Characterizing the Determinants of Vehicle Traffic Emissions Exposure: Measurement and Modeling of Land-Use, Traffic, Emissions, Transformation, and Transport

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INTRODUCTION

Needs

- Better exposure assessment methods for vulnerable near-road populations
- Fill knowledge gaps on how traffic emissions contribute to air quality in freeway and urban settings

Goals

1) To improve inputs that might be used in spatiotemporal statistical models of near road air quality
2) To test the usefulness of such inputs

Hypothesis

Regression models of near road pollutant concentrations could be improved by refining estimates or indices for explanatory variables

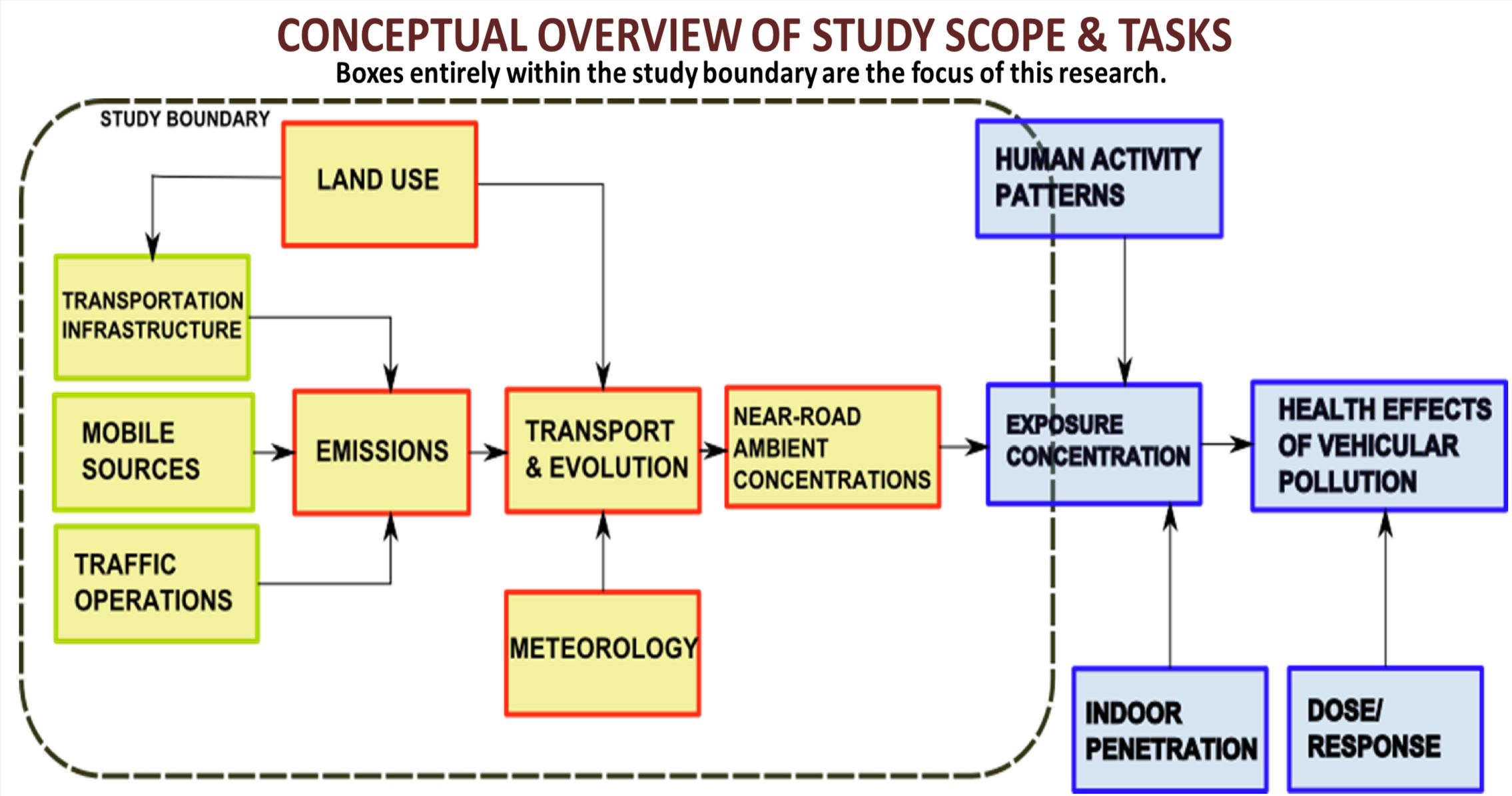
Aims

1) Develop and test regression models that could be used to model traffic-related air pollutant concentrations
2) Develop and test more refined estimates of proxies for land-use, traffic, emissions, and dispersion than have been used previously
3) Prioritize which inputs are important and which are not, to help focus efforts for future data collection and model development.

General Approach

1) Data regarding land-use, traffic activity, vehicle emissions, and air quality were collected at a freeway site and an urban site for winter and summer
2) These data or indicators derived from these data were used to develop statistical models for near-road air quality
3) The importance of detailed characterization of land-use, traffic, emissions, and other determinants were assessed to identify where research efforts should be focused.

METHODOLOGY

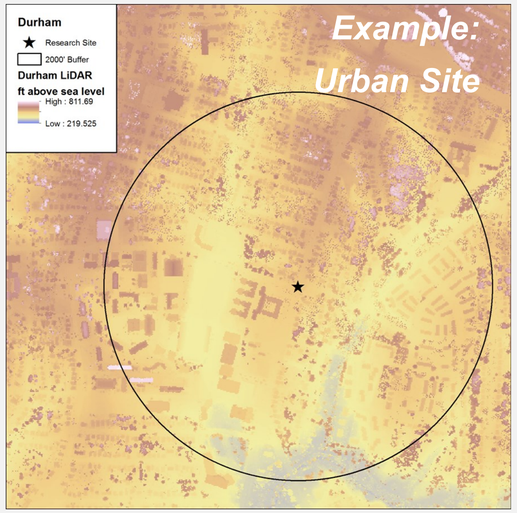


LAND-USE

Detailed land use characteristics quantified within a 2000 ft buffer around each site.

LIDAR-based elevations for each buffer were validated.

Built environment data were collected for each study area.

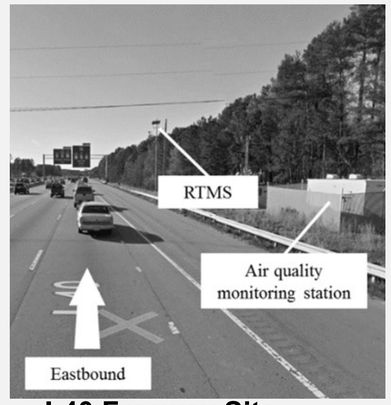


Example Data for Urban Site

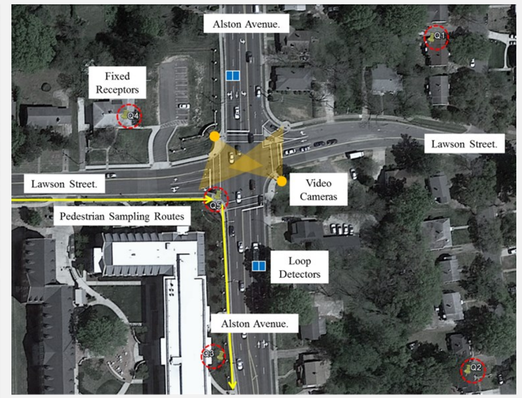
Descriptive statistics for selected built environment attributes within 2000ft of Durham site

Variable	Obs	Mean	Std. Dev.	Min	Max
Distance to highway next to EPA station (m.)	47160	408.41	144.40	2.90	613.02
Distance to nearest bus stop (m.)	47160	139.24	78.90	0.70	393.95
Distance to RDU airport (m.)	47160	13727.47	306.33	13115.13	14338.50
Distance to nearest street (m.)	47160	32.20	28.04	0.00	186.30
Distance to nearest arterial (m.)	47160	213.26	133.95	0.02	612.08
Housing unit count	47160	0.02	0.03	0.00	0.35
Average elevation of gridcell (m.)	47160	3.8	5.7	-107.9	104.6
Standard deviation of gridcell elevation (m.)	47160	1.4	2.9	0.0	119.0

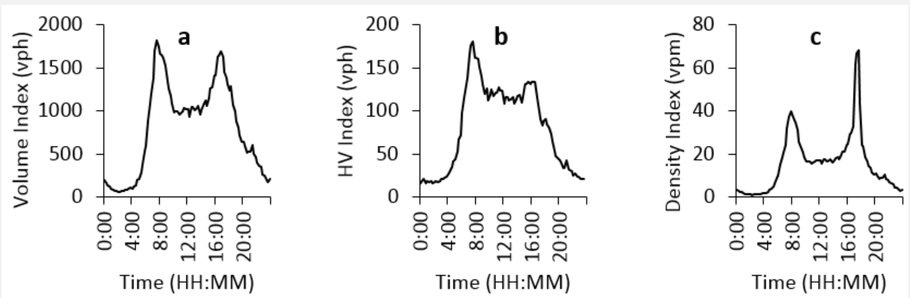
TRAFFIC



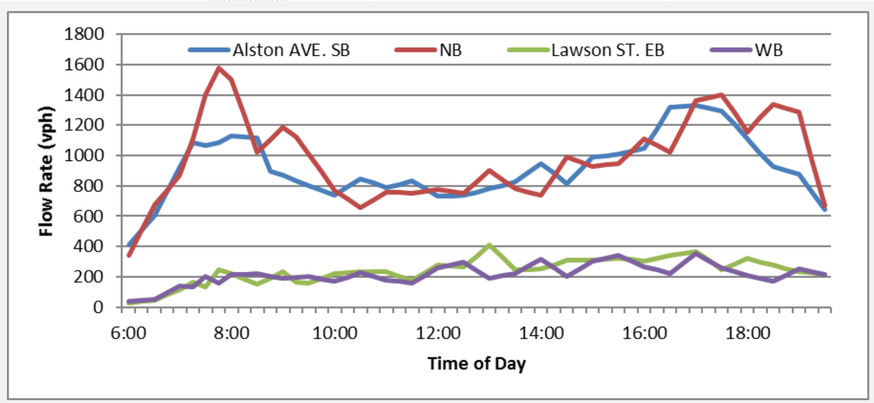
I-40 Freeway Site



Durham Intersection Site



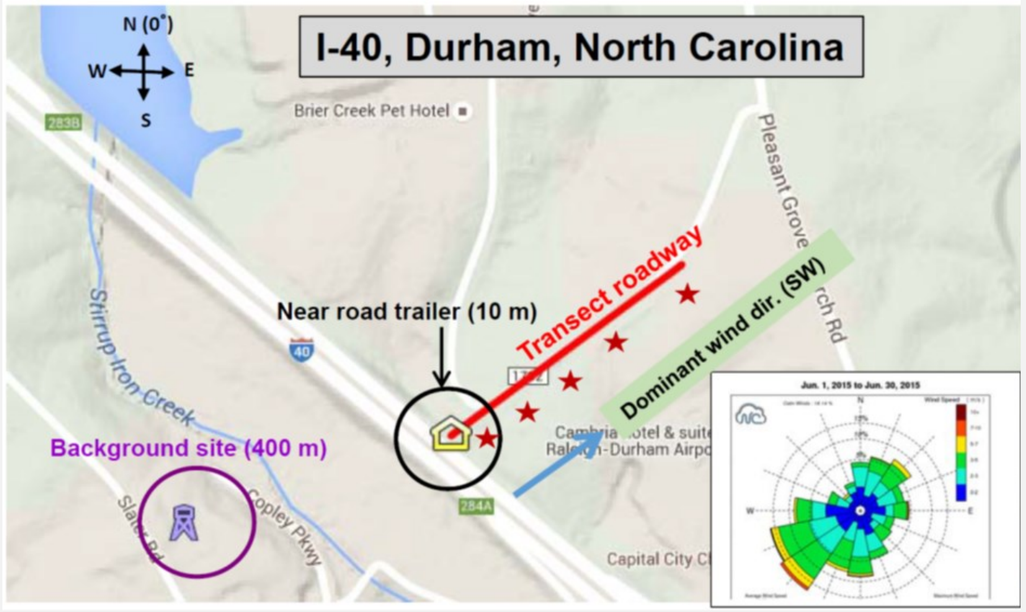
Diurnal variation of traffic indices at the Freeway site on February 9, 2016: (a) volume index; (b) HV index; and (c) density index.



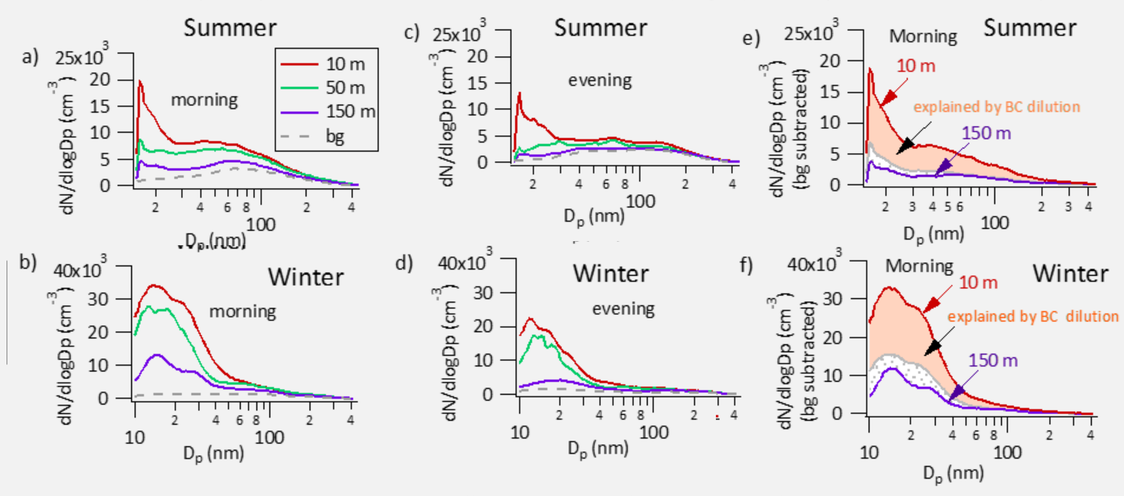
Example of Directional Flow Rate at Urban Site for 5/25/16

EMISSIONS

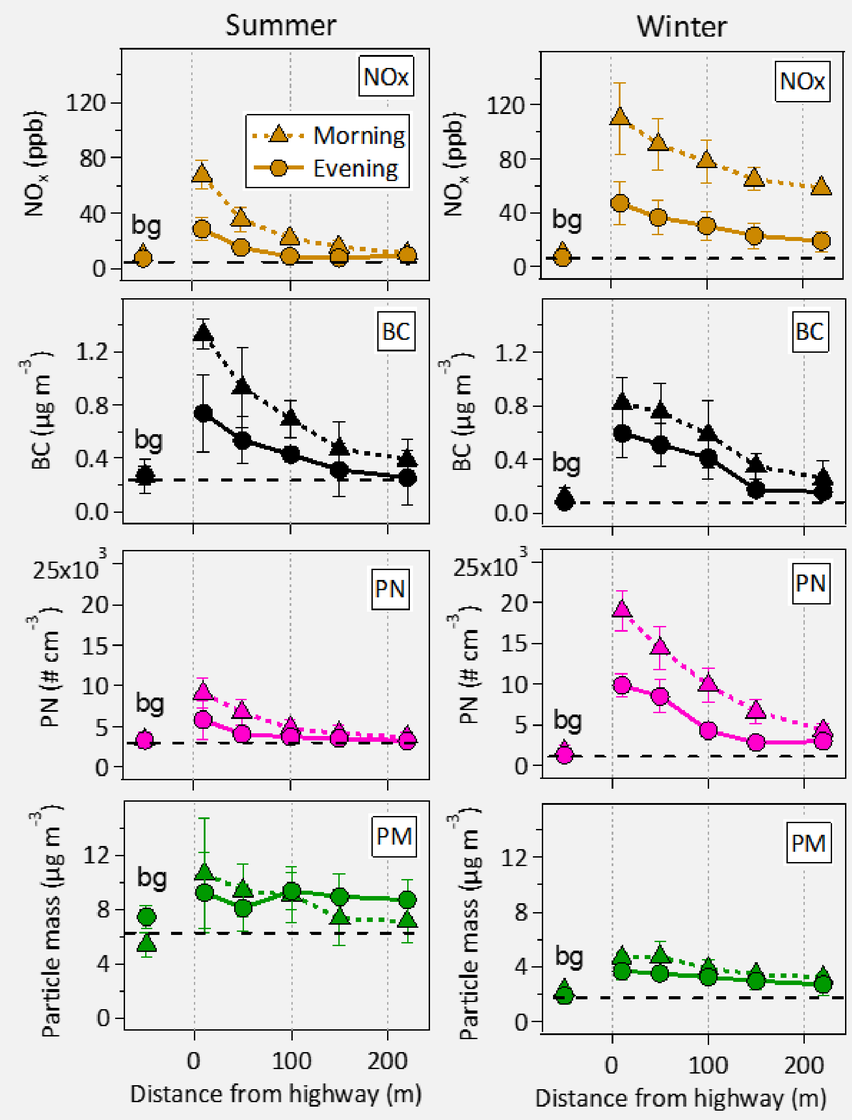
AIR QUALITY MEASUREMENTS AT FREEWAY (I-40) SITE



Study area map showing near-road trailer, transect roadway and upwind background site. Wind rose plot (inset) is shown for the I-40 summer campaign period (June 1 to June 30)

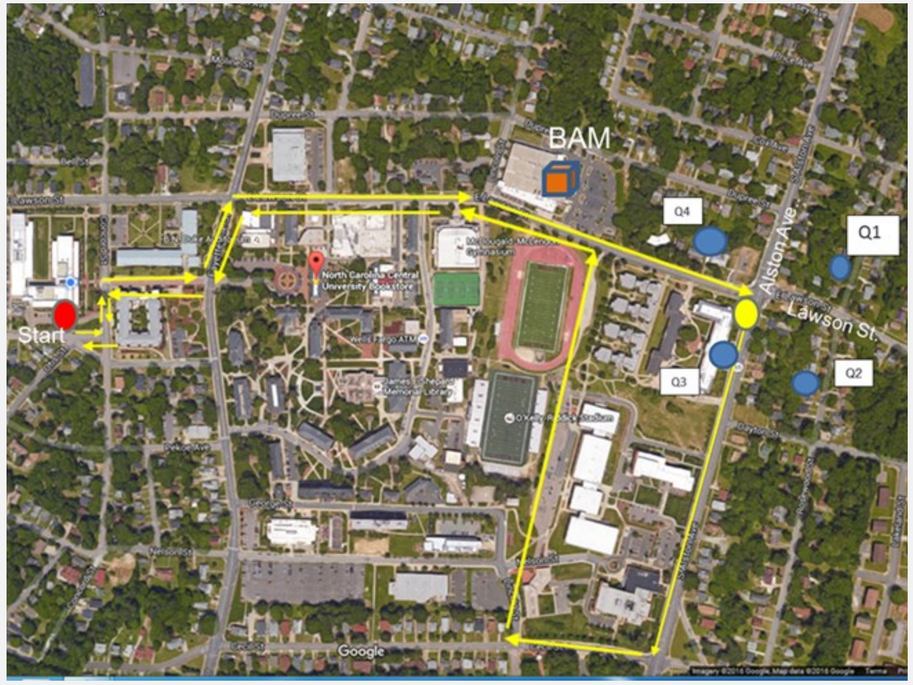


Average particle number size distributions at different distances from the edge of the highway. Downwind measurements are not background-subtracted. (e-f) Background subtracted average particle number size distributions at 10 m (red) and 150 m(purple) downwind distances. The reddish shaded portion of the measured size distribution at 10 m can be explained by applying the dilution factor at 150 m, determined from the decay profile of background-corrected BC concentrations (Fig. 3a). Other processes will be required to explain the gray dotted portion

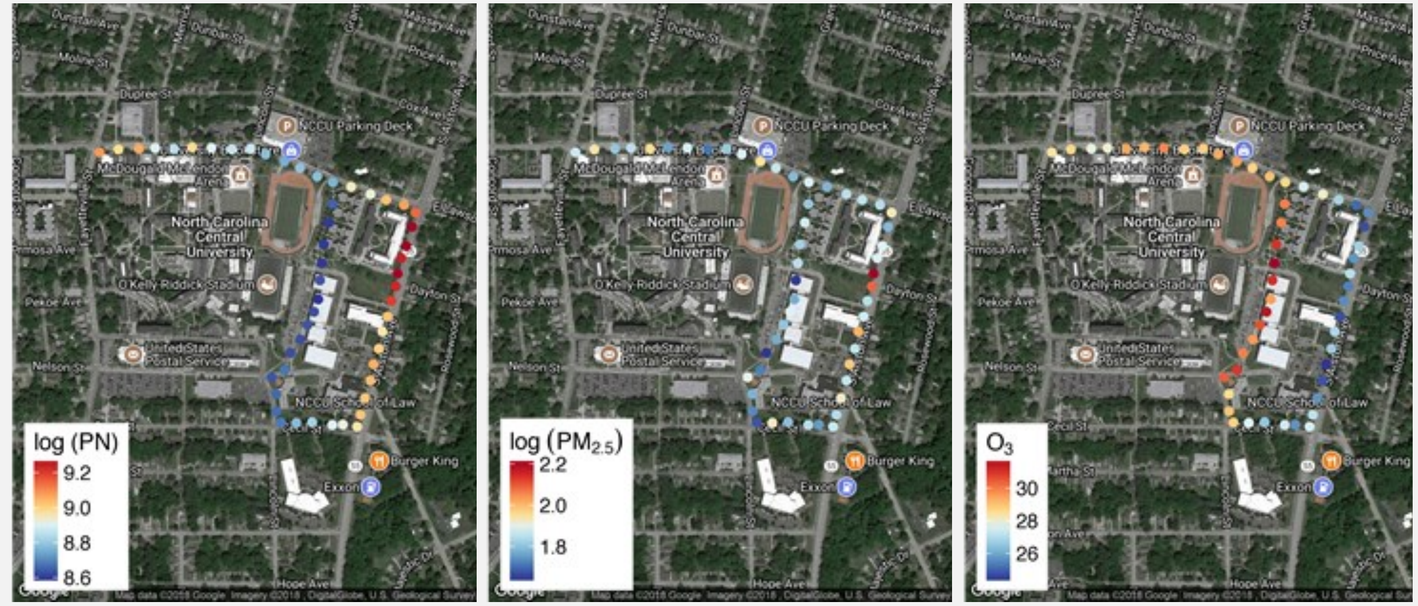


Downwind concentrations of NO_x, BC, PN, and particle mass (< 400 nm) during summer and winter campaigns. Downwind measurements are not background-subtracted. The measured background (bg) concentrations are shown. The background site location is not shown on axis but is approximately 400 m 'upwind' from the main fixed monitor site on the opposite side of I-40.

AIR QUALITY MEASUREMENTS AT URBAN SITE

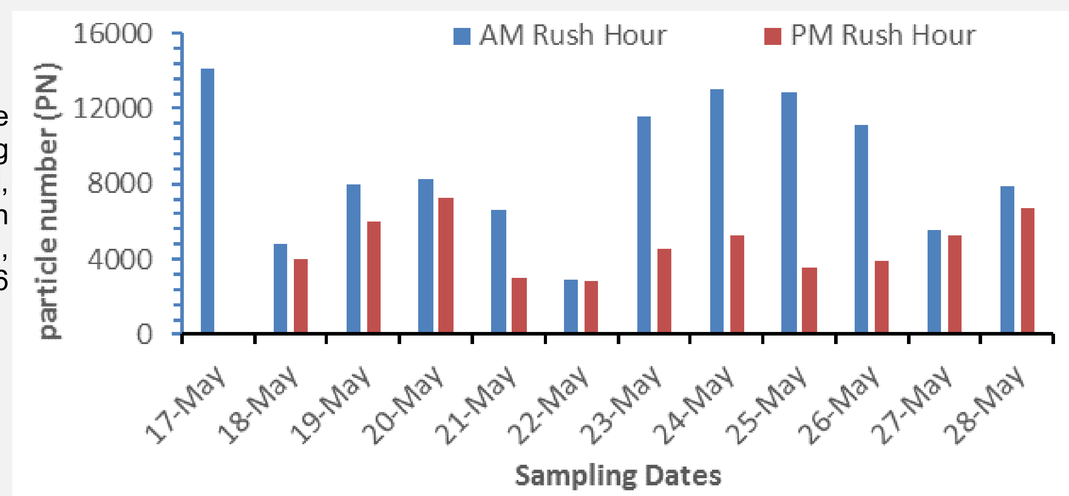


Urban sampling site located in Durham, North Carolina. Morning and afternoon rush-hour sample collection route is in yellow. Blue dots indicate four residential sites where 24-hour long sampling for $PM_{2.5}$, nitrogen oxides (NOx/NO_2) and ozone were collected. BAM is where background level was measured.

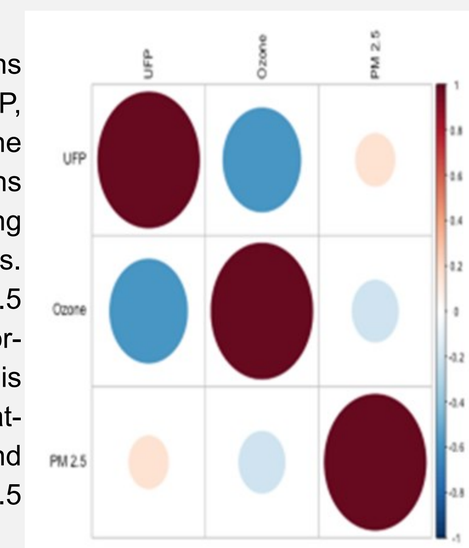


Mean transformed concentrations averaged over season, day, and daily time period for the urban site.

Ultrafine PM during AM & PM, Rush Hours, May 2016

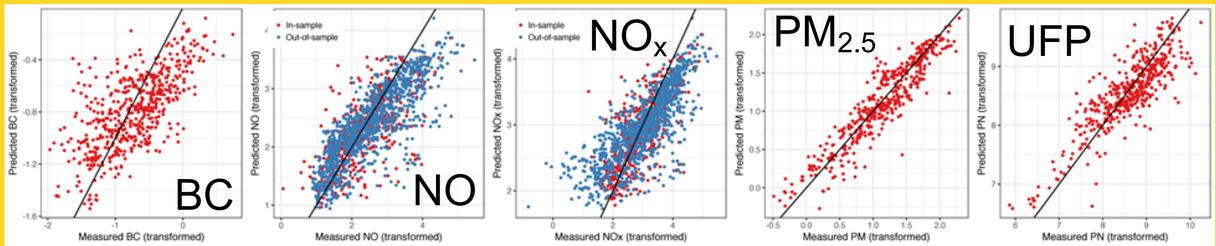


Correlations among UFP, $PM_{2.5}$, and ozone concentrations from walk-along measurements. UFP and PM2.5 are positively correlated. Ozone is inversely correlated with UFP and PM2.5



STATISTICAL MODELS

Freeway Site

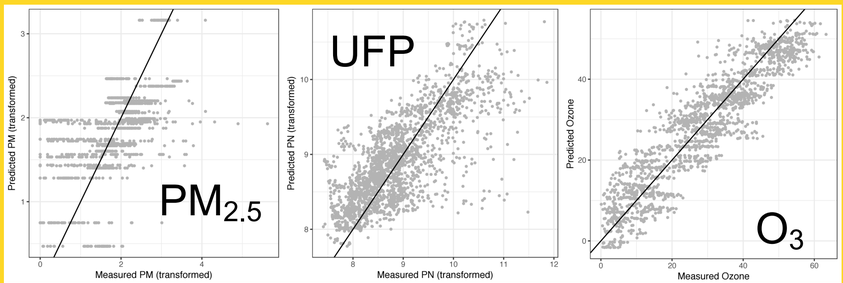


R^2	0.42	0.61	0.56	0.86	0.72

Key Predictors: temperature, heavy vehicle volume index, local wind direction

Other Predictors: background concentration, day type, traffic volume, dispersion model

Urban Site



R^2	0.31	0.52	0.84

Key Predictors: traffic count, wind speed, wind direction

Other Predictors: distance to bus stop, temperature, relative humidity, time of day, day of week, season, dispersion model

SUMMARY AND CONCLUSIONS

Limitations

- This study focused on detailed characterization of one freeway and one urban site. There may be differences in the best choice of predictors at other sites.
- Lack of significance of some predictors at these sites may not imply lack of significance at other sites.

Conclusions

1) The most useful predictors of near-road air quality include traffic volume indices and wind direction
2) Depending on the pollutant, other variables are useful predictors
3) Ultrafine particle counts were very sensitive to traffic at both sites
4) Localized data on traffic and meteorology are useful
5) Heavy vehicle traffic influenced air quality at the freeway site more so than total traffic
6) The statistical models are relatively simple
7) Results help identify priorities for data needed to predict near road concentrations

Acknowledgments

- This work is sponsored by the Health Effects Institute (HEI) under RFA 13-1.
- Sue Kimbrough, US EPA, has provided extensive help with resources, logistics and access to the EPA/DEQ I-40 monitoring site