Chapter 55
Assessment of Fine-Scale Dispersion Modelling for Near-Road Exposure Applications

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Abstract Detailed measurements and dispersion modeling were conducted to develop more accurate integrated metrics to assess exposure to potentially high pollutant levels of primary traffic emissions. A 13-week intensive sampling campaign was conducted at six monitoring sites surrounding one of the busiest highway segment in the US with the study area focusing on the Georgia Institute of Technology campus to capture the heterogeneity in pollutant concentrations related to primary traffic emissions. A dispersion model (RLINE) was used to develop spatial concentration fields at a fine-spatial resolution over the area of primary exposures. Initial RLINE results were highly biased, due either to errors in the emissions or the model. Analysis suggests that both may be important, depending upon species, though the largest errors were due to how the model represents near-source dispersion, especially when the wind aligns with the road segments. To correct for high near-road bias, the RLINE results were calibrated using measurement observations after the urban background was removed. Performing the calibration hourly also reduced the bias observed in the diurnal profile. Both the measurement observations and dispersion modeling results show that the highway has a substantial impact on primary traffic pollutant (particularly elemental carbon and carbon monoxide) concentrations and captures the prominent spatial gradients across the campus domain, though the gradients were highly species dependent. These improved concentration fields were used to enhance the characterization of pollutant spatial distribution around a traffic hotspot and to quantify personal exposure to primary traffic emissions.

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55.1 Introduction

On-road mobile emissions lead to elevated air pollutant concentrations in near-road environments and steep concentration gradients exist with distance from major roads. Exposure to traffic related air pollutants (TRAP), including carbon monoxide (CO), nitrogen oxides (NOx), and fine particulate matter ($PM_{2.5}$), has been linked to many adverse health effects [2]. While vehicles are a significant source of pollutants in the near-road environment, improved vehicle engine technology, emissions control systems, and fuel regulations have reduced emissions leading to a decrease in traffic related air pollutants (TRAP) near heavily trafficked roads [2]. Quantifying the pollutant concentration attributed to traffic pollution from regional pollution through measurement becomes more difficult as vehicle emissions decrease. In addition, near-road measurements are often limited within a city leading to a limited understand of the spatial gradients. Dispersion modeling can provide spatially and temporally resolved concentration fields of TRAPs for assessing exposure.

55.2 Methods

Hourly-modeled primary traffic-related CO, NOx, and $PM_{2.5}$ concentrations at a 25 $\times$ 25 m grid resolution were generated using RLINE (Research Line Source Model), a steady-state, Gaussian plume dispersion model [3]. The Atlanta Regional Commission (ARC) provided link-based, on-road mobile source emissions for the 20-country region surrounding metro Atlanta using a traffic demand and mobile source emissions model. ARC estimated 2010 CO, NOx, and PM2.5 emissions for 43,712 links based on modeled traffic volume, vehicle speed, and fleet demographics. The surface meteorological data was from the National Weather Service at the Hartsfield-Jackson Atlanta International Airport (ATL) and preprocessed using AERMINUTE. The upper air data was from the Peachtree City Falcon Field Airport (FFC).

Initial RLINE results were corrected by applying ARC monthly and hourly diurnal emissions variability, and hours with wind speeds less than 1 ms^{-1} were replaced. The 2010 ARC link-based emissions were scaled to 2014 emissions levels using the mobile emissions ratio from the Motor Vehicle Emissions Simulator [4]. Corrected RLINE results were calibrated to the hourly surface concentrations measurements collected as part of the Dorm Room Inhalation to Vehicle Emissions (DRIVE) study. A linear regression between the hourly-corrected RLINE concentrations and the hourly measurements at the six monitoring locations scaled the corrected results and the intercept was removed to exclude the local background. In a second process, the hourly-corrected RLINE results were calibrated to the hourly DRIVE surface measurements using 24 linear regressions to account for differences in the diurnal profile. A third process averaged three hourly RLINE concentrations at each grid with wind direction varying five degrees in either direction to help reduce bias when the wind aligns with the road links.

The DRIVE study was a 13-week sampling campaign (September 2014–December 2014) focusing on traffic related air pollutants (TRAPs) surrounding the busiest highway in Atlanta, GA with an annual average daily traffic of 320,000 vehicles [1]. The study included six monitoring sites and focused on the Georgia Institute of Technology campus in the geographical core of Atlanta with its eastern edge bordering the major highway. The sites included: a roadside location 10 m from the highway (RD), an EPA Near-road Monitoring Network site located 70 m north of the RD site and 5 m from the highway (EPD), a dormitory room 20 m from the highway (ND), a dormitory room 1.4 km from the highway (FD), and an urban background site located 2.3 km from the highway.

55.3 Results and Discussion

Simulated concentrations from raw RLINE outputs show the spatial gradients, however concentrations in the near-road environment were unreasonably high (Fig. 55.1a). The corrected RLINE output removed all low wind speed events, which led to bias high concentrations due to stagnation events trapping emissions at the road, and reintroduced monthly and hourly diurnal emissions variability (Fig. 55.1b). The single linear regression applied to the corrected RLINE output (Fig. 55.1c) simulate realistic average species concentrations and captures the spatial gradients. The additional processes described will be developed and presented. The average simulated impact of on-road mobile sources on primary $PM_{2.5}$, NOx, and CO concentrations at

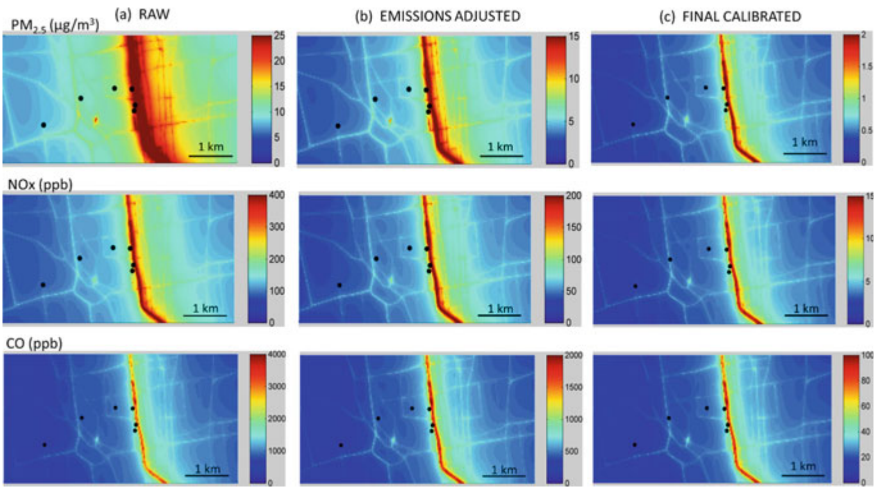

Fig. 55.1 RLINE fine scale dispersion modeling for simulated PM2.5, NOx, and CO concentrations (September–December 2014). **a** Raw RLINE output; **b** Corrected RLINE output; **c** Calibrated by single linear calibration. Black dots represent the sampling locations. Resolution: 25 × 25 m

the RD site was 1.3 $\mu g\ m^{-3}$, 8.6 ppb, and 51.5 ppb respectively, while the concentration at the urban background (JST) site was 0.4 $\mu g\ m^{-3}$, 2.8 ppb, and 16.9 ppb. The maximum hourly concentrations were simulated when wind speeds were low and therefore dispersion was low which often occurring at night when emissions were also low. The wind direction measured at the RS site measured easterly winds more than 70% of the time leading to direct influence from the highway emissions on the monitor sites. Even though the major emissions source in the domain is the highway, the surface streets (AADT 20,000) are an observable source [1].

55.4 Conclusion

These processes reduced unrealistically high concentrations that were observed on and near the main highway emissions source. The linear calibration helped decrease the bias high levels improving the average concentration fields, however hourly bias was observed. The diurnal calibration improved both the bias high concentrations and the distribution of the concentrations.

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