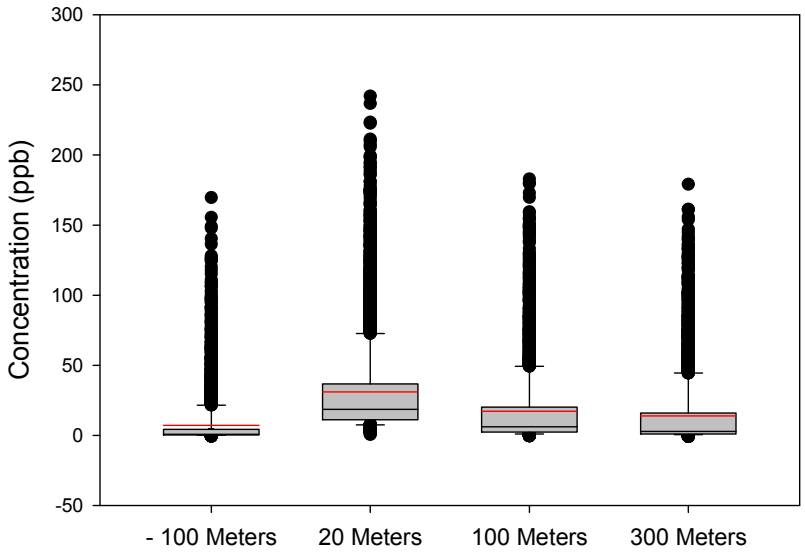
Hourly Average NO Concentations
(all wind directions)



Hourly Average NO Concentrations
(winds from road)



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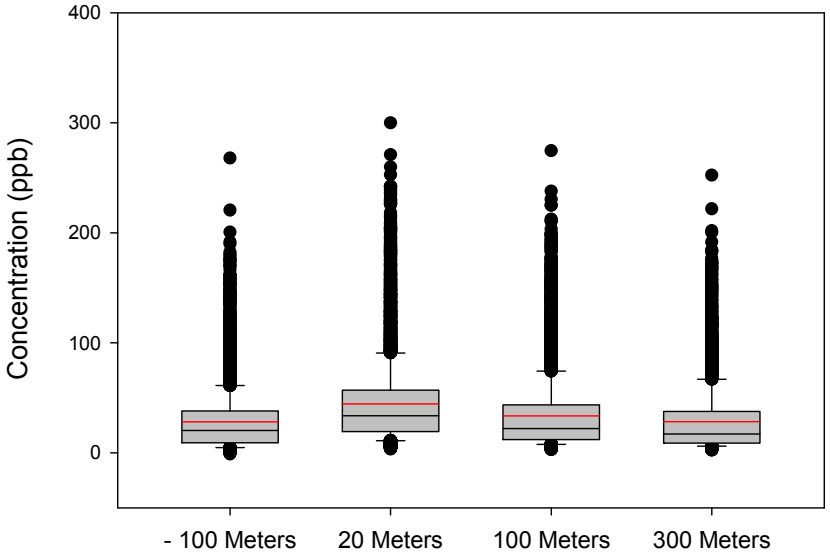
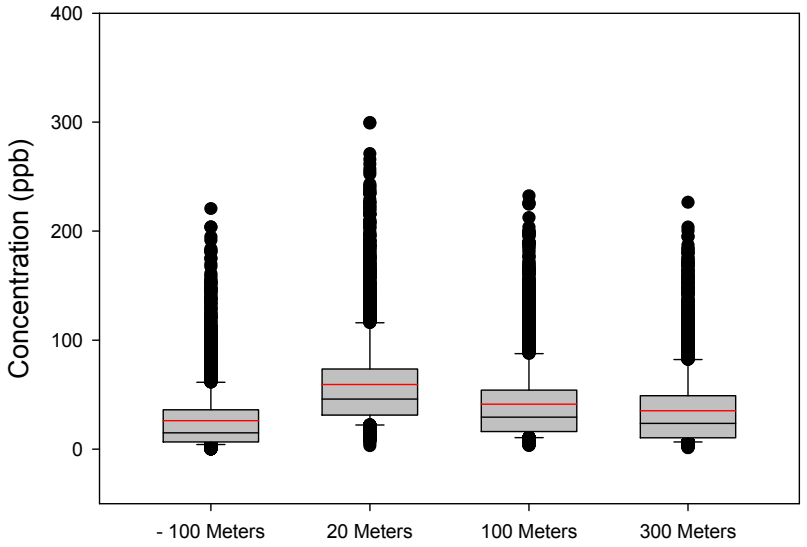
Hourly Average NOX Concentations by Station
(all wind directions)



Hourly Average NOX Concentrations
(winds from road)



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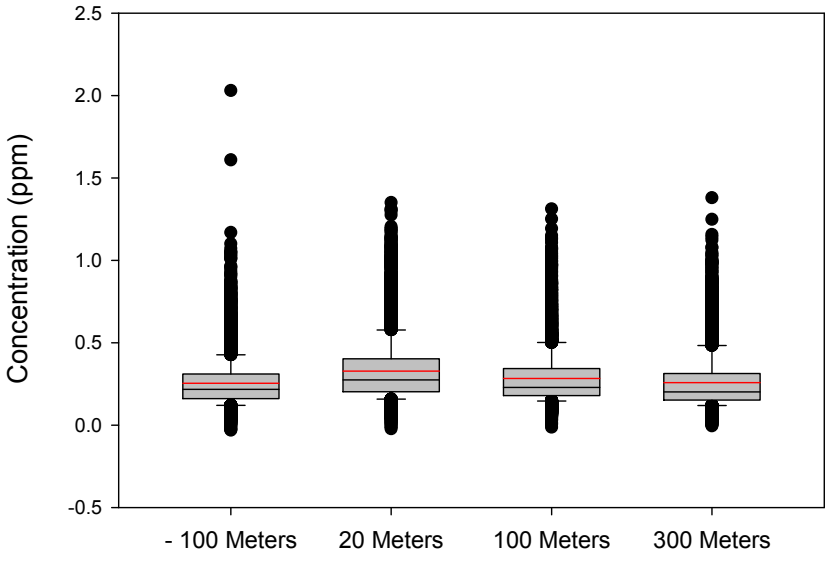
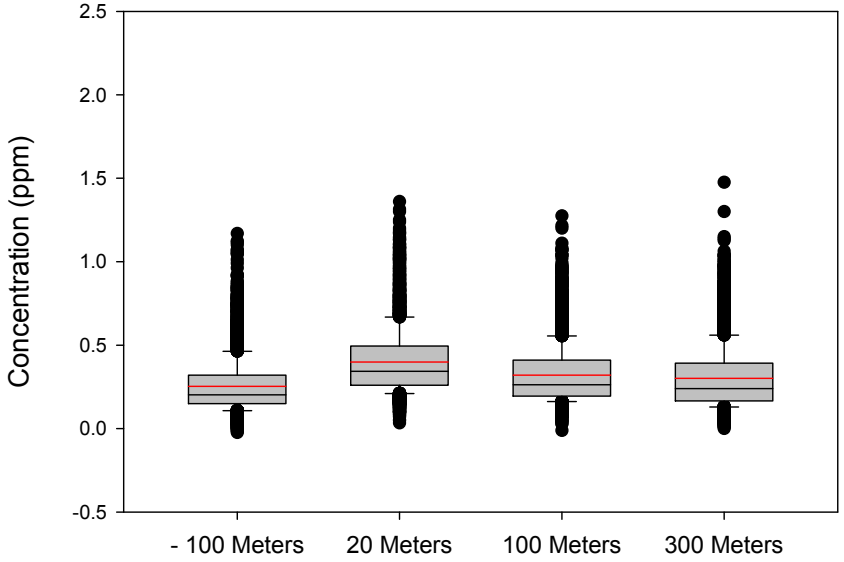
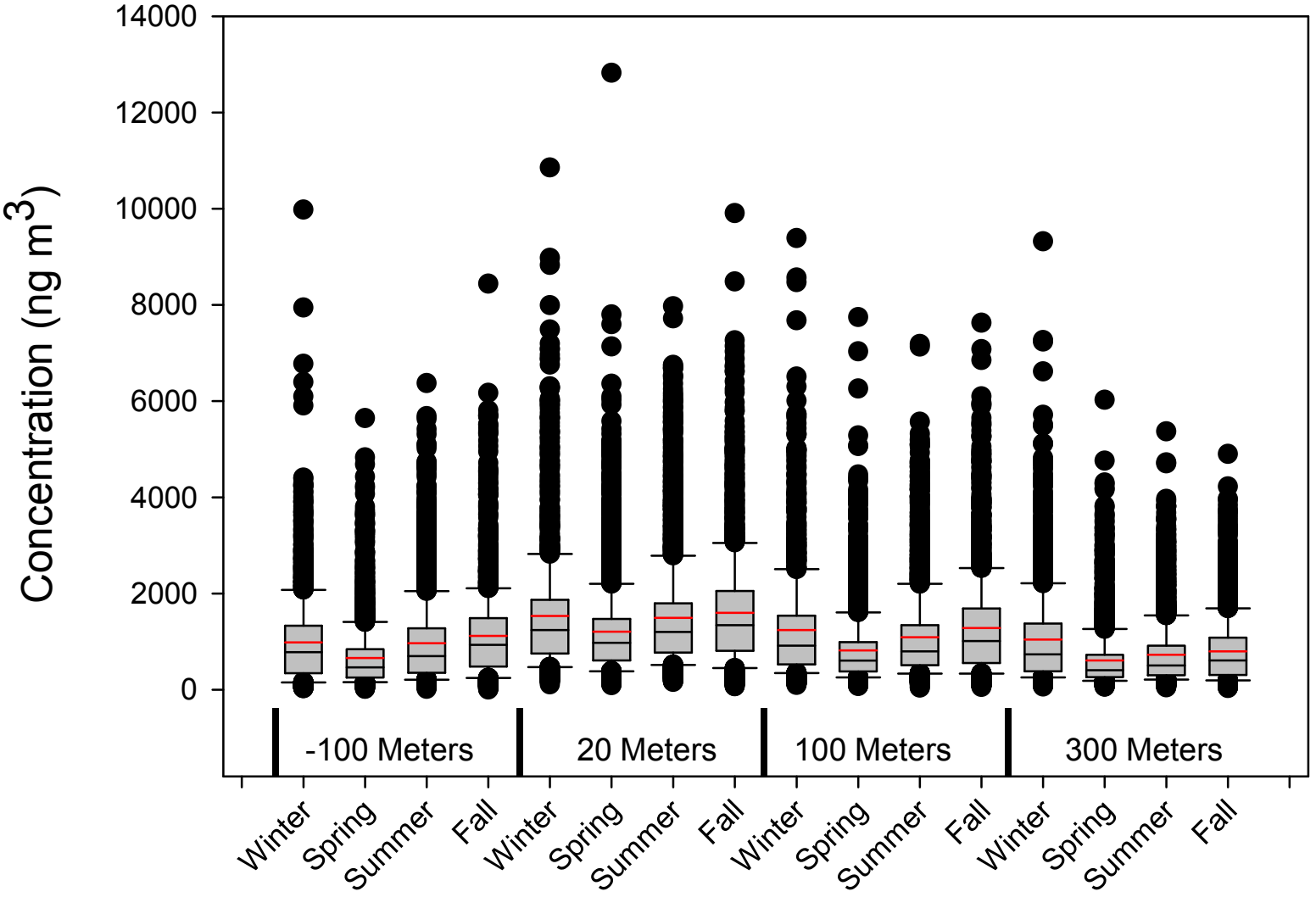
Hourly Average CO Concentations by Station
(all wind directions)



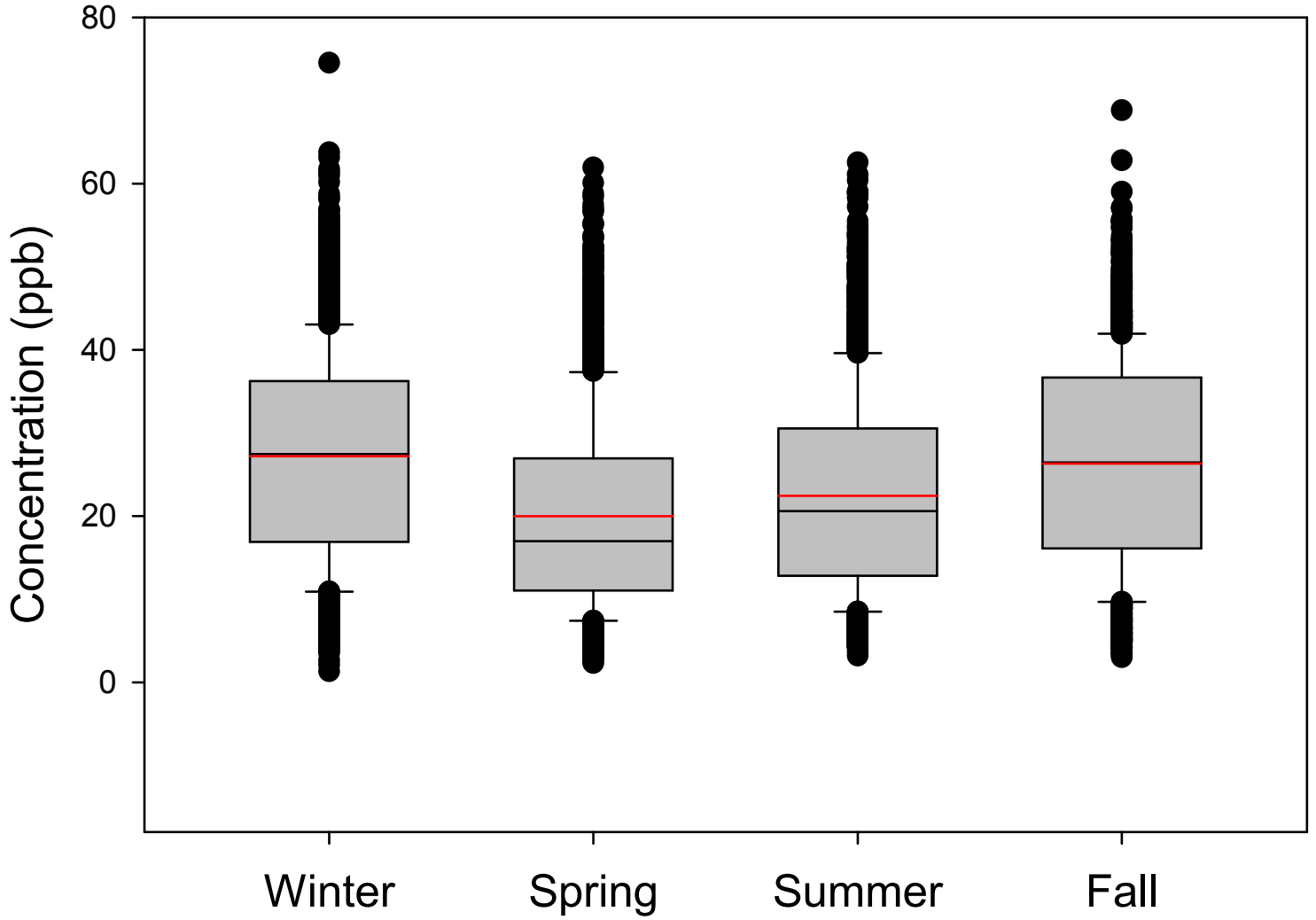
Hourly Average CO Concentrations
(winds from road)



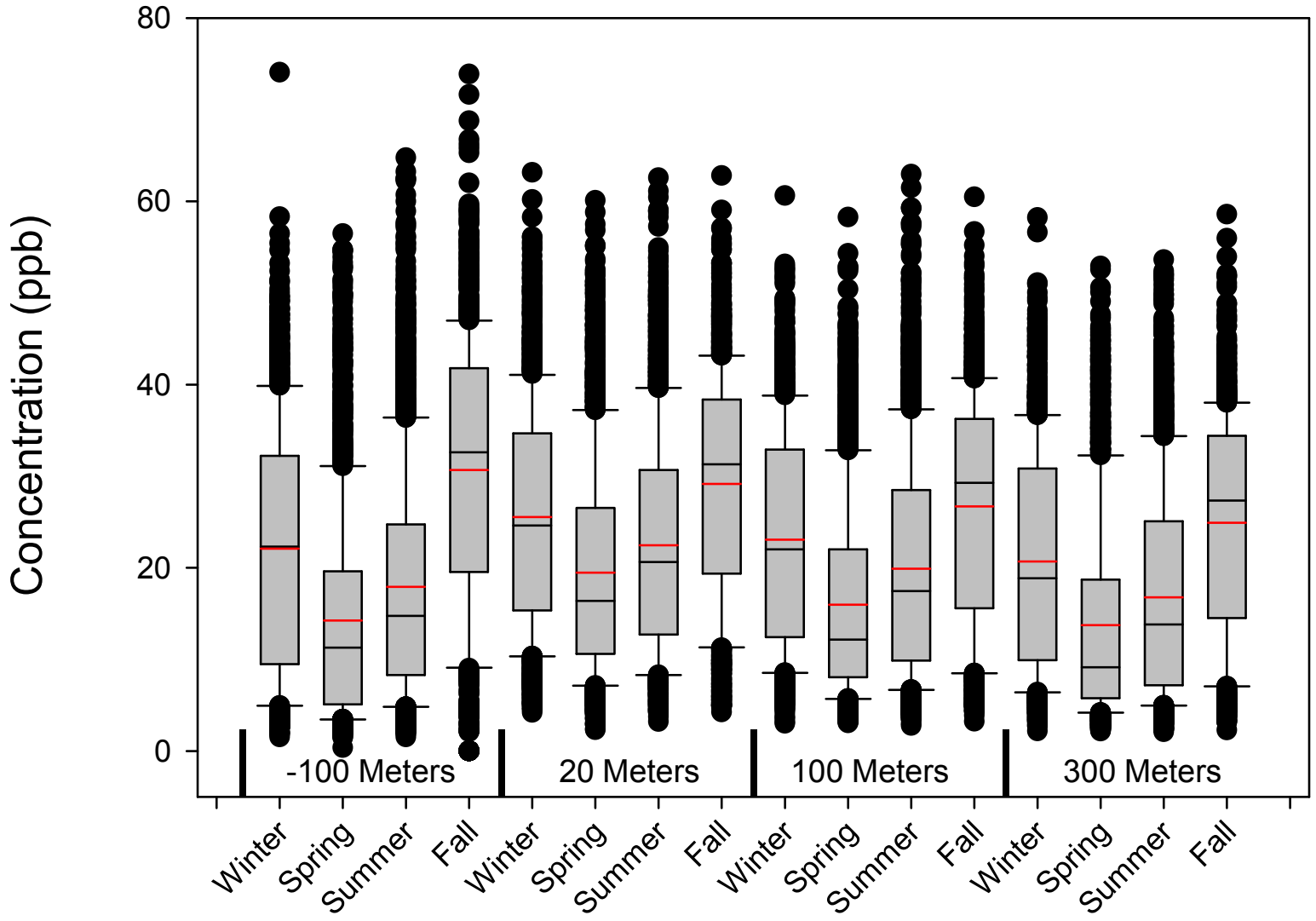
Black Carbon
(all wind directions)



Seasonal NO_2 Trends -- Station 1 (all wind directions)



Seasonal NO_2 Trends (all wind directions)



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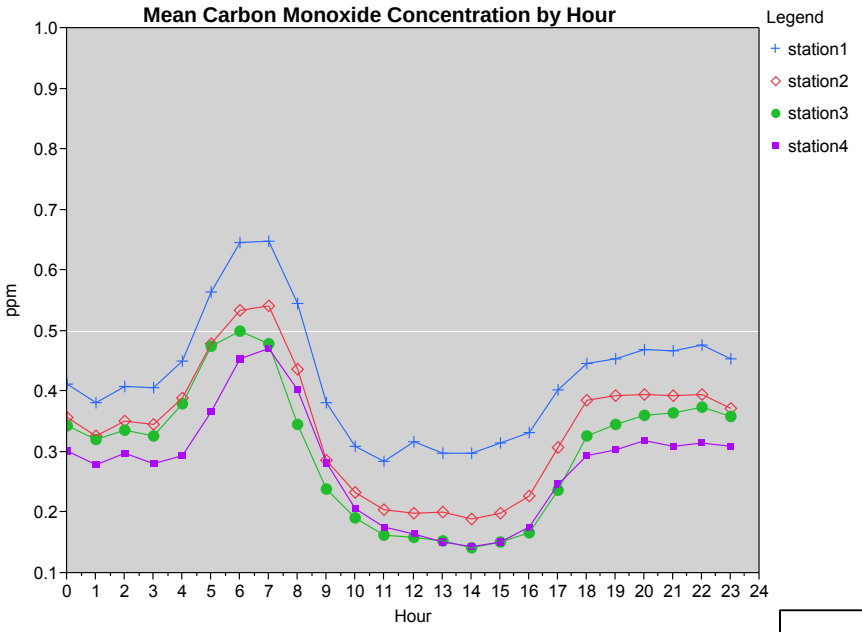
Preliminary Results:
Criteria Pollutants

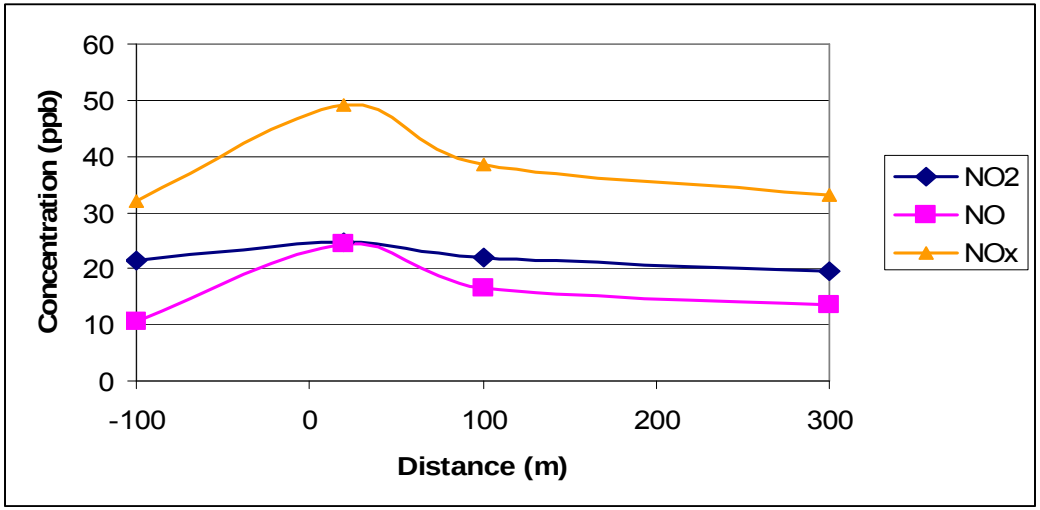


CO hourly average concentrations (ppm)

CO gradients existed, with strong diurnal patterns even without similar traffic signals

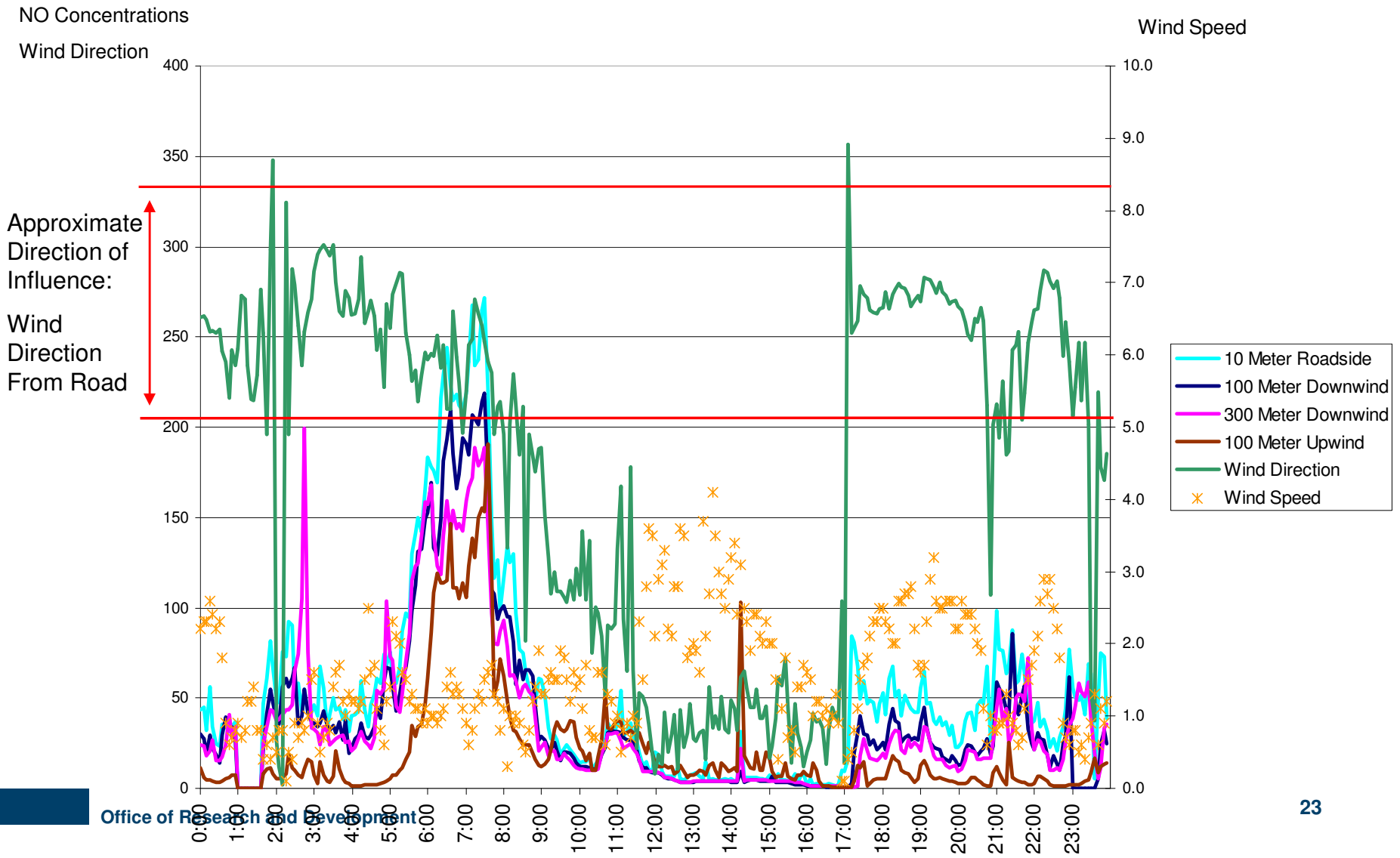
NO_2 gradient existed for hourly average concentrations over the entire study

NO/NO2/NOx Concentrations (ppb)



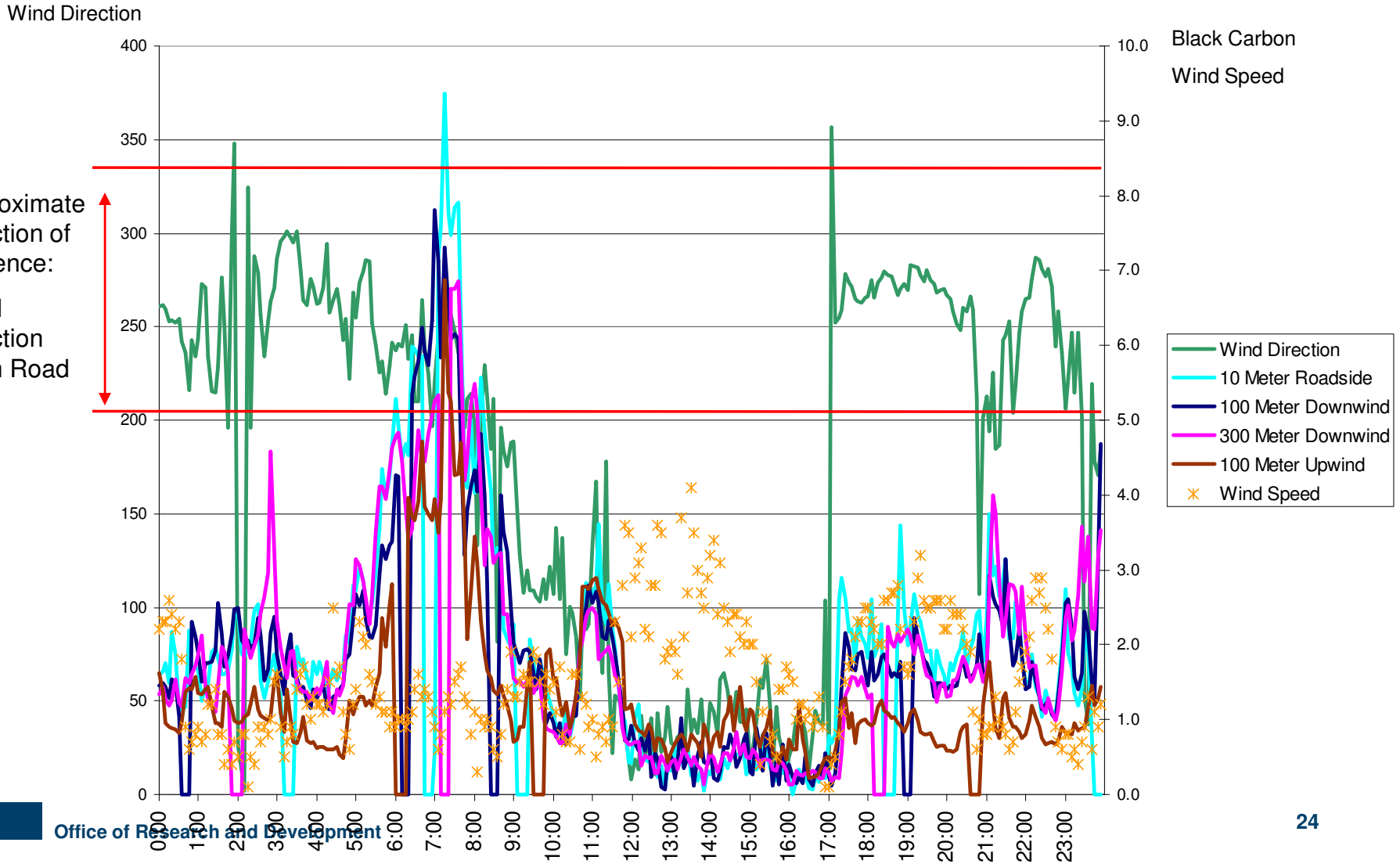
United States Environmental Protection Agency

NO Concentration Gradient: Feb 3, 2009, Day with Low Wind Speed



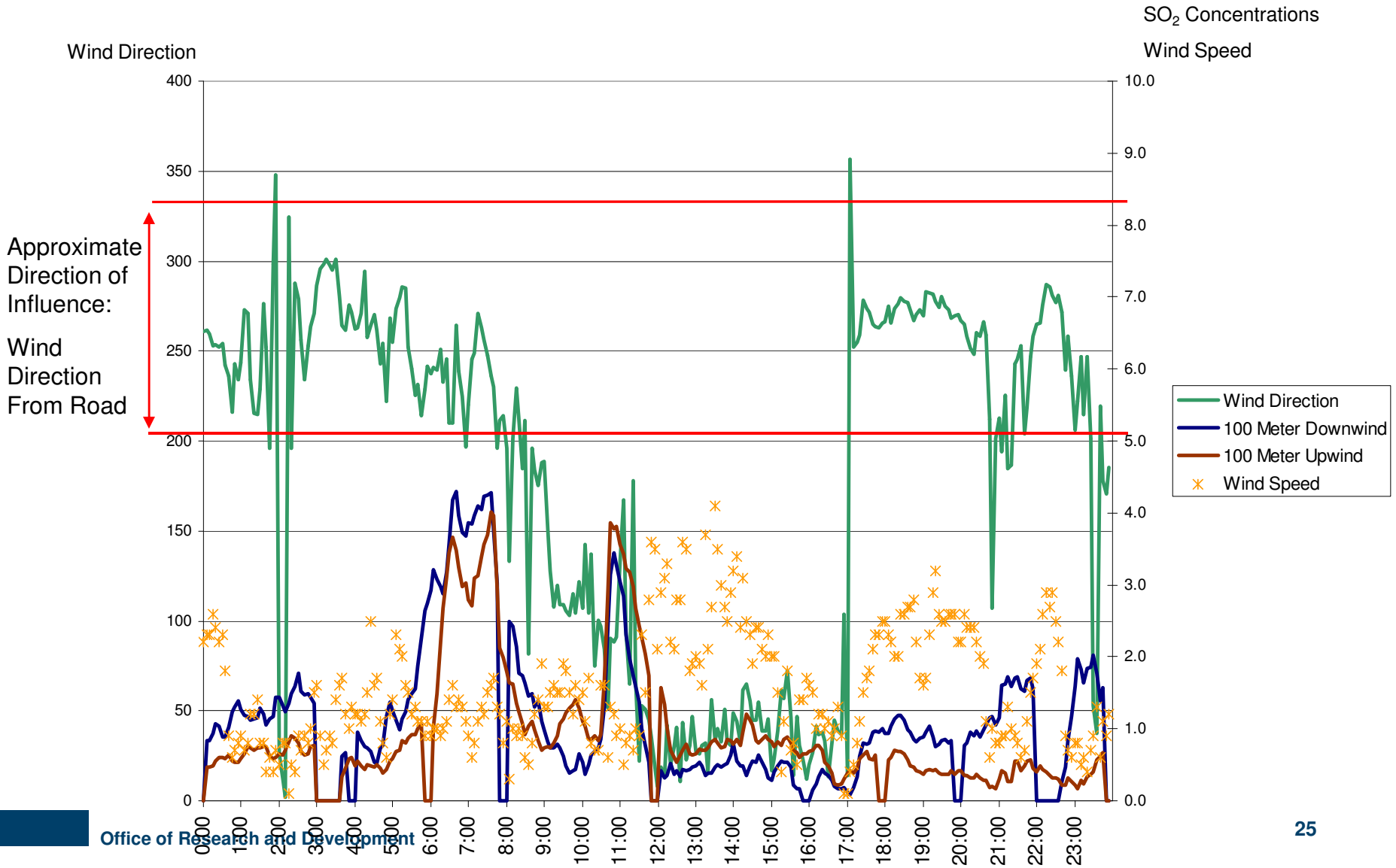
United States Environmental Protection Agency

Black Carbon Concentration Gradient: Feb 3, 2009, Day with Low Wind Speed



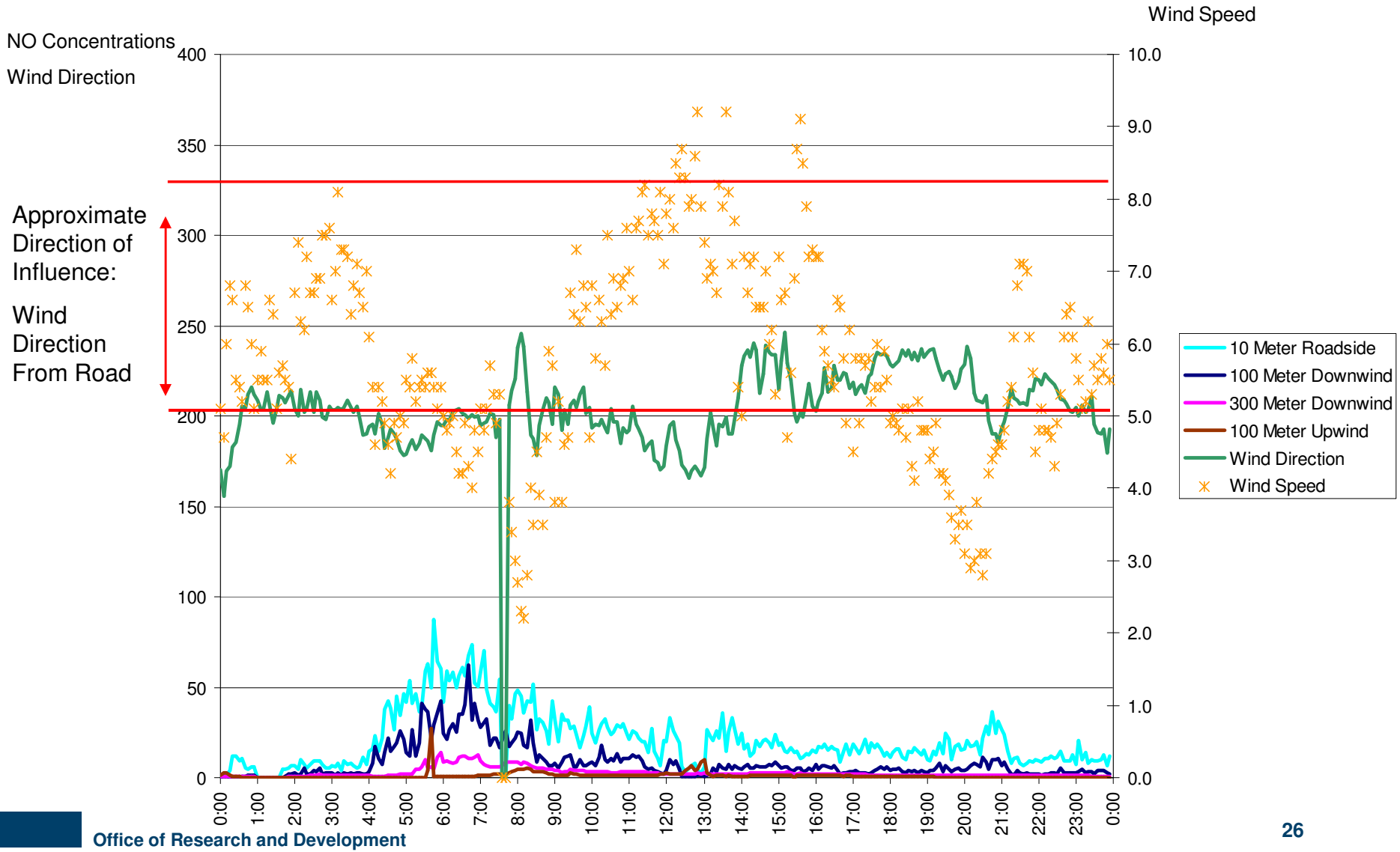
EPA United States Environmental Protection Agency

SO_2 Concentration Gradient: Feb 3, 2009, Day with Low Wind Speed

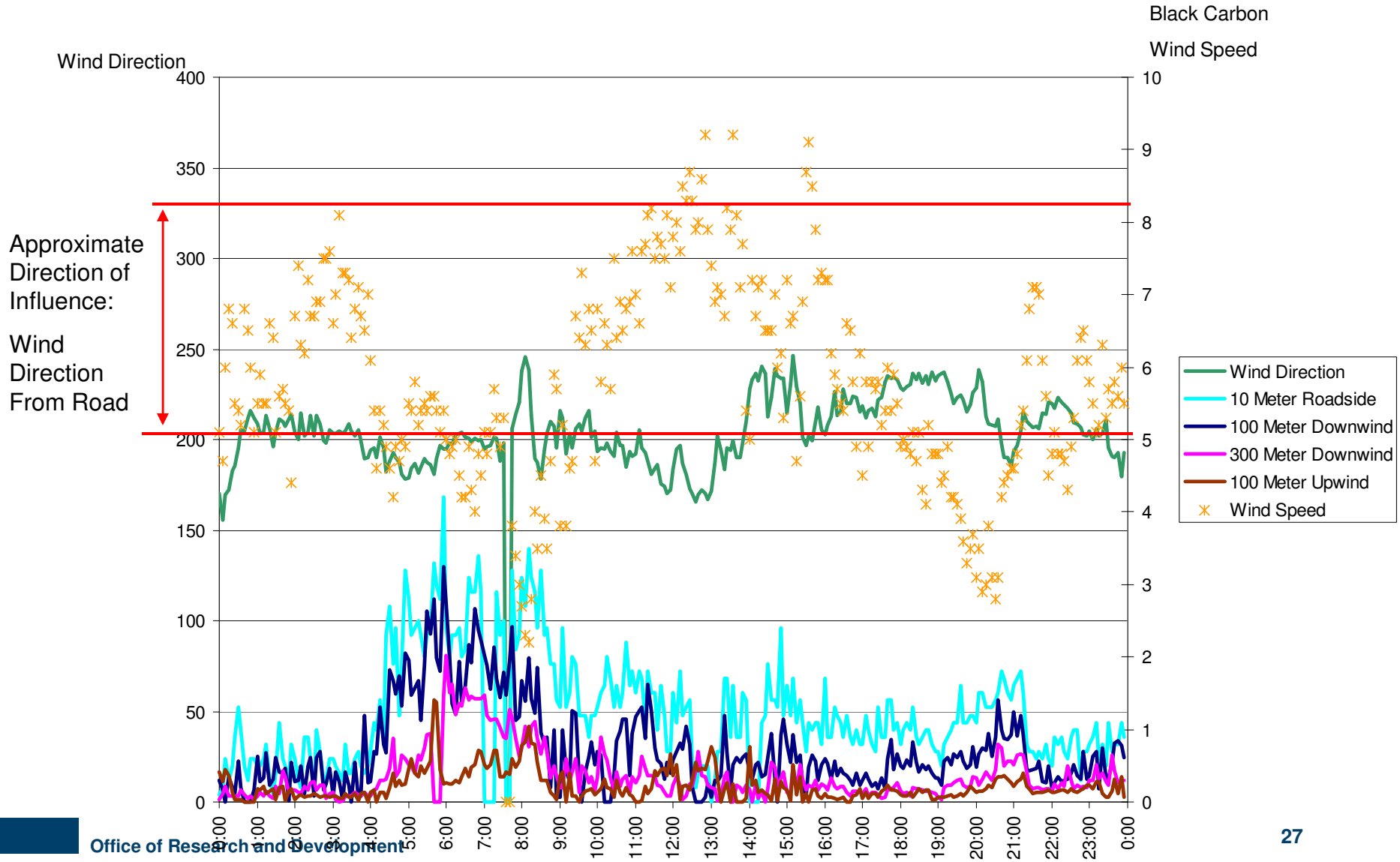


United States Environmental Protection Agency

NO Concentration Gradient: March 3, 2009, Day with High Wind Speed

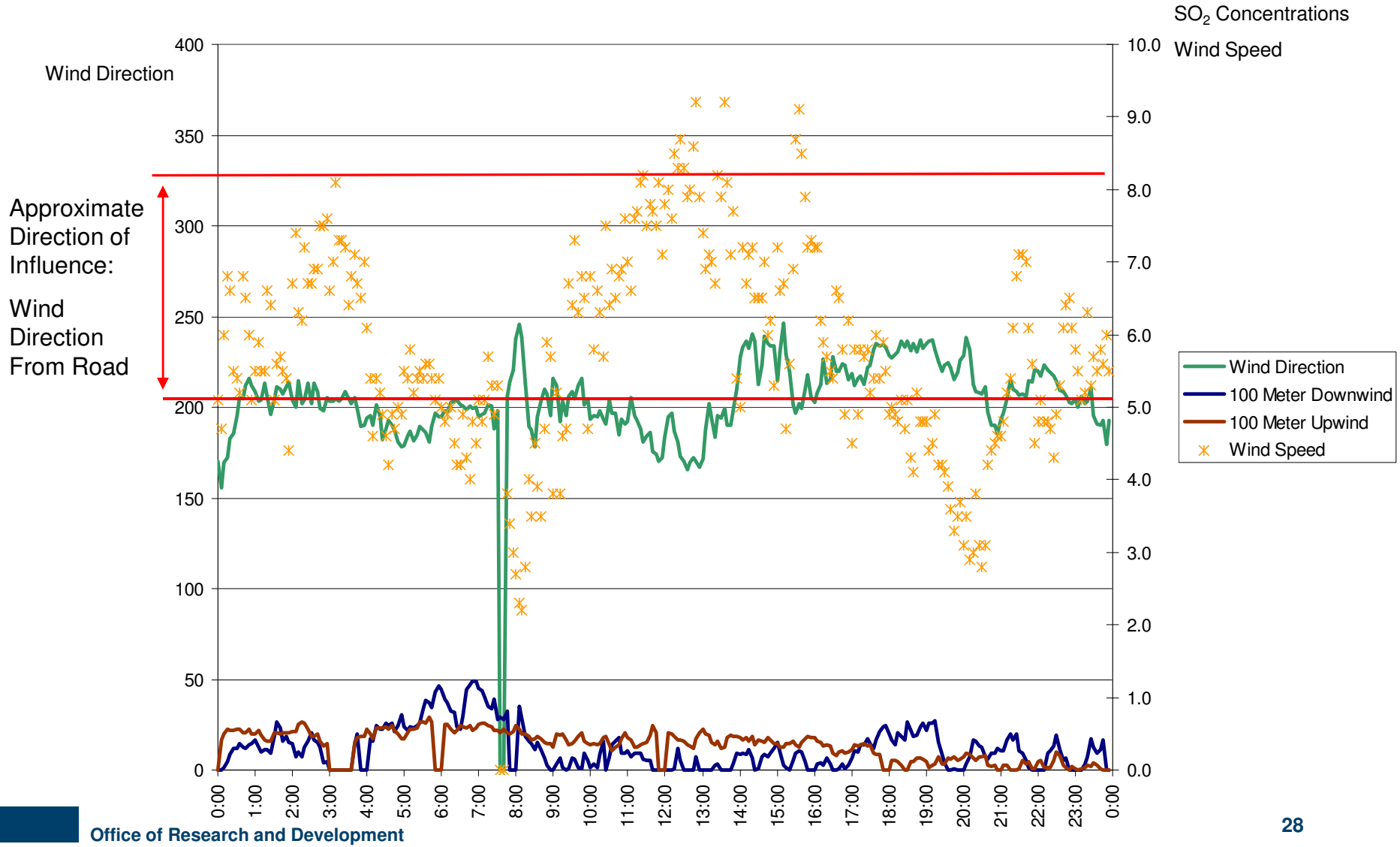


Black Carbon Concentration Gradient: March 3, 2009, Day with High Wind Speed



EPA United States Environmental Protection Agency

SO_2 Concentration Gradient: March 3, 2009, Day with High Wind Speed



Lessons Learned

- Site Selection / Access / Infrastructure: Never too early to start process, no such thing as perfect site (project manager, site operator, modelers, policy makers).
  - Property owners: Environmental Awareness – perhaps?
  - Liability, Insurance, Compensation, Hassle Factor(s), etc.
  - Electrical, Security, Communications…costs can be high.
- Timeline: Site Selection, access, infrastructure – always takes more time than originally anticipated.
- Budget: Field projects are usually more costly than originally anticipated.
  - On-site operator costly (travel, lodging, per diem).
  - Integrated Sampling: Site-operator costs and laboratory analysis costs high (sample prep, shipping, sample analysis).
- Study Design: No perfect design.
- Database Management: Essential to data flow (from field site to data analysts).

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Summary

- Appears to be concentration gradient for gaseous pollutants and black carbon associated with distance from roadway however more analysis is required.
- Appears to be associations with traffic volume (i.e., higher concentrations with higher traffic volumes).
- Effect of wind speed appears to be a factor with regards to concentration gradient (e.g., dilution effect) and needs to be investigated further.
- Train does not appear to be a substantial source.
- Non I-15 sources may be larger contributors than previously expected, for example: parking lot, airport, surrounding streets.
- **Next Study City: Detroit – Study In Progress**

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Overview Map of Detroit

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Detroit Site: Eliza Howell Park

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Acknowledgements

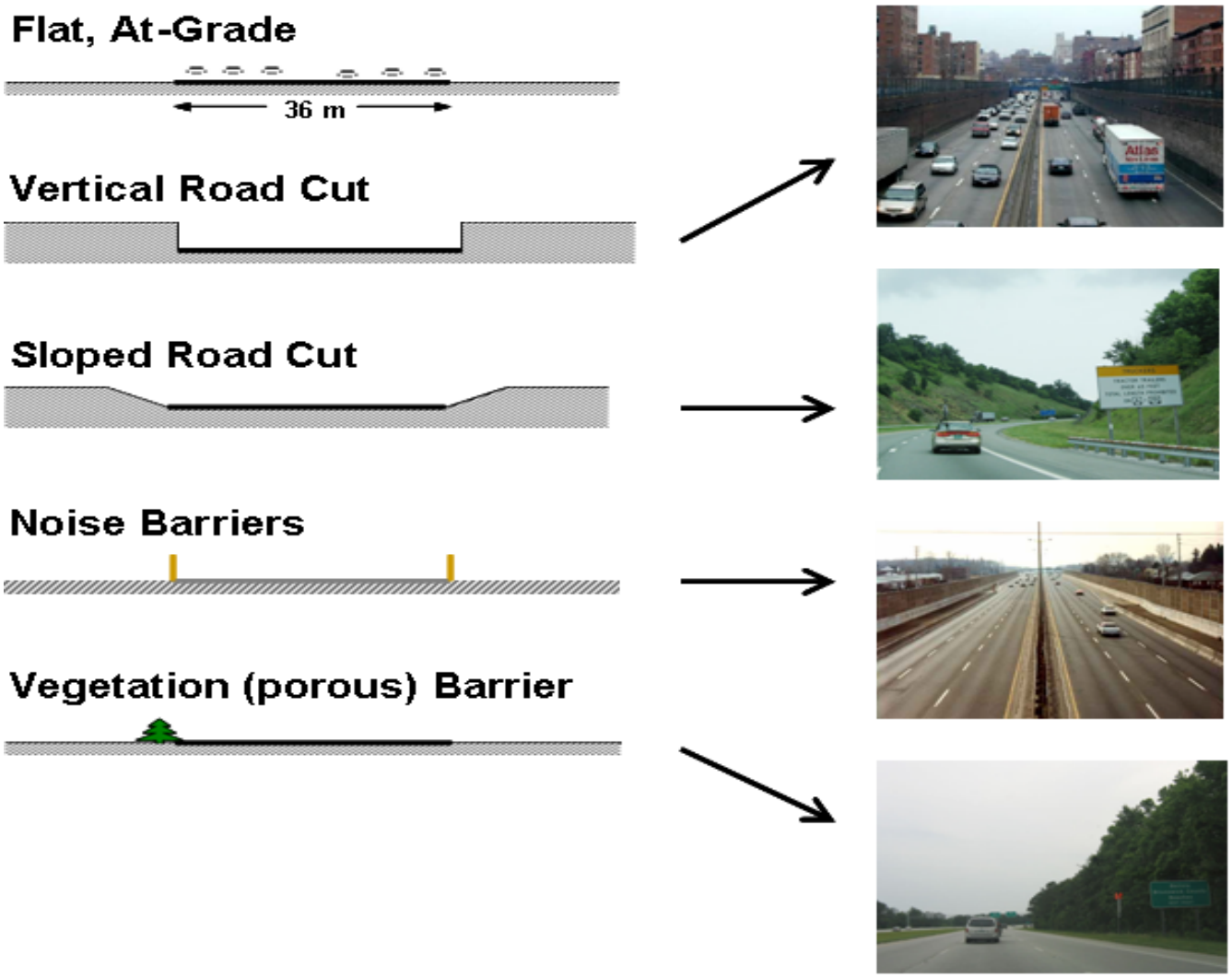
We thank Brian Schumacher and Jeffery Lantz of the EPA Las Vegas Facility for their continuing support of this project. We thank American Ecotech for shelter/instrument operation support. We thank David Proffitt, Michal Derlicki, Richard Snow, Nikki Williams of ARCADIS for site-operation and logistical support, Hunter Daughtrey, Dennis Williams, Karen Oliver, Lydia Brouwer, Herb Jacumin, of Alion Science and Technology for preparation and analysis of sampling media and Jeff Baker of TSI for use of Ultrafine Particulate Samplers.

Mitigation of Near-Road Air Pollution Impacts

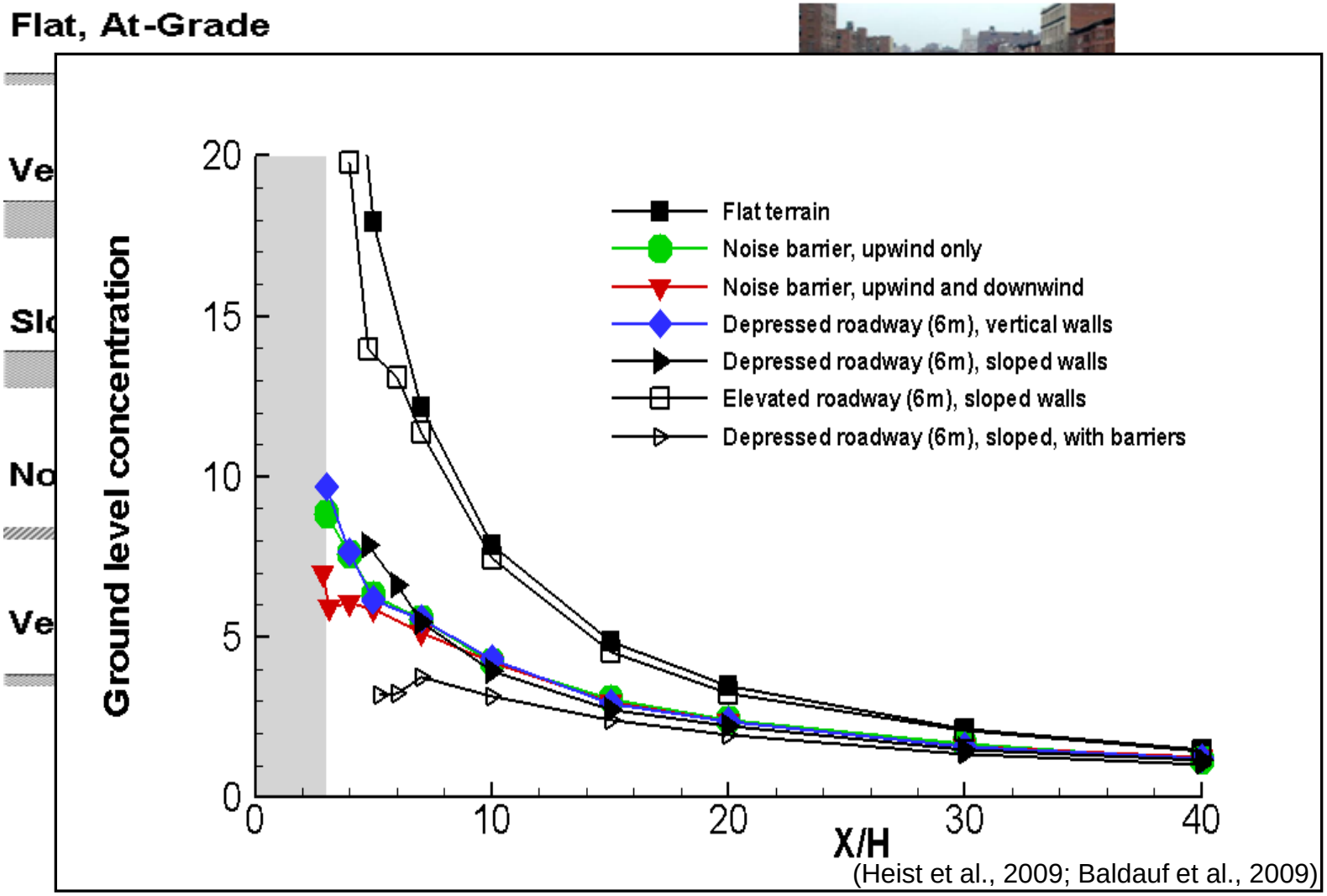
Rich Baldauf
U.S. Environmental Protection Agency
January 11, 2011

One way to mitigate impacts: Roadway Design and Roadside Features?

United States Environmental Protection Agency



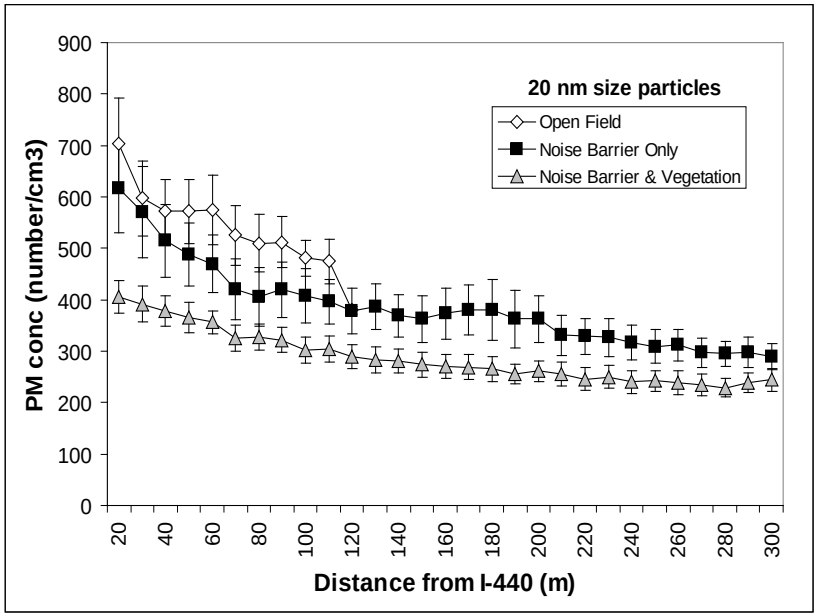
One way to mitigate impacts: Roadway Design and Roadside Features?

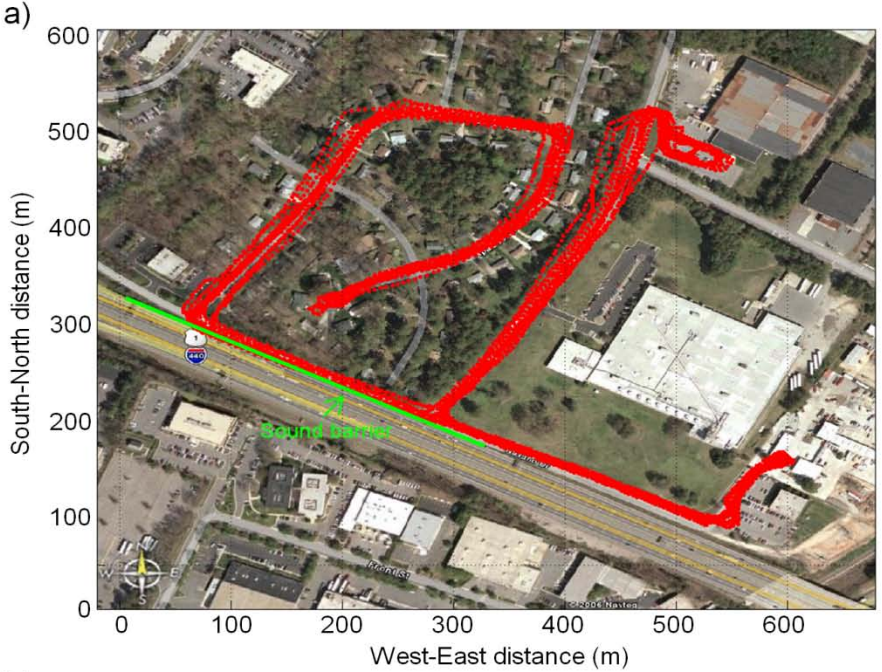


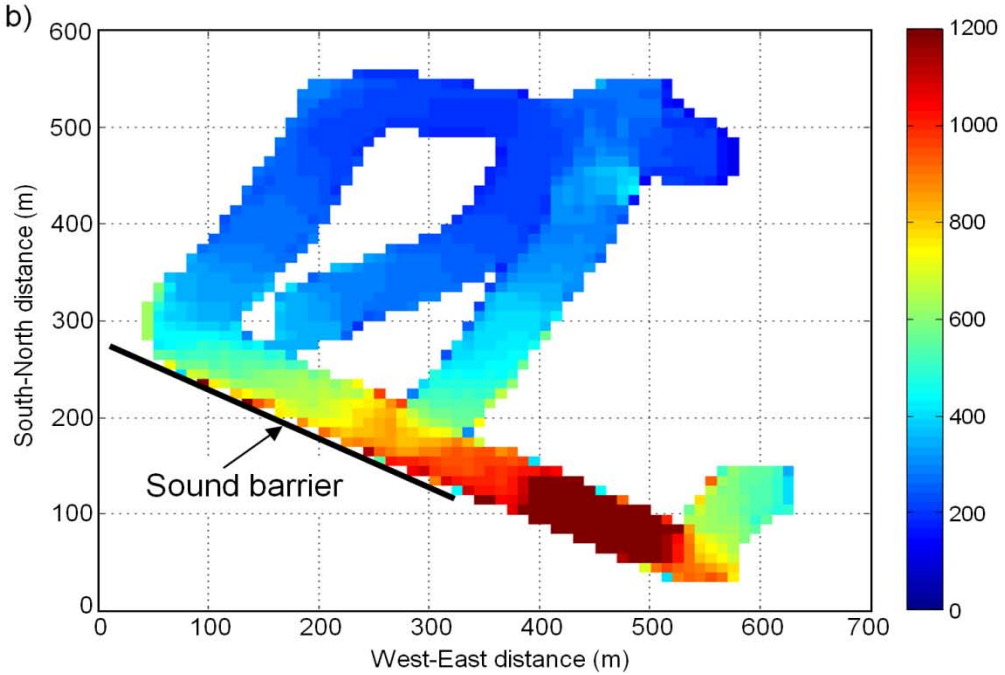
(Heist et al., 2009; Baldauf et al., 2009)

United States Environmental Protection Agency

*Field studies showed the influence of **noise barriers and vegetation** on both pollutant concentrations and gradients*

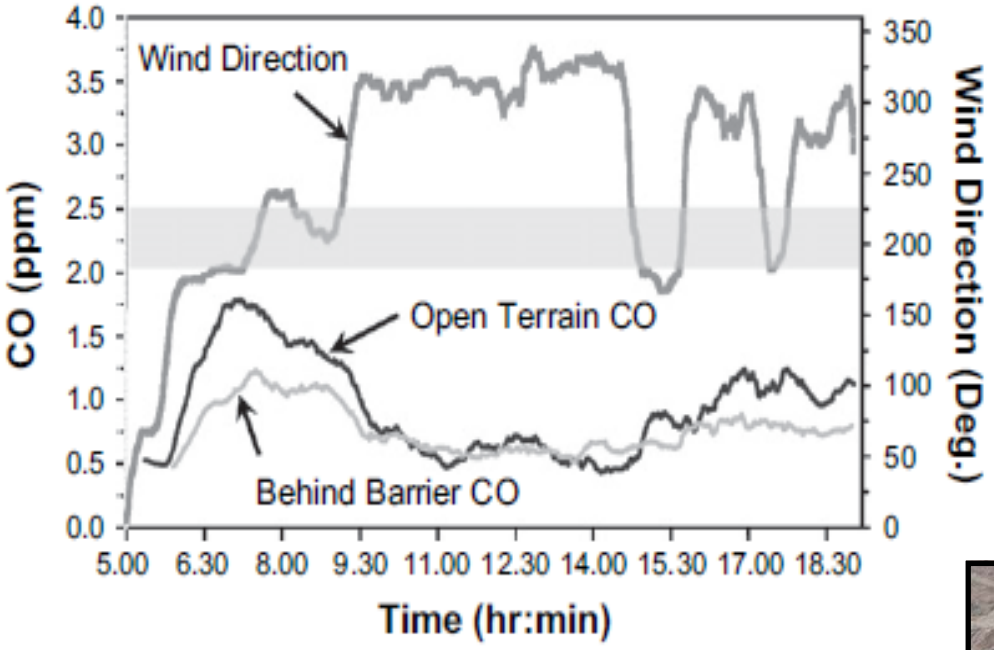






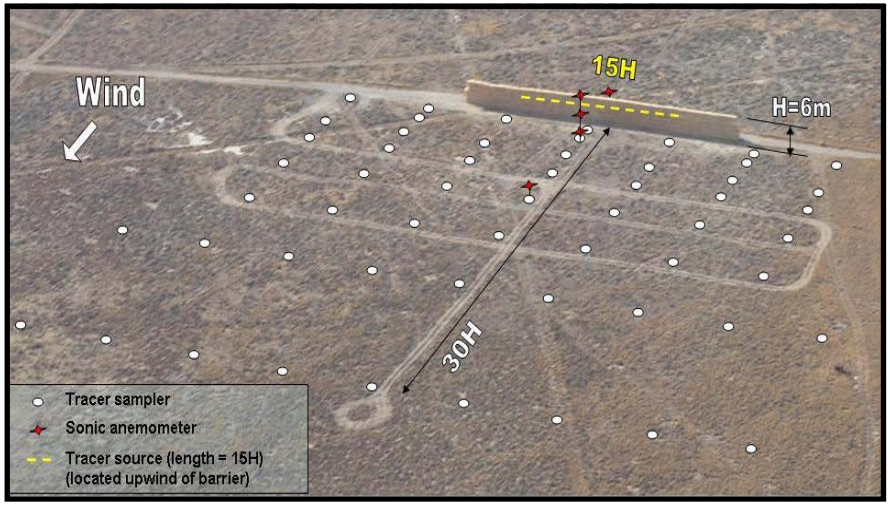
(Baldauf et al., 2008a; 2008b)

Noise Barrier Effects



Baldauf et al., (2008a)

Noise barrier effects most pronounced when winds from the road and higher traffic volumes. Barriers and roadside features may also trap pollutants behind the structure, leading to higher on-road concentrations



Finn et al., (2010)

Vegetation Effects

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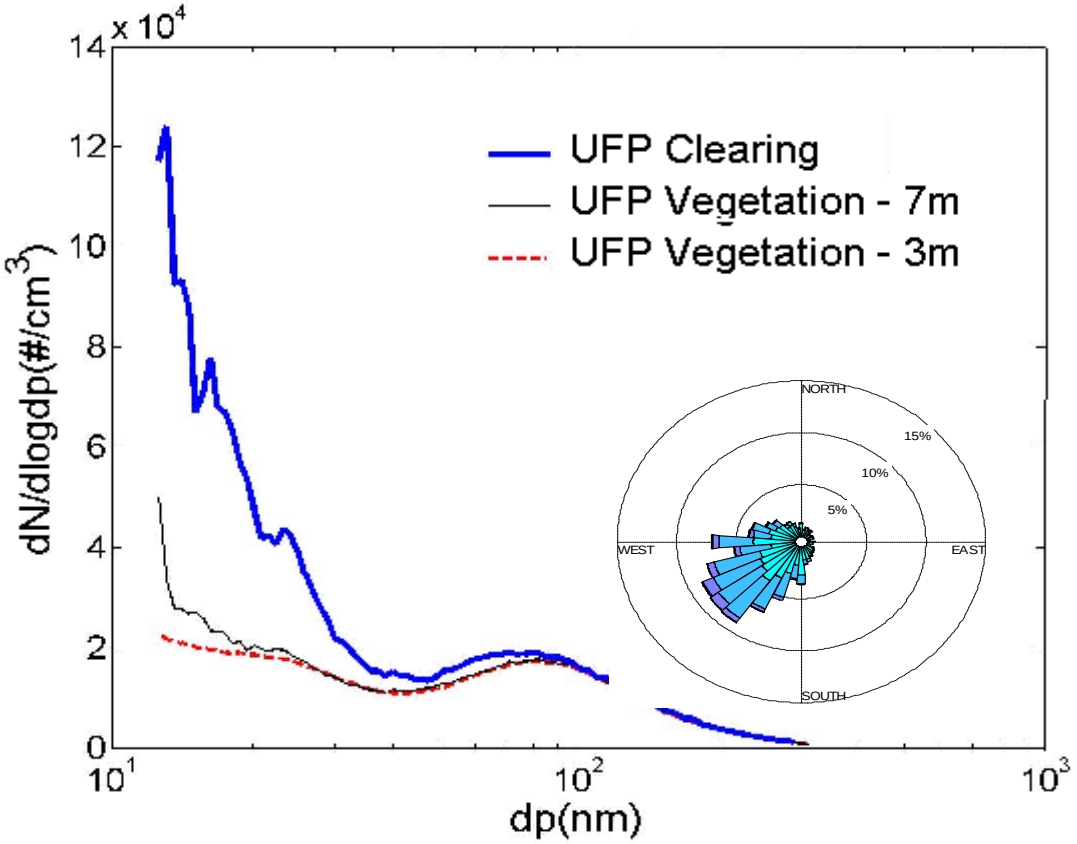
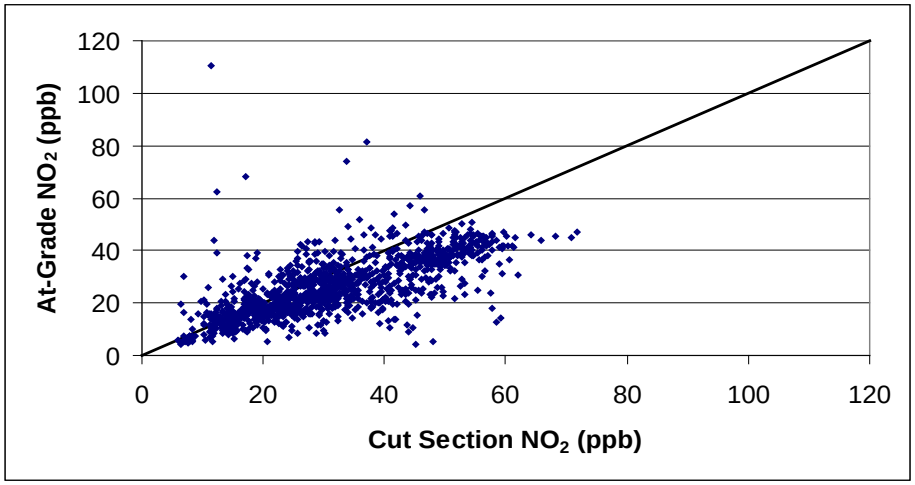


(Ongoing Work - Preliminary Data: do not cite, quote, or reference)

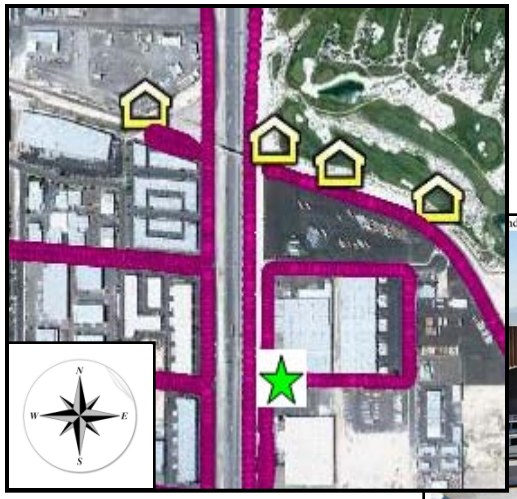
Cut Section Effects

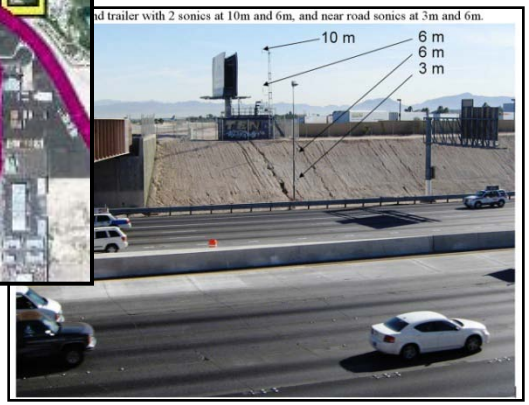
United States Environmental Protection Agency

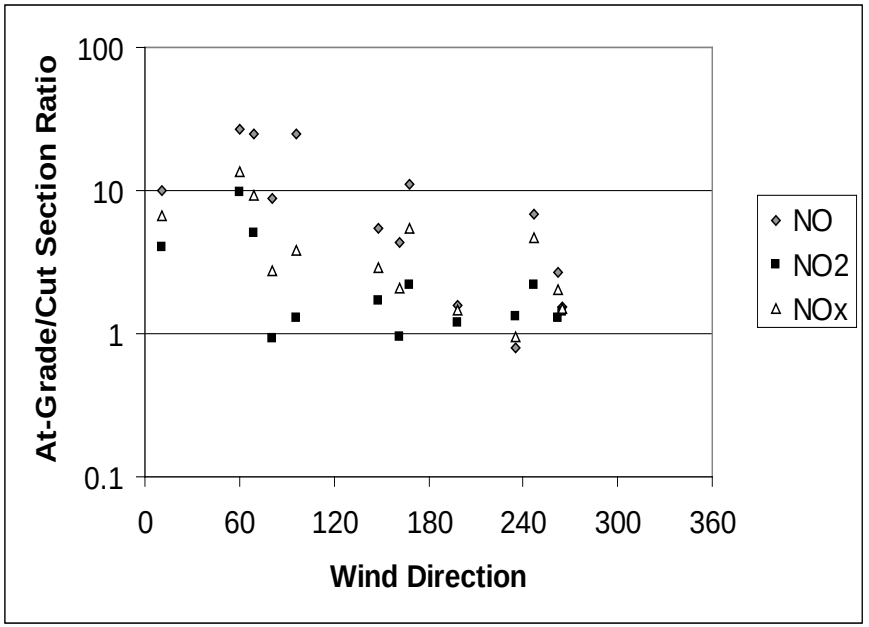


Preliminary data comparing at-grade and cut section NO_2 shows high variability, although highest concentrations occurred at-grade

(Ongoing Work - do not cite, quote, or reference)



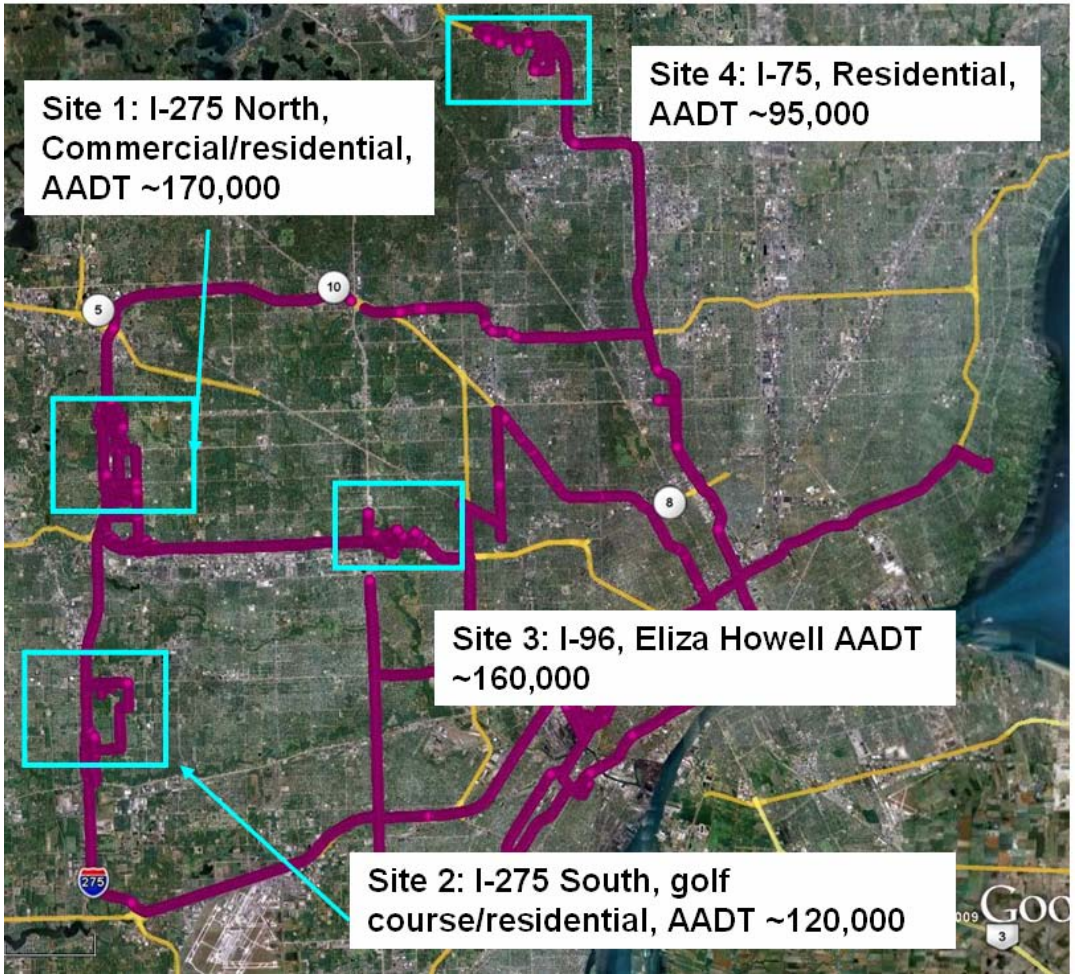




Future Work in Detroit

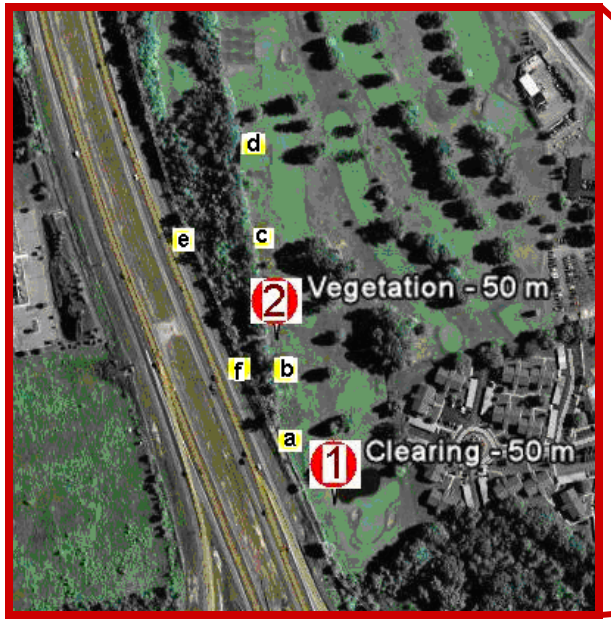
Two primary objectives:

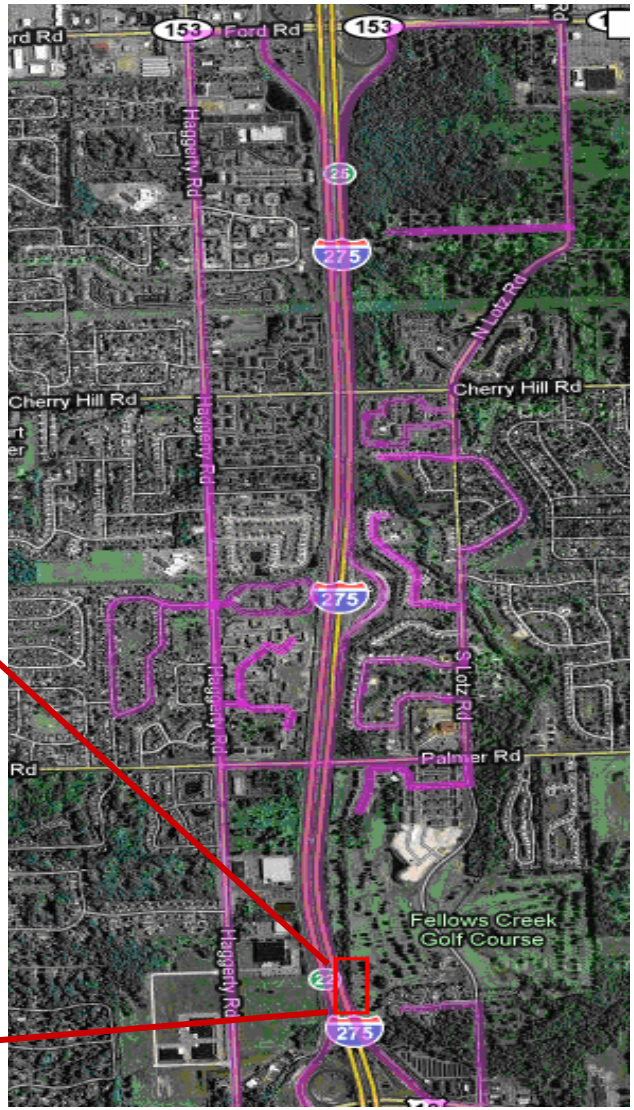
- Quantify vegetation impacts on near-road air quality
- Assess concentration variability for varying neighborhood designs



Site 2: I-275 South

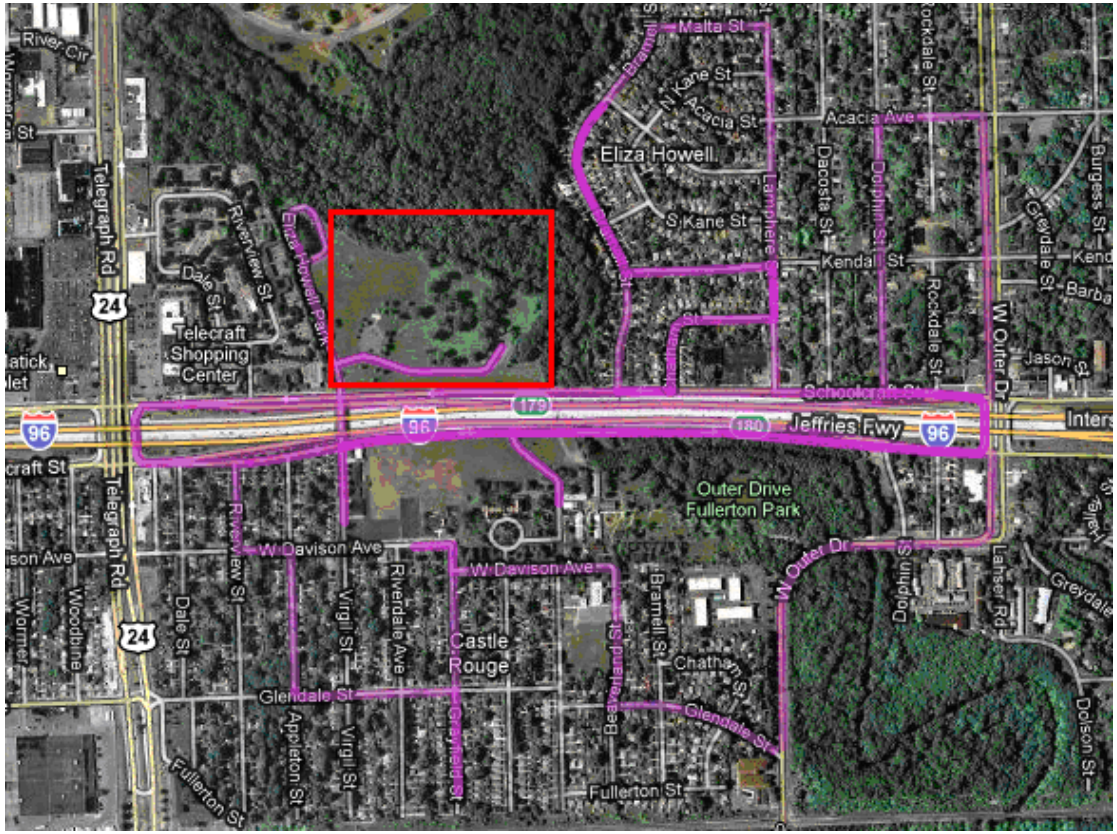
- On-road and near-road mobile monitoring with varying vegetation and neighborhood configurations
- Fixed and backpack monitoring for detailed vegetation assessment





Site 3: I-96 Eliza Howell Park

- On-road and near-road mobile monitoring with varying neighborhood configurations
- Comparison with EPA/FHWA fixed site measurements



Sampling and Schedule

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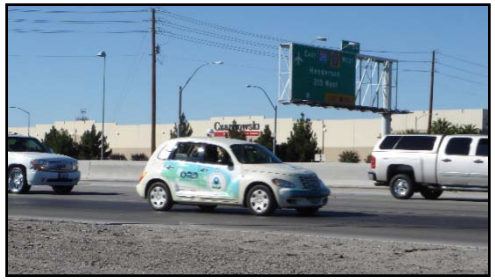
Mobile Electric Vehicle

- ~3 hrs per day (3-4 driving routes)
- Particulate Matter
  - UFP size distributions (EEPS)
  - Coarse and fine size distributions (APS)
  - Black carbon (Micro-aethalometer)
- Gases
  - CO (Single Quantum Cascade Laser)
  - NO2 (tentative)



Stationary and Backpack

- ~22-24 hour stationary sampling
- ~2 hours backpack sampling
- Particulate Matter
  - Particle count in select size bins (HHPC)
  - Black carbon (Micro-aethalometer)

Sampling scheduled to begin late May, 2011

For More Information

- EPA Contacts:
  - Rich Baldauf (baldauf.richard@epa.gov)
  - Gayle Hagler (hagler.gayle@epa.gov)
- Websites:
  - http://www.epa.gov/airscience/quick-finder/near-roadway.htm
  - http://www.epa.gov/nrmrl/appcd/nearroadway/workshop.html
- References

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